GigaDevice Semiconductor Inc.

GD32E231CxT6
ARM® Cortex®-M23 32-bit MCU

Datasheet

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1 General description

The GD32E231CxT6 device belongs to the value line of GD32 MCU family. It is a new 32-bit general-purpose microcontroller based on the ARM® Cortex®-M23 core. The Cortex-M23 processor is an energy-efficient processor with a very low gate count. It is intended to be used for microcontroller and deeply embedded applications that require an area-optimized processor. The processor delivers high energy efficiency through a small but powerful instruction set and extensively optimized design, providing high-end processing hardware including a single-cycle multiplier and a 17-cycle divider.

The GD32E231CxT6 device incorporates the ARM® Cortex®-M23 32-bit processor core operating at up to 72 MHz frequency with Flash accesses 0~2 wait states to obtain maximum efficiency. It provides up to 64 KB embedded Flash memory and up to 8 KB SRAM memory. An extensive range of enhanced I/Os and peripherals connected to two APB buses. The devices offer one 12-bit ADC and one comparator, two OP-AMPs, up to five general 16-bit timers, a basic timer, a PWM advanced timer, as well as standard and advanced communication interfaces: up to two SPIs, two I2Cs, two USARTs, and an I2S.

The device operates from a 1.8 to 3.6 V power supply and available in –40 to +85 °C temperature range. Several power saving modes provide the flexibility for maximum optimization between wakeup latency and power consumption, an especially important consideration in low power applications.

The above features make the GD32E231CxT6 devices suitable for a wide range of applications, especially in areas such as industrial control, motor drives, user interface, power monitor and alarm systems, consumer and handheld equipment, gaming and GPS, E-bike and so on.

2 Device overview

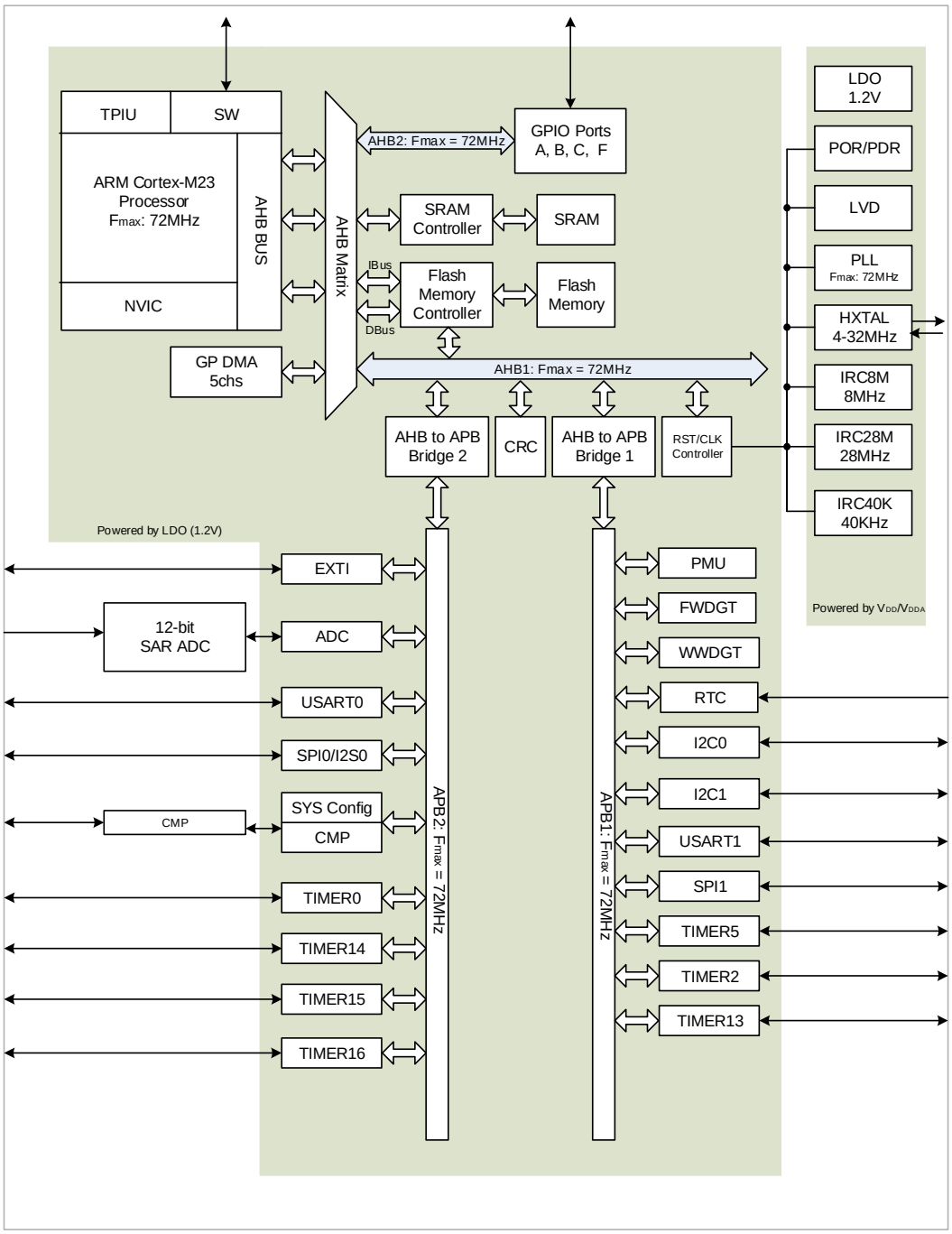
2.1 Device information

Table 2-1. GD32E231CxT6 devices features and peripheral list

Part Number		GD32E231CxT6		
		C4T6	C6T6	C8T6
FLASH (KB)		16	32	64
SRAM (KB)		4	6	8
Timers	General timer(16-bit)	4 (2,13,15,16)	4 (2,13,15,16)	5 (2,13-16)
	Advanced timer(16-bit)	1 (0)	1 (0)	1 (0)
	SysTick	1	1	1
	Basic timer(16-bit)	1 (5)	1 (5)	1 (5)
	Watchdog	2	2	2
	RTC	1	1	1
Connectivity	USART	1 (0)	2 (0-1)	2 (0-1)
	I2C	1 (0)	1 (0)	2 (0-1)
	SPI/I2S	1/1 (0)/(0)	1/1 (0)/(0)	2/1 (0-1)/(0)
GPIO		37	37	37
CMP		1	1	1
OP-AMP		2	2	2
EXTI		16	16	16
ADC	Units	1	1	1
	Channels (External)	10	10	10
	Channels (Internal)	2	2	2
Package		LQFP48		

