RL78/I1B

RENESAS MCU

R01DS0174EJ0230
Rev.2.30
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True Low Power Platform (as low as 63 µA/MHz, and 0.69 µA for RTC + LVD),
1.9 V to 5.5 V Operation, 64 & 128 Kbyte Flash, for Single Phase Electric Power Meter Applications

1. OUTLINE

1.1 Features

Ultra-low power consumption technology
- V_{DD} = single power supply voltage of 1.9 to 5.5 V
- HALT mode
- STOP mode
- SNOOZE mode

RL78 CPU core
- CISC architecture with 3-stage pipeline
- Minimum instruction execution time: Can be changed from high speed (0.04167 µs: @ 24 MHz operation with high-speed on-chip oscillator) to ultra-low speed (30.5 µs: @ 32.768 kHz operation with subsystem clock)
- Multiply/divide/multiply & accumulate instructions are supported.
- Address space: 1 MB
- General-purpose registers: (8-bit register × 8) × 4 banks
- On-chip RAM: 6 KB or 8 KB

Code flash memory
- Code flash memory: 64 KB or 128 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

High-speed on-chip oscillator
- Select from 24 MHz (TYP.), 12 MHz (TYP.), 6 MHz (TYP.), and 3 MHz (TYP.)
- High accuracy: ±1.0 % (V_{DD} = 1.9 to 5.5 V, TA = –20 to +85°C)
- On-chip high-speed on-chip oscillator clock frequency correction function

Operating ambient temperature
- T_A = -40 to +85°C

Power management and reset function
- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 11 levels)

Data transfer controller (DTC)
- Transfer mode: Normal mode, repeat mode, block mode
- Activation source: Start by interrupt sources (40 sources)
- Chain transfer function

Serial interface
<R>
- Simplified SPI (CSI[Note 1]): 1channel
- UART/UART (LIN-bus supported): 3 channels
- I^2C/Simplified I2C communication: 3 channels
- IrDA: 1 channel

Timer
- 16-bit timer: 8 channels
- 12-bit interval timer: 1 channel
- 8-bit interval timer:4 channels
- Real-time clock 2: 1 channel (calendar for 99 years, alarm function, and clock correction function)
- Watchdog timer: 1 channel (operable with the dedicated low-speed on-chip oscillator)
- Oscillation stop detection circuit: 1 channel

LCD controller/driver
- Internal voltage boosting method, capacitor split method, and external resistance division method are switchable
- Segment signal output: 34 (30)[Note 2] to 42 (38)[Note 2]
- Common signal output: 4 (8)[Note 2]

A/D converter
- 8/10-bit resolution A/D converter (V_{DD} = 1.9 to 5.5 V): 4 or 6 channels
- 24-Bit ΔΣ A/D converter: 3 or 4 channels
- Internal reference voltage (1.45 V) and temperature sensor[Note 3]

Comparator
- 2 channels
- Operation mode: Comparator high-speed mode, comparator low-speed mode, or window mode
- External reference voltage and internal reference voltage are selectable

I/O port
- I/O port: 53 or 69 (N-ch open drain I/O [withstand voltage of 6 V]: 3, N-ch open drain I/O [V_{DD} withstand voltage]: 13)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- Different potential interface: Can connect to a 1.8/2.5/3 V device
- On-chip clock output/buzzer output controller

Others
- On-chip BCD (binary-coded decimal) correction circuit
- On-chip battery backup function

<R> **Notes 1.** Although the CSI function is generally called SPI, it is also called CSI in this product, so it is referred to as such in this manual.
2. The values in parentheses are the number of signal outputs when 8 com is used.
3. Can be selected only in HS (high-speed main) mode

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

O ROM, RAM capacities

Flash ROM	Data flash	RAM	RL78/I1B	
			80 pins	100 pins
128 KB	–	8 KB[Note]	R5F10MMG	R5F10MPG
64 KB	–	6 KB	R5F10MME	R5F10MPE

Note This is about 7 KB when the self-programming function is used. (For details, see **CHAPTER 3** in the RL78/I1B User's Manual.)

1.2 List of Part Numbers

Figure 1-1. Part Number, Memory Size, and Package of RL78/I1B

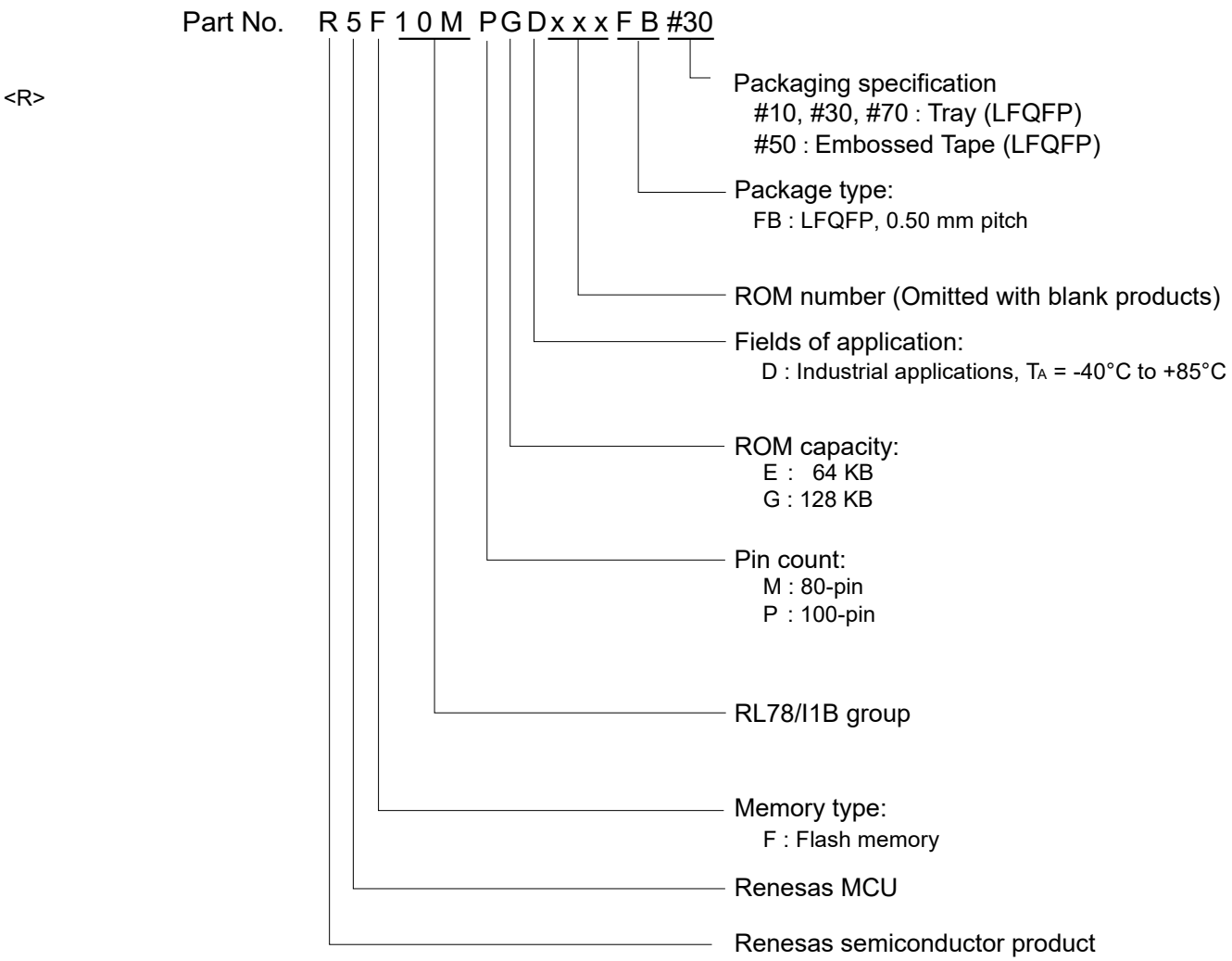


Table 1-1. List of Ordering Part Numbers

Pin count	Package	Data flash	Fields of Application[Note]	Ordering Part Number
80 pins	80-pin plastic LFQFP (12 × 12 mm, 0.5 mm pitch)	–	D	R5F10MMEDFB#10, R5F10MMGDFB#10 R5F10MMEDFB#30, R5F10MMGDFB#30 R5F10MMEDFB#50, R5F10MMGDFB#50 R5F10MMEDFB#70, R5F10MMGDFB#70
100 pins	100-pin plastic LFQFP (14 × 14 mm, 0.5 mm pitch)	–	D	R5F10MPEDFB#10, R5F10MPGDFB#10 R5F10MPEDFB#30, R5F10MPGDFB#30 R5F10MPEDFB#50, R5F10MPGDFB#50 R5F10MPEDFB#70, R5F10MPGDFB#70

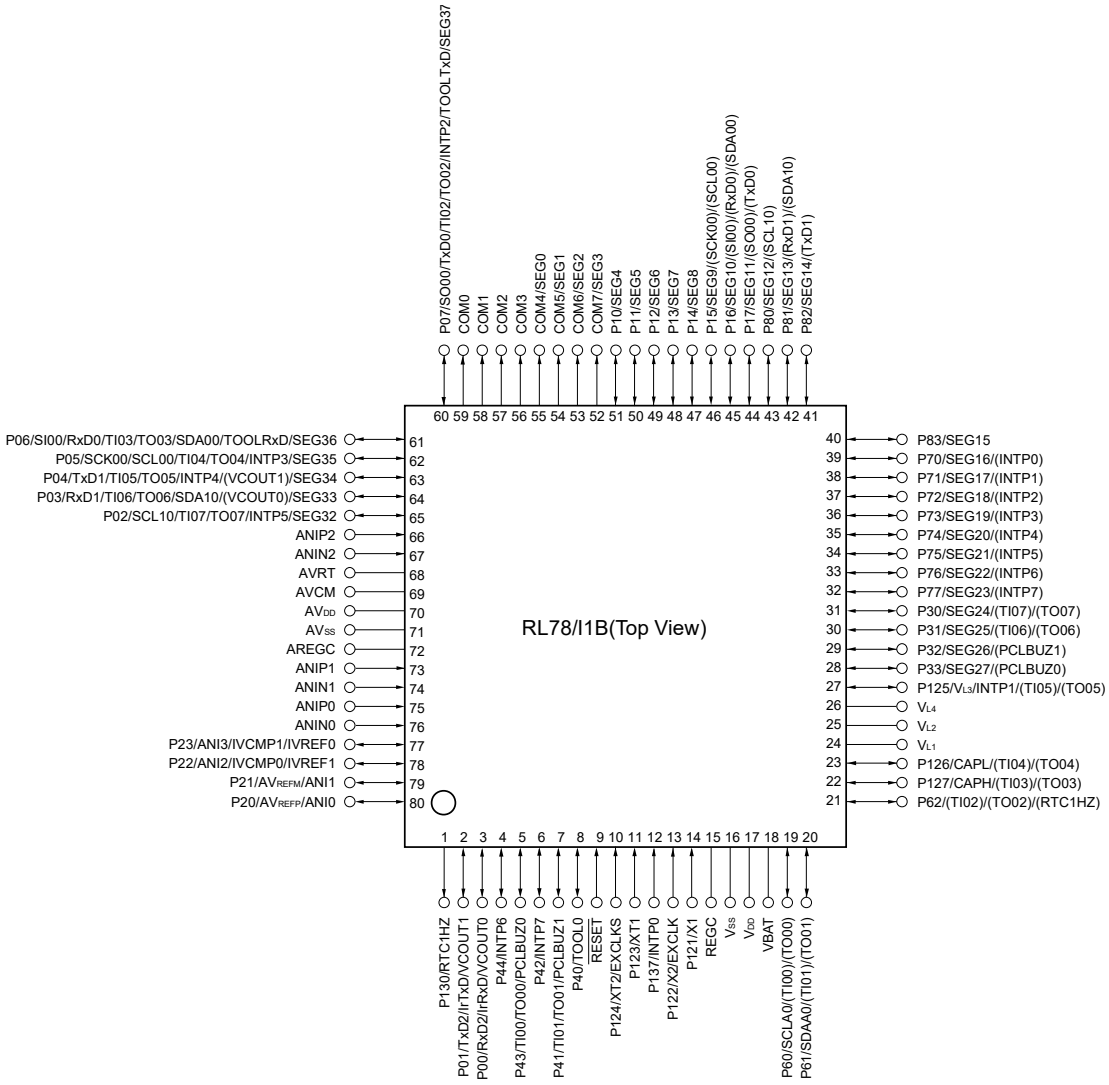
Note For the fields of application, see **Figure 1-1 Part Number, Memory Size, and Package of RL78/I1B**.

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

1.3 Pin Configuration (Top View)

1.3.1 80-pin products

- 80-pin plastic LFQFP (12 × 12 mm, 0.5 mm pitch)



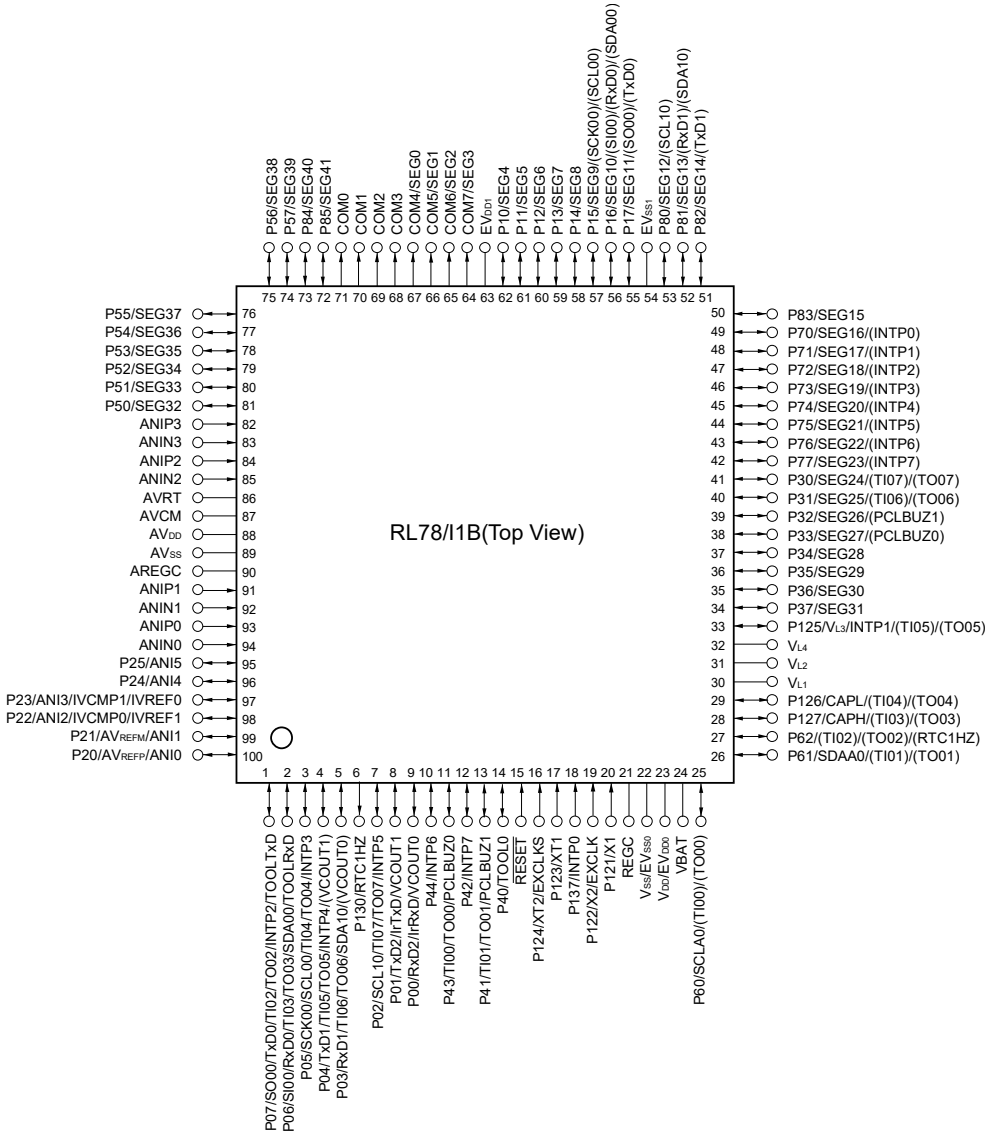
Caution Connect the REGC pin to VSS via a capacitor (0.47 to 1 µF).

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

2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)** in the RL78/I1B User's Manual.

1.3.2 100-pin products

- 100-pin plastic LFQFP (14 × 14 mm, 0.5 mm pitch)



Cautions 1. Make EV_{SS1} the same potential as V_{SS}/EV_{SS0}.

2. Make EV_{DD1} the same potential as V_{DD}/EV_{DD0}.

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

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

2. When using the microcontroller for an application where the noise generated inside the microcontroller must be reduced, it is recommended to supply separate powers to the V_{DD} and EV_{DD1} pins and connect the V_{SS} and EV_{SS1} pins to separate ground lines.

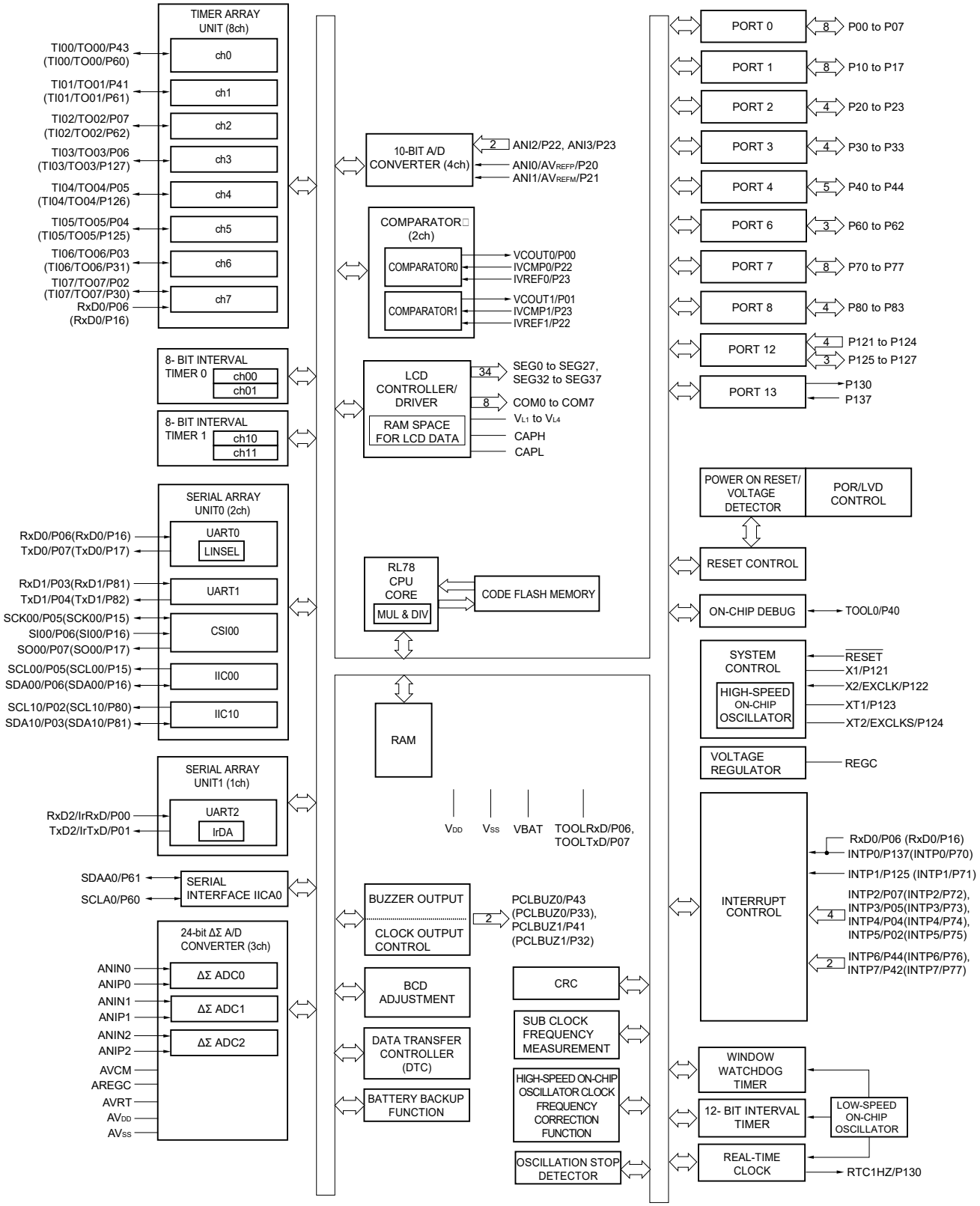
3. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)** in the RL78/I1B User's Manual.

