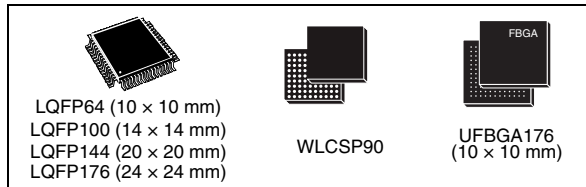


ARM Cortex-M4 32b MCU+FPU, 210DMIPS, up to 1MB Flash/192+4KB RAM, USB OTG HS/FS, Ethernet, 17 TIMs, 3 ADCs, 15 comm. interfaces & camera

Datasheet - production data



Features

- 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 168 MHz, memory protection unit, 210 DMIPS/1.25 DMIPS/MHz (Dhrystone 2.1), and DSP instructions
- Memories
 - Up to 1 Mbyte of Flash memory
 - Up to 192+4 Kbytes of SRAM including 64-Kbyte of CCM (core coupled memory) data RAM
 - Flexible static memory controller supporting Compact Flash, SRAM, PSRAM, NOR and NAND memories
- LCD parallel interface, 8080/6800 modes
- Clock, reset and supply management
 - 1.8 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 A/D converters: 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 168 MHz, each with up to 4

IC/OC/PWM or pulse counter and quadrature (incremental) encoder input

- Debug mode
 - Serial wire debug (SWD) & JTAG interfaces
 - Cortex-M4 Embedded Trace Macrocell™
- Up to 140 I/O ports with interrupt capability
 - Up to 136 fast I/Os up to 84 MHz
 - Up to 138 5 V-tolerant I/Os
- Up to 15 communication interfaces
 - Up to 3 × I²C interfaces (SMBus/PMBus)
 - Up to 4 USARTs/2 UARTs (10.5 Mbit/s, ISO 7816 interface, LIN, IrDA, modem control)
 - Up to 3 SPIs (42 Mbit/s), 2 with muxed full-duplex I²S to achieve audio class accuracy via internal audio PLL or external clock
 - 2 × CAN interfaces (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
 - 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
- 96-bit unique ID
- RTC: subsecond accuracy, hardware calendar

Table 1. Device summary

Reference	Part number
STM32F405xx	STM32F405RG, STM32F405VG, STM32F405ZG, STM32F405OG, STM32F405OE
STM32F407xx	STM32F407VG, STM32F407IG, STM32F407ZG, STM32F407VE, STM32F407ZE, STM32F407IE

Contents

1	Introduction	11
2	Description	12
2.1	Full compatibility throughout the family	15
2.2	Device overview	18
2.2.1	ARM® Cortex™-M4F core with embedded Flash and SRAM	19
2.2.2	Adaptive real-time memory accelerator (ART Accelerator™)	19
2.2.3	Memory protection unit	19
2.2.4	Embedded Flash memory	19
2.2.5	CRC (cyclic redundancy check) calculation unit	20
2.2.6	Embedded SRAM	20
2.2.7	Multi-AHB bus matrix	20
2.2.8	DMA controller (DMA)	21
2.2.9	Flexible static memory controller (FSMC)	22
2.2.10	Nested vectored interrupt controller (NVIC)	22
2.2.11	External interrupt/event controller (EXTI)	22
2.2.12	Clocks and startup	22
2.2.13	Boot modes	23
2.2.14	Power supply schemes	23
2.2.15	Power supply supervisor	23
2.2.16	Voltage regulator	25
2.2.17	Regulator ON/OFF and internal reset ON/OFF availability	28
2.2.18	Real-time clock (RTC), backup SRAM and backup registers	28
2.2.19	Low-power modes	29
2.2.20	V _{BAT} operation	30
2.2.21	Timers and watchdogs	30
2.2.22	Inter-integrated circuit interface (I ² C)	33
2.2.23	Universal synchronous/asynchronous receiver transmitters (USART)	33
2.2.24	Serial peripheral interface (SPI)	34
2.2.25	Inter-integrated sound (I2S)	34
2.2.26	Audio PLL (PLLI2S)	34
2.2.27	Secure digital input/output interface (SDIO)	35
2.2.28	Ethernet MAC interface with dedicated DMA and IEEE 1588 support	35
2.2.29	Controller area network (bxCAN)	36

2.2.30	Universal serial bus on-the-go full-speed (OTG_FS)	36
2.2.31	Universal serial bus on-the-go high-speed (OTG_HS)	36
2.2.32	Digital camera interface (DCMI)	37
2.2.33	Random number generator (RNG)	37
2.2.34	General-purpose input/outputs (GPIOs)	37
2.2.35	Analog-to-digital converters (ADCs)	37
2.2.36	Temperature sensor	37
2.2.37	Digital-to-analog converter (DAC)	38
2.2.38	Serial wire JTAG debug port (SWJ-DP)	38
2.2.39	Embedded Trace Macrocell™	38
3	Pinouts and pin description	39
4	Memory mapping	69
5	Electrical characteristics	74
5.1	Parameter conditions	74
5.1.1	Minimum and maximum values	74
5.1.2	Typical values	74
5.1.3	Typical curves	74
5.1.4	Loading capacitor	74
5.1.5	Pin input voltage	74
5.1.6	Power supply scheme	75
5.1.7	Current consumption measurement	76
5.2	Absolute maximum ratings	76
5.3	Operating conditions	77
5.3.1	General operating conditions	77
5.3.2	VCAP_1/VCAP_2 external capacitor	79
5.3.3	Operating conditions at power-up / power-down (regulator ON)	80
5.3.4	Operating conditions at power-up / power-down (regulator OFF)	80
5.3.5	Embedded reset and power control block characteristics	80
5.3.6	Supply current characteristics	82
5.3.7	Wakeup time from low-power mode	95
5.3.8	External clock source characteristics	96
5.3.9	Internal clock source characteristics	99
5.3.10	PLL characteristics	100
5.3.11	PLL spread spectrum clock generation (SSCG) characteristics	102

5.3.12	Memory characteristics	104
5.3.13	EMC characteristics	106
5.3.14	Absolute maximum ratings (electrical sensitivity)	108
5.3.15	I/O current injection characteristics	109
5.3.16	I/O port characteristics	109
5.3.17	NRST pin characteristics	113
5.3.18	TIM timer characteristics	114
5.3.19	Communications interfaces	116
5.3.20	12-bit ADC characteristics	129
5.3.21	Temperature sensor characteristics	134
5.3.22	V _{BAT} monitoring characteristics	134
5.3.23	Embedded reference voltage	135
5.3.24	DAC electrical characteristics	135
5.3.25	FSMC characteristics	137
5.3.26	Camera interface (DCMI) timing specifications	155
5.3.27	SD/SDIO MMC card host interface (SDIO) characteristics	156
5.3.28	RTC characteristics	157
6	Package characteristics	158
6.1	Package mechanical data	158
6.2	Thermal characteristics	169
7	Part numbering	170
Appendix A	Application block diagrams	171
A.1	USB OTG full speed (FS) interface solutions	171
A.2	USB OTG high speed (HS) interface solutions	173
A.3	Ethernet interface solutions	174
8	Revision history	176

