# STM32F469xx

## Arm®Cortex®-M4 32b MCU+FPU, 225DMIPS, up to 2MB Flash/384+4KB RAM, USB OTG HS/FS, Ethernet, FMC, dual Quad-SPI, Graphical accelerator, Camera IF, LCD-TFT & MIPI DSI

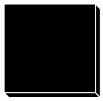
**Datasheet - production data**

## Features

- Includes ST state-of-the-art patented technology
- Core: Arm® 32-bit Cortex®-M4 CPU with FPU, adaptive real-time accelerator (ART Accelerator™) allowing 0-wait state execution from flash memory, frequency up to 180 MHz, MPU, 225 DMIPS/1.25 DMIPS/MHz (Dhrystone 2.1), and DSP instructions
- Memories
  - 512 bytes of OTP memory
  - Up to 2 MB of flash memory organized into two banks allowing read-while-write
  - Up to 384+4 KB of SRAM including 64 KB of CCM (core coupled memory) data RAM
  - Flexible external memory controller with up to 32-bit data bus: SRAM, PSRAM, SDRAM/LPSDR, SDRAM, flash NOR/NAND memories
  - Dual-flash mode Quad-SPI interface
- Graphics
  - Chrom-ART Accelerator™ (DMA2D), graphical hardware accelerator enabling enhanced graphical user interface with minimum CPU load
  - LCD parallel interface, 8080/6800 modes
  - LCD TFT controller supporting up to XGA resolution
  - MIPI® DSI host controller supporting up to 720p 30 Hz resolution
- Clock, reset, and supply management
  - 1.7 V to 3.6 V application supply and I/Os
  - POR, PDR, PVD, and BOR
  - 4-to-26 MHz crystal oscillator
  - Internal 16 MHz factory-trimmed RC (1% accuracy)
  - 32 kHz oscillator for RTC with calibration
  - Internal 32 kHz RC with calibration
- Low power
  - Sleep, Stop, and Standby modes
  - $V_{BAT}$ supply for RTC, 20×32 bit backup registers + optional 4 KB backup SRAM
- 3× 12-bit, 2.4 MSPS ADC: up to 24 channels and 7.2 MSPS in triple interleaved mode
- 2× 12-bit D/A converters
- General-purpose DMA: 16-stream DMA controller with FIFOs and burst support
- Up to 17 timers: up to twelve 16-bit and two 32-bit timers up to 180 MHz, each with up to four IC/OC/PWM or pulse counter and quadrature (incremental) encoder input. 2x watchdogs and SysTick timer

LQFP100 (14 × 14 mm)
LQFP144 (20 × 20 mm)
LQFP176 (24 × 24 mm)
LQFP208 (28 × 28 mm)

WLCSP168



UFBGA169 (7 × 7 mm)
UFBGA176 (10 x 10 mm)
TFBGA216 (13 x 13 mm)

- Debug mode
  - SWD and JTAG interfaces
  - Cortex®-M4 Trace Macrocell™
- Up to 161 I/O ports with interrupt capability
  - Up to 157 fast I/Os up to 90 MHz
  - Up to 159 5 V-tolerant I/Os
- Up to 21 communication interfaces
  - Up to three $I^2C$ interfaces (SMBus/PMBus)
  - Up to four USARTs and four UARTs (11.25 Mbit/s, ISO7816 interface, LIN, IrDA, modem control)
  - Up to six SPIs (45 Mbits/s), two with muxed full-duplex $I^2S$ for audio class accuracy via internal audio PLL or external clock
  - 1x SAI (serial audio interface)
  - 2× CAN (2.0B Active)
  - SDIO interface
- Advanced connectivity
  - USB 2.0 full-speed device/host/OTG controller with on-chip PHY
  - USB 2.0 high-speed/full-speed device/host/OTG controller with dedicated DMA, on-chip full-speed PHY and ULPI
  - Dedicated USB power rail enabling on-chip PHYs operation throughout the entire MCU power supply range
  - 10/100 Ethernet MAC with dedicated DMA: supports IEEE 1588v2 hardware, MII/RMII
- 8- to 14-bit parallel camera interface up to 54 Mbytes/s.
- True random number generator
- CRC calculation unit
- RTC: subsecond accuracy, hardware calendar
- 96-bit unique ID

**Table 1. Device summary**

| Reference | Part numbers |
|---|---|
| STM32F469xx | STM32F469AE, STM32F469AG, STM32F469AI<br>STM32F469BE, STM32F469BG, STM32F469BI<br>STM32F469IE, STM32F469IG, STM32F469II<br>STM32F469NE, STM32F469NG, STM32F469NI<br>STM32F469VE, STM32469VG, STM32469VI<br>STM32F469ZE, STM32469ZG, STM32469ZI |



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# Contents


**1 Description . . . . . 11**

1.1 Compatibility throughout the family . . . . . 14

1.1.1 LQFP176 package . . . . . 15

1.1.2 LQFP208 package . . . . . 16

1.1.3 UFBGA176 package . . . . . 17

1.1.4 TFBGA216 package . . . . . 18

**2 Functional overview . . . . . 20**

2.1 Arm® Cortex®-M4 with FPU and embedded flash and SRAM . . . . . 20

2.2 Adaptive real-time memory accelerator (ART Accelerator™) . . . . . 20

2.3 Memory protection unit . . . . . 20

2.4 Embedded flash memory . . . . . 21

2.5 CRC (cyclic redundancy check) calculation unit . . . . . 21

2.6 Embedded SRAM . . . . . 21

2.7 Multi-AHB bus matrix . . . . . 21

2.8 DMA controller (DMA) . . . . . 22

2.9 Flexible memory controller (FMC) . . . . . 23

2.10 Quad-SPI memory interface (QUADSPI) . . . . . 24

2.11 LCD-TFT controller . . . . . 24

2.12 DSI Host (DSIHOST) . . . . . 24

2.13 Chrom-ART Accelerator™ (DMA2D) . . . . . 26

2.14 Nested vectored interrupt controller (NVIC) . . . . . 26

2.15 External interrupt/event controller (EXTI) . . . . . 26

2.16 Clocks and startup . . . . . 27

2.17 Boot modes . . . . . 27

2.18 Power supply schemes . . . . . 27

2.19 Power supply supervisor . . . . . 29

2.19.1 Internal reset ON . . . . . 29

2.19.2 Internal reset OFF . . . . . 29

2.20 Voltage regulator . . . . . 30

2.20.1 Regulator ON . . . . . 31

2.20.2 Regulator OFF . . . . . 32

2.20.3 Regulator ON/OFF and internal reset ON/OFF availability . . . . . 34
2.21 Real-time clock (RTC), backup SRAM, and backup registers . . . . . 34
2.22 Low-power modes . . . . . 35
2.23 $V_{BAT}$ operation . . . . . 36
2.24 Timers and watchdogs . . . . . 36
2.24.1 Advanced-control timers (TIM1, TIM8) . . . . . 37
2.24.2 General-purpose timers (TIMx) . . . . . 38
2.24.3 Basic timers TIM6 and TIM7 . . . . . 38
2.24.4 Independent watchdog . . . . . 38
2.24.5 Window watchdog . . . . . 38
2.24.6 SysTick timer . . . . . 39
2.25 Inter-integrated circuit interface ($I^2C$) . . . . . 39
2.26 Universal synchronous/asynchronous receiver transmitters (USART) . . 39
2.27 Serial peripheral interface (SPI) . . . . . 40
2.28 Inter-integrated sound ($I^2S$) . . . . . 40
2.29 Serial Audio interface (SAI1) . . . . . 41
2.30 Audio PLL (PLLI2S) . . . . . 41
2.31 Audio and LCD PLL(PLLSAI) . . . . . 41
2.32 Secure digital input/output interface (SDIO) . . . . . 41
2.33 Ethernet MAC interface with dedicated DMA and IEEE 1588 support . . . 42
2.34 Controller area network (bxCAN) . . . . . 42
2.35 Universal serial bus on-the-go full-speed (OTG_FS) . . . . . 43
2.36 Universal serial bus on-the-go high-speed (OTG_HS) . . . . . 43
2.37 Digital camera interface (DCMI) . . . . . 44
2.38 True random number generator (RNG) . . . . . 44
2.39 General-purpose input/outputs (GPIOs) . . . . . 44
2.40 Analog-to-digital converters (ADCs) . . . . . 44
2.41 Temperature sensor . . . . . 45
2.42 Digital-to-analog converter (DAC) . . . . . 45
2.43 Serial wire JTAG debug port (SWJ-DP) . . . . . 45
2.44 Embedded Trace Macrocell™ . . . . . 45

**3 Pinouts and pin description . . . . . 47**

4 Memory mapping . . . . . 83

5 Electrical characteristics . . . . . 88

5.1 Parameter conditions . . . . . 88
5.1.1 Minimum and maximum values . . . . . 88
5.1.2 Typical values . . . . . 88
5.1.3 Typical curves . . . . . 88
5.1.4 Loading capacitor . . . . . 88
5.1.5 Pin input voltage . . . . . 88
5.1.6 Power supply scheme . . . . . 89
5.1.7 Current consumption measurement . . . . . 90
5.2 Absolute maximum ratings . . . . . 90
5.3 Operating conditions . . . . . 92
5.3.1 General operating conditions . . . . . 92
5.3.2 VCAP1/VCAP2 external capacitor . . . . . 94
5.3.3 Operating conditions at power-up / power-down (regulator ON) . . . . . 95
5.3.4 Operating conditions at power-up / power-down (regulator OFF) . . . . . 95
5.3.5 Reset and power control block characteristics . . . . . 95
5.3.6 Overdrive switching characteristics . . . . . 97
5.3.7 Supply current characteristics . . . . . 97
5.3.8 Wake-up time from low-power modes . . . . . 113
5.3.9 External clock source characteristics . . . . . 114
5.3.10 Internal clock source characteristics . . . . . 118
5.3.11 PLL characteristics . . . . . 119
5.3.12 PLL spread spectrum clock generation (SSCG) characteristics . . . . . 122
5.3.13 MIPI D-PHY characteristics . . . . . 123
5.3.14 MIPI D-PHY PLL characteristics . . . . . 126
5.3.15 MIPI D-PHY regulator characteristics . . . . . 127
5.3.16 Memory characteristics . . . . . 128
5.3.17 EMC characteristics . . . . . 130
5.3.18 Absolute maximum ratings (electrical sensitivity) . . . . . 132
5.3.19 I/O current injection characteristics . . . . . 133
5.3.20 I/O port characteristics . . . . . 134
5.3.21 NRST pin characteristics . . . . . 140
5.3.22 TIM timer characteristics . . . . . 141
5.3.23 Communications interfaces . . . . . 141
5.3.24 12-bit ADC characteristics . . . . . 156

5.3.25 Temperature sensor characteristics . . . 163
5.3.26 $V_{BAT}$ monitoring characteristics . . . 163
5.3.27 Reference voltage . . . 163
5.3.28 DAC electrical characteristics . . . 164
5.3.29 FMC characteristics . . . 166
5.3.30 Quad-SPI interface characteristics . . . 185
5.3.31 Camera interface (DCMI) timing specifications . . . 186
5.3.32 LCD-TFT controller (LTDC) characteristics . . . 187
5.3.33 SD/SDIO MMC card host interface (SDIO) characteristics . . . 189
5.3.34 RTC characteristics . . . 191

**6 Package information . . . 192**
6.1 Device marking . . . 192
6.2 LQFP100 package information (1L) . . . 192
6.3 LQFP144 package information (1A) . . . 196
6.4 WLCSP168 package information . . . 200
6.5 UFBGA169 package information (A0YV) . . . 202
6.6 LQFP176 package information (1T) . . . 205
6.7 UFBGA(176+25) package information (A0E7) . . . 209
6.8 TFBGA216 package information (A0L2) . . . 211
6.9 LQFP208 package information . . . 215
6.10 Thermal characteristics . . . 218

**7 Part numbering . . . 219**

**8 Important security notice . . . 220**

**Appendix A Recommendations when using internal reset OFF . . . 221**
A.1 Operating conditions . . . 221

**Revision history . . . 222**

# List of tables


Table 1. Device summary . . . 1
Table 2. STM32F469xx features and peripheral counts . . . 12
Table 3. Voltage regulator configuration mode versus device operating mode . . . 31
Table 4. Regulator ON/OFF and internal reset ON/OFF availability . . . 34
Table 5. Voltage regulator modes in stop mode . . . 36
Table 6. Timer feature comparison . . . 37
Table 7. Comparison of I2C analog and digital filters . . . 39
Table 8. USART feature comparison . . . 40
Table 9. Legend/abbreviations used in the pinout table . . . 55
Table 10. STM32F469xx pin and ball definitions . . . 56
Table 11. FMC pin definition . . . 70
Table 12. Alternate function . . . 73
Table 13. STM32F469xx register boundary addresses . . . 84
Table 14. Voltage characteristics . . . 90
Table 15. Current characteristics . . . 91
Table 16. Thermal characteristics . . . 91
Table 17. General operating conditions . . . 92
Table 18. Limitations depending on the operating power supply range . . . 94
Table 19. VCAP1/VCAP2 operating conditions . . . 95
Table 20. Operating conditions at power-up / power-down (regulator ON) . . . 95
Table 21. Operating conditions at power-up / power-down (regulator OFF) . . . 95
Table 22. Reset and power control block characteristics . . . 96
Table 23. Over-drive switching characteristics . . . 97
Table 24. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled except prefetch) or RAM, regulator ON . . . 99
Table 25. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator disabled), regulator ON . . . 100
Table 26. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled except prefetch), regulator OFF . . . 101
Table 27. Typical and maximum current consumption in Sleep mode, regulator ON . . . 102
Table 28. Typical and maximum current consumption in Sleep mode, regulator OFF . . . 103
Table 29. Typical and maximum current consumption in Stop mode . . . 104
Table 30. Typical and maximum current consumption in Standby mode . . . 105
Table 31. Typical and maximum current consumption in $V_{BAT}$ mode . . . 106
Table 32. Switching output I/O current consumption . . . 108
Table 33. Peripheral current consumption . . . 110
Table 34. Low-power mode wakeup timings . . . 113
Table 35. High-speed external user clock characteristics . . . 114
Table 36. Low-speed external user clock characteristics . . . 114
Table 37. HSE 4-26 MHz oscillator characteristics . . . 116
Table 38. LSE oscillator characteristics ($f_{LSE}$ = 32.768 kHz) . . . 117
Table 39. HSI oscillator characteristics . . . 118
Table 40. LSI oscillator characteristics . . . 119
Table 41. Main PLL characteristics . . . 119
Table 42. PLLI2S (audio PLL) characteristics . . . 120
Table 43. PLLSAI (audio and LCD-TFT PLL) characteristics . . . 121

Table 44. SSCG parameters constraint . . . 122
Table 45. MIPI D-PHY characteristics . . . 123
Table 46. MIPI D-PHY AC characteristics LP mode and HS/LP transitions . . . 125
Table 47. DSI-PLL characteristics . . . 126
Table 48. DSI regulator characteristics . . . 127
Table 49. Flash memory characteristics . . . 128
Table 50. Flash memory programming . . . 128
Table 51. Flash memory programming with $V_{PP}$ . . . 129
Table 52. Flash memory endurance and data retention . . . 130
Table 53. EMS characteristics . . . 130
Table 54. EMI characteristics for fHSE=8 MHz and fCPU=168 MHz . . . 131
Table 55. EMI characteristics for fHSE=8 MHz and fCPU=180 MHz . . . 132
Table 56. ESD absolute maximum ratings . . . 132
Table 57. Electrical sensitivities . . . 133
Table 58. I/O current injection susceptibility . . . 133
Table 59. I/O static characteristics . . . 134
Table 60. Output voltage characteristics . . . 137
Table 61. I/O AC characteristics . . . 138
Table 62. NRST pin characteristics . . . 140
Table 63. TIMx characteristics . . . 141
Table 64. I2C analog filter characteristics . . . 141
Table 65. SPI dynamic characteristics . . . 142
Table 66. $I^2S$ dynamic characteristics . . . 146
Table 67. SAI characteristics . . . 148
Table 68. USB OTG full speed startup time . . . 150
Table 69. USB OTG full speed DC electrical characteristics . . . 150
Table 70. USB OTG full speed electrical characteristics . . . 151
Table 71. USB HS DC electrical characteristics . . . 151
Table 72. USB HS clock timing parameters . . . 152
Table 73. Dynamic characteristics: USB ULPI . . . 153
Table 74. Dynamics characteristics: Ethernet MAC signals for SMI . . . 154
Table 75. Dynamics characteristics: Ethernet MAC signals for RMII . . . 155
Table 76. Dynamics characteristics: Ethernet MAC signals for MII . . . 155
Table 77. ADC characteristics . . . 156
Table 78. ADC static accuracy at $f_{ADC}$ = 18 MHz . . . 159
Table 79. ADC static accuracy at $f_{ADC}$ = 30 MHz . . . 159
Table 80. ADC static accuracy at $f_{ADC}$ = 36 MHz . . . 159
Table 81. ADC dynamic accuracy at $f_{ADC}$ = 18 MHz - limited test conditions . . . 160
Table 82. ADC dynamic accuracy at $f_{ADC}$ = 36 MHz - limited test conditions . . . 160
Table 83. Temperature sensor characteristics . . . 163
Table 84. Temperature sensor calibration values . . . 163
Table 85. $V_{BAT}$ monitoring characteristics . . . 163
Table 86. internal reference voltage . . . 163
Table 87. Internal reference voltage calibration values . . . 164
Table 88. DAC characteristics . . . 164
Table 89. Asynchronous non-multiplexed SRAM/PSRAM/NOR - read timings . . . 168
Table 90. Asynchronous non-multiplexed SRAM/PSRAM/NOR read - NWAIT timings . . . 168
Table 91. Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings . . . 169
Table 92. Asynchronous non-multiplexed SRAM/PSRAM/NOR write - NWAIT timings . . . 170
Table 93. Asynchronous multiplexed PSRAM/NOR read timings . . . 171
Table 94. Asynchronous multiplexed PSRAM/NOR read-NWAIT timings . . . 171
Table 95. Asynchronous multiplexed PSRAM/NOR write timings . . . 172

Table 96. Asynchronous multiplexed PSRAM/NOR write-NWAIT timings . . . 173
Table 97. Synchronous multiplexed NOR/PSRAM read timings . . . 175
Table 98. Synchronous multiplexed PSRAM write timings . . . 177
Table 99. Synchronous non-multiplexed NOR/PSRAM read timings . . . 178
Table 100. Synchronous non-multiplexed PSRAM write timings . . . 179
Table 101. Switching characteristics for NAND Flash read cycles . . . 181
Table 102. Switching characteristics for NAND Flash write cycles . . . 181
Table 103. SDRAM read timings . . . 182
Table 104. LPSDR SDRAM read timings . . . 183
Table 105. SDRAM write timings . . . 184
Table 106. LPSDR SDRAM write timings . . . 184
Table 107. Quad-SPI characteristics in SDR mode . . . 185
Table 108. Quad-SPI characteristics in DDR mode . . . 186
Table 109. DCMI characteristics . . . 187
Table 110. LTDC characteristics . . . 188
Table 111. Dynamic characteristics: SD / MMC characteristics, VDD = 2.7 to 3.6 V . . . 190
Table 112. Dynamic characteristics: SD / MMC characteristics, VDD = 1.71 to 1.9 V . . . 191
Table 113. RTC characteristics . . . 191
Table 114. LQFP100 - Mechanical data . . . 193
Table 115. LQFP144 - Mechanical data . . . 197
Table 116. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package mechanical data . . . 201
Table 117. WLCSP168 recommended PCB design rules . . . 202
Table 118. UFBGA169 - Mechanical data . . . 202
Table 119. UFBGA169 - Example of PCB design rules (0.5 mm pitch BGA) . . . 203
Table 120. LQFP176 - Mechanical data . . . 206
Table 121. UFBGA(176+25) - Mechanical data . . . 209
Table 122. UFBGA(176+25) - Example of PCB design rules (0.65 mm pitch BGA) . . . 210
Table 123. TFBGA216 - Mechanical data . . . 212
Table 124. TFBGA216 - Example of PCB design rules (0.8 mm pitch) . . . 214
Table 125. LQFP208 - Mechanical data . . . 216
Table 126. Package thermal characteristics . . . 218
Table 127. Limitations depending on the operating power supply range . . . 221
Table 128. Document revision history . . . 222

# List of figures


Figure 1. Incompatible board design for LQFP176 package . . . 15
Figure 2. Incompatible board design for LQFP208 package . . . 16
Figure 3. UFBGA176 port-to-terminal assignment differences . . . 17
Figure 4. TFBGA216 port-to-terminal assignment differences. . . . 18
Figure 5. STM32F469xx block diagram . . . 19
Figure 6. STM32F469xx Multi-AHB matrix . . . 22
Figure 7. VDDUSB connected to an external independent power supply . . . 28
Figure 8. Power supply supervisor interconnection with internal reset OFF . . . 29
Figure 9. PDR_ON control with internal reset OFF . . . 30
Figure 10. Regulator OFF . . . 32
Figure 11. Startup in regulator OFF: slow $V_{DD}$ slope
- power-down reset risen after $V_{CAP_1}$, $V_{CAP_2}$ stabilization . . . 33
Figure 12. Startup in regulator OFF mode: fast $V_{DD}$ slope
- power-down reset risen before $V_{CAP_1}$, $V_{CAP_2}$ stabilization . . . 34
Figure 13. STM32F46x LQFP100 pinout . . . 47
Figure 14. STM32F46x LQFP144 pinout . . . 48
Figure 15. STM32F46x WLCSP168 pinout . . . 49
Figure 16. STM32F46x UFBGA169 ballout . . . 50
Figure 17. STM32F46x UFBGA176 ballout . . . 51
Figure 18. STM32F46x LQFP176 pinout . . . 52
Figure 19. STM32F46x LQFP208 pinout . . . 53
Figure 20. STM32F46x TFBGA216 ballout . . . 54
Figure 21. Memory map . . . 83
Figure 22. Pin loading conditions . . . 88
Figure 23. Pin input voltage . . . 88
Figure 24. Power supply scheme . . . 89
Figure 25. Current consumption measurement scheme . . . 90
Figure 26. External capacitor $C_{EXT}$ . . . 94
Figure 27. Typical $V_{BAT}$ current consumption
(RTC ON / backup SRAM ON and LSE in Low drive mode) . . . 106
Figure 28. Typical $V_{BAT}$ current consumption
(RTC ON / backup SRAM ON and LSE in High drive mode) . . . 107
Figure 29. High-speed external clock source AC timing diagram . . . 115
Figure 30. Low-speed external clock source AC timing diagram . . . 115
Figure 31. Typical application with an 8 MHz crystal . . . 116
Figure 32. Typical application with a 32.768 kHz crystal . . . 117
Figure 33. ACCHSI vs. temperature . . . 118
Figure 34. $ACC_{LSI}$ versus temperature . . . 119
Figure 35. PLL output clock waveforms in center spread mode . . . 123
Figure 36. PLL output clock waveforms in down spread mode . . . 123
Figure 37. MIPI D-PHY HS/LP clock lane transition timing diagram . . . 126
Figure 38. MIPI D-PHY HS/LP data lane transition timing diagram . . . 126
Figure 39. FT I/O input characteristics . . . 136
Figure 40. I/O AC characteristics definition . . . 139
Figure 41. Recommended NRST pin protection . . . 140
Figure 42. SPI timing diagram - slave mode and CPHA = 0 . . . 144
Figure 43. SPI timing diagram - slave mode and CPHA = 1 . . . 144
Figure 44. SPI timing diagram - master mode . . . 145

Figure 45. $I^2S$ slave timing diagram (Philips protocol)(1) . . . 147
Figure 46. $I^2S$ master timing diagram (Philips protocol)(1) . . . 147
Figure 47. SAI master timing waveforms . . . 149
Figure 48. SAI slave timing waveforms . . . 149
Figure 49. USB OTG full speed timings: definition of data signal rise and fall time . . . 151
Figure 50. ULPI timing diagram . . . 152
Figure 51. Ethernet SMI timing diagram . . . 153
Figure 52. Ethernet RMII timing diagram . . . 154
Figure 53. Ethernet MII timing diagram . . . 155
Figure 54. ADC accuracy characteristics . . . 161
Figure 55. Typical connection diagram using the ADC with FT/TT pins featuring analog switch funcion 161
Figure 56. Power supply and reference decoupling ($V_{REF+}$ not connected to $V_{DDA}$) . . . 162
Figure 57. Power supply and reference decoupling ($V_{REF+}$ connected to $V_{DDA}$) . . . 162
Figure 58. 12-bit buffered/non-buffered DAC . . . 166
Figure 59. Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms . . . 167
Figure 60. Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms . . . 169
Figure 61. Asynchronous multiplexed PSRAM/NOR read waveforms . . . 170
Figure 62. Asynchronous multiplexed PSRAM/NOR write waveforms . . . 172
Figure 63. Synchronous multiplexed NOR/PSRAM read timings . . . 174
Figure 64. Synchronous multiplexed PSRAM write timings . . . 176
Figure 65. Synchronous non-multiplexed NOR/PSRAM read timings . . . 178
Figure 66. Synchronous non-multiplexed PSRAM write timings . . . 179
Figure 67. NAND controller waveforms for read access . . . 180
Figure 68. NAND controller waveforms for write access . . . 181
Figure 69. SDRAM read access waveforms (CL = 1) . . . 182
Figure 70. SDRAM write access waveforms . . . 183
Figure 71. Quad-SPI SDR timing diagram . . . 185
Figure 72. Quad-SPI DDR timing diagram . . . 186
Figure 73. DCMI timing diagram . . . 187
Figure 74. LCD-TFT horizontal timing diagram . . . 188
Figure 75. LCD-TFT vertical timing diagram . . . 189
Figure 76. SDIO high-speed mode . . . 189
Figure 77. SD default mode . . . 190
Figure 78. LQFP100 - Outline(15) . . . 193
Figure 79. LQFP100 - Footprint example . . . 195
Figure 80. LQFP144 - Outline(15) . . . 196
Figure 81. LQFP144 - Footprint example . . . 199
Figure 82. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package outline . . . 200
Figure 83. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package recommended footprint . . . 201
Figure 84. UFBGA169 - Outline . . . 202
Figure 85. UFBGA169 - Footprint example . . . 203
Figure 86. LQFP176 - Outline(15) . . . 205
Figure 87. LQFP176 - Footprint example . . . 208
Figure 88. UFBGA(176+25) - Outline . . . 209
Figure 89. UFBGA(176+25) - Footprint example . . . 210
Figure 90. TFBGA216 - Outline . . . 211
Figure 91. TFBGA216 - Footprint example . . . 213
Figure 92. LQFP208 - Outline(15) . . . 215
Figure 93. LQFP208 - footprint example . . . 217

# 1 Description

The STM32F469xx devices are based on the high-performance Arm®(a) Cortex®-M4 32-bit RISC core operating at a frequency of up to 180 MHz. The Cortex®-M4 core features a floating-point unit (FPU) single precision which supports all Arm® single-precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The STM32F469xx devices incorporate high-speed embedded memories (Flash memory up to 2 Mbytes, up to 384 Kbytes of SRAM), up to 4 Kbytes of backup SRAM, and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

All devices offer three 12-bit ADCs, two DACs, a low-power RTC, twelve general-purpose 16-bit timers including two PWM timers for motor control, two general-purpose 32-bit timers, and a true random number generator (RNG). They also feature standard and advanced communication interfaces.

- Up to three $I^2C$s
- Six SPIs, two $I^2S$s full duplex. To achieve audio class accuracy, the $I^2S$ peripherals can be clocked via a dedicated internal audio PLL or via an external clock to allow synchronization.
- Four USARTs plus four UARTs
- One USB OTG full-speed and one USB OTG high-speed with full-speed capability (with the ULPI)
- Two CANs
- One SAI serial audio interface
- An SDMMC host interface
- Ethernet and camera interface
- LCD-TFT display controller
- Chrom-ART Accelerator™
- DSI Host.

Advanced peripherals include an SDMMC interface, a flexible memory control (FMC) interface, a Quad-SPI flash memory, and a camera interface for CMOS sensors. Refer to *Table 2* for the list of peripherals available on each part number.

The STM32F469xx devices operate in the –40 to +105 °C temperature range from a 1.7 to 3.6 V power supply. A dedicated supply input for USB (OTG_FS and OTG_HS) only in full speed mode, is available on all packages.

The supply voltage can drop to 1.7 V (refer to *Section 2.19.2*). A comprehensive set of power-saving modes allows the design of low-power applications.

The STM32F469xx devices are offered in eight packages, ranging from 100 to 216 pins. The set of included peripherals changes with the device chosen, according to *Table 2*.

arm

a. Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

These features make the STM32F469xx microcontrollers suitable for a wide range of applications:

- Motor drive and application control
- Medical equipment
- Industrial applications: PLC, inverters, circuit breakers
- Printers, and scanners
- Alarm systems, video intercom, and HVAC
- Home audio appliances

*Figure 5* shows the general block diagram of the device family.

**Table 2. STM32F469xx features and peripheral counts**

| Peripherals | | STM32F469Vx | STM32F469Zx | STM32F469Ax | STM32F469Ix | STM32F469Bx | STM32F469Nx |
|---|---|---|---|---|---|---|---|
| Flash memory in Kbytes | | 512<br>1024<br>2048 | 512<br>1024<br>2048 | 512<br>1024<br>2048 | 512<br>1024<br>2048 | 512<br>1024<br>2048 | 512<br>1024<br>2048 |
| SRAM in Kbytes | System | 384 (160+32+128+64) | | | | | |
| | Backup | 4 | | | | | |
| FMC memory controller | | Yes | | | | | |
| Quad-SPI | | Yes | | | | | |
| Ethernet | | No | | | Yes | | |
| Timers | General-purpose | 10 | | | | | |
| | Advanced-control | 2 | | | | | |
| | Basic | 2 | | | | | |
| Random number generator | | Yes | | | | | |
| Communication interfaces | SPI / $I^2S$ | 4/2(full duplex)(1) | | 6/2(full duplex)(1) | | | |
| | $I^2C$ | 3 | | | | | |
| | USART/UART | 4/3 | | 4/4 | | | |
| | USB OTG FS | Yes | | | | | |
| | USB OTG HS | Yes | | | | | |
| | CAN | 2 | | | | | |
| | SAI | 1 | | | | | |
| | SDIO | Yes | | | | | |
| Camera interface | | Yes | | | | | |
| MIPI-DSI Host | | Yes | | | | | |

**Table 2. STM32F469xx features and peripheral counts (continued)**

| Peripherals | STM32F469Vx | STM32F469Zx | STM32F469Ax | STM32F469Ix | STM32F469Bx | STM32F469Nx |
|---|---|---|---|---|---|---|
| LCD-TFT | Yes | | | | | |
| Chrom-ART Accelerator™ (DMA2D) | Yes | | | | | |
| GPIOs | 71 | 106 | 128 | 131 | 161 | 161 |
| 12-bit ADC<br>Number of channels | 3 | | | | | |
| | 14 | 20 | 24 | 16 | 24 | 24 |
| 12-bit DAC<br>Number of channels | Yes<br>2 | | | | | |
| Maximum CPU frequency | 180 MHz | | | | | |
| Operating voltage | 1.7 to 3.6V(2) | | | | | |
| Operating temperatures | Ambient operating temperature: −40 to 85 °C / −40 to 105 °C<br>Junction temperature: −40 to 105 °C / −40 to 125 °C | | | | | |
| Package | LQFP100 | LQPF144 | UFBGA169<br>WLCSP168 | LQFP176<br>UFBGA176 | LQFP208 | TFBGA216 |

1. The SPI2 and SPI3 interfaces give the flexibility to work in an exclusive way in either the SPI mode or the I2S audio mode.
2. VDD/VDDA minimum value of 1.7 V is obtained when the internal reset is OFF (refer to *Section 2.19.2*).

For information on the device errata with respect to the datasheet and reference manual, refer to the errata sheet (ES0321), available from the STMicroelectronics website *www.st.com*.

## 1.1 Compatibility throughout the family

STM32F469xx devices are not compatible with other STM32F4xx devices.

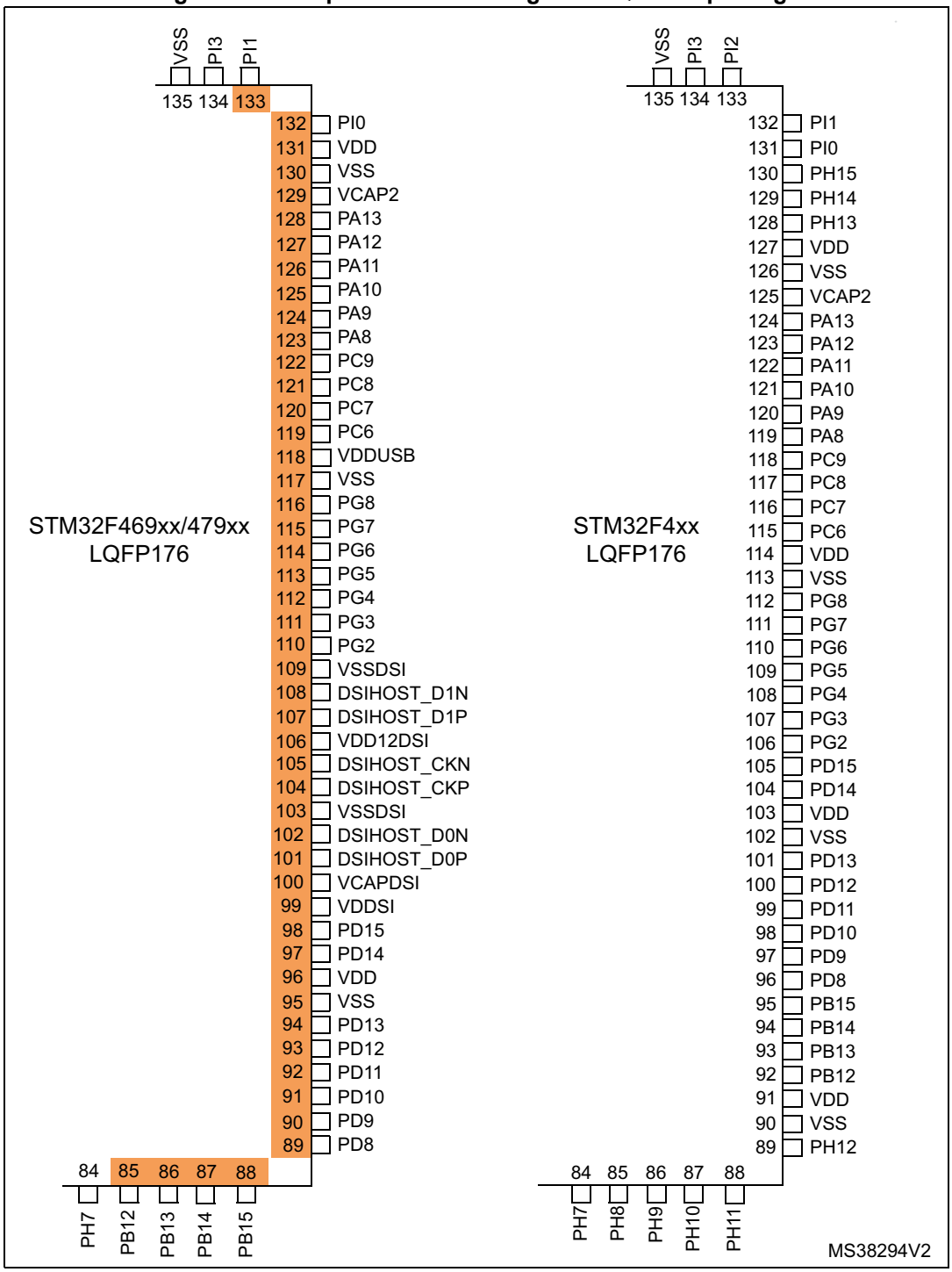
*Figure 1* and *Figure 2* show incompatible board designs, respectively, for LQFP176 and LQFP208 packages (highlighted pins).

The UFBGA176 and TFBGA216 ballouts are compatible with other STM32F4xx devices, only a few IO port pins are substituted, as shown in *Figure 3* and *Figure 4*.

The LQFP100, LQFP144, and UFBGA169 packages are incompatible with other STM32F4xx devices.

### 1.1.1 LQFP176 package

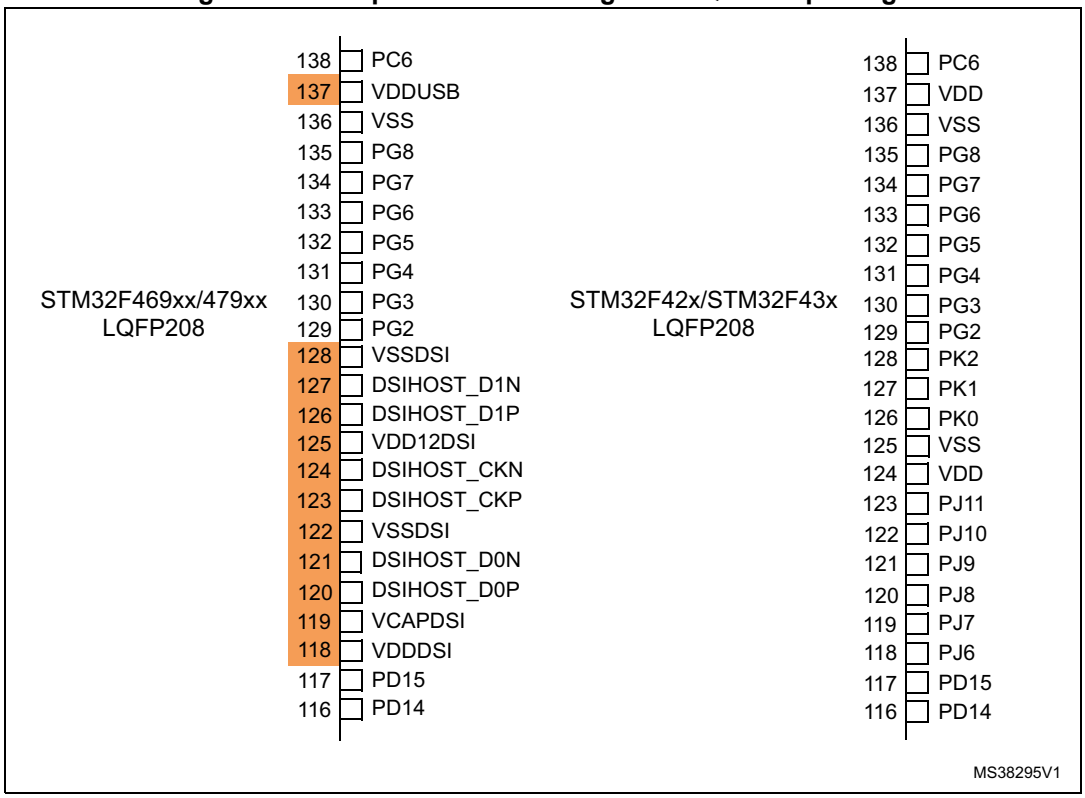
**Figure 1. Incompatible board design for LQFP176 package**




1. Pins from 85 to 133 are not compatible.

### 1.1.2 LQFP208 package

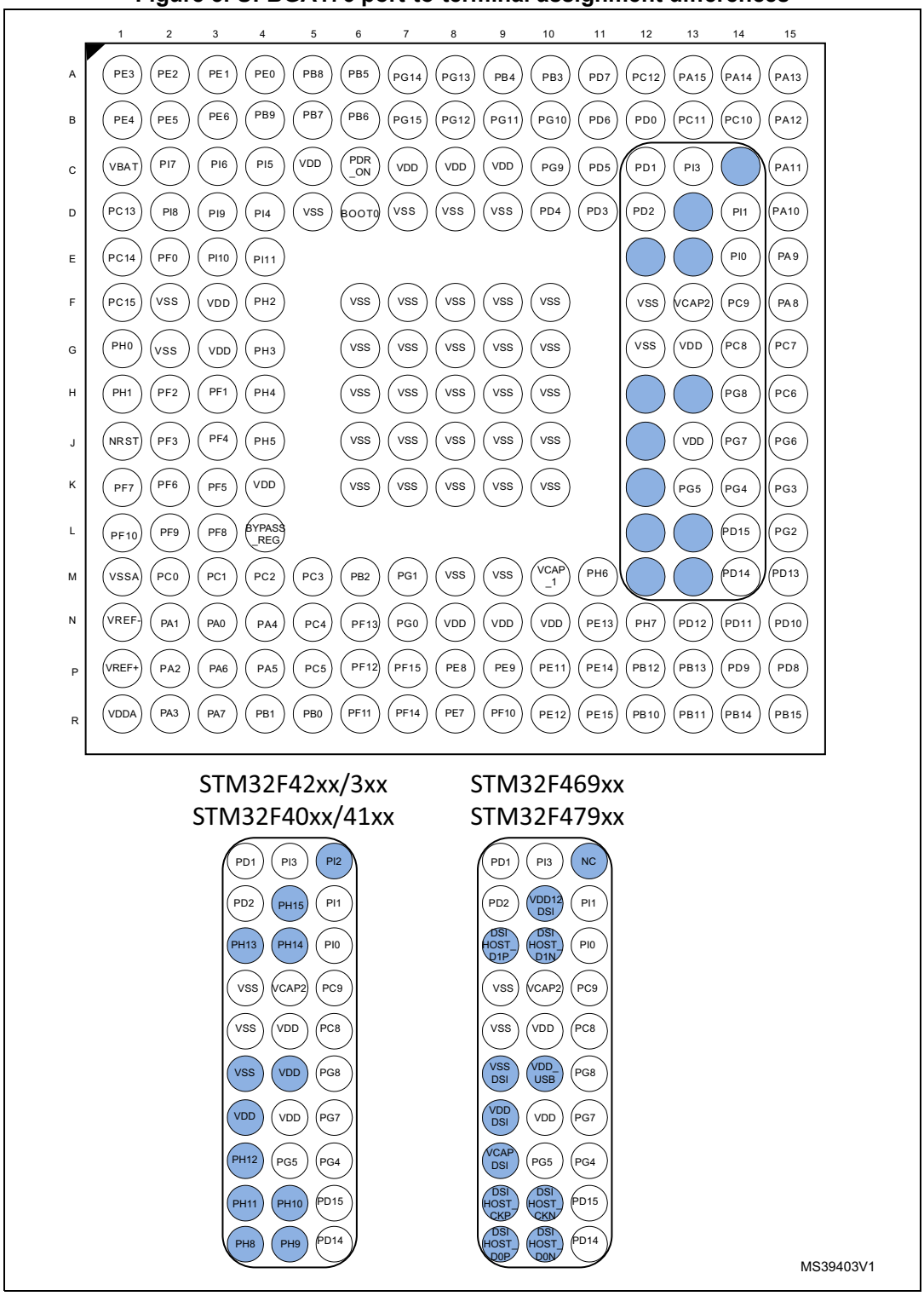
**Figure 2. Incompatible board design for LQFP208 package**




1. Pins from 118 to 128 and pin 137 are not compatible.

### 1.1.3 UFBGA176 package

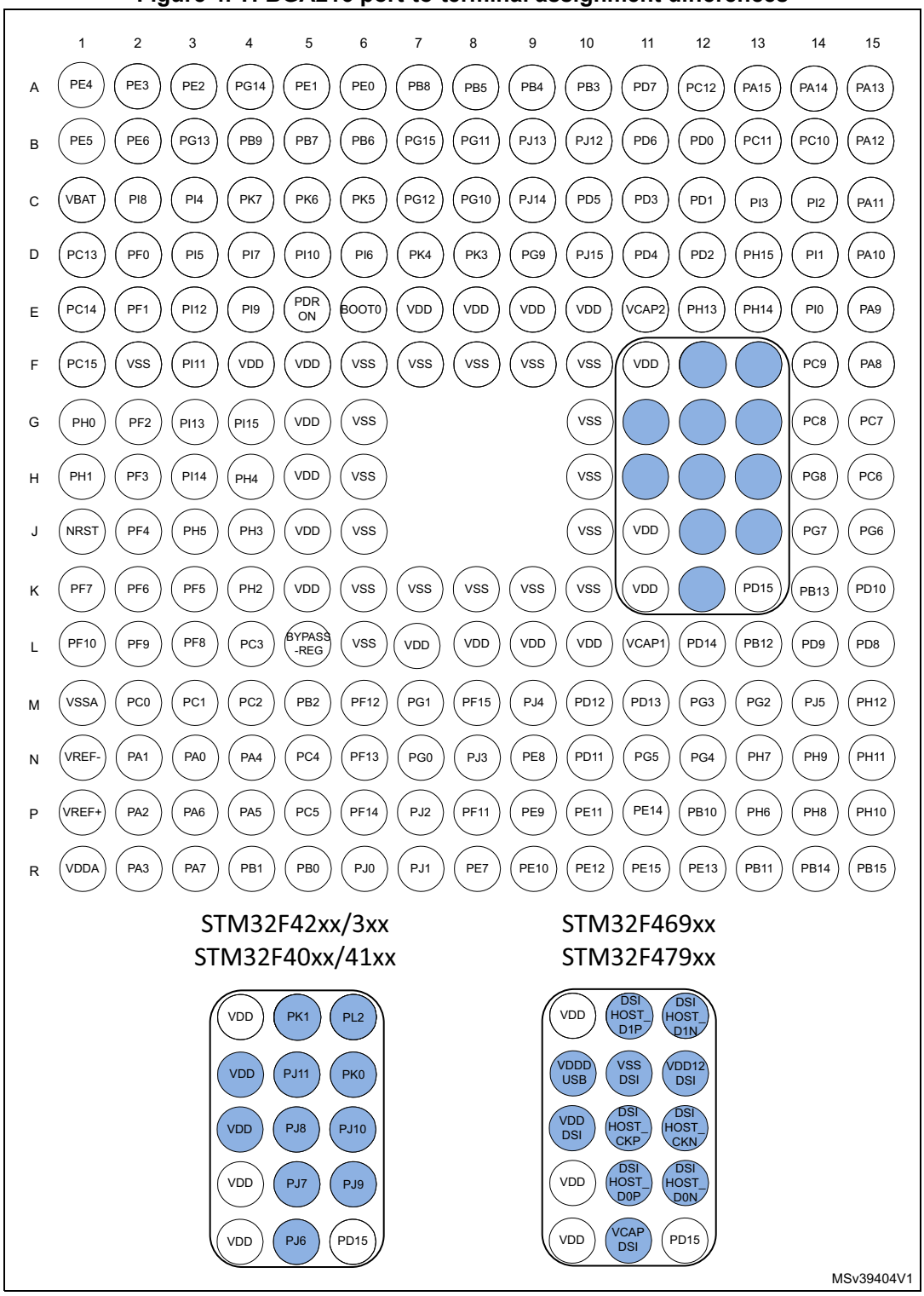
**Figure 3. UFBGA176 port-to-terminal assignment differences**




1. The highlighted pins are substituted with dedicated DSI IO pins on STM32F469xx/479xx devices.

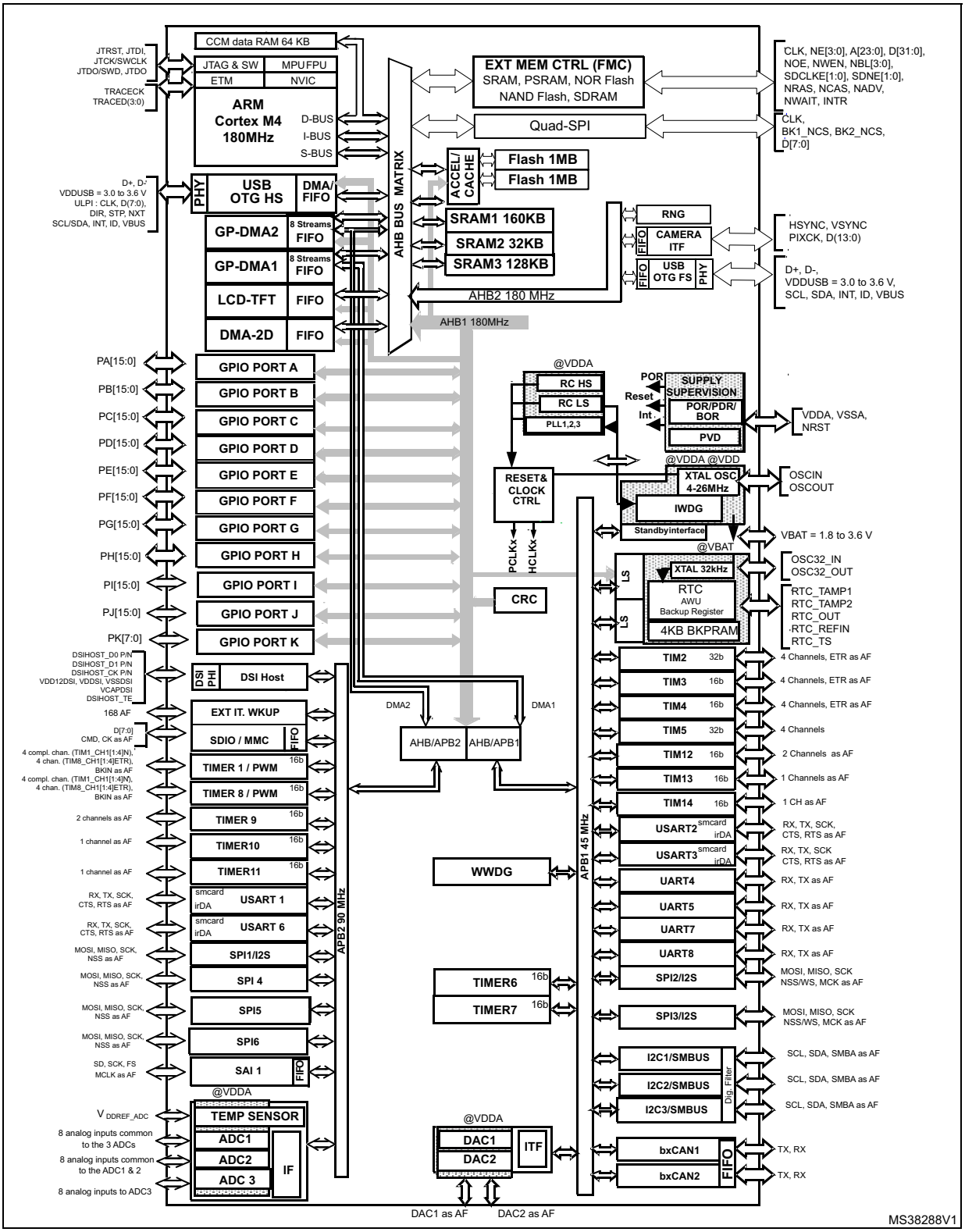
### 1.1.4 TFBGA216 package

**Figure 4. TFBGA216 port-to-terminal assignment differences**




1. The highlighted pins are substituted with dedicated DSI IO pins on STM32F469xx/479xx devices.

**Figure 5. STM32F469xx block diagram**




1. The timers connected to APB2 are clocked from TIMxCLK up to 180 MHz, while the timers connected to APB1 are clocked from TIMxCLK either up to 90 MHz or 180 MHz depending on TIMPRE bit configuration in the RCC_DCKCFGR register.

# 2 Functional overview

## 2.1 Arm® Cortex®-M4 with FPU and embedded flash and SRAM

The Arm® Cortex®-M4 with FPU processor is the latest generation of Arm® processors for embedded systems, 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 response to interrupts.

The Arm® Cortex®-M4 with FPU core is a 32-bit RISC processor that 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 processor supports a set of DSP instructions that allow efficient signal processing and complex algorithm execution. Its single-precision FPU (floating-point unit) speeds up software development by using metalanguage development tools, while avoiding saturation.

The STM32F46x line is compatible with all Arm® tools and software.

*Figure 5* shows the general block diagram of the STM32F46x line.

*Note: Cortex®-M4 with FPU core is binary compatible with the Cortex®-M3 core.*

## 2.2 Adaptive real-time memory accelerator (ART Accelerator™)

The ART Accelerator™ is a memory accelerator optimized for STM32 industry-standard Arm® Cortex®-M4 with FPU processors. It balances the inherent performance advantage of the Arm® Cortex®-M4 with FPU over flash memory technologies, which normally require the processor to wait for the flash memory at higher frequencies.

To release the processor full 225 DMIPS performance at this frequency, the accelerator implements an instruction prefetch queue and branch cache, which increases program execution speed from the 128-bit flash memory. Based on the CoreMark® benchmark, the performance achieved thanks to the ART Accelerator is equivalent to 0 wait state program execution from flash memory at a CPU frequency up to 180 MHz.

## 2.3 Memory protection unit

The memory protection unit (MPU) is used to manage the CPU access to memory to prevent one task to accidentally corrupt the memory or resources used by any other active task. This memory area is organized into up to 8 protected areas that can in turn be divided up into 8 subareas. The protection area sizes are between 32 bytes and the whole 4 Gbytes of addressable memory.

The MPU is especially helpful for applications where some critical or certified code has to be protected against the misbehavior of other tasks. It is usually managed by an RTOS (real-time operating system). If a program accesses a memory location that is prohibited by the MPU, the RTOS can detect it and take action. In an RTOS environment, the kernel can dynamically update the MPU area setting, based on the process to be executed.

The MPU is optional and can be bypassed for applications that do not need it.

## 2.4 Embedded flash memory

The devices embed 512 bytes of OTP memory and a flash memory of up to 2 Mbytes available for storing programs and data.

## 2.5 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 software signature during runtime, to be compared with a reference signature generated at link-time and stored at a given memory location.

## 2.6 Embedded SRAM

All devices embed:

- Up to 384 Kbytes of system SRAM including 64 Kbytes of CCM (core coupled memory) data RAM

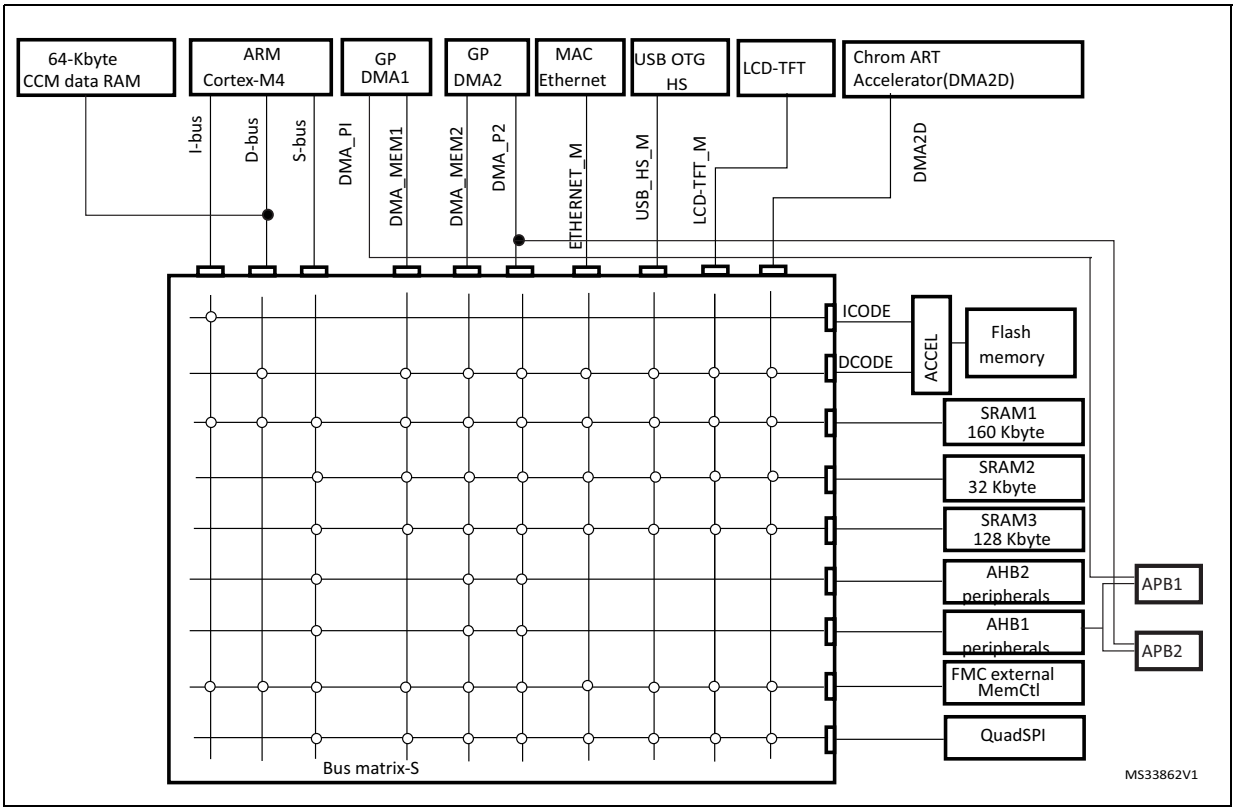
  RAM is accessed (read/write) at CPU clock speed with 0 wait states.
- 4 Kbytes of backup SRAM

  This area is accessible only from the CPU. Its content is protected against possible unwanted write access, and is retained in Standby or $V_{BAT}$ mode.

## 2.7 Multi-AHB bus matrix

The 32-bit multi-AHB bus matrix interconnects all the masters (CPU, DMAs, Ethernet, USB HS, LCD-TFT, and DMA2D) and the slaves (Flash memory, RAM, FMC, QUADSPI, AHB, and APB peripherals) and ensures a seamless and efficient operation even when several high-speed peripherals work simultaneously.

**Figure 6. STM32F469xx Multi-AHB matrix**




## 2.8 DMA controller (DMA)

The devices feature two general-purpose dual-port DMAs (DMA1 and DMA2) with 8 streams each. They are able to manage memory-to-memory, peripheral-to-memory, and memory-to-peripheral transfers. They feature dedicated FIFOs for APB/AHB peripherals, support burst transfer and are designed to provide the maximum peripheral bandwidth (AHB/APB).

The two DMA controllers support circular buffer management, so that no specific code is needed when the controller reaches the end of the buffer. The two DMA controllers also have a double buffering feature, which automates the use and switching of two memory buffers without requiring any special code.

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

The DMA can be used with the main peripherals:

- SPI and $I^2S$
- $I^2C$
- USART
- General-purpose, basic, and advanced-control timers TIMx
- DAC
- SDIO
- Camera interface (DCMI)
- ADC
- SAI1
- QUADSPI.

## 2.9 Flexible memory controller (FMC)

The flexible memory controller (FMC) includes three memory controllers:

- The NOR/PSRAM memory controller
- The NAND/memory controller
- The synchronous DRAM (SDRAM/Mobile LPSDR SDRAM) controller

The main features of the FMC controller are the following:

- Interface with static-memory mapped devices including:
  - Static random-access memory (SRAM)
  - NOR flash memory/OneNAND flash memory
  - PSRAM
  - NAND flash memory with ECC hardware to check up to 8 Kbytes of data
- Interface with synchronous DRAM (SDRAM/Mobile LPSDR SDRAM) memories
- 8-,16-,32-bit data bus width
- Independent Chip Select control for each memory bank
- Independent configuration for each memory bank
- Write FIFO
- Read FIFO for SDRAM controller
- The Maximum FMC_CLK/FMC_SDCLK frequency for synchronous access is HCLK/2.

### LCD parallel interface

The FMC can be configured to interface seamlessly with most graphic LCD controllers. It supports the Intel 8080 and Motorola 6800 modes, and is flexible enough to adapt to specific LCD interfaces. This LCD parallel interface capability makes it easy to build cost-effective graphic applications using LCD modules with embedded controllers or high performance solutions using external controllers with dedicated acceleration.

## 2.10 Quad-SPI memory interface (QUADSPI)

All STM32F469xx devices embed a Quad-SPI memory interface, which is a specialized communication interface targeting Single, Dual, Quad or Dual-flash SPI memories. It can work in direct mode through registers, external flash status register polling mode and memory mapped mode. Up to 256 Mbytes external flash memory are mapped, supporting 8, 16 and 32-bit access. Code execution is supported.

The opcode and the frame format are fully programmable. Communication can be either in Single Data Rate or Dual Data Rate.

## 2.11 LCD-TFT controller

The LCD-TFT display controller provides a 24-bit parallel digital RGB (Red, Green, Blue) and delivers all signals to interface directly to a broad range of LCD and TFT panels up to XGA (1024x768) resolution with the following features:

- 2 display layers with dedicated FIFO (64x32-bit)
- Color Look-Up table (CLUT) up to 256 colors (256x24-bit) per layer
- Up to 8 Input color formats selectable per layer
- Flexible blending between two layers using alpha value (per pixel or constant)
- Flexible programmable parameters for each layer
- Color keying (transparency color)
- Up to 4 programmable interrupt events.

## 2.12 DSI Host (DSIHOST)

The DSI Host is a dedicated peripheral for interfacing with MIPI® DSI compliant displays. It includes a dedicated video interface internally connected to the LTDC and a generic APB interface that can be used to transmit information to the display.

These interfaces are as follows:

- LTDC interface:
  - Used to transmit information in Video Mode, in which the transfers from the host processor to the peripheral take the form of a real-time pixel stream (DPI).
  - Through a customized for mode, this interface can be used to transmit information in full bandwidth in the Adapted Command Mode (DBI).
- APB slave interface:
  - Allows the transmission of generic information in Command mode, and follows a proprietary register interface.
  - Can operate concurrently with either LTDC interface in either Video Mode or Adapted Command Mode.
- Video mode pattern generator:
  - Allows the transmission of horizontal/vertical color bar and D-PHY BER testing pattern without any kind of stimuli.

The DSI Host main features:

- Compliant with MIPI® Alliance standards
- Interface with MIPI® D-PHY
- Supports all commands defined in the MIPI® Alliance specification for DCS:
  - Transmission of all Command mode packets through the APB interface
  - Transmission of commands in low-power and high-speed during Video Mode
- Supports up to two D-PHY data lanes
- Bidirectional communication and escape mode support through data lane 0
- Supports non-continuous clock in D-PHY clock lane for additional power saving
- Supports Ultra Low-Power mode with PLL disabled
- ECC and Checksum capabilities
- Support for End of Transmission Packet (EoTp)
- Fault recovery schemes
- 3D transmission support
- Configurable selection of system interfaces:
  - AMBA APB for control and optional support for Generic and DCS commands
  - Video Mode interface through LTDC
  - Adapted Command Mode interface through LTDC
- Independently programmable Virtual Channel ID in
  - Video Mode
  - Adapted Command Mode
  - APB Slave

### Video Mode interfaces features

- LTDC interface color coding mappings into 24-bit interface:
  - 16-bit RGB, configurations 1, 2, and 3
  - 18-bit RGB, configurations 1 and 2
  - 24-bit RGB
- Programmable polarity of all LTDC interface signals
- Maximum resolution is limited by available DSI physical link bandwidth:
  - Number of lanes: 2
  - Maximum speed per lane: 500 Mbps

### Adapted interface features

- Support for sending large amounts of data through the *memory_write_start* (WMS) and *memory_write_continue* (WMC) DCS commands
- LTDC interface color coding mappings into 24-bit interface:
  - 16-bit RGB, configurations 1, 2, and 3
  - 18-bit RGB, configurations 1 and 2
  - 24-bit RGB

### Video mode pattern generator

- Vertical and horizontal color bar generation without LTDC stimuli
- BER pattern without LTDC stimuli

## 2.13 Chrom-ART Accelerator™ (DMA2D)

The Chrom-Art Accelerator™ (DMA2D) is a graphic accelerator which offers advanced bit blitting, row data copy and pixel format conversion. It supports the following functions:

- Rectangle filling with a fixed color
- Rectangle copy
- Rectangle copy with pixel format conversion
- Rectangle composition with blending and pixel format conversion.

Various image format coding are supported, from indirect 4bpp color mode up to 32bpp direct color. It embeds dedicated memory to store color lookup tables.

An interrupt can be generated when an operation is complete or at a programmed watermark.

All the operations are fully automatized and are running independently from the CPU or the DMAs.

## 2.14 Nested vectored interrupt controller (NVIC)

The devices embed a nested vectored interrupt controller able to manage 16 priority levels, and handle up to 93 maskable interrupt channels plus the 16 interrupt lines of the Cortex®-M4 with FPU core.

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

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

## 2.15 External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 23 edge-detector lines used to generate interrupt/event requests. Each line can be independently configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the Internal APB2 clock period. Up to 159 GPIOs can be connected to the 16 external interrupt lines.

## 2.16 Clocks and startup

On reset the 16 MHz internal RC oscillator is selected as the default CPU clock. The 16 MHz internal RC oscillator is factory-trimmed to offer 1% accuracy over the full temperature range. The application can then select as system clock either the RC oscillator or an external 4-26 MHz clock source. This clock can be monitored for failure. If a failure is detected, the system automatically switches back to the internal RC oscillator and a software interrupt is generated (if enabled). This clock source is input to a PLL thus allowing to increase the frequency up to 180 MHz. Similarly, full interrupt management of the PLL clock entry is available when necessary (for example if an indirectly used external oscillator fails).

Several prescalers allow the configuration of the two AHB buses, the high-speed APB (APB2) and the low-speed APB (APB1) domains. The maximum frequency of the two AHB buses is 180 MHz while the maximum frequency of the high-speed APB domains is 90 MHz. The maximum allowed frequency of the low-speed APB domain is 45 MHz.

The devices embed a dedicated PLL (PLLI2S) and PLLSAI, which allows to achieve audio class performance. In this case, the $I^2S$ master clock can generate all standard sampling frequencies from 8 kHz to 192 kHz.

## 2.17 Boot modes

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

- Boot from user flash
- Boot from system memory
- Boot from embedded SRAM

The bootloader is located in system memory. It is used to reprogram the flash memory through a serial interface. Refer to application note AN2606 for details.

## 2.18 Power supply schemes

- $V_{DD}$ = 1.7 to 3.6 V: external power supply for I/Os and the internal regulator (when enabled), provided externally through $V_{DD}$ pins.
- $V_{SSA}$, $V_{DDA}$ = 1.7 to 3.6 V: external analog power supplies for ADC, DAC, Reset blocks, RCs, and PLL. $V_{DDA}$ and $V_{SSA}$ must be connected to $V_{DD}$ and $V_{SS}$, respectively.

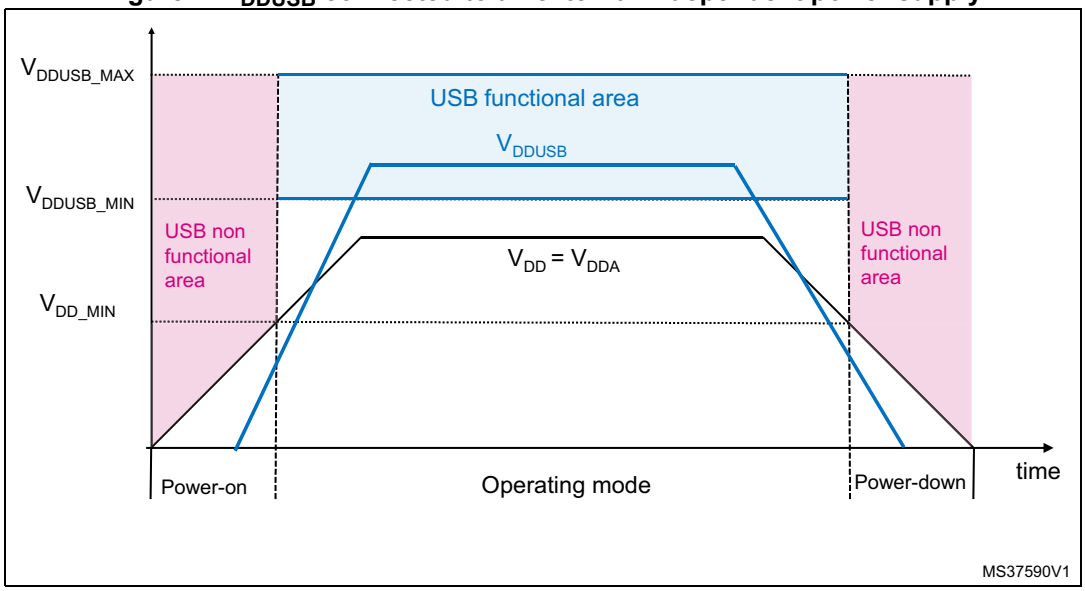
*Note: $V_{DD}/V_{DDA}$ minimum value of 1.7 V is obtained when the internal reset is OFF (refer to Section 2.19.2). Refer to Table 3 to identify the packages supporting this option.*

- $V_{BAT}$ = 1.65 to 3.6 V: power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch) when $V_{DD}$ is not present.
- $V_{DDUSB}$ can be connected either to $V_{DD}$ or an external independent power supply (3.0 to 3.6 V) for USB transceivers.
  For example, when the device is powered at 1.8 V, an independent power supply 3.3 V can be connected to $V_{DDUSB}$. When the $V_{DDUSB}$ is connected to a separated power supply, it is independent from $V_{DD}$ or $V_{DDA}$ but it must be the last supply to be provided and the first to disappear.

The following conditions must be respected:

– During the power-on phase ($V_{DD}$ < $V_{DD_MIN}$), $V_{DDUSB}$ should be always lower than $V_{DD}$
– During the power-down phase ($V_{DD}$ < $V_{DD_MIN}$), $V_{DDUSB}$ should be always lower than $V_{DD}$
– $V_{DDUSB}$ rising and falling time rate specifications must be respected.
– In operating mode phase, $V_{DDUSB}$ could be lower or higher than VDD:
  –If USB (USB OTG_HS/OTG_FS) is used, the associated GPIOs powered by $V_{DDUSB}$ are operating between $V_{DDUSB_MIN}$ and $V_{DDUSB_MAX}$.The $V_{DDUSB}$ supplies both USB transceivers (USB OTG_HS and USB OTG_FS).
  –If only one USB transceiver is used in the application, the GPIOs associated to the other USB transceiver are still supplied by $V_{DDUSB}$.
  –If USB (USB OTG_HS/OTG_FS) is not used, the associated GPIOs powered by $V_{DDUSB}$ are operating between $V_{DD_MIN}$ and $V_{DD_MAX}$.
  –If USB (USB OTG_HS/OTG_FS) is not used and the associated GPIOs powered by $V_{DDUSB}$ are not used, then $V_{DDUSB}$ should be tied to $V_{SS}$ or $V_{DD}$ ($V_{DDUSB}$ must not be floating).

**Figure 7. $V_{DDUSB}$ connected to an external independent power supply**




The DSI (Display serial interface) subsystem uses several power supply pins that are independent from the other supply pins:

- VDDDSI is an independent DSI power supply dedicated for DSI regulator and MIPI D-PHY. This supply must be connected to global VDD.
- VCAPDSI pin is the output of DSI regulator (1.2 V), which must be connected externally to VDD12DSI.
- VDD12DSI pin is used to supply the MIPI D-PHY, and to supply clock and data lanes pins. An external capacitor of 2.2 µF must be connected on VDD12DSI pin.
- VSSDSI pin is an isolated supply ground used for DSI subsystem.
- If DSI functionality is not used at all, then:
  – VDDDSI pin must be connected to global VDD.

– VCAPDSI pin must be connected externally to VDD12DSI but the external capacitor is no more needed.
– VSSDSI pin must be grounded.

## 2.19 Power supply supervisor

### 2.19.1 Internal reset ON

On packages embedding the PDR_ON pin, the power supply supervisor is enabled by holding PDR_ON high. On other packages the power supply supervisor is always enabled.

The device has an integrated power-on reset (POR)/ power-down reset (PDR) circuitry coupled with a brownout reset (BOR) circuitry. At power-on, POR/PDR is always active and ensures proper operation starting from 1.8 V. After the 1.8 V POR threshold level is reached, the option byte loading process starts, either to confirm or modify default BOR thresholds, or to disable BOR permanently. Three BOR thresholds are available through option bytes. The device remains in reset mode when $V_{DD}$ is below a specified threshold, $V_{POR/PDR}$ or $V_{BOR}$, without the need for an external reset circuit.

