

Ultra low power 32-MHz Arm® Cortex®-M0+ core, up to 256-KB code flash memory, 24-KB SRAM, Digital Addressable Lighting Interface, Capacitive Touch Sensing Unit, 14-bit A/D Converter, 8-bit D/A Converter, security and safety features.

Features

■ Arm Cortex-M0+ Core

- Arm®v6-M architecture
- Maximum operating frequency: 32 MHz
- Arm® Memory Protection Unit (Arm MPU) with 8 regions
- Debug and Trace: DWT, BPU, CoreSight™ MTB-M0+
- CoreSight Debug Port: SW-DP

■ Memory

- Up to 256-KB code flash memory
- 4-KB data flash memory (100,000 erase/write cycles)
- Up to 24-KB SRAM
- Memory protection units
- 128-bit unique ID

■ Connectivity

- USB 2.0 Full-Speed (USBFS) module
 - On-chip transceiver with voltage regulator
 - Compliant with USB Battery Charging Specification 1.2
- Serial Communications Interface (SCI) × 3
 - UART
 - Simple IIC
 - Simple SPI
- Serial Peripheral Interface (SPI) × 2
- I²C bus interface (IIC) × 2
- Controller Area Network (CAN) module
- Digital Addressable Lighting Interface (DALI)

■ Analog

- 14-bit A/D Converter (ADC14)
- 8-bit D/A Converter (DAC8) × 3
- High-Speed Analog Comparator (ACMPHS) × 3
- Low-Power Analog Comparator (ACMPLP) × 2
- Operational Amplifier (OPAMP) × 4
- Temperature Sensor (TSN)

■ Timers

- General PWM Timer 32-bit (GPT32)
- General PWM Timer 16-bit High Resolution (GPT16H) × 3
- General PWM Timer 16-bit (GPT16) × 3
- Low Power Asynchronous General-Purpose Timer (AGT) × 2
- Watchdog Timer (WDT)

■ Safety

- Error Correction Code (ECC) in SRAM
- SRAM parity error check
- Flash area protection
- ADC self-diagnosis function
- Clock Frequency Accuracy Measurement Circuit (CAC)
- Cyclic Redundancy Check (CRC) calculator
- Data Operation Circuit (DOC)
- Port Output Enable for GPT (POEG)
- Independent Watchdog Timer (IWDT)
- GPIO readback level detection
- Register write protection
- Main oscillator stop detection
- Illegal memory access

■ System and Power Management

- Low power modes
- Realtime clock (RTC)
- Event Link Controller (ELC)
- Data Transfer Controller (DTC)
- Key Interrupt Function (KINT)
- Power-on reset
- Low Voltage Detection (LVD) with voltage settings

■ Security and Encryption

- AES128/256
- True Random Number Generator (TRNG)

■ Human Machine Interface (HMI)

- Capacitive Touch Sensing Unit (CTSUs)

■ Multiple Clock Sources

- Main clock oscillator (MOSC)
 - (1 to 20 MHz when VCC = 2.4 to 5.5 V)
 - (1 to 8 MHz when VCC = 1.8 to 5.5 V)
 - (1 to 4 MHz when VCC = 1.6 to 5.5 V)
- Sub-clock oscillator (SOSC) (32.768 kHz)
- High-speed on-chip oscillator (HOCO)
 - (24, 32, 48, 64 MHz when VCC = 2.4 to 5.5 V)
 - (24, 32, 48 MHz when VCC = 1.8 to 5.5 V)
 - (24, 32 MHz when VCC = 1.6 to 5.5 V)
- Middle-speed on-chip oscillator (MOCO) (8 MHz)
- Low-speed on-chip oscillator (LOCO) (32.768 kHz)
- IWDT-dedicated on-chip oscillator (15 kHz)
- Clock trim function for HOCO/MOCO/LOCO
- Clock out support

■ General Purpose I/O Ports

- Up to 53 input/output pins
 - Up to 3 CMOS input
 - Up to 50 CMOS input/output
 - Up to 5V tolerant input/output
 - Up to 2 high current (20 mA)

■ Operating Voltage

- VCC: 1.6 to 5.5 V

■ Operating Temperature and Packages

- Ta = -40°C to +85°C
 - 36-pin LGA (4 mm × 4 mm, 0.5 mm pitch)
- Ta = -40°C to +105°C
 - 64-pin LQFP (10 mm × 10 mm, 0.5 mm pitch)
 - 48-pin LQFP (7 mm × 7 mm, 0.5 mm pitch)
 - 32-pin LQFP (7 mm × 7 mm, 0.8 mm pitch)
 - 48-pin QFN (7 mm × 7 mm, 0.5 mm pitch)
 - 32-pin QFN (5 mm × 5 mm, 0.5 mm pitch)

1. Overview

The MCU integrates multiple series of software- and pin-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 an energy-efficient Arm Cortex[®]-M0+ 32-bit core that is particularly well suited for cost-sensitive and low-power applications, with the following features:

- Up to 256 KB code flash memory
- 24-KB SRAM
- Capacitive Touch Sensing Unit (CTSU)
- 14-bit A/D Converter (ADC14)
- 8-bit D/A Converter (DAC8)
- Security features.

1.1 Function Outline

Table 1.1 Arm core

| Feature | Functional description |
|---------------------|--|
| Arm Cortex-M0+ core | <ul style="list-style-type: none"> • Maximum operating frequency: up to 32 MHz • Arm Cortex-M0+ core: <ul style="list-style-type: none"> - Revision: r0p1-00rel0 - Armv6-M architecture profile - Single-cycle integer multiplier. • Arm Memory Protection Unit (Arm MPU) <ul style="list-style-type: none"> - Armv6 Protected Memory System Architecture - 8 protect regions. • SysTick timer <ul style="list-style-type: none"> - Driven by SYSTICCLK (LOCO) or ICLK. |

Table 1.2 Memory

| Feature | Functional description |
|-----------------------|---|
| Code flash memory | Maximum 256 KB of code flash memory. See section 42, Flash Memory in User's Manual. |
| Data flash memory | 4 KB of data flash memory. See section 42, Flash Memory in User's Manual. |
| Option-setting memory | The option-setting memory determines the state of the MCU after a reset. See section 6, Option-Setting Memory in User's Manual. |
| SRAM | On-chip high-speed SRAM with either parity bit or Error Correction Code (ECC). See section 41, SRAM in User's Manual. |

Table 1.3 System (1 of 2)

| Feature | Functional description |
|----------------|--|
| Operating mode | Two operating modes: <ul style="list-style-type: none"> • Single-chip mode • SCI boot mode. See section 3, Operating Modes in User's Manual. |

Table 1.3 System (2 of 2)

| Feature | Functional description |
|--|--|
| Resets | <p>13 resets:</p> <ul style="list-style-type: none"> • RES pin reset • Power-on reset • Independent watchdog timer reset • Watchdog timer reset • Voltage monitor 0 reset • Voltage monitor 1 reset • Voltage monitor 2 reset • SRAM parity error reset • SRAM ECC error reset • Bus master MPU error reset • Bus slave MPU error reset • CPU stack pointer error reset • Software reset. <p>See section 5, Resets in User's Manual.</p> |
| Low Voltage Detection (LVD) | <p>The Low Voltage Detection (LVD) monitors the voltage level input to the VCC pin, and the detection level can be selected using a software program. See section 7, Low Voltage Detection (LVD) in User's Manual.</p> |
| Clock | <ul style="list-style-type: none"> • 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) • IWDT-dedicated on-chip oscillator • Clock out support. <p>See section 8, Clock Generation Circuit in User's Manual.</p> |
| Clock Frequency Accuracy Measurement Circuit (CAC) | <p>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 to be used as a measurement reference (measurement reference clock), and determines the accuracy depending on whether the number of pulses is within the allowable range.</p> <p>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.</p> <p>See section 9, Clock Frequency Accuracy Measurement Circuit (CAC) in User's Manual.</p> |
| Interrupt Controller Unit (ICU) | <p>The Interrupt Controller Unit (ICU) controls which event signals are linked to the NVIC/DTC module. The ICU also controls NMI interrupts. See section 12, Interrupt Controller Unit (ICU) in User's Manual.</p> |
| Key Interrupt Function (KINT) | <p>A key interrupt can be generated by setting the Key Return Mode Register (KRM) and inputting a rising or falling edge to the key interrupt input pins. See section 18, Key Interrupt Function (KINT) in User's Manual.</p> |
| Low Power Mode | <p>Power consumption can be reduced in multiple ways, such as by setting clock dividers, stopping modules, selecting power control mode in normal operation, and transitioning to low power modes. See section 10, Low Power Modes in User's Manual.</p> |
| Register Write Protection | <p>The register write protection function protects important registers from being overwritten because of software errors. See section 11, Register Write Protection in User's Manual.</p> |
| Memory Protection Unit (MPU) | <p>Four Memory Protection Units (MPUs) and a CPU stack pointer monitor function are provided for memory protection. See section 14, Memory Protection Unit (MPU) in User's Manual.</p> |
| Watchdog Timer (WDT) | <p>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, a non-maskable interrupt or interrupt can be generated by an underflow. The refresh-permitted period can be set to refresh the counter and used as the condition for detecting when the system runs out of control. See section 24, Watchdog Timer (WDT) in User's Manual.</p> |
| Independent Watchdog Timer (IWDT) | <p>The Independent Watchdog Timer (IWDT) consists of a 14-bit down-counter that must be serviced periodically to prevent counter underflow. The IWDT provides functionality to reset the MCU or to generate a non-maskable interrupt/interrupt for a timer underflow. Because the timer operates with an independent, dedicated clock source, it is particularly useful in returning the MCU to a known state as a fail safe mechanism when the system runs out of control. The IWDT can be triggered automatically on a reset, underflow, refresh error, or by a refresh of the count value in the registers. See section 25, Independent Watchdog Timer (IWDT) in User's Manual.</p> |

Table 1.4 Event Link

| Feature | Functional description |
|-----------------------------|--|
| Event Link Controller (ELC) | The Event Link Controller (ELC) uses the interrupt requests generated by various peripheral modules as event signals to connect them to different modules, enabling direct interaction between the modules without CPU intervention. See section 16, Event Link Controller (ELC) in User's Manual. |

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. See section 15, Data Transfer Controller (DTC) in User's Manual. |

Table 1.6 Timers

| Feature | Functional description |
|--|---|
| General PWM Timer (GPT) | The General PWM Timer (GPT) is a 32-bit timer with one channel and a 16-bit timer with six channels. PWM waveforms can be generated by controlling the up-counter, down-counter, or the up- and down-counter. In addition, PWM waveforms can be generated for controlling brushless DC motors. The GPT can also be used as a general-purpose timer. See section 20, General PWM Timer (GPT) in User's Manual. |
| Port Output Enable for GPT (POEG) | Use the Port Output Enable for GPT (POEG) function to place the General PWM Timer (GPT) output pins in the output disable state. See section 19, Port Output Enable for GPT (POEG) in User's Manual. |
| 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 16-bit timer consists of a reload register and a down-counter. The reload register and the down-counter are allocated to the same address, and they can be accessed with the AGT register. See section 22, Low Power Asynchronous General Purpose Timer (AGT) in User's Manual. |
| Realtime Clock (RTC) | The Realtime Clock (RTC) has two counting modes, calendar count mode and binary count mode, that are controlled by the 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. See section 23, Realtime Clock (RTC) in User's Manual. |

Table 1.7 Communication interfaces (1 of 2)

| Feature | Functional description |
|---|--|
| Serial Communications Interface (SCI) | The Serial Communication Interface (SCI) is configurable to five asynchronous and synchronous serial interfaces: <ul style="list-style-type: none"> Asynchronous interfaces (UART and asynchronous communications interface adapter (ACIA)) 8-bit clock synchronous interface Simple IIC (master-only) Simple SPI Smart card interface. The smart card interface complies with the ISO/IEC 7816-3 standard for electronic signals and transmission protocol. SCI0 has 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. See section 27, Serial Communications Interface (SCI) in User's Manual. |
| Digital Addressable Lighting Interface (DALI) | A Digital Addressable Lighting Interface (DALI) module is provided. DALI is an international open lighting control communication protocol that includes dimming control of electronic ballasts and LED lights from different manufacturers. The DALI interface module is designed to allow compliance with international standard IEC62386-101 Edition 1.0/2.0 (DALI 2), that includes software control. See section 28, Digital Addressable Lighting Interface (DALI) in User's Manual. |

Table 1.7 Communication interfaces (2 of 2)

| Feature | Functional description |
|--------------------------------------|---|
| I ² C bus interface (IIC) | The 2-channel I ² C bus interface (IIC) conforms with and provides a subset of the NXP I ² C (Inter-Integrated Circuit) bus interface functions. See section 29, I ² C Bus Interface (IIC) in User's Manual. |
| Serial Peripheral Interface (SPI) | Two independent Serial Peripheral Interface (SPI) channels are capable of high-speed, full-duplex synchronous serial communications with multiple processors and peripheral devices. See section 31, Serial Peripheral Interface (SPI) in User's Manual. |
| Control Area Network (CAN) module | The Controller Area Network (CAN) module provides functionality to receive and transmit data using a message-based protocol between multiple slaves and masters in electromagnetically noisy applications. The CAN module complies with the ISO 11898-1 (CAN 2.0A/CAN 2.0B) standard and supports up to 32 mailboxes, which can be configured for transmission or reception in normal mailbox and FIFO modes. Both standard (11-bit) and extended (29-bit) messaging formats are supported. See section 30, Controller Area Network (CAN) Module in User's Manual. |
| USB 2.0 Full-Speed (USBFS) module | The USB 2.0 Full-Speed (USBFS) module is a USB controller that can operate as a device controller. The module supports full-speed and low-speed transfer as defined in the Universal Serial Bus Specification 2.0. The module has an internal USB transceiver and supports all of the transfer types defined in the Universal Serial Bus Specification 2.0. The USB has buffer memory for data transfer, providing a maximum of 5 pipes. Pipe 0 and pipe 4 to pipe 7 can be assigned any endpoint number based on the peripheral devices used for communication or based on the user system. The MCU supports Battery Charging Specification revision 1.2. Because the MCU can be powered at 5 V, the USB LDO regulator provides the internal USB transceiver power supply 3.3 V. See section 26, USB 2.0 Full-Speed Module (USBFS) in User's Manual. |

Table 1.8 Analog

| Feature | Functional description |
|---------------------------------------|---|
| 14-bit A/D Converter (ADC14) | A 14-bit successive approximation A/D converter is provided. Up to 21 analog input channels are selectable. Temperature sensor output and internal reference voltage are selectable for conversion. The A/D conversion accuracy is selectable from 12-bit and 14-bit conversion making it possible to optimize the tradeoff between speed and resolution in generating a digital value. See section 33, 14-Bit A/D Converter (ADC14) in User's Manual. |
| 8-bit D/A Converter (DAC8) | An 8-bit D/A converter (DAC8) is provided. See section 34, 8-Bit D/A Converter (DAC8) in User's Manual. |
| Temperature Sensor (TSN) | The on-chip temperature sensor 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 linear. The output voltage is provided to the ADC14 for conversion and can be further used by the end application. See section 35, Temperature Sensor (TSN) in User's Manual. |
| High-Speed Analog Comparator (ACMPHS) | The analog comparator compares a test voltage with a reference voltage and to provide a digital output based on the result of conversion. Both the test voltage and the reference voltage can be provided to the ACMPHS from internal sources (D/A converter output) 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. See section 37, High-Speed Analog Comparator (ACMPHS) in User's Manual. |
| Low-Power Analog Comparator (ACMPLP) | The analog comparator compares a reference input voltage and analog input voltage. The comparison result can be read by software and also be output externally. The reference input voltage can be selected from either an input to the CMPREFi (i = 0, 1) pin, an output from internal D/A converter, or from the internal reference voltage (Vref) generated internally in the MCU. The ACMPLP response speed can be set before starting an operation. Setting high-speed mode decreases the response delay time, but increases current consumption. Setting low-speed mode increases the response delay time, but decreases current consumption. See section 38, Low-Power Analog Comparator (ACMPLP) in User's Manual. |
| Operational Amplifier (OPAMP) | The operational amplifier amplifies small analog input voltages and outputs the amplified voltages. A total of four differential operational amplifier units with two input pins and one output pin are provided. See section 36, Operational Amplifier (OPAMP) in User's Manual. |

Table 1.9 Human machine interfaces

| Feature | Functional description |
|---------------------------------------|--|
| Capacitive Touch Sensing Unit (CTSUS) | The Capacitive Touch Sensing Unit (CTSUS) measures the electrostatic capacitance of the touch sensor. Changes in the electrostatic capacitance are determined by software, which enables the CTSUS to detect whether a finger is in contact with the touch sensor. The electrode surface of the touch sensor is usually enclosed with an electrical insulator so that a finger does not come into direct contact with the electrode. See section 39, Capacitive Touch Sensing Unit (CTSUS) in User's Manual. |

Table 1.10 Data processing

| Feature | Functional description |
|--|---|
| Cyclic Redundancy Check (CRC) Calculator | The 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. See section 32, Cyclic Redundancy Check (CRC) Calculator in User's Manual. |
| Data Operation Circuit (DOC) | The Data Operation Circuit (DOC) compares, adds, and subtracts 16-bit data. See section 40, Data Operation Circuit (DOC) in User's Manual. |

Table 1.11 Security

| Feature | Functional description |
|-------------------------------------|---|
| AES | See section 43, AES Engine in User's Manual. |
| True Random Number Generator (TRNG) | See section 44, True Random Number Generator (TRNG) in User's Manual. |

Table 1.12 I/O ports

| Feature | Functional description |
|-----------|---|
| I/O ports | <ul style="list-style-type: none"> • I/O ports for the 64-pin LQFP, 64-pin QFN <ul style="list-style-type: none"> - I/O pins: 50 - Input pins: 3 - Pull-up resistors: 48 - N-ch open-drain outputs: 19 - 5-V tolerance: 5 • I/O ports for the 48-pin LQFP, 48-pin QFN <ul style="list-style-type: none"> - I/O pins: 34 - Input pins: 3 - Pull-up resistors: 32 - N-ch open-drain outputs: 14 - 5-V tolerance: 4 • I/O ports for the 36-pin LGA <ul style="list-style-type: none"> - I/O pins: 25 - Input pins: 3 - Pull-up resistors: 23 - N-ch open-drain outputs: 8 - 5-V tolerance: 1 • I/O ports for the 32-pin LQFP, 32-pin QFN <ul style="list-style-type: none"> - I/O pins: 21 - Input pins: 3 - Pull-up resistors: 19 - N-ch open-drain outputs: 8 - 5-V tolerance: 1 |

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.

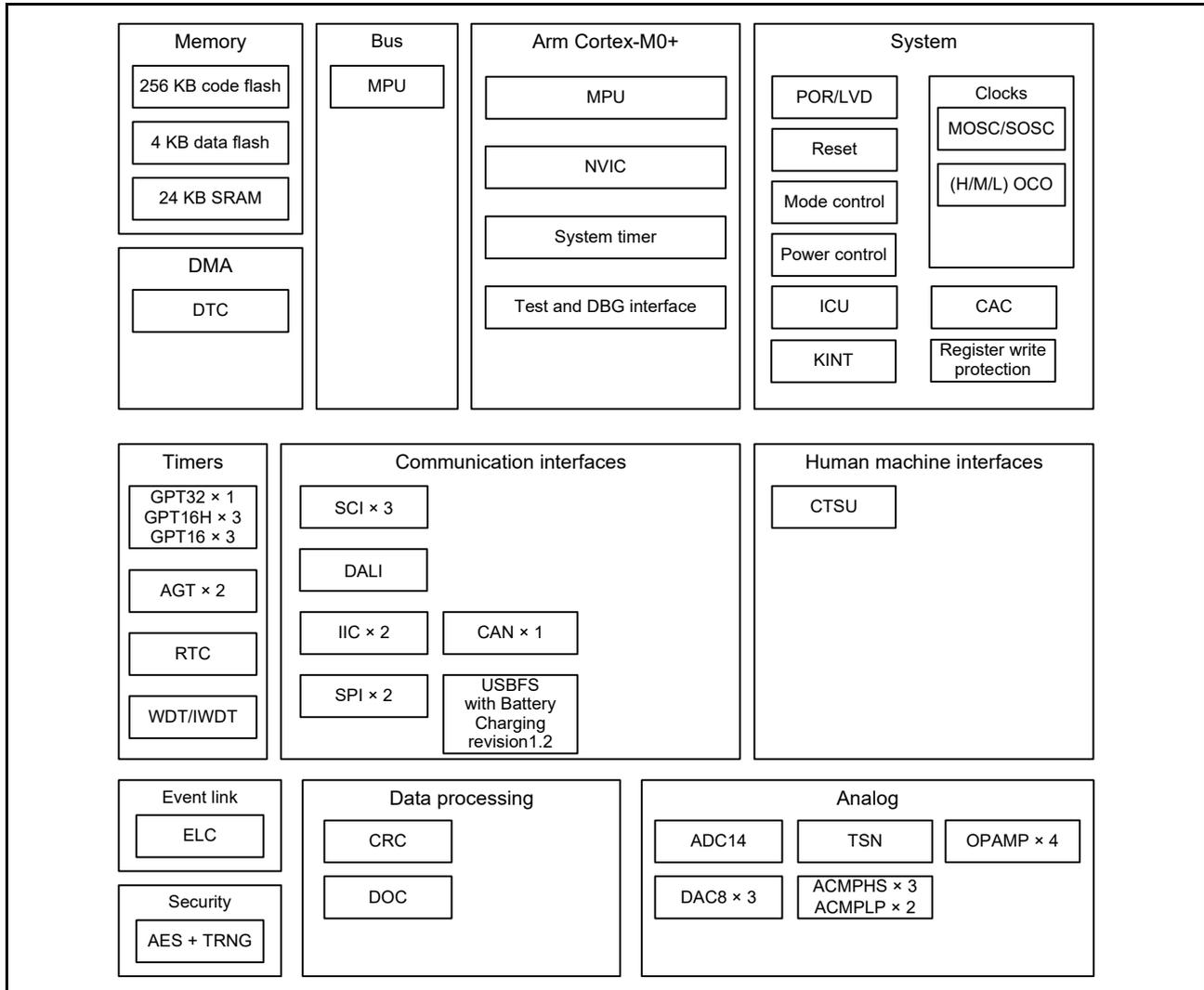


Figure 1.1 Block diagram

1.3 Part Numbering

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

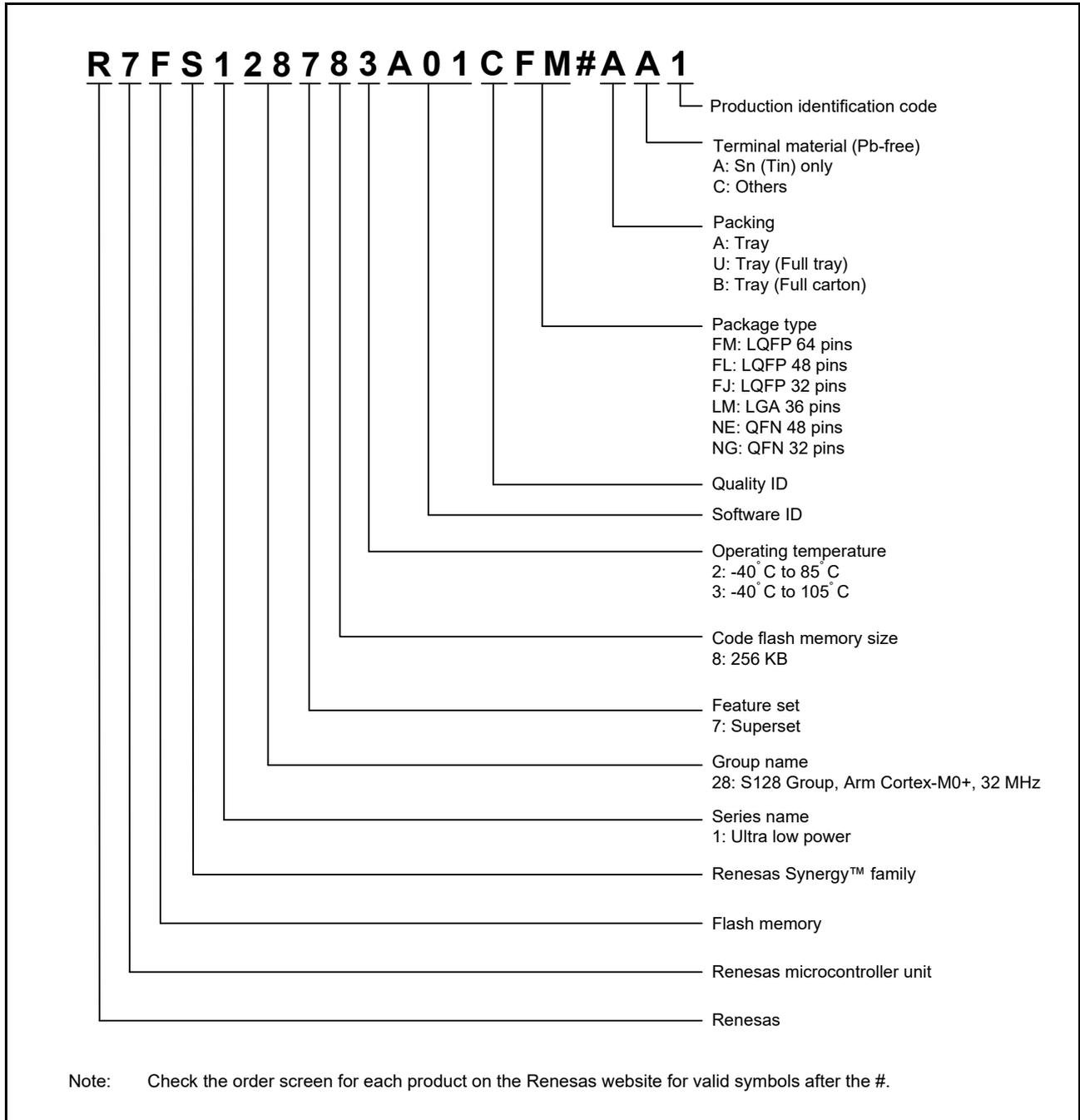


Figure 1.2 Part numbering scheme

Table 1.13 Product list

| Product part number | Package code | Code flash | Data flash | SRAM | Operating temperature |
|---------------------|--------------|------------|------------|-------|-----------------------|
| R7FS128783A01CFM | PLQP0064KB-C | 256 KB | 4 KB | 24 KB | -40 to +105°C |
| R7FS128783A01CFL | PLQP0048KB-B | | | | -40 to +105°C |
| R7FS128783A01CNE | PWQN0048KB-A | | | | -40 to +105°C |
| | PWQN0048KC-A | | | | |
| R7FS128782A01CLM | PWLG0036KA-A | | | | -40 to +85°C |
| R7FS128783A01CFJ | PLQP0032GB-A | | | | -40 to +105°C |
| R7FS128783A01CNG | PWQN0032KB-A | | | | -40 to +105°C |
| | PWQN0032KF-A | | | | |

1.4 Function Comparison

Table 1.14 Function comparison

| Parts number | R7FS128783A01CFM | R7FS128783A01CFL R7FS128783A01CNE | R7FS128782A01CLM | R7FS128783A01CFJ R7FS128783A01CNG | |
|-------------------|-------------------------|--------------------------------------|------------------|--------------------------------------|----|
| Pin count | 64 | 48 | 36 | 32 | |
| Package | LQFP | LQFP/QFN | LGA | LQFP/QFN | |
| Code flash memory | 256 KB | | | | |
| Data flash memory | 4 KB | | | | |
| SRAM | 24 KB | | | | |
| | Parity | 8 KB | | | |
| | ECC | 16 KB | | | |
| System | CPU clock | 32 MHz | | | |
| | ICU | Yes | | | |
| | KINT | 8 | 5 | 4 | 4 |
| Event control | ELC | Yes | | | |
| DMA | DTC | Yes | | | |
| Timers | GPT32 | 1 | | | |
| | GPT16H | 3 | 3 | 3 | 2 |
| | GPT16 | 3 | 3 | 1 | 1 |
| | AGT | 2 | | | |
| | RTC | Yes | | | |
| | WDT/IWDT | Yes | | | |
| Communication | SCI | 3 | | | |
| | DALI | Yes | | | |
| | IIC | 2 | 2 | 1 | 1 |
| | SPI | 2 | 2 | 2 | 1 |
| | CAN | Yes | | | |
| | USBFS | Yes | | | |
| Analog | ADC14 | 21 | 15 | 13 | 10 |
| | DAC8 | 3 | | | |
| | ACMPHS | 3 | | | |
| | ACMPLP | 2 | | | |
| | OPAMP | 4 | 3 | 3 | 2 |
| | TSN | Yes | | | |
| HMI | CTSU | 28 | 21 | 12 | 9 |
| Data processing | CRC | Yes | | | |
| | DOC | Yes | | | |
| Security | AES and TRNG | | | | |
| I/O ports | I/O pins | 50 | 34 | 25 | 21 |
| | Input pins | 3 | | | |
| | Pull-up resistors | 48 | 32 | 23 | 19 |
| | N-ch open-drain outputs | 19 | 14 | 8 | 8 |
| | 5-V tolerance | 5 | 4 | 1 | 1 |

1.5 Pin Functions

Table 1.15 Pin functions (1 of 3)

| Function | Signal | I/O | Description |
|------------------------|--|----------------|--|
| Power supply | VCC | Input | Power supply pin. Connect it to the system power supply. Connect this pin to VSS by a 0.1- μ F capacitor. The capacitor should be placed close to the pin. |
| | VCL | I/O | 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. |
| | VSS | 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 | |
| | CLKOUT | Output | |
| Operating mode control | MD | Input | Pins for setting the operating mode. The signal levels on these pins must not be changed during operation mode transition at the time of 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 debug | SWDIO | I/O | Serial wire debug data input/output pin |
| | SWCLK | Input | Serial wire clock pin |
| Interrupt | NMI | Input | Non-maskable interrupt request pin |
| | IRQ0 to IRQ7 | Input | Maskable interrupt request pins |
| GPT | GTETRGA, GTETRGB | Input | External trigger input pin |
| | GTIOC0A to GTIOC6A, GTIOC0B to GTIOC6B | I/O | Input capture, output compare, or PWM output pin |
| | GTIU | Input | Hall sensor input pin U |
| | GTIV | Input | Hall sensor input pin V |
| | GTIW | Input | Hall sensor input pin W |
| | GTOUUP | Output | 3-phase PWM output for BLDC motor control (positive U phase) |
| | GTOULO | Output | 3-phase PWM output for BLDC motor control (negative U phase) |
| | GTOVUP | Output | 3-phase PWM output for BLDC motor control (positive V phase) |
| | GTOVLO | Output | 3-phase PWM output for BLDC motor control (negative V phase) |
| | GTOUWP | Output | 3-phase PWM output for BLDC motor control (positive W phase) |
| | GTOWLO | Output | 3-phase PWM output for BLDC motor control (negative W phase) |
| | AGT | AGTEE0, AGTEE1 | Input |
| AGTIO0, AGTIO1 | | I/O | External event input and pulse output |
| AGTO0, AGTO1 | | Output | Pulse output |
| AGTOA0, AGTOA1 | | Output | Output compare match A output |
| AGTOB0, AGTOB1 | | Output | Output compare match B output |
| RTC | RTCOUT | Output | Output pin for 1-Hz/64-Hz clock |

Table 1.15 Pin functions (2 of 3)

| Function | Signal | I/O | Description |
|---------------------|---------------------------------|--------|---|
| SCI | SCK0, SCK1, SCK9 | I/O | Input/output pins for the clock (clock synchronous mode) |
| | RXD0, RXD1, RXD9 | Input | Input pins for received data (asynchronous mode/clock synchronous mode) |
| | TXD0, TXD1, TXD9 | Output | Output pins for transmitted data (asynchronous mode/clock synchronous mode) |
| | CTS0_RTS0, CTS1_RTS1, CTS9_RTS9 | I/O | Input/output pins for controlling the start of transmission and reception (asynchronous mode/clock synchronous mode), active-low |
| | SCL0, SCL1, SCL9 | I/O | Input/output pins for the IIC clock (simple IIC) |
| | SDA0, SDA1, SDA9 | I/O | Input/output pins for the IIC data (simple IIC) |
| | SCK0, SCK1, SCK9 | I/O | Input/output pins for the clock (simple SPI) |
| | MISO0, MISO1, MISO9 | I/O | Input/output pins for slave transmission of data (simple SPI) |
| | MOSI0, MOSI1, MOSI9 | I/O | Input/output pins for master transmission of data (simple SPI) |
| DALI | SS0, SS1, SS9 | Input | Chip-select input pins (simple SPI), active-low |
| | DRX0 | Input | Input pin for DALI received data |
| IIC | DTX0 | Output | Output pin for DALI transmitted data |
| | SCL0, SCL1 | I/O | Input/output pins for clock |
| SPI | SDA0, SDA1 | I/O | Input/output pins for data |
| | RSPCKA, RSPCKB | I/O | Clock input/output pin |
| | MOSIA, MOSIB | I/O | Inputs or outputs data output from the master |
| | MISOA, MISOB | I/O | Inputs or outputs data output from the slave |
| | SSLA0, SSLB0 | I/O | Input or output pin for slave selection |
| | SSLA1 to SSLA3, SSLB1 to SSLB3 | Output | Output pin for slave selection |
| CAN | CRX0 | Input | Receive data |
| | CTX0 | Output | Transmit data |
| USBFS | VSS_USB | Input | Ground pins |
| | VCC_USB_LDO | Input | Power supply pin for USB LDO regulator |
| | VCC_USB | I/O | Input: Power supply pin for USB transceiver. Output: USB LDO regulator output pin. This pin should be connected to an external capacitor. |
| | USB_DP | I/O | D+ I/O pin of the USB on-chip transceiver. This pin should be connected to the D+ pin of the USB bus. |
| | USB_DM | I/O | D- I/O pin of the USB on-chip transceiver. This pin should be connected to the D- pin of the USB bus. |
| | USB_VBUS | Input | USB cable connection monitor pin. This pin should be connected to VBUS of the USB bus. The VBUS pin status (connected or disconnected) can be detected when the USB module is operating as a device controller. |
| Analog power supply | AVCC0 | Input | Analog block power supply pin |
| | AVSS0 | Input | Analog block power supply ground pin |
| | VREFH0 | Input | Reference power supply pin |
| | VREFL0 | Input | Reference power supply ground pin |

Table 1.15 Pin functions (3 of 3)

| Function | Signal | I/O | Description |
|-------------------|-----------------------------------|-----------------------------------|---|
| ADC14 | AN000 to AN013, AN016 to AN022 | Input | Input pins for the analog signals to be processed by the A/D converter |
| | ADTRG0 | Input | Input pins for the external trigger signals that start the A/D conversion, active-low |
| DAC8 | DA0 to DA2 | Output | Output pins for the analog signals to be processed by the D/A converter |
| Comparator output | VCOOUT | Output | Comparator output pin |
| ACMPHS | IVREF0 to IVREF2 | Input | Reference voltage input pin |
| | IVCMP0 to IVCMP2 | Input | Analog voltage input pin |
| ACMPLP | CMPREF0, CMPREF1 | Input | Reference voltage input pins |
| | CMPIN0, CMPIN1 | Input | Analog voltage input pins |
| OPAMP | AMP0+ to AMP3+ | Input | Analog voltage input pins |
| | AMP0- to AMP3- | Input | Analog voltage input pins |
| | AMP00 to AMP30 | Output | Analog voltage output pins |
| CTSU | TS00 to TS22, TS25 to TS29 | Input | Capacitive touch detection pins (touch pins) |
| | TSCAP | - | Secondary power supply pin for the touch driver |
| KINT | KR00 to KR07 | Input | Key interrupt input pins |
| I/O ports | P000 to P004, P010 to P015 | I/O | General-purpose input/output pins |
| | P100 to P113 | I/O | General-purpose input/output pins |
| | P200 | Input | General-purpose input pin |
| | P201, P204 to P206, P212, P213 | I/O | General-purpose input/output pins |
| | P214, P215 | Input | General-purpose input pins |
| | P300 to P304 | I/O | General-purpose input/output pins |
| | P400 to P403, P407 to P411 | I/O | General-purpose input/output pins |
| | P500 to P502 | I/O | General-purpose input/output pins |
| P914, P915 | I/O | General-purpose input/output pins | |

1.6 Pin Assignments

Figure 1.3 to Figure 1.8 show the pin assignments.

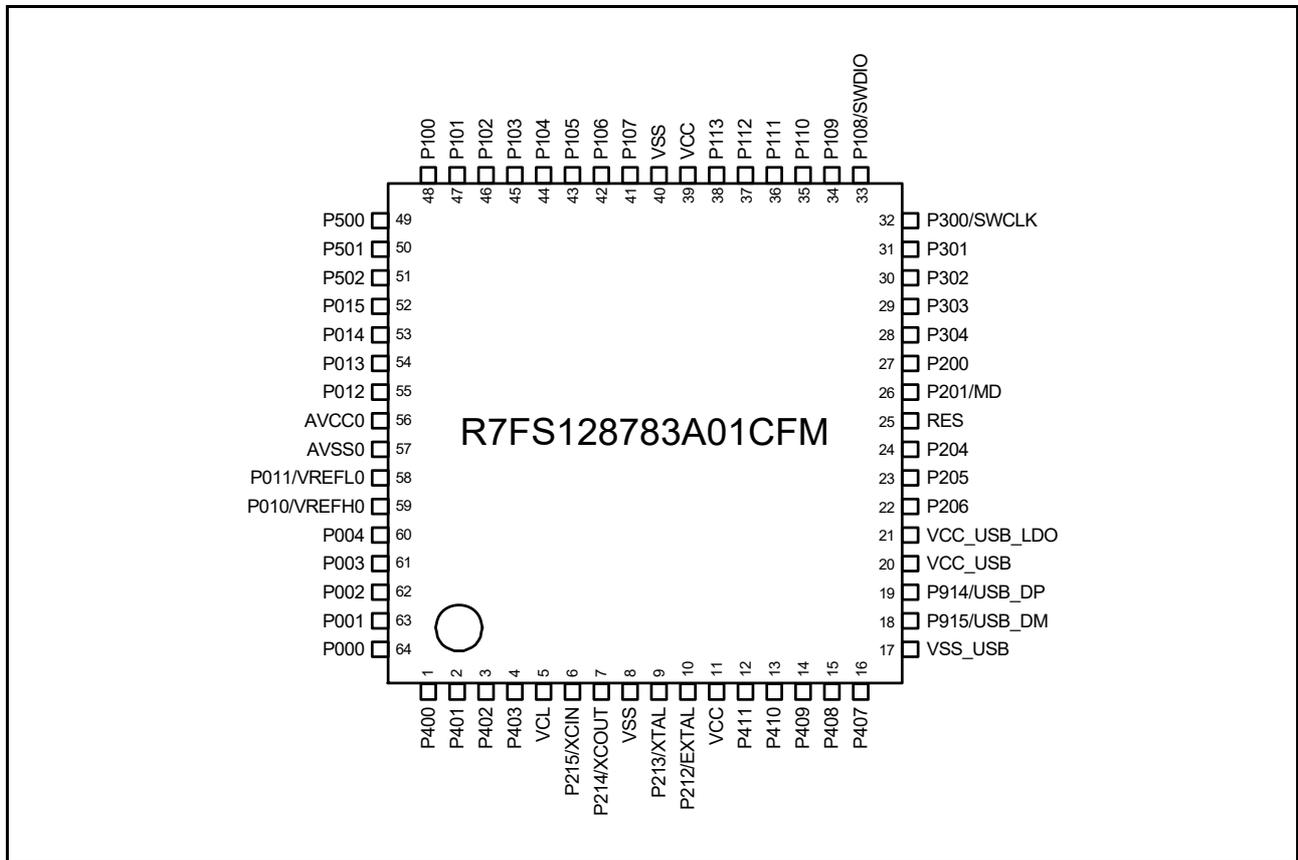


Figure 1.3 Pin assignment for LQFP 64-pin

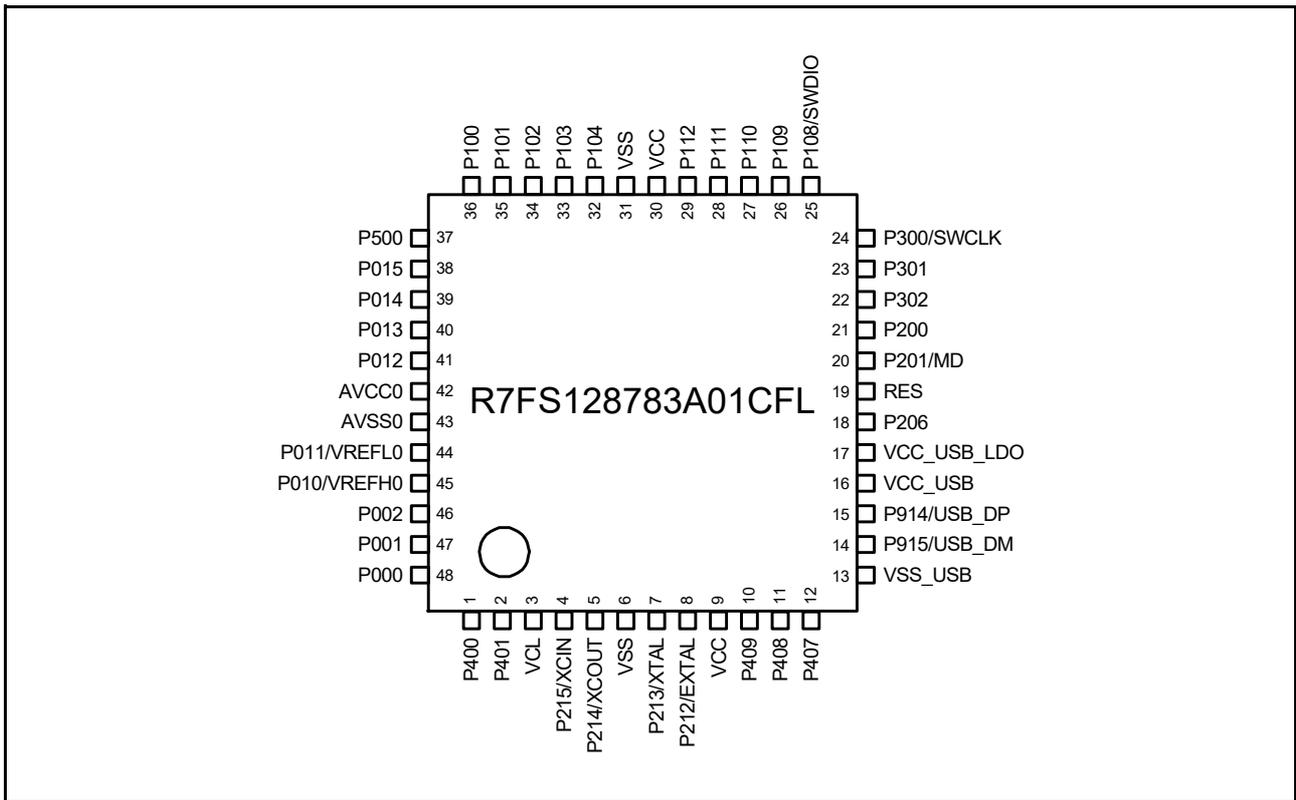


Figure 1.4 Pin assignment for LQFP 48-pin

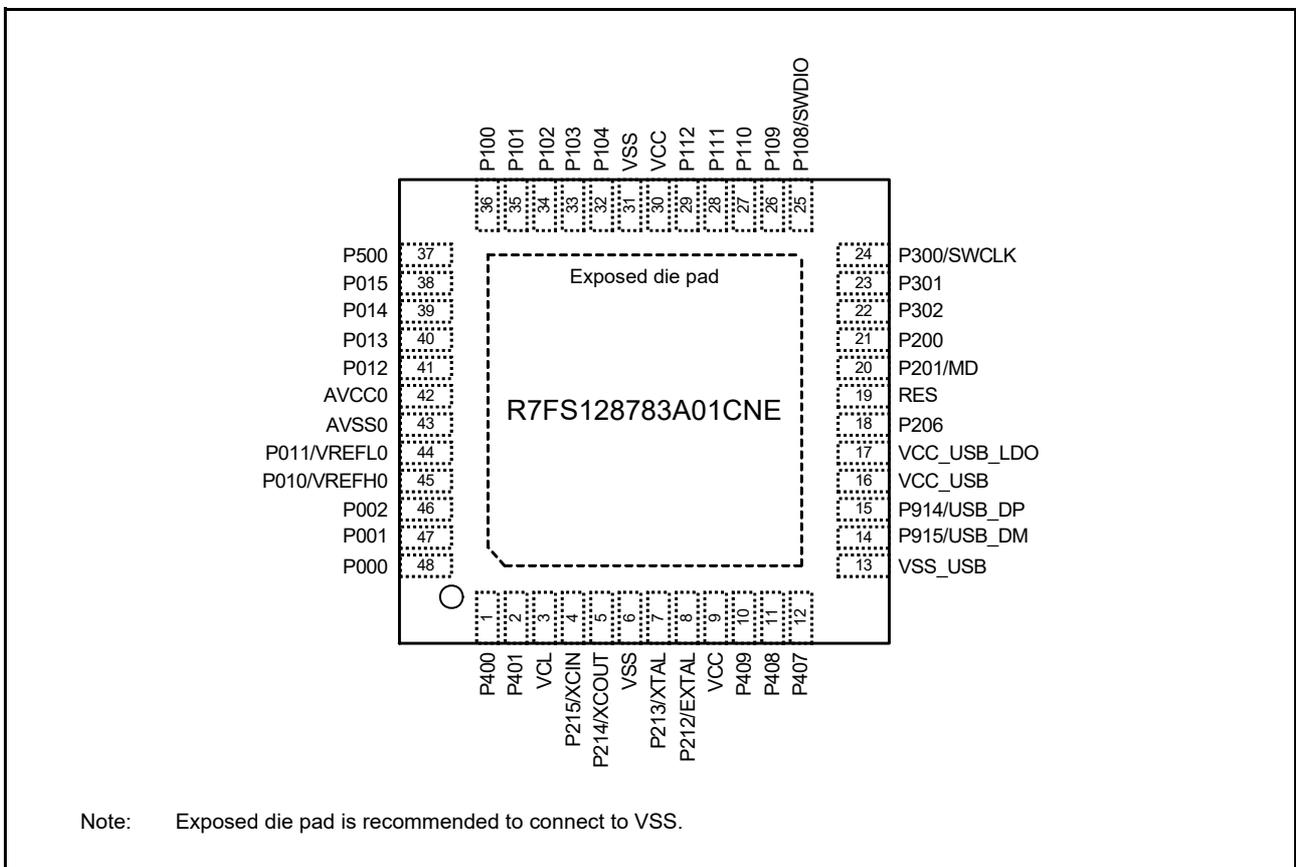


Figure 1.5 Pin assignment for QFN 48-pin

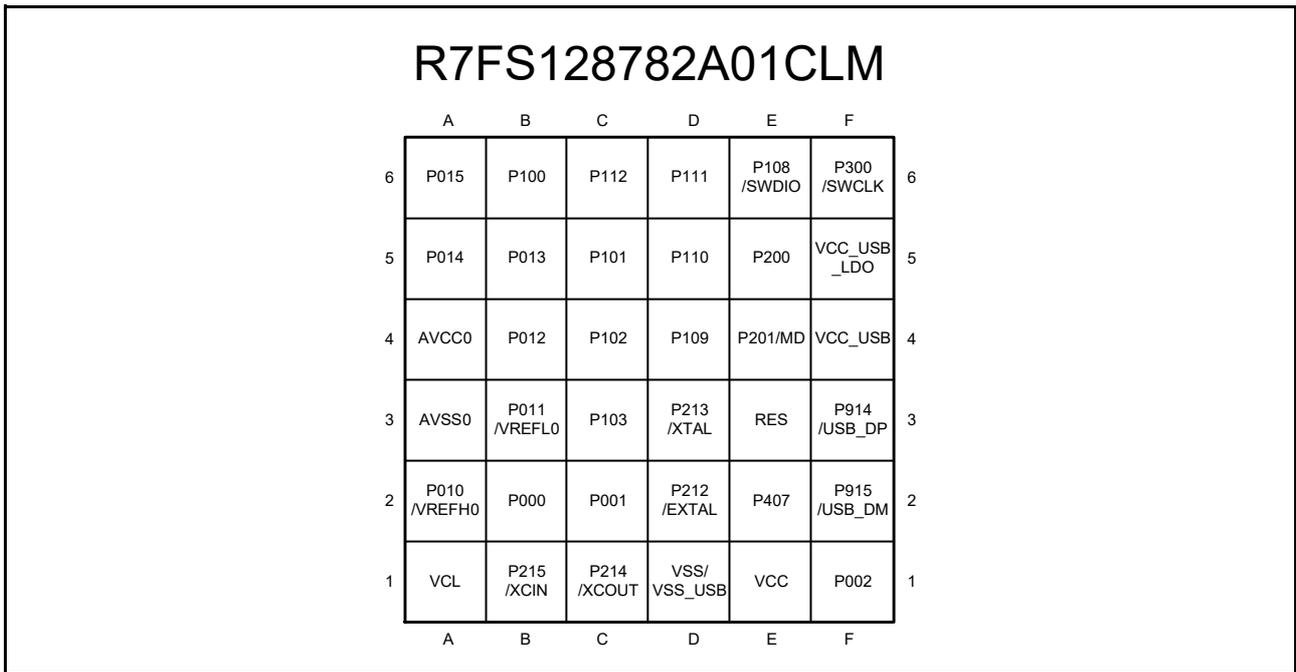


Figure 1.6 Pin assignment for LGA 36-pin (top view, pad side down)

