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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®-M3
Core Size	32-Bit Single-Core
Speed	32MHz
Connectivity	I²C, IrDA, LINbus, SPI, UART/USART, USB
Peripherals	Brown-out Detect/Reset, DMA, I²S, LCD, POR, PWM, WDT
Number of I/O	51
Program Memory Size	384KB (384K x 8)
Program Memory Type	FLASH
EEPROM Size	12K x 8
RAM Size	48K x 8
Voltage - Supply (Vcc/Vdd)	1.8V ~ 3.6V
Data Converters	A/D 21x12b; D/A 2x12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	64-LQFP
Supplier Device Package	64-LQFP (10x10)
Purchase URL	https://www.e-xfl.com/product-detail/stmicroelectronics/stm32l162rdt6

Contents

3.5 Low-power real-time clock and backup registers

The real-time clock (RTC) is an independent BCD timer/counter. Dedicated registers contain the sub-second, second, minute, hour (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 made automatically. The RTC provides two programmable alarms and programmable periodic interrupts with wakeup from Stop and Standby modes.

The programmable wakeup time ranges from 120 µs to 36 hours.

The RTC can be calibrated with an external 512 Hz output, and a digital compensation circuit helps reduce drift due to crystal deviation.

The RTC can also be automatically corrected with a 50/60Hz stable powerline.

The RTC calendar can be updated on the fly down to sub second precision, which enables network system synchronization.

A time stamp can record an external event occurrence, and generates an interrupt.

There are thirty-two 32-bit backup registers provided to store 128 bytes of user application data. They are cleared in case of tamper detection.

Three pins can be used to detect tamper events. A change on one of these pins can reset backup register and generate an interrupt. To prevent false tamper event, like ESD event, these three tamper inputs can be digitally filtered.

3.6 GPIOs (general-purpose inputs/outputs)

Each of the GPIO pins can be configured by software as output (push-pull or open-drain), as input (with or without pull-up or pull-down) or as peripheral alternate function. Most of the GPIO pins are shared with digital or analog alternate functions, and can be individually remapped using dedicated AFIO registers. All GPIOs are high current capable. The alternate function configuration of I/Os can be locked if needed following a specific sequence in order to avoid spurious writing to the I/O registers. The I/O controller is connected to the AHB with a toggling speed of up to 16 MHz.

External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 24 edge detector lines used to generate interrupt/event requests. Each line can be individually 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 115 GPIOs can be connected to the 16 external interrupt lines. The 8 other lines are connected to RTC, PVD, USB, comparator events or capacitive sensing acquisition.

3.7 Memories

The STM32L162xD devices have the following features:

- 48 Kbytes of embedded RAM accessed (read/write) at CPU clock speed with 0 wait states. With the enhanced bus matrix, operating the RAM does not lead to any performance penalty during accesses to the system bus (AHB and APB buses).
- The non-volatile memory is divided into three arrays:
  - 384 Kbytes of embedded Flash program memory
  - 12 Kbytes of data EEPROM
  - Options bytes

  Flash program and data EEPROM are divided into two banks, this enables writing in one bank while running code or reading data in the other bank.

  The options bytes are used to write-protect or read-out protect the memory (with 4 Kbytes granularity) and/or readout-protect the whole memory with the following options:
  - 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 or boot in RAM is selected
  - Level 2: chip readout protection, debug features (ARM Cortex-M3 JTAG and serial wire) and boot in RAM selection disabled (JTAG fuse)

  The whole non-volatile memory embeds the error correction code (ECC) feature.

3.8 FSMC (flexible static memory controller)

The FSMC supports the following modes: SRAM, PSRAM, NOR/OneNAND Flash.

Functionality overview:

- Up to 26 bit address bus
- Up to 16-bit data bus
- Write FIFO
- Burst mode
- Code execution from external memory
- Four chip select signals
- Up to 32 MHz external access

3.9 DMA (direct memory access)

The flexible 12-channel, general-purpose DMA is able to manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers. The DMA controller supports circular buffer management, avoiding the generation of interrupts when the controller reaches the end of the buffer.

Each channel is connected to dedicated hardware DMA requests, with software trigger support for each channel. Configuration is done by software and transfer sizes between source and destination are independent.

The DMA can be used with the main peripherals: AES, SPI, I^2C, USART, SDIO, general-purpose timers, DAC and ADC.

3.10 LCD (liquid crystal display)

The LCD drives up to 8 common terminals and 44 segment terminals to drive up to 320 pixels.

- Internal step-up converter to guarantee functionality and contrast control irrespective of V_{DD}. This converter can be deactivated, in which case the V_{LCD} pin is used to provide the voltage to the LCD
- Supports static, 1/2, 1/3, 1/4 and 1/8 duty
- Supports static, 1/2, 1/3 and 1/4 bias
- Phase inversion to reduce power consumption and EMI
- Up to 8 pixels can be programmed to blink
- Unneeded segments and common pins can be used as general I/O pins
- LCD RAM can be updated at any time owing to a double-buffer
- The LCD controller can operate in Stop mode

3.11 ADC (analog-to-digital converter)

A 12-bit analog-to-digital converters is embedded into STM32L162xD devices with up to 40 external channels, performing conversions in single-shot or scan mode. In scan mode, automatic conversion is performed on a selected group of analog inputs with up to 28 external channels in a group.

The ADC can be served by the DMA controller.

An analog watchdog feature allows very precise monitoring of the converted voltage of one, some or all scanned channels. An interrupt is generated when the converted voltage is outside the programmed thresholds.

