

RL78/G1D

R01DS0258EJ0130

RENESAS MCU

Rev.1.30

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The RL78/G1D is a microcontroller incorporating the RL78 CPU core and low power consumption RF transceiver supporting the Bluetooth ver.4.2 (Low Energy Single mode) specifications.

1. OUTLINE

1.1 Features

Low Power Technology (3.0V / MCU part: STOP)

- RF transmitter active: 4.3 mA (TYP.)
- RF receiver active: 3.5 mA (TYP.)
- RF sleep (POWER_DOWN mode) operation: 0.3 μ A (TYP.)

On-Chip RF Transceiver

- <R> • Bluetooth v4.2 Specification (Low Energy Single mode)
- 2.4 GHz ISM Band, GFSK modulation, TDMA/TDD Frequency Hopping (included AES encryption circuit)
- Adaptivity, exclusively for use in operation as a slave device
- Single ended RF interface

<R> 16-bit RL78-S2 CPU Core

- CISC Architecture (Harvard) 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 Signed & Unsigned: 16 x 16 to 32-bit result in 1 clock cycle
- 1-wire on-chip debug function

Main Flash Memory

- 128 KB / 192KB / 256 KB (Block size: 1 KB)
- On-chip single voltage flash memory with protection from block erase/writing
- Self-programming with secure boot swap function and flash shield window function

Data Flash Memory

- Data Flash with background operation
- Data flash size: 8 KB size (Erase block size: 1 KB)
- Erase Cycles: 1 Million (typ.)
- Erase/programming voltage: 1.8 V to 3.6 V

RAM

- 12 KB / 16KB / 20 KB size
- Supports operands or instructions
- Back-up retention in all modes

On-chip Oscillator

- High accuracy on-chip Oscillator for MCU
- 15kHz low-speed on-chip oscillator for MCU
- 32.768 kHz On-chip oscillator for the RF slow clock

Data Memory Access (DMA) Controller

- Up to 4 fully programmable channels
- Transfer unit: 8- or 16-bit

Multiple Communication Interfaces

- Simplified I²C×2
- CSI (7-, 8-bit) ×2,
- UART (7-, 8-, 9-bit) ×2
- I²C ×1

Supply voltage Management

- Low voltage detection (LVD) with 12 setting options (Notification to Interrupt and/or reset function)
- Power-on reset (POR) monitor/generator

Extended-Function Timers

- Multi-function 16-bit timers: 8 channels
- Real-time clock (RTC): 1 channel (full calendar and alarm function with watch correction function)
- Interval Timer: 12-bit, 1 channel
- Watchdog timer: 1 channel (window function)

Rich Analog

- 8/10-bit resolution A/D converter ($V_{DD} = 1.6$ to 3.6 V)
- Analog input: 8 channels
- Internal voltage reference (1.45 V) and temperature sensor^{Note}

Note Can be selected only in HS (high-speed main) mode

Safety Functions

- Comply with the IEC60730 and IEC61508 safety standards

General Purpose I/O

- I/O port: 32 (N-ch open drain I/O [withstand voltage of 6 V]: 2, N-ch open drain I/O [VDD withstand voltage]: 9
- Different potential interface support: Can connect to a 1.8/2.5 V device

Standby function

- MCU part: Low power consumption mode: HALT, STOP
Power saving mode: SNOOZE
- RF part :Low power saving mode with 6 setting (min. 0.1 μ A)

Operating Voltage / Operating Ambient Temperature

1.6 V to 3.6 V / -40 to +85°C

Package Type and Pin Count

48-pin HWQFN (6 × 6) (0.4mm pitch)

- ROM, RAM capacities

| Flash ROM | Data Flash | RAM | RL78/G1D |
|-----------|------------|-----------------------|----------|
| 128 KB | 8 KB | 12 KB | R5F11AGG |
| 192 KB | 8 KB | 16 KB | R5F11AGH |
| 256 KB | 8 KB | 20 KB ^{Note} | R5F11AGJ |

Note 19 KB when the self-programming function is used.

1.2 List of Part Numbers

Figure 1-1. Part Number, Memory Size, and Package of RL78/G1D

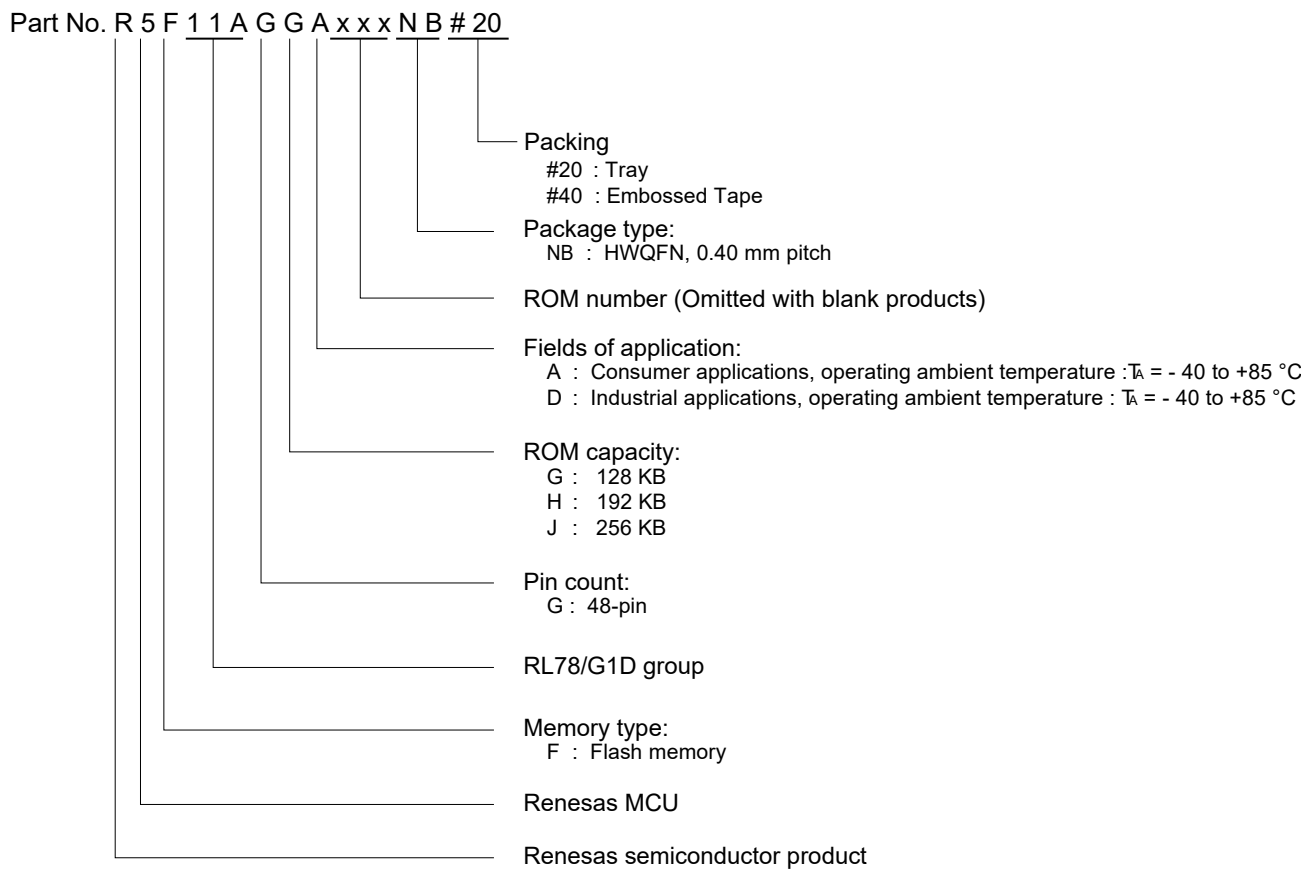


Table 1-1. List of Ordering Part Numbers

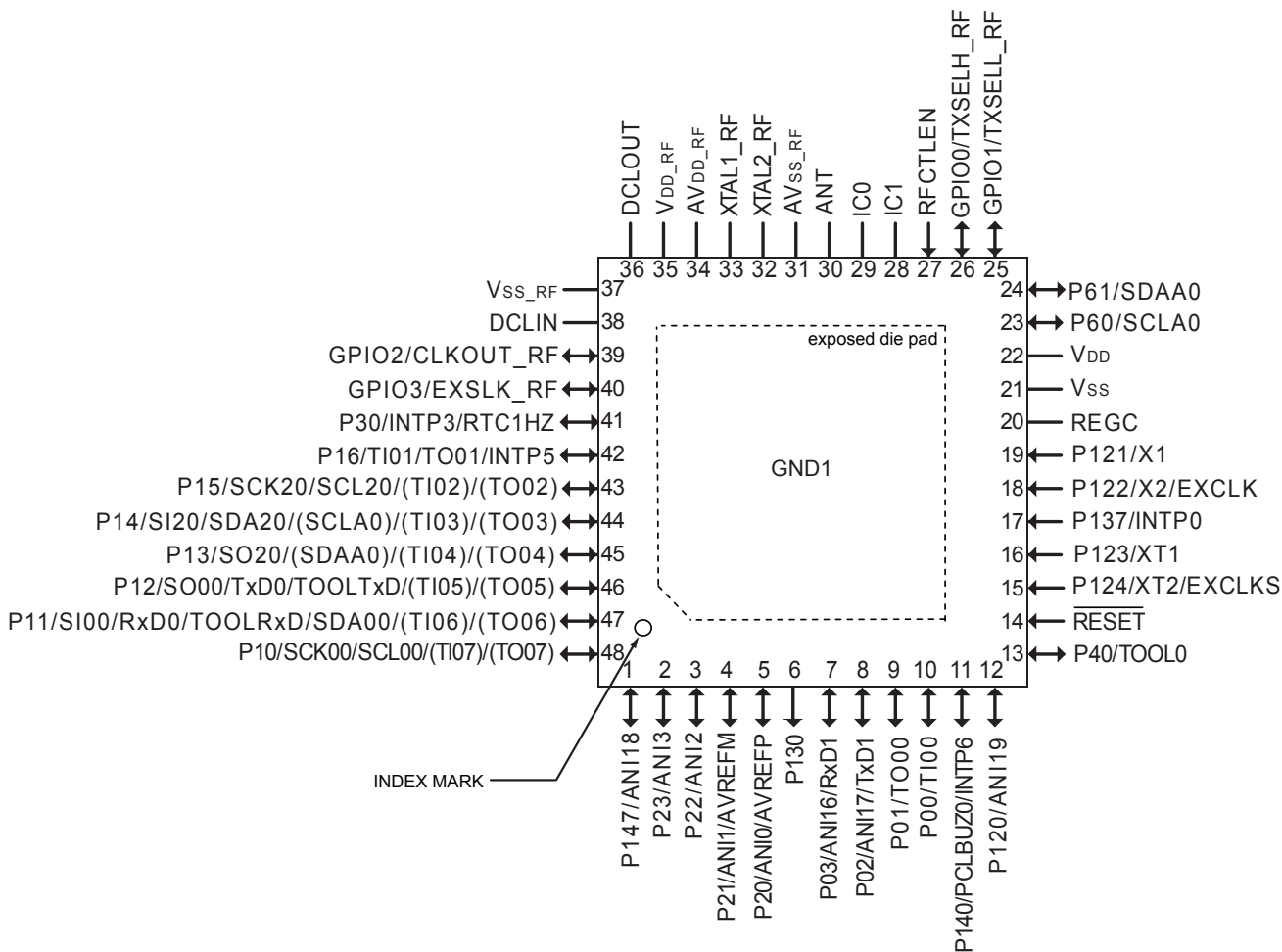
| Pin count | Package | Fields of Application ^{Note} | Ordering Part Number | Code Flash Memory | Data Flash Memory |
|-----------|----------------------|---------------------------------------|----------------------------------|-------------------|-------------------|
| 48 pins | Plastic WQFN (6 × 6) | A | R5F11AGGANB#20 R5F11AGGANB#40 | 128 KB | 8 KB |
| | | D | R5F11AGGDNB#20 R5F11AGGDNB#40 | | |
| | | A | R5F11AGHANB#20 R5F11AGHANB#40 | 192 KB | 8 KB |
| | | D | R5F11AGHDNB#20 R5F11AGHDNB#40 | | |
| | | A | R5F11AGJANB#20 R5F11AGJANB#40 | 256 KB | 8 KB |
| | | D | R5F11AGJDNB#20 R5F11AGJDNB#40 | | |

Note For the fields of application, see Figure 1-1 Part Number, Memory Size, and Package of RL78/G1D.

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)

- 48-pin plastic WQFN (6 × 6 mm, 0.4 mm pitch)



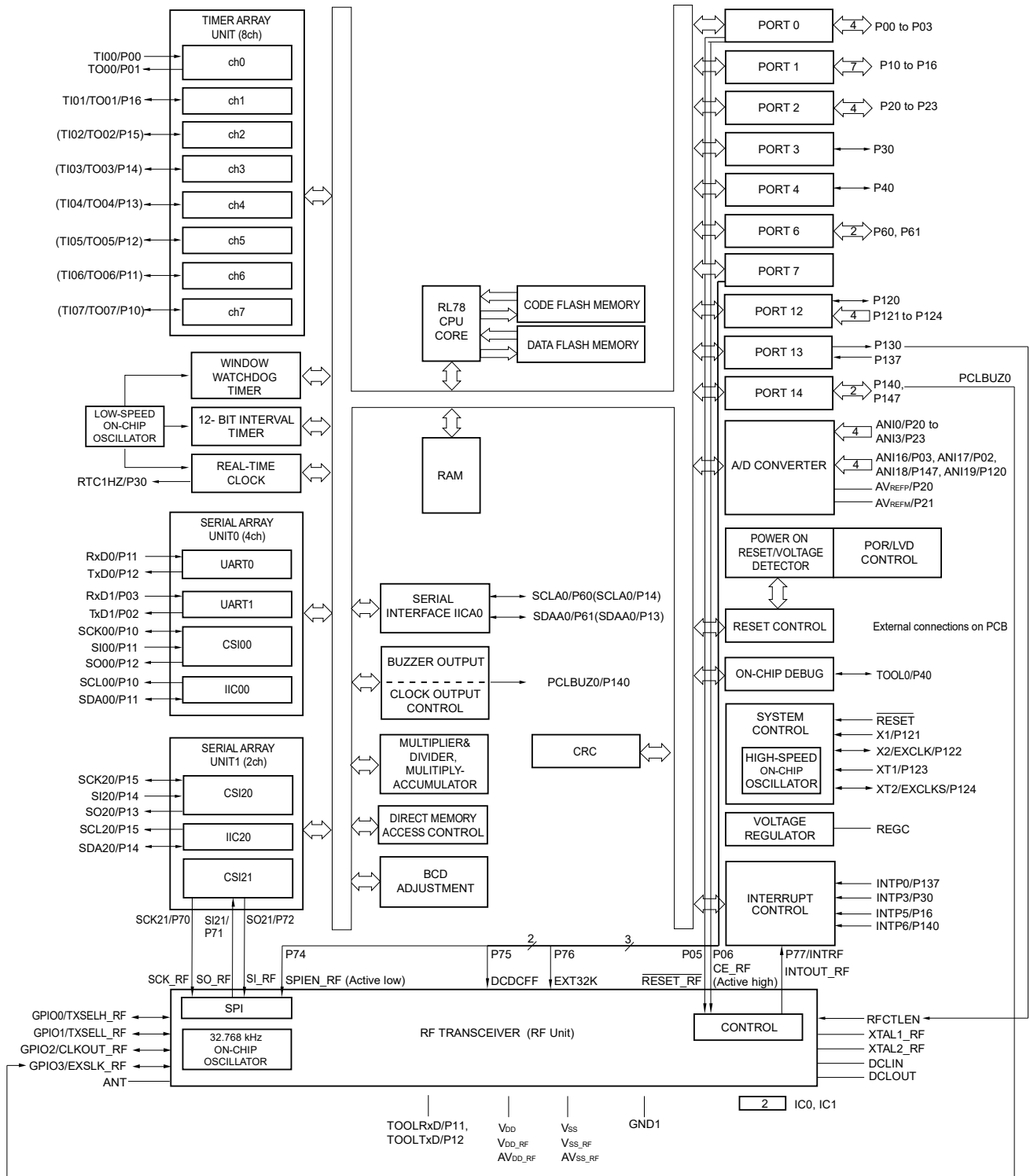
- Caution 1.** Connect the REGC pin to V_{SS} via a capacitor (0.47 to 1 μF).
- 2.** Connect the metal pad (GND1) on the back of the package that has the same potential as AV_{SS}_RF.

- Remark 1.** For pin identification, see 1.4 Pin Identification.
- 2.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR)..

1.4 Pin Identification

| | | | |
|----------------------------------|--|--------------------------------|---|
| ANI0 to ANI3, ANI16 to ANI19: | Analog input | PCLBUZ0: | Programmable clock output/buzzer output |
| ANT: | Antenna connection | REGC: | Regulator capacitance |
| AVDD_RF: | Power supply for RF analog | RFCTLEN: | RF control enable |
| AVREFM: | Analog reference voltage minus | RTC1HZ: | Real-time clock correction clock (1 Hz) output |
| AVREFP: | Analog reference voltage plus | RESET: | Reset |
| AVSS_RF: | Ground for RF analog | RxD0, RxD1: | Receive data |
| CLKOUT_RF: | Clock output | SCLA0: | Serial clock input/output |
| DCLIN: | DC-DC converter inductor and DCLOUT capacitor | SCK00, SCK20, SCL00, SCL20: | Serial clock output |
| DCLOUT: | DC-DC converter output | SDAA0, SDA00, SDA20: | Serial data input/output |
| EXCLK: | External clock input (Main system clock) | SI00, SI20: | Serial data input |
| EXCLKS: | External clock input (Subsystem clock) | SO00, SO20: | Serial data output |
| EXSLK_RF: | External slow clock input | TI00 to TI07: | Timer input |
| GND1: | Package exposed die pad | TO00 to TO07: | Timer output |
| GPIO0 to GPIO3: | GPIO at RF unit | TOOL0: | Data input/output for tool |
| IC0, IC1: | Internal circuit | TOOLRxD, TOOLTxD: | Data input/output for external device |
| INTP0, INTP3, INTP5, INTP6: | External interrupt input | TxD0, TxD1: | Transmit data |
| P00 to P03: | Port 0 | TXSELL_RF, TXSELH_RF: | External PA/LNA control |
| P10 to P16: | Port 1 | VDD: | Power supply |
| P20 to P23: | Port 2 | VDD_RF: | Power Supply for RF |
| P30: | Port 3 | VSS: | Ground |
| P40: | Port 4 | VSS_RF: | Ground for RF |
| P60, P61: | Port 6 | X1, X2: | Crystal oscillator (Main system clock) |
| P120 to P124: | Port 12 | XT1, XT2: | Crystal oscillator (Subsystem clock) |
| P130, P137: | Port 13 | XTAL1_RF, XTAL2_RF: | Crystal oscillator (RF clock) |
| P140, P147: | Port 14 | | |

<R> 1.5 Block Diagram



Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).

1.6 Outline of Functions

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

(1/2)

| Item | | R5F11AGG | R5F11AGH | R5F11AGJ |
|------------------------------------|--|---|----------|-------------------------|
| Code flash memory | | 128 KB | 192 KB | 256 KB |
| Data flash memory | | 8 KB | 8 KB | 8 KB |
| RAM | | 12 KB | 16 KB | 20 KB ^{Note 1} |
| Address space | | 1 MB | | |
| System clock (RF side) | | 32 MHz | | |
| 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 3.6 V), HS (High-speed main) mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 3.6 V), LS (Low-speed main) mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 3.6 V), LV (Low-voltage main) mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 3.6 V) | | |
| | High-speed on-chip oscillator | HS (High-speed main) mode: 1 to 32 MHz ($V_{DD} = 2.7$ to 3.6 V), HS (High-speed main) mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 3.6 V), LS (Low-speed main) mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 3.6 V), LV (Low-voltage main) mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 3.6 V) | | |
| Subsystem clock | | XT1 (Crystal) oscillation, External main system clock input (EXCLKS) 32.768 kHz | | |
| RF slow clock | External input | External clock input for RF block (EXSLK_RF) 32.768 kHz (TYP.) | | |
| | On-chip Oscillator | 32.768 kHz (TYP.) | | |
| Low-speed on-chip oscillator | | 15 kHz (TYP.) | | |
| General-purpose register | | (8-bit register × 8) × 4 banks | | |
| Minimum instruction execution time | | 0.03125 μ s (High-speed on-chip oscillation clock: $f_{IH} = 32$ MHz operation) | | |
| | | 0.05 μ s (High-speed system clock: $f_{MX} = 20$ MHz operation) | | |
| | | 30.5 μ s (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) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc. | | |
| I/O port | Total | 32 ^{Note 2} | | |
| | CMOS I/O | 20 ^{Note 2} | | |
| | CMOS input | 5 ^{Note 2} | | |
| | CMOS output | 1 ^{Note 2} | | |
| | N-ch O.D. I/O (withstand voltage: 6 V) | 2 | | |
| | GPIO (RF block) | 4 | | |
| 2.4 GHz RF transceiver | | Supporting Bluetooth v4.2 Specification (Single mode). 2.4 GHz ISM Band, GFSK modulation, TDMA/TDD frequency hopping (Including AES encryption circuit.) Adaptivity (Only in slave operation) | | |
| Timer | 16-bit timer | 8 channels | | |
| | Watchdog timer | 1 channel | | |
| | Real-time clock (RTC) | 1 channel | | |
| | 12-bit interval timer | 1 channel | | |

(Notes are listed on the next page.)

- Note 1.** This is about 19 KB when the self-programming function is used.
2. When RF is used, this count includes the pins that connect the MCU with the RF transceiver by the user externally on the board.

