RA8E1 Group
Renesas Microcontrollers

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High-performance 360 MHz Arm® Cortex®-M85 core with Helium™, 1 MB code flash memory with Dual-bank, background and SWAP operation, 12 KB Data flash memory, and 544 KB SRAM with Parity. High-integration with Ethernet MAC controller, USB 2.0 Full-Speed, CANFD, Octal SPI and advanced analog.

Features

■ Arm® Cortex®-M85 core with Helium™

- Armv8.1-M architecture profile
- Armv8-M Security Extension
- Maximum operating frequency: 360 MHz
- Memory Protection Unit (Arm MPU)
  - Protected Memory System Architecture (PMSAv8)
  - Secure MPU (MPU_S): 8 regions
  - Non-secure MPU (MPU_NS): 8 regions
- SysTick timer
  - Embeds two Systick timers: Secure and Non-secure instance
  - Driven by CPUCLK or MOCO divided by 8
- CoreSight™ ETM-M85

■ Memory

- 1 MB code flash memory
- 12 KB data flash memory (100,000 program/erase (P/E) cycles)
- 544 KB SRAM including 32 KB of TCM

■ Connectivity

- Serial Communications Interface (SCI) × 6 , up to 60 Mbps
  - Asynchronous interfaces
  - 8 bit clock synchronous interface
  - Smart card interface
  - Simple IIC
  - Simple SPI
  - Manchester coding (SCI0)
  - Simple LIN (SCI0, SCI1)
- I^2C bus interface (IIC) × 2
- Serial Peripheral Interface (SPI) × 2, up to 60 Mbps
- Octal Serial Peripheral Interface (OSPI)
- USB 2.0 Full-Speed Module (USBFS)
- CAN with Flexible Data-rate (CANFD) × 2
- Ethernet MAC/DMA Controller (ETHERC/EDMAC)
- Serial Sound Interface Enhanced (SSIE) × 2

■ Analog

- 12-bit A/D Converter (ADC12) × 2
- 12-bit D/A Converter (DAC12)
- High-Speed Analog Comparator (ACMPHS) × 2
- Temperature Sensor (TSN)

■ Timers

- General PWM Timer 32-bit (GPT32) × 6
- General PWM Timer 16-bit (GPT16) × 4
- Low Power Asynchronous General Purpose Timer (AGT) × 2
- Ultra-Low-Power Timer (ULPT) × 2

■ Security and Encryption

- Renesas Secure IP (RSIP-E51A)
  - 128 bit unique ID
- Arm® TrustZone®
  - Up to two or four regions for the code flash, depending on the bank mode
  - Up to two regions for the data flash
  - Up to two regions for the SRAM
  - Individual Secure or Non-secure security attribution for each peripheral
- Privileged control
- Device lifecyle management
- Pin function
  - Up to three tamper-resistant pins
  - Secure pin multiplexing

■ System and Power Management

- Low power modes
- Battery backup function (VBATT)
- Realtime Clock (RTC) with calendar and VBATT support
- Event Link Controller (ELC)
- Data Transfer Controller (DTC)
- DMA Controller (DMAC) × 8
- Power-on reset
- Programable Voltage Detection (PVD) with voltage settings
- Watchdog Timer (WDT)
- Independent Watchdog Timer (IWDT)

■ Human Machine Interface (HMI)

- Capture Engine Unit (CEU)

■ Multiple Clock Sources

- Main clock oscillator (MOSC) (8 to 48 MHz)
- Sub-clock oscillator (SOSC) (32.768 kHz)
- High-speed on-chip oscillator (HOCO) (16/18/20/32/48 MHz)
- Middle-speed on-chip oscillator (MOCO) (8 MHz)
- Low-speed on-chip oscillator (LOCO) (32.768 kHz)
- Clock trim function for HOCO/MOCO/LOCO
- PLL1/PLL2
- Clock out support

■ General-Purpose I/O Ports

- 5-V tolerance, open drain, input pull-up, switchable driving ability

■ Operating Voltage

- VCC: 1.68 to 3.6 V
- VCC2: 1.65 to 3.6 V

■ Operating Junction Temperature and Packages

- Tj = -40°C to +105°C
  - 100-pin LQFP (14 mm × 14 mm, 0.5 mm pitch)
  - 144-pin LQFP (20 mm × 20 mm, 0.5 mm pitch)

1. Overview

The MCU integrates multiple series of software-compatible Arm®-based 32-bit cores that share a common set of Renesas peripherals to facilitate design scalability and efficient platform-based product development.

The MCU in this series incorporates a high-performance Arm® Cortex®-M85 core with Helium™running up to 360 MHz with the following features:

- 1 MB code flash memory
- 544 KB SRAM (32 KB of TCM RAM, 512 KB of user SRAM)
- Octal Serial Peripheral Interface (OSPI)
- Ethernet MAC Controller (ETHERC), USBFS
- Analog peripherals
- Security and safety features

1.1 Function Outline

Table 1.1 Arm core

Feature	Functional description
Arm® Cortex®-M85 core	• Maximum operating frequency: up to 360 MHz • Arm® Cortex®-M85 core – Revision: (r0p2-00rel0) – ARMv8.1-M architecture profile – Armv8-M Security Extension – Floating Point Unit (FPU) compliant with the ANSI/IEEE Std 754-2008 Scalar half, single, and double-precision floating-point operation – M-profile Vector Extension (MVE) Integer, half-precision, and single-precision floating-point MVE (MVE-F) – Helium™ technology is M-profile Vector Extension (MVE) • Arm® Memory Protection Unit (Arm MPU) – Protected Memory System Architecture (PMSAv8) – Secure MPU (MPU_S): 8 regions – Non-secure MPU (MPU_NS): 8 regions • SysTick timer – Embeds two Systick timers: Secure instance (SysTick_S) and Non-secure instance (SysTick_NS) – Driven by CPUCLK or MOCO divided by 8 • CoreSight™ ETM-M85

Table 1.2 Memory

Feature	Functional description
Code flash memory	1 MB of code flash memory.
Data flash memory	12 KB of data flash memory.
Option-setting memory	The option-setting memory determines the state of the MCU after a reset.
SRAM	On-chip high-speed SRAM with parity bit.
Standby SRAM	On-chip SRAM that can retain data in Deep Software Standby mode 1.

Table 1.3 System (1 of 2)

Feature	Functional description
Operating modes	Three operating modes: • Single-chip mode • JTAG boot mode • SCI/USB boot mode
Resets	This MCU provides 13 types of reset.

Table 1.3 System (2 of 2)

Feature	Functional description
Programable Voltage Detection (PVD)	The Programable Voltage Detection (PVD) module monitors the voltage level input to the VCC pin. The detection level can be selected by register settings. The PVD module consists of three separate voltage level detectors (PVD0, PVD1, PVD2). PVD0, PVD1, and PVD2 measure the voltage level input to the VCC pin. PVD registers allow your application to configure detection of VCC changes at various voltage thresholds.
Clocks	• Main clock oscillator (MOSC) • Sub-clock oscillator (SOSC) • High-speed on-chip oscillator (HOCO) • Middle-speed on-chip oscillator (MOCO) • Low-speed on-chip oscillator (LOCO) • PLL1/PLL2 • Clock out support
Clock Frequency Accuracy Measurement Circuit (CAC)	The Clock Frequency Accuracy Measurement Circuit (CAC) counts pulses of the clock to be measured (measurement target clock) within the time generated by the clock selected as the measurement reference (measurement reference clock), and determines the accuracy depending on whether the number of pulses is within the allowable range. When measurement is complete or the number of pulses within the time generated by the measurement reference clock is not within the allowable range, an interrupt request is generated.
Interrupt Controller Unit (ICU)	The Interrupt Controller Unit (ICU) controls which event signals are linked to the Nested Vector Interrupt Controller (NVIC), the DMA Controller (DMAC), and the Data Transfer Controller (DTC) modules. The ICU also controls non-maskable interrupts.
Low power modes	Power consumption can be reduced in multiple ways, including setting clock dividers, stopping modules, power gating control, selecting operating power control modes in normal operation, and transitioning to low power modes and processor low power modes.
Battery backup function	A battery backup function is provided for partial powering by a battery. The battery-powered area includes the RTC, SOSC, backup register, tamper detection and VBATT_R voltage drop detection and switch between VCC and VBATT.
Register write protection	The register write protection function protects important registers from being overwritten due to software errors. The registers to be protected are set with the Protect Register (PRCR_S and PRCR_NS).
Memory Protection Unit (MPU)	All bus masters have Memory Protection Units (MPUs).

Table 1.4 Event link

Feature	Functional description
Event Link Controller (ELC)	The Event Link Controller (ELC) uses the event requests generated by various peripheral modules as source signals to connect them to different modules, allowing direct link between the modules without CPU intervention.

Table 1.5 Direct memory access

Feature	Functional description
Data Transfer Controller (DTC)	A Data Transfer Controller (DTC) module is provided for transferring data when activated by an interrupt request.
DMA Controller (DMAC)	The 8-channel direct memory access controller (DMAC) that can transfer data without intervention from the CPU. When a DMA transfer request is generated, the DMAC transfers data stored at the transfer source address to the transfer destination address.

Table 1.6 External bus interface

Feature	Functional description
External buses	• OSPI area (EOBI): Connected to the OSPI (external device interface)

Table 1.7 Timers (1 of 2)

Feature	Functional description
General PWM Timer (GPT)	The General PWM Timer (GPT) is a 32-bit timer with GPT32 × 6 channels and a 16-bit timer with GPT16 × 4 channels. PWM waveforms can be generated by controlling the up-counter, down-counter, or the up- and down-counter. The GPT can also be used as a general-purpose timer.

Table 1.7 Timers (2 of 2)

Feature	Functional description
Port Output Enable for GPT (POEG)	The Port Output Enable (POEG) function can place the General PWM Timer (GPT) output pins in the output disable state
Low Power Asynchronous General Purpose Timer (AGT)	The Low Power Asynchronous General Purpose Timer (AGT) is a 16-bit timer that can be used for pulse output, external pulse width or period measurement, and counting external events. This timer consists of a reload register and a down counter. The reload register and the down counter are allocated to the same address, and can be accessed with the AGT register.
Ultra-Low-Power Timer (ULPT)	The Ultra-Low-Power Timer (ULPT) is a 32-bit timer which can be used for outputting pulses or counting external events. This 32-bit timer consists of reload registers and a down-counter. The reload registers and the down-counter are allocated to the same address and can be accessed through the ULPTCNT register.
Realtime Clock (RTC)	The realtime clock (RTC) has two counting modes, calendar count mode and binary count mode, that are used by switching register settings. For calendar count mode, the RTC has a 100-year calendar from 2000 to 2099 and automatically adjusts dates for leap years. For binary count mode, the RTC counts seconds and retains the information as a serial value. Binary count mode can be used for calendars other than the Gregorian (Western) calendar.
Watchdog Timer (WDT)	The Watchdog Timer (WDT) is a 14-bit down counter that can be used to reset the MCU when the counter underflows because the system has run out of control and is unable to refresh the WDT. In addition, the WDT can be used to generate a non-maskable interrupt or an underflow interrupt.
Independent Watchdog Timer (IWDT)	The Independent Watchdog Timer (IWDT) has a 14-bit down-counter, which resets the MCU by a reset output when the down-counter underflows. Alternatively, generation of an interrupt request when the counter underflows can be selected. This enables detection of a program runaway taking the refresh interval into account. The IWDT has two start modes: auto start mode, in which counting automatically starts after release from the reset state, and register start mode, in which counting is started by refreshing (writing to a specific register).

Table 1.8 Communication interfaces (1 of 2)

Feature	Functional description
Serial Communications Interface (SCI)	The Serial Communications Interface (SCI) × 6 channels have asynchronous and synchronous serial interfaces: ● Asynchronous interfaces (UART and Asynchronous Communications Interface Adapter (ACIA)) ● 8-bit clock synchronous interface ● Simple IIC (master-only) ● Simple SPI ● Smart card interface ● Manchester interface ● Simple LIN interface The smart card interface complies with the ISO/IEC 7816-3 standard for electronic signals and transmission protocol. All channels have FIFO buffers to enable continuous and full-duplex communication, and the data transfer speed can be configured independently using an on-chip baud rate generator. The maximum rate supported on this MCU. Refer to the electrical characteristics for the actual rate.
I^2C Bus interface (IIC)	The I^2C Bus interface (IIC) has 2 channels. The IIC module conforms with and provides a subset of the NXP I^2C (Inter-Integrated Circuit) bus interface functions.
Serial Peripheral Interface (SPI)	The Serial Peripheral Interface (SPI) provides high-speed full-duplex synchronous serial communications with multiple processors and peripheral devices. The maximum rate supported on this MCU. Refer to the electrical characteristics for the actual rate.
Control Area Network with Flexible Data-Rate Module (CANFD)	The CAN with Flexible Data-Rate (CANFD) module can handle classical CAN frames and CANFD frames complied with ISO 11898-1 standard. The module supports 4 transmit buffers per channel and 16 receive buffers per channel.
USB 2.0 Full-Speed module (USBFS)	The USB 2.0 Full-Speed module (USBFS) can operate as a host controller or device controller. The module supports full-speed and low-speed (host controller only) transfer as defined in Universal Serial Bus Specification 2.0. The module has an internal USB transceiver and supports all of the transfer types defined in Universal Serial Bus Specification 2.0. The USB has buffer memory for data transfer, providing a maximum of 10 pipes. Pipes 1 to 9 can be assigned any endpoint number based on the peripheral devices used for communication or based on your system.

Table 1.8 Communication interfaces (2 of 2)

Feature	Functional description
Octal Serial Peripheral Interface (OSPI)	The Octal Serial Peripheral Interface (OSPI) is a memory controller that supports EXpanded Serial Peripheral Interface (xSPI) (JEDEC Standard JESD251, JESD251-1 and JESD252) . The OSPI supports 1-bit, 2-bit, 4-bit and 8-bit protocols. JESD251 specifies two interface profiles where profile 1.0 is Octal SPI and profile 2.0 is HyperBus™ (HyperRAM™ and HyperFlash™). OSPI supports QSPI protocol.
Serial Sound Interface Enhanced (SSIE)	The Serial Sound Interface Enhanced (SSIE) peripheral provides functionality to interface with digital audio devices for transmitting I²S/Monaural/TDM audio data over a serial bus. The SSIE supports an audio clock frequency of up to 50 MHz, and can be operated as a slave or master receiver, transmitter, or transceiver to suit various applications. The SSIE includes 32-stage FIFO buffers in the receiver and transmitter, and supports interrupts and DMA-driven data reception and transmission.
Ethernet Controller (ETHERC)	One-channel Ethernet Controller (ETHERC) compliant with the Ethernet/IEEE802.3 Media Access Control (MAC) layer protocol. An ETHERC channel provides one channel of the MAC layer interface, connecting the MCU to the physical layer LSI (PHY-LSI) that allows transmission and reception of frames compliant with the Ethernet and IEEE802.3 standards. The ETHERC is connected to the Ethernet DMA Controller (EDMAC) so data can be transferred without using the CPU.

Table 1.9 Analog

Feature	Functional description
12-bit A/D Converter (ADC12)	A 12-bit successive approximation A/D Converter is provided. Up to 13 analog input channels are selectable. Temperature sensor output, and internal reference voltage and VBATT 1/3 voltage monitor are selectable for conversion.
12-bit D/A Converter (DAC12)	A 12-bit D/A Converter (DAC12) is provided.
Temperature Sensor (TSN)	The on-chip Temperature Sensor (TSN) determines and monitors the die temperature for reliable operation of the device. The sensor outputs a voltage directly proportional to the die temperature, and the relationship between the die temperature and the output voltage is fairly linear. The output voltage is provided to the ADC12 for conversion and can be further used by the end application.
High-Speed Analog Comparator (ACMPHS)	The High-Speed Analog Comparator (ACMPHS) can be used to compare an analog input voltage with a reference voltage and to provide a digital output based on the result of conversion. Both the analog input voltage and the reference voltage can be provided to the ACMPHS from internal sources (D/A converter output or internal reference voltage) and an external source. Such flexibility is useful in applications that require go/no-go comparisons to be performed between analog signals without necessarily requiring A/D conversion.

Table 1.10 Human machine interfaces

Feature	Functional description
Capture Engine Unit (CEU)	The Capture Engine Unit (CEU) is a capture module that fetches image data externally input and transfers it to the memory.

Table 1.11 Data processing

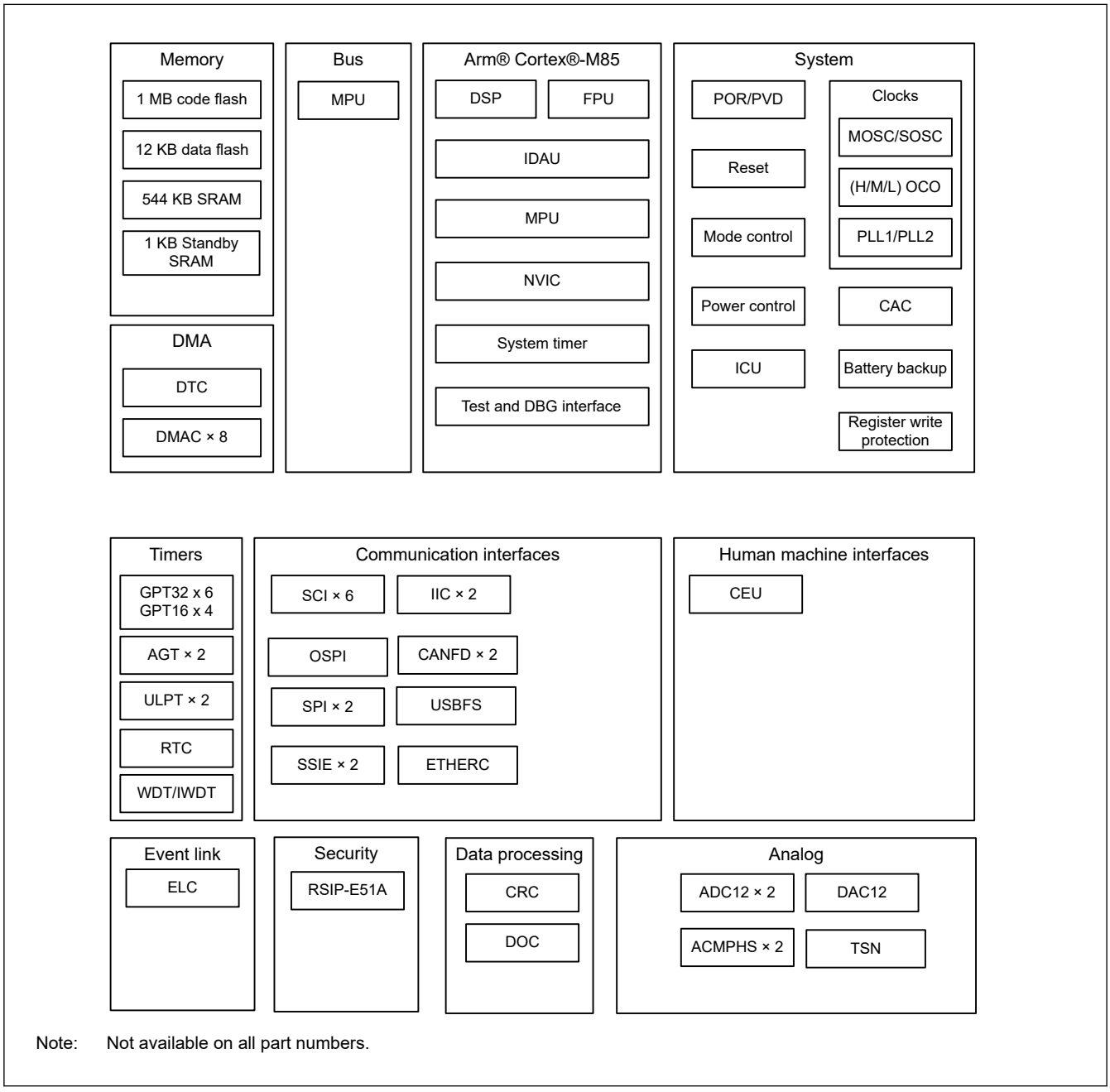
Feature	Functional description
Cyclic Redundancy Check (CRC) calculator	The Cyclic Redundancy Check (CRC) calculator generates CRC codes to detect errors in the data. The bit order of CRC calculation results can be switched for LSB-first or MSB-first communication. Additionally, various CRC-generation polynomials are available. The snoop function allows monitoring reads from and writes to specific addresses. This function is useful in applications that require CRC code to be generated automatically in certain events, such as monitoring writes to the serial transmit buffer and reads from the serial receive buffer.
Data Operation Circuit (DOC)	The Data Operation Circuit (DOC) compares, adds, and subtracts 32-bits data. When a selected condition applies, 32-bit data is compared and an interrupt can be generated.

Table 1.12 Security

Feature	Functional description
Security function	• ARMv8-M TrustZone security • Privileged control • Device lifecycle management • Authentication Level (AL) • Key injection • Secure pin multiplexing • VBATT backup registers zeroization • Secure boot • Secure factory programming
Renesas Secure IP (RSIP-E51A)	• 128-bit true random number generation circuit • 256-bit Hardware Unique Key (HUK) • 128-bit unique ID

1.2 Block Diagram

Figure 1.1 shows a block diagram of the MCU superset. Some individual devices within the group have a subset of the features.



Note: Not available on all part numbers.

Figure 1.1 Block diagram

1.3 Part Numbering

Figure 1.2 shows the product part number information, including memory capacity and package type. Table 1.13 shows a list of products.

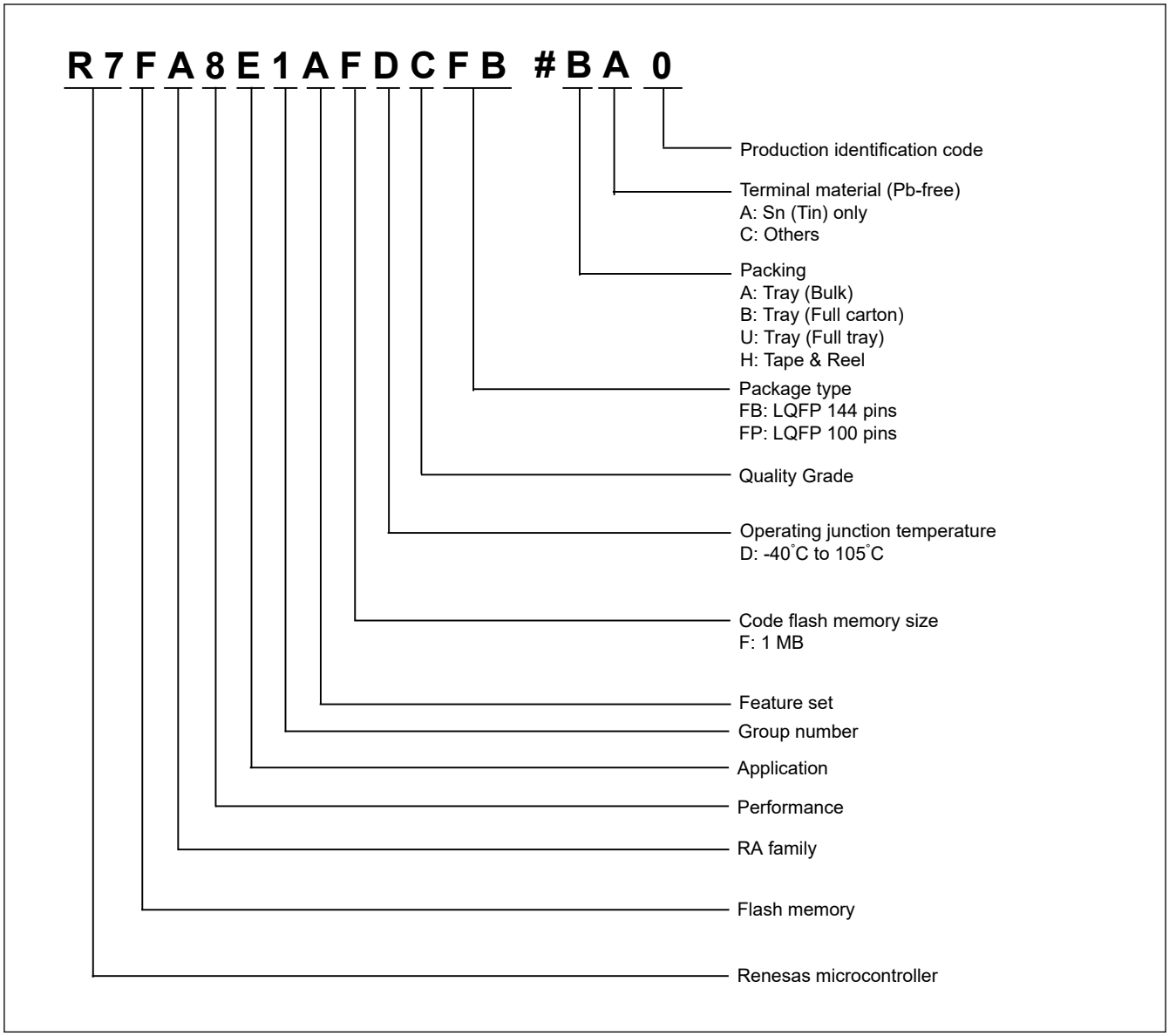


Figure 1.2 Part numbering scheme

Table 1.13 Product list

Product part number	Package code	Code flash	Data flash	SRAM	Operating junction temperature
R7FA8E1AFDCFB	PLQP0144KA-B	1 MB	12 KB	544 KB	−40 to +105°C
R7FA8E1AFDCFP	PLQP0100KP-A				

1.4 Function Comparison

Table 1.14 Function Comparison

Parts number		R7FA8E1AFDCFB	R7FA8E1AFDCFP
Pin count		144	100
Package		LQFP	
I/O Port		106	70
Code flash memory		1 MB	
Data flash memory		12 KB	
TCM		32 KB	
I/D Caches		32 KB	
SRAM	Parity	512 KB	
Standby SRAM		1 KB	
DMA	DTC	Yes	
	DMAC	8	
System	CPU clock	360 MHz (max.)	
	CPU clock sources	MOSC, SOSC, HOCO, MOCO, PLL1P	
	CAC	Yes	
	WDT/IWDT	Yes	
	Backup register	128 B	
Communication	SCI	6	
	IIC	2	
	SPI	2	
	CANFD	2	
	USBFS	Yes	
	OSPI	Yes	
	SSIE	2	1
	ETHERC	Yes	
Timers	GPT32[*1]	6	
	GPT16[*1]	4	
	AGT[*1]	2	
	ULPT[*1]	2	
	RTC	Yes	
Analog	ADC12	Unit 0: 8 Unit 1: 5	Unit 0: 6 Unit 1: 5
	DAC12	1	
	ACMPHS	2	
	TSN	Yes	
HMI	CEU	Yes	No
Data processing	CRC	Yes	
	DOC	Yes	
Event control	ELC	Yes	
Security		RSIP-E51A, Secure Debug, TrustZone, and Lifecycle management	

Note 1. Available pins depend on the Pin count. For details, see section 1.7. Pin Lists.

1.5 Pin Functions

Table 1.15 Pin functions (1 of 5)

Function	Signal	I/O	Description
Power supply	VCC, VCC2	Input	Power supply pin. Connect it to the system power supply. Connect this pin to VSS by a 0.1-μF capacitor. The capacitor should be placed close to the pin.
	VCC_DCDC	Input	Switching regulator power supply pin.
	VLO	I/O	Switching regulator pin.
	VCL	Input	Connect this pin to the VSS pin by the smoothing capacitor used to stabilize the internal power supply. Place the capacitor close to the pin.
	VBATT	Input	Battery Backup power pin
	VSS, VSS_DCDC	Input	Ground pin. Connect it to the system power supply (0 V).
Clock	XTAL	Output	Pins for a crystal resonator. An external clock signal can be input through the EXTAL pin.
	EXTAL	Input	
	XCIN	Input	Input/output pins for the sub-clock oscillator. Connect a crystal resonator between XCOUT and XCIN.
	XCOUT	Output	
	EXCIN	Input	External sub-clock input
	CLKOUT	Output	Clock output pin
Operating mode control	MD	Input	Pin for setting the operating mode. The signal level on this pin must not be changed during operation mode transition on release from the reset state.
System control	RES	Input	Reset signal input pin. The MCU enters the reset state when this signal goes low.
CAC	CACREF	Input	Measurement reference clock input pin
On-chip emulator	TMS	Input	On-chip emulator or boundary scan pins
	TDI	Input	
	TCK	Input	
	TDO	Output	
	TCLK	Output	Output clock for synchronization with the trace data
	TDATA0 to TDATA3	Output	Trace data output
	SWO	Output	Serial wire trace output pin
	SWDIO	I/O	Serial wire debug data input/output pin
	SWCLK	Input	Serial wire clock pin
Interrupt	NMI	Input	Non-maskable interrupt request pin
	IRQn	Input	Maskable interrupt request pins
	IRQn-DS	Input	Maskable interrupt request pins that can also be used in Deep Software Standby mode
GPT	GTETRGA, GTETRGB, GTETRGC, GTETRGD	Input	External trigger input pins
	GTIOCnA, GTIOCnB	I/O	Input capture, output compare, or PWM output pins
	GTADSM0, GTADSM1	Output	A/D conversion start request monitoring output pins

Table 1.15 Pin functions (2 of 5)

Function	Signal	I/O	Description
AGT	AGTEEn	Input	External event input enable signals
	AGTIOn	I/O	External event input and pulse output pins
	AGTOn	Output	Pulse output pins
	AGTOAn	Output	Output compare match A output pins
	AGTOBn	Output	Output compare match B output pins
ULPT	ULPTEEn	Input	External count control input
	ULPTEVIn	Input	External event input
	ULPTOn	Output	Pulse output
	ULPTOAn	Output	Output compare match A output
	ULPTOBn	Output	Output compare match B output
	ULPTEEn-DS	Input	External count control input that can also be used in Deep Software Standby mode1
	ULPTEVIn-DS	Input	External event input that can also be used in Deep Software Standby mode1
	ULPTOn-DS	Output	Pulse output that can also be used in Deep Software Standby mode1
	ULPTOAn-DS	Output	Output compare match A output that can also be used in Deep Software Standby mode1
	ULPTOBn-DS	Output	Output compare match B output that can also be used in Deep Software Standby mode1
RTC	RTCOUT	Output	Output pin for 1-Hz or 64-Hz clock
	RTCICn	Input	Time capture event input pins
SCI	SCKn	I/O	Input/output pins for the clock (clock synchronous mode)
	RXDn	Input	Input pins for received data (asynchronous mode/clock synchronous mode)
	TXDn	Output	Output pins for transmitted data (asynchronous mode/clock synchronous mode)
	CTSn_RTSn	I/O	Input/output pins for controlling the start of transmission and reception (asynchronous mode/clock synchronous mode), active-low.
	CTSn	Input	Input for the start of transmission.
	DEn	Output	Driver enable signal for RS-485
	SCLn	I/O	Input/output pins for the IIC clock (simple IIC mode)
	SDAn	I/O	Input/output pins for the IIC data (simple IIC mode)
	SCKn	I/O	Input/output pins for the clock (simple SPI mode)
	MISOn	I/O	Input/output pins for slave transmission of data (simple SPI mode)
	MOSIn	I/O	Input/output pins for master transmission of data (simple SPI mode)
	SSn	Input	Chip-select input pins (simple SPI mode), active-low
IIC	SCLn	I/O	Input/output pins for the clock
	SDAn	I/O	Input/output pins for data

Table 1.15 Pin functions (3 of 5)

Function	Signal	I/O	Description
SPI	RSPCKA, RSPCKB	I/O	Clock input/output pin
	MOSIA, MOSIB	I/O	Input or output pins for data output from the master
	MISOA, MISOB	I/O	Input or output pins for data output from the slave
	SSLA0, SSLB0	I/O	Input or output pin for slave selection
	SSLA1 to SSLA3, SSLB1 to SSLB3	Output	Output pins for slave selection
CANFD	CRXn	Input	Receive data
	CTXn	Output	Transmit data
USBFS	VCC_USB	Input	Power supply pin
	VSS_USB	Input	Ground pin
	USB_DP	I/O	D+ pin of the USB on-chip transceiver. Connect this pin to the D+ pin of the USB bus.
	USB_DM	I/O	D- pin of the USB on-chip transceiver. Connect this pin to the D- pin of the USB bus.
	USB_VBUS	Input	USB cable connection monitor pin. Connect this pin to VBUS of the USB bus. The VBUS pin status (connected or disconnected) can be detected when the USB module is operating as a function controller.
	USB_EXICEN	Output	Low-power control signal for external power supply (OTG) chip
	USB_VBUSEN	Output	VBUS (5 V) supply enable signal for external power supply chip
	USB_OVRCURA, USB_OVRCURB	Input	Connect the external overcurrent detection signals to these pins. Connect the VBUS comparator signals to these pins when the OTG power supply chip is connected.
	USB_OVRCURA-DS, USB_OVRCURB-DS	Input	Overcurrent pins for USBFS that can also be used in Deep Software Standby mode1. Connect the external overcurrent detection signals to these pins. Connect the VBUS comparator signals to these pins when the OTG power supply chip is connected.
	USB_ID	Input	Connect the MicroAB connector ID input signal to this pin during operation in OTG mode
OSPI	OM_SCLK	Output	Clock output (OCTACLK divided by 2)
	OM_SCLKN	Output	Inverted clock output (OCTACLK divided by 2)
	OM_CSn	Output	Chip select signal for an OctaFlash device, active-low
	OM_DQS	I/O	Read data strobe/write data mask signal
	OM_SIOn	I/O	Data input/output
	OM_RESET	Output	Reset signal for both slave devices, active-low
	OM_ECSINT1	Input	Error Correction Status and Interrupt for slave1
	OM_RSTO1	Input	Slave reset status for slave1
	OM_WP1	Output	Write Protect for slave1, active-low
SSIE	SSIBCK0, SSIBCK1	I/O	SSIE serial bit clock pins
	SSILRCK0/SSIFS0, SSILRCK1/SSIFS1	I/O	LR clock/frame synchronization pins
	SSITXD0	Output	Serial data output pin
	SSIRXD0	Input	Serial data input pin
	SSIDATA1	I/O	Serial data input/output pins
	AUDIO_CLK	Input	External clock pin for audio (input oversampling clock)

Table 1.15 Pin functions (4 of 5)

Function	Signal	I/O	Description
ETHERC	REF50CK0	Input	50-MHz reference clock. This pin inputs reference signal for transmission/reception timing in RMII mode.
	RMII0_CRS_DV	Input	Indicates carrier detection signals and valid receive data on RMII0_RXD1 and RMII0_RXD0 in RMII mode
	RMII0_TXDn	Output	2-bit transmit data in RMII mode
	RMII0_RXDn	Input	2-bit receive data in RMII mode
	RMII0_TXD_EN	Output	Output pin for data transmit enable signal in RMII mode
	RMII0_RX_ER	Input	Indicates an error occurred during reception of data in RMII mode
	ET0_CRS	Input	Carrier detection/data reception enable signal
	ET0_RX_DV	Input	Indicates valid receive data on ET0_ERXD3 to ET0_ERXD0
	ET0_EXOUT	Output	General-purpose external output pin
	ET0_LINKSTA	Input	Input link status from the PHY-LSI
	ET0_ETXDn	Output	4 bits of MII transmit data
	ET0_ERXDn	Input	4 bits of MII receive data
	ET0_TX_EN	Output	Transmit enable signal. Functions as signal indicating that transmit data is ready on ET0_ETXD3 to ET0_ETXD0.
	ET0_TX_ER	Output	Transmit error pin. Functions as signal notifying the PHY_LSI of an error during transmission.
	ET0_RX_ER	Output	Receive error pin. Functions as signal to recognize an error during reception.
	ET0_TX_CLK	Input	Transmit clock pin. This pin inputs reference signal for output timing from ET0_TX_EN, ET0_ETXD3 to ET0_ETXD0, and ET0_TX_ER.
	ET0_RX_CLK	Input	Receive clock pin. This pin inputs reference signal for input timing to ET0_RX_DV, ET0_ERXD3 to ET0_ERXD0, and ET0_RX_ER.
	ET0_COL	Input	Input collision detection signal
	ET0_WOL	Output	Receive Magic packets
	ET0_MDC	Output	Output reference clock signal for information transfer through ET0_MDIO
	ET0_MDIO	I/O	Input or output bidirectional signal for exchange of management data with PHY-LSI
Analog power supply	AVCC0	Input	Analog voltage supply pin. This is used as the analog power supply for the respective modules.
	AVSS0	Input	Analog ground pin. This is used as the analog ground for the respective modules. Supply this pin with the same voltage as the VSS pin.
	VREFH	Input	Analog reference voltage supply pin for the ADC12 (unit 1) and D/A Converter. Connect this pin to AVCC0 when not using the ADC12 (unit 1) and D/A Converter.
	VREFL	Input	Analog reference ground pin for the ADC12 and D/A Converter. Connect this pin to AVSS0 when not using the ADC12 (unit 1) and D/A Converter.
	VREFH0	Input	Analog reference voltage supply pin for the ADC12 (unit 0). Connect this pin to AVCC0 when not using the ADC12 (unit 0).
	VREFL0	Input	Analog reference ground pin for the ADC12. Connect this pin to AVSS0 when not using the ADC12 (unit 0).

Table 1.15 Pin functions (5 of 5)

Function	Signal	I/O	Description
ADC12	ANmn	Input	Input pins for the analog signals to be processed by the A/D converter. (m: ADC unit number, n: pin number)
	ADTRGm	Input	Input pins for the external trigger signals that start the A/D conversion, active-low.
DAC12	DA0	Output	Output pin for the analog signals processed by the D/A converter.
ACMPHS	VCOUT	Output	Comparator output pin
	IVREFn	Input	Reference voltage input pins for comparator
	IVCMPn	Input	Analog voltage input pins for comparator
I/O ports	Pmn	I/O	General-purpose input/output pins (m: port number, n: pin number)
	P200	Input	General-purpose input pin
CEU	VIO_D7 to VIO_D0	Input	CEU data bus pins
	VIO_CLK	Input	CEU clock pin
	VIO_VD	Input	CEU vertical sync pin
	VIO_HD	Input	CEU horizontal sync pin

1.6 Pin Assignments

The following figures show the pin assignments from the top view.

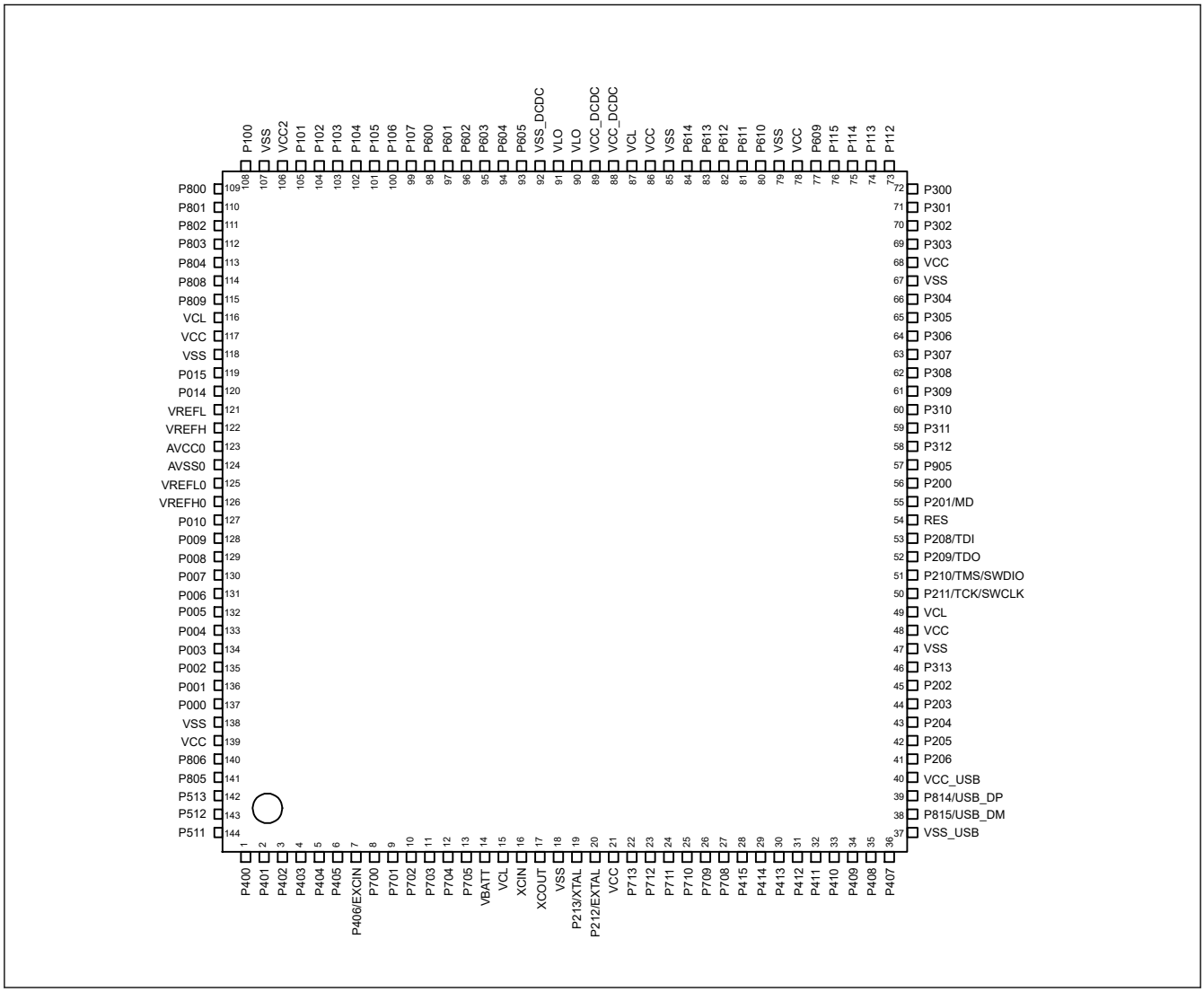


Figure 1.3 Pin assignment for LQFP 144-pin

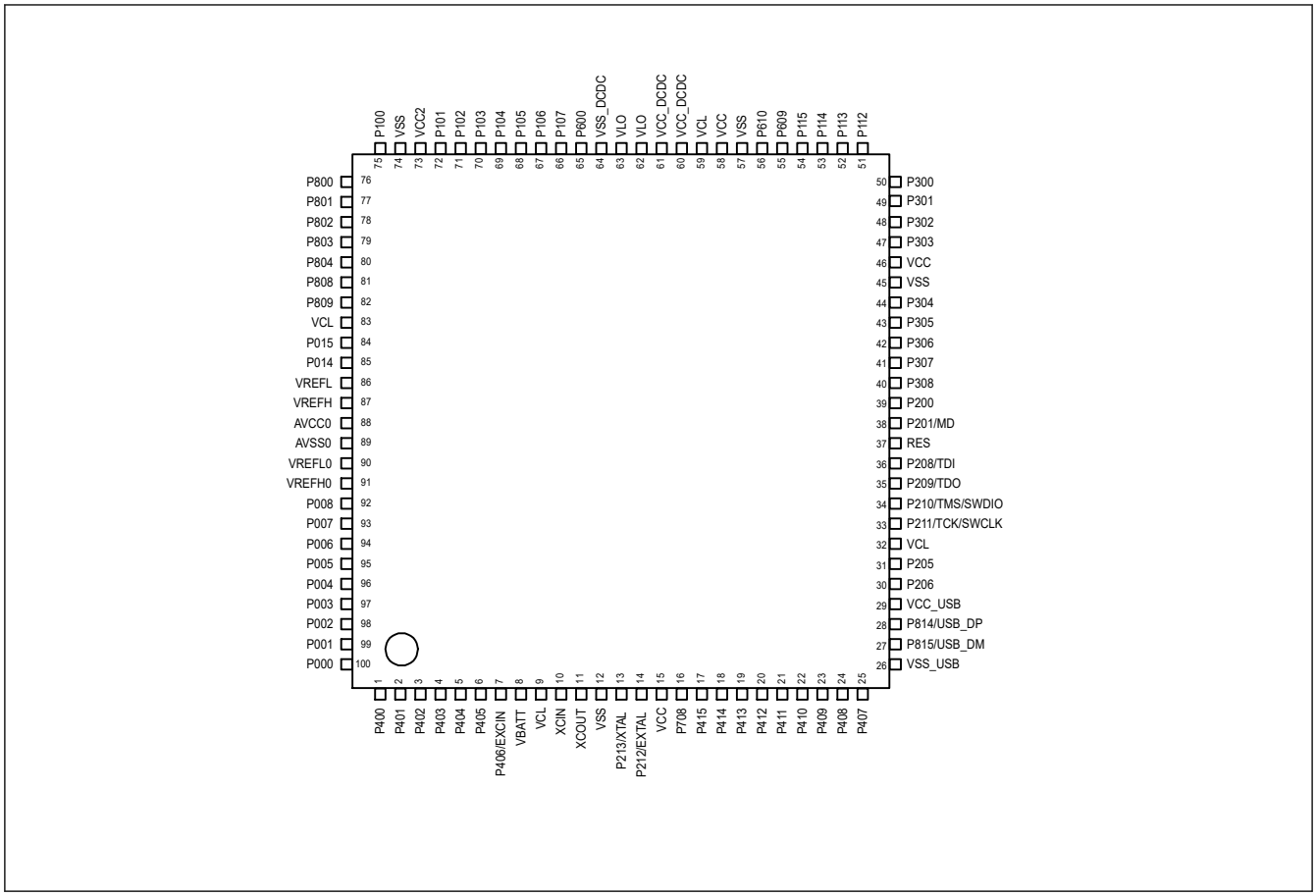


Figure 1.4 Pin assignment for LQFP 100-pin

1.7 Pin Lists

Table 1.16 Pin list (1 of 4)

LQFP144	LQFP100	Power, System, Clock, Debug, CAC	I/O ports	Ex. Interrupt	SCI/IIC/SPI/CANFD/USBFS/OSPI/SSIE/EHTERC(MII,RMII)	GPT/AGT/ULPT/RTC	ADC12/DAC12/ ACMPHS	CEU
1	1	-	P400	IRQ0	TXD1_A/MOSI1_A/SDA1_A/AUDIO_CLK/ET0_WOL/ ET0_WOL	AGTIO1	ADTRG1	VIO_D0
2	2	-	P401	IRQ5-DS	RXD1_A/MISO1_A/SCL1_A/CTX0/ET0_MDC/ET0_MDC	GTETRGA	-	VIO_D1
3	3	CACREF	P402	IRQ4-DS	SCK1_A/DE1/CRX0/AUDIO_CLK/ET0_MDIO/ET0_MDIO	RTCIC0	-	-
4	4	-	P403	IRQ14-DS	CTS_RTS4_A/SS4_A/DE1/SSIBCK0_A/ET0_LINKSTA/ ET0_LINKSTA	GTIOC3A/RTCIC1	-	-
5	5	-	P404	IRQ15-DS	CTS1_A/SSILRCK0/SSIFS0_A/ET0_EXOUT/ET0_EXOUT	GTIOC3B/RTCIC2	-	VIO_D3
6	6	-	P405	-	SCK2_B/DE2/SSITXD0_A/ET0_TX_EN/RMII0_TXD_EN_B	GTIOC1A/AGTIO1	-	VIO_D2
7	7	EXCIN	P406	-	TXD2_B/MOSI2_B/SDA2_B/SSLA3_C/SSIRXD0_A/ ET0_RX_ER/RMII0_TXD1_B	GTIOC1B	-	VIO_D3
8	-	-	P700	-	RXD2_B/MISO2_B/SCL2_B/MISOA_C/SSIDATA1_B/ ET0_ETXD1/RMII0_TXD0_B	GTIOC5A	-	VIO_D4
9	-	-	P701	-	CTS_RTS2_B/SS2_B/DE2/MOSIA_C/SSILRCK1/SSIFS1_B/ ET0_ETXD0/REF50CK0_B	GTIOC5B/ULPTO1	-	VIO_D5
10	-	-	P702	-	CTS2_B/RSPCKA_C/SSIBCK1_B/ET0_ERXD1/ RMII0_RXD0_B	ULPTO0	-	VIO_D6
11	-	-	P703	-	SSLA0_C/ET0_ERXD0/RMII0_RXD1_B	AGTO1	VCOUT	VIO_D7
12	-	-	P704	-	SSLA1_C/CTX0/ET0_RX_CLK/RMII0_RX_ER_B	GTADSM0/AGTO0	-	-
13	-	-	P705	-	CTS1_B/SSLA2_C/CRX0/ET0_CRS/RMII0_CRS_DV_B	GTADSM1/AGTIO0	-	-
14	8	VBATT	-	-	-	-	-	-
15	9	VCL	-	-	-	-	-	-
16	10	XCIN	-	-	-	-	-	-
17	11	XCOUT	-	-	-	-	-	-
18	12	VSS	-	-	-	-	-	-
19	13	XTAL	P213	IRQ2	TXD1_C/MOSI1_C/SDA1_C	GTETRGC/GTIOC0A/ ULPTEE0	ADTRG1	-
20	14	EXTAL	P212	IRQ3	RXD1_C/MISO1_C/SCL1_C	GTETRGD/GTIOC0B/ AGTEE1	-	-
21	15	VCC	-	-	-	-	-	-
22	-	-	P713	-	-	GTIOC2A/AGTOA0	-	-
23	-	-	P712	-	-	GTIOC2B/AGTOB0	-	-
24	-	-	P711	-	-	AGTEE0	-	-
25	-	-	P710	-	CTS4_B	-	-	VIO_VD
26	-	-	P709	IRQ10	CTS_RTS4_B/SS4_B/DE4	-	-	VIO_HD
27	16	CACREF	P708	IRQ11	SCK4_B/DE4/SSLB3_B/AUDIO_CLK	-	-	VIO_CLK
28	17	-	P415	IRQ8	TXD4_B/MOSI4_B/SDA4_B/SSLB2_B/CTX1	GTADSM0/GTIOC0A	-	-
29	18	-	P414	IRQ9	RXD4_B/MISO4_B/SCL4_B/SSLB1_B/CRX1	GTADSM1/GTIOC0B	-	-
30	19	-	P413	-	SSLB0_B	ULPTEE1	-	-
31	20	-	P412	-	CTS3_A/RSPCKB_B/USB_EXICEN	AGTEE1	-	-
32	21	-	P411	IRQ4	CTS_RTS3_A/SS3_A/DE3/MOSIB_B/USB_ID	AGTOA1	-	-
33	22	-	P410	IRQ5	SCK3_A/DE3/SCL0_A/MISOB_B/USB_OVRCURB-DS	AGTOB1	-	-
34	23	-	P409	IRQ6	TXD3_A/MOSI3_A/SDA3_A/SDA0_A/USB_OVRCURA-DS	ULPTOA0	-	-
35	24	-	P408	IRQ7	CTS4_A/RXD3_A/MISO3_A/SCL3_A/SCL0_B/ USB_VBUSEN	GTIOC10A/ULPTOB0	-	-
36	25	-	P407	-	CTS_RTS4_A/SS4_A/DE4/SDA0_B/SSLA3_A/USB_VBUS	GTIOC10B/AGTIO0/ RTCOUT	ADTRG0	-
37	26	VSS_USB	-	-	-	-	-	-
38	27	-	P815	-	CTX0/USB_DM	-	-	-
39	28	-	P814	-	CRX0/USB_DP	-	-	-
40	29	VCC_USB	-	-	-	-	-	-
41	30	-	P206	IRQ0-DS	RXD4_A/MISO4_A/SCL4_A/SDA1_B/SSLA2_A/ USB_VBUSEN/SSIDATA1_A	-	-	-

Table 1.16 Pin list (2 of 4)

LQFP144	LQFP100	Power, System, Clock, Debug, CAC	I/O ports	Ex. Interrupt	SCI/IIC/SPI/CANFD/USBFS/OSPI/SSIE/EHTERC(MII,RMII)	GPT/AGT/ULPT/RTC	ADC12/DAC12/ ACMPHS	CEU
42	31	CLKOUT	P205	IRQ1-DS	TXD4_A/MOSI4_A/SDA4_A/SCL1_B/SSLA1_A/ USB_OVRCURA/SSILRCK1/SSIFS1_A	GTIOC4A/AGTO1	-	-
43	-	CACREF	P204	-	SCK4_A/DE4/SSLA0_A/USB_OVRCURB/SSIBCK1_A	GTIOC4B/AGTIO1	-	-
44	-	-	P203	IRQ2-DS	RSPCKA_A/CTX0	GTIOC5A/ULPTOA1	-	-
45	-	-	P202	IRQ3-DS	MOSIA_A/CRX0	GTIOC5B/ULPTOB1	-	-
46	-	-	P313	-	CTS3_C/MISOA_A	-	-	-
47	-	VSS	-	-	-	-	-	-
48	-	VCC	-	-	-	-	-	-
49	32	VCL	-	-	-	-	-	-
50	33	TCK/SWCLK	P211	-	SCK9_B/DE9	GTIOC0A	-	-
51	34	TMS/SWDIO	P210	-	CTS_RTS9_B/SS9_B/DE9	GTIOC0B	-	-
52	35	TDO/SWO/CLKOUT	P209	-	TXD9_B/MOSI9_B/SDA9_B/CTX1	GTIOC1A	-	-
53	36	TDI	P208	IRQ3	RXD9_B/MISO9_B/SCL9_B/CRX1	GTIOC1B	VCOUT	-
54	37	RES	-	-	-	-	-	-
55	38	MD	P201	-	-	-	-	-
56	39	-	P200	NMI	-	-	-	-
57	-	-	P905	IRQ8	CTS3_B	-	-	-
58	-	-	P312	-	CTS_RTS3_B/SS3_B/DE3/CTX0/ET0_TX_CLK	GTADSM0/AGTOA1	-	-
59	-	-	P311	-	SCK3_B/DE3/CRX0/ET0_TX_ER	GTADSM1/AGTOB1	-	-
60	-	-	P310	-	TXD3_B/MOSI3_B/SDA3_B/ET0_ETXD2	AGTEE1	-	-
61	-	-	P309	-	RXD3_B/MISO3_B/SCL3_B/ET0_ETXD3	-	-	-
62	40	TCLK	P308	-	CTS9_B/ET0_MDC/ET0_MDC	ULPTOB1	-	-
63	41	TDATA0	P307	-	ET0_MDIO/ET0_MDIO	ULPTOA1	-	-
64	42	TDATA1	P306	-	ET0_TX_EN/RMII0_TXD_EN_A	ULPTEVI1	-	-
65	43	TDATA2	P305	IRQ8	ET0_RX_ER/RMII0_TXD1_A	ULPTEE1	-	-
66	44	TDATA3	P304	IRQ9	ET0_ETXD1/RMII0_TXD0_A	ULPTO1	-	-
67	45	VSS	-	-	-	-	-	-
68	46	VCC	-	-	-	-	-	-
69	47	-	P303	-	ET0_ETXD0/REF50CK0_A	-	-	-
70	48	-	P302	IRQ5	ET0_ERXD1/RMII0_RXD0_A	GTIOC4A/ULPTO0-DS	-	-
71	49	-	P301	IRQ6	ET0_ERXD0/RMII0_RXD1_A	GTIOC4B/AGTIO0/ ULPTEE0-DS	-	-
72	50	-	P300	IRQ4	SCK0_A/DE0/SSLA3_B/ET0_RX_CLK/RMII0_RX_ER_A	GTIOC3A/ULPTEVI0-DS	-	-
73	51	-	P112	-	TXD0_A/MOSI0_A/SDA0_A/SSLA2_B/SSIBCK0_B/ ET0_CRS/RMII0_CRS_DV_A	GTIOC3B/ULPTOB0-DS	-	-
74	52	-	P113	-	RXD0_A/MISO0_A/SCL0_A/SSLA1_B/SSILRCK0/ SSIFS0_B/ET0_EXOUT/ET0_EXOUT	GTIOC2A/ULPTOA0-DS	-	-
75	53	-	P114	-	CTS0_RTS0_A/SS0_A/DE0/SSLA0_B/SSIRXD0_B/ ET0_LINKSTA/ET0_LINKSTA	GTIOC2B	-	-
76	54	-	P115	-	CTS0_A/MOSIA_B/SSITXD0_B/ET0_WOL/ET0_WOL	GTIOC5A	-	-
77	55	-	P609	-	TXD0_C/MOSI0_C/SDA0_C/MISOA_B/CTX1/ET0_RX_DV	GTIOC5B/ULPTOA1-DS	-	-
78	-	VCC	-	-	-	-	-	-
79	-	VSS	-	-	-	-	-	-
80	56	-	P610	-	RXD0_C/MISO0_C/SCL0_C/RSPCKA_B/CRX1/ET0_COL	GTIOC4A/ULPTOB1-DS	-	-
81	-	CLKOUT/CACREF	P611	-	SCK0_C/DE0/MOSIA_B/ET0_ERXD2	GTIOC4B	-	-
82	-	-	P612	-	CTS_RTS0_C/SS0_C/DE0/SSLA0_B/ET0_ERXD3	-	-	-
83	-	-	P613	-	CTS0_C	GTETRGA/AGTO1	-	-
84	-	-	P614	-	-	GTETRGB/AGTO0	-	-
85	57	VSS	-	-	-	-	-	-
86	58	VCC	-	-	-	-	-	-
87	59	VCL	-	-	-	-	-	-

Table 1.16 Pin list (3 of 4)

LQFP144	LQFP100	Power, System, Clock, Debug, CAC	I/O ports	Ex. Interrupt	SCI/IIC/SPI/CANFD/USBFS/OSPI/SSIE/EHTERC(MII,RMII)	GPT/AGT/ULPT/RTC	ADC12/DAC12/ ACMPHS	CEU
88	60	VCC_DCDC	-	-	-	-	-	-
89	61	VCC_DCDC	-	-	-	-	-	-
90	62	VLO	-	-	-	-	-	-
91	63	VLO	-	-	-	-	-	-
92	64	VSS_DCDC	-	-	-	-	-	-
93	-	-	P605	-	CTS0_B	-	-	-
94	-	-	P604	-	CTS_RTS0_B/SS0_B/DE0	-	-	-
95	-	-	P603	-	TXD0_B/MOSI0_B/SDA0_B	ULPTO0	-	-
96	-	-	P602	-	RXD0_B/MISO0_B/SCL0_B	ULPTEE0	-	-
97	-	-	P601	-	SCK0_B/DE0/OM_WP1	ULPTEVI0/RTCOUT	-	-
98	65	CACREF	P600	-	OM_RSTO1	ULPTEVI1-DS	-	-
99	66	-	P107	-	OM_CS0	AGTOA0	-	-
100	67	-	P106	-	SSLB3_A/OM_RESET	AGTOB0/ULPTEE1-DS	-	-
101	68	-	P105	IRQ0	SSLB2_A/OM_ECSINT1	GTIOC1A/ULPTO1-DS	-	-
102	69	-	P104	IRQ1	CTS9_A/SSLB1_A/OM_CS1	GTETRGB/GTIOC1B	-	-
103	70	-	P103	-	CTS9_RTS9_A/SS9_A/DE9/SSLB0_A/CTX0/OM_SIO2	GTIOC2A	-	-
104	71	-	P102	-	TXD9_A/MOSI9_A/SDA9_A/RSPCKB_A/CRX0/OM_SIO4	GTIOC2B/AGTO0	ADTRG0	-
105	72	-	P101	IRQ1	RXD9_A/MISO9_A/SCL9_A/MOSIB_A/OM_SIO3	GTETRGB/AGTEE0	-	-
106	73	VCC2	-	-	-	-	-	-
107	74	VSS	-	-	-	-	-	-
108	75	-	P100	IRQ2	SCK9_A/DE9/MISOB_A/OM_SIO0	GTETRGA/AGTIO0	-	-
109	76	-	P800	IRQ11	CTS2_A/OM_SIO5	GTIOC11A/AGTOA0	-	-
110	77	-	P801	IRQ12	TXD2_A/MOSI2_A/SDA2_A/OM_DQS	GTIOC11B/AGTOB0	-	-
111	78	-	P802	-	RXD2_A/MISO2_A/SCL2_A/OM_SIO6	GTIOC12A	-	-
112	79	-	P803	-	SCK2_A/DE2/OM_SIO1	GTETRGC/GTIOC12B	-	-
113	80	-	P804	IRQ14	CTS_RTS2_A/SS2_A/DE2/OM_SIO7	GTETRGD/GTIOC13A	-	-
114	81	-	P808	IRQ15	OM_SCLK	GTIOC13B	-	-
115	82	-	P809	-	OM_SCLKN	-	-	-
116	83	VCL	-	-	-	-	-	-
117	-	VCC	-	-	-	-	-	-
118	-	VSS	-	-	-	-	-	-
119	84	-	P015	IRQ13	-	-	AN105	-
120	85	-	P014	-	-	-	AN007/DA0	-
121	86	VREFL	-	-	-	-	-	-
122	87	VREFH	-	-	-	-	-	-
123	88	AVCC0	-	-	-	-	-	-
124	89	AVSS0	-	-	-	-	-	-
125	90	VREFL0	-	-	-	-	-	-
126	91	VREFH0	-	-	-	-	-	-
127	-	-	P010	IRQ14	-	-	AN005/IVCMP0	-
128	-	-	P009	IRQ13-DS	-	-	AN006	-
129	92	-	P008	IRQ12-DS	-	-	AN008	-
130	93	-	P007	-	-	-	AN004	-
131	94	-	P006	IRQ11-DS	-	-	AN002/IVCMP3	-
132	95	-	P005	IRQ10-DS	-	-	AN001	-
133	96	-	P004	IRQ9-DS	-	-	AN000/IVCMP2	-
134	97	-	P003	-	-	-	AN104/IVREF1	-
135	98	-	P002	IRQ8-DS	-	-	AN102/IVCMP3	-
136	99	-	P001	IRQ7-DS	-	-	AN101/IVREF0	-

Table 1.16 Pin list (4 of 4)

LQFP144	LQFP100	Power, System, Clock, Debug, CAC	I/O ports	Ex. Interrupt	SCI/IIC/SPI/CANFD/USBFS/OSPI/SSIE/EHTERC(MII,RMII)	GPT/AGT/ULPT/RTC	ADC12/DAC12/ ACMPHS	CEU
137	100	-	P000	IRQ6-DS	-	-	AN100/IVCMP2	-
138	-	VSS	-	-	-	-	-	-
139	-	VCC	-	-	-	-	-	-
140	-	-	P806	IRQ0	-	-	-	-
141	-	-	P805	-	-	-	-	-
142	-	-	P513	-	-	-	IVCMP0	VIO_FLD
143	-	-	P512	IRQ14	SCL1_A/CTX1	GTIOC0A	-	-
144	-	-	P511	IRQ15	SDA1_A/CRX1	GTIOC0B	-	-

Note: Several pin names have the added suffix of _A, _B, and _C. These suffixes have special conditions for electrical characteristics.