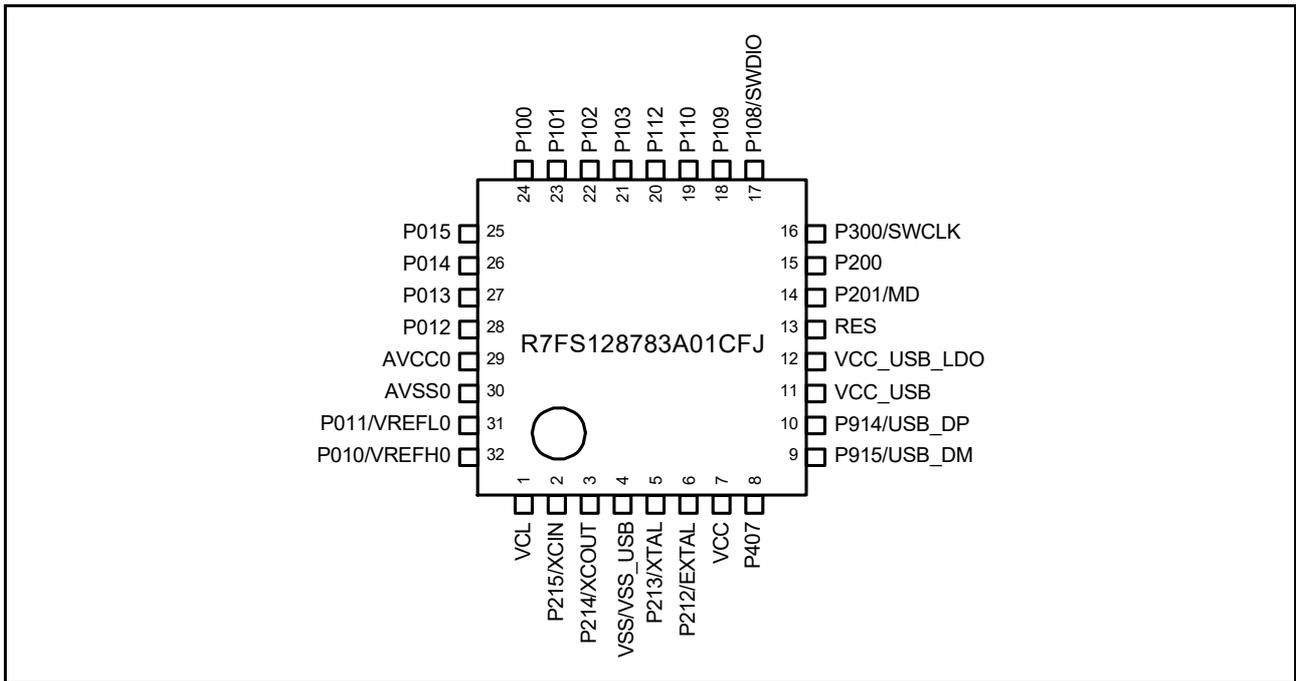


Figure 1.7 Pin assignment for LQFP 32-pin

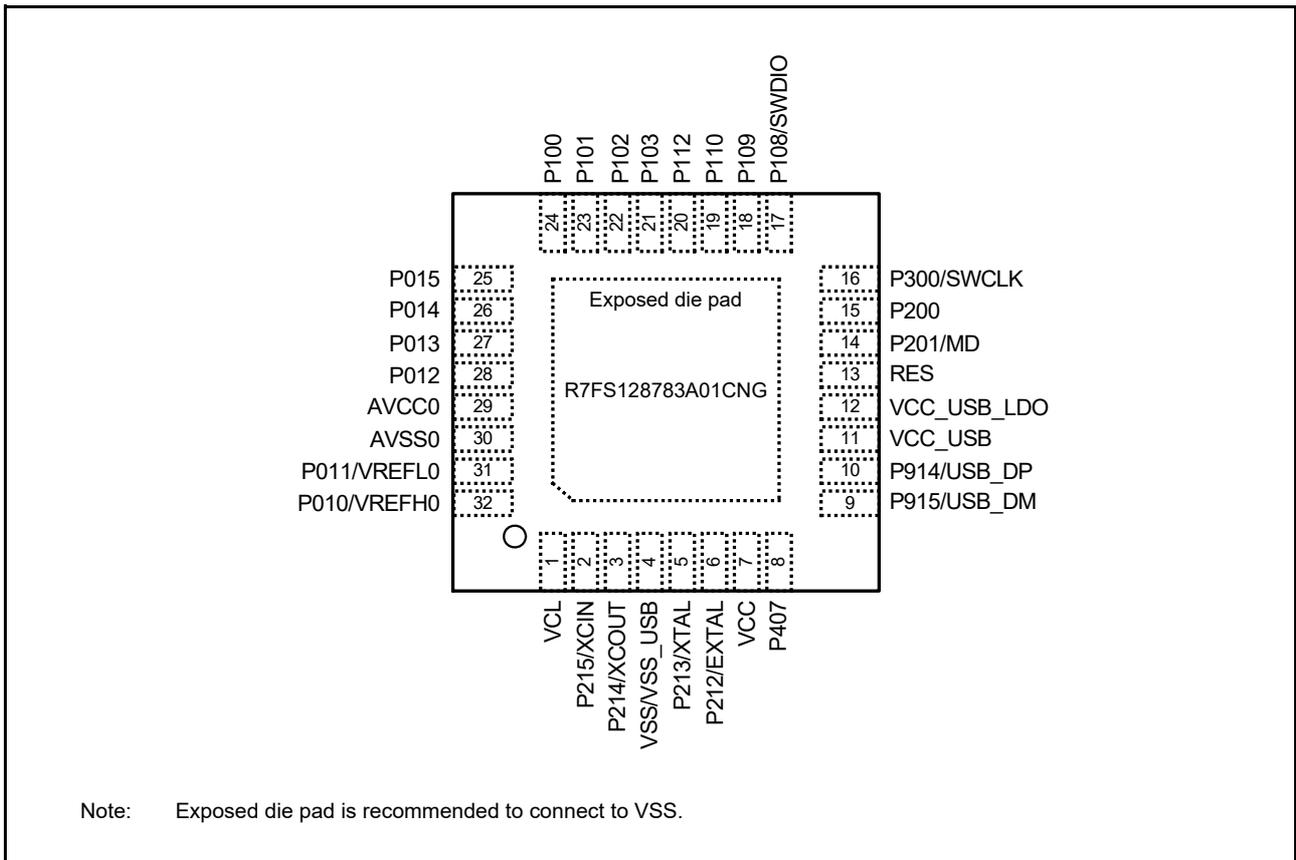


Figure 1.8 Pin assignment for QFN 32-pin

1.7 Pin Lists

| Pin number | | | | | | Power, System, Clock, Debug, CAC | I/O ports | Timers | | | | Communication Interfaces | | | | Analog | | | | HMI | |
|------------|----------|---------|---------|----------|---------|----------------------------------|-----------|----------|---------------|-----------|---------|--------------------------|-------------------|---|---------|----------|---------|----------------|-------|---------|-----------|
| ..LQFP64 | ..LQFP48 | ..QFN48 | ..LGA36 | ..LQFP32 | ..QFN32 | | | AGT | GPT_OPS, POEG | GPT | RTC | USBF, CAN, DALI | SCI | IIC | SPI | ADC14 | DAC8 | ACMPHS, ACMPLP | OPAMP | CTSU | Interrupt |
| 1 | 1 | 1 | - | - | - | CACREF_C | P400 | AGTIO1_D | | GTIOC6A_A | | | | SCK0_B/ SCK1_B | SCL0_A | | | | | TS20 | IRQ0 |
| 2 | 2 | 2 | - | - | - | | P401 | | GTETRGA_B | GTIOC6B_A | | | CTX0_B | CTS0_RTS0_B/SS0_B/ TXD1_B/ MOSI1_B/ SDA1_B | SDA0_A | | | | | TS19 | IRQ5 |
| 3 | - | - | - | - | - | | P402 | | | GTIOC3B_B | | | CRX0_B | RXD1_B/ MISO1_B/ SCL1_B | | | | | | TS18 | IRQ4 |
| 4 | - | - | - | - | - | | P403 | | | GTIOC3A_B | | | | CTS1_RTS1_B/SS1_B | | | | | | TS17 | |
| 5 | 3 | 3 | A1 | 1 | 1 | VCL | | | | | | | | | | | | | | | |
| 6 | 4 | 4 | B1 | 2 | 2 | XCIN | P215 | | | | | | | | | | | | | | |
| 7 | 5 | 5 | C1 | 3 | 3 | XCOUT | P214 | | | | | | | | | | | | | | |
| 8 | 6 | 6 | D1 | 4 | 4 | VSS | | | | | | | | | | | | | | | |
| 9 | 7 | 7 | D3 | 5 | 5 | XTAL | P213 | | GTETRGA_D | GTIOC0A_D | | | | TXD1_A/ MOSI1_A/ SDA1_A | | | | | | | IRQ2 |
| 10 | 8 | 8 | D2 | 6 | 6 | EXTAL | P212 | AGTEE1 | GTETRGA_D | GTIOC0B_D | | | | RXD1_A/ MISO1_A/ SCL1_A | | | | | | | IRQ3 |
| 11 | 9 | 9 | E1 | 7 | 7 | VCC | | | | | | | | | | | | | | | |
| 12 | - | - | - | - | - | | P411 | AGTOA1 | GTOVUP_B | GTIOC6A_B | | | | TXD0_B/ MOSI0_B/ SDA0_B | | | MOSIA_B | | | TS07 | IRQ4 |
| 13 | - | - | - | - | - | | P410 | AGTOB1 | GTOVLO_B | GTIOC6B_B | | | | RXD0_B/ MISO0_B/ SCL0_B | | | MISOA_B | | | TS06 | IRQ5 |
| 14 | 10 | 10 | - | - | - | | P409 | | GTOVUP_B | GTIOC5A_B | | | | TXD0_E/ MOSI0_E/ SDA0_E/ TXD9_A/ MOSI9_A/ SDA9_A | | | | | | TS05 | IRQ6 |
| 15 | 11 | 11 | - | - | - | | P408 | | GTOVLO_B | GTIOC5B_B | | | | RXD9_A/ MISO9_A/ SCL9_A | SCL0_C | | | | | TS04 | IRQ7 |
| 16 | 12 | 12 | E2 | 8 | 8 | | P407 | AGTIO0_C | | GTIOC0A_E | RTC OUT | USB_VBUS | CTS0_RTS0_D/SS0_D | SDA0_B | SSLB3_A | ADTRG0_B | | | | TS03 | |
| 17 | 13 | 13 | D1 | 4 | 4 | VSS_USB | | | | | | | | | | | | | | | |
| 18 | 14 | 14 | F2 | 9 | 9 | | P915 | | | | | | USB_DM | | | | | | | | |
| 19 | 15 | 15 | F3 | 10 | 10 | | P914 | | | | | | USB_DP | | | | | | | | |
| 20 | 16 | 16 | F4 | 11 | 11 | VCC_USB | | | | | | | | | | | | | | | |
| 21 | 17 | 17 | F5 | 12 | 12 | VCC_USB_LDO | | | | | | | | | | | | | | | |
| 22 | 18 | 18 | - | - | - | | P206 | | GTIU_A | | | | | RXD0_D/ MISO0_D/ SCL0_D | SDA1_A | SSLB1_A | | | | TS01 | IRQ0 |
| 23 | - | - | - | - | - | CLKOUT_A | P205 | AGTO1 | GTIV_A | GTIOC4A_B | | | | TXD0_D/ MOSI0_D/ SDA0_D/ CTS9_RTS9_A/SS9_A | SCL1_A | SSLB0_A | | | | TSCAP_A | IRQ1 |
| 24 | - | - | - | - | - | CACREF_A | P204 | AGTIO1_A | GTIW_A | GTIOC4B_B | | | | SCK0_D/ SCK9_A | SCL0_B | RSPCKB_A | | | | TS00 | |
| 25 | 19 | 19 | E3 | 13 | 13 | RES | | | | | | | | | | | | | | | |
| 26 | 20 | 20 | E4 | 14 | 14 | MD | P201 | | | | | | | | | | | | | | |
| 27 | 21 | 21 | E5 | 15 | 15 | | P200 | | | | | | | | | | | | | | NMI |
| 28 | - | - | - | - | - | | P304 | | | GTIOC1A_B | | | | | | | | | | | |
| 29 | - | - | - | - | - | | P303 | | | GTIOC1B_B | | | | | | | | | | | TS02 |
| 30 | 22 | 22 | - | - | - | | P302 | | GTOUUP_A | GTIOC4A_A | | | | | | SSLB3_B | | | | TS08 | IRQ5 |
| 31 | 23 | 23 | - | - | - | | P301 | AGTIO0_D | GTOULO_A | GTIOC4B_A | | | | CTS9_RTS9_D/SS9_D | | SSLB2_B | | | | TS09 | IRQ6 |
| 32 | 24 | 24 | F6 | 16 | 16 | SWCLK | P300 | | GTOUUP_C | GTIOC0A_A | | | | | | SSLB1_B | | | | | |
| 33 | 25 | 25 | E6 | 17 | 17 | SWDIO | P108 | | GTOULO_C | GTIOC0B_A | | | | CTS9_RTS9_B/SS9_B | | SSLB0_B | | | | | |
| 34 | 26 | 26 | D4 | 18 | 18 | CLKOUT_B | P109 | | GTOVUP_A | GTIOC1A_A | | | CTX0_A | SCK1_E/ TXD9_B/ MOSI9_B/ SDA9_B | | MOSIB_B | | | | TS10 | |

| Pin number | | | | | | Power, System, Clock, Debug, CAC | I/O ports | Timers | | | | Communication Interfaces | | | | Analog | | | | HMI | |
|------------|--------|-------|-------|--------|-------|----------------------------------|-----------|-----------|---------------|-----------|---|--------------------------|----------|--------------------|-------|---------|-------|-----------------|---------------|------|-----------|
| LQFP64 | LQFP48 | QFN48 | LGA36 | LQFP32 | QFN32 | | | AGT | GPT_OPS, POEG | GPT | RTC | USBFS, CAN, DALI | SCI | IIC | SPi | ADC14 | DAC8 | ACMPHS, ACMPPLP | OPAMP | CTSU | Interrupt |
| 35 | 27 | 27 | D5 | 19 | 19 | | P110 | | | CRX0_A | CTS0_RTS0_C/ SS0_C/ RXD0_B/ MISO0_B/ SCL9_B | | MISOB_B | | | VCOUT | | TS11 | IRQ3 | | |
| 36 | 28 | 28 | D6 | - | - | | P111 | AGTOA0 | | | SCK0_C/ SCK9_B | | RSPCKB_B | | | | | TS12 | IRQ4 | | |
| 37 | 29 | 29 | C6 | 20 | 20 | | P112 | AGTOB0 | | | TXD0_C/ MOSI0_C/ SDA0_C/ SCK1_D | | SSLB0_C | | | | | TSCAP_C | | | |
| 38 | - | - | - | - | - | | P113 | | | | | | | | | | | | | | |
| 39 | 30 | 30 | - | - | - | VCC | | | | | | | | | | | | | | | |
| 40 | 31 | 31 | - | - | - | VSS | | | | | | | | | | | | | | | |
| 41 | - | - | - | - | - | | P107 | | | | | | | | | | | | KR07 | | |
| 42 | - | - | - | - | - | | P106 | | | | | | SSLA3_A | AN016 | | | | | KR06 | | |
| 43 | - | - | - | - | - | | P105 | | GTETRGAC | GTIOC1A_C | | | SSLA2_A | AN017 | | | | | KR05/ IRQ0 | | |
| 44 | 32 | 32 | - | - | - | | P104 | GTETRGB_B | GTIOC1B_C | | RXD0_C/ MISO0_C/ SCL0_C | | SSLA1_A | AN018 | | | | TS13 | KR04/ IRQ1 | | |
| 45 | 33 | 33 | C3 | 21 | 21 | | P103 | GTOWUP_A | GTIOC2A_A | CTX0_C | CTS0_RTS0_A/SS0_A | | SSLA0_A | AN019 | | CMPREF1 | | TS14 | KR03 | | |
| 46 | 34 | 34 | C4 | 22 | 22 | | P102 | AGTO0 | GTOWLO_A | CRX0_C | SCK0_A | | RSPCKA_A | AN020/ ADTRG0_A | | CMPIN1 | | TS15 | KR02 | | |
| 47 | 35 | 35 | C5 | 23 | 23 | | P101 | AGTEE0 | GTETRGB_A | DTX0 | TXD0_A/ MOSI0_A/ SDA0_A/ CTS1_RTS1_A/SS1_A | SDA1_B | MOSIA_A | AN021 | | CMPREF0 | | TS16 | KR01/ IRQ1 | | |
| 48 | 36 | 36 | B6 | 24 | 24 | | P100 | AGTIO0_A | GTETRGA_A | DRX0 | RXD0_A/ MISO0_A/ SCL0_A/ SCK1_A | SCL1_B | MISOA_A | AN022 | | CMPIN0 | | TS26 | KR00/ IRQ2 | | |
| 49 | 37 | 37 | - | - | - | | P500 | | | | | | | AN013 | DA1_B | | | TS27 | | | |
| 50 | - | - | - | - | - | | P501 | | | | | | | AN012 | | | AMP3+ | | | | |
| 51 | - | - | - | - | - | | P502 | | | | | | | AN011 | | | AMP3- | | | | |
| 52 | 38 | 38 | A6 | 25 | 25 | | P015 | | | | | | | AN010 | DA1_A | IVCMP1 | AMP2+ | TS28 | IRQ7 | | |
| 53 | 39 | 39 | A5 | 26 | 26 | | P014 | | | | | | | AN009 | DA0 | IVREF1 | AMP2- | TS29 | | | |
| 54 | 40 | 40 | B5 | 27 | 27 | | P013 | | | | | | | AN008 | | IVCMP0 | AMP1+ | | | | |
| 55 | 41 | 41 | B4 | 28 | 28 | | P012 | | | | | | | AN007 | | IVREF0 | AMP1- | | | | |
| 56 | 42 | 42 | A4 | 29 | 29 | AVCC0 | | | | | | | | | | | | | | | |
| 57 | 43 | 43 | A3 | 30 | 30 | AVSS0 | | | | | | | | | | | | | | | |
| 58 | 44 | 44 | B3 | 31 | 31 | VREFL0 | P011 | | | | | | | AN006 | DA2_A | | AMP20 | | | | |
| 59 | 45 | 45 | A2 | 32 | 32 | VREFH0 | P010 | | | | | | | AN005 | | | AMP10 | | | | |
| 60 | - | - | - | - | - | | P004 | | | | | | | AN004 | DA2_B | | | TS25 | IRQ3 | | |
| 61 | - | - | - | - | - | | P003 | | | | | | | AN003 | | | AMP30 | | | | |
| 62 | 46 | 46 | F1 | - | - | | P002 | | | | | | | AN002 | | | AMP00 | | IRQ2 | | |
| 63 | 47 | 47 | C2 | - | - | | P001 | | | | | | | AN001 | | IVREF2 | AMP0- | TS22 | IRQ7 | | |
| 64 | 48 | 48 | B2 | - | - | | P000 | | | | | | | AN000 | | IVCMP2 | AMP0+ | TS21 | IRQ6 | | |

Note: Several pin names have the added suffix of _A, _B, _C, _D and _E. The suffix can be ignored when assigning functionality.

2. Electrical Characteristics

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

$VCC^{*1} = AVCC0 = VCC_USB^{*2} = VCC_USB_LDO^{*2} = 1.6$ to $5.5V$, $VREFH0 = 1.6$ to $AVCC0$,

$VSS = AVSS0 = VREFL0 = VSS_USB = 0$ V, $T_a = T_{opr}$

Note 1. The typical condition is set to $VCC = 3.3V$.

Note 2. When USBFS is not used.

Figure 2.1 shows the timing conditions.

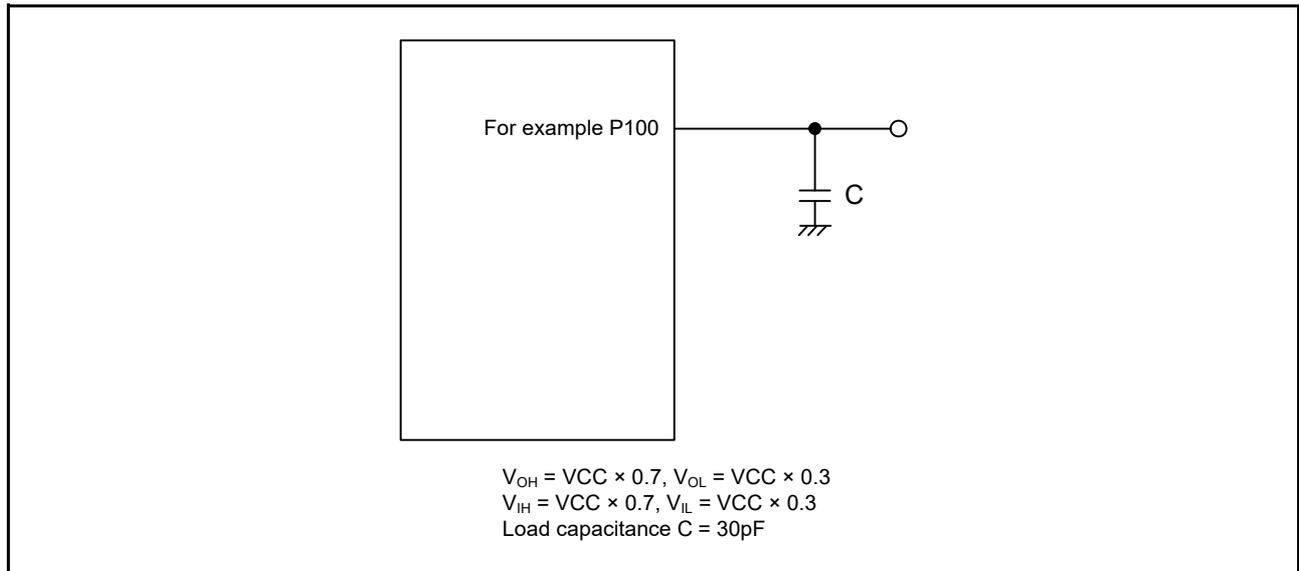


Figure 2.1 Input or output timing measurement conditions

The measurement conditions of the timing specifications for each peripheral are recommended for the best peripheral operation. However, make sure to adjust driving abilities for each pin to meet the conditions of your system.

Each function pin used for the same function must select the same drive ability. If the I/O drive ability of each function pin is mixed, the A/C specification of each function is not guaranteed.

2.1 Absolute Maximum Ratings

Table 2.1 Absolute maximum ratings

| Parameter | Symbol | Value | Unit |
|--------------------------------|--|---------------------------|---------------------|
| Power supply voltage | VCC | -0.5 to +6.5 | V |
| Input voltage | 5 V tolerant ports*1 | V_{in} | -0.3 to +6.5 |
| | P000 to P004 P010 to P015 P500 to P502 | V_{in} | -0.3 to AVCC0 + 0.3 |
| | Others | V_{in} | -0.3 to VCC + 0.3 |
| Reference power supply voltage | VREFH0 | -0.3 to +6.5 | V |
| Analog power supply voltage | AVCC0 | -0.5 to +6.5 | V |
| USB power supply voltage | VCC_USB | -0.5 to +6.5 | V |
| | VCC_USB_LDO | -0.5 to +6.5 | V |
| Analog input voltage | When AN000 to AN013 are used | V_{AN} | -0.3 to AVCC0 + 0.3 |
| | When AN016 to AN022 are used | | -0.3 to VCC + 0.3 |
| Operating temperature*2 *3 | T_{opr} | -40 to +85 -40 to +105 | °C |
| Storage temperature | T_{stg} | -55 to +125 | °C |

Note: Contact Renesas Electronics sales office for information on derating operation under $T_a = +85^{\circ}\text{C}$ to $+105^{\circ}\text{C}$. Derating is the systematic reduction of load for improved reliability.

Note 1. Ports P205, P206, P400, P401, and P407 are 5V-tolerant.

Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up might cause malfunction and the abnormal current that passes in the device at this time might cause degradation of internal elements.

Note 2. See [section 2.2.1, Tj/Ta Definition](#).

Note 3. The upper limit of the operating temperature is 85°C or 105°C , depending on the product. For details, see [section 1.3, Part Numbering](#).

Caution: Permanent damage to the MCU might result if absolute maximum ratings are exceeded. To preclude any malfunctions due to noise interference, insert capacitors of high frequency characteristics between the VCC and VSS pins, between the AVCC0 and AVSS0 pins, between the VCC_USB and VSS_USB pins, and between the VREFH0 and VREFL0 pins. Place capacitors of about $0.1\ \mu\text{F}$ as close as possible to every power supply pin and use the shortest and heaviest possible traces. Also, connect capacitors as stabilization capacitance. Connect the VCL pin to a VSS pin by a $4.7\text{-}\mu\text{F}$ capacitor. The capacitor must be placed close to the pin.

Table 2.2 Recommended operating conditions

| Parameter | Symbol | Value | Min | Typ | Max | Unit |
|------------------------------|-------------------------|---|-----------------|-----|-------|------|
| Power supply voltages | VCC ^{*1, *2} | When USBFS is not used | 1.6 | - | 5.5 | V |
| | | When USBFS is used USB Regulator Disable | VCC_USB | - | 3.6 | V |
| | | When USBFS is used USB Regulator Enable | VCC_USB _LDO | - | 5.5 | V |
| | VSS | - | 0 | - | V | |
| USB power supply voltages | VCC_USB | When USBFS is not used | - | VCC | - | V |
| | | When USBFS is used USB Regulator Disable (Input) | 3.0 | 3.3 | 3.6 | V |
| | VCC_USB_LDO | When USBFS is not used | - | VCC | - | V |
| | | When USBFS is used USB Regulator Disable | - | VCC | - | V |
| | | When USBFS is used USB Regulator Enable | 3.8 | - | 5.5 | V |
| | VSS_USB | - | 0 | - | V | |
| Analog power supply voltages | AVCC0 ^{*1, *2} | | 1.6 | - | 5.5 | V |
| | AVSS0 | | - | 0 | - | V |
| | VREFH0 | When used as ADC14 Reference | 1.6 | - | AVCC0 | V |
| | VREFL0 | | - | 0 | - | V |

Note 1. Use AVCC0 and VCC under the following conditions:

AVCC0 and VCC can be set individually within the operating range when $VCC \geq 2.2\text{ V}$ and $AVCC0 \geq 2.2\text{ V}$.

$AVCC0 = VCC$ when $VCC < 2.2\text{ V}$ or $AVCC0 < 2.2\text{ V}$.

Note 2. When powering on the VCC and AVCC0 pins, power them on at the same time or the VCC pin first and then the AVCC0 pin.

2.2 DC Characteristics

2.2.1 T_j/T_a Definition

Table 2.3 DC characteristics

Conditions: Products with operating temperature (T_a) -40 to +105°C

| Parameter | Symbol | Typ | Max | Unit | Test conditions |
|----------------------------------|----------------|-----|-------|------|---|
| Permissible junction temperature | T _j | - | 125 | °C | High-speed mode Middle-speed mode Low-voltage mode Low-speed mode SubOSC-speed mode |
| | | | 105*1 | | |

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

Note 1. The upper limit of operating temperature is 85°C or 105°C, depending on the product. For details, see [section 1.3, Part Numbering](#). If the part number shows an operation temperature to 85°C, then T_j max is 105°C, otherwise, it is 125°C.

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

Table 2.4 I/O V_{IH}, V_{IL} (1)

Conditions: VCC = AVCC0 = VCC_USB = VCC_USB_LDO = 2.7 to 5.5 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions | |
|---|---|-----------------|---------------|-----|---------------|-----------------|-----------------------|
| Schmitt trigger input voltage | IIC (except for SMBus)*1 | V _{IH} | VCC × 0.7 | - | 5.8 | V | - |
| | | V _{IL} | - | - | VCC × 0.3 | | |
| | | ΔV _T | VCC × 0.05 | - | - | | |
| | RES, NMI Other peripheral input pins excluding IIC | V _{IH} | VCC × 0.8 | - | - | | |
| | | V _{IL} | - | - | VCC × 0.2 | | |
| | | ΔV _T | VCC × 0.1 | - | - | | |
| Input voltage (except for Schmitt trigger input pin) | IIC (SMBus)*2 | V _{IH} | 2.2 | - | - | V | VCC = 3.6 to 5.5 V |
| | | V _{IH} | 2.0 | - | - | | |
| | | V _{IL} | - | - | 0.8 | | - |
| | 5V-tolerant ports*3 | V _{IH} | VCC × 0.8 | - | 5.8 | | - |
| | | V _{IL} | - | - | VCC × 0.2 | | |
| | P000 to P004 P010 to P015 P500 to P502 | V _{IH} | AVCC0 × 0.8 | - | - | | |
| | | V _{IL} | - | - | AVCC0 × 0.2 | | |
| | P914, P915 | V _{IH} | VCC_USB × 0.8 | - | VCC_USB + 0.3 | | |
| | | V _{IL} | - | - | VCC_USB × 0.2 | | |
| | EXTAL Input ports pins except for P000 to P004, P010 to P015, P500 to P502, P914, P915 | V _{IH} | VCC × 0.8 | - | - | | |
| | | V _{IL} | - | - | VCC × 0.2 | | |

Note 1. SCL0_A, SDA0_A, SDA0_B, SCL1_A, SDA1_A (total 5 pins)

Note 2. SCL0_A, SDA0_A, SCL0_B, SDA0_B, SCL0_C, SCL1_A, SDA1_A, SCL1_B, SDA1_B (total 9 pins)

Note 3. P205, P206, P400, P401, P407 (total 5pins)

Table 2.5 I/O V_{IH} , V_{IL} (2)Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 1.6$ to 2.7 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test Conditions |
|--|---|--------------|--------------------------|-----|--------------------------|------|-----------------|
| Schmitt trigger input voltage | RES, NMI Peripheral input pins | V_{IH} | $V_{CC} \times 0.8$ | - | - | V | - |
| | | V_{IL} | - | - | $V_{CC} \times 0.2$ | | |
| | | ΔV_T | $V_{CC} \times 0.01$ | - | - | | |
| Input voltage (except for Schmitt trigger input pin) | 5V-tolerant ports*1 | V_{IH} | $V_{CC} \times 0.8$ | - | 5.8 | | |
| | | V_{IL} | - | - | $V_{CC} \times 0.2$ | | |
| | P000 to P004 P010 to P015 P500 to P502 | V_{IH} | $AV_{CC0} \times 0.8$ | - | - | | |
| | | V_{IL} | - | - | $AV_{CC0} \times 0.2$ | | |
| | P914, P915 | V_{IH} | $V_{CC_USB} \times 0.8$ | - | $V_{CC_USB} + 0.3$ | | |
| | | V_{IL} | - | - | $V_{CC_USB} \times 0.2$ | | |
| | EXTAL Input ports pins except for P000 to P004, P010 to P015, P500 to P502, P914, P915 | V_{IH} | $V_{CC} \times 0.8$ | - | - | | |
| | | V_{IL} | - | - | $V_{CC} \times 0.2$ | | |

Note 1. P205, P206, P400, P401, P407 (total 5pins)

2.2.3 I/O I_{OH} , I_{OL} **Table 2.6** I/O I_{OH} , I_{OL} Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 1.6$ to 5.5 V

| Parameter | | Symbol | Min | Typ | Max | Unit | |
|---|--|--------------------------------------|----------|-----|------|-------|----|
| Permissible output current (average value per pin) | Ports P000 to P004, P010 to P015, P212, P213, P500 to P502 | - | I_{OH} | - | - | -4.0 | mA |
| | | | I_{OL} | - | - | 4.0 | mA |
| | Ports P408, P409 | Low drive*1 | I_{OH} | - | - | -4.0 | mA |
| | | | I_{OL} | - | - | 4.0 | mA |
| | | Middle drive*2 VCC = 2.7 to 3.0 V | I_{OH} | - | - | -8.0 | mA |
| | | | I_{OL} | - | - | 8.0 | mA |
| | | Middle drive*2 VCC = 3.0 to 5.5 V | I_{OH} | - | - | -20.0 | mA |
| | | | I_{OL} | - | - | 20.0 | mA |
| | Ports P914, P915 | I_{OH} | - | - | -4.0 | mA | |
| | | I_{OL} | - | - | 4.0 | mA | |
| | Other output pins*3 | 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 |
| Permissible output current (max value per pin) | Ports P000 to P004, P010 to P015, P212, P213, P500 to P502 | - | I_{OH} | - | - | -4.0 | mA |
| | | | I_{OL} | - | - | 4.0 | mA |
| | Ports P408, P409 | Low drive*1 | I_{OH} | - | - | -4.0 | mA |
| | | | I_{OL} | - | - | 4.0 | mA |
| | | Middle drive*2 VCC = 2.7 to 3.0 V | I_{OH} | - | - | -8.0 | mA |
| | | | I_{OL} | - | - | 8.0 | mA |
| | | Middle drive*2 VCC = 3.0 to 5.5 V | I_{OH} | - | - | -20.0 | mA |
| | | | I_{OL} | - | - | 20.0 | mA |
| | Ports P914, P915 | I_{OH} | - | - | -4.0 | mA | |
| | | I_{OL} | - | - | 4.0 | mA | |
| | Other output pins*3 | 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 |
| Permissible output current (max value total pins) | Total of ports P000 to P004, P010 to P015, P500 to P502 | $\Sigma I_{OH} (max)$ | - | - | -30 | mA | |
| | | $\Sigma I_{OL} (max)$ | - | - | 30 | mA | |
| | Total of ports P914, P915 | ΣI_{OH} | - | - | -4.0 | mA | |
| | | ΣI_{OL} | - | - | 4.0 | mA | |
| | Total of all output pin | $\Sigma I_{OH} (max)$ | - | - | -60 | mA | |
| | | $\Sigma I_{OL} (max)$ | - | - | 60 | mA | |

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 μ s.

Note 1. This is the value when low driving ability is selected with the Port Drive Capability bit in the PmnPFS register.

Note 2. This is the value when middle driving ability is selected with the Port Drive Capability bit in the PmnPFS register.

Note 3. Except for Ports P200, P214, P215, which are input ports.

2.2.4 I/O V_{OH} , V_{OL} , and Other Characteristics**Table 2.7 I/O V_{OH} , V_{OL} (1)**Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 4.0$ to 5.5 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions | |
|----------------|--|----------------|---------------------|------------------|-----|------|---------------------|--------------------|
| Output voltage | IIC*1, *2 | V_{OL} | - | - | 0.4 | V | $I_{OL} = 3.0$ mA | |
| | | V_{OL} | - | - | 0.6 | | $I_{OL} = 6.0$ mA | |
| | Ports P408, P409*2, *3 | V_{OH} | $V_{CC} - 1.0$ | - | - | | $I_{OH} = -20.0$ mA | |
| | | V_{OL} | - | - | 1.0 | | $I_{OL} = 20$ mA | |
| | Ports P000 to P004, P010 to P015, P500 to P502 | Low drive | V_{OH} | $AV_{CC0} - 0.8$ | - | | - | $I_{OH} = -2.0$ mA |
| | | | V_{OL} | - | - | | 0.8 | $I_{OL} = 2.0$ mA |
| | | Middle drive | V_{OH} | $AV_{CC0} - 0.8$ | - | | - | $I_{OH} = -4.0$ mA |
| | | | V_{OL} | - | - | | 0.8 | $I_{OL} = 4.0$ mA |
| | Ports P914, P915 | V_{OH} | $V_{CC_USB} - 0.8$ | - | - | | $I_{OH} = -2.0$ mA | |
| | | V_{OL} | - | - | 0.8 | | $I_{OL} = 2.0$ mA | |
| | Other output pins*4 | Low drive | V_{OH} | $V_{CC} - 0.8$ | - | | - | $I_{OH} = -2.0$ mA |
| | | | V_{OL} | - | - | | 0.8 | $I_{OL} = 2.0$ mA |
| | | Middle drive*5 | V_{OH} | $V_{CC} - 0.8$ | - | | - | $I_{OH} = -4.0$ mA |
| | | | V_{OL} | - | - | | 0.8 | $I_{OL} = 4.0$ mA |

Note 1. SCL0_A, SDA0_A, SCL0_B, SDA0_B, SCL0_C, SCL1_A, SDA1_A, SCL1_B, SDA1_B (total 9 pins).

Note 2. This is the value when middle driving ability is selected with the Port Drive Capability bit in the PmnPFS register.

Note 3. Based on characterization data, not tested in production.

Note 4. Except for Ports P200, P214, P215, which are input ports.

Note 5. Except for P212, P213.

Table 2.8 I/O V_{OH} , V_{OL} (2)Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 2.7$ to 4.0 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions | |
|----------------|--|----------------|---------------------|------------------|-----|------|---|--------------------|
| Output voltage | IIC*1, *2 | V_{OL} | - | - | 0.4 | V | $I_{OL} = 3.0$ mA | |
| | | V_{OL} | - | - | 0.6 | | $I_{OL} = 6.0$ mA | |
| | Ports P408, P409*2, *3 | V_{OH} | $V_{CC} - 1.0$ | - | - | | $I_{OH} = -20.0$ mA $V_{CC} = 3.3$ V | |
| | | V_{OL} | - | - | 1.0 | | $I_{OL} = 20$ mA $V_{CC} = 3.3$ V | |
| | Ports P000 to P004, P010 to P015, P500 to P502 | Low drive | V_{OH} | $AV_{CC0} - 0.5$ | - | | - | $I_{OH} = -1.0$ mA |
| | | | V_{OL} | - | - | | 0.5 | $I_{OL} = 1.0$ mA |
| | | Middle drive | V_{OH} | $AV_{CC0} - 0.5$ | - | | - | $I_{OH} = -2.0$ mA |
| | | | V_{OL} | - | - | | 0.5 | $I_{OL} = 2.0$ mA |
| | Ports P914, P915 | V_{OH} | $V_{CC_USB} - 0.5$ | - | - | | $I_{OH} = -1.0$ mA | |
| | | V_{OL} | - | - | 0.5 | | $I_{OL} = 1.0$ mA | |
| | Other output pins*4 | Low drive | V_{OH} | $V_{CC} - 0.5$ | - | | - | $I_{OH} = -1.0$ mA |
| | | | V_{OL} | - | - | | 0.5 | $I_{OL} = 1.0$ mA |
| | | Middle drive*5 | V_{OH} | $V_{CC} - 0.5$ | - | | - | $I_{OH} = -2.0$ mA |
| | | | V_{OL} | - | - | | 0.5 | $I_{OL} = 2.0$ mA |

Note 1. SCL0_A, SDA0_A, SCL0_B, SDA0_B, SCL0_C, SCL1_A, SDA1_A, SCL1_B, SDA1_B (total 9 pins).

Note 2. This is the value when middle driving ability is selected with the Port Drive Capability bit in the PmnPFS register.

Note 3. Based on characterization data, not tested in production.

Note 4. Except for Ports P200, P214, P215, which are input ports.

Note 5. Except for P212, P213.

Table 2.9 I/O V_{OH} , V_{OL} (3)

Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 1.6$ to 2.7 V

| Parameter | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|----------------|--|----------------------------|---------------------|------------------|-----|--------------------|------|--------------------|
| Output voltage | Ports P000 to P004, P010 to P015, P500 to P502 | Low drive | V_{OH} | $AV_{CC0} - 0.3$ | - | - | V | $I_{OH} = -0.5$ mA |
| | | | V_{OL} | - | - | 0.3 | | $I_{OL} = 0.5$ mA |
| | | Middle drive | V_{OH} | $AV_{CC0} - 0.3$ | - | - | | $I_{OH} = -1.0$ mA |
| | | | V_{OL} | - | - | 0.3 | | $I_{OL} = 1.0$ mA |
| | Ports P914, P915 | V_{OH} | $V_{CC_USB} - 0.3$ | - | - | $I_{OH} = -0.5$ mA | | |
| | | V_{OL} | - | - | 0.3 | $I_{OL} = 0.5$ mA | | |
| | Other output pins* ¹ | Low drive | V_{OH} | $V_{CC} - 0.3$ | - | - | | $I_{OH} = -0.5$ mA |
| | | | V_{OL} | - | - | 0.3 | | $I_{OL} = 0.5$ mA |
| | | Middle drive* ² | V_{OH} | $V_{CC} - 0.3$ | - | - | | $I_{OH} = -1.0$ mA |
| | | | V_{OL} | - | - | 0.3 | | $I_{OL} = 1.0$ mA |

Note 1. Except for Ports P200, P214, P215, which are input ports.

Note 2. Except for P212, P213.