(2/2)

| Item | | R5F11AGG | R5F11AGH | R5F11AGJ |
|---|---------------------------|---|-----------|----------|
| Timer | Timer output | 8 channels (PWM outputs: 7 ^{Note 1} Note 2) | | |
| | RTC output | 1 channel 1 Hz (subsystem clock: $f_{SUB} = 32.768$ kHz) | | |
| Clock output/buzzer output | | 1 ^{Note 3} | | |
| | | <ul style="list-style-type: none"> 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) 256 Hz, 512 Hz, 1.024 kHz, 2.048 kHz, 4.096 kHz, 8.192 kHz, 16.384 kHz, 32.768 kHz (Subsystem clock: $f_{SUB} = 32.768$ kHz operation) | | |
| | RF unit (Clock output) | <ul style="list-style-type: none"> 16 MHz, 8 MHz, 4 MHz | | |
| 8/10-bit resolution A/D converter | | 8 channels | | |
| Serial interface | | <ul style="list-style-type: none"> CSI/simplified I²C/UART: 1 channel CSI/simplified I²C: 1 channel UART: 1 channel CSI: 1 channel (dedicated for internal communications) | | |
| | | I ² C bus | 1 channel | |
| Multiplier and divider/multiply-accumulator | | Multiplication: 16 bits × 16 bits = 32 bits (Unsigned or signed) Division: 32 bits ÷ 32 bits = 32 bits (Unsigned) Multiply-accumulate: 16 bits × 16 bits + 32 bits = 32 bits (Unsigned or signed) | | |
| DMA controller | | 4 channels | | |
| Vectored interrupt sources | Internal | 29 | | |
| | External | 4 | | |
| Reset | | <ul style="list-style-type: none"> Reset by 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 4} 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 (TYP.) Power-down-reset: 1.50 (TYP.) | | |
| Voltage detector | | <ul style="list-style-type: none"> Rising edge : 1.67 V to 3.13 V (12 stages) Falling edge : 1.63 V to 3.06 V (12 stages) | | |
| On-chip debug function | | Provided | | |
| Power supply voltage | | $V_{DD} = 1.6$ to 3.6 V ($V_{DD} = 1.8$ to 3.6 V on usage of DC-DC converter) | | |
| Operating ambient temperature | | $T_A = -40$ to $+85$ °C | | |
| Package | | 48-pin QFN (6 × 6), (0.4 mm pitch) | | |

Note 1. The number of outputs varies, depending on the setting of channels in use and the number of the master (see **7.9.3 Operation as multiple PWM output function**).

2. When setting to PIOR0 = 1

3. When RF is used, this count includes the pins that connect the MCU with the RF transceiver by the user externally on the board.

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

2. ELECTRICAL SPECIFICATIONS

Caution 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.

2.1 Absolute Maximum Ratings

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

| Parameter | Symbols | Conditions | Ratings | Unit |
|------------------------|--------------------|---|---|------|
| Supply voltage | V _{DD} | V _{DD} | -0.5 to +6.5 | V |
| | V _{DDRF1} | V _{DD_RF} | -0.5 to +4.0 | V |
| | V _{DDRF2} | AV _{DD_RF} | -0.5 to +4.0 | V |
| | V _{DDRF3} | DCLIN | -0.5 to +4.0 | V |
| | V _{SSRF} | V _{SS_RF} , AV _{SS_RF} | -0.5 to +0.3 | V |
| Input voltage | V _{I1} | P00, P01, P02, P03, P10, P11, P12, P14, P15, P16, P20, P21, P22, P23, P30, P40, P120, P121, P122, P123, P124, P137, P140, P147, RESET | -0.3 to V _{DD} +0.3 ^{Note 1} | V |
| | V _{I2} | P60, P61 | -0.3 to +6.5 | V |
| | V _{IRF1} | GPIO0, GPIO1, GPIO2, GPIO3 | -0.3 to V _{DD_RF} +0.3 ^{Note 2} | V |
| | V _{IRF2} | ANT | -0.5 to +1.4 | V |
| Output voltage | V _O | P00, P01, P02, P03, P10, P11, P12, P14, P15, P16, P20, P21, P22, P23, P30, P40, P60, P61, P120, P130, P140, P147 | -0.3 to V _{DD} +0.3 ^{Note 1} | V |
| | V _{ORF} | GPIO0, GPIO1, GPIO2, GPIO3, DCLOUT | -0.3 to V _{DD_RF} +0.3 ^{Note 2} | V |
| Analog input voltage | V _{AI} | ANI0, ANI1, ANI2, ANI3, ANI16, ANI17, ANI18, ANI19 | -0.3 to V _{DD} +0.3 and -0.3 to V _{REF(+)} +0.3 ^{Note 2, 4} | V |
| REGC pin input voltage | V _{IREGC} | REGC | -0.3 to +2.8 and -0.3 to V _{DD} +0.3 ^{Note 3} | V |
| IC pin input voltage | V _{IIC} | IC0, IC1 | -0.5 to +0.3 | V |

Note 1. Must be 6.5 V or lower.

2. Must be 4.0 V or lower.

3. 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.

4. 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.

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

3. Reference voltage is V_{SS}.

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

| Parameter | Symbols | Conditions | Ratings | Unit | |
|-------------------------------|--------------------|----------------------------------|--|------|----|
| Output current, high | I _{OH1} | Per pin | (This is applicable to all pins listed below.) | -40 | mA |
| | | Total of all pins -170mA | P00, P01, P02, P03, P40, P120, P130, P140 | -70 | mA |
| | | | P10, P11, P12, P13, P14, P15, P16, P30, P147 | -100 | mA |
| | I _{OH2} | Per pin | (This is applicable to all pins listed below.) | -0.5 | mA |
| | | Total of all pins | P20, P21, P22, P23 | -2 | mA |
| | I _{OHMRF} | Per pin | GPIO0, GPIO1, GPIO2, GPIO3 | -17 | mA |
| Output current, low | I _{OL1} | Per pin | (This is applicable to all pins listed below.) | 40 | mA |
| | | Total of all pins 170mA | P00, P01, P02, P03, P40, P120, P130, P140 | 70 | mA |
| | | | P10, P11, P12, P13, P14, P15, P16, P30, P60, P61, P147 | 100 | mA |
| | I _{OL2} | Per pin | (This is applicable to all pins listed below.) | 1 | mA |
| | | Total of all pins | P20, P21, P22, P23 | 5 | mA |
| | I _{OLRF} | Per pin | GPIO0, GPIO1, GPIO2, GPIO3 | 17 | mA |
| Operating ambient temperature | T _A | In normal operation mode | -40 to +85 | °C | |
| | | In flash memory programming mode | -40 to +85 | °C | |
| 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 1. Unless specified otherwise, the characteristics of alternate-function pins are the same as those of the port pins.

2. AV_{REF (+)} : + side reference voltage of the A/D converter.
3. Reference voltage is V_{SS}.

2.2 Operating Voltage

($T_A = -40$ to $+85^\circ\text{C}$, $V_{DD} = V_{DD_RF} = AV_{DD_RF}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0$ V)

| Clock generator | | Flash operation mode | Operation voltage | CPU operation clocks (f_{CLK}) ^{Note 1} | | |
|-------------------------------------|---|--|--|---|--|-----------------|
| Main system clock (f_{MAIN}) | High-speed on-chip oscillator (f_{IH}) | HS (high-speed main) mode | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 32 MHz | | |
| | | | $2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$ | 1 MHz to 16 MHz | | |
| | | LS (low-speed main) mode | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 8 MHz | | |
| | X1 clock oscillator (f_X) | HS (high-speed main) mode | HS (high-speed main) mode | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 20 MHz | |
| | | | | $2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$ | 1 MHz to 16 MHz | |
| | | | LS (low-speed main) mode | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 8 MHz | |
| | | External main system clock (f_{EX}) | HS (high-speed main) mode | HS (high-speed main) mode | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 20 MHz |
| | | | | | $2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$ | 1 MHz to 16 MHz |
| | | | LS (low-speed main) mode | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 MHz to 8 MHz | |
| Subsystem clock (f_{SUB}) | XT1 clock oscillator (f_{XT}) | – | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 32.768 kHz | | |
| | External subsystem clock (f_{EXT}) | – | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 32.768 kHz | | |

Note 1. 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.

2. This mode is prohibited to use in case of using DC-DC converter.

2.3 Oscillator Characteristics

2.3.1 X1, XT1, XRF oscillator characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|-------------------|------------|--|------|--------|------|------|
| X1 clock oscillation frequency ^{Note 1} | Ceramic resonator | f_x | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 | | 20 | MHz |
| | Crystal resonator | | $1.8\text{ V} \leq V_{DD} < 2.7\text{ V}$ | 1 | | 8 | MHz |
| | | | $1.6\text{ V} \leq V_{DD} \leq 1.8\text{ V}$ | 1 | | 4 | MHz |
| XT1 clock oscillation frequency ^{Note 1} | | f_{XT} | | 32 | 32.768 | 35 | kHz |
| RF base clock oscillation frequency ^{Note 2} | | f_{XRF} | | | 32 | | MHz |
| RF base clock oscillation frequency accuracy ^{Note 2} | | f_{XRFP} | | -20 | | +20 | ppm |

Note 1. 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.

2. This Oscillator characteristics is base clock for RF Transceiver.

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.

2.3.2 On-chip oscillator characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Oscillators | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|-------------|----------------------------|--|--------|--------|-------|------|
| High-speed on-chip oscillator clock frequency ^{Note 1, 2} | f_{IH} | | | 1 | | 32 | MHz |
| High-speed on-chip oscillator clock frequency accuracy | f_{IHP} | -20 to $+85^\circ\text{C}$ | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | -1.5 | | +1.5 | % |
| | | | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | -5.0 | | +5.0 | % |
| | | -40 to -20°C | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | -2.5 | | +2.5 | % |
| | | | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | -5.5 | | +5.5 | % |
| Low-speed on-chip oscillator clock frequency ^{Note 3} | f_{IL} | | | | 15 | | kHz |
| Low-speed on-chip oscillator clock frequency accuracy | f_{ILP} | | | -15 | | +15 | % |
| On-chip oscillator clock frequency for the RF slow clock ^{Note 3} | f_{ILRF} | | | | 32.768 | | kHz |
| On-chip oscillator clock frequency accuracy for the RF slow clock | f_{ILRFP} | | | -0.025 | | 0.025 | % |

Note 1. High-speed on-chip oscillator frequency is selected by bits 0 to 3 of option byte (000C2H/010C2H) and bits 0 to 2 of HOCODIV register.

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

3. This indicates the oscillator characteristics only.

2.4 DC Characteristics

2.4.1 Output current

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|--|--|---|--|--|-------|--------------------------|----|
| Output current, high ^{Note 1} | I _{OH1} | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P130, P140, P147 | Per pin | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $-10.0^{\text{Note 2}}$ | mA |
| | | P00, P01, P02, P03, P40, P120, P130, P140 | Total ^{Note 3} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | -10.0 | mA |
| | | | | $1.8\text{ V} \leq V_{DD} < 2.7\text{ V}$ | | -5.0 | mA |
| | | | | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | | -2.5 | mA |
| | P10, P11, P12, P13, P14, P15, P16, P30, P147 | Total ^{Note 3} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | -19.0 | mA | |
| | | | $1.8\text{ V} \leq V_{DD} < 2.7\text{ V}$ | | -10.0 | mA | |
| | | | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | | -5.0 | mA | |
| | Total of all pins ^{Note 3} | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | $-135.0^{\text{Note 4}}$ | mA |
| | I _{OH2} | P20, P21, P22, P23 | Per pin | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $-0.1^{\text{Note 2}}$ | mA |
| | | | Total ^{Note 3} | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | -1.5 | mA |
| I _{OH_{RF}} | GPIO0, GPIO1, GPIO2, GPIO3 | Per pin | $1.6\text{ V} \leq V_{DD_RF} \leq 3.6\text{ V}$ | | -2.0 | mA | |
| Output current, low ^{Note 1} | I _{OL1} | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P130, P140, P147 | Per pin | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $20.0^{\text{Note 2}}$ | mA |
| | | P60, P61 | Per pin | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $15.0^{\text{Note 2}}$ | mA |
| | | P00, P01, P02, P03, P40, P120, P130, P140 | Total ^{Note 3} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 15.0 | mA |
| | | | | $1.8\text{ V} \leq V_{DD} < 2.7\text{ V}$ | | 9.0 | mA |
| | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | | | | 4.5 | mA | |
| | P10, P11, P12, P13, P14, P15, P16, P30, P60, P61, P147 | Total ^{Note 3} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 35.0 | mA | |
| | | | $1.8\text{ V} \leq V_{DD} < 2.7\text{ V}$ | | 20.0 | mA | |
| | | | $1.6\text{ V} \leq V_{DD} < 1.8\text{ V}$ | | 10.0 | mA | |
| | Total of all pins ^{Note 3} | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | 150.0 | mA |
| | I _{OL2} | P20, P21, P22, P23 | Per pin | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $0.4^{\text{Note 2}}$ | mA |
| Total ^{Note 3} | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 5.0 | mA | |
| I _{OL_{RF}} | GPIO0, GPIO1, GPIO2, GPIO3 | Per pin | $1.6\text{ V} \leq V_{DD_RF} \leq 3.6\text{ V}$ | | 2.0 | mA | |

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

- However, do not exceed the total current value.
- Specification under conditions where the duty factor $\leq 70\%$.

The output current value that has changed to the duty factor $> 70\%$ the duty ratio can be calculated with the following expression (when changing the duty factor from 70% to n%).

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

<Example> Where $n = 50\%$ and $I_{OH} = -10.0\text{ mA}$

$$\text{Total output current of pins} = (-10.0 \times 0.7)/(50 \times 0.01) = -14.0\text{ mA}$$

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.

- Product for industrial applications (R5F11AGGDNB, R5F11AGHDNB, R5F11AGJDNB) is -100.0 mA .

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

Caution P00, P02, P03, and P10 to P15 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.

2.4.2 Input current

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|---------------------|------------|---|--|------------------|------|-----------------|---|
| Input voltage, high | V_{IH1} | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P130, P140, P147 | Normal mode ($I_{THL} = 1$) | $0.8V_{DD}$ | | V_{DD} | V |
| | V_{IH2} | P01, P03, P10, P11, P13, P14, P15, P16 | TTL mode $3.3\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 2.0 | | V_{DD} | V |
| | | | TTL mode $1.6\text{ V} \leq V_{DD} < 3.3\text{ V}$ | 1.5 | | V_{DD} | V |
| | V_{IH3} | P20, P21, P22, P23 | | $0.7V_{DD}$ | | V_{DD} | V |
| | V_{IH4} | P60, P61 | | $0.7V_{DD}$ | | 6.0 | V |
| | V_{IH5} | P121, P122, P123, P124, P137, RESET | | $0.8V_{DD}$ | | V_{DD} | V |
| | V_{IHRF} | GPIO0, GPIO1, GPIO2, GPIO3 | | $0.85V_{DD_RF}$ | | V_{DD_RF} | V |
| Input voltage, low | V_{IL1} | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P140, P147 | Normal mode ($I_{THL} = 1$) | 0 | | $0.2V_{DD}$ | V |
| | V_{IL2} | P01, P03, P10, P11, P13, P14, P15, P16 | TTL mode $3.3\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 0 | | 0.5 | V |
| | | | TTL mode $1.6\text{ V} \leq V_{DD} < 3.3\text{ V}$ | 0 | | 0.32 | V |
| | V_{IL3} | P20, P21, P22, P23 | | 0 | | $0.3V_{DD}$ | V |
| | V_{IL4} | P60, P61 | | 0 | | $0.3V_{DD}$ | V |
| | V_{IL5} | P121, P122, P123, P124, P137, RESET | | 0 | | $0.2V_{DD}$ | V |
| | V_{ILRF} | GPIO0, GPIO1, GPIO2, GPIO3 | | 0 | | $0.1V_{DD_RF}$ | V |

Caution The maximum value of V_{IH} of pins P00, P02, P03, and P10 to P15 is V_{DD} , even in the N-ch open-drain mode.

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

2.4.3 Output voltage

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---------------------------|------------------------------|---------------------------|---|--|------------------------------------|------------------------------------|------|
| Output voltage, high | V _{OH1} | I _{OH} = -2.0 mA | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P140, P147 | 2.7 V ≤ V _{DD} ≤ 3.6 V | | V _{DD} - 0.6 | V |
| | | I _{OH} = -1.5 mA | | 1.8 V ≤ V _{DD} ≤ 3.6 V | | V _{DD} - 0.5 | V |
| | | I _{OH} = -1.0 mA | | 1.6 V ≤ V _{DD} ≤ 3.6 V | | V _{DD} - 0.5 | V |
| | | I _{OH} = -10 μA | P130 | | | V _{DD} - 0.3 | V |
| | V _{OH2} | I _{OH} = -100 μA | P20, P21, P22, P23 | | | V _{DD} - 0.5 | V |
| | V _{OH_{RF}} | I _{OH} = -2.0 mA | GPIO0, GPIO1, GPIO2, GPIO3 | 2.7 V ≤ V _{DD_{RF}} ≤ 3.6 V | | V _{DD_{RF}} - 0.3 | V |
| I _{OH} = -1.5 mA | | | 1.8 V ≤ V _{DD_{RF}} ≤ 3.6 V | | V _{DD_{RF}} - 0.3 | V | |
| Output voltage, low | V _{OL1} | I _{OL} = 3.0 mA | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P130, P140, P147 | 2.7 V ≤ V _{DD} ≤ 3.6 V | | 0.6 | V |
| | | I _{OL} = 1.5 mA | | | | 0.4 | V |
| | | I _{OL} = 0.6 mA | | 1.8 V ≤ V _{DD} ≤ 3.6 V | | 0.4 | V |
| | | I _{OL} = 0.3 mA | | 1.6 V ≤ V _{DD} ≤ 3.6 V | | 0.4 | V |
| | V _{OL2} | I _{OL} = 400 μA | P20, P21, P22, P23 | | | 0.4 | V |
| | V _{OL_{RF}} | | GPIO0, GPIO1, GPIO2, GPIO3 | | | 0.3 | V |

Caution P00, P02, P03, and P10 to P15 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.

2.4.4 Input leakage current

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | |
|-----------------------------|--------------------|----------------------------|---|-------------------------|------|------|---------------|---------------|
| Input leakage current, high | ILIH1 | $V_I = V_{DD}$ | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P60, P61, P120, P140, P147 | | | 1 | μA | |
| | ILIH2 | $V_I = V_{DD}$ | P20, P21, P22, P23, P137, $\overline{\text{RESET}}$ | | | 1 | μA | |
| | ILIH3 | $V_I = V_{DD}$ | P121, P122, P123, P124 (EXCLK, EXCLKS) (XT1, XT2) | In input port | | | 1 | μA |
| | | | | In external clock input | | | 1 | μA |
| | | | | In resonator connection | | | 10 | μA |
| ILIH _{RF} | $V_I = V_{DD_RF}$ | GPIO0, GPIO1, GPIO2, GPIO3 | | | | 10 | μA | |
| Input leakage current, low | ILIL1 | $V_I = V_{SS}$ | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P60, P61, P120, P140, P147 | | | -1 | μA | |
| | ILIL2 | $V_I = V_{SS}$ | P20, P21, P22, P23, P137, $\overline{\text{RESET}}$ | | | -1 | μA | |
| | ILIL3 | $V_I = V_{SS}$ | P121, P122, P123, P124 (EXCLK, EXCLKS) (XT1, XT2) | In input port | | | -1 | μA |
| | | | | In external clock input | | | -1 | μA |
| | | | | In resonator connection | | | -10 | μA |
| ILIL _{RF} | $V_I = V_{SS_RF}$ | GPIO0, GPIO1, GPIO2, GPIO3 | | | | -10 | μA | |

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

2.4.5 Resistance

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---------------------------|----------------|----------------|--|------|------|------|------------|
| On-chip pll-up resistance | R _u | $V_I = V_{SS}$ | P00, P01, P02, P03, P10, P11, P12, P13, P14, P15, P16, P30, P40, P120, P140, P147 In input mode | 10 | 20 | 100 | k Ω |

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

2.5 Current Consumption

The Current Consumption by the RL78/G1D is the total current including that for the MCU (current flowing into the V_{DD} pin) and that for the RF unit (current flowing into the V_{DD_RF}, AV_{DD_RF} pins).

The characteristics of the MCU (current flowing into the V_{DD} pin) are given in 2.5.1 and the characteristics of the RF unit (current flowing into the V_{DD_RF}/AV_{DD_RF} pins) are given in 2.5.2

2.5.1 MCU

(1) Operating current

(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

| Parameter | Symbol | Conditions | | | MIN. | TYP. | MAX. | Unit | | |
|--|--|--|------------------|---|---|--|---|------|-----|-----|
| Operating current ^{Note 1} | I _{DD1} | HS (high-speed main) mode ^{Note 5} | Basic operation | f _{IH} = 32 MHz ^{Note 2} | V _{DD} = 3.0 V | | 2.3 | | mA | |
| | | | Normal operation | f _{IH} = 32 MHz ^{Note 2} | V _{DD} = 3.0 V | | 5.2 | 8.5 | mA | |
| | | | | f _{IH} = 24 MHz ^{Note 2} | V _{DD} = 3.0 V | | 4.1 | 6.6 | mA | |
| | | | | f _{IH} = 16 MHz ^{Note 2} | V _{DD} = 3.0 V | | 3.0 | 4.7 | mA | |
| | | LS (low-speed main) mode ^{Note 5} | Normal operation | f _{IH} = 8 MHz ^{Note 2} | V _{DD} = 3.0 V | | 1.3 | 2.1 | mA | |
| | | | | | V _{DD} = 2.0 V | | 1.3 | 2.1 | mA | |
| | | LV (low-voltage main) mode ^{Note 5} | Normal operation | f _{IH} = 4 MHz ^{Note 2} | V _{DD} = 3.0 V | | 1.3 | 1.8 | mA | |
| | | | | | V _{DD} = 2.0 V | | 1.3 | 1.8 | mA | |
| | | HS (high-speed main) mode ^{Note 5} | Normal operation | f _{MX} = 20 MHz ^{Note 3} | V _{DD} = 3.0 V ^{Note 6} | | 3.4 | 5.5 | mA | |
| | | | | | | | 3.6 | 5.7 | mA | |
| | | | | | | f _{MX} = 10 MHz ^{Note 3} | V _{DD} = 3.0 V ^{Note 6} | | 2.1 | 3.2 |
| | | LS (low-speed main) mode ^{Note 5} | Normal operation | f _{MX} = 8 MHz ^{Note 3} | V _{DD} = 3.0 V ^{Note 6} | | 1.2 | 2.0 | mA | |
| | | | | | | | 1.2 | 2.0 | mA | |
| | | | | | V _{DD} = 2.0 V ^{Note 6} | | 1.2 | 2.0 | mA | |
| | | | | | | | 1.2 | 2.0 | mA | |
| | | Subsystem clock operation | Normal operation | f _{SUB} = 32.768 kHz ^{Note 4} | T _A = -40°C ^{Note 6} | | 4.8 | 5.9 | μA | |
| | | | | | | | 4.9 | 6.0 | μA | |
| | | | | | | T _A = +25°C ^{Note 6} | | 4.9 | 5.9 | μA |
| | | | | | | | 5.0 | 6.0 | μA | |
| | | | | | | T _A = +50°C ^{Note 6} | | 5.0 | 7.6 | μA |
| | 5.1 | | | | | 7.7 | μA | | | |
| T _A = +70°C ^{Note 6} | | | | | | 5.2 | 9.3 | μA | | |
| | 5.3 | 9.4 | μA | | | | | | | |
| | T _A = +85°C ^{Note 6} | | 5.7 | 13.3 | μA | | | | | |
| | | | 5.8 | 13.4 | μA | | | | | |

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

- Note 1.** Current flowing into V_{DD} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} or V_{SS} . The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
2. When high-speed system clock and subsystem clock are stopped.
 3. When high-speed on-chip oscillator and subsystem clock are stopped.
 4. When high-speed on-chip oscillator and high-speed system clock are stopped. When setting ultra-low current consumption (AMPHS1 = 1). Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.
 5. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.

| | |
|-----------------------------|---|
| HS (high-speed main) mode: | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 32 MHz |
| | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 16 MHz |
| LS (low-speed main) mode: | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 8 MHz |
| LV (low-voltage main) mode: | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 4 MHz |
 6. The upper value is for square-wave input and the lower is with an oscillator connected.

