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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	I²C, IrDA, LINbus, MMC/SD/SDIO, SPI, UART/USART, USB OTG
Peripherals	Brown-out Detect/Reset, DMA, I²S, POR, PWM, WDT
Number of I/O	36
Program Memory Size	512KB (512K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	128K x 8
Voltage - Supply (Vcc/Vdd)	1.7V ~ 3.6V
Data Converters	A/D 10x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	49-UFBGA, WLCSP
Supplier Device Package	49-WLCSP (3x3.19)
Purchase URL	https://www.e-xfl.com/product-detail/stmicroelectronics/stm32f411cey6tr

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 STM32F411xC/xE devices are compatible with all ARM tools and software.

Figure 3 shows the general block diagram of the STM32F411xC/xE.

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 105 DMIPS performance at this frequency, the accelerator implements an instruction prefetch queue and branch cache, which increases program execution speed from the -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 Batch Acquisition mode (BAM)

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 I2S 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. A dedicated application note (AN4515) describes how to implement the BAM to allow the best power efficiency.

The DMA can be used with the main peripherals:

- SPI and I^2S
- I^2C
- USART
- General-purpose, basic and advanced-control timers TIMx
- SD/SDIO/MMC/eMMC host interface
- ADC

3.10 Nested vectored interrupt controller (NVIC)

The devices embed a nested vectored interrupt controller able to manage 16 priority levels, and handle up to 62 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.

3.11 External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 21 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 81 GPIOs can be connected to the 16 external interrupt lines.

3.12 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 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 two AHB buses, the high-speed APB (APB2) and the low-speed APB (APB1) domains. The maximum frequency of the two AHB

buses is 100 MHz while the maximum frequency of the 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 (PLLI2S) which allows to achieve audio class performance. In this case, the I^2S master clock can generate all standard sampling frequencies from 8 kHz to 192 kHz.

3.13 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 bootloader is located in system memory. It is used to reprogram the Flash memory by using USART1(PA9/10), USART2(PD5/6), USB OTG FS in device mode (PA11/12) through DFU (device firmware upgrade), I2C1(PB6/7), I2C2(PB10/3), I2C3(PA8/PB4), SPI1(PA4/5/6/7), SPI2(PB12/13/14/15) or SPI3(PA15, PC10/11/12).

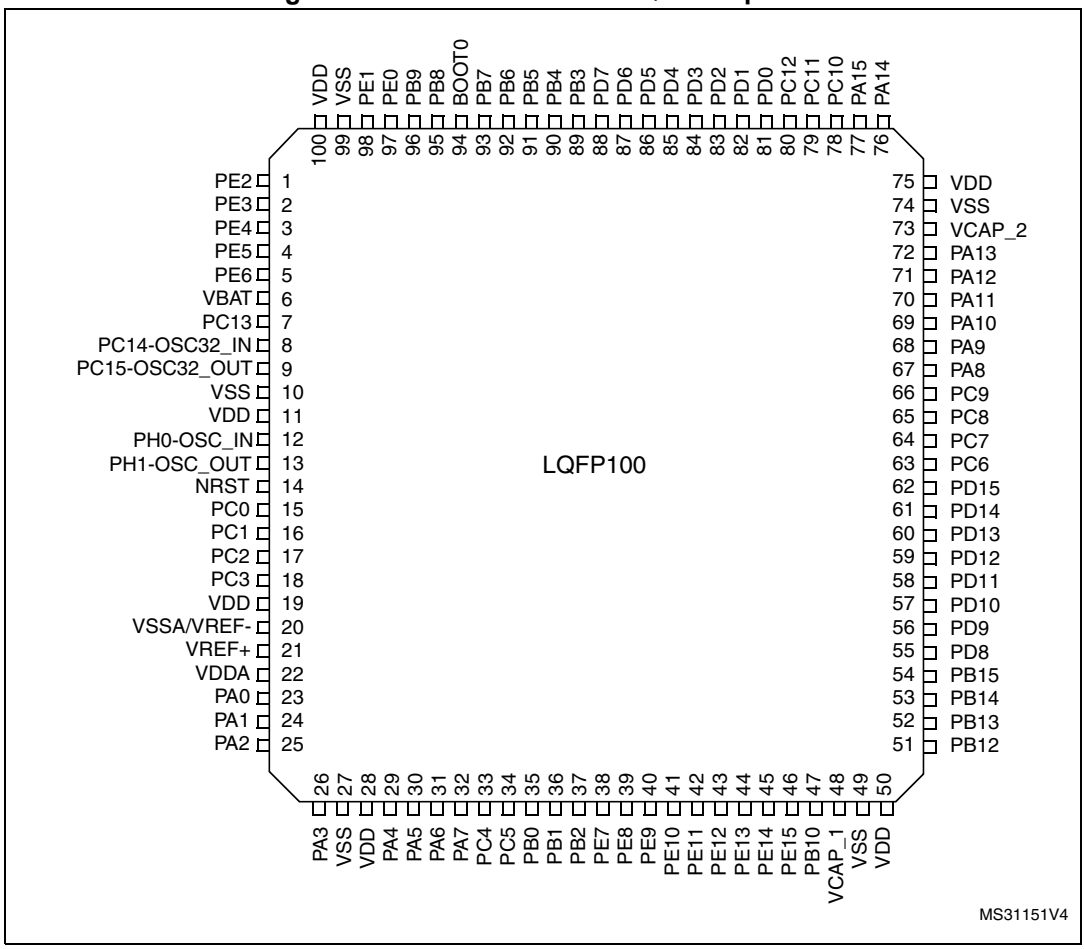
For more detailed information on the bootloader, refer to Application Note: AN2606, *STM32™ microcontroller system memory boot mode*.

