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"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	80MHz
Connectivity	CANbus, I²C, IrDA, LINbus, QSPI, SAI, SPI, UART/USART, USB
Peripherals	Brown-out Detect/Reset, DMA, PWM, WDT
Number of I/O	38
Program Memory Size	256KB (256K x 8)
Program Memory Type	FLASH
EEPROM Size	-
RAM Size	160K x 8
Voltage - Supply (Vcc/Vdd)	1.71V ~ 3.6V
Data Converters	A/D 10x12b; D/A 1x12b
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/stm32l452ccu6

2 Description

The STM32L452xx devices are the ultra-low-power microcontrollers based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 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 STM32L452xx devices embed high-speed memories (Flash memory up to 512 Kbyte, 160 Kbyte of SRAM), a Quad SPI flash memories interface (available on all packages) and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

The STM32L452xx devices embed several protection mechanisms for embedded Flash memory and SRAM: readout protection, write protection, proprietary code readout protection and Firewall.

The devices offer a fast 12-bit ADC (5 Msps), two comparators, one operational amplifier, one DAC channel, an internal voltage reference buffer, a low-power RTC, one general-purpose 32-bit timer, one 16-bit PWM timer dedicated to motor control, four general-purpose 16-bit timers, and two 16-bit low-power timers.

In addition, up to 21 capacitive sensing channels are available.

They also feature standard and advanced communication interfaces.

- Four I2Cs
- Three SPIs
- Three USARTs, one UART and one Low-Power UART.
- One SAI (Serial Audio Interfaces)
- One SDMMC
- One CAN
- One USB full-speed device crystal less

The STM32L452xx operates in the -40 to +85 °C (+105 °C junction) and -40 to +125 °C (+130 °C junction) temperature ranges from a 1.71 to 3.6 V V_{DD} power supply when using internal LDO regulator and a 1.05 to 1.32V V_{DD12} power supply when using external SMPS supply. A comprehensive set of power-saving modes allows the design of low-power applications.

Some independent power supplies are supported: analog independent supply input for ADC, DAC, OPAMP and comparators. A VBAT input allows to backup the RTC and backup registers. Dedicated V_{DD12} power supplies can be used to bypass the internal LDO regulator when connected to an external SMPS.

The STM32L452xx family offers six packages from 48 to 100-pin packages.

3.4 Embedded Flash memory

STM32L452xx devices feature up to 512 Kbyte of embedded Flash memory available for storing programs and data in single bank architecture. The Flash memory contains 256 pages of 2 Kbyte.

Flexible protections can be configured thanks to option bytes:

- Readout protection (RDP) to protect the whole memory. Three levels are available:
  - Level 0: no readout protection
  - Level 1: memory readout protection: the Flash memory cannot be read from or written to if either debug features are connected, boot in RAM or bootloader is selected
  - Level 2: chip readout protection: debug features (Cortex-M4 JTAG and serial wire), boot in RAM and bootloader selection are disabled (JTAG fuse). This selection is irreversible.

Table 3. Access status versus readout protection level and execution modes

Area	Protection level	User execution			Debug, boot from RAM or boot from system memory (loader)		
		Read	Write	Erase	Read	Write	Erase
Main memory	1	Yes	Yes	Yes	No	No	No
	2	Yes	Yes	Yes	N/A	N/A	N/A
System memory	1	Yes	No	No	Yes	No	No
	2	Yes	No	No	N/A	N/A	N/A
Option bytes	1	Yes	Yes	Yes	Yes	Yes	Yes
	2	Yes	No	No	N/A	N/A	N/A
Backup registers	1	Yes	Yes	N/A(1)	No	No	N/A(1)
	2	Yes	Yes	N/A	N/A	N/A	N/A
SRAM2	1	Yes	Yes	Yes(1)	No	No	No(1)
	2	Yes	Yes	Yes	N/A	N/A	N/A

1. Erased when RDP change from Level 1 to Level 0.

- Write protection (WRP): the protected area is protected against erasing and programming. Two areas can be selected, with 2-Kbyte granularity.
- Proprietary code readout protection (PCROP): a part of the flash memory can be protected against read and write from third parties. The protected area is execute-only: it can only be reached by the STM32 CPU, as an instruction code, while all other accesses (DMA, debug and CPU data read, write and erase) are strictly prohibited. The PCROP area granularity is 64-bit wide. An additional option bit (PCROP_RDP) allows to select if the PCROP area is erased or not when the RDP protection is changed from Level 1 to Level 0.

3.23.1 Advanced-control timer (TIM1)

The advanced-control timer can each be seen as a three-phase PWM multiplexed on 6 channels. They have complementary PWM outputs with programmable inserted dead-times. They can also be seen as complete general-purpose timers. The 4 independent channels can be used for:

- Input capture
- Output compare
- PWM generation (edge or center-aligned modes) with full modulation capability (0-100%)
- One-pulse mode output

In debug mode, the advanced-control timer counter can be frozen and the PWM outputs disabled to turn off any power switches driven by these outputs.

Many features are shared with those of the general-purpose TIMx timers (described in *Section 3.23.2*) using the same architecture, so the advanced-control timer can work together with the TIMx timers via the Timer Link feature for synchronization or event chaining.

3.23.2 General-purpose timers (TIM2, TIM3, TIM15, TIM16)

There are up to three synchronizable general-purpose timers embedded in the STM32L452xx (see *Table 11* for differences). Each general-purpose timer can be used to generate PWM outputs, or act as a simple time base.

- TIM2, TIM3

  They are full-featured general-purpose timers:
  - TIM2 has a 32-bit auto-reload up/downcounter and 32-bit prescaler.
  - TIM3 has 16-bit auto-reload up/downcounter and 16-bit prescaler.

  These timers feature 4 independent channels for input capture/output compare, PWM or one-pulse mode output. They can work with the other general-purpose timers via the Timer Link feature for synchronization or event chaining.

  The counters can be frozen in debug mode.