Table 2.10 I/O other characteristicsConditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = V_{CC_USB_LDO} = 1.6$ to 5.5 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions |
|---|---|-------------|-----|-----|-----|-----------|---|
| Input leakage current | RES, Ports P200, P214, P215 | $ I_{in} $ | - | - | 1.0 | μA | $V_{in} = 0$ V $V_{in} = V_{CC}$ |
| Three-state leakage current (off state) | 5V-tolerant ports | $ I_{TSI} $ | - | - | 1.0 | μA | $V_{in} = 0$ V $V_{in} = 5.8$ V |
| | Other ports | | - | - | 1.0 | | $V_{in} = 0$ V $V_{in} = V_{CC}$ |
| Input pull-up resistor | All ports (except for P200, P214, P215, P914, P915) | R_U | 10 | 20 | 50 | $k\Omega$ | $V_{in} = 0$ V |
| Input capacitance | USB_DP, USB_DM, P200 | C_{in} | - | - | 30 | pF | $V_{in} = 0$ V $f = 1$ MHz $T_a = 25^\circ C$ |
| | Other input pins | | - | - | 15 | | |

2.2.5 Output Characteristics for I/O Pins (Low Drive Capacity)

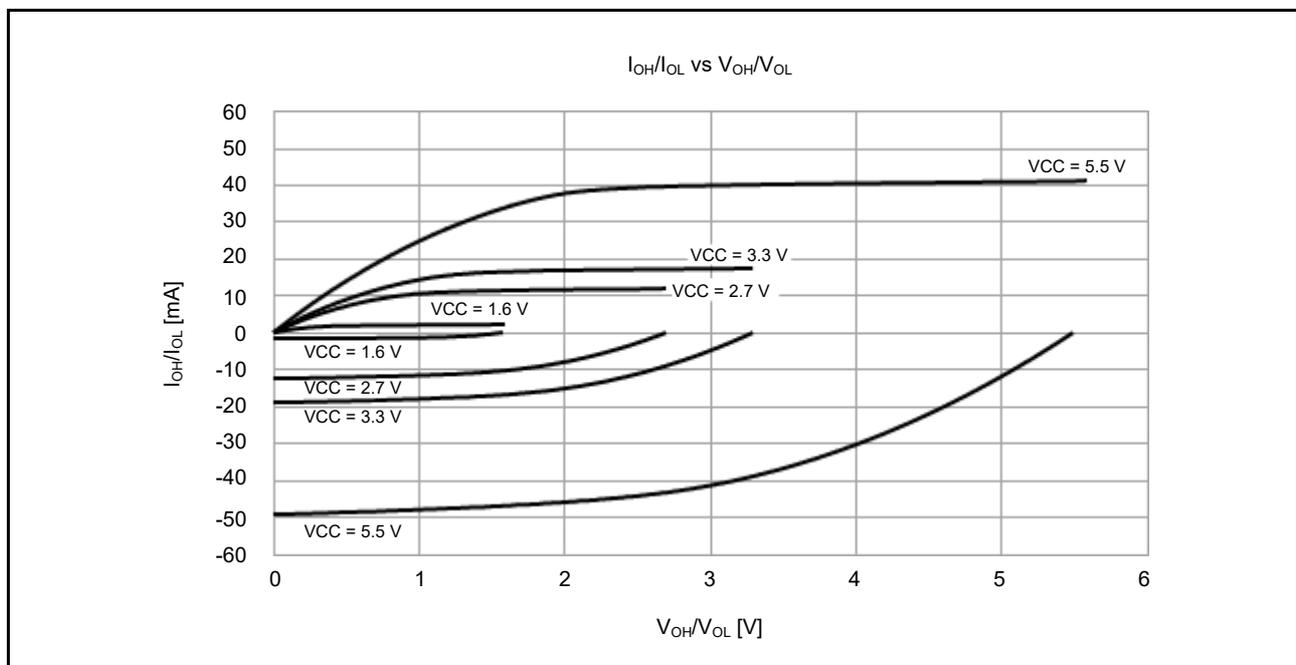


Figure 2.2 V_{OH}/V_{OL} and I_{OH}/I_{OL} voltage characteristics at $T_a = 25^\circ C$ when low drive output is selected (reference data, except for P914 and P915)

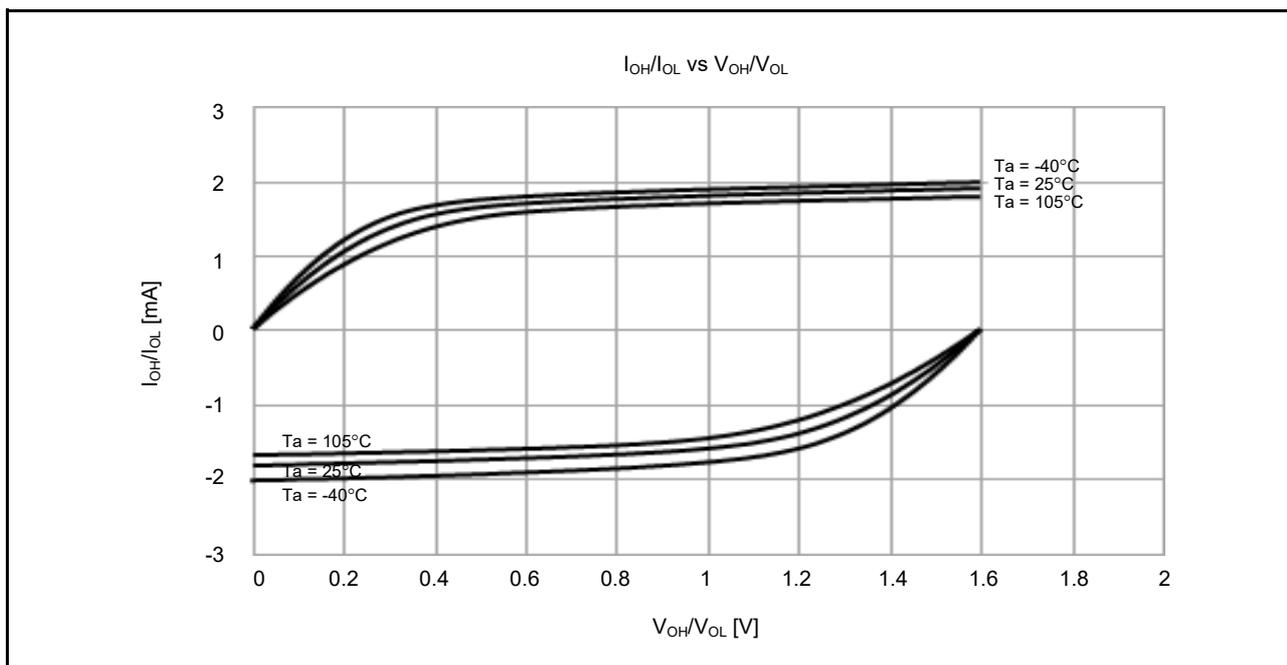


Figure 2.3 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 1.6$ V when low drive output is selected (reference data, except for P914 and P915)

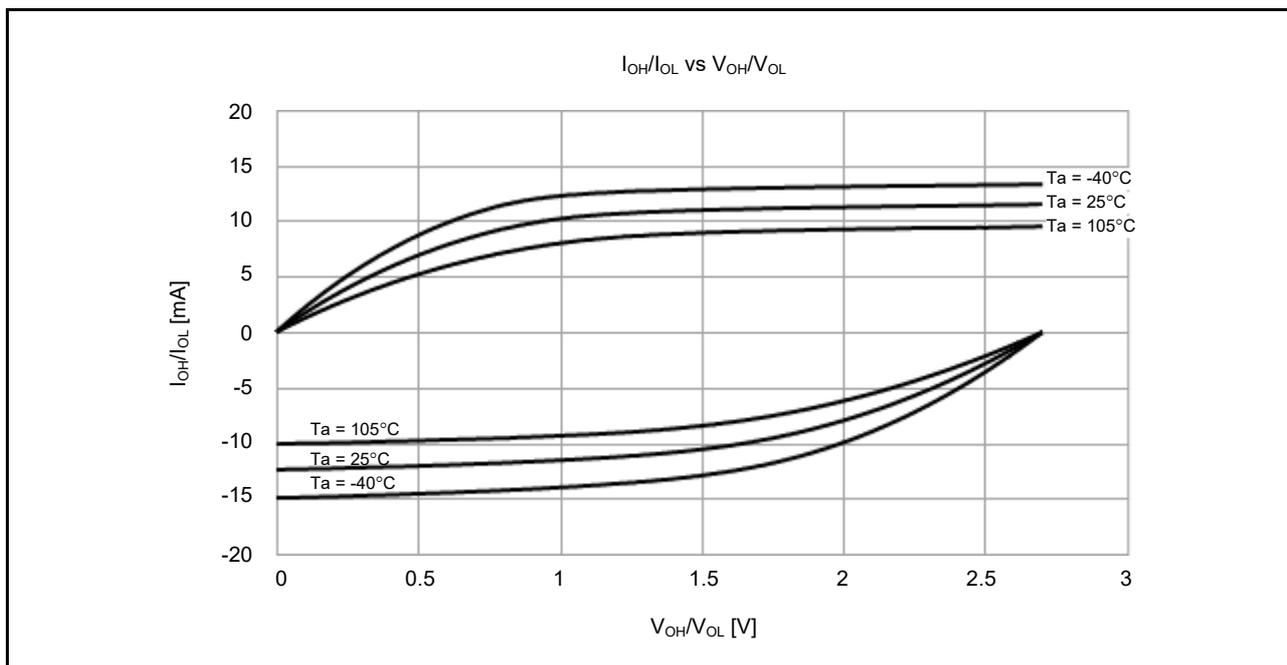


Figure 2.4 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 2.7$ V when low drive output is selected (reference data, except for P914 and P915)

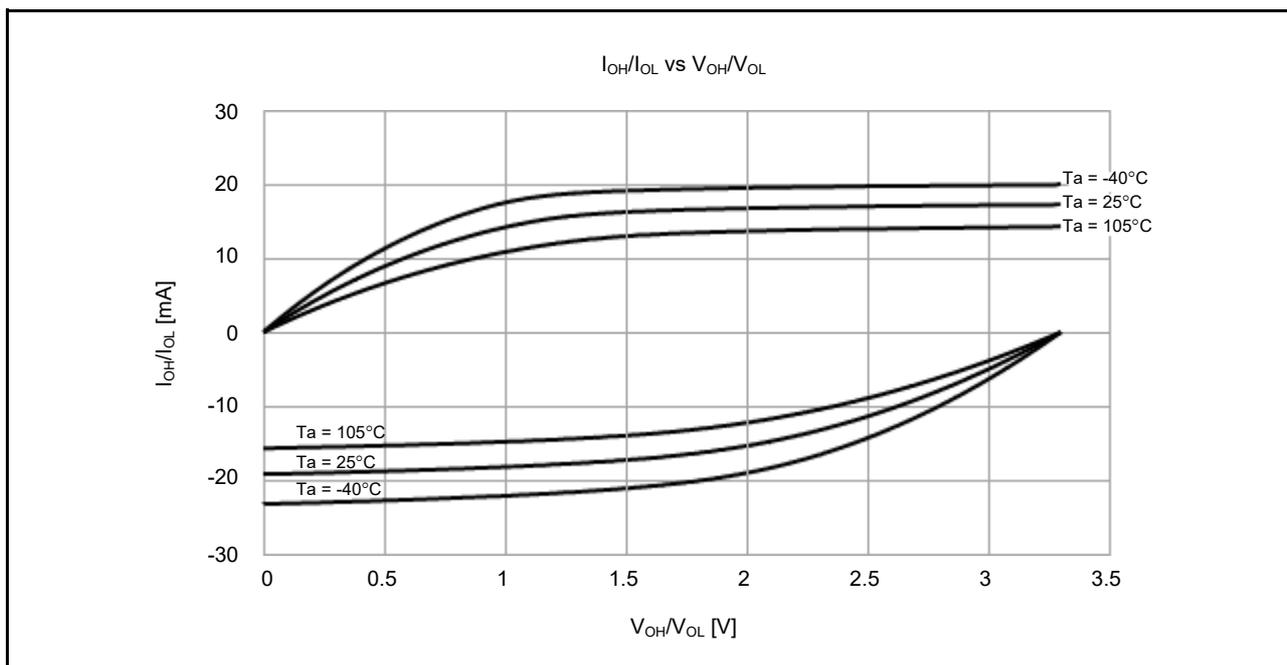


Figure 2.5 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 3.3$ V when low drive output is selected (reference data, except for P914 and P915)

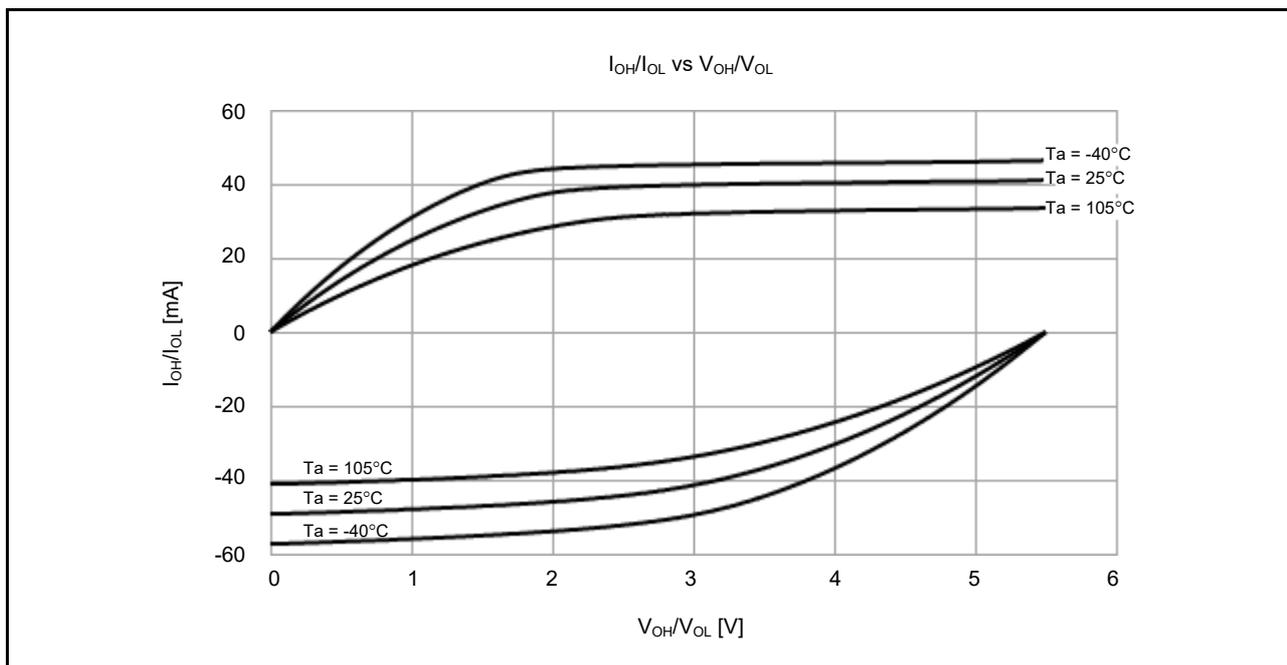


Figure 2.6 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 5.5$ V when low drive output is selected (reference data, except for P914 and P915)

2.2.6 Output Characteristics for I/O Pins (Middle Drive Capacity)

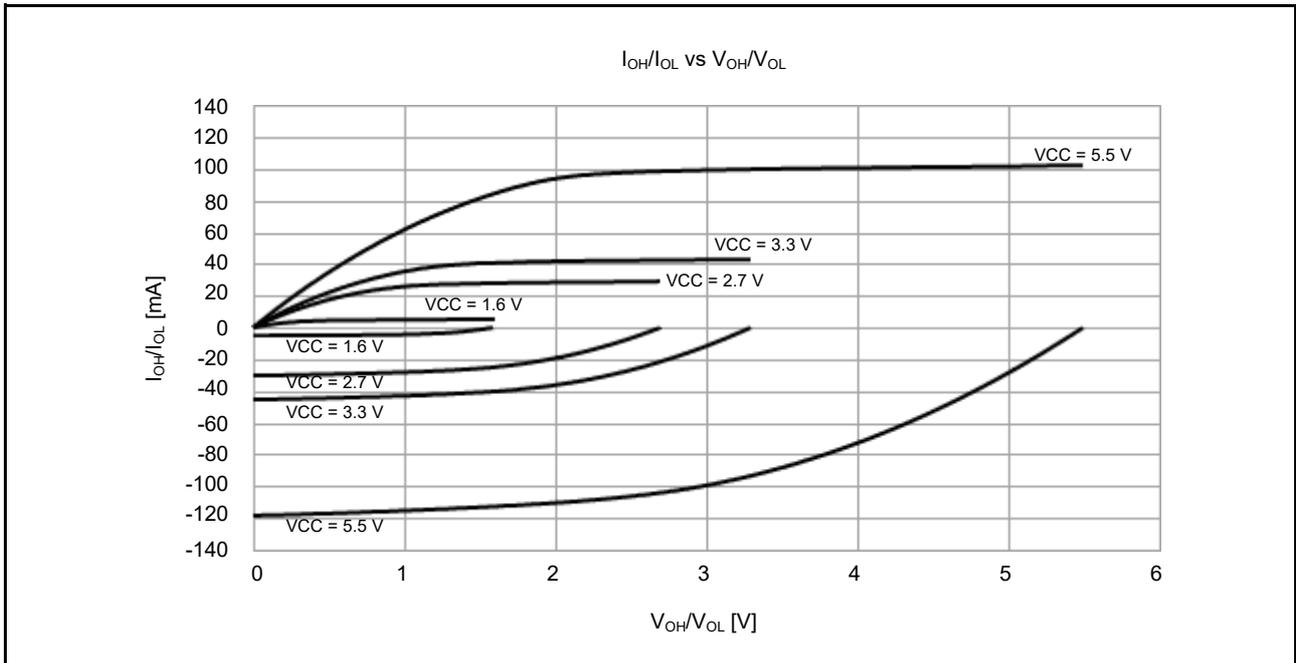


Figure 2.7 VOH/VOL and IOH/IOL voltage characteristics at Ta = 25°C when middle drive output is selected (reference data, except for P914 and P915)

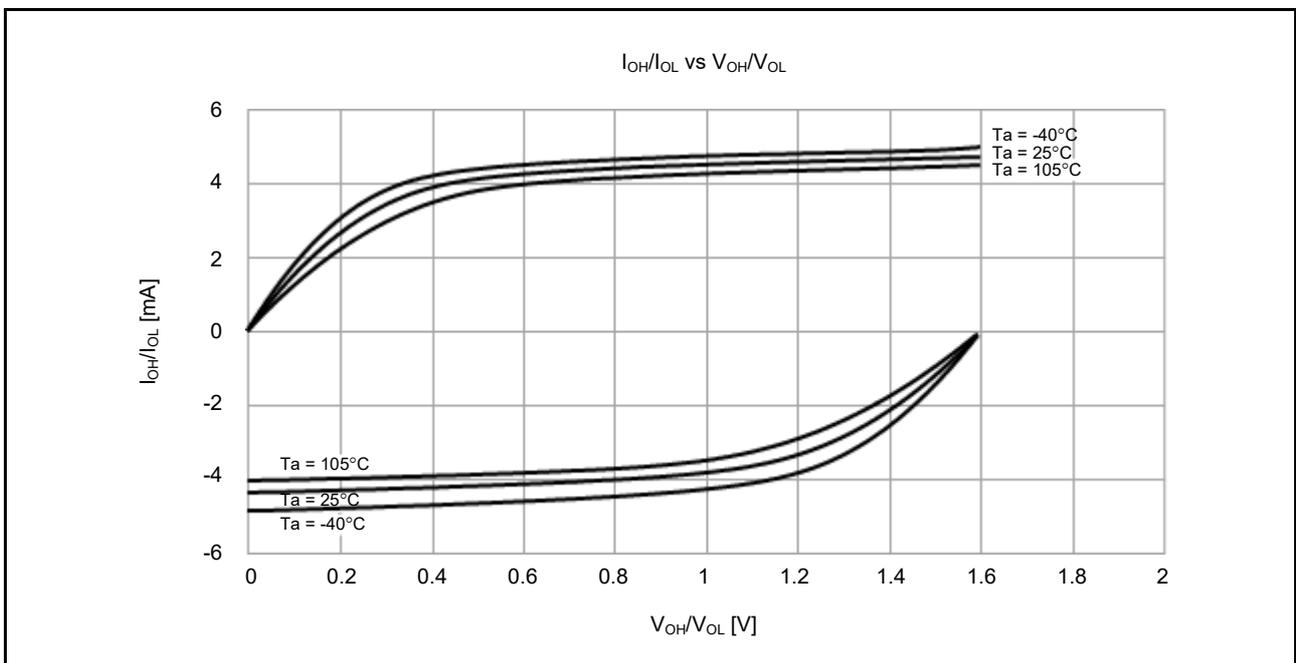


Figure 2.8 VOH/VOL and IOH/IOL temperature characteristics at VCC = 1.6 V when middle drive output is selected (reference data, except for P914 and P915)

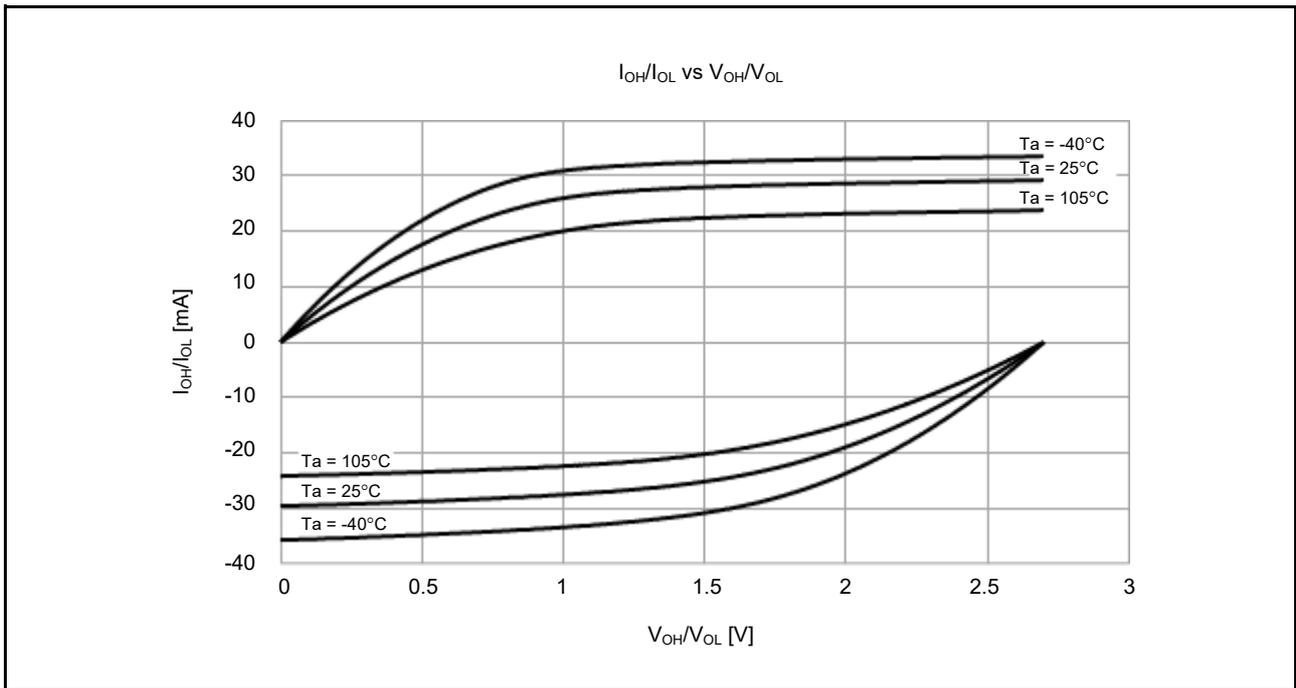


Figure 2.9 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 2.7$ V when middle drive output is selected (reference data, except for P914 and P915)

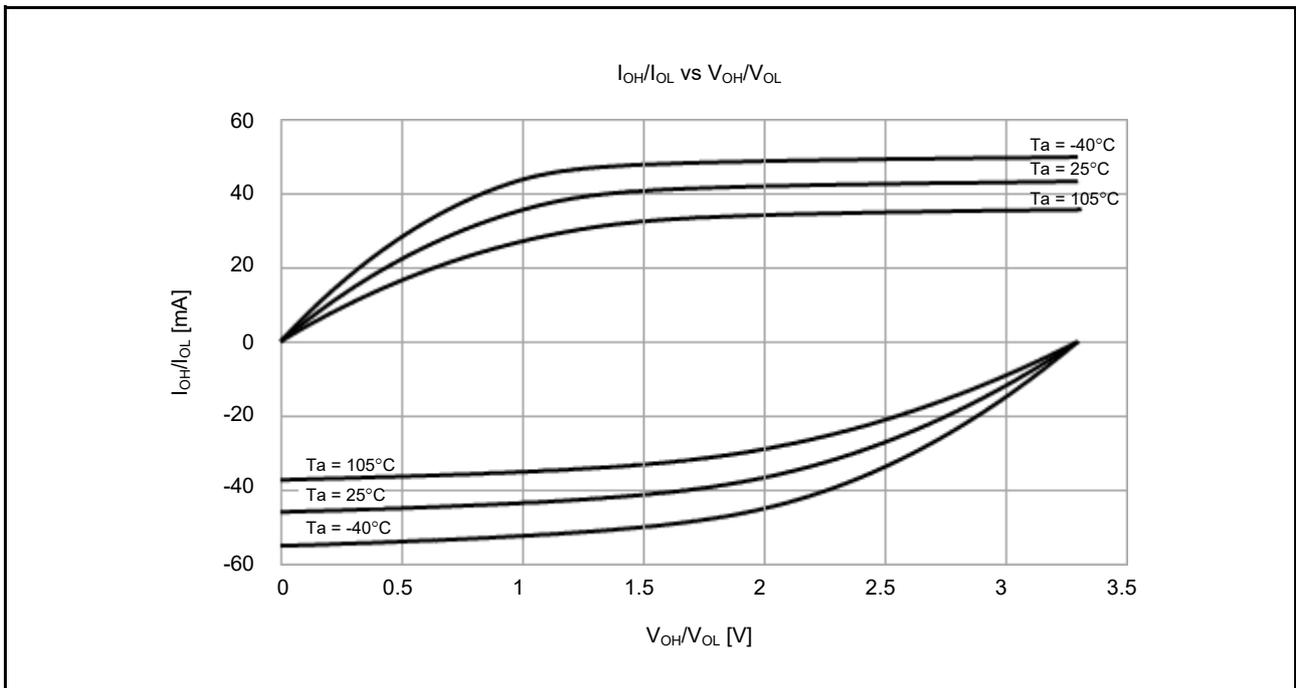


Figure 2.10 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 3.3$ V when middle drive output is selected (reference data, except for P914 and P915)

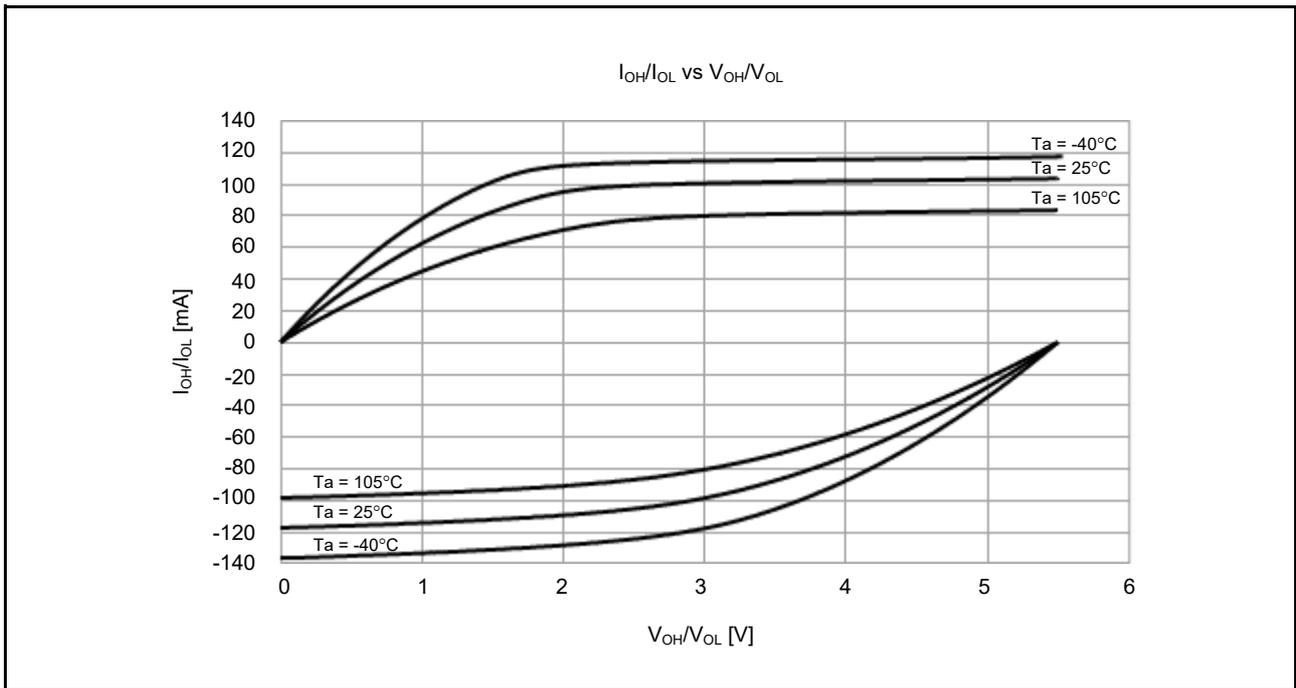


Figure 2.11 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 5.5$ V when middle drive output is selected (reference data, except for P914 and P915)

2.2.7 Output Characteristics for P408 and P409 I/O Pins (Middle Drive Capacity)

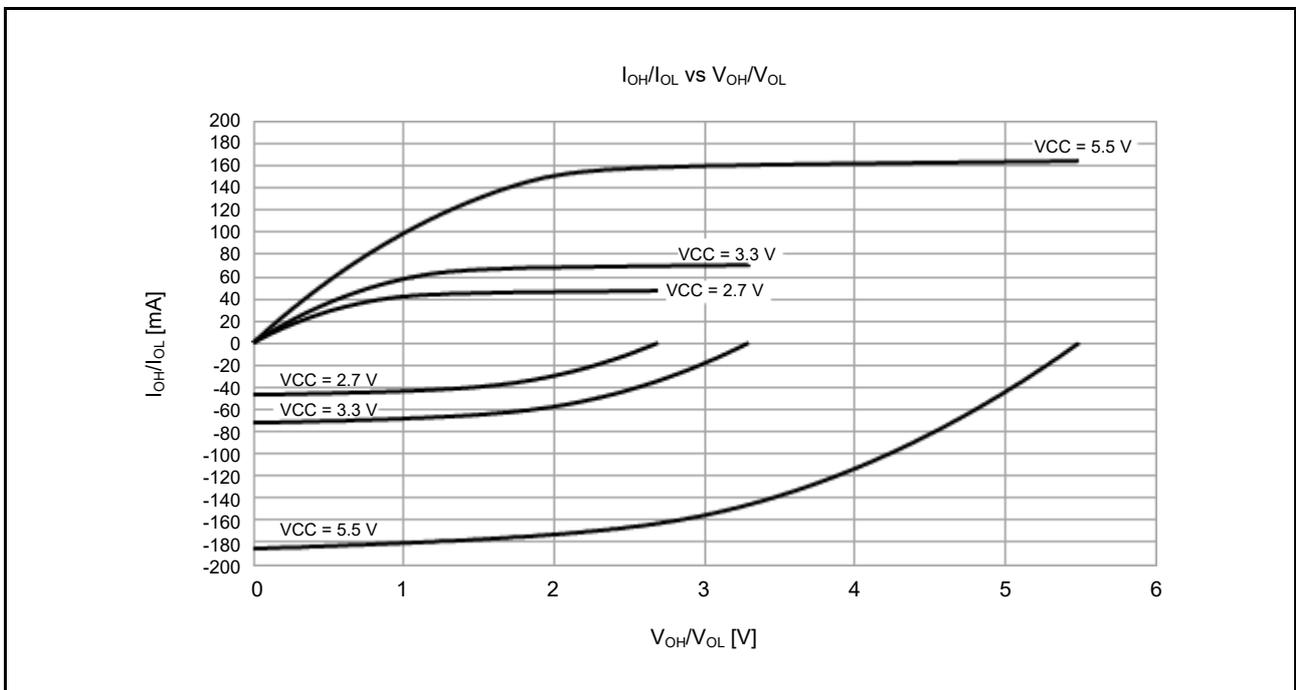


Figure 2.12 V_{OH}/V_{OL} and I_{OH}/I_{OL} voltage characteristics at $T_a = 25^\circ\text{C}$ when middle drive output is selected (reference data)

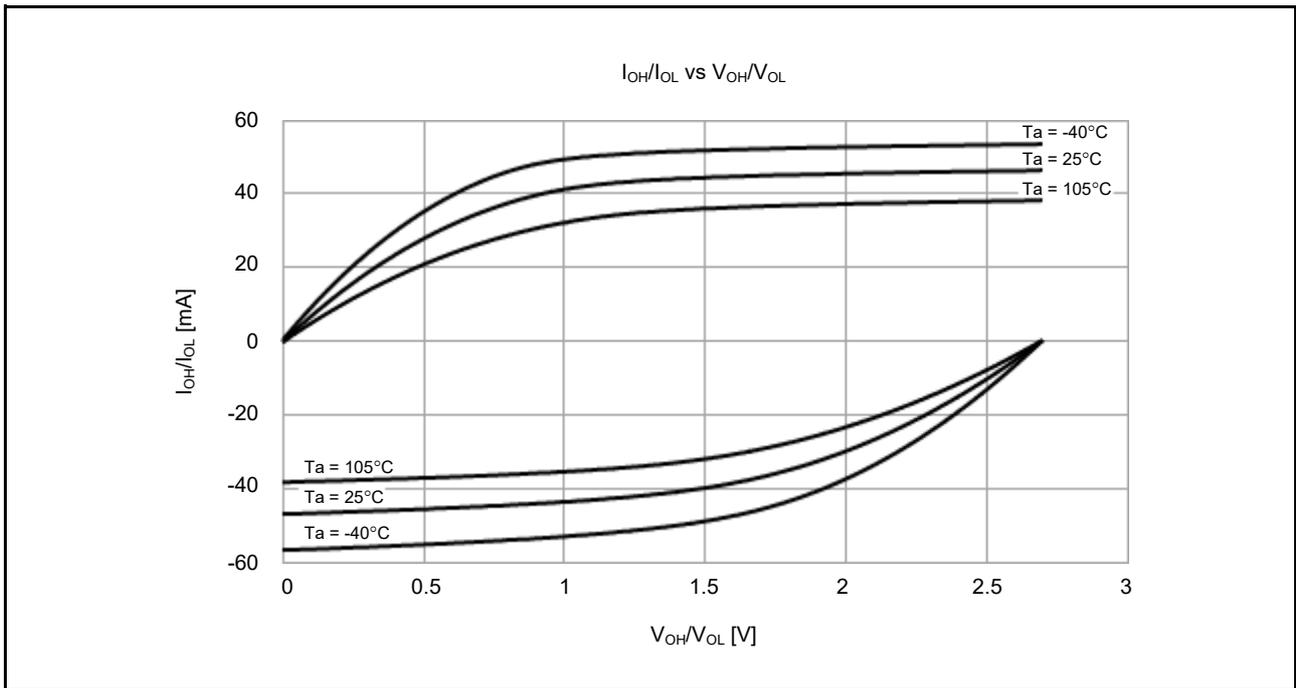


Figure 2.13 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 2.7$ V when middle drive output is selected (reference data)

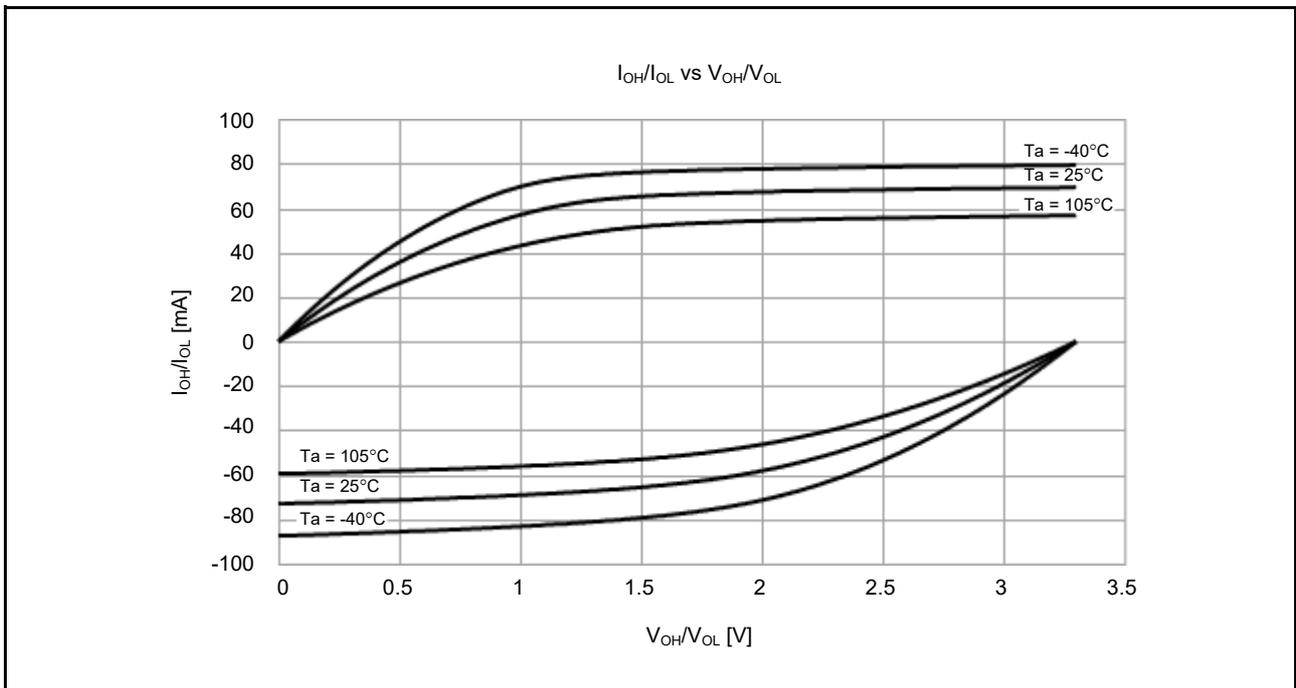


Figure 2.14 V_{OH}/V_{OL} and I_{OH}/I_{OL} temperature characteristics at $V_{CC} = 3.3$ V when middle drive output is selected (reference data)

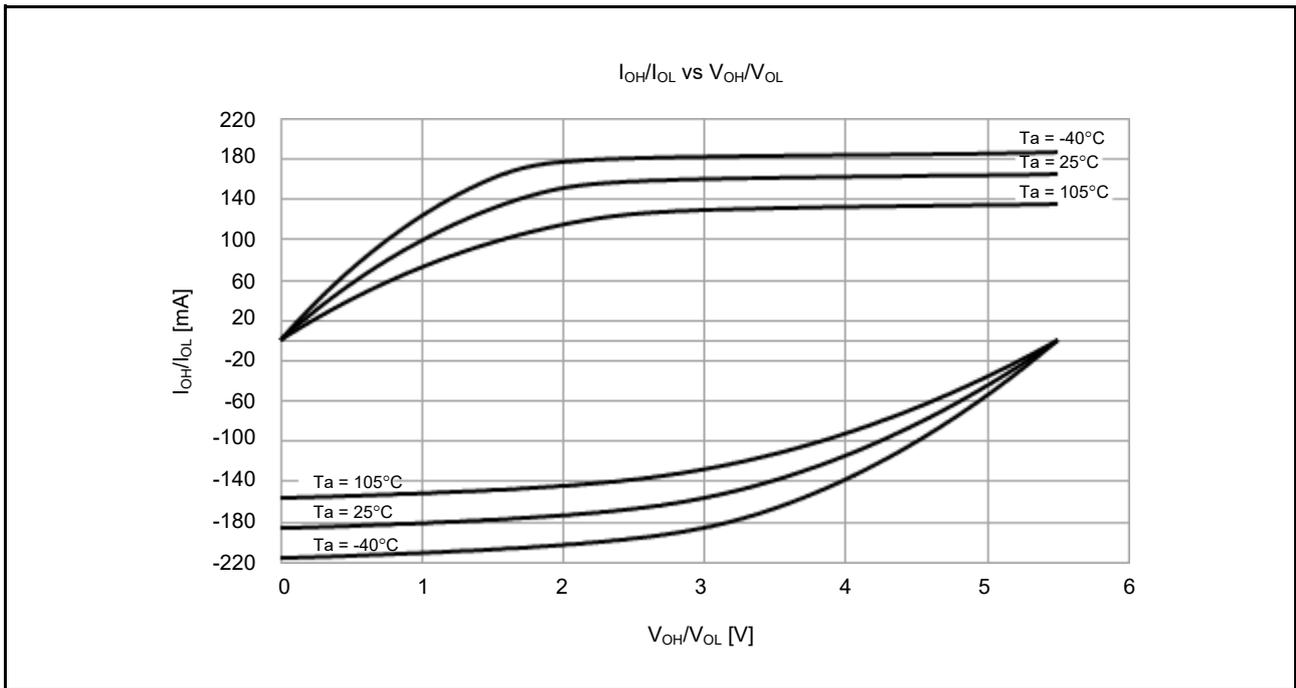


Figure 2.15 VOH/VOL and IOH/IOL temperature characteristics at VCC = 5.5 V when middle drive output is selected (reference data)

2.2.8 Output Characteristics for IIC I/O Pins

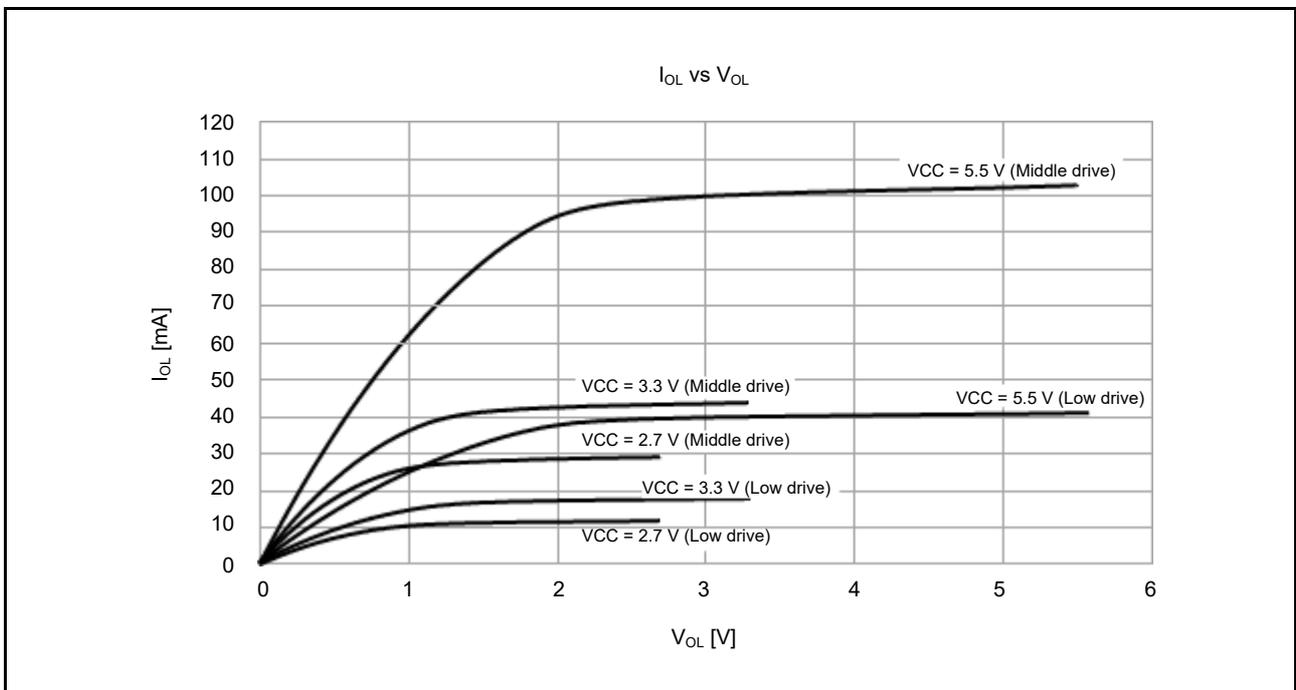


Figure 2.16 VOH/VOL and IOH/IOL voltage characteristics at Ta = 25°C

2.2.9 Operating and Standby Current

Table 2.11 Operating and standby current (1) (1 of 2)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | | | Symbol | Typ*9 | Max | Unit | Test Conditions | | | |
|---|---------------------------------|---------------------------------|--|--|-----------------|-----------------|------|-----------------|----|----|----|
| Supply current*1 | High-speed mode*2 | Normal mode | All peripheral clock disabled, while (1) code executing from flash*5 | ICLK = 32 MHz | I _{CC} | 4.2 | - | mA | *7 | | |
| | | | | ICLK = 16 MHz | | 2.6 | - | | | | |
| | | | | ICLK = 8 MHz | | 1.8 | - | | | | |
| | | | All peripheral clock disabled, CoreMark code executing from flash*5 | ICLK = 32 MHz | | 6.2 | - | | | | |
| | | | | ICLK = 16 MHz | | 3.6 | - | | | | |
| | | | | ICLK = 8 MHz | | 2.4 | - | | | | |
| | | | All peripheral clock enabled, while (1) code executing from flash*5 | ICLK = 32 MHz | | 10.5 | - | | | *8 | |
| | | | | ICLK = 16 MHz | | 5.8 | - | | | | |
| | | | | ICLK = 8 MHz | | 3.4 | - | | | | |
| | | Sleep mode | All peripheral clock disabled*5 | ICLK = 32 MHz | 1.6 | - | *7 | | | | |
| | | | | ICLK = 16 MHz | 1.2 | - | | | | | |
| | | | | ICLK = 8 MHz | 0.9 | - | | | | | |
| | | | All peripheral clock enabled*5 | ICLK = 32 MHz | 7.5 | - | *8 | | | | |
| | | | | ICLK = 16 MHz | 4.1 | - | | | | | |
| | | | | ICLK = 8 MHz | 2.4 | - | | | | | |
| | Increase during BGO operation*6 | | | | | 2.5 | - | - | | | |
| | Middle-speed mode*2 | Normal mode | All peripheral clock disabled, while (1) code executing from flash*5 | ICLK = 12 MHz | I _{CC} | 1.9 | - | mA | *7 | | |
| | | | | ICLK = 8 MHz | | 1.6 | - | | | | |
| | | | | All peripheral clock disabled, CoreMark code executing from flash*5 | | ICLK = 12 MHz | 2.7 | | | - | |
| | | | All peripheral clock disabled, CoreMark code executing from flash*5 | ICLK = 8 MHz | | 2.1 | - | | | | |
| | | | | All peripheral clock enabled, while (1) code executing from flash*5 | | ICLK = 12 MHz | 4.3 | | | - | *8 |
| All peripheral clock enabled, while (1) code executing from flash*5 | | | ICLK = 8 MHz | 3.1 | | - | | | | | |
| | | | All peripheral clock enabled, code executing from flash*5 | ICLK = 12 MHz | | - | 8.1 | | | | |
| Sleep mode | | | All peripheral clock disabled*5 | ICLK = 12 MHz | | 0.8 | - | | | *7 | |
| | | | | ICLK = 8 MHz | | 0.8 | - | | | | |
| | | All peripheral clock enabled*5 | | ICLK = 12 MHz | 3.0 | - | *8 | | | | |
| | | ICLK = 8 MHz | 2.2 | - | | | | | | | |
| | | Increase during BGO operation*6 | | | | | 2.5 | | - | - | |
| | | Low-speed mode*3 | Normal mode | All peripheral clock disabled, while (1) code executing from flash*5 | ICLK = 1 MHz | I _{CC} | 0.3 | | - | mA | *7 |
| All peripheral clock disabled, CoreMark code executing from flash*5 | | | | | ICLK = 1 MHz | | 0.4 | | - | | |
| All peripheral clock enabled, while (1) code executing from flash*5 | | | | | ICLK = 1 MHz | | 0.5 | | - | | |
| All peripheral clock enabled, code executing from flash*5 | ICLK = 1 MHz | | | - | 2.0 | | | | | | |
| Sleep mode | All peripheral clock disabled*5 | | | ICLK = 1 MHz | 0.2 | | - | *7 | | | |
| | | | | All peripheral clock enabled*5 | ICLK = 1 MHz | | 0.4 | - | *8 | | |

Table 2.11 Operating and standby current (1) (2 of 2)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | | | | Symbol | Typ*9 | Max | Unit | Test Conditions | |
|--------------------------------|---------------------|-------------|--|-------------------|-----------------|-----------------|-------|------|-----------------|----|
| Supply current*1 | Low-voltage mode*3 | Normal mode | All peripheral clock disabled, while (1) code executing from flash*5 | ICLK = 4 MHz | I _{CC} | 1.5 | - | mA | *7 | |
| | | | All peripheral clock disabled, CoreMark code executing from flash*5 | ICLK = 4 MHz | | 1.7 | - | | | |
| | | | All peripheral clock enabled, while (1) code executing from flash*5 | ICLK = 4 MHz | | 2.3 | - | | | *8 |
| | | | All peripheral clock enabled, code executing from flash*5 | ICLK = 4 MHz | | - | 4.0 | | | |
| | | Sleep mode | All peripheral clock disabled*5 | ICLK = 4 MHz | | 0.9 | - | | *7 | |
| | | | All peripheral clock enabled*5 | ICLK = 4 MHz | | 1.7 | - | | *8 | |
| | Subosc-speed mode*4 | Normal mode | All peripheral clock disabled, while (1) code executing from flash*5 | ICLK = 32.768 kHz | I _{CC} | 5.9 | - | μA | *7 | |
| | | | All peripheral clock enabled, while (1) code executing from flash*5 | ICLK = 32.768 kHz | | 13.0 | - | | *8 | |
| | | | All peripheral clock enabled, code executing from flash*5 | ICLK = 32.768 kHz | | 128.3 (17.8)*10 | 163.7 | | | |
| | | Sleep mode | All peripheral clock disabled*5 | ICLK = 32.768 kHz | | 3.2 | - | | *7 | |
| All peripheral clock enabled*5 | | | ICLK = 32.768 kHz | 10.0 | | - | *8 | | | |

Note 1. Supply current values do not include output charge/discharge current from all pins. The values apply when internal pull-up MOSs are in the off state.

Note 2. The clock source is HOCO.

Note 3. The clock source is MOCO.

Note 4. The clock source is the sub-clock oscillator.

Note 5. This does not include BGO operation.

Note 6. This is the increase for programming or erasure of the flash memory for data storage during program execution.

Note 7. PCLKB and PCLKD are set to divided by 64.

Note 8. PCLKB and PCLKD are the same frequency as that of ICLK.

Note 9. VCC = 3.3 V.

Note 10. MOCO and DAC is stopped.