List of tables

Table 1.	Device summary	1
Table 2.	STM32F405xx and STM32F407xx: features and peripheral counts.	13
Table 3.	Regulator ON/OFF and internal reset ON/OFF availability.	28
Table 4.	Timer feature comparison.	30
Table 5.	USART feature comparison	34
Table 6.	Legend/abbreviations used in the pinout table	44
Table 7.	STM32F40x pin and ball definitions	45
Table 8.	FSMC pin definition	57
Table 9.	Alternate function mapping	60
Table 10.	STM32F40x register boundary addresses	70
Table 11.	Voltage characteristics	76
Table 12.	Current characteristics	77
Table 13.	Thermal characteristics.	77
Table 14.	General operating conditions	77
Table 15.	Limitations depending on the operating power supply range	79
Table 16.	VCAP_1/VCAP_2 operating conditions	80
Table 17.	Operating conditions at power-up / power-down (regulator ON)	80
Table 18.	Operating conditions at power-up / power-down (regulator OFF).	80
Table 19.	Embedded reset and power control block characteristics.	81
Table 20.	Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled) or RAM	83
Table 21.	Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator disabled)	84
Table 22.	Typical and maximum current consumption in Sleep mode	87
Table 23.	Typical and maximum current consumptions in Stop mode	88
Table 24.	Typical and maximum current consumptions in Standby mode	88
Table 25.	Typical and maximum current consumptions in V _{BAT} mode.	89
Table 26.	Switching output I/O current consumption	92
Table 27.	Peripheral current consumption	93
Table 28.	Low-power mode wakeup timings	95
Table 29.	High-speed external user clock characteristics.	96
Table 30.	Low-speed external user clock characteristics	96
Table 31.	HSE 4-26 MHz oscillator characteristics	98
Table 32.	LSE oscillator characteristics (f _{LSE} = 32.768 kHz)	99
Table 33.	HSI oscillator characteristics	99
Table 34.	LSI oscillator characteristics	100
Table 35.	Main PLL characteristics.	101
Table 36.	PLLI2S (audio PLL) characteristics	101
Table 37.	SSCG parameters constraint	102
Table 38.	Flash memory characteristics	104
Table 39.	Flash memory programming	104
Table 40.	Flash memory programming with V _{PP}	106
Table 41.	Flash memory endurance and data retention	106
Table 42.	EMS characteristics	107
Table 43.	EMI characteristics	108
Table 44.	ESD absolute maximum ratings	108
Table 45.	Electrical sensitivities	109
Table 46.	I/O current injection susceptibility	109

Table 47.	I/O static characteristics	110
Table 48.	Output voltage characteristics	111
Table 49.	I/O AC characteristics	112
Table 50.	NRST pin characteristics	114
Table 51.	Characteristics of TIMx connected to the APB1 domain	115
Table 52.	Characteristics of TIMx connected to the APB2 domain	116
Table 53.	I ² C characteristics	116
Table 54.	SCL frequency ($f_{PCLK1} = 42 \text{ MHz}$, $V_{DD} = 3.3 \text{ V}$)	118
Table 55.	SPI dynamic characteristics	118
Table 56.	I2S dynamic characteristics	122
Table 57.	USB OTG FS startup time	124
Table 58.	USB OTG FS DC electrical characteristics	124
Table 59.	USB OTG FS electrical characteristics	125
Table 60.	USB HS DC electrical characteristics	125
Table 61.	USB HS clock timing parameters	125
Table 62.	ULPI timing	126
Table 63.	Ethernet DC electrical characteristics	127
Table 64.	Dynamic characteristics: Ethernet MAC signals for SMI	127
Table 65.	Dynamic characteristics: Ethernet MAC signals for RMII	128
Table 66.	Dynamic characteristics: Ethernet MAC signals for MII	128
Table 67.	ADC characteristics	129
Table 68.	ADC accuracy at $f_{ADC} = 30 \text{ MHz}$	131
Table 69.	Temperature sensor characteristics	134
Table 70.	Temperature sensor calibration values	134
Table 71.	V_{BAT} monitoring characteristics	134
Table 72.	Embedded internal reference voltage	135
Table 73.	Internal reference voltage calibration values	135
Table 74.	DAC characteristics	135
Table 75.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read timings	138
Table 76.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings	139
Table 77.	Asynchronous multiplexed PSRAM/NOR read timings	140
Table 78.	Asynchronous multiplexed PSRAM/NOR write timings	141
Table 79.	Synchronous multiplexed NOR/PSRAM read timings	143
Table 80.	Synchronous multiplexed PSRAM write timings	144
Table 81.	Synchronous non-multiplexed NOR/PSRAM read timings	145
Table 82.	Synchronous non-multiplexed PSRAM write timings	147
Table 83.	Switching characteristics for PC Card/CF read and write cycles in attribute/common space	151
Table 84.	Switching characteristics for PC Card/CF read and write cycles in I/O space	152
Table 85.	Switching characteristics for NAND Flash read cycles	154
Table 86.	Switching characteristics for NAND Flash write cycles	155
Table 87.	DCMI characteristics	155
Table 88.	Dynamic characteristics: SD / MMC characteristics	157
Table 89.	RTC characteristics	157
Table 90.	WLCSP90 - 0.400 mm pitch wafer level chip size package mechanical data	159
Table 91.	LQFP64 - 10 x 10 mm 64 pin low-profile quad flat package mechanical data	160
Table 92.	LQFP100 - 14 x 14 mm 100-pin low-profile quad flat package mechanical data	162
Table 93.	LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package mechanical data	164
Table 94.	UFBGA176+25 - ultra thin fine pitch ball grid array 10 x 10 x 0.6 mm mechanical data	166
Table 95.	LQFP176, 24 x 24 mm, 176-pin low-profile quad flat package mechanical data	167

Table 96.	Package thermal characteristics	169
Table 97.	Ordering information scheme	170
Table 98.	Document revision history	176

List of figures

Figure 1.	Compatible board design between STM32F10xx/STM32F4xx for LQFP64	15
Figure 2.	Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP100 package	16
Figure 3.	Compatible board design between STM32F10xx/STM32F2xx/STM32F4xx for LQFP144 package	16
Figure 4.	Compatible board design between STM32F2xx and STM32F4xx for LQFP176 and BGA176 packages	17
Figure 5.	STM32F40x block diagram	18
Figure 6.	Multi-AHB matrix	21
Figure 7.	Power supply supervisor interconnection with internal reset OFF	24
Figure 8.	PDR_ON and NRST control with internal reset OFF	25
Figure 9.	Regulator OFF	26
Figure 10.	Startup in regulator OFF mode: slow V_{DD} slope - power-down reset risen after V_{CAP_1}/V_{CAP_2} stabilization	27
Figure 11.	Startup in regulator OFF mode: fast V_{DD} slope - power-down reset risen before V_{CAP_1}/V_{CAP_2} stabilization	28
Figure 12.	STM32F40x LQFP64 pinout	39
Figure 13.	STM32F40x LQFP100 pinout	40
Figure 14.	STM32F40x LQFP144 pinout	41
Figure 15.	STM32F40x LQFP176 pinout	42
Figure 16.	STM32F40x UFBGA176 ballout	43
Figure 17.	STM32F40x WLCSP90 ballout	44
Figure 18.	STM32F40x memory map	69
Figure 19.	Pin loading conditions	74
Figure 20.	Pin input voltage	74
Figure 21.	Power supply scheme	75
Figure 22.	Current consumption measurement scheme	76
Figure 23.	External capacitor C_{EXT}	80
Figure 24.	Typical current consumption versus temperature, Run mode, code with data processing running from Flash (ART accelerator ON) or RAM, and peripherals OFF	85
Figure 25.	Typical current consumption versus temperature, Run mode, code with data processing running from Flash (ART accelerator ON) or RAM, and peripherals ON	85
Figure 26.	Typical current consumption versus temperature, Run mode, code with data processing running from Flash (ART accelerator OFF) or RAM, and peripherals OFF . . .	86
Figure 27.	Typical current consumption versus temperature, Run mode, code with data processing running from Flash (ART accelerator OFF) or RAM, and peripherals ON . . .	86
Figure 28.	Typical V_{BAT} current consumption (LSE and RTC ON/backup RAM OFF)	89
Figure 29.	Typical V_{BAT} current consumption (LSE and RTC ON/backup RAM ON)	90
Figure 30.	High-speed external clock source AC timing diagram	97
Figure 31.	Low-speed external clock source AC timing diagram	97
Figure 32.	Typical application with an 8 MHz crystal	98
Figure 33.	Typical application with a 32.768 kHz crystal	99
Figure 34.	ACC_{LSI} versus temperature	100
Figure 35.	PLL output clock waveforms in center spread mode	103
Figure 36.	PLL output clock waveforms in down spread mode	104
Figure 37.	I/O AC characteristics definition	113
Figure 38.	Recommended NRST pin protection	114
Figure 39.	I ² C bus AC waveforms and measurement circuit	117