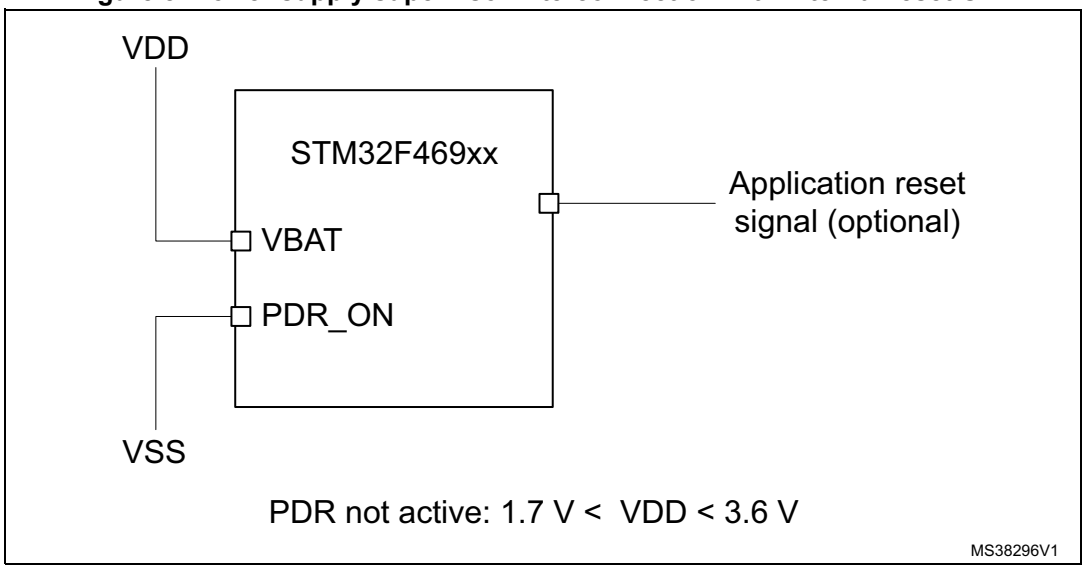
The device also features an embedded programmable voltage detector (PVD) that monitors the $V_{DD}/V_{DDA}$ power supply and compares it to the $V_{PVD}$ threshold. An interrupt can be generated when $V_{DD}/V_{DDA}$ drops below the $V_{PVD}$ threshold and/or when $V_{DD}/V_{DDA}$ is higher than the $V_{PVD}$ 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.

### 2.19.2 Internal reset OFF

This feature is available only on packages featuring the PDR_ON pin. The internal power-on reset (POR) / power-down reset (PDR) circuitry is disabled through the PDR_ON pin.

An external power supply supervisor should monitor $V_{DD}$ and NRST and should maintain the device in reset mode as long as $V_{DD}$ is below a specified threshold. PDR_ON must be connected to VSS, as shown in *Figure 8*.

**Figure 8. Power supply supervisor interconnection with internal reset OFF**



The $V_{DD}$ specified threshold, below which the device must be maintained under reset, is 1.7 V (see *Figure 9*).

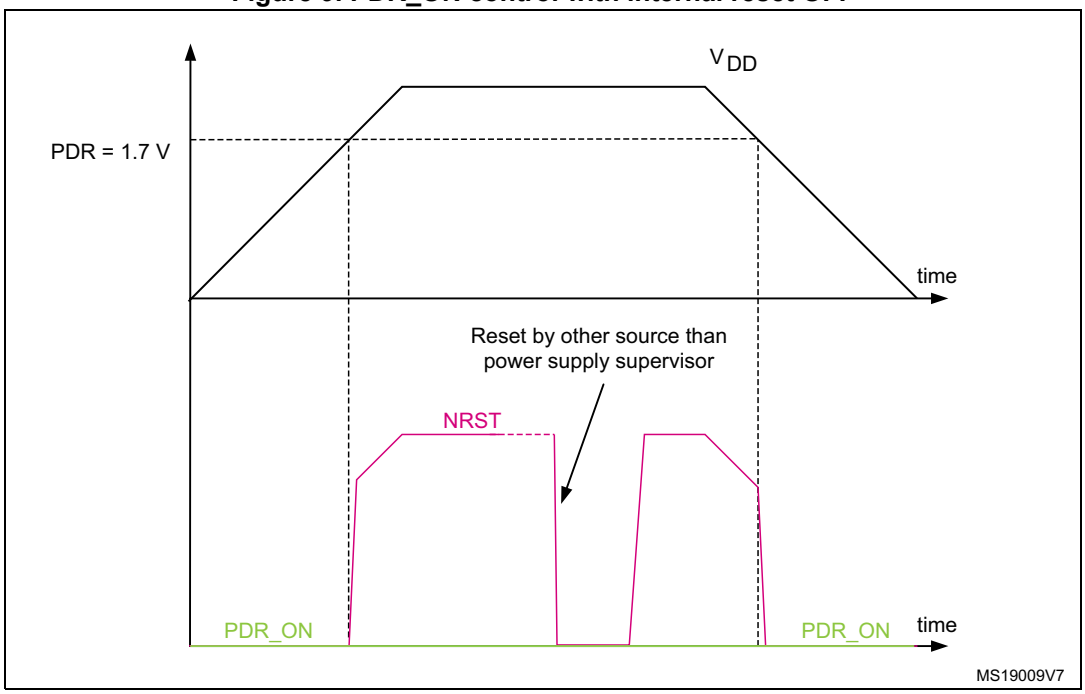
A comprehensive set of power-saving modes allows to design low-power applications.

When the internal reset is OFF, the following integrated features are no more supported:

- The integrated power-on reset (POR) / power-down reset (PDR) circuitry is disabled
- The brownout reset (BOR) circuitry must be disabled
- The embedded programmable voltage detector (PVD) is disabled
- $V_{BAT}$ functionality is no more available and $V_{BAT}$ pin should be connected to $V_{DD}$.

All packages allow to disable the internal reset through the PDR_ON signal when connected to $V_{SS}$.

**Figure 9. PDR_ON control with internal reset OFF**




1. PDR_ON signal to be kept always low.

## 2.20 Voltage regulator

The regulator has four operating modes:

- Regulator ON
  - Main regulator mode (MR)
  - Low power regulator (LPR)
  - Power-down
- Regulator OFF

### 2.20.1 Regulator ON

On packages embedding the BYPASS_REG pin, the regulator is enabled by holding BYPASS_REG low. On all other packages, the regulator is always enabled.

There are three power modes configured by software when the regulator is ON:

- MR mode used in Run/sleep modes or in Stop modes
  - In Run/Sleep mode

    The MR mode is used either in the normal mode (default mode) or the overdrive mode (enabled by software). Different voltage scalings are provided to reach the best compromise between maximum frequency and dynamic power consumption. The overdrive mode allows operating at a higher frequency than the normal mode for a given voltage scaling.
  - In Stop modes

    The MR can be configured in two ways during stop mode:

    MR operates in normal mode (default mode of MR in stop mode).

    MR operates in underdrive mode (reduced leakage mode).
- LPR is used in the Stop modes:

  The LP regulator mode is configured by software when entering Stop mode.

  Like the MR mode, the LPR can be configured in two ways during stop mode:
  - LPR operates in normal mode (default mode when LPR is ON)
  - LPR operates in underdrive mode (reduced leakage mode).
- Power-down is used in Standby mode.

  The Power-down mode is activated only when entering in Standby mode. The regulator output is in high impedance and the kernel circuitry is powered down, inducing zero consumption. The contents of the registers and SRAM are lost.

Refer to *Table 3* for a summary of voltage regulator modes versus device operating modes.

Two external ceramic capacitors should be connected on $V_{CAP_1}$ and $V_{CAP_2}$ pin. Refer to *Section 2.18* and *Table 126: Package thermal characteristics*.

All packages have the regulator ON feature.

**Table 3. Voltage regulator configuration mode versus device operating mode(1)**

| Voltage regulator configuration | Run mode | Sleep mode | Stop mode | Standby mode |
|---|---|---|---|---|
| Normal mode | MR | MR | MR or LPR | - |
| Over-drive mode(2) | MR | MR | - | - |
| Under-drive mode | - | - | MR or LPR | - |
| Power-down mode | - | - | - | Yes |

1. '-' means that the corresponding configuration is not available.
2. The overdrive mode is not available when $V_{DD}$ = 1.7 to 2.1 V.

### 2.20.2 Regulator OFF

This feature is available only on packages featuring the BYPASS_REG pin. The regulator is disabled by holding BYPASS_REG high. The regulator OFF mode allows to supply externally a $V_{12}$ voltage source through $V_{CAP_1}$ and $V_{CAP_2}$ pins.

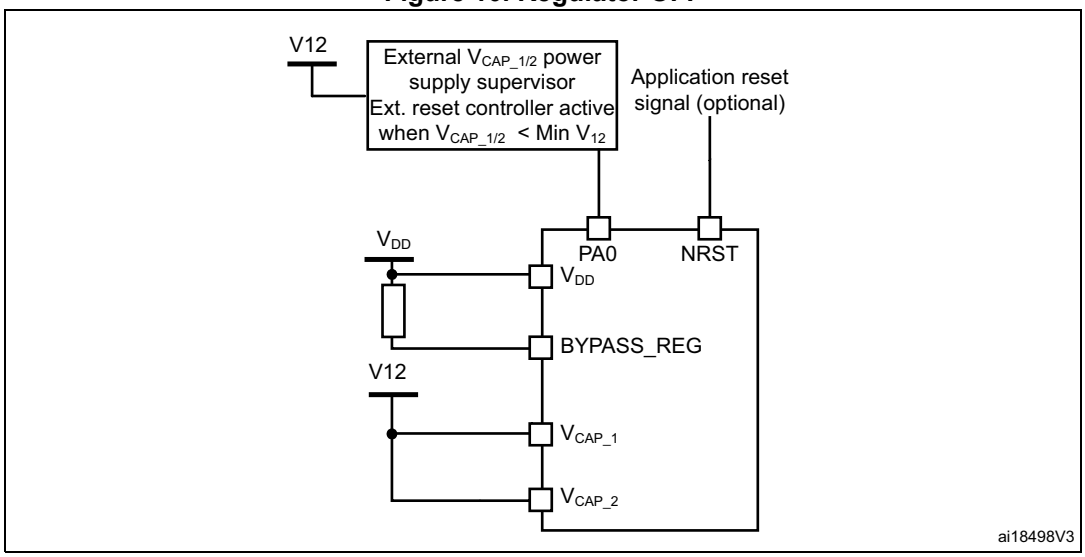
Since the internal voltage scaling is not managed internally, the external voltage value must be aligned with the targeted maximum frequency. Refer to *Section A.1: Operating conditions*.The two 2.2 µF ceramic capacitors should be replaced by two 100 nF decoupling capacitors. Refer to *Section 2.18*.

When the regulator is OFF, there is no more internal monitoring on $V_{12}$. An external power supply supervisor should be used to monitor the $V_{12}$ of the logic power domain. PA0 pin should be used for this purpose, and act as a power-on reset on $V_{12}$ power domain.

In regulator OFF mode, the following features are no more supported:

- PA0 cannot be used as a GPIO pin since it allows to reset a part of the $V_{12}$ logic power domain, which is not reset by the NRST pin.
- As long as PA0 is kept low, the debug mode cannot be used under power-on reset. As a consequence, PA0 and NRST pins must be managed separately if the debug connection under reset or prereset is required.
- The overdrive and underdrive modes are not available.
- The Standby mode is not available.

**Figure 10. Regulator OFF**

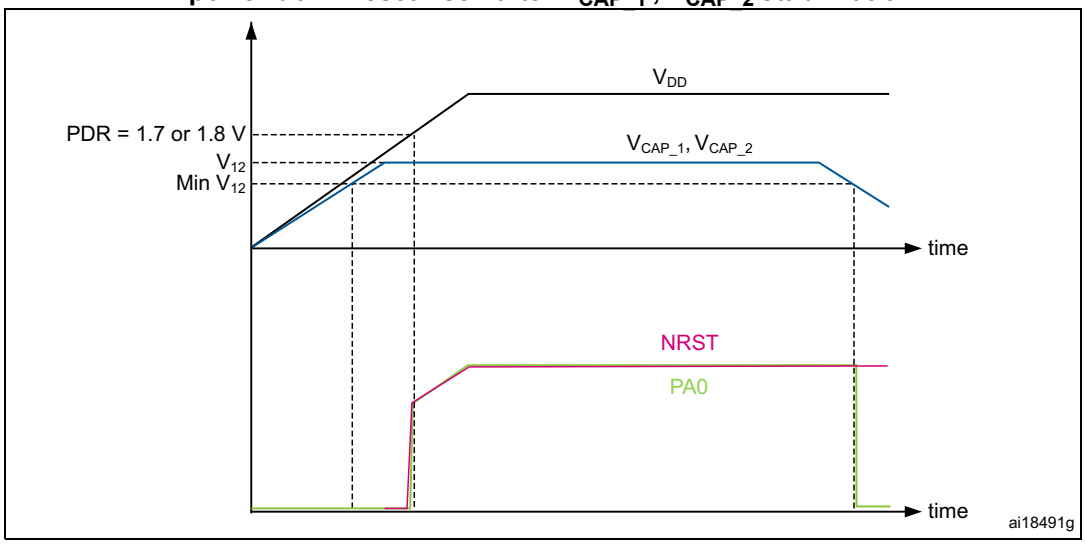


The following conditions must be respected:

- $V_{DD}$ must always be higher than $V_{CAP_1}$ and $V_{CAP_2}$ to avoid current injection between power domains.
- If the time for $V_{CAP_1}$ and $V_{CAP_2}$ to reach $V_{12}$ minimum value is faster than the time for $V_{DD}$ to reach 1.7 V, then PA0 must be kept low to cover both conditions: until $V_{CAP_1}$ and $V_{CAP_2}$ reach $V_{12}$ minimum value and until $V_{DD}$ reaches 1.7 V (see *Figure 11*).
- Otherwise, if the time for $V_{CAP_1}$ and $V_{CAP_2}$ to reach $V_{12}$ minimum value is slower than the time for $V_{DD}$ to reach 1.7 V, then PA0 can be asserted low externally (see *Figure 12*).
- If $V_{CAP_1}$ and $V_{CAP_2}$ go below $V_{12}$ minimum value and $V_{DD}$ is higher than 1.7 V, then a reset must be asserted on PA0 pin.

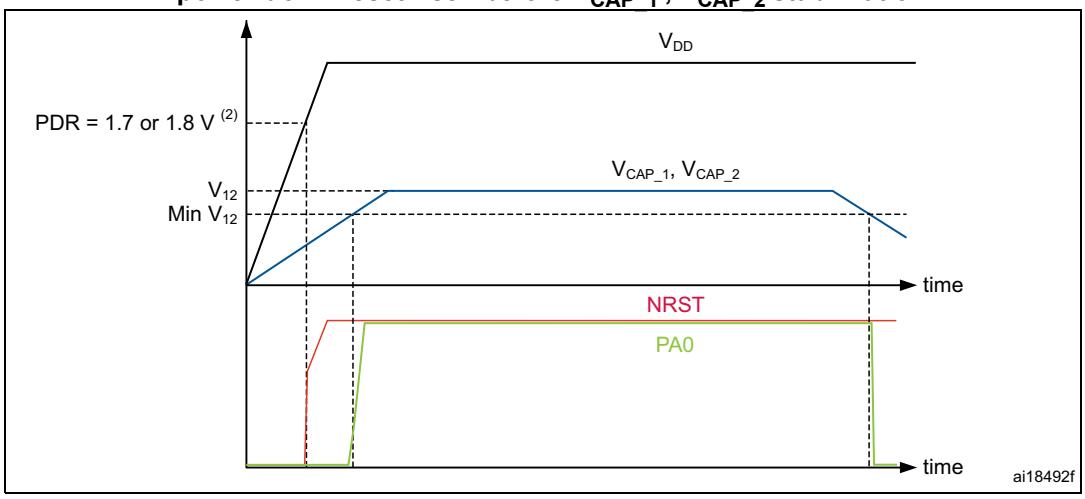
*Note: The minimum value of $V_{12}$ depends on the maximum frequency targeted in the application (see Section A.1: Operating conditions).*

**Figure 11. Startup in regulator OFF: slow $V_{DD}$ slope - power-down reset risen after $V_{CAP_1}$, $V_{CAP_2}$ stabilization**




1. This figure is valid whatever the internal reset mode (ON or OFF).

**Figure 12. Startup in regulator OFF mode: fast $V_{DD}$ slope - power-down reset risen before $V_{CAP_1}$, $V_{CAP_2}$ stabilization**




1. This figure is valid whatever the internal reset mode (ON or OFF).

### 2.20.3 Regulator ON/OFF and internal reset ON/OFF availability

**Table 4. Regulator ON/OFF and internal reset ON/OFF availability**

| Package | Regulator ON | Regulator OFF | Internal reset ON | Internal reset OFF |
|---|---|---|---|---|
| WLCSP168<br>UFBGA169<br>LQFP144<br>LQFP208 | Yes | No | Yes<br>PDR_ON set to $V_{DD}$ | Yes<br>PDR_ON set to $V_{SS}$ |
| LQFP176<br>UFBGA176<br>TFBGA216 | Yes<br>BYPASS_REG set to $V_{SS}$ | Yes<br>BYPASS_REG set to $V_{DD}$ | | |
| LQFP100 | Yes | No | Yes | No |

## 2.21 Real-time clock (RTC), backup SRAM, and backup registers

The backup domain includes:

- The real-time clock (RTC)
- 4 Kbytes of backup SRAM
- 20 backup registers

The real-time clock (RTC) is an independent BCD timer/counter. Dedicated registers contain the second, minute, hour (in 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 performed automatically. The RTC provides a programmable alarm and programmable periodic interrupts with wake-up from Stop and Standby modes. The subseconds value is also available in binary format.

It is clocked by a 32.768 kHz external crystal, resonator or oscillator, the internal low-power RC oscillator or the high-speed external clock divided by 128. The internal low-speed RC

has a typical frequency of 32 kHz. The RTC can be calibrated using an external 512 Hz output to compensate for any natural quartz deviation.

Two alarm registers are used to generate an alarm at a specific time and calendar fields can be independently masked for alarm comparison. To generate a periodic interrupt, a 16-bit programmable binary autoreload downcounter with programmable resolution is available and allows automatic wake-up and periodic alarms from every 120 µs to every 36 hours.

A 20-bit prescaler is used for the time base clock. It is by default configured to generate a time base of 1 second from a clock at 32.768 kHz.

The 4-Kbyte backup SRAM is an EEPROM-like memory area. It can be used to store data, which need to be retained in VBAT and standby mode. This memory area is disabled by default to minimize power consumption (see *Section 2.22*). It can be enabled by software.

The backup registers are 32-bit registers used to store 80 bytes of user application data when $V_{DD}$ power is not present. Backup registers are not reset by a system, a power reset, or when the device wakes up from the Standby mode (see *Section 2.22*).

Additional 32-bit registers contain the programmable alarm subseconds, seconds, minutes, hours, day, and date.

Like backup SRAM, the RTC and backup registers are supplied through a switch that is powered either from the $V_{DD}$ supply when present or from the $V_{BAT}$ pin.

## 2.22 Low-power modes

The devices support three low-power modes to achieve the best compromise between low power consumption, short startup time and available wake-up 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.

- **Stop mode**

  The Stop mode achieves the lowest power consumption while retaining the contents of SRAM and registers. All clocks in the 1.2 V domain are stopped, the PLL, the HSI RC and the HSE crystal oscillators are disabled.

  The voltage regulator can be put either in main regulator mode (MR) or in low-power mode (LPR). Both modes can be configured as follows (see *Table 5*):

  – Normal mode (default mode when MR or LPR is enabled)

  – Underdrive mode.

  The device can be woken up from the Stop mode by any of the EXTI lines (the EXTI line source can be one of the 16 external lines, the PVD output, the RTC alarm / wake-up / tamper / time stamp events, the USB OTG FS/HS wake-up or the Ethernet wake-up).

Table 5. Voltage regulator modes in stop mode

| Voltage regulator configuration | Main regulator (MR) | Low-power regulator (LPR) |
|---|---|---|
| Normal mode | MR ON | LPR ON |
| Under-drive mode | MR in under-drive mode | LPR in under-drive mode |

- **Standby mode**

  The Standby mode is used to achieve the lowest power consumption. The internal voltage regulator is switched off so that the entire 1.2 V domain is powered off. The PLL, the HSI RC and the HSE crystal oscillators are also switched off. After entering Standby mode, the SRAM and register contents are lost except for registers in the backup domain and the backup SRAM when selected.

  The device exits the Standby mode when an external reset (NRST pin), an IWDG reset, a rising edge on the WKUP pin, or an RTC alarm / wake-up / tamper /time stamp event occurs.

  The standby mode is not supported when the embedded voltage regulator is bypassed and the 1.2 V domain is controlled by an external power.

## 2.23 $V_{BAT}$ operation

The $V_{BAT}$ pin allows to power the device $V_{BAT}$ domain from an external battery, an external supercapacitor, or from $V_{DD}$ when no external battery neither an external supercapacitor are present.

$V_{BAT}$ operation is activated when $V_{DD}$ is not present.

The $V_{BAT}$ pin supplies the RTC, the backup registers, and the backup SRAM.

*Note: When the microcontroller is supplied from $V_{BAT}$, external interrupts and RTC alarm/events do not exit it from $V_{BAT}$ operation.*

*When PDR_ON pin is connected to $V_{SS}$ (Internal Reset OFF), the $V_{BAT}$ functionality is no more available and $V_{BAT}$ pin should be connected to $V_{DD}$.*

## 2.24 Timers and watchdogs

The devices include two advanced-control timers, eight general-purpose timers, two basic timers and two watchdog timers.

All timer counters can be frozen in debug mode.

*Table 6* compares the features of the advanced-control, general-purpose and basic timers.

**Table 6. Timer feature comparison**

| Timer type | Timer | Counter resolution | Counter type | Prescaler factor | DMA request generation | Capture/ compare channels | Complementary output | Max interface clock (MHz) | Max timer clock (MHz)(1) |
|---|---|---|---|---|---|---|---|---|---|
| Advanced control | TIM1, TIM8 | 16-bit | Up, Down, Up/down | Any integer between 1 and 65536 | Yes | 4 | Yes | 90 | 180 |
| General purpose | TIM2, TIM5 | 32-bit | Up, Down, Up/down | Any integer between 1 and 65536 | Yes | 4 | No | 45 | 90/180 |
| | TIM3, TIM4 | 16-bit | Up, Down, Up/down | Any integer between 1 and 65536 | Yes | 4 | No | 45 | 90/180 |
| | TIM9 | 16-bit | Up | Any integer between 1 and 65536 | No | 2 | No | 90 | 180 |
| | TIM10, TIM11 | 16-bit | Up | Any integer between 1 and 65536 | No | 1 | No | 90 | 180 |
| | TIM12 | 16-bit | Up | Any integer between 1 and 65536 | No | 2 | No | 45 | 90/180 |
| | TIM13, TIM14 | 16-bit | Up | Any integer between 1 and 65536 | No | 1 | No | 45 | 90/180 |
| Basic | TIM6, TIM7 | 16-bit | Up | Any integer between 1 and 65536 | Yes | 0 | No | 45 | 90/180 |

1. The maximum timer clock is either 90 or 180 MHz depending on the TIMPRE bit configuration in the RCC_DCKCFGR register.

### 2.24.1 Advanced-control timers (TIM1, TIM8)

The advanced-control timers (TIM1, TIM8) can be seen as three-phase PWM generators multiplexed on 6 channels. They have complementary PWM outputs with programmable inserted dead times. They can also be considered as complete general-purpose timers. Their 4 independent channels can be used for:

- Input capture
- Output compare
- PWM generation (edge- or center-aligned modes)
- One-pulse mode output

If configured as standard 16-bit timers, they have the same features as the general-purpose TIMx timers. If configured as 16-bit PWM generators, they have full modulation capability (0-100%).

The advanced-control timer can work together with the TIMx timers via the Timer Link feature for synchronization or event chaining.

TIM1 and TIM8 support independent DMA request generation.

### 2.24.2 General-purpose timers (TIMx)

There are ten synchronizable general-purpose timers embedded in the STM32F46x devices (see *Table 6* for differences).

- **TIM2, TIM3, TIM4, TIM5**

  The STM32F46x include 4 full-featured general-purpose timers: TIM2, TIM5, TIM3, and TIM4.The TIM2 and TIM5 timers are based on a 32-bit autoreload up/down counter and a 16-bit prescaler. The TIM3 and TIM4 timers are based on a 16-bit autoreload up/down counter and a 16-bit prescaler. They all feature 4 independent channels for input capture/output compare, PWM, or one-pulse mode output. This gives up to 16 input capture/output compare/PWMs on the largest packages.

  The TIM2, TIM3, TIM4, TIM5 general-purpose timers can work together, or with the other general-purpose timers and the advanced-control timers TIM1 and TIM8 via the Timer Link feature for synchronization or event chaining.

  Any of these general-purpose timers can be used to generate PWM outputs.

  TIM2, TIM3, TIM4, TIM5 all have independent DMA request generation. They are capable of handling quadrature (incremental) encoder signals and the digital outputs from 1 to 4 hall-effect sensors.

- **TIM9, TIM10, TIM11, TIM12, TIM13, and TIM14**

  These timers are based on a 16-bit autoreload upcounter and a 16-bit prescaler. TIM10, TIM11, TIM13, and TIM14 feature one independent channel, whereas TIM9 and TIM12 have 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.

### 2.24.3 Basic timers TIM6 and TIM7

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

TIM6 and TIM7 support independent DMA request generation.

### 2.24.4 Independent watchdog

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

### 2.24.5 Window watchdog

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.

### 2.24.6 SysTick timer

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

- a 24-bit downcounter
- autoreload capability
- maskable system interrupt generation when the counter reaches 0
- programmable clock source.

## 2.25 Inter-integrated circuit interface ($I^2C$)

Up to three I²C bus interfaces can operate in multimaster and slave modes. They can support the standard (up to 100 kHz), and fast (up to 400 kHz) modes. They support the 7/10-bit addressing mode and the 7-bit dual addressing mode (as slave). A hardware CRC generation/verification is embedded.

The I²C bus interfaces can be served by DMA and support SMBus 2.0/PMBus.

The devices also include programmable analog and digital noise filters (see *Table 7*).

**Table 7. Comparison of I2C analog and digital filters**

| Filter | Analog | Digital |
|---|---|---|
| Pulse width of suppressed spikes | ≥ 50 ns | Programmable length, from one to fifteen I2C peripheral clocks |

## 2.26 Universal synchronous/asynchronous receiver transmitters (USART)

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

These six interfaces provide asynchronous communication, IrDA SIR ENDEC support, multiprocessor communication mode, single-wire half-duplex communication mode and have LIN Master/Slave capability. The USART1 and USART6 interfaces are able to communicate at speeds of up to 11.25 Mbit/s. The other available interfaces communicate at up to 5.62 Mbit/s.

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

Table 8. USART feature comparison(1)

| Name | Standard features | Modem (RTS/CTS) | LIN | SPI master | irDA | Smartcard (ISO 7816) | Max. baud rate in Mbit/s | | APB mapping |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Oversampling by 16 | Oversampling by 8 | |
| USART1 | X | X | X | X | X | X | 5.62 | 11.25 | APB2 (max. 90 MHz) |
| USART2 | X | X | X | X | X | X | 2.81 | 5.62 | APB1 (max. 45 MHz) |
| USART3 | X | X | X | X | X | X | 2.81 | 5.62 | APB1 (max. 45 MHz) |
| UART4 | X | - | X | - | X | - | 2.81 | 5.62 | APB1 (max. 45 MHz) |
| UART5 | X | - | X | - | X | - | 2.81 | 5.62 | APB1 (max. 45 MHz) |
| USART6 | X | X | X | X | X | X | 5.62 | 11.25 | APB2 (max. 90 MHz) |
| UART7 | X | - | X | - | X | - | 2.81 | 5.62 | APB1 (max. 45 MHz) |
| UART8 | X | - | X | - | X | - | 2.81 | 5.62 | APB1 (max. 45 MHz) |

1. X = feature supported.

## 2.27 Serial peripheral interface (SPI)

The devices feature up to six SPIs in slave and master modes in full-duplex and simplex communication modes. SPI1, SPI4, SPI5, and SPI6 can communicate at up to 45 Mbits/s, SPI2 and SPI3 can communicate at up to 22.5 Mbit/s. 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. All SPIs can be served by the DMA controller.

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

## 2.28 Inter-integrated sound ($I^2S$)

Two standard $I^2S$ interfaces (multiplexed with SPI2 and SPI3) are available. They can be operated in master or slave mode, in full duplex and simplex communication modes, and can be configured to operate with a 16-/32-bit resolution as an input or output channel.

Audio sampling frequencies from 8 kHz up to 192 kHz are supported. When either or both of the $I^2S$ interfaces is/are configured in master mode, the master clock can be output to the external DAC/CODEC at 256 times the sampling frequency.

All I2Sx can be served by the DMA controller.

*Note: For* I2S2 *full-duplex mode, I2S2_CK and I2S2_WS signals can be used only on GPIO Port B and GPIO Port D.*

## 2.29 Serial Audio interface (SAI1)

The serial audio interface (SAI1) is based on two independent audio subblocks which can operate as transmitter or receiver with their FIFO. Many audio protocols are supported by each block: I2S standards, LSB or MSB-justified, PCM/DSP, TDM, AC'97 and SPDIF output, supporting audio sampling frequencies from 8 kHz up to 192 kHz. Both subblocks can be configured in master or in slave mode.

In master mode, the master clock can be output to the external DAC/CODEC at 256 times of the sampling frequency.

The two subblocks can be configured in synchronous mode when full-duplex mode is required.

SAI1 can be served by the DMA controller.

## 2.30 Audio PLL (PLLI2S)

The devices feature an additional dedicated PLL for audio $I^2S$ and SAI applications. It allows to achieve error-free $I^2S$ sampling clock accuracy without compromising on the CPU performance, while using USB peripherals.

The PLLI2S configuration can be modified to manage an $I^2S$/SAI sample rate change without disabling the main PLL (PLL) used for CPU, USB, and Ethernet interfaces.

The audio PLL can be programmed with very low error to obtain sampling rates ranging from 8 kHz to 192 kHz.

In addition to the audio PLL, a master clock input pin can be used to synchronize the $I^2S$/SAI flow with an external PLL (or Codec output).

## 2.31 Audio and LCD PLL(PLLSAI)

An additional PLL dedicated to audio and LCD-TFT is used for SAI1 peripheral in case the PLLI2S is programmed to achieve another audio sampling frequency (49.152 MHz or 11.2896 MHz) and the audio application requires both sampling frequencies simultaneously.

The PLLSAI is also used to generate the LCD-TFT clock.

## 2.32 Secure digital input/output interface (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 48 MHz, 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.

## 2.33 Ethernet MAC interface with dedicated DMA and IEEE 1588 support

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

The devices include the following features:

- Supports 10 and 100 Mbit/s rates
- A dedicated DMA controller allowing high-speed transfers between the dedicated SRAM and the descriptors (see the STM32F4xx reference manual for details)
- Tagged MAC frame support (VLAN support)
- Half-duplex (CSMA/CD) and full-duplex operation
- MAC control sublayer (control frames) support
- 32-bit CRC generation and removal
- Several address filtering modes for physical and multicast address (multicast and group addresses)
- 32-bit status code for each transmitted or received frame
- Internal FIFOs to buffer transmit and receive frames. The transmit FIFO and the receive FIFO are both 2 Kbytes.
- Supports hardware PTP (precision time protocol) in accordance with IEEE 1588 2008 (PTP V2) with the time stamp comparator connected to the TIM2 input
- Triggers interrupt when system time becomes greater than target time

## 2.34 Controller area network (bxCAN)

The two CANs are compliant with the 2.0A and B (active) specifications with a bitrate up to 1 Mbit/s. They can receive and transmit standard frames with 11-bit identifiers as well as extended frames with 29-bit identifiers. Each CAN has three transmit mailboxes, two receive FIFOS with 3 stages and 28 shared scalable filter banks (all of them can be used even if one CAN is used). 256 bytes of SRAM are allocated for each CAN.

## 2.35 Universal serial bus on-the-go full-speed (OTG_FS)

The device embeds one USB OTG full-speed device/host/OTG peripheral with integrated transceivers. The USB OTG FS peripheral is compliant with the USB 2.0 specification and with the OTG 2.0 specification. It has software-configurable endpoint settings and supports suspend/resume. The USB OTG controller requires a dedicated 48 MHz clock that is generated by a PLL connected to the HSE oscillator.

The main features are:

- Combined Rx and Tx FIFO size of 1.28 KB with dynamic FIFO sizing
- Supports the session request protocol (SRP) and host negotiation protocol (HNP)
- 1 bidirectional control endpoint + 5 IN endpoints + 5 OUT endpoints
- 12 host channels with periodic OUT support
- Software configurable to OTG1.3 and OTG2.0 modes of operation
- USB 2.0 LPM (Link Power Management) support
- Internal FS OTG PHY support
- HNP/SNP/IP inside (no need for any external resistor)

For OTG/Host modes, a power switch is needed in case bus-powered devices are connected.

## 2.36 Universal serial bus on-the-go high-speed (OTG_HS)

The device embeds a USB OTG high-speed (up to 480 Mb/s) device/host/OTG peripheral. The USB OTG HS supports both full-speed and high-speed operations. It integrates the transceivers for full-speed operation (12 MB/s) and features a UTMI low-pin interface (ULPI) for high-speed operation (480 MB/s). When using the USB OTG HS in HS mode, an external PHY device connected to the ULPI is required.

The USB OTG HS peripheral is compliant with the USB 2.0 specification and with the OTG 2.0 specification. It has software-configurable endpoint settings and supports suspend/resume. The USB OTG controller requires a dedicated 48 MHz clock that is generated by a PLL connected to the HSE oscillator.

The main features are:

- Combined Rx and Tx FIFO size of 4 KB with dynamic FIFO sizing
- Supports the session request protocol (SRP) and host negotiation protocol (HNP)
- 8 bidirectional endpoints
- 16 host channels with periodic OUT support
- Software configurable to OTG1.3 and OTG2.0 modes of operation
- USB 2.0 LPM (Link Power Management) support
- Internal FS OTG PHY support
- External HS or HS OTG operation supporting ULPI in SDR mode. The OTG PHY is connected to the microcontroller ULPI port through 12 signals. It can be clocked using the 60 MHz output.
- Internal USB DMA
- HNP/SNP/IP inside (no need for any external resistor)
- for OTG/Host modes, a power switch is needed in case bus-powered devices are connected

## 2.37 Digital camera interface (DCMI)

The devices embed a camera interface that can connect with camera modules and CMOS sensors through an 8-bit to 14-bit parallel interface, to receive video data. The camera interface can sustain a data transfer rate up to 54 Mbyte/s at 54 MHz. It features:

- Programmable polarity for the input pixel clock and synchronization signals
- Parallel data communication can be 8-, 10-, 12- or 14-bit
- Supports 8-bit progressive video monochrome or raw bayer format, YCbCr 4:2:2 progressive video, RGB 565 progressive video or compressed data (like JPEG)
- Supports continuous mode or snapshot (a single frame) mode
- Capability to automatically crop the image black & white.

## 2.38 True random number generator (RNG)

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

All devices embed an RNG that delivers 32-bit random numbers generated by an integrated analog circuit.

## 2.39 General-purpose input/outputs (GPIOs)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain, with or without pull-up or pull-down), as input (floating, with or without pull-up or pull-down) or as peripheral alternate function. Most of the GPIO pins are shared with digital or analog alternate functions. All GPIOs are high-current-capable and have speed selection to better manage internal noise, power consumption and electromagnetic emission.

The I/O configuration can be locked if needed by following a specific sequence in order to avoid spurious writing to the I/Os registers.

Fast I/O handling allowing maximum I/O toggling up to 90 MHz.

## 2.40 Analog-to-digital converters (ADCs)

Three 12-bit analog-to-digital converters are embedded and each ADC shares up to 16 external channels, performing conversions in the single-shot or scan mode. In scan mode, automatic conversion is performed on a selected group of analog inputs.

Additional logic functions embedded in the ADC interface allow:

- Simultaneous sample and hold
- Interleaved sample and hold

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 selected channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

To synchronize A/D conversion and timers, the ADCs could be triggered by any of TIM1, TIM2, TIM3, TIM4, TIM5, or TIM8 timer.

## 2.41 Temperature sensor

The temperature sensor has to generate a voltage that varies linearly with temperature. The conversion range is between 1.7 V and 3.6 V. The temperature sensor is internally connected to the same input channel as $V_{BAT}$, ADC1_IN18, which is used to convert the sensor output voltage into a digital value. When the temperature sensor and $V_{BAT}$ conversion are enabled at the same time, only $V_{BAT}$ conversion is performed.

As the offset of the temperature sensor varies from chip to chip due to process variation, the internal temperature sensor is mainly suitable for applications that detect temperature changes instead of absolute temperatures. If an accurate temperature reading is needed, then an external temperature sensor part should be used.

## 2.42 Digital-to-analog converter (DAC)

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

This dual digital interface supports the following features:

- two DAC converters: one for each output channel
- 8-bit or 10-bit monotonic output
- left or right data alignment in 12-bit mode
- synchronized update capability
- noise-wave generation
- triangular-wave generation
- dual DAC channel independent or simultaneous conversions
- DMA capability for each channel
- external triggers for conversion
- input voltage reference $V_{REF+}$

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

## 2.43 Serial wire JTAG debug port (SWJ-DP)

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

Debug is performed using 2 pins only instead of 5 required by the JTAG (JTAG pins could be reused as GPIO with an alternate function): the JTAG TMS and TCK pins are shared with SWDIO and SWCLK, respectively, and a specific sequence on the TMS pin is used to switch between JTAG-DP and SW-DP.

## 2.44 Embedded Trace Macrocell™

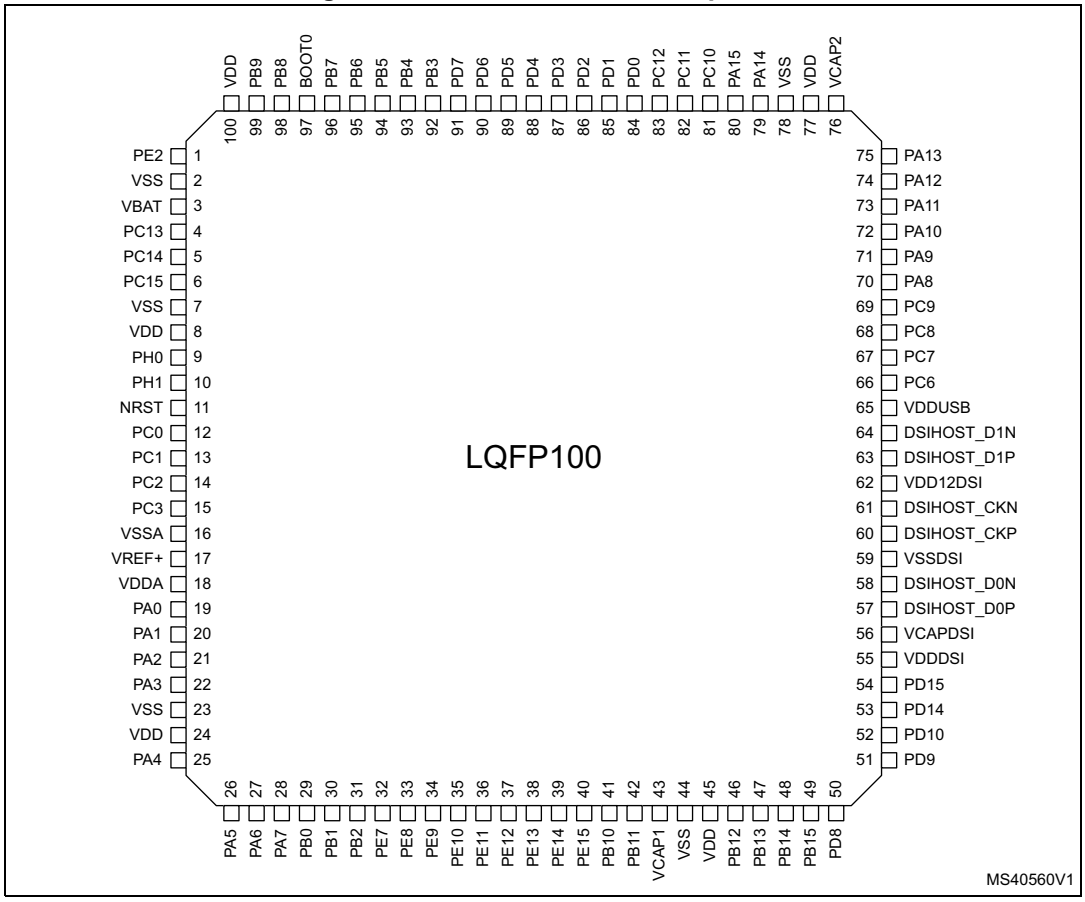
The Arm Embedded Trace Macrocell provides a greater visibility of the instruction and data flow inside the CPU core by streaming compressed data at a very high rate from the STM32F46x through a small number of ETM pins to an external hardware trace port analyzer (TPA) device. The TPA is connected to 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 that runs the debugger software. TPA hardware is commercially available from common development tool vendors.

The Embedded Trace Macrocell operates with third-party debugger software tools.

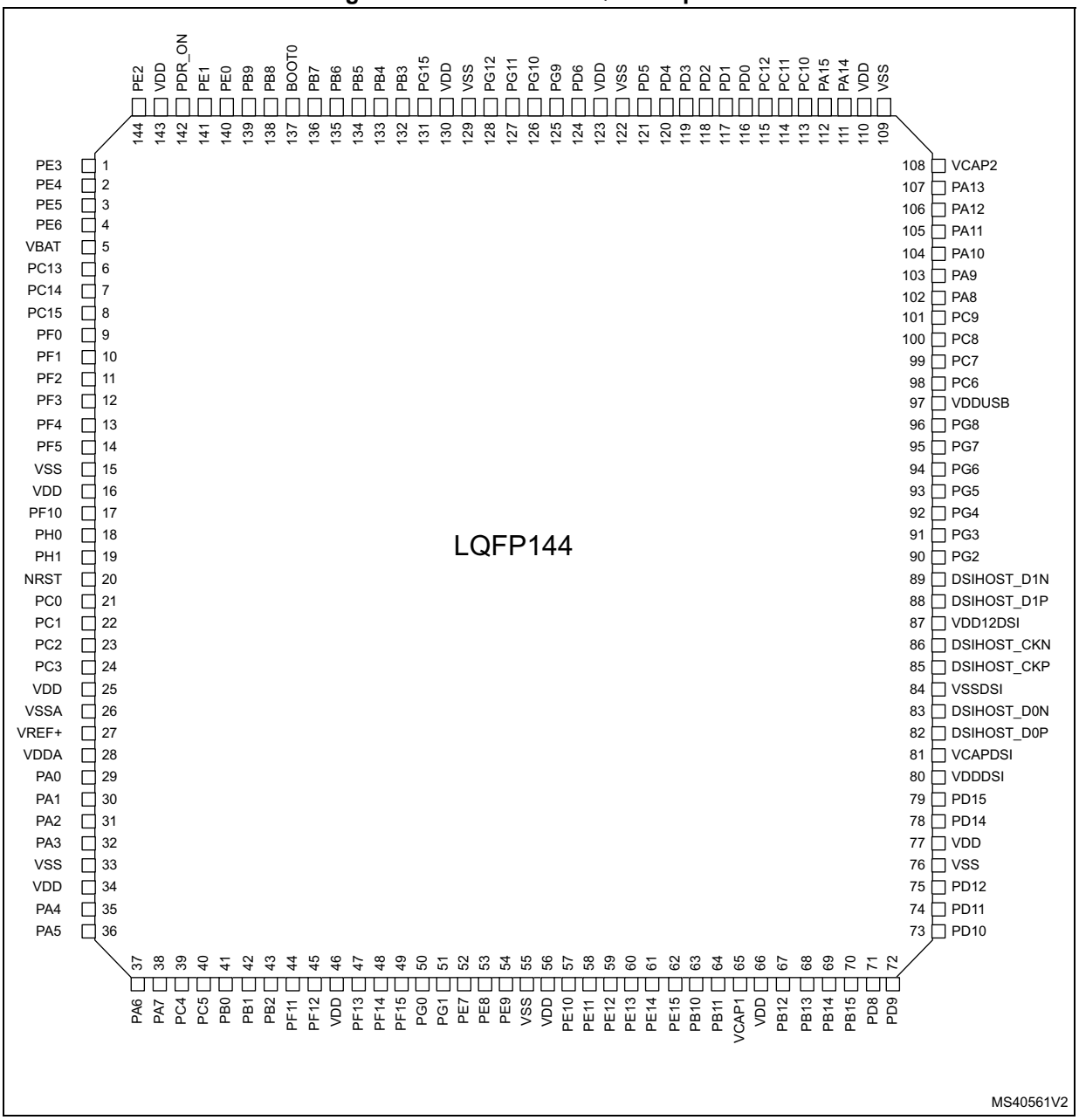
# 3 Pinouts and pin description

**Figure 13. STM32F46x LQFP100 pinout**



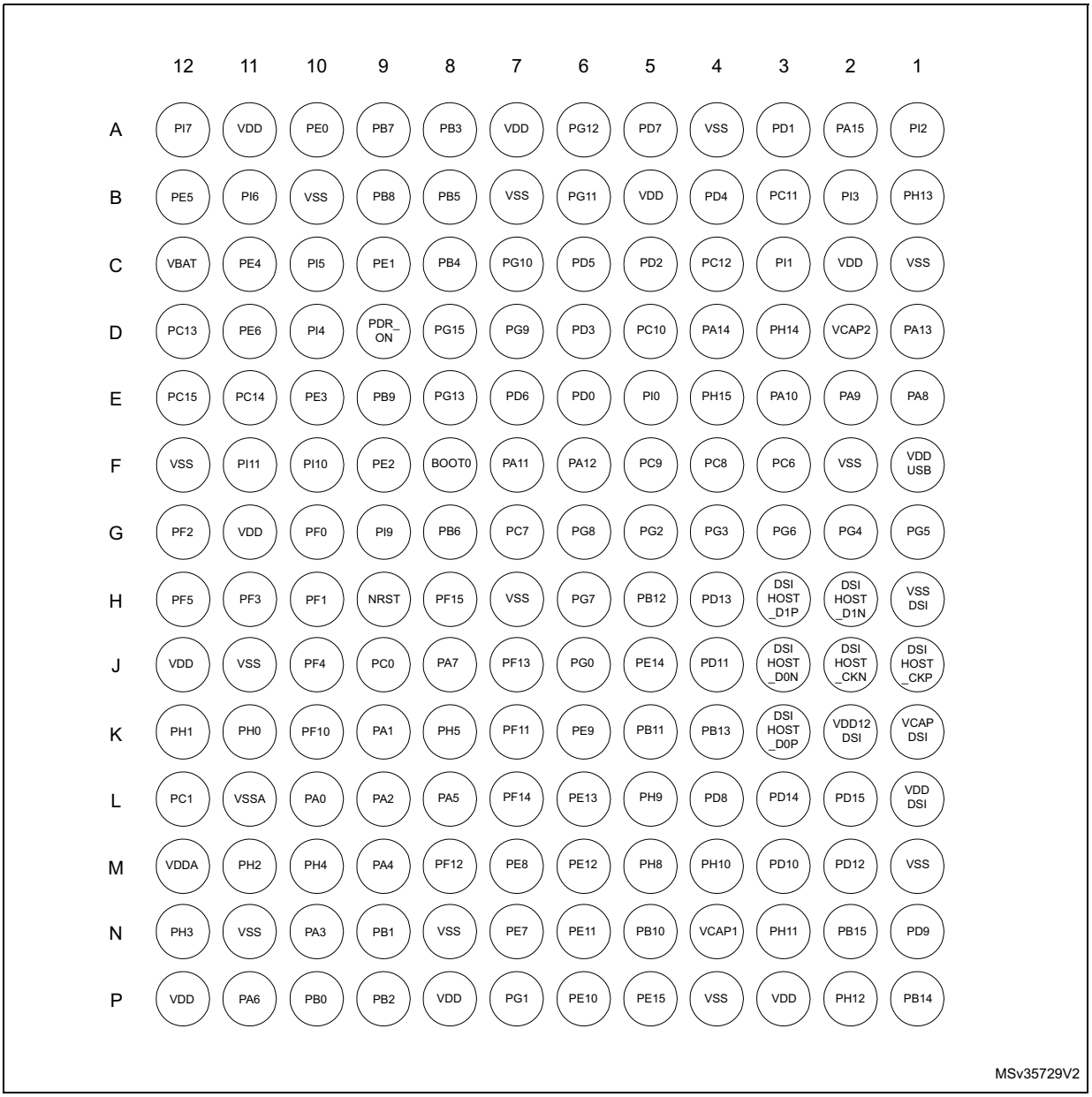

1. The above figure shows the package top view.

**Figure 14. STM32F46x LQFP144 pinout**



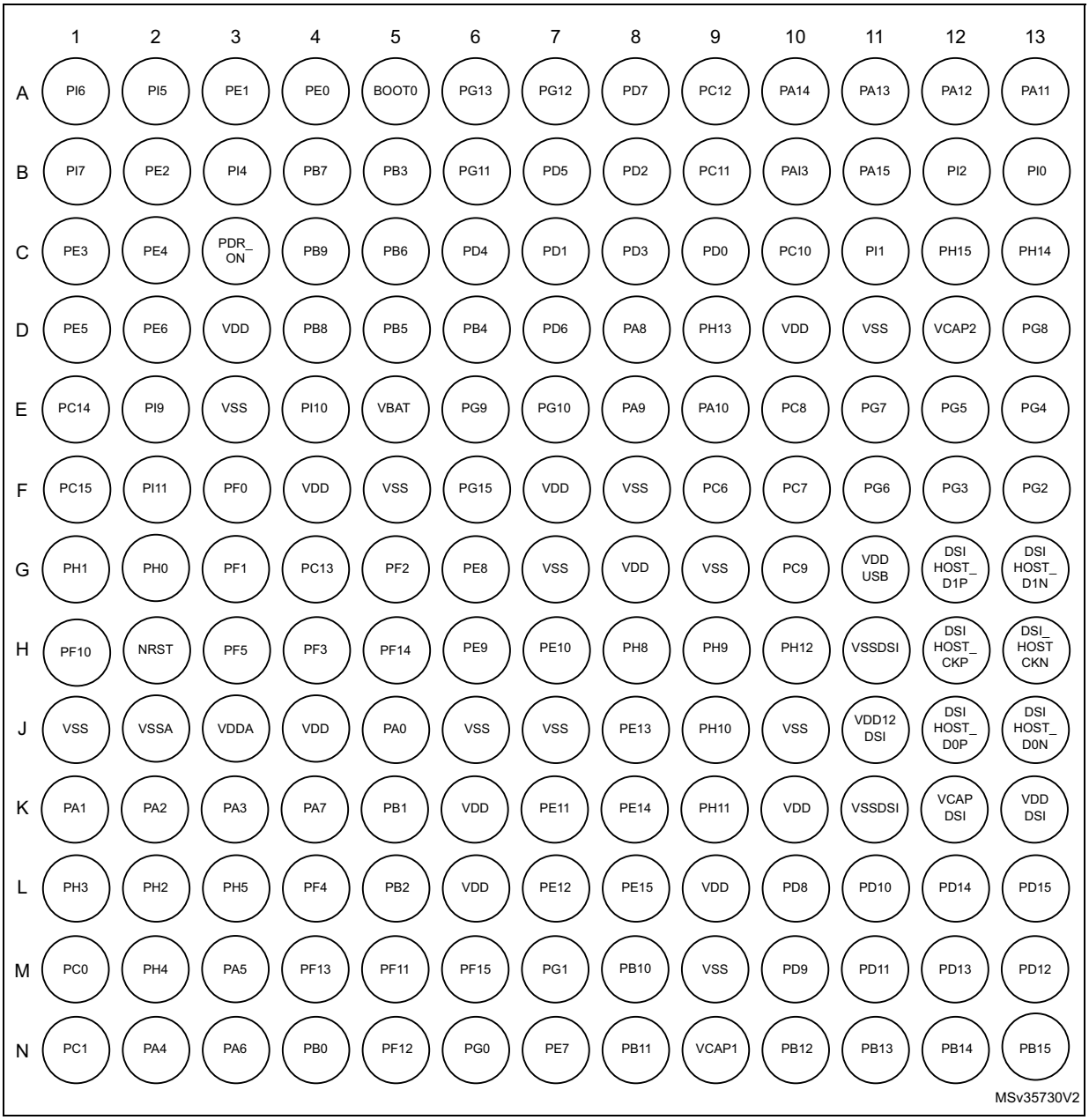

1. The above figure shows the package top view.

**Figure 15. STM32F46x WLCSP168 pinout**



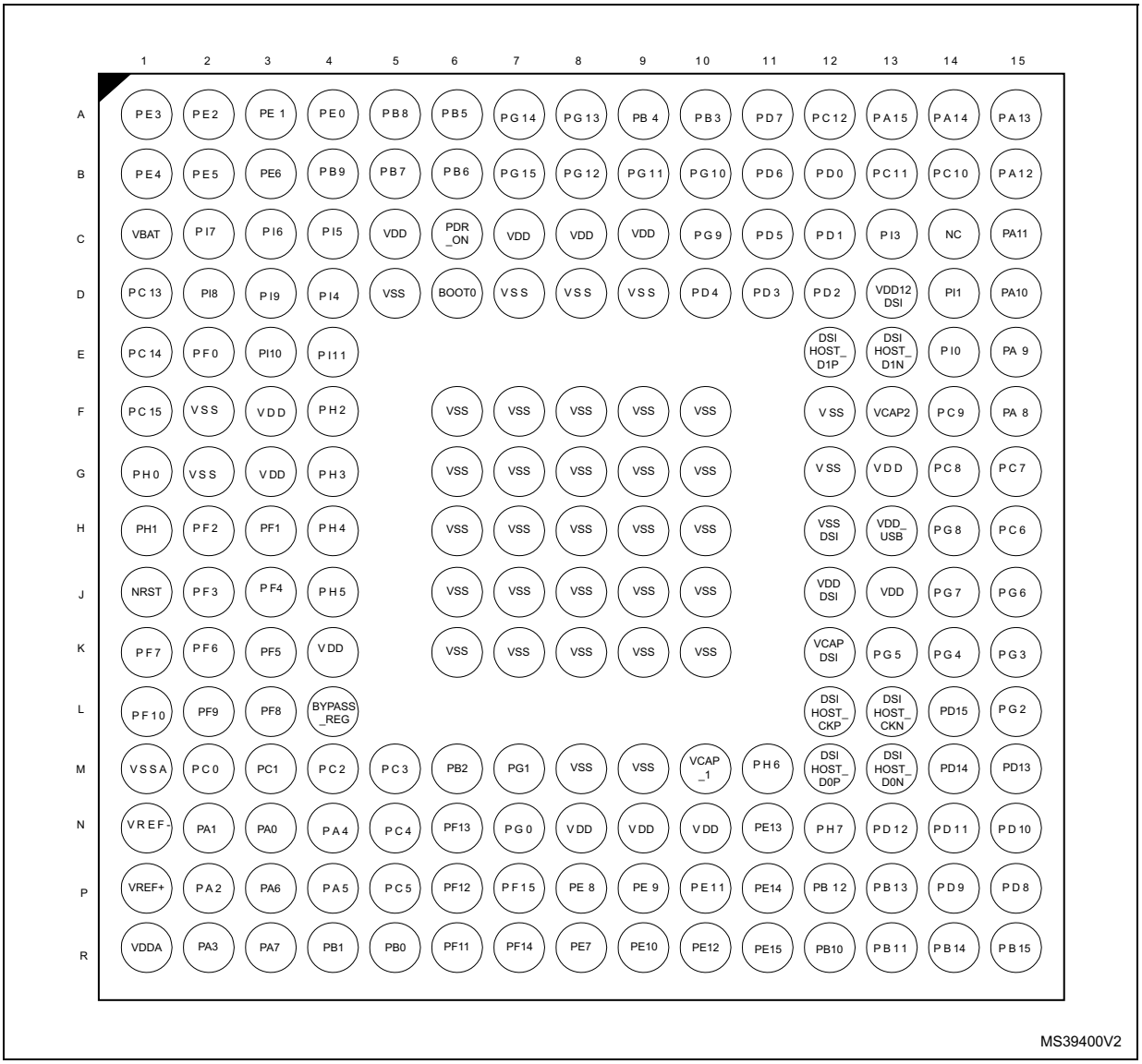

1. The above figure shows the package bottom view.

**Figure 16. STM32F46x UFBGA169 ballout**



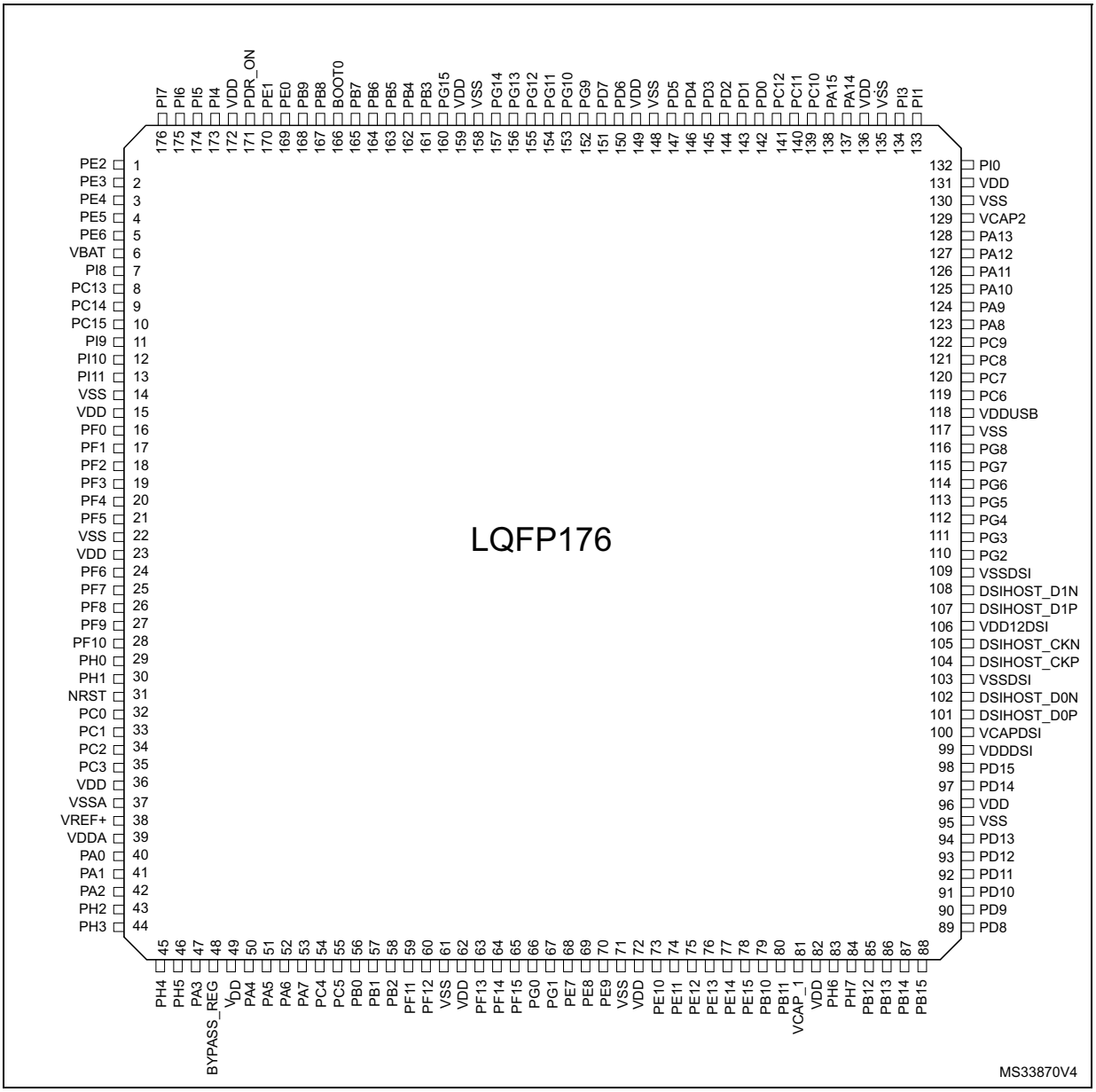

1. The above figure shows the package top view.

**Figure 17. STM32F46x UFBGA176 ballout**



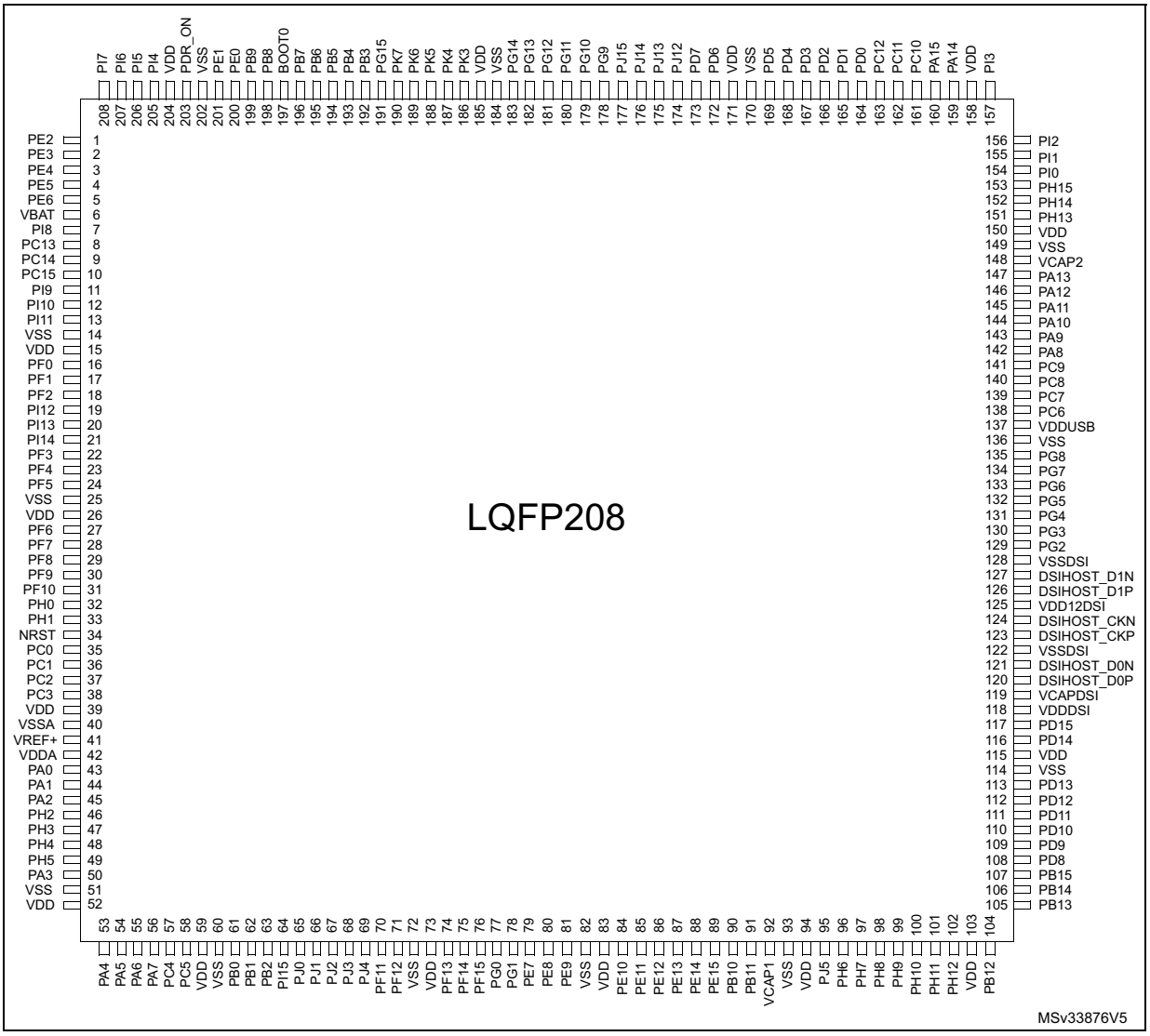

1. The above figure shows the package top view.

**Figure 18. STM32F46x LQFP176 pinout**



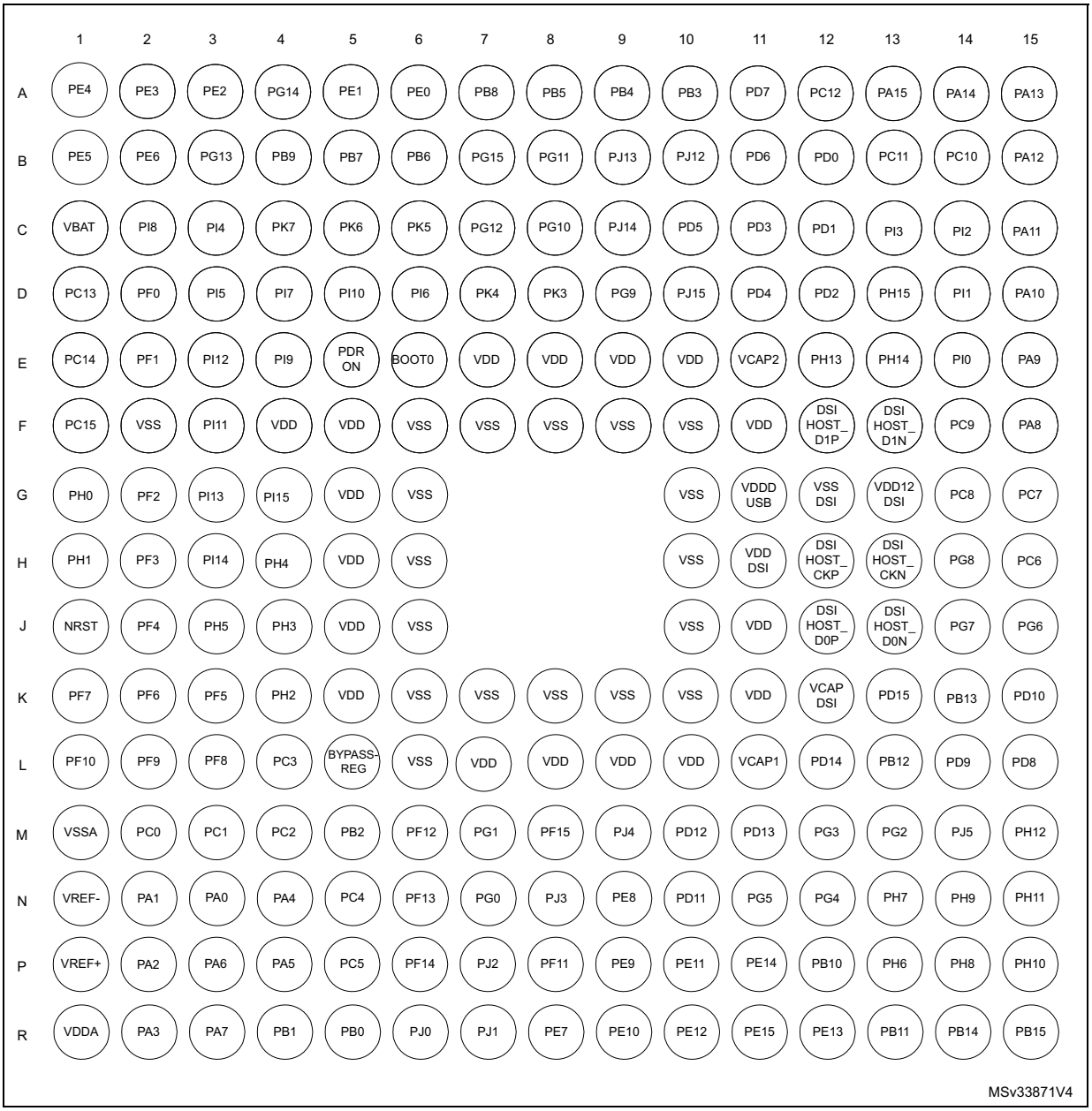

1. The above figure shows the package top view.

**Figure 19. STM32F46x LQFP208 pinout**




1. The above figure shows the package top view.

**Figure 20. STM32F46x TFBGA216 ballout**




1. The above figure shows the package top view.

**Table 9. Legend/abbreviations used in the pinout table**

| Name | Abbreviation | Definition |
|---|---|---|
| Pin name | Unless otherwise specified in brackets below the pin name, the pin function during and after reset is the same as the actual pin name | |
| Pin type | S | Supply pin |
| | I | Input only pin |
| | I/O | Input / output pin |
| I/O structure | FT | 5 V tolerant I/O |
| | TTa | 3.3 V tolerant I/O directly connected to analog parts |
| | B | Dedicated BOOT0 pin |
| | RST | Bidirectional reset pin with weak pull-up resistor |
| Notes | Unless otherwise specified by a note, all I/Os are set as floating inputs during and after reset | |
| Alternate functions | Functions selected through GPIOx_AFR registers | |
| Additional functions | Functions directly selected/enabled through peripheral registers | |