3.14 Power supply schemes

- VDD = 1.7 to 3.6 V: external power supply for I/Os with the internal supervisor (POR/PDR) disabled, provided externally through VDD pins. Requires the use of an external power supply supervisor connected to the VDD 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.
- 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 17: Power supply scheme* for more details.

Figure 12. STM32F411xC/xE LQFP100 pinout



1. The above figure shows the package top view.

Table 8. STM32F411xC/xE pin definitions (continued)

Pin number					Pin name (function after reset)[1]	Pin type	I/O structure	Notes	Alternate functions	Additional functions
UFQFPN48	LQFP64	WLCSP49	LQFP100	UFBGA100						
43	59	D4	93	B4	PB7	I/O	FT	-	TIM4_CH2, I2C1_SDA, USART1_RX, SDIO_D0, EVENTOUT	-
44	60	A5	94	A4	BOOT0	I	B	-	-	VPP
45	61	B5	95	A3	PB8	I/O	FT	-	TIM4_CH3, TIM10_CH1, I2C1_SCL, SPI5_MOSI/I2S5_SD, I2C3_SDA, SDIO_D4, EVENTOUT	-
46	62	C5	96	B3	PB9	I/O	FT	-	TIM4_CH4, TIM11_CH1, I2C1_SDA, SPI2_NSS/I2S2_WS, I2C2_SDA, SDIO_D5, EVENTOUT	-
-	-	-	97	C3	PE0	I/O	FT	-	TIM4_ETR, EVENTOUT	-
-	-	-	98	A2	PE1	I/O	FT	-	EVENTOUT	-
47	63	A6	99	-	VSS	S	-	-	-	-
-	-	B6	-	H3	PDR_ON	I	FT	-	-	-
48	64	A7	100	-	VDD	S	-	-	-	-

1. Function availability depends on the chosen device.
2. PC13, PC14 and PC15 are supplied through the power switch. Since the switch only sinks a limited amount of current (3 mA), the use of GPIOs PC13 to PC15 in output mode is limited:
   - The speed should not exceed 2 MHz with a maximum load of 30 pF.
   - These I/Os must not be used as a current source (e.g. to drive an LED).
3. Main function after the first backup domain power-up. Later on, it depends on the contents of the RTC registers even after reset (because these registers are not reset by the main reset). For details on how to manage these I/Os, refer to the RTC register description sections in the STM32F411xx reference manual.
4. FT = 5 V tolerant except when in analog mode or oscillator mode (for PC14, PC15, PH0 and PH1).
5. If the device is delivered in an UFBGA100 and the BYPASS_REG pin is set to VDD (Regulator off/internal reset ON mode), then PA0 is used as an internal Reset (active low)

Table 14. General operating conditions (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
P_D	Power dissipation at T_A = 125 °C (range 3)(7)	UFQFPN48	-	-	156	mW
		WLCSP49	-	-	98	
		LQFP64	-	-	106	
		LQFP100	-	-	116	
		UFBGA100	-	-	81	
T_A	Ambient temperature for range 6	Maximum power dissipation	- 40	-	85	°C
		Low power dissipation(8)	- 40	-	105	
	Ambient temperature for range 7	Maximum power dissipation	- 40	-	105	
		Low power dissipation(8)	- 40	-	125	
	Ambient temperature for range 3	Maximum power dissipation	- 40	-	110	
		Low power dissipation(8)	- 40	-	130	
T_J	Junction temperature range	Range 6	- 40	-	105	
		Range 7	- 40	-	125	
		Range 3	- 40	-	130	

1. V_{DD}/V_{DDA} minimum value of 1.7 V with the use of an external power supply supervisor (refer to *Section 3.15.2: Internal reset OFF*).
2. When the ADC is used, refer to *Table 65: ADC characteristics*.
3. If VREF+ pin is present, it must respect the following condition: VDDA-VREF+ < 1.2 V.
4. It is recommended to power V_{DD} and V_{DDA} from the same source. A maximum difference of 300 mV between V_{DD} and V_{DDA} can be tolerated during power-up and power-down operation.
5. Guaranteed by test in production.
6. To sustain a voltage higher than VDD+0.3, the internal Pull-up and Pull-Down resistors must be disabled
7. If T_A is lower, higher P_D values are allowed as long as T_J does not exceed T_{Jmax}.
8. In low power dissipation state, T_A can be extended to this range as long as T_J does not exceed T_{Jmax}.