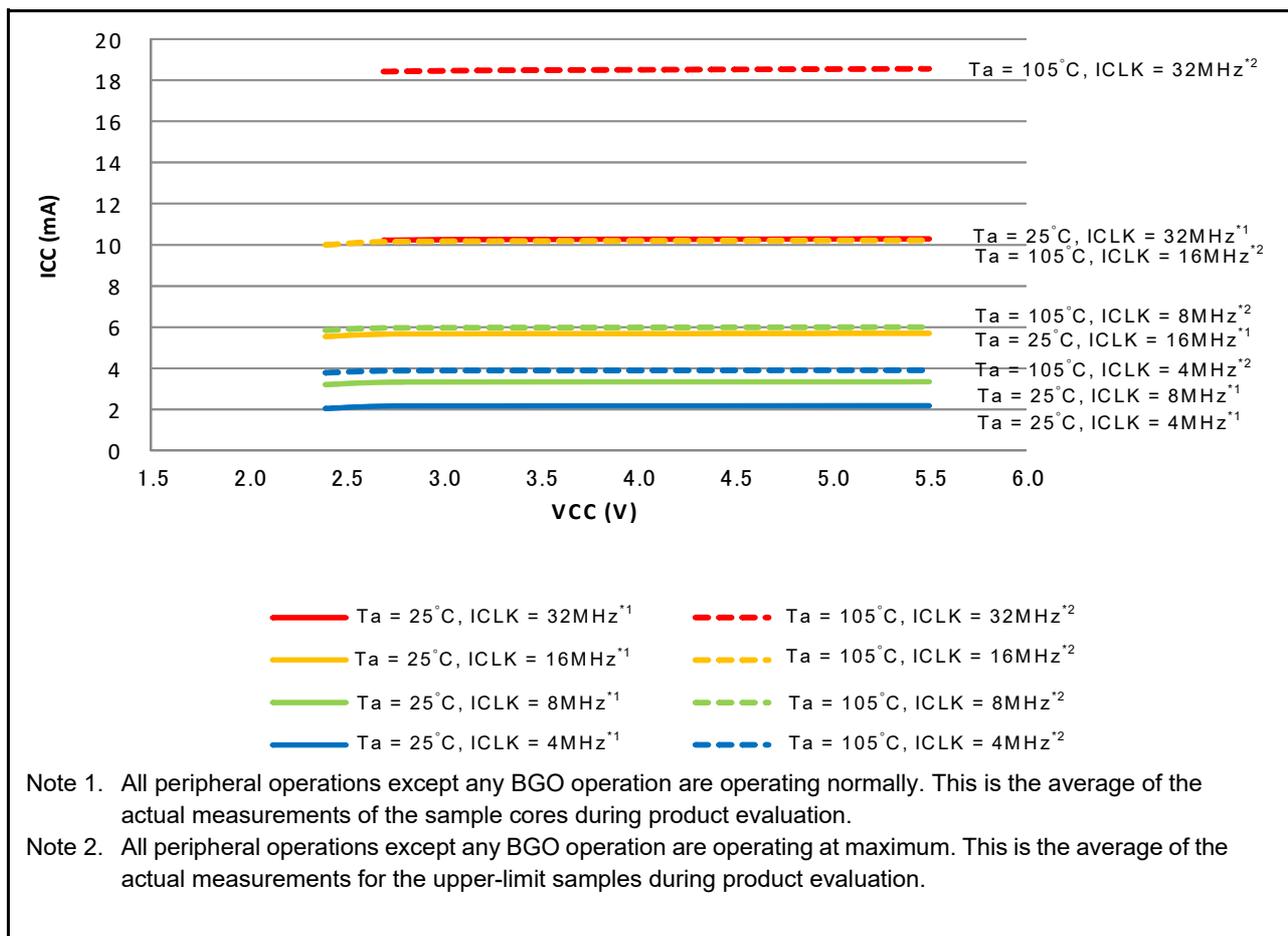


Figure 2.17 Voltage dependency in high-speed mode (reference data)

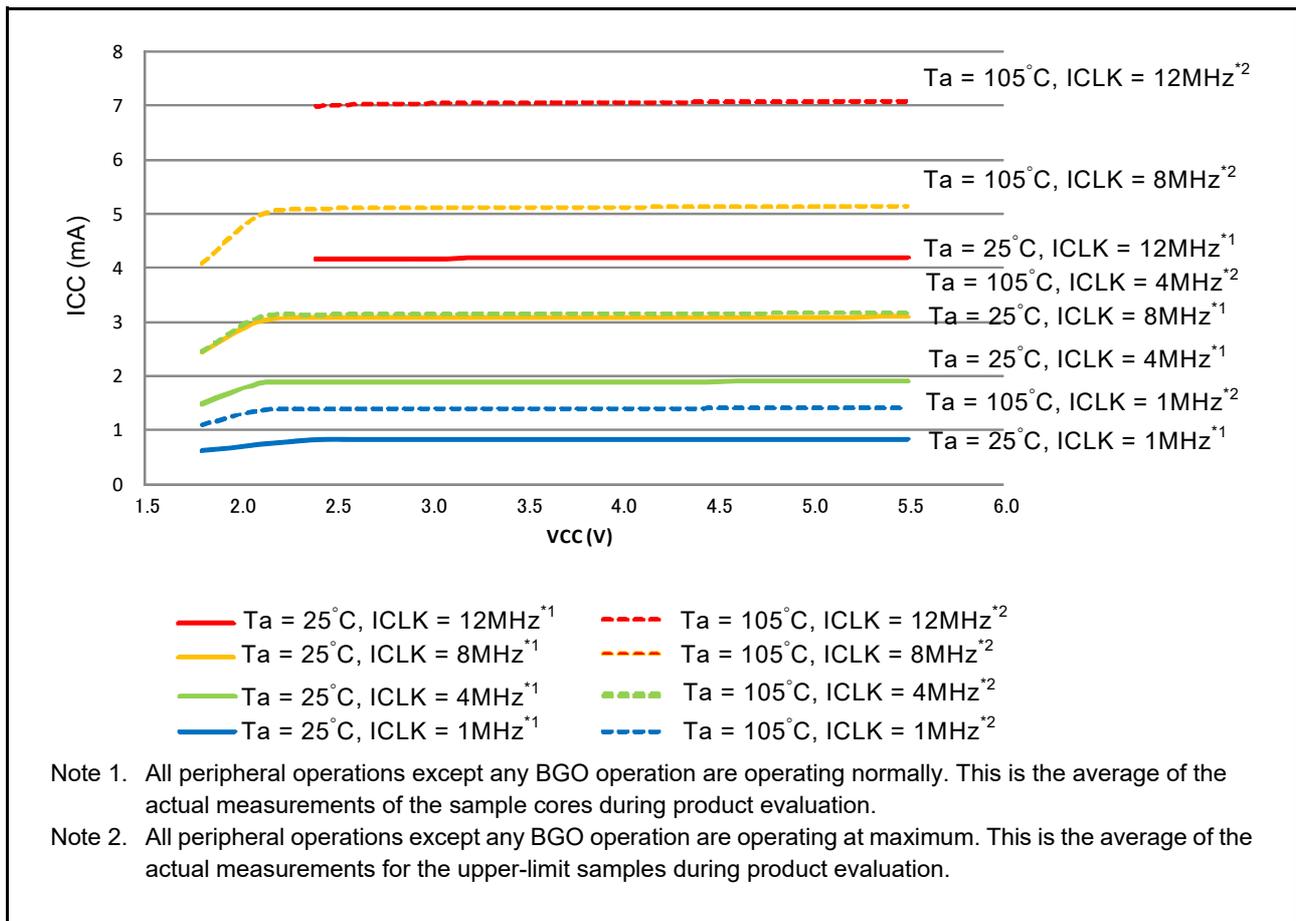


Figure 2.18 Voltage dependency in middle-speed mode (reference data)

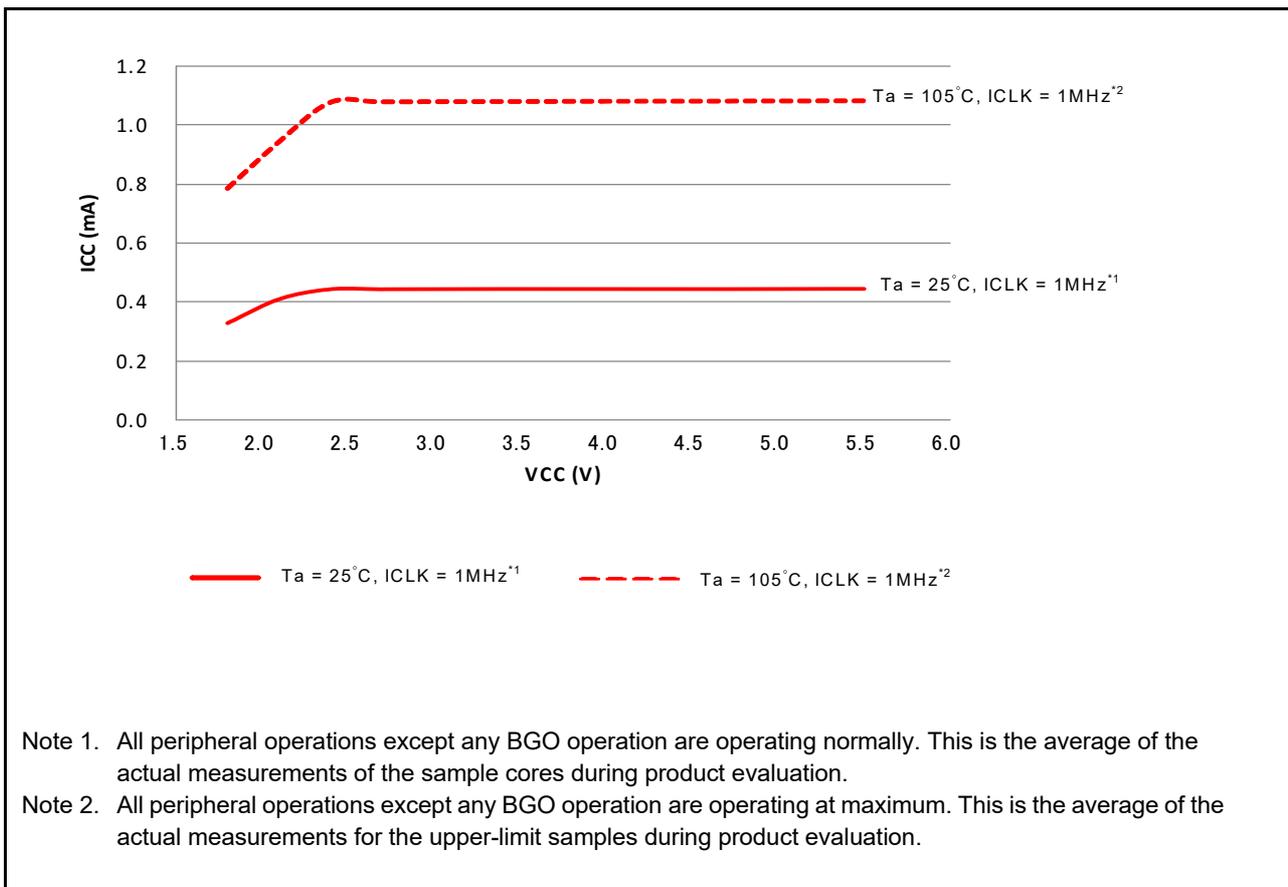


Figure 2.19 Voltage dependency in low-speed mode (reference data)

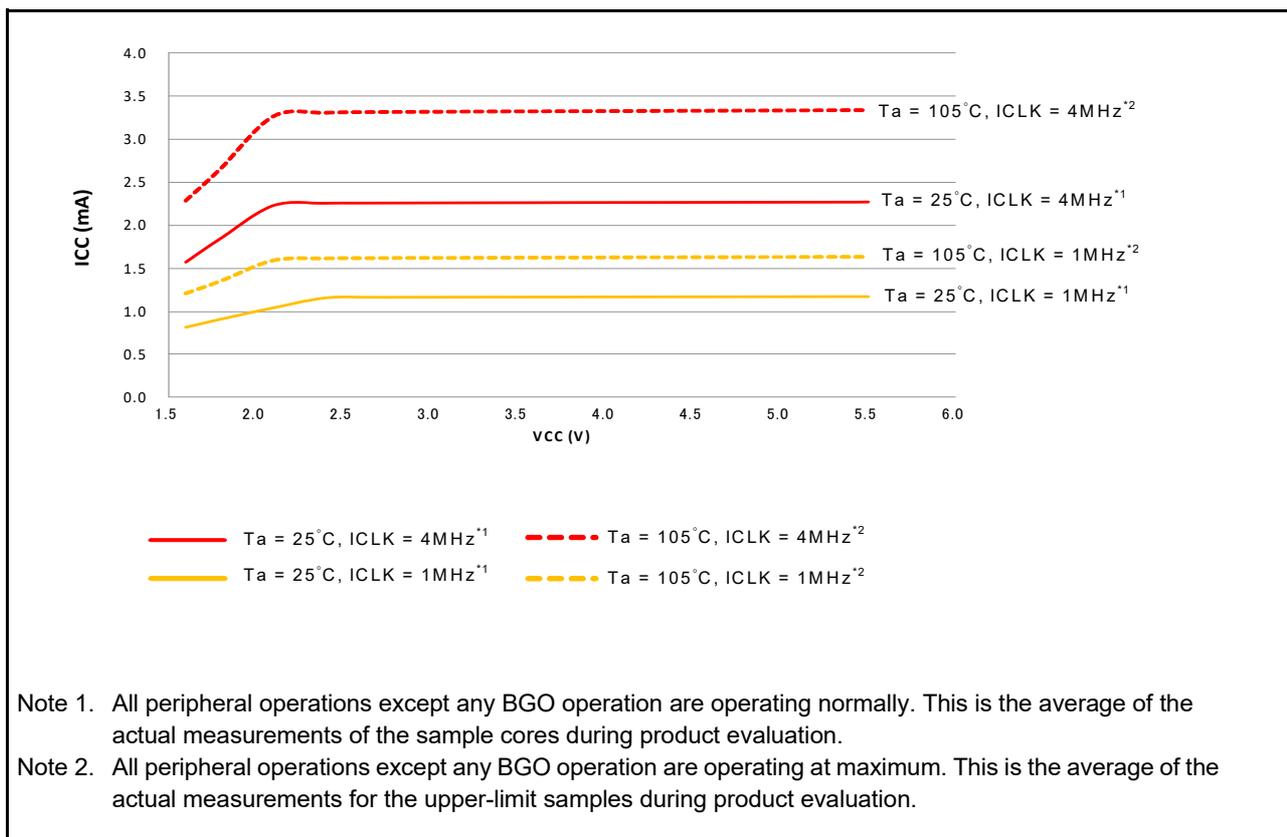


Figure 2.20 Voltage dependency in low-voltage mode (reference data)

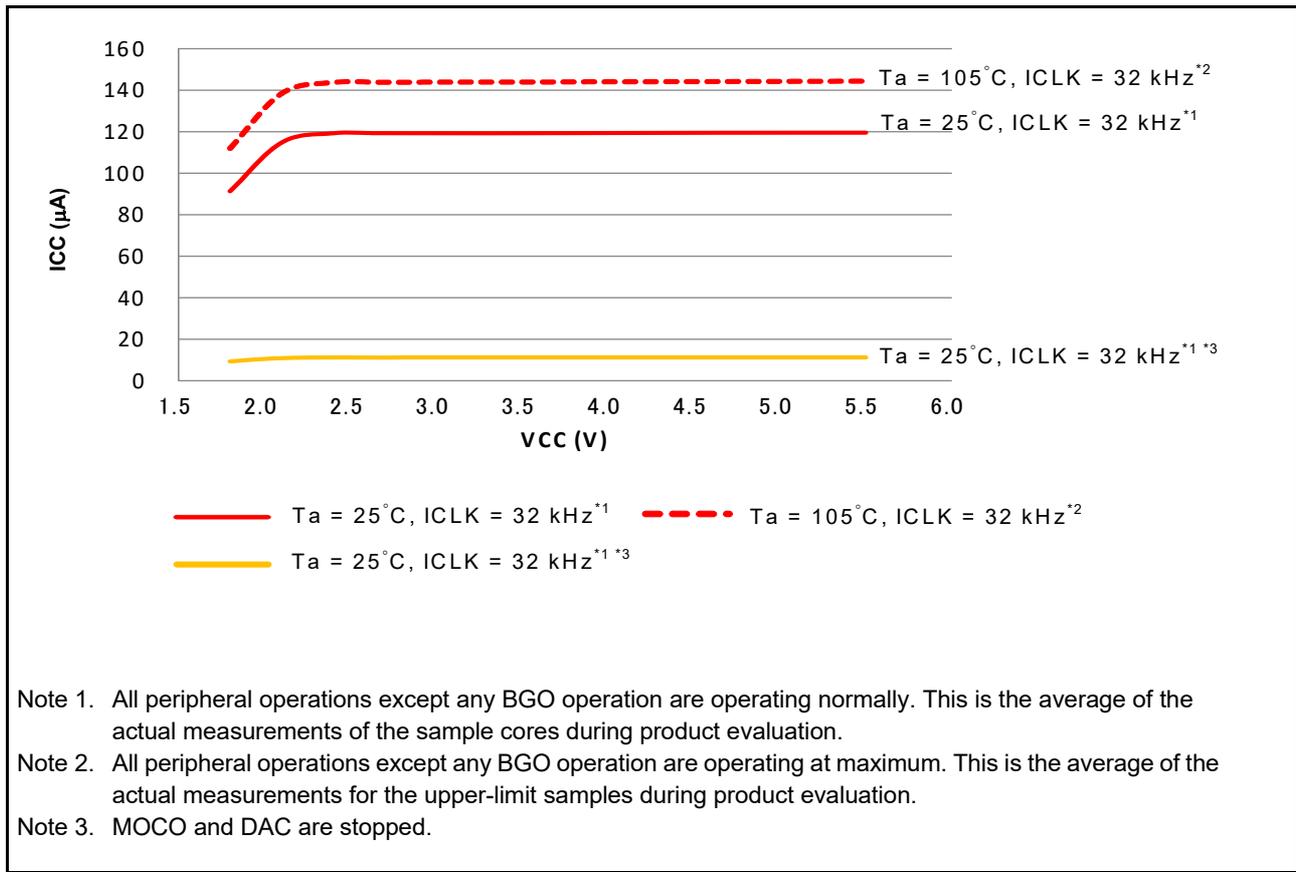


Figure 2.21 Voltage dependency in subosc-speed mode (reference data)

Table 2.12 Operating and standby current (2)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | Symbol | Typ*3 | Max | Unit | Test conditions | |
|------------------|---|-----------------|------------------------|-----|------|-----------------|---|
| Supply current*1 | Software Standby mode*2 | I _{CC} | T _a = 25°C | 0.5 | 2.0 | µA | - |
| | | | T _a = 55°C | 0.8 | 7.0 | | |
| | | | T _a = 85°C | 2.9 | 12.0 | | |
| | | | T _a = 105°C | 6.3 | 42.0 | | |
| | Increment for RTC operation with low-speed on-chip oscillator*4 | | | 0.4 | - | | - |
| | Increment for RTC operation with sub-clock oscillator*4 | | | 0.5 | - | | SOMCR.SODRV[1:0] are 11b (Low power mode 3) |
| | | | | 1.6 | - | | SOMCR.SODRV[1:0] are 00b (normal mode) |

Note 1. Supply current values do not include output charge/discharge current from all pins. The values apply when internal pull-up MOS transistors are in the off state.

Note 2. The IWDT and LVD are not operating.

Note 3. VCC = 3.3 V.

Note 4. Includes the current of low-speed on-chip oscillator or sub-oscillation circuit.

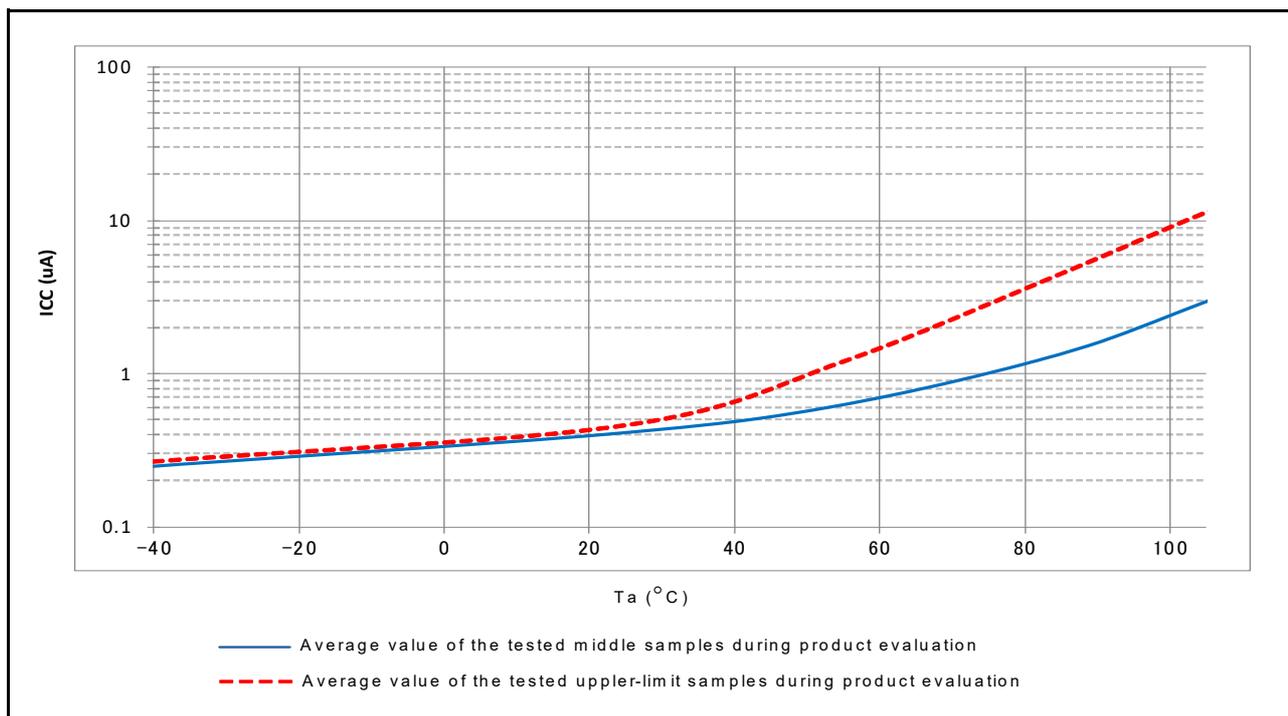
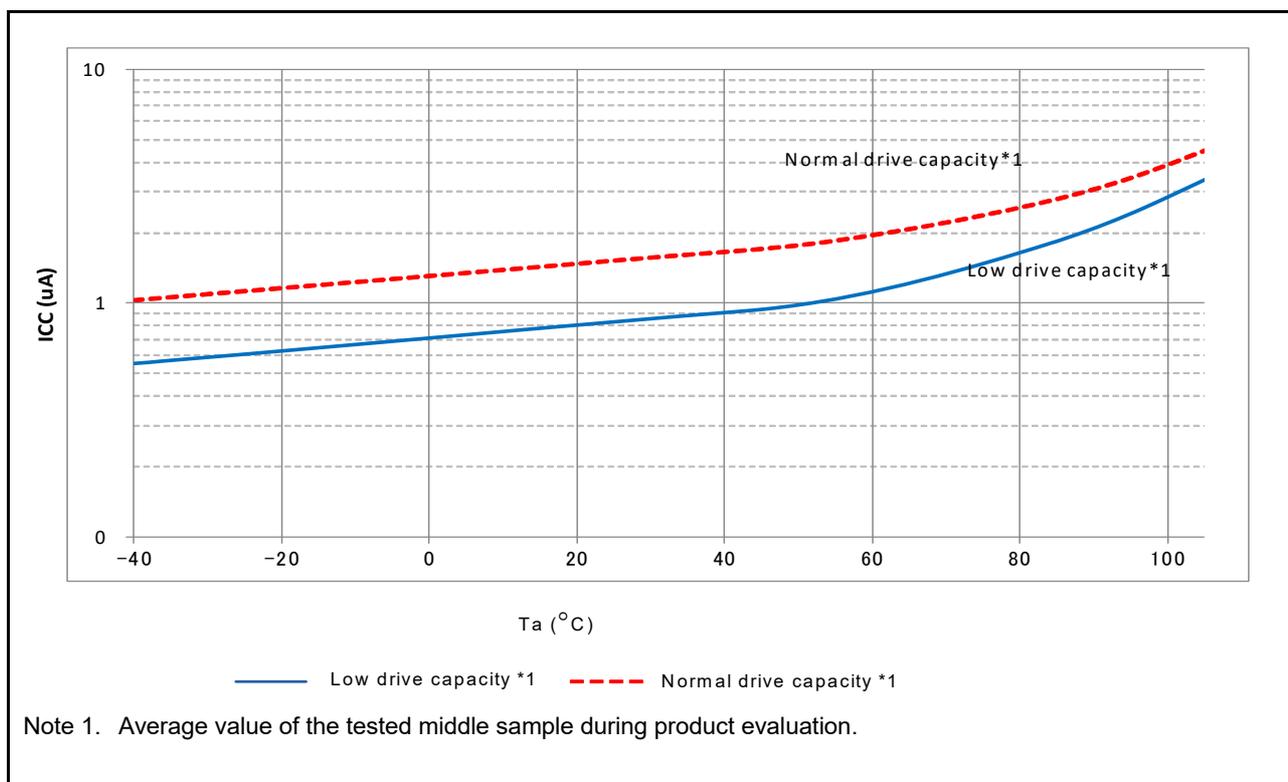


Figure 2.22 Temperature dependency in Software Standby mode (reference data)



Note 1. Average value of the tested middle sample during product evaluation.

Figure 2.23 Temperature dependency of RTC operation (reference data)

Table 2.13 Operating and standby current (3)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions | |
|---|---|----------------------|------------------|-------------------------------|-----|------|-----------------|---|
| Analog power supply current | During A/D conversion (at high-speed conversion) | I _{AVCC} | - | - | 3.0 | mA | - | |
| | During A/D conversion (at low-power conversion) | | - | - | 1.0 | mA | - | |
| | During D/A conversion *1 (per channel) | | - | - | 1.6 | mA | - | |
| | Waiting for A/D and D/A conversion (all units)*5 | | - | - | 1.0 | μA | - | |
| Reference power supply current | During A/D conversion | I _{REFH0} | - | - | 150 | μA | - | |
| | Waiting for A/D conversion (all units) | | - | - | 60 | nA | - | |
| Temperature sensor | | I _{TNS} | - | 75 | - | μA | - | |
| Low-power analog comparator (ACMPLP) operating current | Window comparator (high-speed mode) | I _{CMPLP} | - | 15 | - | μA | - | |
| | Window comparator (low-speed mode) | | - | 3 | - | μA | - | |
| | Comparator (high-speed mode) | | - | 10 | - | μA | - | |
| | Comparator (low-speed mode) | | - | 2 | - | μA | - | |
| High-speed analog comparator (ACMPHS) operating current | | I _{CMPHS} | - | 70 | 100 | μA | AVCC0 ≥ 2.7V | |
| Operational Amplifier operating current | Low power mode | I _{AMP} | 1-unit operating | - | 1.0 | 2.0 | μA | - |
| | | | 2-unit operating | - | 1.5 | 3.0 | μA | - |
| | | | 3-unit operating | - | 2.0 | 3.5 | μA | - |
| | | | 4-unit operating | - | 2.5 | 4.5 | μA | - |
| | High speed mode | | 1-unit operating | - | 200 | 280 | μA | - |
| | | | 2-unit operating | - | 320 | 450 | μA | - |
| | | | 3-unit operating | - | 440 | 620 | μA | - |
| | | | 4-unit operating | - | 560 | 790 | μA | - |
| USB operating current | During USB communication under the following settings and conditions: • Function controller is in Full-Speed mode and - Bulk OUT transfer is (64 bytes) × 1 - Bulk IN transfer is (64 bytes) × 1 • Host device is connected by a 1-meter USB cable from the USB port. | I _{USBF} *2 | - | 3.6 (VCC) 1.1 (VCC_USB)*4 | - | mA | - | |
| | During suspended state under the following setting and conditions: • Function controller is in Full-Speed mode (the USB_DP pin is pulled up) • Software Standby mode • Host device is connected by a 1-meter USB cable from the USB port. | I _{SUSP} *3 | - | 0.35 (VCC) 170 (VCC_USB)*4 | - | μA | - | |
| PWM Delay Generation Circuit current | PCLKD = 64 MHz, DLL Mode = 5-bit mode | I _{CC} | - | 3.3 | 4.6 | mA | - | |
| | PCLKD = 64 MHz, DLL Mode = 4-bit mode | | - | 3.0 | 4.2 | mA | - | |
| | PCLKD = 32 MHz, DLL Mode = 5-bit mode | | - | 2.0 | 2.8 | mA | - | |

Note 1. The reference power supply current is included in the power supply current value for D/A conversion.

Note 2. Current is consumed only by the USBFS.

Note 3. Includes the current supplied from the pull-up resistor of the USB_DP pin to the pull-down resistor of the host device, in addition to the current consumed by the MCU in the suspended state.

Note 4. When VCC = VCC_USB = 3.3 V.

Note 5. When the MCU is in Software Standby mode or the MSTPCRD.MSTPD16 (ADC140 module-stop bit) is in the module-stop state.

2.2.10 VCC Rise and Fall Gradient and Ripple Frequency

Table 2.14 Rise and fall gradient characteristics

Conditions: VCC = AVCC0 = 0 to 5.5 V

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions |
|------------------------------|--|--------|------|-----|-----|------|-----------------|
| Power-on VCC rising gradient | Voltage monitor 0 reset disabled at startup | SrVCC | 0.02 | - | 2 | ms/V | - |
| | Voltage monitor 0 reset enabled at startup*1, *2 | | | | - | | |
| | SCI boot mode*2 | | | | 2 | | |

Note 1. When OFS1.LVDAS = 0.

Note 2. At boot mode, the reset from voltage monitor 0 is disabled regardless of the value of OFS1.LVDAS bit.

Table 2.15 Rising and falling gradient and ripple frequency characteristics

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

The ripple voltage must meet the allowable ripple frequency $f_r(VCC)$ within the range between the VCC upper limit (5.5 V) and lower limit (1.6 V).

When the VCC change exceeds VCC $\pm 10\%$, 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 | kHz | Figure 2.24 $V_r(VCC) \leq VCC \times 0.2$ |
| | | - | - | 1 | MHz | Figure 2.24 $V_r(VCC) \leq VCC \times 0.08$ |
| | | - | - | 10 | MHz | Figure 2.24 $V_r(VCC) \leq VCC \times 0.06$ |
| Allowable voltage change rising and falling gradient | dt/dVCC | 1.0 | - | - | ms/V | When VCC change exceeds VCC $\pm 10\%$ |

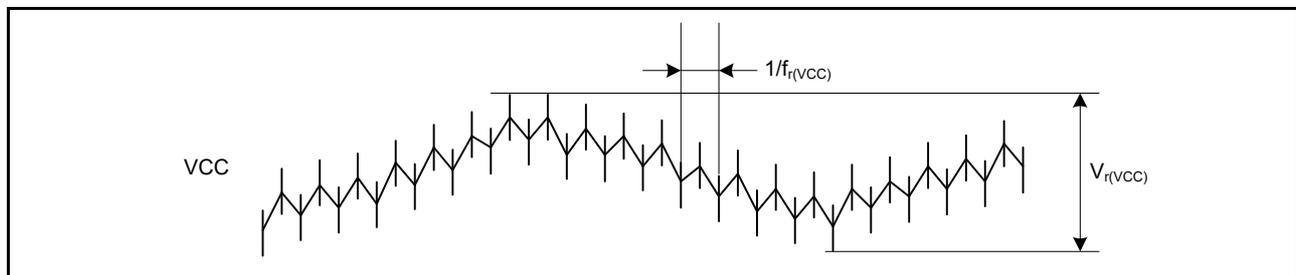


Figure 2.24 Ripple waveform

2.2.11 Thermal Characteristics

Maximum value of junction temperature (T_j) must not exceed the value of [section 2.2.1, \$T_j/T_a\$ Definition](#).

T_j is calculated by either of the following equations.

- $T_j = T_a + \theta_{ja} \times \text{Total power consumption}$
- $T_j = T_t + \Psi_{jt} \times \text{Total power consumption}$

T_j : Junction temperature ($^{\circ}\text{C}$)

T_a : Ambient temperature ($^{\circ}\text{C}$)

T_t : Top center case temperature ($^{\circ}\text{C}$)

θ_{ja} : Thermal resistance of “Junction”-to-“Ambient” ($^{\circ}\text{C}/\text{W}$)

Ψ_{jt} : Thermal resistance of “Junction”-to-“Top center case” ($^{\circ}\text{C}/\text{W}$)

- Total power consumption = Voltage \times (Leakage current + Dynamic current)
- Leakage current of IO = $\Sigma (IOL \times VOL) / \text{Voltage} + \Sigma (|IOH| \times |VCC - VOH|) / \text{Voltage}$

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

Cin: Input capacitance

Cload: Output capacitance

Regarding θ_{ja} and Ψ_{jt} , see [Table 2.16](#).

Table 2.16 Thermal Resistance

| Parameter | Package | Symbol | Value | Unit | Test conditions | |
|--------------------|-------------|---------------|--------|------|------------------------------|------------------------------|
| Thermal Resistance | 32-pin QFN | θ_{ja} | 24.2*1 | °C/W | JESD 51-2 and 51-7 compliant | |
| | 48-pin QFN | | 21.8*1 | | | |
| | 32-pin LQFP | | 56.2 | | | |
| | 48-pin LQFP | | 57.7 | | | |
| | 64-pin LQFP | | 48.9 | | | |
| | 36-pin LGA | | 32.9 | | | JESD 51-2 and 51-9 compliant |
| | 32-pin QFN | Ψ_{jt} | 0.17*1 | °C/W | JESD 51-2 and 51-7 compliant | |
| | 48-pin QFN | | 0.17*1 | | | |
| | 32-pin LQFP | | 1.71 | | | |
| | 48-pin LQFP | | 1.71 | | | |
| | 64-pin LQFP | | 1.22 | | | |
| | 36-pin LGA | | 0.10 | | | JESD 51-2 and 51-9 compliant |

Note: 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, refer to the JEDEC standards.

Note 1. This value applies when the Exposed die pad for this purpose is connected to VSS.

2.3 AC Characteristics

2.3.1 Frequency

Table 2.17 Operation frequency in high-speed operating mode

Conditions: VCC = AVCC0 = 2.4 to 5.5 V

| Parameter | | Symbol | Min | Typ | Max*5 | Unit | |
|---------------------|---------------------------------------|--------|--------------|----------|-------|------|-----|
| Operation frequency | System clock (ICLK)*1, *2, *4 | f | 2.7 to 5.5 V | 0.032768 | - | 32 | MHz |
| | | | 2.4 to 2.7 V | 0.032768 | - | 16 | |
| | Peripheral module clock (PCLKB)*4 | | 2.7 to 5.5 V | - | - | 32 | |
| | | | 2.4 to 2.7 V | - | - | 16 | |
| | Peripheral module clock (PCLKD)*3, *4 | | 2.7 to 5.5 V | - | - | 64 | |
| | | | 2.4 to 2.7 V | - | - | 16 | |

- Note 1. The lower-limit frequency of ICLK is 1 MHz while programming or erasing the flash memory. When using ICLK for programming or erasing the flash memory at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.
- Note 2. The frequency accuracy of ICLK must be $\pm 3.5\%$ during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.
- Note 3. The lower-limit frequency of PCLKD is 4 MHz at 2.4 V or above and 1 MHz at below 2.4 V when the 14-bit A/D converter is in use.
- Note 4. See section 8, Clock Generation Circuit in User's Manual for the relationship of frequencies between ICLK, PCLKB, and PCLKD.
- Note 5. The maximum value of operation frequency does not include internal oscillator errors. For details on the range of guaranteed operation, see [Table 2.22, Clock timing](#).

Table 2.18 Operation frequency in middle-speed mode

Conditions: VCC = AVCC0 = 1.8 to 5.5 V

| Parameter | | Symbol | Min | Typ | Max*5 | Unit | |
|---------------------|---------------------------------------|--------|--------------|----------|-------|------|-----|
| Operation frequency | System clock (ICLK)*1, *2, *4 | f | 2.7 to 5.5 V | 0.032768 | - | 12 | MHz |
| | | | 2.4 to 2.7 V | 0.032768 | - | 12 | |
| | | | 1.8 to 2.4 V | 0.032768 | - | 8 | |
| | Peripheral module clock (PCLKB)*4 | | 2.7 to 5.5 V | - | - | 12 | |
| | | | 2.4 to 2.7 V | - | - | 12 | |
| | | | 1.8 to 2.4 V | - | - | 8 | |
| | Peripheral module clock (PCLKD)*3, *4 | | 2.7 to 5.5 V | - | - | 12 | |
| | | | 2.4 to 2.7 V | - | - | 12 | |
| | | | 1.8 to 2.4 V | - | - | 8 | |

- Note 1. The lower-limit frequency of ICLK is 1 MHz while programming or erasing the flash memory. When using ICLK for programming or erasing the flash memory at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.
- Note 2. The frequency accuracy of ICLK must be $\pm 3.5\%$ during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.
- Note 3. The lower-limit frequency of PCLKD is 4 MHz at 2.4 V or above and 1 MHz at below 2.4 V when the 14-bit A/D converter is in use.
- Note 4. See section 8, Clock Generation Circuit in User's Manual for the relationship of frequencies between ICLK, PCLKB, and PCLKD.
- Note 5. The maximum value of operation frequency does not include internal oscillator errors. For details on the range of guaranteed operation, see [Table 2.22, Clock timing](#).

Table 2.19 Operation frequency in low-speed mode

Conditions: VCC = AVCC0 = 1.8 to 5.5 V

| Parameter | | | Symbol | Min | Typ | Max*5 | Unit |
|---------------------|---------------------------------------|--------------|--------|----------|-----|-------|------|
| Operation frequency | System clock (ICLK)*1, *2, *4 | 1.8 to 5.5 V | f | 0.032768 | - | 1 | MHz |
| | Peripheral module clock (PCLKB)*4 | 1.8 to 5.5 V | | - | - | 1 | |
| | Peripheral module clock (PCLKD)*3, *4 | 1.8 to 5.5 V | | - | - | 1 | |

Note 1. The lower-limit frequency of ICLK is 1 MHz while programming or erasing the flash memory.

Note 2. The frequency accuracy of ICLK must be $\pm 3.5\%$ during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

Note 3. The lower-limit frequency of PCLKD is 1 MHz when the A/D converter is in use.

Note 4. See section 8, Clock Generation Circuit in User's Manual for the relationship of frequencies between ICLK, PCLKB, and PCLKD.

Note 5. The maximum value of operation frequency does not include internal oscillator errors. For details on the range of guaranteed operation, see [Table 2.22, Clock timing](#).

Table 2.20 Operation frequency in low-voltage mode

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | | Symbol | Min | Typ | Max*5 | Unit |
|---------------------|---------------------------------------|--------------|--------|----------|-----|-------|------|
| Operation frequency | System clock (ICLK)*1, *2, *4 | 1.6 to 5.5 V | f | 0.032768 | - | 4 | MHz |
| | Peripheral module clock (PCLKB)*4 | 1.6 to 5.5 V | | - | - | 4 | |
| | Peripheral module clock (PCLKD)*3, *4 | 1.6 to 5.5 V | | - | - | 4 | |

Note 1. The lower-limit frequency of ICLK is 1 MHz while programming or erasing the flash memory. When using ICLK for programming or erasing the flash memory at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.

Note 2. The frequency accuracy of ICLK must be $\pm 3.5\%$ during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

Note 3. The lower-limit frequency of PCLKD is 4 MHz at 2.4 V or above and 1 MHz at below 2.4 V when the 14-bit A/D converter is in use.

Note 4. See section 8, Clock Generation Circuit in User's Manual for the relationship of frequencies between ICLK, PCLKB, and PCLKD.

Note 5. The maximum value of operation frequency does not include internal oscillator errors. For details on the range of guaranteed operation, see [Table 2.22, Clock timing](#).

Table 2.21 Operation frequency in Subosc-speed mode

Conditions: VCC = AVCC0 = 1.8 to 5.5 V

| Parameter | | | Symbol | Min | Typ | Max | Unit |
|---------------------|---------------------------------------|--------------|--------|---------|--------|---------|------|
| Operation frequency | System clock (ICLK)*1, *3 | 1.8 to 5.5 V | f | 27.8528 | 32.768 | 37.6832 | kHz |
| | Peripheral module clock (PCLKB)*3 | 1.8 to 5.5 V | | - | - | 37.6832 | |
| | Peripheral module clock (PCLKD)*2, *3 | 1.8 to 5.5 V | | - | - | 37.6832 | |

Note 1. Programming and erasing the flash memory is not possible.

Note 2. The 14-bit A/D converter cannot be used.

Note 3. See section 8, Clock Generation Circuit in User's Manual for the relationship between ICLK, PCLKB, and PCLKD frequencies.

2.3.2 Clock Timing

Table 2.22 Clock timing (1 of 2)

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions | |
|---|-------------------------|--------------|--------|--|---------|---|------|
| EXTAL external clock input cycle time | t_{Xcyc} | 50 | - | - | ns | Figure 2.25 | |
| EXTAL external clock input high pulse width | t_{XH} | 20 | - | - | ns | | |
| EXTAL external clock input low pulse width | t_{XL} | 20 | - | - | ns | | |
| EXTAL external clock rising time | t_{Xr} | - | - | 5 | ns | | |
| EXTAL external clock falling time | t_{Xf} | - | - | 5 | ns | | |
| EXTAL external clock input wait time*1 | t_{EXWT} | 0.3 | - | - | μ s | - | |
| EXTAL external clock input frequency | f_{EXTAL} | - | - | 20 | MHz | $2.4 \leq VCC \leq 5.5$ | |
| | | - | - | 8 | | $1.8 \leq VCC < 2.4$ | |
| | | - | - | 1 | | $1.6 \leq VCC < 1.8$ | |
| Main clock oscillator oscillation frequency | f_{MAIN} | 1 | - | 20 | MHz | $2.4 \leq VCC \leq 5.5$ | |
| | | 1 | - | 8 | | $1.8 \leq VCC < 2.4$ | |
| | | 1 | - | 4 | | $1.6 \leq VCC < 1.8$ | |
| LOCO clock oscillation frequency | f_{LOCO} | 27.8528 | 32.768 | 37.6832 | kHz | - | |
| LOCO clock oscillation stabilization time | t_{LOCO} | - | - | 100 | μ s | Figure 2.26 | |
| IWDT-dedicated clock oscillation frequency | f_{ILOCO} | 12.75 | 15 | 17.25 | kHz | - | |
| MOCO clock oscillation frequency | f_{MOCO} | 6.8 | 8 | 9.2 | MHz | - | |
| MOCO clock oscillation stabilization time | t_{MOCO} | - | - | 1 | μ s | - | |
| HOCO clock oscillation frequency | f_{HOCO24} | 23.64 | 24 | 24.36 | MHz | $T_a = -40$ to -20°C $1.8 \leq VCC \leq 5.5$ | |
| | | 22.68 | 24 | 25.32 | | $T_a = -40$ to 85°C $1.6 \leq VCC < 1.8$ | |
| | | 23.76 | 24 | 24.24 | | $T_a = -20$ to 85°C $1.8 \leq VCC \leq 5.5$ | |
| | | 23.52 | 24 | 24.48 | | $T_a = 85$ to 105°C $2.4 \leq VCC \leq 5.5$ | |
| | f_{HOCO32} | 31.52 | 32 | 32.48 | | $T_a = -40$ to -20°C $1.8 \leq VCC \leq 5.5$ | |
| | | 30.24 | 32 | 33.76 | | $T_a = -40$ to 85°C $1.6 \leq VCC < 1.8$ | |
| | | 31.68 | 32 | 32.32 | | $T_a = -20$ to 85°C $1.8 \leq VCC \leq 5.5$ | |
| | | 31.36 | 32 | 32.64 | | $T_a = 85$ to 105°C $2.4 \leq VCC \leq 5.5$ | |
| | f_{HOCO48}^{*3} | 47.28 | 48 | 48.72 | | $T_a = -40$ to -20°C $1.8 \leq VCC \leq 5.5$ | |
| | | 47.52 | 48 | 48.48 | | $T_a = -20$ to 85°C $1.8 \leq VCC \leq 5.5$ | |
| | | 47.04 | 48 | 48.96 | | $T_a = 85$ to 105°C $2.4 \leq VCC \leq 5.5$ | |
| | f_{HOCO64}^{*4} | 63.04 | 64 | 64.96 | | $T_a = -40$ to -20°C $2.4 \leq VCC \leq 5.5$ | |
| 63.36 | | 64 | 64.64 | $T_a = -20$ to 85°C $2.4 \leq VCC \leq 5.5$ | | | |
| 62.72 | | 64 | 65.28 | $T_a = 85$ to 105°C $2.4 \leq VCC \leq 5.5$ | | | |
| HOCO clock oscillation stabilization time*5, *6 | Except low-voltage mode | t_{HOCO24} | - | - | μ s | Figure 2.27 | |
| | | t_{HOCO32} | - | - | | | |
| | | t_{HOCO48} | - | - | | | |
| | t_{HOCO64} | - | - | | | | |
| | Low-voltage mode | t_{HOCO24} | - | - | | | 37.1 |
| | | t_{HOCO32} | - | - | | | 43.3 |
| t_{HOCO48} t_{HOCO64} | | - | - | 80.6 | | | |
| Sub-clock oscillator oscillation frequency | f_{SUB} | - | 32.768 | - | kHz | - | |

Table 2.22 Clock timing (2 of 2)

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|--------------|-----|-----|-----|------|-----------------|
| Sub-clock oscillation stabilization time*2 | t_{SUBOSC} | - | 0.5 | - | s | Figure 2.28 |

Note 1. Time until the clock can be used after the main clock oscillator stop bit (MOSCCR.MOSTP) is set to 0 (operating) when the external clock is stable.

Note 2. After changing the setting of the SOSCCR.SOSTP bit to start sub-clock oscillator operation, only start using the sub-clock oscillator after the sub-clock oscillation stabilization wait time elapsed. Use the oscillator wait time value recommended by the oscillator manufacturer.

Note 3. The 48-MHz HOCO can be used within a VCC range of 1.8 V to 5.5 V.

Note 4. The 64-MHz HOCO can be used within a VCC range of 2.4 V to 5.5 V.

Note 5. This is a characteristic when the HOCOCCR.HCSTP bit is cleared to 0 (oscillation) in the MOCO stop state. When the HOCOCCR.HCSTP bit is cleared to 0 (oscillation) during MOCO oscillation, this specification is shortened by 1 μ s.

Note 6. Check OSCSF.HOCOSF to confirm whether stabilization time has elapsed.