  All have independent DMA request generation and support quadrature encoder.
- TIM15 and 16

  They are general-purpose timers with mid-range features:

  They have 16-bit auto-reload upcounters and 16-bit prescalers.
  - TIM15 has 2 channels and 1 complementary channel
  - TIM16 has 1 channel and 1 complementary channel

  All channels can be used for input capture/output compare, PWM or one-pulse mode output.

  The timers can work together via the Timer Link feature for synchronization or event chaining. The timers have independent DMA request generation.

  The counters can be frozen in debug mode.

3.23.3 Basic timer (TIM6)

The basic timer is mainly used for DAC trigger generation. It can also be used as generic 16-bit timebase.

3.28 Serial peripheral interface (SPI)

Three SPI interfaces allow communication up to 40 Mbits/s in master and up to 24 Mbits/s slave modes, in half-duplex, full-duplex and simplex modes. The 3-bit prescaler gives 8 master mode frequencies and the frame size is configurable from 4 bits to 16 bits. The SPI interfaces support NSS pulse mode, TI mode and Hardware CRC calculation.

All SPI interfaces can be served by the DMA controller.

3.29 Serial audio interfaces (SAI)

The device embeds 1 SAI. Refer to *Table 14: SAI implementation* for the features implementation. The SAI bus interface handles communications between the microcontroller and the serial audio protocol.

The SAI peripheral supports:

- Two independent audio sub-blocks which can be transmitters or receivers with their respective FIFO.
- 8-word integrated FIFOs for each audio sub-block.
- Synchronous or asynchronous mode between the audio sub-blocks.
- Master or slave configuration independent for both audio sub-blocks.
- Clock generator for each audio block to target independent audio frequency sampling when both audio sub-blocks are configured in master mode.
- Data size configurable: 8-, 10-, 16-, 20-, 24-, 32-bit.
- Peripheral with large configurability and flexibility allowing to target as example the following audio protocol: I2S, LSB or MSB-justified, PCM/DSP, TDM, AC’97 and SPDIF out.
- Up to 16 slots available with configurable size and with the possibility to select which ones are active in the audio frame.
- Number of bits by frame may be configurable.
- Frame synchronization active level configurable (offset, bit length, level).
- First active bit position in the slot is configurable.
- LSB first or MSB first for data transfer.
- Mute mode.
- Stereo/Mono audio frame capability.
- Communication clock strobing edge configurable (SCK).
- Error flags with associated interrupts if enabled respectively.
  - Overrun and underrun detection.
  - Anticipated frame synchronization signal detection in slave mode.
  - Late frame synchronization signal detection in slave mode.
  - Codec not ready for the AC’97 mode in reception.
- Interruption sources when enabled:
  - Errors.
  - FIFO requests.
- DMA interface with 2 dedicated channels to handle access to the dedicated integrated FIFO of each SAI audio sub-block.

Figure 7. STM32L452Vx UFBGA100 ballout[(1)]

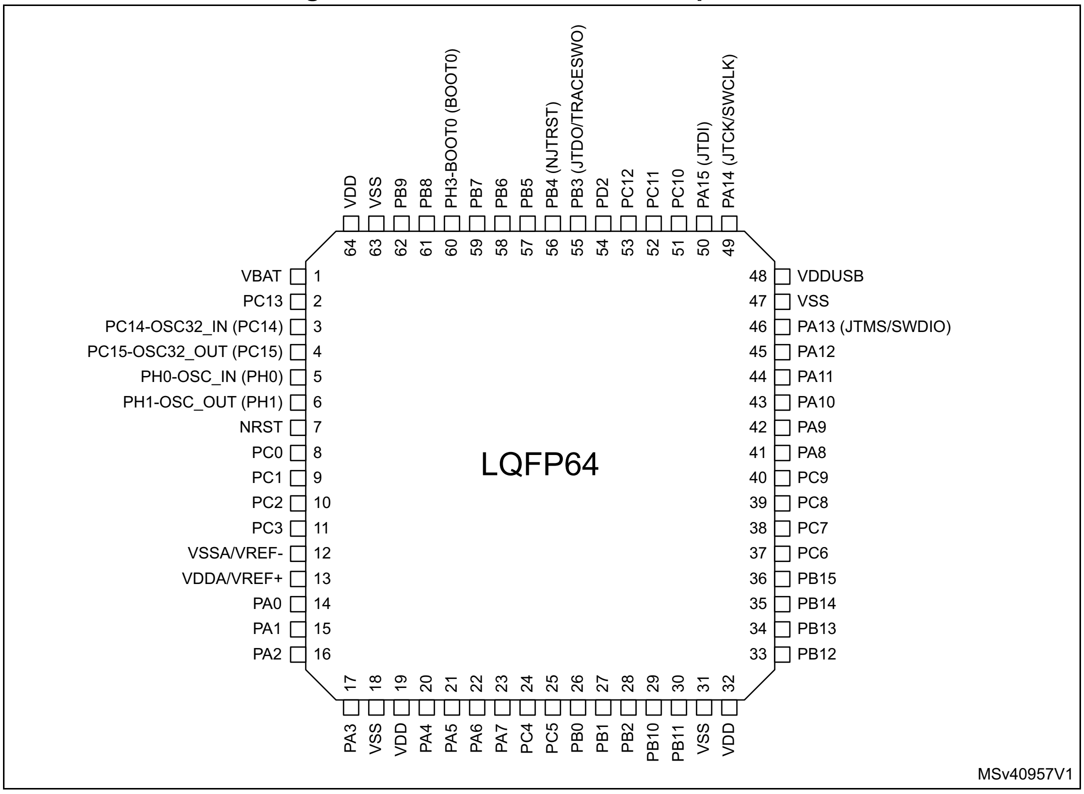
	1	2	3	4	5	6	7	8	9	10	11	12
A	PE3	PE1	PB8	PH3-BOOT0 (BOOT0)	PD7	PD5	PB4 (NJTRST)	PB3 (JTDO/ TRACESWO)	PA15 (JTDI)	PA14 (JTCK/ SWCLK)	PA13 (JTMS/ SWDIO)	PA12
B	PE4	PE2	PB9	PB7	PB6	PD6	PD4	PD3	PD1	PC12	PC10	PA11
C	PC13	PE5	PE0	VDD	PB5			PD2	PD0	PC11	VDDUSB	PA10
D	PC14-OSC32_IN (PC14)	PE6	VSS							PA9	PA8	PC9
E	PC15-OSC32_OUT (PC15)	VBAT	VSS							PC8	PC7	PC6
F	PH0-OSC_IN (PH0)	VSS									VSS	VSS
G	PH1-OSC_OUT (PH1)	VDD									VDD	VDD
H	PC0	NRST	VDD							PD15	PD14	PD13
J	VSSA	PC1	PC2							PD12	PD11	PD10
K	VREF-	PC3	PA2	PA5	PC4			PD9	PD8	PB15	PB14	PB13
L	VREF+	PA0	PA3	PA6	PC5	PB2	PE8	PE10	PE12	PB10	PB11	PB12
M	VDDA	PA1	PA4	PA7	PB0	PB1	PE7	PE9	PE11	PE13	PE14	PE15

