

RL78/L1C

R01DS0192EJ0210

RENESAS MCU

Rev. 2.10

Aug 12, 2016

Integrated LCD controller/driver, 12-bit resolution A/D Converter, USB 2.0 controller (function), True Low Power Platform (as low as 112.5 μ A/MHz, and 0.68 μ A for RTC2 + LVD), 1.6 V to 3.6 V operation, 64 to 256 Kbyte Flash, 33 DMIPS at 24 MHz, for All LCD Based Applications

1. OUTLINE

1.1 Features

Ultra-Low Power Technology

- V_{DD} = single power supply voltage of 1.6 to 3.6 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 μ s: @ 24 MHz operation with high-speed on-chip oscillator clock or PLL clock) to ultra-low speed (30.5 μ s: @ 32.768 kHz operation with subsystem clock)
- Multiply/divide and multiply/accumulate instructions are supported.
- Address space: 1 Mbyte
- General-purpose registers: (8-bit register $\times$ 8) $\times$ 4 banks
- On-chip RAM: 8 to 16 KB

Code Flash Memory

- Code flash memory: 64 to 256 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

Data Flash Memory

- Data flash memory: 8 KB
- Background operation (BGO): Instructions can be executed from the program memory while rewriting the data flash memory.
- Number of rewrites: 1,000,000 times (TYP.)
- Voltage of rewrites: V_{DD} = 1.8 to 3.6 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 to 3.6 V, T_A = -20 to +85 $^{\circ}$ C)

Operating ambient temperature

- T_A = -40 to +85 $^{\circ}$ C (A: Consumer applications)
- T_A = -40 to +105 $^{\circ}$ 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 12 levels)

Data transfer controller (DTC)

- Transfer modes: Normal transfer mode, repeat transfer mode, block transfer mode
- Activation sources: Activated by interrupt sources (30 to 33 sources).
- Chain transfer function

Event link controller (ELC)

- Event signals of 30 or 31 types can be linked to the specified peripheral function.

Serial interfaces

- CSI:4 channels
- UART/UART (LIN-bus supported):4 channels
- I²C/simplified I²C:5 channels

Timers

- 16-bit timer:11 channels
- 12-bit interval timer:1 channel
- Real-time clock 2:1 channel (calendar for 99 years, alarm function, and clock correction function)
- Watchdog timer:1 channel (operable with the dedicated low-speed on-chip oscillator)

LCD controller/driver

- Internal voltage boosting method, capacitor split method, and external resistance division method are switchable.
- Segment signal output: 44 (40) ^{Note 1} to 56 (52) ^{Note 1}
- Common signal output: 4 (8) ^{Note 1}

USB ^{Note 2}

- USB version 2.0 (function controller)
- Full-speed transfer (12 Mbps) and low-speed transfer (1.5 Mbps) are supported
- Compliant to Battery Charging Specification Revision 1.2

A/D converter

- 8/10-bit resolution A/D converter (V_{DD} = 1.6 to 3.6 V)
- 12-bit resolution A/D converter (V_{DD} = 2.4 to 3.6 V)
- Analog input: 9 to 13 channels
- Internal reference voltage (TYP. 1.45 V) and temperature sensor ^{Note 2}

D/A converter

- 8-bit resolution D/A converter (V_{DD} = 1.6 to 3.6 V)
- Analog output: 2 channels
- Output voltage: 0 V to V_{DD}
- Real-time output function

Comparator

- 2 channels
- Operating modes: Comparator high-speed mode, comparator low-speed mode, window mode
- The external reference voltage or internal reference voltage can be selected as the reference voltage.

I/O ports

- I/O ports: 59 to 77 (N-ch open drain I/O [withstand voltage of 6 V]: 2)
- Can be set to N-ch open drain, TTL input buffer, and on-chip pull-up resistor
- On-chip key interrupt function
- On-chip clock output/buzzer output controller

Others

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

Note 1. The number in parentheses indicates the number of signal outputs when 8 coms are used.

Note 2. Selectable only in HS (high-speed main) mode.

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

○ ROM, RAM capacities

Products with USB

Flash ROM	Data Flash	RAM	RL78/L1C		
			80 pins	85 pins	100 pins
256 KB	8 KB	16 KB Note	R5F110MJ	R5F110NJ	R5F110PJ
192 KB	8 KB	16 KB Note	R5F110MH	R5F110NH	R5F110PH
128 KB	8 KB	12 KB	R5F110MG	R5F110NG	R5F110PG
96 KB	8 KB	10 KB	R5F110MF	R5F110NF	R5F110PF
64 KB	8 KB	8 KB	R5F110ME	R5F110NE	R5F110PE

Products without USB

Flash ROM	Data Flash	RAM	RL78/L1C		
			80 pins	85 pins	100 pins
256 KB	8 KB	16 KB Note	R5F111MJ	R5F111NJ	R5F111PJ
192 KB	8 KB	16 KB Note	R5F111MH	R5F111NH	R5F111PH
128 KB	8 KB	12 KB	R5F111MG	R5F111NG	R5F111PG
96 KB	8 KB	10 KB	R5F111MF	R5F111NF	R5F111PF
64 KB	8 KB	8 KB	R5F111ME	R5F111NE	R5F111PE

Note This is about 15 KB when the self-programming function and data flash function are used.

1.2 Ordering Information

Products with USB

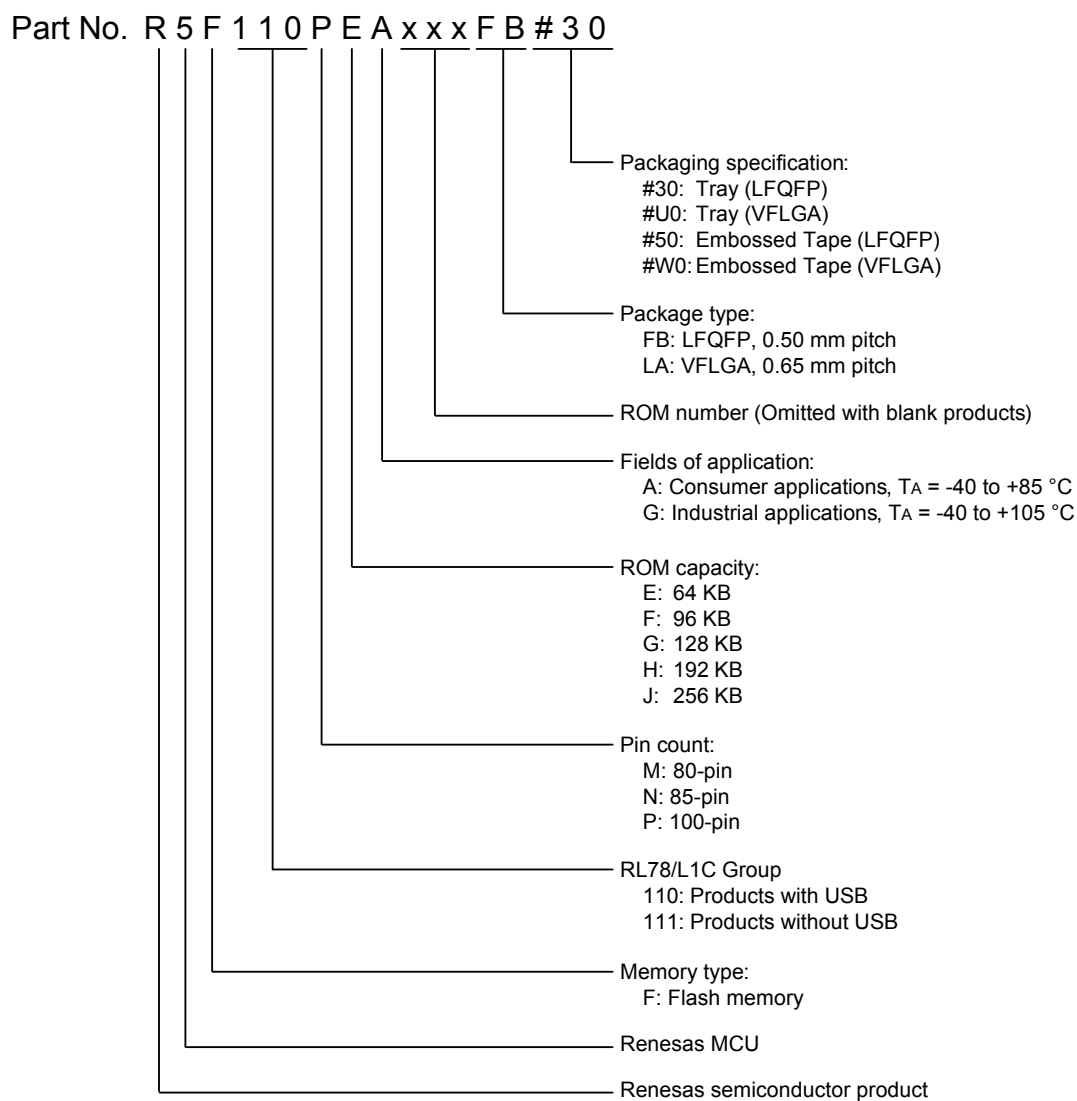
Pin Count	Package	Fields of Application	Orderable Part Number
80 pins	80-pin plastic LFQFP (12 × 12 mm, 0.5 mm pitch)	A	R5F110MEAFB#30, R5F110MFAFB#30, R5F110MGAFB#30, R5F110MHAFB#30, R5F110MJAFB#30 R5F110MEAFB#50, R5F110MFAFB#50, R5F110MGAFB#50, R5F110MHAFB#50, R5F110MJAFB#50
		G	R5F110MEGFB#30, R5F110MFGFB#30, R5F110MGGFB#30, R5F110MHGFB#30, R5F110MJGFB#30 R5F110MEGFB#50, R5F110MFGFB#50, R5F110MGGFB#50, R5F110MHGFB#50, R5F110MJGFB#50
85 pins	85-pin plastic VFLGA (7 × 7 mm, 0.65 mm pitch)	A	R5F110NEALA#U0, R5F110NFALA#U0, R5F110NGALA#U0, R5F110NHALA#U0, R5F110NJALA#U0 R5F110NEALA#W0, R5F110NFALA#W0, R5F110NGALA#W0, R5F110NHALA#W0, R5F110NJALA#W0
		G	R5F110NEGLA#U0, R5F110NFGLA#U0, R5F110NGGLA#U0, R5F110NHGLA#U0, R5F110NJGLA#U0 R5F110NEGLA#W0, R5F110NFGLA#W0, R5F110NGGLA#W0, R5F110NHGLA#W0, R5F110NJGLA#W0
100 pins	100-pin plastic LFQFP (14 × 14 mm, 0.5 mm pitch)	A	R5F110PEAFB#30, R5F110PFAFB#30, R5F110PGAFB#30, R5F110PHAFB#30, R5F110PJAFB#30 R5F110PEAFB#50, R5F110PFAFB#50, R5F110PGAFB#50, R5F110PHAFB#50, R5F110PJAFB#50
		G	R5F110PEGFB#30, R5F110PFGFB#30, R5F110PGGFB#30, R5F110PHGFB#30, R5F110PJGFB#30 R5F110PEGFB#50, R5F110PFGFB#50, R5F110PGGFB#50, R5F110PHGFB#50, R5F110PJGFB#50

Products without USB

Pin Count	Package	Fields of Application	Orderable Part Number
80 pins	80-pin plastic LFQFP (12 × 12 mm, 0.5 mm pitch)	A	R5F111MEAFB#30, R5F111MFAFB#30, R5F111MGAFB#30, R5F111MHAFB#30, R5F111MJAFB#30 R5F111MEAFB#50, R5F111MFAFB#50, R5F111MGAFB#50, R5F111MHAFB#50, R5F111MJAFB#50
		G	R5F111MEGFB#30, R5F111MFGFB#30, R5F111MGGFB#30, R5F111MHGFB#30, R5F111MJGFB#30 R5F111MEGFB#50, R5F111MFGFB#50, R5F111MGGFB#50, R5F111MHGFB#50, R5F111MJGFB#50
85 pins	85-pin plastic VFLGA (7 × 7 mm, 0.65 mm pitch)	A	R5F111NEALA#U0, R5F111NFALA#U0, R5F111NGALA#U0, R5F111NHALA#U0, R5F111NJALA#U0 R5F111NEALA#W0, R5F111NFALA#W0, R5F111NGALA#W0, R5F111NHALA#W0, R5F111NJALA#W0
		G	R5F111NEGLA#U0, R5F111NFGLA#U0, R5F111NGGLA#U0, R5F111NHGLA#U0, R5F111NJGLA#U0 R5F111NEGLA#W0, R5F111NFGLA#W0, R5F111NGGLA#W0, R5F111NHGLA#W0, R5F111NJGLA#W0
100 pins	100-pin plastic LFQFP (14 × 14 mm, 0.5 mm pitch)	A	R5F111PEAFB#30, R5F111PFAFB#30, R5F111PGAFB#30, R5F111PHAFB#30, R5F111PJAFB#30 R5F111PEAFB#50, R5F111PFAFB#50, R5F111PGAFB#50, R5F111PHAFB#50, R5F111PJAFB#50
		G	R5F111PEGFB#30, R5F111PFGFB#30, R5F111PGGFB#30, R5F111PHGFB#30, R5F111PJGFB#30 R5F111PEGFB#50, R5F111PFGFB#50, R5F111PGGFB#50, R5F111PHGFB#50, R5F111PJGFB#50

Figure 1 - 1 Part Number, Memory Size, and Package of RL78/L1C

Figure 1 - 2

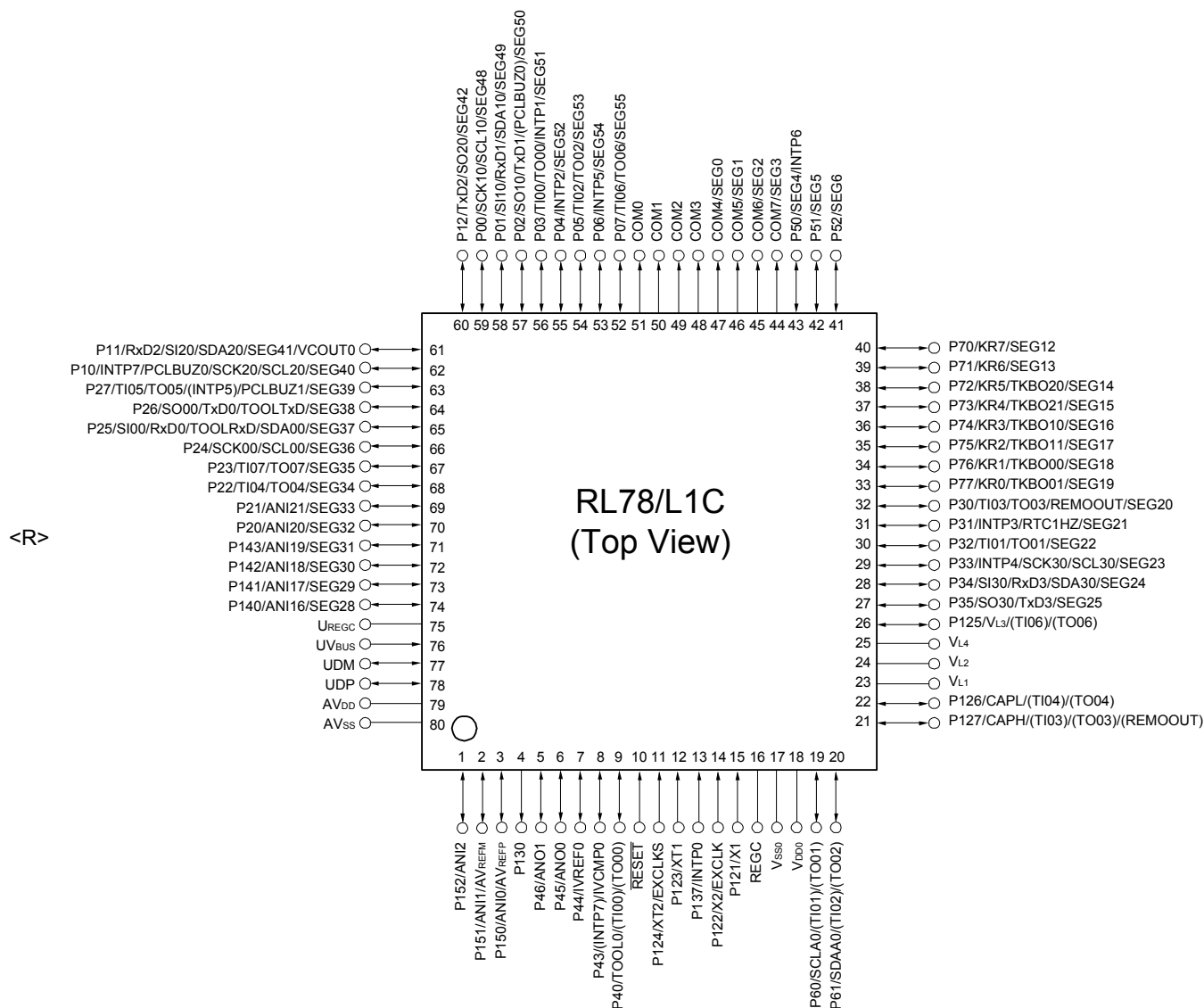


Caution Orderable part numbers are current as of when this manual was published.
Please make sure to refer to the relevant product page on the Renesas website for the latest part numbers.

1.3 Pin Configuration (Top View)

1.3.1 80-pin products (with USB)

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



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

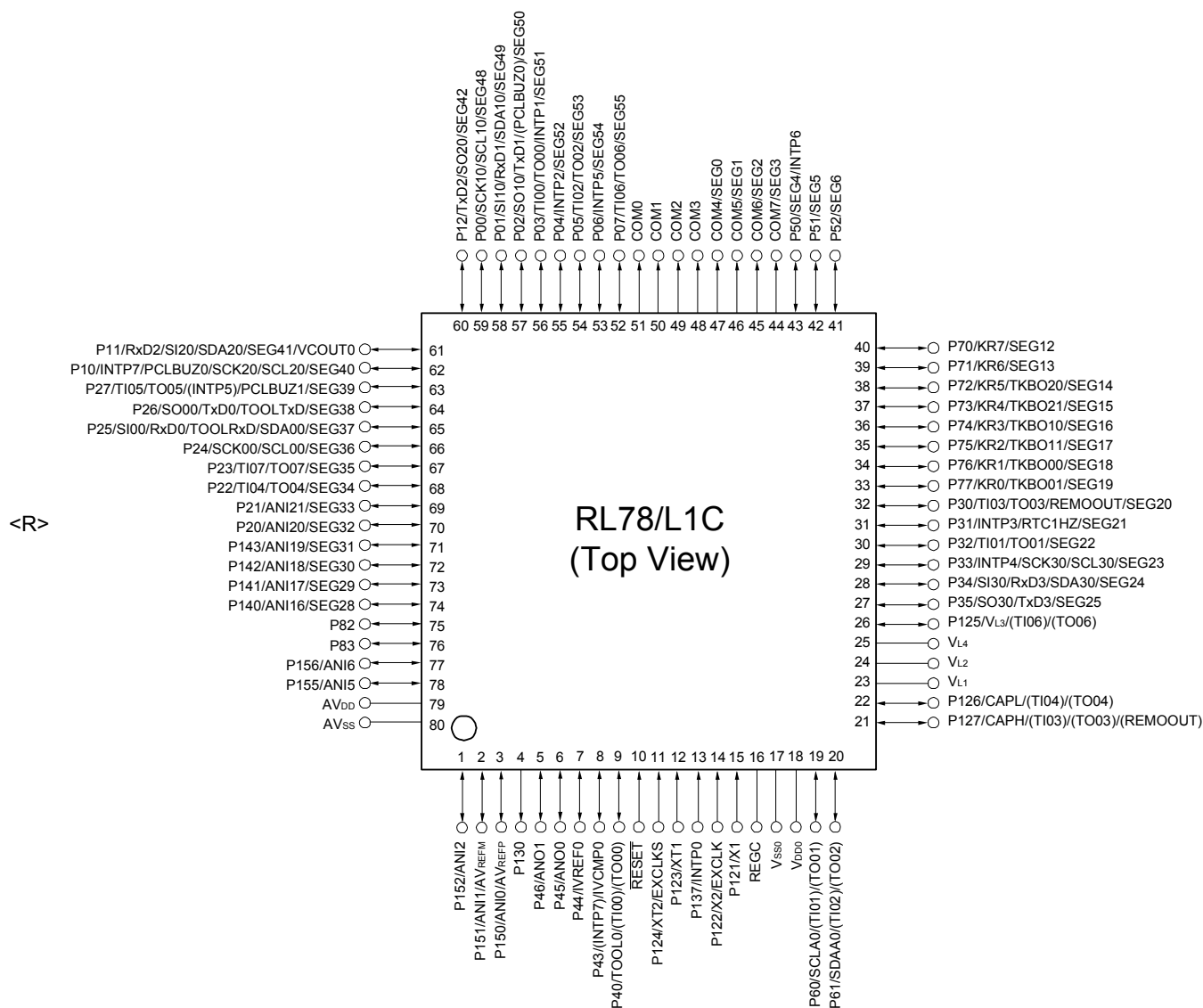
Caution 2. Connect the UREGC pin to Vss pin via a capacitor (0.33 μ F).

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 (PIOR).

1.3.2 80-pin products (without USB)

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

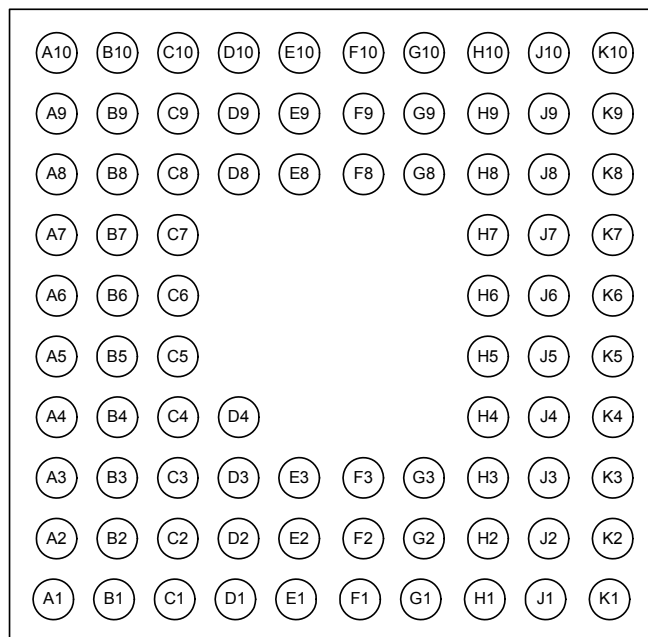


Caution Connect the REGC pin to Vss pin via a capacitor (0.47 to 1 μF).

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

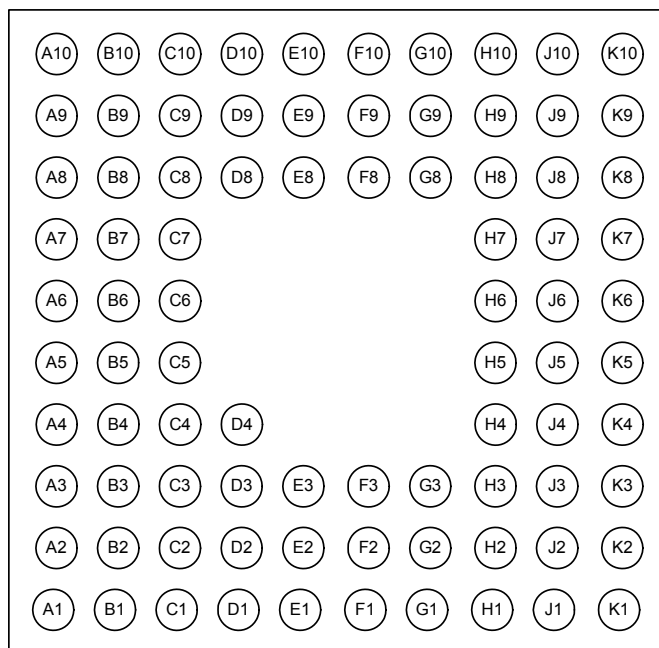
Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).

1.3.3 85-pin products (with USB)



Pin	Name	Pin	Name	Pin	Name	Pin	Name	Pin	Name
A1	COM7/SEG3	C1	COM2	E1	P04/INTP2/SEG52	G1	P00/SCK10/SCL10/SEG48	J1	V _{SS0}
A2	P51/SEG5	C2	COM5/SEG1	E2	P05/TI02/TO02/SEG53	G2	V _{SS0}	J2	P11/RxD2/SI20/SDA20/SEG41/VCOUT0
A3	P70/KR7/SEG12	C3	COM6/SEG2	E3	P06/INTP5/SEG54	G3	P12/TxD2/SO20/SEG42/VCOUT1	J3	P26/SO00/TxD0/TOOLTxD/SEG38
A4	P73/KR4/TKBO21/SEG15	C4	P71/KR6/SEG13	E4	—	G4	—	J4	P23/TI07/TO07/SEG35
A5	P74/KR3/TKBO10/SEG16	C5	P76/KR1/TKBO00/SEG18	E5	—	G5	—	J5	P20/ANI20/SEG32
A6	P31/INTP3/RTC1HZ/SEG21	C6	P77/KR0/TKBO01/SEG19	E6	—	G6	—	J6	P141/ANI17/SEG29
A7	P33/INTP4/SCK30/SCL30/SEG23	C7	P34/SI30/RxD3/SDA30/SEG24	E7	—	G7	—	J7	U _{REGC}
A8	P35/SO30/TxD3/SEG25	C8	V _{L1}	E8	P40/TOOL0/(TI00)/(TO00)	G8	P44/(SCK10)/(SCL10)/IVREF0	J8	UV _{BUS}
A9	V _{L4}	C9	P61/SDAA0/(TI02)/(TO02)	E9	P137/INTP0	G9	P45/ANO0	J9	AV _{DD}
A10	P126/CAPL/(TI04)/(TO04)	C10	V _{DD0}	E10	P122/X2/EXCLK	G10	P123/XT1	J10	P150/ANI0/AV _{REFP}
B1	COM4/SEG0	D1	COM0	F1	P03/TI00/TO00/INTP1/SEG51	H1	V _{SS0}	K1	V _{SS0}
B2	P50/SEG4/INTP6	D2	COM1	F2	P02/SO10/TxD1/(PCLBUZ0)/SEG50	H2	V _{SS0}	K2	P27/TI05/TO05/(INTP5)/PCLBUZ1/SEG39
B3	P52/SEG6	D3	P07/TI06/TO06/SEG55	F3	P01/SI10/RxD1/SDA10/SEG49	H3	P10/INTP7/PCLBUZ0/SCK20/SCL20/SEG40	K3	P25/SI00/RxD0/TOOLRxD/SDA00/SEG37
B4	P72/KR5/TKBO20/SEG14	D4	COM3	F4	—	H4	P24/SCK00/SCL00/SEG36	K4	P22/TI04/TO04/SEG34
B5	P75/KR2/TKBO11/SEG17	D5	—	F5	—	H5	P21/ANI21/SEG33	K5	P143/ANI19/SEG31
B6	P30/TI03/TO03/REMOOUT/SEG20	D6	—	F6	—	H6	P140/ANI16/SEG28	K6	P142/ANI18/SEG30
B7	P32/TI01/TO01/SEG22	D7	—	F7	—	H7	P152/ANI2	K7	UDM
B8	P125/V _{L3} /(TI06)/(TO06)	D8	P60/SCLA0/(TI01)/(TO01)	F8	P43/(INTP7)/(SI10)/(RxD1)/(SDA10)/IVCMP0	H8	P46/ANO1	K8	UDP
B9	V _{L2}	D9	REGC	F9	RESET	H9	P130	K9	AV _{SS}
B10	P127/CAPH/(TI03)/(TO03)/(REMOOUT)	D10	P121/X1	F10	V _{SS0}	H10	P124/XT2/EXCLKS	K10	P151/ANI1/AV _{REFM}

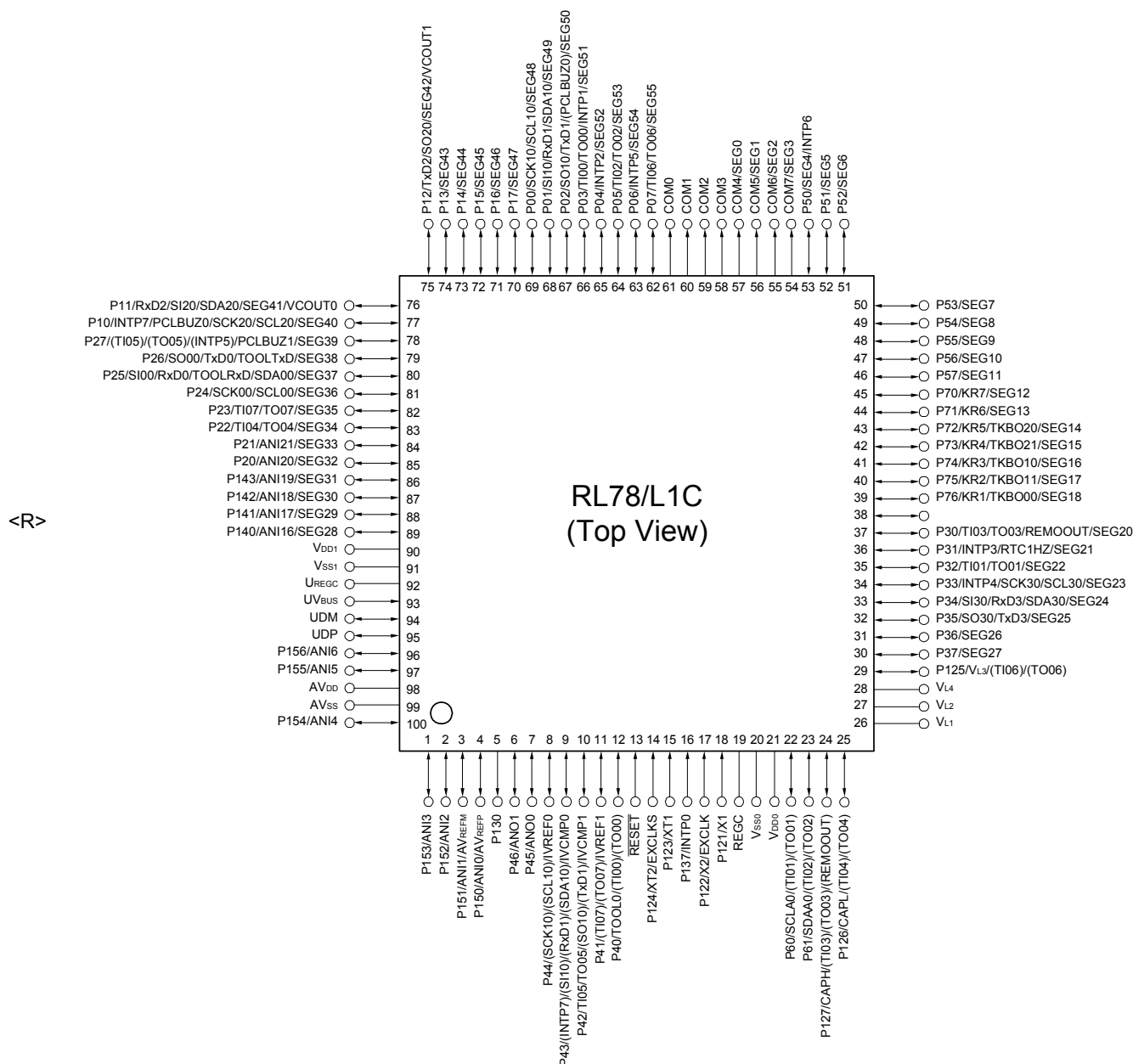
1.3.4 85-pin products (without USB)



Pin	Name	Pin	Name	Pin	Name	Pin	Name	Pin	Name
A1	COM7/SEG3	C1	COM2	E1	P04/INTP2/SEG52	G1	P00/SCK10/SCL10/SEG48	J1	V _{SS0}
A2	P51/SEG5	C2	COM5/SEG1	E2	P05/TI02/TO02/SEG53	G2	V _{SS0}	J2	P11/RxD2/SI20/SDA20/SEG41/VCOU0
A3	P70/KR7/SEG12	C3	COM6/SEG2	E3	P06/INTP5/SEG54	G3	P12/TxD2/SO20/SEG42/VCOU1	J3	P26/SO00/TxD0/TOOLTxD/SEG38
A4	P73/KR4/TKBO21/SEG15	C4	P71/KR6/SEG13	E4	—	G4	—	J4	P23/TI07/TO07/SEG35
A5	P74/KR3/TKBO10/SEG16	C5	P76/KR1/TKBO00/SEG18	E5	—	G5	—	J5	P20/ANI20/SEG32
A6	P31/INTP3/RTC1HZ/SEG21	C6	P77/KR0/TKBO01/SEG19	E6	—	G6	—	J6	P141/ANI17/SEG29
A7	P33/INTP4/SCK30/SCL30/SEG23	C7	P34/SI30/RxD3/SDA30/SEG24	E7	—	G7	—	J7	P82
A8	P35/SO30/TxD3/SEG25	C8	V _{L1}	E8	P40/TOOL0/(TI00)/(TO00)	G8	P44/(SCK10)/(SCL10)/IVREF0	J8	P83
A9	V _{L4}	C9	P61/SDAA0/(TI02)/(TO02)	E9	P137/INTP0	G9	P45/ANO0	J9	AV _{DD}
A10	P126/CAPL/(TI04)/(TO04)	C10	V _{DD0}	E10	P122/X2/EXCLK	G10	P123/XT1	J10	P150/ANI0/AV _{REFP}
B1	COM4/SEG0	D1	COM0	F1	P03/TI00/TO00/INTP1/SEG51	H1	V _{SS0}	K1	V _{SS0}
B2	P50/SEG4/INTP6	D2	COM1	F2	P02/SO10/TxD1/(PCLBUZ0)/SEG50	H2	V _{SS0}	K2	P27/TI05/TO05/(INTP5)/PCLBUZ1/SEG39
B3	P52/SEG6	D3	P07/TI06/TO06/SEG55	F3	P01/SI10/RxD1/SDA10/SEG49	H3	P10/INTP7/PCLBUZ0/SCK20/SCL20/SEG40	K3	P25/SI00/RxD0/TOOLRxD/SDA00/SEG37
B4	P72/KR5/TKBO20/SEG14	D4	COM3	F4	—	H4	P24/SCK00/SCL00/SEG36	K4	P22/TI04/TO04/SEG34
B5	P75/KR2/TKBO11/SEG17	D5	—	F5	—	H5	P21/ANI21/SEG33	K5	P143/ANI19/SEG31
B6	P30/TI03/TO03/REMOOUT/SEG20	D6	—	F6	—	H6	P140/ANI16/SEG28	K6	P142/ANI18/SEG30
B7	P32/TI01/TO01/SEG22	D7	—	F7	—	H7	P152/ANI2	K7	P156/ANI6
B8	P125/V _{L3} /(TI06)/(TO06)	D8	P60/SCLA0/(TI01)/(TO01)	F8	P43/(INTP7)/(SI10)/(RxD1)/(SDA10)/IVCMP0	H8	P46/ANO1	K8	P155/ANI5
B9	V _{L2}	D9	REGC	F9	RESET	H9	P130	K9	AV _{SS}
B10	P127/CAPH/(TI03)/(TO03)/(REMOOUT)	D10	P121/X1	F10	V _{SS0}	H10	P124/XT2/EXCLKS	K10	P151/ANI1/AV _{REFM}

1.3.5 100-pin products (with USB)

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



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

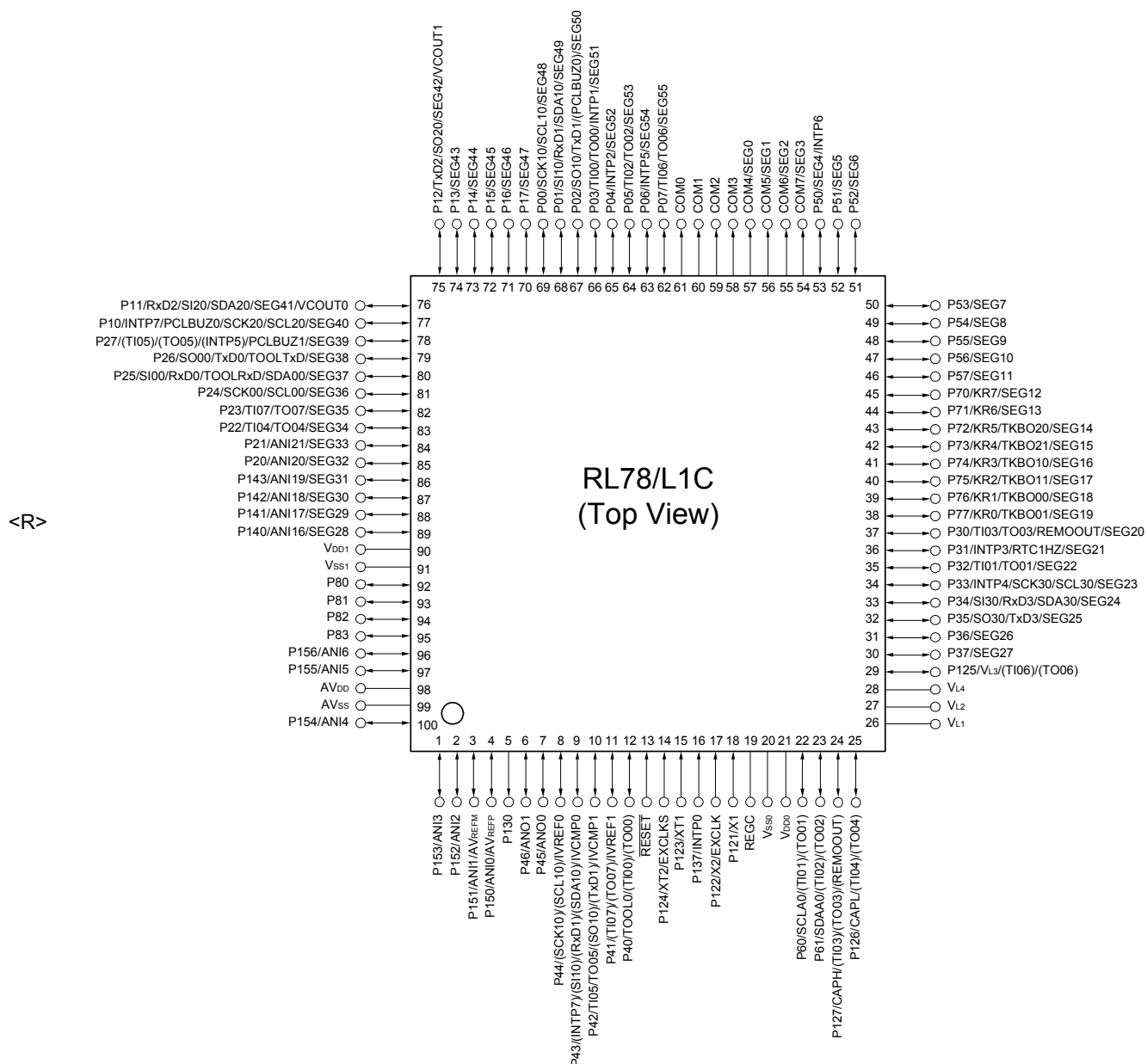
Caution 2. Connect the UREGC pin to Vss pin via a capacitor (0.33 μ F).

