# RL78/I1A

RENESAS MCU

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True Low Power Platform, High Resolution PWM and Rich Analog, 2.7 V to 5.5 V operation, 32 to 64 Kbyte Flash, for Inverter Control, Digital Power Control and Lighting Control Applications

## 1. OUTLINE

### 1.1 Features

**Ultra-Low Power Technology**
- 2.7 V to 5.5 V operation from a single supply
- Stop (RAM retained): 0.23 μA, (LVD enabled): 0.31 μA
- Halt (RTC + LVD): 0.60 μA
- Operating: 156.25 μA/MHz

**16-bit RL78 CPU Core**
- Delivers 41 DMIPS at maximum operating frequency of 32 MHz
- <R> Instruction execution: 86% of instructions can be executed in 1 to 2 clock cycles
- CISC architecture (Harvard) with 3-stage pipeline
- <R> Multiply signed & unsigned: 16 x 16 to 32-bit result in 1 clock cycle
- MAC: 16 x 16 to 32-bit result in 2 clock cycles
- 16-bit barrel shifter for shift & rotate in 1 clock cycle
- 1-wire on-chip debug function

**Main Flash Memory**
- Density: 32 KB to 64 KB
- Block size: 1 KB
- On-chip single voltage flash memory with protection from block erase/writing
- Self-programming with secure boot swap function and flash shield window function

**Data Flash Memory**
- Data flash with background operation
- Data flash size: 4 KB
- Erase cycles: 1 million (typ.)
- Erase/programming voltage: 2.7 V to 5.5 V

**RAM**
- 2 KB to 4 KB size options
- Supports operands or instructions
- Back-up retention in all modes

**High-speed On-chip Oscillator**
- 32 MHz with +/– 1% accuracy over voltage (2.7 V to 5.5 V) and temperature (–20°C to 85°C)
- Pre-configured settings: 32 MHz, 24 MHz, 16 MHz, 12 MHz, 8 MHz, 6 MHz, 4 MHz, 3 MHz, 2 MHz & 1 MHz

**Reset and Supply Management**
- Power-on reset (POR) monitor/generator
- Low voltage detection (LVD) with 6 setting options (Interrupt and/or reset function)

**Data Memory Access (DMA) Controller**
- Up to 2 fully programmable channels
- Transfer unit: 8- or 16-bit

**16-bit timers KB0 to KB2, and KC0 for PWM output**

16-bit timers KB0 to KB2: maximum 6 outputs (3 channels × 2)
- Smooth start function, dithering function, forced output stop function (unsynchronized with comparator or external interrupt) enables over-voltage protection, over-current protection and peak current control, and single/interleave PFC function
- Average resolution < 0.98 nsec output, 64 MHz (when using PLL) + dithering option

16-bit timer KC0 (1 channel × 6 (output))
- PWM output gating function by interlocking with 16-bit timers KB0, KB1, and KB2

**Extended-Function Timers**
- Multi-function 16-bit timers: Up to 8 channels
- Real-time clock (RTC): 1 channel (full calendar and alarm function with watch correction function)
- Interval timer: 12-bit, 1 channel
- 15 kHz watchdog timer: 1 channel (window function)

**Multiple Communication Interfaces**
- Up to 1 channel x $I^2C$ multi-master (SMBus/PMBus support)
- Up to 1 channel x CSI/SPI (7-, 8-bit)
- Up to 3 channels x UART (7-, 8-, 9-bit), DALI support 1 channel (8-, 16-, 17-, 24-bit, master and slave)
- Up to 1 channel x LIN

**Rich Analog**
- ADC: Up to 11 channels, 8/10-bit resolution, 2.125 μs conversion time
- Supports 2.7 V
- Internal voltage reference (1.45 V)
- Comparator: High response time 70 ns (typ.), up to 6 channels, internal DAC 3 channels 8-bit resolution, window comparator mode
- PGA (x4 to x32): 6 input channels
- On-chip temperature sensor

**Safety Features (IEC or UL 60730 compliance)**
- Flash memory CRC calculation
- RAM parity error check
- RAM/SFR write protection
- Illegal memory access detection
- Clock stop/frequency detection
- ADC self-test

**General Purpose I/O**
- 5-V tolerant, high-current (up to 8.5 mA per pin)
- Open-drain, internal pull-up support

**Operating Ambient Temperature**
- Standard: –40°C to +105°C
- Extend: –40°C to +125°C

**Package Type and Pin Count**

SSOP: 20, 30, 38

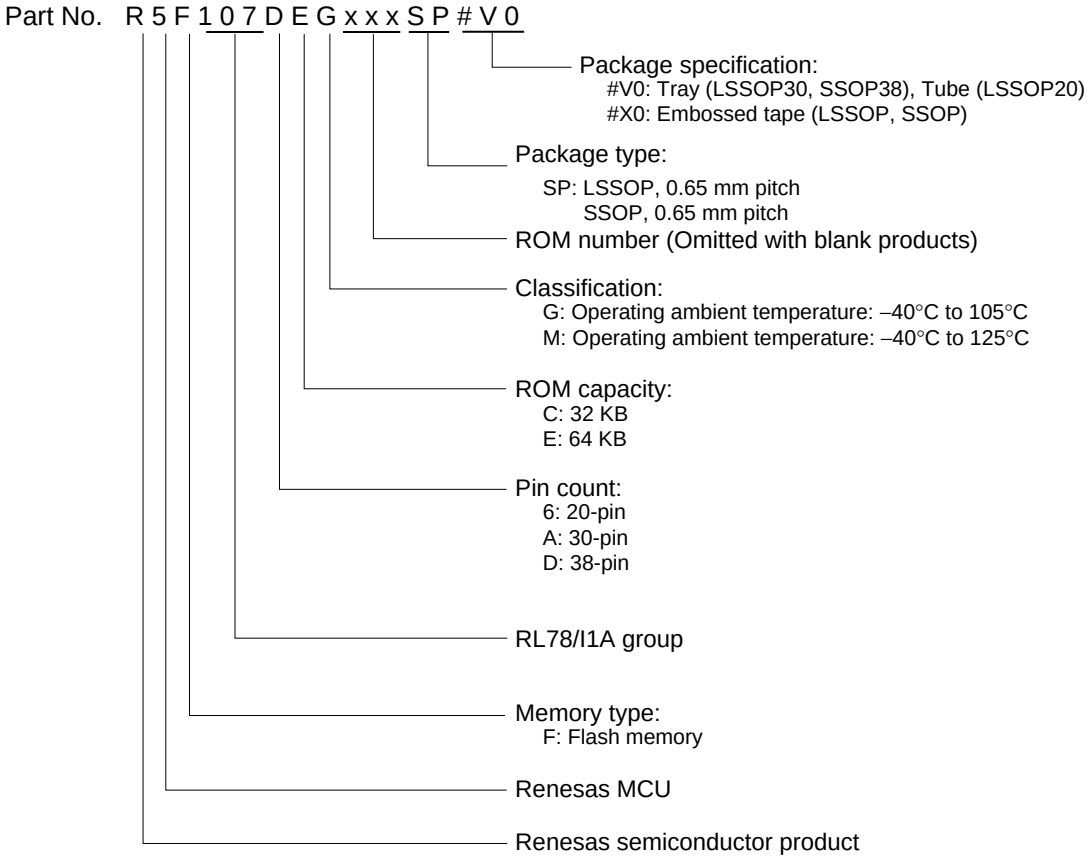
○ ROM, RAM capacities

| Flash ROM | Data flash | RAM | RL78/I1A | | |
|---|---|---|---|---|---|
| | | | 20 pins | 30 pins | 38 pins |
| 64 KB | 4 KB | 4 KB Note | – | R5F107AE | R5F107DE |
| 32 KB | 4 KB | 2 KB | R5F1076C | R5F107AC | – |

**Note** This is about 3 KB when the self-programming function and data flash function are used.

## 1.2 List of Part Numbers

**Figure 1-1. Part Number, Memory Size, and Package of RL78/I1A**



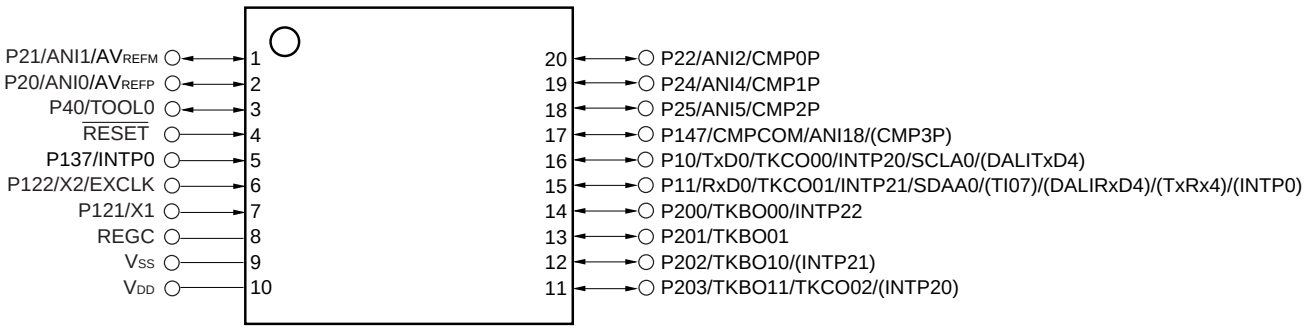

| Pin count | Package | Operating Ambient Temperature | Part Number |
|---|---|---|---|
| 20 pins | 20-pin plastic LSSOP (4.4 × 6.5) | $T_A$ = –40 to +105°C | R5F1076CGSP#V0, R5F1076CGSP#X0 |
| | | $T_A$ = –40 to +125°C | R5F1076CMSP#V0, R5F1076CMSP#X0 |
| 30 pins | 30-pin plastic LSSOP (7.62 mm (300)) | $T_A$ = –40 to +105°C | R5F107ACGSP#V0, R5F107AEGSP#V0, R5F107ACGSP#X0, R5F107AEGSP#X0 |
| | | $T_A$ = –40 to +125°C | R5F107ACMSP#V0, R5F107AEMSP#V0, R5F107ACMSP#X0, R5F107AEMSP#X0 |
| 38 pins | 38-pin plastic SSOP (7.62 mm (300)) | $T_A$ = –40 to +105°C | R5F107DEGSP#V0, R5F107DEGSP#X0 |
| | | $T_A$ = –40 to +125°C | R5F107DEMSP#V0, R5F107DEMSP#X0 |

**Caution The ordering part numbers represent the numbers at the time of publication. For the latest ordering part numbers, refer to the target product page of the Renesas Electronics website.**

## 1.3 Pin Configuration (Top View)

### 1.3.1 20-pin products

- 20-pin plastic LSSOP (4.4 x 6.5)




**Caution Connect the REGC pin to Vss via a capacitor (0.47 to 1 μF).**

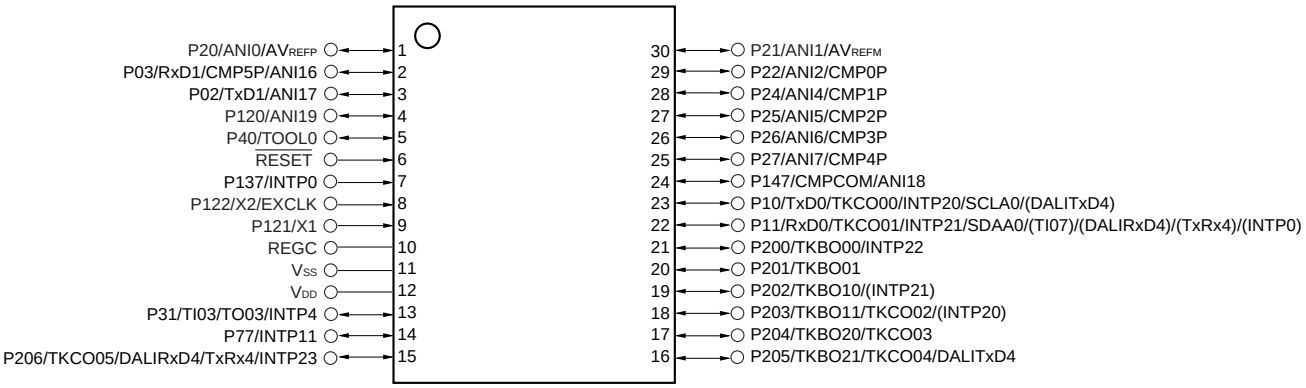
**Remarks 1.** For pin identification, see **1.4 Pin Identification**.

**2.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

**3.** The shared function CMP3P can be assigned to P147 by setting the CMPSEL0 bit in the comparator input switch control register (CMPSEL).

### 1.3.2 30-pin products

- 30-pin plastic LSSOP (7.62 mm (300))



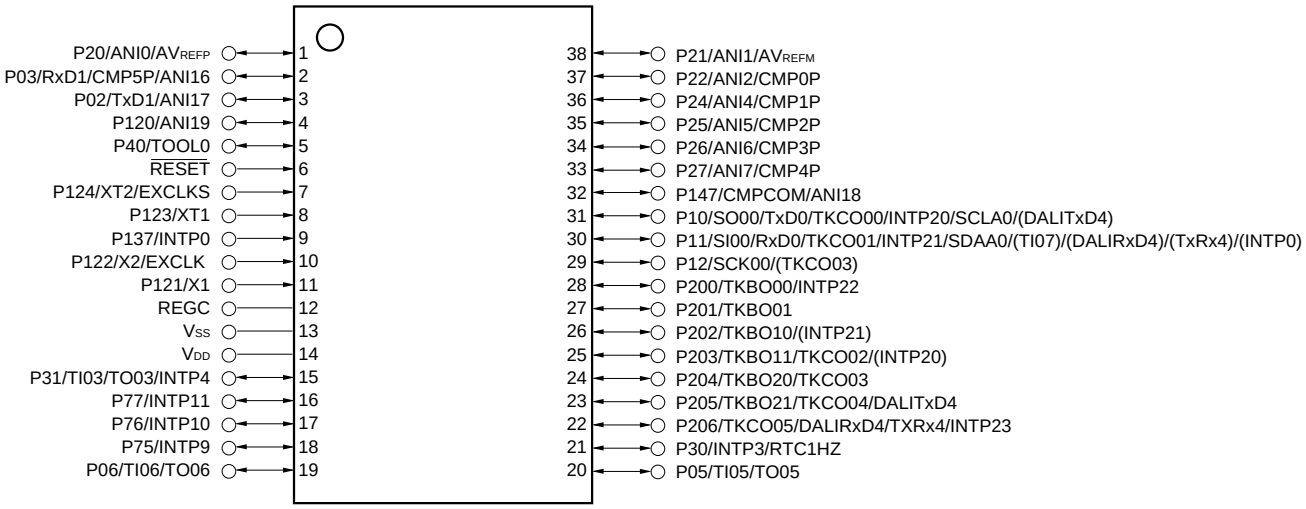

**Caution Connect the REGC pin to Vss via a capacitor (0.47 to 1 μF).**

**Remarks 1.** For pin identification, see **1.4 Pin Identification**.

**2.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

### 1.3.3 38-pin products

- 38-pin plastic SSOP (7.62 mm (300))




**Caution Connect the REGC pin to Vss via a capacitor (0.47 to 1 μF).**

**Remarks 1.** For pin identification, see **1.4 Pin Identification**.

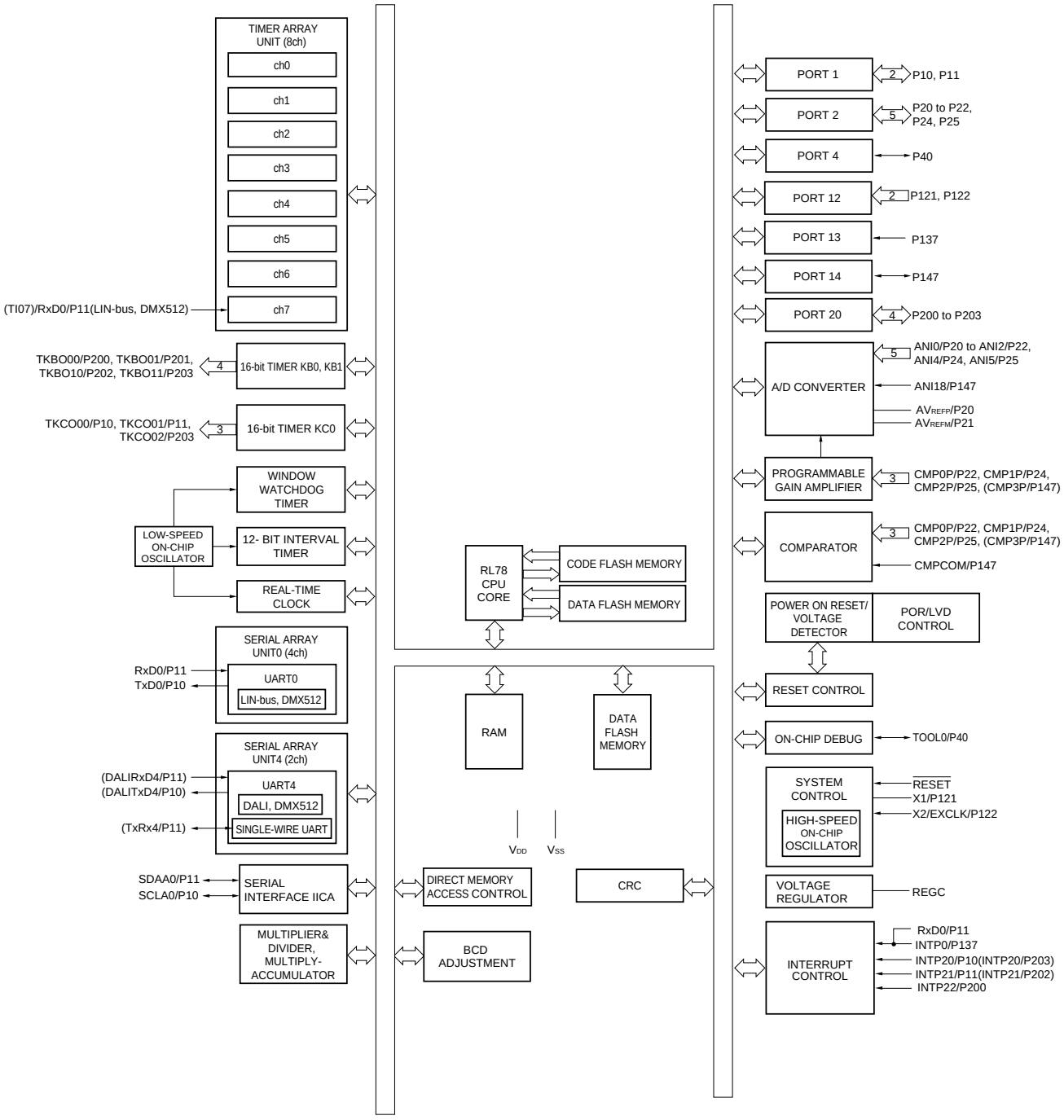
**2.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

## 1.4 Pin Identification

| | |
|---|---|
| ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19: | Analog Input |
| $AV_{REFM}$: | Analog Reference Voltage Minus |
| $AV_{REFP}$: | Analog Reference Voltage Plus |
| CMP0P to CMP5P: | Comparator Analog Input |
| CMPCOM: | Comparator External Reference Voltage |
| EXCLK: | External Clock Input (Main System Clock) |
| EXCLKS: | External Clock Input (Subsystem Clock) |
| INTP0, INTP3, INTP4, INTP9, INTP10, INTP11, INTP20 to INTP23: | Interrupt Request from Peripheral |
| P02, P03, P05, P06: | Port 0 |
| P10 to P12: | Port 1 |
| P20 to P22, P24 to P27: | Port 2 |
| P30, P31: | Port 3 |
| P40: | Port 4 |
| P75 to P77: | Port 7 |
| P120 to P124: | Port 12 |
| P137: | Port 13 |
| P147: | Port 14 |
| P200 to P206: | Port 20 |
| REGC: | Regulator Capacitance |
| RESET: | Reset |
| RTC1HZ: | Real-time Clock Correction Clock (1 Hz) Output |
| RxD0, RxD1, DALIRxD4: | Receive Data |
| SCK00: | Serial Clock Input/Output |
| SCLA0: | Serial Clock Input/Output |
| SDAA0: | Serial Data Input/Output |
| SI00: | Serial Data Input |
| SO00: | Serial Data Output |
| TI03, TI05, TI06, TI07: | Timer Input |
| TO03, TO05, TO06, TKBO00, TKBO01 to TKBO20, TKBO21, TKCO00 to TKCO05: | Timer Output |
| TOOL0: | Data Input/Output for Tool |
| TxRx4: | Serial Data Input/Output for Single Wired UART |
| TxD0, TxD1 DALITxD4: | Transmit Data |
| $V_{DD}$: | Power Supply |
| $V_{SS}$: | Ground |
| X1, X2: | Crystal Oscillator (Main System Clock) |
| XT1, XT2: | Crystal Oscillator (Subsystem Clock) |

## 1.5 Block Diagram

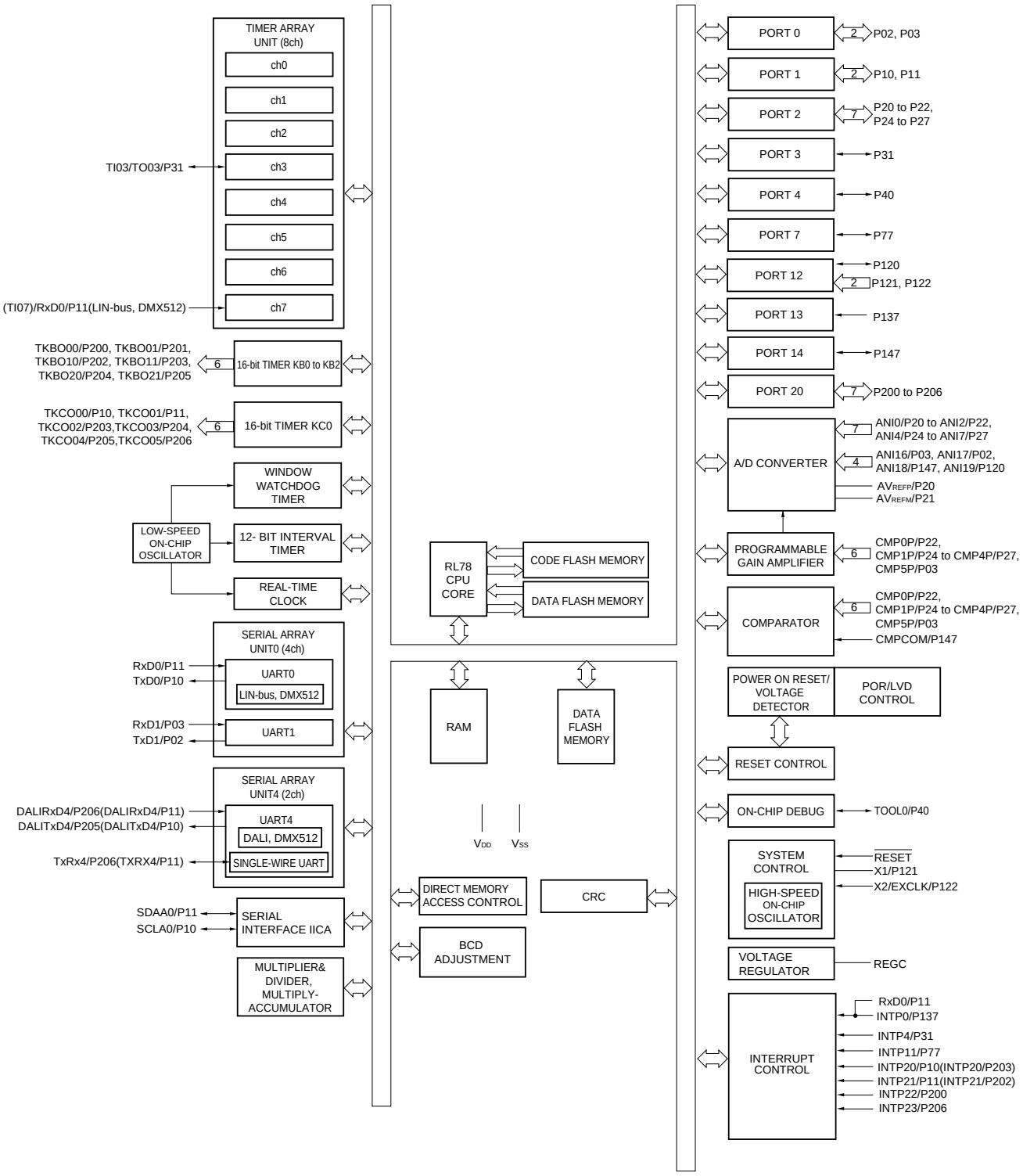
### 1.5.1 20-pin products




**Remarks 1.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

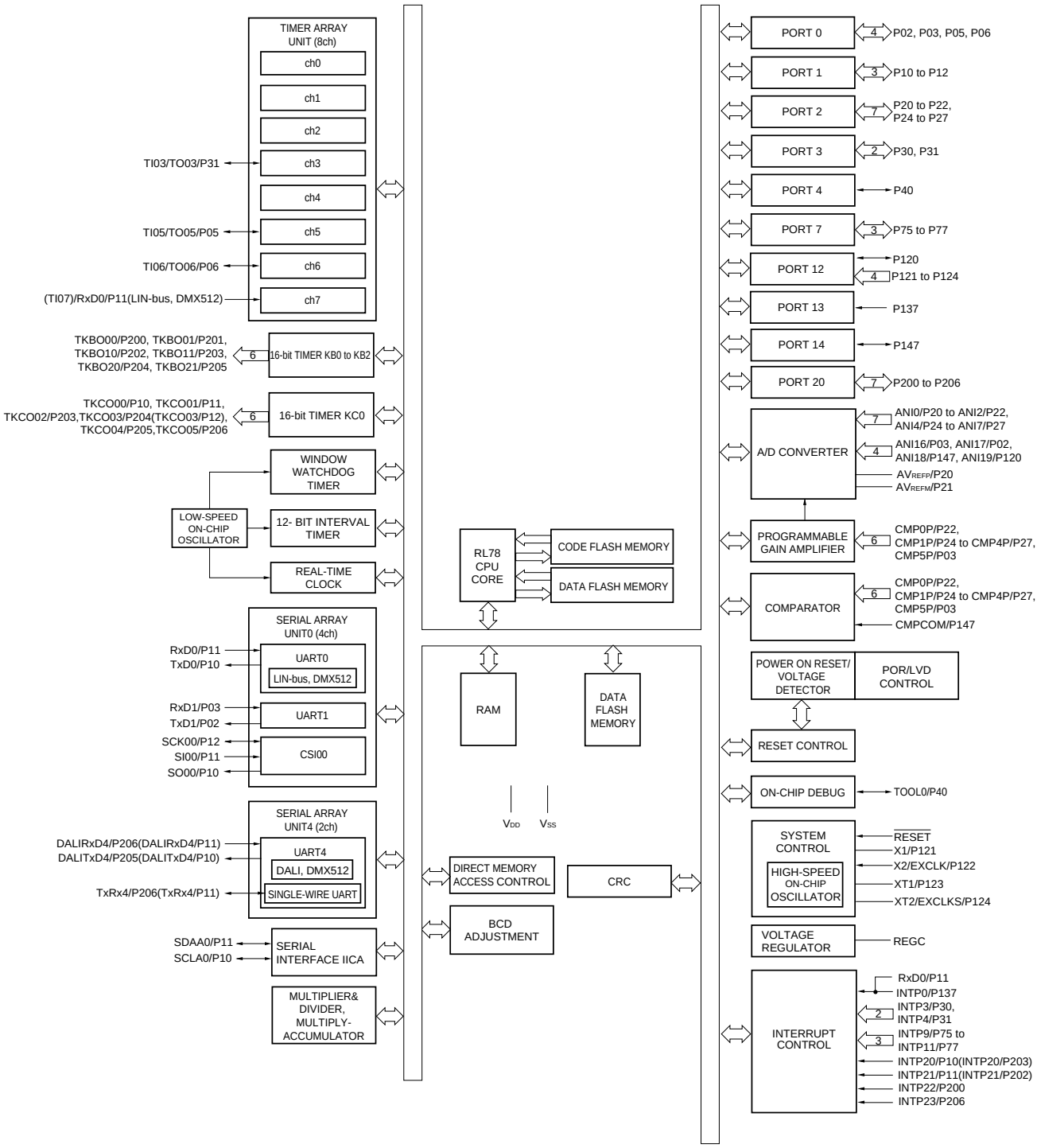
**2.** The shared function CMP3P can be assigned to P147 by setting the CMPSEL0 bit in the comparator input switch control register (CMPSEL).