**Table 10. STM32F469xx pin and ball definitions**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 1 | 144 | B2 | F9 | A2 | 1 | 1 | A3 | PE2 | I/O | FT | - | TRACECLK, SPI4_SCK, SAI1_MCLK_A, QUADSPI_BK1_IO2, ETH_MII_TXD3, FMC_A23, EVENTOUT | - |
| NC (3) | 1 | C1 | E10 | A1 | 2 | 2 | A2 | PE3 | I/O | FT | - | TRACED0, SAI1_SD_B, FMC_A19, EVENTOUT | - |
| NC (3) | 2 | C2 | C11 | B1 | 3 | 3 | A1 | PE4 | I/O | FT | - | TRACED1, SPI4_NSS, SAI1_FS_A, FMC_A20, DCMI_D4, LCD_B0, EVENTOUT | - |
| NC (3) | 3 | D1 | B12 | B2 | 4 | 4 | B1 | PE5 | I/O | FT | - | TRACED2, TIM9_CH1, SPI4_MISO, SAI1_SCK_A, FMC_A21, DCMI_D6, LCD_G0, EVENTOUT | - |
| NC (3) | 4 | D2 | D11 | B3 | 5 | 5 | B2 | PE6 | I/O | FT | - | TRACED3, TIM9_CH2, SPI4_MOSI, SAI1_SD_A, FMC_A22, DCMI_D7, LCD_G1, EVENTOUT | - |
| 2 | - | - | - | - | - | - | G6 | VSS | S | - | - | - | - |
| - | - | - | - | - | - | - | F5 | VDD | S | - | - | - | - |
| 3 | 5 | E5 | C12 | C1 | 6 | 6 | C1 | VBAT | S | - | - | - | - |
| - | - | - | - | D2 | 7 | 7 | C2 | PI8 | I/O | FT | (4) (5) | EVENTOUT | RTC_TAMP1/ RTC_TAMP2/ RTC_TS |
| 4 | 6 | G4 | D12 | D1 | 8 | 8 | D1 | PC13 | I/O | FT | (4) (5) | EVENTOUT | RTC_TAMP1/ RTC_TS/ RTC_OUT |
| 5 | 7 | E1 | E11 | E1 | 9 | 9 | E1 | PC14-OSC32_IN (PC14) | I/O | FT | (4) (5) | EVENTOUT | OSC32_IN |
| 6 | 8 | F1 | E12 | F1 | 10 | 10 | F1 | PC15-OSC32_OUT (PC15) | I/O | FT | (4) (5) | EVENTOUT | OSC32_OUT |
| - | - | - | - | - | - | - | G5 | VDD | S | - | - | - | - |
| - | - | E2 | G9 | D3 | 11 | 11 | E4 | PI9 | I/O | FT | | CAN1_RX, FMC_D30, LCD_VSYNC, EVENTOUT | - |
| - | - | E4 | F10 | E3 | 12 | 12 | D5 | PI10 | I/O | FT | | ETH_MII_RX_ER, FMC_D31, LCD_HSYNC, EVENTOUT | - |
| - | - | F2 | F11 | E4 | 13 | 13 | F3 | PI11 | I/O | FT | | LCD_G6, OTG_HS_ULPI_DIR, EVENTOUT | - |
| - | - | F5 | F12 | F2 | 14 | 14 | F2 | VSS | S | - | - | - | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | - | F4 | G11 | F3 | 15 | 15 | F4 | VDD | S | - | - | - | - |
| - | 9 | F3 | G10 | E2 | 16 | 16 | D2 | PF0 | I/O | FT | | I2C2_SDA, FMC_A0, EVENTOUT | - |
| - | 10 | G3 | H10 | H3 | 17 | 17 | E2 | PF1 | I/O | FT | | I2C2_SCL, FMC_A1, EVENTOUT | - |
| - | 11 | G5 | G12 | H2 | 18 | 18 | G2 | PF2 | I/O | FT | | I2C2_SMBA, FMC_A2, EVENTOUT | - |
| - | - | - | - | - | - | 19 | E3 | PI12 | I/O | FT | | LCD_HSYNC, EVENTOUT | - |
| - | - | - | - | - | - | 20 | G3 | PI13 | I/O | FT | | LCD_VSYNC, EVENTOUT | - |
| - | - | - | - | - | - | 21 | H3 | PI14 | I/O | FT | | LCD_CLK, EVENTOUT | - |
| - | 12 | H4 | H11 | J2 | 19 | 22 | H2 | PF3 | I/O | FT | (6) | FMC_A3, EVENTOUT | ADC3_IN9 |
| - | 13 | L4 | J10 | J3 | 20 | 23 | J2 | PF4 | I/O | FT | (6) | FMC_A4, EVENTOUT | ADC3_IN14 |
| - | 14 | H3 | H12 | K3 | 21 | 24 | K3 | PF5 | I/O | FT | (6) | FMC_A5, EVENTOUT | ADC3_IN15 |
| 7 | 15 | G7 | J11 | G2 | 22 | 25 | H6 | VSS | S | - | - | - | - |
| 8 | 16 | G8 | J12 | G3 | 23 | 26 | H5 | VDD | S | - | - | - | - |
| - | - | - | - | K2 | 24 | 27 | K2 | PF6 | I/O | FT | (6) | TIM10_CH1, SPI5_NSS, SAI1_SD_B, UART7_Rx, QUADSPI_BK1_IO3, EVENTOUT | ADC3_IN4 |
| - | - | - | - | K1 | 25 | 28 | K1 | PF7 | I/O | FT | (6) | TIM11_CH1, SPI5_SCK, SAI1_MCLK_B, UART7_Tx, QUADSPI_BK1_IO2, EVENTOUT | ADC3_IN5 |
| - | - | - | - | L3 | 26 | 29 | L3 | PF8 | I/O | FT | (6) | SPI5_MISO, SAI1_SCK_B, TIM13_CH1, QUADSPI_BK1_IO0, EVENTOUT | ADC3_IN6 |
| - | - | - | - | L2 | 27 | 30 | L2 | PF9 | I/O | FT | (6) | SPI5_MOSI, SAI1_FS_B, TIM14_CH1, QUADSPI_BK1_IO1, EVENTOUT | ADC3_IN7 |
| - | 17 | H1 | K10 | L1 | 28 | 31 | L1 | PF10 | I/O | FT | (6) | QUADSPI_CLK, DCMI_D11, LCD_DE, EVENTOUT | ADC3_IN8 |
| 9 | 18 | G2 | K11 | G1 | 29 | 32 | G1 | PH0-OSC_IN (PH0) | I/O | FT | - | EVENTOUT | OSC_IN |
| 10 | 19 | G1 | K12 | H1 | 30 | 33 | H1 | PH1-OSC_OUT (PH1) | I/O | FT | - | EVENTOUT | OSC_OUT |
| 11 | 20 | H2 | H9 | J1 | 31 | 34 | J1 | NRST | I/O | RST | - | | |
| 12 | 21 | M1 | J9 | M2 | 32 | 35 | M2 | PC0 | I/O | FT | (6) | OTG_HS_ULPI_STP, FMC_SDNWE, LCD_R5, EVENTOUT | ADC123_ IN10 |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 13 | 22 | N1 | L12 | M3 | 33 | 36 | M3 | PC1 | I/O | FT | (6) | TRACED0, SPI2_MOSI/I2S2_SD, SAI1_SD_A, ETH_MDC, EVENTOUT | ADC123_IN11 |
| 14 | 23 | - | - | M4 | 34 | 37 | M4 | PC2 | I/O | FT | (6) | SPI2_MISO, I2S2ext_SD, OTG_HS_ULPI_DIR, ETH_MII_TXD2, FMC_SDNE0, EVENTOUT | ADC123_IN12 |
| 15 | 24 | - | - | M5 | 35 | 38 | L4 | PC3 | I/O | FT | (6) | SPI2_MOSI/I2S2_SD, OTG_HS_ULPI_NXT, ETH_MII_TX_CLK, FMC_SDCKE0, EVENTOUT | ADC123_IN13 |
| - | 25 | - | - | - | 36 | 39 | J5 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | - | J6 | VSS | S | - | - | - | - |
| 16 | 26 | J2 | L11 | M1 | 37 | 40 | M1 | VSSA | S | - | - | - | - |
| - | - | - | - | N1 | - | - | N1 | VREF- | S | - | - | - | - |
| 17 | 27 | - | - | P1 | 38 | 41 | P1 | VREF+ | S | - | - | - | - |
| 18 | 28 | J3 | M12 | R1 | 39 | 42 | R1 | VDDA | S | - | - | - | - |
| 19 | 29 | J5 | L10 | N3 | 40 | 43 | N3 | PA0-WKUP(PA0) | I/O | FT | (7) | TIM2_CH1/TIM2_ETR, TIM5_CH1, TIM8_ETR, USART2_CTS, UART4_TX, ETH_MII_CRS, EVENTOUT | ADC123_IN0, WKUP |
| 20 | 30 | K1 | K9 | N2 | 41 | 44 | N2 | PA1 | I/O | FT | (6) | TIM2_CH2, TIM5_CH2, USART2_RTS, UART4_RX, QUADSPI_BK1_IO3, ETH_MII_RX_CLK/ETH_RMII_REF_CLK, LCD_R2, EVENTOUT | ADC123_IN1 |
| 21 | 31 | K2 | L9 | P2 | 42 | 45 | P2 | PA2 | I/O | FT | (6) | TIM2_CH3, TIM5_CH3, TIM9_CH1, USART2_TX, ETH_MDIO, LCD_R1, EVENTOUT | ADC123_IN2 |
| - | - | L2 | M11 | F4 | 43 | 46 | K4 | PH2 | I/O | FT | - | QUADSPI_BK2_IO0, ETH_MII_CRS, FMC_SDCKE0, LCD_R0, EVENTOUT | - |
| - | - | L1 | N12 | G4 | 44 | 47 | J4 | PH3 | I/O | FT | - | QUADSPI_BK2_IO1, ETH_MII_COL, FMC_SDNE0, LCD_R1, EVENTOUT | - |
| - | - | M2 | M10 | H4 | 45 | 48 | H4 | PH4 | I/O | FT | - | I2C2_SCL, LCD_G5, OTG_HS_ULPI_NXT, LCD_G4, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | - | L3 | K8 | J4 | 46 | 49 | J3 | PH5 | I/O | FT | - | I2C2_SDA, SPI5_NSS, FMC_SDNWE, EVENTOUT | - |
| 22 | 32 | K3 | N10 | R2 | 47 | 50 | R2 | PA3 | I/O | FT | (6) | TIM2_CH4, TIM5_CH4, TIM9_CH2, USART2_RX, LCD_B2, OTG_HS_ULPI_D0, ETH_MII_COL, LCD_B5, EVENTOUT | ADC123_IN3 |
| 23 | 33 | J1 | N11 | - | - | 51 | K6 | VSS | S | - | - | - | - |
| - | - | - | - | L4 | 48 | - | L5 | BYPASS_REG | I | FT | - | - | - |
| 24 | 34 | J4 | P12 | K4 | 49 | 52 | K5 | VDD | S | - | - | - | - |
| 25 | 35 | N2 | M9 | N4 | 50 | 53 | N4 | PA4 | I/O | TTa | - | SPI1_NSS, SPI3_NSS/I2S3_WS, USART2_CK, OTG_HS_SOF, DCMI_HSYNC, LCD_VSYNC, EVENTOUT | ADC12_IN4, DAC_OUT1 |
| 26 | 36 | M3 | L8 | P4 | 51 | 54 | P4 | PA5 | I/O | TTa | - | TIM2_CH1/TIM2_ETR, TIM8_CH1N, SPI1_SCK, OTG_HS_ULPI_CK, LCD_R4, EVENTOUT | ADC12_IN5, DAC_OUT2 |
| 27 | 37 | N3 | P11 | P3 | 52 | 55 | P3 | PA6 | I/O | FT | (6) | TIM1_BKIN, TIM3_CH1, TIM8_BKIN, SPI1_MISO, TIM13_CH1, DCMI_PIXCLK, LCD_G2, EVENTOUT | ADC12_IN6 |
| 28 | 38 | K4 | J8 | R3 | 53 | 56 | R3 | PA7 | I/O | FT | (6) | TIM1_CH1N, TIM3_CH2, TIM8_CH1N, SPI1_MOSI, TIM14_CH1, QUADSPI_CLK, ETH_MII_RX_DV/ETH_RMII_CRS_DV, FMC_SDNWE, EVENTOUT | ADC12_IN7 |
| NC (3) | 39 | - | - | N5 | 54 | 57 | N5 | PC4 | I/O | FT | (6) | ETH_MII_RXD0/ETH_RMII_RXD0, FMC_SDNE0, EVENTOUT | ADC12_IN14 |
| NC (3) | 40 | - | - | P5 | 55 | 58 | P5 | PC5 | I/O | FT | (6) | ETH_MII_RXD1/ETH_RMII_RXD1, FMC_SDCKE0, EVENTOUT | ADC12_IN15 |
| - | - | - | - | - | - | 59 | L7 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | 60 | L6 | VSS | S | - | - | - | - |
| 29 | 41 | N4 | P10 | R5 | 56 | 61 | R5 | PB0 | I/O | FT | (6) | TIM1_CH2N, TIM3_CH3, TIM8_CH2N, LCD_R3, OTG_HS_ULPI_D1, ETH_MII_RXD2, LCD_G1, EVENTOUT | ADC12_IN8 |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)(1) | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176(2) | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 30 | 42 | K5 | N9 | R4 | 57 | 62 | R4 | PB1 | I/O | FT | (6) | TIM1_CH3N, TIM3_CH4, TIM8_CH3N, LCD_R6, OTG_HS_ULPI_D2, ETH_MII_RXD3, LCD_G0, EVENTOUT | ADC12_IN9 |
| 31 | 43 | L5 | P9 | M6 | 58 | 63 | M5 | PB2-BOOT1(PB2) | I/O | FT | - | EVENTOUT | - |
| - | - | - | - | - | - | 64 | G4 | PI15 | I/O | FT | - | LCD_G2, LCD_R0, EVENTOUT | - |
| - | - | - | - | - | - | 65 | R6 | PJ0 | I/O | FT | - | LCD_R7, LCD_R1, EVENTOUT | - |
| - | - | - | - | - | - | 66 | R7 | PJ1 | I/O | FT | - | LCD_R2, EVENTOUT | - |
| - | - | - | - | - | - | 67 | P7 | PJ2 | I/O | FT | - | DSIHOST_TE, LCD_R3, EVENTOUT | - |
| - | - | - | - | - | - | 68 | N8 | PJ3 | I/O | FT | - | LCD_R4, EVENTOUT | - |
| - | - | - | - | - | - | 69 | M9 | PJ4 | I/O | FT | - | LCD_R5, EVENTOUT | - |
| - | 44 | M5 | K7 | R6 | 59 | 70 | P8 | PF11 | I/O | FT | - | SPI5_MOSI, FMC_SDNRAS, DCMI_D12, EVENTOUT | - |
| - | 45 | N5 | M8 | P6 | 60 | 71 | M6 | PF12 | I/O | FT | - | FMC_A6, EVENTOUT | - |
| - | - | J6 | N8 | M8 | 61 | 72 | K7 | VSS | S | - | - | - | - |
| - | 46 | K6 | P8 | N8 | 62 | 73 | L8 | VDD | S | - | - | - | - |
| - | 47 | M4 | J7 | N6 | 63 | 74 | N6 | PF13 | I/O | FT | - | FMC_A7, EVENTOUT | - |
| - | 48 | H5 | L7 | R7 | 64 | 75 | P6 | PF14 | I/O | FT | - | FMC_A8, EVENTOUT | - |
| - | 49 | M6 | H8 | P7 | 65 | 76 | M8 | PF15 | I/O | FT | - | FMC_A9, EVENTOUT | - |
| - | 50 | N6 | J6 | N7 | 66 | 77 | N7 | PG0 | I/O | FT | - | FMC_A10, EVENTOUT | - |
| - | 51 | M7 | P7 | M7 | 67 | 78 | M7 | PG1 | I/O | FT | - | FMC_A11, EVENTOUT | - |
| 32 | 52 | N7 | N7 | R8 | 68 | 79 | R8 | PE7 | I/O | FT | - | TIM1_ETR, UART7_Rx, QUADSPI_BK2_IO0, FMC_D4, EVENTOUT | - |
| 33 | 53 | G6 | M7 | P8 | 69 | 80 | N9 | PE8 | I/O | FT | - | TIM1_CH1N, UART7_Tx, QUADSPI_BK2_IO1, FMC_D5, EVENTOUT | - |
| 34 | 54 | H6 | K6 | P9 | 70 | 81 | P9 | PE9 | I/O | FT | - | TIM1_CH1, QUADSPI_BK2_IO2, FMC_D6, EVENTOUT | - |
| - | 55 | J7 | - | M9 | 71 | 82 | K8 | VSS | S | - | - | - | - |
| - | 56 | L6 | - | N9 | 72 | 83 | L9 | VDD | S | - | - | - | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 35 | 57 | H7 | P6 | R9 | 73 | 84 | R9 | PE10 | I/O | FT | - | TIM1_CH2N, QUADSPI_BK2_IO3, FMC_D7, EVENTOUT | - |
| 36 | 58 | K7 | N6 | P10 | 74 | 85 | P10 | PE11 | I/O | FT | - | TIM1_CH2, SPI4_NSS, FMC_D8, LCD_G3, EVENTOUT | - |
| 37 | 59 | L7 | M6 | R10 | 75 | 86 | R10 | PE12 | I/O | FT | - | TIM1_CH3N, SPI4_SCK, FMC_D9, LCD_B4, EVENTOUT | - |
| 38 | 60 | J8 | L6 | N11 | 76 | 87 | R12 | PE13 | I/O | FT | - | TIM1_CH3, SPI4_MISO, FMC_D10, LCD_DE, EVENTOUT | - |
| 39 | 61 | K8 | J5 | P11 | 77 | 88 | P11 | PE14 | I/O | FT | - | TIM1_CH4, SPI4_MOSI, FMC_D11, LCD_CLK, EVENTOUT | - |
| 40 | 62 | L8 | P5 | R11 | 78 | 89 | R11 | PE15 | I/O | FT | - | TIM1_BKIN, FMC_D12, LCD_R7, EVENTOUT | - |
| 41 | 63 | M8 | N5 | R12 | 79 | 90 | P12 | PB10 | I/O | FT | - | TIM2_CH3, I2C2_SCL, SPI2_SCK/I2S2_CK, USART3_TX, QUADSPI_BK1_NCS, OTG_HS_ULPI_D3, ETH_MII_RX_ER, LCD_G4, EVENTOUT | - |
| 42 | 64 | N8 | K5 | R13 | 80 | 91 | R13 | PB11 | I/O | FT | - | TIM2_CH4, I2C2_SDA, USART3_RX, OTG_HS_ULPI_D4, ETH_MII_TX_EN/ETH_RMII_TX_EN, DSIHOST_TE, LCD_G5, EVENTOUT | - |
| 43 | 65 | N9 | N4 | M10 | 81 | 92 | L11 | VCAP1 | S | - | - | - | - |
| 44 | - | M9 | P4 | - | - | 93 | K9 | VSS | S | - | - | - | - |
| 45 | 66 | L9 | P3 | N10 | 82 | 94 | L10 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | 95 | M14 | PJ5 | I/O | FT | - | LCD_R6, EVENTOUT | - |
| - | - | - | - | M11 | 83 | 96 | P13 | PH6 | I/O | FT | - | I2C2_SMBA, SPI5_SCK, TIM12_CH1, ETH_MII_RXD2, FMC_SDNE1, DCMI_D8, EVENTOUT | - |
| - | - | - | - | N12 | 84 | 97 | N13 | PH7 | I/O | FT | - | I2C3_SCL, SPI5_MISO, ETH_MII_RXD3, FMC_SDCKE1, DCMI_D9, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | - | H8 | M5 | - | - | 98 | P14 | PH8 | I/O | FT | - | I2C3_SDA, FMC_D16, DCMI_HSYNC, LCD_R2, EVENTOUT | - |
| - | - | H9 | L5 | - | - | 99 | N14 | PH9 | I/O | FT | - | I2C3_SMBA, TIM12_CH2, FMC_D17, DCMI_D0, LCD_R3, EVENTOUT | - |
| - | - | J9 | M4 | - | - | 100 | P15 | PH10 | I/O | FT | - | TIM5_CH1, FMC_D18, DCMI_D1, LCD_R4, EVENTOUT | - |
| - | - | K9 | N3 | - | - | 101 | N15 | PH11 | I/O | FT | - | TIM5_CH2, FMC_D19, DCMI_D2, LCD_R5, EVENTOUT | - |
| - | - | H10 | P2 | - | - | 102 | M15 | PH12 | I/O | FT | - | TIM5_CH3, FMC_D20, DCMI_D3, LCD_R6, EVENTOUT | - |
| - | - | - | H7 | - | - | - | K10 | VSS | S | - | - | - | - |
| - | 66 | - | - | - | - | 103 | K11 | VDD | S | - | - | - | - |
| 46 | 67 | N10 | H5 | P12 | 85 | 104 | L13 | PB12 | I/O | FT | - | TIM1_BKIN, I2C2_SMBA, SPI2_NSS/I2S2_WS, USART3_CK, CAN2_RX, OTG_HS_ULPI_D5, ETH_MII_TXD0/ETH_RMII_TXD0, OTG_HS_ID, EVENTOUT | - |
| 47 | 68 | N11 | K4 | P13 | 86 | 105 | K14 | PB13 | I/O | FT | - | TIM1_CH1N, SPI2_SCK/I2S2_CK, USART3_CTS, CAN2_TX, OTG_HS_ULPI_D6, ETH_MII_TXD1/ETH_RMII_TXD1, EVENTOUT | OTG_HS_VBUS |
| 48 | 69 | N12 | P1 | R14 | 87 | 106 | R14 | PB14 | I/O | FT | - | TIM1_CH2N, TIM8_CH2N, SPI2_MISO, I2S2ext_SD, USART3_RTS, TIM12_CH1, OTG_HS_DM, EVENTOUT | - |
| 49 | 70 | N13 | N2 | R15 | 88 | 107 | R15 | PB15 | I/O | FT | - | RTC_REFIN, TIM1_CH3N, TIM8_CH3N, SPI2_MOSI/I2S2_SD, TIM12_CH2, OTG_HS_DP, EVENTOUT | - |
| 50 | 71 | L10 | L4 | P15 | 89 | 108 | L15 | PD8 | I/O | FT | - | USART3_TX, FMC_D13, EVENTOUT | - |
| 51 | 72 | M10 | N1 | P14 | 90 | 109 | L14 | PD9 | I/O | FT | - | USART3_RX, FMC_D14, EVENTOUT | - |
| 52 | 73 | L11 | M3 | N15 | 91 | 110 | K15 | PD10 | I/O | FT | - | USART3_CK, FMC_D15, LCD_B3, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | 74 | M11 | J4 | N14 | 92 | 111 | N10 | PD11 | I/O | FT | - | USART3_CTS, QUADSPI_BK1_IO0, FMC_A16/FMC_CLE, EVENTOUT | - |
| - | 75 | M13 | M2 | N13 | 93 | 112 | M10 | PD12 | I/O | FT | - | TIM4_CH1, USART3_RTS, QUADSPI_BK1_IO1, FMC_A17/FMC_ALE, EVENTOUT | - |
| - | - | M12 | H4 | M15 | 94 | 113 | M11 | PD13 | I/O | FT | - | TIM4_CH2, QUADSPI_BK1_IO3, FMC_A18, EVENTOUT | - |
| - | 76 | J10 | M1 | - | 95 | 114 | J10 | VSS | S | - | - | - | - |
| - | 77 | K10 | - | J13 | 96 | 115 | J11 | VDD | S | - | - | - | - |
| 53 | 78 | L12 | L3 | M14 | 97 | 116 | L12 | PD14 | I/O | FT | - | TIM4_CH3, FMC_D0, EVENTOUT | - |
| 54 | 79 | L13 | L2 | L14 | 98 | 117 | K13 | PD15 | I/O | FT | - | TIM4_CH4, FMC_D1, EVENTOUT | - |
| 55 | 80 | K13 | L1 | J12 | 99 | 118 | H11 | VDDDSI | S | - | - | - | - |
| - | - | - | - | - | - | - | H10 | VSS | S | - | - | - | - |
| 56 | 81 | K12 | K1 | K12 | 100 | 119 | K12 | VCAPDSI | S | - | - | - | - |
| - | - | - | K2 | D13 | - | - | G13 | VDD12DSI | S | - | - | - | - |
| 57 | 82 | J12 | K3 | M12 | 101 | 120 | J12 | DSIHOST_D0P | I/O | - | - | - | - |
| 58 | 83 | J13 | J3 | M13 | 102 | 121 | J13 | DSIHOST_D0N | I/O | - | - | - | - |
| 59 | 84 | K11 | H1 | H12 | 103 | 122 | G12 | VSSDSI | S | - | - | - | - |
| 60 | 85 | H12 | J1 | L12 | 104 | 123 | H12 | DSIHOST_CKP | I/O | - | - | - | - |
| 61 | 86 | H13 | J2 | L13 | 105 | 124 | H13 | DSIHOST_CKN | I/O | - | - | - | - |
| 62 | 87 | J11 | - | D13 | 106 | 125 | - | VDD12DSI | S | - | - | - | - |
| 63 | 88 | G12 | H3 | E12 | 107 | 126 | F12 | DSIHOST_D1P | I/O | - | - | - | - |
| 64 | 89 | G13 | H2 | E13 | 108 | 127 | F13 | DSIHOST_D1N | I/O | - | - | - | - |
| - | - | H11 | - | H12 | 109 | 128 | - | VSSDSI | S | - | - | - | - |
| - | 90 | F13 | G5 | L15 | 110 | 129 | M13 | PG2 | I/O | FT | - | FMC_A12, EVENTOUT | - |
| - | 91 | F12 | G4 | K15 | 111 | 130 | M12 | PG3 | I/O | FT | - | FMC_A13, EVENTOUT | - |
| - | 92 | E13 | G2 | K14 | 112 | 131 | N12 | PG4 | I/O | FT | - | FMC_A14/FMC_BA0, EVENTOUT | - |
| - | 93 | E12 | G1 | K13 | 113 | 132 | N11 | PG5 | I/O | FT | - | FMC_A15/FMC_BA1, EVENTOUT | - |
| - | 94 | F11 | G3 | J15 | 114 | 133 | J15 | PG6 | I/O | FT | - | DCMI_D12, LCD_R7, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | 95 | E11 | H6 | J14 | 115 | 134 | J14 | PG7 | I/O | FT | - | SAI1_MCLK_A, USART6_CK, FMC_INT, DCMI_D13, LCD_CLK, EVENTOUT | - |
| - | 96 | D13 | G6 | H14 | 116 | 135 | H14 | PG8 | I/O | FT | - | SPI6_NSS, USART6_RTS, ETH_PPS_OUT, FMC_SDCLK, LCD_G7, EVENTOUT | - |
| - | - | G9 | F2 | G12 | 117 | 136 | G10 | VSS | S | - | - | - | - |
| 65 | 97 | G11 | F1 | H13 | 118 | 137 | G11 | VDDUSB | S | - | - | - | - |
| 66 | 98 | F9 | F3 | H15 | 119 | 138 | H15 | PC6 | I/O | FT | - | TIM3_CH1, TIM8_CH1, I2S2_MCK, USART6_TX, SDIO_D6, DCMI_D0, LCD_HSYNC, EVENTOUT | - |
| 67 | 99 | F10 | G7 | G15 | 120 | 139 | G15 | PC7 | I/O | FT | - | TIM3_CH2, TIM8_CH2, I2S3_MCK, USART6_RX, SDIO_D7, DCMI_D1, LCD_G6, EVENTOUT | - |
| 68 | 100 | E10 | F4 | G14 | 121 | 140 | G14 | PC8 | I/O | FT | - | TRACED1, TIM3_CH3, TIM8_CH3, USART6_CK, SDIO_D0, DCMI_D2, EVENTOUT | - |
| 69 | 101 | G10 | F5 | F14 | 122 | 141 | F14 | PC9 | I/O | FT | - | MCO2, TIM3_CH4, TIM8_CH4, I2C3_SDA, I2S_CKIN, QUADSPI_BK1_IO0, SDIO_D1, DCMI_D3, EVENTOUT | - |
| 70 | 102 | D8 | E1 | F15 | 123 | 142 | F15 | PA8 | I/O | FT | - | MCO1, TIM1_CH1, I2C3_SCL, USART1_CK, OTG_FS_SOF, LCD_R6, EVENTOUT | - |
| 71 | 103 | E8 | E2 | E15 | 124 | 143 | E15 | PA9 | I/O | FT | - | TIM1_CH2, I2C3_SMBA, SPI2_SCK/I2S2_CK, USART1_TX, DCMI_D0, EVENTOUT | OTG_FS_ VBUS |
| 72 | 104 | E9 | E3 | D15 | 125 | 144 | D15 | PA10 | I/O | FT | - | TIM1_CH3, USART1_RX, OTG_FS_ID, DCMI_D1, EVENTOUT | - |
| 73 | 105 | A13 | F7 | C15 | 126 | 145 | C15 | PA11 | I/O | FT | - | TIM1_CH4, USART1_CTS, CAN1_RX, OTG_FS_DM, LCD_R4, EVENTOUT | - |
| 74 | 106 | A12 | F6 | B15 | 127 | 146 | B15 | PA12 | I/O | FT | - | TIM1_ETR, USART1_RTS, CAN1_TX, OTG_FS_DP, LCD_R5, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 75 | 107 | A11 | D1 | A15 | 128 | 147 | A15 | PA13(JTMS-SWDIO) | I/O | FT | - | JTMS-SWDIO, EVENTOUT | - |
| 76 | 108 | D12 | D2 | F13 | 129 | 148 | E11 | VCAP2 | S | - | - | - | - |
| - | 109 | D11 | C1 | F12 | 130 | 149 | F10 | VSS | S | - | - | - | - |
| 77 | 110 | D10 | C2 | G13 | 131 | 150 | F11 | VDD | S | - | - | - | - |
| - | - | D9 | B1 | - | - | 151 | E12 | PH13 | I/O | FT | - | TIM8_CH1N, CAN1_TX, FMC_D21, LCD_G2, EVENTOUT | - |
| - | - | C13 | D3 | - | - | 152 | E13 | PH14 | I/O | FT | - | TIM8_CH2N, FMC_D22, DCMI_D4, LCD_G3, EVENTOUT | - |
| - | - | C12 | E4 | - | - | 153 | D13 | PH15 | I/O | FT | - | TIM8_CH3N, FMC_D23, DCMI_D11, LCD_G4, EVENTOUT | - |
| - | - | B13 | E5 | E14 | 132 | 154 | E14 | PI0 | I/O | FT | - | TIM5_CH4, SPI2_NSS/I2S2_WS[8], FMC_D24, DCMI_D13, LCD_G5, EVENTOUT | - |
| - | - | C11 | C3 | D14 | 133 | 155 | D14 | PI1 | I/O | FT | - | SPI2_SCK/I2S2_CK[8], FMC_D25, DCMI_D8, LCD_G6, EVENTOUT | - |
| - | - | B12 | A1 | - | NC (3) | 156 | C14 | PI2 | I/O | FT | - | TIM8_CH4, SPI2_MISO, I2S2ext_SD, FMC_D26, DCMI_D9, LCD_G7, EVENTOUT | - |
| - | - | B10 | B2 | C13 | 134 | 157 | C13 | PI3 | I/O | FT | - | TIM8_ETR, SPI2_MOSI/I2S2_SD, FMC_D27, DCMI_D10, EVENTOUT | - |
| 78 | - | - | - | D9 | 135 | - | F9 | VSS | S | - | - | - | - |
| - | - | - | B5 | C9 | 136 | 158 | E10 | VDD | S | - | - | - | - |
| 79 | 111 | A10 | D4 | A14 | 137 | 159 | A14 | PA14(JTCK-SWCLK) | I/O | FT | - | JTCK-SWCLK, EVENTOUT | - |
| 80 | 112 | B11 | A2 | A13 | 138 | 160 | A13 | PA15(JTDI) | I/O | FT | - | JTDI, TIM2_CH1/TIM2_ETR, SPI1_NSS, SPI3_NSS/I2S3_WS, EVENTOUT | - |
| 81 | 113 | C10 | D5 | B14 | 139 | 161 | B14 | PC10 | I/O | FT | - | SPI3_SCK/I2S3_CK, USART3_TX, UART4_TX, QUADSPI_BK1_IO1, SDIO_D2, DCMI_D8, LCD_R2, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 82 | 114 | B9 | B3 | B13 | 140 | 162 | B13 | PC11 | I/O | FT | - | I2S3ext_SD, SPI3_MISO, USART3_RX, UART4_RX, QUADSPI_BK2_NCS, SDIO_D3, DCMI_D4, EVENTOUT | - |
| 83 | 115 | A9 | C4 | A12 | 141 | 163 | A12 | PC12 | I/O | FT | - | TRACED3, SPI3_MOSI/I2S3_SD, USART3_CK, UART5_TX, SDIO_CK, DCMI_D9, EVENTOUT | - |
| 84 | 116 | C9 | E6 | B12 | 142 | 164 | B12 | PD0 | I/O | FT | - | CAN1_RX, FMC_D2, EVENTOUT | - |
| 85 | 117 | C7 | A3 | C12 | 143 | 165 | C12 | PD1 | I/O | FT | - | CAN1_TX, FMC_D3, EVENTOUT | - |
| 86 | 118 | B8 | C5 | D12 | 144 | 166 | D12 | PD2 | I/O | FT | - | TRACED2, TIM3_ETR, UART5_RX, SDIO_CMD, DCMI_D11, EVENTOUT | - |
| 87 | 119 | C8 | D6 | D11 | 145 | 167 | C11 | PD3 | I/O | FT | - | SPI2_SCK/I2S2_CK, USART2_CTS, FMC_CLK, DCMI_D5, LCD_G7, EVENTOUT | - |
| 88 | 120 | C6 | B4 | D10 | 146 | 168 | D11 | PD4 | I/O | FT | - | USART2_RTS, FMC_NOE, EVENTOUT | - |
| 89 | 121 | B7 | C6 | C11 | 147 | 169 | C10 | PD5 | I/O | FT | - | USART2_TX, FMC_NWE, EVENTOUT | - |
| - | 122 | F8 | A4 | D8 | 148 | 170 | F8 | VSS | S | - | - | - | - |
| - | 123 | F7 | - | C8 | 149 | 171 | E9 | VDD | S | - | - | - | - |
| 90 | 124 | D7 | E7 | B11 | 150 | 172 | B11 | PD6 | I/O | FT | - | SPI3_MOSI/I2S3_SD, SAI1_SD_A, USART2_RX, FMC_NWAIT, DCMI_D10, LCD_B2, EVENTOUT | - |
| 91 | - | A8 | A5 | A11 | 151 | 173 | A11 | PD7 | I/O | FT | - | USART2_CK, FMC_NE1, EVENTOUT | - |
| - | - | - | - | - | - | 174 | B10 | PJ12 | I/O | FT | - | LCD_G3, LCD_B0, EVENTOUT | - |
| - | - | - | - | - | - | 175 | B9 | PJ13 | I/O | FT | - | LCD_G4, LCD_B1, EVENTOUT | - |
| - | - | - | - | - | - | 176 | C9 | PJ14 | I/O | FT | - | LCD_B2, EVENTOUT | - |
| - | - | - | - | - | - | 177 | D10 | PJ15 | I/O | FT | - | LCD_B3, EVENTOUT | - |
| - | 125 | E6 | D7 | C10 | 152 | 178 | D9 | PG9 | I/O | FT | - | USART6_RX, QUADSPI_BK2_IO2, FMC_NE2/FMC_NCE, DCMI_VSYNC, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | 126 | E7 | C7 | B10 | 153 | 179 | C8 | PG10 | I/O | FT | - | LCD_G3, FMC_NE3, DCMI_D2, LCD_B2, EVENTOUT | - |
| - | 127 | B6 | B6 | B9 | 154 | 180 | B8 | PG11 | I/O | FT | - | ETH_MII_TX_EN/ETH_RMII_TX_EN, DCMI_D3, LCD_B3, EVENTOUT | - |
| - | 128 | A7 | A6 | B8 | 155 | 181 | C7 | PG12 | I/O | FT | - | SPI6_MISO, USART6_RTS, LCD_B4, FMC_NE4, LCD_B1, EVENTOUT | - |
| - | - | A6 | E8 | A8 | 156 | 182 | B3 | PG13 | I/O | FT | - | TRACED0, SPI6_SCK, USART6_CTS, ETH_MII_TXD0/ETH_RMII_TXD0, FMC_A24, LCD_R0, EVENTOUT | - |
| - | - | - | - | A7 | 157 | 183 | A4 | PG14 | I/O | FT | - | TRACED1, SPI6_MOSI, USART6_TX, QUADSPI_BK2_IO3, ETH_MII_TXD1/ETH_RMII_TXD1, FMC_A25, LCD_B0, EVENTOUT | - |
| - | 129 | - | B7 | D7 | 158 | 184 | F7 | VSS | S | - | - | - | - |
| - | 130 | - | A7 | C7 | 159 | 185 | E8 | VDD | S | - | - | - | - |
| - | - | - | - | - | - | 186 | D8 | PK3 | I/O | FT | - | LCD_B4, EVENTOUT | - |
| - | - | - | - | - | - | 187 | D7 | PK4 | I/O | FT | - | LCD_B5, EVENTOUT | - |
| - | - | - | - | - | - | 188 | C6 | PK5 | I/O | FT | - | LCD_B6, EVENTOUT | - |
| - | - | - | - | - | - | 189 | C5 | PK6 | I/O | FT | - | LCD_B7, EVENTOUT | - |
| - | - | - | - | - | - | 190 | C4 | PK7 | I/O | FT | - | LCD_DE, EVENTOUT | - |
| - | 131 | F6 | D8 | B7 | 160 | 191 | B7 | PG15 | I/O | FT | - | USART6_CTS, FMC_SDNCAS, DCMI_D13, EVENTOUT | - |
| 92 | 132 | B5 | A8 | A10 | 161 | 192 | A10 | PB3(JTDO/TRACESWO) | I/O | FT | - | JTDO/TRACESWO, TIM2_CH2, SPI1_SCK, SPI3_SCK/I2S3_CK, EVENTOUT | - |
| 93 | 133 | D6 | C8 | A9 | 162 | 193 | A9 | PB4(NJTRST) | I/O | FT | - | NJTRST, TIM3_CH1, SPI1_MISO, SPI3_MISO, I2S3ext_SD, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)[1] | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176[2] | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| 94 | 134 | D5 | B8 | A6 | 163 | 194 | A8 | PB5 | I/O | FT | - | TIM3_CH2, I2C1_SMBA, SPI1_MOSI, SPI3_MOSI/I2S3_SD, CAN2_RX, OTG_HS_ULPI_D7, ETH_PPS_OUT, FMC_SDCKE1, DCMI_D10, LCD_G7, EVENTOUT | - |
| 95 | 135 | C5 | G8 | B6 | 164 | 195 | B6 | PB6 | I/O | FT | - | TIM4_CH1, I2C1_SCL, USART1_TX, CAN2_TX, QUADSPI_BK1_NCS, FMC_SDNE1, DCMI_D5, EVENTOUT | - |
| 96 | 136 | B4 | A9 | B5 | 165 | 196 | B5 | PB7 | I/O | FT | - | TIM4_CH2, I2C1_SDA, USART1_RX, FMC_NL, DCMI_VSYNC, EVENTOUT | - |
| 97 | 137 | A5 | F8 | D6 | 166 | 197 | E6 | BOOT0 | I | B | - | - | VPP |
| 98 | 138 | D4 | B9 | A5 | 167 | 198 | A7 | PB8 | I/O | FT | - | TIM4_CH3, TIM10_CH1, I2C1_SCL, CAN1_RX, ETH_MII_TXD3, SDIO_D4, DCMI_D6, LCD_B6, EVENTOUT | - |
| 99 | 139 | C4 | E9 | B4 | 168 | 199 | B4 | PB9 | I/O | FT | - | TIM4_CH4, TIM11_CH1, I2C1_SDA, SPI2_NSS/I2S2_WS, CAN1_TX, SDIO_D5, DCMI_D7, LCD_B7, EVENTOUT | - |
| NC (3) | 140 | A4 | A10 | A4 | 169 | 200 | A6 | PE0 | I/O | FT | - | TIM4_ETR, UART8_Rx, FMC_NBL0, DCMI_D2, EVENTOUT | - |
| NC (3) | 141 | A3 | C9 | A3 | 170 | 201 | A5 | PE1 | I/O | FT | - | UART8_Tx, FMC_NBL1, DCMI_D3, EVENTOUT | - |
| - | - | E3 | B10 | D5 | - | 202 | F6 | VSS | S | - | - | - | - |
| - | 142 | C3 | D9 | C6 | 171 | 203 | E5 | PDR_ON | S | - | - | - | - |
| 100 | 143 | D3 | A11 | C5 | 172 | 204 | E7 | VDD | S | - | - | - | - |
| - | - | B3 | D10 | D4 | 173 | 205 | C3 | PI4 | I/O | FT | - | TIM8_BKIN, FMC_NBL2, DCMI_D5, LCD_B4, EVENTOUT | - |
| - | - | A2 | C10 | C4 | 174 | 206 | D3 | PI5 | I/O | FT | - | TIM8_CH1, FMC_NBL3, DCMI_VSYNC, LCD_B5, EVENTOUT | - |

**Table 10. STM32F469xx pin and ball definitions (continued)**

| Pin number | | | | | | | | Pin name (function after reset)(1) | Pin types | I/O structures | Notes | Alternate functions | Additional functions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LQFP100 | LQFP144 | UFBGA169 | WLCSP168 | UFBGA176(2) | LQFP176 | LQFP208 | TFBGA216 | | | | | | |
| - | - | A1 | B11 | C3 | 175 | 207 | D6 | PI6 | I/O | FT | - | TIM8_CH2, FMC_D28, DCMI_D6, LCD_B6, EVENTOUT | - |
| - | - | B1 | A12 | C2 | 176 | 208 | D4 | PI7 | I/O | FT | - | TIM8_CH3, FMC_D29, DCMI_D7, LCD_B7, EVENTOUT | - |

1. **Function availability depends on the chosen device.**
2. For the UFBGA176 package, the balls F6, F7, F8, F9, F10, G6, G7, G8, G9, G10, H6, H7, H8, H9, H10, J6, J7, J8, J9, J10, K6, K7, K8, K9, K10 are connected to VSS. Their purpose is heat dissipation and package mechanical stability.
3. NC (not-connected) pins are not bonded. They must be configured by software to output push-pull and forced to “0” in the output data register to avoid extra current consumption in low power modes.
4. PC13, PC14, PC15, and PI8 are supplied through the power switch. Since the switch only sinks a limited amount of current (3 mA), the use of GPIOs PC13 to PC15 and PI8 in output mode is limited:
   - The speed should not exceed 2 MHz with a maximum load of 30 pF.
   - These I/Os must not be used as a current source (for example, to drive one LED).
5. Main function after the first backup domain power-up. Later on, it depends on the contents of the RTC registers even after reset (because these registers are not reset by the main reset). For details on how to manage these I/Os, refer to the RTC register description sections in the STM32F4xx reference manual, available from *www.st.com*.
6. FT = 5 V tolerant except when in analog mode or oscillator mode (for PC14, PC15, PH0, and PH1).
7. If the device is delivered in one WLCSP168, UFBGA169, UFBGA176, LQFP176 or TFBGA216 package, and the BYPASS_REG pin is set to VDD (Regulator OFF/internal reset ON mode), then PA0 is used as an internal reset (active low).
8. PI0 and PI1 cannot be used for I2S2 full-duplex mode.

Table 11. FMC pin definition

| Pin name | NOR/PSRAM/SRAM | NOR/PSRAM Mux | NAND16 | SDRAM |
|---|---|---|---|---|
| PF0 | A0 | - | - | A0 |
| PF1 | A1 | - | - | A1 |
| PF2 | A2 | - | - | A2 |
| PF3 | A3 | - | - | A3 |
| PF4 | A4 | - | - | A4 |
| PF5 | A5 | - | - | A5 |
| PF12 | A6 | - | - | A6 |
| PF13 | A7 | - | - | A7 |
| PF14 | A8 | - | - | A8 |
| PF15 | A9 | - | - | A9 |
| PG0 | A10 | - | - | A10 |
| PG1 | A11 | - | - | A11 |
| PG2 | A12 | - | - | A12 |
| PG3 | A13 | - | - | |
| PG4 | A14 | - | - | BA0 |
| PG5 | A15 | - | - | BA1 |
| PD11 | A16 | A16 | CLE | - |
| PD12 | A17 | A17 | ALE | - |
| PD13 | A18 | A18 | - | - |
| PE3 | A19 | A19 | - | - |
| PE4 | A20 | A20 | - | - |
| PE5 | A21 | A21 | - | - |
| PE6 | A22 | A22 | - | - |
| PE2 | A23 | A23 | - | - |
| PG13 | A24 | A24 | - | - |
| PG14 | A25 | A25 | - | - |
| PD14 | D0 | DA0 | D0 | D0 |
| PD15 | D1 | DA1 | D1 | D1 |
| PD0 | D2 | DA2 | D2 | D2 |
| PD1 | D3 | DA3 | D3 | D3 |
| PE7 | D4 | DA4 | D4 | D4 |
| PE8 | D5 | DA5 | D5 | D5 |
| PE9 | D6 | DA6 | D6 | D6 |
| PE10 | D7 | DA7 | D7 | D7 |
| PE11 | D8 | DA8 | D8 | D8 |

Table 11. FMC pin definition (continued)

| Pin name | NOR/PSRAM/SRAM | NOR/PSRAM Mux | NAND16 | SDRAM |
|---|---|---|---|---|
| PE12 | D9 | DA9 | D9 | D9 |
| PE13 | D10 | DA10 | D10 | D10 |
| PE14 | D11 | DA11 | D11 | D11 |
| PE15 | D12 | DA12 | D12 | D12 |
| PD8 | D13 | DA13 | D13 | D13 |
| PD9 | D14 | DA14 | D14 | D14 |
| PD10 | D15 | DA15 | D15 | D15 |
| PH8 | D16 | - | - | D16 |
| PH9 | D17 | - | - | D17 |
| PH10 | D18 | - | - | D18 |
| PH11 | D19 | - | - | D19 |
| PH12 | D20 | - | - | D20 |
| PH13 | D21 | - | - | D21 |
| PH14 | D22 | - | - | D22 |
| PH15 | D23 | - | - | D23 |
| PI0 | D24 | - | - | D24 |
| PI1 | D25 | - | - | D25 |
| PI2 | D26 | - | - | D26 |
| PI3 | D27 | - | - | D27 |
| PI6 | D28 | - | - | D28 |
| PI7 | D29 | - | - | D29 |
| PI9 | D30 | - | - | D30 |
| PI10 | D31 | - | - | D31 |
| PD7 | NE1 | NE1 | - | - |
| PG9 | NE2 | NE2 | NCE | - |
| PG10 | NE3 | NE3 | - | - |
| PG11 | - | - | - | - |
| PG12 | NE4 | NE4 | - | - |
| PD3 | CLK | CLK | - | - |
| PD4 | NOE | NOE | NOE | - |
| PD5 | NWE | NWE | NWE | - |
| PD6 | NWAIT | NWAIT | NWAIT | - |
| PB7 | NADV | NADV | - | - |
| PF6 | - | - | - | - |
| PF7 | - | - | - | - |

Table 11. FMC pin definition (continued)

| Pin name | NOR/PSRAM/SRAM | NOR/PSRAM Mux | NAND16 | SDRAM |
|---|---|---|---|---|
| PF8 | - | - | - | - |
| PF9 | - | - | - | - |
| PF10 | - | - | - | - |
| PG6 | - | - | - | - |
| PG7 | - | - | INT | - |
| PE0 | NBL0 | NBL0 | - | NBL0 |
| PE1 | NBL1 | NBL1 | - | NBL1 |
| PI4 | NBL2 | - | - | NBL2 |
| PI5 | NBL3 | - | - | NBL3 |
| PG8 | - | - | - | SDCLK |
| PC0 | - | - | - | SDNWE |
| PF11 | - | - | - | SDNRAS |
| PG15 | - | - | - | SDNCAS |
| PH2 | - | - | - | SDCKE0 |
| PH3 | - | - | - | SDNE0 |
| PH6 | - | - | - | SDNE1 |
| PH7 | - | - | - | SDCKE1 |
| PH5 | - | - | - | SDNWE |
| PC2 | - | - | - | SDNE0 |
| PC3 | - | - | - | SDCKE0 |
| PB5 | - | - | - | SDCKE1 |
| PB6 | - | - | - | SDNE1 |

**Table 12. Alternate function**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port A | PA0 | - | TIM2_CH1/TIM2_ETR | TIM5_CH1 | TIM8_ETR | - | - | - | USART2_CTS | UART4_TX | - | - | ETH_MII_CRS | - | - | - | EVENTOUT |
| | PA1 | - | TIM2_CH2 | TIM5_CH2 | - | - | - | - | USART2_RTS | UART4_RX | QUADSPI_BK1_IO3 | - | ETH_MII_RX_CLK/ETH_RMII_REF_CLK | - | - | LCD_R2 | EVENTOUT |
| | PA2 | - | TIM2_CH3 | TIM5_CH3 | TIM9_CH1 | - | - | - | USART2_TX | - | - | - | ETH_MDIO | - | - | LCD_R1 | EVENTOUT |
| | PA3 | - | TIM2_CH4 | TIM5_CH4 | TIM9_CH2 | - | - | - | USART2_RX | - | LCD_B2 | OTG_HS_ULPI_D0 | ETH_MII_COL | - | - | LCD_B5 | EVENTOUT |
| | PA4 | - | - | - | - | - | SPI1_NSS | SPI3_NSS/I2S3_WS | USART2_CK | - | - | - | - | OTG_HS_SOF | DCMI_HSYNC | LCD_VSYNC | EVENTOUT |
| | PA5 | - | TIM2_CH1/TIM2_ETR | - | TIM8_CH1N | - | SPI1_SCK | - | - | - | - | OTG_HS_ULPI_CK | - | - | - | LCD_R4 | EVENTOUT |
| | PA6 | - | TIM1_BKIN | TIM3_CH1 | TIM8_BKIN | - | SPI1_MISO | - | - | - | TIM13_CH1 | - | - | - | DCMI_PIXCLK | LCD_G2 | EVENTOUT |
| | PA7 | - | TIM1_CH1N | TIM3_CH2 | TIM8_CH1N | - | SPI1_MOSI | - | - | - | TIM14_CH1 | QUADSPI_CLK | ETH_MII_RX_DV/ETH_RMII_CRS_DV | FMC_SDNWE | - | - | EVENTOUT |
| | PA8 | MCO1 | TIM1_CH1 | - | - | I2C3_SCL | - | - | USART1_CK | - | - | OTG_FS_SOF | - | - | - | LCD_R6 | EVENTOUT |
| | PA9 | - | TIM1_CH2 | - | - | I2C3_SMBA | SPI2_SCK/I2S2_CK | - | USART1_TX | - | - | - | - | - | DCMI_D0 | - | EVENTOUT |
| | PA10 | - | TIM1_CH3 | - | - | - | - | - | USART1_RX | - | - | OTG_FS_ID | - | - | DCMI_D1 | - | EVENTOUT |
| | PA11 | - | TIM1_CH4 | - | - | - | - | - | USART1_CTS | - | CAN1_RX | OTG_FS_DM | - | - | - | LCD_R4 | EVENTOUT |
| | PA12 | - | TIM1_ETR | - | - | - | - | - | USART1_RTS | - | CAN1_TX | OTG_FS_DP | - | - | - | LCD_R5 | EVENTOUT |
| | PA13 | JTMS-SWDIO | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PA14 | JTCK-SWCLK | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PA15 | JTDI | TIM2_CH1/TIM2_ETR | - | - | - | SPI1_NSS | SPI3_NSS/I2S3_WS | - | - | - | - | - | - | - | - | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUADSPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port B | PB0 | - | TIM1_CH2N | TIM3_CH3 | TIM8_CH2N | - | - | - | - | - | LCD_R3 | OTG_HS_ULPI_D1 | ETH_MII_RXD2 | - | - | LCD_G1 | EVENTOUT |
| | PB1 | - | TIM1_CH3N | TIM3_CH4 | TIM8_CH3N | - | - | - | - | - | LCD_R6 | OTG_HS_ULPI_D2 | ETH_MII_RXD3 | - | - | LCD_G0 | EVENTOUT |
| | PB2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PB3 | JTDO/TRACESWO | TIM2_CH2 | | - | - | SPI1_SCK | SPI3_SCK/I2S3_CK | - | - | - | - | - | - | - | - | EVENTOUT |
| | PB4 | NJTRST | - | TIM3_CH1 | - | - | SPI1_MISO | SPI3_MISO | I2S3ext_SD | - | - | - | - | - | - | - | EVENTOUT |
| | PB5 | - | - | TIM3_CH2 | - | I2C1_SMBA | SPI1_MOSI | SPI3_MOSI/I2S3_SD | | - | CAN2_RX | OTG_HS_ULPI_D7 | ETH_PPS_OUT | FMC_SDCKE1 | DCMI_D10 | LCD_G7 | EVENTOUT |
| | PB6 | - | - | TIM4_CH1 | - | I2C1_SCL | - | - | USART1_TX | - | CAN2_TX | QUADSPI_BK1_NCS | - | FMC_SDNE1 | DCMI_D5 | | EVENTOUT |
| | PB7 | - | - | TIM4_CH2 | - | I2C1_SDA | - | - | USART1_RX | - | - | - | - | FMC_NL | DCMI_VSYNC | | EVENTOUT |
| | PB8 | - | - | TIM4_CH3 | TIM10_CH1 | I2C1_SCL | - | - | - | - | CAN1_RX | - | ETH_MII_TXD3 | SDIO_D4 | DCMI_D6 | LCD_B6 | EVENTOUT |
| | PB9 | - | - | TIM4_CH4 | TIM11_CH1 | I2C1_SDA | SPI2_NSS/I2S2_WS | - | - | - | CAN1_TX | - | - | SDIO_D5 | DCMI_D7 | LCD_B7 | EVENTOUT |
| | PB10 | - | TIM2_CH3 | - | - | I2C2_SCL | SPI2_SCK/I2S2_CK | - | USART3_TX | - | QUADSPI_BK1_NCS | OTG_HS_ULPI_D3 | ETH_MII_RX_ER | - | - | LCD_G4 | EVENTOUT |
| | PB11 | - | TIM2_CH4 | - | - | I2C2_SDA | | - | USART3_RX | - | | OTG_HS_ULPI_D4 | ETH_MII_TX_EN/ETH_RMII_TX_EN | - | DSIHOST_TE | LCD_G5 | EVENTOUT |
| | PB12 | - | TIM1_BKIN | - | - | I2C2_SMBA | SPI2_NSS/I2S2_WS | - | USART3_CK | - | CAN2_RX | OTG_HS_ULPI_D5 | ETH_MII_TXD0/ETH_RMII_TXD0 | OTG_HS_ID | - | - | EVENTOUT |
| | PB13 | - | TIM1_CH1N | - | - | - | SPI2_SCK/I2S2_CK | - | USART3_CTS | - | CAN2_TX | OTG_HS_ULPI_D6 | ETH_MII_TXD1/ETH_RMII_TXD1 | - | - | - | EVENTOUT |
| | PB14 | - | TIM1_CH2N | - | TIM8_CH2N | - | SPI2_MISO | I2S2ext_SD | USART3_RTS | - | TIM12_CH1 | - | - | OTG_HS_‘DM | - | - | EVENTOUT |
| | PB15 | RTC_REFIN | TIM1_CH3N | - | TIM8_CH3N | - | SPI2_MOSI/I2S2_SD | - | - | - | TIM12_CH2 | - | - | OTG_HS_DP | - | - | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port C | PC0 | - | - | - | - | - | - | - | - | - | - | OTG_HS_ULPI_STP | - | FMC_SDNWE | - | LCD_R5 | EVENTOUT |
| | PC1 | TRACED0 | - | - | - | - | SPI2_MOSI/I2S2_SD | SAI1_SD_A | - | - | - | | ETH_MDC | - | - | - | EVENTOUT |
| | PC2 | - | - | - | - | - | SPI2_MISO | I2S2ext_SD | - | - | - | OTG_HS_ULPI_DIR | ETH_MII_TXD2 | FMC_SDNE0 | - | - | EVENTOUT |
| | PC3 | - | - | - | - | - | SPI2_MOSI/I2S2_SD | - | - | - | - | OTG_HS_ULPI_NXT | ETH_MII_TX_CLK | FMC_SDCKE0 | - | - | EVENTOUT |
| | PC4 | - | - | - | - | - | - | - | - | - | - | - | ETH_MII_RXD0/ETH_RMII_RXD0 | FMC_SDNE0 | - | - | EVENTOUT |
| | PC5 | - | - | - | - | - | - | - | - | - | - | - | ETH_MII_RXD1/ETH_RMII_RXD1 | FMC_SDCKE0 | - | - | EVENTOUT |
| | PC6 | - | - | TIM3_CH1 | TIM8_CH1 | - | I2S2_MCK | - | - | USART6_TX | - | - | - | SDIO_D6 | DCMI_D0 | LCD_HSYNC | EVENTOUT |
| | PC7 | - | - | TIM3_CH2 | TIM8_CH2 | - | - | I2S3_MCK | - | USART6_RX | - | - | - | SDIO_D7 | DCMI_D1 | LCD_G6 | EVENTOUT |
| | PC8 | TRACED1 | - | TIM3_CH3 | TIM8_CH3 | - | - | - | - | USART6_CK | - | - | - | SDIO_D0 | DCMI_D2 | - | EVENTOUT |
| | PC9 | MCO2 | - | TIM3_CH4 | TIM8_CH4 | I2C3_SDA | I2S_CKIN | - | - | - | QUADSPI_BK1_IO0 | - | - | SDIO_D1 | DCMI_D3 | - | EVENTOUT |
| | PC10 | - | - | - | - | - | - | SPI3_SCK/I2S3_CK | USART3_TX | UART4_TX | QUADSPI_BK1_IO1 | - | - | SDIO_D2 | DCMI_D8 | LCD_R2 | EVENTOUT |
| | PC11 | - | - | - | - | - | I2S3ext_SD | SPI3_MISO | USART3_RX | UART4_RX | QUADSPI_BK2_NCS | - | - | SDIO_D3 | DCMI_D4 | - | EVENTOUT |
| | PC12 | TRACED3 | - | - | - | - | - | SPI3_MOSI/I2S3_SD | USART3_CK | UART5_TX | - | - | - | SDIO_CK | DCMI_D9 | - | EVENTOUT |
| | PC13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PC14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PC15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART1/2/3 | USART6/UART4/5/7/8 | CAN1/2/TIM12/13/14/QUADSPI/LCD | QUADSPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port D | PD0 | - | - | - | - | - | - | - | - | - | CAN1_RX | - | - | FMC_D2 | - | - | EVENTOUT |
| | PD1 | - | - | - | - | - | - | - | - | - | CAN1_TX | - | - | FMC_D3 | - | - | EVENTOUT |
| | PD2 | TRACED2 | - | TIM3_ETR | - | - | - | - | - | UART5_RX | - | - | - | SDIO_CMD | DCMI_D11 | - | EVENTOUT |
| | PD3 | - | - | - | - | - | SPI2_SCK/I2S2_CK | - | USART2_CTS | - | - | - | - | FMC_CLK | DCMI_D5 | LCD_G7 | EVENTOUT |
| | PD4 | - | - | - | - | - | - | - | USART2_RTS | - | - | - | - | FMC_NOE | - | - | EVENTOUT |
| | PD5 | - | - | - | - | - | - | - | USART2_TX | - | - | - | - | FMC_NWE | - | - | EVENTOUT |
| | PD6 | - | - | - | - | - | SPI3_MOSI/I2S3_SD | SAI1_SD_A | USART2_RX | - | - | - | - | FMC_NWAIT | DCMI_D10 | LCD_B2 | EVENTOUT |
| | PD7 | - | - | - | - | - | - | - | USART2_CK | - | - | - | - | FMC_NE1 | - | - | EVENTOUT |
| | PD8 | - | - | - | - | - | - | - | USART3_TX | - | - | - | - | FMC_D13 | - | - | EVENTOUT |
| | PD9 | - | - | - | - | - | - | - | USART3_RX | - | - | - | - | FMC_D14 | - | - | EVENTOUT |
| | PD10 | - | - | - | - | - | - | - | USART3_CK | - | - | - | - | FMC_D15 | - | LCD_B3 | EVENTOUT |
| | PD11 | - | - | - | - | - | - | - | USART3_CTS | - | QUADSPI_BK1_IO0 | - | - | FMC_A16/FMC_CLE | - | - | EVENTOUT |
| | PD12 | - | - | TIM4_CH1 | - | - | - | - | USART3_RTS | - | QUADSPI_BK1_IO1 | - | - | FMC_A17/FMC_ALE | - | - | EVENTOUT |
| | PD13 | - | - | TIM4_CH2 | - | - | - | - | - | - | QUADSPI_BK1_IO3 | - | - | FMC_A18 | - | - | EVENTOUT |
| | PD14 | - | - | TIM4_CH3 | - | - | - | - | - | - | - | - | - | FMC_D0 | - | - | EVENTOUT |
| | PD15 | - | - | TIM4_CH4 | - | - | - | - | - | - | - | - | - | FMC_D1 | - | - | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port E | PE0 | - | - | TIM4_ETR | - | - | - | - | - | UART8_Rx | - | - | - | FMC_NBL0 | DCMI_D2 | - | EVENTOUT |
| | PE1 | - | - | - | - | - | - | - | - | UART8_Tx | - | - | - | FMC_NBL1 | DCMI_D3 | - | EVENTOUT |
| | PE2 | TRACECLK | - | - | - | - | SPI4_SCK | SAI1_MCLK_A | - | - | QUADSPI_BK1_IO2 | - | ETH_MII_TXD3 | FMC_A23 | - | - | EVENTOUT |
| | PE3 | TRACED0 | - | - | - | - | - | SAI1_SD_B | - | - | - | - | - | FMC_A19 | - | - | EVENTOUT |
| | PE4 | TRACED1 | - | - | - | - | SPI4_NSS | SAI1_FS_A | - | - | - | - | - | FMC_A20 | DCMI_D4 | LCD_B0 | EVENTOUT |
| | PE5 | TRACED2 | - | - | TIM9_CH1 | - | SPI4_MISO | SAI1_SCK_A | - | - | - | - | - | FMC_A21 | DCMI_D6 | LCD_G0 | EVENTOUT |
| | PE6 | TRACED3 | - | - | TIM9_CH2 | - | SPI4_MOSI | SAI1_SD_A | - | - | - | - | - | FMC_A22 | DCMI_D7 | LCD_G1 | EVENTOUT |
| | PE7 | - | TIM1_ETR | - | - | - | - | - | - | UART7_Rx | - | QUADSPI_BK2_IO0 | - | FMC_D4 | - | - | EVENTOUT |
| | PE8 | - | TIM1_CH1N | - | - | - | - | - | - | UART7_Tx | - | QUADSPI_BK2_IO1 | - | FMC_D5 | - | - | EVENTOUT |
| | PE9 | - | TIM1_CH1 | - | - | - | - | - | - | - | - | QUADSPI_BK2_IO2 | - | FMC_D6 | - | - | EVENTOUT |
| | PE10 | - | TIM1_CH2N | - | - | - | - | - | - | - | - | QUADSPI_BK2_IO3 | - | FMC_D7 | - | - | EVENTOUT |
| | PE11 | - | TIM1_CH2 | - | - | - | SPI4_NSS | - | - | - | - | - | - | FMC_D8 | - | LCD_G3 | EVENTOUT |
| | PE12 | - | TIM1_CH3N | - | - | - | SPI4_SCK | - | - | - | - | - | - | FMC_D9 | - | LCD_B4 | EVENTOUT |
| | PE13 | - | TIM1_CH3 | - | - | - | SPI4_MISO | - | - | - | - | - | - | FMC_D10 | - | LCD_DE | EVENTOUT |
| | PE14 | - | TIM1_CH4 | - | - | - | SPI4_MOSI | - | - | - | - | - | - | FMC_D11 | - | LCD_CLK | EVENTOUT |
| | PE15 | - | TIM1_BKIN | - | - | - | - | - | - | - | - | - | - | FMC_D12 | - | LCD_R7 | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port F | PF0 | - | - | - | - | I2C2_SDA | - | - | - | - | - | - | - | FMC_A0 | - | - | EVENT OUT |
| | PF1 | - | - | - | - | I2C2_SCL | - | - | - | - | - | - | - | FMC_A1 | - | - | EVENT OUT |
| | PF2 | - | - | - | - | I2C2_SMBA | - | - | - | - | - | - | - | FMC_A2 | - | - | EVENT OUT |
| | PF3 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A3 | - | - | EVENT OUT |
| | PF4 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A4 | - | - | EVENT OUT |
| | PF5 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A5 | - | - | EVENT OUT |
| | PF6 | - | - | - | TIM10_CH1 | - | SPI5_NSS | SAI1_SD_B | - | UART7_Rx | QUADSPI_BK1_IO3 | - | - | - | - | - | EVENT OUT |
| | PF7 | - | - | - | TIM11_CH1 | - | SPI5_SCK | SAI1_MCLK_B | - | UART7_Tx | QUADSPI_BK1_IO2 | - | - | - | - | - | EVENT OUT |
| | PF8 | - | - | - | - | - | SPI5_MISO | SAI1_SCK_B | - | - | TIM13_CH1 | QUADSPI_BK1_IO0 | - | - | - | - | EVENT OUT |
| | PF9 | - | - | - | - | - | SPI5_MOSI | SAI1_FS_B | - | - | TIM14_CH1 | QUADSPI_BK1_IO1 | - | - | - | - | EVENT OUT |
| | PF10 | - | - | - | - | - | - | - | - | - | QUADSPI_CLK | | - | - | DCMI_D11 | LCD_DE | EVENT OUT |
| | PF11 | - | - | - | - | - | SPI5_MOSI | - | - | - | - | - | - | FMC_SDNRAS | DCMI_D12 | - | EVENT OUT |
| | PF12 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A6 | - | - | EVENT OUT |
| | PF13 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A7 | - | - | EVENT OUT |
| | PF14 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A8 | - | - | EVENT OUT |
| | PF15 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A9 | - | - | EVENT ‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port G | PG0 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A10 | - | - | EVENT OUT |
| | PG1 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A11 | - | - | EVENT OUT |
| | PG2 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A12 | - | - | EVENT OUT |
| | PG3 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A13 | - | - | EVENT OUT |
| | PG4 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A14/FMC_BA0 | - | - | EVENT OUT |
| | PG5 | - | - | - | - | - | - | - | - | - | - | - | - | FMC_A15/FMC_BA1 | - | - | EVENT OUT |
| | PG6 | - | - | - | - | - | - | - | - | - | - | - | - | | DCMI_D12 | LCD_R7 | EVENT OUT |
| | PG7 | - | - | - | - | - | | SAI1_MCLK_A | | USART6_CK | - | - | - | FMC_INT | DCMI_D13 | LCD_CLK | EVENT OUT |
| | PG8 | - | - | - | - | - | SPI6_NSS | - | - | USART6_RTS | - | - | ETH_PPS_OUT | FMC_SDCLK | | LCD_G7 | EVENT OUT |
| | PG9 | - | - | - | - | - | - | - | - | USART6_RX | QUADSPI_BK2_IO2 | - | - | FMC_NE2/FMC_NCE | DCMI_VSYNC | | EVENT OUT |
| | PG10 | - | - | - | - | - | - | - | - | | LCD_G3 | - | - | FMC_NE3 | DCMI_D2 | LCD_B2 | EVENT OUT |
| | PG11 | - | - | - | - | - | - | - | - | - | - | - | ETH_MII_TX_EN / ETH_RMII_TX_EN | - | DCMI_D3 | LCD_B3 | EVENT OUT |
| | PG12 | - | - | - | - | - | SPI6_MISO | - | - | USART6_RTS | LCD_B4 | - | - | FMC_NE4 | - | LCD_B1 | EVENT OUT |
| | PG13 | TRACED0 | - | - | - | - | SPI6_SCK | - | - | USART6_CTS | - | - | ETH_MII_TXD0 / ETH_RMII_TXD0 | FMC_A24 | - | LCD_R0 | EVENT OUT |
| | PG14 | TRACED1 | - | - | - | - | SPI6_MOSI | - | - | USART6_TX | QUADSPI_BK2_IO3 | - | ETH_MII_TXD1 / ETH_RMII_TXD1 | FMC_A25 | - | LCD_B0 | EVENT OUT |
| | PG15 | - | - | - | - | - | - | - | - | USART6_CTS | - | - | - | FMC_SDNCAS | DCMI_D13 | - | EVENT ‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUADSPI/LCD | QUADSPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port H | PH0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | EVENTOUT |
| | PH1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | EVENTOUT |
| | PH2 | - | - | - | - | - | - | - | - | - | QUADSPI_BK2_IO0 | - | ETH_MII_CRS | FMC_SDCKE0 | - | LCD_R0 | EVENTOUT |
| | PH3 | - | - | - | - | - | - | - | - | - | QUADSPI_BK2_IO1 | - | ETH_MII_COL | FMC_SDNE0 | - | LCD_R1 | EVENTOUT |
| | PH4 | - | - | - | - | I2C2_SCL | - | - | - | - | LCD_G5 | OTG_HS_ULPI_NXT | - | - | - | LCD_G4 | EVENTOUT |
| | PH5 | - | - | - | - | I2C2_SDA | SPI5_NSS | - | - | - | - | - | - | FMC_SDNWE | - | - | EVENTOUT |
| | PH6 | - | - | - | - | I2C2_SMBA | SPI5_SCK | - | - | - | TIM12_CH1 | - | ETH_MII_RXD2 | FMC_SDNE1 | - | - | EVENTOUT |
| | PH7 | - | - | - | - | I2C3_SCL | SPI5_MISO | - | - | - | - | - | ETH_MII_RXD3 | FMC_SDCKE1 | DCMI_D9 | - | EVENTOUT |
| | PH8 | - | - | - | - | I2C3_SDA | - | - | - | - | - | - | - | FMC_D16 | DCMI_HSYNC | LCD_R2 | EVENTOUT |
| | PH9 | - | - | - | - | I2C3_SMBA | - | - | - | - | TIM12_CH2 | - | - | FMC_D17 | DCMI_D0 | LCD_R3 | EVENTOUT |
| | PH10 | - | - | TIM5_CH1 | - | - | - | - | - | - | - | - | - | FMC_D18 | DCMI_D1 | LCD_R4 | EVENTOUT |
| | PH11 | - | - | TIM5_CH2 | - | - | - | - | - | - | - | - | - | FMC_D19 | DCMI_D2 | LCD_R5 | EVENTOUT |
| | PH12 | - | - | TIM5_CH3 | - | - | - | - | - | - | - | - | - | FMC_D20 | DCMI_D3 | LCD_R6 | EVENTOUT |
| | PH13 | - | - | - | TIM8_CH1N | - | - | - | - | - | CAN1_TX | - | - | FMC_D21 | - | LCD_G2 | EVENTOUT |
| | PH14 | - | - | - | TIM8_CH2N | - | - | - | - | - | - | - | - | FMC_D22 | DCMI_D4 | LCD_G3 | EVENTOUT |
| | PH15 | - | - | - | TIM8_CH3N | - | - | - | - | - | - | - | - | FMC_D23 | DCMI_D11 | LCD_G4 | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUADSPI/LCD | QUADSPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port I | PI0 | - | - | TIM5_CH4 | - | - | SPI2_NSS/I2S2_WS | - | - | - | - | - | - | FMC_D24 | DCMI_D13 | LCD_G5 | EVENTOUT |
| | PI1 | - | - | - | - | - | SPI2_SCK/I2S2_CK | - | - | - | - | - | - | FMC_D25 | DCMI_D8 | LCD_G6 | EVENTOUT |
| | PI2 | - | - | - | TIM8_CH4 | - | SPI2_MISO | I2S2ext_SD | - | - | - | - | - | FMC_D26 | DCMI_D9 | LCD_G7 | EVENTOUT |
| | PI3 | - | - | - | TIM8_ETR | - | SPI2_MOSI/I2S2_SD | - | - | - | - | - | - | FMC_D27 | DCMI_D10 | | EVENTOUT |
| | PI4 | - | - | - | TIM8_BKIN | - | - | - | - | - | - | - | - | FMC_NBL2 | DCMI_D5 | LCD_B4 | EVENTOUT |
| | PI5 | - | - | - | TIM8_CH1 | - | - | - | - | - | - | - | - | FMC_NBL3 | DCMI_VSYNC | LCD_B5 | EVENTOUT |
| | PI6 | - | - | - | TIM8_CH2 | - | - | - | - | - | - | - | - | FMC_D28 | DCMI_D6 | LCD_B6 | EVENTOUT |
| | PI7 | - | - | - | TIM8_CH3 | - | - | - | - | - | - | - | - | FMC_D29 | DCMI_D7 | LCD_B7 | EVENTOUT |
| | PI8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | EVENTOUT |
| | PI9 | - | - | - | - | - | - | - | - | - | CAN1_RX | - | - | FMC_D30 | - | LCD_VSYNC | EVENTOUT |
| | PI10 | - | - | - | - | - | - | - | - | - | - | - | ETH_MII_RX_ER | FMC_D31 | - | LCD_HSYNC | EVENTOUT |
| | PI11 | - | - | - | - | - | - | - | - | - | LCD_G6 | OTG_HS_ULPI_DIR | - | - | - | - | EVENTOUT |
| | PI12 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_HSYNC | EVENTOUT |
| | PI13 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_VSYNC | EVENTOUT |
| | PI14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_CLK | EVENTOUT |
| | PI15 | - | - | - | - | - | - | - | - | - | LCD_G2 | - | - | - | - | LCD_R0 | EVENT‘OUT |

**Table 12. Alternate function (continued)**

| Port | | AF0 | AF1 | AF2 | AF3 | AF4 | AF5 | AF6 | AF7 | AF8 | AF9 | AF10 | AF11 | AF12 | AF13 | AF14 | AF15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SYS | TIM1/2 | TIM3/4/5 | TIM8/9/10/11 | I2C1/2/3 | SPI1/2/3/4/5/6 | SPI2/3/SAI1 | SPI2/3/USART 1/2/3 | USART6/UART 4/5/7/8 | CAN1/2/TIM12/13/14/QUAD SPI/LCD | QUAD SPI/OTG2_HS/OTG1_FS | ETH | FMC/SDIO/OTG2_FS | DCMI/DSI HOST | LCD | SYS |
| Port J | PJ0 | - | - | - | - | - | - | - | - | - | LCD_R7 | - | - | - | - | LCD_R1 | EVENTOUT |
| | PJ1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_R2 | EVENTOUT |
| | PJ2 | - | - | - | - | - | - | - | - | - | - | - | - | - | DSIHOST_TE | LCD_R3 | EVENTOUT |
| | PJ3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_R4 | EVENTOUT |
| | PJ4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_R5 | EVENTOUT |
| | PJ5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_R6 | EVENTOUT |
| | PJ12 | - | - | - | - | - | - | - | - | - | LCD_G3 | - | - | - | - | LCD_B0 | EVENTOUT |
| | PJ13 | - | - | - | - | - | - | - | - | - | LCD_G4 | - | - | - | - | LCD_B1 | EVENTOUT |
| | PJ14 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B2 | EVENTOUT |
| | PJ15 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B3 | EVENTOUT |
| Port K | PK3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B4 | EVENTOUT |
| | PK4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B5 | EVENTOUT |
| | PK5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B6 | EVENTOUT |
| | PK6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_B7 | EVENTOUT |
| | PK7 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | LCD_DE | EVENTOUT |

# 4 Memory mapping

The memory map is shown in *Figure 21*.