UFBGA100

MSv40961V1

1. The above figure shows the package top view.

Figure 8. STM32L452Rx LQFP64 pinout[(1)]



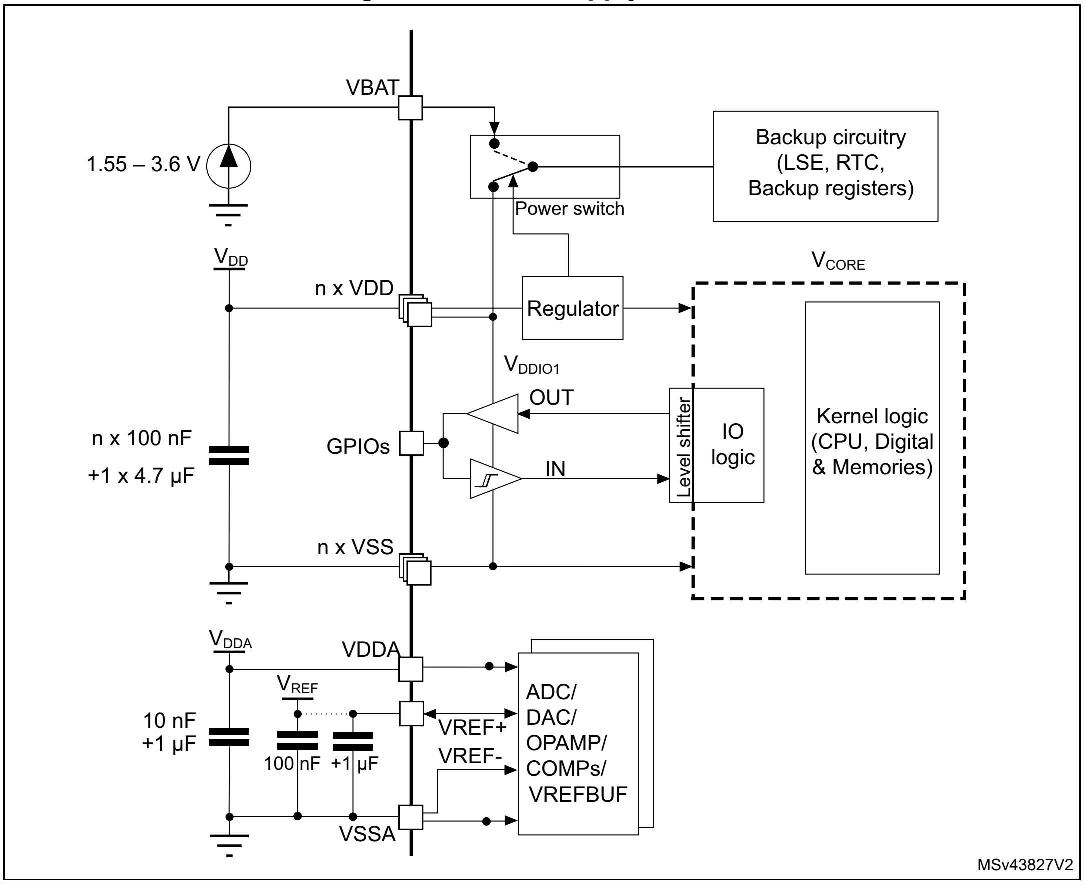
1. The above figure shows the package top view.

Table 17. Alternate function AF0 to AF7(1) (continued)

Port		AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		SYS_AF	TIM1/TIM2 LPTIM1	I2C4/TIM1/ TIM2/TIM3	I2C4/USART2/ CAN1/TIM1	I2C1/I2C2/ I2C3/I2C4	SPI1/SPI2/I2C4	SPI3/DFSDM/ COMP1	USART1/ USART2/ USART3
Port C	PC0	-	LPTIM1_IN1	I2C4_SCL	-	I2C3_SCL	-	-	-
	PC1	TRACED0	LPTIM1_OUT	I2C4_SDA	-	I2C3_SDA	-	-	-
	PC2	-	LPTIM1_IN2	-	-	-	SPI2_MISO	DFSDM1_ CKOUT	-
	PC3	-	LPTIM1_ETR	-	-	-	SPI2_MOSI	-	-
	PC4	-	-	-	-	-	-	-	USART3_TX
	PC5	-	-	-	-	-	-	-	USART3_RX
	PC6	-	-	TIM3_CH1	-	-	-	DFSDM1_ CKIN3	-
	PC7	-	-	TIM3_CH2	-	-	-	DFSDM1_ DATIN3	-
	PC8	-	-	TIM3_CH3	-	-	-	-	-
	PC9	-	-	TIM3_CH4	-	-	-	-	-
	PC10	TRACED1	-	-	-	-	-	SPI3_SCK	USART3_TX
	PC11	-	-	-	-	-	-	SPI3_MISO	USART3_RX
	PC12	TRACED3	-	-	-	-	-	SPI3_MOSI	USART3_CK
	PC13	-	-	-	-	-	-	-	-
	PC14	-	-	-	-	-	-	-	-
	PC15	-	-	-	-	-	-	-	-

6.1.6 Power supply scheme

Figure 16. Power supply scheme



Caution: Each power supply pair (V_{DD}/V_{SS}, V_{DDA}/V_{SSA} etc.) must be decoupled with filtering ceramic capacitors as shown above. These capacitors must be placed as close as possible to, or below, the appropriate pins on the underside of the PCB to ensure the good functionality of the device.

