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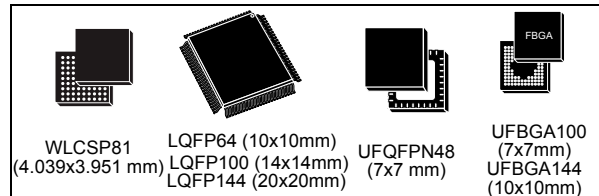


ARM[®]-Cortex[®]-M4 32b MCU+FPU, 125 DMIPS, 1.5MB Flash, 320KB RAM, USB OTG FS, 1 ADC, 2 DACs, 2 DFSDMs, AES

Datasheet - production data

Features

- Dynamic Efficiency Line with eBAM (enhanced Batch Acquisition Mode)
 - 1.7 V to 3.6 V power supply
 - -40 °C to 85/105/125 °C temperature range
- 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 100 MHz, memory protection unit, 125 DMIPS/1.25 DMIPS/MHz (Dhrystone 2.1), and DSP instructions
- Memories
 - 1.5 Mbytes of Flash memory
 - 320 Kbytes of SRAM
 - Flexible external static memory controller with up to 16-bit data bus: SRAM, PSRAM, NOR Flash memory
 - Dual mode Quad-SPI interface
- LCD parallel interface, 8080/6800 modes
- Clock, reset and supply management
 - 1.7 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
 - 32 kHz oscillator for RTC with calibration
 - Internal 32 kHz RC with calibration
- Power consumption
 - Run: 112 µA/MHz (peripheral off)
 - Stop (Flash in Stop mode, fast wakeup time): 42 µA Typ.; 80 µA max @25 °C
 - Stop (Flash in Deep power down mode, slow wakeup time): 15 µA Typ.; 46 µA max @25 °C
 - Standby without RTC: 1.1 µA Typ.; 14.7 µA max at @85 °C
 - V_{BAT} supply for RTC: 1 µA @25 °C
- 2x12-bit D/A converters
- 1x12-bit, 2.4 MSPS ADC: up to 16 channels
- 6x digital filters for sigma delta modulator, 12x PDM interfaces, with stereo microphone and sound source localization support
- General-purpose DMA: 16-stream DMA



- Up to 18 timers: up to twelve 16-bit timers, two 32-bit timers up to 100 MHz each with up to four IC/OC/PWM or pulse counter and quadrature (incremental) encoder input, two watchdog timers (independent and window), one SysTick timer, and a low-power timer
- Debug mode
 - Serial wire debug (SWD) & JTAG
 - Cortex[®]-M4 Embedded Trace Macrocell™
- Up to 114 I/O ports with interrupt capability
 - Up to 109 fast I/Os up to 100 MHz
 - Up to 114 five V-tolerant I/Os
- Up to 24 communication interfaces
 - Up to 4x I²C interfaces (SMBus/PMBus)
 - Up to 10 UARTS: 4 USARTs / 6 UARTS (2 x 12.5 Mbit/s, 2 x 6.25 Mbit/s), ISO 7816 interface, LIN, IrDA, modem control)
 - Up to 5 SPI/I2Ss (up to 50 Mbit/s, SPI or I2S audio protocol), out of which 2 muxed full-duplex I2S interfaces
 - SDIO interface (SD/MMC/eMMC)
 - Advanced connectivity: USB 2.0 full-speed device/host/OTG controller with PHY
 - 3x CAN (2.0B Active)
 - 1xSAI
- True random number generator
- CRC calculation unit
- 96-bit unique ID
- RTC: subsecond accuracy, hardware calendar
- 128/256-bit hardware encryption accelerator (AES)
- All packages are ECOPACK[®]2

Table 1. Device summary

Reference	Part number
STM32F423xH	STM32F423CH STM32F423MH STM32F423RH STM32F423VH STM32F423ZH

Contents

- 1 Introduction 12**
- 2 Description 13**
 - 2.1 Compatibility with STM32F4 series 16
- 3 Functional overview 19**
 - 3.1 ARM® Cortex®-M4 with FPU core with embedded Flash and SRAM ... 19
 - 3.2 Adaptive real-time memory accelerator (ART Accelerator™) 19
 - 3.3 Enhanced Batch Acquisition mode (eBAM) 19
 - 3.4 Memory protection unit 20
 - 3.5 Embedded Flash memory 20
 - 3.6 CRC (cyclic redundancy check) calculation unit 20
 - 3.7 Embedded SRAM 21
 - 3.8 Multi-AHB bus matrix 21
 - 3.9 DMA controller (DMA) 22
 - 3.10 Flexible static memory controller (FSMC) 22
 - 3.11 Quad-SPI memory interface (QUAD-SPI) 23
 - 3.12 Nested vectored interrupt controller (NVIC) 23
 - 3.13 External interrupt/event controller (EXTI) 23
 - 3.14 Clocks and startup 23
 - 3.15 Boot modes 24
 - 3.16 Power supply schemes 25
 - 3.17 Power supply supervisor 26
 - 3.17.1 Internal reset ON 26
 - 3.17.2 Internal reset OFF 27
 - 3.18 Voltage regulator 27
 - 3.18.1 Regulator ON 28
 - 3.18.2 Regulator OFF 28
 - 3.18.3 Regulator ON/OFF and internal reset ON/OFF availability 31
 - 3.19 Real-time clock (RTC) and backup registers 31
 - 3.20 Low-power modes 32
 - 3.21 VBAT operation 32

3.22	Timers and watchdogs	33
3.22.1	Advanced-control timers (TIM1, TIM8)	34
3.22.2	General-purpose timers (TIMx)	34
3.22.3	Basic timer (TIM6, TIM7)	35
3.22.4	Low-power timer (LPTIM1)	35
3.22.5	Independent watchdog	35
3.22.6	Window watchdog	36
3.22.7	SysTick timer	36
3.23	Inter-integrated circuit interface (I2C)	36
3.24	Universal synchronous/asynchronous receiver transmitters (USART)	36
3.25	Serial peripheral interface (SPI)	38
3.26	Inter-integrated sound (I ² S)	38
3.27	Serial Audio interface (SAI1)	38
3.28	Audio PLL (PLLI2S)	38
3.29	Digital filter for sigma-delta modulators (DFSDM)	39
3.30	Dynamic tuning of PDM delays for sound source localization	39
3.31	Secure digital input/output interface (SDIO)	40
3.32	Controller area network (bxCAN)	40
3.33	Universal serial bus on-the-go full-speed (USB_OTG_FS)	40
3.34	Random number generator (RNG)	41
3.35	Advanced encryption standard hardware accelerator (AES)	41
3.36	General-purpose input/outputs (GPIOs)	42
3.37	Analog-to-digital converter (ADC)	42
3.38	Digital to analog converter (DAC)	42
3.39	Temperature sensor	43
3.40	Serial wire JTAG debug port (SWJ-DP)	43
3.41	Embedded Trace Macrocell™	43
4	Pinouts and pin description	44
5	Memory mapping	76
6	Electrical characteristics	80
6.1	Parameter conditions	80
6.1.1	Minimum and maximum values	80