**Figure 21. Memory map**

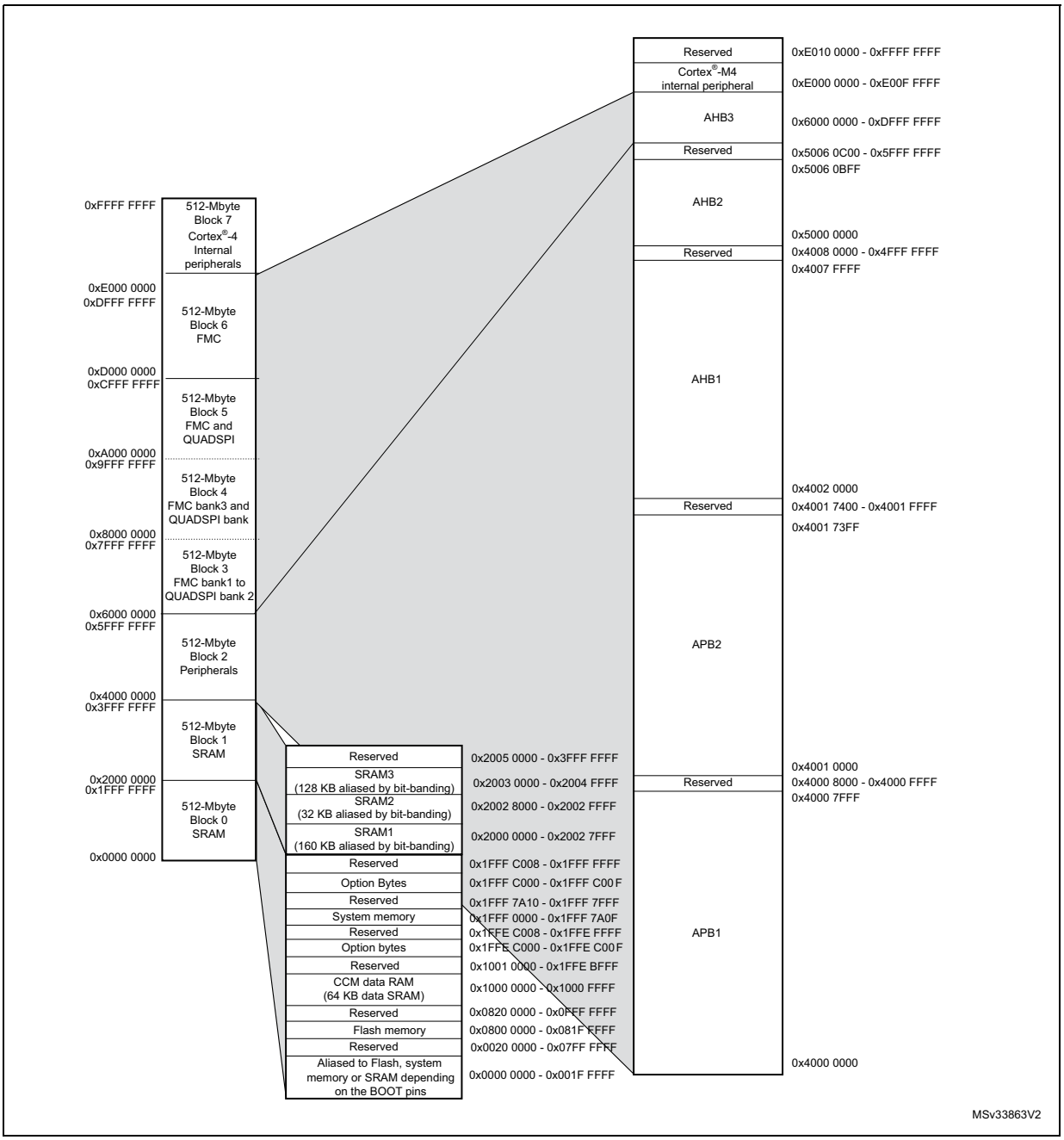


**Table 13. STM32F469xx register boundary addresses(1)**

| Bus | Boundary address | Peripheral |
|---|---|---|
| - | 0xE00F FFFF - 0xFFFF FFFF | Reserved |
| Cortex®-M4 | 0xE000 0000 - 0xE00F FFFF | Cortex®-M4 internal peripherals |
| AHB3 | 0xD000 0000 - 0xDFFF FFFF | FMC bank 6 |
| | 0xC000 0000 - 0xCFFF FFFF | FMC bank 5 |
| | 0xA000 1000 - 0xA0001FFF | Quad-SPI control register |
| | 0xA000 2000 - 0xBFFF FFFF | Reserved |
| | 0xA000 0000- 0xA000 0FFF | FMC control register |
| | 0x9000 0000 - 0x9FFF FFFF | Quad-SPI bank |
| | 0x8000 0000 - 0x8FFF FFFF | FMC bank 3 |
| | 0x7000 0000 - 0x7FFF FFFF | FMC bank 2 (reserved) |
| | 0x6000 0000 - 0x6FFF FFFF | FMC bank 1 |
| - | 0x5006 0C00- 0x5FFF FFFF | Reserved |
| AHB2 | 0x5006 0800 - 0x5006 0BFF | RNG |
| | 0x5005 0400 - 0x5006 07FF | Reserved |
| | 0x5005 0000 - 0x5005 03FF | DCMI |
| | 0x5004 0000- 0x5004 FFFF | Reserved |
| | 0x5000 0000 - 0x5003 FFFF | USB OTG FS |

**Table 13. STM32F469xx register boundary addresses(1) (continued)**

| Bus | Boundary address | Peripheral |
|---|---|---|
| - | 0x4008 0000- 0x4FFF FFFF | Reserved |
| AHB1 | 0x4004 0000 - 0x4007 FFFF | USB OTG HS |
| | 0x4002 BC00- 0x4003 FFFF | Reserved |
| | 0x4002 B000 - 0x4002 BBFF | Chrom (DMA2D) |
| | 0x4002 9400 - 0x4002 AFFF | Reserved |
| | 0x4002 9000 - 0x4002 93FF | ETHERNET MAC |
| | 0x4002 8C00 - 0x4002 8FFF | |
| | 0x4002 8800 - 0x4002 8BFF | |
| | 0x4002 8400 - 0x4002 87FF | |
| | 0x4002 8000 - 0x4002 83FF | |
| | 0x4002 6800 - 0x4002 7FFF | Reserved |
| | 0x4002 6400 - 0x4002 67FF | DMA2 |
| | 0x4002 6000 - 0x4002 63FF | DMA1 |
| | 0x4002 5000 - 0x4002 5FFF | Reserved |
| | 0x4002 4000 - 0x4002 4FFF | BKPSRAM |
| | 0x4002 3C00 - 0x4002 3FFF | Flash interface register |
| | 0x4002 3800 - 0x4002 3BFF | RCC |
| | 0x4002 3400 - 0x4002 37FF | Reserved |
| | 0x4002 3000 - 0x4002 33FF | CRC |
| | 0x4002 2C00 - 0x4002 2FFF | Reserved |
| | 0x4002 2800 - 0x4002 2BFF | GPIOK |
| | 0x4002 2400 - 0x4002 27FF | GPIOJ |
| | 0x4002 2000 - 0x4002 23FF | GPIOI |
| | 0x4002 1C00 - 0x4002 1FFF | GPIOH |
| | 0x4002 1800 - 0x4002 1BFF | GPIOG |
| | 0x4002 1400 - 0x4002 17FF | GPIOF |
| | 0x4002 1000 - 0x4002 13FF | GPIOE |
| | 0x4002 0C00 - 0x4002 0FFF | GPIOD |
| | 0x4002 0800 - 0x4002 0BFF | GPIOC |
| | 0x4002 0400 - 0x4002 07FF | GPIOB |
| | 0x4002 0000 - 0x4002 03FF | GPIOA |

Table 13. STM32F469xx register boundary addresses[1] (continued)

| Bus | Boundary address | Peripheral |
|---|---|---|
| APB2 | 0x4001 7400 - 0x4001 FFFF | Reserved |
| | 0x4001 6C00 - 0x4001 73FF | DSI Host |
| | 0x4001 6800 - 0x4001 6BFF | LCD-TFT |
| | 0x4001 5C00 - 0x4001 67FF | Reserved |
| | 0x4001 5800 - 0x4001 5BFF | SAI1 |
| | 0x4001 5400 - 0x4001 57FF | SPI6 |
| | 0x4001 5000 - 0x4001 53FF | SPI5 |
| | 0x4001 4C00 - 0x4001 4FFF | Reserved |
| | 0x4001 4800 - 0x4001 4BFF | TIM11 |
| | 0x4001 4400 - 0x4001 47FF | TIM10 |
| | 0x4001 4000 - 0x4001 43FF | TIM9 |
| | 0x4001 3C00 - 0x4001 3FFF | EXTI |
| | 0x4001 3800 - 0x4001 3BFF | SYSCFG |
| | 0x4001 3400 - 0x4001 37FF | SPI4 |
| | 0x4001 3000 - 0x4001 33FF | SPI1 |
| | 0x4001 2C00 - 0x4001 2FFF | SDIO |
| | 0x4001 2400 - 0x4001 2BFF | Reserved |
| | 0x4001 2000 - 0x4001 23FF | ADC1 - ADC2 - ADC3 |
| | 0x4001 1800 - 0x4001 1FFF | Reserved |
| | 0x4001 1400 - 0x4001 17FF | USART6 |
| | 0x4001 1000 - 0x4001 13FF | USART1 |
| | 0x4001 0800 - 0x4001 0FFF | Reserved |
| | 0x4001 0400 - 0x4001 07FF | TIM8 |
| | 0x4001 0000 - 0x4001 03FF | TIM1 |

**Table 13. STM32F469xx register boundary addresses(1) (continued)**

| Bus | Boundary address | Peripheral |
|---|---|---|
| - | 0x4000 8000- 0x4000 FFFF | Reserved |
| APB1 | 0x4000 7C00 - 0x4000 7FFF | UART8 |
| | 0x4000 7800 - 0x4000 7BFF | UART7 |
| | 0x4000 7400 - 0x4000 77FF | DAC |
| | 0x4000 7000 - 0x4000 73FF | PWR |
| | 0x4000 6C00 - 0x4000 6FFF | Reserved |
| | 0x4000 6800 - 0x4000 6BFF | CAN2 |
| | 0x4000 6400 - 0x4000 67FF | CAN1 |
| | 0x4000 6000 - 0x4000 63FF | Reserved |
| | 0x4000 5C00 - 0x4000 5FFF | I2C3 |
| | 0x4000 5800 - 0x4000 5BFF | I2C2 |
| | 0x4000 5400 - 0x4000 57FF | I2C1 |
| | 0x4000 5000 - 0x4000 53FF | UART5 |
| | 0x4000 4C00 - 0x4000 4FFF | UART4 |
| | 0x4000 4800 - 0x4000 4BFF | USART3 |
| | 0x4000 4400 - 0x4000 47FF | USART2 |
| | 0x4000 4000 - 0x4000 43FF | I2S3ext |
| | 0x4000 3C00 - 0x4000 3FFF | SPI3 / I2S3 |
| | 0x4000 3800 - 0x4000 3BFF | SPI2 / I2S2 |
| | 0x4000 3400 - 0x4000 37FF | I2S2ext |
| | 0x4000 3000 - 0x4000 33FF | IWDG |
| | 0x4000 2C00 - 0x4000 2FFF | WWDG |
| | 0x4000 2800 - 0x4000 2BFF | RTC & BKP Registers |
| | 0x4000 2400 - 0x4000 27FF | Reserved |
| | 0x4000 2000 - 0x4000 23FF | TIM14 |
| | 0x4000 1C00 - 0x4000 1FFF | TIM13 |
| | 0x4000 1800 - 0x4000 1BFF | TIM12 |
| | 0x4000 1400 - 0x4000 17FF | TIM7 |
| | 0x4000 1000 - 0x4000 13FF | TIM6 |
| | 0x4000 0C00 - 0x4000 0FFF | TIM5 |
| | 0x4000 0800 - 0x4000 0BFF | TIM4 |
| | 0x4000 0400 - 0x4000 07FF | TIM3 |
| | 0x4000 0000 - 0x4000 03FF | TIM2 |

1. The reserved boundary addresses are shown in grayed cells.

# 5 Electrical characteristics

## 5.1 Parameter conditions

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

### 5.1.1 Minimum and maximum values

Unless otherwise specified the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage and frequencies by tests in production on 100% of the devices with an ambient temperature at $T_A$ = 25°C and $T_A$ = $T_A$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 (mean±3σ).

### 5.1.2 Typical values

Unless otherwise specified, typical data is based on $T_A$ = 25°C, $V_{DD}$ = 3.3 V (for the 1.7 V ≤$V_{DD}$ ≤3.6 V voltage range). They are given only as design guidelines and are not tested.

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

### 5.1.3 Typical curves

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

### 5.1.4 Loading capacitor

The loading conditions used for pin parameter measurement are shown in *Figure 22*.

### 5.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in *Figure 23*.

**Figure 22. Pin loading conditions**

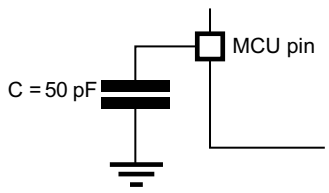
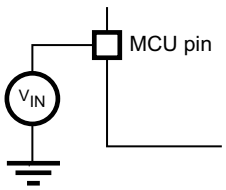
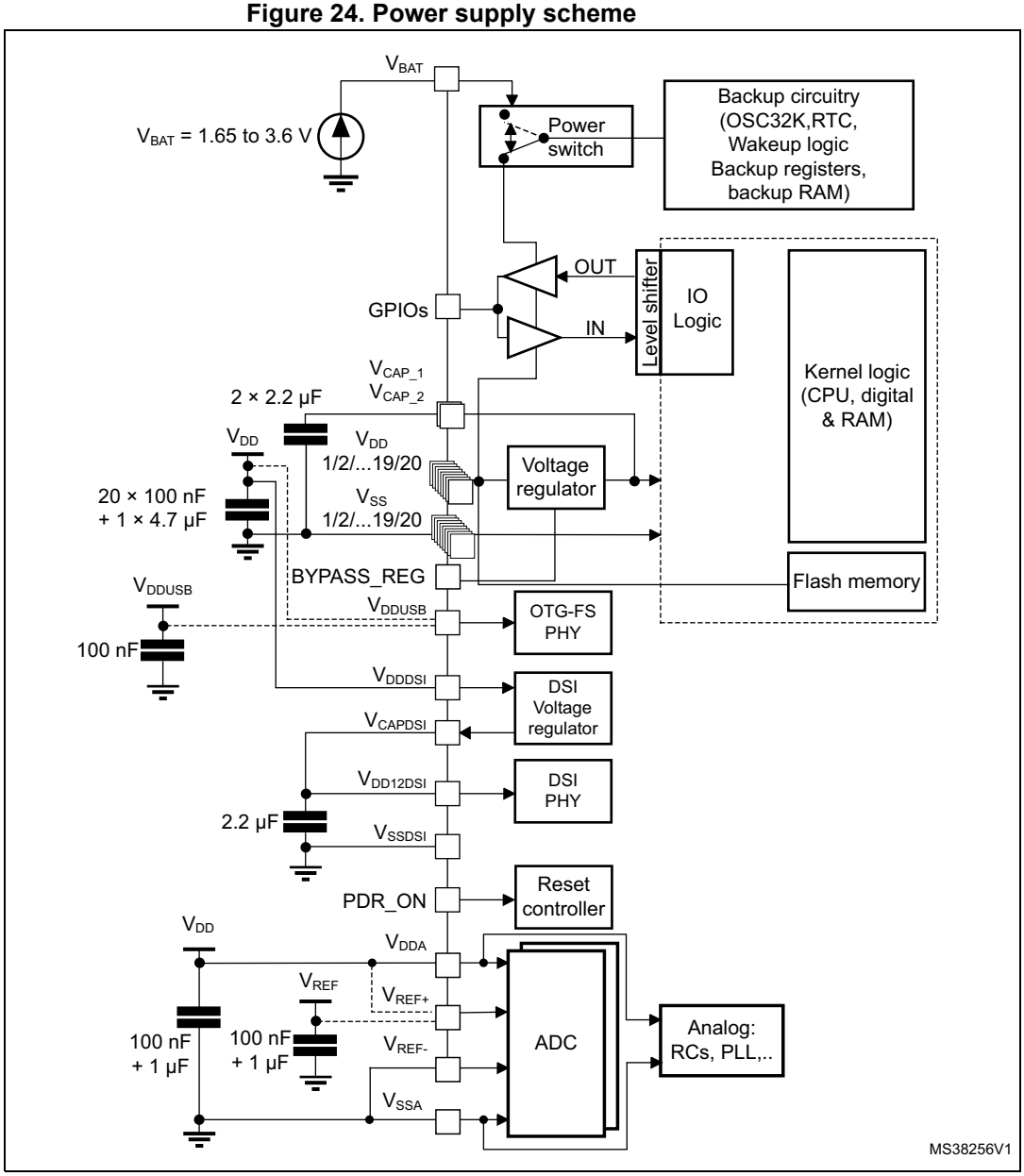



**Figure 23. Pin input voltage**



### 5.1.6 Power supply scheme

**Figure 24. Power supply scheme**

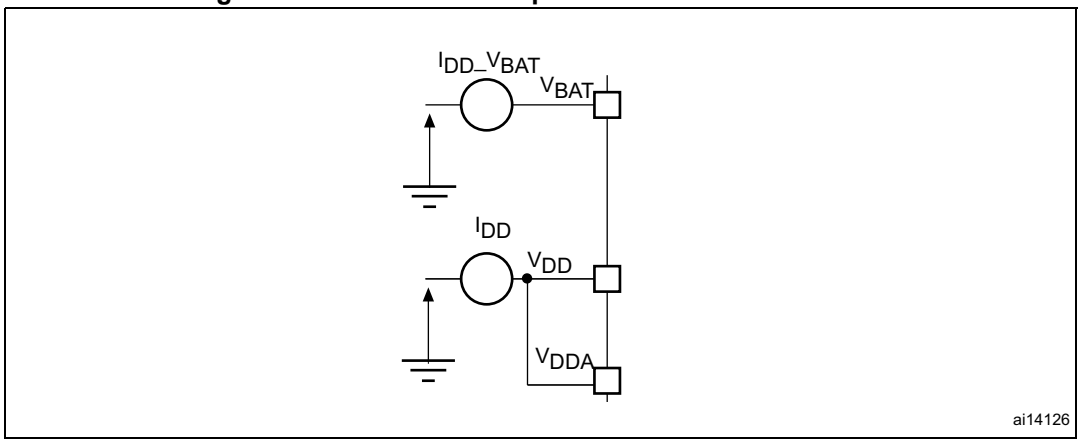



1. To connect BYPASS_REG and PDR_ON pins, refer to *Section 2.19* and *Section 2.20*.
2. The two 2.2 µF ceramic capacitors on $V_{CAP_1}$ and $V_{CAP_2}$ should be replaced by two 100 nF decoupling capacitors when the voltage regulator is OFF.
3. The 4.7 µF ceramic capacitor must be connected to one of the $V_{DD}$ pins.
4. $V_{DDA}$ and $V_{SSA}$ must be connected to $V_{DD}$ and $V_{SS}$, respectively.

**Caution:** Each power supply pair ($V_{DD}/V_{SS}$, $V_{DDA}/V_{SSA}$ ...) must be decoupled with filtering ceramic capacitors as shown above. These capacitors must be placed as close as possible to, or below, the appropriate pins on the underside of the PCB to ensure good operation of the device. It is not recommended to remove filtering capacitors to reduce PCB size or cost. This might cause incorrect operation of the device.

### 5.1.7 Current consumption measurement

**Figure 25. Current consumption measurement scheme**




## 5.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in *Table 14*, *Table 15*, and *Table 16* 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 14. Voltage characteristics**

| Symbol | Ratings | Min | Max | Unit |
|---|---|---|---|---|
| $V_{DD}$–$V_{SS}$ | External main supply voltage (including $V_{DDA}$, $V_{DD}$, $V_{DDUSB}$, $V_{DDDSI}$ and $V_{BAT}$)(1) | − 0.3 | 4.0 | V |
| $V_{IN}$ | Input voltage on FT pins(2) | $V_{SS}$ − 0.3 | $V_{DD}$+4.0 | |
| | Input voltage on TTa pins | $V_{SS}$ − 0.3 | 4.0 | |
| | Input voltage on any other pin | $V_{SS}$ − 0.3 | 4.0 | |
| | Input voltage on BOOT pin | $V_{SS}$ | 9.0 | |
| $\lvert\Delta V_{DDx}\rvert$ | Variations between different $V_{DD}$ power pins | - | 50 | mV |
| $\lvert V_{SSX} - V_{SS}\rvert$ | Variations between all the different ground pins(3) | - | 50 | |
| $V_{ESD(HBM)}$ | Electrostatic discharge voltage (human body model) | see *Section 5.3.18* | | |

1. All main power ($V_{DD}$, $V_{DDA}$, $V_{DDUSB}$, $V_{DDDSI}$) and ground ($V_{SS}$, $V_{SSA}$) pins must always be connected to the external power supply, in the permitted range.
2. $V_{IN}$ maximum value must always be respected. Refer to *Table 15* for the values of the maximum allowed injected current.
3. Including $V_{REF-}$ pin

**Table 15. Current characteristics**

| Symbol | Ratings | Max. | Unit |
|---|---|---|---|
| $\Sigma I_{VDD}$ | Total current into sum of all $V_{DD_x}$ power lines (source)(1) | 290 | mA |
| $\Sigma I_{VSS}$ | Total current out of sum of all $V_{SS_x}$ ground lines (sink)(1) | − 290 | |
| $\Sigma I_{VDDUSB}$ | Total current into $V_{DDUSB}$ power line (source) | 25 | |
| $I_{VDD}$ | Maximum current into each $V_{DD_x}$ power line (source)(1) | 100 | |
| $I_{VSS}$ | Maximum current out of each $V_{SS_x}$ ground line (sink)(1) | − 100 | |
| $I_{IO}$ | Output current sunk by any I/O and control pin | 25 | |
| | Output current sourced by any I/Os and control pin | − 25 | |
| $\Sigma I_{IO}$ | Total output current sunk by sum of all I/O and control pins (2) | 120 | |
| | Total output current sunk by sum of all USB I/Os | 25 | |
| | Total output current sourced by sum of all I/Os and control pins(2) | − 120 | |
| $I_{INJ(PIN)}$ (3) | Injected current on FT pins (4) | − 5/+0 | |
| | Injected current on NRST and BOOT0 pins (4) | | |
| | Injected current on TTa pins(5) | ±5 | |
| $\Sigma I_{INJ(PIN)}$(5) | Total injected current (sum of all I/O and control pins)(6) | ±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. This current consumption must be correctly distributed over all I/Os and control pins. The total output current must not be sunk/sourced between two consecutive power supply pins referring to high pin count LQFP packages.
3. Negative injection disturbs the analog performance of the device. See note in *Section 5.3.24*.
4. Positive injection is not possible on these I/Os and does not occur for input voltages lower than the specified maximum value.
5. A positive injection is induced by $V_{IN}>V_{DDA}$ while a negative injection is induced by $V_{IN}<V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to *Table 14* for the values of the maximum allowed input voltage.
6. 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 16. Thermal characteristics**

| Symbol | Ratings | Value | Unit |
|---|---|---|---|
| $T_{STG}$ | Storage temperature range | − 65 to +150 | °C |
| $T_J$ | Maximum junction temperature | 125 | °C |

# 5.3 Operating conditions

## 5.3.1 General operating conditions

**Table 17. General operating conditions**

| Symbol | Parameter | Conditions[1] | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $f_{HCLK}$ | Internal AHB clock frequency | Power Scale 3 (VOS[1:0] bits in PWR_CR register = 0x01), Regulator ON, over-drive OFF | | 0 | - | 120 | MHz |
| | | Power Scale 2 (VOS[1:0] bits in PWR_CR register = 0x10), Regulator ON | Over-drive OFF | 0 | - | 144 | |
| | | | Over-drive ON | | - | 168 | |
| | | Power Scale 1 (VOS[1:0] bits in PWR_CR register= 0x11), Regulator ON | Over-drive OFF | 0 | - | 168 | |
| | | | Over-drive ON | | - | 180 | |
| $f_{PCLK1}$ | Internal APB1 clock frequency | Over-drive OFF | | 0 | - | 42 | |
| | | Over-drive ON | | 0 | - | 45 | |
| $f_{PCLK2}$ | Internal APB2 clock frequency | Over-drive OFF | | 0 | - | 84 | |
| | | Over-drive ON | | 0 | - | 90 | |
| $V_{DD}$ | Standard operating voltage | - | | 1.7[2] | - | 3.6 | V |
| $V_{DDA}$[3][4] | Analog operating voltage (ADC limited to 1.2 M samples) | Must be the same potential as $V_{DD}$[5] | | 1.7[2] | - | 2.4 | |
| | Analog operating voltage (ADC limited to 2.4 M samples) | | | 2.4 | - | 3.6 | |
| $V_{DDUSB}$ | USB supply voltage (supply voltage for PA11, PA12, PB14 and PB15 pins) | USB not used | | 0 | 3.3 | 3.6 | |
| | | USB used | | 3.0 | - | 3.6 | |
| $V_{DDDSI}$ | DSI system operating voltage | - | | 1.7[2] | - | 3.6 | |
| $V_{BAT}$ | Backup operating voltage | - | | 1.65 | - | 3.6 | |

**Table 17. General operating conditions (continued)**

| Symbol | Parameter | Conditions[1] | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{12}$ | Regulator ON: 1.2 V internal voltage on $V_{CAP_1}/V_{CAP_2}$ pins | Power Scale 3 ((VOS[1:0] bits in PWR_CR register = 0x01), 120 MHz HCLK max frequency | 1.08 | 1.14 | 1.20 | V |
| | | Power Scale 2 ((VOS[1:0] bits in PWR_CR register = 0x10), 144 MHz HCLK max frequency with over-drive OFF or 168 MHz with over-drive ON | 1.20 | 1.26 | 1.32 | |
| | | Power Scale 1 ((VOS[1:0] bits in PWR_CR register = 0x11), 168 MHz HCLK max frequency with over-drive OFF or 180 MHz with over-drive ON | 1.26 | 1.32 | 1.40 | |
| | Regulator OFF: 1.2 V external voltage must be supplied from external regulator on $V_{CAP_1}/V_{CAP_2}$ pins[6] | Max frequency 120 MHz | 1.10 | 1.14 | 1.20 | |
| | | Max frequency 144 MHz | 1.20 | 1.26 | 1.32 | |
| | | Max frequency 168 MHz | 1.26 | 1.32 | 1.38 | |
| $V_{IN}$ | Input voltage on RST and FT pins[7] | 2 V ≤ $V_{DD}$ ≤ 3.6 V | − 0.3 | - | 5.5 | V |
| | | $V_{DD}$ ≤ 2 V | − 0.3 | - | 5.2 | |
| | Input voltage on TTa pins | - | − 0.3 | - | $V_{DDA}$ +0.3 | |
| | Input voltage on BOOT0 pin | - | 0 | - | 9 | |
| $P_D$ | Power dissipation at $T_A$ = 85 °C for suffix 6 or $T_A$ = 105 °C for suffix 7[8] | LQFP100 | - | - | 465 | mW |
| | | LQFP144 | - | - | 500 | |
| | | WLCSP168 | - | - | 645 | |
| | | UFBGA169 | - | - | 385 | |
| | | LQFP176 | - | - | 526 | |
| | | UFBGA176 | - | - | 513 | |
| | | LQFP208 | - | - | 1053 | |
| | | TFBGA216 | - | - | 690 | |
| $T_A$ | Ambient temperature for 6 suffix version | Maximum power dissipation | − 40 | - | 85 | °C |
| | | Low power dissipation[9] | − 40 | - | 105 | |
| | Ambient temperature for 7 suffix version | Maximum power dissipation | − 40 | - | 105 | |
| | | Low power dissipation[9] | − 40 | - | 125 | |
| $T_J$ | Junction temperature range | 6 suffix version | − 40 | - | 105 | |
| | | 7 suffix version | − 40 | - | 125 | |

1. The overdrive mode is not supported at the voltage ranges from 1.7 to 2.1 V.
2. $V_{DD}/V_{DDA}$ minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to *Section 2.19.2*).
3. When the ADC is used, refer to *Table 77*.
4. If $V_{REF+}$ pin is present, it must respect the following condition: $V_{DDA}$-$V_{REF+}$ < 1.2 V.
5. 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 power-down operation.
6. The overdrive mode is not supported when the internal regulator is OFF.

7. To sustain a voltage higher than VDD+0.3, the internal Pull-up and Pull-Down resistors must be disabled.
8. If $T_A$ is lower, higher $P_D$ values are allowed as long as $T_J$ does not exceed $T_{Jmax}$.
9. In low power dissipation state, $T_A$ can be extended to this range as long as $T_J$ does not exceed $T_{Jmax}$.

**Table 18. Limitations depending on the operating power supply range**

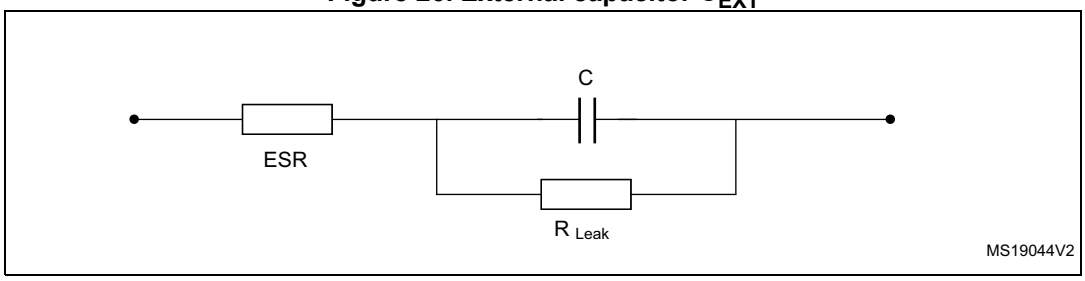
| Operating power supply range | ADC operation | Maximum Flash memory access frequency with no wait states ($f_{Flashmax}$) | Maximum HCLK frequency vs. Flash memory wait states (1)(2) | I/O operation | Possible Flash memory operations |
|---|---|---|---|---|---|
| $V_{DD}$ = 1.7 to 2.1 V(3) | Conversion time up to 1.2 Msps | 20 MHz(4) | 168 MHz with 8 wait states and over-drive OFF | No I/O compensation | 8-bit erase and program operations only |
| $V_{DD}$ = 2.1 to 2.4 V | | 22 MHz | 180 MHz with 8 wait states and over-drive ON | | 16-bit erase and program operations |
| $V_{DD}$ = 2.4 to 2.7 V | Conversion time up to 2.4 Msps | 24 MHz | 180 MHz with 7 wait states and over-drive ON | I/O compensation works | 16-bit erase and program operations |
| $V_{DD}$ = 2.7 to 3.6 V(5) | | 30 MHz | 180 MHz with 5 wait states and over-drive ON | | 32-bit erase and program operations |

1. Applicable only when the code is executed from flash memory. When the code is executed from RAM, no wait state is required.
2. Thanks to the ART Accelerator and the 128-bit flash memory, the number of wait states given here does not impact the execution speed from flash memory since the ART Accelerator allows to achieve a performance equivalent to 0 wait state program execution.
3. $V_{DD}/V_{DDA}$ minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to *Section 2.19.2*).
4. Prefetch is not available.
5. When $V_{DDUSB}$ is connected to $V_{DD}$, the voltage range for USB full speed PHYs can drop down to 2.7 V. However, the electrical characteristics of D- and D+ pins are degraded between 2.7 and 3 V.

## 5.3.2 VCAP1/VCAP2 external capacitor

Stabilization for the main regulator is achieved by connecting an external capacitor $C_{EXT}$ to the VCAP1/VCAP2 pins. $C_{EXT}$ is specified in *Table 19*.

**Figure 26. External capacitor $C_{EXT}$**




1. Legend: ESR is the equivalent series resistance.

**Table 19. VCAP1/VCAP2 operating conditions(1)**

| Symbol | Parameter | Conditions |
|---|---|---|
| CEXT | Capacitance of external capacitor | 2.2 µF |
| ESR | ESR of external capacitor | < 2 Ω |

1. When bypassing the voltage regulator, the two 2.2 µF $V_{CAP}$ capacitors are not required and should be replaced by two 100 nF decoupling capacitors.

### 5.3.3 Operating conditions at power-up / power-down (regulator ON)

Subject to general operating conditions for $T_A$.

**Table 20. Operating conditions at power-up / power-down (regulator ON)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{VDD}$ | $V_{DD}$ rise time rate | 20 | ∞ | µs/V |
| | $V_{DD}$ fall time rate | 20 | ∞ | |

### 5.3.4 Operating conditions at power-up / power-down (regulator OFF)

Subject to general operating conditions for $T_A$.

**Table 21. Operating conditions at power-up / power-down (regulator OFF)(1)**

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $t_{VDD}$ | $V_{DD}$ rise time rate | Power-up | 20 | ∞ | µs/V |
| | $V_{DD}$ fall time rate | Power-down | 20 | ∞ | |
| $t_{VCAP}$ | $V_{CAP_1}$ and $V_{CAP_2}$ rise time rate | Power-up | 20 | ∞ | |
| | $V_{CAP_1}$ and $V_{CAP_2}$ fall time rate | Power-down | 20 | ∞ | |

1. To reset the internal logic at power-down, a reset must be applied on pin PA0 when $V_{DD}$ reaches below 1.08 V.

### 5.3.5 Reset and power control block characteristics

The parameters given in *Table 22* are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 22. Reset and power control block characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{PVD}$ | Programmable voltage detector level selection | PLS[2:0]=000 (rising edge) | 2.09 | 2.14 | 2.19 | V |
| | | PLS[2:0]=000 (falling edge) | 1.98 | 2.04 | 2.08 | |
| | | PLS[2:0]=001 (rising edge) | 2.23 | 2.30 | 2.37 | |
| | | PLS[2:0]=001 (falling edge) | 2.13 | 2.19 | 2.25 | |
| | | PLS[2:0]=010 (rising edge) | 2.39 | 2.45 | 2.51 | |
| | | PLS[2:0]=010 (falling edge) | 2.29 | 2.35 | 2.39 | |
| | | PLS[2:0]=011 (rising edge) | 2.54 | 2.60 | 2.65 | |
| | | PLS[2:0]=011 (falling edge) | 2.44 | 2.51 | 2.56 | |
| | | PLS[2:0]=100 (rising edge) | 2.70 | 2.76 | 2.82 | |
| | | PLS[2:0]=100 (falling edge) | 2.59 | 2.66 | 2.71 | |
| | | PLS[2:0]=101 (rising edge) | 2.86 | 2.93 | 2.99 | |
| | | PLS[2:0]=101 (falling edge) | 2.75 | 2.84 | 2.92 | |
| | | PLS[2:0]=110 (rising edge) | 2.96 | 3.03 | 3.10 | |
| | | PLS[2:0]=110 (falling edge) | 2.85 | 2.93 | 2.99 | |
| | | PLS[2:0]=111 (rising edge) | 3.07 | 3.14 | 3.21 | |
| | | PLS[2:0]=111 (falling edge) | 2.95 | 3.03 | 3.09 | |
| $V_{PVDhyst}$(1) | PVD hysteresis | - | - | 100 | - | mV |
| $V_{POR/PDR}$ | Power-on/power-down reset threshold | Falling edge | 1.60 | 1.68 | 1.76 | V |
| | | Rising edge | 1.64 | 1.72 | 1.80 | |
| $V_{PDRhyst}$(1) | PDR hysteresis | - | - | 40 | - | mV |
| $V_{BOR1}$ | Brownout level 1 threshold | Falling edge | 2.13 | 2.19 | 2.24 | V |
| | | Rising edge | 2.23 | 2.29 | 2.33 | |
| $V_{BOR2}$ | Brownout level 2 threshold | Falling edge | 2.44 | 2.50 | 2.56 | |
| | | Rising edge | 2.53 | 2.59 | 2.63 | |
| $V_{BOR3}$ | Brownout level 3 threshold | Falling edge | 2.75 | 2.83 | 2.88 | |
| | | Rising edge | 2.85 | 2.92 | 2.97 | |
| $V_{BORhyst}$(1) | BOR hysteresis | - | - | 100 | - | mV |
| $T_{RSTTEMPO}$(1)(2) | POR reset temporization | - | 0.5 | 1.5 | 3.0 | ms |
| $I_{RUSH}$(1) | InRush current on voltage regulator power-on (POR or wakeup from Standby) | - | - | 160 | 200 | mA |
| $E_{RUSH}$(1) | InRush energy on voltage regulator power-on (POR or wakeup from Standby) | $V_{DD}$ = 1.7 V, $T_A$ = 105 °C, $I_{RUSH}$ = 171 mA for 31 µs | - | - | 5.4 | µC |

1. Guaranteed by design.
2. The reset temporization is measured from the power-on (POR reset or wake-up from $V_{BAT}$) to the instant when first instruction is read by the user application code.

### 5.3.6 Overdrive switching characteristics

When the overdrive mode switches from enabled to disabled, or disabled to enabled, the system clock is stalled during the internal voltage set-up.

The overdrive switching characteristics are given in *Table 23*. They are subject to general operating conditions for $T_A$.

**Table 23. Over-drive switching characteristics(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $T_{od_swen}$ | Over_drive switch enable time | HSI | - | 45 | - | µs |
| | | HSE max for 4 MHz and min for 26 MHz | 45 | - | 100 | |
| | | External HSE 50 MHz | - | 40 | - | |
| $T_{od_swdis}$ | Over_drive switch disable time | HSI | - | 20 | - | |
| | | HSE max for 4 MHz and min for 26 MHz. | 20 | - | 80 | |
| | | External HSE 50 MHz | - | 15 | - | |

1. Guaranteed by design.

### 5.3.7 Supply current characteristics

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

The current consumption is measured as described in *Figure 25*.

All the run mode current consumption measurements given in this section are performed with a reduced code that gives a consumption equivalent to the CoreMark® code.

### Typical and maximum current consumption

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 except if it is explicitly mentioned.
- The flash memory access time is adjusted both to $f_{HCLK}$ frequency and $V_{DD}$ range (see *Table 18: Limitations depending on the operating power supply range*).
- When the regulator is OFF, the $V_{12}$ is provided externally, as described in *Table 17: General operating conditions*.
- The voltage scaling and overdrive mode are adjusted to $f_{HCLK}$ frequency as follows:
  - Scale 3 for $f_{HCLK} \leq 120$ MHz
  - Scale 2 for 120 MHz < $f_{HCLK} \leq 144$ MHz
  - Scale 1 for 144 MHz < $f_{HCLK} \leq 180$ MHz. The overdrive is only ON at 180 MHz.
- The system clock is HCLK, $f_{PCLK1} = f_{HCLK}/4$, and $f_{PCLK2} = f_{HCLK}/2$.
- External clock frequency is 25 MHz and PLL is ON when $f_{HCLK}$ is higher than 25 MHz.
- The typical current consumption values are obtained for 1.7 V≤ $V_{DD}$ ≤ 3.6 V voltage range and for ambient temperature $T_A$= 25 °C unless otherwise specified.
- The maximum values are obtained for 1.7 V≤ $V_{DD}$ ≤ 3.6 V voltage range and a maximum ambient temperature ($T_A$), unless otherwise specified.
- For the voltage range 1.7 V≤ $V_{DD}$ ≤ 2.1 V the maximum frequency is 168 MHz.

**Table 24. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled except prefetch) or RAM, regulator ON**

| Symbol | Parameter | Conditions | $f_{HCLK}$ (MHz) | Typ | Max(1) | | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| $I_{DD}$ | Supply current in Run mode | All peripherals enabled(2)(3) | 180 | 103 | 109(4) | 142 | 175(4) | mA |
| | | | 168 | 94 | 99 | 124 | 149 | |
| | | | 150 | 84 | 89 | 114 | 140 | |
| | | | 144 | 77 | 81 | 104 | 127 | |
| | | | 120 | 57 | 60 | 79 | 98 | |
| | | | 90 | 43 | 46 | 64 | 84 | |
| | | | 60 | 30 | 33 | 51 | 70 | |
| | | | 30 | 16 | 19 | 37 | 57 | |
| | | | 25 | 14 | 16 | 34 | 54 | |
| | | | 16 | 7 | 10 | 28 | 48 | |
| | | | 8 | 4 | 7 | 26 | 46 | |
| | | | 4 | 3 | 6 | 24 | 44 | |
| | | | 2 | 3 | 5 | 23 | 43 | |
| | | All peripherals disabled(2) | 180 | 50 | 56(4) | 89 | 124(4) | |
| | | | 168 | 45 | 51 | 75 | 102 | |
| | | | 150 | 41 | 46 | 70 | 97 | |
| | | | 144 | 37 | 42 | 63 | 88 | |
| | | | 120 | 28 | 31 | 49 | 69 | |
| | | | 90 | 21 | 24 | 42 | 63 | |
| | | | 60 | 15 | 17 | 36 | 56 | |
| | | | 30 | 9 | 11 | 29 | 49 | |
| | | | 25 | 7 | 10 | 28 | 48 | |
| | | | 16 | 4 | 7 | 25 | 45 | |
| | | | 8 | 3 | 6 | 22 | 44 | |
| | | | 4 | 3 | 5 | 23 | 43 | |
| | | | 2 | 2 | 5 | 23 | 43 | |

1. Guaranteed based on test during characterization.
2. When analog peripheral blocks such as ADCs, DACs, HSE, LSE, HSI, or LSI are ON, an additional power consumption should be considered.
3. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA per ADC for the analog part.
4. Guaranteed by test in production.

**Table 25. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator disabled), regulator ON**

| Symbol | Parameter | Conditions | $f_{HCLK}$ (MHz) | Typ | Max(1) | | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| $I_{DD}$ | Supply current in Run mode | All peripherals enabled(2)(3) | 168 | 97 | 102 | 128 | 154 | mA |
| | | | 150 | 87 | 92 | 118 | 143 | |
| | | | 144 | 80 | 84 | 108 | 131 | |
| | | | 120 | 65 | 68 | 88 | 108 | |
| | | | 90 | 51 | 54 | 73 | 93 | |
| | | | 60 | 37 | 41 | 59 | 79 | |
| | | | 30 | 21 | 23 | 42 | 62 | |
| | | | 25 | 18 | 20 | 39 | 59 | |
| | | All peripherals disabled | 168 | 49 | 55 | 79 | 105 | |
| | | | 150 | 44 | 49 | 44 | 100 | |
| | | | 144 | 40 | 45 | 68 | 92 | |
| | | | 120 | 36 | 39 | 58 | 78 | |
| | | | 90 | 29 | 32 | 51 | 71 | |
| | | | 60 | 22 | 25 | 44 | 64 | |
| | | | 30 | 13 | 15 | 34 | 54 | |
| | | | 25 | 11 | 13 | 32 | 52 | |

1. Guaranteed based on test during characterization.
2. When analog peripheral blocks such as ADCs, DACs, HSE, LSE, HSI, or LSI are ON, an additional power consumption should be considered.
3. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA per ADC for the analog part.

**Table 26. Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled except prefetch), regulator OFF**

| Symbol | Parameter | Conditions | $f_{HCLK}$ (MHz) | Typ | | Max(1) | | | | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $I_{DD12}$ | $I_{DD}$ | $T_A$ = 25 °C | | $T_A$ = 85 °C | | $T_A$ = 105 °C | | |
| | | | | | | $I_{DD12}$ | $I_{DD}$ | $I_{DD12}$ | $I_{DD}$ | $I_{DD12}$ | $I_{DD}$ | |
| $I_{DD12}$ / $I_{DD}$ | Supply current in Run mode from $V_{12}$ and $V_{DD}$ supply | All peripherals enabled(2) (3) | 168 | 93 | 1 | 98 | 1 | 123 | 1 | 148 | 1 | mA |
| | | | 150 | 83 | 1 | 88 | 1 | 113 | 1 | 138 | 1 | |
| | | | 144 | 76 | 1 | 80 | 1 | 103 | 1 | 126 | 1 | |
| | | | 120 | 56 | 1 | 59 | 1 | 78 | 1 | 97 | 1 | |
| | | | 90 | 43 | 1 | 45 | 1 | 64 | 1 | 83 | 1 | |
| | | | 60 | 29 | 1 | 32 | 1 | 50 | 1 | 70 | 1 | |
| | | | 30 | 15 | 1 | 18 | 1 | 36 | 1 | 56 | 1 | |
| | | | 25 | 13 | 1 | 15 | 1 | 34 | 1 | 53 | 1 | |
| | | All peripherals disabled | 168 | 44 | 1 | 50 | 1 | 72 | 1 | 94 | 1 | |
| | | | 150 | 40 | 1 | 45 | 1 | 68 | 1 | 90 | 1 | |
| | | | 144 | 36 | 1 | 40 | 1 | 62 | 1 | 82 | 1 | |
| | | | 120 | 27 | 1 | 30 | 1 | 48 | 1 | 66 | 1 | |
| | | | 90 | 20 | 1 | 23 | 1 | 41 | 1 | 60 | 1 | |
| | | | 60 | 14 | 1 | 16 | 1 | 35 | 1 | 53 | 1 | |
| | | | 30 | 8 | 1 | 10 | 1 | 28 | 1 | 47 | 1 | |
| | | | 25 | 7 | 1 | 9 | 1 | 27 | 1 | 46 | 1 | |

1. Guaranteed based on test during characterization.
2. When analog peripheral blocks such as ADCs, DACs, HSE, LSE, HSI, or LSI are ON, DSI regulator, an additional power consumption should be considered.
3. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA per ADC for the analog part.

**Table 27. Typical and maximum current consumption in Sleep mode, regulator ON**

| Symbol | Parameter | Conditions | $f_{HCLK}$ (MHz) | Typ | Max(1)(2)(3) | | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| $I_{DD}$ | Supply current in Sleep mode | All peripherals enabled | 180 | 78 | 88(4) | 118 | 151(4) | mA |
| | | | 168 | 71 | 76 | 101 | 127 | |
| | | | 150 | 64 | 71 | 94 | 119 | |
| | | | 144 | 58 | 62 | 85 | 109 | |
| | | | 120 | 43 | 46 | 65 | 85 | |
| | | | 90 | 33 | 37 | 54 | 74 | |
| | | | 60 | 23 | 25 | 44 | 63 | |
| | | | 30 | 13 | 15 | 34 | 53 | |
| | | | 25 | 11 | 13 | 32 | 52 | |
| | | | 16 | 5 | 8 | 27 | 47 | |
| | | | 8 | 4 | 7 | 25 | 45 | |
| | | | 4 | 3 | 5 | 24 | 44 | |
| | | | 2 | 2 | 5 | 23 | 43 | |
| | | All peripherals disabled | 180 | 23 | 29(4) | 63 | 96(4) | |
| | | | 168 | 21 | 25 | 50 | 76 | |
| | | | 150 | 19 | 23 | 48 | 74 | |
| | | | 144 | 17 | 31 | 43 | 67 | |
| | | | 120 | 13 | 16 | 34 | 54 | |
| | | | 90 | 10 | 13 | 31 | 51 | |
| | | | 60 | 7 | 10 | 28 | 48 | |
| | | | 30 | 5 | 7 | 25 | 45 | |
| | | | 25 | 4 | 7 | 25 | 45 | |
| | | | 16 | 2 | 5 | 23 | 43 | |
| | | | 8 | 2 | 5 | 23 | 43 | |
| | | | 4 | 2 | 5 | 23 | 43 | |
| | | | 2 | 2 | 4 | 23 | 42 | |

1. Guaranteed based on test during characterization.
2. When analog peripheral blocks such as ADCs, DACs, HSE, LSE, HSI, or LSI are ON, an additional power consumption should be considered.
3. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA per ADC for the analog part.
4. Guaranteed by test in production.

**Table 28. Typical and maximum current consumption in Sleep mode, regulator OFF**

| Symbol | Parameter | Conditions | $f_{HCLK}$ (MHz) | Typ | | Max(1) | | | | | | Unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $I_{DD12}$ | $I_{DD}$ | $T_A$ = 25 °C | | $T_A$ = 85 °C | | $T_A$ = 105 °C | | |
| | | | | | | $I_{DD12}$ | $I_{DD}$ | $I_{DD12}$ | $I_{DD}$ | $I_{DD12}$ | $I_{DD}$ | |
| $I_{DD12}$ / $I_{DD}$ | Supply current in Run mode from $V_{12}$ and $V_{DD}$ supply | All peripherals enabled | 168 | 70 | 1 | 75 | 1 | 100 | 1 | 126 | 1 | mA |
| | | | 150 | 63 | 1 | 70 | 1 | 93 | 1 | 118 | 1 | |
| | | | 144 | 57 | 1 | 61 | 1 | 84 | 1 | 108 | 1 | |
| | | | 120 | 42 | 1 | 45 | 1 | 64 | 1 | 84 | 1 | |
| | | | 90 | 32 | 1 | 36 | 1 | 53 | 1 | 73 | 1 | |
| | | | 60 | 22 | 1 | 24 | 1 | 43 | 1 | 63 | 1 | |
| | | | 30 | 12 | 1 | 14 | 1 | 33 | 1 | 53 | 1 | |
| | | | 25 | 10 | 1 | 12 | 1 | 31 | 1 | 51 | 1 | |
| | | All peripherals disabled | 168 | 20 | 1 | 24 | 1 | 49 | 1 | 75 | 1 | |
| | | | 150 | 18 | 1 | 22 | 1 | 47 | 1 | 73 | 1 | |
| | | | 144 | 16 | 1 | 19 | 1 | 42 | 1 | 66 | 1 | |
| | | | 120 | 12 | 1 | 14 | 1 | 33 | 1 | 53 | 1 | |
| | | | 90 | 10 | 1 | 12 | 1 | 30 | 1 | 50 | 1 | |
| | | | 60 | 7 | 1 | 9 | 1 | 27 | 1 | 47 | 1 | |
| | | | 30 | 4 | 1 | 6 | 1 | 24 | 1 | 44 | 1 | |
| | | | 25 | 4 | 1 | 6 | 1 | 24 | 1 | 44 | 1 | |

1. Guaranteed based on test during characterization.

**Table 29. Typical and maximum current consumption in Stop mode**

| Symbol | Parameter | Conditions | Typ | Max(1) | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| $I_{DD_STOP_NM}$ (normal mode) | Supply current in Stop mode with voltage regulator in main regulator mode | Flash memory in Stop mode, all oscillators OFF, no independent watchdog | 0.63 | 3 | 17 | 33 | mA |
| | | Flash memory in Deep power down mode, all oscillators OFF, no independent watchdog | 0.58 | 3 | 17 | 33 | |
| | Supply current in Stop mode with voltage regulator in Low Power regulator mode | Flash memory in Stop mode, all oscillators OFF, no independent watchdog | 0.50 | 2 | 15 | 28 | |
| | | Flash memory in Deep power down mode, all oscillators OFF, no independent watchdog | 0.44 | 2 | 15 | 28 | |
| $I_{DD_STOP_UDM}$ (under-drive mode) | Supply current in Stop mode with voltage regulator in main regulator and under-drive mode | Flash memory in Deep power down mode, main regulator in under-drive mode, all oscillators OFF, no independent watchdog | 0.21 | 1 | 6 | 12 | |
| | Supply current in Stop mode with voltage regulator in Low Power regulator and under-drive mode | Flash memory in Deep power down mode, Low Power regulator in under-drive mode, all oscillators OFF, no independent watchdog | 0.14 | 1 | 6 | 13 | |

1. Data based on characterization, tested in production.

**Table 30. Typical and maximum current consumption in Standby mode**

| Symbol | Parameter | Conditions | Typ(1) | | | Max(2) | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | $T_A$ = 25 °C | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| | | | $V_{DD}$ = 1.7 V | $V_{DD}$= 2.4 V | $V_{DD}$ = 3.3 V | $V_{DD}$ = 3.3 V | | | |
| $I_{DD_STBY}$ | Supply current in Standby mode | Backup SRAM ON, RTC and LSE oscillator OFF | 1.7 | 2.5 | 2.9 | 6(3) | 18 | 35(3) | µA |
| | | Backup SRAM OFF, RTC and LSE oscillator OFF | 1.0 | 1.8 | 2.20 | 5(3) | 15 | 30(3) | |
| | | Backup SRAM OFF, RTC ON and LSE oscillator in Power Drive mode | 1.7 | 2.7 | 3.2 | 7 | 20 | 39 | |
| | | Backup SRAM ON, RTC ON and LSE oscillator in Power Drive mode | 2.4 | 3.4 | 4.0 | 8 | 25 | 48 | |
| | | Backup SRAM ON, RTC ON and LSE oscillator in High Drive mode | 3.2 | 4.2 | 4.8 | 10 | 29 | 57 | |
| | | Backup SRAM OFF, RTC ON and LSE oscillator in High Drive mode | 2.5 | 3.5 | 4.1 | 8 | 25 | 48 | |

1. PDR is off for $V_{DD}$=1.7 V. When the PDR is OFF (internal reset OFF), the typical current consumption is reduced by additional 1.2 µA.
2. Based on characterization, not tested in production unless otherwise specified.
3. Based on characterization, tested in production.

**Table 31. Typical and maximum current consumption in $V_{BAT}$ mode**

| Symbol | Parameter | Conditions[1] | Typ | | | Max[2] | | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | $T_A$ = 25 °C | | | $T_A$ = 25 °C | $T_A$ = 85 °C | $T_A$ = 105 °C | |
| | | | $V_{BAT}$ = 1.7 V | $V_{BAT}$= 2.4 V | $V_{BAT}$ = 3.3 V | $V_{BAT}$ = 3.3 V | | | |
| $I_{DD_VBAT}$ | Backup domain supply current | Backup SRAM ON, RTC ON and LSE oscillator in Low Power mode | 1.431 | 1.577 | 1.825 | 1.9 | 12.0 | 24.0 | µA |
| | | Backup SRAM OFF, RTC ON and LSE oscillator in Low Power mode | 0.720 | 0.849 | 1.060 | 1.1 | 7.0 | 13.9 | |
| | | Backup SRAM ON, RTC ON and LSE oscillator in High Drive mode | 2.212 | 2.368 | 2.630 | 2.80 | 17.3 | 34.6 | |
| | | Backup SRAM OFF, RTC ON and LSE oscillator in High Drive mode | 1.499 | 1.637 | 1.862 | 2.0 | 12.3 | 24.5 | |
| | | Backup SRAM ON, RTC and LSE OFF | 0.710 | 0.720 | 0.760 | 0.8[3] | 5.0 | 10.0[3] | |
| | | Backup SRAM OFF, RTC and LSE OFF | 0.018 | 0.020 | 0.024 | 0.2[3] | 2.0 | 4.0[3] | |

1. Crystal used: Abracon ABS07-120-32.768 kHz-T with a $C_L$ of 6 pF for typical values.
2. Based on characterization, tested in production.
3. Based on test during characterization.

**Figure 27. Typical $V_{BAT}$ current consumption (RTC ON / backup SRAM ON and LSE in Low drive mode)**

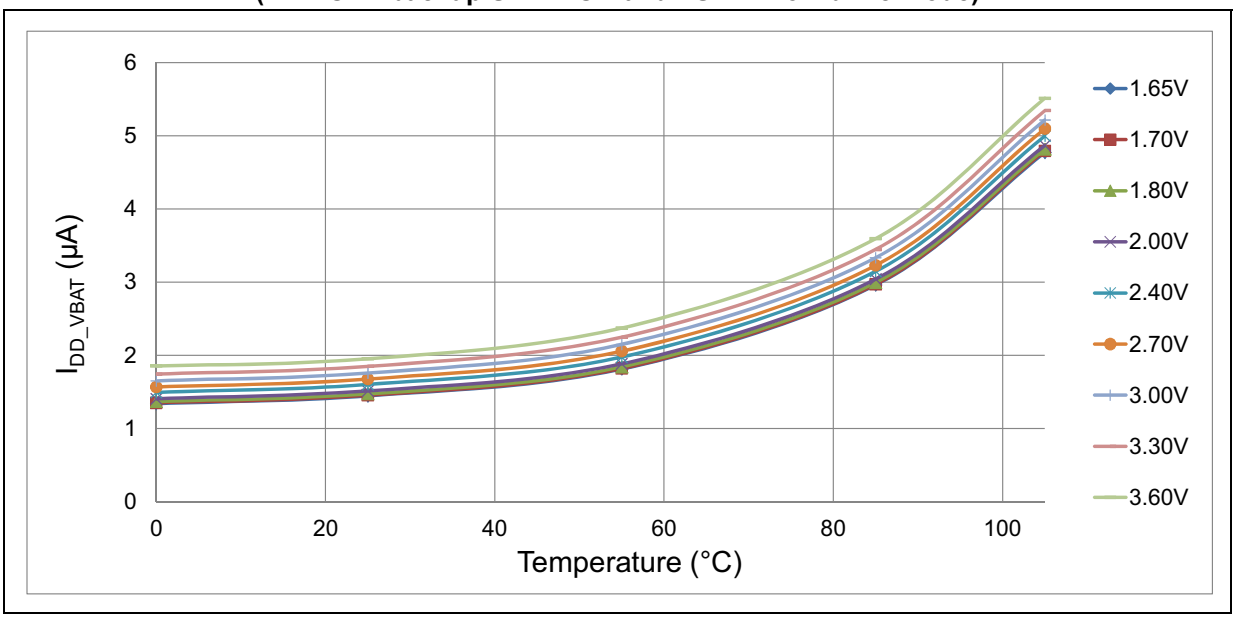
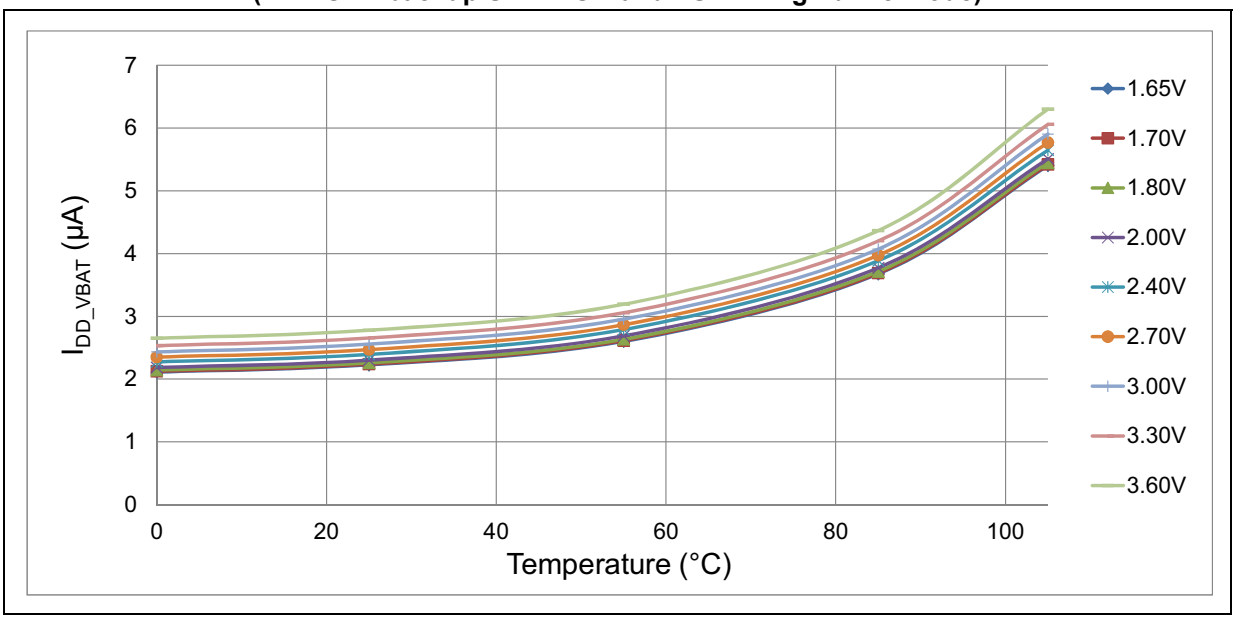


**Figure 28. Typical $V_{BAT}$ current consumption (RTC ON / backup SRAM ON and LSE in High drive mode)**




### I/O system current consumption

The current consumption of the I/O system has two components: static and dynamic.

I/O static current consumption

All the I/Os used as inputs with pull resistors generate current consumption when the pin is externally held to the opposite level. The value of this current consumption can be simply computed by using the pull-up/pull-down resistors values given in *Table 59: I/O static characteristics*.

For the output pins, any external pull-down or external load must also be considered to estimate the current consumption.

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

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

### I/O dynamic current consumption

In addition to the internal peripheral current consumption (see *Table 33*), the I/Os used by an application also contribute to the current consumption. When an I/O pin switches, it uses

the current from the MCU supply voltage to supply the I/O pin circuitry and to charge/discharge the capacitive load internal or external connected to the pin:

$$I_{SW} = V_{DD} \times f_{SW} \times C$$

where

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

$V_{DD}$ is the MCU supply voltage.

$f_{SW}$ is the I/O switching frequency.

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

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

**Table 32. Switching output I/O current consumption(1)**

| Symbol | Parameter | Conditions | I/O toggling frequency (fsw) | Typ | Unit |
|---|---|---|---|---|---|
| $I_{DDIO}$ | I/O switching Current | $V_{DD}$ = 3.3 V C= $C_{INT}$(2) | 2 MHz | 0.0 | mA |
| | | | 8 MHz | 0.2 | |
| | | | 25 MHz | 0.6 | |
| | | | 50 MHz | 1.1 | |
| | | | 60 MHz | 1.3 | |
| | | | 84 MHz | 1.8 | |
| | | | 90 MHz | 1.9 | |
| | | $V_{DD}$ = 3.3 V $C_{EXT}$ = 0 pF $C = C_{INT} + C_{EXT} + C_S$ | 2 MHz | 0.1 | |
| | | | 8 MHz | 0.4 | |
| | | | 25 MHz | 1.23 | |
| | | | 50 MHz | 2.43 | |
| | | | 60 MHz | 2.93 | |
| | | | 84 MHz | 3.86 | |
| | | | 90 MHz | 4.07 | |

**Table 32. Switching output I/O current consumption(1) (continued)**

| Symbol | Parameter | Conditions | I/O toggling frequency (fsw) | Typ | Unit |
|---|---|---|---|---|---|
| $I_{DDIO}$ | I/O switching Current | $V_{DD}$ = 3.3 V<br>$C_{EXT}$ = 10 pF<br>C = $C_{INT}$ + $C_{EXT}$ + $C_S$ | 2 MHz | 0.18 | mA |
| | | | 8 MHz | 0.67 | |
| | | | 25 MHz | 2.09 | |
| | | | 50 MHz | 3.6 | |
| | | | 60 MHz | 4.5 | |
| | | | 84 MHz | 7.8 | |
| | | | 90 MHz | 9.8 | |
| | | $V_{DD}$ = 3.3 V<br>$C_{EXT}$ = 22 pF<br>C = $C_{INT}$ + $C_{EXT}$ + $C_S$ | 2 MHz | 0.26 | |
| | | | 8 MHz | 1.01 | |
| | | | 25 MHz | 3.14 | |
| | | | 50 MHz | 6.39 | |
| | | | 60 MHz | 10.68 | |
| | | $V_{DD}$ = 3.3 V<br>$C_{EXT}$ = 33 pF<br>C = $C_{INT}$ + Cext + $C_S$ | 2 MHz | 0.33 | |
| | | | 8 MHz | 1.29 | |
| | | | 25 MHz | 4.23 | |
| | | | 50 MHz | 11.02 | |

1. $C_S$ is the PCB board capacitance including the pad pin. $C_S$ = 7 pF (estimated value).
2. This test is performed by cutting the LQFP176 package pin (pad removal).

### On-chip peripheral current consumption

The MCU is placed under the following conditions:

- At startup, all I/O pins are in analog input configuration.
- All peripherals are disabled unless otherwise mentioned.
- I/O compensation cell enabled.
- The ART Accelerator is ON.
- Scale 1 mode selected, internal digital voltage V12 = 1.32 V.
- HCLK is the system clock. $f_{PCLK1} = f_{HCLK}/4$, and $f_{PCLK2} = f_{HCLK}/2$.
  The given value is calculated by measuring the difference of current consumption:
  - with all peripherals clocked off
  - with only one peripheral clocked on
  - $f_{HCLK}$ = 180 MHz (Scale1 + overdrive ON), $f_{HCLK}$ = 144 MHz (Scale 2), $f_{HCLK}$ = 120 MHz (Scale 3)
- Ambient operating temperature is 25 °C and $V_{DD}$=3.3 V.

**Table 33. Peripheral current consumption**

| Peripheral | | $I_{DD}$(Typ)(1) | | | Unit |
|---|---|---|---|---|---|
| | | Scale 1 | Scale 2 | Scale 3 | |
| AHB1 (up to 180 MHz) | GPIOA | 3.16 | 3.00 | 2.58 | µA/MHz |
| | GPIOB | 2.67 | 2.62 | 2.25 | |
| | GPIOC | 2.42 | 2.31 | 2.10 | |
| | GPIOD | 2.22 | 2.10 | 1.79 | |
| | GPIOE | 2.60 | 2.48 | 2.23 | |
| | GPIOF | 2.39 | 2.27 | 2.08 | |
| | GPIOG | 2.27 | 2.13 | 1.98 | |
| | GPIOH | 2.34 | 2.20 | 2.02 | |
| | GPIOI | 2.52 | 2.37 | 2.17 | |
| | GPIOJ | 2.16 | 2.03 | 1.86 | |
| | GPIOK | 2.20 | 2.06 | 1.89 | |
| | OTG_HS+ULPI | 36.49 | 33.89 | 29.90 | |
| | CRC | 0.62 | 0.55 | 0.50 | |
| | BKPSRAM | 0.83 | 0.74 | 0.63 | |
| | DMA1(2) | 3.3 x N + 6.8 | 3 x N + 6.3 | 2.7 x N + 5.5 | |
| | DMA2(2) | 3.4 x N + 5.7 | 3.1 x N + 5.3 | 2.8 x N + 4.6 | |
| | DMA2D | 33.33 | 30.66 | 26.98 | |
| | ETH_MAC<br>ETH_MAC_TX<br>ETH_MAC_RX<br>ETH_MAC_PTP | 22.30 | 20.69 | 18.19 | |
| AHB2 (up to 180 MHz) | USB_OTG_FS | 34.33 | 31.96 | 28.35 | µA/MHz |
| | DVCMI | 3.61 | 3.35 | 2.98 | |
| | RNG | 1.94 | 1.82 | 1.61 | |
| AHB3 (up to 180 MHz) | QUADSPI | 16.83 | 15.57 | 13.83 | µA/MHz |
| | FMC | 17.22 | 15.92 | 14.00 | |
| Bus matrix(3) | | 12.17 | 11.19 | 9.97 | µA/MHz |

**Table 33. Peripheral current consumption (continued)**

| Peripheral | | $I_{DD}$(Typ)(1) | | | Unit |
|---|---|---|---|---|---|
| | | Scale 1 | Scale 2 | Scale 3 | |
| APB1 (up to 45 MHz) | TIM2 | 19.11 | 17.56 | 15.33 | µA/MHz |
| | TIM3 | 15.62 | 14.22 | 12.17 | |
| | TIM4 | 16.22 | 14.64 | 12.83 | |
| | TIM5 | 18.44 | 16.72 | 14.00 | |
| | TIM6 | 3.18 | 2.69 | 2.17 | |
| | TIM7 | 3.11 | 2.56 | 2.00 | |
| | TIM12 | 8.67 | 7.56 | 6.50 | |
| | TIM13 | 6.11 | 5.33 | 4.43 | |
| | TIM14 | 6.44 | 5.61 | 4.67 | |
| | PWR | 17.44 | 15.61 | 13.53 | |
| | USART2 | 5.44 | 4.64 | 3.93 | |
| | USART3 | 5.51 | 4.72 | 4.00 | |
| | UART4 | 5.22 | 4.64 | 3.83 | |
| | UART5 | 5.33 | 4.64 | 3.83 | |
| | UART7 | 5.56 | 4.78 | 4.10 | |
| | UART8 | 5.24 | 4.64 | 3.93 | |
| | I2C1 | 4.78 | 4.08 | 3.43 | |
| | I2C2 | 5.11 | 4.50 | 3.73 | |
| | I2C3 | 4.78 | 4.08 | 3.43 | |
| | SPI2/I2S2(4) | 4.11 | 3.53 | 3.00 | |
| | SPI3/I2S3(4) | 4.33 | 3.67 | 3.17 | |
| | CAN1 | 8.89 | 7.83 | 6.87 | |
| | CAN2 | 7.22 | 6.44 | 5.50 | |
| | DAC(5) | 2.89 | 2.69 | 2.40 | |
| | WWDG | 1.73 | 1.44 | 1.00 | |

**Table 33. Peripheral current consumption (continued)**

| Peripheral | | $I_{DD}$(Typ)(1) | | | Unit |
|---|---|---|---|---|---|
| | | Scale 1 | Scale 2 | Scale 3 | |
| APB2 (up to 90 MHz) | SDIO | 7.94 | 7.18 | 6.37 | µA/MHz |
| | TIM1 | 19.44 | 17.81 | 15.80 | |
| | TIM8 | 19.44 | 17.81 | 15.80 | |
| | TIM9 | 8.44 | 7.60 | 6.77 | |
| | TIM10 | 5.67 | 5.03 | 4.50 | |
| | TIM11 | 5.72 | 5.10 | 4.55 | |
| | ADC1(6) | 5.06 | 4.54 | 4.05 | |
| | ADC2(6) | 5.00 | 4.47 | 3.97 | |
| | ADC3(6) | 5.26 | 4.75 | 4.17 | |
| | USART1 | 4.83 | 4.33 | 3.83 | |
| | USART6 | 4.83 | 4.33 | 3.83 | |
| | SPI1 | 2.11 | 1.76 | 1.60 | |
| | SPI4 | 2.11 | 1.69 | 1.60 | |
| | SPI5 | 2.11 | 1.76 | 1.60 | |
| | SPI6 | 2.11 | 1.76 | 1.60 | |
| | SYSCFG | 1.72 | 1.35 | 1.22 | |
| | LTDC | 37.61 | 34.53 | 30.60 | |
| | SAI1 | 3.44 | 3.01 | 2.72 | |
| | DSI | 32.98 | 30.32 | 26.87 | |

1. When the I/O compensation cell is ON, $I_{DD}$ typical value increases by 0.22 mA.
2. DMA1/DMA2 current consumption is calculated by the equation. N: is the number of streams enabled, N= [1..8]
3. The BusMatrix is automatically active when at least one master is ON.
4. To enable an I2S peripheral, first set the I2SMOD bit and then the I2SE bit in the SPI_I2SCFGR register.
5. When the DAC is ON and EN1/2 bits are set in DAC_CR register, add an additional power consumption of 0.8 mA per DAC channel for the analog part.
6. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA per ADC for the analog part.

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

The wake up times given in *Table 34* are measured starting from the wake-up event trigger up to the first instruction executed by the CPU:

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

All timings are derived from tests performed under ambient temperature and $V_{DD}$ = 3.3 V.

**Table 34. Low-power mode wakeup timings**

| Symbol | Parameter | Conditions | Typ(1) | Max(1) | Unit |
|---|---|---|---|---|---|
| $t_{WUSLEEP}$(2) | Wakeup from Sleep | - | 5 | 6 | CPU clock cycles |
| $t_{WUSTOP}$(2) | Wakeup from Stop mode with MR/LP regulator in normal mode | Main regulator is ON | 12.9 | 15.0 | µs |
| | | Main regulator is ON and Flash memory in Deep power down mode | 105 | 120 | |
| | | Low power regulator is ON | 22 | 28 | |
| | | Low power regulator is ON and Flash memory in Deep power down mode | 114 | 130 | |
| $t_{WUSTOP}$(2) | Wakeup from Stop mode with MR/LP regulator in Under-drive mode | Main regulator in under-drive mode (Flash memory in Deep power-down mode) | 107 | 114 | |
| | | Low power regulator in under-drive mode (Flash memory in Deep power-down mode) | 115 | 121 | |
| $t_{WUSTDBY}$ (2)(3) | Wakeup from Standby mode | - | 318 | 371 | |

1. Based on test during characterization.
2. The wake-up times are measured from the wake-up event to the point in which the application code reads the first
3. $t_{WUSTDBY}$ maximum value is given at –40 °C.

## 5.3.9 External clock source characteristics

### High-speed external user clock generated from an external source

In bypass mode the HSE oscillator is switched off and the input pin is a standard I/O. The external clock signal has to respect the *Table 59*. However, the recommended clock input waveform is shown in *Figure 29*.

The characteristics given in *Table 35* result from tests performed using a high-speed external clock source, and under ambient temperature and supply voltage conditions summarized in *Table 17*.

**Table 35. High-speed external user clock characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{HSE_ext}$ | External user clock source frequency(1) | - | 1 | - | 50 | 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(1) | | 5 | - | - | ns |
| $t_{r(HSE)}$ $t_{f(HSE)}$ | OSC_IN rise or fall time(1) | | - | - | 10 | |
| $C_{in(HSE)}$ | OSC_IN input capacitance(1) | - | - | 5 | - | pF |
| $DuCy_{(HSE)}$ | Duty cycle | - | 45 | - | 55 | % |
| $I_L$ | OSC_IN Input leakage current | $V_{SS} \le V_{IN} \le V_{DD}$ | - | - | ±1 | µA |

1. Guaranteed by design.

### Low-speed external user clock generated from an external source

In bypass mode the LSE oscillator is switched off and the input pin is a standard I/O. The external clock signal has to respect the *Table 59: I/O static characteristics*. However, the recommended clock input waveform is shown in *Figure 30*.

