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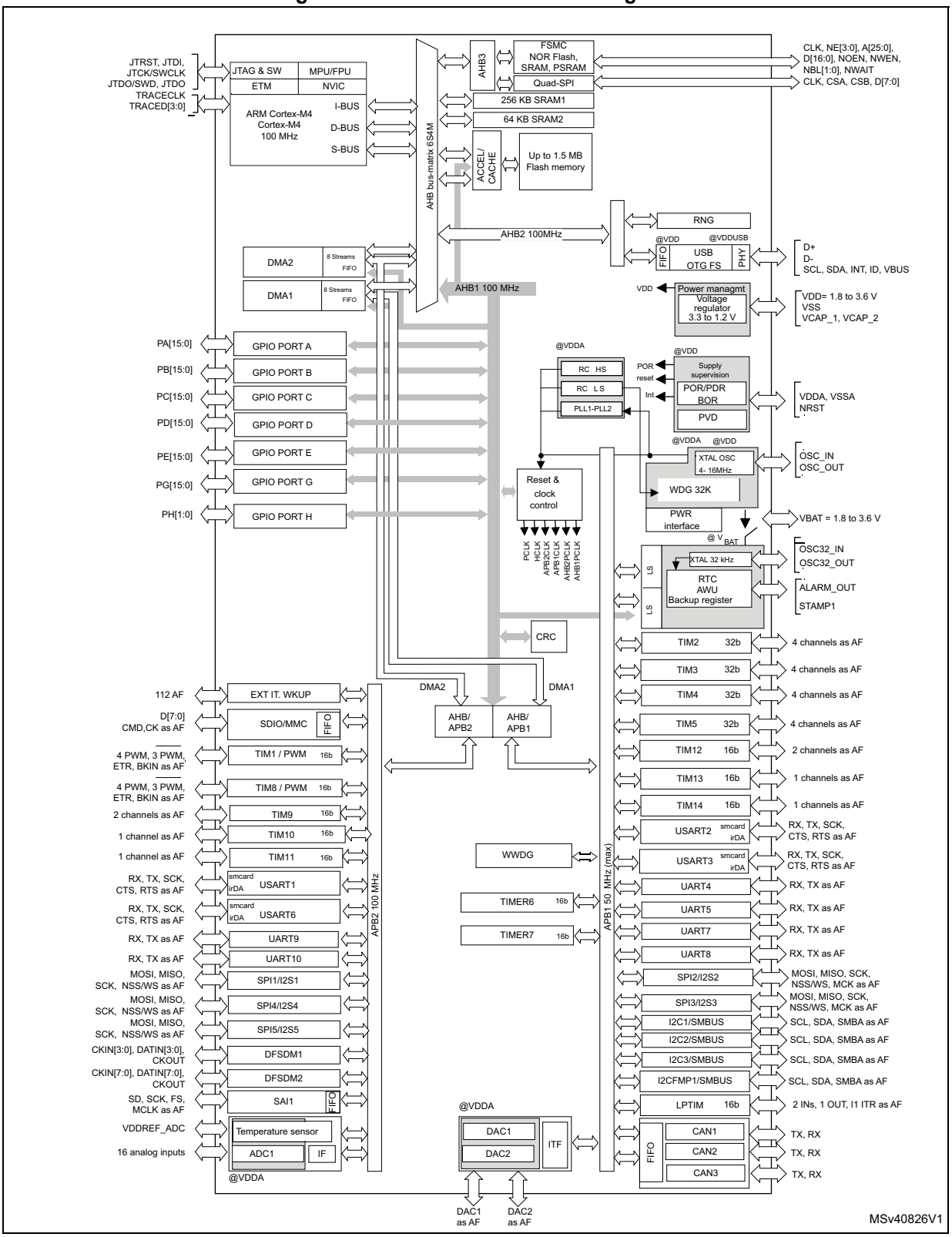
What is "Embedded - Microcontrollers"?

"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Active
Core Processor	ARM® Cortex®-M4
Core Size	32-Bit Single-Core
Speed	100MHz
Connectivity	CANbus, EBI/EMI, I²C, IrDA, LINbus, MMC/SDIO, QSPI, SAI, SPI, UART/USART, USB OTG
Peripherals	Brown-out Detect/Reset, DMA, I²S, LCD, POR, PWM, WDT
Number of I/O	36
Program Memory Size	1.5MB (1.5M x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	320K x 8
Voltage - Supply (Vcc/Vdd)	1.7V ~ 3.6V
Data Converters	A/D 10x12b; D/A 2x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	48-UFQFN Exposed Pad
Supplier Device Package	48-UFQFPN (7x7)
Purchase URL	https://www.e-xfl.com/product-detail/stmicroelectronics/stm32f413chu6

Figure 4. STM32F413xG/H 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.

A dedicated application note (AN4515) describes how to implement the STM32F413xG/H 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 up to 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.

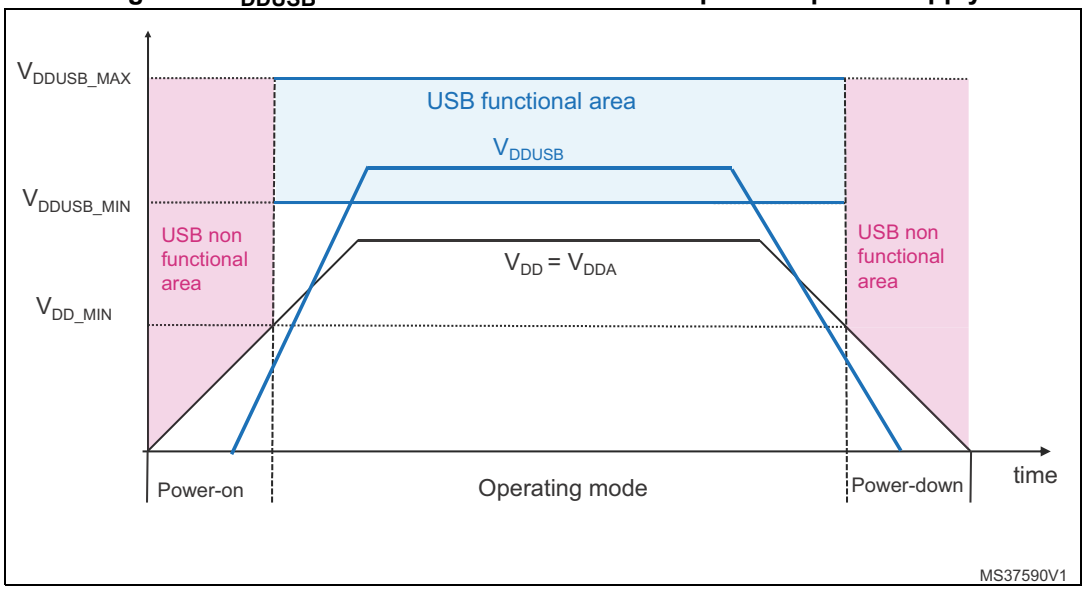
Before disabling the Flash, the code must be executed from the internal RAM.