6.1.2	Typical values	80
6.1.3	Typical curves	80
6.1.4	Loading capacitor	80
6.1.5	Pin input voltage	80
6.1.6	Power supply scheme	81
6.1.7	Current consumption measurement	82
6.2	Absolute maximum ratings	82
6.3	Operating conditions	84
6.3.1	General operating conditions	84
6.3.2	VCAP_1/VCAP_2 external capacitors	87
6.3.3	Operating conditions at power-up/power-down (regulator ON)	87
6.3.4	Operating conditions at power-up / power-down (regulator OFF)	88
6.3.5	Embedded reset and power control block characteristics	88
6.3.6	Supply current characteristics	89
6.3.7	Wakeup time from low-power modes	108
6.3.8	External clock source characteristics	110
6.3.9	Internal clock source characteristics	115
6.3.10	PLL characteristics	117
6.3.11	PLL spread spectrum clock generation (SSCG) characteristics	119
6.3.12	Memory characteristics	120
6.3.13	EMC characteristics	123
6.3.14	Absolute maximum ratings (electrical sensitivity)	124
6.3.15	I/O current injection characteristics	125
6.3.16	I/O port characteristics	126
6.3.17	NRST pin characteristics	131
6.3.18	TIM timer characteristics	132
6.3.19	Communications interfaces	133
6.3.20	12-bit ADC characteristics	147
6.3.21	Temperature sensor characteristics	153
6.3.22	V _{BAT} monitoring characteristics	154
6.3.23	Embedded reference voltage	154
6.3.24	DAC electrical characteristics	155
6.3.25	DFSDM characteristics	158
6.3.26	FSMC characteristics	161
6.3.27	SD/SDIO MMC/eMMC card host interface (SDIO) characteristics	175
6.3.28	RTC characteristics	177

7	Package information	178
7.1	WLCSP81 package information	178
7.2	UFQFPN48 package information	182
7.3	LQFP64 package information	185
7.4	LQFP100 package information	189
7.5	LQFP144 package information	192
7.6	UFBGA100 package information	196
7.7	UFBGA144 package information	199
7.8	Thermal characteristics	202
7.8.1	Reference document	202
8	Ordering information	203
Appendix A Recommendations when using the internal reset OFF		204
Appendix B Application block diagrams		205
B.1	Sensor Hub application example	205
B.2	Display application example	206
B.3	USB OTG full speed (FS) interface solutions	207
Revision history		209

List of tables

Table 1.	Device summary	1
Table 2.	STM32F423xH features and peripheral counts	15
Table 3.	Embedded bootloader interfaces	24
Table 4.	Regulator ON/OFF and internal power supply supervisor availability.	31
Table 5.	Timer feature comparison	33
Table 6.	Comparison of I2C analog and digital filters	36
Table 7.	USART feature comparison	37
Table 8.	DFSDM feature comparison	39
Table 9.	Legend/abbreviations used in the pinout table	50
Table 10.	STM32F423xH pin definition	51
Table 11.	FSMC pin definition	65
Table 12.	STM32F423xH alternate functions	68
Table 13.	STM32F423xH register boundary addresses	77
Table 14.	Voltage characteristics	82
Table 15.	Current characteristics	83
Table 16.	Thermal characteristics	83
Table 17.	General operating conditions	84
Table 18.	Features depending on the operating power supply range	86
Table 19.	VCAP_1/VCAP_2 operating conditions	87
Table 20.	Operating conditions at power-up / power-down (regulator ON)	87
Table 21.	Operating conditions at power-up / power-down (regulator OFF).	88
Table 22.	Embedded reset and power control block characteristics	88
Table 23.	Typical and maximum current consumption, code with data processing (ART accelerator disabled) running from SRAM - $V_{DD} = 1.7\text{ V}$	90
Table 24.	Typical and maximum current consumption, code with data processing (ART accelerator disabled) running from SRAM - $V_{DD} = 3.6\text{ V}$	91
Table 25.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator enabled except prefetch) running from Flash memory- $V_{DD} = 1.7\text{ V}$	92
Table 26.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator enabled except prefetch) running from Flash memory - $V_{DD} = 3.6\text{ V}$	93
Table 27.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator disabled) running from Flash memory - $V_{DD} = 3.6\text{ V}$	94
Table 28.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator disabled) running from Flash memory - $V_{DD} = 1.7\text{ V}$	95
Table 29.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator enabled with prefetch) running from Flash memory - $V_{DD} = 3.6\text{ V}$	96
Table 30.	Typical and maximum current consumption in run mode, code with data processing (ART accelerator enabled with prefetch) running from Flash memory - $V_{DD} = 1.7\text{ V}$	97
Table 31.	Typical and maximum current consumption in Sleep mode - $V_{DD} = 3.6\text{ V}$	98
Table 32.	Typical and maximum current consumption in Sleep mode - $V_{DD} = 1.7\text{ V}$	100
Table 33.	Typical and maximum current consumptions in Stop mode - $V_{DD} = 1.7\text{ V}$	101
Table 34.	Typical and maximum current consumption in Stop mode - $V_{DD}=3.6\text{ V}$	101
Table 35.	Typical and maximum current consumption in Standby mode - $V_{DD}= 1.7\text{ V}$	101
Table 36.	Typical and maximum current consumption in Standby mode - $V_{DD}= 3.6\text{ V}$	102
Table 37.	Typical and maximum current consumptions in V_{BAT} mode.	102
Table 38.	Switching output I/O current consumption	105
Table 39.	Peripheral current consumption	106
Table 40.	Low-power mode wakeup timings	110