Table 15. Features depending on the operating power supply range

Operating power supply range	ADC operation	Maximum Flash memory access frequency with no wait states ($f_{Flashmax}$)	Maximum Flash memory access frequency with wait states (1)(2)	I/O operation	Clock output frequency on I/O pins(3)	Possible Flash memory operations
V_{DD} =1.7 to 2.1 V(4)	Conversion time up to 1.2 Msps	16 MHz(5)	100 MHz with 6 wait states	– No I/O compensation	up to 30 MHz	8-bit erase and program operations only
V_{DD} = 2.1 to 2.4 V	Conversion time up to 1.2 Msps	18 MHz	100 MHz with 5 wait states	– No I/O compensation	up to 30 MHz	16-bit erase and program operations

Table 23. 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 V

Symbol	Parameter	Conditions	f_{HCLK} (MHz)	Typ	Max(1)				Unit
					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(2), all peripherals enabled(3)(4)	100	20.7	22.2	22.5	23.2	24.4	mA
			84	16.8	18.0	18.3	19.0	20.1	
			64	11.8	12.7	12.9	13.6	14.6	
			50	9.3	10.2	10.4	11.1	12.0	
			20	4.8	5.5	5.8	6.5	7.4	
		HSI, PLL OFF(2), all peripherals enabled(3)	16	3.0	3.3	3.8	4.5	5.4	
			1	0.7	1.0	1.4	2.1	3.0	
		External clock, PLL ON(2) all peripherals disabled(3)	100	11.6	12.6	12.9	13.6	14.8	
			84	9.7	10.2(5)	11.1	11.3	12.5	
			64	6.7	7.4	7.7	8.3	9.4	
			50	5.4	6.0	6.3	7.0	8.0	
			20	2.9	3.4	3.7	4.4	5.4	
		HSI, PLL OFF(2), all peripherals disabled(3)	16	1.9	2.2	2.6	3.3	4.3	
			1	0.7	0.9	1.3	2.1	3.1	

1. Guaranteed by characterization results.
2. Refer to *Table 41* and RM0383 for the possible PLL VCO setting
3. Add an additional power consumption of 1.6 mA per ADC for the analog part. In applications, this consumption occurs only while the ADC is ON (ADON bit is set in the ADC_CR2 register).
4. When the ADC is ON (ADON bit set in the ADC_CR2), add an additional power consumption of 1.6mA per ADC for the analog part.
5. Guaranteed by test in production.

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

Symbol	Parameter	Conditions	f_{HCLK} (MHz)	Typ	Max(1)				Unit
					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(2), all peripherals enabled(3)(4)	100	29.5	31.5	32.3	33.3	34.7	mA
			84	25.5	27.1	27.9	28.9	30.2	
			64	18.6	19.8	20.4	21.2	22.4	
			50	15.2	16.4	16.9	17.7	18.7	
			20	7.6	8.4	8.8	9.5	10.5	
		HSI, PLL OFF(2), all peripherals enabled(3)	16	4.8	5.2	5.7	6.5	7.5	
			1	0.9	1.3	1.6	2.4	3.4	
		External clock, PLL ON(2) all peripherals disabled(3)	100	20.4	21.8	22.7	23.8	25.1	
			84	18.4	19.2(5)	20.9	21.1	22.4	
			64	13.5	14.5	15.2	15.9	17.2	
			50	11.3	12.2	12.8	13.6	14.7	
			20	5.6	6.4	6.7	7.4	8.5	
		HSI, PLL OFF(2), all peripherals disabled(3)	16	3.6	4.1	4.5	5.2	6.3	
			1	0.9	1.2	1.6	2.3	3.4	

1. Guaranteed by characterization results.
2. Refer to *Table 41* and RM0383 for the possible PLL VCO setting
3. Add an additional power consumption of 1.6 mA per ADC for the analog part. In applications, this consumption occurs only while the ADC is ON (ADON bit is set in the ADC_CR2 register).
4. When the ADC is ON (ADON bit set in the ADC_CR2), add an additional power consumption of 1.6mA per ADC for the analog part.
5. Guaranteed by test in production.

Table 25. 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 V

Symbol	Parameter	Conditions	f_{HCLK} (MHz)	Typ	Max(1)				Unit
					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(2), all peripherals enabled(3)(4)	100	31.7	33.6	34.5	35.5	37.0	mA
			84	26.9	28.6	29.4	30.3	31.6	
			64	19.6	20.9	21.5	22.3	23.5	
			50	15.6	16.7	17.2	18.0	19.1	
			20	7.6	8.4	8.8	9.5	10.6	
		HSI, PLL OFF(2), all peripherals enabled(3)	16	5.1	5.6	6.1	6.8	7.9	
			1	1.0	1.3	1.7	2.3	3.4	
		External clock, PLL ON(2) all peripherals disabled(3)	100	22.5	24.2	24.9	26.0	27.3	
			84	19.5	21.1(5)	21.8	22.8	24.1	
			64	14.5	15.7	16.3	17.1	18.3	
			50	11.7	12.7	13.2	14.0	15.1	
			20	5.6	6.4	6.8	7.4	8.5	
		HSI, PLL OFF(2), all peripherals disabled(3)	16	4.0	4.5	4.9	5.6	6.7	
			1	0.9	1.2	1.6	2.2	3.3	

1. Guaranteed by characterization results.
2. Refer to *Table 41* and RM0383 for the possible PLL VCO setting
3. Add an additional power consumption of 1.6 mA per ADC for the analog part. In applications, this consumption occurs only while the ADC is ON (ADON bit is set in the ADC_CR2 register).
4. When the ADC is ON (ADON bit set in the ADC_CR2), add an additional power consumption of 1.6mA per ADC for the analog part.
5. Guaranteed by test in production.