Figure 40.	SPI timing diagram - slave mode and CPHA = 0	120
Figure 41.	SPI timing diagram - slave mode and CPHA = 1	120
Figure 42.	SPI timing diagram - master mode	121
Figure 43.	I2S slave timing diagram (Philips protocol)	123
Figure 44.	I2S master timing diagram (Philips protocol) ⁽¹⁾	123
Figure 45.	USB OTG FS timings: definition of data signal rise and fall time	124
Figure 46.	ULPI timing diagram	126
Figure 47.	Ethernet SMI timing diagram	127
Figure 48.	Ethernet RMII timing diagram	127
Figure 49.	Ethernet MII timing diagram	128
Figure 50.	ADC accuracy characteristics	131
Figure 51.	Typical connection diagram using the ADC	132
Figure 52.	Power supply and reference decoupling (V_{REF+} not connected to V_{DDA})	133
Figure 53.	Power supply and reference decoupling (V_{REF+} connected to V_{DDA})	133
Figure 54.	12-bit buffered /non-buffered DAC	137
Figure 55.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms	138
Figure 56.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms	139
Figure 57.	Asynchronous multiplexed PSRAM/NOR read waveforms	140
Figure 58.	Asynchronous multiplexed PSRAM/NOR write waveforms	141
Figure 59.	Synchronous multiplexed NOR/PSRAM read timings	143
Figure 60.	Synchronous multiplexed PSRAM write timings	144
Figure 61.	Synchronous non-multiplexed NOR/PSRAM read timings	145
Figure 62.	Synchronous non-multiplexed PSRAM write timings	146
Figure 63.	PC Card/CompactFlash controller waveforms for common memory read access	148
Figure 64.	PC Card/CompactFlash controller waveforms for common memory write access	148
Figure 65.	PC Card/CompactFlash controller waveforms for attribute memory read access	149
Figure 66.	PC Card/CompactFlash controller waveforms for attribute memory write access	150
Figure 67.	PC Card/CompactFlash controller waveforms for I/O space read access	150
Figure 68.	PC Card/CompactFlash controller waveforms for I/O space write access	151
Figure 69.	NAND controller waveforms for read access	153
Figure 70.	NAND controller waveforms for write access	153
Figure 71.	NAND controller waveforms for common memory read access	154
Figure 72.	NAND controller waveforms for common memory write access	154
Figure 73.	DCMI timing diagram	155
Figure 74.	SDIO high-speed mode	156
Figure 75.	SD default mode	157
Figure 76.	WLCSP90 - 0.400 mm pitch wafer level chip size package outline	159
Figure 77.	LQFP64 – 10 x 10 mm 64 pin low-profile quad flat package outline	160
Figure 78.	LQFP64 recommended footprint	161
Figure 79.	LQFP100, 14 x 14 mm 100-pin low-profile quad flat package outline	162
Figure 80.	LQFP100 recommended footprint	163
Figure 81.	LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package outline	164
Figure 82.	LQFP144 recommended footprint	165
Figure 83.	UFBGA176+25 - ultra thin fine pitch ball grid array 10 × 10 × 0.6 mm, package outline	166
Figure 84.	LQFP176 24 x 24 mm, 176-pin low-profile quad flat package outline	167
Figure 85.	LQFP176 recommended footprint	168
Figure 86.	USB controller configured as peripheral-only and used in Full speed mode	171
Figure 87.	USB controller configured as host-only and used in full speed mode	171

Figure 88.	USB controller configured in dual mode and used in full speed mode	172
Figure 89.	USB controller configured as peripheral, host, or dual-mode and used in high speed mode.	173
Figure 90.	MII mode using a 25 MHz crystal	174
Figure 91.	RMII with a 50 MHz oscillator	174
Figure 92.	RMII with a 25 MHz crystal and PHY with PLL	175

1 Introduction

This datasheet provides the description of the STM32F405xx and STM32F407xx lines of microcontrollers. For more details on the whole STMicroelectronics STM32™ family, please refer to [Section 2.1: Full compatibility throughout the family](#).

The STM32F405xx and STM32F407xx datasheet should be read in conjunction with the STM32F4xx reference manual.

The reference and Flash programming manuals are both available from the STMicroelectronics website www.st.com.

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

2 Description

The STM32F405xx and STM32F407xx family is based on the high-performance ARM® Cortex™-M4 32-bit RISC core operating at a frequency of up to 168 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 Cortex-M4 core with FPU will be referred to as Cortex-M4F throughout this document.

The STM32F405xx and STM32F407xx family incorporates high-speed embedded memories (Flash memory up to 1 Mbyte, up to 192 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, three 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, a true random number generator (RNG). They also feature standard and advanced communication interfaces.

- Up to three I²Cs
- Three SPIs, two I²Ss full duplex. To achieve audio class accuracy, the I2S peripherals can be clocked via a dedicated internal audio PLL or via an external clock to allow synchronization.
- Four USARTs plus two UARTs
- An USB OTG full-speed and a USB OTG high-speed with full-speed capability (with the ULPI),
- Two CANs
- An SDIO/MMC interface
- Ethernet and the camera interface available on STM32F407xx devices only.

New advanced peripherals include an SDIO, an enhanced flexible static memory control (FSMC) interface (for devices offered in packages of 100 pins and more), a camera interface for CMOS sensors. Refer to [Table 2: STM32F405xx and STM32F407xx: features and peripheral counts](#) for the list of peripherals available on each part number.

The STM32F405xx and STM32F407xx family operates in the –40 to +105 °C temperature range from a 1.8 to 3.6 V power supply. The supply voltage can drop to 1.7 V when the device operates in the 0 to 70 °C temperature range using an external power supply supervisor: refer to [Section : Internal reset OFF](#). A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F405xx and STM32F407xx family offers devices in various packages ranging from 64 pins to 176 pins. The set of included peripherals changes with the device chosen.

These features make the STM32F405xx and STM32F407xx microcontroller family 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. STM32F405xx and STM32F407xx: features and peripheral counts

Peripherals		STM32F405RG	STM32F405OG	STM32F405VG	STM32F405ZG	STM32F405OE	STM32F407Vx		STM32F407Zx		STM32F407Ix	
Flash memory in Kbytes		1024				512	512	1024	512	1024	512	1024
SRAM in Kbytes	System	192(112+16+64)										
	Backup	4										
FSMC memory controller		No	Yes ⁽¹⁾									
Ethernet		No					Yes					
Timers	General-purpose	10										
	Advanced-control	2										
	Basic	2										
	IWDG	Yes										
	WWDG	Yes										
	RTC	Yes										
Random number generator		Yes										



Table 2. STM32F405xx and STM32F407xx: features and peripheral counts

Peripherals		STM32F405RG	STM32F405OG	STM32F405VG	STM32F405ZG	STM32F405OE	STM32F407Vx	STM32F407Zx	STM32F407Ix
Communi- cation interfaces	SPI / I2S	3/2 (full duplex) ⁽²⁾							
	I ² C	3							
	USART/ UART	4/2							
	USB OTG FS	Yes							
	USB OTG HS	Yes							
	CAN	2							
	SDIO	Yes							
Camera interface		No					Yes		
GPIOs		51	72	82	114	72	82	114	140
12-bit ADC		3							
Number of channels		16	13	16	24	13	16	24	24
12-bit DAC		Yes							
Number of channels		2							
Maximum CPU frequency		168 MHz							
Operating voltage		1.8 to 3.6 V ⁽³⁾							
Operating temperatures		Ambient temperatures: –40 to +85 °C / –40 to +105 °C							
		Junction temperature: –40 to + 125 °C							
Package		LQFP64	WLCSP90	LQFP100	LQFP144	WLCSP90	LQFP100	LQFP144	UFBGA176 LQFP176

1. For the LQFP100 and WLCSP90 packages, only FSMC Bank1 or Bank2 are available. Bank1 can only support a multiplexed NOR/PSRAM memory using the NE1 Chip Select. Bank2 can only support a 16- or 8-bit NAND Flash memory using the NCE2 Chip Select. The interrupt line cannot be used since Port G is not available in this package.