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.

Figure 6. V_{DDUSB} connected to an external independent power supply



3.17 Power supply supervisor

3.17.1 Internal reset ON

This feature is available for V_{DD} operating voltage range 1.8 V to 3.6 V.

On packages embedding the PDR_ON pin, the power supply supervisor is enabled by holding PDR_ON high. On the other package, 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 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 thresholds, or to disable BOR permanently. Three BOR thresholds are available through option bytes.

The device remains in reset mode when V_{DD} is below a specified threshold, $V_{POR/PDR}$ or V_{BOR}, without the need for an external reset circuit.

The device also features an embedded programmable voltage detector (PVD) that monitors the V_{DD}/V_{DDA} power supply and compares it to the V_{PVD} threshold. An interrupt can be generated when V_{DD}/V_{DDA} drops below the V_{PVD} threshold and/or when V_{DD}/V_{DDA} is higher than the V_{PVD} threshold. The interrupt service routine can then generate a warning message and/or put the MCU into a safe state. The PVD is enabled by software.

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

The RTC and backup registers are supplied through a switch that is powered either from the V_{DD} supply when present or from the VBAT pin.

3.20 Low-power modes

The devices 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.

  To further reduce the power consumption, the Flash memory can be switched off before entering in Sleep mode. Note that this requires a code execution from the RAM.

- **Stop mode**

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

- **Standby mode**

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

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

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

3.21 V_{BAT} operation

The VBAT pin allows to power the device V_{BAT} domain from an external battery, an external super-capacitor, or from V_{DD} when no external battery and an external super-capacitor are present.

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

The VBAT pin supplies the RTC and the backup registers.

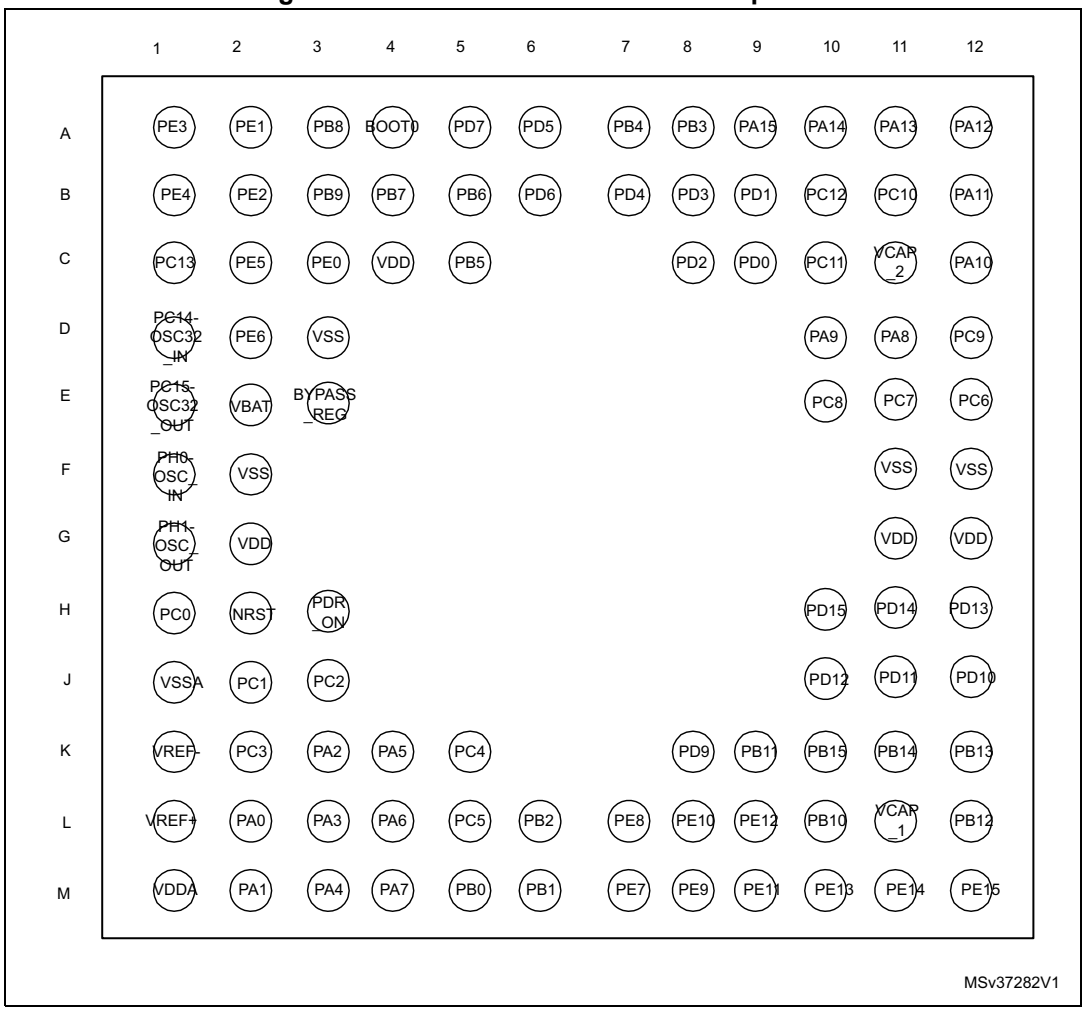
Note: When the microcontroller is supplied from V_{BAT}, external interrupts and RTC alarm/events do not exit it from V_{BAT} operation. When PDR_ON pin is not connected to V_{DD} (internal Reset OFF), the V_{BAT} functionality is no more available and VBAT pin should be connected to V_{DD}.