Table 41.	High-speed external user clock characteristics	111
Table 42.	Low-speed external user clock characteristics	111
Table 43.	HSE 4-26 MHz oscillator characteristics	113
Table 44.	LSE oscillator characteristics ($f_{LSE} = 32.768$ kHz)	114
Table 45.	HSI oscillator characteristics	115
Table 46.	LSI oscillator characteristics	116
Table 47.	Main PLL characteristics	117
Table 48.	PLLI2S (audio PLL) characteristics	118
Table 49.	SSCG parameter constraints	119
Table 50.	Flash memory characteristics	120
Table 51.	Flash memory programming	121
Table 52.	Flash memory programming with V_{PP} voltage	122
Table 53.	Flash memory endurance and data retention	122
Table 54.	EMS characteristics for LQFP144 package	123
Table 55.	EMI characteristics for LQFP144	124
Table 56.	ESD absolute maximum ratings	125
Table 57.	Electrical sensitivities	125
Table 58.	I/O current injection susceptibility	126
Table 59.	I/O static characteristics	126
Table 60.	Output voltage characteristics	129
Table 61.	I/O AC characteristics	130
Table 62.	NRST pin characteristics	131
Table 63.	TIMx characteristics	132
Table 64.	I ² C characteristics	133
Table 65.	SCL frequency ($f_{PCLK1} = 50$ MHz, $V_{DD} = V_{DD_I2C} = 3.3$ V)	134
Table 66.	FMPI ² C characteristics	135
Table 67.	SPI dynamic characteristics	137
Table 68.	I ² S dynamic characteristics	140
Table 69.	SAI characteristics	142
Table 70.	QSPI dynamic characteristics in SDR mode	144
Table 71.	QSPI dynamic characteristics in DDR mode	144
Table 72.	USB OTG FS startup time	145
Table 73.	USB OTG FS DC electrical characteristics	145
Table 74.	USB OTG FS electrical characteristics	146
Table 75.	ADC characteristics	147
Table 76.	ADC accuracy at $f_{ADC} = 18$ MHz	148
Table 77.	ADC accuracy at $f_{ADC} = 30$ MHz	149
Table 78.	ADC accuracy at $f_{ADC} = 36$ MHz	149
Table 79.	ADC dynamic accuracy at $f_{ADC} = 18$ MHz - limited test conditions	149
Table 80.	ADC dynamic accuracy at $f_{ADC} = 36$ MHz - limited test conditions	149
Table 81.	Temperature sensor characteristics	153
Table 82.	Temperature sensor calibration values	153
Table 83.	V_{BAT} monitoring characteristics	154
Table 84.	Embedded internal reference voltage	154
Table 85.	Internal reference voltage calibration values	154
Table 86.	DAC characteristics	155
Table 87.	DFSDM characteristics	158
Table 88.	Asynchronous non-multiplexed SRAM/PSRAM/NOR - read timings	163
Table 89.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read - NWAIT timings	163
Table 90.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings	164

Table 91.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write - NWAIT timings	165
Table 92.	Asynchronous multiplexed PSRAM/NOR read timings	166
Table 93.	Asynchronous multiplexed PSRAM/NOR read-NWAIT timings	166
Table 94.	Asynchronous multiplexed PSRAM/NOR write timings	168
Table 95.	Asynchronous multiplexed PSRAM/NOR write-NWAIT timings	168
Table 96.	Synchronous multiplexed NOR/PSRAM read timings	170
Table 97.	Synchronous multiplexed PSRAM write timings	172
Table 98.	Synchronous non-multiplexed NOR/PSRAM read timings	173
Table 99.	Synchronous non-multiplexed PSRAM write timings	174
Table 100.	SD / MMC characteristics	176
Table 101.	eMMC characteristics VDD = 1.7 V to 1.9 V	176
Table 102.	RTC characteristics	177
Table 103.	WLCSP81 - 81-ball, 4.039 x 3.951 mm, 0.4 mm pitch wafer level chip scale package mechanical data	179
Table 104.	WLCSP81 recommended PCB design rules (0.4 mm pitch)	180
Table 105.	UFQFPN48 - 48-lead, 7x7 mm, 0.5 mm pitch, ultra thin fine pitch quad flat package mechanical data	183
Table 106.	LQFP64 - 64-pin, 10 x 10 mm low-profile quad flat package mechanical data	186
Table 107.	LQPF100 - 100-pin, 14 x 14 mm low-profile quad flat package mechanical data	189
Table 108.	LQFP144 - 144-pin, 20 x 20 mm low-profile quad flat package mechanical data	193
Table 109.	UFBGA100 - 100-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package mechanical data	196
Table 110.	UFBGA100 recommended PCB design rules (0.5 mm pitch BGA)	197
Table 111.	UFBGA144 - 144-ball, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package mechanical data	199
Table 112.	UFBGA144 recommended PCB design rules (0.80 mm pitch BGA)	200
Table 113.	Package thermal characteristics	202
Table 114.	Ordering information scheme	203
Table 115.	Document revision history	209

List of figures

Figure 1.	Compatible board design for LQFP100 package	16
Figure 2.	Compatible board design for LQFP64 package	17
Figure 3.	Compatible board design for LQFP144 package	17
Figure 4.	STM32F423xH block diagram	18
Figure 5.	Multi-AHB matrix	21
Figure 6.	VDDUSB connected to an external independent power supply	26
Figure 7.	Power supply supervisor interconnection with internal reset OFF	27
Figure 8.	Regulator OFF	29
Figure 9.	Startup in regulator OFF: slow V_{DD} slope power-down reset risen after V_{CAP_1}/V_{CAP_2} stabilization	30
Figure 10.	Startup in regulator OFF mode: fast V_{DD} slope power-down reset risen before V_{CAP_1}/V_{CAP_2} stabilization	30
Figure 11.	STM32F423xH WLCSP81 pinout	44
Figure 12.	STM32F423xH UFQFPN48 pinout	45
Figure 13.	STM32F423xH LQFP64 pinout	46
Figure 14.	STM32F423xH LQFP100 pinout	47
Figure 15.	STM32F423xH LQFP144 pinout	48
Figure 16.	STM32F423xH UFBGA100 pinout	49
Figure 17.	STM32F423xH UFBGA144 pinout	50
Figure 18.	Memory map	76
Figure 19.	Pin loading conditions	80
Figure 20.	Input voltage measurement	80
Figure 21.	Power supply scheme	81
Figure 22.	Current consumption measurement scheme	82
Figure 23.	External capacitor C_{EXT}	87
Figure 24.	Typical V_{BAT} current consumption (LSE and RTC ON/LSE oscillator “low power” mode selection)	103
Figure 25.	Typical V_{BAT} current consumption (LSE and RTC ON/LSE oscillator “high drive” mode selection)	103
Figure 26.	Low-power mode wakeup	109
Figure 27.	High-speed external clock source AC timing diagram	112
Figure 28.	Low-speed external clock source AC timing diagram	112
Figure 29.	Typical application with an 8 MHz crystal	113
Figure 30.	Typical application with a 32.768 kHz crystal	114
Figure 31.	ACC_{HSI} versus temperature	115
Figure 32.	ACC_{LSI} versus temperature	116
Figure 33.	PLL output clock waveforms in center spread mode	120
Figure 34.	PLL output clock waveforms in down spread mode	120
Figure 35.	FT/TC I/O input characteristics	128
Figure 36.	I/O AC characteristics definition	131
Figure 37.	Recommended NRST pin protection	132
Figure 38.	I ² C bus AC waveforms and measurement circuit	134
Figure 39.	FMPI ² C timing diagram and measurement circuit	136
Figure 40.	SPI timing diagram - slave mode and CPHA = 0	138
Figure 41.	SPI timing diagram - slave mode and CPHA = 1	139
Figure 42.	SPI timing diagram - master mode	139
Figure 43.	I ² S slave timing diagram (Philips protocol)	141
Figure 44.	I ² S master timing diagram (Philips protocol)	141