Table 28. Typical and maximum current consumption in Stop mode - V_{DD}=3.6 V

Symbol	Conditions	Parameter	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_STOP}	Flash in Stop mode, all oscillators OFF, no independent watchdog	Main regulator usage	113.7	145(2)	410	720(2)	1217	µA
		Low power regulator usage	43.1	68(2)	310	600(2)	1073	
	Flash in Deep power down mode, all oscillators OFF, no independent watchdog	Main regulator usage	76.2	105(2)	320	600(2)	1019	
		Low power regulator usage	14	38(2)	275	560(2)	1025	
		Low power low voltage regulator usage	10	30(2)	235	510(2)	928	

1. Guaranteed by characterization results.
2. Guaranteed by test in production.

Table 29. Typical and maximum current consumption in Standby mode - V_{DD}= 1.7 V

Symbol	Parameter	Conditions	Typ(1)	Max(2)				Unit
			T_A = 25 °C	T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	T_A = 125 °C	
I_{DD_STBY}	Supply current in Standby mode	Low-speed oscillator (LSE) and RTC ON	2.4	4	12	25	50	µA
		RTC and LSE OFF	1.8	3(3)	11	24(3)	49	

1. When the PDR is OFF (internal reset is OFF), the typical current consumption is reduced by 1.2 µA.
2. Guaranteed by characterization results.
3. Guaranteed by test in production.

Table 30. Typical and maximum current consumption in Standby mode - V_{DD}= 3.6 V

Symbol	Parameter	Conditions	Typ(1)	Max(2)				Unit
			T_A = 25 °C	T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	T_A = 125 °C	
I_{DD_STBY}	Supply current in Standby mode	Low-speed oscillator (LSE) and RTC ON	2.8	5	14	29	59	µA
		RTC and LSE OFF	2.1	4(3)	13.5	28(3)	58	

1. When the PDR is OFF (internal reset is OFF), the typical current consumption is reduced by 1.2 µA.
2. Guaranteed by characterization results.
3. Guaranteed by test in production.

Table 31. Typical and maximum current consumptions in V_{BAT} mode

Symbol	Parameter	Conditions[1]	Typ			Max[2]			Unit
			T_A = 25 °C			T_A = 85 °C	T_A = 105 °C	T_A = 125 °C	
			V_{BAT} = 1.7 V	V_{BAT}= 2.4 V	V_{BAT} = 3.3 V	V_{BAT} = 3.6 V			
I_{DD_VBAT}	Backup domain supply current	Low-speed oscillator (LSE in low-drive mode) and RTC ON	0.7	0.8	1.0	3	5	6.8	µA
		Low-speed oscillator (LSE in high-drive mode) and RTC ON	1.5	1.6	1.9	3.8	5.8	8.6	
		RTC and LSE OFF	0.1	0.1	0.1	2	4	5.8	

1. Crystal used: Abracon ABS07-120-32.768 kHz-T with a C_L of 6 pF for typical values.
2. Guaranteed by characterization results.

Figure 20. Typical V_{BAT} current consumption (LSE in low-drive mode and RTC ON)

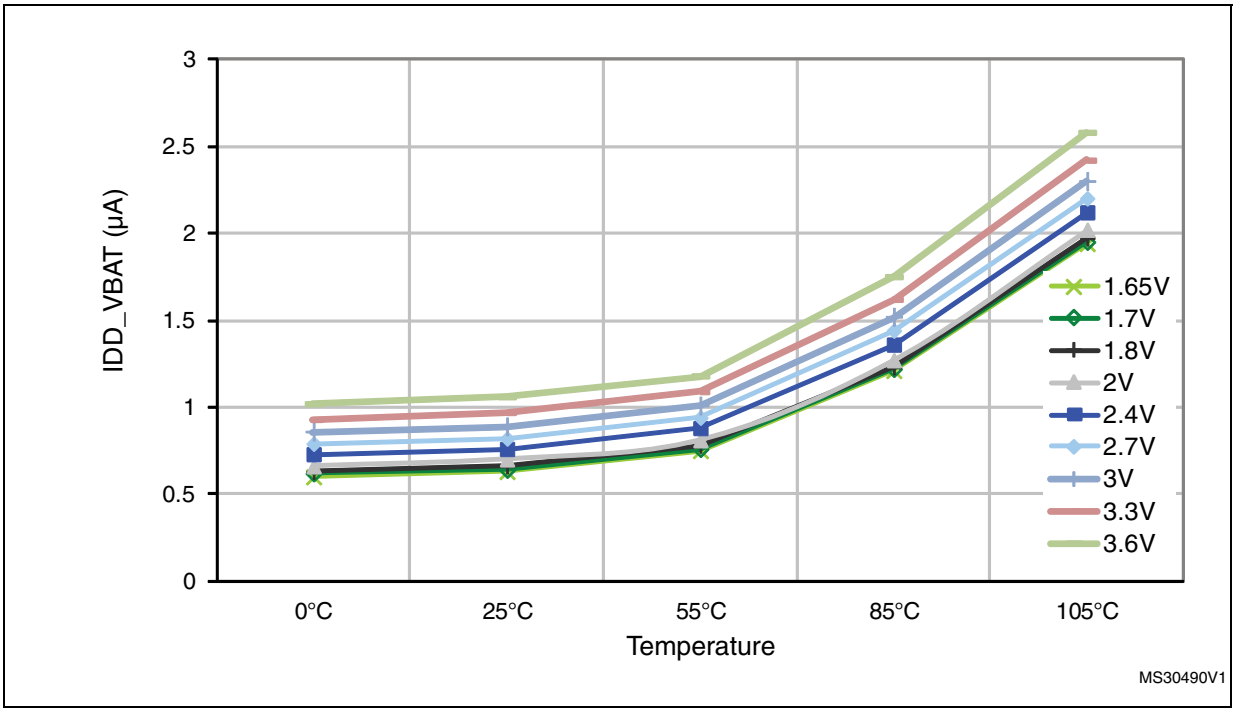


Table 34. Low-power mode wakeup timings(1)