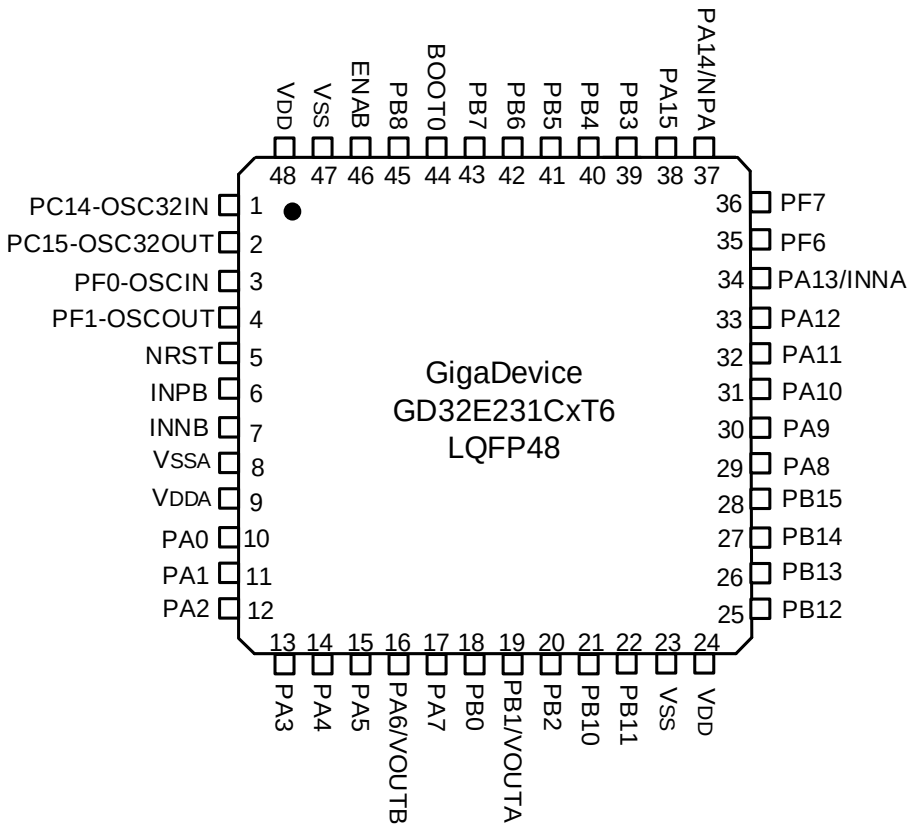
2.2 Block diagram

Figure 2-1. GD32E231CxT6 block diagram



2.3 Pinouts and pin assignment

Figure 2-2. GD32E231CxT6 LQFP48 pinouts



2.4 Memory map

Table 2-2. GD32E231CxT6 memory map

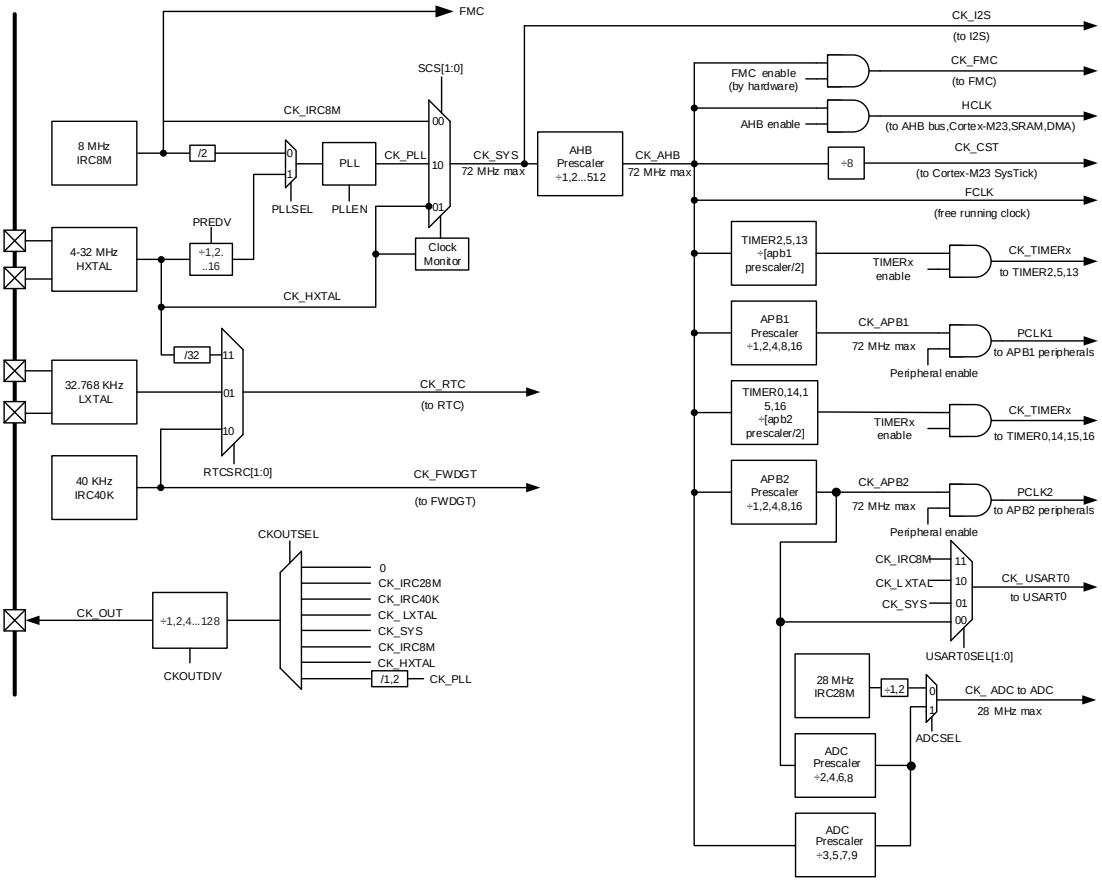
Pre-defined Regions	Bus	ADDRESS	Peripherals
		0xE000 0000 - 0xE00F FFFF	Cortex M23 internal peripherals
External Device		0xA000 0000 - 0xDFFF FFFF	Reserved
External RAM		0x6000 0000 - 0x9FFF FFFF	Reserved
Peripherals	AHB1	0x5004 0000 - 0x5FFF FFFF	Reserved
		0x5000 0000 - 0x5003 FFFF	Reserved
	AHB2	0x4800 1800 - 0x4FFF FFFF	Reserved
		0x4800 1400 - 0x4800 17FF	GPIOF
		0x4800 1000 - 0x4800 13FF	Reserved
		0x4800 0C00 - 0x4800 0FFF	Reserved
		0x4800 0800 - 0x4800 0BFF	GPIOC
		0x4800 0400 - 0x4800 07FF	GPIOB
		0x4800 0000 - 0x4800 03FF	GPIOA
	AHB1	0x4002 4400 - 0x47FF FFFF	Reserved
		0x4002 4000 - 0x4002 43FF	Reserved
		0x4002 3400 - 0x4002 3FFF	Reserved
		0x4002 3000 - 0x4002 33FF	CRC
		0x4002 2400 - 0x4002 2FFF	Reserved
		0x4002 2000 - 0x4002 23FF	FMC
		0x4002 1400 - 0x4002 1FFF	Reserved
		0x4002 1000 - 0x4002 13FF	RCU
		0x4002 0400 - 0x4002 0FFF	Reserved
		0x4002 0000 - 0x4002 03FF	DMA
	APB2	0x4001 8000 - 0x4001 FFFF	Reserved
		0x4001 5C00 - 0x4001 7FFF	Reserved
		0x4001 5800 - 0x4001 5BFF	DBG
		0x4001 4C00 - 0x4001 57FF	Reserved
		0x4001 4800 - 0x4001 4BFF	TIMER16
		0x4001 4400 - 0x4001 47FF	TIMER15
		0x4001 4000 - 0x4001 43FF	TIMER14
		0x4001 3C00 - 0x4001 3FFF	Reserved
		0x4001 3800 - 0x4001 3BFF	USART0
		0x4001 3400 - 0x4001 37FF	Reserved
		0x4001 3000 - 0x4001 33FF	SPI0/I2S0
		0x4001 2C00 - 0x4001 2FFF	TIMER0
		0x4001 2800 - 0x4001 2BFF	Reserved
		0x4001 2400 - 0x4001 27FF	ADC
		0x4001 0800 - 0x4001 23FF	Reserved

Pre-defined Regions	Bus	ADDRESS	Peripherals
		0x4001 0400 - 0x4001 07FF	EXTI
		0x4001 0000 - 0x4001 03FF	SYSCFG + CMP
	APB1	0x4000 CC00 - 0x4000 FFFF	Reserved
		0x4000 C800 - 0x4000 CBFF	Reserved
		0x4000 C400 - 0x4000 C7FF	Reserved
		0x4000 C000 - 0x4000 C3FF	Reserved
		0x4000 8000 - 0x4000 BFFF	Reserved
		0x4000 7C00 - 0x4000 7FFF	Reserved
		0x4000 7800 - 0x4000 7BFF	Reserved
		0x4000 7400 - 0x4000 77FF	Reserved
		0x4000 7000 - 0x4000 73FF	PMU
		0x4000 6400 - 0x4000 6FFF	Reserved
		0x4000 6000 - 0x4000 63FF	Reserved
		0x4000 5C00 - 0x4000 5FFF	Reserved
		0x4000 5800 - 0x4000 5BFF	I2C1
		0x4000 5400 - 0x4000 57FF	I2C0
		0x4000 4800 - 0x4000 53FF	Reserved
		0x4000 4400 - 0x4000 47FF	USART1
		0x4000 4000 - 0x4000 43FF	Reserved
		0x4000 3C00 - 0x4000 3FFF	Reserved
		0x4000 3800 - 0x4000 3BFF	SPI1
		0x4000 3400 - 0x4000 37FF	Reserved
		0x4000 3000 - 0x4000 33FF	FWDGT
		0x4000 2C00 - 0x4000 2FFF	WWDGT
		0x4000 2800 - 0x4000 2BFF	RTC
		0x4000 2400 - 0x4000 27FF	Reserved
		0x4000 2000 - 0x4000 23FF	TIMER13
		0x4000 1400 - 0x4000 1FFF	Reserved
		0x4000 1000 - 0x4000 13FF	TIMER5
		0x4000 0800 - 0x4000 0FFF	Reserved
		0x4000 0400 - 0x4000 07FF	TIMER2
		0x4000 0000 - 0x4000 03FF	Reserved
SRAM		0x2000 2000 - 0x3FFF FFFF	Reserved
		0x2000 0000 - 0x2000 1FFF	SRAM
Code		0x1FFF F810 - 0x1FFF FFFF	Reserved
		0x1FFF F800 - 0x1FFF F80F	Option bytes
		0x1FFF EC00 - 0x1FFF F7FF	System memory
		0x0801 0000 - 0x1FFF EBFF	Reserved
		0x0800 0000 - 0x0800 FFFF	Main Flash memory
		0x0001 0000 - 0x07FF FFFF	Reserved

Pre-defined Regions	Bus	ADDRESS	Peripherals
		0x00000000 - 0x0000FFFF	Aliased to Flash or system memory

2.5 Clock tree

Figure 2-3. GD32E231CxT6 clock tree



Note:

If the APB prescaler is 1, the timer clock frequencies are set to AHB frequency divide by 1. Otherwise, they are set to the AHB frequency divide by half of APB prescaler.

Legend:

HXTAL: High speed crystal oscillator

LXTAL: Low speed crystal oscillator

IRC8M: Internal 8M RC oscillator

IRC40K: Internal 40K RC oscillator

IRC28M: Internal 28M RC oscillator

2.6 Pin definitions

2.6.1 GD32E231CxT6 LQFP48 pin definitions

Table 2-3. GD32E231CxT6 LQFP48 pin definitions

Pin Name	Pins	Pin Type(1)	I/O Level(2)	Functions description
PC14-OSC32IN	1	I/O		Default: PC14 Additional: OSC32IN
PC15-OSC32OUT	2	I/O		Default: PC15 Additional: OSC32OUT
PF0-OSCIN	3	I/O	5VT	Default: PF0 Alternate: I2C0_SDA Additional: OSCIN
PF1-OSCOUT	4	I/O	5VT	Default: PF1 Alternate: I2C0_SCL Additional: OSCOUT
NRST	5	I/O		Default: NRST
INPB	6	I		Default: V_{IN+B}
INNB	7	I		Default: V_{IN-B}
V_{SSA}	8	P		Default: V_{SSA}
V_{DDA}	9	P		Default: V_{DDA}
PA0-WKUP	10	I/O		Default: PA0 Alternate: USART0_CTS(3), USART1_CTS(4), CMP_OUT, I2C1_SCL(5) Additional: ADC_IN0, CMP_IM6, RTC_TAMP1, WKUP0
PA1	11	I/O		Default: PA1 Alternate: USART0_RTS(3), USART1_RTS(4), I2C1_SDA(5), EVENTOUT, TIMER14_CH0_ON(5) Additional: ADC_IN1, CMP_IP
PA2	12	I/O		Default: PA2 Alternate: USART0_TX(3), USART1_TX(4), TIMER14_CH0(5) Additional: ADC_IN2, CMP_IM7
PA3	13	I/O		Default: PA3 Alternate: USART0_RX(3), USART1_RX(4), TIMER14_CH1(5) Additional: ADC_IN3
PA4	14	I/O		Default: PA4 Alternate: SPI0_NSS, I2S0_WS, USART0_CK(3), USART1_CK(4), TIMER13_CH0, SPI1_NSS(5) Additional: ADC_IN4, CMP_IM4
PA5	15	I/O		Default: PA5 Alternate: SPI0_SCK, I2S0_CK Additional: ADC_IN5, CMP_IM5

Pin Name	Pins	Pin Type(1)	I/O Level(2)	Functions description
PA6/VOUTB	16	I/O		Default: PA6 Alternate: SPI0_MISO, I2S0_MCK, TIMER2_CH0, TIMER0_BRKIN, TIMER15_CH0, EVENTOUT, CMP_OUT Additional: ADC_IN6, V_{OUTB}
PA7	17	I/O		Default: PA7 Alternate: SPI0_MOSI, I2S0_SD, TIMER2_CH1, TIMER13_CH0, TIMER0_CH0_ON, TIMER16_CH0, EVENTOUT Additional: ADC_IN7
PB0	18	I/O		Default: PB0 Alternate: TIMER2_CH2, TIMER0_CH1_ON, USART1_RX(4), EVENTOUT Additional: ADC_IN8
PB1/VOUTA	19	I/O		Default: PB1 Alternate: TIMER2_CH3, TIMER13_CH0, TIMER0_CH2_ON, SPI1_SCK(5) Additional: ADC_IN9, V_{OUTA}
PB2	20	I/O	5VT	Default: PB2 Alternate: TIMER2_ETI
PB10	21	I/O	5VT	Default: PB10 Alternate: I2C0_SCL(3), I2C1_SCL(5), SPI1_IO2(5), SPI1_SCK(5)
PB11	22	I/O	5VT	Default: PB11 Alternate: I2C0_SDA(3), I2C1_SDA(5), EVENTOUT, SPI1_IO3(5)
V_{SS}	23	P		Default: V_{SS}
V_{DD}	24	P		Default: V_{DD}
PB12	25	I/O	5VT	Default: PB12 Alternate: SPI0_NSS(3), SPI1_NSS(5), TIMER0_BRKIN, I2C1_SMBA(5), EVENTOUT
PB13	26	I/O	5VT	Default: PB13 Alternate: SPI0_SCK(3), SPI1_SCK(5), TIMER0_CH0_ON, I2C1_TXFRAME(5), I2C1_SCL(5)
PB14	27	I/O	5VT	Default: PB14 Alternate: SPI0_MISO(3), SPI1_MISO(5), TIMER0_CH1_ON, TIMER14_CH0(5), I2C1_SDA(5)
PB15	28	I/O	5VT	Default: PB15 Alternate: SPI0_MOSI(3), SPI1_MOSI(5), TIMER0_CH2_ON, TIMER14_CH0_ON(5), TIMER14_CH1(5) Additional: RTC_REFIN, WKUP6
PA8	29	I/O	5VT	Default: PA8 Alternate: USART0_CK, TIMER0_CH0, CK_OUT, USART1_TX(4), EVENTOUT