2. Electrical Characteristics

Unless otherwise specified, minimum and maximum values are guaranteed by either design simulation, characterization results or test in production.

Supported peripheral functions and pins differ from one product name to another.

Unless otherwise specified, the electrical characteristics of the MCU are defined under the following conditions:

- VCC = VCC_DCDC = VCC_USB = VBATT = 1.68 to 3.6 V
- VCC2 = 1.65 to 3.6 V
- AVCC0 = 1.65 to 3.6 V
- VREFH0 = 2.7 V to AVCC0
- VREFH = 1.65 V to AVCC0
- VSS = VSS_DCDC = AVSS0 = VREFL0 /VREFL = VSS_USB = 0 V
- VCC voltage is lower than 2.7 V : LVOCR.LVO0E = 1, otherwise LVOCR.LVO0E = 0
- VCC2 voltage is lower than 2.7 V : LVOCR.LVO1E = 1, otherwise LVOCR.LVO1E = 0
- $T_j = T_{opj}$

When not specified otherwise, typical values are measured at room temperature of 25 °C and VCC = VCC_DCDC = VCC_USB = VBATT = AVCC0 = VREFH0 = VREFH = 3.3V.

Figure 2.1 shows the timing conditions.

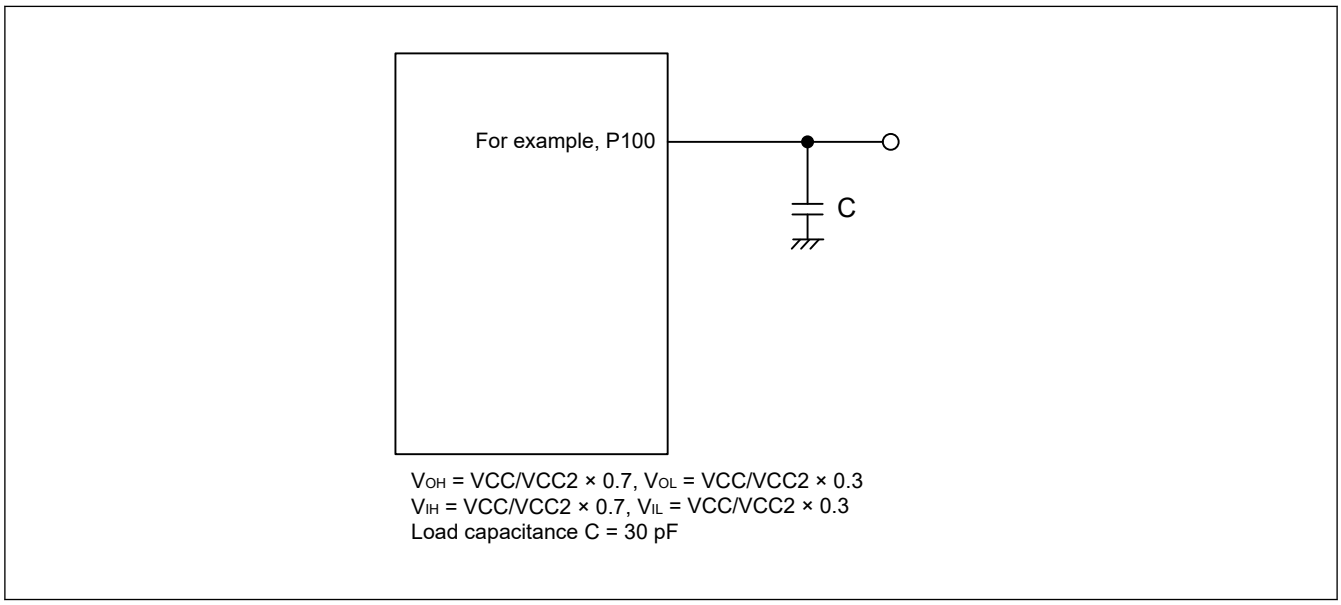


Figure 2.1 Input or output timing measurement conditions

The recommended measurement conditions for the timing specification of each peripheral provided are for the best peripheral operation. Make sure to adjust the driving abilities of each pin to meet your conditions.

2.1 Absolute Maximum Ratings

Table 2.1 Absolute maximum ratings (1 of 2)

Parameter	Symbol	Value	Unit
Power supply voltage	VCC, VCC2, VCC_DCDC, VCC_USB*2	–0.3 to +4.0	V
External power supply voltage	VCL	–0.3 to +1.6	V
VBATT power supply voltage	VBATT	–0.3 to +4.0	V

Table 2.1 Absolute maximum ratings (2 of 2)

Parameter	Symbol	Value	Unit
Input voltage (except for 5 V-tolerant ports*1)	V_{in}	–0.3 to VCC + 0.3 or –0.3 to VCC2 + 0.3	V
Input voltage (5 V-tolerant ports*1)	V_{in}	–0.3 to + VCC + 4.0 (max. 5.8)	V
Reference power supply voltage	VREFH/VREFH0	–0.3 to AVCC0 + 0.3	V
Analog power supply voltage	AVCC0	–0.3 to +4.0	V
Analog input voltage	V_{AN}	–0.3 to AVCC0 + 0.3	V
Operating junction temperature*3	T_{opj}	–40 to +105	°C
Storage temperature	T_{stg}	–55 to +125	°C

Note 1. Ports P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P715 and PB01 are 5 V tolerant.
Note 2. Connect VCC_DCDC and VCC_USB to VCC.
Note 3. See section 2.2.1. Tj/Ta Definition.

Caution: Permanent damage to the MCU might result if absolute maximum ratings are exceeded.

Table 2.2 Recommended operating conditions

Parameter	Symbol		Min	Typ	Max	Unit
Power supply voltages	VCC, VCC_DCDC	Other than the following	1.68	—	3.60	V
		When ETHERC/IIC Fast-mode+ is used	2.70	—	3.60	V
		When USB is used	3.00	—	3.60	V
	VCC2		1.65	—	3.60	V
	VCL	When external VDD is used*2	1.20	—	1.25	V
		When DCDC is used (High-speed mode)	—	1.21	—	V
		When DCDC is used (Low-speed mode or Software Standby mode)	—	1.18	—	V
	VSS, VSS_DCDC		—	0	—	V
USB power supply voltages	VCC_USB		—	VCC	—	V
	VSS_USB		—	0	—	V
VBATT power supply voltage	VBATT		1.62	—	3.60	V
Analog power supply voltages	AVCC0*1	When ADC is not used	1.65	—	3.60	V
		When ADC is used	2.70	—	3.60	V
	AVSS0		—	0	—	V

Note 1. When the A/D converter, the D/A converter and the High-Speed Analog Comparator are not in use, do not leave the AVCC0, VREFH/VREFH0, AVSS0, and VREFL/VREFL0 pins open. Connect the AVCC0 and VREFH/VREFH0 pins to VCC, and the AVSS0 and VREFL/VREFL0 pins to VSS, respectively.
Note 2. VCL voltage must never be higher than VCC voltage.

2.2 DC Characteristics

2.2.1 Tj/Ta Definition

Table 2.3 DC characteristics

Parameter	Symbol	Typ	Max	Unit	Test conditions
Permissible operating junction temperature	T_j	—	105	°C	High-speed mode Low-speed mode

Note: Make sure that $T_j = T_a + \theta_{ja} \times$ total power consumption (W), where total power consumption = $(VCC - V_{OH}) \times \Sigma I_{OH} + V_{OL} \times \Sigma I_{OL} + (I_{CC}max + I_{CC\_DCDC}max) \times VCC$.

Note: Minimum Ambient Temperature(Ta) is -40℃

2.2.2 I/O V_{IH}, V_{IL}

Table 2.4 I/O V_{IH}, V_{IL} except for Schmitt trigger input pins

Parameter		VCC/VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit
Peripheral function pins	EXTAL (external clock input), WAIT, SPI*1 (except RSPCK)	1.68 V or above	V_{IH}	VCC × 0.8	—	—	V
			V_{IL}	—	—	VCC × 0.2	
	SPI*2 (except RSPCKB_A)	1.65 V or above	V_{IH}	VCC2 × 0.8	—	—	
			V_{IL}	—	—	VCC2 × 0.2	
	OSPI (except OM_RSTO1 and OM_ECSINT1)	2.70 V or above	V_{IH}	VCC2 × 0.8	—	—	
			V_{IL}	—	—	VCC2 × 0.2	
		1.65 V or above	V_{IH}	VCC2 × 0.7	—	VCC2 + 0.3	
			V_{IL}	VSS - 0.3	—	VCC2 × 0.3	
	TMS, TDI, TCK, SWDIO, SWCLK	1.68 V or above	V_{IH}	VCC × 0.7	—	—	
			V_{IL}	—	—	VCC × 0.3	
	ETHERC	2.70 V or above	V_{IH}	2.3	—	—	
			V_{IL}	—	—	VCC × 0.2	
	IIC (SMBus)	2.70 V or above	V_{IH}	2.1	—	VCC + 3.6 (max 5.8)	
			V_{IL}	—	—	0.8	
	RTCIC0, RTCIC1, RTCIC2, EXCIN when VCC power supply is selected	1.68 V or above	V_{IH}	0.9	—	3.9	
			V_{IL}	—	—	0.3	
	RTCIC0, RTCIC1, RTCIC2, EXCIN when VBATT power supply is selected		V_{IH}	0.9	—	3.9	
			V_{IL}	—	—	0.3	

Note 1. SPI0_A, SPI0_B, SPI0_C and SPI1_B
Note 2. SPI1_A
Note 3. RES and peripheral function pins associated with P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins).
Note 4. All input pins except for the peripheral function pins already described in the table. There is an item for each power supply voltage for each port. Refer to the IO chapter for the power supply of the port.
Note 5. P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins).
Note 6. All input pins except for the ports already described in the table. There is an item for each power supply voltage for each port. Refer to the IO chapter for the power supply of the port.
Note 7. When VCC is less than 1.68 V, the input voltage of 5 V-tolerant ports should be less than 3.6 V, otherwise breakdown may occur because 5 V-tolerant ports are electrically controlled so as not to violate the break down voltage.

Table 2.5 I/O V_{IH}, V_{IL} of Schmitt trigger input pins

Parameter		VCC/VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit
Peripheral function pins	IIC (except for SMBus)	1.68 V or above	V_{IH}	VCC × 0.7	—	VCC + 3.6 (max 5.8)	V
			V_{IL}	—	—	VCC × 0.3	
			ΔV_T	VCC × 0.05	—	—	
	5 V-tolerant ports*3*7	1.68 V or above	V_{IH}	VCC × 0.8	—	VCC + 3.6 (max 5.8)	
			V_{IL}	—	—	VCC × 0.2	
			ΔV_T	VCC × 0.05	—	—	
	Other VCC input pins*4	1.68 V or above	V_{IH}	VCC × 0.8	—	—	
			V_{IL}	—	—	VCC × 0.2	
			ΔV_T	VCC × 0.05	—	—	
	Other VCC2 input pins*4	1.65 V or above	V_{IH}	VCC2 × 0.8	—	—	
			V_{IL}	—	—	VCC2 × 0.2	
			ΔV_T	VCC2 × 0.05	—	—	
	Other AVCC0 input pins*4	1.65 V or above	V_{IH}	AVCC0 × 0.8	—	—	
			V_{IL}	—	—	AVCC0 × 0.2	
			ΔV_T	AVCC0 × 0.05	—	—	
Ports	5 V-tolerant port*5*7	1.68 V or above	V_{IH}	VCC × 0.8	—	VCC + 3.6 (max 5.8)	V
			V_{IL}	—	—	VCC × 0.2	
	Other VCC input pins*6	1.68 V or above	V_{IH}	VCC × 0.8	—	—	
			V_{IL}	—	—	VCC × 0.2	
	Other VCC2 input pins*6	1.65 V or above	V_{IH}	VCC2 × 0.8	—	—	
			V_{IL}	—	—	VCC2 × 0.2	
	Other AVCC0 input pins*6	1.65 V or above	V_{IH}	AVCC0 × 0.8	—	—	
			V_{IL}	—	—	AVCC0 × 0.2	

Note 1. SPI0_A, SPI0_B, SPI0_C and SPI1_B
Note 2. SPI1_A
Note 3. RES and peripheral function pins associated with P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins).
Note 4. All input pins except for the peripheral function pins already described in the table. There is an item for each power supply voltage for each port. Refer to the IO chapter for the power supply of the port.
Note 5. P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins).
Note 6. All input pins except for the ports already described in the table. There is an item for each power supply voltage for each port. Refer to the IO chapter for the power supply of the port.
Note 7. When VCC is less than 1.68 V, the input voltage of 5 V-tolerant ports should be less than 3.6 V, otherwise breakdown may occur because 5 V-tolerant ports are electrically controlled so as not to violate the break down voltage.

2.2.3 I/O I_{OH}, I_{OL}

Table 2.6 I/O I_{OH}, I_{OL} (1 of 2)

Parameter			VCC/ VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit
Permissible output current (average value per pin)	Ports P000 to P010, P014, P015, P201	—	—	I_{OH}	—	—	−2.0	mA
				I_{OL}	—	—	2.0	mA
	Ports P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins)	Low drive*1	—	I_{OH}	—	—	−2.0	mA
				I_{OL}	—	—	2.0	mA
		Middle drive*2	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		High drive*3	—	I_{OH}	—	—	−20	mA
				I_{OL}	—	—	20.0	mA
	Ports P100 to P103, P304 to P308, P800 to P804, P808 to P809 (total 16 pins)	Low drive*1	—	I_{OH}	—	—	−2.0	mA
				I_{OL}	—	—	2.0	mA
		Middle drive*2	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		High drive*3	—	I_{OH}	—	—	−16	mA
				I_{OL}	—	—	16.0	mA
		High-speed high drive*4	—	I_{OH}	—	—	−20	mA
				I_{OL}	—	—	20.0	mA
	Other output pins*5	Low drive*1	—	I_{OH}	—	—	−2.0	mA
				I_{OL}	—	—	2.0	mA
		Middle drive*2	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		High drive*3	—	I_{OH}	—	—	−16	mA
				I_{OL}	—	—	16.0	mA

Table 2.6 I/O I_{OH}, I_{OL} (2 of 2)

Parameter			VCC/ VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit
Permissible output current (max value per pin)	Ports P000 to P010, P014, P015, P201	—	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
	Ports P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins)	Low drive*1	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		Middle drive*2	—	I_{OH}	—	—	−8.0	mA
				I_{OL}	—	—	8.0	mA
		High drive*3	—	I_{OH}	—	—	−40	mA
				I_{OL}	—	—	40.0	mA
	Ports P100 to P103, P304 to P308, P800 to P804, P808 to P809 (total 16 pins)	Low drive*1	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		Middle drive*2	—	I_{OH}	—	—	−8.0	mA
				I_{OL}	—	—	8.0	mA
		High drive*3	—	I_{OH}	—	—	−32	mA
				I_{OL}	—	—	32.0	mA
		High-speed high drive*4	—	I_{OH}	—	—	−40	mA
				I_{OL}	—	—	40.0	mA
	Other output pins*5	Low drive*1	—	I_{OH}	—	—	−4.0	mA
				I_{OL}	—	—	4.0	mA
		Middle drive*2	—	I_{OH}	—	—	−8.0	mA
				I_{OL}	—	—	8.0	mA
		High drive*3	—	I_{OH}	—	—	−32	mA
				I_{OL}	—	—	32.0	mA
Permissible output current (max value of total of all pins)	Maximum of all output pins	VCC I/O	1.68 V or above	$\Sigma I_{OH\ (max)}$	—	—	−80	mA
		VCC2 I/O	1.65 V or above		—	—	−80	
		AVCC0 I/O	1.65 V or above		—	—	−33	
		VCC and VCC2 I/O	1.65 V or above	$\Sigma I_{OL\ (max)}$	—	—	80	mA
		AVCC0 I/O	1.65 V or above		—	—	33	

Note 1. This is the value when low driving ability is selected in the Port Drive Capability bit in the PmnPFS register. The selected driving ability except for 400 and P401 is retained in Deep Software Standby mode.
Note 2. This is the value when middle driving ability is selected in the Port Drive Capability bit in the PmnPFS register. The selected driving ability except for 400 and P401 is retained in Deep Software Standby mode.
Note 3. This is the value when high driving ability is selected in the Port Drive Capability bit in the PmnPFS register. The selected driving ability except for 400 and P401 is retained in Deep Software Standby mode.
Note 4. This is the value when high-speed high driving ability is selected in the Port Drive Capability in the PmnPFS register. The selected driving ability is retained in Deep Software Standby mode.
Note 5. Except for P200, which is an input port.

Caution: To protect the reliability of the MCU, the output current values should not exceed the values in this table. The average output current indicates the average value of current measured during 100 µs.

2.2.4 I/O V_{OH}, V_{OL}, and Other Characteristics

Table 2.7 I/O V_{OH}, V_{OL}, and other characteristics (1 of 2)

Parameter		VCC/VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit	Test conditions
Output voltage	IIC	2.70 V or above	V_{OL}	—	—	0.4	V	I_{OL} = 3.0 mA
			V_{OL}	—	—	0.6		I_{OL} = 6.0 mA
		1.68 V or above	V_{OL}	—	—	VCC × 0.2		I_{OL} = 3.0 mA
			V_{OL}	—	—	0.6		I_{OL} = 6.0 mA
	IIC*1	2.70 V or above	V_{OL}	—	—	0.4		I_{OL} = 15.0 mA (ICFER.FMPE = 1)
			V_{OL}	—	0.4	—		I_{OL} = 20.0 mA (ICFER.FMPE = 1)
	ETHERC	2.70 V or above	V_{OH}	VCC − 0.5	—	—		I_{OH} = −1.0 mA
			V_{OL}	—	—	0.4		I_{OL} = 1.0 mA
	Ports P205, P206, P402 to P404, P406 to P415, P511, P512, P709 to P713 (total 22 pins)*2	—	V_{OH}	VCC − 1.0	—	—		I_{OH} = −20 mA VCC = 3.3 V
		—	V_{OL}	—	—	1		I_{OL} = 20 mA VCC = 3.3 V
	Other output pins	1.68 V or above	V_{OH}	VCC − 0.5	—	—		I_{OH} = −1.0 mA
			V_{OL}	—	—	0.5		I_{OL} = 1.0 mA
		1.65V or above	V_{OH}	VCC2 − 0.5	—	—		I_{OH} = −1.0 mA
			V_{OL}	—	—	0.5		I_{OL} = 1.0 mA
			V_{OH}	AVCC0 − 0.5	—	—		I_{OH} = −1.0 mA
			V_{OL}	—	—	0.5		I_{OL} = 1.0 mA
Input leakage current	RES	1.68 V or above	$\|I_{in}\|$	—	—	5.0	µA	V_{in} = 0 V V_{in} = 5.5 V
	Port P200	1.68 V or above		—	—	1.0		V_{in} = 0 V V_{in} = VCC
Three-state leakage current (off state)	5 V-tolerant ports	1.68 V or above	$\|I_{TSI}\|$	—	—	5.0	µA	V_{in} = 0 V V_{in} = 5.5 V
	Other ports (except for port P200)	1.68 V or above		—	—	1.0		V_{in} = 0 V V_{in} = VCC
		1.65 V or above		—	—	1.0		V_{in} = 0 V V_{in} = VCC2, AVCC0
Input pull-up MOS current	Ports P0 to P9	2.70 V or above	I_p	−300	—	−10	µA	VCC, VCC2, AVCC0 = 2.7 to 3.6 V V_{in} = 0 V
		1.68 V or above		−300	—	−5	µA	VCC = 1.68 to 3.6 V V_{in} = 0 V
		1.65 V or above		−300	—	−5	µA	VCC2, AVCC0 = 1.65 to 3.6 V V_{in} = 0 V

Table 2.7 I/O V_{OH}, V_{OL}, and other characteristics (2 of 2)

Parameter		VCC/VCC2/ AVCC0	Symbol	Min	Typ	Max	Unit	Test conditions
Input capacitance	Ports P014, P015	—	C_{in}	—	—	16	pF	Vbias = 0 V Vamp = 20 mV f = 1 MHz Ta = 25°C
	Ports P814/ USB_DP, P815/ USB_DM	—		—	—	12		
	Ports P400, P401, P409, P410, P511, P512	—		—	—	10		
	Other input pins	—		—	—	8		

Note 1. SCL0_A, SDA0_A, SCL1_A, SDA1_A (total 4 pins).
Note 2. This is the value when high driving ability is selected in the Port Drive Capability bit in the PmnPFS register. The selected driving ability is retained in Deep Software Standby mode.

2.2.5 Operating and Standby Current

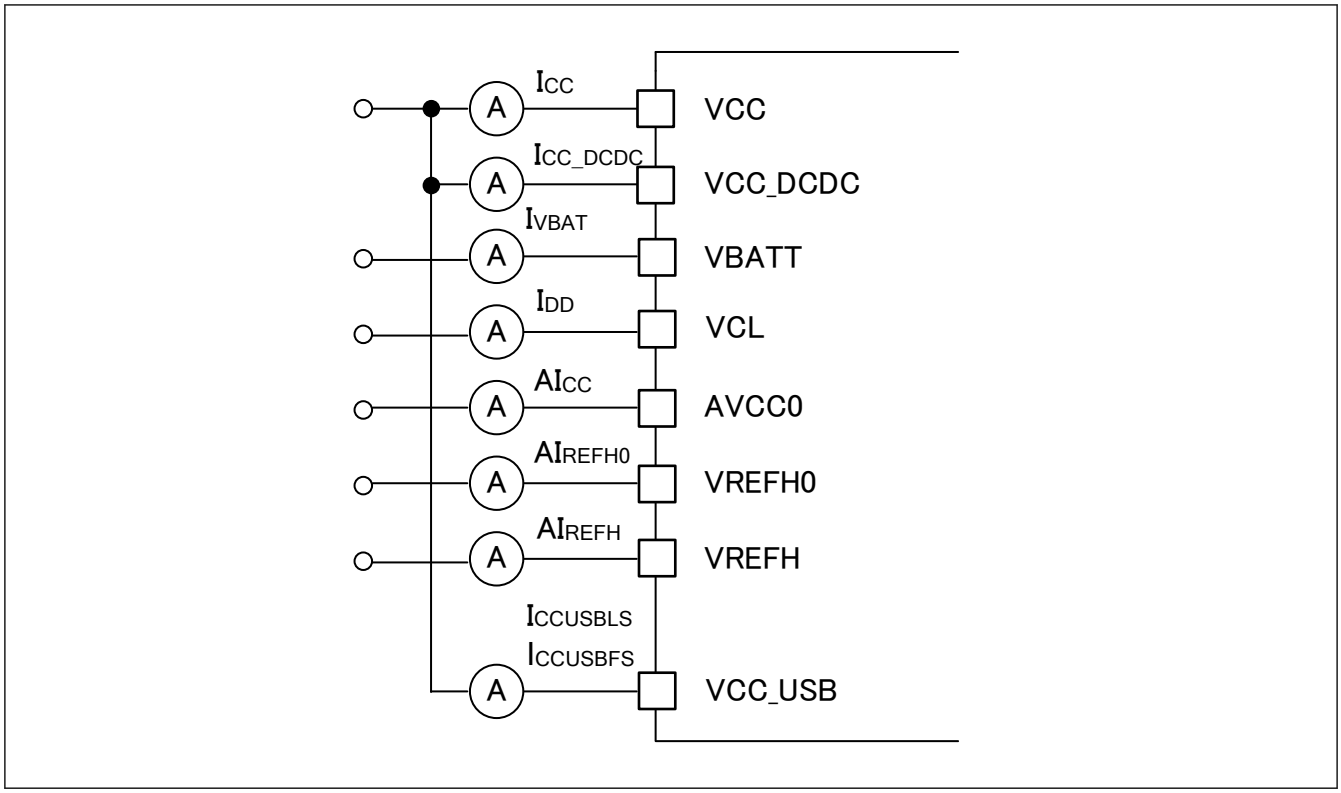


Figure 2.2 Consumption current measurement diagram

Table 2.8 Current of high-speed mode, maximum condition (MVE and peripheral operation) (DCDC mode)

Parameter			Symbol	Typ	Max	Unit	Test conditions
Supply current *1*2	—		I_{CC}	2.8	7.05	mA	
	CPUCLK = 360 MHz	VCC_DCDC ≧ 2.5 V	I_{CC_DCDC}*5	122	243	mA	VCC_DCDC = 3.3 V CPUCLK = 360 MHz, ICLK = 120 MHz, PCLKA = 120 MHz, PCLKB = 60 MHz, PCLKC = 60 MHz, PCLKD = 120 MHz, PCLKE = 120 MHz, FCLK = 60 MHz
			I_{DD}*3	287	501		
		VCC_DCDC < 2.5 V	I_{CC_DCDC}*5	224	320		VCC_DCDC = 1.8 V
			I_{DD}	287	400*4		
	CPUCLK = 240 MHz	VCC_DCDC ≧ 2.5 V	I_{CC_DCDC}*5	95	210	mA	VCC_DCDC = 3.3 V CPUCLK = 240 MHz, ICLK = 240 MHz, PCLKA = 120 MHz, PCLKB = 60 MHz, PCLKC = 60 MHz, PCLKD = 120 MHz, PCLKE = 120 MHz, FCLK = 60 MHz
			I_{DD}*3	224	432		
		VCC_DCDC < 2.5 V	I_{CC_DCDC}*5	175	320		VCC_DCDC = 1.8 V
			I_{DD}	224	400*4		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Measured with clocks supplied to the peripheral functions and peripherals being operated. This does not include the BGO operation.
Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.68 × f CPUCLK + 0.41 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 4. Do not actual consumption current during operation exceed the current value described here in VCC_DCDC < 2.5V.
Note 5. Typical DCDC efficiency is applied.

Table 2.9 Current of high-speed mode, maximum condition (MVE and peripheral operation) (External VDD mode)

Parameter	CPUCLK Frequency	Symbol	Typ	Max	Unit	Test conditions
Supply current*1 *2	—	I_{CC}	2.8	7.05	mA	
	CPUCLK = 360 MHz	I_{DD}*3	287	501	mA	CPUCLK = 360 MHz, ICLK = 120 MHz, PCLKA = 120 MHz, PCLKB = 60 MHz, PCLKC = 60 MHz, PCLKD = 120 MHz, PCLKE = 120 MHz, FCLK = 60 MHz
	CPUCLK = 240 MHz	I_{DD}*3	224	432	mA	CPUCLK = 240 MHz, ICLK = 240 MHz, PCLKA = 120 MHz, PCLKB = 60 MHz, PCLKC = 60 MHz, PCLKD = 120 MHz, PCLKE = 120 MHz, FCLK = 60 MHz

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Measured with clocks supplied to the peripheral functions and peripherals being operated. This does not include the BGO operation.
Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.68 × f CPUCLK + 0.41 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)

Table 2.10 Current of high-speed mode, maximum data processing (MVE operation), peripheral clock ON (DCDC mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2	CPUCLK = 360 MHz	I_{CC_DCDC}*4	119	228	mA	VCC_DCDC = 3.3 V *5
		I_{DD}*3	279	469		
	CPUCLK = 240 MHz	I_{CC_DCDC}*4	92	194		
		I_{DD}*3	215	399		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Measured with clocks supplied to the peripheral functions and peripherals being operated. This does not include the BGO operation.

Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.67 × f CPUCLK + 0.29 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 4. Typical DCDC efficiency is applied.
Note 5. Same frequency condition is applied as in the maximum condition.

Table 2.11 Current of high-speed mode, maximum data processing (MVE operation), peripheral clock ON (External VDD mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2	CPUCLK = 360 MHz	I_{DD}*3	279	469	mA	*4
	CPUCLK = 240 MHz	I_{DD}*3	215	399		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Measured with clocks supplied to the peripheral functions and peripherals being operated. This does not include the BGO operation.
Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.67 × f CPUCLK + 0.29 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 4. Same frequency condition is applied as in the maximum condition.

Table 2.12 Current of high-speed mode, maximum data processing (MVE operation), peripheral clock OFF (DCDC mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2	CPUCLK = 360 MHz	I_{CC_DCDC}*4	111	216	mA	VCC_DCDC = 3.3 V *5
		I_{DD}*3	261	445		
	CPUCLK = 240 MHz	I_{CC_DCDC}*4	83	181		
		I_{DD}*3	194	373		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.
Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.68 × f CPUCLK + 0.17 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 4. Typical DCDC efficiency is applied.
Note 5. Same frequency condition is applied as in the maximum condition.

Table 2.13 Current of high-speed mode, maximum data processing (MVE operation), peripheral clock OFF (External VDD mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2	CPUCLK = 360 MHz	I_{DD}*3	261	445	mA	*4
	CPUCLK = 240 MHz	I_{DD}*3	194	373		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.
Note 3. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Max. = 0.68 × f CPUCLK + 0.17 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 4. Same frequency condition is applied as in the maximum condition.

Table 2.14 Current of high-speed mode, CPU Sleep mode (DCDC mode and External VDD mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*3*4	CPUCLK = 240 MHz	I_{DD}*2	29	216	mA	—

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. I_{DD} depends on f (CPUCLK and ICLK) as follows.
I_{DD} Typ. = 0.063 × f CPUCLK + 0.13 × fICLK + 17.6 (unit : mA, fCPUCLK and fICLK are MHz)
I_{DD} Max. = 0.063 × f CPUCLK + 0.13 × fICLK + 175 (unit : mA, fCPUCLK and fICLK are MHz)
Note 3. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.
Note 4. ICLK, FCLK, PCLKA, PCLKB, PCLKC, PCLKD and PCLKE are set to divided by 64.

Table 2.15 Current of high-speed mode, CPU Deep Sleep mode (DCDC mode and External VDD mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1*3*4	CPUCLK = 240 MHz	I_{DD}*2	12	85	mA	—

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. I_{DD} depends on f (ICLK) as follows.
I_{DD} Typ. = 0.13 × fICLK + 5 (unit : mA, fCPUCLK and fICLK are MHz)
I_{DD} Max. = 0.13 × fICLK + 69 (unit : mA, fCPUCLK and fICLK are MHz)
Note 3. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.
Note 4. ICLK, FCLK, PCLKA, PCLKB, PCLKC, PCLKD and PCLKE are set to divided by 64.

Table 2.16 Increase during BGO operation (DCDC mode and External VDD mode)

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current*1	Data flash P/E	I_{CC}	6	—	mA	—
	Code flash P/E		8	—		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.

Table 2.17 Current of Low-speed mode (DCDC mode)

Parameter	Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2*3	I_{DD}	14.5	—	mA	CPUCLK = ICLK = 1MHz

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.
Note 3. FCLK, PCLKA, PCLKB, PCLKC, PCLKD and PCLKE are set to divided by 64 (15.6 kHz).

Table 2.18 Standby current (DCDC mode)

Parameter				Symbol	Typ	Max	Unit	Test conditions
Supply current*1	Software Standby mode*2			I_{CC}	0.02	0.94	mA	—
	Data of SRAM and TCM is retained			I_{CC_DCDC}	0.88	28.29		VCC_DCDC = 3.3 V PDRAMSCR0.RKEEPn = 1 (n = 0 to 6) PDRAMSCR1.RKEEP0 = 1
	Data of SRAM and TCM is not retained			I_{CC_DCDC}	0.83	26.64		VCC_DCDC = 3.3 V PDRAMSCR0.RKEEPn = 0 (n = 0 to 6) PDRAMSCR1.RKEEP0 = 0
	Deep Software Standby mode 1			I_{CC}	5.21	148	μA	—
				I_{CC_DCDC}	0.57	5.50		—
		Increase when the function is activated	Data of Standby SRAM is retained	I_{CC}	0.12	2.60		—
			PVD0, PVD1,PVD2 or Battery power supply switch		See Table 2.20			—
			When the LOCO is in use		3.10	—		—
			Crystal oscillator and RTC		See Table 2.21			—
			IWDT and ULPT(all units) are operating		0.07	—		—
	Deep Software Standby mode 2			I_{CC}	1.68	43.99		—
				I_{CC_DCDC}	0.57	5.50		—
		Increase when the function is activated	PVD0, PVD1,PVD2 or Battery power supply switch	I_{CC}	See Table 2.20			—
			Crystal oscillator and RTC		See Table 2.21			—
	Deep Software Standby mode 3			I_{CC}	0.99	42.90		—
				I_{CC_DCDC}	0.57	5.50		—
		Increase when the function is activated	Crystal oscillator and RTC		See Table 2.21			—
	RTC operating while VCC is off (with the battery backup function, only the RTC operate)	When a crystal oscillator with low power mode 3 is in use		I_{VBAT}	0.52	—		VBATT=1.8 V, VCC=0 V
					1.05	—		VBATT=3.3 V, VCC=0 V
		When a crystal oscillator with low power mode 2 is in use			0.56	—		VBATT=1.8 V, VCC=0 V
					1.10	—		VBATT=3.3 V, VCC=0 V
		When a crystal oscillator with low power mode 1 is in use			0.62	—		VBATT=1.8 V, VCC=0V
					1.17	—		VBATT=3.3 V, VCC=0 V
		When a crystal oscillator with standard mode is in use			0.93	—		VBATT=1.8 V, VCC=0 V
					1.50	—		VBATT=3.3 V, VCC=0 V
		When EXCIN is in use			0.37	—		VBATT=1.8 V, VCC=0 V
					0.86	—		VBATT=3.3 V, VCC=0 V
		Increase when the function is activated	Common circuit when using RTCICn (n = 0~2) input or EXCIN		0.04	—		VBATT=1.8 V, VCC=0 V
					0.04	—		VBATT=3.3 V, VCC=0 V
			RTCICn (n = 0～2) input is in use per channel		0.02	—		VBATT=1.8 V, VCC=0 V
					0.02	—		VBATT=3.3 V, VCC=0 V

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. When an external clock is used, EXTAL pin is pull-up or pull-down. In case clock is toggled, software standby mode current consumption is increased by 130μA at 48MHz under typical conditions.

Table 2.19 Coremark and normal mode current (DCDC and External power supply mode)

Parameter			Symbol	Typ	Max	Unit	Test conditions
Supply current*1*2	Coremark	Cache off, executing from flash	I_{DD}	165	—	µA/MHz	CPUCLK = 360 MHz ICLK = 120 MHz PCLKA = 30 MHz PCLKB = 30 MHz PCLKC = 30 MHz PCLKD = 30 MHz PCLKE = 30 MHz FCLK = 30 MHz
	Normal mode	All peripheral disabled, Cache off, while (1) code executing from flash		137	—		

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. Supply of the clock signal to peripherals is stopped in this state. This does not include the BGO operation.

Table 2.20 Increase when the PVD0, PVD1, PVD2 or Battery power supply switch is enabled in Deep Software Standby mode 1 and 2.

Parameter		Symbol	Typ	Max	Unit	Test conditions
Supply current	Common circuit when enabling PVDn (n = 0 to 2) or Battery power supply switch in Deep Software Standby mode 1	I_{CC}	4.51	—	µA	—
	Common circuit when enabling PVDn (n = 0 to 2) or Battery power supply switch in Deep Software Standby mode 2		4.97	—		—
	PVD0 enabled with OFS1(_SEC).PVDLPSEL = 1		2.16	—		—
	PVD1 enabled		2.16	—		—
	PVD2 enabled		2.16	—		—
	Battery power supply switch enabled with following conditions.*1 ● Battery power supply switch enable (VBTBPCR1.BPWSWSTP = 0), voltage monitor 0 reset enable (OFS1(_SEC).PVDAS = 0) and low power consumption function of PVD0 disable (OFS1(_SEC).PVDLPSEL = 1). ● Battery power supply switch enable (VBTBPCR1.BPWSWSTP=0) and voltage monitor 0 reset disable (OFS1(_SEC).PVDAS = 1).		2.16	—		—

Note 1. Consumption current is not increased in other condition.

Table 2.21 Increase when the sub-clock oscillator and RTC are enabled in Deep Software Standby mode 1, 2 and 3.

Parameter			Symbol	Typ	Max	Unit	Test conditions
Supply current	When a crystal oscillator is in use	Low Power mode 3	I_{CC}	0.22	—	µA	—
		Low Power mode 2		0.27	—		—
		Low Power mode 1		0.34	—		—
		Standard mode		0.67	—		—
	RTC is operating			0.33	—		—

Table 2.22 Inrush current

Parameter				Symbol	Typ	Max	Unit	Test conditions
Supply current	Inrush current on returning from deep software standby mode	Inrush current of VCC_DCDC*1	DPSBYCR.DCSSMODE = 0	I_{RUSH}	—	630	mA	—
			DPSBYCR.DCSSMODE = 1		—	1020		—

Note 1. Reference value

Table 2.23 Operating current (Analog)

Parameter				Symbol	Typ	Max	Unit	Test conditions
Supply current *1	Oscillator	Main clock oscillator		I_{CC}	0.48	—	mA	MOMCR.MODRV0[2:0] = 000b
					0.58	—	mA	MOMCR.MODRV0[2:0] = 011b
					0.90	—	mA	MOMCR.MODRV0[2:0] = 101b
	Analog power supply current	During 12-bit A/D conversion		AI_{CC}	0.8	1.1	mA	—
		During 12-bit A/D conversion with S/H amp			2.3	3.3	mA	—
		ACMPHS(1unit)			100	150	µA	—
		Temperature sensor			0.1	0.2	mA	—
		During D/A conversion	Without AMP output		0.1	0.2	mA	—
			With AMP output		0.8	1.6	mA	—
		Waiting for A/D, D/A conversion (all units)			0.9	1.6	mA	—
		ADC12, DAC12 in standby modes (all units)*2			2	8	µA	—
	Reference power supply current (VREFH0)	During 12-bit A/D conversion (unit 0)		AI_{REFH0}	70	120	µA	—
		Waiting for 12-bit A/D conversion (unit 0)			0.07	0.5	µA	—
		ADC12 in standby modes (unit 0)			0.07	0.5	µA	—
	Reference power supply current (VREFH)	During 12-bit A/D conversion (unit 1)		AI_{REFH}	70	120	µA	—
		During D/A conversion	Without AMP output		0.1	0.4	mA	—
			With AMP output		0.1	0.4	mA	—
		Waiting for 12-bit A/D (unit 1), D/A (all units) conversion			0.07	0.8	µA	—
		ADC12 in standby modes (unit 1)			0.07	0.8	µA	—
	USB operating current	Low speed	USBFS	$I_{CCUSBLS}$	3.5	6.5	µA	VCC_USB
		Full speed	USBFS	$I_{CCUSBFS}$	4.00	10.00	mA	VCC_USB

Note 1. Supply current values are with all output pins unloaded and all input pull-up MOSs in the off state.
Note 2. When the MCU is in Software Standby mode or the MSTPCRD.MSTPD16 (12-Bit A/D Converter 0 Module Stop bit) and MSTPCRD.MSTPD15 (12-bit A/D converter 1 module stop bit) are in the module-stop state.

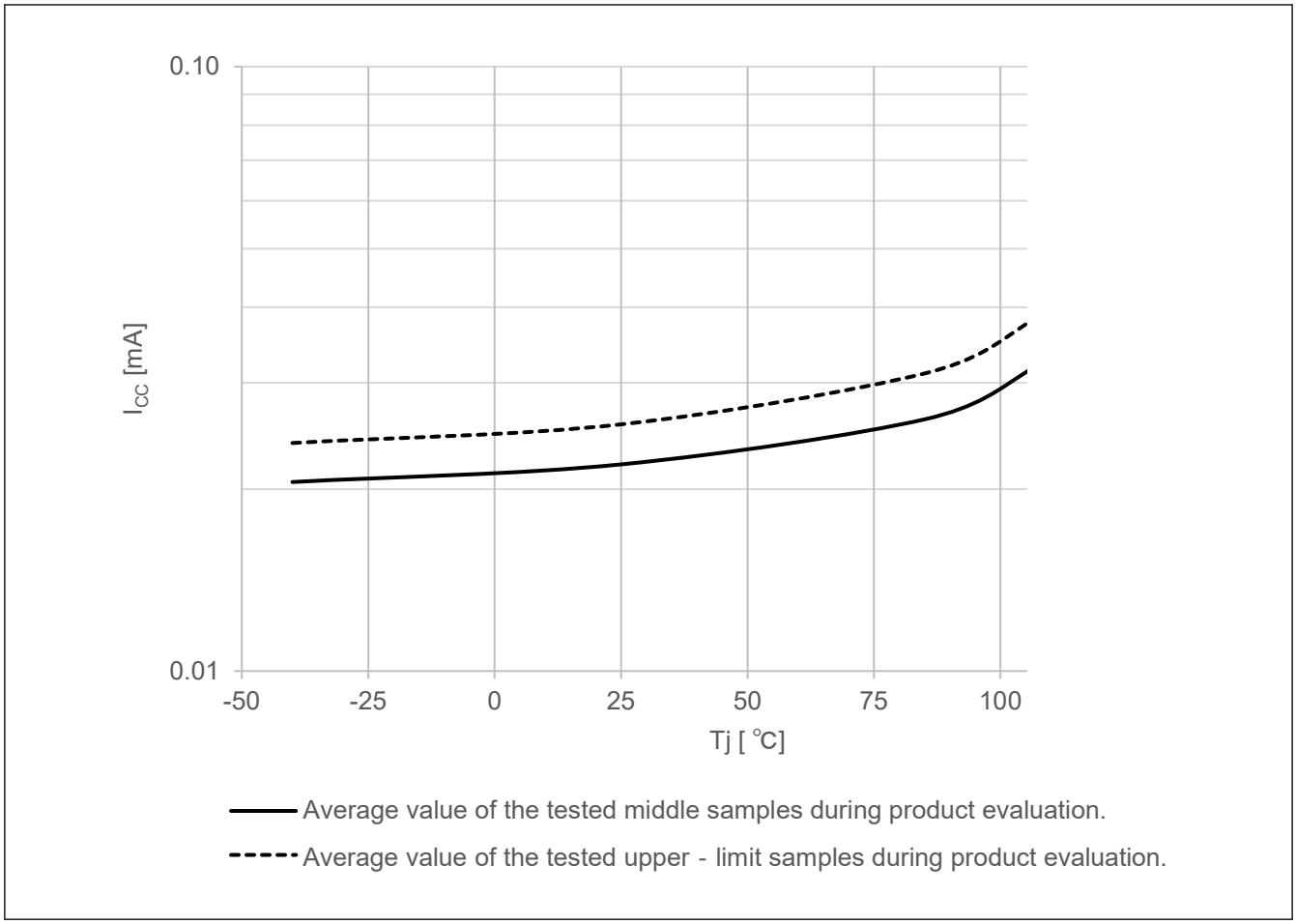


Figure 2.3 Temperature dependency in Software Standby mode (I_{CC}) (reference data)

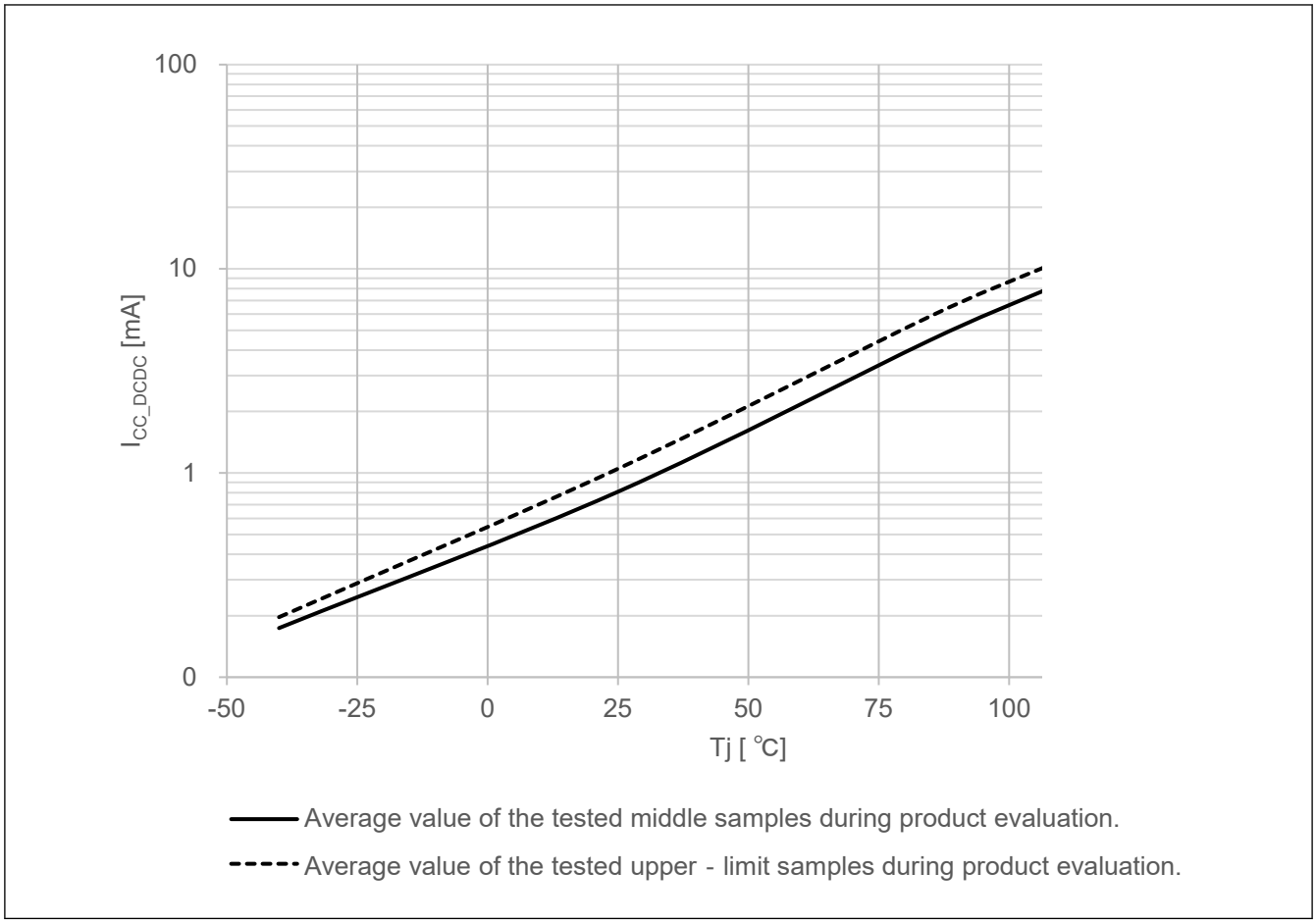


Figure 2.4 Temperature dependency in Software Standby mode (I_{CC_DCDC}) (reference data)

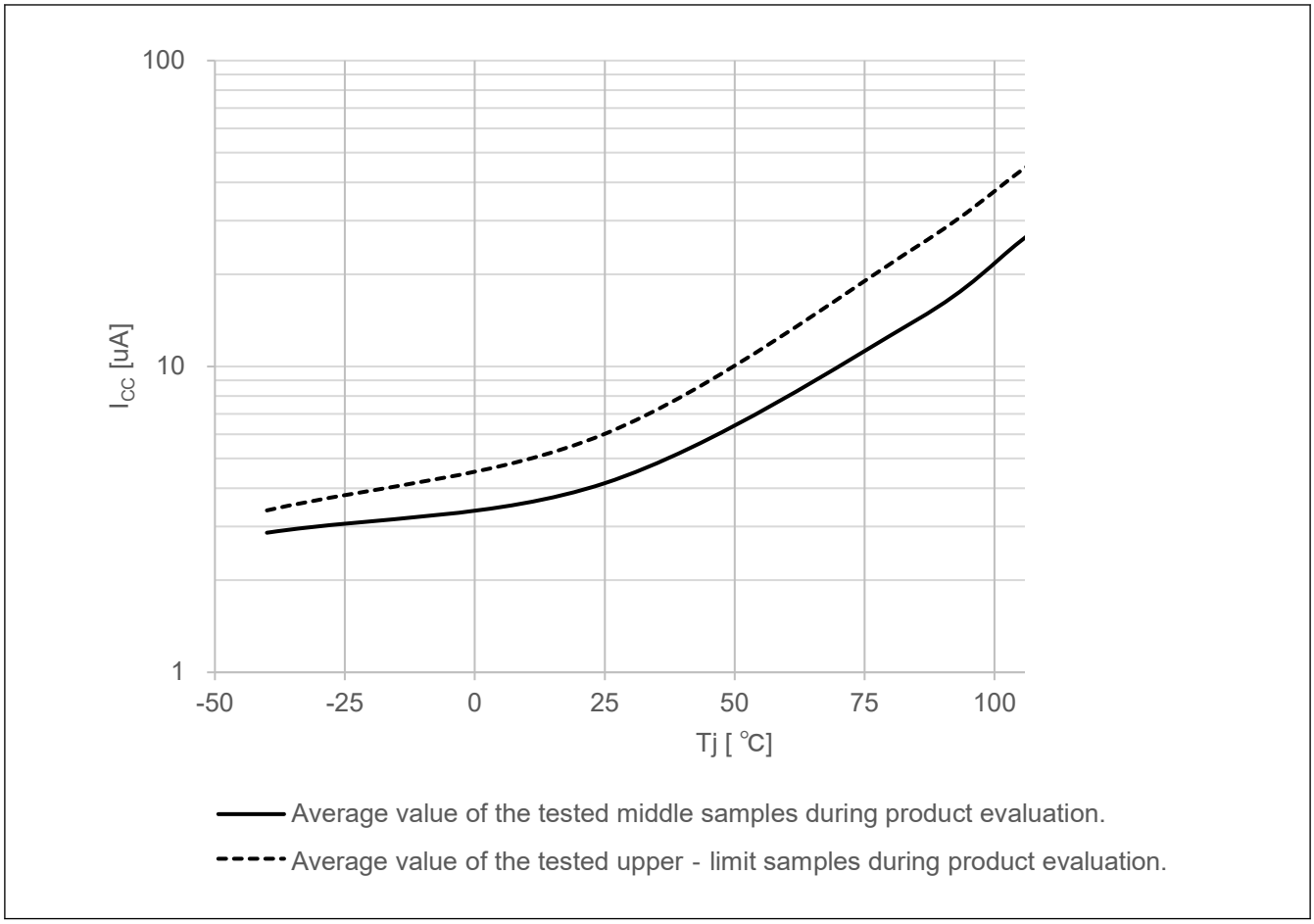


Figure 2.5 Temperature dependency in Deep Software Standby mode 1 (reference data)