Symbol	Parameter	Min(1)	Typ(1)	Max(1)	Unit
$t_{WUSLEEP}$(2)	Wakeup from Sleep mode	-	4	6	CPU clock cycle
t_{WUSTOP}(2)	Wakeup from Stop mode, usage of main regulator	-	13.5	14.5	µs
	Wakeup from Stop mode, usage of main regulator, Flash memory in Deep power down mode	-	105	111	
	Wakeup from Stop mode, regulator in low power mode	-	21	33	
	Wakeup from Stop mode, regulator in low power mode, Flash memory in Deep power down mode	-	113	130	
$t_{WUSTDBY}$(2)(3)	Wakeup from Standby mode	-	314	407	µs
$t_{WUFLASH}$	Wakeup of Flash from Flash_Stop mode	-	-	8	µs
	Wakeup of Flash from Flash Deep power down mode	-	-	100	

1. Guaranteed by characterization results.
2. The wakeup times are measured from the wakeup event to the point in which the application code reads the first instruction.
3. $t_{WUSTDBY}$ maximum value is given at –40 °C.

6.3.8 External clock source characteristics

High-speed external user clock generated from an external source

In bypass mode the HSE oscillator is switched off and the input pin is a standard I/O. The external clock signal has to respect the *Table 53*. However, the recommended clock input waveform is shown in *Figure 22*.

The characteristics given in *Table 35* result from tests performed using an high-speed external clock source, and under ambient temperature and supply voltage conditions summarized in *Table 14*.

Table 35. High-speed external user clock characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HSE_ext}	External user clock source frequency(1)	-	1	-	50	MHz
V_{HSEH}	OSC_IN input pin high level voltage		$0.7V_{DD}$	-	V_{DD}	V
V_{HSEL}	OSC_IN input pin low level voltage		V_{SS}	-	$0.3V_{DD}$	
$t_{w(HSEH)}$ $t_{w(HSEL)}$	OSC_IN high or low time(1)		5	-	-	ns
$t_{r(HSE)}$ $t_{f(HSE)}$	OSC_IN rise or fall time(1)		-	-	10	
$C_{in(HSE)}$	OSC_IN input capacitance(1)	-	-	5	-	pF
$DuCy_{(HSE)}$	Duty cycle	-	45	-	55	%
I_L	OSC_IN Input leakage current	$V_{SS} \leq V_{IN} \leq V_{DD}$	-	-	±1	µA

1. Guaranteed by design.

Input/output AC characteristics

The definition and values of input/output AC characteristics are given in *Figure 31* and *Table 55*, respectively.

Unless otherwise specified, the parameters given in *Table 55* are derived from tests performed under the ambient temperature and V_{DD} supply voltage conditions summarized in *Table 14*.

Table 55. I/O AC characteristics(1)(2)

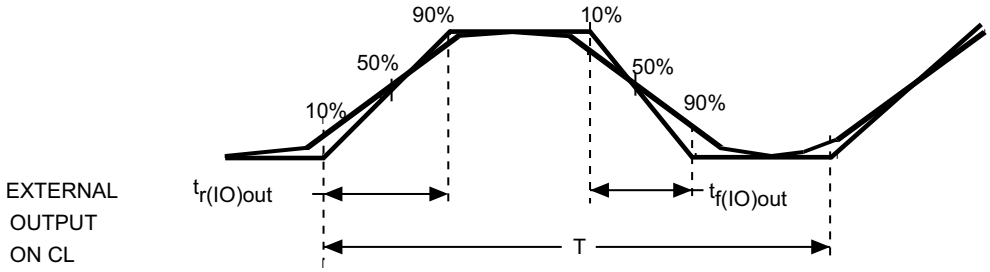
OSPEEDRy [1:0] bit value(1)	Symbol	Parameter	Conditions	Min	Typ	Max	Unit
00	$f_{max(IO)out}$	Maximum frequency(3)	C_L = 50 pF, V_{DD} ≥ 2.70 V	-	-	4	MHz
			C_L = 50 pF, V_{DD}≥ 1.7 V	-	-	2	
			C_L = 10 pF, V_{DD} ≥ 2.70 V	-	-	8	
			C_L = 10 pF, V_{DD} ≥ 1.7 V	-	-	4	
	$t_{f(IO)out}$/ $t_{r(IO)out}$	Output high to low level fall time and output low to high level rise time	C_L = 50 pF, V_{DD} = 1.7 V to 3.6 V	-	-	100	ns
01	$f_{max(IO)out}$	Maximum frequency(3)	C_L = 50 pF, V_{DD} ≥ 2.70 V	-	-	25	MHz
			C_L = 50 pF, V_{DD} ≥ 1.7 V	-	-	12.5	
			C_L = 10 pF, V_{DD} ≥ 2.70 V	-	-	50	
			C_L = 10 pF, V_{DD} ≥ 1.7 V	-	-	20	
	$t_{f(IO)out}$/ $t_{r(IO)out}$	Output high to low level fall time and output low to high level rise time	C_L = 50 pF, V_{DD} ≥2.7 V	-	-	10	ns
			C_L = 50 pF, V_{DD} ≥ 1.7 V	-	-	20	
			C_L = 10 pF, V_{DD} ≥ 2.70 V	-	-	6	
			C_L = 10 pF, V_{DD} ≥ 1.7 V	-	-	10	
10	$f_{max(IO)out}$	Maximum frequency(3)	C_L = 40 pF, V_{DD} ≥ 2.70 V	-	-	50(4)	MHz
			C_L = 40 pF, V_{DD} ≥ 1.7 V	-	-	25	
			C_L = 10 pF, V_{DD} ≥ 2.70 V	-	-	100(4)	
			C_L = 10 pF, V_{DD} ≥ 1.7 V	-	-	50(4)	
	$t_{f(IO)out}$/ $t_{r(IO)out}$	Output high to low level fall time and output low to high level rise time	C_L = 40 pF, V_{DD}≥ 2.70 V	-	-	6	ns
			C_L = 40 pF, V_{DD}≥ 1.7 V	-	-	10	
			C_L = 10 pF, V_{DD}≥ 2.70 V	-	-	4	
			C_L = 10 pF, V_{DD}≥ 1.7 V	-	-	6	