- Remark 1.** f_{MX} : High-speed system clock frequency (External main system clock frequency)
2. f_{IH} : High-speed on-chip oscillator clock frequency
 3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
 4. Except subsystem clock operation, temperature condition of the TYP. value is $T_A = 25^\circ\text{C}$

(2) Standby current

(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | | |
|---|--|--|--|---|--|------|------|------|----|
| HALT current Note 1, 2 | I _{DD2} | HS (high-speed main) mode ^{Note 7} | f _{IH} = 32 MHz ^{Note 4} | V _{DD} = 3.0 V | | 0.62 | 1.86 | mA | |
| | | | f _{IH} = 24 MHz ^{Note 4} | V _{DD} = 3.0 V | | 0.50 | 1.45 | mA | |
| | | | f _{IH} = 16 MHz ^{Note 4} | V _{DD} = 3.0 V | | 0.44 | 1.11 | mA | |
| | | LS (low-speed main) mode ^{Note 7} | f _{IH} = 8 MHz ^{Note 4} | V _{DD} = 3.0 V | | 290 | 620 | μA | |
| | | | | V _{DD} = 2.0 V | | 290 | 620 | μA | |
| | | LV (low-voltage main) mode ^{Note 7} | f _{IH} = 4 MHz ^{Note 4} | V _{DD} = 3.0 V | | 440 | 680 | μA | |
| | | | | V _{DD} = 2.0 V | | 440 | 680 | μA | |
| | | HS (high-speed main) mode ^{Note 7} | f _{MX} = 20 MHz ^{Note 3} | V _{DD} = 3.0 V ^{Note 9} | | 0.31 | 1.08 | mA | |
| | | | | | | 0.48 | 1.28 | mA | |
| | | | | | | 0.21 | 0.63 | mA | |
| | | LS (low-speed main) mode ^{Note 7} | f _{MX} = 10 MHz ^{Note 3} | V _{DD} = 3.0 V ^{Note 9} | | 0.28 | 0.71 | mA | |
| | | | | | | 110 | 360 | μA | |
| | | | | | | 160 | 420 | μA | |
| | | Subsystem clock operation | f _{SUB} = 32.768kHz ^{Note 5} | V _{DD} = 3.0 V ^{Note 9} | T _A = -40°C ^{Note 9} | | 0.28 | 0.61 | μA |
| | | | | | | | 0.47 | 0.80 | μA |
| V _{DD} = 2.0 V ^{Note 9} | T _A = +25°C ^{Note 9} | | | | 0.34 | 0.61 | μA | | |
| | | | | | 0.53 | 0.80 | μA | | |
| T _A = +50°C ^{Note 9} | | | | | 0.41 | 2.30 | μA | | |
| | | | | | 0.60 | 2.49 | μA | | |
| T _A = +70°C ^{Note 9} | | | 0.64 | 4.03 | μA | | | | |
| | | | 0.83 | 4.22 | μA | | | | |
| STOP current ^{Note 6, 8} | I _{DD3} | T _A = -40°C | | | 0.19 | 0.52 | μA | | |
| | | T _A = +25°C | | | 0.25 | 0.52 | μA | | |
| | | T _A = +50°C | | | 0.32 | 2.21 | μA | | |
| | | T _A = +70°C | | | 0.55 | 3.94 | μA | | |
| | | T _A = +85°C | | | 1.00 | 7.95 | μA | | |

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

- Note**
1. Current flowing into V_{DD} , including the input leakage current flowing when the level of the input pin is fixed to V_{DD} or V_{SS} . The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the A/D converter, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
 2. During HALT instruction execution by flash memory.
 3. When high-speed on-chip oscillator and subsystem clock are stopped.
 4. When high-speed system clock and subsystem clock are stopped.
 5. When high-speed on-chip oscillator and high-speed system clock are stopped. When setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the RTC is included. However, not including the current flowing into the 12-bit interval timer and watchdog timer.
 6. Not including the current flowing into the RTC, 12-bit interval timer, and watchdog timer.
 7. Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }32\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$
LS (low-speed main) mode: $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
LV (low-voltage main) mode: $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }4\text{ MHz}$
 8. If operation of the subsystem clock when STOP mode, same as when HALT mode of subsystem clock operation.
 9. The upper value is for square-wave input and the lower is with an oscillator connected.

- Remark**
1. f_{MX} : High-speed system clock frequency (External main system clock frequency)
 2. f_{IH} : High-speed on-chip oscillator clock frequency
 3. f_{SUB} : Subsystem clock frequency (XT1 clock oscillation frequency)
 4. Except subsystem clock operation and STOP mode, temperature condition of the TYP. value is $T_A = 25^\circ\text{C}$

(3) Current for each peripheral circuit

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|---|-----------------------------------|----------------------------------|--|------|------|-------|---------------|
| Low-speed on-chip oscillator operating current | I_{FIL} ^{Note 1} | | | | 0.20 | | μA |
| Current when PCLBUZ0 and EXSLK_RF are connected together and MCU supplies RF slow clock to RF | I_{PCEX} ^{Note 1} | | | | 1.0 | | μA |
| RTC operating current | I_{RTC} ^{Note 1, 2, 3} | | | | 0.02 | | μA |
| 12-bit interval timer operating current | I_{IT} ^{Note 1, 2, 4} | | | | 0.02 | | μA |
| Watchdog timer operating current | I_{WDT} ^{Note 1, 2, 5} | f _{IL} is 15 kHz | | | 0.22 | | μA |
| A/D converter operating current | I_{ADC} ^{Note 1, 6} | When conversion at maximum speed | $AV_{REFP} = V_{DD} = 3.0\text{ V}$ | | 0.5 | 0.7 | mA |
| A/D converter reference voltage current | I_{ADREF} ^{Note 1} | | | | 75.0 | | μA |
| Thermometer sensor operating current | I_{TMPS} ^{Note 1} | | | | 75.0 | | μA |
| LVD operating current | I_{LVI} ^{Note 1, 7} | | | | 0.08 | | μA |
| Flash self-programming operating current | I_{FSP} ^{Note 1, 9} | | | | 2.50 | 12.20 | mA |
| BGO current | I_{BGO} ^{Note 1, 8} | | | | 2.50 | 12.20 | mA |
| SNOOZE operating current | I_{SNOZ} ^{Note 1} | ADC operation | The mode is performed ^{Note 10} | | 0.50 | 0.60 | mA |
| | | | The A/D conversion operations are performed, Low voltage mode, $AV_{REFP} = V_{DD} = 3.0\text{ V}$ | | 1.20 | 1.44 | mA |
| | | CSI/UART operation | | | 0.70 | 0.84 | mA |

Note 1. Current flowing to V_{DD} .

2. When high speed on-chip oscillator and high-speed system clock are stopped.
3. Current flowing only to the real-time clock (RTC) (excluding the operating current of the XT1 oscillator). The value of the current value of the RL78 microcontroller is the sum of the values of either I_{DD1} or I_{DD2} , and I_{RTC} , when the real-time clock operates in operation mode or HALT mode. Also, add the value of I_{FIL} in case of selecting low-speed on-chip oscillator. I_{DD2} subsystem clock operation includes the operational current of the real-time clock.
4. Current flowing only to the 12 bit interval timer (including the operating current of the low-speed on-chip oscillator). The current value of the MCU is the sum of I_{DD1} or I_{DD2} and I_{IT} when $f_{CLK} = f_{SUB}$ when the watchdog timer operates in STOP mode. When using low-speed on-chip oscillator, add I_{FIL} .
5. Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The current value of the MCU is the sum of I_{DD1} , I_{DD2} or I_{DD3} and I_{WDT} when the watchdog timer is in operation.
6. Current flowing only to the A/D converter. The current value of MCU is the sum of I_{DD1} or I_{DD2} and I_{ADC} when the A/D converter operates in an operation mode or the HALT mode.
7. Current flowing only to the LVD circuit. The current value of MCU is the sum of I_{DD1} , I_{DD2} or I_{DD3} and I_{LVI} when the LVD circuit is in operation.
8. Current flowing when operates rewriting to Data flash.
9. Current flowing when operates flash self-programming.
10. Shift time to the SNOOZE mode is referred User's Manual: Hardware.

(Remarks are listed on the next page.)

- Remark 1.** f_{IL} : Low-speed on-chip oscillator clock frequency
2. f_{SUB} : Subsystem clock frequency
3. f_{CLK} : CPU and peripheral hardware clock frequency
4. Temperature condition of the TYP. value is $T_A = 25^\circ\text{C}$

2.5.2 RF unit

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | |
|--------------------------------|--------------------------------|---|---------------------------------|--------------------------|------|------|------|----|
| Supply current Note 1, 2 | I _{DDRF_{TX}} | Transmission peak current | Transmission output power 0 dBm | RF normal mode | - | 4.3 | 5.7 | mA |
| | | | | | - | 7.4 | 9.0 | mA |
| | | | | RF low power mode | - | 2.6 | 4.1 | mA |
| | | | | | - | 4.4 | 6.0 | mA |
| | | | | RF high performance mode | - | 4.3 | 5.7 | mA |
| | | | | | - | 7.4 | 9.0 | mA |
| | I _{DDRF_{RX}} | Reception peak current | RF normal mode | | - | 3.5 | 5.0 | mA |
| | | | | | - | 6.2 | 7.5 | mA |
| | | | RF low power mode | | - | 3.3 | 4.8 | mA |
| | | | | | - | 5.8 | 7.1 | mA |
| | | | RF high performance mode | | - | 3.7 | 5.2 | mA |
| | | | | | - | 6.6 | 7.9 | mA |
| I _{DDRF_{ST}} | STANDBY_RF current | | | - | 0.40 | 0.9 | mA | |
| | | | | - | 0.28 | 0.8 | mA | |
| I _{DDRF_{SL}} | SLEEP_RF current | | | - | 0.50 | 1.1 | mA | |
| | | | | - | 0.36 | 0.8 | mA | |
| I _{DDRF_{DS}} | DEEP_SLEEP current | RF slow clock externally input through EXSLK_RF | | - | 0.14 | 3.6 | μA | |
| | | | | - | 0.14 | 3.6 | μA | |
| | | RF slow clock from on-chip oscillator | | - | 1.8 | 6.8 | μA | |
| | | | | - | 1.8 | 6.8 | μA | |
| I _{DDRF_{PD}} | POWER_DOWN current | | | - | 0.10 | 3.0 | μA | |
| | | | | - | 0.10 | 3.0 | μA | |
| I _{DDRF_{RS}} | RESET_RF current | | | - | 0.10 | 3.0 | μA | |
| | | | | - | 0.10 | 3.0 | μA | |
| I _{DDRF_{IL}} | IDLE_RF current | | | - | 0.50 | 1.1 | mA | |
| | | | | - | 0.60 | 1.1 | mA | |
| I _{DDRF_{SU}} | SETUP_RF current | | | - | 2.5 | 4.7 | mA | |
| | | | | - | 3.5 | 5.0 | mA | |

Note 1. Total current flowing into V_{DD_RF} , and AV_{DD_RF} .

- 2.** For each item, the values in the upper and lower row apply respectively when the DC/DC converter embedded in the RF chip is and is not in use.

2.6 AC Characteristics

(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

| Items | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit | | | |
|--|--|--|----------------------------|---------------------------------|-----------|--------|-----------|-----|-----|-----|
| Cycle time (minimum instruction execution time) | T _{CY} | Main system (f _{MAIN}) clock operation | HS (high-speed main) mode | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.03125 | | 1 | μs | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | 0.0625 | | 1 | μs | | |
| | | | LV (low-voltage main) mode | | 0.25 | | 1 | μs | | |
| | | | LS (low-speed main) mode | | 0.125 | | 1 | μs | | |
| | | Subsystem clock (f _{SUB}) operation | | | 28.5 | 30.5 | 31.3 | μs | | |
| | | In the self programming mode | HS (high-speed main) mode | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.03125 | | 1 | μs | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | 0.0625 | | 1 | μs | | |
| | | | LV (low-voltage main) mode | | 0.25 | | 1 | μs | | |
| LS (low-speed main) mode | | | 0.125 | | 1 | μs | | | | |
| External clock frequency | f _{EX} | EXCLK | | 2.7 V ≤ V _{DD} ≤ 3.6 V | 1 | | 20 | MHz | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | 1 | | 16 | MHz | | |
| | | | | 1.8 V ≤ V _{DD} < 2.4 V | 1 | | 8 | MHz | | |
| | f _{EXS} | EXCLKS | | 32 | | 35 | kHz | | | |
| | f _{EXRF} | EXSLK_RF | When 32.768 kHz input | ±500 ppm | 32.751616 | 32.768 | 32.784384 | kHz | | |
| | | | When 16.384 kHz input | ±500 ppm | 16.375808 | 16.384 | 16.392192 | kHz | | |
| External clock input high-level width, low-level width | t _{EXH} , t _{EXL} | EXCLK | | 2.7 V ≤ V _{DD} ≤ 3.6 V | 24 | | | ns | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | 30 | | | ns | | |
| | | | | 1.8 V ≤ V _{DD} < 2.4 V | 60 | | | ns | | |
| | t _{EXHS} , t _{EXLS} | EXCLKS | | 13.7 | | | μs | | | |
| | t _{EXHRF} , t _{EXLRF} | EXSLK_RF | When 32.768 kHz input | | 0.08 | 15.258 | 32.69 | μs | | |
| | | | When 16.384 kHz input | | 0.08 | 8.192 | 16.304 | μs | | |
| Timer input high-level width, low-level width | t _{TIH} , t _{TIL} | TI00, TI01, TI02, TI03, TI04, TI05, TI06, TI07 | | 1/f _{MCK} +10 | | | ns | | | |
| Timer output frequency | t _{TO} | TI00, TI01, TI02, TI03, TI04, TI05, TI06, TI07 | HS (high-speed main) mode | 2.7 V ≤ V _{DD} < 3.6 V | | | 8 | MHz | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | | | 4 | MHz | | |
| | | LV (low-voltage main) mode | | | | | | 4 | MHz | |
| | | LS (low-speed main) mode | | | | | | 4 | MHz | |
| Clock/buzzer output frequency | t _{PLC} | PCLBUZ0 | HS (high-speed main) mode | 2.7 V ≤ V _{DD} < 3.6 V | | | 8 | MHz | | |
| | | | | 2.4 V ≤ V _{DD} < 2.7 V | | | 4 | MHz | | |
| | | | LV (low-voltage main) mode | | | | | | 4 | MHz |
| | | | LS (low-speed main) mode | | | | | | 4 | MHz |
| | t _{PLCRF} | CLKOUT_RF | | | | | 16 | MHz | | |

Remark f_{MCK}: Timer array unit operation clock frequency

(Operation clock to be set by the CKSmn0, CKSmn1 bits of timer mode register mn (TMRmn).

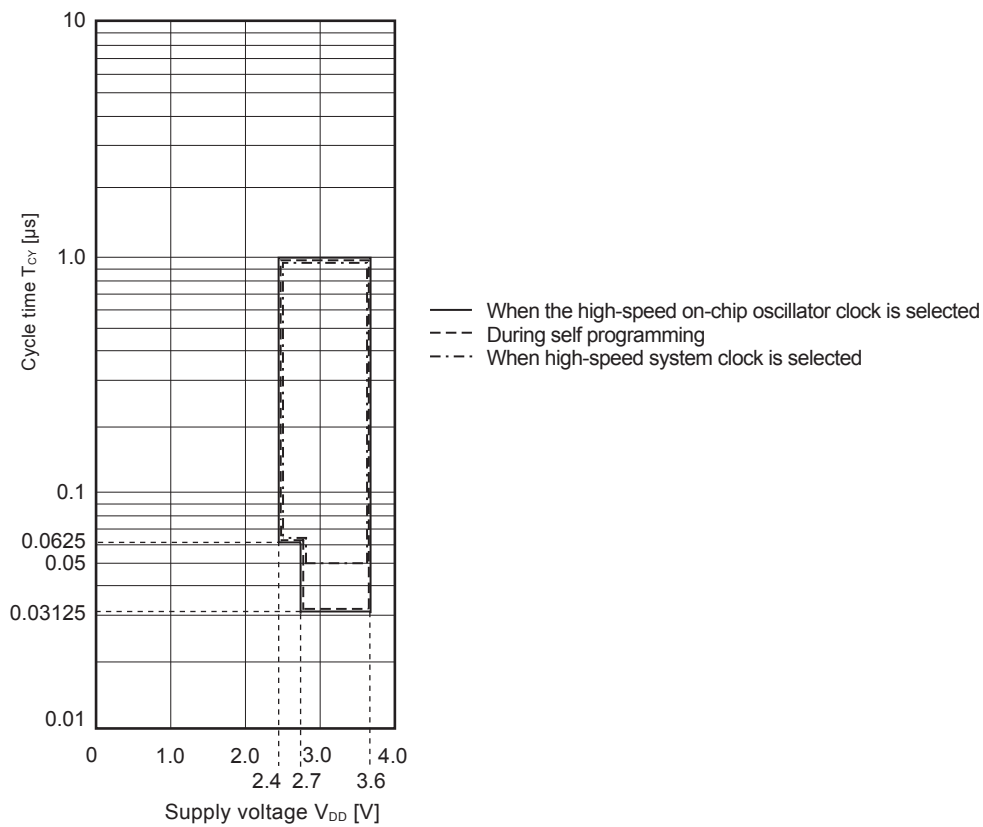
m: Unit number (m = 0, 1), n: Channel number (n = 0 to 7))

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$) (2/2)

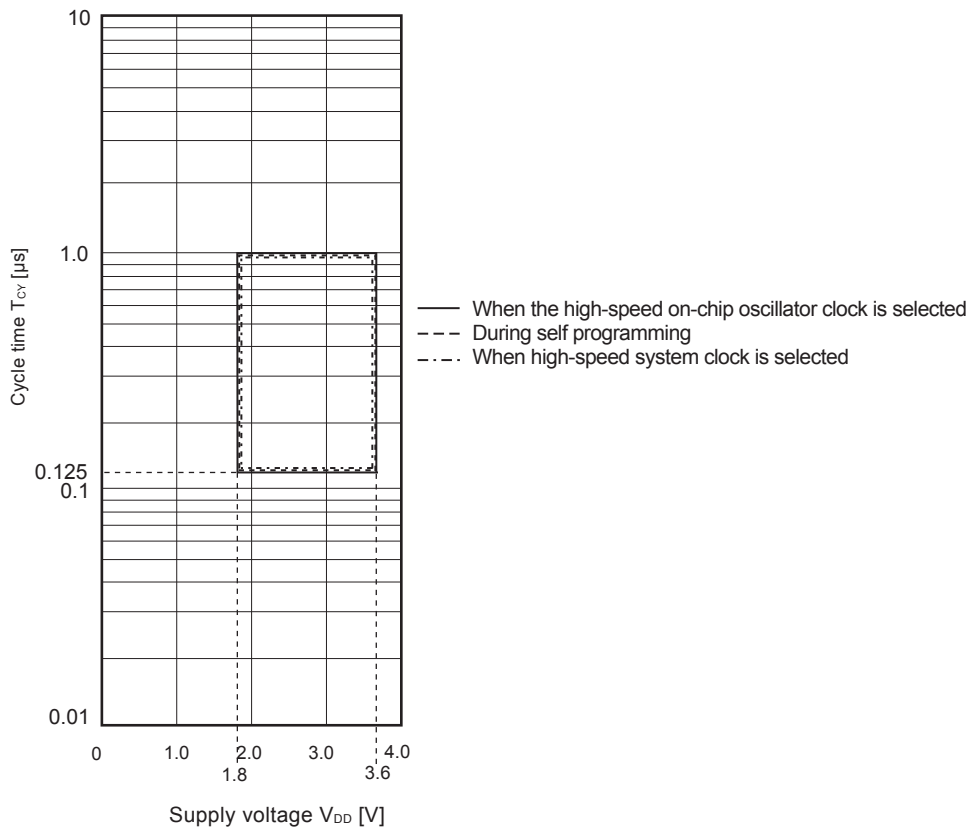
| Items | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|----------------------------|----------------------------|------|------|------|---------------|
| Interrupt input high-level width, low-level width | t_{INTH} , t_{INTL} | INTP0, INTP3, INTP5, INTP6 | 1 | | | μs |
| External PA control output High- level width | t_{PAHRF} | TXSELH_RF | 283 | | | μs |
| External PA control output low- level width | t_{PALRF} | TXSELL_RF | 283 | | | μs |
| RESET low-level width | t_{RSL} | RESET | 10 | | | μs |
| RESET_RF internal pin low- level width | t_{RSTLRF} | RESET_RF internal pin | 31 | | | μs |