1.4 Pin Identification

ANI0 to ANI5:	Analog Input
ANIN0 to ANIN3, ANIP0 to ANIP3:	Analog Input for ΔΣ ADC
AREGC:	Regulator Capacitance for ΔΣ ADC
AVCM:	Control forΔΣADC
AV_{DD}:	Power Supply forΔΣADC
AV_{REFM}:	A/D Converter Reference Potential (– side) Input
AV_{REFP}:	A/D Converter Reference Potential (+ side) Input
AVRT:	Reference Potential for ΔΣ ADC
AV_{SS}:	Ground forΔΣADC
CAPH, CAPL:	Capacitor Connection for LCD Controller/Driver
COM0 to COM7:	Common Signal Output for LCD Controller/Driver
EV_{DD0}, EV_{DD1}:	Power Supply for Port
EV_{SS0}, EV_{SS1}:	Ground for Port
EXCLK:	External Clock Input (Main System Clock)
EXCLKS:	External Clock Input (Subsystem clock)
INTP0 to INTP7:	Interrupt Request From Peripheral
IrRxD:	Receive Data for IrDA
IrTxD:	Transmit Data for IrDA
IVCMP0, IVCMP1:	Comparator Input
IVREF0, IVREF1:	Comparator Reference Input
P00 to P07:	Port 0
P10 to P17:	Port 1
P20 to P25:	Port 2
P30 to P37:	Port 3
P40 to P44:	Port 4
P50 to P57:	Port 5
P60 to P62:	Port 6
P70 to P77:	Port 7
P80 to P85:	Port 8
P121 to P127:	Port 12
P130, P137:	Port 13
PCLBUZ0, PCLBUZ1:	Programmable Clock Output/Buzzer Output
REGC:	Regulator Capacitance
RESET:	Reset
RTC1HZ:	Real-time Clock Correction Clock (1 Hz) Output
RxD0 to RxD2:	Receive Data for UART
SCK00:	Serial Clock Input/Output for CSI
SCLA0, SCL00, SCL10:	Serial Clock Input/Output for IIC
SDAA0, SDA00, SDA10:	Serial Data Input/Output for IIC
SEG0 to SEG41:	Segment Signal Output for LCD Controller/Driver
SI00:	Serial Data Input for CSI
SO00:	Serial Data Output for CSI
TI00 to TI07:	Timer Input
TO00 to TO07:	Timer Output
TOOL0:	Data Input/Output for Tool
TOOLRxD, TOOLTxD:	Data Input/Output for External Device
TxD0 to TxD2:	Transmit Data for UART
VBAT:	Battery Backup Power Supply
VCOUT0, VCOUT1:	Comparator Output
V_{DD}:	Power Supply
V_{L1} to V_{L4}:	Voltage for Driving LCD
V_{SS}:	Ground
X1, X2:	Crystal Oscillator (Main System Clock)
XT1, XT2:	Crystal Oscillator (Subsystem Clock)

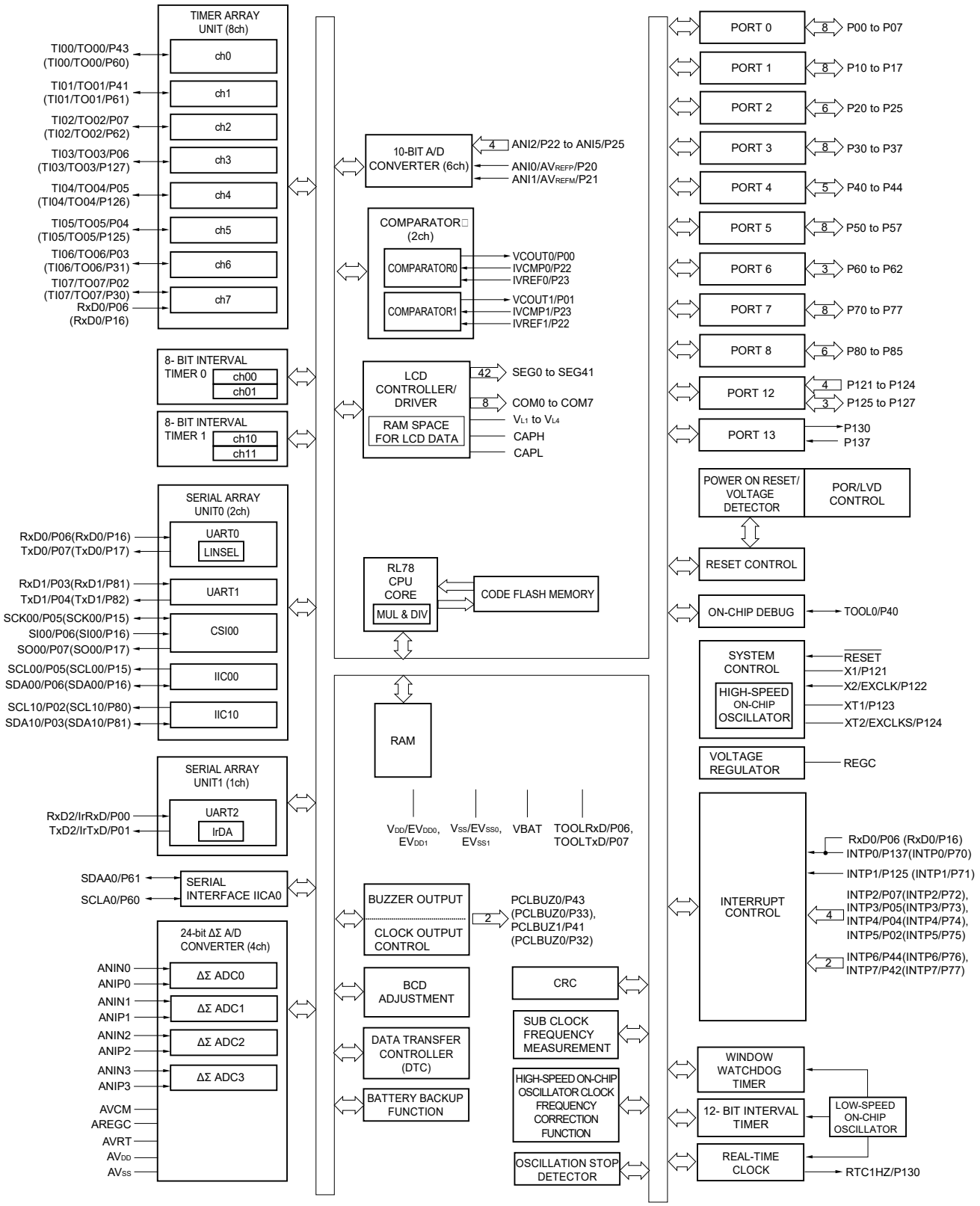
1.5 Block Diagram

1.5.1 80-pin products



Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)** in the RL78/I1B User's Manual.

1.5.2 100-pin products



Remark Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR). See **Figure 4-8 Format of Peripheral I/O Redirection Register (PIOR)** in the RL78/I1B User's Manual.

1.6 Outline of Functions

(1/2)

Item		80-pin		100-pin	
		R5F10MMEDFB	R5F10MMGDFB	R5F10MPEDFB	R5F10MPGDFB
Code flash memory (KB)		64	128	64	128
Data flash memory (KB)		–			
RAM (KB)		6	8 Note 1	6	8 Note 1
Address space		1 MB			
Main system clock	High-speed system clock	X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) HS (High-speed main) mode: 1 to 20 MHz (V_{DD} = 2.7 to 5.5 V), HS (High-speed main) mode: 1 to 16 MHz (V_{DD} = 2.4 to 5.5 V), LS (Low-speed main) mode: 1 to 8 MHz (V_{DD} = 1.9 to 5.5 V)			
	High-speed on-chip oscillator clock	HS (High-speed main) mode: 24/12/6/3 MHz (V_{DD} = 2.7 to 5.5 V), HS (High-speed main) mode: 12/6/3 MHz (V_{DD} = 2.4 to 5.5 V), LS (Low-speed main) mode: 6/3 MHz (V_{DD} = 1.9 to 5.5 V)			
Subsystem clock		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.): V_{DD} = 1.9 to 5.5 V			
High-speed on-chip oscillator clock frequency correction function		Correct the frequency of the high-speed on-chip oscillator clock by the subsystem clock.			
Low-speed on-chip oscillator		15 kHz (TYP.): V_{DD} = 1.9 to 5.5 V			
General-purpose register		8 bits × 8 registers × 4 banks			
Minimum instruction execution time		0.04167 μs (High-speed on-chip oscillator: f_{IH} = 24 MHz operation)			
		0.05 μs (High-speed system clock: f_{MX} = 20 MHz operation)			
		30.5 μs (Subsystem clock: f_{SUB} = 32.768 kHz operation)			
Instruction set		• Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (16 bits × 16 bits), division (32 bits ÷ 32 bits) • Multiplication and accumulation (16 bits × 16 bits + 32 bits) • Rotate, barrel shift, and bit manipulation (set, reset, test, and boolean operation), etc.			
I/O port	Total	53		69	
	CMOS I/O	44		60	
	CMOS input	5		5	
	CMOS output	1		1	
	N-ch O.D I/O (6 V tolerance)	3		3	
Timer	16-bit timer TAU	8 channels			
	Watchdog timer	1 channel			
	12-bit interval timer	1 channel			
	8-bit interval timer	4 channels			
	Real-time clock 2	1 channel			
	Oscillation stop detection circuit	1 channel			
	Timer output	Timer outputs: 8 channels PWM outputs: 7 Note 2			
	RTC output	1 channel • 1 Hz (subsystem clock: f_{SUB} = 32.768 kHz)			

Notes 1. In the case of the 8 KB, this is about 7 KB when the self-programming function is used.

2. 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** in the RL78/I1B User's Manual).

(2/2)

Item			80-pin		100-pin	
			R5F10MMEDFB	R5F10MMGDFB	R5F10MPEDFB	R5F10MPGDFB
Clock output/buzzer output			2			
			• 2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 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)			
10-bit resolution A/D converter			4 channels		6 channels	
24-Bit ΔΣ A/D Converter			3 channels		4 channels	
	SNDR		Typ. 80 dB (gain ×1) Min. 69 dB (gain ×16) Min. 65 dB (gain ×32)			
	Sampling frequency		3.906 kHz/1.953 kHz			
	PGA		Current ch: ×1, ×2, ×4, ×8, ×16, ×32 Voltage ch: ×1, ×2, ×4, ×8, ×16			
Comparator			2 channels			
Serial interface			• Simplified SPI (CSI)/UART/simplified I^2C: 1 channel • UART/simplified I^2C: 1 channel • UART/IrDA: 1 channel			
	I^2C bus		1 channel			
Data transfer controller (DTC)			30 sources			
LCD controller/driver			Internal voltage boosting method, capacitor split method, and external resistance division method are switchable.			
	Segment signal output		34 (30)Note 1		42 (38)Note 1	
	Common signal output		4 (8)Note 1			
Vectored interrupt sources		Internal	34			
		External	10			
Reset			• Reset by $\overline{\text{RESET}}$ pin • Internal reset by watchdog timer • Internal reset by power-on-reset • Internal reset by voltage detector • Internal reset by illegal instruction executionNote 2 • Internal reset by RAM parity error • Internal reset by illegal-memory access			
Power-on-reset circuit			• Power-on-reset: 1.51 V (TYP.) • Power-down-reset: 1.50 V (TYP.)			
Voltage detector			• Rising edge : 1.98 V to 4.06 V (11 stages) • Falling edge : 1.94 V to 3.98 V (11 stages)			
Battery backup function			Provided			
On-chip debug function			Provided			
Power supply voltage			V_{DD} = 1.9 to 5.5 V			
Operating ambient temperature			T_A = −40 to +85 °C			

Notes 1. The values in parentheses are the number of signal outputs when 8 com is used.

2. This reset occurs when instruction code FFH is executed.
This reset does not occur during emulation using an in-circuit emulator or an on-chip debugging emulator.

2. ELECTRICAL SPECIFICATIONS

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

2. The pins mounted depend on the product. See 2.1 Port Function List to 2.2.1 With functions for each product in the RL78/I1B User's Manual.

Remarks 1. In the descriptions in this chapter, read EV_{DD} as EV_{DD0} and EV_{DD1}, and EV_{SS} as EV_{SS0} and EV_{SS1}.

2. For 80-pin products, read EV_{DD} as V_{DD} and EV_{SS} as V_{SS}.

2.1 Absolute Maximum Ratings

Absolute Maximum Ratings (1/3)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V_{DD}		−0.5 to +6.5	V
	EV_{DD}	$EV_{DD1} = V_{DD}$	−0.5 to +6.5	V
	VBAT		−0.5 to +6.5	V
	AV_{DD}		−0.5 to +6.5 and −0.5 to V_{DD} Note 4 +0.6	V
REGC pin input voltage	V_{IREGC}	REGC	−0.3 to +2.8 and −0.3 to V_{DD} Note 4 +0.3 Note 1	V
Input voltage	V_{I1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127	−0.3 to EV_{DD} +0.3 and −0.3 to V_{DD} Note 4 +0.3 Note 2	V
	V_{I2}	P60 to P62 (N-ch open-drain)	−0.3 to +6.5	V
	V_{I3}	P20 to P25, P121 to P124, P137, EXCLK, EXCLKS	−0.3 to V_{DD} Note 4 +0.3 Note 2	V
	V_{I4}	$\overline{\text{RESET}}$	−0.3 to +6.5	V
Output voltage	V_{O1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P60 to P62, P70 to P77, P80 to P85, P125 to P127, P130	−0.3 to EV_{DD} +0.3 and −0.3 to V_{DD} Note 4 +0.3 Note 2	V
	V_{O2}	P20 to P25	−0.3 to V_{DD} Note 4 +0.3 Note 2	V
Analog input voltage	V_{AI1}	ANI0 to ANI5	−0.3 to V_{DD} Note 4 +0.3 and −0.3 to $AV_{REF(+)}$ +0.3 Notes 2, 3	V
	V_{AI2}	ANIP0 to ANIP3, ANIN0 to ANIN3	−0.6 to +2.8 and −0.6 to AREGC +0.3 Note 5	V
Reference supply voltage	V_{IDSAD}	AREGC, AVCM, AVRT	−0.3 to +2.8 and −0.3 to AV_{DD} +0.3 Note 6	V

Notes 1. Connect the REGC pin to Vss 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.

2. Must be 6.5 V or lower.

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

4. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

5. The ΔΣ A/D conversion target pin must not exceed AREGC +0.3 V.

6. Connect AREGC, AVCM, and AVRT terminals to V_{SS} via capacitor (0.47 μF).
This value defines the absolute maximum rating of AREGC, AVCM, and AVRT terminal. Do not use with voltage applied.

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

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

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

3. V_{SS}: Reference voltage

Absolute Maximum Ratings (2/3)

Parameter	Symbols	Conditions		Ratings	Unit
LCD voltage	V_{LI1}	V_{L1} voltage[Note 1]		−0.3 to 2.8 and −0.3 to V_{L4} +0.3	V
	V_{LI2}	V_{L2} voltage[Note 1]		−0.3 to V_{L4} +0.3[Note 2]	V
	V_{LI3}	V_{L3} voltage[Note 1]		−0.3 to V_{L4} +0.3[Note 2]	V
	V_{LI4}	V_{L4} voltage[Note 1]		−0.3 to +6.5	V
	V_{LCAP}	CAPL, CAPH voltage[Note 1]		−0.3 to V_{L4} +0.3[Note 2]	V
	V_{OUT}	COM0 to COM7, SEG0 to SEG41, output voltage	External resistance division method	−0.3 to V_{DD}[Note 3] +0.3[Note 2]	V
			Capacitor split method	−0.3 to V_{DD}[Note 3] +0.3[Note 2]	V
			Internal voltage boosting method	−0.3 to V_{L4} +0.3[Note 2]	V

Notes 1. This value only indicates the absolute maximum ratings when applying voltage to the V_{L1}, V_{L2}, V_{L3}, and V_{L4} pins; it does not mean that applying voltage to these pins is recommended. When using the internal voltage boosting method or capacitance split method, connect these pins to V_{SS} via a capacitor (0.47 μF ± 30%) and connect a capacitor (0.47 μF ± 30%) between the CAPL and CAPH pins.

2. Must be 6.5 V or lower.

3. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

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 V_{SS}: Reference voltage

Absolute Maximum Ratings (3/3)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	I_{OH1}	Per pin	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127, P130	−40	mA
		Total of all pins −170 mA	P00 to P07, P40 to P44, P130	−70	mA
			P10 to P17, P30 to P37, P50 to P57, P70 to P77, P80 to P85, P125 to P127	−100	mA
	I_{OH2}	Per pin	P20 to P25	−0.5	mA
		Total of all pins		−2	mA
Output current, low	I_{OL1}	Per pin	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P60 to P62, P70 to P77, P80 to P85, P125 to P127, P130	40	mA
		Total of all pins 170 mA	P00 to P07, P40 to P44, P130	70	mA
			P10 to P17, P30 to P37, P50 to P57, P60 to P62, P70 to P77, P80 to P85, P125 to P127	100	mA
	I_{OL2}	Per pin	P20 to P25	1	mA
		Total of all pins		5	mA
Operating ambient temperature	T_A	In normal operation mode		−40 to +85	°C
		In flash memory programming mode			
Storage temperature	T_{stg}			−65 to +150	°C

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

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

2.2 Oscillator Characteristics

2.2.1 X1, XT1 oscillator characteristics

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = 0 V)

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (f_X)Notes 1, 2	Ceramic resonator/ crystal resonator	2.7 V ≤ V_{DD} ≤ 5.5 V	1.0		20.0	MHz
		2.4 V ≤ V_{DD} < 2.7 V	1.0		16.0	MHz
		1.9 V ≤ V_{DD} < 2.4 V	1.0		8.0	MHz
XT1 clock oscillation frequency (f_{XT})Notes 1, 2	Crystal resonator		32	32.768	35	kHz

Notes 1. Indicates only permissible oscillator frequency ranges. See **2.4 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. Voltage range is the power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup function.

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

Remark When using the X1 oscillator and XT1 oscillator, see **5.4 System Clock Oscillator** in the RL78/I1B User's Manual.

2.2.2 On-chip oscillator characteristics

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Oscillators	Parameters	Conditions		MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency[Notes 1, 2]	f_{IH}			3		24	MHz
High-speed on-chip oscillator clock frequency accuracy		–20 to +85°C	1.9 V ≤ V_{DD}[Note 3] ≤ 5.5 V	–1.0		+1.0	%
		–40 to –20°C	1.9 V ≤ V_{DD}[Note 3] ≤ 5.5 V	–1.5		+1.5	%
Low-speed on-chip oscillator clock frequency	f_{IL}				15		kHz
Low-speed on-chip oscillator clock frequency accuracy				–15		+15	%

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

2. This indicates the oscillator characteristics only. See **2.4 AC Characteristics** for the instruction execution time.

3. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

2.3 DC Characteristics

2.3.1 Pin characteristics

(T_A = −40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output current, high[Note 1]	I_{OH1}	Per pin for P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127, P130	1.9 V ≤ EV_{DD} ≤ 5.5 V			−10.0[Note 2]	mA
		Total of P00 to P07, P40 to P44, P130 (When duty = 70%[Note 3])	4.0 V ≤ EV_{DD} ≤ 5.5 V			−55.0	mA
			2.7 V ≤ EV_{DD} < 4.0 V			−10.0	mA
			1.9 V ≤ EV_{DD} < 2.7 V			−5.0	mA
		Total of P10 to P17, P30 to P37, P50 to P57, P70 to P77, P80 to P85, P125 to P127 (When duty = 70%[Note 3])	4.0 V ≤ EV_{DD} ≤ 5.5 V			−80.0	mA
			2.7 V ≤ EV_{DD} < 4.0 V			−19.0	mA
			1.9 V ≤ EV_{DD} < 2.7 V			−10.0	mA
		Total of all pins (When duty = 70%[Note 3])				−100.0	mA
	I_{OH2}	Per pin for P20 to P25	1.9 V ≤ V_{DD}[Note 4] ≤ 5.5 V			−0.1[Note 2]	mA
		Total of all pins (When duty = 70%[Note 3])	1.9 V ≤ V_{DD}[Note 4] ≤ 5.5 V			−0.6	mA

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

2. Do not exceed the total current value.

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

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

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

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

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

4. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

Caution P01 to P07, P15 to P17, and P80 to P82 do not output high level in N-ch open-drain mode.