The characteristics given in *Table 36* result from tests performed using a low-speed external clock source, and under ambient temperature and supply voltage conditions summarized in *Table 17*.

**Table 36. Low-speed external user clock characteristics**

| 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 | | $V_{SS}$ | - | $0.3V_{DD}$ | |
| $t_{w(LSE)}$ $t_{f(LSE)}$ | OSC32_IN high or low time(1) | | 450 | - | - | ns |
| $t_{r(LSE)}$ $t_{f(LSE)}$ | OSC32_IN rise or fall time(1) | | - | - | 50 | |

**Table 36. Low-speed external user clock characteristics (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $C_{in(LSE)}$ | OSC32_IN input capacitance(1) | - | - | 5 | - | pF |
| $DuCy_{(LSE)}$ | Duty cycle | - | 30 | - | 70 | % |
| $I_L$ | OSC32_IN Input leakage current | $V_{SS} \le V_{IN} \le V_{DD}$ | - | - | ±1 | µA |

1. Guaranteed by design.

**Figure 29. High-speed external clock source AC timing diagram**

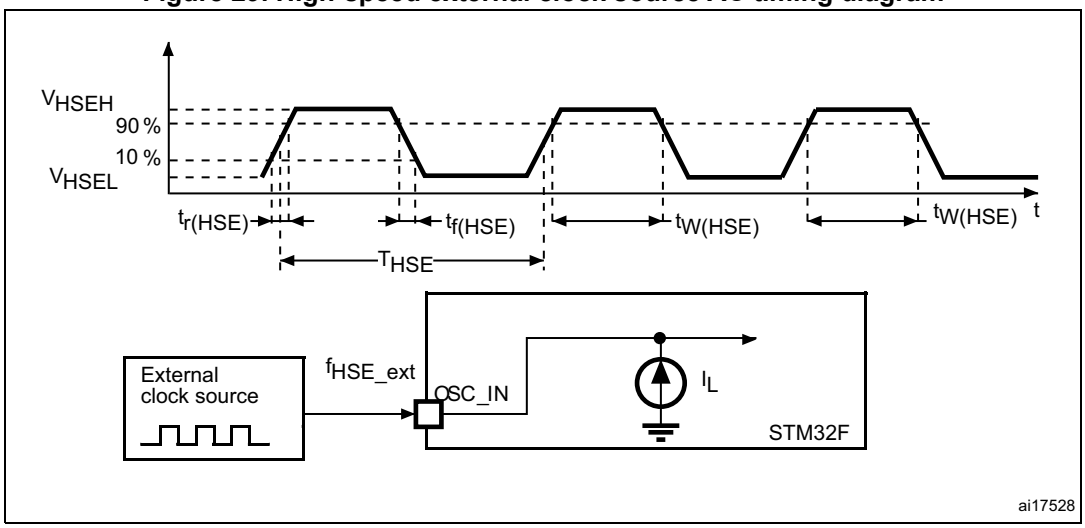
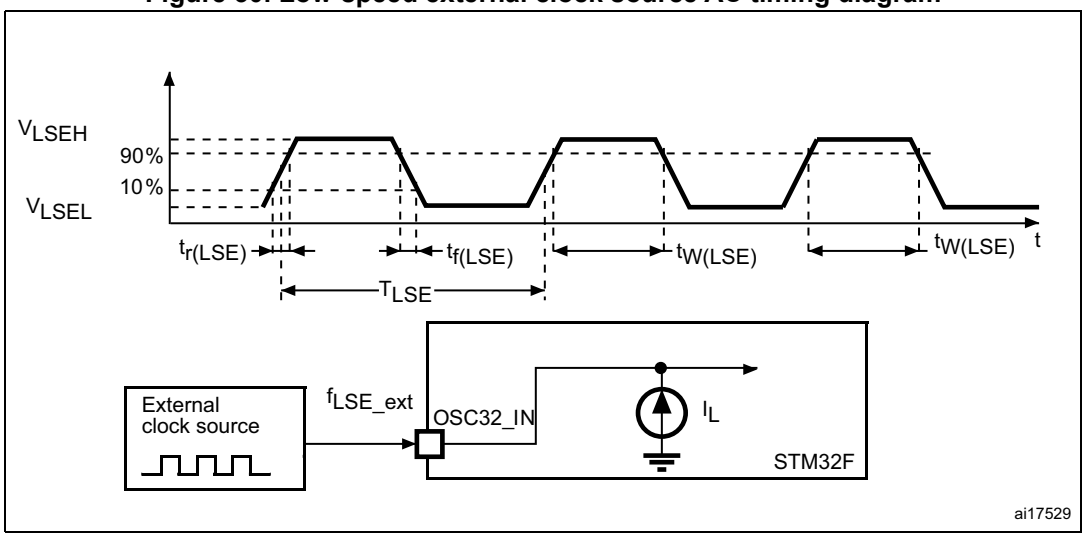



**Figure 30. Low-speed external clock source AC timing diagram**




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

The high-speed external (HSE) clock can be supplied with a 4 to 26 MHz crystal/ceramic resonator oscillator. All the information given in this paragraph is based on characterization results obtained with typical external components specified in *Table 37*. In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins tortion and startup stabilization time. Refer to the crystal resonator

manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

**Table 37. HSE 4-26 MHz oscillator characteristics (1)**

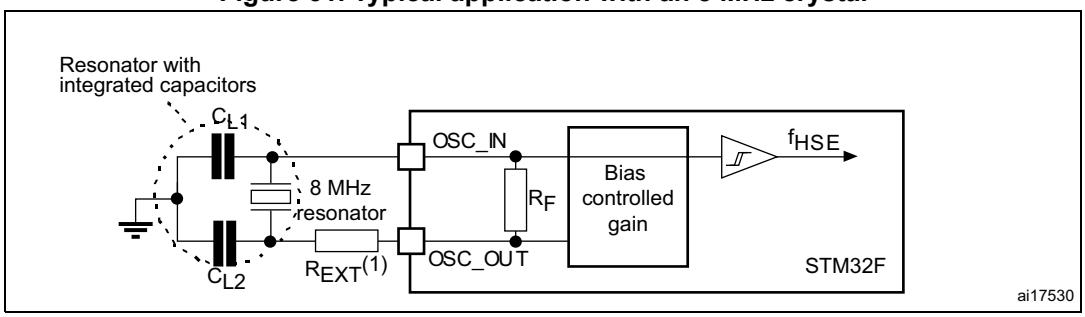
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{OSC_IN}$ | Oscillator frequency | - | 4 | - | 26 | MHz |
| $R_F$ | Feedback resistor | - | - | 200 | - | kΩ |
| $I_{DD}$ | HSE current consumption | $V_{DD}$=3.3 V, ESR= 30 Ω, $C_L$=5 pF@25 MHz | - | 450 | - | µA |
| | | $V_{DD}$=3.3 V, ESR= 30 Ω, $C_L$=10 pF@25 MHz | - | 530 | - | |
| $ACC_{HSE}$ (2) | HSE accuracy | - | − 500 | - | 500 | ppm |
| $G_m$_crit_max | Maximum critical crystal $g_m$ | Startup | - | - | 1 | mA/V |
| $t_{SU(HSE)}$ (3) | Startup time | $V_{DD}$ is stabilized | - | 2 | - | ms |

1. Guaranteed by design.
2. This parameter depends on the crystal used in the application. The minimum and maximum values must be respected to comply with USB standard specifications.
3. $t_{SU(HSE)}$ is the startup time measured from the moment it is enabled (by software) to a stabilized 8 MHz oscillation is reached. This value is based on characterization and not tested in production. It 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 31*). $C_{L1}$ 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 $C_{L2}$.

*Note: For information on selecting the crystal, refer to the application note AN2867 "Oscillator design guide for ST microcontrollers" available from www.st.com.*

**Figure 31. Typical application with an 8 MHz crystal**




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 is based on characterization results obtained with typical external components specified in *Table 38*.

In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

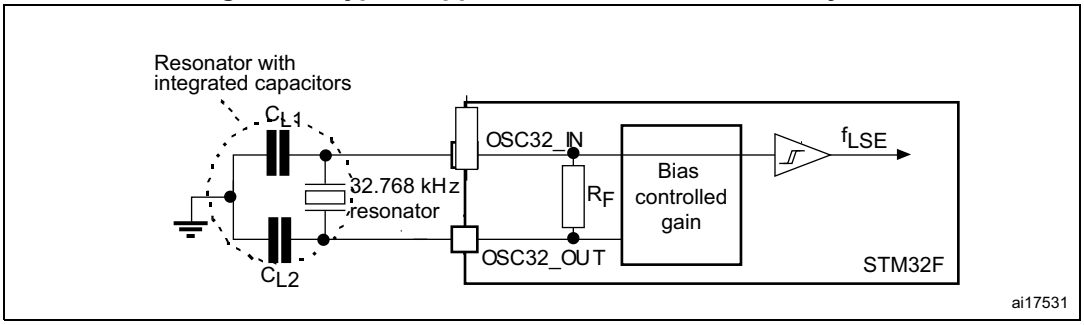
**Table 38. LSE oscillator characteristics ($f_{LSE}$ = 32.768 kHz)(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $R_F$ | Feedback resistor | - | - | 18.4 | - | MΩ |
| $I_{DD}$ | LSE current consumption | Low power mode(2) | - | - | 1 | µA |
| | | High drive mode(2) | - | - | 3 | |
| $ACC_{LSE}$(3) | LSE accuracy | - | − 500 | - | 500 | ppm |
| $G_m$_crit_max | Maximum critical crystal $g_m$ | Low power mode(2) | - | - | 0.56 | µA/V |
| | | High drive mode(2) | - | - | 1.5 | |
| $t_{SU(LSE)}$(4) | Startup time | $V_{DD}$ is stabilized | - | 2 | - | s |

1. Guaranteed by design.
2. LSE mode cannot be changed “on the fly” otherwise, a glitch can be generated on OSCIN pin.
3. This parameter depends on the crystal used in the application. Refer to application note AN2867.
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 based on characterization and not tested in production. It is measured for a standard crystal resonator and it can vary significantly with the crystal manufacturer.

*Note: For information on selecting the crystal, refer to the application note AN2867 “Oscillator design guide for ST microcontrollers” available from www.st.com.*

**Figure 32. Typical application with a 32.768 kHz crystal**



## 5.3.10 Internal clock source characteristics

The parameters given in *Table 39* and *Table 40* are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

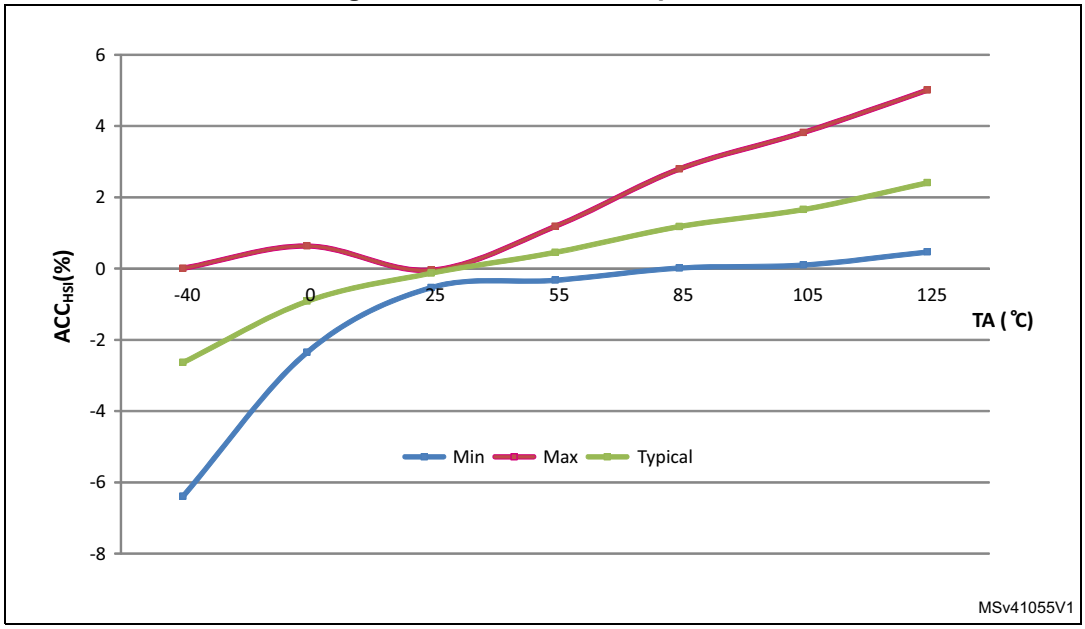
### High-speed internal (HSI) RC oscillator

**Table 39. HSI oscillator characteristics (1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{HSI}$ | Frequency | - | - | 16 | - | MHz |
| $ACC_{HSI}$ | HSI user trimming step(2) | - | - | - | 1 | % |
| | HSI oscillator accuracy | $T_A$ = –40 to 105 °C(3) | − 8 | - | 4.5 | % |
| | | $T_A$ = –10 to 85 °C(3) | − 4 | - | 4 | % |
| | | $T_A$ = 25 °C(4) | − 1 | - | 1 | % |
| $t_{su(HSI)}$(2) | HSI oscillator startup time | - | - | 2.2 | 4 | µs |
| $I_{DD(HSI)}$(2) | HSI oscillator power consumption | - | - | 60 | 80 | µA |

1. $V_{DD}$ = 3.3 V, PLL OFF, $T_A$ = –40 to 125 °C unless otherwise specified.
2. Guaranteed by design.
3. Based on test during characterization.
4. Factory calibrated, parts not soldered.

**Figure 33. ACCHSI vs. temperature**




1. Based on test during characterization.

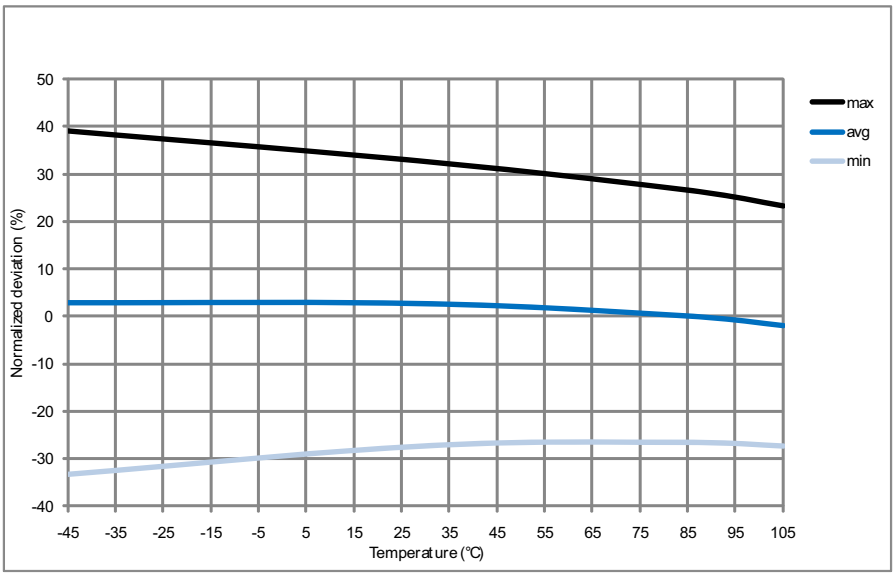
### Low-speed internal (LSI) RC oscillator

**Table 40. LSI oscillator characteristics (1)**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $f_{LSI}$(2) | Frequency | 17 | 32 | 47 | kHz |
| $t_{su(LSI)}$(3) | Startup time | - | 15 | 40 | µs |
| $I_{DD(LSI)}$(3) | Power consumption | - | 0.4 | 0.6 | µA |

1. $V_{DD}$ = 3 V, $T_A$ = –40 to 105°C unless otherwise specified.
2. Based on test during characterization.
3. Guaranteed by design.

**Figure 34. $ACC_{LSI}$ versus temperature**




MS19013V1

## 5.3.11 PLL characteristics

The parameters given in *Table 41* and *Table 42* are derived from tests performed under temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 41. Main PLL characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{PLL_IN}$ | PLL input clock(1) | - | 0.95(2) | 1 | 2.10 | MHz |
| $f_{PLL_OUT}$ | PLL multiplier output clock | - | 24 | - | 180 | |
| $f_{PLL48_OUT}$ | 48 MHz PLL multiplier output clock | - | - | 48 | 75 | |
| $f_{VCO_OUT}$ | PLL VCO output | - | 192 | - | 432 | |

**Table 41. Main PLL characteristics (continued)**

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $t_{LOCK}$ | PLL lock time | VCO frequency = 192 MHz | | 75 | - | 200 | µs |
| | | VCO frequency = 432 MHz | | 100 | - | 300 | |
| Jitter(3) | Cycle-to-cycle jitter | System clock 120 MHz | RMS | - | 25 | - | ps |
| | | | peak to peak | - | ±150 | - | |
| | Period jitter | | RMS | - | 15 | - | |
| | | | peak to peak | - | ±200 | - | |
| | Main clock output (MCO) for RMII Ethernet | Cycle to cycle at 50 MHz on 1000 samples | | - | 32 | - | |
| | Main clock output (MCO) for MII Ethernet | Cycle to cycle at 25 MHz on 1000 samples | | - | 40 | - | |
| | Bit time CAN jitter | Cycle to cycle at 1 MHz on 1000 samples | | - | 330 | - | |
| $I_{DD(PLL)}$(4) | PLL power consumption on $V_{DD}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | | 0.15<br>0.45 | - | 0.40<br>0.75 | mA |
| $I_{DDA(PLL)}$(4) | PLL power consumption on $V_{DDA}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | | 0.30<br>0.55 | - | 0.40<br>0.85 | |

1. Take care of using the appropriate division factor M to obtain the specified PLL input clock values. The M factor is shared between PLL and PLLI2S.
2. Guaranteed by design.
3. The use of two PLLs in parallel can degrade the jitter up to +30%.
4. Based on test during characterization.

**Table 42. PLLI2S (audio PLL) characteristics**

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $f_{PLLI2S_IN}$ | PLLI2S input clock(1) | - | | 0.95(2) | 1 | 2.10 | MHz |
| $f_{PLLI2S_OUT}$ | PLLI2S multiplier output clock | - | | - | - | 216 | |
| $f_{VCO_OUT}$ | PLLI2S VCO output | - | | 192 | - | 432 | |
| $t_{LOCK}$ | PLLI2S lock time | VCO frequency = 192 MHz | | 75 | - | 200 | µs |
| | | VCO frequency = 432 MHz | | 100 | - | 300 | |
| Jitter(3) | Master I2S clock jitter | Cycle to cycle at 12.288 MHz on 48KHz period, N=432, R=5 | RMS | - | 90 | - | - |
| | | | peak to peak | - | ±280 | - | ps |
| | | Average frequency of 12.288 MHz, N=432, R=5 on 1000 samples | | - | 90 | - | ps |
| | WS I2S clock jitter | Cycle to cycle at 48 KHz on 1000 samples | | - | 400 | - | ps |

**Table 42. PLLI2S (audio PLL) characteristics (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $I_{DD(PLLI2S)}$(4) | PLLI2S power consumption on $V_{DD}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | 0.15<br>0.45 | - | 0.40<br>0.75 | mA |
| $I_{DDA(PLLI2S)}$(4) | PLLI2S power consumption on $V_{DDA}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | 0.30<br>0.55 | - | 0.40<br>0.85 | |

1. Take care of using the appropriate division factor M to have the specified PLL input clock values.
2. Guaranteed by design.
3. Value given with main PLL running.
4. Based on test during characterization.

**Table 43. PLLSAI (audio and LCD-TFT PLL) characteristics**

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $f_{PLLSAI_IN}$ | PLLSAI input clock(1) | - | | 0.95(2) | 1 | 2.10 | MHz |
| $f_{PLLSAI_OUT}$ | PLLSAI multiplier output clock | - | | - | - | 216 | |
| $f_{VCO_OUT}$ | PLLSAI VCO output | - | | 192 | - | 432 | |
| $t_{LOCK}$ | PLLSAI lock time | VCO frequency = 192 MHz | | 75 | - | 200 | µs |
| | | VCO frequency = 432 MHz | | 100 | - | 300 | |
| Jitter(3) | Main SAI clock jitter | Cycle to cycle at 12.288 MHz on 48 KHz period, N=432, R=5 | RMS | - | 90 | - | ps |
| | | | peak to peak | - | ±280 | - | |
| | | Average frequency of 12.288 MHz<br>N = 432, R = 5<br>on 1000 samples | | - | 90 | - | ps |
| | FS clock jitter | Cycle to cycle at 48 KHz on 1000 samples | | - | 400 | - | ps |
| $I_{DD(PLLSAI)}$(4) | PLLSAI power consumption on $V_{DD}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | | 0.15<br>0.45 | - | 0.40<br>0.75 | mA |
| $I_{DDA(PLLSAI)}$(4) | PLLSAI power consumption on $V_{DDA}$ | VCO frequency = 192 MHz<br>VCO frequency = 432 MHz | | 0.30<br>0.55 | - | 0.40<br>0.85 | |

1. Take care of using the appropriate division factor M to have the specified PLL input clock values.
2. Guaranteed by design.
3. Value given with main PLL running.
4. Based on test during characterization.

### 5.3.12 PLL spread spectrum clock generation (SSCG) characteristics

The spread spectrum clock generation (SSCG) feature allows to reduce electromagnetic interferences (see *Table 54*). It is available only on the main PLL.

**Table 44. SSCG parameters constraint**

| Symbol | Parameter | Min | Typ | Max(1) | Unit |
|---|---|---|---|---|---|
| $f_{Mod}$ | Modulation frequency | - | - | 10 | KHz |
| md | Peak modulation depth | 0.25 | - | 2 | % |
| MODEPER * INCSTEP | - | - | - | $2^{15} - 1$ | - |

1. Guaranteed by design.

Equation 1

The frequency modulation period (MODEPER) is given by the equation below:

$$MODEPER = round[f_{PLL_IN} / (4 \times f_{Mod})]$$

$f_{PLL_IN}$ and $f_{Mod}$ must be expressed in Hz.

As an example:

If $f_{PLL_IN}$ = 1 MHz, and $f_{MOD}$ = 1 kHz, the modulation depth (MODEPER) is given by equation 1:

$$MODEPER = round[10^6 / (4 \times 10^3)] = 250$$

Equation 2

Equation 2 allows to calculate the increment step (INCSTEP):

$$INCSTEP = round[((2^{15} - 1) \times md \times PLLN) / (100 \times 5 \times MODEPER)]$$

$f_{VCO_OUT}$ must be expressed in MHz.

With a modulation depth (md) = ±2 % (4 % peak to peak), and PLLN = 240 (in MHz):

$$INCSTEP = round[((2^{15} - 1) \times 2 \times 240) / (100 \times 5 \times 250)] = 126md(quantitazed)\%$$

An amplitude quantization error may be generated because the linear modulation profile is obtained by taking the quantized values (rounded to the nearest integer) of MODPER and INCSTEP. As a result, the achieved modulation depth is quantized. The percentage quantized modulation depth is given by the following formula:

$$md_{quantized}\% = (MODEPER \times INCSTEP \times 100 \times 5) / ((2^{15} - 1) \times PLLN)$$

As a result:

$$md_{quantized}\% = (250 \times 126 \times 100 \times 5) / ((2^{15} - 1) \times 240) = 2.002\%(peak)$$

*Figure 35* and *Figure 36* show the main PLL output clock waveforms in center spread and down spread modes, where:

F0 is $f_{PLL_OUT}$ nominal.

$T_{mode}$ is the modulation period.

md is the modulation depth.

**Figure 35. PLL output clock waveforms in center spread mode**

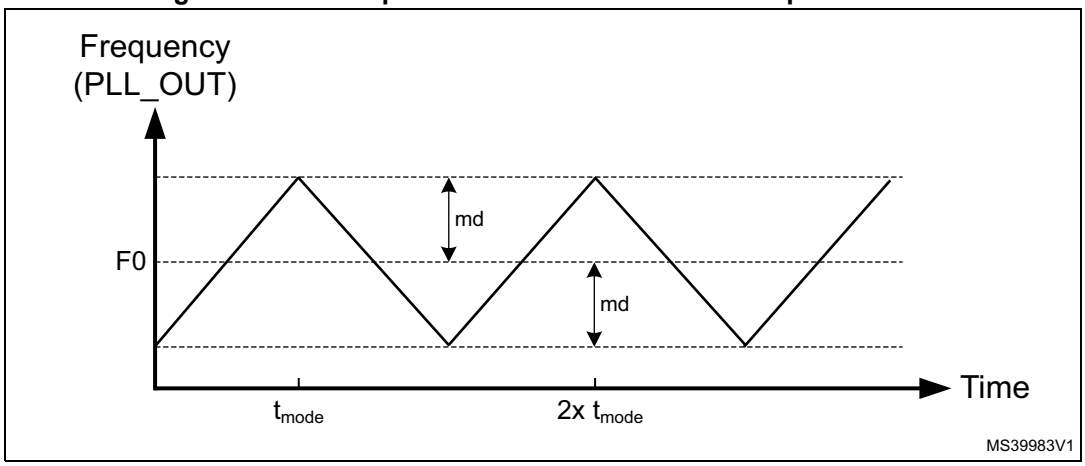
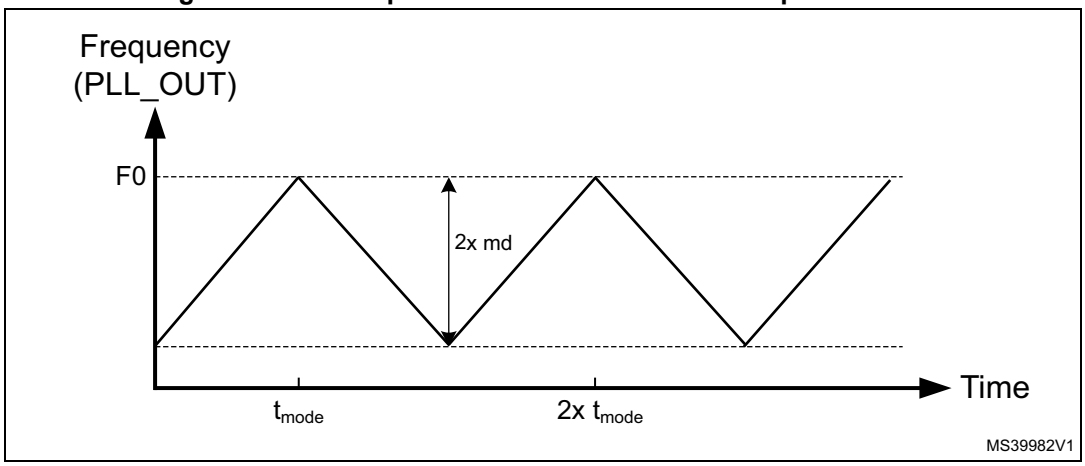



**Figure 36. PLL output clock waveforms in down spread mode**




## 5.3.13 MIPI D-PHY characteristics

The parameters given in *Table 45* and *Table 46* are derived from tests performed under temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 45. MIPI D-PHY characteristics(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Hi-Speed Input/Output characteristics | | | | | | |
| $U_{INST}$ | UI instantaneous | - | 2 | - | 12.5 | ns |

**Table 45. MIPI D-PHY characteristics(1) (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{CMTX}$ | HS transmit common mode voltage | - | 150 | 200 | 250 | mV |
| $\|\Delta V_{CMTX}\|$ | $V_{CMTX}$ mismatch when output is Differential-1 or Differential-0 | - | - | - | 5 | |
| $\|V_{OD}\|$ | HS transmit differential voltage | - | 140 | 200 | 270 | |
| $\|\Delta V_{OD}\|$ | $V_{OD}$ mismatch when output is Differential-1 or Differential-0 | - | - | - | 14 | |
| $V_{OHHS}$ | HS output high voltage | - | - | - | 360 | |
| $Z_{OS}$ | Single ended output impedance | - | 40 | 50 | 62.5 | Ω |
| $\Delta Z_{OS}$ | Single ended output impedance mismatch | - | - | - | 10 | % |
| $t_{HSr}$ & $t_{HSf}$ | 20% - 80% rise and fall time | - | 100 | - | 0.35*UI | ps |
| LP receiver input characteristics | | | | | | |
| $V_{IL}$ | Logic 0 input voltage (not in ULP State) | - | - | - | 550 | mV |
| $V_{IL-ULPS}$ | Logic 0 input voltage in ULP State | - | - | - | 300 | |
| $V_{IH}$ | Input high level voltage | - | 880 | - | - | |
| $V_{hys}$ | Voltage hysteresis | - | 25 | - | - | |
| LP emitter output characteristics | | | | | | |
| $V_{IL}$ | Output low level voltage | - | 1.1 | 1.2 | 1.2 | V |
| $V_{IL-ULPS}$ | Output high level voltage | - | -50 | - | 50 | mV |
| $V_{IH}$ | Output impedance of LP transmitter | - | 110 | - | - | Ω |
| $V_{hys}$ | 15%-85% rise and fall time | - | - | - | 25 | ns |
| LP contention detector characteristics | | | | | | |
| $V_{ILCD}$ | Logic 0 contention threshold | - | - | - | 200 | mV |
| $V_{IHCD}$ | Logic 0 contention threshold | - | 450 | - | - | |

1. Guaranteed based on test during characterization.

**Table 46. MIPI D-PHY AC characteristics LP mode and HS/LP transitions(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $T_{LPX}$ | Transmitted length of any Low-Power state period | - | 50 | - | - | ns |
| $T_{CLK-PREPARE}$ | Time that the transmitter drives the Clock Lane LP-00 Line state immediately before the HS-0 Line state starting the HS transmission. | - | 38 | - | 95 | |
| $T_{CLK-PREPARE}$ + $T_{CLK-ZERO}$ | Time that the transmitter drives the HS-0 state prior to starting the clock. | - | 300 | - | - | |
| $T_{CLK-PRE}$ | Time that the HS clock shall be driven by the transmitter prior to any associated Data Lane beginning the transition from LP to HS mode. | - | 8 | - | - | UI |
| $T_{CLK-POST}$ | Time that the transmitter continues to send HS clock after the last associated Data Lane has transitioned to LP Mode. | - | 62+52*UI | - | - | ns |
| $T_{CLK-TRAIL}$ | Time that the transmitter drives the HS-0 state after the last payload clock bit of an HS transmission burst. | - | 60 | - | - | |
| $T_{HS-PREPARE}$ | Time that the transmitter drives the Data Lane LP-00 Line state immediately before the HS-0 Line state starting the HS transmission. | - | 40+4*UI | - | 85+6*UI | |
| $T_{HS-PREPARE}$ + $T_{HS-ZERO}$ | $T_{HS-PREPARE+}$ Time that the transmitter drives the HS-0 state prior to transmitting the Sync sequence. | - | 145+10*UI | - | - | |
| $T_{HS-TRAIL}$ | Time that the transmitter drives the flipped differential state after last payload data bit of a HS transmission burst. | - | Max (n*8*UI, 60+n*4*UI) | - | - | |
| $T_{HS-EXIT}$ | Time that the transmitter drives LP-11 following a HS burst. | - | 100 | - | - | |
| $T_{REOT}$ | 30% - 85% rise time and fall time | - | - | - | 35 | |
| $T_{EOT}$ | Transmitted time interval from the start of $T_{HS-TRAIL}$ or $T_{CLK-TRAIL}$, to the start of the LP-11 state following a HS burst. | - | - | - | 105+ n*12UI | |

1. Guaranteed based on test during characterization.

**Figure 37. MIPI D-PHY HS/LP clock lane transition timing diagram**

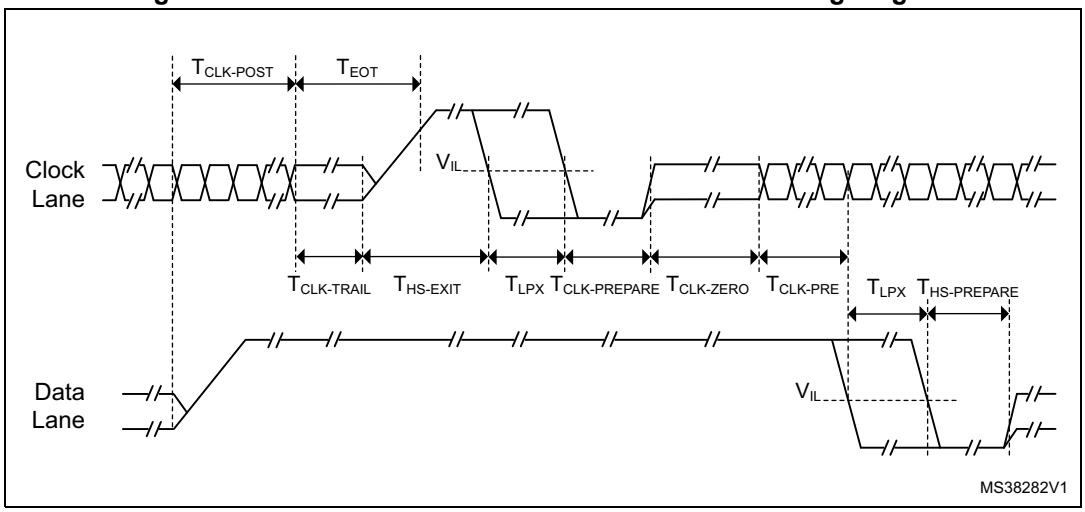
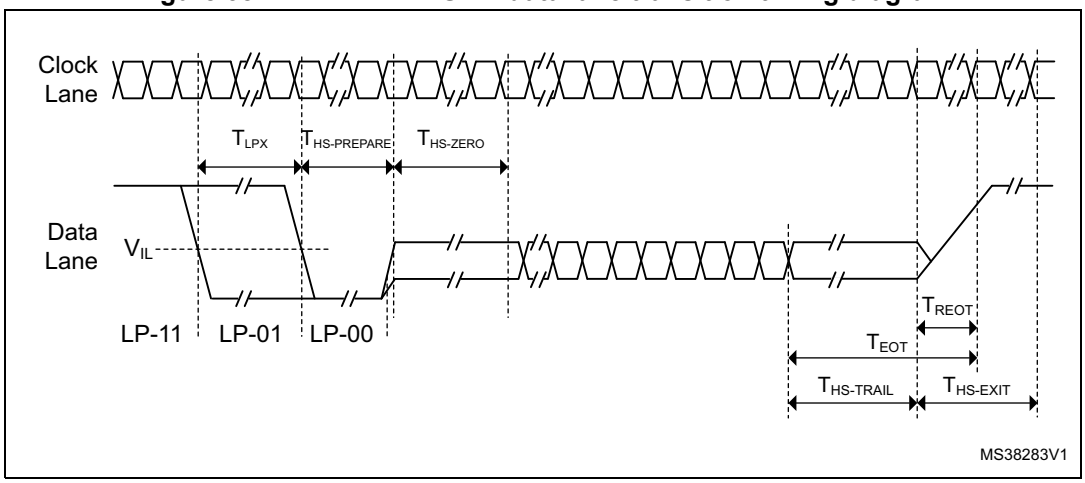



**Figure 38. MIPI D-PHY HS/LP data lane transition timing diagram**




## 5.3.14 MIPI D-PHY PLL characteristics

The parameters given in *Table 47* are derived from tests performed under temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 47. DSI-PLL characteristics(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{PLL_IN}$ | PLL input clock | - | 4 | - | 100 | MHz |
| $f_{PLL_INFIN}$ | PFD input clock | - | 4 | - | 25 | |
| $f_{PLL_OUT}$ | PLL multiplier output clock | - | 31.25 | - | 500 | |
| $f_{VCO_OUT}$ | PLL VCO output | - | 500 | - | 1000 | |
| $t_{LOCK}$ | PLL lock time | - | - | - | 200 | µs |

**Table 47. DSI-PLL characteristics(1) (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $I_{DD(PLL)}$ | PLL power consumption on $V_{DD12}$ | $f_{VCO_OUT}$ = 500 MHz | - | 0.55 | 0.70 | mA |
| | | $f_{VCO_OUT}$ = 600 MHz | - | 0.65 | 0.80 | |
| | | $f_{VCO_OUT}$ = 1000 MHz | - | 0.95 | 1.20 | |

1. Based on test during characterization.

## 5.3.15 MIPI D-PHY regulator characteristics

The parameters given in *Table 48* are derived from tests performed under temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 48. DSI regulator characteristics(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD12DSI}$ | 1.2 V internal voltage on $V_{DD12DSI}$ | - | 1.15 | 1.20 | 1.30 | V |
| $C_{EXT}$ | External capacitor on $V_{CAPDSI}$ | - | 1.1 | 2.2 | 3.3 | µF |
| ESR | External Serial Resistor | - | 0 | 25 | 600 | mΩ |
| $I_{DDDSIREG}$ | Regulator power consumption | - | 100 | 120 | 125 | µA |
| $I_{DDDSI}$ | DSI system (regulator, PLL and D-PHY) current consumption on $V_{DDDSI}$ | Ultra Low Power Mode (Reg. ON + PLL OFF) | - | 290 | 600 | µA |
| | | Stop State (Reg. ON + PLL OFF) | - | 290 | 600 | |
| $I_{DDDSILP}$ | DSI system current consumption on $V_{DDDSI}$ in LP mode communication(2) | 10 MHz escape clock (Reg. ON + PLL OFF) | - | 4.3 | 5.0 | mA |
| | | 20 MHz escape clock (Reg. ON + PLL OFF) | - | 4.3 | 5.0 | |
| $I_{DDDSIHS}$ | DSI system (regulator, PLL and D-PHY) current consumption on $V_{DDDSI}$ in HS mode communication(3) | 300 Mbps - 1 data lane (Reg. ON + PLL ON) | - | 8.0 | 8.8 | mA |
| | | 300 Mbps - 2data lane (Reg. ON + PLL ON) | - | 11.4 | 12.5 | |
| | | 500 Mbps - 1 data lane (Reg. ON + PLL ON) | - | 13.5 | 14.7 | |
| | | 500 Mbps - 2data lane (Reg. ON + PLL ON) | - | 18.0 | 19.6 | |
| | DSI system (regulator, PLL and D-PHY) current consumption on $V_{DDDSI}$ in HS mode with CLK like payload | 500 Mbps - 2data lane (Reg. ON + PLL ON) | - | 21.4 | 23.3 | |
| $t_{WAKEUP}$ | Startup delay | $C_{EXT}$ = 2.2 µF | - | 110 | - | µs |
| | | $C_{EXT}$ = 3.3 µF | - | - | 160 | |
| $I_{INRUSH}$ | Inrush current on $V_{DDDSI}$ | External capacitor load at start | - | 60 | 200 | mA |

1. Based on test during characterization.
2. Values based on an average traffic in LP Command Mode.
3. Values based on an average traffic (3/4 HS traffic & 1/4 LP) in Video Mode.

### 5.3.16 Memory characteristics

#### Flash memory

The characteristics are given at TA = –40 to 105°C unless otherwise specified.

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

**Table 49. Flash memory characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $I_{DD}$ | Supply current | Write / Erase 8-bit mode, $V_{DD}$ = 1.7 V | - | 5 | - | mA |
| | | Write / Erase 16-bit mode, $V_{DD}$ = 2.1 V | - | 8 | - | |
| | | Write / Erase 32-bit mode, $V_{DD}$ = 3.3 V | - | 12 | - | |

**Table 50. Flash memory programming**

| Symbol | Parameter | Conditions | Min(1) | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{prog}$ | Word programming time | Program/erase parallelism (PSIZE) = x 8/16/32 | - | 16 | 100(2) | µs |
| $t_{ERASE16KB}$ | Sector (16 KB) erase time | Program/erase parallelism (PSIZE) = x 8 | - | 400 | 800 | ms |
| | | Program/erase parallelism (PSIZE) = x 16 | - | 300 | 600 | |
| | | Program/erase parallelism (PSIZE) = x 32 | - | 250 | 500 | |
| $t_{ERASE64KB}$ | Sector (64 KB) erase time | Program/erase parallelism (PSIZE) = x 8 | - | 1200 | 2400 | ms |
| | | Program/erase parallelism (PSIZE) = x 16 | - | 700 | 1400 | |
| | | Program/erase parallelism (PSIZE) = x 32 | - | 550 | 1100 | |
| $t_{ERASE128KB}$ | Sector (128 KB) erase time | Program/erase parallelism (PSIZE) = x 8 | - | 2 | 4 | s |
| | | Program/erase parallelism (PSIZE) = x 16 | - | 1.3 | 2.6 | |
| | | Program/erase parallelism (PSIZE) = x 32 | - | 1 | 2 | |

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

| Symbol | Parameter | Conditions | Min(1) | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{ME}$ | Mass erase time | Program/erase parallelism (PSIZE) = x 8 | - | 16 | 32 | s |
| | | Program/erase parallelism (PSIZE) = x 16 | - | 11 | 22 | |
| | | Program/erase parallelism (PSIZE) = x 32 | - | 8 | 16 | |
| $t_{BE}$ | Bank erase time | Program/erase parallelism (PSIZE) = x 8 | - | 16 | 32 | |
| | | Program/erase parallelism (PSIZE) = x 16 | - | 11 | 22 | |
| | | Program/erase parallelism (PSIZE) = x 32 | - | 8 | 16 | |
| $V_{prog}$ | Programming voltage | 32-bit program operation | 2.7 | - | 3.6 | V |
| | | 16-bit program operation | 2.1 | - | 3.6 | |
| | | 8-bit program operation | 1.7 | - | 3.6 | |

1. Based on test during characterization.
2. The maximum programming time is measured after 100 K erase operations.

**Table 51. Flash memory programming with $V_{PP}$**

| Symbol | Parameter | Conditions | Min(1) | Typ | Max(1) | Unit |
|---|---|---|---|---|---|---|
| $t_{prog}$ | Double word programming | $T_A$ = 0 to +40 °C<br>$V_{DD}$ = 3.3 V<br>$V_{PP}$ = 8.5 V | - | 16 | 100(2) | µs |
| $t_{ERASE16KB}$ | Sector (16 KB) erase time | | - | 230 | - | ms |
| $t_{ERASE64KB}$ | Sector (64 KB) erase time | | - | 490 | - | |
| $t_{ERASE128KB}$ | Sector (128 KB) erase time | | - | 875 | - | |
| $t_{ME}$ | Mass erase time | | - | 6.9 | - | s |
| $t_{BE}$ | Bank erase time | - | - | 6.9 | - | s |
| $V_{prog}$ | Programming voltage | - | 2.7 | - | 3.6 | V |
| $V_{PP}$ | $V_{PP}$ voltage range | - | 7 | - | 9 | |
| $I_{PP}$ | Minimum current sunk on the $V_{PP}$ pin | - | 10 | - | - | mA |
| $t_{VPP}$(3) | Cumulative time during which $V_{PP}$ is applied | - | - | - | 1 | hour |

1. Guaranteed by design.
2. The maximum programming time is measured after 100K erase operations.
3. $V_{PP}$ should only be connected during programming/erasing.

**Table 52. Flash memory endurance and data retention**

| Symbol | Parameter | Conditions | Value | Unit |
|---|---|---|---|---|
| | | | Min(1) | |
| $N_{END}$ | Endurance | $T_A$ = –40 to +85 °C (6 suffix versions)<br>$T_A$ = –40 to +105 °C (7 suffix versions) | 10 | kcycles |
| $t_{RET}$ | Data retention | 1 kcycle(2) at $T_A$ = 85 °C | 30 | Years |
| | | 1 kcycle(2) at $T_A$ = 105 °C | 10 | |
| | | 10 kcycles(2) at $T_A$ = 55 °C | 20 | |

1. Based on test during characterization.
2. Cycling performed over the whole temperature range.

## 5.3.17 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 53*. They are based on the EMS levels and classes defined in application note AN1709.

**Table 53. 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 V, TFBGA216, $T_A$ = +25 °C, $f_{HCLK}$ = 168 MHz, conforming 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 V, TFBGA216, $T_A$ = +25 °C, $f_{HCLK}$ = 168 MHz, conforming to IEC 61000-4-2 | 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 is monitored while a simple application, executing EEMBC? code, is running. This emission test is compliant with SAE IEC61967-2 standard, which specifies the test board and the pin loading.

**Table 54. EMI characteristics for $f_{HSE}$=8 MHz and $f_{CPU}$=168 MHz**

| Symbol | Parameter | Conditions | Monitored frequency band | Max vs. [$f_{HSE}/f_{CPU}$] | Unit |
|---|---|---|---|---|---|
| | | | | 8/168 MHz | |
| $S_{EMI}$ | Peak(1) | $V_{DD}$ = 3.3 V, $T_A$ = 25 °C, TFBGA216 package, conforming to SAE J1752/3 EEMBC, ART ON, all peripheral clocks enabled, clock dithering disabled. | 0.1 to 30 MHz | 2 | dBµV |
| | | | 30 to 130 MHz | 4 | |
| | | | 130 MHz to 1GHz | 10 | |
| | Level(2) | | 0.1 MHz to 1 GHz | 3 | - |
| | Peak(1) | $V_{DD}$ = 3.3 V, $T_A$ = 25 °C, TFBGA216 package, conforming to SAE J1752/3 EEMBC, ART ON, all peripheral clocks enabled, clock dithering enabled | 0.1 to 30 MHz | 5 | dBµV |
| | | | 30 to 130 MHz | 3 | |
| | | | 130 MHz to 1GHz | 8 | |
| | Level(2) | | 0.1 MHz to 1 GHz | 2 | - |

1. Refer to AN1709 “EMI radiated test” chapter.
2. Refer to AN1709 “EMI level classification” chapter.

**Table 55. EMI characteristics for $f_{HSE}$=8 MHz and $f_{CPU}$=180 MHz**

| Symbol | Parameter | Conditions | Monitored frequency band | Max vs. [$f_{HSE}/f_{CPU}$] 8/180 MHz | Unit |
|---|---|---|---|---|---|
| $S_{EMI}$ | Peak(1) | $V_{DD}$ = 3.3 V, $T_A$ = 25 °C, TFBGA216 package, conforming to SAE J1752/3 EEMBC, ART ON, all peripheral clocks enabled, clock dithering disabled. | 0.1 to 30 MHz | 2 | dBµV |
| | | | 30 to 130 MHz | 1 | |
| | | | 130 MHz to 1GHz | 10 | |
| | Level(2) | | 0.1 MHz to 1 GHz | 3 | - |
| | Peak(1) | $V_{DD}$ = 3.3 V, $T_A$ = 25 °C, TFBGA216 package, conforming to SAE J1752/3 EEMBC, ART ON, all peripheral clocks enabled, clock dithering enabled | 0.1 to 30 MHz | -10 | dBµV |
| | | | 30 to 130 MHz | -15 | |
| | | | 130 MHz to 1GHz | 0 | |
| | Level(2) | | 0.1 MHz to 1 GHz | 2 | - |

1. Refer to AN1709 “EMI radiated test” chapter.
2. Refer to AN1709 “EMI level classification” chapter.

## 5.3.18 Absolute maximum ratings (electrical sensitivity)

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

### Electrostatic discharge (ESD)

Electrostatic discharges (a positive 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 ANSI/ESDA/JEDEC JS-001 and ANSI/ESD S5.3.1 standards.

**Table 56. 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 ANSI/ESDA/JEDEC JS-001 | 2 | 2000 | V |
| $V_{ESD(CDM)}$ | Electrostatic discharge voltage (charge device model) | $T_A$ = +25 °C conforming to ANSI/ESD S5.3.1, LQFP100, LQFP144, LQFP176, LQFP208, UFBGA169, UFBGA176, TFBGA216 and WLCSP148 packages | C3 | 250 | |

1. Guaranteed based on test during characterization.

### Static latchup

Two complementary static tests are required on six parts to assess the latchup 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 latchup standard.

**Table 57. Electrical sensitivities(1)**

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

1. MSV on PA4 and PA5 is 5 V, versus 5.4 V on all IOs.

## 5.3.19 I/O current injection characteristics

Generally, current injection to the I/O pins, due to external voltage below $V_{SS}$ or above $V_{DD}$ (for standard, 3 V-capable I/O pins) should be avoided during normal product operation. However, 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 above a certain limit (>5 LSB TUE), out of conventional limits of induced leakage current on adjacent pins (out of –5 µA/+0 µA range), or other functional failure (for example reset, oscillator frequency deviation).

Negative induced leakage current is caused by negative injection and positive induced leakage current by positive injection.

The test results are given in *Table 58*.

**Table 58. I/O current injection susceptibility**

| Symbol | Description | Functional susceptibility | | Unit |
|---|---|---|---|---|
| | | Negative injection | Positive injection | |
| $I_{INJ}$ | Injected current on BOOT0 and NRST pins | − 0 | NA(1) | mA |
| | Injected current on DSIHOST_D0P, DSIHOST_D0N, DSIHOST_D1P, DSIHOST_D0N, DSIHOST_CKP, DSIHOST_CKN pins | − 0 | 0 | |
| | Injected current on PA0 and PC0 pins | − 0 | NA(1) | |
| | Injected current on any other FT pin | − 5 | NA(1) | |
| | Injected current on any other pin | − 5 | + 5 | |

1. Injection is not possible.

*Note: It is recommended to add a Schottky diode (pin to ground) to analog pins, which may potentially inject negative currents.*

## 5.3.20 I/O port characteristics

### General input/output characteristics

Unless otherwise specified, the parameters given in *Table 59* are derived from tests performed under the conditions summarized in *Table 17*. All I/Os are CMOS and TTL compliant.

Note: For information on GPIO configuration, refer to the application note AN4899 “STM32 GPIO configuration for hardware settings and low-power consumption” available from www.st.com.

**Table 59. I/O static characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{IL}$ | FT, TTa and NRST I/O input low level voltage | 1.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | - | $0.35V_{DD}-0.04$(1)<br>$0.3V_{DD}$(2) | V |
| | BOOT0 I/O input low level voltage | 1.75 V≤$V_{DD}$ ≤3.6 V, –40 °C≤$T_A$ ≤105 °C | - | - | $0.1V_{DD}+0.1$(1) | |
| | | 1.7 V≤ $V_{DD}$ ≤ 3.6 V, 0°C ≤ $T_A$ ≤ 105°C | - | - | | |
| $V_{IH}$ | FT, TTa and NRST I/O input high level voltage(5) | 1.7 V ≤ $V_{DD}$ ≤ 3.6 V | $0.45V_{DD}+0.3$(1)<br>$0.7V_{DD}$(2) | - | - | |
| | BOOT0 I/O input high level voltage | 1.75 V≤ $V_{DD}$ ≤ 3.6 V, –40 °C ≤ $T_A$ ≤105 °C | $0.17V_{DD}+0.7$(1) | - | - | |
| | | 1.7 V≤ $V_{DD}$ ≤ 3.6 V, 0 °C ≤ $T_A$ ≤ 105 °C | | | | |
| $V_{HYS}$ | FT, TTa and NRST I/O input hysteresis | 1.7 V ≤ $V_{DD}$ ≤ 3.6 V | $10\%V_{DD}$(3) | - | - | V |
| | BOOT0 I/O input hysteresis | 1.75 V≤ $V_{DD}$ ≤ 3.6 V, –40 °C≤ $T_A$ ≤ 105 °C | 0.1 | - | - | |
| | | 1.7 V ≤ $V_{DD}$ ≤ 3.6 V, 0 °C≤ $T_A$ ≤105 °C | | | | |
| $I_{lkg}$ | I/O input leakage current (4) | $V_{SS}$ ≤ $V_{IN}$ ≤ $V_{DD}$ | - | - | ±1 | µA |
| | I/O FT input leakage current (5) | $V_{IN}$ = 5 V | - | - | 3 | |

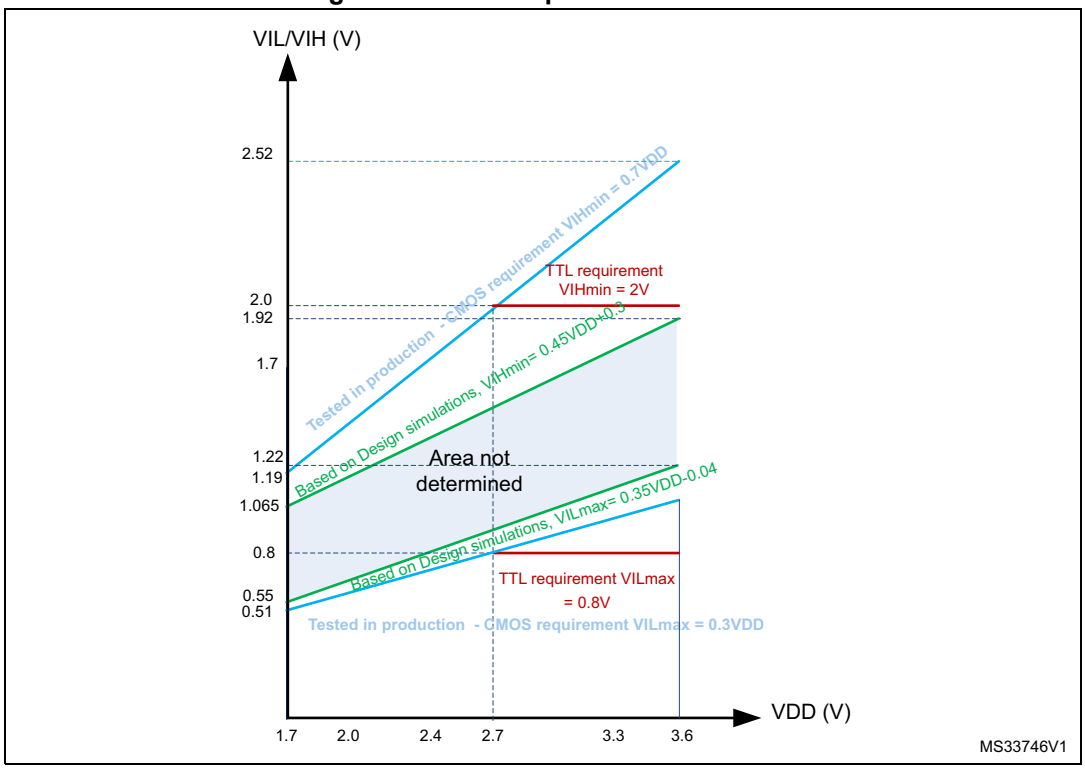
**Table 59. I/O static characteristics (continued)**

| Symbol | Parameter | | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $R_{PU}$ | Weak pull-up equivalent resistor(6) | All pins except for PA10/PB12 (OTG_FS_ID, OTG_HS_ID) | $V_{IN} = V_{SS}$ | 30 | 40 | 50 | kΩ |
| | | PA10/PB12 (OTG_FS_ID, OTG_HS_ID) | | 7 | 10 | 14 | |
| $R_{PD}$ | Weak pull-down equivalent resistor(7) | All pins except for PA10/PB12 (OTG_FS_ID, OTG_HS_ID) | $V_{IN} = V_{DD}$ | 30 | 40 | 50 | |
| | | PA10/PB12 (OTG_FS_ID, OTG_HS_ID) | | 7 | 10 | 14 | |
| $C_{IO}$(8) | I/O pin capacitance | | - | - | 5 | - | pF |

1. Guaranteed by design.
2. Tested in production.
3. With a minimum of 200 mV.
4. Leakage could be higher than the maximum value, if negative current is injected on adjacent pins, refer to *Table 58*
5. To sustain a voltage higher than VDD +0.3 V, the internal pull-up/pull-down resistors must be disabled. Leakage could be higher than the maximum value, if negative current is injected on adjacent pins. Refer to *Table 58*
6. Pull-up resistors are designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance is minimum (~10%).
7. Pull-down resistors are designed with a true resistance in series with a switchable NMOS. This NMOS contribution to the series resistance is minimum (~10%).
8. Hysteresis voltage between Schmitt trigger switching levels. Based on test during characterization.

All I/Os are CMOS and TTL compliant (no software configuration required). Their characteristics cover more than the strict CMOS-technology or TTL parameters. The coverage of these requirements for FT I/Os is shown in *Figure 39*.

**Figure 39. FT I/O input characteristics**




## Output driving current

The GPIOs (general purpose input/outputs) can sink or source up to ±8 mA, and sink or source up to ±20 mA (with a relaxed $V_{OL}/V_{OH}$) except PC13, PC14, PC15, and PI8, which can sink or source up to ±3 mA. When using the PC13 to PC15 and PI8 GPIOs in output mode, the speed should not exceed 2 MHz with a maximum load of 30 pF.

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 5.2*. In particular:

- The sum of the currents sourced by all the I/Os on $V_{DD,}$ plus the maximum Run consumption of the MCU sourced on $V_{DD,}$ cannot exceed the absolute maximum rating $\sum I_{VDD}$ (see *Table 15*).
- The sum of the currents sunk by all the I/Os on $V_{SS}$ plus the maximum Run consumption of the MCU sunk on $V_{SS}$ cannot exceed the absolute maximum rating $\sum I_{VSS}$ (see *Table 15*).

### Output voltage levels

Unless otherwise specified, the parameters given in *Table 60* are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*. All I/Os are CMOS and TTL compliant.

**Table 60. Output voltage characteristics**

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{OL}$(1) | Output low level voltage for an I/O pin | CMOS port(2) $I_{IO}$ = +8 mA 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | V |
| $V_{OH}$(3) | Output high level voltage for an I/O pin | | $V_{DD}$ − 0.4 | - | |
| $V_{OL}$ (1) | Output low level voltage for an I/O pin | TTL port(2) $I_{IO}$ =+ 8mA 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4 | |
| $V_{OH}$ (3) | Output high level voltage for an I/O pin | | 2.4 | - | |
| $V_{OL}$(1) | Output low level voltage for an I/O pin | $I_{IO}$ = +20 mA 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 1.3(4) | |
| $V_{OH}$(3) | Output high level voltage for an I/O pin | | $V_{DD}$−1.3(4) | - | |
| $V_{OL}$(1) | Output low level voltage for an I/O pin | $I_{IO}$ = +6 mA 1.8 V ≤ $V_{DD}$ ≤ 3.6 V | - | 0.4(4) | |
| $V_{OH}$(3) | Output high level voltage for an I/O pin | | $V_{DD}$−0.4(4) | - | |
| $V_{OL}$(1) | Output low level voltage for an I/O pin | $I_{IO}$ = +4 mA 1.7 V ≤ $V_{DD}$ ≤ 3.6V | - | 0.4(5) | |
| $V_{OH}$(3) | Output high level voltage for an I/O pin | | $V_{DD}$−0.4(5) | - | |

1. The $I_{IO}$ current sunk by the device must always respect the absolute maximum rating specified in *Table 15*. and the sum of $I_{IO}$ (I/O ports and control pins) must not exceed $I_{VSS}$.
2. TTL and CMOS outputs are compatible with JEDEC standards JESD36 and JESD52.
3. The $I_{IO}$ current sourced by the device must always respect the absolute maximum rating specified in *Table 15* and the sum of $I_{IO}$ (I/O ports and control pins) must not exceed $I_{VDD}$.
4. Based on characterization data.
5. Guaranteed by design.

### Input/output AC characteristics

The definition and values of input/output AC characteristics are given in *Figure 40* and *Table 61*, respectively.

Unless otherwise specified, the parameters given in *Table 61* are derived from tests performed under the ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 61. I/O AC characteristics(1)(2)**

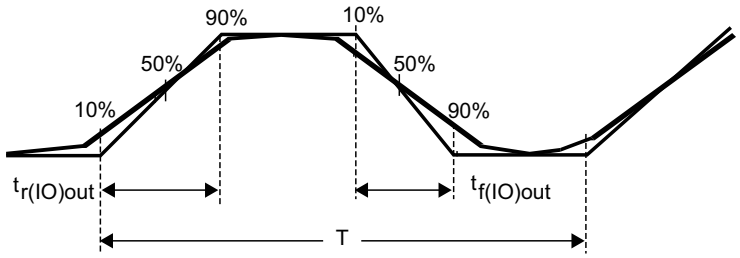
| OSPEEDRy [1:0] bit value(1) | Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| 00 | $f_{max(IO)out}$ | Maximum frequency(3) | $C_L$ = 50 pF, $V_{DD}$ ≥ 2.7 V | - | - | 4 | MHz |
| | | | $C_L$ = 50 pF, $V_{DD}$ ≥ 1.7 V | - | - | 2 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 8 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.8 V | - | - | 4 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.7 V | - | - | 3 | |
| | $t_{f(IO)out}$/ $t_{r(IO)out}$ | Output high to low level fall time and output low to high level rise time | $C_L$ = 50 pF, $V_{DD}$ = 1.7 V to 3.6 V | - | - | 100 | ns |
| 01 | $f_{max(IO)out}$ | Maximum frequency(3) | $C_L$ = 50 pF, $V_{DD}$≥ 2.7 V | - | - | 25 | MHz |
| | | | $C_L$ = 50 pF, $V_{DD}$≥ 1.8 V | - | - | 12.5 | |
| | | | $C_L$ = 50 pF, $V_{DD}$≥ 1.7 V | - | - | 10 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 50 | |
| | | | $C_L$ = 10 pF, $V_{DD}$≥ 1.8 V | - | - | 20 | |
| | | | $C_L$ = 10 pF, $V_{DD}$≥ 1.7 V | - | - | 12.5 | |
| | $t_{f(IO)out}$/ $t_{r(IO)out}$ | Output high to low level fall time and output low to high level rise time | $C_L$ = 50 pF, $V_{DD}$ ≥ 2.7 V | - | - | 10 | ns |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 6 | |
| | | | $C_L$ = 50 pF, $V_{DD}$ ≥ 1.7 V | - | - | 20 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.7 V | - | - | 10 | |
| 10 | $f_{max(IO)out}$ | Maximum frequency(3) | $C_L$ = 40 pF, $V_{DD}$ ≥ 2.7 V | - | - | 50(4) | MHz |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 100(4) | |
| | | | $C_L$ = 40 pF, $V_{DD}$ ≥ 1.7 V | - | - | 25 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.8 V | - | - | 50 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.7 V | - | - | 42.5 | |
| | $t_{f(IO)out}$/ $t_{r(IO)out}$ | Output high to low level fall time and output low to high level rise time | $C_L$ = 40 pF, $V_{DD}$ ≥2.7 V | - | - | 6 | ns |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 4 | |
| | | | $C_L$ = 40 pF, $V_{DD}$ ≥ 1.7 V | - | - | 10 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.7 V | - | - | 6 | |

**Table 61. I/O AC characteristics(1)(2) (continued)**

| OSPEEDRy [1:0] bit value(1) | Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| 11 | $f_{max(IO)out}$ | Maximum frequency(3) | $C_L$ = 30 pF, $V_{DD}$ ≥ 2.7 V | - | - | 100(4) | MHz |
| | | | $C_L$ = 30 pF, $V_{DD}$ ≥ 1.8 V | - | - | 50 | |
| | | | $C_L$ = 30 pF, $V_{DD}$ ≥ 1.7 V | - | - | 42.5 | |
| | | | $C_L$ = 10 pF, $V_{DD}$≥ 2.7 V | - | - | 180(4) | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.8 V | - | - | 100 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 1.7 V | - | - | 72.5 | |
| | $t_{f(IO)out}$/ $t_{r(IO)out}$ | Output high to low level fall time and output low to high level rise time | $C_L$ = 30 pF, $V_{DD}$ ≥ 2.7 V | - | - | 4 | ns |
| | | | $C_L$ = 30 pF, $V_{DD}$ ≥1.8 V | - | - | 6 | |
| | | | $C_L$ = 30 pF, $V_{DD}$ ≥1.7 V | - | - | 7 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥ 2.7 V | - | - | 2.5 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥1.8 V | - | - | 3.5 | |
| | | | $C_L$ = 10 pF, $V_{DD}$ ≥1.7 V | - | - | 4 | |
| - | tEXTIpw | Pulse width of external signals detected by the EXTI controller | - | 10 | - | - | ns |

1. Guaranteed by design.
2. The I/O speed is configured using the OSPEEDRy[1:0] bits. Refer to the STM32F4xx reference manual for a description of the GPIOx_SPEEDR GPIO port output speed register.
3. The maximum frequency is defined in *Figure 40*.
4. For maximum frequencies above 50 MHz and $V_{DD}$ > 2.4 V, the compensation cell should be used.

**Figure 40. I/O AC characteristics definition**




Maximum frequency is achieved with a duty cycle at (45 - 55%) when loaded by the specified capacitance.

MS32132V4

### 5.3.21 NRST pin characteristics

The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, $R_{PU}$ (see *Table 59*).

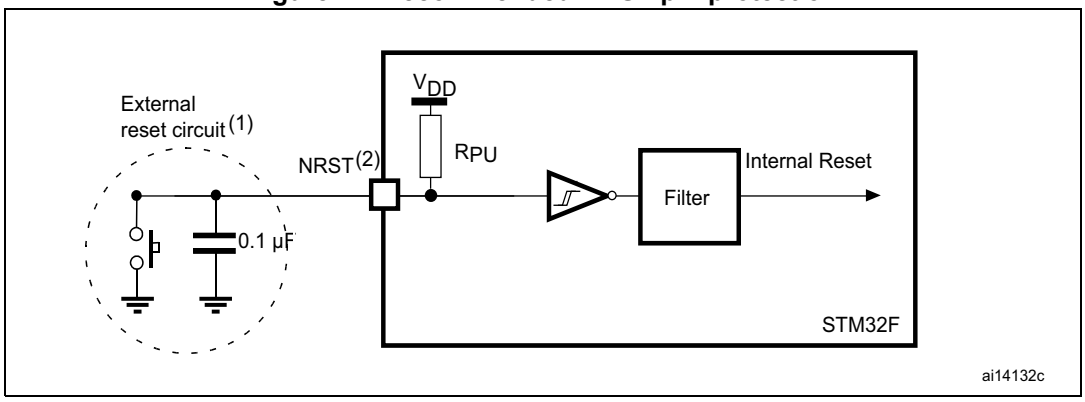
Unless otherwise specified, the parameters given in *Table 62* are derived from tests performed under the ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 62. NRST pin characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $R_{PU}$ | Weak pull-up equivalent resistor(1) | $V_{IN} = V_{SS}$ | 30 | 40 | 50 | kΩ |
| $V_{F(NRST)}$(2) | NRST Input filtered pulse | - | - | - | 100 | ns |
| $V_{NF(NRST)}$(2) | NRST Input not filtered pulse | $V_{DD} > 2.7$ V | 300 | - | - | |
| $T_{NRST_OUT}$ | Generated reset pulse duration | Internal Reset source | 20 | - | - | µs |

1. The pull-up is designed with a true resistance in series with a switchable PMOS. This PMOS contribution to the series resistance must be minimum (~10%).
2. Guaranteed by design.

**Figure 41. 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 59*. Otherwise, the reset is not taken into account by the device.

### 5.3.22 TIM timer characteristics

The parameters given in *Table 63* are guaranteed by design. Refer to *Section 5.3.20* for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

**Table 63. TIMx characteristics(1)(2)**

| Symbol | Parameter | Conditions(3) | Min | Max | Unit |
|---|---|---|---|---|---|
| $t_{res(TIM)}$ | Timer resolution time | AHB/APBx prescaler = 1 or 2 or 4, $f_{TIMxCLK}$ = 180 MHz | 1 | - | $t_{TIMxCLK}$ |
| | | AHB/APBx prescaler > 4, $f_{TIMxCLK}$ = 90 MHz | 1 | - | $t_{TIMxCLK}$ |
| $f_{EXT}$ | Timer external clock frequency on CH1 to CH4 | $f_{TIMxCLK}$ = 180 MHz | 0 | $f_{TIMxCLK}/2$ | MHz |
| $Res_{TIM}$ | Timer resolution | | - | 16/32 | bit |
| $t_{MAX_COUNT}$ | Maximum possible count with 32-bit counter | - | - | 65536 × 65536 | $t_{TIMxCLK}$ |

1. TIMx is used as a general term to refer to the TIM1 to TIM12 timers.
2. Guaranteed by design.
3. The maximum timer frequency on APB1 or APB2 is up to 180 MHz, by setting the TIMPRE bit in the RCC_DCKCFGR register, if APBx prescaler is 1 or 2 or 4, then TIMxCLK = HCKL, otherwise TIMxCLK = 4x PCLKx.

### 5.3.23 Communications interfaces

#### I²C interface characteristics

The I²C interface meets the timings requirements of the I²C-bus specification and user manual rev. 03 for:

- Standard-mode (Sm): bit rate up to 100 Kbit/s
- Fast-mode (Fm): bit rate up to 400 Kbit/s.

The I²C timings requirements are guaranteed by design when the I2C peripheral is properly configured (refer to RM0386 reference manual).

The SDA and SCL I/O requirements are met with the following restrictions: the SDA and SCL I/O pins are not “true” open-drain. When configured as open-drain, the PMOS connected between the I/O pin and $V_{DD}$ is disabled, but is still present. Refer to *Section 5.3.20* for more details on the I²C I/O characteristics.

All I²C SDA and SCL I/Os embed an analog filter, whose characteristics are detailed in *Table 64*.

**Table 64. I2C analog filter characteristics(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{AF}$ | Maximum pulse width of spikes suppressed by the analog filter | 50(2) | 150(3) | ns |

1. Guaranteed based on test during characterization.

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

### SPI interface characteristics

Unless otherwise specified, the parameters given in *Table 65* for the SPI interface are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency, and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- output speed set to OSPEEDRy[1:0] = 10
- capacitive load C = 30 pF
- measurement points at CMOS levels: 0.5 $V_{DD}$

Refer to *Section 5.3.20* for more details on the input/output alternate function characteristics (NSS, SCK, MOSI, MISO for SPI).