The events generated by the general-purpose timers (TIMx) can be internally connected to the ADC start triggers, to allow the application to synchronize A/D conversions and timers. An injection mode allows high priority conversions to be done by interrupting a scan mode which runs in as a background task.

The ADC includes a specific low-power mode. The converter is able to operate at maximum speed even if the CPU is operating at a very low frequency and has an auto-shutdown function. The ADC's runtime and analog front-end current consumption are thus minimized whatever the MCU operating mode.

3.11.1 Temperature sensor

The temperature sensor (TS) generates a voltage V_{SENSE} that varies linearly with temperature.

The temperature sensor is internally connected to the ADC_IN16 input channel which is used to convert the sensor output voltage into a digital value.

The sensor provides good linearity but it has to be calibrated to obtain good overall accuracy of the temperature measurement. As the offset of the temperature sensor varies

3.21 Development support

3.21.1 Serial wire JTAG debug port (SWJ-DP)

The ARM SWJ-DP interface is embedded, and is a combined JTAG and serial wire debug port that enables either a serial wire debug or a JTAG probe to be connected to the target. The JTAG JTMS and JTCK pins are shared with SWDAT and SWCLK, respectively, and a specific sequence on the JTMS pin is used to switch between JTAG-DP and SW-DP.

The JTAG port can be permanently disabled with a JTAG fuse.

3.21.2 Embedded Trace Macrocell™

The ARM® Embedded Trace Macrocell provides a greater visibility of the instruction and data flow inside the CPU core by streaming compressed data at a very high rate from the STM32L162xD device through a small number of ETM pins to an external hardware trace port analyzer (TPA) device. The TPA is connected to a host computer using USB, Ethernet, or any other high-speed channel. Real-time instruction and data flow activity can be recorded and then formatted for display on the host computer running debugger software. TPA hardware is commercially available from common development tool vendors. It operates with third party debugger software tools.

Table 7. STM32L162xD pin definitions (continued)

Pins					Pin name	Type[1]	I / O Level[2]	Main function[3] (after reset)	Pin functions	
LQFP144	UFBGA132	LQFP100	LQFP64	WLCSP64					Alternate functions	Additional functions
20	H4	-	-	-	PF8	I/O	FT	PF8	TIM5_CH3	ADC_IN29/ COMP1_INP
21	J6	-	-	-	PF9	I/O	FT	PF9	TIM5_CH4	ADC_IN30/ COMP1_INP
22	-	-	-	-	PF10	I/O	FT	PF10	-	ADC_IN31/ COMP1_INP
23	F1	12	5	D8	PH0-OSC_IN[5]	I/O	-	PH0	-	OSC_IN
24	G1	13	6	D7	PH1-OSC_OUT[5]	I/O	-	PH1	-	OSC_OUT
25	H2	14	7	C7	NRST	I/O	-	NRST	-	-
26	H1	15	8	E8	PC0	I/O	FT	PC0	LCD_SEG18	ADC_IN10/ COMP1_INP
27	J2	16	9	F8	PC1	I/O	FT	PC1	LCD_SEG19	ADC_IN11/ COMP1_INP/ OPAMP3_VINP
28	-	17	10	D6	PC2	I/O	FT	PC2	LCD_SEG20	ADC_IN12/ COMP1_INP/ OPAMP3_VINM
-	J3	-	-	-	PC2	I/O	FT	PC2	LCD_SEG20	ADC_IN12/ COMP1_INP
-	K1	-	-	-	OPAMP3_VINM	I	-	OPAMP3_ VINM	-	-
29	K2	18	11	F7	PC3	I/O	-	PC3	LCD_SEG21	ADC_IN13/ COMP1_INP/ OPAMP3_VOUT
30	J1	19	12	E7	V_{SSA}	S	-	V_{SSA}	-	-
31	-	20	-	-	V_{REF-}	S	-	V_{REF-}	-	-
32	L1	21	-	-	V_{REF+}	S	-	V_{REF+}	-	-
33	M1	22	13	G8	V_{DDA}	S	-	V_{DDA}	-	-
34	L2	23	14	F6	PA0-WKUP1	I/O	FT	PA0	TIM2_CH1_ETR/ TIM5_CH1/ USART2_CTS	WKUP1/ RTC_TAMP2/ ADC_IN0 /COMP1_INP

Table 8. Alternate function input/output (continued)