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output current, low[Note 1]	I_{OL1}	Per pin for P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127, P130				20.0[Note 2]	mA
		Per pin for P60 to P62				15.0[Note 2]	mA
		Total of P00 to P07, P40 to P44, P130 (When duty = 70%[Note 3])	4.0 V ≤ V_{DD} ≤ 5.5 V			70.0	mA
			2.7 V ≤ V_{DD} < 4.0 V			15.0	mA
			1.9 V ≤ V_{DD} < 2.7 V			9.0	mA
		Total of P10 to P17, P30 to P37, P50 to P57, P60 to P62, P70 to P77, P80 to P85, P125 to P127 (When duty = 70%[Note 3])	4.0 V ≤ V_{DD} ≤ 5.5 V			80.0	mA
			2.7 V ≤ V_{DD} < 4.0 V			35.0	mA
			1.9 V ≤ V_{DD} < 2.7 V			20.0	mA
		Total of all pins (When duty = 70%[Note 3])				150.0	mA
	I_{OL2}	Per pin for P20 to P25	1.9 V ≤ V_{DD}[Note 4] ≤ 5.5 V			0.4[Note 2]	mA
		Total of all pins (When duty = 70%[Note 3])	1.9 V ≤ V_{DD}[Note 4] ≤ 5.5 V			2.4	mA

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

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

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

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

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

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

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

4. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage, high	V_{IH1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127	Normal input buffer	0.8EV_{DD}		EV_{DD}	V
	V_{IH2}	P00, P03, P05, P06, P15, P16, P81	TTL input buffer 4.0 V ≤ EV_{DD} ≤ 5.5 V	2.2		EV_{DD}	V
			TTL input buffer 3.3 V ≤ EV_{DD} < 4.0 V	2.0		EV_{DD}	V
			TTL input buffer 1.9 V ≤ EV_{DD} < 3.3 V	1.5		EV_{DD}	V
	V_{IH3}	P20 to P25		0.7V_{DD} Note		V_{DD} Note	V
	V_{IH4}	P60 to P62		0.7EV_{DD}		6.0	V
	V_{IH5}	P121 to P124, P137, EXCLK, EXCLKS		0.8V_{DD} Note		V_{DD} Note	V
	V_{IH6}	$\overline{\text{RESET}}$		0.8V_{DD} Note		6.0	V
Input voltage, low	V_{IL1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127	Normal input buffer	0		0.2EV_{DD}	V
	V_{IL2}	P00, P03, P05, P06, P15, P16, P81	TTL input buffer 4.0 V ≤ EV_{DD} ≤ 5.5 V	0		0.8	V
			TTL input buffer 3.3 V ≤ EV_{DD} < 4.0 V	0		0.5	V
			TTL input buffer 1.9 V ≤ EV_{DD} < 3.3 V	0		0.32	V
	V_{IL3}	P20 to P25		0		0.3V_{DD} Note	V
	V_{IL4}	P60 to P62		0		0.3EV_{DD}	V
	V_{IL5}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$		0		0.2V_{DD} Note	V

Note The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

Caution The maximum value of V_{IH} of pins P01 to P07, P15 to P17, and P80 to P82 is V_{DD}, even in the N-ch open-drain mode.

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output voltage, high	V_{OH1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127, P130	4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OH1} = –10.0 mA	EV_{DD} – 1.5			V
			4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OH1} = –3.0 mA	EV_{DD} – 0.7			V
			2.7 V ≤ EV_{DD} ≤ 5.5 V, I_{OH} = –2.0 mA	EV_{DD} – 0.6			V
			1.9 V ≤ EV_{DD} ≤ 5.5 V, I_{OH} = –1.5 mA	EV_{DD} – 0.5			V
	V_{OH2}	P20 to P25	1.9 V ≤ V_{DD}[Note] ≤ 5.5 V, I_{OH2} = –100 μA	V_{DD} – 0.5			V
Output voltage, low	V_{OL1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P85, P125 to P127, P130	4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OL1} = 20 mA			1.3	V
			4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OL1} = 8.5 mA			0.7	V
			2.7 V ≤ EV_{DD} ≤ 5.5 V, I_{OL} = 3.0 mA			0.6	V
			2.7 V ≤ EV_{DD} ≤ 5.5 V, I_{OL1} = 1.5 mA			0.4	V
			1.9 V ≤ EV_{DD} ≤ 5.5 V, I_{OL1} = 0.6 mA			0.4	V
	V_{OL2}	P20 to P25	1.9 V ≤ V_{DD}[Note] ≤ 5.5 V, I_{OL2} = 400 μA			0.4	V
	V_{OL3}	P60 to P62	4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OL3} = 15.0 mA			2.0	V
			4.0 V ≤ EV_{DD} ≤ 5.5 V, I_{OL3} = 5.0 mA			0.4	V
			2.7 V ≤ EV_{DD} ≤ 5.5 V, I_{OL3} = 3.0 mA			0.4	V
			1.9 V ≤ EV_{DD} ≤ 5.5 V, I_{OL3} = 2.0 mA			0.4	V

Note The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

Caution P01 to P07, P15 to P17, and P80 to P82 do not output high level in N-ch open-drain mode.

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Input leakage current, high	I_{LIH1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P60 to P62, P70 to P77, P80 to P85, P125 to P127	$V_I = EV_{DD}$				1	μA
	I_{LIH2}	P20 to P25, P137, $\overline{\text{RESET}}$	$V_I = V_{DD}$ Note				1	μA
	I_{LIH3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	$V_I = V_{DD}$ Note	In input port or external clock input			1	μA
				In resonator connection			10	μA
Input leakage current, low	I_{LIL1}	P00 to P07, P10 to P17, P30 to P37, P40 to P44, P60 to P62, P70 to P77, P80 to P85, P125 to P127	$V_I = EV_{SS}$				–1	μA
	I_{LIL2}	P20 to P25, P137, $\overline{\text{RESET}}$	$V_I = V_{SS}$				–1	μA
	I_{LIL3}	P121 to P124 (X1, X2, XT1, XT2, EXCLK, EXCLKS)	$V_I = V_{SS}$	In input port or external clock input			–1	μA
				In resonator connection			–10	μA
On-chip pull-up resistance	R_{U1}	P10 to P17, P30 to P37, P50 to P57, P70 to P77, P80 to P85, P125 to P127	$V_I = V_{SS}$	2.4 V ≤ EV_{DD} ≤ 5.5 V	10	20	100	kΩ
				1.9 V ≤ EV_{DD} ≤ 5.5 V	10	30	100	kΩ
	R_{U2}	P00 to P07, P40 to P44	$V_I = V_{SS}$		10	20	100	kΩ

Note The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

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

2.3.2 Supply current characteristics

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V) (1/4)

Parameter	Symbol	Conditions						MIN.	TYP.	MAX.	Unit
Supply current[Note 1]	I_{DD1}	Operating mode	HS (high-speed main) mode[Note 5]	f_{IH} = 24 MHz[Note 3]	Basic operation	V_{DD} = 5.0 V			1.5		mA
						V_{DD} = 3.0 V			1.5		mA
					Normal operation	V_{DD} = 5.0 V			4.1	6.6	mA
						V_{DD} = 3.0 V			4.1	6.6	mA
				f_{IH} = 12 MHz[Note 3]	Normal operation	V_{DD} = 5.0 V			2.5	3.8	mA
						V_{DD} = 3.0 V			2.5	3.8	mA
				f_{IH} = 6 MHz[Note 3]	Normal operation	V_{DD} = 5.0 V			1.6	2.5	mA
						V_{DD} = 3.0 V			1.6	2.5	mA
				f_{IH} = 3 MHz[Note 3]	Normal operation	V_{DD} = 5.0 V			1.2	1.9	mA
						V_{DD} = 3.0 V			1.2	1.9	mA
			LS (low-speed main) mode[Note 5]	f_{IH} = 6 MHz[Note 3]	Normal operation	V_{DD} = 3.0 V			1.3	2.1	mA
						V_{DD} = 2.0 V			1.3	2.1	mA
				f_{IH} = 3 MHz[Note 3]	Normal operation	V_{DD} = 3.0 V			0.9	1.5	mA
						V_{DD} = 2.0 V			0.9	1.5	mA
			HS (high-speed main) mode[Note 5]	f_{MX} = 20 MHz[Note 2], V_{DD} = 5.0 V	Normal operation	Square wave input			3.4	5.5	mA
						Resonator connection			3.6	5.7	mA
				f_{MX} = 20 MHz[Note 2], V_{DD} = 3.0 V	Normal operation	Square wave input			3.4	5.5	mA
						Resonator connection			3.6	5.7	mA
				f_{MX} = 16 MHz[Note 2], V_{DD} = 5.0 V	Normal operation	Square wave input			2.8	4.4	mA
						Resonator connection			2.9	4.6	mA
				f_{MX} = 16 MHz[Note 2], V_{DD} = 3.0 V	Normal operation	Square wave input			2.8	4.4	mA
						Resonator connection			2.9	4.6	mA
				f_{MX} = 12 MHz[Note 2], V_{DD} = 5.0 V	Normal operation	Square wave input			2.3	3.6	mA
						Resonator connection			2.4	3.7	mA
				f_{MX} = 12 MHz[Note 2], V_{DD} = 3.0 V	Normal operation	Square wave input			2.3	3.6	mA
						Resonator connection			2.4	3.7	mA
				f_{MX} = 10 MHz[Note 2], V_{DD} = 5.0 V	Normal operation	Square wave input			2.1	3.2	mA
						Resonator connection			2.1	3.3	mA
				f_{MX} = 10 MHz[Note 2], V_{DD} = 3.0 V	Normal operation	Square wave input			2.1	3.2	mA
						Resonator connection			2.1	3.3	mA
			LS (low-speed main) mode[Note 5]	f_{MX} = 8 MHz[Note 2], V_{DD} = 3.0 V	Normal operation	Square wave input			1.2	2.0	mA
						Resonator connection			1.2	2.1	mA
				f_{MX} = 8 MHz[Note 2], V_{DD} = 2.0 V	Normal operation	Square wave input			1.2	2.0	mA
						Resonator connection			1.2	2.1	mA
			Subclock operation	f_{SUB} = 32.768 kHz[Note 4], T_A = –40°C	Normal operation	Square wave input			4.8	5.9	µA
						Resonator connection			4.9	6.0	µA
				f_{SUB} = 32.768 kHz[Note 4], T_A = +25°C	Normal operation	Square wave input			4.9	5.9	µA
						Resonator connection			5.0	6.0	µA
				f_{SUB} = 32.768 kHz[Note 4], T_A = +50°C	Normal operation	Square wave input			4.9	7.6	µA
						Resonator connection			5.0	7.7	µA
				f_{SUB} = 32.768 kHz[Note 4], T_A = +70°C	Normal operation	Square wave input			5.2	9.3	µA
						Resonator connection			5.3	9.4	µA
				f_{SUB} = 32.768 kHz[Note 4], T_A = +85°C	Normal operation	Square wave input			6.1	13.3	µA
						Resonator connection			6.2	13.4	µA

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

Notes 1. Total current flowing into V_{DD} and EV_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD} or V_{SS}, EV_{SS}.

<R> When the VBAT pin (pin for battery backup) is selected, current flowing into VBAT.

The following points apply in the HS (high-speed main), and LS (low-speed main) modes.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the LCD controller/driver, A/D converter, ΔΣ A/D converter, LVD circuit, comparator, battery backup circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the real-time clock 2.

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

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

<R> **4.** When high-speed on-chip oscillator and high-speed system clock are stopped. When setting ultra-low current consumption (AMPHS1 = 1).

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

HS (high-speed main) mode: $2.7\ V \le V_{DD} \le 5.5\ V$@1 MHz to 24 MHz

$2.4\ V \le V_{DD} \le 5.5\ V$@1 MHz to 16 MHz

LS (low-speed main) mode: $1.9\ V \le V_{DD} \le 5.5\ V$@1 MHz to 8 MHz

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

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

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

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V) (2/4)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
<R> Supply current[Note 1]	I_{DD2}[Note 2]	HALT mode	HS (high-speed main) mode[Note 6]	f_{IH} = 24 MHz[Note 4]	V_{DD} = 5.0 V		0.50	1.45	mA
					V_{DD} = 3.0 V		0.50	1.45	mA
				f_{IH} = 12 MHz[Note 4]	V_{DD} = 5.0 V		0.40	0.91	mA
					V_{DD} = 3.0 V		0.40	0.91	mA
				f_{IH} = 6 MHz[Note 4]	V_{DD} = 5.0 V		0.33	0.63	mA
					V_{DD} = 3.0 V		0.33	0.63	mA
				f_{IH} = 3 MHz[Note 4]	V_{DD} = 5.0 V		0.29	0.49	mA
					V_{DD} = 3.0 V		0.29	0.49	mA
<R>			LS (low-speed main) mode[Note 6]	f_{IH} = 6 MHz[Note 4]	V_{DD} = 3.0 V		290	620	μA
					V_{DD} = 2.0 V		290	620	μA
				f_{IH} = 3 MHz[Note 4]	V_{DD} = 3.0 V		250	534	μA
					V_{DD} = 2.0 V		250	534	μA
<R>			HS (high-speed main) mode[Note 6]	f_{MX} = 20 MHz[Note 3], V_{DD} = 5.0 V	Square wave input		0.31	1.08	mA
					Resonator connection		0.48	1.28	mA
				f_{MX} = 20 MHz[Note 3], V_{DD} = 3.0 V	Square wave input		0.31	1.08	mA
					Resonator connection		0.48	1.28	mA
				f_{MX} = 16 MHz[Note 3], V_{DD} = 5.0 V	Square wave input		0.26	0.86	mA
					Resonator connection		0.38	1.00	mA
				f_{MX} = 16 MHz[Note 3], V_{DD} = 3.0 V	Square wave input		0.26	0.86	mA
					Resonator connection		0.38	1.00	mA
				f_{MX} = 12 MHz[Note 3], V_{DD} = 5.0 V	Square wave input		0.22	0.70	mA
					Resonator connection		0.31	0.79	mA
				f_{MX} = 12 MHz[Note 3], V_{DD} = 3.0 V	Square wave input		0.22	0.70	mA
					Resonator connection		0.31	0.79	mA
				f_{MX} = 10 MHz[Note 3], V_{DD} = 5.0 V	Square wave input		0.21	0.63	mA
					Resonator connection		0.28	0.71	mA
				f_{MX} = 10 MHz[Note 3], V_{DD} = 3.0 V	Square wave input		0.21	0.63	mA
					Resonator connection		0.28	0.71	mA
<R>			LS (low-speed main) mode[Note 6]	f_{MX} = 8 MHz[Note 3], V_{DD} = 3.0 V	Square wave input		110	360	μA
					Resonator connection		160	420	μA
				f_{MX} = 8 MHz[Note 3], V_{DD} = 2.0 V	Square wave input		110	360	μA
					Resonator connection		160	420	μA
			Subsystem clock operation	f_{SUB} = 32.768 kHz[Note 5], T_A = –40°C	Square wave input		0.36	0.77	μA
					Resonator connection		0.55	0.98	μA
				f_{SUB} = 32.768 kHz[Note 5], T_A = +25°C	Square wave input		0.42	0.91	μA
					Resonator connection		0.61	1.30	μA
				f_{SUB} = 32.768 kHz[Note 5], T_A = +50°C	Square wave input		0.50	2.45	μA
					Resonator connection		0.69	2.64	μA
				f_{SUB} = 32.768 kHz[Note 5], T_A = +70°C	Square wave input		0.86	4.28	μA
					Resonator connection		1.05	4.47	μA
				f_{SUB} = 32.768 kHz[Note 5], T_A = +85°C	Square wave input		2.29	8.44	μA
					Resonator connection		2.48	8.63	μA
<R>	I_{DD3}	STOP mode[Note 7]	T_A = –40°C				0.27	0.70	μA
			T_A = +25°C				0.33	0.82	μA
			T_A = +50°C				0.41	2.36	μA
			T_A = +70°C				0.77	4.19	μA
			T_A = +85°C				2.20	8.35	μA

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

Notes 1. Total current flowing into V_{DD} and EV_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, EV_{DD} or V_{SS}, EV_{SS}.

<R> When the VBAT pin (pin for battery backup) is selected, current flowing into VBAT.

The following points apply in the HS (high-speed main), and LS (low-speed main) modes.

- The currents in the “TYP.” column do not include the operating currents of the peripheral modules.
- The currents in the “MAX.” column include the operating currents of the peripheral modules, except for those flowing into the LCD controller/driver, the A/D converter, ΔΣ A/D converter, LVD circuit, comparator, battery backup circuit, I/O port, and on-chip pull-up/pull-down resistors, and those flowing while the data flash memory is being rewritten.

In the subsystem clock operation, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules. However, in HALT mode, including the current flowing into the RTC.

In the STOP mode, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules.

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.

<R> **5.** When operating real-time clock 2 (RTC2) and setting ultra-low current consumption (AMPHS1 = 1). When high-speed on-chip oscillator and high-speed system clock are stopped.

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

HS (high-speed main) mode: $2.7\ V \le V_{DD} \le 5.5\ V$@1 MHz to 24 MHz

$2.4\ V \le V_{DD} \le 5.5\ V$@1 MHz to 16 MHz

LS (low-speed main) mode: $1.9\ V \le V_{DD} \le 5.5\ V$@1 MHz to 8 MHz

7. If operation of the subsystem clock when STOP mode, same as when HALT mode of subsystem clock operation.

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

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

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

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V) (3/4)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	I_{FIL} Note 1				0.24		μA
RTC2 operating current	I_{RTC} Notes 1, 2, 3	f_{SUB} = 32.768 kHz			0.02		μA
12-bit interval timer operating current	I_{TMKA} Notes 1, 2, 4	f_{SUB} = 32.768 kHz, f_{MAIN} is stopped			0.04		μA
8-bit interval timer operating current	I_{TMT} Notes 1, 2, 5	f_{SUB} = 32.768 kHz, f_{MAIN} is stopped, per unit	8-bit counter mode × 2 ch operation		0.12		μA
			16-bit counter mode operation		0.10		μA
Watchdog timer operating current	I_{WDT} Notes 1, 2, 6	f_{IL} = 15 kHz, f_{MAIN} is stopped			0.22		μA
LVD operating current	I_{LVD} Notes 1, 7				0.08		μA
Oscillation stop detection circuit operating current	I_{OSDC} Note 1				0.02		μA
Battery backup circuit operating current	I_{BUP} Note 1				0.05		μA
A/D converter operating current	I_{ADC} Notes 1, 8	When conversion at maximum speed	Normal mode, AV_{REFP} = V_{DD} = 5.0 V		1.3	2.4	mA
			Low voltage mode, AV_{REFP} = V_{DD} = 3.0 V		0.5	1.0	mA
A/D converter reference voltage current	I_{ADREF} Note 1				75.0		μA
Temperature sensor operating current	I_{TMPS} Note 1				105		μA
Comparator operating current	I_{CMP} Notes 1, 9	V_{DD} = 5.0 V, Regulator output voltage = 2.1 V	Window mode		12.5		μA
			Comparator high-speed mode		6.5		μA
			Comparator low-speed mode		1.7		μA
		V_{DD} = 5.0 V, Regulator output voltage = 1.8 V	Window mode		8.0		μA
			Comparator high-speed mode		4.0		μA
			Comparator low-speed mode		1.3		μA
		V_{DD} = 5.0 V, STOP mode	Window mode		8.0		μA
			Comparator high-speed mode		4.0		μA
			Comparator low-speed mode		1.3		μA
BGO operating current	I_{BGO} Notes 1, 10				2.00	12.20	mA
Self-programming operating current	I_{FSP} Notes 1, 11				2.00	12.20	mA

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V) (4/4)

Parameter	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
24-Bit ΔΣ A/D Converter operating current	I_{DSAD} Notes 1, 12	In 4 ch ΔΣ A/D converter operation				1.50	2.25	mA
		In 3 ch ΔΣ A/D converter operation				1.18	1.77	mA
		In 1 ch ΔΣ A/D converter operation				0.53	0.80	mA
SNOOZE operating current	I_{SNOZ} Notes 1, 13	ADC operation	The mode is performed			0.50	0.80	mA
			The A/D conversion operations are performed, low voltage mode, AV_{REFP} = V_{DD} = 3.0 V			1.20	1.80	mA
		Simplified SPI (CSI)/UART operation				0.70	1.05	mA
		DTC operation				2.20		mA
LCD operating current	I_{LCD1} Notes 1, 14, 15	External resistance division method	f_{LCD} = f_{SUB} LCD clock = 128 Hz 1/3 bias, four-time-slices	V_{DD} = 5.0 V, V_{L4} = 5.0 V		0.06		μA
	I_{LCD2} Notes 1, 14	Internal voltage boosting method	f_{LCD} = f_{SUB} LCD clock = 128 Hz 1/3 bias, four-time-slices	V_{DD} = 3.0 V, V_{L4} = 3.0 V (VLCD = 04H)		0.85		μA
				V_{DD} = 5.0 V, V_{L4} = 5.1 V (VLCD = 12H)		1.55		μA
	I_{LCD3} Notes 1, 14	Capacitor split method	f_{LCD} = f_{SUB} LCD clock = 128 Hz 1/3 bias, four-time-slices	V_{DD} = 3.0 V, V_{L4} = 3.0 V		0.20		μA

Notes 1. Current flowing to V_{DD}. When the VBAT pin (battery backup power supply pin) is selected, current flowing to the VBAT.