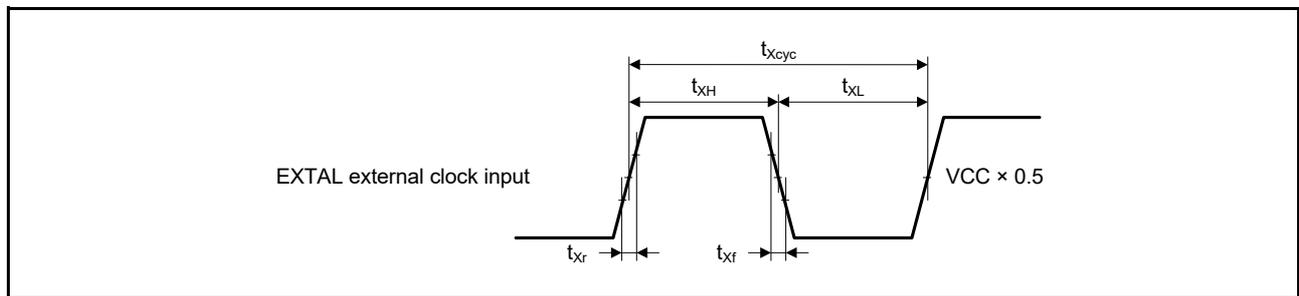


Figure 2.25 EXTAL external clock input timing

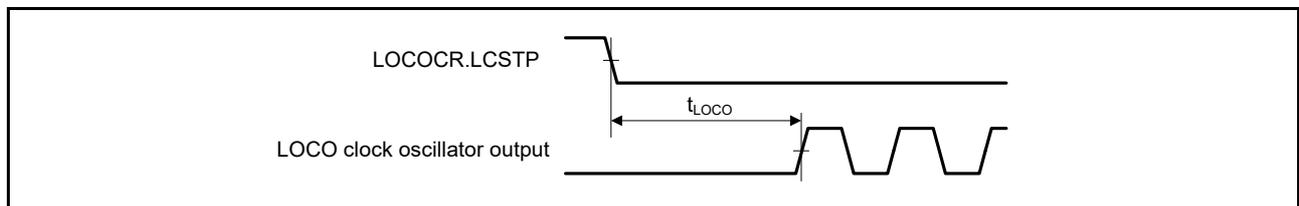


Figure 2.26 LOCO clock oscillator start timing

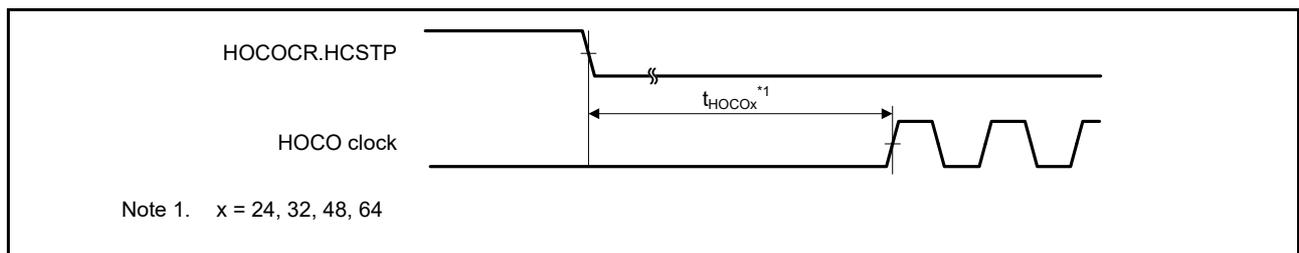


Figure 2.27 HOCO clock oscillator start timing (started by setting the HOCOCCR.HCSTP bit)

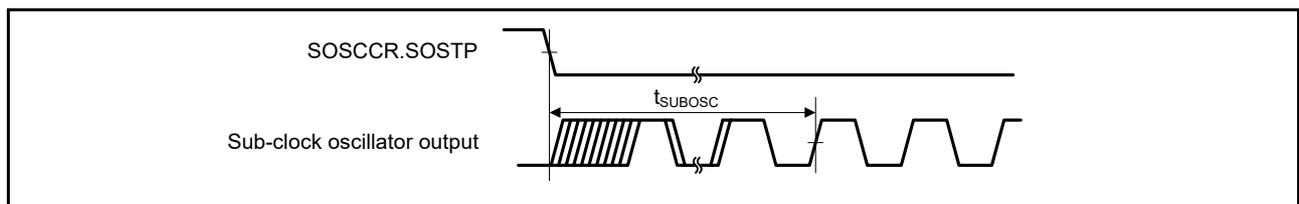


Figure 2.28 Sub-clock oscillator start timing

2.3.3 Reset Timing

Table 2.23 Reset timing

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions |
|---|-----------------|--------------|-----|------|-----|---------|-----------------|
| RES pulse width | At power-on | t_{RESWP} | 3 | - | - | ms | Figure 2.29 |
| | Not at power-on | t_{RESW} | 30 | - | - | μ s | Figure 2.30 |
| Wait time after RES cancellation (at power-on) | LVD0 enabled*1 | t_{RESWT} | - | 0.7 | - | ms | Figure 2.29 |
| | LVD0 disabled*2 | | - | 0.3 | - | | |
| Wait time after RES cancellation (during powered-on state) | LVD0 enabled*1 | t_{RESWT2} | - | 0.5 | - | ms | Figure 2.30 |
| | LVD0 disabled*2 | | - | 0.05 | - | | |
| Wait time after internal reset cancellation (watchdog timer reset, SRAM parity error reset, SRAM ECC error reset, bus master MPU error reset, bus slave MPU error reset, stack pointer error reset, software reset) | LVD0 enabled*1 | t_{RESWT3} | - | 0.6 | - | ms | |
| | LVD0 disabled*2 | | - | 0.15 | - | | |

Note 1. When OFS1.LVDAS = 0.

Note 2. When OFS1.LVDAS = 1.

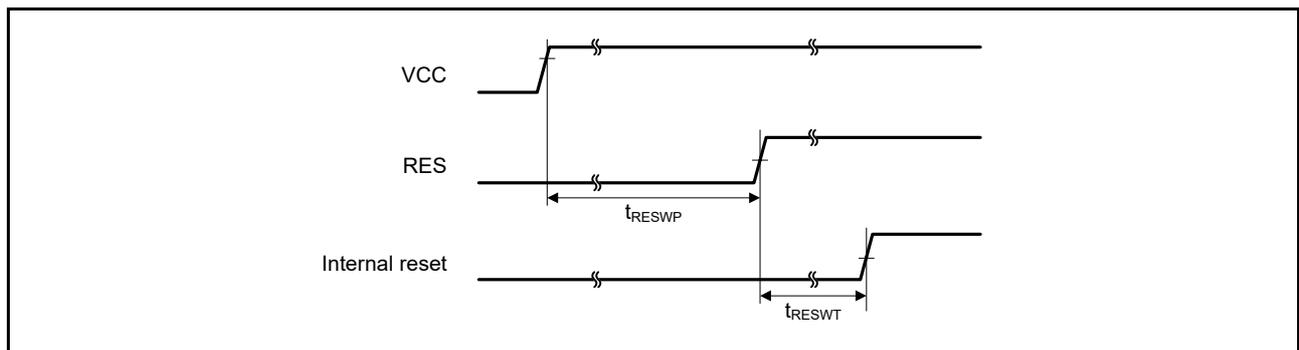


Figure 2.29 Reset input timing at power-on

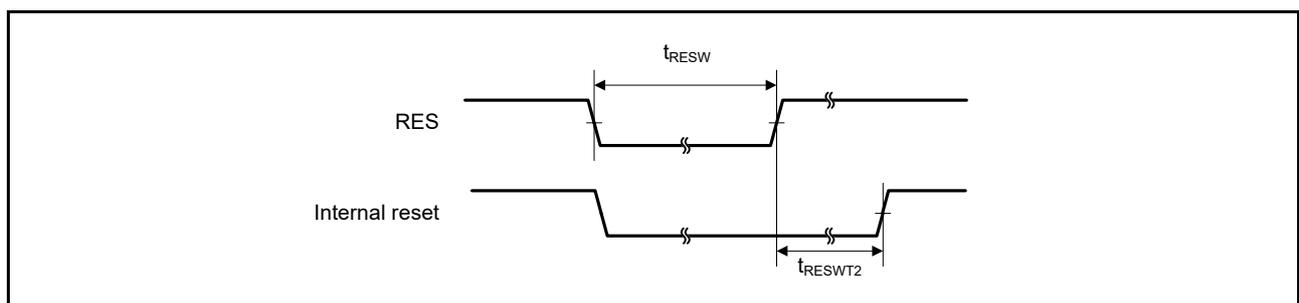


Figure 2.30 Reset input timing

2.3.4 Wakeup Time

Table 2.24 Timing of recovery from low power modes (1)

| Parameter | | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|-----------------|--|---|-------------|-----|-----|-----|---------|-----------------|
| Recovery time from Software Standby mode*1 | High-speed mode | Crystal resonator connected to main clock oscillator | System clock source is main clock oscillator (20 MHz)*2 | t_{SBYMC} | - | 2 | 3 | ms | Figure 2.31 |
| | | External clock input to main clock oscillator | System clock source is main clock oscillator (20 MHz)*3 | t_{SBYEX} | - | 14 | 25 | μ s | |
| | | System clock source is HOCO*4 (HOCO clock is 32 MHz) | | t_{SBYHO} | - | 43 | 52 | μ s | |
| | | System clock source is HOCO*4 (HOCO clock is 48 MHz) | | t_{SBYHO} | - | 44 | 52 | μ s | |
| | | System clock source is HOCO*5 (HOCO clock is 64 MHz) | | t_{SBYHO} | - | 82 | 110 | μ s | |
| | | System clock source is MOCO | | t_{SBYMO} | - | 16 | 25 | μ s | |

Note 1. The division ratio of ICK and PCKx is the minimum division ratio within the allowable frequency range. The recovery time is determined by the system clock source.

Note 2. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 05h.

Note 3. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 00h.

Note 4. The HOCO clock wait control register (HOCOWTCR) is set to 05h.

Note 5. The HOCO clock wait control register (HOCOWTCR) is set to 06h.

Table 2.25 Timing of recovery from low power modes (2)

| Parameter | | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|-------------------|--|---|-------------|-----|-----|-----|---------|-----------------|
| Recovery time from Software Standby mode*1 | Middle-speed mode | Crystal resonator connected to main clock oscillator | System clock source is main clock oscillator (12 MHz)*2 | t_{SBYMC} | - | 2 | 3 | ms | Figure 2.31 |
| | | External clock input to main clock oscillator | System clock source is main clock oscillator (12 MHz)*3 | t_{SBYEX} | - | 2.9 | 10 | μ s | |
| | | System clock source is HOCO*4 | | t_{SBYHO} | - | 38 | 50 | μ s | |
| | | System clock source is MOCO (8 MHz) | | t_{SBYMO} | - | 3.5 | 5.5 | μ s | |

Note 1. The division ratio of ICK and PCKx is the minimum division ratio within the allowable frequency range. The recovery time is determined by the system clock source.

Note 2. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 05h.

Note 3. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 00h.

Note 4. The system clock is 12 MHz.

Table 2.26 Timing of recovery from low power modes (3)

| Parameter | | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|----------------|--|--|--------------------|-----|-----|-----|------|-----------------|
| Recovery time from Software Standby mode*1 | Low-speed mode | Crystal resonator connected to main clock oscillator | System clock source is main clock oscillator (1 MHz)*2 | t _{SBYMC} | - | 2 | 3 | ms | Figure 2.31 |
| | | External clock input to main clock oscillator | System clock source is main clock oscillator (1 MHz)*3 | t _{SBYEX} | - | 28 | 50 | μs | |
| | | System clock source is MOCO (1 MHz) | | t _{SBYMO} | - | 25 | 35 | μs | |

Note 1. The division ratio of ICK and PCKx is the minimum division ratio within the allowable frequency range. The recovery time is determined by the system clock source.

Note 2. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 05h.

Note 3. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 00h.

Table 2.27 Timing of recovery from low power modes (4)

| Parameter | | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|------------------|--|--|--------------------|-----|-----|-----|------|-----------------|
| Recovery time from Software Standby mode*1 | Low-voltage mode | Crystal resonator connected to main clock oscillator | System clock source is main clock oscillator (4 MHz)*2 | t _{SBYMC} | - | 2 | 3 | ms | Figure 2.31 |
| | | External clock input to main clock oscillator | System clock source is main clock oscillator (4 MHz)*3 | t _{SBYEX} | - | 108 | 130 | μs | |
| | | System clock source is HOCO (4 MHz) | | t _{SBYHO} | - | 108 | 130 | μs | |

Note 1. The division ratio of ICK and PCKx is the minimum division ratio within the allowable frequency range. The recovery time is determined by the system clock source.

Note 2. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 05h.

Note 3. The Main Clock Oscillator Wait Control Register (MOSCWTCR) is set to 00h.

Table 2.28 Timing of recovery from low power modes (5)

| Parameter | | | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|-------------------|--|--------------------|-----|------|-----|------|-----------------|
| Recovery time from Software Standby mode*1 | SubOSC-speed mode | System clock source is sub-clock oscillator (32.768 kHz) | t _{SBYSC} | - | 0.85 | 1 | ms | Figure 2.31 |
| | | System clock source is LOCO (32.768 kHz) | t _{SBYLO} | - | 0.85 | 1.2 | ms | |

Note 1. The sub-clock oscillator or LOCO itself continues oscillating in Software Standby mode during Subosc-speed mode.

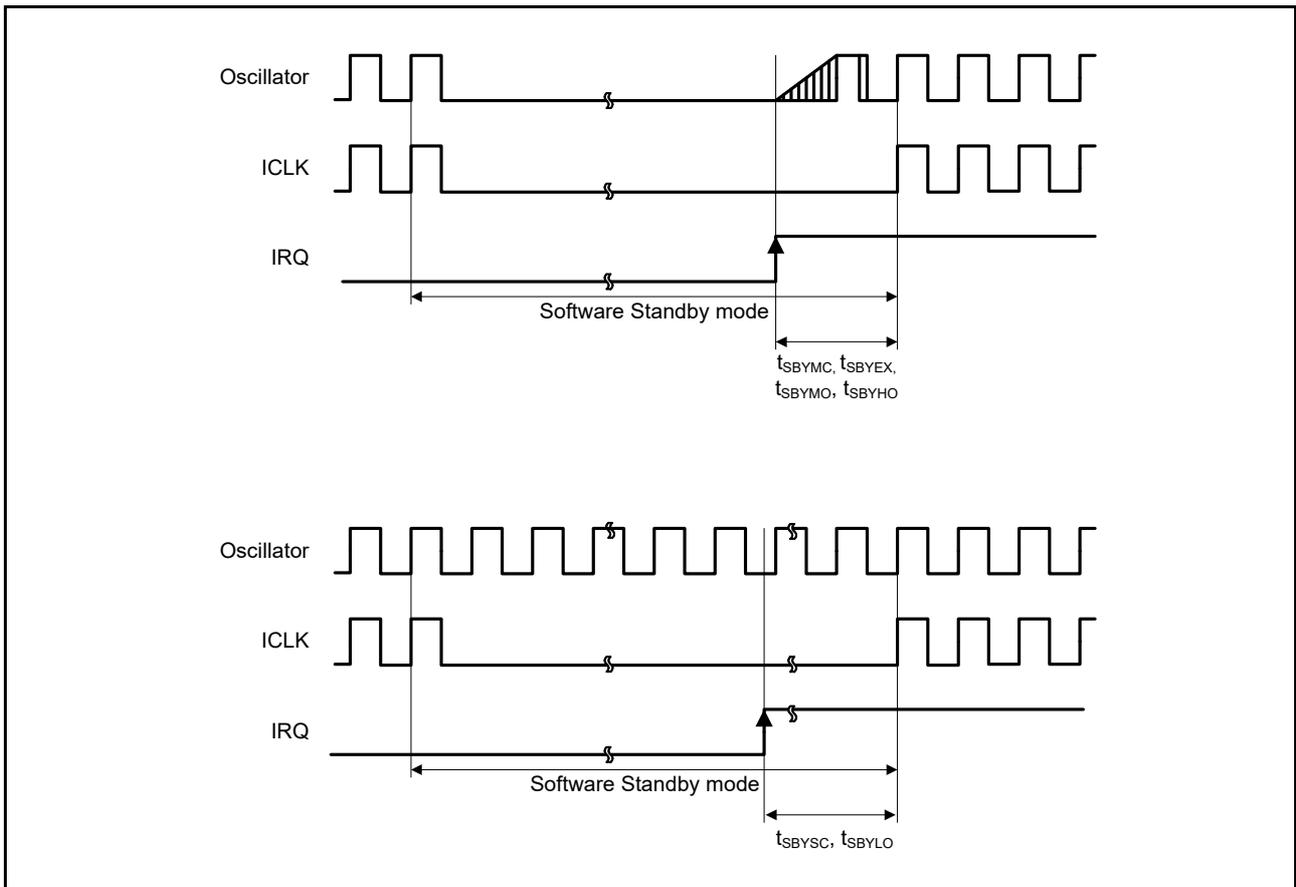


Figure 2.31 Software Standby mode cancellation timing

Table 2.29 Timing of recovery from low power modes (6)

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions |
|---|--|-----------|-----|-----|-----|---------|-----------------|
| Recovery time from Software Standby mode to Snooze mode | High-speed mode System clock source is HOCO | t_{SNZ} | - | 36 | 45 | μs | Figure 2.32 |
| | Middle-speed mode System clock source is MOCO (8 MHz) | t_{SNZ} | - | 1.3 | 3.6 | μs | |
| | Low-speed mode System clock source is MOCO (1 MHz) | t_{SNZ} | - | 10 | 13 | μs | |
| | Low-voltage mode System clock source is HOCO (4 MHz) | t_{SNZ} | - | 87 | 110 | μs | |

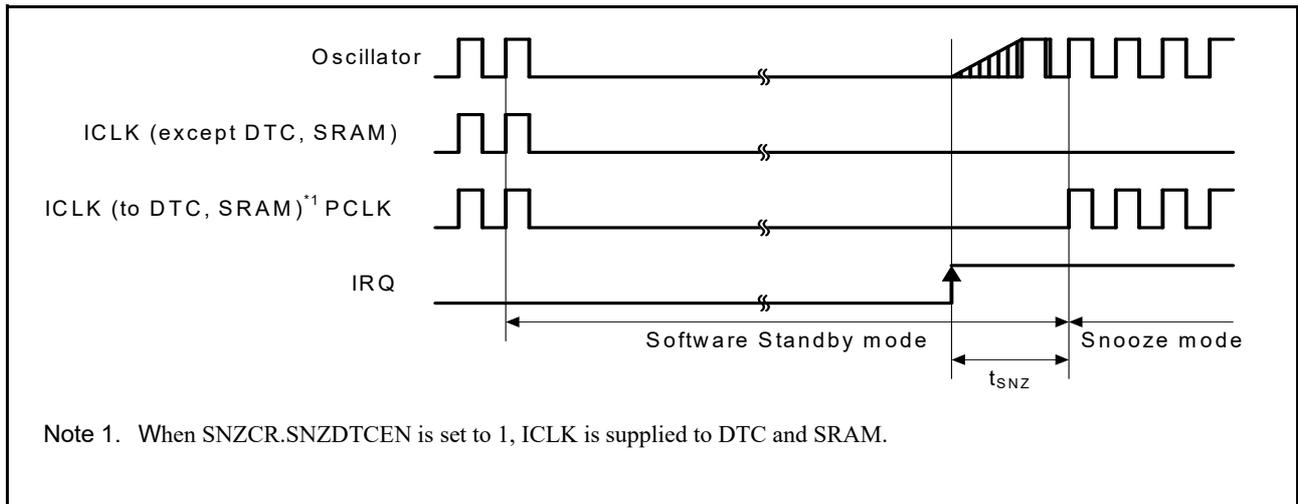


Figure 2.32 Recovery timing from Software Standby mode to Snooze mode

2.3.5 NMI and IRQ Noise Filter

Table 2.30 NMI and IRQ noise filter

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions | |
|-----------------|------------|-----------------------------|-----|-----|------|-----------------------------|----------------------------------|
| NMI pulse width | t_{NMIW} | 200 | - | - | ns | NMI digital filter disabled | |
| | | $t_{Pcyc} \times 2^{*1}$ | - | - | | | $t_{Pcyc} \times 2 \leq 200$ 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 | |
| | | $t_{Pcyc} \times 2^{*1}$ | - | - | | | $t_{Pcyc} \times 2 \leq 200$ 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 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 IRQ_i digital filter sampling clock (i = 0 to 7).

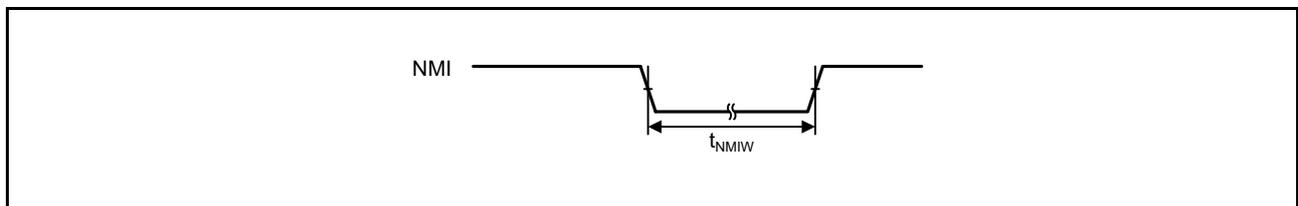


Figure 2.33 NMI interrupt input timing

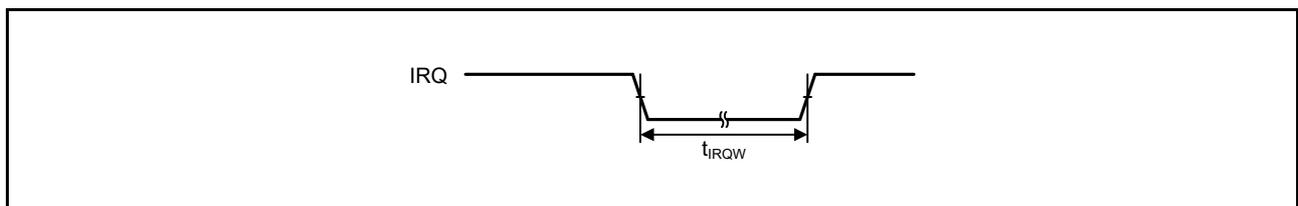


Figure 2.34 IRQ interrupt input timing

2.3.6 I/O Ports, POEG, GPT, AGT, KINT, and ADC14 Trigger Timing

Table 2.31 I/O Ports, POEG, GPT, AGT, KINT, and ADC14 trigger timing

| Parameter | | Symbol | Min | Max | Unit | Test conditions | |
|--|--|-----------------------------|------------------------------|------|------------|-----------------|-------------|
| I/O Ports | Input data pulse width | t_{PRW} | 1.5 | - | t_{Pcyc} | Figure 2.35 | |
| | Input/output data cycle (P002, P003, P010, P011) | t_{POCyc} | 10 | - | μs | - | |
| POEG | POEG input trigger pulse width | t_{POEW} | 3 | - | t_{Pcyc} | Figure 2.36 | |
| GPT | Input capture pulse width | Single edge | t_{GTICW} | 1.5 | - | t_{PDcyc} | Figure 2.37 |
| | | Dual edge | | 2.5 | - | | |
| AGT | AGTIO, AGTEE input cycle | $2.7 V \leq VCC \leq 5.5 V$ | t_{ACYC}^{*1} | 250 | - | ns | Figure 2.38 |
| | | $2.4 V \leq VCC < 2.7 V$ | | 500 | - | ns | |
| | | $1.8 V \leq VCC < 2.4 V$ | | 1000 | - | ns | |
| | | $1.6 V \leq VCC < 1.8 V$ | | 2000 | - | ns | |
| | AGTIO, AGTEE input high level width, low-level width | $2.7 V \leq VCC \leq 5.5 V$ | t_{ACKWH} , t_{ACKWL} | 100 | - | ns | |
| | | $2.4 V \leq VCC < 2.7 V$ | | 200 | - | ns | |
| | | $1.8 V \leq VCC < 2.4 V$ | | 400 | - | ns | |
| | | $1.6 V \leq VCC < 1.8 V$ | | 800 | - | ns | |
| AGTIO, AGTO, AGTOA, AGTOB output cycle | $2.7 V \leq VCC \leq 5.5 V$ | t_{ACYC2} | 62.5 | - | ns | Figure 2.38 | |
| | $2.4 V \leq VCC < 2.7 V$ | | 125 | - | ns | | |
| | $1.8 V \leq VCC < 2.4 V$ | | 250 | - | ns | | |
| | $1.6 V \leq VCC < 1.8 V$ | | 500 | - | ns | | |
| ADC14 | 14-bit A/D converter trigger input pulse width | t_{TRGW} | 1.5 | - | t_{Pcyc} | Figure 2.39 | |
| KINT | KRn (n = 00 to 07) pulse width | t_{KR} | 250 | - | ns | Figure 2.40 | |

Note 1. Constraints on AGTIO input: $t_{Pcyc} \times 2 (t_{Pcyc}: PCLKB \text{ cycle}) < t_{ACYC}$.

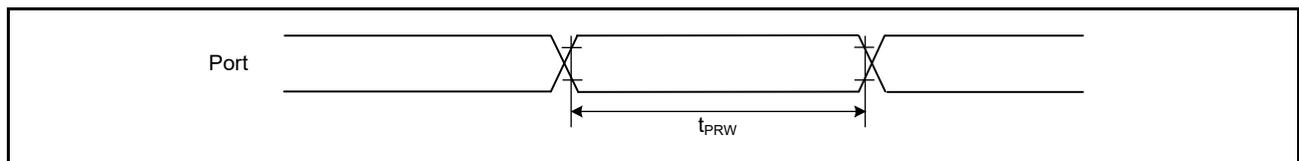


Figure 2.35 I/O ports input timing

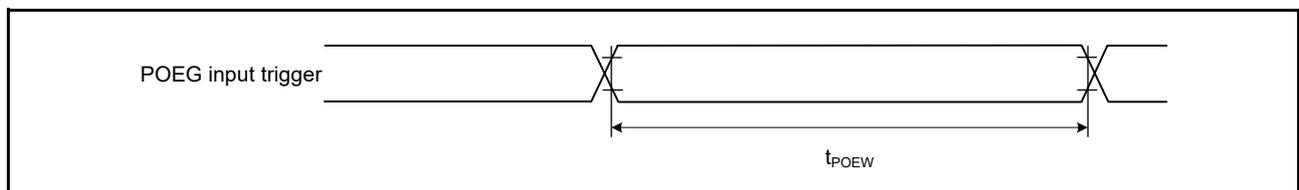


Figure 2.36 POEG input trigger timing

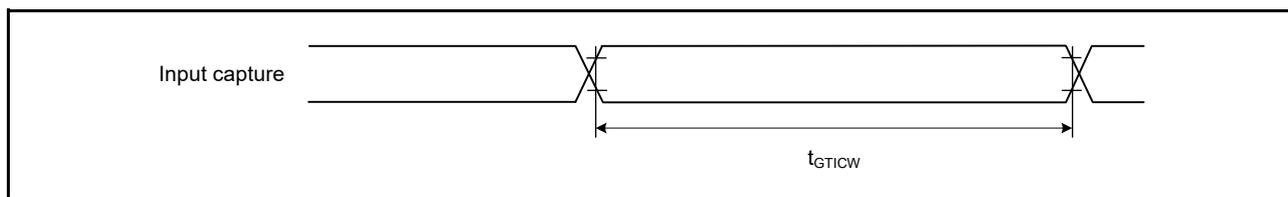


Figure 2.37 GPT input capture timing

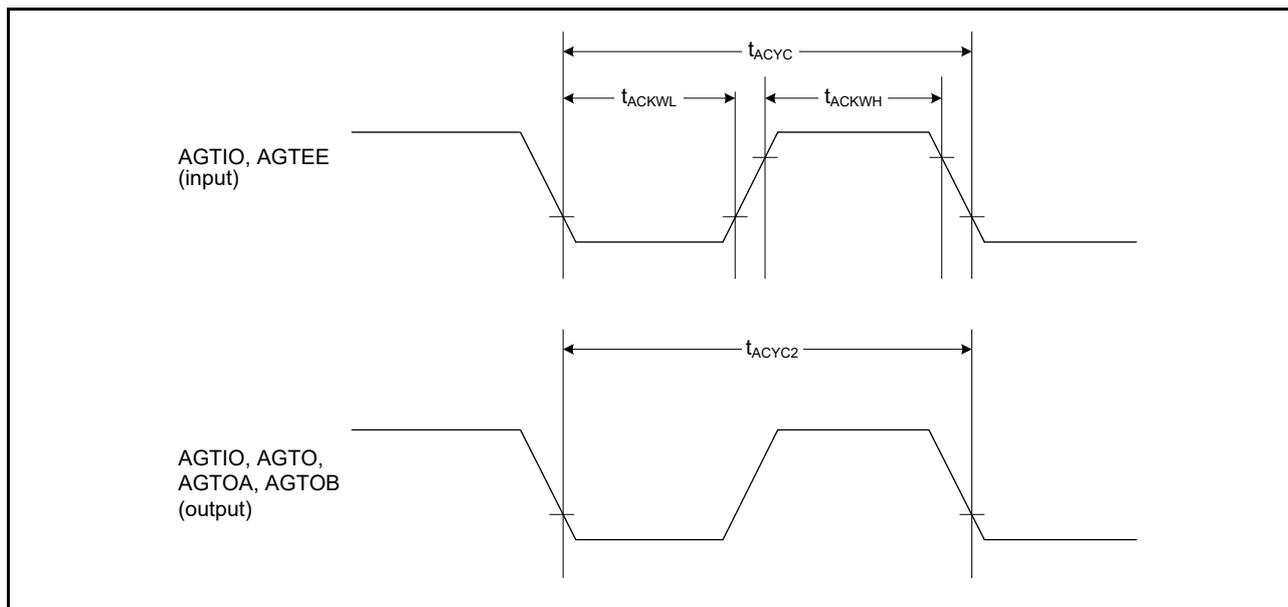


Figure 2.38 AGT I/O timing

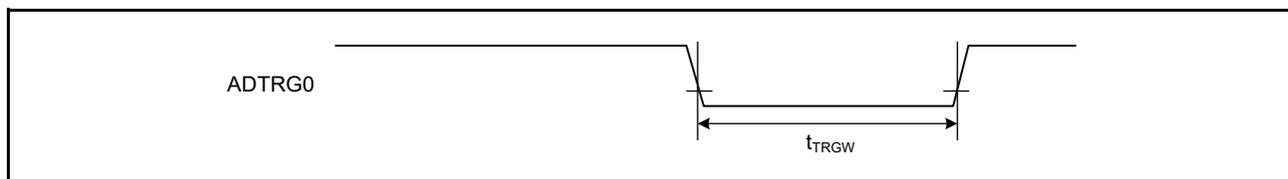


Figure 2.39 ADC14 trigger input timing

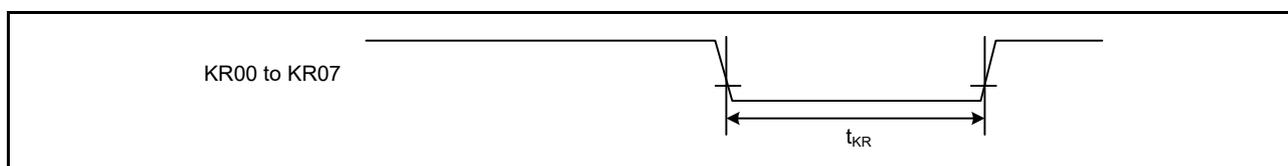


Figure 2.40 Key interrupt input timing

2.3.7 PWM Delay Generation Circuit Timing

Table 2.32 PWM delay generation circuit timing
 Conditions: $V_{CC} = AV_{CC0} = 2.7$ to 5.5 V 32 MHz \leq PCLKD \leq 64 MHz

| Parameter | | Min | Typ | Max | Unit | Test conditions |
|------------|---------------------------------------|-----|-----|-----|------|-----------------|
| Resolution | PCLKD = 64 MHz, DLL Mode = 5-bit mode | - | 488 | - | ps | - |
| | PCLKD = 64 MHz, DLL Mode = 4-bit mode | - | 976 | - | ps | - |
| | PCLKD = 32 MHz, DLL Mode = 5-bit mode | - | 976 | - | ps | - |
| DNL*1,*2 | | - | 5 | - | LSB | - |

Note 1. The differences among lines in 1-LSB resolution are normalized by this value.

Note 2. The drive capability of the PWM delay generation circuit output port is middle drive.

2.3.8 CAC Timing

Table 2.33 CAC timing

| Parameter | | Symbol | Min | Typ | Max | Unit | Test conditions |
|-----------|--------------------------|-----------------------------------|--|-----|-----|------|-----------------|
| CAC | CACREF input pulse width | $t_{Pcyc}^{*1} \leq t_{cac}^{*2}$ | $4.5 \times t_{cac} + 3 \times t_{Pcyc}$ | - | - | ns | - |
| | | $t_{Pcyc}^{*1} > t_{cac}^{*2}$ | $5 \times t_{cac} + 6.5 \times t_{Pcyc}$ | - | - | ns | |

Note 1. t_{Pcyc} : PCLKB cycle.

Note 2. t_{cac} : CAC count clock source cycle.

2.3.9 SCI Timing

Table 2.34 SCI timing (1)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | Symbol | Min | Max | Unit*1 | Test conditions | |
|----------------------------------|-------------------|-------------------|---------------|-----|------------|-----------------|-------------|
| SCI | Input clock cycle | Asynchronous | t_{Scyc} | 4 | - | t_{Pcyc} | Figure 2.41 |
| | | Clock synchronous | | 6 | - | | |
| Input clock pulse width | | t_{SCKW} | 0.4 | 0.6 | t_{Scyc} | | |
| Input clock rise time | | t_{SCKr} | - | 20 | ns | | |
| Input clock fall time | | t_{SCKf} | - | 20 | ns | | |
| Output clock cycle | Asynchronous | t_{Scyc} | 6 | - | t_{Pcyc} | | |
| | Clock synchronous | | 4 | - | | | |
| Output clock pulse width | | t_{SCKW} | 0.4 | 0.6 | t_{Scyc} | | |
| Output clock rise time | 1.8V or above | t_{SCKr} | - | 20 | ns | | |
| | | | 1.6V or above | - | | | 30 |
| Output clock fall time | 1.8V or above | t_{SCKf} | - | 20 | ns | | |
| | | | 1.6V or above | - | | | 30 |
| Transmit data delay (master) | Clock synchronous | t_{TXD} | - | 40 | ns | Figure 2.42 | |
| | | | 1.6V or above | - | | | 45 |
| Transmit data delay (slave) | Clock synchronous | t_{RXS} | - | 55 | ns | | |
| | | | 2.4V or above | - | | | 60 |
| | | | 1.8V or above | - | | | 100 |
| | | | 1.6V or above | - | | | 125 |
| Receive data setup time (master) | Clock synchronous | t_{RXS} | 45 | - | ns | | |
| | | | 55 | - | | | |
| | | | 90 | - | | | |
| | | | 110 | - | | | |
| Receive data setup time (slave) | Clock synchronous | t_{RXS} | 40 | - | ns | | |
| | | | 45 | - | | | |
| Receive data hold time (master) | Clock synchronous | t_{RXH} | 5 | - | ns | | |
| Receive data hold time (slave) | Clock synchronous | t_{RXH} | 40 | - | ns | | |

Note 1. t_{Pcyc} : PCLKB cycle.

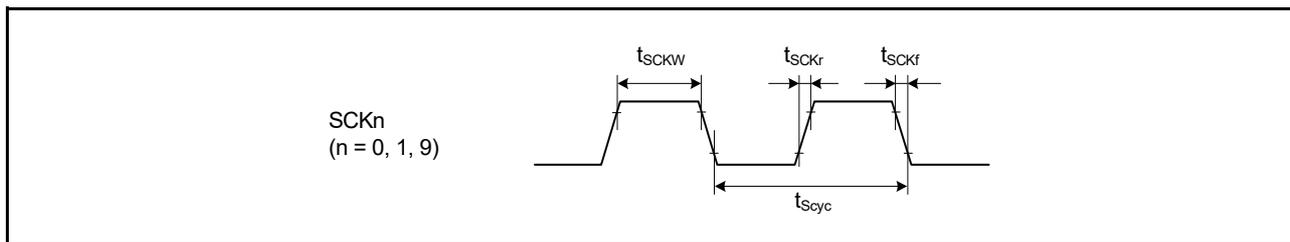


Figure 2.41 SCK clock input timing

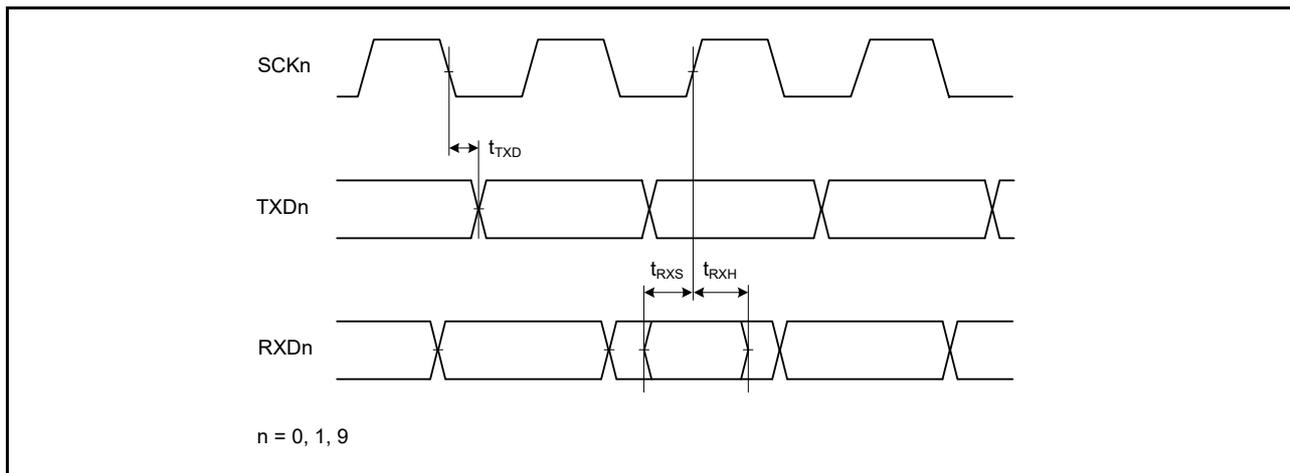


Figure 2.42 SCI input/output timing in clock synchronous mode

Table 2.35 SCI timing (2)

Conditions: VCC = AVCC0 = 1.6 to 5.5 V

| Parameter | | | Symbol | Min | Max | Unit*1 | Test conditions | | |
|-----------------------|---------------------------------|---------------|------------------------------|---------------|---------------------|-------------|-----------------|----|-------------------------------|
| Simple SPI | SCK clock cycle output (master) | | t_{SPcyc} | 4 | 65536 | t_{Pcyc} | Figure 2.43 | | |
| | SCK clock cycle input (slave) | | | 6 | 65536 | | | | |
| | SCK clock high pulse width | | t_{SPCKWH} | 0.4 | 0.6 | t_{SPcyc} | | | |
| | SCK clock low pulse width | | t_{SPCKWL} | 0.4 | 0.6 | t_{SPcyc} | | | |
| | SCK clock rise and fall time | | t_{SPCKr} , t_{SPCKf} | 1.8V or above | - | 20 | | ns | |
| | | | | 1.6V or above | - | 30 | | | |
| | Data input setup time | Master | 2.7V or above | t_{SU} | 45 | - | | ns | Figure 2.44 to Figure 2.47 |
| | | | 2.4V or above | | 55 | - | | | |
| | | | 1.8V or above | | 80 | - | | | |
| | | | 1.6V or above | | 110 | - | | | |
| | | Slave | 2.7V or above | | 40 | - | | | |
| | | | 1.6V or above | | 45 | - | | | |
| Data input hold time | Master | | t_H | 33.3 | - | ns | | | |
| | Slave | | | 40 | - | | | | |
| SS input setup time | | | t_{LEAD} | 1 | - | t_{SPcyc} | | | |
| SS input hold time | | | t_{LAG} | 1 | - | t_{SPcyc} | | | |
| Data output delay | Master | 1.8V or above | t_{OD} | - | 40 | ns | | | |
| | | 1.6V or above | | - | 50 | | | | |
| | Slave | 2.4V or above | | - | 65 | | | | |
| | | 1.8V or above | | - | 100 | | | | |
| | | 1.6V or above | | - | 125 | | | | |
| Data output hold time | Master | 2.7V or above | t_{OH} | -10 | - | ns | | | |
| | | 2.4V or above | | -20 | - | | | | |
| | | 1.8V or above | | -30 | - | | | | |
| | | 1.6V or above | | -40 | - | | | | |
| | Slave | | | | -10 | | - | | |
| | Data rise and fall time | Master | | | t_{Dr} , t_{Df} | | - | 20 | ns |
| Slave | | 1.8V or above | - | 20 | | | | | |
| | | 1.6V or above | - | 30 | | | | | |
| Simple SPI | Slave access time | | t_{SA} | - | 6 | t_{Pcyc} | Figure 2.47 | | |
| | Slave output release time | | t_{REL} | - | 6 | t_{Pcyc} | | | |

Note 1. t_{Pcyc} : PCLKB cycle.

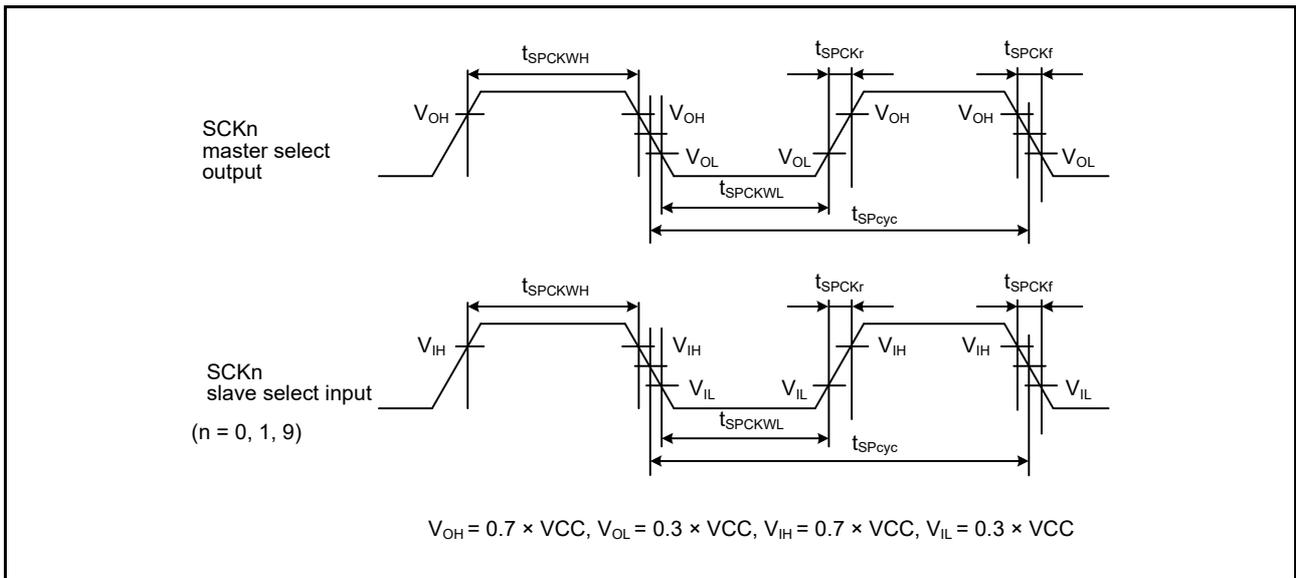


Figure 2.43 SCI simple SPI mode clock timing

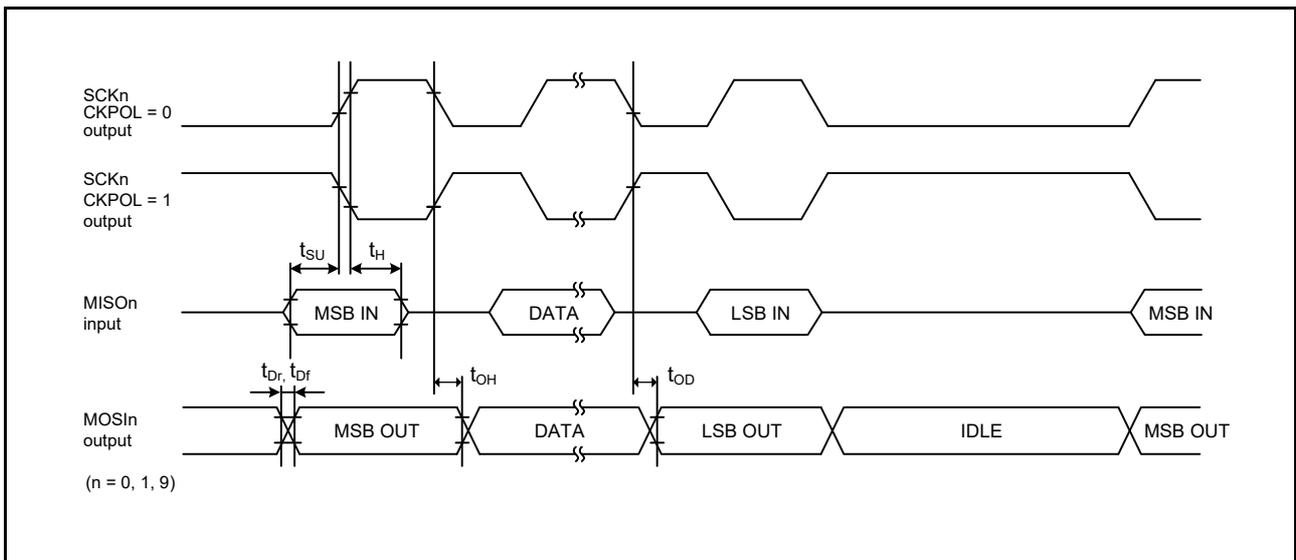


Figure 2.44 SCI simple SPI mode timing (master, CKPH = 1)

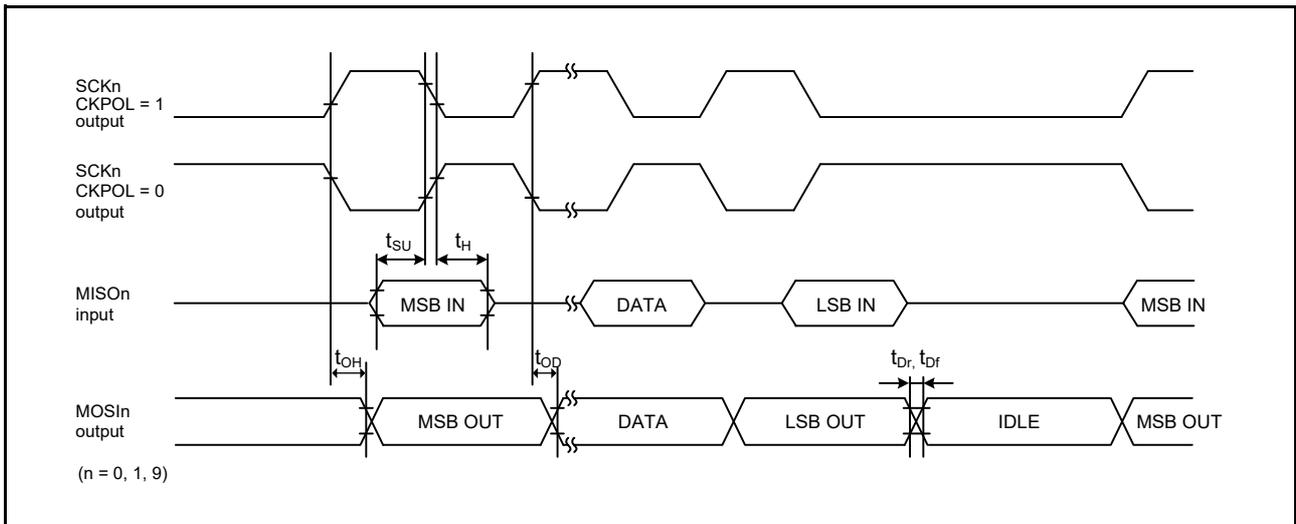


Figure 2.45 SCI simple SPI mode timing (master, CKPH = 0)

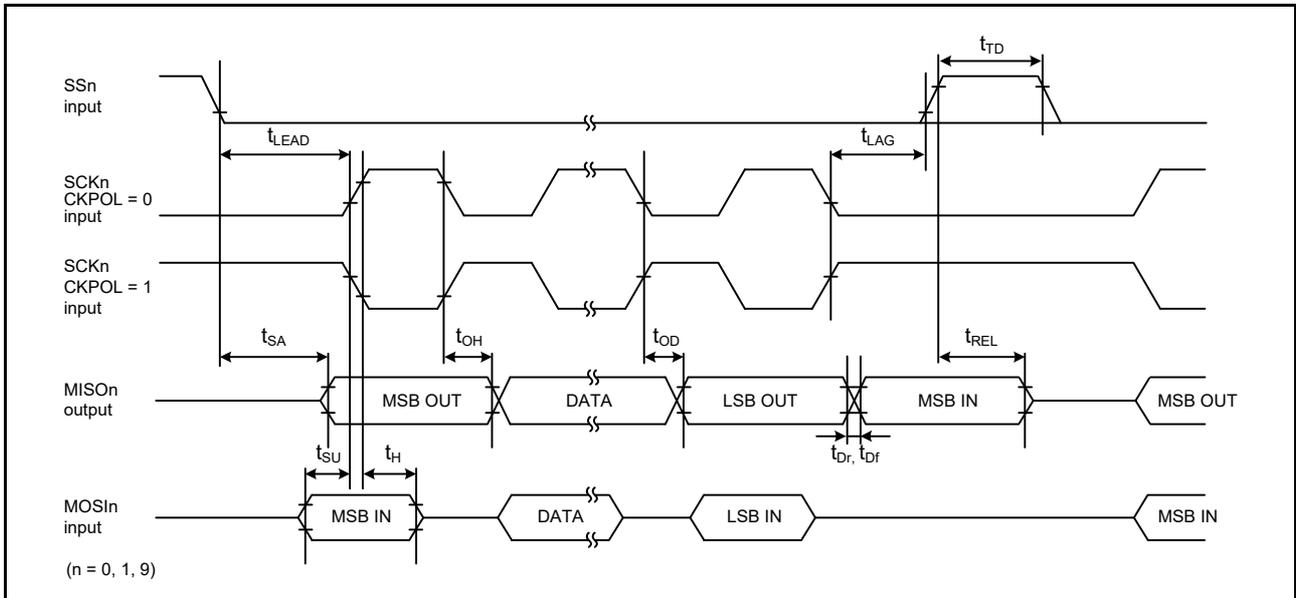


Figure 2.46 SCI simple SPI mode timing (slave, CKPH = 1)

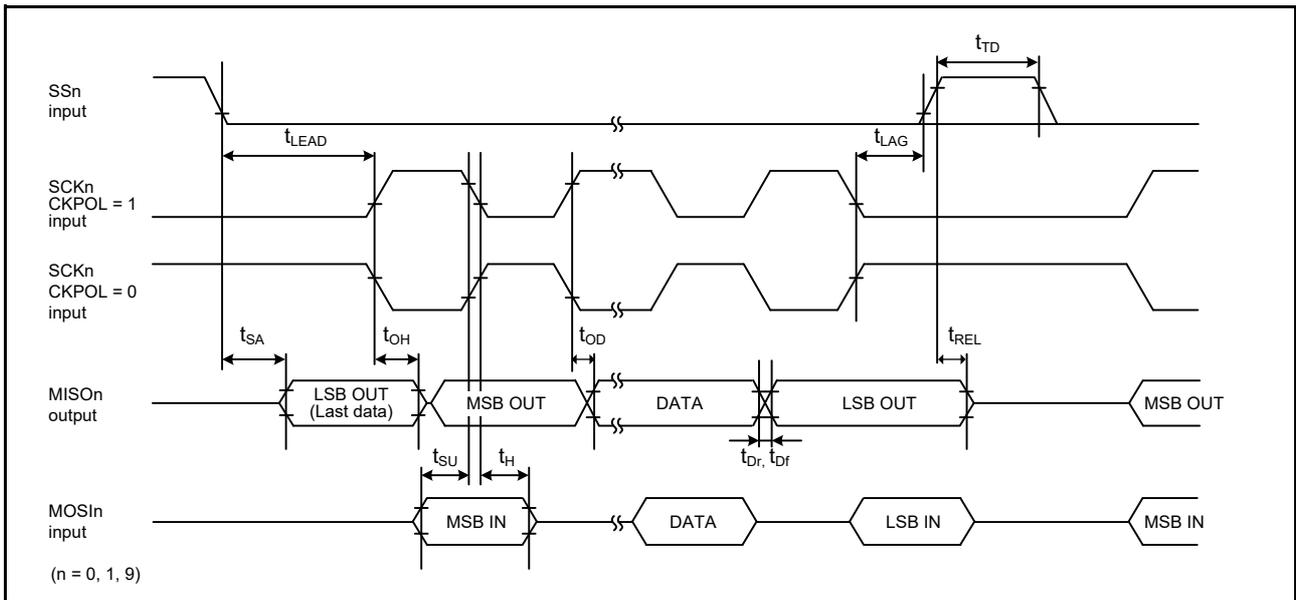


Figure 2.47 SCI simple SPI mode timing (slave, CKPH = 0)

Table 2.36 SCI timing (3)

Conditions: VCC = AVCC0 = 2.7 to 5.5 V

| Parameter | Symbol | Min | Max | Unit | Test conditions | |
|----------------------------|------------------------------------|------------|-----|-----------------------|-----------------|-------------|
| Simple IIC (Standard mode) | SDA input rise time | t_{Sr} | - | 1000 | ns | Figure 2.48 |
| | SDA input fall time | t_{Sf} | - | 300 | ns | |
| | SDA input spike pulse removal time | t_{SP} | 0 | $4 \times t_{IICcyc}$ | 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) | SDA input rise time | t_{Sr} | - | 300 | ns | Figure 2.48 |
| | SDA input fall time | t_{Sf} | - | 300 | ns | |
| | SDA input spike pulse removal time | t_{SP} | 0 | $4 \times t_{IICcyc}$ | 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_{IICcyc} : IIC internal reference clock (IIC ϕ) cycle.