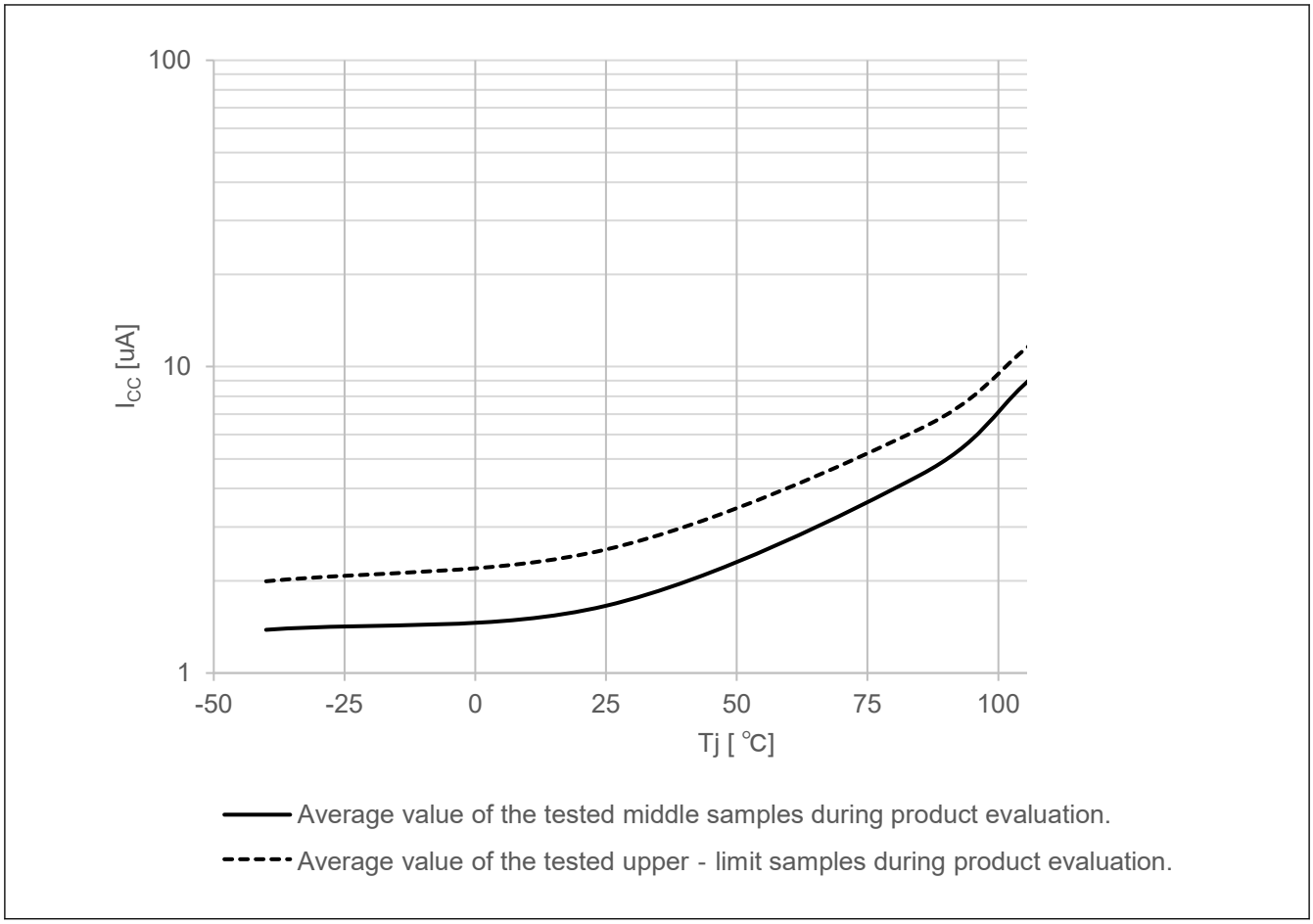


Figure 2.6 Temperature dependency in Deep Software Standby mode 2 (reference data)

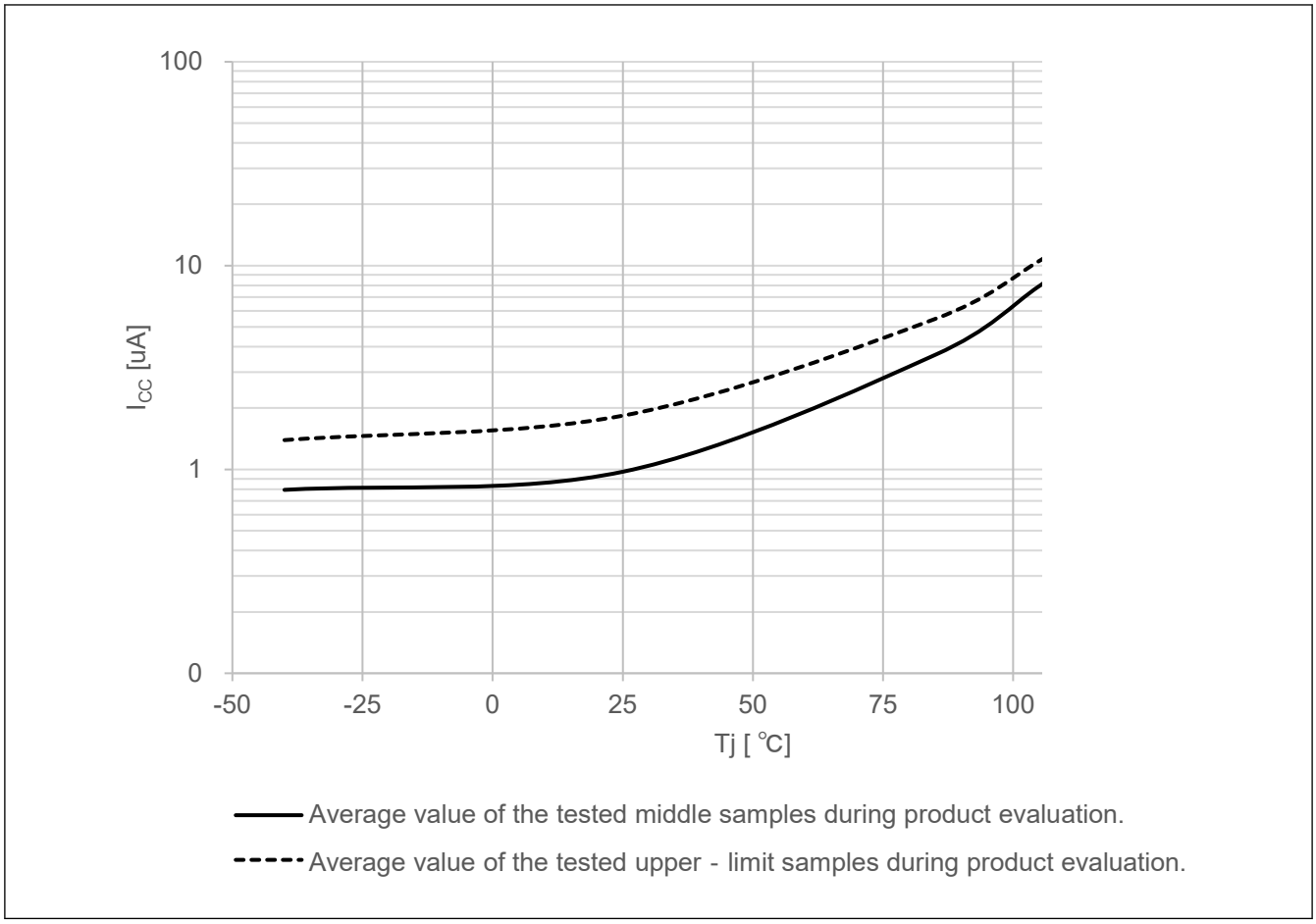


Figure 2.7 Temperature dependency in Deep Software Standby mode 3 (reference data)

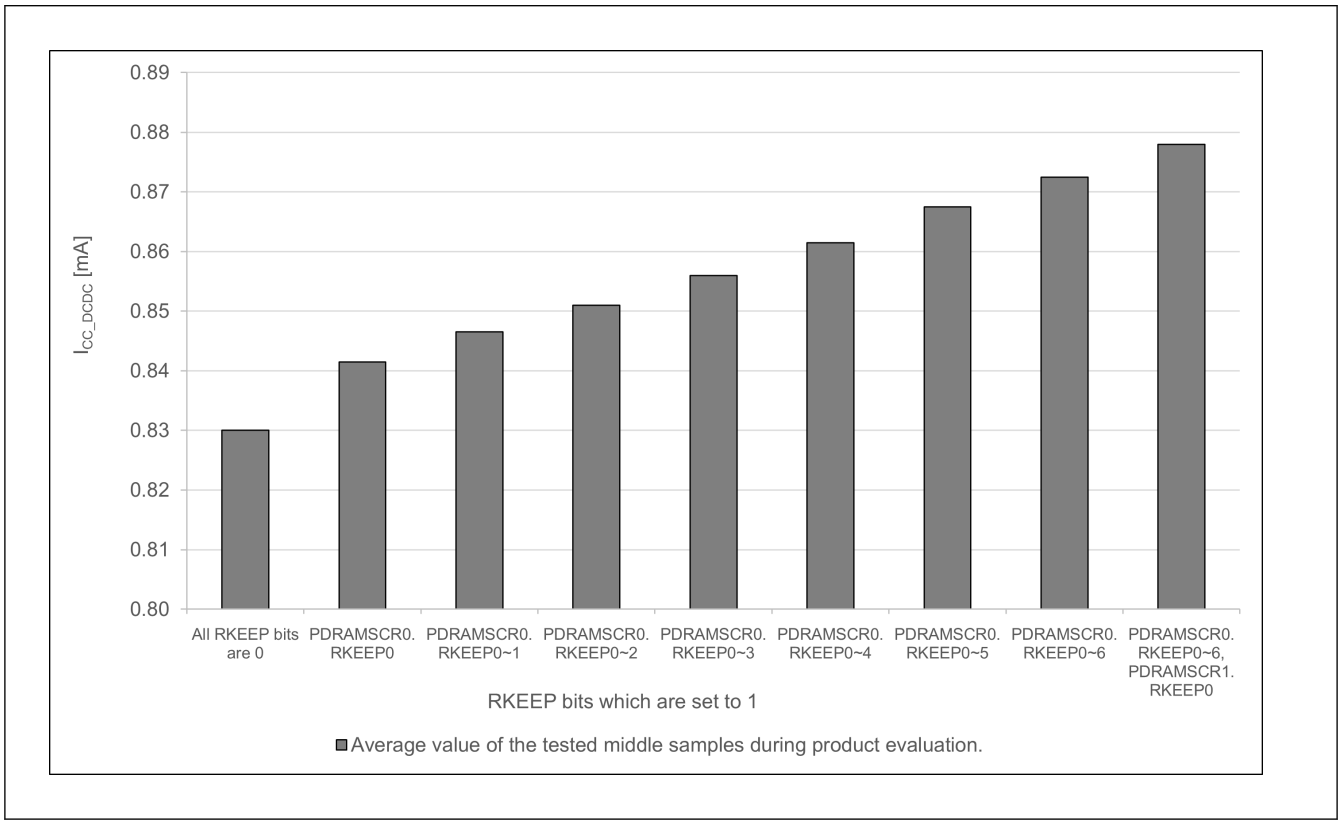


Figure 2.8 Software Standby current per SRAM state (reference data)

The more practical I_{CC_DCDC} value can be obtained with the following formula.

$I_{CC\_DCDC} = I_{DD} \times (VCL \div VCC) \div efficiency$

Where: VCL and VCC are the voltage of VCL pin and VCC pin respectively, and efficiency is shown in the following figures.

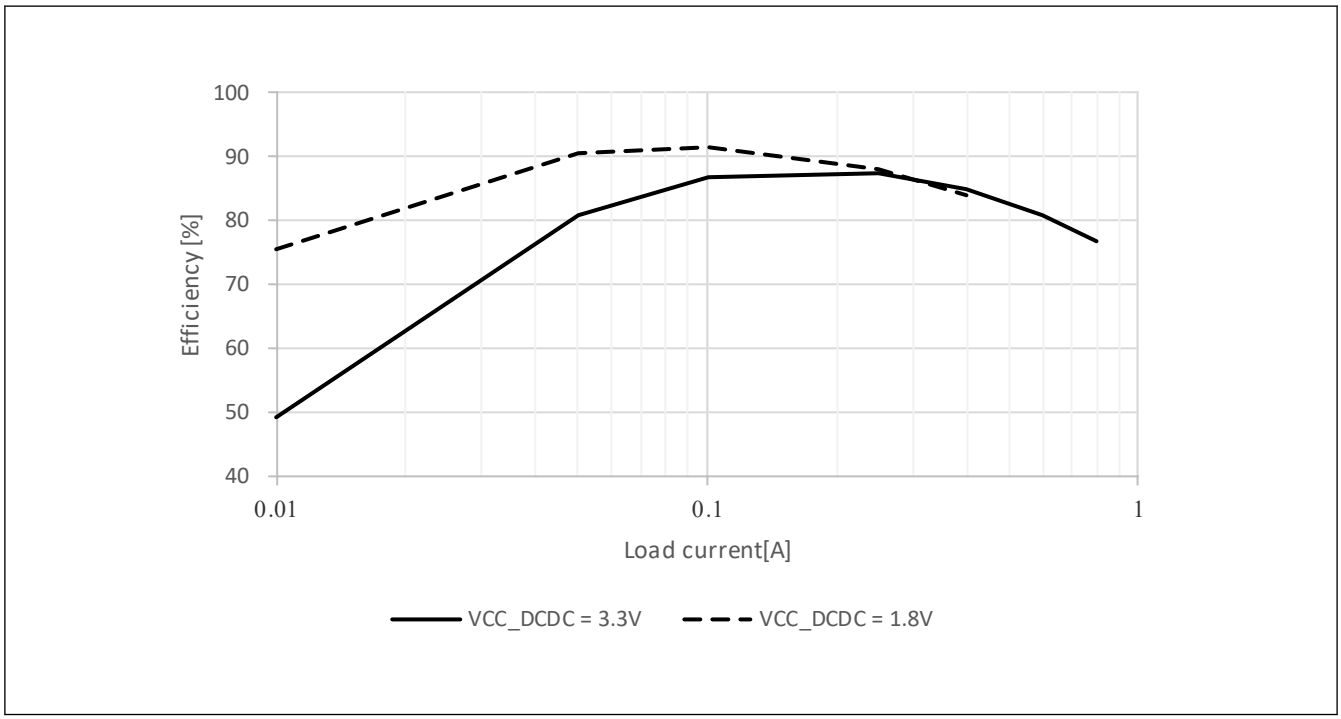


Figure 2.9 Typical DCDC efficiency (%) vs load current (A) in High-speed mode , Tj = 25℃

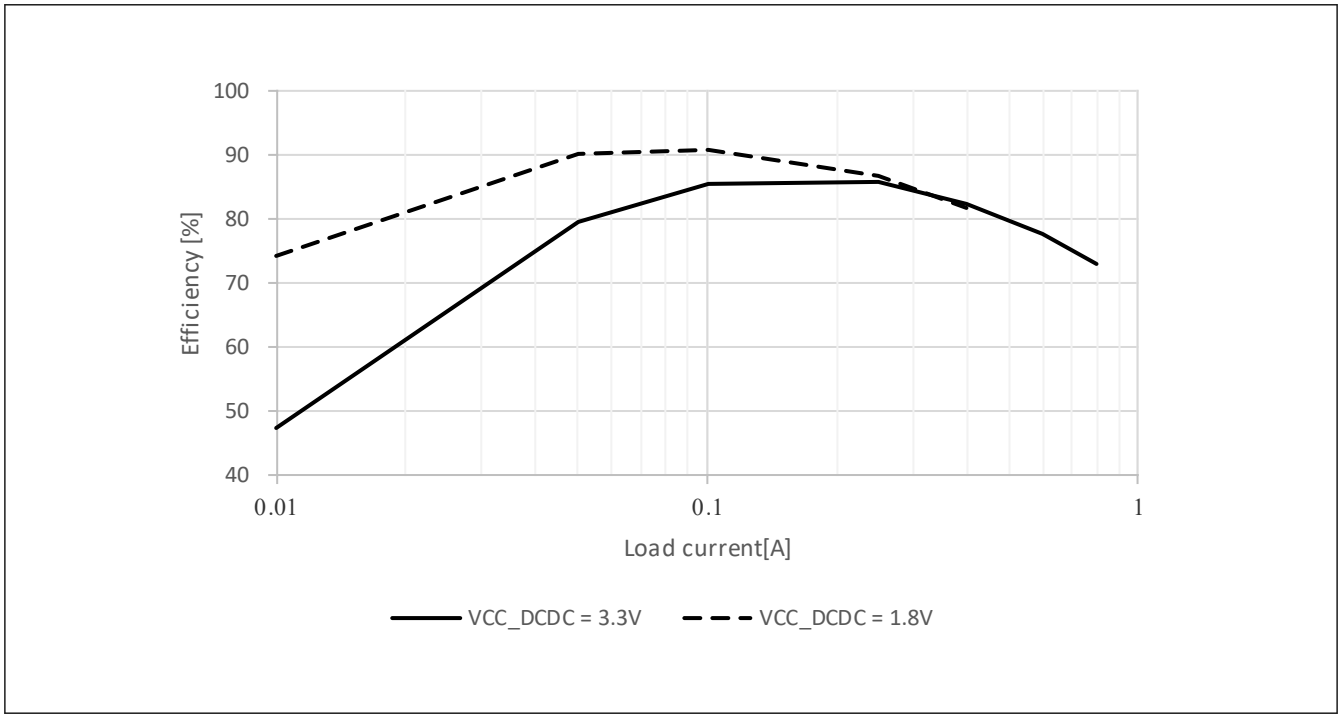


Figure 2.10 Typical DCDC efficiency (%) vs load current (A) in High-speed mode , Tj = 105℃

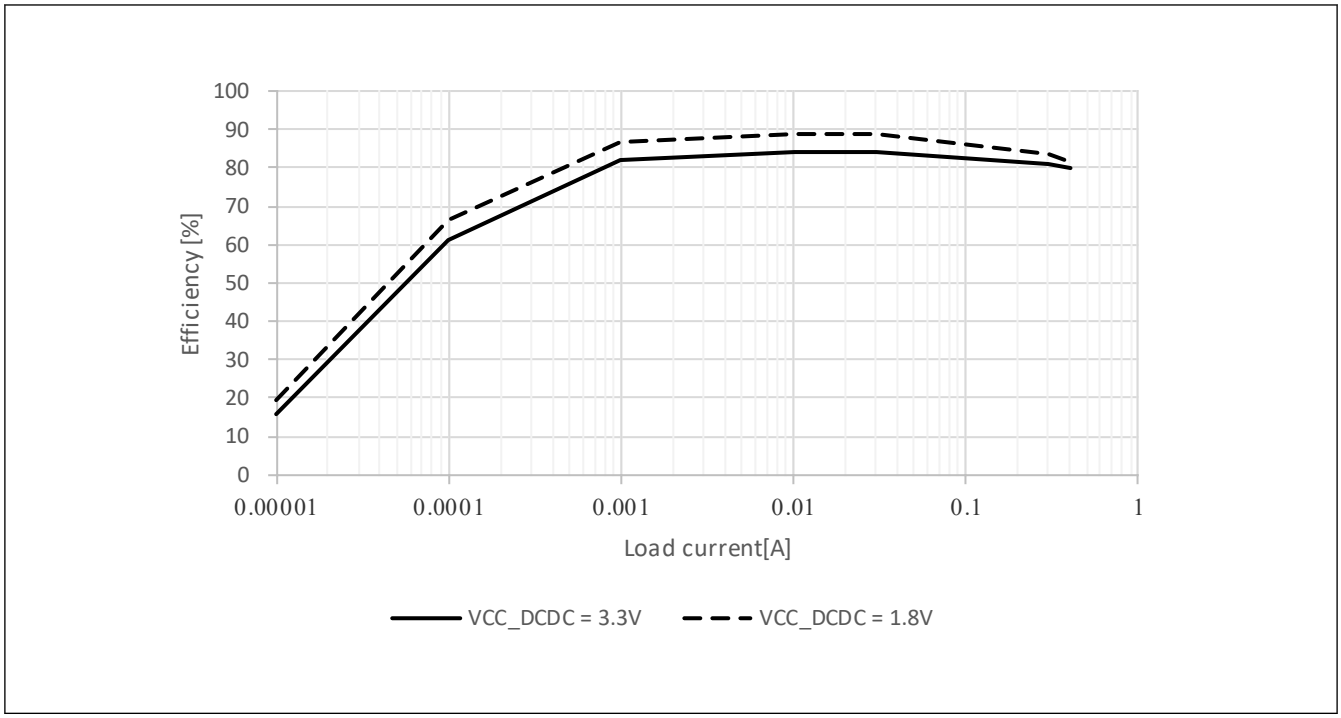


Figure 2.11 Typical DCDC efficiency (%) vs load current (A) in Low-speed mode and Software Standby mode, Tj = 25℃

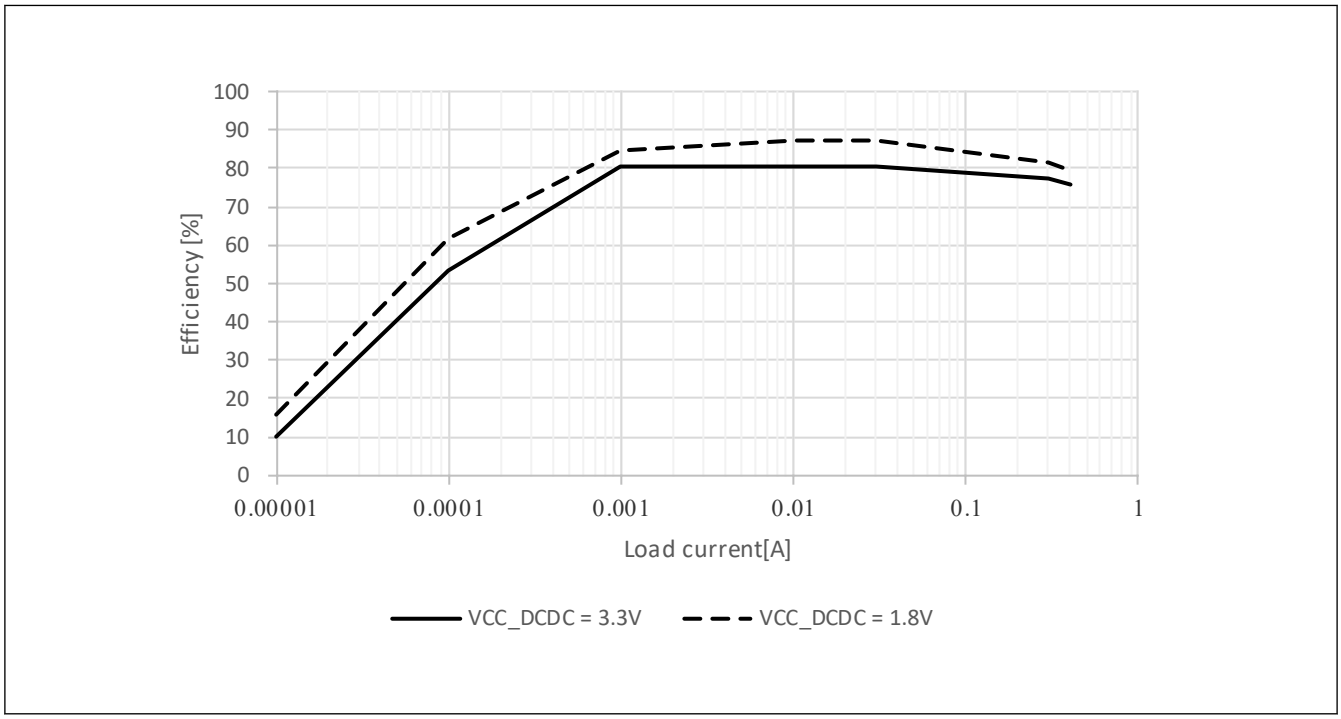


Figure 2.12 Typical DCDC efficiency (%) vs load current (A) in Low-speed mode and Software Standby mode, Tj = 105℃

Note: DCDC efficiency is obtained based on the VCC_DCDC current.

2.2.6 VCC Rise and Fall Gradient and Ripple Frequency

Table 2.24 VCC rise and fall gradient characteristics at power on/off

Parameter		Symbol	Min	Typ	Max	Unit	Test conditions
VCC rising gradient at power on*1		SrVCC	0.0084	—	20	ms/V	—
VCC falling gradient at power off	VBATT function is disabled*1	SfVCC1	0.0084	—	—	ms/V	—
	VBATT function is enabled	SfVCC2	1.0000	—	—		—

Note 1. In case the VCC voltage crosses V_{POR1}.

Table 2.25 VCC ripple frequency and gradient characteristics during operation

The ripple voltage must meet the allowable ripple frequency $f_{r(VCC)}$ within the range between the VCC upper limit (3.6 V) and lower limit (1.68 V). When the VCC change exceeds VCC ±10%, the allowable voltage change rising and falling gradient dt/dVCC must be met.

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
Allowable ripple frequency	$f_{r\ (VCC)}$	—	—	10.0	kHz	Figure 2.13 $V_{r\ (VCC)} \leq VCC \times 0.2$
		—	—	1.0	MHz	Figure 2.13 $V_{r\ (VCC)} \leq VCC \times 0.08$
		—	—	10.0	MHz	Figure 2.13 $V_{r\ (VCC)} \leq VCC \times 0.06$
Allowable voltage change rising and falling gradient	dt/dVCC*1	1.0	—	—	ms/V	When VCC change exceeds VCC ±10%

Note 1. In case the VCC voltage does not cross V_{POR1}.

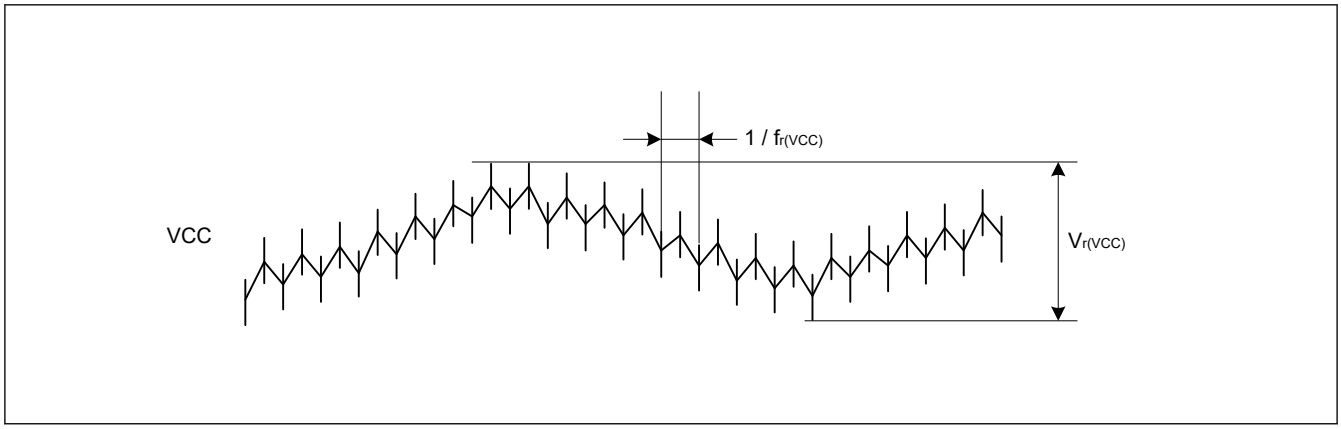


Figure 2.13 Ripple waveform

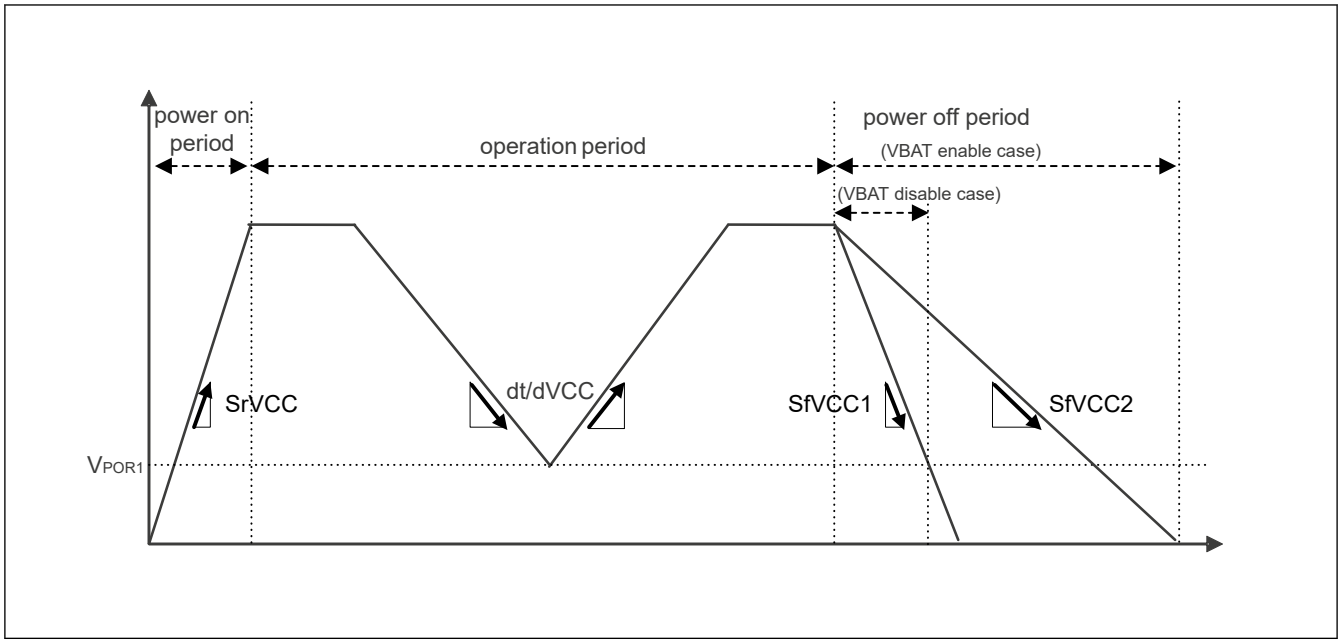


Figure 2.14 VCC rising and falling waveform

2.2.7 Thermal Characteristics

Maximum value of junction temperature (Tj) must not exceed the value of section 2.2.1. Tj/Ta Definition.

Tj is calculated by either of the following equations.

- Tj = Ta + θja × Total power consumption
- Tj = Tt + Ψjt × Total power consumption
  - Tj : Junction Temperature (°C)
  - Ta : Ambient Temperature (°C)
  - Tt : Top Center Case Temperature (°C)
  - θja : Thermal Resistance of “Junction”-to-“Ambient” (°C/W)
  - Ψjt : Thermal Resistance of “Junction”-to-“Top Center Case” (°C/W)
- Total power consumption = Voltage × (Leakage current + Dynamic current)
- Leakage current of IO = Σ (I_{OL} × V_{OL}) /Voltage + Σ (|I_{OH}| × |VCC – V_{OH}|) /Voltage
- Dynamic current of IO = Σ IO (C_{in} + C_{load}) × IO switching frequency × Voltage
  - C_{in}: Input capacitance
  - C_{load}: Output capacitance

Regarding θja and Ψjt, see Table 2.26.

Table 2.26 Thermal Resistance

Parameter	Package	Symbol	Value*1	Unit	Test conditions
Thermal Resistance	100-pin LQFP (PLQP0100KP-A)	θja	32.9	°C/W	JESD 51-2 and 51-7 compliant
	144-pin LQFP (PLQP0144KA-B)		31.7		
	100-pin LQFP (PLQP0100KP-A)	Ψjt	0.42	°C/W	JESD 51-2 and 51-7 compliant
	144-pin LQFP (PLQP0144KA-B)		0.40		

Note 1. The values are reference values when the 4-layer board is used. Thermal resistance depends on the number of layers or size of the board. For details, see the JEDEC standards.

2.2.7.1 Calculation guide of maximum current

Table 2.27 Power consumption of each unit (1 of 2)

Dynamic current/ Leakage current	MCU Domain	Category	Item	Symbol	Frequency [MHz]	Current [uA/MHz]	Current*1 [mA]	Condition
Leakage current	Analog	Regulator and Leak*1	Tj = 95°C	I_{CC}	—	—	0.54	—
			Tj = 105°C		—	—	0.64	
			Tj = 95°C	I_{CC_DCDC}	—	—	62	VCC_DCDC = 3.3V, High speed mode
			Tj = 105°C		—	—	75	
			Tj = 95°C		—	—	112	VCC_DCDC = 1.8V, High speed mode
			Tj = 105°C		—	—	134	
			Tj = 95°C	I_{DD}	—	—	146	—
			Tj = 105°C		—	—	175	
Dynamic current	CPU	Operation with Cache	CoreMark	I_{DD}	360	307	111	CPUCLK = 360MHz
	Peripheral Unit	Timer	RTC		60	1.299	0.078	—
			GPT16 (4ch)*2		120	11.325	1.359	
			GPT32 (6ch)*2		120	15.209	1.825	
			POEG (4 Groups)*2		60	1.363	0.082	
			AGT (2ch)*2		60	2.233	0.134	
			ULPT (2ch)*2		60	0.350	0.021	
			WDT		60	0.775	0.047	
			IWDT		60	0.100	0.006	

Table 2.27 Power consumption of each unit (2 of 2)

Dynamic current/ Leakage current	MCU Domain	Category	Item	Symbol	Frequency [MHz]	Current [uA/MHz]	Current*1 [mA]	Condition
Dynamic current	Peripheral Unit	Communication interfaces	ETHERC	I_{DD}	120	8.149	0.978	—
			USBFS		60	8.713	0.523	
			SCI (6ch)*2		120	22.717	2.726	
			IIC (2ch)*2		60	2.867	0.172	
			CANFD (2ch)*2		120	9.050	1.086	
			SPI (2ch)*2		120	7.950	0.954	
			OSPI		60	40.796	2.448	
			SSIE (2ch)*2		60	6.818	0.409	
		Analog	ADC (2Units)*2		120	3.961	0.475	—
			DAC12		120	0.540	0.647	
			TSN		60	0.092	0.005	
			ACMPHS (2ch)*2		60	0.083	0.005	
		Human machine interfaces	CEU		120	24.143	2.897	—
		Event link	ELC		60	1.670	0.100	—
		Security	RSIP-E51A		120	311.301	37.4	—
		Data processing	CRC		120	4.372	0.525	—
			DOC		120	0.427	0.051	
		System	CAC		60	0.738	0.044	—
		DMA	DMAC (per 1ch)		240	9.012	2.163	—
			DTC		240	11.175	2.682	
	FSBL operation				240	—	93.4	—
					120	—	72.9	—

Note 1. Regulator and Leak are Internal voltage regulator's current and MCU's leakage current.
It is selected according to the temperature of Tj.
Note 2. To determine the current consumption per channel or unit, divide Current [mA] by the number of channels, groups or units.

Table 2.28 Outline of operation for each unit (1 of 2)

Peripheral	Outline of operation
RTC	RTC is operating with LOCO.
GPT	Operating modes is set to saw-wave PWM mode.
POEG	Only clear module stop bit.
AGT	AGT is operating with PCLKB.
ULPT	ULPT is operating with LOCO.
WDT	WDT is operating with PCLKB.
IWDT	IWDT is operating with IWDTCLK.
ETHERC	Operation modes is set to full-duplex mode. ETHERC is operating using Reduced Media Independent Interface (RMII).
USBFS	Transfer types is set to bulk transfer. USBFS is operating using Full-speed transfer (12 Mbps).
SCI	SCI is transmitting data in clock synchronous mode.
IIC	Communication format is set to I2C-bus format. IIC is transmitting data in master mode.

Table 2.28 Outline of operation for each unit (2 of 2)

Peripheral	Outline of operation
CANFD	CANFD is transmitting and receiving data in self-test mode 1.
SPI	SPI mode is set to SPI operation (4-wire method). SPI master/slave mode is set to master mode. SPI is transmitting 32-bit width data.
OSPI	OSPI is issuing memory write command to HyperRAM.
SSIE	Communication mode is set to Master. System word length is set to 32 bits. Data word length is set to 20 bits. SSIE is transmitting data using I2S format.
ADC	Resolution is set to 12-bit accuracy. Data registers is set to A/D-converted value addition mode. ADC12 is converting the analog input in continuous scan mode.
DAC12	DAC12 is outputting the conversion result while updating the value of data register.
TSN	TSN is operating.
ACMPHS	ACMPHS is operating.
CEU	CEU is capturing data and transferring to the SRAM.
ELC	Only clear module stop bit.
RSIP-E51A	RSIP is doing self-test operation.
CRC	CRC is generating CRC code using 32-bit CRC32-C polynomial.
DOC	DOC is operating in data comparison mode.
CAC	Measurement target clocks is set to PCLKB. Measurement reference clocks is set to PCLKB. CAC is measuring the clock frequency accuracy.
DMAC	Bit length of transfer data is set to 32 bits. Transfer mode is set to block transfer mode. DMAC is transferring data from SRAM to SRAM.
DTC	Bit length of transfer data is set to 32 bits. Transfer mode is set to block transfer mode. DTC is transferring data from SRAM to SRAM.

2.2.7.2 Example of Tj calculation

Assumption :

- Package 144-pin LQFP : θja = 31.7 °C/W
- Ta = 60 °C
- $I_{CC} + I_{CC\_DCDC}$ = 240 mA
- VCC = 3.5 V (VCC = VCC2 = AVCC0 = VCC_USB)
- I_{OH} = 1 mA, V_{OH} = VCC – 0.5 V, 12 Outputs
- I_{OL} = 20 mA, V_{OL} = 1.0 V, 8 Outputs
- I_{OL} = 1 mA, V_{OL} = 0.5 V, 12 Outputs
- C_{in} = 8 pF, 32 pins, Input frequency = 10 MHz
- C_{load} = 30 pF, 32 pins, Output frequency = 10 MHz

Static current of IO = Σ (VOL × IOL) / Voltage + Σ ((VCC - VOH) × IOH) / Voltage

= (20 mA × 1 V) × 8 / 3.5 V + (1 mA × 0.5 V) × 12 / 3.5 V + ((VCC - (VCC - 0.5 V)) × 1 mA) × 12 / 3.5 V

= 45.7 mA + 1.71 mA + 1.71 mA

= 49.1 mA

Dynamic current of IO = Σ IO (Cin + Cload) × IO switching frequency × Voltage

= ((8 pF × 32) × 10 MHz + (30 pF × 32) × 10 MHz) × 3.5 V

= 42.6 mA

Total power consumption = Voltage × (Static current + Dynamic current)

= (240 mA × 3.5 V) + (49.1 mA + 42.6 mA) × 3.5 V

= 1161 mW (1.161 W)

Tj = Ta + θja × Total power consumption

= 60 °C + 31.7 °C/W × 1.161W

= 96.8 °C

2.3 AC Characteristics

2.3.1 Frequency

Table 2.29 Operation frequency value in high-speed mode

Parameter			Symbol	Min	Typ	Max	Unit
Operation frequency	CPU clock (CPUCLK)	DCDC, 144-pin LQFP and 100-pin LQFP package, Tj ≤ 105°C*3	f	—	—	360	MHz
		External VDD, 144-pin LQFP and 100-pin LQFP package, Tj ≤ 105°C		—	—	360	
	System clock (ICLK)			—	—	240	
	Peripheral module clock (PCLKA)			—	—	120	
	Peripheral module clock (PCLKB)			—	—	60	
	Peripheral module clock (PCLKC)			—*2	—	60	
	Peripheral module clock (PCLKD)			—	—	120	
	Peripheral module clock (PCLKE)			—	—	240	
	Flash interface clock (FCLK)			—*1	—	60	
	SCI clock (SCICLK)			—	—	120	
	SPI clock (SPICLK)			—	—	120	
	Octal SPI clock (OCTACLK)			—	—	200	
	CANFD core clock (CANFDCLK)			—	—	80	
	USB clock (USBCLK)			—	—	48	

Note 1. FCLK must run at a frequency of at least 4 MHz when programming or erasing the flash memory.
Note 2. When the ADC12 is used, the PCLKC frequency must be at least 1 MHz.
Note 3. When DCDC is used with VCC_DCDC < 2.5V, I_{DD} current must be less than the value specified in operating current. Please see Table 2.8.

Table 2.30 Operation frequency value in low-speed mode

Parameter		Symbol	Min	Typ	Max	Unit
Operation frequency	CPU clock (CPUCLK)	f	—	—	1	MHz
	System clock (ICLK)		—	—	1	
	Peripheral module clock (PCLKA)		—	—	1	
	Peripheral module clock (PCLKB)		—	—	1	
	Peripheral module clock (PCLKC)		—*2	—	1	
	Peripheral module clock (PCLKD)		—	—	1	
	Peripheral module clock (PCLKE)		—	—	1	
	Flash interface clock (FCLK)		—*1	—	1	
	SCI clock (SCICLK)		—	—	1	
	SPI clock (SPICLK)		—	—	1	
	Octal SPI clock (OCTACLK)		—	—	1	
	CANFD core clock (CANFDCLK)		—	—	1	
	USB clock (USBCLK)		—	—	1	

Note 1. Programming or erasing the flash memory is disabled in low-speed mode.
Note 2. When the ADC12 is used, the PCLKC frequency must be at least 1 MHz.

2.3.2 Clock Timing

Table 2.31 Clock timing except for sub-clock oscillator (1 of 2)

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
EXTAL external clock input cycle time	t_{EXcyc}	20.80	—	—	ns	Figure 2.15
EXTAL external clock input high pulse width	t_{EXH}	5.30	—	—	ns	
EXTAL external clock input low pulse width	t_{EXL}	5.30	—	—	ns	
EXTAL external clock rise time	t_{EXr}	—	—	3.0	ns	
EXTAL external clock fall time	t_{EXf}	—	—	3.0	ns	
Main clock oscillator frequency	f_{MAIN}	8	—	48	MHz	—
Main clock oscillation stabilization wait time (crystal)*1	$t_{MAINOSCWT}$	—	—	—*1	ms	Figure 2.16
LOCO clock oscillation frequency	f_{LOCO}	29.4912	32.768	36.0448	kHz	—
LOCO clock oscillation stabilization wait time	t_{LOCOWT}	—	—	60.4	µs	Figure 2.17
MOCO clock oscillation frequency	f_{MOCO}	6.8	8.0	9.2	MHz	—
MOCO clock oscillation stabilization wait time	t_{MOCOWT}	—	—	15.0	µs	—

Table 2.31 Clock timing except for sub-clock oscillator (2 of 2)

Parameter		Symbol	Min	Typ	Max	Unit	Test conditions
HOCO clock oscillator oscillation frequency	Without FLL	f_{HOCO16}	15.78	16.00	16.22	MHz	–20 ≤ Tj ≤ 105 °C
		f_{HOCO18}	17.75	18.00	18.25		
		f_{HOCO20}	19.72	20.00	20.28		
		f_{HOCO32}	31.55	32.00	32.45		
		f_{HOCO48}	47.33	48.00	48.67		
		f_{HOCO16}	15.71	16.00	16.29		–40 ≤ Tj ≤ –20 °C
		f_{HOCO18}	17.68	18.00	18.32		
		f_{HOCO20}	19.64	20.00	20.36		
		f_{HOCO32}	31.42	32.00	32.58		
		f_{HOCO48}	47.14	48.00	48.86		
	With FLL	f_{HOCO16}	15.960	16.000	16.040		–40 ≤ Tj ≤ 105 °C Sub-clock frequency accuracy is ±50 ppm.
		f_{HOCO18}	17.955	18.000	18.045		
		f_{HOCO20}	19.950	20.000	20.050		
		f_{HOCO32}	31.920	32.000	32.080		
		f_{HOCO48}	47.880	48.000	48.120		
HOCO clock oscillation stabilization wait time*2		t_{HOCOWT}	—	—	64.7	µs	—
HOCO stop width time		$t_{HOCOSTP}$	1	—	—	µs	Figure 2.20
HOCO period jitter		Jitter	-3	—	3	%	—
FLL stabilization wait time		t_{FLLWT}	—	—	1.8	ms	—
PLL1/PLL2 VCO frequency		f_{VCO}	640	—	1440.0	MHz	—
PLL1/PLL2 Output frequency for output clock P		t_{PLL}	40	—	480	MHz	—
PLL1/PLL2 Output frequency for output clock Q, R		t_{PLL}	71	—	480	MHz	—
PLL1/PLL2 clock oscillation stabilization wait time		t_{PLLWT}	—	—	40	µs	Figure 2.18
PLL1/PLL2 period jitter		—	—	±70	—	ps	—
PLL1/PLL2 long term jitter		—	—	±300	—	ps	Term: 1 µs, 10 µs

Note 1. When setting up the main clock oscillator, ask the oscillator manufacturer for an oscillation evaluation, and use the results as the recommended oscillation stabilization time. Set the MOSCWTCR register to a value equal to or greater than the recommended value.
After changing the setting in the MOSCCR.MOSTP bit to start main clock operation, read the OSCSF.MOSCSF flag to confirm that it is 1, and then start using the main clock oscillator.

Note 2. This is the time from release from reset state until the HOCO oscillation frequency (f_{HOCO}) reaches the range for guaranteed operation.

Table 2.32 Clock timing for the sub-clock oscillator

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
Sub-clock frequency	f_{SUB}	—	32.768	—	kHz	—
Sub-clock oscillation stabilization wait time	$t_{SUBOSCWT}$	—	—	—*1	s	Figure 2.19

Note 1. When setting up the sub-clock oscillator, ask the oscillator manufacturer for an oscillation evaluation and use the results as the recommended oscillation stabilization time.
After changing the setting in the SOSCCR.SOSTP bit to start sub-clock operation, only start using the sub-clock oscillator after the sub-clock oscillation stabilization time elapses with an adequate margin. A value that is two times the value shown is recommended.

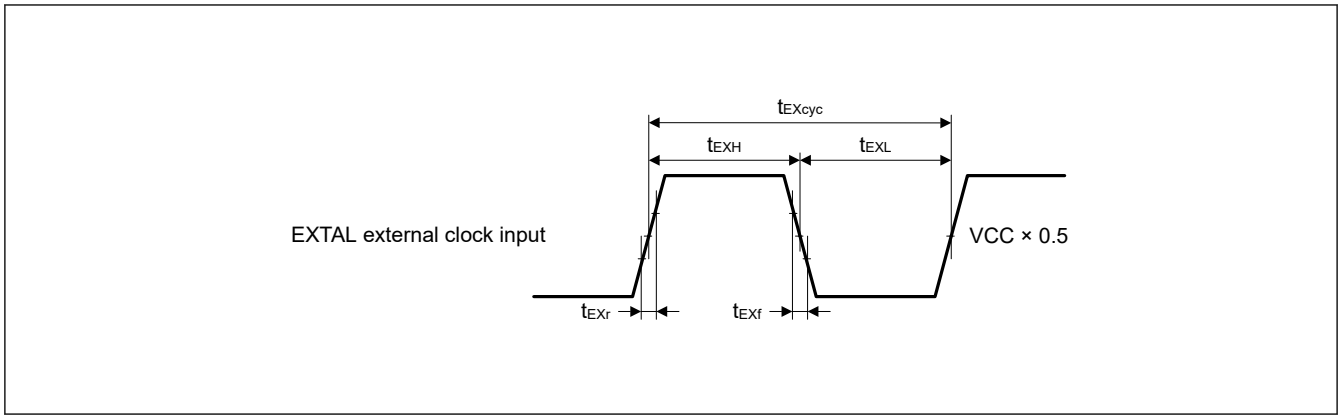


Figure 2.15 EXTAL external clock input timing

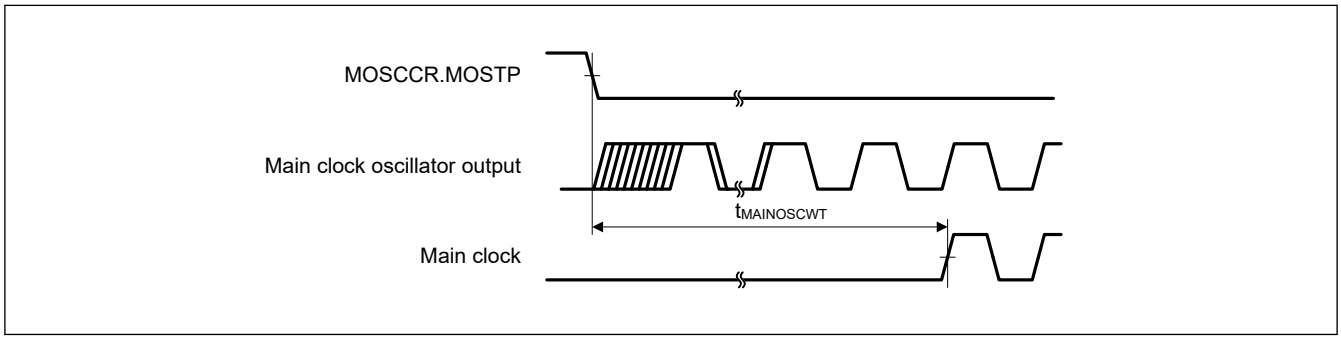


Figure 2.16 Main clock oscillation start timing

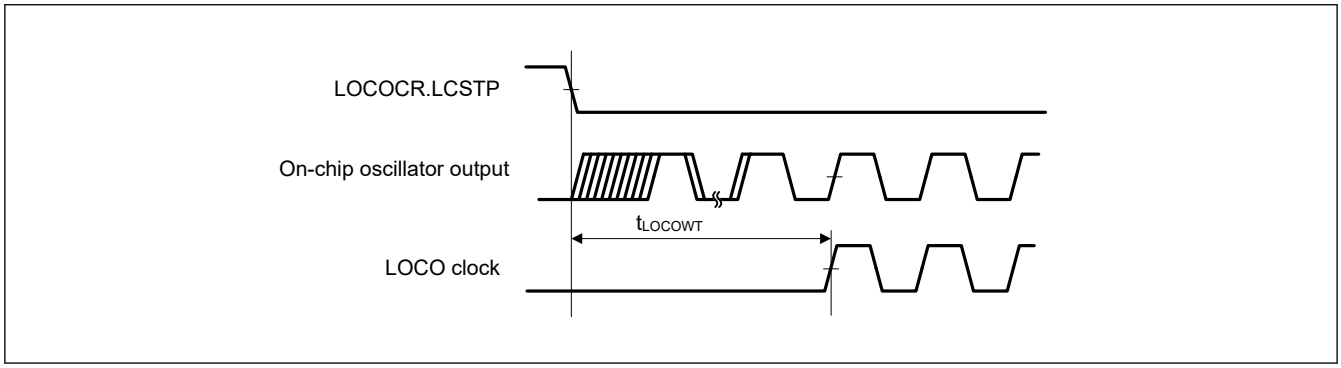
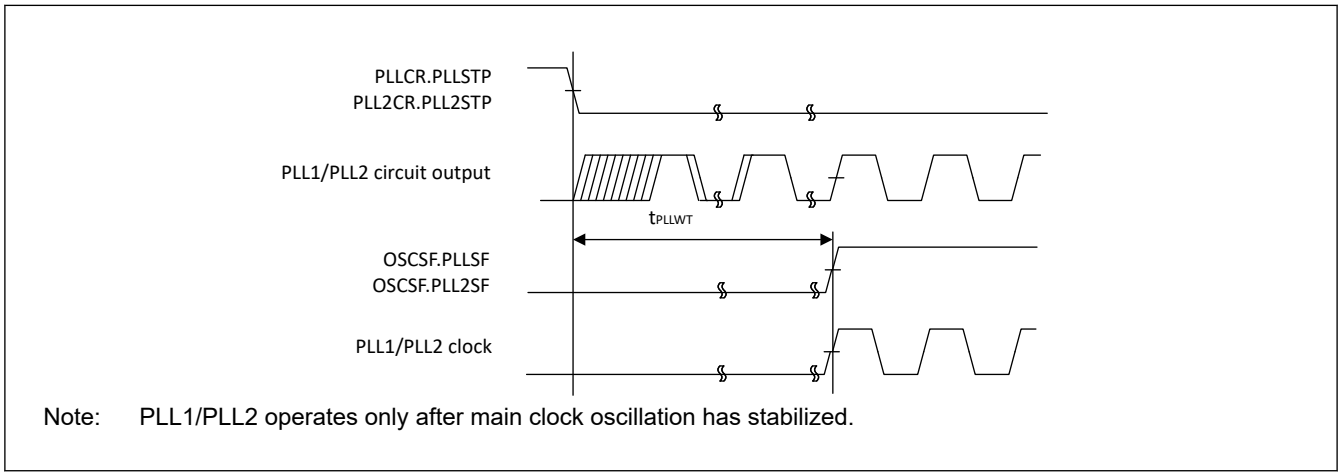


Figure 2.17 LOCO clock oscillation start timing



Note: PLL1/PLL2 operates only after main clock oscillation has stabilized.