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

3. Current flowing only to real-time clock 2 (excluding the low-speed on-chip oscillator and operating current of the XT1 oscillator). The value of the current value of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2}, and I_{RTC}, when real-time clock 2 operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of real-time clock 2.

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

5. Current flowing only to the 8-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and XT1 oscillator). The value of the current value of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2}, and I_{TMT}, when the 8-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added.

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

7 Current flowing only to the LVD circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{LVD} when the LVD circuit operates.

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

9. Current flowing only to the comparator circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{CMP} when the comparator circuit operates.

Notes 10. Current flowing only during rewrite of 1 KB code flash memory.

11. Current flowing only during self programming.

12. Current flowing only to the 24-bit ΔΣ A/D converter. The current value of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2}, and I_{DSAD} when the 24-bit ΔΣ A/D converter operates.

13. For shift time to the SNOOZE mode, see **24.3.3 SNOOZE mode** in the RL78/I1B User's Manual.

14. Current flowing only to the LCD controller/driver. The current value of the RL78 microcontrollers is the sum of the LCD operating current (I_{LCD1}, I_{LCD2} or I_{LCD3}) to the supply current (I_{DD1}, or I_{DD2}) when the LCD controller/driver operates in an operation mode or HALT mode. Not including the current that flows through the LCD panel. Conditions of the TYP. value and MAX. value are as follows.

- Setting 20 pins as the segment function and blinking all
- Selecting f_{SUB} for system clock when LCD clock = 128 Hz (LCDC0 = 07H)
- Setting four time slices and 1/3 bias

15. Not including the current flowing into the external division resistor when using the external resistance division method.

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

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

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

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

2.4 AC Characteristics

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	T_{CY}	Main system clock (f_{MAIN}) operation	HS (high-speed main) mode	2.7 V ≤ V_{DD} Note 1 ≤ 5.5 V	0.0417		1	μs
				2.4 V ≤ V_{DD} Note 1 < 2.7 V	0.0625		1	μs
			LS (low-speed main) mode	1.9 V ≤ V_{DD} Note 1 ≤ 5.5 V	0.125		1	μs
		Subsystem clock (f_{SUB}) operation		1.9 V ≤ V_{DD} Note 1 ≤ 5.5 V	28.5	30.5	31.3	μs
		In the self programming mode	HS (high-speed main) mode	2.7 V ≤ V_{DD} Note 1 ≤ 5.5 V	0.0417		1	μs
				2.4 V ≤ V_{DD} Note 1 < 2.7 V	0.0625		1	μs
			LS (low-speed main) mode	1.9 V ≤ V_{DD} Note 1 ≤ 5.5 V	0.125		1	μs
External system clock frequency	f_{EX}	2.7 V ≤ V_{DD} Note 1 ≤ 5.5 V			1.0		20.0	MHz
		2.4 V ≤ V_{DD} Note 1 < 2.7 V			1.0		16.0	MHz
		1.9 V ≤ V_{DD} Note 1 < 2.4 V			1.0		8.0	MHz
	f_{EXS}				32		35	kHz
External system clock input high-level width, low-level width	t_{EXH}, t_{EXL}	2.7 V ≤ V_{DD} Note 1 ≤ 5.5 V			24			ns
		2.4 V ≤ V_{DD} Note 1 < 2.7 V			30			ns
		1.9 V ≤ V_{DD} Note 1 < 2.4 V			60			ns
	t_{EXHS}, t_{EXLS}				13.7			μs
TI00 to TI07 input high-level width, low-level width	t_{TIH}, t_{TIL}				1/f_{MCK}+10			ns Note 2
TO00 to TO07 output frequency	f_{TO}	HS (high-speed main) mode		4.0 V ≤ EV_{DD} ≤ 5.5 V			12	MHz
				2.7 V ≤ EV_{DD} < 4.0 V			8	MHz
				2.4 V ≤ EV_{DD} < 2.7 V			4	MHz
		LS (low-speed main) mode		1.9 V ≤ EV_{DD} ≤ 5.5 V			4	MHz
PCLBUZ0, PCLBUZ1 output frequency	f_{PCL}	HS (high-speed main) mode		4.0 V ≤ EV_{DD} ≤ 5.5 V			16	MHz
				2.7 V ≤ EV_{DD} < 4.0 V			8	MHz
				2.4 V ≤ EV_{DD} < 2.7 V			4	MHz
		LS (low-speed main) mode		1.9 V ≤ EV_{DD} ≤ 5.5 V			4	MHz
Interrupt input high-level width, low-level width	t_{INTH}, t_{INTL}	INTP0		1.9 V ≤ V_{DD} Note 1 ≤ 5.5 V	1			μs
		INTP1 to INTP7		1.9 V ≤ EV_{DD} ≤ 5.5 V	1			μs
$\overline{\text{RESET}}$ low-level width	t_{RSL}				10			μs

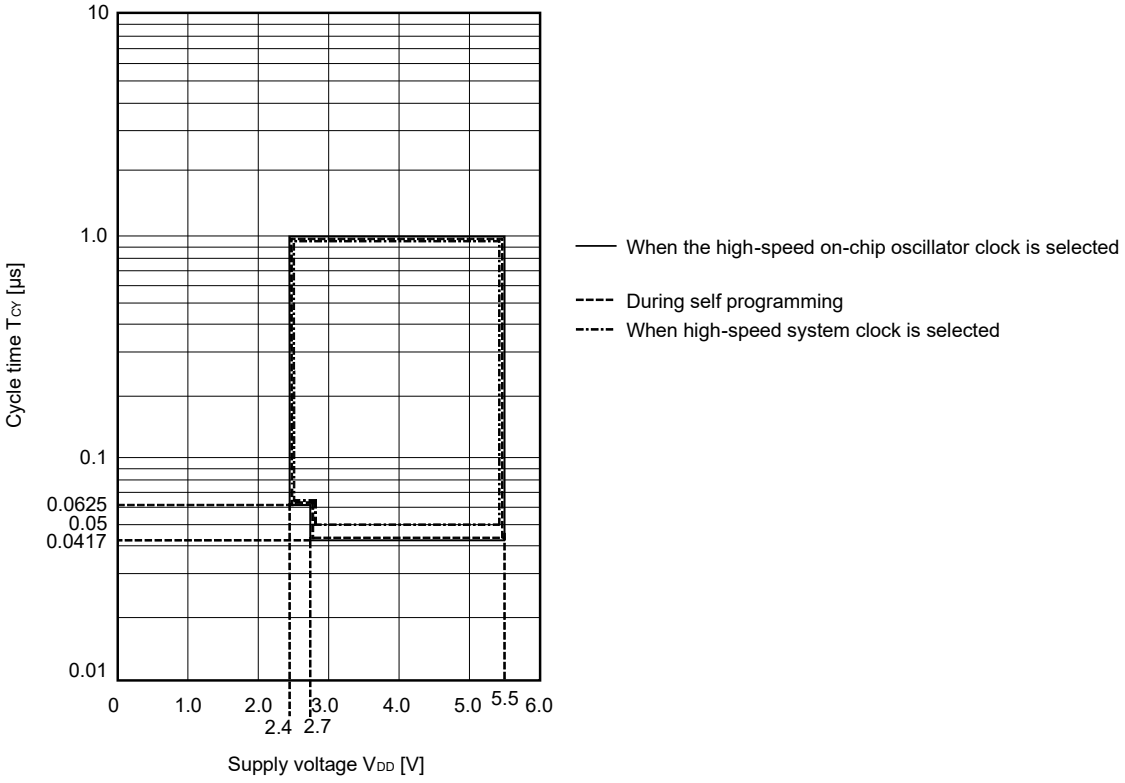
Notes 1. The power supply voltage (VBAT pin or V_{DD} pin) selected by the battery backup feature.

2. The following conditions are required for low voltage interface:
1.9 V ≤ V_{DD} < 2.7 V: MIN. 125 ns

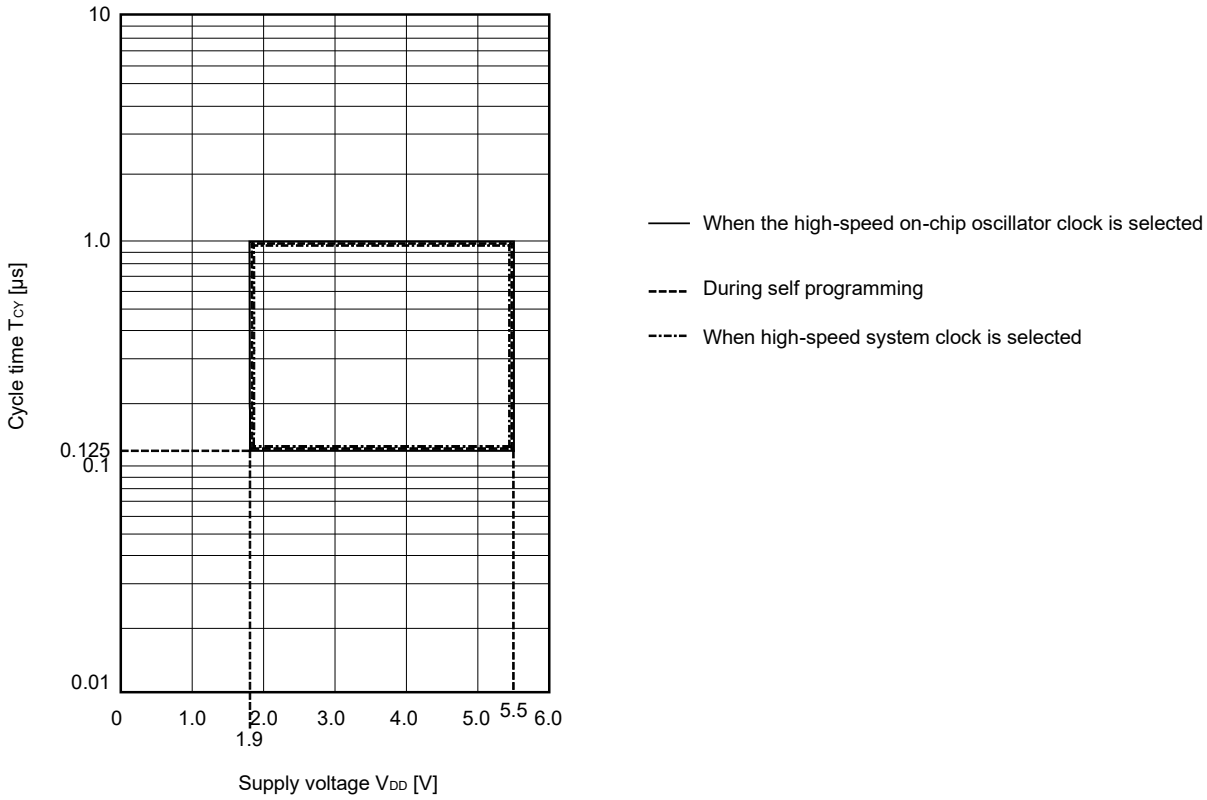
Remark f_{MCK}: Timer array unit operation clock frequency
(Operation clock to be set by the CKSmn0, CKSmn1 bits of timer mode register mn (TMRmn)
m: Unit number (m = 0), n: Channel number (n = 0 to 7))

Minimum Instruction Execution Time during Main System Clock Operation

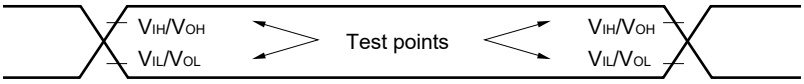
T_{CY} vs V_{DD} (HS (high-speed main) mode)



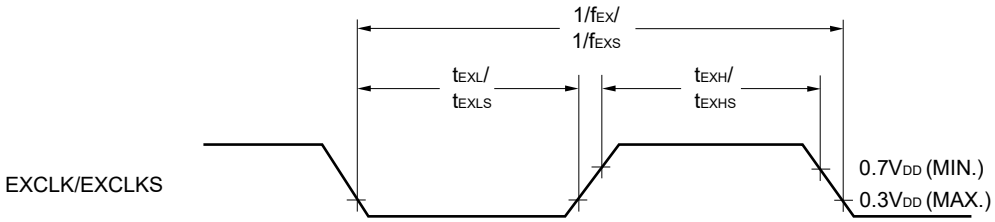
T_{CY} vs V_{DD} (LS (low-speed main) mode)



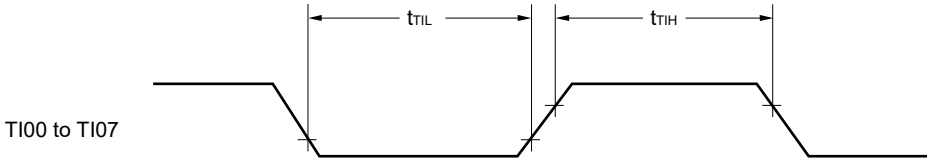
AC Timing Test Points

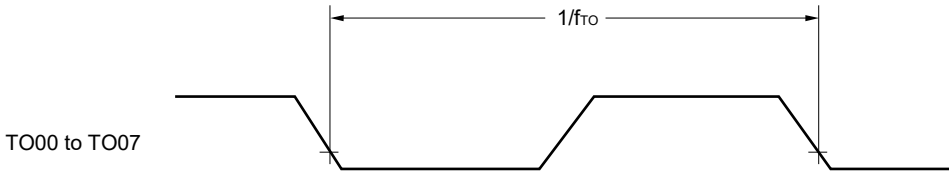


External System Clock Timing

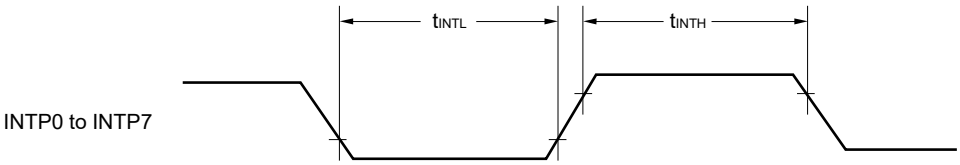


TI/TO Timing

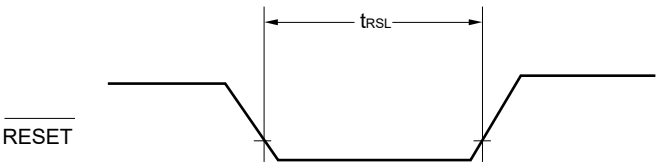




Interrupt Request Input Timing

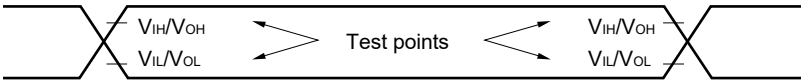


$\overline{\text{RESET}}$ Input Timing



2.5 Peripheral Functions Characteristics

AC Timing Test Points



2.5.1 Serial array unit

(1) During communication at same potential (UART mode) (dedicated baud rate generator output)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
Transfer rate[Note 1]		2.4 V≤ V_{DD} ≤ 5.5 V		$f_{MCK}/6$[Note 2]		$f_{MCK}/6$[Note 2]	bps
		Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$[Note 3]		4.0		1.3	Mbps
		1.9 V ≤ V_{DD} ≤ 5.5 V				$f_{MCK}/6$[Note 2]	bps
		Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$[Note 3]				1.3	Mbps

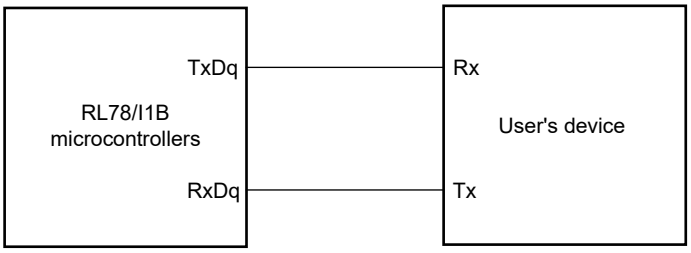
Notes 1. Transfer rate in the SNOOZE mode is 4800 bps only.

2. The following conditions are required for low voltage interface.
2.4 V ≤ EV_{DD} < 2.7 V: MAX. 2.6 Mbps
1.9 V ≤ EV_{DD} < 2.4 V: MAX. 1.3 Mbps

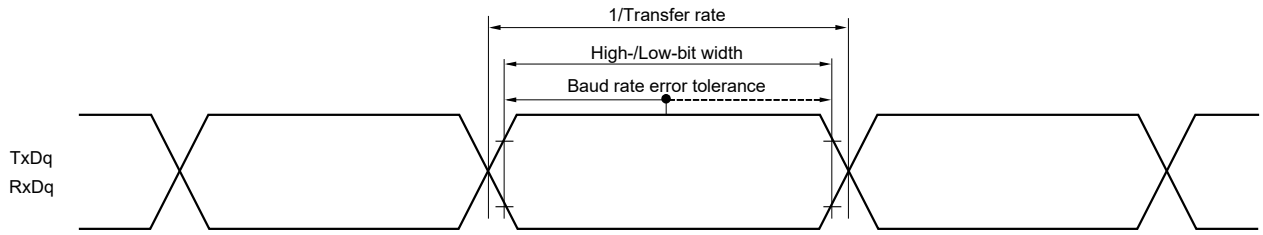
3. The maximum operating frequencies of the CPU/peripheral hardware clock (f_{CLK}) are:
HS (high-speed main) mode: 24 MHz
LS (low-speed main) mode: 8 MHz

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)



Remarks 1. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 8)

2. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	2.7 V ≤ EV_{DD} ≤ 5.5 V		167		500		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		250		500		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				500		ns
SCKp high-/low-level width	t_{KH1}, t_{KL1}	4.0 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY1}/2 – 12		t_{KCY1}/2 – 50		ns
		2.7 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY1}/2 – 18		t_{KCY1}/2 – 50		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY1}/2 – 38		t_{KCY1}/2 – 50		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				t_{KCY1}/2 – 50		ns
SIp setup time (to SCKp↑)[Note 1]	t_{SIK1}	4.0 V ≤ EV_{DD} ≤ 5.5 V		44		110		ns
		2.7 V ≤ EV_{DD} ≤ 5.5 V		44		110		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		75		110		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				110		ns
SIp hold time (from SCKp↑)[Note 2]	t_{KSI1}	2.4 V ≤ EV_{DD} ≤ 5.5 V		19		19		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				19		ns
Delay time from SCKp↓ to SOp output[Note 3]	t_{KSO1}	C = 30 pF[Note 4]	2.4 V ≤ EV_{DD} ≤ 5.5 V		25		25	ns
			1.9 V ≤ EV_{DD} ≤ 5.5 V				25	ns

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

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

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

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

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

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

2. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00))

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

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time[Note 5]	t_{KCY2}	4.0 V ≤ EV_{DD} ≤ 5.5 V	20 MHz < f_{MCK}	8/f_{MCK}		—		ns
			f_{MCK} ≤ 20 MHz	6/f_{MCK}		6/f_{MCK}		ns
		2.7 V ≤ EV_{DD} ≤ 5.5 V	16 MHz < f_{MCK}	8/f_{MCK}		—		ns
			f_{MCK} ≤ 16 MHz	6/f_{MCK}		6/f_{MCK}		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		6/f_{MCK} and 500		6/f_{MCK}		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				6/f_{MCK}		ns
SCKp high-/low-level width	t_{KH2}, t_{KL2}	4.0 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY2}/2 – 7		t_{KCY2}/2 – 7		ns
		2.7 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY2}/2 – 8		t_{KCY2}/2 – 8		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		t_{KCY2}/2 – 18		t_{KCY2}/2 – 18		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				t_{KCY2}/2 – 18		ns
SIp setup time (to SCKp↑)[Note 1]	t_{SIK2}	2.7 V ≤ EV_{DD} ≤ 5.5 V		1/f_{MCK}+20		1/f_{MCK}+30		ns
		2.4 V ≤ EV_{DD} ≤ 5.5 V		1/f_{MCK}+30		1/f_{MCK}+30		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				1/f_{MCK}+30		ns
SIp hold time (from SCKp↑)[Note 2]	t_{KSI2}	2.4 V ≤ EV_{DD} ≤ 5.5 V		1/f_{MCK}+31		1/f_{MCK}+31		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V				1/f_{MCK}+31		ns
Delay time from SCKp↓ to SOp output[Note 3]	t_{KSO2}	C = 30 pF[Note 4]	2.7 V ≤ EV_{DD} ≤ 5.5 V		2/f_{MCK}+44		2/f_{MCK}+110	ns
			2.4 V ≤ EV_{DD} ≤ 5.5 V		2/f_{MCK}+75		2/f_{MCK}+110	ns
			1.9 V ≤ EV_{DD} ≤ 5.5 V				2/f_{MCK}+110	ns