Figure 45.	SAI master timing waveforms	143
Figure 46.	SAI slave timing waveforms	143
Figure 47.	USB OTG FS timings: definition of data signal rise and fall time	146
Figure 48.	ADC accuracy characteristics	150
Figure 49.	Typical connection diagram using the ADC	151
Figure 50.	Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})	152
Figure 51.	Power supply and reference decoupling (V_{REF+} connected to V_{DDA})	153
Figure 52.	12-bit buffered /non-buffered DAC	157
Figure 53.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms	162
Figure 54.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms	164
Figure 55.	Asynchronous multiplexed PSRAM/NOR read waveforms	165
Figure 56.	Asynchronous multiplexed PSRAM/NOR write waveforms	167
Figure 57.	Synchronous multiplexed NOR/PSRAM read timings	169
Figure 58.	Synchronous multiplexed PSRAM write timings	171
Figure 59.	Synchronous non-multiplexed NOR/PSRAM read timings	173
Figure 60.	Synchronous non-multiplexed PSRAM write timings	174
Figure 61.	SDIO high-speed mode	175
Figure 62.	SD default mode	175
Figure 63.	WLCSP81 - 81-ball, 4.039 x 3.951 mm, 0.4 mm pitch wafer level chip scale package outline	178
Figure 64.	WLCSP81- 81-ball, 4.039 x 3.951 mm, 0.4 mm pitch wafer level chip scale package recommended footprint	180
Figure 65.	WLCSP81 marking example (package top view)	181
Figure 66.	UFQFPN48 - 48-lead, 7x7 mm, 0.5 mm pitch, ultra thin fine pitch quad flat package outline	182
Figure 67.	UFQFPN48 recommended footprint	183
Figure 68.	UFQFPN48 marking example (package top view)	184
Figure 69.	LQFP64 - 64-pin, 10 x 10 mm low-profile quad flat package outline	185
Figure 70.	LQFP64 recommended footprint	187
Figure 71.	LQFP64 marking example (package top view)	188
Figure 72.	LQFP100 - 100-pin, 14 x 14 mm low-profile quad flat package outline	189
Figure 73.	LQFP100 - 100-pin, 14 x 14 mm low-profile quad flat recommended footprint	190
Figure 74.	LQFP100 marking example (package top view)	191
Figure 75.	LQFP144 - 144-pin, 20 x 20 mm low-profile quad flat package outline	192
Figure 76.	LQFP144 - 144-pin, 20 x 20 mm low-profile quad flat package recommended footprint	194
Figure 77.	LQFP144 marking example (package top view)	195
Figure 78.	UFBGA100 - 100-pin, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package outline	196
Figure 79.	UFBGA100 - 100-pin, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package recommended footprint	197
Figure 80.	UFBGA100 marking example (package top view)	198
Figure 81.	UFBGA144 - 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package outline	199
Figure 82.	UFBGA144 - 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array recommended footprint	200
Figure 83.	UFBGA144 marking example (package top view)	201
Figure 84.	Sensor Hub application example	205
Figure 85.	Display application example	206
Figure 86.	USB controller configured as peripheral-only and used in Full speed mode	207
Figure 87.	USB peripheral-only Full speed mode with direct connection	

	for VBUS sense	207
Figure 88.	USB peripheral-only Full speed mode, VBUS detection using GPIO	208
Figure 89.	USB controller configured as host-only and used in full speed mode	208

1 Introduction

This datasheet provides the description of the STM32F423xH microcontrollers.

For information on the Cortex[®]-M4 core, please refer to the Cortex[®]-M4 programming manual (PM0214) available from www.st.com.



2 Description

The STM32F423xH devices are based on the high-performance ARM[®] Cortex[®]-M4 32-bit RISC core operating at a frequency of up to 100 MHz. Their 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 STM32F423xH devices belong to the STM32F423xH access product lines (with products combining power efficiency, performance and integration) while adding a new innovative feature called Batch Acquisition Mode (BAM) allowing to save even more power consumption during data batching.

The STM32F423xH devices incorporate high-speed embedded memories (1.5 Mbytes of Flash memory, 320 Kbytes of SRAM), and an extensive range of enhanced I/Os and peripherals connected to two APB buses, three AHB buses and a 32-bit multi-AHB bus matrix.

All devices offer a 12-bit ADC, two 12-bit DACs, a low-power RTC, twelve general-purpose 16-bit timers including two PWM timer for motor control, two general-purpose 32-bit timers and a low power timer.

They also feature standard and advanced communication interfaces.

- Up to four I²Cs, including one I²C supporting Fast-Mode Plus
- Five SPIs
- Five I²Ss out of which two are full duplex. To achieve audio class accuracy, the I²S peripherals can be clocked via a dedicate internal audio PLL or via an external clock to allow synchronization.
- Four USARTs and six UARTs
- An SDIO/MMC interface
- An USB 2.0 OTG full-speed interface
- Three CANs
- An SAI.

In addition, the STM32F423xH devices embed advanced peripherals:

- A flexible static memory control interface (FSMC)
- A Quad-SPI memory interface
- Two digital filter for sigma modulator (DFSDM) supporting microphone MEMs and sound source localization, one with two filters and up to four inputs, and the second one with four filters and up to eight inputs

The STM32F423xH devices embed an AES hardware accelerator.

