

True low-power platform (58.3 $\mu\text{A}/\text{MHz}$, and 0.64 μA for operation with only LVD) for the general-purpose applications, with 1.6-V to 5.5-V operation, 16-Kbyte code flash memory, and 33 DMIPS at 24 MHz

1. OUTLINE

1.1 Features

Ultra-low power consumption technology

- $V_{DD} = 1.6 \text{ V to } 5.5 \text{ V}$
- 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 (66.6 μs : @ 15 kHz operation with low-speed on-chip oscillator clock)
- Multiply/divide/multiply & accumulate instructions are supported.
- Address space: 1 Mbytes
- General-purpose registers: (8-bit register $\times 8$) \times 4 banks
- On-chip RAM: 1.5 Kbytes

Code flash memory

- Code flash memory: 16 Kbytes
- Block size: 1 Kbytes
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

Data flash memory

- Data flash memory: 2 Kbytes
- Back ground operation (BGO): Instructions can be executed from the program memory while rewriting the data flash memory.
- Number of rewrites: 1,000,000 times (TYP.)
- Voltage of rewrites: $V_{DD} = 1.8 \text{ to } 5.5 \text{ V}$

High-speed on-chip oscillator

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

Middle-speed on-chip oscillator

- Selectable from 4 MHz, 2 MHz, and 1 MHz.

Operating ambient temperature

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

Power management and reset function

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

Data transfer controller (DTC)

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

Event link controller (ELC)

- Event signals of 18 types can be linked to the specified peripheral function.

Serial interfaces

- Simplified SPI (CSI Note 1): 4 channels
- UART: 2 channels
- I²C/simplified I²C: 4 channels
- Multimaster I²C: 2 channels

Timers

- 16-bit timer (TAU): 4 channels
- TKB: 1 channel
- 12-bit interval timer: 1 channel
- 8-bit interval timer: 2 channels
- Watchdog timer: 1 channel

A/D converter

- 8/10-bit resolution A/D converter (VDD = 1.6 to 5.5 V)
- Analog input: 10 to 11 channels
- Internal reference voltage (1.45 V) and temperature sensor

D/A converter

- 8/10-bit resolution D/A converter (VDD = 1.6 to 5.5 V)
- Analog input: 2 channels (channel 1: output to the ANO1 pin, channel 0: output to the comparator)
- Output voltage: 0 V to VDD
- Real-time output function

Comparator

- 2 channels
- Operating modes: Comparator high-speed mode, comparator low-speed mode, window mode

PGA

- 1 channels

I/O ports

- I/O port: 17 to 21 (N-ch open drain I/O [VDD withstand voltage^{Note 2}/EVDD withstand voltage^{Note 3}]: 10 to 14)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- Different potential interface: Can connect to a 1.8/2.5/3.0 V device
- On-chip key interrupt function
- On-chip clock output/buzzer output controller

Others

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

Note 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.

Note 2. 16, 20, 24-pin products

Note 3. 25-pin products

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

○ ROM, RAM capacities

Flash ROM	Data flash	RAM	RL78/G11				
			10 pins	16 pins	20 pins	24 pins	25 pins
16 KB	2 KB	1.5 KB	R5F1051A	R5F1054A	R5F1056A	R5F1057A	R5F1058A

Remark The flash library uses RAM in self-programming and rewriting of the data flash memory. The target products and start address of the RAM areas used by the flash library are shown below.

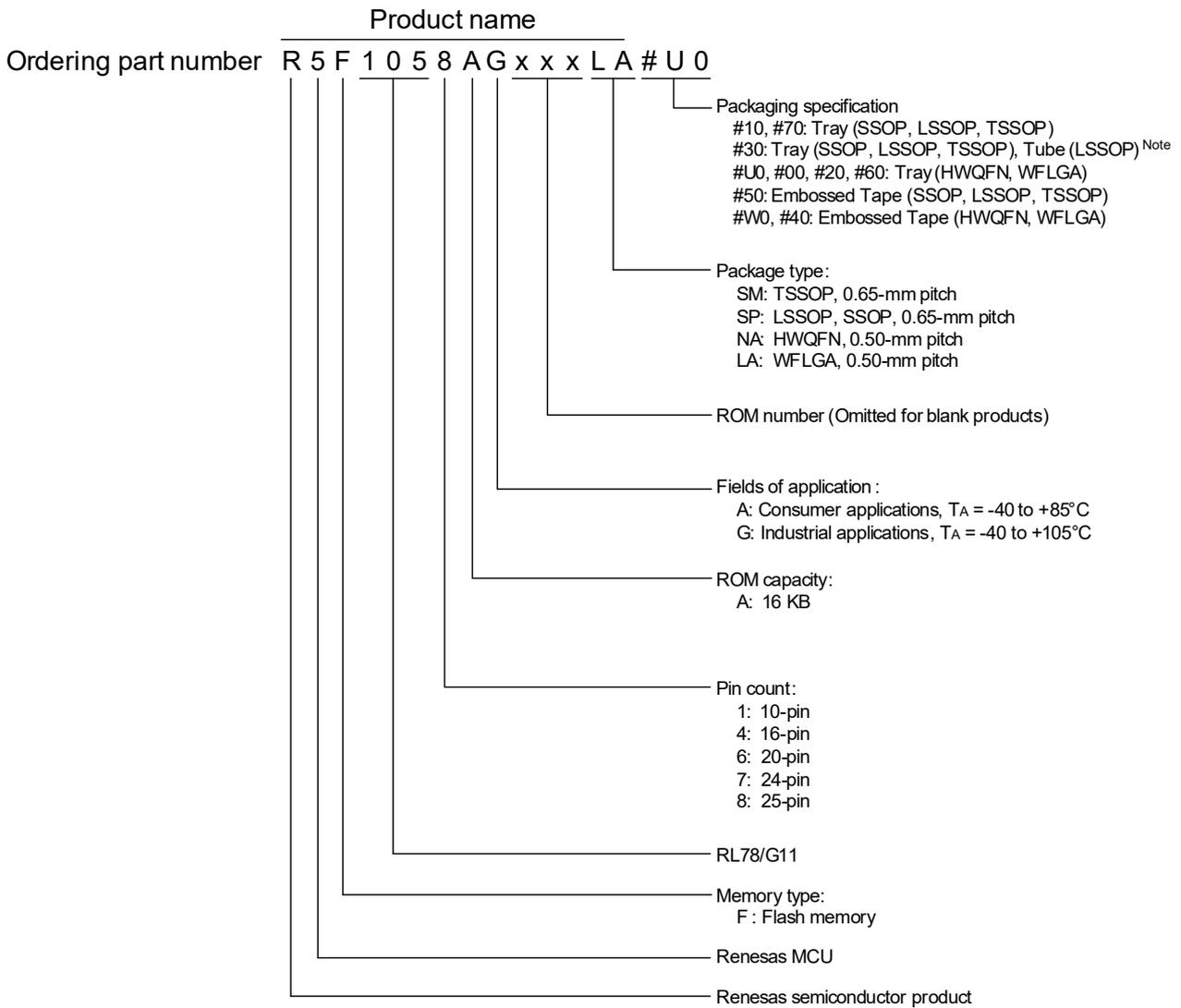
R5F105xA (x = 1, 4, 6, 7, 8): Start address FF900H

For the RAM areas used by the flash library, see **Self RAM list of Flash Self-Programming Library for RL78 Family (R20UT2944)**.

1.2 Ordering Information

<R>

Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11



Note The packaging specification is only "Tube" for products in the 20-pin LSSOP.

Table 1 - 1 List of Ordering Part Numbers

Pin Count	Package	Ordering Part Number		RENESAS Code
		Product Name	Packaging Specifications	
<R> 10 pins	10-pin plastic LSSOP (4.4 × 3.6 mm, 0.65-mm pitch)	R5F1051AGSP, R5F1051AASP	#10, #30, #50, #70	PLSP0010JA-A
<R> 16 pins	16-pin plastic SSOP (4.4 × 5.0 mm, 0.65-mm pitch)	R5F1054AGSP, R5F1054AASP	#10, #30, #50, #70	PRSP0016JC-B
<R>	16-pin plastic HWQFN (3 × 3 mm, 0.50-mm pitch)	R5F1054AGNA, R5F1054AANA	#00, #20, #40, #60	PWQN0016KD-A PWQN0016KE-A
<R> 20 pins	20-pin plastic LSSOP (4.4 × 6.5 mm, 0.65-mm pitch)	R5F1056AGSP, R5F1056AASP	#30, #50	PLSP0020JB-A
<R>	20-pin plastic TSSOP (4.4 × 6.5 mm, 0.65-mm pitch)	R5F1056AGSM, R5F1056AASM	#10, #30, #50, #70	PTSP0020JI-A
<R> 24 pins	24-pin plastic HWQFN (4 × 4 mm, 0.50-mm pitch)	R5F1057AGNA, R5F1057AANA	#U0, #W0	PWQN0024KE-A
<R>		R5F1057AGNA, R5F1057AANA	#00, #20, #40, #60	PWQN0024KF-A PWQN0024KH-A
25 pins	25-pin plastic WFLGA (3 × 3 mm, 0.50-mm pitch)	R5F1058AGLA, R5F1058AALA	#U0, #W0	PWLG0025KA-A

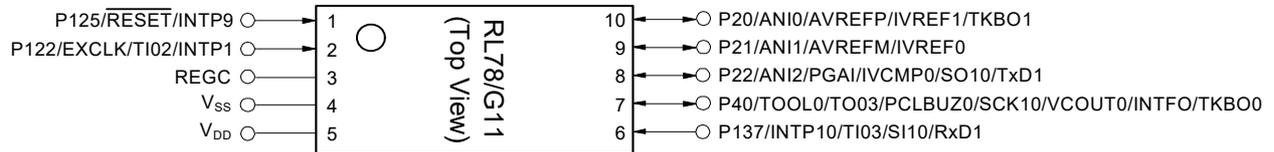
Caution 1. For the fields of application, refer to Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11.

- 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)

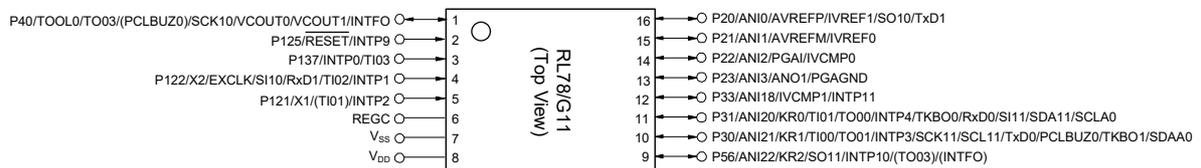
1.3.1 10-pin products

- 10-pin plastic LSSOP (4.4 × 3.6 mm, 0.65-mm pitch)

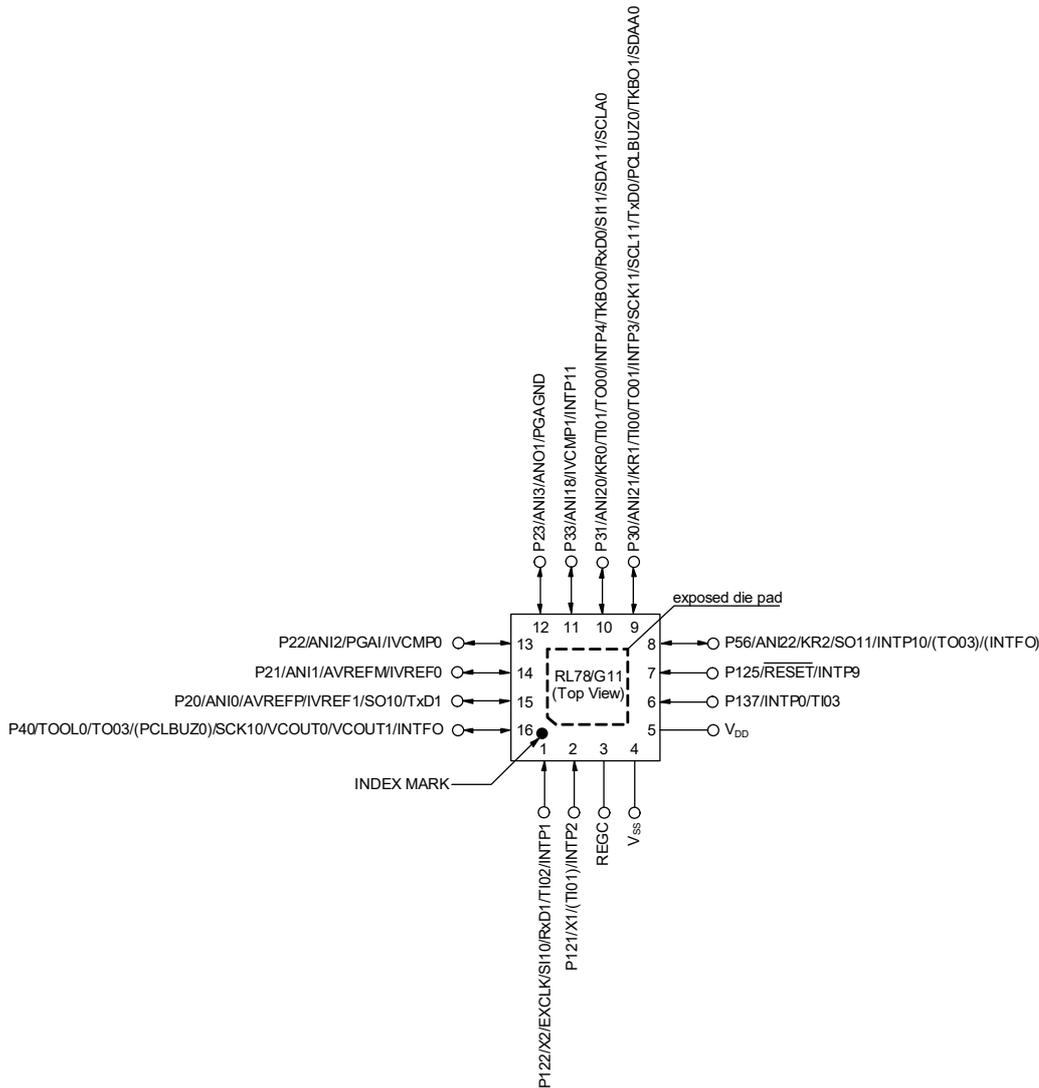


1.3.2 16-pin products

- 16-pin plastic SSOP (4.4 × 5.0 mm, 0.65-mm pitch)

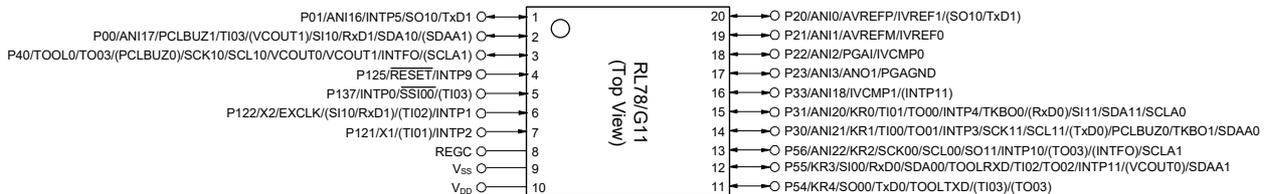


- 16-pin plastic HWQFN (3 × 3 mm, 0.5-mm pitch)



1.3.3 20-pin products

- 20-pin plastic LSSOP (4.4 × 6.5 mm, 0.65-mm pitch)
- 20-pin plastic TSSOP (4.4 × 6.5 mm, 0.65-mm pitch)



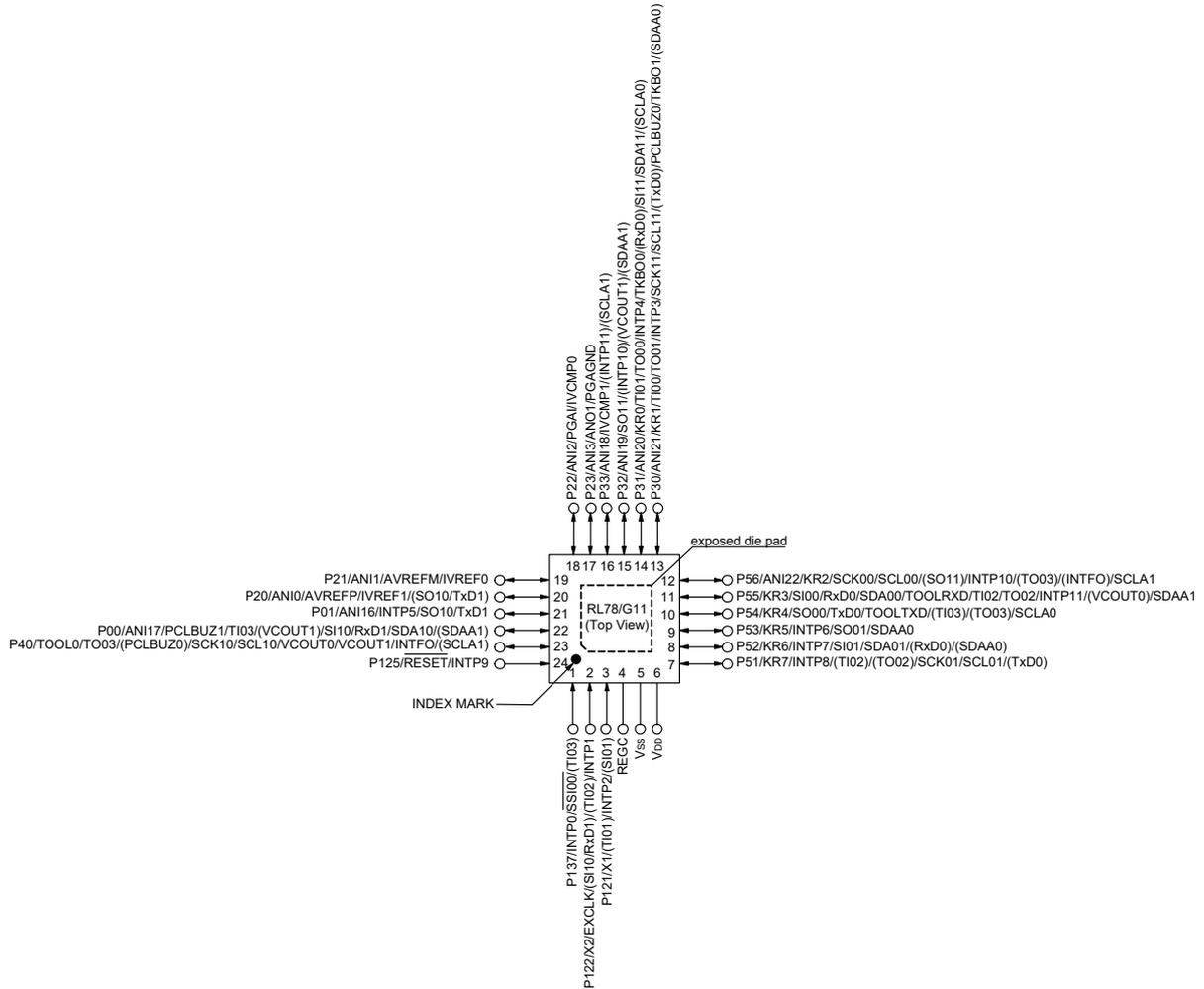
Caution Connect the REGC pin to Vss pin via a capacitor (0.47 to 1 μF).

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

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

1.3.4 24-pin products

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



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

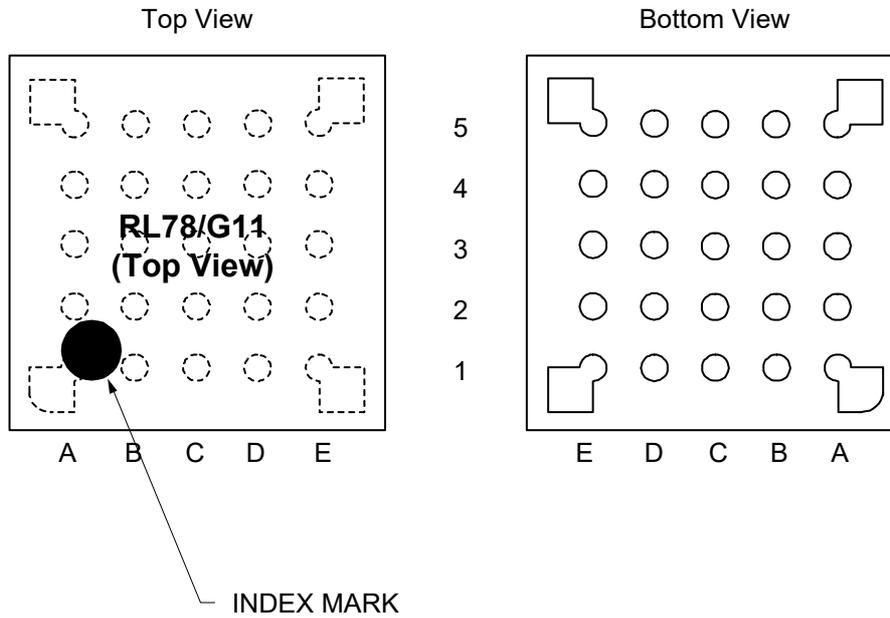
Remark 1. For pin identification, see 1.4 Pin Identification.

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

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

1.3.5 25-pin products

- 25-pin plastic WFLGA (3 × 3 mm, 0.5-mm pitch)



	A	B	C	D	E	
5	P40/TOOL0/TO03/(PCLBUZ0)/SCK10/SCL10/VCOU0/VCOU1/INTFO/(SCLA1)	P125/RESET/INTP9	P01/ANI16/INTP5/SO10/TxD1	P20/ANI0/AVREFP/IVREF1/(SO10/TxD1)	P21/ANI1/AVREFM/IVREF0	5
4	P122/X2/EXCLK/(SI10/RxD1)/(TI02)/INTP1	P137/INTP0/SSI00/(TI03)	P00/ANI17/PCLBUZ1/TI03/(VCOU1)/SI10/RxD1/SDA10/(SDAA1)	P22/ANI2/PGAI/IVCMP0	P23/ANI3/ANO1/PGAGND	4
3	P121/X1/(TI01)/INTP2/(SI01)	V _{DD}	EV _{DD}	P33/ANI18/IVCMP1/(INTP11)/(SCLA1)	P32/ANI19/SO11/(INTP10)/(VCOU1)/(SDAA1)	3
2	REGC	V _{SS}	P30/ANI21/KR1/TI00/TO01/INTP3/SCK11/SCL11/(TxD0)/PCLBUZ0/TKBO1/(SDAA0)	P31/ANI20/KR0/TI01/TO00/INTP4/TKBO0/(RxD0)/SI11/SDA11/(SCLA0)	P56/ANI22/KR2/SCK00/SCL00/(SO11)/INTP10/(TO03)/(INTFO)/SCLA1	2
1	P51/KR7/INTP8/(TI02)/(TO02)/SCK01/SCL01/(TxD0)	P52/KR6/INTP7/SI01/SDA01/(RxD0)/(SDAA0)	P53/KR5/INTP6/SO01/SDAA0	P54/KR4/SO00/TxD0/TOOLTxD/(TI03)/(TO03)/SCLA0	P55/KR3/SI00/RxD0/SDA00/TOOLRXD/TI02/TO02/INTP11/(VCOU0)/SDAA1	1
	A	B	C	D	E	

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

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

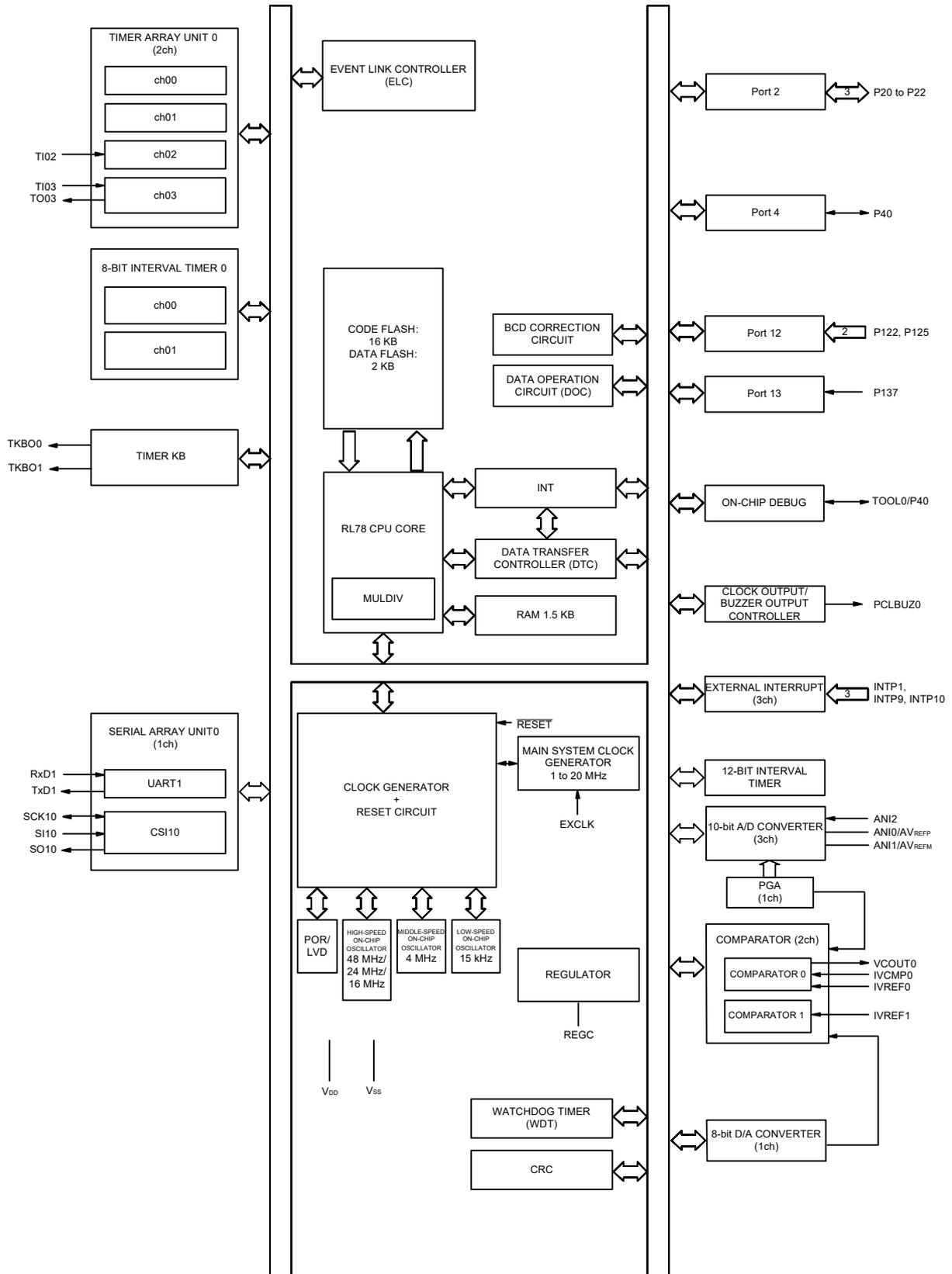
Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register 0 to 3 (PIOR0 to PIOR3).

1.4 Pin Identification

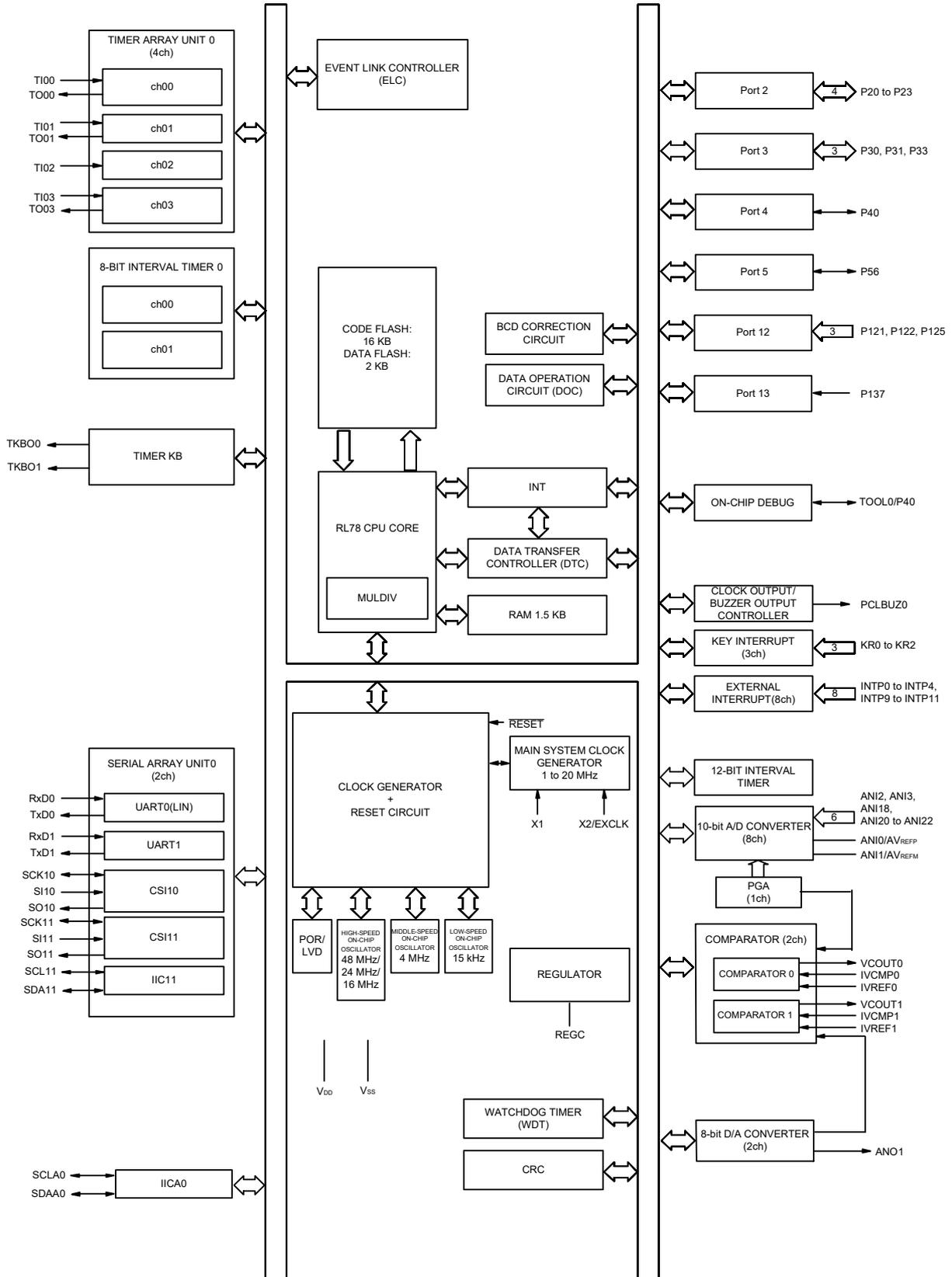
ANI0 to ANI3,		PCLBUZ0, PCLBUZ1	: Programmable clock output/buzzer output
ANI16 to ANI22	: Analog input	REGC	: Regulator capacitance
ANO1	: Analog output	$\overline{\text{RESET}}$: Reset
AVREFM	: A/D converter reference potential (- side) input	RxD0, RxD1	: Receive data
AVREFP	: A/D converter reference potential (+ side) input	SCK00, SCK01, SCK10, SCK11	: Serial clock input/output
EVDD	: Power supply	SCLA0, SCLA1	: Serial clock input/output
EXCLK	: External clock input (main system clock)	SCL00, SCL01, SCL10, SCL11	: Serial clock output
INTP0 to INTP11	: External interrupt input	SDAA0, SDAA1	: Serial data input/output
INTFO	: Interrupt Flag output	SDA00, SDA01, SDA10, SDA11	: Serial data input/output
IVCMP0, IVCMP1	: Comparator input	SI00, SI01, SI10, SI11	: Serial data input
IVREF0, IVREF1	: Comparator reference input	SO00, SO01, SO10, SO11	: Serial data output
KR0 to KR7	: Key return	$\overline{\text{SSI00}}$: Serial interface chip select input
PGAI, PGAGND	: PGA Input	TI00 to TI03	: Timer input
P00 to P01	: Port 0	TKBO0, TKBO1	: TMKB output
P20 to P23	: Port 2	TO00 to TO03	: Timer output
P30 to P33	: Port 3	TOOL0	: Data input/output for tool
P40	: Port 4	TOOLRXD, TOOLTXD	: Data input/output for external device
P51 to P56	: Port 5	TxD0, TxD1	: Transmit data
P121, P122, P125	: Port 12	VCOU00, VCOU01	: Comparator output
P137	: Port 13	VDD	: Power supply
		VSS	: Ground
		X1, X2	: Crystal oscillator (main system clock)

1.5 Block Diagram

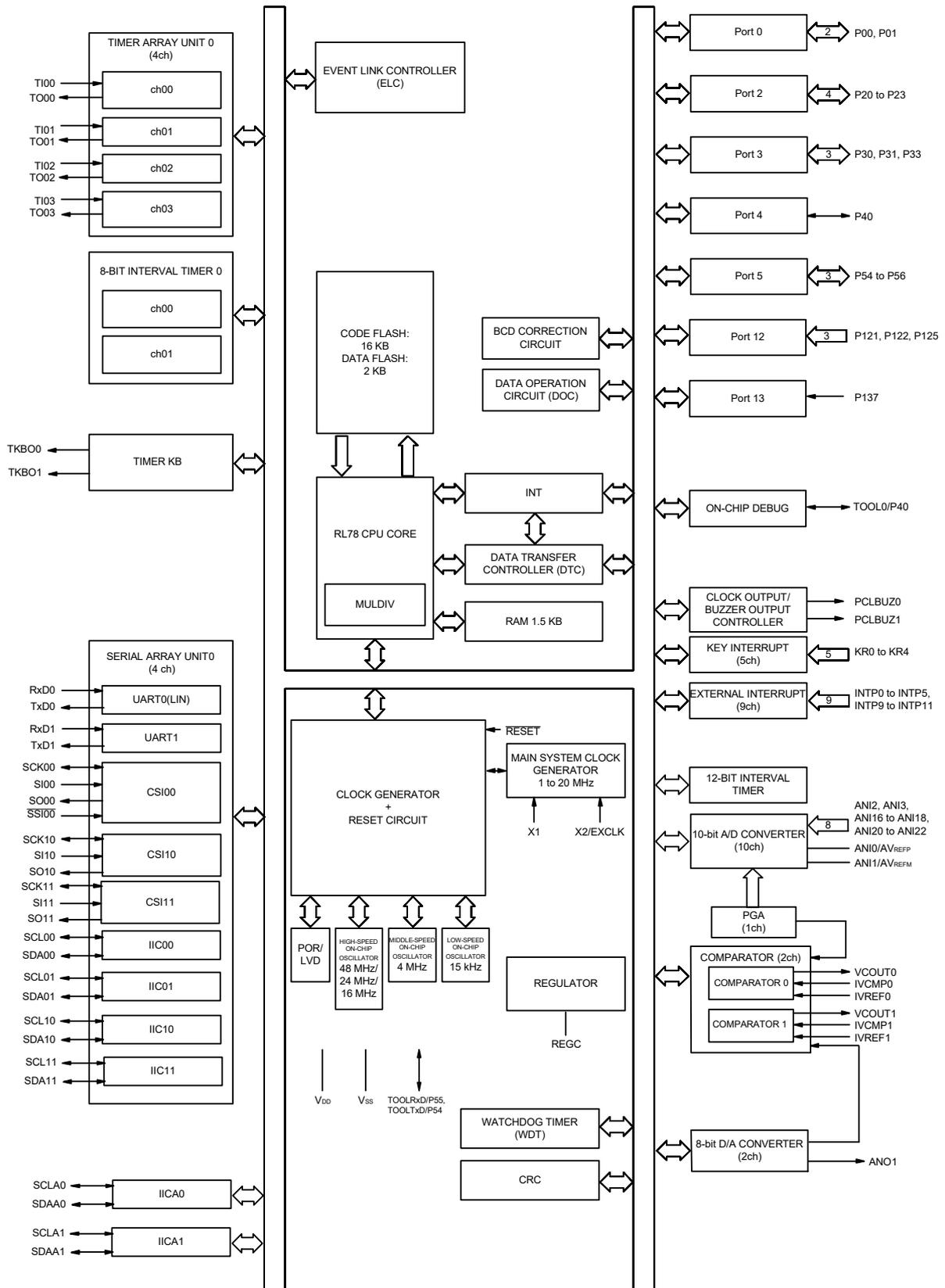
1.5.1 10-pin products



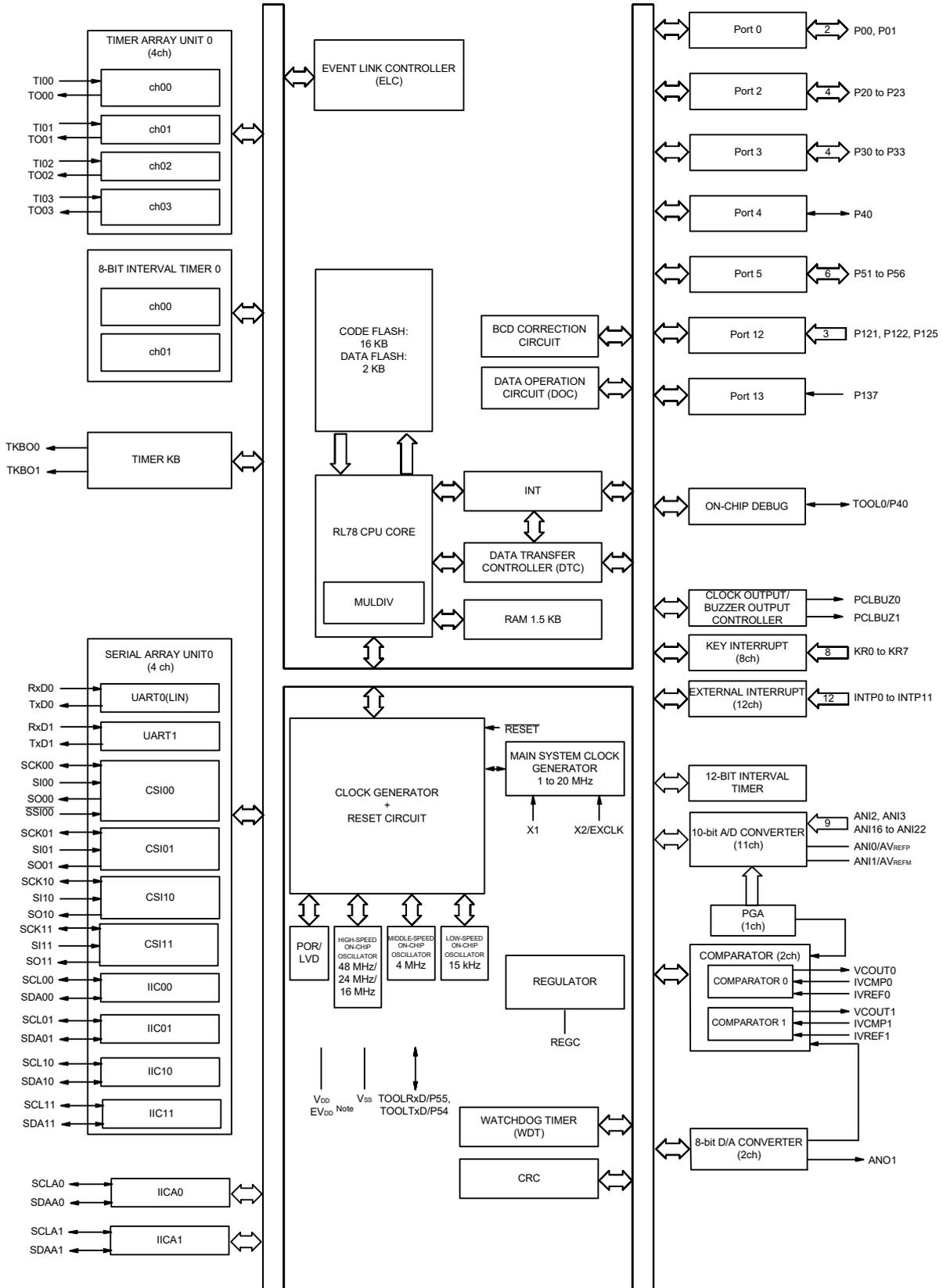
1.5.2 16-pin products



1.5.3 20-pin products



1.5.4 24-pin, 25-pin products



Note 25-pin products

1.6 Outline of Functions

This outline describes the functions at the time when Peripheral I/O redirection register 0 to 3 (PIOR0 to PIOR3) are set to 00H.