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

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

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

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

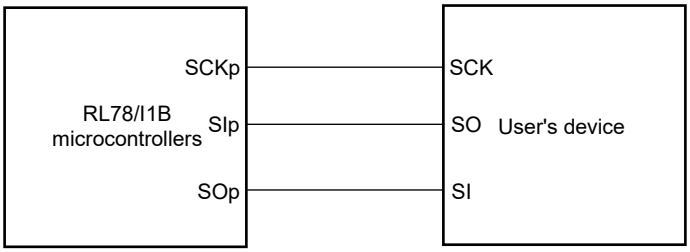
5. Transfer rate in the SNOOZE mode: MAX. 1 Mbps

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

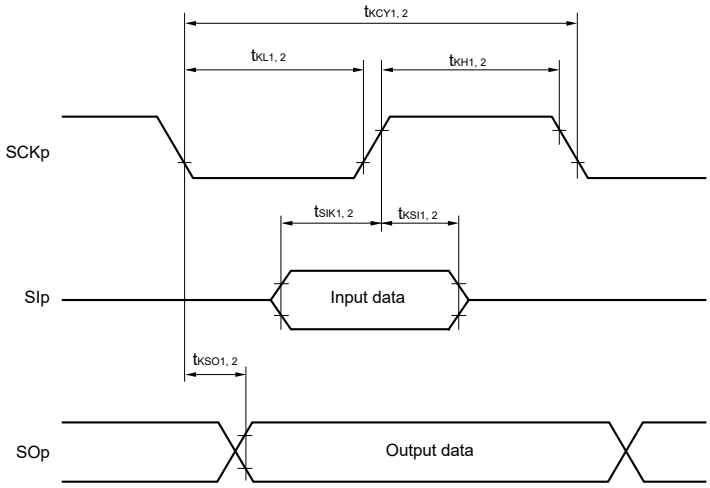
Remarks 1. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM number (g = 0, 1)

2. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00))

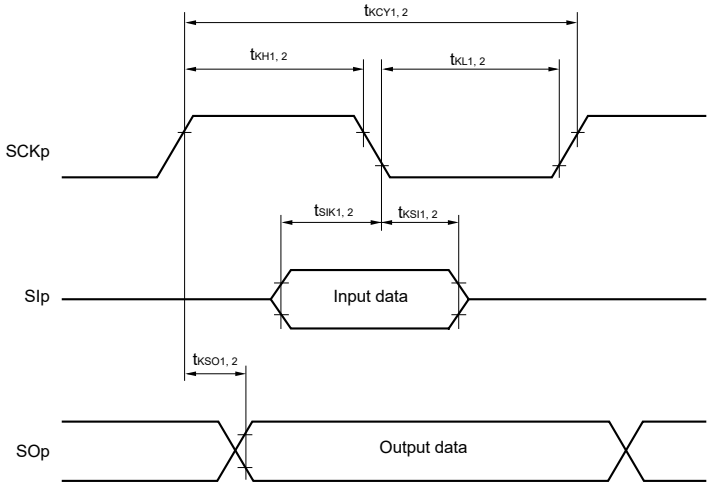
Simplified SPI (CSI) mode connection diagram (during communication at same potential)



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



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



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

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

(4) During communication at same potential (simplified I^2C mode)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f_{SCL}	2.7 V ≤ EV_{DD} ≤ 5.5 V, C_b = 50 pF, R_b = 2.7 kΩ		1000 Note 1		400 Note 1	kHz
		1.9 V ≤ EV_{DD} ≤ 5.5 V, C_b = 100 pF, R_b = 3 kΩ		400 Note 1		400 Note 1	kHz
		1.9 V Note 3 ≤ EV_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ		300 Note 1		300 Note 1	kHz
Hold time when SCLr = “L”	t_{LOW}	2.7 V ≤ EV_{DD} ≤ 5.5 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1150		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V, C_b = 100 pF, R_b = 3 kΩ	1150		1150		ns
		1.9 V Note 3 ≤ EV_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	1550		1550		ns
Hold time when SCLr = “H”	t_{HIGH}	2.7 V ≤ EV_{DD} ≤ 5.5 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1150		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V, C_b = 100 pF, R_b = 3 kΩ	1150		1150		ns
		1.9 V Note 3 ≤ EV_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	1550		1550		ns
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V, C_b = 50 pF, R_b = 2.7 kΩ	$1/f_{MCK}$ + 85 Notes 1, 2		$1/f_{MCK}$ + 145 Notes 1, 2		ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V, C_b = 100 pF, R_b = 3 kΩ	$1/f_{MCK}$ + 145 Notes 1, 2		$1/f_{MCK}$ + 145 Notes 1, 2		ns
		1.9 V Note 3 ≤ EV_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	$1/f_{MCK}$ + 230 Notes 1, 2		$1/f_{MCK}$ + 230 Notes 1, 2		ns
Data hold time (transmission)	$t_{HD:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V, C_b = 50 pF, R_b = 2.7 kΩ	0	305	0	305	ns
		1.9 V ≤ EV_{DD} ≤ 5.5 V, C_b = 100 pF, R_b = 3 kΩ	0	355	0	355	ns
		1.9 V Note 3 ≤ EV_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	0	405	0	405	ns

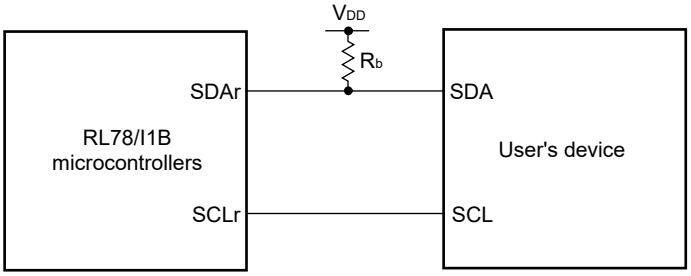
Notes 1. The value must also be equal to or less than f_{MCK}/4.

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

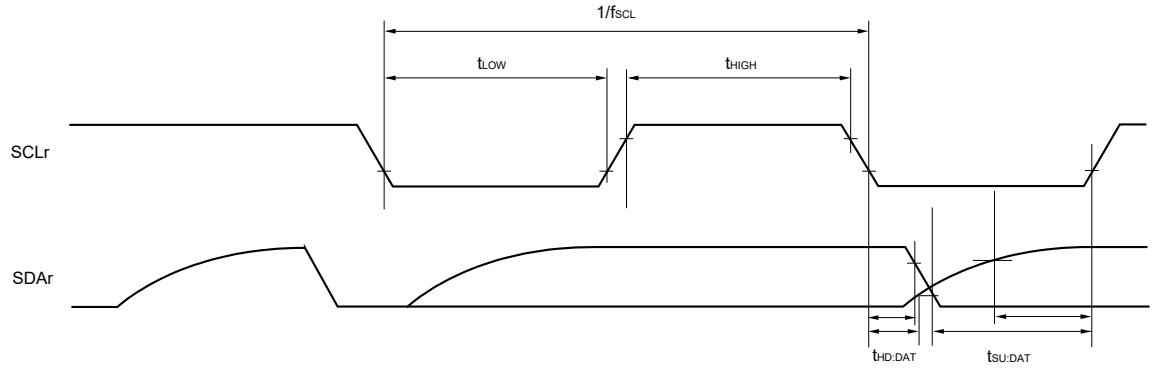
3. When HS (high-speed main) mode, this value becomes 2.4 V.

(**Caution** and **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)



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 g (POMg).

Remarks 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, 10), g: PIM and POM number (g = 0, 1)

3. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number (m = 0), n: Channel number (n = 0, 2), mn = 00, 02))

(5) Communication at different potential (1.9 V, 2.5 V, 3 V) (UART mode) (1/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
Transfer rate		Reception	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V		$f_{MCK}/6$ Note 1		$f_{MCK}/6$ Note 1	bps
			Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} Note 4		4.0		1.3	Mbps
			2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V		$f_{MCK}/6$ Note 1		$f_{MCK}/6$ Note 1	bps
			Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} Note 4		4.0		1.3	Mbps
			1.9 V Note 5 ≤ EV_{DD} < 3.3 V, 1.8 V ≤ V_b ≤ 2.0 V		$f_{MCK}/6$ Notes 1 to 3		$f_{MCK}/6$ Notes 1, 2	bps
			Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} Note 4		4.0		1.3	Mbps

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

2. Use it with $EV_{DD} \geq V_b$.

3. The following conditions are required for low voltage interface.
2.4 V ≤ EV_{DD} < 2.7 V: MAX. 2.6 Mbps
1.9 V ≤ EV_{DD} < 2.4 V: MAX. 1.3 Mbps

4. The maximum operating frequencies of the CPU/peripheral hardware clock (f_{CLK}) are:
HS (high-speed main) mode: 24 MHz
LS (low-speed main) mode: 8 MHz

5. When HS (high-speed main) mode, this value becomes 2.4 V.

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

Remarks 1. V_b[V]: Communication line voltage

2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 8)

3. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

(5) Communication at different potential (1.8 V, 2.5 V, 3 V) (UART mode) (2/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
Transfer rate		Transmission	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V		**Notes 1, 2**		**Notes 1, 2**	bps
			Theoretical value of the maximum transfer rate C_b = 50 pF, R_b = 1.4 kΩ, V_b = 2.7 V		2.8 Note 3		2.8 Note 3	Mbps
			2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V		**Notes 2, 4**		**Notes 2, 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	Mbps
			1.9 V Note 9 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V		**Notes 2, 6, 7**		**Notes 2, 6, 7**	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 8		0.43 Note 8	Mbps

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

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

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

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

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

2. Transfer rate in the SNOOZE mode is 4800 bps only.

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

4. 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 ≤ EV_{DD} < 4.0 V and 2.3 V ≤ V_b ≤ 2.7 V

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

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

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

5. 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.

6. Use it with $EV_{DD} \geq V_b$.

Notes 7. 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 $1.9\ V \leq EV_{DD} < 2.7\ V$ and $1.6\ V \leq V_b \leq 2.0\ V$

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

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

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

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

9. When HS (high-speed main) mode, this value becomes 2.4 V.

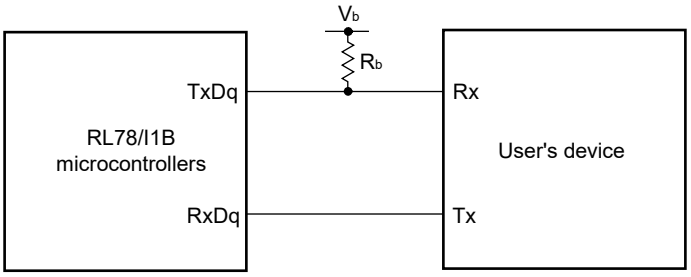
Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (V_{DD} tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

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

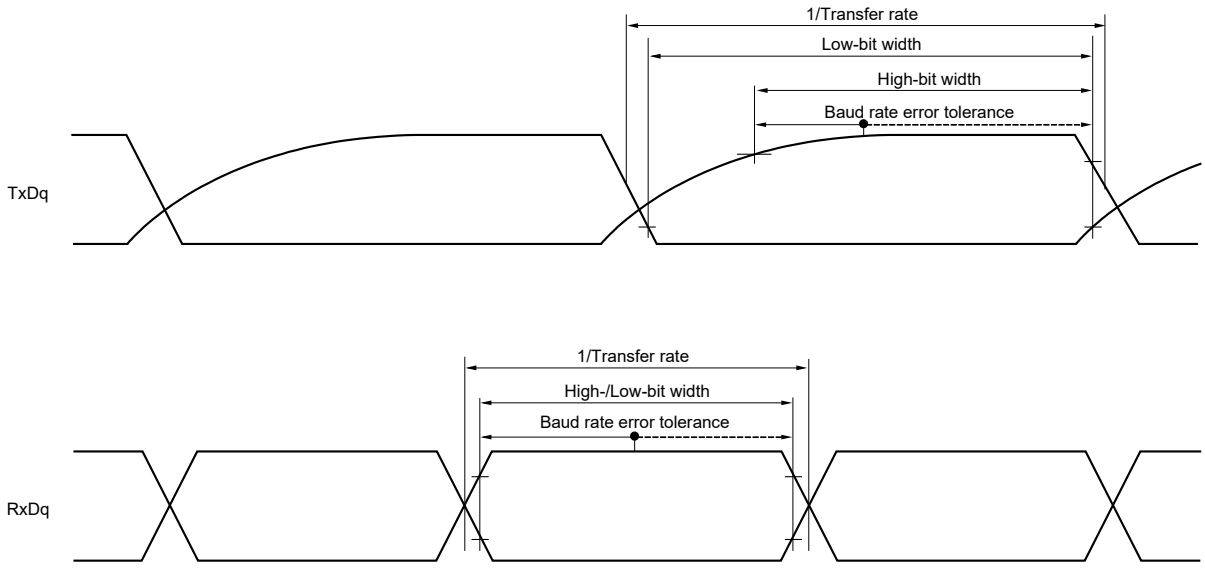
2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 8)

3. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00 to 03, 10, 11))

UART mode connection diagram (during communication at different potential)



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



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

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

2. q: UART number (q = 0 to 2), g: PIM and POM number (g = 0, 1, 8)

(6) Communication at different potential (2.5 V, 3 V) (f_{MCK}/2) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq 2/f_{CLK}$	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ	200		1150		ns
			2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ	300		1150		ns
SCKp high-level width	t_{KH1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		t_{KCY1}/2 – 50		t_{KCY1}/2 – 50		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		t_{KCY1}/2 – 120		t_{KCY1}/2 – 120		ns
SCKp low-level width	t_{KL1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		t_{KCY1}/2 – 7		t_{KCY1}/2 – 50		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		t_{KCY1}/2 – 10		t_{KCY1}/2 – 50		ns
SIp setup time (to SCKp↑)[Note 1]	t_{SIK1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		58		479		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		121		479		ns
SIp hold time (from SCKp↑)[Note 1]	t_{KSI1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		10		10		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		10		10		ns
Delay time from SCKp↓ to SOp output[Note 1]	t_{KSO1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ			60		60	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ			130		130	ns
SIp setup time (to SCKp↓)[Note 2]	t_{SIK1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		23		110		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		33		110		ns
SIp hold time (from SCKp↓)[Note 2]	t_{KSI1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ		10		10		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ		10		10		ns
Delay time from SCKp↑ to SOp output[Note 2]	t_{KSO1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 20 pF, R_b = 1.4 kΩ			10		10	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 20 pF, R_b = 2.7 kΩ			10		10	ns

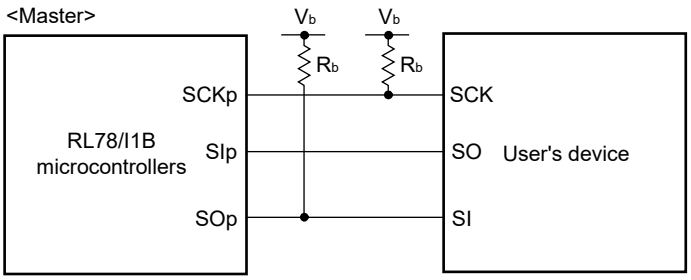
(**Caution** and **Remarks** are listed on the next page.)

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

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

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

Simplified SPI (CSI) mode connection diagram (during communication at different potential)



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

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

3. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00))

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

(7) Communication at different potential (1.8 V, 2.5 V, 3 V) (f_{MCK}/4) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (1/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq 4/f_{CLK}$	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ	300		1150		ns
			2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	500		1150		ns
			1.9 V[Note 4] ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V, C_b = 30 pF, R_b = 5.5 kΩ	1150		1150		ns
SCKp high-level width	t_{KH1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ		t_{KCY1}/2 – 75		t_{KCY1}/2 – 75		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ		t_{KCY1}/2 – 170		t_{KCY1}/2 – 170		ns
		1.9 V[Note 4] ≤ EV_{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	t_{KL1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ		t_{KCY1}/2 – 12		t_{KCY1}/2 – 50		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ		t_{KCY1}/2 – 18		t_{KCY1}/2 – 50		ns
		1.9 V[Note 4] ≤ EV_{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

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

(7) Communication at different potential (1.8 V, 2.5 V, 3 V) (f_{MCK}/4) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output) (2/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SIp setup time (to SCKp↑)Note 1	t_{SIK1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ	81		479		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	177		479		ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ	479		479		ns
SIp hold time (from SCKp↑)Note 1	t_{KSI1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ	19		19		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	19		19		ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ	19		19		ns
Delay time from SCKp↓ to SOp outputNote 1	t_{KSO1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ		100		100	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ		195		195	ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ		483		483	ns
SIp setup time (to SCKp↓)Note 2	t_{SIK1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ	44		110		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	44		110		ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ	110		110		ns
SIp hold time (from SCKp↓)Note 2	t_{KSI1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ	19		19		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	19		19		ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ	19		19		ns
Delay time from SCKp↑ to SOp outputNote 2	t_{KSO1}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ		25		25	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ		25		25	ns
		1.9 VNote 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 VNote 3, C_b = 30 pF, R_b = 5.5 kΩ		25		25	ns

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

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

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

3. Use it with $EV_{DD} \geq V_b$.

4. When HS (high-speed main) mode, this value becomes 2.4 V.

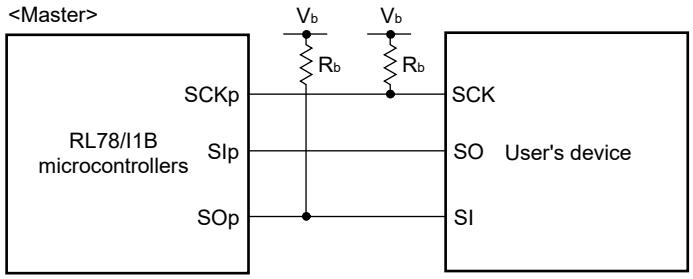
Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output (V_{DD} tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

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

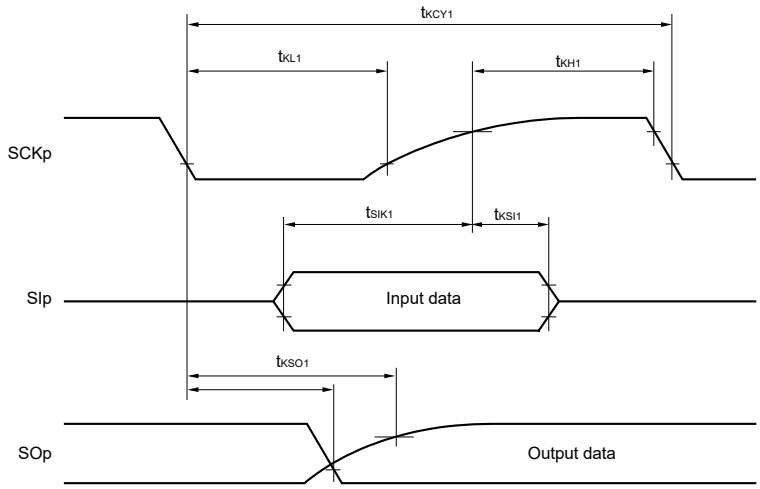
2. p: CSI number (p = 00), m: Unit number , n: Channel number (mn = 00),
g: PIM and POM number (g = 0, 1)

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))

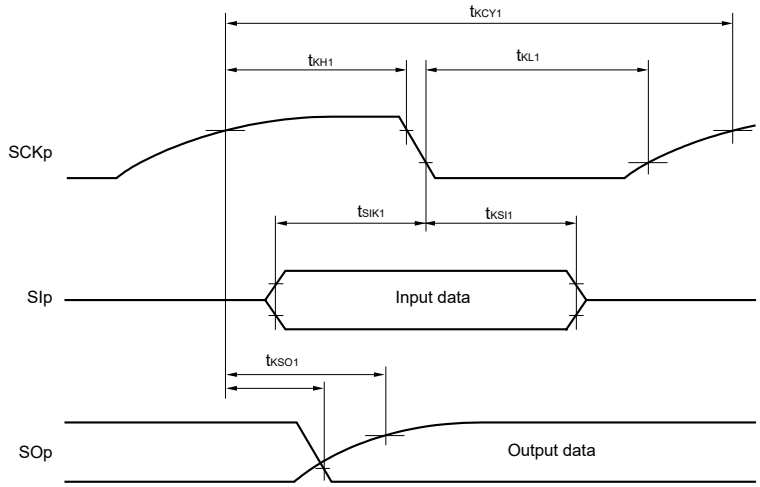
Simplified SPI (CSI) mode connection diagram (during communication at different potential)



