

True Low Power Platform (as low as 66 μ A/MHz, and 0.57 μ A for RTC + LVD), 1.6 V to 5.5 V operation, 32/64 Kbyte Flash, Max.32 MHz CPU operation, Enhanced analog functions, for General Purpose Applications

1. OUTLINE

1.1 Features

Ultra-low power consumption technology

- V_{DD} = single power supply voltage of 1.6 to 5.5 V which can operate a 1.8 V device at a low voltage
- HALT mode
- STOP mode
- SNOOZE mode

RL78 CPU core

- CISC architecture with 3-stage pipeline
- Minimum instruction execution time: Can be changed from high speed (0.03125 μ s: @ 32 MHz operation with high-speed on-chip oscillator) to ultra-low speed (30.5 μ s: @ 32.768 kHz operation with subsystem clock)
- Multiply/divide/multiply & accumulate instructions are supported.
- Address space: 1 MB
- General-purpose registers: (8-bit register \times 8) \times 4 banks
- On-chip RAM: 5.5 KB

Code flash memory

- Code flash memory: 32/64 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

Data flash memory

- Data flash memory: 4 KB
- Back ground operation (BGO): Instructions can be executed from the program memory while rewriting the data flash memory.
- Number of rewrites: 1,000,000 times (TYP.)
- Voltage of rewrites: $V_{DD} = 1.8$ to 5.5 V

High-speed on-chip oscillator

- Select from 64 MHz, 48 MHz, 32 MHz, 24 MHz, 16 MHz, 12 MHz, 8 MHz, 6 MHz, 4 MHz, 3 MHz, 2 MHz, and 1 MHz
- High accuracy: $\pm 1.0\%$ ($V_{DD} = 1.8$ to 5.5 V, $T_A = -20$ to $+85^\circ\text{C}$)

Operating ambient temperature

- $T_A = -40$ to $+85^\circ\text{C}$ (A: Consumer applications)
- $T_A = -40$ to $+105^\circ\text{C}$ (G: Industrial applications)

Power management and reset function

- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 14 levels)

Data transfer controller (DTC)

- Transfer modes: Normal transfer mode, repeat transfer mode, block transfer mode
- Activation sources: Activated by interrupt sources.
- Chain transfer function

Event link controller (ELC)

- Event signals of 22 types can be linked to the specified peripheral function.

Serial interfaces

- CSI: 3 to 6 channels
- UART/UART (LIN-bus supported): 3 channels
- I²C/simplified I²C: 3 to 6 channels
- IrDA: 1 channel

Timer

- 16-bit timer: 9 channels
(Timer Array Unit (TAU): 4 channels, Timer RJ: 1 channel, Timer RD: 2 channels (with PWMOPA), Timer RG: 1 channel, Timer RX: 1 channel)
- 12-bit interval timer: 1 channel
- Real-time clock: 1 channel (calendar for 99 years, alarm function, and clock correction function)
- Watchdog timer: 1 channel (operable with the dedicated low-speed on-chip oscillator)

A/D converter

- 8/10-bit resolution A/D converter ($V_{DD} = 1.6$ to 5.5 V)
- Analog input: 8 to 17 channels
- Internal reference voltage (1.45 V) and temperature sensor

D/A converter

- 8-bit resolution D/A converter ($V_{DD} = 1.6$ to 5.5 V)
- Analog output: 1 or 2 channels
- Output voltage: 0 V to V_{DD}
- Real-time output function

Comparator

- 2 channels (pin selector is provided for 1 channel)
- Incorporates a function for the output of a timer window in combination with the timer array unit.
- The external reference voltage or internal reference voltage can be selected as the reference voltage.

Programmable gain amplifier (PGA)

- 1 channel

I/O port

- I/O port: 20 to 58 (N-ch open drain I/O [withstand voltage of 6 V]: 2 to 4, N-ch open drain I/O [VDD withstand voltage/EVDD withstand voltage]: 10 to 16)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- Different potential interface: Can connect to a 1.8/2.5/3 V device
- On-chip key interrupt function
- On-chip clock output/buzzer output controller

Others

- On-chip BCD (binary-coded decimal) correction circuit

Remark The functions mounted depend on the product. See **1.6 Outline of Functions**.

○ ROM, RAM capacities

| Flash ROM | Data flash | RAM | RL78/G1F | | | | |
|-----------|------------|----------------------------|----------|----------|----------|----------|----------|
| | | | 24 pins | 32 pins | 36 pins | 48 pins | 64 pins |
| 64 KB | 4 KB | 5.5 KB <small>Note</small> | R5F11B7E | R5F11BBE | R5F11BCE | R5F11BGE | R5F11BLE |
| 32 KB | 4 KB | 5.5 KB <small>Note</small> | R5F11B7C | R5F11BBC | R5F11BCC | R5F11BGC | R5F11BLC |

Note This is about 4.5 KB when performing self-programming and rewriting the data flash memory (For details, see **CHAPTER 3 CPU ARCHITECTURE** in the RL78/G1F User's Manual).

1.2 Ordering Information

Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G1F

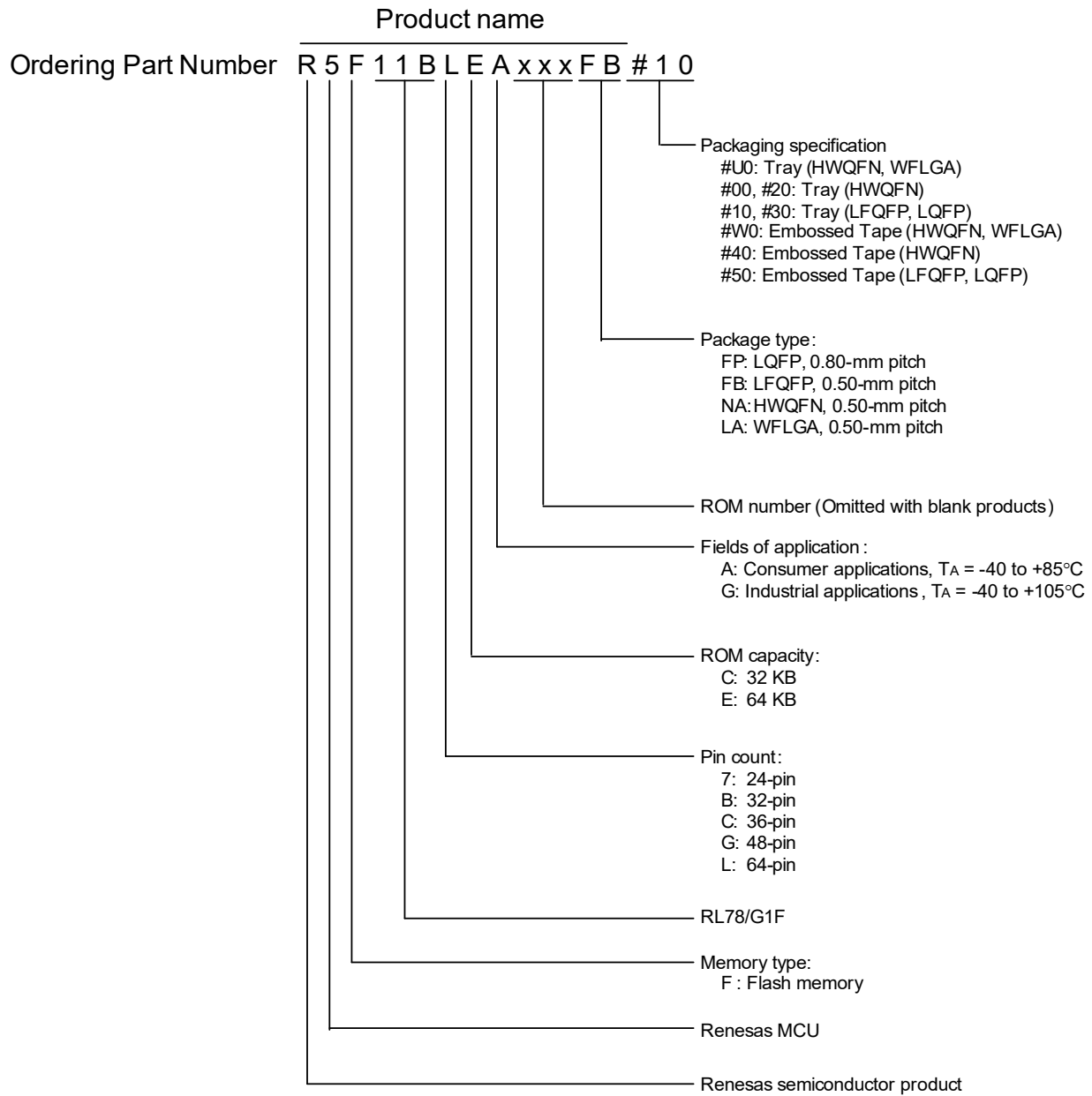


Table 1 - 1 List of Ordering Part Numbers

| Pin count | Package | Fields of Application Note | Ordering Part Number | | RENESAS Code |
|-----------|--|----------------------------|-----------------------------|-------------------------|--------------|
| | | | Product name | Packaging specification | |
| 24 pins | 24-pin plastic HWQFN (4 × 4 mm, 0.5-mm pitch) | A | R5F11B7CANA, R5F11B7EANA | #U0, #W0 | PWQN0024KE-A |
| | | | | #00, #20, #40 | PWQN0024KF-A |
| | | G | R5F11B7CGNA, R5F11B7EGNA | #U0, #W0 | PWQN0024KE-A |
| | | | | #00, #20, #40 | PWQN0024KF-A |
| 32 pins | 32-pin plastic HWQFN (5 × 5 mm, 0.5-mm pitch) | A | R5F11BBCANA, R5F11BBEANA | #00, #20, #40 | PWQN0032KE-A |
| | | G | R5F11BBCGNA, R5F11BBEGNA | | |
| | 32-pin plastic LQFP (7 × 7 mm, 0.8-mm pitch) | A | R5F11BBCAFP, R5F11BBEAFP | #10, #30, #50 | PLQP0032GB-A |
| | | G | R5F11BBCGFP, R5F11BBEGFP | | |
| 36 pins | 36-pin plastic WFLGA (4 × 4 mm, 0.5-mm pitch) | A | R5F11BCCALA, R5F11BCEALA | #U0, #W0 | PWLG0036KA-A |
| | | G | R5F11BCCGLA, R5F11BCEGLA | | |
| 48 pins | 48-pin plastic LFQFP (7 × 7 mm, 0.5-mm pitch) | A | R5F11BGCAF B, R5F11BG EAF B | #10, #30, #50 | PLQP0048KB-B |
| | | G | R5F11BGCGFB, R5F11BGEGFB | | |
| 64 pins | 64-pin plastic LFQFP (10 × 10 mm, 0.5-mm pitch) | A | R5F11BLCAF B, R5F11BLEAF B | #10, #30, #50 | PLQP0064KB-C |
| | | G | R5F11BLCGFB, R5F11BLEGFB | | |

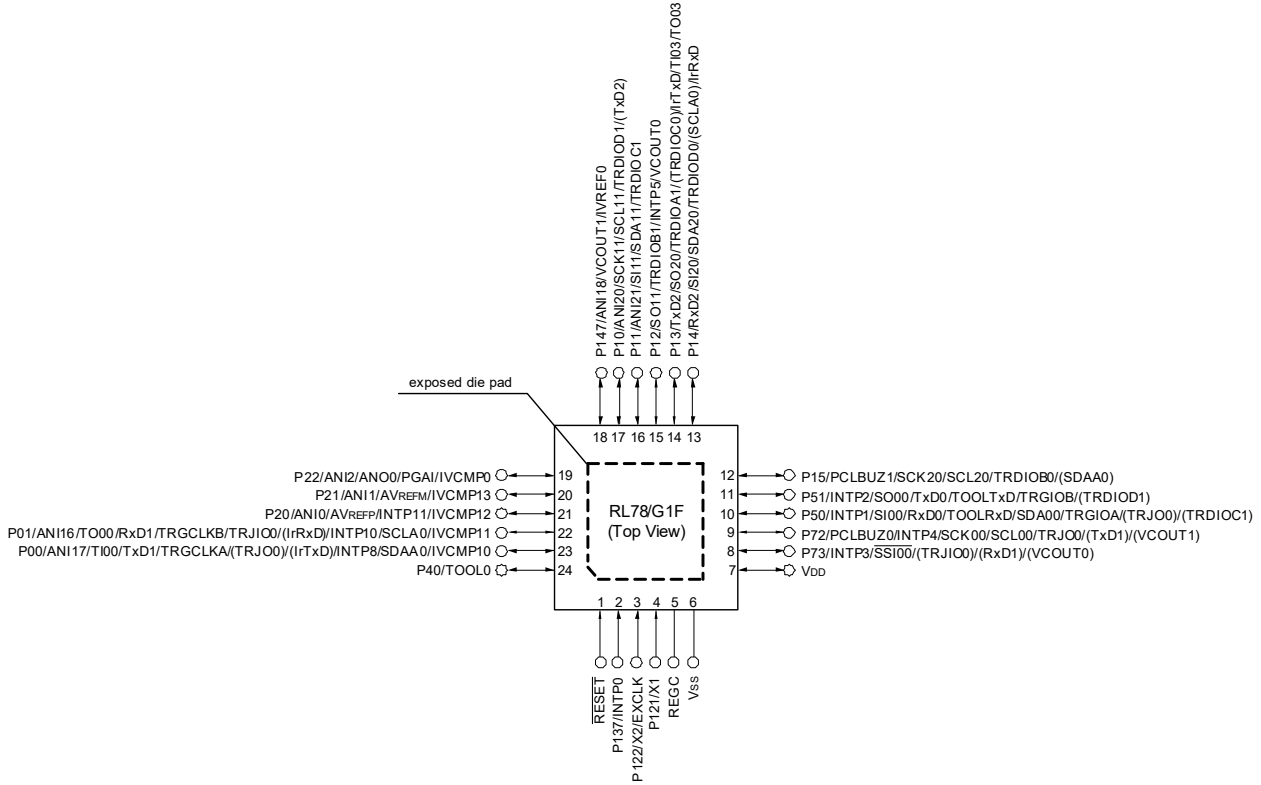
Note For the fields of application, refer to **Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G1F**.

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 24-pin products

- 24-pin plastic HWQFN (4 × 4 mm, 0.5-mm pitch)



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

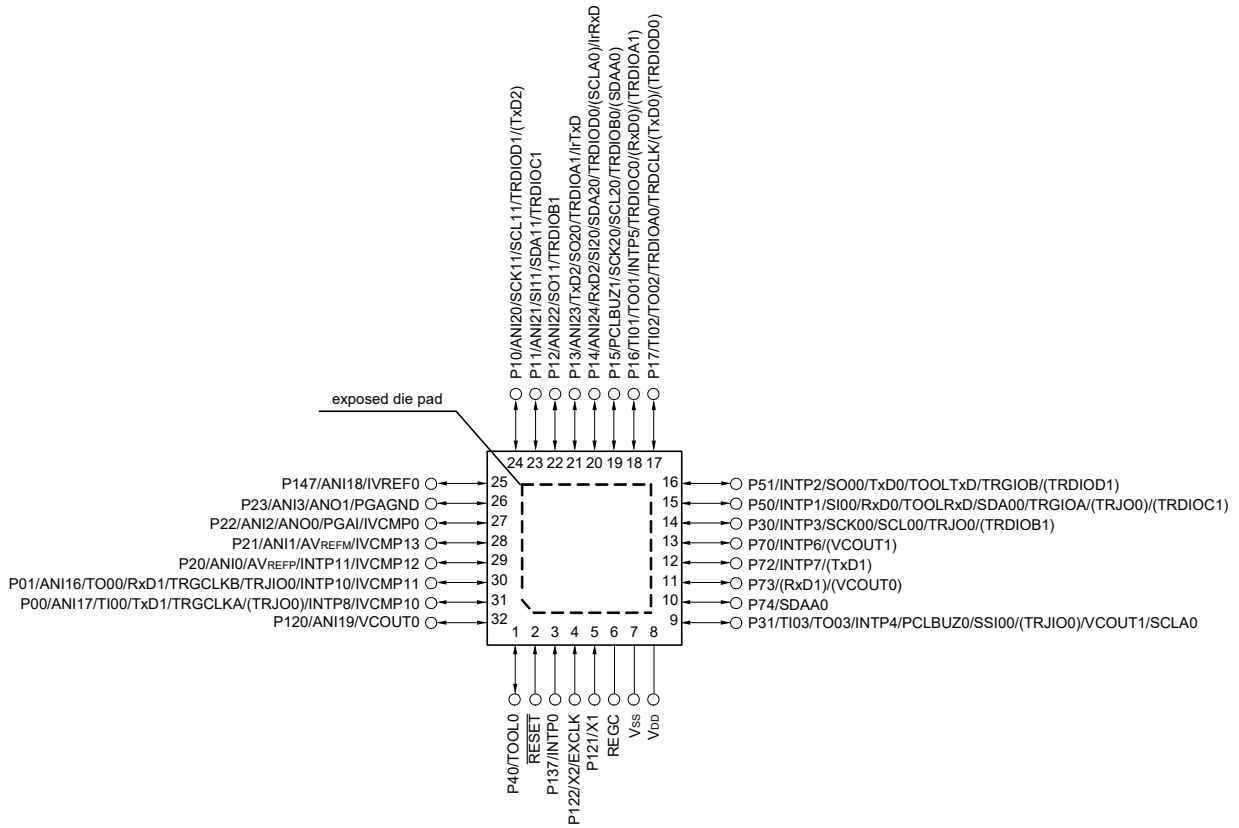
Remark 1. For pin identification, see 1.4 Pin Identification.

Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

1.3.2 32-pin products

<R>

- 32-pin plastic HWQFN (5 × 5 mm, 0.5-mm pitch)

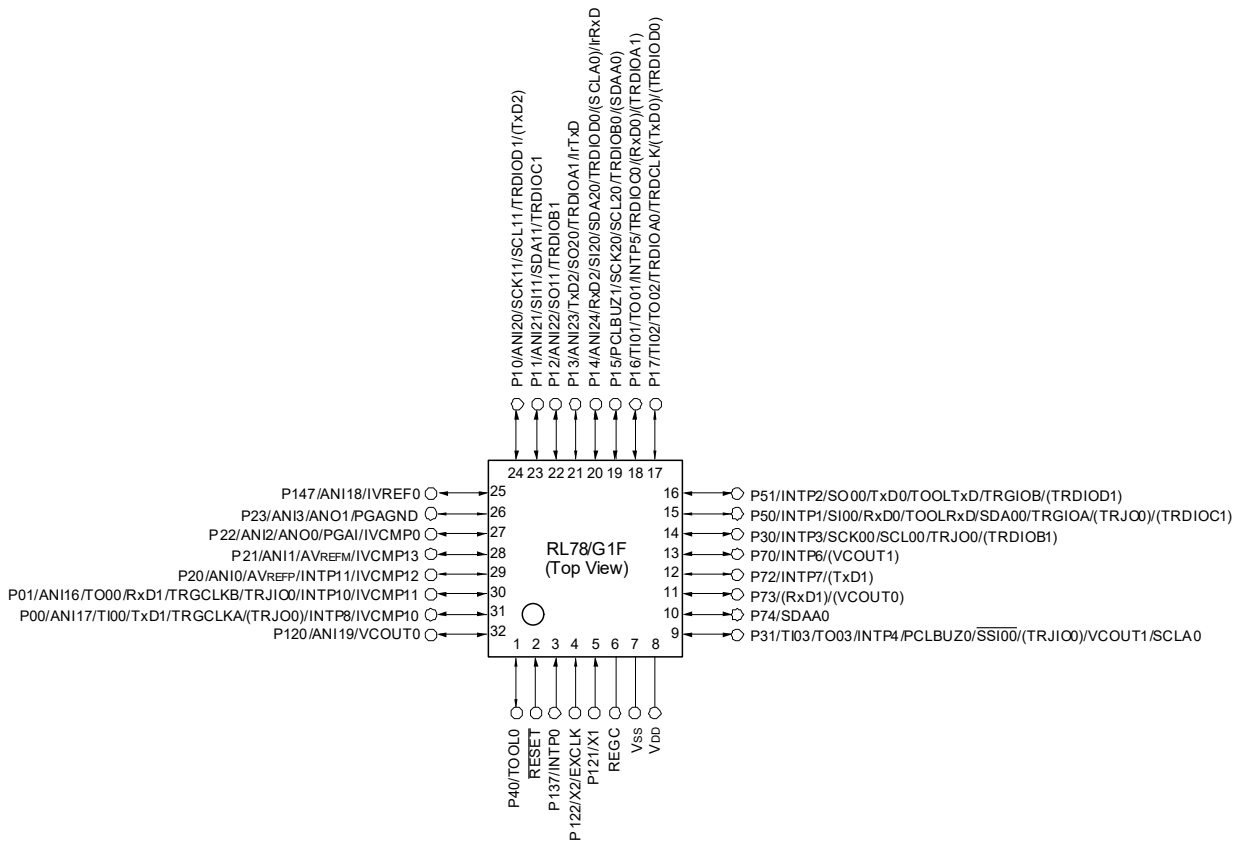


Caution Connect the REGC pin to Vss pin via a capacitor (0.47 to 1 μF).

Remark 1. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

Remark 2. It is recommended to connect an exposed die pad to Vss.

- 32-pin plastic LQFP (7 × 7 mm, 0.8-mm pitch)



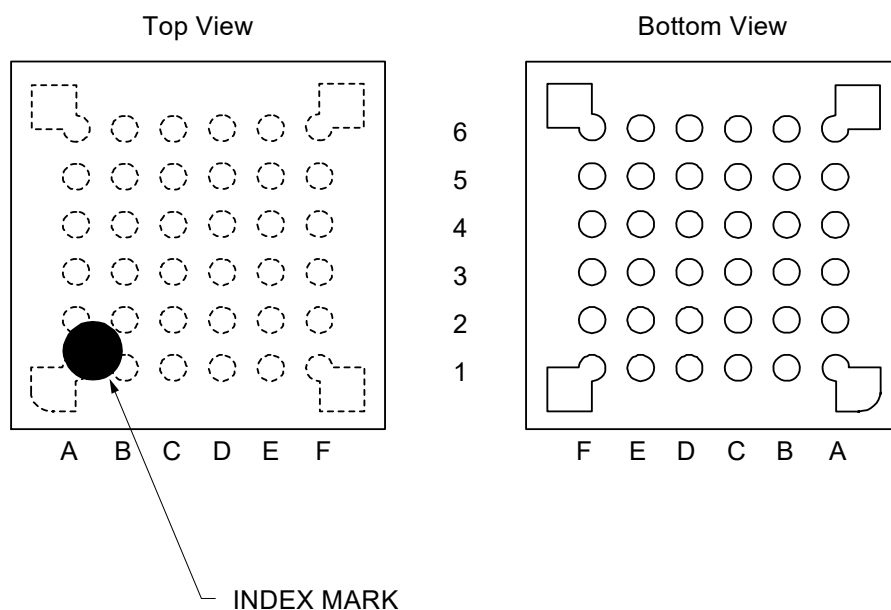
Caution Connect the REGC pin to V_{SS} pin via a capacitor (0.47 to 1 μF).

Remark 1. For pin identification, see 1.4 Pin Identification.

Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

1.3.3 36-pin products

- 36-pin plastic WFLGA (4 × 4 mm, 0.5-mm pitch)



| | A | B | C | D | E | F | |
|---|--|---|---|--|---|-------------------------------|---|
| 6 | EVDD0 | VDD | P121/X1 | P122/X2/EXCLK | P137/INTP0 | P40/TOOL0 | 6 |
| 5 | P61/SDAA0 | P60/SCLA0 | Vss | REGC | RESET | P124/XT2/ EXCLKS | 5 |
| 4 | P31/TI03/TO03/ INTP4/PCLBUZ0/ SSI00/(TRJIO0)/ VCOUT1 | P14/ANI24/RxD2/ SI20/SDA20/ TRDIOD0/ (SCLA0)/IIRxD | P20/ANI0/ AVREFP/IVCMP12/ INTP11 | P21/ANI1/ AVREFM/IVCMP13 | P01/ANI16/TO00/ RxD1/TRGCLKB/ TRJIO0/INTP10/ IVCMP11 | P123/XT1 | 4 |
| 3 | P50/INTP1/SI00/ RxD0/TOOLRxD/ SDA00/TRGIOA/ (TRJO0)/ (TRDI0C1) | P70/INTP6/ (VCOUT0)/ (VCOUT1) | P15/PCLBUZ1/ SCK20/SCL20/ TRDIOB0/ (SDAA0) | P23/ANI3/ANO1/ PGAGND | P00/ANI17/TI00/ TxD1/TRGCLKA/ (TRJO0)/INTP8/ IVCMP10 | P120/ANI19/ VCOUT0 | 3 |
| 2 | P30/INTP3/ RTC1HZ/SCK00/ SCL00/TRJO0/ (TRDI0B1) | P16/TI01/TO01/ INTP5/TRDI0C0/ (RxD0)/ (TRDIOA1) | P12/ANI22/SO11/ TRDIOB1 | P11/ANI21/SI11/ SDA11/TRDI0C1 | P24/ANI4 | P22/ANI2/ANO0/ PGAI/IVCMP0 | 2 |
| 1 | P51/INTP2/SO00/ TxD0/TOOLTxD/ TRGIOB/ (TRDI0D1) | P17/TI02/TO02/ TRDIOA0/ TRDCLK0/(TxD0)/ (TRDI0D0) | P13/ANI23/TxD2/ SO20/TRDIOA1/ IIRxD | P10/ANI20/ SCK11/SCL11/ TRDI0D1/(TxD2) | P147/ANI18/ IVREF0 | P25/ANI5 | 1 |
| | A | B | C | D | E | F | |

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

Caution 2. Make VDD pin the potential that is higher than EVDD0 pin.

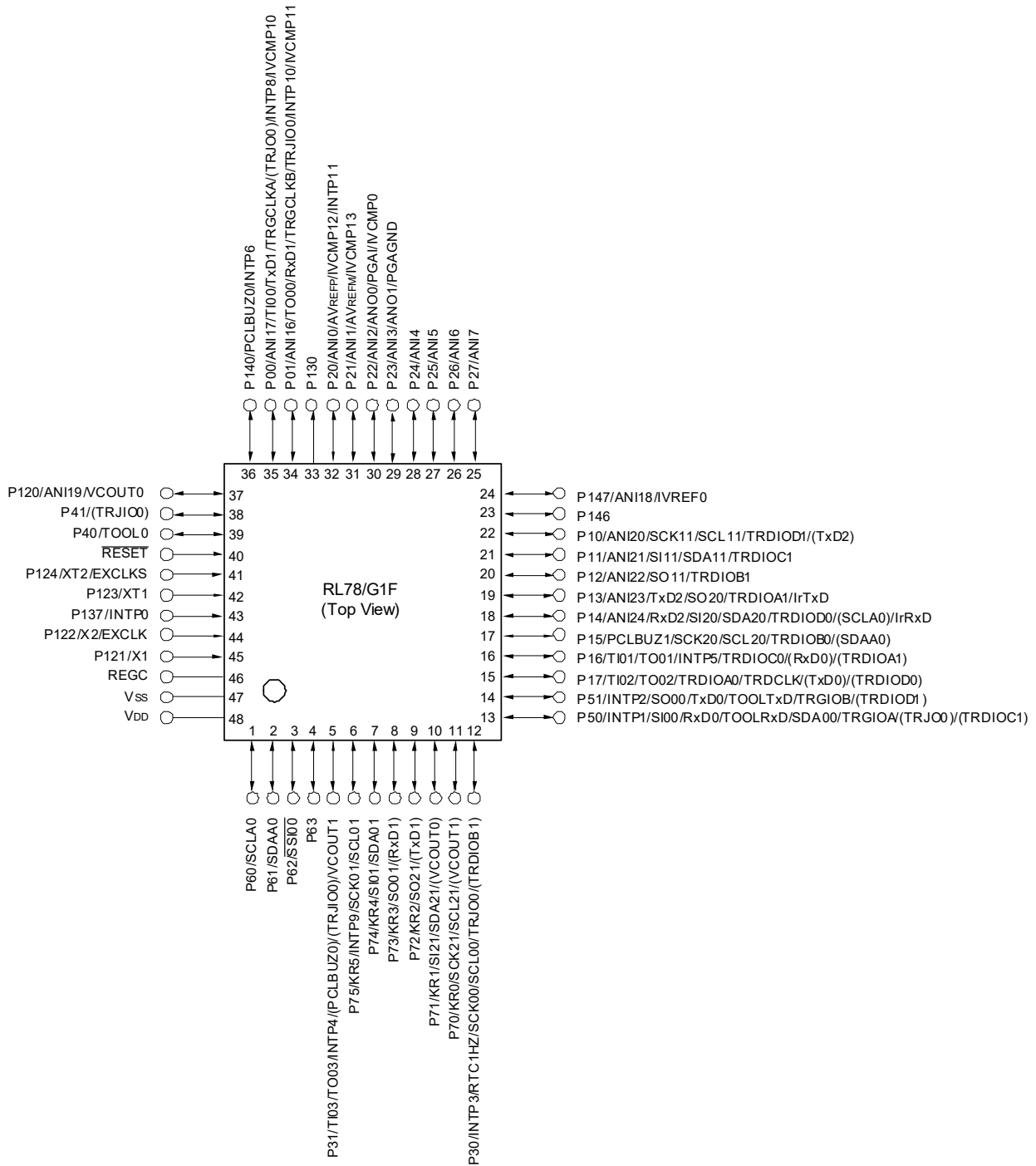
Remark 1. For pin identification, see 1.4 Pin Identification.

Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

Remark 3. When using the microcontroller for an application where the noise generated inside the microcontroller must be reduced, it is recommended to supply separate powers to the VDD and EVDD0 pins.

1.3.4 48-pin products

- 48-pin plastic LQFP (7 × 7 mm, 0.5-mm pitch)



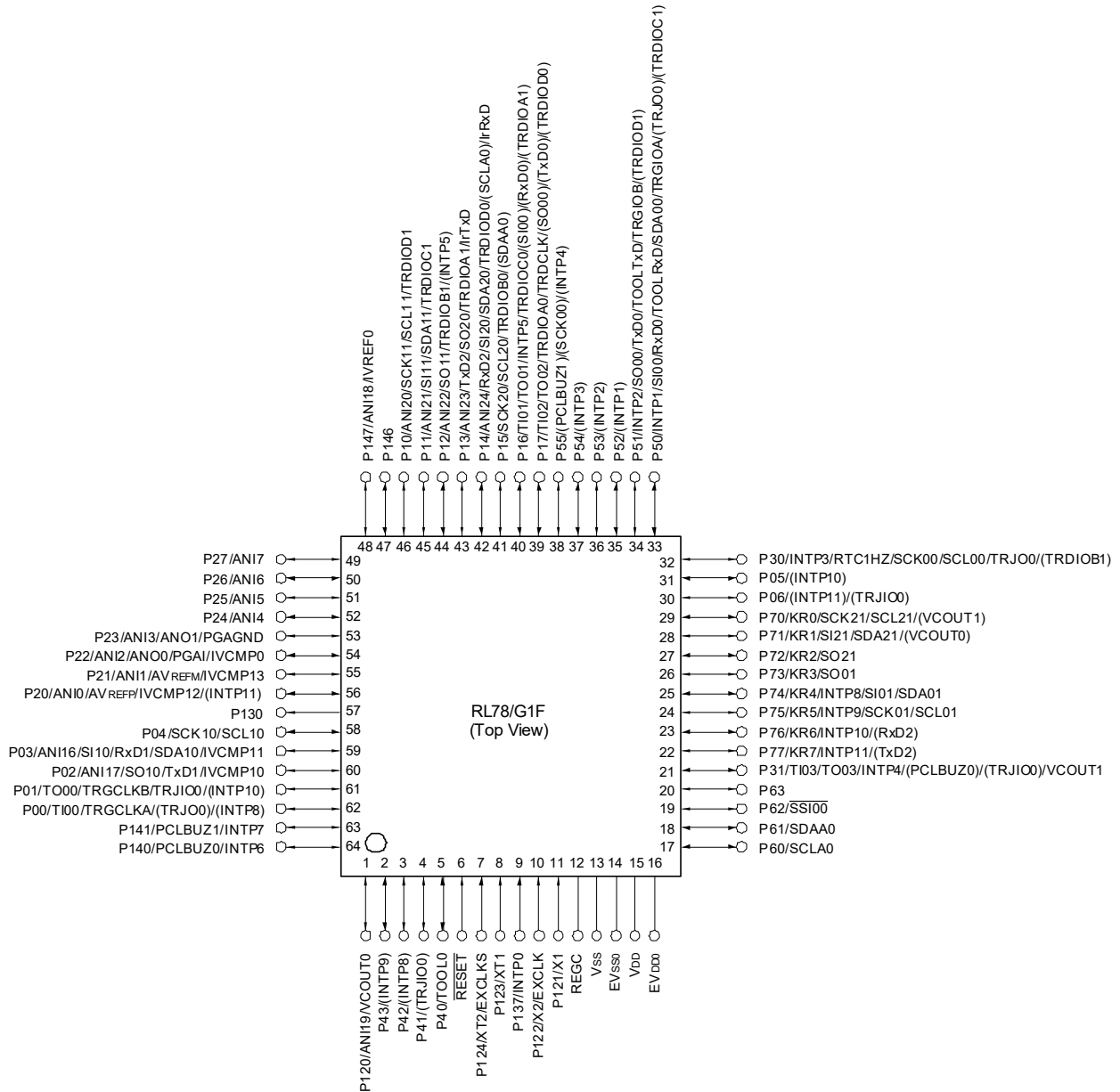
Caution Connect the REGC pin to Vss pin via a capacitor (0.47 to 1 μF).

Remark 1. For pin identification, see 1.4 Pin Identification.

Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

1.3.5 64-pin products

- 64-pin plastic LQFP (10 × 10 mm, 0.5-mm pitch)



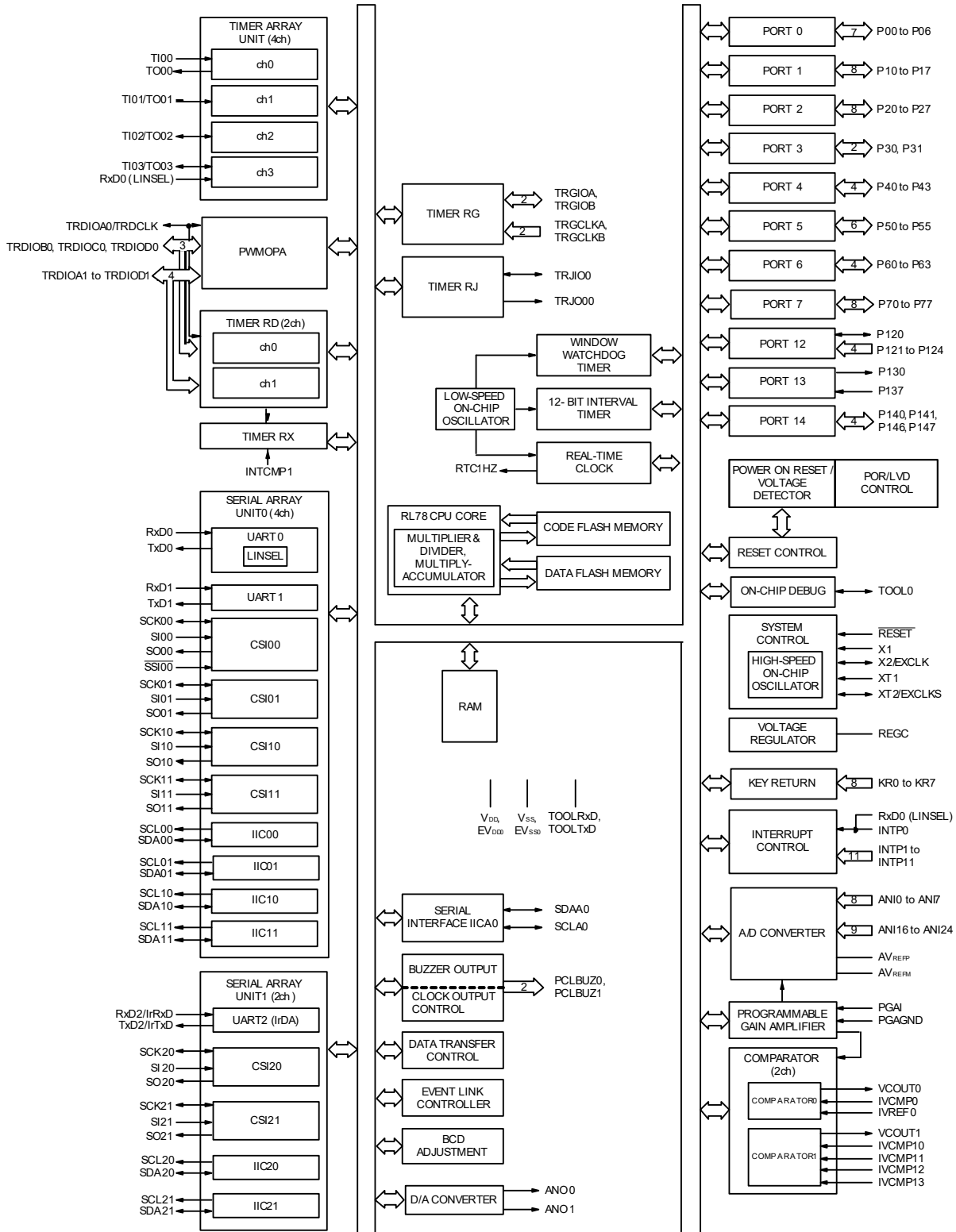
- Caution 1.** Make EV_{SS0} pin the same potential as V_{SS} pin.
- Caution 2.** Make V_{DD} pin the potential that is higher than EV_{DD0} pin.
- Caution 3.** Connect the REGC pin to V_{SS} pin via a capacitor (0.47 to 1 μF).

- Remark 1.** For pin identification, see 1.4 Pin Identification.
- Remark 2.** When using the microcontroller for an application where the noise generated inside the microcontroller must be reduced, it is recommended to supply separate powers to the V_{DD} and EV_{DD0} pins and connect the V_{SS} and EV_{SS0} pins to separate ground lines.
- Remark 3.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection registers 0 to 3 (PIOR0 to PIOR3).

1.4 Pin Identification

| | | | |
|---------------------|---|-----------------------------|---|
| ANI0 to ANI7: | Analog input | PGAI: | PGA input |
| ANI16 to ANI24: | Analog input | PGAGND: | PGA input |
| ANO0, ANO1: | Analog output | RTC1HZ: | Real-time clock correction clock (1 Hz) output |
| AVREFM: | Analog reference voltage minus | RxD0 to RxD2: | Receive data |
| AVREFP: | Analog reference voltage plus | SCK00, SCK01, SCK10: | Serial clock input/output |
| EVDD0: | Power supply for port | SCK11, SCK20, SCK21: | Serial clock input/output |
| EVSS0: | Ground for port | SCLA0: | Serial clock input/output |
| EXCLK: | External clock input (main system clock) | SCL00, SCL01, SCL10, SCL11: | Serial clock output |
| EXCLKS: | External clock input (subsystem clock) | SCL20, SCL21: | Serial clock output |
| INTP0 to INTP11: | External interrupt input | SDAA0: | Serial data input/output |
| IrRxD: | Receive Data for IrDA | SDA00, SDA01, SDA10: | Serial data input/output |
| IrTxD: | Transmit Data for IrDA | SDA11, SDA20, SDA21: | Serial data input/output |
| IVCMP0: | Comparator 0 input | SI00, SI01, SI10, SI11: | Serial data input |
| IVCMP10 to IVCMP13: | Comparator 1 input / reference input | SI20, SI21: | Serial data input |
| IVREF0: | Comparator 0 reference input | SO00, SO01, SO10: | Serial data output |
| KR0 to KR7: | Key return | SO11, SO20, SO21: | Serial data output |
| P00 to P06: | Port 0 | <u>SSI00</u> : | Serial interface chip select input |
| P10 to P17: | Port 1 | TI00 to TI03: | Timer input |
| P20 to P27: | Port 2 | TO00 to TO03: | Timer output |
| P30, P31: | Port 3 | TRJ00: | Timer output |
| P40 to P43: | Port 4 | TOOL0: | Data input/output for tool |
| P50 to P55: | Port 5 | TOOLRxD, TOOLTxD: | Data input/output for external device |
| P60 to P63: | Port 6 | TRDCLK, TRGCLKA: | Timer external input clock |
| P70 to P77: | Port 7 | TRGCLKB: | Timer external Input clock |
| P120 to P124: | Port 12 | TRDIOA0, TRDIOB0: | Timer input/output |
| P130, P137 | Port 13 | TRDIOC0, TRDIOD0: | Timer input/output |
| P140, P141, P146, | Port 14 | TRDIOA1, TRDIOB1: | Timer input/output |
| P147: | | TRDIOC1, TRDIOD1: | Timer input/output |
| PCLBUZ0, PCLBUZ1: | Programmable clock output/ buzzer output | TRGIOA, TRGIOB, TRJIO0: | Timer input/output |
| REGC: | Regulator capacitance | TxD0 to TxD2: | Transmit data |
| <u>RESET</u> : | Reset | VCOUT0, VCOUT1: | Comparator output |
| | | VDD: | Power supply |
| | | VSS: | Ground |
| | | X1, X2: | Crystal oscillator (main system clock) |
| | | XT1, XT2: | Crystal oscillator (subsystem clock) |

1.5 Block Diagram



Remark Block diagram of 64-pin products is shown as an example. For difference of the block diagram other than 64-pin products, refer to **1.6 Outline of Functions**.