Figure 2.18 PLL1/PLL2 clock oscillation start timing

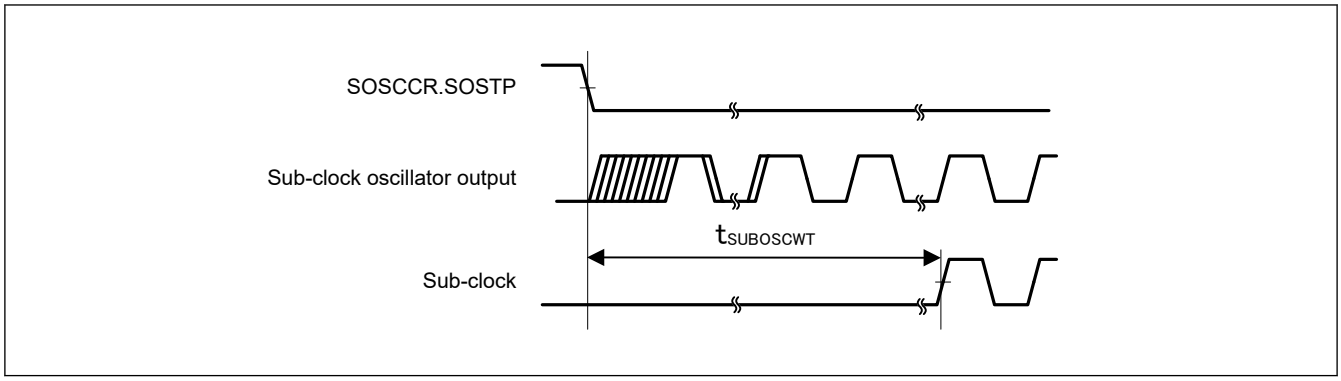


Figure 2.19 Sub-clock oscillation start timing

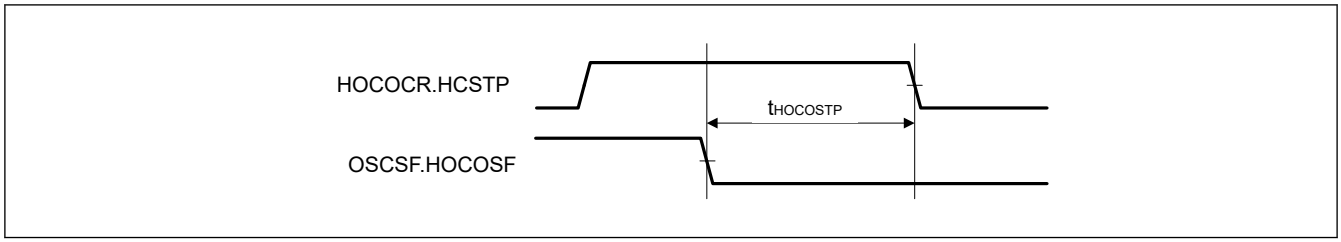


Figure 2.20 HOCO stop width time

2.3.3 Reset Timing

Table 2.33 Reset timing

Parameter			Symbol	Min	Typ	Max	Unit	Test conditions
RES pulse width	Power-on		t_{RESWP}	4.2	—	—	ms	Figure 2.21
	Deep Software Standby mode 1	DPSBYCR.DCSSMODE = 0	t_{RESWD}	1.30	—	—	ms	Figure 2.22
		DPSBYCR.DCSSMODE = 1		0.71	—	—		
	Deep Software Standby mode 2	DPSBYCR.DCSSMODE = 0		2.00	—	—		
		DPSBYCR.DCSSMODE = 1		1.50	—	—		
	Deep Software Standby mode 3	DPSBYCR.DCSSMODE = 0		3.50	—	—		
		DPSBYCR.DCSSMODE = 1		2.90	—	—		
	Software Standby mode		t_{RESWS}	0.66	—	—	ms	
	Low-speed Mode		t_{RESWLS}	0.46	—	—	ms	
	CPU Deep Sleep mode (SOSC operation)		$t_{RESWSODS}$	0.36	—	—	ms	
	CPU Deep Sleep mode (Other than SOSC operation)		t_{RESWDS}	0.24	—	—	ms	
	SOSC operation		t_{RESWSO}	0.19	—	—	ms	
	Other than above		t_{RESW}	62.0	—	—	µs	
Wait time after RES cancellation			t_{RESWT}	—	54.9	64.6	µs	Figure 2.21
Wait time after internal reset cancellation (IWDT reset, WDT reset, CPU Lockup reset, Bus Error reset, Common Memory Error reset, Software reset)			t_{RESW2}	—	54.9	64.6	µs	—

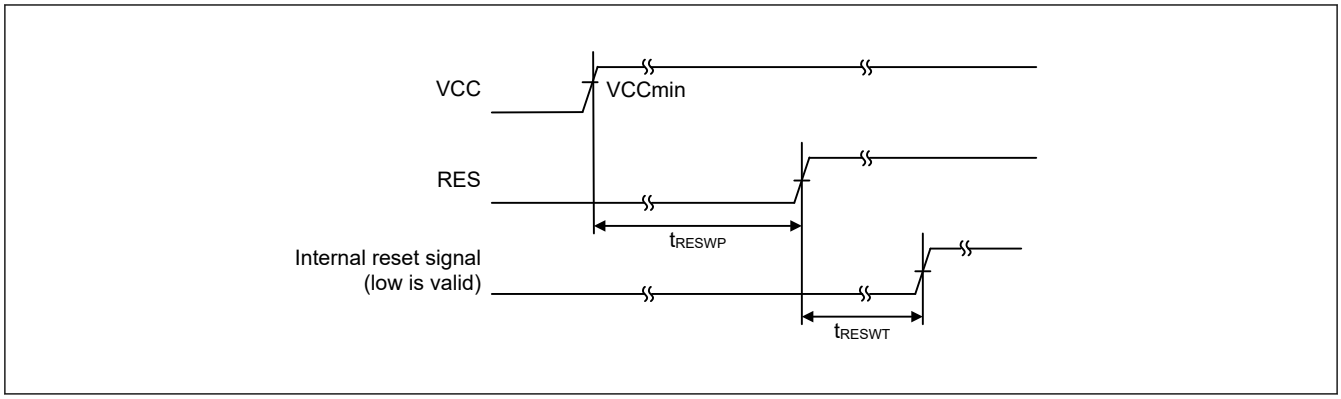


Figure 2.21 RES pin input timing under the condition that VCC exceeds V_{POR} voltage threshold

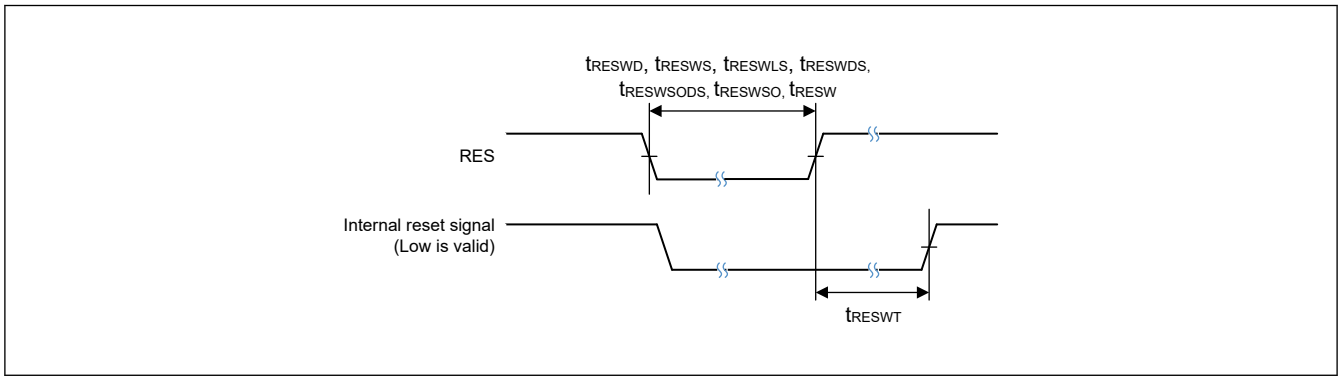


Figure 2.22 Reset input timing

2.3.4 Wakeup Timing

Table 2.34 Timing of recovery from low power modes (1 of 2)

Parameter	Fast return function	Symbol	Min	Typ	Max	Unit	Test conditions
Recovery time from CPU Deep Sleep mode	—	t_{DSLP}*10	—	182	214	µs	—

Table 2.34 Timing of recovery from low power modes (2 of 2)

Parameter			Fast return function	Symbol	Min	Typ	Max	Unit	Test conditions
Recovery time from Software Standby mode	Crystal resonator connected to main clock oscillator	System clock source is main clock oscillator*1 MOSCSCR.MOSCSOKP = 0	Enabled	t_{SBYMC}*9	—	2.33	2.43	ms	Figure 2.23 The division ratio of all oscillators is 1.
		System clock source is main clock oscillator*1 MOSCSCR.MOSCSOKP = 1	Enabled		—	310	385	µs	
		System clock source is PLL1P with main clock oscillator*2 MOSCSCR.MOSCSOKP = 0	Enabled	t_{SBYPC}*9	—	2.47	2.59	ms	
		System clock source is PLL1P with main clock oscillator*2 MOSCSCR.MOSCSOKP = 1	Enabled		—	388	511	µs	
	External clock input to main clock oscillator	System clock source is main clock oscillator*3	Enabled	t_{SBYEX}*9	—	310	385	µs	
		System clock source is PLL1P with main clock oscillator*4	Enabled	t_{SBYPE}*9	—	388	511		
	System clock source is sub-clock oscillator*5		Enabled	t_{SBYSC}*9	—	0.81	0.87	ms	
	System clock source is HOCO clock oscillator*6		Enabled	t_{SBYHO}*9	—	310	385	µs	
	System clock source is PLL1P with HOCO*7		Enabled	t_{SBYPH}*9	—	398	522	µs	
	System clock source is MOCO clock oscillator*8		Enabled	t_{SBYMO}*9	—	312	387	µs	
Recovery time from Deep Software Standby mode	Deep Software Standby mode 1	Any of PVD0(OFS1(_SEC).PVDLPSEL=1), PVD1, PVD2, or Battery power supply switch is enabled	Standard	t_{DSBY}	—	0.68	1.20	ms	Figure 2.24
			Fast		—	0.29	0.62	ms	
		All of PVD0(OFS1(_SEC).PVDLPSEL=1), PVD1, PVD2, and Battery power supply switch are disabled	Standard			0.73	1.30		
			Fast			0.33	0.71		
	Deep Software Standby mode 2	DPSWCR.WSTS = 0x0B	Standard		—	0.73	1.10	ms	
			Fast		—	0.33	0.50	ms	
		DPSWCR.WSTS = 0x9A	Standard		—	1.60	2.00	ms	
			Fast		—	1.20	1.50	ms	
	Deep Software Standby mode 3		Standard		—	2.10	3.50	ms	
			Fast		—	1.70	2.90	ms	
Wait time after cancellation of Deep Software Standby mode			—	t_{DSBYWT}	47.7	—	64.6	µs	

Note 1. When the frequency of the crystal is 48 MHz (Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 0x05) and the greatest value of the internal clock division setting is 1.

Note 2. When the frequency of PLL1P is 480 MHz (Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 0x05) and the greatest value of the internal clock division setting is 8.

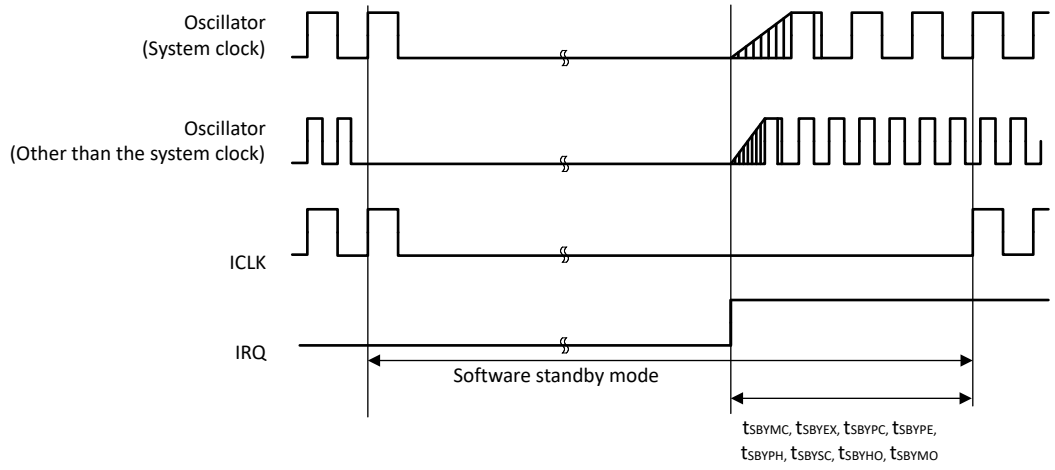
Note 3. When the frequency of the external clock is 48 MHz (Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 0x00) and the greatest value of the internal clock division setting is 1.
Note 4. When the frequency of PLL1P is 480 MHz (Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 0x00) and the greatest value of the internal clock division setting is 8.
Note 5. The Sub-clock oscillator frequency is 32.768 kHz and the greatest value of the internal clock division setting is 1.
Note 6. The HOCO frequency is 20 MHz and the greatest value of the internal clock division setting is 1.
Note 7. The PLL frequency is 480 MHz and the greatest value of the internal clock division setting is 8.
Note 8. The MOCO frequency is 8 MHz and the greatest value of the internal clock division setting is 1.
Note 9. The recovery time can be calculated with the equation of t_{Common} + max(t_{OSCSTB}, t_{PG1}, t_{PGCK}) + max(t_{PG2}, t_{LPW}). And they can be determined with the following values and equations. For n, the greatest value is selected from among the internal clock(CPUCLK, ICLK, PCLKm, FCLK) division settings (m = A to E).
t_{OSCSTB} in the table below means the time when each oscillator is active. When multiple oscillators are active, t_{OSCSTB} is determined by the longest t_{OSCSTB} among the active oscillators.
Note 10. The ICLK frequency is 240 MHz. This recovery time corresponds to t_{PG2}.

Table 2.35 Each element of recovery time

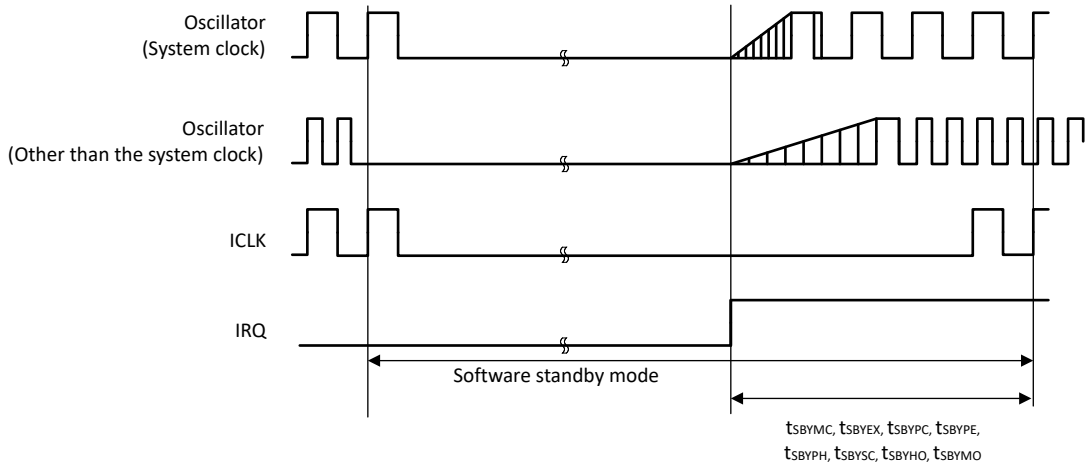
Wakeup time	Oscillation keep	Fast return function	Typ						Max						Unit
			t_{Common}	t_{OSCSTB} *1	t_{PG1}	t_{PGCK}	t_{PG2}	t_{LPW}	t_{Common}	t_{OSCSTB} *1	t_{PG1}	t_{PGCK}	t_{PG2}	t_{LPW}	
t_{SBYMC}	MOSC disabled	Enabled	52.667 + 4/ fICLK	$t_{MAINOSCWT}$	75.5	2.1 + 10.5/ fMOCO + 2.5n/ fMOCO + 2.5/ fSRCCLK + 2/ fICLK	1449/ fMOCO + 10/ fICLK	10 + 2/ fICLK + 2n/ fMAIN	82.369 + 4/ fICLK	$t_{MAINOSCWT}$ + 11/0.236	88.8	2.5 + 10.5/ fMOCO + 2.5n/ fMOCO + 2.5/ fSRCCLK + 2/ fICLK	1449/ fMOCO+ 10/ fICLK	10 + 2/ fICLK + 2n/ fMAIN	µs
	MOSC enabled	Enabled	52.667 + 4/ fICLK	3/0.262				10 + 2/ fICLK + 2n/ fMAIN	82.369 + 4/ fICLK	14/0.236				10 + 2/ fICLK + 2n/ fMAIN	µs
t_{SBYPC}	MOSC disabled	Enabled	52.667 + 4/ fICLK	24.125 +$t_{MAINOSCWT}$ + 31/0.262 *2				10 + 2/ fICLK + 2n/ fPLL	82.369 + 4/ fICLK	24.05 + $t_{MAINOSCWT}$ + 42/0.236 *3				10 + 2/ fICLK + 2n/ fPLL	µs
	MOSC enabled	Enabled	52.667 + 4/ fICLK	24.125 + 34/0.262 *2				10 + 2/ fICLK + 2n/ fPLL	82.369 + 4/ fICLK	24.05 + 45/0.236 *3				10 + 2/ fICLK + 2n/ fPLL	µs
t_{SBYEX}	—	Enabled	52.667 + 4/ fICLK	3/0.262				10 + 2/ fICLK + 2n/ fEXMAIN	82.369 + 4/ fICLK	14/0.236				10 + 2/ fICLK + 2n/ fEXMAIN	µs
t_{SBYPE}	—	Enabled	52.667 + 4/ fICLK	24.125 + 34/0.262 *2				10 + 2/ fICLK + 2n/ fPLL	82.369 + 4/ fICLK	24.05 +45/0.236*3				10 + 2/ fICLK + 2n/ fPLL	µs
t_{SBYSC}	—	Enabled	52.667 + 4/ fICLK	0				10 + 2/ fICLK + 2n/ fSOSC	82.369 + 4/ fICLK	0				10 + 2/ fICLK + 2n/ fSOSC	µs
t_{SBYHO}	—	Enabled	52.667 + 4/ fICLK	23.375				10 + 2/ fICLK + 2n/ fHOCO	82.369 + 4/ fICLK	70.234				10 + 2/ fICLK + 2n/ fHOCO	µs
t_{SBYPH}	—	Enabled	52.667 + 4/ fICLK	24.125 + 140*2				10 + 2/ fICLK + 2n/ fPLL	82.369 + 4/ fICLK	24.05 +202*3				10 + 2/ fICLK + 2n/ fPLL	µs
t_{SBYMO}	—	Enabled	52.667 + 4/ fICLK	0				10 + 2/ fICLK + 2n/ fMOCO	82.369 + 4/ fICLK	0				10 + 2/ fICLK + 2n/ fMOCO	µs

Note: The unit of frequency is MHz.
Note 1. If more than one oscillator is operating, the largest value of the operating oscillator in this column is applied.
Note 2. "24.125" can be reduced when both PLL1LDOCR.SKEEP and PLL2LDOCR.SKEEP are 1.

Note 3. "24.05" can be reduced when both PLL1LDOCR.SKEEP and PLL2LDOCR.SKEEP are 1.



When stabilization of the system clock oscillator is slower



When stabilization of an oscillator other than the system clock is slower

Figure 2.23 Software Standby mode cancellation timing

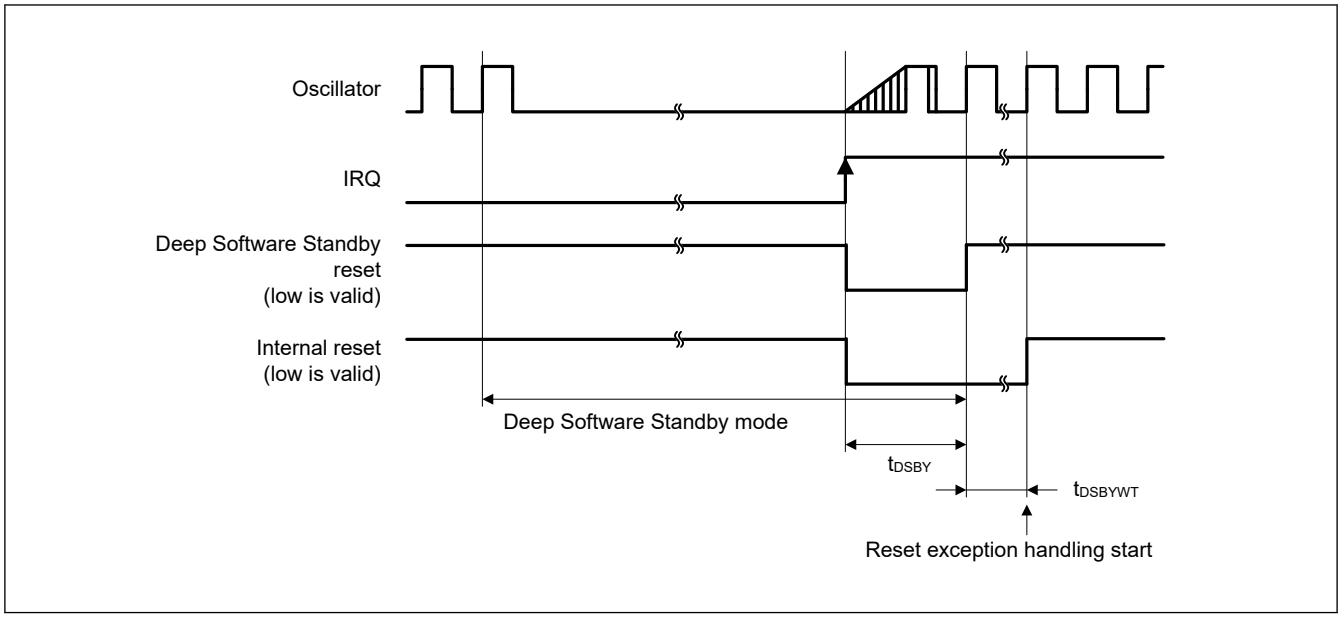


Figure 2.24 Deep Software Standby mode cancellation timing

2.3.5 NMI and IRQ Noise Filter

Table 2.36 NMI and IRQ noise filter

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions	
NMI pulse width	t_{NMIW}	200	—	—	ns	NMI digital filter disabled	$t_{Pcyc} \times 2 \leq 200$ ns
		$t_{Pcyc} \times 2$*1	—	—			$t_{Pcyc} \times 2 > 200$ ns
		200	—	—		NMI digital filter enabled	$t_{NMICK} \times 3 \leq 200$ ns
		$t_{NMICK} \times 3.5$*2	—	—			$t_{NMICK} \times 3 > 200$ ns
IRQ pulse width	t_{IRQW}	200	—	—	ns	IRQ digital filter disabled	$t_{Pcyc} \times 2 \leq 200$ ns
		$t_{Pcyc} \times 2$*1	—	—			$t_{Pcyc} \times 2 > 200$ ns
		200	—	—		IRQ digital filter enabled	$t_{IRQCK} \times 3 \leq 200$ ns
		$t_{IRQCK} \times 3.5$*3	—	—			$t_{IRQCK} \times 3 > 200$ ns

Note: 200 ns minimum in Software Standby mode.
Note: If the system clock source is switched, add 4 clock cycles of the switched source.
Note 1. t_{Pcyc} indicates the PCLKB cycle.
Note 2. t_{NMICK} indicates the cycle of the NMI digital filter sampling clock.
Note 3. t_{IRQCK} indicates the cycle of the IRQi digital filter sampling clock.

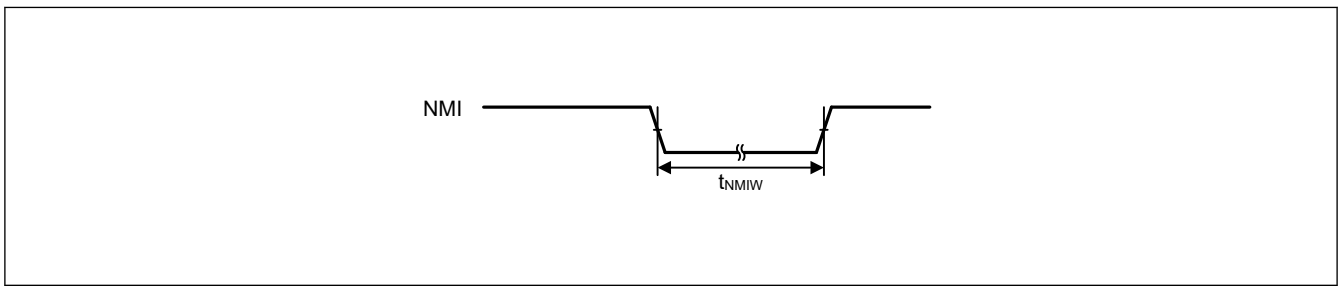


Figure 2.25 NMI interrupt input timing

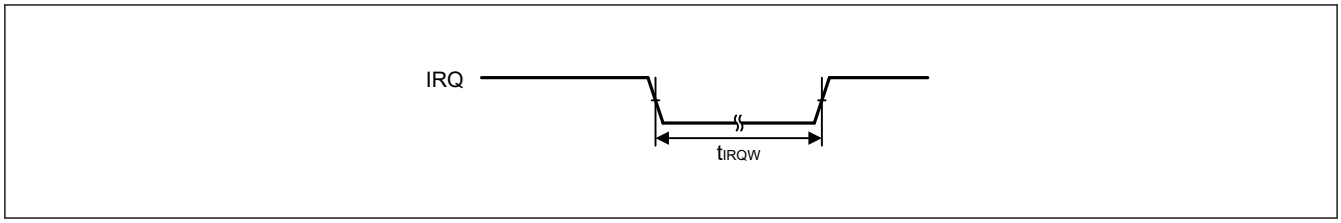


Figure 2.26 IRQ interrupt input timing

2.3.6 I/O Ports, POEG, GPT, AGT, ULPT and ADC12 Trigger Timing

Table 2.37 I/O ports, POEG, GPT, AGT, ULPT and ADC12 trigger timing (1 of 2)

GPT Conditions:
Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If GPT pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.
AGT Conditions:
Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.

Parameter			Symbol	Min	Max	Unit	Test conditions
I/O ports	Input data pulse width		t_{PRW}	5.5	—	t_{Icyc}	Figure 2.27
	EXCIN input frequency		t_{EXCIN}	—	36	kHz	
	RTCICn (n = 0 to 2) input pulse width		t_{RTCICW}	13.89	—	μs	Figure 2.28
POEG	POEG input trigger pulse width		t_{POEW}	3	—	t_{Pcyc}	Figure 2.29
GPT	Input capture pulse width (Cycle)	Single edge	t_{GTICW} *1	1.5	—	t_{PDcyc}	Figure 2.30
		Dual edge		2.5	—		
	Input capture pulse width (Time)	2.70V or above	t_{GTICW} *1	12.5	—	ns	
		1.68V or above (VCC) 1.65V or above (VCC2)		25.0	—		
	GTIOCxY output skew (x = 0 to 5, Y = A or B)	2.70V or above	t_{GTISK}	—	4	ns	Figure 2.31
		1.68V or above (VCC) 1.65V or above (VCC2)		—	5		
	GTIOCxY output skew (x = 10 to 13, Y = A or B)	2.70V or above		—	4		
		1.68V or above (VCC) 1.65V or above (VCC2)		—	5		
	GTIOCxY output skew (x = 0 to 5, 10 to 13, Y = A or B)	2.70V or above		—	6		
		1.68V or above (VCC) 1.65V or above (VCC2)		—	7		

Table 2.37 I/O ports, POEG, GPT, AGT, ULPT and ADC12 trigger timing (2 of 2)

GPT Conditions:
Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If GPT pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.
AGT Conditions:
Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.

Parameter			Symbol	Min	Max	Unit	Test conditions
AGT	AGTIO, AGTEE input cycle	2.70V or above	t_{ACYC} *2	100	—	ns	Figure 2.32
		1.68V or above (VCC) 1.65V or above (VCC2)		100	—		
	AGTIO, AGTEE input high width, low width	2.70V or above	t_{ACKWH}, t_{ACKWL}	40	—	ns	
		1.68V or above (VCC) 1.65V or above (VCC2)		40	—		
	AGTIO, AGTO, AGTOA, AGTOB output cycle	2.70V or above	t_{ACYC2}	62.5	—	ns	
		1.68V or above (VCC) 1.65V or above (VCC2)		62.5	—		
ULPT	ULPTEE, ULPTEVI input cycle	2.70V or above	t_{ULCYC} *3	32	-	µs	Figure 2.33
		1.68V or above (VCC) 1.65V or above (VCC2)		32	-		
	ULPTEE, ULPTVI input high width, low width	2.70V or above	t_{ULCKWH}, t_{ULCKWL}	12	-	µs	
		1.68V or above (VCC) 1.65V or above (VCC2)		12	-		
	ULPTO, ULPTOA, ULPTOB output cycle	2.70V or above	t_{ULCYC2}	64	-	µs	
		1.68V or above (VCC) 1.65V or above (VCC2)		64	-		
ADC12	ADC12 trigger input pulse width	2.70V or above	t_{TRGW}	1.5	—	t_{Pcyc}	Figure 2.34
		1.68V or above (VCC) 1.65V or above (VCC2)		3.0	—		

Note: t_{Icyc}: ICLK cycle, t_{Pcyc}: PCLKB cycle, t_{PDcyc}: PCLKD cycle, $t_{ULPTLCLK}$: ULPTLCLK cycle..
Note 1. For Cycle and Time, the longer time characteristics is applied.
Note 2. Constraints on input cycle:
When not switching the source clock: $t_{Pcyc} \times 2 < t_{ACYC}$ should be satisfied.
When switching the source clock: $t_{Pcyc} \times 6 < t_{ACYC}$ should be satisfied.
Note 3. Constraints on input cycle:
ULPTEVI : $t_{Pcyc} \times 2 < t_{ULCYC}$ should be satisfied.
ULPTEE: $t_{ULPTLCLK} \times 2 < t_{ULCYC}$ should be satisfied.

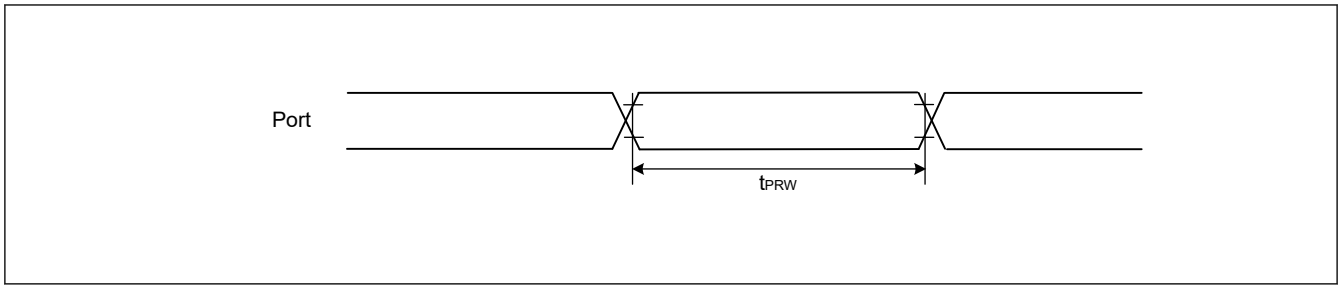


Figure 2.27 I/O ports input timing

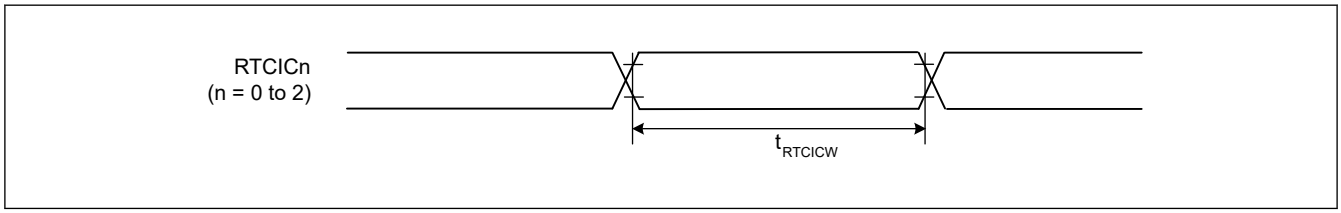


Figure 2.28 RTCICn input timing

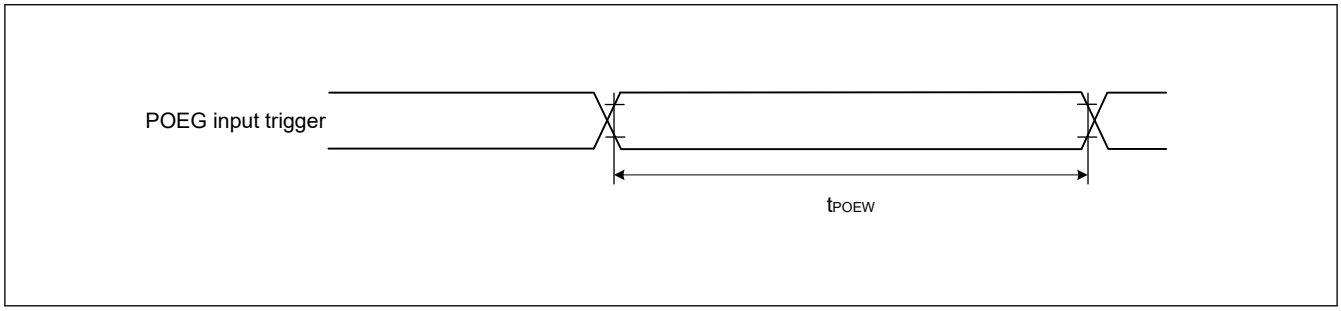


Figure 2.29 POEG input trigger timing

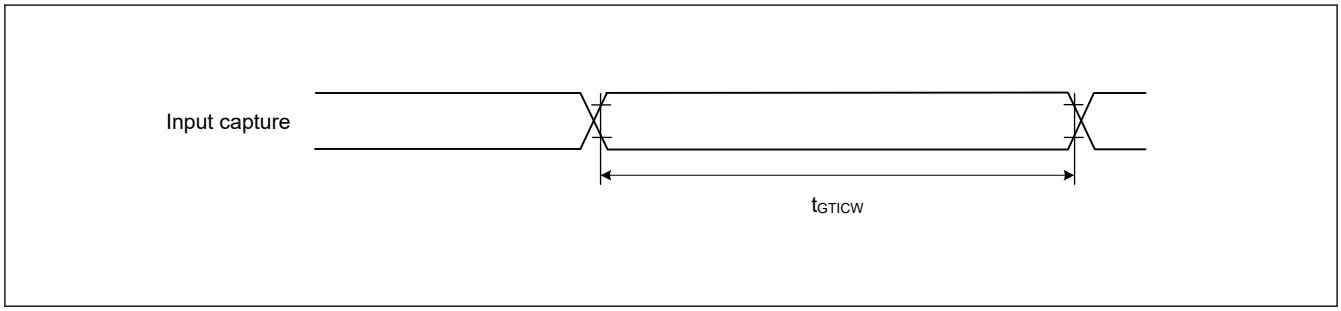


Figure 2.30 GPT input capture timing

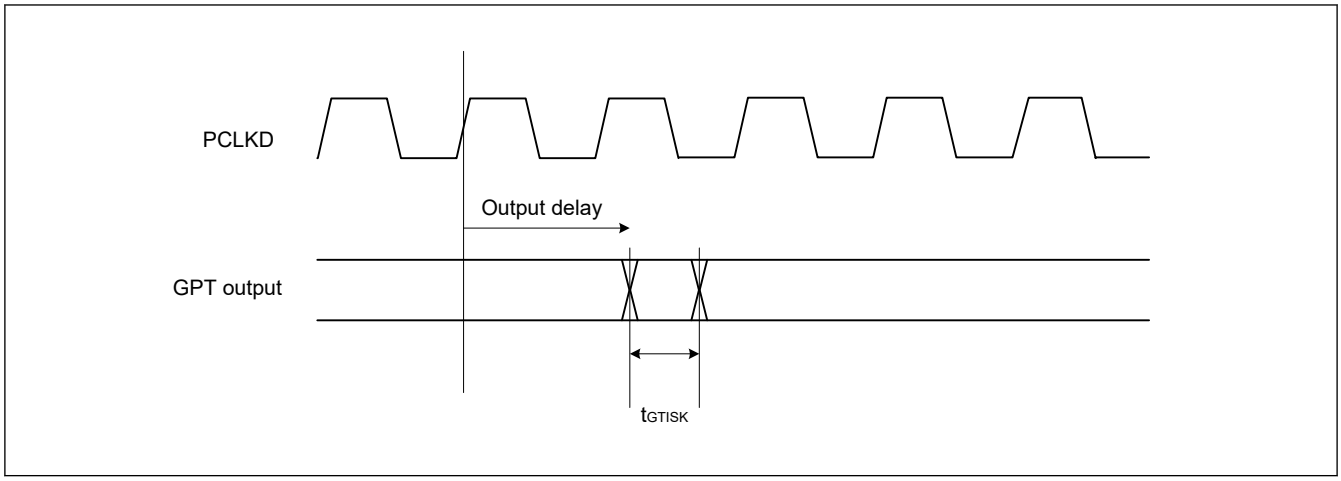


Figure 2.31 GPT output delay skew

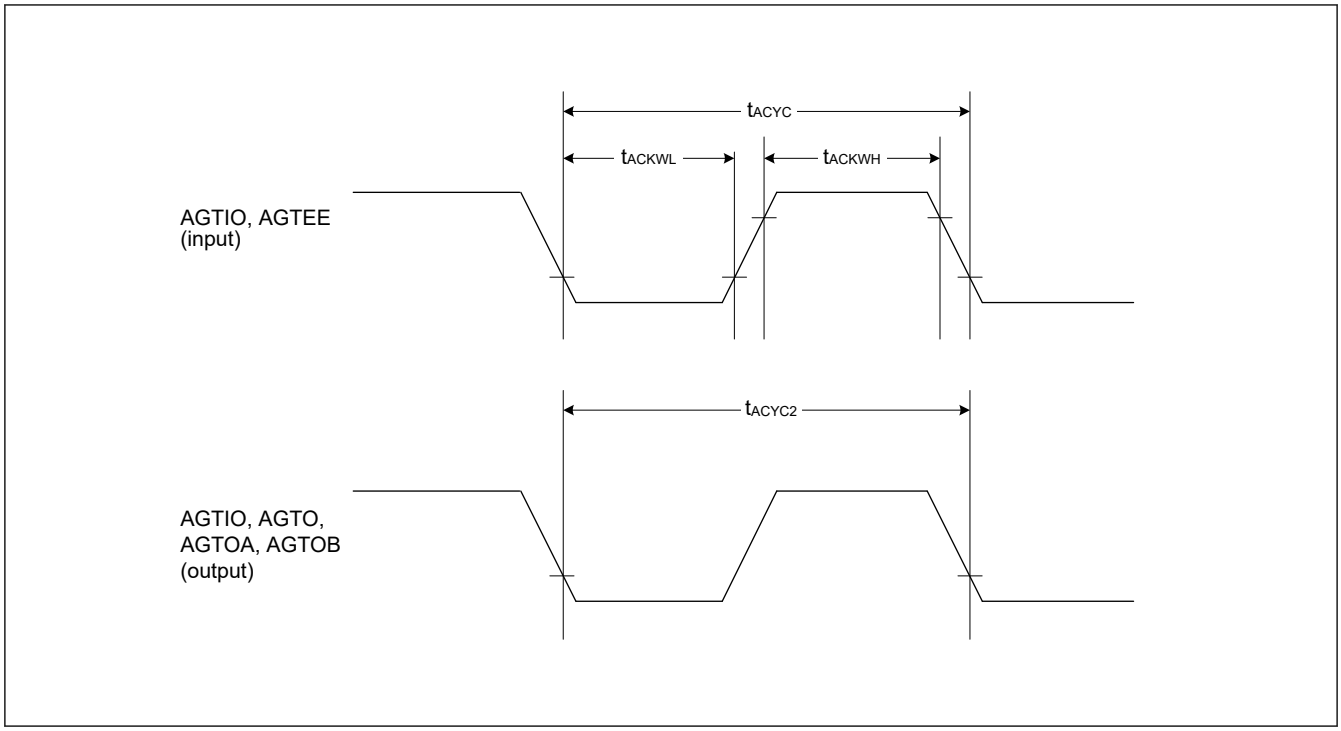


Figure 2.32 AGT input/output timing

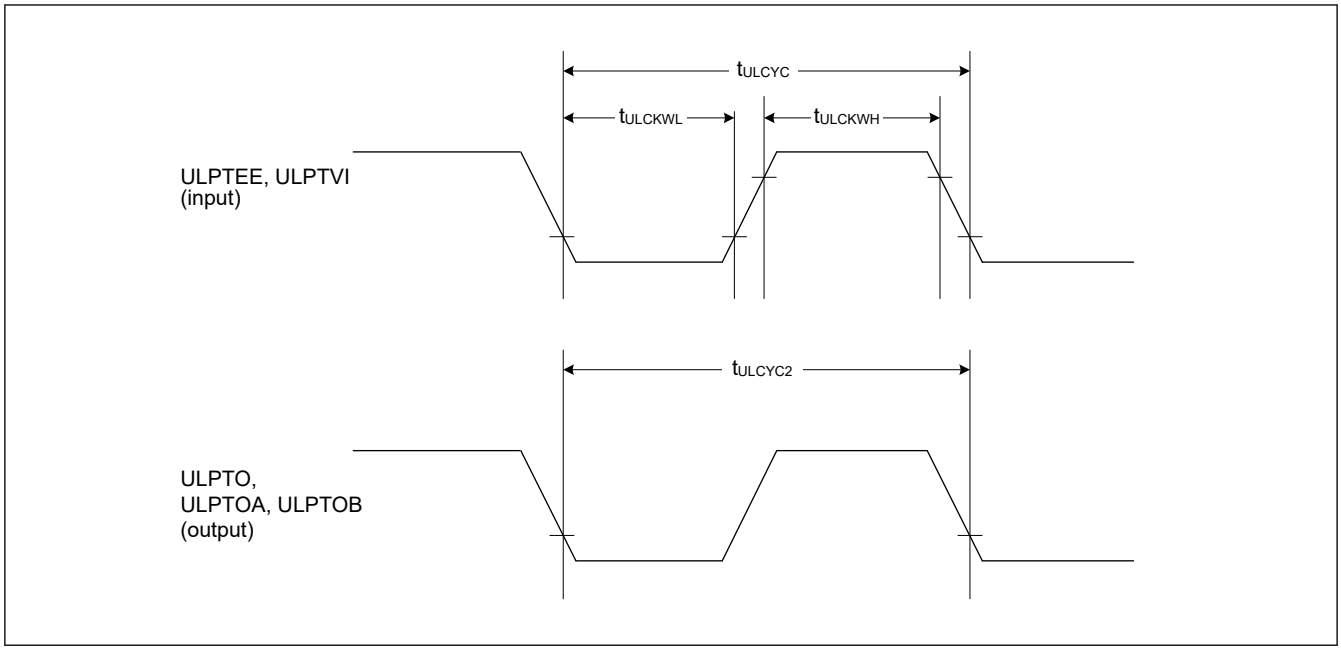


Figure 2.33 ULPT input/output timing

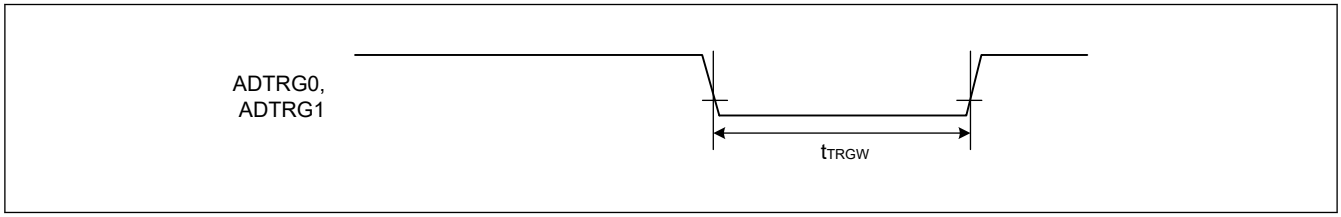


Figure 2.34 ADC12 trigger input timing

2.3.7 CAC Timing

Table 2.38 CAC timing

Parameter			Symbol	Min	Typ	Max	Unit	Test conditions
CAC	CACREF input pulse width	$t_{PBcyc} \leq t_{cac}$ *1	t_{CACREF}	4.5 × t_{cac} + 3 × t_{PBcyc}	—	—	ns	—
		$t_{PBcyc} > t_{cac}$ *1		5 × t_{cac} + 6.5 × t_{PBcyc}	—	—	ns	

Note: t_{PBcyc}: PCLKB cycle.
Note 1. t_{cac}: CAC count clock source cycle.

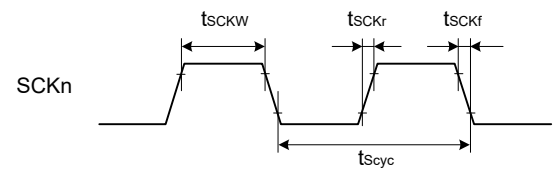
2.3.8 SCI Timing

Table 2.39 SCI timing (Asynchronous mode)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter	VCC/VCC2	Symbol	Min	Max	Unit	Note
Input clock cycle	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{Scyc}	4.0	—	t_{Tcyc}	Figure 2.35
Input clock pulse width	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SCKW}	0.4	—	t_{Scyc}	
Input clock rise time	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SCKr}	—	0.1*1	t_{Scyc}	
Input clock fall time	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SCKf}	—	0.1*1	t_{Scyc}	
Output clock cycle	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{Scyc}	6.0	—	t_{Tcyc}	
Output clock pulse width	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SCKW}	0.4	—	t_{Scyc}	
Output clock rise time	2.70 V or above	t_{SCKr}	—	3.3	ns	
	1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		
Output clock fall time	2.70 V or above	t_{SCKf}	—	3.3	ns	
	1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		

Note: tT_{cyc}: TCLK cycle.
Note 1. 1 µs at the longest



Note: n = 0 to 4, 9

Figure 2.35 SCK clock input/output timing

Table 2.40 SCI timing (Simple SPI) (1 of 2)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter		High Speed/ Default	VCC/VCC2	Symbol	Min	Max	Unit	Note
SCK clock cycle output	Master	—	2.70 V or above	t_{SPcyc}	2.0	65536	t_{Tcyc}	Figure 2.36
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	65536		
SCK clock cycle input	Slave	—	2.70 V or above		2.0	65536		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	65536		
SCK clock high pulse width	Master	—	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SPCKWH}	0.4	—	t_{SPcyc}	
	Slave	—						
SCK clock low pulse width	Master	—	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SPCKWL}	0.4	—	t_{SPcyc}	
	Slave	—						
SCK clock rise and fall time	Output	—	2.70 V or above	t_{SPCKr}, t_{SPCKf}	—	3.3	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		
	Input	—	2.70 V or above		—	0.1*3	t_{SPcyc}	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	0.1*3		
Data input setup time	Master	High Speed*1	2.70 V or above	t_{SU}	14.9 - (AST[2:0] settings)	—	ns	Figure 2.37, Figure 2.38
			1.68 V or above (VCC) 1.65 V or above (VCC2)		23.1 - (AST[2:0] settings)	—		
		Default*2	2.70 V or above		16.2 - (AST[2:0] settings)	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		23.8 - (AST[2:0] settings)	—		
	Slave	Default*2	2.70 V or above		2.5	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.5	—		
Data input hold time	Master	High Speed*1	2.70 V or above	t_H	-3.2 + (AST[2:0] settings)	—	ns	Figure 2.37, Figure 2.38
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-3.2 + (AST[2:0] settings)	—		
		Default*2	2.70 V or above		-3.2 + (AST[2:0] settings)	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-3.2 + (AST[2:0] settings)	—		
	Slave	Default*2	2.70 V or above		2.5	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.5	—		

Table 2.40 SCI timing (Simple SPI) (2 of 2)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter		High Speed/ Default	VCC/VCC2	Symbol	Min	Max	Unit	Note
Data output delay	Master	High Speed*1	2.70 V or above	t_{OD}	—	3.0	ns	Figure 2.37, Figure 2.38
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	4.5		
		Default*2	2.70 V or above		—	3.5		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	5.5		
	Slave	High Speed*1	2.70 V or above		—	15.0		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	23.0		
		Default*2	2.70 V or above		—	21.0		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	29.0		
Data output hold time	Master	High Speed*1	2.70 V or above	t_{OH}	-3.0	—	ns	Figure 2.37, Figure 2.38
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-4.5	—		
		Default*2	2.70 V or above		-3.5	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-5.5	—		
	Slave	Default*2	2.70 V or above		0.0	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		0.0	—		
Data rise and fall time	Output	—	2.70 V or above	t_{Dr}, t_{Df}	—	3.3	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		
	Input	—	2.70 V or above		—	1.0	µs	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	1.0		
SS input setup time		—	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{LEAD}	1.0	—	t_{SPcyc}	Figure 2.39, Figure 2.40
SS input hold time		—	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{LAG}	1.0	—	t_{SPcyc}	
SS input rise and fall time		—	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SSLr}, t_{SSLf}	—	1.0	µs	—
Slave access time		—	2.70 V or above	t_{SA}	—	$3 \times t_{Tcyc} + 25$	ns	Figure 2.39, Figure 2.40
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	$3 \times t_{Tcyc} + 32$		
Slave output release time		—	2.70 V or above	t_{REL}	—	$3 \times t_{Tcyc} + 25$	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	$3 \times t_{Tcyc} + 32$		

Note: t_{Tcyc}: TCLK cycle.
Note 1. Must use pins that have a letter appended to their name, for instance _A, _B, _C, to indicate group membership. SCI0, SCI1, SCI2, SCI3 and SCI9 are instance _A, SCI4 is instance _B.
Note 2. All pins of group membership can be used.
Note 3. 1 µs at the longest

Table 2.41 SCI timing (Clock synchronous mode) (1 of 3)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter		High Speed/ Default	VCC/VCC2	Symbol	Min	Max	Unit	Note
SCK clock cycle output	Master	—	2.70 V or above	t_{Scyc}	2.0	—	t_{Tcyc}	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	—		
SCK clock cycle input	Slave	—	2.70 V or above		2.0	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	—		
SCK clock high pulse width	Master	—	2.70 V or above	t_{SCKWH}	0.4	—	t_{Scyc}	
	Slave		1.68 V or above (VCC) 1.65 V or above (VCC2)					
SCK clock low pulse width	Master	—	2.70 V or above	t_{SCKWL}	0.4	—	t_{Scyc}	
	Slave		1.68 V or above (VCC) 1.65 V or above (VCC2)					
SCK clock rise and fall time	Output	—	2.70 V or above	$t_{SCKr, SCKf}$	—	3.3	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		
	Input	—	1.68 V or above (VCC) 1.65 V or above (VCC2)		—	0.1*3	t_{Scyc}	
Data input setup time	Master	High Speed*1	2.70 V or above	t_{SU}	15.1 - (AST[2:0] settings)	—	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		23.2 - (AST[2:0] settings)	—		
		Default*2	2.70 V or above		16.5 - (AST[2:0] settings)	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		24.2 - (AST[2:0] settings)	—		
	Slave	Default*2	2.70 V or above		3.3	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		5.3	—		

Table 2.41 SCI timing (Clock synchronous mode) (2 of 3)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

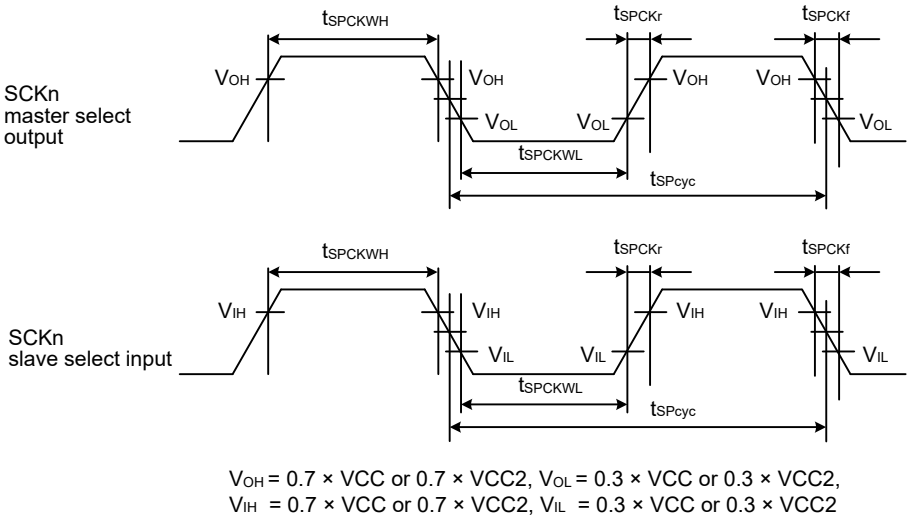
Parameter		High Speed/ Default	VCC/VCC2	Symbol	Min	Max	Unit	Note
Data input hold time	Master	High Speed*1	2.70 V or above	t_H	-3.3 + (AST[2:0] settings)	—	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-3.3 + (AST[2:0] settings)	—		
		Default*2	2.70 V or above		-3.2 + (AST[2:0] settings)	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-3.2 + (AST[2:0] settings)	—		
	Slave	Default*2	2.70 V or above		3.0	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		5.0	—		
Data output delay	Master	High Speed*1	2.70 V or above	t_{OD}	—	5.0	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	5.0		
		Default*2	2.70 V or above		—	7.3		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	7.3		
	Slave	High Speed*1	2.70 V or above		—	15.0		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	23.0		
		Default*2	2.70 V or above		—	21.0		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		—	29.0		

Table 2.41 SCI timing (Clock synchronous mode) (3 of 3)

Conditions: High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter		High Speed/ Default	VCC/VCC2	Symbol	Min	Max	Unit	Note
Data output hold time	Master	High Speed*1	2.70 V or above	t_{OH}	-5.0	—	ns	
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-5.0	—		
		Default*2	2.70 V or above		-7.3	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		-7.3	—		
	Slave	High Speed*1	2.70 V or above		0	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		0	—		
		Default*2	2.70 V or above		0	—		
			1.68 V or above (VCC) 1.65 V or above (VCC2)		0	—		
Data rise and fall time	Output	—	2.70 V or above	t_{Dr}, t_{Df}	—	3.3	ns	
		—	1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.6		
	Input	—	1.68 V or above (VCC) 1.65 V or above (VCC2)		—	1.0	µs	

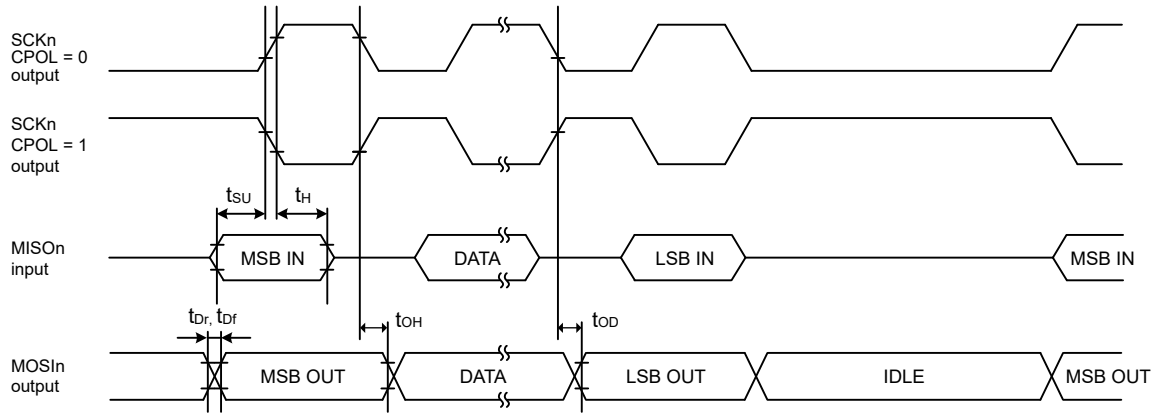
Note: t_{Tcyc}: TCLK cycle.
Note 1. Must use pins that have a letter appended to their name, for instance _A, _B, _C, to indicate group membership. SCI0, SCI1, SCI2, SCI3 and SCI9 are instance _A, SCI4 is instance _B.
Note 2. All pins of group membership can be used.
Note 3. 1 µs at the longest



V_{OH} = 0.7 × VCC or 0.7 × VCC2, V_{OL} = 0.3 × VCC or 0.3 × VCC2,
V_{IH} = 0.7 × VCC or 0.7 × VCC2, V_{IL} = 0.3 × VCC or 0.3 × VCC2

Note: n = 0 to 4, 9

Figure 2.36 SCI simple SPI mode clock timing



Note: n = 0 to 4, 9

Figure 2.37 SCI simple SPI mode timing for master when CPHA = 0

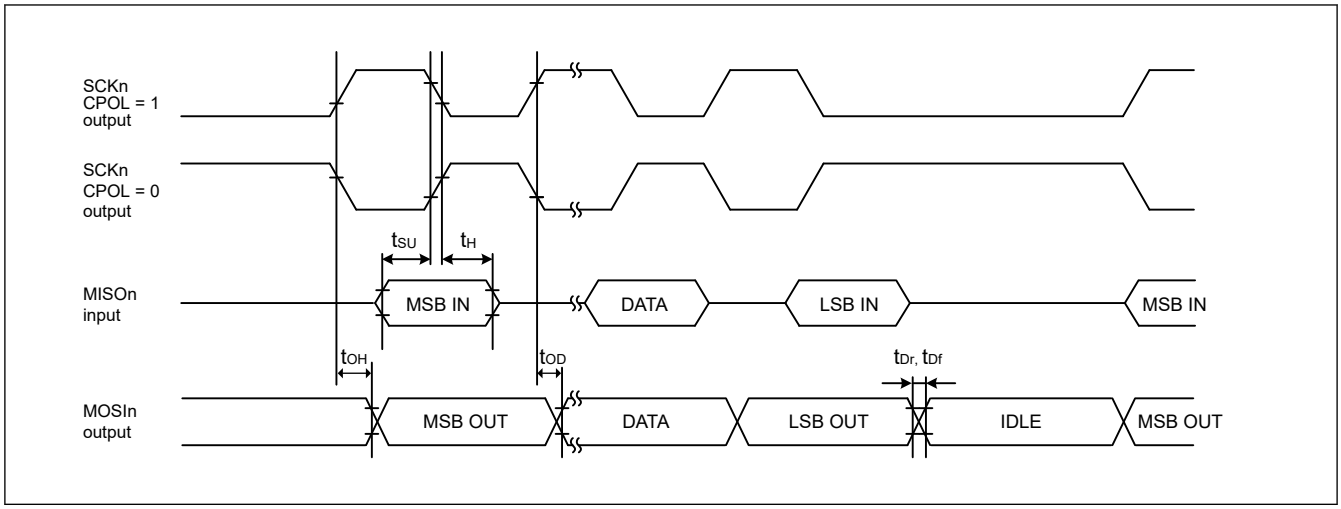
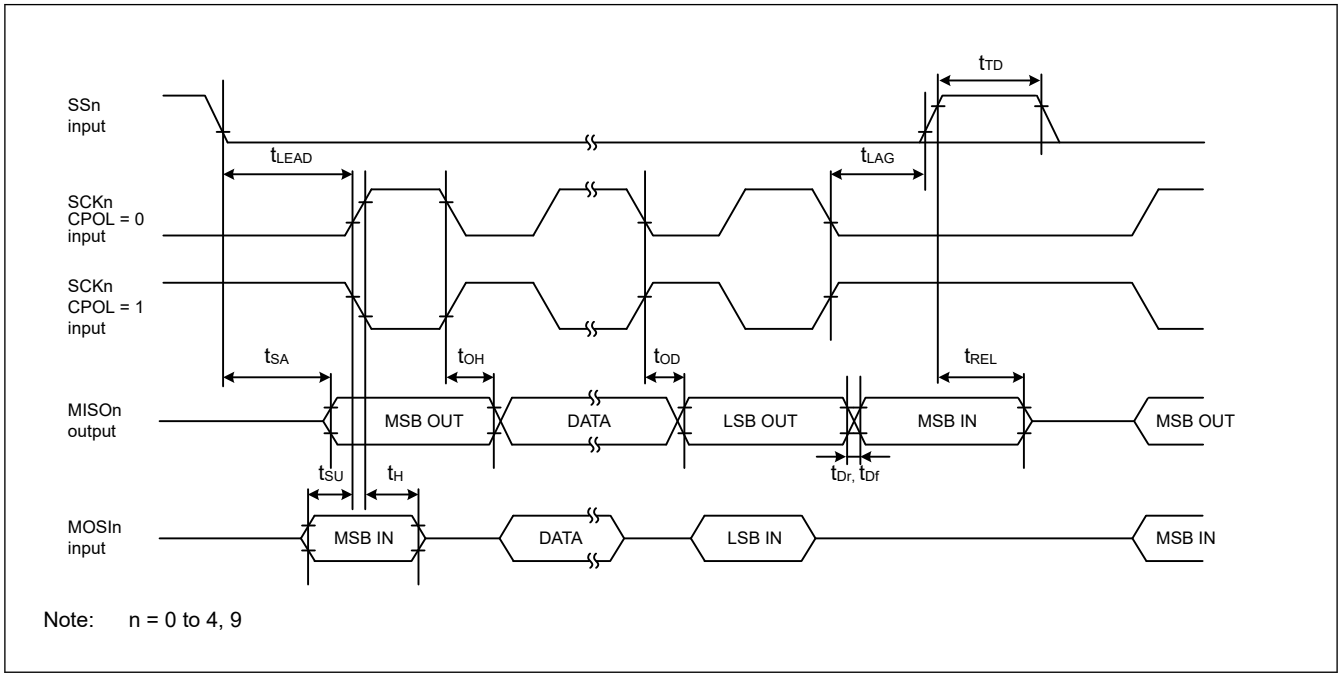
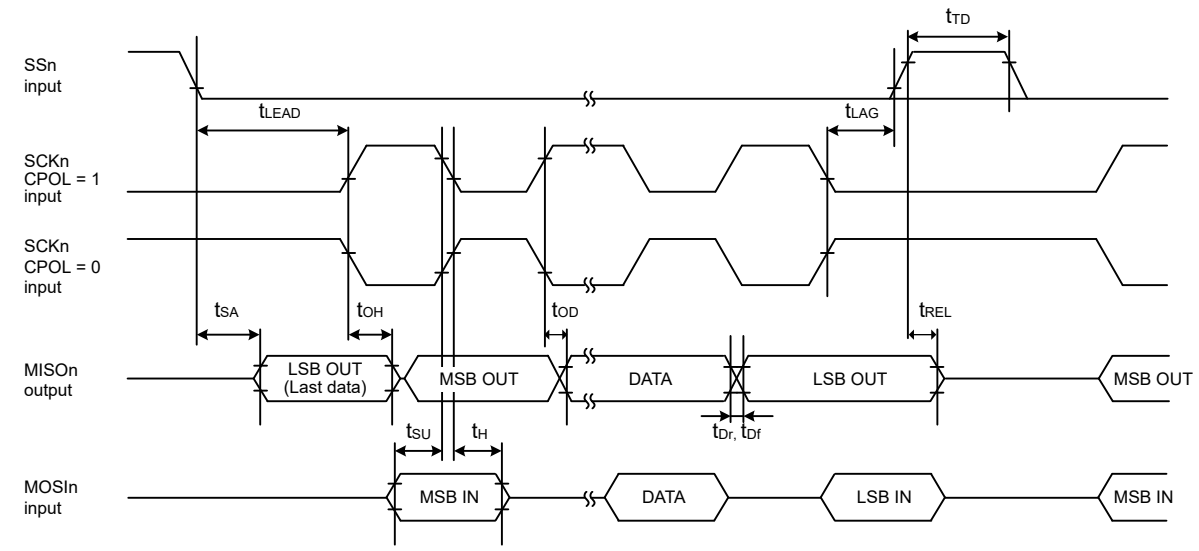


Figure 2.38 SCI simple SPI mode timing for master when CPHA = 1



Note: n = 0 to 4, 9

Figure 2.39 SCI simple SPI mode timing for slave when CPHA = 0



Note: n = 0 to 4, 9

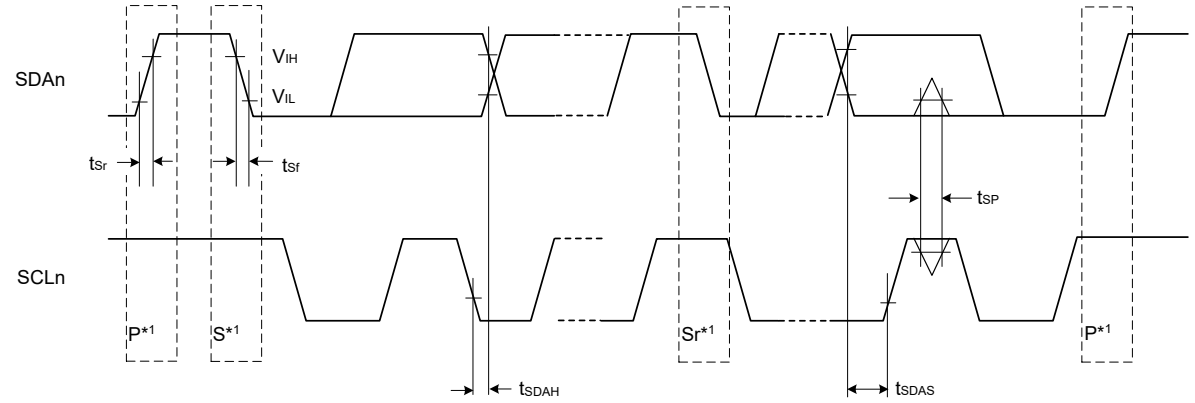
Figure 2.40 SCI simple SPI mode timing for slave when CPHA = 1

Table 2.42 SCI timing (Simple IIC mode)

Conditions: Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.
VCC: 1.68V or above, VCC2: 1.65V or above
If SCI pins are specified across the VCC I/O and VCC2 I/O, characteristics below is guaranteed only when VCC = VCC2.