Pin Name	Pins	Pin Type(1)	I/O Level(2)	Functions description
PA9	30	I/O	5VT	Default: PA9 Alternate: USART0_TX, TIMER0_CH1, TIMER14_BRKIN(5), I2C0_SCL, CK_OUT
PA10	31	I/O	5VT	Default: PA10 Alternate: USART0_RX, TIMER0_CH2, TIMER16_BRKIN, I2C0_SDA
PA11	32	I/O	5VT	Default: PA11 Alternate: USART0_CTS, TIMER0_CH3, CMP_OUT, EVENTOUT, SPI1_IO2(5), I2C0_SMBA, I2C1_SCL(5)
PA12	33	I/O	5VT	Default: PA12 Alternate: USART0_RTS, TIMER0_ETI, EVENTOUT, SPI1_IO3(5), I2C0_TXFRAME, I2C1_SDA(5)
PA13/INNA	34	I/O	5VT	Default: PA13 Alternate: SWDIO, IFRP_OUT, SPI1_MISO(5) Additional: V_{IN-A}
PF6	35	I/O	5VT	Default: PF6 Alternate: I2C0_SCL(3), I2C1_SCL(5)
PF7	36	I/O	5VT	Default: PF7 Alternate: I2C0_SDA(3), I2C1_SDA(5)
PA14/INPA	37	I/O	5VT	Default: PA14 Alternate: USART0_TX(3), USART1_TX(4), SWCLK, SPI1_MOSI(5) Additional: V_{IN+A}
PA15	38	I/O	5VT	Default: PA15 Alternate: SPI0_NSS, I2S0_WS, USART0_RX(3), USART1_RX(4), SPI1_NSS(5), EVENTOUT
PB3	39	I/O	5VT	Default: PB3 Alternate: SPI0_SCK, I2S0_CK, EVENTOUT
PB4	40	I/O	5VT	Default: PB4 Alternate: SPI0_MISO, I2S0_MCK, TIMER2_CH0, EVENTOUT, I2C0_TXFRAME, TIMER16_BRKIN
PB5	41	I/O	5VT	Default: PB5 Alternate: SPI0_MOSI,I2S0_SD, I2C0_SMBA, TIMER15_BRKIN, TIMER2_CH1 Additional: WKUP5
PB6	42	I/O	5VT	Default: PB6 Alternate: I2C0_SCL, USART0_TX, TIMER15_CH0_ON
PB7	43	I/O	5VT	Default: PB7 Alternate:I2C0_SDA, USART0_RX,TIMER16_CH0_ON
BOOT0	44	I		Default: BOOT0
PB8	45	I/O	5VT	Default: PB8 Alternate: I2C0_SCL, TIMER15_CH0
ENAB	46	I		Default: ENAB
V_{SS}	47	P		Default: V_{SS}
V_{DD}	48	P		Default: V_{DD}

Notes:

(1) Type: I = input, O = output, P = power.

(2) I/O Level: 5VT = 5 V tolerant.

(3) Functions are available on GD32E231C4T6 devices only.

(4) Functions are available on GD32E231C8/6T6 devices.

(5) Functions are available on GD32E231C8T6 devices only.

2.6.2 GD32E231CxT6 pin alternate functions

Table 2-4. Port A alternate functions summary

Pin Name	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PA0		USART0_CTS(1) /USART1_CTS(2)			I2C1_SCL(3)			CMP_OUT
PA1	EVENTOUT	USART0_RTS(1) /USART1_RTS(2)			I2C1_SDA(3)	TIMER14_CH0_ON(3)		
PA2	TIMER14_CH0(3)	USART0_TX(1)/ USART1_TX(2)						
PA3	TIMER14_CH1(3)	USART0_RX(1)/ USART1_RX(2)						
PA4	SPI0_NSS/I2S0_WS	USART0_CK(1)/ USART1_CK(2)			TIMER13_CH0		SPI1_NSS(3)	
PA5	SPI0_SCK/I2S0_CK							
PA6	SPI0_MISO/ I2S0_MCK	TIMER2_CH0	TIMER0_BRKIN			TIMER15_CH0	EVENTOUT	CMP_OUT
PA7	SPI0_MOSI/ I2S0_SD	TIMER2_CH1	TIMER0_CH0_ON		TIMER13_CH0	TIMER16_CH0	EVENTOUT	
PA8	CK_OUT	USART0_CK	TIMER0_CH0	EVENTOUT	USART1_TX(2)			
PA9	TIMER14_BRKIN(3)	USART0_TX	TIMER0_CH1		I2C0_SCL			
PA10	TIMER16_BRKIN	USART0_RX	TIMER0_CH2		I2C0_SDA			
PA11	EVENTOUT	USART0_CTS	TIMER0_CH3		I2C0_SMBA	I2C1_SCL(3)	SPI1_IO2(3)	CMP_OUT
PA12	EVENTOUT	USART0_RTS	TIMER0_ETI		I2C0_TXFRAME	I2C1_SDA(3)	SPI1_IO3(3)	
PA13	SWDIO	IFRP_OUT					SPI1_MISO(3)	
PA14	SWCLK	USART0_TX(1)/					SPI1_M	

Pin Name	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
		USART1_TX(2)					OSI(3)	
PA15	SPI0_NSS/I2S0_WS	USART0_RX(1)/ USART1_RX(2)		EVENTOUT			SPI1_NSS(3)	

Table 2-5. Port B alternate functions summary

Pin Name	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PB0	EVENTOUT	TIMER2_CH2	TIMER0_CH1_ON		USART1_RX(2)			
PB1	TIMER13_CH0	TIMER2_CH3	TIMER0_CH2_ON				SPI1_SCK(3)	
PB2			TIMER2_ETI					
PB3	SPI0_SCK/I2S0_CK	EVENTOUT						
PB4	SPI0_MISO /I2S0_MCK	TIMER2_CH0	EVENTOUT		I2C0_TXFRAME		TIMER16_BRKIN	
PB5	SPI0_MOSI /I2S0_SD	TIMER2_CH1	TIMER15_BRKIN	I2C0_SMBA				
PB6	USART0_TX	I2C0_SCL	TIMER15_CH0_ON					
PB7	USART0_RX	I2C0_SDA	TIMER16_CH0_ON					
PB8		I2C0_SCL	TIMER15_CH0					
PB10		I2C0_SCL(1)/I2C1_SCL(3)					SPI1_IO2(3)	SPI1_SCK(3)
PB11	EVENTOUT	I2C0_SDA(1)/I2C1_SDA(3)					SPI1_IO3(3)	
PB12	SPI0_NSS(1) /SPI1_NSS(3)	EVENTOUT	TIMER0_BRKIN		I2C1_SMBA(3)			
PB13	SPI0_SCK(1) /SPI1_SCK(3)	I2C1_TXFRAME(3)	TIMER0_CH0_ON			I2C1_SCL(3)		
PB14	SPI0_MISO(1) /SPI1_MISO(3)	TIMER14_CH0(3)	TIMER0_CH1_ON			I2C1_SDA(3)		
PB15	SPI0_MOSI(1) /SPI1_MOSI(3)	TIMER14_CH1(3)	TIMER0_CH2_ON	TIMER14_CH0_ON(3)				

Table 2-6. Port F alternate functions summary

Pin Name	AF0	AF1	AF2	AF3	AF4	AF5	AF6	AF7
PF0		I2C0_SDA						
PF1		I2C0_SCL						
PF6	I2C0_SCL(1) /I2C1_SCL(3)							
PF7	I2C0_SDA(1) /I2C1_SDA(3)							

Notes:

(1) Functions are available on GD32E231C4T6 devices only.

(2) Functions are available on GD32E231C8/6T6 devices.

(3) Functions are available on GD32E231C8T6 devices only.

3 Functional description

3.1 ARM® Cortex®-M23 core

The Cortex-M23 processor is an energy-efficient processor with a very low gate count. It is intended to be used for microcontroller and deeply embedded applications that require an area-optimized processor. The processor is highly configurable enabling a wide range of implementations from those requiring memory protection and powerful trace technology to cost sensitive devices requiring minimal area, while delivering outstanding computational performance and an advanced system response to interrupts.

32-bit ARM® Cortex®-M23 processor core

- Up to 72 MHz operation frequency
- Single-cycle multiplication and hardware divider
- Ultra-low power, energy-efficient operation
- Excellent code density
- Integrated Nested Vectored Interrupt Controller (NVIC)
- 24-bit SysTick timer

The Cortex®-M23 processor is based on the ARMv8-M architecture and supports both Thumb and Thumb-2 instruction sets. Some system peripherals listed below are also provided by Cortex®-M23:

- Internal Bus Matrix connected with AHB master, Serial Wire Debug Port and Single-cycle IO port
- Nested Vectored Interrupt Controller (NVIC)
- Breakpoint Unit(BPU)
- Data Watchpoint and Trace (DWT)
- Serial Wire JTAG Debug Port (SWJ-DP)

3.2 Embedded memory

- Up to 64 Kbytes of Flash memory
- Up to 8 Kbytes of SRAM with hardware parity checking

64 Kbytes of inner Flash and 8 Kbytes of inner SRAM at most is available for storing programs and data, both accessed (R/W) at CPU clock speed with 0~2 wait states. ***Table 2-2. GD32E231CxT6 memory map*** shows the memory map of the GD32E231CxT6 series of devices, including code, SRAM, peripheral, and other pre-defined regions.

3.3 Clock, reset and supply management

- Internal 8 MHz factory-trimmed RC and external 4 to 32 MHz crystal oscillator

- Internal 28 MHz RC oscillator
- Internal 40 KHz RC calibrated oscillator and external 32.768 KHz crystal oscillator
- Integrated system clock PLL
- 1.8 to 3.6 V application supply and I/Os
- Supply Supervisor: POR (Power On Reset), PDR (Power Down Reset), and low voltage detector (LVD)

The Clock Control Unit (CCU) provides a range of oscillator and clock functions. These include speed internal RC oscillator and external crystal oscillator, high speed and low speed two types. Several prescalers allow the frequency configuration of the AHB and two APB domains. The maximum frequency of the AHB, APB2 and APB1 domains is 72 MHz/72 MHz/72 MHz. See ***Figure 2-3. GD32E231CxT6 clock tree*** for details on the clock tree.

The Reset Control Unit (RCU) controls three kinds of reset: system reset resets the processor core and peripheral IP components. Power-on reset (POR) and power-down reset (PDR) are always active, and ensures proper operation starting from 2.6 V and down to 1.8V. The device remains in reset mode when V_{DD} is below a specified threshold. The embedded low voltage detector (LVD) monitors the power supply, compares it to the voltage threshold and generates an interrupt as a warning message for leading the MCU into security.

Power supply schemes:

- V_{DD} range: 1.8 to 3.6 V, external power supply for I/Os and the internal regulator. Provided externally through V_{DD} pins.
- V_{SSA}, V_{DDA} range: 1.8 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.
- V_{BAK} range: 1.8 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.

3.4 Boot modes

At startup, boot pins are used to select one of three boot options:

- Boot from main Flash memory (default)
- Boot from system memory
- Boot from on-chip SRAM

In default condition, boot from main Flash memory is selected. The boot loader is located in the internal boot ROM memory (system memory). It is used to reprogram the Flash memory by using USART0 (PA9 and PA10) or USART1 (PA14 and PA15).

3.5 Power saving modes

The MCU supports three kinds of power saving modes to achieve even lower power consumption. They are sleep mode, deep-sleep mode, and standby mode. These operating modes reduce the power consumption and allow the application to achieve the best balance

between the CPU operating time, speed and power consumption.

- **Sleep** mode
  In sleep mode, only the clock of CPU core is off. All peripherals continue to operate and any interrupt/event can wake up the system.
- **Deep-sleep** mode
  In deep-sleep mode, all clocks in the 1.2V domain are off, and all of the high speed crystal oscillator (IRC8M, HXTAL) and PLL are disabled. Only the contents of SRAM and registers are retained. Any interrupt or wakeup event from EXTI lines can wake up the system from the deep-sleep mode including the 16 external lines, the RTC alarm, RTC tamper and timestamp, CMP output, LVD output and USART wakeup. When exiting the deep-sleep mode, the IRC8M is selected as the system clock.
- **Standby** mode
  In standby mode, the whole 1.2V domain is power off, the LDO is shut down, and all of IRC8M, HXTAL and PLL are disabled. The contents of SRAM and registers (except backup registers) are lost. There are four wakeup sources for the standby mode, including the external reset from NRST pin, the RTC alarm, the FWDGT reset, and the rising edge on WKUP pin.