1.6 Outline of Functions

Caution This outline describes the functions at the time when Peripheral I/O redirection register 0, 1 (PIOR0, 1) are set to 00H.

(1/2)

| Item | | 24-pin | 32-pin | 36-pin | 48-pin | 64-pin |
|------------------------------------|--|--|--|---|--|--|
| | | R5F11B7x (x = C, E) | R5F11BBx (x = C, E) | R5F11BCx (x = C, E) | R5F11BGx (x = C, E) | R5F11BLx (x = C, E) |
| Code flash memory (KB) | | 32, 64 | 32, 64 | 32, 64 | 32, 64 | 32, 64 |
| Data flash memory (KB) | | 4 | 4 | 4 | 4 | 4 |
| RAM (KB) | | 5.5 Note | 5.5 Note | 5.5 Note | 5.5 Note | 5.5 Note |
| Address space | | 1 MB | | | | |
| Main system clock | High-speed system clock | X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) HS (high-speed main) mode: 1 to 20 MHz ($V_{DD} = 2.7$ to 5.5 V), HS (high-speed main) mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 5.5 V), LS (low-speed main) mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 2.7 V), LV (low-voltage main) mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 1.8 V) | | | | |
| | High-speed on-chip oscillator clock (f _{IH}) | HS (high-speed main) mode: 1 to 32 MHz ($V_{DD} = 2.7$ to 5.5 V), HS (high-speed main) mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 5.5 V), LS (low-speed main) mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 5.5 V), LV (low-voltage main) mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 5.5 V) | | | | |
| Subsystem clock | | — | | XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz | | |
| Low-speed on-chip oscillator clock | | 15 kHz (TYP.): $V_{DD} = 1.6$ to 5.5 V | | | | |
| General-purpose register | | 8 bits × 32 registers (8 bits × 8 registers × 4 banks) | | | | |
| Minimum instruction execution time | | 0.03125 μs (High-speed on-chip oscillator clock: 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) | | |
| Instruction set | | <ul style="list-style-type: none"> • Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (8 bits × 8 bits, 16 bits × 16 bits), Division (16 bits ÷ 16 bits, 32 bits ÷ 32 bits) • Multiplication and Accumulation (16 bits × 16 bits + 32 bits) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc. | | | | |
| I/O port | Total | 20 | 28 | 31 | 44 | 58 |
| | CMOS I/O | 17 (N-ch O.D. output [V_{DD} withstand voltage]: 10) | 25 (N-ch O.D. output [V_{DD} withstand voltage]: 12) | 24 (N-ch O.D. output [V_{DD} withstand voltage]: 10) | 34 (N-ch O.D. output [V_{DD} withstand voltage]: 12) | 48 (N-ch O.D. output [V_{DD} withstand voltage]: 12) |
| | CMOS input | 3 | 3 | 5 | 5 | 5 |
| | CMOS output | — | — | — | 1 | 1 |
| | N-ch open-drain I/O (6 V tolerance) | — | — | 2 | 4 | 4 |
| Timer | 16-bit timer | 9 channels (TAU: 4 channels, Timer RJ: 1 channel, Timer RD: 2 channels (with PWMOPA), Timer RX: 1 channel, Timer RG: 1 channel) | | | | |
| | Watchdog timer | 1 channel | | | | |
| | Real-time clock (RTC) | 1 channel | | | | |
| | 12-bit interval timer | 1 channel | | | | |
| | Timer output | Timer outputs: 13 channels PWM outputs: 8 channels | Timer outputs: 16 channels PWM outputs: 9 channels | | | |
| | RTC output | — | | | 1 • 1 Hz (subsystem clock: f _{SUB} = 32.768 kHz) | |

Note This is about 4.5 KB when the self-programming function and data flash function are used (For details, see CHAPTER 3 in the RL78/G1F User's Manual).

(2/2)

| Item | 24-pin | 32-pin | 36-pin | 48-pin | 64-pin | |
|-----------------------------------|---|------------------------|------------------------|------------------------|------------------------|----|
| | R5F11B7x (x = C, E) | R5F11BBx (x = C, E) | R5F11BCx (x = C, E) | R5F11BGx (x = C, E) | R5F11BLx (x = C, E) | |
| Clock output/buzzer output | 2 | 2 | 2 | 2 | 2 | |
| | • 2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: f _{MAIN} = 20 MHz operation) | | | | | |
| 8/10-bit resolution A/D converter | 8 channels | 13 channels | 15 channels | 17 channels | 17 channels | |
| 8-bit D/A converter | 1 channel | 2 channels | | | | |
| Comparator | 2 channels | | | | | |
| Programmable gain amplifier (PGA) | 1 channel | | | | | |
| Serial interface | [24-pin, 32-pin, 36-pin products] | | | | | |
| | <ul style="list-style-type: none"> • CSI: 1 channel/UART (UART supporting LIN-bus): 1 channel/simplified I²C: 1 channel • CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel • CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel | | | | | |
| I ² C bus | [48-pin products] | | | | | |
| | <ul style="list-style-type: none"> • CSI: 2 channels/UART (UART supporting LIN-bus): 1 channel/simplified I²C: 2 channels • CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel • CSI: 2 channels/UART: 1 channel/simplified I²C: 2 channels | | | | | |
| I ² C bus | [64-pin products] | | | | | |
| | <ul style="list-style-type: none"> • CSI: 2 channels/UART (UART supporting LIN-bus): 1 channel/simplified I²C: 2 channels • CSI: 2 channels/UART: 1 channel/simplified I²C: 2 channels • CSI: 2 channels/UART: 1 channel/simplified I²C: 2 channels | | | | | |
| Data transfer controller (DTC) | 30 sources | 32 sources | 31 sources | 32 sources | 33 sources | |
| Event link controller (ELC) | Event input | 21 | 21 | 21 | 22 | 22 |
| | Event trigger output | 9 | 10 | 10 | 10 | 10 |
| Vectored interrupt sources | Internal | 25 | 25 | 25 | 25 | 25 |
| | External | 9 | 11 | 10 | 12 | 13 |
| Key interrupt | — | — | — | 6 | 8 | |
| Reset | <ul style="list-style-type: none"> • Reset by $\overline{\text{RESET}}$ pin • Internal reset by watchdog timer • Internal reset by power-on-reset • Internal reset by voltage detector • Internal reset by illegal instruction execution ^{Note} • Internal reset by RAM parity error • Internal reset by illegal-memory access | | | | | |
| Power-on-reset circuit | <ul style="list-style-type: none"> • Power-on-reset: 1.51 ±0.04 V (T_A = -40 to +85°C) 1.51 ±0.06 V (T_A = -40 to +105°C) • Power-down-reset: 1.50 ±0.04 V (T_A = -40 to +85°C) 1.50 ±0.06 V (T_A = -40 to +105°C) | | | | | |
| Voltage detector | <p>[T_A = -40 to +85°C]</p> <ul style="list-style-type: none"> • Rising edge: 1.67 ±0.03 V to 4.00 ±0.08 V (14 stages) • Falling edge: 1.63 ±0.03 V to 3.98 ±0.08 V (14 stages) <p>[T_A = -40 to +105°C (G: Industrial applications)]</p> <ul style="list-style-type: none"> • Rising edge: 2.61 ±0.1 V to 4.06 ±0.16 V (8 stages) • Falling edge: 2.55 ±0.1 V to 3.98 ±0.15 V (8 stages) | | | | | |
| On-chip debug function | Provided | | | | | |
| Power supply voltage | V _{DD} = 1.6 to 5.5 V (T _A = -40 to +85°C) V _{DD} = 2.4 to 5.5 V (T _A = -40 to +105°C) | | | | | |
| Operating ambient temperature | T _A = -40 to +85°C (A: Consumer applications), T _A = -40 to +105°C (Industrial applications), | | | | | |

The illegal instruction is generated when instruction code FFH is executed.

Reset by the illegal instruction execution not is issued by emulation with the in-circuit emulator or on-chip debug emulator.

2. ELECTRICAL SPECIFICATIONS (T_A = -40 to +85°C)

This chapter describes the following electrical specifications.

Target products A: Consumer applications T_A = -40 to +85°C

R5F11BxxAxx

G: Industrial applications when T_A = -40 to +105°C products is used in the range of T_A = -40 to +85°C

R5F11BxxGxx

Caution 1. The RL78 microcontrollers have 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.

Caution 2. With products not provided with an EV_{DD0}, EV_{SS0} pin, replace EV_{DD0} with V_{DD}, or replace EV_{SS0} with V_{SS}.

Caution 3. The pins mounted depend on the product. Refer to 2.1 Port Functions to 2.2.1 Functions for each product in the RL78/G1F User's Manual.

2.1 Absolute Maximum Ratings

Absolute Maximum Ratings

(1/2)

| Parameter | Symbols | Conditions | Ratings | Unit |
|------------------------|--------------------|---|---|------|
| Supply voltage | V _{DD} | | -0.5 to +6.5 | V |
| | EV _{DD0} | | -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} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | -0.3 to EV _{DD0} +0.3 and -0.3 to V _{DD} +0.3 Note 2 | V |
| | V _{I2} | P60 to P63 (N-ch open-drain) | -0.3 to +6.5 | V |
| | V _{I3} | P20 to P27, P121 to P124, P137, EXCLK, EXCLKS, RESET | -0.3 to V _{DD} +0.3 Note 2 | V |
| Output voltage | V _{O1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P60 to P63, P70 to P77, P120, P130, P140, P141, P146, P147 | -0.3 to EV _{DD0} +0.3 and -0.3 to V _{DD} +0.3 Note 2 | V |
| | V _{O2} | P20 to P27 | -0.3 to V _{DD} +0.3 Note 2 | V |
| Analog input voltage | V _{AI1} | ANI16 to ANI24 | -0.3 to EV _{DD0} +0.3 and -0.3 to AV _{REF} (+) +0.3 Notes 2, 3 | V |
| | V _{AI2} | ANI0 to ANI7 | -0.3 to V _{DD} +0.3 and -0.3 to AV _{REF} (+) +0.3 Notes 2, 3 | V |

Note 1. Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.

Note 2. Must be 6.5 V or lower.

Note 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.

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

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

Remark 3. V_{SS}: Reference voltage

Absolute Maximum Ratings**(2/2)**

| Parameter | Symbols | Conditions | | Ratings | Unit |
|-------------------------------|----------------------------------|------------------------------|--|---|------------|
| Output current, high | IOH1 | Per pin | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | -40 | mA |
| | | Total of all pins -170 mA | P00 to P04, P40 to P43, P120, P130, P140, P141 | -70 | mA |
| | | | P05, P06, P10 to P17, P30, P31, P50 to P55, P70 to P77, P146, P147 | -100 | mA |
| | IOH2 | Per pin | P20 to P27 | -0.5 | mA |
| | | Total of all pins | | -2 | mA |
| | Output current, low | IOL1 | Per pin | P00 to P06, P10 to P17, P30, P31, P40-P43, P50 to P55, P60 to P63, P70 to P77, P120, P130, P140, P141, P146, P147 | 40 |
| Total of all pins 170 mA | | | P00 to P04, P40 to P47, P120, P130, P140, P141 | 70 | mA |
| | | | P05, P06, P10 to P17, P30, P31, P50 to P55, P70 to P77, P146, P147 | 100 | mA |
| IOL2 | | Per pin | P20 to P27 | 1 | mA |
| | | Total of all pins | | 5 | mA |
| Operating ambient temperature | | TA | In normal operation mode | | -40 to +85 |
| | In flash memory programming mode | | | | |
| Storage temperature | Tstg | | | -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 characteristics

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 = VDD ≤ 5.5 V, VSS = 0 V)

| Resonator | Resonator | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---------------------|------|--------|------|------|
| X1 clock oscillation frequency (fx) ^{Note} | Ceramic resonator/ crystal resonator | 2.7 V ≤ VDD ≤ 5.5 V | 1.0 | | 20.0 | MHz |
| | | 2.4 V ≤ VDD < 2.7 V | 1.0 | | 16.0 | |
| | | 1.8 V ≤ VDD < 2.4 V | 1.0 | | 8.0 | |
| | | 1.6 V ≤ VDD < 1.8 V | 1.0 | | 4.0 | |
| XT1 clock oscillation frequency (fxT) ^{Note} | Crystal resonator | | 32 | 32.768 | 35 | kHz |

Note Indicates only permissible oscillator frequency ranges. Refer to **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, refer to **5.4 System Clock Oscillator** in the RL78/G1F User's Manual.

2.2.2 On-chip oscillator characteristics

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 = VDD ≤ 5.5 V, VSS = 0 V)

| Oscillators | Parameters | Conditions | MIN. | TYP. | MAX. | Unit | |
|---|-----------------|---------------------|---------------------|------|------|------|---|
| High-speed on-chip oscillator clock frequency Notes 1, 2 | f _{IH} | 2.7 V ≤ VDD ≤ 5.5 V | 1 | | 32 | MHz | |
| | | 2.4 V ≤ VDD < 2.7 V | 1 | | 16 | MHz | |
| | | 1.8 V ≤ VDD < 2.4 V | 1 | | 8 | MHz | |
| | | 1.6 V ≤ VDD < 1.8 V | 1 | | 4 | MHz | |
| High-speed on-chip oscillator clock frequency accuracy | | TA = -20 to +85°C | 1.8 V ≤ VDD ≤ 5.5 V | -1 | | 1 | % |
| | | | 1.6 V ≤ VDD < 1.8 V | -5 | | 5 | % |
| | | TA = -40 to -20°C | 1.8 V ≤ VDD < 5.5 V | -1.5 | | 1.5 | % |
| | | | 1.6 V ≤ VDD < 1.8 V | -5.5 | | 5.5 | % |
| Low-speed on-chip oscillator clock frequency | f _{IL} | | | 15 | | kHz | |
| Low-speed on-chip oscillator clock frequency accuracy | | | -15 | | +15 | % | |

Note 1. High-speed on-chip oscillator frequency is selected with bits 0 to 4 of the option byte (000C2H) and bits 0 to 2 of the HOCODIV register.

Note 2. This only indicates the oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

2.3 DC Characteristics

2.3.1 Pin characteristics

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|--|--------|--|---|---------------------|------------------|----------------|----|
| Output current, high ^{Note 1} | IOH1 | Per pin for P00 to P06, P10 to P17, P30, P31, P40 to P47, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | | | -10.0 Note 2 | mA | |
| | | Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | -55.0 | mA | |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | -10.0 | mA | |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | -5.0 | mA | |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | -2.5 | mA | |
| | | Total of P05, P06, P10 to P17, P30, P31, P50 to P53, P70 to P77, P146, P147 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | -80.0 | mA | |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | -19.0 | mA | |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | -10.0 | mA | |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | -5.0 | mA | |
| | | Total of all pins (When duty ≤ 70% ^{Note 3}) | | | -135.0 Note 4 | mA | |
| | | IOH2 | Per pin for P20 to P27 | | | -0.1 Note 2 | mA |
| | | | Total of all pins (When duty ≤ 70% ^{Note 3}) | 1.6 V ≤ VDD ≤ 5.5 V | | -1.5 | mA |

Note 1. Value of current at which the device operation is guaranteed even if the current flows from the EVDD0, VDD pins to an output pin.

Note 2. Do not exceed the total current value.

Note 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 = (IOH × 0.7)/(n × 0.01)

<Example> Where n = 80% and IOH = -10.0 mA

$$\text{Total output current of pins} = (-10.0 \times 0.7)/(80 \times 0.01) \approx -8.7 \text{ mA}$$

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.

Note 4. The applied current for the products for industrial application (R5F11BxxGxx) is -100 mA.

Caution P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 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.

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------------------------------|---|---|-----------------------|---------------------|----------------|------|
| Output current, low ^{Note 1} | IOL1 | Per pin for P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | | | 20.0 Note 2 | mA |
| | | | | | 15.0 Note 2 | mA |
| | | Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | 70.0 | mA |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | 15.0 | mA |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | 9.0 | mA |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | 4.5 | mA |
| | | Total of P05, P06, P10 to P17, P30, P31, P50 to P55, P60 to P63, P70 to P77, P146, P147 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | 80.0 | mA |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | 35.0 | mA |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | 20.0 | mA |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | 10.0 | mA |
| | Total of all pins (When duty ≤ 70% ^{Note 3}) | | | | 150.0 | mA |
| | IOL2 | Per pin for P20 to P27 | | | 0.4 Note 2 | mA |
| | | | | | | |
| | | Total of all pins (When duty ≤ 70% ^{Note 3}) | | 1.6 V ≤ VDD ≤ 5.5 V | | 5.0 |

Note 1. Value of current at which the device operation is guaranteed even if the current flows from an output pin to the EVSS0 and VSS pins.

Note 2. Do not exceed the total current value.

Note 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 = $(I_{OL} \times 0.7) / (n \times 0.01)$

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

$$\text{Total output current of pins} = (10.0 \times 0.7) / (80 \times 0.01) \approx 8.7 \text{ mA}$$

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.

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(3/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|---------------------|---|--|---|-----------|---------|-----------|---|
| Input voltage, high | V _{IH1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | Normal input buffer | 0.8 EVDD0 | | EVDD0 | V |
| | V _{IH2} | P01, P03, P04, P10, P14 to P17, P30, P43, P50, P53 to P55, | TTL input buffer 4.0 V ≤ EVDD0 ≤ 5.5 V | 2.2 | | EVDD0 | V |
| | | | TTL input buffer 3.3 V ≤ EVDD0 < 4.0 V | 2.0 | | EVDD0 | V |
| | | | TTL input buffer 1.6 V ≤ EVDD0 < 3.3 V | 1.5 | | EVDD0 | V |
| | V _{IH3} | P20 to P27 (when P20 is used as a port pin) | | 0.7 VDD | | VDD | V |
| | V _{IH4} | P60 to P63 | | 0.7 EVDD0 | | 6.0 | V |
| V _{IH5} | P121 to P123, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$ (when P20 is used as INTP11 pin) | | 0.8 VDD | | VDD | V | |
| Input voltage, low | V _{IL1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | Normal input buffer | 0 | | 0.2 EVDD0 | V |
| | V _{IL2} | P01, P03, P04, P10, P14 to P17, P30, P43, P50, P53 to P55, | TTL input buffer 4.0 V ≤ EVDD0 ≤ 5.5 V | 0 | | 0.8 | V |
| | | | TTL input buffer 3.3 V ≤ EVDD0 < 4.0 V | 0 | | 0.5 | V |
| | | | TTL input buffer 1.6 V ≤ EVDD0 < 3.3 V | 0 | | 0.32 | V |
| | V _{IL3} | P20 to P27 (when P20 is used as a port pin) | | 0 | | 0.3 VDD | V |
| | V _{IL4} | P60 to P63 | | 0 | | 0.3 EVDD0 | V |
| V _{IL5} | P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$ (when P20 is used as INTP11 pin) | | 0 | | 0.2 VDD | V | |

Caution The maximum value of V_{IH} of pins P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 is EVDD0, 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.

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(4/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|----------------------|--------|--|---|-------------|------|------|
| Output voltage, high | VOH1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -10.0 mA | EVDD0 - 1.5 | | V |
| | | | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -3.0 mA | EVDD0 - 0.7 | | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -2.0 mA | EVDD0 - 0.6 | | V |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -1.5 mA | EVDD0 - 0.5 | | V |
| | | | 1.6 V ≤ EVDD0 < 1.8 V, IOH1 = -1.0 mA | EVDD0 - 0.5 | | V |
| | VOH2 | P20 to P27 | 1.6 V ≤ VDD ≤ 5.5 V, IOH2 = -100 μA | VDD - 0.5 | | V |
| Output voltage, low | VOL1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 20.0 mA | | 1.3 | V |
| | | | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 8.5 mA | | 0.7 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 3.0 mA | | 0.6 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 1.5 mA | | 0.4 | V |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 0.6 mA | | 0.4 | V |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 0.3 mA | | 0.4 | V |
| | VOL2 | P20 to P27 | 1.6 V ≤ VDD ≤ 5.5 V, IOL2 = 400 μA | | 0.4 | V |
| | VOL3 | P60 to P63 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 15.0 mA | | 2.0 | V |
| | | | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 5.0 mA | | 0.4 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 3.0 mA | | 0.4 | V |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 2.0 mA | | 0.4 | V |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 1.0 mA | | 0.4 | V |

Caution P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 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.

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(5/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|-----------------------------|--------|--|----------|---------------------------------------|------|------|----|
| Input leakage current, high | ILIH1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | | | 1 | μA | |
| | ILIH2 | P20 to P27, P137, $\overline{\text{RESET}}$ | | | 1 | μA | |
| | ILIH3 | P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS) | Vi = VDD | In input port or external clock input | | 1 | μA |
| | | | | In resonator connection | | 10 | μA |
| Input leakage current, low | ILIL1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | | | -1 | μA | |
| | ILIL2 | P20 to P27, P137, $\overline{\text{RESET}}$ | | | -1 | μA | |
| | ILIL3 | P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS) | Vi = VSS | In input port or external clock input | | -1 | μA |
| | | | | In resonator connection | | -10 | μA |
| On-chip pull-up resistance | Ru | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | 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

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit |
|--|--|--|--|--|----------------------|-------------|------|------|------|
| Supply current Note 1 | IDD1 | Operating mode | HS (high-speed main) mode Note 5 | fHOCO = 64 MHz, fIH = 32 MHz Note 3 | Basic operation | VDD = 5.0 V | 2.4 | | mA |
| | | | | | | VDD = 3.0 V | 2.4 | | |
| | | | | fHOCO = 32 MHz, fIH = 32 MHz Note 3 | Basic operation | VDD = 5.0 V | 2.1 | | |
| | | | | VDD = 3.0 V | | 2.1 | | | |
| | | | | | | | | | |
| | | | HS (high-speed main) mode Note 5 | fHOCO = 64 MHz, fIH = 32 MHz Note 3 | Normal operation | VDD = 5.0 V | 5.2 | 8.7 | |
| | | | | VDD = 3.0 V | | 5.2 | 8.7 | | |
| | | fHOCO = 32 MHz, fIH = 32 MHz Note 3 | | Normal operation | VDD = 5.0 V | 4.8 | 8.1 | | |
| | | | | | VDD = 3.0 V | 4.8 | 8.1 | | |
| | | | | | | | | | |
| | | | | fHOCO = 48 MHz, fIH = 24 MHz Note 3 | Normal operation | VDD = 5.0 V | 4.1 | 6.9 | |
| | | | VDD = 3.0 V | 4.1 | | 6.9 | | | |
| | | | fHOCO = 24 MHz, fIH = 24 MHz Note 3 | Normal operation | VDD = 5.0 V | 3.8 | 6.3 | | |
| | | | VDD = 3.0 V | | 3.8 | 6.3 | | | |
| | | | fHOCO = 16 MHz, fIH = 16 MHz Note 3 | Normal operation | VDD = 5.0 V | 2.8 | 4.6 | | |
| | | | VDD = 3.0 V | | 2.8 | 4.6 | | | |
| | | LS (low-speed main) mode Note 5 | fHOCO = 8 MHz, fIH = 8 MHz Note 3 | Normal operation | VDD = 3.0 V | 1.3 | 2.1 | mA | |
| | | | VDD = 2.0 V | | 1.3 | 2.1 | | | |
| | | LV (low-voltage main) mode Note 5 | fHOCO = 4 MHz, fIH = 4 MHz Note 3 | Normal operation | VDD = 3.0 V | 1.3 | 1.9 | mA | |
| | | | VDD = 2.0 V | | 1.3 | 1.9 | | | |
| | | HS (high-speed main) mode Note 5 | fMX = 20 MHz Note 2, VDD = 5.0 V | Normal operation | Square wave input | 3.3 | 5.3 | mA | |
| | | | | | Resonator connection | 3.5 | 5.5 | | |
| | | | | Normal operation | Square wave input | 3.3 | 5.3 | | |
| | | | | | Resonator connection | 3.5 | 5.5 | | |
| fMX = 10 MHz Note 2, VDD = 5.0 V | Normal operation | | Square wave input | 2 | 3.1 | | | | |
| | | | Resonator connection | 2.1 | 3.2 | | | | |
| fMX = 10 MHz Note 2, VDD = 3.0 V | Normal operation | | Square wave input | 2 | 3.1 | | | | |
| | | | Resonator connection | 2.1 | 3.2 | | | | |
| LS (low-speed main) mode Note 5 | fMX = 8 MHz Note 2, VDD = 3.0 V | Normal operation | Square wave input | 1.2 | 1.9 | mA | | | |
| | | | Resonator connection | 1.2 | 2 | | | | |
| | fMX = 8 MHz Note 2, VDD = 2.0 V | Normal operation | Square wave input | 1.2 | 1.9 | | | | |
| | | | Resonator connection | 1.2 | 2 | | | | |
| Subsystem clock operation | fSUB = 32.768 kHz Note 4 TA = -40°C | Normal operation | Square wave input | 4.7 | 6.1 | μA | | | |
| | | | Resonator connection | 4.7 | 6.1 | | | | |
| | fSUB = 32.768 kHz Note 4 TA = +25°C | Normal operation | Square wave input | 4.7 | 6.1 | | | | |
| | | | Resonator connection | 4.7 | 6.1 | | | | |
| | fSUB = 32.768 kHz Note 4 TA = +50°C | Normal operation | Square wave input | 4.8 | 6.7 | | | | |
| | | | Resonator connection | 4.8 | 6.7 | | | | |
| fSUB = 32.768 kHz Note 4 TA = +70°C | Normal operation | Square wave input | 4.8 | 7.5 | | | | | |
| | | Resonator connection | 4.8 | 7.5 | | | | | |
| fSUB = 32.768 kHz Note 4 TA = +85°C | Normal operation | Square wave input | 5.4 | 8.9 | | | | | |
| | | Resonator connection | 5.4 | 8.9 | | | | | |

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

- Note 1.** Total current flowing into V_{DD} and EV_{DD0}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD0} or V_{SS}, EV_{SS0}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 3.** When high-speed system clock and subsystem clock are stopped.
- Note 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.
- Note 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 |
| | 2.4 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 16 MHz |
| LS (low-speed main) mode: | 1.8 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 8 MHz |
| LV (low-voltage main) mode: | 1.6 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 4 MHz |
- Remark 1.** f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f_{HOCO}: High-speed on-chip oscillator clock frequency (64 MHz max.)
- Remark 3.** f_{IH}: High-speed on-chip oscillator clock frequency (32 MHz max.)
- Remark 4.** f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/2)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | | | | |
|--|----------------------|-------------------------------------|---|--|------------------------------------|----------------------|------|------|----|------|----|
| Supply current Note 1 | IDD2 Note 2 | HALT mode | HS (high-speed main) mode Note 7 | fHOCO = 64 MHz, fIH = 32 MHz Note 4 | VDD = 5.0 V | | 0.8 | 3.09 | mA | | |
| | | | | | VDD = 3.0 V | | 0.8 | 3.09 | | | |
| | | | | fHOCO = 32 MHz, fIH = 32 MHz Note 4 | VDD = 5.0 V | | 0.54 | 2.4 | | | |
| | | | | | VDD = 3.0 V | | 0.54 | 2.4 | | | |
| | | | | fHOCO = 48 MHz, fIH = 24 MHz Note 4 | VDD = 5.0 V | | 0.62 | 2.4 | | | |
| | | | | | VDD = 3.0 V | | 0.62 | 2.4 | | | |
| | | | fHOCO = 24 MHz, fIH = 24 MHz Note 4 | VDD = 5.0 V | | 0.44 | 1.83 | | | | |
| | | | | VDD = 3.0 V | | 0.44 | 1.83 | | | | |
| | | | fHOCO = 16 MHz, fIH = 16 MHz Note 4 | VDD = 5.0 V | | 0.4 | 1.38 | | | | |
| | | | | VDD = 3.0 V | | 0.4 | 1.38 | | | | |
| | | | LS (low-speed main) mode Note 7 | fHOCO = 8 MHz, fIH = 8 MHz Note 4 | VDD = 3.0 V | | 260 | 790 | μA | | |
| | | | | | VDD = 2.0 V | | 260 | 790 | | | |
| | | | LV (low-voltage main) mode Note 7 | fHOCO = 4 MHz, fIH = 4 MHz Note 4 | VDD = 3.0 V | | 420 | 830 | μA | | |
| | | | | | VDD = 2.0 V | | 420 | 830 | | | |
| | | | HS (high-speed main) mode Note 7 | fMX = 20 MHz Note 3, VDD = 5.0 V | Square wave input | | 0.28 | 1.55 | mA | | |
| | | | | | | Resonator connection | | 0.49 | | 1.74 | |
| | | | | | Square wave input | | 0.28 | 1.55 | | | |
| | | | | | | Resonator connection | | 0.49 | | 1.74 | |
| | | fMX = 10 MHz Note 3, VDD = 5.0 V | | | Square wave input | | 0.19 | 0.86 | | | |
| | | | | | | Resonator connection | | 0.3 | | 0.93 | |
| | | fMX = 10 MHz Note 3, VDD = 3.0 V | | | Square wave input | | 0.19 | 0.86 | | | |
| | | | | | | Resonator connection | | 0.3 | | 0.93 | |
| | | LS (low-speed main) mode Note 7 | | | fMX = 8 MHz Note 3, VDD = 3.0 V | Square wave input | | 95 | | 640 | μA |
| | | | | | | Resonator connection | | 145 | | 680 | |
| | | | | | fMX = 8 MHz Note 3, VDD = 2.0 V | Square wave input | | 95 | | 640 | |
| | | | | | | Resonator connection | | 145 | | 680 | |
| | | Subsystem clock operation | fsUB = 32.768 kHz Note 5, TA = -40°C | Square wave input | | 0.25 | 0.57 | μA | | | |
| Resonator connection | | | | 0.44 | 0.76 | | | | | | |
| fsUB = 32.768 kHz Note 5, TA = 25°C | Square wave input | | | 0.3 | 0.57 | | | | | | |
| | Resonator connection | | | 0.49 | 0.76 | | | | | | |
| fsUB = 32.768 kHz Note 5, TA = 50°C | Square wave input | | | 0.36 | 1.17 | | | | | | |
| | Resonator connection | | | 0.59 | 1.36 | | | | | | |
| fsUB = 32.768 kHz Note 5, TA = 70°C | Square wave input | | | 0.49 | 1.97 | | | | | | |
| | Resonator connection | | | 0.72 | 2.16 | | | | | | |
| fsUB = 32.768 kHz Note 5, TA = 85°C | Square wave input | | 0.97 | 3.37 | | | | | | | |
| | Resonator connection | | 1.16 | 3.56 | | | | | | | |
| IDD3 Note 6 | STOP mode Note 8 | TA = -40°C | | 0.18 | 0.51 | μA | | | | | |
| | | TA = +25°C | | 0.24 | 0.51 | | | | | | |
| | | TA = +50°C | | 0.29 | 1.1 | | | | | | |
| | | TA = +70°C | | 0.41 | 1.9 | | | | | | |
| | | TA = +85°C | | 0.9 | 3.3 | | | | | | |

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

- Note 1.** Total current flowing into V_{DD} and EV_{DD0}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD0} or V_{SS}, EV_{SS0}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** During HALT instruction execution by flash memory.
- Note 3.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 4.** When high-speed system clock and subsystem clock are stopped.
- Note 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.
- Note 6.** Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.
- Note 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
2.4 V ≤ V_{DD} ≤ 5.5 V@1 MHz to 16 MHz
- LS (low-speed main) mode: 1.8 V ≤ V_{DD} ≤ 5.5 V@1 MHz to 8 MHz
- LV (low-voltage main) mode: 1.6 V ≤ V_{DD} ≤ 5.5 V@1 MHz to 4 MHz
- Note 8.** Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.
- Remark 1.** f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f_{HOCO}: High-speed on-chip oscillator clock frequency (64 MHz max.)
- Remark 3.** f_{IH}: High-speed on-chip oscillator clock frequency (32 MHz max.)
- Remark 4.** f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is TA = 25°C

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|--------------------|--|--|------|------|------|------|
| Low-speed on-chip oscillator operating current | IFIL Note 1 | | | | 0.2 | | μA |
| RTC operating current | IRTC Notes 1, 2, 3 | | | | 0.02 | | μA |
| 12-bit interval timer operating current | IIT Notes 1, 2, 4 | | | | 0.02 | | μA |
| Watchdog timer operating current | IWDT Notes 1, 2, 5 | fil = 15 kHz | | | 0.22 | | μA |
| A/D converter operating current | IADC Notes 1, 6 | When conversion at maximum speed | Normal mode, AVREFP = VDD = 5.0 V | | 1.3 | 1.7 | mA |
| | | | Low voltage mode, AVREFP = VDD = 3.0 V | | 0.5 | 0.7 | mA |
| A/D converter reference voltage current | IADREF Note 1 | | | | 75 | | μA |
| Temperature sensor operating current | ITMPS Note 1 | | | | 75 | | μA |
| D/A converter operating current | IDAC Notes 1, 11 | Per D/A converter channel | | | | 1.5 | mA |
| PGA operating current | | Operation | | | 480 | 700 | μA |
| Comparator operating current | ICMP Notes 1, 12 | Operation (per comparator channel, constant current for comparator included) | When the internal reference voltage is not in use | | 50 | 100 | μA |
| | | | When the internal reference voltage is in use | | 60 | 110 | μA |
| LVD operating current | ILVD Notes 1, 7 | | | | 0.08 | | μA |
| Self-programming operating current | IFSP Notes 1, 9 | | | | 2.5 | 12.2 | mA |
| BGO operating current | IBGO Notes 1, 8 | | | | 2.5 | 12.2 | mA |
| SNOOZE operating current | ISNOZ Note 1 | ADC operation | The mode is performed Note 10 | | 0.5 | 0.6 | mA |
| | | | The A/D conversion operations are performed, Low voltage mode, AVREFP = VDD = 3.0 V | | 1.2 | 1.44 | |
| | | CSI/JART operation | | 0.7 | 0.84 | | |
| | | DTC operation | | 3.1 | | | |

Note 1. Current flowing to VDD.

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

Note 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 IDD1 or IDD2, and IRTC, when the real-time clock operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added. IDD2 subsystem clock operation includes the operational current of the real-time clock.

Note 4. Current flowing only to the 12-bit interval timer (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 IDD1 or IDD2, and IIT, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.

Note 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 IDD1, IDD2 or IDD3 and IWDT when the watchdog timer is in operation.

Note 6. Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IADC when the A/D converter operates in an operation mode or the HALT mode.

Note 7. Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and ILVD when the LVD circuit is in operation.

Note 8. Current flowing during programming of the data flash.

Note 9. Current flowing during self-programming.

Note 10. For shift time to the SNOOZE mode, see **26.3.3 SNOOZE mode** in the RL78/G1F User's Manual.