(1/2)

Item		10-pin	16-pin	20-pin	24-pin	25-pin
		R5F1051A	R5F1054A	R5F1056A	R5F1057A	R5F1058A
Code flash memory (KB)		16 Kbytes				
Data flash memory (KB)		2 Kbytes				
RAM		1.5 Kbytes				
Address space		1 Mbytes				
Main system clock	High-speed system clock (f _{MX})	X1 (crystal/ceramic) oscillation ^{Note} , external main system clock input (EXCLK) 1 to 20 MHz: V _{DD} = 2.7 to 5.5 V 1 to 16 MHz: V _{DD} = 2.4 to 5.5 V 1 to 8 MHz: V _{DD} = 1.8 to 5.5 V 1 to 4 MHz: V _{DD} = 1.6 to 5.5 V				
	High-speed on-chip oscillator clock (f _H) Max: 24 MHz	HS (High-speed main) mode: 1 to 24 MHz (V _{DD} = 2.7 to 5.5 V), HS (High-speed main) mode: 1 to 16 MHz (V _{DD} = 2.4 to 5.5 V), LS (Low-speed main) mode: 1 to 8 MHz (V _{DD} = 1.8 to 5.5 V), LV (Low-voltage main) mode: 1 to 4 MHz (V _{DD} = 1.6 to 5.5 V), LP (Low-power main) mode: 1 MHz (V _{DD} = 1.8 to 5.5 V)				
	Middle-speed on-chip oscillator clock (f _M) Max: 4 MHz	LV (Low-voltage main) mode: 1 to 4 MHz (V _{DD} = 1.6 to 5.5 V), LP (Low-power main) mode: 1 MHz (V _{DD} = 1.8 to 5.5 V)				
Subsystem clock	Low-speed on-chip oscillator clock (f _L)	15 kHz (typ.): V _{DD} = 1.6 to 5.5 V				
General-purpose register		8 bits × 32 registers (8 bits × 8 registers × 4 banks)				
Minimum instruction execution time		0.04167 μs (High-speed on-chip oscillator clock: f _H = 24 MHz operation)				
		0.05 μs (High-speed system clock: f _{MX} = 20 MHz operation)				
Instruction set		<ul style="list-style-type: none"> Data transfer (8/16 bits) Adder and subtractor/logical operation (8/16 bits) Multiplication (8 bits × 8 bits, 16 bits × 16 bits), Division (16 bits ÷ 16 bits, 32 bits ÷ 32 bits) Multiplication and Accumulation (16 bits × 16 bits + 32 bits) Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc. 				
I/O port	Total	7	13	17	21	
	CMOS I/O	4	9	13	17	
	CMOS input	3	4			
Timer	16-bit timer	4 channels				
	Watchdog timer	1 channel				
	Timer KB	1 channel				
	12-bit interval timer	1 channel				
	8/16-bit interval timer	2 channels (8 bit)/1 channel (16 bit)				
	Timer output	3	5	6		

Note 16, 20, 24, 25-pin products

Caution The flash library uses RAM in self-programming and rewriting of the data flash memory. The target products and start address of the RAM areas used by the flash library are shown below.

R5F105xA (x = 1, 4, 6, 7, 8): Start address FF900H

For the RAM areas used by the flash library, see Self RAM list of Flash Self-Programming Library for RL78 Family (R20UT2944).

(2/2)

Item	10-pin		16-pin		20-pin		24-pin		25-pin	
	R5F1051A		R5F1054A		R5F1056A		R5F1057A		R5F1058A	
Clock output/buzzer output	1				2					
	<ul style="list-style-type: none"> • 2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: $f_{MAIN} = 20$ MHz operation) • 117 Hz, 234 Hz, 469 Hz, 938 Hz, 1.875 kHz, 3.75 kHz, 7.5 kHz (subsystem clock: $f_{IL} = 15$ kHz operation) 									
10-bit resolution A/D converter	External	3 channels		8 channels		10 channels		11 channels		
	Internal	1 channel								
8-bit D/A converter	1 channel			2 channels						
Comparator (Window Comparator)	1 channel			2 channels						
PGA	1 channel									
Data Operation Circuit (DOC)	Comparison, addition, and subtraction of 16-bit data									
Serial interface	[10-pin products] <ul style="list-style-type: none"> • Simplified SPI (CSI): 1 channel/UART: 1 channel [16-pin products] <ul style="list-style-type: none"> • Simplified SPI (CSI): 2 channels/UART: 2 channels/simplified I²C: 1 channel [20-pin products] <ul style="list-style-type: none"> • Simplified SPI (CSI): 3 channels/UART: 2 channels/simplified I²C: 3 channels [24-pin, 25-pin products] <ul style="list-style-type: none"> • Simplified SPI (CSI): 4 channels/UART: 2 channels/simplified I²C: 4 channels 									
	I ² C bus	None		1 channel		2 channels				
Data transfer controller (DTC)	13 sources		22 sources		23 sources		24 sources			
Event link controller (ELC)	Event input: 11 Event trigger output: 3		Event input: 16 Event trigger output: 4		Event input: 17 Event trigger output: 4		Event input: 18 Event trigger output: 4			
Vectored interrupt sources	Internal	20		24		25				
	External	3		9		10		13		
Key interrupt	None		3		5		8			
Reset	<ul style="list-style-type: none"> • Reset by \overline{RESET} pin • Internal reset by watchdog timer • Internal reset by power-on-reset • Internal reset by voltage detector • Internal reset by illegal instruction execution • Internal reset by RAM parity error • Internal reset by illegal-memory access 									
Power-on-reset circuit	<ul style="list-style-type: none"> • Power-on-reset: $1.51 \pm 0.04V$ ($T_A = -40$ to $+85^\circ C$) $1.51 \pm 0.06V$ ($T_A = +85$ to $+105^\circ C$) • Power-down-reset: $1.50 \pm 0.04 V$ ($T_A = -40$ to $+85^\circ C$) $1.50 \pm 0.06V$ ($T_A = +85$ to $+105^\circ C$) 									
Voltage detector	Power on	1.67 V to 4.06 V (14 stages)								
	Power down	1.63 V to 3.98 V (14 stages)								
On-chip debug function	Provided (Disable to tracing)									
Power supply voltage	$V_{DD} = 1.6$ to $5.5 V$									
Operating ambient temperature	$T_A = -40$ to $+85^\circ C$ (Consumer applications) $T_A = -40$ to $+105^\circ C$ (Industrial applications)									

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

This chapter describes the following electrical specifications.

Target products A: Consumer applications (TA = -40 to +85°C)

R5F105xxAxx

G: When the products "G: Industrial applications (TA = -40 to +105°C)" is used in the range of TA = -40 to +85°C

R5F105xxGxx

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

Caution 2. The pins mounted depend on the product. Refer to 2.1 Port Functions to 2.2.1 Functions for each product in the RL78/G11 User's Manual.

Caution 3. The EVDD pin is not present on products with 24 or less pins. Accordingly, replace EVDD with VDD and the voltage condition $1.6 \leq EVDD \leq VDD \leq 5.5 \text{ V}$ with $1.6 \leq VDD \leq 5.5 \text{ V}$.

2.1 Absolute Maximum Ratings

(1/2)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V _{DD}		-0.5 to +6.5	V
	EV _{DD}		-0.5 to +6.5	V
	AV _{REFP}		0.3 to V _{DD} + 0.3 Note 2	V
	AV _{REFM}		-0.3 to V _{DD} + 0.3 Note 2 and AV _{REFM} ≤ AV _{REFP}	V
REGC pin input voltage	V _I REGC	REGC	-0.3 to +2.8 and -0.3 to V _{DD} + 0.3 Note 1	V
Input voltage	V _{I1}	P00, P01, P30 to P33, P40, and P51 to P56	-0.3 to EV _{DD} + 0.3 and -0.3 to V _{DD} + 0.3 Note 2	V
	V _{I2}	P20 to P23, P121, P122, P125, P137, EXCLK, RESET	-0.3 to V _{DD} + 0.3 Note 2	V
Output voltage	V _{O1}	P00, P01, P30 to P33, P40, and P51 to P56	-0.3 to EV _{DD} + 0.3 and -0.3 to V _{DD} + 0.3 Note 2	V
	V _{O2}	P20 to P23	-0.3 to V _{DD} + 0.3 Note 2	V
Analog input voltage	V _{AI1}	ANI16 to ANI22	-0.3 to EV _{DD} + 0.3 and -0.3 to AV _{REF} (+) + 0.3 Notes 2, 3	V
	V _{AI2}	ANI0 to ANI3	-0.3 to V _{DD} + 0.3 and -0.3 to AV _{REF} (+) + 0.3 Notes 2, 3	V

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

Note 2. Must be 6.5 V or lower.

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

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

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

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

Remark 3. V_{SS}: Reference voltage

(2/2)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	IOH1	Per pin		-40	mA
		Total of all pins -170 mA	P00, P01, P40	-70	mA
			P30 to P33, P51 to P56	-100	mA
	IOH2	Per pin	P20 to P23	-0.5	mA
		Total of all pins		-2	mA
Output current, low	IOL1	Per pin		40	mA
		Total of all pins 170 mA	P00, P01, P40	70	mA
			P30 to P33, P51 to P56	100	mA
	IOL2	Per pin	P20 to P23	1	mA
		Total of all pins		4	mA
Operating ambient temperature	TA	In normal operation mode		-40 to +85	°C
		In flash memory programming mode			
Storage temperature	Tstg			-65 to +150	°C

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

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

2.2 Oscillator Characteristics

2.2.1 X1 characteristics

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

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

Note Indicates only permissible oscillator frequency ranges. Refer to **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.

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, refer to **6.4 System Clock Oscillator** in the RL78/G11 User's Manual.

2.2.2 On-chip oscillator characteristics

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

Oscillators	Parameters	Conditions	MIN.	TYP.	MAX.	Unit	
High-speed on-chip oscillator clock frequency ^{Notes 1, 2}	f _{IH}	2.7 V ≤ VDD ≤ 5.5 V	1		24	MHz	
		2.4 V ≤ VDD ≤ 5.5 V	1		16		
		1.8 V ≤ VDD ≤ 5.5 V	1		8		
		1.6 V ≤ VDD ≤ 5.5 V	1		4		
High-speed on-chip oscillator clock frequency accuracy		TA = -20 to +85°C	1.8 V ≤ VDD ≤ 5.5 V	-1		1	%
			1.6 V ≤ VDD < 1.8 V	-5		5	
		TA = -40 to -20°C	1.8 V ≤ VDD ≤ 5.5 V	-1.5		1.5	%
			1.6 V ≤ VDD < 1.8 V	-5.5		5.5	
Middle-speed on-chip oscillator oscillation frequency ^{Note 2}	f _{IM}		1		4	MHz	
Middle-speed on-chip oscillator oscillation frequency accuracy			-12		+12	%	
Temperature drift of Middle-speed on-chip oscillator oscillation frequency accuracy	D _{IMT}			0.008		%/°C	
Voltage drift of Middle-speed on-chip oscillator oscillation frequency accuracy	D _{IMV}	TA = 25°C	2.1 V ≤ VDD ≤ 5.5 V		0.02	%V	
			2.0 V ≤ VDD < 2.1 V		-12		
			1.6 V ≤ VDD < 2.0 V		10		
Low-speed on-chip oscillator clock frequency ^{Note 2}	f _{IL}			15		kHz	
Low-speed on-chip oscillator clock frequency accuracy			-15		+15	%	

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

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

2.3 DC Characteristics

2.3.1 Pin characteristics

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

(1/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output current, high Note 1	IOH1	Per pin for P00, P01, P30 to P33, P40, and P51 to P56			-10.0 Note 2	mA
		Total of P00, P01, and P40 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		-42.0	mA
			2.7 V ≤ EVDD < 4.0 V		-10.0	mA
			1.8 V ≤ EVDD < 2.7 V		-5.0	mA
			1.6 V ≤ EVDD < 1.8 V		-2.5	mA
		Total of P30 to P33, and P51 to P56 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		-80.0	mA
			2.7 V ≤ EVDD < 4.0 V		-19.0	mA
			1.8 V ≤ EVDD < 2.7 V		-10.0	mA
			1.6 V ≤ EVDD < 1.8 V		-5.0	mA
		Total of all pins (When duty ≤ 70% Note 3)				-122.0
	IOH2	Per pin for P20 to P23			-0.1 Note 2	mA
Total of all pins (When duty ≤ 70% Note 3)		1.6 V ≤ VDD ≤ 5.5 V			-0.4	mA

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

Note 2. Do not exceed the total current value.

Note 3. Specification under conditions where the duty factor ≤ 70%.

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

- Total output current of pins = (IOH × 0.7)/(n × 0.01)
<Example> Where n = 80% and IOH = -10.0 mA
Total output current of pins = (-10.0 × 0.7)/(80 × 0.01) ≈ -8.7 mA

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

Caution P00, P01, P20, P30 to P33, P40 and P51 to P56 do not output high level in N-ch open-drain mode.

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

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

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Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output current, low Note 1	IOL1	Per pin for P00, P01, P30 to P33, P40, and P51 to P56			20.0	mA Note 2	
		Total of P00, P01, and P40 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V			70.0	mA
			2.7 V ≤ EVDD < 4.0 V			15.0	
			1.8 V ≤ EVDD < 2.7 V			9.0	
			1.6 V ≤ EVDD < 1.8 V			4.5	
		Total of P30 to P33, and P51 to P56 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V			80.0	mA
			2.7 V ≤ EVDD < 4.0 V			35.0	
			1.8 V ≤ EVDD < 2.7 V			20.0	
			1.6 V ≤ EVDD < 1.8 V			10.0	
	Total of all pins (When duty ≤ 70% Note 3)					150.0	mA
IOL2	Per pin for P20 to P23				0.4	mA Note 2	
Total of all pins (When duty ≤ 70% Note 3)		1.6 V ≤ VDD ≤ 5.5 V			1.6	mA	

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

Note 2. Do not exceed the total current value.

Note 3. Specification under conditions where the duty factor ≤ 70%.

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

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

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

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

However, the current that is allowed to flow into one pin does not vary depending on the duty factor.

A current higher than the absolute maximum rating must not flow into one pin.

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

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

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage, high	V _{IH1}	P00, P01, P30 to P33, P40, and P51 to P56	Normal mode	0.8 EV _{DD}		EV _{DD}	V
	V _{IH2}	P00, P30 to P32, P40, P51 to P56	TTL mode 4.0 V ≤ EV _{DD} ≤ 5.5 V	2.2		EV _{DD}	V
			TTL mode 3.3 V ≤ EV _{DD} < 4.0 V	2.0		EV _{DD}	V
			TTL mode 1.6 V ≤ EV _{DD} < 3.3 V	1.5		EV _{DD}	V
	V _{IH3}	P20 to P23 (digital input)		0.7 V _{DD}		V _{DD}	V
	V _{IH4}	P121, P122, P125, P137, EXCLK, $\overline{\text{RESET}}$		0.8 V _{DD}		V _{DD}	V
Input voltage, low	V _{IL1}	P00, P01, P30 to P33, P40, and P51 to P56	Normal mode	0		0.2 EV _{DD}	V
	V _{IL2}	P00, P30 to P32, P40, P51 to P56	TTL mode 4.0 V ≤ EV _{DD} ≤ 5.5 V	0		0.8	V
			TTL mode 3.3 V ≤ EV _{DD} < 4.0 V	0		0.5	V
			TTL mode 1.6 V ≤ EV _{DD} < 3.3 V	0		0.32	V
	V _{IL3}	P20 to P23 (digital input)		0		0.3 V _{DD}	V
	V _{IL4}	P121, P122, P125, P137, EXCLK, $\overline{\text{RESET}}$		0		0.2 V _{DD}	V

Caution The maximum value of V_{IH} of pins P00, P01, P20, P30 to P33, P40 and P51 to P56 is V_{DD} or EV_{DD}, even in the N-ch open-drain mode.

(P20: V_{DD})

P00, P01, P30 to P33, P40, P51 to P56: EV_{DD})

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

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

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Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output voltage, high	VOH1	P00, P01, P30 to P33, P40, and P51 to P56	4.0 V ≤ EVDD ≤ 5.5 V, IOH = -10.0 mA	EVDD - 1.5			V
			4.0 V ≤ EVDD ≤ 5.5 V, IOH = -3.0 mA	EVDD - 0.7			V
			2.7 V ≤ EVDD ≤ 5.5 V, IOH = -2.0 mA	EVDD - 0.6			V
			1.8 V ≤ EVDD ≤ 5.5 V, IOH = -1.5 mA	EVDD - 0.5			V
			1.6 V ≤ EVDD ≤ 5.5 V, IOH = -1.0 mA	EVDD - 0.5			V
	VOH2	P20 to P23	1.6 V ≤ VDD ≤ 5.5 V, IOH = -100 μA	VDD - 0.5			V
Output voltage, low	VOL1	P00, P01, P30 to P33, P40, and P51 to P56	4.0 V ≤ EVDD ≤ 5.5 V, IOL = 20.0 mA			1.3	V
			4.0 V ≤ EVDD ≤ 5.5 V, IOL = 8.5 mA			0.7	V
			2.7 V ≤ EVDD ≤ 5.5 V, IOL = 3.0 mA			0.6	V
			2.7 V ≤ EVDD ≤ 5.5 V, IOL = 1.5 mA			0.4	V
			1.8 V ≤ EVDD ≤ 5.5 V, IOL = 0.6 mA			0.4	V
			1.6 V ≤ EVDD ≤ 5.5 V, IOL = 0.3 mA			0.4	V
	VOL2	P20 to P23	1.6 V ≤ VDD ≤ 5.5 V, IOL = 400 μA			0.4	V

Caution P00, P01, P20, P30 to P33, P40 and P51 to P56 do not output high level in N-ch open-drain mode.

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

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

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Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit		
Input leakage current, high	ILI1	P00, P01, P30 to P33, P40, and P51 to P56	VI = EVDD			1	μA	
	ILI2	P20 to P23, P125, P137, RESET	VI = VDD			1	μA	
	ILI3	P121, P122, X1, X2, EXCLK	VI = VDD	In input port or external clock input			1	μA
				In resonator connection			10	μA
Input leakage current, low	ILIL1	P00, P01, P30 to P33, P40, and P51 to P56	VI = VSS			-1	μA	
	ILIL2	P20 to P23, P125, P137, RESET	VI = VSS			-1	μA	
	ILIL3	P121, P122, X1, X2, EXCLK	VI = VSS	In input port or external clock input			-1	μA
				In resonator connection			-10	μA
On-chip pull-up resistance	Ru	P00, P01, P30 to P33, P40, P51 to P56, P125	VI = VSS, In input port		10	20	100	kΩ

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

2.3.2 Supply current characteristics

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

(1/4)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit				
Supply current Note 1	IDD1	Operating mode	Basic operation	HS (high-speed main) mode	fHOCO = 48 MHz ^{Note 3} fH = 24 MHz ^{Note 3}	VDD = 5.0 V		1.7		mA			
						VDD = 3.0 V		1.7					
					fHOCO = 24 MHz ^{Note 3} fH = 24 MHz ^{Note 3}	VDD = 5.0 V		1.4					
						VDD = 3.0 V		1.4					
			Normal operation	HS (high-speed main) mode	fHOCO = 48 MHz ^{Note 3} fH = 24 MHz ^{Note 3}	VDD = 5.0 V		3.5	6.9	mA			
						VDD = 3.0 V		3.5	6.9				
					fHOCO = 24 MHz ^{Note 3} fH = 24 MHz ^{Note 3}	VDD = 5.0 V		3.2	6.3				
						VDD = 3.0 V		3.2	6.3				
			Normal operation	LS (low-speed main) mode (MCSEL = 0)	fH = 8 MHz ^{Note 3}	VDD = 3.0 V		1.1	2.0	mA			
						VDD = 2.0 V		1.1	2.0				
			Normal operation	LS (low-speed main) mode (MCSEL = 1)	fH = 4 MHz ^{Note 3}	VDD = 3.0 V		0.72	1.3	mA			
						VDD = 2.0 V		0.72	1.3				
		fM = 4 MHz ^{Note 6}			VDD = 3.0 V		0.58	1.1					
					VDD = 2.0 V		0.58	1.1					
		Normal operation	LV (low-voltage main) mode	fH = 4 MHz ^{Note 3}	VDD = 3.0 V		1.2	1.8	mA				
					VDD = 2.0 V		1.2	1.8					
		Normal operation	LP (low-power main) mode (MCSEL = 1)	fH = 1 MHz ^{Note 3}	VDD = 3.0 V		290	480	μA				
					VDD = 2.0 V		290	480					
				fM = 1 MHz ^{Note 6}	VDD = 3.0 V		124	230					
					VDD = 2.0 V		124	230					
		Normal operation	HS (high-speed main) mode	fMX = 20 MHz ^{Note 2}	VDD = 5.0 V	Square wave input		2.7	5.3	mA			
						Resonator connection		2.8	5.5				
					VDD = 3.0 V	Square wave input		2.7	5.3				
						Resonator connection		2.8	5.5				
					fMX = 10 MHz ^{Note 2}	VDD = 5.0 V	Square wave input		1.8		3.1		
							Resonator connection		1.9		3.2		
				VDD = 3.0 V		Square wave input		1.8	3.1				
						Resonator connection		1.9	3.2				
				Normal operation	LS (low-speed main) mode (MCSEL = 0)	fMX = 8 MHz ^{Note 2}	VDD = 3.0 V	Square wave input			0.9	1.9	mA
								Resonator connection			1.0	2.0	
Normal operation				fMX = 8 MHz ^{Note 2}	VDD = 2.0 V	Square wave input		0.9	1.9				
						Resonator connection		1.0	2.0				
Normal operation	LS (low-speed main) mode (MCSEL = 1)	fMX = 4 MHz ^{Note 2}	VDD = 3.0 V	Square wave input		0.6	1.1	mA					
				Resonator connection		0.6	1.2						
Normal operation		fMX = 4 MHz ^{Note 2}	VDD = 2.0 V	Square wave input		0.6	1.1						
				Resonator connection		0.6	1.2						
Normal operation	LP (low-power main) mode (MCSEL = 1)	fMX = 1 MHz ^{Note 2}	VDD = 3.0 V	Square wave input		100	190	μA					
				Resonator connection		145	250						
Normal operation		fMX = 1 MHz ^{Note 2}	VDD = 2.0 V	Square wave input		100	190						
				Resonator connection		145	250						

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

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

(2/4)

Parameter	Symbol	Conditions						MIN.	TYP.	MAX.	Unit
Supply current Note 1	I _{DD1}	Operating mode	Normal operation	Subsystem clock operation	f _{IL} = 15 kHz, T _A = -40°C Note 5	Normal operation		1.8	5.9	μA	
					f _{IL} = 15 kHz, T _A = +25°C Note 5	Normal operation		1.9	5.9		
					f _{IL} = 15 kHz, T _A = +85°C Note 5	Normal operation		2.3	8.7		

Note 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} or V_{SS}. The following points apply in the HS (high-speed main), LS (low-speed main), LV (low-voltage main), and LP (low-power 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 A/D converter, D/A converter, comparator, programmable gain amplifier, LVD 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.

Note 2. When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

Note 3. When the high-speed system clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

Note 4. When the high-speed system clock is stopped.

Note 5. When the high-speed system clock, high-speed on-chip oscillator clock and middle-speed on-chip oscillator clock are stopped.

Note 6. When the high-speed system clock, high-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

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

Remark 2. f_{IH}: High-speed on-chip oscillator clock frequency (24 MHz max.)

Remark 3. f_{IM}: Middle-speed on-chip oscillator clock frequency (4 MHz max.)

Remark 4. f_{IL}: Low-speed on-chip oscillator clock frequency

Remark 5. f_{SUB}: Subsystem clock frequency (Low-speed on-chip oscillator clock frequency)

Remark 6. Except subsystem clock operation, temperature condition of the TYP. value is T_A = 25°C

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

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Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit		
Supply current Note 1	I _{DD2} Note 2	HALT mode	HS (high-speed main) mode	f _{HOCO} = 48 MHz ^{Note 4}	V _{DD} = 5.0 V	0.59	2.43	mA	
				f _{IH} = 24 MHz ^{Note 4}	V _{DD} = 3.0 V	0.59	2.43		
				f _{HOCO} = 24 MHz ^{Note 4}	V _{DD} = 5.0 V	0.41	1.83		
				f _{IH} = 24 MHz ^{Note 4}	V _{DD} = 3.0 V	0.41	1.83		
				f _{HOCO} = 16 MHz ^{Note 4}	V _{DD} = 5.0 V	0.39	1.38		
				f _{IH} = 16 MHz ^{Note 4}	V _{DD} = 3.0 V	0.39	1.38		
			LS (low-speed main) mode (MCSEL = 0)	f _{IH} = 8 MHz ^{Note 4}	V _{DD} = 3.0 V	250	710	μA	
					V _{DD} = 2.0 V	250	710		
			LS (low-speed main) mode (MCSEL = 1)	f _{IH} = 4 MHz ^{Note 4}	V _{DD} = 3.0 V	204	400	μA	
					V _{DD} = 2.0 V	204	400		
			LM (low-voltage main) mode	f _{IH} = 4 MHz ^{Note 4}	V _{DD} = 3.0 V	450	700	μA	
					V _{DD} = 2.0 V	450	700		
			LP (low-power main) mode (MCSEL = 1)	f _{IH} = 1 MHz ^{Note 4}	V _{DD} = 3.0 V	192	400	μA	
					V _{DD} = 2.0 V	192	400		
				f _{IM} = 1 MHz ^{Note 6}	V _{DD} = 3.0 V	28	100		
			HS (high-speed main) mode	f _{MX} = 20 MHz ^{Note 3}	V _{DD} = 5.0 V	Square wave input	0.20	1.55	mA
						Resonator connection	0.40	1.74	
					V _{DD} = 3.0 V	Square wave input	0.20	1.55	
					Resonator connection	0.40	1.74		
				f _{MX} = 10 MHz ^{Note 3}	V _{DD} = 5.0 V	Square wave input	0.15	0.86	
						Resonator connection	0.30	0.93	
			V _{DD} = 3.0 V		Square wave input	0.15	0.86		
			LS (low-speed main) mode (MCSEL = 0)	f _{MX} = 8 MHz ^{Note 3}	V _{DD} = 3.0 V	Square wave input	68	550	μA
						Resonator connection	125	590	
			LS (low-speed main) mode (MCSEL = 1)	f _{MX} = 8 MHz ^{Note 3}	V _{DD} = 2.0 V	Square wave input	68	550	μA
						Resonator connection	125	590	
			LS (low-speed main) mode (MCSEL = 1)	f _{MX} = 4 MHz ^{Note 3}	V _{DD} = 3.0 V	Square wave input	23	128	μA
						Resonator connection	65	200	
			LP (low-power main) mode (MCSEL = 1)	f _{MX} = 1 MHz ^{Note 3}	V _{DD} = 2.0 V	Square wave input	23	128	μA
						Resonator connection	65	200	
			LP (low-power main) mode (MCSEL = 1)	f _{MX} = 4 MHz ^{Note 3}	V _{DD} = 3.0 V	Square wave input	10	64	μA
						Resonator connection	59	150	
			LP (low-power main) mode (MCSEL = 1)	f _{MX} = 1 MHz ^{Note 3}	V _{DD} = 2.0 V	Square wave input	10	64	μA
	Resonator connection	59			150				
Subsystem clock operation			f _L = 15 kHz, TA = -40°C ^{Note 5}	0.48	1.22	μA			
			f _L = 15 kHz, TA = +25°C ^{Note 5}	0.55	1.22				
			f _L = 15 kHz, TA = +85°C ^{Note 5}	0.80	3.30				

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

- Note 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} or V_{SS}. The following points apply in the HS (high-speed main), LS (low-speed main), LV (low-voltage main), and LP (low-power 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 A/D converter, D/A converter, comparator, programmable gain amplifier, LVD 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.
- Note 2.** When the HALT instruction is executed in the flash memory.
- Note 3.** When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock, and low-speed on-chip oscillator clock are stopped.
- Note 4.** When the high-speed system clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.
- Note 5.** When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock and high-speed system clock are stopped.
- Note 6.** When the high-speed system clock, high-speed on-chip oscillator clock, and low-speed on-chip oscillator clock are stopped.
- Remark 1.** f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f_{IH}: High-speed on-chip oscillator clock frequency (24 MHz max.)
- Remark 3.** f_{IM}: Middle-speed on-chip oscillator clock frequency (4 MHz max.)
- Remark 4.** f_{IL}: Low-speed on-chip oscillator clock frequency
- Remark 5.** f_{SUB}: Subsystem clock frequency (Low-speed on-chip oscillator clock frequency)
- Remark 6.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

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Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Supply current Note 1	IDD3	STOP mode Note 2	TA = -40°C		0.19	0.51	μA
			TA = +25°C		0.25	0.51	
			TA = +50°C		0.28	1.10	
			TA = +70°C		0.38	1.90	
			TA = +85°C		0.60	3.30	

Note 1. Total current flowing into VDD and EVDD, including the input leakage current flowing when the level of the input pin is fixed to VDD or VSS. In the STOP mode, the currents in both the "TYP." and "MAX." columns do not include the operating currents of the peripheral modules.

Note 2. For the setting of the current values when operating the subsystem clock in STOP mode, see the current values when operating the subsystem clock in HALT mode.

Peripheral Functions (Common to all products)

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	IFIL Note 1				0.22		μA
12-bit interval timer operating current	ITMKA Notes 1, 3, 4	fIL = 15 kHz fMAIN stopped (per unit)			0.02		μA
8-bit interval timer operating current Notes 1, 9	ITMT	fIL = 15 kHz fMAIN stopped (per unit)	8-bit counter mode × 2-channel operation		0.04		μA
			16-bit counter mode operation		0.03		μA
Watchdog timer operating current	IWD _T Notes 1, 3, 5	fIL = 15 kHz fMAIN stopped (per unit)			0.22		μA
A/D converter operating current	IADC Notes 1, 6	During maximum-speed conversion	Normal mode, AVREFP = VDD = 5.0 V		1.3	1.7	mA
			Low voltage mode, AVREFP = VDD = 3.0 V		0.5	0.7	mA
Internal reference voltage (1.45 V) current Notes 1, 10	IADREF				85.0		μA
Temperature sensor operating current	ITMPS Note 1				85.0		μA
D/A converter operating current	IDAC Notes 1, 14	Per channel				1.5	mA
PGA operating current	IPGA Notes 1, 2				480	700	μA
Comparator operating current	ICMP Note 8	VDD = 5.0 V, Regulator output voltage = 2.1 V	Comparator high-speed mode Window mode		12.5		μA
			Comparator low-speed mode Window mode		3.0		
			Comparator high-speed mode Standard mode		6.5		
			Comparator low-speed mode Standard mode		1.9		
		VDD = 5.0 V, Regulator output voltage = 1.8 V	Comparator high-speed mode Window mode		8.0		
			Comparator low-speed mode Window mode		2.2		
			Comparator high-speed mode Standard mode		4.0		
			Comparator low-speed mode Standard mode		1.3		
LVD operating current	ILVD Notes 1, 7				0.10		μA
Self-programming operating current	IFSP Notes 1, 12				2.0	12.20	mA
BGO current	IBGO Notes 1, 11				2.0	12.20	mA
SNOOZE operating current	ISNOZ Note 1	ADC operation fIH = 24 MHz, AVREFP = VDD = 3.0 V	Mode transition Note 13		0.50	0.60	mA
			The A/D conversion operations are performed		1.20	1.44	mA
		Simplified SPI (CSI)/UART operation fIH = 24 MHz		0.70	0.84	mA	
	ISNOZM Note 1	ADC operation fIM = 4 MHz, AVREFP = VDD = 3.0 V	Mode transition Note 13		0.05	0.08	mA
			The A/D conversion operations are performed		0.67	0.78	mA
		Simplified SPI (CSI) operation, fIM = 4 MHz		0.06	0.08	mA	

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

- Note 1.** Current flowing to VDD.
- Note 2.** Operable range is 2.7 to 5.5 V.
- Note 3.** When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock, and high-speed system clock are stopped.
- Note 4.** Current flowing only to the 12-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either IDD1 or IDD2, and IIT, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.
- Note 5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and IWDT when the watchdog timer is in operation.
- Note 6.** Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IADC when the A/D converter operates in an operation mode or the HALT mode.
- Note 7.** Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and ILVD when the LVD circuit is in operation.
- Note 8.** Current flowing only to the comparator circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2, or IDD3 and ICMP when the comparator circuit is in operation.
- Note 9.** Current flowing only to the 8-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either IDD1 or IDD2, and IIT, when the 8-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.
- Note 10.** Current consumed by generating the internal reference voltage (1.45 V).
- Note 11.** Current flowing during programming of the data flash.
- Note 12.** Current flowing during self-programming.
- Note 13.** For transition time to the SNOOZE mode, see **24.3.3 SNOOZE mode** in the RL78/G11 User's Manual.
- Note 14.** Current flowing only to the D/A converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IDAC when the D/A converter operates in an operation mode or the HALT mode.