### 1.5.2 30-pin products




**Remark** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

### 1.5.3 38-pin products




**Remark** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR1) or the input switch control register (ISC). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR1)** and **Figure 15-20 Format of Input Switch Control Register (ISC) in the RL78/I1A User's Manual**.

## 1.6 Outline of Functions

**Caution This outline describes the functions at the time when Peripheral I/O redirection register (PIOR1) is set to 00H.**

(1/3)

| Item | | 20-pin | 30-pin | | 38-pin |
|---|---|---|---|---|---|
| | | R5F1076C | R5F107AC | R5F107AE | R5F107DE |
| Code flash memory (KB) | | 32 | 32 | 64 | 64 |
| Data flash memory (KB) | | 4 | 4 | 4 | 4 |
| RAM (KB) | | 2 | 2 | 4Note 1 | 4Note 1 |
| Address space | | 1 MB | | | |
| Main system clock | High-speed system clock | X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK)<br>HS (High-speed main) mode: 1 to 20 MHz ($V_{DD}$ = 2.7 to 5.5 V),<br>LS (Low-speed main) mode: 1 to 8 MHz ($V_{DD}$ = 2.7 to 5.5 V) | | | |
| | High-speed on-chip oscillator | HS (High-speed main) mode: 1 to 32 MHz ($V_{DD}$ = 2.7 to 5.5 V),<br>LS (Low-speed main) mode: 1 to 8 MHz ($V_{DD}$ = 2.7 to 5.5 V) | | | |
| Clock for 16-bit timers KB0 to KB2, and KC0 | | 64 MHz (TYP.) | | | |
| Subsystem clock (38-pin products only) | | XT1 (crystal) oscillation, external subsystem clock input (EXCLKS)<br>32.768 kHz | | | |
| Low-speed on-chip oscillator | | 15 kHz (TYP.) | | | |
| General-purpose register | | (8-bit register × 8) × 4 banks | | | |
| Minimum instruction execution time | | 0.03125 μs (High-speed on-chip oscillator: $f_{IH}$ = 32 MHz operation) | | | |
| | | 0.05 μs (High-speed system clock: $f_{MX}$ = 20 MHz operation) | | | |
| | | 30.5 μs (Subsystem clock: $f_{SUB}$ = 32.768 kHz operation) (38-pin products only) | | | |
| Instruction set | | • 8-bit operation, 16-bit operation<br>• Multiplication (8 bits × 8 bits)<br>• Bit manipulation (Set, reset, test, and Boolean operation), etc. | | | |
| I/O port | Total | 16 | 26 | | 34 |
| | CMOS I/O | 13 | 23 | | 29 |
| | CMOS input | 3 | 3 | | 5 |
| | CMOS output | – | – | | – |
| Timer | 16-bit timer TAU | 8 channels (no timer output) | 8 channels (timer output: 1, PWM output: 1Note 2) | | 8 channels (timer outputs: 3, PWM outputs: 3Note 2) |
| | 16-bit timer KB | 2 channels (PWM outputs: 4) | 3 channels (PWM outputs: 6) | | |
| | 16-bit timer KC | 1 channel (PWM outputs: 3) | 1 channel (PWM outputs: 6) | | |

**Notes 1.** This is about 3 KB when the self-programming function and data flash function are used. (For details, see **CHAPTER 3 in the RL78/I1A User's Manual**.)

**2.** The number of PWM outputs varies depending on the setting of channels in use (the number of masters and slaves) (see **6.9.3 Operation as multiple PWM output function in the RL78/I1A User's Manual**).

(2/3)

| Item | | | 20-pin | 30-pin | 38-pin |
|---|---|---|---|---|---|
| | | | R5F1076C | R5F107AC, R5F107AE | R5F107DE |
| Timer | Watchdog timer | | 1 channel | | |
| | Real-time clock (RTC) | | 1 channel[Notes 1, 2] | | |
| | 12-bit interval timer (IT) | | 1 channel | | |
| | RTC output | | – | | 1<br>1 Hz (subsystem clock: $f_{SUB}$ = 32.768 kHz) |
| 8/10-bit resolution A/D converter | | | 6 channels | 11 channels | 11 channels |
| Comparator | | | 4 channels | 6 channels | 6 channels |
| Programmable gain amplifier | | | 1 channel | | |
| | | Input[Note 3] | 4 channels | 6 channels | 6 channels |
| Serial interface | | | [20-pin] [Note 5]<br>• UART (Supporting LIN-bus and DMX512): 1 channel<br>• UART (Supporting DALI communication): 1 channel<br>[30-pin products]<br>• UART (Supporting LIN-bus and DMX512): 1 channel<br>• UART: 1 channel<br>• UART (Supporting DALI communication): 1 channel<br>[38-pin products]<br>• CSI: 1 channel/UART (Supporting LIN-bus and DMX512): 1 channel<br>• UART: 1 channel<br>• UART (Supporting DALI communication): 1 channel | | |
| | $I^2C$ bus | | 1 channel | 1 channel | 1 channel |
| Multiplier and divider/multiply-accumulator | | | • 16 bits × 16 bits = 32 bits (Unsigned or signed)<br>• 32 bits ÷ 32 bits = 32 bits (Unsigned)<br>• 16 bits × 16 bits + 32 bits = 32 bits (Unsigned or signed) | | |
| DMA controller | | | 2 channels | | |
| Vectored interrupt sources | Internal | | 27 | 30 | 30 |
| | External | | 7 | 10 | 11 |
| Reset | | | • Reset by $\overline{\text{RESET}}$ pin<br>• Internal reset by watchdog timer<br>• Internal reset by power-on-reset<br>• Internal reset by voltage detector<br>• Internal reset by illegal instruction execution[Note 4]<br>• Internal reset by RAM parity error<br>• Internal reset by illegal-memory access | | |

**Notes 1.** The subsystem clock ($f_{SUB}$) can be selected as the operating clock only for 38-pin products.

**2.** The 20- and 30-pin products can only be used as the constant-period interrupt function.

**3.** The comparator input is alternatively used with analog input pin (ANI pin).

**4.** The illegal instruction is generated when instruction code FFH is executed.
Reset by the illegal instruction execution not issued by emulation with the in-circuit emulator or on-chip debug emulator.

**5.** The 20 pin products can only be used 1 UART simultaneously due to sharing of the same I/O pins.

(3/3)

| Item | 20-pin | 30-pin | 38-pin |
|---|---|---|---|
| | R5F1076C | R5F107AC, R5F107AE | R5F107DE |
| Power-on-reset circuit | • Power-on-reset: 1.51 V (TYP.)<br>• Power-down-reset: 1.50 V (TYP.) | | |
| Voltage detector | • Rising edge: 2.81 V to 4.06 V (6 stages)<br>• Falling edge: 2.75 V to 3.98 V (6 stages) | | |
| On-chip debug function | Provided | | |
| Power supply voltage | $V_{DD}$ = 2.7 to 5.5 V | | |
| Operating ambient temperature | $T_A$ = –40 to +105°C (G: Industrial applications), $T_A$ = –40 to +125°C (M: Industrial applications) | | |

# 2. ELECTRICAL SPECIFICATIONS (G: Industrial applications, $T_A$ = –40 to +105°C)

In this chapter, shows the electrical specifications of the target products.

Target products (G: Industrial applications): $T_A$ = – 40 to + 105°C
R5F107xxGxx

**Cautions 1. The RL78/I1A has an on-chip debug function, which is provided for development and evaluation. Do not use the on-chip debug function in products designated for mass production, because the guaranteed number of rewritable times of the flash memory may be exceeded when this function is used, and product reliability therefore cannot be guaranteed. Renesas Electronics is not liable for problems occurring when the on-chip debug function is used.**

**2. The pins mounted depend on the product. See 2.1 Port Function to 2.2.1 Functions for each product in the RL78/I1A User's Manual.**

## 2.1 Absolute Maximum Ratings

**Absolute Maximum Ratings ($T_A$ = 25°C) (1/2)**

| Parameter | Symbols | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | –0.5 to +6.5 | V |
| REGC pin input voltage | $V_{IREGC}$ | REGC | –0.3 to +2.8 and –0.3 to $V_{DD}$ +0.3 Note 1 | V |
| Input voltage | $V_{I1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | –0.3 to $V_{DD}$ +0.3 Note 2 | V |
| Output voltage | $V_{O1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | –0.3 to $V_{DD}$ +0.3 Note 2 | V |
| Analog input voltage | $V_{AI1}$ | ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19 | –0.3 to $V_{DD}$ +0.3 and –0.3 to $AV_{REF(+)}$ +0.3 Notes 2, 3 | V |

**Notes 1.** Connect the REGC pin to Vss via a capacitor (0.47 to 1 $\mu$F). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.

**2.** Must be 6.5 V or lower.

**3.** Do not exceed $AV_{REF(+)}$ + 0.3 V in case of A/D conversion target pin.

**Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.**

**Remarks 1.** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**2.** $AV_{REF(+)}$: + side reference voltage of the A/D converter.

**3.** $V_{SS}$: Reference voltage

**Absolute Maximum Ratings ($T_A$ = 25°C) (2/2)**

| Parameter | Symbols | Conditions | | Ratings | Unit |
|---|---|---|---|---|---|
| Output current, high | $I_{OH1}$ | Per pin | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | –40 | mA |
| | | Total of all pins –170 mA | P02, P03, P40, P120 | –70 | mA |
| | | | P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 | –100 | mA |
| | $I_{OH2}$ | Per pin | P20 to P22, P24 to P27 | –0.5 | mA |
| | | Total of all pins | | –2 | mA |
| Output current, low | $I_{OL1}$ | Per pin | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 40 | mA |
| | | Total of all pins 170 mA | P02, P03, P40, P120 | 70 | mA |
| | | | P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 | 100 | mA |
| | $I_{OL2}$ | Per pin | P20 to P22, P24 to P27 | 1 | mA |
| | | Total of all pins | | 5 | mA |
| Operating ambient temperature | $T_A$ | In normal operation mode | | –40 to +105 | °C |
| | | In flash memory programming mode | | | |
| Storage temperature | $T_{stg}$ | | | –65 to +150 | °C |

**Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

## 2.2 Oscillator Characteristics

### 2.2.1 X1, XT1 oscillator characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Resonator | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| X1 clock oscillation frequency ($f_X$)Note | Ceramic resonator/crystal resonator | | 1.0 | | 20.0 | MHz |
| XT1 clock oscillation frequency ($f_{XT}$)Note | Crystal resonator | | 32 | 32.768 | 35 | kHz |

**Note** Indicates only permissible oscillator frequency ranges. See **AC Characteristics** for instruction execution time. Request evaluation by the manufacturer of the oscillator circuit mounted on a board to check the oscillator characteristics.

**Caution Since the CPU is started by the high-speed on-chip oscillator clock after a reset release, check the X1 clock oscillation stabilization time using the oscillation stabilization time counter status register (OSTC) by the user. Determine the oscillation stabilization time of the OSTC register and the oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.**

**Remark** When using the X1 oscillator and XT1 oscillator, see **5.4 System Clock Oscillator in the RL78/I1A User's Manual.**

### 2.2.2 On-chip oscillator characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Oscillators | Parameters | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| High-speed on-chip oscillator clock frequency[Note 1] | $f_{IH}$ | | 1 | | 32 | MHz |
| High-speed on-chip oscillator clock frequency accuracy[Note 2] | | $T_A$ = –20 to 85°C | –1 | | +1 | % |
| | | $T_A$ = –40 to 105°C | –1.5 | | +1.5 | % |
| Low-speed on-chip oscillator clock frequency | $f_{IL}$ | | | 15 | | kHz |
| Low-speed on-chip oscillator clock frequency accuracy | | | –15 | | +15 | % |

**Notes 1.** Frequency can be selected in a high-speed on-chip oscillator. Selected by bits 0 to 3 of option byte (000C2H/010C2H).

**2.** This indicates the oscillator characteristics only. See **AC Characteristics** for instruction execution time.

### 2.2.3 PLL characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| PLL input clock frequency[Note] | $f_{PLLIN}$ | High-speed system clock is selected ($f_{MX}$ = 4 MHz) | 3.94 | 4.00 | 4.06 | MHz |
| | | High-speed on-chip oscillator clock is selected ($f_{IH}$ = 4 MHz) | 3.94 | 4.00 | 4.06 | MHz |
| PLL output clock frequency[Note] | $f_{PLL}$ | | $f_{PLLIN}$ × 16 | | | MHz |

**Note** This only indicates the oscillator characteristics. See **AC Characteristics** for instruction execution time.

## 2.3 DC Characteristics

### 2.3.1 Pin characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output current, high[Note 1] | $I_{OH1}$ | Per pin for P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –3.0[Note 2] | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –1.0 | mA |
| | | Total of P02, P03, P40, P120 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –12.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –4.0 | mA |
| | | Total of P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –30.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –10.0 | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –30.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –14.0 | mA |
| | $I_{OH2}$ | Per pin for P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | –0.1[Note 2] | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | –0.7 | mA |

**Notes 1.** Value of current at which the device operation is guaranteed even if the current flows from the $V_{DD}$ pin to an output pin.

**2.** However, do not exceed the total current value.

**3.** Specification under conditions where the duty factor ≤ 70%.
The output current value that has changed to the duty factor > 70% the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = ($I_{OH}$ × 0.7)/(n × 0.01)

<Example> Where n = 80% and $I_{OH}$ = –10.0 mA

Total output current of pins = (–10.0 × 0.7)/(80 × 0.01) ≅ –8.7 mA

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

**Caution P02, P10 to P12 do not output high level in N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output current, low[Note 1] | $I_{OL1}$ | Per pin for P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 8.5[Note 2] | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 1.5[Note 2] | mA |
| | | Total of P02, P03, P40, P120 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 40.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 7.5 | mA |
| | | Total of P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 40.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 17.5 | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 80.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 25.0 | mA |
| | $I_{OL2}$ | Per pin for P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | 0.4[Note 2] | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | 2.8 | mA |

**Notes 1.** Value of current at which the device operation is guaranteed even if the current flows from an output pin to the $V_{SS}$ pin.

**2.** However, do not exceed the total current value.

**3.** Specification under conditions where the duty factor ≤ 70%.
The output current value that has changed to the duty factor > 70% the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = ($I_{OL}$ × 0.7)/(n × 0.01)

<Example> Where n = 80% and $I_{OL}$ = –10.0 mA

Total output current of pins = (–10.0 × 0.7)/(80 × 0.01) ≅ – 8.7 mA

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Input voltage, high | $V_{IH1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | Normal input buffer | 0.8$V_{DD}$ | | $V_{DD}$ | V |
| | $V_{IH2}$ | P03, P10, P11 | TTL input buffer 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 2.1 | | $V_{DD}$ | V |
| | | | TTL input buffer 3.3 V ≤ $V_{DD}$ < 4.0 V | 2.0 | | $V_{DD}$ | V |
| | | | TTL input buffer 2.7 V ≤ $V_{DD}$ < 3.3 V | 1.5 | | $V_{DD}$ | V |
| Input voltage, low | $V_{IL1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | Normal input buffer | 0 | | 0.2$V_{DD}$ | V |
| | $V_{IL2}$ | P03, P10, P11 | TTL input buffer 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 0 | | 0.8 | V |
| | | | TTL input buffer 3.3 V ≤ $V_{DD}$ < 4.0 V | 0 | | 0.5 | V |
| | | | TTL input buffer 2.7 V ≤ $V_{DD}$ < 3.3 V | 0 | | 0.32 | V |

**Caution The maximum value of $V_{IH}$ of pins P02, P10 to P12 is $V_{DD}$, even in the N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output voltage, high | $V_{OH1}$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH1}$ = –3.0 mA | $V_{DD}$ – 0.7 | | | V |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH1}$ = –1.0 mA | $V_{DD}$ – 0.5 | | | V |
| | $V_{OH2}$ | P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH2}$ = –100 μA | $V_{DD}$ – 0.5 | | | V |
| Output voltage, low | $V_{OL1}$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 8.5 mA | | | 0.7 | V |
| | | | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 4.0 mA | | | 0.4 | V |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 1.5 mA | | | 0.4 | V |
| | $V_{OL2}$ | P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL2}$ = 400 μA | | | 0.4 | V |

**Caution P02, P10 to P12 do not output high level in N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = −40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Input leakage current, high | $I_{LIH1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P137, P147, P200 to P206, $\overline{\text{RESET}}$ | $V_I = V_{DD}$ | | | | 1 | μA |
| | $I_{LIH2}$ | P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS) | $V_I = V_{DD}$ | In input port or external clock input | | | 1 | μA |
| | | | | In resonator connection | | | 10 | μA |
| Input leakage current, low | $I_{LIL1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P137, P147, P200 to P206, $\overline{\text{RESET}}$ | $V_I = V_{SS}$ | | | | −1 | μA |
| | $I_{LIL2}$ | P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS) | $V_I = V_{SS}$ | In input port or external clock input | | | −1 | μA |
| | | | | In resonator connection | | | −10 | μA |
| On-chip pull-up resistance | $R_U$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | $V_I = V_{SS}$, In input port | | 10 | 20 | 100 | kΩ |

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

## 2.3.2 Supply current characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V) (1/2)**

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Supply current Note 1 | $I_{DD1}$ | Operating mode | HS (high-speed main) mode Note 5 | $f_{IH}$ = 32 MHz Note 3 | $V_{DD}$ = 5.0 V | | 5.0 | 7.5 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 5.0 | 7.5 | mA |
| | | | | $f_{IH}$ = 24 MHz Note 3 | $V_{DD}$ = 5.0 V | | 3.9 | 5.8 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 3.9 | 5.8 | mA |
| | | | | $f_{IH}$ = 16 MHz Note 3 | $V_{DD}$ = 5.0 V | | 2.9 | 4.2 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 2.9 | 4.2 | mA |
| | | | LS (low-speed main) mode Note 5 | $f_{IH}$ = 8 MHz Note 3, $T_A$ = –40 to + 85°C | $V_{DD}$ = 3.0 V | | 1.3 | 2.0 | mA |
| | | | HS (high-speed main) mode Note 5 | $f_{MX}$ = 20 MHz Note 2, $V_{DD}$ = 5.0 V | Square wave input | | 3.2 | 4.9 | mA |
| | | | | | Resonator connection | | 3.3 | 5.0 | mA |
| | | | | $f_{MX}$ = 20 MHz Note 2, $V_{DD}$ = 3.0 V | Square wave input | | 3.2 | 4.9 | mA |
| | | | | | Resonator connection | | 3.3 | 5.0 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 2, $V_{DD}$ = 5.0 V | Square wave input | | 2.0 | 2.9 | mA |
| | | | | | Resonator connection | | 2.0 | 2.9 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 2, $V_{DD}$ = 3.0 V | Square wave input | | 2.0 | 2.9 | mA |
| | | | | | Resonator connection | | 2.0 | 2.9 | mA |
| | | | LS (low-speed main) mode Note 5 | $f_{MX}$ = 8 MHz Note 2, $V_{DD}$ = 3.0 V, $T_A$ = –40 to + 85°C | Square wave input | | 1.2 | 1.8 | mA |
| | | | | | Resonator connection | | 1.2 | 1.8 | mA |
| | | | HS (high-speed main) mode Note 5 | $f_{IH}$ = 4 MHz Note 3 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 32 MHz | $V_{DD}$ = 5.0 V | | 5.4 | 8.5 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 5.4 | 8.5 | mA |
| | | | | $f_{IH}$ = 4 MHz Note 3 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 16 MHz | $V_{DD}$ = 5.0 V | | 3.3 | 5.7 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 3.3 | 5.7 | mA |
| | | | Subsystem clock operation | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = –40°C | Square wave input | | 4.2 | 6.0 | μA |
| | | | | | Resonator connection | | 4.4 | 6.2 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +25°C | Square wave input | | 4.2 | 6.0 | μA |
| | | | | | Resonator connection | | 4.4 | 6.2 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +50°C | Square wave input | | 4.3 | 7.2 | μA |
| | | | | | Resonator connection | | 4.5 | 7.4 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +70°C | Square wave input | | 4.4 | 8.1 | μA |
| | | | | | Resonator connection | | 4.6 | 8.3 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +85°C | Square wave input | | 5.2 | 11.4 | μA |
| | | | | | Resonator connection | | 5.4 | 11.6 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +105°C | Square wave input | | 6.9 | 20.8 | μA |
| | | | | | Resonator connection | | 7.1 | 21.0 | μA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Total current flowing into $V_{DD}$, including the input leakage current flowing when the level of the input pin is fixed to $V_{DD}$ or $V_{SS}$. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, comparator, programmable gain amplifier, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

**2.** When high-speed on-chip oscillator and subsystem clock are stopped.

**3.** When high-speed system clock and subsystem clock are stopped.

**4.** When high-speed on-chip oscillator and high-speed system clock are stopped. When AMPHS1 = 1 (Ultra-low power consumption oscillation). However, not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.

**5.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 32 MHz

LS (low-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 8 MHz

**Remarks 1.** $f_{MX}$: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

**2.** $f_{IH}$: High-speed on-chip oscillator clock frequency

**3.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**4.** Except subsystem clock operation, temperature condition of the TYP. value is $T_A$ = 25°C

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V) (2/2)**

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Supply current Note 1 | $I_{DD2}$ Note 2 | HALT mode | HS (high-speed main) mode Note 7 | $f_{IH}$ = 32 MHz Note 4 | $V_{DD}$ = 5.0 V | | 0.72 | 2.9 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.72 | 2.9 | mA |
| | | | | $f_{IH}$ = 24 MHz Note 4 | $V_{DD}$ = 5.0 V | | 0.57 | 2.3 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.57 | 2.3 | mA |
| | | | | $f_{IH}$ = 16 MHz Note 4 | $V_{DD}$ = 5.0 V | | 0.50 | 1.7 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.50 | 1.7 | mA |
| | | | LS (low-speed main) mode Note 7 | $f_{IH}$ = 8 MHz Note 4, $T_A$ = –40 to +85°C | $V_{DD}$ = 3.0 V | | 320 | 910 | μA |
| | | | HS (high-speed main) mode Note 7 | $f_{MX}$ = 20 MHz Note 3, $V_{DD}$ = 5.0 V | Square wave input | | 0.40 | 1.9 | mA |
| | | | | | Resonator connection | | 0.50 | 2.0 | mA |
| | | | | $f_{MX}$ = 20 MHz Note 3, $V_{DD}$ = 3.0 V | Square wave input | | 0.40 | 1.9 | mA |
| | | | | | Resonator connection | | 0.50 | 2.0 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 3, $V_{DD}$ = 5.0 V | Square wave input | | 0.24 | 1.02 | mA |
| | | | | | Resonator connection | | 0.30 | 1.08 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 3, $V_{DD}$ = 3.0 V | Square wave input | | 0.24 | 1.02 | mA |
| | | | | | Resonator connection | | 0.30 | 1.08 | mA |
| | | | LS (low-speed main) mode Note 7 | $f_{MX}$ = 8 MHz Note 3, $V_{DD}$ = 3.0 V, $T_A$ = –40 to +85°C | Square wave input | | 130 | 720 | μA |
| | | | | | Resonator connection | | 170 | 760 | μA |
| | | | HS (high-speed main) mode Note 7 | $f_{IH}$ = 4 MHz Note 4 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 32 MHz | $V_{DD}$ = 5.0 V | | 1.15 | 4.0 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 1.15 | 4.0 | mA |
| | | | | $f_{IH}$ = 4 MHz Note 4 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 16 MHz | $V_{DD}$ = 5.0 V | | 0.95 | 3.2 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.95 | 3.2 | mA |
| | | | Subsystem clock operation | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = –40°C | Square wave input | | 0.28 | 0.70 | μA |
| | | | | | Resonator connection | | 0.47 | 0.89 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +25°C | Square wave input | | 0.33 | 0.70 | μA |
| | | | | | Resonator connection | | 0.52 | 0.89 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +50°C | Square wave input | | 0.41 | 1.90 | μA |
| | | | | | Resonator connection | | 0.60 | 2.09 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +70°C | Square wave input | | 0.54 | 2.80 | μA |
| | | | | | Resonator connection | | 0.73 | 2.99 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +85°C | Square wave input | | 1.27 | 6.10 | μA |
| | | | | | Resonator connection | | 1.46 | 6.29 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +105°C | Square wave input | | 3.04 | 15.5 | μA |
| | | | | | Resonator connection | | 3.23 | 15.7 | μA |
| | $I_{DD3}$ Note 6 | STOP mode Note 8 | $T_A$ = –40°C | | | | 0.18 | 0.50 | μA |
| | | | $T_A$ = +25°C | | | | 0.23 | 0.50 | μA |
| | | | $T_A$ = +50°C | | | | 0.27 | 1.70 | μA |
| | | | $T_A$ = +70°C | | | | 0.44 | 2.60 | μA |
| | | | $T_A$ = +85°C | | | | 1.17 | 5.90 | μA |
| | | | $T_A$ = +105°C | | | | 2.94 | 15.3 | μA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Total current flowing into $V_{DD}$, including the input leakage current flowing when the level of the input pin is fixed to $V_{DD}$ or $V_{SS}$. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, comparator, programmable gain amplifier, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

**2.** During HALT instruction execution by flash memory.

**3.** When high-speed on-chip oscillator and subsystem clock are stopped.

**4.** When high-speed system clock and subsystem clock are stopped.

**5.** When high-speed on-chip oscillator and high-speed system clock are stopped. When RTCLPC = 1 and setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the RTC is included. However, not including the current flowing into the 12-bit interval timer and watchdog timer.