- Note 11.** Current flowing only to the D/A converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IDAC when the D/A converter operates in an operation mode or the HALT mode.
- Note 12.** Current flowing only to the comparator circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2, or IDD3 and ICMP when the comparator circuit is in operation.
- Remark 1.** f_{IL}: Low-speed on-chip oscillator clock frequency
- Remark 2.** f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 3.** f_{CLK}: CPU/peripheral hardware clock frequency
- Remark 4.** Temperature condition of the TYP. value is TA = 25°C

2.4 AC Characteristics

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | | |
|---|--------------|-------------------------------------|----------------------------------|-----------------------|---------------------|---------|------|------|----|
| Instruction cycle (minimum instruction execution time) | Tcy | Main system clock (fMAIN) operation | HS (high-speed main) mode | 2.7 V ≤ VDD ≤ 5.5 V | 0.03125 | | 1 | μs | |
| | | | | 2.4 V ≤ VDD < 2.7 V | 0.0625 | | 1 | μs | |
| | | | LS (low-speed main) mode | 1.8 V ≤ VDD ≤ 5.5 V | 0.125 | | 1 | μs | |
| | | | LV (low-voltage main) mode | 1.6 V ≤ VDD ≤ 5.5 V | 0.25 | | 1 | μs | |
| | | | Subsystem clock (fSUB) operation | | 1.8 V ≤ VDD ≤ 5.5 V | 28.5 | 30.5 | 31.3 | μs |
| | | In the self-programming mode | HS (high-speed main) mode | | 2.7 V ≤ VDD ≤ 5.5 V | 0.03125 | | 1 | μs |
| | | | | | 2.4 V ≤ VDD < 2.7 V | 0.0625 | | 1 | μs |
| | | | LS (low-speed main) mode | | 1.8 V ≤ VDD ≤ 5.5 V | 0.125 | | 1 | μs |
| LV (low-voltage main) mode | | | 1.8 V ≤ VDD ≤ 5.5 V | 0.25 | | 1 | μs | | |
| External system clock frequency | fex | 2.7 V ≤ VDD ≤ 5.5 V | | | | 20.0 | MHz | | |
| | | 2.4 V ≤ VDD ≤ 2.7 V | | | | 16.0 | MHz | | |
| | | 1.8 V ≤ VDD < 2.4 V | | | | 8.0 | MHz | | |
| | | 1.6 V ≤ VDD < 1.8 V | | | | 4.0 | MHz | | |
| | fexs | | | | | 35 | kHz | | |
| External system clock input high-level width, low-level width | texH, texL | 2.7 V ≤ VDD ≤ 5.5 V | | | 24 | | ns | | |
| | | 2.4 V ≤ VDD ≤ 2.7 V | | | 30 | | ns | | |
| | | 1.8 V ≤ VDD < 2.4 V | | | 60 | | ns | | |
| | | 1.6 V ≤ VDD < 1.8 V | | | 120 | | ns | | |
| | texHS, texLS | | | | 13.7 | | μs | | |
| Ti00 to Ti03 input high-level width, low-level width | tTiH, tTiL | | | | 1/fMCK + 10 | | ns | | |
| Timer RJ input cycle | fc | TRJIO | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 100 | | ns | | |
| | | | | 1.8 V ≤ EVDD0 < 2.7 V | 300 | | ns | | |
| | | | | 1.6 V ≤ EVDD0 < 1.8 V | 500 | | ns | | |
| Timer RJ input high-level width, low-level width | tTjIH, tTjIL | TRJIO | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 40 | | ns | | |
| | | | | 1.8 V ≤ EVDD0 < 2.7 V | 120 | | ns | | |
| | | | | 1.6 V ≤ EVDD0 < 1.8 V | 200 | | ns | | |

Note The following conditions are required for low voltage interface when EVDD0 < VDD

1.8 V ≤ EVDD0 < 2.7 V: MIN. 125 ns

1.6 V ≤ EVDD0 < 1.8 V: MIN. 250 ns

Remark fMCK: Timer array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3))

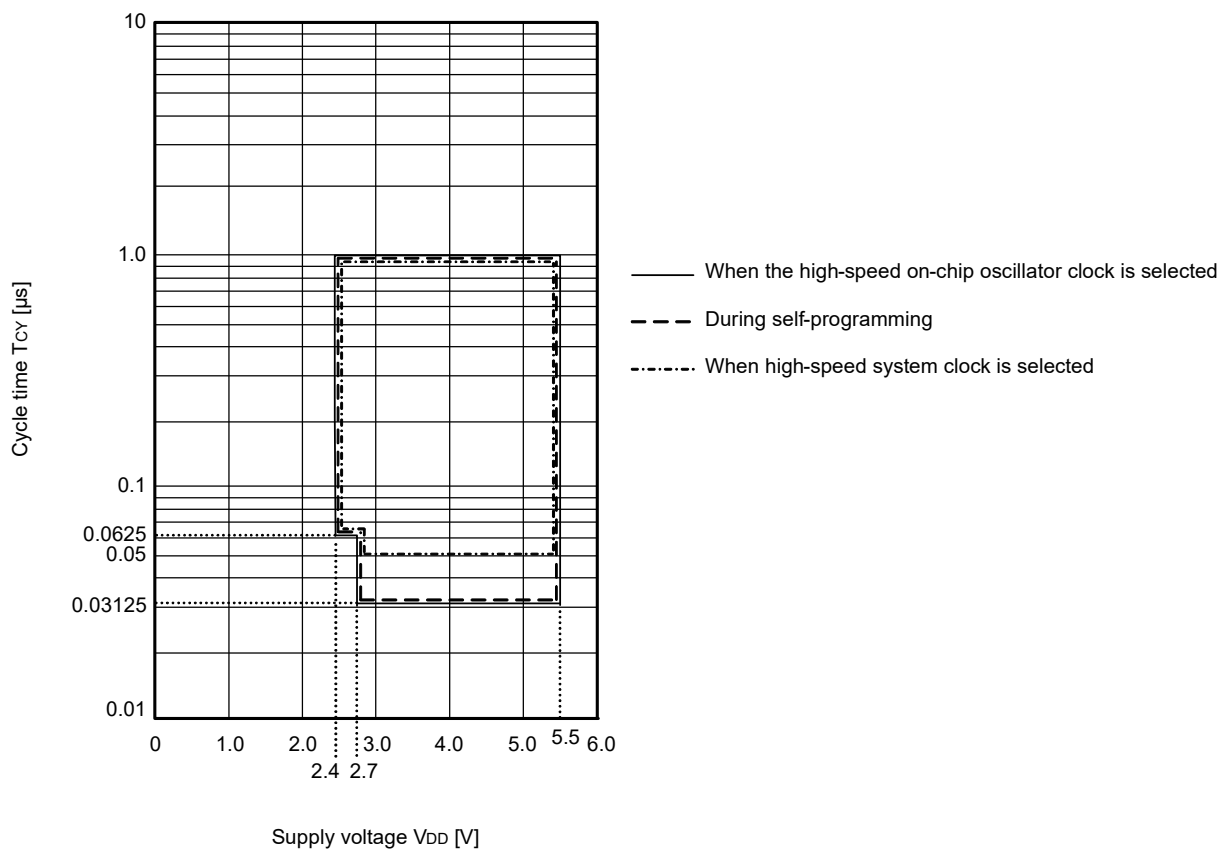
(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/2)

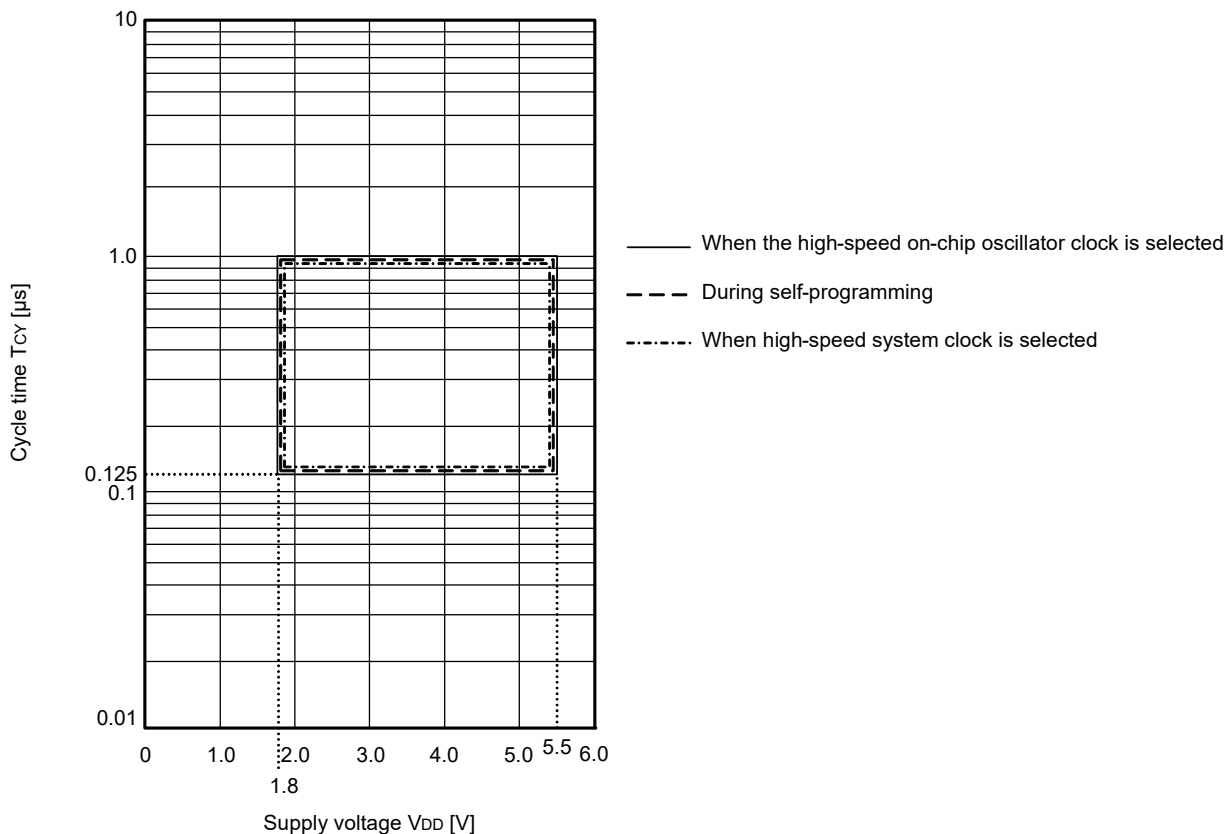
| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|-----------------------|---|-----------------------|------------|------|------|------|
| Timer RD input high-level width, low-level width | tTDIH, tTDIL | TRDIOA0, TRDIOA1, TRDIOB0, TRDIOB1, TRDIOC0, TRDIOC1, TRDIOD0, TRDIOD1 | | 3/fCLK | | | ns |
| Timer RD forced cutoff signal input low-level width | tTDSIL | P130/INTP0 | 2MHz < fCLK ≤ 32 MHz | 1 | | | μs |
| | | | fCLK ≤ 2 MHz | 1/fCLK + 1 | | | |
| Timer RG input high-level width, low-level width | tTGIH, tTGIL | TRGIOA, TRGIOB | | 2.5/fCLK | | | ns |
| TO00 to TO03, TRJIO0, TRJO0, TRDIOA0, TRDIOA1, TRDIOB0, TRDIOB1, TRDIOC0, TRDIOC1, TRDIOD0, TRDIOD1, TRGIOA, TRGIOB output frequency | fTO | HS (high-speed main) mode | 4.0 V ≤ EVDD0 ≤ 5.5 V | | | 16 | MHz |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | | 8 | MHz |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | | 4 | MHz |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | | 2 | MHz |
| | | LS (low-speed main) mode | 1.8 V ≤ EVDD0 ≤ 5.5 V | | | 4 | MHz |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | | 2 | MHz |
| LV (low-voltage main) mode | 1.6 V ≤ EVDD0 ≤ 5.5 V | | | 2 | MHz | | |
| PCLBUZ0, PCLBUZ1 output frequency | fPCL | HS (high-speed main) mode | 4.0 V ≤ EVDD0 ≤ 5.5 V | | | 16 | MHz |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | | 8 | MHz |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | | 4 | MHz |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | | 2 | MHz |
| | | LS (low-speed main) mode | 1.8 V ≤ EVDD0 ≤ 5.5 V | | | 4 | MHz |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | | 2 | MHz |
| | | LV (low-voltage main) mode | 1.8 V ≤ EVDD0 ≤ 5.5 V | | | 4 | MHz |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | | | 2 | MHz |
| Interrupt input high-level width, low-level width | tINTH, tINTL | INTP0 | 1.6 V ≤ VDD ≤ 5.5 V | 1 | | | μs |
| | | INTP1 to INTP11 | 1.6 V ≤ EVDD0 ≤ 5.5 V | 1 | | | μs |
| Key interrupt input low-level width | tKR | KR0 to KR7 | 1.8 V ≤ EVDD0 ≤ 5.5 V | 250 | | | ns |
| | | | 1.6 V ≤ EVDD0 < 1.8 V | 1 | | | μs |
| RESET low-level width | tRSL | | | 10 | | | μs |

Minimum Instruction Execution Time during Main System Clock Operation

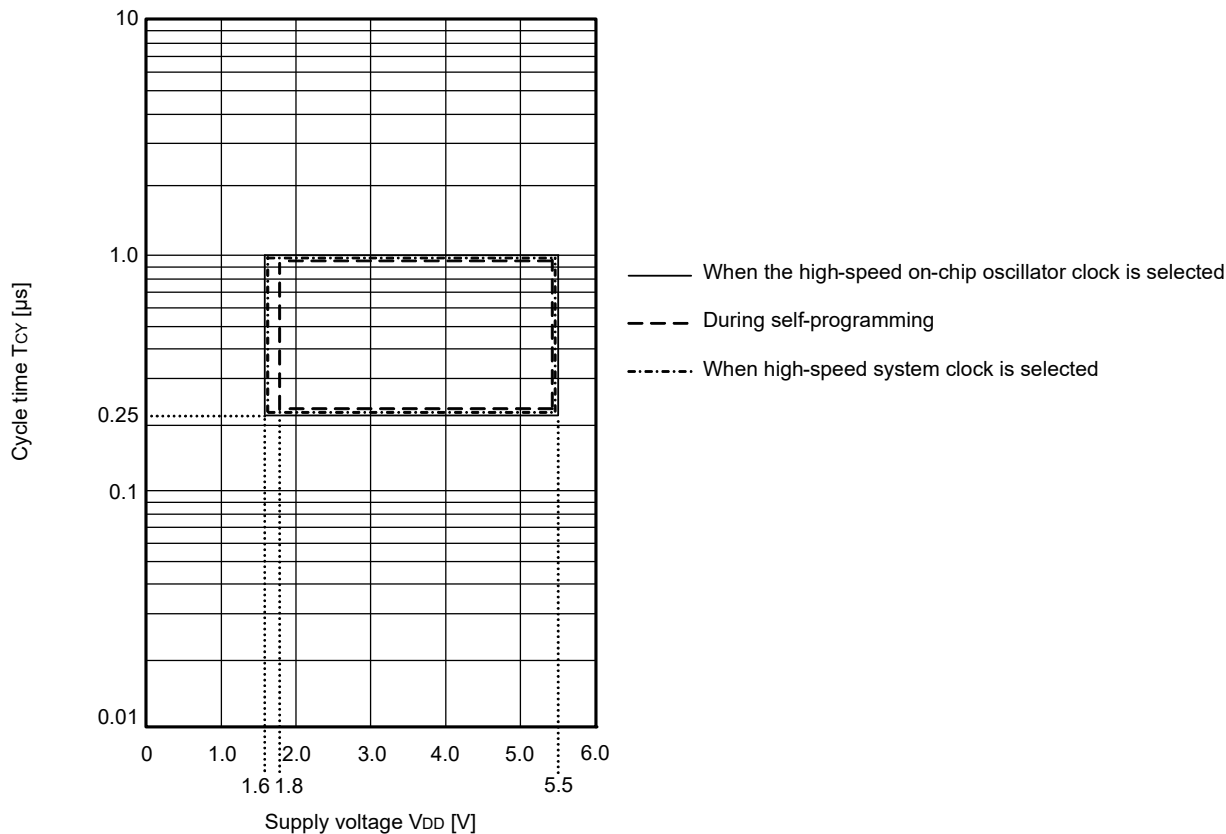
T_{cy} vs V_{DD} (HS (high-speed main) mode)



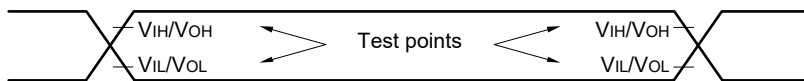
T_{CY} vs V_{DD} (LS (low-speed main) mode)



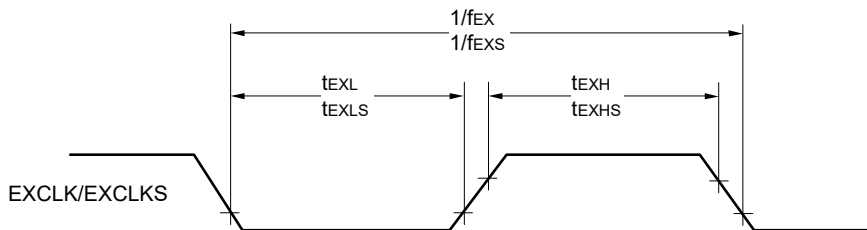
T_{CY} vs V_{DD} (LV (low-voltage main) mode)



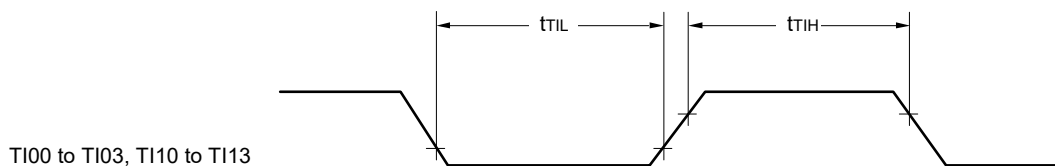
AC Timing Test Points



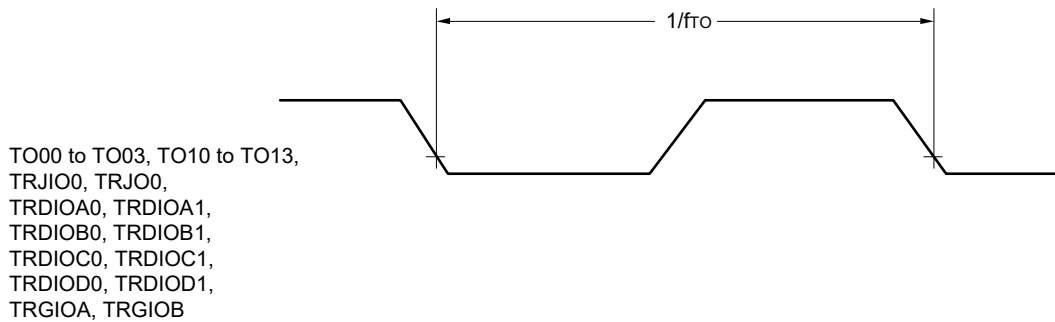
External System Clock Timing



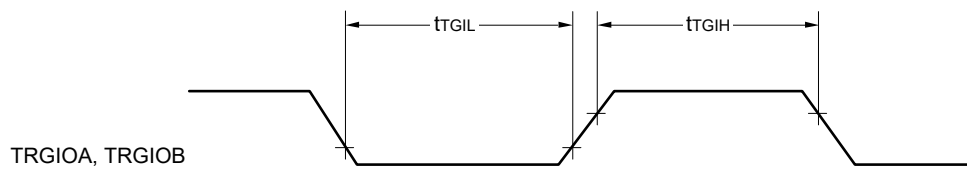
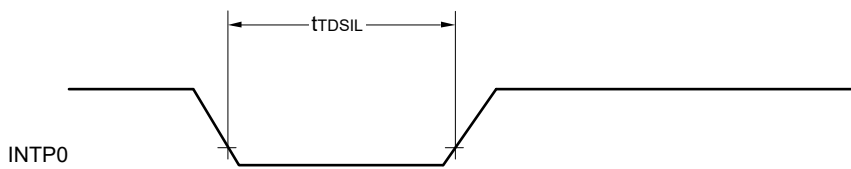
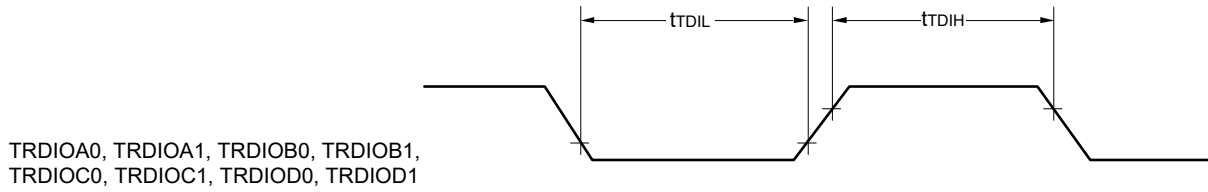
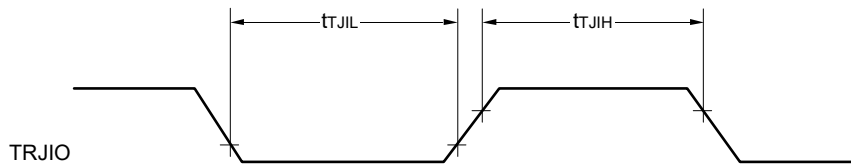
TI/TO Timing



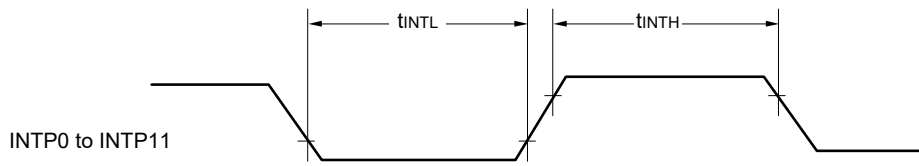
TI00 to TI03, TI10 to TI13



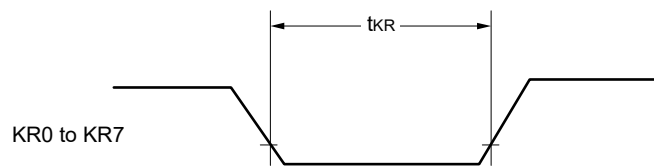
TO00 to TO03, TO10 to TO13,
 TRJIO0, TRJO0,
 TRDIOA0, TRDIOA1,
 TRDIOB0, TRDIOB1,
 TRDIOC0, TRDIOC1,
 TRDIOD0, TRDIOD1,
 TRGIOA, TRGIOB



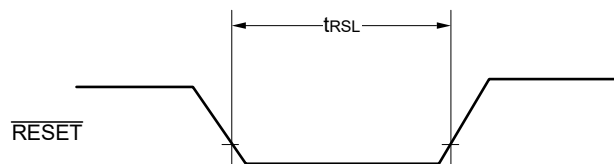
Interrupt Request Input Timing



Key Interrupt Input Timing

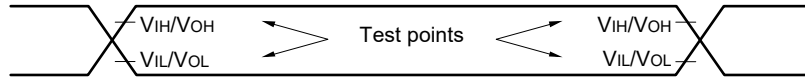


$\overline{\text{RESET}}$ Input Timing



2.5 Peripheral Functions Characteristics

AC Timing Test Points



2.5.1 Serial array unit

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

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | LV (low-voltage main) Mode | | Unit |
|-------------------------|--------|--|---------------------------|---------------|--------------------------|---------------|----------------------------|--------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Transfer rate Note 1 | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | fMCK/6 Note 2 | | fMCK/6 | | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 3 | | 5.3 | | 1.3 | | 0.6 | Mbps |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | | fMCK/6 Note 2 | | fMCK/6 | | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 3 | | 5.3 | | 1.3 | | 0.6 | Mbps |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | | fMCK/6 Note 2 | | fMCK/6 Note 2 | | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 3 | | 5.3 | | 1.3 | | 0.6 | Mbps |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | | — | | fMCK/6 Note 2 | | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 3 | | — | | 1.3 | | 0.6 | Mbps |

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

However, the SNOOZE mode cannot be used when FRQSEL4 = 1.

Note 2. The following conditions are required for low voltage interface when EVDD0 < VDD.

2.4 V ≤ EVDD0 < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ EVDD0 < 2.4 V: MAX. 1.3 Mbps

1.6 V ≤ EVDD0 < 1.8 V: MAX. 0.6 Mbps

Note 3. The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

HS (high-speed main) mode: 32 MHz (2.7 V ≤ VDD ≤ 5.5 V)

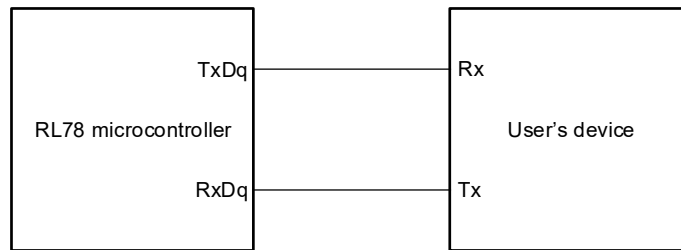
16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

LS (low-speed main) mode: 8 MHz (1.8 V ≤ VDD ≤ 5.5 V)

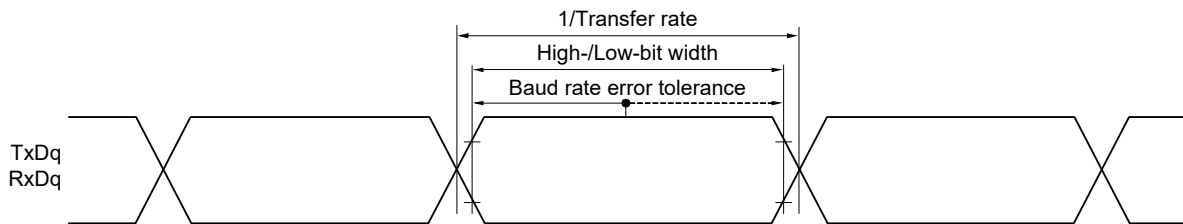
LV (low-voltage main) mode: 4 MHz (1.6 V ≤ VDD ≤ 5.5 V)

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)



Remark 1. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 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, 10, 11))

(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)**(TA = -40 to +85°C, 2.7 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---|---------------|---|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 2/fCLK 4.0 V ≤ EVDD0 ≤ 5.5 V | 62.5 | | 250 | | 500 | | ns |
| | | | 83.3 | | 250 | | 500 | | ns |
| SCKp high-/low-level width | tkH1, tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 7 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 10 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| Slp setup time (to SCKp↑) Note 1 | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | 23 | | 110 | | 110 | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 33 | | 110 | | 110 | | ns |
| Slp hold time (from SCKp↑) Note 2 | tsIH1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp↓ to SOp output Note 3 | tkSO1 | C = 20 pF Note 4 | | 10 | | 10 | | 10 | ns |

- Note 1.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 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.
- Note 4.** C is the load capacitance of the SCKp and SOp output lines.

Caution Select the normal input buffer for the Slp 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).

Remark 1. This value is valid only when CSI00's peripheral I/O redirect function is not used.

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

Remark 3. fMCK: 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) (master mode, SCKp... internal clock output)
(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|--|---------------|---|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 4/fCLK | 2.7 V ≤ EVDD0 ≤ 5.5 V | 125 | | 500 | | 1000 | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 250 | | 500 | | 1000 | ns |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 500 | | 500 | | 1000 | ns |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 1000 | | 1000 | | 1000 | ns |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 1000 | | 1000 | ns |
| SCKp high-/low-level width | tkH1, tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 12 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | ns | |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 18 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | ns | |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 38 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | ns | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 50 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | ns | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 100 | | tkCY1/2 - 100 | | tkCY1/2 - 100 | ns | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | tkCY1/2 - 100 | | tkCY1/2 - 100 | ns | |
| Slp setup time (to SCKp↑) Note 1 | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | 44 | | 110 | | 110 | ns | |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 44 | | 110 | | 110 | ns | |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 75 | | 110 | | 110 | ns | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 110 | | 110 | | 110 | ns | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 220 | | 220 | | 220 | ns | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 220 | | 220 | ns | |
| Slp hold time (from SCKp↑) Note 2 | tkSI1 | 1.7 V ≤ EVDD0 ≤ 5.5 V | 19 | | 19 | | 19 | ns | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 19 | | 19 | ns | |
| Delay time from SCKp↓ to SOp output Note 3 | tkSO1 | 1.7 V ≤ EVDD0 ≤ 5.5 V C = 30 pF Note 4 | | 25 | | 25 | 25 | ns | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V C = 30 pF Note 4 | | — | | 25 | 25 | ns | |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 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.

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

Caution Select the normal input buffer for the Slp 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).

Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1, 3, 5, 7)

Remark 2. fMCK: 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, 10, 11))

(4) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)
(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|--|------------|-----------------------|-----------------------|---------------------------|-----------------|--------------------------|-----------------|----------------------------|------|------|
| | | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time Note 5 | tkCY2 | 4.0 V ≤ EVDD0 ≤ 5.5 V | 20 MHz < fMCK | 8/fMCK | — | — | — | — | ns | |
| | | | fMCK ≤ 20 MHz | 6/fMCK | — | 6/fMCK | 6/fMCK | ns | | |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 16 MHz < fMCK | 8/fMCK | — | — | — | ns | | |
| | | | fMCK ≤ 16 MHz | 6/fMCK | — | 6/fMCK | 6/fMCK | ns | | |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | 6/fMCK and 500 | 6/fMCK and 500 | 6/fMCK and 500 | 6/fMCK and 500 | ns | | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | | 6/fMCK and 750 | 6/fMCK and 750 | 6/fMCK and 750 | 6/fMCK and 750 | ns | | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | | 6/fMCK and 1500 | 6/fMCK and 1500 | 6/fMCK and 1500 | 6/fMCK and 1500 | ns | | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | | — | 6/fMCK and 1500 | 6/fMCK and 1500 | 6/fMCK and 1500 | ns | | |
| SCKp high-/low-level width | tkH2, tkL2 | 4.0 V ≤ EVDD0 ≤ 5.5 V | | tkCY2/2 - 7 | tkCY2/2 - 7 | tkCY2/2 - 7 | tkCY2/2 - 7 | ns | | |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | | tkCY2/2 - 8 | tkCY2/2 - 8 | tkCY2/2 - 8 | tkCY2/2 - 8 | ns | | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | | tkCY2/2 - 18 | tkCY2/2 - 18 | tkCY2/2 - 18 | tkCY2/2 - 18 | ns | | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | | tkCY2/2 - 66 | tkCY2/2 - 66 | tkCY2/2 - 66 | tkCY2/2 - 66 | ns | | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | | — | tkCY2/2 - 66 | tkCY2/2 - 66 | tkCY2/2 - 66 | ns | | |
| Slp setup time (to SCKp↑) Note 1 | tsIK2 | 2.7 V ≤ EVDD0 ≤ 5.5 V | | 1/fMCK + 20 | 1/fMCK + 30 | 1/fMCK + 30 | 1/fMCK + 30 | ns | | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | | 1/fMCK + 30 | 1/fMCK + 30 | 1/fMCK + 30 | 1/fMCK + 30 | ns | | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | | 1/fMCK + 40 | 1/fMCK + 40 | 1/fMCK + 40 | 1/fMCK + 40 | ns | | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | | — | 1/fMCK + 40 | 1/fMCK + 40 | 1/fMCK + 40 | ns | | |
| Slp hold time (from SCKp↑) Note 2 | tkSI2 | 1.8 V ≤ EVDD0 ≤ 5.5 V | | 1/fMCK + 31 | 1/fMCK + 31 | 1/fMCK + 31 | 1/fMCK + 31 | ns | | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | | 1/fMCK + 250 | 1/fMCK + 250 | 1/fMCK + 250 | 1/fMCK + 250 | ns | | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | | — | 1/fMCK + 250 | 1/fMCK + 250 | 1/fMCK + 250 | ns | | |
| Delay time from SCKp↓ to SOp output Note 3 | tkSO2 | C = 30 pF Note 4 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 2/fMCK + 44 | 2/fMCK + 110 | 2/fMCK + 110 | 2/fMCK + 110 | ns | | |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 2/fMCK + 75 | 2/fMCK + 110 | 2/fMCK + 110 | 2/fMCK + 110 | ns | | |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 2/fMCK + 100 | 2/fMCK + 110 | 2/fMCK + 110 | 2/fMCK + 110 | ns | | |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 2/fMCK + 220 | 2/fMCK + 220 | 2/fMCK + 220 | 2/fMCK + 220 | ns | | |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | 2/fMCK + 220 | 2/fMCK + 220 | 2/fMCK + 220 | ns | | |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 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.

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

Note 5. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

Caution Select the normal input buffer for the Slp 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).

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- Remark 1.** p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1),
n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1, 3, 5, 7)
- Remark 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, 10, 11))

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

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

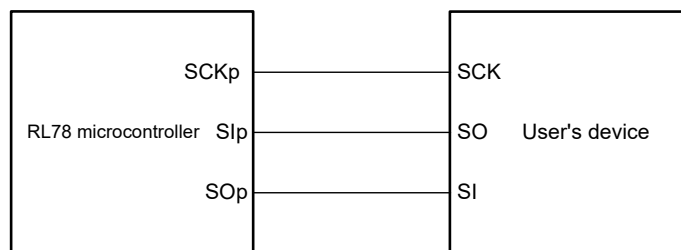
(2/2)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit | |
|------------------|--------|------------|---------------------------|--------------|--------------------------|--------------|----------------------------|--------------|------|----|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | | |
| SSI00 setup time | tSSIK | DAPmn = 0 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 120 | | 120 | | 120 | | ns |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 200 | | 200 | | 200 | | ns |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 400 | | 400 | | 400 | | ns |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 400 | | 400 | | ns |
| | | DAPmn = 1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 120 | | 1/fMCK + 120 | | 1/fMCK + 120 | | ns |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 200 | | 1/fMCK + 200 | | 1/fMCK + 200 | | ns |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 400 | | 1/fMCK + 400 | | 1/fMCK + 400 | | ns |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 1/fMCK + 400 | | 1/fMCK + 400 | | ns |
| SSI00 hold time | tkSSI | DAPmn = 0 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 120 | | 1/fMCK + 120 | | 1/fMCK + 120 | | ns |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 200 | | 1/fMCK + 200 | | 1/fMCK + 200 | | ns |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 400 | | 1/fMCK + 400 | | 1/fMCK + 400 | | ns |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 1/fMCK + 400 | | 1/fMCK + 400 | | ns |
| | | DAPmn = 1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 120 | | 120 | | 120 | | ns |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 200 | | 200 | | 200 | | ns |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 400 | | 400 | | 400 | | ns |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 400 | | 400 | | ns |

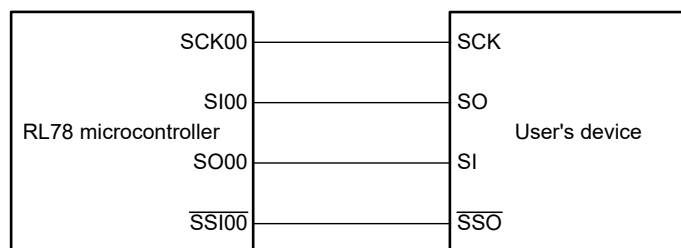
Caution Select the normal input buffer for the Slp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

Remark p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM number (g = 3, 5)

CSI mode connection diagram (during communication at same potential)



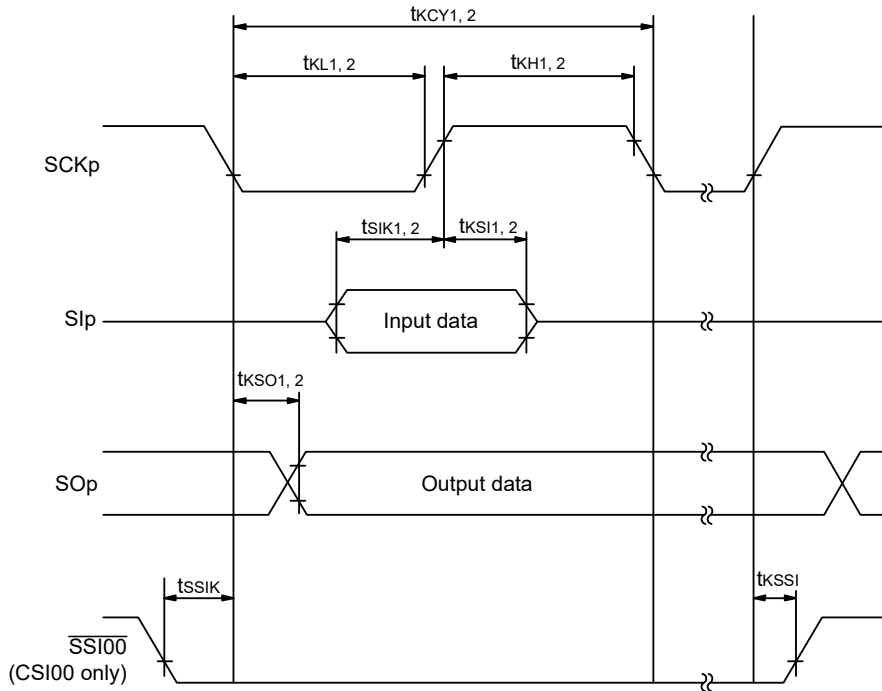
**CSI mode connection diagram (during communication at same potential)
(Slave Transmission of slave select input function (CSI00))**



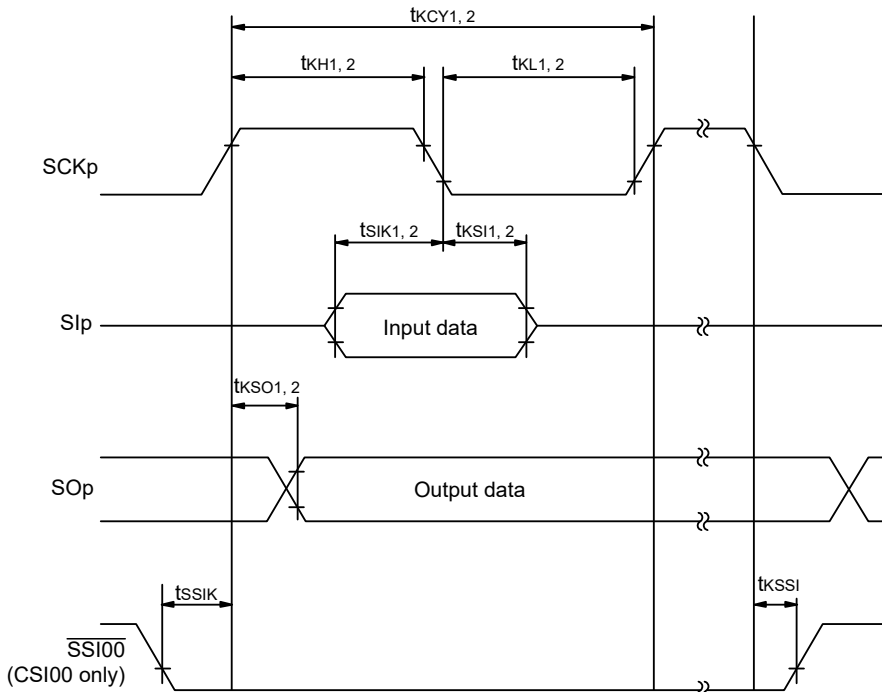
Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

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.)



Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

(5) During communication at same potential (simplified I²C mode)**(TA = -40 to +85°C, 1.6 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 0 V)****(1/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---------------------------|-------------------|---|---------------------------|-------------|--------------------------|------------|----------------------------|------------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCLr clock frequency | f _{SCL} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | | 1000 Note 1 | | 400 Note 1 | | 400 Note 1 | kHz |
| | | 1.8 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | | 400 Note 1 | | 400 Note 1 | | 400 Note 1 | kHz |
| | | 1.8 V ≤ EV _{DD0} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | | 300 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 1.7 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | | 250 Note 1 | | 250 Note 1 | | 250 Note 1 | kHz |
| | | 1.6 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | | — | | 250 Note 1 | | 250 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 475 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 1150 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ EV _{DD0} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1550 | | 1550 | | 1550 | | ns |
| | | 1.7 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | 1850 | | 1850 | | 1850 | | ns |
| | | 1.6 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | — | | 1850 | | 1850 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 475 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 1150 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ EV _{DD0} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1550 | | 1550 | | 1550 | | ns |
| | | 1.7 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | 1850 | | 1850 | | 1850 | | ns |
| | | 1.6 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | — | | 1850 | | 1850 | | ns |

(Notes and Caution are listed on the next page, and Remarks are listed on the page after the next page.)

(5) During communication at same potential (simplified I²C mode)**(TA = -40 to +85°C, 1.6 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|-------------------------------|-----------------------|--|---------------------------------|------|---------------------------------|------|---------------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Data setup time (reception) | tsu: DAT | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 85 Note 2 | | 1/f _{MCK} + 145 Note 2 | | 1/f _{MCK} + 145 Note 2 | | ns |
| | | 1.8 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 1/f _{MCK} + 145 Note 2 | | 1/f _{MCK} + 145 Note 2 | | 1/f _{MCK} + 145 Note 2 | | ns |
| | | 1.8 V ≤ EV _{DD0} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1/f _{MCK} + 230 Note 2 | | 1/f _{MCK} + 230 Note 2 | | 1/f _{MCK} + 230 Note 2 | | ns |
| | | 1.7 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | 1/f _{MCK} + 290 Note 2 | | 1/f _{MCK} + 290 Note 2 | | 1/f _{MCK} + 290 Note 2 | | ns |
| | | 1.6 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | — | | 1/f _{MCK} + 290 Note 2 | | 1/f _{MCK} + 290 Note 2 | | ns |
| Data hold time (transmission) | t _{HD} : DAT | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 0 | 305 | 0 | 305 | 0 | 305 | ns |
| | | 1.8 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 0 | 355 | 0 | 355 | 0 | 355 | ns |
| | | 1.8 V ≤ EV _{DD0} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 0 | 405 | 0 | 405 | 0 | 405 | ns |
| | | 1.7 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | 0 | 405 | 0 | 405 | 0 | 405 | ns |
| | | 1.6 V ≤ EV _{DD0} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | — | | 0 | 405 | 0 | 405 | ns |

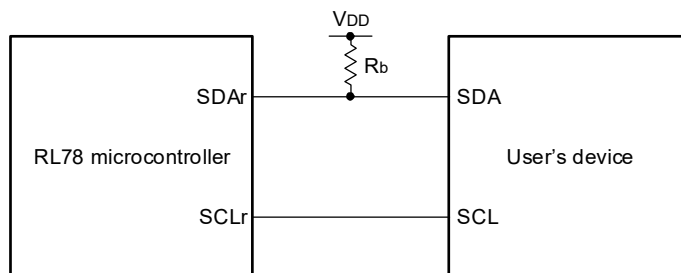
Note 1. The value must also be equal to or less than f_{MCK}/4.

Note 2. Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

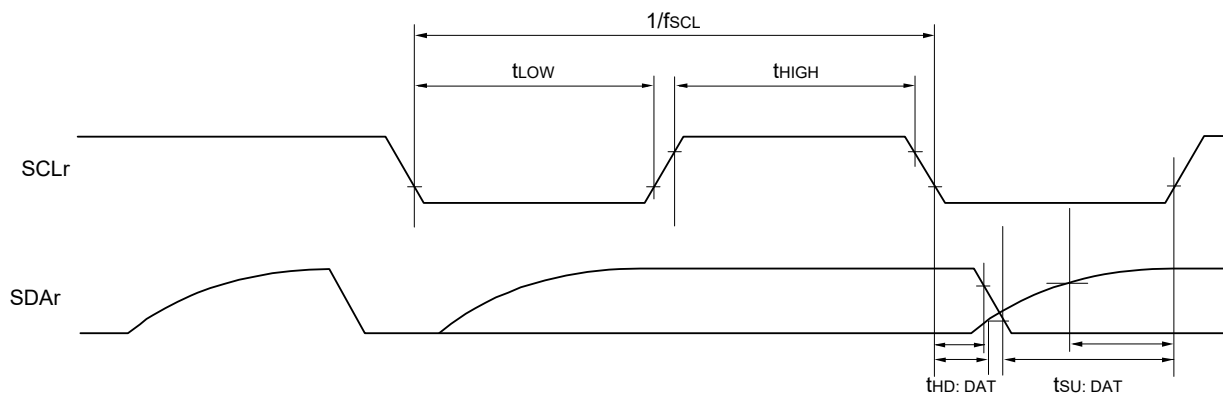
Caution Select the normal input buffer and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the SDAr pin and the normal output mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register h (POMh).