2. The SPI2 and SPI3 interfaces give the flexibility to work in an exclusive way in either the SPI mode or the I²S audio mode.

3. V_{DD}/V_{DDA} minimum value of 1.7 V is obtained when the device operates in reduced temperature range, and with the use of an external power supply supervisor (refer to [Section : Internal reset OFF](#)).

2.1 Full compatibility throughout the family

The STM32F405xx and STM32F407xx are part of the STM32F4 family. They are fully pin-to-pin, software and feature compatible with the STM32F2xx devices, allowing the user to try different memory densities, peripherals, and performances (FPU, higher frequency) for a greater degree of freedom during the development cycle.

The STM32F405xx and STM32F407xx devices maintain a close compatibility with the whole STM32F10xxx family. All functional pins are pin-to-pin compatible. The STM32F405xx and STM32F407xx, however, are not drop-in replacements for the STM32F10xxx devices: the two families do not have the same power scheme, and so their power pins are different. Nonetheless, transition from the STM32F10xxx to the STM32F40x family remains simple as only a few pins are impacted.

[Figure 4](#), [Figure 3](#), [Figure 2](#), and [Figure 1](#) give compatible board designs between the STM32F40x, STM32F2xxx, and STM32F10xxx families.

Figure 1. Compatible board design between STM32F10xx/STM32F4xx for LQFP64

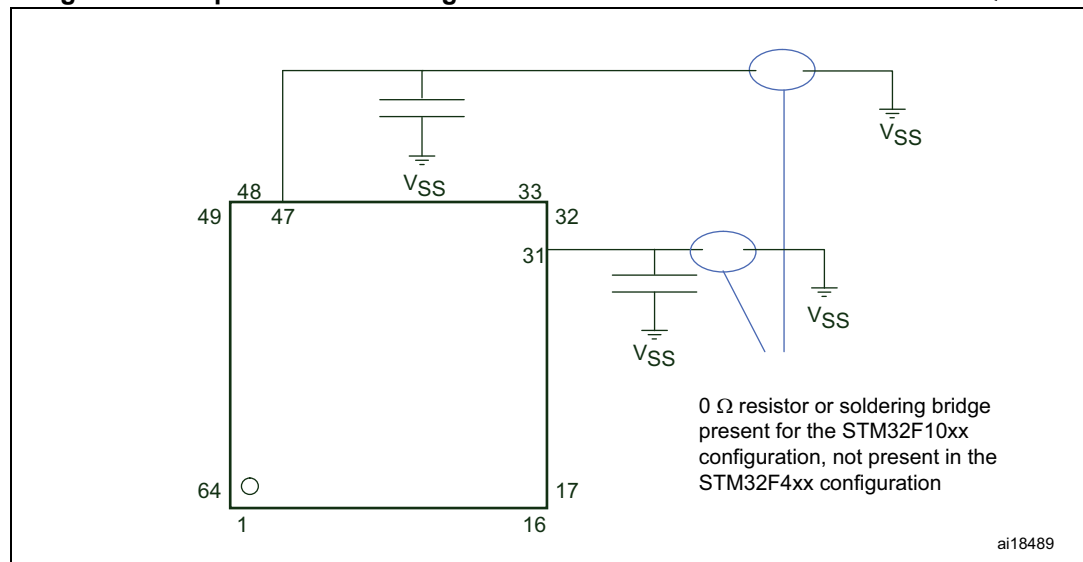


Figure 2. Compatible board design STM32F10xx/STM32F2xx/STM32F4xx for LQFP100 package

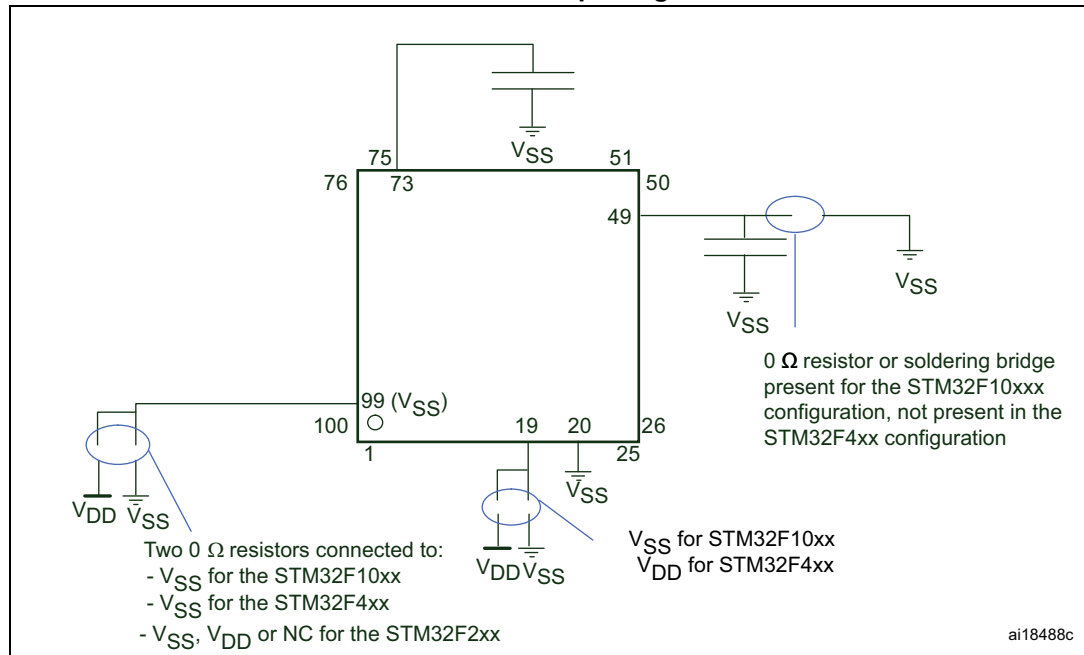


Figure 3. Compatible board design between STM32F10xx/STM32F2xx/STM32F4xx for LQFP144 package