- Remark 1.** f_{IL}: Low-speed on-chip oscillator clock frequency
- Remark 2.** f_{CLK}: CPU/peripheral hardware clock frequency
- Remark 3.** Temperature condition of the TYP. value is TA = 25°C

2.4 AC Characteristics

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

(1/2)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	TCY	Main system clock (fMAIN) operation	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 5.5 V	0.04167	1	μs
				2.4 V ≤ VDD < 2.7 V	0.0625	1	μs
			LS (low-speed main) mode	1.8 V ≤ VDD ≤ 5.5 V PMMC. MCSEL = 0	0.125	1	μs
				1.8 V ≤ VDD ≤ 5.5 V PMMC. MCSEL = 1	0.25	1	μs
			LP (low-power main) mode	1.8 V ≤ VDD ≤ 5.5 V	1		μs
		LV (low-voltage main) mode	1.6 V ≤ VDD ≤ 5.5 V	0.25	1	μs	
		Subsystem clock (fSUB) operation	fil	1.8 V ≤ VDD ≤ 5.5 V		66.7	μs
		In the self- programming mode	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 5.5 V	0.04167	1	μs
				2.4 V ≤ VDD < 2.7 V	0.0625	1	μs
			LS (low-speed main) mode	1.8 V ≤ VDD ≤ 5.5 V	0.125	1	μs
LV (low-voltage main) mode	1.8 V ≤ VDD ≤ 5.5 V		0.25	1	μs		
External system clock frequency	fEX	2.7 V ≤ VDD ≤ 5.5 V		1		20	MHz
		2.4 V ≤ VDD < 2.7 V		1		16	MHz
		1.8 V ≤ VDD < 2.4 V		1		8	MHz
		1.6 V ≤ VDD < 1.8 V		1		4	MHz
External system clock input high-/low- level width	tEXH, tEXL	2.7 V ≤ VDD ≤ 5.5 V		24			ns
		2.4 V ≤ VDD < 2.7 V		30			ns
		1.8 V ≤ VDD < 2.4 V		60			ns
		1.6 V ≤ VDD < 1.8 V		120			ns
Ti00 to Ti03 input high-/low-level width	tTIH, tTIL ^{Note}			1/fMCK + 10			ns

Note Following conditions must be satisfied on low level interface of EVDD < VDD.

1.8 V ≤ EVDD ≤ 2.7 V: MIN. 125 ns

1.6 V ≤ EVDD < 1.8 V: MIN. 250 ns

Remark fMCK: Timer array unit operation clock frequency

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

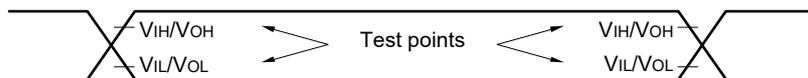
(TA = -40 to +85°C, 1.6 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

(2/2)

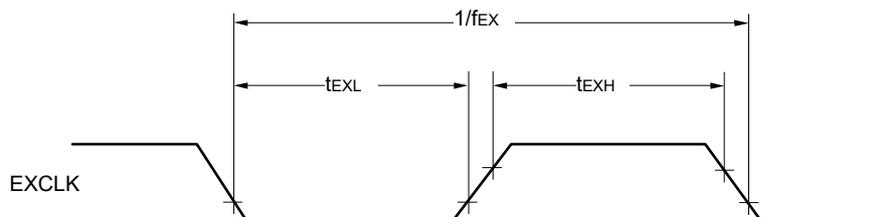
Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit	
TO00 to TO03, TKBO0, and TKBO1 output frequency Note	fro	TO00 to TO03, TKBO0, and TKBO1 (in the case of output from port pins other than P20)	HS (high-speed main) mode	4.0 V ≤ EVDD ≤ 5.5 V			12	MHz	
				2.7 V ≤ EVDD < 4.0 V			8		
				1.8 V ≤ EVDD < 2.7 V			4		
				1.6 V ≤ EVDD < 1.8 V			2		
			LS (low-speed main) mode	1.8 V ≤ EVDD ≤ 5.5 V			4		
				1.6 V ≤ EVDD < 1.8 V			2		
			LP (low-power main) mode	1.8 V ≤ EVDD ≤ 5.5 V			0.5		
			LV (low-voltage main) mode	1.6 V ≤ EVDD ≤ 5.5 V			2		
			TKBO1 (in the case of output from P20)	HS (high-speed main) mode	4.0 V ≤ VDD ≤ 5.5 V				1.5
					2.7 V ≤ VDD < 4.0 V				1.2
		2.4 V ≤ VDD < 2.7 V					1		
		LS (low-speed main) mode		4.0 V ≤ VDD ≤ 5.5 V			1.5		
				2.7 V ≤ VDD < 4.0 V			1.2		
				2.4 V ≤ VDD < 2.7 V			1		
				1.8 V ≤ VDD < 2.4 V			0.75		
		LP (low-power main) mode		1.8 V ≤ VDD ≤ 5.5 V			0.5		
		LV (low-voltage main) mode		4.0 V ≤ VDD ≤ 5.5 V			1.5		
				2.7 V ≤ VDD < 4.0 V			1.2		
2.4 V ≤ VDD < 2.7 V				1					
1.8 V ≤ VDD < 2.4 V				0.75					
PCLBUZ0, PCLBUZ1 output frequency	fpCL	HS (high-speed main) mode	4.0 V ≤ EVDD ≤ 5.5 V			16	MHz		
			2.7 V ≤ EVDD < 4.0 V			8			
			1.8 V ≤ EVDD < 2.7 V			4			
			1.6 V ≤ EVDD < 1.8 V			2			
		LS (low-speed main) mode	1.8 V ≤ EVDD ≤ 5.5 V			4			
			1.6 V ≤ EVDD < 1.8 V			2			
		LP (low-power main) mode	1.6 V ≤ EVDD ≤ 5.5 V			1			
		LV (low-voltage main) mode	1.8 V ≤ EVDD ≤ 5.5 V			4			
1.6 V ≤ EVDD < 1.8 V				2					
Interrupt input high-/ low-level width	tINTH, tINTL	INTP0 to INTP2, INTP9	1.6 V ≤ VDD ≤ 5.5 V	1			μs		
		INTP3 to INTP8, INTP10, INTP11	1.6 V ≤ EVDD ≤ 5.5 V	1					
Key interrupt input low-level width	tKR	KR0 to KR7	1.8 V ≤ EVDD ≤ 5.5 V	250			ns		
			1.6 V ≤ EVDD < 1.8 V	1			μs		
RESET low-level width	trSL			10			μs		

Note When duty is 50%.

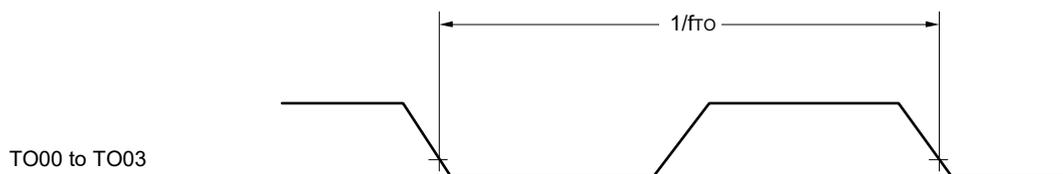
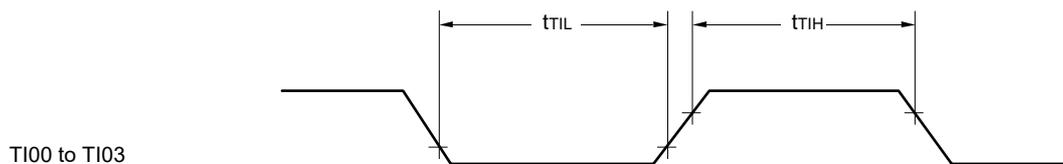
AC Timing Test Points



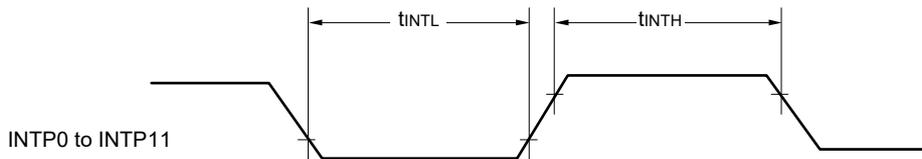
External System Clock Timing



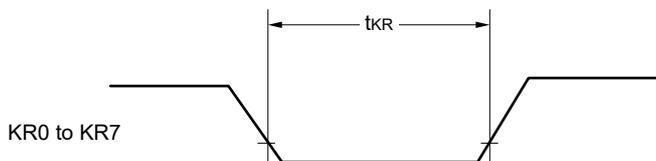
TI/TO Timing



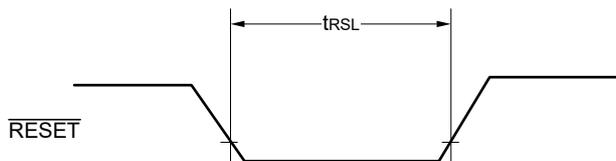
Interrupt Request Input Timing



Key Interrupt Input Timing

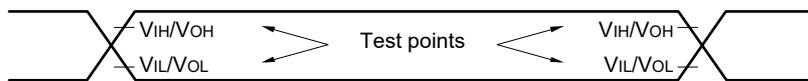


$\overline{\text{RESET}}$ Input Timing



2.5 Peripheral Functions Characteristics

AC Timing Test Points



2.5.1 Serial array unit

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

When P01, P30, P31 and P54 are used as Tx/Dq pins

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate Note 1, 2		2.7 V ≤ EVDD ≤ 5.5 V		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		4.0		1.3		0.1		0.6	Mbps
		1.8 V ≤ EVDD ≤ 5.5 V		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		4.0		1.3		0.1		0.6	Mbps
		1.7 V ≤ EVDD ≤ 5.5 V		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		4.0		1.3		0.1		0.6	Mbps
		1.6 V ≤ EVDD ≤ 5.5 V		—		f _{MCK} /6		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		—		1.3		0.1		0.6	Mbps

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

Note 2. Following conditions must be satisfied on low level interface of EVDD < VDD.

2.4 V ≤ EVDD < 2.7 V: MAX.2.6 Mbps

1.8 V ≤ EVDD < 2.4 V: MAX.1.3 Mbps

1.6 V ≤ EVDD < 1.8 V: MAX.0.6 Mbps

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

HS (high-speed main) mode: 24 MHz (2.7 V ≤ EVDD ≤ 5.5 V)

16 MHz (2.4 V ≤ EVDD ≤ 5.5 V)

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

LP (low-power main) mode: 1 MHz (1.8 V ≤ EVDD ≤ 5.5 V)

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

Caution Select the normal input buffer for the Rx/Dq pin and the normal output mode for the Tx/Dq pin by using port input mode register g (PIMg) and port output mode register g (POMg).

When P20 is used as TxD1 pin**(TA = -40 to +85°C, 1.6 V ≤ EVDD = VDD ≤ 5.5 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit	
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
Transfer rate		4.0 V ≤ VDD ≤ 5.5 V		f _{mck} /6 Notes 1, 2, 3		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2	bps	
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3		1.5		1.3		0.1		0.6	Mbps	
		2.7 V ≤ VDD ≤ 5.5 V		f _{mck} /6 Notes 1, 2, 3		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2	bps	
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3		1.2		1.2		0.1		0.6	Mbps	
		2.4 V ≤ VDD ≤ 5.5 V		f _{mck} /6 Notes 1, 2, 3		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2	bps	
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3		1.0		1.0		0.1		0.6	Mbps	
		1.8 V ≤ VDD ≤ 5.5 V				f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2		f _{mck} /6 Notes 1, 2	bps	
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3				0.6		0.1		0.6	Mbps	
		1.7 V ≤ VDD ≤ 5.5 V			Using prohibited		Using prohibited		Using prohibited		f _{mck} /6 Notes 1, 2	bps
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3			Using prohibited		Using prohibited		Using prohibited		0.5	Mbps
		1.6 V ≤ VDD ≤ 5.5 V									f _{mck} /6 Notes 1, 2	bps
		Theoretical value of the maximum transfer rate f _{mck} = f _{clk} Notes 1, 3									0.5	Mbps

Note 1. f_{mck} is a frequency selected by setting the CKS bit in the SPS and SMR registers.

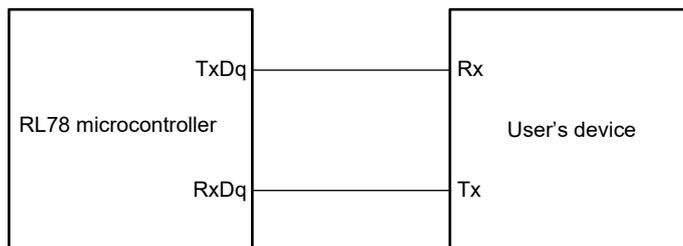
Note 2. The transfer rate of 4800 bps is only supported in the SNOOZE mode.
Note that the SNOOZE mode is not supported when f_{HOCO} is 48 MHz.

Note 3. f_{clk} in each operating mode is as follows.:

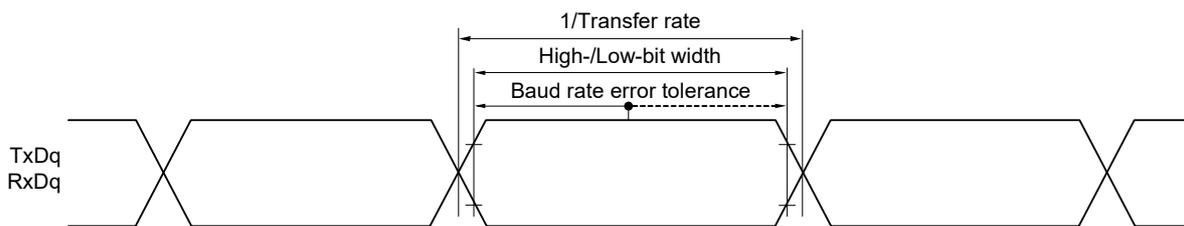
- HS (high-speed main) mode: 24 MHz (2.7 V ≤ VDD ≤ 5.5 V)
16 MHz (2.4 V ≤ VDD ≤ 5.5 V)
- LS (low-speed main) mode: 8 MHz (1.8 V ≤ VDD ≤ 5.5 V)
- LP (low-power main) mode: 1 MHz (1.8 V ≤ VDD ≤ 5.5 V)
- LV (low-voltage main) mode: 4 MHz (1.6 V ≤ VDD ≤ 5.5 V)

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

UART mode connection diagram (during communication at same potential)



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



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

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

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

(2) During communication at same potential (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ 2/f _{CLK}	83.3		250		2000		500		ns
SCKp high-/low-level width	t _{KL1}	4.0 V ≤ EVDD ≤ 5.5 V	t _{KCY1} /2 - 7		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
		2.7 V ≤ EVDD ≤ 5.5 V	t _{KCY1} /2 - 10								ns
Slp setup time (to SCKp↑) Note 1	t _{SIK1}	4.0 V ≤ EVDD ≤ 5.5 V	23		110		110		110		ns
		2.7 V ≤ EVDD ≤ 5.5 V	33								ns
Slp hold time (from SCKp↑) Note 2	t _{SIH1}		10		10		10		10		ns
Delay time from SCKp↓ to SOp output Note 3	t _{KSO1}	C = 20 pF Note 4		10		20		20		20	ns

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

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

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

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

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

Remark 1. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM numbers (g = 5)

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

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

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

When P01, P32, P53, P54 and P56 are used as SOMn pins

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

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	tkCY1	tkCY1 ≥ 4/fCLK	2.7 V ≤ EVDD ≤ 5.5 V	167		500		4000		1000		ns
			2.4 V ≤ EVDD ≤ 5.5 V	250								
			1.8 V ≤ EVDD ≤ 5.5 V	500								
			1.7 V ≤ EVDD ≤ 5.5 V	1000	1000							
			1.6 V ≤ EVDD ≤ 5.5 V	Using prohibited								
SCKp high-/low-level width	tkH1, tkL1	4.0 V ≤ EVDD ≤ 5.5 V		tkCY1/2- 12		tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50	ns	
		2.7 V ≤ EVDD ≤ 5.5 V		tkCY1/2- 18								
		2.4 V ≤ EVDD ≤ 5.5 V		tkCY1/2- 38								
		1.8 V ≤ EVDD ≤ 5.5 V		tkCY1/2- 50								
		1.7 V ≤ EVDD ≤ 5.5 V		tkCY1/2- 100		tkCY1/2 - 100		tkCY1/2 - 100		tkCY1/2 - 100		
		1.6 V ≤ EVDD ≤ 5.5 V		Using prohibited								
Slp setup time (to SCKp↑) Note 1	tsIK1	4.0 V ≤ EVDD ≤ 5.5 V		44		110		110		110	ns	
		2.7 V ≤ EVDD ≤ 5.5 V										
		2.4 V ≤ EVDD ≤ 5.5 V		75								
		1.8 V ≤ EVDD ≤ 5.5 V		110								
		1.7 V ≤ EVDD ≤ 5.5 V		220		220		220		220		
		1.6 V ≤ EVDD ≤ 5.5 V		Using prohibited								
Slp hold time (from SCKp↑) Note 2	tkSI1	1.7 V ≤ EVDD ≤ 5.5 V		19		19		19		19	ns	
		1.6 V ≤ EVDD ≤ 5.5 V		Using prohibited								
Delay time from SCKp↓ to SOp output Note 3	tkSO1	C = 30 pF Note 4	1.7 V ≤ EVDD ≤ 5.5 V		33.4	33.4		33.4		33.4	ns	
			1.6 V ≤ EVDD ≤ 5.5 V		Using prohibited							

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

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

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

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

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

When P20 is used as SO10 pin**(TA = -40 to +85°C, 1.6 V ≤ EVDD = VDD ≤ 5.5 V, VSS = 0 V)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	tkCY1	tkCY1 ≥ 4/fCLK	4.0 V ≤ VDD ≤ 5.5 V	600		600		4000		1000		ns
			2.7 V ≤ VDD ≤ 5.5 V	850		850						
			2.4 V ≤ VDD ≤ 5.5 V	1000		1000						
			1.8 V ≤ VDD ≤ 5.5 V	—		1500				1500		
			1.7 V ≤ VDD ≤ 5.5 V	—		—		—		2000		
			1.6 V ≤ VDD ≤ 5.5 V	—		—		—		—		
SCKp high-/low-level width	tkH1, tkL1	4.0 V ≤ VDD ≤ 5.5 V		tkCY1/2 - 12		tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50		ns
		2.7 V ≤ VDD ≤ 5.5 V		tkCY1/2 - 18								
		2.4 V ≤ VDD ≤ 5.5 V		tkCY1/2 - 38								
		1.8 V ≤ VDD ≤ 5.5 V		—								
		1.7 V ≤ VDD ≤ 5.5 V		—		—		—		tkCY1/2 - 100		
		1.6 V ≤ VDD ≤ 5.5 V		—		—		—		—		
Slp setup time (to SCKp↑) Note 1	tSIK1	4.0 V ≤ VDD ≤ 5.5 V		44		110		110		110		ns
		2.7 V ≤ VDD ≤ 5.5 V										
		2.4 V ≤ VDD ≤ 5.5 V		75								
		1.8 V ≤ VDD ≤ 5.5 V		—								
		1.7 V ≤ VDD ≤ 5.5 V		—		—		—		220		
		1.6 V ≤ VDD ≤ 5.5 V		—		—		—		—		
Slp hold time (from SCKp↑) Note 2	tkSI1	2.4 V ≤ VDD ≤ 5.5 V		19		19		19		19		ns
		1.8 V ≤ VDD ≤ 5.5 V		—								
		1.6 V ≤ VDD ≤ 5.5 V		—		—		—				
Delay time from SCKp↓ to SOp output Note 3	tkSO1	C = 30 pF Note 4	2.4 V ≤ VDD ≤ 5.5 V		150		250		250		300	ns
			1.8 V ≤ VDD ≤ 5.5 V		—							
			1.6 V ≤ VDD ≤ 5.5 V		—		—		—			

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

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

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

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

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 4 and 12)

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

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

When P01, P32, P53, P54 and P56 are used as SOMn pins

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

(1/2)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time Note 3	tkcy2	4.0 V ≤ EVDD ≤ 5.5 V	f _{MCK} > 20 MHz	8/f _{MCK}	—	—	—	—	—	—	ns	
			f _{MCK} ≤ 20 MHz	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}				
		2.7 V ≤ EVDD ≤ 5.5 V	f _{MCK} > 16 MHz	8/f _{MCK}	—	—	—	—	—			
			f _{MCK} ≤ 16 MHz	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}	6/f _{MCK}				
		2.4 V ≤ EVDD ≤ 5.5 V		6/f _{MCK} and 500								
		1.8 V ≤ EVDD ≤ 5.5 V		6/f _{MCK} and 750								
		1.7 V ≤ EVDD ≤ 5.5 V		6/f _{MCK} and 1500		6/f _{MCK} and 1500						
1.6 V ≤ EVDD ≤ 5.5 V		—										
SCKp high-/low-level width	tkH2, tkL2	4.0 V ≤ EVDD ≤ 5.5 V		tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	ns		
		2.7 V ≤ EVDD ≤ 5.5 V		tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8			
		1.8 V ≤ EVDD ≤ 5.5 V		tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18			
		1.7 V ≤ EVDD ≤ 5.5 V		tkcy2/2 - 66	tkcy2/2 - 66	tkcy2/2 - 66	tkcy2/2 - 66	tkcy2/2 - 66	tkcy2/2 - 66			
		1.6 V ≤ EVDD ≤ 5.5 V		—								
Slp setup time (to SCKp) Note 1	tsIK2	2.7 V ≤ EVDD ≤ 5.5 V		1/f _{MCK} + 20	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	ns		
		1.8 V ≤ EVDD ≤ 5.5 V		1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30	1/f _{MCK} + 30			
		1.7 V ≤ EVDD ≤ 5.5 V		1/f _{MCK} + 40	1/f _{MCK} + 40	1/f _{MCK} + 40	1/f _{MCK} + 40	1/f _{MCK} + 40	1/f _{MCK} + 40			
		1.6 V ≤ EVDD ≤ 5.5 V		—								
Slp hold time (from SCKp) Note 2	tsIS2	1.8 V ≤ EVDD ≤ 5.5 V		1/f _{MCK} + 31	1/f _{MCK} + 31	1/f _{MCK} + 31	1/f _{MCK} + 31	1/f _{MCK} + 31	1/f _{MCK} + 31	ns		
		1.7 V ≤ EVDD ≤ 5.5 V		1/f _{MCK} + 250	1/f _{MCK} + 250	1/f _{MCK} + 250	1/f _{MCK} + 250	1/f _{MCK} + 250	1/f _{MCK} + 250			
		1.6 V ≤ EVDD ≤ 5.5 V		—								

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

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

Note 3. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

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

(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit		
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.			
Delay time from SCKp↓ to SOp output Note 1	tkso2	C = 30 pF Note 2	2.7 V ≤ EVDD ≤ 5.5 V		2/fmck + 44		2/fmck + 110		2/fmck + 110		2/fmck + 110	ns	
			2.4 V ≤ EVDD ≤ 5.5 V		2/fmck + 75								
			1.8 V ≤ EVDD ≤ 5.5 V		2/fmck + 110								
			1.7 V ≤ EVDD ≤ 5.5 V		2/fmck + 220		2/fmck + 220		2/fmck + 220		2/fmck + 220		
			1.6 V ≤ EVDD ≤ 5.5 V		—								
SSi00 setup time	tssik	DAPmn = 0	2.7 V ≤ VDD ≤ 5.5 V	120		120		120		120		ns	
			1.8 V ≤ VDD < 2.7 V	200		200		200		200			
			1.7 V ≤ VDD < 1.8 V	400		400		400		400			
			1.6 V ≤ VDD < 1.7 V	—									
		DAPmn = 1	2.7 V ≤ VDD ≤ 5.5 V	1/fmck + 120		1/fmck + 120		1/fmck + 120		1/fmck + 120		1/fmck + 120	ns
			1.8 V ≤ VDD < 2.7 V	1/fmck + 200		1/fmck + 200		1/fmck + 200		1/fmck + 200		1/fmck + 200	
			1.7 V ≤ VDD < 1.8 V	1/fmck + 400		1/fmck + 400		1/fmck + 400		1/fmck + 400		1/fmck + 400	
			1.6 V ≤ VDD < 1.7 V	—									
SSi00 hold time	tkssi	DAPmn = 0	2.7 V ≤ VDD ≤ 5.5 V	1/fmck + 120		1/fmck + 120		1/fmck + 120		1/fmck + 120		ns	
			1.8 V ≤ VDD < 2.7 V	1/fmck + 200		1/fmck + 200		1/fmck + 200		1/fmck + 200			
			1.7 V ≤ VDD < 1.8 V	1/fmck + 400		1/fmck + 400		1/fmck + 400		1/fmck + 400			
			1.6 V ≤ VDD < 1.7 V	—									
		DAPmn = 1	2.7 V ≤ VDD ≤ 5.5 V	120		120		120		120		120	ns
			1.8 V ≤ VDD < 2.7 V	200		200		200		200		200	
			1.7 V ≤ VDD < 1.8 V	400		400		400		400		400	
			1.6 V ≤ VDD < 1.7 V	—									

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

Note 2. C is the load capacitance of the SOp output lines.

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

When P20 is used as SO10 pin

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

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time Note 5	tkcy2	4.0 V ≤ VDD ≤ 5.5 V	fMCK > 20 MHz	14/fMCK	—	—	—	—	—	—	ns	
			fMCK ≤ 20 MHz	12/fMCK	12/fMCK	12/fMCK	12/fMCK	12/fMCK				
		2.7 V ≤ VDD ≤ 5.5 V	fMCK > 16 MHz and 850	14/fMCK	—	—	—	—	—			
			fMCK ≤ 16 MHz	12/fMCK and 850	12/fMCK	12/fMCK	12/fMCK	12/fMCK				
		2.4 V ≤ VDD ≤ 5.5 V		12/fMCK and 1000	12/fMCK	12/fMCK	12/fMCK	12/fMCK	12/fMCK			
		1.8 V ≤ VDD ≤ 5.5 V		—	12/fMCK	12/fMCK	12/fMCK	12/fMCK	12/fMCK			
		1.7 V ≤ VDD ≤ 5.5 V		—	—	—	—	12/fMCK	—			
1.6 V ≤ VDD ≤ 5.5 V		—	—	—	—	—	—					
SCKp high-/low-level width	tkH2, tkL2	4.0 V ≤ VDD ≤ 5.5 V		tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	tkcy2/2 - 7	ns			
		2.7 V ≤ VDD ≤ 5.5 V		tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8	tkcy2/2 - 8				
		1.8 V ≤ VDD ≤ 5.5 V		—	tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18	tkcy2/2 - 18				
		1.7 V ≤ VDD ≤ 5.5 V		—	—	—	—	tkcy2/2 - 66				
		1.6 V ≤ VDD ≤ 5.5 V		—	—	—	—	—				
Slp setup time (to SCKp↑) Note 1	tsIK2	2.7 V ≤ VDD ≤ 5.5 V		1/fMCK + 20	1/fMCK + 30	1/fMCK + 30	1/fMCK + 30	1/fMCK + 30	ns			
		2.4 V ≤ VDD ≤ 5.5 V		1/fMCK + 30	—	—	—	—				
		1.8 V ≤ VDD ≤ 5.5 V		—	—	—	—	—				
		1.7 V ≤ VDD ≤ 5.5 V		—	—	—	—	1/fMCK + 40				
		1.6 V ≤ VDD ≤ 5.5 V		—	—	—	—	—				
Slp hold time (from SCKp↑) Note 2	tkSI2	2.4 V ≤ VDD ≤ 5.5 V		1/fMCK + 31	1/fMCK + 31	1/fMCK + 31	1/fMCK + 31	1/fMCK + 31	ns			
		1.8 V ≤ VDD ≤ 5.5 V		—	1/fMCK + 31	1/fMCK + 31	1/fMCK + 31	1/fMCK + 31				
		1.7 V ≤ VDD ≤ 5.5 V		—	—	—	—	1/fMCK + 250				
		1.6 V ≤ VDD ≤ 5.5 V		—	—	—	—	—				
Delay time from SCKp↓ to SOp output Note 3	tkSO2	C = 30 pF Note 4	2.7 V ≤ VDD ≤ 5.5 V	2/fMCK + 160	2/fMCK + 260	2/fMCK + 260	2/fMCK + 260	2/fMCK + 260	ns			
			2.4 V ≤ VDD ≤ 5.5 V	2/fMCK + 190	—	—	—	—				
			1.8 V ≤ VDD ≤ 5.5 V	—	—	—	—	—				
			1.7 V ≤ VDD ≤ 5.5 V	—	—	—	—	2/fMCK + 320				
			1.6 V ≤ VDD ≤ 5.5 V	—	—	—	—	—				

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

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

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

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

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

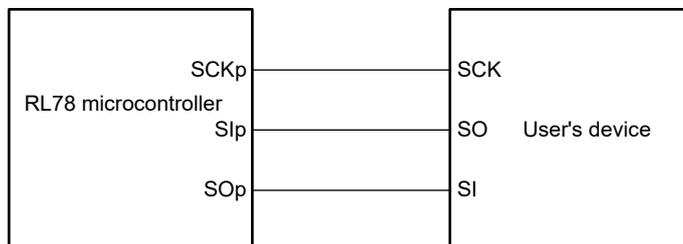
Caution Select the normal input buffer for the Slp pin and the normal output mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg).

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

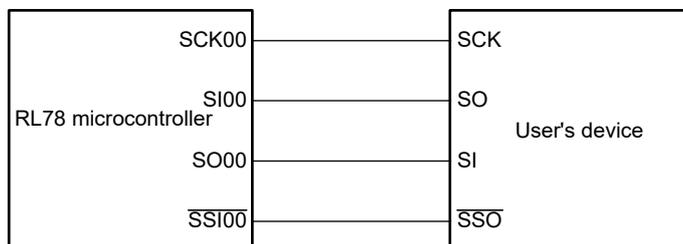
numbers (g = 0, 4 and 12)

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

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

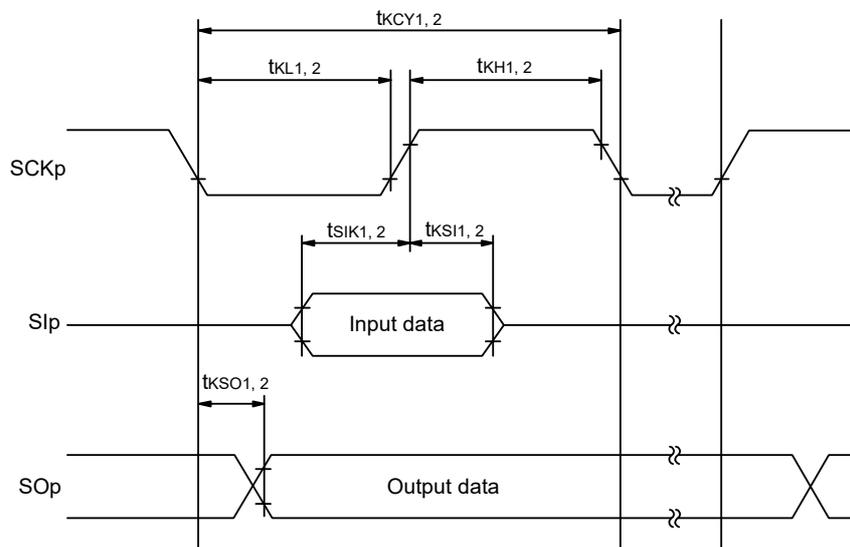


**Simplified SPI (CSI) mode connection diagram (during communication at same potential)
 (Slave Transmission of slave select input function (CSI00))**

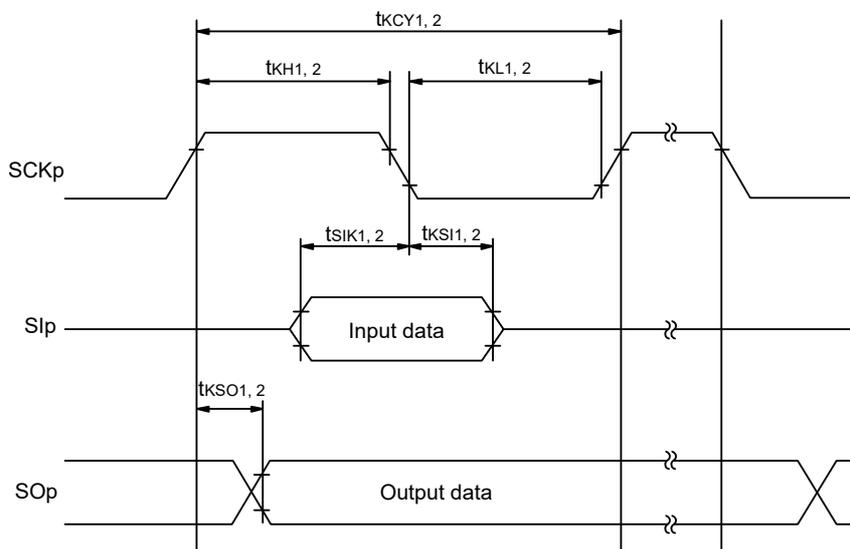


Remark p: CSI number (p = 00, 01, 10 and 11)

**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.)**



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

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

(5) During communication at same potential (simplified I²C mode)

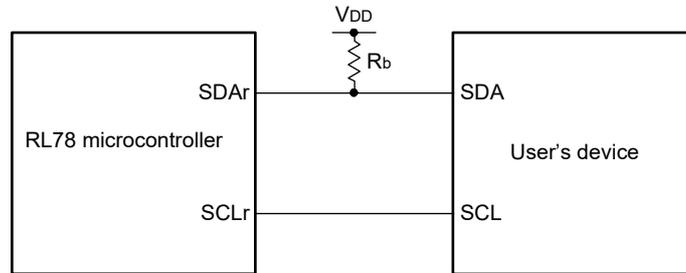
(TA = -40 to +85°C, 1.6 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f _{SCL}	2.7 V ≤ EVDD ≤ 5.5 V, Cb = 50 pF, Rb = 2.7 kΩ		1000 Note 1		400 Note 1		250 Note 1		400 Note 1	kHz
		1.8 V ≤ EVDD ≤ 5.5 V, Cb = 100 pF, Rb = 3 kΩ		400 Note 1							
		1.8 V ≤ EVDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ		300 Note 1		300 Note 1		250 Note 1		300 Note 1	
		1.7 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ		250 Note 1		250 Note 1		250 Note 1		250 Note 1	
		1.6 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ		—							
Hold time when SCLr = "L"	t _{LOW}	2.7 V ≤ EVDD ≤ 5.5 V, Cb = 50 pF, Rb = 2.7 kΩ	475		1150		1150		1150		ns
		1.8 V ≤ EVDD ≤ 5.5 V, Cb = 100 pF, Rb = 3 kΩ	1150								
		1.8 V ≤ EVDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1550		1550		1550		1550		
		1.7 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	1850		1850		1850		1850		
		1.6 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—								
Hold time when SCLr = "H"	t _{HIGH}	2.7 V ≤ EVDD ≤ 5.5 V, Cb = 50 pF, Rb = 2.7 kΩ	475		1150		1150		1150		ns
		1.8 V ≤ EVDD ≤ 5.5 V, Cb = 100 pF, Rb = 3 kΩ	1150								
		1.8 V ≤ EVDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1550		1550		1550		1550		
		1.7 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	1850		1850		1850		1850		
		1.6 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—								
Data setup time (reception)	t _{SETUP: DAT}	2.7 V ≤ EVDD ≤ 5.5 V, Cb = 50 pF, Rb = 2.7 kΩ	1/f _{MCK} + 85 Note 2		1/f _{MCK} + 145 Note 2		1/f _{MCK} + 145 Note 2		1/f _{MCK} + 145 Note 2		ns
		1.8 V ≤ EVDD ≤ 5.5 V, Cb = 100 pF, Rb = 3 kΩ	1/f _{MCK} + 145 Note 2								
		1.8 V ≤ EVDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1/f _{MCK} + 230 Note 2		1/f _{MCK} + 230 Note 2		1/f _{MCK} + 230 Note 2		1/f _{MCK} + 230 Note 2		
		1.7 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	1/f _{MCK} + 290 Note 2		1/f _{MCK} + 290 Note 2		1/f _{MCK} + 290 Note 2		1/f _{MCK} + 290 Note 2		
		1.6 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—								
Data hold time (transmission)	t _{HOLD: DAT}	2.7 V ≤ EVDD ≤ 5.5 V, Cb = 50 pF, Rb = 2.7 kΩ	0	305	0	305	0	305	0	305	ns
		1.8 V ≤ EVDD ≤ 5.5 V, Cb = 100 pF, Rb = 3 kΩ		355		355		355		355	
		1.8 V ≤ EVDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ		405		405		405		405	
		1.7 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ									
		1.6 V ≤ EVDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—	—							

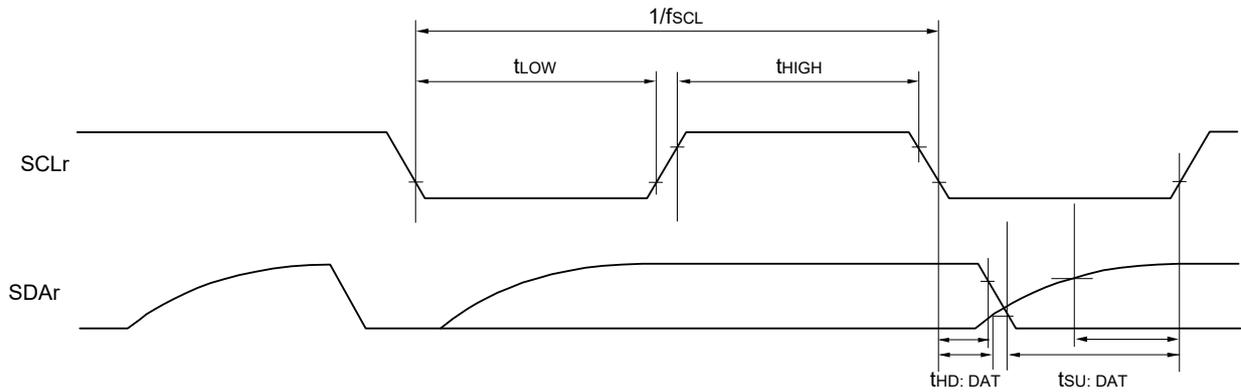
- Note 1.** The value must be equal to or less than $f_{MCK}/4$.
- Note 2.** Set the f_{MCK} value to keep the hold time of $SCLr = "L"$ and $SCLr = "H"$.