Parameter		Symbol	Min	Max	Unit	Note
Simple IIC (Standard mode)	SCL, SDA input rise time	t_{Sr}	—	1000	ns	
	SCL, SDA input fall time	t_{Sf}	—	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	4 × t_{Tcyc}	ns	
	Data input setup time	t_{SDAS}	250	—	ns	
	Data input hold time	t_{SDAH}	0	—	ns	
	SCL, SDA capacitive load	C_b*1	—	400	pF	
Simple IIC (Fast mode)	SCL, SDA input rise time	t_{Sr}	—	300	ns	
	SCL, SDA input fall time	t_{Sf}	—	300	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	0	4 × t_{Tcyc}	ns	
	Data input setup time	t_{SDAS}	100	—	ns	
	Data input hold time	t_{SDAH}	0	—	ns	
	SCL, SDA capacitive load	C_b*1	—	400	pF	

Note: t_{Tcyc}: TCLK cycle.
Note 1. C_b indicates the total capacity of the bus line.



Test conditions:
V_{IH} = VCC × 0.7 or VCC2 × 0.7
V_{IL} = VCC × 0.3 or VCC2 × 0.3
V_{OL} = 0.6 V, I_{OL} = 6 mA

Note: n = 0 to 4, 9
Note 1. S, P, and Sr indicate the following conditions:
S: Start condition
P: Stop condition
Sr: Restart condition

Figure 2.41 SCI simple IIC mode timing

2.3.9 SPI Timing

Table 2.43 SPI timing (1 of 4)

Conditions:

1. High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
2. Use pins that have a letter appended to their names, for instance “_A” or “_B” to indicate group membership.
3. Load capacitance C = 15pF is applied to the VCC/VCC2 condition "3.00 V or above".

Parameter		VCC/VCC2	Symbol	Min	Max	Unit	Note
RSPCK clock cycle	Master	3.00 V or above	t_{SPcyc}	2.0	4096	t_{Tcyc}	Figure 2.42
		2.70 V or above		2.0	4096		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	4096		
	Slave	3.00 V or above		2.0	—		
		2.70 V or above		2.0	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	—		
RSPCK clock high pulse width	Master	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SPCKWH}	$(t_{SPcyc} - t_{SPCKr} - t_{SPCKf}) / 2 - 3$	—	ns	
	Slave	1.68 V or above (VCC) 1.65 V or above (VCC2)		0.4	—	t_{SPcyc}	
RSPCK clock low pulse width	Master	1.68 V or above (VCC) 1.65 V or above (VCC2)	t_{SPCKWL}	$(t_{SPcyc} - t_{SPCKr} - t_{SPCKf}) / 2 - 3$	—	ns	
	Slave	1.68 V or above (VCC) 1.65 V or above (VCC2)		0.4	—	t_{SPcyc}	
RSPCK clock rise and fall time	Output	3.00 V or above	t_{SPCKr}, t_{SPCKf}	—	1.66	ns	
		2.70 V or above		—	3.30		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.60		
	Input	3.00 V or above		—	0.1*1	t_{SPcyc}	
		2.70 V or above		—	0.1*1		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	0.1*1		

Table 2.43 SPI timing (2 of 4)

Conditions:

1. High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
2. Use pins that have a letter appended to their names, for instance “_A” or “_B” to indicate group membership.
3. Load capacitance C = 15pF is applied to the VCC/VCC2 condition "3.00 V or above".

Parameter		VCC/VCC2	Symbol	Min	Max	Unit	Note
Data input setup time	Master	3.00 V or above	t_{SU}	-2.5	—	ns	Figure 2.43, Figure 2.44
		2.70 V or above		0.0	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		0.0	—		
	Slave	3.00 V or above		2.5	—		
		2.70 V or above		2.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		2.5	—		
Data input hold time	Master	3.00 V or above	t_{H}	7.5	—	ns	
		2.70 V or above		7.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		9.5	—		
	Slave	3.00 V or above		2.5	—		
		2.70 V or above		2.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		5.5	—		
SSL setup time	Master	3.00 V or above	t_{LEAD}	1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10	ns	
		2.70 V or above		1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10		
	Slave	3.00 V or above		4.0	—	t_{Tcyc}	
		2.70 V or above		4.0	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	—		
SSL hold time	Master	3.00 V or above	t_{LAG}	1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10	ns	
		2.70 V or above		1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		1 × t_{SPcyc} - 10	8 × t_{SPcyc} + 10		
	Slave	3.00 V or above		4.0	—	t_{Tcyc}	
		2.70 V or above		4.0	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		4.0	—		

Table 2.43 SPI timing (3 of 4)

Conditions:

1. High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
2. Use pins that have a letter appended to their names, for instance “_A” or “_B” to indicate group membership.
3. Load capacitance C = 15pF is applied to the VCC/VCC2 condition "3.00 V or above".

Parameter		VCC/VCC2	Symbol	Min	Max	Unit	Note
TI SSP SS input setup time	Slave	3.00 V or above	t_{TISS}	2.5	—	ns	Figure 2.48
		2.70 V or above		2.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		2.5	—		
TI SSP SS input hold time	Slave	3.00 V or above	t_{TISH}	2.5	—	ns	
		2.70 V or above		2.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		5.5	—		
TI SSP next-access time	Slave	3.00 V or above	t_{TIND}	$2 \times t_{Tcyc} + SLNDL \times t_{Tcyc}$	—	ns	
		2.70 V or above		$2 \times t_{Tcyc} + SLNDL \times t_{Tcyc}$	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		$2 \times t_{Tcyc} + SLNDL \times t_{Tcyc}$	—		
TI SSP master SS output delay	Master	3.00 V or above	t_{TISSOD}	—	4.0	ns	Figure 2.45
		2.70 V or above		—	8.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	8.0		
Data output delay time	Master	3.00 V or above	t_{OD1}	—	2.0	ns	Figure 2.43, Figure 2.44
		2.70 V or above		—	3.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.0		
		3.00 V or above	t_{OD2}	—	2.5		
		2.70 V or above		—	2.5		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	4.5		
	Slave	3.00 V or above	t_{OD}	—	12.5		
		2.70 V or above		—	16.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	24.0		
Data output hold time	Master	3.00 V or above	t_{OH}	-2.5	—	ns	Figure 2.43, Figure 2.44
		2.70 V or above		-2.5	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		-4.5	—		
	Slave	3.00 V or above		0.0	—		
		2.70 V or above		0.0	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		0.0	—		

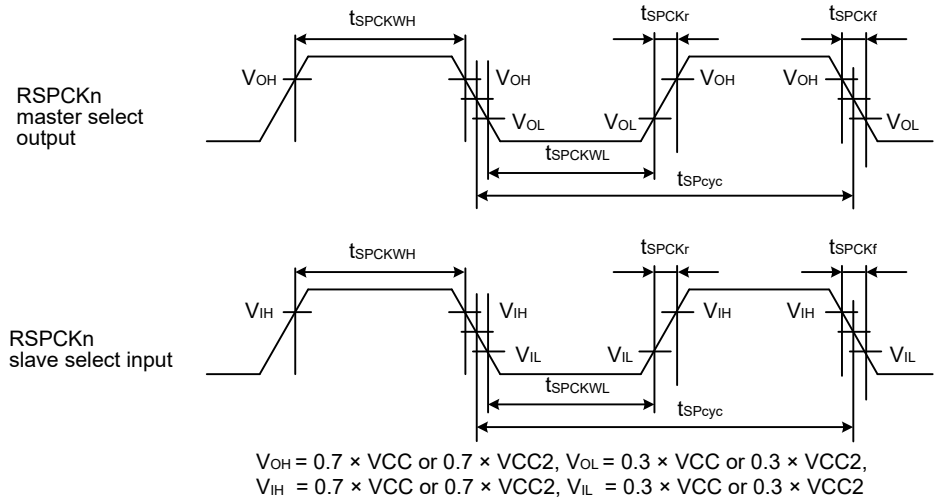
Table 2.43 SPI timing (4 of 4)

Conditions:

1. High drive output is selected in the Port Drive Capability bit in the PmnPFS register.
2. Use pins that have a letter appended to their names, for instance “_A” or “_B” to indicate group membership.
3. Load capacitance C = 15pF is applied to the VCC/VCC2 condition "3.00 V or above".

Parameter		VCC/VCC2	Symbol	Min	Max	Unit	Note
Successive transmission delay time	Master	3.00 V or above	t_{TD}	$t_{SPcyc} + 2 \times t_{Tcyc}$	$8 \times t_{SPcyc} + 2 \times t_{Tcyc}$	ns	Figure 2.43, Figure 2.44
		2.70 V or above		$t_{SPcyc} + 2 \times t_{Tcyc}$	$8 \times t_{SPcyc} + 2 \times t_{Tcyc}$		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		$t_{SPcyc} + 2 \times t_{Tcyc}$	$8 \times t_{SPcyc} + 2 \times t_{Tcyc}$		
	Slave	3.00 V or above		t_{Tcyc}	—	ns	
		2.70 V or above		t_{Tcyc}	—		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		t_{Tcyc}	—		
MOSI and MISO rise and fall time	Output	3.00 V or above	t_{Dr}, t_{Df}	—	1.66	ns	Figure 2.43, Figure 2.44
		2.70 V or above		—	3.30		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.60		
	Input	3.00 V or above		—	1.0	µs	
		2.70 V or above		—	1.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	1.0		
SSL rise and fall time	Output	3.00- V or above	t_{SSLr}, t_{SSLf}	—	1.66	ns	Figure 2.43, Figure 2.44
		2.70 V or above		—	3.30		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	6.60		
	Input	3.00 V or above		—	1.0	µs	
		2.70 V or above		—	1.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	1.0		
Slave access time	Slave	3.00 V or above	t_{SA}	—	20.0	ns	Figure 2.46, Figure 2.47
		2.70 V or above		—	20.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	25.0		
Slave output release time	Slave	3.00 V or above	t_{REL}	—	20.0	ns	
		2.70 V or above		—	20.0		
		1.68 V or above (VCC) 1.65 V or above (VCC2)		—	25.0		

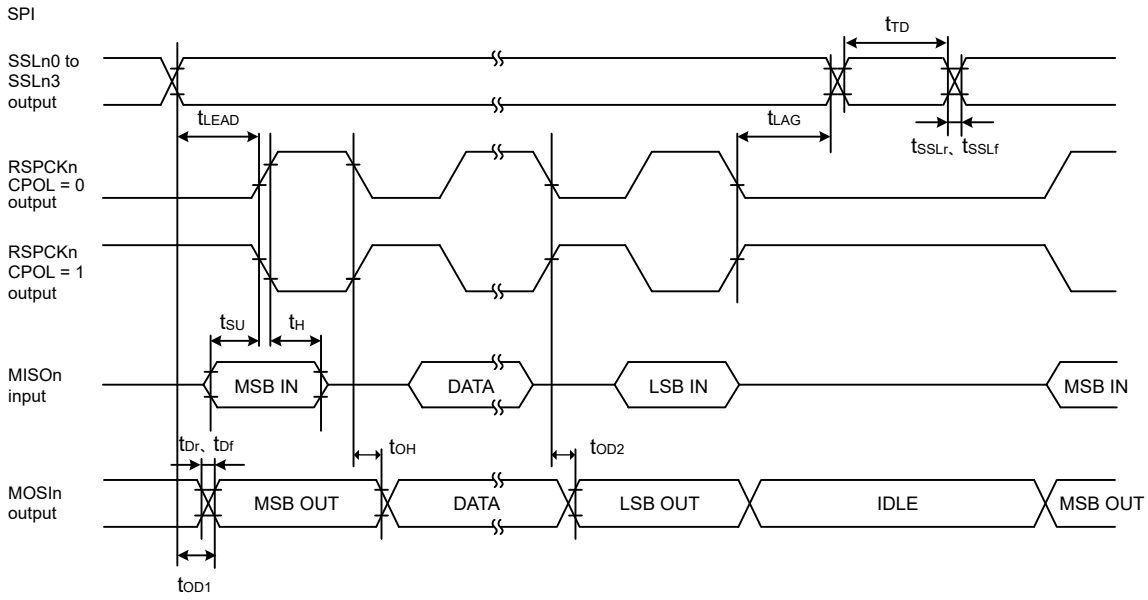
Note 1. 1 µs at the longest



V_{OH} = 0.7 × VCC or 0.7 × VCC2, V_{OL} = 0.3 × VCC or 0.3 × VCC2,
V_{IH} = 0.7 × VCC or 0.7 × VCC2, V_{IL} = 0.3 × VCC or 0.3 × VCC2

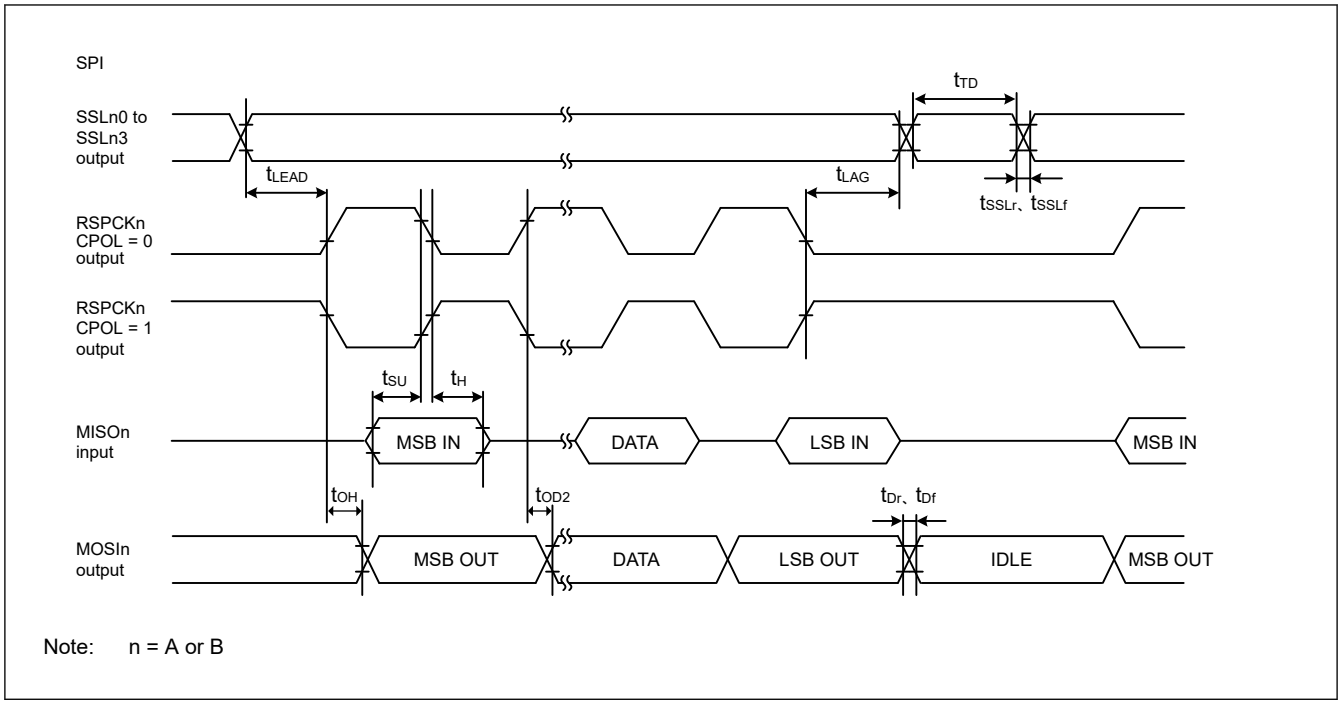
Note: n = A or B

Figure 2.42 SPI clock timing



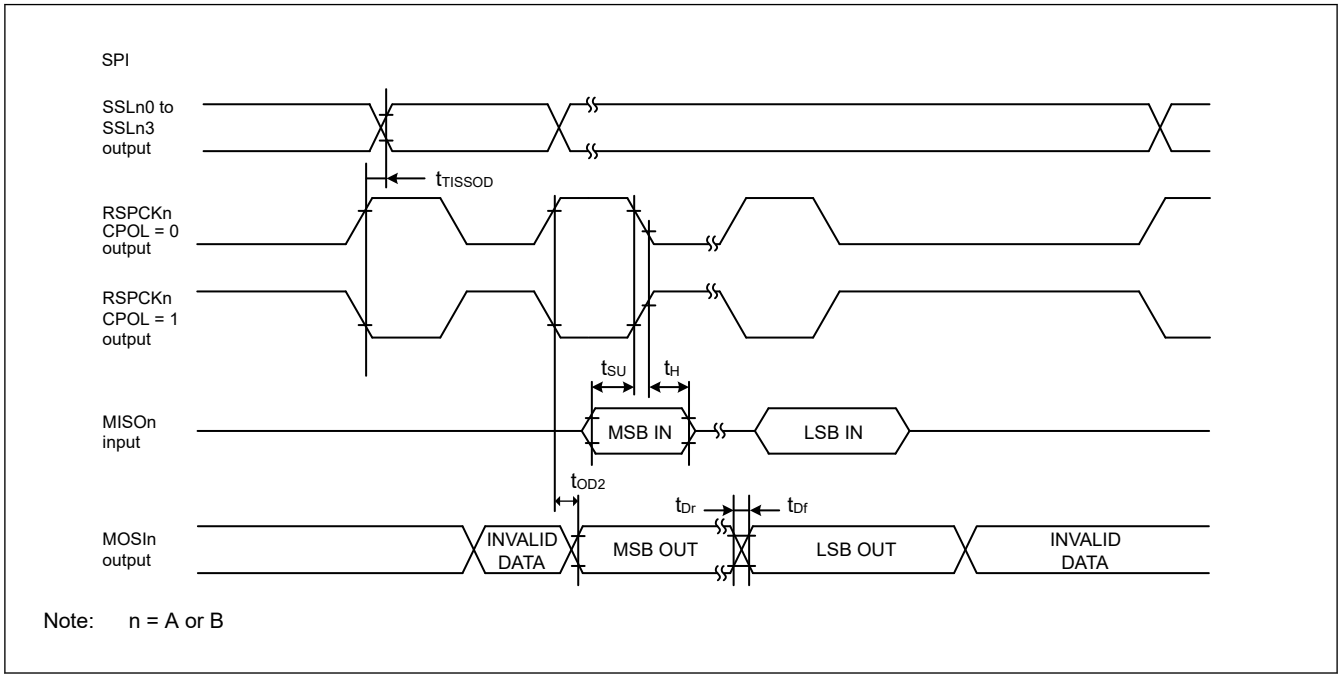
Note: n = A or B

Figure 2.43 SPI timing for Motorola SPI master when CPHA = 0



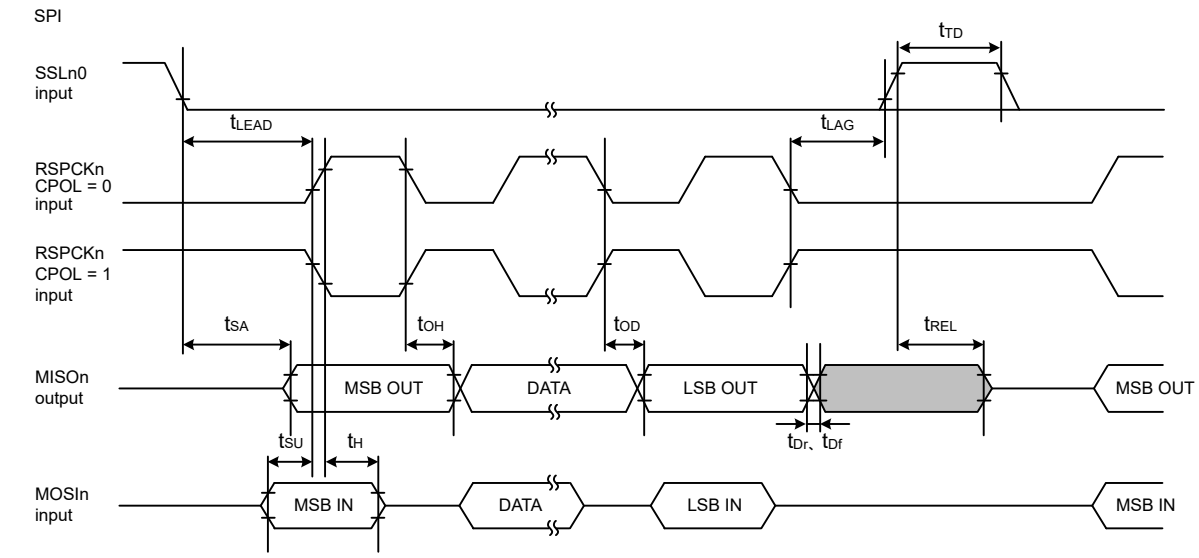
Note: n = A or B

Figure 2.44 SPI timing for Motorola SPI master when CPHA = 1



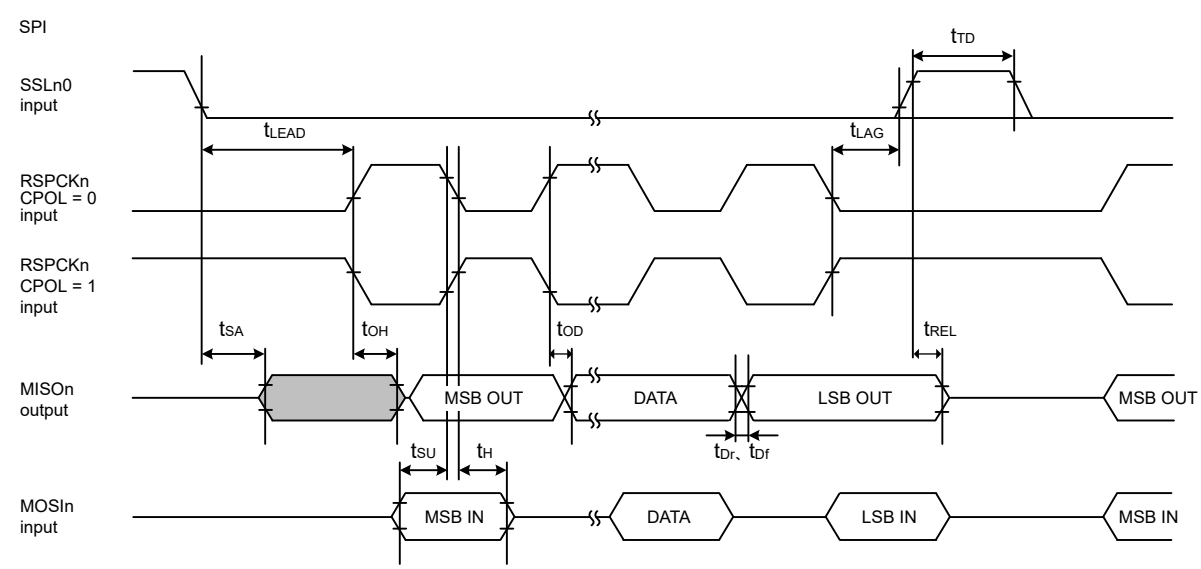
Note: n = A or B

Figure 2.45 SPI timing for TI SSP master



Note: n = A or B

Figure 2.46 SPI timing for Motorola SPI slave when CPHA = 0



Note: n = A or B

Figure 2.47 SPI timing for Motorola SPI slave when CPHA = 1

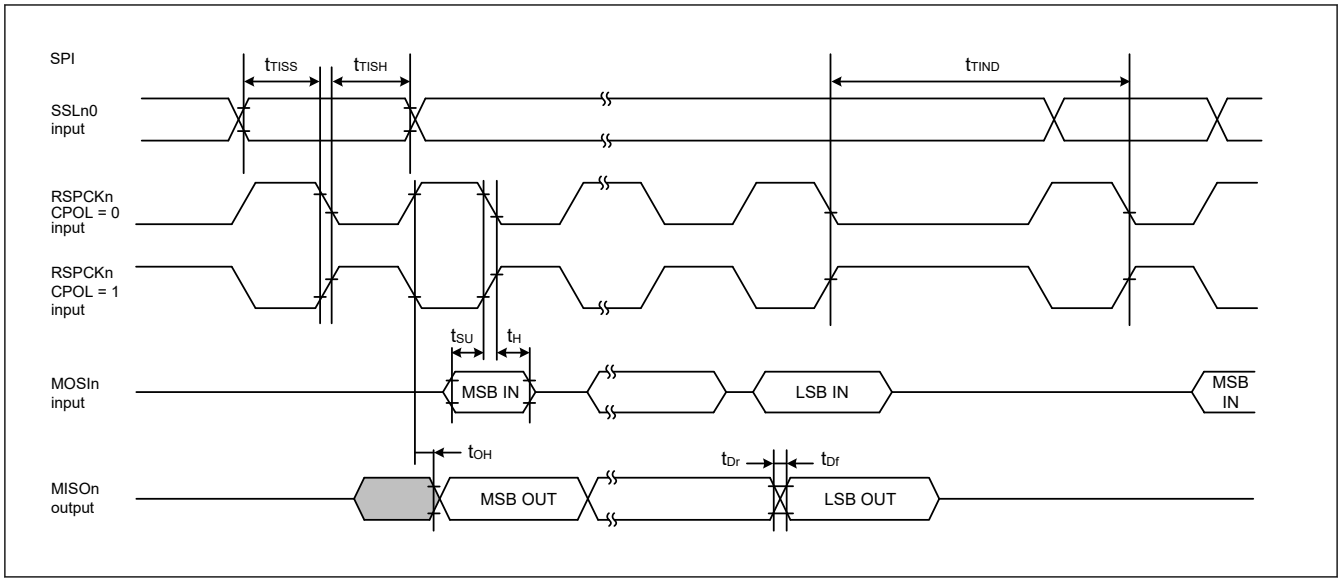


Figure 2.48 SPI timing for TI SSP slave when transmit with delay between frames

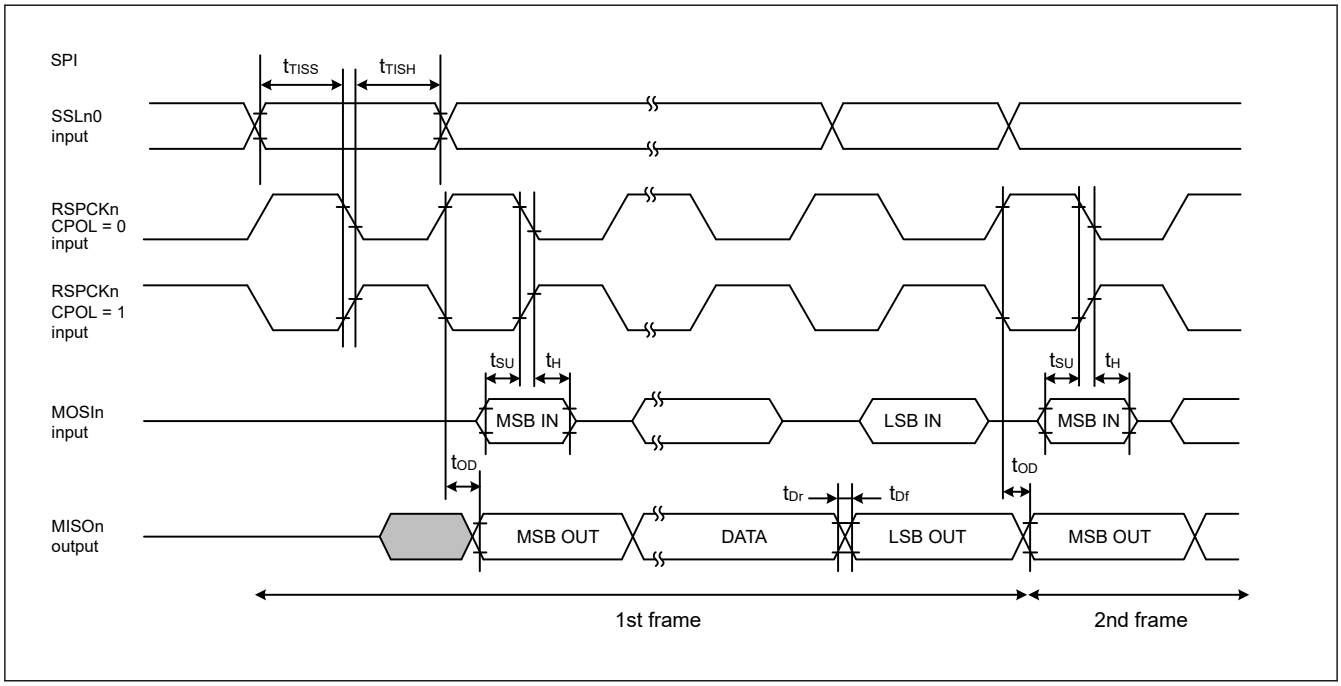


Figure 2.49 SPI timing for TI SSP slave when transmit with no delay between frames

2.3.10 OSPI Timing

Table 2.44 OSPI timing (1 of 2)

Conditions:
High-speed high drive output is selected in the port drive capability bit in the PmnPFS register for the following pins: OM_SCLK, OM_SCLKN, OM_SIO7-0, OM_DQS.
High drive output is selected in the port drive capability bit in the PmnPFS register for the following pins: OM_CS0, OM_CS1.
Load capacitance C = 20 pF

Item		Symbol	VCC/VCC2	Min	Max	Unit	Note
Cycle time	SDR without OM_DQS	t_{PERIOD}	2.70 V or above	20	—	ns	Figure 2.50
			1.65 V to 2.00 V	20	—		
	SDR with OM_DQS/DDR	t_{PERIOD}	2.70 V or above	10	—	ns	
			1.65 V to 2.00 V	10	—		
Clock output slew rate		t_{SRck}	2.70 V or above	0.56	—	V/ns	
			1.65 V to 2.00 V	0.56	—		
Clock Duty cycle-distortion		t_{CKDCD}	2.70 V or above	0	0.5	ns	
			1.65 V to 2.00 V	0	0.5		
Clock Minimum Pulse width		t_{CKMPW}	2.70 V or above	4.5	—	ns	
			1.65 V to 2.00 V	4.5	—		
Differential clock crossing volate		V_{ox}(AC)	2.70 V or above	0.4 × VCC2	0.6 × VCC2	V	
			1.65 V to 2.00 V	0.4 × VCC2	0.6 × VCC2		
DS Duty cycle distortion		t_{DSDCD}	2.70 V or above	0	0.4	ns	
			1.65 V to 2.00 V	0	0.4		
DS Minimum Pulse width		t_{DSMPW}	2.70 V or above	4.1	—	ns	
			1.65 V to 2.00 V	4.1	—		
Data input/output slew rate		t_{SR}	2.70 V or above	1.03	—	ns	
			1.65 V to 2.00 V	0.56	—		
Data input setup time (to OM_SCLK/ OM_SCLKN)	SDR without OM_DQS	t_{SU}	2.70 V or above	8.0	—	ns	Figure 2.51
			1.65 V to 2.00 V	12.5	—		
Data input hold time (to OM_SCLK/ OM_SCLKN)		t_H	2.70 V or above	0.5	—	ns	
			1.65 V to 2.00 V	0.5	—		
Data output valid time		t_{OV}*2	2.70 V or above	—	4.0	ns	
			1.65 V to 2.00 V	—	4.0		
Data output hold time		t_{OH}	2.70 V or above	−2.0	—	ns	
			1.65 V to 2.00 V	−2.0	—		
Data output buffer off time		t_{BOFF}	2.70 V or above	−2.0	—	ns	
			1.65 V to 2.00 V	−2.0	—		

Table 2.44 OSPI timing (2 of 2)

Conditions:
High-speed high drive output is selected in the port drive capability bit in the PmnPFS register for the following pins: OM_SCLK, OM_SCLKN, OM_SIO7-0, OM_DQS.
High drive output is selected in the port drive capability bit in the PmnPFS register for the following pins: OM_CS0, OM_CS1.
Load capacitance C = 20 pF

Item		Symbol	VCC/VCC2	Min	Max	Unit	Note
Data input setup time (to OM_DQS)	SDR with OM_DQS/DDR	t_{SU}	2.70 V or above	−0.9	—	ns	Figure 2.52, Figure 2.53
			1.65 V to 2.00 V	−0.9	—		
Data input hold time (to OM_DQS)		t_{H}	2.70 V or above	3.2	—	ns	
			1.65 V to 2.00 V	3.2	—		
Data output valid time		t_{OV}*2	2.70 V or above	—	$t_{PERIOD}/4$ + 0.9	ns	
			1.65 V to 2.00 V	—	$t_{PERIOD}/4$ + 0.9		
Data output hold time		t_{HO}	2.70 V or above	1.1	—	ns	
			1.65 V to 2.00 V	1.1	—		
Data output buffer off time		t_{BOFF}	2.70 V or above	1.1	—	ns	
			1.65 V to 2.00 V	1.1	—		
Clock Low to CS Low		t_{CKLCSL}	2.70 V or above	8	—	ns	Figure 2.51, Figure 2.52, Figure 2.53
			1.65 V to 2.00 V	8	—		
CS Low to Clock High		t_{CSLCKH}*3	2.70 V or above	8	—	ns	
			1.65 V to 2.00 V	8	—		
Cock Low to CS High		t_{CKLCSH}	2.70 V or above	8	—	ns	
			1.65 V to 2.00 V	8	—		
CS High to Clock High		t_{CSHCKH}	2.70 V or above	8	—	ns	
			1.65 V to 2.00 V	8	—		
DS Low output to CS High		t_{DSLCSH}	2.70 V or above	0.8 × t_{PERIOD}	—	ns	Figure 2.54
			1.65 V to 2.00 V	0.8 × t_{PERIOD}	—		
CS High to DS Tri-State		t_{CSHDST}	2.70 V or above	—	t_{PERIOD}	ns	
			1.65 V to 2.00V	—	t_{PERIOD}		
CS Low to DS Low input*1		t_{CSLDSL}	2.70 V or above	0	18.5	ns	
			1.65 V to 2.00 V	0	12.5		
DS Tri-State to CS Low		t_{DSTCSL}	2.70 V or above	0	—	ns	
			1.65 V to 2.00 V	0	—		

Note 1. This restriction does not need to be met when using the JESD251 Profile 1.0 memory with an external pull-down attached to the OM_DQS pin.
Note 2. Condition: COMCFG.OEASTEX = 1
Note 3. Condition: LIOCFGCSx.CSASTEX = 1

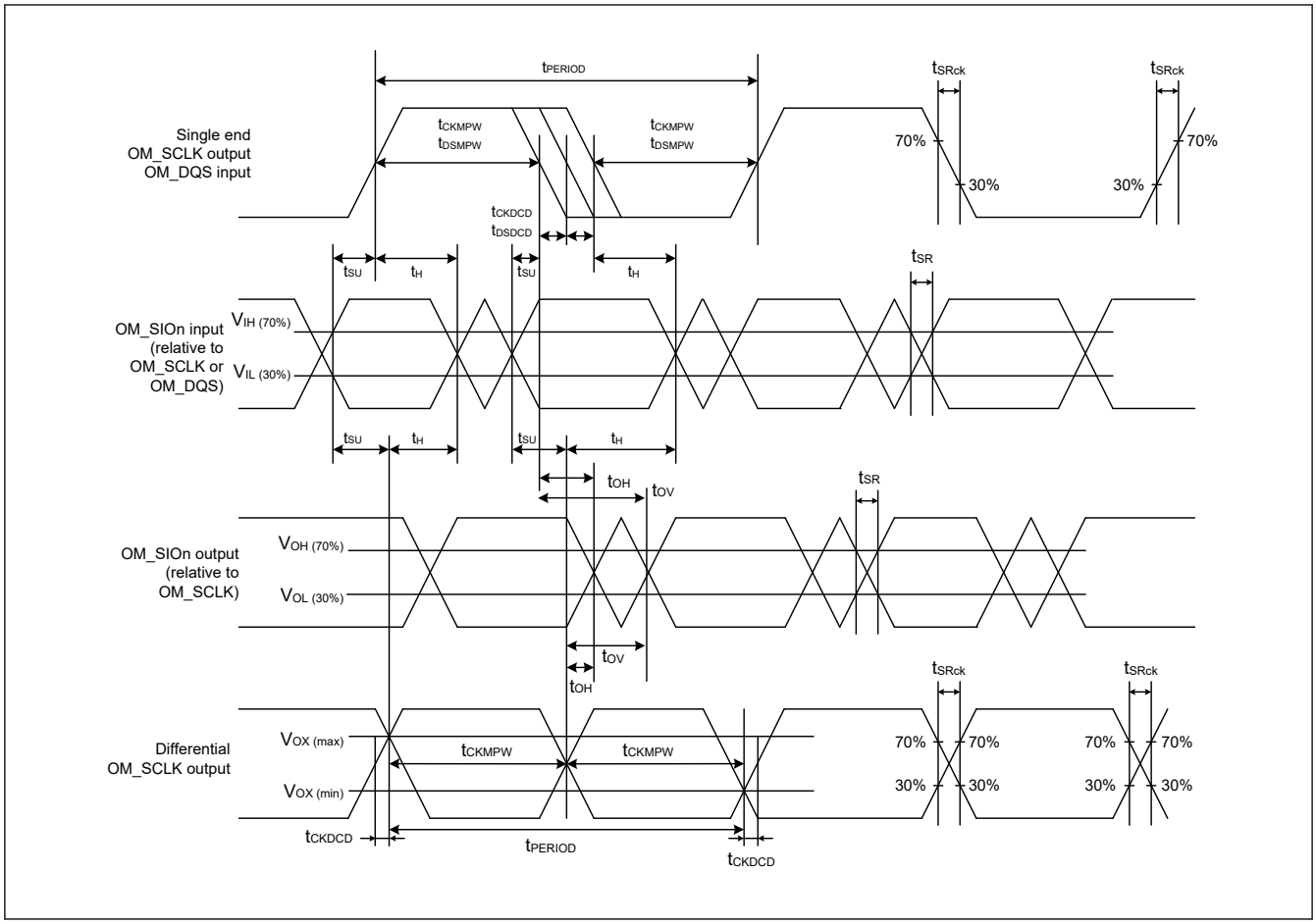


Figure 2.50 OSPI clock / DS timing

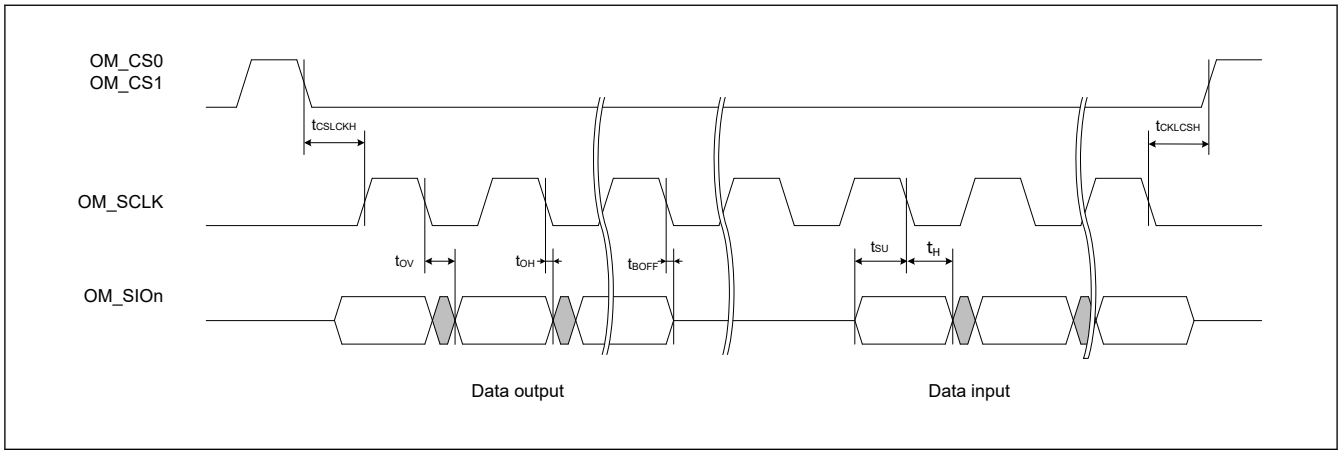


Figure 2.51 SDR transmit/receive timing (1S-1S-1S, 1S-2S-2S, 2S-2S-2S, 1S-4S-4S, 4S-4S-4S)

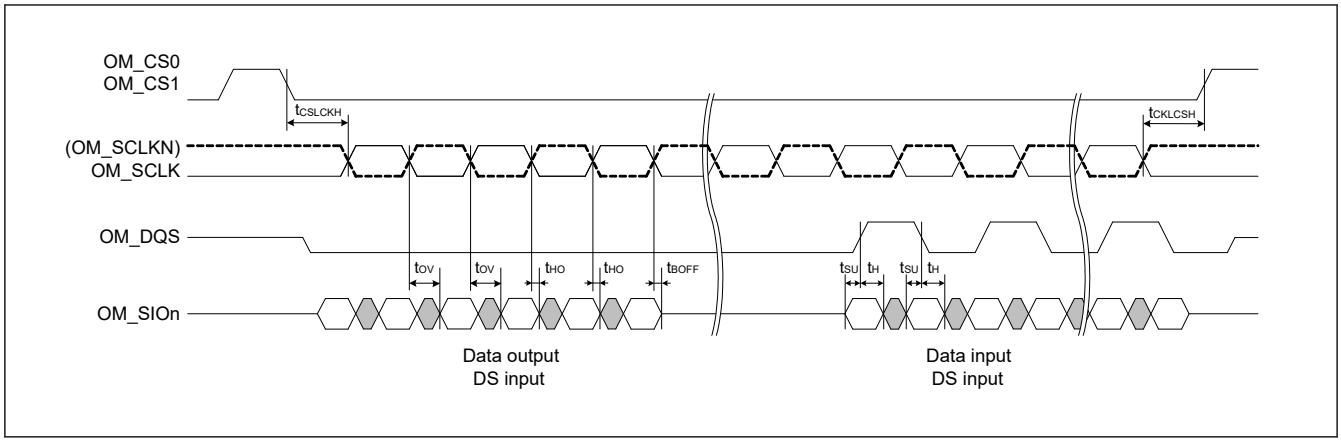


Figure 2.52 DDR transmit/receive timing (4S-4D-4D, 8D-8D-8D)

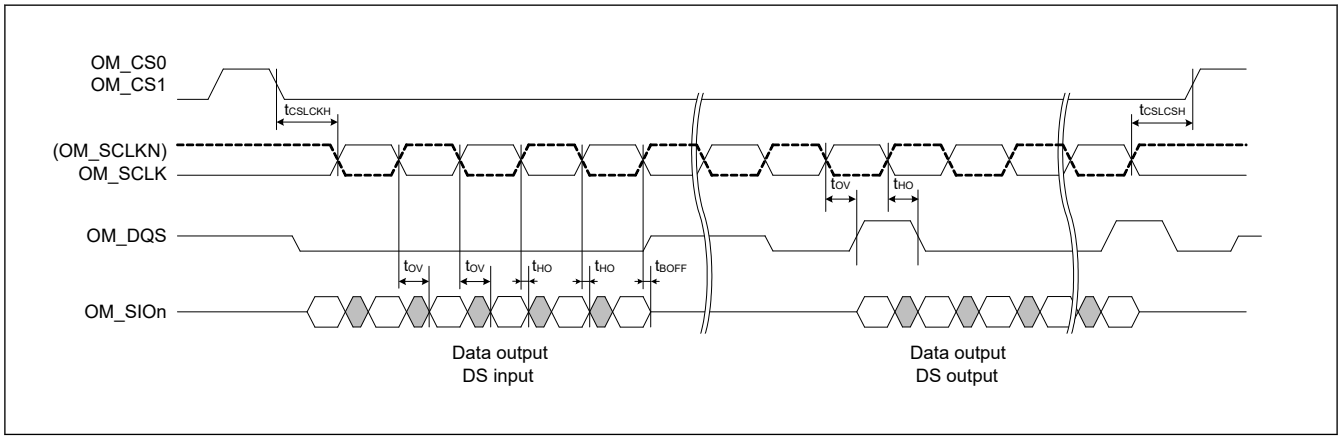


Figure 2.53 DDR transmit/receive timing (HyperRAM write)

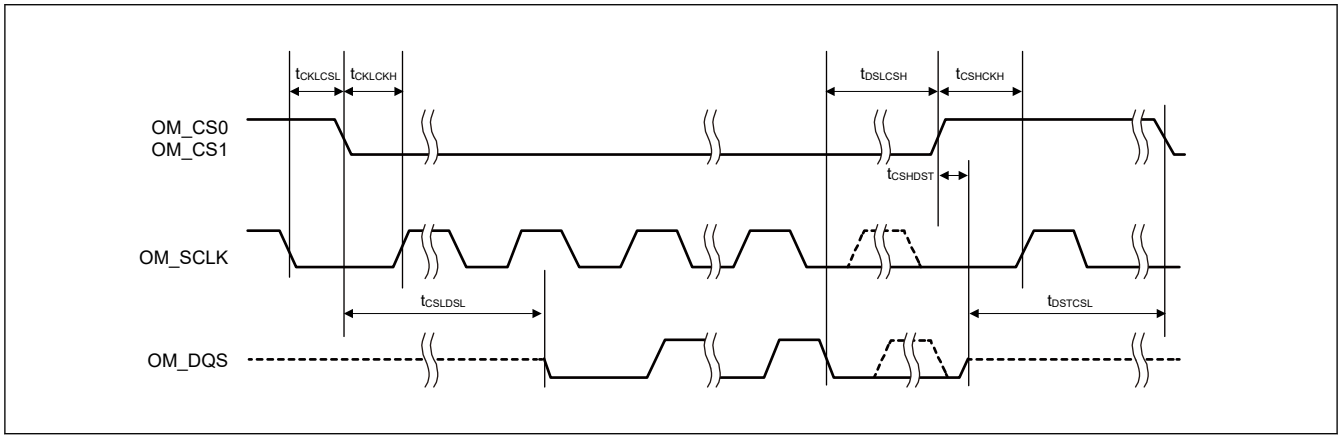


Figure 2.54 DS to CS signal timing

2.3.11 IIC Timing

Table 2.45 IIC timing (1) (1 of 2)

(1) Conditions: Middle drive output is selected when VCC is 2.70 V or above, High drive output is selected when VCC is 1.68 to 1.95 V in the port drive capability bit in the PmnPFS register for the following pins: SDA0_B, SCL0_B, SDA1_B, SCL1_B
(2) The following pins do not require setting: SCL0_A, SDA0_A. SCL1_A, SDA1_A
(3) Use pins that have a letter appended to their names, for instance "_A" or "_B", to indicate group membership.
For the IIC interface, the AC portion of the electrical characteristics is measured for each group.

Parameter		Symbol	VCC	Min	Max	Unit	Test conditions
IIC (Standard mode, SMBus) ICFER.FMPE = 0 when VCC is 2.70 V or above, ICFER.FMPE = 1 when VCC is 1.68 to 1.95 V	SCL input cycle time	t_{SCL}	2.70 V or above	6 (12) × t_{IICcyc} + 1300	—	ns	Figure 2.55
			1.68 to 1.95 V				
	SCL input high pulse width	t_{SCLH}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SCL input low pulse width	t_{SCLL}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SCL, SDA rise time	t_{Sr}	2.70 V or above	—	1000	ns	
			1.68 to 1.95 V				
	SCL, SDA fall time	t_{Sf}	2.70 V or above	—	300	ns	
			1.68 to 1.95 V				
	SCL, SDA input spike pulse removal time	t_{SP}	2.70 V or above	0	1 (4) × t_{IICcyc}	ns	
			1.68 to 1.95 V				
	SDA input bus free time when wakeup function is disabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SDA input bus free time when wakeup function is enabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 4 × t_{Pcyc} + 300	—	ns	
			1.68 to 1.95 V				
	START condition input hold time when wakeup function is disabled	t_{STAH}	2.70 V or above	t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	START condition input hold time when wakeup function is enabled	t_{STAH}	2.70 V or above	1 (5) × t_{IICcyc} + t_{Pcyc} + 300	—	ns	
			1.68 to 1.95 V				
	Repeated START condition input setup time	t_{STAS}	2.70 V or above	1000	—	ns	
			1.68 to 1.95 V				
	STOP condition input setup time	t_{STOS}	2.70 V or above	1000	—	ns	
			1.68 to 1.95 V				
	Data input setup time	t_{SDAS}	2.70 V or above	t_{IICcyc} + 50	—	ns	
			1.68 to 1.95 V				
	Data input hold time	t_{SDAH}	2.70 V or above	0	—	ns	
			1.68 to 1.95 V				
	SCL, SDA capacitive load	C_b	2.70 V or above	—	400	pF	
			1.68 to 1.95 V				

Table 2.45 IIC timing (1) (2 of 2)

(1) Conditions: Middle drive output is selected when VCC is 2.70 V or above, High drive output is selected when VCC is 1.68 to 1.95 V in the port drive capability bit in the PmnPFS register for the following pins: SDA0_B, SCL0_B, SDA1_B, SCL1_B
(2) The following pins do not require setting: SCL0_A, SDA0_A. SCL1_A, SDA1_A
(3) Use pins that have a letter appended to their names, for instance "_A" or "_B", to indicate group membership. For the IIC interface, the AC portion of the electrical characteristics is measured for each group.

Parameter		Symbol	VCC	Min	Max	Unit	Test conditions
IIC (Fast mode) ICFER.FMPE = 0 when VCC is 2.70 V or above, ICFER.FMPE = 1 when VCC is 1.68 to 1.95 V	SCL input cycle time	t_{SCL}	2.70 V or above	6 (12) × t_{IICcyc} + 600	—	ns	Figure 2.55
			1.68 to 1.95 V				
	SCL input high pulse width	t_{SCLH}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SCL input low pulse width	t_{SCLL}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SCL, SDA rise time	t_{Sr}	2.70 V or above	20	300	ns	
			1.68 to 1.95 V				
	SCL, SDA fall time	t_{Sf}	2.70 V or above	20 × (external pullup voltage/5.5 V)*1	300	ns	
			1.68 to 1.95 V				
	SCL, SDA input spike pulse removal time	t_{SP}	2.70 V or above	0	1 (4) × t_{IICcyc}	ns	
			1.68 to 1.95 V				
	SDA input bus free time when wakeup function is disabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	SDA input bus free time when wakeup function is enabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 4 × t_{Pcyc} + 300	—	ns	
			1.68 to 1.95 V				
	START condition input hold time when wakeup function is disabled	t_{STAH}	2.70 V or above	t_{IICcyc} + 300	—	ns	
			1.68 to 1.95 V				
	START condition input hold time when wakeup function is enabled	t_{STAH}	2.70 V or above	1 (5) × t_{IICcyc} + t_{Pcyc} + 300	—	ns	
			1.68 to 1.95 V				
	Repeated START condition input setup time	t_{STAS}	2.70 V or above	300	—	ns	
			1.68 to 1.95 V				
	STOP condition input setup time	t_{STOS}	2.70 V or above	300	—	ns	
			1.68 to 1.95 V				
	Data input setup time	t_{SDAS}	2.70 V or above	t_{IICcyc} + 50	—	ns	
			1.68 to 1.95 V				
	Data input hold time	t_{SDAH}	2.70 V or above	0	—	ns	
			1.68 to 1.95 V				
	SCL, SDA capacitive load	C_b	2.70 V or above	—	400	pF	
			1.68 to 1.95 V				

Note: t_{IICcyc}: IIC internal reference clock (IICφ) cycle, t_{Pcyc}: PCLKB cycle.
Note: Values in parentheses apply when ICMR3.NF[1:0] is set to 11b while the digital filter is enabled with ICFER.NFE set to 1.
Note: Must use pins that have a letter appended to their name, for instance "_A", "_B", to indicate group membership. For the IIC interface, the AC portion of the electrical characteristics is measured for each group.
Note 1. Only supported for SCL0_A, SDA0_A, SCL1_A, and SDA1_A.