Port name	Digital alternate function number									..			..		
	AFIO0	AFIO1	AFIO2	AFIO3	AFIO4	AFIO5	AFIO6	AFIO7	AFIO8		AFIO11	AFIO12		AFIO14	AFIO15
	Alternate function														
	SYSTEM	TIM2	TIM3/4/5	TIM9/ 10/11	I2C1/2	SPI1/2	SPI3	USART1/2/3	UART4/5		LCD	FSMC/ SDIO		CPRI	SYSTEM
PD8	-	-	-	-	-	-	-	USART3_TX	-		SEG28	D13/DA13		TIMx_IC1	EVENT OUT
PD9	-	-	-	-	-	-	-	USART3_RX	-		SEG29	D14/DA14		TIMx_IC2	EVENT OUT
PD10	-	-	-	-	-	-	-	USART3_CK	-		SEG30	D15/DA15		TIMx_IC3	EVENT OUT
PD11	-	-	-	-	-	-	-	USART3_CTS	-		SEG31	A16		TIMx_IC4	EVENT OUT
PD12	-	-	TIM4_CH1	-	-	-	-	USART3_RTS	-		SEG32	A17		TIMx_IC1	EVENT OUT
PD13	-	-	TIM4_CH2	-	-	-	-	-	-		SEG33	A18		TIMx_IC2	EVENT OUT
PD14	-	-	TIM4_CH3	-	-	-	-	-	-		SEG34	D0/DA0		TIMx_IC3	EVENT OUT
PD15	-	-	TIM4_CH4	-	-	-	-	-	-		SEG35	D1/DA1		TIMx_IC4	EVENT OUT
PE0	-	-	TIM4_ETR	TIM10_CH1	-	-	-	-	-		SEG36	NBL0		TIMx_IC1	EVENT OUT
PE1	-	-	-	TIM11_CH1	-	-	-	-	-		SEG37	NBL1		TIMx_IC2	EVENT OUT
PE2	TRACECK	-	TIM3_ETR	-	-	-	-	-	-		SEG 38	A23		TIMx_IC3	EVENT OUT
PE3	TRACED0	-	TIM3_CH1	-	-	-	-	-	-		SEG 39	A19		TIMx_IC4	EVENT OUT
PE4	TRACED1	-	TIM3_CH2	-	-	-	-	-	-		-	A20		TIMx_IC1	EVENT OUT
PE5	TRACED2	-	-	TIM9_CH1	-	-	-	-	-		-	A21		TIMx_IC2	EVENT OUT
PE6-WKUP3	TRACED3	-	-	TIM9_CH2	-	-	-	-	-		-	-		TIMx_IC3	EVENT OUT

Table 8. Alternate function input/output (continued)

Port name	Digital alternate function number														
	AFIO0	AFIO1	AFIO2	AFIO3	AFIO4	AFIO5	AFIO6	AFIO7	AFIO8	..	AFIO11	AFIO12	..	AFIO14	AFIO15
	Alternate function														
	SYSTEM	TIM2	TIM3/4/5	TIM9/ 10/11	I2C1/2	SPI1/2	SPI3	USART1/2/3	UART4/5		LCD	FSMC/ SDIO		CPRI	SYSTEM
PF6	-	-	TIM5_ETR	-	-	-	-	-	-		-	-		-	EVENT OUT
PF7	-	-	TIM5_CH2	-	-	-	-	-	-		-	-		-	EVENT OUT
PF8	-	-	TIM5_CH3	-	-	-	-	-	-		-	-		-	EVENT OUT
PF9	-	-	TIM5_CH4	-	-	-	-	-	-		-	-		-	EVENT OUT
PF10	-	-	-	-	-	-	-	-	-		-	-		-	EVENT OUT
PF11	-	-	-	-	-	-	-	-	-		-	-		-	EVENT OUT
PF12	-	-	-	-	-	-	-	-	-		-	A6		-	EVENT OUT
PF13	-	-	-	-	-	-	-	-	-		-	A7		-	EVENT OUT
PF14	-	-	-	-	-	-	-	-	-		-	A8		-	EVENT OUT
PF15	-	-	-	-	-	-	-	-	-		-	A9		-	EVENT OUT
PG0	-	-	-	-	-	-	-	-	-		-	A10		-	EVENT OUT
PG1	-	-	-	-	-	-	-	-	-		-	A11		-	EVENT OUT
PG2	-	-	-	-	-	-	-	-	-		-	A12		-	EVENT OUT
PG3	-	-	-	-	-	-	-	-	-		-	A13		-	EVENT OUT
PG4	-	-	-	-	-	-	-	-	-		-	A14		-	EVENT OUT

6 Electrical characteristics

6.1 Parameter conditions

Unless otherwise specified, all voltages are referenced to V_{SS}.

6.1.1 Minimum and maximum values

Unless otherwise specified the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage and frequencies by tests in production on 100% of the devices with an ambient temperature at T_A = 25 °C and T_A = $T_A$max (given by the selected temperature range).

Data based on characterization results, design simulation and/or technology characteristics are indicated in the table footnotes. Based on characterization, the minimum and maximum values refer to sample tests and represent the mean value plus or minus three times the standard deviation (mean ±3σ).

6.1.2 Typical values

Unless otherwise specified, typical data are based on T_A = 25 °C, V_{DD} = 3.6 V (for the 1.65 V ≤V_{DD} ≤3.6 V voltage range). They are given only as design guidelines and are not tested.

Typical ADC accuracy values are determined by characterization of a batch of samples from a standard diffusion lot over the full temperature range, where 95% of the devices have an error less than or equal to the value indicated (mean ±2σ).

6.1.3 Typical curves

Unless otherwise specified, all typical curves are given only as design guidelines and are not tested.

6.1.4 Loading capacitor

The loading conditions used for pin parameter measurement are shown in *Figure 9*.

6.1.5 Pin input voltage

The input voltage measurement on a pin of the device is described in *Figure 10*.