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 (PIOR).

1.3.6 100-pin products (without USB)

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



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

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

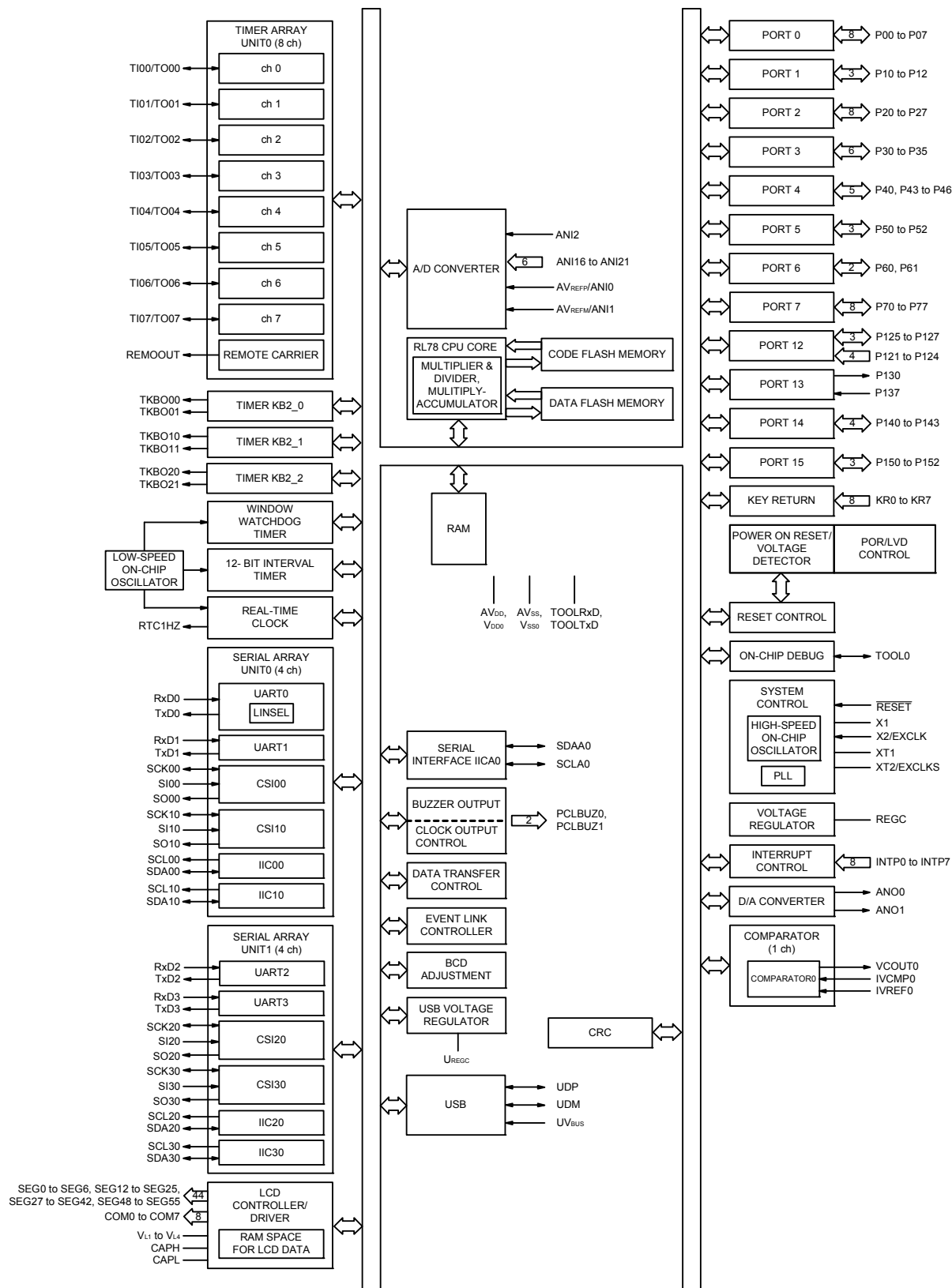
Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).

1.4 Pin Identification

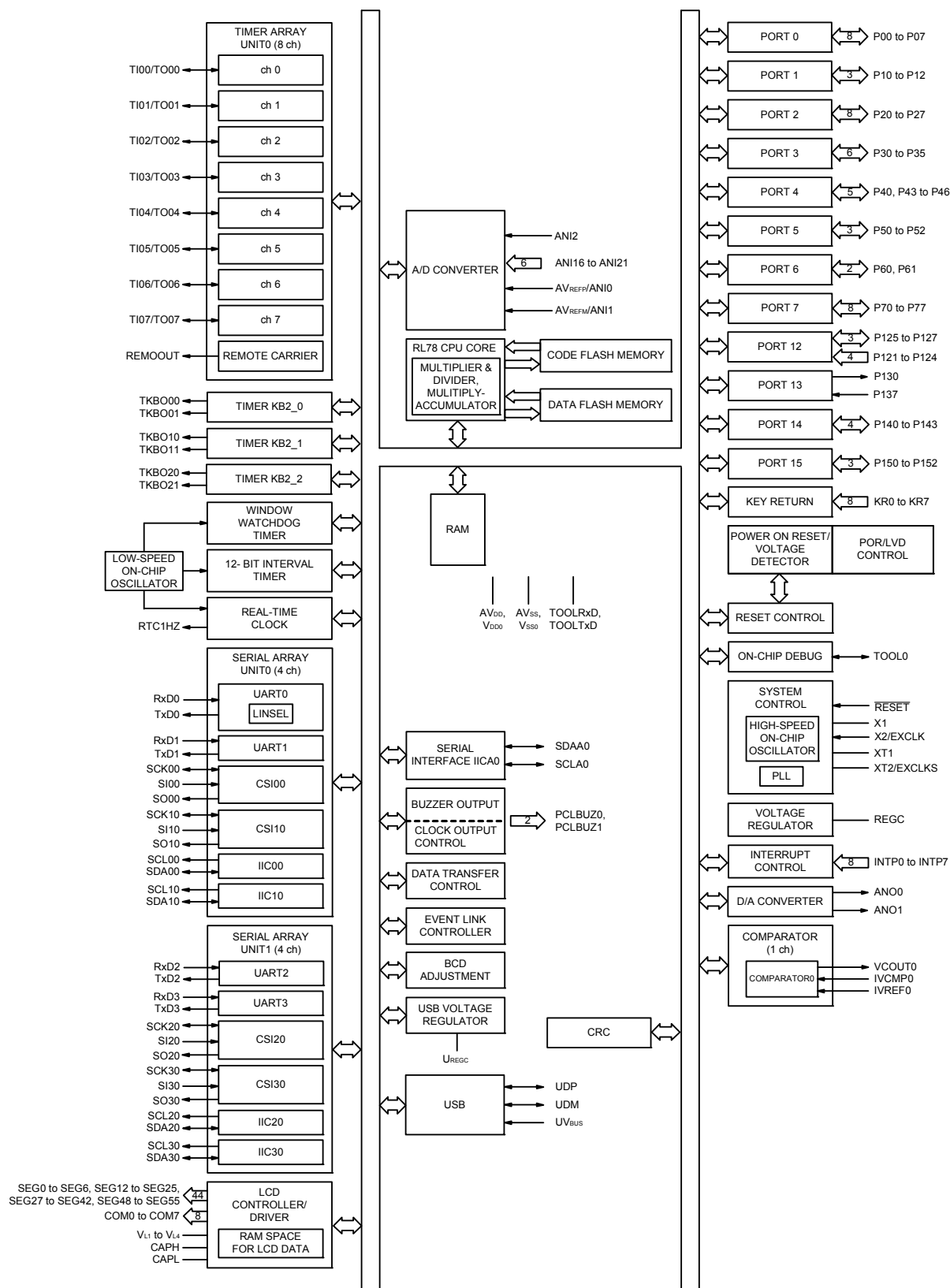
ANI0 to ANI6,	: Analog Input	SCL00, SCL10, SCL20, SCL30	: Serial Clock Output
ANI16 to ANI21		SDAA0, SDA00, SDA10,	: Serial Data Input/Output
ANO0, ANO1	: Analog Output	SDA20, SDA30	
AVDD	: Analog Power Supply	SEG0 to SEG55	: LCD Segment Output
AVREFM	: Analog Reference Voltage Minus	SI00, SI10, SI20, SI30	: Serial Data Input
AVREFP	: Analog Reference Voltage Plus	SO00, SO10, SO20, SO30	: Serial Data Output
AVSS	: Analog Ground	TI00 to TI07	: Timer Input
CAPH, CAPL	: Capacitor for LCD	TO00 to TO07	: Timer Output
COM0 to COM7	: LCD Common Output	TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21	
EXCLK	: External Clock Input (Main System Clock)	TOOL0	: Data Input/Output for Tool
EXCLKS	: External Clock Input (Subsystem Clock)	TOOLRxD, TOOLTxD	: Data Input/Output for External Device
INTP0 to INTP7	: External Interrupt Input	UDM, UDP	: USB Input/Output
IVCMP0, IVCMP1	: Comparator Input	UREGC	: USB Regulator Capacitance
IVREF0, IVREF1	: Comparator Reference Input	UVBUS	: USB Input/USB Power Supply
KR0 to KR7	: Key Return	TxD0 to TxD3	: Transmit Data
P00 to P07	: Port 0	VCOUT0, VCOUT1	: Comparator Output
P10 to P17	: Port 1	VDD0, VDD1	: Power Supply
P20 to P27	: Port 2	VL1 to VL4	: LCD Power Supply
P30 to P37	: Port 3	VSS0, VSS1	: Ground
P40 to P46	: Port 4	X1, X2	: Crystal Oscillator (Main System Clock)
P50 to P57	: Port 5	XT1, XT2	: Crystal Oscillator (Subsystem Clock)
P60 to P62	: Port 6		
P70 to P77	: Port 7		
P80 to P83	: Port 8		
P121 to P127	: Port 12		
P130, P137	: Port 13		
P140 to P143	: Port 14		
P150 to P156	: Port 15		
PCLBUZ0, PCLBUZ1	: Programmable Clock Output/ Buzzer Output		
REGC	: Regulator Capacitance		
REMOOUT	: Remote Control Output		
RESET	: Reset		
RTC1HZ	: Real-time Clock Correction Clock (1 Hz) Output		
RxD0 to RxD3	: Receive Data		
SCK00, SCK10, SCK20, SCK30	: Serial Clock Input/Output		
SCLA0	: Serial Clock Input/Output		

1.5 Block Diagram

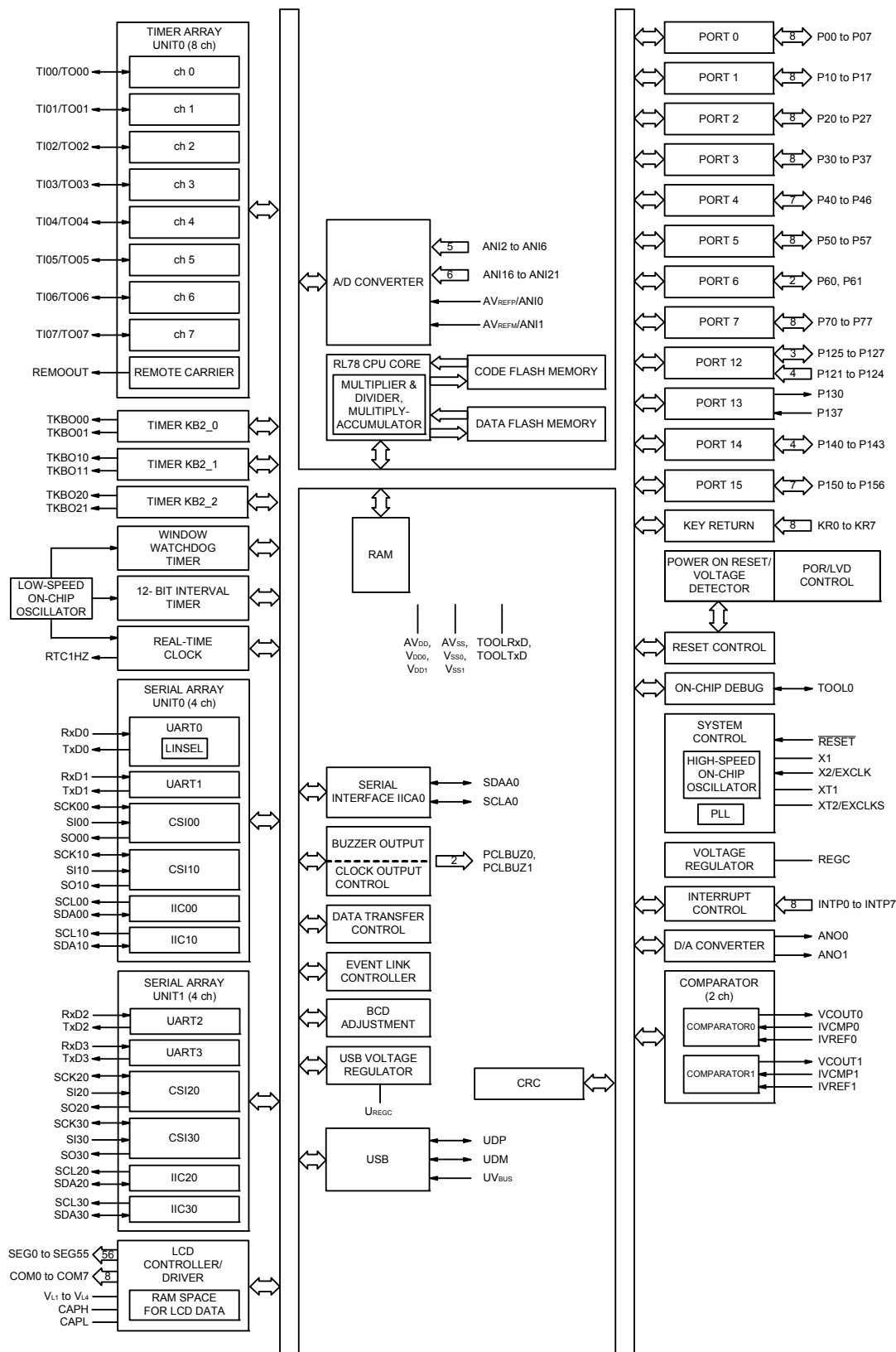
1.5.1 80/85-pin products (with USB)



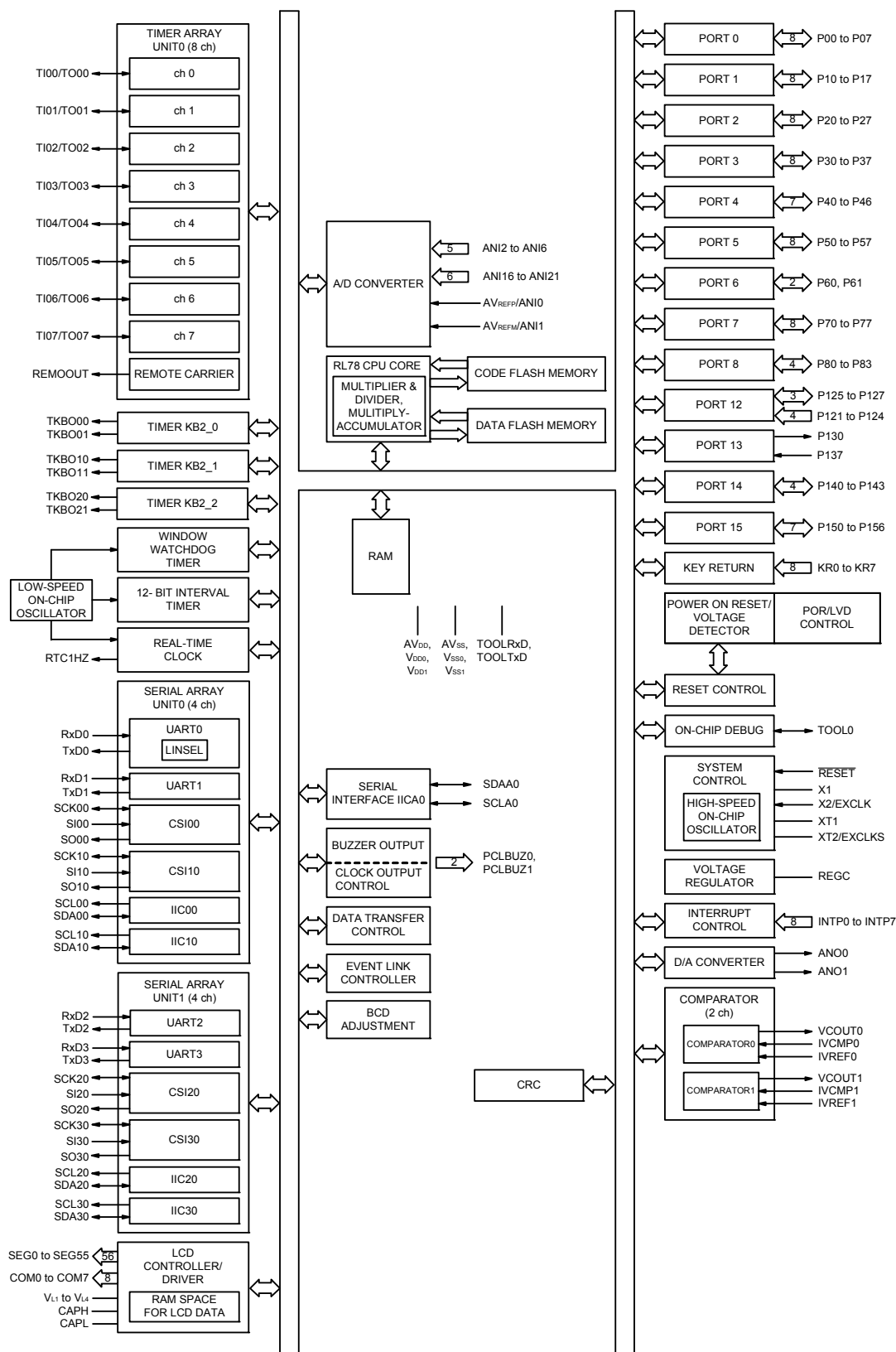
1.5.2 80/85-pin products (without USB)



1.5.3 100-pin products (with USB)



1.5.4 100-pin products (without USB)



1.6 Outline of Functions

[80/85-pin, 100-pin products (with USB)]

(1/2)

Item		80/85-pin	100-pin
		R5F110Mx/R5F110Nx (x = E to H, J)	R5F110Px (x = E to H, J)
Code flash memory (KB)		64 to 256	64 to 256
Data flash memory (KB)		8	8
RAM (KB)		8 to 16 Note 1	8 to 16 Note 1
Memory space		1 MB	
Main system clock	High-speed system clock	X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) 1 to 20 MHz: $V_{DD} = 2.7$ to 3.6 V, 1 to 8 MHz: $V_{DD} = 1.8$ to 2.7 V, 1 to 4 MHz: $V_{DD} = 1.6$ to 1.8 V	
	High-speed on-chip oscillator clock	HS (high-speed main) operation mode: 1 to 24 MHz ($V_{DD} = 2.7$ to 3.6 V), HS (high-speed main) operation mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 3.6 V), LS (low-speed main) operation mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 3.6 V), LV (low-voltage main) operation mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 3.6 V)	
	PLL clock	6, 12, 24 MHz Note 2: $V_{DD} = 2.4$ to 3.6 V	
Subsystem clock		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.): $V_{DD} = 1.6$ to 3.6 V	
Low-speed on-chip oscillator clock		15 kHz (TYP.): $V_{DD} = 1.6$ to 3.6 V	
General-purpose register		8 bits $\times$ 32 registers (8 bits $\times$ 8 registers $\times$ 4 banks)	
Minimum instruction execution time		0.04167 μ s (High-speed on-chip oscillator clock: $f_{HOCO} = f_{IH} = 24$ MHz operation)	
		0.04167 μ s (PLL clock: $f_{PLL} = 48$ MHz/ $f_{IH} = 24$ MHz Note 2 operation)	
		0.05 μ s (High-speed system clock: $f_{MX} = 20$ MHz operation)	
		30.5 μ s (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
Instruction set		• Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (8 bits $\times$ 8 bits, 16 bits $\times$ 16 bits), Division (16 bits $\div$ 16 bits, 32 bits $\div$ 32 bits) • Multiplication and Accumulation (16 bits $\times$ 16 bits + 32 bits) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc.	
I/O port	Total	59	77
	CMOS I/O	51	69
	CMOS input	5	5
	CMOS output	1	1
	N-ch open-drain I/O (6 V tolerance)	2	2
Timer	16-bit timer TAU	8 channels (with 1 channel remote control output function) (Timer outputs: 8, PWM outputs: 7 Note 3)	
	16-bit timer KB2	3 channels (PWM outputs: 6)	
	Watchdog timer	1 channel	
	12-bit interval timer	1 channel	
	Real-time clock 2	1 channel	
	RTC output	1 1 Hz (subsystem clock: $f_{SUB} = 32.768$ kHz)	

Note 1. In the case of the 16 KB, this is about 15 KB when the self-programming function and data flash function are used.

Note 2. In the PLL clock 48 MHz operation, the system clock is 2/4/8 dividing ratio.

Note 3. The number of outputs varies, depending on the setting of channels in use and the number of the master.

(2/2)

Item		80/85-pin	100-pin
		R5F110Mx/R5F110Nx (x = E to H, J)	R5F110Px (x = E to H, J)
Clock output/buzzer output		2	2
		2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: $f_{MAIN} = 20$ MHz operation) 256 Hz, 512 Hz, 1.024 kHz, 2.048 kHz, 4.096 kHz, 8.192 kHz, 16.384 kHz, 32.768 kHz (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
8/12-bit resolution A/D converter		9 channels	13 channels
D/A converter		2 channels	2 channels
Comparator		1 channel	2 channels
Serial interface		- CSI: 1 channel/UART (UART supporting LIN-bus): 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel	
	I ² C bus	1 channel	1 channel
USB	Function	1 channel	
LCD controller/driver		Internal voltage boosting method, capacitor split method, and external resistance division method are switchable.	
	Segment signal output	44 (40) Note 1	56 (52) Note 1
	Common signal output	4 (8) Note 1	
Data transfer controller (DTC)		32 sources	33 sources
Event link controller (ELC)		Event input: 30, Event trigger output: 22	Event input: 31, Event trigger output: 22
Vectored interrupt sources	Internal	36	37
	External	9	9
Key interrupt		8	8
Reset		- 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 Note 2 - Internal reset by RAM parity error - Internal reset by illegal-memory access	
Power-on-reset circuit		- Power-on-reset: 1.51 ± 0.03 V - Power-down-reset: 1.50 ± 0.03 V	
Voltage detector		- Rising edge: 1.67 V to 3.13 V (12 stages) - Falling edge: 1.63 V to 3.06 V (12 stages)	
On-chip debug function		Provided	
Power supply voltage		$V_{DD} = 1.6$ to 5.5 V ($T_A = -40$ to $+85^\circ\text{C}$) $V_{DD} = 2.4$ to 5.5 V ($T_A = -40$ to $+105^\circ\text{C}$)	
Operating ambient temperature		$T_A = -40$ to $+85^\circ\text{C}$ (A: Consumer applications), $T_A = -40$ to $+105^\circ\text{C}$ (G: Industrial applications)	

Note 1. The number in parentheses indicates the number of signal outputs when 8 coms are used.

Note 2. The illegal instruction is generated when instruction code FFH is executed.

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

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[80/85-pin, 100-pin products (without USB)]**(1/2)**

Item		80/85-pin	100-pin
		R5F111Mx/R5F111Nx (x = E to H, J)	R5F111Px (x = E to H, J)
Code flash memory (KB)		64 to 256	64 to 256
Data flash memory (KB)		8	8
RAM (KB)		8 to 16 ^{Note 1}	8 to 16 ^{Note 1}
Memory space		1 MB	
Main system clock	High-speed system clock	X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) 1 to 20 MHz: $V_{DD} = 2.7$ to 3.6 V, 1 to 8 MHz: $V_{DD} = 1.8$ to 2.7 V, 1 to 4 MHz: $V_{DD} = 1.6$ to 1.8 V	
	High-speed on-chip oscillator clock	HS (high-speed main) operation mode: 1 to 24 MHz ($V_{DD} = 2.7$ to 3.6 V), HS (high-speed main) operation mode: 1 to 16 MHz ($V_{DD} = 2.4$ to 3.6 V), LS (low-speed main) operation mode: 1 to 8 MHz ($V_{DD} = 1.8$ to 3.6 V), LV (low-voltage main) operation mode: 1 to 4 MHz ($V_{DD} = 1.6$ to 3.6 V)	
Subsystem clock		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.): $V_{DD} = 1.6$ to 3.6 V	
Low-speed on-chip oscillator clock		15 kHz (TYP.): $V_{DD} = 1.6$ to 3.6 V	
General-purpose register		8 bits $\times$ 32 registers (8 bits $\times$ 8 registers $\times$ 4 banks)	
Minimum instruction execution time		0.04167 μ s (High-speed on-chip oscillator clock: $f_{HOCO} = f_{IH} = 24$ MHz operation)	
		0.05 μ s (High-speed system clock: $f_{MX} = 20$ MHz operation)	
		30.5 μ s (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
Instruction set		• Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (8 bits $\times$ 8 bits, 16 bits $\times$ 16 bits), Division (16 bits $\div$ 16 bits, 32 bits $\div$ 32 bits) • Multiplication and Accumulation (16 bits $\times$ 16 bits + 32 bits) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc.	
I/O port	Total	63	81
	CMOS I/O	55	73
	CMOS input	5	5
	CMOS output	1	1
	N-ch open-drain I/O (6 V tolerance)	2	2
Timer	16-bit timer TAU	8 channels (with 1 channel remote control output function) (Timer outputs: 8, PWM outputs: 7 ^{Note 2})	
	16-bit timer KB2	3 channels (PWM outputs: 6)	
	Watchdog timer	1 channel	
	12-bit interval timer	1 channel	
	Real-time clock 2	1 channel	
	RTC output	1 1 Hz (subsystem clock: $f_{SUB} = 32.768$ kHz)	

Note 1. In the case of the 16 KB, this is about 15 KB when the self-programming function and data flash function are used.

Note 2. The number of outputs varies, depending on the setting of channels in use and the number of the master.

(2/2)

Item		80/85-pin	100-pin
		R5F111Mx/R5F111Nx (x = E to H, J)	R5F111Px (x = E to H, J)
Clock output/buzzer output		2	2
		2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: $f_{MAIN} = 20$ MHz operation) 256 Hz, 512 Hz, 1.024 kHz, 2.048 kHz, 4.096 kHz, 8.192 kHz, 16.384 kHz, 32.768 kHz (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
8/12-bit resolution A/D converter		11 channels	13 channels
D/A converter		2 channels	2 channels
Comparator		1 channel	2 channels
Serial interface		- CSI: 1 channel/UART (UART supporting LIN-bus): 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel - CSI: 1 channel/UART: 1 channel/simplified I²C: 1 channel	
	I ² C bus	1 channel	1 channel
LCD controller/driver		Internal voltage boosting method, capacitor split method, and external resistance division method are switchable.	
	Segment signal output	44 (40) Note 1	56 (52) Note 1
	Common signal output	4 (8) Note 1	
Data transfer controller (DTC)		30 sources	31 sources
Event link controller (ELC)		Event input: 30, Event trigger output: 22	Event input: 31, Event trigger output: 22
Vectored interrupt sources	Internal	32	33
	External	9	9
Key interrupt		8	8
Reset		- 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 Note 2 - Internal reset by RAM parity error - Internal reset by illegal-memory access	
Power-on-reset circuit		- Power-on-reset: 1.51 ± 0.03 V - Power-down-reset: 1.50 ± 0.03 V	
Voltage detector		- Rising edge: 1.67 V to 3.13 V (12 stages) - Falling edge: 1.63 V to 3.06 V (12 stages)	
On-chip debug function		Provided	
Power supply voltage		$V_{DD} = 1.6$ to 5.5 V ($T_A = -40$ to $+85^\circ\text{C}$) $V_{DD} = 2.4$ to 5.5 V ($T_A = -40$ to $+105^\circ\text{C}$)	
Operating ambient temperature		$T_A = -40$ to $+85^\circ\text{C}$ (A: Consumer applications), $T_A = -40$ to $+105^\circ\text{C}$ (G: Industrial applications)	

Note 1. The number in parentheses indicates the number of signal outputs when 8 coms are used.

Note 2. The illegal instruction is generated when instruction code FFH is executed.

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

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

This chapter describes the electrical specifications for the products A: Consumer applications (TA = -40 to +85 °C) and G: Industrial applications (when used in the range of TA = -40 to +85 °C).

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

2.1 Absolute Maximum Ratings

Absolute Maximum Ratings (TA = 25°C)

(1/3)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V _{DD}		-0.5 to + 6.5	V
	UV _{BUS}		-0.5 to + 6.5	V
	AV _{DD}	AV _{DD} ≤ V _{DD}	-0.5 to + 4.6	V
REGC pin input voltage	V _{IREGC}	REGC	-0.3 to + 2.8 and -0.3 to V _{DD} + 0.3 Note 1	V
UREGC pin input voltage	VI _{UREGC}	UREGC	-0.3 to UV _{BUS} + 0.3 Note 2	V
Input voltage	Vi1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, EXCLK, EXCLKS, RESET	-0.3 to V _{DD} + 0.3 Note 3	V
	Vi2	P60, P61 (N-ch open-drain)	-0.3 to + 6.5	V
	Vi3	UDP, UDM	-0.3 to + 6.5	V
	Vi4	P150 to P156	-0.3 to AV _{DD} + 0.3 Note 4	V
Output voltage	Vo1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-0.3 to V _{DD} + 0.3 Note 3	V
	Vo2	P150 to P156	-0.3 to AV _{DD} + 0.3 Note 3	V
	Vo3	UDP, UDM	-0.3 to + 3.8	V
Analog input voltage	VAi1	ANI16 to ANI21	-0.3 to V _{DD} + 0.3 and AV _{REF} (+) + 0.3 Notes 3, 5	V
	VAi2	ANI0 to ANI6	-0.3 to AV _{DD} + 0.3 and AV _{REF} (+) + 0.3 Notes 3, 5	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. Connect the UREGC pin to V_{SS} via a capacitor (0.33 μF). This value regulates the absolute maximum rating of the UREGC pin. Do not use this pin with voltage applied to it.

Note 3. Must be 6.5 V or lower.

Note 4. Must be 4.6 V or lower.

Note 5. Do not exceed AV_{REF}(+) + 0.3 V in case of A/D conversion target pin.

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

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

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

Remark 3. V_{SS}: Reference voltage

Absolute Maximum Ratings (TA = 25°C)

(2/3)

Parameter	Symbols	Conditions		Ratings	Unit
LCD voltage	VL11	VL1 input voltage Note 1		-0.3 to +2.8	V
	VL12	VL2 input voltage Note 1		-0.3 to +6.5	V
	VL13	VL3 input voltage Note 1		-0.3 to +6.5	V
	VL14	VL4 input voltage Note 1		-0.3 to +6.5	V
	VL15	CAPL, CAPH input voltage Note 1		-0.3 to +6.5	V
	VL01	VL1 output voltage		-0.3 to +2.8	V
	VL02	VL2 output voltage		-0.3 to +6.5	V
	VL03	VL3 output voltage		-0.3 to +6.5	V
	VL04	VL4 output voltage		-0.3 to +6.5	V
	VL05	CAPL, CAPH output voltage		-0.3 to +6.5	V
	VL06	COM0 to COM7 SEG0 to SEG55 output voltage	External resistance division method	-0.3 to VDD + 0.3 Note 2	V
			Capacitor split method	-0.3 to VDD + 0.3 Note 2	V
			Internal voltage boosting method	-0.3 to VL14 + 0.3 Note 2	V

Note 1. This value only indicates the absolute maximum ratings when applying voltage to the VL1, VL2, VL3, and VL4 pins; it does not mean that applying voltage to these pins is recommended. When using the internal voltage boosting method or capacitance split method, connect these pins to Vss via a capacitor (0.47 ± 30%) and connect a capacitor (0.47 ± 30%) between the CAPL and CAPH pins.

Note 2. Must be 6.5 V or lower.

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.