Table 55. I/O AC characteristics[1][2] (continued)

OSPEEDRy [1:0] bit value[1]	Symbol	Parameter	Conditions	Min	Typ	Max	Unit
11	$F_{max(IO)out}$	Maximum frequency[3]	C_L = 30 pF, V_{DD} ≥ 2.70 V	-	-	100[4]	MHz
			C_L = 30 pF, V_{DD} ≥ 1.7 V	-	-	50[4]	
	$t_{f(IO)out}$/ $t_{r(IO)out}$	Output high to low level fall time and output low to high level rise time	C_L = 30 pF, V_{DD} ≥ 2.70 V	-	-	4	ns
			C_L = 30 pF, V_{DD} ≥ 1.7 V	-	-	6	
			C_L = 10 pF, V_{DD}≥ 2.70 V	-	-	2.5	
			C_L = 10 pF, V_{DD}≥ 1.7 V	-	-	4	
-	t_{EXTIpw}	Pulse width of external signals detected by the EXTI controller		10	-	-	ns

1. Guaranteed by characterization results.
2. The I/O speed is configured using the OSPEEDRy[1:0] bits. Refer to the STM32F4xx reference manual for a description of the GPIOx_SPEEDR GPIO port output speed register.
3. The maximum frequency is defined in *Figure 31*.
4. For maximum frequencies above 50 MHz and V_{DD} > 2.4 V, the compensation cell should be used.

Figure 31. I/O AC characteristics definition



Maximum frequency is achieved if (t_r + t_f) ≤ (2/3)T and if the duty cycle is (45-55%) when loaded by CL specified in the table " *I/O AC characteristics*".

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Table 65. ADC characteristics (continued)

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

1. V_{DDA} minimum value of 1.7 V is possible with the use of an external power supply supervisor (refer to *Section 3.15.2: Internal reset OFF*).
2. Guaranteed by characterization results.
3. V_{REF+} is internally connected to V_{DDA} and V_{REF-} is internally connected to V_{SSA}.
4. R_{ADC} maximum value is given for V_{DD}=1.7 V, and minimum value for V_{DD}=3.3 V.
5. For external triggers, a delay of $1/f_{PCLK2}$ must be added to the latency specified in *Table 65*.

6.3.25 RTC characteristics

Table 77. Dynamic characteristics: eMMC characteristics V_{DD} = 1.7 V to 1.9 V(1)(2)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{PP}	Clock frequency in data transfer mode	-	0	-	50	MHz
-	SDIO_CK/fPCLK2 frequency ratio	-	-	-	8/3	-
$t_{W(CKL)}$	Clock low time	fpp = 50 MHz	10	10.5	-	ns
$t_{W(CKH)}$	Clock high time	fpp = 50 MHz	9	9.5	-	
CMD, D inputs (referenced to CK) in eMMC mode						
t_{ISU}	Input setup time HS	fpp = 50 MHz	0	-	-	ns
t_{IH}	Input hold time HS	fpp = 50 MHz	6	-	-	
CMD, D outputs (referenced to CK) in eMMC mode						
t_{OV}	Output valid time HS	fpp = 50 MHz	-	3.5	5	ns
t_{OH}	Output hold time HS	fpp = 50 MHz	2	-	-	