Figure 9. Pin loading conditions

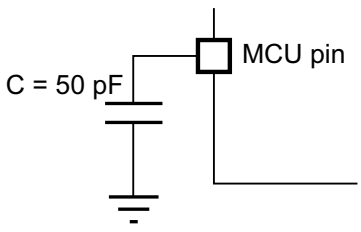


Figure 10. Pin input voltage

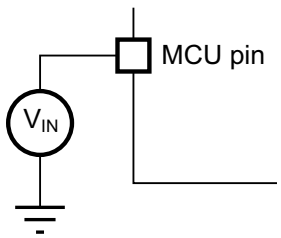


Table 18. Current consumption in Sleep mode

Symbol	Parameter	Conditions		f_{HCLK}	Typ	Max (1)	Unit
$I_{DD(SLEEP)}$	Supply current in Sleep mode, code executed from RAM, Flash switched OFF	f_{HSE} = f_{HCLK} up to 16 MHz, included f_{HSE} = f_{HCLK}/2 above 16 MHz (PLL ON)(2)	Range3, Vcore=1.2 V VOS[1:0]=11	1	58	220	µA
				2	96	300	
				4	170	380	
			Range2, Vcore=1.5 V VOS[1:0]=10	4	210	500	
				8	400	700	
				16	810	1100	
			Range1, Vcore=1.8 V VOS[1:0]=01	8	485	800	
				16	955	1250	
				32	2100	2700	
		HSI clock source (16 MHz)	Range2, Vcore=1.5 V VOS[1:0]=10	16	835	1100	
			Range1, Vcore=1.8 V VOS[1:0]=01	32	2100	2700	
		MSI clock, 65 kHZ	Range3, Vcore=1.2 V VOS[1:0]=11	0.065	18.5	72	
		MSI clock, 524 kHZ		0.524	37	92	
		MSI clock, 4.2 MHZ		4.2	180	273	
	Supply current in Sleep mode, Flash switched ON	f_{HSE} = f_{HCLK} up to 16 MHz, included f_{HSE} = f_{HCLK}/2 above 16MHz (PLL ON)(2)	Range3, Vcore=1.2 V VOS[1:0]=11	1	75	250	
				2	115	300	
				4	200	380	
			Range2, Vcore=1.5 V VOS[1:0]=10	4	230	500	
				8	430	700	
				16	840	1120	
			Range1, Vcore=1.8 V VOS[1:0]=01	8	500	800	
				16	980	1300	
				32	2100	2700	
		HSI clock source (16 MHz)	Range2, Vcore=1.5 V VOS[1:0]=10	16	860	1160	
			Range1, Vcore=1.8 V VOS[1:0]=01	32	2150	2800	
		MSI clock, 65 kHZ	Range3, Vcore=1.2 V VOS[1:0]=11	0.065	33,5	90	
		MSI clock, 524 kHZ		0.524	53	110	
		MSI clock, 4.2 MHZ		4.2	200	290	

1. Guaranteed by characterization results, unless otherwise specified.

Table 23. Peripheral current consumption(1)

Peripheral		Typical consumption, V_{DD} = 3.0 V, T_A = 25 °C				Unit
		Range 1, V_{CORE}= 1.8 V VOS[1:0] = 01	Range 2, V_{CORE}= 1.5 V VOS[1:0] = 10	Range 3, V_{CORE}= 1.2 V VOS[1:0] = 11	Low-power sleep and run	
APB1	TIM2	14.3	12.1	9.5	12.1	µA/MHz (f_{HCLK})
	TIM3	13.8	11.7	9.2	11.7	
	TIM4	13.2	11.1	8.7	11.1	
	TIM5	17.7	14.9	11.8	14.9	
	TIM6	4.8	4.0	3.0	4.0	
	TIM7	4.7	3.9	3.0	3.9	
	LCD	5.0	4.1	3.3	4.1	
	WWDG	3.5	2.9	2.3	2.9	
	SPI2	8.9	7.4	5.8	7.4	
	SPI3	7.3	6.0	4.8	6.0	
	USART2	9.4	7.7	6.1	7.7	
	USART3	9.4	7.6	6.0	7.6	
	USART4	10.1	8.4	6.7	8.4	
	USART5	9.5	7.9	6.3	7.9	
	I2C1	8.9	7.4	5.8	7.4	
	I2C2	7.9	6.4	5.1	6.4	
	USB	21.2	18.0	14.3	18.0	
	PWR	4.0	3.2	2.5	3.2	
	DAC	6.3	5.5	4.4	5.5	
	COMP	4.9	3.9	3.2	3.9	

Table 25. High-speed external user clock characteristics(1) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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		12	-	-	ns
$t_{r(HSE)}$ $t_{f(HSE)}$	OSC_IN rise or fall time		-	-	20	
$C_{in(HSE)}$	OSC_IN input capacitance		-	2.6	-	pF