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



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



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

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

(8) Communication at different potential (1.8 V, 2.5 V, 3 V) (Simplified SPI (CSI) mode) (slave mode, SCKp ... external clock input)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time[Note 1]	t_{KCY2}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V	20 MHz < f_{MCK} ≤ 24 MHz	12/f_{MCK}		—		ns
			8 MHz < f_{MCK} ≤ 20 MHz	10/f_{MCK}		—		ns
			4 MHz < f_{MCK} ≤ 8 MHz	8/f_{MCK}		16/f_{MCK}		ns
			f_{MCK} ≤ 4 MHz	6/f_{MCK}		10/f_{MCK}		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V	20 MHz < f_{MCK} ≤ 24 MHz	16/f_{MCK}		—		ns
			16 MHz < f_{MCK} ≤ 20 MHz	14/f_{MCK}		—		ns
			8 MHz < f_{MCK} ≤ 16 MHz	12/f_{MCK}		—		ns
			4 MHz < f_{MCK} ≤ 8 MHz	8/f_{MCK}		16/f_{MCK}		ns
			f_{MCK} ≤ 4 MHz	6/f_{MCK}		10/f_{MCK}		ns
		1.9 V[Note 6] ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V[Note 2]	20 MHz < f_{MCK} ≤ 24 MHz	36/f_{MCK}		—		ns
			16 MHz < f_{MCK} ≤ 20 MHz	32/f_{MCK}		—		ns
			8 MHz < f_{MCK} ≤ 16 MHz	26/f_{MCK}		—		ns
			4 MHz < f_{MCK} ≤ 8 MHz	16/f_{MCK}		16/f_{MCK}		ns
			f_{MCK} ≤ 4 MHz	10/f_{MCK}		10/f_{MCK}		ns
SCKp high-/low-level width	t_{KH2}, t_{KL2}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V		t_{KCY2}/2 – 12		t_{KCY2}/2 – 50		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V		t_{KCY2}/2 – 18		t_{KCY2}/2 – 50		ns
		1.9 V[Note 6] ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V[Note 2]		t_{KCY2}/2 – 50		t_{KCY2}/2 – 50		ns
SIp setup time (to SCKp↑)[Note 3]	t_{SIK2}	2.7 V ≤ EV_{DD} ≤ 5.5 V, 2.3 V ≤ V_b ≤ 4.0 V[Note 2]		1/f_{MCK} + 20		1/f_{MCK} + 30		ns
		1.9 V[Note 6] ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V[Note 2]		1/f_{MCK} + 30		1/f_{MCK} + 30		ns
SIp hold time (from SCKp↑)[Note 4]	t_{KSI2}	2.7 V ≤ EV_{DD} ≤ 5.5 V, 2.3 V ≤ V_b ≤ 4.0 V[Note 2]		1/f_{MCK} + 31		1/f_{MCK} + 31		ns
		1.9 V[Note 6] ≤ EV_{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 5]	t_{KSO2}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 30 pF, R_b = 1.4 kΩ			2/f_{MCK} + 120		2/f_{MCK} + 573	ns
		2.7 V ≤ EV_{DD} < 4.0 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	ns
		1.9 V[Note 6] ≤ EV_{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

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

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

2. Use it with $EV_{DD} \geq V_b$.

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

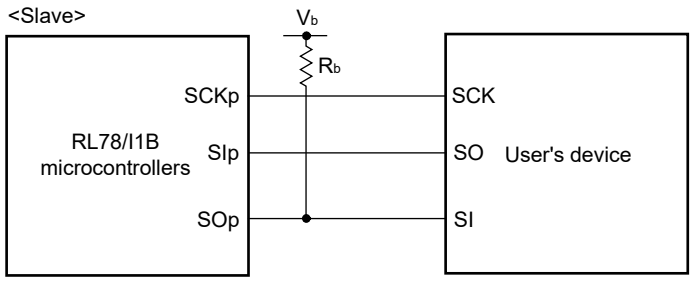
4. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

5. 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.

6. When HS (high-speed main) mode, this value becomes 2.4 V.

Caution Select the TTL input buffer for the SIp 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.

Simplified SPI (CSI) mode connection diagram (during communication at different potential)

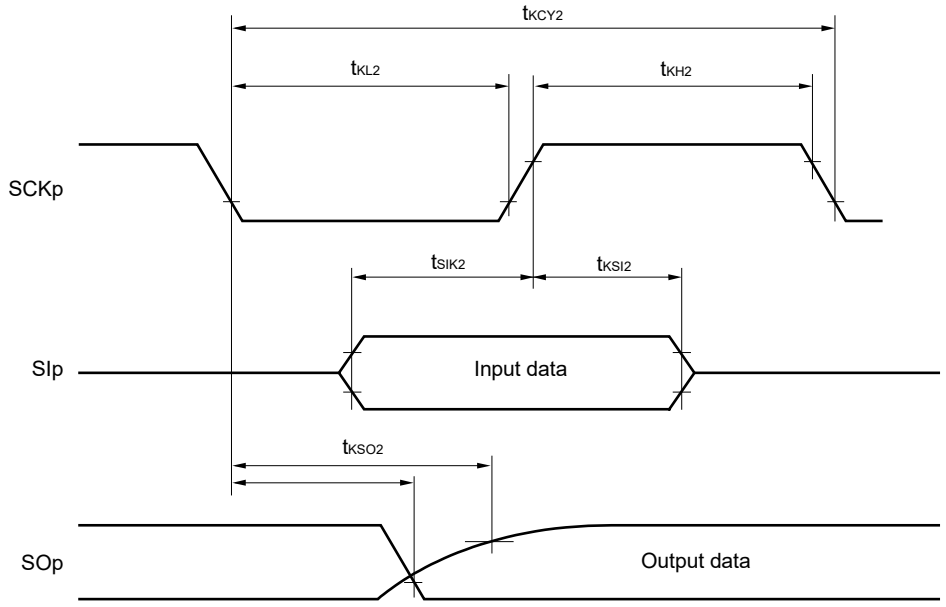


Remarks 1. R_b[Ω]:Communication line (SOp) pull-up resistance, C_b[F]: Communication line (SOp) load capacitance, V_b[V]: Communication line voltage

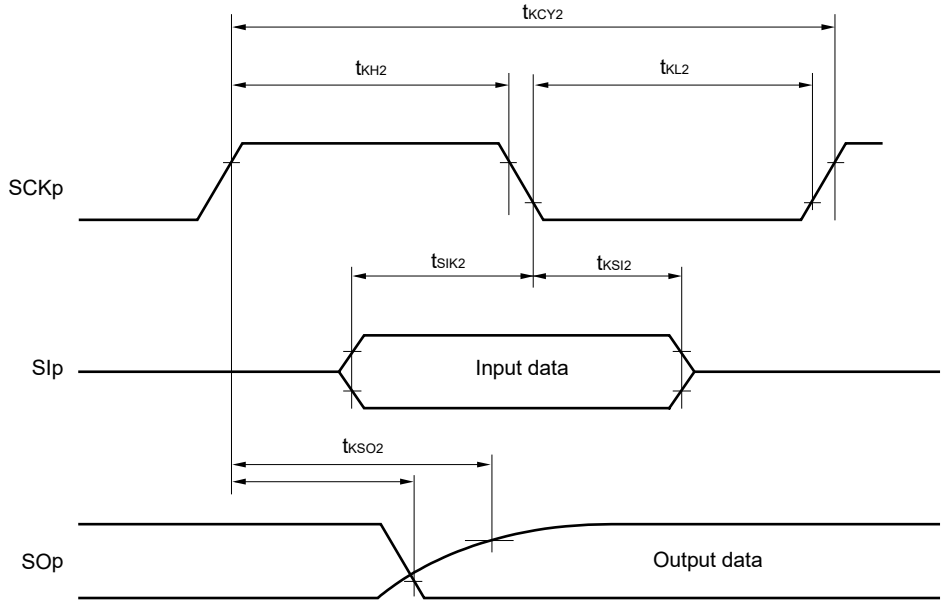
2. p: CSI number (p = 00), m: Unit number, n: Channel number (mn = 00),
g: PIM and POM number (g = 0, 1)

3. f_{MCK}: Serial array unit operation clock frequency
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00))

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



Simplified SPI (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 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.

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

(9) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I^2C mode) (1/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f_{SCL}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 50 pF, R_b = 2.7 kΩ		1000 Note 1		300 Note 1	kHz
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ		1000 Note 1		300 Note 1	kHz
		4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 100 pF, R_b = 2.8 kΩ		400 Note 1		300 Note 1	kHz
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 100 pF, R_b = 2.7 kΩ		400 Note 1		300 Note 1	kHz
		1.9 V Note 4 ≤ EV_{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}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1550		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1550		ns
		4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 100 pF, R_b = 2.8 kΩ	1150		1550		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 100 pF, R_b = 2.7 kΩ	1150		1550		ns
		1.9 V Note 4 ≤ EV_{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}	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 50 pF, R_b = 2.7 kΩ	245		610		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	200		610		ns
		4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 100 pF, R_b = 2.8 kΩ	675		610		ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 100 pF, R_b = 2.7 kΩ	600		610		ns
		1.9 V Note 4 ≤ EV_{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

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

(9) Communication at different potential (1.8 V, 2.5 V, 3 V) (simplified I^2C mode) (2/2)

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
Data setup time (reception)	$t_{SU:DAT}$	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 50 pF, R_b = 2.7 kΩ	1/f_{MCK} + 135 Note 3		1/f_{MCK} + 190 Note 3		ns
		2.7 V ≤ EV_{DD} < 4.0 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		ns
		4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 100 pF, R_b = 2.8 kΩ	1/f_{MCK} + 190 Note 3		1/f_{MCK} + 190 Note 3		ns
		2.7 V ≤ EV_{DD} < 4.0 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		ns
		1.9 V Note 4 ≤ EV_{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)	$t_{HD:DAT}$	4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 50 pF, R_b = 2.7 kΩ	0	305		305	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	0	305		305	ns
		4.0 V ≤ EV_{DD} ≤ 5.5 V, 2.7 V ≤ V_b ≤ 4.0 V, C_b = 100 pF, R_b = 2.8 kΩ	0	355		355	ns
		2.7 V ≤ EV_{DD} < 4.0 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 100 pF, R_b = 2.7 kΩ	0	355		355	ns
		1.9 V Note 4 ≤ EV_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2, C_b = 100 pF, R_b = 5.5 kΩ	0	405		405	ns

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

2. Use it with EV_{DD} ≥ V_b.

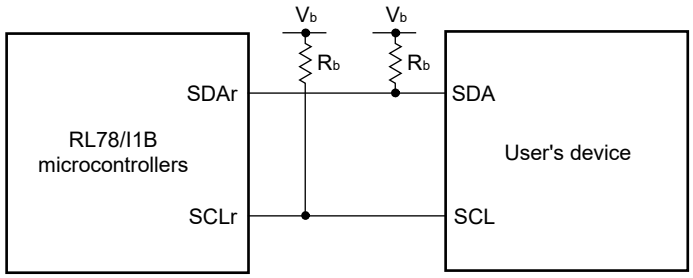
3. Set the f_{MCK} value to keep the hold time of SCLr = “L” and SCLr = “H”.

4. When HS (high-speed main) mode, this value becomes 2.4 V.

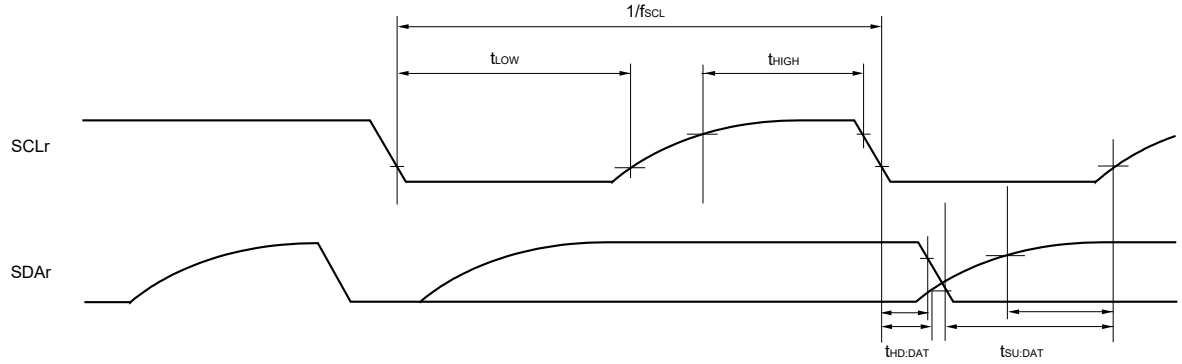
Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics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

(**Remarks** is listed on the next page.)

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



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



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.

Remarks 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
(Operating clock that is set with the serial clock select register m (SPSm) and the CKSmn bit of serial mode register mn (SMRmn).
m: Unit number, n: Channel number (mn = 00, 02))

2.5.2 Serial interface IICA

(1) I^2C standard mode

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Standard mode: f_{CLK} ≥ 1 MHz	2.7 V ≤ EV_{DD} ≤ 5.5 V	0	100	0	100	kHz
			1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V	0	100	0	100	kHz
Setup time of restart condition	$t_{SU:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs
Hold time[Note 1]	$t_{HD:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
Hold time when SCLA0 = “L”	t_{LOW}	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs
Hold time when SCLA0 = “H”	t_{HIGH}	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		250		250		ns
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		250		250		ns
Data hold time (transmission)[Note 2]	$t_{HD:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0	3.45	0	3.45	μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0	3.45	0	3.45	μs
Setup time of stop condition	$t_{SU:STO}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.0		4.0		μs
Bus-free time	t_{BUF}	2.7 V ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		4.7		4.7		μs

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

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

3. When HS (high-speed main) mode, this value becomes 2.4 V.

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

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

(2) I^2C fast mode

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Fast mode: f_{CLK} ≥ 3.5 MHz	2.7 V ≤ EV_{DD} ≤ 5.5 V	0	400	0	400	kHz
			1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V	0	400	0	400	kHz
Setup time of restart condition	$t_{SU:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
Hold time[Note 1]	$t_{HD:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
Hold time when SCLA0 = “L”	t_{LOW}	2.7 V ≤ EV_{DD} ≤ 5.5 V		1.3		1.3		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		1.3		1.3		µs
Hold time when SCLA0 = “H”	t_{HIGH}	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		100		100		ns
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		100		100		ns
Data hold time (transmission)[Note 2]	$t_{HD:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0	0.9	0	0.9	µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0	0.9	0	0.9	µs
Setup time of stop condition	$t_{SU:STO}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		0.6		0.6		µs
Bus-free time	t_{BUF}	2.7 V ≤ EV_{DD} ≤ 5.5 V		1.3		1.3		µs
		1.9 V[Note 3] ≤ EV_{DD} ≤ 5.5 V		1.3		1.3		µs

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

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

3. When HS (high-speed main) mode, this value becomes 2.4 V.

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) I^2C fast mode plus

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Fast mode plus: f_{CLK} ≥ 10 MHz	2.7 V ≤ EV_{DD} ≤ 5.5 V	0	1000	–	–	kHz
Setup time of restart condition	$t_{SU:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.26		–	–	μs
Hold time[Note 1]	$t_{HD:STA}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.26		–	–	μs
Hold time when SCLA0 = “L”	t_{LOW}	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.5		–	–	μs
Hold time when SCLA0 = “H”	t_{HIGH}	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.26		–	–	μs
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		50		–	–	ns
Data hold time (transmission)[Note 2]	$t_{HD:DAT}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0	0.45	–	–	μs
Setup time of stop condition	$t_{SU:STO}$	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.26		–	–	μs
Bus-free time	t_{BUF}	2.7 V ≤ EV_{DD} ≤ 5.5 V		0.5		–	–	μs

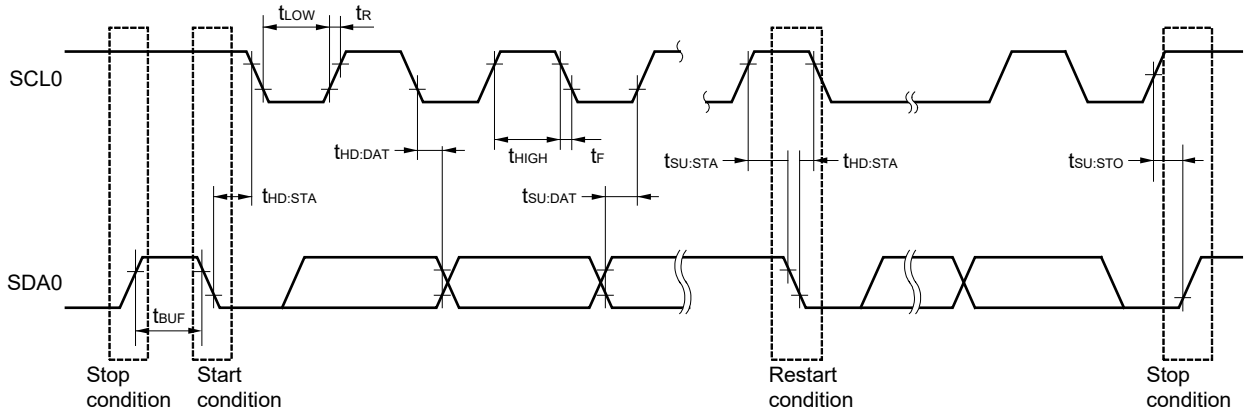
Notes 1. The first clock pulse is generated after this period when the start/restart condition is detected.

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

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

IICA serial transfer timing



2.6 Analog Characteristics

2.6.1 A/D converter characteristics

(1) When reference voltage (+) = AV_{REFP}/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (–) = AV_{REFM}/ANI1 (ADREFM = 1), target pins: ANI2 to ANI5 and internal reference voltage

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V, reference voltage (+) = AV_{REFP}, reference voltage (–) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			8		10	bit
Overall error[Notes 1, 2]	AINL	10-bit resolution AV_{REFP} = V_{DD}	1.9 V ≤ AV_{REFP} ≤ 5.5 V		1.2	±5.0	LSB
Conversion time	t_{CONV}	10-bit resolution	3.6 V ≤ V_{DD} ≤ 5.5 V	2.125		39	μs
			2.7 V ≤ V_{DD} ≤ 5.5 V	3.1875		39	μs
			1.9 V ≤ V_{DD} ≤ 5.5 V	17		39	μs
Zero-scale error[Notes 1, 2]	E_{ZS}	10-bit resolution AV_{REFP} = V_{DD}	1.9 V ≤ AV_{REFP} ≤ 5.5 V			±0.35	%FSR
Full-scale error[Notes 1, 2]	E_{FS}	10-bit resolution AV_{REFP} = V_{DD}	1.9 V ≤ AV_{REFP} ≤ 5.5 V			±0.35	%FSR
Integral linearity error[Note 1]	ILE	10-bit resolution AV_{REFP} = V_{DD}	1.9 V ≤ AV_{REFP} ≤ 5.5 V			±3.5	LSB
Differential linearity error[Note 1]	DLE	10-bit resolution AV_{REFP} = V_{DD}	1.9 V ≤ AV_{REFP} ≤ 5.5 V			±2.0	LSB
Reference voltage (+)	AV_{REFP}			1.9		V_{DD}	V
Analog input voltage	V_{AIN}			0		AV_{REFP}	V
	V_{BGR}	Select interanal reference voltage output 2.4 V ≤ V_{DD} ≤ 5.5 V, HS (high-speed main) mode		1.38	1.45	1.5	V

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

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

(2) When reference voltage (+) = V_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (–) = V_{SS} (ADREFM = 0), target pins: ANI0 to ANI5 and internal reference voltage

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V, reference voltage (+) = V_{DD}, reference voltage (–) = V_{SS})

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			8		10	bit
Overall error[Notes 1, 2]	AINL	10-bit resolution	1.9 V ≤ V_{DD} ≤ 5.5 V		1.2	±10.5	LSB
Conversion time	t_{CONV}	10-bit resolution	3.6 V ≤ V_{DD} ≤ 5.5 V	2.125		39	µs
			2.7 V ≤ V_{DD} ≤ 5.5 V	3.1875		39	µs
			1.9 V ≤ V_{DD} ≤ 5.5 V	17		39	µs
Zero-scale error[Notes 1, 2]	E_{ZS}	10-bit resolution	1.9 V ≤ V_{DD} ≤ 5.5 V			±0.85	%FSR
Full-scale error[Notes 1, 2]	E_{FS}	10-bit resolution	1.9 V ≤ V_{DD} ≤ 5.5 V			±0.85	%FSR
Integral linearity error[Note 1]	ILE	10-bit resolution	1.9 V ≤ V_{DD} ≤ 5.5 V			±4.0	LSB
Differential linearity error[Note 1]	DLE	10-bit resolution	1.9 V ≤ V_{DD} ≤ 5.5 V			±2.0	LSB
Analog input voltage	V_{AIN}			0		V_{DD}	V
	V_{BGR}	Select interanal reference voltage output, 2.4 V ≤ V_{DD} ≤ 5.5 V, HS (high-speed main) mode		1.38	1.45	1.5	V

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

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

Caution When using reference voltage (+) = V_{DD}, taking into account the voltage drop due to the effect of the power switching circuit of the battery backup function and use the A/D conversion result. In addition, enter HALT mode during A/D conversion and set V_{DD} port to input.