Table 2.46 IIC timing (2)

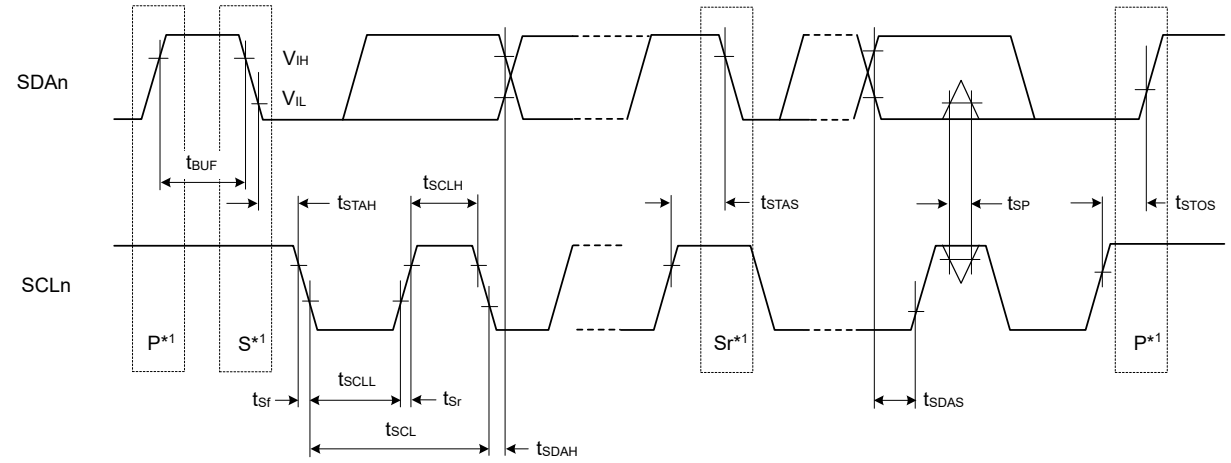
Setting of the SCL0_A, SDA0_A, SCL1_A, SDA1_A pins are not required with the port drive capability bit in the PmnPFS register.

Parameter		Symbol	VCC	Min	Max	Unit	Test conditions
IIC (Fast-mode+) ICFER.FMPE = 1	SCL input cycle time	t_{SCL}	2.70 V or above	6 (12) × t_{IICcyc} + 240	—	ns	Figure 2.55
	SCL input high pulse width	t_{SCLH}	2.70 V or above	3 (6) × t_{IICcyc} + 120	—	ns	
	SCL input low pulse width	t_{SCLL}	2.70 V or above	3 (6) × t_{IICcyc} + 120	—	ns	
	SCL, SDA rise time	t_{Sr}	2.70 V or above	—	120	ns	
	SCL, SDA fall time	t_{Sf}	2.70 V or above	20 × (external pullup voltage/ 5.5V)	120	ns	
	SCL, SDA input spike pulse removal time	t_{SP}	2.70 V or above	0	1 (4) × t_{IICcyc}	ns	
	SDA input bus free time when wakeup function is disabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 120	—	ns	
	SDA input bus free time when wakeup function is enabled	t_{BUF}	2.70 V or above	3 (6) × t_{IICcyc} + 4 × t_{Pcyc} + 120	—	ns	
	Start condition input hold time when wakeup function is disabled	t_{STAH}	2.70 V or above	t_{IICcyc} + 120	—	ns	
	START condition input hold time when wakeup function is enabled	t_{STAH}	2.70 V or above	1 (5) × t_{IICcyc} + t_{Pcyc} + 120	—	ns	
	Restart condition input setup time	t_{STAS}	2.70 V or above	120	—	ns	
	Stop condition input setup time	t_{STOS}	2.70 V or above	120	—	ns	
	Data input setup time	t_{SDAS}	2.70 V or above	t_{IICcyc} + 30	—	ns	
	Data input hold time	t_{SDAH}	2.70 V or above	0	—	ns	
	SCL, SDA capacitive load	C_b*1	2.70 V or above	—	550	pF	

Note: t_{IICcyc}: IIC internal reference clock (IICφ) cycle, tPcyc: PCLKB cycle.

Note: Values in parentheses apply when ICMR3.NF[1:0] is set to 11b while the digital filter is enabled with ICFER.NFE set to 1.

Note 1. Cb indicates the total capacity of the bus line.



Note 1. S, P, and Sr indicate the following conditions:
S: Start condition
P: Stop condition
Sr: Restart condition

Figure 2.55 I²C bus interface input/output timing

2.3.12 SSIE Timing

Table 2.47 SSIE timing (1 of 2)

(1) High drive output is selected with the Port Drive Capability bit in the PmnPFS register.
(2) Use pins that have a letter appended to their names, for instance "_A" , "_B" or "_C" to indicate group membership. For the SSIE interface, the AC portion of the electrical characteristics is measured for each group.

Parameter			Symbol	VCC	Min.	Max.	Unit	Comments
SSIBCK	Cycle	Master	t_O	2.70V or above	80	—	ns	Figure 2.56
				1.68V or above	80	—		
		Slave	t_I	2.70V or above	80	—	ns	
				1.68V or above	80	—		
	High level/ low level	Master	t_{HC}/t_{LC}	2.70V or above	0.35	—	t_O	
				1.68V or above	0.35	—		
		Slave		2.70V or above	0.35	—	t_I	
				1.68V or above	0.35	—		
	Rising time/ falling time	Master	t_{RC}/t_{FC}	2.70V or above	—	0.15	t_O / t_I	
				1.68V or above	—	0.15		
		Slave		2.70V or above	—	0.15	t_O / t_I	
				1.68V or above	—	0.15		

Table 2.47 SSIE timing (2 of 2)

(1) High drive output is selected with the Port Drive Capability bit in the PmnPFS register.
(2) Use pins that have a letter appended to their names, for instance "_A" , "_B" or "_C" to indicate group membership. For the SSIE interface, the AC portion of the electrical characteristics is measured for each group.

Parameter			Symbol	VCC	Min.	Max.	Unit	Comments
SSILRCK0/ SSIFS0, SSITXD0, SSIRXD0	Input set up time	Master	t_{SR}	2.70V or above	12	—	ns	Figure 2.58, Figure 2.59
				1.68V or above	20	—		
		Slave		2.70V or above	12	—	ns	
				1.68V or above	12	—		
	Input hold time	Master	t_{HR}	2.70V or above	8	—	ns	
				1.68V or above	8	—		
		Slave		2.70V or above	15	—	ns	
				1.68V or above	15	—		
	Output delay time	Master	t_{DTR}	2.70V or above	-10	5	ns	
				1.68V or above	-10	7		
		Slave		2.70V or above	0	20	ns	
				1.68V or above	0	25		
	Output delay time from SSILRCK/ SSIFS change	Slave	t_{DTRW}	2.70V or above	—	20	ns	Figure 2.60
				1.68V or above	—	25		
GTIOC2A, AUDIO_CLK	Cycle		t_{EXcyc}	2.70V or above	20	—	ns	Figure 2.57*1
				1.68V or above	40	—		
	High level/ low level		t_{EXL}/t_{EXH}	2.70V or above	0.4	—	t_{EXcyc}	
				1.68V or above	0.4	—		
	Rising time/ falling time		t_{EXr}/t_{EXr}	2.70V or above	—	0.1*2	t_{EXcyc}	
				1.68V or above	—	0.1*2		

Note 1. For slave-mode transmission, SSIE has a path, through which the signal input from the SSILRCK/SSIFS pin is used to generate transmit data, and the transmit data is logically output to the SSITXD0 or SSIDATA1 pin.
Note 2. 1µs at the longest

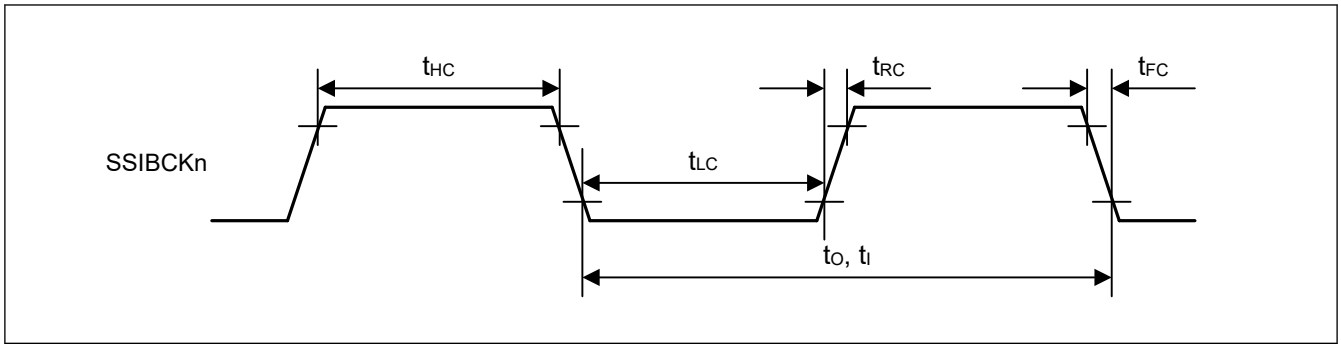


Figure 2.56 SSIE clock input/output timing

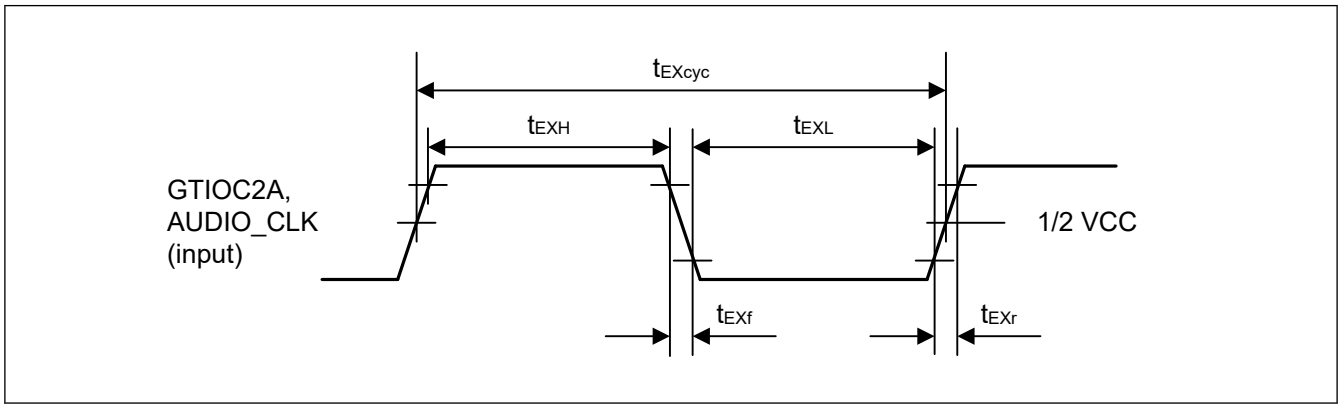


Figure 2.57 Clock input timing

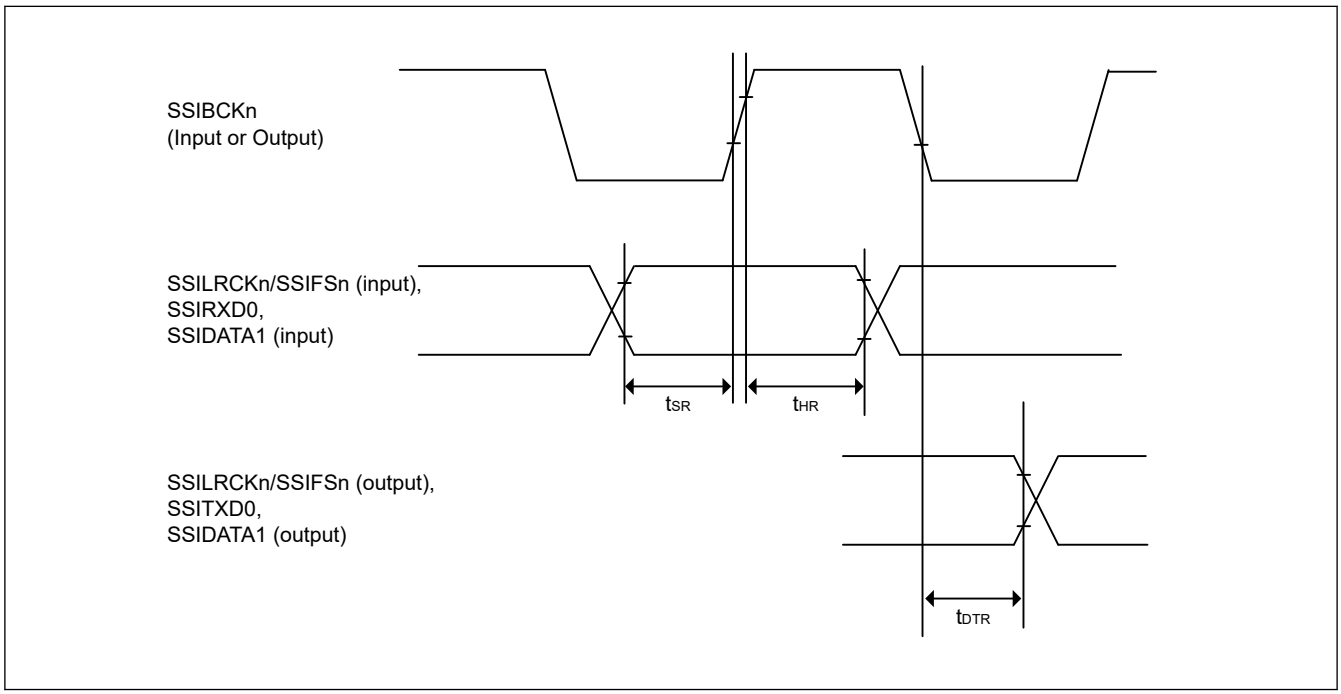


Figure 2.58 SSIE data transmit and receive timing when SSICR.BCKP = 0

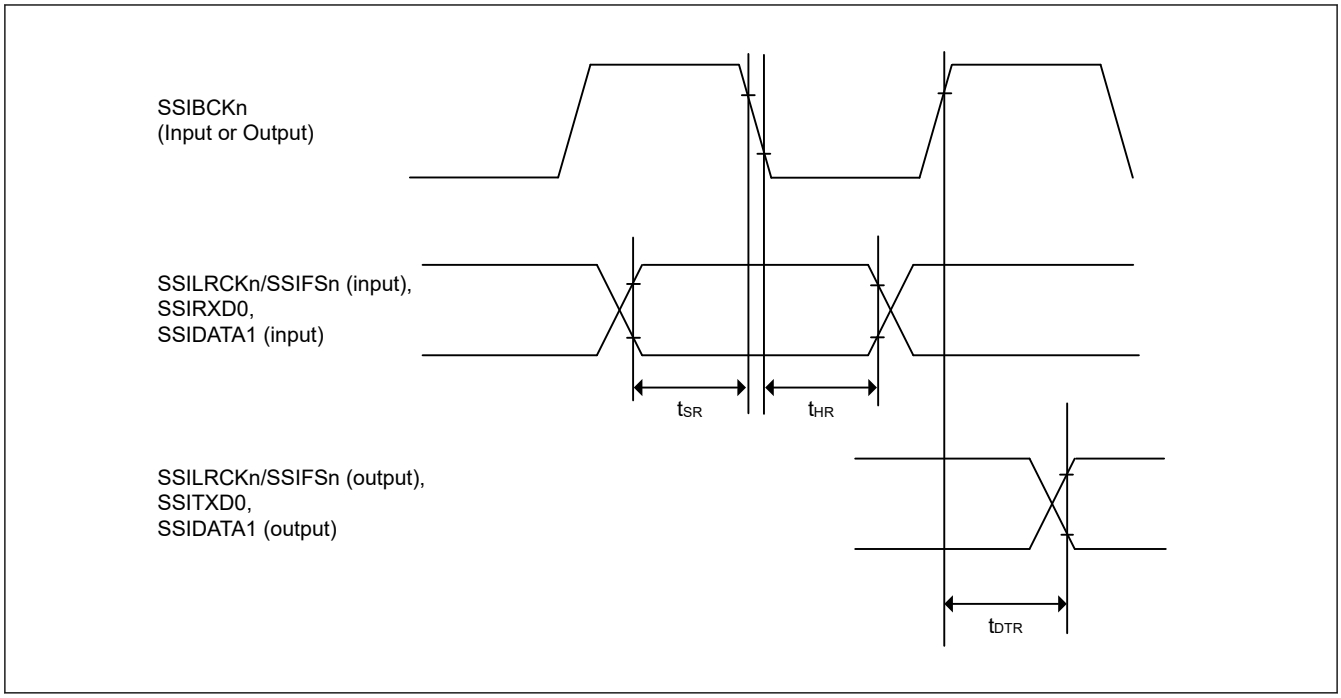


Figure 2.59 SSIE data transmit and receive timing when SSICR.BCKP = 1

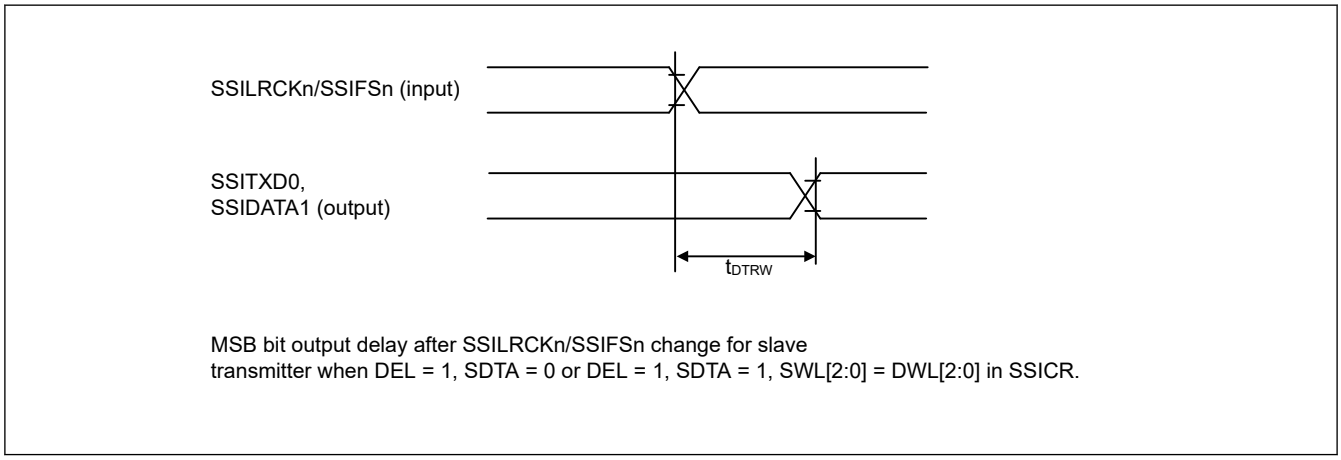


Figure 2.60 SSIE data output delay after SSILRCK0/SSIFS0 change

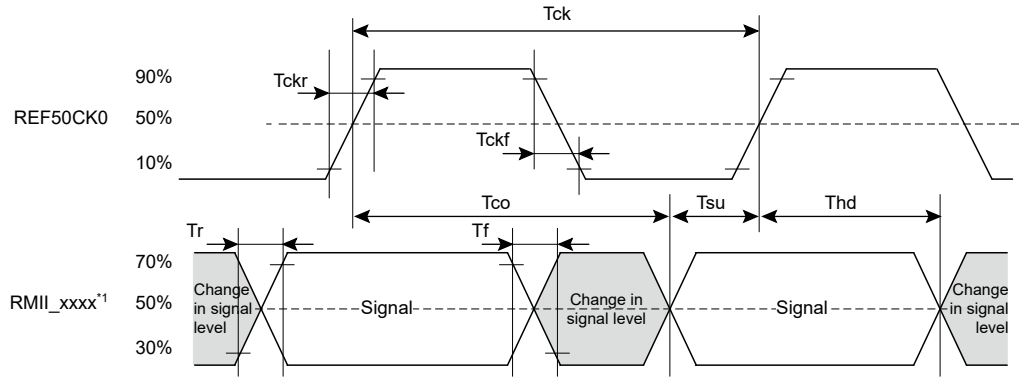
2.3.13 ETHERC Timing

Table 2.48 ETHERC timing

Conditions: ETHERC (RMII): Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register for the following pins: ET0_MDC, ET0_MDIO.
For other pins, high drive output is selected in the Port Drive Capability bit in the PmnPFS register.
ETHERC (MII): Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.

Parameter		Symbol	VCC	Min	Max	Unit	Test conditions
ETHERC (RMII)	REF50CK0 cycle time	T_{ck}	2.70V or above	20	—	ns	Figure 2.61 to Figure 2.64
	REF50CK0 frequency, typical 50 MHz	—		—	50 + 100 ppm	MHz	
	REF50CK0 duty	—		35	65	%	
	REF50CK0 rise/fall time	$T_{ckr/ckf}$		0.5	3.5	ns	
	RMII_xxxx*1 output delay	T_{co}		2.5	12.0	ns	
	RMII_xxxx*2 setup time	T_{su}		3	—	ns	
	RMII_xxxx*2 hold time	T_{hd}		1	—	ns	
	RMII_xxxx*1, *2 rise/fall time	T_r/T_f		0.5	5.0	ns	
	ET0_WOL output delay	t_{WOLd}		1	23.5	ns	Figure 2.65
ETHERC (MII)	ET0_TX_CLK cycle time	t_{Tcyc}		40	—	ns	—
	ET0_TX_EN output delay	t_{TENd}		1	20	ns	Figure 2.66
	ET0_ETXD0 to ET_ETXD3 output delay	t_{MTDd}		1	20	ns	
	ET0_CRS setup time	t_{CRSs}		10	—	ns	
	ET0_CRS hold time	t_{CRSh}		10	—	ns	
	ET0_COL setup time	t_{COLs}		10	—	ns	Figure 2.67
	ET0_COL hold time	t_{COLh}		10	—	ns	
	ET0_RX_CLK cycle time	t_{TRcyc}		40	—	ns	—
	ET0_RX_DV setup time	t_{RDVs}		10	—	ns	Figure 2.68
	ET0_RX_DV hold time	t_{RDVh}		10	—	ns	
	ET0_ERXD0 to ET_ERXD3 setup time	t_{MRDs}		10	—	ns	
	ET0_ERXD0 to ET_ERXD3 hold time	t_{MRDh}		10	—	ns	
	ET0_RX_ER setup time	t_{RERs}		10	—	ns	Figure 2.69
	ET0_RX_ER hold time	t_{RESh}		10	—	ns	
	ET0_WOL output delay	t_{WOLd}		1	23.5	ns	Figure 2.70

Note: The following pins must use pins that have a letter appended to their name, for instance "_A", "_B", to indicate group membership. For the ETHERC (RMII) Host interface, the AC portion of the electrical characteristics is measured for each group. REF50CK0_A, REF50CK0_B, RMII0_xxxx_A, RMII0_xxxx_B.
Note 1. RMII_TXD_EN, RMII_TXD1, RMII_TXD0.
Note 2. RMII_CRS_DV, RMII_RXD1, RMII_RXD0, RMII_RX_ER.



Note 1. RMII_TXD_EN, RMII_TXD1, RMII_TXD0, RMII_CRS_DV, RMII_RXD1, RMII_RXD0, RMII_RX_ER

Figure 2.61 REF50CK0 and RMII signal timing

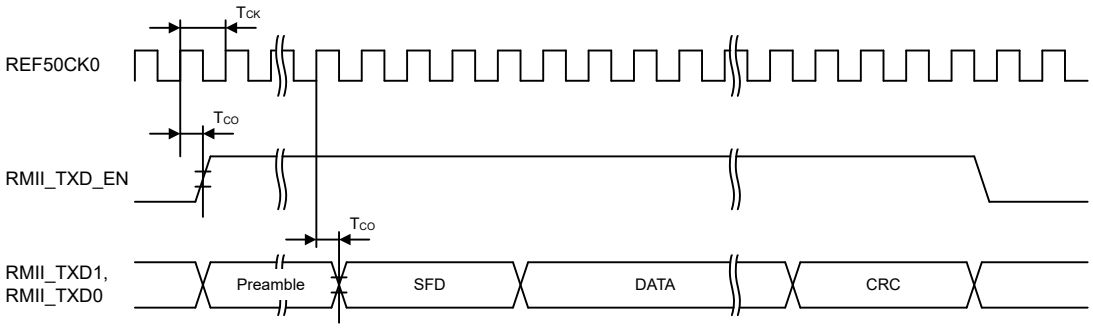


Figure 2.62 RMII transmission timing

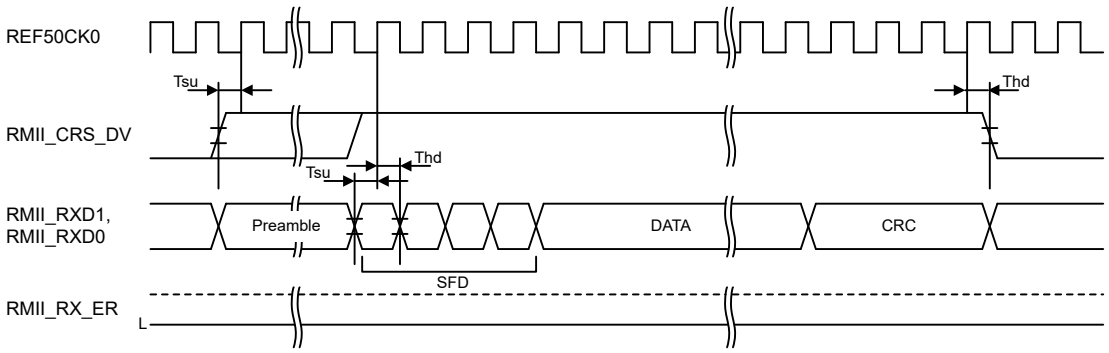


Figure 2.63 RMII reception timing in normal operation

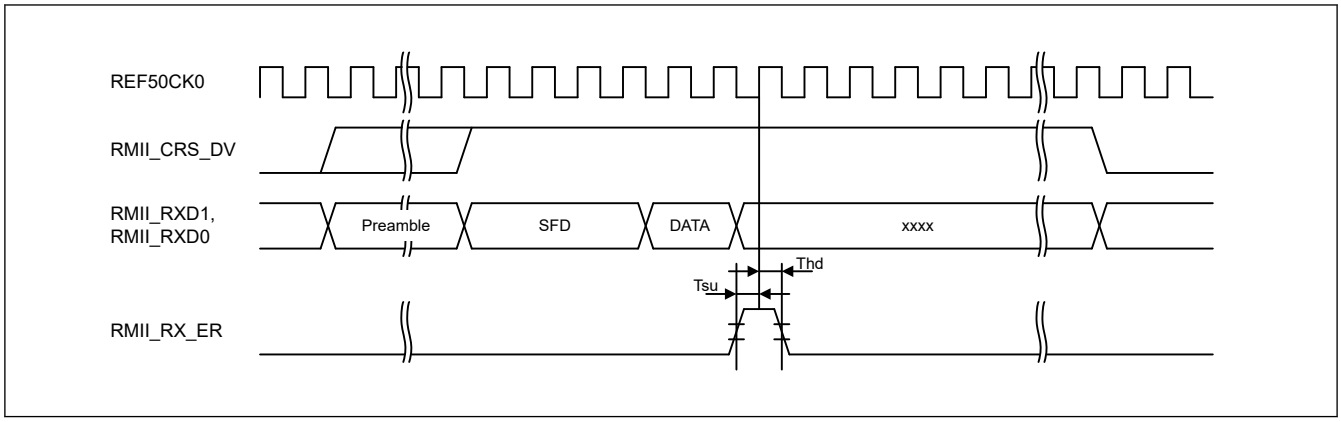


Figure 2.64 RMII reception timing when an error occurs

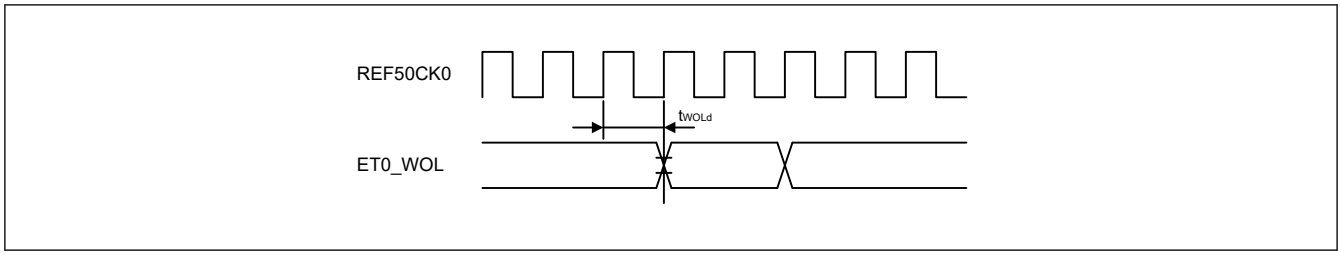


Figure 2.65 WOL output timing for RMII

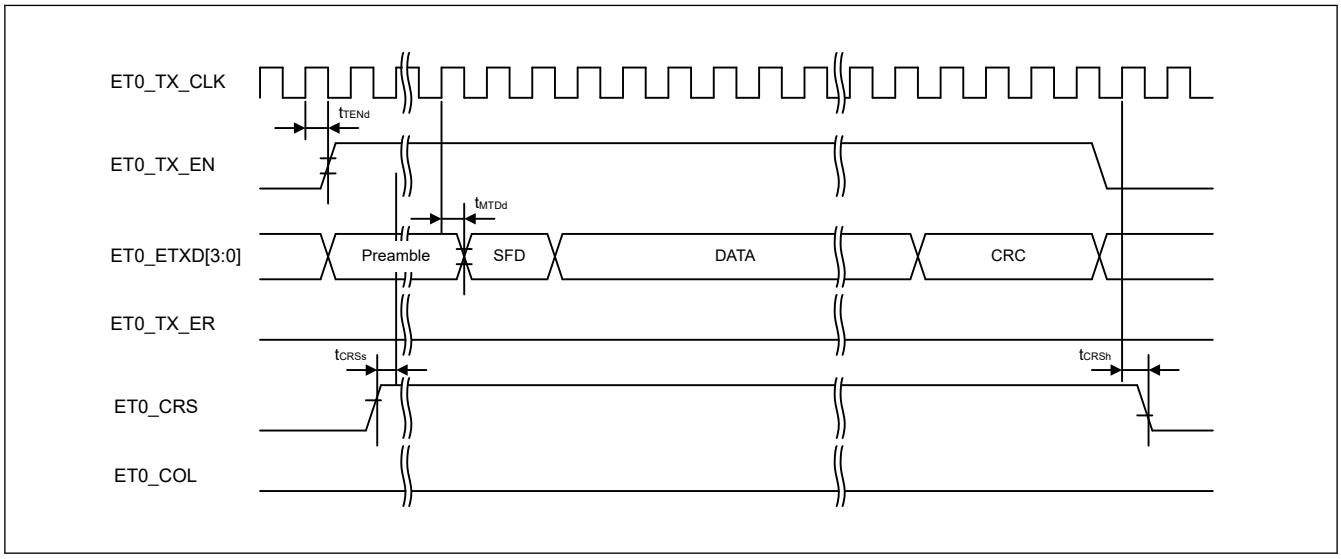


Figure 2.66 MII transmission timing in normal operation

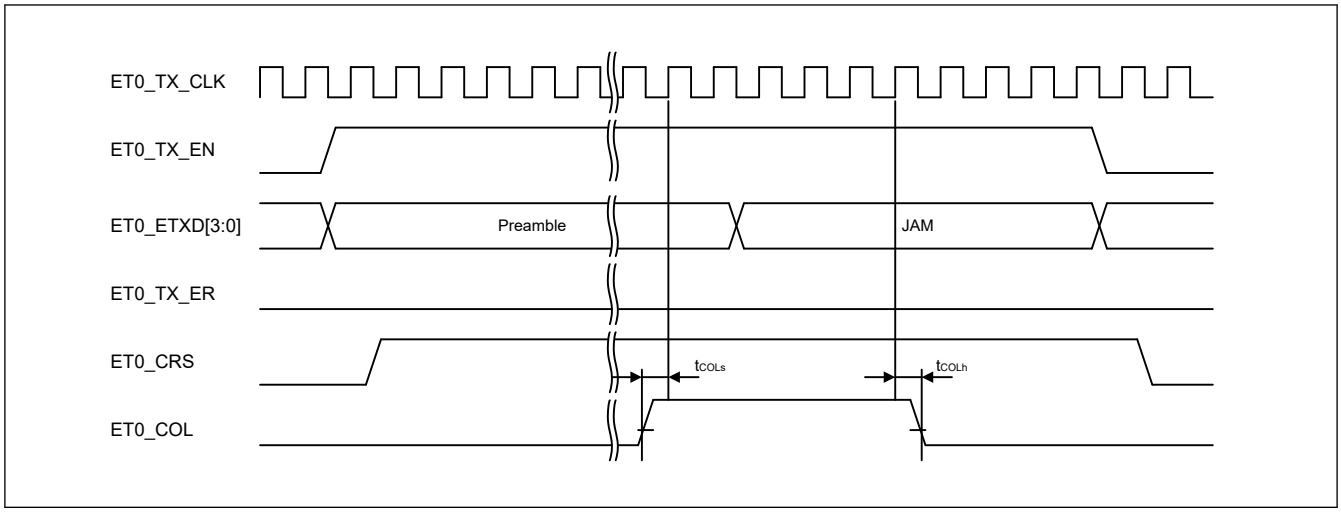


Figure 2.67 MII transmission timing when a conflict occurs

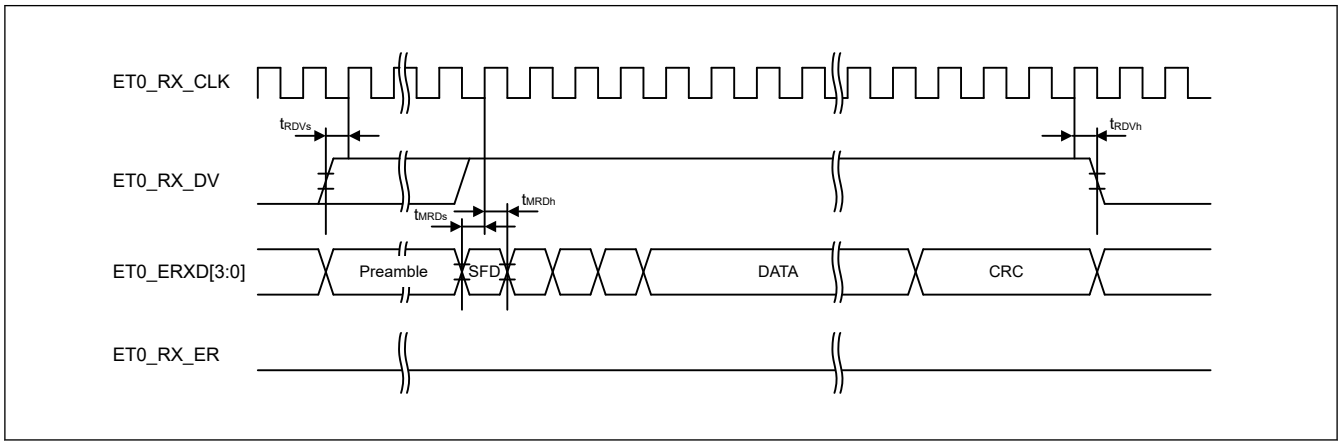


Figure 2.68 MII reception timing in normal operation

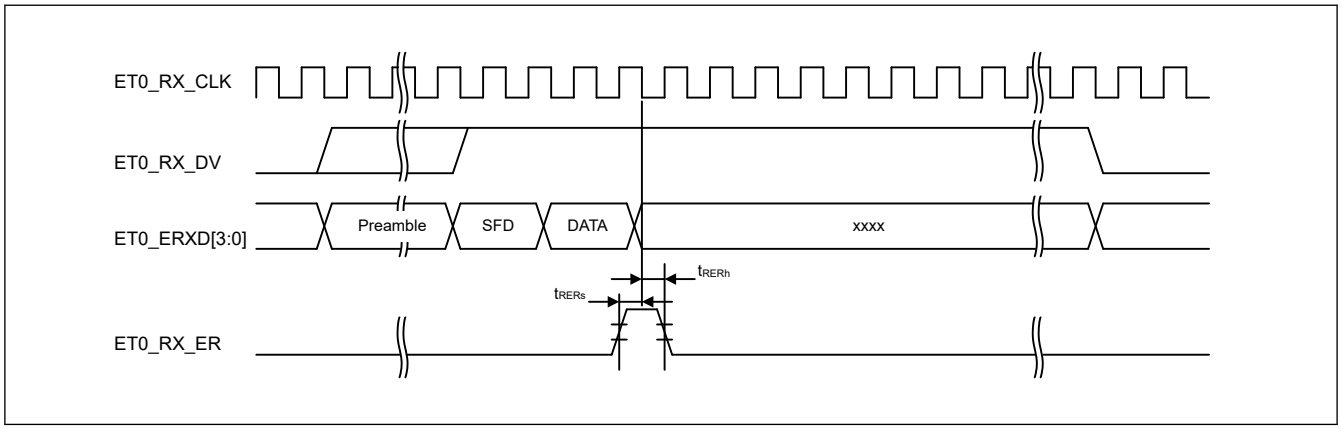


Figure 2.69 MII reception timing when an error occurs

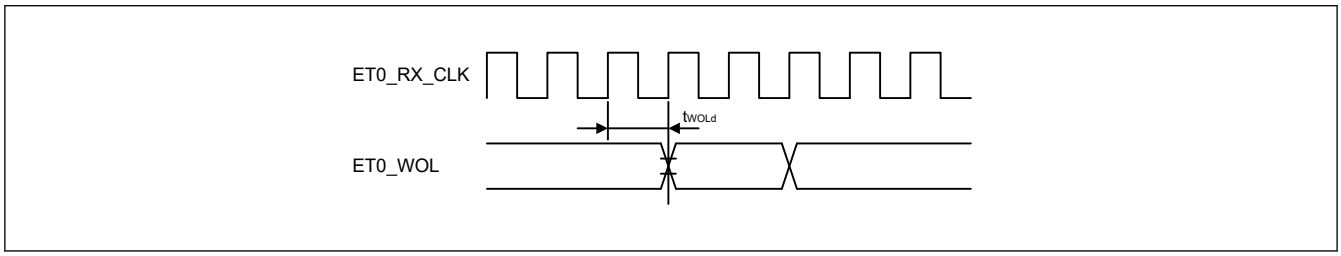


Figure 2.70 WOL output timing for MII

2.3.14 CEU Timing

Table 2.49 Capture Engine Unit Signal Timing

Parameter	Symbol	VCC	Min	Max	Unit	Test conditions
Vertical sync (VIO_VD) setup time (Camera clock rising)	t_{VVDS}	2.70 V or above	2.0	—	ns	Figure 2.71 Figure 2.72
		1.68 V or above	4.5	—		
Vertical sync (VIO_VD) setup time (Camera clock falling)	t_{VVDS}	2.70 V or above	2.5	—	ns	
		1.68 V or above	4.5	—		
Vertical sync (VIO_VD) hold time	t_{VVDH}	2.70 V or above	3.5	—	ns	
		1.68 V or above	5.5	—		
Horizontal sync (VIO_HD) setup time (Camera clock rising)	t_{VHDS}	2.70 V or above	2.0	—	ns	
		1.68 V or above	4.5	—		
Horizontal sync (VIO_HD) setup time (Camera clock falling)	t_{VHDS}	2.70 V or above	2.5	—	ns	
		1.68 V or above	4.5	—		
Horizontal sync (VIO_HD) hold time	t_{VHDH}	2.70 V or above	3.5	—	ns	
		1.68 V or above	5.5	—		
Capture image data (VIO_D) setup time (Camera clock rising)	t_{VDTS}	2.70 V or above	2.0	—	ns	
		1.68 V or above	4.5	—		
Capture image data (VIO_D) setup time (Camera clock falling)	t_{VDTS}	2.70 V or above	2.5	—	ns	
		1.68 V or above	4.5	—		
Capture image data (VIO_D) hold time	t_{VDTH}	2.70 V or above	3.5	—	ns	
		1.68 V or above	5.5	—		
Camera clock cycle	t_{VCYC}	2.70 V or above	11.5	—	ns	
		1.68 V or above	23.0	—		
Camera clock high level width	t_{VHW}	2.70 V or above	0.4 × t_{VCYC}	—	ns	
		1.68 V or above	0.4 × t_{VCYC}	—		
Camera clock low level width	t_{VLW}	2.70 V or above	0.4 × t_{VCYC}	—	ns	
		1.68 V or above	0.4 × t_{VCYC}	—		
Field identification signal (VIO_FLD) setup time (Camera clock rising)	t_{VFDS}	2.70 V or above	2.0	—	ns	
		1.68 V or above	4.5	—		
Field identification signal (VIO_FLD) setup time (Camera clock falling)	t_{VFDS}	2.70 V or above	2.5	—	ns	
		1.68 V or above	4.5	—		
Field identification signal (VIO_FLD) hold time	t_{VFDH}	2.70 V or above	3.5	—	ns	
		1.68 V or above	5.5	—		

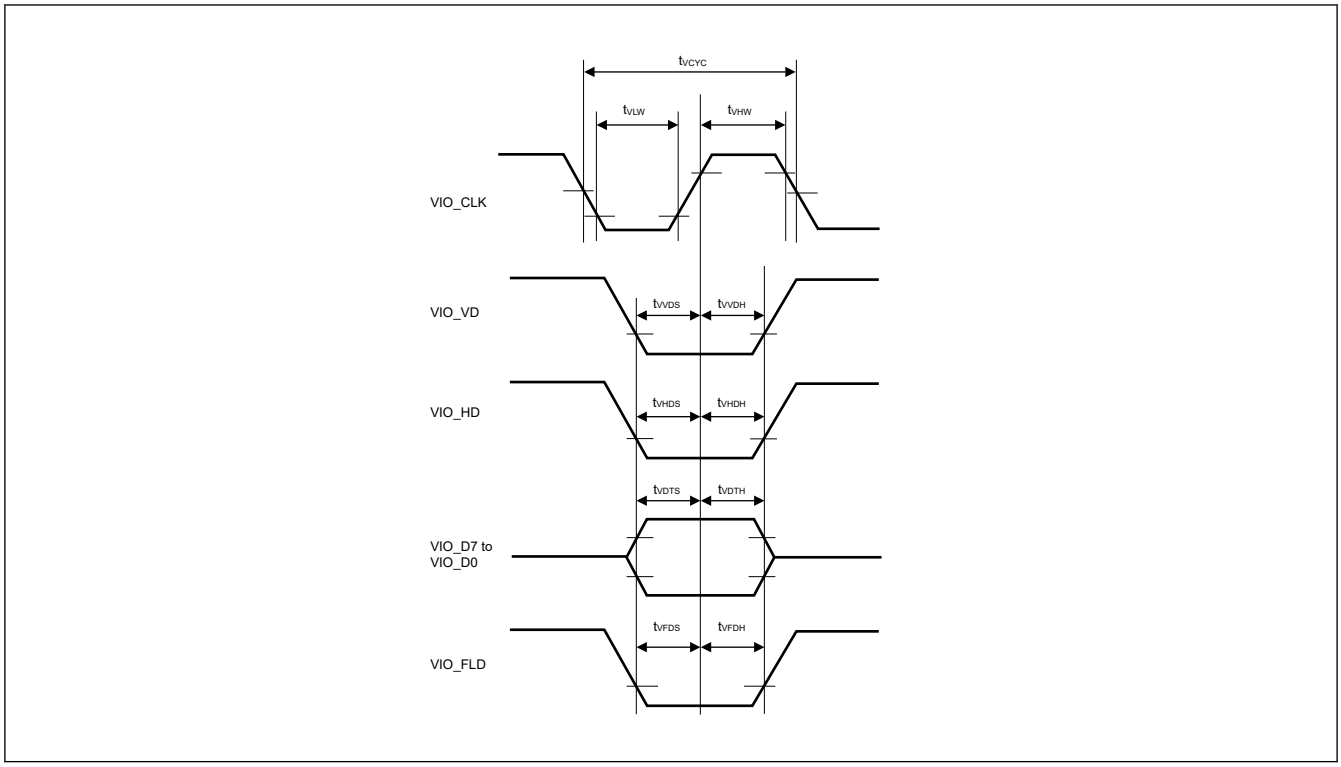


Figure 2.71 Capture Engine Unit Module Signal Timing of data capturing on the rising edge of VIO_CLK

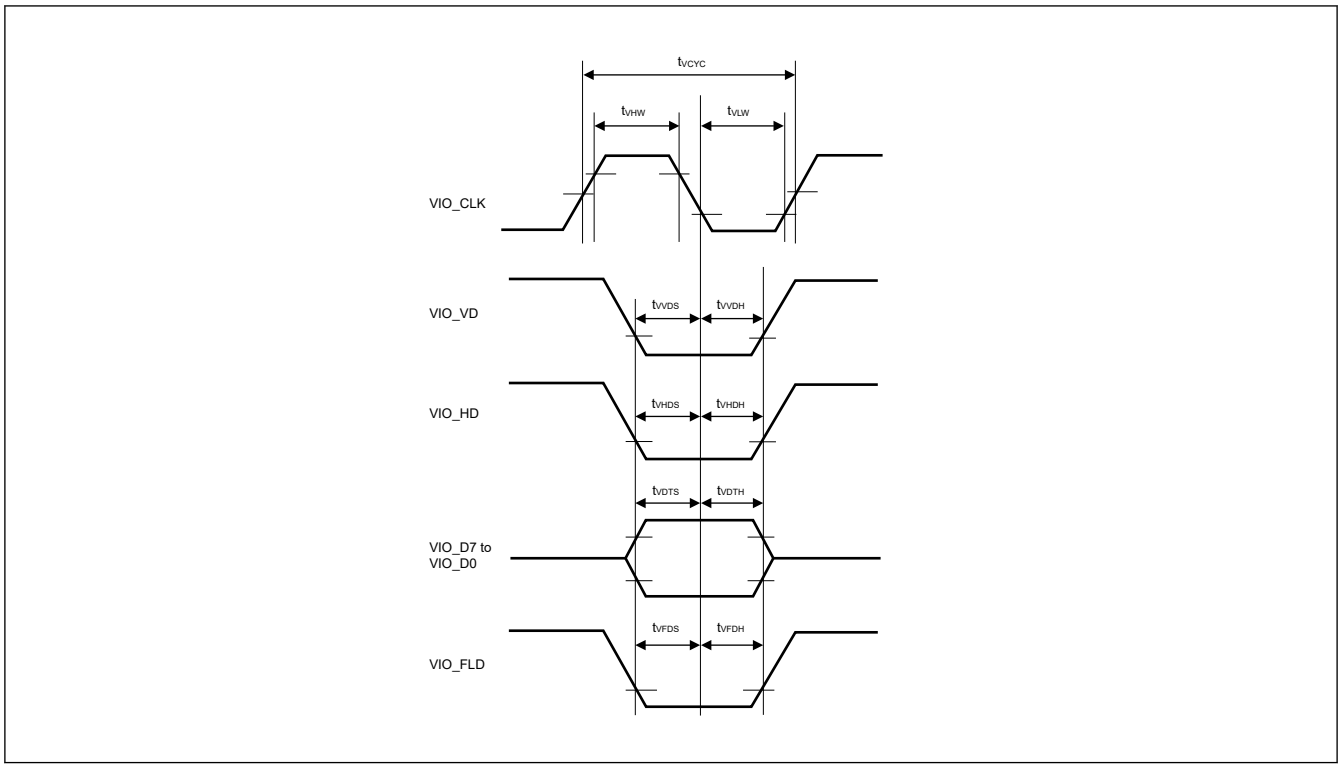


Figure 2.72 Capture Engine Unit Module Signal Timing of data capturing on the falling edge of VIO_CLK

2.3.15 CANFD Timing

Table 2.50 CANFD interface timing

Parameter	Symbol	VCC/VCC2	Min	Max	Unit	Test conditions
Internal delay time	t_{node}	2.70 V or above	—	50	ns	Figure 2.73
		1.68 V or above (VCC) 1.65 V or above (VCC2)	—	50		

Note: Internal delay time (t_{node}) = Internal transfer delay time (t_{output}) + Internal receive delay time (t_{input})

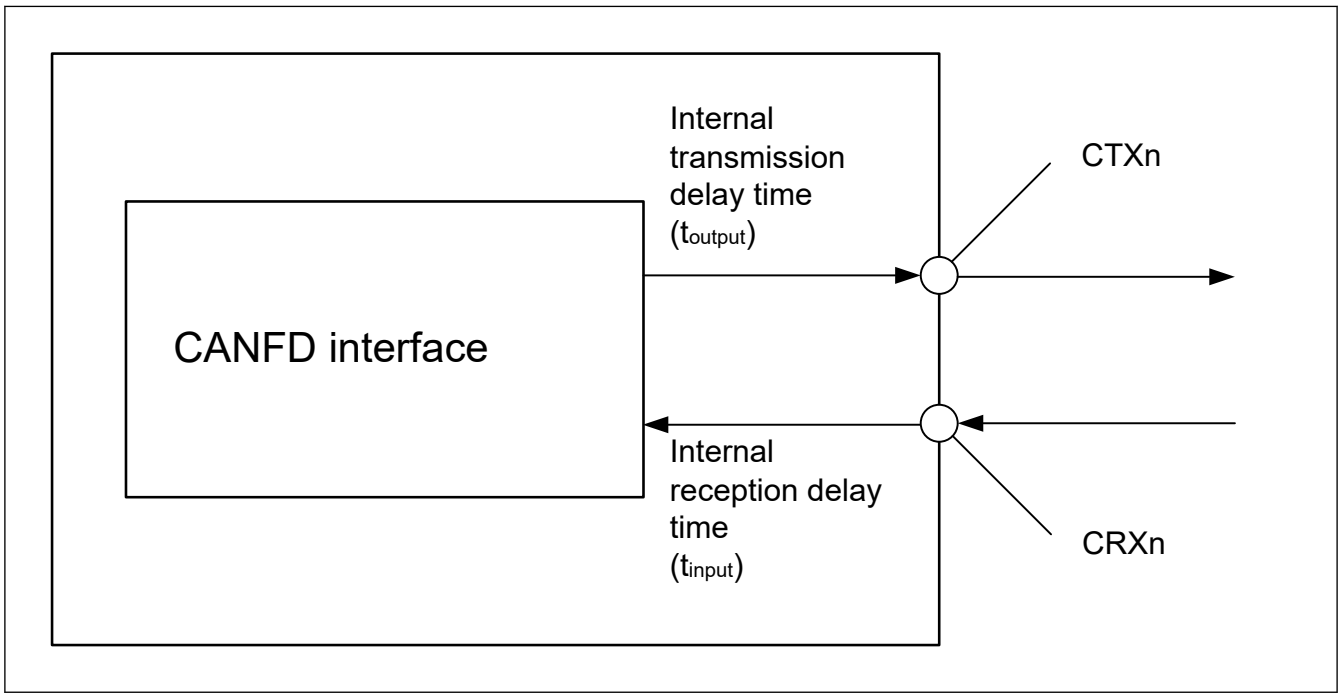


Figure 2.73 CANFD interface condition

2.4 USB Characteristics

2.4.1 USBFS Timing

Table 2.51 USBFS low-speed characteristics for host only (USB_DP and USB_DM pin characteristics) (1 of 2)

Conditions: VCC = VCC_USB = 3.0 to 3.6 V, USBCLK = 48 MHz

Parameter		Symbol	Min	Typ	Max	Unit	Test conditions
Input characteristics	Input high voltage	V_{IH}	2.0	—	—	V	—
	Input low voltage	V_{IL}	—	—	0.8	V	—
	Differential input sensitivity	V_{DI}	0.2	—	—	V	| USB_DP - USB_DM |
	Differential common-mode range	V_{CM}	0.8	—	2.5	V	—
Output characteristics	Output high voltage	V_{OH}	2.8	—	3.6	V	I_{OH} = –200 µA
	Output low voltage	V_{OL}	0.0	—	0.3	V	I_{OL} = 2 mA
	Cross-over voltage	V_{CRS}	1.3	—	2.0	V	Figure 2.74
	Rise time	t_{LR}	75	—	300	ns	
	Fall time	t_{LF}	75	—	300	ns	
	Rise/fall time ratio	t_{LR} / t_{LF}	80	—	125	%	t_{LR}/ t_{LF}

Table 2.51 USBFS low-speed characteristics for host only (USB_DP and USB_DM pin characteristics) (2 of 2)

Conditions: VCC = VCC_USB = 3.0 to 3.6 V, USBCLK = 48 MHz

Parameter		Symbol	Min	Typ	Max	Unit	Test conditions
Pull-up and pull-down characteristics	USB_DP and USB_DM pull-down resistance in host controller mode	R_{pd}	14.25	—	24.80	kΩ	—

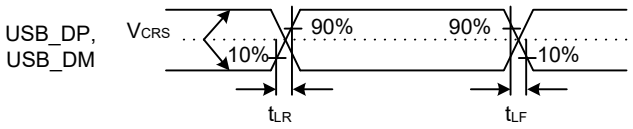


Figure 2.74 USB_DP and USB_DM output timing in low-speed mode

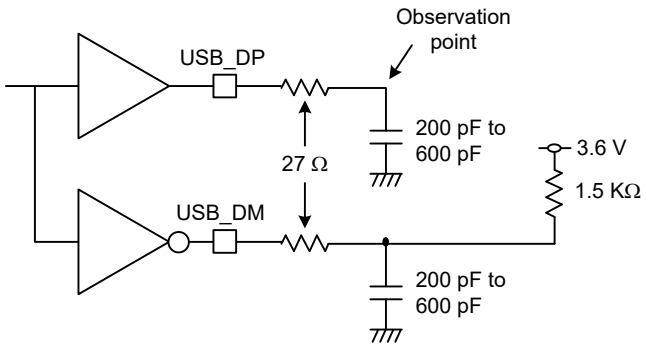


Figure 2.75 Test circuit in low-speed mode

Table 2.52 USBFS full-speed characteristics (USB_DP and USB_DM pin characteristics)

Conditions: VCC = VCC_USB = 3.0 to 3.6 V, USBCLK = 48 MHz

Parameter		Symbol	Min	Typ	Max	Unit	Test conditions
Input characteristics	Input high voltage	V_{IH}	2.0	—	—	V	—
	Input low voltage	V_{IL}	—	—	0.8	V	—
	Differential input sensitivity	V_{DI}	0.2	—	—	V	| USB_DP - USB_DM |
	Differential common-mode range	V_{CM}	0.8	—	2.5	V	—
Output characteristics	Output high voltage	V_{OH}	2.8	—	3.6	V	I_{OH} = –200 µA
	Output low voltage	V_{OL}	0.0	—	0.3	V	I_{OL} = 2 mA
	Cross-over voltage	V_{CRS}	1.3	—	2.0	V	Figure 2.76
	Rise time	t_{LR}	4	—	20	ns	
	Fall time	t_{LF}	4	—	20	ns	
	Rise/fall time ratio	t_{LR} / t_{LF}	90	—	111.11	%	t_{FR}/ t_{FF}
	Output resistance	Z_{DRV}	28	—	44	Ω	USBFS: Rs = 27 Ω included
Pull-up and pull-down characteristics	DM pull-up resistance in device controller mode	R_{pu}	0.900	—	1.575	kΩ	During idle state
			1.425	—	3.090	kΩ	During transmission and reception
	USB_DP and USB_DM pull-down resistance in host controller mode	R_{pd}	14.25	—	24.80	kΩ	—

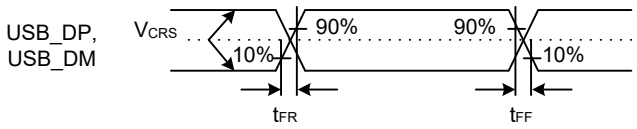


Figure 2.76 USB_DP and USB_DM output timing in full-speed mode

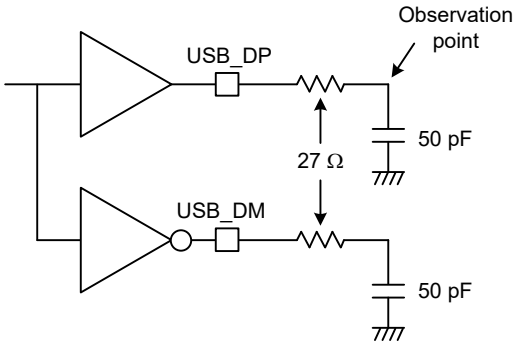


Figure 2.77 Test circuit in full-speed mode

2.5 ADC12 Characteristics

Table 2.53 A/D conversion characteristics for unit 0 (DCDC mode) (1 of 2)

Conditions: PCLKC = 1 to 60 MHz

Parameter			Min	Typ	Max	Unit	Test conditions
Frequency			1	—	60	MHz	—
Analog input capacitance			—	—	30	pF	—
Quantization error			—	±0.5	—	LSB	—
Resolution			—	—	12	Bits	—
Channel-dedicated sample-and-hold circuits in use (AN000, AN001)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	1.06 (0.4 + 0.25)*2	—	—	μs	• Sampling of channel-dedicated sample-and-hold circuits in 24 states • Sampling in 15 states
	Offset error		—	±1.5	±3.5	LSB	AN000 to AN002 = 0.25 V
	Full-scale error		—	±1.5	±3.5	LSB	AN000 to AN002 = VREFH0 - 0.25 V
	Absolute accuracy		—	±2.5	±10.5	LSB	LQFP package AVCC0 = 2.7 to 3.6V VREFH0 = 2.7V to AVCC0
			—	±2.5	±7.5		LQFP package AVCC0 = VREFH0 = 2.7 to 3.6V
	DNL differential nonlinearity error		—	±1.0	±2.0	LSB	—
	INL integral nonlinearity error		—	±1.5	±4.0	LSB	—
	Holding characteristics of sample-and hold circuits		—	—	20	μs	—
	Dynamic range		0.25	—	VREFH 0 - 0.25	V	—

Table 2.53 A/D conversion characteristics for unit 0 (DCDC mode) (2 of 2)

Conditions: PCLKC = 1 to 60 MHz

Parameter			Min	Typ	Max	Unit	Test conditions
High-precision channels, Channel-dedicated sample-and-hold circuits not in use (AN000 to AN002, AN004 to AN008)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	0.48 (0.267)*2	—	—	µs	Sampling in 16 states
		Max. = 400 Ω	0.40 (0.183)*2	—	—	µs	Sampling in 11 states AVCC0 = VREFH0 = 3.0 to 3.6 V
	Offset error		—	±1.0	±2.5	LSB	—
	Full-scale error		—	±1.0	±3.5	LSB	—
	Absolute accuracy		—	±2.0	±7.5	LSB	LQFP package AVCC0 = 2.7 to 3.6V VREFH0 = 2.7V to AVCC0
			—	±2.0	±6.0		LQFP package AVCC0 = VREFH0 = 2.7 to 3.6V
	DNL differential nonlinearity error		—	±0.5	±2.0	LSB	—
	INL integral nonlinearity error		—	±1.0	±2.5	LSB	—

Note: These specification values apply when only one A/D is operating and D/A and ACMPHS are not operating during A/D conversion. If other A/D, D/A, or ACMPHS is operating or bus access occurs during A/D conversion, values might not fall within the indicated ranges.
The use of ports 0 as digital outputs is not allowed when the 12-Bit A/D converter is used.
The characteristics apply when AVCC0, AVSS0, VREFH0, VREFH, VREFL0, VREFL, and 12-bit A/D converter input voltage is stable.