Absolute Maximum Ratings (TA = 25°C)

(3/3)

	Parameter	Symbols	Conditions		Ratings	Unit
<R>	Output current, high	IOH1	Per pin	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-40	mA
			Total of all pins -170 mA	P40 to P46	-70	mA
				P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-100	mA
		IOH2	Per pin	P150 to P156	-0.1	mA
			Total of all pins		-0.7	mA
	IOH3	Per pin	UDP, UDM	-3	mA	
<R>	Output current, low	IOL1	Per pin	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	40	mA
			Total of all pins 170 mA	P40 to P46	70	mA
				P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	100	mA
		IOL2	Per pin	P150 to P156	0.4	mA
			Total of all pins		2.8	mA
	IOL3	Per pin	UDP, UDM	3	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 and XT1 oscillator characteristics

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

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (fx) Note	Ceramic resonator/crystal resonator	2.7 V ≤ VDD ≤ 3.6 V	1.0		20.0	MHz
		2.4 V ≤ VDD < 2.7 V	1.0		16.0	
		1.8 V ≤ VDD < 2.4 V	1.0		8.0	
		1.6 V ≤ VDD < 1.8 V	1.0		4.0	
XT1 clock oscillation frequency (fXT) Note	Crystal resonator		32	32.768	35	kHz

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

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

2.2.2 On-chip oscillator characteristics

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

Oscillators	Parameters	Conditions		MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency Notes 1, 2	fHOCO			1		48	MHz
High-speed on-chip oscillator clock frequency accuracy		-20 to +85°C	1.8 V ≤ VDD ≤ 3.6 V	-1.0		+1.0	%
			1.6 V ≤ VDD ≤ 1.8 V	-5.0		+5.0	%
		-40 to -20°C	1.8 V ≤ VDD < 3.6 V	-1.5		+1.5	%
			1.6 V ≤ VDD ≤ 1.8 V	-5.5		+5.5	%
Low-speed on-chip oscillator clock frequency	fIL				15		kHz
Low-speed on-chip oscillator clock frequency accuracy				-15		+15	%

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

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

2.2.3 PLL oscillator characteristics

(TA = -40 to +85 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Oscillators	Parameters	Conditions	MIN.	TYP.	MAX.	Unit
PLL input frequency Note	fPLLIN	High-speed system clock	6.00		16.00	MHz
PLL output frequency Note	fPLL			48.00		MHz

Note Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

2.3 DC Characteristics

2.3.1 Pin characteristics

(TA = -40 to +85 °C, 1.6 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
<R> <R> <R> <R> <R>	IOH1	Per pin for P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143			-10.0 Note 2	mA
		Total of P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ VDD ≤ 3.6 V		-15.0	mA
			1.8 V ≤ VDD < 2.7 V		-7.0	mA
			1.6 V ≤ VDD < 1.8 V		-3	mA
	IOH2	Per pin for P150-P156	1.6 V ≤ VDD ≤ 3.6 V		-0.1 Note 2	mA
		Total of all pins	1.6 V ≤ VDD ≤ 3.6 V		-0.7	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. However, do not exceed the total current value.

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

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

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

<Example> Where n = 50% and IOH = -10.0 mA

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

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

Caution P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
<R>	IOL1	Per pin for P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143			20.0 Note 2	mA
		Per pin for P60 and P61			15.0 Note 2	mA
		Total of P40 to P46 (When duty = 70% Note 3)	2.7 V ≤ VDD ≤ 3.6 V		15.0	mA
			1.8 V ≤ VDD < 2.7 V		9.0	mA
			1.6 V ≤ VDD < 1.8 V		4.5	mA
		Total of P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143 (When duty = 70% Note 3)	2.7 V ≤ VDD ≤ 3.6 V		35.0	mA
			1.8 V ≤ VDD < 2.7 V		20.0	mA
			1.6 V ≤ VDD < 1.8 V		10.0	mA
		Total of all pins (When duty = 70% Note 3)			50.0	mA
<R>	IOL2	Per pin for P150 to P156			0.4 Note 2	mA
		Total of all pins	1.6 V ≤ VDD ≤ 3.6 V		2.8	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.** However, do not exceed the total current value.**Note 3.** Specification under conditions where the duty factor is 70%.

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

- Total output current of pins = (IOL × 0.7)/(n × 0.01)

<Example> Where n = 50% and IOL = 10.0 mA

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

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

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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage, high	VIH1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P140 to P143	0.8 VDD		VDD	V
	VIH2	P00, P01, P10, P11, P24, P25, P33, P34, P43, P44	TTL input buffer 3.3 V ≤ VDD ≤ 3.6 V	2.0	VDD	V
			TTL input buffer 1.6 V ≤ VDD < 3.3 V	1.50	VDD	V
	VIH3	P150 to P156	0.7 AVDD		AVDD	V
	VIH4	P60, P61	0.7 VDD		6.0	V
	VIH5	P121 to P124, P137, EXCLK, EXCLKS, RESET	0.8 VDD		VDD	V
Input voltage, low	VIL1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P140 to P143	0		0.2 VDD	V
	VIL2	P00, P01, P10, P11, P24, P25, P33, P34, P43, P44	TTL input buffer 3.3 V ≤ VDD ≤ 3.6 V	0	0.5	V
			TTL input buffer 1.6 V ≤ VDD < 3.3 V	0	0.32	V
	VIL3	P150 to P156	0		0.3 AVDD	V
	VIL4	P60, P61	0		0.3 VDD	V
	VIL5	P121 to P124, P137, EXCLK, EXCLKS, RESET	0		0.2 VDD	V

Caution The maximum value of VIH of pins P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 is VDD, even in the N-ch open-drain mode.

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

(TA = -40 to +85 °C, 1.6 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

	Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
<R>	Output voltage, high	VOH1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ VDD ≤ 3.6 V, IOH1 = -2.0 mA	VDD - 0.6			V
				1.8 V ≤ VDD ≤ 3.6 V, IOH1 = -1.5 mA	VDD - 0.5			V
				1.6 V ≤ VDD < 3.6 V, IOH1 = -1.0 mA	VDD - 0.5			V
<R>		VOH2	P150 to P156	1.6 V ≤ VDD ≤ 3.6 V, IOH2 = -100 μA	AVDD - 0.5			V
<R>	Output voltage, low	VOL1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ VDD ≤ 3.6 V, IOL1 = 3.0 mA			0.6	V
				2.7 V ≤ VDD ≤ 3.6 V, IOL1 = 1.5 mA			0.4	V
				1.8 V ≤ VDD ≤ 3.6 V, IOL1 = 0.6 mA			0.4	V
				1.6 V ≤ VDD < 1.8 V, IOL1 = 0.3 mA			0.4	V
<R>		VOL2	P150 to P156	1.6 V ≤ VDD ≤ 3.6 V, IOL2 = 400 μA			0.4	V
		VOL3	P60, P61	2.7 V ≤ VDD ≤ 3.6 V, IOL3 = 3.0 mA			0.4	V
				1.8 V ≤ VDD ≤ 3.6 V, IOL3 = 2.0 mA			0.4	V
				1.6 V ≤ VDD ≤ 1.8 V, IOL3 = 1.0 mA			0.4	V

Caution P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Input leakage current, high	ILI _{H1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, $\overline{\text{RESET}}$	V _I = V _{DD}				1	μA
	ILI _{H2}	P20, P21, P140 to P143	V _I = V _{DD}				1	μA
	ILI _{H3}	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	V _I = V _{DD}	In input port or external clock input			1	μA
				In resonator connection			10	μA
	ILI _{H4}	P150 to P156	V _I = AV _{DD}				1	μA
Input leakage current, low	ILI _{L1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, $\overline{\text{RESET}}$	V _I = V _{SS}				-1	μA
	ILI _{L2}	P20, P21, P140 to P143	V _I = V _{SS}				-1	μA
	ILI _{L3}	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	V _I = V _{SS}	In input port or external clock input			-1	μA
				In resonator connection			-10	μA
	ILI _{L4}	P150 to P156	V _I = AV _{SS}				-1	μA
On-chip pull-up resistance	RU ₁	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P140 to P143, P125 to P127	V _I = V _{SS}	2.4 V ≤ V _{DD} ≤ 3.6 V	10	20	100	kΩ
				1.6 V ≤ V _{DD} ≤ 2.4 V	10	30	100	
	RU ₂	P40 to P46, P80 to P83	V _I = V _{SS}		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 ≤ VDD ≤ 3.6 V, VSS = 0 V)

(1/2)

Parameter	Symbol	Conditions					MIN.	TYP.	MAX.	Unit		
Supply current Note 1	IDD1	Operating mode	HS (high-speed main) mode Note 5	fHOCO = 48 MHz Note 3, fIH = 24 MHz Note 3	Basic operation	VDD = 3.6 V		2.2	2.8	mA		
						VDD = 3.0 V		2.2	2.8			
					Normal operation	VDD = 3.6 V		4.4	8.5			
						VDD = 3.0 V		4.4	8.5			
				fHOCO = 24 MHz Note 3, fIH = 24 MHz Note 3	Basic operation	VDD = 3.6 V		2.0	2.6			
						VDD = 3.0 V		2.0	2.6			
					Normal operation	VDD = 3.6 V		4.2	6.8			
						VDD = 3.0 V		4.2	6.8			
				fHOCO = 16 MHz Note 3, fIH = 16 MHz Note 3	Normal operation	VDD = 3.6 V		3.1	4.9			
						VDD = 3.0 V		3.1	4.9			
			LS (low-speed main) mode Note 5	fHOCO = 8 MHz Note 3, fIH = 8 MHz Note 3	Normal operation	VDD = 3.0 V		1.4	2.2	mA		
						VDD = 2.0 V		1.4	2.2			
			LV (low-voltage main) mode Note 5	fHOCO = 4 MHz Note 3, fIH = 4 MHz Note 3	Normal operation	VDD = 3.0 V		1.3	1.8	mA		
						VDD = 2.0 V		1.3	1.8			
			HS (high-speed main) mode Note 5	fMX = 20 MHz Note 2, VDD = 3.6 V	Normal operation	Square wave input		3.5	5.5	mA		
						Resonator connection		3.6	5.7			
					Normal operation	Square wave input		3.5	5.5			
						Resonator connection		3.6	5.7			
					Normal operation	Square wave input		2.9	4.5			
						Resonator connection		3.1	4.6			
					Normal operation	Square wave input		2.9	4.5			
						Resonator connection		3.1	4.6			
					Normal operation	Square wave input		2.1	3.2			
						Resonator connection		2.2	3.2			
		Normal operation			Square wave input		2.1	3.2				
					Resonator connection		2.2	3.2				
		LS (low-speed main) mode Note 5			fMX = 8 MHz Note 2, VDD = 3.6 V	Normal operation	Square wave input		1.2		2.0	mA
							Resonator connection		1.3		2.0	
					fMX = 8 MHz Note 2, VDD = 3.0 V	Normal operation	Square wave input		1.2		2.1	
							Resonator connection		1.3		2.2	
		HS (High-speed main) mode (PLL operation)	fPLL = 48 MHz, fCLK = 24 MHz Note 2	Normal operation	VDD = 3.6 V		4.7	7.5	mA			
					VDD = 3.0 V		4.7	7.5				
			fPLL = 48 MHz, fCLK = 12 MHz Note 2	Normal operation	VDD = 3.6 V		3.1	5.1				
					VDD = 3.0 V		3.1	5.1				
			fPLL = 48 MHz, fCLK = 6 MHz Note 2	Normal operation	VDD = 3.6 V		2.3	3.9				
					VDD = 3.0 V		2.3	3.9				
		Subsystem clock operation	fSUB = 32.768 kHz Note 4 TA = -40°C	Normal operation	Square wave input		4.6	6.9	μA			
					Resonator connection		4.7	6.9				
			fSUB = 32.768 kHzNote 4 TA = +25°C	Normal operation	Square wave input		4.9	7.0				
					Resonator connection		5.0	7.2				
			fSUB = 32.768 kHzNote 4 TA = +50°C	Normal operation	Square wave input		5.2	7.6				
					Resonator connection		5.2	7.7				
			fSUB = 32.768 kHzNote 4 TA = +70°C	Normal operation	Square wave input		5.5	9.3				
					Resonator connection		5.6	9.4				
			fSUB = 32.768 kHzNote 4 TA = +85°C	Normal operation	Square wave input		6.2	13.3				
					Resonator connection		6.2	13.4				

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

- Note 1.** Total current flowing into V_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, or V_{SS}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the LCD controller/driver, A/D converter, D/A converter, comparator, LVD circuit, USB 2.0 function module, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 3.** When high-speed system clock and subsystem clock are stopped.
- Note 4.** When high-speed on-chip oscillator and high-speed system clock are stopped. When AMPHS1 = 1 (Ultra-low power consumption oscillation). However, not including the current flowing into the real-time clock 2, 12-bit interval timer, and watchdog timer.
- Note 5.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- | | |
|----------------------------|---|
| HS (high-speed main) mode: | 2.7 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 24 MHz |
| | 2.4 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 16 MHz |
| LS (low-speed main) mode: | 1.8 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 8 MHz |
| LV (low-voltage main) mode | 1.6 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 4 MHz |
- Remark 1.** f_{MX}: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f_{HOCO}: High-speed on-chip oscillator clock frequency (48 MHz max.)
- Remark 3.** f_{IH}: Main system clock source frequency when the high-speed on-chip oscillator clock divided 1, 2, 4, or 8, or the PLL clock divided by 2, 4, or 8 is selected (24 MHz max.)
- Remark 4.** f_{SUB}: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

(2/2)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit				
Supply current Note 1	IDD2 Note 2	HALT mode	HS (high-speed main) mode Note 7	fHOCO = 48 MHz Note 4, fIH = 24 MHz Note 4	VDD = 3.6 V		0.77	2.70	mA		
					VDD = 3.0 V		0.77	2.70			
				fHOCO = 24 MHz Note 4, fIH = 24 MHz Note 4	VDD = 3.6 V		0.55	1.91			
					VDD = 3.0 V		0.55	1.90			
				fHOCO = 16 MHz Note 4, fIH = 16 MHz Note 4	VDD = 3.6 V		0.48	1.41			
					VDD = 3.0 V		0.47	1.41			
			LS (low-speed main) mode Note 7	fHOCO = 8 MHz Note 4, fIH = 8 MHz Note 4	VDD = 3.0 V		300	770	μA		
					VDD = 2.0 V		300	770			
			LV (low-voltage main) mode Note 7	fHOCO = 4 MHz Note 4, fIH = 4 MHz Note 4	VDD = 3.0 V		440	770	μA		
					VDD = 2.0 V		440	770			
			HS (high-speed main) mode Note 7	fMX = 20 MHz Note 3, VDD = 3.6 V	Square wave input		0.35	1.63	mA		
					Resonator connection		0.51	1.68			
				fMX = 20 MHz Note 3, VDD = 3.0 V	Square wave input		0.34	1.63			
					Resonator connection		0.51	1.68			
				fMX = 16 MHz Note 3, VDD = 3.6 V	Square wave input		0.30	1.22			
					Resonator connection		0.45	1.39			
				fMX = 16 MHz Note 3, VDD = 3.0 V	Square wave input		0.29	1.20			
					Resonator connection		0.45	1.38			
				fMX = 10 MHz Note 3, VDD = 3.6 V	Square wave input		0.23	0.82			
					Resonator connection		0.30	0.90			
				fMX = 10 MHz Note 3, VDD = 3.0 V	Square wave input		0.22	0.81			
					Resonator connection		0.30	0.89			
				LS (low-speed main) mode Note 7	fMX = 8 MHz Note 3, VDD = 3.0 V	Square wave input		120		510	μA
						Resonator connection		170		560	
			fMX = 8 MHz Note 3, VDD = 2.0 V		Square wave input		130	520			
					Resonator connection		170	570			
			HS (High-speed main) mode (PLL operation)	fMX = 48 MHz, fCLK = 24 MHz Note 3	VDD = 3.6 V		0.99	2.89	mA		
					VDD = 3.0 V		0.99	2.88			
				fMX = 48 MHz, fCLK = 12 MHz Note 3	VDD = 3.6 V		0.89	2.48			
					VDD = 3.0 V		0.89	2.47			
				fMX = 48 MHz, fCLK = 6 MHz Note 3	VDD = 3.6 V		0.84	2.27			
					VDD = 3.0 V		0.84	2.27			
			Subsystem clock operation	fSUB = 32.768 kHz Note 5 TA = -40°C	Square wave input		0.32	0.61	μA		
					Resonator connection		0.51	0.80			
				fSUB = 32.768 kHz Note 5 TA = +25°C	Square wave input		0.41	0.74			
					Resonator connection		0.62	0.91			
				fSUB = 32.768 kHz Note 5 TA = +50°C	Square wave input		0.52	2.30			
					Resonator connection		0.75	2.49			
				fSUB = 32.768 kHz Note 5 TA = +70°C	Square wave input		0.82	4.03			
					Resonator connection		1.08	4.22			
			fSUB = 32.768 kHz Note 5 TA = +85°C	Square wave input		1.38	8.04				
				Resonator connection		1.62	8.23				
IDD3 Note 6	STOP mode Note 8	TA = -40°C				0.18	0.52	μA			
		TA = +25°C				0.25	0.52				
		TA = +50°C				0.34	2.21				
		TA = +70°C				0.64	3.94				
		TA = +85°C				1.18	7.95				

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

- Note 1.** Total current flowing into VDD, including the input leakage current flowing when the level of the input pin is fixed to VDD or Vss. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the LCD controller/driver, A/D converter, D/A converter, comparator, LVD circuit, USB 2.0 function module, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** During HALT instruction execution by flash memory.
- Note 3.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 4.** When high-speed system clock and subsystem clock are stopped.
- Note 5.** When high-speed on-chip oscillator and high-speed system clock are stopped. When RTCLPC = 1 and setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the real-time clock 2 is included. However, not including the current flowing into the 12-bit interval timer and watchdog timer.
- Note 6.** Not including the current flowing into the real-time clock 2, 12-bit interval timer, and watchdog timer.
- Note 7.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- | | |
|-----------------------------|-------------------------------------|
| HS (high-speed main) mode: | 2.7 V ≤ VDD ≤ 3.6 V@1 MHz to 24 MHz |
| | 2.4 V ≤ VDD ≤ 3.6 V@1 MHz to 16 MHz |
| LS (low-speed main) mode: | 1.8 V ≤ VDD ≤ 3.6 V@1 MHz to 8 MHz |
| LV (low-voltage main) mode: | 1.6 V ≤ VDD ≤ 3.6 V@1 MHz to 4 MHz |
- Note 8.** Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.
- Remark 1.** fMX: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** fHOCO: High-speed on-chip oscillator clock frequency (48 MHz max.)
- Remark 3.** fIH: Main system clock source frequency when the high-speed on-chip oscillator clock divided 1, 2, 4, or 8, or the PLL clock divided by 2, 4, or 8 is selected (24 MHz max.)
- Remark 4.** fSUB: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	IFIL Note 1						0.20		μA
RTC2 operating current	IRTC Notes 1, 3						0.02		μA
12-bit interval timer operating current	ITMKA Notes 1, 2, 4						0.02		μA
Watchdog timer operating current	IWDTC Notes 1, 4	fIL = 15 kHz					0.22		μA
A/D converter operating current	IADC Notes 6, 7	AVDD = 3.0 V, when conversion at maximum speed					422	720	μA
AVREF (+) current	IAVREF Note 8	AVDD = 3.0 V, ADREFF1 = 0, ADREFF0 = 0 Note 7					14.0	25.0	μA
		AVREFF = 3.0 V, ADREFF1 = 0, ADREFF0 = 1 Note 10					14.0	25.0	
		ADREFF1 = 1, ADREFF0 = 0 Note 1					14.0	25.0	
A/D converter reference voltage current	IADREF Notes 1, 9	VDD = 3.0 V					75.0		μA
Temperature sensor operating current	ITMPS Note 1						78		μA
D/A converter operating current	IDAC Notes 1, 11	Per D/A converter channel					0.53	1.5	mA
Comparator operating current	ICMP Notes 1, 12	VDD = 3.6 V, Regulator output voltage = 2.1 V	Window mode				12.5		μA
			Comparator high-speed mode				4.5		μA
			Comparator low-speed mode				1.2		μA
		VDD = 3.6 V, Regulator output voltage = 1.8 V	Window mode				7.05		μA
			Comparator high-speed mode				2.2		μA
			Comparator low-speed mode				0.9		μA
LVD operating current	ILVI Notes 1, 13						0.06		μA
Self-programming operating current	IFSP Notes 1, 14						2.50	12.20	mA
BGO operating current	IBGO Notes 1, 15						1.68	12.20	mA
SNOOZE operating current	ISNOZ Note 1	ADC operation	The mode is performed				0.34	1.10	mA
			The A/D conversion operations are performed, Low voltage mode, AVREFF = VDD = 3.0 V				0.53	2.04	
		CSI/UART operation					0.70	1.54	mA
LCD operating current	ILCD1 Notes 16, 17	External resistance division method	fLCD = fSUB LCD clock = 128 Hz	1/3 bias 4-time slice	VDD = 3.6 V, LV4 = 3.6 V		0.14		μA
	ILCD2 Note 16	Internal voltage boosting method	fLCD = fSUB LCD clock = 128 Hz	1/3 bias 4-time slice	VDD = 3.0 V, LV4 = 3.0 V (VLCD = 04H)		0.61		μA
	ILCD3 Note 16	Capacitor split method	fLCD = fSUB LCD clock = 128 Hz	1/3 bias 4-time slice	VDD = 3.0 V, LV4 = 3.0 V		0.12		μA
USB current Note 18	IUSB Note 19	Operating current during USB communication					4.88		mA
	IUSB Note 20	Operating current in the USB suspended state					0.04		mA

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

- Note 1.** Current flowing to VDD.
- Note 2.** When high speed on-chip oscillator and high-speed system clock are stopped.
- Note 3.** Current flowing only to the real-time clock 2 (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2}, and I_{RTC}, when the real-time clock 2 operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the real-time clock 2.
- 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 I_{DD1} or I_{DD2}, and I_{TMKA}, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the 12-bit interval timer.
- Note 5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{WDT} when the watchdog timer operates in STOP mode.
- Note 6.** Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{ADC}, I_{AVREF}, I_{ADREF} when the A/D converter operates in an operation mode or the HALT mode.
- Note 7.** Current flowing to the AVDD.
- Note 8.** Current flowing from the reference voltage source of A/D converter.
- Note 9.** Operation current flowing to the internal reference voltage.
- Note 10.** Current flowing to the AVREFP.
- Note 11.** Current flowing only to the D/A converter. The current value of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{DA} when the D/A converter operates in an operation mode or the HALT mode.
- Note 12.** Current flowing only to the comparator circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{CMP} when the comparator circuit operates in the Operating, HALT or STOP mode.
- Note 13.** Current flowing only to the LVD circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{LVI} when the LVD circuit operates in the Operating, HALT or STOP mode.
- Note 14.** Current flowing only during self-programming.
- Note 15.** Current flowing only during data flash rewrite.
- Note 16.** Current flowing only to the LCD controller/driver (VDD pin). The current value of the RL78 microcontrollers is the sum of the LCD operating current (I_{LCD1}, I_{LCD2} or I_{LCD3}) to the supply current (I_{DD1}, or I_{DD2}) when the LCD controller/driver operates in an operation mode or HALT mode. Not including the current that flows through the LCD panel.
- Note 17.** Not including the current that flows through the external divider resistor divider resistor.
- Note 18.** Current flowing to the UVBUS.
- Note 19.** Including the operating current when f_{PLL} = 48 MHz.
- Note 20.** Including the current supplied from the pull-up resistor of the UDP pin to the pull-down resistor of the host device, in addition to the current consumed by this MCU during the suspended state.

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

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

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

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

2.4 AC Characteristics

2.4.1 Basic operation

(TA = -40 to +85 °C, 1.6 V ≤ AVDD = VDD ≤ 3.6 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 ≤ 3.6 V	0.0417		1	μs
				2.4 V ≤ VDD < 2.7 V	0.0625		1	μs
			LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V	0.125		1	μs
				LV (low-voltage main) mode	1.6 V ≤ VDD ≤ 3.6 V	0.25		1
		Subsystem clock (fSUB) operation		1.8 V ≤ VDD ≤ 3.6 V	28.5	30.5	31.3	μs
		In the self- programming mode	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V	0.0417		1	μs
				2.4 V ≤ VDD < 2.7 V	0.0625		1	μs
			LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V	0.125		1	μs
				LV (low-voltage main) mode	1.8 V ≤ VDD ≤ 3.6 V	0.25		1
External main system clock frequency	fex	2.7 V ≤ VDD ≤ 3.6 V			1.0		20.0	MHz
		2.4 V ≤ VDD < 2.7 V			1.0		16.0	MHz
		1.8 V ≤ VDD < 2.4 V			1.0		8.0	MHz
		1.6 V ≤ VDD < 1.8 V			1.0		4.0	MHz
	fEXT				32		35	kHz
External main system clock input high-level width, low-level width	texH, texL	2.7 V ≤ VDD ≤ 3.6 V			24			ns
		2.4 V ≤ VDD < 2.7 V			30			ns
		1.8 V ≤ VDD < 2.4 V			60			ns
		1.6 V ≤ VDD < 1.8 V			120			ns
	texHS, texLS				13.7			μs
TI00 to TI07 input high-level width, low-level width	tTIH, tTIL				1/fMCK + 10			ns

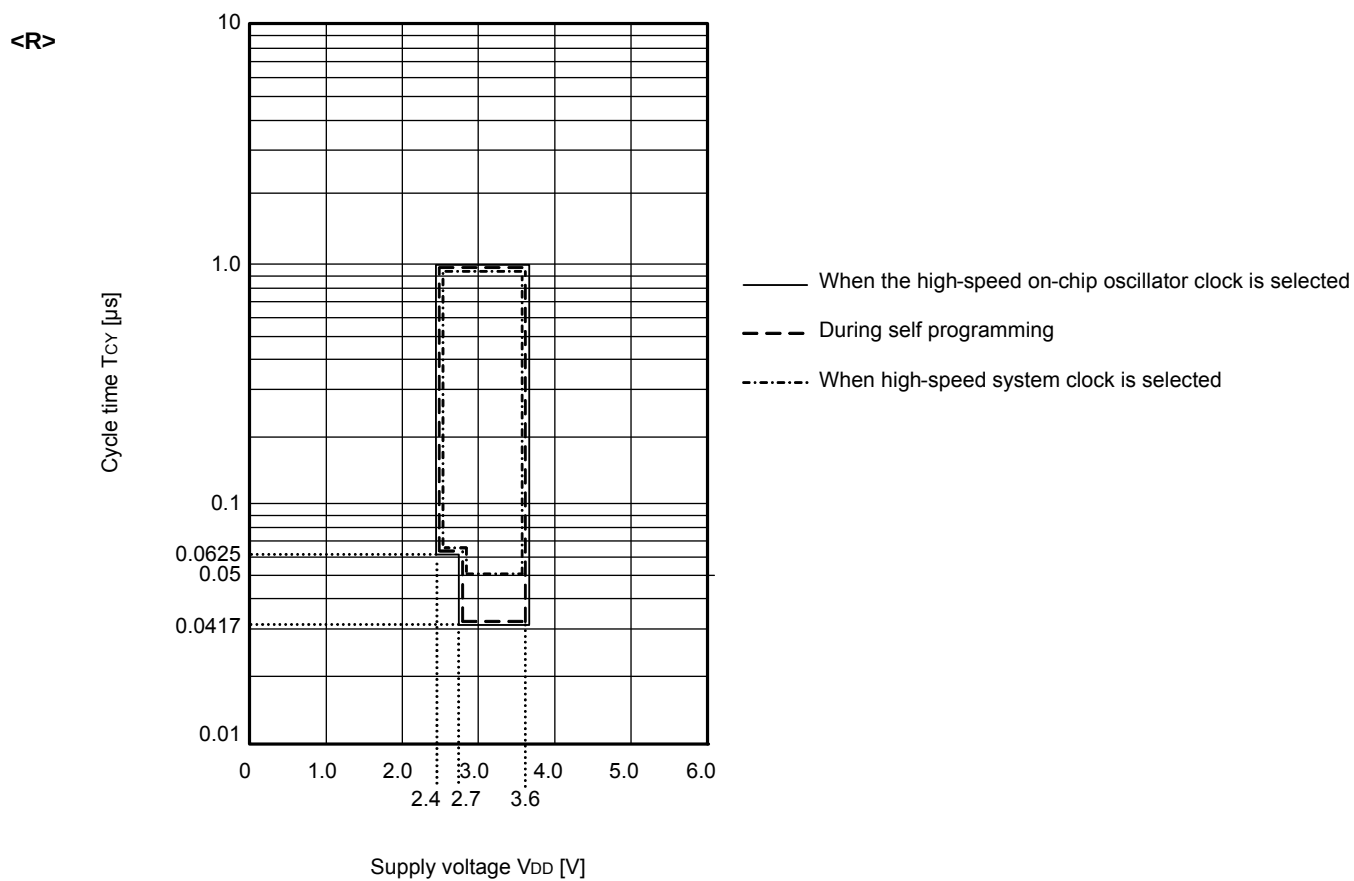
Remark fMCK: Timer array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0),
n: Channel number (n = 0 to 7))

(TA = -40 to +85 °C, 1.6 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

(2/2)

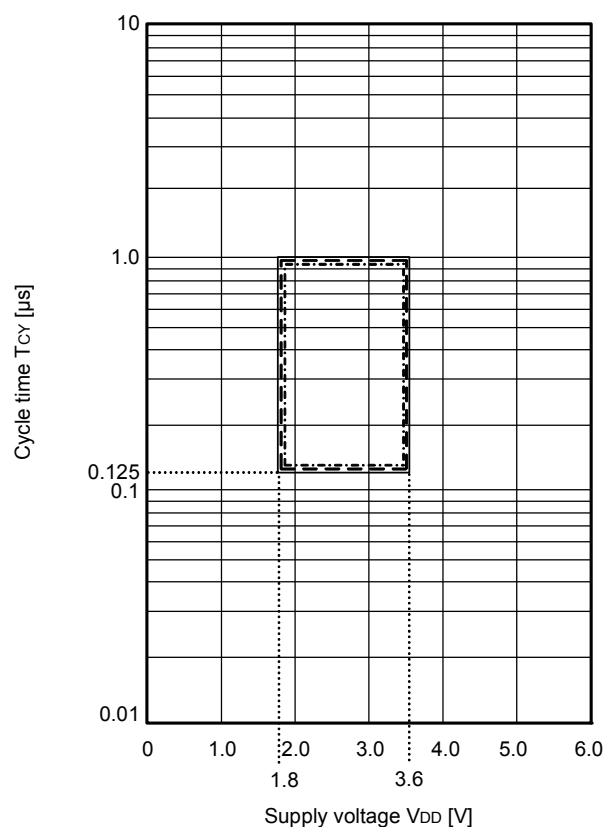
Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
TO00 to TO07, TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21 output frequency	fro	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V			8	MHz
			2.4 V ≤ VDD < 2.7 V			8	MHz
		LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V			4	MHz
		LV (low-voltage main) mode	1.6 V ≤ VDD ≤ 3.6 V			2	MHz
PCLBUZ0, PCLBUZ1 output frequency	fPCL	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V			8	MHz
			2.4 V ≤ VDD < 2.7 V			8	MHz
		LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V			4	MHz
		LV (low-voltage main) mode	1.8 V ≤ VDD ≤ 3.6 V			2	MHz
Interrupt input high-level width, low-level width	tINTH, tINTL	INTP0 to INTP7	1.6 V ≤ VDD ≤ 3.6 V	1			μs
Key interrupt input low-level width	tkR	1.8 V ≤ VDD ≤ 3.6 V		250			ns
		1.6 V ≤ VDD < 1.8 V		1			μs
TMKB2 forced output stop input high-level width	tiHR	INTP0 to INTP7	fCLK > 16 MHz	125			ns
			fCLK ≤ 16 MHz	2			fCLK
RESET low-level width	trSL			10			μs

Minimum Instruction Execution Time during Main System Clock Operation

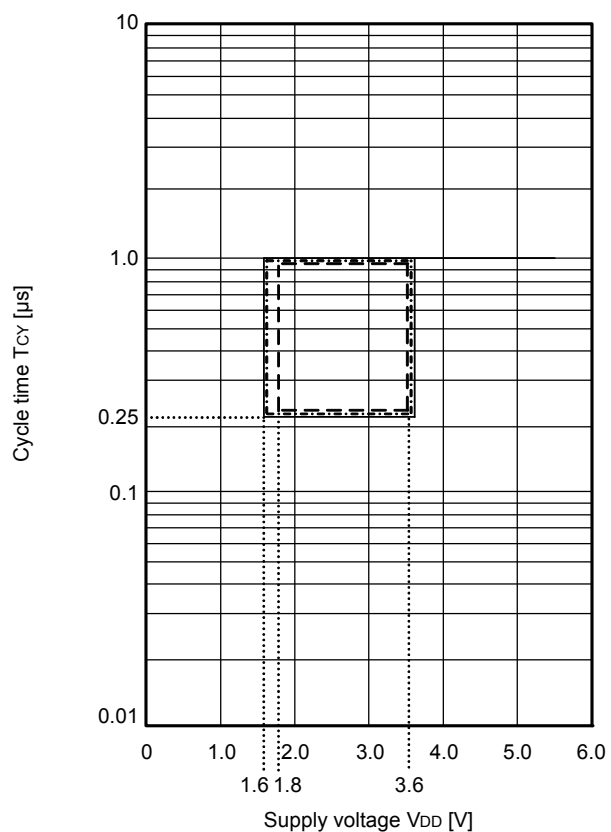
T_{CY} vs V_{DD} (HS (high-speed main) mode)

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

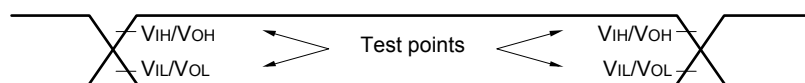
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T_{CY} vs V_{DD} (LV (low-voltage main) mode)

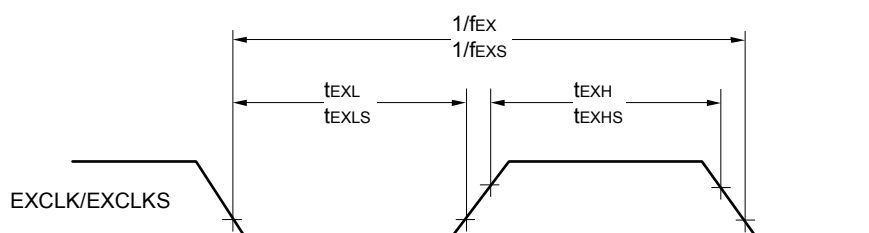
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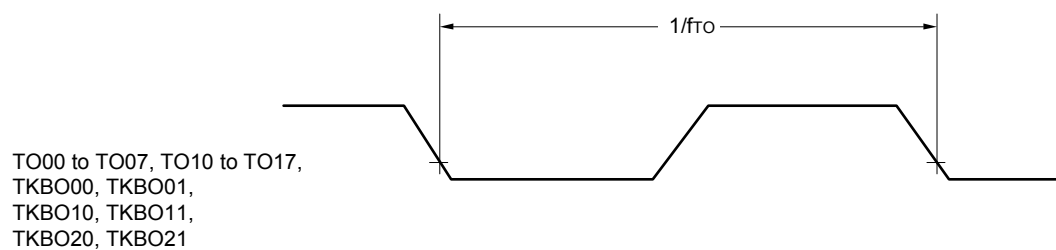
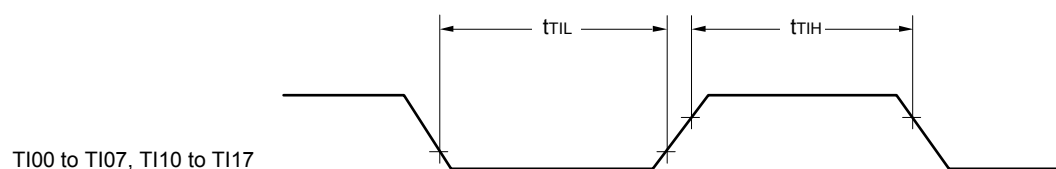
AC Timing Test Points



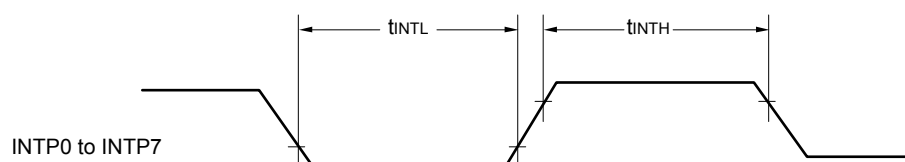
External System Clock Timing



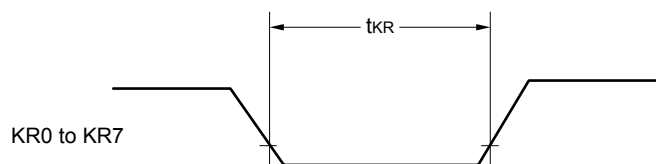
TI/TO Timing



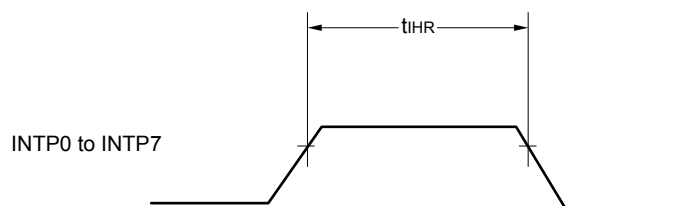
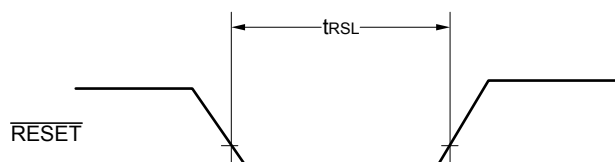
Interrupt Request Input Timing



Key Interrupt Input Timing

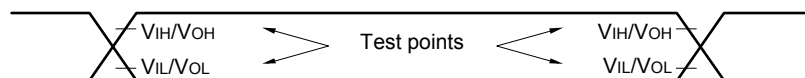


Timer KB2 Input Timing

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

2.5 Peripheral Functions Characteristics

AC Timing Test Points



2.5.1 Serial array unit

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

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate Note 1		2.7 V ≤ V _{DD} ≤ 3.6 V		f _{MCK} /6 Note 2		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		4.0		1.3		0.6	Mbps
		2.4 V ≤ V _{DD} ≤ 3.6 V		f _{MCK} /6 Note 2		f _{MCK} /6		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3		2.6		1.3		0.6	Mbps
		1.8 V ≤ V _{DD} ≤ 3.6 V	—			f _{MCK} /6 Note 2		f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3	—			1.3		0.6	Mbps
		1.6 V ≤ V _{DD} ≤ 3.6 V	—		—			f _{MCK} /6	bps
		Theoretical value of the maximum transfer rate f _{MCK} = f _{CLK} Note 3	—		—			0.6	Mbps

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

Note 2. The following conditions are required for low voltage interface.