They are offered in 7 packages ranging from 48 to 144 pins. The set of available peripherals depends on the selected package. Refer to [Table 2: STM32F423xH features and peripheral counts](#) for the peripherals available for each part number.

The STM32F423xH operate in the – 40 to + 125 °C temperature range from a 1.7 (PDR OFF) to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power applications.

These features make the STM32F423xH 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
- Mobile phone sensor hub
- Wearable devices
- Connected objects
- Wifi modules

Figure 4 shows the general block diagram of the devices.

Table 2. STM32F423xH features and peripheral counts

Peripherals		STM32F423xH				
Flash memory (Kbyte)		1536				
SRAM (Kbyte)	System	320 (256 + 64)				
FSMC memory controller		-	1 ⁽¹⁾	1 ⁽¹⁾	1 ⁽¹⁾	1
FSMC LCD parallel interface Data bus size		-	8	16		
Quad-SPI memory interface		-	1			
Timers	General-purpose	10 ⁽²⁾	10	10 ⁽³⁾	10	
	Advanced-control	2 ⁽⁴⁾	2			
	Basic	2				
	Low-power timer	1				
Random number generator		1				
AES		1				
Comm. interfaces	SPI/ I ² S	5/5 (2 full duplex)				
	I ² C	3				
	I ² CFMP	1				
	USART/UART	3/3	4/3		4/6	
	SDIO/MMC	1				
	USB/OTG FS Dual power rail	1 No	1 Yes	1 No	1 Yes	
	CAN	3				
	SAI	1				
Number of digital Filtersfor Sigma-delta modulator		6				
Number of channels		7	11	12		
GPIOs		36	50	60	81	114
12-bit ADC		1				
Number of channels		10	16			
12-bit DAC		Yes				
Number of channels		2				
Maximum CPU frequency		100 MHz				
Operating voltage		1.7 to 3.6 V				
Operating temperatures		Ambient temperatures: – 40 to + 85 °C/– 40 to + 105 °C / – 40 to + 125 °C Junction temperature: – 40 to + 130 °C				
Package		UFQFPN48	LQFP64	WLCSP81	UFBGA100 LQFP100	UFBGA144 LQFP144

- 64 pins packages support only 8 bits multiplexed mode interface
81 pins packages support 1 external memory of up to 64KB in multiplexed mode
100 pins packages support 2 external memories of up to 64MB in multiplexed mode
Refer to [Table 11: FSMC pin definition](#) for more detailed information.
- 48 pins packages: TIM3 and TIM4: ETR pin not available.



- 3. 81 pins packages: TIM4: ETR pin not available.
- 4. 48 pins packages: TIM8:CH1, CH2, CH3 and CH4 pins not available.

2.1 Compatibility with STM32F4 series

The STM32F423xH are fully software and feature compatible with the STM32F4 series (STM32F42x, STM32F401, STM32F43x, STM32F41x, STM32F405 and STM32F407)

The STM32F423xH can be used as drop-in replacement of the other STM32F4 products but some slight changes have to be done on the PCB board.