Note 1. The conversion time includes the sampling and comparison times. The number of sampling states is indicated for the test conditions.

Note 2. Values in parentheses indicate the sampling time.

Table 2.54 A/D conversion characteristics for unit 1 (DCDC mode)

Conditions: PCLKC = 1 to 60 MHz

Parameter			Min	Typ	Max	Unit	Test conditions
Frequency			1	—	60	MHz	—
Analog input capacitance			—	—	30	pF	—
Quantization error			—	±0.5	—	LSB	—
Resolution			—	—	12	Bits	—
High-precision channels (AN100 to AN102, AN104, AN105)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	0.48 (0.267)*2	—	—	µs	Sampling in 16 states
		Max. = 400 Ω	0.40 (0.183)*2	—	—	µs	Sampling in 11 states AVCC0 = VREFH = 3.0 to 3.6 V
	Offset error		—	±1.0	±2.5	LSB	—
	Full-scale error		—	±1.0	±3.5	LSB	—
	Absolute accuracy		—	±2.0	±7.5	LSB	LQFP package AVCC0 = 2.7 to 3.6V VREFH = 2.7V to AVCC0
			—	±2.0	±6.0		LQFP package AVCC0 = VREFH = 2.7 to 3.6V
	DNL differential nonlinearity error		—	±0.5	±2.0	LSB	—
	INL integral nonlinearity error		—	±1.0	±2.5	LSB	—

Note: These specification values apply when only one A/D is operating and D/A and ACMPHS are not operating during A/D conversion. If other A/D, D/A, or ACMPHS is operating or bus access occurs during A/D conversion, values might not fall within the indicated ranges.
The use of ports 0 as digital outputs is not allowed when the 12-Bit A/D converter is used.

The characteristics apply when AVCC0, AVSS0, VREFH0, VREFH, VREFL0, VREFL, and 12-bit A/D converter input voltage are stable.

Note 1. The conversion time includes the sampling and comparison times. The number of sampling states is indicated for the test conditions.

Note 2. Values in parentheses indicate the sampling time.

Table 2.55 A/D conversion characteristics for unit 0 (External VDD mode)

Conditions: PCLKC = 1 to 60 MHz
AVCC0 = 2.7 to 3.6 V, VREFH0 = 2.7 to 3.6 V

Parameter			Min	Typ	Max	Unit	Test conditions
Frequency			1	—	60	MHz	—
Analog input capacitance			—	—	30	pF	—
Quantization error			—	±0.5	—	LSB	—
Resolution			—	—	12	Bits	—
Channel-dedicated sample-and-hold circuits in use (AN000, AN001)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	1.06 (0.4 + 0.25)*2	—	—	μs	• Sampling of channel-dedicated sample-and-hold circuits in 24 states • Sampling in 15 states
	Offset error		—	±1.5	±3.5	LSB	AN000 to AN002 = 0.25 V
	Full-scale error		—	±1.5	±3.5	LSB	AN000 to AN002 = VREFH0 - 0.25 V
	Absolute accuracy		—	±2.5	±5.5	LSB	—
	DNL differential nonlinearity error		—	±1.0	±2.0	LSB	—
	INL integral nonlinearity error		—	±1.5	±3.0	LSB	—
	Holding characteristics of sample-and hold circuits		—	—	20	μs	—
	Dynamic range		0.25	—	VREFH 0 - 0.25	V	—
High-precision channels, Channel-dedicated sample-and-hold circuits not in use (AN000 to AN002, AN004 to AN008)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	0.48 (0.267)*2	—	—	μs	Sampling in 16 states
		Max. = 400 Ω	0.40 (0.183)*2	—	—	μs	Sampling in 11 states AVCC0 = 3.0 to 3.6 V 3.0 V ≤ VREFH0 ≤ AVCC0
	Offset error		—	±1.0	±2.5	LSB	—
	Full-scale error		—	±1.0	±3.5	LSB	—
	Absolute accuracy		—	±2.0	±4.5	LSB	—
	DNL differential nonlinearity error		—	±0.5	±1.5	LSB	—
	INL integral nonlinearity error		—	±1.0	±2.5	LSB	—

Note: These specification values apply when only one A/D is operating and D/A and ACMPHS are not operating during A/D conversion. If other A/D, D/A, or ACMPHS is operating or bus access occurs during A/D conversion, values might not fall within the indicated ranges.
The use of ports 0 as digital outputs is not allowed when the 12-Bit A/D converter is used.
The characteristics apply when AVCC0, AVSS0, VREFH0, VREFH, VREFL0, VREFL, and 12-bit A/D converter input voltage is stable.

Note 1. The conversion time includes the sampling and comparison times. The number of sampling states is indicated for the test conditions.

Note 2. Values in parentheses indicate the sampling time.

Table 2.56 A/D conversion characteristics for unit 1 (External VDD mode) (1 of 2)

Conditions: PCLKC = 1 to 60 MHz
AVCC0 = 2.7 to 3.6 V, VREFH = 2.7 to 3.6 V

Parameter	Min	Typ	Max	Unit	Test conditions
Frequency	1	—	60	MHz	—
Analog input capacitance	—	—	30	pF	—

Table 2.56 A/D conversion characteristics for unit 1 (External VDD mode) (2 of 2)

Conditions: PCLKC = 1 to 60 MHz
AVCC0 = 2.7 to 3.6 V, VREFH = 2.7 to 3.6 V

Parameter			Min	Typ	Max	Unit	Test conditions
Quantization error			—	±0.5	—	LSB	—
Resolution			—	—	12	Bits	—
High-precision channels (AN100 to AN102, AN104, AN105)	Conversion time*1 (operation at PCLKC = 60 MHz)	Permissible signal source impedance Max. = 1 kΩ	0.48 (0.267)*2	—	—	µs	Sampling in 16 states
		Max. = 400 Ω	0.40 (0.183)*2	—	—	µs	Sampling in 11 states AVCC0 = 3.0 to 3.6 V 3.0 V ≤ VREFH ≤ AVCC0
	Offset error		—	±1.0	±2.5	LSB	—
	Full-scale error		—	±1.0	±3.5	LSB	—
	Absolute accuracy		—	±2.0	±4.5	LSB	—
	DNL differential nonlinearity error		—	±0.5	±1.5	LSB	—
	INL integral nonlinearity error		—	±1.0	±2.5	LSB	—

Note: These specification values apply when only one A/D is operating and D/A and ACMPHS are not operating during A/D conversion. If other A/D, D/A, or ACMPHS is operating or bus access occurs during A/D conversion, values might not fall within the indicated ranges.
The use of ports 0 as digital outputs is not allowed when the 12-Bit A/D converter is used.
The characteristics apply when AVCC0, AVSS0, VREFH0, VREFH, VREFL0, VREFL, and 12-bit A/D converter input voltage are stable.
Note 1. The conversion time includes the sampling and comparison times. The number of sampling states is indicated for the test conditions.
Note 2. Values in parentheses indicate the sampling time.

Table 2.57 A/D internal reference voltage characteristics

Parameter	Min	Typ	Max	Unit	Test conditions
A/D internal reference voltage	1.13	1.18	1.28	V	—
Sampling time	4.15	—	—	µs	—

For the characteristics of VBATT 1/3 voltage monitor, see section 2.10. VBATT Characteristics.

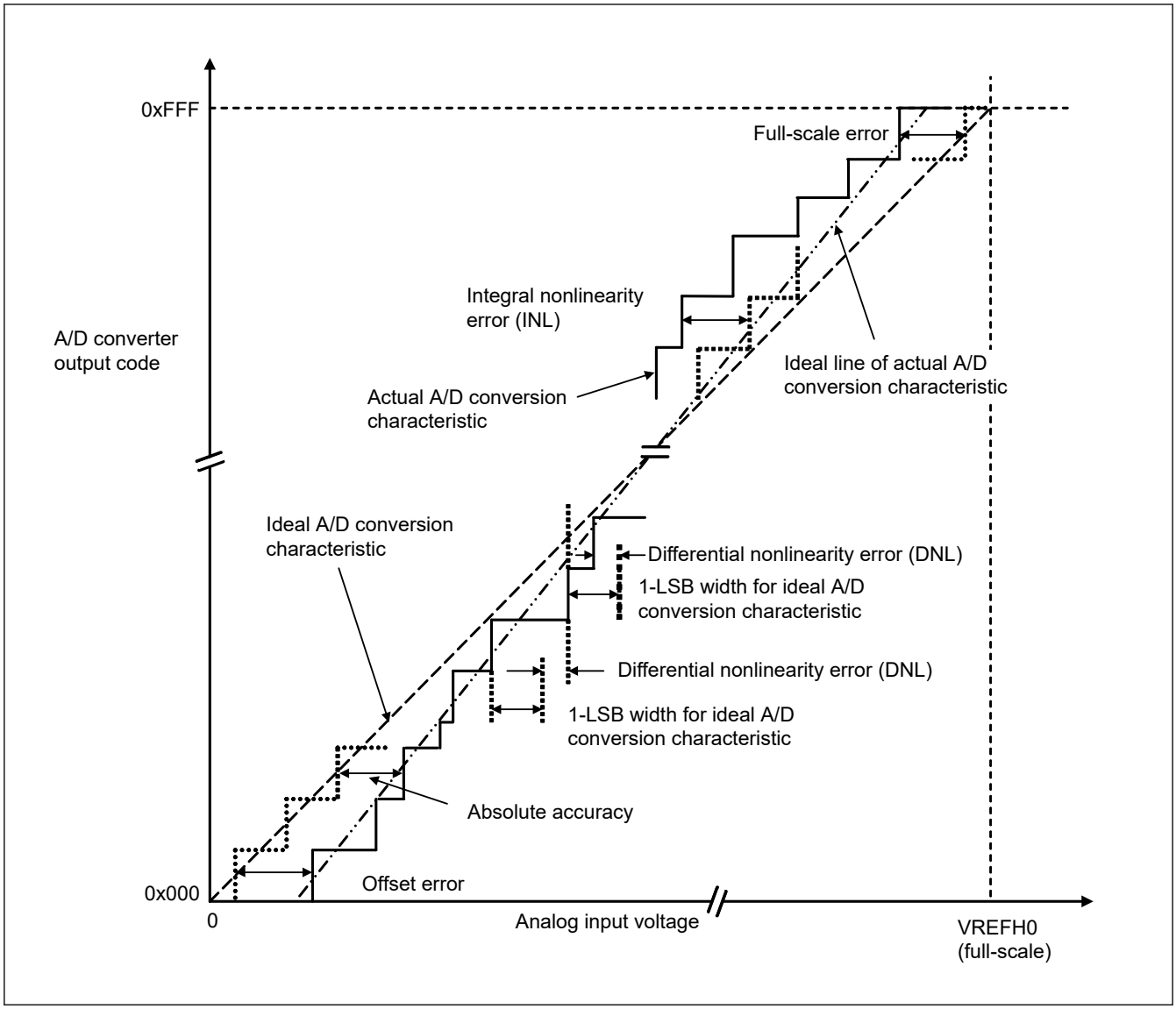


Figure 2.78 Illustration of ADC12 characteristic terms

Absolute accuracy

Absolute accuracy is the difference between output code based on the theoretical A/D conversion characteristics, and the actual A/D conversion result. When measuring absolute accuracy, the voltage at the midpoint of the width of the analog input voltage (1-LSB width), which can meet the expectation of outputting an equal code based on the theoretical A/D conversion characteristics, is used as an analog input voltage. For example, if 12-bit resolution is used and the reference voltage VREFH0 = 3.072 V, then the 1-LSB width becomes 0.75 mV, and 0 mV, 0.75 mV, and 1.5 mV are used as the analog input voltages. If the analog input voltage is 6 mV, an absolute accuracy of ±5 LSB means that the actual A/D conversion result is in the range of 0x003 to 0x00D, though an output code of 0x008 can be expected from the theoretical A/D conversion characteristics.

Integral nonlinearity error (INL)

Integral nonlinearity error is the maximum deviation between the ideal line when the measured offset and full-scale errors are zeroed, and the actual output code.

Differential nonlinearity error (DNL)

Differential nonlinearity error is the difference between the 1-LSB width based on the ideal A/D conversion characteristics and the width of the actual output code.

Offset error

Offset error is the difference between the transition point of the ideal first output code and the actual first output code.

Full-scale error

Full-scale error is the difference between the transition point of the ideal last output code and the actual last output code.

2.6 DAC12 Characteristics

Table 2.58 D/A conversion characteristics

Parameter		Min	Typ	Max	Unit	Test conditions
Resolution		—	—	12	Bits	—
Without output amplifier (for pin output, AVCC0 ≥ 1.65V)						
Absolute accuracy	VREFH ≥ 2.7V	—	—	±24	LSB	Resistive load 2 MΩ
	VREFH < 2.7V	—	—	±36		
INL	VREFH ≥ 2.7V	—	±2.0	±8.0	LSB	Resistive load 2 MΩ
	VREFH < 2.7V	—	±2.0	±8.0		
DNL	VREFH ≥ 2.7V	—	±1.0	±2.0	LSB	—
	VREFH < 2.7V		±1.0	±3.0		
Output impedance		—	8.5	—	kΩ	—
Conversion time	VREFH ≥ 2.7V	—	—	3.0	µs	Resistive load 2 MΩ, Capacitive load 20 pF
	VREFH < 2.7V	—	—	6.0		
Output voltage range		0	—	VREFH	V	—
Without output amplifier (for internal output, AVCC0 ≥ 1.65V)						
Absolute accuracy	VREFH≥2.7V	—	—	±4.0	LSB	—
	VREFH < 2.7V	—	—	±6.0		
Conversion time	VREFH ≥ 2.7V	—	—	3.0	µs	—
	VREFH < 2.7V	—	—	6.0		
Output voltage range		0	—	VREFH	V	—
With output amplifier (AVCC0 ≥ 2.70V)						
INL		—	±2.0	±4.0	LSB	—
DNL		—	±1.0	±2.0	LSB	—
Conversion time		—	—	3.5	µs	—
Resistive load		5	—	—	kΩ	—
Capacitive load		—	—	50	pF	—
Output voltage range	VREFH ≥ 2.7V	0.20	—	VREFH – 0.20	V	—
	VREFH < 2.7V	0.22	—	VREFH – 0.22		—

2.7 TSN Characteristics

Table 2.59 TSN characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
Relative accuracy	—	—	± 1.0	—	°C	—
Temperature slope	—	—	4.0	—	mV/°C	—
Output voltage (at 25 °C)	—	—	1.24	—	V	—
Temperature sensor start time	t_{START}	—	—	30	µs	—
Sampling time	—	4.15	—	—	µs	—

2.8 OSC Stop Detect Characteristics

Table 2.60 Oscillation stop detection circuit characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
Detection time	t_{dr}	—	—	1	ms	Figure 2.79

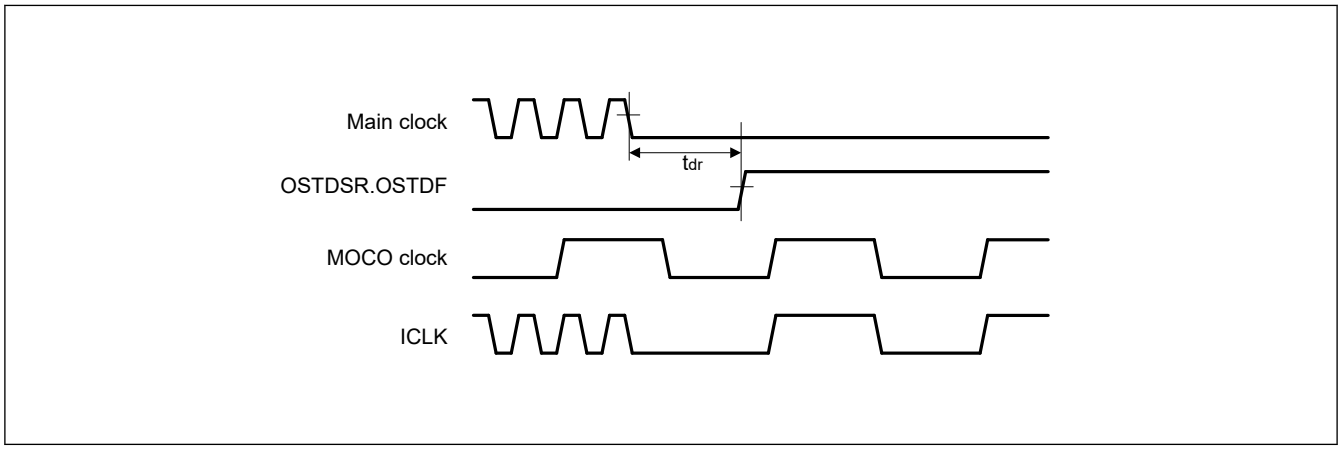


Figure 2.79 Oscillation stop detection timing

2.9 POR and PVD Characteristics

Table 2.61 Power-on reset circuit and voltage detection circuit characteristics (1 of 2)

Parameter			Symbol	Min	Typ	Max	Unit	Test conditions
Voltage detection level	Power-on reset (POR)	Tj = 25℃	V_{POR1}	1.55	1.60	1.68	V	Figure 2.80
		Tj = 105℃		1.55	1.60	1.70		
		Tj = 25℃	V_{POR2}	1.65	1.70	1.79		
		Tj = 105℃		1.65	1.70	1.81		
	Voltage detection circuit (PVD0)		V_{det0_0}	2.76	2.85	2.99		Figure 2.81
			V_{det0_1}	2.50	2.58	2.71		
			V_{det0_2}	2.08	2.15	2.27		
			V_{det0_3}	1.94	2.00	2.12		
			V_{det0_4}	1.84	1.90	2.01		
			V_{det0_5}	1.74	1.80	1.91		
			V_{det0_6}	1.65	1.70	1.81		
			V_{det0_7}	1.55	1.60	1.70		
	Voltage detection circuit (PVDn) (n = 1, 2)		$V_{detn\_3\_rise}$	3.78	3.92	4.10		Figure 2.82
			$V_{detn\_3\_fall}$	3.72	3.86	4.04		
			$V_{detn\_4\_rise}$	3.09	3.20	3.35		
			$V_{detn\_4\_fall}$	3.03	3.14	3.29		
			$V_{detn\_5\_rise}$	3.05	3.16	3.31		
			$V_{detn\_5\_fall}$	2.99	3.10	3.25		
			$V_{detn\_6\_rise}$	3.03	3.14	3.29		
			$V_{detn\_6\_fall}$	2.97	3.08	3.23		
			$V_{detn\_7\_rise}$	2.81	2.91	3.05		
			$V_{detn\_7\_fall}$	2.75	2.85	2.99		
			$V_{detn\_8\_rise}$	2.79	2.89	3.03		
			$V_{detn\_8\_fall}$	2.73	2.83	2.97		
			$V_{detn\_9\_rise}$	2.76	2.86	3.00		
			$V_{detn\_9\_fall}$	2.70	2.80	2.94		
			$V_{detn\_10\_rise}$	2.58	2.67	2.80		
			$V_{detn\_10\_fall}$	2.53	2.62	2.75		
			$V_{detn\_11\_rise}$	2.30	2.38	2.51		
			$V_{detn\_11\_fall}$	2.25	2.33	2.46		
Voltage detection level	Voltage detection circuit (PVDn) (n = 1, 2)		$V_{detn\_12\_rise}$	1.88	1.94	2.05	V	Figure 2.82
			$V_{detn\_12\_fall}$	1.84	1.90	2.01		
			$V_{detn\_13\_rise}$	1.84	1.90	2.01		
			$V_{detn\_13\_fall}$	1.80	1.86	1.97		
			$V_{detn\_14\_rise}$	1.72	1.78	1.89		
			$V_{detn\_14\_fall}$	1.68	1.74	1.85		
			$V_{detn\_15\_rise}$	1.69	1.75	1.85		
			$V_{detn\_15\_fall}$	1.65	1.71	1.81		

Table 2.61 Power-on reset circuit and voltage detection circuit characteristics (2 of 2)

Parameter			Symbol	Min	Typ	Max	Unit	Test conditions
Internal reset time*1	Power-on reset time		t_{POR1}	—	—	8.2	ms	Figure 2.80
			t_{POR2}	—	—	4.5		Figure 2.80
	PVD0 reset time		t_{PVD0}	—	—	*1		Figure 2.80
	PVD1 reset time		t_{PVD1}	—	—	*1		Figure 2.81
	PVD2 reset time		t_{PVD2}	—	—	*1		
Minimum VCC down time (POR)*2	100mV < VD		t_{VOFFP}	500	—	—	µs	Figure 2.80
	50mV < VD ≤ 100mV			900	—	—		
	VD ≤ 50mV			2000	—	—		
Minimum VCC down time (PVD)*2	PVD0 (OFS1(_SEC).PVDLPSEL = 0 in Deep Software Standby mode 1, 2)		t_{VOFF}	400	—	—	µs	Figure 2.81
	PVD0 (Other than above), PVD1, PVD2			200	—	—	µs	Figure 2.81
Response delay time (POR)	100mV < VD		t_{detp}	—	—	500	µs	Figure 2.80
	50mV < VD ≤ 100mV			—	—	900		
	VD ≤ 50mV			—	—	2000		
Response delay time (PVD)	PVD0 (OFS1(_SEC).PVDLPSEL = 0 in Deep Software Standby mode 1, 2)	50mV < VD	t_{det}	—	—	200	µs	Figure 2.81, Figure 2.82
		50mV ≥ VD		—	—	400		
	PVD0 (Other than above), PVD1, PVD2	100mV < VD		—	—	10		
		100mV ≥ VD		—	—	200		
PVD operation stabilization time (after PVD is enabled)			$T_{d\ (E-A)}$	—	—	20	µs	Figure 2.82

Note 1. The maximum value of t_{PVD0} is equal to t_{DSBY} because the internal reset time is maximized when returning from Deep Software Standby mode.
The maximum value of t_{PVD1}, t_{PVD2} are equal to t_{DSTBY} because the internal reset time is maximized when returning from Deep Software Standby mode.

Note 2. The minimum VCC down time indicates the time when VCC is below the minimum value of voltage detection levels V_{POR1}, V_{det1}, and V_{det2} for the POR / PVD.

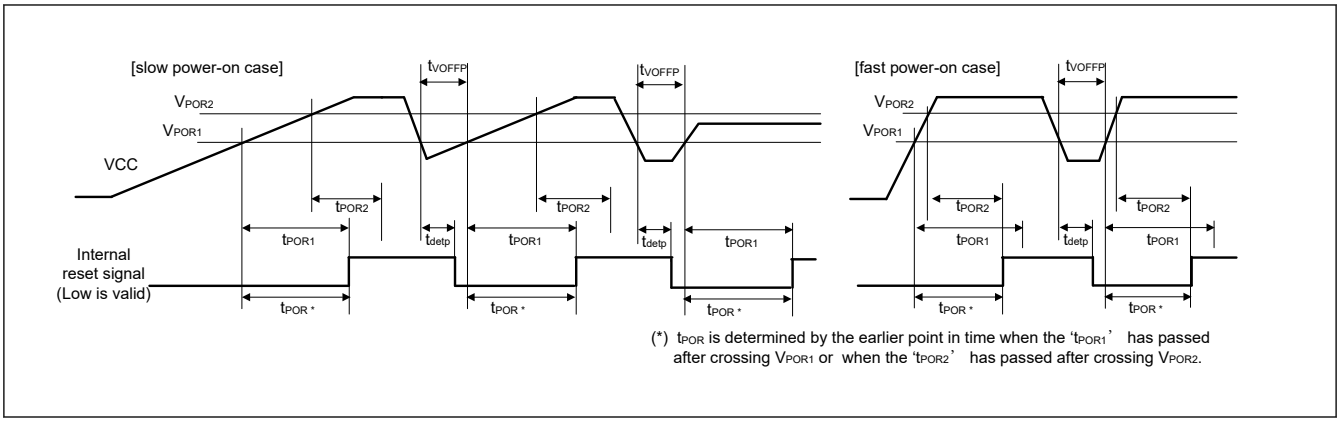


Figure 2.80 Power-on reset timing

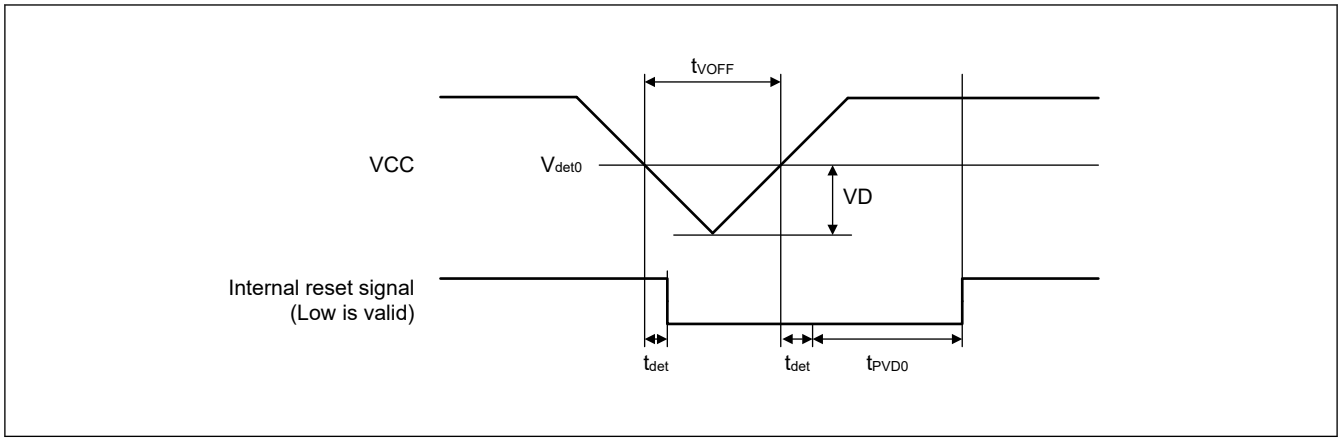


Figure 2.81 Voltage detection circuit timing (V_{det0})

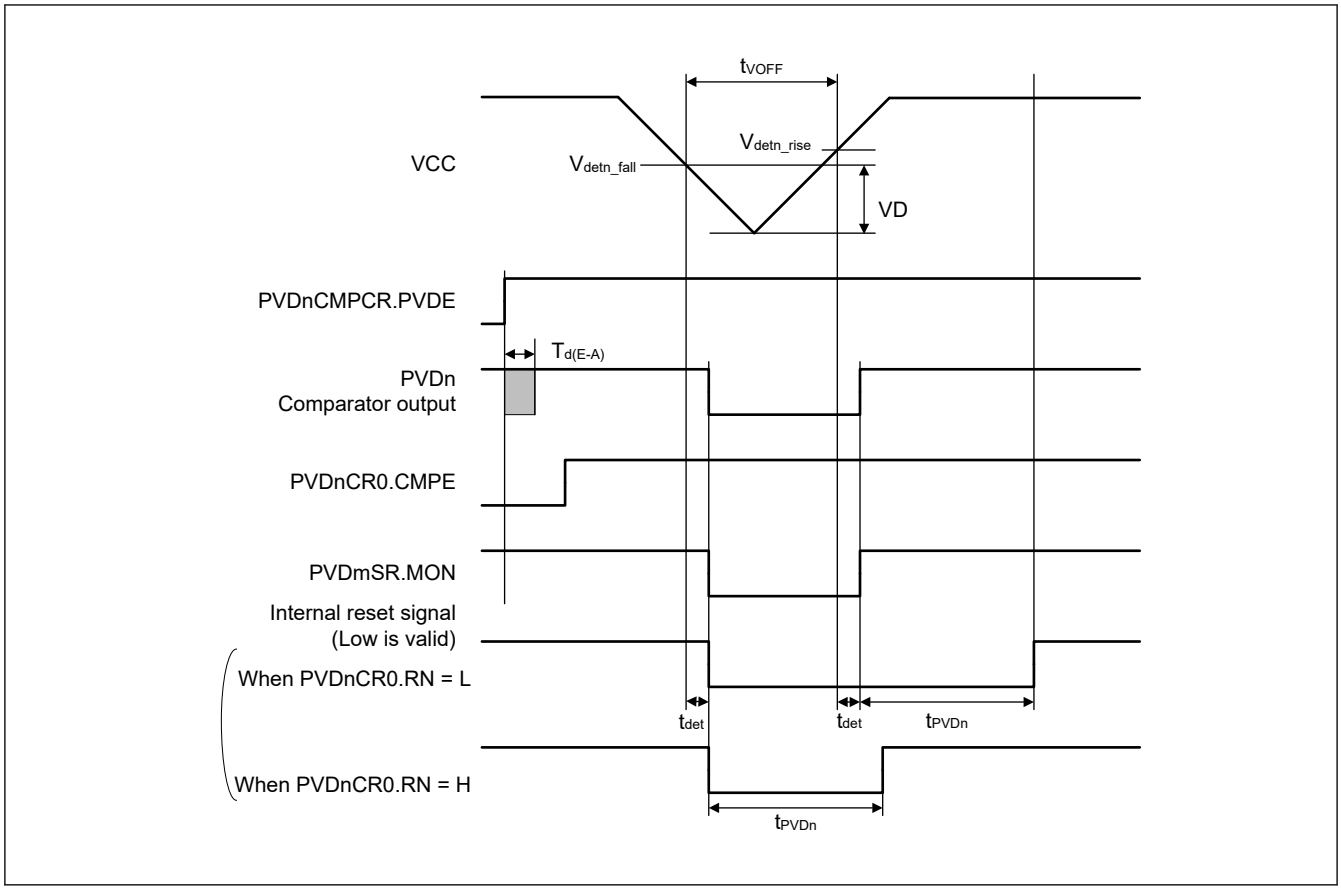


Figure 2.82 Voltage detection circuit timing (V_{detn}) (n = 1, 2)

2.10 VBATT Characteristics

Table 2.62 Battery backup function characteristics

Conditions: VCC = VCC_DCDC = VCC_USB = 1.68 to 3.6 V, VBATT = 1.62 to 3.6 V

Parameter	Symbol	Min	Typ	Max	Unit	Test conditions
Voltage level for switching to battery backup OFS1(_SEC).PVDAS and PVDLPSEL are 0 in Deep Software Standby mode 1, 2 (VDETVATT_n follows VDSEL[2:0] setting for PVD0)	$V_{DETBATT\_0}$	2.760	2.850	2.990	V	Figure 2.83
	$V_{DETBATT\_1}$	2.500	2.580	2.710		
	$V_{DETBATT\_2}$	2.080	2.150	2.270		
	$V_{DETBATT\_3}$	1.940	2.000	2.120		
	$V_{DETBATT\_4}$	1.840	1.900	2.010		
	$V_{DETBATT\_5}$	1.740	1.800	1.910		
	$V_{DETBATT\_6}$	1.650	1.700	1.810		
Voltage level for switching to battery backup (Other than above)	$V_{DETBATT\_0}$	2.710	2.800	2.940	V	
	$V_{DETBATT\_1}$	2.450	2.530	2.660		
	$V_{DETBATT\_2}$	2.030	2.100	2.220		
	$V_{DETBATT\_3}$	1.855	1.950	2.065		
	$V_{DETBATT\_4}$	1.790	1.850	1.960		
	$V_{DETBATT\_5}$	1.690	1.750	1.860		
VCC drop detection stabilization wait time*2	t_{DETWT}	—	—	20	µs	
Lower-limit VBATT voltage for power supply switching caused by VCC voltage drop	V_{BATTSW}	2.0	—	—	V	Figure 2.83
VCC-off period for starting power supply switching*1 (OFS1(_SEC).PVDAS and PVDLPSEL are 0 in Deep Software Standby mode 1, 2)	$t_{VOFFBATT}$	400	—	—	µs	
VCC-off period for starting power supply switching*1 (Other than above)		200	—	—		
Backup domain power-down detection level	$V_{PDR\ (BATR)}$	1.45	1.50	1.60	V	Figure 2.84
Time delay in assertion of the reset signal for the backup domain*3	$t_{p\ (PDRL)}$	—	—	2000	µs	
Time delay in negation of the reset signal for the backup domain	$t_{p\ (PDRH)}$	—	—	3000		
VBATT monitor operation stabilization time (after VBATTMNSELR.VBTMNSEL is changed to 1)	t_{MONWT}	—	—	4.2	µs	—
VBATT voltage monitor level	$V_{MONBATT}$	—	VBATT / 3	—	V	—
VBATT current increase (when VBATTMNSELR.VBTMNSEL is 1 compared to the case that VBATTMNSELR.VBTMNSEL is 0)	$I_{VBATTSELB}$	—	1.50	2.35	µA	—
VCC current increase (when VBATTMNSELR.VBTMNSEL is 1 compared to the case that VBATTMNSELR.VBTMNSEL is 0)	$I_{VBATTSELC}$	—	330	577	µA	—

Note 1. The VCC-off period for starting power supply switching indicates the period in which VCC is below the minimum value of the voltage level for switching to battery backup ($V_{DETBATT}$).
In addition, this period indicates the time tVOFFP when VCC is below the minimum value of voltage detection levels V_{POR1}.
Note 2. Stable time when VBTBPCR2.VDETLVL is changed or VBTBPCR2.VDETLVL is changed from 0 to 1.
Note 3. When the VBATT_R recovers within this period, the backup domain reset signal may not be generated.

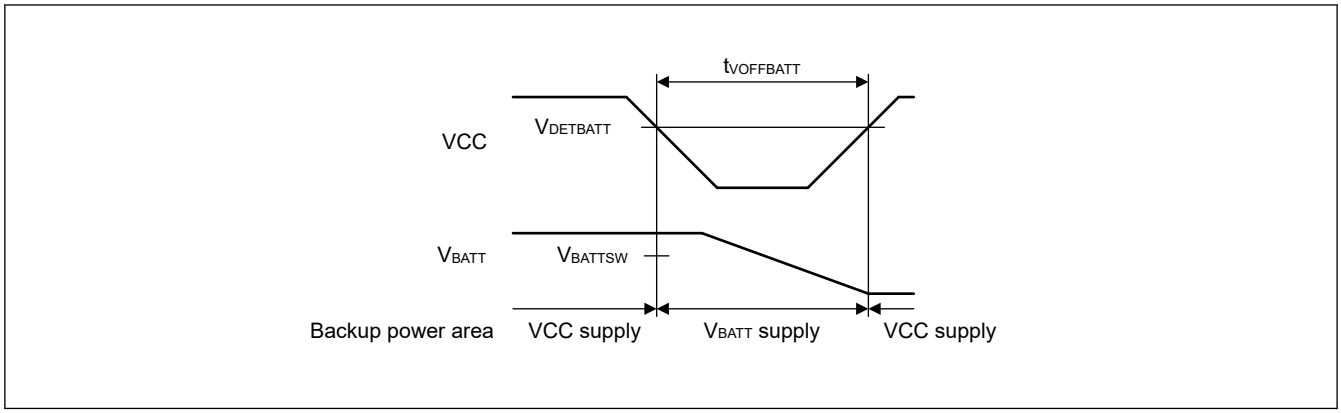


Figure 2.83 Battery backup function characteristics

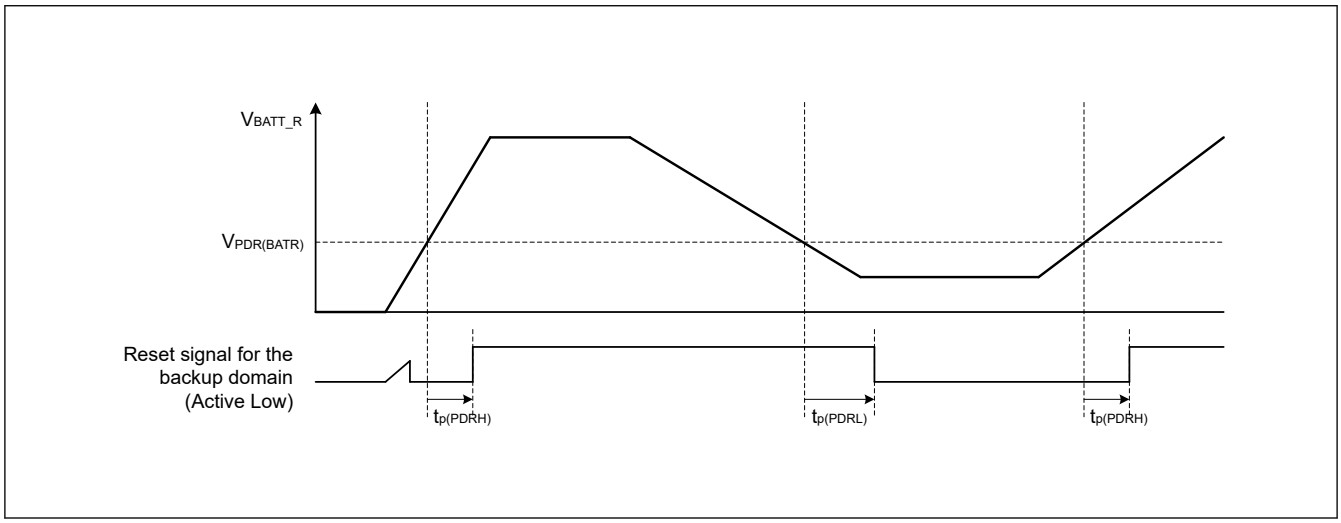


Figure 2.84 Backup Domain Reset Characteristics

2.11 ACMPHS Characteristics

Table 2.63 ACMPHS

Parameter			Symbol	Min	Typ	Max	Unit	Test conditions
Reference voltage range			VREF	0	—	AVCC0	V	—
Input voltage range	ACMPHS0		VI	0	—	AVCC0	V	—
	ACMPHS1	IVCMP1 to IVCMP3		0	—	AVCC0		—
		IVCMP0		0	—	AVCC0		VCC >= AVCC0
				0	—	VCC		VCC < AVCC0
Output delay*1			Td	—	50	100	ns	VI = VREF ± 100mV
Internal reference voltage			Vref	1.13	1.18	1.28	V	—

Note 1. This value is the internal propagation delay.

2.12 Flash Memory Characteristics

2.12.1 Code Flash Memory Characteristics

Table 2.64 Code flash memory characteristics

Conditions: Program or erase: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter		Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
			Min	Typ*6	Max	Min	Typ*6	Max		
Programming time N_{PEC} ≤ 100 times	128-byte	t_{P128}	—	0.75	13.2	—	0.34	6.0	ms	
	8-KB	t_{P8K}	—	49	176	—	22	80	ms	
	32-KB	t_{P32K}	—	194	704	—	88	320	ms	
Programming time N_{PEC} > 100 times	128-byte	t_{P128}	—	0.91	15.8	—	0.41	7.2	ms	
	8-KB	t_{P8K}	—	60	212	—	27	96	ms	
	32-KB	t_{P32K}	—	234	848	—	106	384	ms	
Erasure time N_{PEC} ≤ 100 times	8-KB	t_{E8K}	—	78	216	—	43	120	ms	
	32-KB	t_{E32K}	—	283	864	—	157	480	ms	
Erasure time N_{PEC} > 100 times	8-KB	t_{E8K}	—	94	260	—	52	144	ms	
	32-KB	t_{E32K}	—	341	1040	—	189	576	ms	
Reprogramming/erasure cycle*4		N_{PEC}	10000*1	—	—	10000*1	—	—	Times	
Suspend delay during programming		t_{SPD}	—	—	264	—	—	120	µs	
Programming resume time		t_{PRT}	—	—	110	—	—	50	µs	
First suspend delay during erasure in suspend priority mode		t_{SESD1}	—	—	216	—	—	120	µs	
Second suspend delay during erasure in suspend priority mode		t_{SESD2}	—	—	1.7	—	—	1.7	ms	
Suspend delay during erasure in erasure priority mode		t_{SEED}	—	—	1.7	—	—	1.7	ms	
First erasing resume time during erasure in suspend priority mode*5		t_{REST1}	—	—	1.7	—	—	1.7	ms	
Second erasing resume time during erasure in suspend priority mode		t_{REST2}	—	—	144	—	—	80	µs	
Erasing resume time during erasure in erasure priority mode		t_{REET}	—	—	144	—	—	80	µs	
Forced stop command		t_{FD}	—	—	32	—	—	20	µs	
Data hold time*2		t_{DRP}	20*2 *3	—	—	20*2 *3	—	—	Years	Tj = +105°C
			30*2 *3	—	—	30*2 *3	—	—		Tj = +85°C

Note 1. This is the minimum number of times to guarantee all the characteristics after reprogramming. The guaranteed range is from 1 to the minimum value.
Note 2. This indicates the minimum value of the characteristic when reprogramming is performed within the specified range.
Note 3. This result is obtained from reliability testing.
Note 4. The reprogram/erase cycle is the number of erasures for each block. When the reprogram/erase cycle is n times (n = 10,000), erasing can be performed n times for each block. For example, when 128-byte programming is performed 64 times for different addresses in 8-KB blocks, and then the entire block is erased, the reprogram/erase cycle is counted as one. However, programming the same address several times as one erasure is not enabled. Overwriting is prohibited.
Note 5. Time for resumption includes time for reapplying the erasing pulse (up to one full pulse) that was cut off at the time of suspension.
Note 6. The reference value at VCC = 3.3V and room temperature.

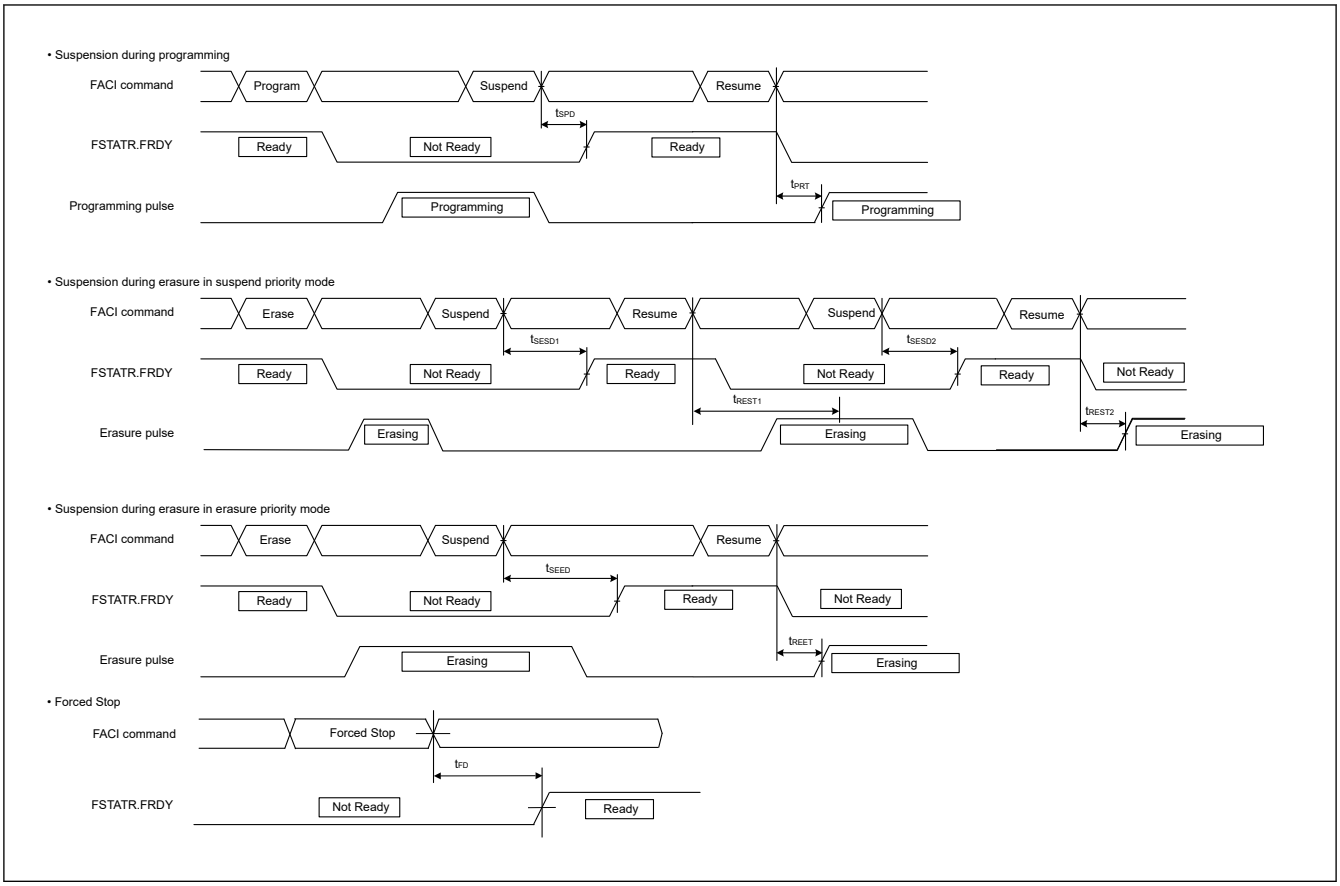


Figure 2.85 Suspension and forced stop timing for flash memory programming and erasure

2.12.2 Data Flash Memory Characteristics

Table 2.65 Data flash memory characteristics (1 of 2)

Conditions: Program or erase: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter		Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
			Min	Typ*6	Max	Min	Typ*6	Max		
Programming time	4-byte	t_{DP4}	—	0.36	3.8	—	0.16	1.7	ms	
	8-byte	t_{DP8}	—	0.38	4.0	—	0.17	1.8		
	16-byte	t_{DP16}	—	0.42	4.5	—	0.19	2.0		
Erasure time	64-byte	t_{DE64}	—	3.1	18	—	1.7	10	ms	
	128-byte	t_{DE128}	—	4.7	27	—	2.6	15		
	256-byte	t_{DE256}	—	8.9	50	—	4.9	28		
Blank check time	4-byte	t_{DBC4}	—	—	84	—	—	30	µs	
Reprogramming/erasure cycle*1		N_{DPEC}	125000*2	—	—	125000*2	—	—	—	
Suspend delay during programming	4-byte	t_{DSPD}	—	—	264	—	—	120	µs	
	8-byte		—	—	264	—	—	120		
	16-byte		—	—	264	—	—	120		
Programming resume time		t_{DPRT}	—	—	110	—	—	50	µs	

Table 2.65 Data flash memory characteristics (2 of 2)

Conditions: Program or erase: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter		Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
			Min	Typ*6	Max	Min	Typ*6	Max		
First suspend delay during erasure in suspend priority mode	64-byte	t_{DSESD1}	—	—	216	—	—	120	µs	
	128-byte		—	—	216	—	—	120		
	256-byte		—	—	216	—	—	120		
Second suspend delay during erasure in suspend priority mode	64-byte	t_{DSESD2}	—	—	300	—	—	300	µs	
	128-byte		—	—	390	—	—	390		
	256-byte		—	—	570	—	—	570		
Suspend delay during erasing in erasure priority mode	64-byte	t_{DSEED}	—	—	300	—	—	300	µs	
	128-byte		—	—	390	—	—	390		
	256-byte		—	—	570	—	—	570		
First erasing resume time during erasure in suspend priority mode*5		t_{DREST1}	—	—	300	—	—	300	µs	
Second erasing resume time during erasure in suspend priority modeFirst erasing resume time during erasure in suspend priority mode		t_{DREST2}	—	—	126	—	—	70	µs	
Erasing resume time during erasure in erasure priority mode		t_{DREET}	—	—	126	—	—	70	µs	
Forced stop command		t_{FD}	—	—	32	—	—	20	µs	
Data hold time*3		t_{DRP}	20*3 *4	—	—	20*3 *4	—	—	Year	Tj = +105°C
			30*3 *4	—	—	30*3 *4	—	—		Tj = +85°C

Note 1. The reprogram/erase cycle is the number of erasures for each block. When the reprogram/erase cycle is n times (n = 125,000), erasing can be performed n times for each block. For example, when 4-byte programming is performed 16 times for different addresses in 64-byte blocks, and then the entire block is erased, the reprogram/erase cycle is counted as one. However, programming the same address several times as one erasure is not enabled. Overwriting is prohibited.
Note 2. This is the minimum number of times to guarantee all the characteristics after reprogramming. The guaranteed range is from 1 to the minimum value.
Note 3. This indicates the minimum value of the characteristic when reprogramming is performed within the specified range.
Note 4. This result is obtained from reliability testing.
Note 5. Time for resumption includes time for reapplying the erasing pulse (up to one full pulse) that was cut off at the time of suspension.
Note 6. The reference value at VCC = 3.3 V and room temperature.

2.12.3 Option Setting Memory (Code flash memory) Characteristics

Table 2.66 Option setting memory (Code flash memory) characteristics (1 of 2)

Conditions: Program: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter	Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
		Min	Typ*4	Max	Min	Typ*4	Max		
Programming time N_{OPC} ≤ 200 times	t_{OP}	—	83	309	—	45	162	ms	
Programming time N_{OPC} > 200 times	t_{OP}	—	100	371	—	55	195	ms	

Table 2.66 Option setting memory (Code flash memory) characteristics (2 of 2)

Conditions: Program: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter	Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
		Min	Typ*4	Max	Min	Typ*4	Max		
Reprogramming cycle	N_{OPC}	20000*1	—	—	20000*1	—	—	Times	
Data hold time*2	t_{DRP}	20*2 *3	—	—	20*2 *3	—	—	Years	Tj = +105°C
		30*2 *3	—	—	30*2 *3	—	—		Tj = +85°C

Note 1. This is the minimum number of times to guarantee all the characteristics after reprogramming. The guaranteed range is from 1 to the minimum value.
Note 2. This indicates the minimum value of the characteristic when reprogramming is performed within the specified range.
Note 3. This result is obtained from reliability testing.
Note 4. The reference value at VCC = 3.3 V and room temperature.

2.12.4 Option Setting Memory (Data flash memory) Characteristics

Table 2.67 Option Setting Memory (Data flash memory) characteristics

Conditions: Program: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter	Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
		Min	Typ*4	Max	Min	Typ*4	Max		
Command time for configuration set (4 / 16 Byte)	t_{DCCT}	—	68	515	—	35	255	ms	
Update Cycles in Configuration area	N_{cupc}	125000 *1	—	—	125000 *1	—	—	Times	
Data hold time*2	t_{DRP}	20*2 *3	—	—	20*2 *3	—	—	Years	Tj = +105°C
		30*2 *3	—	—	30*2 *3	—	—		Tj = +85°C

Note 1. This is the minimum number of times to guarantee all the characteristics after reprogramming. The guaranteed range is from 1 to the minimum value.
Note 2. This indicates the minimum value of the characteristic when reprogramming is performed within the specified range.
Note 3. This result is obtained from reliability testing.
Note 4. The reference value at VCC = 3.3 V and room temperature.

2.12.5 Anti-rollback counter Characteristics

Table 2.68 Anti-rollback counter characteristics

Conditions: Program: FCLK = 4 to 60 MHz
Read: FCLK ≤ 60 MHz

Parameter	Symbol	FCLK = 4 MHz			20 MHz ≤ FCLK ≤ 60 MHz			Unit	Test conditions
		Min	Typ*4	Max	Min	Typ*4	Max		
Command time for increment counter and refresh counter	t_{IRCT}	—	11.9	81	—	6.3	42	ms	
Command time for read counter	t_{RCT}	—	—	25	—	—	5	µs	
Update Cycles (total of increment and refreshing)	N_{cupc}	125000 *1	—	—	125000 *1	—	—	Times	
Data hold time*2	t_{DRP}	20*2 *3	—	—	20*2 *3	—	—	Years	Tj = +105°C
		30*2 *3	—	—	30*2 *3	—	—		Tj = +85°C

Note 1. This is the minimum number of times to guarantee all the characteristics after reprogramming. The guaranteed range is from 1 to the minimum value.
Note 2. This indicates the minimum value of the characteristic when reprogramming is performed within the specified range.
Note 3. This result is obtained from reliability testing.
Note 4. The reference value at VCC = 3.3 V and room temperature.