2.4 V ≤ V_{DD} < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ V_{DD} < 2.4 V: MAX. 1.3 Mbps

1.6 V ≤ V_{DD} < 1.8 V: MAX. 0.6 Mbps

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

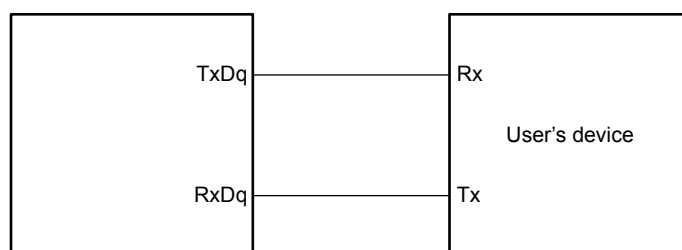
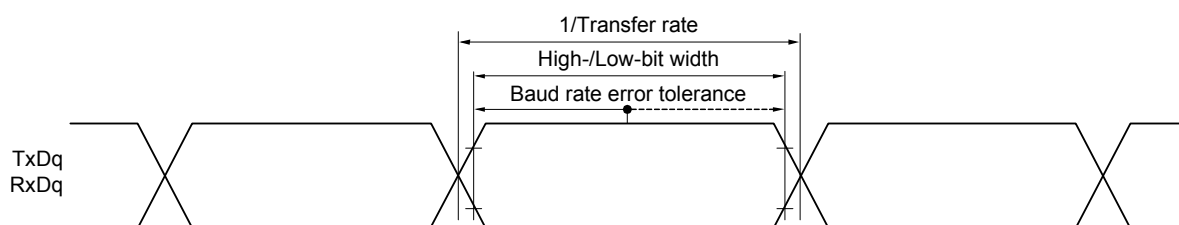
HS (high-speed main) mode: 24 MHz (2.7 V ≤ V_{DD} ≤ 3.6 V)

16 MHz (2.4 V ≤ V_{DD} ≤ 3.6 V)

LS (low-speed main) mode: 8 MHz (1.8 V ≤ V_{DD} ≤ 3.6 V)

LV (low-voltage main) mode: 4 MHz (1.6 V ≤ V_{DD} ≤ 3.6 V)

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

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

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

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

(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number,
n: Channel number (mn = 00 to 03, 10 to 13))

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

(TA = -40 to +85 °C, 2.7 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ f _{CLK} /2	2.7 V ≤ V _{DD} ≤ 3.6 V	167		250		500		ns
SCKp high-/low-level width	t _{KL1}	2.7 V ≤ V _{DD} ≤ 3.6 V		t _{KCY1} /2 - 10		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
Slp setup time (to SCKp↑) Note 1	t _{SIK1}	2.7 V ≤ V _{DD} ≤ 3.6 V		33		110		110		ns
Slp hold time (from SCKp↑) Note 2	t _{KSI1}	2.7 V ≤ V _{DD} ≤ 3.6 V		10		10		10		ns
Delay time from SCKp↓ to SOp output Note 3	t _{KSO1}	C = 20 pF Note 4		10		10		10		ns

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

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

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

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

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

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

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 (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85 °C, 1.6 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ f _{CLK} /4	2.7 V ≤ V _{DD} ≤ 3.6 V	167		500		1000		ns
			2.4 V ≤ V _{DD} ≤ 3.6 V	250		500		1000		ns
			1.8 V ≤ V _{DD} ≤ 3.6 V	—		500		1000		ns
			1.6 V ≤ V _{DD} ≤ 3.6 V	—		—		1000		ns
SCKp high-/low-level width	t _{KH1} , t _{KL1}	2.7 V ≤ V _{DD} ≤ 3.6 V	t _{KCY1} /2 - 18			t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V	t _{KCY1} /2 - 38			t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
		1.8 V ≤ V _{DD} ≤ 3.6 V	—			t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
		1.6 V ≤ V _{DD} ≤ 3.6 V	—			—		t _{KCY1} /2 - 100		ns
Slp setup time (to SCKp↑) Note 1	t _{SIK1}	2.7 V ≤ V _{DD} ≤ 3.6 V	44			110		110		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V	75			110		110		ns
		1.8 V ≤ V _{DD} ≤ 3.6 V	—			110		110		ns
		1.6 V ≤ V _{DD} ≤ 3.6 V	—			—		220		ns
Slp hold time (from SCKp↑) Note 2	t _{SH1}	2.4 V ≤ V _{DD} ≤ 3.6 V	19			19		19		ns
		1.8 V ≤ V _{DD} ≤ 3.6 V	—			19		19		ns
		1.6 V ≤ V _{DD} ≤ 3.6 V	—			—		19		ns
Delay time from SCKp↓ to SOp output Note 3	t _{KSO1}	C = 30 pF Note 4	2.7 V ≤ V _{DD} ≤ 3.6 V		25		50		50	ns
			2.4 V ≤ V _{DD} ≤ 3.6 V		25		50		50	ns
			1.8 V ≤ V _{DD} ≤ 3.6 V		—		50		50	ns
			1.6 V ≤ V _{DD} ≤ 3.6 V		—		—		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, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM number (g = 0 to 3)

Remark 2. f_{MCK}: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number,
n: Channel number (mn = 00 to 03, 10 to 13))

(4) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)**(TA = -40 to +85 °C, 1.6 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time Note 5	tkCY2	2.7 V ≤ VDD < 3.6 V	fMCK > 16 MHz	8/fMCK		—		—		ns
			fMCK ≤ 16 MHz	6/fMCK		6/fMCK		6/fMCK		ns
		2.4 V ≤ VDD < 3.6 V		6/fMCK and 500		6/fMCK and 500		6/fMCK and 500		ns
		1.8 V ≤ VDD < 3.6 V		—		6/fMCK and 750		6/fMCK and 750		ns
		1.6 V ≤ VDD < 3.6 V		—		—		6/fMCK and 1500		ns
SCKp high-/low-level width	tkH2, tkL2	2.7 V ≤ VDD ≤ 3.6 V		tkCY2/2 - 8		tkCY2/2 - 8		tkCY2/2 - 8		ns
		1.8 V ≤ VDD ≤ 3.6 V		—		tkCY2/2 - 18		tkCY2/2 - 18		ns
		1.6 V ≤ VDD ≤ 3.6 V		—		—		tkCY1/2 - 66		ns
Slp setup time (to SCKp↑) Note 1	tsiK2	2.7 V ≤ VDD ≤ 3.6 V		1/fMCK + 20		1/fMCK + 30		1/fMCK + 30		ns
		2.4 V ≤ VDD ≤ 3.6 V		1/fMCK + 30		1/fMCK + 30		1/fMCK + 30		ns
		1.8 V ≤ VDD < 3.6 V		—		1/fMCK + 30		1/fMCK + 30		ns
		1.6 V ≤ VDD < 3.6 V		—		—		1/fMCK + 40		ns
Slp hold time (from SCKp↑) Note 2	tksi2	2.4 V ≤ VDD < 3.6 V		1/fMCK + 31		1/fMCK + 31		1/fMCK + 31		ns
		1.8 V ≤ VDD < 3.6 V		—		1/fMCK + 31		1/fMCK + 31		ns
		1.6 V ≤ VDD < 3.6 V		—		—		1/fMCK + 250		ns
Delay time from SCKp↓ to SOp output Note 3	tkSO2	C = 30 pF Note 4	2.7 V ≤ VDD ≤ 3.6 V		2/fMCK + 44		2/fMCK + 110		2/fMCK + 110	ns
			2.4 V ≤ VDD < 3.6 V		2/fMCK + 75		2/fMCK + 110		2/fMCK + 110	ns
			1.8 V ≤ VDD < 3.6 V		—		2/fMCK + 110		2/fMCK + 110	ns
			1.6 V ≤ VDD < 3.6 V		—		—		2/fMCK + 220	ns

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

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

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

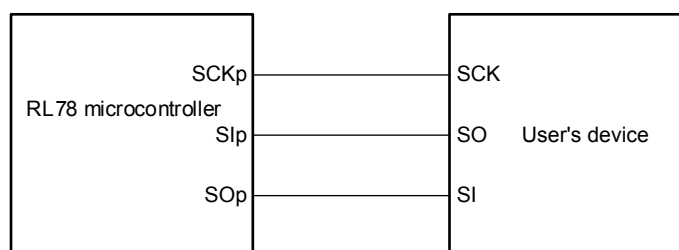
Note 4. C is the load capacitance of the SOp output lines.

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

Caution Select the normal input buffer for the Slp pin and 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, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0 to 3)

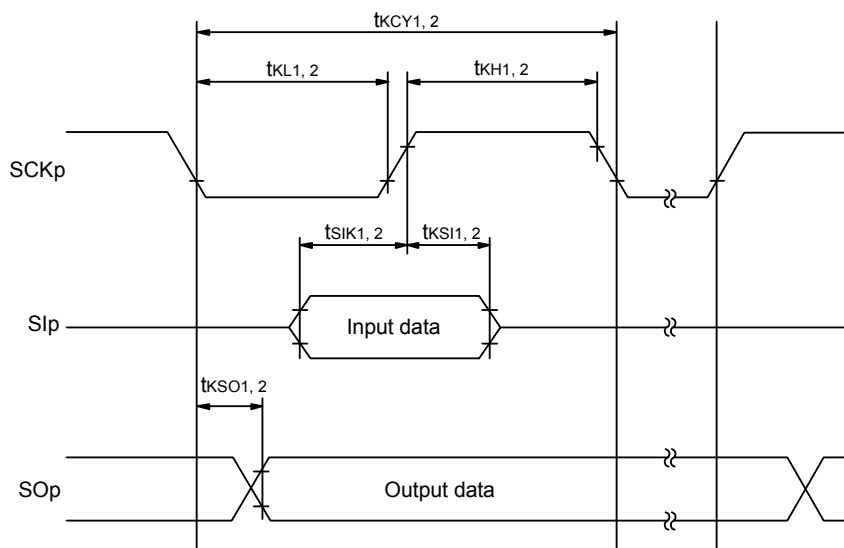
Remark 2. fMCK: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13))

CSI mode connection diagram (during communication at same potential)

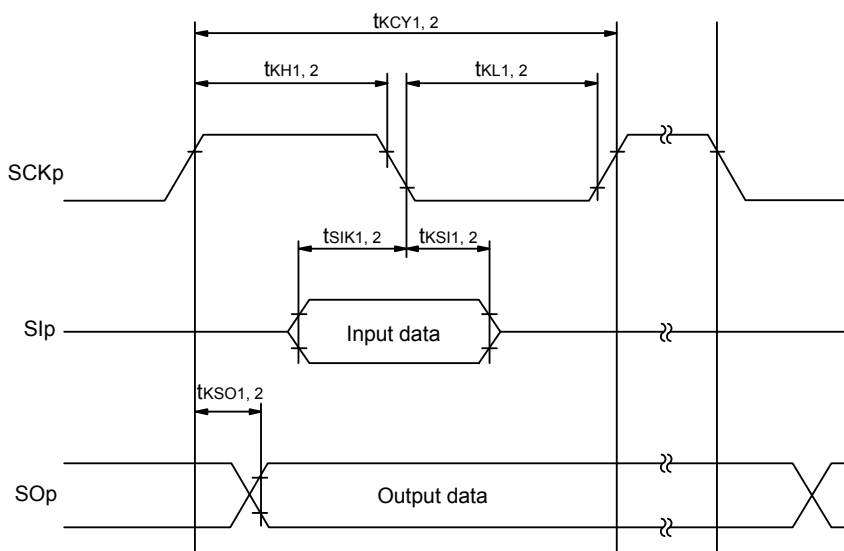
Remark 1. p: CSI number (p = 00, 10, 20, 30)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13)

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



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



Remark 1. p: CSI number (p = 00, 10, 20, 30)

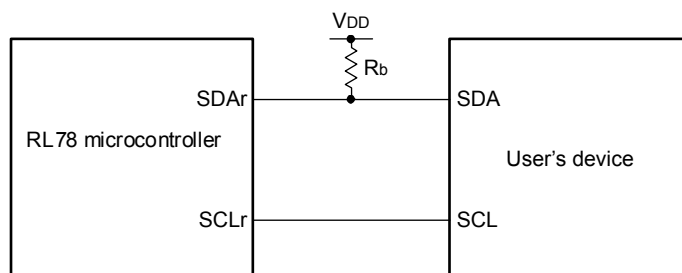
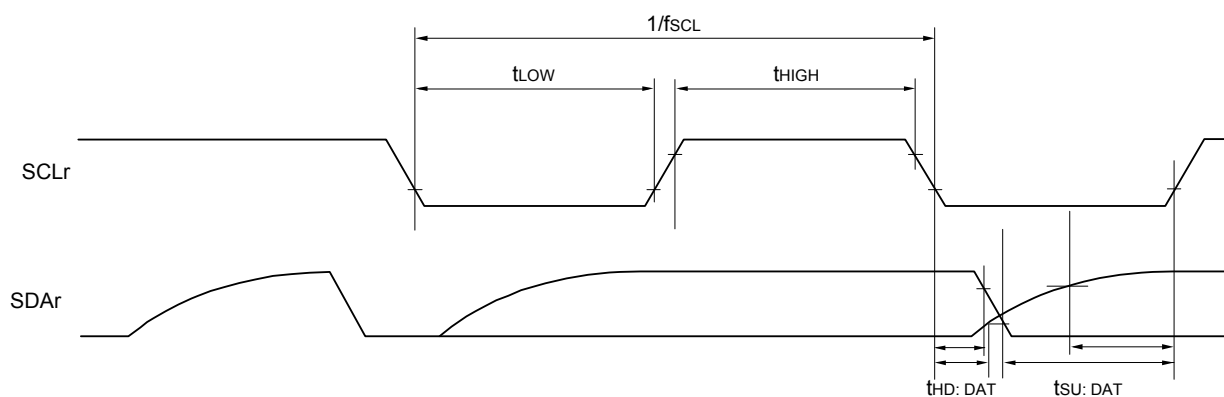
Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13)

(5) During communication at same potential (simplified I²C mode)**(TA = -40 to +85 °C, 1.6 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	fSCL	2.7 V ≤ VDD ≤ 3.6 V, Cb = 50 pF, Rb = 2.7 kΩ		1000 Note 1		400 Note 1		400 Note 1	kHz
		1.8 V ≤ VDD ≤ 3.6 V, Cb = 100 pF, Rb = 3 kΩ		400 Note 1		400 Note 1		400 Note 1	kHz
		1.8 V ≤ VDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ		300 Note 1		300 Note 1		300 Note 1	kHz
		1.6 V ≤ VDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ		—		—		250	kHz
Hold time when SCLr = "L"	tLOW	2.7 V ≤ VDD ≤ 3.6 V, Cb = 50 pF, Rb = 2.7 kΩ	475		1150		1150		ns
		1.8 V ≤ VDD ≤ 3.6 V, Cb = 100 pF, Rb = 3 kΩ	1150		1150		1150		ns
		1.8 V ≤ VDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1550		1550		1550		ns
		1.6 V ≤ VDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—		—		1850		ns
Hold time when SCLr = "H"	tHIGH	2.7 V ≤ VDD ≤ 3.6 V, Cb = 50 pF, Rb = 2.7 kΩ	475		1150		1150		ns
		1.8 V ≤ VDD ≤ 3.6 V, Cb = 100 pF, Rb = 3 kΩ	1150		1150		1150		ns
		1.8 V ≤ VDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1550		1550		1550		ns
		1.6 V ≤ VDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—		—		1850		ns
Data setup time (reception)	tsu: DAT	2.7 V ≤ VDD ≤ 3.6 V, Cb = 50 pF, Rb = 2.7 kΩ	1/fMCK + 85 Note 2		1/fMCK + 145 Note 2		1/fMCK + 145 Note 2		ns
		1.8 V ≤ VDD ≤ 3.6 V, Cb = 100 pF, Rb = 3 kΩ	1/fMCK + 145 Note 2		1/fMCK + 145 Note 2		1/fMCK + 145 Note 2		ns
		1.8 V ≤ VDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	1/fMCK + 230 Note 2		1/fMCK + 230 Note 2		1/fMCK + 230 Note 2		ns
		1.6 V ≤ VDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—		—		1/fMCK + 290 Note 2		ns
Data hold time (transmission)	tHD: DAT	2.7 V ≤ VDD ≤ 3.6 V, Cb = 50 pF, Rb = 2.7 kΩ	0	305	0	305	0	305	ns
		1.8 V ≤ VDD ≤ 3.6 V, Cb = 100 pF, Rb = 3 kΩ	0	355	0	355	0	355	ns
		1.8 V ≤ VDD < 2.7 V, Cb = 100 pF, Rb = 5 kΩ	0	405	0	405	0	405	ns
		1.6 V ≤ VDD < 1.8 V, Cb = 100 pF, Rb = 5 kΩ	—		—		0	405	ns

Note 1. The value must also be equal to or less than fMCK/4.**Note 2.** Set the fMCK 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 (VDD 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

Remark 2. r: IIC number (r = 00, 10, 20, 30), g: PIM number (g = 0 to 3),
h: POM number (h = 0 to 3)

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0, 1),
n: Channel number (n = 0-3), mn = 00 to 03, 10 to 13)

(6) Communication at different potential (1.8 V, 2.5 V) (UART mode)**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate Notes 1, 2		reception	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V			fMCK/6 Note 1		fMCK/6 Note 1	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 4			4.0		1.3	Mbps
			1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V			fMCK/6 Notes 1, 2, 3		fMCK/6 Notes 1, 2, 3	bps
			Theoretical value of the maximum transfer rate fMCK = fCLK Note 4			4.0		1.3	Mbps

Note 1. Transfer rate in the SNOOZE mode is 4,800 bps only.**Note 2.** Use it with VDD ≥ Vb.**Note 3.** The following conditions are required for low voltage interface.

2.4 V ≤ VDD < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ VDD < 2.4 V: MAX. 1.3 Mbps

1.6 V ≤ VDD < 1.8 V: MAX. 0.6 Mbps

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

HS (high-speed main) mode: 24 MHz (2.7 V ≤ VDD ≤ 3.6 V)

16 MHz (2.4 V ≤ VDD ≤ 3.6 V)

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

LV (low-voltage main) mode: 4 MHz (1.6 V ≤ VDD ≤ 3.6 V)

Caution Select the TTL input buffer for the RxDq pin and the N-ch open drain output (VDD 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 to 3), g: PIM and POM number (g = 0 to 3)**Remark 3.** fMCK: Serial array unit operation clock frequency

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

n: Channel number (mn = 00 to 03, 10 to 13)

(6) Communication at different potential (1.8 V, 2.5V) (UART mode)**(TA = -40 to +85 °C, 1.8 ≤ VDD ≤ 3.6 V, VSS = 0 V)****(2/2)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Transfer rate Note 2		transmission	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V		Note 1		Note 1		Note 1	bps
			Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 2.7 kΩ, Vb = 2.3 V		1.2 Note 2		1.2 Note 2		1.2 Note 2	Mbps
			1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V		Notes 3, 4		Notes 3, 4		Notes 3, 4	bps
			Theoretical value of the maximum transfer rate Cb = 50 pF, Rb = 5.5 kΩ, Vb = 1.6 V		0.43 Note 5		0.43 Note 5		0.43 Note 5	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 $2.7\text{ V} \leq V_{DD} < 3.6\text{ V}$ 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 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. Use it with $V_{DD} \geq V_b$.

Note 4. The smaller maximum transfer rate derived by using $f_{MCK}/6$ or the following expression is the valid maximum transfer rate.
Expression for calculating the transfer rate when $1.8\text{ V} \leq V_{DD} < 3.3\text{ V}$ and $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$

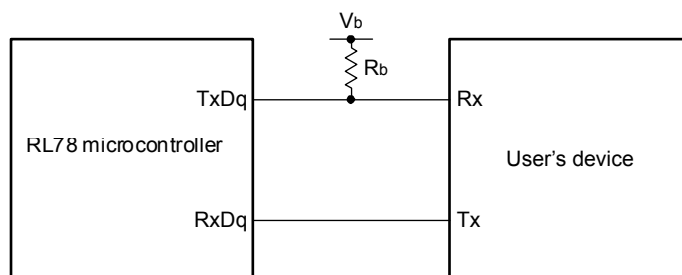
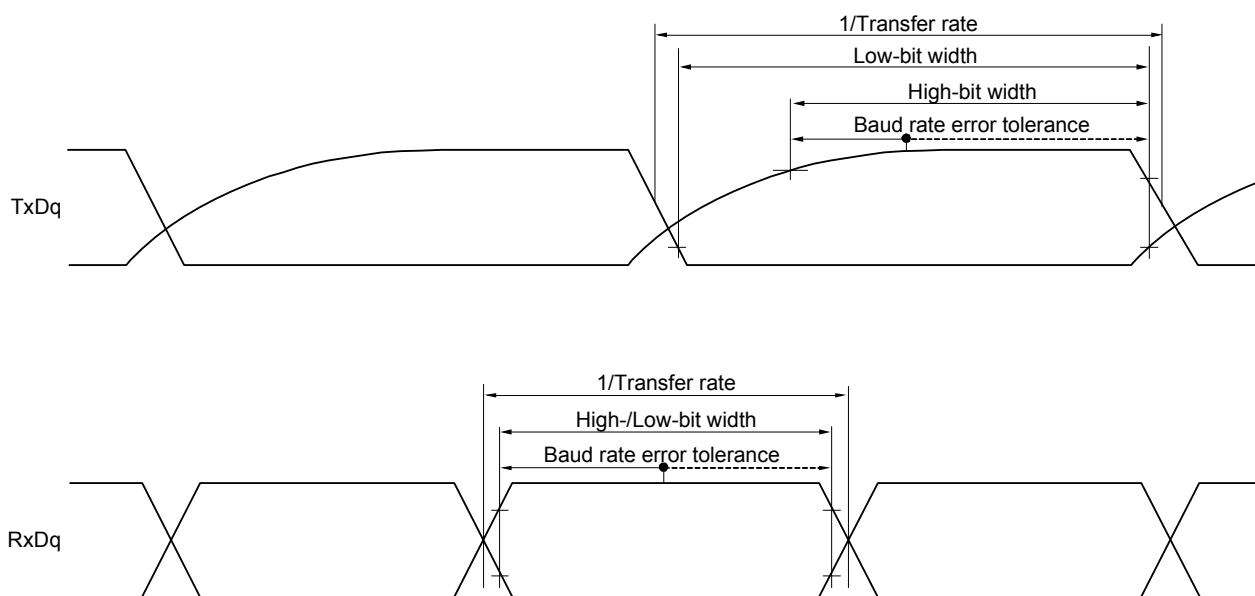
$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \text{ [bps]}$$

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

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

Note 5. This value as an example is calculated when the conditions described in the "Conditions" column are met.
Refer to Note 4 above to calculate the maximum transfer rate under conditions of the customer.

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

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

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

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

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13))

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

(TA = -40 to +85 °C, 2.7 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ f _{CLK} /2 2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ		300		1150		1150		ns
SCKp high-level width	t _{KH1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ		t _{KCY1} /2 - 120		t _{KCY1} /2 - 120		t _{KCY1} /2 - 120		ns
SCKp low-level width	t _{KL1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 1.4 kΩ		t _{KCY1} /2 - 10		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
Slp setup time (to SCKp↑) Note 1	t _{SIK1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ		121		479		479		ns
Slp hold time (from SCKp↑) Note 1	t _{KSI1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 1.4 kΩ		10		10		10		ns
Delay time from SCKp↓ to SOp output Note 1	t _{KSO1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 1.4 kΩ			130		130		130	ns
Slp setup time (to SCKp↓) Note 2	t _{SIK1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ		33		110		110		ns
Slp hold time (from SCKp↓) Note 2	t _{KSI1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ		10		10		10		ns
Delay time from SCKp↑ to SOp output Note 2	t _{KSO1}	2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 20 pF, R _b = 2.7 kΩ			10		10		10	ns

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

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

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

Remark 1. R_b[i]: 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), m: Unit number (m = 0),
n: Channel number (n = 0), g: PIM and POM number (g = 2)

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))

(8) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ f _{CLK} /4 2.7 V ≤ V _{DD} < 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	500 Note		1150		1150		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 1.8 V, C _b = 30 pF, R _b = 5.5 kΩ	1150 Note		1150		1150		ns
SCKp high-level width	t _{KH1}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	t _{KCY1} /2 - 170		t _{KCY1} /2 - 170		t _{KCY1} /2 - 170		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 30 pF, R _b = 5.5 kΩ	t _{KCY1} /2 - 458		t _{KCY1} /2 - 458		t _{KCY1} /2 - 458		ns
SCKp low-level width	t _{KL1}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V, C _b = 30 pF, R _b = 2.7 kΩ	t _{KCY1} /2 - 18		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V, C _b = 30 pF, R _b = 5.5 kΩ	t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		t _{KCY1} /2 - 50		ns

Note Use it with V_{DD} ≥ V_b.

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

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

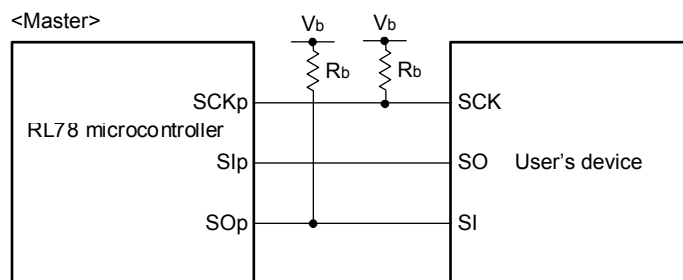
(8) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (master mode, SCKp... internal clock output)**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)****(2/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
Slp setup time (to SCKp↑) Note 1	tSIK1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	177		479		479		ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	479		479		479		ns
Slp hold time (from SCKp↑) Note 1	tKSI1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	19		19		19		ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	19		19		19		ns
Delay time from SCKp↓ to SOp output Note 1	tKSO1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ		195		195		195	ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ		483		483		483	ns
Slp setup time (to SCKp↓) Note 2	tSIK1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	44		110		110		ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	110		110		110		ns
Slp hold time (from SCKp↓) Note 2	tKSI1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ	19		19		19		ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ	19		19		19		ns
Delay time from SCKp↑ to SOp output Note 2	tKSO1	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 30 pF, Rb = 2.7 kΩ		25		25		25	ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 3, Cb = 30 pF, Rb = 5.5 kΩ		25		25		25	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 VDD ≥ Vb.

Caution Select the TTL input buffer for the Slp pin and the N-ch open drain output (VDD 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.)

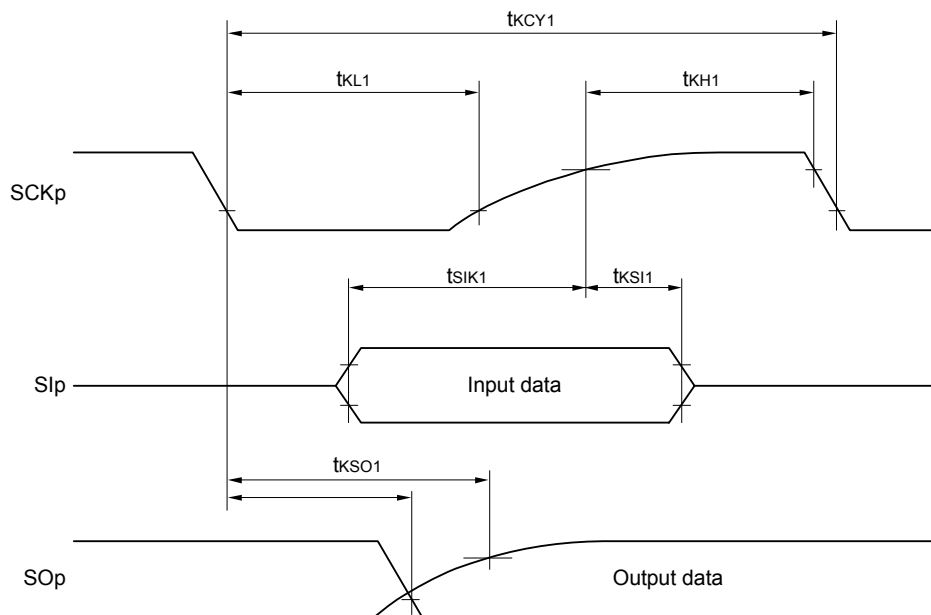
CSI mode connection diagram (during communication at different potential)

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

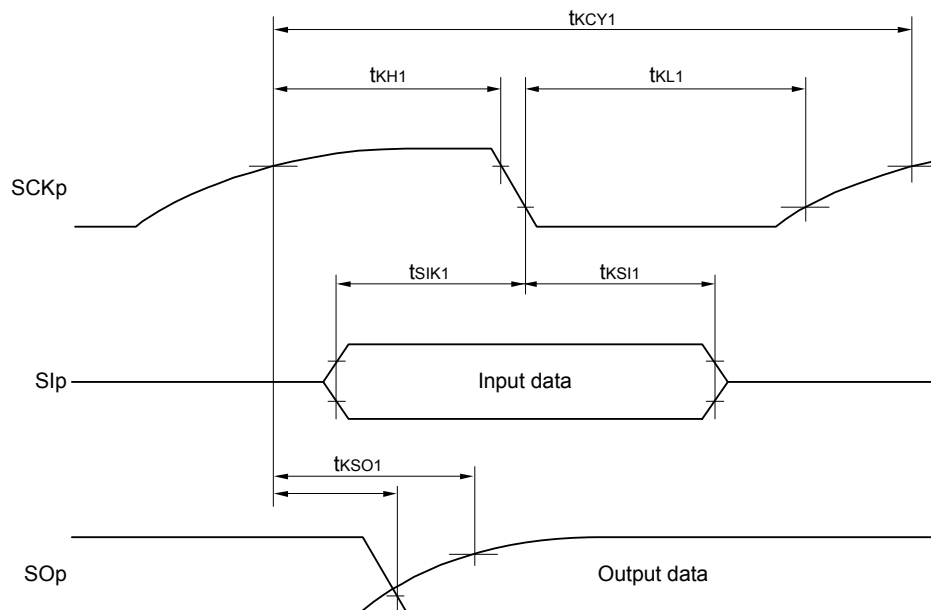
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0 to 3)

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))

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



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



Remark p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM and POM number (g = 0 to 3)

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

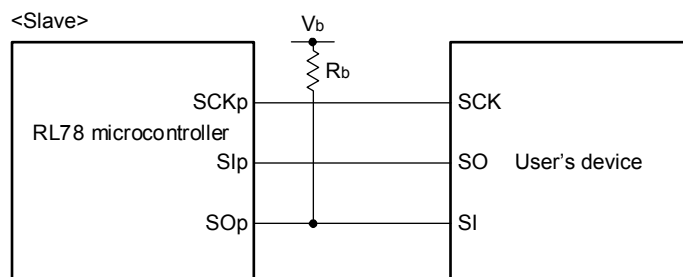
(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCKp cycle time ^{Note 1}	t _{KCY2}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V	20 MHz < f _{MCK} ≤ 24 MHz	16/f _{MCK}		—		—		ns
			16 MHz < f _{MCK} ≤ 20 MHz	14/f _{MCK}		—		—		ns
			8 MHz < f _{MCK} ≤ 16 MHz	12/f _{MCK}		—		—		ns
			4 MHz < f _{MCK} ≤ 8 MHz	8/f _{MCK}		16/f _{MCK}		—		ns
			f _{MCK} ≤ 4 MHz	6/f _{MCK}		10/f _{MCK}		10/f _{MCK}		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2}	20 MHz < f _{MCK} ≤ 24 MHz	36/f _{MCK}		—		—		ns
			16 MHz < f _{MCK} ≤ 20 MHz	32/f _{MCK}		—		—		ns
			8 MHz < f _{MCK} ≤ 16 MHz	26/f _{MCK}		—		—		ns
			4 MHz < f _{MCK} ≤ 8 MHz	16/f _{MCK}		16/f _{MCK}		—		ns
			f _{MCK} ≤ 4 MHz	10/f _{MCK}		10/f _{MCK}		10/f _{MCK}		ns
SCKp high-/low-level width	t _{KH2} , t _{KL2}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V		t _{KCY2} /2 - 18		t _{KCY2} /2 - 50		t _{KCY2} /2 - 50		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2}		t _{KCY2} /2 - 50		t _{KCY2} /2 - 50		t _{KCY2} /2 - 50		ns
Slp setup time (to SCKp↑) ^{Note 3}	t _{SIK2}	2.7 V ≤ V _{DD} ≤ 3.6 V		1/f _{MCK} + 20		1/f _{MCK} + 30		1/f _{MCK} + 30		ns
		1.8 V ≤ V _{DD} < 3.3 V		1/f _{MCK} + 30		1/f _{MCK} + 30		1/f _{MCK} + 30		ns
Slp hold time (from SCKp↑) ^{Note 4}	t _{KSI2}			1/f _{MCK} + 31		1/f _{MCK} + 31		1/f _{MCK} + 31		ns
Delay time from SCKp↓ to SOp output ^{Note 5}	t _{KSO2}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V C _b = 30 pF, R _b = 2.7 kΩ		2/f _{MCK} + 214		2/f _{MCK} + 573		2/f _{MCK} + 573		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V ^{Note 2} C _b = 30 pF, R _b = 5.5 kΩ		2/f _{MCK} + 573		2/f _{MCK} + 573		2/f _{MCK} + 573		ns