(3) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (–) = AV_{REFM}/ANI1 (ADREFM = 1), target pins: ANI0, ANI2 to ANI5

(T_A = –40 to +85°C, 2.4 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V, reference voltage (+) = V_{BGR}, reference voltage (–) = AV_{REFM} = 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} ≤ 5.5 V	17		39	µs
Zero-scale error[Notes 1, 2]	E_{ZS}	8-bit resolution	2.4 V ≤ V_{DD} ≤ 5.5 V			±0.60	%FSR
Integral linearity error[Note 1]	ILE	8-bit resolution	2.4 V ≤ V_{DD} ≤ 5.5 V			±2.0	LSB
Differential linearity error[Note 1]	DLE	8-bit resolution	2.4 V ≤ V_{DD} ≤ 5.5 V			±1.0	LSB
Reference voltage (+)	V_{BGR}			1.38	1.45	1.5	V
Analog input voltage	V_{AIN}			0		V_{BGR}	V

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

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

2.6.2 24-bit ΔΣ A/D converter characteristics

(1) Reference voltage

(T_A = –40 to +85°C, $AV_{DD} \leq V_{DD}$ + 0.3 V, 2.4 V ≤ AV_{DD} ≤ 5.5 V, 2.4 V ≤ V_{DD} ≤ 5.5 V, $V_{SS} = AV_{SS}$ = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Internal reference voltage	V_{AVRTO}			0.8		V
Temperature coefficient for internal reference voltage	dREF/dt	0.47 µF capacitor connected to AREGC, AVRT, and AVCM pins		30	90	ppm/°C

(2) Analog input

(T_A = –40 to +85°C, $AV_{DD} \leq V_{DD}$ + 0.3 V, 2.4 V ≤ AV_{DD} ≤ 5.5 V, 2.4 V ≤ V_{DD} ≤ 5.5 V, $V_{SS} = AV_{SS}$ = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage range (differential voltage)	V_{AIN}	x1 gain	–500		500	mV
		x2 gain	–250		250	
		x4 gain	–125		125	
		x8 gain	–62.5		62.5	
		x16 gain	–31.25		31.25	
		x32 gain (for current channels)	–15.625		15.625	
Input gain	ainGAIN	x1 gain		1		dB
		x2 gain		2		
		x4 gain		4		
		x8 gain		8		
		x16 gain		16		
		x32 gain (for current channels)		32		
Input impedance	ainRIN	Differential voltage	150	360		kΩ
		Single-ended voltage	100	240		

(3) 4 kHz sampling mode

(T_A = –40 to +85°C, $AV_{DD} \leq V_{DD}$ + 0.3 V, 2.4 V ≤ AV_{DD} ≤ 5.5 V, 2.4 V ≤ V_{DD} ≤ 5.5 V, $V_{SS} = AV_{SS}$ = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Operation clock	f_{DSAD}	f_X oscillation clock, input external clock or high-speed on-chip oscillator clock is used		12		MHz
Sampling frequency	f_S			3906.25		Hz
Oversampling frequency	f_{OS}			1.5		MHz
Output data rate	T_{DATA}			256		µs
Data width	RES			24		bit
SNDR	SNDR	x1 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)		80		dB
		x16 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)	69	74		
		x32 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)	65	69		
Passband (low pass band)	f_{Chpf}	At –3 dB (phase in high pass filter not adjusted) Bits 7 and 6 of DSADHPFCR register (DSADCOF1, DSADCOF0) = 00		0.607		Hz
		At –3 dB (phase in high pass filter not adjusted) Bits 7 and 6 of DSADHPFCR register (DSADCOF1, DSADCOF0) = 01		1.214		Hz
		At –3 dB (phase in high pass filter not adjusted) Bits 7 and 6 of DSADHPFCR register (DSADCOF1, DSADCOF0) = 10		2.429		Hz
		At –3 dB (phase in high pass filter not adjusted) Bits 7 and 6 of DSADHPFCR register (DSADCOF1, DSADCOF0) = 11		4.857		Hz
In-band ripple 1	rp1	45 Hz to 55 Hz @50 Hz 54 Hz to 66 Hz @60 Hz	–0.01		0.01	dB
In-band ripple 2	rp2	45 Hz to 275 Hz @50 Hz 54 Hz to 330 Hz @60 Hz	–0.1		0.1	
In-band ripple 3	rp3	45 Hz to 1100 Hz @50 Hz 54 Hz to 1320 Hz @60 Hz	–0.1		0.1	
Passband (high pass band)	f_{Clpf}	–3 dB		1672		Hz
Stopband (high pass band)	fatt	–80 dB		2545		Hz
Out-band attenuation	ATT1	f_S	–80			dB
	ATT2	2 f_S	–80			dB

(4) 2 kHz sampling mode

(T_A = –40 to +85°C, $AV_{DD} \leq V_{DD}$ + 0.3 V, 2.4 V ≤ AV_{DD} ≤ 5.5 V, 2.4 V ≤ V_{DD} ≤ 5.5 V, V_{SS} = AV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Operation clock	f_{DSAD}	f_X oscillation clock, input external clock or high-speed on-chip oscillator clock is used		12		MHz
Sampling frequency	f_S			1953.125		Hz
Oversampling frequency	f_{OS}			0.75		MHz
Output data rate	T_{DATA}			512		µs
Data width	RES			24		bit
SNDR	SNDR	x1 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)		80		dB
		x16 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)	69	74		
		x32 gain High-speed system clock is selected as operating clock of 24-bit ΔΣ A/D converter (bit 0 of PCKC register (DSADCK) = 1)	65	69		
Passband (low pass band)	f_{Chpf}	At –3 dB (phase in high pass filter not adjusted)		0.303		Hz
In-band ripple 1	rp1	45 Hz to 55 Hz @50 Hz 54 Hz to 66 Hz @60 Hz	–0.01		0.01	dB
In-band ripple 2	rp2	45 Hz to 275 Hz @50 Hz 54 Hz to 330 Hz @60 Hz	–0.1		0.1	
In-band ripple 3	rp3	45 Hz to 660 Hz @50 Hz 54 Hz to 550 Hz @60 Hz	–0.1		0.1	
Passband (high pass band)	f_{Clpf}	–3 dB		836		Hz
Stopband (high pass band)	fatt	–80 dB		1273		Hz
Out-band attenuation	ATT1	f_S	–80			dB
	ATT2	2 f_S	–80			dB

2.6.3 Temperature sensor 2 characteristics

(T_A = –40 to +85°C, 2.4 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V, HS (high-speed main) mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor 2 output voltage	V_{OUT}			0.67		V
Temperature coefficient	F_{VTMPS2}	Temperature sensor that depends on the temperature	–11.7	–10.7	–9.7	mV/°C
Operation stabilization wait time[Note]	t_{TMPON}	Operable		15	50	µs
	t_{TMPCHG}	Switching mode		5	15	µs

Note Time to drop to output stable value ±5LSB (±7 mV) or less.

2.6.4 Comparator

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage range	Ivref			0		V_{DD} – 1.4	V
	Ivcmp			–0.3		V_{DD} + 0.3	V
Output delay	td	V_{DD} = 3.0 V Input slew rate > 50 mV/μs	Comparator high-speed mode, standard mode			1.2	μs
			Comparator high-speed mode, window mode			2.0	μs
			Comparator low-speed mode, standard mode		3	5.0	μs
High-electric-potential reference voltage	VTW+	Comparator high-speed mode, window mode			0.76V_{DD}		V
Low-electric-potential reference voltage	VTW–	Comparator high-speed mode, window mode			0.24V_{DD}		V
Operation stabilization wait time	t_{CMP}			100			μs
Reference output voltage	V_{CMPREF}			1.00	1.45	1.50	V

2.6.5 POR circuit characteristics

(T_A = –40 to +85°C, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{POR}	When power supply rises[Note 1]	1.47	1.51	1.55	V
	V_{PDR}	When power supply falls[Note 2]	1.46	1.50	1.54	V

Notes 1. Be sure to maintain the reset state until the power supply voltage rises over the minimum V_{DD} value in the operating voltage range specified in **2.4 AC Characteristics**, by using the voltage detector or external reset pin.

2. If the power supply voltage falls while the voltage detector is off, be sure to either shift to STOP mode or execute a reset by using the voltage detector or external reset pin before the power supply voltage falls below the minimum operating voltage specified in **2.4 AC Characteristics**.

2.6.6 LVD circuit characteristics

LVD Detection Voltage of Reset Mode and Interrupt Mode

(T_A = –40 to +85°C, $V_{PDR} \leq V_{DD} = EV_{DD} \leq 5.5$ V, $V_{SS} = EV_{SS}$ = 0 V)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	Supply voltage level	V_{LVD0}	When power supply rises	3.98	4.06	4.24	V
			When power supply falls	3.90	3.98	4.16	V
		V_{LVD1}	When power supply rises	3.68	3.75	3.92	V
			When power supply falls	3.60	3.67	3.84	V
		V_{LVD2}	When power supply rises	3.07	3.13	3.29	V
			When power supply falls	3.00	3.06	3.22	V
		V_{LVD3}	When power supply rises	2.96	3.02	3.18	V
			When power supply falls	2.90	2.96	3.12	V
		V_{LVD4}	When power supply rises	2.86	2.92	3.07	V
			When power supply falls	2.80	2.86	3.01	V
		V_{LVD5}	When power supply rises	2.76	2.81	2.97	V
			When power supply falls	2.70	2.75	2.91	V
		V_{LVD6}	When power supply rises	2.66	2.71	2.86	V
			When power supply falls	2.60	2.65	2.80	V
		V_{LVD7}	When power supply rises	2.56	2.61	2.76	V
			When power supply falls	2.50	2.55	2.70	V
		V_{LVD8}	When power supply rises	2.45	2.50	2.65	V
			When power supply falls	2.40	2.45	2.60	V
		V_{LVD9}	When power supply rises	2.05	2.09	2.23	V
			When power supply falls	2.00	2.04	2.18	V
		V_{LVD10}	When power supply rises	1.94	1.98	2.12	V
			When power supply falls	1.90	1.94	2.08	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°C, $V_{PDR} \leq V_{DD} = EV_{DD} \leq 5.5$ V, $V_{SS} = EV_{SS}$ = 0 V)

Parameter	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
	V_{LVD8}	VPOC2, VPOC1, VPOC0 = 0, 1, 0, falling reset voltage			2.40	2.45	2.60	V
	V_{LVD7}		LVIS1, LVIS0 = 1, 0	Rising release reset voltage	2.56	2.61	2.76	V
				Falling interrupt voltage	2.50	2.55	2.70	V
	V_{LVD6}		LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.66	2.71	2.86	V
				Falling interrupt voltage	2.60	2.65	2.80	V
	V_{LVD1}		LVIS1, LVIS0 = 0, 0	Rising release reset voltage	3.68	3.75	3.92	V
				Falling interrupt voltage	3.60	3.67	3.84	V
	V_{LVD5}	VPOC2, VPOC1, VPOC0 = 0, 1, 1, falling reset voltage			2.70	2.75	2.91	V
	V_{LVD4}		LVIS1, LVIS0 = 1, 0	Rising release reset voltage	2.86	2.92	3.07	V
				Falling interrupt voltage	2.80	2.86	3.01	V
	V_{LVD3}		LVIS1, LVIS0 = 0, 1	Rising release reset voltage	2.96	3.02	3.18	V
				Falling interrupt voltage	2.90	2.96	3.12	V
	V_{LVD0}		LVIS1, LVIS0 = 0, 0	Rising release reset voltage	3.98	4.06	4.24	V
				Falling interrupt voltage	3.90	3.98	4.16	V

2.6.7 Power supply voltage rising slope characteristics

(T_A = –40 to +85°C, V_{SS} = 0 V)

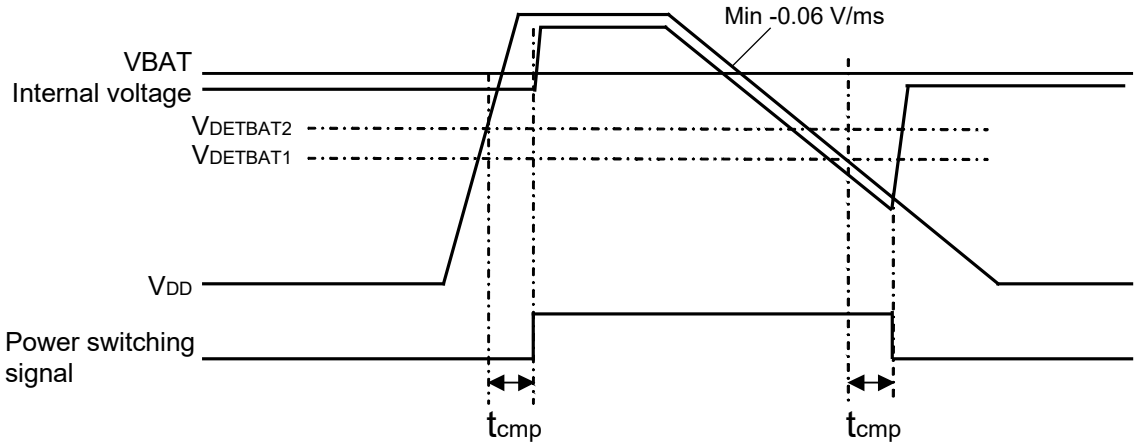
Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Power supply voltage rising slope	SV_{DDR}				54	V/ms

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 2.4 AC Characteristics.

2.7 Battery Backup Function

(T_A = –40 to +85°C, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Power swiching detection voltage	$V_{DETBAT1}$	V_{DD} → VBAT	1.92	2.00	2.08	V
	$V_{DETBAT2}$	VBAT → V_{DD}	2.02	2.10	2.18	V
V_{DD} fall slope	SV_{DDF}		–0.06			V/ms
Response time of power switch detector	t_{cmp}				300	µs



2.8 LCD Characteristics

2.8.1 Resistance division method

(1) Static display mode

(T_A = –40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	V_{L4}		2.0		V_{DD}	V

(2) 1/2 bias method, 1/4 bias method

(T_A = –40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	V_{L4}		2.7		V_{DD}	V

(3) 1/3 bias method

(T_A = –40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	V_{L4}		2.5		V_{DD}	V

2.8.2 Internal voltage boosting method

(1) 1/3 bias method

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	V_{L1}	C1 to C4[Note 1] = 0.47 μF[Note 2]	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
			VLCD = 0BH	1.25	1.35	1.43	V
			VLCD = 0CH	1.30	1.40	1.48	V
			VLCD = 0DH	1.35	1.45	1.53	V
			VLCD = 0EH	1.40	1.50	1.58	V
			VLCD = 0FH	1.45	1.55	1.63	V
			VLCD = 10H	1.50	1.60	1.68	V
			VLCD = 11H	1.55	1.65	1.73	V
			VLCD = 12H	1.60	1.70	1.78	V
			VLCD = 13H	1.65	1.75	1.83	V
Doubler output voltage	V_{L2}	C1 to C4[Note 1] = 0.47 μF		2 V_{L1}–0.10	2 V_{L1}	2 V_{L1}	V
Tripler output voltage	V_{L4}	C1 to C4[Note 1] = 0.47 μF		3 V_{L1}–0.15	3 V_{L1}	3 V_{L1}	V
Reference voltage setup time[Note 2]	t_{VWAIT1}			5			ms
Voltage boost wait time[Note 3]	t_{VWAIT2}	C1 to C4[Note 1] = 0.47 μF		500			ms

Notes 1. This is a capacitor that is connected between voltage pins used to drive the LCD.
C1: A capacitor connected between CAPH and CAPL
C2: A capacitor connected between V_{L1} and GND
C3: A capacitor connected between V_{L2} and GND
C4: A capacitor connected between V_{L4} and GND
C1 = C2 = C3 = C4 = 0.47 μF±30 %

2. This is the time required to wait from when the reference voltage is specified by using the VLCD register (or when the internal voltage boosting method is selected (by setting the MDSET1 and MDSET0 bits of the LCDM0 register to 01B) if the default value reference voltage is used) until voltage boosting starts (VLCON = 1).

3. This is the wait time from when voltage boosting is started (VLCON = 1) until display is enabled (LCDON = 1).

(2) 1/4 bias method

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	V_{L1}	C1 to C5[Note 1] = 0.47 μF[Note 2]	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
Doubler output voltage	V_{L2}	C1 to C5[Note 1] = 0.47 μF		2 V_{L1}–0.08	2 V_{L1}	2 V_{L1}	V
Tripler output voltage	V_{L3}	C1 to C5[Note 1] = 0.47 μF		3 V_{L1}–0.12	3 V_{L1}	3 V_{L1}	V
Quadruply output voltage	V_{L4}	C1 to C5[Note 1] = 0.47 μF		4 V_{L1}–0.16	4 V_{L1}	4 V_{L1}	V
Reference voltage setup time[Note 2]	t_{VWAIT1}			5			ms
Voltage boost wait time[Note 3]	t_{VWAIT2}	C1 to C5[Note 1] = 0.47 μF		500			ms

Notes 1. This is a capacitor that is connected between voltage pins used to drive the LCD.
C1: A capacitor connected between CAPH and CAPL
C2: A capacitor connected between V_{L1} and GND
C3: A capacitor connected between V_{L2} and GND
C4: A capacitor connected between V_{L3} and GND
C5: A capacitor connected between V_{L4} and GND
C1 = C2 = C3 = C4 = C5 = 0.47 μF±30 %

2. This is the time required to wait from when the reference voltage is specified by using the VLCD register (or when the internal voltage boosting method is selected (by setting the MDSET1 and MDSET0 bits of the LCDM0 register to 01B) if the default value reference voltage is used) until voltage boosting starts (VLCON = 1).

3. This is the wait time from when voltage boosting is started (VLCON = 1) until display is enabled (LCDON = 1).

2.8.3 Capacitor split method

(1) 1/3 bias method

(T_A = –40 to +85°C, 2.2 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
V_{L4} voltage	V_{L4}	C1 to C4 = 0.47 μF[Note 2]		V_{DD}		V
V_{L2} voltage	V_{L2}	C1 to C4 = 0.47 μF[Note 2]	2/3 V_{L4}– 0.1	2/3 V_{L4}	2/3 V_{L4} + 0.1	V
V_{L1} voltage	V_{L1}	C1 to C4 = 0.47 μF[Note 2]	1/3 V_{L4}– 0.1	1/3 V_{L4}	1/3 V_{L4} + 0.1	V
Capacitor split wait time[Note 1]	t_{VWAIT}		100			ms

Notes 1. This is the wait time from when voltage bucking is started (VLCON = 1) until display is enabled (LCDON = 1).