2.13 Boundary Scan

Table 2.69 Boundary scan characteristics

Parameter	VCC	Symbol	Min	Typ	Max	Unit	Test conditions
TCK clock cycle time	1.68 V or above	t_{TCKcyc}	100	—	—	ns	Figure 2.86
TCK clock high pulse width	1.68 V or above	t_{TCKH}	0.45	—	—	t_{TCKcyc}	
TCK clock low pulse width	1.68 V or above	t_{TCKL}	0.45	—	—	t_{TCKcyc}	
TCK clock rise time	1.68 V or above	t_{TCKr}	—	—	0.05*2	t_{TCKcyc}	
TCK clock fall time	1.68 V or above	t_{TCKf}	—	—	0.05*2	t_{TCKcyc}	
TMS setup time	1.68 V or above	t_{TMSS}	20	—	—	ns	Figure 2.87
TMS hold time	1.68 V or above	t_{TMSH}	20	—	—	ns	
TDI setup time	1.68 V or above	t_{TDIS}	20	—	—	ns	
TDI hold time	1.68 V or above	t_{TDIH}	20	—	—	ns	
TDO data delay	1.68 V or above	t_{TDOD}	—	—	40	ns	
Capture register setup time	1.68 V or above	t_{CAPTS}	20	—	—	ns	Figure 2.88
Capture register hold time	1.68 V or above	t_{CAPTH}	20	—	—	ns	
Update register delay time	1.68 V or above	$t_{UPDATED}$	—	—	40	ns	
Boundary scan circuit startup time*1	1.68 V or above	T_{BSSTUP}	t_{RESWP}	—	—	—	Figure 2.89

Note 1. Boundary scan does not function until the power-on reset becomes negative.
Note 2. 1 µs at the longest

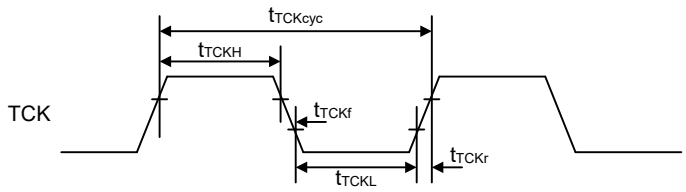


Figure 2.86 Boundary scan TCK timing

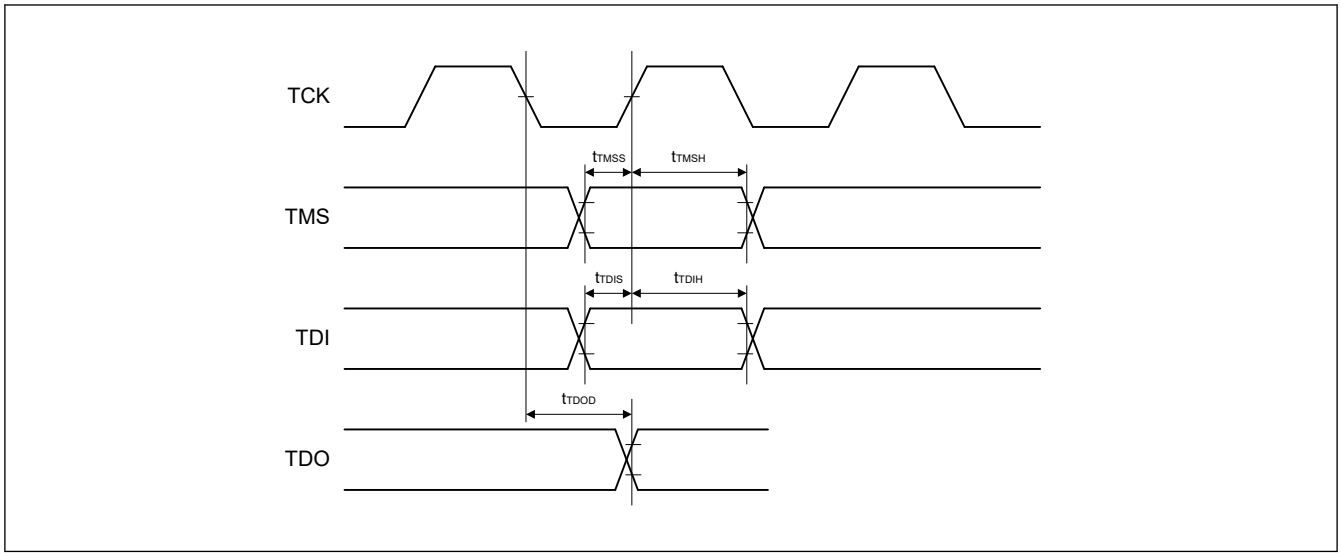


Figure 2.87 Boundary scan input/output timing (1)

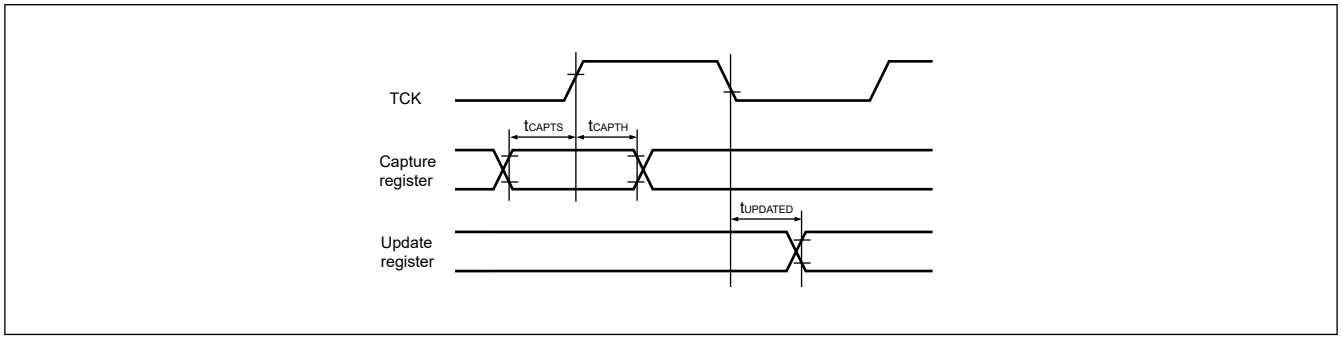


Figure 2.88 Boundary scan input/output timing (2)

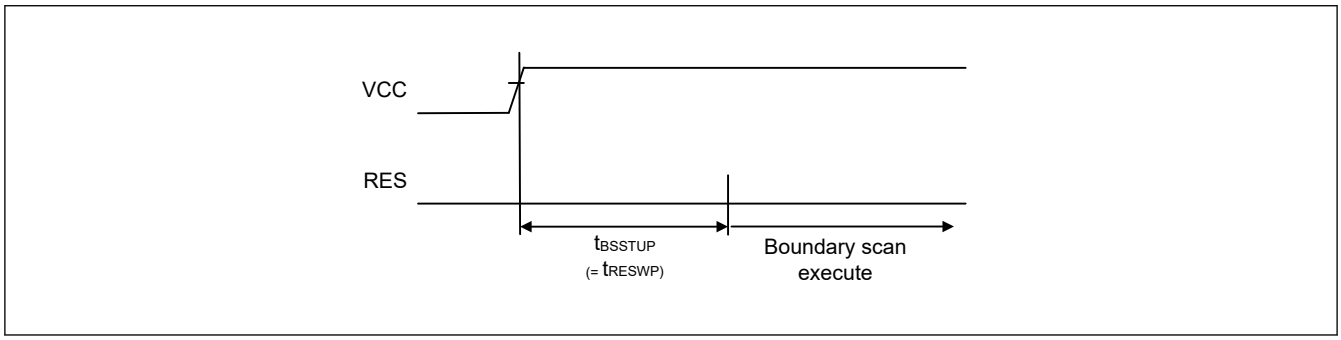


Figure 2.89 Boundary scan circuit startup timing

2.14 Joint European Test Action Group (JTAG)

Table 2.70 JTAG

Parameter	VCC	Symbol	Min	Typ	Max	Unit	Test conditions
TCK clock cycle time	2.7 V or above	t_{TCKcyc}	40.0	—	—	ns	Figure 2.90
	1.68 V or above		40.0	—	—	ns	
TCK clock high pulse width	2.7 V or above	t_{TCKH}	0.375	—	—	t_{TCKcyc}	
	1.68 V or above		0.375	—	—	t_{TCKcyc}	
TCK clock low pulse width	2.7 V or above	t_{TCKL}	0.375	—	—	t_{TCKcyc}	
	1.68 V or above		0.375	—	—	t_{TCKcyc}	
TCK clock rise time	2.7 V or above	t_{TCKr}	—	—	0.125*1	t_{TCKcyc}	
	1.68 V or above		—	—	0.125*1	t_{TCKcyc}	
TCK clock fall time	2.7 V or above	t_{TCKf}	—	—	0.125*1	t_{TCKcyc}	
	1.68 V or above		—	—	0.125*1	t_{TCKcyc}	
TMS setup time	2.7 V or above	t_{TMSS}	8.0	—	—	ns	Figure 2.91
	1.68 V or above		8.0	—	—	ns	
TMS hold time	2.7 V or above	t_{TMSH}	8.0	—	—	ns	
	1.68 V or above		8.0	—	—	ns	
TDI setup time	2.7 V or above	t_{TDIS}	8.0	—	—	ns	
	1.68 V or above		8.0	—	—	ns	
TDI hold time	2.7 V or above	t_{TDIH}	8.0	—	—	ns	
	1.68 V or above		8.0	—	—	ns	
TDO data delay time	2.7 V or above	t_{TDOD}	—	—	20.0	ns	
	1.68 V or above		—	—	28.0	ns	

Note 1. 1 µs at the longest

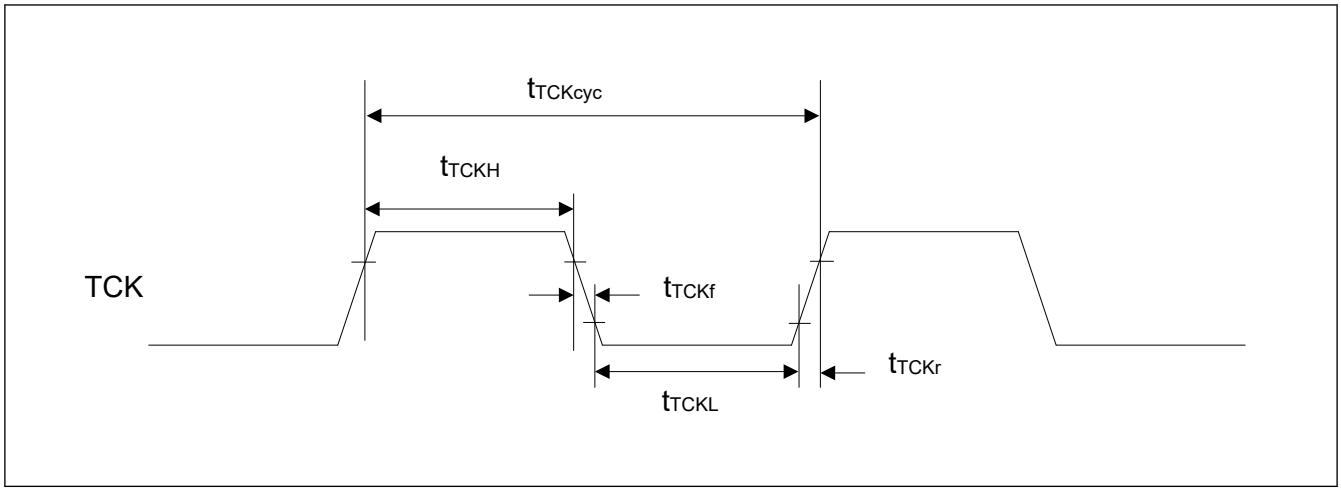


Figure 2.90 JTAG TCK timing

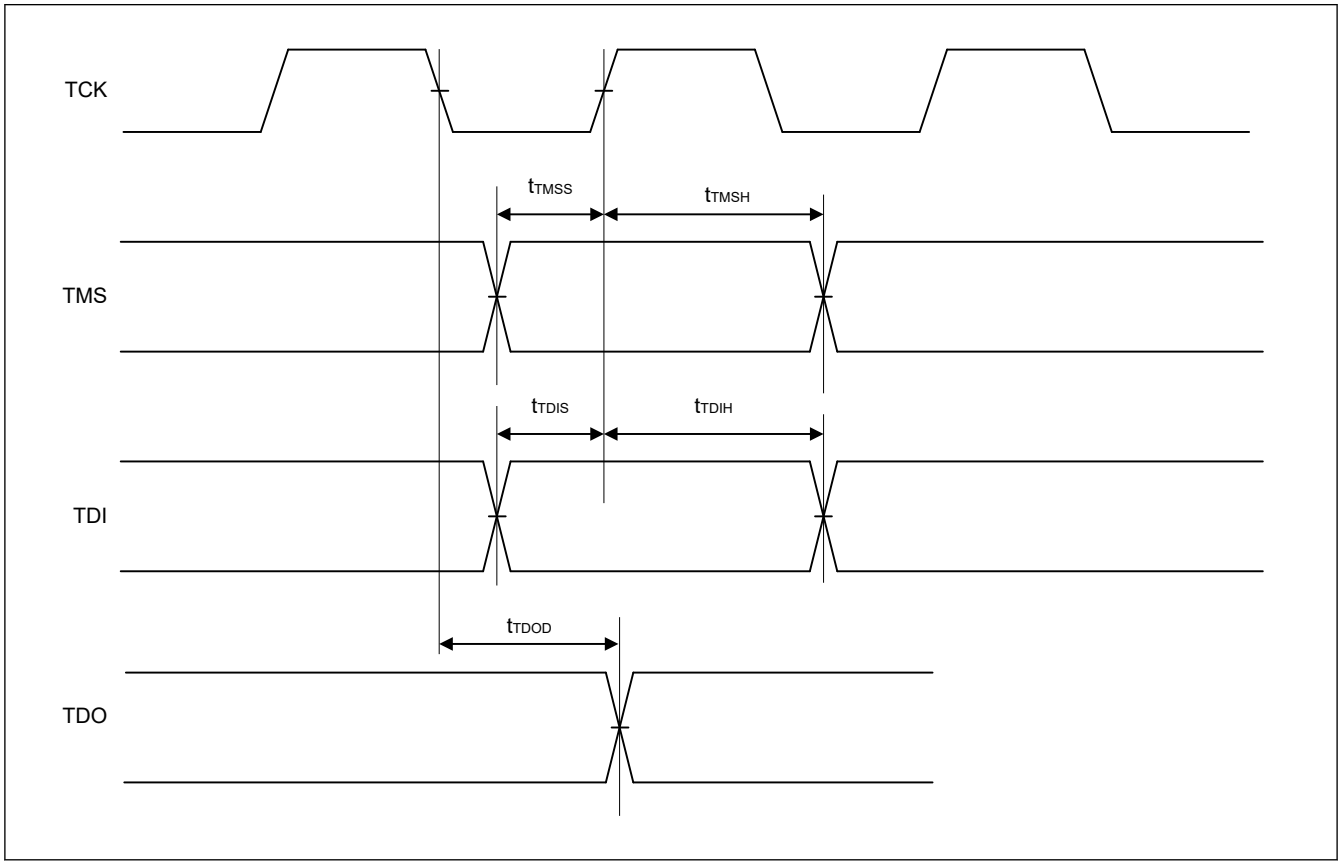


Figure 2.91 JTAG input/output timing

2.15 Serial Wire Debug (SWD)

Table 2.71 SWD

Parameter	VCC	Symbol	Min	Typ	Max	Unit	Test conditions
SWCLK clock cycle time	2.7 V or above	$t_{SWCKcyc}$	40.0	—	—	ns	Figure 2.92
	1.68 V or above		40.0	—	—	ns	
SWCLK clock high pulse width	2.7 V or above	t_{SWCKH}	0.375	—	—	$t_{SWCKcyc}$	
	1.68 V or above		0.375	—	—	$t_{SWCKcyc}$	
SWCLK clock low pulse width	2.7 V or above	t_{SWCKL}	0.375	—	—	$t_{SWCKcyc}$	
	1.68 V or above		0.375	—	—	$t_{SWCKcyc}$	
SWCLK clock rise time	2.7 V or above	t_{SWCKr}	—	—	0.125*1	$t_{SWCKcyc}$	
	1.68 V or above		—	—	0.125*1	$t_{SWCKcyc}$	
SWCLK clock fall time	2.7 V or above	t_{SWCKf}	—	—	0.125*1	$t_{SWCKcyc}$	
	1.68 V or above		—	—	0.125*1	$t_{SWCKcyc}$	
SWDIO setup time	2.7 V or above	t_{SWDS}	8.0	—	—	ns	Figure 2.93
	1.68 V or above		8.0	—	—	ns	
SWDIO hold time	2.7 V or above	t_{SWDH}	8.0	—	—	ns	
	1.68 V or above		8.0	—	—	ns	
SWDIO data delay time	2.7 V or above	t_{SWDD}	2.0	—	28.0	ns	
	1.68 V or above		2.0	—	32.0	ns	

Note 1. 1 µs at the longest

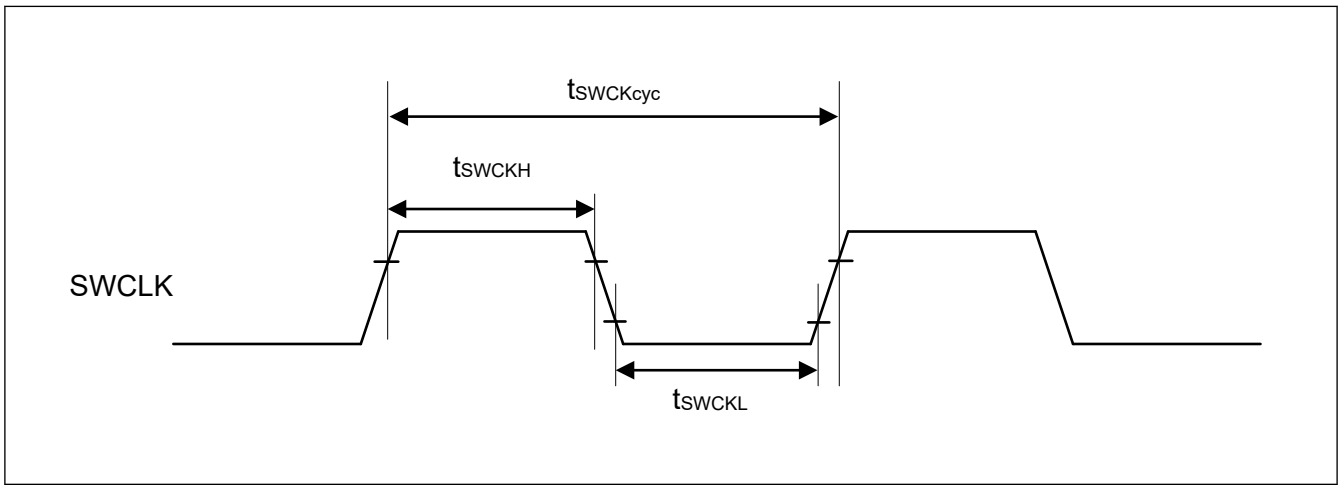


Figure 2.92 SWD SWCLK timing

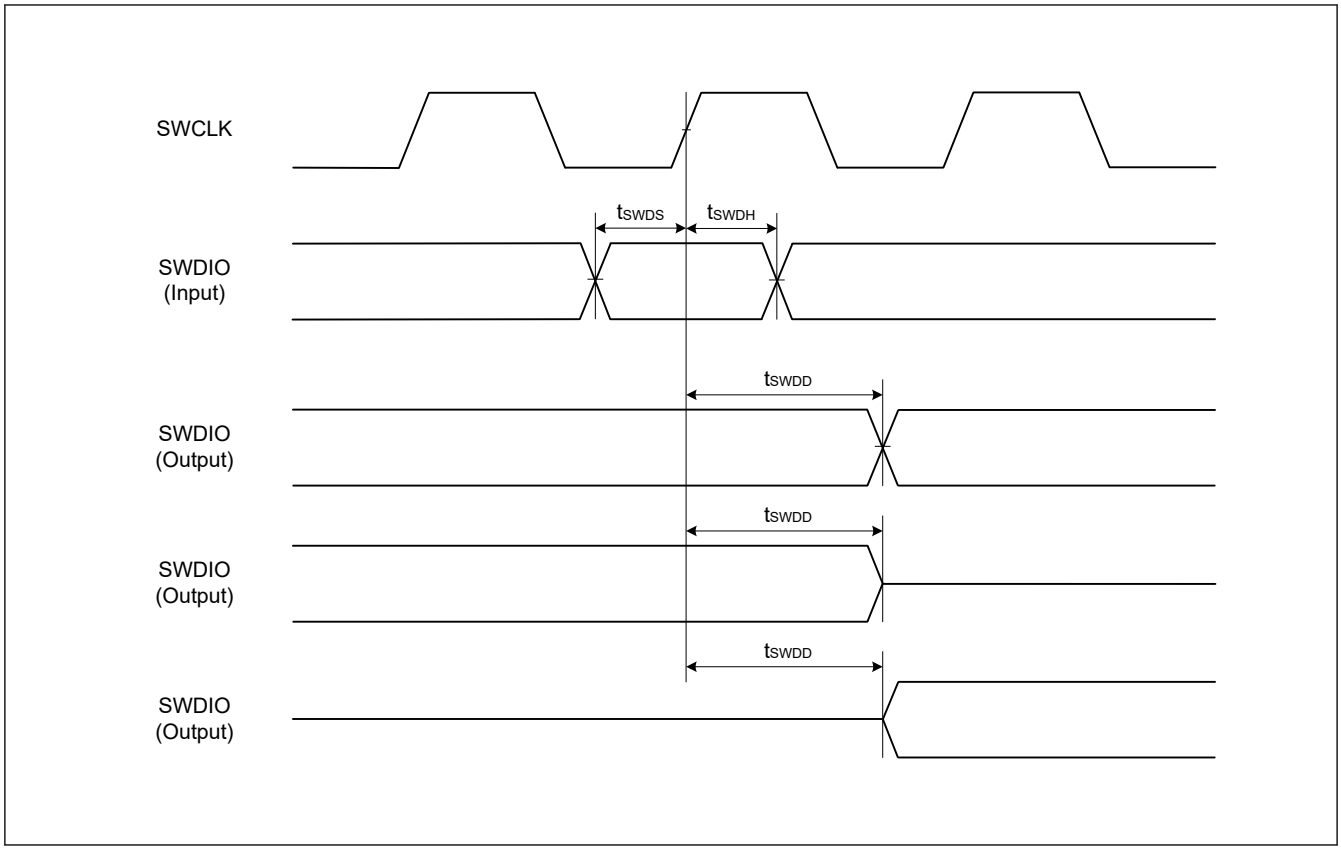


Figure 2.93 SWD input/output timing

2.16 Embedded Trace Macro Interface (ETM)

Table 2.72 ETM (1 of 2)

Conditions: High-speed high drive output is selected in the Port Drive Capability bit in the PmnPFS register.

Parameter	VCC	Symbol	Min	Typ	Max	Unit	Test conditions
TCLK clock cycle time	2.7 V or above	$t_{TCLKcyc}$	16.6	—	—	ns	Figure 2.94
	1.68 V or above		16.6	—	—	ns	
TCLK clock high pulse width	2.7 V or above	t_{TCLKH}	7.3	—	—	ns	
	1.68 V or above		6.3	—	—	ns	
TCLK clock low pulse width	2.7 V or above	t_{TCLKL}	7.3	—	—	ns	
	1.68 V or above		6.3	—	—	ns	
TCLK clock rise time	2.7 V or above	t_{TCLKr}	—	—	1.0	ns	
	1.68 V or above		—	—	2.0	ns	
TCLK clock fall time	2.7 V or above	t_{TCLKf}	—	—	1.0	ns	
	1.68 V or above		—	—	2.0	ns	

Table 2.72 ETM (2 of 2)

Conditions: High-speed high drive output is selected in the Port Drive Capability bit in the PmnPFS register.

Parameter	VCC	Symbol	Min	Typ	Max	Unit	Test conditions
TDATA[3:0] output valid time	2.7 V or above	t_{TRDV}	—	—	$t_{TCLKcyc}/4 + 1.6$	ns	Figure 2.95
	1.68 V or above		—	—	$t_{TCLKcyc}/4 + 1.6$	ns	
TDATA[3:0] output hold time	2.7 V or above	t_{TRDH}	1.5	—	—	ns	
	1.68 V or above		1.5	—	—	ns	

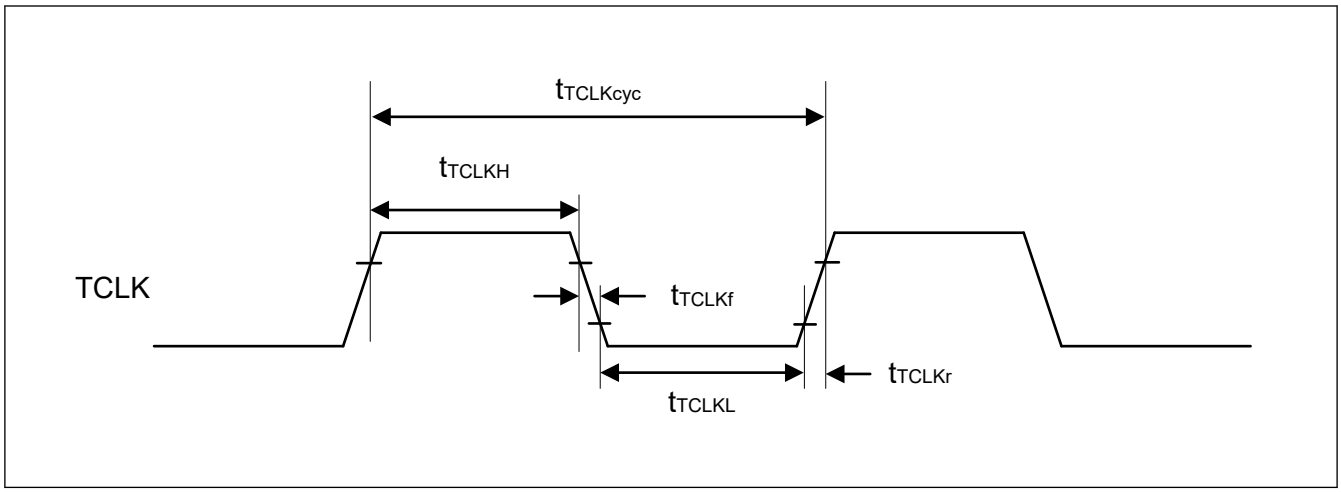


Figure 2.94 ETM TCLK timing

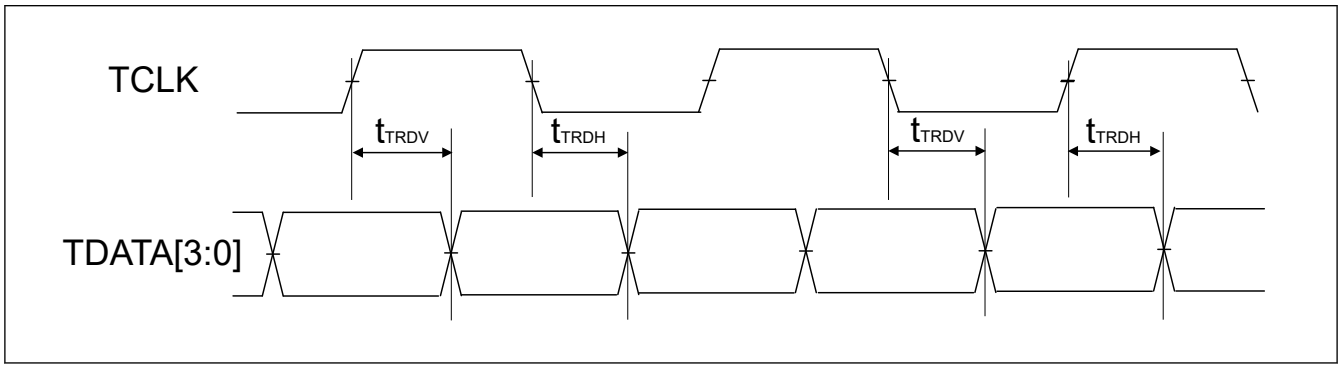


Figure 2.95 ETM output timing

Appendix 1. Port States in Each Processing Mode

Function	Pin function	Reset	Software Standby mode(SSTBY)		Deep Software Standby mode 1,2,3 (DSTBY1,2,3)		After Deep Software Standby mode is canceled (return to startup mode)	
			OPE=0	OPE=1	DSTBY1	DSTBY2/ DSTBY3	IOKEEP = 0	IOKEEP = 1*1
Mode	MD	Pull-up	Keep-I		Keep		Pull-up	Keep
JTAG/SWD	TCK/TMS/TDI/SWCLK	Pull-up	TCK/TDI/TMS/SWCLK input		TCK/TDI/TMS/SWCLK input		TCK/TDI/TMS/SWCLK input	
	TDO	Output	TDO output		TDO output		TDO output	
	SWDIO	Pull-up	SWDIO inout		SWDIO inout		SWDIO inout	
Trace	TCLK/TDATAx/SWO	TCLK/ TDATAx/SWO output	TCLK/TDATAx/SWO output		TCLK/TDATAx/SWO output		TCLK/TDATAx/SWO output	
IRQ	IRQx	Hi-Z	Hi-Z*2		Keep		Hi-Z	Keep
	IRQx-DS (x:Other than 5)	Hi-Z	Hi-Z*2		Keep*3		Hi-Z	Keep
	IRQ5-DS	Hi-Z	Hi-Z*2		Keep*3		Hi-Z	
AGT	AGTIOn	Hi-Z	AGTIOn inout		Keep		Hi-Z	Keep
	AGTOn/AGTOAn/ AGTOBn	Hi-Z	AGTOn/AGTOAn/AGTOBn output		Keep		Hi-Z	Keep
ULPT	ULPTEEn/ULPTEVIn	Hi-Z	ULPTEEn/ULPTEVIn input		Keep		Hi-Z	Keep
	ULPTEEn-DS/ ULPTEVIn-DS	Hi-Z	ULPTEEn-DS/ULPTEVIn-DS input		ULPTEEn-DS/ ULPTEVIn-DS input	Hi-Z	Hi-Z	Keep
	ULPTOn/ ULPTOAn/ ULPTOBn	Hi-Z	ULPTOn/ULPTOAn/ULPTOBn output		Keep		Hi-Z	Keep
	ULPTOn-DS/ ULPTOAn-DS/ ULPTOBn-DS	Hi-Z	ULPTOn/ULPTOAn-DS/ ULPTOBn-DS output		ULPTOn/ ULPTOAn-DS/ ULPTOBn-DS output	Keep	Hi-Z	From DSTBY1: ULPTOn/ ULPTOAn-DS/ ULPTOBn-DS output From DSTBY2,3: Keep
IIC	SCLn/SDAn	Hi-Z	Keep-O*2		Keep		Hi-Z	Keep
USBFS	USB_OVRCURx	Hi-Z	Hi-Z*2		Keep		Hi-Z	Keep
	USB_OVRCURx-DS/ USB_VBUS	Hi-Z	Hi-Z*2		Keep*3	Keep	Hi-Z	Keep
	USB_DP/USB_DM	Hi-Z	Keep-O*4		Keep*3	Keep	Hi-Z	Keep
RTC	RTCICx	Hi-Z	Hi-Z*2		Keep*3		Hi-Z	Keep
	RTCOUT	Hi-Z	RTCOUT output		Keep		Hi-Z	Keep
ACMPHS	VCOUT	Hi-Z	VCOUT output		Keep		Hi-Z	Keep
CLKOUT	CLKOUT	Hi-Z	CLKOUT output		Keep		Hi-Z	Keep
DAC	DA0	Hi-Z	D/A output retained		Hi-Z		Hi-Z	
P400/P401	Other than function IRQ5-DS	Hi-Z	Keep-O*2		Hi-Z		Hi-Z	
Others	—	Hi-Z	Keep-O		Keep		Hi-Z	Keep

Note: Hi-Z: High-impedance
Keep-O: Output pins retain their previous values. Input pins go to high-impedance.
Keep-I: Pin states are retained same as during periods in Normal mode.
Keep: Pin states are retained same as during periods in Software Standby mode.

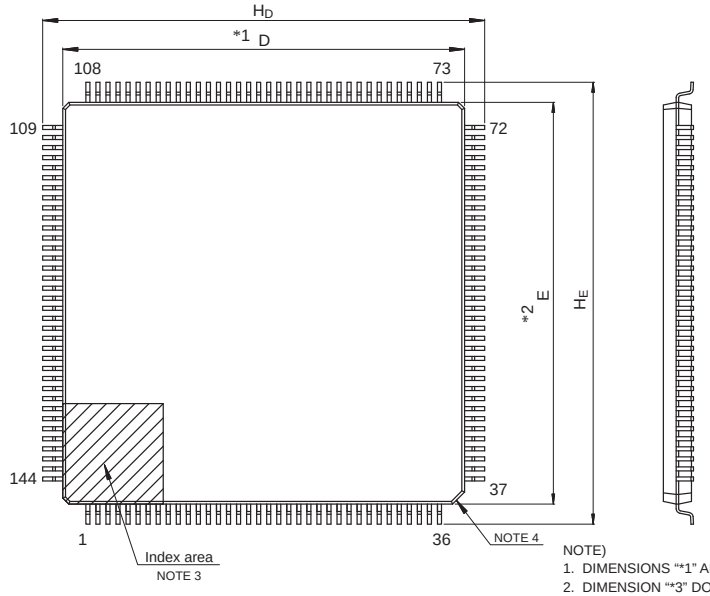
Note 1. Retains the I/O port state until the DPSBYCR.IOKEEP bit is cleared to 0.
Note 2. Input is enabled if the pin is specified as the Software Standby canceling source while it is used as an external interrupt pin.
Note 3. Input is enabled if the pin is specified as the Deep Software Standby canceling source.
Note 4. Input is enabled while the pin is used as an input pin.

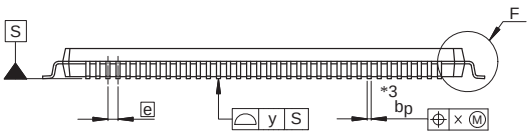
Appendix 2. Package Dimensions

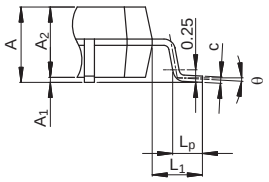
Information on the latest version of the package dimensions or mountings is displayed in “Packages” on the Renesas Electronics Corporation website.

JEITA Package Code	RENESAS Code	Previous Code	MASS (Typ) [g]
P-LFQFP144-20x20-0.50	PLQP0144KA-B	—	1.2

Unit: mm







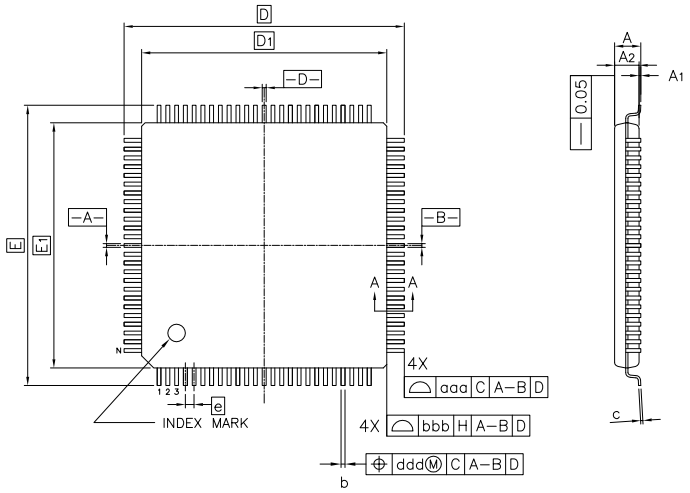
Detail F

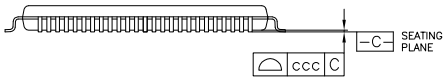
NOTE)
1. DIMENSIONS “*1” AND “*2” DO NOT INCLUDE MOLD FLASH.
2. DIMENSION “*3” DOES NOT INCLUDE TRIM OFFSET.
3. PIN 1 VISUAL INDEX FEATURE MAY VARY, BUT MUST BE LOCATED WITHIN THE HATCHED AREA.
4. CHAMFERS AT CORNERS ARE OPTIONAL, SIZE MAY VARY.

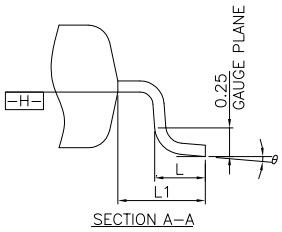
Reference Symbol	Dimensions in millimeters		
	Min	Nom	Max
D	19.9	20.0	20.1
E	19.9	20.0	20.1
A_2	—	1.4	—
H_D	21.8	22.0	22.2
H_E	21.8	22.0	22.2
A	—	—	1.7
A_1	0.05	—	0.15
b_p	0.17	0.20	0.27
c	0.09	—	0.20
θ	0°	3.5°	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
L_p	0.45	0.6	0.75
L_1	—	1.0	—

Figure 2.1 LQFP 144-pin

JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-LFQFP100-14x14-0.50	PLQP0100KP-A	0.67







Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	–	–	1.60
A_1	0.05	–	0.15
A_2	1.35	1.40	1.45
D	–	16.00	–
D_1	–	14.00	–
E	–	16.00	–
E_1	–	14.00	–
N	–	100	–
e	–	0.50	–
b	0.17	0.22	0.27
c	0.09	–	0.20
θ	0°	3.5°	7°
L	0.45	0.60	0.75
L_1	–	1.00	–
aaa	–	–	0.20
bbb	–	–	0.20
ccc	–	–	0.08
ddd	–	–	0.08

Figure 2.2 LQFP 100-pin

Appendix 3. I/O Registers

This appendix describes I/O register address and access cycles by function.

3.1 Peripheral Base Addresses

This section provides the base addresses for peripherals described in this manual. Table 3.1 shows the name, description, and the base address of each peripheral.

Table 3.1 Peripheral base address (1 of 3)

Description	Name of Secure registers	Base address of Secure registers in Secure alias region	Name of Non-secure registers	Base address of Non-secure registers in Non-secure alias region
Renesas Memory Protection Unit	RMPU	0x4000_0000	RMPU_NS	0x5000_0000
SRAM Control	SRAM	0x4000_2000	SRAM_NS	0x5000_2000
BUS Control	BUS	0x4000_3000	BUS_NS	0x5000_3000
Common Interrupt Controller	ICU_COMMON	0x4000_6000	ICU_COMMON_NS	0x5000_6000
CPU System Security Control Unit	CPSCU	0x4000_8000	CPSCU_NS	0x5000_8000
Direct memory access controller 00	DMAC00	0x4000_A000	DMAC00_NS	0x5000_A000
Direct memory access controller 01	DMAC01	0x4000_A040	DMAC01_NS	0x5000_A040
Direct memory access controller 02	DMAC02	0x4000_A080	DMAC02_NS	0x5000_A080
Direct memory access controller 03	DMAC03	0x4000_A0C0	DMAC03_NS	0x5000_A0C0
Direct memory access controller 04	DMAC04	0x4000_A100	DMAC04_NS	0x5000_A100
Direct memory access controller 05	DMAC05	0x4000_A140	DMAC05_NS	0x5000_A140
Direct memory access controller 06	DMAC06	0x4000_A180	DMAC06_NS	0x5000_A180
Direct memory access controller 07	DMAC07	0x4000_A1C0	DMAC07_NS	0x5000_A1C0
DMAC Module Activation 0	DMA0	0x4000_A800	DMA0_NS	0x5000_A800
Data Transfer Controller 0	DTC0	0x4000_AC00	DTC0_NS	0x5000_AC00
Interrupt Controller	ICU	0x4000_C000	ICU_NS	0x5000_C000
CPU Control Registers	CPU_CTRL	0x4000_F000	CPU_CTRL_NS	0x5000_F000
On-Chip Debug	OCD_CPU	0x4001_1000	OCD_CPU_NS	0x5001_1000
DAP Function	DAP_CPU	0x8001_1000		
Debug Function	CPU_DBG	0x4001_B000	CPU_DBG_NS	0x5001_B000
System Control	SYSC	0x4001_E000	SYSC_NS	0x5001_E000
Temperature Sensor Data	TSD	0x4011_B000	TSD_NS	0x5011_B000
Event Link Controller	ELC	0x4020_1000	ELC_NS	0x5020_1000
Realtime Clock	RTC	0x4020_2000	RTC_NS	0x5020_2000
Independent Watchdog Timer	IWDT	0x4020_2200	IWDT_NS	0x5020_2200
Clock Frequency Accuracy Measurement Circuit	CAC	0x4020_2400	CAC_NS	0x5020_2400
Watchdog Timer 0	WDT0	0x4020_2600	WDT0_NS	0x5020_2600
Module Stop Control A,B,C,D,E	MSTP	0x4020_3000	MSTP_NS	0x5020_3000
Peripheral Security Control Unit	PSCU	0x4020_4000	PSCU_NS	0x5020_4000
Port Output Enable Module for GPT	POEG	0x4021_2000	POEG_NS	0x5021_2000
Ultra-Low Power Timer 0	ULPT0	0x4022_0000	ULPT0_NS	0x5022_0000
Ultra-Low Power Timer 1	ULPT1	0x4022_0100	ULPT1_NS	0x5022_0100

Table 3.1 Peripheral base address (2 of 3)

Description	Name of Secure registers	Base address of Secure registers in Secure alias region	Name of Non-secure registers	Base address of Non-secure registers in Non-secure alias region
Low Power Asynchronous General purpose Timer 0	AGT0	0x4022_1000	AGT0_NS	0x5022_1000
Low Power Asynchronous General purpose Timer 1	AGT1	0x4022_1100	AGT1_NS	0x5022_1100
Temperature Sensor	TSN	0x4023_5000	TSN_NS	0x5023_5000
High-Speed Analog Comparator 0	ACMPHS0	0x4023_6000	ACMPHS0_NS	0x5023_6000
High-Speed Analog Comparator 1	ACMPHS1	0x4023_6100	ACMPHS1_NS	0x5023_6100
USB 2.0 FS Module	USBFS	0x4025_0000	USBFS_NS	0x5025_0000
Serial Sound Interface Enhanced (SSIE) 0	SSIE0	0x4025_D000	SSIE0_NS	0x5025_D000
Serial Sound Interface Enhanced (SSIE) 1	SSIE1	0x4025_D100	SSIE1_NS	0x5025_D100
Inter-Integrated Circuit 0	IIC0	0x4025_E000	IIC0_NS	0x5025_E000
Inter-Integrated Circuit 0 Wake-up Unit	IIC0WU	0x4025_E014	IIC0WU_NS	0x5025_E014
Inter-Integrated Circuit 1	IIC1	0x4025_E100	IIC1_NS	0x5025_E100
Octal Serial Peripheral Interface 0	OSPI0_B	0x4026_8000	OSPI0_B_NS	0x5026_8000
CRC Calculator	CRC	0x4031_0000	CRC_NS	0x5031_0000
Data Operation Circuit	DOC_B	0x4031_1000	DOC_B_NS	0x5031_1000
General PWM 32-bit Timer 0	GPT320	0x4032_2000	GPT320_NS	0x5032_2000
General PWM 32-bit Timer 1	GPT321	0x4032_2100	GPT321_NS	0x5032_2100
General PWM 32-bit Timer 2	GPT322	0x4032_2200	GPT322_NS	0x5032_2200
General PWM 32-bit Timer 3	GPT323	0x4032_2300	GPT323_NS	0x5032_2300
General PWM 32-bit Timer 4	GPT324	0x4032_2400	GPT324_NS	0x5032_2400
General PWM 32-bit Timer 5	GPT325	0x4032_2500	GPT325_NS	0x5032_2500
General PWM 16-bit Timer 10	GPT1610	0x4032_2A00	GPT1610_NS	0x5032_2A00
General PWM 16-bit Timer 11	GPT1611	0x4032_2B00	GPT1611_NS	0x5032_2B00
General PWM 16-bit Timer 12	GPT1612	0x4032_2C00	GPT1612_NS	0x5032_2C00
General PWM 16-bit Timer 13	GPT1613	0x4032_2D00	GPT1613_NS	0x5032_2D00
12bit A/D Converter 0	ADC120	0x4033_2000	ADC120_NS	0x5033_2000
12bit A/D Converter 1	ADC121	0x4033_2200	ADC121_NS	0x5033_2200
12-bit D/A converter	DAC12	0x4033_3000	DAC12_NS	0x5033_3000
Capture Engine Unit	CEU	0x4034_8000	CEU_NS	0x5034_8000
DMA Controller for the Ethernet Controller Channel 0	EDMAC0	0x4035_4000	EDMAC0_NS	0x5035_4000
Ethernet Controller Channel 0	ETHERC0	0x4035_4100	ETHERC0_NS	0x5035_4100
Serial Communication Interface 0	SCI0_B	0x4035_8000	SCI0_B_NS	0x5035_8000
Serial Communication Interface 1	SCI1_B	0x4035_8100	SCI1_B_NS	0x5035_8100
Serial Communication Interface 2	SCI2_B	0x4035_8200	SCI2_B_NS	0x5035_8200
Serial Communication Interface 3	SCI3_B	0x4035_8300	SCI3_B_NS	0x5035_8300
Serial Communication Interface 4	SCI4_B	0x4035_8400	SCI4_B_NS	0x5035_8400
Serial Communication Interface 9	SCI9_B	0x4035_8900	SCI9_B_NS	0x5035_8900

Table 3.1 Peripheral base address (3 of 3)

Description	Name of Secure registers	Base address of Secure registers in Secure alias region	Name of Non-secure registers	Base address of Non-secure registers in Non-secure alias region
Serial Peripheral Interface 0	SPI0	0x4035_C000	SPI0_NS	0x5035_C000
Serial Peripheral Interface 1	SPI1	0x4035_C100	SPI1_NS	0x5035_C100
Error correction circuit for MBRAM0	ECCMB0	0x4036_F200	ECCMB0_NS	0x5036_F200
Error correction circuit for MBRAM1	ECCMB1	0x4036_F300	ECCMB1_NS	0x5036_F300
CANFD Module 0	CANFD0	0x4038_0000	CANFD0_NS	0x5038_0000
CANFD Module 1	CANFD1	0x4038_2000	CANFD1_NS	0x5038_2000
Port 0 Control Registers	PORT0	0x4040_0000	PORT0_NS	0x5040_0000
Port 1 Control Registers	PORT1	0x4040_0020	PORT1_NS	0x5040_0020
Port 2 Control Registers	PORT2	0x4040_0040	PORT2_NS	0x5040_0040
Port 3 Control Registers	PORT3	0x4040_0060	PORT3_NS	0x5040_0060
Port 4 Control Registers	PORT4	0x4040_0080	PORT4_NS	0x5040_0080
Port 5 Control Registers	PORT5	0x4040_00A0	PORT5_NS	0x5040_00A0
Port 6 Control Registers	PORT6	0x4040_00C0	PORT6_NS	0x5040_00C0
Port 7 Control Registers	PORT7	0x4040_00E0	PORT7_NS	0x5040_00E0
Port 8 Control Registers	PORT8	0x4040_0100	PORT8_NS	0x5040_0100
Port 9 Control Registers	PORT9	0x4040_0120	PORT9_NS	0x5040_0120
Pmn Pin Function Control Register	PFS	0x4040_0800	PFS_NS	0x5040_0800
Flash Cache	FCACHE	0x4001_C100	FCACHE_NS	0x5001_C100
Data Flash	FLAD	0x4011_C000	FLAD_NS	0x5011_C000
Flash Application Command Interface	FACI	0x4011_E000	FACI_NS	0x5011_E000
Data Flash Secuirty Setting	FDFS	0x2703_0000		

Note: Name = Peripheral name
Description = Peripheral functionality
Base address = Lowest reserved address or address used by the peripheral

3.2 Access Cycles

This section provides access cycle information for the I/O registers described in this manual.

- Registers are grouped by associated module.
- The number of access cycles indicates the number of cycles based on the specified reference clock.
- In the internal I/O area, reserved addresses that are not allocated to registers must not be accessed, otherwise operations cannot be guaranteed.
- The number of I/O access cycles depends on bus cycles of the internal peripheral bus, divided clock synchronization cycles, and wait cycles of each module. Divided clock synchronization cycles differ depending on the frequency ratio between ICLK and PCLK.
- When the frequency of ICLK is equal to that of PCLK, the number of divided clock synchronization cycles is always constant.
- When the frequency of ICLK is greater than that of PCLK, at least 1 PCLK cycle is added to the number of divided clock synchronization cycles.
- The number of write access cycles indicates the number of cycles obtained by non-bufferable write access.

Note: This applies to the number of cycles when access from the CPU does not conflict with the instruction fetching to the external memory or bus access from other bus masters such as DTC or DMAC.

Table 3.2 Access cycles (1 of 3)

Peripheral base address symbol	Address*1		Number of access cycles				Cycle Unit	Related function
			ICLK = PCLK		ICLK > PCLK*2			
	From	To	Read	Write	Read	Write		
RMPU, SRAM, BUS, ICU_COMMON, CPSCU, DMAC0n, DMA0, DTC0, ICU, CPU_CTRL	0x4000_0000	0x4001_CFFF	3	2	3	2	ICLK	Renesas Memory Protection Unit, SRAM Control, BUS Control, Common Interrupt Controller, CPU System Security Control Unit, Direct memory access controller 0 n, DMAC Module Activation 0, Data Transfer Controller 0, Interrupt Controller, CPU Control Registers
CPU_OCD	0x4001_1004	0x4001_1FFF	7	2	7	2	ICLK	On-Chip Debug
CPU_DBG, FCACHE	0x4000_B000	0x4001_CFFF	3	2	3	2	ICLK	Debug Function, Flash Cache
SYSC	0x4001_E000	0x4001_E9FF	4	3	2 to 4	1 to 3	PCLKB	System Control
SYSC	0x4001_EA00	0x4001_ED7F	7	6	5 to 7	4 to 6	PCLKB	System Control
TSD	0x4011_B17C	0x4011_B17C	4	3	4	3	ICLK	Temperature Sensor Data
ELC, RTC	0x4020_1000	0x4020_21FF	4	3	2 to 4	1 to 3	PCLKB	Event Link Controller, Realtime Clock
IWDT	0x4020_2200	0x4020_22FF	4	65	2 to 4	63 to 65	PCLKB	Independent Watchdog Timer
CAC, WDT0, MSTP, PSCU, POEG	0x4020_2400	0x4021_2FFF	4	3	2 to 4	1 to 3	PCLKB	Clock Frequency Accuracy Measurement Circuit, Watchdog Timer 0, Module Stop Control, Peripheral Security Control Unit, Port Outupt Enable Module for GPT
ULPTn	0x4022_0000	0x4022_01FF	6	65	4 to 6	63 to 65	PCLKB	Ultra-Low Power Timer n
AGTn	0x4022_1000	0x4022_11FF	6	3	4 to 6	1 to 3	PCLKB	Low Power Asynchronous General purpose Timer n
TSN	0x4023_5000	0x4023_5FFF	4	3	2 to 4	1 to 3	PCLKB	Temperature Sensor
ACMPHSn	0x4023_6000	0x4023_61FF	3	3	1 to 3	1 to 3	PCLKB	High-Speed Analog Comparator n
USBFS	0x4025_0000	0x4025_03FF	5	4	3 to 5	2 to 4	PCLKB	USB 2.0 FS Module
USBFS	0x4025_0400	0x4025_04FF	4	65	2 to 4	63 to 65	PCLKB	USB 2.0 FS Module
SSIEn, IICn, OSPI0	0x4025_2000	0x4026_88FF	4	3	2 to 4	1 to 3	PCLKB	Serial Sound Interface Enhanced n, Inter-Integretad Circuit n, Octal Serial Peripheral Interface 0
CRC, DOC	0x4031_0000	0x4031_1FFF	4	3	2 to 4	1 to 3	PCLKA	CRC Calculator, Data Operation Circuit
GPT32n, GPT16n	0x4032_2000	0x4032_3FFF	7	4	5 to 7	2 to 4	PCLKA	General PWM 32-Bit Timer n, General PWM 16-Bit Timer n
ADC12n, DAC12n	0x4033_2000	0x4034_6FFF	4	3	2 to 4	1 to 3	PCLKA	12-bit A/D Converter n, 12-bit D/A Converter n
CEU	0x4034_8000	0x4034_FFFF	7	5	5 to 7	3 to 5	PCLKA	Capture Engine Unit
EDMAC0	0x4035_4000	0x4035_40FF	5	4	3 to 5	2 to 4	PCLKA	DMA Controller for the Ethernet Controller Channel 0
ETHERC0	0x4035_4100	0x4035_43FF	14	13	12 to 14	11 to 13	PCLKA	Ethernet Controller Channel 0
SCIn, SPIn	0x4035_8000	0x4035_FFFF	4	3	2 to 4	1 to 3	PCLKA	Serial Communication Interface n, Serial Peripheral Interface n
ECCMBn	0x4036_F200	0x4036_F3FF	5	4	3 to 5	2 to 4	PCLKA	Error correction circuit for MBRAMn
CANFDn	0x4038_0000	0x4038_3FFF	4	3	2 to 4	1 to 3	PCLKA	CANFD Module n

Table 3.2 Access cycles (2 of 3)

Peripheral base address symbol	Address*1		Number of access cycles				Cycle Unit	Related function
			ICLK = PCLK		ICLK > PCLK*2			
	From	To	Read	Write	Read	Write		
PORTn	0x4040_0000	0x4040_01FF	4	2	4	2	ICLK	Port n Control Registers
PFS	0x4040_0800	0x4040_0FFF	8	2	8	2	ICLK	Pmn Pin Function Control Register
RSIP-E51A	—	—	1 to 3	2	1 to 3	1 to 2	PCLKA	Renesas Security IP

Table 3.2 Access cycles (3 of 3)

Peripheral base address symbol	Address*1		Number of access cycles				Cycle Unit	Related function
			ICLK = FCLK		ICLK > FCLK*2			
	From	To	Read	Write	Read	Write		
FLAD, FACI	0x4011_C040	0x4011_EFFF	4	3	4	3	FCLK	Data Flash, Flash Application Command Interface

Note 1. This table only shows secure address. Access cycle of the non-secure address is the same as its secure address.
Note 2. If the number of PCLK or FCLK cycles is non-integer (for example 1.5), the minimum value is without the decimal point, and the maximum value is rounded up to the decimal point. For example, 1.5 to 2. 5 is 1 to 3.

Appendix 4. Note for Register R/W

- A secure bus master issues a "secure access" using an address marked as secure by IDAU/SAU or MSAU.
- A secure bus master issues a "non-secure access" using an address marked as non-secure by IDAU/SAU or MSAU.
- A non-secure bus master issues a "non-secure access" using an address marked as non-secure by IDAU/SAU or MSAU.

Table 4.1 Type of Register Notes(S-TYPE)

TYPE	UM Description
S-TYPE-1	Only Secure access can write to this register. Read access is always allowed. Non-secure write access is ignored, but TrustZone access error is not generated.
S-TYPE-2	Read access is always allowed If the security attribution is configured as Secure, ● Secure write access is allowed. ● Non-secure write access is ignored, but TrustZone access error is not generated.
	If the security attribution is configured as Non-secure, ● Secure write access is ignored, but TrustZone access error is not generated. ● Non-secure access is allowed.
S-TYPE-3	If the security attribution is configured as Secure, ● Secure access is allowed. ● Non-secure write access is ignored and Non-secure read access is read as 0, TrustZone access error is generated
	If the security attribution is configured as Non-secure, ● Secure write access is ignored and Secure read access is read as 0, TrustZone access error is generated. ● Non-secure access is allowed
S-TYPE-4	If the security attribution is configured as Secure, ● Secure access is allowed ● Non-secure write access is ignored and Non-secure read access is read as 0, but TrustZone access error is not generated.
	If the security attribution is configured as Non-secure, ● Secure write access is ignored and Secure read access is read as 0, but TrustZone access error is not generated. ● Non-secure access is allowed.
S-TYPE-5	No note required.
S-TYPE-6	Secure access is allowed. Non-secure write access is ignored, and Non-secure read access is read as 0, TrustZone access error is generated.
S-TYPE-7	Secure write access is ignored, and Secure read access is read as 0, TrustZone access error is generated. Non-secure access is allowed.

Note: A non-secure bus master does NOT issue any access using an address marked as secure by IDAU/SAU or MSAU.

Table 4.2 Type of Register Notes(P-TYPE)

TYPE	UM Description
P-TYPE-1	Privileged write access is allowed. Read access is always allowed. Unprivileged write access is ignored, but TrustZone access error is not generated.
P-TYPE-2	Privileged access is allowed. Unprivileged write access is ignored, and Unprivileged read access is read as 0, TrustZone access error is generated.
P-TYPE-3	If the privilege attribution is configured as Privileged, ● Privileged access is allowed. ● Unprivileged write access is ignored and Unprivileged read access is read as 0, TrustZone access error is generated.
	If the privilege attribution is configured as Unprivilege, ● Privileged access and Unprivileged access are allowed.
P-TYPE-4	If the privilege attribution is configured as Privileged, ● Privileged access is allowed. ● Unprivileged write access is ignored and Unprivileged read access is read as 0, TrustZone access error is not generated.
	If the privilege attribution is configured as Unprivilege, ● Privileged access and Unprivileged access are allowed.
P-TYPE-5	No note required.

Revision History

Revision 1.00 — October 23, 2024

Initial release

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)
   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on
   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state
   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins
   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals
   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin
   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses
   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products
   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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