Table 20. Voltage characteristics(1) (continued)

Symbol	Ratings	Min	Max	Unit
$\|\Delta V_{DDx}\|$	Variations between different V_{DDX} power pins of the same domain	-	50	mV
$\|V_{SSx}-V_{SS}\|$	Variations between all the different ground pins(5)	-	50	mV

1. All main power (V_{DD}, V_{DDA}, V_{DDUSB}, V_{BAT}) and ground (V_{SS}, V_{SSA}) pins must always be connected to the external power supply, in the permitted range.
2. V_{IN} maximum must always be respected. Refer to *Table 21: Current characteristics* for the maximum allowed injected current values.
3. This formula has to be applied only on the power supplies related to the IO structure described in the pin definition table.
4. To sustain a voltage higher than 4 V the internal pull-up/pull-down resistors must be disabled.
5. Include VREF- pin.

Table 21. Current characteristics

Symbol	Ratings	Max	Unit
$\sum IV_{DD}$	Total current into sum of all V_{DD} power lines (source)(1)(2)	140	mA
$\sum IV_{SS}$	Total current out of sum of all V_{SS} ground lines (sink)(1)	140	
$IV_{DD(PIN)}$	Maximum current into each V_{DD} power pin (source)(1)	100	
$IV_{SS(PIN)}$	Maximum current out of each V_{SS} ground pin (sink)(1)	100	
$I_{IO(PIN)}$	Output current sunk by any I/O and control pin except FT_f	20	
	Output current sunk by any FT_f pin	20	
	Output current sourced by any I/O and control pin	20	
$\sum I_{IO(PIN)}$	Total output current sunk by sum of all I/Os and control pins(3)	100	
	Total output current sourced by sum of all I/Os and control pins(3)	100	
$I_{INJ(PIN)}$(4)	Injected current on FT_xxx, TT_xx, RST and B pins, except PA4, PA5	-5/+0(5)	
	Injected current on PA4, PA5	-5/0	
$\sum \|I_{INJ(PIN)}\|$	Total injected current (sum of all I/Os and control pins)(6)	25	

1. All main power (V_{DD}, V_{DDA}, V_{DDUSB}, V_{BAT}) and ground (V_{SS}, V_{SSA}) pins must always be connected to the external power supplies, in the permitted range.
2. Valid also for V_{DD12} on SMPS packages.
3. This current consumption must be correctly distributed over all I/Os and control pins. The total output current must not be sunk/sourced between two consecutive power supply pins referring to high pin count QFP packages.
4. Positive injection (when $V_{IN} > V_{DDIOx}$) is not possible on these I/Os and does not occur for input voltages lower than the specified maximum value.
5. A negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer also to *Table 20: Voltage characteristics* for the maximum allowed input voltage values.
6. When several inputs are submitted to a current injection, the maximum $\sum|I_{INJ(PIN)}|$ is the absolute sum of the negative injected currents (instantaneous values).

Table 31. Current consumption in Run and Low-power run modes, code with data processing running from SRAM1

Symbol	Parameter	Conditions			TYP					MAX[1]					Unit
		-	Voltage scaling	f_{HCLK}	25 °C	55 °C	85 °C	105 °C	125 °C	25 °C	55 °C	85 °C	105 °C	125 °C	
I_{DD_ALL} (Run)	Supply current in Run mode	$f_{HCLK} = f_{HSE}$ up to 48MHz included, bypass mode PLL ON above 48 MHz all peripherals disable	Range 2	26 MHz	2.40	2.40	2.55	2.70	3.05	2.70	2.75	2.90	3.20	3.80	mA
				16 MHz	1.50	1.55	1.65	1.80	2.15	1.70	1.80	1.95	2.25	2.80	
				8 MHz	0.820	0.850	0.950	1.10	1.45	0.95	1.00	1.15	1.45	2.00	
				4 MHz	0.470	0.500	0.600	0.765	1.10	0.55	0.60	0.75	1.05	1.60	
				2 MHz	0.295	0.325	0.420	0.585	0.915	0.35	0.40	0.55	0.85	1.40	
				1 MHz	0.210	0.235	0.330	0.495	0.825	0.25	0.30	0.45	0.75	1.30	
				100 kHz	0.130	0.155	0.250	0.415	0.750	0.15	0.25	0.35	0.65	1.25	
			Range 1	80 MHz	8.55	8.60	8.75	8.95	9.35	9.55	9.65	9.85	10.5	11.0	
				72 MHz	7.70	7.80	7.90	8.15	8.50	8.60	8.70	8.90	9.25	9.95	
				64 MHz	6.90	6.95	7.10	7.30	7.70	7.70	7.75	7.95	8.35	9.00	
				48 MHz	5.15	5.20	5.30	5.55	5.90	5.75	5.85	6.05	6.40	7.05	
				32 MHz	3.45	3.50	3.65	3.85	4.25	3.90	4.00	4.20	4.50	5.15	
				24 MHz	2.65	2.70	2.80	3.00	3.40	3.00	3.05	3.25	3.55	4.20	
				16 MHz	1.80	1.85	1.95	2.15	2.55	2.05	2.10	2.30	2.60	3.25	
I_{DD_ALL} (LPRun)	Supply current in low-power run mode	$f_{HCLK} = f_{MSI}$ all peripherals disable FLASH in power-down		2 MHz	220	255	360	540	895	270	330	460	760	1400	µA
				1 MHz	120	155	260	440	795	165	215	370	660	1300	
				400 kHz	60.0	92.0	195	375	730	100	160	330	585	1250	
				100 kHz	36.0	62.5	165	345	695	63.0	130	305	555	1200	