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

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



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



- Remark 1.** $R_b[\Omega]$: Communication line ($SDAr$) pull-up resistance, $C_b[F]$: Communication line ($SDAr$, $SCLr$) load capacitance
 r: IIC number (r = 00, 01, 10 and 11), g: PIM number (g = 0, 3 and 5), h: POM number (h = 0, 3 and 5)
- Remark 2.** f_{MCK} : Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0),
 n: Channel number (n = 0 to 3), mn = 00 to 03)

(6) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (UART mode) (dedicated baud rate generator output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit	
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
Transfer rate		reception	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V		fMCK/6 Note 1		fMCK/6 Note 1		fMCK/6 Note 1		fMCK/6 Note 1	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		4.0		1.3		0.1		0.6	Mbps
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V		fMCK/6 Note 1		fMCK/6 Note 1		fMCK/6 Note 1		fMCK/6 Note 1	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		4.0		1.3		0.1		0.6	Mbps
			1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V		fMCK/6 Notes 1, 2, 4		fMCK/6 Notes 1, 2		fMCK/6 Notes 1, 2		fMCK/6 Notes 1, 2	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		4.0		1.3		0.1		0.6	Mbps

Note 1. Transfer rate in the SNOOZE mode is 4,800 bps only.**Note 2.** Use it with EVDD ≥ Vb.**Note 3.** The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

HS (high-speed main) mode: 24 MHz (2.7 V ≤ VDD ≤ 5.5 V)

16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

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

LP (low-power main) mode: 1 MHz (1.8 V ≤ VDD ≤ 5.5 V)

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

Note 4. The following conditions are required for low voltage interface when EVDD < VDD

2.4 V ≤ EVDD < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ EVDD < 2.4 V: MAX. 1.3 Mbps

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (EVDD tolerance) mode for the TxDq pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.**Remark 1.** Vb[V]: Communication line voltage**Remark 2.** q: UART number (q = 0 and 1), g: PIM and POM number (g = 0, 2, 3, 5 and 12)**Remark 3.** fMCK: Serial array unit operation clock frequency

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

n: Channel number (mn = 00 to 03))

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

(2/2)

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

Note 1. The smaller maximum transfer rate derived by using $f_{MCK}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when $4.0\text{ V} \leq EV_{DD} \leq 5.5\text{ V}$ and $2.7\text{ V} \leq V_b \leq 4.0\text{ V}$

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

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

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

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

Note 3. The smaller maximum transfer rate derived by using $f_{MCK}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when $2.7\text{ V} \leq EV_{DD} \leq 4.0\text{ V}$ and $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$

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

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

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

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

Note 5. Use it with $EV_{DD} \geq V_b$.

Note 6. The smaller maximum transfer rate derived by using $f_{MCK}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when $1.8\text{ V} \leq EV_{DD} < 3.3\text{ V}$ and $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$

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

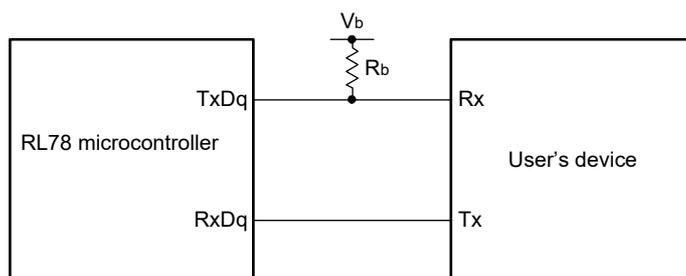
$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{\left(\frac{1}{\text{Transfer rate}}\right) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

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

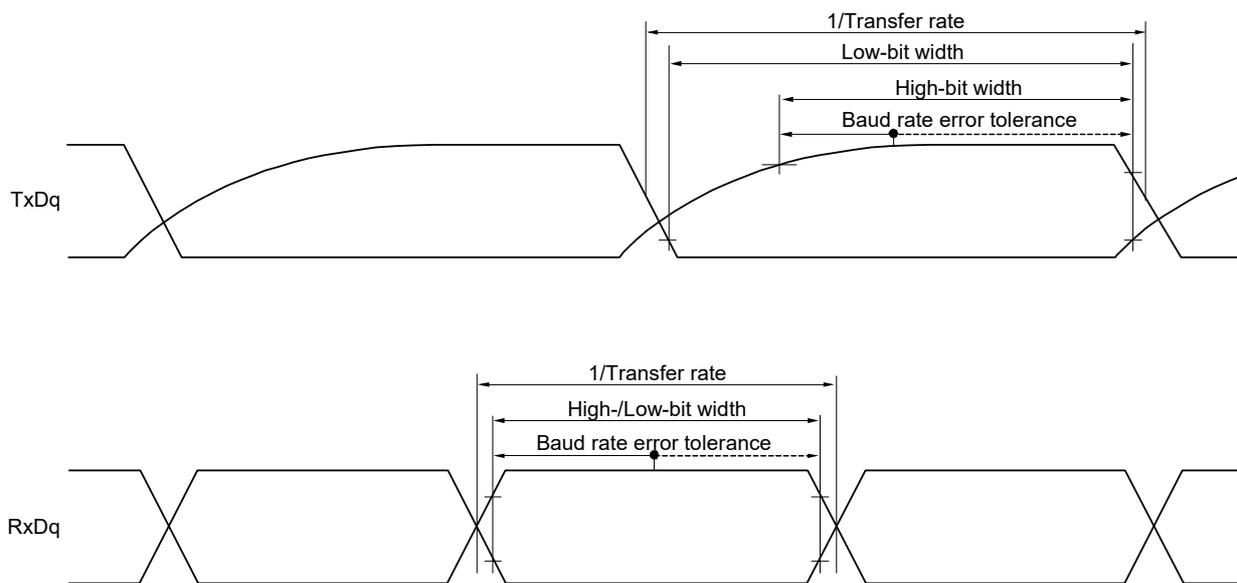
Note 7. This value as an example is calculated when the conditions described in the "Conditions" column are met. Refer to Note 6 above to calculate the maximum transfer rate under conditions of the customer.

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (EV_{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.

UART mode connection diagram (during communication at different potential)



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



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

Remark 2. q: UART number (q = 0 and 1), g: PIM and POM number (g = 0, 2, 3, 5 and 12)

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

(7) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)

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

(1/2)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	tkCY1	tkCY1 ≥ 2/fCLK	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	200		1150		1150		1150		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	300								ns
SCKp high-level width	tkH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	tkCY1/2 - 120		tkCY1/2 - 120		tkCY1/2 - 120		tkCY1/2 - 120		ns
SCKp low-level width	tkL1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	tkCY1/2 - 7		tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	tkCY1/2 - 10								
Slp setup time (to SCKp↑) Note 1	tSIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	58		479		479		479		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	121								
Slp hold time (from SCKp↑) Note 1	tKSI1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	10		10		10		10		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ									
Delay time from SCKp↓ to SOp output Note 1	tkSO1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ		60		60		60		60	ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ		130		130		130		130	
Slp setup time (to SCKp↓) Note 2	tSIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	23		110		110		110		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	33								
Slp hold time (from SCKp↓) Note 2	tKSI1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	10		10		10		10		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ									

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

(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Delay time from SCKp↑ to SOp output ^{Note 2}	tkSO1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 20 pF, Rb = 1.4 kΩ		10		10		10		10	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ									

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

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

Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output (EVDD 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 VIH and VIL, see the DC characteristics with TTL input buffer selected.

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

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

Remark 3. fмck: 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))

(8) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit	
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
SCKp cycle time	tkCY1	tkCY1 ≥ 4/fCLK	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	300		1150		1150		1150		ns
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	500								ns
			1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note, Cb = 30 pF, Rb = 5.5 kΩ	1150								ns
SCKp high-level width	tkH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	tkCY1/2 - 75		tkCY1/2 - 75		tkCY1/2 - 75		tkCY1/2 - 75		ns	
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	tkCY1/2 - 170		tkCY1/2 - 170		tkCY1/2 - 170		tkCY1/2 - 170		ns
			1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note, Cb = 30 pF, Rb = 5.5 kΩ	tkCY1/2 - 458		tkCY1/2 - 458		tkCY1/2 - 458		tkCY1/2 - 458		ns
SCKp low-level width	tkL1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	tkCY1/2 - 12		tkCY1/2 - 50		tkCY1/2 - 50		tkCY1/2 - 50		ns	
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	tkCY1/2 - 18								
			1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note, Cb = 30 pF, Rb = 5.5 kΩ	tkCY1/2 - 50								ns

Note Use it with EVDD ≥ Vb.**Caution** Select the TTL input buffer for the SIp pin and the N-ch open drain output (EVDD 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 VIH and VIL, see the DC characteristics with TTL input buffer selected.

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

(8) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85°C, 1.8 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(2/2)**

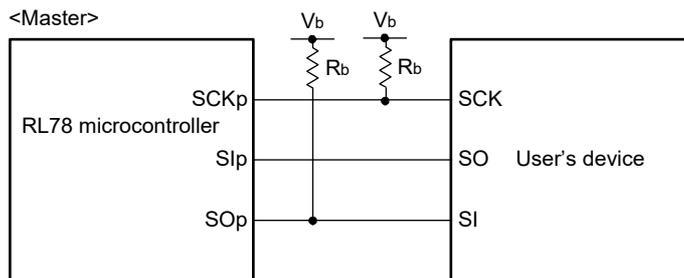
Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Slp setup time (to SCKp↑) Note 1	tsIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	81		479		479		479		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	177								
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	479								
Slp hold time (from SCKp↑) Note 1	tkSH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	19		19		19		19		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ									
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ									
Delay time from SCKp↓ to SOp output Note 1	tkSO1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ		100		100		100		100	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ		195		195		195		195	
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ		483		483		483		483	
Slp setup time (to SCKp↓) Note 2	tsIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	44		110		110		110		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ									
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	110								
Slp hold time (from SCKp↓) Note 2	tkSH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	19		19		19		19		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ									
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ									
Delay time from SCKp↑ to SOp output Note 2	tkSO1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ		25		25		25		25	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ									
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ									

Note 1. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1.**Note 2.** When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Note 3.** Use it with EVDD ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (EVDD 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 VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

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

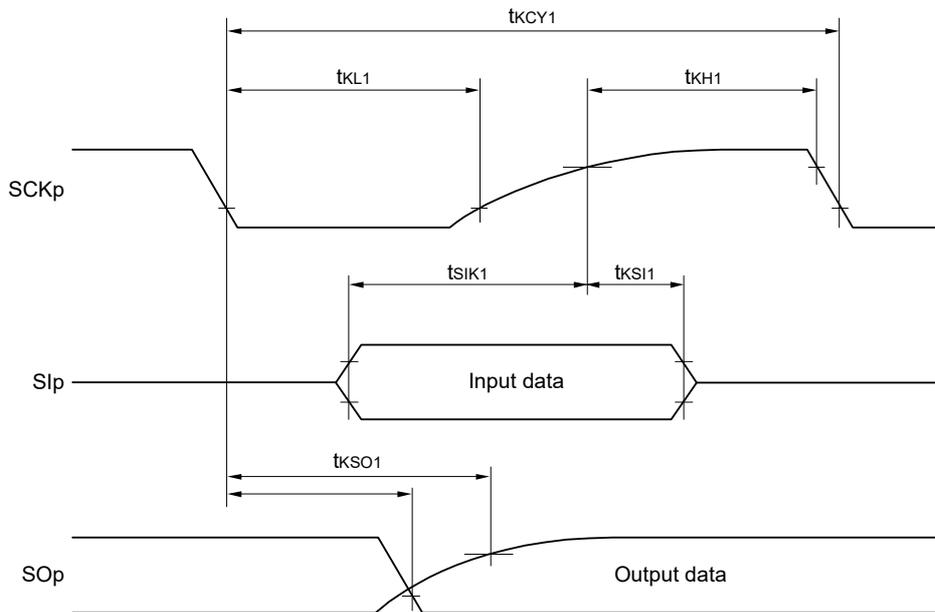


Remark 1. $R_b[\Omega]$: Communication line (SCKp, SOp) pull-up resistance, $C_b[F]$: Communication line (SCKp, SOp) load capacitance, $V_b[V]$: Communication line voltage

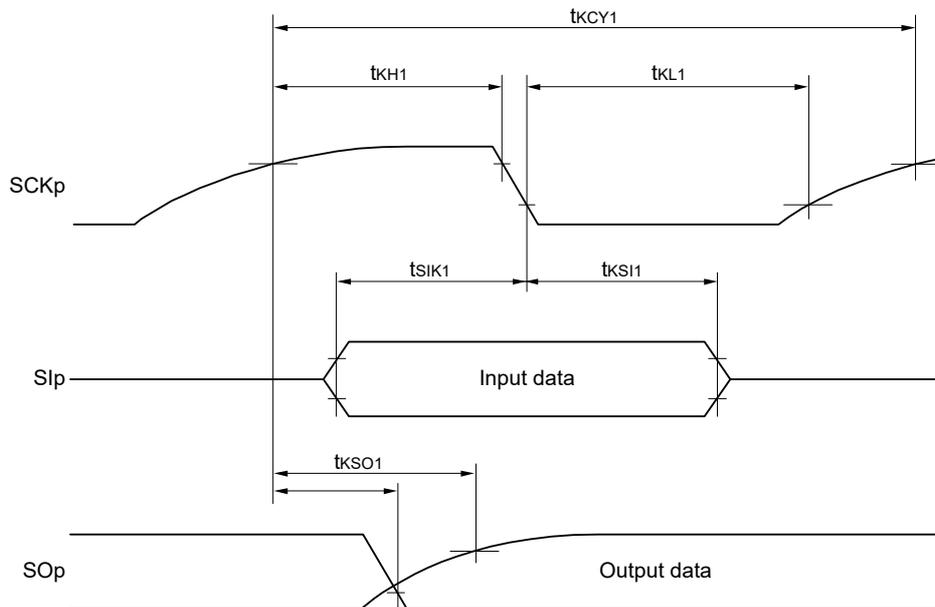
Remark 2. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

**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.)**



Remark p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

(9) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)

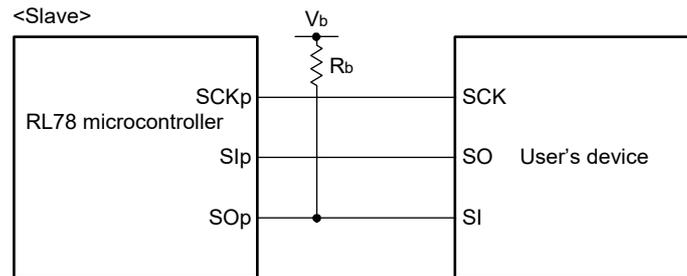
(TA = -40 to 85°C, 1.8 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time ^{Note 1}	tkcy2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V	20 MHz < fMCK ≤ 24 MHz	12/fMCK	—	—	—	—	—	—	ns
			8 MHz < fMCK ≤ 20 MHz	10/fMCK	—	—	—	—	—	—	ns
			4 MHz < fMCK ≤ 8 MHz	8/fMCK	—	16/fMCK	—	—	—	—	ns
			fMCK ≤ 4 MHz	6/fMCK	—	10/fMCK	10/fMCK	—	10/fMCK	—	ns
	2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V	20 MHz < fMCK ≤ 24 MHz	16/fMCK	—	—	—	—	—	—	ns	
		16 MHz < fMCK ≤ 20 MHz	14/fMCK	—	—	—	—	—	—	ns	
		8 MHz < fMCK ≤ 16 MHz	12/fMCK	—	—	—	—	—	—	ns	
		4 MHz < fMCK ≤ 8 MHz	8/fMCK	—	16/fMCK	—	—	—	—	ns	
	1.8 V ≤ EVDD < 2.7 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	20 MHz < fMCK ≤ 24 MHz	36/fMCK	—	—	—	—	—	—	ns	
		16 MHz < fMCK ≤ 20 MHz	32/fMCK	—	—	—	—	—	—	ns	
		8 MHz < fMCK ≤ 16 MHz	26/fMCK	—	—	—	—	—	—	ns	
		4 MHz < fMCK ≤ 8 MHz	16/fMCK	—	16/fMCK	—	—	—	—	ns	
fMCK ≤ 4 MHz	10/fMCK	—	10/fMCK	—	10/fMCK	—	10/fMCK	—	ns		
	10/fMCK	—	10/fMCK	—	10/fMCK	—	10/fMCK	—	ns		
	10/fMCK	—	10/fMCK	—	10/fMCK	—	10/fMCK	—	ns		
	10/fMCK	—	10/fMCK	—	10/fMCK	—	10/fMCK	—	ns		
SCKp high-/low-level width	tkH2, tkL2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V	tkcy2/2 - 12	—	tkcy2/2 - 50	—	tkcy2/2 - 50	—	tkcy2/2 - 50	ns	
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V	tkcy2/2 - 18	—	tkcy2/2 - 50	—	tkcy2/2 - 50	—	tkcy2/2 - 50	ns	
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	tkcy2/2 - 50	—	tkcy2/2 - 50	—	tkcy2/2 - 50	—	tkcy2/2 - 50	ns	
Slp setup time (to SCKp1) ^{Note 3}	tsiK2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V	1/fMCK + 20	—	1/fMCK + 30	—	1/fMCK + 30	—	1/fMCK + 30	ns	
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V	1/fMCK + 20	—	1/fMCK + 30	—	1/fMCK + 30	—	1/fMCK + 30	ns	
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	1/fMCK + 30	—	1/fMCK + 30	—	1/fMCK + 30	—	1/fMCK + 30	ns	
Slp hold time (from SCKp1) ^{Note 3}	tkSi2		1/fMCK + 31	—	1/fMCK + 31	—	1/fMCK + 31	—	1/fMCK + 31	ns	
Delay time from SCKp↓ to SOP output ^{Note 4}	tkSO2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	—	2/fMCK + 120	—	2/fMCK + 573	—	2/fMCK + 573	—	2/fMCK + 573	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	—	2/fMCK + 214	—	2/fMCK + 573	—	2/fMCK + 573	—	2/fMCK + 573	ns
		1.8 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2} , Cb = 30 pF, Rb = 5.5 kΩ	—	2/fMCK + 573	—	2/fMCK + 573	—	2/fMCK + 573	—	2/fMCK + 573	ns

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

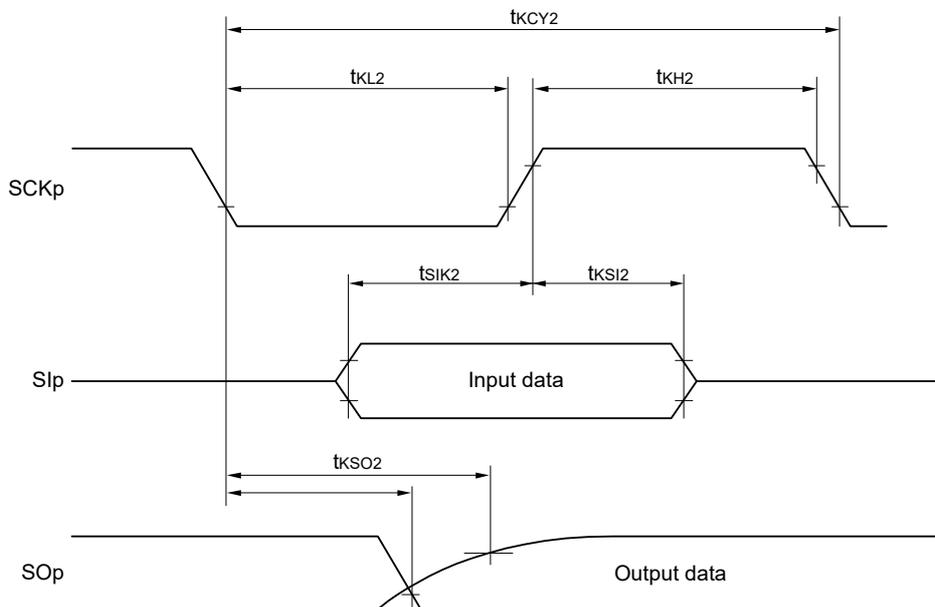
- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** Use it with $EV_{DD} \geq V_b$.
- Note 3.** When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The Slp setup time becomes “to $SCKp\downarrow$ ” and the Slp hold time becomes “from $SCKp\downarrow$ ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.
- Note 4.** When $DAP_{mn} = 0$ and $CKP_{mn} = 0$, or $DAP_{mn} = 1$ and $CKP_{mn} = 1$. The delay time to SOp output becomes “from $SCKp\uparrow$ ” when $DAP_{mn} = 0$ and $CKP_{mn} = 1$, or $DAP_{mn} = 1$ and $CKP_{mn} = 0$.
- Caution** Select the TTL input buffer for the Slp pin and $SCKp$ pin and the N-ch open drain output (EV_{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)

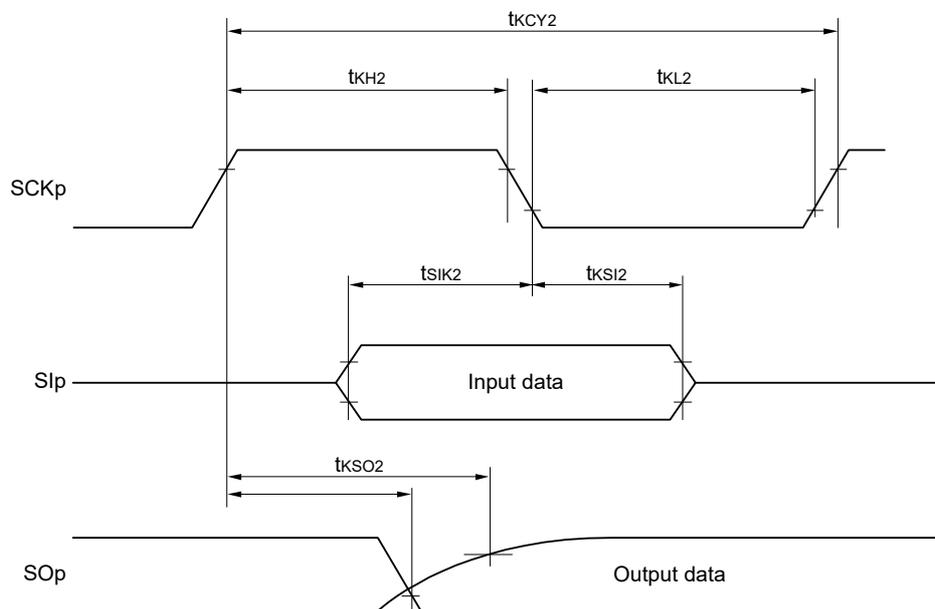


- Remark 1.** $R_b[\Omega]$: Communication line (SOp) pull-up resistance, $C_b[F]$: Communication line (SOp) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** p: CSI number (p = 00 to 03), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)
- Remark 3.** f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the $CKSmn$ bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03))

**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.)**



Remark p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

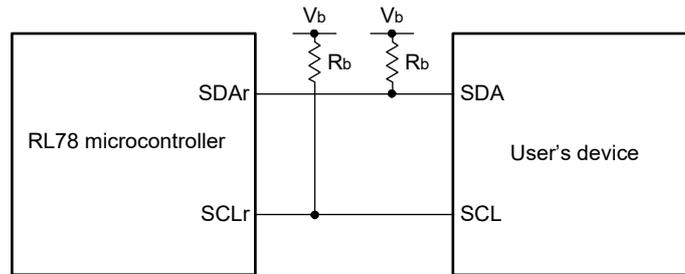
(10) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (simplified I²C mode)(TA = -40 to 85°C, 1.8 V ≤ EV_{DD} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LP (Low-power main) mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	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		250 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		250 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		250 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		250 Note 1		300 Note 1	kHz
		1.8 V ≤ 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		250 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		1550		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		1550		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		1550		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		1550		1550		ns
		1.8 V ≤ 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		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		610		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		610		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		610		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		610		610		ns
		1.8 V ≤ 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		610		610		ns
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 2		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 = 50 pF, R _b = 2.7 kΩ	1/f _{MCK} + 135 Note 3		1/f _{MCK} + 190 Note 2		1/f _{MCK} + 190 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		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		1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		ns
		1.8 V ≤ EV _{DD} < 4.0 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		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	0	305	0	305	0	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	0	305	0	305	0	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	0	355	0	355	0	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	0	355	0	355	0	355	ns
		1.8 V ≤ 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	0	405	0	405	0	405	ns

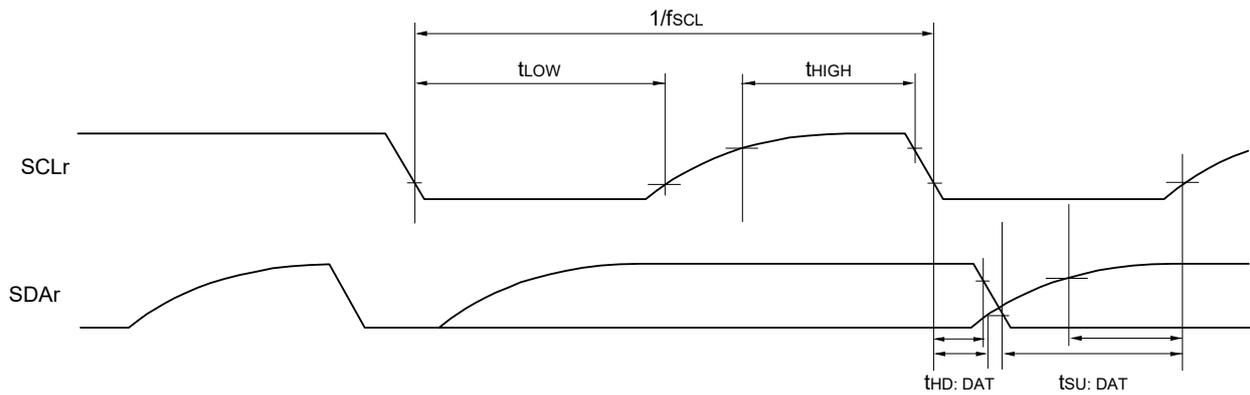
- Note 1.** The value must be equal to or less than $f_{MCK}/4$.
- Note 2.** Use it with $EV_{DD} \geq V_b$.
- Note 3.** Set the f_{MCK} value to keep the hold time of $SCLr = "L"$ and $SCLr = "H"$.

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

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



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



- Remark 1.** $R_b[\Omega]$: Communication line (SDA_r, SCL_r) pull-up resistance, $C_b[F]$: Communication line (SDA_r, SCL_r) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** r: IIC number (r = 00, 01, 10 and 11), g: PIM, POM number (g = 0, 3 and 5)
- Remark 3.** f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0), n: Channel number (n = 0 to 3), mn = 00 to 03)

2.5.2 Serial interface IICA

(1) I²C standard mode

(TA = -40 to +85°C, 1.6 V ≤ EV_{DD} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) mode		LS (low-speed main) mode		LP (Low-power main) mode		LV (low-voltage main) mode		Unit	
			MIN.	MAX.	MIN.	MAX.	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	0	100	0	100	kHz
			1.8 V ≤ EV _{DD} ≤ 5.5 V	0	100	0	100	0	100	0	100	kHz
			1.7 V ≤ EV _{DD} ≤ 5.5 V	0	100	0	100	0	100	0	100	kHz
			1.6 V ≤ EV _{DD} ≤ 5.5 V	—		0	100	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		4.7		4.7		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.7		4.7		4.7		μs	
Hold time Note 1	t _{HD: STA}	2.7 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.0		4.0		4.0		μs	
Hold time when SCLA0 = "L"	t _{LOW}	2.7 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.7		4.7		4.7		μs	
Hold time when SCLA0 = "H"	t _{HIGH}	2.7 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.0		4.0		4.0		μs	
Data setup time (reception)	t _{SU: DAT}	2.7 V ≤ EV _{DD} ≤ 5.5 V	250		250		250		250		ns	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	250		250		250		250		ns	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	250		250		250		250		ns	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		250		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	0	3.45	0	3.45	μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	0	3.45	0	3.45	0	3.45	0	3.45	μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	0	3.45	0	3.45	0	3.45	0	3.45	μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		0	3.45	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		4.0		4.0		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.0		4.0		4.0		4.0		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.0		4.0		4.0		μs	
Bus-free time	t _{BUF}	2.7 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.8 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.7 V ≤ EV _{DD} ≤ 5.5 V	4.7		4.7		4.7		4.7		μs	
		1.6 V ≤ EV _{DD} ≤ 5.5 V	—		4.7		4.7		4.7		μs	

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

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

Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (I_{OH1}, I_{OL1}, V_{OH1}, V_{OL1}) must satisfy the values in the redirect destination.

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

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

(2) I²C fast mode

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

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

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

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

Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IO L1, VO H1, VO L1) must satisfy the values in the redirect destination.

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

Fast mode: C_b = 320 pF, R_b = 1.1 kΩ

(3) I²C fast mode plus

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

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

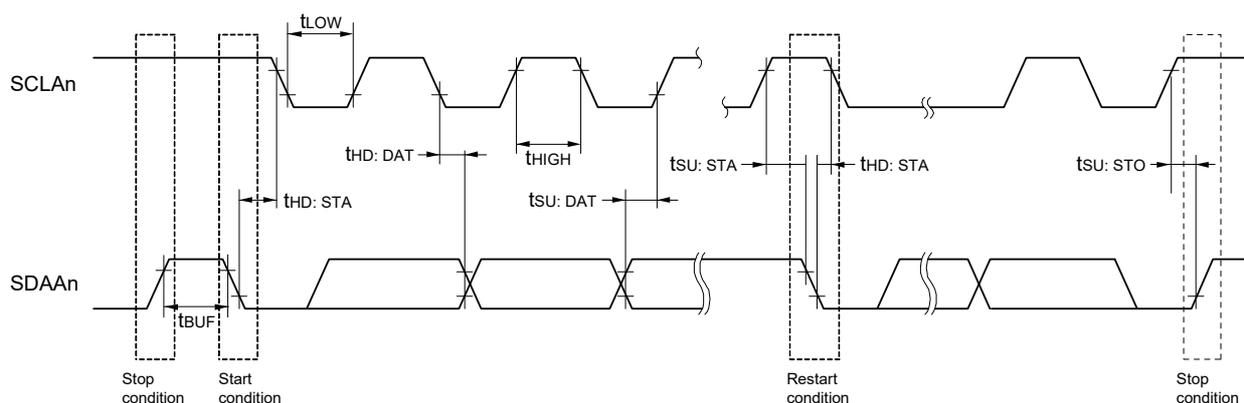
Note 1. The first clock pulse is generated after this period when the start/restart condition is detected.

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

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

Remark The maximum value of C_b (communication line capacitance) and the value of R_b (communication line pull-up resistor) at that time in each mode are as follows.
Fast mode plus: C_b = 120 pF, R_b = 1.1 kΩ

I²C serial transfer timing



Remark n = 0, 1

2.6 Analog Characteristics

2.6.1 A/D converter characteristics

Classification of A/D converter characteristics

Input channel	Reference Voltage	Reference voltage (+) = AV _{REFP} Reference voltage (-) = AV _{REFM}	Reference voltage (+) = V _{DD} Reference voltage (-) = V _{SS}	Reference voltage (+) = V _{BGR} Reference voltage (-) = AV _{REFM}
ANI0 to ANI3		Refer to 2.6.1 (1).	Refer to 2.6.1 (3).	Refer to 2.6.1 (4).
ANI16 to ANI22		Refer to 2.6.1 (2).		
Internal reference voltage Temperature sensor output voltage		Refer to 2.6.1 (1).		

(1) When reference voltage (+) = AV_{REFP}/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AV_{REFM}/ANI1 (ADREFM = 1), target pin: ANI2 and ANI3, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +85°C, 1.6 V ≤ AV_{REFP} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V, Reference voltage (+) = AV_{REFP}, Reference voltage (-) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES		8		10	bit
Overall error Note 1	AINL	10-bit resolution AV _{REFP} = V _{DD} Note 3	1.8 V ≤ AV _{REFP} ≤ 5.5 V	1.2	±3.5	LSB
			1.6 V ≤ AV _{REFP} ≤ 5.5 V Note 4	1.2	±7.0	LSB
Conversion time	t _{CONV}	10-bit resolution Target pin: ANI2 and ANI3	3.6 V ≤ V _{DD} ≤ 5.5 V	2.125	39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.1875	39	μs
			1.8 V ≤ V _{DD} ≤ 5.5 V	17	39	μs
			1.6 V ≤ V _{DD} ≤ 5.5 V	57	95	μs
		10-bit resolution Target pin: Internal reference voltage, and temperature sensor output voltage	3.6 V ≤ V _{DD} ≤ 5.5 V	2.375	39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.5625	39	μs
Zero-scale error Notes 1, 2	EZs	10-bit resolution AV _{REFP} = V _{DD} Note 3	1.8 V ≤ AV _{REFP} ≤ 5.5 V		±0.25	%FSR
			1.6 V ≤ AV _{REFP} ≤ 5.5 V Note 4		±0.50	%FSR
Full-scale error Notes 1, 2	EFS	10-bit resolution AV _{REFP} = V _{DD} Note 3	1.8 V ≤ AV _{REFP} ≤ 5.5 V		±0.25	%FSR
			1.6 V ≤ AV _{REFP} ≤ 5.5 V Note 4		±0.50	%FSR
Integral linearity error Note 1	ILE	10-bit resolution AV _{REFP} = V _{DD} Note 3	1.8 V ≤ AV _{REFP} ≤ 5.5 V		±2.5	LSB
			1.6 V ≤ AV _{REFP} ≤ 5.5 V Note 4		±5.0	LSB
Differential linearity error Note 1	DLE	10-bit resolution AV _{REFP} = V _{DD} Note 3	1.8 V ≤ AV _{REFP} ≤ 5.5 V		±1.5	LSB
			1.6 V ≤ AV _{REFP} ≤ 5.5 V Note 4		±2.0	LSB
Analog input voltage	V _{AIN}	ANI2 and ANI3	0		AV _{REFP}	V
		Internal reference voltage (1.8 V ≤ V _{DD} ≤ 5.5 V)			V _{BGR} Note 5	V
		Temperature sensor output voltage (1.8 V ≤ V _{DD} ≤ 5.5 V)			V _{TMP25} Note 5	V

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

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

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

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

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

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

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

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

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), target pin: ANI16 to ANI22

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

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit	
Resolution	RES			8		10	bit	
Overall error Note 1	AINL	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$		1.2	± 5.0	LSB	
			$1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5		1.2	± 8.5	LSB	
Conversion time	tCONV	10-bit resolution Target ANI pin: ANI16 to ANI22	$3.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$	2.125		39	μs	
			$2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$	3.1875		39	μs	
			$1.8\text{ V} \leq V_{DD} \leq 5.5\text{ V}$		17		39	μs
			$1.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$		57		95	μs
Zero-scale error Notes 1, 2	EzS	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 0.35	%FSR	
			$1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5			± 0.60	%FSR	
Full-scale error Notes 1, 2	EFS	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 0.35	%FSR	
			$1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5			± 0.60	%FSR	
Integral linearity error Note 1	ILE	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 3.5	LSB	
			$1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5			± 6.0	LSB	
Differential linearity error Note 1	DLE	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$1.8\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 2.0	LSB	
			$1.6\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$ Note 5			± 2.5	LSB	
Analog input voltage	VAIN	ANI16 to ANI22		0		AV_{REFP} and EV_{DD}	V	

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

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

Note 3. When $EV_{DD} \leq AV_{REFP} < V_{DD}$, the MAX. values are as follows.