**6.** Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.

**7.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 32 MHz

LS (low-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 8 MHz

**8.** Regarding the value for current operate the subsystem clock in STOP mode, refer to that in HALT mode.

**Remarks 1.** $f_{MX}$: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

**2.** $f_{IH}$: High-speed on-chip oscillator clock frequency

**3.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**4.** Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is $T_A$ = 25°C

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Low-speed on-chip oscillator operating current | $I_{FIL}$ Note 1 | | | | 0.20 | | μA |
| RTC operating current | $I_{RTC}$ Notes 1, 2, 3 | | | | 0.02 | | μA |
| 12-bit interval timer operating current | $I_{IT}$ Notes 1, 2, 4 | | | | 0.02 | | μA |
| Watchdog timer operating current | $I_{WDT}$ Notes 1, 2, 5 | $f_{IL}$ = 15 kHz | | | 0.22 | | μA |
| A/D converter operating current | $I_{ADC}$ Notes 1, 6 | When conversion at maximum speed | Normal mode, $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 1.3 | 1.7 | mA |
| | | | Low voltage mode, $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 0.5 | 0.7 | mA |
| A/D converter reference voltage current | $I_{ADREF}$ Note 1 | | | | 75.0 | | μA |
| Temperature sensor operating current | $I_{TMPS}$ Note 1 | | | | 75.0 | | μA |
| LVD operating current | $I_{LVD}$ Notes 1, 7 | | | | 0.08 | | μA |
| Self-programming operating current | $I_{FSP}$ Notes 1, 8 | | | | 2.50 | 12.2 | mA |
| Programmable gain amplifier operating current | $I_{PGA}$ Note 9 | | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 0.21 | 0.31 | mA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 0.18 | 0.29 | mA |
| Comparator operating current | $I_{CMP}$ Note 10 | When one comparator channel is operating | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 41.4 | 62 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 37.2 | 59 | μA |
| | $I_{VREF}$ | When one internal reference voltage circuit is operating | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 14.8 | 26 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 8.9 | 20 | μA |
| Programmable gain amplifier/ comparator reference current source | $I_{IREF}$ Note 11 | | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 3.2 | 5.1 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 2.9 | 4.9 | μA |
| BGO operating current | $I_{BGO}$ Note 12 | | | | 2.50 | 12.2 | mA |
| SNOOZE operating current | $I_{SNOZ}$ Note 1 | ADC operation | The mode is performed Note 13 | | 0.50 | 1.1 | mA |
| | | | The A/D conversion operations are performed, Standard mode, $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 2.0 | 3.04 | mA |
| | | CSI/UART operation | | | 0.70 | 1.54 | mA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Current flowing to the $V_{DD}$.

**2.** When the high-speed on-chip oscillator and high-speed system clock are stopped.

**3.** Current flowing only to the real-time clock (RTC) (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either $I_{DD1}$ or $I_{DD2}$, and $I_{RTC}$, when the real-time clock operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, $I_{FIL}$ should be added. $I_{DD2}$ subsystem clock operation includes the operational current of the real-time clock.

**4.** Current flowing only to the 12-bit interval timer (excluding the operating current of the XT1 oscillator and $f_{IL}$ operating current). The current of the RL78 microcontrollers is the sum of the values of either $I_{DD1}$ or $I_{DD2}$, and $I_{IT}$, when the 12-bit interval timer operates in operation mode or HALT mode.

**5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$ and $I_{WDT}$ when the watchdog timer is in operation.

**6.** Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of $I_{DD1}$ or $I_{DD2}$ and $I_{ADC}$ when the A/D converter operates in an operation mode or the HALT mode.

**7.** Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$ and $I_{LVD}$ when the LVD circuit is in operation.

**8.** Current flowing during self-programming operation.

**9.** Current flowing only to the programmable gain amplifier. The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$, and $I_{PGA}$, when the programmable gain amplifier is operating in operating mode or in HALT mode.

**10.** Current flowing only to the comparator. The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$, and $I_{CMP}$, when the comparator is operating.

**11.** This is the current required to flow to $V_{DD}$ pin of the current circuit that is used as the programmable gain amplifier and the comparator.

**12.** Current flowing only during data flash rewrite.

**13.** See **21.3.3 SNOOZE mode in the RL78/I1A User's Manual** for shift time to the SNOOZE mode .

**Remarks 1.** $f_{IL}$: Low-speed on-chip oscillator clock frequency

**2.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**3.** $f_{CLK}$: CPU/peripheral hardware clock frequency

**4.** Temperature condition of the TYP. value is $T_A$ = 25°C

**5.** Example of calculating current value when using programmable gain amplifier and comparator.

Examples 1) TYP. operating current value when three comparator channels, one internal reference voltage generator, and PGA are operating (when $AV_{REFP}$ = $V_{DD}$ = 5.0 V)

$I_{CMP} \times 3 + I_{VREF} + I_{PGA} + I_{IREF}$

= 41.4 [$\mu$A] × 3 + 14.8 [$\mu$A] × 1 + 210 [$\mu$A] + 3.2 [$\mu$A]

= 352.2 [$\mu$A]

Examples 2) TYP. operating current value when using two comparator channels, without using internal reference voltage generator (when $AV_{REFP}$ = $V_{DD}$ = 5.0 V)

$I_{CMP} \times 2 + I_{IREF}$

= 41.4 [$\mu$A] × 2 + 3.2 [$\mu$A]

= 86.0 [$\mu$A]

## 2.4 AC Characteristics

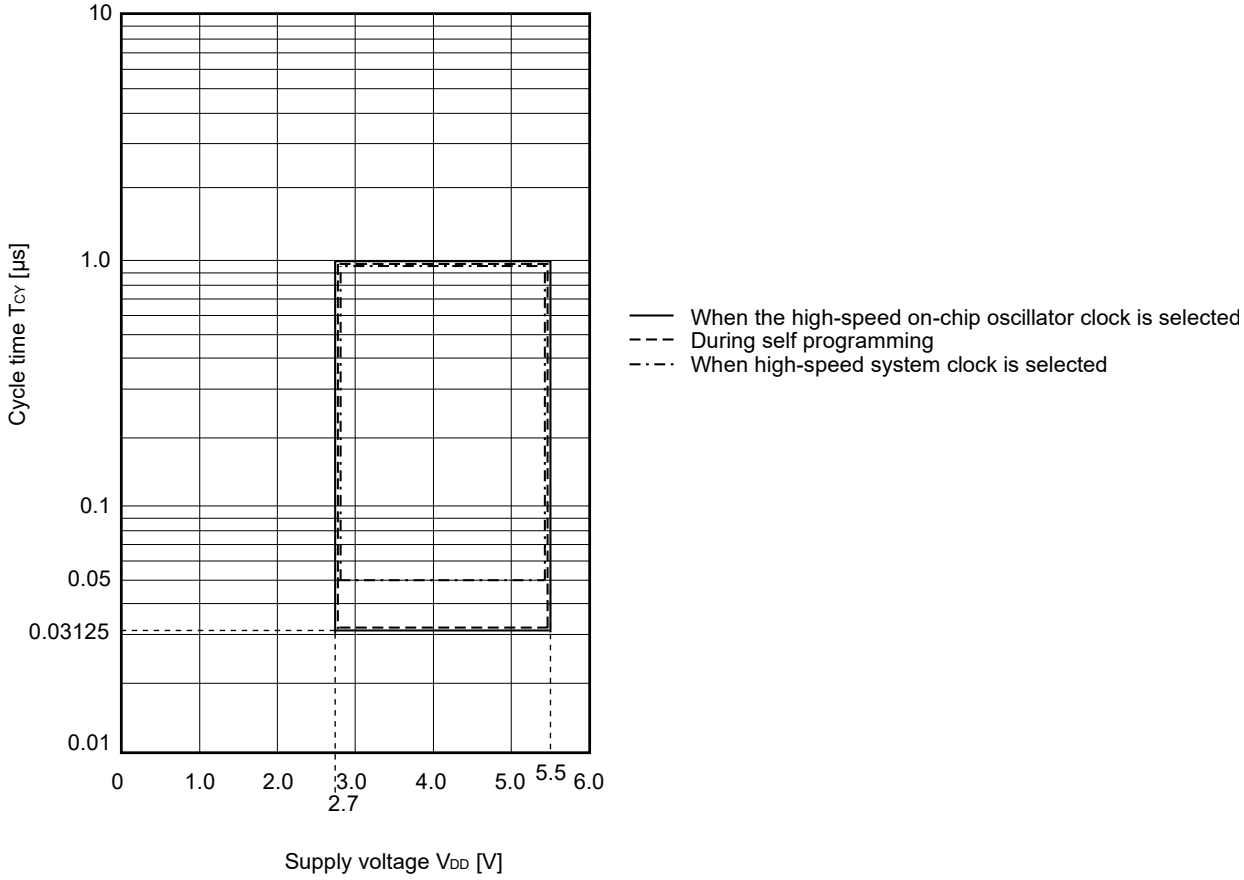
**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$ | Main system clock ($f_{MAIN}$) operation | HS (high-speed main) mode | | 0.03125 | | 1 | μs |
| | | | LS (low-speed main) mode | $T_A$ = –40 to +85°C | 0.125 | | 1 | μs |
| | | Subsystem clock ($f_{SUB}$) operation | | | 28.5 | 30.5 | 31.3 | μs |
| | | In the self programming mode | HS (high-speed main) mode | | 0.03125 | | 1 | μs |
| | | | LS (low-speed main) mode | $T_A$ = –40 to +85°C | 0.125 | | 1 | μs |
| External system clock frequency | $f_{EX}$ | | | | 1.0 | | 20.0 | MHz |
| | $f_{EXS}$ | | | | 32 | | 35 | kHz |
| External system clock input high-level width, low-level width | $t_{EXH}$, $t_{EXL}$ | | | | 24 | | | ns |
| | $t_{EXHS}$, $t_{EXLS}$ | | | | 13.7 | | | μs |
| TI03, TI05, TI06, TI07 input high-level width, low-level width | $t_{TIH}$, $t_{TIL}$ | | | | 2/$f_{MCK}$+10 | | | ns |
| TO03, TO05, TO06, TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21, TKCO00 to TKCO05 output frequency (When duty = 50%) | $f_{TO}$ | HS (high-speed main) mode | | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 8 | MHz |
| | | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 4 | MHz |
| | | LS (low-speed main) mode, $T_A$ = –40 to +85°C | | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 4 | MHz |
| | | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 2 | MHz |
| Interrupt input high-level width, low-level width | $t_{INTH}$, $t_{INTL}$ | INTP0, INTP3, INTP4, INTP9 to INTP11, INTP20 to INTP23 | | | 1 | | | μs |
| $\overline{RESET}$ low-level width | $t_{RSL}$ | | | | 10 | | | μs |

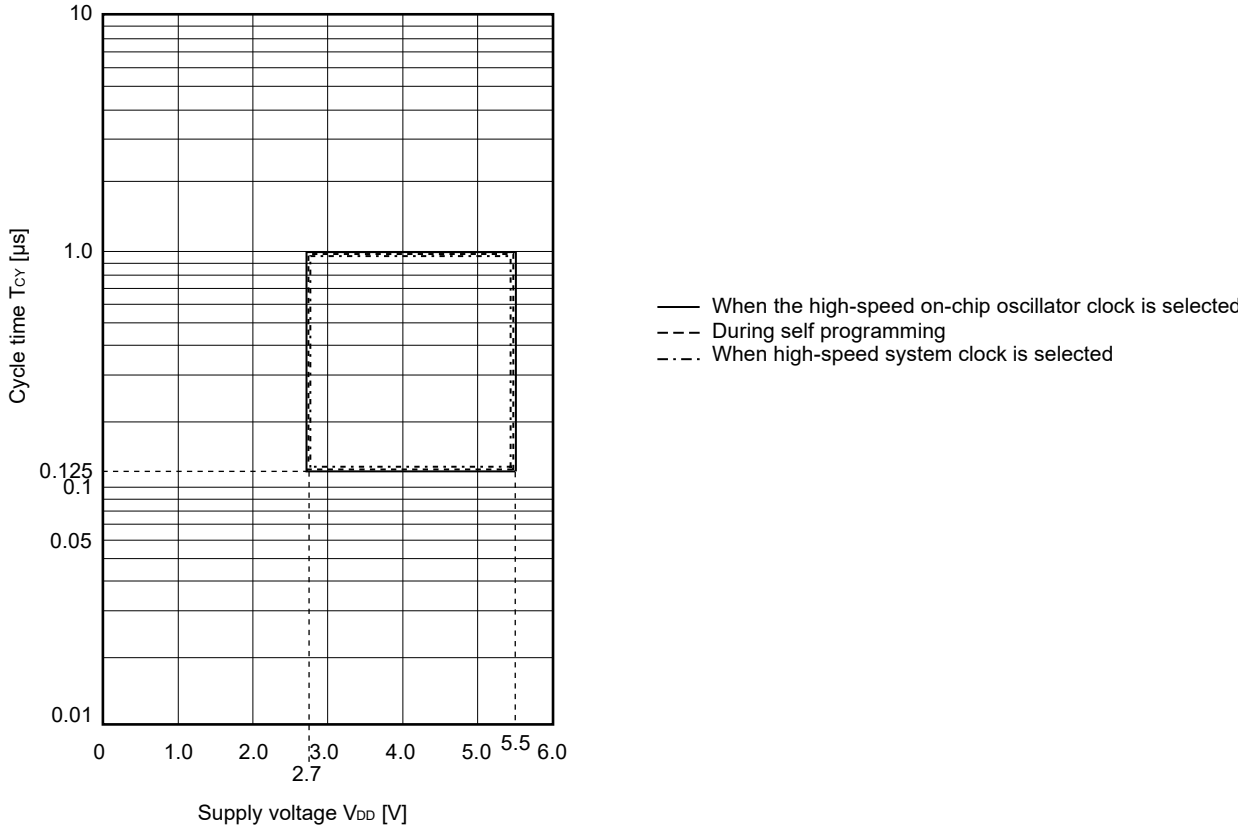
**Remark** $f_{MCK}$: Timer array unit operation clock frequency
(Operation clock to be set by the CKS0n bit of timer mode register 0n (TMR0n). n: Channel number (n = 0 to 7))

**Minimum Instruction Execution Time during Main System Clock Operation**

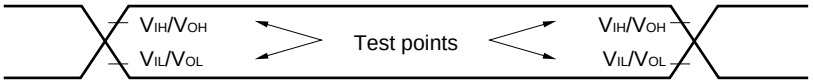
$T_{CY}$ vs $V_{DD}$ (HS (high-speed main) mode)



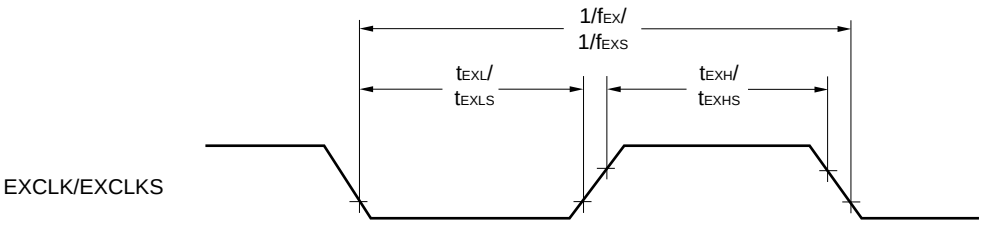

$T_{CY}$ vs $V_{DD}$ (LS (low-speed main) mode)



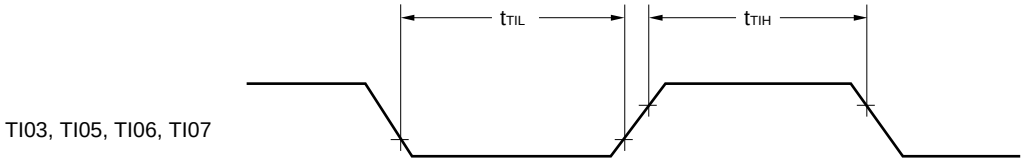
### AC Timing Test Points

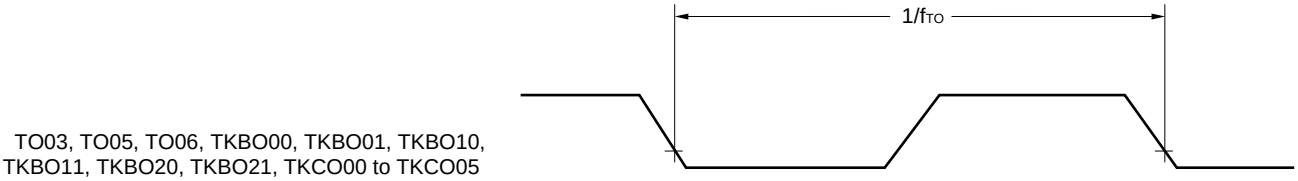



### External System Clock Timing

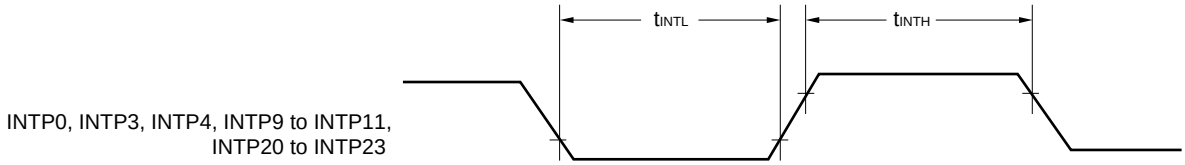



### TI/TO Timing

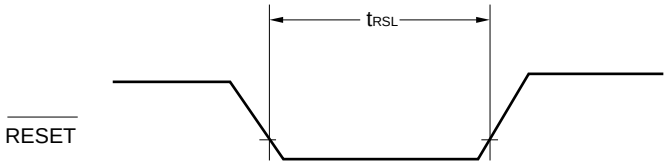



### Interrupt Request Input Timing

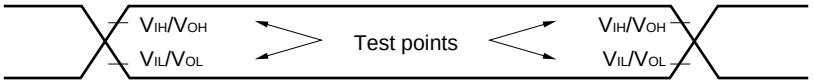



### $\overline{\text{RESET}}$ Input Timing



## 2.5 Peripheral Functions Characteristics

**AC Timing Test Points**




### 2.5.1 Serial array unit 0, 4 (UART0, UART1, CSI00, DALI/UART4)

**(1) During communication at same potential (UART mode)**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

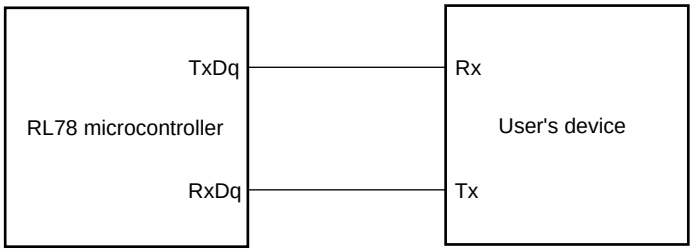
| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. | |
| Transfer rate[Note 1] | | 2.7 V≤ $V_{DD}$ ≤ 5.5 V | | $f_{MCK}$/6 | | $f_{MCK}$/6 | bps |
| | | Theoretical value of the maximum transfer rate $f_{MCK}$ = $f_{CLK}$[Note 2] | | 5.3 | | 1.3 | Mbps |

**Notes 1.** Transfer rate in the SNOOZE mode is 4800 bps only.

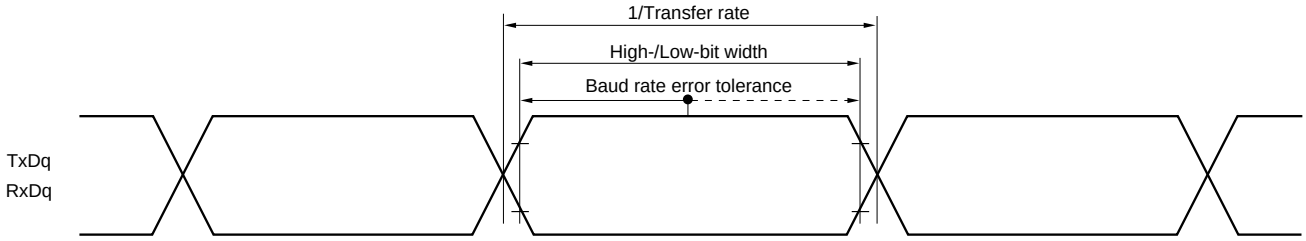
**2.** The maximum operating frequencies of the CPU/peripheral hardware clock ($f_{CLK}$) are:
HS (high-speed main) mode: 32 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V)
LS (low-speed main) mode: 8 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V), $T_A$ = –40 to +85°C

**Caution Select the normal input buffer for the RxDq pin and the normal output mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**UART mode connection diagram (during communication at same potential)**




**UART mode bit width (during communication at same potential) (reference)**




**Caution Select the normal input buffer for the RxDq pin and the normal output mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03))

**(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output)**

**($T_A$ = –40 to +105°C[Note 5], 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | $t_{KCY1}$ | $t_{KCY1} \geq 4/f_{CLK}$ | 125 | | 500 | | ns |
| SCKp high-/low-level width | $t_{KH1}$, $t_{KL1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | $t_{KCY1}/2 - 12$ | | $t_{KCY1}/2 - 50$ | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | $t_{KCY1}/2 - 18$ | | $t_{KCY1}/2 - 50$ | | ns |
| SIp setup time (to SCKp↑) Note 1 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 44 | | 110 | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 44 | | 110 | | ns |
| SIp hold time (from SCKp↑) Note 2 | $t_{KSI1}$ | | 19 | | 19 | | ns |
| Delay time from SCKp↓ to SOp output Note 3 | $t_{KSO1}$ | C = 30 pF Note 4 | | 25 | | 25 | ns |

**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes "to SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp↑" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**4.** C is the load capacitance of the SCKp and SOp output lines.

**5.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Caution Select the normal input buffer for the SIp pin and the normal output mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))

**(3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)**

**($T_A$ = –40 to +105°C[Note 6], 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time [Note 5] | $t_{KCY2}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 20 MHz < $f_{MCK}$ | 8/$f_{MCK}$ | | – | | ns |
| | | | $f_{MCK}$ ≤ 20 MHz | 6/$f_{MCK}$ | | 6/$f_{MCK}$ | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 16 MHz < $f_{MCK}$ | 8/$f_{MCK}$ | | – | | ns |
| | | | $f_{MCK}$ ≤ 16 MHz | 6/$f_{MCK}$ | | 6/$f_{MCK}$ | | ns |
| SCKp high-/low-level width | $t_{KH2}$, $t_{KL2}$ | | | $t_{KCY2}$/2 | | $t_{KCY2}$/2 | | ns |
| SIp setup time (to SCKp↑)[Note 1] | $t_{SIK2}$ | | | 1/$f_{MCK}$+20 | | 1/$f_{MCK}$+30 | | ns |
| SIp hold time (from SCKp↑)[Note 2] | $t_{KSI2}$ | | | 1/$f_{MCK}$+31 | | 1/$f_{MCK}$+31 | | ns |
| Delay time from SCKp↓ to SOp output[Note 3] | $t_{KSO2}$ | C = 30 pF[Note 4] | | | 2/$f_{MCK}$+ 44 | | 2/$f_{MCK}$+ 110 | ns |

**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes "to SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp↑" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**4.** C is the load capacitance of the SOp output lines.

**5.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps

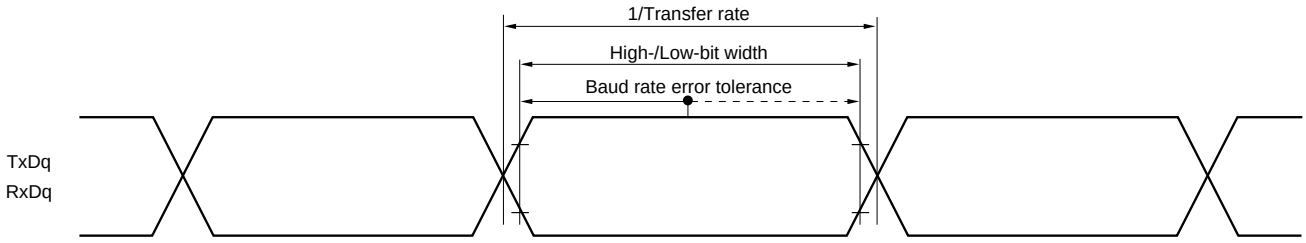
**6.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Caution Select the normal input buffer for the SIp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

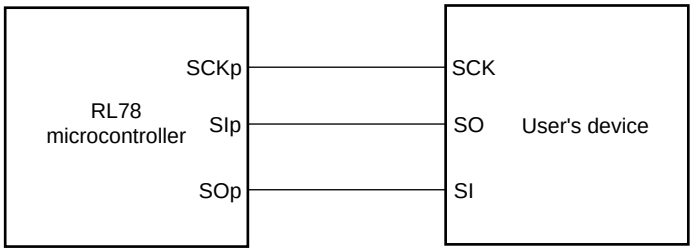
**Remarks 1.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency

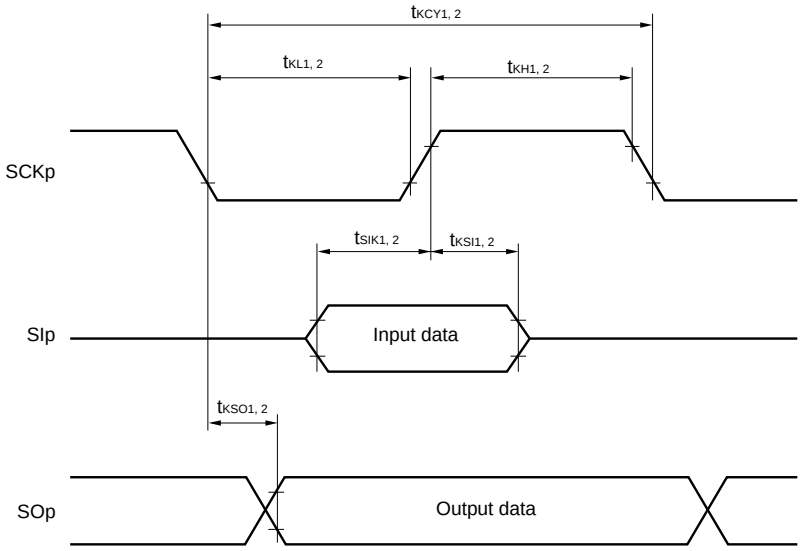
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))



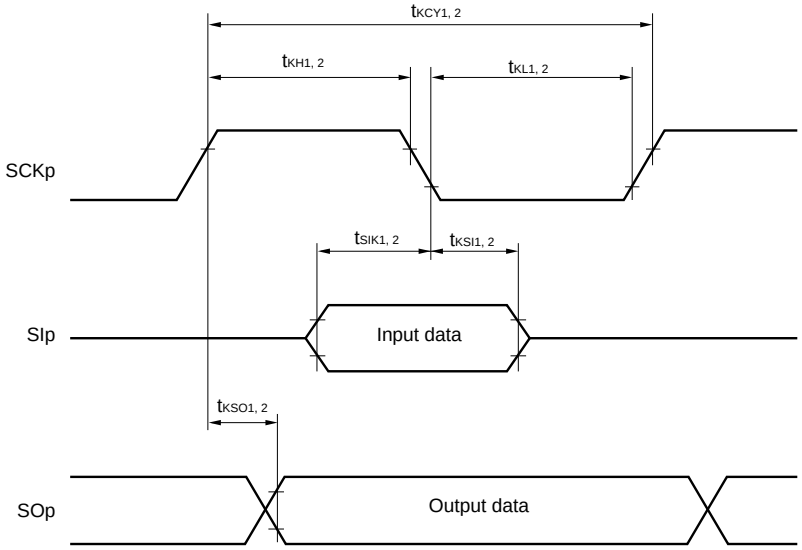
**CSI mode connection diagram (during communication at same potential)**




**CSI mode serial transfer timing (during communication at same potential)**
**(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)**




**CSI mode serial transfer timing (during communication at same potential)**
**(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)**




**Remarks 1.** p: CSI number (p = 00)

**2.** m: Unit number, n: Channel number (mn = 00)

**(4) Communication at different potential (2.5 V, 3 V) (UART mode) (1/2)**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| Transfer rate | | Reception | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V | | $f_{MCK}/6$ Note 1 | | $f_{MCK}/6$ Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$ Note 2 | | 5.3 | | 1.3 | Mbps |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V | | $f_{MCK}/6$ Note 1 | | $f_{MCK}/6$ Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$ Note 2 | | 5.3 | | 1.3 | Mbps |

**Notes 1.** Transfer rate in the SNOOZE mode is 4800 bps only.

**2.** The maximum operating frequencies of the CPU/peripheral hardware clock ($f_{CLK}$) are:

HS (high-speed main) mode: 32 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V)

LS (low-speed main) mode: 8 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V), $T_A$ = –40 to +85°C.