3.6 Analog to digital converter (ADC)

- 12-bit SAR ADC's conversion rate is up to 2 MSPS
- 12-bit, 10-bit, 8-bit or 6-bit configurable resolution
- Hardware oversampling ratio adjustable from 2 to 256x improves resolution to 16-bit
- Input voltage range: V_{SSA} to V_{DDA}
- Temperature sensor

One 12-bit 2 MSPS multi-channel ADC is integrated in the device. It has a total of 12 multiplexed channels: up to 10 external channels, 1 channel for internal temperature sensor (V_{SENSE}) and 1 channel for internal reference voltage (V_{REFINT}). The input voltage range is between V_{SSA} and V_{DDA}. An on-chip hardware oversampling scheme improves performance while off-loading the related computational burden from the CPU. An analog watchdog block can be used to detect the channels, which are required to remain within a specific threshold window. A configurable channel management block can be used to perform conversions in single, continuous, scan or discontinuous mode to support more advanced use.

The ADC can be triggered from the events generated by the general level 0 timers (TIMERx) and the advanced timer (TIMER0) with internal connection. The temperature sensor can be used to generate a voltage that varies linearly with temperature. It is internally connected to the ADC_IN16 input channel which is used to convert the sensor output voltage in a digital value.

3.7 DMA

- 5 channels DMA controller
- Peripherals supported: Timers, ADC, SPIs, I2Cs, USARTs and I2S

The flexible general-purpose DMA controllers provide a hardware method of transferring data between peripherals and/or memory without intervention from the CPU, thereby freeing up bandwidth for other system functions. Three types of access method are supported: peripheral to memory, memory to peripheral, memory to memory.

Each channel is connected to fixed hardware DMA requests. The priorities of DMA channel requests are determined by software configuration and hardware channel number. Transfer size of source and destination are independent and configurable.

3.8 General-purpose inputs/outputs (GPIOs)

- Up to 37 fast GPIOs, all mappable on 16 external interrupt lines
- Analog input/output configurable
- Alternate function input/output configurable

There are up to 37 general purpose I/O pins (GPIO) in GD32E231CxT6, named PA0 ~ PA15 and PB0 ~ PB8, PB10 ~ PB15, PC14 ~ PC15, PF0 ~ PF1, PF6 ~ PF7 to implement logic input/output functions. Each of the GPIO ports has related control and configuration registers to satisfy the requirements of specific applications. The external interrupts on the GPIO pins of the device have related control and configuration registers in the Interrupt/event controller (EXTI). The GPIO ports are pin-shared with other alternative functions (AFs) to obtain maximum flexibility on the package pins. Each of the GPIO pins can be configured by software as output (push-pull open-drain or analog), 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. All GPIOs are high-current capable except for analog inputs.

3.9 Timers and PWM generation

- One 16-bit advanced timer (TIMER0), up to five 16-bit general timers (TIMER2, TIMER13 ~ TIMER16), and one 16-bit basic timer (TIMER5)
- Up to 4 independent channels of PWM, output compare or input capture for each general timer and external trigger input
- 16-bit, motor control PWM advanced timer with programmable dead-time generation for output match
- Encoder interface controller with two inputs using quadrature decoder
- 24-bit SysTick timer down counter
- 2 watchdog timers (free watchdog timer and window watchdog timer)

The advanced timer (TIMER0) can be used as a three-phase PWM multiplexed on 6 channels.

It has complementary PWM outputs with programmable dead-time generation. It can also be used as a complete general timer. The 4 independent channels can be used for input capture, output compare, PWM generation (edge- or center- aligned counting modes) and single pulse mode output. If configured as a general 16-bit timer, it has the same functions as the TIMERx timer. It can be synchronized with external signals or to interconnect with other general timers together which have the same architecture and features.

The general timer can be used for a variety of purposes including general time, input signal pulse width measurement or output waveform generation such as a single pulse generation or PWM output, up to 4 independent channels for input capture/output compare. TIMER2 is based on a 16-bit auto-reload up/down counter and a 16-bit prescaler. TIMER13 ~ TIMER16 is based on a 16-bit auto-reload up counter and a 16-bit prescaler. The general timer also supports an encoder interface with two inputs using quadrature decoder.

The basic timer, known as TIMER5 can also be used as a simple 16-bit time base.

The GD32E231CxT6 have two watchdog peripherals, free watchdog and window watchdog. They offer a combination of high safety level, flexibility of use and timing accuracy.

The free watchdog timer includes a 12-bit down-counting counter and an 8-bit prescaler. It is clocked from an independent 40 KHz internal RC and as it operates independently of the main clock, it can operate in deep-sleep and standby modes. It can be used either as a watchdog to reset the device when a problem occurs, or as a free-running timer for application timeout management.

The window watchdog is based on a 7-bit down counter that can be set as free-running. It can be used as a watchdog to reset the device when a problem occurs. It is clocked from the main clock. It has an early wakeup interrupt capability and the counter can be frozen in debug mode.

The SysTick timer is dedicated for OS, but could also be used as a standard down counter. The features are shown below:

- A 24-bit down counter
- Auto reload capability
- Maskable system interrupt generation when the counter reaches 0
- Programmable clock source

3.10 Real time clock (RTC)

- Independent binary-coded decimal (BCD) format timer/counter with five 32-bit backup registers.
- Calendar with subsecond, second, minute, hour, week day, date, year and month automatically correction
- Alarm function with wake up from deep-sleep and standby mode capability
- On-the-fly correction for synchronization with master clock. Digital calibration with 0.954 ppm resolution for compensation of quartz crystal inaccuracy.

The real time clock is an independent timer which provides a set of continuously running counters in backup registers to provide a real calendar function, and provides an alarm interrupt or an expected interrupt. It is not reset by a system or power reset, or when the device wakes up from standby mode. In the RTC unit, there are two prescalers used for implementing the calendar and other functions. One prescaler is a 7-bit asynchronous prescaler and the other is a 15-bit synchronous prescaler.

3.11 Inter-integrated circuit (I2C)

- Up to two I2C bus interfaces can support both master and slave mode with a frequency up to 1 MHz (Fast mode plus)
- Provide arbitration function, optional PEC (packet error checking) generation and checking
- Supports 7-bit and 10-bit addressing mode and general call addressing mode
- Supports SAM_V mode

The I2C interface is an internal circuit allowing communication with an external I2C interface which is an industry standard two line serial interface used for connection to external hardware. These two serial lines are known as a serial data line (SDA) and a serial clock line (SCL). The I2C module provides different data transfer rates: up to 100 KHz in standard mode, up to 400 KHz in the fast mode and up to 1 MHz in the fast mode plus. The I2C module also has an arbitration detect function to prevent the situation where more than one master attempts to transmit data to the I2C bus at the same time. A CRC-8 calculator is also provided in I2C interface to perform packet error checking for I2C data.

3.12 Serial peripheral interface (SPI)

- Up to two SPI interfaces with a frequency of up to 18 MHz
- Support both master and slave mode
- Hardware CRC calculation and transmit automatic CRC error checking
- Separate transmit and receive 32-bit FIFO with DMA capability (only in SPI1)
- Data frame size can be 4 to 16 bits (only in SPI1)
- Quad-SPI configuration available in master mode (only in SPI1)

The SPI interface uses 4 pins, among which are the serial data input and output lines (MISO & MOSI), the clock line (SCK) and the slave select line (NSS). Both SPIs can be served by the DMA controller. The SPI interface may be used for a variety of purposes, including simplex synchronous transfers on two lines with a possible bidirectional data line or reliable communication using CRC checking. Specially, SPI1 has separate transmit and receive 32-bit FIFO with DMA capability and its data frame size can be 4 to 16 bits. Quad-SPI master mode is also supported in SPI1.

3.13 Universal synchronous asynchronous receiver transmitter (USART)

- Up to two USARTs with operating frequency up to 4.5 MBits/s
- Supports both asynchronous and clocked synchronous serial communication modes
- IrDA SIR encoder and decoder support
- LIN break generation and detection
- ISO 7816-3 compliant smart card interface

The USART (USART0, USART1) are used to translate data between parallel and serial interfaces, provides a flexible full duplex data exchange using synchronous or asynchronous transfer. It is also commonly used for RS-232 standard communication. The USART includes a programmable baud rate generator which is capable of dividing the system clock to produce a dedicated clock for the USART transmitter and receiver. The USART also supports DMA function for high speed data communication.

3.14 Inter-IC sound (I2S)

- One I2S bus Interfaces with sampling frequency from 8 KHz to 192 KHz, multiplexed with SPI0
- Support either master or slave mode

The Inter-IC sound (I2S) bus provides a standard communication interface for digital audio applications by 3-wire serial lines. GD32E231CxT6 contain an I2S-bus interface that can be operated with 16/32 bit resolution in master or slave mode, pin multiplexed with SPI0. The audio sampling frequency from 8 KHz to 192 KHz is supported with less than 0.5% accuracy error.

3.15 Comparators (CMP)

- One fast rail-to-rail low-power comparators with software configurable
- Programmable reference voltage (internal or external I/O)

One Comparator (CMP) is implemented within the devices. It can wake up from deep-sleep mode to generate interrupts and breaks for the timers and also can be combined as a window comparator. The internal voltage reference is also connected to ADC_IN17 input channel of the ADC.

3.16 Operational amplifier (OP-AMP)

- Two 6MHz, rail-to-rail I/O CMOS operational amplifiers

- Low offset voltage: 1mV (typ)
- High gain: 95dB (typ)
- Low I_B: 5pA (typ)
- Low supply voltage: + 2.7 V to + 3.6V

Two operational amplifiers (OP-AMP) are low noise, low voltage and low power operational amplifiers with high gain-bandwidth product of 6MHz and slew rate of 5V/μs. The maximum input offset voltage is only 3.5mV and the input common mode range extends beyond the supply rails.

3.17 Debug mode

- 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.

3.18 Package and operation temperature

- LQFP48 (GD32E231CxT6).
- Operation temperature range: -40°C to +85°C (industrial level)

4 Electrical characteristics

4.1 Absolute maximum ratings

The maximum ratings are the limits to which the device can be subjected without permanently damaging the device. Note that the device is not guaranteed to operate properly at the maximum ratings. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

Table 4-1. Absolute maximum ratings(1) (4)

Symbol	Parameter	Min	Max	Unit
V_{DD}	External voltage range(2)	V_{SS} - 0.3	V_{SS} + 3.6	V
V_{DDA}	External analog supply voltage	V_{SSA} - 0.3	V_{SSA} + 3.6	V
V_{IN}	Input voltage on 5V tolerant pin(3)	V_{SS} - 0.3	V_{DD} + 3.6	V
	Input voltage on other I/O	V_{SS} - 0.3	3.6	V
$\|\Delta V_{DDx}\|$	Variations between different V_{DD} power pins	—	50	mV
$\|V_{SSX} - V_{SS}\|$	Variations between different ground pins	—	50	mV
I_{IO}	Maximum current for GPIO pin	—	±25	mA
T_A	Operating temperature range	-40	+85	°C
T_{STG}	Storage temperature range	-55	+150	°C
T_J	Maximum junction temperature	—	125	°C

(1). Guaranteed by design, not tested in production.

(2). All main power and ground pins should be connected to an external power source within the allowable range.

(3). V_{IN} maximum value cannot exceed 6.5 V.

(4). It is recommended that V_{DD} and V_{DDA} are powered by the same source. The maximum difference between V_{DD} and V_{DDA} does not exceed 300 mV during power-up and operation.