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

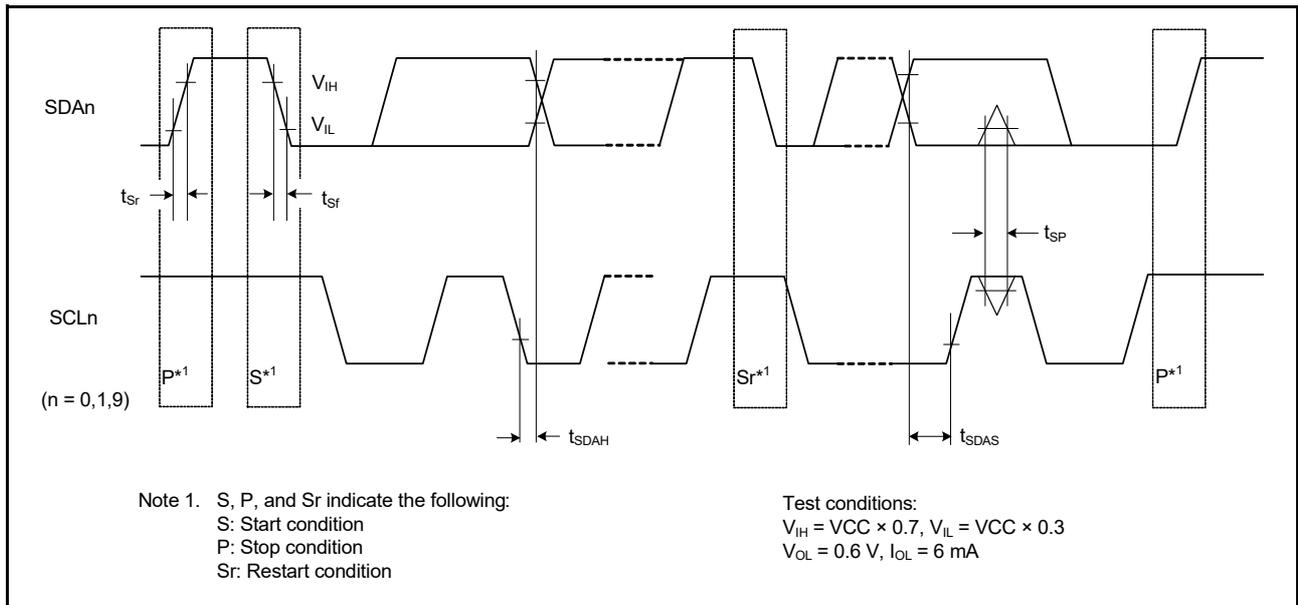


Figure 2.48 SCI simple IIC mode timing

2.3.10 SPI Timing

Table 2.37 SPI timing (1 of 2)

Conditions: Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.

| Parameter | | Symbol | Min | Max | Unit*1 | Test conditions | | |
|-----------|--------------------------------|--------|--------------|---|---------------|-----------------|-------------------------|----|
| SPI | RSPCK clock cycle | Master | t_{SPCyc} | 2 | 4096 | t_{Pcyc} | Figure 2.49 C = 30pF | |
| | | Slave | | 6 | 4096 | | | |
| | RSPCK clock high pulse width | Master | t_{SPCKWH} | $(t_{SPCyc} - t_{SPCKr} - t_{SPCKf}) / 2 - 3$ | | ns | | |
| | | Slave | | $3 \times t_{Pcyc}$ | | | | |
| | RSPCK clock low pulse width | Master | t_{SPCKWL} | $(t_{SPCyc} - t_{SPCKr} - t_{SPCKf}) / 2 - 3$ | | ns | | |
| | | Slave | | $3 \times t_{Pcyc}$ | | | | |
| | RSPCK clock rise and fall time | Output | | 2.7V or above | - | 10 | | ns |
| | | | | 2.4V or above | - | 15 | | |
| | | | | 1.8V or above | - | 20 | | |
| | | | | 1.6V or above | - | 30 | | |
| | | Input | - | 1 | μs | | | |

Table 2.37 SPI timing (2 of 2)

Conditions: Middle drive output is selected in the Port Drive Capability bit in the PmnPFS register.

| Parameter | | | Symbol | Min | Max | Unit*1 | Test conditions | | |
|----------------------------------|-----------------------|-------------------------------|---------------------------------|--|---------|--|---|----|---|
| SPI | Data input setup time | Master | t_{SU} | 10 | - | ns | Figure 2.50 to Figure 2.55 C = 30pF | | |
| | | Slave | | 2.4V or above | 10 | | | - | |
| | | | | 1.8V or above | 15 | | | - | |
| | | | | 1.6V or above | 20 | | | - | |
| | Data input hold time | Master (RSPCK is PCLKB/2) | t_{HF} | 0 | - | ns | | | |
| | | Master (RSPCK is not PCLKB/2) | t_H | t_{Pcyc} | - | | | | |
| | | Slave | t_H | 20 | - | | | | |
| | SSL setup time | Master | t_{LEAD} | $-30 + N \times t_{SPcyc}^{*2}$ | - | ns | | | |
| | | Slave | | $6 \times t_{Pcyc}$ | - | ns | | | |
| | SSL hold time | Master | t_{LAG} | $-30 + N \times t_{SPcyc}^{*3}$ | - | ns | | | |
| | | Slave | | $6 \times t_{Pcyc}$ | - | ns | | | |
| | Data output delay | Master | 2.7V or above | t_{OD} | - | 14 | | ns | Figure 2.50 to Figure 2.55 C = 30pF |
| | | | 2.4V or above | | - | 20 | | | |
| | | | 1.8V or above | | - | 25 | | | |
| | | | 1.6V or above | | - | 30 | | | |
| | | Slave | 2.7V or above | | - | 50 | | | |
| | | | 2.4V or above | | - | 60 | | | |
| | | | 1.8V or above | | - | 85 | | | |
| | | | 1.6V or above | | - | 110 | | | |
| | Data output hold time | Master | t_{OH} | 0 | - | ns | | | |
| Slave | | 0 | | - | | | | | |
| Successive transmission delay | Master | t_{TD} | $t_{SPcyc} + 2 \times t_{Pcyc}$ | $8 \times t_{SPcyc} + 2 \times t_{Pcyc}$ | ns | | | | |
| | Slave | | $6 \times t_{Pcyc}$ | - | | | | | |
| MOSI and MISO rise and fall time | Output | 2.7V or above | t_{Dr}, t_{Df} | - | 10 | ns | | | |
| | | 2.4V or above | | - | 15 | | | | |
| | | 1.8V or above | | - | 20 | | | | |
| | | 1.6V or above | | - | 30 | | | | |
| | Input | - | | 1 | μs | | | | |
| SSL rise and fall time | Output | 2.7V or above | t_{SSLr}, t_{SSLf} | - | 10 | ns | | | |
| | | 2.4V or above | | - | 15 | | | | |
| | | 1.8V or above | | - | 20 | | | | |
| | | 1.6V or above | | - | 30 | | | | |
| | Input | - | | 1 | μs | | | | |
| Slave access time | 2.4V or above | t_{SA} | - | $2 \times t_{Pcyc} + 100$ | ns | Figure 2.54 and Figure 2.55 C = 30pF | | | |
| | 1.8V or above | | - | $2 \times t_{Pcyc} + 140$ | | | | | |
| | 1.6V or above | | - | $2 \times t_{Pcyc} + 180$ | | | | | |
| Slave output release time | 2.4V or above | t_{REL} | - | $2 \times t_{Pcyc} + 100$ | ns | | | | |
| | 1.8V or above | | - | $2 \times t_{Pcyc} + 140$ | | | | | |
| | 1.6V or above | | - | $2 \times t_{Pcyc} + 180$ | | | | | |

Note 1. t_{Pcyc} : PCLKB cycle.

Note 2. N is set as an integer from 1 to 8 by the SPCKD register.

Note 3. N is set as an integer from 1 to 8 by the SSLND register.

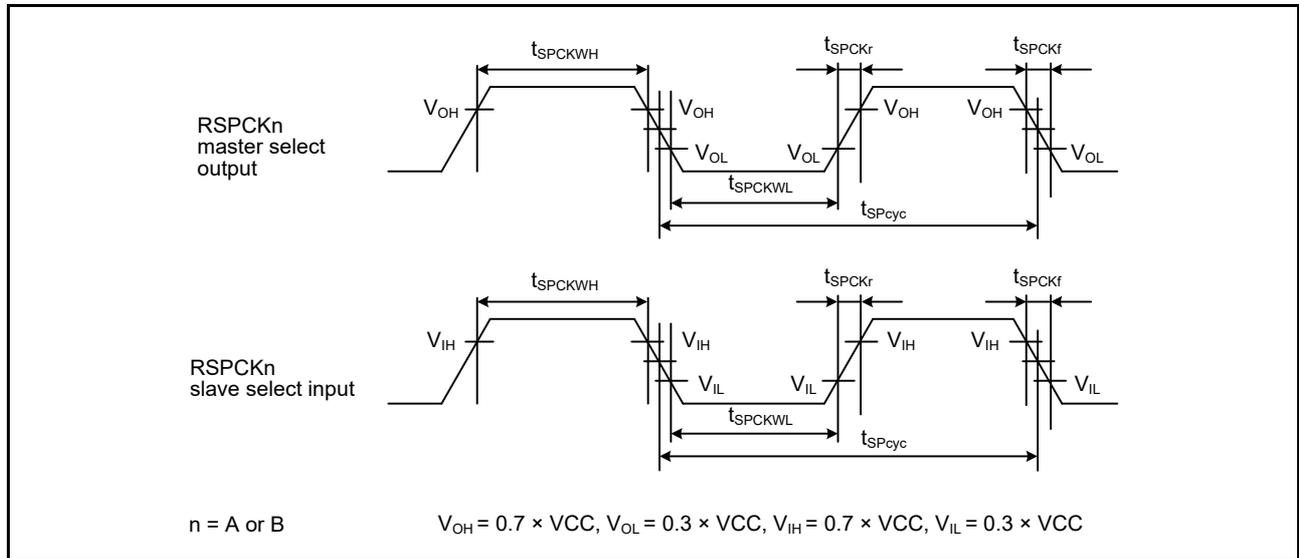


Figure 2.49 SPI clock timing

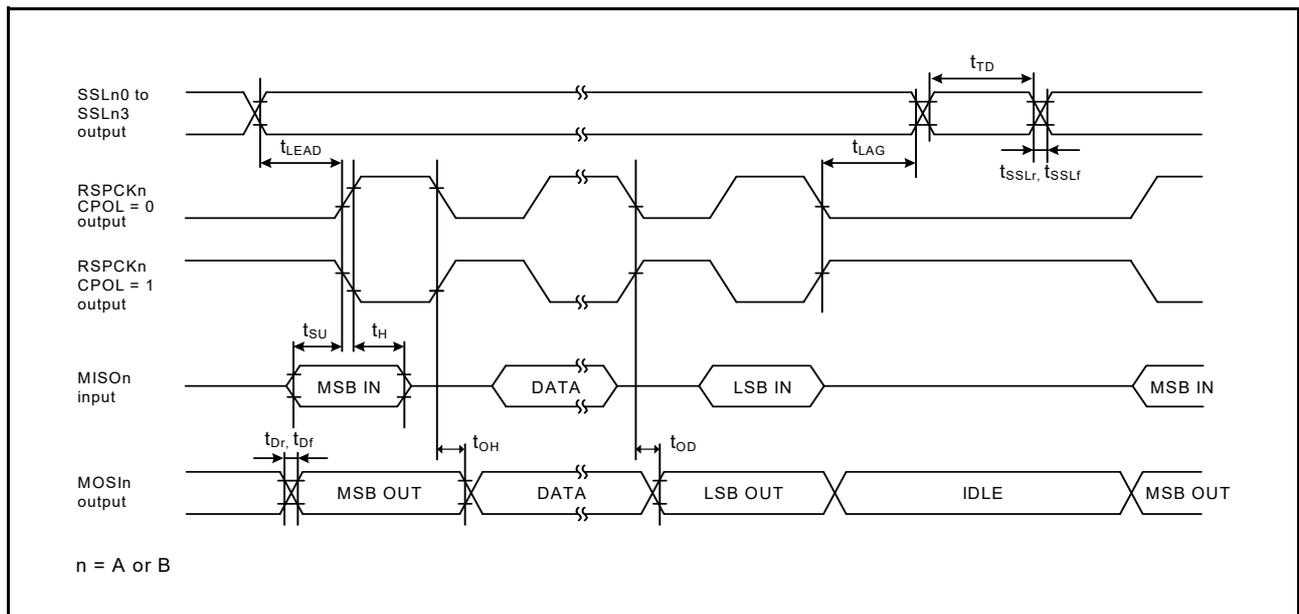


Figure 2.50 SPI timing (master, CPHA = 0) (bit rate: PCLKB division ratio is set to any value other than 1/2)

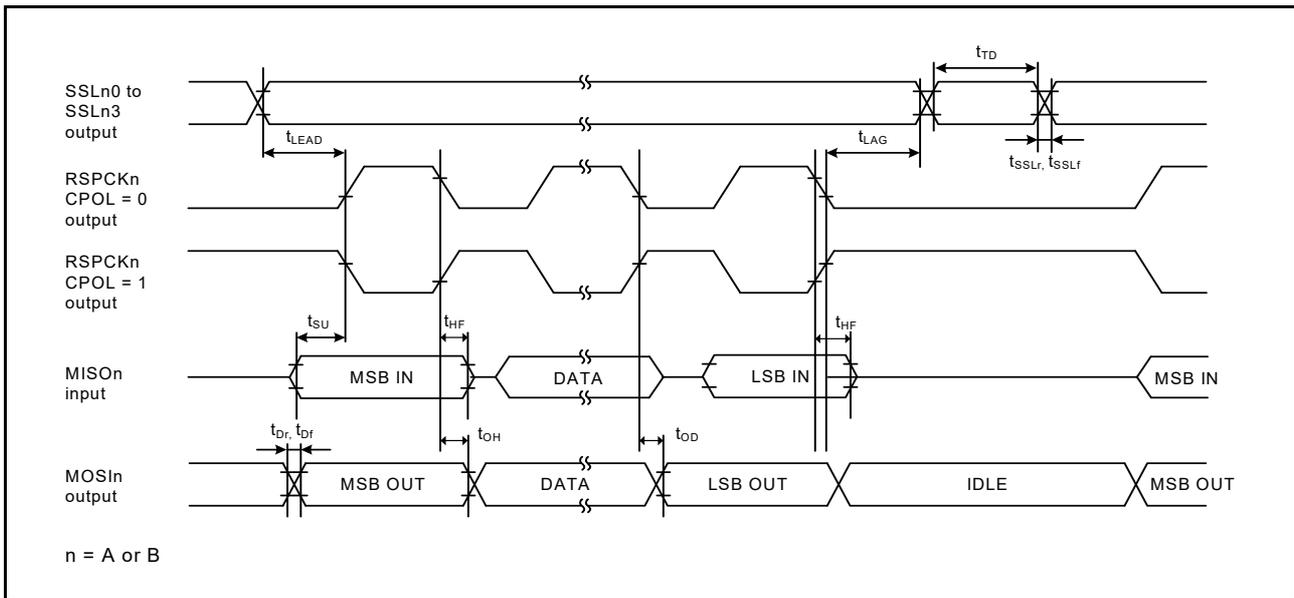


Figure 2.51 SPI timing (master, CPHA = 0) (bit rate: PCLKB division ratio is set to 1/2)

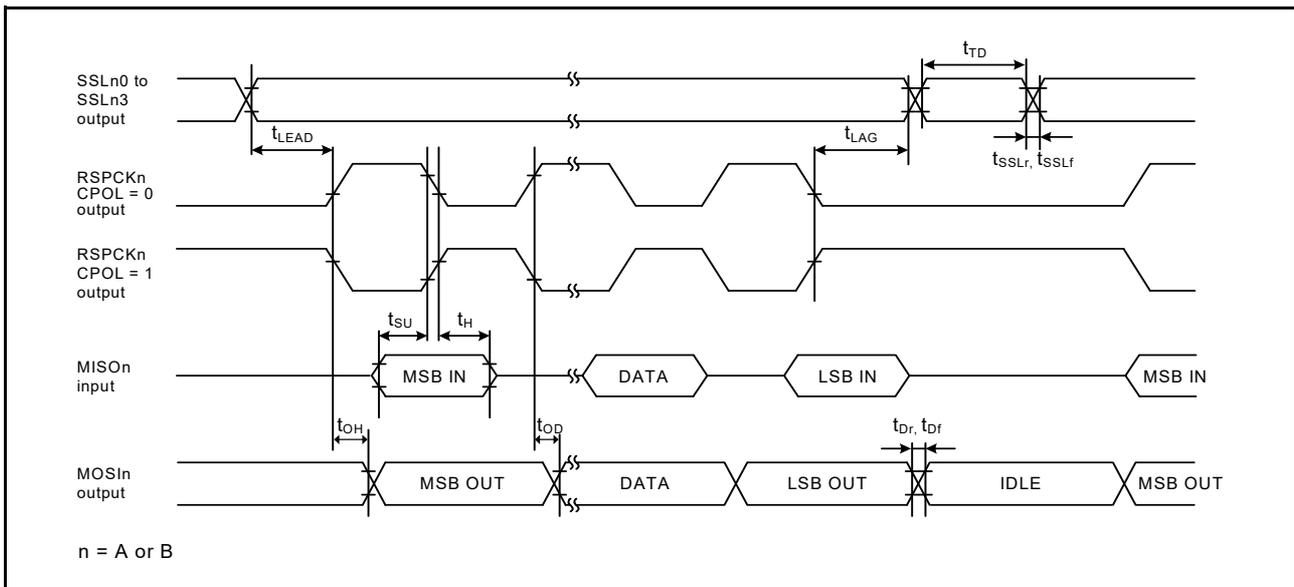


Figure 2.52 SPI timing (master, CPHA = 1) (bit rate: PCLKB division ratio is set to any value other than 1/2)

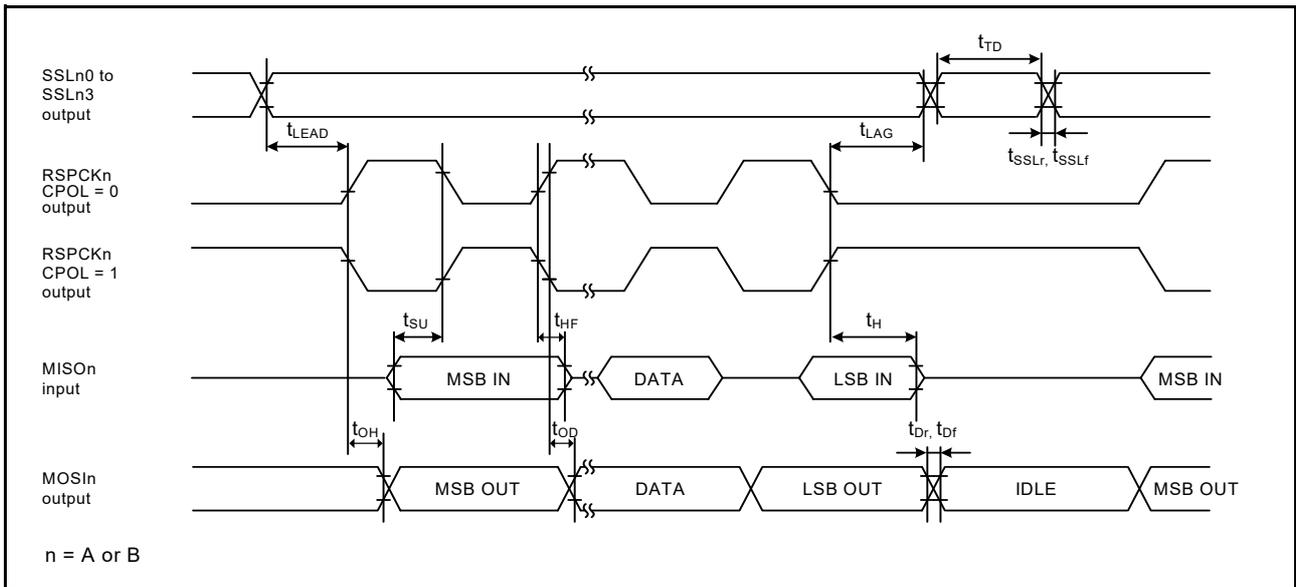


Figure 2.53 SPI timing (master, CPHA = 1) (bit rate: PCLKB division ratio is set to 1/2)

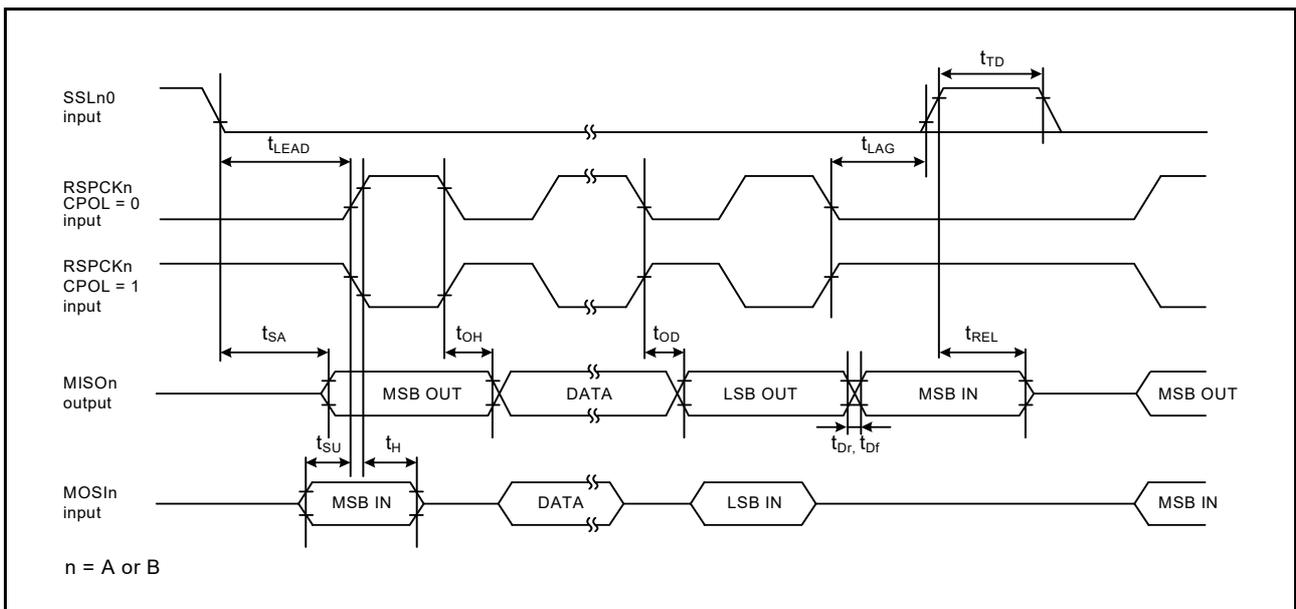


Figure 2.54 SPI timing (slave, CPHA = 0)

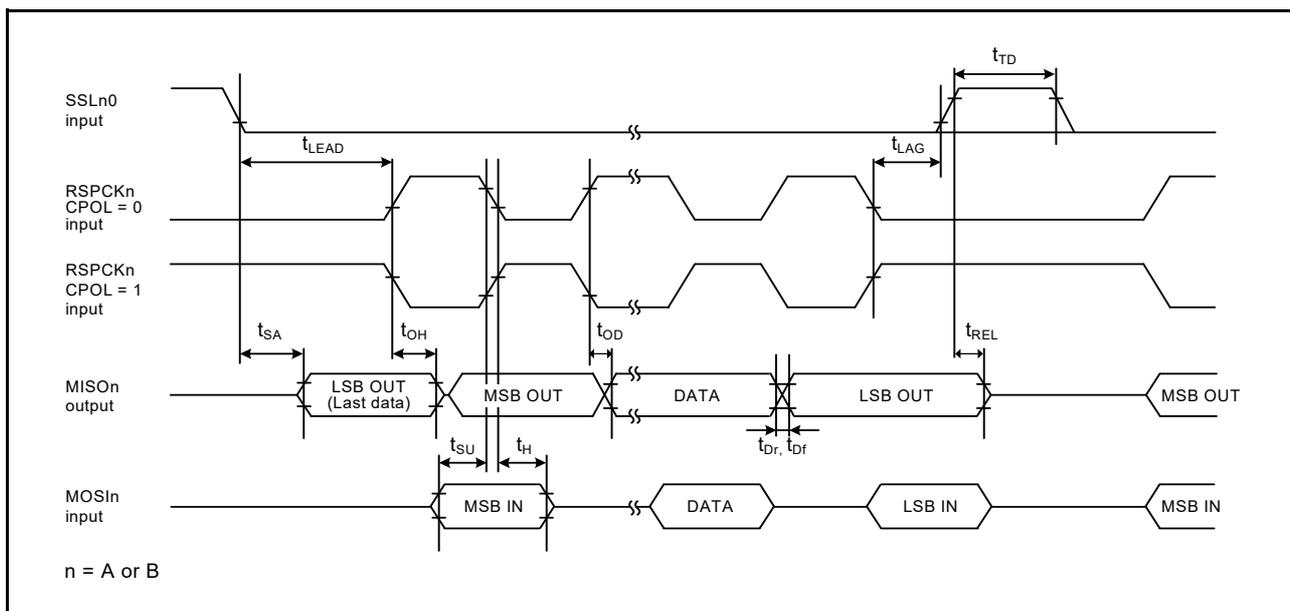


Figure 2.55 SPI timing (slave, CPHA = 1)

2.3.11 IIC Timing

Table 2.38 IIC timing

Conditions: VCC = AVCC0 = 2.7 to 5.5 V

| Parameter | Symbol | Min*1 | Max | Unit | Test conditions | |
|----------------------------------|---|------------|---|---------------------------|-----------------|-------------|
| IIC (standard mode, SMBus) | SCL input cycle time | t_{SCL} | $6 (12) \times t_{IICcyc} + 1300$ | - | ns | Figure 2.56 |
| | SCL input high pulse width | t_{SCLH} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | SCL input low pulse width | t_{SCLL} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | 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 | $1 (4) \times t_{IICcyc}$ | ns | |
| | SDA input bus free time (When wakeup function is disabled) | t_{BUF} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | SDA input bus free time (When wakeup function is enabled) | t_{BUF} | $3 (6) \times t_{IICcyc} + 4 \times t_{Pcyc} + 300$ | - | ns | |
| | START condition input hold time (When wakeup function is disabled) | t_{STAH} | $t_{IICcyc} + 300$ | - | ns | |
| | START condition input hold time (When wakeup function is enabled) | t_{STAH} | $1 (5) \times t_{IICcyc} + t_{Pcyc} + 300$ | - | ns | |
| | Repeated START condition input setup time | t_{STAS} | 1000 | - | ns | |
| | STOP condition input setup time | t_{STOS} | 1000 | - | ns | |
| | Data input setup time | t_{SDAS} | $t_{IICcyc} + 50$ | - | ns | |
| | Data input hold time | t_{SDAH} | 0 | - | ns | |
| SCL, SDA capacitive load | C_b | - | 400 | pF | | |
| IIC (Fast mode) | SCL input cycle time | t_{SCL} | $6 (12) \times t_{IICcyc} + 600$ | - | ns | Figure 2.56 |
| | SCL input high pulse width | t_{SCLH} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | SCL input low pulse width | t_{SCLL} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | 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 | $1 (4) \times t_{IICcyc}$ | ns | |
| | SDA input bus free time (When wakeup function is disabled) | t_{BUF} | $3 (6) \times t_{IICcyc} + 300$ | - | ns | |
| | SDA input bus free time (When wakeup function is enabled) | t_{BUF} | $3 (6) \times t_{IICcyc} + 4 \times t_{Pcyc} + 300$ | - | ns | |
| | START condition input hold time (When wakeup function is disabled) | t_{STAH} | $t_{IICcyc} + 300$ | - | ns | |
| | START condition input hold time (When wakeup function is enabled) | t_{STAH} | $1(5) \times t_{IICcyc} + t_{Pcyc} + 300$ | - | ns | |
| | Repeated START condition input setup time | t_{STAS} | 300 | - | ns | |
| | STOP condition input setup time | t_{STOS} | 300 | - | ns | |
| | Data input setup time | t_{SDAS} | $t_{IICcyc} + 50$ | - | ns | |
| | Data input hold time | t_{SDAH} | 0 | - | ns | |
| SCL, SDA capacitive load | C_b | - | 400 | pF | | |

Note: t_{IICcyc} : IIC internal reference clock (IIC ϕ) cycle, t_{Pcyc} : PCLKB cycle

Note 1. 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.

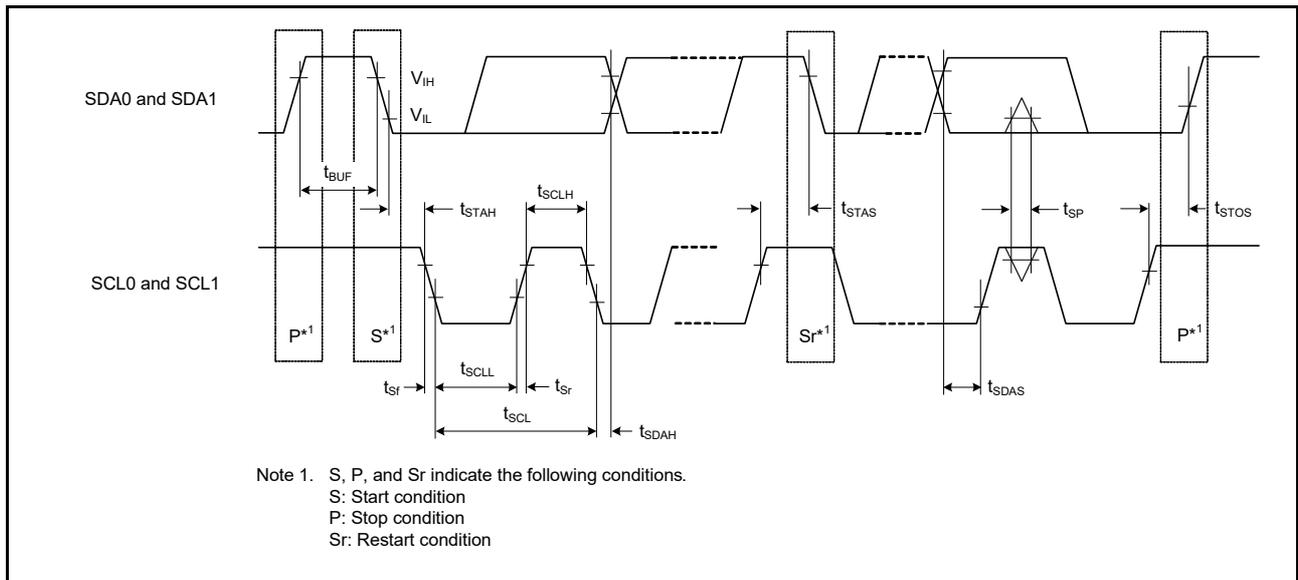


Figure 2.56 I²C bus interface input/output timing

2.3.12 CLKOUT Timing

Table 2.39 CLKOUT timing

| Parameter | | Symbol | Min | Max | Unit | Test conditions | |
|-----------|-------------------------------|------------------|----------------------|------|------|-----------------|-------------|
| CLKOUT | CLKOUT pin output cycle*1 | t _{Cyc} | VCC = 2.7 V or above | 62.5 | - | ns | Figure 2.57 |
| | | | VCC = 1.8 V or above | 125 | - | | |
| | | | VCC = 1.6 V or above | 250 | - | | |
| CLKOUT | CLKOUT pin high pulse width*2 | t _{CH} | VCC = 2.7 V or above | 15 | - | ns | |
| | | | VCC = 1.8 V or above | 30 | - | | |
| | | | VCC = 1.6 V or above | 150 | - | | |
| CLKOUT | CLKOUT pin low pulse width*2 | t _{CL} | VCC = 2.7 V or above | 15 | - | ns | |
| | | | VCC = 1.8 V or above | 30 | - | | |
| | | | VCC = 1.6 V or above | 150 | - | | |
| CLKOUT | CLKOUT pin output rise time | t _{Cr} | VCC = 2.7 V or above | - | 12 | ns | |
| | | | VCC = 1.8 V or above | - | 25 | | |
| | | | VCC = 1.6 V or above | - | 50 | | |
| CLKOUT | CLKOUT pin output fall time | t _{Cf} | VCC = 2.7 V or above | - | 12 | ns | |
| | | | VCC = 1.8 V or above | - | 25 | | |
| | | | VCC = 1.6 V or above | - | 50 | | |

Note 1. When the EXTAL external clock input or an oscillator divided by 1 (the CKOCR.CKOSEL[2:0] bits are 011b and the CKOCR.CKODIV[2:0] bits are 000b) is used for output from CLKOUT, specifications in Table 2.39 should be satisfied with 45% to 55% of input duty cycle.

Note 2. When MOCO is selected as the clock output source (the CKOCR.CKOSEL[2:0] bits are 001b), set the clock output division ratio to 2 (the CKOCR.CKODIV[2:0] bits are 001b).

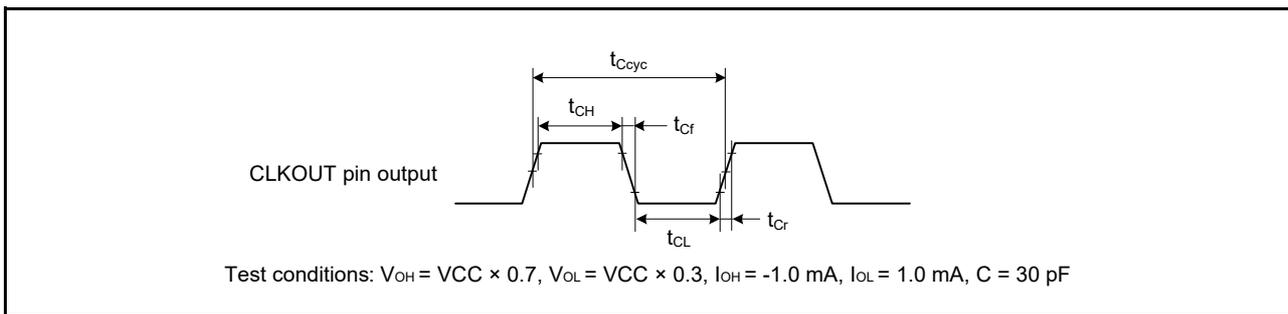


Figure 2.57 CLKOUT output timing

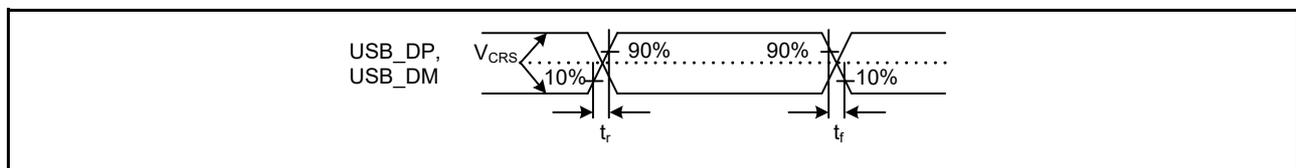
2.4 USB Characteristics

2.4.1 USBFS Timing

Table 2.40 USB characteristics

 Conditions: $V_{CC} = AV_{CC0} = V_{CC_USB} = 3.0$ to 3.6 V, $T_a = -20$ to $+85^\circ\text{C}$

| Parameter | | Symbol | Min | Max | Unit | Test conditions | |
|--|--------------------------------|----------------|---------------------|---------------------|---|---|----|
| Input characteristics | Input high level voltage | V_{IH} | 2.0 | - | V | - | |
| | Input low level 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 level voltage | V_{OH} | 2.8 | V_{CC_USB} | V | $I_{OH} = -200 \mu\text{A}$ | |
| | Output low level voltage | V_{OL} | 0.0 | 0.3 | V | $I_{OL} = 2 \text{ mA}$ | |
| | Cross-over voltage | V_{CRS} | 1.3 | 2.0 | V | Figure 2.58, Figure 2.59, Figure 2.60 | |
| | Rise time | FS | t_r | 4 | 20 | | ns |
| | | LS | | 75 | 300 | | |
| | Fall time | FS | t_f | 4 | 20 | | ns |
| | | LS | | 75 | 300 | | |
| | Rise/fall time ratio | FS | t_r/t_f | 90 | 111.11 | | % |
| LS | | 80 | | 125 | | | |
| Output resistance | Z_{DRV} | 28 | 44 | Ω | (Adjusting the resistance of external elements is not necessary.) | | |
| VBUS characteristics | VBUS input voltage | V_{IH} | $V_{CC} \times 0.8$ | - | V | - | |
| | | V_{IL} | - | $V_{CC} \times 0.2$ | V | - | |
| Pull-up, pull-down | Pull-down resistor | R_{PD} | 14.25 | 24.80 | k Ω | - | |
| | Pull-up resistor | R_{PUI} | 0.9 | 1.575 | k Ω | During idle state | |
| | | R_{PUA} | 1.425 | 3.09 | k Ω | During reception | |
| Battery Charging Specification Ver 1.2 | D + sink current | I_{DP_SINK} | 25 | 175 | μA | - | |
| | D - sink current | I_{DM_SINK} | 25 | 175 | μA | - | |
| | DCD source current | I_{DP_SRC} | 7 | 13 | μA | - | |
| | Data detection voltage | V_{DAT_REF} | 0.25 | 0.4 | V | - | |
| | D + source voltage | V_{DP_SRC} | 0.5 | 0.7 | V | Output current = $250 \mu\text{A}$ | |
| | D - source voltage | V_{DM_SRC} | 0.5 | 0.7 | V | Output current = $250 \mu\text{A}$ | |


Figure 2.58 USB_DP and USB_DM output timing

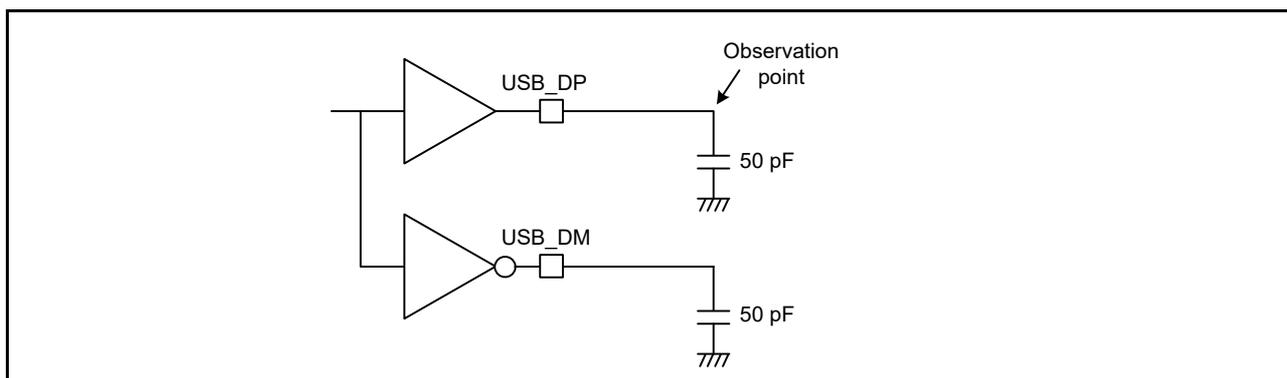


Figure 2.59 Test circuit for Full-Speed (FS) connection

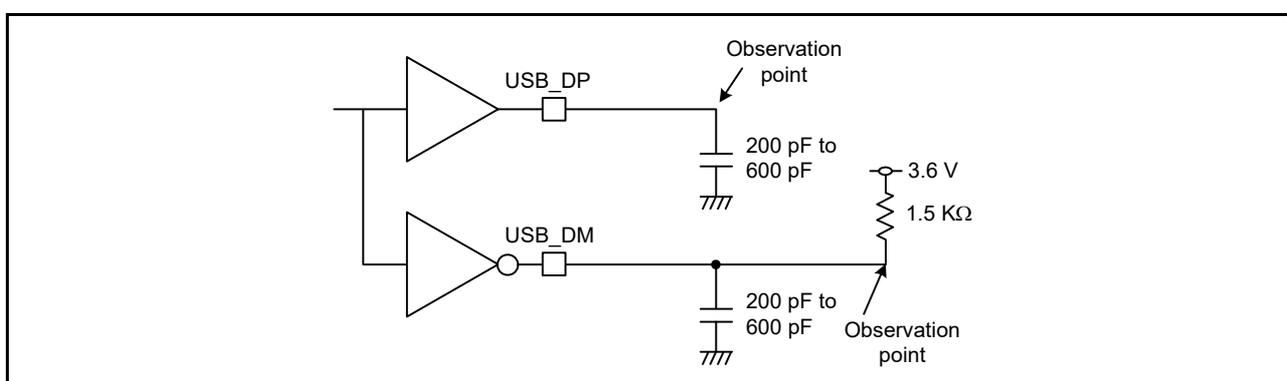


Figure 2.60 Test circuit for Low-Speed (LS) connection

2.4.2 USB External Supply

Table 2.41 USB regulator

| Parameter | Min | Typ | Max | Unit | Test conditions | |
|------------------------|--------------------|-----|-----|------|-----------------|---|
| VCC_USB supply current | VCC_USB_LDO ≥ 3.8V | - | - | 50 | mA | - |
| | VCC_USB_LDO ≥ 4.5V | - | - | 100 | mA | - |
| VCC_USB supply voltage | 3.0 | - | 3.6 | V | - | |