1. Guaranteed by design.

Figure 14. High-speed external clock source AC timing diagram

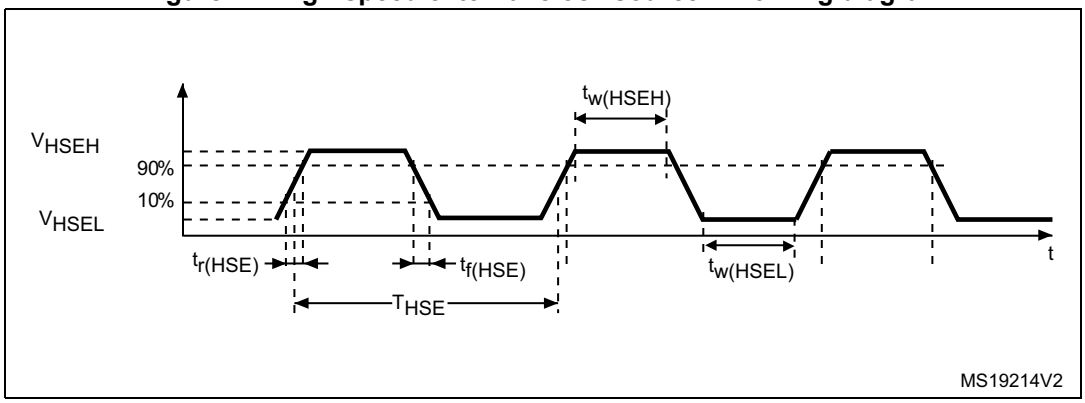
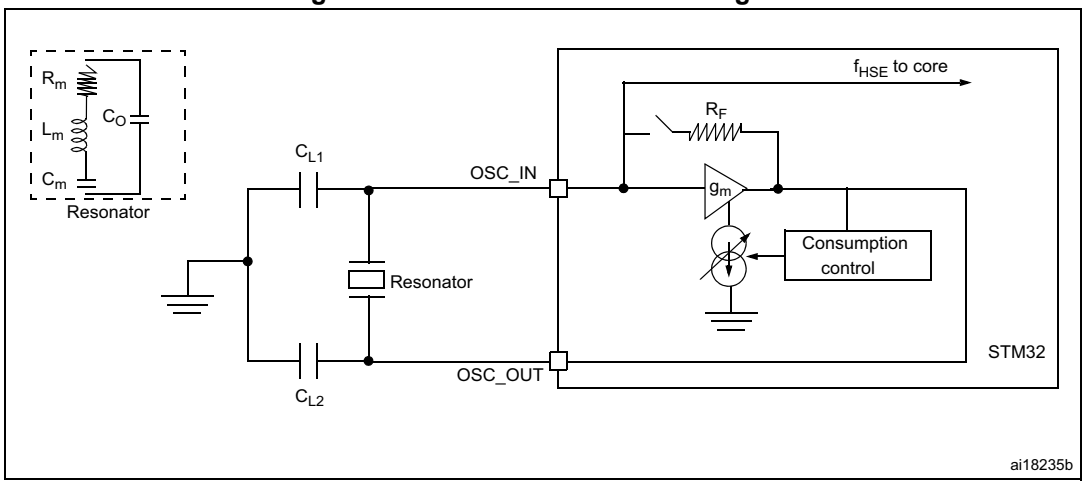


Figure 16. HSE oscillator circuit diagram



1. R_{EXT} value depends on the crystal characteristics.

Low-speed external clock generated from a crystal/ceramic resonator

The low-speed external (LSE) clock can be supplied with a 32.768 kHz crystal/ceramic resonator oscillator. All the information given in this paragraph are based on characterization results obtained with typical external components specified in *Table 28*. In the application, the resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. Refer to the crystal resonator manufacturer for more details on the resonator characteristics (frequency, package, accuracy).

Table 28. LSE oscillator characteristics (f_{LSE} = 32.768 kHz)(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LSE}	Low speed external oscillator frequency	-	-	32.768	-	kHz
R_F	Feedback resistor	-	-	1.2	-	MΩ
$C^{(2)}$	Recommended load capacitance versus equivalent serial resistance of the crystal (R_S)(3)	R_S = 30 kΩ	-	8	-	pF
I_{LSE}	LSE driving current	V_{DD} = 3.3 V, V_{IN} = V_{SS}	-	-	1.1	µA
$I_{DD\ (LSE)}$	LSE oscillator current consumption	V_{DD} = 1.8 V	-	450	-	nA
		V_{DD} = 3.0 V	-	600	-	
		V_{DD} = 3.6V	-	750	-	
g_m	Oscillator transconductance	-	3	-	-	µA/V
$t_{SU(LSE)}$(4)	Startup time	V_{DD} is stabilized	-	1	-	s

1. Guaranteed by characterization results.
2. Refer to the note and caution paragraphs below the table, and to the application note AN2867 “Oscillator design guide for ST microcontrollers”.
3. The oscillator selection can be optimized in terms of supply current using an high quality resonator with small R_S value for example MSIV-TIN32.768kHz. Refer to crystal manufacturer for more details.