**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For $V_{IH}$ and $V_{IL}$, see the DC characteristics with TTL input buffer selected.**

**Remarks 1.** $V_b$[V]: Communication line voltage

**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**3.** $f_{MCK}$: Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03)

**(4) Communication at different potential (2.5 V, 3 V) (UART mode) (2/2)**

**($T_A$ = –40 to +105°C Note 5, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| Transfer rate | | Transmission | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V | | **Note 1** | | **Note 1** | bps |
| | | | Theoretical value of the maximum transfer rate $C_b$ = 50 pF, $R_b$ = 1.4 kΩ, $V_b$ = 2.7 V | | 2.8 Note 2 | | 2.8 Note 2 | Mbps |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V | | **Note 3** | | **Note 3** | bps |
| | | | Theoretical value of the maximum transfer rate $C_b$ = 50 pF, $R_b$ = 2.7 kΩ, $V_b$ = 2.3 V | | 1.2 Note 4 | | 1.2 Note 4 | Mbps |

**Notes 1.** The smaller maximum transfer rate derived by using $f_{MCK}$/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 4.0 V ≤ $V_{DD}$ ≤ 5.5 V and 2.7 V ≤ $V_b$ ≤ 4.0 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.2}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.2}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [\%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

**2.** This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 1** above to calculate the maximum transfer rate under conditions of the customer.

**3.** The smaller maximum transfer rate derived by using $f_{MCK}$/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 2.7 V ≤ $V_{DD}$ < 4.0 V and 2.3 V ≤ $V_b$ ≤ 2.7 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [\%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

**4.** This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 3** above to calculate the maximum transfer rate under conditions of the customer.

**5.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For $V_{IH}$ and $V_{IL}$, see the DC characteristics with TTL input buffer selected.**

**Remarks 1.** $R_b$[Ω]: Communication line (TxDq) pull-up resistance,
$C_b$[F]: Communication line (TxDq) load capacitance, $V_b$[V]: Communication line voltage

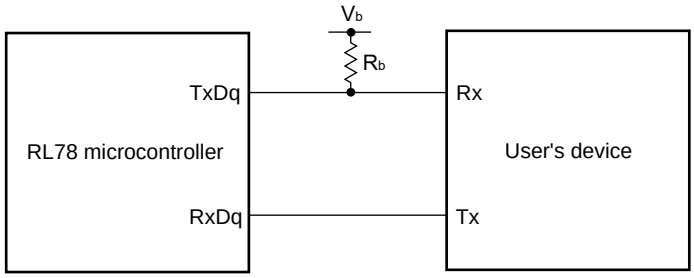
**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**3.** $f_{MCK}$: Serial array unit operation clock frequency

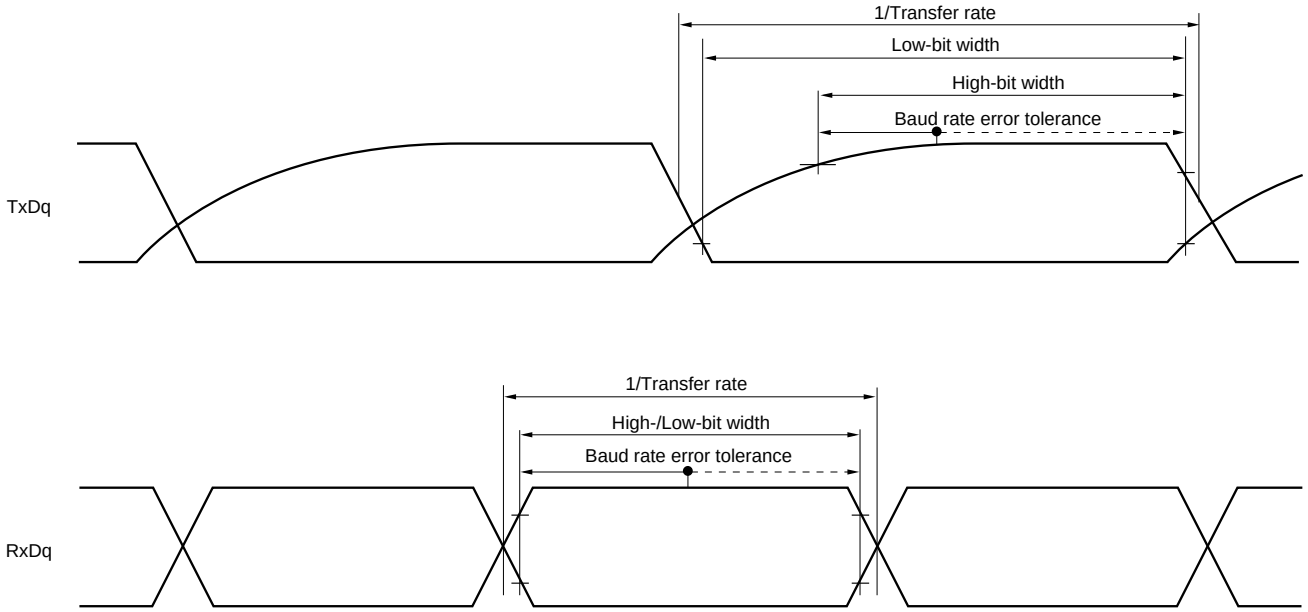
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).

m: Unit number, n: Channel number (mn = 00 to 03))

**UART mode connection diagram (during communication at different potential)**




**UART mode bit width (during communication at different potential) (reference)**




**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** $R_b$[Ω]: Communication line (TxDq) pull-up resistance, $V_b$[V]: Communication line voltage

**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**(5) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**

**($T_A$ = –40 to +105°C Note 3, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | $t_{KCY1}$ | $t_{KCY1} \geq 2/f_{CLK}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | 200 | | 1150 | | ns |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | 300 | | 1150 | | ns |
| SCKp high-level width | $t_{KH1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 50 | | $t_{KCY1}$/2 – 75 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 120 | | $t_{KCY1}$/2 – 170 | | ns |
| SCKp low-level width | $t_{KL1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 7 | | $t_{KCY1}$/2 – 50 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 10 | | $t_{KCY1}$/2 – 50 | | ns |
| SIp setup time (to SCKp↑) Note 1 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 81 | | 479 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 177 | | 479 | | ns |
| SIp hold time (from SCKp↑) Note 1 | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 10 | | 19 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 10 | | 19 | | ns |
| Delay time from SCKp↓ to SOp output Note 1 | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | | 60 | | 100 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | | 130 | | 195 | ns |
| SIp setup time (to SCKp↓) Note 2 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 44 | | 110 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 44 | | 110 | | ns |
| SIp hold time (from SCKp↓) Note 2 | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 10 | | 19 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 10 | | 19 | | ns |
| Delay time from SCKp↑ to SOp output Note 2 | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | | 10 | | 25 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | | 10 | | 25 | ns |

**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.

**2.** When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**3.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For $V_{IH}$ and $V_{IL}$, see the DC characteristics with TTL input buffer selected.**

**Remarks 1.** $R_b$[Ω]: Communication line (SCKp, SOp) pull-up resistance, $C_b$[F]: Communication line (SCKp, SOp) load capacitance, $V_b$[V]: Communication line voltage

**2.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

### (6) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)

**($T_A$ = –40 to +105°C Note 3, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

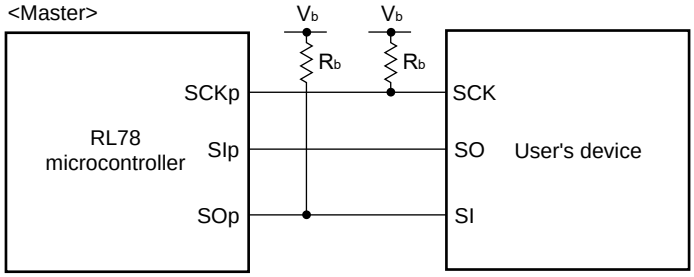
| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | $t_{KCY1}$ | $t_{KCY1} \geq 4/f_{CLK}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | 300 | | 1150 | | ns |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | 500 | | 1150 | | ns |
| SCKp high-level width | $t_{KH1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 75 | | $t_{KCY1}$/2 – 75 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 170 | | $t_{KCY1}$/2 – 170 | | ns |
| SCKp low-level width | $t_{KL1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 12 | | $t_{KCY1}$/2 – 50 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 18 | | $t_{KCY1}$/2 – 50 | | ns |
| SIp setup time (to SCKp↑) Note 1 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 81 | | 479 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 177 | | 479 | | ns |
| SIp hold time (from SCKp↑) Note 1 | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 19 | | 19 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 19 | | 19 | | ns |
| Delay time from SCKp↓ to SOp output Note 1 | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | | 100 | | 100 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | | 195 | | 195 | ns |
| SIp setup time (to SCKp↓) Note 2 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 44 | | 110 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 44 | | 110 | | ns |
| SIp hold time (from SCKp↓) Note 2 | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 19 | | 19 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 19 | | 19 | | ns |
| Delay time from SCKp↑ to SOp output Note 2 | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | | 25 | | 25 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | | 25 | | 25 | ns |

**Notes**
1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.
2. When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
3. Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

(**Caution** and **Remarks** are listed on the next page.)

**Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For $V_{IH}$ and $V_{IL}$, see the DC characteristics with TTL input buffer selected.**

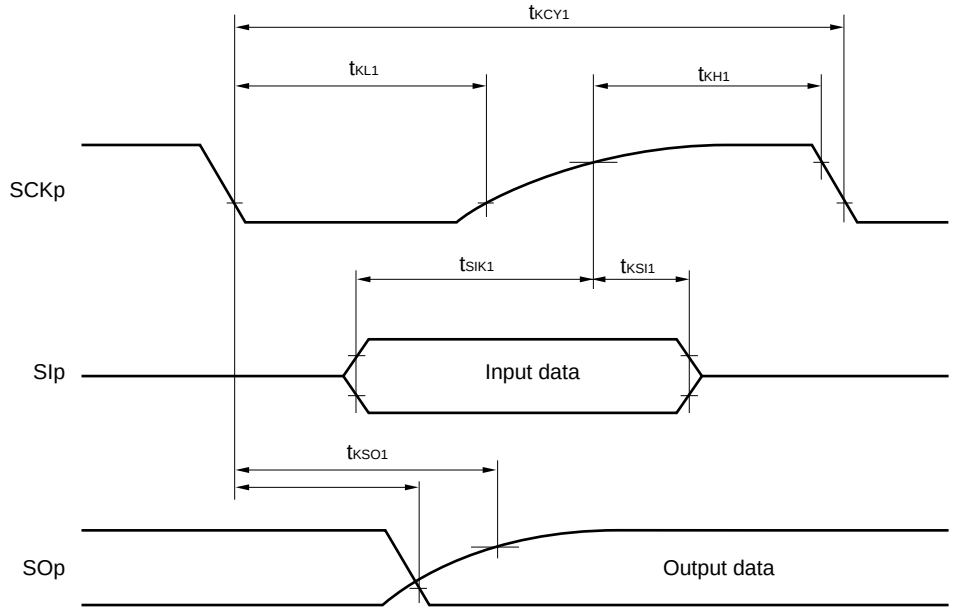
**CSI mode connection diagram (during communication at different potential)**



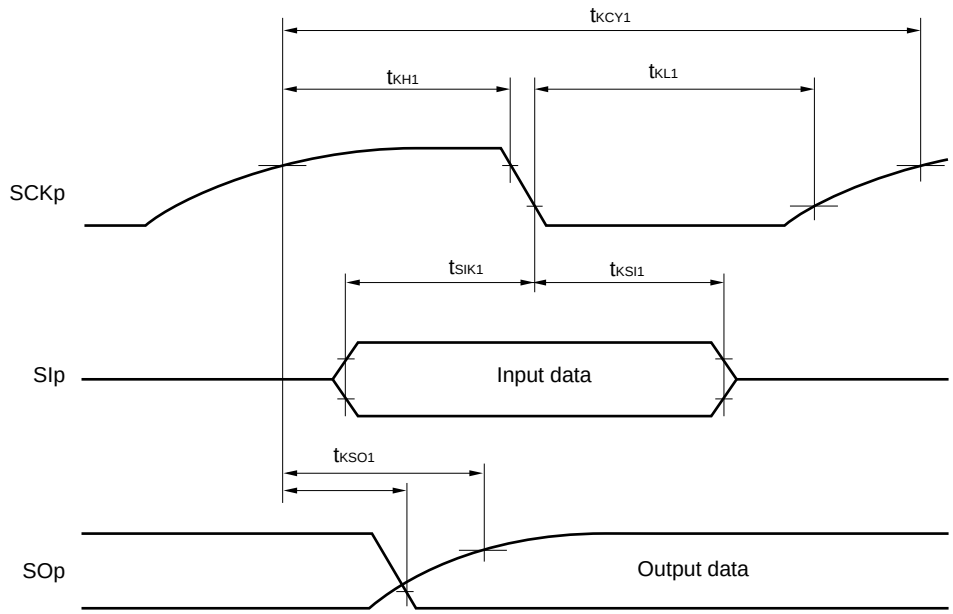

**Remarks 1.** $R_b$[Ω]: Communication line (SCKp, SOp) pull-up resistance, $C_b$[F]: Communication line (SCKp, SOp) load capacitance, $V_b$[V]: Communication line voltage

**2.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**CSI mode serial transfer timing (master mode) (during communication at different potential)**
**(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)**




**CSI mode serial transfer timing (master mode) (during communication at different potential)**
**(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)**




**Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remark** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

### (7) DALI/UART4 mode

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | MIN. | MAX. | |
| Transfer rate | | | | | $f_{MCK}$/12 | | $f_{MCK}$/12 | bps |
| | | | Maximum transfer rate theoretical value<br>HS: $f_{CLK}$ = 32 MHz, $f_{MCK}$ = $f_{CLK}$<br>LS: $f_{CLK}$ = 8 MHz, $f_{MCK}$ = $f_{CLK}$ | | 2.6 | | 0.6 | Mbps |

**Remark** $f_{MCK}$: Operation clock frequency of DALI/UART.
(Operation clock to be set by the serial clock select register mn (SPS4).)

**Caution** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

## 2.5.2 Serial interface IICA

### (1) $I^2C$ standard mode

**($T_A$ = –40 to +105°C [Note 3], 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. | |
| SCLA0 clock frequency | $f_{SCL}$ | Standard mode: $f_{CLK}$ ≥ 1 MHz | 0 | 100 | 0 | 100 | kHz |
| Setup time of restart condition | $t_{SU:STA}$ | | 4.7 | | 4.7 | | μs |
| Hold time[Note 1] | $t_{HD:STA}$ | | 4.0 | | 4.0 | | μs |
| Hold time when SCLA0 = “L” | $t_{LOW}$ | | 4.7 | | 4.7 | | μs |
| Hold time when SCLA0 = “H” | $t_{HIGH}$ | | 4.0 | | 4.0 | | μs |
| Data setup time (reception) | $t_{SU:DAT}$ | | 250 | | 250 | | ns |
| Data hold time (transmission)[Note 2] | $t_{HD:DAT}$ | | 0 | 3.45 | 0 | 3.45 | μs |
| Setup time of stop condition | $t_{SU:STO}$ | | 4.0 | | 4.0 | | μs |
| Bus-free time | $t_{BUF}$ | | 4.7 | | 4.7 | | μs |

**Notes 1.** The first clock pulse is generated after this period when the start/restart condition is detected.

**2.** The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**3.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Remark** The maximum value of Cb (communication line capacitance) and the value of Rb (communication line pull-up resistor) at that time in each mode are as follows.

Standard mode: $C_b$ = 400 pF, $R_b$ = 2.7 kΩ

### (2) $I^2C$ fast mode

**($T_A$ = –40 to +105°C Note 3, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. | |
| SCLA0 clock frequency | $f_{SCL}$ | fast mode: $f_{CLK}$ ≥ 3.5 MHz | 0 | 400 | 0 | 400 | kHz |
| Setup time of restart condition | $t_{SU:STA}$ | | 0.6 | | 0.6 | | μs |
| Hold time Note 1 | $t_{HD:STA}$ | | 0.6 | | 0.6 | | μs |
| Hold time when SCLA0 = “L” | $t_{LOW}$ | | 1.3 | | 1.3 | | μs |
| Hold time when SCLA0 = “H” | $t_{HIGH}$ | | 0.6 | | 0.6 | | μs |
| Data setup time (reception) | $t_{SU:DAT}$ | | 100 | | 100 | | ns |
| Data hold time (transmission) Note 2 | $t_{HD:DAT}$ | | 0 | 0.9 | 0 | 0.9 | μs |
| Setup time of stop condition | $t_{SU:STO}$ | | 0.6 | | 0.6 | | μs |
| Bus-free time | $t_{BUF}$ | | 1.3 | | 1.3 | | μs |

**Notes 1.** The first clock pulse is generated after this period when the start/restart condition is detected.

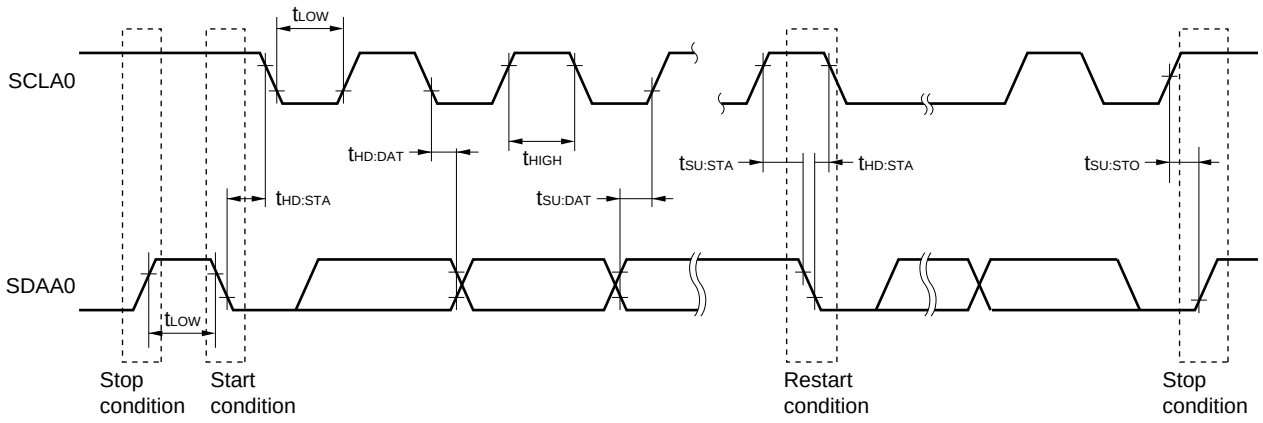
**2.** The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**3.** Operating conditions of LS (low-speed main) mode is $T_A$ = –40 to +85°C.

**Remark** The maximum value of Cb (communication line capacitance) and the value of Rb (communication line pull-up resistor) at that time in each mode are as follows.

Fast mode: $C_b$ = 320 pF, $R_b$ = 1.1 kΩ

**IICA serial transfer timing**



## 2.6 Analog Characteristics

### 2.6.1 A/D converter characteristics

Classification of A/D converter characteristics

| Input channel | Reference Voltage | | |
|---|---|---|---|
| | Reference voltage (+) = $AV_{REFP}$<br>Reference voltage (–) = $AV_{REFM}$ | Reference voltage (+) = $V_{DD}$<br>Reference voltage (–) = $V_{SS}$ | Reference voltage (+) = $V_{BGR}$<br>Reference voltage (–) = $AV_{REFM}$ |
| ANI0 to ANI2, ANI4 to ANI7 | See **2.6.1 (1)**. | See **2.6.1 (3)**. | See **2.6.1 (4)**. |
| ANI16 to ANI19 | See **2.6.1 (2)**. | | |
| Internal reference voltage<br>Temperature sensor output voltage | See **2.6.1 (1)**. | | – |

**(1) When reference voltage (+)= $AV_{REFP}$/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target pin: ANI2, ANI4 to ANI7, internal reference voltage, and temperature sensor output voltage**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $AV_{REFP}$ ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $AV_{REFP}$, Reference voltage (–) = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error[Note 1] | AINL | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | 1.2 | ±3.5 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: ANI2, ANI4 to ANI7 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.1875 | | 39 | μs |
| | | 10-bit resolution<br>Target pin: Internal reference voltage, and temperature sensor output voltage<br>(HS (high-speed main) mode) | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.375 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.5625 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.25 | %FSR |
| Full-scale error[Notes 1, 2] | $E_{FS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.25 | %FSR |
| Integral linearity error[Note 1] | ILE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±2.5 | LSB |
| Differential linearity error[Note 1] | DLE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±1.5 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI2, ANI4 to ANI7 | | 0 | | $AV_{REFP}$ | V |
| | | Internal reference voltage<br>(HS (high-speed main) mode) | | $V_{BGR}$[Note 4] | | | V |
| | | Temperature sensor output voltage<br>(HS (high-speed main) mode) | | $V_{TMPS25}$[Note 4] | | | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** When $AV_{REFP}$ < $V_{DD}$, the MAX. values are as follows.

Overall error: Add ±1.0 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Integral linearity error/Differential linearity error: Add ±0.5 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

**4.** See **2.6.2 Temperature sensor/internal reference voltage characteristics**.

**(2) When reference voltage (+) = $AV_{REFP}$/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target pin: ANI16 to ANI19**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $AV_{REFP}$ ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $AV_{REFP}$, Reference voltage (–) = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error[Note 1] | AINL | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Notes 3] | | | 1.2 | ±5.0 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target ANI pin : ANI16 to ANI19 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.1875 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Notes 3] | | | | ±0.35 | %FSR |
| Full-scale error[Notes 1, 2] | $E_{FS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Notes 3] | | | | ±0.35 | %FSR |
| Integral linearity error[Note 1] | ILE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Notes 3] | | | | ±3.5 | LSB |
| Differential linearity error[Note 1] | DLE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Notes 3] | | | | ±2.0 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI16 to ANI19 | | 0 | | $AV_{REFP}$ and $V_{DD}$ | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** When $AV_{REFP}$ < $V_{DD}$, the MAX. values are as follows.

Overall error: Add ±1.0 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Integral linearity error/Differential linearity error: Add ±0.5 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

**(3) When reference voltage (+) = $V_{DD}$ (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = $V_{SS}$ (ADREFM = 0), target pin: ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19, internal reference voltage, and temperature sensor output voltage**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $V_{DD}$, Reference voltage (–) = $V_{SS}$)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error[Note 1] | AINL | 10-bit resolution | | | 1.2 | ±7.0 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.1875 | | 39 | μs |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: Internal reference voltage, and temperature sensor output voltage (HS (high-speed main) mode) | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.375 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.5625 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 10-bit resolution | | | | ±0.60 | %FSR |
| Full-scale error[Notes 1, 2] | $E_{FS}$ | 10-bit resolution | | | | ±0.60 | %FSR |
| Integral linearity error[Note 1] | ILE | 10-bit resolution | | | | ±4.0 | LSB |
| Differential linearity error[Note 1] | DLE | 10-bit resolution | | | | ±2.0 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI0 to ANI2, ANI4 to ANI7 | | 0 | | $V_{DD}$ | V |
| | | ANI16 to ANI19 | | 0 | | $V_{DD}$ | V |
| | | Internal reference voltage (HS (high-speed main) mode) | | $V_{BGR}$[Note 3] | | | V |
| | | Temperature sensor output voltage (HS (high-speed main) mode) | | $V_{TMPS25}$[Note 3] | | | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** See **2.6.2 Temperature sensor/internal reference voltage characteristics**.

**(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target pin: ANI0, ANI2, ANI4 to ANI7, ANI16 to ANI19**

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $V_{BGR}$[Note 3], Reference voltage (–) = $AV_{REFM}$ = 0 V[Note 4], HS (high-speed main) mode)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Resolution | RES | | 8 | | | bit |
| Conversion time | $t_{CONV}$ | 8-bit resolution | 17 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 8-bit resolution | | | ±0.60 | %FSR |
| Integral linearity error[Note 1] | ILE | 8-bit resolution | | | ±2.0 | LSB |
| Differential linearity error[Note 1] | DLE | 8-bit resolution | | | ±1.0 | LSB |
| Analog input voltage | $V_{AIN}$ | | 0 | | $V_{BGR}$[Note 3] | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** See **2.6.2 Temperature sensor/internal reference voltage characteristics**.

**4.** When reference voltage (–) = $V_{SS}$, the MAX. values are as follows.

Zero-scale error: Add ±0.35%FSR to the MAX. value when reference voltage (–) = $AV_{REFM}$.

Integral linearity error: Add ±0.5 LSB to the MAX. value when reference voltage (–) = $AV_{REFM}$.

Differential linearity error: Add ±0.2 LSB to the MAX. value when reference voltage (–) = $AV_{REFM}$.