4.2 Operating conditions characteristics

Table 4-2. DC operating conditions

Symbol	Parameter	Conditions	Min(1)	Typ	Max(1)	Unit
V_{DD}	Supply voltage	—	1.8	3.3	3.6	V
V_{DDA}	Analog supply voltage ADC not used	—	1.8	3.3	3.6	V
	Analog supply voltage ADC used		2.4	3.3	3.6	

(1). Based on characterization, not tested in production.

Table 4-3. Clock frequency

Symbol	Parameter	Conditions	Min	Max	Unit
f_{HCLK1}	AHB1 clock frequency	—	0	72	MHz
f_{HCLK2}	AHB2 clock frequency	—	0	72	MHz
f_{APB1}	APB1 clock frequency	—	0	72	MHz
f_{APB2}	APB2 clock frequency	—	0	72	MHz

Table 4-4. Operating conditions at Power up/ Power down

Symbol	Parameter	Conditions	Min	Max	Unit
t_{VDD}(1)	V_{DD} rise time rate	—	0	∞	μs/V
	V_{DD} fall time rate		20	∞	

(1). Based on characterization, not tested in production.

Table 4-5. Start-up timings of Operating conditions

Symbol	Parameter	Conditions	Typ	Unit
$t_{start-up}$(1)(2)(3)	Start-up time	Clock source from HXTAL	432	μs
		Clock source from IRC8M	76	

(1). Based on characterization, not tested in production.

(2). After power-up, the start-up time is the time between the rising edge of NRST high and the main function.

(3). PLL is off.

Table 4-6. Power saving mode wakeup timings characteristics(1) (2)

Symbol	Parameter	Typ	Unit
t_{Sleep}(1)	Wakeup from Sleep mode	3.5	μs
$t_{Deep-sleep}$(1)	Wakeup from Deep-sleep mode（LDO On）	17.1	
	Wakeup from Deep-sleep mode（LDO in low power mode）	17.1	
$t_{Standby}$(1)	Wakeup from Standby mode	77.5	

(1). Based on characterization, not tested in production.

(2). The wakeup time is measured from the wakeup event to the point at which the application code reads the first instruction under the below conditions: V_{DD} = V_{DDA} = 3.3 V, IRC8M = System clock = 8 MHz.

4.3 Power consumption

The power measurements specified in the tables represent that code with data executing from embedded Flash with the following specifications.

Table 4-7. Power consumption characteristics(1) (2) (3) (4) (5) (6)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{DD}	Supply current (Run mode)	V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 72 MHz, All peripherals enabled	—	8.5	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 72 MHz, All peripherals disabled	—	5.4	—	mA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 48 MHz, All peripherals enabled	-—	6.2	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 48 MHz, All peripherals disabled	—	4.2	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 36 MHz, All peripherals enabled	—	5.1	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 36 MHz, All peripherals disabled	-—	3.6	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 24 MHz, All peripherals enabled	—	4.0	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 24 MHz, All peripherals disabled	—	2.9	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 16 MHz, All peripherals enabled	-—	3.2	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 16 MHz, All peripherals disabled	—	2.5	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 8 MHz, All peripherals enabled	—	2.4	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 8 MHz, All peripherals disabled	-—	2.1	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 4 MHz, All peripherals enabled	—	0.8	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 4 MHz, All peripherals disabled	—	0.6	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 2 MHz, All peripherals enabled	-—	0.6	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, System clock = 2 MHz, All peripherals disabled	—	0.5	—	mA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	Supply current (Sleep mode)	V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 72 MHz, All peripherals enabled	—	7.4	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 72 MHz, All peripherals disabled	—	3.7	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 48 MHz, All peripherals enabled	-—	5.5	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 48 MHz, All peripherals disabled	—	3.1	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 36 MHz, All peripherals enabled	—	4.5	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 36 MHz, All peripherals disabled	-—	2.7	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock= 24 MHz, All peripherals enabled	—	3.6	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 24 MHz, All peripherals disabled	—	2.4	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 16 MHz, All peripherals enabled	-—	3.0	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 16 MHz, All peripherals disabled	—	2.1	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 8 MHz, All peripherals enabled	—	2.3	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 8 MHz, All peripherals disabled	-—	1.9	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 4 MHz, All peripherals enabled	—	0.7	—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 4 MHz, All peripherals disabled	—	0.5	—	mA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 2 MHz, All peripherals enabled	-—	0.5	-—	mA
		V_{DD} = V_{DDA} = 3.3 V, HXTAL = 8 MHz, CPU clock off, System clock = 2 MHz, All peripherals disabled	—	0.4	—	mA
	Supply current (Deep-sleep mode)	V_{DD} = V_{DDA} = 3.3 V, LDO in run mode, IRC40K off, RTC off, All GPIOs analog mode	—	25.5	100	μA
		V_{DD} = V_{DDA} = 3.3 V, LDO in low power mode, IRC40K off, RTC off, All GPIOs analog mode	—	12.3	60	μA
	Supply current (Standby mode)	V_{DD} = V_{DDA} = 3.3 V, LXTAL off, IRC40K on, RTC on	—	4.3	10	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL off, IRC40K on, RTC off	—	4.1	10	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL off, IRC40K off, RTC off, V_{DDA} Monitor on	—	3.6	10	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL off, IRC40K off, RTC off, V_{DDA} Monitor off	—	2.1	5	μA
$I_{LXTAL+RTC}$	LXTAL+RTC current	V_{DD} = V_{DDA} = 3.6 V, LXTAL on with external crystal, RTC on, Higher driving	—	1.43	—	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL on with external crystal, RTC on, Higher driving	—	1.36	—	μA
		V_{DD} = V_{DDA} = 2.5 V, LXTAL on with external crystal, RTC on, Higher driving	—	1.23	—	μA
		V_{DD} = V_{DDA} = 1.8 V, LXTAL on with external crystal, RTC on, Higher driving	—	1.15	—	μA
		V_{DD} = V_{DDA} = 3.6 V, LXTAL on with external crystal, RTC on, Medium High driving	—	1.13	—	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL on with external crystal, RTC on, Medium High driving	—	1.06	—	μA
		V_{DD} = V_{DDA} = 2.5 V, LXTAL on with external crystal, RTC on, Medium High driving	—	0.95	—	μA
		V_{DD} = V_{DDA} = 1.8 V, LXTAL on with external crystal, RTC on, Medium High driving	—	0.86	—	μA
		V_{DD} = V_{DDA} = 3.6 V, LXTAL on with external crystal, RTC on, Medium Low driving	—	0.84	—	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL on with external crystal, RTC on, Medium Low driving	—	0.76	—	μA
		V_{DD} = V_{DDA} = 2.5 V, LXTAL on with external crystal, RTC on, Medium Low driving	—	0.64	—	μA
		V_{DD} = V_{DDA} = 1.8 V, LXTAL on with external crystal, RTC on, Medium Low driving	—	0.56	—	μA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_{DD} = V_{DDA} = 3.6 V, LXTAL on with external crystal, RTC on, Low driving	—	0.74	—	μA
		V_{DD} = V_{DDA} = 3.3 V, LXTAL on with external crystal, RTC on, Low driving	—	0.67	—	μA
		V_{DD} = V_{DDA} = 2.5 V, LXTAL on with external crystal, RTC on, Low driving	—	0.56	—	μA
		V_{DD} = V_{DDA} = 1.8 V, LXTAL on with external crystal, RTC on, Low driving	—	0.47	—	μA

(1). Based on characterization, not tested in production.

(2). Unless otherwise specified, all values given for T_A = 25 ℃ and test result is mean value.

(3). When System Clock is less than 4 MHz, an external source is used, and the HXTAL bypass function is needed, no PLL.

(4). When System Clock is greater than 8 MHz, a crystal 8MHz is used, and the HXTAL bypass function is closed, using PLL.

(5). When analog peripheral blocks such as ADCs, HXTAL, LXTAL, IRC8M, or IRC40K are ON, an additional power consumption should be considered.

(6). The power measurements specified in the tables represent that code with data executing from on-chip Flash with the following specifications.

Table 4-8. Peripheral current consumption characteristics(1)

Peripherials(3)		Typical consumption at 25℃ （TYP）	Unit
APB1	PMU	1.44	mA
	I2C1	1.38	
	I2C0	1.38	
	USART1	1.34	
	SPI1	1.37	
	WWDGT	1.32	
	TIMER13	1.36	
	TIMER5	0.17	
	TIMER2	0.23	
APB2	DBGMCU	1.3	
	TIMER16	1.42	
	TIMER15	1.42	
	TIMER14	1.49	
	USART0	1.63	
	SPI0	1.38	
	TIMER0	1.68	
	ADC(2)	0.95	
	CFG & CMP	1.27	
AHB	GPIOF	1.31	
	GPIOC	1.31	
	GPIOB	1.34	
	GPIOA	1.34	
	CRC	0.16	

Peripherials[3]		Typical consumption at 25℃ (TYP)	Unit
	DMA	0.15	

(1). Based on characterization, not tested in production.

(2). system clock = f_{HCLK} = 72 MHz, $f_{APB1} = f_{HCLK}/2$, $f_{APB2} = f_{HCLK}$, $f_{ADCCLK} = f_{APB2}/2$, ADON bit is set to 1.

(3). If there is no other description, HXTAL = 8 MHz, system clock = f_{HCLK} = 72 MHz, $f_{APB1} = f_{HCLK}/2$, $f_{APB2} = f_{HCLK}$.

4.4 EMC characteristics

EMS (electromagnetic susceptibility) includes ESD (Electrostatic discharge, positive and negative) and FTB (Burst of Fast Transient voltage, positive and negative) testing result is given in ***Table 4-9. EMS characteristics***, based on the EMS levels and classes compliant with IEC 61000 series standard.

Table 4-9. EMS characteristics

Symbol	Parameter	Conditions	Level/Class
V_{ESD}	Voltage applied to all device pins to induce a functional disturbance	V_{DD} = 3.3 V, T_A = +25 °C, LQFP48, f_{HCLK} = 72 MHz conforms to IEC 61000-4-2	3A
V_{FTB}	Fast transient voltage burst applied to induce a functional disturbance through 100 pF on V_{DD} and V_{SS} pins	V_{DD} = 3.3 V, T_A = +25 °C, LQFP48, f_{HCLK} = 72 MHz conforms to IEC 61000-4-4	4A

4.5 Power supply supervisor characteristics

Table 4-10. Power supply supervisor characteristics[1]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{LVD}	Low Voltage Detector Threshold	LVDT[2:0] = 000, rising edge	—	2.11	—	V
		LVDT[2:0] = 000, falling edge	—	2.01	—	V
		LVDT[2:0] = 001, rising edge	—	2.25	—	V
		LVDT[2:0] = 001, falling edge	—	2.16	—	V
		LVDT[2:0] = 010, rising edge	—	2.39	—	V
		LVDT[2:0] = 010, falling edge	—	2.29	—	V
		LVDT[2:0] = 011, rising edge	—	2.52	—	V
		LVDT[2:0] = 011, falling edge	—	2.43	—	V
		LVDT[2:0] = 100, rising edge	—	2.66	—	V
		LVDT[2:0] = 100, falling edge	—	2.57	—	V
		LVDT[2:0] = 101, rising edge	—	2.80	—	V
		LVDT[2:0] = 101, falling edge	—	2.71	—	V
		LVDT[2:0] = 110, rising edge	—	2.95	—	V
		LVDT[2:0] = 110, falling edge	—	2.84	—	V
		LVDT[2:0] = 111, rising edge	—	3.08	—	V
		LVDT[2:0] = 111, falling edge	—	2.98	—	V
$V_{LVDhyst}$	LVD hysteresis	—	—	100	—	mV
V_{POR}	Power on reset threshold	Rising edge	—	1.71	—	V
V_{PDR}	Power down reset threshold	Falling edge	—	1.67	—	V
$V_{PDRhyst}$	PDR hysteresis	—	—	40	—	mV
$t_{RSTTEMP}$	Reset temporization	—	—	2.5	—	ms

(1) Based on characterization, not tested in production.