Minimum Instruction Execution Time during Main System Clock Operation

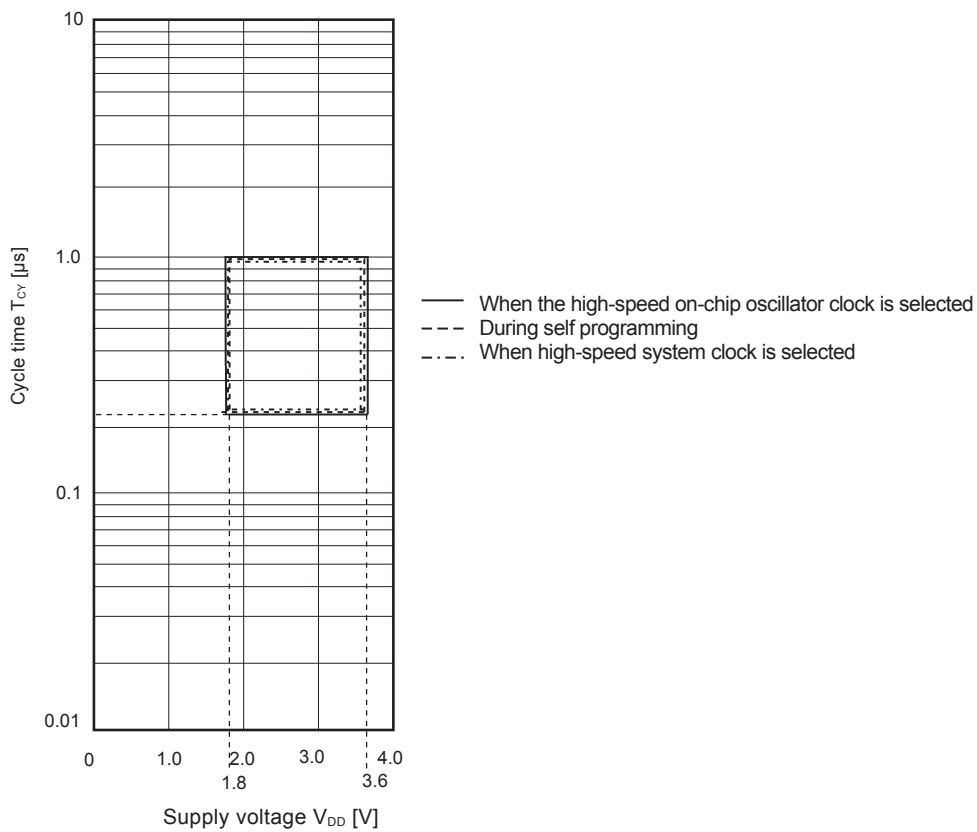
T_{CY} vs V_{DD} (HS (high-speed main) mode)



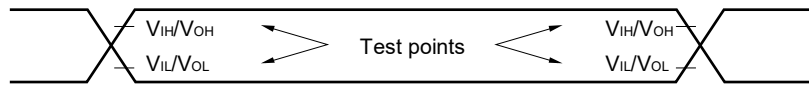
T_{CY} vs V_{DD} (LS (low-speed main) mode)



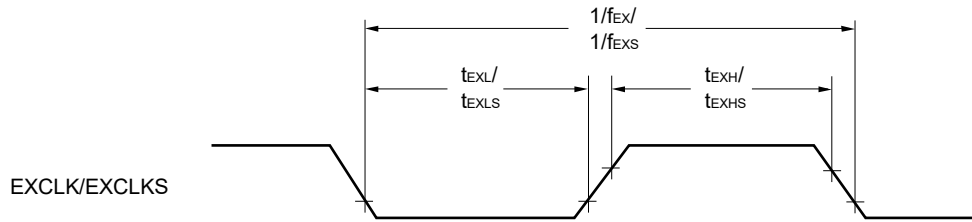
T_{CY} vs V_{DD} (LV (low-voltage main) mode)



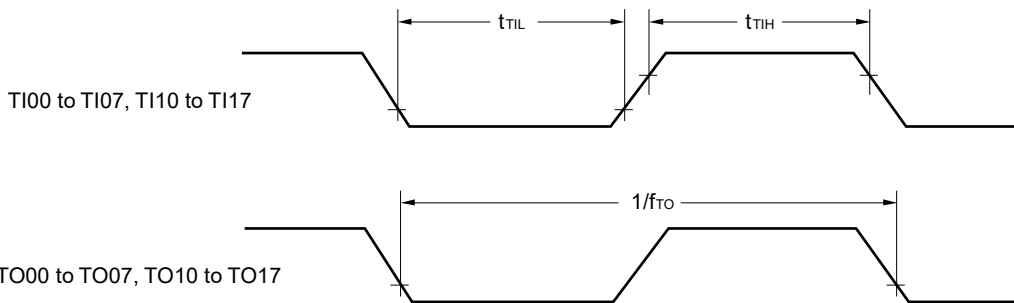
AC Timing Test Points



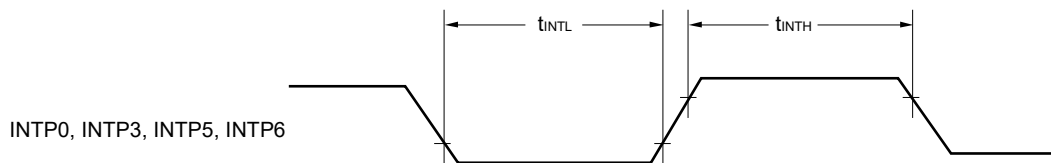
External System Clock Timing



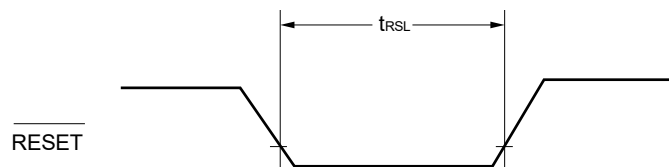
TI/TO Timing



Interrupt Request Input Timing

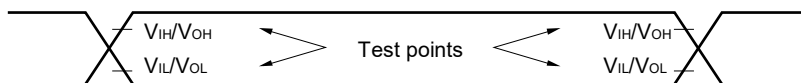


RESET Input Timing



2.7 Peripheral Functions Characteristics

AC Timing Test Points



2.7.1 Serial array unit

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

(TA = -40 to +85°C, 1.6 V ≤ VDD = VDD_RF = AVDD_RF ≤ 3.6 V, VSS = VSS_RF = AVSS_RF = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | LS (low-speed main) Mode | LV (low-voltage main) Mode | Unit |
|---------------------------------|--------|---|---------------------------|--------------------------|----------------------------|------|
| | | | MAX. | MAX. | MAX. | |
| Transfer rate ^{Note 1} | | 2.4 V ≤ VDD ≤ 3.6 V | fMCK/6 | fMCK/6 | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK ^{Note 2} | 5.3 | 1.3 | 0.6 | Mbps |
| | | 1.8 V ≤ VDD ≤ 3.6 V | — | fMCK/6 | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK ^{Note 2} | — | 1.3 | 0.6 | Mbps |
| | | 1.6 V ≤ VDD ≤ 3.6 V | — | — | fMCK/6 | bps |
| | | Theoretical value of the maximum transfer rate fMCK = fCLK ^{Note 2} | — | — | 0.6 | Mbps |

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

2. Maximum operating frequency of CPU and peripheral hardware clock (fCLK) is following

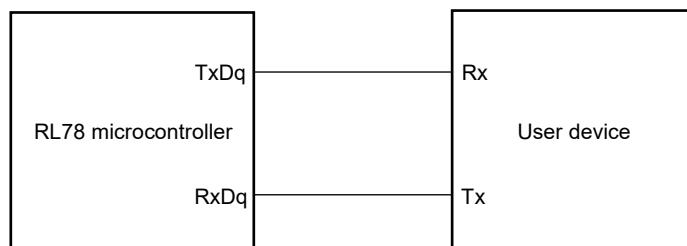
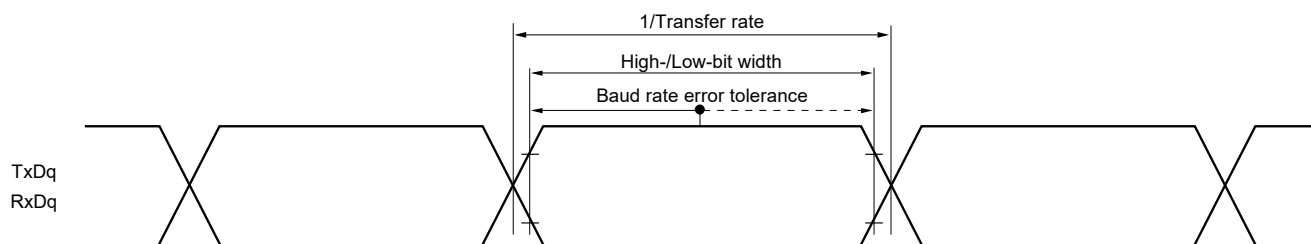
HS (high-speed main) mode: 32 MHz (2.7 V ≤ VDD ≤ 3.6 V)

16 MHz (2.4 V ≤ VDD ≤ 3.6 V)

LS (low-speed main) mode: 8 MHz (1.8 V ≤ VDD ≤ 3.6 V)

LV (low-voltage main) mode: 4 MHz (1.6 V ≤ VDD ≤ 3.6 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, 1), g: PIM and POM number (g = 0, 1)
- 2.** f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00, 01))

(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output, supporting CSI00 only)**($T_A = -40$ to $+85^\circ\text{C}$, $2.7\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| 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 | t_{KCY1} | $t_{KCY1} \geq 2/f_{CLK}$ | 83.3 | | 250 | | 500 | | ns |
| SCKp high-/low-level width | t_{KH1} , t_{KL1} | | $t_{KCY1}/2 - 10$ | | $t_{KCY1}/2 - 50$ | | $t_{KCY1}/2 - 50$ | | ns |
| Slp setup time (to SCKp \uparrow) Note 1 | t_{SIK1} | | 33 | | 110 | | 110 | | ns |
| Slp hold time (from SCKp \uparrow) Note 1 | t_{SH1} | | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp \downarrow to SOp output Note 2 | t_{KSO1} | $C = 20\text{ pF}$ Note 3 | | 10 | | 10 | | 10 | ns |

Note 1. When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The Slp time becomes “to SCKp \downarrow ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.

2. When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The delay time to SOp output becomes “from SCKp \uparrow ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.

3. 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 specification is valid only when CSI00's peripheral I/O redirect function is not used.

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

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

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

(3) During communication at same potential (CSI mode) (Internal communication, supporting CSI21 only)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| 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 | t_{KCY1} | $t_{KCY1} \geq 2/f_{CLK}$ ^{Note} | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 250 | | 250 | | 500 | | ns |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | 250 | | 500 | | ns |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | – | | 500 | | ns |

Note Use the f_{CLK} more than 6.5 MHz and lower than 24 MHz.**Remark** This specification is for CSI21 only.

(4) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output, supporting CSI00 and CSI20)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| 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 | t_{KCY1} | $t_{KCY1} \geq 4/f_{CLK}$ | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 125 | | 500 | | 1000 | ns |
| | | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 250 | | 500 | | 1000 | ns |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | 500 | | 1000 | ns |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | – | | 1000 | ns |
| SCKp high-/low-level width | t_{KH1} , t_{KL1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | $t_{KCY1}/2 - 18$ | | $t_{KCY1}/2 - 50$ | | $t_{KCY1}/2 - 50$ | ns | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | $t_{KCY1}/2 - 38$ | | $t_{KCY1}/2 - 50$ | | $t_{KCY1}/2 - 50$ | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | $t_{KCY1}/2 - 50$ | | $t_{KCY1}/2 - 50$ | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | – | | $t_{KCY1}/2 - 100$ | ns | |
| Slp setup time (to SCKp \uparrow) ^{Note 1} | t_{SIK1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 44 | | 110 | | 110 | ns | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 75 | | 110 | | 110 | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | 110 | | 110 | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | – | | 220 | ns | |
| Slp hold time (from SCKp \uparrow) ^{Note 1} | t_{SIH1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 19 | | 19 | | 19 | ns | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 19 | | 19 | | 19 | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | 19 | | 19 | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | – | | – | | 19 | ns | |
| Delay time from SCKp \downarrow to SOp output ^{Note 2} | t_{KSO1} | C = 30 pF ^{Note 3} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 25 | | 25 | 25 | ns |
| | | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 25 | | 25 | 25 | ns |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | 25 | 25 | ns |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | – | 25 | ns |

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

2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes “from SCKp \uparrow ” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

3. 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, 10), m: Unit number (m = 0, 1), n: Channel number (n = 0, 1), g: PIM and POM numbers (g = 0, 1)

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

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00, 02, 11))

(5) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input, supporting CSI00 and CSI20)**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| 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 4 | t_{KCY2} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | $f_{MCK} > 16\text{ MHz}$ | $8/f_{MCK}$ | | – | | – | | ns | |
| | | | $f_{MCK} \leq 16\text{ MHz}$ | $6/f_{MCK}$ | | $6/f_{MCK}$ | | $6/f_{MCK}$ | | | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | $6/f_{MCK}$ and 500 | | $6/f_{MCK}$ and 500 | | $6/f_{MCK}$ and 500 | | ns |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | – | | $6/f_{MCK}$ and 750 | | $6/f_{MCK}$ and 750 | | ns |
| $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | – | | – | | $6/f_{MCK}$ and 1500 | | ns | | |
| SCKp high-/low-level width | t_{KH2} , t_{KL2} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $t_{KCY2}/2-8$ | | $t_{KCY2}/2-8$ | | $t_{KCY2}/2-8$ | | ns | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $t_{KCY2}/2-18$ | | $t_{KCY2}/2-18$ | | $t_{KCY2}/2-18$ | | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | $t_{KCY2}/2-18$ | | $t_{KCY2}/2-18$ | | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | – | | $t_{KCY2}/2-66$ | | ns | |
| Slp setup time (to SCKp \uparrow) Note 1 | t_{SIK2} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $1/f_{MCK} + 20$ | | $1/f_{MCK} + 30$ | | $1/f_{MCK} + 30$ | | ns | |
| | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $1/f_{MCK} + 30$ | | $1/f_{MCK} + 30$ | | $1/f_{MCK} + 30$ | | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | $1/f_{MCK} + 30$ | | $1/f_{MCK} + 30$ | | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | – | | $1/f_{MCK} + 40$ | | ns | |
| Slp hold time (from SCKp \uparrow) Note 1 | t_{KSI2} | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $1/f_{MCK} + 31$ | | $1/f_{MCK} + 31$ | | $1/f_{MCK} + 31$ | | ns | |
| | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | $1/f_{MCK} + 31$ | | $1/f_{MCK} + 31$ | | ns | |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | – | | $1/f_{MCK} + 250$ | | ns | |
| Delay time from SCKp \downarrow to SOP output Note 2 | t_{KSO2} | C = 30 pF Note 3 | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $2/f_{MCK} + 44$ | | $2/f_{MCK} + 110$ | | $2/f_{MCK} + 110$ | | ns |
| | | | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | $2/f_{MCK} + 75$ | | $2/f_{MCK} + 110$ | | $2/f_{MCK} + 110$ | | ns |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | $2/f_{MCK} + 110$ | | $2/f_{MCK} + 110$ | | ns |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | – | | – | | $2/f_{MCK} + 220$ | | ns |

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

2. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOP output becomes “from SCKp \uparrow ” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

3. C is the load capacitance of the SOP output lines.

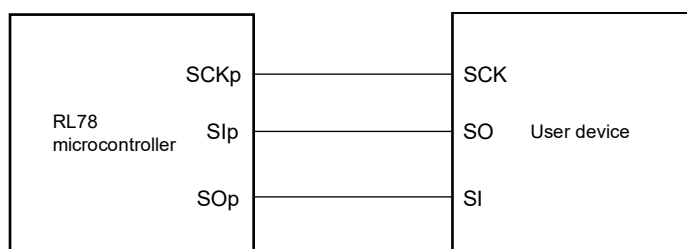
4. Transfer rate in the SNOOZE mode: MAX. 1 Mbps

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

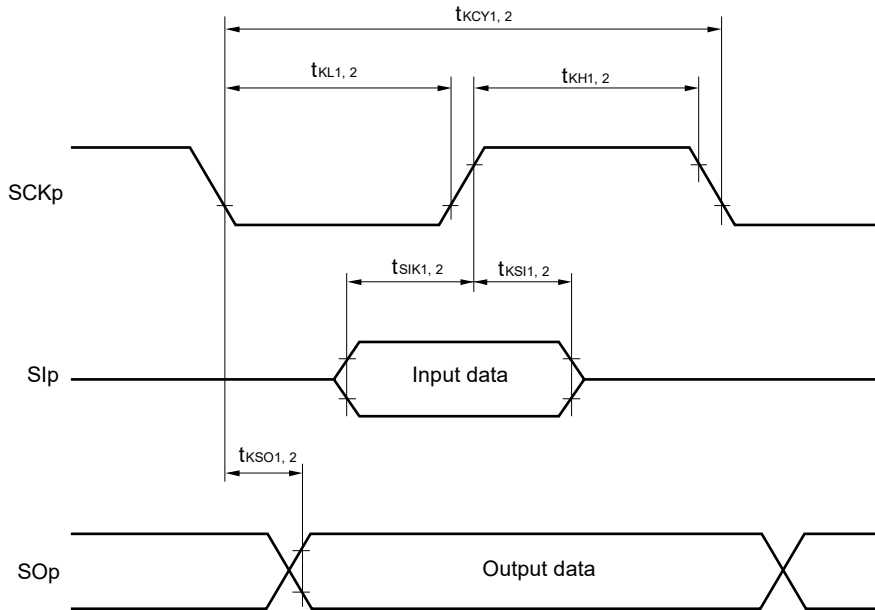
Caution Select the normal input buffer for the SIp pin and SCKp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

- Remark**
1. p: CSI number (p = 00, 20), m: Unit number (m = 0, 1),
n: Channel number (n = 0), g: PIM and POM numbers (g = 1)
 2. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00, 10))

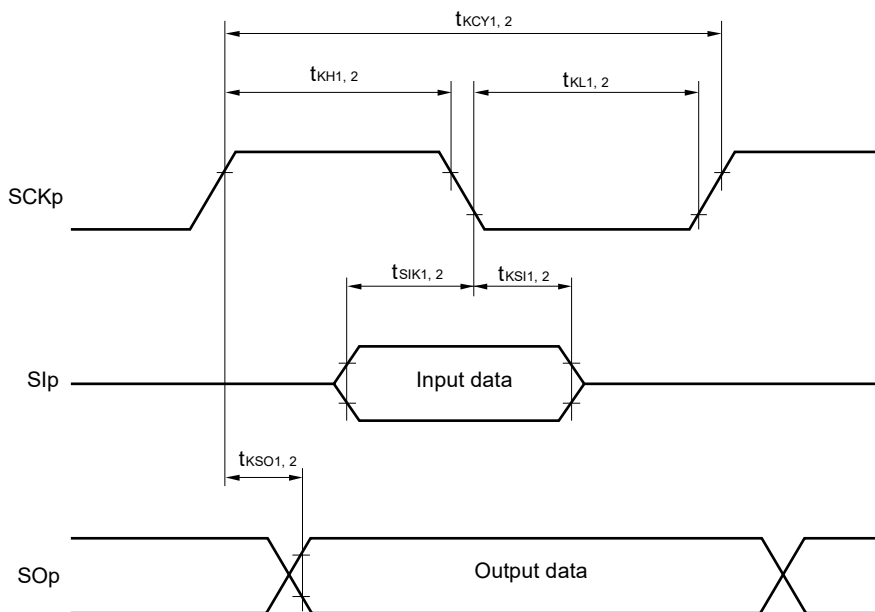
CSI mode connection diagram (during communication at same potential)



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



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



- Remark 1.** p: CSI number (p = 00, 10, 21)
2. m: Unit number, n: Channel number (mn = 00, 02, 11)

(6) During communication at same potential (simplified I²C mode) (1/2)(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 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} | 2.7 V ≤ V _{DD} ≤ 3.6 V, C _b = 50 pF, R _b = 2.7 kΩ | | 1000 Note 1 | | 400 Note 1 | | 400 Note 1 | kHz |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V, C _b = 100 pF, R _b = 3 kΩ | | 400 Note 1 | | 400 Note 1 | | 400 Note 1 | kHz |
| | | 1.8 V ≤ V _{DD} < 3.6 V, C _b = 100 pF, R _b = 3 kΩ | | – | | 400 Note 1 | | 400 Note 1 | kHz |
| | | 2.4 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | | 300 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 1.8 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | | – | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | | – | | – | | 250 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 2.7 V ≤ V _{DD} ≤ 3.6 V, C _b = 50 pF, R _b = 2.7 kΩ | 475 | | 1150 | | 1150 | | ns |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V, C _b = 100 pF, R _b = 3 kΩ | 1150 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.6 V, C _b = 100 pF, R _b = 3 kΩ | – | | 1150 | | 1150 | | ns |
| | | 2.4 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1550 | | 1550 | | 1550 | | ns |
| | | 1.8 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | – | | 1550 | | 1550 | | ns |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | – | | – | | 1850 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 2.7 V ≤ V _{DD} ≤ 3.6 V, C _b = 50 pF, R _b = 2.7 kΩ | 475 | | 1150 | | 1150 | | ns |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V, C _b = 100 pF, R _b = 3 kΩ | 1150 | | 1150 | | 1150 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.6 V, C _b = 100 pF, R _b = 3 kΩ | – | | 1150 | | 1150 | | ns |
| | | 2.4 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1550 | | 1550 | | 1550 | | ns |
| | | 1.8 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | – | | 1550 | | 1550 | | ns |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | – | | – | | 1850 | | ns |

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

(6) During communication at same potential (simplified I²C mode) (2/2)(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