2. This is a capacitor that is connected between voltage pins used to drive the LCD.

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between V_{L1} and GND

C3: A capacitor connected between V_{L2} and GND

C4: A capacitor connected between V_{L4} and GND

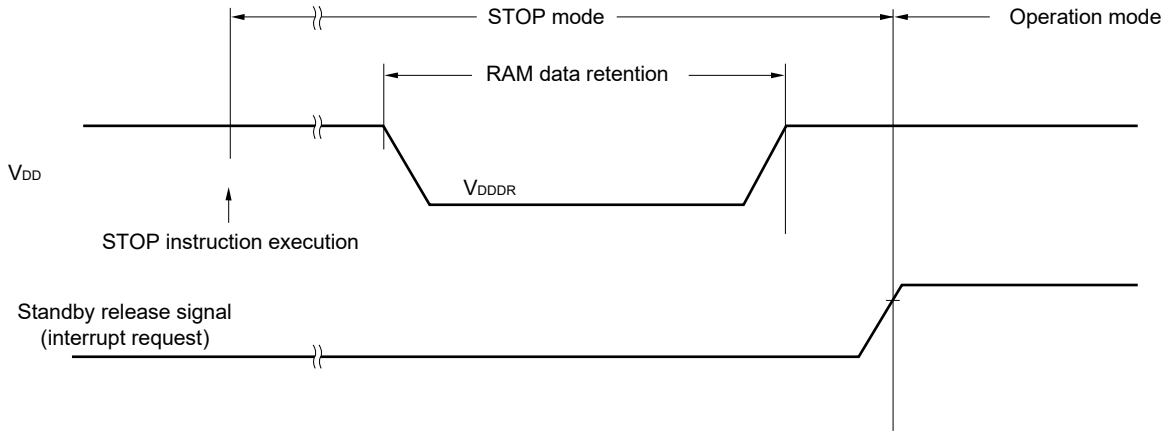
C1 = C2 = C3 = C4 = 0.47 μF±30 %

2.9 RAM Data Retention Characteristics

(T_A = –40 to +85°C, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	V_{DDDR}		1.46[Note]		5.5	V

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



2.10 Flash Memory Programming Characteristics

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
System clock frequency	f_{CLK}	1.9 V ≤ V_{DD} ≤ 5.5 V	1		24	MHz
Number of code flash rewrites[Notes 1, 2, 3]	C_{erwr}	Retained for 20 years T_A = 85°C	1,000			Times

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

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

3. This characteristic indicates the flash memory characteristic and based on Renesas Electronics reliability test.

2.11 Dedicated Flash Memory Programmer Communication (UART)

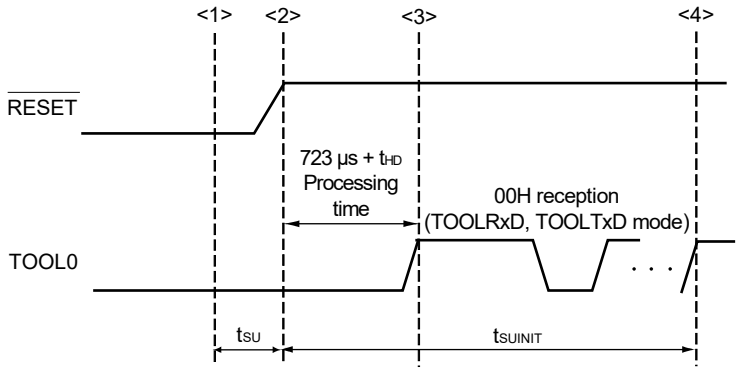
(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

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

2.12 Timing Specs for Switching Flash Memory Programming Modes

(T_A = –40 to +85°C, 1.9 V ≤ V_{DD} = EV_{DD} ≤ 5.5 V, V_{SS} = EV_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Time to complete the communication for the initial setting after the external reset is released	t_{SUINIT}	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_{SUINIT}: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.

t_{SU}: 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)

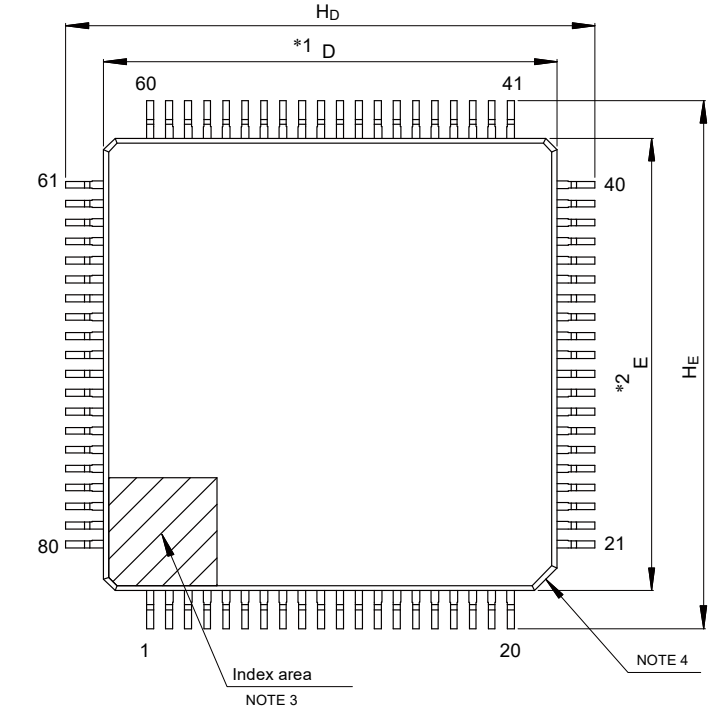
3. PACKAGE DRAWINGS

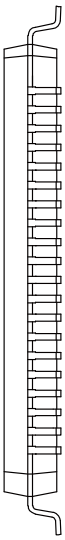
<R> 3.1 80-pin Products

R5F10MMEDFB, R5F10MMGDFB

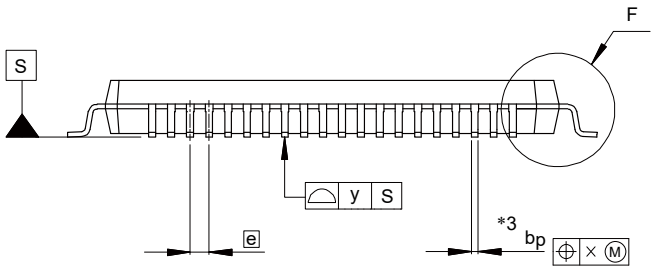
JEITA Package Code	RENESAS Code	Previous Code	MASS (Typ) [g]
P-LFQFP80-12x12-0.50	PLQP0080KB-B	—	0.5

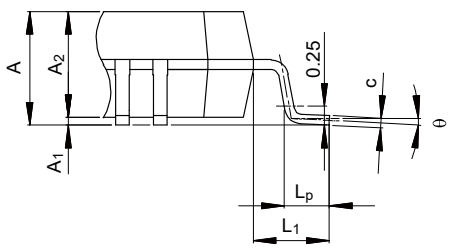
Unit: mm





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



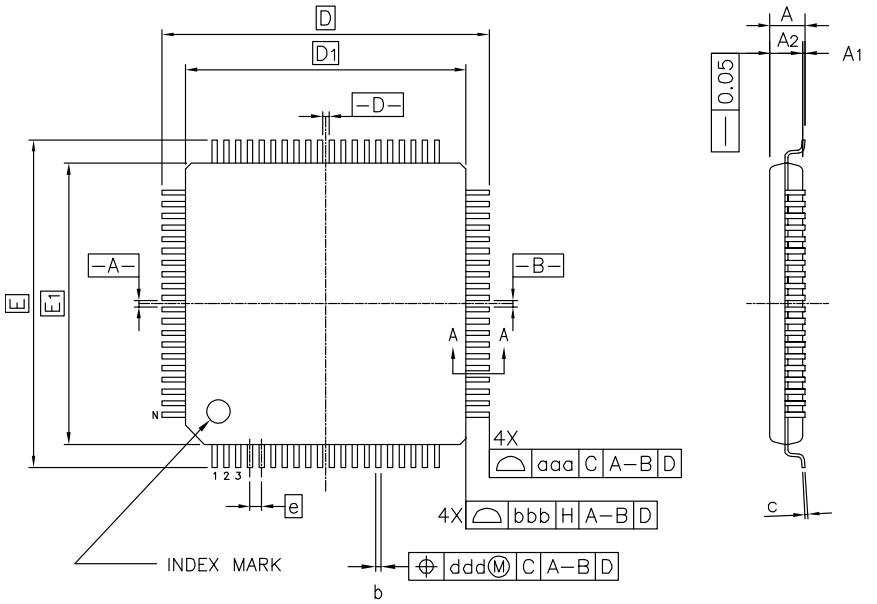


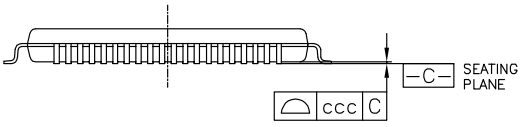
Detail F

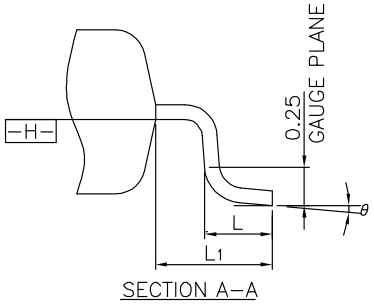
Reference Symbol	Dimensions in millimeters		
	Min	Nom	Max
D	11.9	12.0	12.1
E	11.9	12.0	12.1
A_2	—	1.4	—
H_D	13.8	14.0	14.2
H_E	13.8	14.0	14.2
A	—	—	1.7
A_1	0.05	—	0.15
b_p	0.15	0.20	0.27
c	0.09	—	0.20
θ	0°	3.5°	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
L_p	0.45	0.6	0.75
L_1	—	1.0	—

<R>

JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-LFQFP80-12x12-0.50	PLQP0080KJ-A	0.49



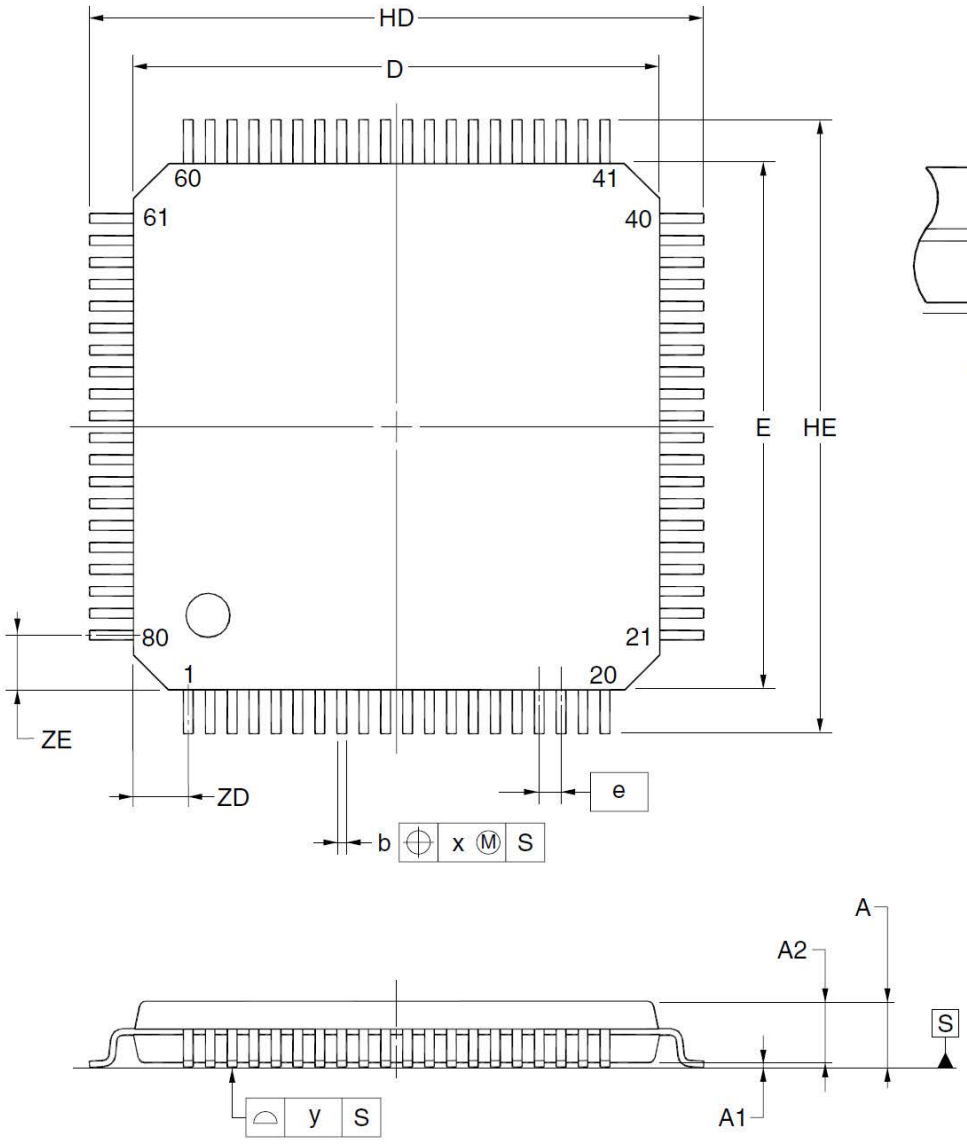


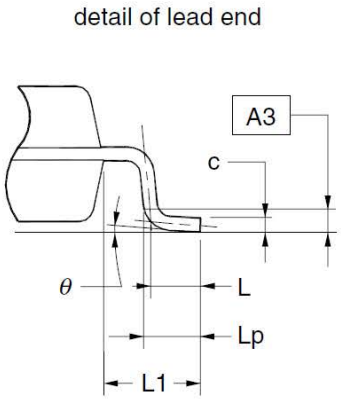


Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	1.60
A_1	0.05	—	0.15
A_2	1.35	1.40	1.45
D	—	14.00	—
D_1	—	12.00	—
E	—	14.00	—
E_1	—	12.00	—
N	—	80	—
e	—	0.50	—
b	0.17	0.22	0.27
c	0.09	—	0.20
θ	0°	3.5°	7°
L	0.45	0.60	0.75
L_1	—	1.00	—
aaa	—	—	0.20
bbb	—	—	0.20
ccc	—	—	0.08
ddd	—	—	0.08

<R>

JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-LFQFP80-12x12-0.50	PLQP0080KE-A	P80GK-50-8EU	0.53





(UNIT:mm)

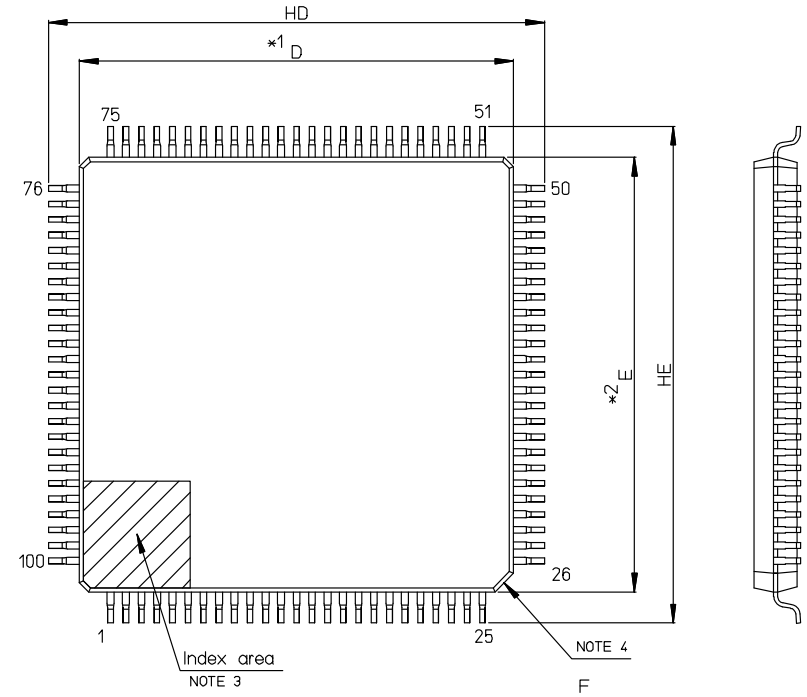
ITEM	DIMENSIONS
D	12.00±0.20
E	12.00±0.20
HD	14.00±0.20
HE	14.00±0.20
A	1.60 MAX.
A1	0.10±0.05
A2	1.40±0.05
A3	0.25
b	0.22±0.05
c	$0.145^{+0.055}_{-0.045}$
L	0.50
Lp	0.60±0.15
L1	1.00±0.20
θ	$3^{\circ}{}^{+5^{\circ}}_{-3^{\circ}}$
e	0.50
x	0.08
y	0.08
ZD	1.25
ZE	1.25

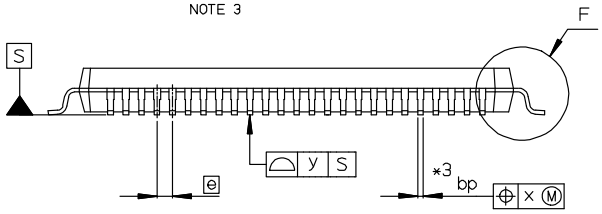
NOTE
Each lead centerline is located within 0.08 mm of its true position at maximum material condition.

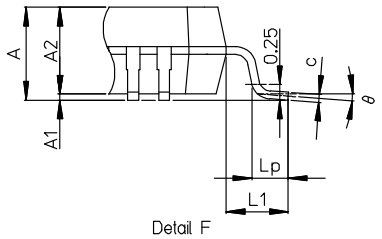
3.2 100-pin Products

<R> R5F10MPEDFB, R5F10MPGDFB

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LFQFP100-14x14-0.50	PLQP0100KB-B	——	0.6g





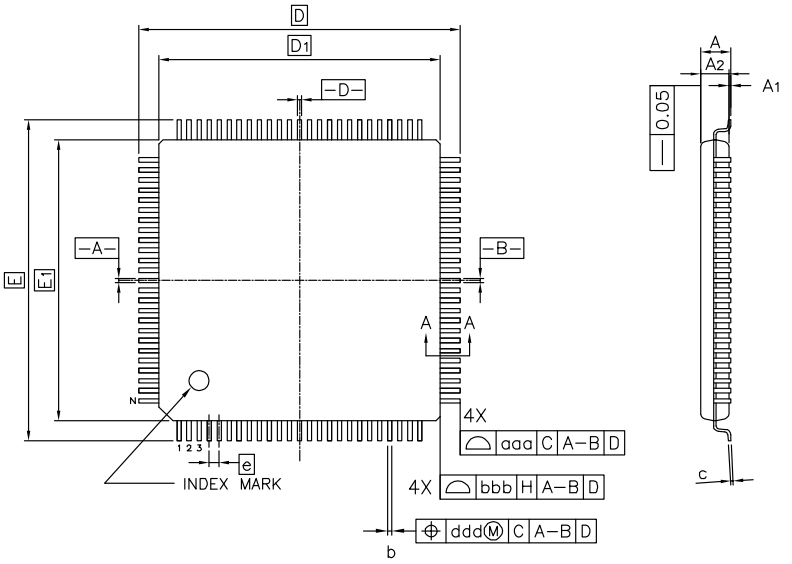


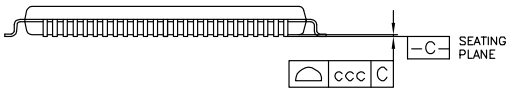
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.
3. PIN 1 VISUAL INDEX FEATURE MAY VARY, BUT MUST BE LOCATED WITHIN THE HATCHED AREA.
4. CHAMFERS AT CORNERS ARE OPTIONAL; SIZE MAY VARY.

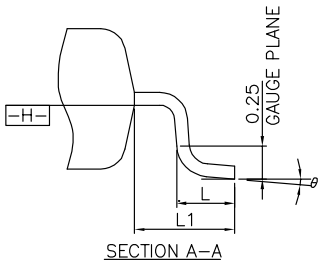
Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A2	——	1.4	——
HD	15.8	16.0	16.2
HE	15.8	16.0	16.2
A	——	——	1.7
A1	0.05	——	0.15
bp	0.15	0.20	0.27
c	0.09	——	0.20
θ	0°	3.5°	8°
e	——	0.5	——
x	——	——	0.08
y	——	——	0.08
Lp	0.45	0.6	0.75
L1	——	1.0	——

<R>

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







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

Rev.	Date	Description	
		Page	Summary
0.10	Dec 27, 2012	–	First Edition issued
1.00	Sep 17, 2013	1	Modification of 1.1 Features
		2, 3	Modification of 1.2 Ordering Information
		11-71	Modification of 2. ELECTRICAL SPECIFICATION
2.00	Mar 26, 2014	1	Modification of 1.1 Features
		3	Modification of 1.2 List of Part Numbers
		4, 5	Modification of 1.3 Pin Configuration (Top View)
		13, 15, 16, 21, 26 to 28, 30, 32, 34, 58, 59, 61, 63, 69 to 71	Modification of 2. ELECTRICAL SPECIFICATION
		73	Modification of 3.1 80-pin products
2.10	Apr 25, 2016	4	Modification of Top View in 1.3.1 80-pin products
		5	Modification of Top View in 1.3.2 100-pin products
		9	Modification of Main system clock in1.6 Outline of Functions
		21	Modification of on-chip pull-up resistance in 2.3.1 Pin characteristics
		22	Modification of supply current in 2.3.2 Supply current characteristics
		62	Modification of sampling frequency in 2.6.2 24-bit ΔΣ A/D converter characteristics
		71	Modification of title in 2.9 RAM Data Retention Characteristics
		71	Modification of note in 2.9 RAM Data Retention Characteristics
		71	Modification of figure in 2.9 RAM Data Retention Characteristics
		71	Modification of table in 2.10 Flash Memory Programming Characteristics
2.30	Jun, 28 2024	ALL	The module name for 3-wire serial I/O and 3-wire serial were changed to simplified SPI.
		ALL	The module name for CSI was changed to simplified SPI
		ALL	"Wait" was modified to "clock stretch"
		1	Addition of Note 1 in 1.1 Features
		3	Modification of Figure 1-1. Part Number, Memory Size, and Package of RL78/I1B
		3	Modification of Table 1-1. List of Ordering Part Numbers
		23	Modification of Notes 1 and 4 in 2.3.2 Supply current characteristics
		24	Modification of Note 7 to Note 6 in 2.3.2 Supply current characteristics
		24	Modification of Note 8 to Note 7 in 2.3.2 Supply current characteristics
		24	Deletion of Note 6 in 2.3.2 Supply current characteristics
		25	Modification of Notes 1 and 5 and delete Notes 6 in 2.3.2 Supply current characteristics
		73	Modification of package drawing in 3.1 80-pin Package (PLQP0080KB-B)
		74	Addition of package drawing in 3.1 80-pin Package (PLQP0080KJ-A)
		75	Addition of PLQP0080KE-A in 3.1 80-pin Products
		76	Modification of package drawing in 3.2 100-pin Package (PLQP0100KB-B)
		77	Addition of package drawing in 3.2 100-pin Package (PLQP0100KP-A)

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

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

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

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