4.6 Electrical sensitivity

The device is strained in order to determine its performance in terms of electrical sensitivity. Electrostatic discharges (ESD) are applied directly to the pins of the sample. Static latch-up (LU) test is based on the two measurement methods.

Table 4-11. ESD characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	T_A = 25 °C; JESD22-A114	—	—	6000	V
$V_{ESD(CDM)}$	Electrostatic discharge voltage (charge device model)	T_A = 25 °C; JESD22-C101	—	—	2000	V

(1). Based on characterization, not tested in production.

Table 4-12. Static latch-up characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
LU	I-test	T_A = 25 °C; JESD78	—	—	±200	mA
	V_{supply} over voltage		—	—	5.4	V

(1). Based on characterization, not tested in production.

4.7 External clock characteristics

Table 4-13. High speed external clock (HXTAL) generated from a crystal/ceramic characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HXTAL}	Crystal or ceramic frequency(1)	1.8 V ≤ V_{DD} ≤ 3.6 V	4	8	32	MHz
R_F	Feedback resistor	V_{DD} = 3.3 V	—	400	—	kΩ
C_{HXTAL}	Recommended matching capacitance on OSCIN and OSCOUT	—	—	20	30	pF
$Ducy_{(HXTAL)}$(2)	Crystal or ceramic duty cycle	—	30	50	70	%
$I_{DDHXTAL}$(1)	Crystal or ceramic operating current	V_{DD} = 3.3 V, T_A = 25 °C	—	1.2	—	mA
$t_{SUHXTAL}$(1)	Crystal or ceramic startup time	V_{DD} = 3.3 V, T_A = 25 °C	—	1.8	—	ms

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

(3). $C_{HXTAL1} = C_{HXTAL2} = 2*(C_{LOAD} - C_S)$, For C_{HXTAL1} and C_{HXTAL2}, it is recommended matching capacitance on OSCIN and OSCOUT. For C_{LOAD}, it is crystal/ceramic load capacitance, provided by the crystal or ceramic manufacturer. For C_S, it is PCB and MCU pin stray capacitance.

Table 4-14. High speed external user clock characteristics (HXTAL in bypass mode)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{HXTAL_ext}(1)	External clock source or oscillator frequency	1.8 V ≤ V_{DD} ≤ 3.6 V	1	8	50	MHz
V_{HXTALH}(2)	OSCIN input pin high level voltage	V_{DD} = 3.3 V	0.7V_{DD}	—	V_{DD}	V
V_{HXTALL}(2)	OSCIN input pin low level voltage		V_{SS}	—	0.3V_{DD}	
$t_{H/L(HXTAL)}$ (2)	OSCIN high or low time	—	5	—	—	ns
$t_{R/F(HXTAL)}$ (2)	OSCIN rise or fall time	—	—	—	10	
C_{IN}(1)	OSCIN input capacitance	—	—	5	—	pF
$Ducy_{(HXTAL)}$ (2)	Duty cycle	—	30	50	70	%

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

Table 4-15. Low speed external clock (LXTAL) generated from a crystal/ceramic characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LXTAL}(1)	Crystal or ceramic frequency	V_{DD} = 3.3 V	—	32.768	—	kHz
C_{LXTAL}(2) (3)	Recommended matching capacitance on OSC32IN and OSC32OUT	—	—	—	15	pF
$Ducy_{(LXTAL)}$(2)	Crystal or ceramic duty cycle	—	30	—	70	%
$I_{DDLXTAL}$ (1)	Crystal or ceramic operating current	LXTALDRI[1:0] = 00	—	0.5	—	μA
		LXTALDRI[1:0] = 01	—	0.6	—	
		LXTALDRI[1:0] = 10	—	1.0	—	
		LXTALDRI[1:0] = 11	—	1.2	—	
$t_{SULXTAL}$(1) (4)	Crystal or ceramic startup time	V_{DD} = 3.3 V	—	1.8	—	s

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

(3). $C_{LXTAL1} = C_{LXTAL2} = 2*(C_{LOAD} - C_S)$, For C_{LXTAL1} and C_{LXTAL2}, it is recommended matching capacitance on OSC32IN and OSC32OUT. For C_{LOAD}, it is crystal/ceramic load capacitance, provided by the crystal or ceramic manufacturer. For C_S, it is PCB and MCU pin stray capacitance.

Table 4-16. Low speed external user clock characteristics (LXTAL in bypass mode)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{LXTAL_ext}	External clock source or oscillator frequency	V_{DD} = 3.3 V	—	32.768	1000	kHz
V_{LXTALH}(1)	OSC32IN input pin high level voltage	V_{DD} = 3.3 V	0.7V_{DD}	—	V_{DD}	V
V_{LXTALL}(1)	OSC32IN input pin low level voltage		V_{SS}	—	0.3V_{DD}	
$t_{H/L(LXTAL)}$ (1)	OSC32IN high or low time	—	450	—	—	ns
$t_{R/F(LXTAL)}$ (1)	OSC32IN rise or fall time	—	—	—	50	
C_{IN}(1)	OSC32IN input capacitance	—	—	5	—	pF
$Ducy_{(LXTAL)}$ (1)	Duty cycle	—	30	50	70	%

(1). Guaranteed by design, not tested in production.

4.8 Internal clock characteristics

Table 4-17. High speed internal clock (IRC8M) characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{IRC8M}	High Speed Internal Oscillator (IRC8M) frequency	V_{DD} = V_{DDA} = 3.3 V	—	8	—	MHz
ACC_{IRC8M}	IRC8M oscillator Frequency accuracy, Factory-trimmed	V_{DD} = V_{DDA} = 3.3 V, T_A = -40 °C ~ +105 °C(1)	-4.0	—	+5.0	%

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_{DD} = V_{DDA} = 3.3 V, T_A = 0 °C ~ +85 °C(1)	-2.0	—	+2.0	%
		V_{DD} = V_{DDA} = 3.3 V, T_A = 25°C	-1.0	—	+1.0	%
	IRC8M oscillator Frequency accuracy, User trimming step(1)	—	—	0.5	—	%
$Ducy_{IRC8M}$(2) (3)	IRC8M oscillator duty cycle	V_{DD} = V_{DDA} = 3.3 V, f_{IRC8M} = 8 MHz	45	50	55	%
$I_{DDAIRC8M}$(1) (3)	IRC8M oscillator operating current	V_{DD} = V_{DDA} = 3.3 V, f_{IRC8M} = 8 MHz	—	52	—	μA
$t_{SUIRC8M}$(1) (3)	IRC8M oscillator startup time	V_{DD} = V_{DDA} = 3.3 V, f_{IRC8M} = 8 MHz	—	1.8	—	μs

(1). Based on characterization, not tested in production.
(2). Guaranteed by design, not tested in production.
(3). HXTAL = 8 MHz, system clock = f_{HCLK} = 72 MHz.

Table 4-18. Low speed internal clock (IRC40K) characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{IRC40K}(1)	Low Speed Internal oscillator (IRC40K) frequency	V_{DD} = V_{DDA} = 3.3 V, T_A = -40 °C ~ +85 °C	30	39.8	60	kHz
$I_{DDAIRC40K}$(2) (3)	IRC40K oscillator operating current	V_{DD} = V_{DDA} = 3.3 V, T_A = 25 °C	—	0.41	—	μA
$t_{SUIRC40K}$(2) (3)	IRC40K oscillator startup time	V_{DD} = V_{DDA} = 3.3 V, T_A = 25 °C	—	35	—	μs

(1). Guaranteed by design, not tested in production.
(2). Based on characterization, not tested in production.
(3). HXTAL = 8 MHz, system clock = f_{HCLK} = 72 MHz.

Table 4-19. High speed internal clock (IRC28M) characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{IRC28M}	High Speed Internal Oscillator (IRC28M) frequency	V_{DD} = V_{DDA} = 3.3 V	—	28	—	MHz
ACC_{IRC28M}	IRC28M oscillator Frequency accuracy, Factory-trimmed	V_{DD} = V_{DDA} = 3.3 V, T_A = -40 °C ~ +105 °C(2)	-4.0	—	+5.0	%
		V_{DD} = V_{DDA} = 3.3 V, T_A = 0 °C ~ +85 °C(2)	-3.0	—	+3.0	%
		V_{DD} = V_{DDA} = 3.3 V, T_A = 25 °C	-2.0	—	+2.0	%
	IRC28M oscillator Frequency accuracy, User trimming step(1)	—	—	0.5	—	%
D_{IRC28M}(2) (3)	IRC28M oscillator duty cycle	V_{DD} = V_{DDA} = 3.3 V, f_{IRC28M} = 28 MHz	45	50	55	%
$I_{DDAIRC28M}$(1) (3)	IRC28M oscillator operating	V_{DD} = V_{DDA} = 3.3 V,	—	121	—	μA

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	current	f_{IRC28M} = 28 MHz				
$t_{SUIRC28M}$(1)(3)	IRC28M oscillator startup time	V_{DD} = V_{DDA} = 3.3 V, f_{IRC28M} = 28 MHz	—	1.5	—	μs

(1). Based on characterization, not tested in production.
(2). Guaranteed by design, not tested in production.
(3). HXTAL = 8 MHz, system clock = f_{HCLK} = 72 MHz.

4.9 PLL characteristics

Table 4-18. PLL characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{PLLIN}	PLL input clock frequency	—	1	—	25	MHz
f_{PLLOUT}	PLL output clock frequency	—	16	—	72	MHz
t_{LOCK}	PLL lock time	—	—	—	300	μs
I_{DDA}(1)	Current consumption on V_{DDA}	VCO freq = 72 MHz		130		μA
$Jitter_{PLL}$(1)(3)	Cycle to cycle Jitter（rms）	System clock	—	69	—	ps
	Cycle to cycle Jitter（peak to peak）		—	704	—	ps

(1). Based on characterization, not tested in production.
(2). Guaranteed by design, not tested in production.
(3). Value given with main PLL running.

4.10 Memory characteristics

Table 4-19. Flash memory characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
PE_{CYC}(1)	Number of guaranteed program /erase cycles before failure(Endurance)	T_A = -40 °C ~ +85 °C	100	—	—	kcycles
t_{RET}(1)	Data retention time	10k cycles at T_A = 85 °C	10	—	—	years
t_{PROG}(2)	Word(3) programming time	T_A = -40 °C ~ +85 °C	37	—	44	μs
t_{ERASE}(2)	Page erase time	T_A = -40 °C ~ +85 °C	3.2	—	4	ms
t_{MERASE}(2)	Mass erase time	T_A = -40 °C ~ +85 °C	8	—	10	ms

(1). Based on characterization, not tested in production.
(2). Guaranteed by design, not tested in production.
(3). Word is 32bits or 64bits depend on PGW bit in FMC_WS register.