1. Guaranteed by characterization results, unless otherwise specified.

Table 45. Current consumption in Stop 2 mode

Symbol	Parameter	Conditions		TYP					MAX[1]					Unit
		-	V_{DD}	25 °C	55 °C	85 °C	105 °C	125 °C	25 °C	55 °C	85 °C	105 °C	125 °C	
I_{DD_ALL} (Stop 2)	Supply current in Stop 2 mode, RTC disabled	-	1.8 V	2.05	5.40	19.0	44.0	97.0	4.00	11.5	41.5	100	220	µA
			2.4 V	2.10	5.45	19.0	44.5	98.5	4.05	11.5	42.0	100	225	
			3 V	2.05	5.55	19.5	45.0	100	4.10	12.0	43.0	105	230	
			3.6 V	2.05	5.65	20.0	46.5	105	4.20	12.0	44.0	105	235	
I_{DD_ALL} (Stop 2 with RTC)	Supply current in Stop 2 mode, RTC enabled	RTC clocked by LSI	1.8 V	2.30	5.65	19.0	44.0	97.0	4.50	12.0	42.0	100	220	µA
			2.4 V	2.35	5.80	19.5	44.5	99.0	4.65	12.0	42.5	100	225	
			3 V	2.50	5.90	20.0	45.5	100	4.90	12.5	43.5	105	230	
			3.6 V	2.60	6.15	20.5	47.0	105	5.20	13.0	44.5	105	235	
		RTC clocked by LSE bypassed at 32768 Hz	1.8 V	2.60	6.05	21.0	48.0	97.0	-	-	-	-	-	
			2.4 V	2.55	6.20	21.0	49.0	98.5	-	-	-	-	-	
			3 V	2.80	6.35	21.5	49.5	100	-	-	-	-	-	
			3.6 V	2.85	6.60	22.5	51.5	105	-	-	-	-	-	
		RTC clocked by LSE quartz[2] in low drive mode	1.8 V	2.40	5.70	19.0	44.5	98.0	-	-	-	-	-	
			2.4 V	2.50	5.85	19.5	45.0	99.5	-	-	-	-	-	
			3 V	2.60	6.00	20.0	46.0	100	-	-	-	-	-	
			3.6 V	2.65	6.25	20.5	47.0	105	-	-	-	-	-	
I_{DD_ALL} (wakeup from Stop 2)	Supply current during wakeup from Stop 2 mode	Wakeup clock is MSI = 48 MHz, voltage Range 1. See [3].	3 V	1.85	-	-	-	-	-	-	-	-	-	mA
		Wakeup clock is MSI = 4 MHz, voltage Range 2. See [3].	3 V	1.50	-	-	-	-	-	-	-	-	-	
		Wakeup clock is HSI16 = 16 MHz, voltage Range 1. See [3].	3 V	1.55	-	-	-	-	-	-	-	-	-	

1. Guaranteed based on test during characterization, unless otherwise specified.
2. Based on characterization done with a 32.768 kHz crystal (MC306-G-06Q-32.768, manufacturer JFVNY) with two 6.8 pF loading capacitors.

3. Wakeup with code execution from Flash. Average value given for a typical wakeup time as specified in *Table 52: Low-power mode wakeup timings*.

Table 48. Current consumption in Standby mode (continued)

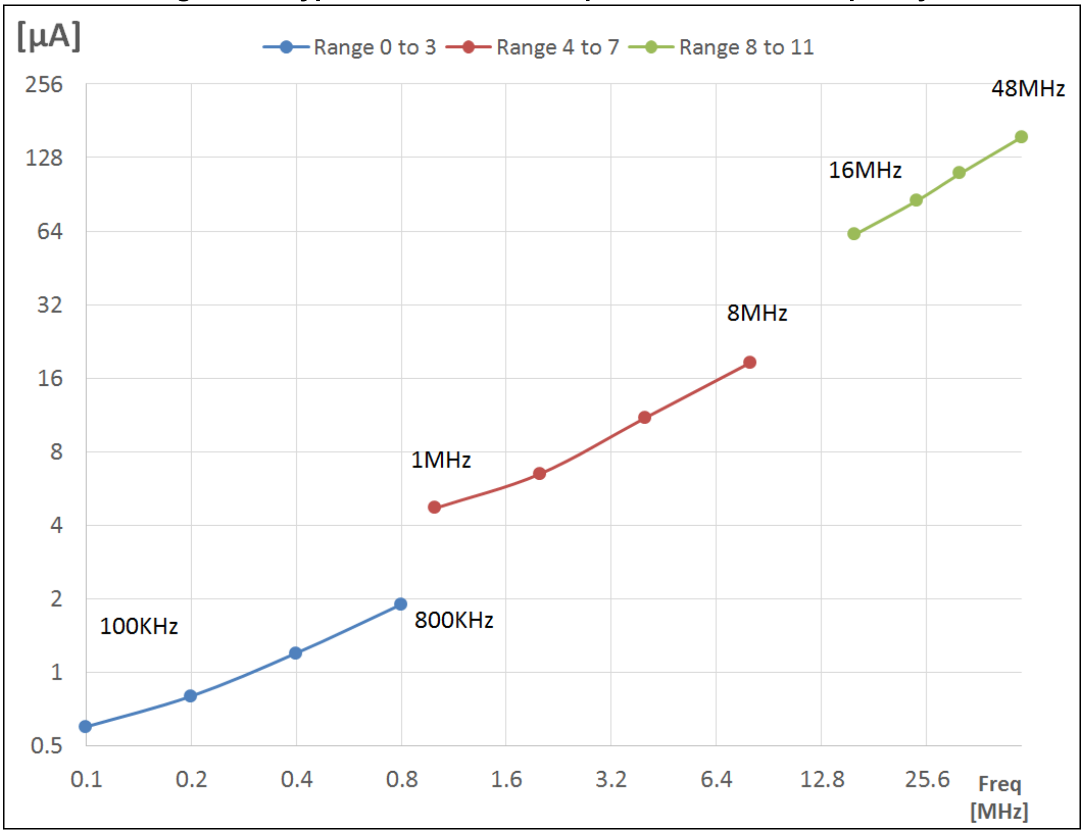
Symbol	Parameter	Conditions		TYP					MAX(1)					Unit
		-	V_{DD}	25 °C	55 °C	85 °C	105 °C	125 °C	25 °C	55 °C	85 °C	105 °C	125 °C	
I_{DD_ALL} (SRAM2)(3)	Supply current to be added in Standby mode when SRAM2 is retained	-	1.8 V	250	730	2700	6350	13850	575	1800	6350	14500	32000	nA
			2.4 V	250	740	2700	6150	14000	620	1800	6450	14500	32000	
			3 V	255	740	2700	6450	13500	645	1850	6500	15000	32500	
			3.6 V	255	755	2800	6500	13500	790	1950	6500	15000	33000	
I_{DD_ALL} (wakeup from Standby)	Supply current during wakeup from Standby mode	Wakeup clock is MSI = 4 MHz. See (4).	3 V	2.00	-	-	-	-	-	-	-	-	-	mA