## 2.6.2 Temperature sensor/internal reference voltage characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, HS (high-speed main) mode)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Temperature sensor output voltage | $V_{TMPS25}$ | Setting ADS register = 80H, $T_A$ = +25°C | | 1.05 | | V |
| Internal reference voltage | $V_{BGRT}$ | Setting ADS register = 81H | 1.38 | 1.45 | 1.5 | V |
| Temperature coefficient | $F_{VTMPS}$ | Temperature sensor that depends on the temperature | | –3.6 | | mV/C |
| Operation stabilization wait time | $t_{AMP}$ | | 5 | | | μs |

## 2.6.3 Programmable gain amplifier

**($T_A$ = –40 to +105°C, 2.7 V ≤ $AV_{REFP}$ = $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IOPGA}$ | | | | | ±5 | ±10 | mV |
| Input voltage range | $V_{IPGA}$ | | | | 0 | | 0.9$V_{DD}$/gain | V |
| Gain error[Note 1] | | 4, 8 times | | | | | ±1 | % |
| | | 16 times | | | | | ±1.5 | % |
| | | 32 times | | | | | ±2 | % |
| Slew rate[Note 1] | $SR_{RPGA}$ | Rising edge | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 4, 8 times | 4 | | | V/μs |
| | | | | 16, 32 times | 1.4 | | | V/μs |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | 4, 8 times | 1.8 | | | V/μs |
| | | | | 16, 32 times | 0.5 | | | V/μs |
| | $SR_{FPGA}$ | Falling edge | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 4, 8 times | 3.2 | | | V/μs |
| | | | | 16, 32 times | 1.4 | | | V/μs |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | 4, 8 times | 1.2 | | | V/μs |
| | | | | 16, 32 times | 0.5 | | | V/μs |
| Operation stabilization wait time[Note 2] | $t_{PGA}$ | 4, 8 times | | | 5 | | | μs |
| | | 16, 32 times | | | 10 | | | μs |

**Notes 1.** When $V_{IPGA}$ = 0.1$V_{DD}$/gain to 0.9$V_{DD}$/gain.

**2.** Time required until a state is entered where the DC and AC specifications of the PGA are satisfied after the PGA operation has been enabled (PGAEN = 1).

**Remark** These characteristics apply when $AV_{REFM}$ is selected as GND of the PGA by using the CVRVS1 bit.

## 2.6.4 Comparator

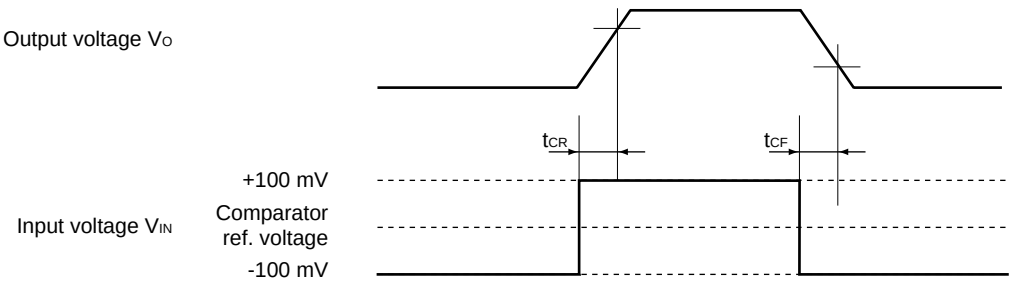
**($T_A$ = –40 to +105°C, 2.7 V ≤ $AV_{REFP}$ = $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IOCMP}$ | | | ±5 | ±40 | mV |
| Input voltage range | $V_{ICMP}$ | CMP0P to CMP5P | 0 | | $V_{DD}$ | V |
| | | CMPCOM | 0.045 | | 0.9$V_{DD}$ | V |
| Internal reference voltage deviation | $\Delta V_{IREF}$ | CmRVM register values: 7FH to 80H (m = 0 to 2) | | | ±2 | LSB |
| | | Other than above | | | ±1 | LSB |
| Response time | $t_{CR}$, $t_{CF}$ | Input amplitude = ±100 mV | | 70 | 150 | ns |
| Operation stabilization wait time[Note 1] | $t_{CMP}$ | 3.3 V ≤ $V_{DD}$ ≤ 5.5 V | 1 | | | μs |
| | | 2.7 V ≤ $V_{DD}$ < 3.3 V | 3 | | | μs |
| Reference voltage stabilization wait time | $t_{VR}$ | CVRE: 0 to 1[Note 2] | 10 | | | μs |

**Notes 1.** Time required until a state is entered where the DC and AC specifications of the comparator are satisfied after the operation of the comparator has been enabled (CMPnEN bit = 1: n = 0 to 5)

**2.** Enable comparator output (CnOE bit = 1; n = 0 to 5) after enabling operation of the internal reference voltage generator (by setting the CVREm bit to 1; m = 0 to 2) and waiting for the operation stabilization time to elapse.

**Remark** These characteristics apply when $AV_{REFP}$ is selected as the power supply source of the internal reference voltage by using the CVRVS0 bit, and when $AV_{REFM}$ is selected as GND of the internal reference voltage by using the CVRVS1 bit.

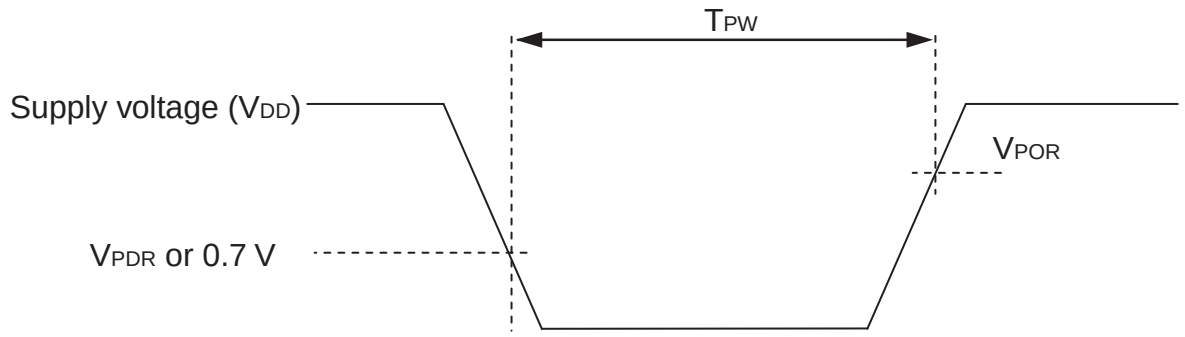


## 2.6.5 POR circuit characteristics

**($T_A$ = –40 to +105°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Detection voltage | $V_{POR}$ | Power supply rise time | 1.45 | 1.51 | 1.57 | V |
| | $V_{PDR}$ | Power supply fall time | 1.44 | 1.50 | 1.56 | V |
| Minimum pulse width[Note] | $T_{PW}$ | | 300 | | | μs |

**Note** Minimum time required for a POR reset when $V_{DD}$ exceeds below $V_{PDR}$. This is also the minimum time required for a POR reset from when $V_{DD}$ exceeds below 0.7 V to when $V_{DD}$ exceeds $V_{POR}$ while STOP mode is entered or the main system clock is stopped through setting bit 0 (HIOSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).



## 2.6.6 LVD circuit characteristics

**LVD Detection Voltage of Reset Mode and Interrupt Mode**

**($T_A$ = –40 to +105°C, $V_{PDR} \le V_{DD} \le 5.5$ V, $V_{SS}$ = 0 V)**

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Detection voltage | Supply voltage level | $V_{LVD0}$ | Power supply rise time | 3.97 | 4.06 | 4.14 | V |
| | | | Power supply fall time | 3.89 | 3.98 | 4.06 | V |
| | | $V_{LVD1}$ | Power supply rise time | 3.67 | 3.75 | 3.82 | V |
| | | | Power supply fall time | 3.59 | 3.67 | 3.74 | V |
| | | $V_{LVD2}$ | Power supply rise time | 3.06 | 3.13 | 3.19 | V |
| | | | Power supply fall time | 2.99 | 3.06 | 3.12 | V |
| | | $V_{LVD3}$ | Power supply rise time | 2.95 | 3.02 | 3.08 | V |
| | | | Power supply fall time | 2.89 | 2.96 | 3.02 | V |
| | | $V_{LVD4}$ | Power supply rise time | 2.85 | 2.92 | 2.97 | V |
| | | | Power supply fall time | 2.79 | 2.86 | 2.91 | V |
| | | $V_{LVD5}$ | Power supply rise time | 2.75 | 2.81 | 2.87 | V |
| | | | Power supply fall time | 2.70 | 2.75 | 2.81 | V |
| Minimum pulse width | | $t_{LW}$ | | 300 | | | μs |
| Detection delay time | | | | | | 300 | μs |

**LVD Detection Voltage of Interrupt & Reset Mode**

**($T_A$ = –40 to +105°C, $V_{PDR} \le V_{DD} \le 5.5$ V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Interrupt and reset mode | $V_{LVD0}$ | $V_{POC2}$, $V_{POC1}$, $V_{POC0}$ = 0, 1, 1, falling reset voltage: 2.7 V | | 2.70 | 2.75 | 2.81 | V |
| | $V_{LVD1}$ | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 2.85 | 2.92 | 2.97 | V |
| | | | Falling interrupt voltage | 2.79 | 2.86 | 2.91 | V |
| | $V_{LVD2}$ | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.95 | 3.02 | 3.08 | V |
| | | | Falling interrupt voltage | 2.89 | 2.96 | 3.02 | V |
| | $V_{LVD3}$ | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.97 | 4.06 | 4.14 | V |
| | | | Falling interrupt voltage | 3.89 | 3.98 | 4.06 | V |

## 2.6.7 Supply voltage rise inclination characteristics

**($T_A$ = –40 to +105°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Supply voltage rise | $SV_{DD}$ | | | | 54 | V/ms |

**Caution Keep the internal reset status by using the LVD circuit or an external reset signal until $V_{DD}$ rises to within the operating voltage range shown in 32.4 AC Characteristics.**

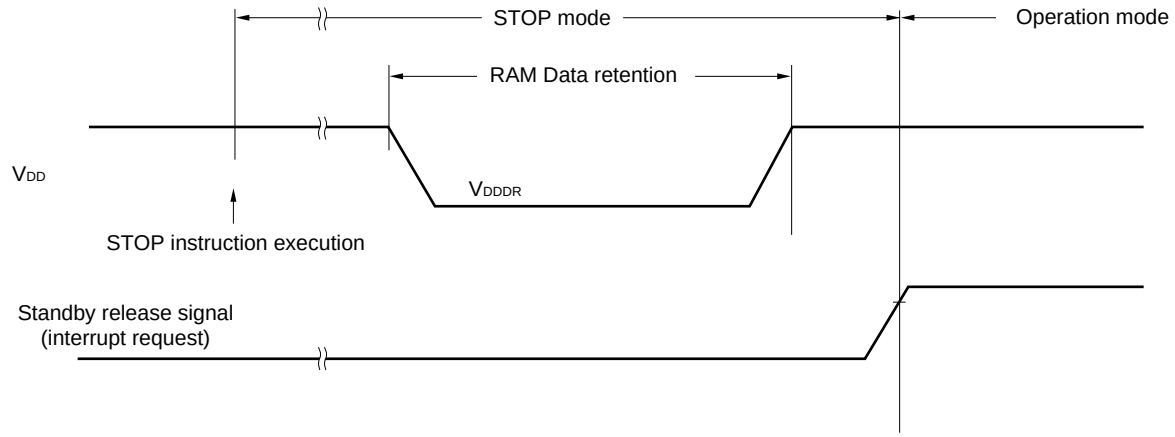
## 2.7 RAM Data Retention Characteristics

**($T_A$ = –40 to +105°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Data retention supply voltage[Note 2] | $V_{DDDR}$ | | 1.44[Note 1] | | 5.5 | V |

**Note** The value depends on the POR detection voltage. When the voltage drops, the RAM data is retained before a POR reset is effected, but RAM data is not retained when a POR reset is effected.

**Caution When CPU is operated at the voltage of out of the operation voltage range, RAM data is not retained. Therefore, set STOP mode before the supplied voltage is below the operation voltage range.**



## 2.8 Flash Memory Programming Characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| CPU/peripheral hardware clock frequency | $f_{CLK}$ | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 1 | | 32 | MHz |
| Number of code flash rewrites Notes 1, 2, 3 | $C_{erwr}$ | Retained for 20 years, $T_A$ = 85°C Note 3 | 1,000 | | | Times |
| Number of data flash rewrites Notes 1, 2, 3 | | Retained for 1 year, $T_A$ = 25°C Note 3 | | 1,000,000 | | |
| | | Retained for 5 years, $T_A$ = 85°C Note 3 | 100,000 | | | |
| | | Retained for 20 years, $T_A$ = 85°C Note 3 | 10,000 | | | |

**Notes 1.** 1 erase + 1 write after the erase is regarded as 1 rewrite. The retaining years are until next rewrite after the rewrite.

**2.** When using flash memory programmer and Renesas Electronics self programming library

**3.** These are the characteristics of the flash memory and the results obtained from reliability testing by Renesas Electronics Corporation.

## 2.9 Dedicated Flash Memory Programmer Communication (UART)

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

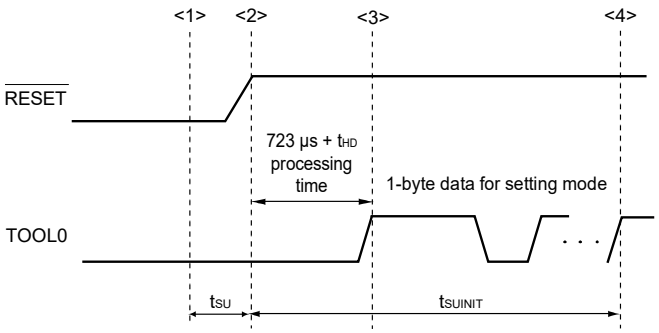
| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Transfer rate | | During serial programming | 115.2 k | | 1 M | bps |

## 2.10 Timing of Entry to Flash Memory Programming Modes

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| How long from when an external reset ends until the initial communication settings are specified | $t_{SUINIT}$ | POR and LVD reset must end before the external reset ends. | | | 100 | ms |
| How long from when the TOOL0 pin is placed at the low level until an external reset ends | $t_{SU}$ | POR and LVD reset must end before the external reset ends. | 10 | | | μs |
| How long the TOOL0 pin must be kept at the low level after a reset ends (except soft processing time) | $t_{HD}$ | POR and LVD reset must end before the external reset ends. | 1 | | | ms |

<R>




<1> The low level is input to the TOOL0 pin.
<2> The external reset ends (POR and LVD reset must end before the pin reset ends.).
<3> The TOOL0 pin is set to the high level.
<4> Complete the baud rate setting by UART reception.

**Remark** $t_{SUINIT}$: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

$t_{SU}$: How long from when the TOOL0 pin is placed at the low level until an external reset ends

$t_{HD}$: How long to keep the TOOL0 pin at the low level from when the external and internal resets end (except soft processing time)

# 3. ELECTRICAL SPECIFICATIONS (M: Industrial applications, $T_A$ = –40 to +125°C)

In this chapter, shows the electrical specifications of the target products.

Target products (M: Industrial applications): $T_A$ = – 40 to +125°C
R5F107xxMxx

**Cautions 1. The RL78/I1A has an on-chip debug function, which is provided for development and evaluation. Do not use the on-chip debug function in products designated for mass production, because the guaranteed number of rewritable times of the flash memory may be exceeded when this function is used, and product reliability therefore cannot be guaranteed. Renesas Electronics is not liable for problems occurring when the on-chip debug function is used.**

**2. The pins mounted depend on the product. See 2.1 Port Function to 2.2.1 Functions for each product in the RL78/I1A User's Manual.**

**3. When any of these products are used at 105°C or lower, see 2. ELECTRICAL SPECIFICATIONS ($T_A$ = –40 to +105°C).**

## 3.1 Absolute Maximum Ratings

**Absolute Maximum Ratings ($T_A$ = 25°C) (1/2)**

| Parameter | Symbols | Conditions | Ratings | Unit |
|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | –0.5 to +6.5 | V |
| REGC pin input voltage | $V_{IREGC}$ | REGC | –0.3 to +2.8 and –0.3 to $V_{DD}$ +0.3 Note 1 | V |
| Input voltage | $V_{I1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | –0.3 to $V_{DD}$ +0.3 Note 2 | V |
| Output voltage | $V_{O1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | –0.3 to $V_{DD}$ +0.3 Note 2 | V |
| Analog input voltage | $V_{AI1}$ | ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19 | –0.3 to $V_{DD}$ +0.3 and –0.3 to $AV_{REF(+)}$ +0.3 Notes 2, 3 | V |

**Notes 1.** Connect the REGC pin to Vss via a capacitor (0.47 to 1 $\mu$F). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.

**2.** Must be 6.5 V or lower.

**3.** Do not exceed $AV_{REF(+)}$ + 0.3 V in case of A/D conversion target pin.

**Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.**

**Remarks 1.** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**2.** $AV_{REF(+)}$: + side reference voltage of the A/D converter.

**3.** $V_{SS}$ : Reference voltage

**Absolute Maximum Ratings ($T_A$ = 25°C) (2/2)**

| Parameter | Symbols | Conditions | | Ratings | Unit |
|---|---|---|---|---|---|
| Output current, high | $I_{OH1}$ | Per pin | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | –40 | mA |
| | | Total of all pins –170 mA | P02, P03, P40, P120 | –70 | mA |
| | | | P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 | –100 | mA |
| | $I_{OH2}$ | Per pin | P20 to P22, P24 to P27 | –0.5 | mA |
| | | Total of all pins | | –2 | mA |
| Output current, low | $I_{OL1}$ | Per pin | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 40 | mA |
| | | Total of all pins 170 mA | P02, P03, P40, P120 | 70 | mA |
| | | | P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 | 100 | mA |
| | $I_{OL2}$ | Per pin | P20 to P22, P24 to P27 | 1 | mA |
| | | Total of all pins | | 5 | mA |
| Operating ambient temperature | $T_A$ | In normal operation mode | | –40 to +125 | °C |
| | | In flash memory programming mode | | –40 to +105 | |
| Storage temperature | $T_{stg}$ | | | –65 to +150 | °C |

**Caution Product quality may suffer if the absolute maximum rating is exceeded even momentarily for any parameter. That is, the absolute maximum ratings are rated values at which the product is on the verge of suffering physical damage, and therefore the product must be used under conditions that ensure that the absolute maximum ratings are not exceeded.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

## 3.2 Oscillator Characteristics

### 3.2.1 X1, XT1 oscillator characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Resonator | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| X1 clock frequency ($f_X$)Note | Ceramic resonator/ crystal resonator | | 1.0 | | 20.0 | MHz |
| XT1 clock frequency ($f_{XT}$)Note | Crystal resonator | | 32 | 32.768 | 35 | kHz |

**Note** Indicates only permissible oscillator frequency ranges. See **AC Characteristics** for instruction execution time. Request evaluation by the manufacturer of the oscillator circuit mounted on a board to check the oscillator characteristics.

**Caution** **Since the CPU is started by the high-speed on-chip oscillator clock after a reset release, check the X1 clock oscillation stabilization time using the oscillation stabilization time counter status register (OSTC) by the user. Determine the oscillation stabilization time of the OSTC register and the oscillation stabilization time select register (OSTS) after sufficiently evaluating the oscillation stabilization time with the resonator to be used.**

**Remark** When using the X1 oscillator and XT1 oscillator, see 5.4 System Clock Oscillator in the RL78/I1A User's Manual.

### 3.2.2 On-chip oscillator characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Oscillators | Parameters | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| High-speed on-chip oscillator clock frequency[Note 1] | $f_{IH}$ | | 1 | | 32 | MHz |
| High-speed on-chip oscillator clock frequency accuracy[Note 2] | | $T_A$ = –20 to 85°C | –1 | | +1 | % |
| | | $T_A$ = –40 to 105°C | –1.5 | | +1.5 | % |
| | | $T_A$ = –40 to 125°C<br>When 16 MHz selected | –2 | | +2 | % |
| Low-speed on-chip oscillator clock frequency | $f_{IL}$ | | | 15 | | kHz |
| Low-speed on-chip oscillator clock frequency accuracy | | | –15 | | +15 | % |

**Notes 1.** Frequency can be selected in a high-speed on-chip oscillator. Selected by bits 0 to 3 of option byte (000C2H/010C2H).

**2.** This indicates the oscillator characteristics only. See **AC Characteristics** for instruction execution time.

**Remark** When using the device at an ambient temperature that exceeds $T_A$ = 105°C, the selectable oscillation frequency is 16 MHz max.

### 3.2.3 PLL characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| PLL input clock frequency[Note] | $f_{PLLIN}$ | High-speed system clock is selected ($f_{MX}$ = 4 MHz) | 3.92 | 4.00 | 4.08 | MHz |
| | | High-speed on-chip oscillator clock is selected ($f_{IH}$ = 4 MHz) | 3.92 | 4.00 | 4.08 | MHz |
| PLL output clock frequency[Note] | $f_{PLL}$ | | $f_{PLLIN}$ × 16 | | | MHz |

**Note** This only indicates the oscillator characteristics. See **AC Characteristics** for instruction execution time.

**Remark** When using the device at an ambient temperature that exceeds $T_A$ = 105°C, only 16 MHz ($f_{PLL}$ × 1/4) can be selected as the CPU operating frequency.

## 3.3 DC Characteristics

### 3.3.1 Pin characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output current, high[Note 1] | $I_{OH1}$ | Per pin for P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –3.0[Note 2] | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –1.0 | mA |
| | | Total of P02, P03, P40, P120 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –9.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –3.0 | mA |
| | | Total of P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –21.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –6.0 | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | –21.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | –9.0 | mA |
| | $I_{OH2}$ | Per pin for P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | –0.1[Note 2] | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | –0.4 | mA |

**Notes 1.** Value of current at which the device operation is guaranteed even if the current flows from the $V_{DD}$ pin to an output pin.

**2.** However, do not exceed the total current value.

**3.** Specification under conditions where the duty factor ≤ 70%.
The output current value that has changed to the duty factor > 70% the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = ($I_{OH}$ × 0.7)/(n × 0.01)

<Example> Where n = 80% and $I_{OH}$ = –10.0 mA

Total output current of pins = (–10.0 × 0.7)/(80 × 0.01) ≅ –8.7 mA

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

**Caution P02, P10 to P12 do not output high level in N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output current, low[Note 1] | $I_{OL1}$ | Per pin for P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 8.5[Note 2] | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 1.5[Note 2] | mA |
| | | Total of P02, P03, P40, P120 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 20.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 5.0 | mA |
| | | Total of P05, P06, P10 to P12, P30, P31, P75 to P77, P147, P200 to P206 (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 20.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 10.0 | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 40.0 | mA |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 15.0 | mA |
| | $I_{OL2}$ | Per pin for P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | 0.4[Note 2] | mA |
| | | Total of all pins (When duty ≤ 70%[Note 3]) | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | | 1.6 | mA |

**Notes 1.** Value of current at which the device operation is guaranteed even if the current flows from an output pin to the $V_{SS}$ pin.

**2.** However, do not exceed the total current value.

**3.** Specification under conditions where the duty factor ≤ 70%.
The output current value that has changed to the duty factor > 70% the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

- Total output current of pins = ($I_{OL}$ × 0.7)/(n × 0.01)

<Example> Where n = 80% and $I_{OL}$ = –10.0 mA

Total output current of pins = (–10.0 × 0.7)/(80 × 0.01) ≅ –8.7 mA

However, the current that is allowed to flow into one pin does not vary depending on the duty factor. A current higher than the absolute maximum rating must not flow into one pin.

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Input voltage, high | $V_{IH1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | Normal input buffer | 0.8$V_{DD}$ | | $V_{DD}$ | V |
| | $V_{IH2}$ | P03, P10, P11 | TTL input buffer 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 2.1 | | $V_{DD}$ | V |
| | | | TTL input buffer 3.3 V ≤ $V_{DD}$ < 4.0 V | 2.0 | | $V_{DD}$ | V |
| | | | TTL input buffer 2.7 V ≤ $V_{DD}$ < 3.3 V | 1.5 | | $V_{DD}$ | V |
| Input voltage, low | $V_{IL1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120 to P124, P137, P147, P200 to P206, EXCLK, EXCLKS, $\overline{\text{RESET}}$ | Normal input buffer | 0 | | 0.2$V_{DD}$ | V |
| | $V_{IL2}$ | P03, P10, P11 | TTL input buffer 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 0 | | 0.8 | V |
| | | | TTL input buffer 3.3 V ≤ $V_{DD}$ < 4.0 V | 0 | | 0.5 | V |
| | | | TTL input buffer 2.7 V ≤ $V_{DD}$ < 3.3 V | 0 | | 0.32 | V |

**Caution The maximum value of $V_{IH}$ of pins P02, P10 to P12 is $V_{DD}$, even in the N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Output voltage, high | $V_{OH1}$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH1}$ = –3.0 mA | $V_{DD}$ – 0.7 | | | V |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH1}$ = –1.0 mA | $V_{DD}$ – 0.5 | | | V |
| | $V_{OH2}$ | P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OH2}$ = –100 μA | $V_{DD}$ – 0.5 | | | V |
| Output voltage, low | $V_{OL1}$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 8.5 mA | | | 0.7 | V |
| | | | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 4.0 mA | | | 0.4 | V |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL1}$ = 1.5 mA | | | 0.4 | V |
| | $V_{OL2}$ | P20 to P22, P24 to P27 | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $I_{OL2}$ = 400 μA | | | 0.4 | V |

**Caution P02, P10 to P12 do not output high level in N-ch open-drain mode.**

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Input leakage current, high | $I_{LIH1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P137, P147, P200 to P206, RESET | $V_I = V_{DD}$ | | | | 1 | μA |
| | $I_{LIH2}$ | P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS) | $V_I = V_{DD}$ | In input port or external clock input | | | 1 | μA |
| | | | | In resonator connection | | | 10 | μA |
| Input leakage current, low | $I_{LIL1}$ | P02, P03, P05, P06, P10 to P12, P20 to P22, P24 to P27, P30, P31, P40, P75 to P77, P120, P137, P147, P200 to P206, RESET | $V_I = V_{SS}$ | | | | –1 | μA |
| | $I_{LIL2}$ | P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS) | $V_I = V_{SS}$ | In input port or external clock input | | | –1 | μA |
| | | | | In resonator connection | | | –10 | μA |
| On-chip pull-up resistance | $R_U$ | P02, P03, P05, P06, P10 to P12, P30, P31, P40, P75 to P77, P120, P147, P200 to P206 | $V_I = V_{SS}$, In input port | | 10 | 20 | 100 | kΩ |

**Remark** Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

## 3.3.2 Supply current characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V) (1/2)**

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Supply current Note 1 | $I_{DD1}$ | Operating mode | HS (high-speed main) mode Note 5 | $f_{IH}$ = 16 MHz Note 3 | $V_{DD}$ = 5.0 V | | 2.9 | 4.8 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 2.9 | 4.8 | mA |
| | | | HS (high-speed main) mode Note 5 | $f_{MX}$ = 20 MHz Note 2, $V_{DD}$ = 5.0 V | Square wave input | | 3.2 | 5.6 | mA |
| | | | | | Resonator connection | | 3.3 | 5.7 | mA |
| | | | | $f_{MX}$ = 20 MHz Note 2, $V_{DD}$ = 3.0 V | Square wave input | | 3.2 | 5.6 | mA |
| | | | | | Resonator connection | | 3.3 | 5.7 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 2, $V_{DD}$ = 5.0 V | Square wave input | | 2.0 | 3.3 | mA |
| | | | | | Resonator connection | | 2.0 | 3.3 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 2, $V_{DD}$ = 3.0 V | Square wave input | | 2.0 | 3.3 | mA |
| | | | | | Resonator connection | | 2.0 | 3.3 | mA |
| | | | HS (high-speed main) mode Note 5 | $f_{IH}$ = 4 MHz Note 3 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 16 MHz | $V_{DD}$ = 5.0 V | | 3.3 | 6.5 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 3.3 | 6.5 | mA |
| | | | Subsystem clock operation | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = –40°C | Square wave input | | 4.2 | 6.0 | μA |
| | | | | | Resonator connection | | 4.4 | 6.2 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +25°C | Square wave input | | 4.2 | 6.0 | μA |
| | | | | | Resonator connection | | 4.4 | 6.2 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +50°C | Square wave input | | 4.3 | 7.2 | μA |
| | | | | | Resonator connection | | 4.5 | 7.4 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +70°C | Square wave input | | 4.4 | 8.1 | μA |
| | | | | | Resonator connection | | 4.6 | 8.3 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +85°C | Square wave input | | 5.2 | 11.4 | μA |
| | | | | | Resonator connection | | 5.4 | 11.6 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +105°C | Square wave input | | 6.9 | 20.8 | μA |
| | | | | | Resonator connection | | 7.1 | 21.0 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 4 $T_A$ = +125°C | Square wave input | | 11.1 | 51.2 | μA |
| | | | | | Resonator connection | | 11.3 | 51.4 | μA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Total current flowing into $V_{DD}$, including the input leakage current flowing when the level of the input pin is fixed to $V_{DD}$ or $V_{SS}$. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, comparator, programmable gain amplifier, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

**2.** When high-speed on-chip oscillator and subsystem clock are stopped.

**3.** When high-speed system clock and subsystem clock are stopped.

**4.** When high-speed on-chip oscillator and high-speed system clock are stopped. When AMPHS1 = 1 (Ultra-low power consumption oscillation). However, not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.