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

- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** Use it with $V_{DD} \geq V_b$.
- Note 3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes "to SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 4.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 5.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes "from SCKp↑" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Caution** Select the TTL input buffer for the SIp pin and SCKp pin and the N-ch open drain output (V_{DD} tolerance) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

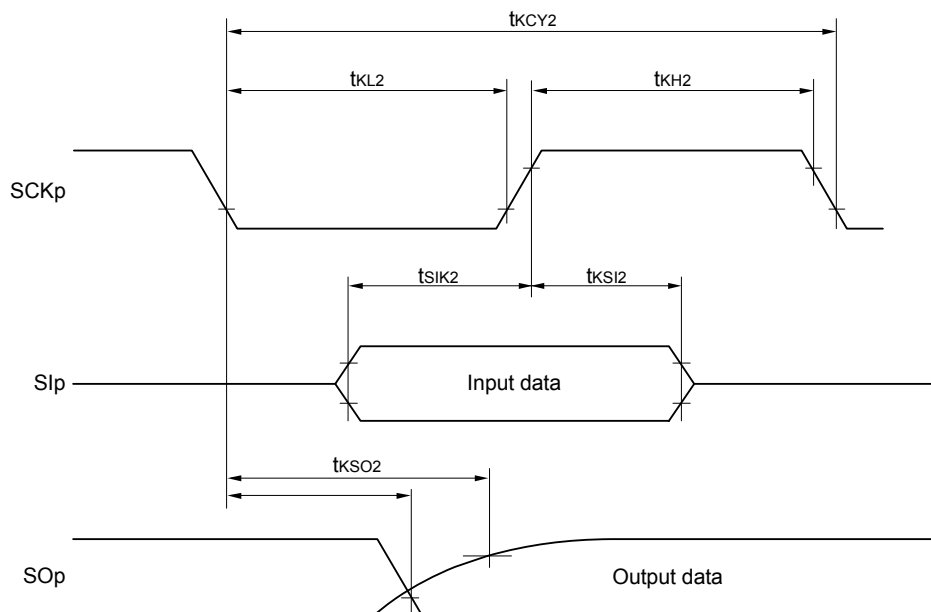
CSI mode connection diagram (during communication at different potential)

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

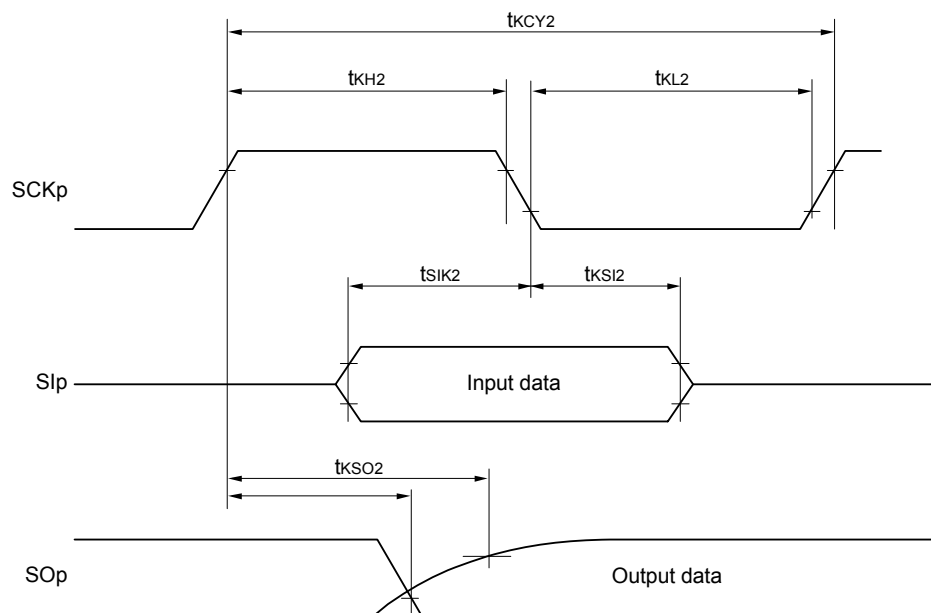
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0 to 3)

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, 02, 10, 12))

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



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



Remark p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1),
 n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0 to 3)

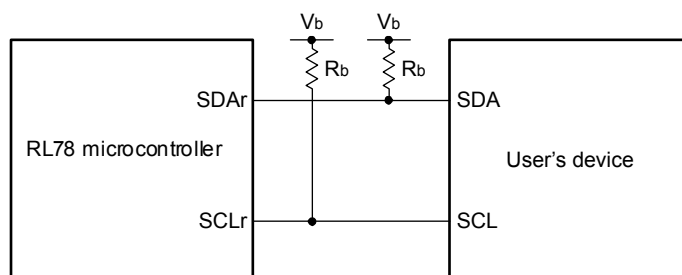
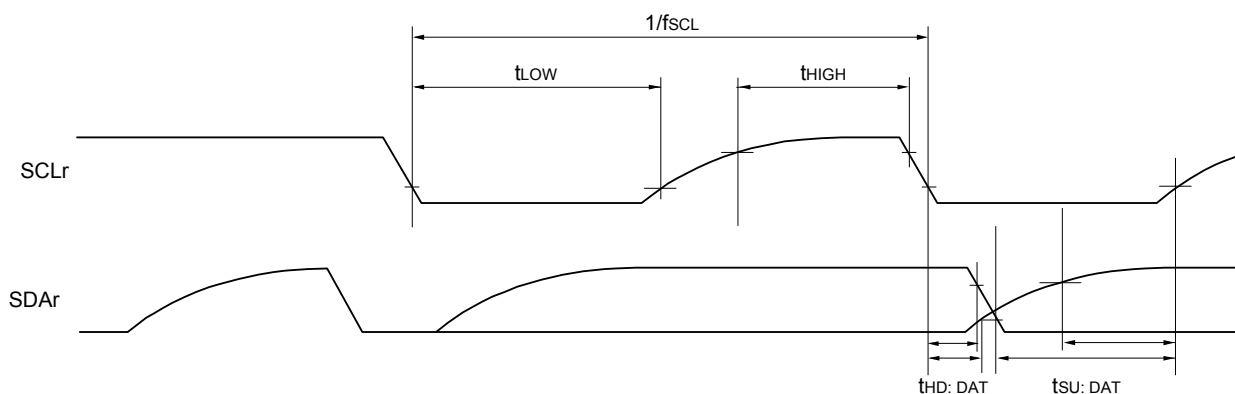
(10) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode)**(TA = -40 to +85 °C, 1.8 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f _{SCL}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ		1000 Note 1		300 Note 1		300 Note 1	kHz
		2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ		400 Note 1		300 Note 1		300 Note 1	kHz
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 2, C _b = 100 pF, R _b = 5.5 kΩ		400 Note 1		300 Note 1		300 Note 1	kHz
Hold time when SCLr = "L"	t _{LOW}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ	475		1550		1550		ns
		2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ	1150		1550		1550		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 2, C _b = 100 pF, R _b = 5.5 kΩ	1550		1550		1550		ns
Hold time when SCLr = "H"	t _{HIGH}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ	200		610		610		ns
		2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ	600		610		610		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 2, C _b = 100 pF, R _b = 5.5 kΩ	610		610		610		ns
Data setup time (reception)	t _{SD:DAT}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ	1/f _{MCK} + 135 Note 3		1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		ns
		2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ	1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 2, C _b = 100 pF, R _b = 5.5 kΩ	1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		1/f _{MCK} + 190 Note 3		ns
Data hold time (transmission)	t _{HD:DAT}	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 50 pF, R _b = 2.7 kΩ	0	305	0	305	0	305	ns
		2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b < 2.7 V, C _b = 100 pF, R _b = 2.7 kΩ	0	355	0	355	0	355	ns
		1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V Note 2, C _b = 100 pF, R _b = 5.5 kΩ	0	405	0	405	0	405	ns

Note 1. The value must also be equal to or less than f_{MCK}/4.**Note 2.** Use it with V_{DD} ≥ 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 (V_{DD} tolerance) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

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

Remark 1. $R_b[\Omega]$: 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, 10, 20, 30), g: PIM, POM number (g = 0 to 3)

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0, 1),
n: Channel number (n = 0, 2), mn = 00, 02, 10, 12)

2.5.2 Serial interface IICA

(1) I²C standard mode

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

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	fSCL	Standard mode: fCLK ≥ 1 MHz	2.7 V ≤ VDD ≤ 3.6 V	0	100	0	100	0	100	kHz
			1.8 V ≤ VDD ≤ 3.6 V	—	—	0	100	0	100	kHz
			1.6 V ≤ VDD ≤ 3.6 V	—	—	—	—	0	100	kHz
Setup time of restart condition	tSU: STA	2.7 V ≤ VDD ≤ 3.6 V		4.7		4.7		4.7		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.7		4.7		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		4.7		μs
Hold time ^{Note 1}	tHD: STA	2.7 V ≤ VDD ≤ 3.6 V		4.0		4.0		4.0		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.0		4.0		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		4.0		μs
Hold time when SCLA0 = “L”	tLOW	2.7 V ≤ VDD ≤ 3.6 V		4.7		4.7		4.7		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.7		4.7		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		4.7		μs
Hold time when SCLA0 = “H”	tHIGH	2.7 V ≤ VDD ≤ 3.6 V		4.0		4.0		4.0		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.0		4.0		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		4.0		μs
Data setup time (reception)	tSU: DAT	2.7 V ≤ VDD ≤ 3.6 V		250		250		250		ns
		1.8 V ≤ VDD ≤ 3.6 V		—		250		250		ns
		1.6 V ≤ VDD ≤ 3.6 V		—		—		250		ns
Data hold time (transmission) ^{Note 2}	tHD: DAT	2.7 V ≤ VDD ≤ 3.6 V		0	3.45	0	3.45	0	3.45	μs
		1.8 V ≤ VDD ≤ 3.6 V		—	—	0	3.45	0	3.45	μs
		1.6 V ≤ VDD ≤ 3.6 V		—	—	—	—	0	3.45	μs
Setup time of stop condition	tSU: STO	2.7 V ≤ VDD ≤ 3.6 V		4.0		4.0		4.0		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.0		4.0		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		4.0		μs
Bus-free time	tBUF	2.7 V ≤ VDD ≤ 3.6 V		4.7		4.7		4.7		μs
		1.8 V ≤ VDD ≤ 3.6 V		—		4.7		4.7		μs
		1.6 V ≤ VDD ≤ 3.6 V		—		—		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 wait state is inserted in the ACK (acknowledge) timing.

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

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

(2) I²C fast mode

(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	fSCL	Fast mode: fCLK ≥ 3.5 MHz	2.7 V ≤ VDD ≤ 3.6 V	0	400	0	400	0	400	kHz
			1.8 V ≤ VDD ≤ 3.6 V	0	400	0	400	0	400	kHz
Setup time of restart condition	tSU: STA	2.7 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
		1.8 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
Hold time ^{Note 1}	tHD: STA	2.7 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
		1.8 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
Hold time when SCLA0 = "L"	tLOW	2.7 V ≤ VDD ≤ 3.6 V		1.3		1.3		1.3		μs
		1.8 V ≤ VDD ≤ 3.6 V		1.3		1.3		1.3		μs
Hold time when SCLA0 = "H"	tHIGH	2.7 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
		1.8 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
Data setup time (reception)	tSU: DAT	2.7 V ≤ VDD ≤ 3.6 V		100		100		100		ns
		1.8 V ≤ VDD ≤ 3.6 V		100		100		100		ns
Data hold time (transmission) ^{Note 2}	tHD: DAT	2.7 V ≤ VDD ≤ 3.6 V		0	0.9	0	0.9	0	0.9	μs
		1.8 V ≤ VDD ≤ 3.6 V		0	0.9	0	0.9	0	0.9	μs
Setup time of stop condition	tSU: STO	2.7 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
		1.8 V ≤ VDD ≤ 3.6 V		0.6		0.6		0.6		μs
Bus-free time	tBUF	2.7 V ≤ VDD ≤ 3.6 V		1.3		1.3		1.3		μs
		1.8 V ≤ VDD ≤ 3.6 V		1.3		1.3		1.3		μs

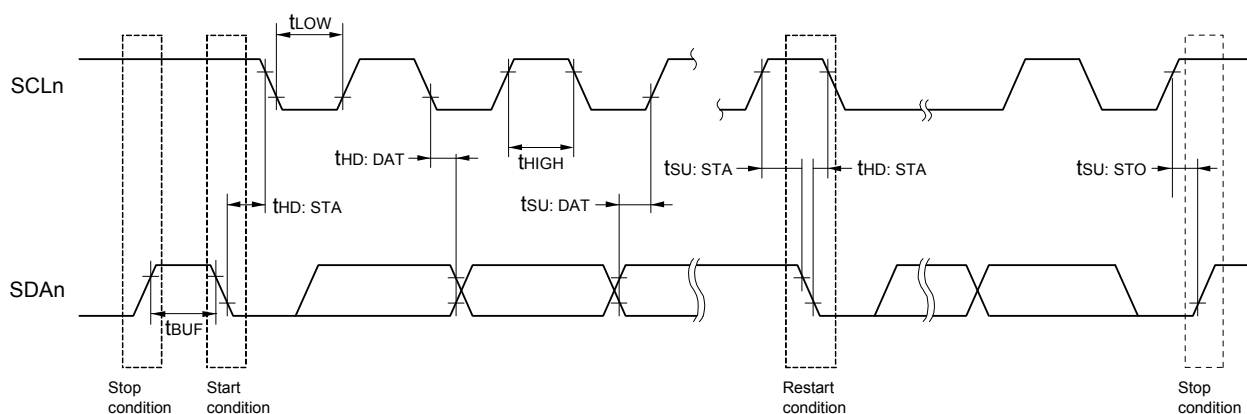
Note 1. The first clock pulse is generated after this period when the start/restart condition is detected.**Note 2.** The maximum value (MAX.) of tHD: DAT is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.**Remark** The maximum value of C_b (communication line capacitance) 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, 2.7 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		LV (low-voltage main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	fSCL	Fast mode plus: fCLK ≥ 10 MHz	2.7 V ≤ VDD ≤ 3.6 V	0	1000	—	—	—	—	kHz
Setup time of restart condition	tSU: STA	2.7 V ≤ VDD ≤ 3.6 V		0.26		—	—	—	—	μs
Hold time Note 1	tHD: STA	2.7 V ≤ VDD ≤ 3.6 V		0.26		—	—	—	—	μs
Hold time when SCLA0 = "L"	tLOW	2.7 V ≤ VDD ≤ 3.6 V		0.5		—	—	—	—	μs
Hold time when SCLA0 = "H"	tHIGH	2.7 V ≤ VDD ≤ 3.6 V		0.26		—	—	—	—	μs
Data setup time (reception)	tSU: DAT	2.7 V ≤ VDD ≤ 3.6 V		50		—	—	—	—	ns
Data hold time (transmission) Note 2	tHD: DAT	2.7 V ≤ VDD ≤ 3.6 V		0	0.45	—	—	—	—	μs
Setup time of stop condition	tSU: STO	2.7 V ≤ VDD ≤ 3.6 V		0.26		—	—	—	—	μs
Bus-free time	tBUF	2.7 V ≤ VDD ≤ 3.6 V		0.5		—	—	—	—	μs

Note 1. The first clock pulse is generated after this period when the start/restart condition is detected.**Note 2.** The maximum value (MAX.) of tHD: DAT is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.**Remark** The maximum value of Cb (communication line capacitance) and the value of Rb (communication line pull-up resistor) at that time in each mode are as follows.

Fast mode plus: Cb = 120 pF, Rb = 1.1 kΩ

I²C serial transfer timing

2.5.3 USB

(1) Electrical specifications

(TA = -40 to +85 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)

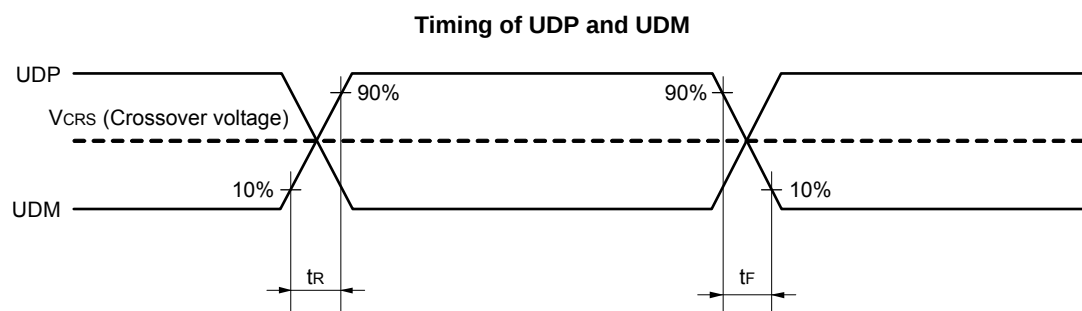
Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
UREGC	UREGC output voltage characteristic	UREGC	UVBUS = 4.0 to 5.5 V, PXXCON = VDDUSBE = 1	3.0	3.3	3.6	V
UVBUS	UVBUS input voltage characteristic	UVBUS	Function	4.35 (4.02 Note)	5.00	5.25	V

Note Value of instantaneous voltage

(TA = -40 to +85 °C, 4.35 V ≤ UVBUS ≤ 5.25 V, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)

Parameter			Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input characteristic (FS/LS receiver)	Input voltage		V _{IH}		2.0			V
			V _{IL}				0.8	V
	Difference input sensitivity		V _{DI}	UDP voltage - UDM voltage	0.2			V
	Difference common mode range		V _{CM}		0.8		2.5	V
Output characteristic (FS driver)	Output voltage		V _{OH}	I _{OH} = -200 μA	2.8		3.6	V
			V _{OL}	I _{OL} = 2 mA	0		0.3	V
	Transition time	Rising	t _{FR}	Rising: From 10% to 90% of amplitude, Falling: From 90% to 10% of amplitude, CL = 50 pF	4		20	ns
		Falling	t _{FF}		4		20	ns
	Matching (TFR/TFF)		V _{FRFM}		90		111.1	%
	Crossover voltage		V _{FCRS}		1.3		2.0	V
	Output Impedance		Z _{DRV}		28		44	Ω
Output characteristic (LS driver)	Output voltage		V _{OH}		2.8		3.6	V
			V _{OL}		0		0.3	V
	Transition time	Rising	t _{LR}	Rising: From 10% to 90% of amplitude, Falling: From 90% to 10% of amplitude, CL = 250 pF to 750 pF The UDP and UDM pins are individually pulled down via 15 kΩ	75		300	ns
		Falling	t _{LF}		75		300	ns
	Matching (TFR/TFF) Note		V _{LTFM}		80		125	%
	Crossover voltage Note		V _{LCRS}		1.3		2.0	V
Pull-up, Pull-down	Pull-down resistor		R _{PD}		14.25		24.80	kΩ
	Pull-up resistor	Idle	R _{PUI}		0.9		1.575	kΩ
		Reception	R _{PUA}		1.425		3.09	kΩ
UVBUS	UVBUS pull-down resistor		R _{VBUS}	UVBUS voltage = 5.5 V		1000		kΩ
	UVBUS input voltage		V _{IH}		3.20			V
			V _{IL}				0.8	V

Note Excludes the first signal transition from the idle state.

**(2) BC standard**

(TA = -40 to +85 °C, 4.35 V ≤ UVBUS ≤ 5.25 V, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
USB standard BC1.2	UDP sink current	IDP_SINK		25	100	175	μA
	UDM sink current	IDM_SINK		25	100	175	μA
	DCD source current	IDP_SRC		7	10	13	μA
	Data detection voltage	VDAT_REF		0.25	0.325	0.4	V
	UDP source voltage	VDP_SRC	Output current 250 μA	0.5	0.6	0.7	V
	UDM source voltage	VDM_SRC	Output current 250 μA	0.5	0.6	0.7	V

(3) BC option standard**(TA = -40 to +85 °C, 4.35 V ≤ UVBUS ≤ 5.25 V, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)**

Parameter			Symbol	Conditions	MIN.	TYP.	MAX.	Unit
UDP/UDM input reference voltage (UVBUS divider ratio) (Function)	VDSELi [3: 0] (i = 0, 1)	0000	VDDDET0		27	32	37	%UVBUS
		0001	VDDDET1		29	34	39	%UVBUS
		0010	VDDDET2		32	37	42	%UVBUS
		0011	VDDDET3		35	40	45	%UVBUS
		0100	VDDDET4		38	43	48	%UVBUS
		0101	VDDDET5		41	46	51	%UVBUS
		0110	VDDDET6		44	49	54	%UVBUS
		0111	VDDDET7		47	52	57	%UVBUS
		1000	VDDDET8		51	56	61	%UVBUS
		1001	VDDDET9		55	60	65	%UVBUS
		1010	VDDDET10		59	64	69	%UVBUS
		1011	VDDDET11		63	68	73	%UVBUS
		1100	VDDDET12		67	72	73	%UVBUS
		1101	VDDDET13		71	76	81	%UVBUS
		1110	VDDDET14		75	80	85	%UVBUS
		1111	VDDDET15		79	84	89	%UVBUS

2.6 Analog Characteristics

2.6.1 A/D converter characteristics

Classification of A/D converter characteristics

Reference Voltage Input Channel	Reference voltage (+) = AVREFP Reference voltage (-) = AVREFM	Reference voltage (+) = AVDD Reference voltage (-) = AVSS	Reference voltage (+) = Internal reference voltage Reference voltage (-) = AVSS
High-accuracy channel; ANI0 to ANI6 (input buffer power supply: AVDD)	Refer to 2.6.1 (1). Refer to 2.6.1 (2).	Refer to 2.6.1 (3).	Refer to 2.6.1 (6).
Standard channel; ANI16 to ANI21 (input buffer power supply: VDD)	Refer to 2.6.1 (4).	Refer to 2.6.1 (5).	
Internal reference voltage, Temperature sensor output voltage	Refer to 2.6.1 (4).	Refer to 2.6.1 (5).	—

(1) When reference voltage (+) = AVREFP/ANI0 (ADREFP1 = 0, ADREFP0 = 1), reference voltage (-) = AVREFM/ANI1 (ADREFM = 1), target for conversion: ANI2 to ANI6

<R>

(TA = -40 to +85 °C, 2.4 V ≤ AVREFP ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V, AVSS = 0 V, reference voltage (+) = AVREFP, reference voltage (-) = AVREFM = 0 V, HALT mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES				12	bit
Overall error Notes 1, 2, 3	AINL	12-bit resolution		±1.7	±3.3	LSB
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	3.375			μs
Zero-scale error Notes 1, 2, 3	Ezs	12-bit resolution		±1.3	±3.2	LSB
Full-scale error Notes 1, 2, 3	EFS	12-bit resolution		±0.7	±2.9	LSB
Integral linearity error Notes 1, 2, 3	ILE	12-bit resolution		±1.0	±1.4	LSB
Differential linearity error Notes 1, 2, 3	DLE	12-bit resolution		±0.9	±1.2	LSB
Analog input voltage	VAIN		0		AVREFP	V

Note 1. TYP. Value is the average value at AVDD = AVREFP = 3 V and TA = 25 °C. MAX. value is the average value ±3σ at normalized distribution.

Note 2. These values are the results of characteristic evaluation and are not checked for shipment.

Note 3. Excludes quantization error (±1/2 LSB).

Caution 1. Route the wiring so that noise will not be superimposed on each power line and ground line, and insert a capacitor to suppress noise.

In addition, separate the reference voltage line of AVREFP from the other power lines to keep it free from the influences of noise.

Caution 2. During A/D conversion, keep a pulse, such as a digital signal, that abruptly changes its level from being input to or output from the pins adjacent to the converter pins and P150 to P156.

(2) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), conversion target: $ANI2$ to $ANI6$

(TA = -40 to +85 °C, $1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (-) = $AV_{REFM} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	8		12	bit
			$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	8		10 Note 1	
			$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	8 Note 2			
Overall error Note 3	AINL	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±6.0	LSB
		10-bit resolution	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±2.5	
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	3.375			μs
		ADTYP = 0, 10-bit resolution Note 1	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	6.75			
		ADTYP = 0, 8-bit resolution Note 2	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	13.5			
		ADTYP = 1, 8-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	2.5625			
			$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	5.125			
			$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	10.25			
Zero-scale error Note 3	Ezs	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±4.5	LSB
		10-bit resolution	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±4.5	
		8-bit resolution	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±2.0	
Full-scale error Note 3	Efs	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±4.5	LSB
		10-bit resolution	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±4.5	
		8-bit resolution	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±2.0	
Integral linearity error Note 3	ILE	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±2.0	LSB
		10-bit resolution	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±1.5	
		8-bit resolution	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±1.0	
Differential linearity error Note 3	DLE	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±1.5	LSB
		10-bit resolution	$1.8\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±1.5	
		8-bit resolution	$1.6\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±1.0	
Analog input voltage	VAIN			0		AVREFP	V

Note 1. Cannot be used for lower 2 bit of ADCR register

Note 2. Cannot be used for lower 4 bit of ADCR register

Note 3. Excludes quantization error ($\pm 1/2$ LSB).

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

(3) When reference voltage (+) = AVDD (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = AVSS (ADREFM = 0), conversion target: ANI0 to ANI6

(TA = -40 to +85 °C, 1.6 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V, AVSS = 0 V, Reference voltage (+) = AVDD, Reference voltage (-) = AVSS = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		2.4 V ≤ AV _{DD} ≤ 3.6 V	8		12	bit
			1.8 V ≤ AV _{DD} ≤ 3.6 V	8		10 Note 1	
			1.6 V ≤ AV _{DD} ≤ 3.6 V	8 Note 2			
Overall error Note 3	AINL	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±7.5	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±3.0	
Conversion time	t _{CONV}	ADTYP = 0, 12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	3.375			μs
		ADTYP = 0, 10-bit resolution Note 1	1.8 V ≤ AV _{DD} ≤ 3.6 V	6.75			
		ADTYP = 0, 8-bit resolution Note 2	1.6 V ≤ AV _{DD} ≤ 3.6 V	13.5			
		ADTYP = 1, 8-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	2.5625			
			1.8 V ≤ AV _{DD} ≤ 3.6 V	5.125			
			1.6 V ≤ AV _{DD} ≤ 3.6 V	10.25			
Zero-scale error Note 3	E _{ZS}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±6.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
Full-scale error Note 3	E _{FS}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±6.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
Integral linearity error Note 3	ILE	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±3.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±1.5	
Differential linearity error Note 3	DLE	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±2.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±1.5	
Analog input voltage	V _{AIN}	ANI0 to ANI6		0		AV _{DD}	V

Note 1. Cannot be used for lower 2 bit of ADCR register

Note 2. Cannot be used for lower 4 bit of ADCR register

Note 3. Excludes quantization error (±1/2 LSB).

Caution Always use AVDD pin with the same potential as the VDD pin.

- (4) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), conversion target: ANI16 to ANI21, internal reference voltage, temperature sensor output voltage

(TA = -40 to +85 °C, $1.6\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$,

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		10 Note 1	
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8 Note 2			
Overall error ^{Note 3}	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±7.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.5	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
		ADTYP = 0, 10-bit resolution ^{Note 1}	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	9.5			
		ADTYP = 0, 8-bit resolution ^{Note 2}	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	57.5			
		ADTYP = 1, 8-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	3.3125			
			$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	7.875			
			$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	54.25			
Zero-scale error ^{Note 3}	Ezs	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
Full-scale error ^{Note 3}	Efs	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±5.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.5	
Integral linearity error ^{Note 3}	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±3.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
Differential linearity error ^{Note 3}	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	LSB
		10-bit resolution	$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±2.0	
		8-bit resolution	$1.6\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			±1.5	
Analog input voltage	VAIN			0		AVREFP	V
		Internal reference voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		VBGR ^{Note 4}			
		Temperature sensor output voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		VTMP25 ^{Note 4}			

Note 1. Cannot be used for lower 2 bits of ADCR register

Note 2. Cannot be used for lower 4 bits of ADCR register

Note 3. Excludes quantization error ($\pm 1/2$ LSB).

Note 4. Refer to 2.6.2 Temperature sensor, internal reference voltage output characteristics.

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

(5) When reference voltage (+) = AVDD (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = AVSS (ADREFM = 0), conversion target: ANI16 to ANI21, internal reference voltage, temperature sensor output voltage

(TA = -40 to +85 °C, 1.6 V ≤ VDD ≤ 3.6 V, 1.6 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V, AVSS = 0 V, Reference voltage (+) = AVDD, Reference voltage (-) = AVSS = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	Res		2.4 V ≤ AV _{DD} ≤ 3.6 V	8		12	bit
			1.8 V ≤ AV _{DD} ≤ 3.6 V	8		10 Note 1	
			1.6 V ≤ AV _{DD} ≤ 3.6 V	8 Note 2			
Overall error Note 3	AINL	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±8.5	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±6.0	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±3.5	
Conversion time	t _{CONV}	ADTYP = 0, 12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	4.125			μs
		ADTYP = 0, 10-bit resolution Note 1	1.8 V ≤ AV _{DD} ≤ 3.6 V	9.5			
		ADTYP = 0, 8-bit resolution Note 2	1.6 V ≤ AV _{DD} ≤ 3.6 V	57.5			
		ADTYP = 1, 8-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V	3.3125			
			1.8 V ≤ AV _{DD} ≤ 3.6 V	7.875			
			1.6 V ≤ AV _{DD} ≤ 3.6 V	54.25			
Zero-scale error Note 3	E _{zs}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±8.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±3.0	
Full-scale error Note 3	E _{fs}	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±8.0	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±5.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±3.0	
Integral linearity error Note 3	ILE	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±3.5	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±1.5	
Differential linearity error Note 3	DLE	12-bit resolution	2.4 V ≤ AV _{DD} ≤ 3.6 V			±2.5	LSB
		10-bit resolution	1.8 V ≤ AV _{DD} ≤ 3.6 V			±2.5	
		8-bit resolution	1.6 V ≤ AV _{DD} ≤ 3.6 V			±2.0	
Analog input voltage	V _{AIN}			0		AV _{DD}	V
		Internal reference voltage (2.4 V ≤ V _{DD} ≤ 3.6 V, HS (high-speed main) mode)		V _{BGR} Note 4			
		Temperature sensor output voltage (2.4 V ≤ V _{DD} ≤ 3.6 V, HS (high-speed main) mode)		V _{TMP25} Note 4			

Note 1. Cannot be used for lower 2 bits of ADCR register

Note 2. Cannot be used for lower 4 bits of ADCR register

Note 3. Excludes quantization error (±1/2 LSB).

Note 4. Refer to 2.6.2 Temperature sensor, internal reference voltage output characteristics.

Caution Always use AVDD pin with the same potential as the VDD pin.

(6) When reference voltage (+) = Internal reference voltage (1.45 V) (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVss (ADREFM = 0), conversion target: ANI0 to ANI6, ANI16 to ANI21

(TA = -40 to +85 °C, 2.4 V ≤ VDD ≤ 3.6 V, 1.6 V ≤ VDD, 1.6 V ≤ AVDD = VDD, VSS = 0 V, AVSS = 0 V, Reference voltage (+) = internal reference voltage, Reference voltage (-) = AVss = 0 V, HS (high-speed main) mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES		8			bit
Conversion time	tCONV	8-bit resolution	16			μs
Zero-scale error ^{Note}	EZS	8-bit resolution			±4.0	LSB
Integral linearity error ^{Note}	ILE	8-bit resolution			±2.0	LSB
Differential linearity error ^{Note}	DLE	8-bit resolution			±2.5	LSB
Reference voltage (+)	AVREF(+)	= Internal reference voltage (VBGR)	1.38	1.45	1.5	V
Analog input voltage	VAIN		0		VBGR	V

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

Caution Always use AVDD pin with the same potential as the VDD pin.

2.6.2 Temperature sensor, internal reference voltage output characteristics

(TA = -40 to +85 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V (HS (high-speed main) mode))

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

2.6.3 D/A converter characteristics

(TA = -40 to +85 °C, 1.6 V ≤ VDD ≤ 3.6 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 ≤ 3.6 V			±2.5	LSB
		Rload = 8 MΩ	1.8 V ≤ VDD ≤ 3.6 V			±2.5	LSB
Settling time	tSET	Cload = 20 pF	2.7 V ≤ VDD ≤ 3.6 V			3	μs
			1.6 V ≤ VDD < 2.7 V			6	μs

2.6.4 Comparator

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage range	Ivref		0		VDD - 1.4	V
	Ivcmp		-0.3		VDD + 0.3	V
Output delay	td	VDD = 3.0 V Input slew rate > 50 mV/μs High-speed comparator mode, standard mode			1.2	μs
		High-speed comparator mode, window mode			2.0	μs
		Low-speed comparator mode, standard mode		3	5.0	μs
High-electric-potential judgment voltage	VTW+	High-speed comparator mode, window mode		0.76 VDD		V
Low-electric-potential judgment voltage	VTW-	High-speed comparator mode, window mode		0.24 VDD		V
Operation stabilization wait time	tcMP		100			μs
Internal reference voltage Note	VBGR		1.38	1.45	1.50	V

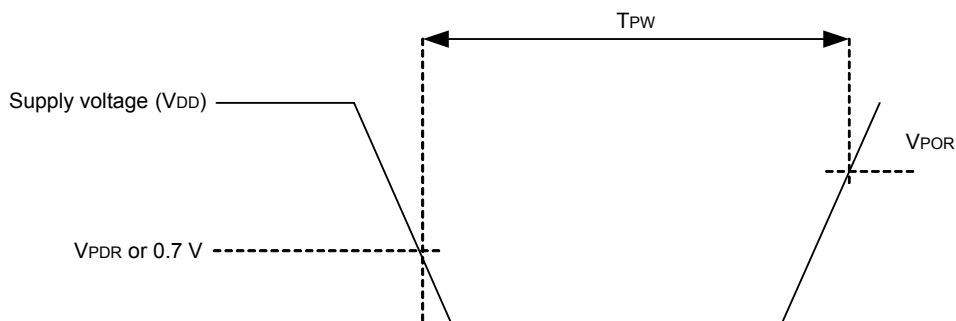
Note Not usable in LS (low-speed main) mode, LV (low-voltage main) mode, sub-clock operation, or STOP mode.

2.6.5 POR circuit characteristics

(TA = -40 to +85 °C, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	VPOR	Power supply rise time	1.47	1.51	1.55	V
	VPDR	Power supply fall time Note	1.46	1.50	1.54	V
Minimum pulse width	TPW		300			μs

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



2.6.6 LVD circuit characteristics

(TA = -40 to +85 °C, VPDR ≤ VDD ≤ 3.6 V ≤ VSS = 0 V)

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

Caution Set the detection voltage (VLVD) to be within the operating voltage range. The operating voltage range depends on the setting of the user option byte (00C2H/010C2H). The following shows the operating voltage range.

HS (high-speed main) mode: VDD = 2.7 to 3.6 V at 1 MHz to 24 MHz

VDD = 2.4 to 3.6 V at 1 MHz to 16 MHz

LS (low-speed main) mode: VDD = 1.8 to 3.6 V at 1 MHz to 8 MHz

LV (low-voltage main) mode: VDD = 1.6 to 3.6 V at 1 MHz to 4 MHz

LVD Detection Voltage of Interrupt & Reset Mode

(TA = -40 to +85 °C, VPDR ≤ VDD ≤ 3.6 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: 1.6 V		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: 1.8 V		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: 2.4 V		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
	VLVDD0	VPOC0, VPOC1, VPOC2 = 0, 1, 1, falling reset voltage: 2.7 V		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

2.7 Power supply voltage rising slope characteristics

(TA = -40 to +85 °C, VSS = 0 V)

Parameter	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.