1. Guaranteed by characterization results.
2. C_{load} = 20 pF

Table 78. RTC characteristics

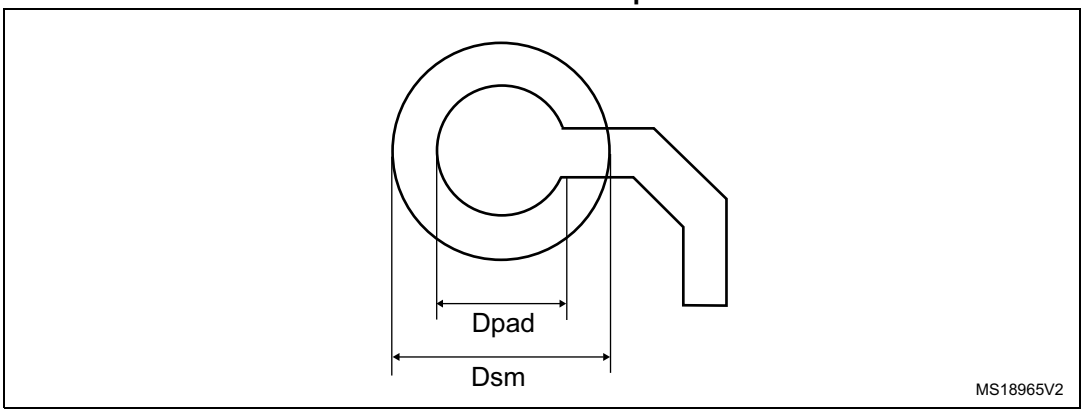
Symbol	Parameter	Conditions	Min	Max
-	f_{PCLK1}/RTCCLK frequency ratio	Any read/write operation from/to an RTC register	4	-

Table 79. WLCSP49 - 49-ball, 2.999 x 3.185 mm, 0.4 mm pitch wafer level chip scale package mechanical data

Symbol	millimeters			inches[1]		
	Min	Typ	Max	Min	Typ	Max
A	0.525	0.555	0.585	0.0207	0.0219	0.0230
A1	-	0.175	-	-	0.0069	-
A2	-	0.380	-	-	0.0150	-
A3[2]	-	0.025	-	-	0.0010	-
b[3]	0.220	0.250	0.280	0.0087	0.0098	0.0110
D	2.964	2.999	3.034	0.1167	0.1181	0.1194
E	3.150	3.185	3.220	0.1240	0.1254	0.1268
e	-	0.400	-	-	0.0157	-
e1	-	2.400	-	-	0.0945	-
e2	-	2.400	-	-	0.0945	-
F	-	0.2995	-	-	0.0118	-
G	-	0.3925	-	-	0.0155	-
aaa	-	0.100	-	-	0.0039	-
bbb	-	0.100	-	-	0.0039	-
ccc	-	0.100	-	-	0.0039	-
ddd	-	0.050	-	-	0.0020	-
eee	-	0.050	-	-	0.0020	-

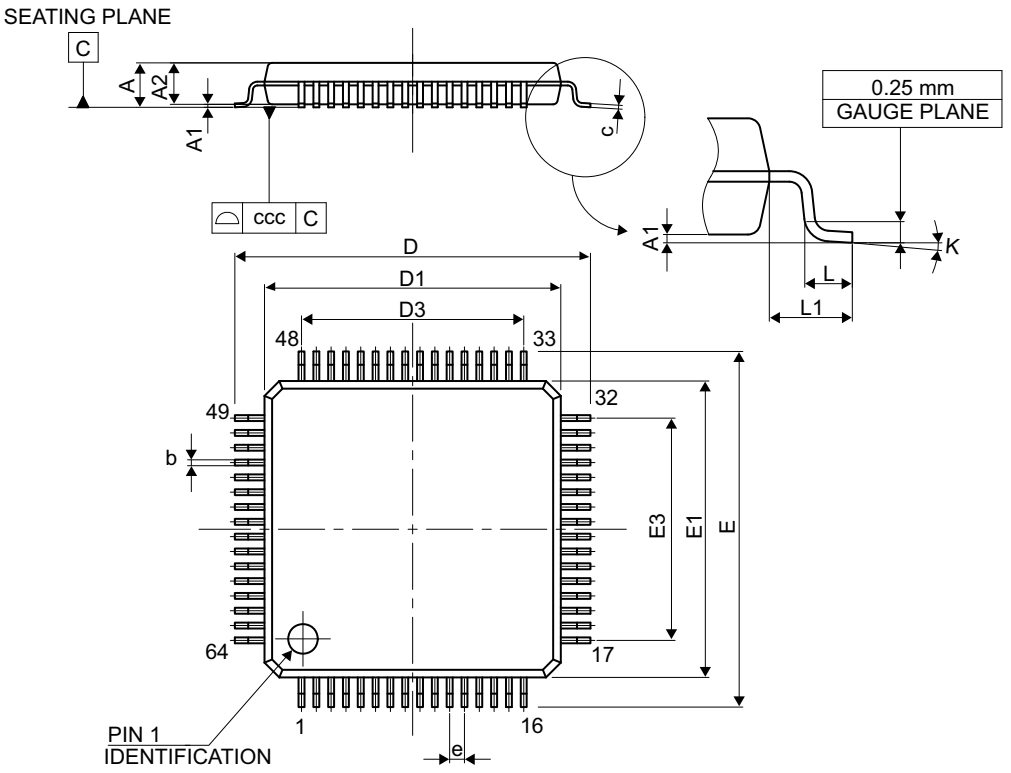
1. Values in inches are converted from mm and rounded to 4 decimal digits.
2. Back side coating
3. Dimension is measured at the maximum bump diameter parallel to primary datum Z.