1. Guaranteed by characterization results, unless otherwise specified.
2. Based on characterization done with a 32.768 kHz crystal (MC306-G-06Q-32.768, manufacturer JFVNY) with two 6.8 pF loading capacitors.
3. The supply current in Standby with SRAM2 mode is: I_{DD_ALL}(Standby) + I_{DD_ALL}(SRAM2). The supply current in Standby with RTC with SRAM2 mode is: I_{DD_ALL}(Standby + RTC) + I_{DD_ALL}(SRAM2).
4. Wakeup with code execution from Flash. Average value given for a typical wakeup time as specified in *Table 52: Low-power mode wakeup timings*.

Table 49. Current consumption in Shutdown mode

Symbol	Parameter	Conditions		TYP					MAX(1)					Unit
		-	V_{DD}	25 °C	55 °C	85 °C	105 °C	125 °C	25 °C	55 °C	85 °C	105 °C	125 °C	
I_{DD_ALL} (Shutdown)	Supply current in Shutdown mode (backup registers retained) RTC disabled	-	1.8 V	19.0	120	720	2200	6400	38.0	350	2050	6350	19500	nA
			2.4 V	26.0	145	855	2600	7450	62.0	400	2400	7450	22500	
			3 V	37.0	185	1050	3100	8700	105	500	2850	8750	26000	
			3.6 V	67.0	260	1350	3950	11000	160	650	3500	10500	30000	

Figure 24. Typical current consumption versus MSI frequency



High-speed internal 48 MHz (HSI48) RC oscillator

Table 61. HSI48 oscillator characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HSI48}	HSI48 Frequency	V_{DD}=3.0V, T_A=30°C	-	48	-	MHz
TRIM	HSI48 user trimming step	-	-	0.11(2)	0.18(2)	%
USER TRIM COVERAGE	HSI48 user trimming coverage	±32 steps	±3(3)	±3.5(3)	-	%
DuCy(HSI48)	Duty Cycle	-	45(2)	-	55(2)	%
ACC_{HSI48_REL}	Accuracy of the HSI48 oscillator over temperature (factory calibrated)	V_{DD} = 3.0 V to 3.6 V, T_A = –15 to 85 °C	-	-	±3(3)	%
		V_{DD} = 1.65 V to 3.6 V, T_A = –40 to 125 °C	-	-	±4.5(3)	
D_{VDD}(HSI48)	HSI48 oscillator frequency drift with V_{DD}	V_{DD} = 3 V to 3.6 V	-	0.025(3)	0.05(3)	%
		V_{DD} = 1.65 V to 3.6 V	-	0.05(3)	0.1(3)	
t_{su}(HSI48)	HSI48 oscillator start-up time	-	-	2.5(2)	6(2)	µs
I_{DD}(HSI48)	HSI48 oscillator power consumption	-	-	340(2)	380(2)	µA

Unless otherwise specified, the parameters given are derived from tests performed under the ambient temperature and supply voltage conditions summarized in *Table 23: General operating conditions*.

Table 73. I/O AC characteristics(1)(2)

Speed	Symbol	Parameter	Conditions	Min	Max	Unit
00	Fmax	Maximum frequency	C=50 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	5	MHz
			C=50 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	1	
			C=50 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	0.1	
			C=10 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	10	
			C=10 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	1.5	
			C=10 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	0.1	
	Tr/Tf	Output rise and fall time	C=50 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	25	ns
			C=50 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	52	
			C=50 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	140	
			C=10 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	17	
			C=10 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	37	
			C=10 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	110	
01	Fmax	Maximum frequency	C=50 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	25	MHz
			C=50 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	10	
			C=50 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	1	
			C=10 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	50	
			C=10 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	15	
			C=10 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	1	
	Tr/Tf	Output rise and fall time	C=50 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	9	ns
			C=50 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	16	
			C=50 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	40	
			C=10 pF, 2.7 V≤V_{DDIOx}≤3.6 V	-	4.5	
			C=10 pF, 1.62 V≤V_{DDIOx}≤2.7 V	-	9	
			C=10 pF, 1.08 V≤V_{DDIOx}≤1.62 V	-	21	