**5.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 20 MHz

**Remarks 1.** $f_{MX}$: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

**2.** $f_{IH}$: High-speed on-chip oscillator clock frequency

**3.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**4.** Except subsystem clock operation, temperature condition of the TYP. value is $T_A$ = 25°C

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V) (2/2)**

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Supply current Note 1 | $I_{DD2}$ Note 2 | HALT mode | HS (high-speed main) mode Note 7 | $f_{IH}$ = 16 MHz Note 4 | $V_{DD}$ = 5.0 V | | 0.50 | 2.0 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.50 | 2.0 | mA |
| | | | HS (high-speed main) mode Note 7 | $f_{MX}$ = 20 MHz Note 3, $V_{DD}$ = 5.0 V | Square wave input | | 0.40 | 2.2 | mA |
| | | | | | Resonator connection | | 0.50 | 2.3 | mA |
| | | | | $f_{MX}$ = 20 MHz Note 3, $V_{DD}$ = 3.0 V | Square wave input | | 0.40 | 2.2 | mA |
| | | | | | Resonator connection | | 0.50 | 2.3 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 3, $V_{DD}$ = 5.0 V | Square wave input | | 0.24 | 1.22 | mA |
| | | | | | Resonator connection | | 0.30 | 1.28 | mA |
| | | | | $f_{MX}$ = 10 MHz Note 3, $V_{DD}$ = 3.0 V | Square wave input | | 0.24 | 1.22 | mA |
| | | | | | Resonator connection | | 0.30 | 1.28 | mA |
| | | | HS (high-speed main) mode Note 7 | $f_{IH}$ = 4 MHz Note 4 $f_{PLL}$ = 64 MHz, $f_{CLK}$ = 16 MHz | $V_{DD}$ = 5.0 V | | 0.95 | 3.7 | mA |
| | | | | | $V_{DD}$ = 3.0 V | | 0.95 | 3.7 | mA |
| | | | Subsystem clock operation | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = –40°C | Square wave input | | 0.28 | 0.70 | μA |
| | | | | | Resonator connection | | 0.47 | 0.89 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +25°C | Square wave input | | 0.33 | 0.70 | μA |
| | | | | | Resonator connection | | 0.52 | 0.89 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +50°C | Square wave input | | 0.41 | 1.90 | μA |
| | | | | | Resonator connection | | 0.60 | 2.09 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +70°C | Square wave input | | 0.54 | 2.80 | μA |
| | | | | | Resonator connection | | 0.73 | 2.99 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +85°C | Square wave input | | 1.27 | 6.10 | μA |
| | | | | | Resonator connection | | 1.46 | 6.29 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +105°C | Square wave input | | 3.04 | 15.5 | μA |
| | | | | | Resonator connection | | 3.23 | 15.7 | μA |
| | | | | $f_{SUB}$ = 32.768 kHz Note 5 $T_A$ = +125°C | Square wave input | | 7.20 | 45.2 | μA |
| | | | | | Resonator connection | | 7.53 | 45.5 | μA |
| | $I_{DD3}$ Note 6 | STOP mode Note 8 | $T_A$ = –40°C | | | | 0.18 | 0.50 | μA |
| | | | $T_A$ = +25°C | | | | 0.23 | 0.50 | μA |
| | | | $T_A$ = +50°C | | | | 0.27 | 1.70 | μA |
| | | | $T_A$ = +70°C | | | | 0.44 | 2.60 | μA |
| | | | $T_A$ = +85°C | | | | 1.17 | 5.90 | μA |
| | | | $T_A$ = +105°C | | | | 2.94 | 15.3 | μA |
| | | | $T_A$ = +125°C | | | | 7.14 | 45.1 | μA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Total current flowing into $V_{DD}$, including the input leakage current flowing when the level of the input pin is fixed to $V_{DD}$ or $V_{SS}$. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, comparator, programmable gain amplifier, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

**2.** During HALT instruction execution by flash memory.

**3.** When high-speed on-chip oscillator and subsystem clock are stopped.

**4.** When high-speed system clock and subsystem clock are stopped.

**5.** When high-speed on-chip oscillator and high-speed system clock are stopped. When RTCLPC = 1 and setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the RTC is included. However, not including the current flowing into the 12-bit interval timer and watchdog timer.

**6.** Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.

**7.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

HS (high-speed main) mode: 2.7 V ≤ $V_{DD}$ ≤ 5.5 V@1 MHz to 20 MHz

**8.** Regarding the value for current operate the subsystem clock in STOP mode, refer to that in HALT mode.

**Remarks 1.** $f_{MX}$: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

**2.** $f_{IH}$: High-speed on-chip oscillator clock frequency

**3.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**4.** Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is $T_A$ = 25°C

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Low-speed on-chip oscillator operating current | $I_{FIL}$ Note 1 | | | | 0.20 | | μA |
| RTC operating current | $I_{RTC}$ Notes 1, 2, 3 | | | | 0.02 | | μA |
| 12-bit interval timer operating current | $I_{IT}$ Notes 1, 2, 4 | | | | 0.02 | | μA |
| Watchdog timer operating current | $I_{WDT}$ Notes 1, 2, 5 | $f_{IL}$ = 15 kHz | | | 0.22 | | μA |
| A/D converter operating current | $I_{ADC}$ Notes 1, 6 | When conversion at maximum speed | Normal mode, $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 1.3 | 1.7 | mA |
| A/D converter reference voltage current | $I_{ADREF}$ Note 1 | | | | 75.0 | | μA |
| Temperature sensor operating current | $I_{TMPS}$ Note 1 | | | | 75.0 | | μA |
| LVD operating current | $I_{LVD}$ Notes 1, 7 | | | | 0.08 | | μA |
| Self-programming operating current | $I_{FSP}$ Notes 1, 8 | | | | 2.5 | 12.2 | mA |
| Programmable gain amplifier operating current | $I_{PGA}$ Note 9 | | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 0.21 | 0.37 | mA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 0.18 | 0.35 | mA |
| Comparator operating current | $I_{CMP}$ Note 10 | When one comparator channel is operating | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 41.4 | 74 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 37.2 | 71 | μA |
| | $I_{VREF}$ | When one internal reference voltage circuit is operating | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 14.8 | 31 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 8.9 | 24 | μA |
| Programmable gain amplifier/ comparator reference current source | $I_{IREF}$ Note 11 | | $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 3.2 | 6.1 | μA |
| | | | $AV_{REFP}$ = $V_{DD}$ = 3.0 V | | 2.9 | 4.9 | μA |
| BGO operating current | $I_{BGO}$ Note 12 | | | | 2.50 | 12.2 | mA |
| SNOOZE operating current | $I_{SNOZ}$ Note 1 | A/D converter operation | The mode is performed Note 13 | | 0.50 | 1.10 | mA |
| | | | The A/D conversion operations are performed, Normal mode, $AV_{REFP}$ = $V_{DD}$ = 5.0 V | | 1.20 | 2.17 | mA |
| | | CSI/UART operation | | | 0.70 | 1.27 | mA |

(**Notes** and **Remarks** are listed on the next page.)

**Notes 1.** Current flowing to the $V_{DD}$.

**2.** When the high-speed on-chip oscillator and high-speed system clock are stopped.

**3.** Current flowing only to the real-time clock (RTC) (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either $I_{DD1}$ or $I_{DD2}$, and $I_{RTC}$, when the real-time clock is operating in operating mode or in HALT mode. When the low-speed on-chip oscillator is selected, $I_{FIL}$ should be added. $I_{DD2}$ subsystem clock operation includes the operational current of the real-time clock.

**4.** Current flowing only to the 12-bit interval timer (excluding the operating current of the XT1 oscillator and $f_{IL}$ operating current). The current of the RL78 microcontrollers is the sum of the values of either $I_{DD1}$ or $I_{DD2}$, and $I_{IT}$, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, $I_{FIL}$ should be added.

**5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$, and $I_{WDT}$, when the watchdog timer is operating.

**6.** Current flowing only to the A/D converter. The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$ or $I_{DD2}$ and $I_{ADC}$, when the A/D converter is operating in operating mode or in HALT mode.

**7.** Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$ and $I_{LVD}$ when the LVD circuit is in operation.

**8.** Current flowing during self-programming operation.

**9.** Current flowing only to the programmable gain amplifier. The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$, and $I_{PGA}$, when the programmable gain amplifier is operating in operating mode or in HALT mode.

**10.** Current flowing only to the comparator. The supply current value of the RL78 microcontrollers is the sum of $I_{DD1}$, $I_{DD2}$ or $I_{DD3}$, and $I_{CMP}$, when the comparator is operating.

**11.** This is the current required to flow to $V_{DD}$ pin of the current circuit that is used as the programmable gain amplifier and the comparator.

**12.** Current flowing only during data flash rewrite.

**13.** See **21.3.3 SNOOZE mode in the RL78/I1A User's Manual** for shift time to the SNOOZE mode.

**Remarks 1.** $f_{IL}$: Low-speed on-chip oscillator clock frequency

**2.** $f_{SUB}$: Subsystem clock frequency (XT1 clock oscillation frequency)

**3.** $f_{CLK}$: CPU/peripheral hardware clock frequency

**4.** Temperature condition of the TYP. value is $T_A$ = 25°C

**5.** Example of calculating current value when using programmable gain amplifier and comparator.

Examples 1) TYP. operating current value when three comparator channels, one internal reference voltage generator, and PGA are operating (when $AV_{REFP}$ = $V_{DD}$ = 5.0 V)

$I_{CMP} \times 3 + I_{VREF} + I_{PGA} + I_{IREF}$

= 41.4 [$\mu$A] × 3 + 14.8 [$\mu$A] × 1 + 210 [$\mu$A] + 3.2 [$\mu$A]

= 352.2 [$\mu$ A]

Examples 2) TYP. operating current value when using two comparator channels, without using internal reference voltage generator (when $AV_{REFP}$ = $V_{DD}$ = 5.0 V)

$I_{CMP} \times 2 + I_{IREF}$

= 41.4 [$\mu$A] × 2 + 3.2 [$\mu$A]

= 86.0 [$\mu$A]

## 3.4 AC Characteristics

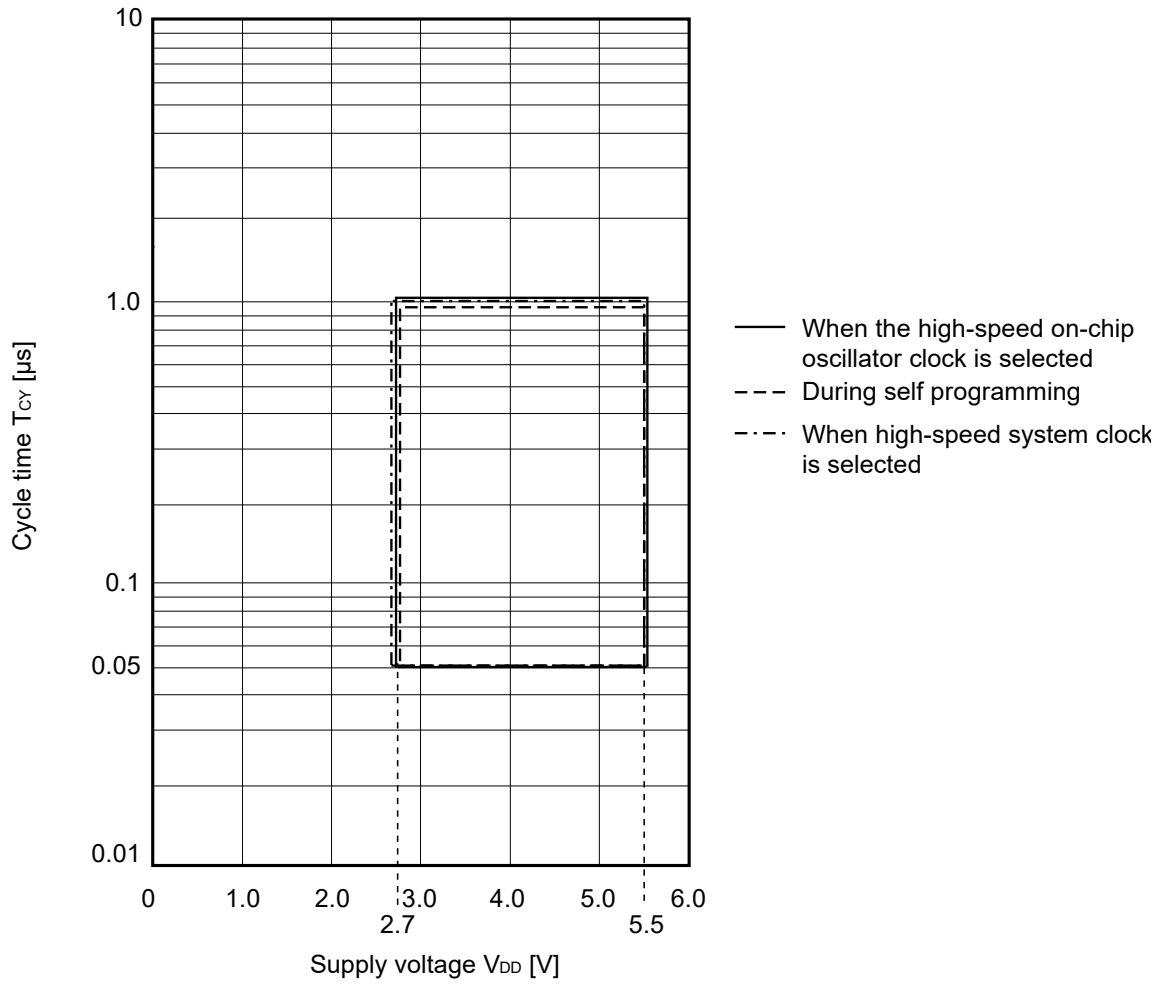
**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Items | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Instruction cycle (minimum instruction execution time) | $T_{CY}$ | Main system clock ($f_{MAIN}$) operation | HS (high-speed main) mode | | 0.05 | | 1 | μs |
| | | Subsystem clock ($f_{SUB}$) operation | | | 28.5 | 30.5 | 31.3 | μs |
| | | In the self programming mode | HS (high-speed main) mode | $T_A$ = –40 to +105°C | 0.05 | | 1 | μs |
| External system clock frequency | $f_{EX}$ | | | | 1.0 | | 20.0 | MHz |
| | $f_{EXS}$ | | | | 32 | | 35 | kHz |
| External system clock input high-level width, low-level width | $t_{EXH}$, $t_{EXL}$ | | | | 24 | | | ns |
| | $t_{EXHS}$, $t_{EXLS}$ | | | | 13.7 | | | μs |
| TI03, TI05, TI06, TI07 input high-level width, low-level width | $t_{TIH}$, $t_{TIL}$ | | | | 2/$f_{MCK}$+10 | | | ns |
| TO03, TO05, TO06, TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21, TKCO00 to TKCO05 output frequency (When duty = 50%) | $f_{TO}$ | HS (high-speed main) mode | | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | | 5 | MHz |
| | | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | | | 4 | MHz |
| Interrupt input high-level width, low-level width | $t_{INTH}$, $t_{INTL}$ | INTP0, INTP3, INTP4, INTP9 to INTP11, INTP20 to INTP23 | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 1 | | | μs |
| $\overline{RESET}$ low-level width | $t_{RSL}$ | | | | 10 | | | μs |

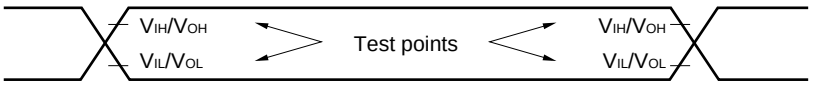
**Remark** $f_{MCK}$: Timer array unit operation clock frequency
(Operation clock to be set by the CKS0n bit of timer mode register 0n (TMR0n). n: Channel number (n = 0 to 7))

**Minimum Instruction Execution Time during Main System Clock Operation**

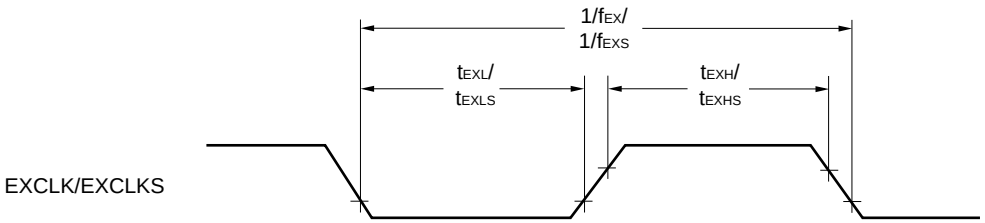
$T_{CY}$ vs $V_{DD}$ (HS (high-speed main) mode)




**AC Timing Test Points**

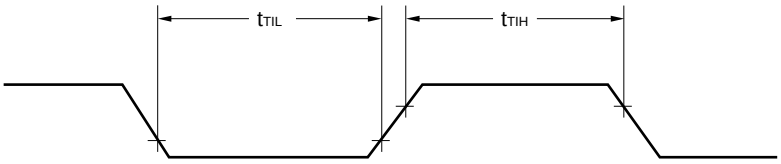



**External System Clock Timing**

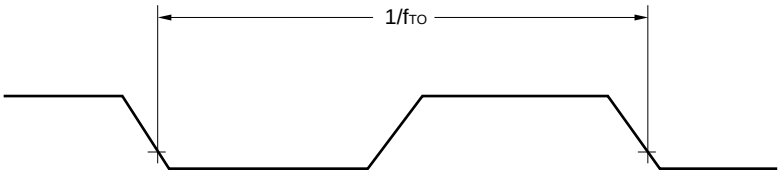


**TI/TO Timing**

TI03, TI05, TI06, TI07

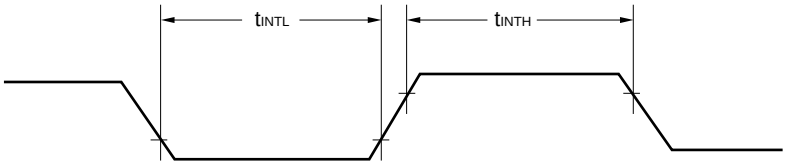



TO03, TO05, TO06, TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21, TKCO00 to TKCO05



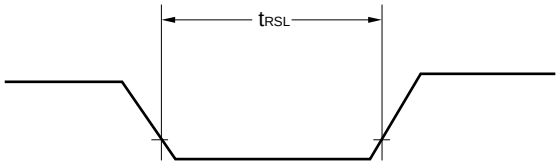

**Interrupt Request Input Timing**

INTP0, INTP3, INTP4, INTP9 to INTP11, INTP20 to INTP23



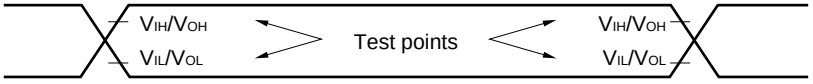

**$\overline{\text{RESET}}$ Input Timing**

$\overline{\text{RESET}}$



## 3.5 Peripheral Functions Characteristics

**AC Timing Test Points**




### 3.5.1 Serial array unit 0, 4 (UART0, UART1, CSI00, DALI/UART4)

**(1) During communication at same potential (UART mode)**

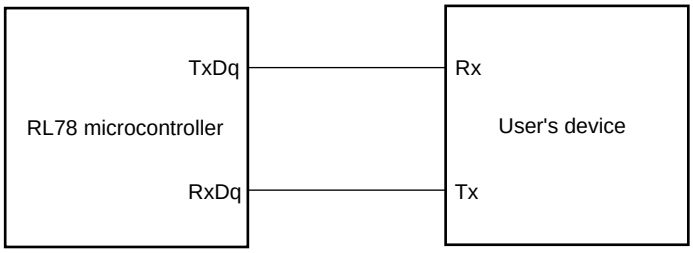
**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|
| | | | MIN. | MAX. | |
| Transfer rate[Note 1] | | | | $f_{MCK}$/6 | bps |
| | | Theoretical value of the maximum transfer rate<br>$f_{MCK}$ = $f_{CLK}$[Note 2] | | 3.3 | Mbps |

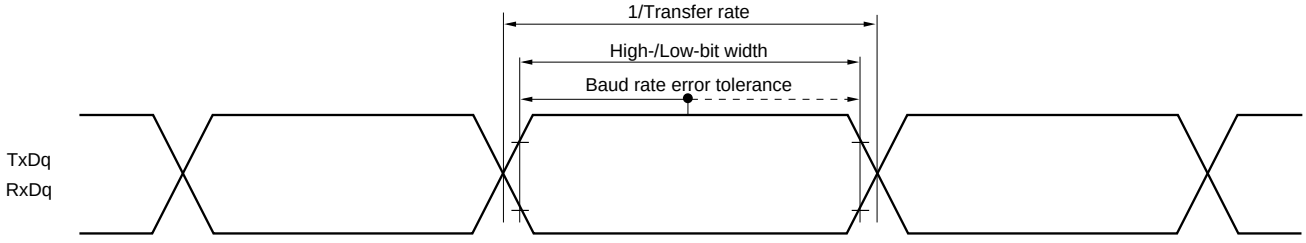
**Notes 1.** Transfer rate in the SNOOZE mode is 4800 bps only.

**2.** The operating frequencies of the CPU/peripheral hardware clock ($f_{CLK}$) are:
HS (high-speed main) mode: 20 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V)

**UART mode connection diagram (during communication at same potential)**




**UART mode bit width (during communication at same potential) (reference)**




**Caution Select the normal input buffer for the RxDq pin and the normal output mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03))

**(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output)**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | |
| SCKp cycle time | $t_{KCY1}$ | $t_{KCY1} \geq 4/f_{CLK}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 250 | | ns |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 500 | | ns |
| SCKp high-/low-level width | $t_{KH1}$, $t_{KL1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | $t_{KCY1}/2 - 20$ | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | $t_{KCY1}/2 - 40$ | | ns |
| SIp setup time (to SCKp↑)Note 1 | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | | 80 | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | | 80 | | ns |
| SIp hold time (from SCKp↑)Note 2 | $t_{KSI1}$ | | | 40 | | ns |
| Delay time from SCKp↓ to SOp outputNote 3 | $t_{KSO1}$ | C = 30 pFNote 4 | | | 80 | ns |

**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes "to SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp↑" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**4.** C is the load capacitance of the SCKp and SOp output lines.