(Remarks are listed on the next page.)

Simplified I²C mode connection diagram (during communication at same potential)



Simplified I²C mode serial transfer timing (during communication at same potential)



Remark 1. R_b[Ω]: Communication line (SDAr) pull-up resistance, C_b[F]: Communication line (SDAr, SCLr) load capacitance

Remark 2. r: IIC number (r = 00, 01, 10, 11, 20, 21), g: PIM number (g = 0, 1, 3, 5, 7),
h: POM number (h = 0, 1, 3, 5, 7)

Remark 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 (m = 0, 1),
n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11)

(6) Communication at different potential (1.8 V, 2.5 V, 3 V) (UART mode)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit | |
|---------------|--------|------------|--|------|--------------------------|------|----------------------------|------|----------------------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | | |
| Transfer rate | | reception | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | | fMCK/6 Note 1 | | fMCK/6 Note 1 | | fMCK/6 Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 4 | | 5.3 | | 1.3 | | 0.6 | Mbps |
| | | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | | fMCK/6 Note 1 | | fMCK/6 Note 1 | | fMCK/6 Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 4 | | 5.3 | | 1.3 | | 0.6 | Mbps |
| | | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | | fMCK/6 Notes 1, 2, 3 | | fMCK/6 Notes 1, 2 | | fMCK/6 Notes 1, 2 | bps |
| | | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 4 | | 5.3 | | 1.3 | | 0.6 | Mbps |

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

However, the SNOOZE mode cannot be used when FRQSEL4 = 1.

Note 2. Use it with EVDD0 ≥ Vb.

Note 3. The following conditions are required for low voltage interface when EVDD0 < VDD.

2.4 V ≤ EVDD0 < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ EVDD0 < 2.4 V: MAX. 1.3 Mbps

Note 4. The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

HS (high-speed main) mode: 32 MHz (2.7 V ≤ VDD ≤ 5.5 V)

16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

LS (low-speed main) mode: 8 MHz (1.8 V ≤ VDD ≤ 5.5 V)

LV (low-voltage main) mode: 4 MHz (1.6 V ≤ VDD ≤ 5.5 V)

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

Remark 1. Vb [V]: Communication line voltage

Remark 2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 5, 7)

Remark 3. fMCK: 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, 10, 11)

Remark 4. UART2 cannot communicate at different potential when bit 1 (PIOR01) of peripheral I/O redirection register 0 (PIOR0) is 1.

(6) Communication at different potential (1.8 V, 2.5 V, 3 V) (UART mode)

(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/2)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit | |
|---------------|--------|--------------|--|------|--------------------------|------|----------------------------|------|-------------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | | |
| Transfer rate | | transmission | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | | Note 1 | | Note 1 | | Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 1.4 kΩ, Vb = 2.7 V | | 2.8 Note 2 | | 2.8 Note 2 | | 2.8 Note 2 | Mbps |
| | | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | | Note 3 | | Note 3 | | Note 3 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 2.7 kΩ, Vb = 2.3 V | | 1.2 Note 4 | | 1.2 Note 4 | | 1.2 Note 4 | Mbps |
| | | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | | Notes 5, 6 | | Notes 5, 6 | | Notes 5, 6 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 5.5 kΩ, Vb = 1.6 V | | 0.43 Note 7 | | 0.43 Note 7 | | 0.43 Note 7 | Mbps |

Note 1. The smaller maximum transfer rate derived by using fmCK/6 or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when 4.0 V ≤ EVDD0 ≤ 5.5 V and 2.7 V ≤ Vb ≤ 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.

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

Note 3. The smaller maximum transfer rate derived by using fmCK/6 or the following expression is the valid maximum transfer rate.

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

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

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

Expression for calculating the transfer rate when 2.7 V ≤ EVDD0 < 4.0 V and 2.3 V ≤ Vb ≤ 2.7 V

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

Note 5. Use it with EVDD0 ≥ Vb.

Note 6. 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 $1.8\text{ V} \leq \text{EV}_{DD} < 3.3\text{ V}$ and $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{\left(\frac{1}{\text{Transfer rate}}\right) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

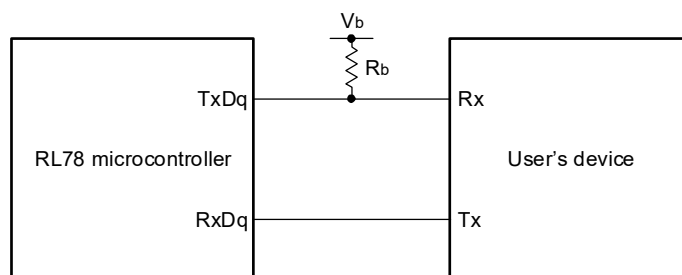
* This value is the theoretical value of the relative difference between the transmission and reception sides.

Note 7. This value as an example is calculated when the conditions described in the "Conditions" column are met. Refer to **Note 6** above to calculate the maximum transfer rate under conditions of the customer.

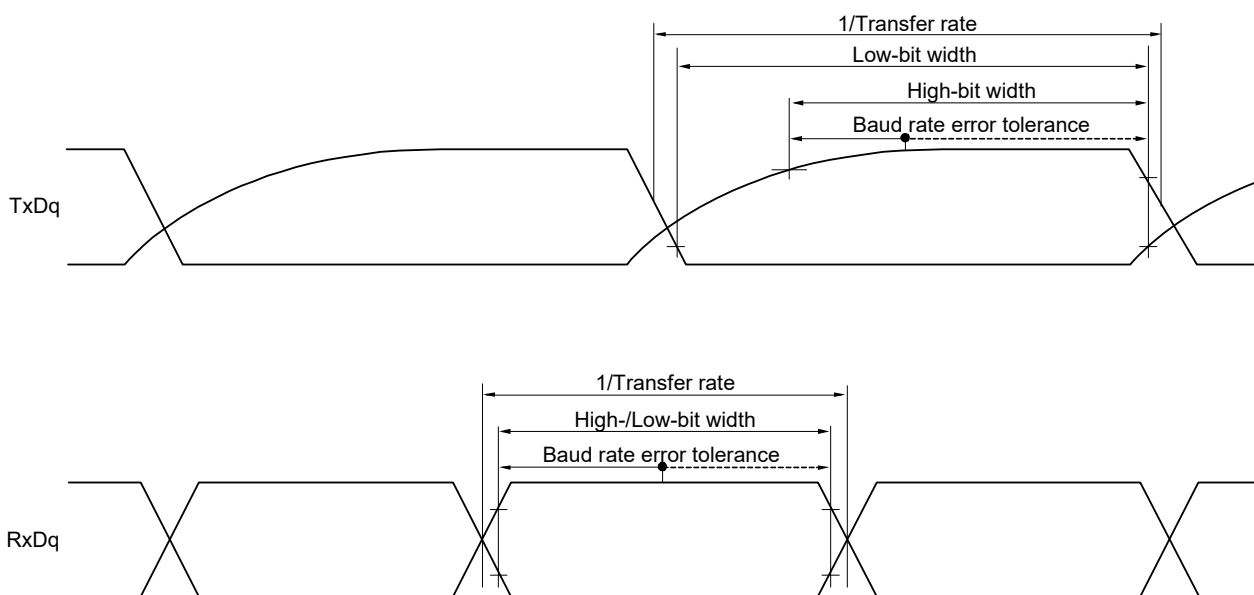
Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

UART mode connection diagram (during communication at different potential)



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



- Remark 1.** $R_b[\Omega]$: Communication line (TxDq) pull-up resistance,
 $C_b[F]$: Communication line (TxDq) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 5, 7)
- Remark 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, 10, 11))
- Remark 4.** UART2 cannot communicate at different potential when bit 1 (PIOR01) of peripheral I/O redirection register 0 (PIOR0) is 1.

(7) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

(TA = -40 to +85°C, 2.7 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|--|--------|--|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 2/fCLK 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | 200 | | 1150 | | 1150 | | ns |
| | | | 300 | | 1150 | | 1150 | | ns |
| SCKp high-level width | tkH1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | tkCY1/2 - 50 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | tkCY1/2 - 120 | | tkCY1/2 - 120 | | tkCY1/2 - 120 | | ns |
| SCKp low-level width | tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | tkCY1/2 - 7 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | tkCY1/2 - 10 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| Slp setup time (to SCKp↑) Note 1 | tSIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | 58 | | 479 | | 479 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | 121 | | 479 | | 479 | | ns |
| Slp hold time (from SCKp↑) Note 1 | tKSI1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | 10 | | 10 | | 10 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp↓ to SOP out- put Note 1 | tkSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | | 60 | | 60 | | 60 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | | 130 | | 130 | | 130 | ns |

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

(7) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)**(TA = -40 to +85°C, 2.7 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---|--------|--|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Slp setup time (to SCKp↓) Note 2 | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | 23 | | 110 | | 110 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | 33 | | 110 | | 110 | | ns |
| Slp hold time (from SCKp↓) Note 2 | tKSI1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | 10 | | 10 | | 10 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp↑ to SOp output Note 2 | tKSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ | | 10 | | 10 | | 10 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ | | 10 | | 10 | | 10 | ns |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.

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

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

Remark 1. Rb[Ω]: Communication line (SCKp, SOp) pull-up resistance, Cb[F]: Communication line (SCKp, SOp) load capacitance, Vb[V]: Communication line voltage

Remark 2. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 3, 5)

Remark 3. fMCK: 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))

Remark 4. This value is valid only when CSI00's peripheral I/O redirect function is not used.

(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(1/3)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|-----------------------|--------|--|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 4/fCLK 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 300 | | 1150 | | 1150 | | ns |
| | | | 500 | | 1150 | | 1150 | | ns |
| | | | 1150 | | 1150 | | 1150 | | ns |
| SCKp high-level width | tkH1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | tkCY1/2 - 75 | | tkCY1/2 - 75 | | tkCY1/2 - 75 | | ns |
| | | | tkCY1/2 - 170 | | tkCY1/2 - 170 | | tkCY1/2 - 170 | | ns |
| | | | tkCY1/2 - 458 | | tkCY1/2 - 458 | | tkCY1/2 - 458 | | ns |
| SCKp low-level width | tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | tkCY1/2 - 12 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| | | | tkCY1/2 - 18 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |
| | | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | tkCY1/2 - 50 | | ns |

Note Use it with EVDD0 ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed two pages after the next page.)

(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/3)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---|--------|---|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Slp setup time (to SCKp↑) Note 1 | tSIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 81 | | 479 | | 479 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 177 | | 479 | | 479 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | 479 | | 479 | | 479 | | ns |
| Slp hold time (from SCKp↑) Note 1 | tKSI1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 19 | | 19 | | 19 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 19 | | 19 | | 19 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | 19 | | 19 | | 19 | | ns |
| Delay time from SCKp↓ to SOp output Note 1 | tKSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 100 | | 100 | | 100 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 195 | | 195 | | 195 | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | | 483 | | 483 | | 483 | ns |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.**Note 2.** Use it with EVDD0 ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the page after the next page.)

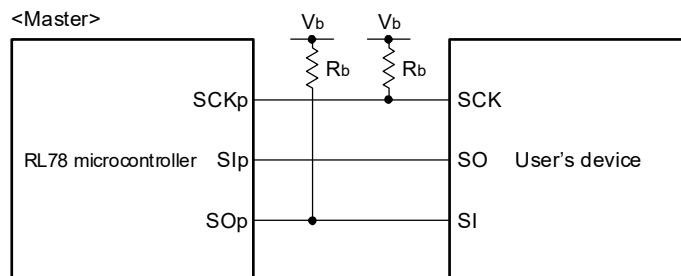
(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(3/3)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---|--------|---|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Slp setup time (to SCKp↓) Note 1 | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 44 | | 110 | | 110 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 44 | | 110 | | 110 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | 110 | | 110 | | 110 | | ns |
| Slp hold time (from SCKp↓) Note 1 | tkSI1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 19 | | 19 | | 19 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 19 | | 19 | | 19 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | 19 | | 19 | | 19 | | ns |
| Delay time from SCKp↑ to SOp output Note 1 | tkSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 25 | | 25 | | 25 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 25 | | 25 | | 25 | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rb = 5.5 kΩ | | 25 | | 25 | | 25 | ns |

Note 1. When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Note 2.** Use it with EVDD0 ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

CSI mode connection diagram (during communication at different potential)

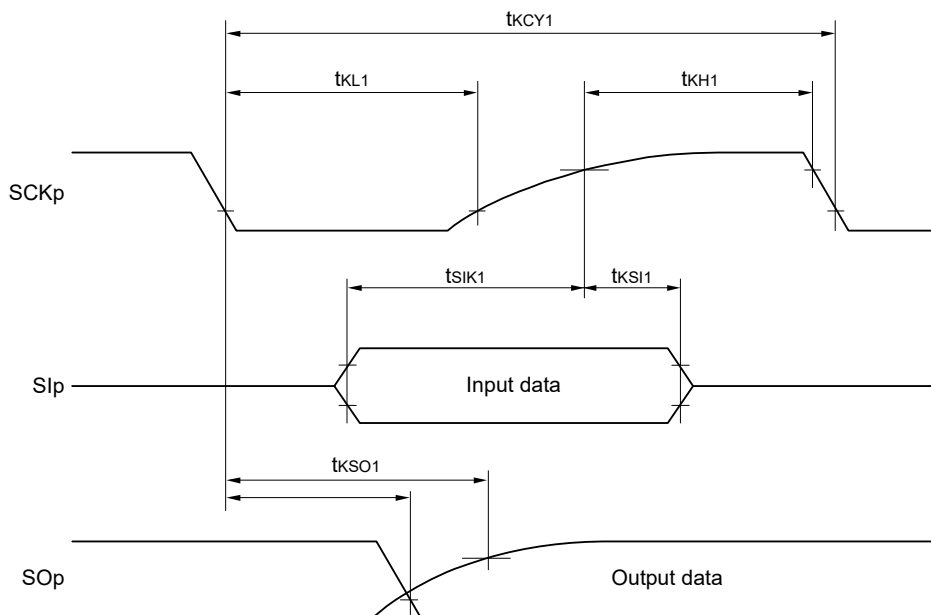
Remark 1. R_b[Ω]: Communication line (SCK_p, SOp) pull-up resistance, C_b[F]: Communication line (SCK_p, SOp) load capacitance, V_b[V]: Communication line voltage

Remark 2. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 5, 7)

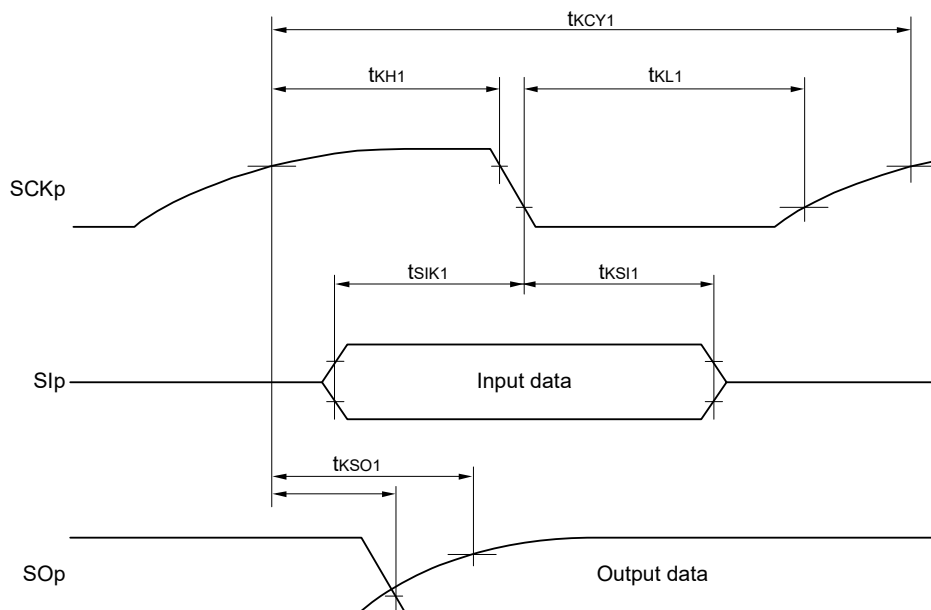
Remark 3. f_{MCK}: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))

Remark 4. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

**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.)**



Remark 1. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 2. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

(9) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (slave mode, SCKp... external clock input)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

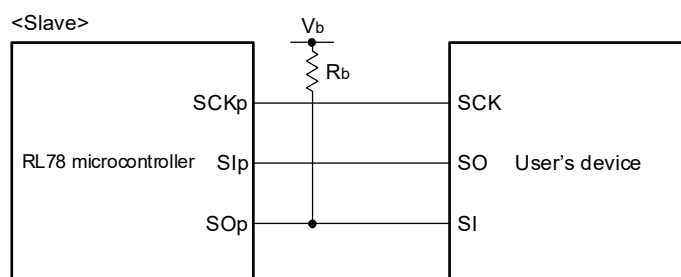
| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|--|---------------|--|---------------------------|-----------------|--------------------------|-----------------|----------------------------|-----------------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCKp cycle time Note 1 | tkcy2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | 24 MHz < fmck | 14/fmck | — | — | — | — | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 12/fmck | — | — | — | — | ns |
| | | | 8 MHz < fmck ≤ 20 MHz | 10/fmck | — | — | — | — | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 8/fmck | — | 16/fmck | — | — | ns |
| | | | fmck ≤ 4 MHz | 6/fmck | — | 10/fmck | 10/fmck | — | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | 24 MHz < fmck | 20/fmck | — | — | — | — | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 16/fmck | — | — | — | — | ns |
| | | | 16 MHz < fmck ≤ 20 MHz | 14/fmck | — | — | — | — | ns |
| | | | 8 MHz < fmck ≤ 16 MHz | 12/fmck | — | — | — | — | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 8/fmck | — | 16/fmck | — | — | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2 | 24 MHz < fmck | 48/fmck | — | — | — | — | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 36/fmck | — | — | — | — | ns |
| | | | 16 MHz < fmck ≤ 20 MHz | 32/fmck | — | — | — | — | ns |
| | | | 8 MHz < fmck ≤ 16 MHz | 26/fmck | — | — | — | — | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 16/fmck | — | 16/fmck | — | — | ns |
| | | fmck ≤ 4 MHz | 10/fmck | — | 10/fmck | 10/fmck | — | ns | |
| | | | 10/fmck | — | 10/fmck | 10/fmck | — | ns | |
| | | | 10/fmck | — | 10/fmck | 10/fmck | — | ns | |
| | | | 10/fmck | — | 10/fmck | 10/fmck | — | ns | |
| | | | 10/fmck | — | 10/fmck | 10/fmck | — | ns | |
| SCKp high-/low-level width | tkH2, tkL2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | tkcy2/2 - 12 | — | tkcy2/2 - 50 | — | tkcy2/2 - 50 | — | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | tkcy2/2 - 18 | — | tkcy2/2 - 50 | — | tkcy2/2 - 50 | — | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2 | tkcy2/2 - 50 | — | tkcy2/2 - 50 | — | tkcy2/2 - 50 | — | ns |
| Slp setup time (to SCKp↑) Note 3 | tsik2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | 1/fmck + 20 | — | 1/fmck + 30 | — | 1/fmck + 30 | — | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | 1/fmck + 20 | — | 1/fmck + 30 | — | 1/fmck + 30 | — | ns |
| | | 1.8 V ≤ EVDD0 ≤ 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2 | 1/fmck + 30 | — | 1/fmck + 30 | — | 1/fmck + 30 | — | ns |
| Slp hold time (from SCKp↑) Note 4 | tksl2 | | 1/fmck + 31 | — | 1/fmck + 31 | — | 1/fmck + 31 | — | ns |
| Delay time from SCKp↓ to SOp output Note 5 | tkso2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | — | 2/fmck + 120 | — | 2/fmck + 573 | — | 2/fmck + 573 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | — | 2/fmck + 214 | — | 2/fmck + 573 | — | 2/fmck + 573 | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 30 pF, Rv = 5.5 kΩ | — | 2/fmck + 573 | — | 2/fmck + 573 | — | 2/fmck + 573 | ns |

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

- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** Use it with $EV_{DD0} \geq V_b$.
- Note 3.** When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The S_{lp} setup time becomes “to $SCK_{p\downarrow}$ ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.
- Note 4.** When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The S_{lp} hold time becomes “from $SCK_{p\downarrow}$ ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.
- Note 5.** When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The delay time to S_{Op} output becomes “from $SCK_{p\uparrow}$ ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.

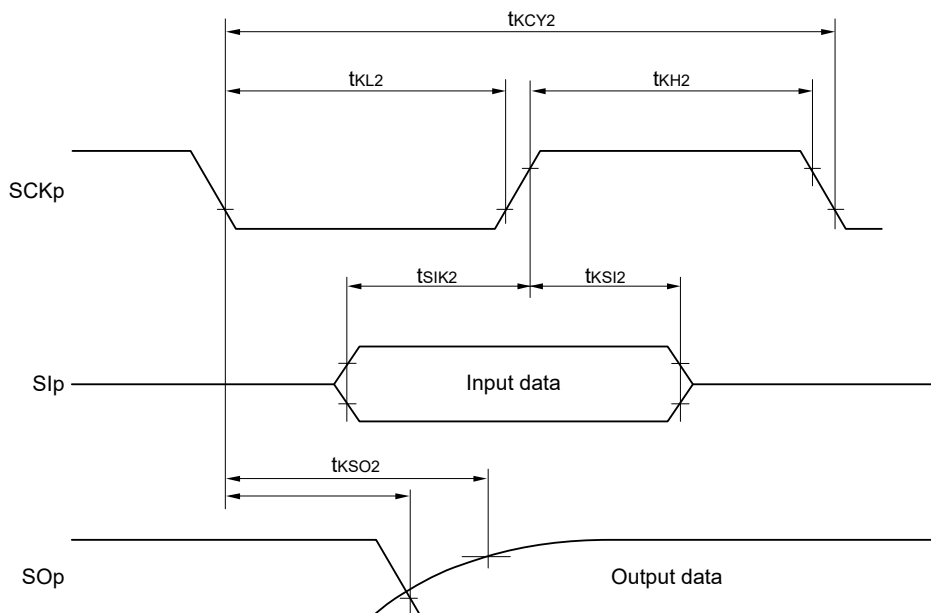
Caution Select the TTL input buffer for the S_{lp} pin and SCK_{p} pin, and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/ EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the S_{Op} pin by using port input mode register g (PIMg) and port output mode register 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)

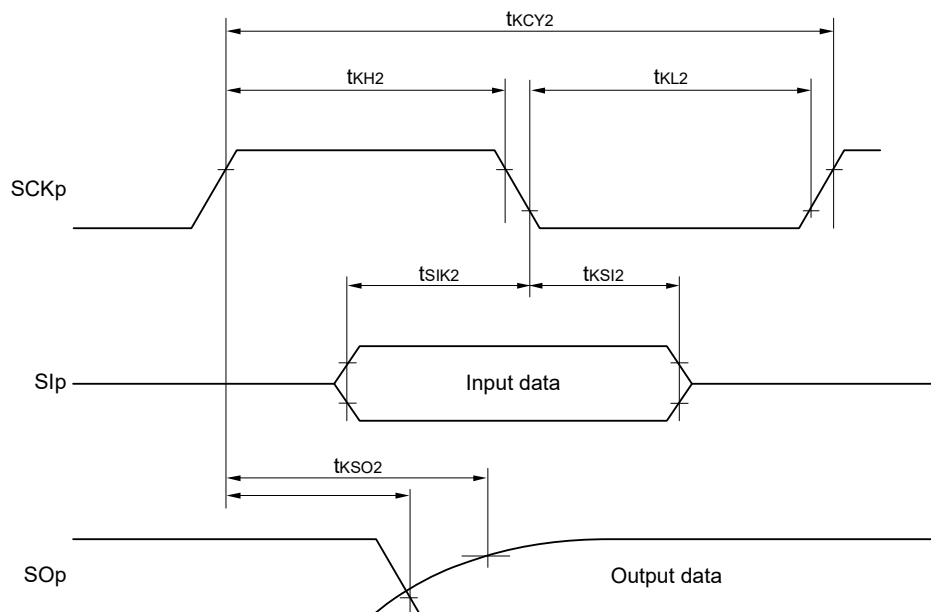


- Remark 1.** $R_b[\Omega]$: Communication line (S_{Op}) pull-up resistance, $C_b[F]$: Communication line (S_{Op}) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 5, 7)
- Remark 3.** f_{mck} : Serial array unit operation clock frequency
(Operation clock to be set by the CKS_{mn} bit of serial mode register mn (SMR_{mn}).
m: Unit number, n: Channel number (mn = 00, 01, 02, 10))
- Remark 4.** CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.
Also, communication at different potential cannot be performed during clock synchronous serial communication with the slave select function.

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



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



Remark 1. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
 g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 2. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.
 Also, communication at different potential cannot be performed during clock synchronous serial communication with the slave select function.

(10) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I²C mode)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---------------------------|-------------------|--|---------------------------|-------------|--------------------------|------------|----------------------------|------------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCLr clock frequency | f _{SCL} | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ | | 1000 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ | | 1000 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ | | 400 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ | | 400 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ | | 300 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ | 475 | | 1550 | | 1550 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ | 475 | | 1550 | | 1550 | | ns |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ | 1150 | | 1550 | | 1550 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ | 1150 | | 1550 | | 1550 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ | 1550 | | 1550 | | 1550 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ | 245 | | 610 | | 610 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ | 200 | | 610 | | 610 | | ns |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ | 675 | | 610 | | 610 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ | 600 | | 610 | | 610 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ | 610 | | 610 | | 610 | | ns |

(10) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I²C mode)**(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|-------------------------------|---------|--|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Data setup time (reception) | tsu:DAT | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ | 1/fMCK + 135 Note 3 | | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ | 1/fMCK + 135 Note 3 | | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | ns |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | 1/fMCK + 190 Note 3 | | ns |
| Data hold time (transmission) | tHD:DAT | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ | 0 | 305 | 0 | 305 | 0 | 305 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ | 0 | 305 | 0 | 305 | 0 | 305 | ns |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ | 0 | 355 | 0 | 355 | 0 | 355 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ | 0 | 355 | 0 | 355 | 0 | 355 | ns |
| | | 1.8 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ | 0 | 405 | 0 | 405 | 0 | 405 | ns |

Note 1. The value must also be equal to or less than fMCK/4.

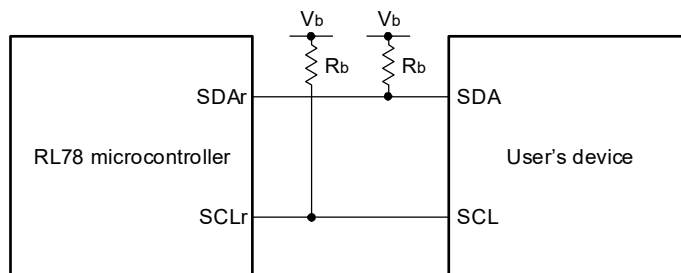
Note 2. Use it with EVDD0 ≥ Vb.

Note 3. Set the fMCK value to keep the hold time of SCLr = "L" and SCLr = "H".

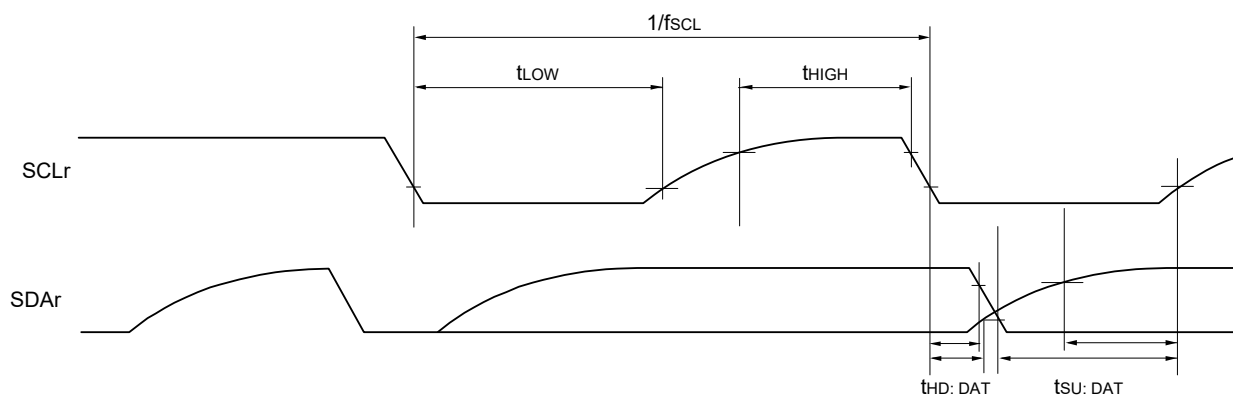
Caution Select the TTL input buffer and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SDAr pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

Simplified I²C mode connection diagram (during communication at different potential)



Simplified I²C mode serial transfer timing (during communication at different potential)



- Remark 1.** R_b[Ω]: Communication line (SDAr, SCLr) pull-up resistance, C_b[F]: Communication line (SDAr, SCLr) load capacitance, V_b[V]: Communication line voltage
- Remark 2.** r: IIC number (r = 00, 01, 10, 11, 20), g: PIM, POM number (g = 0, 1, 3, 5, 7)
- Remark 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 (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 01, 02, 10)

2.5.2 Serial interface IICA

(1) I²C standard mode

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit | |
|---------------------------------|----------------------|--|---------------------------|------|--------------------------|------|----------------------------|------|------|-----|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | | |
| SCLA0 clock frequency | f _{SCL} | Standard mode: f _{CLK} ≥ 1 MHz | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 100 | 0 | 100 | 0 | 100 | kHz |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0 | 100 | 0 | 100 | 0 | 100 | kHz |
| | | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 100 | 0 | 100 | 0 | 100 | kHz |
| | | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 0 | 100 | 0 | 100 | kHz |
| Setup time of restart condition | t _{SU, STA} | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.7 | | 4.7 | | μs | |
| Hold time Note 1 | t _{HD, STA} | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.0 | | 4.0 | | μs | |
| Hold time when SCLA0 = "L" | t _{LOW} | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.7 | | 4.7 | | μs | |
| Hold time when SCLA0 = "H" | t _{HIGH} | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.0 | | 4.0 | | μs | |

(Notes, Caution, and Remark are listed on the next page.)

(1) I²C standard mode**(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|---|----------|-----------------------|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Data setup time (reception) | tsu: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 250 | | 250 | | 250 | | ns |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 250 | | 250 | | 250 | | ns |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 250 | | 250 | | 250 | | ns |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 250 | | 250 | | ns |
| Data hold time (transmission) Note 2 | tHD: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 3.45 | 0 | 3.45 | 0 | 3.45 | μs |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0 | 3.45 | 0 | 3.45 | 0 | 3.45 | μs |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 3.45 | 0 | 3.45 | 0 | 3.45 | μs |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 0 | 3.45 | 0 | 3.45 | μs |
| Setup time of stop condition | tsu: STO | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.0 | | 4.0 | | 4.0 | | μs |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.0 | | 4.0 | | μs |
| Bus-free time | tBUF | 2.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs |
| | | 1.7 V ≤ EVDD0 ≤ 5.5 V | 4.7 | | 4.7 | | 4.7 | | μs |
| | | 1.6 V ≤ EVDD0 ≤ 5.5 V | — | | 4.7 | | 4.7 | | μs |

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

Note 2. The maximum value (MAX.) of tHD: DAT is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IOL1, VOH1, VOL1) must satisfy the values in the redirect destination.

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (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) I²C fast mode

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit | |
|--|----------|------------------------------|---------------------------|------|--------------------------|------|----------------------------|------|------|-----|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | | |
| SCLA0 clock frequency | fSCL | Fast mode: fCLK ≥ 3.5 MHz | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 400 | 0 | 400 | 0 | 400 | kHz |
| | | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0 | 400 | 0 | 400 | 0 | 400 | kHz |
| Setup time of restart condition | tsu: STA | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| Hold time ^{Note 1} | tHD: STA | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| Hold time when SCLA0 = "L" | tLOW | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| Hold time when SCLA0 = "H" | tHIGH | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| Data setup time (reception) | tsu: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 100 | | 100 | | 100 | | ns | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 100 | | 100 | | 100 | | ns | |
| Data hold time (transmission) ^{Note 2} | tHD: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 0.9 | 0 | 0.9 | 0 | 0.9 | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0 | 0.9 | 0 | 0.9 | 0 | 0.9 | μs | |
| Setup time of stop condition | tsu: STO | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| Bus-free time | tBUF | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 1.8 V ≤ EVDD0 ≤ 5.5 V | 1.3 | | 1.3 | | 1.3 | | μs | |

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

Note 2. The maximum value (MAX.) of tHD: DAT is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IOL1, VOH1, VOL1) must satisfy the values in the redirect destination.

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (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

(3) I²C fast mode plus

(TA = -40 to +85°C, 1.6 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | LS (low-speed main) mode | | LV (low-voltage main) mode | | Unit |
|--------------------------------------|----------|---|---------------------------|------|--------------------------|------|----------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| SCLA0 clock frequency | fSCL | Fast mode plus: fCLK ≥ 10 MHz 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 1000 | — | — | — | — | kHz |
| Setup time of restart condition | tSU: STA | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.26 | | — | — | — | — | μs |
| Hold time Note 1 | tHD: STA | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.26 | | — | — | — | — | μs |
| Hold time when SCLA0 = "L" | tLOW | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.5 | | — | — | — | — | μs |
| Hold time when SCLA0 = "H" | tHIGH | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.26 | | — | — | — | — | μs |
| Data setup time (reception) | tSU: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 50 | | — | — | — | — | ns |
| Data hold time (transmission) Note 2 | tHD: DAT | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0 | 0.45 | — | — | — | — | μs |
| Setup time of stop condition | tSU: STO | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.26 | | — | — | — | — | μs |
| Bus-free time | tBUF | 2.7 V ≤ EVDD0 ≤ 5.5 V | 0.5 | | — | — | — | — | μs |

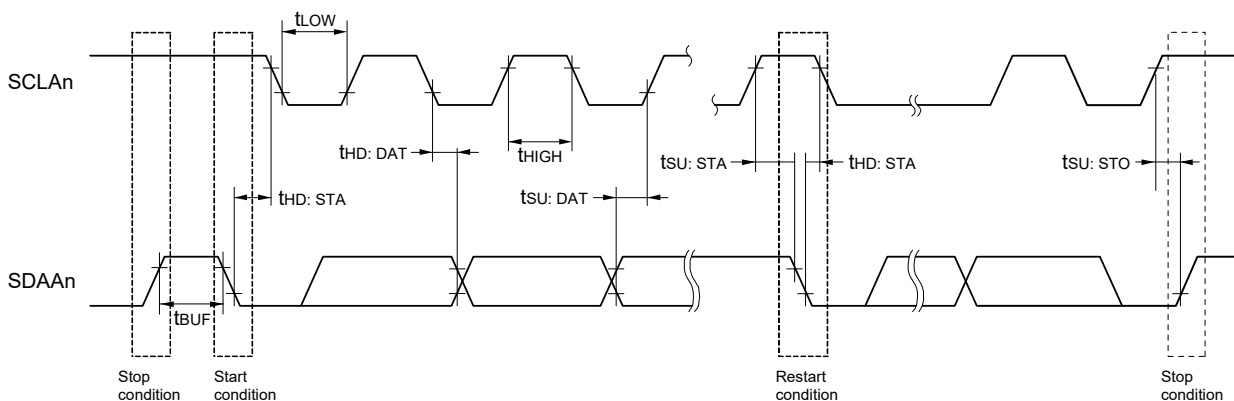
Note 1. The first clock pulse is generated after this period when the start/restart condition is detected.

Note 2. The maximum value (MAX.) of tHD: DAT is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IOL1, VOH1, VOL1) must satisfy the values in the redirect destination.

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 plus: Cb = 120 pF, Rb = 1.1 kΩ

I²C serial transfer timing



Remark n = 0, 1

2.6 Analog Characteristics

2.6.1 A/D converter characteristics

Classification of A/D converter characteristics

| Input channel | Reference Voltage | Reference voltage (+) = AVREFP Reference voltage (-) = AVREFM | Reference voltage (+) = VDD Reference voltage (-) = VSS | Reference voltage (+) = VBGR Reference voltage (-) = AVREFM |
|---|-------------------|--|--|--|
| ANI0 to ANI7 | | Refer to 2.6.1 (1). | Refer to 2.6.1 (3). | Refer to 2.6.1 (4). |
| ANI16 to ANI24 | | Refer to 2.6.1 (2). | | |
| Internal reference voltage Temperature sensor output voltage | | Refer to 2.6.1 (1). | | |

(1) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI2 to ANI7, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +85°C, 1.6 V ≤ AVREFP ≤ VDD ≤ 5.5 V, VSS = 0 V, Reference voltage (+) = AVREFP, Reference voltage (-) = AVREFM = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|--------|--|-------------------------------|--------|----------------|------|
| Resolution | RES | | 8 | | 10 | bit |
| Overall error Note 1 | AINL | 10-bit resolution AVREFP = VDD Note 3 | 1.8 V ≤ AVREFP ≤ 5.5 V | 1.2 | ±3.5 | LSB |
| | | | 1.6 V ≤ AVREFP ≤ 5.5 V Note 4 | 1.2 | ±7.0 | LSB |
| Conversion time | tCONV | 10-bit resolution Target pin: ANI2 to ANI14 | 3.6 V ≤ VDD ≤ 5.5 V | 2.125 | 39 | μs |
| | | | 2.7 V ≤ VDD ≤ 5.5 V | 3.1875 | 39 | μs |
| | | | 1.8 V ≤ VDD ≤ 5.5 V | 17 | 39 | μs |
| | | | 1.6 V ≤ VDD ≤ 5.5 V | 57 | 95 | μs |
| | | 10-bit resolution Target pin: Internal reference voltage, and temperature sensor output voltage (HS (high-speed main) mode) | 3.6 V ≤ VDD ≤ 5.5 V | 2.375 | 39 | μs |
| | | | 2.7 V ≤ VDD ≤ 5.5 V | 3.5625 | 39 | μs |
| Zero-scale error Notes 1, 2 | Ezs | 10-bit resolution AVREFP = VDD Note 3 | 1.8 V ≤ AVREFP ≤ 5.5 V | | ±0.25 | %FSR |
| | | | 1.6 V ≤ AVREFP ≤ 5.5 V Note 4 | | ±0.50 | %FSR |
| Full-scale error Notes 1, 2 | Efs | 10-bit resolution AVREFP = VDD Note 3 | 1.8 V ≤ AVREFP ≤ 5.5 V | | ±0.25 | %FSR |
| | | | 1.6 V ≤ AVREFP ≤ 5.5 V Note 4 | | ±0.50 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution AVREFP = VDD Note 3 | 1.8 V ≤ AVREFP ≤ 5.5 V | | ±2.5 | LSB |
| | | | 1.6 V ≤ AVREFP ≤ 5.5 V Note 4 | | ±5.0 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution AVREFP = VDD Note 3 | 1.8 V ≤ AVREFP ≤ 5.5 V | | ±1.5 | LSB |
| | | | 1.6 V ≤ AVREFP ≤ 5.5 V Note 4 | | ±2.0 | LSB |
| Analog input voltage | VAIN | ANI2 to ANI7 | 0 | | AVREFP | V |
| | | Internal reference voltage (2.4 V ≤ VDD ≤ 5.5 V, HS (high-speed main) mode) | | | VBGR Note 5 | V |
| | | Temperature sensor output voltage (2.4 V ≤ VDD ≤ 5.5 V, HS (high-speed main) mode) | | | VTPMS25 Note 5 | V |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. When AVREFP < VDD, the MAX. values are as follows.

Overall error: Add ±1.0 LSB to the MAX. value when AVREFP = VDD.
 Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when AVREFP = VDD.
 Integral linearity error/ Differential linearity error: Add ±0.5 LSB to the MAX. value when AVREFP = VDD.

Note 4. Values when the conversion time is set to 57 μs (min.) and 95 μs (max.).

Note 5. Refer to 2.6.2 Temperature sensor characteristics/internal reference voltage characteristic.