6.3.19 Digital-to-Analog converter characteristics

Table 83. DAC characteristics(1)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage for DAC ON	DAC output buffer OFF (no resistive load on DAC1_OUT1 pin or internal connection)		1.71	-	3.6	V
		Other modes		1.80	-		
V_{REF+}	Positive reference voltage	DAC output buffer OFF (no resistive load on DAC1_OUT1 pin or internal connection)		1.71	-	V_{DDA}	
		Other modes		1.80	-		
V_{REF-}	Negative reference voltage	-		V_{SSA}			
R_L	Resistive load	DAC output buffer ON	connected to V_{SSA}	5	-	-	kΩ
			connected to V_{DDA}	25	-	-	
R_O	Output Impedance	DAC output buffer OFF		9.6	11.7	13.8	kΩ
R_{BON}	Output impedance sample and hold mode, output buffer ON	V_{DD} = 2.7 V		-	-	2	kΩ
		V_{DD} = 2.0 V		-	-	3.5	
R_{BOFF}	Output impedance sample and hold mode, output buffer OFF	V_{DD} = 2.7 V		-	-	16.5	kΩ
		V_{DD} = 2.0 V		-	-	18.0	
C_L	Capacitive load	DAC output buffer ON		-	-	50	pF
C_{SH}		Sample and hold mode		-	0.1	1	µF
V_{DAC_OUT}	Voltage on DAC1_OUT1 output	DAC output buffer ON		0.2	-	V_{REF+} – 0.2	V
		DAC output buffer OFF		0	-	V_{REF+}	
$t_{SETTLING}$	Settling time (full scale: for a 12-bit code transition between the lowest and the highest input codes when DAC1_OUT1 reaches final value ±0.5LSB, ±1 LSB, ±2 LSB, ±4 LSB, ±8 LSB)	Normal mode DAC output buffer ON CL ≤ 50 pF, RL ≥ 5 kΩ	±0.5 LSB	-	1.7	3	µs
			±1 LSB	-	1.6	2.9	
			±2 LSB	-	1.55	2.85	
			±4 LSB	-	1.48	2.8	
			±8 LSB	-	1.4	2.75	
		Normal mode DAC output buffer OFF, ±1LSB, CL = 10 pF		-	2	2.5	
t_{WAKEUP}(2)	Wakeup time from off state (setting the ENx bit in the DAC Control register) until final value ±1 LSB	Normal mode DAC output buffer ON CL ≤ 50 pF, RL ≥ 5 kΩ		-	4.2	7.5	µs
		Normal mode DAC output buffer OFF, CL ≤ 10 pF		-	2	5	
PSRR	V_{DDA} supply rejection ratio	Normal mode DAC output buffer ON CL ≤ 50 pF, RL = 5 kΩ, DC		-	-80	-28	dB

6.3.20 Voltage reference buffer characteristics

Table 85. VREFBUF characteristics(1)

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DDA}	Analog supply voltage	Normal mode	V_{RS} = 0	2.4	-	3.6	V
			V_{RS} = 1	2.8	-	3.6	
		Degraded mode(2)	V_{RS} = 0	1.65	-	2.4	
			V_{RS} = 1	1.65	-	2.8	
V_{REFBUF_OUT}	Voltage reference output	Normal mode	V_{RS} = 0	2.046(3)	2.048	2.049(3)	
			V_{RS} = 1	2.498(3)	2.5	2.502(3)	
		Degraded mode(2)	V_{RS} = 0	V_{DDA}-150 mV	-	V_{DDA}	
			V_{RS} = 1	V_{DDA}-150 mV	-	V_{DDA}	
TRIM	Trim step resolution	-	-	-	±0.05	±0.1	%
CL	Load capacitor	-	-	0.5	1	1.5	µF
esr	Equivalent Serial Resistor of Cload	-	-	-	-	2	Ω
I_{load}	Static load current	-	-	-	-	4	mA
I_{line_reg}	Line regulation	2.8 V ≤ V_{DDA} ≤ 3.6 V	I_{load} = 500 µA	-	200	1000	ppm/V
			I_{load} = 4 mA	-	100	500	
I_{load_reg}	Load regulation	500 µA ≤ I_{load} ≤4 mA	Normal mode	-	50	500	ppm/mA
T_{Coeff}	Temperature coefficient	-40 °C < T_J < +125 °C		-	-	$T_{coeff\_vrefint}$ + 50	ppm/ °C
		0 °C < T_J < +50 °C		-	-	$T_{coeff\_vrefint}$ + 50	
PSRR	Power supply rejection	DC		40	60	-	dB
		100 kHz		25	40	-	
t_{START}	Start-up time	CL = 0.5 µF(4)		-	300	350	µs
		CL = 1.1 µF(4)		-	500	650	
		CL = 1.5 µF(4)		-	650	800	
I_{INRUSH}	Control of maximum DC current drive on VREFBUF_OUT during start-up phase (5)	-	-	-	8	-	mA

Table 97. QUADSPI characteristics in DDR mode[1]

<table>
<tr><th>Symbol</th><th>Parameter</th><th>Conditions</th><th>Min</th><th>Typ</th><th>Max</th><th>Unit</th></tr>
<tr><td rowspan="4">F_{CK}
$1/t_{(CK)}$</td><td rowspan="4">Quad SPI clock frequency</td><td>1.71 < V_{DD} < 3.6 V, C_{LOAD} = 20 pF
Voltage Range 1</td><td>-</td><td>-</td><td>40</td><td rowspan="4">MHz</td></tr>
<tr><td>2 < V_{DD} < 3.6 V, C_{LOAD} = 20 pF
Voltage Range 1</td><td>-</td><td>-</td><td>48</td></tr>
<tr><td>1.71 < V_{DD} < 3.6 V, C_{LOAD} = 15 pF
Voltage Range 1</td><td>-</td><td>-</td><td>48</td></tr>
<tr><td>1.71 < V_{DD} < 3.6 V C_{LOAD} = 20 pF
Voltage Range 2</td><td>-</td><td>-</td><td>26</td></tr>
<tr><td>$t_{w(CKH)}$</td><td rowspan="2">Quad SPI clock high and low time</td><td rowspan="2">f_{AHBCLK} = 48 MHz, presc=0</td><td>$t_{(CK)}/2-2$</td><td>-</td><td>$t_{(CK)}/2$</td><td rowspan="18">ns</td></tr>
<tr><td>$t_{w(CKL)}$</td><td>$t_{(CK)}/2$</td><td>-</td><td>$t_{(CK)}/2+2$</td></tr>
<tr><td rowspan="2">$t_{sr(IN)}$</td><td rowspan="2">Data input setup time on rising edge</td><td>Voltage Range 1</td><td>1</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>3.5</td></tr>
<tr><td rowspan="2">$t_{sf(IN)}$</td><td rowspan="2">Data input setup time on falling edge</td><td>Voltage Range 1</td><td>1</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>1.5</td></tr>
<tr><td rowspan="2">$t_{hr(IN)}$</td><td rowspan="2">Data input hold time on rising edge</td><td>Voltage Range 1</td><td>6</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>6.5</td></tr>
<tr><td rowspan="2">$t_{hf(IN)}$</td><td rowspan="2">Data input hold time on falling edge</td><td>Voltage Range 1</td><td>5.5</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>5.5</td></tr>
<tr><td rowspan="2">$t_{vr(OUT)}$</td><td rowspan="2">Data output valid time on rising edge</td><td>Voltage Range 1</td><td rowspan="2">-</td><td>5</td><td>5.5</td></tr>
<tr><td>Voltage Range 2</td><td>9.5</td><td>14</td></tr>
<tr><td rowspan="2">$t_{vf(OUT)}$</td><td rowspan="2">Data output valid time on falling edge</td><td>Voltage Range 1</td><td rowspan="2">-</td><td>5</td><td>8.5</td></tr>
<tr><td>Voltage Range 2</td><td>15</td><td>19</td></tr>
<tr><td rowspan="2">$t_{hr(OUT)}$</td><td rowspan="2">Data output hold time on rising edge</td><td>Voltage Range 1</td><td>3.5</td><td>-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>8</td><td>-</td></tr>
<tr><td rowspan="2">$t_{hf(OUT)}$</td><td rowspan="2">Data output hold time on falling edge</td><td>Voltage Range 1</td><td>3.5</td><td>-</td><td rowspan="2">-</td></tr>
<tr><td>Voltage Range 2</td><td>13</td><td>-</td></tr>
</table>