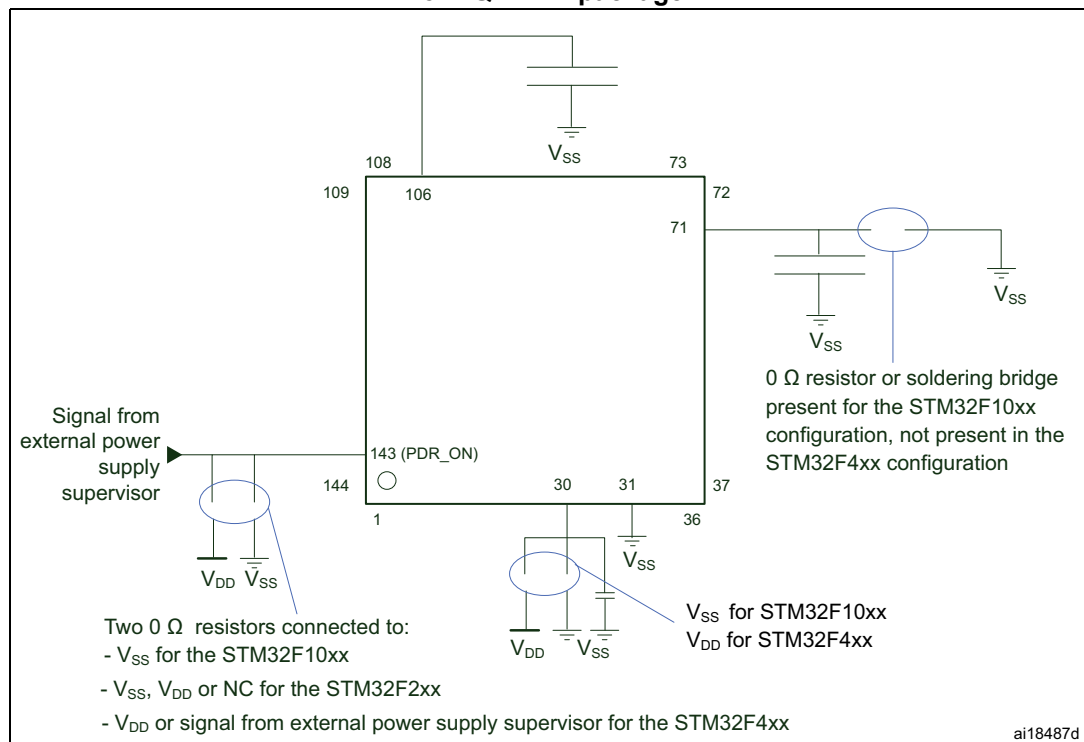
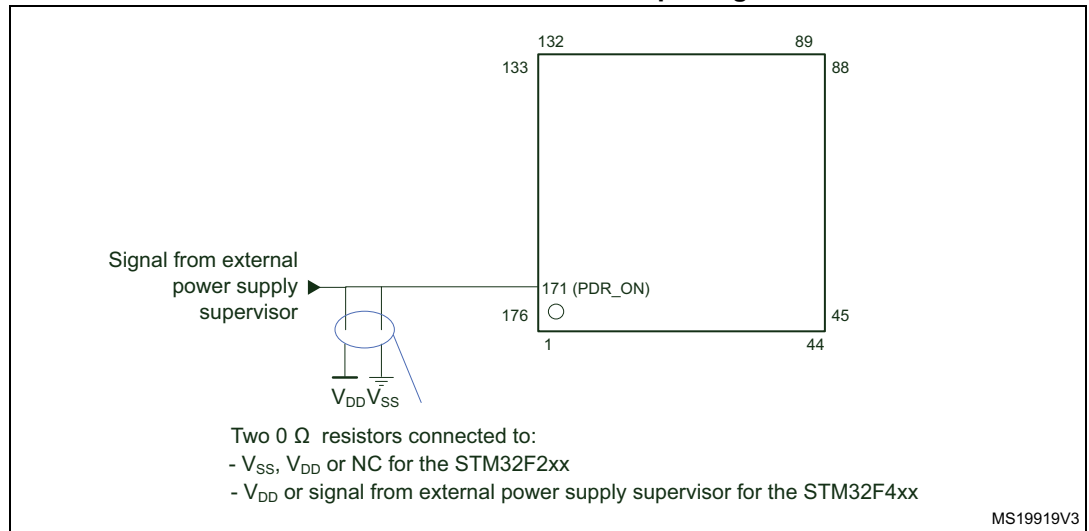
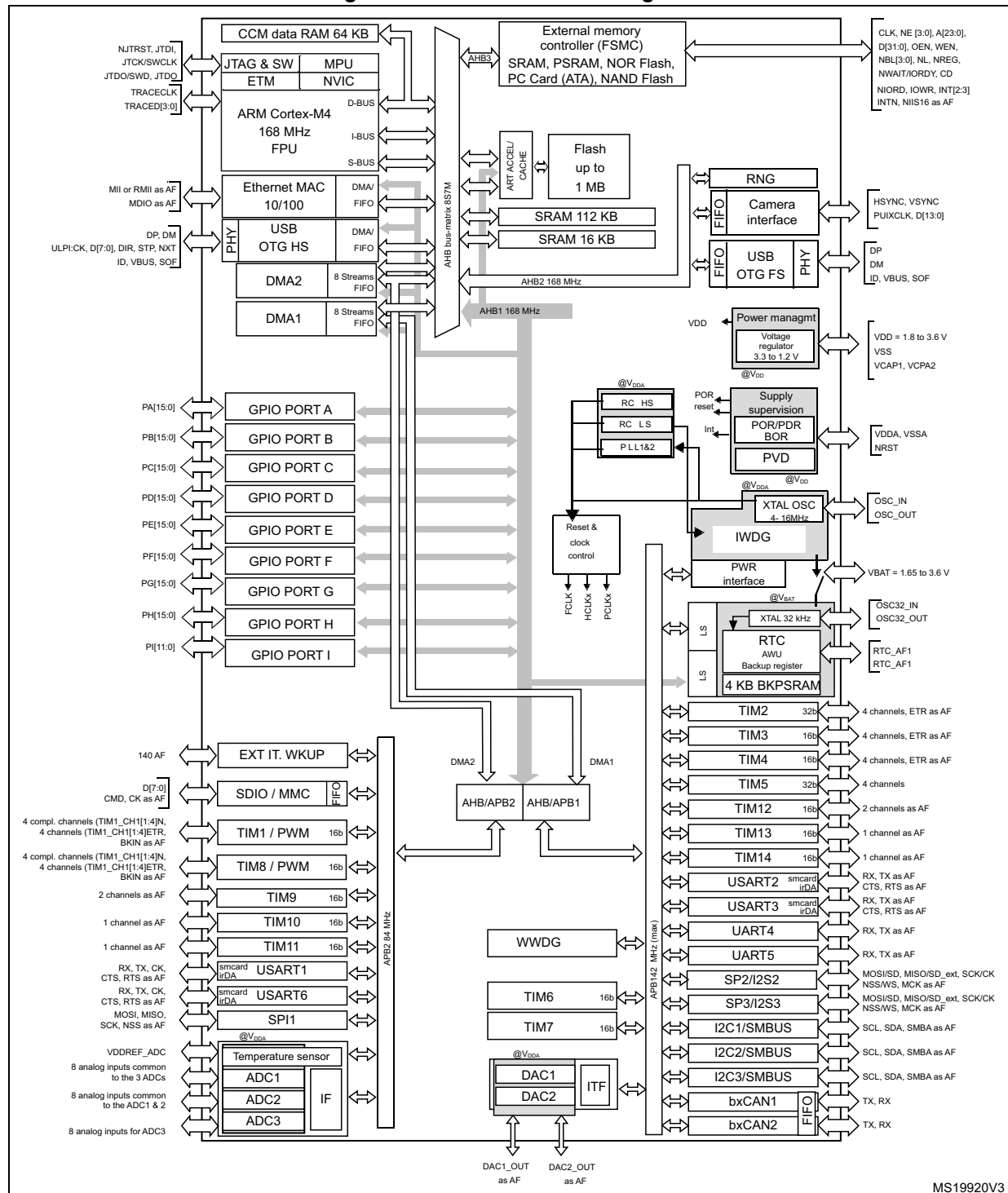


Figure 4. Compatible board design between STM32F2xx and STM32F4xx for LQFP176 and BGA176 packages



2.2 Device overview

Figure 5. STM32F40x block diagram



1. The timers connected to APB2 are clocked from TIMxCLK up to 168 MHz, while the timers connected to APB1 are clocked from TIMxCLK either up to 84 MHz or 168 MHz, depending on TIMPRE bit configuration in the RCC_DCKCFGR register.
2. The camera interface and ethernet are available only on STM32F407xx devices.

2.2.1 ARM® Cortex™-M4F core with embedded Flash and SRAM

The ARM Cortex-M4F 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-M4F 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 STM32F405xx and STM32F407xx family is compatible with all ARM tools and software.

[Figure 5](#) shows the general block diagram of the STM32F40x family.

Note: Cortex-M4F is binary compatible with Cortex-M3.

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

The ART Accelerator™ is a memory accelerator which is optimized for STM32 industry-standard ARM® Cortex™-M4F processors. It balances the inherent performance advantage of the ARM Cortex-M4F over Flash memory technologies, which normally requires the processor to wait for the Flash memory at higher frequencies.

To release the processor full 210 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 168 MHz.

2.2.3 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 bytes and the whole 4 gigabytes 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.

2.2.4 Embedded Flash memory

The STM32F40x devices embed a Flash memory of 512 Kbytes or 1 Mbytes available for storing programs and data.

2.2.5 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.