USART1, USART2, USART3 and USART6 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 7. 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	6.25	12.5	APB2 (max. 100 MHz)
USART2	X	X	X	X	X	X	3.12	6.25	APB1 (max. 50 MHz)
USART3	X	X	X	X	X	X	3.12	6.25	APB1 (max. 50 MHz)
UART4	X	-	X	-	X	-	3.12	6.25	APB1 (max. 50 MHz)
UART5	X	-	X	-	X	-	3.12	6.25	APB1 (max. 50 MHz)
USART6	X	X	X	X	X	X	6.25	12.5	APB2 (max. 100 MHz)
UART7	X	-	X	-	X	-	3.12	6.25	APB1 (max. 50 MHz)
UART8	X	-	X	-	X	-	3.12	6.25	APB1 (max. 50 MHz)
UART9	X	-	X	-	X	-	6.25	12.5	APB2 (max. 100 MHz)
UART10	X	-	X	-	X	-	6.25	12.5	APB2 (max. 100 MHz)

Figure 16. STM32F413xG/H UFBGA100 pinout



1. The above figure shows the package top view.

Table 12. STM32F413xG/H alternate functions (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	AF10	AF11	AF12	AF13	AF14	AF15
		SYS_AF	TIM1/2/ LPTIM1	TIM3/4/5	DFSDM2/ TIM8/9/10/11	I2C1/2/3/ I2CFMP1	SPI1/I2S1/ SPI2/I2S2/ SPI3/I2S3/ SPI4/I2S4	SPI2/I2S2/ SPI3/I2S3/ SPI4/I2S4/ SPI5/I2S5/ DFSDM1/2	SPI3/I2S3/ SAI1/ DFSDM2/ USART1/ USART2/ USART3	DFSDM1/ USART3/4/ 5/6/7/8/ CAN1	I2C2/I2C3/ I2CFMP1/ CAN1/2/ TIM12/13/14/ QUADSPI	SAI1/ DFSDM1/ DFSDM2/ QUADSPI/ FSMC /OTG1_FS	UART4/ UART5/ UART9/ UART10 /CAN3	FSMC /SDIO	-	RNG	SYS_AF
Port C	PC0	-	LPTIM1_IN1	-	DFSDM2_CKIN4	-	-	-	SAI1_MCLK_B	-	-	-	-	-	-	-	EVENTOUT
	PC1	-	LPTIM1_OUT	-	DFSDM2_DATIN4	-	-	-	SAI1_SD_B	-	-	-	-	-	-	-	EVENTOUT
	PC2	-	LPTIM1_IN2	-	DFSDM2_DATIN7	-	SPI2_MISO	I2S2ext_SD	SAI1_SCK_B	DFSDM1_CKOUT	-	-	-	FSMC_NWE	-	-	EVENTOUT
	PC3	-	LPTIM1_ETR	-	DFSDM2_CKIN7	-	SPI2_MOSI/ I2S2_SD	-	SAI1_FS_B	-	-	-	-	FSMC_A0	-	-	EVENTOUT
	PC4	-	-	-	DFSDM2_CKIN2	-	I2S1_MCK	-	-	-	-	QUADSPI_BK2_IO2	-	FSMC_NE4	-	-	EVENTOUT
	PC5	-	-	-	DFSDM2_DATIN2	I2CFMP1_SMBA	-	-	USART3_RX	-	-	QUADSPI_BK2_IO3	-	FSMC_NOE	-	-	EVENTOUT
	PC6	-	-	TIM3_CH1	TIM8_CH1	I2CFMP1_SCL	I2S2_MCK	DFSDM1_CKIN3	DFSDM2_DATIN6	USART6_TX	-	FSMC_D1/ FSMC_DA1	-	SDIO_D6	-	-	EVENTOUT
	PC7	-	-	TIM3_CH2	TIM8_CH2	I2CFMP1_SDA	SPI2_SCK/ I2S2_CK	I2S3_MCK	DFSDM2_CKIN6	USART6_RX	-	DFSDM1_DATIN3	-	SDIO_D7	-	-	EVENTOUT
	PC8	-	-	TIM3_CH3	TIM8_CH3	-	-	-	DFSDM2_CKIN3	USART6_CK	QUADSPI_BK1_IO2	-	-	SDIO_D0	-	-	EVENTOUT
	PC9	MCO_2	-	TIM3_CH4	TIM8_CH4	I2C3_SDA	I2S2_CKIN	-	DFSDM2_DATIN3	-	QUADSPI_BK1_IO0	-	-	SDIO_D1	-	-	EVENTOUT
	PC10	-	-	-	DFSDM2_CKIN5	-	-	SPI3_SCK/ I2S3_CK	USART3_TX	-	QUADSPI_BK1_IO1	-	-	SDIO_D2	-	-	EVENTOUT
	PC11	-	-	-	DFSDM2_DATIN5	-	I2S3ext_SD	SPI3_MISO	USART3_RX	UART4_RX	QUADSPI_BK2_NCS	FSMC_D2/ FSMC_DA2	-	SDIO_D3	-	-	EVENTOUT
	PC12	-	-	-	-	-	-	SPI3_MOSI/ I2S3_SD	USART3_CK	UART5_TX	-	FSMC_D3/ FSMC_DA3	-	SDIO_CK	-	-	EVENTOUT
	PC13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	EVENTOUT
	PC14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	EVENTOUT
	PC15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	EVENTOUT

5 Memory mapping

The memory map is shown in *Figure 18*.