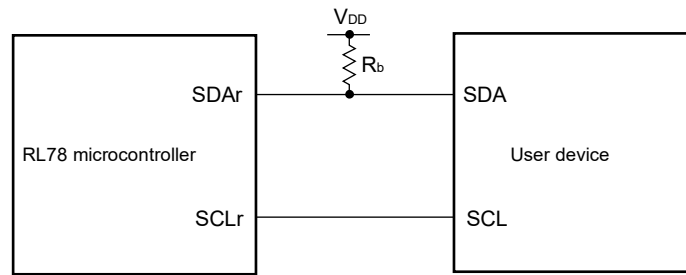
| Parameter | Symbol | Conditions | HS (high-speed main) Mode | | LS (low-speed main) Mode | | LV (low-voltage main) Mode | | Unit |
|-------------------------------|---------------------|---|-----------------------------------|------|-----------------------------------|------|-----------------------------------|------|------|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. | |
| Data setup time (reception) | t _{SU:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V, C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 85 Note2 | | 1/f _{MCK} + 145 Note2 | | 1/f _{MCK} + 145 Note2 | | ns |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V, C _b = 100 pF, R _b = 3 kΩ | 1/f _{MCK} + 145 Note2 | | 1/f _{MCK} + 145 Note2 | | 1/f _{MCK} + 145 Note2 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.6 V, C _b = 100 pF, R _b = 3 kΩ | – | | 1/f _{MCK} + 145 Note2 | | 1/f _{MCK} + 145 Note2 | | ns |
| | | 2.4 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 1/f _{MCK} + 230 Note2 | | 1/f _{MCK} + 230 Note2 | | 1/f _{MCK} + 230 Note2 | | ns |
| | | 1.8 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | – | | 1/f _{MCK} + 230 Note2 | | 1/f _{MCK} + 230 Note2 | | ns |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | – | | – | | 1/f _{MCK} + 290 Note2 | | ns |
| Data hold time (transmission) | t _{HD:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V, C _b = 50 pF, R _b = 2.7 kΩ | 0 | 305 | 0 | 305 | 0 | 305 | ns |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V, C _b = 100 pF, R _b = 3 kΩ | 0 | 355 | 0 | 355 | 0 | 355 | ns |
| | | 1.8 V ≤ V _{DD} < 3.6 V, C _b = 100 pF, R _b = 3 kΩ | – | – | 0 | 355 | 0 | 355 | ns |
| | | 2.4 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | 0 | 405 | 0 | 405 | 0 | 405 | ns |
| | | 1.8 V ≤ V _{DD} < 2.7 V, C _b = 100 pF, R _b = 5 kΩ | – | – | 0 | 405 | 0 | 405 | ns |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | – | – | – | – | 0 | 405 | ns |
| | | 1.6 V ≤ V _{DD} < 1.8 V, C _b = 100 pF, R _b = 5 kΩ | – | – | – | – | 0 | 405 | ns |

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

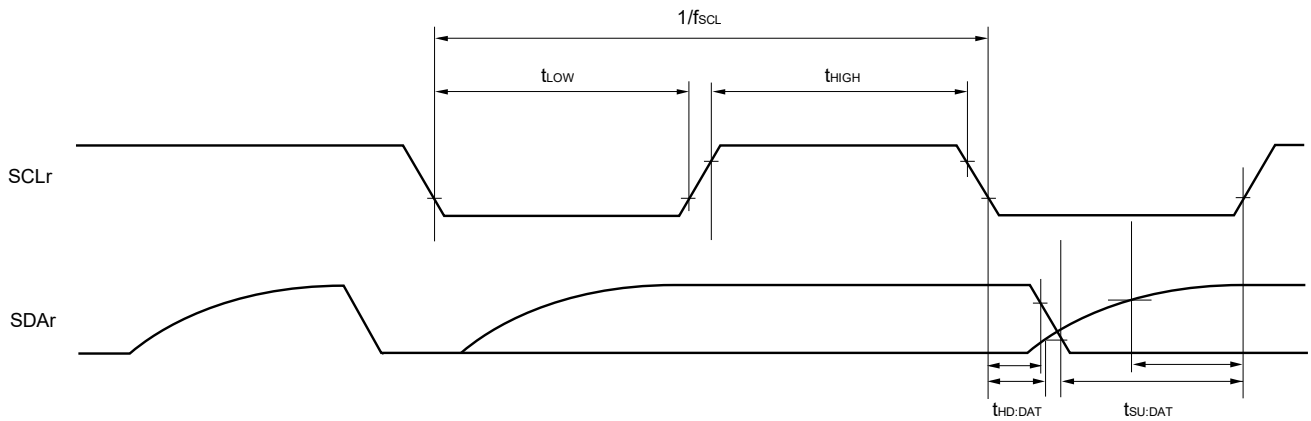
Caution Select the normal input buffer and the N-ch open drain output (V_{DD} tolerance) mode for the SDAr pin and the normal output mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register h (POMh).

(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
- 2.** r: IIC number (r = 00, 20), g: PIM number (g = 1), h: POM number (h = 1)
- 3.** f_{MCK}: Serial array unit operation clock frequency
 (Operation clockw to be set by the CKS_{mn} bit of serial mode register mn (SMR_{mn}). m: Unit number (m = 0, 1), n: Channel number (n = 0), mn = 00, 02)

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

(T_A = -40 to +85°C, 2.4 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

| Parameter | Symbol | Conditions | HS (high-speed main) Mode | LS (low-speed main) Mode | LV (low-voltage main) Mode | Unit | | |
|---------------|---|---|---|---|---------------------------------------|--|--|------|
| | | | MAX. | MAX. | MAX. | | | |
| Transfer rate | | Reception | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V | f _{MCK} /6 ^{Note 1} | f _{MCK} /6 ^{Note 1} | f _{MCK} /6 ^{Note 1} | bps | |
| | | | Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} ^{Note 3} | 5.3 | 1.3 | 0.6 | Mbps | |
| | | | 2.4 V ≤ V _{DD} ≤ 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V | f _{MCK} /6 ^{Note 1} | f _{MCK} /6 ^{Note 1} | f _{MCK} /6 ^{Note 1} | bps | |
| | | | | Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} ^{Note 3} | 2.6 | 1.3 | 0.6 | Mbps |
| | | | | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V | – | f _{MCK} /6 ^{Note 1, 2} | f _{MCK} /6 ^{Note 1, 2} | bps |
| | | | | Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} ^{Note 3} | – | 1.3 | 1.3 | Mbps |
| | | | Transmission | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V | Note 4 | Note 4 | Note 4 | bps |
| | | | | Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 2.7 kΩ, V _b = 2.3 V | 1.2 ^{Note 5} | 1.2 ^{Note 5} | 1.2 ^{Note 5} | Mbps |
| | | | | 2.4 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V | Note 2, 6 | Note 2, 6 | Note 2, 6 | bps |
| | | | | Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 5.5 kΩ, V _b = 1.6 V | 0.43 | 0.43 | 0.43 | Mbps |
| | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V | – | | Note 2, 6 | Note 2, 6 | bps | | |
| | | Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 5.5 kΩ, V _b = 1.6 V | – | 0.43 ^{Note 7} | 0.43 ^{Note 7} | Mbps | | |

- Note**
- Transfer rate in the SNOOZE mode is 4800 bps only.
 - Use it with V_{DD} ≥ V_b.
 - Maximum operating frequency of CPU and peripheral hardware clock (f_{CLK}) is following
 HS (high-speed main) mode: 32 MHz (2.7 V ≤ V_{DD} ≤ 3.6 V)
 16 MHz (2.4 V ≤ V_{DD} ≤ 3.6 V)
 LS (low-speed main) mode: 8 MHz (1.8 V ≤ V_{DD} ≤ 3.6 V)
 LV (low-voltage main) mode: 4 MHz (1.8 V ≤ V_{DD} ≤ 3.6 V)
 - The smaller maximum transfer rate derived by using f_{MCK}/6 or the following expression is the valid maximum transfer rate.
 Expression for calculating the transfer rate when 2.7 V ≤ V_{DD} ≤ 3.6 V and 2.3 V ≤ V_b ≤ 2.7 V
 Maximum transfer rate = 1/{-C_b × R_b × ln (1 - 2.0/V_b)} × 3 [bps]
 Baud rate error (theoretical value) =
 (1/transfer rate × 2 - {-C_b × R_b × ln (1 - 2.0/V_b)} / (1/transfer rate) × number of transferred bits)
 * This value is the theoretical value of the relative difference between the transmission and reception sides.
 - This value as an example is calculated when the conditions described in the “Conditions” column are met.
 Refer to Note 4 above to calculate the maximum transfer rate under conditions of the customer.
 - 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 1.8V ≤ V_{DD} < 3.3 V and 1.6 V ≤ V_b ≤ 2.0 V

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

Baud rate error (theoretical value) =

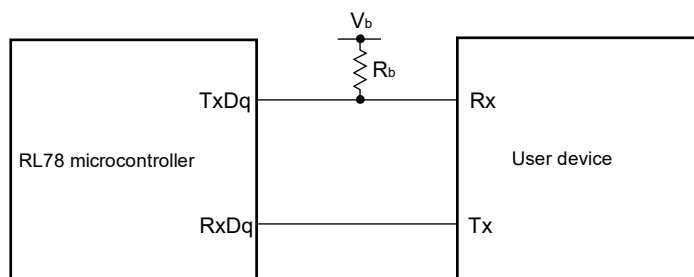
$(1 / \text{transfer rate} \times 2 - \{-C_b \times R_b \times \ln(1 - 1.5/V_b)\} / (1 / \text{transfer rate}) \times \text{number of transferred bits})$

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.

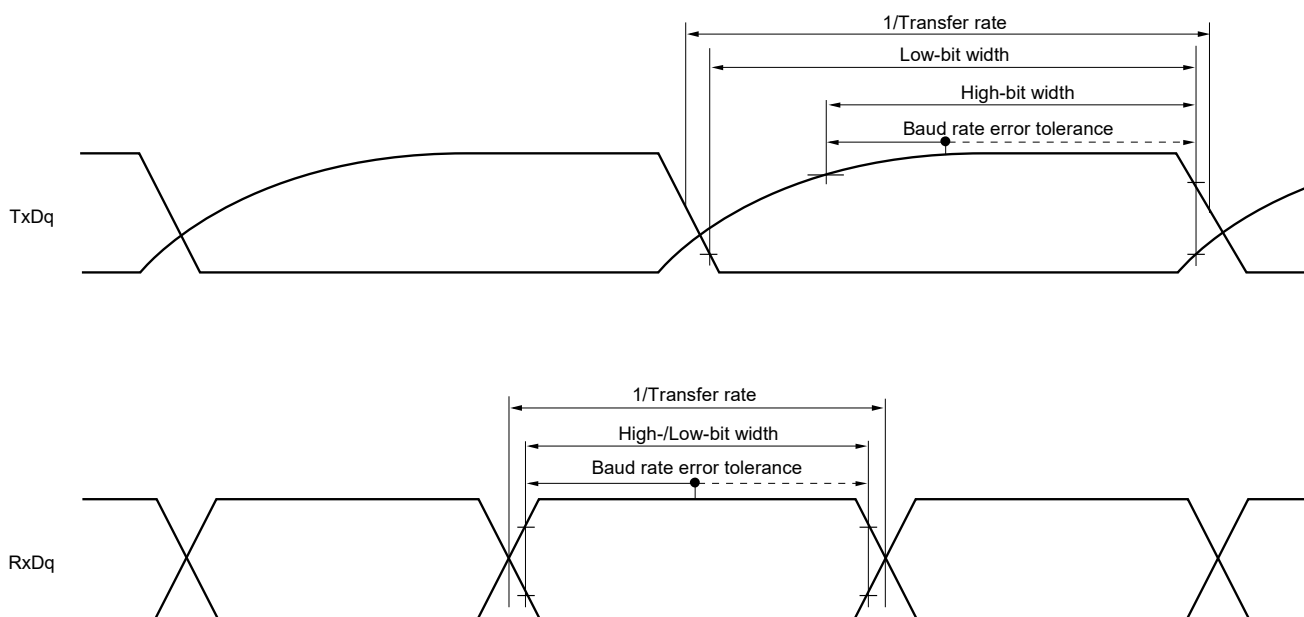
Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

- 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
2. q: UART number (q = 0, 1), g: PIM and POM numbers (g = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00 to 03))

UART mode connection diagram (during communication at different potential)



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



- Remark 1.** $R_b[\Omega]$: Communication line (TxDq) pull-up resistance, $V_b[V]$: Communication line voltage
2. q: UART number (q = 0, 1), g: PIM and POM number (g = 0, 1)

(8) Communication at different potential (2.5 V) (CSI mode) (master mode: SCKp... internal clock output, supporting CSI00 only)**($T_A = -40$ to $+85^\circ\text{C}$, $2.7\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| 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 | t_{KCY1} | $t_{KCY1} \geq 2/f_{CLK}$ $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | 300 | | 1150 | | 1150 | | ns |
| SCKp high-level width | t_{KH1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | $t_{KCY1}/2 - 120$ | | $t_{KCY1}/2 - 120$ | | $t_{KCY1}/2 - 120$ | | ns |
| SCKp low-level width | t_{KL1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | $t_{KCY1}/2 - 10$ | | $t_{KCY1}/2 - 50$ | | $t_{KCY1}/2 - 50$ | | ns |
| Slp setup time (to SCKp \uparrow) ^{Note 1} | t_{SIK1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | 121 | | 479 | | 479 | | ns |
| Slp hold time (from SCKp \uparrow) ^{Note 1} | t_{KSI1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp \downarrow to SOp output ^{Note 1} | t_{KSO1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | | 130 | | 130 | | 130 | ns |
| Slp setup time (to SCKp \downarrow) ^{Note 2} | t_{SIK1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | 33 | | 110 | | 110 | | ns |
| Slp hold time (from SCKp \downarrow) ^{Note 2} | t_{KSI1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | 10 | | 10 | | 10 | | ns |
| Delay time from SCKp \uparrow to SOp output ^{Note 2} | t_{KSO1} | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$ $C_b = 20\text{ pF}$, $R_b = 2.7\text{ k}\Omega$ | | 10 | | 10 | | 10 | ns |

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

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

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

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

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))

(9) Communication at different potential (1.8 V, 2.5 V) (CSI mode: master mode, SCKp... internal clock output)

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 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. | |
| SCKp cycle time Note 1 | t _{KCY1} | t _{KCY1} ≥ 4/f _{CLK} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | 500 | | 1150 | | 1150 | | ns |
| | | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | 1150 | | 1150 | | 1150 | | ns |
| | | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V Note 3 C _b = 30 pF, R _b = 5.5 kΩ | – | | 1150 | | 1150 | | ns |
| SCKp high-level width Note 1 | t _{KH1} | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | t _{KCY1/2} - 170 | | t _{KCY1/2} - 170 | | t _{KCY1/2} - 170 | | ns | |
| | | | 2.4 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | t _{KCY1/2} - 458 | | t _{KCY1/2} - 458 | | t _{KCY1/2} - 458 | | ns |
| | | | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 3 C _b = 30 pF, R _b = 5.5 kΩ | – | | t _{KCY1/2} - 458 | | t _{KCY1/2} - 458 | | ns |
| SCKp low-level width Note 1 | t _{KL1} | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | t _{KCY1/2} - 18 | | t _{KCY1/2} - 50 | | t _{KCY1/2} - 50 | | ns | |
| | | | 2.4 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | t _{KCY1/2} - 50 | | t _{KCY1/2} - 50 | | t _{KCY1/2} - 50 | | ns |
| | | | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 3 C _b = 30 pF, R _b = 5.5 kΩ | – | | t _{KCY1/2} - 50 | | t _{KCY1/2} - 50 | | ns |
| Slp setup time (to SCKp↑) Note 1, 2 | t _{SIK1} | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | 177 | | 479 | | 479 | | ns | |
| | | | 2.4 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | 479 | | 479 | | 479 | | ns |
| | | | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 3 C _b = 30 pF, R _b = 5.5 kΩ | – | | 479 | | 479 | | ns |
| Slp hold time (from SCKp↑) Note 1, 2 | t _{KS1} | 2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | 19 | | 19 | | 19 | | ns | |
| | | | 2.4 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | 19 | | 19 | | 19 | | ns |
| | | | 1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 3 C _b = 30 pF, R _b = 5.5 kΩ | – | | 19 | | 19 | | ns |

Note 1. Supporting CSI00 and CSI20.**2.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.**3.** Use it with V_{DD} ≥ V_b.

(Caution is listed on the next page.)

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

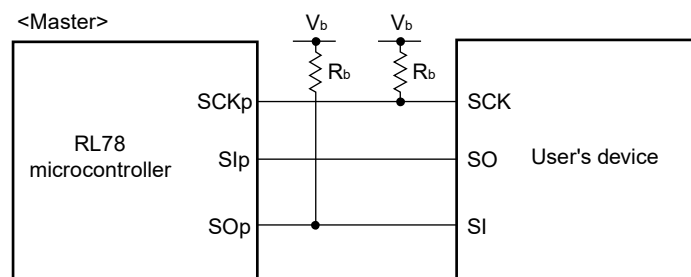
(2/2)

| 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. | |
| Delay time from SCKp↓ to SOp output ^{Note 1, 3} | t _{KSO1} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | | 195 | | 195 | | 195 | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | | 483 | | 483 | | 483 | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 5} C _b = 30 pF, R _b = 5.5 kΩ | | – | | 483 | | 483 | ns |
| Slp setup time (to SCKp↓) ^{Note 2, 4} | t _{SIK1} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | 44 | | 110 | | 110 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | 110 | | 110 | | 110 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 5} C _b = 30 pF, R _b = 5.5 kΩ | – | | 110 | | 110 | | ns |
| Slp hold time (from SCKp↓) ^{Note 2, 4} | t _{KSI1} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | 19 | | 19 | | 19 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | 19 | | 19 | | 19 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 5} C _b = 30 pF, R _b = 5.5 kΩ | – | | 19 | | 19 | | ns |
| Delay time from SCKp↑ to SOp output ^{Note 2, 4} | t _{KSO1} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | | 25 | | 25 | | 25 | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | | 25 | | 25 | | 25 | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 5} C _b = 30 pF, R _b = 5.5 kΩ | | – | | 25 | | 25 | ns |

Note 1. Supporting CSI00 and CSI20.**2.** Supporting CSI00 only.**3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.**4.** When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**5.** Use it with V_{DD} ≥ V_b.

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

(Remarks are listed on the next page.)

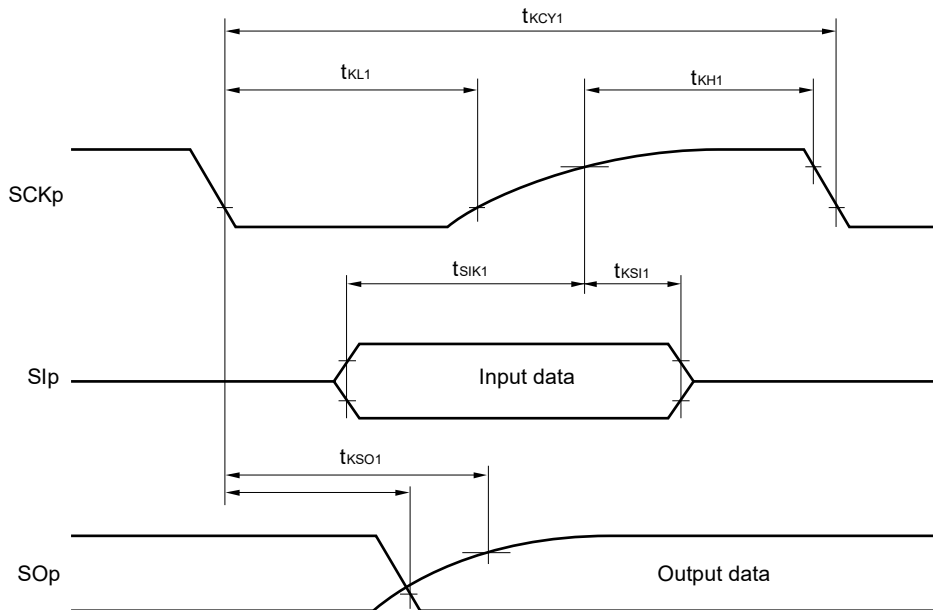
CSI mode connection diagram (during communication at different potential)

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

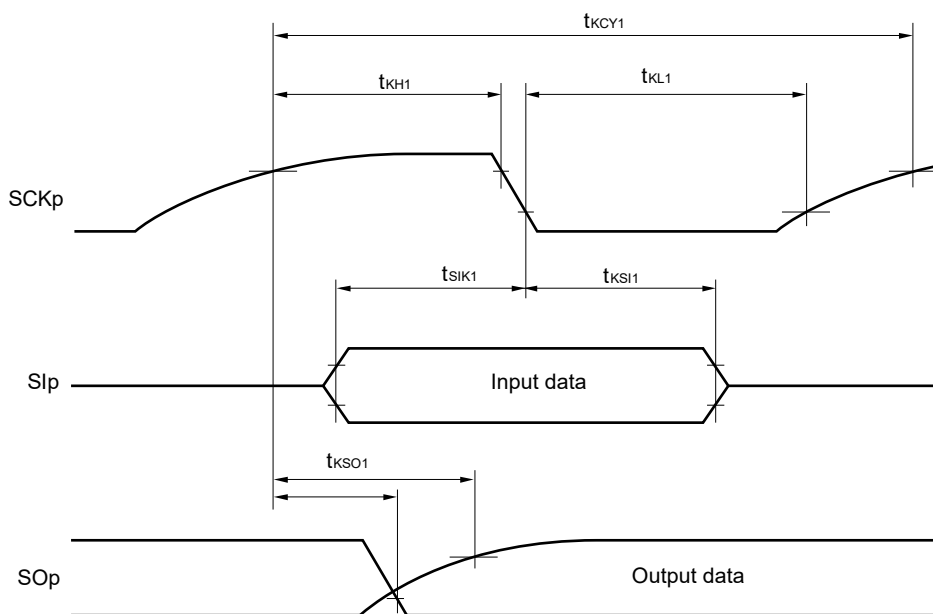
2. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 1)

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

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



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



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

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

(10) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (slave mode, SCKp... external clock input)