2.2.6 Embedded SRAM

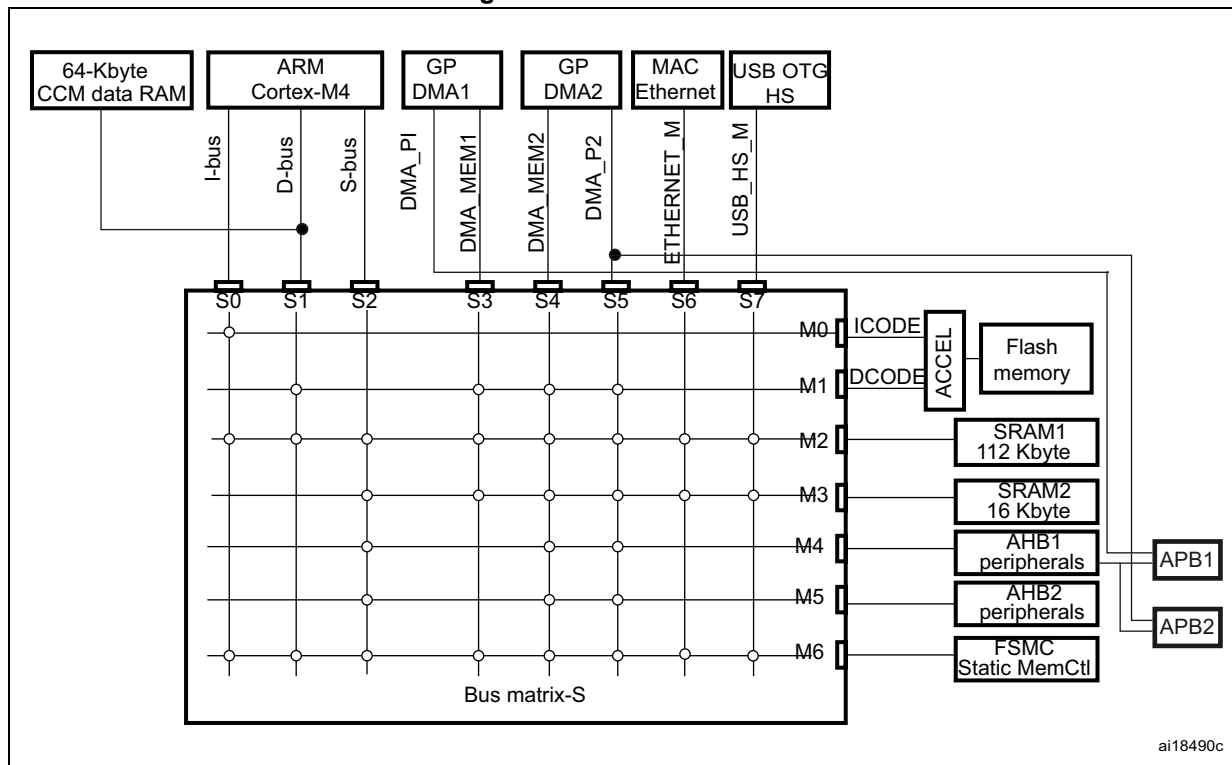
All STM32F40x products embed:

- Up to 192 Kbytes of system SRAM including 64 Kbytes of CCM (core coupled memory) data RAM
RAM memory 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 accesses, and is retained in Standby or VBAT mode.

2.2.7 Multi-AHB bus matrix

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

Figure 6. Multi-AHB matrix



2.2.8 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 I²S
- I²C
- USART
- General-purpose, basic and advanced-control timers TIMx
- DAC
- SDIO
- Camera interface (DCMI)
- ADC.

2.2.9 Flexible static memory controller (FSMC)

The FSMC is embedded in the STM32F405xx and STM32F407xx family. It has four Chip Select outputs supporting the following modes: PCCard/Compact Flash, SRAM, PSRAM, NOR Flash and NAND Flash.

Functionality overview:

- Write FIFO
- Maximum FSMC_CLK frequency for synchronous accesses is 60 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.

2.2.10 Nested vectored interrupt controller (NVIC)

The STM32F405xx and STM32F407xx embed a nested vectored interrupt controller able to manage 16 priority levels, and handle up to 82 maskable interrupt channels plus the 16 interrupt lines of the Cortex™-M4F.

- 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.

2.2.11 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 140 GPIOs can be connected to the 16 external interrupt lines.

2.2.12 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 168 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 is 168 MHz while the maximum frequency of the high-speed APB domains is 84 MHz. The maximum allowed frequency of the low-speed APB domain is 42 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.

2.2.13 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 boot loader is located in system memory. It is used to reprogram the Flash memory by using USART1 (PA9/PA10), USART3 (PC10/PC11 or PB10/PB11), CAN2 (PB5/PB13), USB OTG FS in Device mode (PA11/PA12) through DFU (device firmware upgrade).

2.2.14 Power supply schemes

- $V_{DD} = 1.8$ to 3.6 V: external power supply for I/Os and the internal regulator (when enabled), provided externally through V_{DD} pins.
- V_{SSA} , $V_{DDA} = 1.8$ 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.
- $V_{BAT} = 1.65$ 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.

Refer to [Figure 21: Power supply scheme](#) for more details.

Note: V_{DD}/V_{DDA} minimum value of 1.7 V is obtained when the device operates in reduced temperature range, and with the use of an external power supply supervisor (refer to [Section : Internal reset OFF](#)).

Refer to [Table 2](#) in order to identify the packages supporting this option.

2.2.15 Power supply supervisor

Internal reset ON

On packages embedding the PDR_ON pin, the power supply supervisor is enabled by holding PDR_ON high. On all 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 threshold levels, 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.

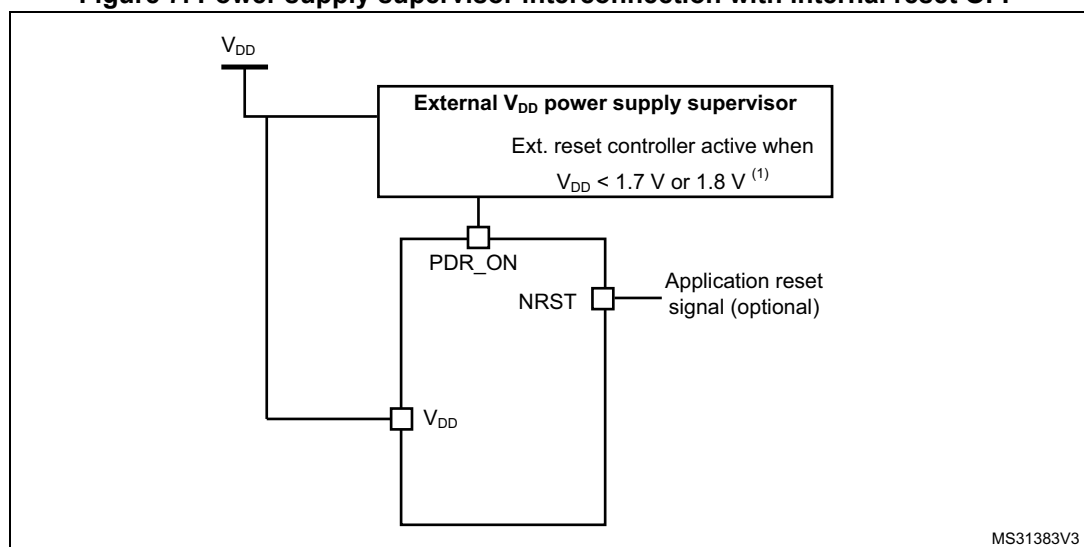
The device also features an embedded programmable voltage detector (PVD) that monitors the V_{DD}/V_{DDA} power supply and compares it to the V_{PVD} threshold. An interrupt can be generated when V_{DD}/V_{DDA} drops below the V_{PVD} threshold and/or when V_{DD}/V_{DDA} is higher than the V_{PVD} threshold.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

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 with the PDR_ON pin.

An external power supply supervisor should monitor V_{DD} and should maintain the device in reset mode as long as V_{DD} is below a specified threshold. PDR_ON should be connected to this external power supply supervisor. Refer to [Figure 7: Power supply supervisor interconnection with internal reset OFF](#).

Figure 7. Power supply supervisor interconnection with internal reset OFF



1. PDR = 1.7 V for reduce temperature range; PDR = 1.8 V for all temperature range.

The V_{DD} specified threshold, below which the device must be maintained under reset, is 1.8 V (see [Figure 7](#)). This supply voltage can drop to 1.7 V when the device operates in the 0 to 70 °C temperature range.