Figure 18. Memory map

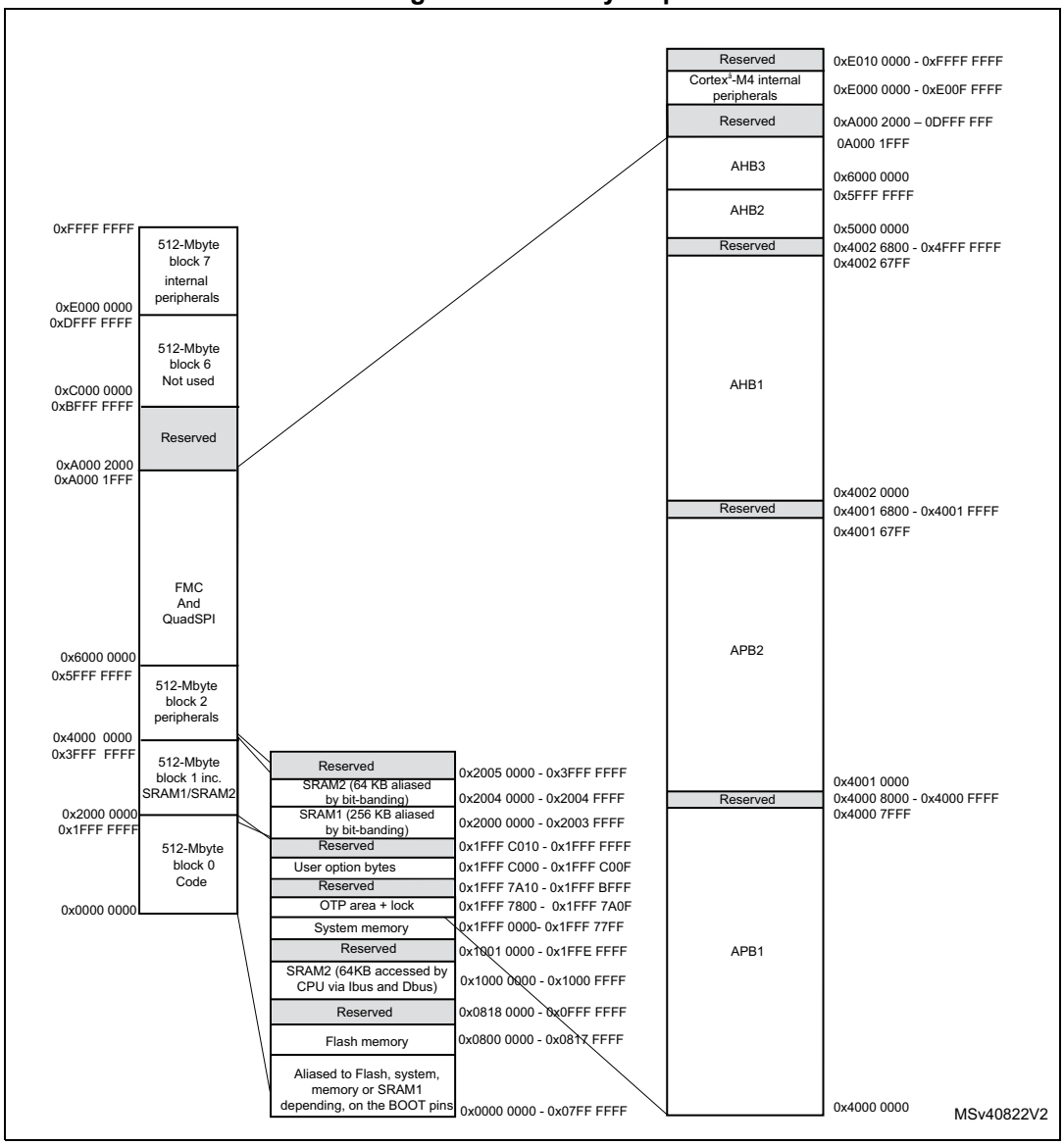


Table 13. STM32F413xG/H register boundary addresses

Bus	Boundary address	Peripheral
	0xE010 0000 - 0xFFFF FFFF	Reserved
Cortex®-M4	0xE000 0000 - 0xE00F FFFF	Cortex-M4 internal peripherals
AHB3	0xA000 2000 - 0xDFFF FFFF	Reserved
	0xA000 1000 - 0xA000 1FFF	QuadSPI control register
	0xA000 0000 - 0xA000 0FFF	FSMC control register
	0x9000 0000 - 0x9FFF FFFF	QUADSPI
	0x7000 0000 - 0x08FFF FFFF	Reserved
	0x6000 0000 - 0x6FFF FFFF	FSMC
AHB2	0x5006 0C00 - 0x5FFF FFFF	Reserved
	0x5006 0800 0x5006 0BFF	RNG
	0x5004 0000 - 0x5006 07FF	Reserved
	0x5000 0000 - 0x5003 FFFF	USB OTG FS
AHB1	0x4002 6800 - 0x4FFF FFFF	Reserved
	0x4002 6400 - 0x4002 67FF	DMA2
	0x4002 6000 - 0x4002 63FF	DMA1
	0x4002 4000 - 0X4002 5FFF	Reserved
	0x4002 3C00 - 0x4002 3FFF	Flash interface register
	0x4002 3800 - 0x4002 3BFF	RCC
	0x4002 3400 - 0x4002 37FF	Reserved
	0x4002 3000 - 0x4002 33FF	CRC
	0x4002 2000 - 0x4002 2FFF	Reserved
	0x4002 1C00 - 0x4002 1FFF	GPIOH
	0x4002 1800 - 0x4002 1BFF	GPIOG
	0x4002 1400 - 0x4002 17FF	GPIOF
	0x4002 1000 - 0x4002 13FF	GPIOE
	0x4002 0C00 - 0x4002 0FFF	GPIOD
	0x4002 0800 - 0x4002 0BFF	GPIOC
	0x4002 0400 - 0x4002 07FF	GPIOB
	0x4002 0000 - 0x4002 03FF	GPIOA

Table 13. STM32F413xG/H register boundary addresses (continued)

Bus	Boundary address	Peripheral
APB2	0x4001 6800- 0x4001 FFFF	Reserved
	0x4001 6400 - 0x4001 67FF	DFSDM2
	0x4001 6000 - 0x4001 63FF	DFSDM1
	0x4001 5C00 - 0x4001 5FFF	Reserved
	0x4001 5800 - 0x4001 5BFF	SAI1
	0x4001 5400 - 0x4001 57FF	Reserved
	0x4001 5000 - 0x4001 53FF	SPI5/I2S5
	0x4001 4C00 - 0x4001 4FFF	Reserved
	0x4001 4800 - 0x4001 4BFF	TIM11
	0x4001 4400 - 0x4001 47FF	TIM10
	0x4001 4000 - 0x4001 43FF	TIM9
	0x4001 3C00 - 0x4001 3FFF	EXTI
	0x4001 3800 - 0x4001 3BFF	SYSCFG
	0x4001 3400 - 0x4001 37FF	SPI4/I2S4
	0x4001 3000 - 0x4001 33FF	SPI1/I2S1
	0x4001 2C00 - 0x4001 2FFF	SDIO
	0x4001 2400 - 0x4001 2BFF	Reserved
	0x4001 2000 - 0x4001 23FF	ADC1/2/3
	0x4001 1C00 - 0x4001 1FFF	UART10
	0x4001 1800 - 0x4001 1BFF	UART9
	0x4001 1400 - 0x4001 17FF	USART6
	0x4001 1000 - 0x4001 13FF	USART1
	0x4001 0800 - 0x4001 0FFF	Reserved
	0x4001 0400 - 0x4001 07FF	TIM8
	0x4001 0000 - 0x4001 03FF	TIM1

3. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA for the analog part.