**Table 65. SPI dynamic characteristics(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max(2) | Unit |
|---|---|---|---|---|---|---|
| $f_{SCK}$<br>$1/t_{c(SCK)}$ | SPI clock frequency | Master mode,<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6, | - | - | 45 | MHz |
| | | Master mode,<br>1.71 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6 | - | - | 22.5 | |
| | | Master transmitter mode,<br>1.7 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6 | - | - | 45 | |
| | | Slave full duplex mode,<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6 | - | - | 45 | |
| | | Slave transmitter mode,<br>1.71 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6 | - | - | 33 | |
| | | Slave transmitter mode,<br>2.7 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI1,4,5,6 | - | - | 45 | |
| | | Slave mode,<br>1.71 V ≤ $V_{DD}$ ≤ 3.6 V,<br>SPI2,3 | - | - | 22.5 | |
| Duty(SCK) | Duty cycle of SPI clock frequency | Slave mode | 30 | 50 | 70 | % |

**Table 65. SPI dynamic characteristics(1) (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max(2) | Unit |
|---|---|---|---|---|---|---|
| $t_{w(SCKH)}$ $t_{w(SCKL)}$ | SCK high and low time | Master mode, SPI presc = 2 | $T_{PCLK}-1.5$ | $T_{PCLK}$ | $T_{PCLK}+1.5$ | ns |
| $t_{su(NSS)}$ | NSS setup time | Slave mode, SPI presc = 2 | 4 $T_{PCLK}$ | - | - | |
| $t_{h(NSS)}$ | NSS hold time | Slave mode, SPI presc = 2 | 2 $T_{PCLK}$ | | | |
| $t_{su(MI)}$ | Data input setup time | Master mode | 2 | - | - | |
| $t_{su(SI)}$ | | Slave mode | 3 | - | - | |
| $t_{h(MI)}$ | Data input hold time | Master mode | 4 | - | - | |
| $t_{h(SI)}$ | | Slave mode | 2 | - | - | |
| $t_{a(SO)}$ | Data output access time | Slave mode, SPI presc = 2 | 7 | - | 21 | |
| $t_{dis(SO)}$ | Data output disable time | Slave mode | 5 | - | 12 | |
| $t_{v(SO)}$ | Data output valid time | Slave mode, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 11 | 15 | |
| | | Slave mode, 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | - | 11 | 11.5 | |
| $t_{h(SO)}$ | Data output hold time | Slave mode | 6 | - | - | |
| $t_{v(MO)}$ | Data output valid time | Master mode | - | 4.5 | 5 | |
| $t_{h(MO)}$ | Data output hold time | Master mode | 2 | - | - | |

1. Guaranteed based on test during characterization.
2. Maximum frequency in Slave transmitter mode is determined by the sum of $t_{v(SO)}$ and $t_{su(MI)}$, which has to fit into SCK low or high phase preceding the SCK sampling edge. This value can be achieved when the SPI communicates with a master having $t_{su(MI)}$ = 0 while Duty(SCK) = 50%

**Figure 42. SPI timing diagram - slave mode and CPHA = 0**

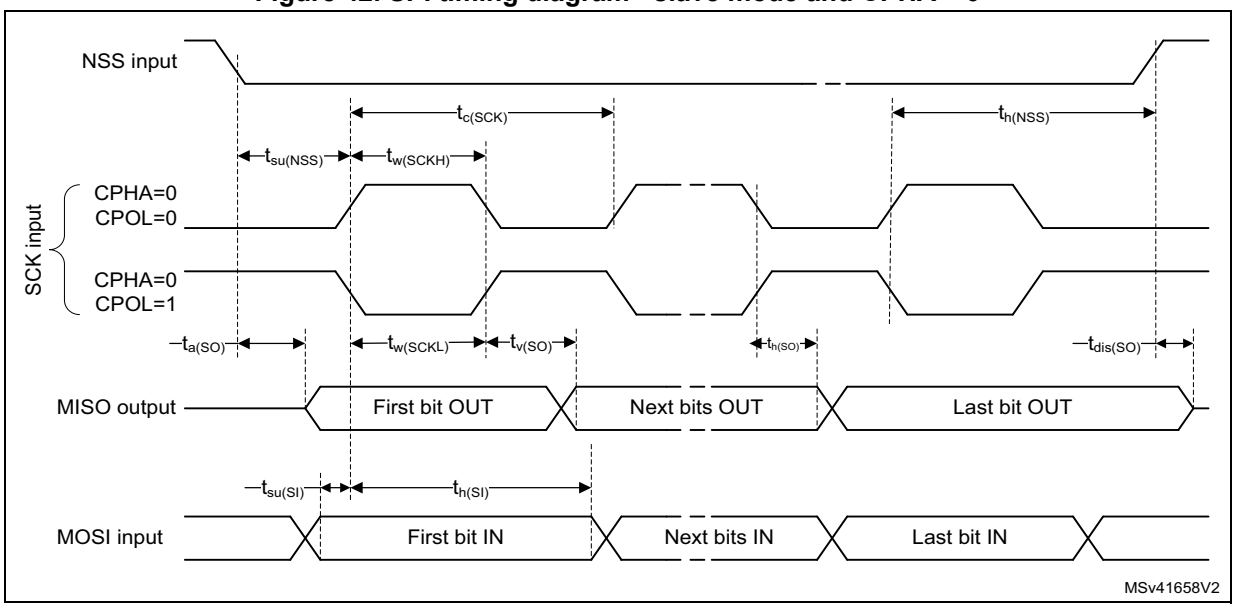



**Figure 43. SPI timing diagram - slave mode and CPHA = 1**

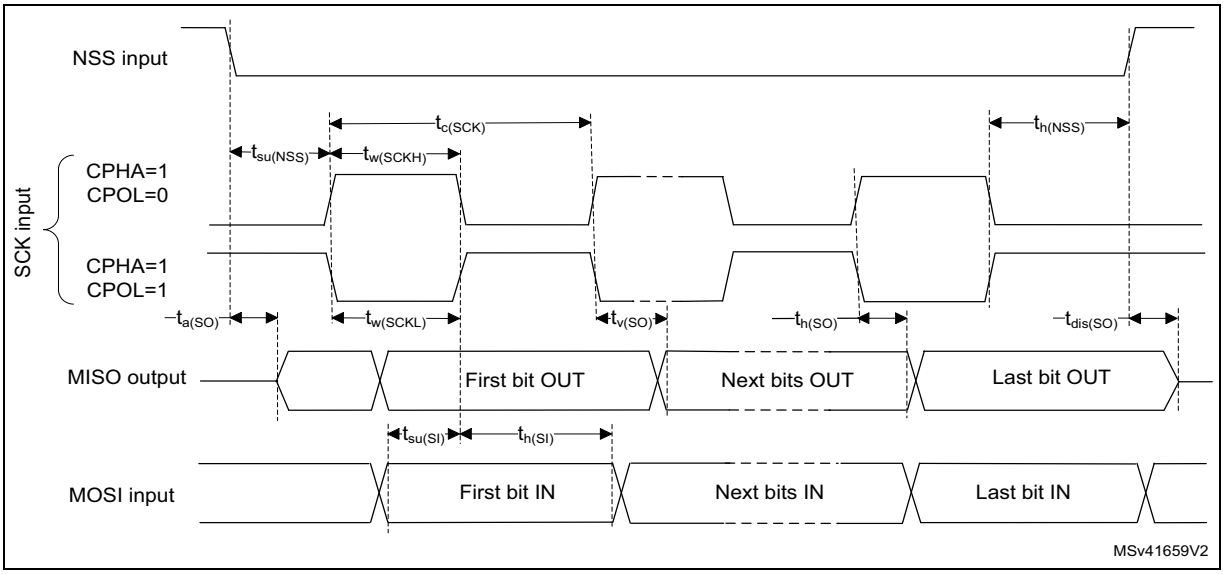
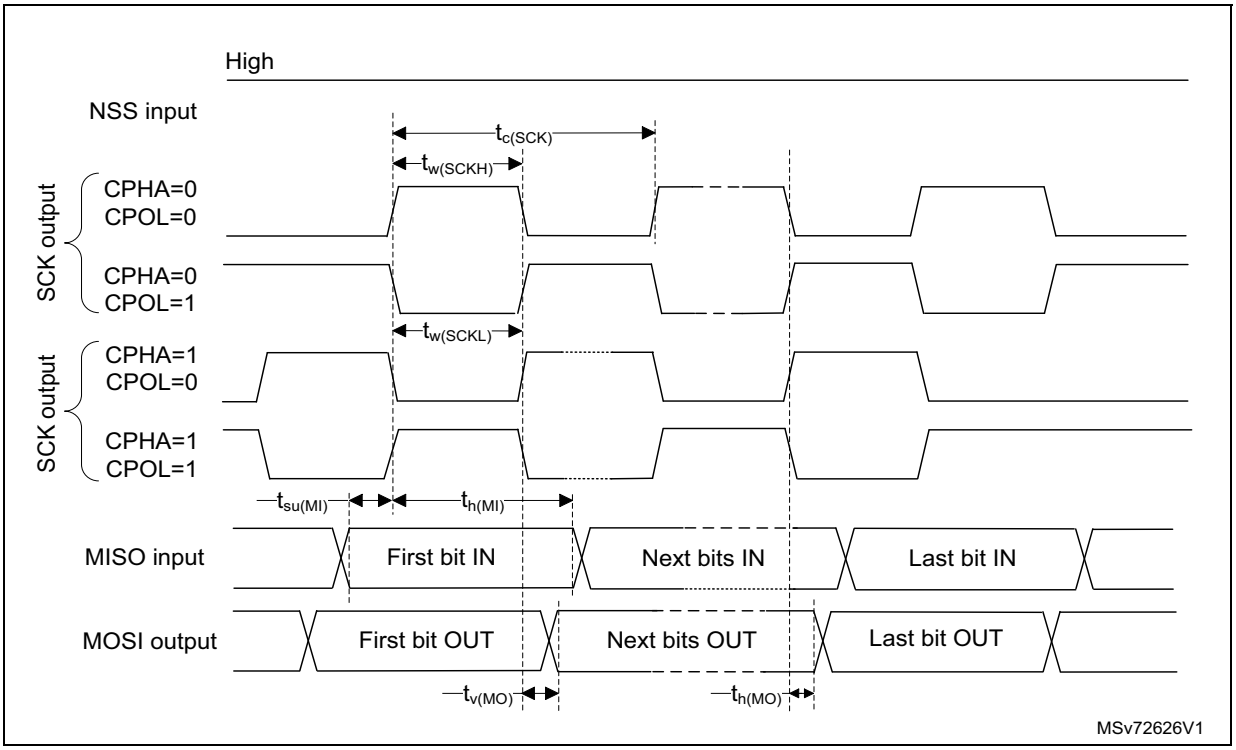


**Figure 44. SPI timing diagram - master mode**



### I²S interface characteristics

Unless otherwise specified, the parameters given in *Table 66* for the I²S interface are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency, and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- output speed set to OSPEEDRy[1:0] = 10
- capacitive load C = 30 pF
- measurement points at CMOS levels: 0.5 $V_{DD}$

Refer to *Section 5.3.20* for more details on the input/output alternate function characteristics (CK, SD, WS).

**Table 66. I²S dynamic characteristics(1)**

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $f_{MCK}$ | I2S main clock output | - | 256x8K | 256xFs(2) | MHz |
| $f_{CK}$ | I2S clock frequency | Master data | - | 64xFs | |
| | | Slave data | - | 64xFs | |
| $D_{CK}$ | I2S clock frequency duty cycle | Slave receiver | 30 | 70 | % |
| $t_{v(WS)}$ | WS valid time | Master mode | 0 | 5 | ns |
| $t_{h(WS)}$ | WS hold time | Master mode | 0 | - | |
| $t_{su(WS)}$ | WS setup time | Slave mode | 3.5 | - | |
| | | Slave mode PCM short pulse mode(3) | 3.5 | - | |
| $t_{h(WS)}$ | WS hold time | Slave mode | 0.5 | - | |
| | | Slave mode PCM short pulse mode(3) | 1 | - | |
| $t_{su(SD_MR)}$ | Data input setup time | Master receiver | 5 | - | |
| $t_{su(SD_SR)}$ | | Slave receiver | 1.5 | - | |
| $t_{h(SD_MR)}$ | Data input hold time | Master receiver | 5 | - | |
| $t_{h(SD_SR)}$ | | Slave receiver | 1.5 | - | |
| $t_{v(SD_ST)}$ | Data output valid time | Slave transmitter (after enable edge) | - | 19 | |
| $t_{v(SD_MT)}$ | | Master transmitter (after enable edge) | - | 2.50 | |
| $t_{h(SD_ST)}$ | Data output hold time | Slave transmitter (after enable edge) | 5 | - | |
| $t_{h(SD_MT)}$ | | Master transmitter (after enable edge) | 0 | - | |

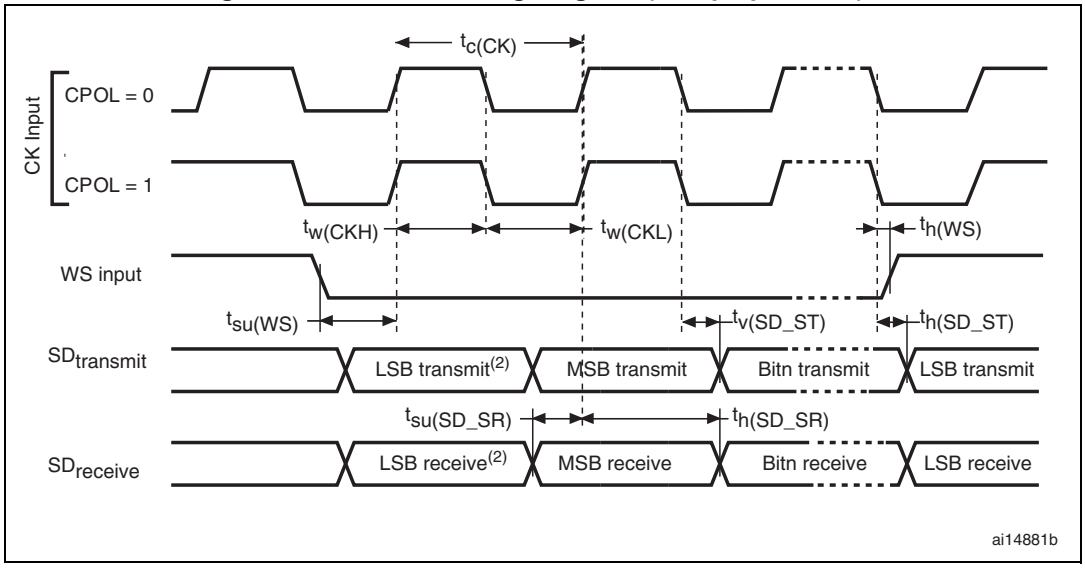
1. Guaranteed based on test during characterization.
2. 128xFs maximum is 24.756 MHz (APB1 Maximum frequency).
3. Measurement done with respect to I2S_CK rising edge.

*Note: Refer to the I2S section of RM0386 reference manual for more details on the sampling frequency ($F_S$).*

*$f_{MCK}$, $f_{CK}$, and $D_{CK}$ values reflect only the digital peripheral behavior, source clock precision might slightly change the values. The values of these parameters might be slightly impacted by the source clock precision. $D_{CK}$ depends mainly on the value of ODD bit. The digital*

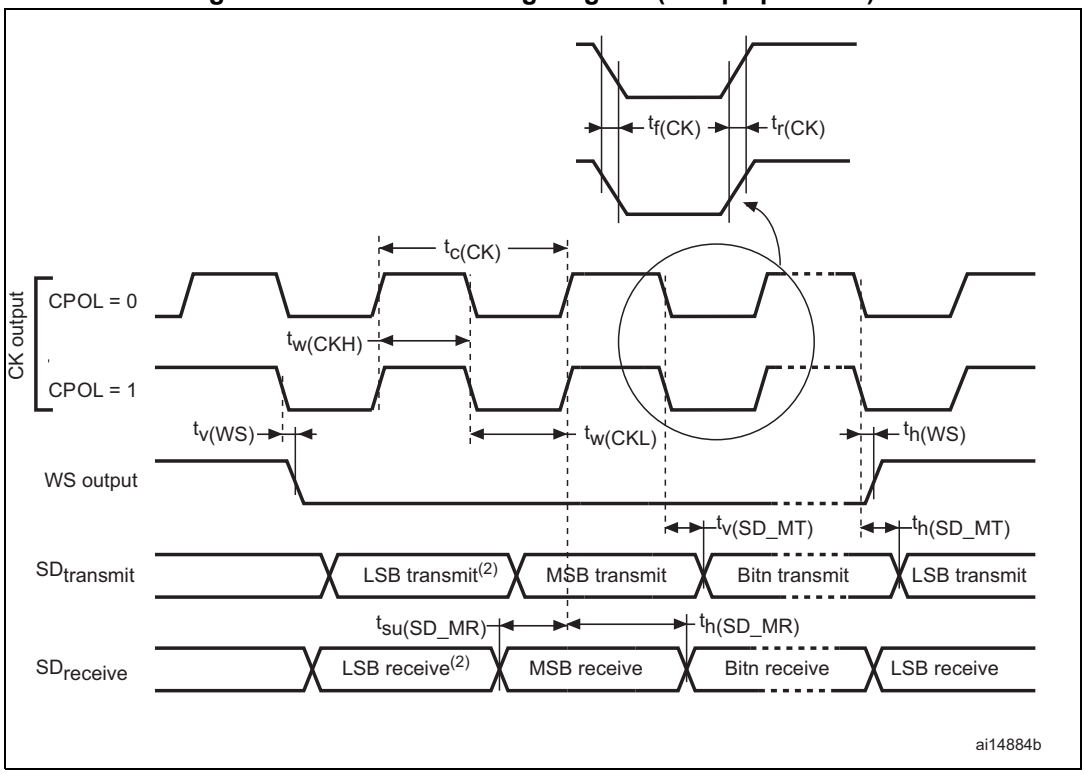
*contribution leads to a minimum value of (I2SDIV/(2*I2SDIV+ODD) and a maximum value of (I2SDIV+ODD)/(2*I2SDIV+ODD). $F_S$ maximum value is supported for each mode/condition.*

**Figure 45. I²S slave timing diagram (Philips protocol)(1)**




1. .LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

**Figure 46. I²S master timing diagram (Philips protocol)(1)**




1. LSB transmit/receive of the previously transmitted byte. No LSB transmit/receive is sent before the first byte.

### SAI characteristics

Unless otherwise specified, the parameters given in *Table 67* for SAI are derived from tests performed under the ambient temperature, $f_{PCLKx}$ frequency, and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- output speed set to OSPEEDRy[1:0] = 10
- capacitive load C=30 pF
- measurement points at CMOS levels: 0.5 $V_{DD}$

Refer to *Section 5.3.20* for more details on the input/output alternate function characteristics (SCK, SD, WS).

**Table 67. SAI characteristics(1)**

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $f_{MCKL}$ | SAI main clock output | - | 256 x 8K | 256xFs | MHz |
| $f_{CK}$ | SAI clock frequency(2) | Master data: 32 bits | - | 128xFs(3) | |
| | | Slave data: 32 bits | - | 128xFs | |
| $t_{v(FS)}$ | FS valid time | Master mode, 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 17 | ns |
| | | Master mode, 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | - | 23 | |
| $t_{su(FS)}$ | FS setup time | Slave mode | 10 | - | |
| $t_{h(FS)}$ | FS hold time | Slave mode | 0 | - | |
| $t_{su(SD_MR)}$ | Data input setup time | Master receiver | 1 | - | |
| $t_{su(SD_SR)}$ | | Slave receiver | 2 | - | |
| $t_{h(SD_MR)}$ | Data input hold time | Master receiver | 6 | - | |
| $t_{h(SD_SR)}$ | | Slave receiver | 1 | - | |
| $t_{h(SD_B_ST)}$ | Data output valid time | Slave transmitter (after enable edge), 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 14 | |
| | | Slave transmitter (after enable edge), 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | - | 23 | |
| $t_{h(SD_B_ST)}$ | Data output hold time | Slave transmitter (after enable edge) | 9 | - | |
| $t_{v(SD_A_MT)}$ | Data output valid time | Master transmitter (after enable edge), 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | - | 20 | |
| | | Master transmitter (after enable edge), 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | - | 26 | |
| $t_{h(SD_A_MT)}$ | Data output hold time | Master transmitter (after enable edge) | 10 | - | |

1. Guaranteed based on test during characterization.
2. APB clock frequency must be at least twice SAI clock frequency.
3. With Fs = 192 kHz.

**Figure 47. SAI master timing waveforms**

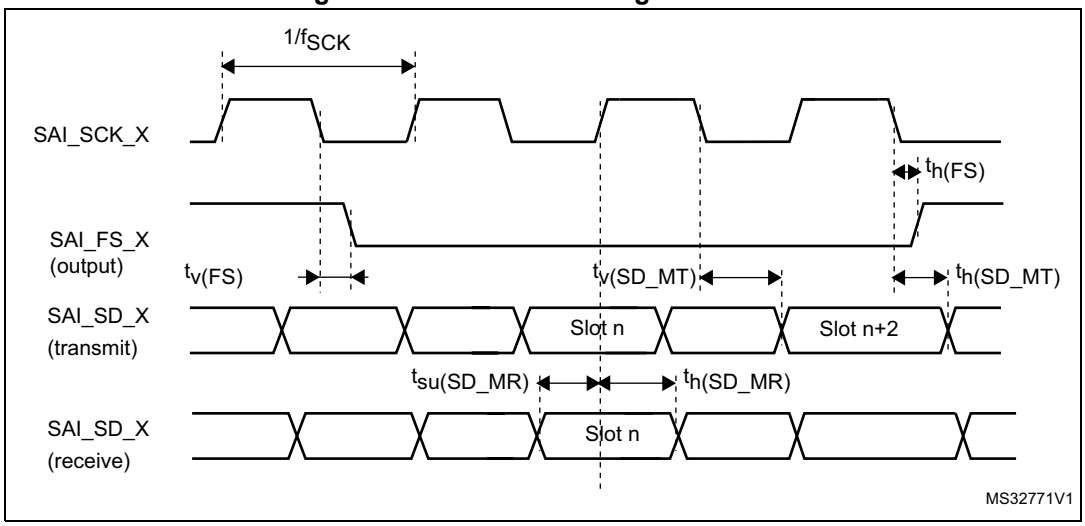
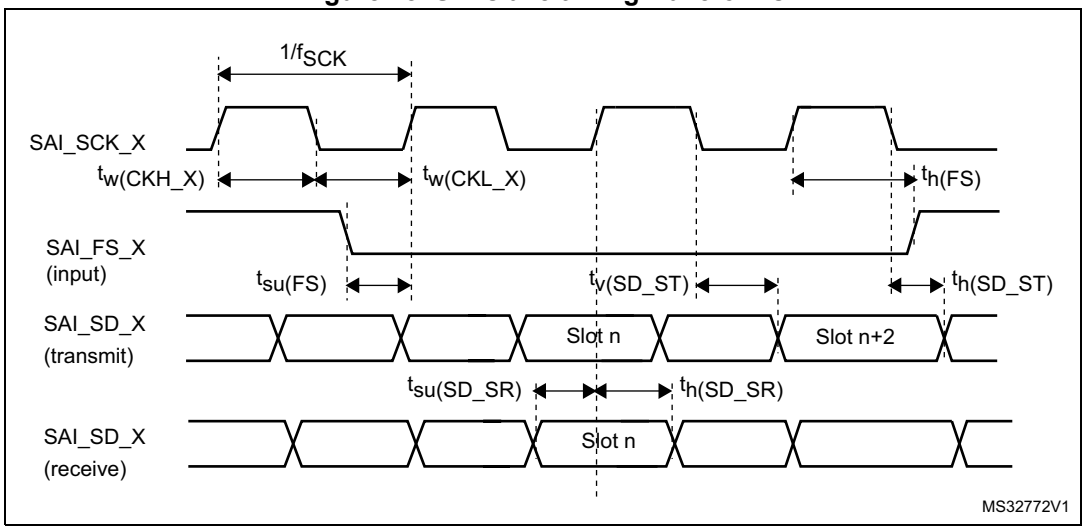



**Figure 48. SAI slave timing waveforms**



### USB OTG full speed (FS) characteristics

This interface is present in both the USB OTG HS and USB OTG FS controllers.

**Table 68. USB OTG full speed startup time**

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

1. Guaranteed by design.

**Table 69. USB OTG full speed DC electrical characteristics**

| Symbol | | Parameter | Conditions | Min.(1) | Typ. | Max.(1) | Unit |
|---|---|---|---|---|---|---|---|
| Input levels | $V_{DD}$ | USB OTG full speed transceiver operating voltage | - | 3.0(2) | - | 3.6 | V |
| | $V_{DI}$(3) | Differential input sensitivity | I(USB_FS_DP/DM, USB_HS_DP/DM) | 0.2 | - | - | |
| | $V_{CM}$(3) | Differential common mode range | Includes $V_{DI}$ range | 0.8 | - | 2.5 | |
| | $V_{SE}$(3) | Single ended receiver threshold | - | 1.3 | - | 2.0 | |
| Output levels | $V_{OL}$ | Static output level low | $R_L$ of 1.5 kΩ to 3.6 V(4) | - | - | 0.3 | |
| | $V_{OH}$ | Static output level high | $R_L$ of 15 kΩ to $V_{SS}$(4) | 2.8 | - | 3.6 | |
| $R_{PD}$ | | PA11, PA12, PB14, PB15 (USB_FS_DP/DM, USB_HS_DP/DM) | $V_{IN}$ = $V_{DD}$ | 17 | 21 | 24 | kΩ |
| | | PA9, PB13 (OTG_FS_VBUS, OTG_HS_VBUS) | | 0.65 | 1.1 | 2.0 | |
| $R_{PU}$ | | PA12, PB15 (USB_FS_DP, USB_HS_DP) | $V_{IN}$ = $V_{SS}$ | 1.5 | 1.8 | 2.1 | |
| | | PA9, PB13 (OTG_FS_VBUS, OTG_HS_VBUS) | $V_{IN}$ = $V_{SS}$ | 0.25 | 0.37 | 0.55 | |

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

*Note: When VBUS sensing feature is enabled, PA9 and PB13 should be left at their default state (floating input), not as alternate function. A typical 200 µA current consumption of the sensing block (current to voltage conversion to determine the different sessions) can be observed on PA9 and PB13 when the feature is enabled.*

**Figure 49. USB OTG full speed timings: definition of data signal rise and fall time**

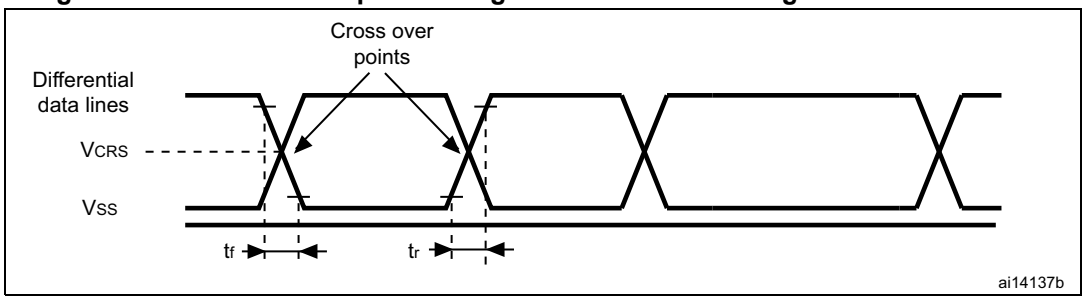



**Table 70. USB OTG full speed electrical characteristics(1)**

| Driver characteristics | | | | | |
|---|---|---|---|---|---|
| **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 | |
| $t_{rfm}$ | Rise/ fall time matching | $t_r$ / $t_f$ | 90 | 110 | % |
| $V_{CRS}$ | Output signal crossover voltage | - | 1.3 | 2.0 | V |
| $Z_{DRV}$ | Output driver impedance(3) | Driving high or low | 28 | 44 | Ω |

1. Guaranteed by design.
2. Measured from 10% to 90% of the data signal. For more detailed informations, please refer to USB Specification - Chapter 7 (version 2.0).
3. No external termination series resistors are required on DP (D+) and DM (D-) pins since the matching impedance is included in the embedded driver.

## USB high speed (HS) characteristics

Unless otherwise specified, the parameters given in *Table 73* for ULPI are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency summarized in *Table 72* and $V_{DD}$ supply voltage conditions summarized in *Table 71*, with the following configuration:

- output speed set to OSPEEDRy[1:0] = 11, unless otherwise specified
- capacitive load C = 20 pF / 15 pF, unless otherwise specified
- measurement points at CMOS levels: 0.5 $V_{DD}$.

Refer to *Section 5.3.20* for more details on the input/output characteristics.

**Table 71. USB HS DC electrical characteristics**

| Symbol | | Parameter | Min.(1) | Max.(1) | Unit |
|---|---|---|---|---|---|
| **Input level** | $V_{DD}$ | USB OTG HS operating voltage | 1.7 | 3.6 | V |

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

**Table 72. USB HS clock timing parameters(1)**

| Symbol | Parameter | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| - | $f_{HCLK}$ value to guarantee proper operation of USB HS interface | | 30 | - | - | MHz |
| $F_{START_8BIT}$ | Frequency (first transition) | 8-bit ±10% | 54 | 60 | 66 | |
| $F_{STEADY}$ | Frequency (steady state) ±500 ppm | | 59.97 | 60 | 60.03 | |
| $D_{START_8BIT}$ | Duty cycle (first transition) | 8-bit ±10% | 40 | 50 | 60 | % |
| $D_{STEADY}$ | Duty cycle (steady state) ±500 ppm | | 49.975 | 50 | 50.025 | |
| $t_{STEADY}$ | Time to reach the steady state frequency and duty cycle after the first transition | | - | - | 1.4 | ms |
| $t_{START_DEV}$ | Clock startup time after the de-assertion of SuspendM | Peripheral | - | - | 5.6 | ms |
| $t_{START_HOST}$ | | Host | - | - | - | |
| $t_{PREP}$ | PHY preparation time after the first transition of the input clock | | - | - | - | µs |

1. Guaranteed by design.

**Figure 50. ULPI timing diagram**

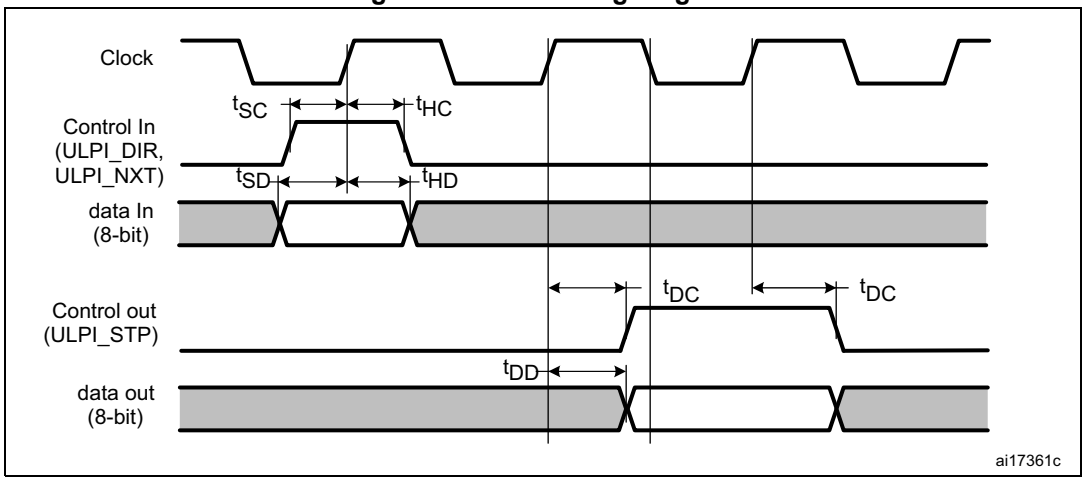


**Table 73. Dynamic characteristics: USB ULPI(1)**

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $t_{SC}$ | Control in (ULPI_DIR, ULPI_NXT) setup time | - | 2.0 | - | - | ns |
| $t_{HC}$ | Control in (ULPI_DIR, ULPI_NXT) hold time | - | 1.5 | - | - | |
| $t_{SD}$ | Data in setup time | - | 1.0 | - | - | |
| $t_{HD}$ | Data in hold time | - | 1.0 | - | - | |
| $t_{DC}/t_{DD}$ | Data/control output delay | 2.7 V < $V_{DD}$ < 3.6 V, $C_L$ = 20 pF | - | 7.5 | 9.0 | |
| | | 2.7 V < $V_{DD}$ < 3.6 V, $C_L$ = 15 pF and -40 < T < 125°C | - | 7.5 | 12.0 | |
| | | 1.7 V < $V_{DD}$ < 3.6 V, $C_L$ = 15 pF and -40 < T < 90°C | - | 7.5 | 11.5 | |

1. Guaranteed based on test during characterization.

## Ethernet characteristics

Unless otherwise specified, the parameters given in *Table 74*, *Table 75* and *Table 76* for SMI, RMII and MII are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency, and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 10
- Capacitive load C = 30 pF
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$.

Refer to *Section 5.3.20* for more details on the input/output characteristics.

*Table 74* gives the list of Ethernet MAC signals for the SMI (station management interface) and *Figure 51* shows the corresponding timing diagram.

**Figure 51. Ethernet SMI timing diagram**

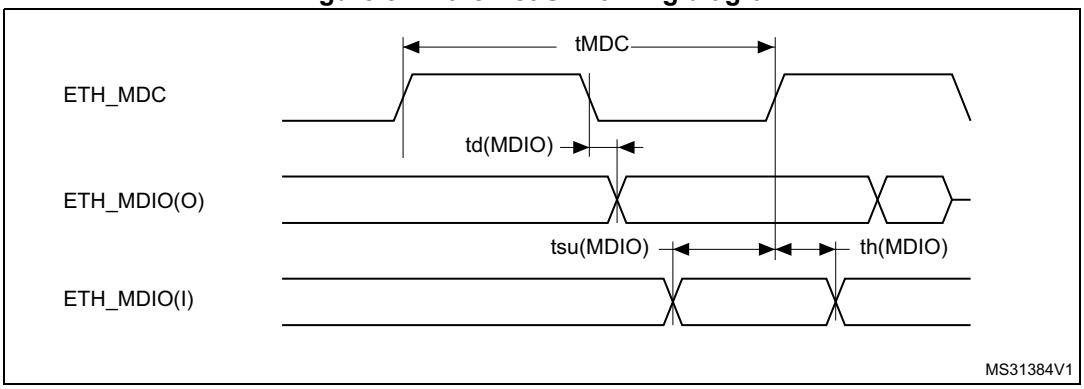


**Table 74. Dynamics characteristics: Ethernet MAC signals for SMI(1)**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $t_{MDC}$ | MDC cycle time(2.38 MHz) | 400 | 400 | 403 | ns |
| $T_{d(MDIO)}$ | Write data valid time | $T_{HCLK}$ - 1 | $T_{HCLK}$ | $T_{HCLK}$ + 1.5 | |
| $t_{su(MDIO)}$ | Read data setup time | 12.5 | - | - | |
| $t_{h(MDIO)}$ | Read data hold time | 0 | - | - | |

1. Guaranteed based on test during characterization.

*Table 75* gives the list of Ethernet MAC signals for the RMII and *Figure 52* shows the corresponding timing diagram.

**Figure 52. Ethernet RMII timing diagram**

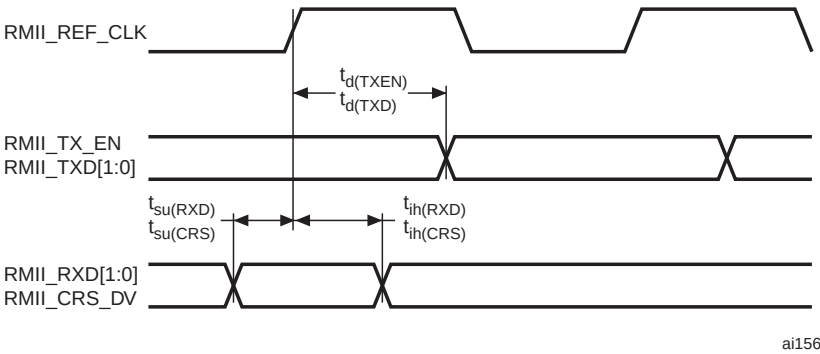


**Table 75. Dynamics characteristics: Ethernet MAC signals for RMII(1)**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $t_{su(RXD)}$ | Receive data setup time | 2.5 | - | - | ns |
| $t_{ih(RXD)}$ | Receive data hold time | 2.0 | - | - | |
| $t_{su(CRS)}$ | Carrier sense setup time | 0.5 | - | - | |
| $t_{ih(CRS)}$ | Carrier sense hold time | 1.5 | - | - | |
| $t_{d(TXEN)}$ | Transmit enable valid delay time | 5.5 | 6.5 | 11 | |
| $t_{d(TXD)}$ | Transmit data valid delay time | 6.0 | 6.5 | 11 | |

1. Guaranteed based on test during characterization.

*Table 76* gives the list of Ethernet MAC signals for MII and *Figure 52* shows the corresponding timing diagram.

**Figure 53. Ethernet MII timing diagram**

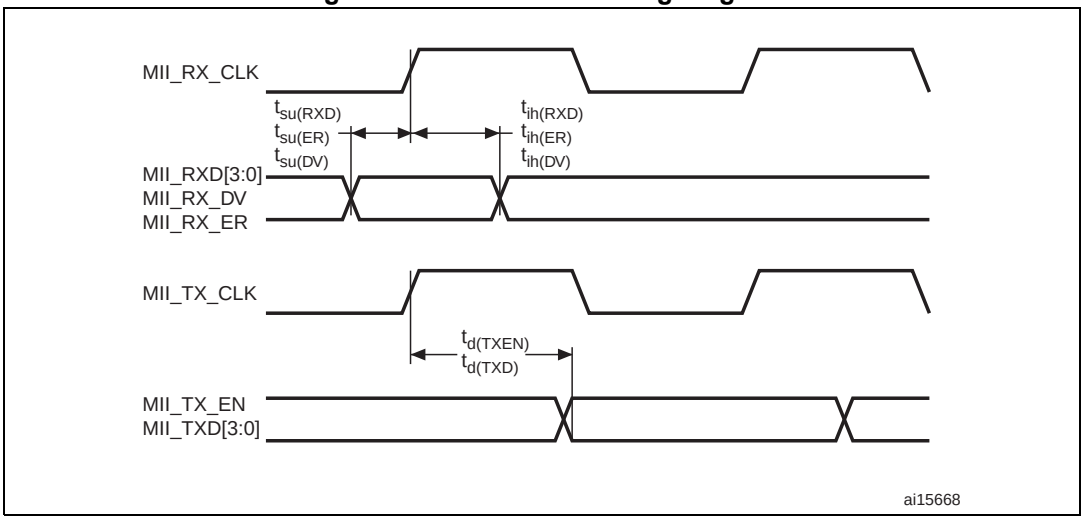



**Table 76. Dynamics characteristics: Ethernet MAC signals for MII(1)**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|

**Table 76. Dynamics characteristics: Ethernet MAC signals for MII(1)**

| | | | | | |
|---|---|---|---|---|---|
| $t_{su(RXD)}$ | Receive data setup time | 1 | - | - | ns |
| $t_{ih(RXD)}$ | Receive data hold time | 3 | - | - | |
| $t_{su(DV)}$ | Data valid setup time | 0 | - | - | |
| $t_{ih(DV)}$ | Data valid hold time | 2.5 | - | - | |
| $t_{su(ER)}$ | Error setup time | 0 | - | - | |
| $t_{ih(ER)}$ | Error hold time | 2 | - | - | |
| $t_{d(TXEN)}$ | Transmit enable valid delay time | 0 | 7 | 13 | |
| $t_{d(TXD)}$ | Transmit data valid delay time | 0 | 7 | 13 | |

1. Guaranteed based on test during characterization.

### CAN (controller area network) interface

Refer to *Section 5.3.20* for more details on the input/output alternate function characteristics (CANx_TX and CANx_RX).

## 5.3.24 12-bit ADC characteristics

Unless otherwise specified, the parameters given in *Table 77* are derived from tests performed under the ambient temperature, $f_{PCLK2}$ frequency and $V_{DDA}$ supply voltage conditions summarized in *Table 17*.

**Table 77. ADC characteristics**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DDA}$ | Power supply | $V_{DDA}$ - $V_{REF+}$ < 1.2 V | 1.7(1) | - | 3.6 | V |
| $V_{REF+}$ | Positive reference voltage | | 1.7(1) | - | $V_{DDA}$ | |
| $V_{REF-}$ | Negative reference voltage | | - | 0 | - | |
| $f_{ADC}$ | ADC clock frequency | $V_{DDA}$ = 1.7(1) to 2.4 V | 0.6 | 15 | 18 | MHz |
| | | $V_{DDA}$ = 2.4 to 3.6 V | 0.6 | 30 | 36 | |
| $f_{TRIG}$(2) | External trigger frequency | $f_{ADC}$ = 30 MHz, 12-bit resolution | - | - | 1764 | kHz |
| | | - | - | - | 17 | $1/f_{ADC}$ |
| $V_{AIN}$ | Conversion voltage range(3) | - | 0 ($V_{SSA}$ or $V_{REF-}$ tied to ground) | - | $V_{REF+}$ | V |
| $R_{AIN}$(2) | External input impedance | Details in *Equation 1* | - | - | 50 | kΩ |
| $R_{ADC}$(2)(4) | Sampling switch resistance | - | - | - | 6 | kΩ |
| $C_{ADC}$(2) | Internal sample and hold capacitor | - | - | 4 | 7 | pF |
| $t_{lat}$(2) | Injection trigger conversion latency | $f_{ADC}$ = 30 MHz | - | - | 0.100 | µs |
| | | - | - | - | 3(5) | $1/f_{ADC}$ |

**Table 77. ADC characteristics (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{latr}$(2) | Regular trigger conversion latency | $f_{ADC}$ = 30 MHz | - | - | 0.067 | µs |
| | | | - | - | 2(5) | $1/f_{ADC}$ |
| $t_S$(2) | Sampling time | $f_{ADC}$ = 30 MHz | 0.100 | - | 16 | µs |
| | | - | 3 | - | 480 | $1/f_{ADC}$ |
| $t_{STAB}$(2) | Power-up time | - | - | 2 | 3 | µs |
| $t_{CONV}$(2) | Total conversion time (including sampling time) | $f_{ADC}$ = 30 MHz 12-bit resolution | 0.50 | - | 16.40 | µs |
| | | $f_{ADC}$ = 30 MHz 10-bit resolution | 0.43 | - | 16.34 | |
| | | $f_{ADC}$ = 30 MHz 8-bit resolution | 0.37 | - | 16.27 | |
| | | $f_{ADC}$ = 30 MHz 6-bit resolution | 0.30 | - | 16.20 | |
| | | 9 to 492 ($t_S$ for sampling +n-bit resolution for successive approximation) | | | | $1/f_{ADC}$ |
| $f_S$(2) | Sampling rate ($f_{ADC}$ = 30 MHz, and $t_S$ = 3 ADC cycles) | 12-bit resolution Single ADC | - | - | 2 | Msps |
| | | 12-bit resolution Interleave Dual ADC mode | - | - | 3.75 | |
| | | 12-bit resolution Interleave Triple ADC mode | - | - | 6 | |
| $I_{VREF+}$(2) | ADC $V_{REF}$ DC current consumption in conversion mode | - | - | 300 | 500 | µA |
| $I_{VDDA}$(2) | ADC $V_{DDA}$ DC current consumption in conversion mode | - | - | 1.6 | 1.8 | mA |

1. $V_{DDA}$ minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to *Section 2.19.2*).
2. Based on test during characterization.
3. $V_{REF+}$ is internally connected to $V_{DDA}$ and $V_{REF-}$ is internally connected to $V_{SSA}$.
4. $R_{ADC}$ maximum value is given for $V_{DD}$=1.7 V, and minimum value for $V_{DD}$=3.3 V.
5. For external triggers, a delay of $1/f_{PCLK2}$ must be added to the latency specified in *Table 77*.

**Equation 1: $R_{AIN}$ max formula**

$$R_{AIN} = \frac{(k - 0.5)}{f_{ADC} \times C_{ADC} \times \ln(2^{N+2})} - R_{ADC}$$

The above formula (*Equation 1*) is used to determine the maximum external impedance allowed for an error below 1/4 of LSB. N = 12 (from 12-bit resolution) and k is the number of sampling periods defined in the ADC_SMPR1 register.

**Table 78. ADC static accuracy at $f_{ADC}$ = 18 MHz(1)**

| Symbol | Parameter | Test conditions | Typ | Max(2) | Unit |
|---|---|---|---|---|---|
| ET | Total unadjusted error | $f_{ADC}$ =18 MHz<br>$V_{DDA}$ = 1.7 to 3.6 V<br>$V_{REF}$ = 1.7 to 3.6 V<br>$V_{DDA}$ - $V_{REF}$ < 1.2 V | ±3 | ±4 | LSB |
| EO | Offset error | | ±2 | ±3 | |
| EG | Gain error | | ±1 | ±3 | |
| ED | Differential linearity error | | ±1 | ±2 | |
| EL | Integral linearity error | | ±2 | ±3 | |

1. Better performance could be achieved in restricted $V_{DD}$, frequency, and temperature ranges.
2. Based on test during characterization.

**Table 79. ADC static accuracy at $f_{ADC}$ = 30 MHz(1)**

| Symbol | Parameter | Test conditions | Typ | Max(2) | Unit |
|---|---|---|---|---|---|
| ET | Total unadjusted error | $f_{ADC}$ = 30 MHz,<br>$R_{AIN}$ < 10 kΩ<br>$V_{DDA}$ = 2.4 to 3.6 V,<br>$V_{REF}$ = 1.7 to 3.6 V,<br>$V_{DDA}$ - $V_{REF}$ < 1.2 V | ±2 | ±5 | LSB |
| EO | Offset error | | ±1.5 | ±2.5 | |
| EG | Gain error | | ±1.5 | ±3 | |
| ED | Differential linearity error | | ±1 | ±2 | |
| EL | Integral linearity error | | ±1.5 | ±3 | |

1. Better performance could be achieved in restricted $V_{DD}$, frequency, and temperature ranges.
2. Based on test during characterization.

**Table 80. ADC static accuracy at $f_{ADC}$ = 36 MHz(1)**

| Symbol | Parameter | Test conditions | Typ | Max(2) | Unit |
|---|---|---|---|---|---|
| ET | Total unadjusted error | $f_{ADC}$ =36 MHz,<br>$V_{DDA}$ = 2.4 to 3.6 V,<br>$V_{REF}$ = 1.7 to 3.6 V<br>$V_{DDA}$ - $V_{REF}$ < 1.2 V | ±4 | ±7 | LSB |
| EO | Offset error | | ±2 | ±3 | |
| EG | Gain error | | ±3 | ±6 | |
| ED | Differential linearity error | | ±2 | ±3 | |
| EL | Integral linearity error | | ±3 | ±6 | |

1. Better performance could be achieved in restricted $V_{DD}$, frequency, and temperature ranges.
2. Based on test during characterization.

**Table 81. ADC dynamic accuracy at $f_{ADC}$ = 18 MHz - limited test conditions(1)**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| ENOB | Effective number of bits | $f_{ADC}$ =18 MHz<br>$V_{DDA}$ = $V_{REF+}$= 1.7 V<br>Input Frequency = 20 KHz<br>Temperature = 25 °C | 10.3 | 10.4 | - | bits |
| SINAD | Signal-to-noise and distortion ratio | | 64 | 64.2 | - | dB |
| SNR | Signal-to-noise ratio | | 64 | 65 | - | |
| THD | Total harmonic distortion | | − 67 | − 72 | - | |

1. Guaranteed based on test during characterization.

**Table 82. ADC dynamic accuracy at $f_{ADC}$ = 36 MHz - limited test conditions(1)**

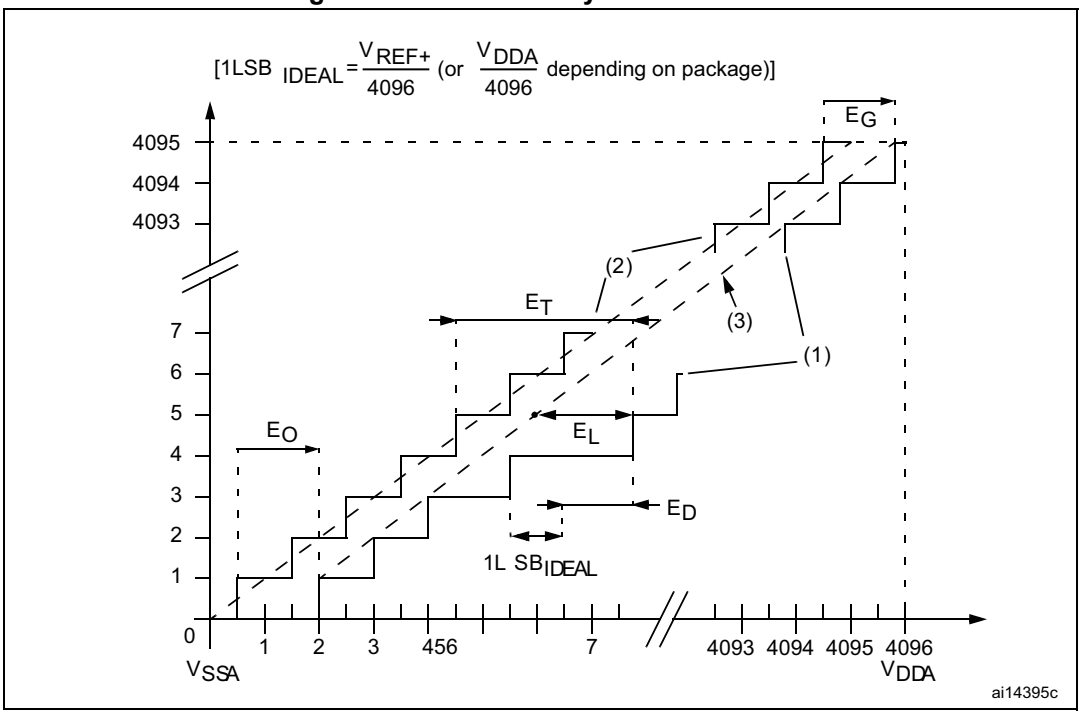
| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| ENOB | Effective number of bits | $f_{ADC}$ =36 MHz<br>$V_{DDA}$ = $V_{REF+}$ = 3.3 V<br>Input Frequency = 20 KHz<br>Temperature = 25 °C | 10.6 | 10.8 | - | bits |
| SINAD | Signal-to noise and distortion ratio | | 66 | 67 | - | dB |
| SNR | Signal-to noise ratio | | 64 | 68 | - | |
| THD | Total harmonic distortion | | − 70 | − 72 | - | |

1. Guaranteed based on test during characterization.

Note: ADC accuracy vs. negative injection current: injecting a negative current on any analog input pins should be avoided as this significantly reduces the accuracy of the conversion being performed on another analog input. It is recommended to add a Schottky diode (pin to ground) to analog pins, which may potentially inject negative currents.

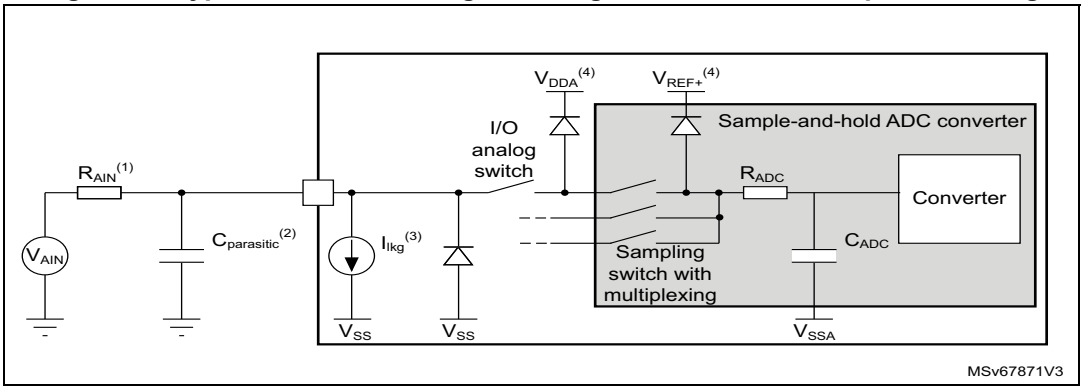
Any positive injection current within the limits specified for $I_{INJ(PIN)}$ and $\sum I_{INJ(PIN)}$ in *Section 5.3.20* does not affect the ADC accuracy.

**Figure 54. ADC accuracy characteristics**




1. See also *Table 79*.
2. Example of an actual transfer curve.
3. Ideal transfer curve.
4. End point correlation line.
5. $E_T$ = Total Unadjusted Error: maximum deviation between the actual and the ideal transfer curves.
   EO = Offset Error: deviation between the first actual transition and the first ideal one.
   EG = Gain Error: deviation between the last ideal transition and the last actual one.
   ED = Differential Linearity Error: maximum deviation between actual steps and the ideal one.
   EL = Integral Linearity Error: maximum deviation between any actual transition and the end point correlation line.

**Figure 55. Typical connection diagram using the ADC with FT/TT pins featuring analog switch funcion**

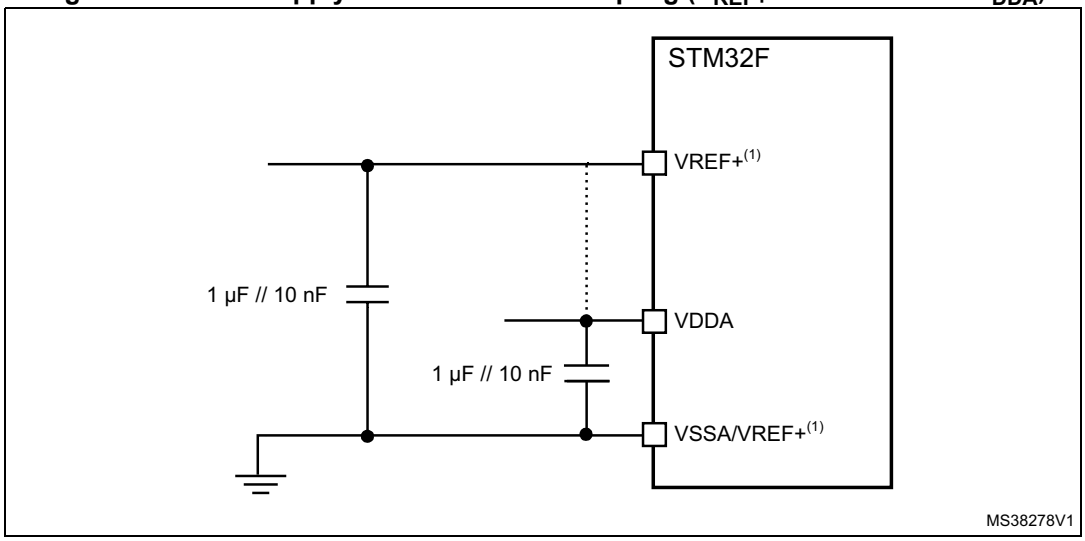



1. Refer to *Table 77* for the values of $R_{AIN}$, $R_{ADC}$, and $C_{ADC}$.
2. $C_{parasitic}$ represents the capacitance of the PCB (dependent on soldering and PCB layout quality) plus the pad capacitance (refer to *Table 59: I/O static characteristics*). A high $C_{parasitic}$ value downgrades conversion accuracy. To remedy this, $f_{ADC}$ should be reduced.
3. Refer to *Table 59: I/O static characteristics* for the value of $I_{lkg}$.
4. Refer to *Table 24: Power supply scheme*.

### General PCB design guidelines

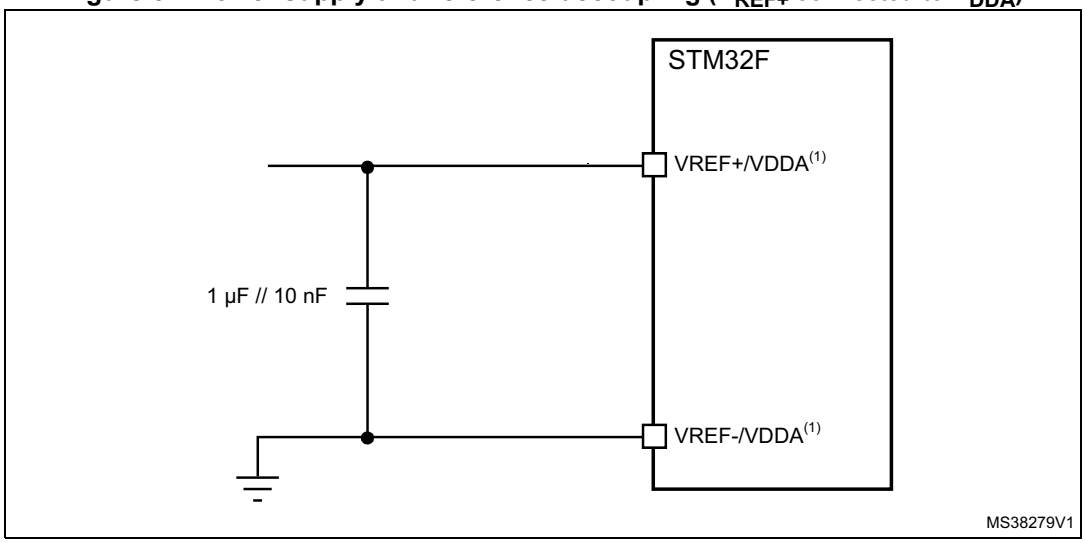
Power supply decoupling should be performed as shown in *Figure 56* or *Figure 57*, depending on whether $V_{REF+}$ is connected to $V_{DDA}$ or not. The 10 nF capacitors should be ceramic (good quality). They should be placed them as close as possible to the chip.

**Figure 56. Power supply and reference decoupling ($V_{REF+}$ not connected to $V_{DDA}$)**




1. $V_{REF+}$ and $V_{REF–}$ inputs are both available on UFBGA176 and TFBGA216. $V_{REF+}$ is also available on LQFP100, LQFP144, LQFP176, and LQFP208. When $V_{REF+}$ and $V_{REF–}$ are not available, they are internally connected to $V_{DDA}$ and $V_{SSA}$.

**Figure 57. Power supply and reference decoupling ($V_{REF+}$ connected to $V_{DDA}$)**




1. $V_{REF+}$ and $V_{REF–}$ inputs are both available on UFBGA176 and TFBGA216. $V_{REF+}$ is also available on LQFP100, LQFP144, LQFP176, and LQFP208. When $V_{REF+}$ and $V_{REF–}$ are not available, they are internally connected to $V_{DDA}$ and $V_{SSA}$.

### 5.3.25 Temperature sensor characteristics

**Table 83. Temperature sensor characteristics**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $T_L$(1) | $V_{SENSE}$ linearity with temperature | - | ±1 | ±2 | °C |
| Avg_Slope(1) | Average slope | - | 2.5 | - | mV/°C |
| $V_{25}$(1) | Voltage at 25 °C | - | 0.76 | - | V |
| $t_{START}$(2) | Startup time | - | 6 | 10 | µs |
| $T_{S_temp}$(2) | ADC sampling time when reading the temperature (1 °C accuracy) | 10 | - | - | |

1. Based on test during characterization.
2. Guaranteed by design.

**Table 84. Temperature sensor calibration values**

| Symbol | Parameter | Memory address |
|---|---|---|
| TS_CAL1 | TS ADC raw data acquired at temperature of 30 °C, $V_{DDA}$= 3.3 V | 0x1FFF 7A2C - 0x1FFF 7A2D |
| TS_CAL2 | TS ADC raw data acquired at temperature of 110 °C, $V_{DDA}$= 3.3 V | 0x1FFF 7A2E - 0x1FFF 7A2F |

### 5.3.26 $V_{BAT}$ monitoring characteristics

**Table 85. $V_{BAT}$ monitoring characteristics**

| Symbol | Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| R | Resistor bridge for $V_{BAT}$ | - | 50 | - | KΩ |
| Q | Ratio on $V_{BAT}$ measurement | - | 4 | - | |
| Er(1) | Error on Q | –1 | - | +1 | % |
| $T_{S_vbat}$(2)(2) | ADC sampling time when reading the $V_{BAT}$ 1 mV accuracy | 5 | - | - | µs |

1. Guaranteed by design.
2. Shortest sampling time can be determined in the application by multiple iterations.

### 5.3.27 Reference voltage

The parameters given in *Table 86* are derived from tests performed under ambient temperature and $V_{DD}$ supply voltage conditions summarized in *Table 17*.

**Table 86. internal reference voltage**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{REFINT}$ | Internal reference voltage | –40 °C < $T_A$ < +105 °C | 1.18 | 1.21 | 1.24 | V |
| $T_{S_vrefint}$(1) | ADC sampling time when reading the internal reference voltage | | 10 | - | - | µs |
| $V_{RERINT_s}$(2) | Internal reference voltage spread over the temperature range | $V_{DD}$ = 3V ± 10mV | - | 3 | 5 | mV |

**Table 86. internal reference voltage (continued)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $T_{Coeff}$(2) | Temperature coefficient | | - | 30 | 50 | ppm/°C |
| $t_{START}$(2) | Startup time | | - | 6 | 10 | µs |

1. Shortest sampling time can be determined in the application by multiple iterations.
2. Guaranteed by design

**Table 87. Internal reference voltage calibration values**

| Symbol | Parameter | Memory address |
|---|---|---|
| $V_{REFIN_CAL}$ | Raw data acquired at temperature of 30 °C $V_{DDA}$ = 3.3 V | 0x1FFF 7A2A - 0x1FFF 7A2B |

## 5.3.28 DAC electrical characteristics

**Table 88. DAC characteristics**

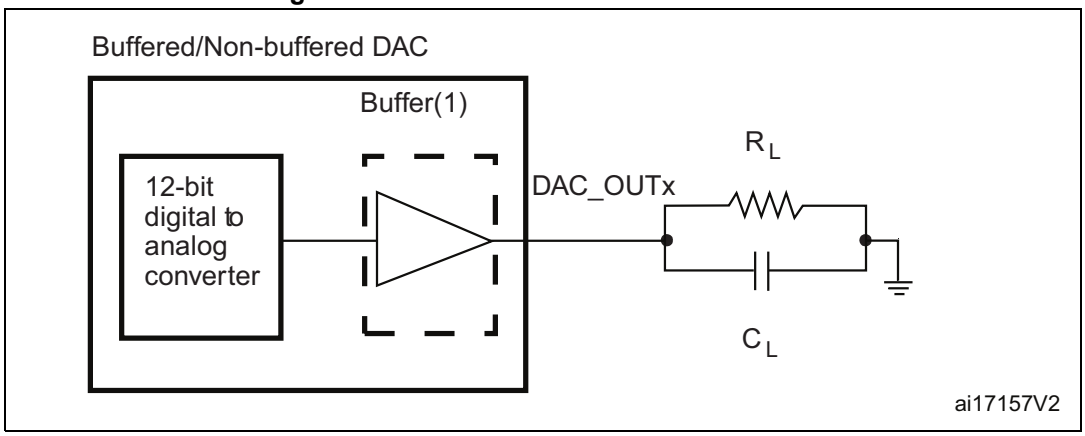
| Symbol | Parameter | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| $V_{DDA}$ | Analog supply voltage | 1.7(1) | - | 3.6 | V | - |
| $V_{REF+}$ | Reference supply voltage | 1.7(1) | - | 3.6 | V | $V_{REF+} \leq V_{DDA}$ |
| $V_{SSA}$ | Ground | 0 | - | 0 | V | - |
| $R_{LOAD}$(2) | Resistive load with buffer ON | 5 | - | - | kΩ | - |
| $R_O$(2) | Impedance output with buffer OFF | - | - | 15 | kΩ | When the buffer is OFF, the Minimum resistive load between DAC_OUT and $V_{SS}$ to have a 1% accuracy is 1.5 MΩ |
| $C_{LOAD}$(2) | Capacitive load | - | - | 50 | pF | Maximum capacitive load at DAC_OUT pin (when the buffer is ON). |
| DAC_OUT min(2) | Lower DAC_OUT voltage with buffer ON | 0.2 | - | - | V | It gives the maximum output excursion of the DAC. It corresponds to 12-bit input code (0x0E0) to (0xF1C) at $V_{REF+}$ = 3.6 V and (0x1C7) to (0xE38) at $V_{REF+}$ = 1.7 V |
| DAC_OUT max(2) | Higher DAC_OUT voltage with buffer ON | - | - | $V_{DDA}$ – 0.2 | V | |
| DAC_OUT min(2) | Lower DAC_OUT voltage with buffer OFF | - | 0.5 | - | mV | It gives the maximum output excursion of the DAC. |
| DAC_OUT max(2) | Higher DAC_OUT voltage with buffer OFF | - | - | $V_{REF+}$ – 1LSB | V | |
| $I_{VREF+}$(4) | DAC DC $V_{REF}$ current consumption in quiescent mode (Standby mode) | - | 170 | 240 | µA | With no load, worst code (0x800) at $V_{REF+}$ = 3.6 V in terms of DC consumption on the inputs |
| | | - | 50 | 75 | | With no load, worst code (0xF1C) at $V_{REF+}$ = 3.6 V in terms of DC consumption on the inputs |

**Table 88. DAC characteristics (continued)**

| Symbol | Parameter | Min | Typ | Max | Unit | Comments |
|---|---|---|---|---|---|---|
| $I_{DDA}$(4) | DAC DC VDDA current consumption in quiescent mode(3) | - | 280 | 380 | µA | With no load, middle code (0x800) on the inputs |
| | | - | 475 | 625 | µA | With no load, worst code (0xF1C) at $V_{REF+}$ = 3.6 V in terms of DC consumption on the inputs |
| DNL(4) | Differential non linearity Difference between two consecutive code-1LSB) | - | - | ±0.5 | LSB | Given for the DAC in 10-bit configuration. |
| | | - | - | ±2 | LSB | Given for the DAC in 12-bit configuration. |
| INL(4) | Integral non linearity (difference between measured value at Code i and the value at Code i on a line drawn between Code 0 and last Code 1023) | - | - | ±1 | LSB | Given for the DAC in 10-bit configuration. |
| | | - | - | ±4 | LSB | Given for the DAC in 12-bit configuration. |
| Offset(4) | Offset error (difference between measured value at Code (0x800) and the ideal value = $V_{REF+}$/2) | - | - | ±10 | mV | Given for the DAC in 12-bit configuration |
| | | - | - | ±3 | LSB | Given for the DAC in 10-bit at $V_{REF+}$ = 3.6 V |
| | | - | - | ±12 | LSB | Given for the DAC in 12-bit at $V_{REF+}$ = 3.6 V |
| Gain error(4) | Gain error | - | - | ±0.5 | % | Given for the DAC in 12-bit configuration |
| $t_{SETTLING}$(4) | Settling time (full scale: for a 10-bit input code transition between the lowest and the highest input codes when DAC_OUT reaches final value ±4LSB | - | 3 | 6 | µs | $C_{LOAD}$ ≤ 50 pF, $R_{LOAD}$ ≥ 5 kΩ |
| THD(4) | Total Harmonic Distortion Buffer ON | - | - | - | dB | $C_{LOAD}$ ≤ 50 pF, $R_{LOAD}$ ≥ 5 kΩ |
| Update rate(2) | Max frequency for a correct DAC_OUT change when small variation in the input code (from code i to i+1LSB) | - | - | 1 | MS/s | $C_{LOAD}$ ≤ 50 pF, $R_{LOAD}$ ≥ 5 kΩ |
| $t_{WAKEUP}$(4) | Wakeup time from off state (Setting the ENx bit in the DAC Control register) | - | 6.5 | 10 | µs | $C_{LOAD}$ ≤ 50 pF, $R_{LOAD}$ ≥ 5 kΩ input code between lowest and highest possible ones. |
| PSRR+ (2) | Power supply rejection ratio (to $V_{DDA}$) (static DC measurement) | - | –67 | –40 | dB | No $R_{LOAD}$, $C_{LOAD}$ = 50 pF |

1. $V_{DDA}$ minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to *Section 2.19.2*).
2. Guaranteed by design.
3. The quiescent mode corresponds to a state where the DAC maintains a stable output level to ensure that no dynamic consumption occurs.
4. Guaranteed based on test during characterization.

**Figure 58. 12-bit buffered/non-buffered DAC**




1. The DAC integrates an output buffer that can be used to reduce the output impedance and to drive external loads directly without the use of an external operational amplifier. The buffer can be bypassed by configuring the BOFFx bit in the DAC_CR register.

## 5.3.29 FMC characteristics

Unless otherwise specified, the parameters given in tables *89* to *102* for the FMC interface are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency, and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$

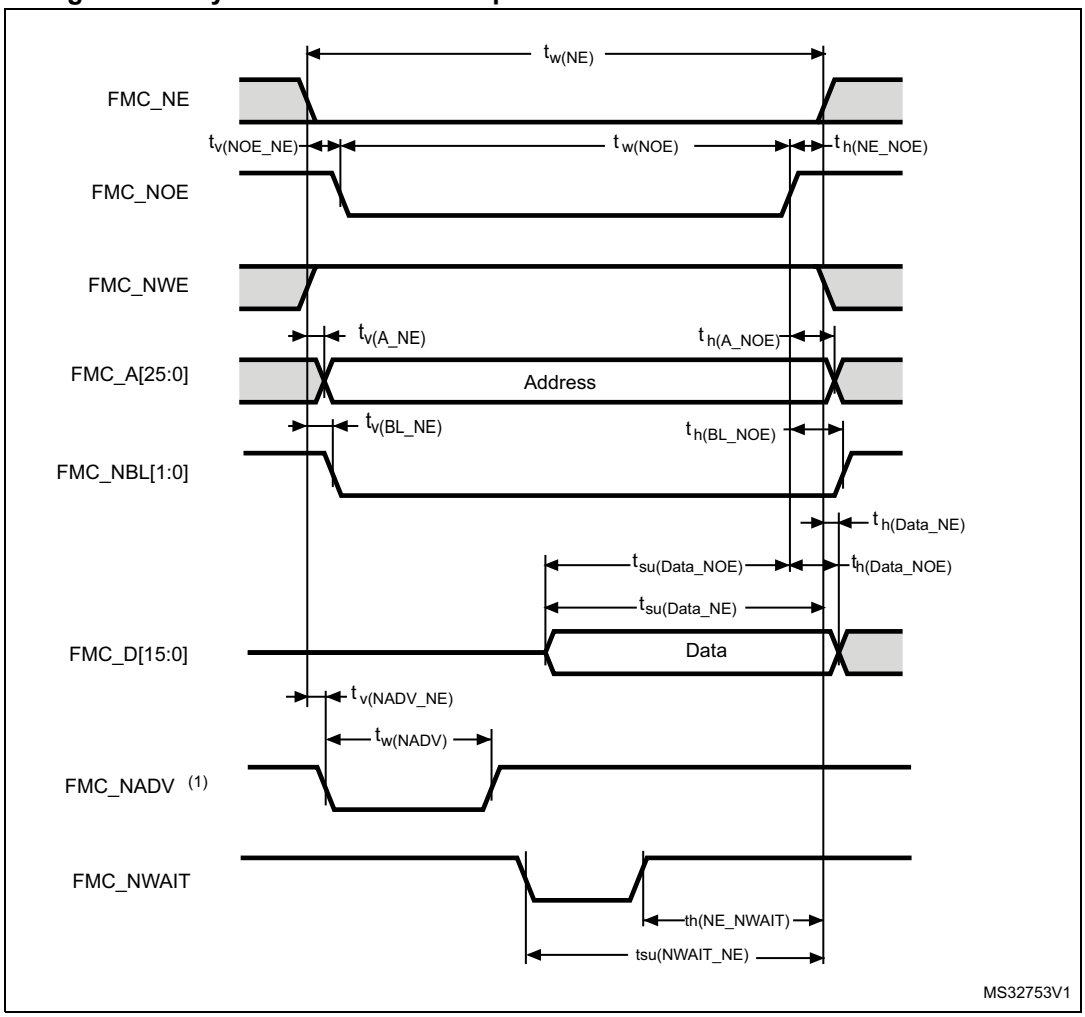
Refer to *Section 5.3.20* for more details on the input/output characteristics.

### Asynchronous waveforms and timings

Figures *59* through *62* represent asynchronous waveforms, and tables *89* through *96* provide the corresponding timings. The results shown in these tables are obtained with the following FMC configuration:

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

**Figure 59. Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms**




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

**Table 89. Asynchronous non-multiplexed SRAM/PSRAM/NOR - read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $2T_{HCLK} - 0.5$ | $2\ T_{HCLK}+0.5$ | ns |
| $t_{v(NOE_NE)}$ | FMC_NEx low to FMC_NOE low | 0 | 1 | |
| $t_{w(NOE)}$ | FMC_NOE low time | $2T_{HCLK}$ | $2T_{HCLK}+ 0.5$ | |
| $t_{h(NE_NOE)}$ | FMC_NOE high to FMC_NE high hold time | 0 | - | |
| $t_{v(A_NE)}$ | FMC_NEx low to FMC_A valid | - | 2 | |
| $t_{h(A_NOE)}$ | Address hold time after FMC_NOE high | 0 | - | |
| $t_{v(BL_NE)}$ | FMC_NEx low to FMC_BL valid | - | 2 | |
| $t_{h(BL_NOE)}$ | FMC_BL hold time after FMC_NOE high | 0 | - | |
| $t_{su(Data_NE)}$ | Data to FMC_NEx high setup time | $T_{HCLK} + 2.5$ | - | |
| $t_{su(Data_NOE)}$ | Data to FMC_NOEx high setup time | $T_{HCLK} +2$ | - | |
| $t_{h(Data_NOE)}$ | Data hold time after FMC_NOE high | 0 | - | |
| $t_{h(Data_NE)}$ | Data hold time after FMC_NEx high | 0 | - | |
| $t_{v(NADV_NE)}$ | FMC_NEx low to FMC_NADV low | - | 0 | |
| $t_{w(NADV)}$ | FMC_NADV low time | - | $T_{HCLK} +1$ | |

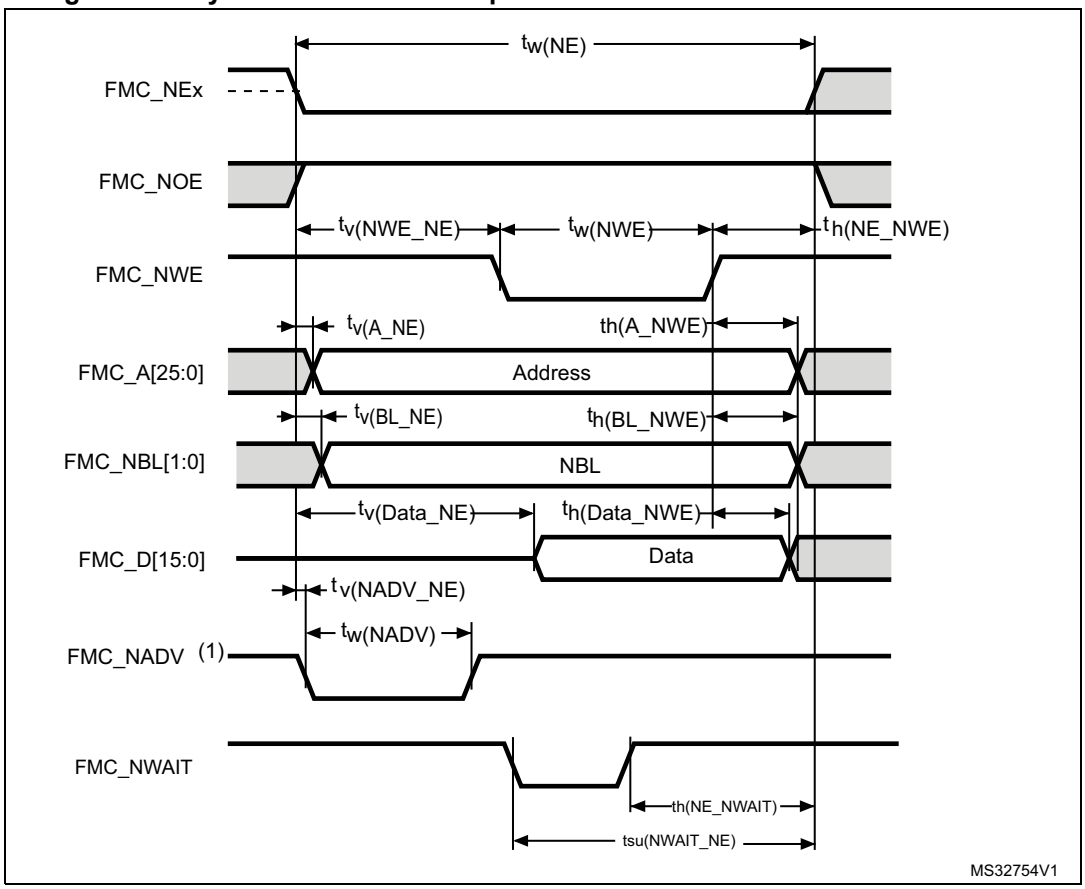
1. Based on test during characterization.