**Caution Select the normal input buffer for the SIp pin and the normal output mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))

**(3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | |
| SCKp cycle time[Note 5] | $t_{KCY2}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | $f_{MCK}$ ≤ 20 MHz | 6/$f_{MCK}$ | | ns |
| | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 16 MHz < $f_{MCK}$ | 8/$f_{MCK}$ | | ns |
| | | | $f_{MCK}$ ≤ 16 MHz | 6/$f_{MCK}$ | | ns |
| SCKp high-/low-level width | $t_{KH2}$, $t_{KL2}$ | | | $t_{KCY2}$/2 | | ns |
| SIp setup time (to SCKp↑)[Note 1] | $t_{SIK2}$ | | | 1/$f_{MCK}$+40 | | ns |
| SIp hold time (from SCKp↑)[Note 2] | $t_{KSI2}$ | | | 1/$f_{MCK}$+60 | | ns |
| Delay time from SCKp↓ to SOp output[Note 3] | $t_{KSO2}$ | C = 30 pF[Note 4] | | | 2/$f_{MCK}$+80 | ns |

**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes "to SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp↑" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

**4.** C is the load capacitance of the SOp output lines.

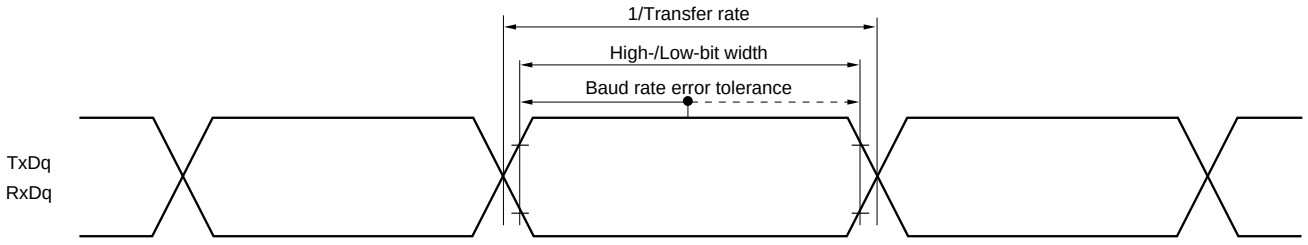
**5.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps

**Caution Select the normal input buffer for the SIp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

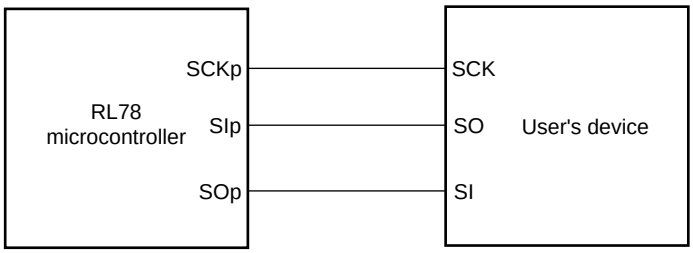
**Remarks 1.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**2.** $f_{MCK}$: Serial array unit operation clock frequency

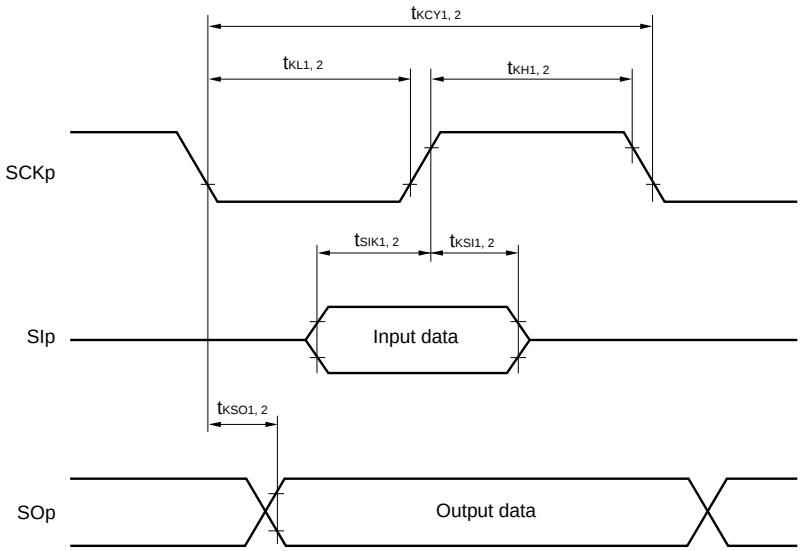
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))



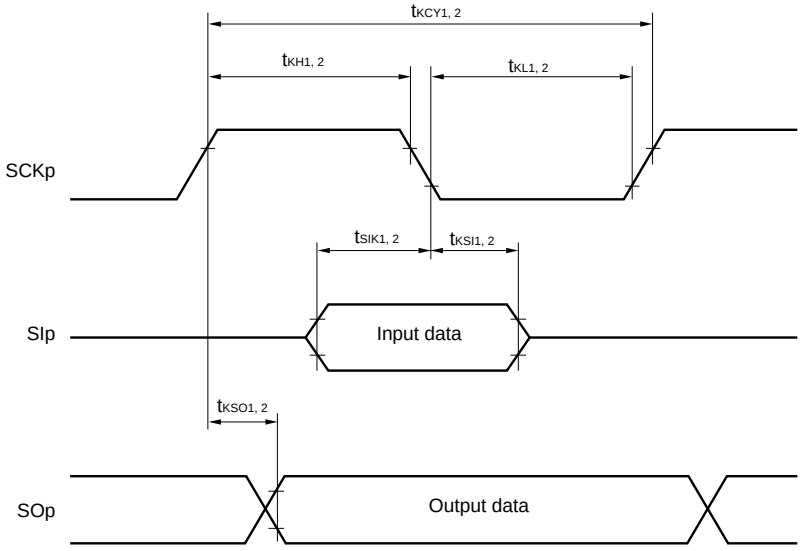
**CSI mode connection diagram (during communication at same potential)**




**CSI mode serial transfer timing (during communication at same potential)**
**(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)**




**CSI mode serial transfer timing (during communication at same potential)**
**(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)**




**Remarks 1.** p: CSI number (p = 00)

**2.** m: Unit number, n: Channel number (mn = 00)

**(4) Communication at different potential (2.5 V, 3 V) (UART mode) (1/2)**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | | MIN. | MAX. | |
| Transfer rate | | Reception | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V | | | $f_{MCK}$/6 Note 1 | bps |
| | | | | Theoretical value of the maximum transfer rate $f_{MCK}$ = $f_{CLK}$ Note 2 | | 3.3 | Mbps |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V | | | $f_{MCK}$/6 Note 1 | bps |
| | | | | Theoretical value of the maximum transfer rate $f_{MCK}$ = $f_{CLK}$ Note 2 | | 3.3 | Mbps |

**Notes 1.** Transfer rate in the SNOOZE mode is 4800 bps only.

**2.** The operating frequencies of the CPU/peripheral hardware clock ($f_{CLK}$) are:
HS (high-speed main) mode: 20 MHz (2.7 V ≤ $V_{DD}$ ≤ 5.5 V)

**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** $V_b$[V]: Communication line voltage

**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**3.** $f_{MCK}$: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03)

**(4) Communication at different potential (2.5 V, 3 V) (UART mode) (2/2)**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | | MIN. | MAX. | |
| Transfer rate | | Transmission | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V | | | **Note 1** | bps |
| | | | | Theoretical value of the maximum transfer rate $C_b$ = 50 pF, $R_b$ = 1.4 kΩ, $V_b$ = 2.7 V | | 2.8 Note 2 | Mbps |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V | | | **Note 3** | bps |
| | | | | Theoretical value of the maximum transfer rate $C_b$ = 50 pF, $R_b$ = 2.7 kΩ, $V_b$ = 2.3 V | | 1.2 Note 4 | Mbps |

**Notes 1.** The smaller maximum transfer rate derived by using $f_{MCK}$/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 4.0 V ≤ $V_{DD}$ ≤ 5.5 V and 2.7 V ≤ $V_b$ ≤ 4.0 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.2}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.2}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [\%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

**2.** This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 1** above to calculate the maximum transfer rate under conditions of the customer.

**3.** The smaller maximum transfer rate derived by using $f_{MCK}$/6 or the following expression is the valid maximum transfer rate.

Expression for calculating the transfer rate when 2.7 V ≤ $V_{DD}$ < 4.0 V and 2.3 V ≤ $V_b$ ≤ 2.7 V

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{2.0}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [\%]}$$

* This value is the theoretical value of the relative difference between the transmission and reception sides.

**4.** This value as an example is calculated when the conditions described in the “Conditions” column are met. See **Note 3** above to calculate the maximum transfer rate under conditions of the customer.

**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** $R_b$[Ω]: Communication line (TxDq) pull-up resistance,
$C_b$[F]: Communication line (TxDq) load capacitance, $V_b$[V]: Communication line voltage

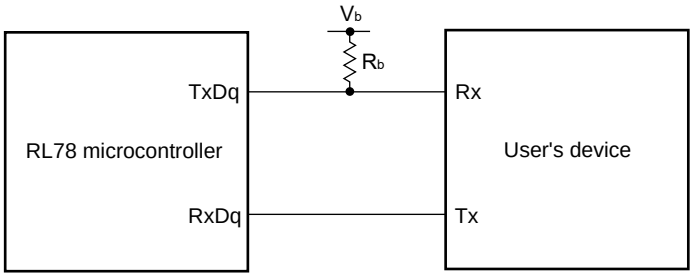
**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**3.** $f_{MCK}$: Serial array unit operation clock frequency

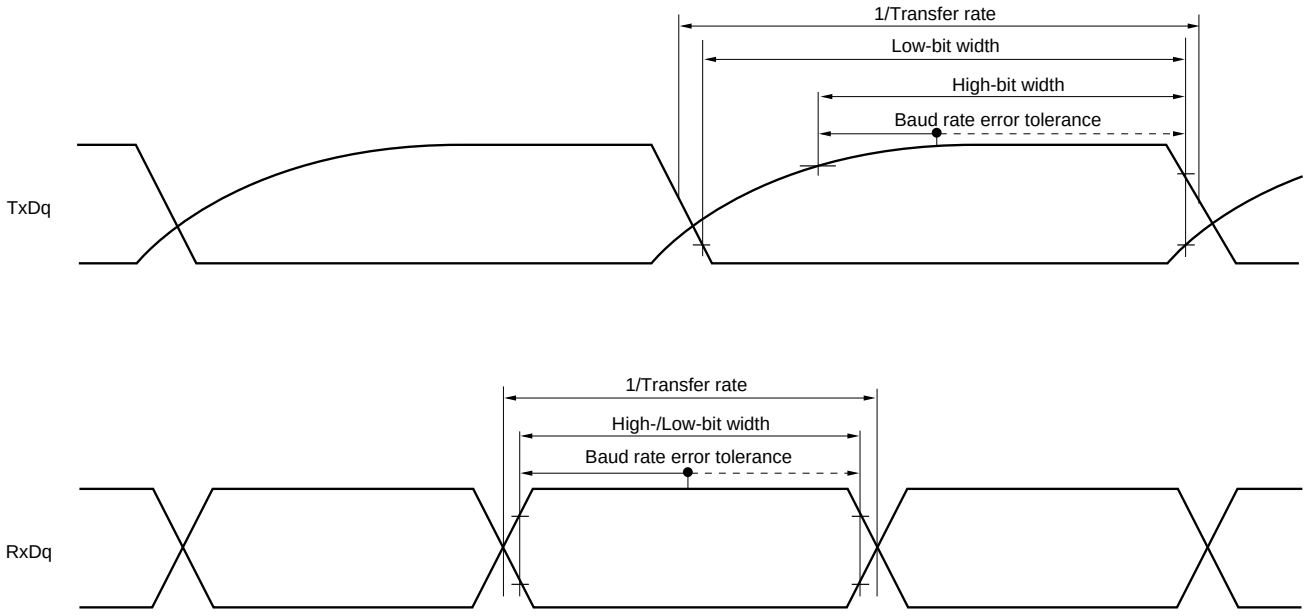
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).

m: Unit number, n: Channel number (mn = 00 to 03))

**UART mode connection diagram (during communication at different potential)**




**UART mode bit width (during communication at different potential) (reference)**




**Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remarks 1.** $R_b$[Ω]: Communication line (TxDq) pull-up resistance, $V_b$[V]: Communication line voltage

**2.** q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

**(5) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|---|
| | | | | MIN. | MAX. | |
| SCKp cycle time | $t_{KCY1}$ | $t_{KCY1} \geq 4/f_{CLK}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | 600 | | ns |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | 1000 | | ns |
| SCKp high-level width | $t_{KH1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 80 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 170 | | ns |
| SCKp low-level width | $t_{KL1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | $t_{KCY1}$/2 – 28 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | $t_{KCY1}$/2 – 40 | | ns |
| SIp setup time (to SCKp↑)[Note 1] | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 160 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 250 | | ns |
| SIp hold time (from SCKp↑)[Note 1] | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 40 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 40 | | ns |
| Delay time from SCKp↓ to SOp output[Note 1] | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | | 160 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | | 250 | ns |
| SIp setup time (to SCKp↓)[Note 2] | $t_{SIK1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 80 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 80 | | ns |
| SIp hold time (from SCKp↓)[Note 2] | $t_{KSI1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | 40 | | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | 40 | | ns |
| Delay time from SCKp↑ to SOp output[Note 2] | $t_{KSO1}$ | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V, 2.7 V ≤ $V_b$ ≤ 4.0 V, $C_b$ = 30 pF, $R_b$ = 1.4 kΩ | | | 80 | ns |
| | | 2.7 V ≤ $V_{DD}$ < 4.0 V, 2.3 V ≤ $V_b$ ≤ 2.7 V, $C_b$ = 30 pF, $R_b$ = 2.7 kΩ | | | 80 | ns |

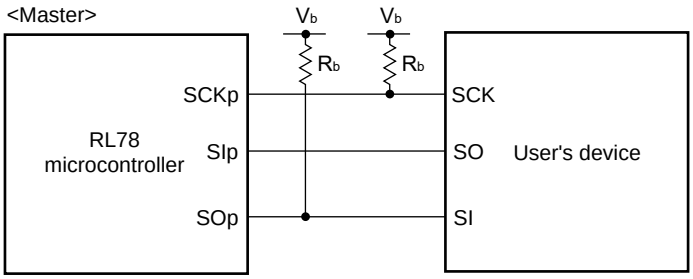
**Notes 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.

**2.** When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

(**Caution** and **Remarks** are listed on the next page.)

**Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For $V_{IH}$ and $V_{IL}$, see the DC characteristics with TTL input buffer selected.**

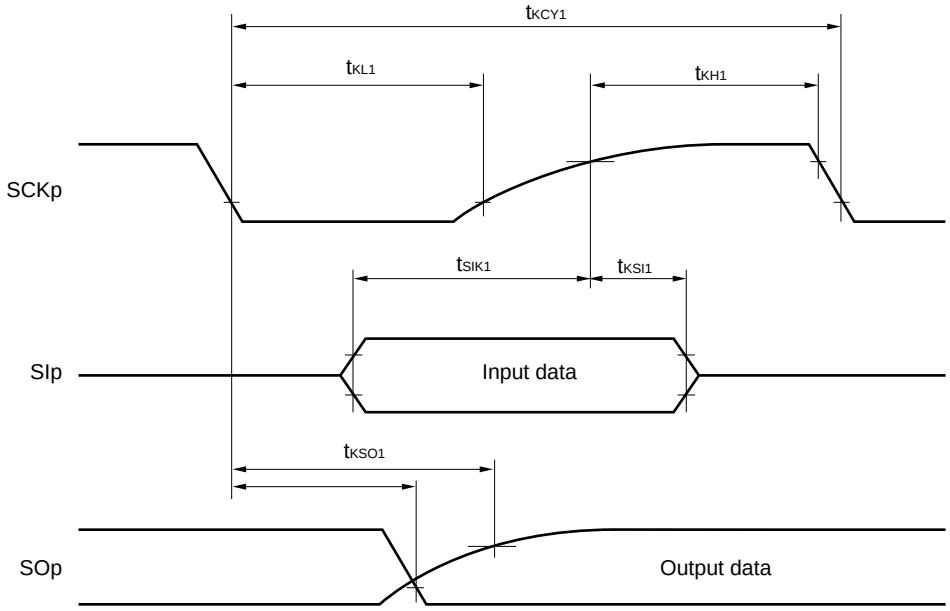
**CSI mode connection diagram (during communication at different potential)**



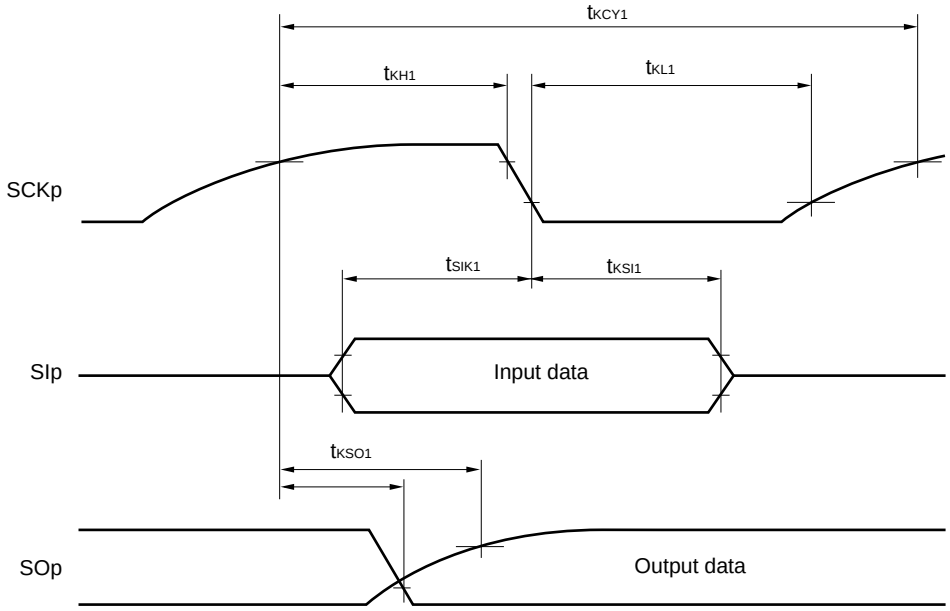

**Remarks 1.** $R_b$[Ω]: Communication line (SCKp, SOp) pull-up resistance, $C_b$[F]: Communication line (SCKp, SOp) load capacitance, $V_b$[V]: Communication line voltage

**2.** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**CSI mode serial transfer timing (master mode) (during communication at different potential)**
**(When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.)**




**CSI mode serial transfer timing (master mode) (during communication at different potential)**
**(When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.)**




**Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output ($V_{DD}$ tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg).**

**Remark** p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

**(6) DALI/UART4 mode**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|
| | | | MIN. | MAX. | |
| Transfer rate | | | | $f_{MCK}$/12 | bps |
| | | Maximum transfer rate theoretical value<br>$f_{CLK}$ = 20 MHz, $f_{MCK}$ = $f_{CLK}$ | | 1.6 | Mbps |

**Remark** $f_{MCK}$: Operation clock frequency of DALI/UART.

(Operation clock to be set by the serial clock select register 4 (SPS4).)

## 3.5.2 Serial interface IICA

### (1) $I^2C$ standard mode

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|
| | | | MIN. | MAX. | |
| SCLA0 clock frequency | $f_{SCL}$ | Standard mode: $f_{CLK}$ ≥ 1 MHz | 0 | 100 | kHz |
| Setup time of restart condition | $t_{SU:STA}$ | | 4.7 | | μs |
| Hold time[Note 1] | $t_{HD:STA}$ | | 4.0 | | μs |
| Hold time when SCLA0 = “L” | $t_{LOW}$ | | 4.7 | | μs |
| Hold time when SCLA0 = “H” | $t_{HIGH}$ | | 4.0 | | μs |
| Data setup time (reception) | $t_{SU:DAT}$ | | 250 | | ns |
| Data hold time (transmission)[Note 2] | $t_{HD:DAT}$ | | 0 | 3.45 | μs |
| Setup time of stop condition | $t_{SU:STO}$ | | 4.0 | | μs |
| Bus-free time | $t_{BUF}$ | | 4.7 | | μs |

**Notes 1.** The first clock pulse is generated after this period when the start/restart condition is detected.

**2.** The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**Remark** The maximum value of Cb (communication line capacitance) and the value of Rb (communication line pull-up resistor) at that time in each mode are as follows.

Standard mode: $C_b$ = 400 pF, $R_b$ = 2.7 kΩ

### (2) $I^2C$ fast mode

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | Unit |
|---|---|---|---|---|---|
| | | | MIN. | MAX. | |
| SCLA0 clock frequency | $f_{SCL}$ | fast mode: $f_{CLK}$ ≥ 3.5 MHz | 0 | 400 | kHz |
| Setup time of restart condition | $t_{SU:STA}$ | | 0.6 | | μs |
| Hold time[Note 1] | $t_{HD:STA}$ | | 0.6 | | μs |
| Hold time when SCLA0 = “L” | $t_{LOW}$ | | 1.3 | | μs |
| Hold time when SCLA0 = “H” | $t_{HIGH}$ | | 0.6 | | μs |
| Data setup time (reception) | $t_{SU:DAT}$ | | 100 | | ns |
| Data hold time (transmission)[Note 2] | $t_{HD:DAT}$ | | 0 | 0.9 | μs |
| Setup time of stop condition | $t_{SU:STO}$ | | 0.6 | | μs |
| Bus-free time | $t_{BUF}$ | | 1.3 | | μs |

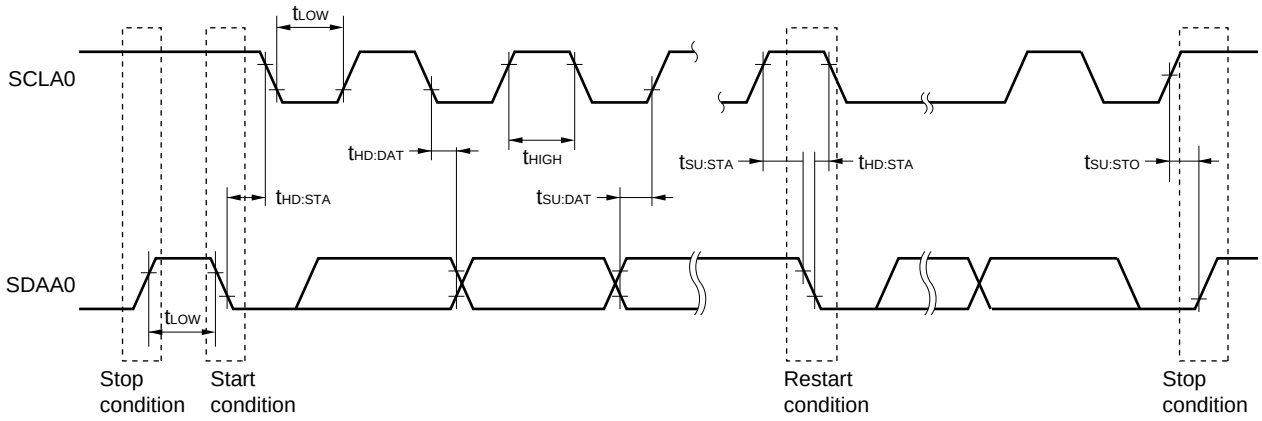
**Notes 1.** The first clock pulse is generated after this period when the start/restart condition is detected.

**2.** The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**Remark** The maximum value of Cb (communication line capacitance) and the value of Rb (communication line pull-up resistor) at that time in each mode are as follows.

fast mode: $C_b$ = 320 pF, $R_b$ = 1.1 kΩ

**IICA serial transfer timing**



## 3.6 Analog Characteristics

### 3.6.1 A/D converter characteristics

Classification of A/D converter characteristics

| Input channel | Reference Voltage | | |
|---|---|---|---|
| | Reference voltage (+) = $AV_{REFP}$<br>Reference voltage (–) = $AV_{REFM}$ | Reference voltage (+) = $V_{DD}$<br>Reference voltage (–) = $V_{SS}$ | Reference voltage (+) = $V_{BGR}$<br>Reference voltage (–) = $AV_{REFM}$ |
| ANI0 to ANI2, ANI4 to ANI7 | See **3.6.1 (1)**. | See **3.6.1 (3)**. | See **3.6.1 (4)**. |
| ANI16 to ANI19 | See **3.6.1 (2)**. | | |
| Internal reference voltage<br>Temperature sensor output voltage | See **3.6.1 (1)**. | | – |

**(1) When reference voltage (+) = $AV_{REFP}$/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target ANI pin: ANI2, ANI4 to ANI7, internal reference voltage, and temperature sensor output voltage**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $AV_{REFP}$ ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $AV_{REFP}$, Reference voltage (–) = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error[Note 1] | AINL | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | 1.2 | ±3.5 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: ANI2, ANI4 to ANI7 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.4 | | 39 | μs |
| | | 10-bit resolution<br>Target pin: Internal reference voltage, and temperature sensor output voltage<br>(HS (high-speed main) mode) | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.375 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.8 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.25 | %FSR |
| Full-scale error[Notes 1, 2] | $E_{FS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.25 | %FSR |
| Integral linearity error[Note 1] | ILE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±2.5 | LSB |
| Differential linearity error[Note 1] | DLE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±1.5 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI2, ANI4 to ANI7 | | 0 | | $AV_{REFP}$ | V |
| | | Internal reference voltage<br>(HS (high-speed main) mode) | | $V_{BGR}$[Note 4] | | | V |
| | | Temperature sensor output voltage<br>(HS (high-speed main) mode) | | $V_{TMPS25}$[Note 4] | | | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** When $AV_{REFP}$ < $V_{DD}$, the MAX. values are as follows.

Overall error: Add ±1.0 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Integral linearity error/Differential linearity error: Add ±0.5 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

**4.** See **3.6.2 Temperature sensor/internal reference voltage characteristics**.

**(2) When reference voltage (+) = $AV_{REFP}$/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target pin: ANI16 to ANI19**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $AV_{REFP}$ ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $AV_{REFP}$, Reference voltage (–) = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error[Note 1] | AINL | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | 1.2 | ±5.0 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target ANI pin : ANI16 to ANI19 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ < 5.5 V | 3.4 | | 39 | μs |
| Zero-scale error[Notes 1, 2] | $E_{ZS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.35 | %FSR |
| Full-scale error[Notes 1, 2] | $E_{FS}$ | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±0.35 | %FSR |
| Integral linearity error[Note 1] | ILE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±3.5 | LSB |
| Differential linearity error[Note 1] | DLE | 10-bit resolution<br>$AV_{REFP}$ = $V_{DD}$[Note 3] | | | | ±2.0 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI16 to ANI19 | | 0 | | $AV_{REFP}$ and $V_{DD}$ | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** When $AV_{REFP}$ < $V_{DD}$, the MAX. values are as follows.

Overall error: Add ±4.0 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Zero-scale error/Full-scale error: Add ±0.2%FSR to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

Integral linearity error/Differential linearity error: Add ±2.0 LSB to the MAX. value when $AV_{REFP}$ = $V_{DD}$.

**(3) When reference voltage (+) = $V_{DD}$ (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = $V_{SS}$ (ADREFM = 0), target pin: ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19, internal reference voltage, and temperature sensor output voltage**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $V_{DD}$, Reference voltage (–) = $V_{SS}$)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Resolution | RES | | | 8 | | 10 | bit |
| Overall error Note 1 | AINL | 10-bit resolution | | | 1.2 | ±7.0 | LSB |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: ANI0 to ANI2, ANI4 to ANI7, ANI16 to ANI19 | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.4 | | 39 | μs |
| Conversion time | $t_{CONV}$ | 10-bit resolution<br>Target pin: Internal reference voltage, and temperature sensor output voltage (HS (high-speed main) mode) | 3.6 V ≤ $V_{DD}$ ≤ 5.5 V | 2.375 | | 39 | μs |
| | | | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 3.8 | | 39 | μs |
| Zero-scale error Notes 1, 2 | $E_{ZS}$ | 10-bit resolution | | | | ±0.60 | %FSR |
| Full-scale error Notes 1, 2 | $E_{FS}$ | 10-bit resolution | | | | ±0.60 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution | | | | ±4.0 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution | | | | ±2.0 | LSB |
| Analog input voltage | $V_{AIN}$ | ANI0 to ANI2, ANI4 to ANI7 | | 0 | | $V_{DD}$ | V |
| | | ANI16 to ANI19 | | 0 | | $V_{DD}$ | V |
| | | Internal reference voltage (HS (high-speed main) mode) | | $V_{BGR}$ Note 3 | | | V |
| | | Temperature sensor output voltage (HS (high-speed main) mode) | | $V_{TMPS25}$ Note 3 | | | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** See **3.6.2 Temperature sensor/internal reference voltage characteristics**.

**(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (–) = $AV_{REFM}$/ANI1 (ADREFM = 1), target pin: ANI0, ANI2, ANI4 to ANI7, ANI16 to ANI19**

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, Reference voltage (+) = $V_{BGR}$ Note 3, Reference voltage (–) = $AV_{REFM}$ Note 4 = 0 V, HS (high-speed main) mode)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Resolution | RES | | 8 | | | bit |
| Conversion time | $t_{CONV}$ | 8-bit resolution | 17 | | 39 | μs |
| Zero-scale error Notes 1, 2 | $E_{ZS}$ | 8-bit resolution | | | ±0.60 | %FSR |
| Integral linearity error Note 1 | ILE | 8-bit resolution | | | ±2.0 | LSB |
| Differential linearity error Note 1 | DLE | 8-bit resolution | | | ±1.0 | LSB |
| Analog input voltage | $V_{AIN}$ | | 0 | | $V_{BGR}$ Note 3 | V |

**Notes 1.** Excludes quantization error (±1/2 LSB).

**2.** This value is indicated as a ratio (%FSR) to the full-scale value.

**3.** See **3.6.2 Temperature sensor/internal reference voltage characteristics**.

**4.** When reference voltage (–) = $V_{SS}$, the MAX. values are as follows.

Zero-scale error: Add ±0.35%FSR to the MAX. value when reference voltage (–) = $AV_{REFM}$.