Table 24. Typical and maximum current consumption, code with data processing (ART accelerator disabled) running from SRAM - V_{DD} = 3.6 V

Symbol	Parameter	Conditions	f_{HCLK} (MHz)	Typ	Max(1)				Unit
				T_A= 25 °C	T_A= 25 °C	T_A= 85 °C	T_A= 105 °C	T_A= 125 °C	
I_{DD}	Supply current in **Run mode**	External clock, PLL ON, all peripherals enabled(2)	100	33.3	35.32(3)	35.65	37.65	41.26(3)	mA
			84	26.8	28.45(3)	28.97	30.82	34.39(3)	
			64	18.6	19.74(3)	20.35	22.11	25.35(3)	
			50	14.6	15.57	16.41	18.21	21.46	
			25	7.8	8.37	9.64	11.32	14.68	
			20	6.7	7.25	8.40	10.25	13.45	
		HSI, PLL OFF(4), all peripherals enabled(2)	16	4.6	4.96	6.39	8.20	11.54	
			1	0.8	0.86	2.51	4.34	7.65	
		External clock, PLL ON, all peripherals disabled(2)	100	15.7	16.74(3)	17.62	19.50	23.16(3)	
			84	12.7	13.57(3)	14.60	16.38	19.98(3)	
			64	9.0	9.62(3)	10.60	12.37	15.58(3)	
			50	7.1	7.69	8.79	10.63	13.79	
			25	4.0	4.52	5.68	7.44	10.68	
			20	3.4	4.03	5.23	6.90	10.27	
		HSI, PLL OFF, all peripherals disabled(2)	16	2.3	2.44	4.00	5.81	9.13	
			1	0.6	0.70	2.35	4.18	7.49	

1. Guaranteed by characterization results.
2. When the ADC is ON (ADON bit set in the ADC_CR2 register), add an additional power consumption of 1.6 mA for the analog part.
3. Tested in production
4. When analog peripheral blocks such as ADC, HSE, LSE, HSI, or LSI are ON, an additional power consumption has to be considered

6.3.10 PLL characteristics

The parameters given in *Table 47* and *Table 48* are derived from tests performed under temperature and V_{DD} supply voltage conditions summarized in *Table 17*.

Table 47. Main PLL characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
f_{PLL_IN}	PLL input clock(1)	-		0.95(2)	1	2.10	MHz
f_{PLLP_OUT}	PLLP multiplier output clock	-		24	-	100	
f_{PLLQ_OUT}	48 MHz PLLQ multiplier output clock	-		-	48	75	
f_{PLLR_OUT}	PLLR multiplier output clock for I2S and SAI	-		-	-	216	
f_{VCO_OUT}	PLL VCO output	-		100	-	432	
t_{LOCK}	PLL lock time	VCO freq = 100 MHz		75	-	200	µs
		VCO freq = 432 MHz		100	-	300	
Jitter(3)	Cycle-to-cycle jitter	System clock 100 MHz	RMS	-	25	-	ps
			peak to peak	-	±150	-	
	Period Jitter		RMS	-	15	-	
			peak to peak	-	±200	-	
	Bit Time CAN jitter	Cycle to cycle at 1 MHz on 1000 samples.		-	330	-	
$I_{DD(PLL)}$(4)	PLL power consumption on VDD	VCO freq = 100 MHz VCO freq = 432 MHz		0.15 0.45	-	0.40 0.75	mA
$I_{DDA(PLL)}$(4)	PLL power consumption on VDDA	VCO freq = 100 MHz VCO freq = 432 MHz		0.30 0.55	-	0.40 0.85	

1. Take care of using the appropriate division factor M to obtain the specified PLL input clock values. The M factor is shared between PLL and PLLI2S.
2. Guaranteed by design.
3. The use of two PLLs in parallel could degraded the Jitter up to +30%.
4. Guaranteed by characterization results.

Table 48. PLLI2S (audio PLL) characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
f_{PLL_IN}	PLL input clock(1)	-		0.95(2)	1	2.10	MHz
$f_{PLLI2SQ\_OUT}$	48 MHz PLLI2SQ multiplier output clock	-		-	48	75	
$f_{PLLI2SR\_OUT}$	PLLI2SR multiplier output clock for I2S and SAI	-		-	-	216	
f_{VCO_OUT}	PLLI2S VCO output	-		100	-	432	
t_{LOCK}	PLLI2S lock time	VCO freq = 100 MHz		75	-	200	µs
		VCO freq = 432 MHz		100	-	300	
Jitter(3)	Master I2S clock jitter	Cycle to cycle at 12.288 MHz on 48 kHz period, N=432, R=5	RMS	-	90	-	ps
			peak to peak	-	±280	-	
		Average frequency of 12.288 MHz N = 432, R = 5 on 1000 samples		-	90	-	
	WS I2S clock jitter	Cycle to cycle at 48 KHz on 1000 samples		-	400	-	
$I_{DD(PLLI2S)}$(4)	PLLI2S power consumption on V_{DD}	VCO freq = 100 MHz VCO freq = 432 MHz		0.15 0.45	-	0.40 0.75	mA
$I_{DDA(PLLI2S)}$(4)	PLLI2S power consumption on V_{DDA}	VCO freq = 100 MHz VCO freq = 432 MHz		0.30 0.55	-	0.40 0.85	

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

Figure 33 and *Figure 34* show the main PLL output clock waveforms in center spread and down spread modes, where:

F0 is f_{PLL_OUT} nominal.

T_{mode} is the modulation period.

md is the modulation depth.

Figure 33. PLL output clock waveforms in center spread mode

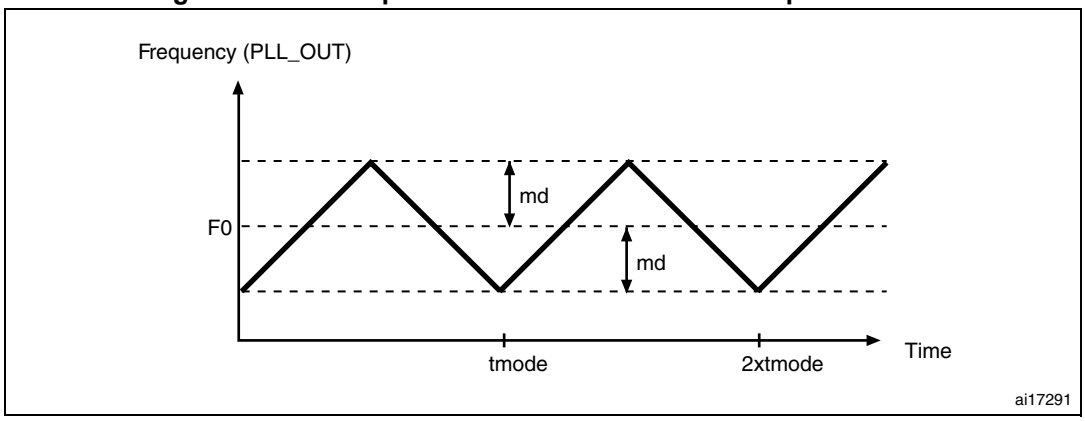
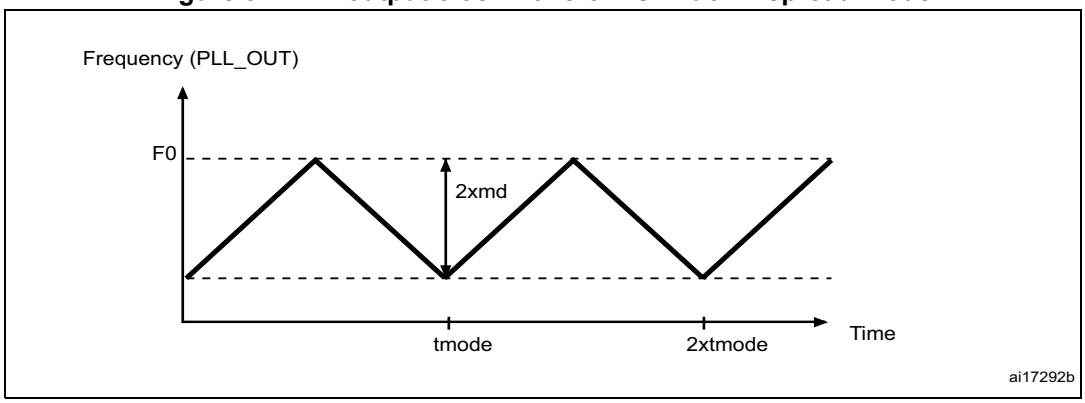