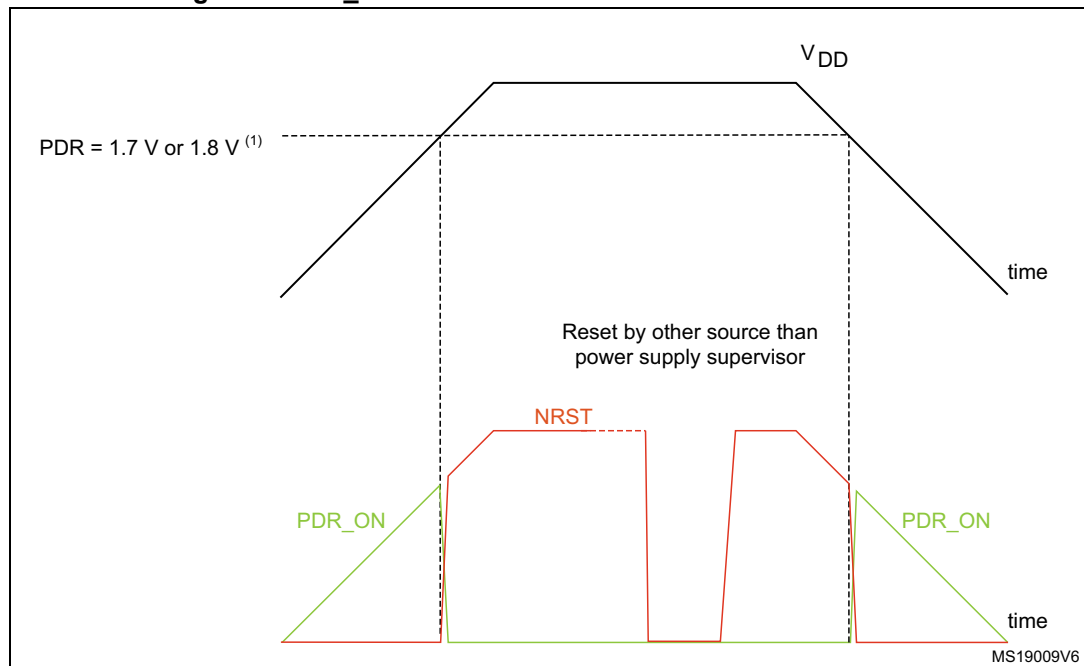
A comprehensive set of power-saving mode allows to design low-power applications.

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 is 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, except for the LQFP64 and LQFP100, allow to disable the internal reset through the PDR_ON signal.

Figure 8. PDR_ON and NRST control with internal reset OFF



1. $PDR = 1.7\text{ V}$ for reduce temperature range; $PDR = 1.8\text{ V}$ for all temperature range.

2.2.16 Voltage regulator

The regulator has four operating modes:

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

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 regulator is ON:

- MR is used in the nominal regulation mode (With different voltage scaling in Run)
In Main regulator mode (MR mode), different voltage scaling are provided to reach the best compromise between maximum frequency and dynamic power consumption. Refer to [Table 14: General operating conditions](#).
- LPR is used in the Stop modes
The LP regulator mode is configured by software when entering Stop 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)

Two external ceramic capacitors should be connected on V_{CAP_1} & V_{CAP_2} pin. Refer to [Figure 21: Power supply scheme](#) and [Figure 16: VCAP_1/VCAP_2 operating conditions](#).

All packages have regulator ON feature.

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 targetted maximum frequency. Refer to [Table 14: General operating conditions](#).

The two 2.2 μ F ceramic capacitors should be replaced by two 100 nF decoupling capacitors.

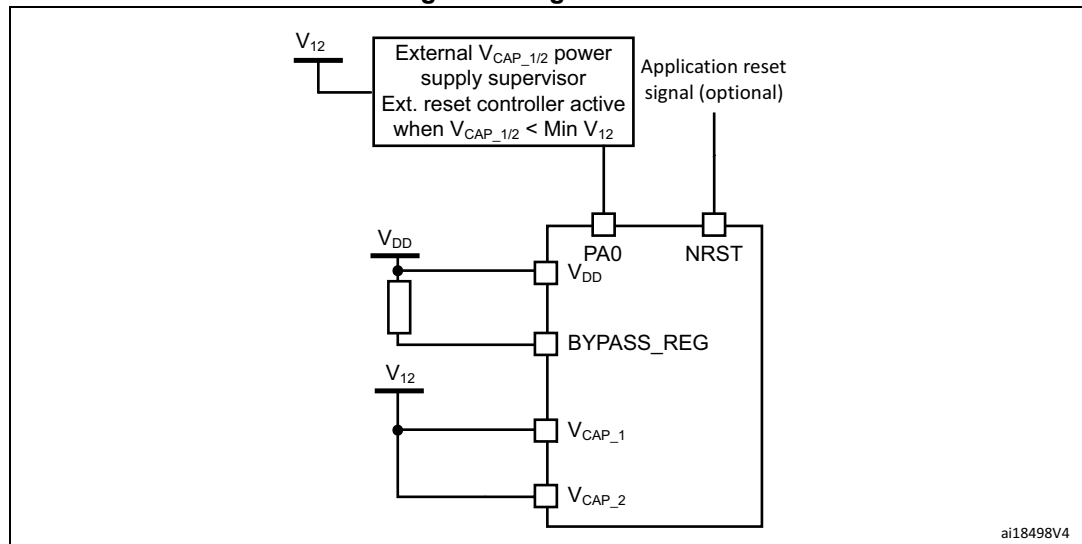
Refer to [Figure 21: Power supply scheme](#)

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 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 pre-reset is required.

Figure 9. Regulator OFF

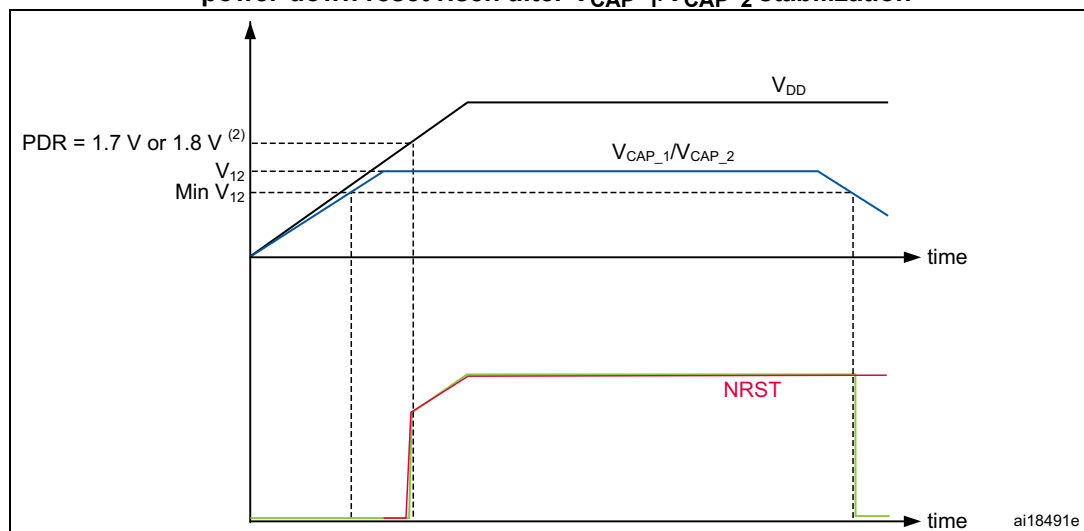


The following conditions must be respected:

- V_{DD} should 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 1.8 V, then PA0 should 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 1.8 V (see [Figure 10](#)).
- 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 1.8 V, then PA0 could be asserted low externally (see [Figure 11](#)).
- If V_{CAP_1} and V_{CAP_2} go below V_{12} minimum value and V_{DD} is higher than 1.8 V, then a reset must be asserted on PA0 pin.