2.8 LCD Characteristics

2.8.1 Resistance division method

(1) Static display mode

(TA = -40 to +85 °C, VL4 (MIN.) ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	VL4		2.0		VDD	V

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

(TA = -40 to +85 °C, VL4 (MIN.) ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	VL4		2.7		VDD	V

(3) 1/3 bias method

(TA = -40 to +85 °C, VL4 (MIN.) ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
LCD drive voltage	VL4		2.5		VDD	V

2.8.2 Internal voltage boosting method

(1) 1/3 bias method

(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	VL1	C1 to C4 ^{Note 1} = 0.47 μF ^{Note 2}	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
			VLCD = 0BH	1.25	1.35	1.43	V
			VLCD = 0CH	1.30	1.40	1.48	V
			VLCD = 0DH	1.35	1.45	1.53	V
			VLCD = 0EH	1.40	1.50	1.58	V
			VLCD = 0FH	1.45	1.55	1.63	V
			VLCD = 10H	1.50	1.60	1.68	V
			VLCD = 11H	1.55	1.65	1.73	V
			VLCD = 12H	1.60	1.70	1.78	V
			VLCD = 13H	1.65	1.75	1.83	V
Doubler output voltage	VL2	C1 to C4 ^{Note 1} = 0.47 μF	2 VL ₁ - 0.1	2 VL ₁	2 VL ₁	V	
Tripler output voltage	VL3	C1 to C4 ^{Note 1} = 0.47 μF	3 VL ₁ - 0.15	3 VL ₁	3 VL ₁	V	
Reference voltage setup time ^{Note 2}	t _{WAIT1}		5			ms	
Voltage boost wait time ^{Note 3}	t _{WAIT2}	C1 to C4 ^{Note 1} = 0.47μF	500			ms	

Note 1. This is a capacitor that is connected between voltage pins used to drive the LCD.

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between VL1 and GND

C3: A capacitor connected between VL2 and GND

C4: A capacitor connected between VL4 and GND

C1 = C2 = C3 = C4 = 0.47 μF ± 30%

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

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

(2) 1/4 bias method**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	VL1	C1 to C4 ^{Note 1} = 0.47 μF ^{Note 2}	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
Doubler output voltage	VL2	C1 to C4 ^{Note 1} = 0.47 μF		2 VL ₁ - 0.08	2 VL ₁	2 VL ₁	V
Tripler output voltage	VL3	C1 to C4 ^{Note 1} = 0.47 μF		3 VL ₁ - 0.12	3 VL ₁	3 VL ₁	V
Quadruply output voltage	VL4	C1 to C5 ^{Note 1} = 0.47 μF		4 VL ₁ - 0.16	4 VL ₁	4 VL ₁	V
Reference voltage setup time ^{Note 2}	t _{WAIT1}			5			ms
Voltage boost wait time ^{Note 3}	t _{WAIT2}	C1 to C5 ^{Note 1} = 0.47μF		500			ms

Note 1. This is a capacitor that is connected between voltage pins used to drive the LCD.

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between VL1 and GND

C3: A capacitor connected between VL2 and GND

C4: A capacitor connected between VL3 and GND

C5: A capacitor connected between VL4 and GND

C1 = C2 = C3 = C4 = 0.47 μF±30%

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

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

2.8.3 Capacitor split method

(1) 1/3 bias method

(TA = -40 to +85 °C, 2.2 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
VL4 voltage	VL4	C1 to C4 = 0.47 μF Note 2		VDD		V
VL2 voltage	VL2	C1 to C4 = 0.47 μF Note 2	2/3 VL4 - 0.1	2/3 VL4	2/3 VL4 + 0.1	V
VL1 voltage	VL1	C1 to C4 = 0.47 μF Note 2	1/3 VL4 - 0.1	1/3 VL4	1/3 VL4 + 0.1	V
Capacitor split wait time Note 1	tvWAIT		100			ms

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

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

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between VL1 and GND

C3: A capacitor connected between VL2 and GND

C4: A capacitor connected between VL4 and GND

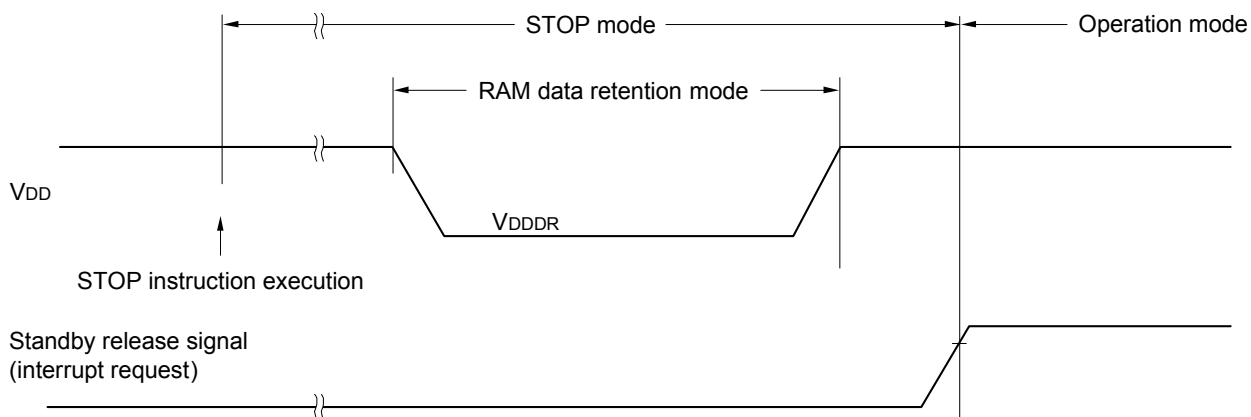
C1 = C2 = C3 = C4 = 0.47 μF±30%

2.9 RAM Data Retention Characteristics

(TA = -40 to +85 °C, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	VDDDR		1.46 Note		3.6	V

Note This depends on the POR detection voltage. For a falling voltage, data in RAM are retained until the voltage reaches the level that triggers a POR reset but not once it reaches the level at which a POR reset is generated.



2.10 Flash Memory Programming Characteristics

(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CPU/peripheral hardware clock frequency	fCLK	2.4 V ≤ VDD ≤ 3.6 V	1		24	MHz
Number of code flash rewrites Notes 1, 2, 3	C _{erwr}	Retained for 20 years TA = 85°C	1,000			Times
Number of data flash rewrites Notes 1, 2, 3		Retained for 1 year TA = 25°C		1,000,000		
		Retained for 5 years TA = 85°C	100,000			
		Retained for 20 years TA = 85°C	10,000			

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

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

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

2.11 Dedicated Flash Memory Programmer Communication (UART)

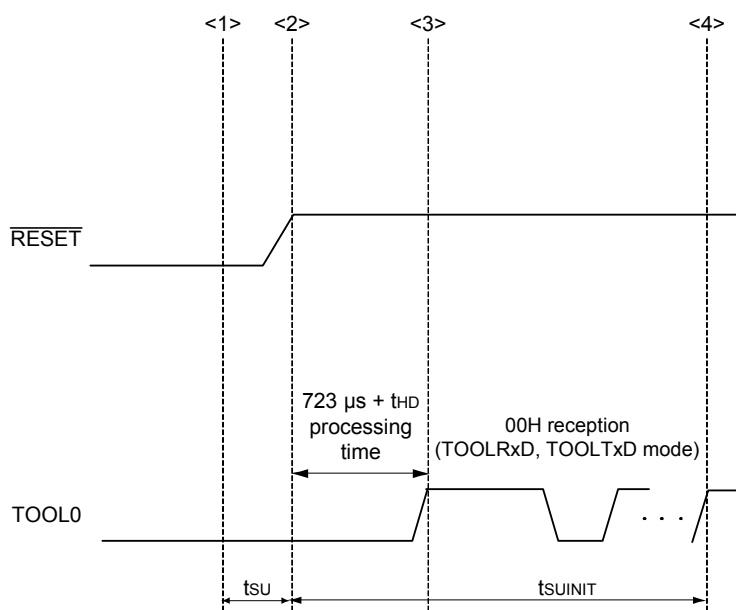
(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

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

2.12 Timing Specs for Switching Modes

(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 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	tsuINIT	POR and LVD reset must end before the external reset ends.			100	ms
How long from when the TOOL0 pin is placed at the low level until an external reset ends	tsu	POR and LVD reset must end before the external reset ends.	10			μs
Time to hold the TOOL0 pin at the low level after an external reset is released (excluding the processing time of the firmware to control the flash memory)	tHD	POR and LVD reset must end before the external reset ends.	1			ms



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

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

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

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

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

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

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

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

<R> This chapter describes the following electrical specifications.

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

R5F110xxGxx, R5F111xxGxx

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

Caution 2. Please contact Renesas Electronics sales office for derating of operation under TA = +85 °C to +105 °C. Derating is the systematic reduction of load for the sake of improved reliability.

Remark When the RL78 microcontroller is used in the range of TA = -40 to +85 °C, see **2. ELECTRICAL SPECIFICATIONS (A: TA = -40 to +85 °C)**.

The following functions differ between the products “G: Industrial applications (TA = -40 to +105 °C)” and the products “A: Consumer applications and G: Industrial applications (when used in the range of TA = -40 to +85 °C)”.

Parameter	A: Consumer applications	G: Industrial applications
Operating ambient temperature	TA = -40 to +85 °C	TA = -40 to +105 °C
Operating mode Operating voltage range	HS (high-speed main) mode: 2.7 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 24 MHz 2.4 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 16 MHz LS (low-speed main) mode: 1.8 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 8 MHz LV (low-voltage main) mode: 1.6 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 4 MHz	HS (high-speed main) mode only: 2.7 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 24 MHz 2.4 V ≤ V _{DD} ≤ 3.6 V@1 MHz to 16 MHz
High-speed on-chip oscillator clock accuracy	1.8 V ≤ V _{DD} ≤ 3.6 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} ≤ 3.6 V: ±2.0% @ TA = +85 to +105 °C ±1.0% @ TA = -20 to +85 °C ±1.5% @ TA = -40 to -20 °C
Serial array unit	UART CSI: f _{CLK} /4 Simplified I ² C communication	UART CSI: f _{CLK} /4 Simplified I ² C communication
IICA	Normal mode Fast mode Fast mode plus	Normal mode Fast mode
Voltage detector	• Rise detection: 1.67 V to 3.13 V (12 levels) • Fall detection: 1.63 V to 3.06 V (12 levels)	• Rise detection voltage: 2.61 V to 3.13 V (6 levels) • Fall detection voltage: 2.55 V to 3.06 V (6 levels)

Remark The electrical characteristics of the products G: Industrial applications (TA = -40 to +105 °C) are different from those of the products “A: Consumer applications”. For details, refer to **3.1** to **3.12**.

3.1 Absolute Maximum Ratings

Absolute Maximum Ratings (TA = 25°C)

(1/3)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V _{DD}		-0.5 to + 6.5	V
	UV _{BUS}		-0.5 to + 6.5	V
	AV _{DD}	AV _{DD} ≤ V _{DD}	-0.5 to + 4.6	V
REGC pin input voltage	V _{IREGC}	REGC	-0.3 to + 2.8 and -0.3 to V _{DD} + 0.3 Note 1	V
UREGC pin input voltage	VI _{UREGC}	UREGC	-0.3 to UV _{BUS} + 0.3 Note 2	V
Input voltage	Vi1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, EXCLK, EXCLKS, RESET	-0.3 to V _{DD} + 0.3 Note 3	V
	Vi2	P60, P61 (N-ch open-drain)	-0.3 to + 6.5	V
	Vi3	UDP, UDM	-0.3 to + 6.5	V
	Vi4	P150 to P156	-0.3 to AV _{DD} + 0.3 Note 4	V
Output voltage	Vo1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-0.3 to V _{DD} + 0.3 Note 3	V
	Vo2	P150 to P156	-0.3 to AV _{DD} + 0.3 Note 3	V
	Vo3	UDP, UDM	-0.3 to + 3.8	V
Analog input voltage	VAi1	ANI16 to ANI21	-0.3 to V _{DD} + 0.3 and AV _{REF} (+) + 0.3 Notes 3, 5	V
	VAi2	ANI0 to ANI6	-0.3 to AV _{DD} + 0.3 and AV _{REF} (+) + 0.3 Notes 3, 5	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. Connect the UREGC pin to V_{SS} via a capacitor (0.33 μF). This value regulates the absolute maximum rating of the UREGC pin. Do not use this pin with voltage applied to it.

Note 3. Must be 6.5 V or lower.

Note 4. Must be 4.6 V or lower.

Note 5. Do not exceed AV_{REF}(+) + 0.3 V in case of A/D conversion target pin.

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

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

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

Remark 3. V_{SS}: Reference voltage

Absolute Maximum Ratings (T_A = 25°C)**(2/3)**

Parameter	Symbols	Conditions		Ratings	Unit
LCD voltage	VL11	VL1 input voltage Note 1		-0.3 to +2.8	V
	VL12	VL2 input voltage Note 1		-0.3 to +6.5	V
	VL13	VL3 input voltage Note 1		-0.3 to +6.5	V
	VL14	VL4 input voltage Note 1		-0.3 to +6.5	V
	VL15	CAPL, CAPH input voltage Note 1		-0.3 to +6.5	V
	VL01	VL1 output voltage		-0.3 to +2.8	V
	VL02	VL2 output voltage		-0.3 to +6.5	V
	VL03	VL3 output voltage		-0.3 to +6.5	V
	VL04	VL4 output voltage		-0.3 to +6.5	V
	VL05	CAPL, CAPH output voltage		-0.3 to +6.5	V
	VL06	COM0 to COM7 SEG0 to SEG55 output voltage	External resistance division method	-0.3 to VDD + 0.3 Note 2	V
			Capacitor split method	-0.3 to VDD + 0.3 Note 2	V
Internal voltage boosting method			-0.3 to VL14 + 0.3 Note 2	V	

Note 1. This value only indicates the absolute maximum ratings when applying voltage to the VL1, VL2, VL3, and VL4 pins; it does not mean that applying voltage to these pins is recommended. When using the internal voltage boosting method or capacitance split method, connect these pins to V_{SS} via a capacitor (0.47 ± 30%) and connect a capacitor (0.47 ± 30%) between the CAPL and CAPH pins.

Note 2. Must be 6.5 V or lower.

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.

Absolute Maximum Ratings (T_A = 25 °C)

(3/3)

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	IOH1	Per pin	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-40	mA
		Total of all pins -170 mA	P40 to P46	-70	mA
			P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	-100	mA
	IOH2	Per pin	P150 to P156	-0.1	mA
		Total of all pins		-0.7	mA
	IOH3	Per pin	UDP, UDM	-3	mA
Output current, low	IOL1	Per pin	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	40	mA
		Total of all pins 170 mA	P40 to P46	70	mA
			P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	100	mA
	IOL2	Per pin	P150 to P156	0.4	mA
		Total of all pins		2.8	mA
	IOL3	Per pin	UDP, UDM	3	mA
Operating ambient temperature	T _A	In normal operation mode		-40 to +105	°C
		In flash memory programming mode		-40 to +85	
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 and XT1 oscillator characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (fx) Note	Ceramic resonator/crystal resonator	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1.0		20.0	MHz
		$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$	1.0		16.0	
XT1 clock oscillation frequency (fx _{XT}) Note	Crystal resonator		32	32.768	35	kHz

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

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

3.2.2 On-chip oscillator characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Oscillators	Parameters	Conditions	MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency Notes 1, 2	f _{HOCO}		1		24	MHz
High-speed on-chip oscillator clock frequency accuracy		-20 to $+85\text{ }^{\circ}\text{C}$	-1.0		+1.0	%
		-40 to $-20\text{ }^{\circ}\text{C}$	-1.5		+1.5	%
		$+85$ to $+105\text{ }^{\circ}\text{C}$	-2.0		+2.0	%
Low-speed on-chip oscillator clock frequency	f _{LIL}			15		kHz
Low-speed on-chip oscillator clock frequency accuracy			-15		+15	%

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

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

3.2.3 PLL oscillator characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Oscillators	Parameters	Conditions	MIN.	TYP.	MAX.	Unit
PLL input frequency Note	f _{PLLIN}	High-speed system clock	6.00		16.00	MHz
PLL output frequency Note	f _{PLL}			48.00		MHz

Note Indicates only oscillator characteristics. Refer to **AC Characteristics** for instruction execution time.

3.3 DC Characteristics

3.3.1 Pin characteristics

(TA = -40 to +105 °C, 2.4 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
<R> <R> <R> <R>	IOH1	Per pin for P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143			-10.0 Note 2	mA
		Total of P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ VDD ≤ 3.6 V		-15.0	mA
		(When duty = 70% Note 3)	2.4 V ≤ VDD < 2.7 V		-7.0	mA
	IOH2	Per pin for P150 to P156			-0.1 Note 2	mA
		Total of all pins	2.4 V ≤ VDD ≤ 3.6 V		-0.7	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. However, do not exceed the total current value.

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

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

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

<Example> Where n = 50% and IOH = -10.0 mA

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

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

Caution P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
<R>	IOL1	Per pin for P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143			20.0 Note 2	mA
		Per pin for P60 and P61			15.0 Note 2	mA
		Total of P40 to P46 (When duty = 70% Note 3)	2.7 V ≤ VDD ≤ 3.6 V		15.0	mA
			2.4 V ≤ VDD < 2.7 V		9.0	mA
		Total of P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143 (When duty = 70% Note 3)	2.7 V ≤ VDD ≤ 3.6 V		35.0	mA
			2.4 V ≤ VDD < 2.7 V		20.0	mA
		Total of all pins (When duty = 70% Note 3)			50.0	mA
<R>	IOL2	Per pin for P150 to P156			0.4 Note 2	mA
		Total of all pins	2.4 V ≤ VDD ≤ 3.6 V		2.8	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. However, do not exceed the total current value.

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

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

- Total output current of pins = (IOL × 0.7)/(n × 0.01)

<Example> Where n = 50% and IOL = 10.0 mA

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

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

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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage, high	V _{IH1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P140 to P143	0.8 V _{DD}		V _{DD}	V
	V _{IH2}	P00, P01, P10, P11, P24, P25, P33, P34, P43, P44	TTL input buffer 3.3 V ≤ V _{DD} ≤ 3.6 V	2.0	V _{DD}	V
			TTL input buffer 2.4 V ≤ V _{DD} < 3.3 V	1.50	V _{DD}	V
	V _{IH3}	P150 to P156	0.7 AV _{DD}		AV _{DD}	V
	V _{IH4}	P60, P61	0.7 V _{DD}		6.0	V
	V _{IH5}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$	0.8 V _{DD}		V _{DD}	V
Input voltage, low	V _{IL1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P140 to P143	0		0.2 V _{DD}	V
	V _{IL2}	P00, P01, P10, P11, P24, P25, P33, P34, P43, P44	TTL input buffer 3.3 V ≤ V _{DD} ≤ 3.6 V	0	0.5	V
			TTL input buffer 2.4 V ≤ V _{DD} < 3.3 V	0	0.32	V
	V _{IL3}	P150 to P156	0		0.3 AV _{DD}	V
	V _{IL4}	P60, P61	0		0.3 V _{DD}	V
	V _{IL5}	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$	0		0.2 V _{DD}	V

Caution The maximum value of V_{IH} of pins P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 is V_{DD}, even in the N-ch open-drain mode.

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

(T_A = -40 to +105 °C, 2.4 V ≤ AV_{DD} = V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output voltage, high	VOH1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OH1} = -2.0 mA	V _{DD} - 0.6		V
			2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OH1} = -1.5 mA	V _{DD} - 0.5		V
	VOH2	P150 to P156	2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OH2} = -100 μA	AV _{DD} - 0.5		V
Output voltage, low	VOL1	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P70 to P77, P80 to P83, P125 to P127, P130, P140 to P143	2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OL1} = 3.0 mA		0.6	V
			2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OL1} = 1.5 mA		0.4	V
			2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OL1} = 0.6 mA		0.4	V
	VOL2	P150 to P156	2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OL2} = 400 μA		0.4	V
	VOL3	P60, P61	2.7 V ≤ V _{DD} ≤ 3.6 V, I _{OL3} = 3.0 mA		0.4	V
			2.4 V ≤ V _{DD} ≤ 3.6 V, I _{OL3} = 2.0 mA		0.4	V

Caution P00 to P02, P10 to P12, P24 to P26, P33 to P35, and P42 to P44 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 ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Input leakage current, high	ILI _{H1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, $\overline{\text{RESET}}$	V _I = V _{DD}				1	μA
	ILI _{H2}	P20, P21, P140 to P143	V _I = V _{DD}				1	μA
	ILI _{H3}	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	V _I = V _{DD}	In input port or external clock input			1	μA
				In resonator connection			10	μA
	ILI _{H4}	P150 to P156	V _I = AV _{DD}				1	μA
Input leakage current, low	ILI _{L1}	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P40 to P46, P50 to P57, P60, P61, P70 to P77, P80 to P83, P125 to P127, P137, P140 to P143, $\overline{\text{RESET}}$	V _I = V _{SS}				-1	μA
	ILI _{L2}	P20, P21, P140 to P143	V _I = V _{SS}				-1	μA
	ILI _{L3}	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	V _I = V _{SS}	In input port or external clock input			-1	μA
				In resonator connection			-10	μA
	ILI _{L4}	P150 to P156	V _I = AV _{SS}				-1	μA
On-chip pull-up resistance	RU ₁	P00 to P07, P10 to P17, P20 to P27, P30 to P37, P50 to P57, P70 to P77, P140 to P143, P125 to P127	V _I = V _{SS}	2.4 V ≤ V _{DD} ≤ 3.6 V	10	20	100	kΩ
	RU ₂	P40 to P46, P80 to P83	V _I = V _{SS}		10	20	100	kΩ

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

3.3.2 Supply current characteristics**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)****(1/2)**

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
Supply current Note 1	I _{DD1}	Operating mode	HS (high-speed main) mode Note 5	$f_{HOCO} = 48\text{ MHz}$ Note 3, $f_{IH} = 24\text{ MHz}$ Note 3	Basic operation	$V_{DD} = 3.6\text{ V}$	2.2	2.9	mA
						$V_{DD} = 3.0\text{ V}$	2.2	2.9	
					Normal operation	$V_{DD} = 3.6\text{ V}$	4.4	9.2	
						$V_{DD} = 3.0\text{ V}$	4.4	9.2	
				$f_{HOCO} = 24\text{ MHz}$ Note 3, $f_{IH} = 24\text{ MHz}$ Note 3	Basic operation	$V_{DD} = 3.6\text{ V}$	2.0	2.6	mA
						$V_{DD} = 3.0\text{ V}$	2.0	2.6	
					Normal operation	$V_{DD} = 3.6\text{ V}$	4.2	7.0	
						$V_{DD} = 3.0\text{ V}$	4.2	7.0	
				$f_{HOCO} = 16\text{ MHz}$ Note 3, $f_{IH} = 16\text{ MHz}$ Note 3	Normal operation	$V_{DD} = 3.6\text{ V}$	3.1	5.0	mA
						$V_{DD} = 3.0\text{ V}$	3.1	5.0	
			HS (high-speed main) mode Note 5	$f_{MX} = 20\text{ MHz}$ Note 2, $V_{DD} = 3.6\text{ V}$	Normal operation	Square wave input	3.5	5.9	mA
						Resonator connection	3.6	6.0	
				$f_{MX} = 20\text{ MHz}$ Note 2, $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input	3.5	5.9	
						Resonator connection	3.6	6.0	
				$f_{MX} = 16\text{ MHz}$ Note 2, $V_{DD} = 3.6\text{ V}$	Normal operation	Square wave input	2.9	4.5	
						Resonator connection	3.1	4.6	
				$f_{MX} = 16\text{ MHz}$ Note 2, $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input	2.9	4.5	
						Resonator connection	3.1	4.6	
				$f_{MX} = 10\text{ MHz}$ Note 2, $V_{DD} = 3.6\text{ V}$	Normal operation	Square wave input	2.1	3.5	
						Resonator connection	2.2	3.5	
				$f_{MX} = 10\text{ MHz}$ Note 2, $V_{DD} = 3.0\text{ V}$	Normal operation	Square wave input	2.1	3.5	
						Resonator connection	2.2	3.5	
			HS (High-speed main) mode (PLL operation)	$f_{PLL} = 48\text{ MHz}$, $f_{CLK} = 24\text{ MHz}$ Note 2	Normal operation	$V_{DD} = 3.6\text{ V}$	4.7	7.6	mA
						$V_{DD} = 3.0\text{ V}$	4.7	7.6	
				$f_{PLL} = 48\text{ MHz}$, $f_{CLK} = 12\text{ MHz}$ Note 2	Normal operation	$V_{DD} = 3.6\text{ V}$	3.1	5.2	
						$V_{DD} = 3.0\text{ V}$	3.1	5.1	
				$f_{PLL} = 48\text{ MHz}$, $f_{CLK} = 6\text{ MHz}$ Note 2	Normal operation	$V_{DD} = 3.6\text{ V}$	2.3	3.9	
						$V_{DD} = 3.0\text{ V}$	2.3	3.9	
			Subsystem clock operation	$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = -40^{\circ}\text{C}$	Normal operation	Square wave input	4.6	6.9	μA
						Resonator connection	4.7	6.9	
				$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = +25^{\circ}\text{C}$	Normal operation	Square wave input	4.9	7.0	
						Resonator connection	5.0	7.2	
				$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = +50^{\circ}\text{C}$	Normal operation	Square wave input	5.2	7.6	
						Resonator connection	5.2	7.7	
				$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = +70^{\circ}\text{C}$	Normal operation	Square wave input	5.5	9.3	
						Resonator connection	5.6	9.4	
				$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = +85^{\circ}\text{C}$	Normal operation	Square wave input	6.2	13.3	
						Resonator connection	6.2	13.4	
				$f_{SUB} = 32.768\text{ kHz}$ Note 4 $T_A = +105^{\circ}\text{C}$	Normal operation	Square wave input	8.3	46.0	
						Resonator connection	8.4	46.0	

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

- Note 1.** Total current flowing into V_{DD}, including the input leakage current flowing when the level of the input pin is fixed to V_{DD}, or V_{SS}. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the LCD controller/driver, A/D converter, D/A converter, comparator, LVD circuit, USB 2.0 function module, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 3.** When high-speed system clock and subsystem clock are stopped.
- Note 4.** When high-speed on-chip oscillator and high-speed system clock are stopped. When AMPHS1 = 1 (Ultra-low power consumption oscillation). However, not including the current flowing into the real-time clock 2, 12-bit interval timer, and watchdog timer.
- Note 5.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
- HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }24\text{ MHz}$
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$

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

Remark 2. f_{HOCO}: High-speed on-chip oscillator clock frequency (48 MHz max.)

Remark 3. f_{IH}: Main system clock source frequency when the high-speed on-chip oscillator clock divided 1, 2, 4, or 8, or the PLL clock divided by 2, 4, or 8 is selected (24 MHz max.)

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

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

(TA = -40 to +105 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

(2/2)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit		
Supply current Note 1	I _{DD2} Note 2	HALT mode	HS (high-speed main) mode Note 7	f _{HOCO} = 48 MHz Note 4, f _{IH} = 24 MHz Note 4	V _{DD} = 3.6 V		0.77	3.4	mA		
					V _{DD} = 3.0 V		0.77	3.4			
				f _{HOCO} = 24 MHz Note 4, f _{IH} = 24 MHz Note 4	V _{DD} = 3.6 V		0.55	2.7			
					V _{DD} = 3.0 V		0.55	2.7			
				f _{HOCO} = 16 MHz Note 4, f _{IH} = 16 MHz Note 4	V _{DD} = 3.6 V		0.48	1.9			
					V _{DD} = 3.0 V		0.47	1.9			
				HS (high-speed main) mode Note 7	f _{MX} = 20 MHz Note 3, V _{DD} = 3.6 V	Square wave input		0.35		2.10	mA
						Resonator connection		0.51		2.20	
					f _{MX} = 20 MHz Note 3, V _{DD} = 3.0 V	Square wave input		0.34		2.10	
						Resonator connection		0.51		2.20	
			f _{MX} = 16 MHz Note 3, V _{DD} = 3.6 V		Square wave input		0.30	1.25			
					Resonator connection		0.45	1.41			
			f _{MX} = 16 MHz Note 3, V _{DD} = 3.0 V		Square wave input		0.29	1.23			
					Resonator connection		0.45	1.41			
			f _{MX} = 10 MHz Note 3, V _{DD} = 3.6 V		Square wave input		0.23	1.10			
					Resonator connection		0.30	1.20			
			f _{MX} = 10 MHz Note 3, V _{DD} = 3.0 V		Square wave input		0.22	1.10			
					Resonator connection		0.30	1.20			
			HS (High-speed main) mode (PLL operation)	f _{MX} = 48 MHz, f _{CLK} = 24 MHz Note 3	V _{DD} = 3.6 V		0.99	2.93	mA		
					V _{DD} = 3.0 V		0.99	2.92			
				f _{MX} = 48 MHz, f _{CLK} = 12 MHz Note 3	V _{DD} = 3.6 V		0.89	2.51			
					V _{DD} = 3.0 V		0.89	2.50			
				f _{MX} = 48 MHz, f _{CLK} = 6 MHz Note 3	V _{DD} = 3.6 V		0.84	2.30			
					V _{DD} = 3.0 V		0.84	2.29			
			Subsystem clock operation	f _{SUB} = 32.768 kHz Note 5 T _A = -40°C	Square wave input		0.32	0.61	μA		
					Resonator connection		0.51	0.80			
				f _{SUB} = 32.768 kHz Note 5 T _A = +25°C	Square wave input		0.41	0.74			
					Resonator connection		0.62	0.91			
				f _{SUB} = 32.768 kHz Note 5 T _A = +50°C	Square wave input		0.52	2.30			
					Resonator connection		0.75	2.49			
				f _{SUB} = 32.768 kHz Note 5 T _A = +70°C	Square wave input		0.82	4.03			
					Resonator connection		1.08	4.22			
				f _{SUB} = 32.768 kHz Note 5 T _A = +85°C	Square wave input		1.38	8.04			
					Resonator connection		1.62	8.23			
			f _{SUB} = 32.768 kHz Note 5 T _A = +105°C	Square wave input		3.29	41.00				
				Resonator connection		3.63	41.00				
I _{DD3} Note 6	STOP mode Note 8	T _A = -40°C					0.18	0.52	μA		
		T _A = +25°C					0.25	0.52			
		T _A = +50°C					0.34	2.21			
		T _A = +70°C					0.64	3.94			
		T _A = +85°C					1.18	7.95			
		T _A = +105°C					2.92	40.00			

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

- Note 1.** Total current flowing into VDD, including the input leakage current flowing when the level of the input pin is fixed to VDD or VSS. The values below the MAX. column include the peripheral operation current. However, not including the current flowing into the LCD controller/driver, A/D converter, D/A converter, comparator, LVD circuit, USB 2.0 function module, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.
- Note 2.** During HALT instruction execution by flash memory.
- Note 3.** When high-speed on-chip oscillator and subsystem clock are stopped.
- Note 4.** When high-speed system clock and subsystem clock are stopped.
- Note 5.** When high-speed on-chip oscillator and high-speed system clock are stopped. When RTCLPC = 1 and setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the real-time clock 2 is included. However, not including the current flowing into the 12-bit interval timer and watchdog timer.
- Note 6.** Not including the current flowing into the real-time clock 2, 12-bit interval timer, and watchdog timer.
- Note 7.** Relationship between operation voltage width, operation frequency of CPU and operation mode is as below.
 HS (high-speed main) mode: $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 24 MHz
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$ @1 MHz to 16 MHz
- Note 8.** Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.
- Remark 1.** fMX: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** fHOCO: High-speed on-chip oscillator clock frequency (48 MHz max.)
- Remark 3.** fIH: Main system clock source frequency when the high-speed on-chip oscillator clock divided 1, 2, 4, or 8, or the PLL clock divided by 2, 4, or 8 is selected (24 MHz max.)
- Remark 4.** fSUB: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 5.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

(TA = -40 to +105 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	I _{FIL} Note 1						0.20		μA
RTC2 operating current	I _{RTC} Notes 1, 3						0.02		μA
12-bit interval timer operating current	I _{TMKA} Notes 1, 2, 4						0.02		μA
Watchdog timer operating current	I _{WDT} Notes 1, 4	f _{IL} = 15 kHz					0.22		μA
A/D converter operating current	I _{ADC} Notes 6, 7	AV _{DD} = 3.0 V, when conversion at maximum speed					422	720	μA
AVREF (+) current	I _{AVREF} Note 8	AV _{DD} = 3.0 V, ADREFP1 = 0, ADREFP0 = 0 Note 7					14.0	25.0	μA
		AV _{REFP} = 3.0 V, ADREFP1 = 0, ADREFP0 = 1 Note 10					14.0	25.0	
		ADREFP1 = 1, ADREFP0 = 0 Note 1					14.0	25.0	
A/D converter reference voltage current	I _{ADREF} Notes 1, 9	V _{DD} = 3.0 V					75.0		μA
Temperature sensor operating current	I _{TMPS} Note 1						78		μA
D/A converter operating current	I _{DAC} Notes 1, 11	Per D/A converter channel					0.53	1.5	mA
Comparator operating current	I _{CMP} Notes 1, 12	V _{DD} = 3.6 V, Regulator output voltage = 2.1 V	Window mode				12.5		μA
			Comparator high-speed mode				4.5		μA
			Comparator low-speed mode				1.2		μA
LVD operating current	I _{LVD} Notes 1, 13						0.06		μA
Self-programming operating current	I _{FSP} Notes 1, 14						2.50	12.20	mA
BGO operating current	I _{BGO} Notes 1, 15						1.68	12.20	mA
SNOOZE operating current	I _{SNOZ} Note 1	ADC operation	The mode is performed Note 16				0.34	1.10	mA
			The A/D conversion operations are performed, Low voltage mode, AV _{REFP} = V _{DD} = 3.0 V				0.53	2.04	
		CSI/UART operation					0.70	1.54	mA
LCD operating current	I _{LCD1} Notes 17, 18	External resistance division method	f _{LCD} = f _{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V _{DD} = 3.6 V, LV4 = 3.6 V		0.14		μA
	I _{LCD2} Note 17	Internal voltage boosting method	f _{LCD} = f _{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V _{DD} = 3.0 V, LV4 = 3.0 V (VLCD = 04H)		0.61		μA
	I _{LCD3} Note 17	Capacitor split method	f _{LCD} = f _{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V _{DD} = 3.0 V, LV4 = 3.0 V		0.12		μA
USB current Note 19	I _{USB} Note 20	Operating current during USB communication					4.88		mA
	I _{USB} Note 21	Operating current in the USB suspended state					0.04		mA

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

- Note 1.** Current flowing to V_{DD}.
- Note 2.** When high speed on-chip oscillator and high-speed system clock are stopped.
- Note 3.** Current flowing only to the real-time clock 2 (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2}, and I_{RTC}, when the real-time clock 2 operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the real-time clock 2.
- 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 I_{DD1} or I_{DD2}, and I_{TMKA}, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added. I_{DD2} subsystem clock operation includes the operational current of the 12-bit interval timer.
- Note 5.** Current flowing only to the watchdog timer (including the operating current of the low-speed on-chip oscillator). The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{WDT} when the watchdog timer operates in STOP mode.
- Note 6.** Current flowing only to the A/D converter. The supply current of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{ADC}, I_{AVREF}, I_{ADREF} when the A/D converter operates in an operation mode or the HALT mode.
- Note 7.** Current flowing to the AV_{DD}.
- Note 8.** Current flowing from the reference voltage source of A/D converter.
- Note 9.** Operation current flowing to the internal reference voltage.
- Note 10.** Current flowing to the AV_{REFP}.
- Note 11.** Current flowing only to the D/A converter. The current value of the RL78 microcontrollers is the sum of I_{DD1} or I_{DD2} and I_{DA} when the D/A converter operates in an operation mode or the HALT mode.
- Note 12.** Current flowing only to the comparator circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{COMP} when the comparator circuit operates in the Operating, HALT or STOP mode.
- Note 13.** Current flowing only to the LVD circuit. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{LVI} when the LVD circuit operates in the Operating, HALT or STOP mode.
- Note 14.** Current flowing only during self-programming.
- Note 15.** Current flowing only during data flash rewrite.
- Note 16.** For shift time to the SNOOZE mode, see **23.3.3 SNOOZE mode**.
- Note 17.** Current flowing only to the LCD controller/driver (V_{DD} pin). The current value of the RL78 microcontrollers is the sum of the LCD operating current (I_{LCD1}, I_{LCD2} or I_{LCD3}) to the supply current (I_{DD1}, or I_{DD2}) when the LCD controller/driver operates in an operation mode or HALT mode. Not including the current that flows through the LCD panel.
- Note 18.** Not including the current that flows through the external divider resistor divider resistor.
- Note 19.** Current flowing to the UV_{BUS}.
- Note 20.** Including the operating current when f_{PLL} = 48 MHz.
- Note 21.** Including the current supplied from the pull-up resistor of the UDP pin to the pull-down resistor of the host device, in addition to the current consumed by this MCU during the suspended state.