4.11 NRST pin characteristics

Table 4-20. NRST pin characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IL(NRST)}$ (1)	NRST Input low level voltage	V_{DD} = V_{DDA} = 1.8 V	-0.5	—	0.71	V
$V_{IH(NRST)}$ (1)	NRST Input high level voltage		1.08	—	V_{DD} + 0.5	
V_{hyst}	Schmidt trigger Voltage hysteresis		—	370	—	mV
$V_{IL(NRST)}$ (1)	NRST Input low level voltage	V_{DD} = V_{DDA} = 2.5 V	-0.5	—	1.05	V
$V_{IH(NRST)}$ (1)	NRST Input high level voltage		1.42	—	V_{DD} + 0.5	
V_{hyst}	Schmidt trigger Voltage hysteresis		—	370	—	mV
$V_{IL(NRST)}$ (1)	NRST Input low level voltage	V_{DD} = V_{DDA} = 3.3 V	-0.5	—	1.4	V
$V_{IH(NRST)}$ (1)	NRST Input high level voltage		1.8	—	V_{DD} + 0.5	
V_{hyst}	Schmidt trigger Voltage hysteresis		—	400	—	mV
$V_{IL(NRST)}$ (1)	NRST Input low level voltage	V_{DD} = V_{DDA} = 3.6 V	-0.5	—	1.53	V
$V_{IH(NRST)}$ (1)	NRST Input high level voltage		1.95	—	V_{DD} + 0.5	
V_{hyst}	Schmidt trigger Voltage hysteresis		—	420	—	mV
R_{pu}(2)	Pull-up equivalent resistor	—	—	40.3	—	kΩ

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

4.12 GPIO characteristics

Table 4-21. I/O port DC characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IL}	Standard IO Low level input voltage	V_{DD} = 1.8 V	V_{SS}	—	0.80	V
		V_{DD} = 2.5 V		—	1.10	
		V_{DD} = 3.3 V		—	1.40	
		V_{DD} = 3.6 V		—	1.60	
	5V-tolerant IO Low level input voltage	V_{DD} = 1.8 V	V_{SS}	—	0.80	V
		V_{DD} = 2.5 V		—	1.10	
		V_{DD} = 3.3 V		—	1.40	
		V_{DD} = 3.6 V		—	1.60	
V_{IH}	Standard IO High level input voltage	V_{DD} = 1.8 V	1.10	—	V_{DD}	V
		V_{DD} = 2.5 V	1.50	—		
		V_{DD} = 3.3 V	1.90	—		
		V_{DD} = 3.6 V	2.00	—		
	5V-tolerant IO High level input voltage	V_{DD} = 1.8 V	1.10	—	V_{DD}	V
		V_{DD} = 2.5 V	1.50	—		
		V_{DD} = 3.3 V	1.90	—		
		V_{DD} = 3.6 V	2.00	—		
V_{OL}	Low level output voltage for an IO Pin	V_{DD} = 1.8 V	—	—	0.20	V
		V_{DD} = 2.5 V	—	—	0.20	

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	(I_{IO} = +8 mA)	V_{DD} = 3.3 V	—	—	0.10	
		V_{DD} = 3.6 V	—	—	0.10	
V_{OL}	Low level output voltage for an IO Pin (I_{IO} = +20 mA)	V_{DD} = 1.8 V	—	—	—	V
		V_{DD} = 2.5 V	—	—	0.50	
		V_{DD} = 3.3 V	—	—	0.40	
		V_{DD} = 3.6 V	—	—	0.40	
V_{OH}	High level output voltage for an IO Pin (I_{IO} = +8 mA)	V_{DD} = 1.8 V	1.50	—	—	V
		V_{DD} = 2.5 V	2.30	—	—	
		V_{DD} = 3.3 V	3.10	—	—	
		V_{DD} = 3.6 V	3.40	—	—	
V_{OH}	High level output voltage for an IO Pin (I_{IO} = +20 mA)	V_{DD} = 1.8 V	—	—	—	V
		V_{DD} = 2.5 V	1.90	—	—	
		V_{DD} = 3.3 V	2.80	—	—	
		V_{DD} = 3.6 V	3.10	—	—	
R_{PU}(2)	Internal pull-up resistor	—	—	40	—	kΩ
R_{PD}(2)	Internal pull-down resistor	—	—	40	—	kΩ

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

Table 4-22. I/O port AC characteristics(1)(2)

GPIOx_OSPD[1:0] bit value(3)	Parameter	Conditions	Max	Unit
GPIOx_OSPD0->OSPDy[1:0] = X0 （IO_Speed = 2MHz）	Maximum frequency(4)	1.8 ≤ V_{DD} ≤ 3.6V, C_L = 10pF	10	MHz
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 30pF	8	
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 50pF	6	
GPIOx_OSPD0->OSPDy[1:0] = 01 （IO_Speed = 10MHz）	Maximum frequency(4)	1.8 ≤ V_{DD} ≤ 3.6V, C_L = 10pF	30	MHz
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 30pF	25	
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 50pF	15	
GPIOx_OSPD0->OSPDy[1:0] = 11 （IO_Speed = 50MHz）	Maximum frequency(4)	1.8 ≤ V_{DD} ≤ 3.6V, C_L = 10pF	60	MHz
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 30pF	50	
		1.8 ≤ V_{DD} ≤ 3.6V, C_L = 50pF	40	

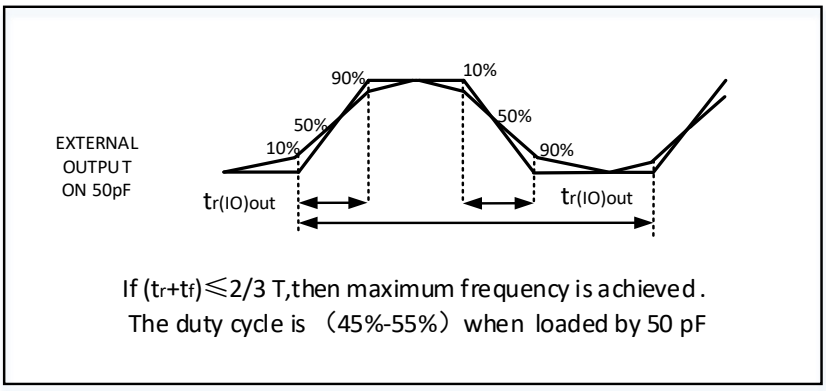
(1). Based on characterization, not tested in production.

(2). Unless otherwise specified, all test results given for T_A = 25℃.

(3). The I/O speed is configured using the GPIOx_OSPD0->OSPDy [1:0] bits. Refer to the GD32E231 user manual which is selected to set the GPIO port output speed.

(4) The maximum frequency is defined in ***Figure 4-1. I/O port AC characteristics definition***.

Figure 4-1. I/O port AC characteristics definition



4.13 ADC characteristics

Table 4-23. ADC characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DDA}(1)	Operating voltage	—	2.4	3.3	3.6	V
V_{IN}(1)	ADC input voltage range	—	0	—	V_{DDA}	V
f_{ADC}(1)	ADC clock	—	0.1	—	28	MHz
f_S(1)	Sampling rate	12-bit	0.007	—	2	MSPS
		10-bit	0.008	—	2.3	
		8-bit	0.01	—	2.8	
		6-bit	0.011	—	3.5	
V_{AIN}(1)	Analog input voltage	10 external; 2 internal	0	—	V_{DDA}	V
V_{REF+}(2)	Positive Reference Voltage	—	—	V_{DDA}	—	V
V_{REF-}(2)	Negative Reference Voltage	—	—	0	—	V
R_{AIN}(2)	External input impedance	See ***Equation 1***	—	—	50.6	kΩ
R_{ADC}(2)	Input sampling switch resistance	—	—	—	0.5	kΩ
C_{ADC}(2)	Input sampling capacitance	No pin/pad capacitance included	—	—	4	pF
t_{CAL}(2)	Calibration time	f_{ADC} = 28 MHz	—	4.68	—	μs
t_s(2)	Sampling time	f_{ADC} = 28 MHz	0.05	—	8.55	μs
t_{CONV}(2)	Total conversion time(including sampling time)	12-bit	—	14	—	1/ f_{ADC}
		10-bit	—	12	—	
		8-bit	—	10	—	
		6-bit	—	8	—	
t_{SU}(2)	Startup time	—	—	—	1	μs

(1). Based on characterization, not tested in production.

(2). Guaranteed by design, not tested in production.

Equation 1: R_{AIN} max formula $R_{AIN} < \frac{T_s}{f_{ADC} * C_{ADC} * \ln(2^{N+2})} - R_{ADC}$

The formula above (Equation 1) is used to determine the maximum external impedance allowed for an error below 1/4 of LSB. Here N = 12 (from 12-bit resolution).

Table 4-24. ADC R_{AIN} max for f_{ADC} = 28 MHz(1)

T_s(cycles)	t_s(μs)	R_{AINmax} (kΩ)
1.5	0.05	0.88
7.5	0.27	6.4
13.5	0.48	11.9
28.5	1.02	25.7
41.5	1.48	37.7
55.5	1.98	50.6
71.5	2.55	NA
239.5	8.55	NA

(1). Based on characterization, not tested in production.

4.14 Temperature sensor characteristics

Table 4-25. Temperature sensor characteristics(1)

Symbol	Parameter	Min	Typ	Max	Unit
T_L	V_{SENSE} linearity with temperature	—	±1.5	—	℃
Avg_Slope	Average slope	—	4.3	—	mV/℃
V_{25}	Voltage at 25 °C	—	1.45	—	V
t_{START}	Startup time	—	—	—	μs
t_{S_temp} (2)	ADC sampling time when reading the temperature	—	17.1	—	μs

(1). Based on characterization, not tested in production.

(2). Shortest sampling time can be determined in the application by multiple iterations.

4.15 Comparators characteristics

Table 4-26. CMP characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max(1)	Unit
V_{DDA}	Operating voltage	—	1.8	3.3	3.6	V
V_{IN}	Input voltage range	—	0	—	V_{DDA}	V
V_{BG}	Scaler input voltage	—	—	1.2	—	V
V_{SC}	Scaler offset voltage	—	—	—	—	mV
t_D	Propagation delay for 200mv step with 100mV overdrive	Ultra low power mode	—	0.98	—	μs
		Low power mode	—	0.25	—	μs
		Medium power mode	—	0.12	—	μs
		High speed power mode	—	33	—	μs
	Propagation delay for full range step with 100mV overdrive	Ultra low power mode	—	—	—	μs
		Low power mode	—	—	—	μs
		Medium power mode	—	—	—	μs
		High speed power mode	—	—	—	ns

Symbol	Parameter	Conditions	Min	Typ	Max(1)	Unit
I_{DD}	Current consumption	Ultra low power mode	—	2.2	—	μA
		Low power mode	—	3.2	—	
		Medium power mode	—	8.1	—	
		High speed power mode	—	46.9	—	
V_{offset}	Offset error	—	—	±4	—	mV
V_{hyst}	Hysteresis Voltage	No Hysteresis	—	0	—	mV
		Low Hysteresis	—	11	—	
		Medium Hysteresis	—	22	—	
		High Hysteresis	—	43	—	

(1). Guaranteed by design, not tested in production.

4.16 Operational amplifier characteristics

Table 4-27. OP-AMP characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Operating voltage	—	2.7	—	3.6	V
V_{CM}	Common mode voltage range	—	0.2	—	V_{DD} - 0.2	V
I_{DD}	Operating current	Io = 0	—	600	—	μA
I_{Load}	Drive current	—	—	—	—	mA
V_{os}	Offset voltage	—	—	1	3.5	mV
T_s	Settling time	Gain = 1, input 2V step Settling to 0.1%	—	1.2	—	μs
SR	Slew rate	Gain = 1	—	5	—	V/μs
CMRR	Common mode rejection ratio	—	58	72	—	dB
PSRR	Power supply rejection ratio	—	65	80	—	dB
GBW	Gain bandwidth	R_L = 10kΩ	—	6	—	MHz
A0	Open-loop gain	R_L = 10kΩ	85	95	—	dB
V_{out}	Output swing from rail	R_L = 10kΩ	—	200	—	mV
V_{noise}	Input voltage noise	F = 0.1Hz to 10Hz	—	8	—	μVpp
e_n	Input voltage noise density	F = 10kHz	—	24	—	nV/√Hz

4.17 I2C characteristics

Table 4-30. I2C characteristics(1)(2)(3)

Symbol	Parameter	Conditions	Standard mode(1)		Fast mode(1)(2)		Fast mode plus(1)		Unit
			Min	Max	Min	Max	Min	Max	
$t_{SCL(H)}$	SCL clock high time	—	4.0	—	0.6	—	0.2	—	μs
$t_{SCL\ (L)}$	SCL clock low time	—	4.7	—	1.3	—	0.5	—	μs
$t_{su(SDA)}$	SDA setup time	—	2	—	0.8	—	0.1	—	μs
$t_{h(SDA)}$	SDA data hold time	—	250	—	250	—	130	—	ns
$t_{r(SDA/SCL)}$	SDA and SCL rise time	—	—	1000	20	300	—	120	ns
$t_{f(SDA/SCL)}$	SDA and SCL fall time	—	4	300	4	300	4	120	ns
$t_{h(STA)}$	Start condition hold time	—	4.0	—	0.6	—	0.26	—	μs

(1). Guaranteed by design, not tested in production.