2.5 ADC14 Characteristics

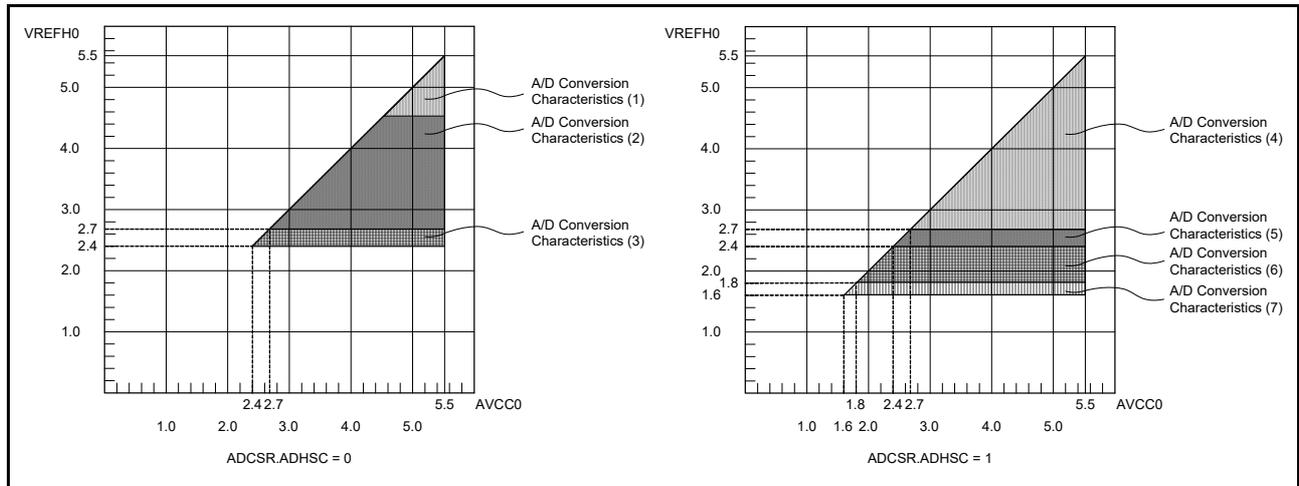


Figure 2.61 AVCC0 to VREFH0 voltage range

Table 2.42 A/D conversion characteristics (1) in high-speed A/D conversion mode (1 of 2)

Conditions: VCC = AVCC0 = 4.5 to 5.5 V, VREFH0 = 4.5 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|--|--|------|-------|----------------------|------|---|
| Frequency | | 1 | - | 64 | MHz | - |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | - | - | 9 (reference data) | pF | Normal-precision channel |
| Analog input resistance | Rs | - | - | 2.5 (reference data) | kΩ | High-precision channel |
| | | - | - | 6.7 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | Ain | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | | - | - | 12 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 64 MHz) | Permissible signal source impedance Max. = 0.3 kΩ | 0.70 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 1.13 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±0.5 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Full-scale error | | - | ±0.75 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±1.25 | ±5.0 | LSB | High-precision channel |
| | | | | ±8.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±1.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±1.0 | ±3.0 | LSB | - |
| 14-bit mode | | | | | | |
| Resolution | | - | - | 14 | Bit | - |

Table 2.42 A/D conversion characteristics (1) in high-speed A/D conversion mode (2 of 2)

Conditions: VCC = AVCC0 = 4.5 to 5.5 V, VREFH0 = 4.5 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|---|---|------|------|-------|------|---|
| Conversion time*1 (Operation at PCLKD = 64 MHz) | Permissible signal source impedance Max. = 0.3 kΩ | 0.80 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 1.22 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±2.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Full-scale error | | - | ±3.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±5.0 | ±20 | LSB | High-precision channel |
| | | | | ±32.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±4.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±4.0 | ±12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (C_{in}), see section [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.43 A/D conversion characteristics (2) in high-speed A/D conversion mode (1 of 2)

Conditions: VCC = AVCC0 = 2.7 to 5.5 V, VREFH0 = 2.7 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|---|---|------|-------|-------------------------|------|---|
| Frequency | | 1 | - | 48 | MHz | - |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | | | 9 (reference data) | pF | Normal-precision channel |
| Analog input resistance | Rs | - | - | 2.5 (reference data) | kΩ | High-precision channel |
| | | | | 6.7 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | A _{in} | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | | - | - | 12 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 48 MHz) | Permissible signal source impedance Max. = 0.3 kΩ | 0.94 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 1.50 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±0.5 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Full-scale error | | - | ±0.75 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |

Table 2.43 A/D conversion characteristics (2) in high-speed A/D conversion mode (2 of 2)

Conditions: VCC = AVCC0 = 2.7 to 5.5 V, VREFH0 = 2.7 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | Min | Typ | Max | Unit | Test Conditions | |
|---|---|-------|-------|------|------------------------|---|
| Quantization error | - | ±0.5 | - | LSB | - | |
| Absolute accuracy | - | ±1.25 | ±5.0 | LSB | High-precision channel | |
| | | | ±8.0 | LSB | Other than above | |
| DNL differential nonlinearity error | - | ±1.0 | - | LSB | - | |
| INL integral nonlinearity error | - | ±1.0 | ±3.0 | LSB | - | |
| 14-bit mode | | | | | | |
| Resolution | - | - | 14 | Bit | - | |
| Conversion time*1 (Operation at PCLKD = 48 MHz) | Permissible signal source impedance Max. = 0.3 kΩ | 1.06 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 1.63 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | - | ±2.0 | ±18 | LSB | High-precision channel | |
| | | | ±24.0 | LSB | Other than above | |
| Full-scale error | - | ±3.0 | ±18 | LSB | High-precision channel | |
| | | | ±24.0 | LSB | Other than above | |
| Quantization error | - | ±0.5 | - | LSB | - | |
| Absolute accuracy | - | ±5.0 | ±20 | LSB | High-precision channel | |
| | | | ±32.0 | LSB | Other than above | |
| DNL differential nonlinearity error | - | ±4.0 | - | LSB | - | |
| INL integral nonlinearity error | - | ±4.0 | ±12.0 | LSB | - | |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (C_{in}), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.44 A/D conversion characteristics (3) in high-speed A/D conversion mode (1 of 2)

Conditions: VCC = AVCC0 = 2.4 to 5.5 V, VREFH0 = 2.4 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | Min | Typ | Max | Unit | Test Conditions | |
|----------------------------|-----------------|-----|-----|-------------------------|-----------------|--------------------------|
| Frequency | 1 | - | 32 | MHz | - | |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | | | 9 (reference data) | pF | Normal-precision channel |
| Analog input resistance | Rs | - | - | 2.5 (reference data) | kΩ | High-precision channel |
| | | | | 6.7 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | A _{in} | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | - | - | 12 | Bit | - | |

Table 2.44 A/D conversion characteristics (3) in high-speed A/D conversion mode (2 of 2)

Conditions: VCC = AVCC0 = 2.4 to 5.5 V, VREFH0 = 2.4 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|---|---|------|-------|-------|------|---|
| Conversion time*1 (Operation at PCLKD = 32 MHz) | Permissible signal source impedance Max. = 1.3 kΩ | 1.41 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 2.25 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±0.5 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Full-scale error | | - | ±0.75 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±1.25 | ±5.0 | LSB | High-precision channel |
| | | | | ±8.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±1.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±1.0 | ±3.0 | LSB | - |
| 14-bit mode | | | | | | |
| Resolution | | - | - | 14 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 32 MHz) | Permissible signal source impedance Max. = 1.3 kΩ | 1.59 | - | - | μs | High-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 0Dh |
| | | 2.44 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 0 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±2.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Full-scale error | | - | ±3.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±5.0 | ±20 | LSB | High-precision channel |
| | | | | ±32.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±4.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±4.0 | ±12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (Cin), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.45 A/D conversion characteristics (4) in low-power A/D conversion mode (1 of 2)

Conditions: VCC = AVCC0 = 2.7 to 5.5 V, VREFH0 = 2.7 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|----------------------------|----|-----|-----|--------------------------|------|--------------------------|
| Frequency | | 1 | - | 24 | MHz | - |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | - | - | 9 (reference data) | pF | Normal-precision channel |

Table 2.45 A/D conversion characteristics (4) in low-power A/D conversion mode (2 of 2)

Conditions: VCC = AVCC0 = 2.7 to 5.5 V, VREFH0 = 2.7 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|---|---|------|-------|-------------------------|------|---|
| Analog input resistance | Rs | - | - | 2.5 (reference data) | kΩ | High-precision channel |
| | | - | - | 6.7 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | Ain | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | | - | - | 12 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 24 MHz) | Permissible signal source impedance Max. = 1.1 kΩ | 2.25 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 3.38 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±0.5 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Full-scale error | | - | ±0.75 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±1.25 | ±5.0 | LSB | High-precision channel |
| | | | | ±8.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±1.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±1.0 | ±3.0 | LSB | - |
| 14-bit mode | | | | | | |
| Resolution | | - | - | 14 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 24 MHz) | Permissible signal source impedance Max. = 1.1 kΩ | 2.50 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 3.63 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±2.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Full-scale error | | - | ±3.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±5.0 | ±20 | LSB | High-precision channel |
| | | | | ±32.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±4.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±4.0 | ±12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (Cin), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.46 A/D conversion characteristics (5) in low-power A/D conversion mode

Conditions: VCC = AVCC0 = 2.4 to 5.5 V, VREFH0 = 2.4 to 5.5 V, VSS = AVSS0 = VREFL0 = 0V

Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|---|---|------|-------|-------------------------|------|---|
| Frequency | | 1 | - | 16 | MHz | - |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | - | - | 9 (reference data) | pF | Normal-precision channel |
| Analog input resistance | Rs | - | - | 2.5 (reference data) | kΩ | High-precision channel |
| | | - | - | 6.7 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | Ain | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | | - | - | 12 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 16 MHz) | Permissible signal source impedance Max. = 2.2 kΩ | 3.38 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 5.06 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±0.5 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Full-scale error | | - | ±0.75 | ±4.5 | LSB | High-precision channel |
| | | | | ±6.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±1.25 | ±5.0 | LSB | High-precision channel |
| | | | | ±8.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±1.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±1.0 | ±3.0 | LSB | - |
| 14-bit mode | | | | | | |
| Resolution | | - | - | 14 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 16 MHz) | Permissible signal source impedance Max. = 2.2 kΩ | 3.75 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 5.44 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±2.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Full-scale error | | - | ±3.0 | ±18 | LSB | High-precision channel |
| | | | | ±24.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±5.0 | ±20 | LSB | High-precision channel |
| | | | | ±32.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±4.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±4.0 | ±12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute

accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (C_{in}), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.47 A/D conversion characteristics (6) in low-power A/D conversion mode (1 of 2)

Conditions: VCC = AVCC0 = 1.8 to 5.5 V (AVCC0 = VCC when VCC < 2.0 V), VREFH0 = 1.8 to 5.5 V, VSS = AVSS0 = VREFL0 = 0 V
Reference voltage range applied to the VREFH0 and VREFL0.

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|--|---|-------|------|-------------------------|------|---|
| Frequency | | 1 | - | 8 | MHz | - |
| Analog input capacitance*2 | Cs | - | - | 8 (reference data) | pF | High-precision channel |
| | | - | - | 9 (reference data) | pF | Normal-precision channel |
| Analog input resistance | Rs | - | - | 3.8 (reference data) | kΩ | High-precision channel |
| | | - | - | 8.2 (reference data) | kΩ | Normal-precision channel |
| Analog input voltage range | Ain | 0 | - | VREFH0 | V | - |
| 12-bit mode | | | | | | |
| Resolution | | - | - | 12 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 8 MHz) | Permissible signal source impedance Max. = 5 kΩ | 6.75 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 10.13 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±1.0 | ±7.5 | LSB | High-precision channel |
| | | | | ±10.0 | LSB | Other than above |
| Full-scale error | | - | ±1.5 | ±7.5 | LSB | High-precision channel |
| | | | | ±10.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |
| Absolute accuracy | | - | ±3.0 | ±8.0 | LSB | High-precision channel |
| | | | | ±12.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ±1.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ±1.0 | ±3.0 | LSB | - |
| 14-bit mode | | | | | | |
| Resolution | | - | - | 14 | Bit | - |
| Conversion time*1 (Operation at PCLKD = 8 MHz) | Permissible signal source impedance Max. = 5 kΩ | 7.50 | - | - | μs | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 10.88 | - | - | μs | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ±4.0 | ±30.0 | LSB | High-precision channel |
| | | | | ±40.0 | LSB | Other than above |
| Full-scale error | | - | ±6.0 | ±30.0 | LSB | High-precision channel |
| | | | | ±40.0 | LSB | Other than above |
| Quantization error | | - | ±0.5 | - | LSB | - |

Table 2.47 A/D conversion characteristics (6) in low-power A/D conversion mode (2 of 2)

Conditions: $V_{CC} = AV_{CC0} = 1.8$ to 5.5 V ($AV_{CC0} = V_{CC}$ when $V_{CC} < 2.0$ V), $V_{REFH0} = 1.8$ to 5.5 V, $V_{SS} = AV_{SS0} = V_{REFL0} = 0$ V
Reference voltage range applied to the V_{REFH0} and V_{REFL0} .

| Parameter | Min | Typ | Max | Unit | Test Conditions |
|-------------------------------------|-----|------------|------------|------|------------------------|
| Absolute accuracy | - | ± 12.0 | ± 32.0 | LSB | High-precision channel |
| | | | ± 48.0 | LSB | Other than above |
| DNL differential nonlinearity error | - | ± 4.0 | - | LSB | - |
| INL integral nonlinearity error | - | ± 4.0 | ± 12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (C_{in}), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

Table 2.48 A/D conversion characteristics (7) in low-power A/D conversion mode (1 of 2)

Conditions: $V_{CC} = AV_{CC0} = 1.6$ to 5.5 V ($AV_{CC0} = V_{CC}$ when $V_{CC} < 2.0$ V), $V_{REFH0} = 1.6$ to 5.5 V, $V_{SS} = AV_{SS0} = V_{REFL0} = 0$ V
Reference voltage range applied to the V_{REFH0} and V_{REFL0} .

| Parameter | Min | Typ | Max | Unit | Test Conditions | |
|--|---|-----------|--------------------------|------------|--------------------------|---|
| Frequency | 1 | - | 4 | MHz | - | |
| Analog input capacitance*2 | C_s | - | 8 (reference data) | pF | High-precision channel | |
| | | | 9 (reference data) | pF | Normal-precision channel | |
| Analog input resistance | R_s | - | 13.1 (reference data) | k Ω | High-precision channel | |
| | | | 14.3 (reference data) | k Ω | Normal-precision channel | |
| Analog input voltage range | A_{in} | 0 | V_{REFH0} | V | - | |
| 12-bit mode | | | | | | |
| Resolution | - | - | 12 | Bit | - | |
| Conversion time*1 (Operation at PCLKD = 4 MHz) | Permissible signal source impedance Max. = 9.9 k Ω | 13.5 | - | - | μ s | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 20.25 | - | - | μ s | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | - | ± 1.0 | ± 7.5 | LSB | High-precision channel | |
| | | | ± 10.0 | LSB | Other than above | |
| Full-scale error | - | ± 1.5 | ± 7.5 | LSB | High-precision channel | |
| | | | ± 10.0 | LSB | Other than above | |
| Quantization error | - | ± 0.5 | - | LSB | - | |
| Absolute accuracy | - | ± 3.0 | ± 8.0 | LSB | High-precision channel | |
| | | | ± 12.0 | LSB | Other than above | |
| DNL differential nonlinearity error | - | ± 1.0 | - | LSB | - | |
| INL integral nonlinearity error | - | ± 1.0 | ± 3.0 | LSB | - | |
| 14-bit mode | | | | | | |
| Resolution | - | - | 14 | Bit | - | |

Table 2.48 A/D conversion characteristics (7) in low-power A/D conversion mode (2 of 2)

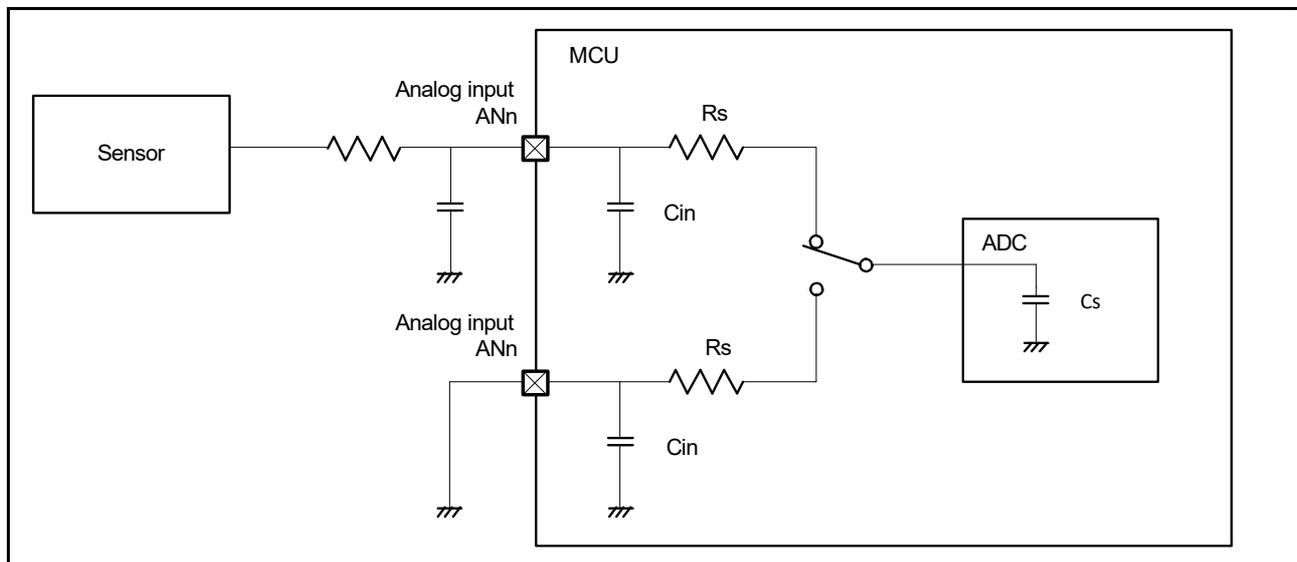
Conditions: $V_{CC} = AV_{CC0} = 1.6$ to 5.5 V ($AV_{CC0} = V_{CC}$ when $V_{CC} < 2.0$ V), $V_{REFH0} = 1.6$ to 5.5 V, $V_{SS} = AV_{SS0} = V_{REFL0} = 0$
Reference voltage range applied to the V_{REFH0} and V_{REFL0} .

| Parameter | | Min | Typ | Max | Unit | Test Conditions |
|--|---|-------|------------|------------|---------|---|
| Conversion time*1 (Operation at PCLKD = 4 MHz) | Permissible signal source impedance Max. = 9.9 k Ω | 15.0 | - | - | μ s | High-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 0Dh |
| | | 21.75 | - | - | μ s | Normal-precision channel ADCSR.ADHSC = 1 ADSSTRn.SST[7:0] = 28h |
| Offset error | | - | ± 4.0 | ± 30.0 | LSB | High-precision channel |
| | | | | ± 40.0 | LSB | Other than above |
| Full-scale error | | - | ± 6.0 | ± 30.0 | LSB | High-precision channel |
| | | | | ± 40.0 | LSB | Other than above |
| Quantization error | | - | ± 0.5 | - | LSB | - |
| Absolute accuracy | | - | ± 12.0 | ± 32.0 | LSB | High-precision channel |
| | | | | ± 48.0 | LSB | Other than above |
| DNL differential nonlinearity error | | - | ± 4.0 | - | LSB | - |
| INL integral nonlinearity error | | - | ± 4.0 | ± 12.0 | LSB | - |

Note: The characteristics apply when no pin functions other than 14-bit A/D converter input are used. Absolute accuracy does not include quantization errors. Offset error, full-scale error, DNL differential nonlinearity error, and INL integral nonlinearity error do not include quantization errors.

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

Note 2. Except for I/O input capacitance (C_{in}), see [section 2.2.4, I/O VOH, VOL, and Other Characteristics](#).

**Figure 2.62 Equivalent circuit for analog input****Table 2.49 14-bit A/D converter channel classification (1 of 2)**

| Classification | Channel | Conditions | Remarks |
|--|----------------------------|-----------------------------|---|
| High-precision channel | AN000 to AN013 | $AV_{CC0} = 1.6$ to 5.5 V | Pins AN000 to AN013 cannot be used as general I/O, IRQ2 input, or for TS transmission when the A/D converter is in use. |
| Normal-precision channel | AN016 to AN022 | | - |
| Internal reference voltage input channel | Internal reference voltage | $AV_{CC0} = 2.0$ to 5.5 V | - |

Table 2.49 14-bit A/D converter channel classification (2 of 2)

| Classification | Channel | Conditions | Remarks |
|----------------------------------|---------------------------|----------------------|---------|
| Temperature sensor input channel | Temperature sensor output | AVCC0 = 2.0 to 5.5 V | - |

Table 2.50 A/D internal reference voltage characteristics

Conditions: VCC = AVCC0 = VREFH0 = 2.0 to 5.5 V*1

| Parameter | Min | Typ | Max | Unit | Test conditions |
|--|------|------|------|------|-----------------|
| Internal reference voltage input channel*2 | 1.36 | 1.43 | 1.50 | V | - |
| Frequency*3 | 1 | - | 2 | MHz | - |
| Sampling time*4 | 5.0 | - | - | μs | - |

Note 1. The internal reference voltage cannot be selected for input channels when AVCC0 < 2.0 V.

Note 2. The 14-bit A/D internal reference voltage indicates the voltage when the internal reference voltage is input to the 14-bit A/D converter.

Note 3. This is a parameter for ADC14 when the internal reference voltage is used as the high-potential reference voltage.

Note 4. This is a parameter for ADC14 when the internal reference voltage is selected for an analog input channel in ADC14.

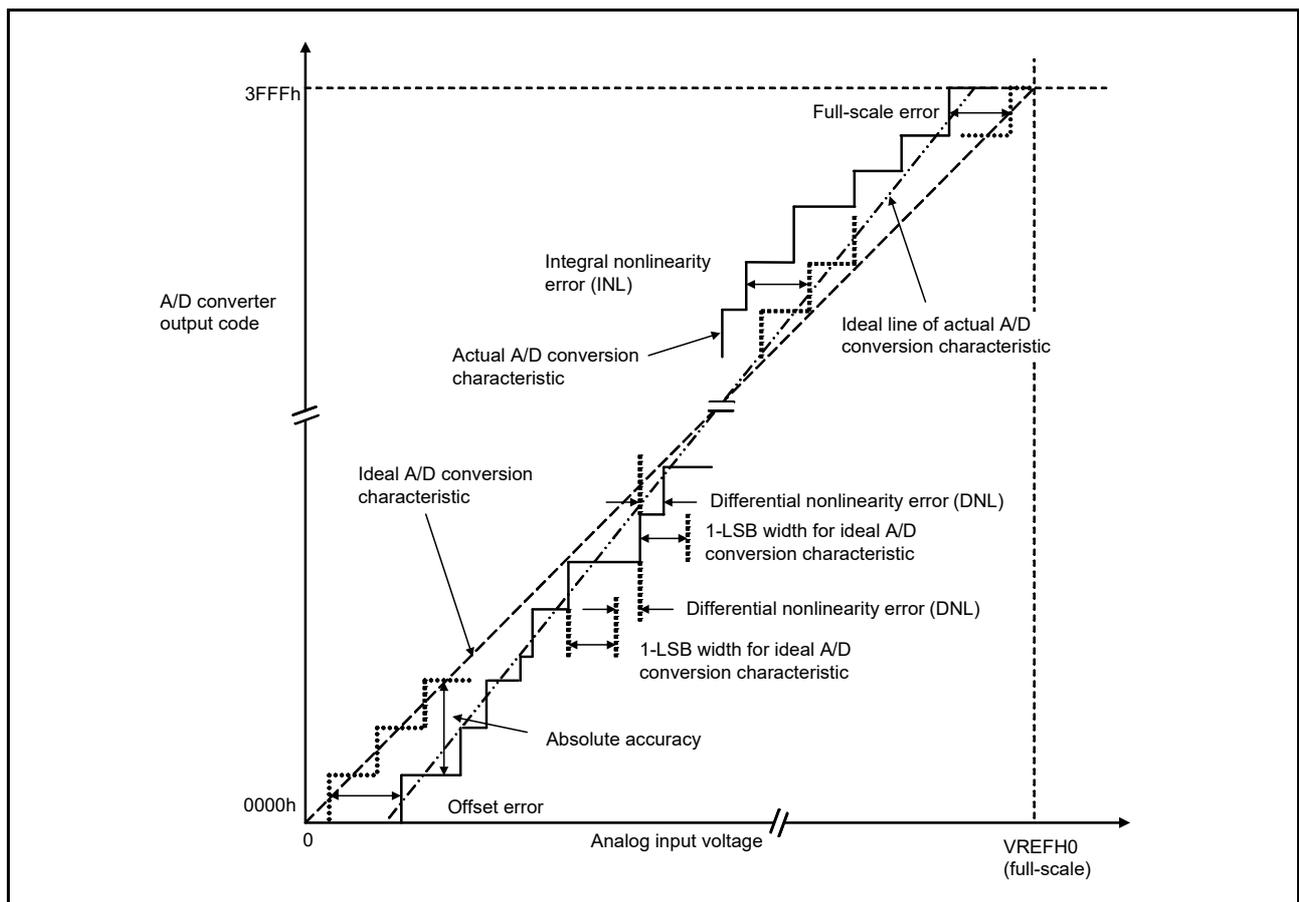


Figure 2.63 Illustration of 14-bit A/D converter characteristic terms

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 the analog input voltage. For example, if 12-bit resolution is used and the reference voltage $V_{REFH0} = 3.072$ V, then 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 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 003h to 00Dh, though an output code of 008h 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 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 DAC8 Characteristics

Table 2.51 D/A conversion characteristics

Conditions: VCC = AVCC0 = 1.8 to 5.5 V

| Parameter | | Min | Typ | Max | Unit | Test conditions |
|--------------------------------|-------------------|-----|-----|------|------|-----------------------|
| Resolution | | - | - | 8 | bit | - |
| Charge pump stabilization time | | - | - | 100 | μs | - |
| Conversion time | VCC = 2.7 to 5.5V | - | - | 3.0 | μs | 35-pF capacitive load |
| | VCC = 1.8 to 2.7V | - | - | 6.0 | μs | |
| Absolute accuracy | VCC = 2.4 to 5.5V | - | - | ±3.0 | LSB | 2-MΩ resistive load |
| | VCC = 1.8 to 2.4V | - | - | ±3.5 | | |
| | VCC = 2.4 to 5.5V | - | - | ±2.0 | LSB | 4-MΩ resistive load |
| | VCC = 1.8 to 2.4V | - | - | ±2.5 | | |
| RO output resistance | | - | 7.4 | - | kΩ | - |

2.7 TSN Characteristics

Table 2.52 TSN characteristics

Conditions: VCC = AVCC0 = 2.0 to 5.5 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|-------------------------------|--------------------|-----|-------|-----|-------|-----------------|
| Relative accuracy | - | - | ±1.5 | - | °C | 2.4 V or above |
| | | - | ±2.0 | - | °C | Below 2.4 V |
| Temperature slope | - | - | -3.65 | - | mV/°C | - |
| Output voltage (at 25°C) | - | - | 1.05 | - | V | VCC = 3.3 V |
| Temperature sensor start time | t _{START} | - | - | 5 | μs | - |
| Sampling time | - | 5 | - | - | μs | - |

2.8 OSC Stop Detect Characteristics

Table 2.53 Oscillation stop detection circuit characteristics

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|----------------|-----------------|-----|-----|-----|------|-----------------|
| Detection time | t _{dr} | - | - | 1 | ms | Figure 2.64 |

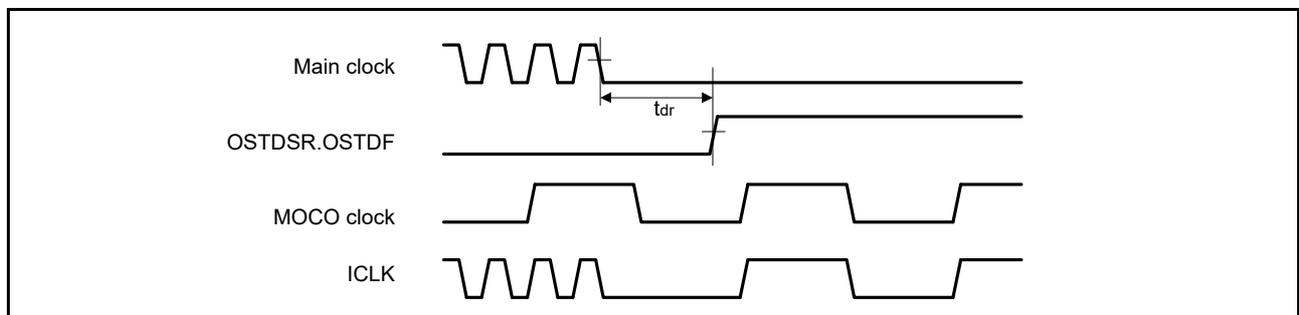


Figure 2.64 Oscillation stop detection timing

2.9 POR and LVD Characteristics

Table 2.54 Power-on reset circuit and voltage detection circuit characteristics (1)

| Parameter | | Symbol | Min | Typ | Max | Unit | Test Conditions |
|---------------------------|------------------------------------|---------------|------|------|------|------|------------------------------------|
| Voltage detection level*1 | Power-on reset (POR) | V_{POR} | 1.27 | 1.42 | 1.57 | V | Figure 2.65, Figure 2.66 |
| | Voltage detection circuit (LVD0)*2 | V_{det0_0} | 3.68 | 3.85 | 4.00 | V | Figure 2.67 At falling edge VCC |
| | | V_{det0_1} | 2.68 | 2.85 | 2.96 | | |
| | | V_{det0_2} | 2.38 | 2.53 | 2.64 | | |
| | | V_{det0_3} | 1.78 | 1.90 | 2.02 | | |
| | | V_{det0_4} | 1.60 | 1.69 | 1.82 | | |
| | Voltage detection circuit (LVD1)*3 | V_{det1_0} | 4.13 | 4.29 | 4.45 | V | Figure 2.68 At falling edge VCC |
| | | V_{det1_1} | 3.98 | 4.16 | 4.30 | | |
| | | V_{det1_2} | 3.86 | 4.03 | 4.18 | | |
| | | V_{det1_3} | 3.68 | 3.86 | 4.00 | | |
| | | V_{det1_4} | 2.98 | 3.10 | 3.22 | | |
| | | V_{det1_5} | 2.89 | 3.00 | 3.11 | | |
| | | V_{det1_6} | 2.79 | 2.90 | 3.01 | | |
| | | V_{det1_7} | 2.68 | 2.79 | 2.90 | | |
| | | V_{det1_8} | 2.58 | 2.68 | 2.78 | | |
| | | V_{det1_9} | 2.48 | 2.58 | 2.68 | | |
| | | V_{det1_A} | 2.38 | 2.48 | 2.58 | | |
| | | V_{det1_B} | 2.10 | 2.20 | 2.30 | | |
| | | V_{det1_C} | 1.84 | 1.96 | 2.05 | | |
| | | V_{det1_D} | 1.74 | 1.86 | 1.95 | | |
| | | V_{det1_E} | 1.63 | 1.75 | 1.84 | | |
| | V_{det1_F} | 1.60 | 1.65 | 1.73 | | | |
| | Voltage detection circuit (LVD2)*4 | V_{det2_0} | 4.11 | 4.31 | 4.48 | V | Figure 2.69 At falling edge VCC |
| | | V_{det2_1} | 3.97 | 4.17 | 4.34 | | |
| | | V_{det2_2} | 3.83 | 4.03 | 4.20 | | |
| | | V_{det2_3} | 3.64 | 3.84 | 4.01 | | |

Note 1. These characteristics apply when noise is not superimposed on the power supply. When a setting causes this voltage detection level to overlap with that of the voltage detection circuit, it cannot be specified whether LVD1 or LVD2 is used for voltage detection.

Note 2. # in the symbol $V_{det0_#}$ denotes the value of the OFS1.VDSEL1[2:0] bits.

Note 3. # in the symbol $V_{det1_#}$ denotes the value of the LVDLVLR.LVD1LVL[4:0] bits.

Note 4. # in the symbol $V_{det2_#}$ denotes the value of the LVDLVLR.LVD2LVL[2:0] bits.

Table 2.55 Power-on reset circuit and voltage detection circuit characteristics (2) (1 of 2)

| Parameter | | Symbol | Min | Typ | Max | Unit | Test Conditions |
|--|----------------|----------------|-----|-----|-----|---------|-----------------------------------|
| Wait time after power-on reset cancellation | LVD0:enable | t_{POR} | - | 1.7 | - | ms | - |
| | LVD0:disable | t_{POR} | - | 1.3 | - | ms | - |
| Wait time after voltage monitor 0,1,2 reset cancellation | LVD0:enable*1 | $t_{LVD0,1,2}$ | - | 0.6 | - | ms | - |
| | LVD0:disable*2 | $t_{LVD1,2}$ | - | 0.2 | - | ms | - |
| Response delay*3 | | t_{det} | - | - | 350 | μ s | Figure 2.65, Figure 2.66 |
| Minimum VCC down time | | t_{VOFF} | 450 | - | - | μ s | Figure 2.65, VCC = 1.0 V or above |

Table 2.55 Power-on reset circuit and voltage detection circuit characteristics (2) (2 of 2)

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions |
|---|--------------|-----|-----|-----|---------|--|
| Power-on reset enable time | $t_{W(POR)}$ | 1 | - | - | ms | Figure 2.66, VCC = below 1.0 V |
| LVD operation stabilization time (after LVD is enabled) | $T_d(E-A)$ | - | - | 300 | μ s | Figure 2.68, Figure 2.69 |
| Hysteresis width (POR) | V_{PORH} | - | 110 | - | mV | - |
| Hysteresis width (LVD0, LVD1 and LVD2) | V_{LVH} | - | 60 | - | mV | LVD0 selected |
| | | - | 100 | - | | V_{det1_0} to V_{det1_2} selected. |
| | | - | 60 | - | | V_{det1_3} to V_{det1_9} selected. |
| | | - | 50 | - | | V_{det1_A} to V_{det1_B} selected. |
| | | - | 40 | - | | V_{det1_C} to V_{det1_F} selected. |
| | | - | 60 | - | | LVD2 selected |

Note 1. When OFS1.LVDAS = 0

Note 2. When OFS1.LVDAS = 1

Note 3. The minimum VCC down time indicates the time when VCC is below the minimum value of voltage detection levels V_{POR} , V_{det0} , V_{det1} , and V_{det2} for the POR/LVD.

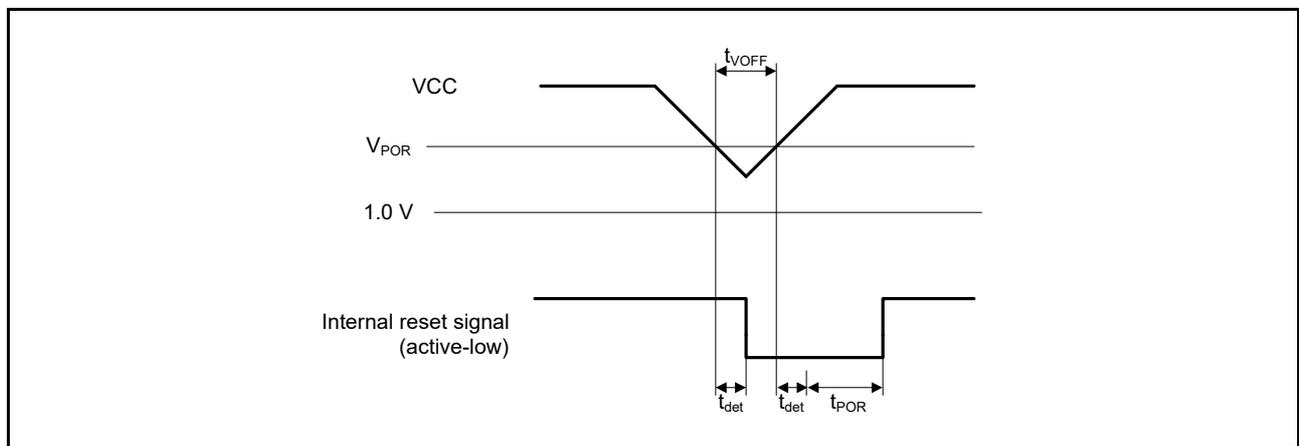


Figure 2.65 Voltage detection reset timing

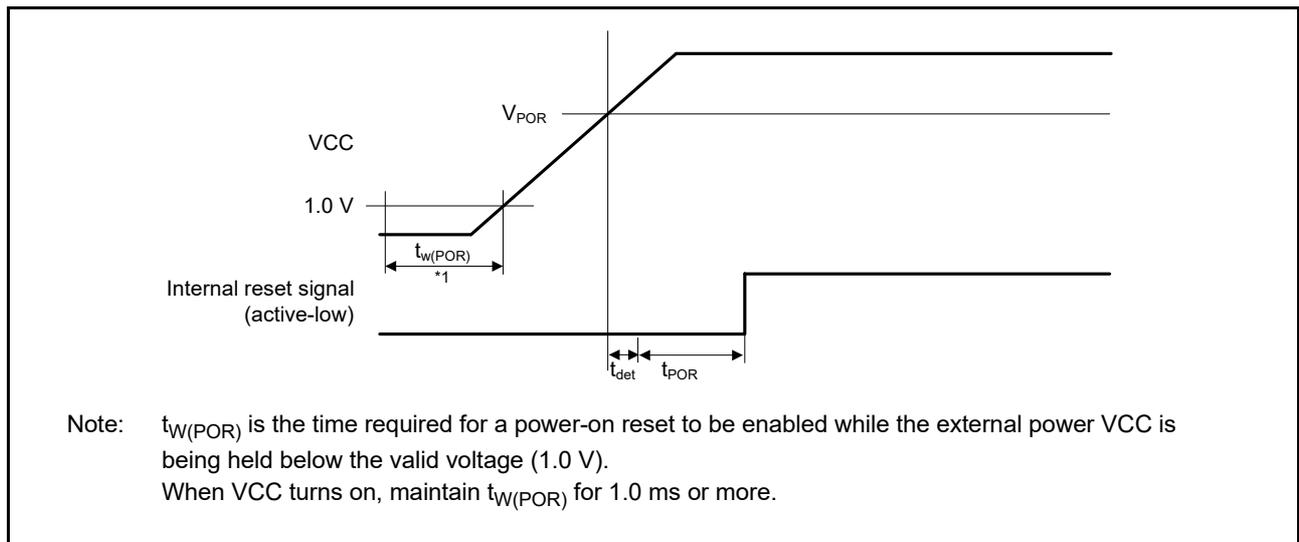


Figure 2.66 Power-on reset timing

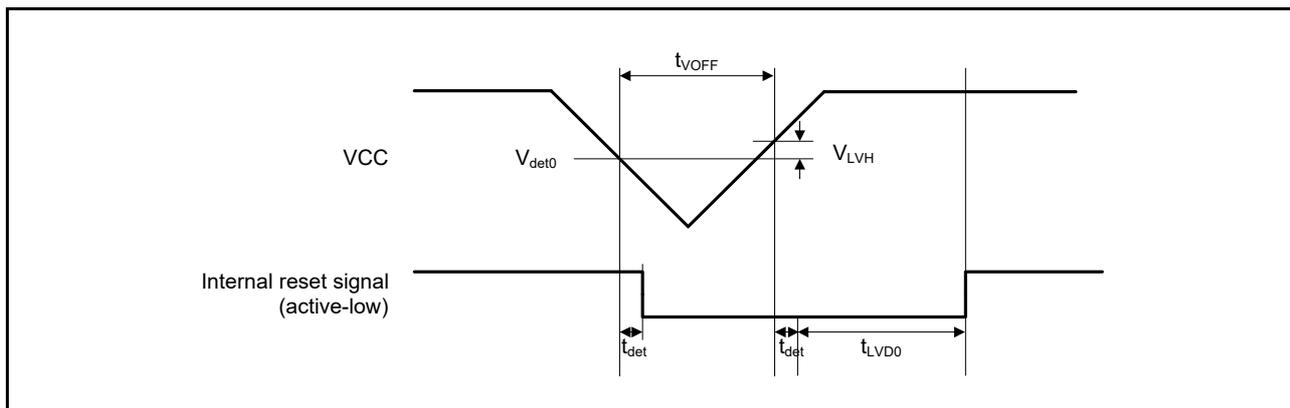


Figure 2.67 Voltage detection circuit timing (V_{det0})

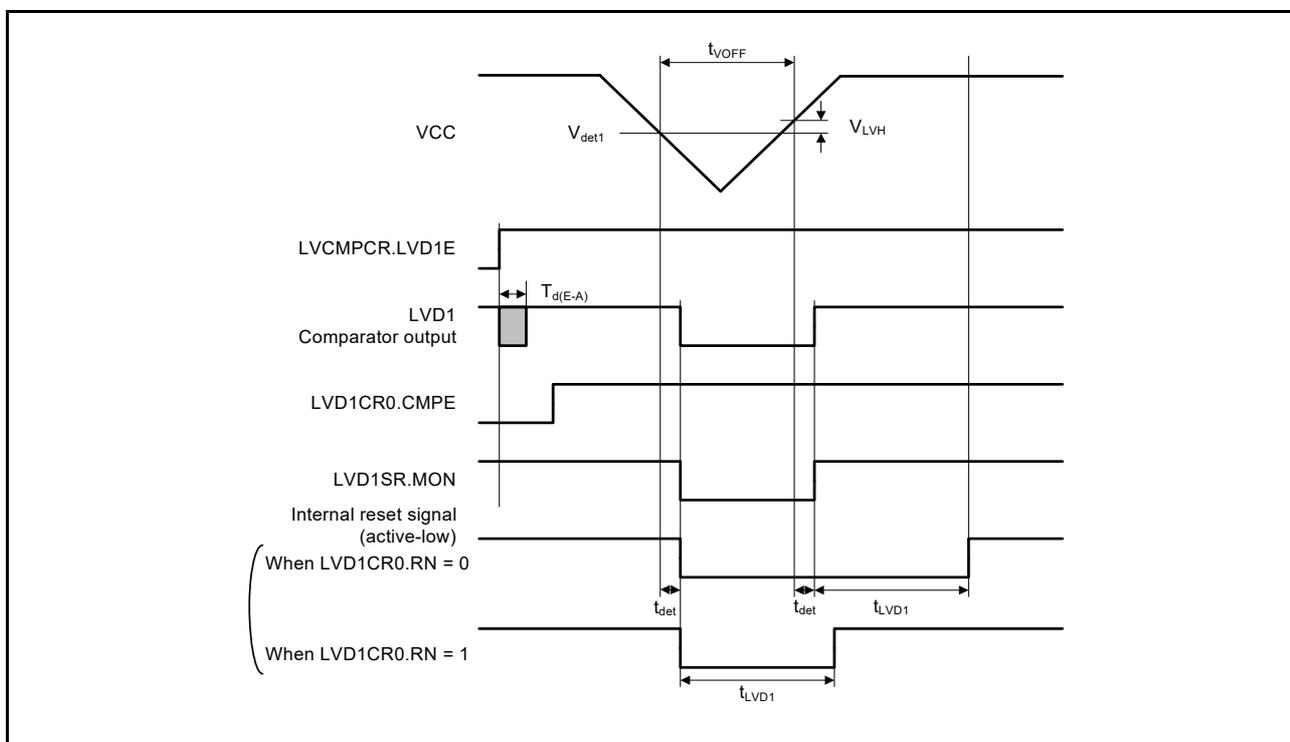


Figure 2.68 Voltage detection circuit timing (V_{det1})

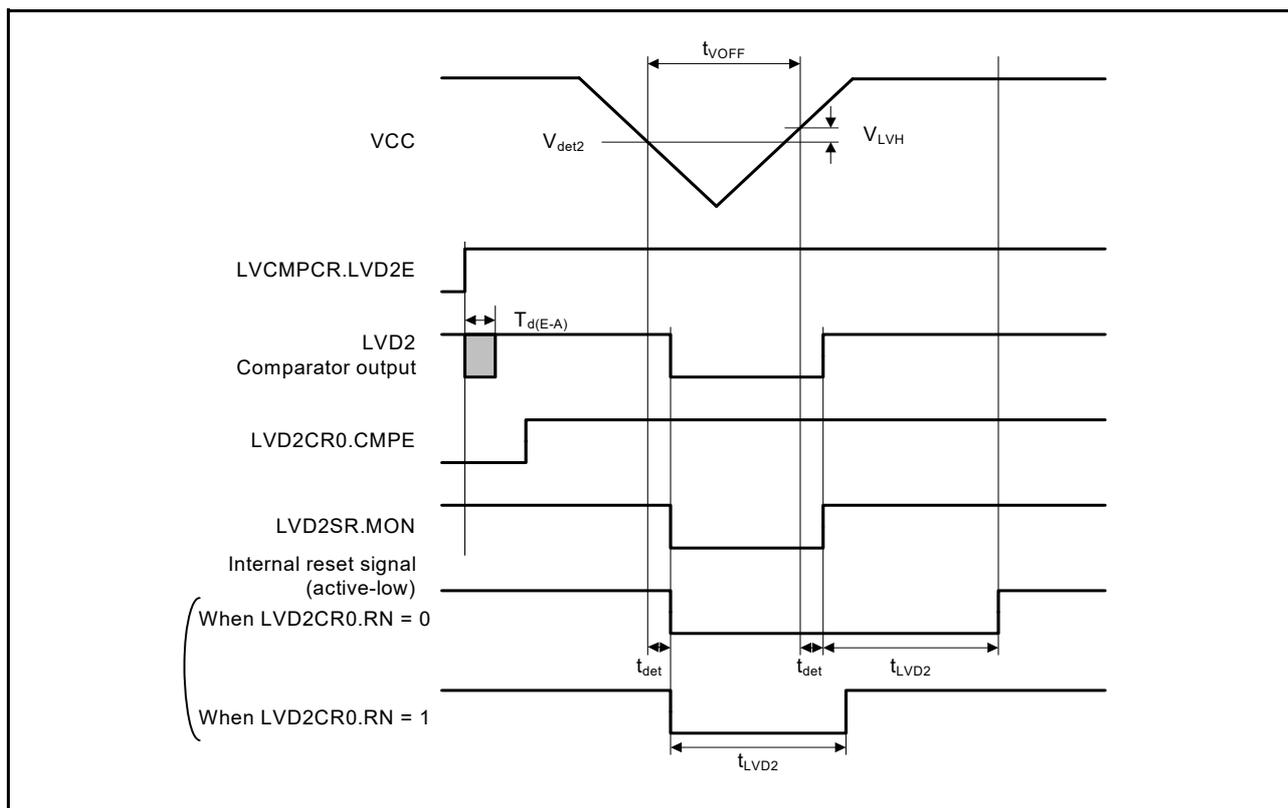


Figure 2.69 Voltage detection circuit timing (V_{det2})

2.10 CTSU Characteristics

Table 2.56 CTSU characteristics

Conditions: VCC = AVCC0 = 1.8 to 5.5 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|---|--------------------|-----|-----|-----|------|---|
| External capacitance connected to TSCAP pin | C _{tscap} | 9 | 10 | 11 | nF | - |
| TS pin capacitive load | C _{base} | - | - | 50 | pF | - |
| Permissible output high current | ΣIoH | - | - | -24 | mA | When the mutual capacitance method is applied |

2.11 Comparator Characteristics

Table 2.57 ACMPHS characteristics

Conditions: VCC = AVCC0 = 2.7 to 5.5 V, VSS = AVSS0 = 0 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|--|---------------------|-----|-----|-------|------|-------------------------|
| Input offset voltage | V _{IOCOMP} | - | ±5 | ±40 | mV | - |
| Input voltage range | V _{ICPM} | 0 | - | AVCC0 | V | - |
| Output delay time | T _d | - | 50 | 100 | ns | Input amplitude ±100 mV |
| Stabilization wait time during input channel switching*1 | T _{WAIT} | 300 | - | - | ns | Input amplitude ±100 mV |
| Operation stabilization wait time*2 | T _{cmp} | 1 | - | - | μs | 3.3 V ≤ AVCC0 ≤ 5.5 V |
| | | 3 | - | - | μs | 2.7 V ≤ AVCC0 < 3.3 V |

Note 1. Period from when the comparator input channel is switched until the switched result reflects in its output.