Figure 34. PLL output clock waveforms in down spread mode



6.3.12 Memory characteristics

Flash memory

The characteristics are given at T_A = –40 to 125 °C unless otherwise specified.

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

Table 50. Flash memory characteristics

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

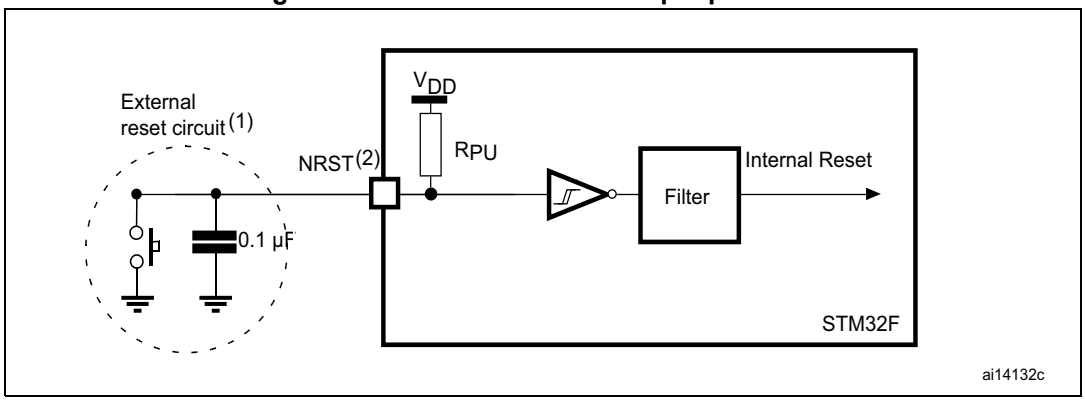
Table 59. I/O static characteristics (continued)

Symbol	Parameter		Conditions	Min	Typ	Max	Unit
I_{lkg}	I/O input leakage current (4)		$V_{SS} \leq V_{IN} \leq V_{DD}$	-	-	±1	µA
	I/O FT/TC input leakage current (5)		V_{IN} = 5 V	-	-	3	
R_{PU}	Weak pull-up equivalent resistor(6)	All pins except for PA10 (OTG_FS_ID)	$V_{IN} = V_{SS}$	30	40	50	kΩ
		PA10 (OTG_FS_ID)	-	7	10	14	
R_{PD}	Weak pull-down equivalent resistor(7)	All pins except for PA10 (OTG_FS_ID)	$V_{IN} = V_{DD}$	30	40	50	
		PA10 (OTG_FS_ID)	-	7	10	14	
C_{IO}(8)	I/O pin capacitance		-	-	5	-	pF

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

All I/Os are CMOS and TTL compliant (no software configuration required). Their characteristics cover more than the strict CMOS-technology or TTL parameters. The coverage of these requirements for FT and TC I/Os is shown in *Figure 35*.

Figure 37. Recommended NRST pin protection



1. The reset network protects the device against parasitic resets.
2. The user must ensure that the level on the NRST pin can go below the $V_{IL(NRST)}$ max level specified in *Table 62*. Otherwise the reset is not taken into account by the device.

6.3.18 TIM timer characteristics

The parameters given in *Table 63* are guaranteed by design.

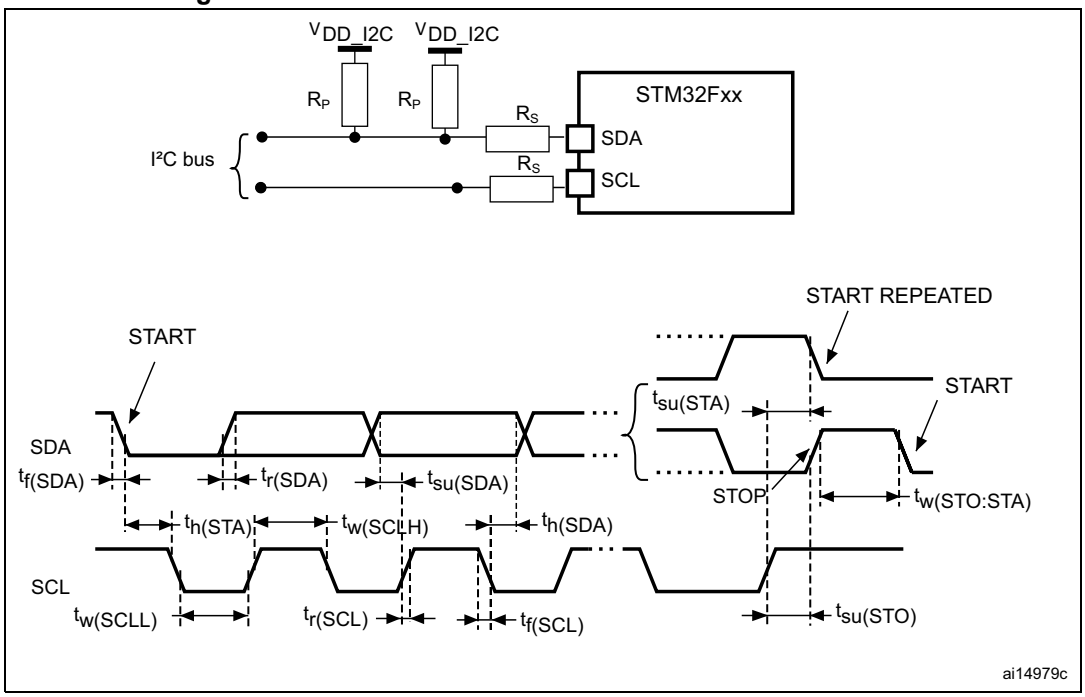
Refer to *Section 6.3.16: I/O port characteristics* for details on the input/output alternate function characteristics (output compare, input capture, external clock, PWM output).