**Table 90. Asynchronous non-multiplexed SRAM/PSRAM/NOR read - NWAIT timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $7T_{HCLK}+0.5$ | $7T_{HCLK}+1$ | ns |
| $t_{w(NOE)}$ | FMC_NWE low time | $5T_{HCLK} - 1.5$ | $5T_{HCLK} +2$ | |
| $t_{su(NWAIT_NE)}$ | FMC_NWAIT valid before FMC_NEx high | $5T_{HCLK}+1.5$ | - | |
| $t_{h(NE_NWAIT)}$ | FMC_NEx hold time after FMC_NWAIT invalid | $4T_{HCLK}+1$ | - | |

1. Based on test during characterization.

**Figure 60. Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms**




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

**Table 91. Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $3T_{HCLK}$ | $3T_{HCLK}+1$ | ns |
| $t_{v(NWE_NE)}$ | FMC_NEx low to FMC_NWE low | $T_{HCLK} - 0.5$ | $T_{HCLK}+ 0.5$ | |
| $t_{w(NWE)}$ | FMC_NWE low time | $T_{HCLK}$ | $T_{HCLK}+ 0.5$ | |
| $t_{h(NE_NWE)}$ | FMC_NWE high to FMC_NE high hold time | $T_{HCLK} +1.5$ | - | |
| $t_{v(A_NE)}$ | FMC_NEx low to FMC_A valid | - | 0 | |
| $t_{h(A_NWE)}$ | Address hold time after FMC_NWE high | $T_{HCLK}+0.5$ | - | |
| $t_{v(BL_NE)}$ | FMC_NEx low to FMC_BL valid | - | 1.5 | |
| $t_{h(BL_NWE)}$ | FMC_BL hold time after FMC_NWE high | $T_{HCLK}+0.5$ | - | |
| $t_{v(Data_NE)}$ | Data to FMC_NEx low to Data valid | - | $T_{HCLK}+ 2$ | |
| $t_{h(Data_NWE)}$ | Data hold time after FMC_NWE high | $T_{HCLK}+0.5$ | - | |
| $t_{v(NADV_NE)}$ | FMC_NEx low to FMC_NADV low | - | 0.5 | |
| $t_{w(NADV)}$ | FMC_NADV low time | - | $T_{HCLK}+ 0.5$ | |

1. Based on test during characterization.

**Table 92. Asynchronous non-multiplexed SRAM/PSRAM/NOR write - NWAIT timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $8T_{HCLK}+1$ | $8T_{HCLK}+2$ | ns |
| $t_{w(NWE)}$ | FMC_NWE low time | $6T_{HCLK} - 1$ | $6T_{HCLK}+2$ | |
| $t_{su(NWAIT_NE)}$ | FMC_NWAIT valid before FMC_NEx high | $6T_{HCLK}+1.5$ | - | |
| $t_{h(NE_NWAIT)}$ | FMC_NEx hold time after FMC_NWAIT invalid | $4T_{HCLK}+1$ | - | |

1. Based on test during characterization.

**Figure 61. Asynchronous multiplexed PSRAM/NOR read waveforms**

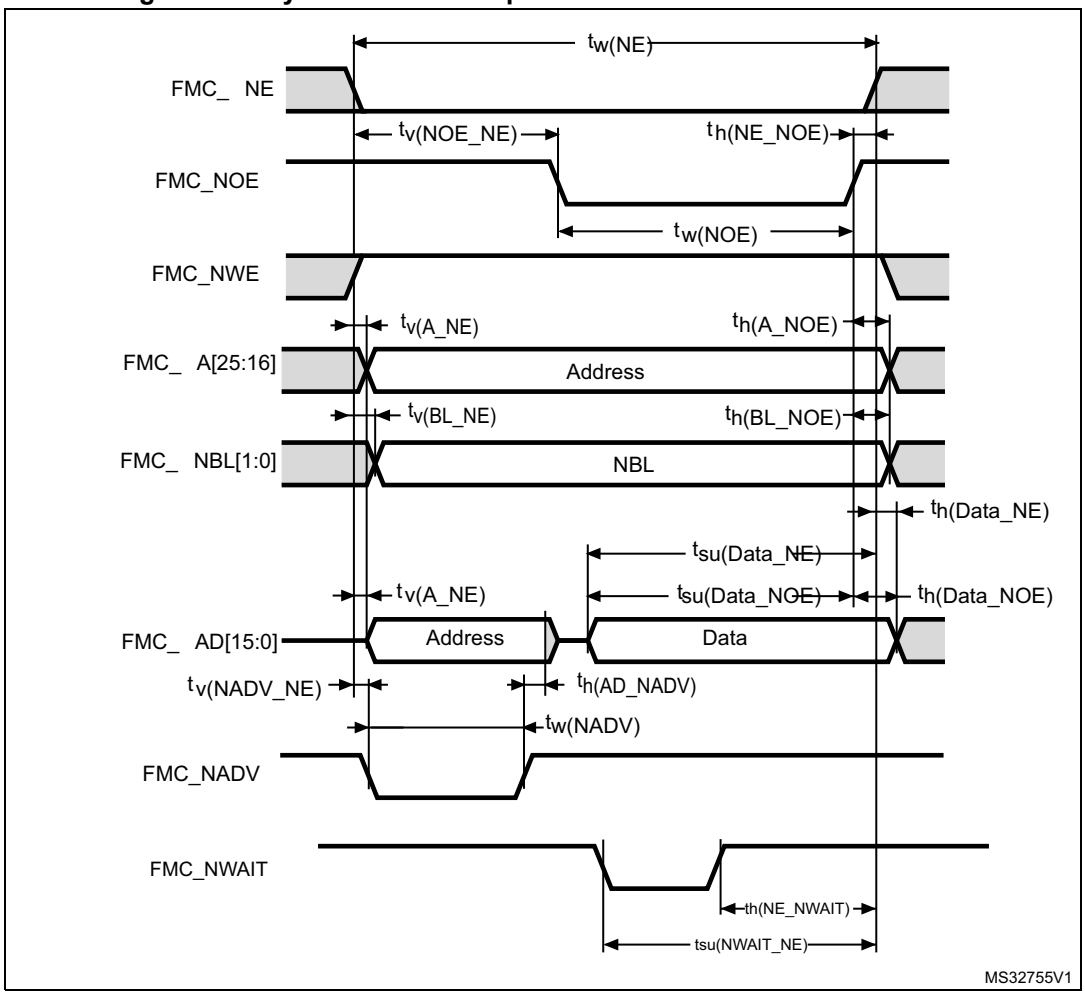


**Table 93. Asynchronous multiplexed PSRAM/NOR read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $3T_{HCLK} - 1$ | $3T_{HCLK}+0.5$ | ns |
| $t_{v(NOE_NE)}$ | FMC_NEx low to FMC_NOE low | $2T_{HCLK} - 0.5$ | $2T_{HCLK}$ | |
| $t_{tw(NOE)}$ | FMC_NOE low time | $T_{HCLK} - 1$ | $T_{HCLK}+1$ | |
| $t_{h(NE_NOE)}$ | FMC_NOE high to FMC_NE high hold time | 1 | - | |
| $t_{v(A_NE)}$ | FMC_NEx low to FMC_A valid | - | 2 | |
| $t_{v(NADV_NE)}$ | FMC_NEx low to FMC_NADV low | 0 | 2 | |
| $t_{w(NADV)}$ | FMC_NADV low time | $T_{HCLK} - 0.5$ | $T_{HCLK}+0.5$ | |
| $t_{h(AD_NADV)}$ | FMC_AD(address) valid hold time after FMC_NADV high) | 0 | - | |
| $t_{h(A_NOE)}$ | Address hold time after FMC_NOE high | $T_{HCLK} - 0.5$ | - | |
| $t_{h(BL_NOE)}$ | FMC_BL time after FMC_NOE high | 0 | - | |
| $t_{v(BL_NE)}$ | FMC_NEx low to FMC_BL valid | - | 2 | |
| $t_{su(Data_NE)}$ | Data to FMC_NEx high setup time | $T_{HCLK}+1.5$ | - | |
| $t_{su(Data_NOE)}$ | Data to FMC_NOE high setup time | $T_{HCLK}+1$ | - | |
| $t_{h(Data_NE)}$ | Data hold time after FMC_NEx high | 0 | - | |
| $t_{h(Data_NOE)}$ | Data hold time after FMC_NOE high | 0 | - | |

1. Based on test during characterization.

**Table 94. Asynchronous multiplexed PSRAM/NOR read-NWAIT timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $8T_{HCLK}+0.5$ | $8T_{HCLK}+2$ | ns |
| $t_{w(NOE)}$ | FMC_NWE low time | $5T_{HCLK} - 1$ | $5T_{HCLK} +1.5$ | |
| $t_{su(NWAIT_NE)}$ | FMC_NWAIT valid before FMC_NEx high | $5T_{HCLK} +1.5$ | - | |
| $t_{h(NE_NWAIT)}$ | FMC_NEx hold time after FMC_NWAIT invalid | $4T_{HCLK}+1$ | - | |

1. Based on test during characterization.

**Figure 62. Asynchronous multiplexed PSRAM/NOR write waveforms**

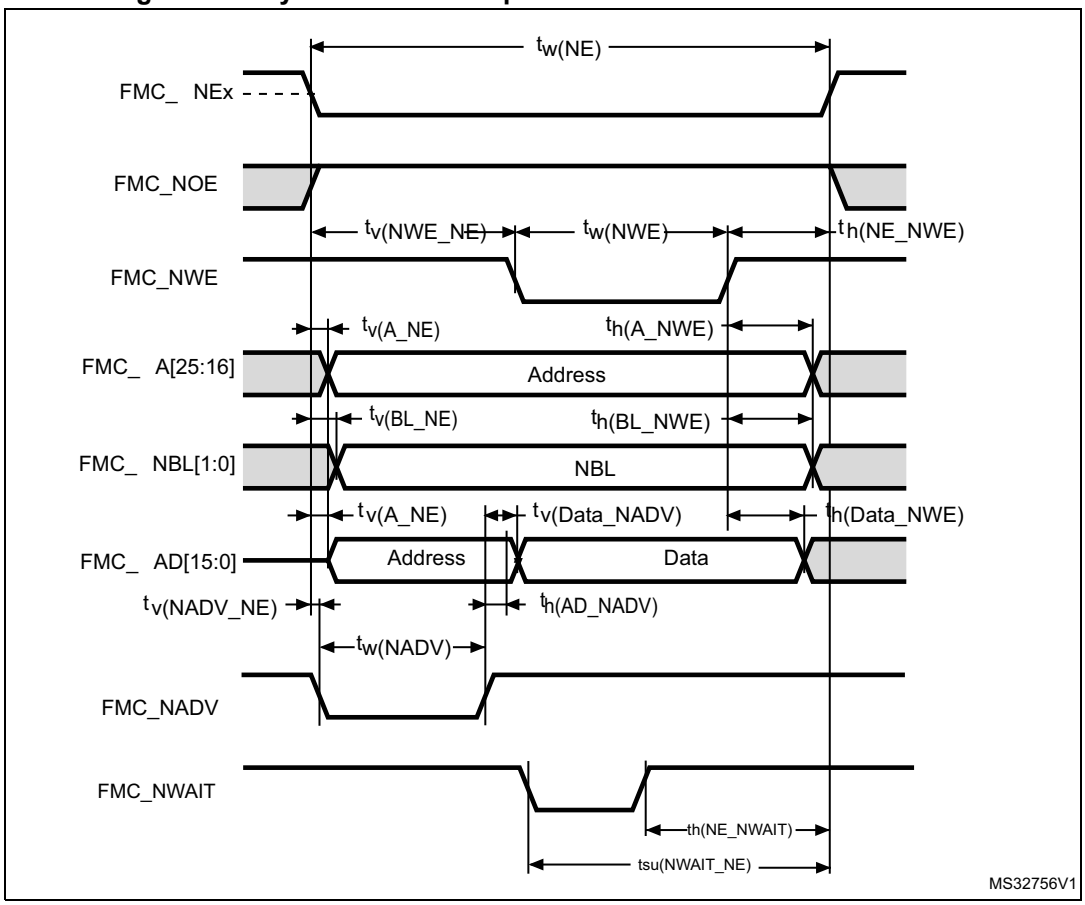



**Table 95. Asynchronous multiplexed PSRAM/NOR write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $4T_{HCLK}$ | $4T_{HCLK}+0.5$ | ns |
| $t_{v(NWE_NE)}$ | FMC_NEx low to FMC_NWE low | $T_{HCLK} - 1$ | $T_{HCLK}+0.5$ | |
| $t_{w(NWE)}$ | FMC_NWE low time | $2T_{HCLK}$ | $2T_{HCLK}+0.5$ | |
| $t_{h(NE_NWE)}$ | FMC_NWE high to FMC_NE high hold time | $T_{HCLK}$ | - | |
| $t_{v(A_NE)}$ | FMC_NEx low to FMC_A valid | - | 0 | |
| $t_{v(NADV_NE)}$ | FMC_NEx low to FMC_NADV low | 0.5 | 1 | |
| $t_{w(NADV)}$ | FMC_NADV low time | $T_{HCLK} - 0.5$ | $T_{HCLK}+ 0.5$ | |
| $t_{h(AD_NADV)}$ | FMC_AD (address) valid hold time after FMC_NADV high | $T_{HCLK} - 2$ | - | |
| $t_{h(A_NWE)}$ | Address hold time after FMC_NWE high | $T_{HCLK}$ | - | |
| $t_{h(BL_NWE)}$ | FMC_BL hold time after FMC_NWE high | $T_{HCLK} - 2$ | - | |
| $t_{v(BL_NE)}$ | FMC_NEx low to FMC_BL valid | - | 2 | |
| $t_{v(Data_NADV)}$ | FMC_NADV high to Data valid | - | $T_{HCLK}+1.5$ | |
| $t_{h(Data_NWE)}$ | Data hold time after FMC_NWE high | $T_{HCLK}+0.5$ | - | |

1. Based on test during characterization.

**Table 96. Asynchronous multiplexed PSRAM/NOR write-NWAIT timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(NE)}$ | FMC_NE low time | $9T_{HCLK}$ | $9T_{HCLK}+0.5$ | ns |
| $t_{w(NWE)}$ | FMC_NWE low time | $7T_{HCLK}$ | $7T_{HCLK}+2$ | |
| $t_{su(NWAIT_NE)}$ | FMC_NWAIT valid before FMC_NEx high | $6T_{HCLK}+1.5$ | - | |
| $t_{h(NE_NWAIT)}$ | FMC_NEx hold time after FMC_NWAIT invalid | $4T_{HCLK}-1$ | - | |

1. Based on test during characterization.

## Synchronous waveforms and timings

Figures *63* through *66* represent synchronous waveforms and *Table 97* through *Table 100* provide the corresponding timings. The results shown in these tables are obtained with the following FMC configuration:

- BurstAccessMode = FMC_BurstAccessMode_Enable;
- MemoryType = FMC_MemoryType_CRAM;
- WriteBurst = FMC_WriteBurst_Enable;
- CLKDivision = 1;
- DataLatency = 1 for NOR flash; DataLatency = 0 for PSRAM
- $C_L$ = 30 pF on data and address lines. $C_L$ = 10 pF on FMC_CLK unless otherwise specified.

In all timing tables, the $T_{HCLK}$ is the HCLK clock period:

- For 2.7 V≤ $V_{DD}$≤ 3.6 V, maximum FMC_CLK = 90 MHz at $C_L$ = 30 pF (on FMC_CLK).
- For 1.71 V≤ $V_{DD}$<1.9 V, maximum FMC_CLK = 60 MHz at $C_L$ = 10 pF (on FMC_CLK).

**Figure 63. Synchronous multiplexed NOR/PSRAM read timings**

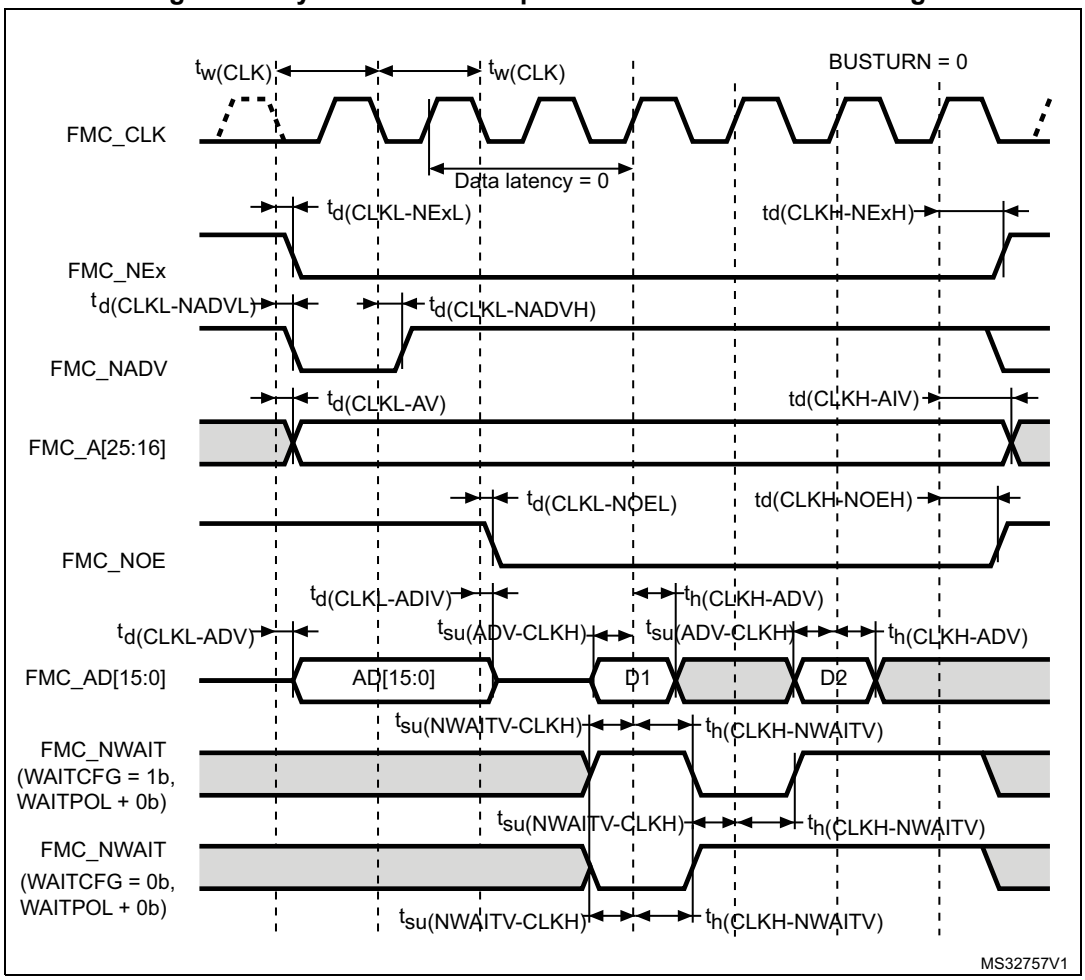


**Table 97. Synchronous multiplexed NOR/PSRAM read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(CLK)}$ | FMC_CLK period | $2T_{HCLK} - 1$ | - | ns |
| $t_{d(CLKL-NExL)}$ | FMC_CLK low to FMC_NEx low (x=0..2) | - | 0 | |
| $t_{d(CLKH_NExH)}$ | FMC_CLK high to FMC_NEx high (x= 0…2) | $T_{HCLK}$ | - | |
| $t_{d(CLKL-NADVL)}$ | FMC_CLK low to FMC_NADV low | - | 0 | |
| $t_{d(CLKL-NADVH)}$ | FMC_CLK low to FMC_NADV high | 0 | - | |
| $t_{d(CLKL-AV)}$ | FMC_CLK low to FMC_Ax valid (x=16…25) | - | 0 | |
| $t_{d(CLKH-AIV)}$ | FMC_CLK high to FMC_Ax invalid (x=16…25) | 0 | - | |
| $t_{d(CLKL-NOEL)}$ | FMC_CLK low to FMC_NOE low | - | $T_{HCLK}$+0.5 | |
| $t_{d(CLKH-NOEH)}$ | FMC_CLK high to FMC_NOE high | $T_{HCLK} - 0.5$ | - | |
| $t_{d(CLKL-ADV)}$ | FMC_CLK low to FMC_AD[15:0] valid | - | 0.5 | |
| $t_{d(CLKL-ADIV)}$ | FMC_CLK low to FMC_AD[15:0] invalid | 0 | - | |
| $t_{su(ADV-CLKH)}$ | FMC_A/D[15:0] valid data before FMC_CLK high | 5 | - | |
| $t_{h(CLKH-ADV)}$ | FMC_A/D[15:0] valid data after FMC_CLK high | 0 | - | |
| $t_{su(NWAIT-CLKH)}$ | FMC_NWAIT valid before FMC_CLK high | 4 | - | |
| $t_{h(CLKH-NWAIT)}$ | FMC_NWAIT valid after FMC_CLK high | 0 | - | |

1. Based on test during characterization.

**Figure 64. Synchronous multiplexed PSRAM write timings**

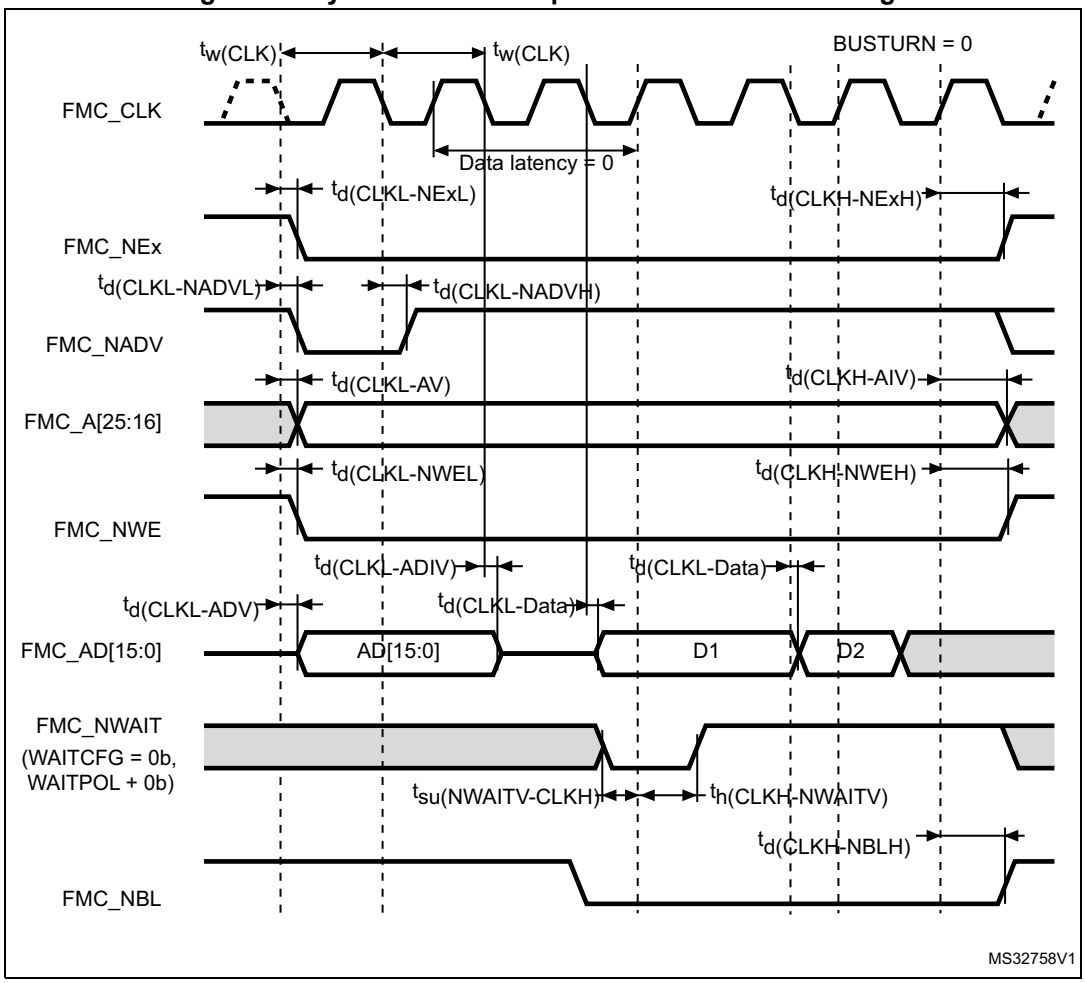


**Table 98. Synchronous multiplexed PSRAM write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(CLK)}$ | FMC_CLK period, $V_{DD}$ range= 2.7 to 3.6 V | $2T_{HCLK} - 1$ | - | ns |
| $t_{d(CLKL-NExL)}$ | FMC_CLK low to FMC_NEx low (x=0…2) | - | 1.5 | |
| $t_{d(CLKH-NExH)}$ | FMC_CLK high to FMC_NEx high (x= 0…2) | $T_{HCLK}$ | - | |
| $t_{d(CLKL-NADVL)}$ | FMC_CLK low to FMC_NADV low | - | 0 | |
| $t_{d(CLKL-NADVH)}$ | FMC_CLK low to FMC_NADV high | 0 | - | |
| $t_{d(CLKL-AV)}$ | FMC_CLK low to FMC_Ax valid (x=16…25) | - | 0 | |
| $t_{d(CLKH-AIV)}$ | FMC_CLK high to FMC_Ax invalid (x=16…25) | $T_{HCLK}$ | - | |
| $t_{d(CLKL-NWEL)}$ | FMC_CLK low to FMC_NWE low | - | 0 | |
| $t_{(CLKH-NWEH)}$ | FMC_CLK high to FMC_NWE high | $T_{HCLK}-0.5$ | - | |
| $t_{d(CLKL-ADV)}$ | FMC_CLK low to FMC_AD[15:0] valid | - | 3 | |
| $t_{d(CLKL-ADIV)}$ | FMC_CLK low to FMC_AD[15:0] invalid | 0 | - | |
| $t_{d(CLKL-DATA)}$ | FMC_A/D[15:0] valid data after FMC_CLK low | - | 3 | |
| $t_{d(CLKL-NBLL)}$ | FMC_CLK low to FMC_NBL low | 0 | - | |
| $t_{d(CLKH-NBLH)}$ | FMC_CLK high to FMC_NBL high | $T_{HCLK}-0.5$ | - | |
| $t_{su(NWAIT-CLKH)}$ | FMC_NWAIT valid before FMC_CLK high | 4 | - | |
| $t_{h(CLKH-NWAIT)}$ | FMC_NWAIT valid after FMC_CLK high | 0 | - | |

1. Based on test during characterization.

**Figure 65. Synchronous non-multiplexed NOR/PSRAM read timings**

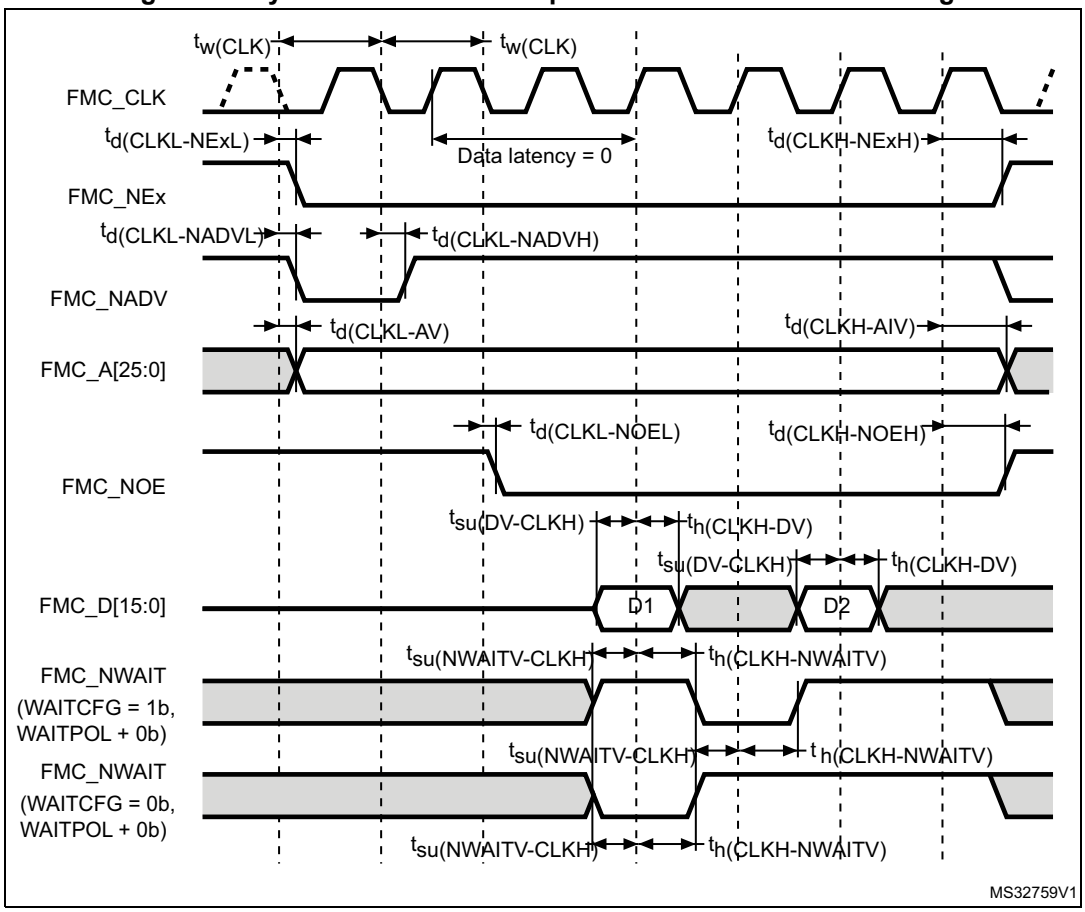



**Table 99. Synchronous non-multiplexed NOR/PSRAM read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(CLK)}$ | FMC_CLK period | $2T_{HCLK} - 1$ | - | ns |
| $t_{(CLKL-NExL)}$ | FMC_CLK low to FMC_NEx low (x=0…2) | - | 0.5 | |
| $t_{d(CLKH-NExH)}$ | FMC_CLK high to FMC_NEx high (x= 0…2) | $T_{HCLK}$ | - | |
| $t_{d(CLKL-NADVL)}$ | FMC_CLK low to FMC_NADV low | - | 0 | |
| $t_{d(CLKL-NADVH)}$ | FMC_CLK low to FMC_NADV high | 0 | - | |
| $t_{d(CLKL-AV)}$ | FMC_CLK low to FMC_Ax valid (x=16…25) | - | 0 | |
| $t_{d(CLKH-AIV)}$ | FMC_CLK high to FMC_Ax invalid (x=16…25) | $T_{HCLK} - 0.5$ | - | |
| $t_{d(CLKL-NOEL)}$ | FMC_CLK low to FMC_NOE low | - | $T_{HCLK}+2$ | |
| $t_{d(CLKH-NOEH)}$ | FMC_CLK high to FMC_NOE high | $T_{HCLK} - 0.5$ | - | |
| $t_{su(DV-CLKH)}$ | FMC_D[15:0] valid data before FMC_CLK high | 5 | - | |
| $t_{h(CLKH-DV)}$ | FMC_D[15:0] valid data after FMC_CLK high | 0 | - | |
| $t_{(NWAIT-CLKH)}$ | FMC_NWAIT valid before FMC_CLK high | 4 | - | |
| $t_{h(CLKH-NWAIT)}$ | FMC_NWAIT valid after FMC_CLK high | 0 | - | |

1. Based on test during characterization.

**Figure 66. Synchronous non-multiplexed PSRAM write timings**

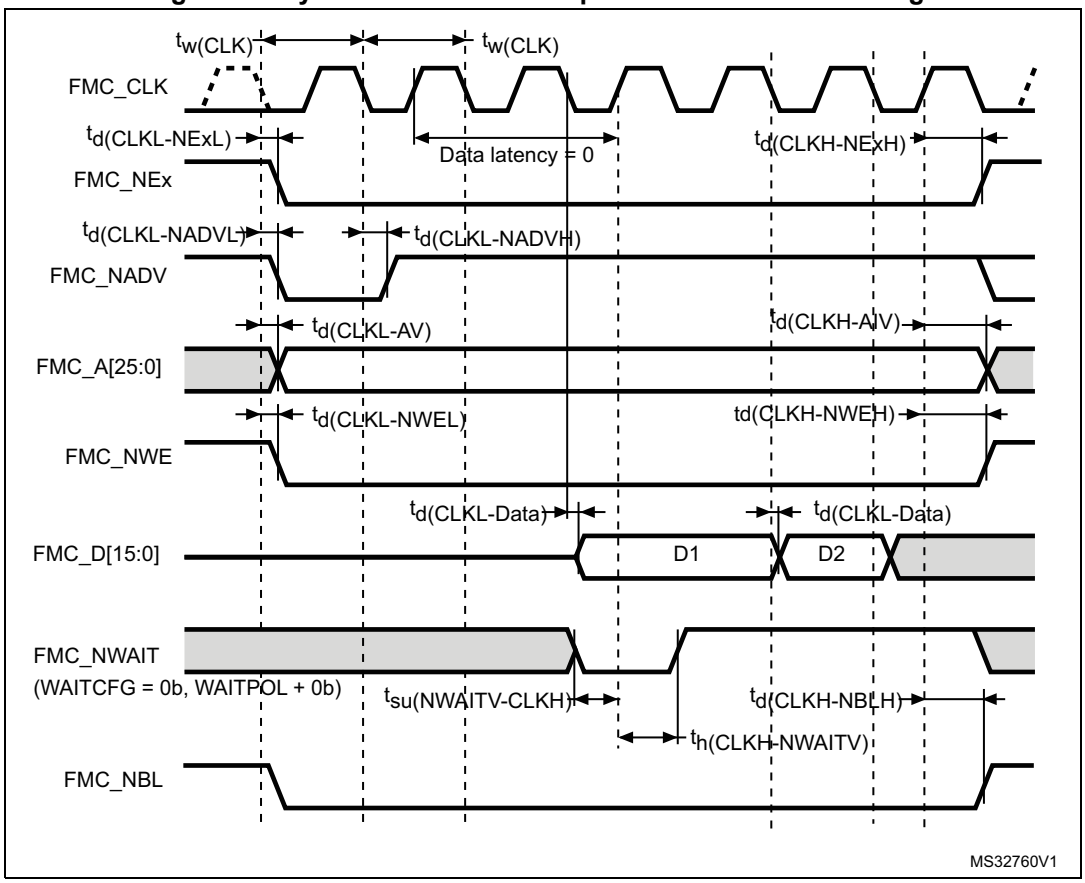



**Table 100. Synchronous non-multiplexed PSRAM write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{(CLK)}$ | FMC_CLK period | $2T_{HCLK} - 1$ | - | ns |
| $t_{d(CLKL-NExL)}$ | FMC_CLK low to FMC_NEx low (x=0…2) | - | 0.5 | |
| $t_{(CLKH-NExH)}$ | FMC_CLK high to FMC_NEx high (x= 0…2) | $T_{HCLK}$ | - | |
| $t_{d(CLKL-NADVL)}$ | FMC_CLK low to FMC_NADV low | - | 0 | |
| $t_{d(CLKL-NADVH)}$ | FMC_CLK low to FMC_NADV high | 0 | - | |
| $t_{d(CLKL-AV)}$ | FMC_CLK low to FMC_Ax valid (x=16…25) | - | 0 | |
| $t_{d(CLKH-AIV)}$ | FMC_CLK high to FMC_Ax invalid (x=16…25) | 0 | - | |
| $t_{d(CLKL-NWEL)}$ | FMC_CLK low to FMC_NWE low | - | 0 | |
| $t_{d(CLKH-NWEH)}$ | FMC_CLK high to FMC_NWE high | $T_{HCLK}-0.5$ | - | |
| $t_{d(CLKL-Data)}$ | FMC_D[15:0] valid data after FMC_CLK low | - | 2.5 | |
| $t_{d(CLKL-NBLL)}$ | FMC_CLK low to FMC_NBL low | 0 | - | |
| $t_{d(CLKH-NBLH)}$ | FMC_CLK high to FMC_NBL high | $T_{HCLK}-0.5$ | - | |
| $t_{su(NWAIT-CLKH)}$ | FMC_NWAIT valid before FMC_CLK high | 4 | - | |
| $t_{h(CLKH-NWAIT)}$ | FMC_NWAIT valid after FMC_CLK high | 0 | - | |

1. Based on test during characterization.

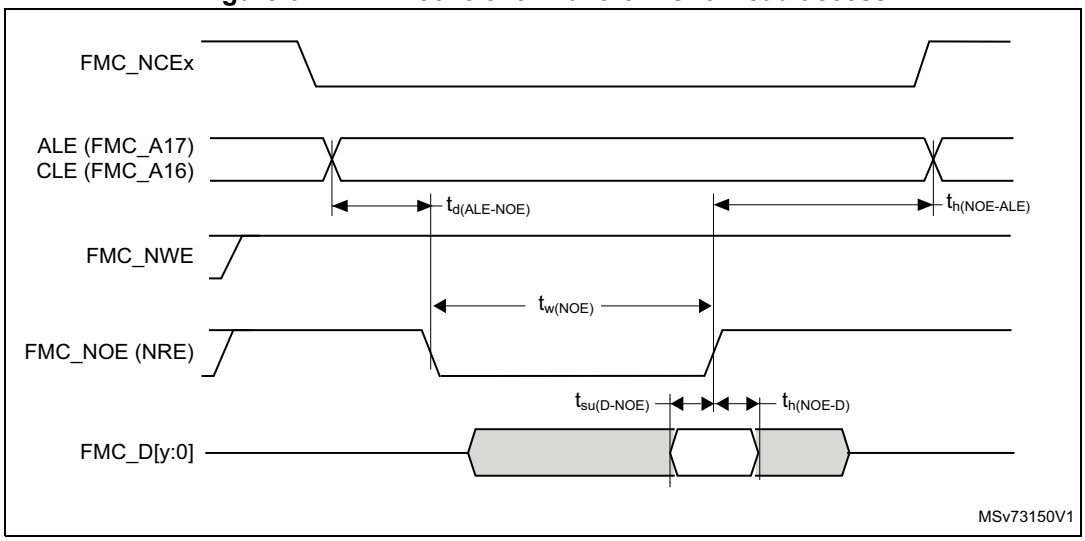
### NAND controller waveforms and timings

Figures *67* through *Figure 69* represent synchronous waveforms, and *Table 101* and *Table 102* provide the corresponding timings. The results shown in this table are obtained with the following FMC configuration:

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

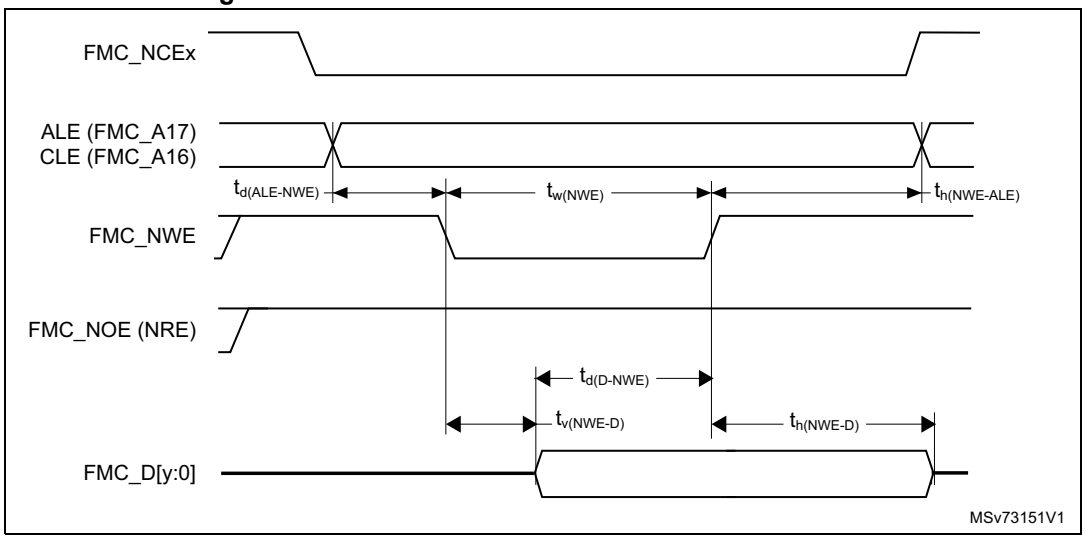
In all timing tables, the $T_{HCLK}$ is the HCLK clock period.

**Figure 67. NAND controller waveforms for read access**




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

**Figure 68. NAND controller waveforms for write access**




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

**Table 101. Switching characteristics for NAND Flash read cycles**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(N0E)}$ | FMC_NOE low width | $4T_{HCLK} - 0.5$ | $4T_{HCLK}+0.5$ | ns |
| $t_{su(D-NOE)}$ | FMC_D[15-0] valid data before FMC_NOE high | 9 | - | |
| $t_{h(NOE-D)}$ | FMC_D[15-0] valid data after FMC_NOE high | 0 | - | |
| $t_{d(ALE-NOE)}$ | FMC_ALE valid before FMC_NOE low | - | $3T_{HCLK} - 0.5$ | |
| $t_{h(NOE-ALE)}$ | FMC_NWE high to FMC_ALE invalid | $3T_{HCLK} - 2$ | - | |

**Table 102. Switching characteristics for NAND Flash write cycles**

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

## SDRAM waveforms and timings

- $C_L$ = 30 pF on data and address lines.
- $C_L$ = 10 pF on FMC_SDCLK unless otherwise specified.

In all timing tables, the $T_{HCLK}$ is the HCLK clock period.

- For 2.7 V ≤ $V_{DD}$ ≤ 3.6 V, maximum FMC_SDCLK = 90 MHz, at $C_L$ = 30 pF (on FMC_SDCLK).
- For 1.71 V≤ $V_{DD}$ <1.9 V, maximum FMC_SDCLK = 75 MHz when CAS Latency = 3 and 60 MHz for CAS latency 1 or 2. $C_L$ = 10 pF (on FMC_SDCLK).

**Figure 69. SDRAM read access waveforms (CL = 1)**

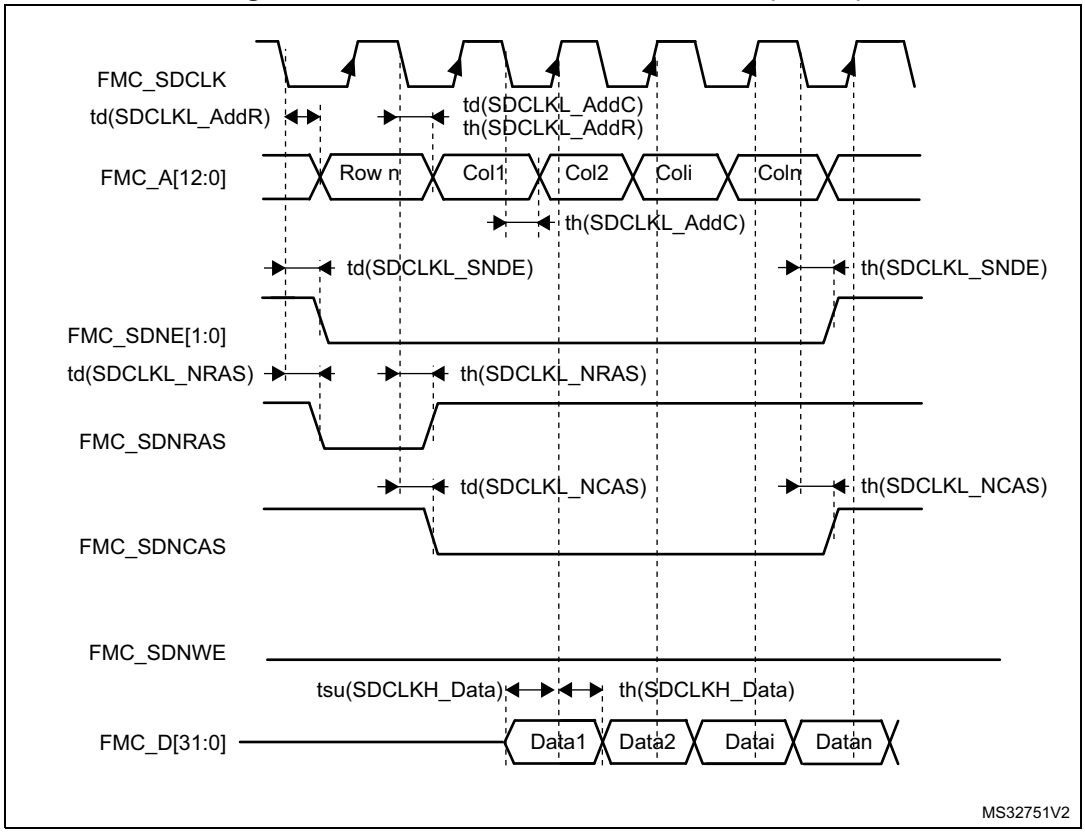



**Table 103. SDRAM read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(SDCLK)}$ | FMC_SDCLK period | $2T_{HCLK}$ − 0.5 | $2T_{HCLK}$+0.5 | ns |
| $t_{su(SDCLKH_Data)}$ | Data input setup time | 2 | - | |
| $t_{h(SDCLKH_Data)}$ | Data input hold time | 0 | - | |
| $t_{d(SDCLKL_Add)}$ | Address valid time | - | 1.5 | |
| $t_{d(SDCLKL-SDNE)}$ | Chip select valid time | - | 0.5 | |
| $t_{h(SDCLKL_SDNE)}$ | Chip select hold time | 0 | - | |
| $t_{d(SDCLKL_SDNRAS)}$ | SDNRAS valid time | - | 0.5 | |
| $t_{h(SDCLKL_SDNRAS)}$ | SDNRAS hold time | 0 | - | |
| $t_{d(SDCLKL_SDNCAS)}$ | SDNCAS valid time | - | 0.5 | |
| $t_{h(SDCLKL_SDNCAS)}$ | SDNCAS hold time | 0 | - | |

1. Guaranteed based on test during characterization.

**Table 104. LPSDR SDRAM read timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{W(SDCLK)}$ | FMC_SDCLK period | $2T_{HCLK} - 0.5$ | $2T_{HCLK}+0.5$ | ns |
| $t_{su(SDCLKH_Data)}$ | Data input setup time | 2.5 | - | |
| $t_{h(SDCLKH_Data)}$ | Data input hold time | 0 | - | |
| $t_{d(SDCLKL_Add)}$ | Address valid time | - | 1 | |
| $t_{d(SDCLKL_SDNE)}$ | Chip select valid time | - | 1 | |
| $t_{h(SDCLKL_SDNE)}$ | Chip select hold time | 1 | - | |
| $t_{d(SDCLKL_SDNRAS}$ | SDNRAS valid time | - | 1 | |
| $t_{h(SDCLKL_SDNRAS)}$ | SDNRAS hold time | 1 | - | |
| $t_{d(SDCLKL_SDNCAS)}$ | SDNCAS valid time | - | 1 | |
| $t_{h(SDCLKL_SDNCAS)}$ | SDNCAS hold time | 1 | - | |

1. Guaranteed based on test during characterization.

**Figure 70. SDRAM write access waveforms**

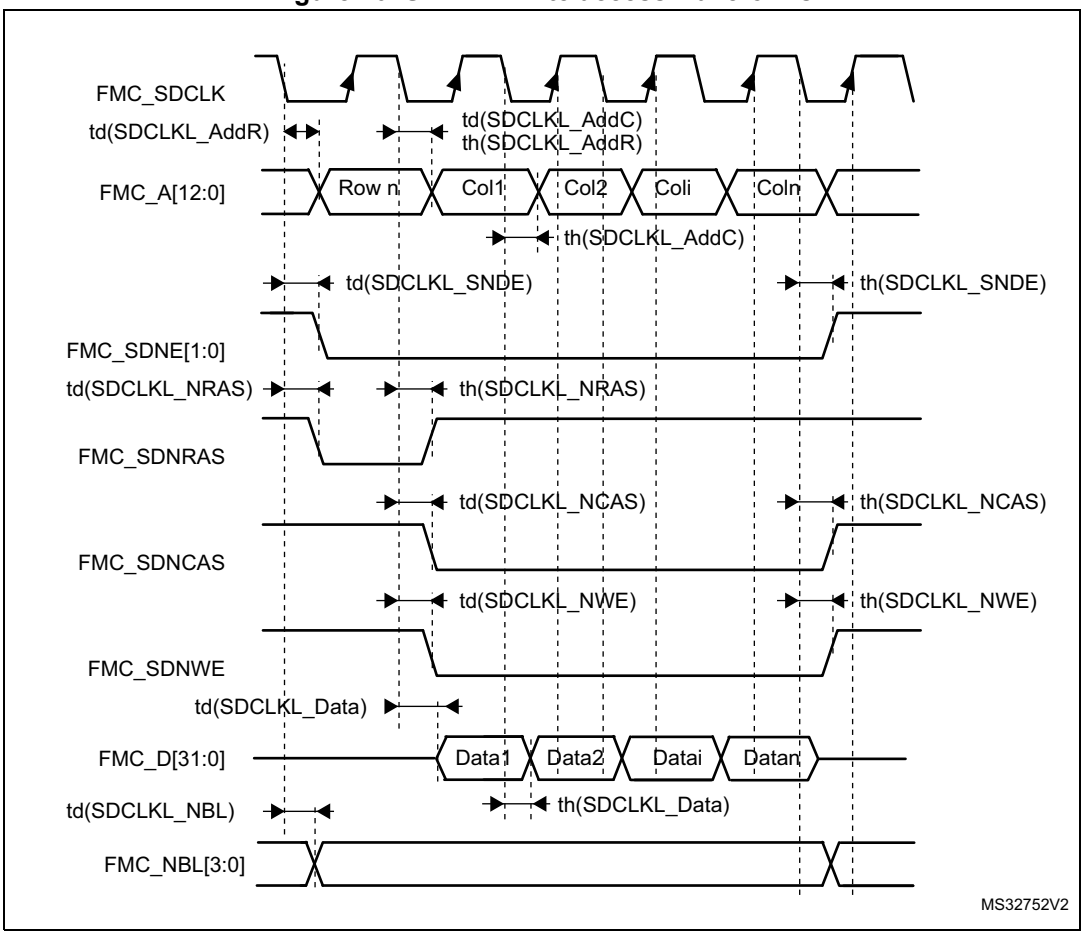


**Table 105. SDRAM write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(SDCLK)}$ | FMC_SDCLK period | $2T_{HCLK} - 0.5$ | $2T_{HCLK}+0.5$ | ns |
| $t_{d(SDCLKL_Data)}$ | Data output valid time | - | 2.5 | |
| $t_{h(SDCLKL_Data)}$ | Data output hold time | 3.5 | - | |
| $t_{d(SDCLKL_Add)}$ | Address valid time | - | 1.5 | |
| $t_{d(SDCLKL_SDNWE)}$ | SDNWE valid time | - | 1 | |
| $t_{h(SDCLKL_SDNWE)}$ | SDNWE hold time | 0 | - | |
| $t_{d(SDCLKL_SDNE)}$ | Chip select valid time | - | 0.5 | |
| $t_{h(SDCLKL-_SDNE)}$ | Chip select hold time | 0 | - | |
| $t_{d(SDCLKL_SDNRAS)}$ | SDNRAS valid time | - | 2 | |
| $t_{h(SDCLKL_SDNRAS)}$ | SDNRAS hold time | 0 | - | |
| $t_{d(SDCLKL_SDNCAS)}$ | SDNCAS valid time | - | 0.5 | |
| $t_{d(SDCLKL_SDNCAS)}$ | SDNCAS hold time | 0 | - | |
| $t_{d(SDCLKL_NBL)}$ | NBL valid time | - | 0.5 | |
| $t_{h(SDCLKL_NBL)}$ | NBL output time | 0 | - | |

1. Guaranteed based on test during characterization.

**Table 106. LPSDR SDRAM write timings(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $t_{w(SDCLK)}$ | FMC_SDCLK period | $2T_{HCLK} - 0.5$ | $2T_{HCLK}+0.5$ | ns |
| $t_{d(SDCLKL_Data)}$ | Data output valid time | - | 5 | |
| $t_{h(SDCLKL_Data)}$ | Data output hold time | 2 | - | |
| $t_{d(SDCLKL_Add)}$ | Address valid time | - | 2.8 | |
| $t_{d(SDCLKL-SDNWE)}$ | SDNWE valid time | - | 2 | |
| $t_{h(SDCLKL-SDNWE)}$ | SDNWE hold time | 1 | - | |
| $t_{d(SDCLKL- SDNE)}$ | Chip select valid time | - | 1.5 | |
| $t_{h(SDCLKL- SDNE)}$ | Chip select hold time | 1 | - | |
| $t_{d(SDCLKL-SDNRAS)}$ | SDNRAS valid time | - | 1.5 | |
| $t_{h(SDCLKL-SDNRAS)}$ | SDNRAS hold time | 1.5 | - | |
| $t_{d(SDCLKL-SDNCAS)}$ | SDNCAS valid time | - | 1.5 | |
| $t_{d(SDCLKL-SDNCAS)}$ | SDNCAS hold time | 1.5 | - | |
| $t_{d(SDCLKL_NBL)}$ | NBL valid time | - | 1.5 | |
| $t_{h(SDCLKL-NBL)}$ | NBL output time | 1.5 | - | |

1. Guaranteed based on test during characterization.

### 5.3.30 Quad-SPI interface characteristics

Unless otherwise specified, the parameters given in *Table 107* and *Table 108* for Quad-SPI are derived from tests performed under the ambient temperature, $f_{AHB}$ frequency, and $V_{DD}$ supply voltage conditions summarized in Table xx, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$

Refer to *Section 5.3.20* for more details on the input/output alternate function characteristics.

**Table 107. Quad-SPI characteristics in SDR mode(1)**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{ck}$ $1/t_{(CK)}$ | Quad-SPI clock frequency | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V, $C_L$ = 20 pF | - | - | 90 | MHz |
| | | 1.71 V ≤ $V_{DD}$ ≤ 3.6 V, $C_L$ = 15 pF | - | - | 84 | |
| $t_{w(CKH)}$ | Quad-SPI clock high time | - | $t_{(CK)}$/2-1 | - | $t_{(CK)}$/2 | ns |
| $t_{w(CKL)}$ | Quad-SPI clock low time | - | $t_{(CK)}$/2 | - | $t_{(CK)}$/2+1 | |
| $t_{s(IN)}$ | Data input set-up time | - | 0.5 | - | - | |
| $t_{h(IN)}$ | Data input hold time | - | 3 | - | - | |
| $t_{v(OUT)}$ | Data output valid time | - | - | 3 | 4 | |
| $t_{h(OUT)}$ | Data output hold time | - | 2.5 | - | - | |

1. Guaranteed based on test during characterization.

**Figure 71. Quad-SPI SDR timing diagram**

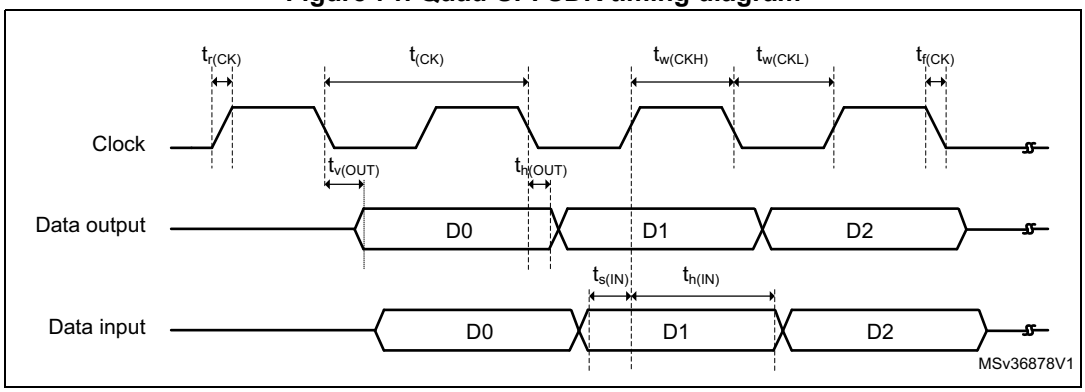
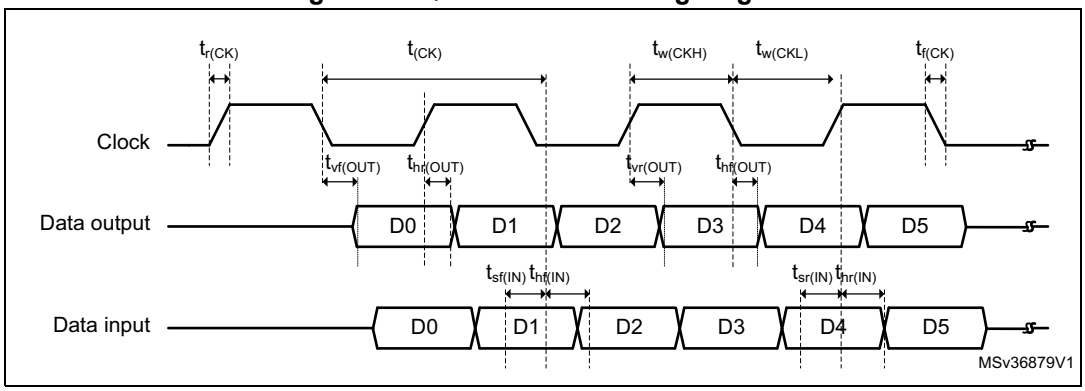


**Table 108. Quad-SPI characteristics in DDR mode(1)**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $F_{ck}$ $1/t_{(CK)}$ | Quad-SPI clock frequency | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V, $C_L$ = 20 pF | - | - | 80 | MHz |
| | | 1.71 V ≤ $V_{DD}$ ≤ 3.6 V, $C_L$ = 15 pF | - | - | 70 | |
| $t_{w(CKH)}$ | Quad-SPI clock high time | - | $t_{(CK)}$/2-1 | - | $t_{(CK)}$/2 | ns |
| $t_{w(CKL)}$ | Quad-SPI clock low time | - | $t_{(CK)}$/2 | - | $t_{(CK)}$/2+1 | |
| $t_{sr(IN)}$ $t_{sf(IN)}$ | Data input set-up time | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 2 | - | - | |
| | | 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | 0.5 | - | - | |
| $t_{hr(IN)}$ $t_{hf(IN)}$ | Data input hold time | 2.7 V ≤ $V_{DD}$ ≤ 3.6 V | 3 | - | - | |
| | | 1.71 V ≤ $V_{DD}$ ≤ 3.6 V | 4.5 | - | - | |
| $t_{vr(OUT)}$ $t_{vf(OUT)}$ | Data output valid time | DHHC=0 | - | 8 | 10.5 | |
| | | DHHC=1 Pres=1,2… | - | $T_{hclk}$/2+2 | $T_{hclk}$/2+2.5 | |
| $t_{h(OUT)}$ $t_{f(OUT)}$ | Data output hold time | DHHC=0 | 7 | - | - | |
| | | DHHC=1 Pres=1,2… | $T_{hclk}$/2+0.5 | - | - | |

1. Guaranteed based on test during characterization.

**Figure 72. Quad-SPI DDR timing diagram**




## 5.3.31 Camera interface (DCMI) timing specifications

Unless otherwise specified, the parameters given in *Table 109* for DCMI are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency, and $V_{DD}$ supply voltage summarized in *Table 17*, with the following configuration:

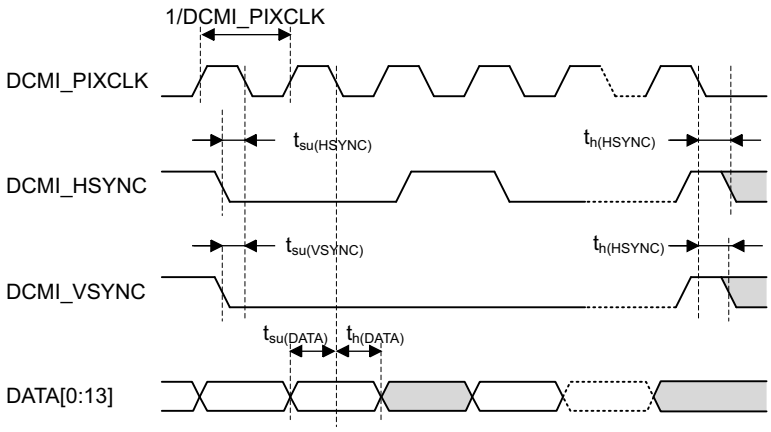
- DCMI_PIXCLK polarity: falling
- DCMI_VSYNC and DCMI_HSYNC polarity: high
- Data formats: 14 bits
- Capacitive load C = 30 pF
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$

**Table 109. DCMI characteristics(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| - | Frequency ratio DCMI_PIXCLK/$f_{HCLK}$ | - | 0.4 | - |
| DCMI_PIXCLK | Pixel clock input | - | 54 | MHz |
| $D_{Pixel}$ | Pixel clock input duty cycle | 30 | 70 | % |
| $t_{su(DATA)}$ | Data input setup time | 4 | - | ns |
| $t_{h(DATA)}$ | Data input hold time | 1 | - | |
| $t_{su(HSYNC)}$ $t_{su(VSYNC)}$ | DCMI_HSYNC/DCMI_VSYNC input setup time | 3.5 | - | |
| $t_{h(HSYNC)}$ $t_{h(VSYNC)}$ | DCMI_HSYNC/DCMI_VSYNC input hold time | 0 | - | |

1. 1.Guaranteed based on test during characterization.

**Figure 73. DCMI timing diagram**




## 5.3.32 LCD-TFT controller (LTDC) characteristics

Unless otherwise specified, the parameters given in *Table 110* for LCD-TFT are derived from tests performed under the ambient temperature, $f_{HCLK}$ frequency, and VDD supply voltage summarized in *Table 17*, with the following configuration:

- LCD_CLK polarity: high
- LCD_DE polarity: low
- LCD_VSYNC and LCD_HSYNC polarity: high
- Pixel formats: 24 bits
- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load $C_L$ = 30 pF
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$

**Table 110. LTDC characteristics(1)**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $f_{CLK}$ | LTDC clock output frequency | - | 83 | MHz |
| $D_{CLK}$ | LTDC clock output duty cycle | 45 | 55 | % |
| $t_{w(CLKH)}$ $t_{w(CLKL)}$ | Clock high time, low time | $t_{w(CLK)}$ / 2 - 0.5 | $t_{w(CLK)}$ / 2 + 0.5 | ns |
| $t_{v(DATA)}$ | Data output valid time | - | 1.5 | |
| $t_{h(DATA)}$ | Data output hold time | 0 | - | |
| $t_{v(HSYNC)}$ | HSYNC/VSYNC/DE output valid time | - | 0.5 | |
| $t_{v(VSYNC)}$ | | | | |
| $t_{v(DE)}$ | | | | |
| $t_{h(HSYNC)}$ | HSYNC/VSYNC/DE output hold time | 0 | - | |
| $t_{h(VSYNC)}$ | | | | |
| $t_{h(DE)}$ | | | | |

1. Based on test during characterization.

**Figure 74. LCD-TFT horizontal timing diagram**

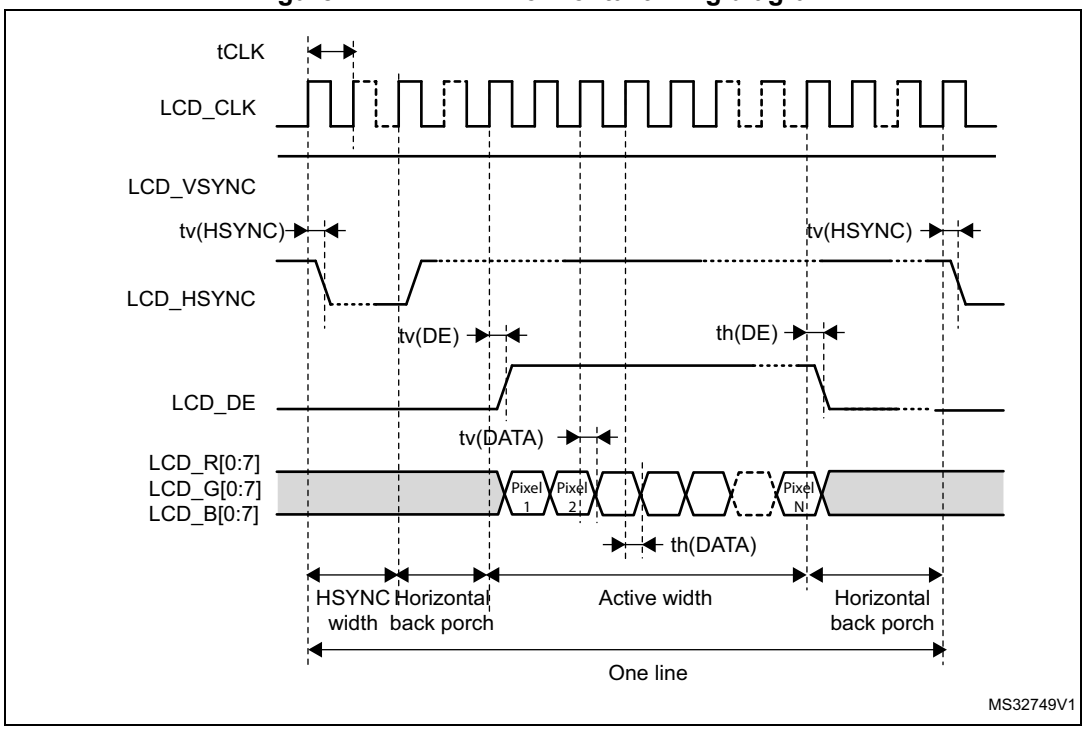
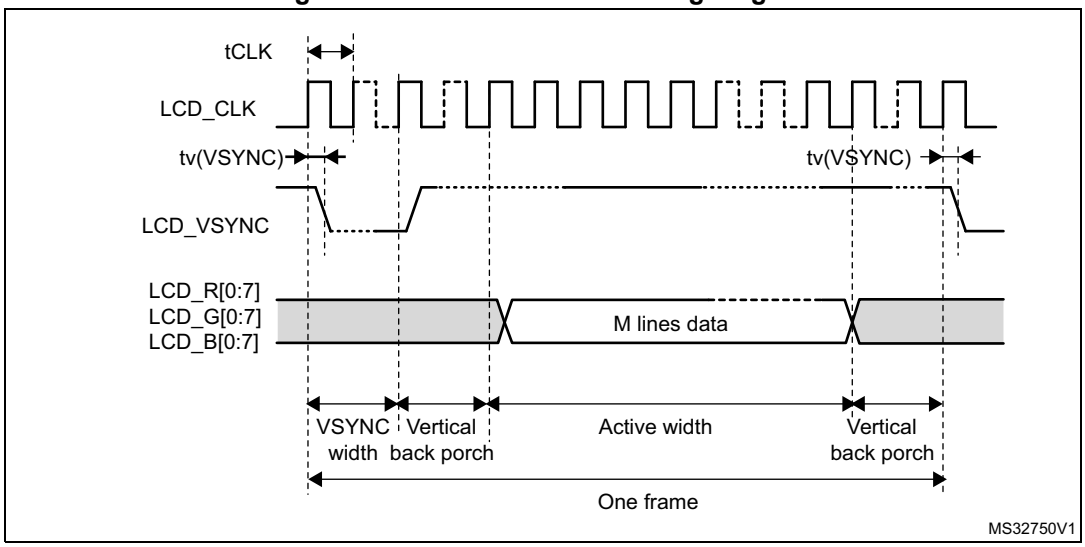


**Figure 75. LCD-TFT vertical timing diagram**




## 5.3.33 SD/SDIO MMC card host interface (SDIO) characteristics

Unless otherwise specified, the parameters given in *Table 111* for the SDIO/MMC interface are derived from tests performed under the ambient temperature, $f_{PCLK2}$ frequency and $V_{DD}$ supply voltage conditions summarized in *Table 17*, with the following configuration:

- Output speed is set to OSPEEDRy[1:0] = 11
- Capacitive load C = 30 pF
- Measurement points are done at CMOS levels: 0.5 $V_{DD}$

Refer to *Section 5.3.20* for more details on the input/output characteristics.