(TA = -40 to +85°C, 1.8 V ≤ VDD = VDD_RF = AVDD_RF ≤ 3.6 V, VSS = VSS_RF = AVSS_RF = 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. | |
| SCKp cycle time ^{Note 1} | tkcy2 | 2.7 V ≤ VDD ≤ 3.6 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 |
| | | | fMCK ≤ 4MHz | 6/fMCK | | 10/ fMCK | | 10/ fMCK | | ns |
| | | 2.4 V ≤ VDD < 3.3 V 1.6 V ≤ Vb ≤ 2.0 V | 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 ≤ 4MHz | 10/ fMCK | | 10/ fMCK | | 10/ fMCK | | ns |
| | | 1.8 V ≤ VDD < 3.3 V 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2} | 24 MHz < fMCK | – | | – | | – | | ns |
| | | | 20 MHz < fMCK ≤ 24 MHz | – | | – | | – | | ns |
| | | | 16 MHz < fMCK ≤ 20 MHz | – | | – | | – | | ns |
| | | | 8 MHz < fMCK ≤ 16 MHz | – | | – | | – | | ns |
| | | | 4 MHz < fMCK ≤ 8 MHz | – | | 16/ fMCK | | – | | ns |
| | | | fMCK ≤ 4MHz | – | | 10/ fMCK | | 10/ fMCK | | ns |

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

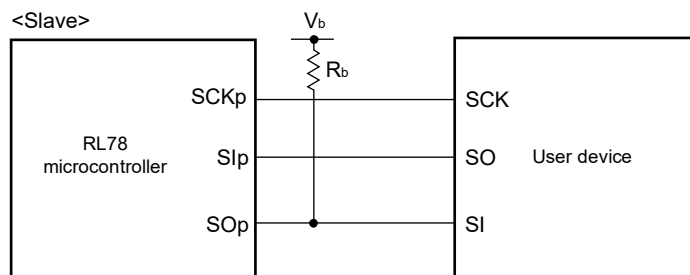
(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

(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. | |
| SCKp high-/low-level width | t _{KH2} , t _{KL2} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V | t _{KCY2} /2 – 18 | | t _{KCY2} /2 – 50 | | t _{KCY2} /2 – 50 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V | t _{KCY2} /2 – 50 | | t _{KCY2} /2 – 50 | | t _{KCY2} /2 – 50 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} | – | | t _{KCY2} /2 – 50 | | t _{KCY2} /2 – 50 | | ns |
| Slp setup time (to SCKp↑) ^{Note 3} | t _{SIK2} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 4.0 V | 1/f _{MCK} + 20 | | 1/f _{MCK} + 30 | | 1/f _{MCK} + 30 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V | 1/f _{MCK} + 30 | | 1/f _{MCK} + 30 | | 1/f _{MCK} + 30 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} | – | | 1/f _{MCK} + 30 | | 1/f _{MCK} + 30 | | ns |
| Slp hold time (from SCKp↑) ^{Note 3} | t _{SI2} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 4.0 V | 1/f _{MCK} + 31 | | 1/f _{MCK} + 31 | | 1/f _{MCK} + 31 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V | 1/f _{MCK} + 31 | | 1/f _{MCK} + 31 | | 1/f _{MCK} + 31 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} | – | | 1/f _{MCK} + 31 | | 1/f _{MCK} + 31 | | ns |
| Delay time from SCKp↓ to SOp output ^{Note 4} | t _{KSO2} | 2.7 V ≤ V _{DD} < 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ | | 2/f _{MCK} + 214 | | 2/f _{MCK} + 573 | | 2/f _{MCK} + 573 | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 30 pF, R _b = 5.5 kΩ | | 2/f _{MCK} + 573 | | 2/f _{MCK} + 573 | | 2/f _{MCK} + 573 | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} C _b = 30 pF, R _b = 5.5 kΩ | | – | | 2/f _{MCK} + 573 | | 2/f _{MCK} + 573 | ns |

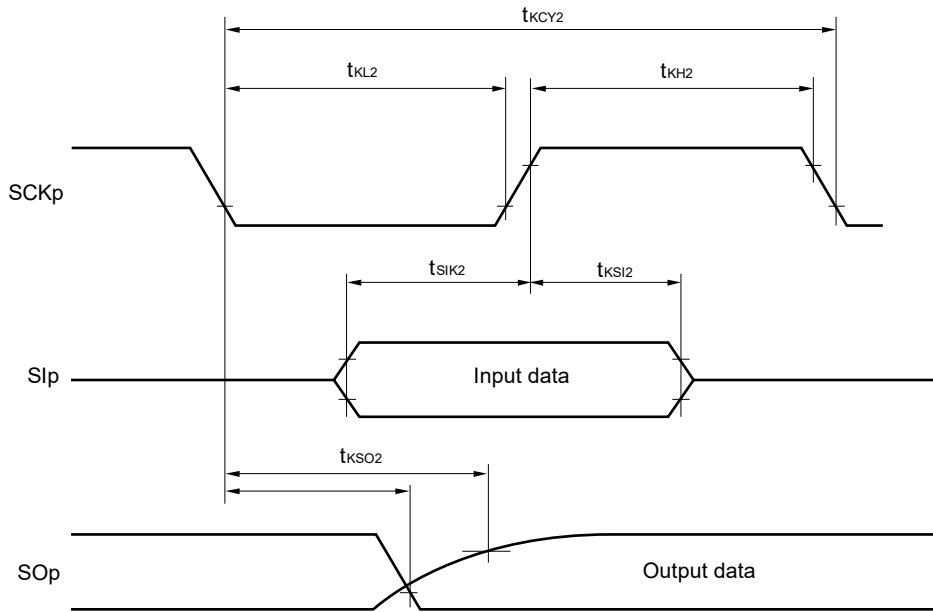
Note 1. Transfer rate in the SNOOZE mode : MAX. 1 Mbps**Note 2.** Use it with V_{DD} ≥ V_b.**Note 3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Note 4.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 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.

Caution Select the TTL input buffer for the Slp pin and SCKp pin and the N-ch open drain output (V_{DD} tolerance) mode for the SOp 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.

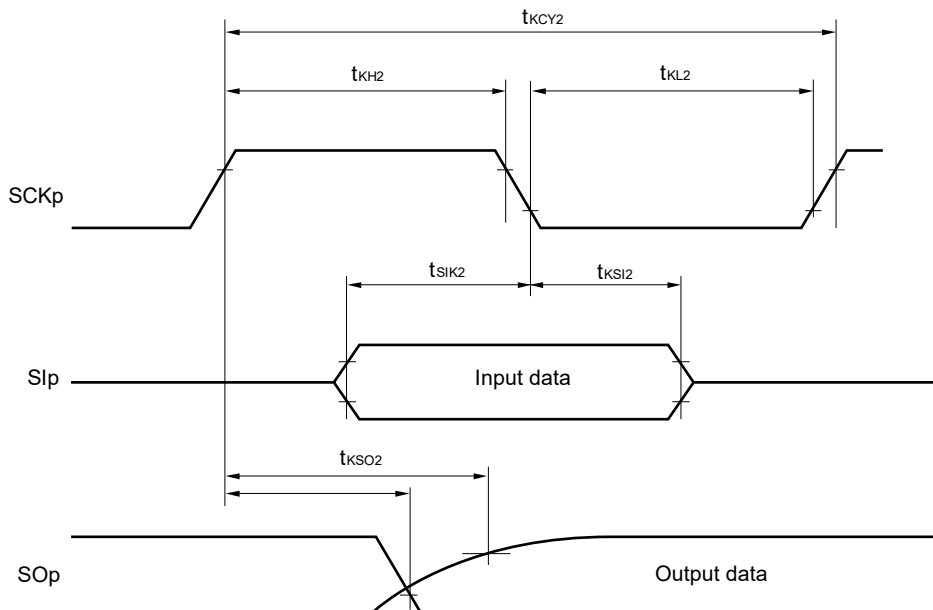
CSI mode connection diagram (during communication at different potential)

- Remark 1.** $R_b[\Omega]$: Communication line (SO_p) pull-up resistance, $C_b[F]$: Communication line (SO_p) load capacitance, $V_b[V]$: Communication line voltage
2. p: CSI number (p = 00, 20), m: Unit number, n: Channel number (mn = 00, 10), g: PIM and POM number (g = 0, 1)
 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00, 10))

**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.)**



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

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

(11) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode)(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 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 ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 50 pF, R _b = 2.7 kΩ | | 1000 Note 1 | | 300 Note 5 | | 300 Note 5 | kHz |
| | | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 100 pF, R _b = 2.7 kΩ | | 400 Note 1 | | 300 Note 5 | | 300 Note 5 | kHz |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 100 pF, R _b = 5.5 kΩ | | 300 Note 1 | | 300 Note 1 | | 300 Note 1 | kHz |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} C _b = 100 pF, R _b = 5.5 kΩ | | – | | 300 Note 1 | | 300 Note 1 | kHz |
| Hold time when SCLr = "L" | t _{LOW} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 50 pF, R _b = 2.7 kΩ | 475 | | 1550 | | 1550 | | ns |
| | | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 100 pF, R _b = 2.7 kΩ | 1150 | | 1550 | | 1550 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 100 pF, R _b = 5.5 kΩ | 1150 | | 1550 | | 1550 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} C _b = 100 pF, R _b = 5.5 kΩ | – | | 1550 | | 1550 | | ns |
| Hold time when SCLr = "H" | t _{HIGH} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 50 pF, R _b = 2.7 kΩ | 200 | | 610 | | 610 | | ns |
| | | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 100 pF, R _b = 2.7 kΩ | 600 | | 610 | | 610 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 100 pF, R _b = 5.5 kΩ | 610 | | 610 | | 610 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} C _b = 100 pF, R _b = 5.5 kΩ | – | | 610 | | 610 | | ns |

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

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

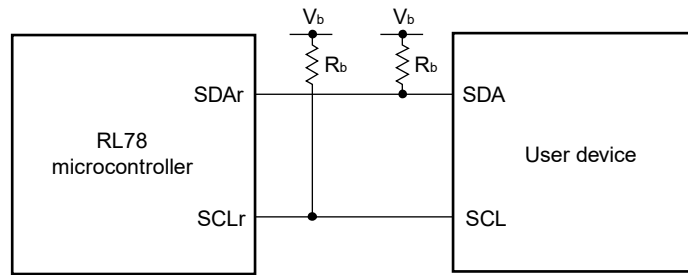
(2/2)

| 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) | t _{SU:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 50 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 135 Note 3 | | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | ns |
| | | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 100 pF, R _b = 2.7 kΩ | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 100 pF, R _b = 5.5 kΩ | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V Note 2 C _b = 100 pF, R _b = 5.5 kΩ | – | | 1/f _{MCK} + 190 Note 3 | | 1/f _{MCK} + 190 Note 3 | | ns |
| Data hold time (transmission) | t _{HD:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 50 pF, R _b = 2.7 kΩ | 0 Note 4 | 305 | 0 Note 4 | 305 | 0 Note 4 | 305 | ns |
| | | 2.7 V ≤ V _{DD} ≤ 3.6 V 2.3 V ≤ V _b ≤ 2.7 V C _b = 100 pF, R _b = 2.7 kΩ | 0 Note 4 | 355 | 0 Note 4 | 355 | 0 Note 4 | 355 | ns |
| | | 2.4 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V C _b = 100 pF, R _b = 5.5 kΩ | 0 Note 4 | 405 | 0 Note 4 | 405 | 0 Note 4 | 405 | ns |
| | | 1.8 V ≤ V _{DD} < 3.3 V 1.6 V ≤ V _b ≤ 2.0 V Note 2 C _b = 100 pF, R _b = 5.5 kΩ | – | – | 0 Note 4 | 405 | 0 Note 4 | 405 | ns |

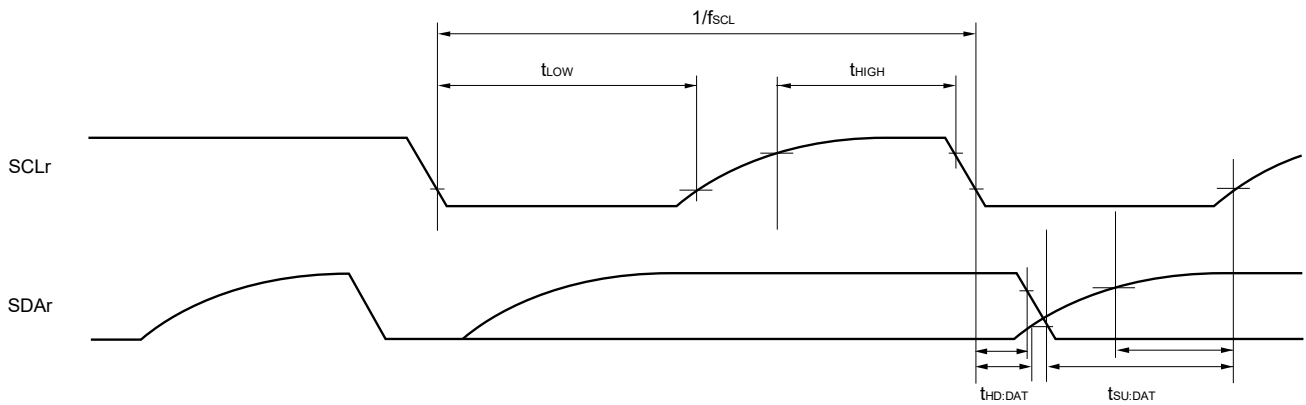
Note 1. The value must also be f_{MCK}/4 or lower.**2.** Use it with V_{DD} ≥ V_b.**3.** Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance) 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.

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
- 2.** r: IIC number (r = 00, 10), g: PIM, POM number (g = 0, 1)
- 3.** f_{MCK} : Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00, 02))

2.7.2 Serial interface IICA

(1) I²C standard mode(T_A = -40 to +85°C, 1.6 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 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 ≤ V _{DD} ≤ 3.6 V | 0 | 100 | | 0 |
| | | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0 | 100 | 0 | 100 | 0 | 100 | kHz |
| | | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0 | 100 | 0 | 100 | kHz |
| | | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 0 | 100 | kHz |
| Setup time of restart condition | t _{SU:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.7 | | 4.7 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.7 | | μs | |
| Hold time ^{Note 1} | t _{HD:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.0 | | 4.0 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.0 | | μs | |
| Hold time when SCLA0 = "L" | t _{LOW} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.7 | | 4.7 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.7 | | μs | |
| Hold time when SCLA0 = "H" | t _{HIGH} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.0 | | 4.0 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.0 | | μs | |
| Data setup time (reception) | t _{SU:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 250 | | 250 | | 250 | | ns | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 250 | | 250 | | 250 | | ns | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 250 | | 250 | | ns | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 250 | | ns | |
| Data hold time (transmission) ^{Note 2} | t _{HD:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0 | 3.45 | 0 | 3.45 | 0 | 3.45 | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0 | 3.45 | 0 | 3.45 | 0 | 3.45 | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0 | 3.45 | 0 | 3.45 | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 0 | 3.45 | μs | |
| Setup time of stop condition | t _{SU:STO} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.0 | | 4.0 | | 4.0 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.0 | | 4.0 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.0 | | μs | |
| Bus-free time | t _{BUF} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 4.7 | | 4.7 | | 4.7 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 4.7 | | 4.7 | | μs | |
| | | 1.6 V ≤ V _{DD} ≤ 3.6 V | - | | - | | 4.7 | | μs | |

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

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- Note**
1. The first clock pulse is generated after this period when the start/restart condition is detected.
 2. The maximum value (MAX.) of $t_{HD:DAT}$ is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

Caution The values in the above table are applied even when bit 2 (PIOR2) in the peripheral I/O redirection register (PIOR) is 1. At this time, the pin characteristics (I_{OH1} , I_{OL1} , V_{OH1} , V_{OL1}) 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, $R_b = 2.7$ k Ω

(2) I²C fast mode

(TA = -40 to +85°C, 1.8 V ≤ VDD = VDD_RF = AVDD_RF ≤ 3.6 V, VSS = VSS_RF = AVSS_RF = 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} | Fast mode: f _{CLK} ≥ 3.5 MHz | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0 | 400 | 0 | 400 | 0 | 400 | kHz |
| | | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0 | 400 | 0 | 400 | 0 | 400 | kHz |
| | | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0 | 400 | 0 | 400 | kHz |
| Setup time of restart condition | t _{SU:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0.6 | | 0.6 | | μs | |
| Hold time ^{Note 1} | t _{HD:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0.6 | | 0.6 | | μs | |
| Hold time when SCLA0 = "L" | t _{LOW} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 1.3 | | 1.3 | | μs | |
| Hold time when SCLA0 = "H" | t _{HIGH} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0.6 | | 0.6 | | μs | |
| Data setup time (reception) | t _{SU:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 100 | | 100 | | 100 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 100 | | 100 | | 100 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 100 | | 100 | | μs | |
| Data hold time (transmission) ^{Note 2} | t _{HD:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0 | 0.9 | 0 | 0.9 | 0 | 0.9 | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0 | 0.9 | 0 | 0.9 | 0 | 0.9 | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0 | 0.9 | 0 | 0.9 | μs | |
| Setup time of stop condition | t _{SU:STO} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 0.6 | | 0.6 | | 0.6 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 0.6 | | 0.6 | | μs | |
| Bus-free time | t _{BUF} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 2.4 V ≤ V _{DD} ≤ 3.6 V | 1.3 | | 1.3 | | 1.3 | | μs | |
| | | 1.8 V ≤ V _{DD} ≤ 3.6 V | - | | 1.3 | | 1.3 | | μs | |

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

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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 (PIOR2) in the peripheral I/O redirection register (PIOR) is 1. At this time, the pin characteristics (I_{OH1}, I_{OL1}, V_{OH1}, V_{OL1}) 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

(T_A = -40 to +85°C, 2.7 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 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} | Fast mode plus: f _{CLK} ≥ 10 MHz 2.7 V ≤ V _{DD} ≤ 3.6 V | 0 | 1000 | – | – | – | – | kHz |
| Setup time of restart condition | t _{SU:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.26 | | – | – | – | – | μs |
| Hold time ^{Note 1} | t _{HD:STA} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.26 | | – | – | – | – | μs |
| Hold time when SCLA0 = "L" | t _{LOW} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.5 | | – | – | – | – | μs |
| Hold time when SCLA0 = "H" | t _{HIGH} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.26 | | – | – | – | – | μs |
| Data setup time (reception) | t _{SU:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 50 | | – | – | – | – | μs |
| Data hold time (transmission) ^{Note 2} | t _{HD:DAT} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0 | 0.45 | – | – | – | – | μs |
| Setup time of stop condition | t _{SU:STO} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.26 | | – | – | – | – | μs |
| Bus-free time | t _{BUF} | 2.7 V ≤ V _{DD} ≤ 3.6 V | 0.5 | | – | – | – | – | μs |

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

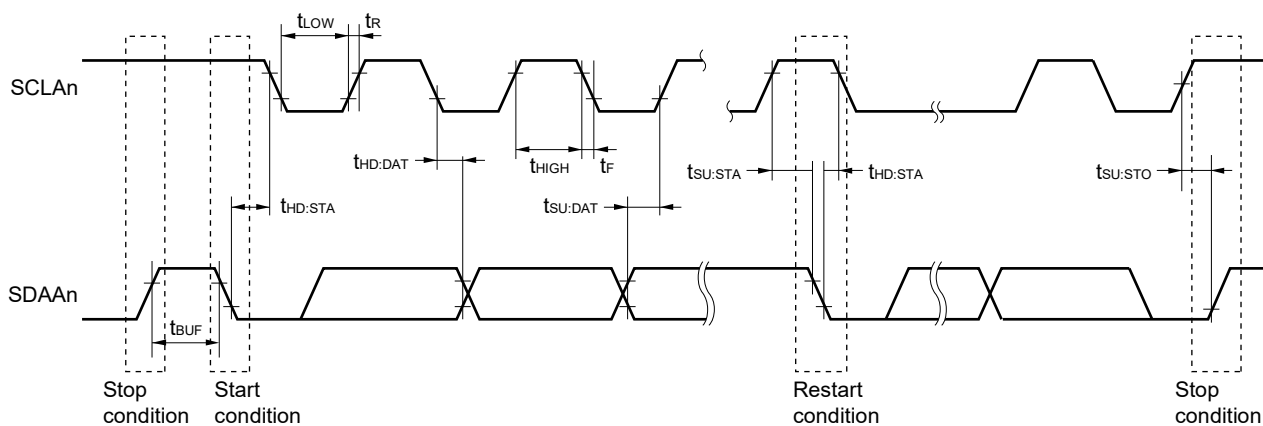
2. The maximum value (MAX.) of t_{HD:DAT} is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

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Caution The values in the above table are applied even when bit 2 (PIOR2) in the peripheral I/O redirection register (PIOR) is 1. At this time, the pin characteristics (I_{OH1}, I_{OL1}, V_{OH1}, V_{OL1}) 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 plus: C_b = 120 pF, R_b = 1.1 kΩ

I²C serial transfer timing



Remark n = 0

2.8 Analog Characteristics

2.8.1 A/D converter characteristics

A/D convertor characteristics category

| Input channel \ Reference voltage | Ref. voltage(+) = AV_{REFP} Ref. voltage(-) = AV_{REFM} | Ref. voltage(+) = V_{DD} Ref. voltage(-) = V_{SS} | Ref. voltage(+) = V_{BGR} Ref. voltage(-) = AV_{REFM} |
|--|--|--|--|
| ANI0 | - | Refer to 2.8.1 (3) | Refer to 2.8.1 (4) |
| ANI1 | | | - |
| ANI2, ANI3 | Refer to 2.8.1 (1) | Refer to 2.8.1 (3) | Refer to 2.8.1 (4) |
| ANI16 to ANI19 | Refer to 2.8.1 (2) | | |
| Internal reference voltage, Temperature sensor output voltage | Refer to 2.8.1 (1) | | |

(1) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), conversion target : ANI2, ANI3, Internal reference voltage, Temperature sensor output voltage

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{REFP} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$, 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 $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | 1.2 | ± 3.5 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | 1.2 | ± 7.0 | LSB |
| Conversion time | t_{conv} | 10-bit resolution | $2.7\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | 3.1875 | 39 | μs |
| | | | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | 17 | 39 | μs |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | 57 | 95 | μs |
| Zero-scale error ^{Note 1, 2} | E _{zs} | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | ± 0.25 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | ± 0.50 | %FSR |
| Full-scale error ^{Note 1, 2} | E _{fs} | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | ± 0.25 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | ± 0.50 | %FSR |
| Integral linearity error ^{Note 1} | ILE | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | ± 2.5 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | ± 5.0 | LSB |
| Differential linearity error ^{Note 1} | DLE | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | ± 1.5 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | ± 2.0 | LSB |
| Analog input voltage | V_{AIN} | ANI2, ANI3 | 0 | | AV_{REFP} | V |
| | | Select internal reference voltage $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode | | | V_{BGR} ^{Note 5} | V |
| | | Select temperature sensor output voltage $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode | | | V_{TMS25} ^{Note 5} | V |

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

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

3. When $AV_{REFP} < V_{DD}$, MAX. value is following.

Overall error: ± 1 LSB is added to the MAX. value of $AV_{REFP} = V_{DD}$.