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

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

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

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

3.4 AC Characteristics

3.4.1 Basic operation

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

(1/2)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	T _{CY}	Main system clock (f _{MAIN}) operation	HS (high-speed main) mode	2.7 V ≤ V _{DD} ≤ 3.6 V	0.0417		1	μs
				2.4 V ≤ V _{DD} < 2.7 V	0.0625		1	μs
		Subsystem clock (f _{SUB}) operation		2.4 V ≤ V _{DD} ≤ 3.6 V	28.5	30.5	31.3	μs
		In the self- programming mode	HS (high-speed main) mode	2.7 V ≤ V _{DD} ≤ 3.6 V	0.0417		1	μs
				2.4 V ≤ V _{DD} < 2.7 V	0.0625		1	μs
External main system clock frequency	f _{EX}	2.7 V ≤ V _{DD} ≤ 3.6 V			1.0		20.0	MHz
		2.4 V ≤ V _{DD} < 2.7 V			1.0		16.0	MHz
	f _{EXT}				32		35	kHz
External main system clock input high-level width, low-level width	t _{EXH} ,	2.7 V ≤ V _{DD} ≤ 3.6 V			24			ns
	t _{EXL}	2.4 V ≤ V _{DD} < 2.7 V			30			ns
	t _{EXHS} , t _{EXLS}				13.7			μs
Ti00 to Ti07 input high-level width, low-level width	t _{TIH} , t _{TIL}				1/f _{MCK} + 10			ns

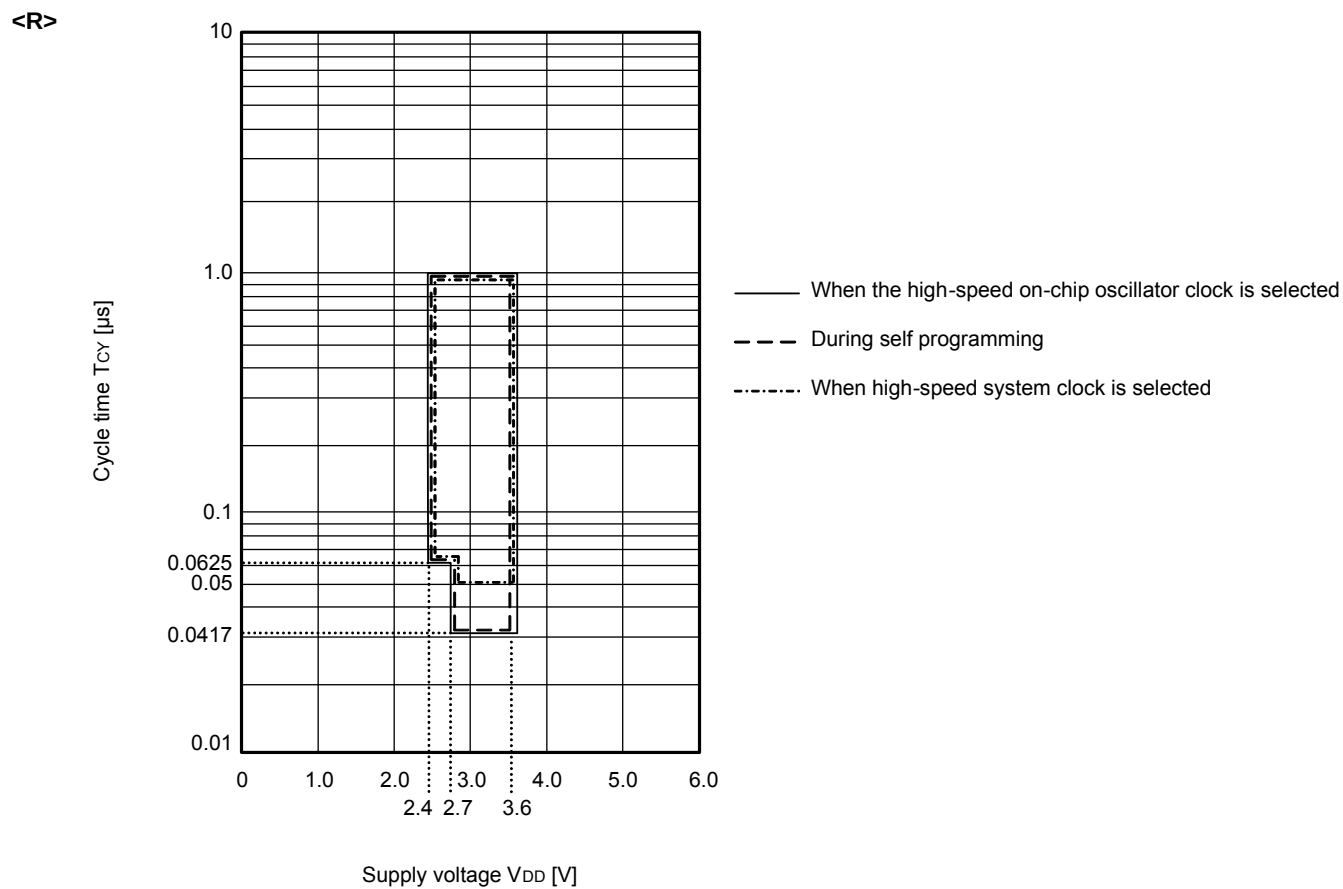
Remark f_{MCK} : Timer array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0),
 n: Channel number (n = 0 to 7))

(TA = -40 to +105 °C, 2.4 V ≤ AVDD = VDD ≤ 3.6 V, VSS = 0 V)

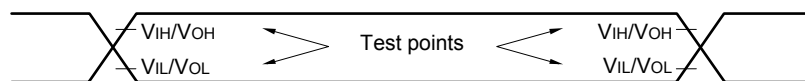
(2/2)

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
TO00 to TO07, TKBO00, TKBO01, TKBO10, TKBO11, TKBO20, TKBO21 output frequency	fro	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V		8	MHz
			2.4 V ≤ VDD < 2.7 V		8	MHz
PCLBUZ0, PCLBUZ1 output frequency	fPCL	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V		8	MHz
			2.4 V ≤ VDD < 2.7 V		8	MHz
Interrupt input high-level width, low-level width	tINTH, tINTL	INTP0 to INTP7	2.4 V ≤ VDD ≤ 3.6 V	1		μs
Key interrupt input low-level width	tKR	2.4 V ≤ VDD ≤ 3.6 V	250			ns
TMKB2 forced output stop input high-level width	tiHR	INTP0 to INTP7	fCLK > 16 MHz	125		ns
			fCLK ≤ 16 MHz	2		fCLK
RESET low-level width	trSL		10			μs

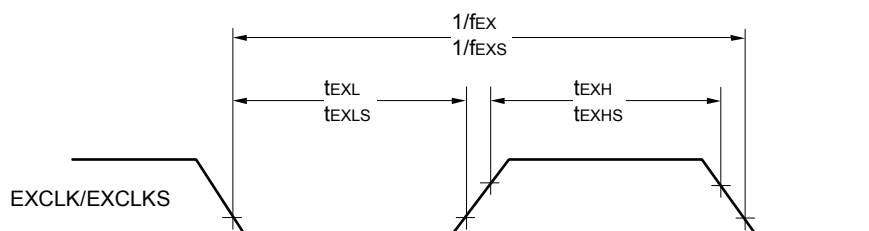
Minimum Instruction Execution Time during Main System Clock Operation

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

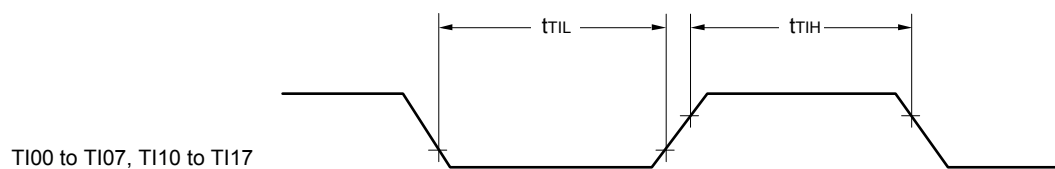
AC Timing Test Points



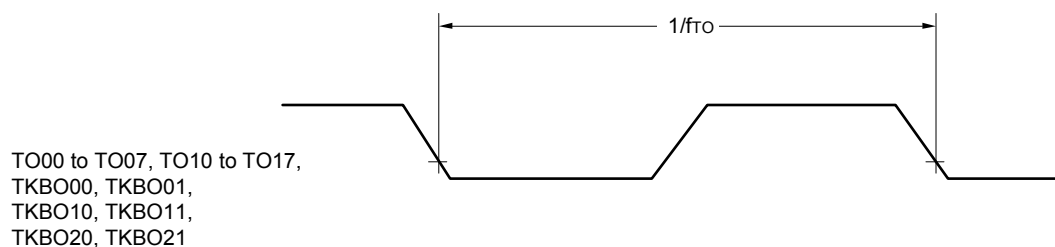
External System Clock Timing



TI/TO Timing

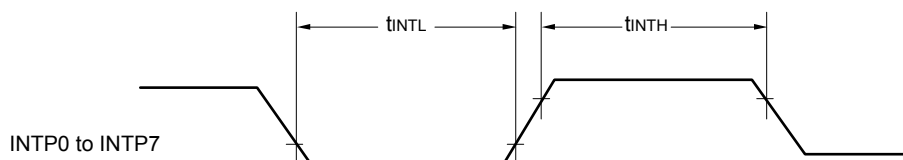


TI00 to TI07, TI10 to TI17



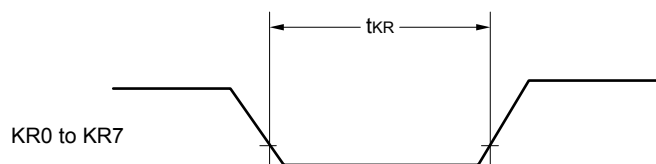
TO00 to TO07, TO10 to TO17,
TKBO00, TKBO01,
TKBO10, TKBO11,
TKBO20, TKBO21

Interrupt Request Input Timing

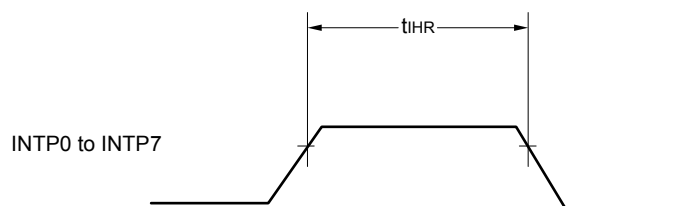
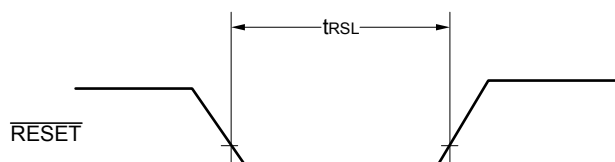


INTP0 to INTP7

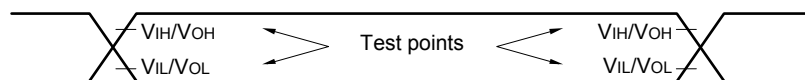
Key Interrupt Input Timing



Timer KB2 Input Timing

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

3.5 Peripheral Functions Characteristics



3.5.1 Serial array unit

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

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Transfer rate Note 1		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$		$f_{MCK}/12$ Note 2	bps
		Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$ Note 3		2.0	Mbps

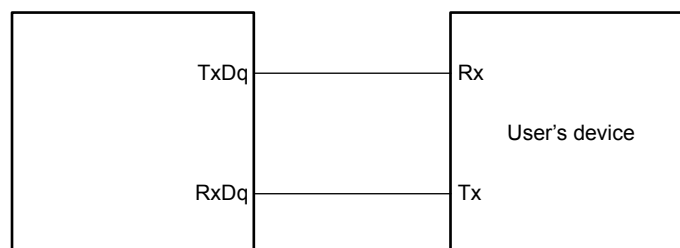
Note 1. Transfer rate in the SNOOZE mode is 4800 bps only.

Note 2. The following conditions are required for low voltage interface.
 $2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$: MAX. 1.3 Mbps

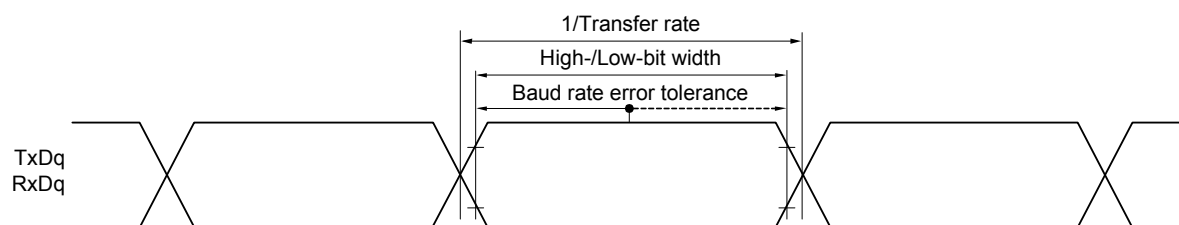
Note 3. The maximum operating frequencies of the CPU/peripheral hardware clock (f_{CLK}) are:
 HS (high-speed main) mode: 24 MHz ($2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$)
 16 MHz ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$)

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

UART mode connection diagram (during communication at same potential)



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



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

Remark 2. f_{MCK} : Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number,
 n: Channel number (mn = 00 to 03, 10 to 13))

(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output)**(T_A = -40 to +105 °C, 2.4 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCKp cycle time	t _{KCY1}	t _{KCY1} ≥ f _{CLK} /4	250		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V	500		ns
SCKp high-/low-level width	t _{KH1} , t _{KL1}	2.7 V ≤ V _{DD} ≤ 3.6 V	t _{KCY1} /2 - 36		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V	t _{KCY1} /2 - 76		ns
Slp setup time (to SCKp↑) Note 1	t _{SIK1}	2.7 V ≤ V _{DD} ≤ 3.6 V	66		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V	133		ns
Slp hold time (from SCKp↑) Note 2	t _{SH1}		38		ns
Delay time from SCKp↓ to SOp output Note 3	t _{SO1}	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, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM number (g = 0 to 3)

Remark 2. f_{MCK}: Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number,
n: Channel number (mn = 00 to 03, 10 to 13))

(3) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)
(T_A = -40 to +105 °C, 2.4 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		Unit
				MIN.	MAX.	
SCKp cycle time Note 5	t _{KCY2}	2.7 V ≤ V _{DD} < 3.6 V	f _{MCK} > 16 MHz	16/f _{MCK}		ns
			f _{MCK} ≤ 16 MHz	12/f _{MCK}		ns
		2.4 V ≤ V _{DD} < 3.6 V		12/f _{MCK} and 1000		ns
SCKp high-/low-level width	t _{KH2} , t _{KL2}	2.7 V ≤ V _{DD} ≤ 3.6 V		t _{KCY2} /2 - 16		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V		t _{KCY2} /2 - 36		ns
Slp setup time (to SCKp↑) Note 1	t _{SIK2}	2.7 V ≤ V _{DD} ≤ 3.6 V		1/f _{MCK} + 40		ns
		2.4 V ≤ V _{DD} ≤ 3.6 V		1/f _{MCK} + 60		ns
Slp hold time (from SCKp↑) Note 2	t _{KSI2}			1/f _{MCK} + 62		ns
Delay time from SCKp↓ to SOp output Note 3	t _{KSO2}	C = 30 pF Note 4	2.7 V ≤ V _{DD} ≤ 3.6 V		2/f _{MCK} + 66	ns
			2.4 V ≤ V _{DD} < 3.6 V		2/f _{MCK} + 113	ns

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

Note 2. When DAP_{mn} = 0 and CKP_{mn} = 0, or DAP_{mn} = 1 and CKP_{mn} = 1. The Slp hold time becomes “from SCKp↓” when DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.

Note 3. 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↑” when DAP_{mn} = 0 and CKP_{mn} = 1, or DAP_{mn} = 1 and CKP_{mn} = 0.

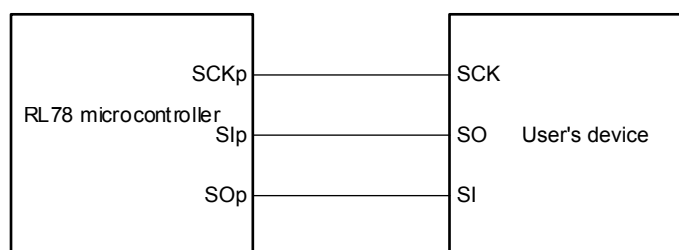
Note 4. C is the load capacitance of the SOp output lines.

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, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM number (g = 0 to 3)

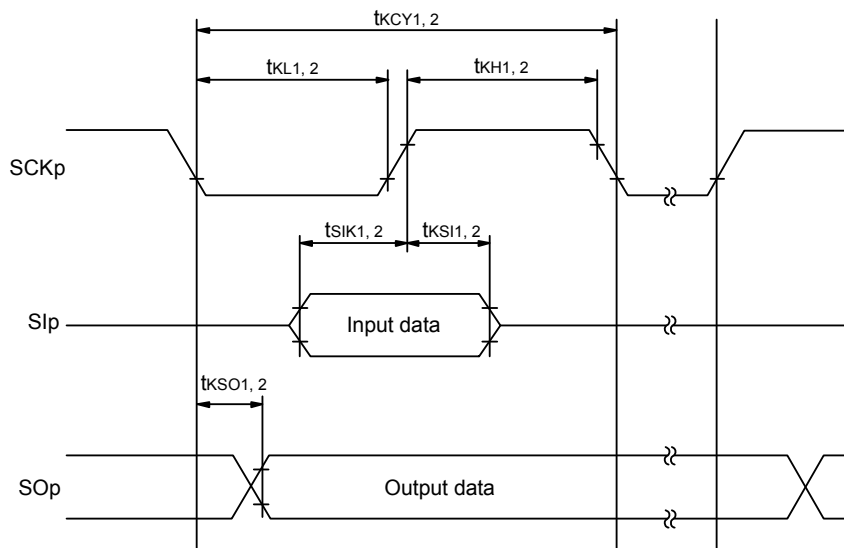
Remark 2. f_{MCK}: Serial array unit operation clock frequency
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13))

CSI mode connection diagram (during communication at same potential)

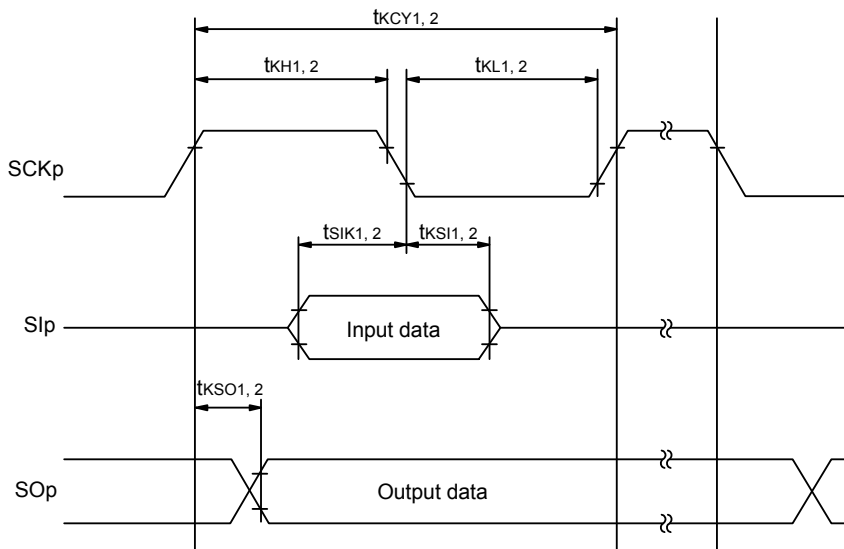
Remark 1. p: CSI number (p = 00, 10, 20, 30)

Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13)

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



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



Remark 1. p: CSI number (p = 00, 10, 20, 30)

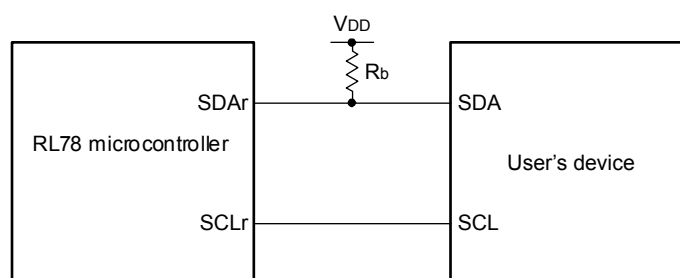
Remark 2. m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13)

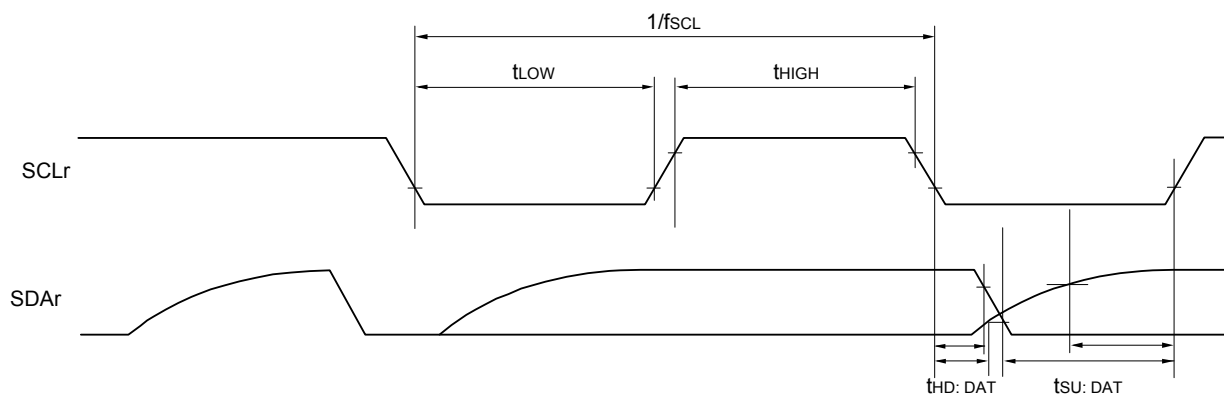
(4) During communication at same potential (simplified I²C mode)**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCLr clock frequency	f _{SCL}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		400 Note 1	kHz
		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$		100 Note 1	kHz
Hold time when SCLr = "L"	t _{LOW}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	4600		ns
Hold time when SCLr = "H"	t _{HIGH}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	4600		ns
Data setup time (reception)	t _{SU: DAT}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$1/f_{MCK} + 200$ Note 2		ns
		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	$1/f_{MCK} + 580$ Note 2		ns
Data hold time (transmission)	t _{HD: DAT}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	0	770	ns
		$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 3\text{ k}\Omega$	0	1420	ns

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

Caution Select the normal input buffer and the N-ch open drain output (V_{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. $R_b[\Omega]$: Communication line (SDAr) pull-up resistance, $C_b[F]$: Communication line (SDAr, SCLr) load capacitance

Remark 2. r: IIC number (r = 00, 10, 20, 30), g: PIM number (g = 0 to 3),
h: POM number (h = 0 to 3)

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0, 1),
n: Channel number (n = 0-3), mn = 00 to 03, 10 to 13)

(5) Communication at different potential (1.8 V, 2.5 V) (UART mode)**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Transfer rate Notes 1, 2		Reception		$f_{MCK}/12$ Note 1	bps
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$			
		Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$ Note 4		2.0	Mbps
		$1.8\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$		$f_{MCK}/12$ Notes 1, 2, 3	bps
		Theoretical value of the maximum transfer rate $f_{MCK} = f_{CLK}$ Note 4		1.3	Mbps

Note 1. Transfer rate in the SNOOZE mode is 4,800 bps only.**Note 2.** Use it with $V_{DD} \geq V_b$.**Note 3.** The following conditions are required for low voltage interface. $2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$: MAX. 2.6 Mbps**Note 4.** The maximum operating frequencies of the CPU/peripheral hardware clock (f_{CLK}) are:HS (high-speed main) mode: 24 MHz ($2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$)16 MHz ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$)

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

Remark 1. $V_b[V]$: Communication line voltage**Remark 2.** q: UART number (q = 0 to 3), g: PIM and POM number (g = 0 to 3)**Remark 3.** f_{MCK} : Serial array unit operation clock frequency

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

n: Channel number (mn = 00 to 03, 10 to 13)

(5) Communication at different potential (1.8 V, 2.5V) (UART mode)**(T_A = -40 to +105 °C, 2.4 ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)****(2/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Transfer rate Note 2		Transmission	2.7 V ≤ V _{DD} ≤ 3.6 V, 2.3 V ≤ V _b ≤ 2.7 V	Note 1	bps
			Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 2.7 kΩ, V _b = 2.3 V	1.2 Note 2	Mbps
			1.8 V ≤ V _{DD} < 3.3 V, 1.6 V ≤ V _b ≤ 2.0 V	Notes 3, 4	bps
			Theoretical value of the maximum transfer rate C _b = 50 pF, R _b = 5.5 kΩ, V _b = 1.6 V	0.43 Note 5	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 2.7 V ≤ V_{DD} < 3.6 V and 2.3 V ≤ V_b ≤ 2.7 V

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

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

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

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. Use it with V_{DD} ≥ V_b.

Note 4. The smaller maximum transfer rate derived by using f_{MCK}/6 or the following expression is the valid maximum transfer rate.
Expression for calculating the transfer rate when 2.4 V ≤ V_{DD} < 3.3 V and 1.6 V ≤ V_b ≤ 2.0 V

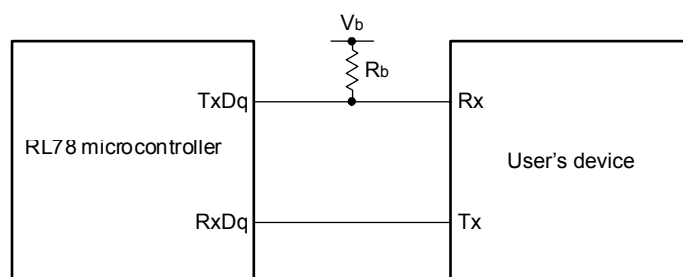
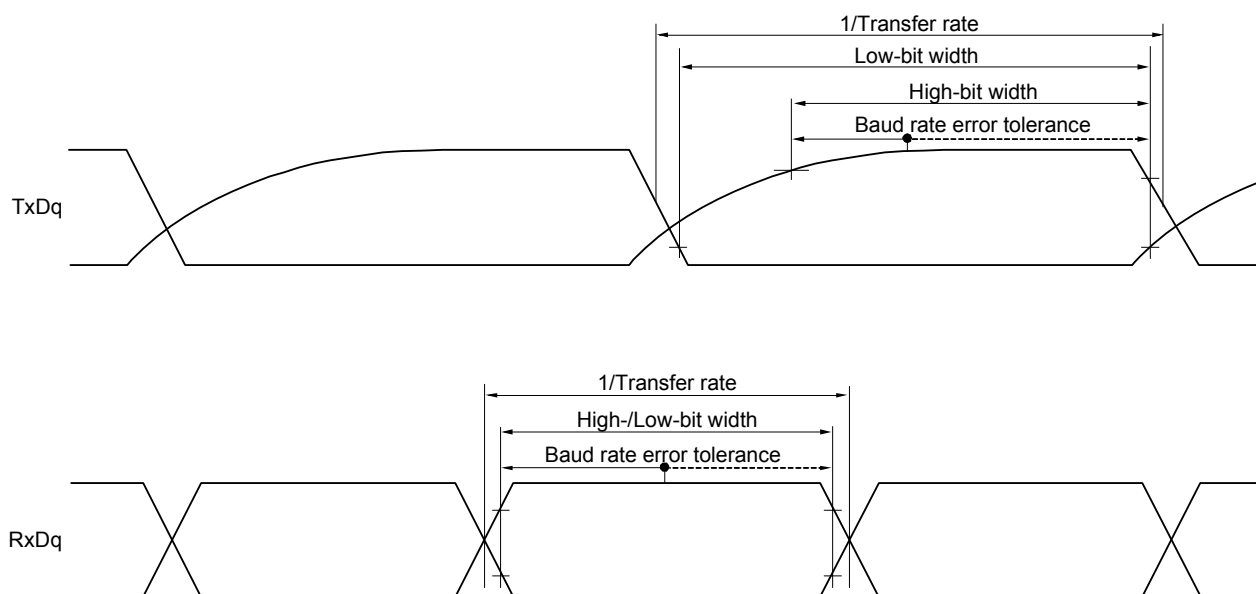
$$\text{Maximum transfer rate} = \frac{1}{\{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\} \times 3} \text{ [bps]}$$

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

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

Note 5. This value as an example is calculated when the conditions described in the "Conditions" column are met.
Refer to Note 4 above to calculate the maximum transfer rate under conditions of the customer.

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

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, $C_b[\text{F}]$: Communication line (TxDq) load capacitance, $V_b[\text{V}]$: Communication line voltage

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

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13))

(6) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (master mode, SCKp... internal clock output)**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)****(1/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq f_{CLK}/4$ $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1000 Note		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 1.8\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	2300 Note		ns
SCKp high-level width	t_{KH1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$t_{KCY1}/2 - 340$		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	$t_{KCY1}/2 - 916$		ns
SCKp low-level width	t_{KL1}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$t_{KCY1}/2 - 36$		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	$t_{KCY1}/2 - 100$		ns

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

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

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

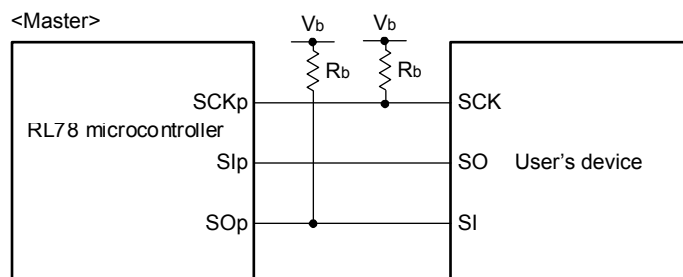
(6) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (master mode, SCKp... internal clock output)**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)****(2/2)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
Slp setup time (to SCKp $\uparrow$) Note 1	tSIK1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	354		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	958		ns
Slp hold time (from SCKp $\uparrow$) Note 1	tKSI1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	38		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	38		ns
Delay time from SCKp $\downarrow$ to SOp output Note 1	tKSO1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		390	ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$		966	ns
Slp setup time (to SCKp $\downarrow$) Note 2	tSIK1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	88		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	220		ns
Slp hold time (from SCKp $\downarrow$) Note 2	tKSI1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	38		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	38		ns
Delay time from SCKp $\uparrow$ to SOp output Note 2	tKSO1	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b \leq 2.7\text{ V}$, $C_b = 30\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		50	ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 3, $C_b = 30\text{ pF}$, $R_b = 5.5\text{ k}\Omega$		50	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 $V_{DD} \geq V_b$.

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

(Remarks are listed on the next page.)