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target pin: ANI16 to ANI24

(TA = -40 to +85°C, $1.6\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 5.5\text{ V}$, $1.6\text{ V} \leq AV_{REFP} \leq V_{DD} \leq 5.5\text{ V}$, $V_{SS} = EV_{SS0} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (-) = $AV_{REFM} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|-------------------------------------|-------------------|--|--|--------|----------------------------------|-------|------|
| Resolution | RES | | 8 | | 10 | bit | |
| Overall error Note 1 | AINL | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | 1.2 | ±5.0 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5 | | 1.2 | ±8.5 | LSB |
| Conversion time | t _{CONV} | 10-bit resolution Target ANI pin: ANI16 to ANI24 | $3.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.125 | | 39 | μs |
| | | | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 3.1875 | | 39 | μs |
| | | | $1.8\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 17 | | 39 | μs |
| | | | $1.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 57 | | 95 | μs |
| Zero-scale error Notes 1, 2 | E _{ZS} | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | | ±0.35 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5 | | | ±0.60 | %FSR |
| Full-scale error Notes 1, 2 | E _{FS} | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | | ±0.35 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5 | | | ±0.60 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | | ±3.5 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5 | | | ±6.0 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | | ±2.0 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5 | | | ±2.5 | LSB |
| Analog input voltage | V _{AIN} | ANI16 to ANI24 | 0 | | AV_{REFP} and EV_{DD0} | V | |

Note 1. Excludes quantization error ($\pm 1/2$ LSB).

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

Note 3. When $EV_{DD0} \leq AV_{REFP} \leq V_{DD}$, 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 $\pm 0.05\%$ 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 $AV_{REFP} = V_{DD}$.

Note 4. When $AV_{REFP} < EV_{DD0} \leq V_{DD}$, 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 $\pm 0.20\%$ 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 $AV_{REFP} = V_{DD}$.

Note 5. When the conversion time is set to 57 μs (min.) and 95 μs (max.).

- (3) When reference voltage (+) = V_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = V_{SS} (ADREFM = 0), target pin: ANI0 to ANI17, ANI16 to ANI24, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +85°C, 1.6 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 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 | 1.8 V ≤ V _{DD} ≤ 5.5 V | | 1.2 | ±7.0 | LSB |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V Note 3 | | 1.2 | ±10.5 | LSB |
| Conversion time | t _{CONV} | 10-bit resolution Target pin: ANI0 to ANI7, ANI16 to ANI24 | 3.6 V ≤ V _{DD} ≤ 5.5 V | 2.125 | | 39 | μs |
| | | | 2.7 V ≤ V _{DD} ≤ 5.5 V | 3.1875 | | 39 | μs |
| | | | 1.8 V ≤ V _{DD} ≤ 5.5 V | 17 | | 39 | μs |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V | 57 | | 95 | μs |
| | | 10-bit resolution 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 |
| 2.4 V ≤ V _{DD} ≤ 5.5 V | 17 | | | 39 | μs | | |
| Zero-scale error Notes 1, 2 | E _{ZS} | 10-bit resolution | 1.8 V ≤ V _{DD} ≤ 5.5 V | | | ±0.60 | %FSR |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V Note 3 | | | ±0.85 | %FSR |
| Full-scale error Notes 1, 2 | E _{FS} | 10-bit resolution | 1.8 V ≤ V _{DD} ≤ 5.5 V | | | ±0.60 | %FSR |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V Note 3 | | | ±0.85 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution | 1.8 V ≤ V _{DD} ≤ 5.5 V | | | ±4.0 | LSB |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V Note 3 | | | ±6.5 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution | 1.8 V ≤ V _{DD} ≤ 5.5 V | | | ±2.0 | LSB |
| | | | 1.6 V ≤ V _{DD} ≤ 5.5 V Note 3 | | | ±2.5 | LSB |
| Analog input voltage | V _{AIN} | ANI0 to ANI7 | 0 | | V _{DD} | V | |
| | | ANI16 to ANI24 | 0 | | EV _{DD0} | V | |
| | | Internal reference voltage (2.4 V ≤ V _{DD} ≤ 5.5 V, HS (high-speed main) mode) | | | V _{BGR} Note 4 | V | |
| | | Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 5.5 V, HS (high-speed main) mode) | | | V _{TMPS25} Note 4 | V | |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. When the conversion time is set to 57 μs (min.) and 95 μs (max.).

Note 4. Refer to 2.6.2 Temperature sensor characteristics/internal reference voltage characteristic.

(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0, ANI2 to ANI7, ANI16 to ANI24

(TA = -40 to +85°C, 2.4 V ≤ VDD ≤ 5.5 V, 1.6 V ≤ EVDD0 ≤ VDD, VSS = EVSS0 = 0 V, Reference voltage (+) = VBGR Note 3, Reference voltage (-) = AVREFM = 0 V Note 4, HS (high-speed main) mode)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|--------|------------------|---------------------|------|------|-------------|-------|
| Resolution | RES | | | 8 | | | bit |
| Conversion time | tCONV | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | 17 | | 39 | μs |
| Zero-scale error Notes 1, 2 | Ezs | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±0.60 | % FSR |
| Integral linearity error Note 1 | ILE | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±2.0 | LSB |
| Differential linearity error Note 1 | DLE | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±1.0 | LSB |
| Analog input voltage | VAIN | | | 0 | | VBGR Note 3 | V |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. Refer to **2.6.2 Temperature sensor characteristics/internal reference voltage characteristic**.

Note 4. When reference voltage (-) = VSS, the MAX. values are as follows.

Zero-scale error: Add ±0.35%FSR to the MAX. value when reference voltage (-) = AVREFM.

Integral linearity error: Add ±0.5 LSB to the MAX. value when reference voltage (-) = AVREFM.

Differential linearity error: Add ±0.2 LSB to the MAX. value when reference voltage (-) = AVREFM.

2.6.2 Temperature sensor characteristics/internal reference voltage characteristic

(TA = -40 to +85°C, 2.4 V ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V, HS (high-speed main) mode)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------------|---------|--|------|------|------|-------|
| Temperature sensor output voltage | VTMPS25 | Setting ADS register = 80H, TA = +25°C | | 1.05 | | V |
| Internal reference voltage | VBGR | Setting ADS register = 81H | 1.38 | 1.45 | 1.5 | V |
| Temperature coefficient | FVTMPS | Temperature sensor that depends on the temperature | | -3.6 | | mV/°C |
| Operation stabilization wait time | tAMP | | 5 | | | μs |

2.6.3 D/A converter characteristics

(TA = -40 to +85°C, 1.6 V ≤ EVSS0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---------------|--------|---------------|---------------------|------|------|------|------|
| Resolution | RES | | | | | 8 | bit |
| Overall error | AINL | Rload = 4 MΩ | 1.8 V ≤ VDD ≤ 5.5 V | | | ±2.5 | LSB |
| | | Rload = 8 MΩ | 1.8 V ≤ VDD ≤ 5.5 V | | | ±2.5 | LSB |
| Settling time | tSET | Cload = 20 pF | 2.7 V ≤ VDD ≤ 5.5 V | | | 3 | μs |
| | | | 1.6 V ≤ VDD < 2.7 V | | | 6 | μs |

2.6.4 Comparator

(TA = -40 to +85°C, 2.7 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|-----------------------------------|---|--------------------------------|------|-----------------|------|
| Input offset voltage | V _{IOCOMP} | | | ±5 | ±40 | mV |
| Input voltage range | V _{ICMP} | | 0 | | V _{DD} | V |
| Internal reference voltage deviation | ΔV _{IREF} | CmRVM register value : 7FH to 80H (m = 0, 1) | | | ±2 | LSB |
| | | Other than above | | | ±1 | LSB |
| Response Time | t _{CR} , t _{CF} | Input amplitude ±100mV | | 70 | 150 | ns |
| Operation stabilization time ^{Note 1} | t _{CMP} | CMPn = 0 → 1 | V _{DD} = 3.3 to 5.5 V | | 1 | μs |
| | | | V _{DD} = 2.7 to 3.3 V | | 3 | μs |
| Reference voltage stabilization wait time | t _{VR} | CVRE : 0 → 1 ^{Note 2} | | | 20 | μs |
| Operation current | I _{COMPDD} | Separately, it is defined as the operation current of peripheral functions. | | | | |

Note 1. Time taken until the comparator satisfies the DC/AC characteristics after the comparator operation enable signal is switched (CMPnEN = 0 → 1).

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

2.6.5 PGA

(TA = -40 to +85°C, 2.7 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|---------------------|--|---|------|-----------------------------|------|
| Input offset voltage | V _{IOPGA} | | | | ±10 | mV |
| Input voltage range | V _{IPGA} | | 0 | | 0.9 × V _{DD} /Gain | V |
| Output voltage range | V _{IOHPGA} | | 0.93 × V _{DD} | | | V |
| | V _{IOHPGA} | | | | 0.07 × V _{DD} | V |
| Gain error | | x4, x8 | | | ±1 | % |
| | | x16 | | | ±1.5 | % |
| | | x32 | | | ±2 | % |
| Slew rate | SR _{RPGA} | Rising When Vin = 0.1V _{DD} /gain to 0.9V _{DD} /gain. 10 to 90% of output voltage amplitude | 4.0 V ≤ V _{DD} ≤ 5.5 V (Other than x32) | 3.5 | | V/μs |
| | | | 4.0 V ≤ V _{DD} ≤ 5.5 V (x32) | 3.0 | | |
| | | | 2.7 V ≤ V _{DD} ≤ 4.0V | 0.5 | | |
| | SR _{FPGA} | Falling When Vin = 0.1V _{DD} /gain to 0.9V _{DD} /gain. 90 to 10% of output voltage amplitude | 4.0 V ≤ V _{DD} ≤ 5.5 V (Other than x32) | 3.5 | | |
| | | | 4.0 V ≤ V _{DD} ≤ 5.5 V (x32) | 3.0 | | |
| | | | 2.7 V ≤ V _{DD} ≤ 4.0V | 0.5 | | |
| Reference voltage stabilization wait time- Note 1 | t _{PGA} | x4, x8 | | | 5 | μs |
| | | x16, x32 | | | 10 | μs |
| Operation current | I _{PGADD} | Separately, it is defined as the operation current of peripheral functions. | | | | |

Note 1. 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).

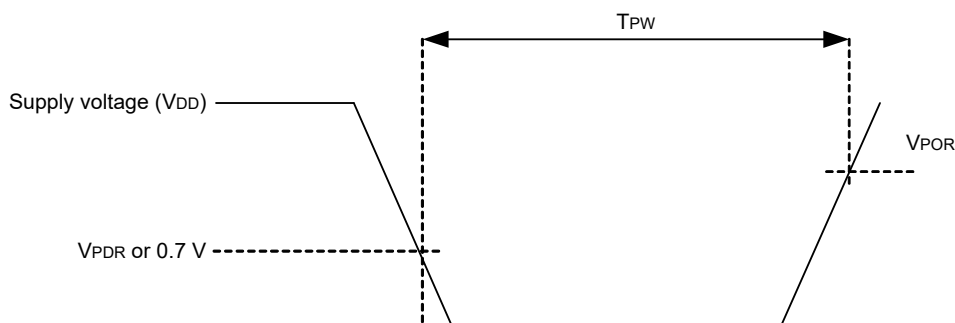
2.6.6 POR circuit characteristics

(TA = -40 to +85°C, Vss = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------------------------------|------------------|--|------|------|------|------|
| Power on/down reset threshold | V _{POR} | Voltage threshold on V _{DD} rising | 1.47 | 1.51 | 1.55 | V |
| | V _{PDR} | Voltage threshold on V _{DD} falling ^{Note 1} | 1.46 | 1.50 | 1.54 | V |
| Minimum pulse width ^{Note 2} | T _{PW} | | 300 | | | μs |

Note 1. However, when the operating voltage falls while the LVD is off, enter STOP mode, or enable the reset status using the external reset pin before the voltage falls below the operating voltage range shown in **2.4 AC Characteristics**.

Note 2. 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).



2.6.7 LVD circuit characteristics

(1) Reset Mode and Interrupt Mode

(TA = -40 to +85°C, VPDR ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------|----------------------|--------|--------------|------|------|------|------|
| Voltage detection threshold | Supply voltage level | VLVD0 | Rising edge | 3.98 | 4.06 | 4.14 | V |
| | | | Falling edge | 3.90 | 3.98 | 4.06 | V |
| | | VLVD1 | Rising edge | 3.68 | 3.75 | 3.82 | V |
| | | | Falling edge | 3.60 | 3.67 | 3.74 | V |
| | | VLVD2 | Rising edge | 3.07 | 3.13 | 3.19 | V |
| | | | Falling edge | 3.00 | 3.06 | 3.12 | V |
| | | VLVD3 | Rising edge | 2.96 | 3.02 | 3.08 | V |
| | | | Falling edge | 2.90 | 2.96 | 3.02 | V |
| | | VLVD4 | Rising edge | 2.86 | 2.92 | 2.97 | V |
| | | | Falling edge | 2.80 | 2.86 | 2.91 | V |
| | | VLVD5 | Rising edge | 2.76 | 2.81 | 2.87 | V |
| | | | Falling edge | 2.70 | 2.75 | 2.81 | V |
| | | VLVD6 | Rising edge | 2.66 | 2.71 | 2.76 | V |
| | | | Falling edge | 2.60 | 2.65 | 2.70 | V |
| | | VLVD7 | Rising edge | 2.56 | 2.61 | 2.66 | V |
| | | | Falling edge | 2.50 | 2.55 | 2.60 | V |
| | | VLVD8 | Rising edge | 2.45 | 2.50 | 2.55 | V |
| | | | Falling edge | 2.40 | 2.45 | 2.50 | V |
| | | VLVD9 | Rising edge | 2.05 | 2.09 | 2.13 | V |
| | | | Falling edge | 2.00 | 2.04 | 2.08 | V |
| | | VLVD10 | Rising edge | 1.94 | 1.98 | 2.02 | V |
| | | | Falling edge | 1.90 | 1.94 | 1.98 | V |
| | | VLVD11 | Rising edge | 1.84 | 1.88 | 1.91 | V |
| | | | Falling edge | 1.80 | 1.84 | 1.87 | V |
| VLVD12 | Rising edge | 1.74 | 1.77 | 1.81 | V | | |
| | Falling edge | 1.70 | 1.73 | 1.77 | V | | |
| VLVD13 | Rising edge | 1.64 | 1.67 | 1.70 | V | | |
| | Falling edge | 1.60 | 1.63 | 1.66 | V | | |
| Minimum pulse width | tLW | | 300 | | | μs | |
| Detection delay time | | | | | 300 | μs | |

(2) Interrupt & Reset Mode**(TA = -40 to +85°C, VPDR ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|-----------------------------|--|--|------------------------------|------|------|------|---|
| Voltage detection threshold | VLVDA0 | VPOC2, VPOC1, VPOC0 = 0, 0, 0, falling reset voltage | 1.60 | 1.63 | 1.66 | V | |
| | VLVDA1 | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 1.74 | 1.77 | 1.81 | V |
| | | | Falling interrupt voltage | 1.70 | 1.73 | 1.77 | V |
| | VLVDA2 | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 1.84 | 1.88 | 1.91 | V |
| | | | Falling interrupt voltage | 1.80 | 1.84 | 1.87 | V |
| | VLVDA3 | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 2.86 | 2.92 | 2.97 | V |
| | | | Falling interrupt voltage | 2.80 | 2.86 | 2.91 | V |
| | VLVDB0 | VPOC2, VPOC1, VPOC0 = 0, 0, 1, falling reset voltage | 1.80 | 1.84 | 1.87 | V | |
| | VLVDB1 | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 1.94 | 1.98 | 2.02 | V |
| | | | Falling interrupt voltage | 1.90 | 1.94 | 1.98 | V |
| | VLVDB2 | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.05 | 2.09 | 2.13 | V |
| | | | Falling interrupt voltage | 2.00 | 2.04 | 2.08 | V |
| VLVDB3 | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.07 | 3.13 | 3.19 | V | |
| | | Falling interrupt voltage | 3.00 | 3.06 | 3.12 | V | |
| VLVDC0 | VPOC2, VPOC1, VPOC0 = 0, 1, 0, falling reset voltage | 2.40 | 2.45 | 2.50 | V | | |
| VLVDC1 | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 2.56 | 2.61 | 2.66 | V | |
| | | Falling interrupt voltage | 2.50 | 2.55 | 2.60 | V | |
| VLVDC2 | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.66 | 2.71 | 2.76 | V | |
| | | Falling interrupt voltage | 2.60 | 2.65 | 2.70 | V | |
| VLVDC3 | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.68 | 3.75 | 3.82 | V | |
| | | Falling interrupt voltage | 3.60 | 3.67 | 3.74 | V | |
| VLVDD0 | VPOC2, VPOC1, VPOC0 = 0, 1, 1, falling reset voltage | 2.70 | 2.75 | 2.81 | V | | |
| VLVDD1 | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 2.86 | 2.92 | 2.97 | V | |
| | | Falling interrupt voltage | 2.80 | 2.86 | 2.91 | V | |
| VLVDD2 | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.96 | 3.02 | 3.08 | V | |
| | | Falling interrupt voltage | 2.90 | 2.96 | 3.02 | V | |
| VLVDD3 | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.98 | 4.06 | 4.14 | V | |
| | | Falling interrupt voltage | 3.90 | 3.98 | 4.06 | V | |

2.6.8 Power supply voltage rising slope characteristics**(TA = -40 to +85°C, VSS = 0 V)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------------|--------|------------|------|------|------|------|
| Power supply voltage rising slope | SVDD | | | | 54 | V/ms |

Caution Make sure to keep the internal reset state by the LVD circuit or an external reset until VDD reaches the operating voltage range shown in 2.4 AC Characteristics.

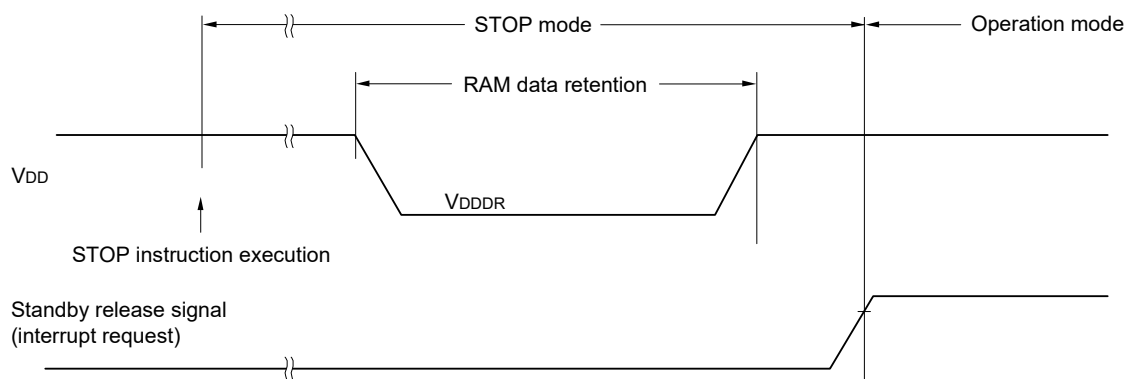
2.7 RAM Data Retention Characteristics

(TA = -40 to +85°C, Vss = 0V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------|--------|------------|------|------------|------|------|
| Data retention supply voltage | VDDDR | | 1.46 | Notes 1, 2 | 5.5 | V |

Note 1. 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.

Note 2. Enter STOP mode before the supply voltage falls below the recommended operating voltage.



2.8 Flash Memory Programming Characteristics

(TA = -40 to +85°C, 1.8 V ≤ VDD ≤ 5.5 V, Vss = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|-------------------|-----------------------|-----------|---------|-----------|------|-------|
| System clock frequency | fCLK | 1.8 V ≤ VDD ≤ 5.5 V | | 1 | | 32 | MHz |
| Number of code flash rewrites Notes 1, 2, 3 | C _{erwr} | Retained for 20 years | TA = 85°C | 1,000 | | | Times |
| | | Retained for 1 year | TA = 25°C | | 1,000,000 | | |
| Number of data flash rewrites Notes 1, 2, 3 | | Retained for 5 years | TA = 85°C | 100,000 | | | |
| | | Retained for 20 years | TA = 85°C | 10,000 | | | |

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

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

Note 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)

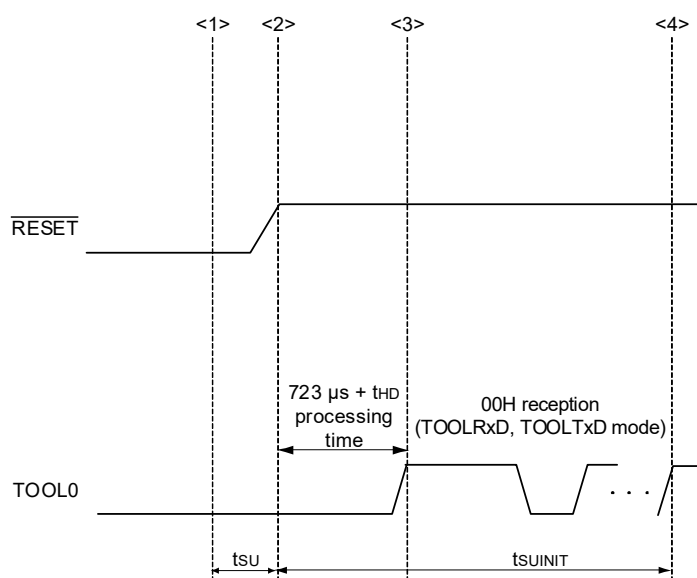
(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, Vss = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------|--------|---------------------------|---------|------|-----------|------|
| Transfer rate | | During serial programming | 115,200 | | 1,000,000 | bps |

2.10 Timing of Entry to Flash Memory Programming Modes

(TA = -40 to +85°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------|--|------|------|------|------|
| How long from when an external reset ends until the initial communication settings are specified | tsuINIT | 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 | tsu | 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 an external reset ends (excluding the processing time of the firmware to control the flash memory) | tHD | POR and LVD reset must end before the external reset ends. | 1 | | | ms |



- <1> The low level is input to the TOOL0 pin.
- <2> The external reset ends (POR and LVD reset must end before the external reset ends).
- <3> The TOOL0 pin is set to the high level.
- <4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

tsuINIT: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the external resets end.

tsu: How long from when the TOOL0 pin is placed at the low level until a pin reset ends

tHD: How long to keep the TOOL0 pin at the low level from when the external resets end (excluding the processing time of the firmware to control the flash memory)

3. ELECTRICAL SPECIFICATIONS (G: TA = -40 to +105°C)

This chapter describes the following electrical specifications.

Target products G: Industrial applications TA = -40 to +105°C

R5F11BxxGxx

Caution 1. The RL78 microcontrollers have 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.

Caution 2. With products not provided with an EVDD0, or EVSS0 pin, replace EVDD0 with VDD, or replace EVSS0 with VSS.

Caution 3. The pins mounted depend on the product. Refer to 2.1 Port Functions to 2.2.1 Functions for each product in the RL78/G1F User's Manual.

Caution 4. Please contact Renesas Electronics sales office for derating of operation under TA = +85 to +105°C. Derating is the systematic reduction of load for the sake of improved reliability.

Remark When the products "G: Industrial applications" is used in the range of TA = -40 to +85°C, see 2. ELECTRICAL SPECIFICATIONS (TA = -40 to +85°C).

Operation of products rated “G: Industrial applications (TA = -40 to + 105°C)” at ambient operating temperatures above 85°C differs from that of products rated “A: Consumer applications” in the ways listed below.

| Parameter | A: Consumer applications | G: Industrial applications |
|--|--|---|
| Operating ambient temperature | TA = -40 to +85°C | TA = -40 to +105°C |
| Operating mode Operating voltage range | HS (high-speed main) mode: 2.7 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 32 MHz 2.4 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 16 MHz LS (low-speed main) mode: 1.8 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 8 MHz LV (low-voltage main) mode: 2.4 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 4 MHz | HS (high-speed main) mode only: 2.7 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 32 MHz 2.4 V ≤ V _{DD} ≤ 5.5 V@1 MHz to 16 MHz |
| High-speed on-chip oscillator clock accuracy | 1.8 V ≤ V _{DD} ≤ 5.5 V: ±1.0% @ TA = -20 to +85°C ±1.5% @ TA = -40 to -20°C 2.4 V ≤ V _{DD} < 1.8 V: ±5.0% @ TA = -20 to +85°C ±5.5% @ TA = -40 to -20°C | 2.4 V ≤ V _{DD} ≤ 5.5 V: ±2.0% @ TA = +85 to +105°C ±1.0% @ TA = -20 to +85°C ±1.5% @ TA = -40 to -20°C |
| Serial array unit | UART CSI: f _{CLK} /2 (16 Mbps supported), f _{CLK} /4 Simplified I ² C communication | UART CSI: f _{CLK} /4 Simplified I ² C communication |
| IICA | Standard mode Fast mode Fast mode plus | Standard mode Fast mode |
| Voltage detector | • Rising: 1.67 V to 4.06 V (14 stages) • Falling: 1.63 V to 3.98 V (14 stages) | • Rising: 2.61 V to 4.06 V (8 stages) • Falling: 2.55 V to 3.98 V (8 stages) |

Remark The electrical characteristics of products rated “G: Industrial applications (TA = -40 to + 105°C)” at ambient operating temperatures above 85°C differ from those of products “A: Consumer applications”. For details, refer to 3.1 to 3.10.

3.1 Absolute Maximum Ratings

Absolute Maximum Ratings

(1/2)

| Parameter | Symbols | Conditions | Ratings | Unit |
|------------------------|--------------------|---|---|------|
| Supply voltage | V _{DD} | | -0.5 to +6.5 | V |
| | EV _{DD0} | | -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} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | -0.3 to EV _{DD0} +0.3 and -0.3 to V _{DD} +0.3 Note 2 | V |
| | V _{I2} | P60 to P63 (N-ch open-drain) | -0.3 to +6.5 | V |
| | V _{I3} | P20 to P27, P121 to P124, P137, EXCLK, EXCLKS, RESET | -0.3 to V _{DD} +0.3 Note 2 | V |
| Output voltage | V _{O1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P60 to P63, P70 to P77, P120, P130, P140, P141, P146, P147 | -0.3 to EV _{DD0} +0.3 and -0.3 to V _{DD} +0.3 Note 2 | V |
| | V _{O2} | P20 to P27 | -0.3 to V _{DD} +0.3 Note 2 | V |
| Analog input voltage | V _{AI1} | ANI16 to ANI24 | -0.3 to EV _{DD0} +0.3 and -0.3 to AV _{REF} (+) +0.3 Notes 2, 3 | V |
| | V _{AI2} | ANI0 to ANI7 | -0.3 to V _{DD} +0.3 and -0.3 to AV _{REF} (+) +0.3 Notes 2, 3 | V |

Note 1. Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF). This value regulates the absolute maximum rating of the REGC pin. Do not use this pin with voltage applied to it.

Note 2. Must be 6.5 V or lower.

Note 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.

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

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

Remark 3. V_{SS}: Reference voltage

Absolute Maximum Ratings**(2/2)**

| Parameter | Symbols | Conditions | | Ratings | Unit |
|-------------------------------|----------------------------------|------------------------------|--|---|-------------|
| Output current, high | IOH1 | Per pin | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | -40 | mA |
| | | Total of all pins -170 mA | P00 to P04, P40 to P43, P120, P130, P140, P141 | -70 | mA |
| | | | P05, P06, P10 to P17, P30, P31, P50 to P55, P70 to P77, P146, P147 | -100 | mA |
| | IOH2 | Per pin | P20 to P27 | -0.5 | mA |
| | | Total of all pins | | -2 | mA |
| | Output current, low | IOL1 | Per pin | P00 to P06, P10 to P17, P30, P31, P40-P43, P50 to P55, P60 to P63, P70 to P77, P120, P130, P140, P141, P146, P147 | 40 |
| Total of all pins 170 mA | | | P00 to P04, P40 to P47, P120, P130, P140, P141 | 70 | mA |
| | | | P05, P06, P10 to P17, P30, P31, P50 to P55, P70 to P77, P146, P147 | 100 | mA |
| IOL2 | | Per pin | P20 to P27 | 1 | mA |
| | | Total of all pins | | 5 | mA |
| Operating ambient temperature | | TA | In normal operation mode | | -40 to +105 |
| | 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.

3.2 Oscillator Characteristics

3.2.1 X1, XT1 characteristics

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 = VDD ≤ 5.5 V, VSS = 0 V)

| Resonator | Resonator | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---------------------|------|--------|------|------|
| X1 clock oscillation frequency (fX) ^{Note} | Ceramic resonator/ crystal resonator | 2.7 V ≤ VDD ≤ 5.5 V | 1.0 | | 20.0 | MHz |
| | | 2.4 V ≤ VDD < 2.7 V | 1.0 | | 16.0 | |
| XT1 clock oscillation frequency (fXT) ^{Note} | Crystal resonator | | 32 | 32.768 | 35 | kHz |

Note Indicates only permissible oscillator frequency ranges. Refer to **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, refer to **5.4 System Clock Oscillator** in the RL78/G1F User's Manual.

3.2.2 On-chip oscillator characteristics

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 = VDD ≤ 5.5 V, VSS = 0 V)

| Oscillators | Parameters | Conditions | MIN. | TYP. | MAX. | Unit |
|---|----------------|---------------------|------|------|------|------|
| High-speed on-chip oscillator clock frequency Notes 1, 2 | f _H | 2.7 V ≤ VDD ≤ 5.5 V | 1 | | 32 | MHz |
| | | 2.4 V ≤ VDD < 2.7 V | 1 | | 16 | MHz |
| High-speed on-chip oscillator clock frequency accuracy | | TA = +85 to +105°C | -2 | | 2 | % |
| | | TA = -20 to +85°C | -1 | | 1 | % |
| | | TA = -40 to -20°C | -1.5 | | 1.5 | % |
| Low-speed on-chip oscillator clock frequency | f _L | | | 15 | | kHz |
| Low-speed on-chip oscillator clock frequency accuracy | | | -15 | | +15 | % |

Note 1. High-speed on-chip oscillator frequency is selected with bits 0 to 4 of the option byte (000C2H/010C2H) and bits 0 to 2 of the HOCODIV register.

Note 2. This only indicates the oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

3.3 DC Characteristics

3.3.1 Pin characteristics

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|--|---|--|-----------------------|------|----------------|----------------|----|
| Output current, high ^{Note 1} | IOH1 | Per pin for P00 to P06, P10 to P17, P30, P31, P40 to P47, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | | | -3.0 Note 2 | mA | |
| | | Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | -30.0 | mA | |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | -10.0 | mA | |
| | | | 2.4 V ≤ EVDD0 < 2.7 V | | -5.0 | mA | |
| | | Total of P05, P06, P10 to P17, P30, P31, P50 to P53, P70 to P77, P146, P147 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | -30.0 | mA | |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | -19.0 | mA | |
| | | | 1.8 V ≤ EVDD0 < 2.7 V | | -10.0 | mA | |
| | Total of all pins (When duty ≤ 70% ^{Note 3}) | | | | -60.0 | mA | |
| | IOH2 | Per pin for P20 to P27 | | | | -0.1 Note 2 | mA |
| | | Total of all pins (When duty ≤ 70% ^{Note 3}) | 2.4 V ≤ VDD ≤ 5.5 V | | | -1.5 | mA |

Note 1. Value of current at which the device operation is guaranteed even if the current flows from the EVDD0, VDD pins to an output pin.

Note 2. Do not exceed the total current value.

Note 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 = (IOH × 0.7)/(n × 0.01)
<Example> Where n = 80% and IOH = -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 P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 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.

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---|---|-----------------------|------|----------------|------|
| Output current, low ^{Note 1} | IOL1 | Per pin for P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | | | 8.5 Note 2 | mA |
| | | Per pin for P60 to P63 | | | 15.0 Note 2 | mA |
| | | Total of P00 to P04, P40 to P43, P120, P130, P140, P141 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | 40.0 | mA |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | 15.0 | mA |
| | | | 2.4 V ≤ EVDD0 < 1.8 V | | 9.0 | mA |
| | | Total of P05, P06, P10 to P17, P30, P31, P50 to P55, P60 to P63, P70 to P77, P146, P147 (When duty ≤ 70% ^{Note 3}) | 4.0 V ≤ EVDD0 ≤ 5.5 V | | 40.0 | mA |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | 35.0 | mA |
| | 2.4 V ≤ EVDD0 < 1.8 V | | | 20.0 | mA | |
| | Total of all pins (When duty ≤ 70% ^{Note 3}) | | | 80.0 | mA | |
| | IOL2 | Per pin for P20 to P27 | | | 0.4 Note 2 | mA |
| Total of all pins (When duty ≤ 70% ^{Note 3}) | | 2.4 V ≤ VDD ≤ 5.5 V | | 5.0 | mA | |

Note 1. Value of current at which the device operation is guaranteed even if the current flows from an output pin to the EVSS0 and VSS pins.

Note 2. Do not exceed the total current value.

Note 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 = (IOL × 0.7)/(n × 0.01)

<Example> Where n = 80% and IOL = 10.0 mA

$$\text{Total output current of pins} = (10.0 \times 0.7)/(80 \times 0.01) \approx 8.7 \text{ mA}$$

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.

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(3/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|---------------------|---|--|---|-----------|---------|-----------|---|
| Input voltage, high | V _{IH1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | Normal input buffer | 0.8 EVDD0 | | EVDD0 | V |
| | V _{IH2} | P01, P03, P04, P10, P14 to P17, P30, P43, P50, P53 to P55, | TTL input buffer 4.0 V ≤ EVDD0 ≤ 5.5 V | 2.2 | | EVDD0 | V |
| | | | TTL input buffer 3.3 V ≤ EVDD0 < 4.0 V | 2.0 | | EVDD0 | V |
| | | | TTL input buffer 2.4 V ≤ EVDD0 < 3.3 V | 1.5 | | EVDD0 | V |
| | V _{IH3} | P20 to P27 (when P20 is used as a port pin) | | 0.7 VDD | | VDD | V |
| | V _{IH4} | P60 to P63 | | 0.7 EVDD0 | | 6.0 | V |
| V _{IH5} | P121 to P123, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$ (when P20 is used as INTP11 pin) | | 0.8 VDD | | VDD | V | |
| Input voltage, low | V _{IL1} | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | Normal input buffer | 0 | | 0.2 EVDD0 | V |
| | V _{IL2} | P01, P03, P04, P10, P14 to P17, P30, P43, P50, P53 to P55, | TTL input buffer 4.0 V ≤ EVDD0 ≤ 5.5 V | 0 | | 0.8 | V |
| | | | TTL input buffer 3.3 V ≤ EVDD0 < 4.0 V | 0 | | 0.5 | V |
| | | | TTL input buffer 2.4 V ≤ EVDD0 < 3.3 V | 0 | | 0.32 | V |
| | V _{IL3} | P20 to P27 (when P20 is used as a port pin) | | 0 | | 0.3 VDD | V |
| | V _{IL4} | P60 to P63 | | 0 | | 0.3 EVDD0 | V |
| V _{IL5} | P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$ (when P20 is used as INTP11 pin) | | 0 | | 0.2 VDD | V | |

Caution The maximum value of V_{IH} of pins P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 is EVDD0, 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.

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(4/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|----------------------|--------|--|--|-------------|------|------|
| Output voltage, high | VOH1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -3.0 mA | EVDD0 - 0.7 | | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOH1 = -2.0 mA | EVDD0 - 0.6 | | V |
| | | | 2.4 V ≤ EVDD0 < 5.5 V, IOH1 = -1.5 mA | EVDD0 - 0.5 | | V |
| | VOH2 | P20 to P27 | 2.4 V ≤ VDD ≤ 5.5 V, IOH2 = -100 μA | VDD - 0.5 | | V |
| Output voltage, low | VOL1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P130, P140, P141, P146, P147 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 8.5 mA | | 0.7 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 3.0 mA | | 0.6 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 1.5 mA | | 0.4 | V |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V, IOL1 = 0.6 mA | | 0.4 | V |
| | VOL2 | P20 to P27 | 2.4 V ≤ VDD ≤ 5.5 V, IOL2 = 400 μA | | 0.4 | V |
| | VOL3 | P60 to P63 | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 15.0 mA | | 2.0 | V |
| | | | 4.0 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 5.0 mA | | 0.4 | V |
| | | | 2.7 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 3.0 mA | | 0.4 | V |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V, IOL3 = 2.0 mA | | 0.4 | V |

Caution P00, P02 to P04, P10, P11, P13 to P15, P17, P30, P43, P50 to P55, P71, P74 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.

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(5/5)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | | |
|-----------------------------|--------|--|---------------------------|---------------------------------------|------|------|-----|----|
| Input leakage current, high | ILIH1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | VI = EVDD0 | | | 1 | μA | |
| | ILIH2 | P20 to P27, P137, $\overline{\text{RESET}}$ | VI = VDD | | | 1 | μA | |
| | ILIH3 | P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS) | VI = VDD | In input port or external clock input | | 1 | μA | |
| | | | | In resonator connection | | 10 | μA | |
| Input leakage current, low | ILIL1 | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | VI = EVSS0 | | | -1 | μA | |
| | ILIL2 | P20 to P27, P137, $\overline{\text{RESET}}$ | VI = VSS | | | -1 | μA | |
| | ILIL3 | P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS) | VI = VSS | In input port or external clock input | | -1 | μA | |
| | | | | In resonator connection | | -10 | μA | |
| On-chip pull-up resistance | Ru | P00 to P06, P10 to P17, P30, P31, P40 to P43, P50 to P55, P70 to P77, P120, P140, P141, P146, P147 | VI = EVSS0, 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

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(1/2)

| Parameter | Symbol | Conditions | | | | MIN. | TYP. | MAX. | Unit | | |
|--------------------------|----------------------|--|-------------------------------------|--|----------------------|-------------------|------|------|------|----|----|
| Supply current Note 1 | IDD1 | Operating mode | HS (high-speed main) mode Note 5 | fHOCO = 64 MHz, fIH = 32 MHz Note 3 | Basic operation | VDD = 5.0 V | | 2.4 | | mA | |
| | | | | | | VDD = 3.0 V | | 2.4 | | | |
| | | | | fHOCO = 32 MHz, fIH = 32 MHz Note 3 | Basic operation | VDD = 5.0 V | | 2.1 | | | |
| | | | | VDD = 3.0 V | | | 2.1 | | | | |
| | | | HS (high-speed main) mode Note 5 | fHOCO = 64 MHz, fIH = 32 MHz Note 3 | Normal operation | VDD = 5.0 V | | 5.2 | 9.3 | | mA |
| | | | | | | VDD = 3.0 V | | 5.2 | 9.3 | | |
| | | fHOCO = 32 MHz, fIH = 32 MHz Note 3 | | Normal operation | VDD = 5.0 V | | 4.8 | 8.7 | | | |
| | | | | | VDD = 3.0 V | | 4.8 | 8.7 | | | |
| | | fHOCO = 48 MHz, fIH = 24 MHz Note 3 | | Normal operation | VDD = 5.0 V | | 4.1 | 7.3 | | | |
| | | | | | VDD = 3.0 V | | 4.1 | 7.3 | | | |
| | | fHOCO = 24 MHz, fIH = 24 MHz Note 3 | Normal operation | VDD = 5.0 V | | 3.8 | 6.7 | | | | |
| | | | | VDD = 3.0 V | | 3.8 | 6.7 | | | | |
| | | HS (high-speed main) mode Note 5 | fMX = 20 MHz Note 2, VDD = 5.0 V | Normal operation | Square wave input | | 3.3 | 5.7 | mA | | |
| | | | | | Resonator connection | | 3.5 | 5.8 | | | |
| | | | fMX = 20 MHz Note 2, VDD = 3.0 V | Normal operation | Square wave input | | 3.3 | 5.7 | | | |
| | | | | | Resonator connection | | 3.5 | 5.8 | | | |
| | | | fMX = 10 MHz Note 2, VDD = 5.0 V | Normal operation | Square wave input | | 2.0 | 3.4 | | | |
| | | | | | Resonator connection | | 2.1 | 3.5 | | | |
| | | | fMX = 10 MHz Note 2, VDD = 3.0 V | Normal operation | Square wave input | | 2.0 | 3.4 | | | |
| | | | | | Resonator connection | | 2.1 | 3.5 | | | |
| | | Subsystem clock operation | fsUB = 32.768 kHz Note 4 | Normal operation | TA = -40°C | Square wave input | | 4.7 | 6.1 | μA | |
| | | | | | Resonator connection | | 4.7 | 6.1 | | | |
| | | | | Normal operation | TA = +25°C | Square wave input | | 4.7 | 6.1 | | |
| | | | | | Resonator connection | | 4.7 | 6.1 | | | |
| Normal operation | TA = +50°C | | | Square wave input | | 4.8 | 6.7 | | | | |
| | Resonator connection | | | | 4.8 | 6.7 | | | | | |
| Normal operation | TA = +70°C | | | Square wave input | | 4.8 | 7.5 | | | | |
| | Resonator connection | | | | 4.8 | 7.5 | | | | | |
| Normal operation | TA = +85°C | | | Square wave input | | 5.4 | 8.9 | | | | |
| | Resonator connection | | | | 5.4 | 8.9 | | | | | |
| Normal operation | TA = +105°C | | | Square wave input | | 7.2 | 21.0 | | | | |
| | Resonator connection | | | | 7.3 | 21.1 | | | | | |

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

- Note 1.** Total current flowing into V_{DD} and EV_{DD0}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD0} or V_{SS}, EV_{SS0}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 3.** When high-speed system clock and subsystem clock are stopped.
- Note 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.
- Note 5.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}@1\text{ MHz to }32\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 5.5\text{ V}@1\text{ MHz to }16\text{ MHz}$

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

Remark 2. f_{HOCO}: High-speed on-chip oscillator clock frequency (64 MHz max.)