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

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

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

5. Refer to 2.8.2 Temperature sensor and internal reference voltage characteristics.

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

($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq AV_{REFP} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$, 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 $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | 1.2 | ± 5.0 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | 1.2 | ± 8.5 | LSB |
| Conversion time | T_{cony} | 10-bit resolution | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 3.1875 | | 39 | μs |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 17 | 39 | μs |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | 57 | 95 | μs |
| Zero-scale error ^{Note 1, 2} | E _{ZS} | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | | ± 0.35 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | | ± 0.60 | %FSR |
| Full-scale error ^{Note 1, 2} | E _{FS} | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | | ± 0.35 | %FSR |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | | ± 0.60 | %FSR |
| Integral linearity error ^{Note 1} | ILE | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | | ± 3.5 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | | ± 6.0 | LSB |
| Differential linearity error ^{Note 1} | DLE | 10-bit resolution $AV_{REFP} = V_{DD}$ ^{Note 3} | $1.8\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ | | | ± 2.0 | LSB |
| | | | $1.6\text{ V} \leq AV_{REFP} \leq 3.6\text{ V}$ ^{Note 4} | | | ± 2.5 | LSB |
| Analog input voltage | V_{AIN} | | | 0 | | AV_{REFP} and V_{DD} | V |

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

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

3. When $AV_{REFP} < V_{DD}$, MAX. value is following.

Overall error: ± 4 LSB is added to the MAX. value of $AV_{REFP} = V_{DD}$.

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

Integral linearity error / Differential linearity error: ± 2 LSB is added to the MAX. value n of $AV_{REFP} = V_{DD}$.

4. When the 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), conversion target : ANI0 to ANI3, ANI16 to ANI19, Internal reference voltage, Temperature sensor output voltage

($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$, 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 | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 1.2 | ± 7.0 | LSB |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ ^{Note 3} | | 1.2 | ± 10.5 | LSB |
| Conversion time | T_{conv} | 10-bit resolution conversion target : ANI0 to ANI3, ANI16 to ANI19 | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 3.1875 | | 39 | μs |
| | | | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 17 | 39 | μs |
| | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 57 | 95 | μs | |
| | | 10-bit resolution conversion target : Internal reference voltage, Temperature sensor output voltage (HS (high-speed main) Mode) | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 3.5635 | | 39 | μs |
| | | | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | 17 | 39 | μs |
| Zero-scale error ^{Note 1, 2} | E_{ZS} | 10-bit resolution | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | ± 0.60 | %FSR |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ ^{Note 3} | | | ± 0.85 | %FSR |
| Full-scale error ^{Note 1, 2} | E_{FS} | 10-bit resolution | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | ± 0.60 | %FSR |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ ^{Note 3} | | | ± 0.85 | %FSR |
| Integral linearity error ^{Note 1} | ILE | 10-bit resolution | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | ± 4.0 | LSB |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ ^{Note 3} | | | ± 6.5 | LSB |
| Differential linearity error ^{Note 1} | DLE | 10-bit resolution | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | | | ± 2.0 | LSB |
| | | | $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ ^{Note 3} | | | ± 2.5 | LSB |
| Analog input voltage | V_{AIN} | ANI0 to ANI3, ANI16 to ANI19 | | 0 | | V_{DD} | V |
| | | Select internal reference voltage $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode | | V_{BGR} ^{Note 4} | | | V |
| | | Select temperature sensor output voltage $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode | | V_{TMS25} ^{Note 4} | | | V |

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

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

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

4. Refer to **2.8.2 Temperature sensor and internal reference voltage characteristics**

(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AV_{REFM}/ANI1 (ADREFM = 1), conversion target : ANI0 to ANI3, ANI16 to ANI19

(T_A = -40 to +85°C, 2.4 V ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V, Reference voltage (+) = V_{BGR} = Note 3, Reference voltage (-) = AV_{REFM} Note 4 = 0 V, HS (high-speed main) mode)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|--|-------------------|------------------|---------------------------------|------|------|-------------------------|------|
| Resolution | RES | | | 8 | | | bit |
| Conversion time | T _{conv} | 8-bit resolution | 2.4 V ≤ V _{DD} ≤ 3.6 V | 17 | | 39 | μs |
| Zero-scale error ^{Note 1, 2} | E _{ZS} | 8-bit resolution | 2.4 V ≤ V _{DD} ≤ 3.6 V | | | ±0.60 | %FSR |
| Integral linearity error ^{Note 1} | ILE | 8-bit resolution | 2.4 V ≤ V _{DD} ≤ 3.6 V | | | ±2.0 | LSB |
| Differential linearity error ^{Note 1} | DLE | 8-bit resolution | 2.4 V ≤ V _{DD} ≤ 3.6 V | | | ±1.0 | LSB |
| Analog input voltage | V _{AIN} | | | 0 | | V _{BGR} Note 3 | V |

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

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

3. Refer to 2.8.2 Temperature sensor and internal reference voltage characteristics.

4. When reference voltage (-) = V_{SS}, MAX. value is following.

Zero-scale error: ±0.35 %FSR is added to the MAX. value of reference voltage (-) = AV_{REFM}.

Integral linearity error: ±0.5 LSB is added to the MAX. value of reference voltage (-) = AV_{REFM}.

Differential linearity error: ±0.2 LSB is added to the MAX. value of reference voltage (-) = AV_{REFM}.

2.8.2 Temperature sensor and internal reference voltage characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $2.4\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$, HS (high-speed main) mode)

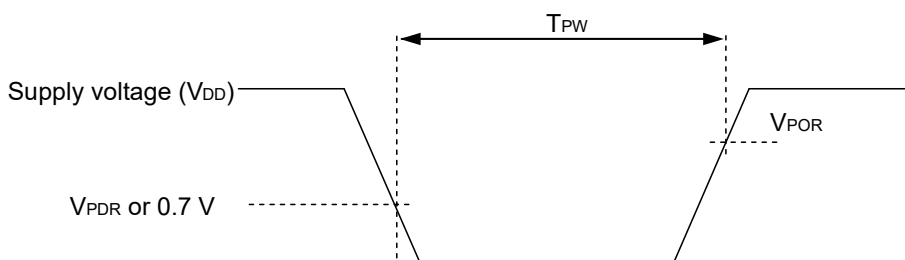
| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-----------------------------------|--------------|---|------|------|------|----------------------|
| Temperature sensor output voltage | V_{TMPS25} | Setting ADS register = 80H, $T_A = +25^\circ\text{C}$ | | 1.05 | | V |
| Internal reference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

2.8.3 POR circuit characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------------|-----------|----------------------------------|------|------|------|---------------|
| Detection voltage | V_{POR} | Rise time | 1.47 | 1.51 | 1.55 | V |
| | V_{PDR} | Fall time | 1.46 | 1.50 | 1.54 | V |
| Minimum pulse width ^{Note} | T_{PW} | Other than STOP/SUB_RUN/SUB_HALT | 300 | | | μs |

Note This is the time required for the POR circuit to execute a reset operation when V_{DD} falls below V_{PDR} . When the main system clock (f_{MAIN}) has been stopped by setting bit 0 (HIOSTOP) and bit 7 (MSTOP) of the clock operation status control register (CSC) or when the microcontroller enters STOP mode, this is the time required for the POR circuit to execute a reset operation between when V_{DD} falls below 0.7 V and when V_{DD} rises to V_{POR} or higher.



2.8.4 LVD circuit characteristics

LVD Detection Voltage of Reset Mode and Interrupt Mode

(TA = -40 to +85°C, V_{PDR} ≤ V_{DD} = V_{DD_RF} = AV_{DD_RF} ≤ 3.6 V, V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0 V)

| Parameter | | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|----------------------|----------------|--------------------|------------------------|------|------|------|------|
| Detection voltage | Supply voltage | V _{LV12} | Power supply rise time | 3.07 | 3.13 | 3.19 | V |
| | | | Power supply fall time | 3 | 3.06 | 3.12 | V |
| | | V _{LV13} | Power supply rise time | 2.96 | 3.02 | 3.08 | V |
| | | | Power supply fall time | 2.9 | 2.96 | 3.02 | V |
| | | V _{LV14} | Power supply rise time | 2.86 | 2.92 | 2.97 | V |
| | | | Power supply fall time | 2.8 | 2.86 | 2.91 | V |
| | | V _{LV15} | Power supply rise time | 2.76 | 2.81 | 2.87 | V |
| | | | Power supply fall time | 2.7 | 2.75 | 2.81 | V |
| | | V _{LV16} | Power supply rise time | 2.66 | 2.71 | 2.76 | V |
| | | | Power supply fall time | 2.6 | 2.65 | 2.7 | V |
| | | V _{LV17} | Power supply rise time | 2.56 | 2.61 | 2.66 | V |
| | | | Power supply fall time | 2.5 | 2.55 | 2.6 | V |
| | | V _{LV18} | Power supply rise time | 2.45 | 2.5 | 2.55 | V |
| | | | Power supply fall time | 2.4 | 2.45 | 2.5 | V |
| | | V _{LV19} | Power supply rise time | 2.05 | 2.09 | 2.13 | V |
| | | | Power supply fall time | 2 | 2.04 | 2.08 | V |
| | | V _{LV110} | Power supply rise time | 1.94 | 1.98 | 2.02 | V |
| | | | Power supply fall time | 1.9 | 1.94 | 1.98 | V |
| | | V _{LV111} | Power supply rise time | 1.84 | 1.88 | 1.91 | V |
| | | | Power supply fall time | 1.8 | 1.84 | 1.87 | V |
| | | V _{LV112} | Power supply rise time | 1.74 | 1.77 | 1.81 | V |
| | | | Power supply fall time | 1.7 | 1.73 | 1.77 | V |
| | | V _{LV113} | Power supply rise time | 1.64 | 1.67 | 1.7 | V |
| | | | Power supply fall time | 1.6 | 1.63 | 1.66 | V |
| Minimum pulse width | | T _{LW} | | 300 | | | μs |
| Detection delay time | | | | | | 300 | μs |

LVD Detection Voltage of Interrupt & Reset Mode**($T_A = -40$ to $+85^\circ\text{C}$, $1.6\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit | |
|--------------------------|--|--|------------------------------|------|------|------|---|
| Interrupt and reset mode | V _{LVDA0} | V _{POC2} , V _{POC1} , V _{POC0} = 0, 0, 0, falling reset voltage | 1.60 | 1.63 | 1.66 | V | |
| | V _{LVDA1} | 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 |
| | V _{LVDA2} | LVIS1, LVIS0 = 0, 1 | Rising release reset voltage | 1.84 | 1.88 | 1.91 | V |
| | | | Falling interrupt voltage | 1.8 | 1.84 | 1.87 | V |
| | V _{LVDA3} | 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 |
| | V _{LVDB0} | V _{POC2} , V _{POC1} , V _{POC0} = 0, 0, 1, falling reset voltage | 1.80 | 1.84 | 1.87 | V | |
| | V _{LVDB1} | 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 |
| | V _{LVDB2} | 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 |
| V _{LVDB3} | 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 | |
| V _{LVDC0} | V _{POC2} , V _{POC1} , V _{POC0} = 0, 1, 0, falling reset voltage | 2.40 | 2.45 | 2.50 | V | | |
| V _{LVDC1} | 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 | |
| V _{LVDC2} | 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 | |
| V _{LVDD0} | V _{POC2} , V _{POC1} , V _{POC0} = 0, 1, 1, falling reset voltage | 2.70 | 2.75 | 2.81 | V | | |
| V _{LVDD1} | 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 | |
| V _{LVDD2} | 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 | |

2.8.5 Supply voltage rise time**($T_A = -40$ to $+85^\circ\text{C}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)**

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|----------------------------|------------------|------------|------|------|------|------|
| V _{DD} rise slope | S _{VDD} | | | | 54 | V/ms |

Caution Make sure to keep the internal reset state by the LVD circuit or an external reset until V_{DD} reaches the operating voltage range shown in 2.6 AC Characteristics.

2.9 RF Transceiver Characteristics

2.9.1 RF transmission characteristics

Unless specified otherwise, the measurement is performed by our evaluation board.

($T_A = +25^\circ\text{C}$, $V_{DD} = V_{DD_RF} = AV_{DD_RF} = 3.0\text{ V}$, $f = 2440\text{ MHz}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|----------------------------------|----------------------|-----------------------------|--------------------------|------|-------|------|------|
| RF frequency range | RF _{CF} | | | 2402 | | 2480 | MHz |
| Data rate | RF _{DATA} | | | | 1 | | Mbps |
| Maximum transmitted output power | RF _{POWER} | RF output pin | RF low power mode | -18 | -15 | -12 | dBm |
| | | | RF normal mode | -3 | 0 | 3 | dBm |
| | | | RF high performance mode | -3 | 0 | 3 | dBm |
| Transmitted output power setting | RF _{TXPOW} | 0, -1, -2, -7, -10, -15 dBm | | -15 | | 0 | dBm |
| Spurious radiation | RF _{TXSP} | 30 to 88 MHz | | | -76 | -55 | dBm |
| | | 88 to 216 MHz | | | -76 | -52 | dBm |
| | | 216 to 960 MHz | | | -74 | -49 | dBm |
| | | 960 to 1000 MHz | | | -74 | -30 | dBm |
| | | 1 to 12.75 GHz | | | -42 | -41 | dBm |
| | | 1.8 to 1.9 GHz | | | -73 | -47 | dBm |
| | | 5.15 to 5.3 GHz | | | -71 | -47 | dBm |
| Harmonics | RF _{TXHC1} | 2 nd Harmonics | | | -52 | -41 | dBm |
| | RF _{TXHC2} | 3 rd Harmonics | | | -51 | -41 | dBm |
| Frequency tolerance | RF _{TXFERR} | | | -30 | | +30 | ppm |
| Impedance | RF _{Z1} | | | | 50+j0 | | Ω |

Caution Install EMI countermeasures as required to prevent EMI effects of the RF transmission characteristics.

2.9.2 RF reception characteristics

Unless specified otherwise, the measurement is performed by our evaluation board.

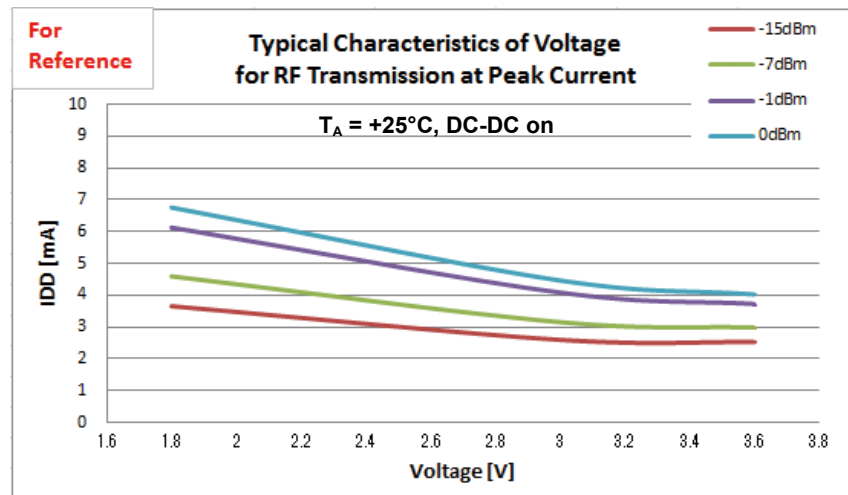
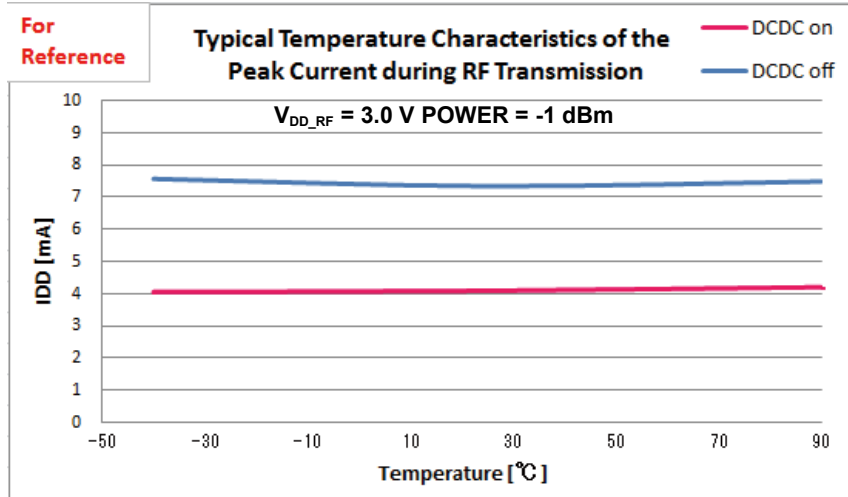
($T_A = +25^\circ\text{C}$, $V_{DD} = V_{DD_RF} = AV_{DD_RF} = 3.0\text{ V}$, $f = 2440\text{ MHz}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

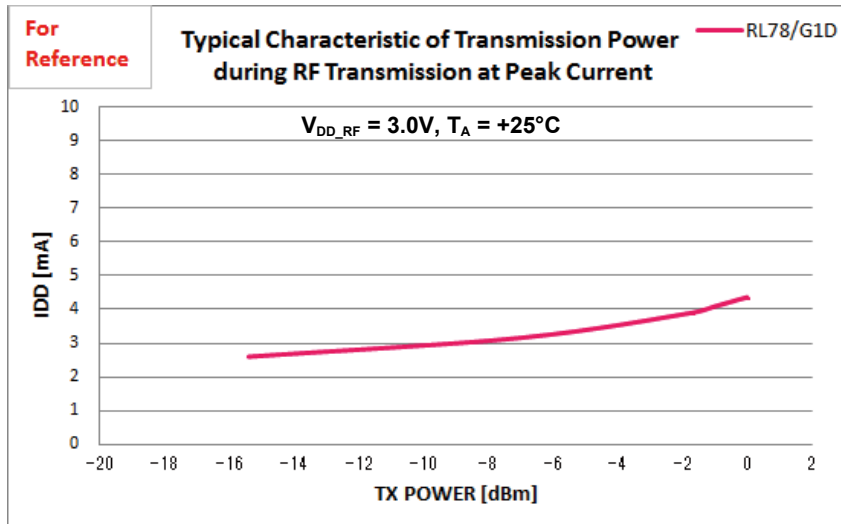
| Parameter | Symbol | Conditions | | MIN. | TYP. | MAX. | Unit |
|----------------------------------|----------------------|--|--------------------------|------|------|------|-----------------|
| RF input frequency | RF _{RXFRIN} | | | 2402 | | 2480 | MHz |
| Maximum input level | RF _{LEVEL} | PER ≤ 30.8% RF input pin | RF low power mode | -10 | 0 | - | dBm |
| | | | RF normal mode | -10 | 1 | - | dBm |
| | | | RF high performance mode | -10 | 1 | - | dBm |
| Receiver sensitivity | RF _{STY} | PER ≤ 30.8% | RF low power mode | - | -60 | -50 | dBm |
| | | | RF normal mode | - | -90 | -70 | dBm |
| | | | RF high performance mode | - | -92 | -70 | dBm |
| Secondary radiation | RF _{RXSP} | | 30 MHz to 1 GHz | - | -72 | -57 | dBm/ 100 kHz |
| | | | 1 GHz to 12 GHz | - | -57 | -54 | dBm/ 100 kHz |
| Common channel rejection ratio | RF _{CCR} | PER ≤ 30.8%, Prf = -67dBm | | -21 | -12 | - | dB |
| Adjacent channel rejection ratio | RF _{ADCR} | PER ≤ 30.8% Prf = -67 dBm | ±1 MHz | -15 | -5 | - | dB |
| | | | ±2 MHz | 17 | 29 | - | dB |
| | | | ±3 MHz | 27 | 34 | - | dB |
| Blocking | RF _{BLK} | PER ≤ 30.8% Prf = -67 dBm | 30 MHz - 2000 MHz | -30 | -13 | - | dB |
| | | | 2000 MHz to 2399 MHz | -35 | -30 | - | dBm |
| | | | 2484 MHz to 3000 MHz | -35 | -30 | - | dBm |
| | | | > 3000 MHz | -30 | -17 | - | dBm |
| Frequency tolerance | RF _{RXFERR} | PER ≤ 30.8% | | -250 | | +250 | kHz |
| RSSI accuracy | RF _{RSSIS} | $T_A = +25^\circ\text{C}$, $-70\text{ dBm} \leq \text{Prf} \leq -10\text{ dBm}$ | | -4 | 0 | 4 | dB |

2.9.3 Performance mapping for typical RF (Reference)

(1) Peak Current during RF Transmission

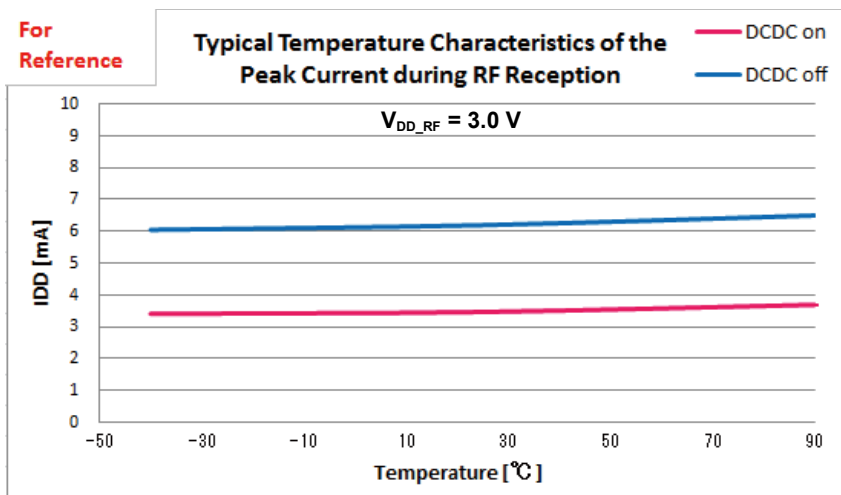
Unless specified otherwise, the measurement is performed by our evaluation board.
 Current consumption is not including MCU unit.