Table 63. TIMx characteristics(1)(2)

Symbol	Parameter	Conditions(3)	Min	Max	Unit
$t_{res(TIM)}$	Timer resolution time	AHB/APBx prescaler=1 or 2 or 4, $f_{TIMxCLK}$ = 100 MHz	1	-	$t_{TIMxCLK}$
			11.9	-	ns
		AHB/APBx prescaler>4, $f_{TIMxCLK}$ = 100 MHz	1	-	$t_{TIMxCLK}$
			11.9	-	ns
f_{EXT}	Timer external clock frequency on CH1 to CH4	$f_{TIMxCLK}$ = 100 MHz	0	$f_{TIMxCLK}/2$	MHz
			0	50	MHz
Res_{TIM}	Timer resolution		-	16/32	bit
$t_{COUNTER}$	16-bit counter clock period when internal clock is selected	$f_{TIMxCLK}$ = 100 MHz	0.0119	780	µs
t_{MAX_COUNT}	Maximum possible count with 32-bit counter	-	-	65536 × 65536	$t_{TIMxCLK}$
		$f_{TIMxCLK}$ = 100 MHz	-	51.1	S

1. TIMx is used as a general term to refer to the TIM1 to TIM11 timers.
2. Guaranteed by design.
3. The maximum timer frequency on APB1 is 50 MHz and on APB2 is up to 100 MHz, by setting the TIMPRE bit in the RCC_DCKCFGR register, if APBx prescaler is 1 or 2 or 4, then TIMxCLK = HCKL, otherwise TIMxCLK >= 4x PCLKx.

Figure 38. I²C bus AC waveforms and measurement circuit



1. R_S = series protection resistor.
2. R_P = external pull-up resistor.
3. V_{DD_I2C} is the I2C bus power supply.

Table 65. SCL frequency (f_{PCLK1}= 50 MHz, V_{DD} = V_{DD_I2C} = 3.3 V)(1)(2)

f_{SCL} (kHz)	I2C_CCR value
	R_P = 4.7 kΩ
400	0x8019
300	0x8021
200	0x8032
100	0x0096
50	0x012C
20	0x02EE

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

Table 88. Asynchronous non-multiplexed SRAM/PSRAM/NOR - read timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FSMC_NE low time	$2 * t_{HCLK} - 1$	$2 * t_{HCLK} + 1$	ns
$t_{v(NOE\_NE)}$	FSMC_NEx low to FSMC_NOE low	0	0.5	
$t_{w(NOE)}$	FSMC_NOE low time	$2 * t_{HCLK} - 1$	$2 * t_{HCLK} + 1$	
$t_{h(NE\_NOE)}$	FSMC_NOE high to FSMC_NE high hold time	0	-	
$t_{v(A\_NE)}$	FSMC_NEx low to FSMC_A valid	-	0.5	
$t_{h(A\_NOE)}$	Address hold time after FSMC_NOE high	0	-	
$t_{v(BL\_NE)}$	FSMC_NEx low to FSMC_BL valid	-	0.5	
$t_{h(BL\_NOE)}$	FSMC_BL hold time after FSMC_NOE high	0	-	
$t_{su(Data\_NE)}$	Data to FSMC_NEx high setup time	$t_{HCLK} - 2$	-	
$t_{su(Data\_NOE)}$	Data to FSMC_NOEx high setup time	$t_{HCLK} - 2$	-	
$t_{h(Data\_NOE)}$	Data hold time after FSMC_NOE high	0	-	
$t_{h(Data\_NE)}$	Data hold time after FSMC_NEx high	0	-	
$t_{v(NADV\_NE)}$	FSMC_NEx low to FSMC_NADV low	-	0	
$t_{w(NADV)}$	FSMC_NADV low time	-	$t_{HCLK} + 1$	

1. C_L = 30 pF.
2. Based on characterization.

Table 89. Asynchronous non-multiplexed SRAM/PSRAM/NOR read - NWAIT timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(NE)}$	FSMC_NE low time	$7 * t_{HCLK} + 1$	$7 * t_{HCLK} + 1$	ns
$t_{w(NOE)}$	FSMC_NWE low time	$5 * t_{HCLK} - 1$	$5 * t_{HCLK} + 1$	
$t_{w(NWAIT)}$	FSMC_NWAIT low time	$t_{HCLK} - 0.5$	-	
$t_{su(NWAIT\_NE)}$	FSMC_NWAIT valid before FSMC_NEx high	$5 * t_{HCLK} + 1.5$	-	
$t_{h(NE\_NWAIT)}$	FSMC_NEx hold time after FSMC_NWAIT invalid	$4 * t_{HCLK} + 1$	-	