Remark 3. f_{IH}: High-speed on-chip oscillator clock frequency (32 MHz max.)

Remark 4. f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)

Remark 5. Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/2)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | | | |
|--|----------------------|------------------------------|---|--|-------------------------------------|----------------------|------|------|----|------|
| Supply current Note 1 | IDD2 Note 2 | HALT mode | HS (high-speed main) mode Note 7 | fHOCO = 64 MHz, fIH = 32 MHz Note 4 | VDD = 5.0 V | | 0.80 | 4.36 | mA | |
| | | | | | VDD = 3.0 V | | 0.80 | 4.36 | | |
| | | | | fHOCO = 32 MHz, fIH = 32 MHz Note 4 | VDD = 5.0 V | | 0.54 | 3.67 | | |
| | | | | | VDD = 3.0 V | | 0.54 | 3.67 | | |
| | | | | fHOCO = 48 MHz, fIH = 24 MHz Note 4 | VDD = 5.0 V | | 0.62 | 3.42 | | |
| | | | | | VDD = 3.0 V | | 0.62 | 3.42 | | |
| | | | | fHOCO = 24 MHz, fIH = 24 MHz Note 4 | VDD = 5.0 V | | 0.44 | 2.85 | | |
| | | | | | VDD = 3.0 V | | 0.44 | 2.85 | | |
| | | | | fHOCO = 16 MHz, fIH = 16 MHz Note 4 | VDD = 5.0 V | | 0.40 | 2.08 | | |
| | | | | | VDD = 3.0 V | | 0.40 | 2.08 | | |
| | | | | HS (high-speed main) mode Note 7 | fMX = 20 MHz Note 3, VDD = 5.0 V | Square wave input | | 0.28 | | 2.45 |
| | | | | | | Resonator connection | | 0.49 | | 2.57 |
| | | | | | fMX = 20 MHz Note 3, VDD = 3.0 V | Square wave input | | 0.28 | | 2.45 |
| | | | | | | Resonator connection | | 0.49 | | 2.57 |
| | | | | | fMX = 10 MHz Note 3, VDD = 5.0 V | Square wave input | | 0.19 | | 1.28 |
| | | | | | | Resonator connection | | 0.30 | | 1.36 |
| | | | | | fMX = 10 MHz Note 3, VDD = 3.0 V | Square wave input | | 0.19 | | 1.28 |
| | | | | | | Resonator connection | | 0.30 | | 1.36 |
| | | Subsystem clock operation | fsUB = 32.768 kHz Note 5, TA = -40°C | Square wave input | | 0.25 | 0.57 | | | |
| | | | | Resonator connection | | 0.44 | 0.76 | | | |
| | | | fsUB = 32.768 kHz Note 5, TA = +25°C | Square wave input | | 0.30 | 0.57 | | | |
| | | | | Resonator connection | | 0.49 | 0.76 | | | |
| | | | fsUB = 32.768 kHz Note 5, TA = +50°C | Square wave input | | 0.36 | 1.17 | | | |
| | | | | Resonator connection | | 0.59 | 1.36 | | | |
| fsUB = 32.768 kHz Note 5, TA = +70°C | Square wave input | | | 0.49 | 1.97 | | | | | |
| | Resonator connection | | | 0.72 | 2.16 | | | | | |
| fsUB = 32.768 kHz Note 5, TA = +85°C | Square wave input | | | 0.97 | 3.37 | | | | | |
| | Resonator connection | | | 1.16 | 3.56 | | | | | |
| fsUB = 32.768 kHz Note 5, TA = +105°C | Square wave input | | | 3.20 | 17.10 | | | | | |
| | Resonator connection | | | 3.40 | 17.50 | | | | | |
| IDD3 Note 6 | STOP mode Note 8 | TA = -40°C | | | 0.18 | 0.51 | μA | | | |
| | | TA = +25°C | | | 0.24 | 0.51 | | | | |
| | | TA = +50°C | | | 0.29 | 1.10 | | | | |
| | | TA = +70°C | | | 0.41 | 1.90 | | | | |
| | | TA = +85°C | | | 0.90 | 3.30 | | | | |
| | | TA = +105°C | | | 3.10 | 17.00 | | | | |

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

- Note 1.** Total current flowing into V_{DD} and EV_{DD0}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD0} or V_{SS}, EV_{SS0}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** During HALT instruction execution by flash memory.
- Note 3.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 4.** When high-speed system clock and subsystem clock are stopped.
- Note 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.
- Note 6.** Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.
- Note 7.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
 HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}@1\text{ MHz to }32\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 5.5\text{ V}@1\text{ MHz to }16\text{ MHz}$
- Note 8.** Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.
- Remark 1.** f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f_{HOCO}: High-speed on-chip oscillator clock frequency (64 MHz max.)
- Remark 3.** f_{IH}: High-speed on-chip oscillator clock frequency (32 MHz max.)
- Remark 4.** f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is TA = 25°C

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|--------------------|--|--|------|------|------|------|
| Low-speed on-chip oscillator operating current | IFIL Note 1 | | | | 0.2 | | μA |
| RTC operating current | IRTC Notes 1, 2, 3 | | | | 0.02 | | μA |
| 12-bit interval timer operating current | IIT Notes 1, 2, 4 | | | | 0.02 | | μA |
| Watchdog timer operating current | IWDT Notes 1, 2, 5 | fil = 15 kHz | | | 0.22 | | μA |
| A/D converter operating current | IADC Notes 1, 6 | When conversion at maximum speed | Normal mode, AVREFP = VDD = 5.0 V | | 1.3 | 1.7 | mA |
| | | | Low voltage mode, AVREFP = VDD = 3.0 V | | 0.5 | 0.7 | mA |
| A/D converter reference voltage current | IADREF Note 1 | | | | 75 | | μA |
| Temperature sensor operating current | ITMPS Note 1 | | | | 75 | | μA |
| D/A converter operating current | IDAC Notes 1, 11 | Per D/A converter channel | | | | 1.5 | mA |
| PGA operating current | | Operation | | | 480 | 700 | μA |
| Comparator operating current | ICMP Notes 1, 12 | Operation (per comparator channel, constant current for comparator included) | When the internal reference voltage is not in use | | 50 | 100 | μA |
| | | | When the internal reference voltage is in use | | 60 | 110 | μA |
| LVD operating current | ILVD Notes 1, 7 | | | | 0.08 | | μA |
| Self-programming operating current | IFSP Notes 1, 9 | | | | 2.50 | 12.2 | mA |
| BGO operating current | IBGO Notes 1, 8 | | | | 2.50 | 12.2 | mA |
| SNOOZE operating current | ISNOZ Note 1 | ADC operation | The mode is performed Note 10 | | 0.50 | 1.10 | mA |
| | | | The A/D conversion operations are performed, Low voltage mode, AVREFP = VDD = 3.0 V | | 1.20 | 2.04 | |
| | | CSI/JART operation | | 0.70 | 1.54 | | |
| | | DTC operation | | 3.10 | | | |

Note 1. Current flowing to VDD.

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

Note 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 IDD1 or IDD2, and IRTC, when the real-time clock operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added. IDD2 subsystem clock operation includes the operational current of the real-time clock.

Note 4. Current flowing only to the 12-bit interval timer (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 IDD1 or IDD2, and IIT, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.

Note 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 IDD1, IDD2 or IDD3 and IWDT when the watchdog timer is in operation.

Note 6. Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IADC when the A/D converter operates in an operation mode or the HALT mode.

Note 7. Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and ILVD when the LVD circuit is in operation.

Note 8. Current flowing during programming of the data flash.

Note 9. Current flowing during self-programming.

Note 10. For shift time to the SNOOZE mode, see **26.3.3 SNOOZE mode** in the RL78/G1F User's Manual.

Note 11. Current flowing only to the D/A converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IDAC when the D/A converter operates in an operation mode or the HALT mode.

Note 12. Current flowing only to the comparator circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2, or IDD3 and ICMP when the comparator circuit is in operation.

Remark 1. f_{IL}: Low-speed on-chip oscillator clock frequency

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

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

Remark 4. Temperature condition of the TYP. value is TA = 25°C

3.4 AC Characteristics

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | |
|---|-----------------|-------------------------------------|---------------------------|-----------------------|---------|------|------|----|
| Instruction cycle (minimum instruction execution time) | Tcy | Main system clock (fMAIN) operation | HS (high-speed main) mode | 2.7 V ≤ VDD ≤ 5.5 V | 0.03125 | | 1 | μs |
| | | | | 2.4 V ≤ VDD < 2.7 V | 0.0625 | | 1 | μs |
| | | Subsystem clock (fSUB) operation | | 2.4 V ≤ VDD ≤ 5.5 V | 28.5 | 30.5 | 31.3 | μs |
| | | In the self-programming mode | HS (high-speed main) mode | 2.7 V ≤ VDD ≤ 5.5 V | 0.03125 | | 1 | μs |
| 2.4 V ≤ VDD < 2.7 V | 0.0625 | | | | 1 | μs | | |
| External system clock frequency | fEX | 2.7 V ≤ VDD ≤ 5.5 V | | 1.0 | | 20.0 | MHz | |
| | | 2.4 V ≤ VDD ≤ 2.7 V | | 1.0 | | 16.0 | MHz | |
| | fEXS | | | 32 | | 35 | kHz | |
| External system clock input high-level width, low-level width | tEXH, | 2.7 V ≤ VDD ≤ 5.5 V | | 24 | | | ns | |
| | tEXL | 2.4 V ≤ VDD ≤ 2.7 V | | 30 | | | ns | |
| | tEXHS, tEXLS | | | 13.7 | | | μs | |
| Ti00 to Ti03 input high-level width, low-level width | tTih, tTil | | | 1/fMCK + 10 Note | | | ns | |
| Timer RJ input cycle | fc | TRJIO | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 100 | | ns | |
| | | | | 2.4 V ≤ EVDD0 < 2.7 V | 300 | | ns | |
| Timer RJ input high-level width, low-level width | tTjH, tTjL | TRJIO | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 40 | | ns | |
| | | | | 2.4 V ≤ EVDD0 < 2.7 V | 120 | | ns | |

Note The following conditions are required for low voltage interface when EVDD0 < VDD
2.4 V ≤ EVDD0 < 2.7 V: MIN. 125 ns

Remark fMCK: Timer array unit operation clock frequency

(Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3))

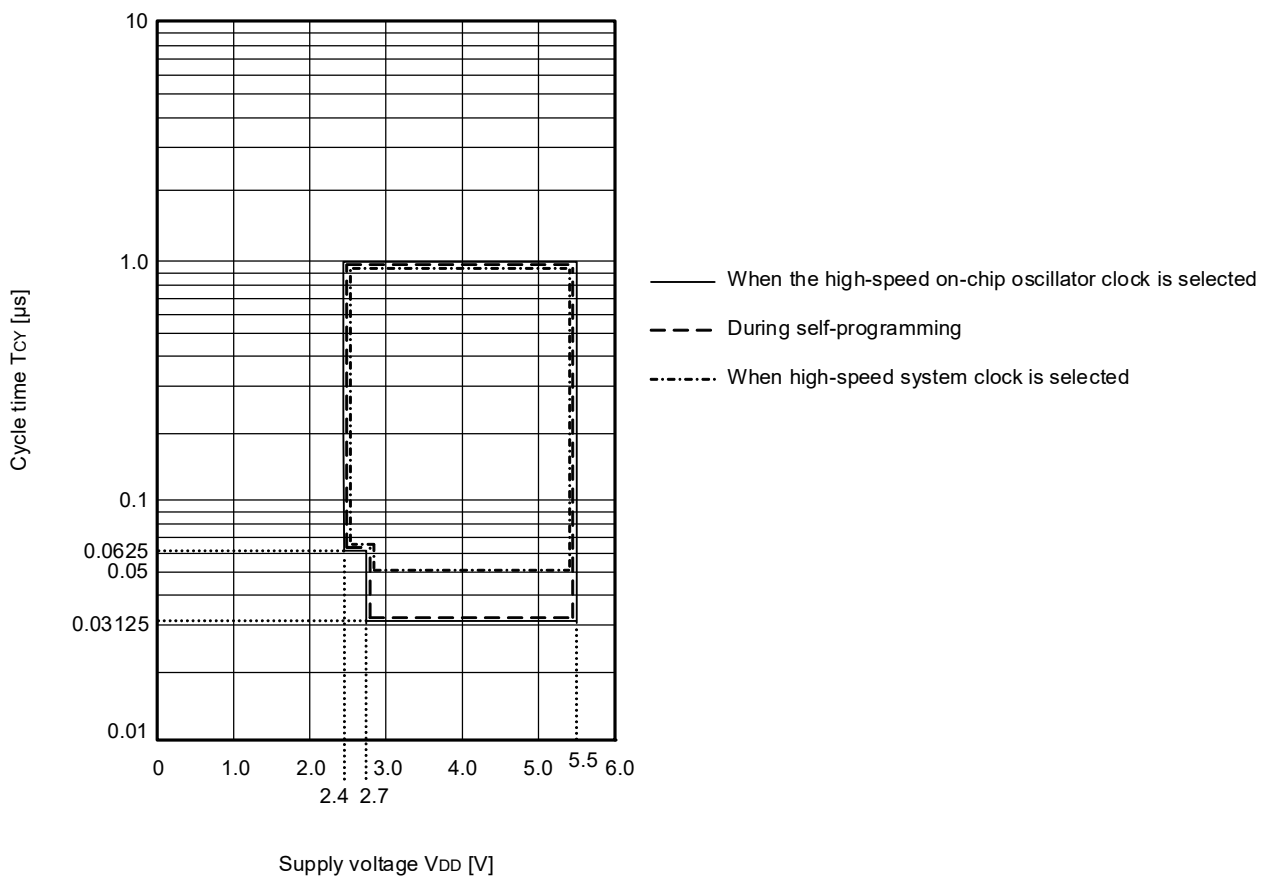
(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

(2/2)

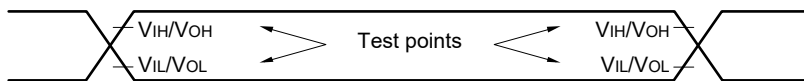
| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|-----------------|---|-----------------------|------------|------|------|------|
| Timer RD input high-level width, low-level width | tTDIH, tTDIL | TRDIOA0, TRDIOA1, TRDIOB0, TRDIOB1, TRDIOC0, TRDIOC1, TRDIOD0, TRDIOD1 | | 3/fCLK | | | ns |
| Timer RD forced cutoff signal input low-level width | tTDSIL | P130/INTP0 | 2MHz < fCLK ≤ 32 MHz | 1 | | | μs |
| | | | fCLK ≤ 2 MHz | 1/fCLK + 1 | | | |
| Timer RG input high-level width, low-level width | tTGIH, tTGIL | TRGIOA, TRGIOB | | 2.5/fCLK | | | ns |
| TO00 to TO03, TRJIO0, TRJO0, TRDIOA0, TRDIOA1, TRDIOB0, TRDIOB1, TRDIOC0, TRDIOC1, TRDIOD0, TRDIOD1, TRGIOA, TRGIOB output frequency | fTO | HS (high-speed main) mode | 4.0 V ≤ EVDD0 ≤ 5.5 V | | | 16 | MHz |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | | 8 | MHz |
| | | | 2.4 V ≤ EVDD0 < 2.7 V | | | 4 | MHz |
| PCLBUZ0, PCLBUZ1 output frequency | fPCL | HS (high-speed main) mode | 4.0 V ≤ EVDD0 ≤ 5.5 V | | | 16 | MHz |
| | | | 2.7 V ≤ EVDD0 < 4.0 V | | | 8 | MHz |
| | | | 2.4 V ≤ EVDD0 < 2.7 V | | | 4 | MHz |
| Interrupt input high-level width, low-level width | tINTH, tINTL | INTP0 | 2.4 V ≤ VDD ≤ 5.5 V | 1 | | | μs |
| | | INTP1 to INTP11 | 2.4 V ≤ EVDD0 ≤ 5.5 V | 1 | | | μs |
| Key interrupt input low-level width | tKR | KR0 to KR7 | 2.4 V ≤ EVDD0 ≤ 5.5 V | 250 | | | ns |
| RESET low-level width | tRSL | | | 10 | | | μs |

Minimum Instruction Execution Time during Main System Clock Operation

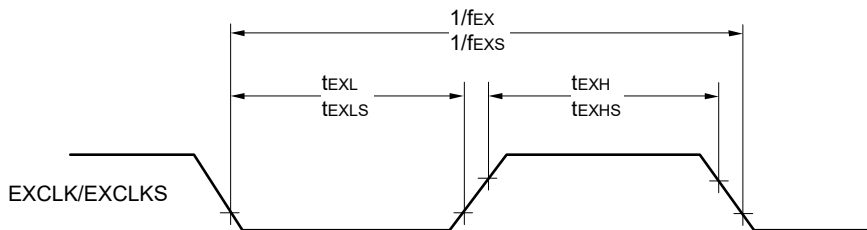
T_{cy} vs V_{DD} (HS (high-speed main) mode)



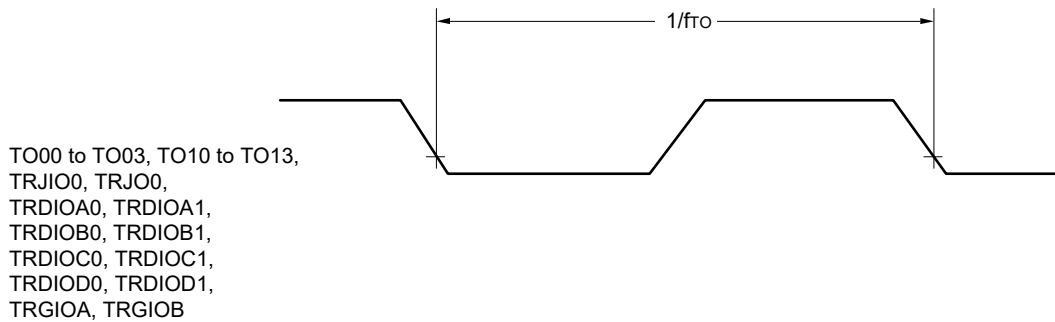
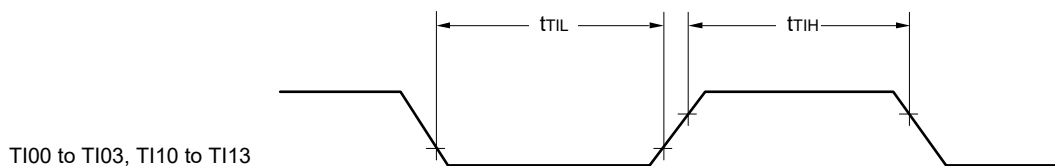
AC Timing Test Points



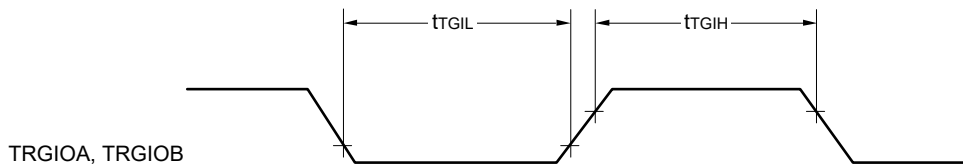
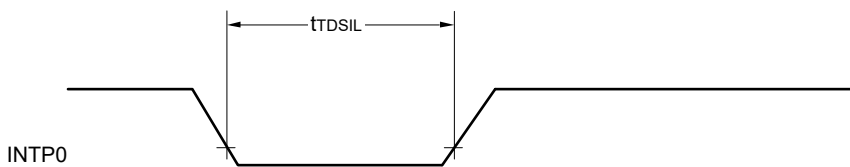
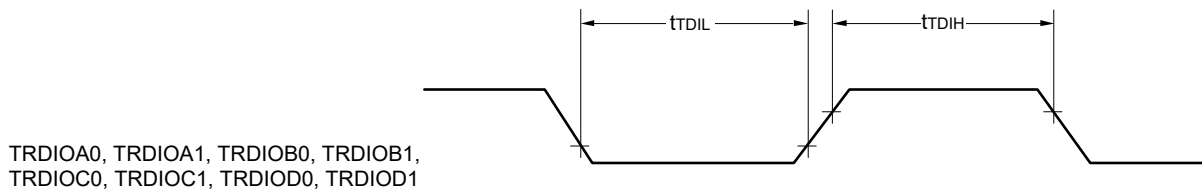
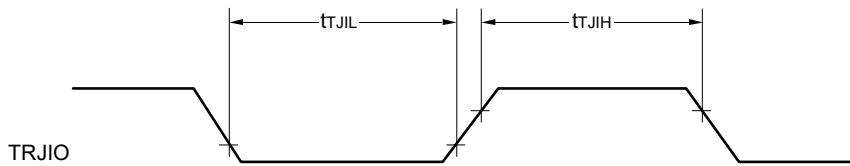
External System Clock Timing



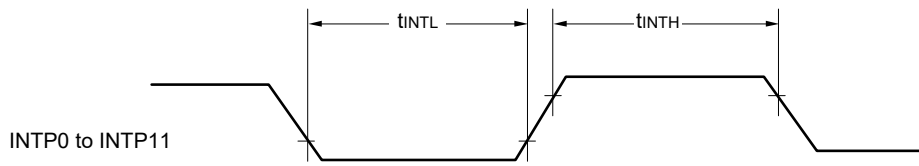
TI/TO Timing



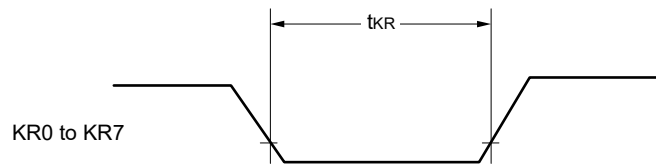
TO00 to TO03, TO10 to TO13,
 TRJIO0, TRJO0,
 TRDIOA0, TRDIOA1,
 TRDIOB0, TRDIOB1,
 TRDIOC0, TRDIOC1,
 TRDIOD0, TRDIOD1,
 TRGIOA, TRGIOB



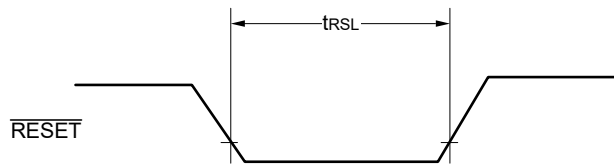
Interrupt Request Input Timing



Key Interrupt Input Timing

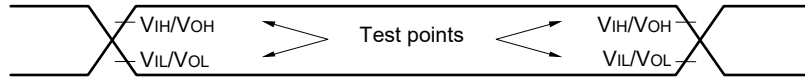


$\overline{\text{RESET}}$ Input Timing



3.5 Peripheral Functions Characteristics

AC Timing Test Points



3.5.1 Serial array unit

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

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | Unit |
|-------------------------|--------|--|---------------------------|----------------|------|
| | | | MIN. | MAX. | |
| Transfer rate Note 1 | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | fMCK/12 Note 2 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK Note 3 | | 2.6 | Mbps |

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

However, the SNOOZE mode cannot be used when FRQSEL4 = 1.

Note 2. The following conditions are required for low voltage interface when EVDD0 < VDD.

2.4 V ≤ EVDD0 < 2.7 V: MAX.1.3 Mbps

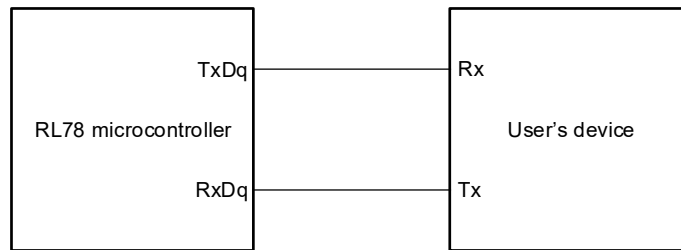
Note 3. The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

HS (high-speed main) mode: 32 MHz (2.7 V ≤ VDD ≤ 5.5 V)

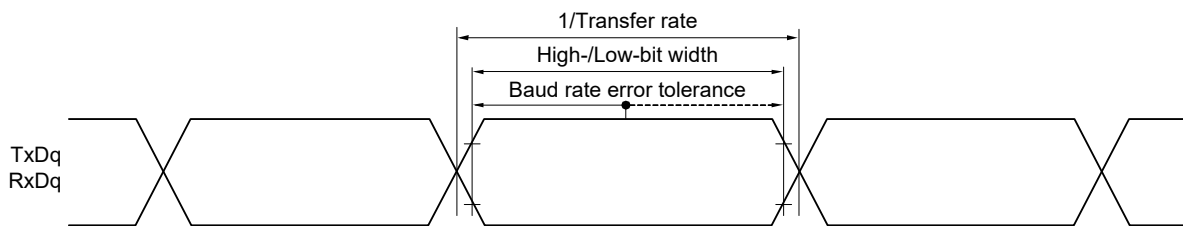
16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

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)



Remark 1. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 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, 10, 11))

(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|--|---------------|---|---------------------------|------|------|
| | | | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 2/fCLK 2.7 V ≤ EVDD0 ≤ 5.5 V | 250 | | ns |
| | | | 500 | | ns |
| SCKp high-/low-level width | tkH1, tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 24 | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 36 | | ns |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | tkCY1/2 - 76 | | |
| Slp setup time (to SCKp↑) Note 1 | tSIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V | 66 | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 66 | | ns |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 113 | | |
| Slp hold time (from SCKp↑) Note 2 | tKSI1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 38 | | ns |
| Delay time from SCKp↓ to SOp output Note 3 | tKSO1 | C = 20 pF Note 4 | | 50 | ns |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 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.

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

Caution Select the normal input buffer for the Slp 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).

Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1, 3, 5, 7)

Remark 2. fMCK: 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, 10, 11))

(3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)
(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | HS (high-speed main) mode | | Unit |
|--|---------------|-----------------------|-----------------------|---------------------------|--------------|------|
| | | | | MIN. | MAX. | |
| SCKp cycle time Note 5 | tkcy2 | 4.0 V ≤ EVDD0 ≤ 5.5 V | 20 MHz < fmck | 16/fmck | | ns |
| | | | fmck ≤ 20 MHz | 12/fmck | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | 16 MHz < fmck | 16/fmck | | ns |
| | | | fmck ≤ 16 MHz | 12/fmck | | ns |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | 12/fmck and 1000 | | ns |
| SCKp high-/low-level width | tkH2, tkL2 | 4.0 V ≤ EVDD0 ≤ 5.5 V | | tkcy2/2 - 14 | | ns |
| | | 2.7 V ≤ EVDD0 ≤ 5.5 V | | tkcy2/2 - 16 | | ns |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | 1/fmck + 36 | | ns |
| Slp setup time (to SCKp↑) Note 1 | tsik2 | 2.7 V ≤ EVDD0 ≤ 5.5 V | | 1/fmck + 40 | | ns |
| | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | 1/fmck + 60 | | ns |
| Slp hold time (from SCKp↑) Note 2 | tkSi2 | | | 1/fmck + 62 | | ns |
| Delay time from SCKp↓ to SOp output Note 3 | tkSO2 | C = 30 pF Note 4 | 2.7 V ≤ EVDD0 ≤ 5.5 V | | 2/fmck + 66 | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | | 2/fmck + 113 | ns |

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 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.

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

Note 5. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

Caution Select the normal input buffer for the Slp 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).

Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21), m: Unit number (m = 0, 1),
n: Channel number (n = 0 to 3), g: PIM number (g = 0, 1, 3, 5, 7)

Remark 2. fmck: 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, 10, 11))

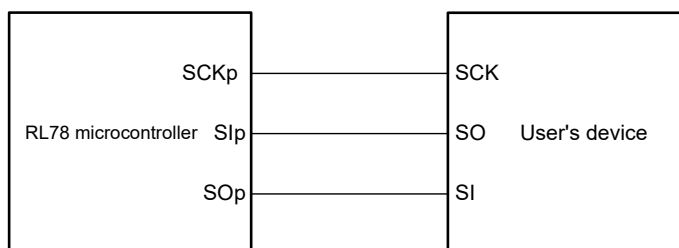
(3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)
(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)(2/2)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit | |
|------------------|--------|------------|---------------------------|--------------|------|----|
| | | | MIN. | MAX. | | |
| SSIO0 setup time | tSSIK | DAPmn = 0 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 240 | | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 400 | | ns |
| | | DAPmn = 1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 240 | | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 400 | | ns |
| SSIO0 hold time | tKSSI | DAPmn = 0 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 240 | | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 1/fMCK + 400 | | ns |
| | | DAPmn = 1 | 2.7 V ≤ EVDD0 ≤ 5.5 V | 240 | | ns |
| | | | 2.4 V ≤ EVDD0 ≤ 5.5 V | 400 | | ns |

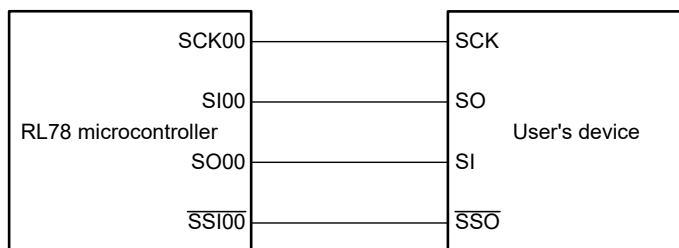
Caution Select the normal input buffer for the Slp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

Remark p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM number (g = 3, 5)

CSI mode connection diagram (during communication at same potential)



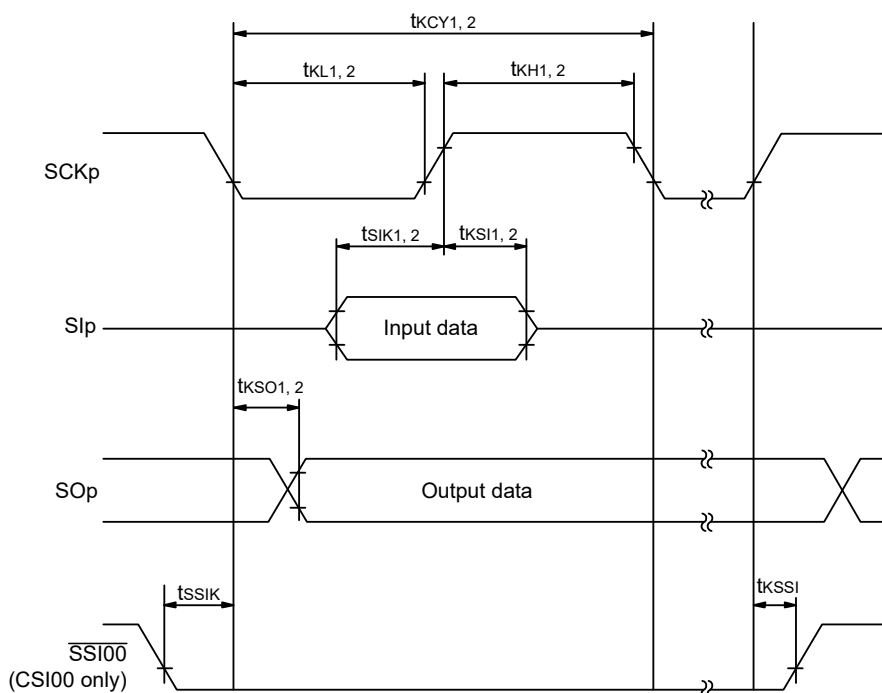
CSI mode connection diagram (during communication at same potential)
(Slave Transmission of slave select input function (CSI00))



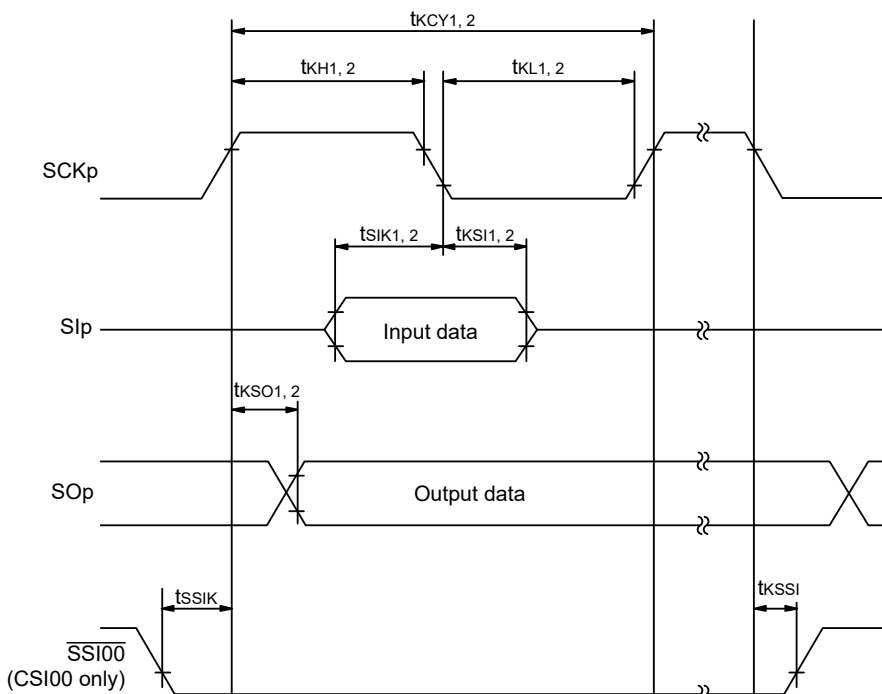
Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

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.)



Remark 1. p: CSI number (p = 00, 01, 10, 11, 20, 21)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10, 11)

(4) During communication at same potential (simplified I²C mode)**(TA = -40 to +105°C, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 0 V)**

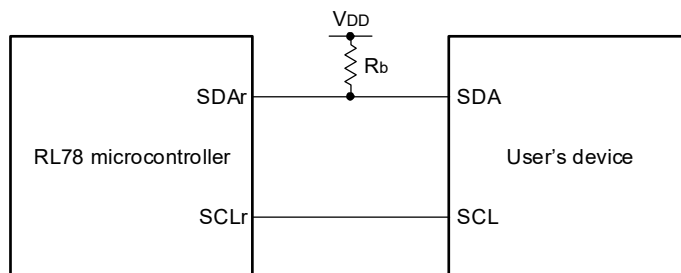
| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|-------------------------------|----------------------|---|---------------------------------|------------|------|
| | | | MIN. | MAX. | |
| SCLr clock frequency | f _{SCL} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | | 400 Note 1 | kHz |
| | | 2.4 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | | 100 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 1200 | | ns |
| | | 2.4 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 4600 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 1200 | | ns |
| | | 2.4 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 4600 | | ns |
| Data setup time (reception) | t _{SU: DAT} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 220 Note 2 | | ns |
| | | 2.4 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 1/f _{MCK} + 580 Note 2 | | ns |
| Data hold time (transmission) | t _{HD: DAT} | 2.7 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ | 0 | 770 | ns |
| | | 2.4 V ≤ EV _{DD0} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ | 0 | 1420 | ns |

Note 1. The value must also be equal to or less than f_{MCK}/4.**Note 2.** Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

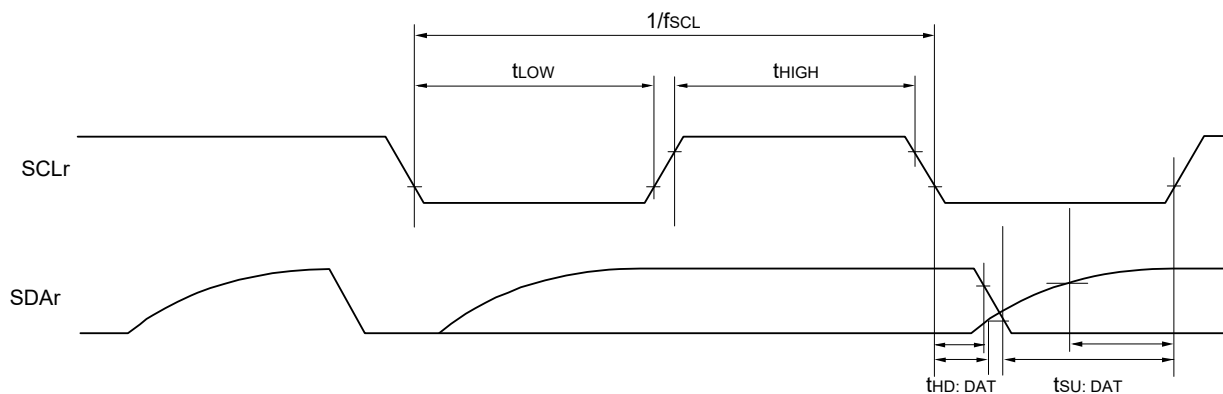
Caution Select the normal input buffer and the N-ch open drain output (V_{bd} tolerance (for the 48-, 32-, 24-pin products)/EV_{bd} tolerance (for the 64-, 36-pin products)) mode for the SDAr pin and the normal output mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register h (POMh).

(Remarks are listed on the next page.)

Simplified I²C mode connection diagram (during communication at same potential)



Simplified I²C mode serial transfer timing (during communication at same potential)



Remark 1. R_b[Ω]: Communication line (SDAr) pull-up resistance, C_b[F]: Communication line (SDAr, SCLr) load capacitance

Remark 2. r: IIC number (r = 00, 01, 10, 11, 20, 21), g: PIM number (g = 0, 1, 3, 5, 7),
h: POM number (h = 0, 1, 3, 5, 7)

Remark 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 (m = 0, 1),
n: Channel number (n = 0 to 3), mn = 00 to 03, 10, 11)

(5) Communication at different potential (1.8 V, 2.5 V, 3 V) (UART mode)**(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(1/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit | |
|---------------|--------|------------|--|------|------------------------------------|------|
| | | | MIN. | MAX. | | |
| Transfer rate | | reception | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | | f _{mck} /12 Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Note 3 | | 2.6 | Mbps |
| | | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | | f _{mck} /12 Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Note 3 | | 2.6 | Mbps |
| | | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | | f _{mck} /12 Notes 1, 2 | bps |
| | | | Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Note 3 | | 1.3 | Mbps |

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

However, the SNOOZE mode cannot be used when FRQSEL4 = 1.

Note 2. The following conditions are required for low voltage interface when EVDD0 < VDD.

2.4 V ≤ EVDD0 < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ EVDD0 < 2.4 V: MAX. 1.3 Mbps

Note 3. The maximum operating frequencies of the CPU/peripheral hardware clock (f_{clk}) are:

HS (high-speed main) mode: 32 MHz (2.7 V ≤ VDD ≤ 5.5 V)

16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

Remark 1. Vb [V]: Communication line voltage

Remark 2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 5, 7)

Remark 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, 10, 11)

Remark 4. UART2 cannot communicate at different potential when bit 1 (PIOR01) of peripheral I/O redirection register 0 (PIOR0) is 1.