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

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

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

Note 4. When $AV_{REFP} < EV_{DD} \leq V_{DD}$, the MAX. values are as follows.

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

Zero-scale error/Full-scale error: Add $\pm 0.20\%$ FSR to the MAX. value when $AV_{REFP} = V_{DD}$.

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

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

- (3) When reference voltage (+) = V_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = V_{SS} (ADREFM = 0), target pin: ANI0 to ANI3, ANI16 to ANI22, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +85°C, 1.6 V ≤ EV_{DD} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V, Reference voltage (+) = V_{DD}, Reference voltage (-) = V_{SS})

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Resolution	RES		8		10	bit	
Overall error Note 1	AINL	10-bit resolution	1.8 V ≤ V _{DD} ≤ 5.5 V		1.2	±7.0	LSB
			1.6 V ≤ V _{DD} ≤ 5.5 V Note 3		1.2	±10.5	LSB
Conversion time	t _{CONV}	10-bit resolution Target pin: ANI0 to ANI3, ANI16 to ANI22	3.6 V ≤ V _{DD} ≤ 5.5 V	2.125		39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.1875		39	μs
			1.8 V ≤ V _{DD} ≤ 5.5 V	17		39	μs
			1.6 V ≤ V _{DD} ≤ 5.5 V	57		95	μs
		10-bit resolution Target pin: internal reference voltage, and temperature sensor output voltage	3.6 V ≤ V _{DD} ≤ 5.5 V	2.375		39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.5625		39	μs
1.8 V ≤ V _{DD} ≤ 5.5 V	17			39	μs		
Zero-scale error Notes 1, 2	E _{zs}	10-bit resolution	1.8 V ≤ V _{DD} ≤ 5.5 V			±0.60	%FSR
			1.6 V ≤ V _{DD} ≤ 5.5 V Note 3			±0.85	%FSR
Full-scale error Notes 1, 2	E _{fs}	10-bit resolution	1.8 V ≤ V _{DD} ≤ 5.5 V			±0.60	%FSR
			1.6 V ≤ V _{DD} ≤ 5.5 V Note 3			±0.85	%FSR
Integral linearity error Note 1	ILE	10-bit resolution	1.8 V ≤ V _{DD} ≤ 5.5 V			±4.0	LSB
			1.6 V ≤ V _{DD} ≤ 5.5 V Note 3			±6.5	LSB
Differential linearity error Note 1	DLE	10-bit resolution	1.8 V ≤ V _{DD} ≤ 5.5 V			±2.0	LSB
			1.6 V ≤ V _{DD} ≤ 5.5 V Note 3			±2.5	LSB
Analog input voltage	V _{AIN}	ANI0 to ANI3	0		V _{DD}	V	
		ANI16 to ANI22	0		EV _{DD}	V	
		Internal reference voltage (1.8 V ≤ V _{DD} ≤ 5.5 V)	V _{BGR} Note 4			V	
		Temperature sensor output voltage (1.8 V ≤ V _{DD} ≤ 5.5 V)	V _{TMPS25} Note 4			V	

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

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

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

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

(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0, ANI2 and ANI3, ANI16 to ANI22

(TA = -40 to +85°C, 1.8 V ≤ VDD ≤ 5.5 V, 1.6 V ≤ EVDD ≤ VDD, VSS = 0 V, Reference voltage (+) = VBGR Note 3, Reference voltage (-) = AVREFM = 0 V Note 4)

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

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

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

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

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

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

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

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

2.6.2 Temperature sensor characteristics/internal reference voltage characteristic

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor output voltage	VTMPS25	Setting ADS register = 80H, TA = +25°C		1.05		V
Internal reference voltage	VBGR	Setting ADS register = 81H	1.38	1.45	1.5	V
Temperature coefficient	FVTMPS	Temperature sensor that depends on the temperature		-3.6		mV/°C
Operation stabilization wait time	tAMP	2.4 V ≤ VDD ≤ 5.5 V	5			μs
		1.8 V ≤ VDD < 2.4 V	10			μs

2.6.3 D/A converter (channel 1)

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

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

2.6.4 Comparator

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

(Comparator 1: TA = -40 to +85°C, 1.6 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage range	VIREF0	IVREF0 pin		0		V _{DD} - 1.4 Note 1	V
	VIREF1	IVREF1 pin		1.4 Note 1		V _{DD}	V
	VICMP	IVCMP0 pin		-0.3		V _{DD} + 0.3	V
		IVCMP1 pin		-0.3		EV _{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		μs
			Comparator low-speed mode, window mode		4		μs
Operation stabilization wait time	tcMP			100			μs
Reference voltage declination in channel 0 of internal DAC Note 2	ΔVIDAC					± 2.5	LSB

Note 1. In window mode, make sure that VREF1 - VREF0 ≥ 0.2 V.

Note 2. Only in CMP0

2.6.5 PGA

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

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

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

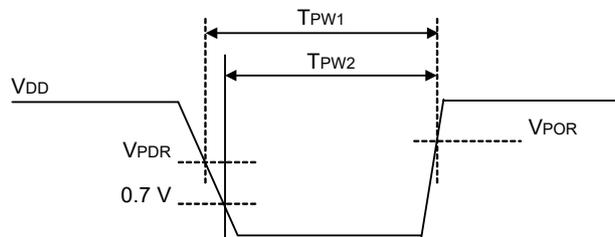
2.6.6 POR circuit characteristics

(TA = -40 to +85°C, Vss = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V _{POR}	The power supply voltage is rising.	1.47	1.51	1.55	V
	V _{PDR}	The power supply voltage is falling. ^{Note 1}	1.46	1.50	1.54	V
Minimum pulse width ^{Note 2}	T _{PW1}	Other than STOP/SUB HALT/SUB RUN	300			μs
	T _{PW2}	STOP/SUB HALT/SUB RUN	300			μs

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

Note 2. Minimum time required for a POR reset when V_{DD} exceeds below V_{PDR}. This is also the minimum time required for a POR reset from when V_{DD} exceeds below 0.7 V to when V_{DD} exceeds V_{POR} while STOP mode is entered or the main system clock is stopped through setting bit 0 (HIOSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).



2.6.7 LVD circuit characteristics

(1) LVD Detection Voltage of Reset Mode and Interrupt Mode

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

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

(2) LVD Detection Voltage of Interrupt & Reset Mode

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

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

2.6.8 Power supply voltage rising slope characteristics

(TA = -40 to +85°C, VSS = 0 V)

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

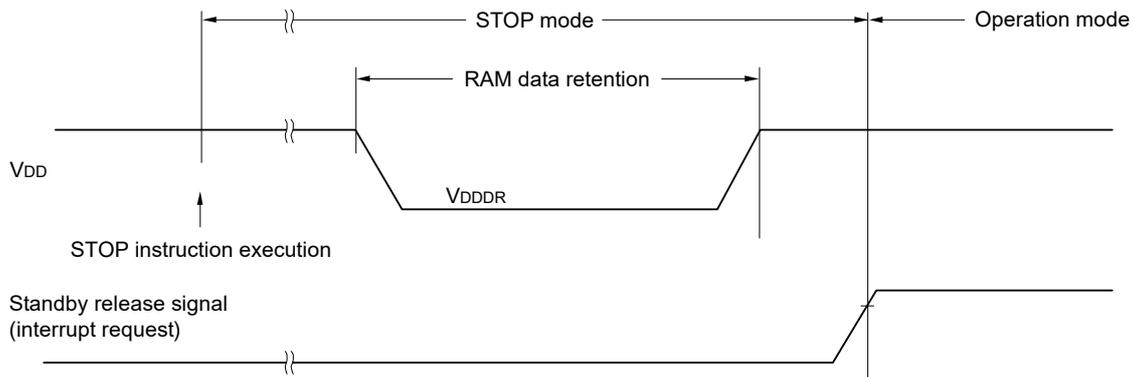
Caution Make sure to keep the internal reset state by the LVD circuit or an external reset until VDD reaches the operating voltage range shown in 2.4 AC Characteristics.

2.7 RAM Data Retention Characteristics

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	VDDDR		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.



2.8 Flash Memory Programming Characteristics

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
System clock frequency	fCLK	1.8 V ≤ VDD ≤ 5.5 V		1		24	MHz
Number of code flash rewrites Notes 1, 2, 3	Cerwr	Retained for 20 years	TA = 85°C	1,000			Times
Number of data flash rewrites Notes 1, 2, 3		Retained for 1 year	TA = 25°C		1,000,000		
		Retained for 5 years	TA = 85°C	100,000			
		Retained for 20 years	TA = 85°C	10,000			

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

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

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

2.9 Dedicated Flash Memory Programmer Communication (UART)

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

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

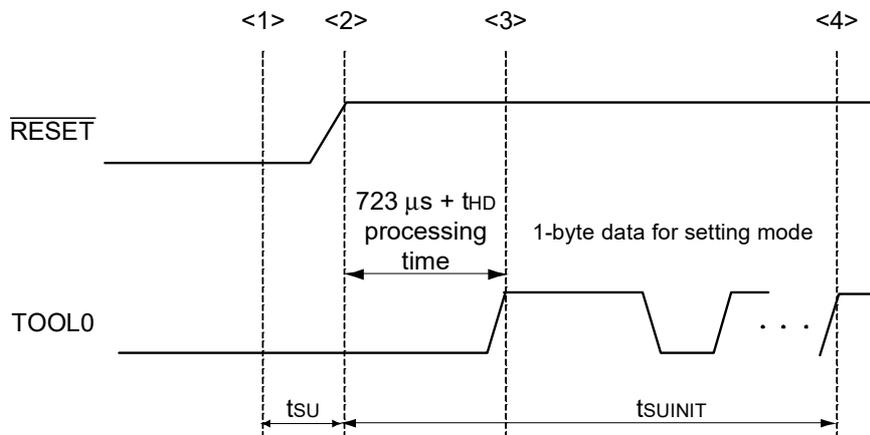
2.10 Timing of Entry to Flash Memory Programming Modes

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
How long from when an external reset ends until the initial communication settings are specified ^{Note 1}	tsuINIT	POR and LVD reset must end before the external reset ends.			100	ms
How long from when the TOOL0 pin is placed at the low level until an external reset ends ^{Note 1}	tsu	POR and LVD reset must end before the external reset ends.	10			μs
How long the TOOL0 pin must be kept at the low level after an external reset ends (excluding the processing time of the firmware to control the flash memory) ^{Notes 1, 2}	tHD	POR and LVD reset must end before the external reset ends.	1			ms

Note 1. Deassertion of the POR and LVD reset signals must precede deassertion of the pin reset signal.

Note 2. This excludes the flash firmware processing time (723 μs).



<1> The low level is input to the TOOL0 pin.

<2> The external reset ends (POR and LVD reset must end before the external reset ends).

<3> The TOOL0 pin is set to the high level.

<4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

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

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

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

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

This chapter describes the following electrical specifications.

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

R5F105xxGxx

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

Caution 2. The pins mounted depend on the product. Refer to 2.1 Port Functions to 2.2.1 Functions for each product in the RL78/G11 User's Manual.

Caution 3. Please contact Renesas Electronics sales office for derating of operation under TA = +85 to +105°C. Derating is the systematic reduction of load for the sake of improved reliability.

Caution 4. When operating temperature exceeds 85°C, only HS (high-speed main) mode can be used as the flash operation mode. Regulator mode should be used with the normal setting (MCSEL = 0).

Caution 5. The EVDD pin is not present on products with 24 or less pins. Accordingly, replace EVDD with VDD and the voltage condition $1.6 \leq EVDD \leq VDD \leq 5.5 \text{ V}$ with $1.6 \leq VDD \leq 5.5 \text{ V}$.

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

Fields of application	A: Consumer applications	G: Industrial applications
Operating ambient temperature	TA = -40 to +85°C	TA = -40 to +105°C
Operating mode Operating Voltage Range	HS (High-speed main) mode: 2.7 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 24 MHz 2.4 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 16 MHz LS (Low-speed main) mode: 1.8 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 8 MHz LV (Low-voltage main) mode: 1.8 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 4 MHz	Only in HS (High-speed main) mode: 2.7 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 24 MHz 2.4 V ≤ V _{DD} ≤ 5.5 V @ 1 MHz to 16 MHz
High-speed on-chip oscillator clock to an accuracy	1.8 V ≤ V _{DD} ≤ 5.5 V: ±1.0% @ TA = -20 to +85°C ±1.5% @ TA = -40 to -20°C 1.6 V ≤ V _{DD} < 1.8 V: ±5.0% @ TA = -20 to +85°C ±5.5% @ TA = -40 to -20°C	2.4 V ≤ V _{DD} ≤ 5.5 V: ±2.0% @ TA = +85 to +105°C ±1.0% @ TA = -20 to +85°C ±1.5% @ TA = -40 to -20°C
Serial array unit	UART Simplified SPI (CSI): f _{CLK} /2 (12 Mbps are supported), f _{CLK} /4 Simplified I ² C	UART Simplified SPI (CSI): f _{CLK} /4 Simplified I ² C
IICA	Standard mode Fast mode Fast mode plus	Standard mode Fast mode
Voltage Detector	• Rising: 1.67 V to 4.06 V (14 levels) • Falling: 1.63 V to 3.98 V (14 levels)	• Rising: 2.61 V to 4.06 V (8 levels) • Falling: 2.55 V to 3.98 V (8 levels)

Remark The electrical characteristics for "G: Industrial applications" differ from those for "A: Consumer applications" when the product is in use in an ambient temperature over 85°C. For details, see 3.1 to 3.10 in the following pages.

3.1 Absolute Maximum Ratings

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Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V _{DD}		-0.5 to +6.5	V
	EV _{DD}		-0.5 to +6.5	V
	AV _{REFP}		0.3 to V _{DD} + 0.3 Note 2	V
	AV _{REFM}		-0.3 to V _{DD} + 0.3 Note 2 and AV _{REFM} ≤ AV _{REFP}	V
REGC pin input voltage	V _I REGC	REGC	-0.3 to +2.8 and -0.3 to V _{DD} + 0.3 Note 1	V
Input voltage	V _{I1}	P00, P01, P30 to P33, P40, and P51 to P56	-0.3 to EV _{DD} + 0.3 and -0.3 to V _{DD} + 0.3 Note 2	V
	V _{I2}	P20 to P23, P121, P122, P125, P137, EXCLK, RESET	-0.3 to V _{DD} + 0.3 Note 2	V
Output voltage	V _{O1}	P00, P01, P30 to P33, P40, and P51 to P56	-0.3 to EV _{DD} + 0.3 and -0.3 to V _{DD} + 0.3 Note 2	V
	V _{O2}	P20 to P23	-0.3 to V _{DD} + 0.3 Note 2	V
Analog input voltage	V _{AI1}	ANI16 to ANI22	-0.3 to EV _{DD} + 0.3 and -0.3 to AV _{REF} (+) + 0.3 Notes 2, 3	V
	V _{AI2}	ANI0 to ANI3	-0.3 to V _{DD} + 0.3 and -0.3 to AV _{REF} (+) + 0.3 Notes 2, 3	V

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

Note 2. Must be 6.5 V or lower.

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

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

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

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

Remark 3. V_{SS}: Reference voltage

(2/2)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	IOH1	Per pin	P00, P01, P30 to P33, P40, P51 to P56	-40	mA
		Total of all pins -170 mA	P00, P01, P40	-70	mA
	P30 to P33, P51 to P56		-100	mA	
	IOH2	Per pin	P20 to P23	-0.5	mA
Total of all pins			-2	mA	
Output current, low	IOL1	Per pin	P00, P01, P30 to P33, P40, P51 to P56	40	mA
		Total of all pins 170 mA	P00, P01, P40	70	mA
			P30 to P33, P51 to P56	100	mA
	IOL2	Per pin	P20 to P23	1	mA
Total of all pins			4	mA	
Operating ambient temperature	T _A	In normal operation mode		-40 to +105	°C
		In flash memory programming mode			
Storage temperature	T _{stg}			-65 to +150	°C

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

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

3.2 Oscillator Characteristics

3.2.1 X1 characteristics

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

Resonator	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (fx) ^{Note}	Ceramic resonator/ crystal resonator	2.7 V ≤ VDD ≤ 5.5 V	1.0		20.0	MHz
		2.4 V ≤ VDD < 2.7 V	1.0		16.0	

Note Indicates only permissible oscillator frequency ranges. Refer to **3.4 AC Characteristics** for instruction execution time. Request evaluation by the manufacturer of the oscillator circuit mounted on a board to check the oscillator characteristics.

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, refer to **6.4 System Clock Oscillator** in the RL78/G11 User's Manual.

3.2.2 On-chip oscillator characteristics

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

Oscillators	Parameters	Conditions	MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency ^{Notes 1, 2}	f _{ih}	2.7 V ≤ VDD ≤ 5.5 V	1		24	MHz
		2.4 V ≤ VDD ≤ 5.5 V	1		16	
High-speed on-chip oscillator clock frequency accuracy		TA = +85°C to +105°C	-2		2	%
		TA = -20°C to +85°C	-1		1	%
		TA = -40°C to -20°C	-1.5		1.5	%
Middle-speed on-chip oscillator oscillation frequency ^{Note 2}	f _{im}		1		4	MHz
Middle-speed on-chip oscillator oscillation frequency accuracy			-12		+12	%
Temperature drift of Middle-speed on-chip oscillator oscillation frequency accuracy	D _{IMT}			0.008		%/°C
Voltage drift of Middle-speed on-chip oscillator oscillation frequency accuracy	D _{IMV}	TA = 25°C		0.02		%/V
Low-speed on-chip oscillator clock frequency ^{Note 2}	f _{il}			15		kHz
Low-speed on-chip oscillator clock frequency accuracy			-15		+15	%

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

Note 2. This only indicates the oscillator characteristics. Refer to **3.4 AC Characteristics** for instruction execution time.

3.3 DC Characteristics

3.3.1 Pin characteristics

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

(1/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output current, high Note 1	IOH1	Per pin for P00, P01, P30 to P33, P40, and P51 to P56			-3.0 Note 2	mA	
		Total of P00, P01, and P40 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		-12.5	mA	
			2.7 V ≤ EVDD < 4.0 V		-10.0	mA	
			2.4 V ≤ EVDD < 2.7 V		-5.0	mA	
		Total of P30 to P33, and P51 to P56 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		-30.0	mA	
			2.7 V ≤ EVDD < 4.0 V		-19.0	mA	
	2.4 V ≤ EVDD < 2.7 V			-10.0	mA		
	Total of all pins (When duty ≤ 70% Note 3)				-42.5	mA	
	IOH2	Per pin for P20 to P23				-0.1 Note 2	mA
		Total of all pins (When duty ≤ 70% Note 3)	2.4 V ≤ VDD ≤ 5.5 V			-0.4	mA

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

Note 2. Do not exceed the total current value.

Note 3. Specification under conditions where the duty factor ≤ 70%.

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

- Total output current of pins = $(I_{OH} \times 0.7) / (n \times 0.01)$
 <Example> Where n = 80% and IOH = -10.0 mA
 Total output current of pins = $(-10.0 \times 0.7) / (80 \times 0.01) \approx -8.7$ mA

However, the current that is allowed to flow into one pin does not vary depending on the duty factor.

A current higher than the absolute maximum rating must not flow into one pin.

Caution P00, P01, P20, P30 to P33, P40 and P51 to P56 do not output high level in N-ch open-drain mode.

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

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

(2/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output current, low Note 1	IOL1	Per pin for P00, P01, P30 to P33, P40, and P51 to P56			8.5 Note 2	mA
		Total of P00, P01, and P40 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		36.0	mA
			2.7 V ≤ EVDD < 4.0 V		15.0	mA
			2.4 V ≤ EVDD < 2.7 V		9.0	mA
		Total of P30 to P33, and P51 to P56 (When duty ≤ 70% Note 3)	4.0 V ≤ EVDD ≤ 5.5 V		40.0	mA
			2.7 V ≤ EVDD < 4.0 V		35.0	mA
	2.4 V ≤ EVDD < 2.7 V			20.0	mA	
	Total of all pins (When duty ≤ 70% Note 3)			76.0	mA	
	IOL2	Per pin for P20 to P23			0.4 Note 2	mA
Total of all pins (When duty ≤ 70% Note 3)		2.4 V ≤ VDD ≤ 5.5 V		1.6	mA	

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

Note 2. Do not exceed the total current value.

Note 3. Specification under conditions where the duty factor ≤ 70%.

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

- Total output current of pins = $(IOL \times 0.7)/(n \times 0.01)$

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

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

However, the current that is allowed to flow into one pin does not vary depending on the duty factor.

A current higher than the absolute maximum rating must not flow into one pin.

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

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

(3/5)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage, high	V _{IH1}	P00, P01, P30 to P33, P40, and P51 to P56	Normal mode	0.8 EV _{DD}		EV _{DD}	V
	V _{IH2}	P00, P30 to P32, P40, P51 to P56	TTL mode 4.0 V ≤ EV _{DD} ≤ 5.5 V	2.2		EV _{DD}	V
			TTL mode 3.3 V ≤ EV _{DD} < 4.0 V	2.0		EV _{DD}	V
			TTL mode 2.4 V ≤ EV _{DD} < 3.3 V	1.5		EV _{DD}	V
	V _{IH3}	P20 to P23 (digital input)		0.7 V _{DD}		V _{DD}	V
	V _{IH4}	P121, P122, P125, P137, EXCLK, $\overline{\text{RESET}}$		0.8 V _{DD}		V _{DD}	V
Input voltage, low	V _{IL1}	P00, P01, P30 to P33, P40, and P51 to P56	Normal mode	0		0.2 EV _{DD}	V
	V _{IL2}	P00, P30 to P32, P40, P51 to P56	TTL mode 4.0 V ≤ EV _{DD} ≤ 5.5 V	0		0.8	V
			TTL mode 3.3 V ≤ EV _{DD} < 4.0 V	0		0.5	V
			TTL mode 2.4 V ≤ EV _{DD} < 3.3 V	0		0.32	V
	V _{IL3}	P20 to P23 (digital input)		0		0.3 V _{DD}	V
	V _{IL4}	P121, P122, P125, P137, EXCLK, $\overline{\text{RESET}}$		0		0.2 V _{DD}	V

Caution The maximum value of V_{IH} of pins P00, P01, P20, P30 to P33, P40 and P51 to P56 is V_{DD} or EV_{DD}, even in the N-ch open-drain mode.

(P20: V_{DD})

(P00, P01, P30 to P33, P40, P51 to P56: EV_{DD})

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

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

(4/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output voltage, high	VOH1	P00, P01, P30 to P33, P40, and P51 to P56	4.0 V ≤ EVDD ≤ 5.5 V, IOH = -3.0 mA	EVDD - 0.7		V
			2.7 V ≤ EVDD ≤ 5.5 V, IOH = -2.0 mA	EVDD - 0.6		V
			2.4 V ≤ EVDD ≤ 5.5 V IOH = -1.5 mA	EVDD - 0.5		V
	VOH2	P20 to P23	2.4 V ≤ VDD ≤ 5.5 V, IOH = -100 μA	VDD - 0.5		V
Output voltage, low	VOL1	P00, P01, P30 to P33, P40, and P51 to P56	4.0 V ≤ EVDD ≤ 5.5 V, IOL = 8.5 mA		0.7	V
			2.7 V ≤ EVDD ≤ 5.5 V, IOL = 3.0 mA		0.6	V
			2.7 V ≤ EVDD ≤ 5.5 V, IOL = 1.5 mA		0.4	V
			2.4 V ≤ EVDD ≤ 5.5 V, IOL = 0.6 mA		0.4	V
	VOL2	P20 to P23	2.4 V ≤ VDD ≤ 5.5 V, IOL = 400 μA		0.4	V

Caution P00, P01, P20, P30 to P33, P40 and P51 to P56 do not output high level in N-ch open-drain mode.

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

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

(5/5)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit		
Input leakage current, high	ILI _{H1}	P00, P01, P30 to P33, P40, and P51 to P56	V _I = EVDD		1	μA		
	ILI _{H2}	P20 to P23, P125, P137, $\overline{\text{RESET}}$	V _I = VDD		1	μA		
	ILI _{H3}	P121, P122, X1, X2, EXCLK	V _I = VDD	In input port or external clock input		1	μA	
				In resonator connection		10	μA	
Input leakage current, low	ILI _{L1}	P00, P01, P30 to P33, P40, and P51 to P56	V _I = VSS		-1	μA		
	ILI _{L2}	P20 to P23, P125, P137, $\overline{\text{RESET}}$	V _I = VSS		-1	μA		
	ILI _{L3}	P121, P122, X1, X2, EXCLK	V _I = VSS	In input port or external clock input		-1	μA	
				In resonator connection		-10	μA	
On-chip pull-up resistance	R _u	P00, P01, P30 to P33, P40, P51 to P56, P125	V _I = VSS, In input port		10	20	100	kΩ

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

3.3.2 Supply current characteristics

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

(1/3)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit		
Supply current Note 1	IDD1	Operating mode	Basic operation	HS (high-speed main) mode	fHOCO = 48 MHz ^{Note 3} fIH = 24 MHz ^{Note 3}	VDD = 5.0 V		1.7		mA	
						VDD = 3.0 V		1.7			
					fHOCO = 24 MHz ^{Note 3} fIH = 24 MHz ^{Note 3}	VDD = 5.0 V		1.4			
						VDD = 3.0 V		1.4			
			Normal operation	HS (high-speed main) mode	fHOCO = 48 MHz ^{Note 3} fIH = 24 MHz ^{Note 3}	VDD = 5.0 V		3.5	7.3		mA
						VDD = 3.0 V		3.5	7.3		
					fHOCO = 24 MHz ^{Note 3} fIH = 24 MHz ^{Note 3}	VDD = 5.0 V		3.2	6.7		
						VDD = 3.0 V		3.2	6.7		
		Normal operation	HS (high-speed main) mode	fMX = 20 MHz ^{Note 2}	VDD = 5.0 V	Square wave input		2.7	5.7	mA	
						Resonator connection		2.8	5.8		
					VDD = 3.0 V	Square wave input		2.7	5.7		
						Resonator connection		2.8	5.8		
				fMX = 10 MHz ^{Note 2}	VDD = 5.0 V	Square wave input		1.8	3.4		
						Resonator connection		1.9	3.5		
					VDD = 3.0 V	Square wave input		1.8	3.4		
						Resonator connection		1.9	3.5		
Normal operation	Subsystem clock operation	fIL = 15 kHz, TA = -40°C ^{Note 4}				1.8	5.9	μA			
			fIL = 15 kHz, TA = +25°C ^{Note 4}				1.9		5.9		
			fIL = 15 kHz, TA = +85°C ^{Note 4}				2.3		8.7		
			fIL = 15 kHz, TA = +105°C ^{Note 4}				3.0		20.9		

Note 1. Total current flowing into VDD and EVDD, including the input leakage current flowing when the level of the input pin is fixed to VDD or VSS. The following points apply in the HS (high-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 A/D converter, D/A converter, comparator, programmable gain amplifier, LVD 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.

Note 2. When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

Note 3. When the high-speed system clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

Note 4. When the high-speed system clock, high-speed on-chip oscillator clock and middle-speed on-chip oscillator clock are stopped.

Remark 1. fMX: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)

Remark 2. fIH: High-speed on-chip oscillator clock frequency (24 MHz max.)

Remark 3. fIM: Middle-speed on-chip oscillator clock frequency (4 MHz max.)

Remark 4. fIL: Low-speed on-chip oscillator clock frequency

Remark 5. fSUB: Subsystem clock frequency (Low-speed on-chip oscillator clock frequency)

Remark 6. Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

(2/3)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit				
Supply current Note 1	I _{DD2} Note 2	HALT mode	HS (high-speed main) mode	f _{HOCO} = 48 MHz Note 3	V _{DD} = 5.0 V		0.59	3.45	mA		
				f _{IH} = 24 MHz Note 4	V _{DD} = 3.0 V		0.59	3.45			
				f _{HOCO} = 24 MHz Note 3	V _{DD} = 5.0 V		0.41	2.85			
				f _{IH} = 16 MHz Note 4	V _{DD} = 3.0 V		0.41	2.85			
				f _{HOCO} = 16 MHz Note 3	V _{DD} = 5.0 V		0.39	2.08			
				f _{IH} = 16 MHz Note 4	V _{DD} = 3.0 V		0.39	2.08			
				HS (high-speed main) mode	f _{MX} = 20 MHz Note 3	V _{DD} = 5.0 V	Square wave input	0.20		2.45	mA
						V _{DD} = 3.0 V	Resonator connection	0.40		2.57	
			V _{DD} = 5.0 V			Square wave input	0.20	2.45			
			V _{DD} = 3.0 V			Resonator connection	0.40	2.57			
			f _{MX} = 10 MHz Note 3		V _{DD} = 5.0 V	Square wave input	0.15	1.28			
					V _{DD} = 3.0 V	Resonator connection	0.30	1.36			
					V _{DD} = 5.0 V	Square wave input	0.15	1.28			
					V _{DD} = 3.0 V	Resonator connection	0.30	1.36			
			Subsystem clock operation	f _{IL} = 15 kHz, T _A = -40°C Note 5			0.48	1.22	μA		
				f _{IL} = 15 kHz, T _A = +25°C Note 5			0.55	1.22			
f _{IL} = 15 kHz, T _A = +85°C Note 5				0.80	3.30						
f _{IL} = 15 kHz, T _A = +105°C Note 5				2.00	17.3						

Note 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} or V_{SS}. The following points apply in the HS (high-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 A/D converter, D/A converter, comparator, programmable gain amplifier, LVD 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.

Note 2. When the HALT instruction is executed in the flash memory.

Note 3. When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock, and low-speed on-chip oscillator clock are stopped.

Note 4. When the high-speed system clock, middle-speed on-chip oscillator clock and low-speed on-chip oscillator clock are stopped.

Note 5. When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock and high-speed system clock are stopped.

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

Remark 2. f_{IH}: High-speed on-chip oscillator clock frequency (24 MHz max.)

Remark 3. f_{IM}: Middle-speed on-chip oscillator clock frequency (4 MHz max.)

Remark 4. f_{IL}: Low-speed on-chip oscillator clock frequency

Remark 5. f_{SUB}: Subsystem clock frequency (Low-speed on-chip oscillator clock frequency)

Remark 6. Except subsystem clock operation, temperature condition of the TYP. value is T_A = 25°C

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

(3/3)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Supply current Note 1	IDD3	STOP mode Note 2	TA = -40°C		0.19	0.51	μA
			TA = +25°C		0.25	0.51	
			TA = +50°C		0.28	1.10	
			TA = +70°C		0.38	1.90	
			TA = +85°C		0.60	3.30	
			TA = +105°C		1.5	17.0	

Note 1. Total current flowing into VDD and EVDD, including the input leakage current flowing when the level of the input pin is fixed to VDD or Vss. In the STOP mode, the currents in both the “TYP.” and “MAX.” columns do not include the operating currents of the peripheral modules.

Note 2. For the setting of the current values when operating the subsystem clock in STOP mode, see the current values when operating the subsystem clock in HALT mode.

Peripheral Functions (Common to all products)

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	IFIL Note 1				0.22		μA
12-bit interval timer operating current	ITMKA Notes 1, 3, 4	fIL = 15 kHz fMAIN stopped (per unit)			0.02		μA
8-bit interval timer operating current Notes 1, 9	ITMT	fIL = 15 kHz fMAIN stopped (per unit)	8-bit counter mode × 2-channel operation		0.04		μA
			16-bit counter mode operation		0.03		μA
Watchdog timer operating current	IWD _T Notes 1, 3, 5	fIL = 15 kHz fMAIN stopped (per unit)			0.22		μA
A/D converter operating current	IADC Notes 1, 6	During maximum-speed conversion	Normal mode, AVREFP = VDD = 5.0 V		1.3	1.7	mA
			Low voltage mode, AVREFP = VDD = 3.0 V		0.5	0.7	mA
Internal reference voltage (1.45 V) current Notes 1, 10	IADREF				85.0		μA
Temperature sensor operating current	ITMPS Note 1				85.0		μA
D/A converter operating current	IDAC Note 1	Per channel				1.5	mA
PGA operating current	IPGA Notes 1, 2				480	700	μA
Comparator operating current	ICMP Note 8	VDD = 5.0 V, Regulator output voltage = 2.1 V	Comparator high-speed mode Window mode		12.5		μA
			Comparator low-speed mode Window mode		3.0		
			Comparator high-speed mode Standard mode		6.5		
			Comparator low-speed mode Standard mode		1.9		
		VDD = 5.0 V, Regulator output voltage = 1.8 V	Comparator high-speed mode Window mode		8.0		
			Comparator low-speed mode Window mode		2.2		
			Comparator high-speed mode Standard mode		4.0		
			Comparator low-speed mode Standard mode		1.3		
LVD operating current	ILVD Notes 1, 7				0.10		μA
Self-programming operating current	IFSP Notes 1, 12				2.0	12.20	mA
BGO current	IBGO Notes 1, 11				2.0	12.20	mA
SNOOZE operating current	ISNOZ Note 1	ADC operation fIH = 24 MHz, AVREFP = VDD = 3.0 V	Mode transition Note 13		0.50	1.10	mA
			The A/D conversion operations are performed		1.20	2.04	mA
		Simplified SPI (CSI)/UART operation fIH = 24 MHz		0.70	1.54	mA	
	ISNOZM Note 1	ADC operation fIM = 4 MHz, AVREFP = VDD = 3.0 V	Mode transition Note 13		0.05	0.13	mA
			The A/D conversion operations are performed		0.67	0.84	mA
		Simplified SPI (CSI) operation, fIM = 4 MHz		0.06	0.15	mA	

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

- Note 1.** Current flowing to VDD.
- Note 2.** Operable range is 2.7 to 5.5 V.
- Note 3.** When the high-speed on-chip oscillator clock, middle-speed on-chip oscillator clock, and high-speed system clock are stopped.
- Note 4.** Current flowing only to the 12-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either IDD1 or IDD2, and IIT, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.
- Note 5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and IWDT when the watchdog timer is in operation.
- Note 6.** Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of IDD1 or IDD2 and IADC when the A/D converter operates in an operation mode or the HALT mode.
- Note 7.** Current flowing only to the LVD circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2 or IDD3 and ILVD when the LVD circuit is in operation.
- Note 8.** Current flowing only to the comparator circuit. The supply current of the RL78 microcontrollers is the sum of IDD1, IDD2, or IDD3 and ICMP when the comparator circuit is in operation.
- Note 9.** Current flowing only to the 8-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either IDD1 or IDD2, and IIT, when the 8-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, IFIL should be added.
- Note 10.** Current consumed by generating the internal reference voltage (1.45 V).
- Note 11.** Current flowing during programming of the data flash.
- Note 12.** Current flowing during self-programming.
- Note 13.** For transition time to the SNOOZE mode, see **24.3.3 SNOOZE mode** in the RL78/G11 User's Manual.