**Figure 76. SDIO high-speed mode**

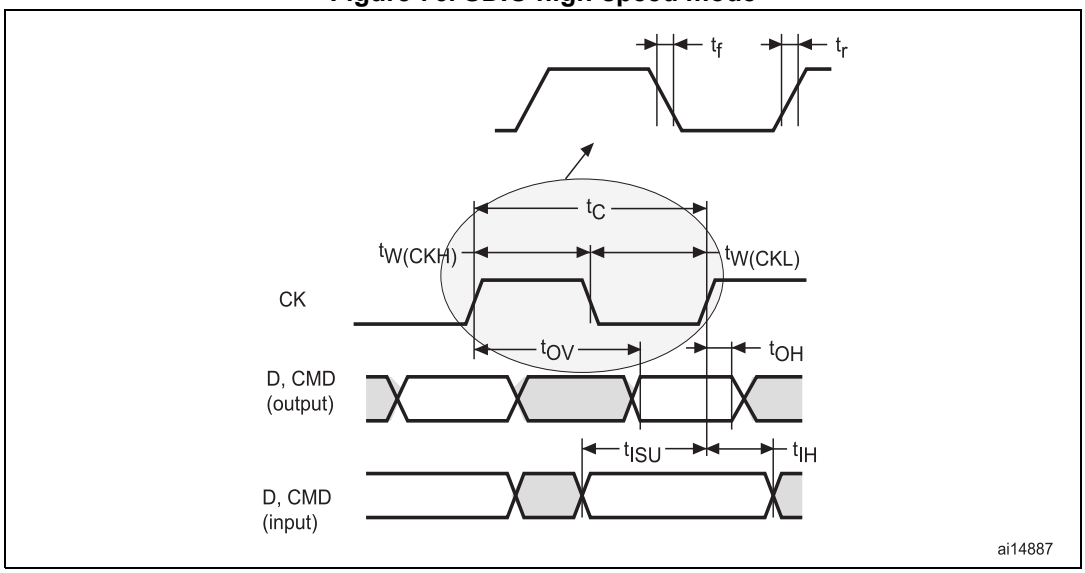


**Figure 77. SD default mode**

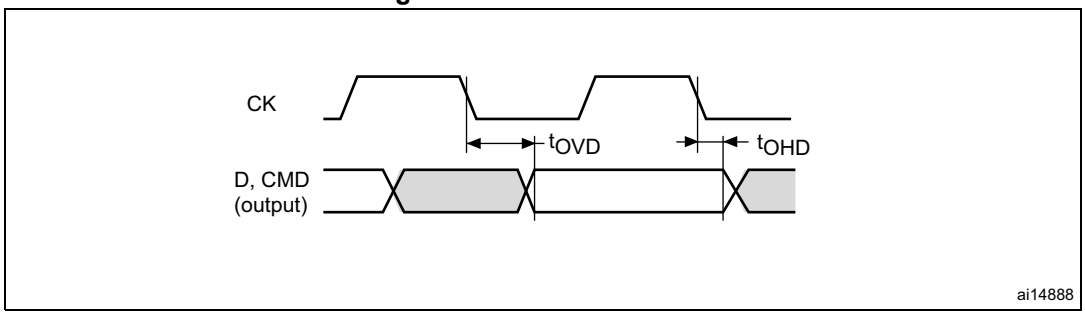



**Table 111. Dynamic characteristics: SD / MMC characteristics, $V_{DD}$ = 2.7 to 3.6 V(1)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{PP}$ | Clock frequency in data transfer mode | - | 0 | - | 50 | MHz |
| - | SDIO_CK/fPCLK2 frequency ratio | - | - | - | 8/3 | - |
| $t_{W(CKL)}$ | Clock low time | $f_{pp}$ =50 MHz | 9.5 | 10.5 | - | ns |
| $t_{W(CKH)}$ | Clock high time | | 8.5 | 9.5 | - | |
| **CMD, D inputs (referenced to CK) in MMC and SD HS mode** | | | | | | |
| $t_{ISU}$ | Input setup time HS | $f_{pp}$ =50 MHz | 2.0 | - | - | ns |
| $t_{IH}$ | Input hold time HS | | 2.0 | - | - | |
| **CMD, D outputs (referenced to CK) in MMC and SD HS mode** | | | | | | |
| $t_{OV}$ | Output valid time HS | $f_{pp}$ =50 MHz | - | 13 | 13.5 | ns |
| $t_{OH}$ | Output hold time HS | | 12.5 | - | - | |
| **CMD, D inputs (referenced to CK) in SD default mode** | | | | | | |
| $t_{ISUD}$ | Input setup time SD | $f_{pp}$ =25 MHz | 2.0 | - | - | ns |
| $t_{IHD}$ | Input hold time SD | | 2.5 | - | - | |
| **CMD, D outputs (referenced to CK) in SD default mode** | | | | | | |
| $t_{OVD}$ | Output valid default time SD | $f_{pp}$ =25 MHz | - | 1.5 | 2.0 | ns |
| $t_{OHD}$ | Output hold default time SD | | 1.0 | - | - | |

1. Guaranteed based on test during characterization.

**Table 112. Dynamic characteristics: SD / MMC characteristics, $V_{DD}$ = 1.71 to 1.9 V(1)(2)**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{PP}$ | Clock frequency in data transfer mode | - | 0 | - | 50 | MHz |
| - | SDIO_CK/fPCLK2 frequency ratio | - | - | - | 8/3 | - |
| $t_{W(CKL)}$ | Clock low time | $f_{pp}$ =50 MHz | 9.5 | 10.5 | - | ns |
| $t_{W(CKH)}$ | Clock high time | | 8.5 | 9.5 | - | |
| **CMD, D inputs (referenced to CK) in eMMC mode** | | | | | | |
| $t_{ISU}$ | Input setup time HS | $f_{pp}$ =50 MHz | 0.5 | - | - | ns |
| $t_{IH}$ | Input hold time HS | | 3.5 | - | - | |
| **CMD, D outputs (referenced to CK) in eMMC mode** | | | | | | |
| $t_{OV}$ | Output valid time HS | $f_{pp}$ =50 MHz | - | 13.5 | 14.5 | ns |
| $t_{OH}$ | Output hold time HS | | 13.0 | - | - | |

1. Guaranteed based on test during characterization.
2. $C_{load}$ = 20 pF.

## 5.3.34 RTC characteristics

**Table 113. RTC characteristics**

| Symbol | Parameter | Conditions | Min | Max |
|---|---|---|---|---|
| - | $f_{PCLK1}$/RTCCLK frequency ratio | Any read/write operation from/to an RTC register | 4 | - |

# 6 Package information

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.

## 6.1 Device marking

Refer to technical note “Reference device marking schematics for STM32 microcontrollers and microprocessors” (TN1433 ) available on www.st.com, for the location of pin 1 / ball A1 as well as the location and orientation of the marking areas versus pin 1 / ball A1.

Parts marked as “ES”, “E” or accompanied by an engineering sample notification letter, are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering samples in production. ST’s Quality department must be contacted prior to any decision to use these engineering samples to run a qualification activity.

A WLCSP simplified marking example (if any) is provided in the corresponding package information subsection.

## 6.2 LQFP100 package information (1L)

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

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

**Figure 78. LQFP100 - Outline(15)**

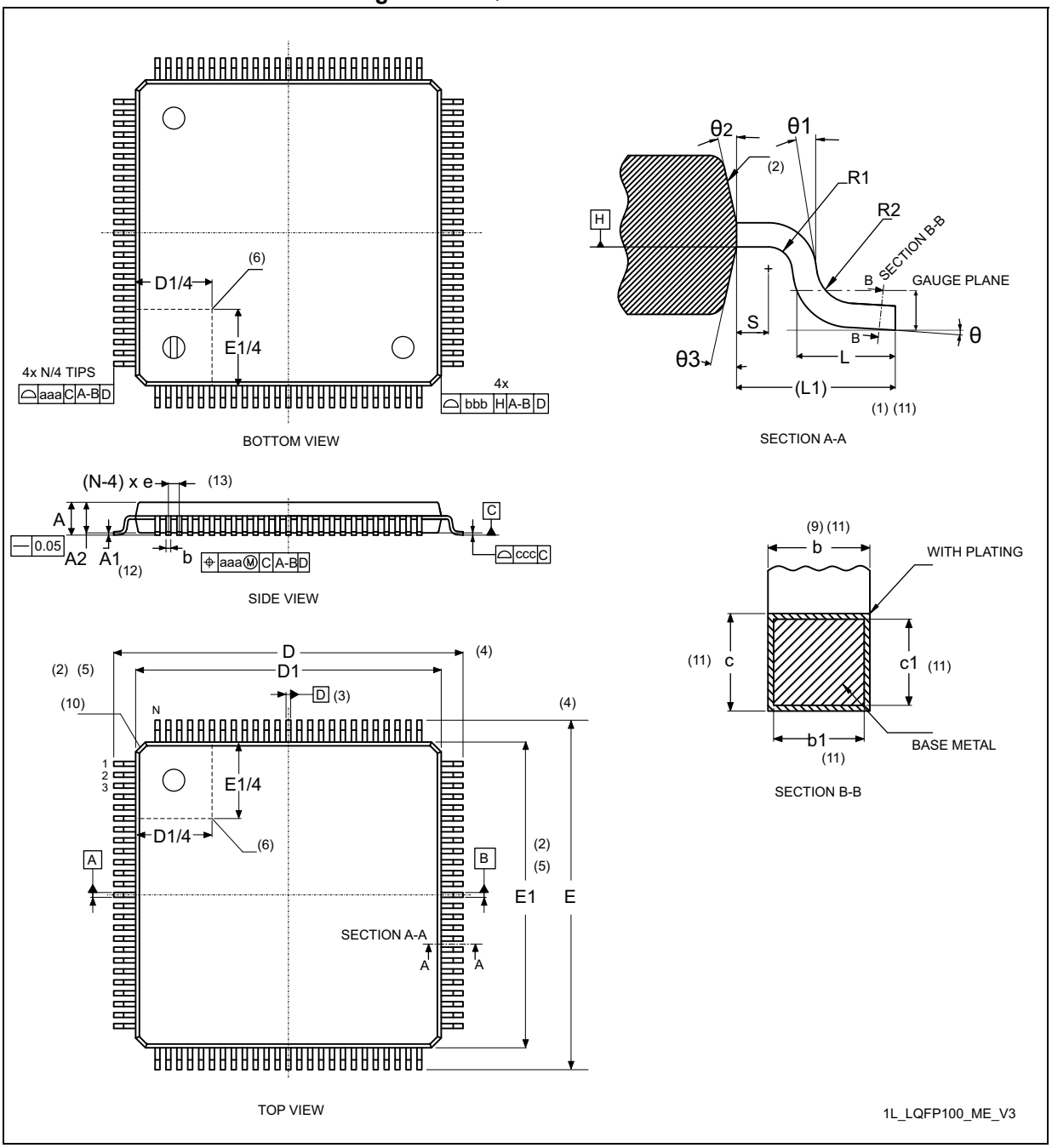



**Table 114. LQFP100 - Mechanical data**

| Symbol | millimeters | | | inches(14) | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | 1.50 | 1.60 | - | 0.0590 | 0.0630 |
| A1(12) | 0.05 | - | 0.15 | 0.0019 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0570 |

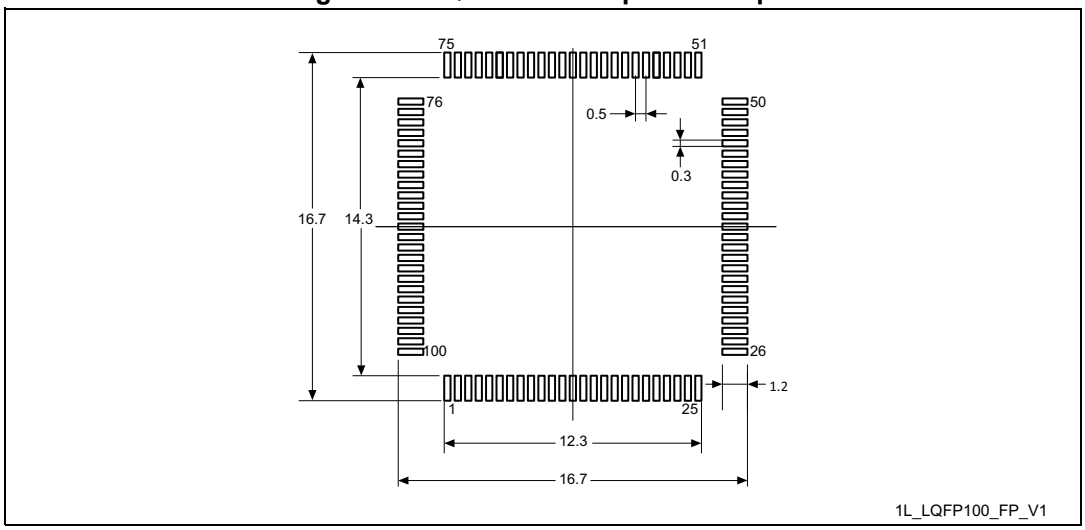
Table 114. LQFP100 - Mechanical data (continued)

| Symbol | millimeters | | | inches[14] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| b[9][11] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[11] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0090 |
| c[11] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[11] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[4] | 16.00 BSC | | | 0.6299 BSC | | |
| D1[2][5] | 14.00 BSC | | | 0.5512 BSC | | |
| E[4] | 16.00 BSC | | | 0.6299 BSC | | |
| E1[2][5] | 14.00 BSC | | | 0.5512 BSC | | |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.177 | 0.0236 | 0.0295 |
| L1[1][11] | 1.00 | | | - | 0.0394 | - |
| N[13] | 100 | | | | | |
| θ | 0° | 3.5° | 7° | 0° | 3.5° | 7° |
| θ1 | 0° | - | - | 0° | - | - |
| θ2 | 10° | 12° | 14° | 10° | 12° | 14° |
| θ3 | 10° | 12° | 14° | 10° | 12° | 14° |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |
| aaa[1] | 0.20 | | | 0.0079 | | |
| bbb[1] | 0.20 | | | 0.0079 | | |
| ccc[1] | 0.08 | | | 0.0031 | | |
| ddd[1] | 0.08 | | | 0.0031 | | |

**Notes:**

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is “0.25 mm” per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All Dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to 4 decimal digits.
15. Drawing is not to scale.

**Figure 79. LQFP100 - Footprint example**




1. Dimensions are expressed in millimeters.

## 6.3 LQFP144 package information (1A)

This LQFP is a 144-pin, 20 x 20 mm low-profile quad flat package.

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

**Figure 80. LQFP144 - Outline(15)**

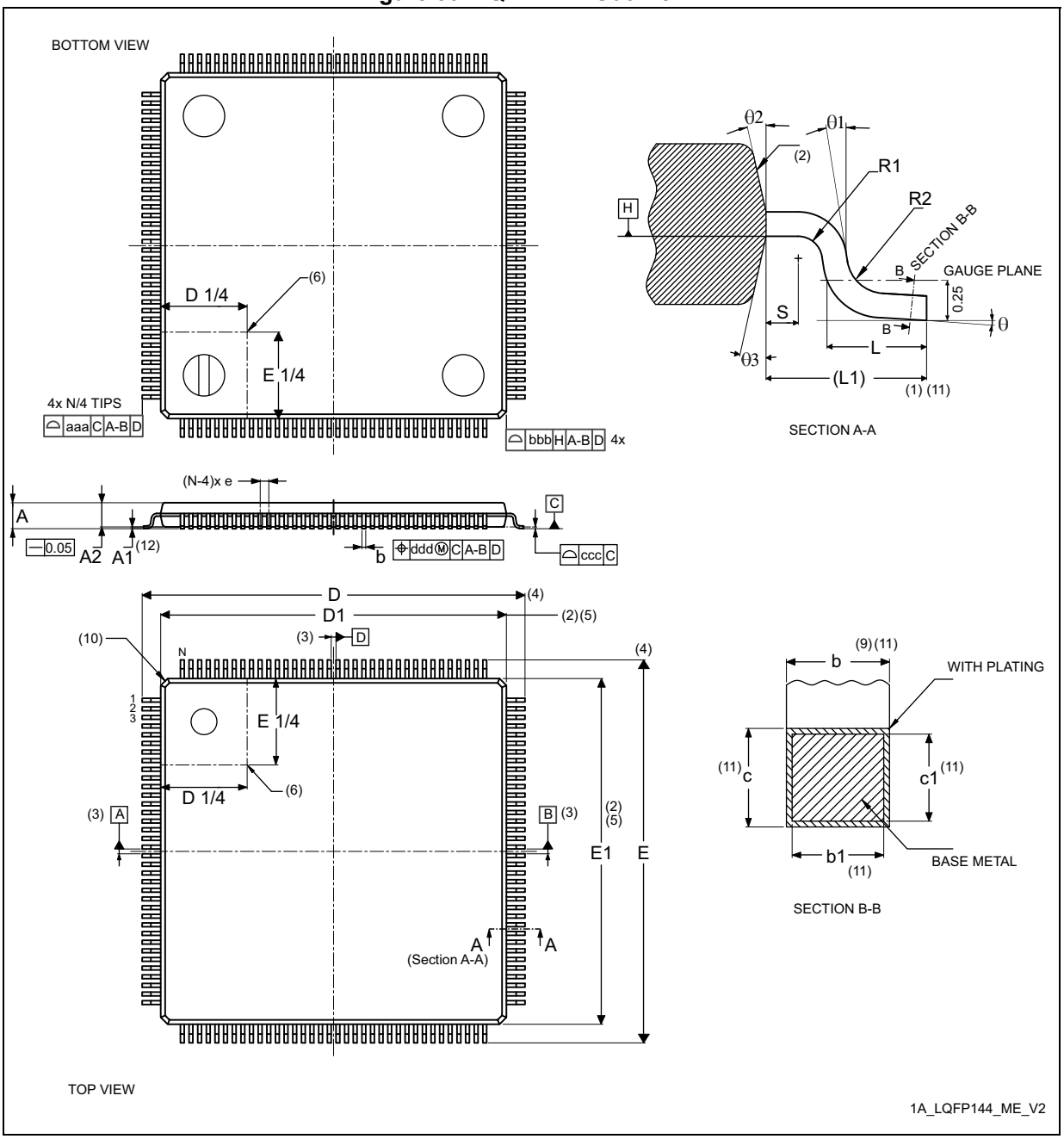


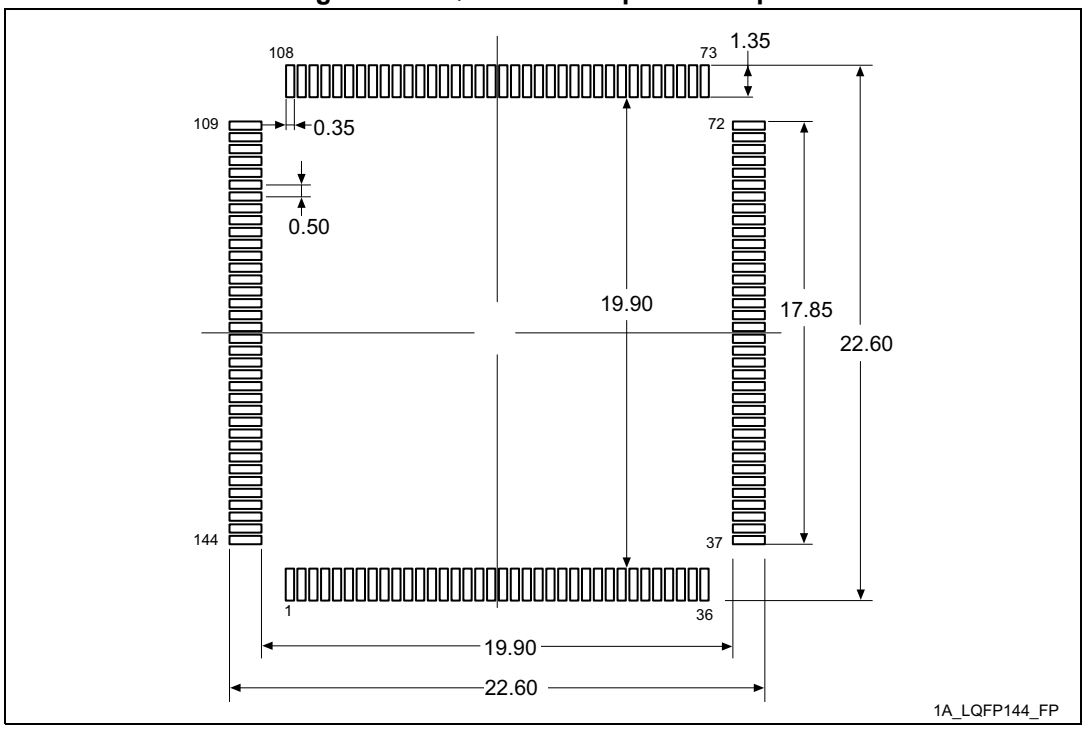
**Table 115. LQFP144 - Mechanical data**

| Symbol | millimeters | | | inches[14] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | - | 1.60 | - | - | 0.0630 |
| A1[12] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[9][11] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[11] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0090 |
| c[11] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[11] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[4] | 22.00 BSC | | | 0.8661 BSC | | |
| D1[2][5] | 20.00 BSC | | | 0.7874 BSC | | |
| E[4] | 22.00 BSC | | | 0.8661 BSC | | |
| E1[2][5] | 20.00 BSC | | | 0.7874 BSC | | |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13] | 144 | | | | | |
| θ | 0° | 3.5° | 7° | 0° | 3.5° | 7° |
| θ1 | 0° | - | - | 0° | - | - |
| θ2 | 10° | 12° | 14° | 10° | 12° | 14° |
| θ3 | 10° | 12° | 14° | 10° | 12° | 14° |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |
| aaa | 0.20 | | | 0.0079 | | |
| bbb | 0.20 | | | 0.0079 | | |
| ccc | 0.08 | | | 0.0031 | | |
| ddd | 0.08 | | | 0.0031 | | |

**Notes:**

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is “0.25 mm” per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All Dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to 4 decimal digits.
15. Drawing is not to scale.

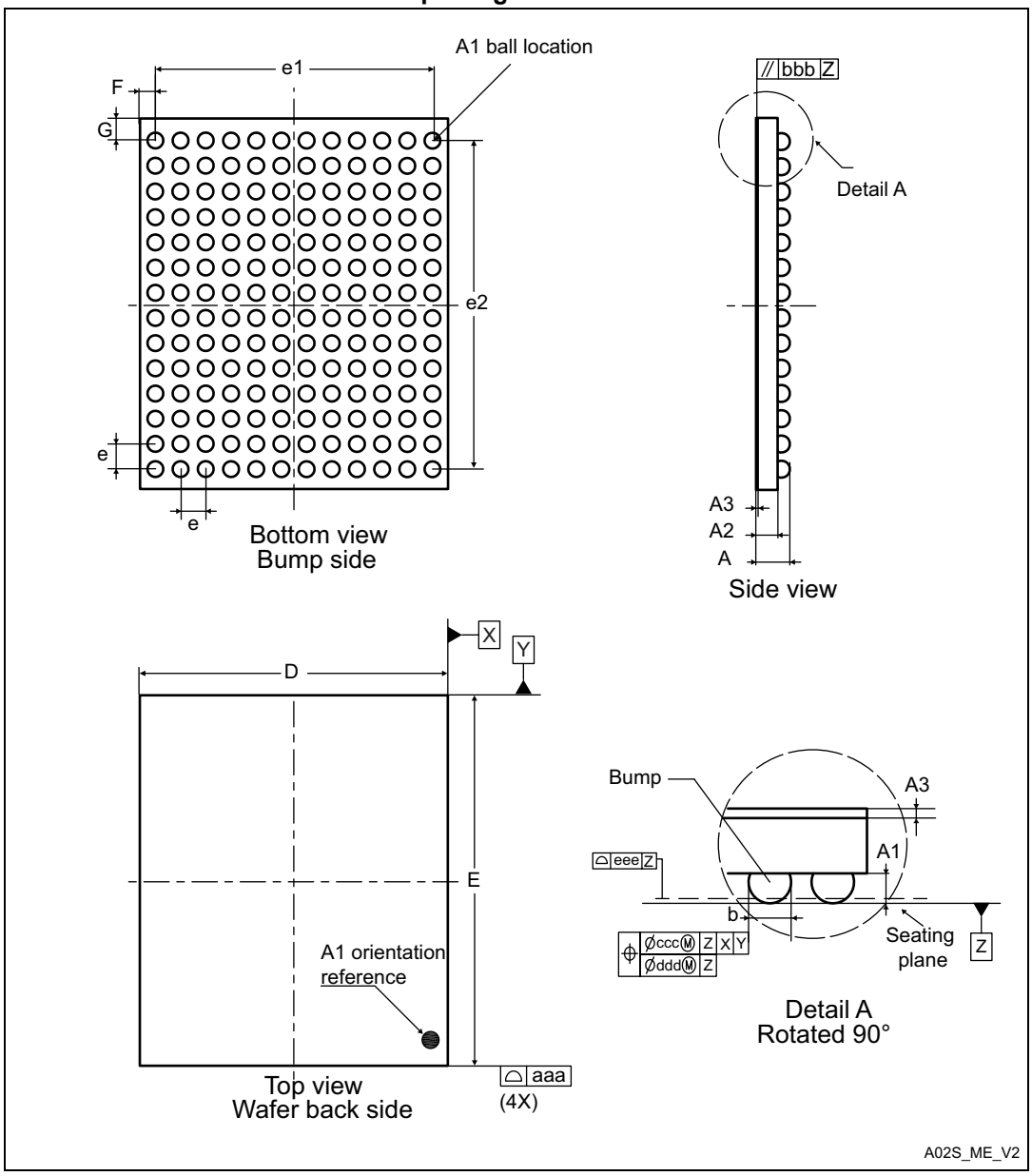
**Figure 81. LQFP144 - Footprint example**




1. Dimensions are expressed in millimeters.

## 6.4 WLCSP168 package information

**Figure 82. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package outline**




1. Drawing is not to scale.

**Table 116. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package mechanical data**

| Symbol | millimeters | | | inches[1] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | 0.525 | 0.555 | 0.585 | 0.0207 | 0.0219 | 0.0230 |
| A1 | - | 0.170 | - | - | 0.0067 | - |
| A2 | - | 0.380 | - | - | 0.0150 | - |
| A3[2] | - | 0.025 | - | - | 0.0010 | - |
| b[3] | 0.220 | 0.250 | 0.280 | 0.0087 | 0.0098 | 0.0110 |
| D | 4.856 | 4.891 | 4.926 | 0.1912 | 0.1926 | 0.1939 |
| E | 5.657 | 5.692 | 5.727 | 0.2227 | 0.2241 | 0.2255 |
| e | - | 0.400 | - | - | 0.0157 | - |
| e1 | - | 4.400 | - | - | 0.1732 | - |
| e2 | - | 5.200 | - | - | 0.2047 | - |
| F | - | 0.2455 | - | - | 0.0097 | - |
| G | - | 0.246 | - | - | 0.0097 | - |
| aaa | - | - | 0.100 | - | - | 0.0039 |
| bbb | - | - | 0.100 | - | - | 0.0039 |
| ccc | - | - | 0.100 | - | - | 0.0039 |
| ddd | - | - | 0.050 | - | - | 0.0020 |
| eee | - | - | 0.050 | - | - | 0.0020 |

1. Values in inches are converted from mm and rounded to 4 decimal digits.
2. Back side coating.
3. Dimension is measured at the maximum bump diameter parallel to primary datum Z.

**Figure 83. WLCSP168 - 168-ball, 4.891 x 5.692 mm, 0.4 mm pitch wafer level chip scale package recommended footprint**

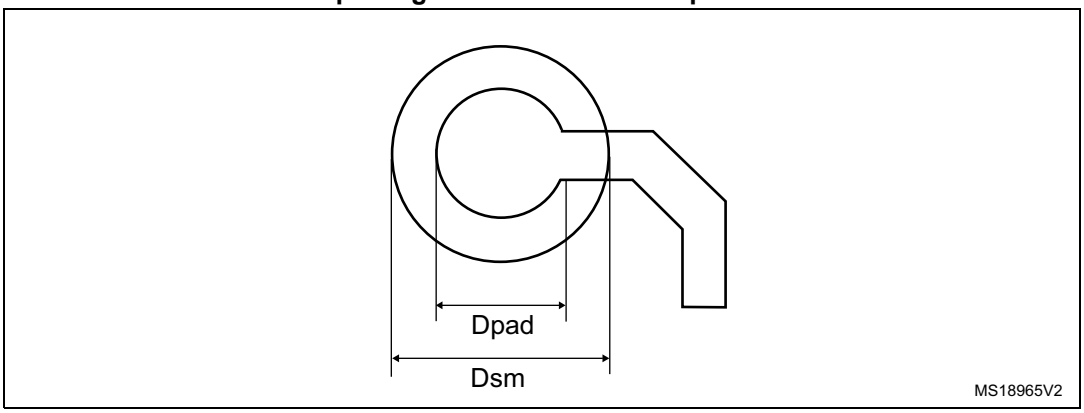


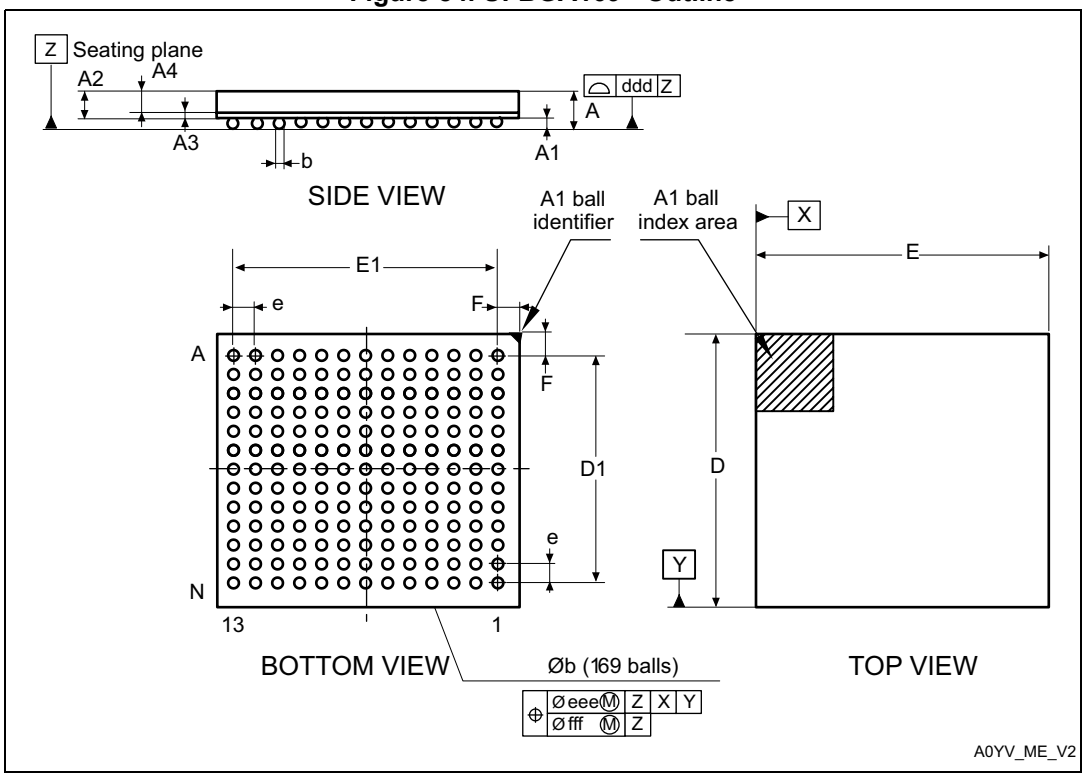
**Table 117. WLCSP168 recommended PCB design rules**

| Dimension | Recommended values |
|---|---|
| Pitch | 0.4 mm |
| Dpad | 260 µm max. (circular)<br>220 µm recommended |
| Dsm | 300 µm min. (for 260 µm diameter pad) |
| PCB pad design | Non-solder mask defined via underbump allowed |

## 6.5 UFBGA169 package information (A0YV)

This UFBGA is a 169-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package.

**Figure 84. UFBGA169 - Outline**




1. Drawing is not to scale.

**Table 118. UFBGA169 - Mechanical data**

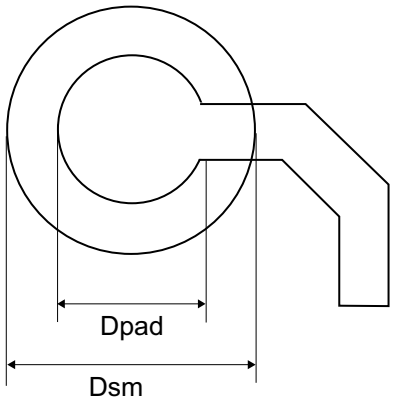
| Symbol | millimeters | | | inches(1) | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 0.460 | 0.530 | 0.600 | 0.0181 | 0.0209 | 0.0236 |
| A1 | 0.050 | 0.080 | 0.110 | 0.0020 | 0.0031 | 0.0043 |

**Table 118. UFBGA169 - Mechanical data (continued)**

| Symbol | millimeters | | | inches[1] | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A2 | 0.400 | 0.450 | 0.500 | 0.0157 | 0.0177 | 0.0197 |
| A3 | - | 0.130 | - | - | 0.0051 | - |
| A4 | 0.270 | 0.320 | 0.370 | 0.0106 | 0.0126 | 0.0146 |
| b | 0.230 | 0.280 | 0.330 | 0.0091 | 0.0110 | 0.0130 |
| D | 6.950 | 7.000 | 7.050 | 0.2736 | 0.2756 | 0.2776 |
| D1 | 5.950 | 6.000 | 6.050 | 0.2343 | 0.2362 | 0.2382 |
| E | 6.950 | 7.000 | 7.050 | 0.2736 | 0.2756 | 0.2776 |
| E1 | 5.950 | 6.000 | 6.050 | 0.2343 | 0.2362 | 0.2382 |
| e | - | 0.500 | - | - | 0.0197 | - |
| F | 0.450 | 0.500 | 0.550 | 0.0177 | 0.0197 | 0.0217 |
| ddd | - | - | 0.100 | - | - | 0.0039 |
| 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 85. UFBGA169 - Footprint example**




BGA_WLCSP_FT_V1

**Table 119. UFBGA169 - Example of PCB design rules (0.5 mm pitch BGA)**

| Dimension | Values |
|---|---|
| Pitch | 0.5 mm |
| Dpad | 0.27 mm |
| Dsm | 0.35 mm typ. (depends on the soldermask registration tolerance) |
| Solder paste | 0.27 mm aperture diameter. |

*Note: Non-solder mask defined (NSMD) pads are recommended.*

*Note: 4 to 6 mils solder paste screen printing process.*

## 6.6 LQFP176 package information (1T)

This LQFP is a 176-pin, 24 x 24 mm, 0.5 mm pitch, low profile quad flat package.

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

**Figure 86. LQFP176 - Outline(15)**

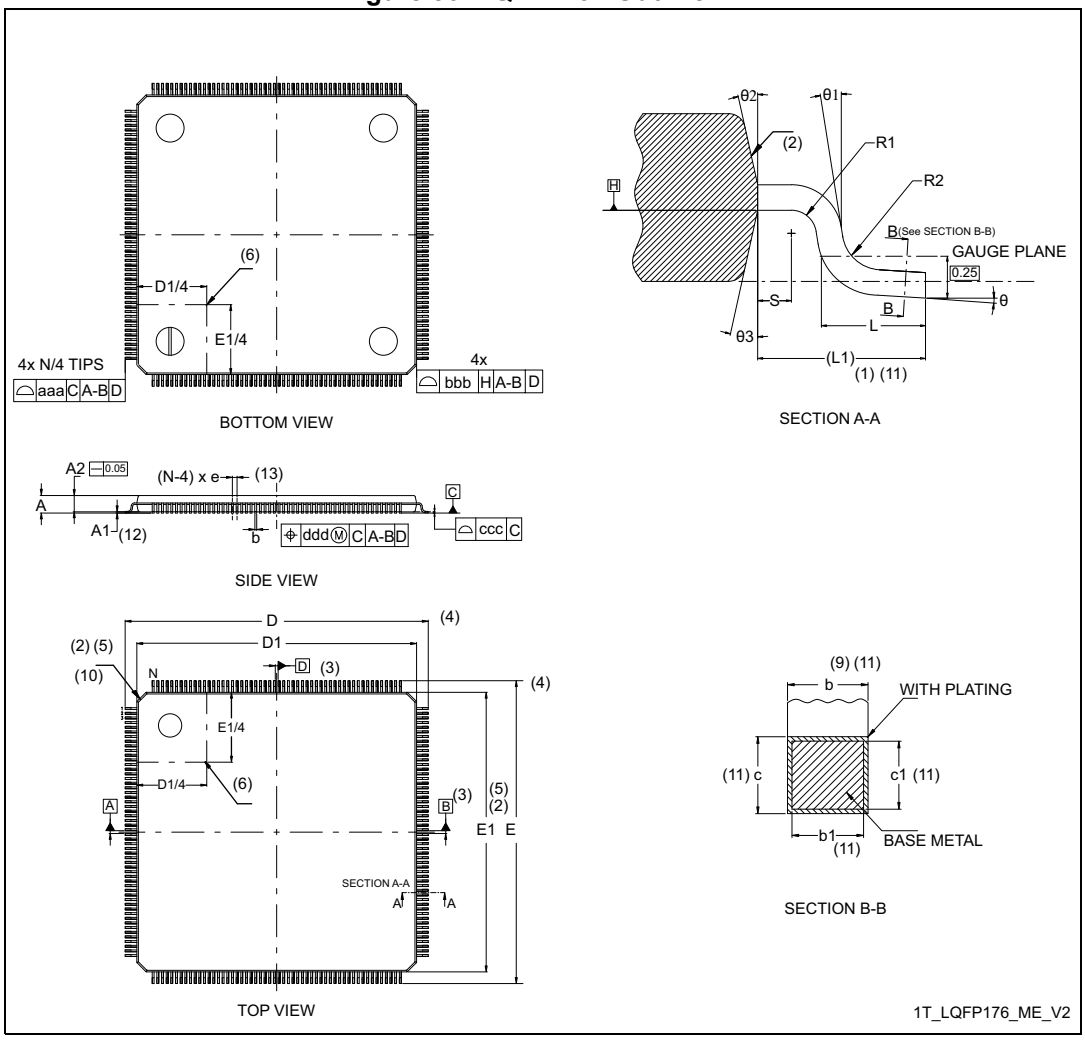


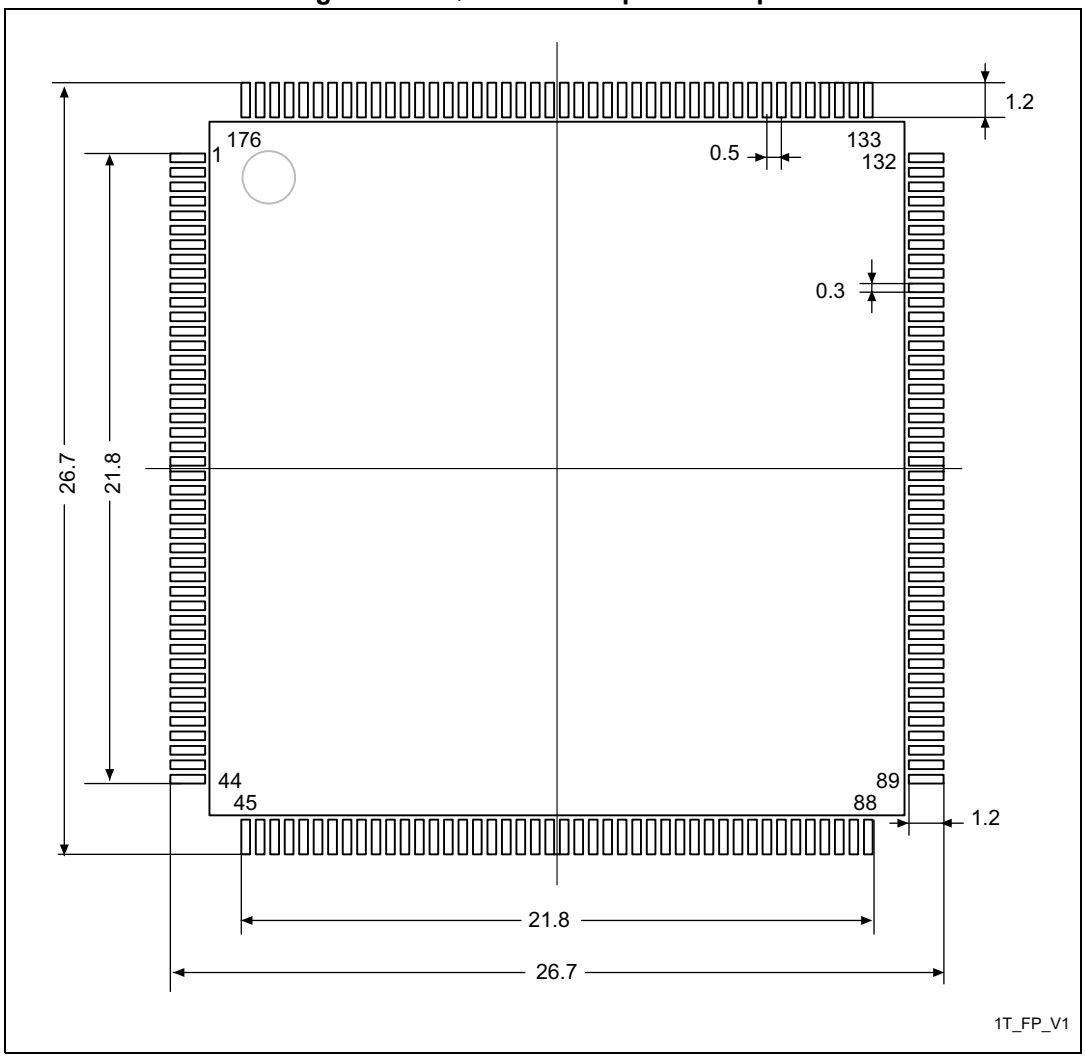
**Table 120. LQFP176 - Mechanical data**

| Symbol | millimeters | | | inches[14] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | - | 1.600 | - | - | 0.0630 |
| A1[12] | 0.050 | - | 0.150 | 0.0020 | - | 0.0059 |
| A2 | 1.350 | 1.400 | 1.450 | 0.0531 | 0.0551 | 0.0571 |
| b[9][11] | 0.170 | 0.220 | 0.270 | 0.0067 | 0.0087 | 0.0106 |
| b1[11] | 0.170 | 0.200 | 0.230 | 0.0067 | 0.0079 | 0.0091 |
| c[11] | 0.090 | - | 0.200 | 0.0035 | - | 0.0079 |
| c1[11] | 0.090 | - | 0.160 | 0.0035 | - | 0.063 |
| D[4] | 26.000 | | | 1.0236 | | |
| D1[2][5] | 24.000 | | | 0.9449 | | |
| E[4] | 26.000 | | | 0.0197 | | |
| E1[2][5] | 24.000 | | | 0.9449 | | |
| e | 0.500 | | | 0.1970 | | |
| L | 0.450 | 0.600 | 0.750 | 0.0177 | 0.0236 | 0.0295 |
| L1[1][11] | 1 | | | 0.0394 REF | | |
| N[13] | 176 | | | | | |
| θ | 0° | 3.5° | 7° | 0° | 3.5° | 7° |
| θ1 | 0° | - | - | 0° | - | - |
| θ2 | 10° | 12° | 14° | 10° | 12° | 14° |
| θ3 | 10° | 12° | 14° | 10° | 12° | 14° |
| R1 | 0.080 | - | - | 0.0031 | - | - |
| R2 | 0.080 | - | 0.200 | 0.0031 | - | 0.0079 |
| S | 0.200 | - | - | 0.0079 | - | - |
| aaa[1] | 0.200 | | | 0.0079 | | |
| bbb[1] | 0.200 | | | 0.0079 | | |
| ccc[1] | 0.080 | | | 0.0031 | | |
| ddd[1] | 0.080 | | | 0.0031 | | |

**Notes:**

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is “0.25 mm” per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All Dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to 4 decimal digits.
15. Drawing is not to scale.

**Figure 87. LQFP176 - Footprint example**

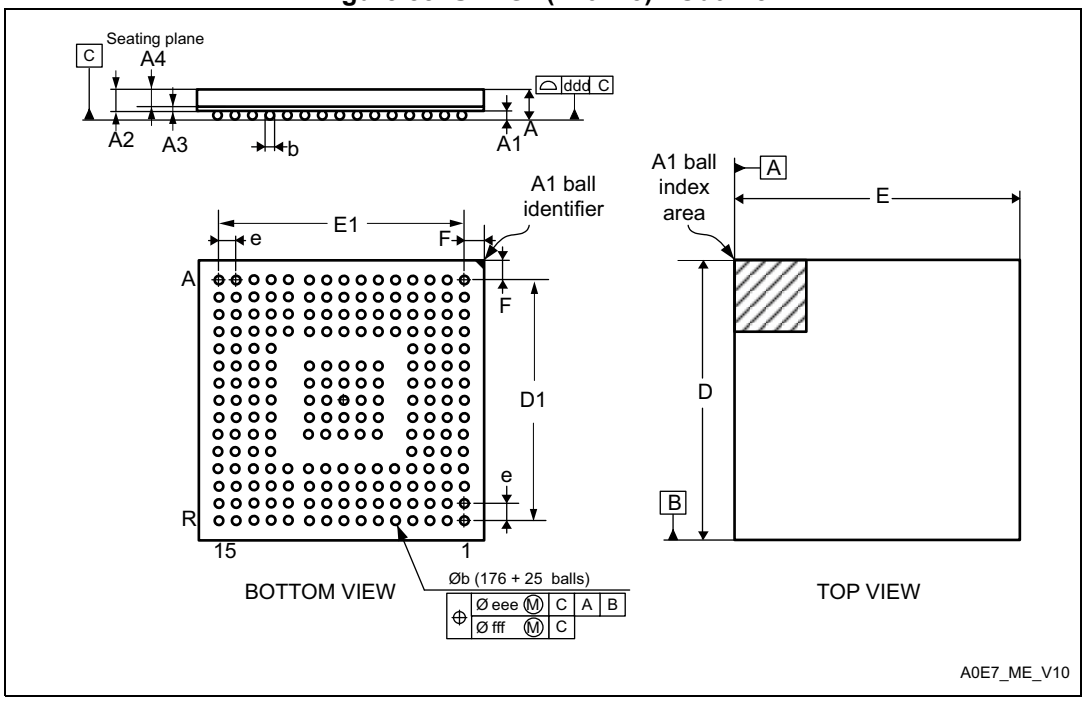



1. Dimensions are expressed in millimeters.

## 6.7 UFBGA(176+25) package information (A0E7)

This UFBGA is a 176+25-ball, 10 x 10 mm, 0.65 mm pitch, ultra fine pitch ball grid array package

**Figure 88. UFBGA(176+25) - Outline**




1. Drawing is not to scale.

**Table 121. UFBGA(176+25) - Mechanical data**

| Symbol | millimeters | | | inches(1) | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | - | - | 0.600 | - | - | 0.0236 |
| A1 | 0.050 | 0.080 | 0.110 | 0.0020 | 0.0031 | 0.0043 |
| A2 | - | 0.450 | - | - | 0.0177 | - |
| A3 | - | 0.130 | - | - | 0.0051 | - |
| A4 | - | 0.320 | - | - | 0.0126 | - |
| b | 0.240 | 0.290 | 0.340 | 0.0094 | 0.0114 | 0.0134 |
| D | 9.850 | 10.000 | 10.150 | 0.3878 | 0.3937 | 0.3996 |
| D1 | - | 9.100 | - | - | 0.3583 | - |
| E | 9.850 | 10.000 | 10.150 | 0.3878 | 0.3937 | 0.3996 |
| E1 | - | 9.100 | - | - | 0.3583 | - |
| e | - | 0.650 | - | - | 0.0256 | - |
| F | - | 0.450 | - | - | 0.0177 | - |
| ddd | - | - | 0.080 | - | - | 0.0031 |

**Table 121. UFBGA(176+25) - Mechanical data (continued)**

| Symbol | millimeters | | | inches[1] | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| eee | - | - | 0.150 | - | - | 0.0059 |
| fff | - | - | 0.050 | - | - | 0.0020 |

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

**Figure 89. UFBGA(176+25) - Footprint example**

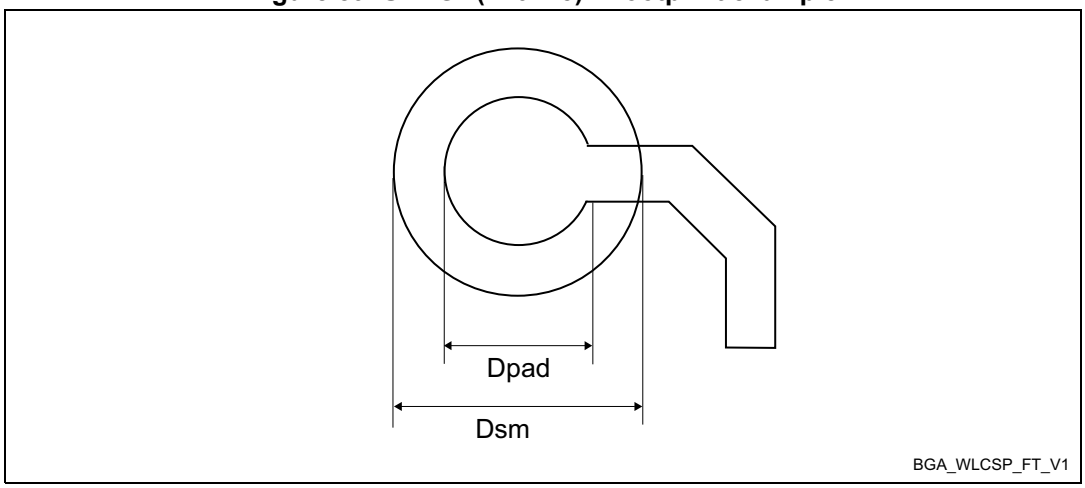


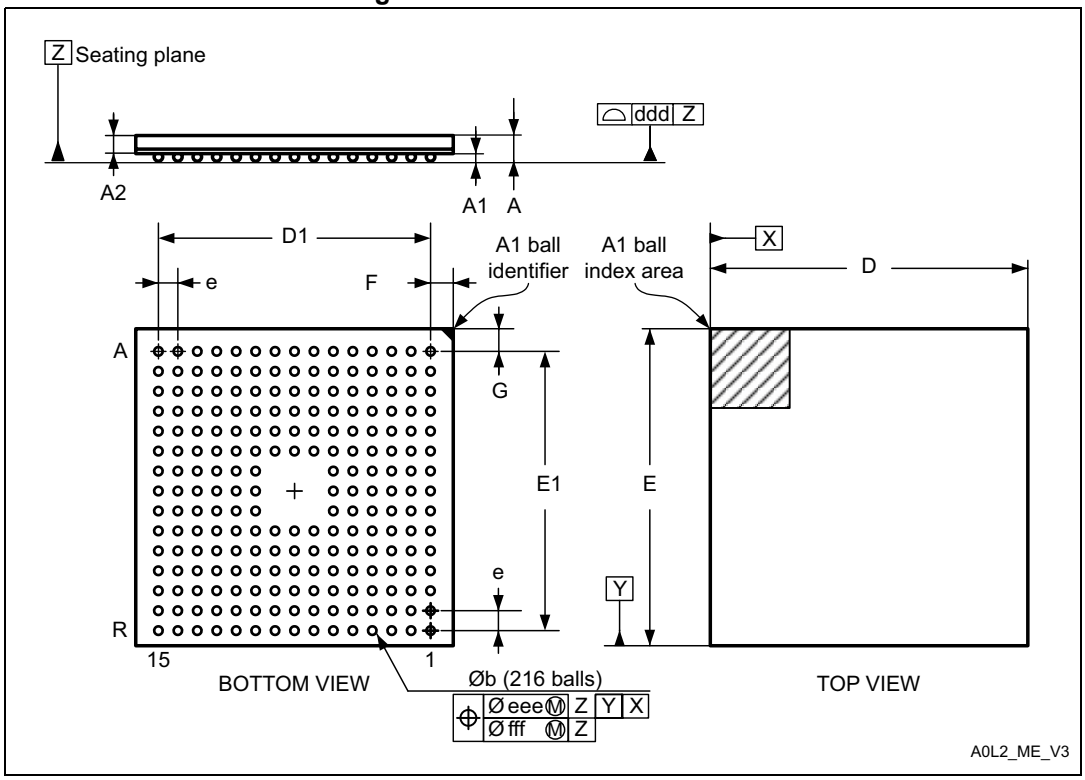

**Table 122. UFBGA(176+25) - Example of PCB design rules (0.65 mm pitch BGA)**

| Dimension | Values |
|---|---|
| Pitch | 0.65 mm |
| Dpad | 0.300 mm |
| Dsm | 0.400 mm typ. (depends on the soldermask registration tolerance) |
| Stencil opening | 0.300 mm |
| Stencil thickness | Between 0.100 mm and 0.125 mm |
| Pad trace width | 0.100 mm |

## 6.8 TFBGA216 package information (A0L2)

This TFBGA is a 216-ball, 13 x 13 mm, 0.8 mm pitch, fine pitch ball grid array package.

**Figure 90. TFBGA216 - Outline**




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

**Table 123. TFBGA216 - Mechanical data**

| Symbol | millimeters | | | inches[1] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | - | 1.200 | - | - | 0.0472 |
| A1[2] | 0.150 | - | - | 0.0059 | - | - |
| A2 | - | 0.760 | - | - | 0.0299 | - |
| b[3] | 0.350 | 0.400 | 0.450 | 0.0138 | 0.0157 | 0.0177 |
| D | 12.850 | 13.000 | 13.150 | 0.5059 | 0.5118 | 0.5177 |
| D1 | - | 11.200 | - | - | 0.4409 | - |
| E | 12.850 | 13.000 | 13.150 | 0.5059 | 0.5118 | 0.5177 |
| E1 | - | 11.200 | - | - | 0.4409 | - |
| e | - | 0.800 | - | - | 0.0315 | - |
| F | - | 0.900 | - | - | 0.0354 | - |
| G | - | 0.900 | - | - | 0.0354 | - |
| ddd | - | - | 0.100 | - | - | 0.0039 |
| eee[4] | - | - | 0.150 | - | - | 0.0059 |
| fff[5] | - | - | 0.080 | - | - | 0.0031 |

1. Values in inches are converted from mm and rounded to four decimal digits.
2. • The terminal A1 corner must be identified on the top surface by using a corner chamfer, ink or metallized markings, or other feature of package body or integral heat slug.
   • A distinguishing feature is allowable on the bottom surface of the package to identify the terminal A1 corner. Exact shape of each corner is optional.
3. Initial ball equal 0.350 mm.
4. The tolerance of position that controls the location of the pattern of balls with respect to datums A and B. For each ball there is a cylindrical tolerance zone eee perpendicular to datum C and located on true position with respect to datums A and B as defined by e. The axis perpendicular to datum C of each ball must lie within this tolerance zone.
5. The tolerance of position that controls the location of the balls within the matrix with respect to each other. For each ball there is a cylindrical tolerance zone fff perpendicular to datum C and located on true position as defined by e. The axis perpendicular to datum C of each ball must lie within this tolerance zone. Each tolerance zone fff in the array is contained entirely in the respective zone eee above The axis of each ball must lie simultaneously in both tolerance zones.

**Figure 91. TFBGA216 - Footprint example**

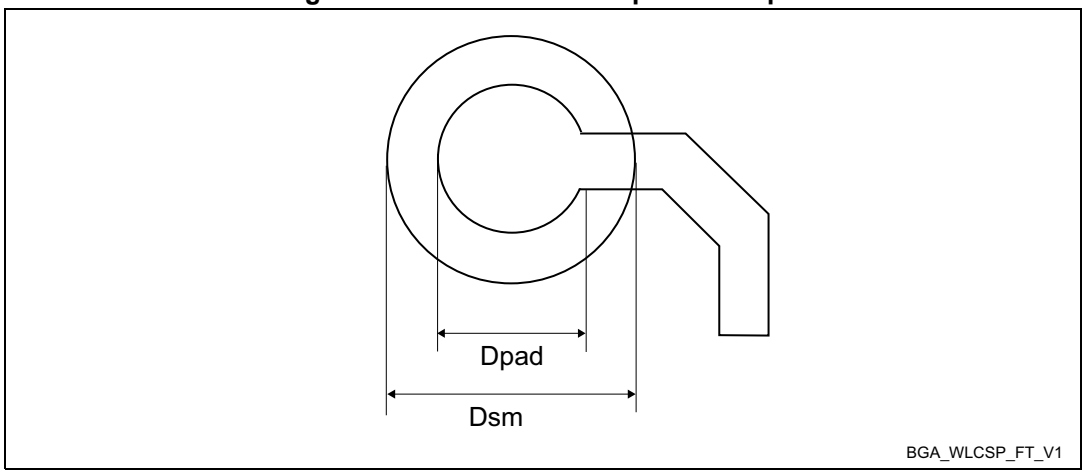


**Table 124. TFBGA216 - Example of PCB design rules (0.8 mm pitch)**

| Dimension | Values |
|---|---|
| Pitch | 0.8 mm |
| Dpad | 0.400 mm |
| Dsm | 0.470 mm typ. (depends on the soldermask registration tolerance) |
| Stencil opening | 0.400 mm |
| Stencil thickness | Between 0.100 mm and 0.125 mm |
| Pad trace width | 0.120 mm |

## 6.9 LQFP208 package information

This LQFP is a 208-pin, 28 x 28 mm low-profile quad flat package.

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

**Figure 92. LQFP208 - Outline(15)**

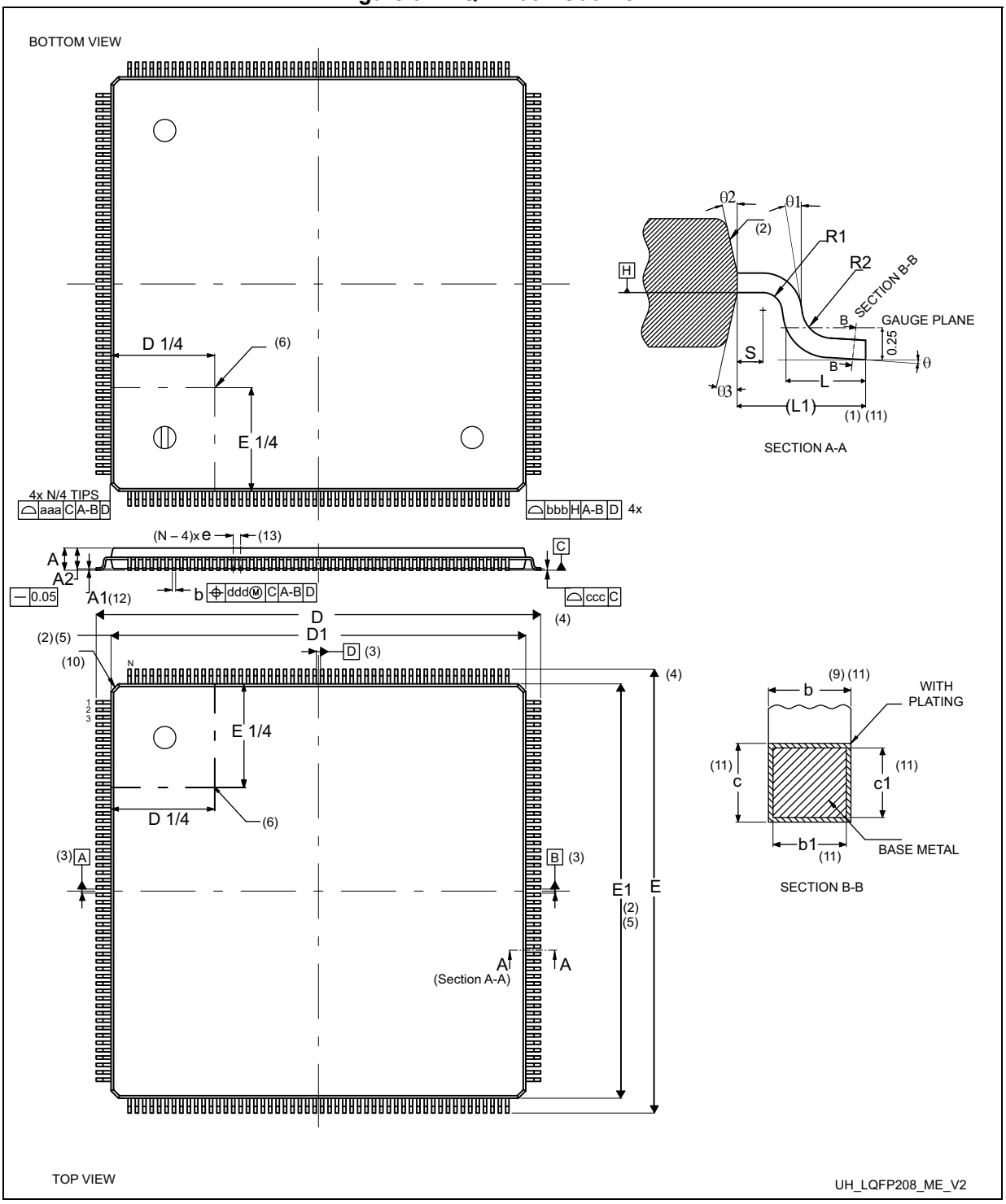


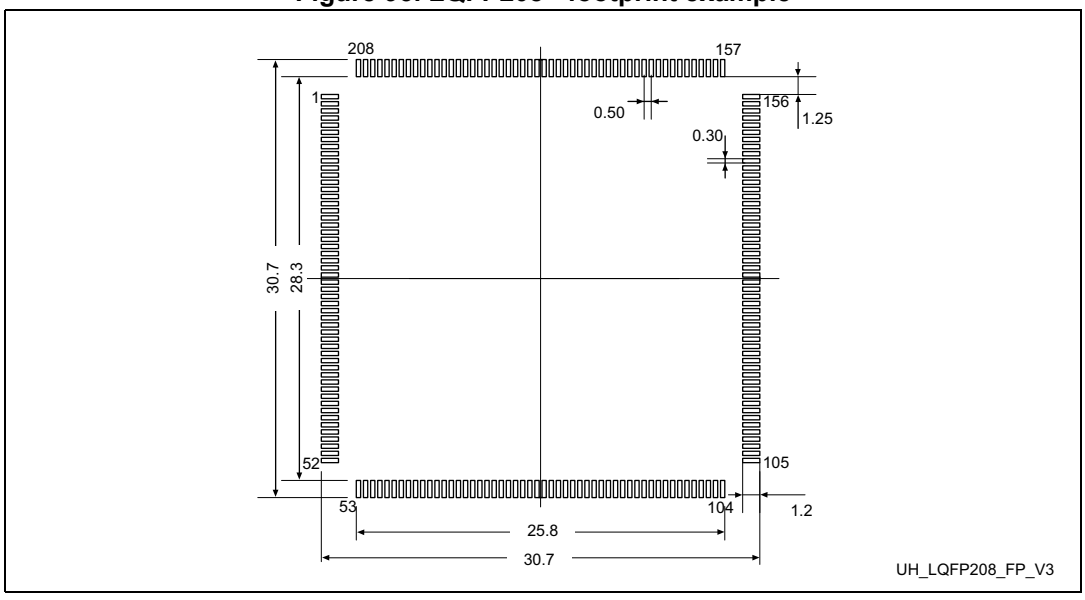
**Table 125. LQFP208 - Mechanical data**

| Symbol | millimeters | | | inches[15] | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | - | - | 1.60 | - | - | 0.0630 |
| A1[12] | 0.05 | - | 0.15 | 0.0020 | - | 0.0059 |
| A2 | 1.35 | 1.40 | 1.45 | 0.0531 | 0.0551 | 0.0571 |
| b[9][11] | 0.17 | 0.22 | 0.27 | 0.0067 | 0.0087 | 0.0106 |
| b1[11] | 0.17 | 0.20 | 0.23 | 0.0067 | 0.0079 | 0.0091 |
| c[11] | 0.09 | - | 0.20 | 0.0035 | - | 0.0079 |
| c1[11] | 0.09 | - | 0.16 | 0.0035 | - | 0.0063 |
| D[4] | 30.00 BSC | | | 1.1732 BSC | | |
| D1[2][5] | 28.00 BSC | | | 1.0945 BSC | | |
| E[4] | 30.00 BSC | | | 1.1732 BSC | | |
| E1[2][5] | 28.00 BSC | | | 1.0945 BSC | | |
| e | 0.50 BSC | | | 0.0197 BSC | | |
| L | 0.45 | 0.60 | 0.75 | 0.0177 | 0.0236 | 0.0295 |
| L1 | 1.00 REF | | | 0.0394 REF | | |
| N[13] | 208 | | | | | |
| θ | 0° | 3.5° | 7° | 0° | 3.5° | 7° |
| θ1 | 0° | - | - | 0° | - | - |
| θ2 | 10° | 12° | 14° | 10° | 12° | 14° |
| θ3 | 10° | 12° | 14° | 10° | 12° | 14° |
| R1 | 0.08 | - | - | 0.0031 | - | - |
| R2 | 0.08 | - | 0.20 | 0.0031 | - | 0.0079 |
| S | 0.20 | - | - | 0.0079 | - | - |
| aaa[1][7] | 0.20 | | | 0.0079 | | |
| bbb[1][7] | 0.20 | | | 0.0079 | | |
| ccc[1][7] | 0.08 | | | 0.0031 | | |
| ddd[1][7] | 0.08 | | | 0.0031 | | |

**Notes:**

1. Dimensioning and tolerancing schemes conform to ASME Y14.5M-1994.
2. The Top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Datums A-B and D to be determined at datum plane H.
4. To be determined at seating datum plane C.
5. Dimensions D1 and E1 do not include mold flash or protrusions. Allowable mold flash or protrusions is “0.25 mm” per side. D1 and E1 are Maximum plastic body size dimensions including mold mismatch.
6. Details of pin 1 identifier are optional but must be located within the zone indicated.
7. All Dimensions are in millimeters.
8. No intrusion allowed inwards the leads.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall not cause the lead width to exceed the maximum “b” dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 mm and 0.5 mm pitch packages.
10. Exact shape of each corner is optional.
11. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
12. A1 is defined as the distance from the seating plane to the lowest point on the package body.
13. “N” is the number of terminal positions for the specified body size.
14. Values in inches are converted from mm and rounded to 4 decimal digits.
15. Drawing is not to scale.

**Figure 93. LQFP208 - footprint example**




1. Dimensions are expressed in millimeters.

## 6.10 Thermal characteristics

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

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

where:

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

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

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

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

**Table 126. Package thermal characteristics**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $\Theta_{JA}$ | **Thermal resistance junction-ambient** LQFP100 | 43 | °C/W |
| | **Thermal resistance junction-ambient** LQFP144 | 40 | |
| | **Thermal resistance junction-ambient** WLCSP168 | 31 | |
| | **Thermal resistance junction-ambient** LQFP176 - 24 × 24 mm / 0.5 mm pitch | 38 | |
| | **Thermal resistance junction-ambient** LQFP208 - 28 × 28 mm / 0.5 mm pitch | 19 | |
| | **Thermal resistance junction-ambient** UFBGA169 - 7 × 7mm / 0.5 mm pitch | 52 | |
| | **Thermal resistance junction-ambient** UFBGA176 - 10 × 10 mm / 0.5 mm pitch | 39 | |
| | **Thermal resistance junction-ambient** TFBGA216 - 13 × 13 mm / 0.8 mm pitch | 29 | |

### Reference document

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

# 7 Part numbering

Example: STM32 F 469 V I T 6 xxx

**Device family**

STM32 = Arm®-based 32-bit microcontroller

**Product type**

F = general-purpose

**Device subfamily**

469= STM32F469xx, USB OTG FS/HS, camera interface, Ethernet, LCD-TFT, DSI Host, Quad-SPI, Chrom-ART graphical accelerator.

**Pin count**

V = 100 pins

Z = 144 pins

A = 168 and 169 pins

I = 176 pins

B = 208 pins

N = 216 pins

**Flash memory size**

E = 512 Kbytes of Flash memory

G = 1024 Kbytes of Flash memory

I = 2048 Kbytes of Flash memory

**Package**

T = LQFP

H = BGA

Y = WLCSP

**Temperature range**

6 = Industrial temperature range, –40 to 85 °C

7 = Industrial temperature range, –40 to 105 °C

**Options**

xxx = programmed parts

TR = tape and reel

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

# 8 Important security notice

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# Appendix A Recommendations when using internal reset OFF

When the internal reset is OFF, the following integrated features are no longer supported:

- The integrated power-on reset (POR) / power-down reset (PDR) circuitry is disabled.
- The brownout reset (BOR) circuitry must be disabled.
- The embedded programmable voltage detector (PVD) is disabled.
- $V_{BAT}$ functionality is no more available and VBAT pin should be connected to $V_{DD}$.
- The over-drive mode is not supported.

## A.1 Operating conditions

**Table 127. Limitations depending on the operating power supply range**

| Operating power supply range | ADC operation | Maximum Flash memory access frequency with no wait states ($f_{Flashmax}$) | Maximum Flash memory access frequency with wait states (1)(2) | I/O operation | Possible Flash memory operations |
|---|---|---|---|---|---|
| $V_{DD}$ =1.7 to 2.1 V(3) | Conversion time up to 1.2 Msps | 20 MHz(4) | 168 MHz with 8 wait states and over-drive OFF | – No I/O compensation | 8-bit erase and program operations only |

1. Applicable only when the code is executed from Flash memory. When the code is executed from RAM, no wait state is required.
2. Thanks to the ART accelerator and the 128-bit Flash memory, the number of wait states given here does not impact the execution speed from Flash memory since the ART accelerator allows to achieve a performance equivalent to 0 wait state program execution.
3. $V_{DD}/V_{DDA}$ minimum value of 1.7 V, with the use of an external power supply supervisor (refer to *Section 2.19.1: Internal reset ON*).
4. Prefetch is not available. Refer to AN3430, available on *www.st.com*, for details on how to adjust performance and power.

# Revision history

**Table 128. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 01-Sep-2015 | 1 | Initial release. |
| 13-Oct-2015 | 2 | Updated Table 4: Regulator ON/OFF and internal reset ON/OFF availability and Table 54: EMI characteristics.<br>Updated Figure 35: PLL output clock waveforms in center spread mode and Figure 36: PLL output clock waveforms in down spread mode.<br>Updated title of Section 6.8: TFBGA216 package information. |
| 08-Mar-2016 | 3 | Updated cover page with introduction of LQFP100 and LQFP144 packages.<br>Updated Section 1: Description and Section 1.1: Compatibility throughout the family.<br>Updated Figure 1: Incompatible board design for LQFP176 package and its footnote.<br>Updated Table 1: Device summary, Table 2: STM32F469xx features and peripheral counts, Table 4: Regulator ON/OFF and internal reset ON/OFF availability, Table 10: STM32F469xx pin and ball definitions, Table 11: FMC pin definition, Table 12: Alternate function, Table 17: General operating conditions, Table 55: ESD absolute maximum ratings, Table 76: ADC characteristics, Table 125: Package thermal characteristics and Table 125: Ordering information scheme.<br>Removed former Table 73: Ethernet DC electrical characteristics.<br>Added Figure 13: STM32F46x LQFP100 pinout and Figure 14: STM32F46x LQFP144 pinout.<br>Updated Figure 17: STM32F46x UFBGA176 ballout, Figure 18: STM32F46x LQFP176 pinout and Figure 33: ACCHSI vs. temperature.<br>Added Section 6.2: LQFP100 package information and Section 6.3: LQFP144 package information.<br>Replaced former footnote 7 of Table 10: STM32F469xx pin and ball definitions with footnote 2.<br>Added footnote 3 to Table 14: Voltage characteristics.<br>Updated footnote 1 of Figure 56 and footnote 1 of Figure 57. |
| 02-Mar-2017 | 4 | Updated Table 12: Alternate function.<br>Corrected maximum characterized wakeup timing values for Stop mode in Table 34: Low-power mode wakeup timings.<br>Updated Figure 14: STM32F46x LQFP144 pinout.<br>Updated Device marking for LQFP100, Device marking for UFBGA169, Device marking for LQFP176, Device marking for LQFP176 and Device marking for LQFP176.<br>Updated footnotes of figures 82, 85, 89, 92, 98 and 100 in Section 6: Package information. |

**Table 128. Document revision history (continued)**

| Date | Revision | Changes |
|---|---|---|
| 04-May-2018 | 5 | Updated Video Mode interfaces features, Section 2.14: Nested vectored interrupt controller (NVIC) and Section 2.18: Power supply schemes.<br>Updated Table 17: General operating conditions, Table 57: I/O current injection susceptibility and Table 64: SPI dynamic characteristics.<br>Updated Figure 49: USB OTG full speed timings: definition of data signal rise and fall time. |
| 18-Jan-2021 | 6 | Updated Table 2: STM32F469xx features and peripheral counts, Table 109: LTDC characteristics and Table 119: UFBGA(176+25) - Mechanical data.<br>Updated footnote 2 of Figure 41: Recommended NRST pin protection and footnote 1 of Table 39: HSI oscillator characteristics.<br>Updated Section 6.3: LQFP144 package information.<br>Updated Figure 93: UFBGA(176+25) - Outline and Figure 94: UFBGA(176+25) - Recommended footprint.<br>Minor text edits across the whole document. |
| 05-May-2021 | 7 | Updated Table 2: STM32F469xx features and peripheral counts.<br>Updated Section 1: Description. |

Table 128. Document revision history (continued)

| Date | Revision | Changes |
|---|---|---|
| 07-Nov-2023 | 8 | **Added the following sections:**<br>*Section 8: Important security notice*<br>*Section 6.1: Device marking*<br><br>**Removed the following sections:**<br>Device marking obsolete content.<br><br>**Updated the following:**<br>*Section 6.2: LQFP100 package information (1L)*<br>*Section 6.3: LQFP144 package information (1A)*<br>*Section 6.4: WLCSP168 package information*<br>*Section 6.5: UFBGA169 package information (A0YV)*<br>*Section 6.7: UFBGA(176+25) package information (A0E7)*<br>*Section 6.8: TFBGA216 package information (A0L2)*<br>*Section 6.9: LQFP208 package information*<br>*Section 2.26: Universal synchronous/asynchronous receiver transmitters (USART)*<br>*Table 2: STM32F469xx features and peripheral counts*<br>*Table 39: HSI oscillator characteristics*<br>*Table 22: Reset and power control block characteristics*<br>*Section 2.4: Embedded flash memory*<br>*Section : Features*<br>*Section Table 10.: STM32F469xx pin and ball definitions*<br>*Section 5.3.20: I/O port characteristics*<br>*Section 2.38: True random number generator (RNG)*<br>*Section 5.3.7: Supply current characteristics* (I/O static current consumption, and I/O dynamic current consumption).<br>*Figure 40: I/O AC characteristics definition*.<br>*Figure 55: Typical connection diagram using the ADC with FT/TT pins featuring analog switch funcion*<br>*Table 54: EMI characteristics for fHSE=8 MHz and fCPU=168 MHz*<br>*Table 55: EMI characteristics for fHSE=8 MHz and fCPU=180 MHz*<br>*Figure 42: SPI timing diagram - slave mode and CPHA = 0*<br>*Figure 43: SPI timing diagram - slave mode and CPHA = 1*<br>*Figure 44: SPI timing diagram - master mode*<br>*Figure 67: NAND controller waveforms for read access*<br>*Figure 68: NAND controller waveforms for write access*<br>Applied minor terminology changes. |

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