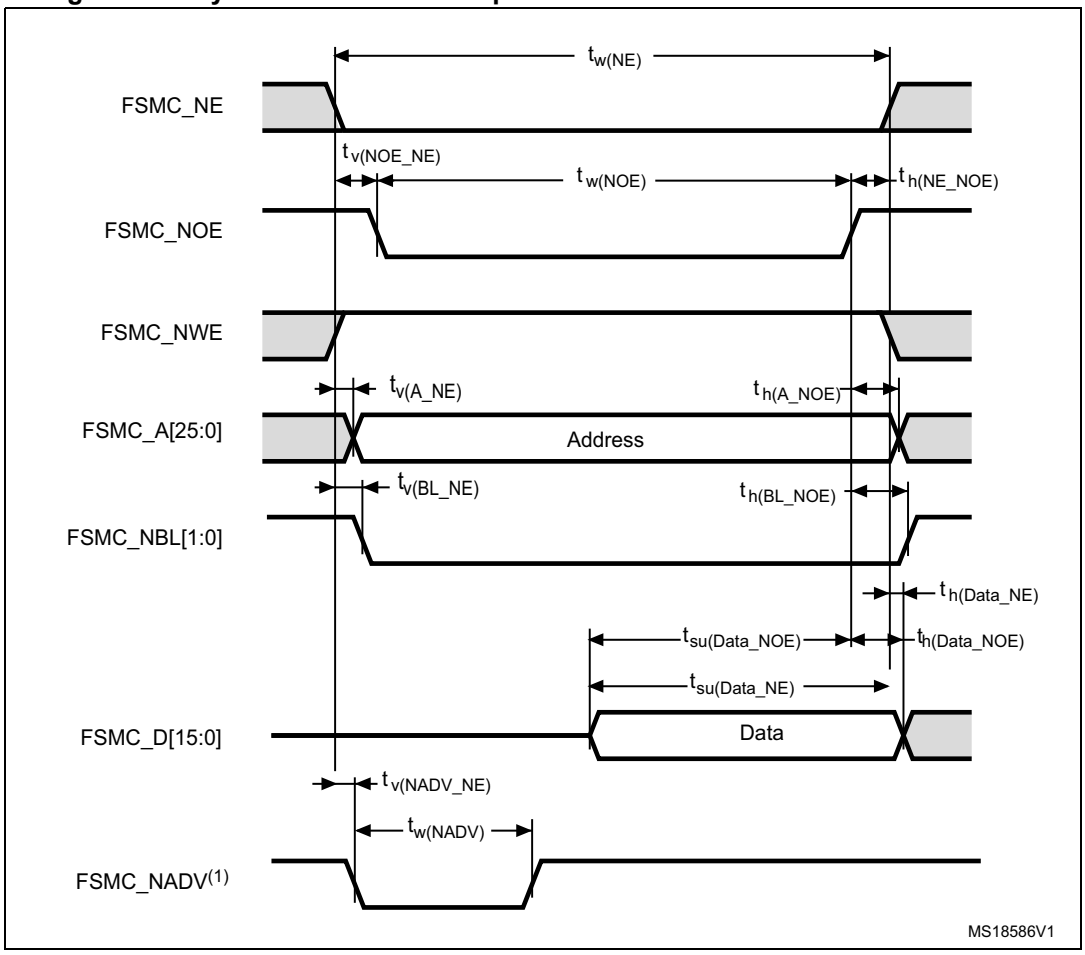
6.3.10 FSMC characteristics

Asynchronous waveforms and timings

Figure 18 through *Figure 21* represent asynchronous waveforms and *Table 36* through *Table 39* provide the corresponding timings. The results shown in these tables are obtained with the following FSMC configuration:

- AddressSetupTime = 0 (AddressSetupTime = 1, for asynchronous multiplexed modes)
- AddressHoldTime = 1
- DataSetupTime = 1

Figure 18. Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms



1. Mode 2/B, C and D only. In Mode 1, FSMC_NADV is not used.

Table 41. Synchronous multiplexed PSRAM write timings(1)

Symbol	Parameter	Min	Max	Unit
$t_{w(CLK)}$	FSMC_CLK period	$2*T_{HCLK}$	-	ns
$t_{d(CLKL-NExL)}$	FSMC_CLK low to FSMC_NEx low (x = 0...2)	-	0	ns
$t_{d(CLKL-NExH)}$	FSMC_CLK low to FSMC_NEx high (x = 0...2)	0	-	ns
$t_{d(CLKL-NADVL)}$	FSMC_CLK low to FSMC_NADV low	-	0	ns
$t_{d(CLKL-NADVH)}$	FSMC_CLK low to FSMC_NADV high	0	-	ns
$t_{d(CLKL-AV)}$	FSMC_CLK low to FSMC_Ax valid (x = 16...25)	-	0	ns
$t_{d(CLKL-AIV)}$	FSMC_CLK low to FSMC_Ax invalid (x = 16...25)	T_{HCLK} + 4	-	ns
$t_{d(CLKL-NWEL)}$	FSMC_CLK low to FSMC_NWE low	-	0	ns
$t_{d(CLKL-NWEH)}$	FSMC_CLK low to FSMC_NWE high	1	-	ns
$t_{d(CLKL-ADIV)}$	FSMC_CLK low to FSMC_AD[15:0] invalid	5	-	ns
$t_{d(CLKL-DATA)}$	FSMC_A/D[15:0] valid after FSMC_CLK low	-	6	ns
$t_{su(NWAITV-CLKH)}$	FSMC_NWAIT valid before FSMC_CLK high	6	-	ns
$t_{h(CLKH-NWAITV)}$	FSMC_NWAIT valid after FSMC_CLK high	0	-	ns
$t_{d(CLKL-NBLH)}$	FSMC_CLK low to FSMC_NBL high	1	-	ns

1. C_L = 30 pF.

Table 43. Synchronous non-multiplexed PSRAM write timings(1) (continued)

Symbol	Parameter	Min	Max	Unit
$t_{d(CLKL-NWEH)}$	FSMC_CLK low to FSMC_NWE high	5	-	ns
$t_{d(CLKL-DATA)}$	FSMC_D[15:0] valid data after FSMC_CLK low	-	7	ns
$t_{d(CLKL-NBLH)}$	FSMC_CLK low to FSMC_NBL high	3	-	ns
$t_{su(NWAITV-CLKH)}$	FSMC_NWAIT valid before FSMC_CLK high	6	-	ns
$t_{h(CLKH-NWAITV)}$	FSMC_NWAIT valid after FSMC_CLK high	0	-	ns

1. C_L = 30 pF.

Output driving current

The GPIOs (general purpose input/outputs) can sink or source up to ±8 mA, and sink or source up to ±20 mA with the non-standard V_{OL}/V_{OH} specifications given in *Table 50*.