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

Remark 2. f_{CLK}: CPU/peripheral hardware clock frequency

Remark 3. Temperature condition of the TYP. value is TA = 25°C

3.4 AC Characteristics

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

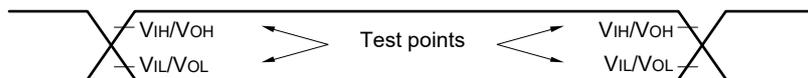
Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit	
Instruction cycle (minimum instruction execution time)	TCY	Main system clock (fMAIN) operation	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 5.5 V	0.04167	1	μs	
				2.4 V ≤ VDD < 2.7 V	0.0625	1	μs	
		Subsystem clock (fSUB) operation	fil	2.4 V ≤ VDD ≤ 5.5 V		66.7		μs
		In the self- programming mode	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 5.5 V	0.04167	1	μs	
2.4 V ≤ VDD < 2.7 V	0.0625			1	μs			
External system clock frequency	fEX	2.7 V ≤ VDD ≤ 5.5 V		1		20	MHz	
		2.4 V ≤ VDD < 2.7 V		1		16	MHz	
External system clock input high-/low- level width	tEXH,	2.7 V ≤ VDD ≤ 5.5 V		24			ns	
	tEXL	2.4 V ≤ VDD < 2.7 V		30			ns	
Ti00 to Ti03 input high-/low-level width	tTIH, tTIL ^{Note 1}			1/fMCK + 10			ns	
TO00 to TO03, TKBO0, and TKBO1 output frequency ^{Note 2}	fTO	TO00 to TO03, TKBO0, and TKBO1 (in the case of output from port pins other than P20)	HS (high-speed main) mode	4.0 V ≤ EVDD ≤ 5.5 V		12	MHz	
				2.7 V ≤ EVDD < 4.0 V		8		
				2.4 V ≤ EVDD < 2.7 V		4		
	TKBO1 (in the case of output from P20)	HS (high-speed main) mode	4.0 V ≤ VDD ≤ 5.5 V		1.5	MHz		
			2.7 V ≤ VDD < 4.0 V		1.2			
			2.4 V ≤ VDD < 2.7 V		1			
PCLBUZ0, PCLBUZ1 output frequency	fPCL	HS (high-speed main) mode		4.0 V ≤ EVDD ≤ 5.5 V		16	MHz	
				2.7 V ≤ EVDD < 4.0 V		8		
				2.4 V ≤ EVDD < 2.7 V		4		
Interrupt input high- /low-level width	tINTH, tINTL	INTP0 to INTP2, INTP9		2.4 V ≤ VDD ≤ 5.5 V	1		μs	
		INTP3 to INTP8, INTP10, INTP11		2.4 V ≤ EVDD ≤ 5.5 V	1			
Key interrupt input low-level width	tKR	KR0 to KR7		2.4 V ≤ EVDD ≤ 5.5 V	250		ns	
RESET low-level width	tRSL				10		μs	

Note 1. Following conditions must be satisfied on low level interface of EVDD < VDD.
2.4 V ≤ EVDD ≤ 2.7 V: MIN.125 ns

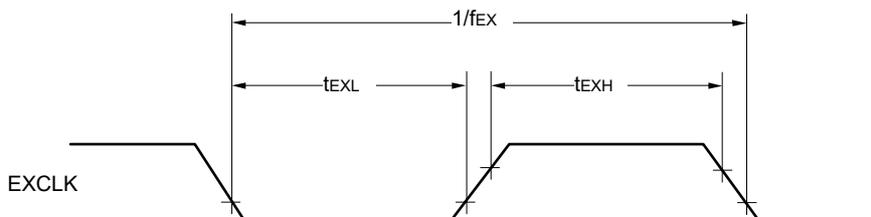
Note 2. When duty is 50%.

Remark fMCK: Timer array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0), n: Channel number (n = 0 to 3))

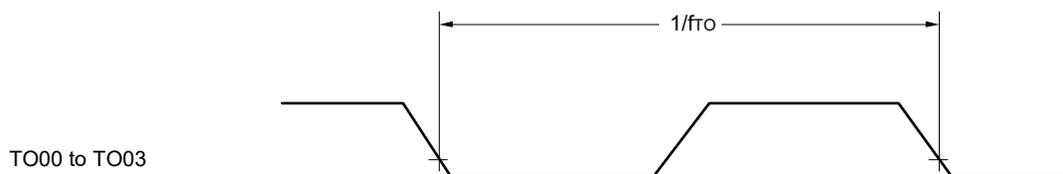
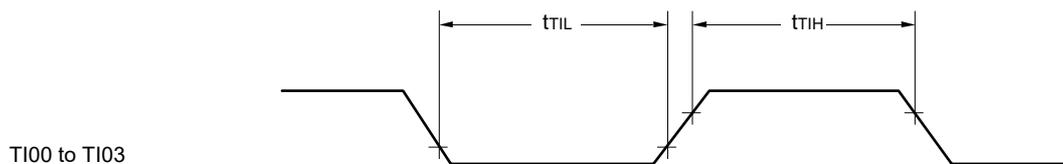
AC Timing Test Points



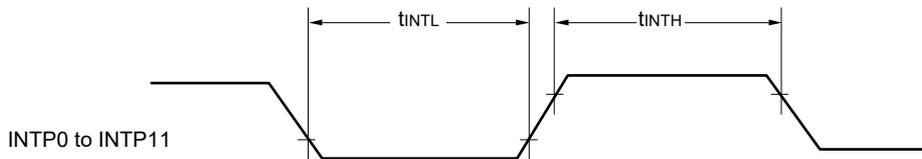
External System Clock Timing



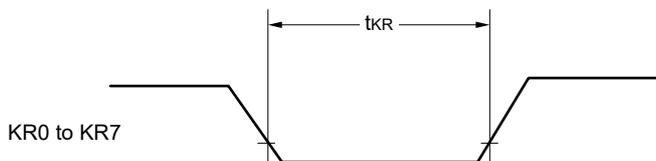
TI/TO Timing



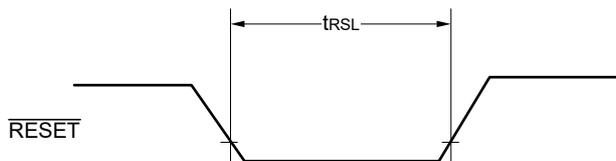
Interrupt Request Input Timing



Key Interrupt Input Timing

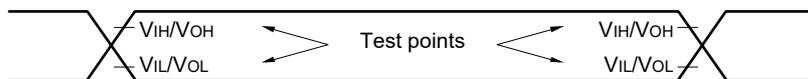


$\overline{\text{RESET}}$ Input Timing



3.5 Peripheral Functions Characteristics

AC Timing Test Points



3.5.1 Serial array unit

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

When P01, P30, P31 and P54 are used as TxDq pin

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Transfer rate		Theoretical value of the maximum transfer rate fMCK = fCLK = 24 MHz		fMCK/12 ^{Notes 1, 2}	bps
				2.0	Mbps

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

Note 2. The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:
HS (high-speed main) mode:
2.4 V ≤ EVDD ≤ 2.7 V: MAX. 1.3 Mbps

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).

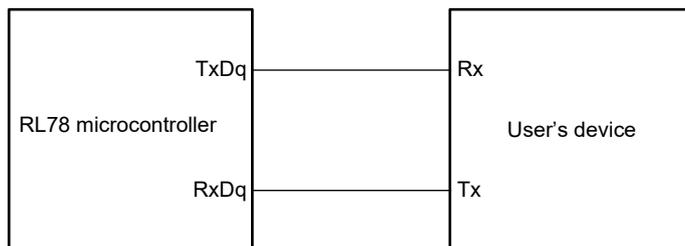
When P20 is used as TxD1 pin

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

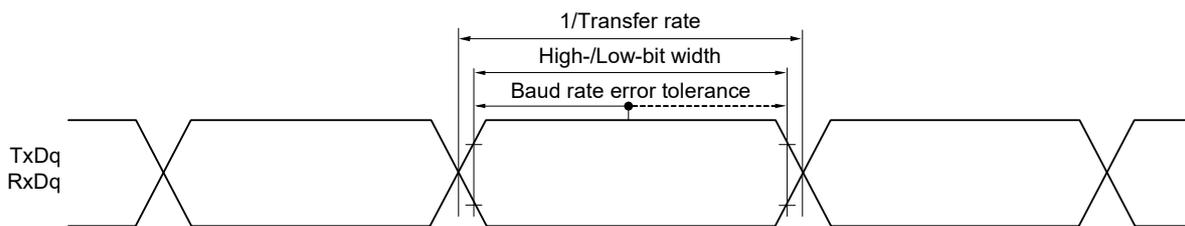
Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Transfer rate		4.0 V ≤ VDD ≤ 5.5 V		fMCK/16 ^{Note}	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK = 24 MHz		1.5
		2.7 V ≤ VDD ≤ 5.5 V		fMCK/20 ^{Note}	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK = 24 MHz		1.2
		2.4 V ≤ VDD ≤ 5.5 V		fMCK/16 ^{Note}	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK = 16 MHz		1.0

Note Transfer rate in the SNOOZE mode is 4800 bps only. When fHOCO = 48 MHz, SNOOZE mode is not supported.

UART mode connection diagram (during communication at same potential)



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



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

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

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

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

When P01, P32, P53, P54 and P56 are used as SOMn pins

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCKp cycle time	tkCY1	tkCY1 ≥ 4/fCLK 2.7 V ≤ EVDD ≤ 5.5 V	250		ns
			500		ns
SCKp high-/low-level width	tkH1, tkL1	4.0 V ≤ EVDD ≤ 5.5 V	tkCY1/2 - 24		ns
		2.7 V ≤ EVDD ≤ 5.5 V	tkCY1/2 - 36		ns
		2.4 V ≤ EVDD ≤ 5.5 V	tkCY1/2 - 76		ns
Slp setup time (to SCKp↑) Note 1	tsIK1	4.0 V ≤ EVDD ≤ 5.5 V	66		ns
		2.7 V ≤ EVDD ≤ 5.5 V			ns
		2.4 V ≤ EVDD ≤ 5.5 V	133		ns
Slp hold time (from SCKp↑) Note 2	tkSI1		38		ns
Delay time from SCKp↓ to SOP output Note 3	tkSO1	C = 30 pF Note 4		50	ns

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

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

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

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

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

When P20 is used as SO10 pin**(TA = -40 to +105°C, 2.4 V ≤ EVDD = VDD ≤ 5.5 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit	
			MIN.	MAX.		
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ 4/f _{CLK}	2.7 V ≤ V _{DD} ≤ 5.5 V	1000		ns
			2.4 V ≤ V _{DD} ≤ 5.5 V	1200		ns
SCKp high-/low-level width	t _{KH1} , t _{KL1}	4.0 V ≤ V _{DD} ≤ 5.5 V	t _{KCY1} /2 - 24		ns	
		2.7 V ≤ V _{DD} ≤ 5.5 V	t _{KCY1} /2 - 36		ns	
		2.4 V ≤ V _{DD} ≤ 5.5 V	t _{KCY1} /2 - 76		ns	
Slp setup time (to SCKp↑) ^{Note 1}	t _{SIK1}	2.7 V ≤ V _{DD} ≤ 5.5 V	66		ns	
		2.4 V ≤ V _{DD} ≤ 5.5 V	133		ns	
Slp hold time (from SCKp↑) ^{Note 2}	t _{KSI1}		38		ns	
Delay time from SCKp↓ to SOp output ^{Note 3}	t _{KSO1}	C = 30 pF ^{Note 4}		180	ns	

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

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

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

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

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

(3) During communication at same potential (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)**When P01, P32, P53, P54 and P56 are used as SOMn pins****(TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		Unit
				MIN.	MAX.	
SCKp cycle time Note 4	tkcy2	4.0 V ≤ EVDD ≤ 5.5 V	fMCK > 20 MHz	16/fMCK		ns
			fMCK ≤ 20 MHz	12/fMCK		ns
		2.7 V ≤ EVDD < 4.0 V	fMCK > 16 MHz	16/fMCK		ns
			fMCK ≤ 16 MHz	12/fMCK		ns
		2.4 V ≤ EVDD < 2.7 V		12/fMCK and 1000		ns
SCKp high-/low-level width	tkH2, tKL2	4.0 V ≤ EVDD ≤ 5.5 V		tkcy2/2 - 14		ns
	tkH2, tKL2	2.7 V ≤ EVDD < 4.0 V		tkcy2/2 - 16		ns
	tkH2, tKL2	2.4 V ≤ EVDD < 2.7 V		tkcy2/2 - 36		ns
Slp setup time (to SCKp↑) Note 1	tsIK2	2.7 V ≤ EVDD ≤ 5.5 V		1/fMCK + 40		ns
		2.4 V ≤ EVDD < 2.7 V		1/fMCK + 60		ns
Slp hold time (from SCKp↑) Note 1	tsIS2			1/fMCK + 62		ns
Delay time from SCKp↓ to SOp output Note 2	tkSO2	C = 30 pF Note 3	2.7 V ≤ EVDD ≤ 5.5 V		2/fMCK + 66	ns
			2.4 V ≤ EVDD < 2.7 V		2/fMCK + 113	ns

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

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

Note 3. C is the load capacitance of the SOp output lines.

Note 4. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

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

Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

Remark 2. fMCK: Serial array unit operation clock frequency
(Operation clock to be set by the CKS_{mn} bit of serial mode register mn (SMR_{mn}). m: Unit number, n: Channel number (mn = 00 to 03))

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

(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit	
			MIN.	MAX.		
$\overline{\text{SSI00}}$ setup time	tSSIK	DAPmn = 0	2.7 V ≤ VDD ≤ 3.6 V	240		ns
			2.4 V ≤ VDD < 2.7 V	400		ns
		DAPmn = 1	2.7 V ≤ VDD ≤ 3.6 V	1/fMCK + 240		ns
			2.4 V ≤ VDD < 2.7 V	1/fMCK + 400		ns
$\overline{\text{SSI00}}$ hold time	tKSSI	DAPmn = 0	2.7 V ≤ VDD ≤ 3.6 V	1/fMCK + 240		ns
			2.4 V ≤ VDD < 2.7 V	1/fMCK + 400		ns
		DAPmn = 1	2.7 V ≤ VDD ≤ 3.6 V	240		ns
			2.4 V ≤ VDD < 2.7 V	400		ns

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

Remark p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5, 12)

When P20 is used as SO10 pin**(TA = -40 to +105°C, 2.4 V ≤ EVDD = VDD ≤ 5.5 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCKp cycle time Note 4	tkCY2	4.0 V ≤ VDD ≤ 5.5 V	fMCK > 20 MHz	20/fMCK	ns
			fMCK ≤ 20 MHz	18/fMCK	ns
		2.7 V ≤ VDD < 4.0 V	fMCK > 16 MHz	20/fMCK and 1000	ns
			fMCK ≤ 16 MHz	18/fMCK	ns
		2.4 V ≤ VDD < 2.7 V	18/fMCK and 1200	ns	
SCKp high-/low-level width	tkH2, tkL2	4.0 V ≤ VDD ≤ 5.5 V	tkCY2/2 - 14	ns	
		2.7 V ≤ VDD < 4.0 V	tkCY2/2 - 16	ns	
		2.4 V ≤ VDD < 2.7 V	tkCY2/2 - 36	ns	
Slp setup time (to SCKp↑) Note 1	tsIK2	2.7 V ≤ VDD ≤ 5.5 V	1/fMCK + 40	ns	
		2.4 V ≤ VDD < 2.7 V	1/fMCK + 60	ns	
Slp hold time (from SCKp↑) Note 1	tkS12		1/fMCK + 62	ns	
Delay time from SCKp↓ to SOp output Note 2	tkS02	C = 30 pF Note 3	2.7 V ≤ VDD ≤ 5.5 V	2/fMCK + 190	ns
			2.4 V ≤ VDD < 2.7 V	2/fMCK + 250	ns

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

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

Note 3. C is the load capacitance of the SOp output lines.

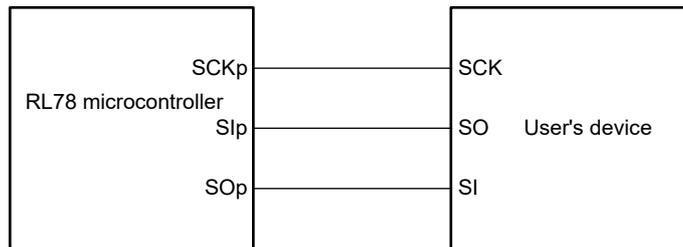
Note 4. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

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

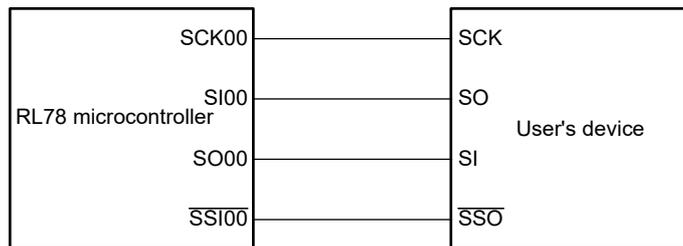
Remark 1. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

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

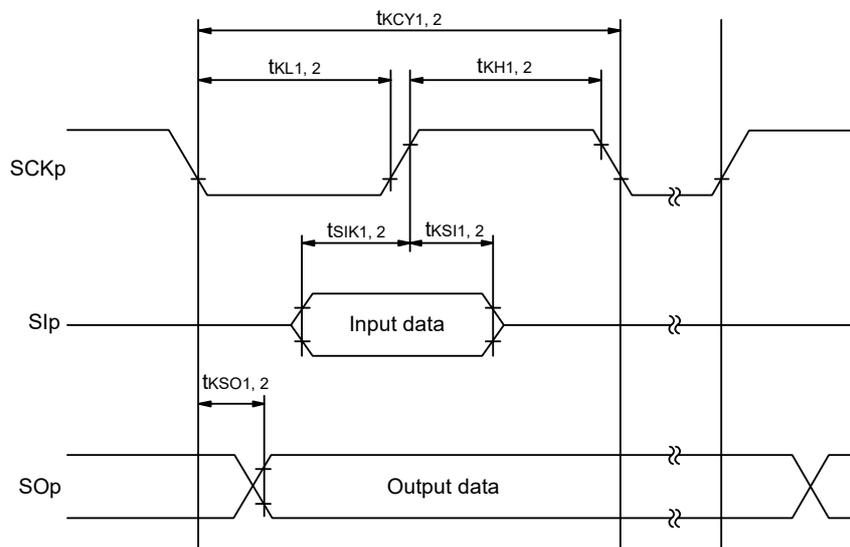


**Simplified SPI (CSI) mode connection diagram (during communication at same potential)
(Slave Transmission of slave select input function (CSI00))**

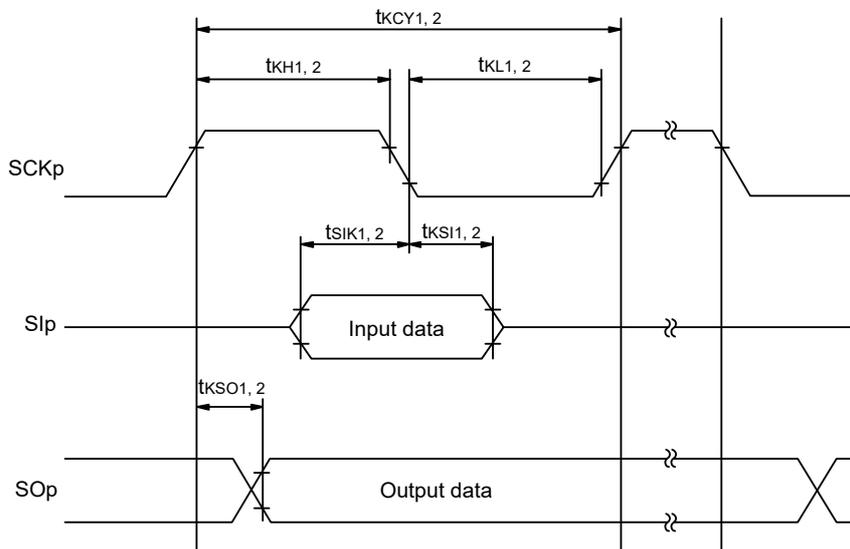


Remark p: CSI number (p = 00, 01, 10 and 11)

**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.)**



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

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

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

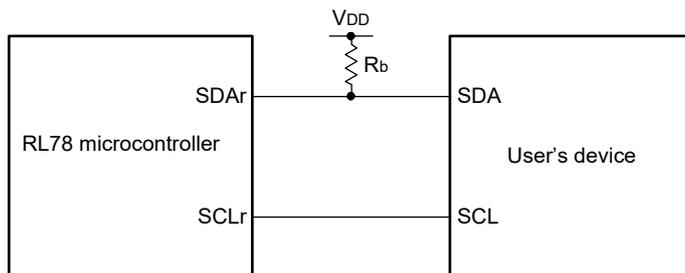
Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCLr clock frequency	f _{SCL}	2.7 V ≤ EV _{DD} ≤ 5.5 V, C _b = 50 pF, R _b = 2.7 kΩ		400 Note 1	kHz
		2.4 V ≤ EV _{DD} ≤ 5.5 V, C _b = 100 pF, R _b = 3 kΩ		100 Note 1	
Hold time when SCLr = "L"	t _{LOW}	2.7 V ≤ EV _{DD} ≤ 5.5 V,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

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

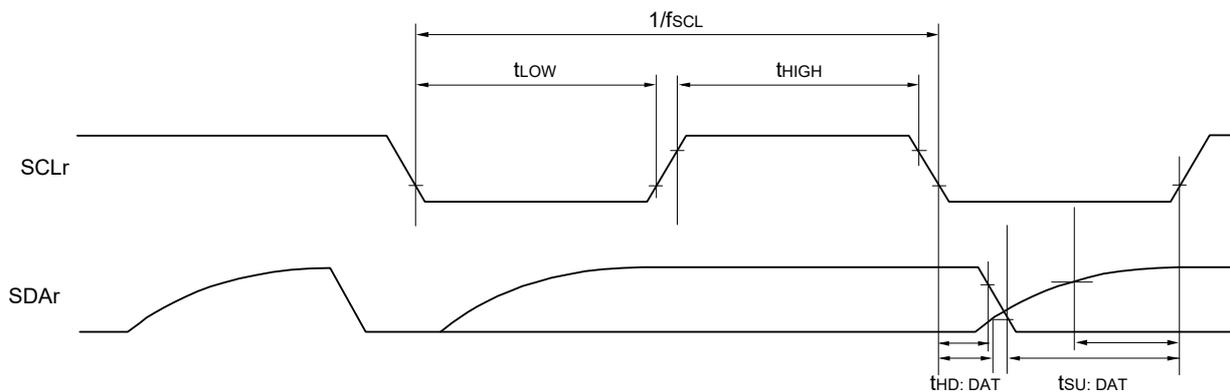
Note 2. Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

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

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



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



- Remark 1.** R_b[Ω]: Communication line (SDAr) pull-up resistance, C_b[F]: Communication line (SDAr, SCLr) load capacitance
- Remark 2.** r: IIC number (r = 00, 01, 10 and 11), g: PIM number (g = 0, 3 and 5), h: POM number (h = 0, 3 and 5)
- Remark 3.** f_{mck}: Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0),
 n: Channel number (n = 0 to 3), mn = 00 to 03)

(5) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (UART mode) (dedicated baud rate generator output)**(TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit	
			MIN.	MAX.		
Transfer rate		Reception	4.0 V ≤ EVDD ≤ 5.5 V, 2.3 V ≤ Vb ≤ 4.0 V		fMCK/12 Note 1	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		2.0	Mbps
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V		fMCK/12 Note 1	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		2.0	Mbps
			2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V		fMCK/12 Notes 1, 2	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		1.3	Mbps

Note 1. Transfer rate in the SNOOZE mode is 4,800 bps only.**Note 2.** Use it with EVDD ≥ Vb.**Note 3.** The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

HS (high-speed main) mode: 24 MHz (2.7 V ≤ VDD ≤ 5.5 V)

16 MHz (2.4 V ≤ VDD ≤ 5.5 V)

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

Remark 1. Vb[V]: Communication line voltage**Remark 2.** q: UART number (q = 0 and 1), g: PIM and POM numbers (g = 0, 2, 3, 5, 12)**Remark 3.** fMCK: Serial array unit operation clock frequency

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

n: Channel number (mn = 00 to 03))

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

(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit	
			MIN.	MAX.		
Transfer rate		Transmission	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V		Note 1	bps
			Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 1.4 kΩ, Vb = 2.7 V		2.6 Note 2	Mbps
			2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V		Note 3	bps
			Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 2.7 kΩ, Vb = 2.3 V		1.2 Note 4	Mbps
			2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V		Notes 5, 6	bps
			Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 5.5 kΩ, Vb = 1.6 V		0.43 Note 7	Mbps

Note 1. The smaller maximum transfer rate derived by using $f_{mck}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when 4.0 V ≤ EVDD ≤ 5.5 V and 2.7 V ≤ Vb ≤ 4.0 V

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

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

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

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

Note 3. The smaller maximum transfer rate derived by using $f_{mck}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when 2.7 V ≤ EVDD ≤ 4.0 V and 2.3 V ≤ Vb ≤ 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

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

Note 5. Use it with EVDD ≥ Vb.

Note 6. The smaller maximum transfer rate derived by using $f_{MCK}/6$ or the following expression is the valid maximum transfer rate. Expression for calculating the transfer rate when $2.4\text{ V} \leq EV_{DD} < 3.3\text{ V}$ and $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$

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

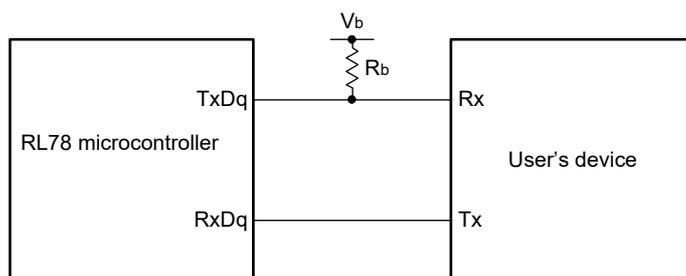
$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{\left(\frac{1}{\text{Transfer rate}}\right) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

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

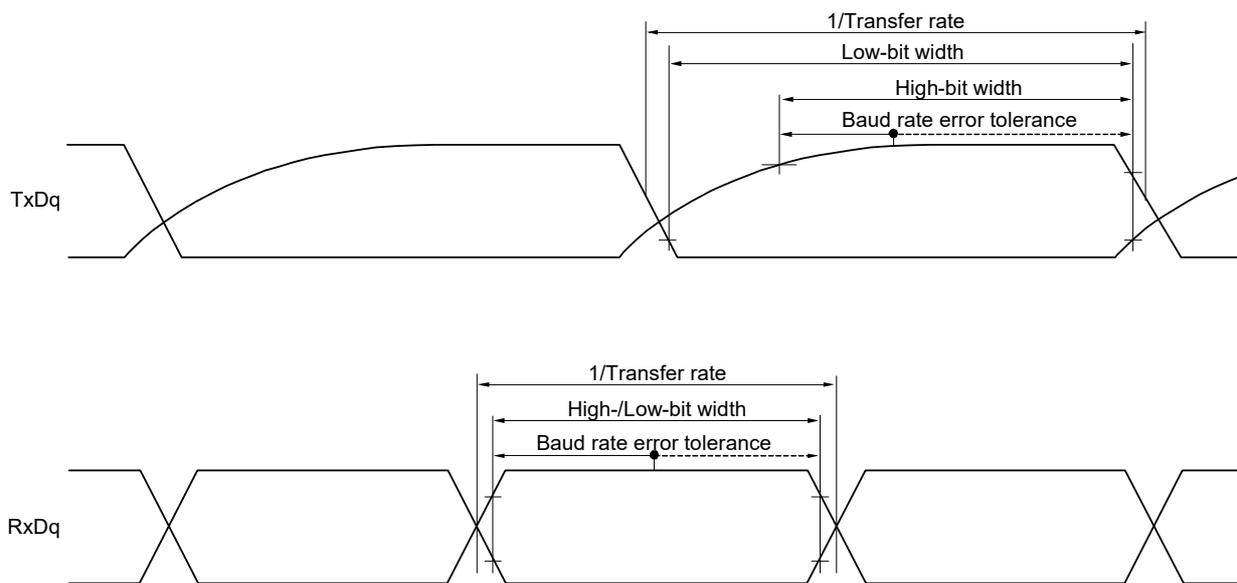
Note 7. This value as an example is calculated when the conditions described in the "Conditions" column are met. Refer to Note 6 above to calculate the maximum transfer rate under conditions of the customer.

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (EV_{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.

UART mode connection diagram (during communication at different potential)



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



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

Remark 2. q: UART number (q = 0 and 1), g: PIM and POM number (g = 0, 2, 3, 5 and 12)

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

(6) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (master mode, SCKp... internal clock output)**(TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)****(1/2)**

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

Caution Select the TTL input buffer for the SIp pin and the N-ch open drain output (EVDD 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 VIH and VIL, see the DC characteristics with TTL input buffer selected.

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

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

(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Slp setup time (to SCKp↑) Note 1	tSIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	162		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	354		ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	958		ns
Slp hold time (from SCKp↑) Note 1	tSIH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	38		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ			ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ			ns
Delay time from SCKp↓ to SOp output Note 1	tKS01	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ		200	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ		390	ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ		966	ns
Slp setup time (to SCKp↓) Note 2	tSIK1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	88		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ			ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	220		ns
Slp hold time (from SCKp↓) Note 2	tSIH1	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ	38		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ			
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ			ns
Delay time from SCKp↑ to SOp output Note 2	tKS01	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 30 pF, Rb = 1.4 kΩ		50	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ			
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ			ns

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

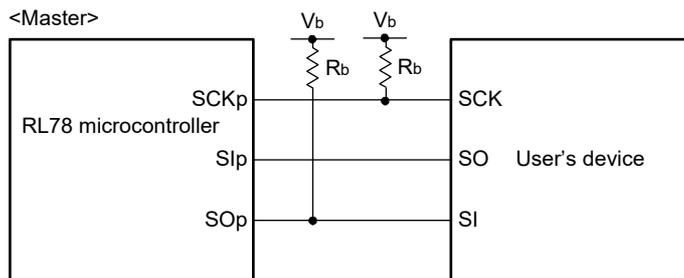
Note 2. When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

Note 3. Use it with EVDD ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (EVDD 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 VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

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

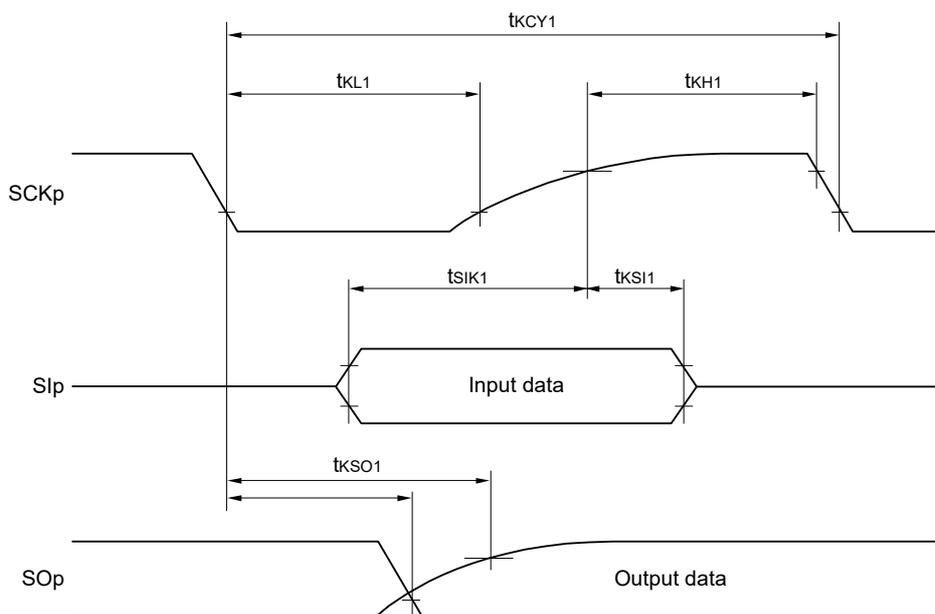


Remark 1. Rb[Ω]: Communication line (SCKp, SOp) pull-up resistance, Cb[F]: Communication line (SCKp, SOp) load capacitance, Vb[V]: Communication line voltage

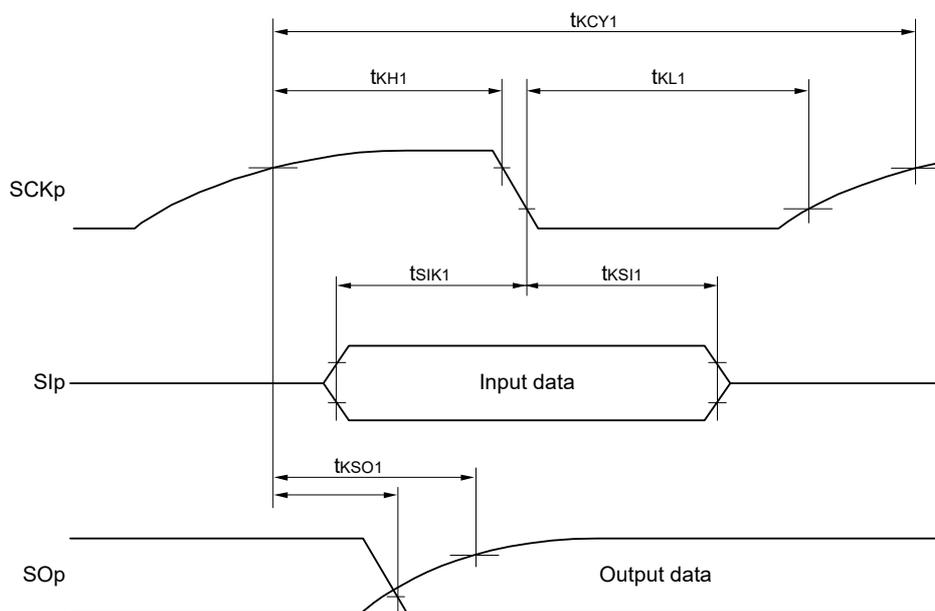
Remark 2. p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

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

**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.)**



Remark p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

(7) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (Simplified SPI (CSI) mode) (slave mode, SCKp... external clock input)

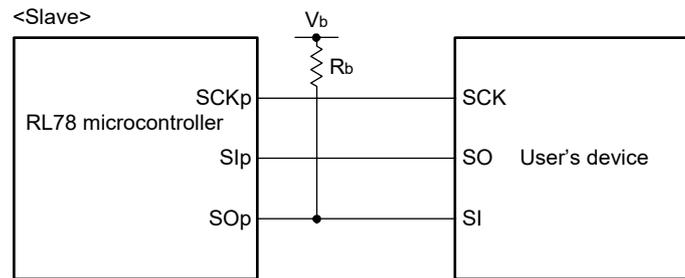
(TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit	
			MIN.	MAX.		
SCKp cycle time ^{Note 1}	tkCY2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V	20 MHz < fMCK ≤ 24 MHz	24/fMCK		ns
			8 MHz < fMCK ≤ 20 MHz	20/fMCK		ns
			4 MHz < fMCK ≤ 8 MHz	16/fMCK		ns
			fMCK ≤ 4 MHz	12/fMCK		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V	20 MHz < fMCK ≤ 24 MHz	32/fMCK		ns
			16 MHz < fMCK ≤ 20 MHz	28/fMCK		ns
			8 MHz < fMCK ≤ 16 MHz	24/fMCK		ns
			4 MHz < fMCK ≤ 8 MHz	16/fMCK		ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	20 MHz < fMCK ≤ 24 MHz	72/fMCK		ns
			16 MHz < fMCK ≤ 20 MHz	64/fMCK		ns
			8 MHz < fMCK ≤ 16 MHz	52/fMCK		ns
			4 MHz < fMCK ≤ 8 MHz	32/fMCK		ns
		fMCK ≤ 4 MHz	20/fMCK		ns	
SCKp high-/low-level width	tkH2, tkL2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V	tkCY2/2 - 24		ns	
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V	tkCY2/2 - 36		ns	
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	tkCY2/2 - 100		ns	
Slp setup time (to SCKp↑) ^{Note 3}	tsIK2	2.7 V ≤ EVDD ≤ 5.5 V, 2.3 V ≤ Vb ≤ 4.0 V	1/fMCK + 40		ns	
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2}	1/fMCK + 60		ns	
Slp hold time (from SCKp↑) ^{Note 4}	tkS12		1/fMCK + 62		ns	
Delay time from SCKp↓ to SOP output ^{Note 5}	tkSO2	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V Cb = 30 pF, Rb = 1.4 kΩ		2/fMCK + 240	ns	
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V Cb = 30 pF, Rb = 2.7 kΩ		2/fMCK + 428	ns	
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V ^{Note 2} Cb = 30 pF, Rb = 5.5 kΩ		2/fMCK + 1146	ns	