(2). Test condition: GPIO_SPEED set 2MHz and external pull-up resistor value is 1kΩ when operate EEPROM with I2C.

(3). The device should provide a data hold time of 300 ns at least in order to bridge the undefined region of the falling edge of SCL.

4.18 SPI characteristics

Table 4-28. Standard SPI characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCK}	SCK clock frequency	—	—	—	18	MHz
$t_{SCK(H)}$	SCK clock high time	Master mode, f_{PCLKx} = 72 MHz, presc = 4	25	27	29	ns
$t_{SCK(L)}$	SCK clock low time	Master mode, f_{PCLKx} = 72 MHz, presc = 4	25	27	29	ns
SPI master mode						
$t_{V(MO)}$	Data output valid time	—	—	7.5	—	ns
$t_{H(MO)}$	Data output hold time	—	—	6	—	ns
$t_{SU(MI)}$	Data input setup time	—	1	—	—	ns
$t_{H(MI)}$	Data input hold time	—	0	—	—	ns
SPI slave mode						
$t_{SU(NSS)}$	NSS enable setup time	—	0	—	—	ns
$t_{H(NSS)}$	NSS enable hold time	—	1	—	—	ns
$t_{A(SO)}$	Data output access time	—	—	7	—	ns
$t_{DIS(SO)}$	Data output disable time	—	—	8	—	ns
$t_{V(SO)}$	Data output valid time	—	—	10	—	ns
$t_{H(SO)}$	Data output hold time	—	—	10	—	ns
$t_{SU(SI)}$	Data input setup time	—	0	—	—	ns

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{H(SI)}$	Data input hold time	—	1	—	—	ns

(1) .Based on characterization, not tested in production.

4.19 I2S characteristics

Table 4-29. I2S characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{CK}	Clock frequency	Master mode (data: 16 bits, Audio frequency = 96 kHz)	—	3.12	—	MHz
		Slave mode	—	10	—	
t_H	Clock high time	—	—	160	—	ns
t_L	Clock low time		—	160	—	ns
$t_{V(WS)}$	WS valid time	Master mode	—	3	—	ns
$t_{H(WS)}$	WS hold time	Master mode	—	3	—	ns
$t_{SU(WS)}$	WS setup time	Slave mode	0	—	—	ns
$t_{H(WS)}$	WS hold time	Slave mode	3	—	—	ns
$DuCy_{(sck)}$	I2S slave input clock duty cycle	Slave mode	—	50	—	%
$t_{SU(SD\_MR)}$	Data input setup time	Master mode	0	—	—	ns
$t_{su(SD\_SR)}$	Data input setup time	Slave mode	0	—	—	ns
$t_{H(SD\_MR)}$	Data input hold time	Master receiver	2	—	—	ns
$t_{H(SD\_SR)}$		Slave receiver	2	—	—	ns
$t_{v(SD\_ST)}$	Data output valid time	Slave transmitter (after enable edge)	—	12	—	ns
$t_{h(SD\_ST)}$	Data output hold time	Slave transmitter (after enable edge)	—	10	—	ns
$t_{v(SD\_MT)}$	Data output valid time	Master transmitter (after enable edge)	—	10	—	ns
$t_{h(SD\_MT)}$	Data output hold time	Master transmitter (after enable edge)	—	7	—	ns

(1) .Based on characterization, not tested in production.

4.20 USART characteristics

Table 4-30. USART characteristics(1)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCK}	SCK clock frequency	f_{PCLKx} = 72 MHz	—	—	36	MHz
$t_{SCK(H)}$	SCK clock high time	f_{PCLKx} = 72 MHz	13.5	—	—	ns
$t_{SCK(L)}$	SCK clock low time	f_{PCLKx} = 72 MHz	13.5	—	—	ns

(1) .Based on characterization, not tested in production.

4.21 TIMER characteristics

Table 4-31. TIMER characteristics(1)

Symbol	Parameter	Conditions	Min	Max	Unit
t_{res}	Timer resolution time	—	1	—	$t_{TIMERxCLK}$
		$f_{TIMERxCLK}$ = 72 MHz	13.9	—	ns
f_{EXT}	Timer external clock frequency	—	0	$f_{TIMERxCLK}/2$	MHz
		$f_{TIMERxCLK}$ = 72 MHz	0	36	MHz
RES	Timer resolution	—	—	16	bit
$t_{COUNTER}$	16-bit counter clock period when internal clock is selected	—	1	65536	$t_{TIMERxCLK}$
		$f_{TIMERxCLK}$ = 72 MHz	0.0139	910	μs
t_{MAX_COUNT}	Maximum possible count	—	—	65536 × 65536	$t_{TIMERxCLK}$
		$f_{TIMERxCLK}$ = 72 MHz	—	59.6	s

(1). Guaranteed by design, not tested in production.

4.22 WDGT characteristics

Table 4-32. FWDGT min/max timeout period at 40 kHz (IRC40K)

Prescaler divider	PR[2:0] bits	Min timeout RLD[11:0] = 0x000	Max timeout RLD[11:0] = 0xFFF	Unit
1/4	000	0.1	409.6	ms
1/8	001	0.2	819.2	
1/16	010	0.4	1638.4	
1/32	011	0.8	3276.8	
1/64	100	1.6	6553.6	
1/128	101	3.2	13107.2	
1/256	110 or 111	6.4	26214.4	

(1). Guaranteed by design, not tested in production.

Table 4-33. WWDGT min-max timeout value at 72 MHz (f_{PCLK1})

Prescaler divider	PSC[2:0]	Min timeout value CNT[6:0] = 0x40	Unit	Max timeout value CNT[6:0] = 0x7F	Unit
1/1	00	56.9	μs	3.64	ms
1/2	01	113.8		7.28	
1/4	10	227.6		14.56	
1/8	11	455.1		29.13	

(1). Guaranteed by design, not tested in production.

4.23 Parameter conditions

Unless otherwise specified, all values given for V_{DD} = V_{DDA} = 3.3 V, TA = 25 ℃.

5 Package information

5.1 LQFP package outline dimensions

Figure 5-1. LQFP package outline

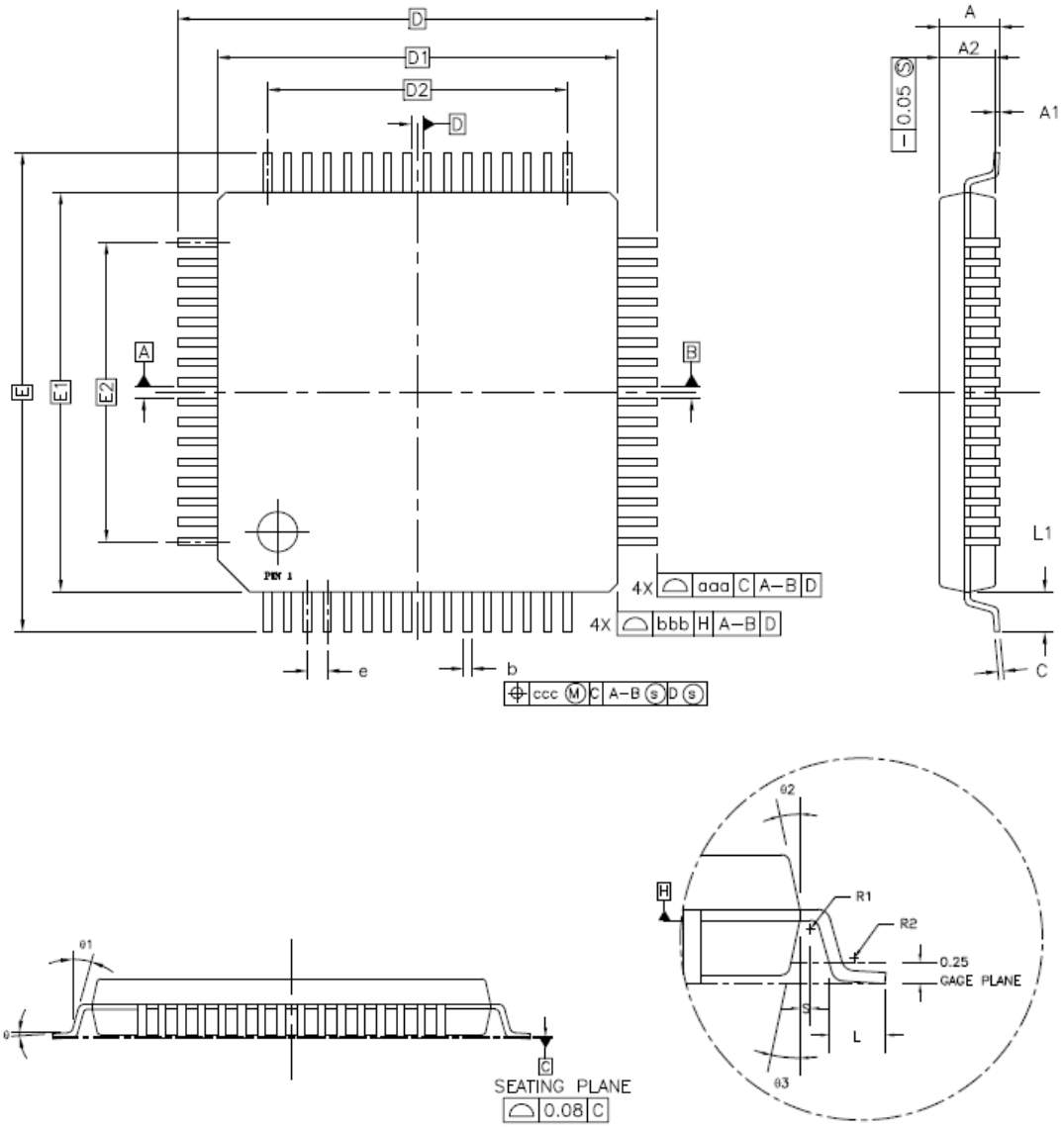


Table 5-1. LQFP package dimensions

Symbol	LQFP48		
	Min	Typ	Max
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.40
D	-	9.00	-
D1	-	7.00	-
E	-	9.00	-
E1	-	7.00	-
R1	0.08	-	-
R2	0.08	-	0.20
θ	0°	3.5°	7°
θ1	0°	-	-
θ2	11°	12°	13°
θ3	11°	12°	13°
c	0.09	-	0.20
L	0.45	0.60	0.75
L1	-	1.00	-
S	0.20	-	-
b	0.17	0.22	0.27
e	-	0.50	-
D2	-	5.50	-
E2	-	5.50	-
aaa	0.20		
bbb	0.20		
ccc	0.08		

(Original dimensions are in millimeters)

6 Ordering information

Table 6-1. Part ordering code for GD32E231CxT6 devices

Ordering code	Flash (KB)	Package	Package type	Temperature operating range
GD32E231C4T6	16	LQFP48	Green	Industrial -40°C to +85°C
GD32E231C6T6	32	LQFP48	Green	Industrial -40°C to +85°C
GD32E231C8T6	64	LQFP48	Green	Industrial -40°C to +85°C

7 Revision history

Table 7-1. Revision history

Revision No.	Description	Date
1.0	Initial Release	Feb15, 2019

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