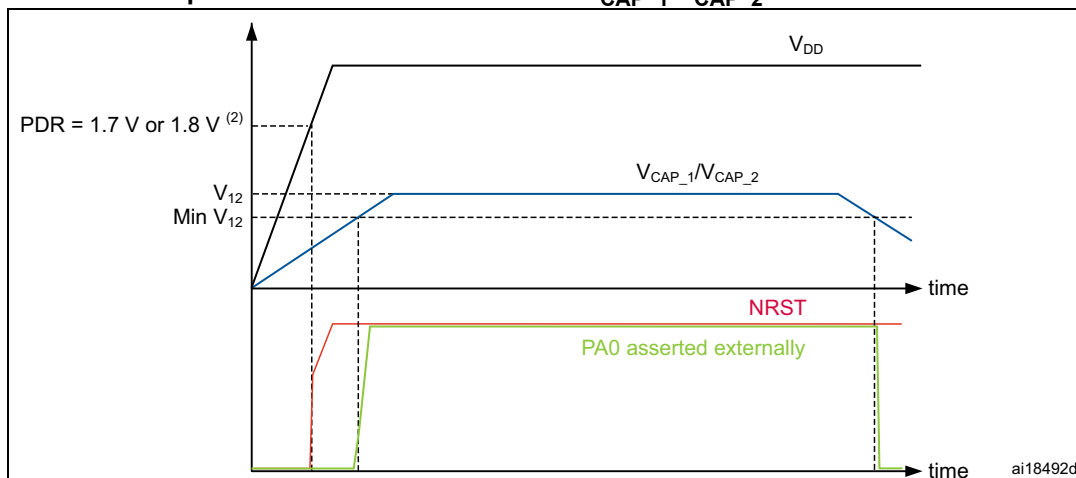
Note: The minimum value of V_{12} depends on the maximum frequency targeted in the application (see [Table 14: General operating conditions](#)).

Figure 10. Startup in regulator OFF mode: slow V_{DD} slope - power-down reset risen after V_{CAP_1}/V_{CAP_2} stabilization



1. This figure is valid both whatever the internal reset mode (onON or OFFoff).
2. PDR = 1.7 V for reduced temperature range; PDR = 1.8 V for all temperature ranges.

**Figure 11. 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 both whatever the internal reset mode (onON or offOFF).
2. PDR = 1.7 V for a reduced temperature range; PDR = 1.8 V for all temperature ranges.

2.2.17 Regulator ON/OFF and internal reset ON/OFF availability

Table 3. Regulator ON/OFF and internal reset ON/OFF availability

	Regulator ON	Regulator OFF	Internal reset ON	Internal reset OFF
LQFP64 LQFP100	Yes	No	Yes	No
LQFP144 LQFP176			Yes	Yes
WLCSP90 UFBGA176	Yes BYPASS_REG set to V_{SS}	Yes BYPASS_REG set to V_{DD}	PDR_ON set to V_{DD}	PDR_ON connected to an external power supply supervisor

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

The backup domain of the STM32F405xx and STM32F407xx 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 wakeup from Stop and Standby modes. The sub-seconds 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 auto-reload downcounter with programmable resolution is available and allows automatic wakeup and periodic alarms from every 120 μ s 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 V_{BAT} and standby mode. This memory area is disabled by default to minimize power consumption (see [Section 2.2.19: Low-power modes](#)). 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 2.2.19: Low-power modes](#)).

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.

2.2.19 Low-power modes

The STM32F405xx and STM32F407xx support three low-power modes to achieve the best compromise between low power consumption, short startup time and available wakeup sources:

- **Sleep mode**

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

- **Stop mode**

The Stop mode achieves the lowest power consumption while retaining the contents of SRAM and registers. All clocks in the V_{12} domain are stopped, the PLL, the HSI RC and the HSE crystal oscillators are disabled. The voltage regulator can also be put either in normal or in low-power mode.

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

- **Standby mode**

The Standby mode is used to achieve the lowest power consumption. The internal voltage regulator is switched off so that the entire V_{12} 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 / wakeup / tamper / time stamp event occurs.

The standby mode is not supported when the embedded voltage regulator is bypassed and the V_{12} domain is controlled by an external power.

2.2.20 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 and 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 not connected to V_{DD} (internal reset OFF), the V_{BAT} functionality is no more available and V_{BAT} pin should be connected to V_{DD} .

2.2.21 Timers and watchdogs

The STM32F405xx and STM32F407xx 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 4](#) compares the features of the advanced-control, general-purpose and basic timers.

Table 4. 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)
Advanced-control	TIM1, TIM8	16-bit	Up, Down, Up/down	Any integer between 1 and 65536	Yes	4	Yes	84	168

Table 4. Timer feature comparison (continued)

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)
General purpose	TIM2, TIM5	32-bit	Up, Down, Up/down	Any integer between 1 and 65536	Yes	4	No	42	84
	TIM3, TIM4	16-bit	Up, Down, Up/down	Any integer between 1 and 65536	Yes	4	No	42	84
	TIM9	16-bit	Up	Any integer between 1 and 65536	No	2	No	84	168
	TIM10, TIM11	16-bit	Up	Any integer between 1 and 65536	No	1	No	84	168
	TIM12	16-bit	Up	Any integer between 1 and 65536	No	2	No	42	84
	TIM13, TIM14	16-bit	Up	Any integer between 1 and 65536	No	1	No	42	84
Basic	TIM6, TIM7	16-bit	Up	Any integer between 1 and 65536	Yes	0	No	42	84

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.

General-purpose timers (TIMx)

There are ten synchronizable general-purpose timers embedded in the STM32F40x devices (see [Table 4](#) for differences).

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

The STM32F40x include 4 full-featured general-purpose timers: TIM2, TIM5, TIM3, and TIM4. The TIM2 and TIM5 timers are based on a 32-bit auto-reload up/downcounter and a 16-bit prescaler. The TIM3 and TIM4 timers are based on a 16-bit auto-reload up/downcounter 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 auto-reload 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.

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.

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.

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.

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.

2.2.22 Inter-integrated circuit interface (I²C)

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

They can be served by DMA and they support SMBus 2.0/PMBus.

2.2.23 Universal synchronous/asynchronous receiver transmitters (USART)

The STM32F405xx and STM32F407xx embed four universal synchronous/asynchronous receiver transmitters (USART1, USART2, USART3 and USART6) and two universal asynchronous receiver transmitters (UART4 and UART5).

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 10.5 Mbit/s. The other available interfaces communicate at up to 5.25 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 5. USART feature comparison

USART name	Standard features	Modem (RTS/CTS)	LIN	SPI master	IrDA	Smartcard (ISO 7816)	Max. baud rate in Mbit/s (oversampling by 16)	Max. baud rate in Mbit/s (oversampling by 8)	APB mapping
USART1	X	X	X	X	X	X	5.25	10.5	APB2 (max. 84 MHz)
USART2	X	X	X	X	X	X	2.62	5.25	APB1 (max. 42 MHz)
USART3	X	X	X	X	X	X	2.62	5.25	APB1 (max. 42 MHz)
UART4	X	-	X	-	X	-	2.62	5.25	APB1 (max. 42 MHz)
UART5	X	-	X	-	X	-	2.62	5.25	APB1 (max. 42 MHz)
USART6	X	X	X	X	X	X	5.25	10.5	APB2 (max. 84 MHz)

2.2.24 Serial peripheral interface (SPI)

The STM32F40x feature up to three SPIs in slave and master modes in full-duplex and simplex communication modes. SPI1 can communicate at up to 42 Mbits/s, SPI2 and SPI3 can communicate at up to 21 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.

2.2.25 Inter-integrated sound (I²S)

Two standard I²S interfaces (multiplexed with SPI2 and SPI3) are available. They can be operated in master or slave mode, in full duplex and half-duplex 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 I²S interfaces is/are configured in master mode, the master clock can be output to the external DAC/CODEC at 256 times the sampling frequency.

All I²Sx can be served by the DMA controller.

2.2.26 Audio PLL (PLLI2S)

The devices feature an additional dedicated PLL for audio I²S application. It allows to achieve error-free I²S sampling clock accuracy without compromising on the CPU performance, while using USB peripherals.