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

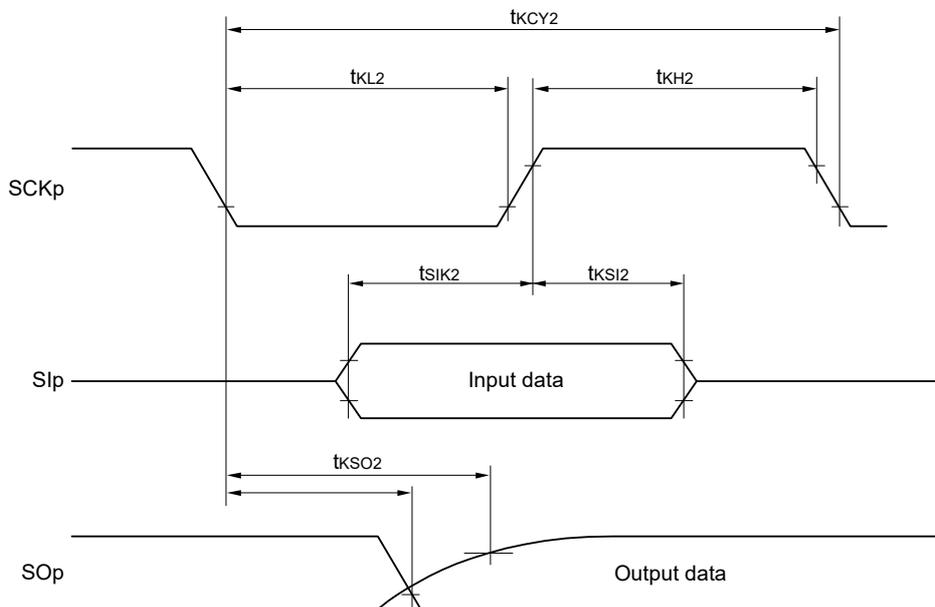
- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** Use it with EV_{DD} ≥ V_b.
- Note 3.** When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1. The SIp setup time becomes “to SCKp↓” when DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.
- Note 4.** When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1. The SIp hold time becomes “from SCKp↓” when DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.
- Note 5.** When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1. The delay time to SO_p output becomes “from SCKp↑” when DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.
- Caution** Select the TTL input buffer for the SIp pin and SCKp pin and the N-ch open drain output (EV_{DD} tolerance) mode for the SO_p 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)

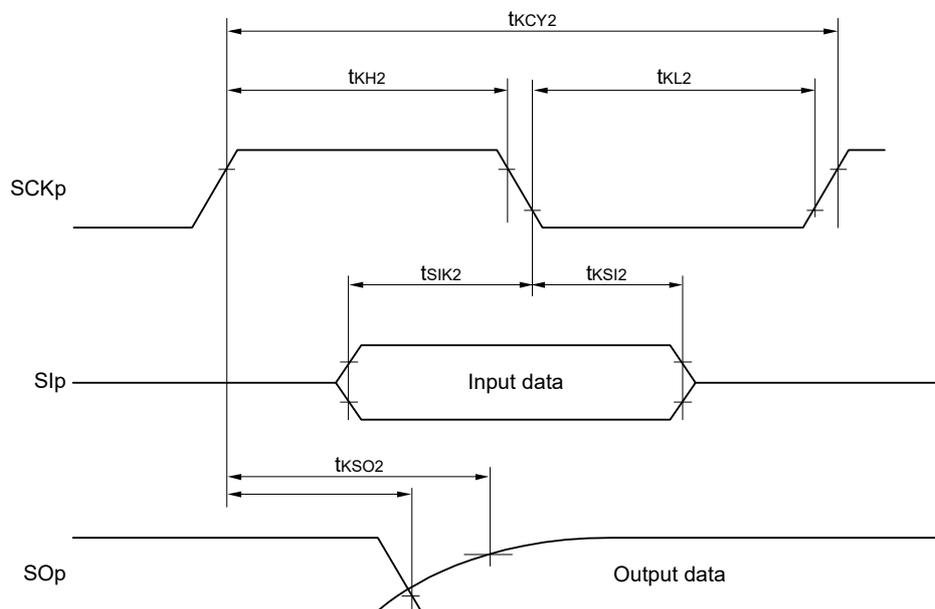


- Remark 1.** R_b[Ω]: Communication line (SO_p) pull-up resistance, C_b[F]: Communication line (SO_p) load capacitance, V_b[V]: Communication line voltage
- Remark 2.** p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)
- Remark 3.** f_{MCK}: Serial array unit operation clock frequency
(Operation clock to be set by the CKS_{mn} bit of serial mode register mn (SMR_{mn}). m: Unit number, n: Channel number (mn = 00 to 03))

**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.)**



Remark p: CSI number (p = 00, 01, 10 and 11), m: Unit number (m = 0), n: Channel number (n = 0 to 3), g: PIM and POM numbers (g = 0, 2, 3 to 5 and 12)

(8) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (simplified I²C mode)

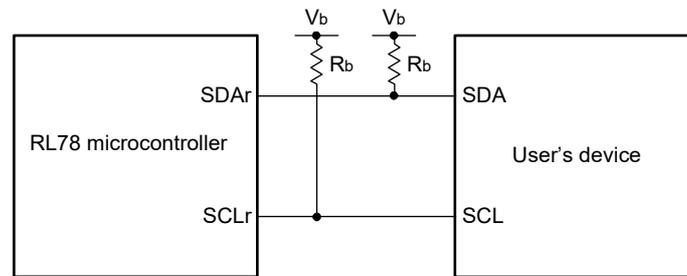
(TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCLr clock frequency	f _{SCL}	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ		400 Note 1	kHz
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ		400 Note 1	kHz
		4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ		100 Note 1	kHz
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ		100 Note 1	kHz
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ		100 Note 1	kHz
Hold time when SCLr = "L"	t _{LOW}	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ	1200		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ	1200		ns
		4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ	4600		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ	4600		ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ	4650		ns
Hold time when SCLr = "H"	t _{HIGH}	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ	620		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ	500		ns
		4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ	2700		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ	2400		ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ	1830		ns
Data setup time (reception)	tsu-DAT	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ	1/f _{MCK} + 340 Note 3		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ	1/f _{MCK} + 340 Note 3		ns
		4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ	1/f _{MCK} + 760 Note 3		ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ	1/f _{MCK} + 760 Note 3		ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ	1/f _{MCK} + 570 Note 3		ns
Data hold time (transmission)	t _{HD-DAT}	4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 50 pF, Rb = 2.7 kΩ	0	770	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 50 pF, Rb = 2.7 kΩ	0	770	ns
		4.0 V ≤ EVDD ≤ 5.5 V, 2.7 V ≤ Vb ≤ 4.0 V, Cb = 100 pF, Rb = 2.8 kΩ	0	1420	ns
		2.7 V ≤ EVDD < 4.0 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 100 pF, Rb = 2.7 kΩ	0	1420	ns
		2.4 V ≤ EVDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2, Cb = 100 pF, Rb = 5.5 kΩ	0	1215	ns

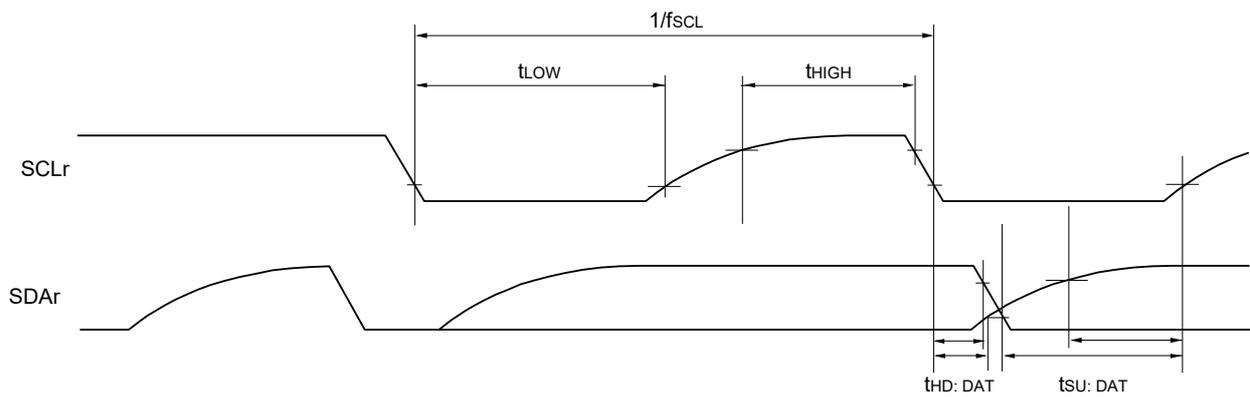
- Note 1.** The value must be equal to or less than $f_{MCK}/4$.
- Note 2.** Use it with $EV_{DD} \geq V_b$.
- Note 3.** Set the f_{MCK} value to keep the hold time of $SCLr = "L"$ and $SCLr = "H"$.

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

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



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



- Remark 1.** $R_b[\Omega]$: Communication line (SDAr, SCLr) pull-up resistance, $C_b[F]$: Communication line (SDAr, SCLr) load capacitance, $V_b[V]$: Communication line voltage
- Remark 2.** r: IIC number (r = 00, 01, 10 and 11), g: PIM, POM number (g = 0, 3 and 5)
- Remark 3.** f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0), n: Channel number (n = 0 to 3), mn = 00 to 03)

3.5.2 Serial interface IICA

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

Parameter	Symbol	Conditions	HS (high-speed main) mode				Unit
			Standard mode		Fast mode		
			MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	fSCL	Fast mode: fCLK ≥ 3.5 MHz	—	—	0	400	kHz
		Standard mode: fCLK ≥ 1 MHz	0	100	—	—	
Setup time of restart condition	tSU: STA		4.7		0.6		μs
Hold time ^{Note 1}	tHD: STA		4.0		0.6		μs
Hold time when SCLA0 = "L"	tLOW		4.7		1.3		μs
Hold time when SCLA0 = "H"	tHIGH		4.0		0.6		μs
Data setup time (reception)	tSU: DAT		250		100		ns
Data hold time (transmission) ^{Note 2}	tHD: DAT		0	3.45	0	0.9	μs
Setup time of stop condition	tSU: STO		4.0		0.6		μs
Bus-free time	tBUF		4.7		1.3		μs

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

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

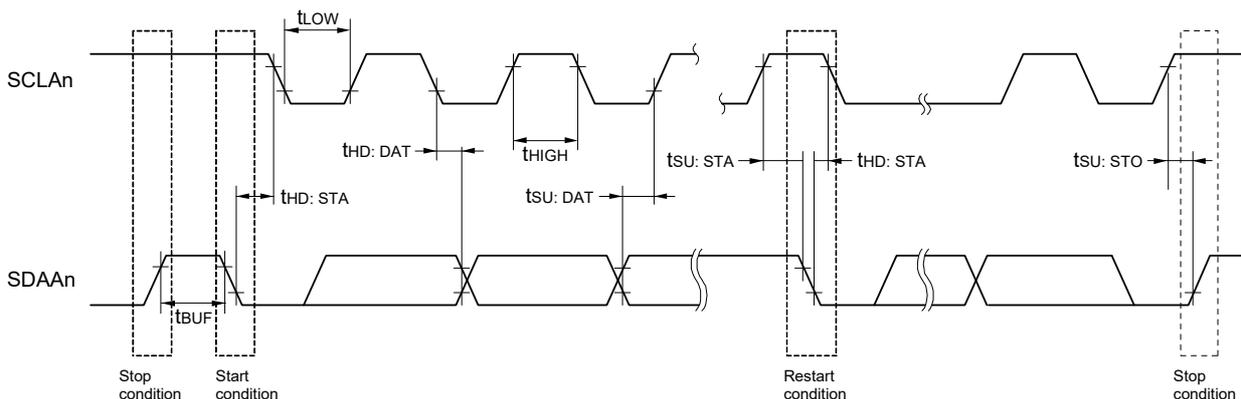
Caution The values in the above table are applied even when bit 2 (PIOR02) in the peripheral I/O redirection register 0 (PIOR0) is 1. At this time, the pin characteristics (IOH1, IOL1, VOH1, VOL1) must satisfy the values in the redirect destination.

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

Standard mode: Cb = 400 pF, Rb = 2.7 kΩ

Fast mode: Cb = 320 pF, Rb = 1.1 kΩ

IICA serial transfer timing



Remark n = 0, 1

3.6 Analog Characteristics

3.6.1 A/D converter characteristics

Classification of A/D converter characteristics

Input channel	Reference Voltage	Reference voltage (+) = AV _{REFP} Reference voltage (-) = AV _{REFM}	Reference voltage (+) = V _{DD} Reference voltage (-) = V _{SS}	Reference voltage (+) = V _{BGR} Reference voltage (-) = AV _{REFM}
ANI0 to ANI3		Refer to 3.6.1 (1).	Refer to 3.6.1 (3).	Refer to 3.6.1 (4).
ANI16 to ANI22		Refer to 3.6.1 (2).		
Internal reference voltage Temperature sensor output voltage		Refer to 3.6.1 (1).		

(1) When reference voltage (+) = AV_{REFP}/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AV_{REFM}/ANI1 (ADREFM = 1), target pin: ANI2 and ANI3, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +105°C, 2.4 V ≤ AV_{REFP} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V, Reference voltage (+) = AV_{REFP}, Reference voltage (-) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES		8		10	bit
Overall error Note 1	AINL	10-bit resolution AV _{REFP} = V _{DD} Note 3	2.4 V ≤ AV _{REFP} ≤ 5.5 V	1.2	±3.5	LSB
Conversion time	t _{CONV}	10-bit resolution Target pin: ANI2 and ANI3	3.6 V ≤ V _{DD} ≤ 5.5 V	2.125	39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.1875	39	μs
			2.4 V ≤ V _{DD} ≤ 5.5 V	17	39	μs
		10-bit resolution Target pin: Internal reference voltage, and temperature sensor output voltage	3.6 V ≤ V _{DD} ≤ 5.5 V	2.375	39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.5625	39	μs
			2.4 V ≤ V _{DD} ≤ 5.5 V	17	39	μs
Zero-scale error Notes 1, 2	EzS	10-bit resolution AV _{REFP} = V _{DD} Note 3	2.4 V ≤ AV _{REFP} ≤ 5.5 V		±0.25	%FSR
Full-scale error Notes 1, 2	EFS	10-bit resolution AV _{REFP} = V _{DD} Note 3	2.4 V ≤ AV _{REFP} ≤ 5.5 V		±0.25	%FSR
Integral linearity error Note 1	ILE	10-bit resolution AV _{REFP} = V _{DD} Note 3	2.4 V ≤ AV _{REFP} ≤ 5.5 V		±2.5	LSB
Differential linearity error Note 1	DLE	10-bit resolution AV _{REFP} = V _{DD} Note 3	2.4 V ≤ AV _{REFP} ≤ 5.5 V		±1.5	LSB
Analog input voltage	V _{AIN}	ANI2 and ANI3	0		AV _{REFP}	V
		Internal reference voltage (2.4 V ≤ V _{DD} ≤ 5.5 V)			V _{BGR} Note 4	V
		Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 5.5 V)			V _{TMPS25} Note 4	V

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

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

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

Overall error: Add ±1.0 LSB to the MAX. value when AV_{REFP} = V_{DD}.
 Zero-scale error/Full-scale error: Add ±0.05%FSR to the MAX. value when AV_{REFP} = V_{DD}.
 Integral linearity error/ Differential linearity error: Add ±0.5 LSB to the MAX. value when AV_{REFP} = V_{DD}.

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

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = $AV_{REFM}/ANI1$ (ADREFM = 1), target pin: ANI16 to ANI22

(TA = -40 to +105°C, $2.4\text{ V} \leq EV_{DD} \leq V_{DD} \leq 5.5\text{ V}$, $2.4\text{ V} \leq AV_{REFP} \leq V_{DD} \leq 5.5\text{ V}$, $V_{SS} = 0\text{ V}$,

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			8		10	bit
Overall error Note 1	AINL	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$		1.2	± 5.0	LSB
Conversion time	tCONV	10-bit resolution Target ANI pin: ANI16 to ANI22	$3.6\text{ V} \leq V_{DD} \leq 5.5\text{ V}$	2.125		39	μs
			$2.7\text{ V} \leq V_{DD} \leq 5.5\text{ V}$	3.1875		39	μs
			$2.4\text{ V} \leq V_{DD} \leq 5.5\text{ V}$	17		39	μs
Zero-scale error Notes 1, 2	Ezs	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 0.35	%FSR
Full-scale error Notes 1, 2	Efs	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 0.35	%FSR
Integral linearity error Note 1	ILE	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 3.5	LSB
Differential linearity error Note 1	DLE	10-bit resolution $EV_{DD} \leq AV_{REFP} = V_{DD}$ Notes 3, 4	$2.4\text{ V} \leq AV_{REFP} \leq 5.5\text{ V}$			± 2.0	LSB
Analog input voltage	VAIN	ANI16 to ANI22		0		AV_{REFP} and EV_{DD}	V

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

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

Note 3. When $EV_{DD} \leq AV_{REFP} < V_{DD}$, the MAX. values are as follows.

Overall error: Add ± 1.0 LSB to the MAX. value when $AV_{REFP} = V_{DD}$.
 Zero-scale error/Full-scale error: Add $\pm 0.05\%$ FSR to the MAX. value when $AV_{REFP} = V_{DD}$.
 Integral linearity error/ Differential linearity error: Add ± 0.5 LSB to the MAX. value when $AV_{REFP} = V_{DD}$.

Note 4. When $AV_{REFP} < EV_{DD} \leq V_{DD}$, the MAX. values are as follows.

Overall error: Add ± 4.0 LSB to the MAX. value when $AV_{REFP} = V_{DD}$.
 Zero-scale error/Full-scale error: Add $\pm 0.20\%$ FSR to the MAX. value when $AV_{REFP} = V_{DD}$.
 Integral linearity error/ Differential linearity error: Add ± 2.0 LSB to the MAX. value when $AV_{REFP} = V_{DD}$.

- (3) When reference voltage (+) = V_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = V_{SS} (ADREFM = 0), target pin: ANI0 to ANI3, ANI16 to ANI22, internal reference voltage, and temperature sensor output voltage

(TA = -40 to +105°C, 2.4 V ≤ EV_{DD} ≤ V_{DD} ≤ 5.5 V, V_{SS} = 0 V,

Reference voltage (+) = V_{DD}, Reference voltage (-) = V_{SS})

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			8		10	bit
Overall error Note 1	AINL	10-bit resolution	2.4 V ≤ V _{DD} ≤ 5.5 V		1.2	±7.0	LSB
Conversion time	t _{CONV}	10-bit resolution Target pin: ANI0 to ANI3, ANI16 to ANI22	3.6 V ≤ V _{DD} ≤ 5.5 V	2.125		39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.1875		39	μs
			2.4 V ≤ V _{DD} ≤ 5.5 V	17		39	μs
		10-bit resolution Target pin: internal reference voltage, and temperature sensor output voltage	3.6 V ≤ V _{DD} ≤ 5.5 V	2.375		39	μs
			2.7 V ≤ V _{DD} ≤ 5.5 V	3.5625		39	μs
			2.4 V ≤ V _{DD} ≤ 5.5 V	17		39	μs
Zero-scale error Notes 1, 2	E _{zs}	10-bit resolution	2.4 V ≤ V _{DD} ≤ 5.5 V			±0.60	%FSR
Full-scale error Notes 1, 2	E _{fs}	10-bit resolution	2.4 V ≤ V _{DD} ≤ 5.5 V			±0.60	%FSR
Integral linearity error Note 1	ILE	10-bit resolution	2.4 V ≤ V _{DD} ≤ 5.5 V			±4.0	LSB
Differential linearity error Note 1	DLE	10-bit resolution	2.4 V ≤ V _{DD} ≤ 5.5 V			±2.0	LSB
Analog input voltage	V _{AIN}	ANI0 to ANI3		0		V _{DD}	V
		ANI16 to ANI22		0		EV _{DD}	V
		Internal reference voltage (2.4 V ≤ V _{DD} ≤ 5.5 V)		V _{BGR} Note 3			V
		Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 5.5 V)		V _{TMPS25} Note 3			V

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

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

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

(4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0 to ANI3, ANI16 to ANI22

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

Reference voltage (+) = VBGR Note 3, Reference voltage (-) = AVREFM = 0 V Note 4)

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

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

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

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

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

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

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

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

3.6.2 Temperature sensor characteristics/internal reference voltage characteristic

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor output voltage	VTMPS25	Setting ADS register = 80H, TA = +25°C		1.05		V
Internal reference voltage	VBGR	Setting ADS register = 81H	1.38	1.45	1.5	V
Temperature coefficient	FVTMPS	Temperature sensor that depends on the temperature		-3.6		mV/°C
Operation stabilization wait time	tAMP	2.4 V ≤ VDD ≤ 3.6 V	5			μs

3.6.3 D/A converter (channel 1)

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

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

3.6.4 Comparator

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

(Comparator 1: TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage range	VIREF0	IVREF0 pin	0		VDD - 1.4 Note 1	V
	VIREF1	IVREF1 pin	1.4 Note 1		VDD	V
	VICMP	IVCMP0 pin	-0.3		VDD + 0.3	V
		IVCMP1 pin	-0.3		EVDD + 0.3	V
Output delay	td	VDD = 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	μs
			Comparator low-speed mode, window mode		4	μs
Operation stabilization wait time	tcMP		100			μs
Reference voltage declination in channel 0 of internal DAC Note 2	ΔVIDAC				±2.5	LSB

Note 1. In window mode, make sure that VREF1 - VREF0 ≥ 0.2 V.

Note 2. Only in CMP0

3.6.5 PGA

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

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

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

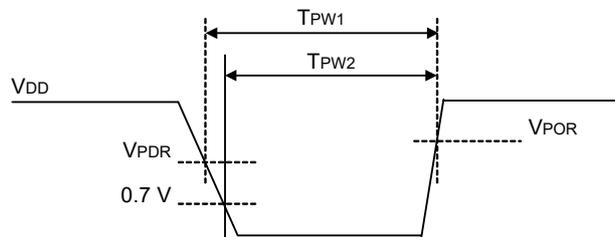
3.6.6 POR circuit characteristics

(TA = -40 to +105°C, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V _{POR}	The power supply voltage is rising.	1.45	1.51	1.57	V
	V _{PDR}	The power supply voltage is falling. ^{Note 1}	1.44	1.50	1.56	V
Minimum pulse width ^{Note 2}	T _{PW1}	Other than STOP/SUB HALT/SUB RUN	300			μs
	T _{PW2}	STOP/SUB HALT/SUB RUN	300			μs

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

Note 2. Minimum time required for a POR reset when V_{DD} exceeds below V_{PDR}. This is also the minimum time required for a POR reset from when V_{DD} exceeds below 0.7 V to when V_{DD} exceeds V_{POR} while STOP mode is entered or the main system clock is stopped through setting bit 0 (HIOSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).



3.6.7 LVD circuit characteristics

(1) LVD Detection Voltage of Reset Mode and Interrupt Mode

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

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	Supply voltage level	VLVD0	The power supply voltage is rising.	3.90	4.06	4.22	V
			The power supply voltage is falling.	3.83	3.98	4.13	V
		VLVD1	The power supply voltage is rising.	3.60	3.75	3.90	V
			The power supply voltage is falling.	3.53	3.67	3.81	V
		VLVD2	The power supply voltage is rising.	3.01	3.13	3.25	V
			The power supply voltage is falling.	2.94	3.06	3.18	V
		VLVD3	The power supply voltage is rising.	2.90	3.02	3.14	V
			The power supply voltage is falling.	2.85	2.96	3.07	V
		VLVD4	The power supply voltage is rising.	2.81	2.92	3.03	V
			The power supply voltage is falling.	2.75	2.86	2.97	V
		VLVD5	The power supply voltage is rising.	2.71	2.81	2.92	V
			The power supply voltage is falling.	2.64	2.75	2.86	V
		VLVD6	The power supply voltage is rising.	2.61	2.71	2.81	V
			The power supply voltage is falling.	2.55	2.65	2.75	V
VLVD7	The power supply voltage is rising.	2.51	2.61	2.71	V		
	The power supply voltage is falling.	2.45	2.55	2.65	V		
Minimum pulse width		tLW		300			μs
Detection delay time						300	μs

(2) LVD Detection Voltage of Interrupt & Reset Mode

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

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

3.6.8 Power supply voltage rising slope characteristics

(TA = -40 to +105°C, VSS = 0 V)

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

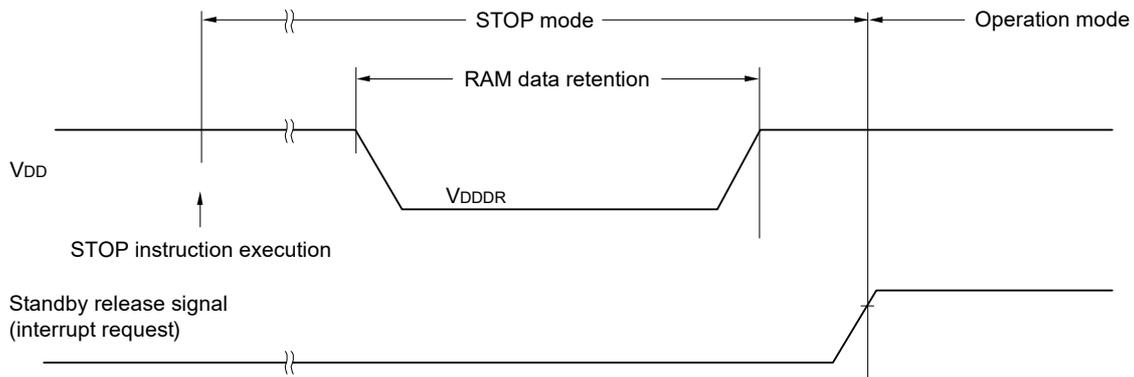
Caution Make sure to keep the internal reset state by the LVD circuit or an external reset until VDD reaches the operating voltage range shown in 3.4 AC Characteristics.

3.7 RAM Data Retention Characteristics

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	VDDDR		1.44 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.



3.8 Flash Memory Programming Characteristics

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
System clock frequency	fCLK	2.4 V ≤ VDD ≤ 5.5 V		1		24	MHz
Number of code flash rewrites Notes 1, 2, 3	Cerwr	Retained for 20 years	TA = 85°C	1,000			Times
Number of data flash rewrites Notes 1, 2, 3		Retained for 1 year	TA = 25°C		1,000,000		
		Retained for 5 years	TA = 85°C	100,000			
		Retained for 20 years	TA = 85°C	10,000			

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

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

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

3.9 Dedicated Flash Memory Programmer Communication (UART)

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

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

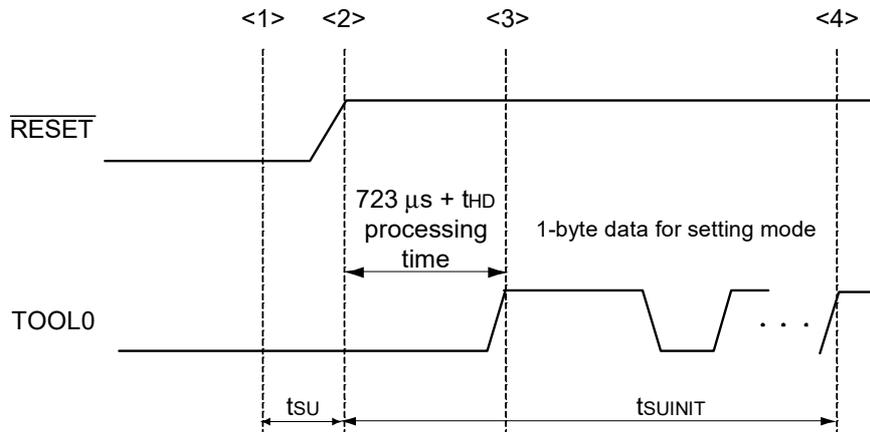
3.10 Timing of Entry to Flash Memory Programming Modes

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
How long from when an external reset ends until the initial communication settings are specified <i>Note 1</i>	tsuINIT	POR and LVD reset must end before the external reset ends.			100	ms
How long from when the TOOL0 pin is placed at the low level until an external reset ends <i>Note 1</i>	tsu	POR and LVD reset must end before the external reset ends.	10			μs
How long the TOOL0 pin must be kept at the low level after an external reset ends (excluding the processing time of the firmware to control the flash memory) <i>Notes 1, 2</i>	tHD	POR and LVD reset must end before the external reset ends.	1			ms

Note 1. Deassertion of the POR and LVD reset signals must precede deassertion of the pin reset signal.

Note 2. This excludes the flash firmware processing time (723 μs).



<1> The low level is input to the TOOL0 pin.

<2> The external reset ends (POR and LVD reset must end before the external reset ends).

<3> The TOOL0 pin is set to the high level.

<4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

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

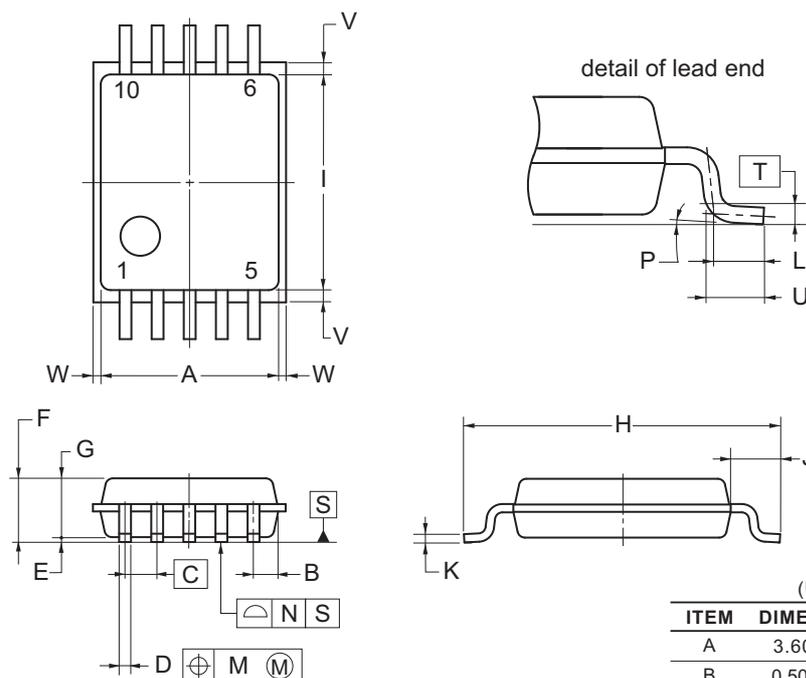
tsu: How long from when the TOOL0 pin is placed at the low level until a pin reset ends

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

4. PACKAGE DRAWINGS

4.1 10-pin package

JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-LSSOP10-4.4x3.6-0.65	PLSP0010JA-A	P10MA-65-CAC-2	0.05



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

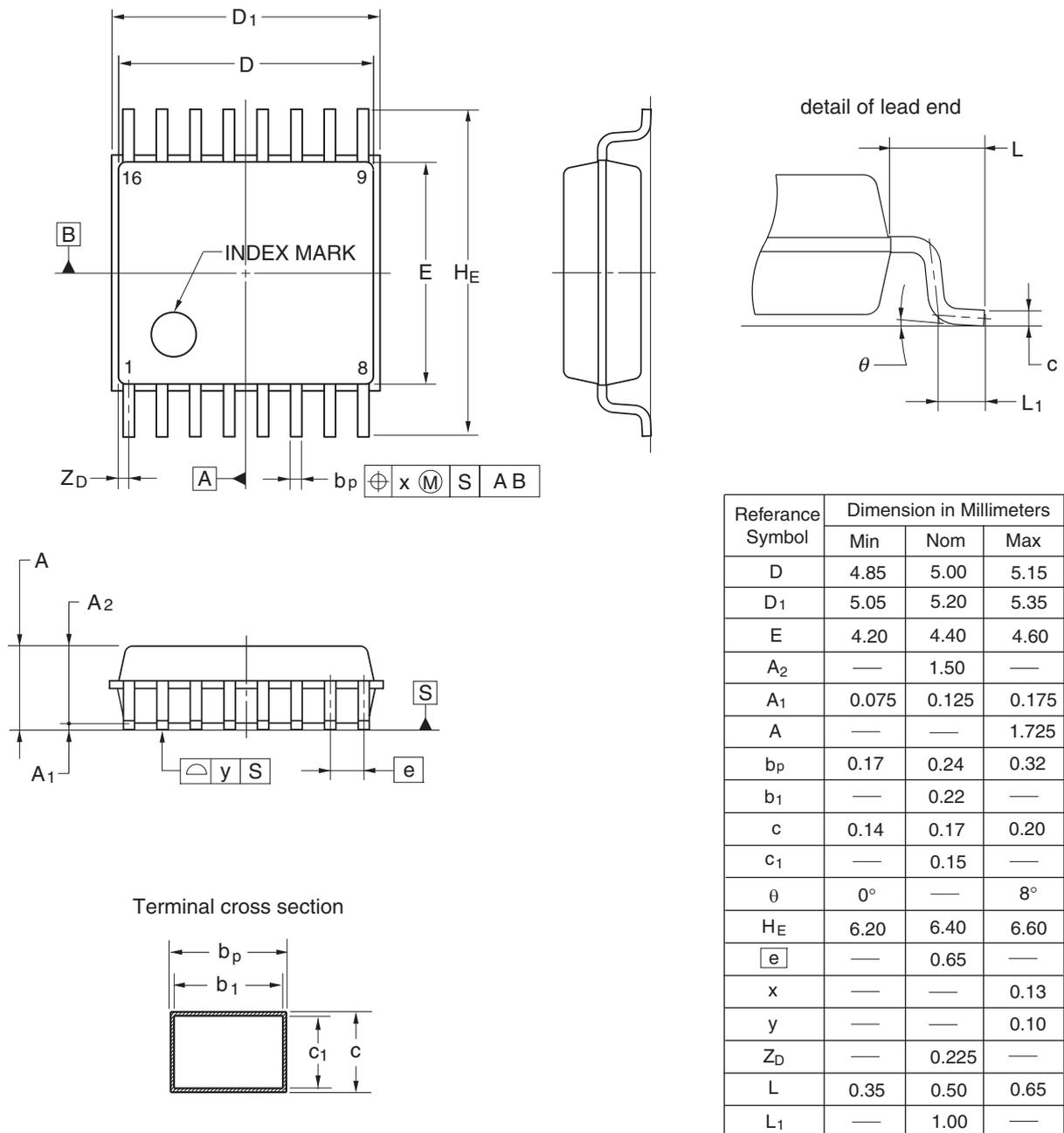
(UNIT:mm)

ITEM	DIMENSIONS
A	3.60±0.10
B	0.50
C	0.65 (T.P.)
D	0.24±0.08
E	0.10±0.05
F	1.45 MAX.
G	1.20±0.10
H	6.40±0.20
I	4.40±0.10
J	1.00±0.20
K	0.17 ^{+0.08} _{-0.07}
L	0.50
M	0.13
N	0.10
P	3° ^{+5°} _{-3°}
T	0.25 (T.P.)
U	0.60±0.15
V	0.25 MAX.
W	0.15 MAX.