Note 2. Period from when comparator operation is enabled (CPMCTL.HCMPON = 1) until the comparator satisfies the DC/AC characteristics.

Table 2.58 ACMLP characteristics

Conditions: VCC = AVCC0 = 1.8 to 5.5 V, VSS = AVSS0 = 0 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions | |
|-----------------------------------|--|------------------|-------|------|-------------|-----------------|---|
| Input voltage range | IVREF0 | V _{REF} | 0 | - | VCC - 1.4*1 | V | - |
| | IVREF1 (Standard mode) | | 0 | - | VCC - 1.4 | V | |
| | IVREF1 (Window mode) | | 1.4*1 | - | VCC | V | |
| | IVCMP0, IVCMP1 | V _I | 0 | - | VCC | V | |
| Internal reference voltage | - | 1.36 | 1.44 | 1.50 | V | - | |
| Output delay | Comparator high-speed mode (Standard mode) | T _d | - | - | 1.2 | μs | VCC = 3.0 Slew rate of input signal > 50 mV/μs |
| | Comparator high-speed mode (Window mode) | | | | 2.0 | μs | |
| | Comparator low-speed mode (Standard mode) | | | | 5.0 | μs | |
| Offset voltage | Comparator high-speed mode (Standard mode) | - | - | - | 50 | mV | - |
| | Comparator high-speed mode (Window mode) | | | | 60 | mV | |
| | Comparator low-speed mode (Standard mode) | | | | 40 | mV | |
| Operation stabilization wait time | T _{cmp} | 100 | - | - | μs | - | |

Note 1. In window mode, be sure to satisfy the following condition: IVREF1 - IVREF0 ≥ 0.2 V.

2.12 OPAMP Characteristics

Table 2.59 OPAMP characteristics (1 of 2)

Conditions: 1.8 V ≤ AVCC0 = VCC ≤ 5.5 V, VSS = AVSS0 = 0 V

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|-------------------------|--------------------|-----------------|-----|-----|-------------|------|
| Common mode input range | V _{icm1} | Low-power mode | 0.1 | - | AVCC0 - 0.5 | V |
| | V _{icm2} | High-speed mode | 0.2 | - | AVCC0 - 0.6 | |
| Output voltage range | V _{o1} | Low-power mode | 0.1 | - | AVCC0 - 0.1 | V |
| | V _{o2} | High-speed mode | 0.1 | - | AVCC0 - 0.1 | |
| Input offset voltage | V _{ioff1} | Low-power mode | -7 | - | 7 | mV |
| | V _{ioff2} | High-speed mode | -5 | - | 5 | |

Table 2.59 OPAMP characteristics (2 of 2)Conditions: $1.8\text{ V} \leq AVCC0 = VCC \leq 5.5\text{ V}$, $VSS = AVSS0 = 0\text{ V}$

| Parameter | Symbol | Conditions | | Min | Typ | Max | Unit |
|------------------------------------|--------------|--|------------------------------|------|-------|------|---------------------------|
| Open gain | A_V | - | | 80 | 120 | - | dB |
| Gain-bandwidth (GB) product | GBW1 | Low-power mode | | - | 0.012 | - | MHz |
| | GBW2 | High-speed mode | | - | 1.7 | - | |
| Phase margin | PM | CL = 20 pF | | 50 | - | - | deg |
| Gain margin | GM | CL = 20 pF | | 10 | - | - | dB |
| Equivalent input noise | V_{noise1} | f = 10 Hz | Low-power mode | - | 700 | - | nV/ $\sqrt{\text{Hz}}$ |
| | V_{noise2} | f = 1 kHz | | - | 400 | - | |
| | V_{noise3} | f = 1 kHz | High-speed mode | - | 90 | - | |
| | V_{noise4} | f = 100 kHz | | - | 50 | - | |
| Power supply reduction ratio | PSRR | - | | - | 90 | - | dB |
| Common mode signal reduction ratio | CMRR | - | | - | 90 | - | dB |
| Stabilization wait time | T_{std1} | CL = 20 pF Only operational amplifier is activated.*1 | Low-power mode VCC < 3.6V | 1800 | - | - | μs |
| | | | Low-power mode VCC < 5.5V | 2500 | - | - | |
| | T_{std2} | | High-speed mode | 13 | - | - | |
| | T_{std3} | | Low-power mode VCC < 3.6V | 1800 | - | - | |
| | | | Low-power mode VCC < 5.5V | 2500 | - | - | |
| | T_{std4} | | High-speed mode | 13 | - | - | |
| Settling time | T_{set1} | CL = 20 pF | Low-power mode VCC < 3.6V | - | - | 1400 | μs |
| | | | Low-power mode VCC < 5.5V | - | - | 2000 | μs |
| | | | High-speed mode | - | - | 13 | μs |
| | T_{set2} | | High-speed mode | - | - | 13 | μs |
| Slew rate | T_{slew1} | CL = 20 pF | Low-power mode | - | 0.005 | - | V/ μs |
| | T_{slew2} | | High-speed mode | - | 1.1 | - | V/ μs |
| Load current | I_{load1} | Low-power mode | | -100 | - | 100 | μA |
| | I_{load2} | High-speed mode | | -100 | - | 100 | |
| Load capacitance | CL | - | | - | - | 20 | pF |

Note 1. When the operational amplifier and the reference current circuit have already been activated.

2.13 Flash Memory Characteristics

2.13.1 Code Flash Memory Characteristics

Table 2.60 Code flash characteristics (1)

| Parameter | Symbol | Min | Typ | Max | Unit | Conditions |
|-------------------------------|-----------------------------------|------------------|----------|-----|-------|------------------------|
| Reprogramming/erasure cycle*1 | N _{PEC} | 1000 | - | - | Times | - |
| Data hold time | After 1000 times N _{PEC} | t _{DRP} | 20*2, *3 | - | Year | T _a = +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 = 1,000), erasing can be performed n times for each block. For instance, when 4-byte programming is performed 256 times for different addresses in 1-KB blocks, and then the entire block is erased, the reprogram/erase cycle is counted as one. However, programming the same address for several times as one erasure is not enabled. (overwriting is prohibited.)

Note 2. Characteristic when using the flash memory programmer and the self-programming library provided by Renesas Electronics.

Note 3. This result is obtained from reliability testing.

Table 2.61 Code flash characteristics (2)

High-speed operating mode

Conditions: VCC = AVCC0 = 2.7 to 5.5 V

| Parameter | Symbol | ICLK = 1 MHz | | | ICLK = 32 MHz | | | Unit | |
|--|---------|-------------------|-----|------|---------------|-----|------|------|----|
| | | Min | Typ | Max | Min | Typ | Max | | |
| Programming time | 4 bytes | t _{P4} | - | 116 | 998 | - | 54 | 506 | μs |
| Erasure time | 1 KB | t _{E1K} | - | 9.03 | 287 | - | 5.67 | 222 | ms |
| Blank check time | 4 bytes | t _{BC4} | - | - | 56.8 | - | - | 16.6 | μs |
| | 1 KB | t _{BC1K} | - | - | 1899 | - | - | 140 | μs |
| Erase suspended time | | t _{SED} | - | - | 22.5 | - | - | 10.7 | μs |
| Startup area switching setting time | | t _{SAS} | - | 21.9 | 585 | - | 12.1 | 447 | ms |
| Access window time | | t _{AWS} | - | 21.9 | 585 | - | 12.1 | 447 | ms |
| OCD/serial programmer ID setting time | | t _{OSIS} | - | 21.9 | 585 | - | 12.1 | 447 | ms |
| Flash memory mode transition wait time 1 | | t _{DIS} | 2 | - | - | 2 | - | - | μs |
| Flash memory mode transition wait time 2 | | t _{MS} | 5 | - | - | 5 | - | - | μs |

Note 1. Does not include the time until each operation of the flash memory is started after instructions are executed by the software.

Note 2. The lower-limit frequency of ICLK is 1 MHz during programming or erasing the flash memory. When using ICLK at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.

Note 3. The frequency accuracy of ICLK must be ±3.5% during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

Table 2.62 Code flash characteristics (3)

Middle-speed operating mode

Conditions: VCC = AVCC0 = 1.8 to 5.5 V, Ta = -40 to +85°C

| Parameter | | Symbol | ICLK = 1 MHz | | | ICLK = 8 MHz | | | Unit |
|--|---------|-------------------|--------------|------|------|--------------|------|------|------|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Programming time | 4 bytes | t _{P4} | - | 157 | 1411 | - | 101 | 966 | μs |
| Erasure time | 1 KB | t _{E1K} | - | 9.10 | 289 | - | 6.10 | 228 | ms |
| Blank check time | 2 bytes | t _{BC4} | - | - | 87.7 | - | - | 52.5 | μs |
| | 1 KB | t _{BC1K} | - | - | 1930 | - | - | 414 | μs |
| Erase suspended time | | t _{SED} | - | - | 32.7 | - | - | 21.6 | μs |
| Startup area switching setting time | | t _{SAS} | - | 22.8 | 592 | - | 14.2 | 465 | ms |
| Access window time | | t _{AWS} | - | 22.8 | 592 | - | 14.2 | 465 | ms |
| OCD/serial programmer ID setting time | | t _{OSIS} | - | 22.8 | 592 | - | 14.2 | 465 | ms |
| Flash memory mode transition wait time 1 | | t _{DIS} | 2 | - | - | 2 | - | - | μs |
| Flash memory mode transition wait time 2 | | t _{MS} | 720 | - | - | 720 | - | - | ns |

Note 1. Does not include the time until each operation of the flash memory is started after instructions are executed by the software.

Note 2. The lower-limit frequency of ICLK is 1 MHz during programming or erasing the flash memory. When using ICLK at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.

Note 3. The frequency accuracy of ICLK must be ±3.5% during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

2.13.2 Data Flash Memory Characteristics

Table 2.63 Data flash characteristics (1)

| Parameter | | Symbol | Min | Typ | Max | Unit | Conditions |
|-------------------------------|--|-------------------|----------|---------|-----|-------|------------|
| Reprogramming/erasure cycle*1 | | N _{DPEC} | 100000 | 1000000 | - | Times | - |
| Data hold time | After 10000 times of N _{DPEC} | t _{DDRP} | 20*2, *3 | - | - | Year | Ta = +85°C |
| | After 100000 times of N _{DPEC} | | 5*2, *3 | - | - | Year | |
| | After 1000000 times of N _{DPEC} | | - | 1*2, *3 | - | Year | |

Note 1. The reprogram/erase cycle is the number of erasure for each block. When the reprogram/erase cycle is n times (n = 100,000), erasing can be performed n times for each block. For instance, when 1-byte programming is performed 1,000 times for different addresses in 1-byte blocks, and then the entire block is erased, the reprogram/erase cycle is counted as one. However, programming the same address for several times as one erasure is not enabled. (overwriting is prohibited.)

Note 2. Characteristics when using the flash memory programmer and the self-programming library provided by Renesas Electronics.

Note 3. These results are obtained from reliability testing.

Table 2.64 Data flash characteristics (2)

High-speed operating mode

Conditions: VCC = AVCC0 = 2.7 to 5.5 V

| Parameter | | Symbol | ICLK = 4 MHz | | | ICLK = 32 MHz | | | Unit |
|-------------------------------|--------|--------------------|--------------|------|------|---------------|------|------|------|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Programming time | 1-byte | t _{DP1} | - | 52.4 | 463 | - | 42.1 | 387 | μs |
| Erase time | 1-KB | t _{DE1K} | - | 8.98 | 286 | - | 6.42 | 237 | ms |
| Blank check time | 1-byte | t _{DBC1} | - | - | 24.3 | - | - | 16.6 | μs |
| | 1-KB | t _{DBC1K} | - | - | 1872 | - | - | 512 | μs |
| Suspended time during erasing | | t _{DSED} | - | - | 13.0 | - | - | 10.7 | μs |
| Data flash STOP recovery time | | t _{DSTOP} | 5 | - | - | 5 | - | - | μs |

Note 1. Does not include the time until each operation of the flash memory is started after instructions are executed by the software.

Note 2. The lower-limit frequency of ICLK is 1 MHz during programming or erasing the flash memory. When using ICLK at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.

Note 3. The frequency accuracy of ICLK must be ±3.5% during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

Table 2.65 Data flash characteristics (3)

Middle-speed operating mode

Conditions: VCC = AVCC0 = 1.8 to 5.5 V, Ta = -40 to +85°C

| Parameter | | Symbol | ICLK = 4 MHz | | | ICLK = 8 MHz | | | Unit |
|-------------------------------|--------|--------------------|--------------|------|------|--------------|------|------|------|
| | | | Min | Typ | Max | Min | Typ | Max | |
| Programming time | 1-byte | t _{DP1} | - | 94.7 | 886 | - | 89.3 | 849 | μs |
| Erase time | 1-KB | t _{DE1K} | - | 9.59 | 299 | - | 8.29 | 273 | ms |
| Blank check time | 1-byte | t _{DBC1} | - | - | 56.2 | - | - | 52.5 | μs |
| | 1-KB | t _{DBC1K} | - | - | 2.17 | - | - | 1.51 | ms |
| Suspended time during erasing | | t _{DSED} | - | - | 23.0 | - | - | 21.7 | μs |
| Data flash STOP recovery time | | t _{DSTOP} | 720 | - | - | 720 | - | - | ns |

Note 1. Does not include the time until each operation of the flash memory is started after instructions are executed by the software.

Note 2. The lower-limit frequency of ICLK is 1 MHz during programming or erasing the flash memory. When using ICLK at below 4 MHz, the frequency can be set to 1 MHz, 2 MHz, or 3 MHz. A non-integer frequency such as 1.5 MHz cannot be set.

Note 3. The frequency accuracy of ICLK must be ±3.5% during programming or erasing the flash memory. Confirm the frequency accuracy of the clock source.

2.13.3 Serial Wire Debug (SWD)

Table 2.66 SWD characteristics (1) (1 of 2)

Conditions: VCC = AVCC0 = 2.4 to 5.5 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|------------------------------|----------------------|-----|-----|-----|------|-----------------|
| SWCLK clock cycle time | t _{SWCKcyc} | 80 | - | - | ns | Figure 2.70 |
| SWCLK clock high pulse width | t _{SWCKH} | 35 | - | - | ns | |
| SWCLK clock low pulse width | t _{SWCKL} | 35 | - | - | ns | |
| SWCLK clock rise time | t _{SWCKr} | - | - | 5 | ns | |
| SWCLK clock fall time | t _{SWCKf} | - | - | 5 | ns | |

Table 2.66 SWD characteristics (1) (2 of 2)

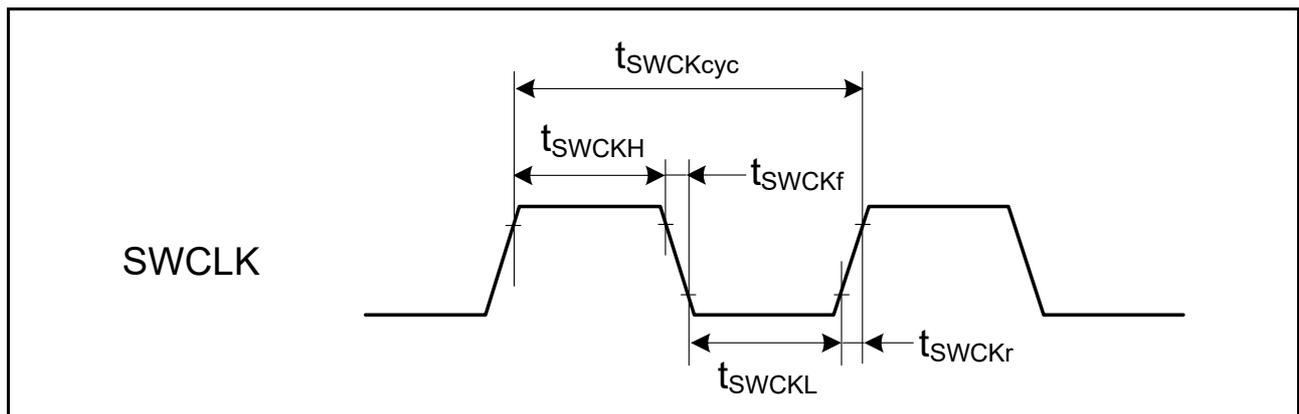
Conditions: VCC = AVCC0 = 2.4 to 5.5 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|-----------------------|-------------------|-----|-----|-----|------|-----------------|
| SWDIO setup time | t_{SWDS} | 16 | - | - | ns | Figure 2.71 |
| SWDIO hold time | t_{SWDH} | 16 | - | - | ns | |
| SWDIO data delay time | t_{SWDD} | 2 | - | 70 | ns | |

Table 2.67 SWD characteristics (2)

Conditions: VCC = AVCC0 = 1.6 to 2.4 V

| Parameter | Symbol | Min | Typ | Max | Unit | Test conditions |
|------------------------------|----------------------|-----|-----|-----|------|-----------------|
| SWCLK clock cycle time | t_{SWCKcyc} | 250 | - | - | ns | Figure 2.70 |
| SWCLK clock high pulse width | t_{SWCKH} | 120 | - | - | ns | |
| SWCLK clock low pulse width | t_{SWCKL} | 120 | - | - | ns | |
| SWCLK clock rise time | t_{SWCKr} | - | - | 5 | ns | Figure 2.71 |
| SWCLK clock fall time | t_{SWCKf} | - | - | 5 | ns | |
| SWDIO setup time | t_{SWDS} | 50 | - | - | ns | |
| SWDIO hold time | t_{SWDH} | 50 | - | - | ns | |
| SWDIO data delay time | t_{SWDD} | 2 | - | 150 | ns | |

**Figure 2.70 SWD SWCLK timing**

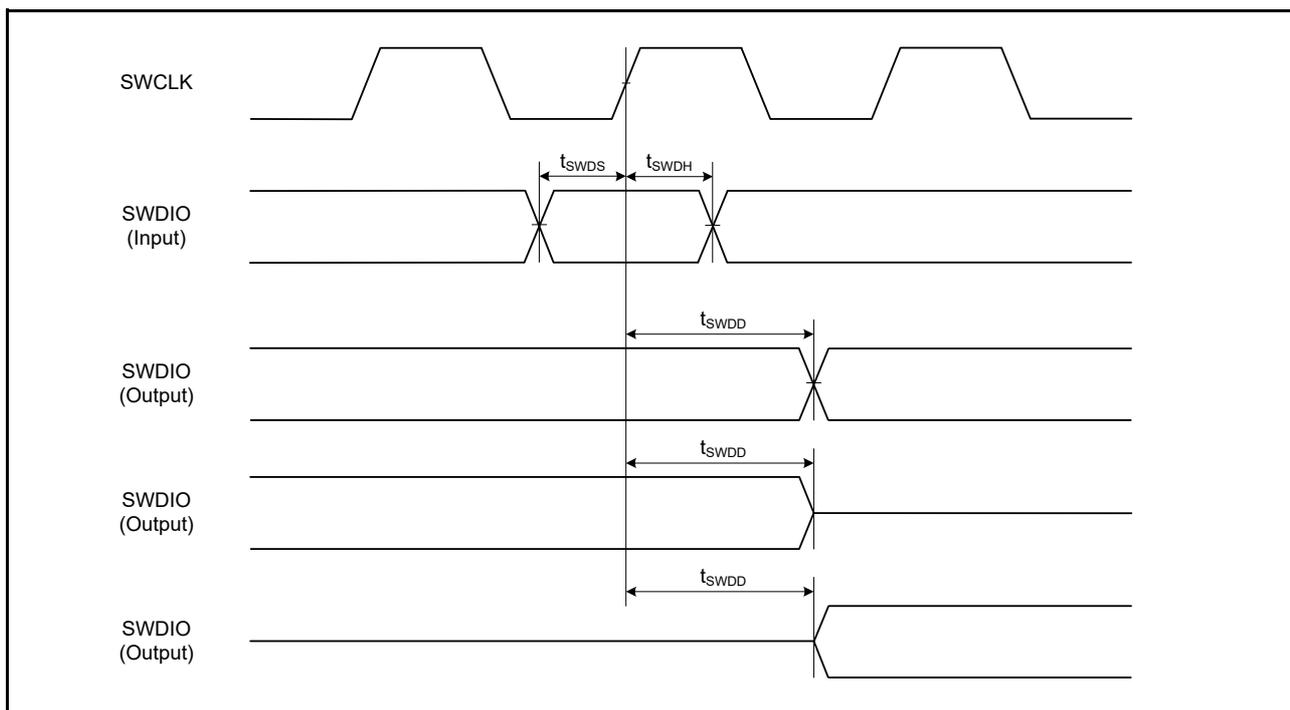


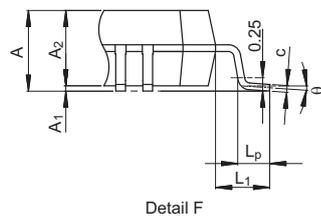
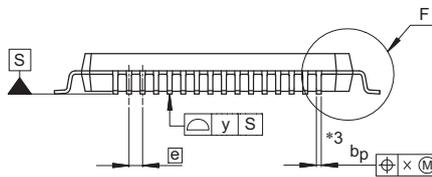
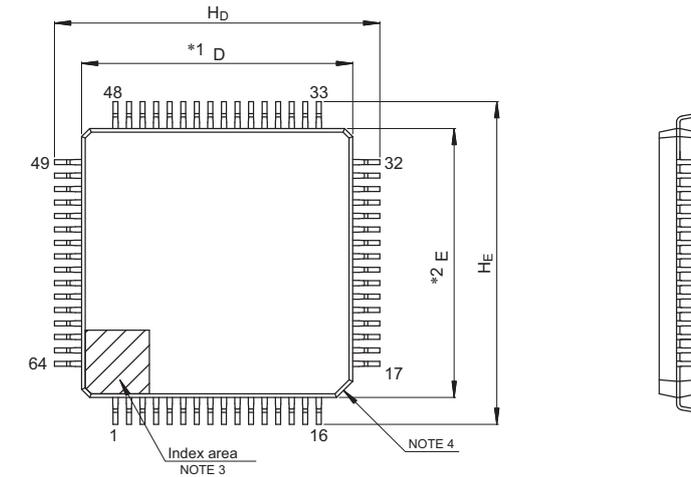
Figure 2.71 SWD input/output timing

Appendix 1.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-LFQFP64-10x10-0.50 | PLQP0064KB-C | — | 0.3 |

Unit: mm



NOTE)

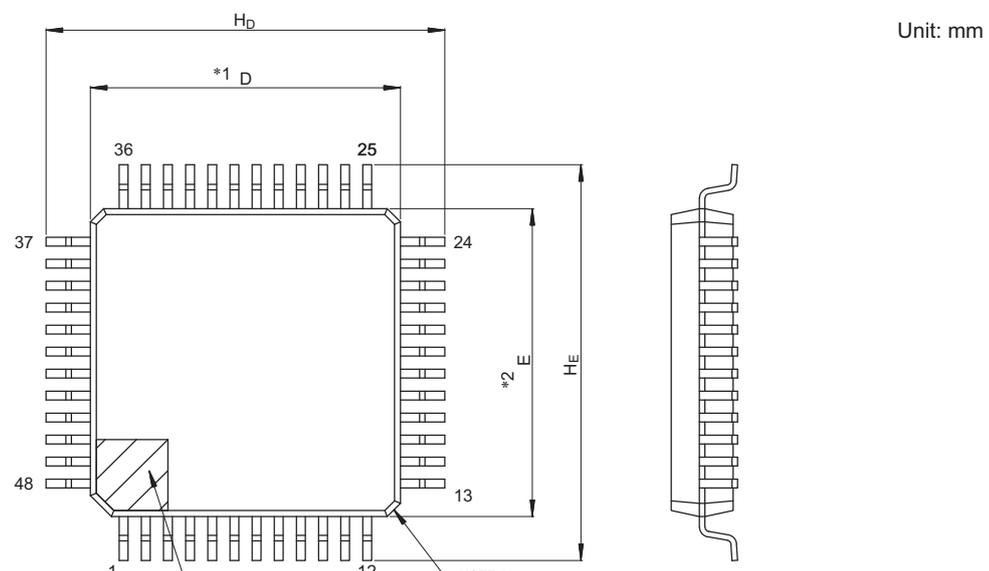
1. DIMENSIONS “*1” AND “*2” DO NOT INCLUDE MOLD FLASH.
2. DIMENSION “*3” DOES NOT INCLUDE TRIM OFFSET.
3. PIN 1 VISUAL INDEX FEATURE MAY VARY, BUT MUST BE LOCATED WITHIN THE HATCHED AREA.
4. CHAMFERS AT CORNERS ARE OPTIONAL, SIZE MAY VARY.

| Reference Symbol | Dimensions in millimeters | | |
|------------------|---------------------------|------|------|
| | Min | Nom | Max |
| D | 9.9 | 10.0 | 10.1 |
| E | 9.9 | 10.0 | 10.1 |
| A ₂ | — | 1.4 | — |
| H _D | 11.8 | 12.0 | 12.2 |
| H _E | 11.8 | 12.0 | 12.2 |
| A | — | — | 1.7 |
| A ₁ | 0.05 | — | 0.15 |
| b _p | 0.15 | 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 | — |

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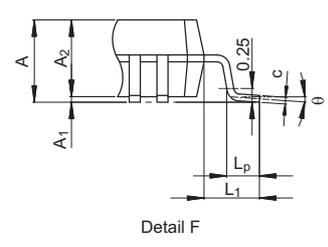
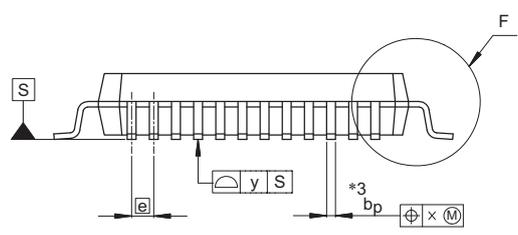
Figure 1.1 LQFP 64-pin

| JEITA Package Code | RENESAS Code | Previous Code | MASS (Typ) [g] |
|--------------------|--------------|---------------|----------------|
| P-LFQFP48-7x7-0.50 | PLQP0048KB-B | — | 0.2 |



Unit: mm

- 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 | 6.9 | 7.0 | 7.1 |
| E | 6.9 | 7.0 | 7.1 |
| A ₂ | — | 1.4 | — |
| H _D | 8.8 | 9.0 | 9.2 |
| H _E | 8.8 | 9.0 | 9.2 |
| 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 | — |

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Figure 1.2 LQFP 48-pin

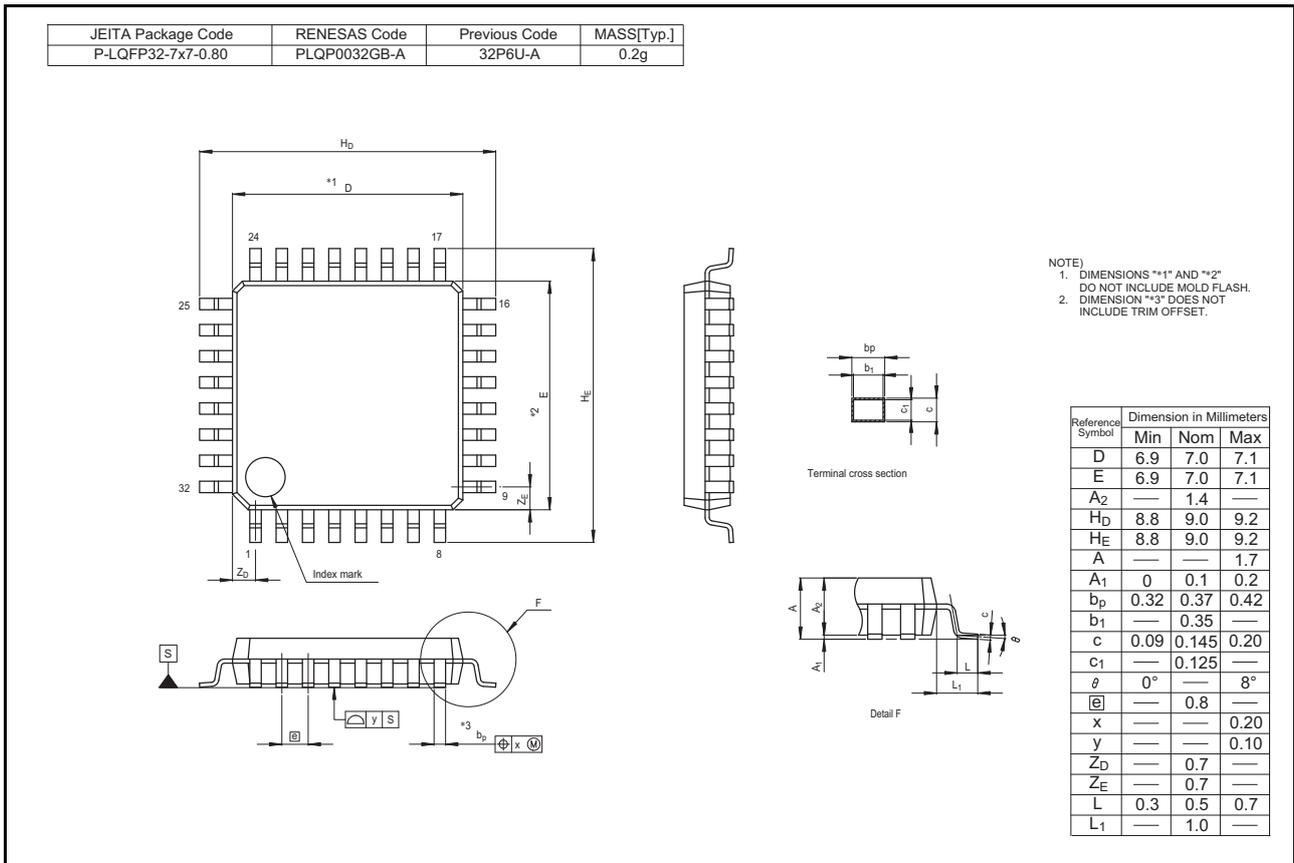


Figure 1.3 LQFP 32-pin

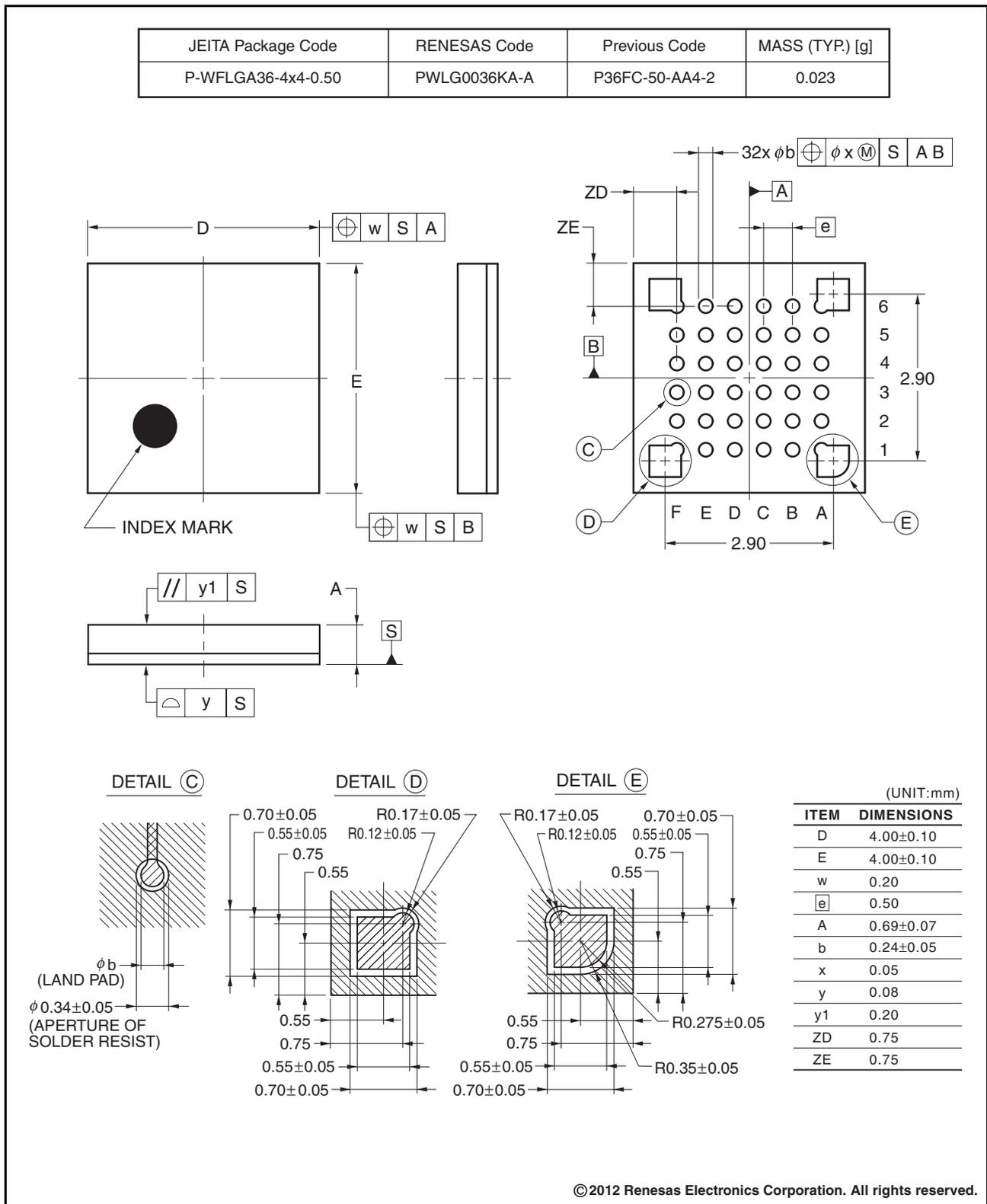
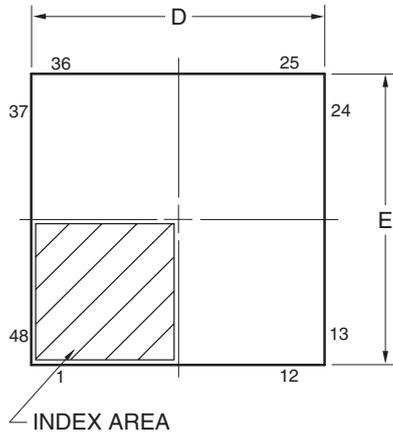
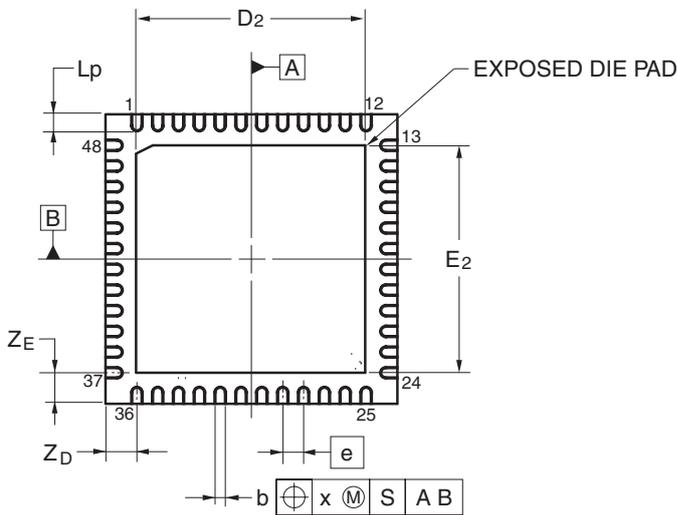
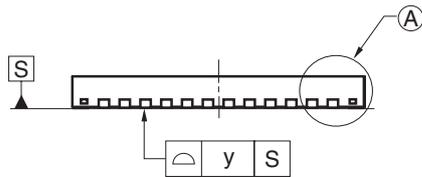
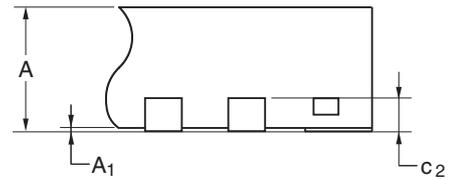


Figure 1.4 LGA 36-pin

| JEITA Package code | RENESAS code | Previous code | MASS(TYP.)[g] |
|--------------------|--------------|---------------------------|---------------|
| P-HWQFN48-7x7-0.50 | PWQN0048KB-A | 48PJN-A P48K8-50-5B4-6 | 0.13 |



DETAIL OF (A) PART

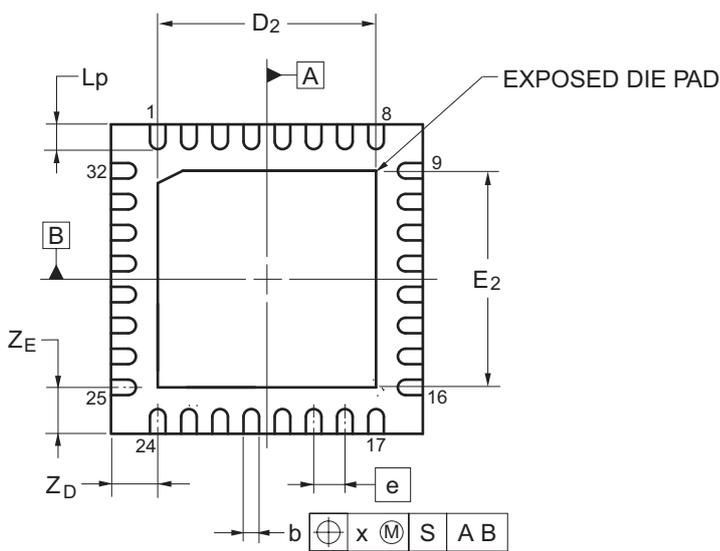
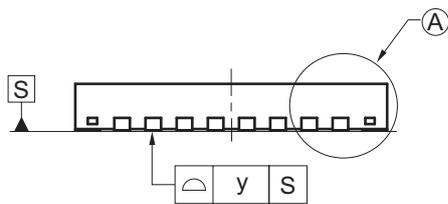
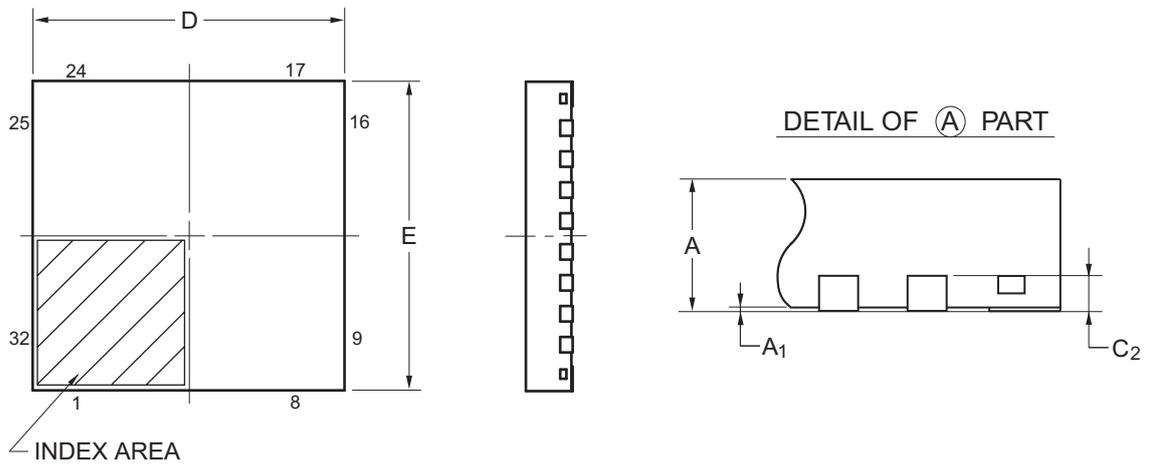


| Reference Symbol | Dimension in Millimeters | | |
|------------------|--------------------------|------|------|
| | Min | Nom | Max |
| D | 6.95 | 7.00 | 7.05 |
| E | 6.95 | 7.00 | 7.05 |
| A | — | — | 0.80 |
| A ₁ | 0.00 | — | — |
| b | 0.18 | 0.25 | 0.30 |
| ⓪ | — | 0.50 | — |
| L _p | 0.30 | 0.40 | 0.50 |
| x | — | — | 0.05 |
| y | — | — | 0.05 |
| Z _D | — | 0.75 | — |
| Z _E | — | 0.75 | — |
| c ₂ | 0.15 | 0.20 | 0.25 |
| D ₂ | — | 5.50 | — |
| E ₂ | — | 5.50 | — |

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Figure 1.5 QFN 48-pin (1)

| JEITA Package code | RENESAS code | Previous code | MASS(TYP.)[g] |
|--------------------|--------------|----------------|---------------|
| P-HWQFN32-5x5-0.50 | PWQN0032KB-A | P32K8-50-3B4-5 | 0.06 |



| Reference Symbol | Dimension in Millimeters | | |
|------------------|--------------------------|------|------|
| | Min | Nom | Max |
| D | 4.95 | 5.00 | 5.05 |
| E | 4.95 | 5.00 | 5.05 |
| A | — | — | 0.80 |
| A ₁ | 0.00 | — | — |
| b | 0.18 | 0.25 | 0.30 |
| e | — | 0.50 | — |
| L _p | 0.30 | 0.40 | 0.50 |
| x | — | — | 0.05 |
| y | — | — | 0.05 |
| Z _D | — | 0.75 | — |
| Z _E | — | 0.75 | — |
| c ₂ | 0.15 | 0.20 | 0.25 |
| D ₂ | — | 3.50 | — |
| E ₂ | — | 3.50 | — |

Figure 1.7 QFN 32-pin (1)

| | | |
|---------------------|--------------|---------------|
| JEITA Package code | RENESAS code | MASS(TYP.)[g] |
| P-HWQFN032-5x5-0.50 | PWQN0032KF-A | 0.06 |

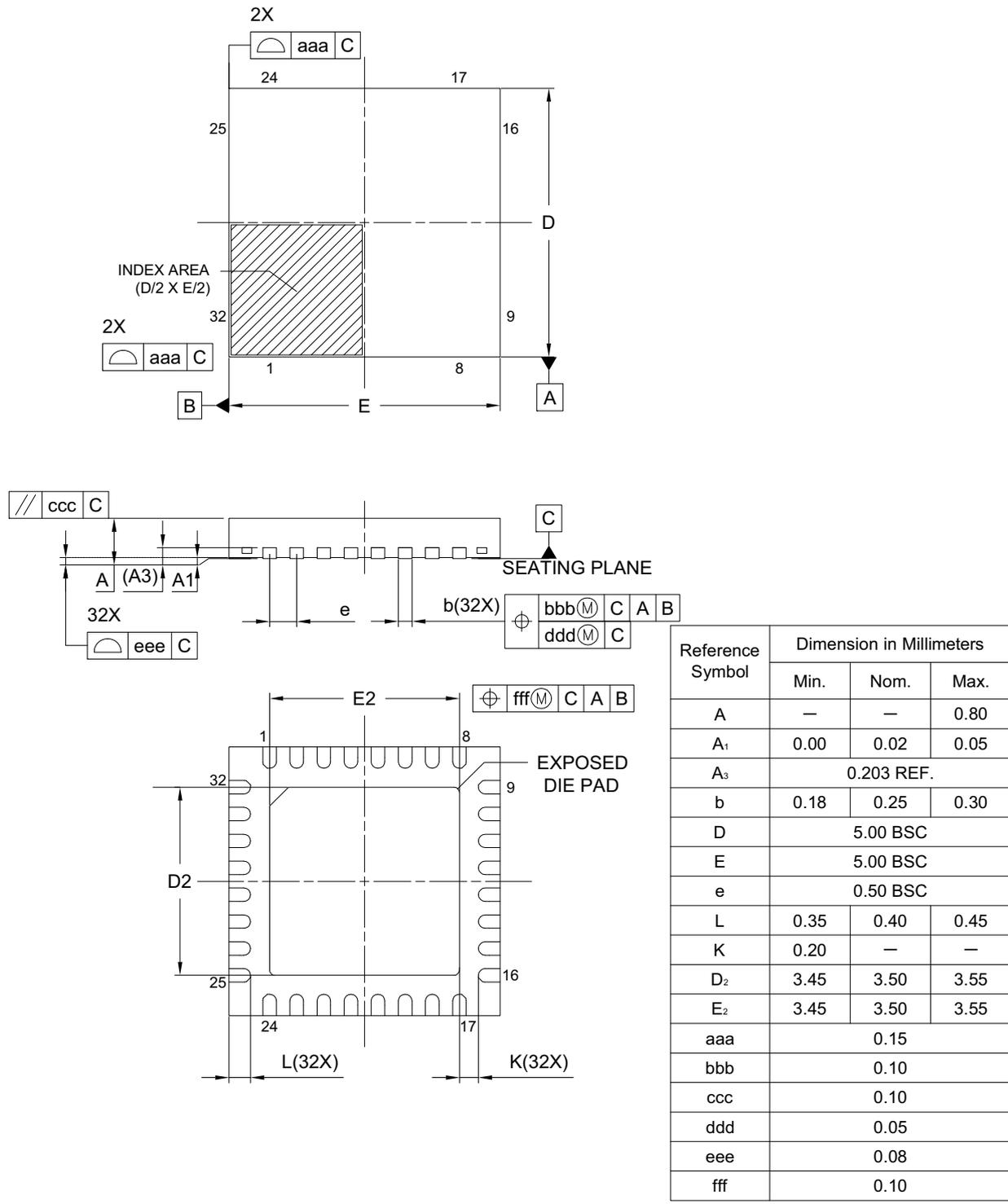


Figure 1.8 QFN 32-pin (2)

| | |
|------------------|--------------------------------------|
| Revision History | S128 Microcontroller Group Datasheet |
|------------------|--------------------------------------|

| Rev. | Date | Description |
|------|--------------|------------------|
| 1.00 | Mar 10, 2017 | First release |
| 1.10 | Nov 28, 2018 | Updated for 1.10 |
| 1.20 | Oct 31, 2024 | Updated for 1.20 |

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| Development tools | renessasynergy.com/tools |
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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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