In the user application, the number of I/O pins which can drive current must be limited to respect the absolute maximum rating specified in *Section 6.2*:

- The sum of the currents sourced by all the I/Os on $V_{DD,}$ plus the maximum Run consumption of the MCU sourced on $V_{DD,}$ cannot exceed the absolute maximum rating $I_{VDD(\Sigma)}$ (see *Table 10*).
- The sum of the currents sunk by all the I/Os on V_{SS} plus the maximum Run consumption of the MCU sunk on V_{SS} cannot exceed the absolute maximum rating $I_{VSS(\Sigma)}$ (see *Table 10*).

Output voltage levels

Unless otherwise specified, the parameters given in *Table 50* are derived from tests performed under the conditions summarized in *Table 12*. All I/Os are CMOS and TTL compliant.

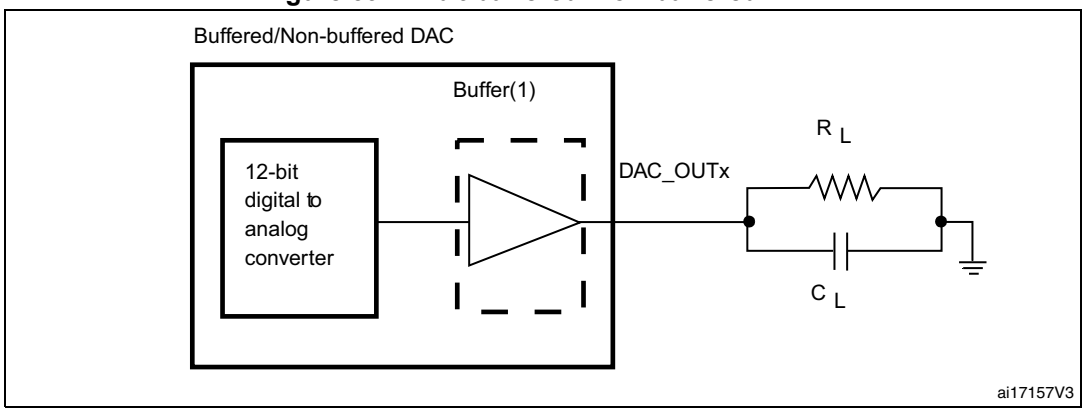
Table 50. Output voltage characteristics

Symbol	Parameter	Conditions	Min	Max	Unit
V_{OL} (1)(2)	Output low level voltage for an I/O pin	I_{IO} = 8 mA 2.7 V < V_{DD} < 3.6 V	-	0.4	V
V_{OH} (2)(3)	Output high level voltage for an I/O pin		V_{DD}-0.4	-	
V_{OL} (3)(4)	Output low level voltage for an I/O pin	I_{IO} = 4 mA 1.65 V < V_{DD} < 3.6 V	-	0.45	
V_{OH} (3)(4)	Output high level voltage for an I/O pin		V_{DD}-0.45	-	
V_{OL} (1)(4)	Output low level voltage for an I/O pin	I_{IO} = 20 mA 2.7 V < V_{DD} < 3.6 V	-	1.3	
V_{OH} (3)(4)	Output high level voltage for an I/O pin		V_{DD}-1.3	-	

1. The I_{IO} current sunk by the device must always respect the absolute maximum rating specified in *Table 10* and the sum of I_{IO} (I/O ports and control pins) must not exceed I_{VSS}.
2. Guaranteed by test in production.
3. The I_{IO} current sourced by the device must always respect the absolute maximum rating specified in *Table 10* and the sum of I_{IO} (I/O ports and control pins) must not exceed I_{VDD}.
4. Guaranteed by characterization results.

4. Difference between measured value at Code i and the value at Code i on a line drawn between Code 0 and last Code 4095.
5. Difference between the value measured at Code (0x800) and the ideal value = $V_{REF+}/2$.
6. Difference between the value measured at Code (0x001) and the ideal value.
7. Difference between ideal slope of the transfer function and measured slope computed from code 0x000 and 0xFFF when buffer is OFF, and from code giving 0.2 V and (V_{DDA} – 0.2) V when buffer is ON.
8. In buffered mode, the output can overshoot above the final value for low input code (starting from min value).

Figure 39. 12-bit buffered /non-buffered DAC



1. The DAC integrates an output buffer that can be used to reduce the output impedance and to drive external loads directly without the use of an external operational amplifier. The buffer can be bypassed by configuring the BOFFx bit in the DAC_CR register.