1. C_L = 30 pF.
2. Based on characterization.

Figure 59. Synchronous non-multiplexed NOR/PSRAM read timings

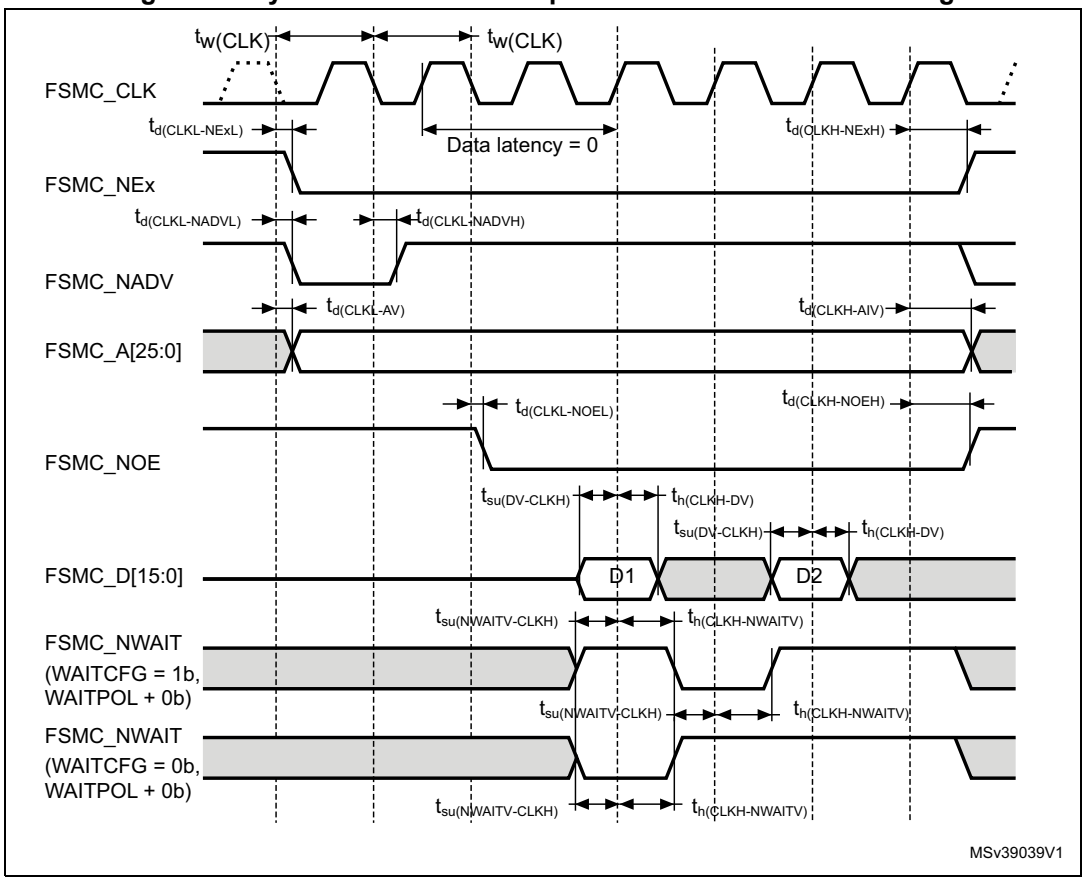


Table 98. Synchronous non-multiplexed NOR/PSRAM read timings(1)(2)

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	FSMC_CLK period	$2T_{HCLK} - 0.5$	-	ns
$t_{(CLKL-NExL)}$	FSMC_CLK low to FSMC_NEx low (x=0..2)	-	2	
$t_{d(CLKH-NExH)}$	FSMC_CLK high to FSMC_NEx high (x= 0…2)	T_{HCLK} +0.5	-	
$t_{d(CLKL-NADVL)}$	FSMC_CLK low to FSMC_NADV low	-	0.5	
$t_{d(CLKL-NADVH)}$	FSMC_CLK low to FSMC_NADV high	0	-	
$t_{d(CLKL-AV)}$	FSMC_CLK low to FSMC_Ax valid (x=16…25)	-	2.5	
$t_{d(CLKH-AIV)}$	FSMC_CLK high to FSMC_Ax invalid (x=16…25)	T_{HCLK}	-	
$t_{d(CLKL-NOEL)}$	FSMC_CLK low to FSMC_NOE low	-	1.5	
$t_{d(CLKH-NOEH)}$	FSMC_CLK high to FSMC_NOE high	T_{HCLK} - 0.5	-	
$t_{su(DV-CLKH)}$	FSMC_D[15:0] valid data before FSMC_CLK high	1.5	-	
$t_{h(CLKH-DV)}$	FSMC_D[15:0] valid data after FSMC_CLK high	3.5	-	
$t_{su(NWAIT-CLKH)}$	FSMC_NWAIT valid before FSMC_CLK high	2.5	-	
$t_{h(CLKH-NWAIT)}$	FSMC_NWAIT valid after FSMC_CLK high	3.5	-	

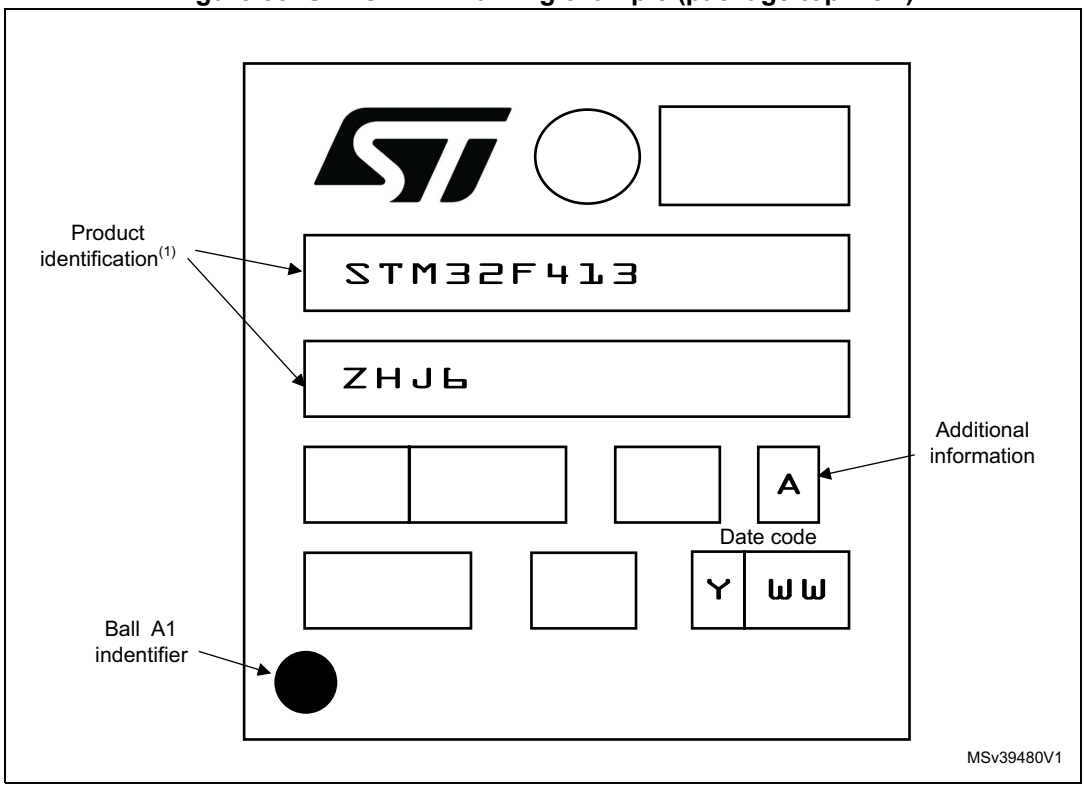
1. C_L = 30 pF.
2. Guaranteed by characterization results.

Device marking for UFBGA144

The following figure gives an example of topside marking and ball A1 position identifier location.

Other optional marking or inset/upset marks, which identify the parts throughout supply chain operations, are not indicated below.

Figure 83. UFBGA144 marking example (package top view)



1. Parts marked as “ES”, “E” or accompanied by an Engineering Sample notification letter, are not yet qualified and therefore not yet ready to be used in production and any consequences deriving from such usage will not be at ST charge. In no event, ST will be liable for any customer usage of these engineering samples in production. ST Quality has to be contacted prior to any decision to use these Engineering Samples to run qualification activity.