Integral linearity error: Add ±0.5 LSB to the MAX. value when reference voltage (–) = $AV_{REFM}$.

Differential linearity error: Add ±0.2 LSB to the MAX. value when reference voltage (–) = $AV_{REFM}$.

## 3.6.2 Temperature sensor/internal reference voltage characteristics

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V, HS (high-speed main) mode)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Temperature sensor output voltage | $V_{TMPS25}$ | Setting ADS register = 80H, $T_A$ = +25°C | | 1.05 | | V |
| Internal reference voltage | $V_{BGR}$ | Setting ADS register = 81H | 1.38 | 1.45 | 1.5 | V |
| Temperature coefficient | $F_{VTMPS}$ | Temperature sensor that depends on the temperature | | –3.6 | | mV/C |
| Operation stabilization wait time | $t_{AMP}$ | | 5 | | | μs |

### 3.6.3 Programmable gain amplifier

**($T_A$ = –40 to +125°C, 2.7 V ≤ $AV_{REFP}$ = $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IOPGA}$ | | | | | ±5 | ±10 | mV |
| Input voltage range | $V_{IPGA}$ | | | | 0 | | 0.9$V_{DD}$/gain | V |
| Gain error[Note 1] | | 4, 8 times | | | | | ±1 | % |
| | | 16 times | | | | | ±1.5 | % |
| | | 32 times | | | | | ±2 | % |
| Slew rate[Note 1] | $SR_{RPGA}$ | Rising edge | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 4, 8 times | 4 | | | V/μs |
| | | | | 16, 32 times | 1.4 | | | V/μs |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | 4, 8 times | 1.8 | | | V/μs |
| | | | | 16, 32 times | 0.5 | | | V/μs |
| | $SR_{FPGA}$ | Falling edge | 4.0 V ≤ $V_{DD}$ ≤ 5.5 V | 4, 8 times | 3.2 | | | V/μs |
| | | | | 16, 32 times | 1.4 | | | V/μs |
| | | | 2.7 V ≤ $V_{DD}$ < 4.0 V | 4, 8 times | 1.2 | | | V/μs |
| | | | | 16, 32 times | 0.5 | | | V/μs |
| Operation stabilization wait time[Note 2] | $t_{PGA}$ | 4, 8 times | | | 5 | | | μs |
| | | 16, 32 times | | | 10 | | | μs |

**Notes 1.** When $V_{IPGA}$ = 0.1$V_{DD}$/gain to 0.9$V_{DD}$/gain.

**2.** Time required until a state is entered where the DC and AC specifications of the PGA are satisfied after the PGA operation has been enabled (PGAEN = 1).

**Remark** These characteristics apply when $AV_{REFM}$ is selected as GND of the PGA by using the CVRVS1 bit.

## 3.6.4 Comparator

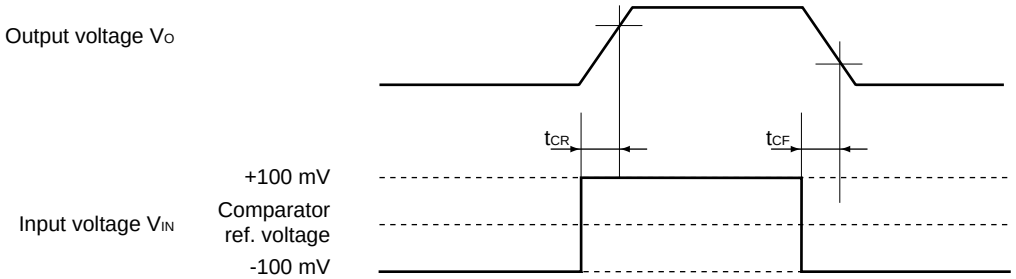
**($T_A$ = –40 to +125°C, 2.7 V ≤ $AV_{REFP}$ = $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = $AV_{REFM}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Input offset voltage | $V_{IOCMP}$ | | | ±5 | ±40 | mV |
| Input voltage range | $V_{ICMP}$ | CMP0P to CMP5P | 0 | | $V_{DD}$ | V |
| | | CMPCOM | 0.045 | | 0.9$V_{DD}$ | V |
| Internal reference voltage deviation | $\Delta V_{IREF}$ | CmRVM register values: 7FH to 80H (m = 0 to 2) | | | ±2 | LSB |
| | | Other than above | | | ±1 | LSB |
| Response time | $t_{CR}$, $t_{CF}$ | Input amplitude = ±100 mV | | 70 | 150 | ns |
| Operation stabilization wait time[Note 1] | $t_{CMP}$ | 3.3 V ≤ $V_{DD}$ ≤ 5.5 V | 1 | | | μs |
| | | 2.7 V ≤ $V_{DD}$ < 3.3 V | 3 | | | μs |
| Reference voltage stabilization wait time | $t_{VR}$ | CVRE: 0 to 1[Note 2] | 10 | | | μs |

**Notes 1.** Time required until a state is entered where the DC and AC specifications of the comparator are satisfied after the operation of the comparator has been enabled (CMPnEN bit = 1: n = 0 to 5)

**2.** Enable comparator output (CnOE bit = 1; n = 0 to 5) after enabling operation of the internal reference voltage generator (by setting the CVREm bit to 1; m = 0 to 2) and waiting for the operation stabilization time to elapse.

**Remark** These characteristics apply when $AV_{REFP}$ is selected as the power supply source of the internal reference voltage by using the CVRVS0 bit, and when $AV_{REFM}$ is selected as GND of the internal reference voltage by using the CVRVS1 bit.

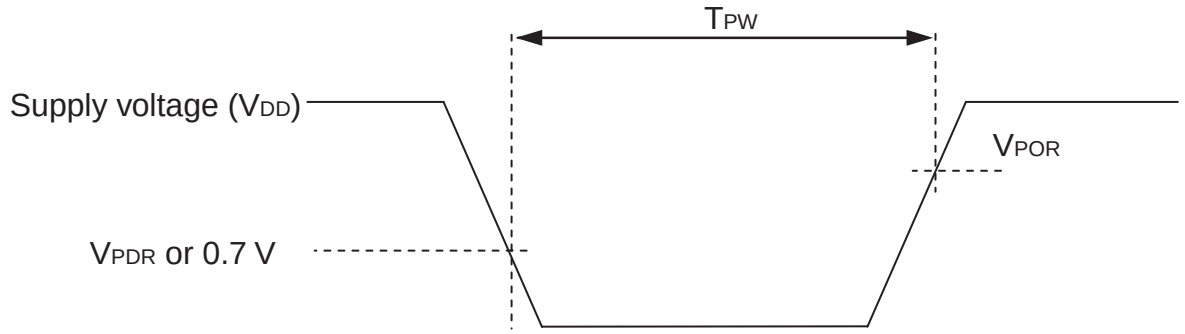


### 3.6.5 POR circuit characteristics

**($T_A$ = –40 to +125°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Detection voltage | $V_{POR}$ | Power supply rise time | 1.45 | 1.51 | 1.62 | V |
| | $V_{PDR}$ | Power supply fall time | 1.44 | 1.50 | 1.61 | V |
| Minimum pulse width[Note] | $T_{PW}$ | | 300 | | | μs |

**Note** Minimum time required for a POR reset when $V_{DD}$ exceeds below $V_{PDR}$. This is also the minimum time required for a POR reset from when $V_{DD}$ exceeds below 0.7 V to when $V_{DD}$ exceeds $V_{POR}$ while STOP mode is entered or the main system clock is stopped through setting bit 0 (HIOSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).




### 3.6.6 LVD circuit characteristics

**LVD Detection Voltage of Reset Mode and Interrupt Mode**

**($T_A$ = –40 to +125°C, $V_{PDR} \leq V_{DD} \leq$ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Detection voltage | Supply voltage level | $V_{LVD0}$ | Power supply rise time | 3.97 | 4.06 | 4.25 | V |
| | | | Power supply fall time | 3.89 | 3.98 | 4.15 | V |
| | | $V_{LVD1}$ | Power supply rise time | 3.67 | 3.75 | 3.93 | V |
| | | | Power supply fall time | 3.59 | 3.67 | 3.83 | V |
| | | $V_{LVD2}$ | Power supply rise time | 3.06 | 3.13 | 3.28 | V |
| | | | Power supply fall time | 2.99 | 3.06 | 3.20 | V |
| | | $V_{LVD3}$ | Power supply rise time | 2.95 | 3.02 | 3.17 | V |
| | | | Power supply fall time | 2.89 | 2.96 | 3.09 | V |
| | | $V_{LVD4}$ | Power supply rise time | 2.85 | 2.92 | 3.07 | V |
| | | | Power supply fall time | 2.79 | 2.86 | 2.99 | V |
| | | $V_{LVD5}$ | Power supply rise time | 2.75 | 2.81 | 2.95 | V |
| | | | Power supply fall time | 2.70 | 2.75 | 2.88 | V |
| Minimum pulse width | | $t_{LW}$ | | 300 | | | μs |
| Detection delay time | | | | | | 300 | μs |

**LVD Detection Voltage of Interrupt & Reset Mode**

**($T_A$ = –40 to +125°C, $V_{PDR} \leq V_{DD} \leq$ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|---|
| Interrupt and reset mode | $V_{LVD0}$ | $V_{POC2}$, $V_{POC1}$, $V_{POC0}$ = 0, 1, 1, falling reset voltage: 2.7 V | | 2.70 | 2.75 | 2.88 | V |
| | $V_{LVD1}$ | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 2.85 | 2.92 | 3.07 | V |
| | | | Falling interrupt voltage | 2.79 | 2.86 | 2.99 | V |
| | $V_{LVD2}$ | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.95 | 3.02 | 3.17 | V |
| | | | Falling interrupt voltage | 2.89 | 2.96 | 3.09 | V |
| | $V_{LVD3}$ | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.97 | 4.06 | 4.25 | V |
| | | | Falling interrupt voltage | 3.89 | 3.98 | 4.15 | V |

## 3.6.7 Supply voltage rise inclination characteristics

**($T_A$ = –40 to +125°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Supply voltage rise | $SV_{DD}$ | | | | 54 | V/ms |

**Caution Keep the internal reset status by using the LVD circuit or an external reset signal until $V_{DD}$ rises to within the operating voltage range shown in 33.4 AC Characteristics.**

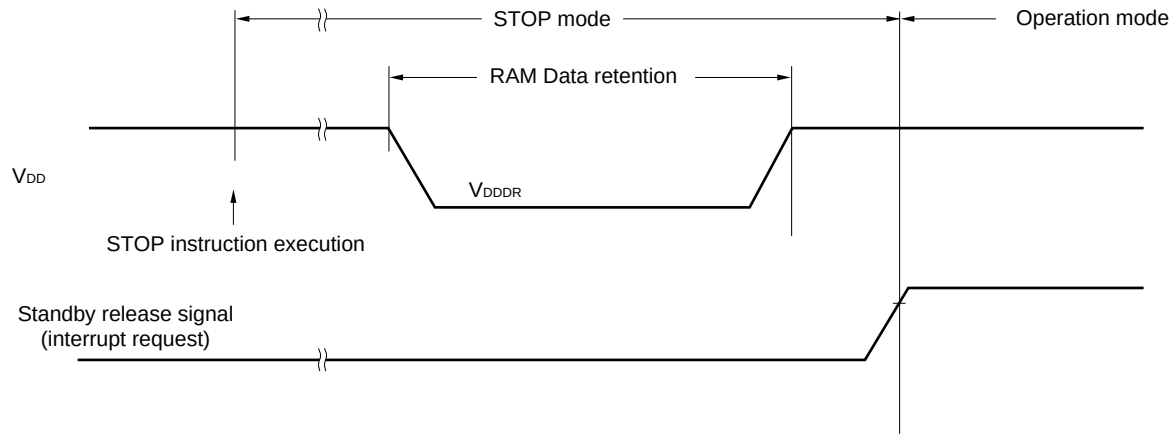
## 3.7 RAM Data Retention Characteristics

**($T_A$ = –40 to +125°C, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Data retention supply voltage[Note 2] | $V_{DDDR}$ | | 1.47[Note 1] | | 5.5 | V |

**Note** The value depends on the POR detection voltage. When the voltage drops, the RAM data is retained before a POR reset is effected, but RAM data is not retained when a POR reset is effected.

**Caution When CPU is operated at the voltage of out of the operation voltage range, RAM data is not retained. Therefore, set STOP mode before the supplied voltage is below the operation voltage range.**



## 3.8 Flash Memory Programming Characteristics

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| CPU/peripheral hardware clock frequency | $f_{CLK}$ | 2.7 V ≤ $V_{DD}$ ≤ 5.5 V | 1 | | 32 | MHz |
| Number of code flash rewrites Notes 1, 2, 3 | $C_{erwr}$ | Retained for 20 years, $T_A$ = 85°C Note 3, 4 | 1,000 | | | Times |
| Number of data flash rewrites Notes 1, 2, 3 | | Retained for 1 year, $T_A$ = 25°C Note 3, 4 | | 1,000,000 | | |
| | | Retained for 5 years, $T_A$ = 85°C Note 3, 4 | 100,000 | | | |
| | | Retained for 20 years, $T_A$ = 85°C Note 3, 4 | 10,000 | | | |

**Notes**
1. 1 erase + 1 write after the erase is regarded as 1 rewrite. The retaining years are until next rewrite after the rewrite.
2. When using flash memory programmer and Renesas Electronics self programming library
3. These are the characteristics of the flash memory and the results obtained from reliability testing by Renesas Electronics Corporation.
4. These are the average temperature of during the retainment.

## 3.9 Dedicated Flash Memory Programmer Communication (UART)

**($T_A$ = –40 to +105°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

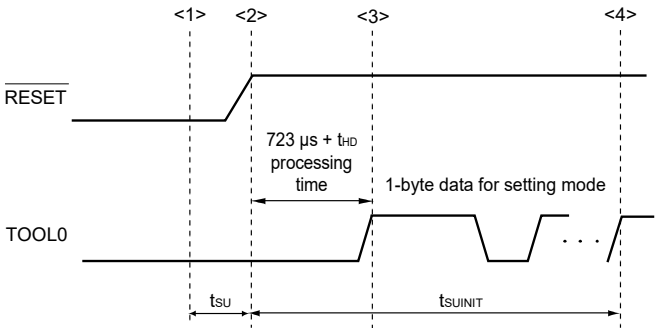
| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| Transfer rate | | During serial programming | 115.2 k | | 1 M | bps |

## 3.10 Timing of Entry to Flash Memory Programming Modes

**($T_A$ = –40 to +125°C, 2.7 V ≤ $V_{DD}$ ≤ 5.5 V, $V_{SS}$ = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|---|---|---|---|
| How long from when an external reset ends until the initial communication settings are specified | $t_{SUINIT}$ | POR and LVD reset must end before the external reset ends. | | | 100 | ms |
| How long from when the TOOL0 pin is placed at the low level until an external reset ends | $t_{SU}$ | POR and LVD reset must end before the external reset ends. | 10 | | | μs |
| How long the TOOL0 pin must be kept at the low level after a reset ends (except soft processing time) | $t_{HD}$ | POR and LVD reset must end before the external reset ends. | 1 | | | ms |

<R>




<1> The low level is input to the TOOL0 pin.
<2> The external reset ends (POR and LVD reset must end before the pin reset ends.).
<3> The TOOL0 pin is set to the high level.
<4> Complete the baud rate setting by UART reception.

**Remark** $t_{SUINIT}$: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

$t_{SU}$: How long from when the TOOL0 pin is placed at the low level until an external reset ends

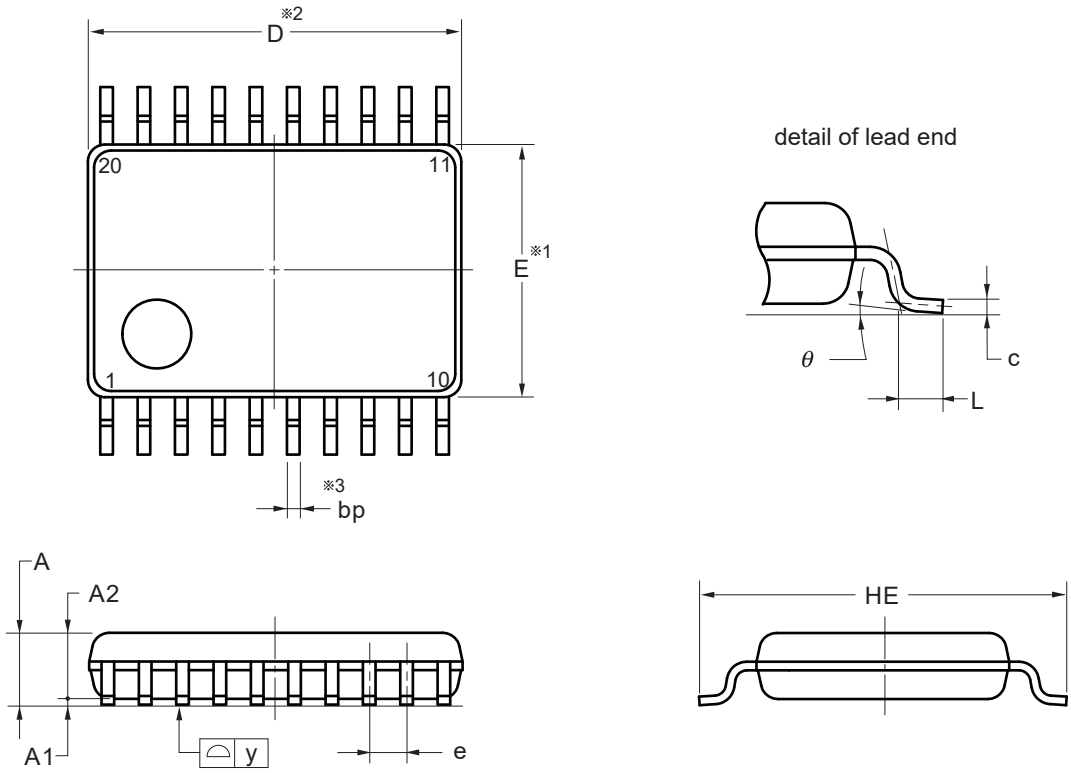
$t_{HD}$: How long to keep the TOOL0 pin at the low level from when the external and internal resets end (except soft processing time)

# 4. PACKAGE DRAWINGS

## <R> 4.1 20-pin Products

R5F1076CGSP#V0, R5F1076CGSP#X0, R5F1076CMSP#V0, R5F1076CMSP#X0

| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
|---|---|---|---|
| P-LSSOP20-4.4x6.5-0.65 | PLSP0020JB-A | P20MA-65-NAA-1 | 0.1 |




(UNIT:mm)

| ITEM | DIMENSIONS |
|---|---|
| D | 6.50±0.10 |
| E | 4.40±0.10 |
| HE | 6.40±0.20 |
| A | 1.45 MAX. |
| A1 | 0.10±0.10 |
| A2 | 1.15 |
| e | 0.65±0.12 |
| bp | $0.22^{+0.10}_{-0.05}$ |
| c | $0.15^{+0.05}_{-0.02}$ |
| L | 0.50±0.20 |
| y | 0.10 |
| θ | 0° to 10° |

**NOTE**

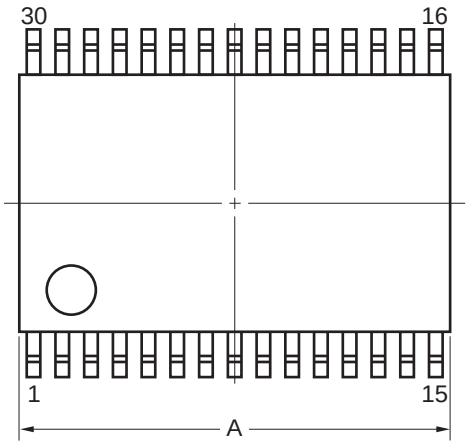
1.Dimensions "※1" and "※2" do not include mold flash.

2.Dimension "※3" does not include trim offset.

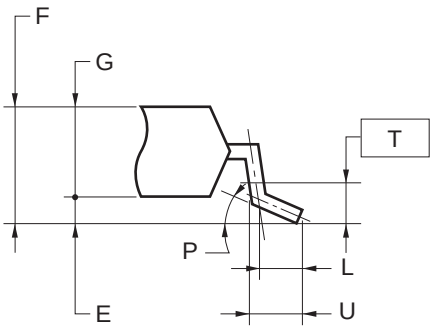
## 4.2 30-pin Products

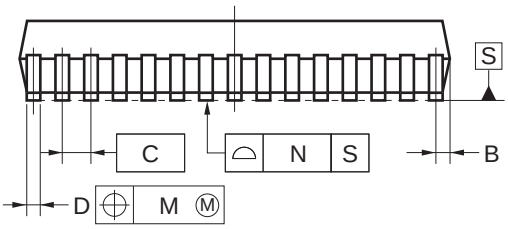
R5F107ACGSP#V0, R5F107AEGSP#V0, R5F107ACGSP#X0, R5F107AEGSP#X0, R5F107ACMSP#V0, R5F107AEMSP#V0, R5F107ACMSP#X0, R5F107AEMSP#X0

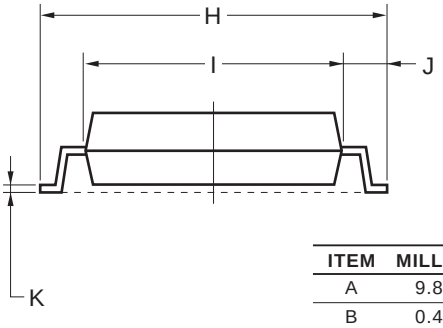
| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
|---|---|---|---|
| P-LSSOP30-0300-0.65 | PLSP0030JB-B | S30MC-65-5A4-3 | 0.18 |




detail of lead end



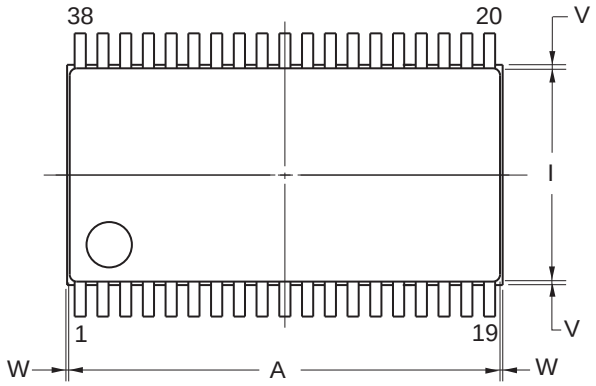

**NOTE**
Each lead centerline is located within 0.13 mm of its true position (T.P.) at maximum material condition.

| ITEM | MILLIMETERS |
|---|---|
| A | 9.85±0.15 |
| B | 0.45 MAX. |
| C | 0.65 (T.P.) |
| D | $0.24^{+0.08}_{-0.07}$ |
| E | 0.1±0.05 |
| F | 1.3±0.1 |
| G | 1.2 |
| H | 8.1±0.2 |
| I | 6.1±0.2 |
| J | 1.0±0.2 |
| K | 0.17±0.03 |
| L | 0.5 |
| M | 0.13 |
| N | 0.10 |
| P | $3^{\circ}{}^{+5^{\circ}}_{-3^{\circ}}$ |
| T | 0.25 |
| U | 0.6±0.15 |

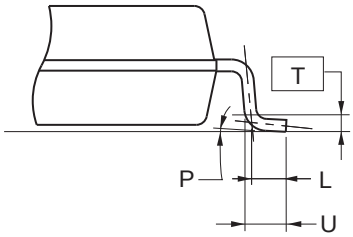
## 4.3 38-pin Products

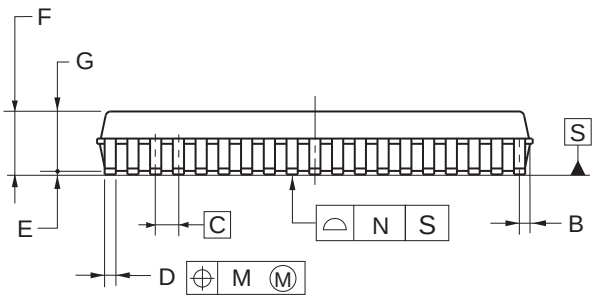
R5F107DEGSP#V0, R5F107DEGSP#X0, R5F107DEMSP#V0, R5F107DEMSP#X0

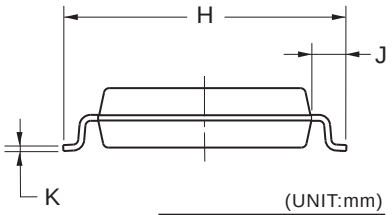
| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
|---|---|---|---|
| P-SSOP38-0300-0.65 | PRSP0038JA-A | P38MC-65-2A4-2 | 0.3 |




detail of lead end




(UNIT:mm)

| ITEM | DIMENSIONS |
|---|---|
| A | 12.30±0.10 |
| B | 0.30 |
| C | 0.65 (T.P.) |
| D | $0.32^{+0.08}_{-0.07}$ |
| E | 0.125±0.075 |
| F | 2.00 MAX. |
| G | 1.70±0.10 |
| H | 8.10±0.20 |
| I | 6.10±0.10 |
| J | 1.00±0.20 |
| K | $0.17^{+0.08}_{-0.07}$ |
| L | 0.50 |
| M | 0.10 |
| N | 0.10 |
| P | $3^{\circ}{}^{+7^{\circ}}_{-3^{\circ}}$ |
| T | 0.25(T.P.) |
| U | 0.60±0.15 |
| V | 0.25 MAX. |
| W | 0.15 MAX. |

**NOTE**

Each lead centerline is located within 0.10 mm of its true position (T.P.) at maximum material condition.

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 3.20 | Sep 29, 2017 | p.1 | Modification of description in 1.1 Features |
| | | p.59 | Modification of figure in 2.10 Timing of Entry to Flash Memory Programming Modes |
| | | p.102 | Modification of figure in 3.10 Timing of Entry to Flash Memory Programming Modes |
| | | p.103 | Modification of figure in 4.1 20-pin Products |

NOTES FOR CMOS DEVICES

(1) 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 VIL (MAX) and VIH (MIN) due to noise, etc., 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 VIL (MAX) and VIH (MIN).

(2) HANDLING OF UNUSED INPUT PINS: Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to VDD or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.

(3) PRECAUTION AGAINST ESD: A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that 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 should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.

(4) STATUS BEFORE INITIALIZATION: Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.

(5) POWER ON/OFF SEQUENCE: In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current. The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.

(6) INPUT OF SIGNAL DURING POWER OFF STATE : 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 power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.

# Notice

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