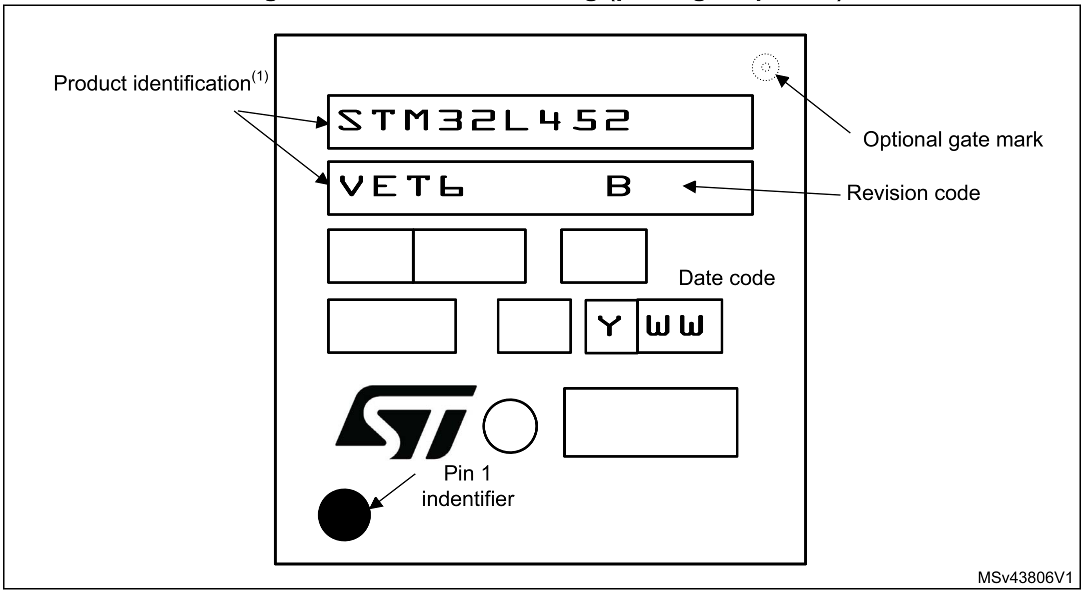
1. Guaranteed by characterization results.

Device marking

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

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

Figure 43. LQFP100 marking (package top view)



1. Parts marked as ES or E or accompanied by an Engineering Sample notification letter are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering samples in production. ST's Quality department must be contacted prior to any decision to use these engineering samples to run a qualification activity.

Table 103. UFBGA100 - 100-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package mechanical data (continued)

Symbol	millimeters			inches(1)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
ddd	-	-	0.080	-	-	0.0031
eee	-	-	0.150	-	-	0.0059
fff	-	-	0.050	-	-	0.0020

1. Values in inches are converted from mm and rounded to 4 decimal digits.

Figure 45. UFBGA100 - 100-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package recommended footprint

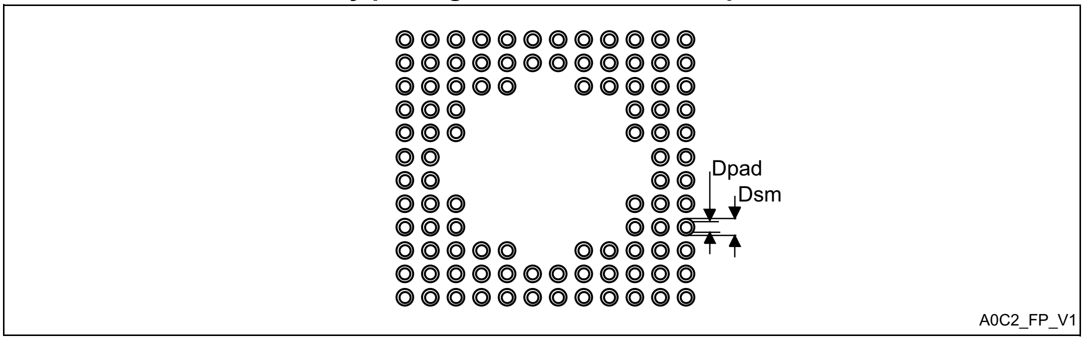


Table 104. UFBGA100 recommended PCB design rules (0.5 mm pitch BGA)

Dimension	Recommended values
Pitch	0.5
Dpad	0.280 mm
Dsm	0.370 mm typ. (depends on the solder mask registration tolerance)
Stencil opening	0.280 mm
Stencil thickness	Between 0.100 mm and 0.125 mm

Device marking

The following figure gives an example of topside marking orientation versus ball A1 identifier location.

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