(5) Communication at different potential (1.8 V, 2.5 V, 3 V) (UART mode)**(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit | |
|---------------|--------|--------------|--|------|-------------|------|
| | | | MIN. | MAX. | | |
| Transfer rate | | transmission | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | | Note 1 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 1.4 kΩ, Vb = 2.7 V | | 2.6 Note 2 | Mbps |
| | | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | | Note 3 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 2.7 kΩ, Vb = 2.3 V | | 1.2 Note 4 | Mbps |
| | | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | | Note 5 | bps |
| | | | Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 5.5 kΩ, Vb = 1.6 V | | 0.43 Note 6 | Mbps |

Note 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 $4.0\text{ V} \leq \text{EVDD0} \leq 5.5\text{ V}$ and $2.7\text{ V} \leq V_b \leq 4.0\text{ V}$

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

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

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

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

Note 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 $2.7\text{ V} \leq \text{EVDD0} < 4.0\text{ V}$ and $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$

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

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

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

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

Note 5. 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 $2.4\text{ V} \leq EV_{DD0} < 3.3\text{ V}$ and $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$

$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \text{ [bps]}$$

$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{\left(\frac{1}{\text{Transfer rate}}\right) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

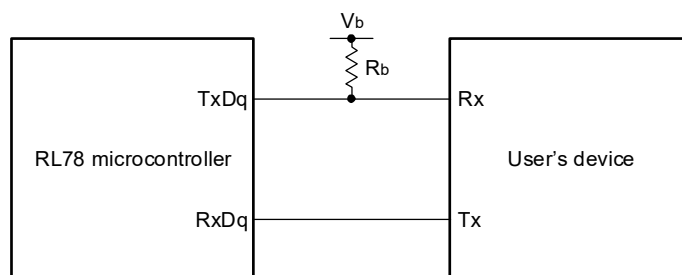
* This value is the theoretical value of the relative difference between the transmission and reception sides.

Note 6. This value as an example is calculated when the conditions described in the "Conditions" column are met. Refer to **Note 5** above to calculate the maximum transfer rate under conditions of the customer.

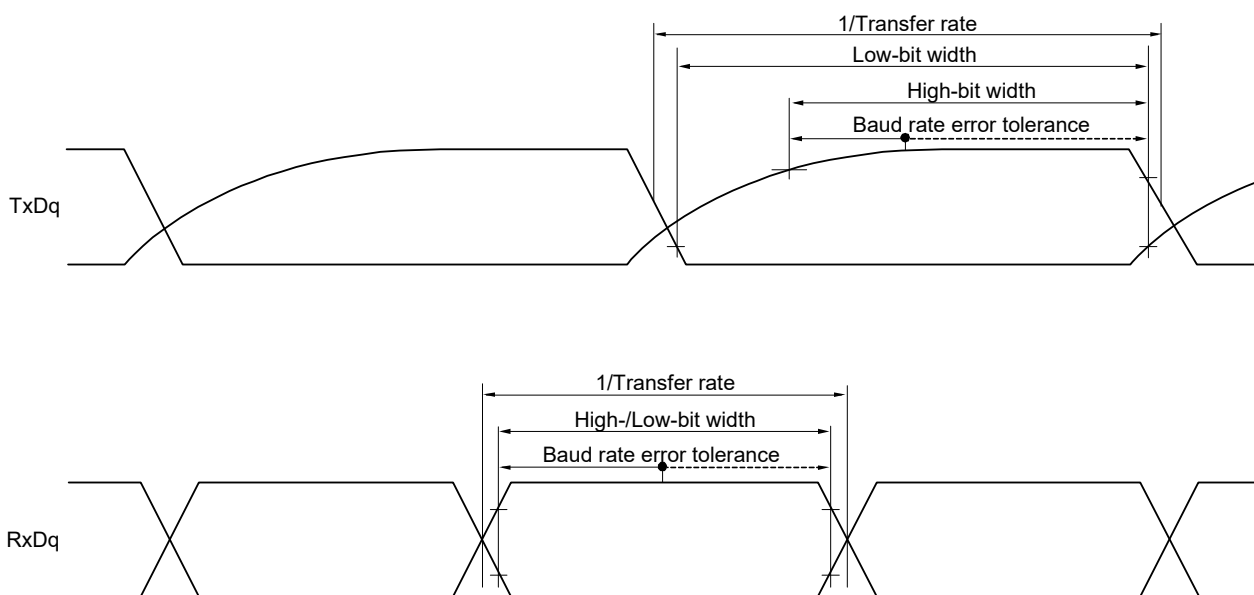
Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/ EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

UART mode connection diagram (during communication at different potential)



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



- Remark 1.** $R_b[\Omega]$: Communication line (TxDq) pull-up resistance,
 $C_b[F]$: Communication line (TxDq) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 5, 7)
- Remark 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, 10, 11))
- Remark 4.** UART2 cannot communicate at different potential when bit 1 (PIOR01) of peripheral I/O redirection register 0 (PIOR0) is 1.

(6) Communication at different potential (2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)
(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|-----------------------|--------|--|---------------------------|------|------|
| | | | MIN. | MAX. | |
| SCKp cycle time | tkCY1 | tkCY1 ≥ 4/fCLK 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 600 | | ns |
| | | | 1000 | | ns |
| | | | 2300 | | ns |
| SCKp high-level width | tkH1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | tkCY1/2 - 150 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | tkCY1/2 - 340 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | tkCY1/2 - 916 | | ns |
| SCKp low-level width | tkL1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | tkCY1/2 - 24 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | tkCY1/2 - 36 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | tkCY1/2 - 100 | | ns |

Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOP pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed two pages after the next page.)

(6) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +105°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(2/3)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|---|--------|--|---------------------------|------|------|
| | | | MIN. | MAX. | |
| Slp setup time (to SCKp↑) ^{Note} | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 162 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 354 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | 958 | | ns |
| Slp hold time (from SCKp↑) ^{Note} | tkSH | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 38 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 38 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | 38 | | ns |
| Delay time from SCKp↓ to SOp output ^{Note} | tkSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 200 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 390 | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | | 966 | ns |

Note When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

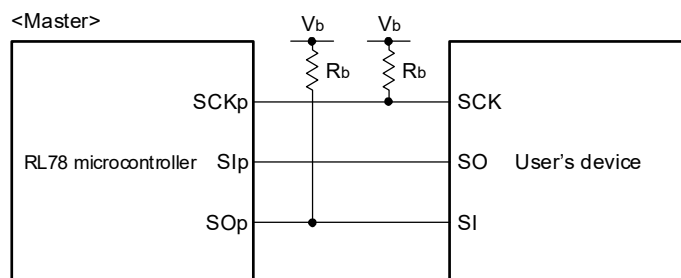
(Remarks are listed on the page after the next page.)

(6) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +105°C, 1.8 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)****(3/3)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|---|--------|--|---------------------------|------|------|
| | | | MIN. | MAX. | |
| Slp setup time (to SCKp↓) ^{Note} | tsIK1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 88 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 88 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | 220 | | ns |
| Slp hold time (from SCKp↓) ^{Note} | tkSH1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | 38 | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | 38 | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | 38 | | ns |
| Delay time from SCKp↑ to SOp output ^{Note} | tkSO1 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 50 | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 50 | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rb = 5.5 kΩ | | 50 | ns |

Note When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Caution** Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD tolerance (for the 48-, 32-, 24-pin products)/EVDD tolerance (for the 64-, 36-pin products)) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

CSI mode connection diagram (during communication at different potential)

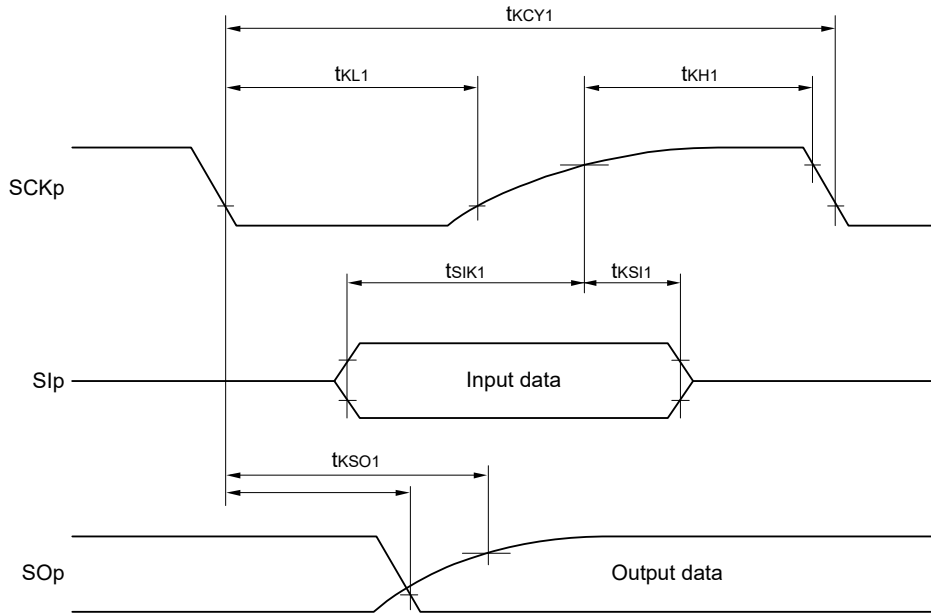
Remark 1. $R_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $C_b[F]$: Communication line (SCKp, SOp) load capacitance, $V_b[V]$: Communication line voltage

Remark 2. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 5, 7)

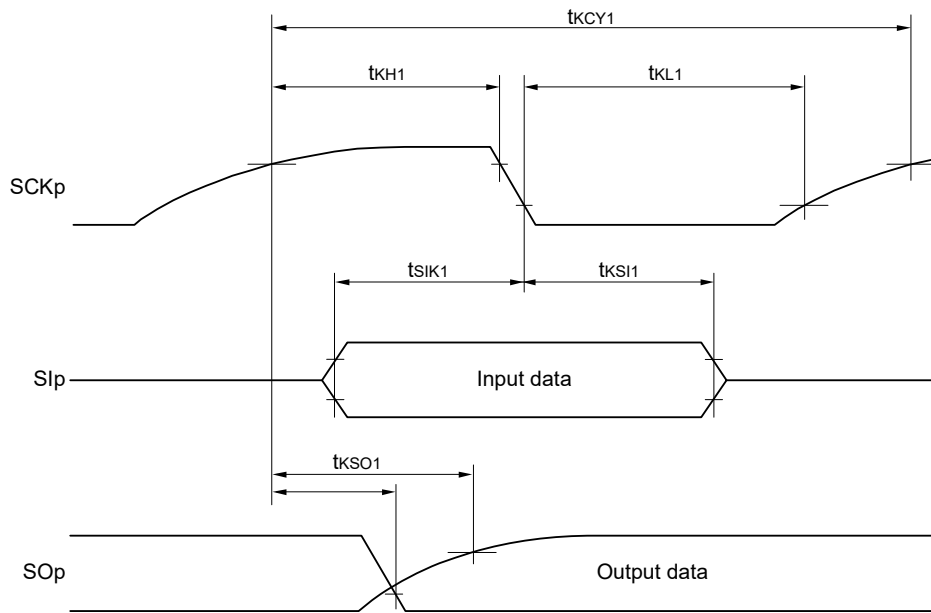
Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00))

Remark 4. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

**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.)**



Remark 1. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 2. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.

Remark 3. Remark 3. fMCK: Serial array unit operation clock frequency (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 01, 02, 10)

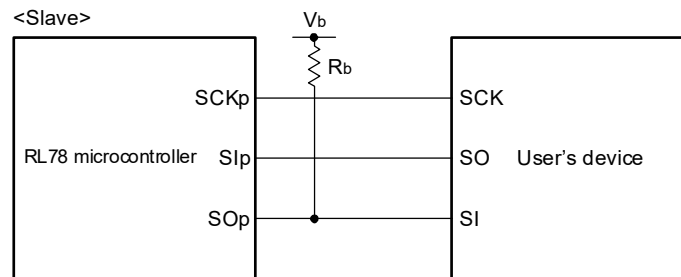
(7) Communication at different potential (1.8 V, 2.5 V, 3 V) (CSI mode) (slave mode, SCKp... external clock input)**(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit | |
|---|--------|---|---------------------------|---------------|------|----|
| | | | MIN. | MAX. | | |
| SCKp cycle time ^{Note 1} | tkcy2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | 24 MHz < fmck | 28/fmck | | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 24/fmck | | ns |
| | | | 8 MHz < fmck ≤ 20 MHz | 20/fmck | | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 16/fmck | | ns |
| | | | fmck ≤ 4 MHz | 12/fmck | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | 24 MHz < fmck | 40/fmck | | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 32/fmck | | ns |
| | | | 16 MHz < fmck ≤ 20 MHz | 28/fmck | | ns |
| | | | 8 MHz < fmck ≤ 16 MHz | 24/fmck | | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 16/fmck | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | 24 MHz < fmck | 96/fmck | | ns |
| | | | 20 MHz < fmck ≤ 24 MHz | 72/fmck | | ns |
| | | | 16 MHz < fmck ≤ 20 MHz | 64/fmck | | ns |
| | | | 8 MHz < fmck ≤ 16 MHz | 52/fmck | | ns |
| | | | 4 MHz < fmck ≤ 8 MHz | 32/fmck | | ns |
| | | fmck ≤ 4 MHz | 20/fmck | | ns | |
| | | SCKp high-/low-level width | | tkcy2/2 - 24 | | ns |
| | | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V | | | | ns |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | | | | ns |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | | tkcy2/2 - 100 | | ns |
| Slp setup time (to SCKp↑) ^{Note 2} | tslk2 | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V | 1/fmck + 40 | | ns | |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V | 1/fmck + 60 | | ns | |
| Slp hold time (from SCKp↑) ^{Note 3} | tksl2 | | 1/fmck + 62 | | ns | |
| Delay time from SCKp↓ to SOP output ^{Note 4} | tkso2 | 4.0 V ≤ EVDD0 ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ | | 2/fmck + 240 | ns | |
| | | 2.7 V ≤ EVDD0 < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ | | 2/fmck + 428 | ns | |
| | | 2.4 V ≤ EVDD0 < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V, Cb = 30 pF, Rv = 5.5 kΩ | | 2/fmck + 1146 | ns | |

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

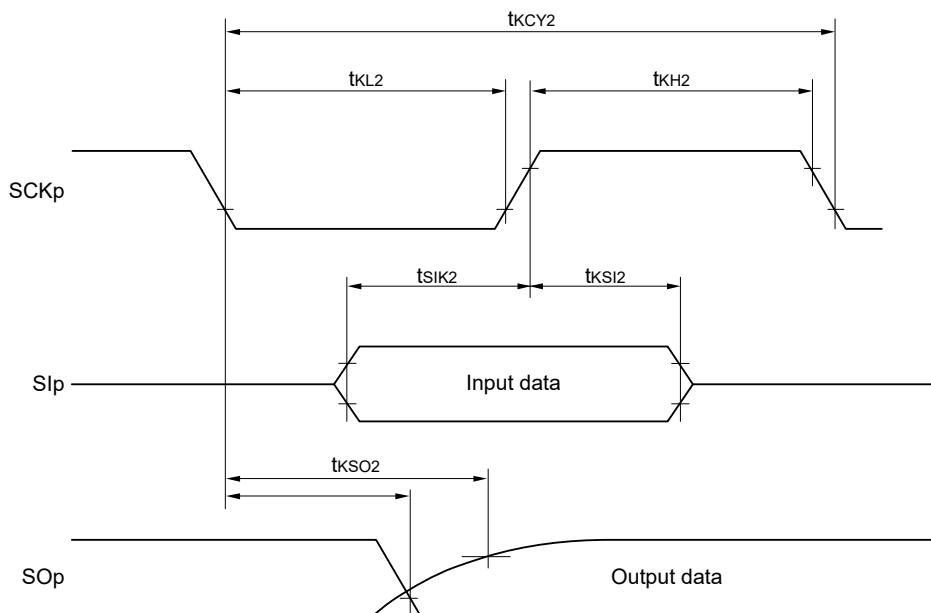
- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 4.** 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.
- Note 5.** Select the TTL input buffer for the SIp pin and SCKp pin, and the N-ch open drain output (VDD tolerance (for the 48, 32, 24-pin products)/EVDD tolerance (for the 64, 36-pin products)) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

CSI mode connection diagram (during communication at different potential)

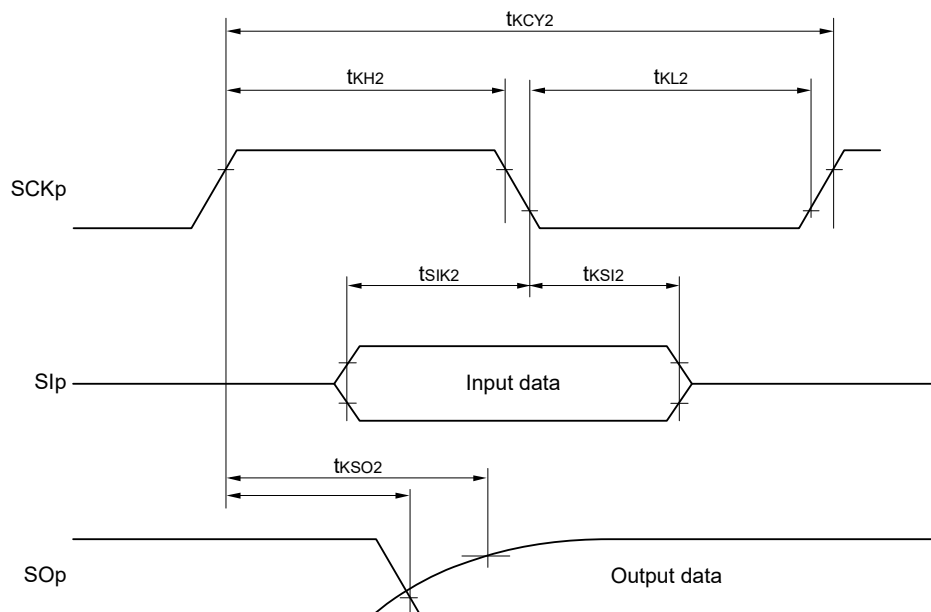


- Remark 1.** Rb[Ω]: Communication line (SOp) pull-up resistance, Cb[F]: Communication line (SOp) load capacitance, Vb[V]: Communication line voltage
- Remark 2.** p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 5, 7)
- Remark 3.** fMCK: 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, 01, 02, 10))
- Remark 4.** CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.
Also, communication at different potential cannot be performed during clock synchronous serial communication with the slave select function.

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



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



Remark 1. p: CSI number (p = 00, 01, 10, 20), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
 g: PIM and POM number (g = 0, 1, 3, 5, 7)

Remark 2. CSI01 of 48-, 64-pin products, and CSI11 and CSI21 cannot communicate at different potential. Use other CSI for communication at different potential.
 Also, communication at different potential cannot be performed during clock synchronous serial communication with the slave select function.

(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I²C mode)**(TA = -40 to +105°C, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 0 V)****(1/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|---------------------------|-------------------|---|---------------------------|------------|------|
| | | | MIN. | MAX. | |
| SCLr clock frequency | f _{SCL} | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 50 pF, R _b = 2.7 kΩ | | 400 Note 1 | kHz |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ | | 400 Note 1 | kHz |
| | | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 100 pF, R _b = 2.8 kΩ | | 100 Note 1 | kHz |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ | | 100 Note 1 | kHz |
| | | 2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 100 pF, R _b = 5.5 kΩ | | 100 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 50 pF, R _b = 2.7 kΩ | 1200 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ | 1200 | | ns |
| | | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 100 pF, R _b = 2.8 kΩ | 4600 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ | 4600 | | ns |
| | | 2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 100 pF, R _b = 5.5 kΩ | 4650 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 50 pF, R _b = 2.7 kΩ | 620 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ | 500 | | ns |
| | | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 100 pF, R _b = 2.8 kΩ | 2700 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ | 2400 | | ns |
| | | 2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 100 pF, R _b = 5.5 kΩ | 1830 | | ns |

(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I²C mode)**(TA = -40 to +105°C, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 0 V)****(2/2)**

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | Unit |
|-------------------------------|---------------------|---|---------------------------------|------|------|
| | | | MIN. | MAX. | |
| Data setup time (reception) | t _{SU:DAT} | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 340 Note 2 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 340 Note 2 | | ns |
| | | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 100 pF, R _b = 2.8 kΩ | 1/f _{MCK} + 760 Note 2 | | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 760 Note 2 | | ns |
| | | 2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 100 pF, R _b = 5.5 kΩ | 1/f _{MCK} + 570 Note 2 | | ns |
| Data hold time (transmission) | t _{HD:DAT} | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 50 pF, R _b = 2.7 kΩ | 0 | 770 | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ | 0 | 770 | ns |
| | | 4.0 V ≤ EV _{DD0} ≤ 5.5 V, 2.7 V ≤ V _b ≤ 4.0 V, C _b = 100 pF, R _b = 2.8 kΩ | 0 | 1420 | ns |
| | | 2.7 V ≤ EV _{DD0} < 4.0 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ | 0 | 1420 | ns |
| | | 2.4 V ≤ EV _{DD0} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 100 pF, R _b = 5.5 kΩ | 0 | 1215 | ns |

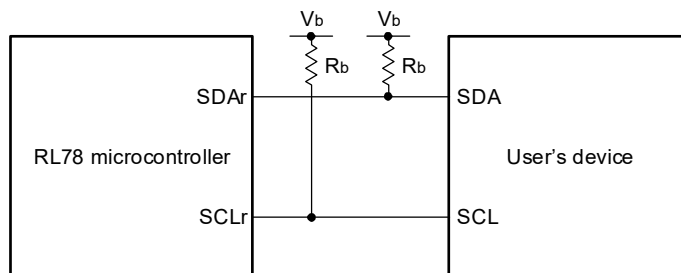
Note 1. The value must also be equal to or less than f_{MCK}/4.

Note 2. Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

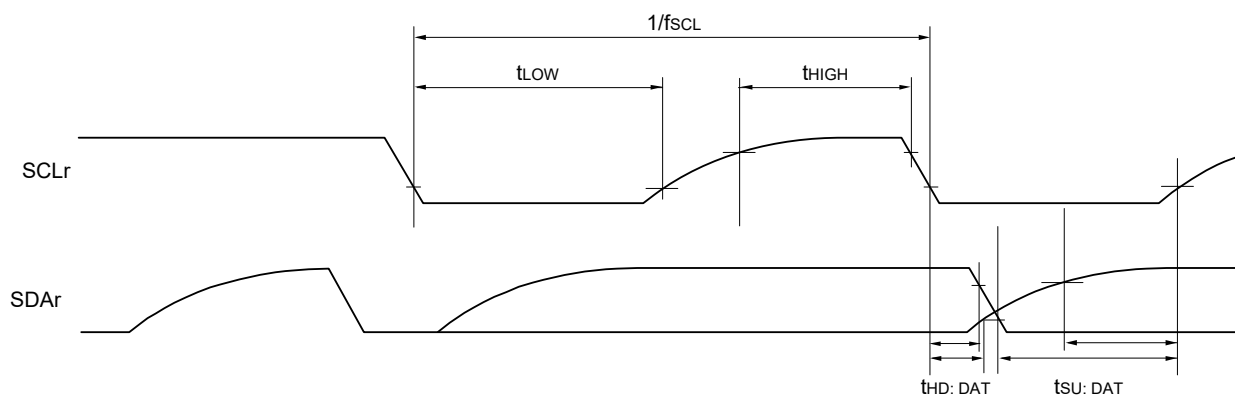
Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance (for the 48-, 32-, 24-pin products)/EV_{DD} tolerance (for the 64-, 36-pin products)) mode for the SCLr 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 are listed on the next page.)

Simplified I²C mode connection diagram (during communication at different potential)



Simplified I²C mode serial transfer timing (during communication at different potential)



- Remark 1.** R_b[Ω]: Communication line (SDAr, SCLr) pull-up resistance, C_b[F]: Communication line (SDAr, SCLr) load capacitance, V_b[V]: Communication line voltage
- Remark 2.** r: IIC number (r = 00, 01, 10, 11, 20), g: PIM, POM number (g = 0, 1, 3, 5, 7)
- Remark 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 (m = 0, 1), n: Channel number (n = 0, 2), mn = 00, 01, 02, 10)

3.5.2 Serial interface IICA

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) mode | | | | Unit |
|---|----------------------|---|---------------------------|------|-----------|------|------|
| | | | Standard mode | | Fast mode | | |
| | | | MIN. | MAX. | MIN. | MAX. | |
| SCLA0 clock frequency | f _{SCL} | Fast mode: f _{CLK} ≥ 3.5 MHz | — | — | 0 | 400 | kHz |
| | | Standard mode: f _{CLK} ≥ 1 MHz | 0 | 100 | — | — | kHz |
| Setup time of restart condition | t _{SU: STA} | | 4.7 | | 0.6 | | μs |
| Hold time ^{Note 1} | t _{HD: STA} | | 4.0 | | 0.6 | | μs |
| Hold time when SCLA0 = "L" | t _{LOW} | | 4.7 | | 1.3 | | μs |
| Hold time when SCLA0 = "H" | t _{HIGH} | | 4.0 | | 0.6 | | μs |
| Data setup time (reception) | t _{SU: DAT} | | 250 | | 100 | | ns |
| Data hold time (transmission) ^{Note 2} | t _{HD: DAT} | | 0 | 3.45 | 0 | 0.9 | μs |
| Setup time of stop condition | t _{SU: STO} | | 4.0 | | 0.6 | | μs |
| Bus-free time | t _{BUF} | | 4.7 | | 1.3 | | μs |

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

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

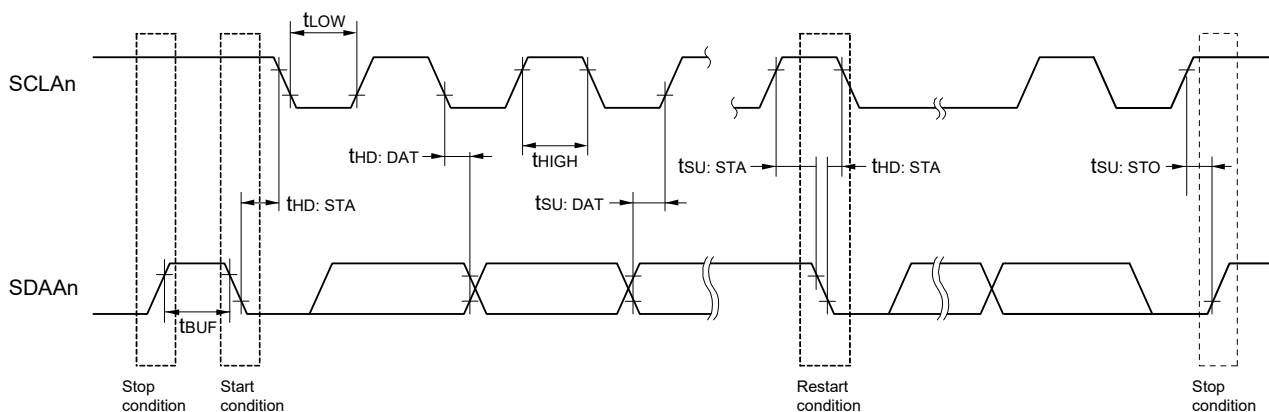
Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IOL1, VOH1, VOL1) must satisfy the values in the redirect destination.

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (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

Fast mode: C_b = 320 pF, R_b = 1.1 kΩ

IICA serial transfer timing



Remark n = 0, 1

3.6 Analog Characteristics

3.6.1 A/D converter characteristics

Classification of A/D converter characteristics

| Input channel | Reference Voltage | Reference voltage (+) = AVREFP Reference voltage (-) = AVREFM | Reference voltage (+) = VDD Reference voltage (-) = VSS | Reference voltage (+) = VBGR Reference voltage (-) = AVREFM |
|---|-------------------|--|--|--|
| ANI0 to ANI7 | | Refer to 3.6.1 (1). | Refer to 3.6.1 (3). | Refer to 3.6.1 (4). |
| ANI16 to ANI24 | | Refer to 3.6.1 (2). | | |
| Internal reference voltage Temperature sensor output voltage | | Refer to 3.6.1 (1). | | |

(1) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI2 to ANI7, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +105°C, 2.4 V ≤ AVREFP ≤ VDD ≤ 5.5 V, VSS = 0 V, Reference voltage (+) = AVREFP,
Reference voltage (-) = AVREFM = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|--------|---|------------------------|--------|----------------|------|
| Resolution | RES | | 8 | | 10 | bit |
| Overall error Note 1 | AINL | 10-bit resolution AVREFP = VDD Note 3 | 2.4 V ≤ AVREFP ≤ 5.5 V | 1.2 | ±3.5 | LSB |
| Conversion time | tCONV | 10-bit resolution Target pin: ANI2 to ANI14 | 3.6 V ≤ VDD ≤ 5.5 V | 2.125 | 39 | μs |
| | | | 2.7 V ≤ VDD ≤ 5.5 V | 3.1875 | 39 | μs |
| | | | 2.4 V ≤ VDD ≤ 5.5 V | 17 | 39 | μs |
| | | 10-bit resolution Target pin: Internal reference voltage, and temperature sensor output voltage (HS (high-speed main) mode) | 3.6 V ≤ VDD ≤ 5.5 V | 2.375 | 39 | μs |
| | | | 2.7 V ≤ VDD ≤ 5.5 V | 3.5625 | 39 | μs |
| | | | 2.4 V ≤ VDD ≤ 5.5 V | 17 | 39 | μs |
| Zero-scale error Notes 1, 2 | EzS | 10-bit resolution AVREFP = VDD Note 3 | 2.4 V ≤ AVREFP ≤ 5.5 V | | ±0.25 | %FSR |
| Full-scale error Notes 1, 2 | EFS | 10-bit resolution AVREFP = VDD Note 3 | 2.4 V ≤ AVREFP ≤ 5.5 V | | ±0.25 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution AVREFP = VDD Note 3 | 2.4 V ≤ AVREFP ≤ 5.5 V | | ±2.5 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution AVREFP = VDD Note 3 | 2.4 V ≤ AVREFP ≤ 5.5 V | | ±1.5 | LSB |
| Analog input voltage | VAIN | ANI2 to ANI7 | 0 | | AVREFP | V |
| | | Internal reference voltage output (2.4 V ≤ VDD ≤ 5.5 V, HS (high-speed main) mode) | | | VBGR Note 4 | V |
| | | Temperature sensor output voltage (2.4 V ≤ VDD ≤ 5.5 V, HS (high-speed main) mode) | | | VTMPS25 Note 4 | V |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. When AVREFP < VDD, the MAX. values are as follows.

Overall error: Add ±1.0 LSB to the MAX. value when AVREFP = VDD.

Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when AVREFP = VDD.

Integral linearity error/ Differential linearity error: Add ±0.5 LSB to the MAX. value when AVREFP = VDD.

Note 4. Refer to 3.6.2 Temperature sensor characteristics/internal reference voltage characteristic.

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = $AV_{REFM}/ANI1$ (ADREFM = 1), target pin: ANI16 to ANI24

(TA = -40 to +105°C, $2.4\text{ V} \leq EV_{DD0} \leq V_{DD} \leq 5.5\text{ V}$, $2.4\text{ V} \leq AV_{REFP} \leq V_{DD} \leq 5.5\text{ V}$,

VSS = EVSS0 = 0 V, Reference voltage (+) = AV_{REFP} , Reference voltage (-) = $AV_{REFM} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|--------|--|---|--------|----------------------------------|-------------|
| Resolution | RES | | 8 | | 10 | bit |
| Overall error Note 1 | AINL | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | 1.2 | ±5.0 LSB |
| Conversion time | tCONV | 10-bit resolution Target ANI pin: ANI16 to ANI20 | $3.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 2.125 | 39 | μs |
| | | | $2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 3.1875 | 39 | μs |
| | | | $2.4\text{ V} \leq V_{DD} \leq 5.5\text{ V}$ | 17 | 39 | μs |
| Zero-scale error Notes 1, 2 | EzS | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | ±0.35 | %FSR |
| Full-scale error Notes 1, 2 | EFS | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | ±0.35 | %FSR |
| Integral linearity error Note 1 | ILE | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | ±3.5 | LSB |
| Differential linearity error Note 1 | DLE | 10-bit resolution $EV_{DD0} \leq AV_{REFP} = V_{DD}$ Notes 3, 4 | $2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ | | ±2.0 | LSB |
| Analog input voltage | VAIN | ANI16 to ANI24 | 0 | | AV_{REFP} and EV_{DD0} | V |

Note 1. Excludes quantization error ($\pm 1/2$ LSB).

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

Note 3. When $EV_{DD0} \leq AV_{REFP} \leq V_{DD}$, 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 $\pm 0.05\%$ 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 $AV_{REFP} = V_{DD}$.

Note 4. When $AV_{REFP} < EV_{DD0} \leq V_{DD}$, 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 $\pm 0.20\%$ 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 ANI7, ANI16 to ANI24, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +105°C, 2.4 V ≤ EV_{DD0} ≤ V_{DD} ≤ 5.5 V, V_{SS} = EV_{SS0} = 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 | 2.4 V ≤ V _{DD} ≤ 5.5 V | | 1.2 | ±7.0 | LSB | |
| Conversion time | t _{CONV} | 10-bit resolution Target pin: ANI0 to ANI14, ANI16 to ANI20 | 3.6 V ≤ V _{DD} ≤ 5.5 V | 2.125 | | 39 | μs | |
| | | | 2.7 V ≤ V _{DD} ≤ 5.5 V | 3.1875 | | 39 | μs | |
| | | | 2.4 V ≤ V _{DD} ≤ 5.5 V | 17 | | 39 | μs | |
| | | 10-bit resolution 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 | |
| | | | 2.4 V ≤ V _{DD} ≤ 5.5 V | 17 | | 39 | μs | |
| Zero-scale error ^{Notes 1, 2} | E _{ZS} | 10-bit resolution | 2.4 V ≤ V _{DD} ≤ 5.5 V | | | ±0.60 | %FSR | |
| Full-scale error ^{Notes 1, 2} | E _{FS} | 10-bit resolution | 2.4 V ≤ V _{DD} ≤ 5.5 V | | | ±0.60 | %FSR | |
| Integral linearity error ^{Note 1} | ILE | 10-bit resolution | 2.4 V ≤ V _{DD} ≤ 5.5 V | | | ±4.0 | LSB | |
| Differential linearity error ^{Note 1} | DLE | 10-bit resolution | 2.4 V ≤ V _{DD} ≤ 5.5 V | | | ±2.0 | LSB | |
| Analog input voltage | V _{AIN} | ANI0 to ANI7 | | 0 | | V _{DD} | V | |
| | | ANI16 to ANI24 | | 0 | | EV _{DD0} | V | |
| | | Internal reference voltage (2.4 V ≤ V _{DD} ≤ 5.5 V, HS (high-speed main) mode) | | V _{BGR} ^{Note 3} | | | | V |
| | | Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 5.5 V, HS (high-speed main) mode) | | V _{TMPS25} ^{Note 3} | | | | V |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. Refer to 3.6.2 Temperature sensor characteristics/internal reference voltage characteristic.

(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0, ANI2 to ANI7, ANI16 to ANI24

(TA = -40 to +105°C, 2.4 V ≤ VDD ≤ 5.5 V, 2.4 V ≤ EVDD0 ≤ VDD, VSS = EVSS0 = 0 V, Reference voltage (+) = VBGR Note 3, Reference voltage (-) = AVREFM = 0 V Note 4, HS (high-speed main) mode)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|--------|------------------|---------------------|------|------|-------------|-------|
| Resolution | RES | | | 8 | | | bit |
| Conversion time | tCONV | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | 17 | | 39 | μs |
| Zero-scale error Notes 1, 2 | Ezs | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±0.60 | % FSR |
| Integral linearity error Note 1 | ILE | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±2.0 | LSB |
| Differential linearity error Note 1 | DLE | 8-bit resolution | 2.4 V ≤ VDD ≤ 5.5 V | | | ±1.0 | LSB |
| Analog input voltage | VAIN | | | 0 | | VBGR Note 3 | V |

Note 1. Excludes quantization error (±1/2 LSB).

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

Note 3. Refer to **3.6.2 Temperature sensor characteristics/internal reference voltage characteristic**.

Note 4. When reference voltage (-) = VSS, the MAX. values are as follows.

Zero-scale error: Add ±0.35%FSR to the MAX. value when reference voltage (-) = AVREFM.

Integral linearity error: Add ±0.5 LSB to the MAX. value when reference voltage (-) = AVREFM.

Differential linearity error: Add ±0.2 LSB to the MAX. value when reference voltage (-) = AVREFM.

3.6.2 Temperature sensor characteristics/internal reference voltage characteristic

(TA = -40 to +105°C, 2.4 V ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V, HS (high-speed main) mode)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------------|---------|--|------|------|------|-------|
| Temperature sensor output voltage | VTMPS25 | Setting ADS register = 80H, TA = +25°C | | 1.05 | | V |
| Internal reference voltage | VBGR | Setting ADS register = 81H | 1.38 | 1.45 | 1.5 | V |
| Temperature coefficient | FVTMPS | Temperature sensor that depends on the temperature | | -3.6 | | mV/°C |
| Operation stabilization wait time | tAMP | | 5 | | | μs |

3.6.3 D/A converter characteristics

(TA = -40 to +105°C, 2.4 V ≤ EVSS0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---------------|--------|---------------|---------------------|------|------|------|------|
| Resolution | RES | | | | | 8 | bit |
| Overall error | AINL | Rload = 4 MΩ | 2.4 V ≤ VDD ≤ 5.5 V | | | ±2.5 | LSB |
| | | Rload = 8 MΩ | 2.4 V ≤ VDD ≤ 5.5 V | | | ±2.5 | LSB |
| Settling time | tSET | Cload = 20 pF | 2.7 V ≤ VDD ≤ 5.5 V | | | 3 | μs |
| | | | 2.4 V ≤ VDD < 2.7 V | | | 6 | μs |

3.6.4 Comparator

(TA = -40 to +105°C, 2.7 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|-----------------------------------|---|--------------------------------|------|-----------------|------|
| Input offset voltage | V _{IOCOMP} | | | ±5 | ±40 | mV |
| Input voltage range | V _{ICMP} | | 0 | | V _{DD} | V |
| Internal reference voltage deviation | ΔV _{IREF} | CmRVM register value : 7FH to 80H (m = 0, 1) | | | ±2 | LSB |
| | | Other than above | | | ±1 | LSB |
| Response Time | t _{CR} , t _{CF} | Input amplitude±100mV | | 70 | 150 | ns |
| Operation stabilization time ^{Note 1} | t _{CMP} | CMPn = 0→1 | V _{DD} = 3.3 to 5.5 V | | 1 | μs |
| | | | V _{DD} = 2.7 to 3.3 V | | 3 | μs |
| Reference voltage stabilization wait time | t _{VR} | CVRE : 0→1 ^{Note 2} | | | 20 | μs |
| Operation current | I _{COMPDD} | Separately, it is defined as the operation current of peripheral functions. | | | | |

Note 1. Time taken until the comparator satisfies the DC/AC characteristics after the comparator operation enable signal is switched (CMPnEN = 0 → 1).

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

3.6.5 PGA

(TA = -40 to +105°C, 2.7 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------------------|--|---|------|-----------------------------|------|
| Input offset voltage | V _{IOPGA} | | | | ±10 | mV |
| Input voltage range | V _{IPGA} | | 0 | | 0.9 × V _{DD} /Gain | V |
| Output voltage range | V _{IOHPGA} | | 0.93 × V _{DD} | | | V |
| | V _{IOHPGA} | | | | 0.07 × V _{DD} | V |
| Gain error | | x4, x8 | | | ±1 | % |
| | | x16 | | | ±1.5 | % |
| | | x32 | | | ±2 | % |
| Slew rate | SR _{RPGA} | Rising When Vin = 0.1V _{DD} /gain to 0.9V _{DD} /gain. 10 to 90% of output voltage amplitude | 4.0 V ≤ V _{DD} ≤ 5.5 V (Other than x32) | 3.5 | | V/μs |
| | | | 4.0 V ≤ V _{DD} ≤ 5.5 V (x32) | 3.0 | | |
| | | | 2.7 V ≤ V _{DD} ≤ 4.0V | 0.5 | | |
| | SR _{FPGA} | Falling When Vin = 0.1V _{DD} /gain to 0.9V _{DD} /gain. 90 to 10% of output voltage amplitude | 4.0 V ≤ V _{DD} ≤ 5.5 V (Other than x32) | 3.5 | | |
| | | | 4.0 V ≤ V _{DD} ≤ 5.5 V (x32) | 3.0 | | |
| | | | 2.7 V ≤ V _{DD} ≤ 4.0V | 0.5 | | |
| Reference voltage stabilization wait time- ^{Note 1} | t _{PGA} | x4, x8 | | | 5 | μs |
| | | x16, x32 | | | 10 | μs |
| Operation current | I _{PGADD} | Separately, it is defined as the operation current of peripheral functions. | | | | |

Note 1. 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).