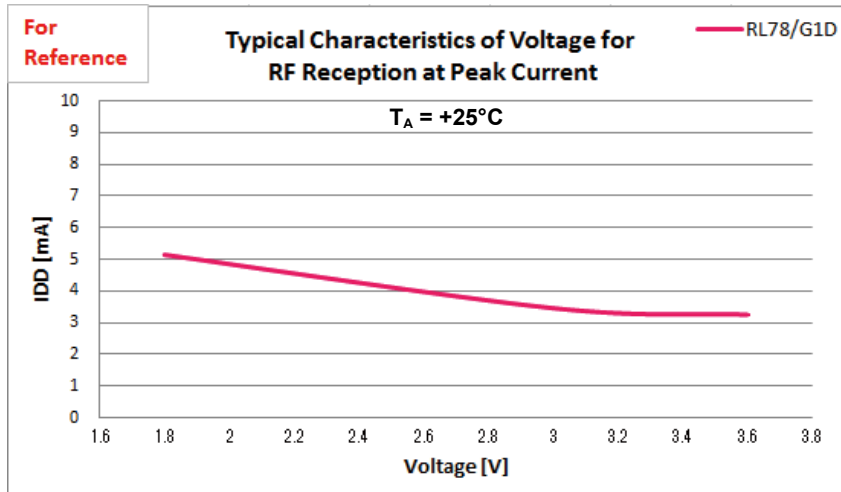




(2) Peak Current during RF Reception

Unless specified otherwise, the measurement is performed by our evaluation board.
Current consumption is not including MCU unit.

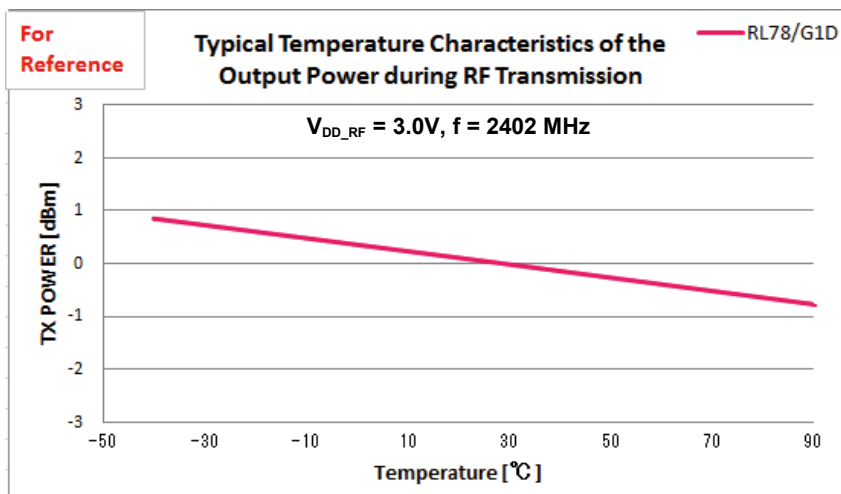


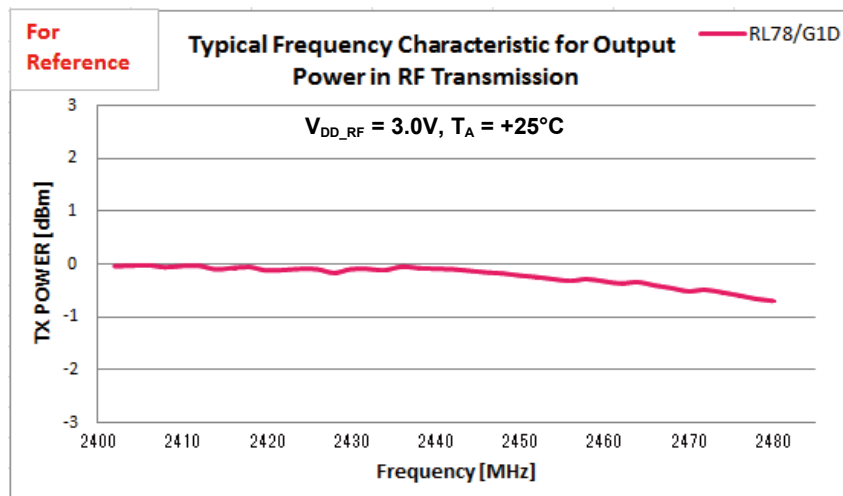
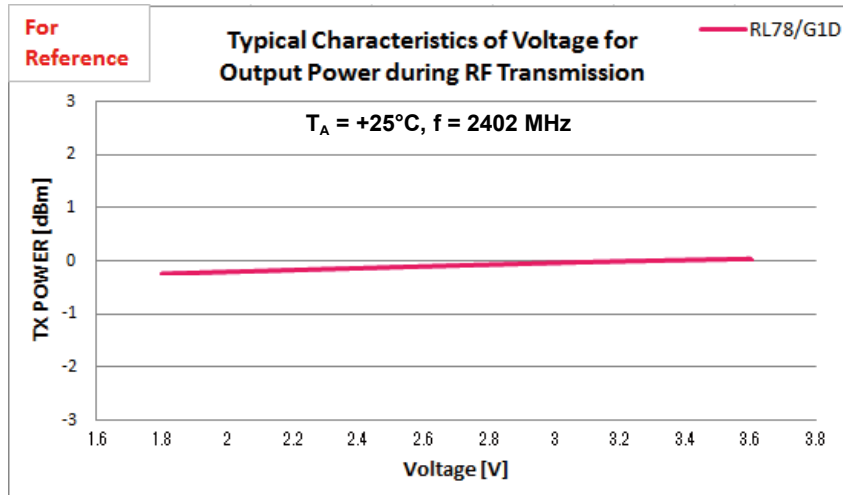


(3) RF Output Power during Transmission

Unless specified otherwise, the measurement is performed by our evaluation board.

Current consumption is not including MCU unit.

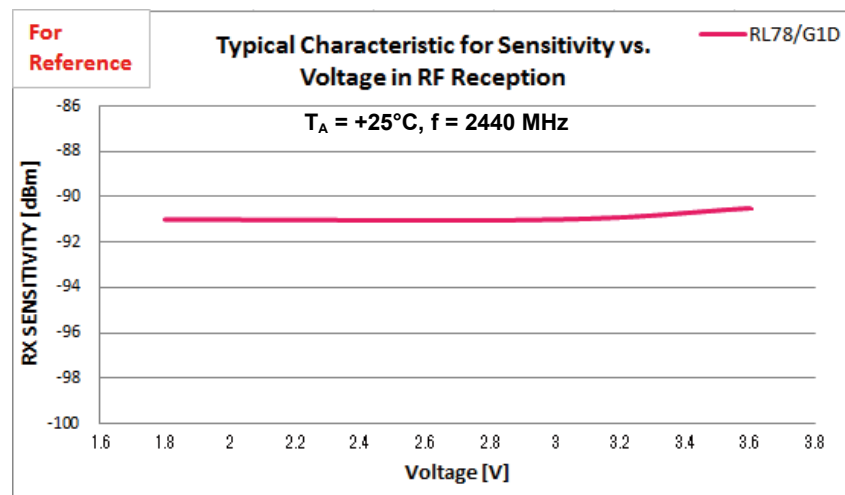
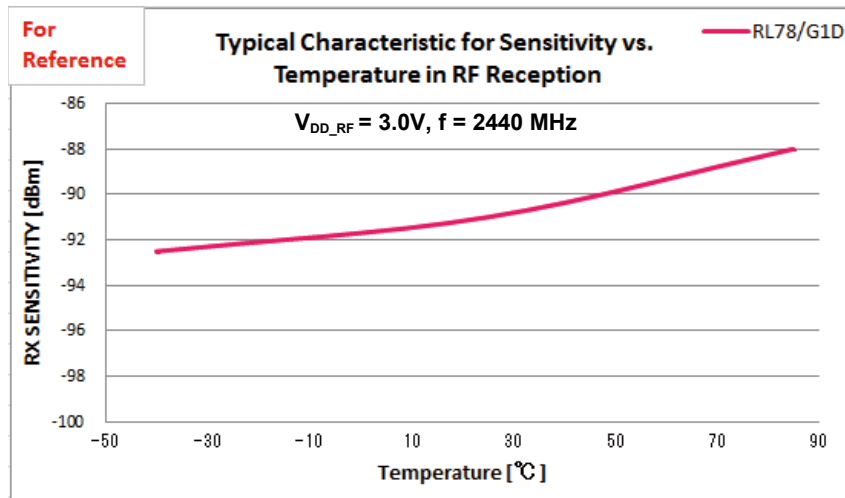




(4) RF Reception Sensitivity

Unless specified otherwise, the measurement is performed by our evaluation board.

Current consumption is not including MCU unit.

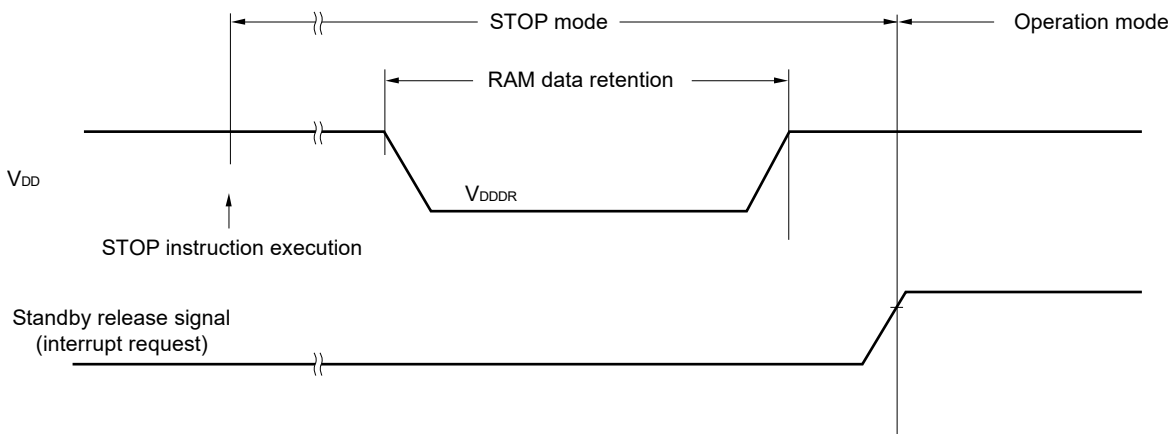


2.10 RAM Data Retention Characteristics

($T_A = -40$ to $+85^\circ\text{C}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|-------------------------------|-------------------|------------|----------------------|------|------|------|
| Data retention supply voltage | V _{DDDR} | | 1.46 ^{Note} | | 3.6 | V |

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



2.11 Flash Memory Programming Characteristics

($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|--|-------------------|---|---------|-----------|------|-------|
| CPU/peripheral hardware clock frequency | f _{CLK} | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ | 1 | | 32 | MHz |
| Number of code flash rewrites <small>Note 1, 2, 3</small> | C _{enwr} | Retained for 20 years, $T_A = 85^\circ\text{C}$ | 1,000 | | | Times |
| Number of data flash rewrites <small>Note 1, 2, 3</small> | | Retained for 1 year, $T_A = 25^\circ\text{C}$ | | 1,000,000 | | Times |
| | | Retained for 5 years, $T_A = 85^\circ\text{C}$ | 100,000 | | | Times |
| | | Retained for 20 years, $T_A = 85^\circ\text{C}$ | 10,000 | | | Times |

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

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

3. This shows the flash memory characteristics. This is a result obtained from Renesas Electronics reliability test.

2.12 Special Flash Memory Programming Communication (UART)

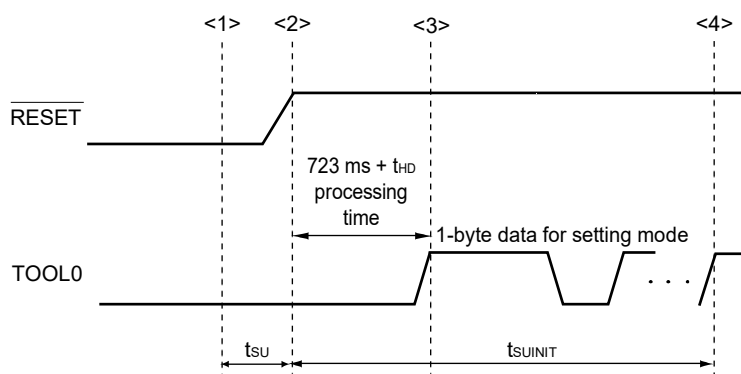
($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | TYP. | MAX. | Unit |
|---------------|--------|----------------------------------|---------|------|-----------|------|
| Transfer rate | | When programming of flash memory | 115,200 | | 1,000,000 | bps |

2.13 Timing of Entry to Flash Memory Programming Modes

($T_A = -40$ to $+85^\circ\text{C}$, $1.8\text{ V} \leq V_{DD} = V_{DD_RF} = AV_{DD_RF} \leq 3.6\text{ V}$, $V_{SS} = V_{SS_RF} = AV_{SS_RF} = 0\text{ V}$)

| Parameter | Symbol | Conditions | MIN. | MAX. | Unit |
|--|---------------|---|------|------|---------------|
| Time to complete the communication for the initial setting after the external reset is released | $t_{SUIINIT}$ | POR and LVD reset must be released before the external reset is released. | | 100 | ms |
| Time to release the external reset after the TOOL0 pin is set to the low level | t_{SU} | POR and LVD reset must be released before the external reset is released. | 10 | | μs |
| Time to hold the TOOL0 pin at the low level after the external reset is released (excluding the processing time of the firmware to control the flash memory) | t_{HD} | POR and LVD reset must be released before the external reset is released. | 1 | | ms |



- <1> The low level is input to the TOOL0 pin.
- <2> The external reset is released (POR and LVD reset must be released before the external reset is released.).
- <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 $t_{SUIINIT}$: Communication for the initial setting must be completed within 100 ms after the external reset is released during this period.

t_{SU} : Time to release the external reset after the TOOL0 pin is set to the low level

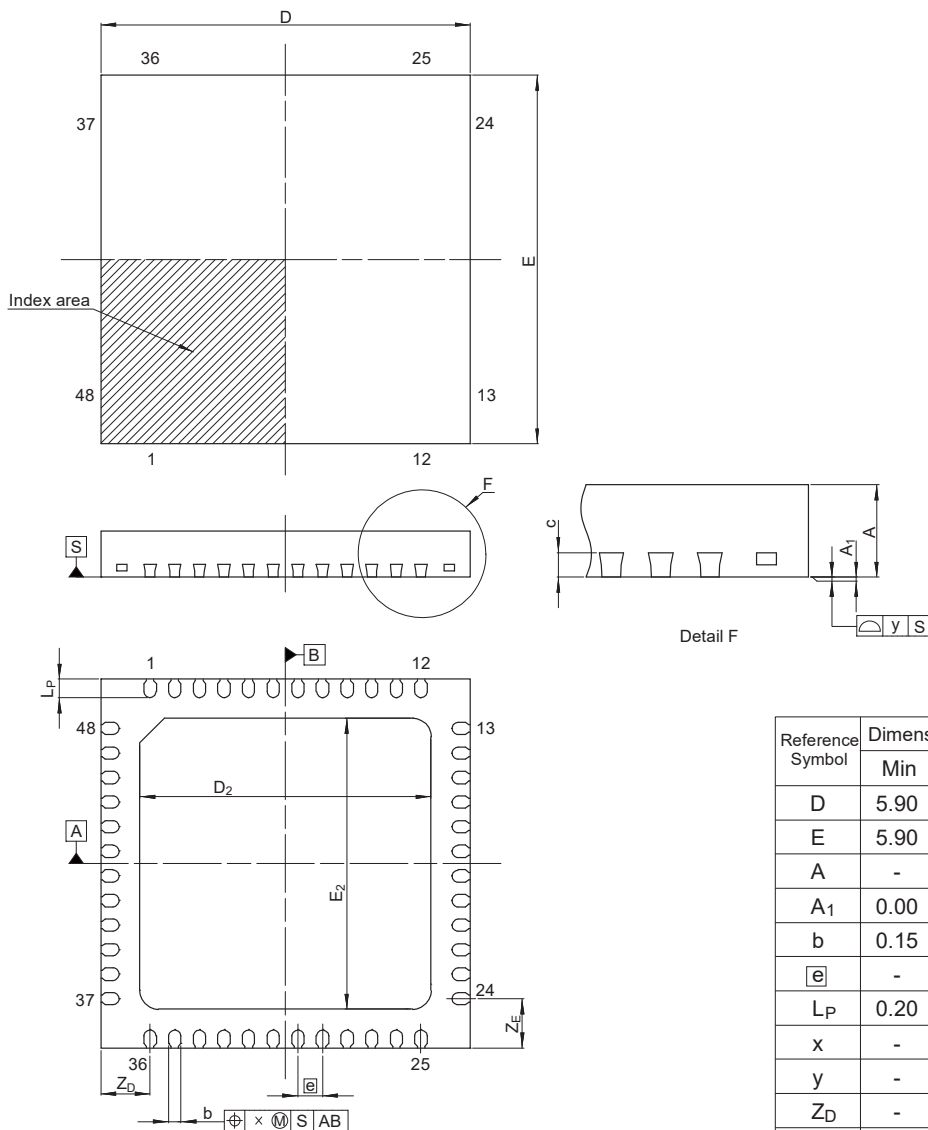
t_{HD} : Time to hold the TOOL0 pin at the low level after the external reset is released (excluding the processing time of the firmware to control the flash memory)

3. PACKAGE DRAWINGS

3.1 48-pin plastic WQFN (6 × 6)

| JEITA Package Code | RENESAS Code | Previous Code | MASS (Typ) [g] |
|--------------------|--------------|---------------|----------------|
| P-HWQFN48-6x6-0.40 | PWQN0048LB-A | - | 0.07 |

Unit: mm



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| | |
|-------------------------|----------------------------|
| Revision History | RL78/G1D Data Sheet |
|-------------------------|----------------------------|

| Rev. | Date | Description | |
|------|--------------|-------------|--|
| | | Page | Summary |
| 1.00 | Apr 24, 2015 | - | First Edition issued |
| 1.10 | Sep 25, 2015 | p.1 | Change of description in 1.1 Features |
| | | p.7, 9 | Change of 1.6 Outline of Functions |
| | | p.14 | Change of description in 2.3.2 On-chip oscillator characteristics |
| | | p.19 | Change of description in 2.5. Current Consumption |
| | | p.23 | Addition of specification to 2.5.1(3) Current for each peripheral circuit |
| | | p.65 | Change of description in 2.9.1 RF transmission characteristics |
| | | p.66 | Change of description in 2.9.2 RF reception characteristics |
| | | p.67 to 71 | Change of description in 30.9.3 Performance mapping for typical RF (Reference) |
| 1.20 | Dec 16, 2016 | p.4 | Change of pin name in 1.3 Pin Configuration (Top View) |
| | | p.58 | Change of pin names in 2.8 Analog Characteristics (1) |
| | | p.60 | Change of pin name in 2.8 Analog Characteristics (3) |
| 1.30 | Feb 23, 2018 | p.1, 7 | Change of Bluetooth version |
| | | p.1 | Identification of CPU core subcode |
| | | p.6 | Change of 1.5 Block Diagram |
| | | p.55 to 57 | Change of Note 2 |

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NOTES FOR CMOS DEVICES

- (1) **VOLTAGE APPLICATION WAVEFORM AT INPUT PIN:** Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between VIL (MAX) and VIH (MIN) due to noise, etc., the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between VIL (MAX) and VIH (MIN).
- (2) **HANDLING OF UNUSED INPUT PINS:** Unconnected CMOS device inputs can be cause of malfunction. If an input pin is unconnected, it is possible that an internal input level may be generated due to noise, etc., causing malfunction. CMOS devices behave differently than Bipolar or NMOS devices. Input levels of CMOS devices must be fixed high or low by using pull-up or pull-down circuitry. Each unused pin should be connected to VDD or GND via a resistor if there is a possibility that it will be an output pin. All handling related to unused pins must be judged separately for each device and according to related specifications governing the device.
- (3) **PRECAUTION AGAINST ESD:** A strong electric field, when exposed to a MOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop generation of static electricity as much as possible, and quickly dissipate it when it has occurred. Environmental control must be adequate. When it is dry, a humidifier should be used. It is recommended to avoid using insulators that easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors should be grounded. The operator should be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions need to be taken for PW boards with mounted semiconductor devices.
- (4) **STATUS BEFORE INITIALIZATION:** Power-on does not necessarily define the initial status of a MOS device. Immediately after the power source is turned ON, devices with reset functions have not yet been initialized. Hence, power-on does not guarantee output pin levels, I/O settings or contents of registers. A device is not initialized until the reset signal is received. A reset operation must be executed immediately after power-on for devices with reset functions.
- (5) **POWER ON/OFF SEQUENCE:** In the case of a device that uses different power supplies for the internal operation and external interface, as a rule, switch on the external power supply after switching on the internal power supply. When switching the power supply off, as a rule, switch off the external power supply and then the internal power supply. Use of the reverse power on/off sequences may result in the application of an overvoltage to the internal elements of the device, causing malfunction and degradation of internal elements due to the passage of an abnormal current. The correct power on/off sequence must be judged separately for each device and according to related specifications governing the device.
- (6) **INPUT OF SIGNAL DURING POWER OFF STATE :** Do not input signals or an I/O pull-up power supply while the device is not powered. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Input of signals during the power off state must be judged separately for each device and according to related specifications governing the device.

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