Figure 47. WLCSP49 - 49-ball, 2.999 x 3.185 mm, 0.4 mm pitch wafer level chip scale recommended footprint



7.3 LQFP64 package information

Figure 52. LQFP64 - 64-pin, 10 x 10 mm, 64-pin low-profile quad flat package outline



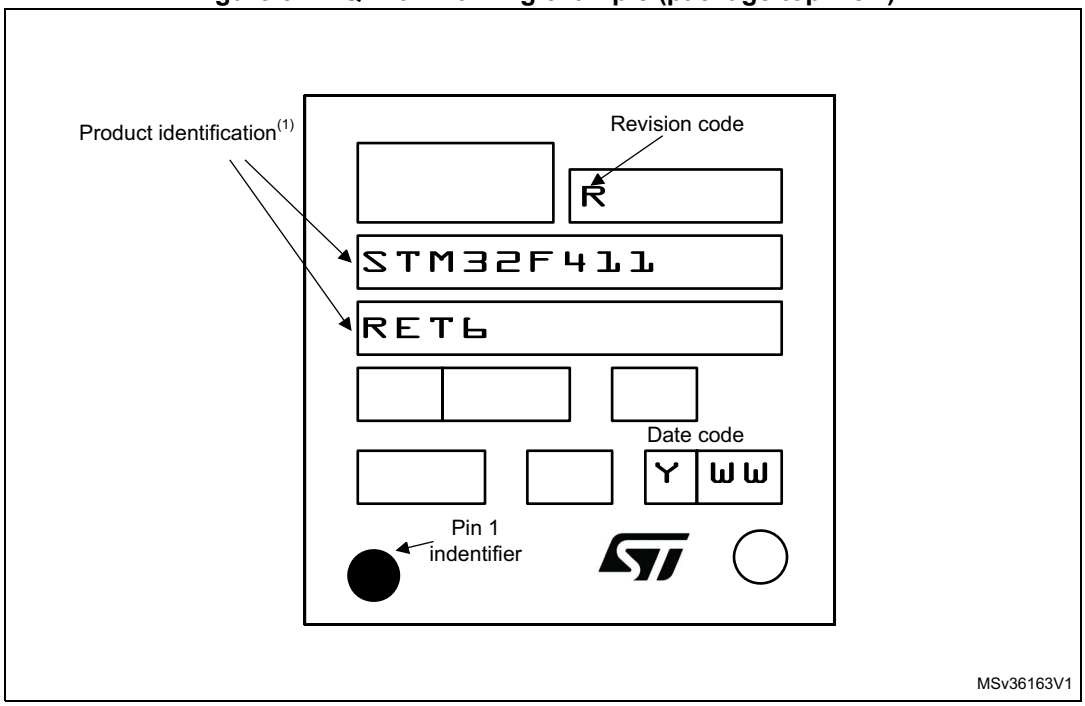
1. Drawing is not to scale.

Device marking for LQFP64

The following figure gives an example of topside marking orientation versus pin 1 identifier location.

Other optional marking or inset/upset marks, which depend on supply chain operations, are not indicated below.

Figure 54. LQFP64 marking example (package top view)



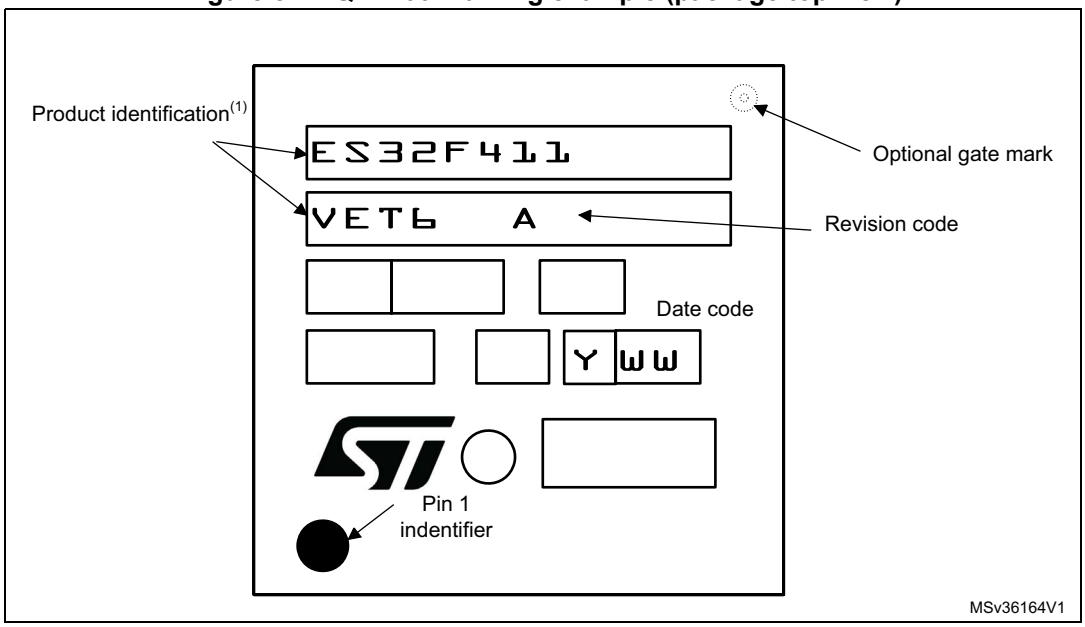
1. Parts marked as “ES”, “E” or accompanied by an Engineering Sample notification letter, are not yet qualified and therefore not yet ready to be used in production and any consequences deriving from such usage will not be at ST charge. In no event, ST will be liable for any customer usage of these engineering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

Device marking for LQFP100

The following figure gives an example of topside marking orientation versus pin 1 identifier location.

Other optional marking or inset/upset marks, which depend on supply chain operations, are not indicated below.

Figure 57. LQPF100 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.