Figure 1. Compatible board design for LQFP100 package

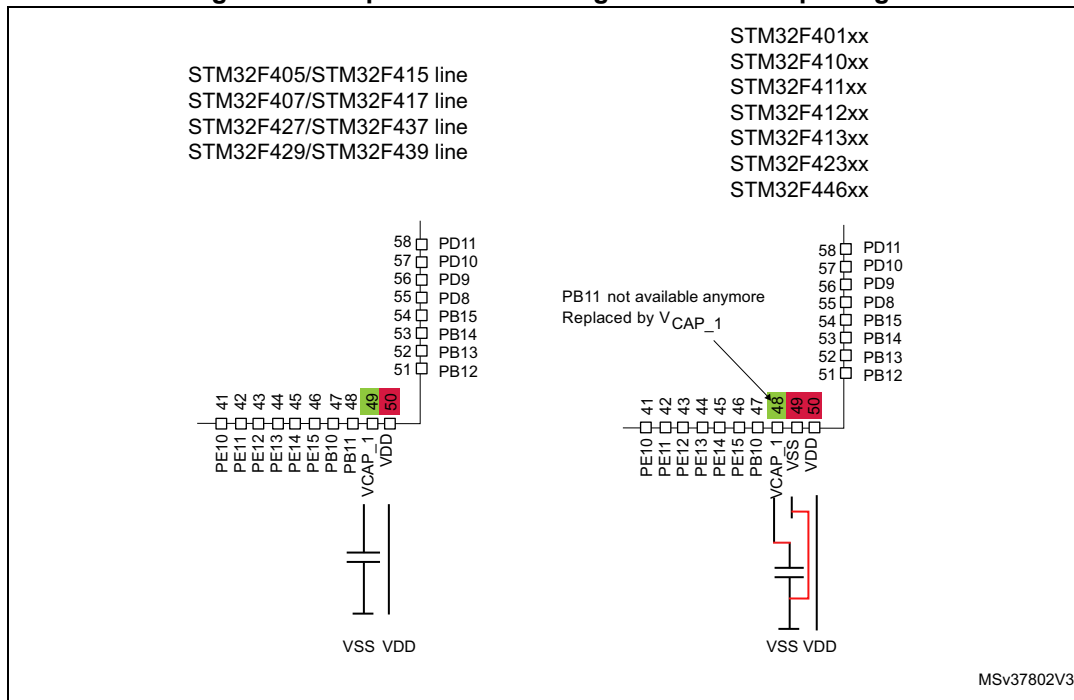


Figure 2. Compatible board design for LQFP64 package

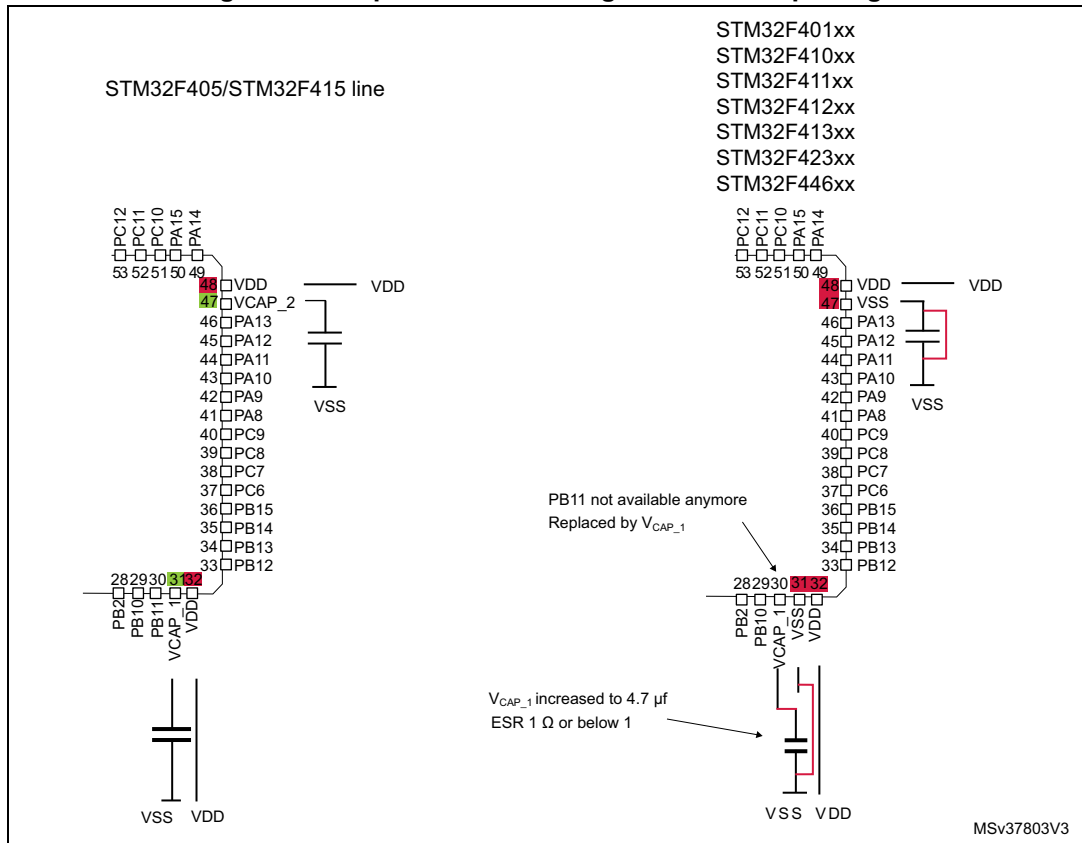


Figure 3. Compatible board design for LQFP144 package

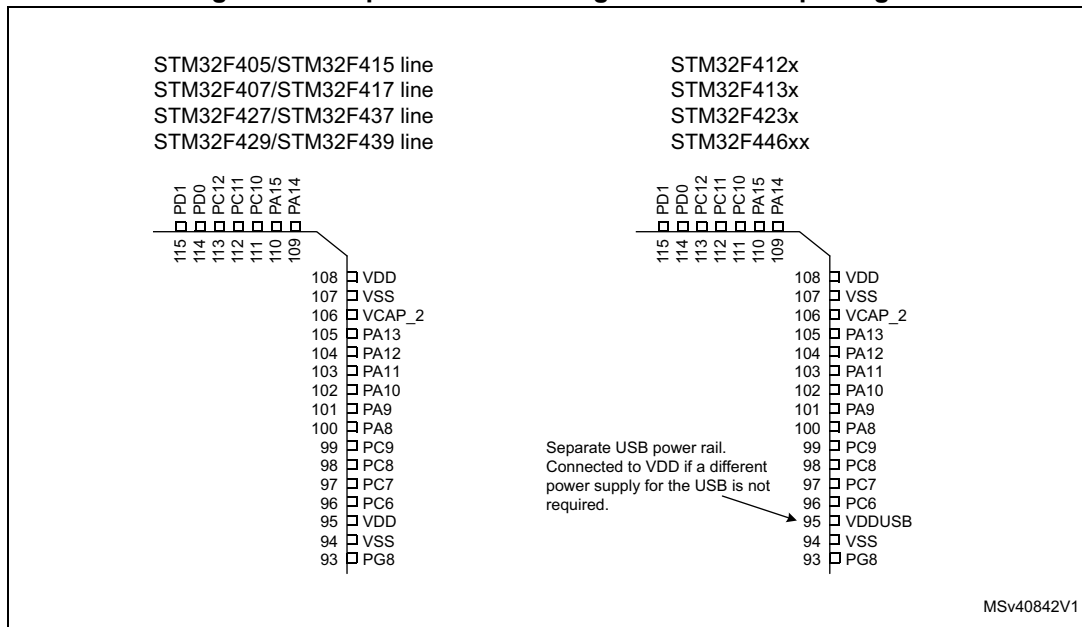
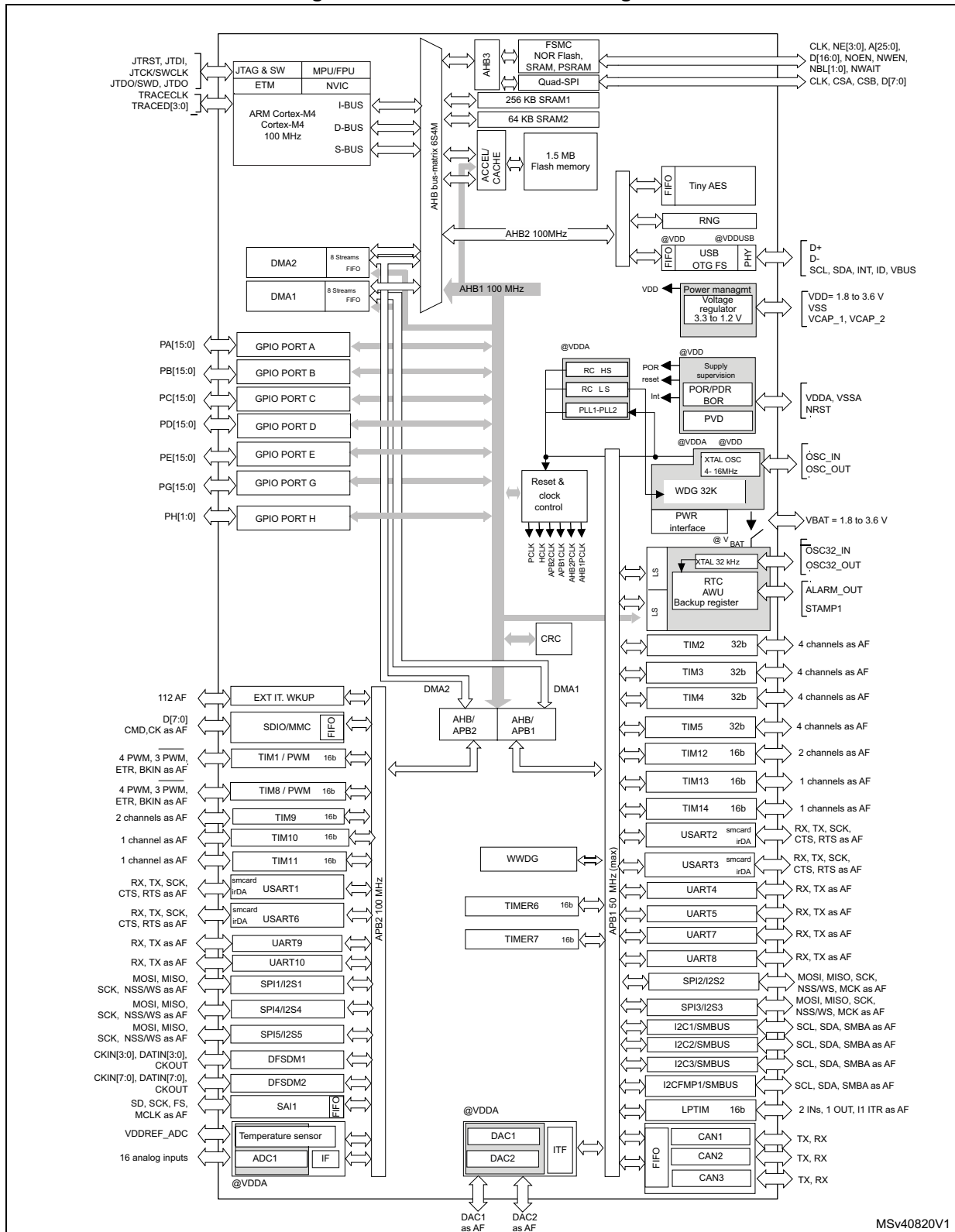