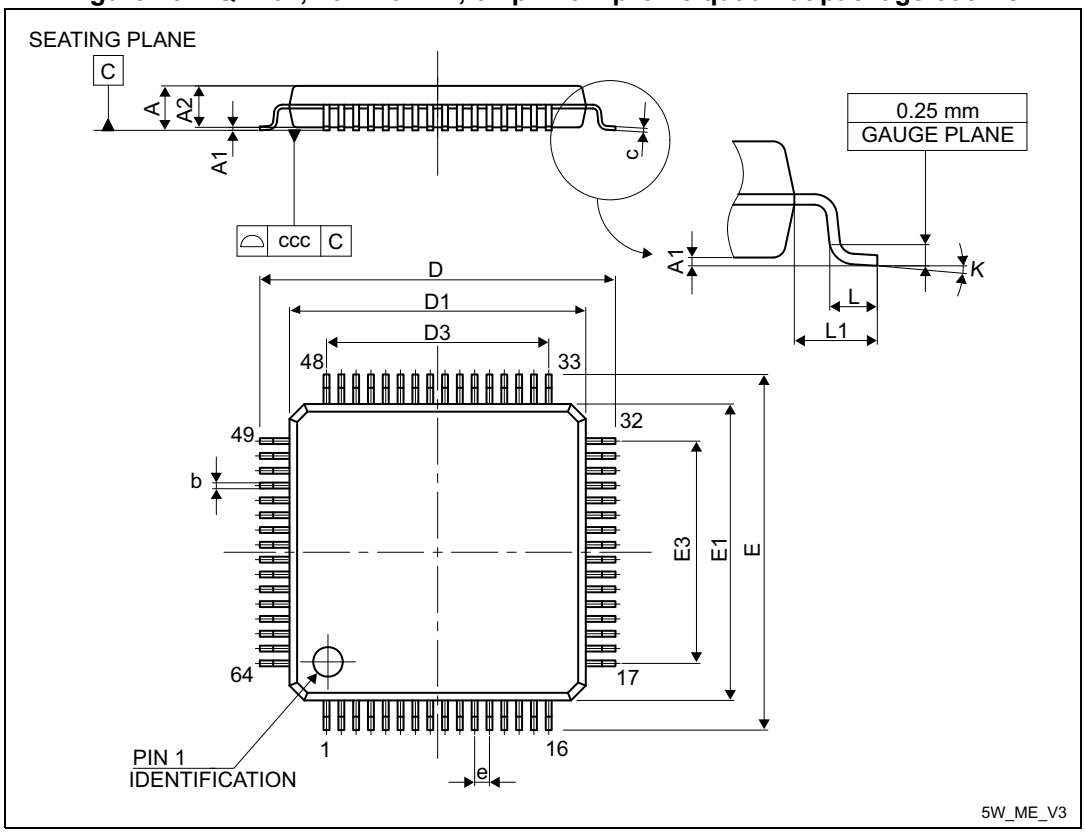
6.3.21 Operational amplifier characteristics

Table 67. Operational amplifier characteristics

Symbol	Parameter		Condition(1)	Min(2)	Typ	Max(2)	Unit
CMIR	Common mode input range		-	0	-	V_{DD}	
VI_{OFFSET}	Input offset voltage	Maximum calibration range	-	-	-	±15	mV
		After offset calibration	-	-	-	±1.5	
ΔVI_{OFFSET}	Input offset voltage drift	Normal mode	-	-	-	±40	µV/°C
		Low-power mode	-	-	-	±80	
I_{IB}	Input current bias	Dedicated input	75 °C	-	-	1	nA
		General purpose input		-	-	10	
I_{LOAD}	Drive current	Normal mode	-	-	-	500	µA
		Low-power mode	-	-	-	100	
I_{DD}	Consumption	Normal mode	No load, quiescent mode	-	100	220	µA
		Low-power mode		-	30	60	
CMRR	Common mode rejection ration	Normal mode	-	-	-85	-	dB
		Low-power mode	-	-	-90	-	

7.3 LQFP64, 10 x 10 mm, 64-pin low-profile quad flat package information

Figure 46. LQFP64, 10 x 10 mm, 64-pin low-profile quad flat package outline



1. Drawing is not to scale.

Table 75. LQFP64, 10 x 10 mm 64-pin low-profile quad flat package mechanical data

Symbol	millimeters			inches[1]		
	Min	Typ	Max	Min	Typ	Max
A	-	-	1.600	-	-	0.0630
A1	0.050	-	0.150	0.0020	-	0.0059
A2	1.350	1.400	1.450	0.0531	0.0551	0.0571
b	0.170	0.220	0.270	0.0067	0.0087	0.0106
c	0.090	-	0.200	0.0035	-	0.0079
D	-	12.000	-	-	0.4724	-
D1	-	10.000	-	-	0.3937	-
D3	-	7.500	-	-	0.2953	-
E	-	12.000	-	-	0.4724	-
E1	-	10.000	-	-	0.3937	-

7.6 Thermal characteristics

The maximum chip-junction temperature, T_J max, in degrees Celsius, may be calculated using the following equation:

T_J max = T_A max + (P_D max × Θ_{JA})

Where:

- T_A max is the maximum ambient temperature in °C,
- Θ_{JA} is the package junction-to-ambient thermal resistance, in °C/W,
- P_D max is the sum of P_{INT} max and $P_{I/O}$ max (P_D max = P_{INT} max + $P_{I/O}$max),
- P_{INT} max is the product of I_{DD} and V_{DD}, expressed in Watts. This is the maximum chip internal power.

$P_{I/O}$ max represents the maximum power dissipation on output pins where:

$P_{I/O}$ max = Σ (V_{OL} × I_{OL}) + Σ((V_{DD} – V_{OH}) × I_{OH}),

taking into account the actual V_{OL} / I_{OL} and V_{OH} / I_{OH} of the I/Os at low and high level in the application.

Table 79. Thermal characteristics

Symbol	Parameter	Value	Unit
Θ_{JA}	**Thermal resistance junction-ambient** LQFP144 - 20 x 20 mm / 0.5 mm pitch	40	°C/W
	Thermal resistance junction-ambient UFBGA132 - 7 x 7 mm	60	
	Thermal resistance junction-ambient LQFP100 - 14 x 14 mm / 0.5 mm pitch	43	
	Thermal resistance junction-ambient LQFP64 - 10 x 10 mm / 0.5 mm pitch	46	
	Thermal resistance junction-ambient WLCSP64 - 0.400 mm pitch	46	