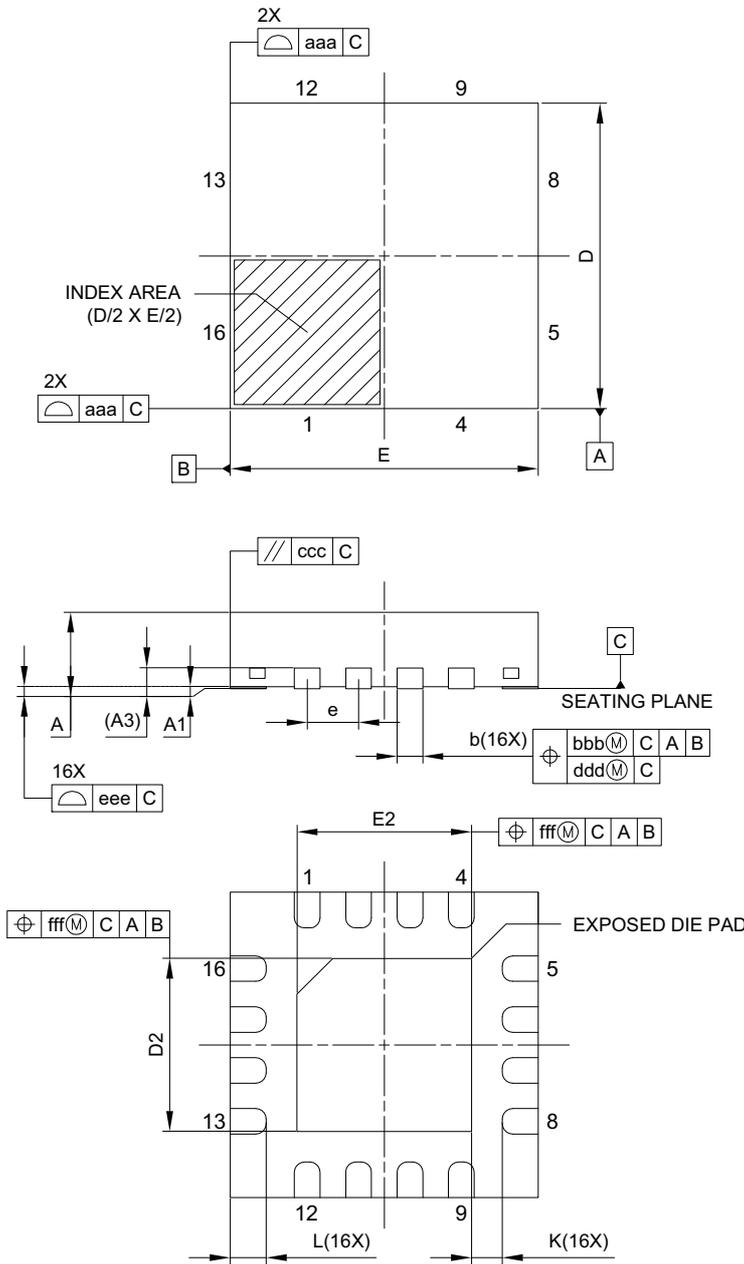
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4.2 16-pin package

JEITA Package code	RENESAS code	Previous code	MASS(TYP.)[g]
P-SSOP16-4.4x5-0.65	PRSP0016JC-B	P16MA-65-FAB	0.08

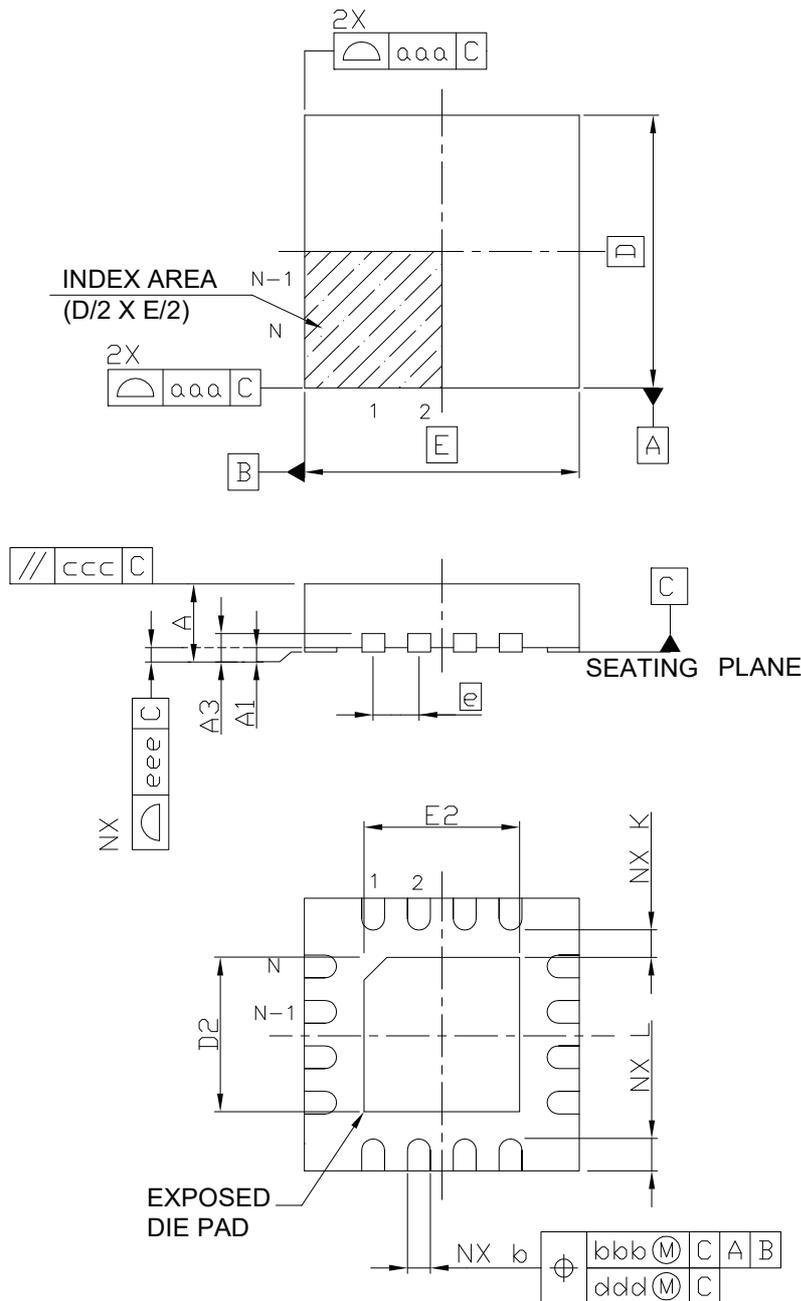


JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-HWQFN016-3x3-0.50	PWQN0016KD-A	0.02



Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	0.80
A1	0.00	0.02	0.05
A3	0.203 REF.		
b	0.20	0.25	0.30
D	3.00 BSC		
E	3.00 BSC		
e	0.50 BSC		
L	0.30	0.35	0.40
K	0.20	—	—
D2	1.65	1.70	1.75
E2	1.65	1.70	1.75
aaa	0.15		
bbb	0.10		
ccc	0.10		
ddd	0.05		
eee	0.08		
fff	0.10		

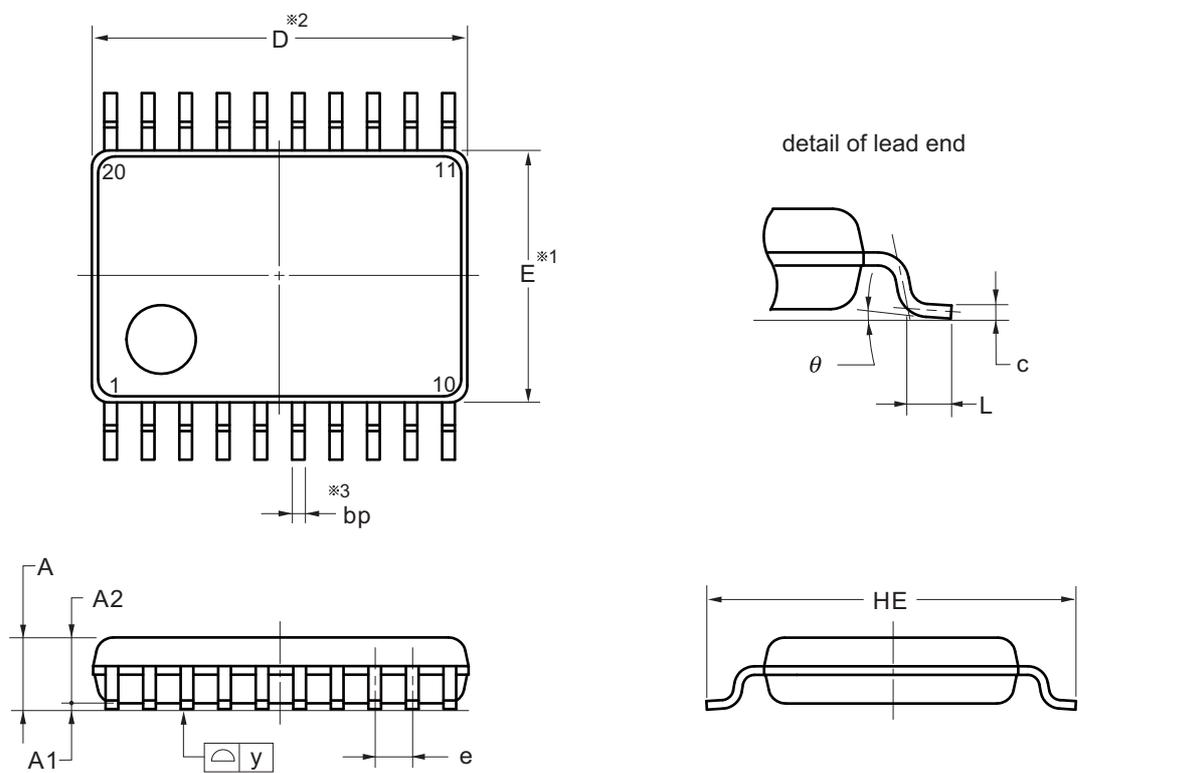
JEITA Package Code	RENESAS Code	MASS(Typ.)[g]
P-HWQFN16-3×3-0.50	PWQN0016KE-A	0.02



Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	0.80
A ₁	0.00	—	0.05
A ₃	0.20 REF.		
b	0.20	0.25	0.30
D	—	3.00	—
E	—	3.00	—
e	—	0.50	—
N	16		
L	0.25	0.35	0.45
K	0.20	—	—
D ₂	1.60	1.70	1.80
E ₂	1.60	1.70	1.80
aaa	—	—	0.15
bbb	—	—	0.10
ccc	—	—	0.10
ddd	—	—	0.05
eee	—	—	0.08

4.3 20-pin package

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



NOTE

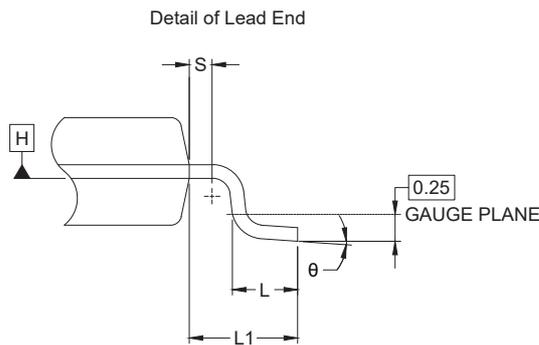
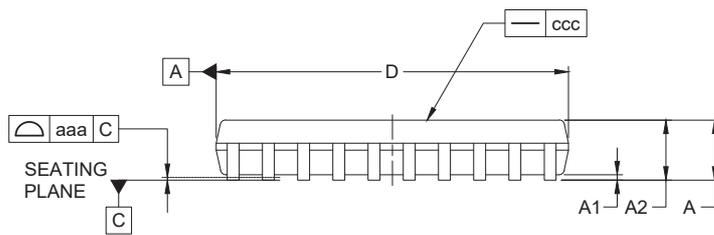
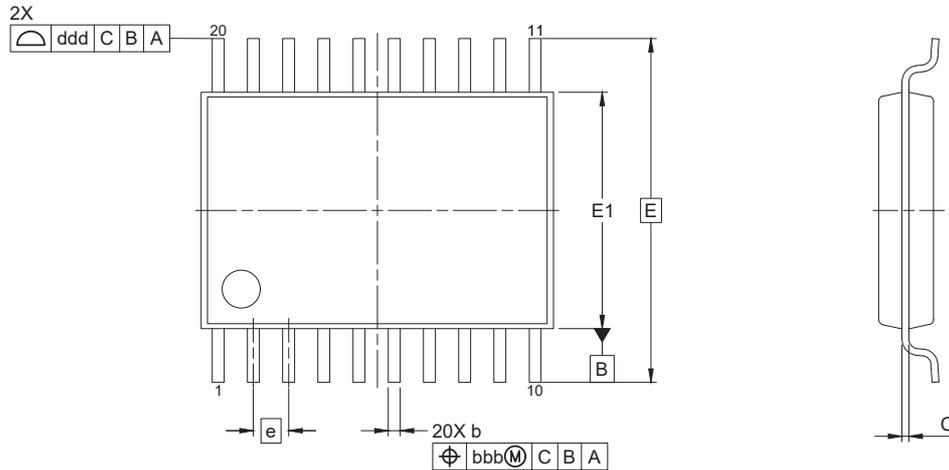
1. Dimensions “ $\times 1$ ” and “ $\times 2$ ” do not include mold flash.
2. Dimension “ $\times 3$ ” does not include trim offset.

(UNIT:mm)

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

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JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-TSSOP20-4.40x6.50-0.65	PTSP0020JI-A	0.08

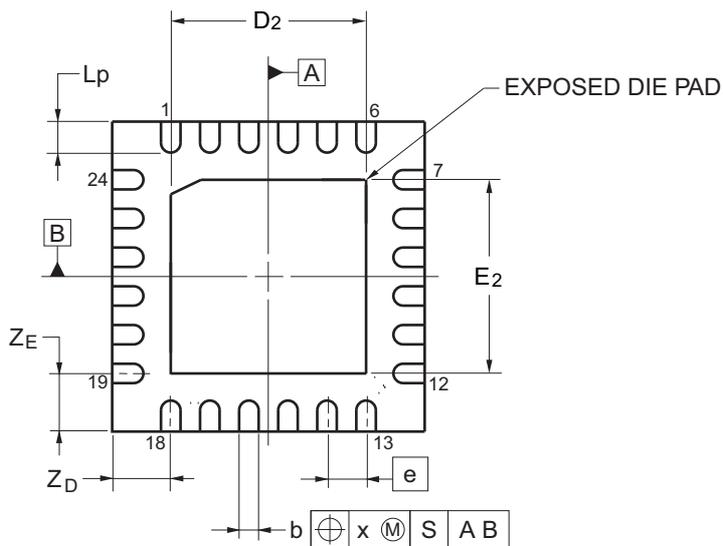
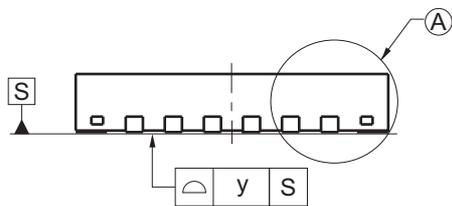
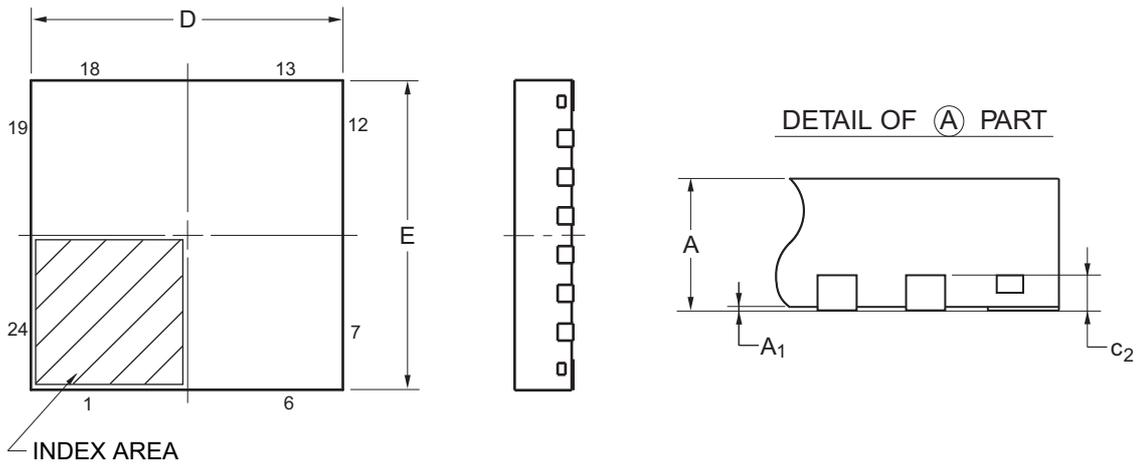


Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	-	-	1.20
A1	0.05	-	0.15
A2	0.80	1.00	1.05
b	0.19	-	0.30
C	0.09	0.127	0.20
D	6.40	6.50	6.60
E1	4.30	4.40	4.50
E	6.40 BSC		
e	0.65 BSC		
L1	1.00 REF		
L	0.50	0.60	0.75
S	0.20	-	-
θ	0°	-	8°
aaa	0.10		
bbb	0.10		
ccc	0.05		
ddd	0.20		

- NOTES:
 1. DIMENSION 'D' AND 'E1' DOES NOT INCLUDE MOLD FLASH.
 2. DIMENSION 'b' DOES NOT INCLUDE TRIM OFFSET.
 3. DIMENSION 'D' AND 'E1' TO BE DETERMINED AT DATUM PLANE [H].

4.4 24-pin package

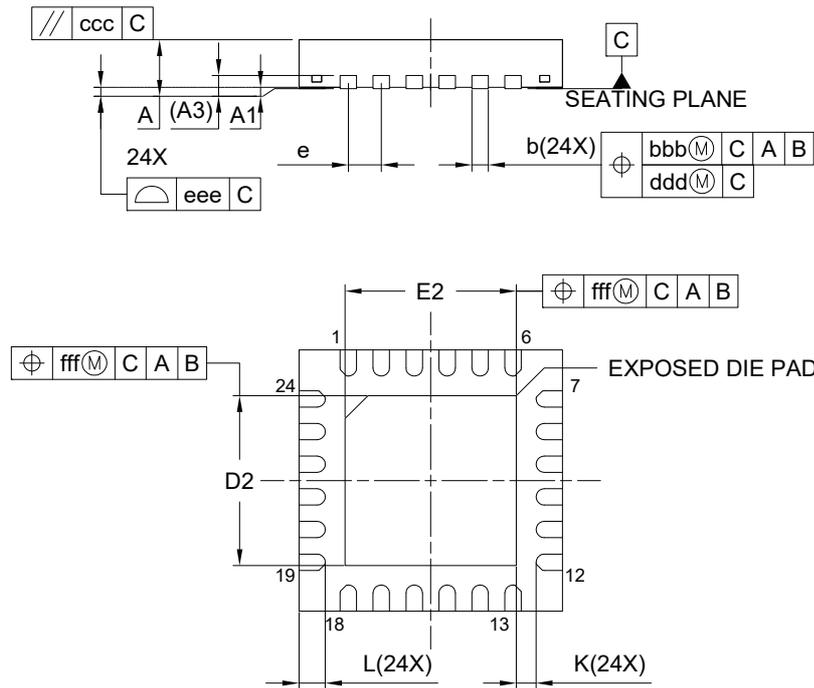
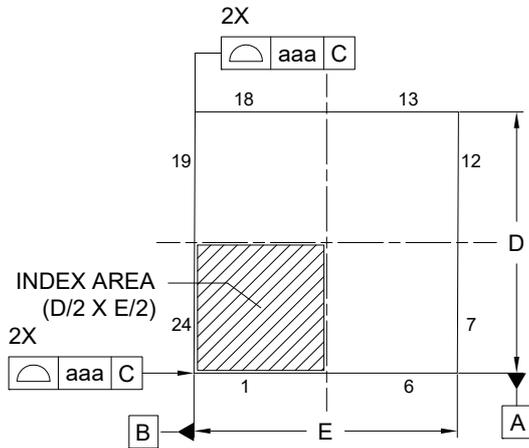
JEITA Package code	RENESAS code	Previous code	MASS(TYP.)[g]
P-HWQFN24-4x4-0.50	PWQN0024KE-A	P24K8-50-CAB-3	0.04



Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	3.95	4.00	4.05
E	3.95	4.00	4.05
A	—	—	0.80
A ₁	0.00	—	—
b	0.18	0.25	0.30
ⓐ	—	0.50	—
L _p	0.30	0.40	0.50
x	—	—	0.05
y	—	—	0.05
Z _D	—	0.75	—
Z _E	—	0.75	—
c ₂	0.15	0.20	0.25
D ₂	—	2.50	—
E ₂	—	2.50	—

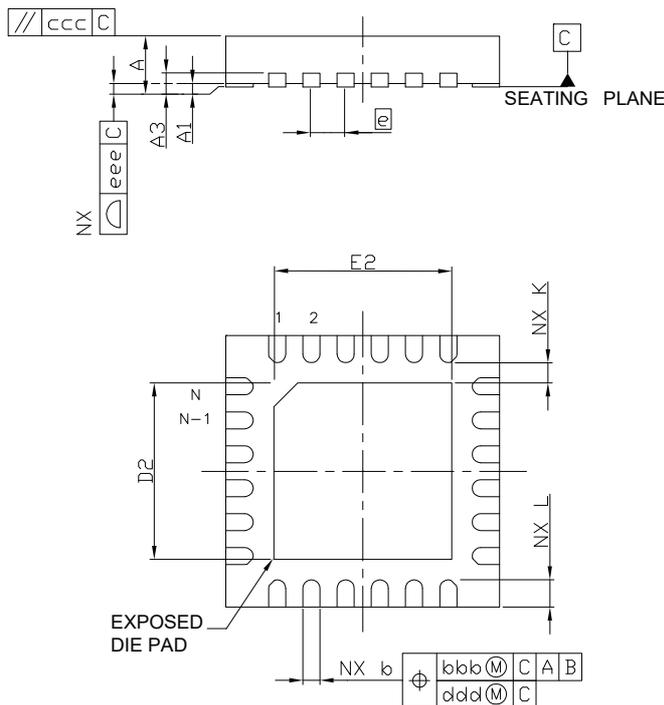
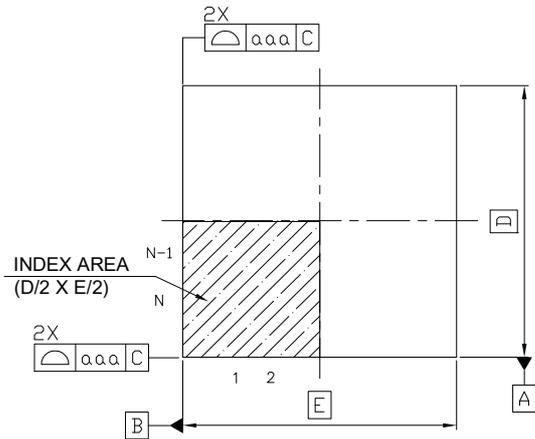
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JEITA Package code	RENESAS code	MASS(TYP.)[g]
P-HWQFN024-4x4-0.50	PWQN0024KF-A	0.04



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

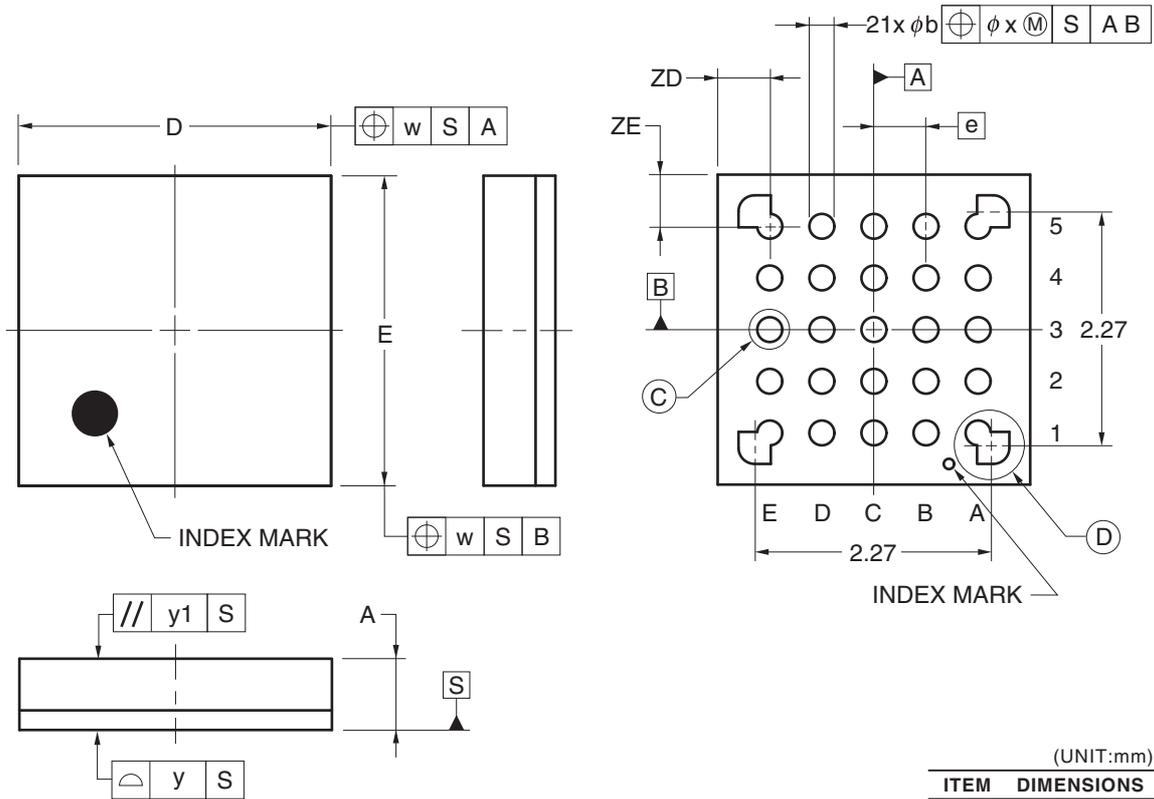
JEITA Package Code	RENESAS Code	MASS(Typ.)[g]
P-HWQFN24-4×4-0.50	PWQN0024KH-A	0.04



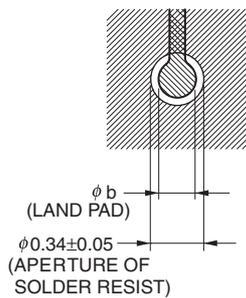
Reference Symbol	Dimension in Millimeters		
	Min.	Nom.	Max.
A	—	—	0.80
A ₁	0.00	—	0.05
A ₃	0.20 REF.		
b	0.20	0.25	0.30
D	—	4.00	—
E	—	4.00	—
e	—	0.50	—
N	24		
L	0.30	0.40	0.50
K	0.20	—	—
D ₂	2.50	2.60	2.70
E ₂	2.50	2.60	2.70
aaa	—	—	0.15
bbb	—	—	0.10
ccc	—	—	0.10
ddd	—	—	0.05
eee	—	—	0.08

4.5 25-pin package

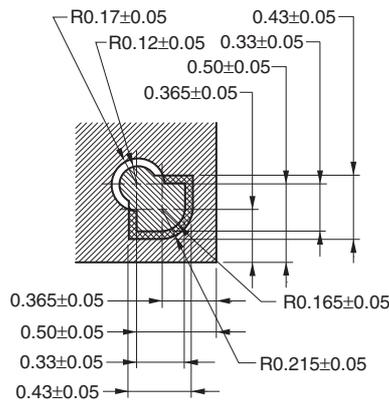
JEITA Package Code	RENESAS Code	Previous Code	MASS (TYP.) [g]
P-WFLGA25-3x3-0.50	PWLG0025KA-A	P25FC-50-2N2-2	0.01



DETAIL OF \textcircled{C} PART



DETAIL OF \textcircled{D} PART



(UNIT:mm)

ITEM	DIMENSIONS
D	3.00±0.10
E	3.00±0.10
w	0.20
e	0.50
A	0.69±0.07
b	0.24±0.05
x	0.05
y	0.08
y1	0.20
ZD	0.50
ZE	0.50

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REVISION HISTORY

RL78/G11 Datasheet

Rev.	Date	Description	
		Page	Summary
0.50	Mar 31 2016	—	First Edition issued
1.00	Sep 28 2016	p.7	Modification of Pin Configuration in 1.3.3 25-pin products
		p.9	Addition of 1.5.1 20-pin products
		p.10	Addition of product name and Modification of Block Diagram in 1.5.2 24-pin, 25-pin products
		p.12	Addition of I ² C bus in 1.6 Outline of Functions
		p.15	Modification of Conditions of IOH ₁ , IOL ₁ in 2.1 Absolute Maximum Ratings
		p.16	Modification of High-speed on-chip oscillator clock frequency accuracy and addition of DIMT, DIMV in 2.2.2 On-chip oscillator characteristics
		p.17	Modification of Caution in 2.3.1 Pin characteristics
		p.19	Modification of Input voltage, high and Input voltage, low in 2.3.1 Pin characteristics
		p.19, 20	Modification of Caution in 2.3.1 Pin characteristics
		p.22, 23, 24, 26, 27	Modification of specifications in 2.3.2 Supply current characteristics
		p.29, 30	Modification of specification in 2.4 AC Characteristics
		p.35	Modification of specifications in 2.5.1 Serial array unit (1)
		p.39	Modification of specifications in 2.5.1 Serial array unit (3)
		p.40, 42	Modification of specification in 2.5.1 Serial array unit (4)
		p.62	Addition of LP (Low-power main) mode in 2.5.2 Serial interface IICA (1)
		p.64	Addition of LP (Low-power main) mode in 2.5.2 Serial interface IICA (2)
		p.65	Addition of LP (Low-power main) mode in 2.5.2 Serial interface IICA (3)
		p.70	Modification of Conditions in 2.6.2 Temperature sensor characteristics/internal reference voltage characteristic
		p.79	Addition of description in 3 ELECTRICAL SPECIFICATIONS (TA = -40 to +105°C)
		p.82	Modification of High-speed on-chip oscillator clock frequency accuracy and addition of DIMT, DIMV in 3.2.2 On-chip oscillator characteristics
		p.83	Modification of Caution in 3.3.1 Pin characteristics
		p.85	Modification of Input voltage, high and Input voltage, low in 3.3.1 Pin characteristics
		p.85, 86	Modification of Caution in 3.3.1 Pin characteristics
		p.88 to 91	Modification of specifications in 3.3.2 Supply current characteristics
		p.97	Modification of specifications and specification table in 3.5.1 Serial array unit (1)
		p.103	Modification of specifications in 3.5.1 Serial array unit (3)
p.125	Modification of Conditions in 3.6.1 A/D converter characteristics (4)		
p.126	Modification of Conditions in 3.6.2 Temperature sensor characteristics/internal reference voltage characteristic		
1.10	Dec 28 2016	p.4	Modification of 1.2 Ordering Information
2.00	Feb 15, 2018	Throughout	Addition of specifications of 10-pin and 16-pin products
		p.2	Modification of description in 1.1 Features
		p.6	Modification of figure in 1.3.4 24-pin products
		p.11	Modification of figure in 1.5.3 20-pin products
		p.12	Modification of figure in 1.5.4 24-pin, 25-pin products

Rev.	Date	Description	
		Page	Summary
2.00	Feb 15, 2018	p.13, 14	Modification of table in 1.6 Outline of Functions
		p.18	Modification of 2.2.2 On-chip oscillator characteristics
		p.19, 21	Modification of 2.3.1 Pin characteristics
		p.24	Modification of 2.3.2 Supply current characteristics
		p.32	Modification of 2.4 AC Characteristics
		p.79	Modification of figure in 2.10 Timing of Entry to Flash Memory Programming Modes
		p.84	Modification of 3.2.1 X1 characteristics
		p.84	Modification of 3.2.2 On-chip oscillator characteristics
		p.85, 86, 87	Modification of 3.3.1 Pin characteristics
		p.95	Modification of 3.4 AC Characteristics
		p.99	Modification of note in 3.5.1 Serial array unit (1)
		p.134	Modification of figure in 3.10 Timing of Entry to Flash Memory Programming Modes
2.20	Apr 26, 2019	p.3	Addition of note in Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11
		p.5	Modification of figure in 1.3.1 10-pin products
		p.5	Modification of figure in 1.3.2 16-pin products
		p.5	Modification of figure in 1.3.3 20-pin products
		p.6	Modification of figure in 1.3.4 24-pin products
		p.13, 14	Modification of table in 1.6 Outline of Functions
		p.16	Modification of specification in 2.1 Absolute Maximum Ratings
		p.19, 22	Modification of specification in 2.3.1 Pin characteristics
		p.25, 27	Modification of note 1 in 2.3.2 Supply current characteristics
		p.29, 30	Modification of specification and addition of note 14 in 2.3.2 Supply current characteristics, Peripheral Functions (Common to all products)
		p.32	Modification of specification in 2.4 AC Characteristics
		p.36	Modification of note 2 in 2.5.1 Serial array unit, (1) During communication at same potential (UART mode)
		p.41	Modification of specification in 2.5.1 Serial array unit, (3) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output), When P20 is used as SO10 pin
		p.43	Modification of specification in 2.5.1 Serial array unit, (4) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input), When P01, P32, P53, P54 and P56 are used as SOMn pins
		p.44	Modification of specification in 2.5.1 Serial array unit, (4) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input), When P20 is used as SO10 pin
p.47	Modification of specification in 2.5.1 Serial array unit, (5) During communication at same potential (simplified I ² C mode)		
p.53, 54	Modification of specification in 2.5.1 Serial array unit, (7) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)		
p.60	Modification of note 3 in 2.5.1 Serial array unit, (9) Communication at different potential (1.8 V, 2.5 V, 3.0 V) (CSI mode) (slave mode, SCKp... external clock input)		

Rev.	Date	Description	
		Page	Summary
2.20	Apr 26, 2019	p.69	Modification of note 3 in 2.6.1 A/D converter characteristics, (2) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI16 to ANI22
		p.70	Modification of specification in 2.6.1 A/D converter characteristics, (3) When reference voltage (+) = VDD (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = Vss (ADREFM = 0), target pin: ANI0 to ANI3, ANI16 to ANI22, internal reference voltage, and temperature sensor output voltage
		p.71	Modification of specification in 2.6.1 A/D converter characteristics, (4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0, ANI2 and ANI3, ANI16 to ANI22
		p.72	Modification of title in 2.6.3 D/A converter (channel 1)
		p.73	Modification of specification in 2.6.4 Comparator
		p.82	Modification of specification in 3.1 Absolute Maximum Ratings
		p.84	Modification of specification in 3.2.1 X1 characteristics
		p.85, 87, 88	Modification of specification in 3.3.1 Pin characteristics
		p.93	Modification of specification in 3.3.2 Supply current characteristics, Peripheral Functions (Common to all products)
		p.99	Modification of specification in 3.5.1 Serial array unit, (1) during communication at same potential (UART mode), When P20 is used as TxD1 pin
		p.101	Modification of specification in 3.5.1 Serial array unit, (2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output), When P01, P32, P53, P54 and P56 are used as Somn pins
		p.102	Modification of specification in 3.5.1 Serial array unit, (2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output), When P20 is used as SO10 pin
		p.103	Modification of note 1 in 3.5.1 Serial array unit, (3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input), When P01, P32, P53, P54 and P56 are used as SOMn pins
		p.105	Modification of specification and note 1 in 3.5.1 Serial array unit, (3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input), When P20 is used as SO10 pin
		p.124	Modification of specification in 3.6.1 A/D converter characteristics, (1) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI2 and ANI3, internal reference voltage, and temperature sensor output voltage
		p.125	Modification of note 3 in 3.6.1 A/D converter characteristics, (2) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI16 to ANI22
		p.127	Modification of specification in 3.6.1 A/D converter characteristics, (4) When reference voltage (+) = Internal reference voltage (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target pin: ANI0 to ANI3, ANI16 to ANI22
		p.128	Modification of title in 3.6.3 D/A converter (channel 1)
		p.129	Modification of specification in 3.6.4 Comparator
p.131	Modification of specification in 3.6.6 POR circuit characteristics		
p.132	Modification of specification in 3.6.7 LVD circuit characteristics, (1) LVD Detection Voltage of Reset Mode and Interrupt Mode		

Rev.	Date	Description	
		Page	Summary
2.30	June 30, 2020	p.3	Modification of Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11
		p.4	Modification of table in 1.2 Ordering Information
		p.5	Modification of description in 1.3.3 20-pin products
		p.26	Modification of specification in 2.3.2 Supply current characteristics
		p.138	Addition of package drawing in 4.3 20-pin package
		p.140	Addition of package drawing in 4.4 24-pin package
2.40	Oct 30, 2020	p.3	Modification of Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11
		p.4	Modification of table in 1.2 Ordering Information
		p.6	Addition of description and figure in 1.3.2 16-pin products
		p.138	Addition of package drawing in 4.2 16-pin package
2.50	Mar 20, 2023	All	The module name for CSI was changed to Simplified SPI (CSI)
		All	"wait" for IIC was modified to "clock stretch"
		p.2	Addition of Note 1 in 1 Features
		p.4	Addition of Table Title and modification of Table 1-1 List of Ordering Part Numbers
		p.26	Modification of Note 1 in Table (TA = -40 to +85°C, 1.6 V ≤ EEVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (2/4) of 2.3.2 Supply current characteristics
		p.28	Modification of Note 1 in Table (TA = -40 to +85°C, 1.6 V ≤ EEVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (3/4) of 2.3.2 Supply current characteristics
		p.29	Modification of Note 1 in Table (TA = -40 to +85°C, 1.6 V ≤ EEVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (4/4) of 2.3.2 Supply current characteristics
		p.91	Modification of Note 1 in Table (TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (1/3) of 2.3.2 Supply current characteristics
		p.92	Modification of Note 1 in Table (TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (2/3) of 2.3.2 Supply current characteristics
		p.93	Modification of Note 1 in Table (TA = -40 to +105°C, 2.4 V ≤ EVDD ≤ VDD ≤ 5.5 V, VSS = 0 V) (3/3) of 2.3.2 Supply current characteristics
		p.139	Addition of package drawing in 4.2 16-pin Package
		p.144	Addition of package drawing in 4.4 24-pin Package
2.60	Mar 29, 2024	p.3	Modification of Figure 1 - 1 Part Number, Memory Size, and Package of RL78/G11
		p.4	Modification of Table 1 - 1 List of Ordering Part Numbers

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

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

1. Precaution against Electrostatic Discharge (ESD)

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

2. Processing at power-on

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

3. Input of signal during power-off state

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

4. Handling of unused pins

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

5. Clock signals

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

6. Voltage application waveform at input pin

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

7. Prohibition of access to reserved addresses

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

8. Differences between products

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

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