Figure 4. STM32F423xH block diagram



1. The timers connected to APB2 are clocked from TIMxCLK up to 100 MHz, while the timers connected to APB1 are clocked from TIMxCLK up to 50 MHz.

3 Functional overview

3.1 ARM[®] Cortex[®]-M4 with FPU core with embedded Flash and SRAM

The ARM[®] Cortex[®]-M4 with FPU processor is the latest generation of ARM processors for embedded systems. It was 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 32-bit RISC processor features exceptional code-efficiency, delivering the high-performance expected from an ARM core in the memory size usually associated with 8- and 16-bit devices.

The processor supports a set of DSP instructions which 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 STM32F423xH devices are compatible with all ARM tools and software.

Figure 4 shows the general block diagram of the STM32F423xH.

Note: Cortex[®]-M4 with FPU is binary compatible with Cortex[®]-M3.

3.2 Adaptive real-time memory accelerator (ART Accelerator™)

The ART Accelerator™ is a memory accelerator which is 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 requires the processor to wait for the Flash memory at higher frequencies.

To release the processor full 125 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 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 100 MHz.

3.3 Enhanced Batch Acquisition mode (eBAM)

The Batch acquisition mode allows enhanced power efficiency during data batching. It enables data acquisition through any communication peripherals directly to memory using the DMA in reduced power consumption as well as data processing while the rest of the system is in low-power mode (including the Flash and ART). For example in an audio system, a smart combination of PDM audio sample acquisition and processing from the DFSDM directly to RAM (Flash and ART™ stopped) with the DMA using BAM followed by some very short processing from Flash allows to drastically reduce the power consumption of the application.

The BAM has been enhanced by adding SRAM2 that allows SRAM code to be executed through the Ibus and Dbus, thus improving code execution performance.

A dedicated application note (AN4515) describes how to implement the STM32F423xH BAM to allow the best power efficiency.

3.4 Memory protection unit

The memory protection unit (MPU) is used to manage the CPU accesses to memory to prevent one task to accidentally corrupt the memory or resources used by any other active task. This memory area 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 byte and the whole 4 Gbyte 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.

3.5 Embedded Flash memory

The devices embed 1.5 Mbytes of Flash memory available for storing programs and data, plus 512 bytes of one-time programmable (OTP) memory organized in 16 blocks of 32 bytes, each which can be independently locked.

The user Flash memory area can be protected against read operations by an entrusted code (read protection or RDP). Different protection levels are available. The user Flash memory is divided into sectors, which can be individually protected against write operation. Flash sectors can also be protected individually against D-bus read accesses by using the proprietary readout protection (PCROP).

Refer to the product line reference manual for additional information on OTP area and protection features.

To optimize the power consumption the Flash memory can also be switched off in Run or in Sleep mode (see [Section 3.20: Low-power modes](#)).

Two modes are available: Flash in Stop mode or in DeepSleep mode (trade off between power saving and startup time).

Before disabling the Flash, the code must be executed from the internal RAM.

3.6 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.

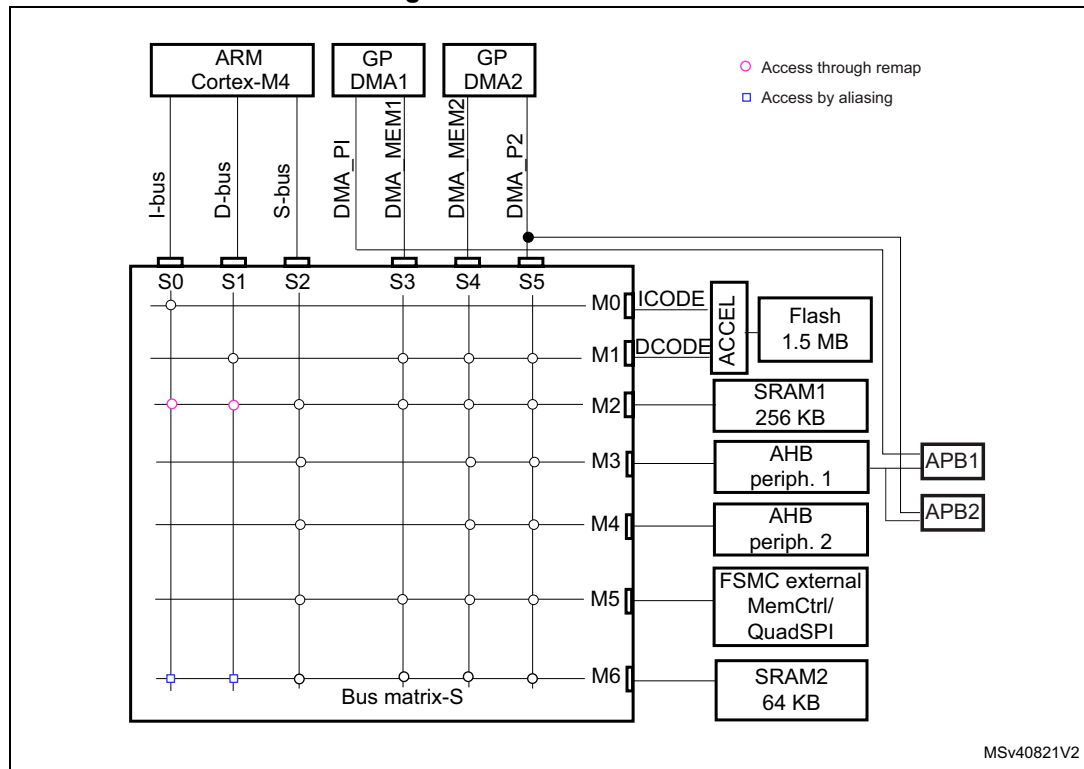
3.7 Embedded SRAM

All devices embed 320 Kbytes of system SRAM which can be accessed (read/write) at CPU clock speed with 0 wait states.