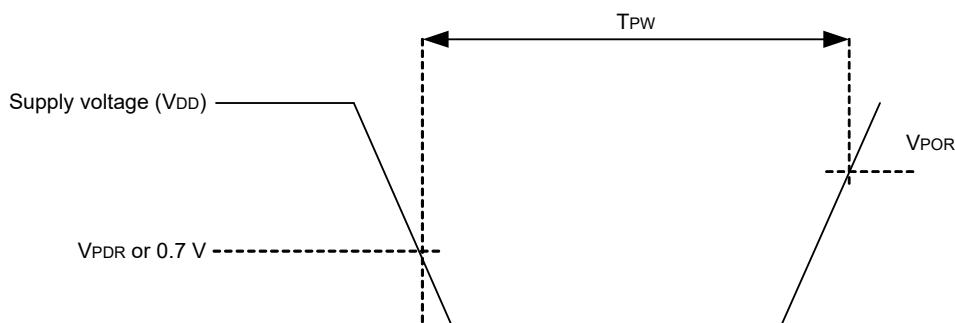
3.6.6 POR circuit characteristics

(TA = -40 to +105°C, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------------------------------|------------------|--|------|------|------|------|
| Power on/down reset threshold | V _{POR} | Voltage threshold on V _{DD} rising | 1.45 | 1.51 | 1.55 | V |
| | V _{PDR} | Voltage threshold on V _{DD} falling ^{Note 1} | 1.44 | 1.50 | 1.54 | V |
| Minimum pulse width ^{Note 2} | T _{PW} | | 300 | | | μs |

Note 1. However, when the operating voltage falls while the LVD is off, enter STOP mode, or enable the reset status using the external reset pin before the voltage falls below the operating voltage range shown in **3.4 AC Characteristics**.

Note 2. 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).



3.6.7 LVD circuit characteristics

(1) Reset Mode and Interrupt Mode

(TA = -40 to +105°C, VPDR ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | | |
|-----------------------------|----------------------|----------------------|--------------|------|------|------|------|-----|----|
| Voltage detection threshold | Supply voltage level | VLVD0 | Rising edge | 3.90 | 4.06 | 4.22 | V | | |
| | | | Falling edge | 3.83 | 3.98 | 4.13 | V | | |
| | | VLVD1 | Rising edge | 3.60 | 3.75 | 3.90 | V | | |
| | | | Falling edge | 3.53 | 3.67 | 3.81 | V | | |
| | | VLVD2 | Rising edge | 3.01 | 3.13 | 3.25 | V | | |
| | | | Falling edge | 2.94 | 3.06 | 3.18 | V | | |
| | | VLVD3 | Rising edge | 2.90 | 3.02 | 3.14 | V | | |
| | | | Falling edge | 2.85 | 2.96 | 3.07 | V | | |
| | | VLVD4 | Rising edge | 2.81 | 2.92 | 3.03 | V | | |
| | | | Falling edge | 2.75 | 2.86 | 2.97 | V | | |
| | | VLVD5 | Rising edge | 2.70 | 2.81 | 2.92 | V | | |
| | | | Falling edge | 2.64 | 2.75 | 2.86 | V | | |
| | | VLVD6 | Rising edge | 2.61 | 2.71 | 2.81 | V | | |
| | | | Falling edge | 2.55 | 2.65 | 2.75 | V | | |
| | | VLVD7 | Rising edge | 2.51 | 2.61 | 2.71 | V | | |
| | | | Falling edge | 2.45 | 2.55 | 2.65 | V | | |
| | | Minimum pulse width | | tlw | | 300 | | | μs |
| | | Detection delay time | | | | | | 300 | μs |

(2) Interrupt & Reset Mode

(TA = -40 to +105°C, VPDR ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|-----------------------------|--------|--|------------------------------|------|------|------|---|
| Voltage detection threshold | VLVDD0 | VPOC2, VPOC1, VPOC0 = 0, 1, 1, falling reset voltage | 2.64 | 2.75 | 2.86 | V | |
| | VLVDD1 | LVIS1, LVIS0 = 1, 0 | Rising release reset voltage | 2.81 | 2.92 | 3.03 | V |
| | | | Falling interrupt voltage | 2.75 | 2.86 | 2.97 | V |
| | VLVDD2 | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 2.90 | 3.02 | 3.14 | V |
| | | | Falling interrupt voltage | 2.85 | 2.96 | 3.07 | V |
| | VLVDD3 | LVIS1, LVIS0 = 0, 0 | Rising release reset voltage | 3.90 | 4.06 | 4.22 | V |
| Falling interrupt voltage | | | 3.83 | 3.98 | 4.13 | V | |

3.6.8 Power supply voltage rising slope characteristics

(TA = -40 to +105°C, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------------|--------|------------|------|------|------|------|
| Power supply voltage rising slope | SVDD | | | | 54 | V/ms |

Caution Make sure to keep the internal reset state by the LVD circuit or an external reset until VDD reaches the operating voltage range shown in 3.4 AC Characteristics.

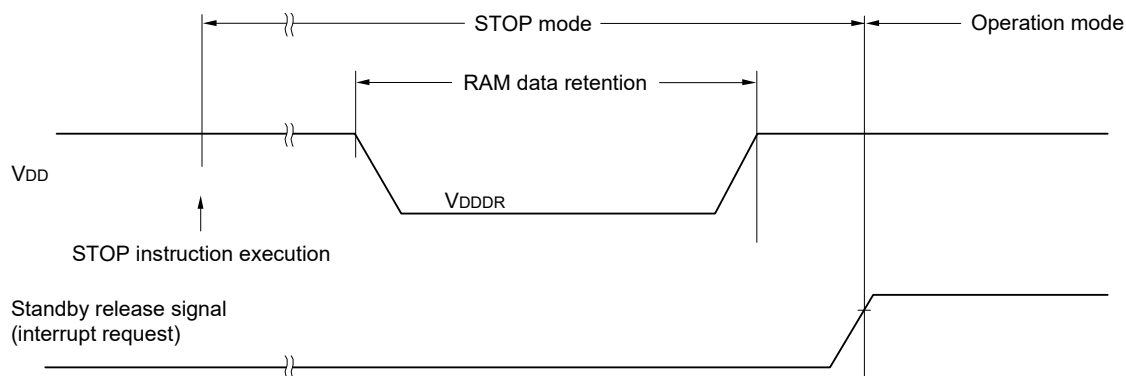
3.7 RAM Data Retention Characteristics

(TA = -40 to +105°C, VSS = 0V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------|--------|------------|-----------------|------|------|------|
| Data retention supply voltage | VDDDR | | 1.44 Notes 1, 2 | | 5.5 | V |

Note 1. 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.

Note 2. Enter STOP mode before the supply voltage falls below the recommended operating voltage.



3.8 Flash Memory Programming Characteristics

(TA = -40 to +105°C, 2.4 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|------------------------|--------|---------------------|------|------|------|------|
| System clock frequency | fCLK | 2.4 V ≤ VDD ≤ 5.5 V | 1 | | 32 | MHz |

(TA = -40 to +105°C, 2.4 V ≤ VDD ≤ 5.5 V, VSS = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|-------------------|-----------------------|-----------|---------|-----------|------|-------|
| Number of code flash rewrites Notes 1, 2, 3 | C _{erwr} | Retained for 20 years | TA = 85°C | 1,000 | | | Times |
| Number of data flash rewrites Notes 1, 2, 3 | | Retained for 1 year | TA = 25°C | | 1,000,000 | | |
| | | Retained for 5 years | TA = 85°C | 100,000 | | | |
| | | Retained for 20 years | TA = 85°C | 10,000 | | | |

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

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

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

3.9 Dedicated Flash Memory Programmer Communication (UART)

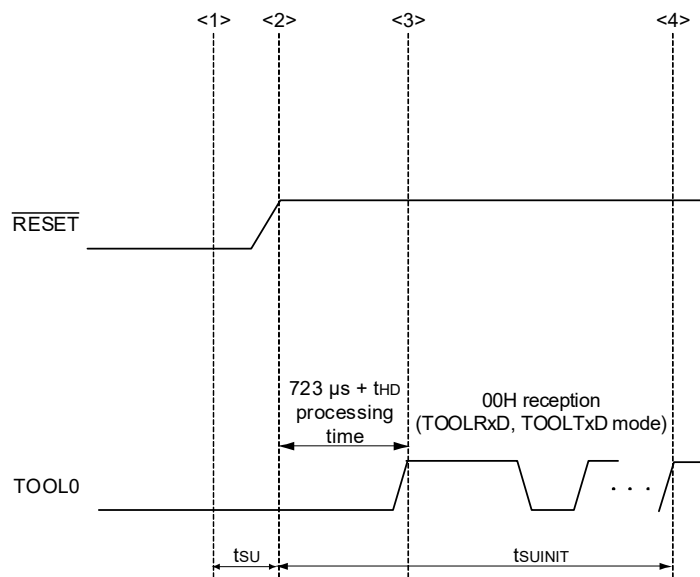
(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------|--------|---------------------------|---------|------|-----------|------|
| Transfer rate | | During serial programming | 115,200 | | 1,000,000 | bps |

3.10 Timing of Entry to Flash Memory Programming Modes

(TA = -40 to +105°C, 2.4 V ≤ EVDD0 ≤ VDD ≤ 5.5 V, VSS = EVSS0 = 0 V)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---|---------|--|------|------|------|------|
| How long from when an external reset ends until the initial communication settings are specified | tsuINIT | 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 | tsu | 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 an external reset ends (excluding the processing time of the firmware to control the flash memory) | tHD | POR and LVD reset must end before the external reset ends. | 1 | | | ms |



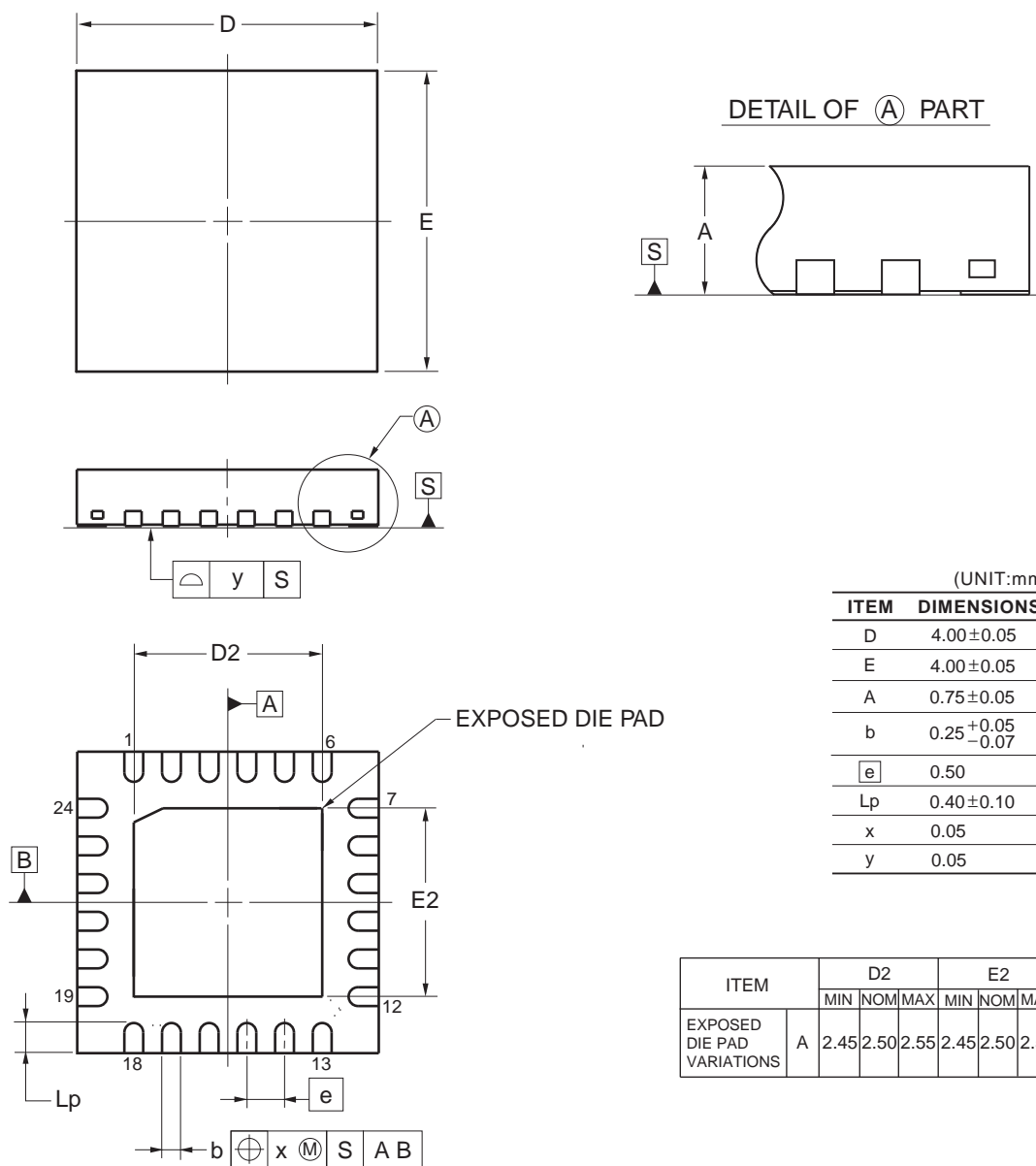
- <1> The low level is input to the TOOL0 pin.
- <2> The external reset ends (POR and LVD reset must end before the external reset ends).
- <3> The TOOL0 pin is set to the high level.
- <4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

Remark tsuINIT: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the external resets end.
 tsu: How long from when the TOOL0 pin is placed at the low level until a pin reset ends
 tHD: How long to keep the TOOL0 pin at the low level from when the external resets end (excluding the processing time of the firmware to control the flash memory)

4. PACKAGE DRAWINGS

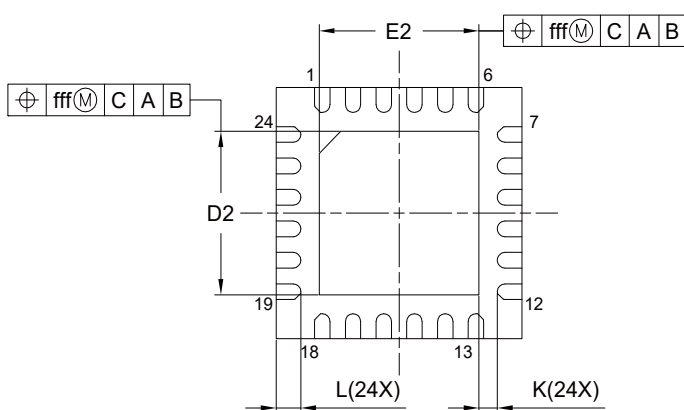
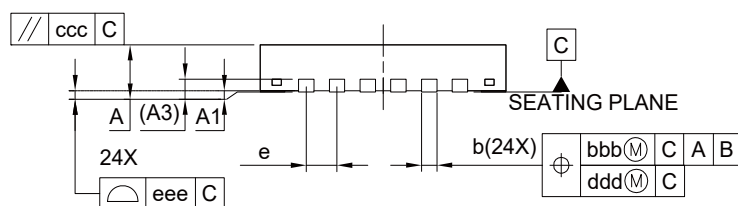
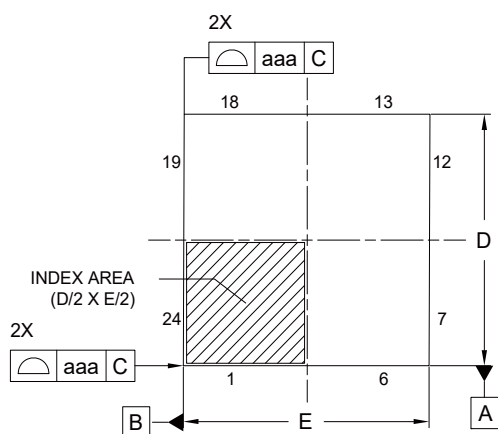
4.1 24-pin products

| | | | |
|--------------------|--------------|----------------|-----------------|
| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
| P-HWQFN24-4x4-0.50 | PWQN0024KE-A | P24K8-50-CAB-1 | 0.04 |



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| | | |
|---------------------|--------------|---------------|
| JEITA Package code | RENESAS code | MASS(TYP.)[g] |
| P-HWQFN024-4x4-0.50 | PWQN0024KF-A | 0.04 |

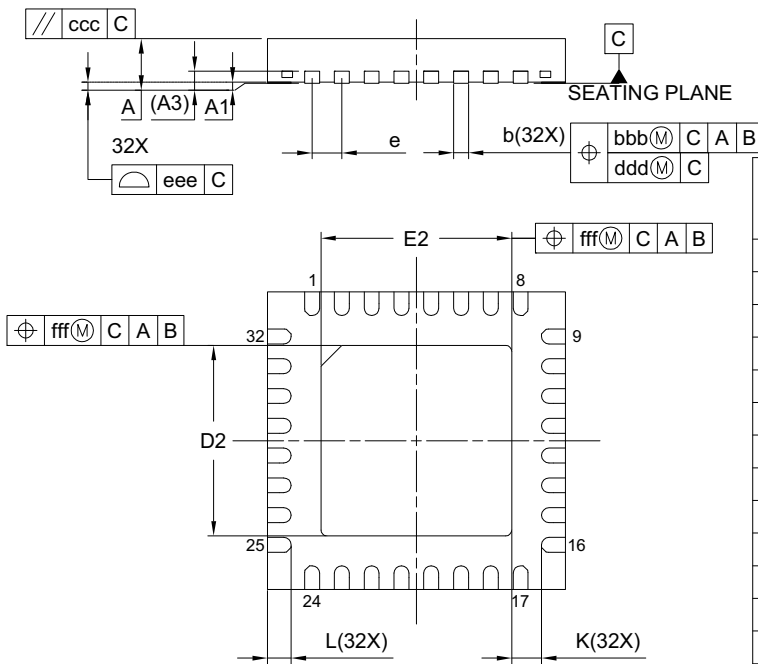
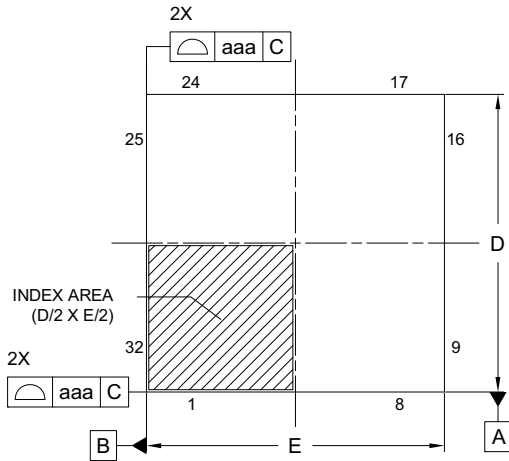


| Reference Symbol | Dimension in Millimeters | | |
|------------------|--------------------------|------|------|
| | Min. | Nom. | Max. |
| A | - | - | 0.80 |
| A1 | 0.00 | 0.02 | 0.05 |
| A3 | 0.203 REF. | | |
| b | 0.18 | 0.25 | 0.30 |
| D | 4.00 BSC | | |
| E | 4.00 BSC | | |
| e | 0.50 BSC | | |
| L | 0.35 | 0.40 | 0.45 |
| K | 0.20 | - | - |
| D2 | 2.55 | 2.60 | 2.65 |
| E2 | 2.55 | 2.60 | 2.65 |
| aaa | 0.15 | | |
| bbb | 0.10 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |
| fff | 0.10 | | |

4.2 32-pin products

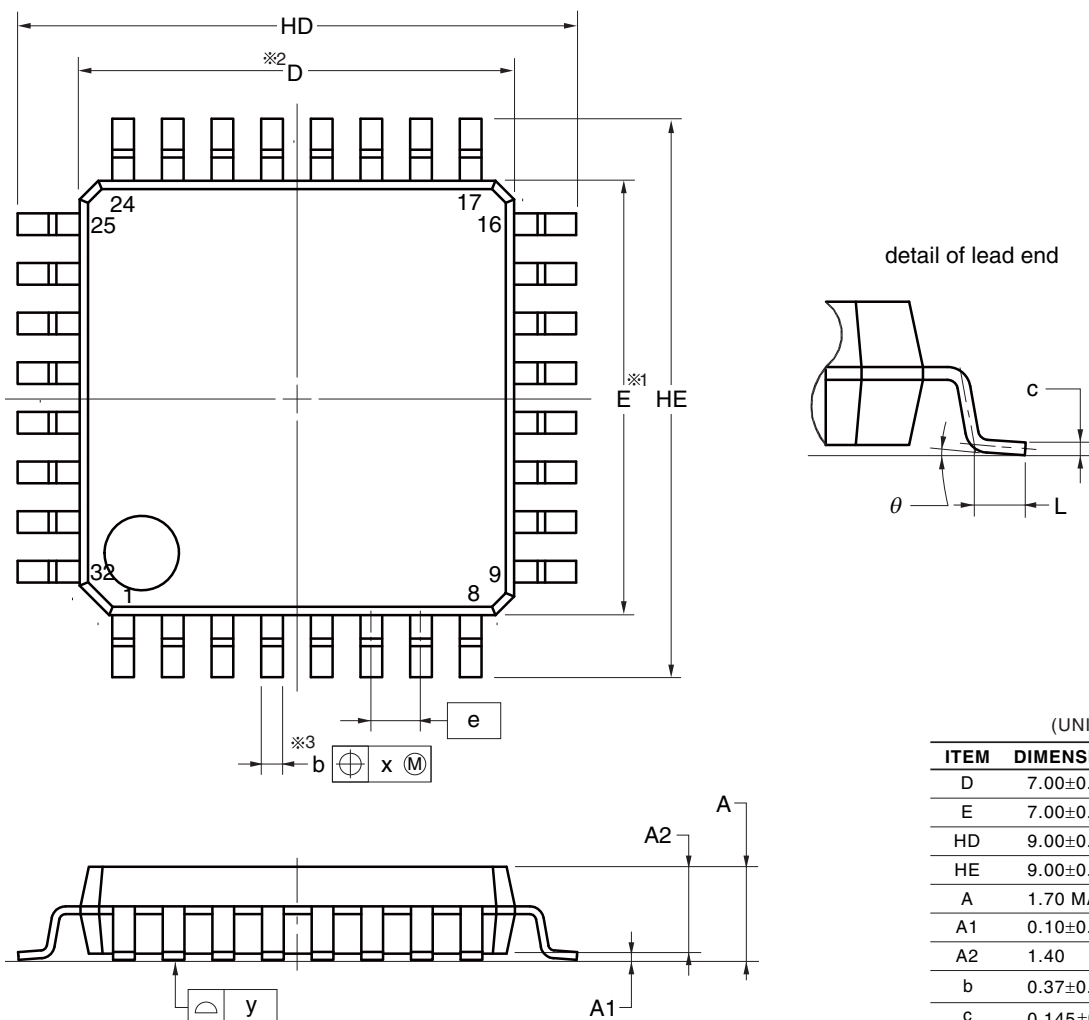
<R>

| | | |
|---------------------|--------------|---------------|
| JEITA Package code | RENESAS code | MASS(TYP.)[g] |
| P-HWQFN032-5x5-0.50 | PWQN0032KE-A | 0.06 |



| Reference Symbol | Dimension in Millimeters | | |
|------------------|--------------------------|------|------|
| | Min. | Nom. | Max. |
| A | — | — | 0.80 |
| A ₁ | 0.00 | 0.02 | 0.05 |
| A ₃ | 0.203 REF. | | |
| b | 0.18 | 0.25 | 0.30 |
| D | 5.00 BSC | | |
| E | 5.00 BSC | | |
| e | 0.50 BSC | | |
| L | 0.35 | 0.40 | 0.45 |
| K | 0.20 | — | — |
| D ₂ | 3.15 | 3.20 | 3.25 |
| E ₂ | 3.15 | 3.20 | 3.25 |
| aaa | 0.15 | | |
| bbb | 0.10 | | |
| ccc | 0.10 | | |
| ddd | 0.05 | | |
| eee | 0.08 | | |
| fff | 0.10 | | |

| | | | |
|--------------------|--------------|----------------|-----------------|
| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
| P-LQFP32-7x7-0.80 | PLQP0032GB-A | P32GA-80-GBT-1 | 0.2 |



(UNIT:mm)

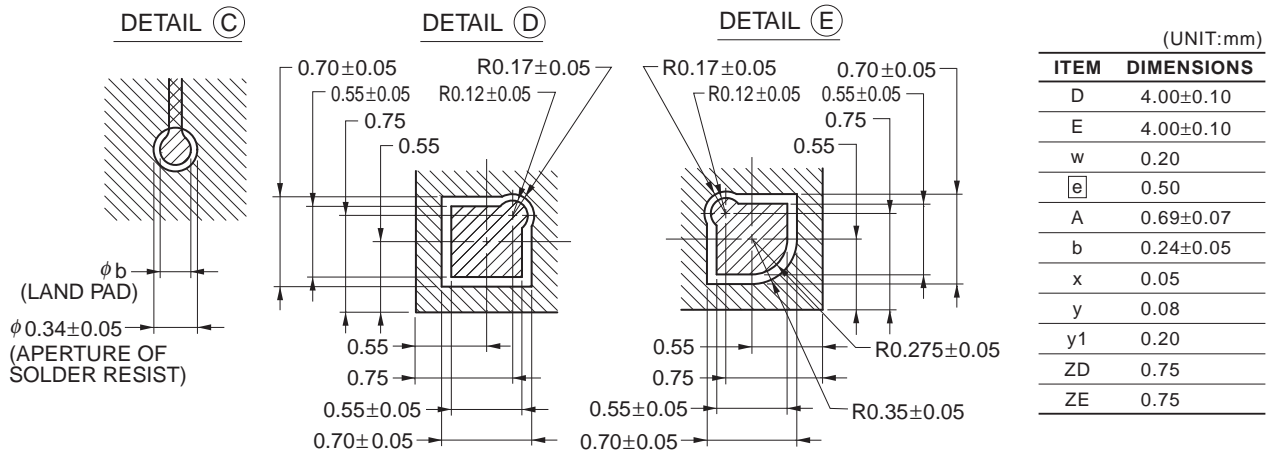
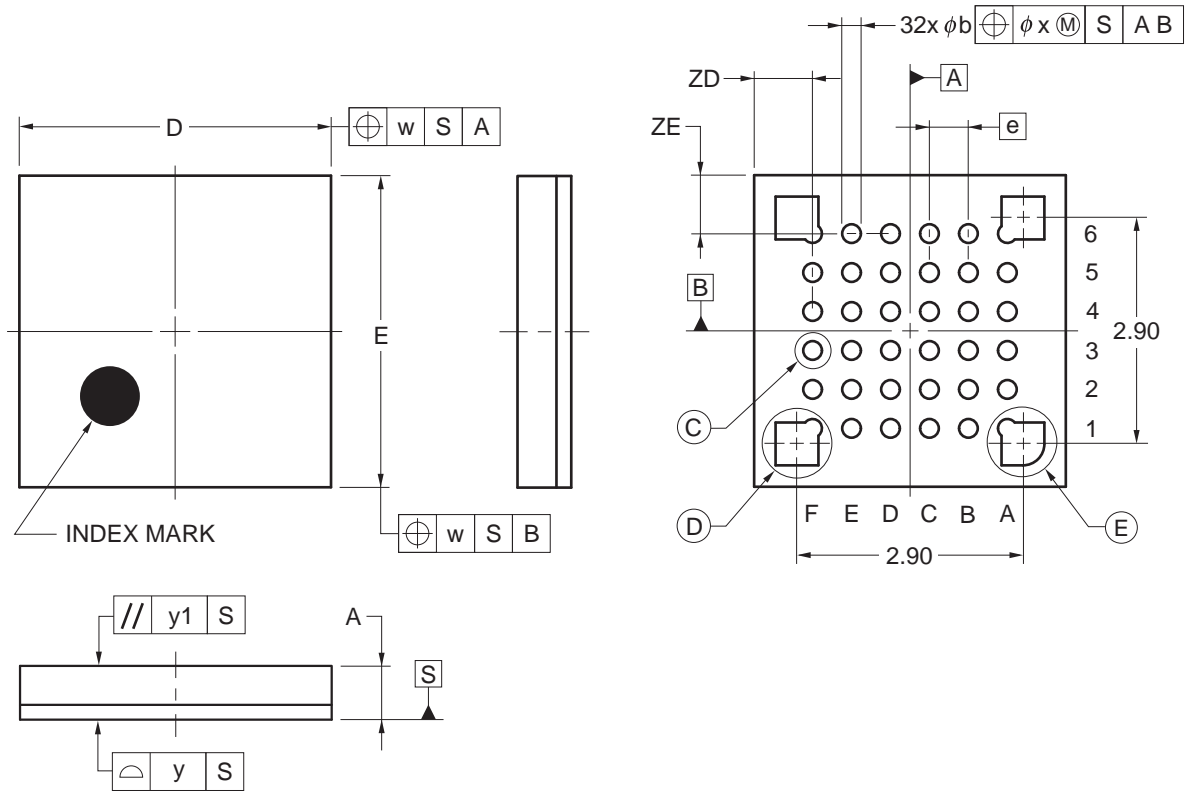
| ITEM | DIMENSIONS |
|----------|-------------|
| D | 7.00±0.10 |
| E | 7.00±0.10 |
| HD | 9.00±0.20 |
| HE | 9.00±0.20 |
| A | 1.70 MAX. |
| A1 | 0.10±0.10 |
| A2 | 1.40 |
| b | 0.37±0.05 |
| c | 0.145±0.055 |
| L | 0.50±0.20 |
| θ | 0° to 8° |
| e | 0.80 |
| x | 0.20 |
| y | 0.10 |

NOTE

1. Dimensions “ $\ast 1$ ” and “ $\ast 2$ ” do not include mold flash.
2. Dimension “ $\ast 3$ ” does not include trim offset.

4.3 36-pin products

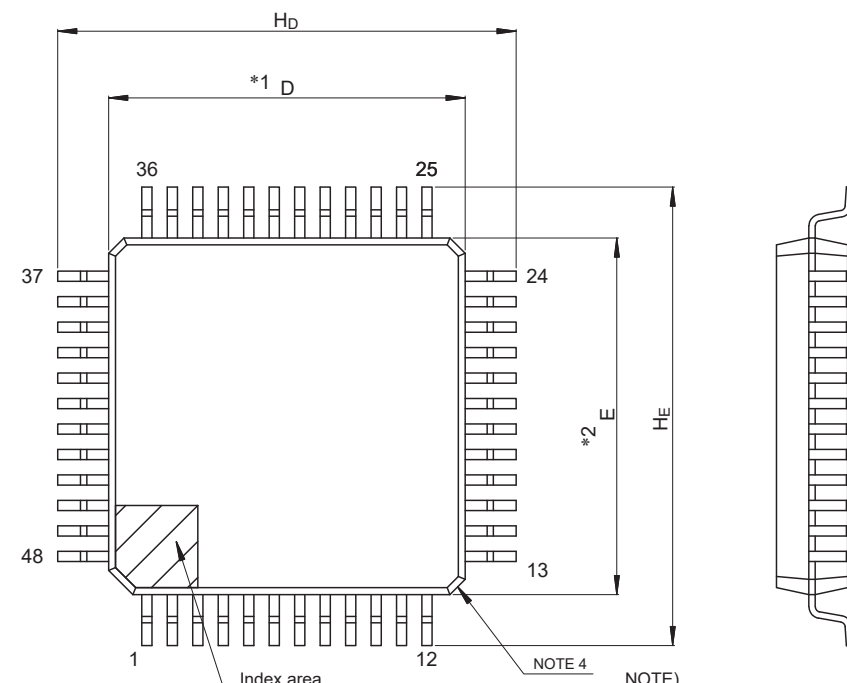
| | | | |
|--------------------|--------------|----------------|-----------------|
| JEITA Package Code | RENESAS Code | Previous Code | MASS (TYP.) [g] |
| P-WFLGA36-4x4-0.50 | PWLG0036KA-A | P36FC-50-AA4-2 | 0.023 |



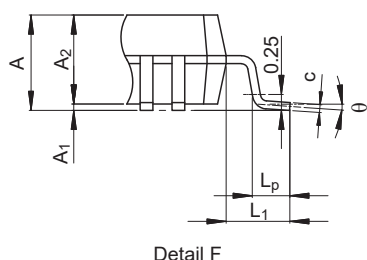
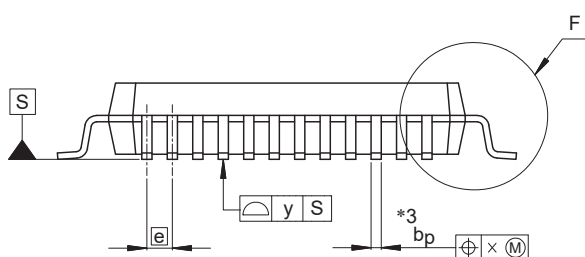
4.4 48-pin products

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

Unit: mm



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



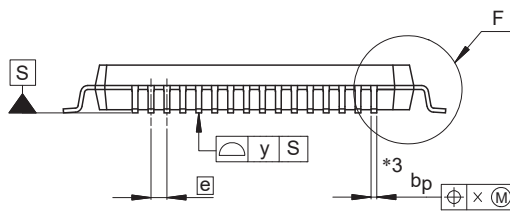
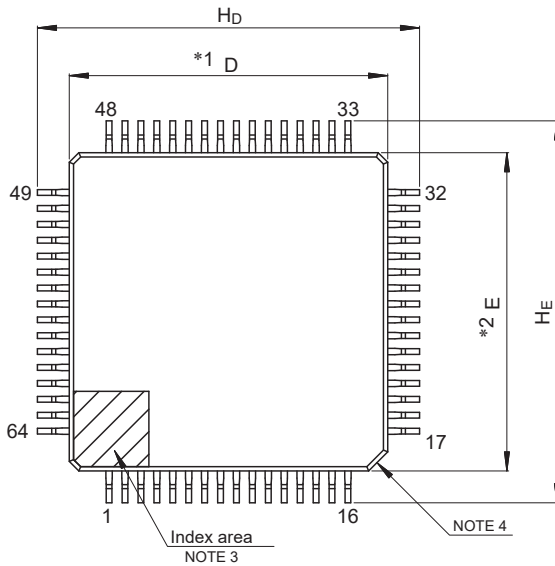
| Reference Symbol | Dimensions in millimeters | | |
|------------------|---------------------------|------|------|
| | Min | Nom | Max |
| D | 6.9 | 7.0 | 7.1 |
| E | 6.9 | 7.0 | 7.1 |
| A ₂ | — | 1.4 | — |
| H _D | 8.8 | 9.0 | 9.2 |
| H _E | 8.8 | 9.0 | 9.2 |
| A | — | — | 1.7 |
| A ₁ | 0.05 | — | 0.15 |
| b _p | 0.17 | 0.20 | 0.27 |
| c | 0.09 | — | 0.20 |
| θ | 0° | 3.5° | 8° |
| e | — | 0.5 | — |
| x | — | — | 0.08 |
| y | — | — | 0.08 |
| L _p | 0.45 | 0.6 | 0.75 |
| L ₁ | — | 1.0 | — |

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4.5 64-pin products

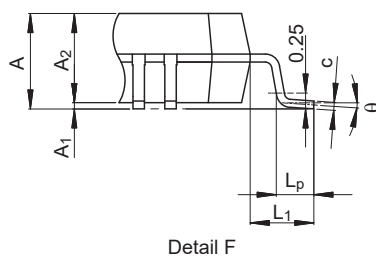
| JEITA Package Code | RENESAS Code | Previous Code | MASS (Typ) [g] |
|----------------------|--------------|---------------|----------------|
| P-LFQFP64-10x10-0.50 | PLQP0064KB-C | — | 0.3 |

Unit: mm



NOTE)

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



| Reference Symbol | Dimensions in millimeters | | |
|------------------|---------------------------|------|------|
| | Min | Nom | Max |
| D | 9.9 | 10.0 | 10.1 |
| E | 9.9 | 10.0 | 10.1 |
| A ₂ | — | 1.4 | — |
| H _D | 11.8 | 12.0 | 12.2 |
| H _E | 11.8 | 12.0 | 12.2 |
| A | — | — | 1.7 |
| A ₁ | 0.05 | — | 0.15 |
| b _p | 0.15 | 0.20 | 0.27 |
| c | 0.09 | — | 0.20 |
| θ | 0° | 3.5° | 8° |
| e | — | 0.5 | — |
| x | — | — | 0.08 |
| y | — | — | 0.08 |
| L _p | 0.45 | 0.6 | 0.75 |
| L ₁ | — | 1.0 | — |

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REVISION HISTORY

RL78/G1F Datasheet

| Rev. | Date | Description | |
|------|--------------|-------------|---|
| | | Page | Summary |
| 0.10 | | — | First Edition issued |
| 0.50 | Jan 14, 2015 | 3 | Modification of description in Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G1F |
| | | 10 | Addition of description in 1.4 Pin Identification |
| | | 11 | Modification of description in 1.5 Block Diagram |
| | | 12, 13 | Modification of description in 1.6 Outline of Functions |
| | | 14 | Addition of target products to the beginning |
| | | 17 | Modification of 2.2.2 On-chip oscillator characteristics |
| | | 18 | Addition of note 4 in 2.3.1 Pin characteristics |
| | | 23, 25, 27 | Modification of 2.3.2 Supply current characteristics |
| | | 73 | Modification of 2.6.4 Comparator |
| | | 73 | Modification of 2.6.5 PGA |
| | | 77 | Renamed to 2.7 RAM Data Retention Characteristics |
| | | 79 | Addition of target products to the beginning |
| | | 83 | Modification of 3.2.2 On-chip oscillator characteristics |
| | | 87 | Modification of "Output voltage, low" |
| | | 89, 91, 93 | Modification of 3.3.2 Supply current characteristics |
| | | 130 | Modification of 3.6.4 Comparator |
| | | 130 | Modification of 3.6.5 PGA |
| | | 133 | Renamed to 3.7 RAM Data Retention Characteristics |
| 1.00 | Jan 14, 2015 | All | Modification of the unit symbol (PWMOP into PWMOPA) |
| | | 1 | Modification of descriptions in 1.1 Features |
| | | 10 | Modification of 1.4 Pin Identification |
| | | 13 | Modification of 1.6 Outline of Functions |
| | | 73 | Modification of 2.6.5 PGA |
| | | 130 | Modification of 3.6.5 PGA |
| 1.10 | Aug 12, 2016 | 5 | Addition of product name (RL78/G1F) and description (Top View) in 1.3.1 24-pin products |
| | | 6 | Addition of product name (RL78/G1F) and description (Top View) in 1.3.2 32-pin products |
| | | 8 | Addition of product name (RL78/G1F) and description (Top View) in 1.3.4 48-pin products |
| | | 9 | Addition of product name (RL78/G1F) and description (Top View) in 1.3.5 64-pin products |
| 1.11 | Dec 22, 2020 | 3 | Modification of Figure 1-1 Part Number, Memory Size, and Package of RL78/G1F |
| | | 4 | Addition of title and modification of description in Table 1-1 List of Ordering Part Numbers |
| | | 136 to 141 | Addition and modification of all in CHAPTER 39 PACKAGE DRAWINGS |

| | |
|------------------|--------------------|
| REVISION HISTORY | RL78/G1F Datasheet |
|------------------|--------------------|

| Rev. | Date | Description | |
|------|--------------|-------------|--|
| | | Page | Summary |
| 1.12 | Apr 28, 2021 | 4 | Modification of Table 1 - 1 List of Ordering Part Numbers |
| | | 6 | Addition of 32-pin plastic HWQFN (5 × 5 mm, 0.5-mm pitch) in 1.3.2 32-pin products |
| | | 139 | Addition of package drawing of PWQN0032KE-A in 4.2 32-pin products |

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

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

1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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