3.8 Multi-AHB bus matrix

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

Figure 5. Multi-AHB matrix



CPU can access SRAM1 memory via S-bus, when SRAM1 is mapped at the address range: 0x2000 0000 to 0x2003 FFFF.

CPU can access SRAM2 memory via S-bus, when SRAM2 is mapped at the address range: 0x2004 0000 to 0x2004 FFFF.

CPU can access SRAM1 memory via I-bus and D-bus, when SRAM1 is remapped at address 0x0000 0000 either by booting from RAM memory or by the remap mode.

CPU can access SRAM2 memory via I-bus and D-bus, when SRAM2 is mapped at the address range: 0x1000 0000 to 0x1000 FFFF.

Performance boosts up, when the CPU access SRAM memory via the I-bus.

3.9 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 I²S
- I²C and I²C/FMP
- USART
- General-purpose, basic and advanced-control timers TIMx
- SD/SDIO/MMC/eMMC host interface
- Quad-SPI
- ADC
- DAC
- Digital Filter for sigma-delta modulator (DFSDM) with a separate stream for each filter
- SAI.

3.10 Flexible static memory controller (FSMC)

The Flexible static memory controller (FSMC) includes a NOR/PSRAM memory controller. It features four Chip Select outputs supporting the following modes: SRAM, PSRAM and NOR Flash memory.

The main functions are:

- 8-, 16-bit data bus width
- Write FIFO
- Maximum FSMC_CLK frequency for synchronous accesses is 90 MHz.

LCD parallel interface

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

3.11 Quad-SPI memory interface (QUAD-SPI)

All devices embed a Quad-SPI memory interface, which is a specialized communication interface targeting single, dual or quad-SPI Flash memories. It can work in direct mode through registers, external Flash status register polling mode and memory mapped mode. Up to 256 Mbyte of external Flash memory are mapped. They can be accessed in 8, 16 or 32-bit mode. Code execution is also supported. The opcode and the frame format are fully programmable. Communication can be performed either in single data rate or dual data rate.

3.12 Nested vectored interrupt controller (NVIC)

The devices embed a nested vectored interrupt controller able to manage 16 priority levels, and handle up to 102 maskable interrupt channels plus the 16 interrupt lines of the Cortex[®]-M4 with FPU.

- 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
- Interrupt entry restored on interrupt exit with no instruction overhead

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

3.13 External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 24 edge-detector lines used to generate interrupt/event requests. Each line can be 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 114 GPIOs can be connected to the 16 external interrupt lines.

3.14 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 at 25 °C. 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 100 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 three AHB buses, the high-speed APB (APB2) and the low-speed APB (APB1) domains. The maximum frequency of the three AHB

buses and high-speed APB domains is 100 MHz. The maximum allowed frequency of the low-speed APB domain is 50 MHz.

The devices embed a dedicated PLL (PLL12S) which allows to achieve audio class performance. In this case, the I²S master clock can generate all standard sampling frequencies from 8 kHz to 192 kHz.

3.15 Boot modes

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

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

The boot loader is located in system memory. It is used to reprogram the Flash memory by using one of the interface listed in the [Table 3](#) or the USB OTG FS in device mode through DFU (device firmware upgrade).

Table 3. Embedded bootloader interfaces

Package	USART1 PA9/ PA10	USART2 PD6/ PD5	USART3 PB11/ PB10	I2C1 PB6/ PB7	I2C2 PF0/ PF1	I2C3 PA8/ PB4	I2C FMP1 PB14/ PB15	SPI1 PA4/ PA5/ PA6/ PA7	SPI3 PA15/ PC10/ PC11/ PC12	SPI4 PE11/ PE12/ PE13/ PE14	CAN2 PB5/ PB13	USB PA11 /P12
UFQFPN48	Y	-	-	Y	-	Y	Y	Y	-	-	Y	Y
LQFP64	Y	-	-	Y	-	Y	Y	Y	Y	-	Y	Y
WLCSP81	Y	-	-	Y	-	Y	Y	Y	Y	Y	Y	Y
LQFP100	Y	Y	-	Y	-	Y	Y	Y	Y	Y	Y	Y
LQFP144	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
UFBGA100	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y
UFBGA144	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

For more detailed information on the bootloader, refer to Application Note: AN2606, *STM32™ microcontroller system memory boot mode*.

3.16 Power supply schemes

- $V_{DD} = 1.7$ to 3.6 V: external power supply for I/Os with the internal supervisor (POR/PDR) disabled, provided externally through V_{DD} pins. Requires the use of an external power supply supervisor connected to the V_{DD} and NRST pins.
- $V_{SSA}, V_{DDA} = 1.7$ to 3.6 V: external analog power supplies for ADC, Reset blocks, RCs and PLL. V_{DDA} and V_{SSA} must be connected to V_{DD} and V_{SS} , respectively, with decoupling technique.

Note: The V_{DD}/V_{DDA} minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to [Section 3.17.2: Internal reset OFF](#)). Refer to [Table 4: Regulator ON/OFF and internal power supply supervisor availability](#) 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 VDD or an external independent power supply (3.0 to 3.6 V) for USB transceivers.

For example, when 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 V_{DDUSB} must be respected:

- During power-on phase ($V_{DD} < V_{DD_MIN}$), V_{DDUSB} should be always lower than V_{DD}
- During 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 is used, the associated GPIOs powered by V_{DDUSB} are operating between V_{DDUSB_MIN} and V_{DDUSB_MAX} .
 - If USB is not used, the associated GPIOs powered by V_{DDUSB} are operating between V_{DD_MIN} and V_{DD_MAX} .