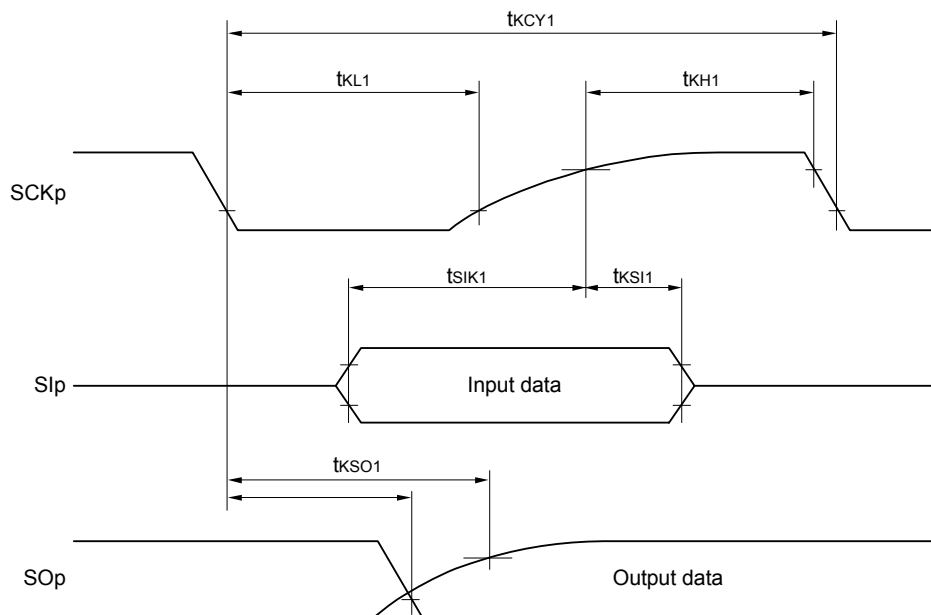
CSI mode connection diagram (during communication at different potential)

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

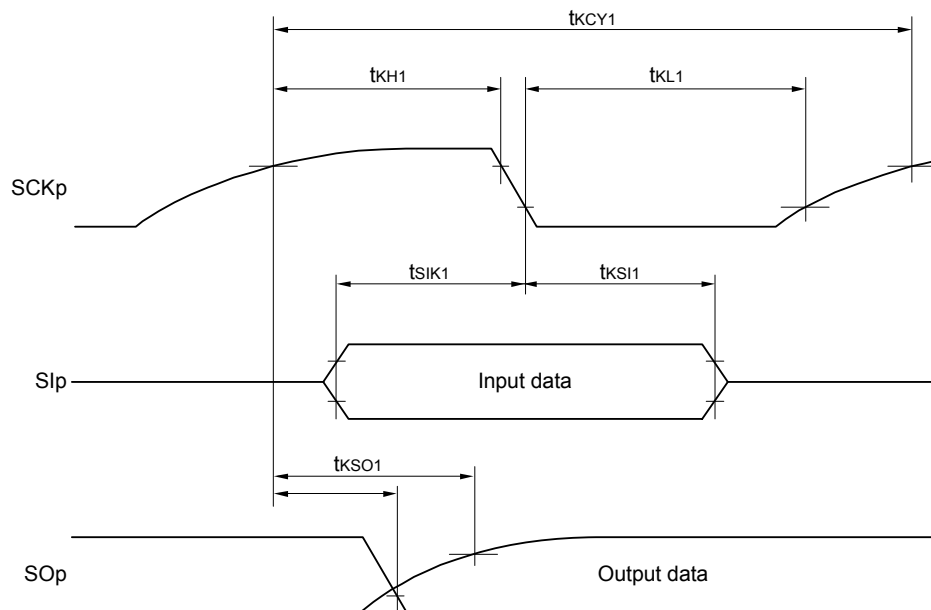
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM and POM number (g = 0 to 3)

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))

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



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



Remark p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3),
g: PIM and POM number (g = 0 to 3)

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

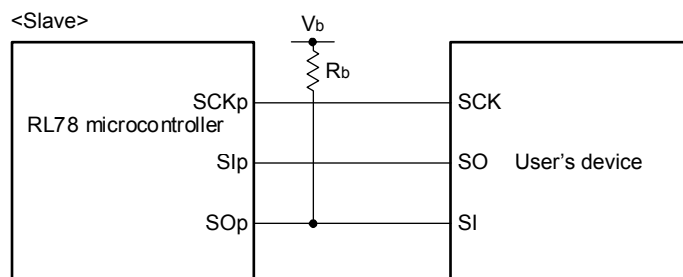
(TA = -40 to +105 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCKp cycle time Note 1	tkCY2	2.7 V ≤ VDD ≤ 3.6 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
			fMCK ≤ 4 MHz	12/fMCK	ns
		2.4 V ≤ VDD < 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	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V	tkCY2/2 - 36		ns
		2.4 V ≤ VDD < 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 ≤ VDD ≤ 3.6 V	1/fMCK + 40		ns
		2.4 V ≤ VDD < 3.3 V	1/fMCK + 60		ns
Slp hold time (from SCKp↑) Note 4	tsIS2		1/fMCK + 62		ns
Delay time from SCKp↓ to SOp output Note 5	tkSO2	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V Cb = 30 pF, Rb = 2.7 kΩ		2/fMCK + 428	ns
		2.4 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V Note 2 Cb = 30 pF, Rb = 5.5 kΩ		2/fMCK + 1146	ns

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

- Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps
- Note 2.** Use it with V_{DD} ≥ V_b.
- Note 3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 4.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Note 5.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The delay time to SOp output becomes “from SCKp↑” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.
- Caution** Select the TTL input buffer for the SIp pin and SCKp pin and the N-ch open drain output (V_{DD} tolerance) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

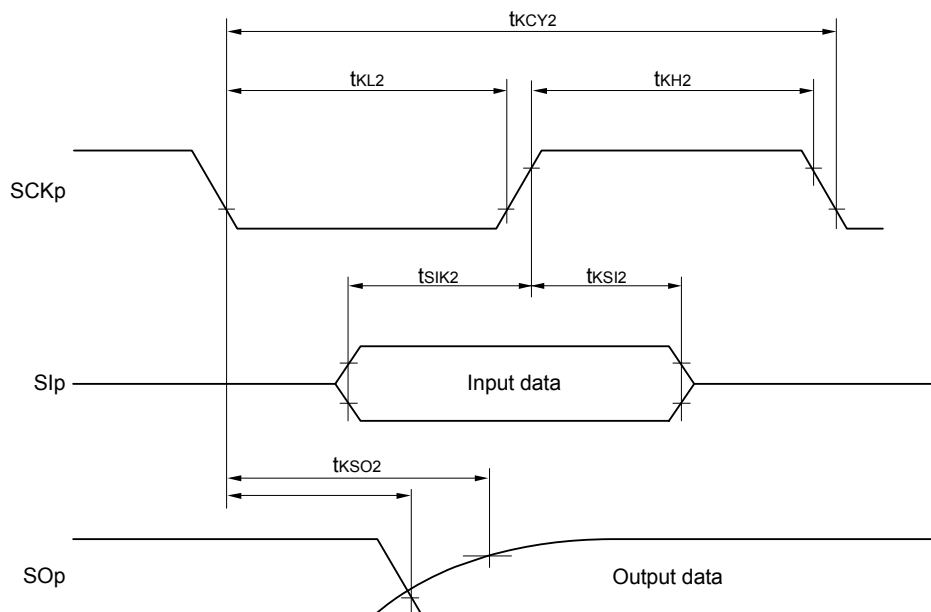
CSI mode connection diagram (during communication at different potential)

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

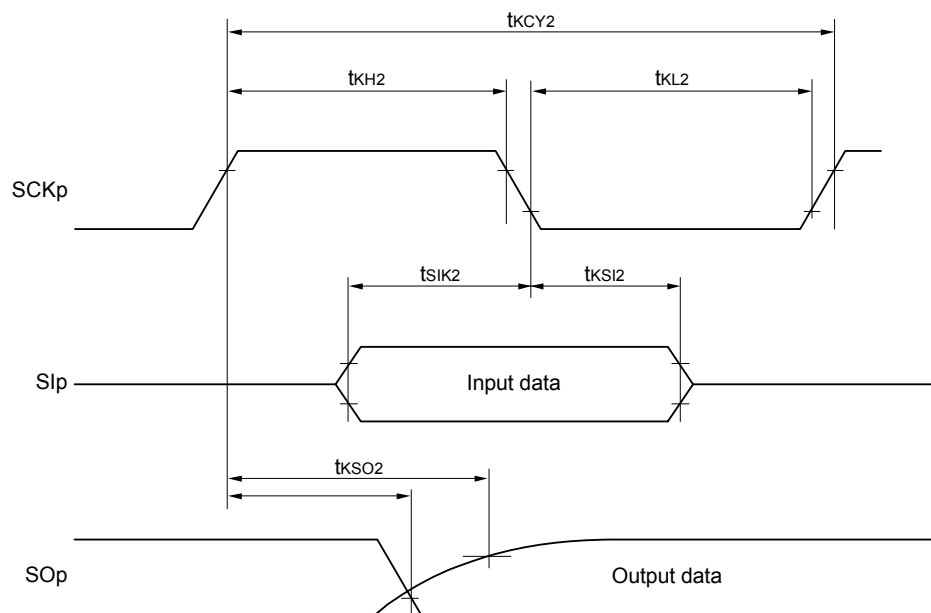
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0 to 3)

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, 02, 10, 12))

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



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



Remark p: CSI number ($p = 00, 10, 20, 30$), m: Unit number ($m = 0, 1$),
 n: Channel number ($n = 0$ to 3), g: PIM and POM number ($g = 0$ to 3)

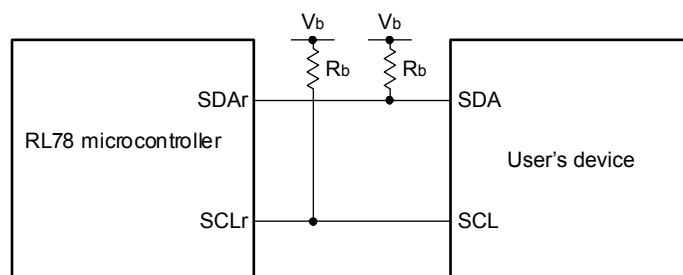
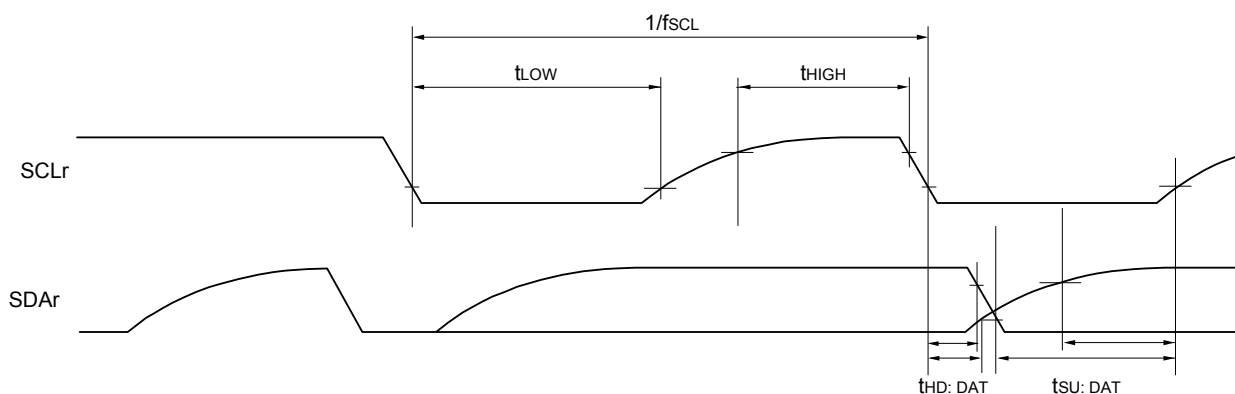
(8) Communication at different potential (1.8 V, 2.5 V) (simplified I²C mode)**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		Unit
			MIN.	MAX.	
SCLr clock frequency	f _{SCL}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		400 Note 1	kHz
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$		100 Note 1	kHz
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 2, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$		100 Note 1	kHz
Hold time when SCLr = "L"	t _{LOW}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	1200		ns
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	4600		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 2, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	4650		ns
Hold time when SCLr = "H"	t _{HIGH}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	500		ns
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	2400		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 2, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	1830		ns
Data setup time (reception)	t _{SD:DAT}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$1/f_{MCK} + 340$ Note 3		ns
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	$1/f_{MCK} + 760$ Note 3		ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 2, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	$1/f_{MCK} + 570$ Note 3		ns
Data hold time (transmission)	t _{HD:DAT}	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 50\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	0	770	ns
		$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.3\text{ V} \leq V_b < 2.7\text{ V}$, $C_b = 100\text{ pF}$, $R_b = 2.7\text{ k}\Omega$	0	1420	ns
		$2.4\text{ V} \leq V_{DD} < 3.3\text{ V}$, $1.6\text{ V} \leq V_b \leq 2.0\text{ V}$ Note 2, $C_b = 100\text{ pF}$, $R_b = 5.5\text{ k}\Omega$	0	1215	ns

Note 1. The value must also be equal to or less than $f_{MCK}/4$.**Note 2.** Use it with $V_{DD} \geq V_b$.**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 (V_{DD} tolerance) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL} , see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

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

Remark 1. $R_b[\Omega]$: 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, 10, 20, 30), g: PIM, POM number (g = 0 to 3)

Remark 3. f_{MCK} : Serial array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number (m = 0, 1),
n: Channel number (n = 0-3), mn = 00, 02, 10, 12)

3.5.2 Serial interface IICA

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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

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

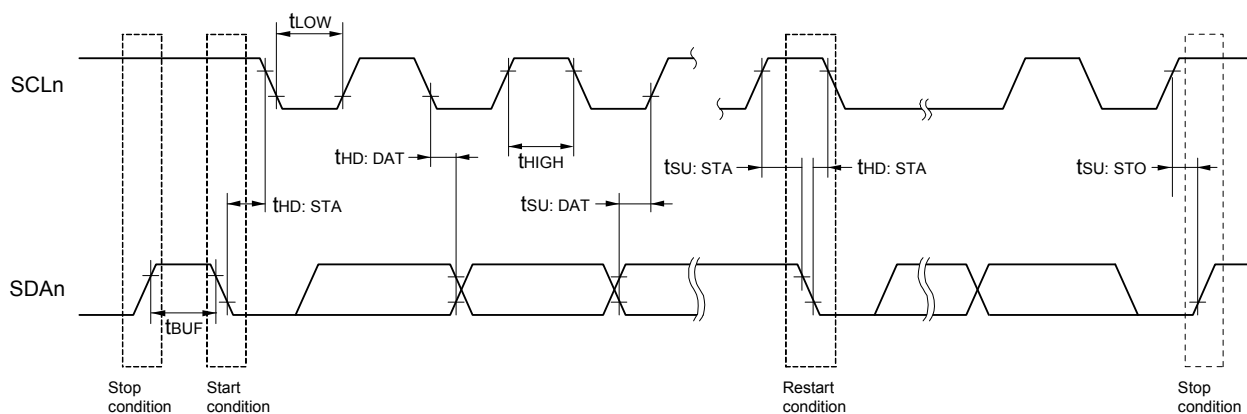
Note 2. The maximum value (MAX.) of t_{HD: DAT} is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

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

Standard mode: C_b = 400 pF, R_b = 2.7 k Ω

Fast mode: C_b = 320 pF, R_b = 1.1 k Ω

IICA serial transfer timing



3.5.3 USB

(1) Electrical specifications

(TA = -40 to +105 °C, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)

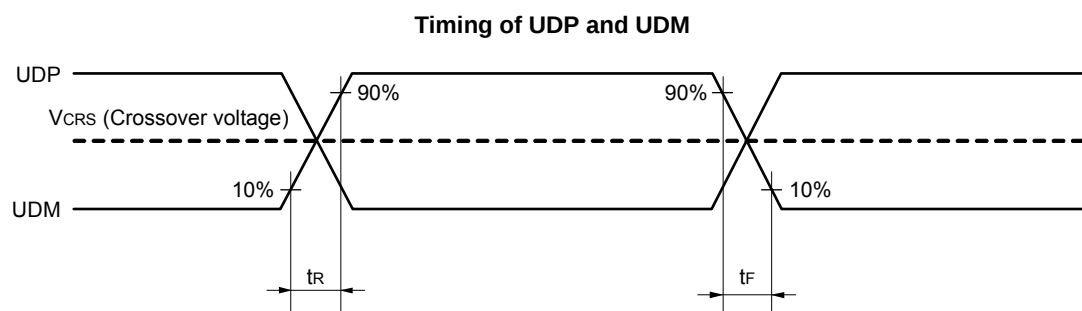
Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
UREGC	UREGC output voltage characteristic	UREGC	UVBUS = 4.0 to 5.5 V, PXXCON = VDDUSBE = 1	3.0	3.3	3.6	V
UVBUS	UVBUS input voltage characteristic	UVBUS	Function	4.35 (4.02 Note)	5.00	5.25	V

Note Value of instantaneous voltage

(TA = -40 to +105 °C, 4.35 V ≤ UVBUS ≤ 5.25 V, 2.4 V ≤ VDD ≤ 3.6 V, VSS = 0 V, HS (High-speed main) mode only)

Parameter			Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input characteristic (FS/LS receiver)	Input voltage		V _{IH}		2.0			V
			V _{IL}				0.8	V
	Difference input sensitivity		V _{DI}	UDP voltage - UDM voltage	0.2			V
	Difference common mode range		V _{CM}		0.8		2.5	V
Output characteristic (FS driver)	Output voltage		V _{OH}	I _{OH} = -200 μA	2.8		3.6	V
			V _{OL}	I _{OL} = 2 mA	0		0.3	V
	Transition time	Rising	t _{FR}	Rising: From 10% to 90% of amplitude, Falling: From 90% to 10% of amplitude, CL = 50 pF	4		20	ns
		Falling	t _{FF}		4		20	ns
	Matching (TFR/TFF)		V _{FRFM}		90		111.1	%
	Crossover voltage		V _{FCRS}		1.3		2.0	V
	Output Impedance		Z _{DRV}		28		44	Ω
Output characteristic (LS driver)	Output voltage		V _{OH}		2.8		3.6	V
			V _{OL}		0		0.3	V
	Transition time	Rising	t _{LR}	Rising: From 10% to 90% of amplitude, Falling: From 90% to 10% of amplitude, CL = 250 pF to 750 pF	75		300	ns
		Falling	t _{LF}		75		300	ns
	Matching (TFR/TFF) Note		V _{LTFM}		80		125	%
	Crossover voltage Note		V _{LCRS}	The UDP and UDM pins are individually pulled down via 15 kΩ	1.3		2.0	V
Pull-up, Pull-down	Pull-down resistor		R _{PD}		14.25		24.80	kΩ
	Pull-up resistor	Idle	R _{PUI}		0.9		1.575	kΩ
		Reception	R _{PUA}		1.425		3.09	kΩ
UVBUS	UVBUS pull-down resistor		R _{VBUS}	UVBUS voltage = 5.5 V		1000		kΩ
	UVBUS input voltage		V _{IH}		3.20			V
			V _{IL}				0.8	V

Note Excludes the first signal transition from the idle state.

**(2) BC standard**

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $4.35\text{ V} \leq UV_{BUS} \leq 5.25\text{ V}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, HS (High-speed main) mode only)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
USB standard BC1.2	UDP sink current	I_{DP_SINK}		25	100	175	μA
	UDM sink current	I_{DM_SINK}		25	100	175	μA
	DCD source current	I_{DP_SRC}		7	10	13	μA
	Data detection voltage	V_{DAT_REF}		0.25	0.325	0.4	V
	UDP source voltage	V_{DP_SRC}	Output current 250 μA	0.5	0.6	0.7	V
	UDM source voltage	V_{DM_SRC}	Output current 250 μA	0.5	0.6	0.7	V

(3) BC option standard**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $4.35\text{ V} \leq \text{UVBUS} \leq 5.25\text{ V}$, $2.4\text{ V} \leq \text{VDD} \leq 3.6$, $\text{VSS} = 0\text{ V}$)**

Parameter			Symbol	Conditions	MIN.	TYP.	MAX.	Unit
UDP/UDM input reference voltage (UVBUS divider ratio) (Function)	VDSELi [3: 0] (i = 0, 1)	0000	VDDDET0		27	32	37	%UVBUS
		0001	VDDDET1		29	34	39	%UVBUS
		0010	VDDDET2		32	37	42	%UVBUS
		0011	VDDDET3		35	40	45	%UVBUS
		0100	VDDDET4		38	43	48	%UVBUS
		0101	VDDDET5		41	46	51	%UVBUS
		0110	VDDDET6		44	49	54	%UVBUS
		0111	VDDDET7		47	52	57	%UVBUS
		1000	VDDDET8		51	56	61	%UVBUS
		1001	VDDDET9		55	60	65	%UVBUS
		1010	VDDDET10		59	64	69	%UVBUS
		1011	VDDDET11		63	68	73	%UVBUS
		1100	VDDDET12		67	72	73	%UVBUS
		1101	VDDDET13		71	76	81	%UVBUS
		1110	VDDDET14		75	80	85	%UVBUS
		1111	VDDDET15		79	84	89	%UVBUS

3.6 Analog Characteristics

3.6.1 A/D converter characteristics

Classification of A/D converter characteristics

Reference Voltage Input Channel	Reference voltage (+) = AV_{REFP} Reference voltage (-) = AV_{REFM}	Reference voltage (+) = AV_{DD} Reference voltage (-) = AV_{SS}	Reference voltage (+) = Internal reference voltage Reference voltage (-) = AV_{SS}
High-accuracy channel; ANI0 to ANI6 (input buffer power supply: AV_{DD})	Refer to 3.6.1 (1).	Refer to 3.6.1 (2).	Refer to 3.6.1 (5).
Standard channel; ANI16 to ANI21 (input buffer power supply: V_{DD})	Refer to 3.6.1 (3).	Refer to 3.6.1 (4).	
Internal reference voltage, Temperature sensor output voltage	Refer to 3.6.1 (3).	Refer to 3.6.1 (4).	—

(1) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), conversion target: ANI2 to ANI6

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{REFP} , Reference voltage (-) = $AV_{REFM} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES	$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error Note	AINL	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Conversion time	t_{CONV}	$ADTYP = 0$, 12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$	3.375			μs
Zero-scale error Note	Ezs	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 4.5	LSB
Full-scale error Note	EFS	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 4.5	LSB
Integral linearity error Note	ILE	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.0	LSB
Differential linearity error Note	DLE	12-bit resolution $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq 3.6\text{ V}$			± 1.5	LSB
Analog input voltage	V_{AIN}		0		AV_{REFP}	V

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

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

- (2) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = AV_{SS} (ADREFM = 0), conversion target: ANI0 to ANI6

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (-) = $AV_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error ^{Note}	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 7.5	LSB
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	3.375			μs
Zero-scale error ^{Note}	Ezs	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Full-scale error ^{Note}	EFS	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 6.0	LSB
Integral linearity error ^{Note}	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 3.0	LSB
Differential linearity error ^{Note}	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.0	LSB
Analog input voltage	V_{AIN}			0		AV_{DD}	V

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

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

- (3) When reference voltage (+) = $AV_{REFP}/ANI0$ ($ADREFP1 = 0$, $ADREFP0 = 1$), reference voltage (-) = $AV_{REFM}/ANI1$ ($ADREFM = 1$), conversion target $ANI16$ to $ANI21$, internal reference voltage, temperature sensor output voltage

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$,

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	8		12	bit
Overall error ^{Note 1}	AINL	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±7.0	LSB
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$	4.125			μs
Zero-scale error ^{Note 1}	EZS	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±5.0	LSB
Full-scale error ^{Note 1}	EFS	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±5.0	LSB
Integral linearity error ^{Note 1}	ILE	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±3.0	LSB
Differential linearity error ^{Note 1}	DLE	12-bit resolution	$2.4\text{ V} \leq \text{AV}_{\text{REFP}} \leq \text{AV}_{\text{DD}} \leq 3.6\text{ V}$			±2.0	LSB
Analog input voltage	VAIN			0		AVREFP	V
		Internal reference voltage ($2.4\text{ V} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, HS (high-speed main) mode)		VBGR ^{Note 2}			
		Temperature sensor output voltage ($2.4\text{ V} \leq \text{V}_{\text{DD}} \leq 3.6\text{ V}$, HS (high-speed main) mode)		VTMP25 ^{Note 2}			

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

Note 2. Refer to 3.6.2 Temperature sensor, internal reference voltage output characteristics.

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

(4) When reference voltage (+) = AV_{DD} (ADREFP1 = 0, ADREFP0 = 0), reference voltage (-) = AV_{SS} (ADREFM = 0), conversion target: ANI16 to ANI21, internal reference voltage, temperature sensor output voltage

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq AV_{DD} = V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$, Reference voltage (+) = AV_{DD} , Reference voltage (-) = $AV_{SS} = 0$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES		$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	8		12	bit
Overall error Note 1	AINL	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.5	LSB
Conversion time	tCONV	ADTYP = 0, 12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$	4.125			μs
Zero-scale error Note 1	Ezs	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.0	LSB
Full-scale error Note 1	EFS	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 8.0	LSB
Integral linearity error Note 1	ILE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 3.5	LSB
Differential linearity error Note 1	DLE	12-bit resolution	$2.4\text{ V} \leq AV_{DD} \leq 3.6\text{ V}$			± 2.5	LSB
Analog input voltage	VAIN			0		AV_{DD}	V
		Internal reference voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V_{BGR} Note 2			
		Temperature sensor output voltage ($2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode)		V_{TMP25} Note 2			

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

Note 2. Refer to 3.6.2 Temperature sensor, internal reference voltage output characteristics.

Caution Always use AV_{DD} pin with the same potential as the V_{DD} pin.

- (5) When reference voltage (+) = Internal reference voltage (1.45 V) (ADREFP1 = 1, ADREFP0 = 0), reference voltage (-) = AVss (ADREFM = 0), conversion target: ANI0 to ANI6, ANI16 to ANI21

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $2.4\text{ V} \leq V_{DD}$, $2.4\text{ V} \leq AV_{DD} = V_{DD}$, $V_{SS} = 0\text{ V}$, $AV_{SS} = 0\text{ V}$,

Reference voltage (+) = internal reference voltage, Reference voltage (-) = AVss = 0 V, HS (high-speed main) mode)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES		8			bit
Conversion time	tCONV	8-bit resolution	16.0			μs
Zero-scale error ^{Note}	EZS	8-bit resolution			± 4.0	LSB
Integral linearity error ^{Note}	ILE	8-bit resolution			± 2.0	LSB
Differential linearity error ^{Note}	DLE	8-bit resolution			± 2.5	LSB
Reference voltage (+)	AVREF(+)	= Internal reference voltage (VBGR)	1.38	1.45	1.5	V
Analog input voltage	VAIN		0		VBGR	V

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

Caution Always use AVDD pin with the same potential as the VDD pin.

3.6.2 Temperature sensor, internal reference voltage output characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$ (HS (high-speed main) mode))

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Temperature sensor output voltage	VTMPS25	Setting ADS register = 80H, $T_A = +25^{\circ}\text{C}$		1.05		V
Internal reference voltage	VBGR	Setting ADS register = 81H	1.38	1.45	1.5	V
Temperature coefficient	FVTMPS	Temperature sensor output voltage that depends on the temperature		-3.6		mV/ $^{\circ}\text{C}$
Operation stabilization wait time	tAMP		10			μs

3.6.3 D/A converter characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES					8	bit
Overall error	AINL	Rload = 4 M Ω	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$			± 2.5	LSB
		Rload = 8 M Ω	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$			± 2.5	LSB
Settling time	tSET	Cload = 20 pF	$2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}$			3	μs
			$2.4\text{ V} \leq V_{DD} < 2.7\text{ V}$			6	μs

3.6.4 Comparator

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input voltage range	Ivref		0		$V_{DD} - 1.4$	V
	Ivcmp		-0.3		$V_{DD} + 0.3$	V
Output delay	td	$V_{DD} = 3.0\text{ V}$ Input slew rate $> 50\text{ mV}/\mu\text{s}$ High-speed comparator mode, standard mode			1.2	μs
		High-speed comparator mode, window mode			2.0	μs
		Low-speed comparator mode, standard mode		3	5.0	μs
High-electric-potential judgment voltage	VTW+	High-speed comparator mode, window mode		$0.76 V_{DD}$		V
Low-electric-potential judgment voltage	VTW-	High-speed comparator mode, window mode		$0.24 V_{DD}$		V
Operation stabilization wait time	tcMP		100			μs
Internal reference voltage Note	VBGR	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, HS (high-speed main) mode	1.38	1.45	1.50	V

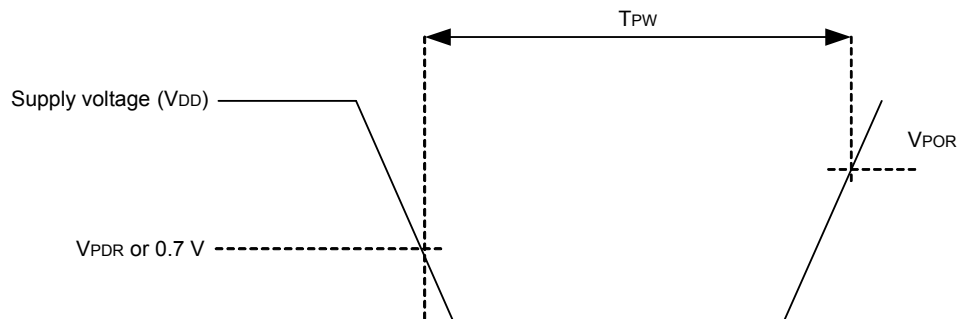
Note Not usable in sub-clock operation or STOP mode.

3.6.5 POR circuit characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	VPOR	Power supply rise time	1.45	1.51	1.57	V
	VPDR	Power supply fall time Note	1.44	1.50	1.56	V
Minimum pulse width	TPW		300			μs

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



3.6.6 LVD circuit characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{PDR} \leq V_{DD} \leq 3.6\text{ V} \leq V_{SS} = 0\text{ V}$)

Parameter		Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	Supply voltage level	VLVD2	Power supply rise time	3.01	3.13	3.25	V
			Power supply fall time	2.94	3.06	3.18	V
		VLVD3	Power supply rise time	2.90	3.02	3.14	V
			Power supply fall time	2.85	2.96	3.07	V
		VLVD4	Power supply rise time	2.81	2.92	3.03	V
			Power supply fall time	2.75	2.86	2.97	V
		VLVD5	Power supply rise time	2.71	2.81	2.92	V
			Power supply fall time	2.64	2.75	2.86	V
		VLVD6	Power supply rise time	2.61	2.71	2.81	V
			Power supply fall time	2.55	2.65	2.75	V
		VLVD7	Power supply rise time	2.51	2.61	2.71	V
			Power supply fall time	2.45	2.55	2.65	V
Minimum pulse width		tLW		300			μs
Detection delay time						300	μs

Caution Set the detection voltage (VLVD) to be within the operating voltage range. The operating voltage range depends on the setting of the user option byte (000C2H/010C2H). The following shows the operating voltage range.

HS (high-speed main) mode: $V_{DD} = 2.7$ to 3.6 V at 1 MHz to 24 MHz

$V_{DD} = 2.4$ to 3.6 V at 1 MHz to 16 MHz

LVD Detection Voltage of Interrupt & Reset Mode**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{PDR} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Interrupt and reset mode	VLVDD0	VPOC0, VPOC1, VPOC2 = 0, 1, 1, falling reset voltage: 2.7 V		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

3.7 Power supply voltage rising slope characteristics**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{SS} = 0\text{ V}$)**

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

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

3.8 LCD Characteristics

3.8.1 Resistance division method

(1) Static display mode

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{L4}(\text{MIN.}) \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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

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

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{L4}(\text{MIN.}) \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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

(3) 1/3 bias method

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{L4}(\text{MIN.}) \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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

3.8.2 Internal voltage boosting method

(1) 1/3 bias method

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	VL1	C1 to C4 ^{Note 1} = 0.47 μF ^{Note 2}	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
			VLCD = 0BH	1.25	1.35	1.43	V
			VLCD = 0CH	1.30	1.40	1.48	V
			VLCD = 0DH	1.35	1.45	1.53	V
			VLCD = 0EH	1.40	1.50	1.58	V
			VLCD = 0FH	1.45	1.55	1.63	V
			VLCD = 10H	1.50	1.60	1.68	V
			VLCD = 11H	1.55	1.65	1.73	V
			VLCD = 12H	1.60	1.70	1.78	V
			VLCD = 13H	1.65	1.75	1.83	V
Doubler output voltage	VL2	C1 to C4 ^{Note 1} = 0.47 μF		2 VL1 - 0.1	2 VL1	2 VL1	V
Tripler output voltage	VL3	C1 to C4 ^{Note 1} = 0.47 μF		3 VL1 - 0.15	3 VL1	3 VL1	V
Reference voltage setup time ^{Note 2}	tvWAIT1			5			ms
Voltage boost wait time ^{Note 3}	tvWAIT2	C1 to C4 ^{Note 1} = 0.47μF		500			ms

Note 1. This is a capacitor that is connected between voltage pins used to drive the LCD.

C1: A capacitor connected between CAPH and CAPL

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

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

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

$C1 = C2 = C3 = C4 = 0.47\text{ }\mu\text{F} \pm 30\%$

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

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

(2) 1/4 bias method**($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)**

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	VL1	C1 to C4 ^{Note 1} = 0.47 μF ^{Note 2}	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
Doubler output voltage	VL2	C1 to C4 ^{Note 1} = 0.47 μF		2 VL1 - 0.08	2 VL1	2 VL1	V
Tripler output voltage	VL3	C1 to C4 ^{Note 1} = 0.47 μF		3 VL1 - 0.12	3 VL1	3 VL1	V
Quadruply output voltage	VL4	C1 to C5 ^{Note 1} = 0.47 μF		4 VL1 - 0.16	4 VL1	4 VL1	V
Reference voltage setup time ^{Note 2}	tVWAIT1			5			ms
Voltage boost wait time ^{Note 3}	tVWAIT2	C1 to C5 ^{Note 1} = 0.47μF		500			ms

Note 1. This is a capacitor that is connected between voltage pins used to drive the LCD.

C1: A capacitor connected between CAPH and CAPL

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

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

C4: A capacitor connected between V_{L3} and GND

C5: A capacitor connected between V_{L4} and GND

$C1 = C2 = C3 = C4 = 0.47\text{ }\mu\text{F} \pm 30\%$

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

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

3.8.3 Capacitor split method

(1) 1/3 bias method

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
V_{L4} voltage	V_{L4}	$C1$ to $C4 = 0.47\text{ }\mu\text{F}$ Note 2		V_{DD}		V
V_{L2} voltage	V_{L2}	$C1$ to $C4 = 0.47\text{ }\mu\text{F}$ Note 2	$2/3 V_{L4} - 0.07$	$2/3 V_{L4}$	$2/3 V_{L4} + 0.07$	V
V_{L1} voltage	V_{L1}	$C1$ to $C4 = 0.47\text{ }\mu\text{F}$ Note 2	$1/3 V_{L4} - 0.08$	$1/3 V_{L4}$	$1/3 V_{L4} + 0.08$	V
Capacitor split wait time Note 1	t_{VWAIT}		100			ms

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

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

$C1$: A capacitor connected between $CAPH$ and $CAPL$

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

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

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

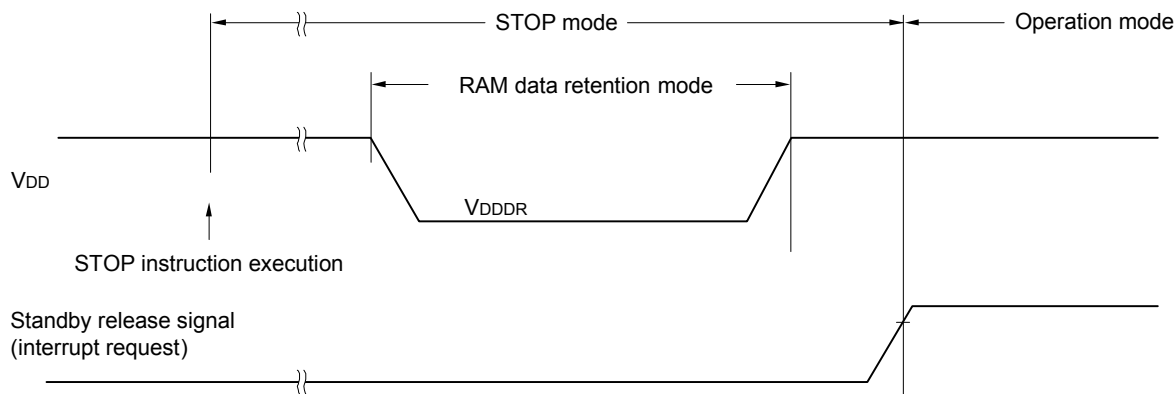
$C1 = C2 = C3 = C4 = 0.47\text{ }\mu\text{F} \pm 30\%$

<R> 3.9 RAM Data Retention Characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $V_{SS} = 0\text{ V}$)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Data retention supply voltage	V_{DDDR}		1.44 Note		3.6	V

Note This depends on the POR detection voltage. For a falling voltage, data in RAM are retained until the voltage reaches the level that triggers a POR reset but not once it reaches the level at which a POR reset is generated.



3.10 Flash Memory Programming Characteristics

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

<R>

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
CPU/peripheral hardware clock frequency	fCLK	$2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$	1		24	MHz
Number of code flash rewrites Notes 1, 2, 3	C _{erwr}	Retained for 20 years $T_A = 85^{\circ}\text{C}$ Note 4	1,000			Times
Number of data flash rewrites Notes 1, 2, 3		Retained for 1 year $T_A = 25^{\circ}\text{C}$		1,000,000		
		Retained for 5 years $T_A = 85^{\circ}\text{C}$ Note 4	100,000			
		Retained for 20 years $T_A = 85^{\circ}\text{C}$ Note 4	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.

<R>

Note 4. This temperature is the average value at which data are retained.

3.11 Dedicated Flash Memory Programmer Communication (UART)

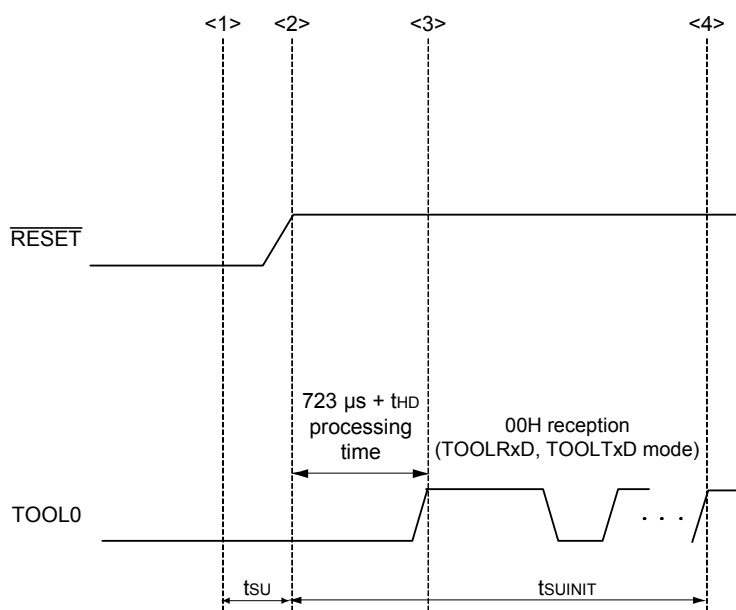
($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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

3.12 Timing Specs for Switching Modes

($T_A = -40$ to $+105\text{ }^{\circ}\text{C}$, $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}$, $V_{SS} = 0\text{ V}$)

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



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

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

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

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

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

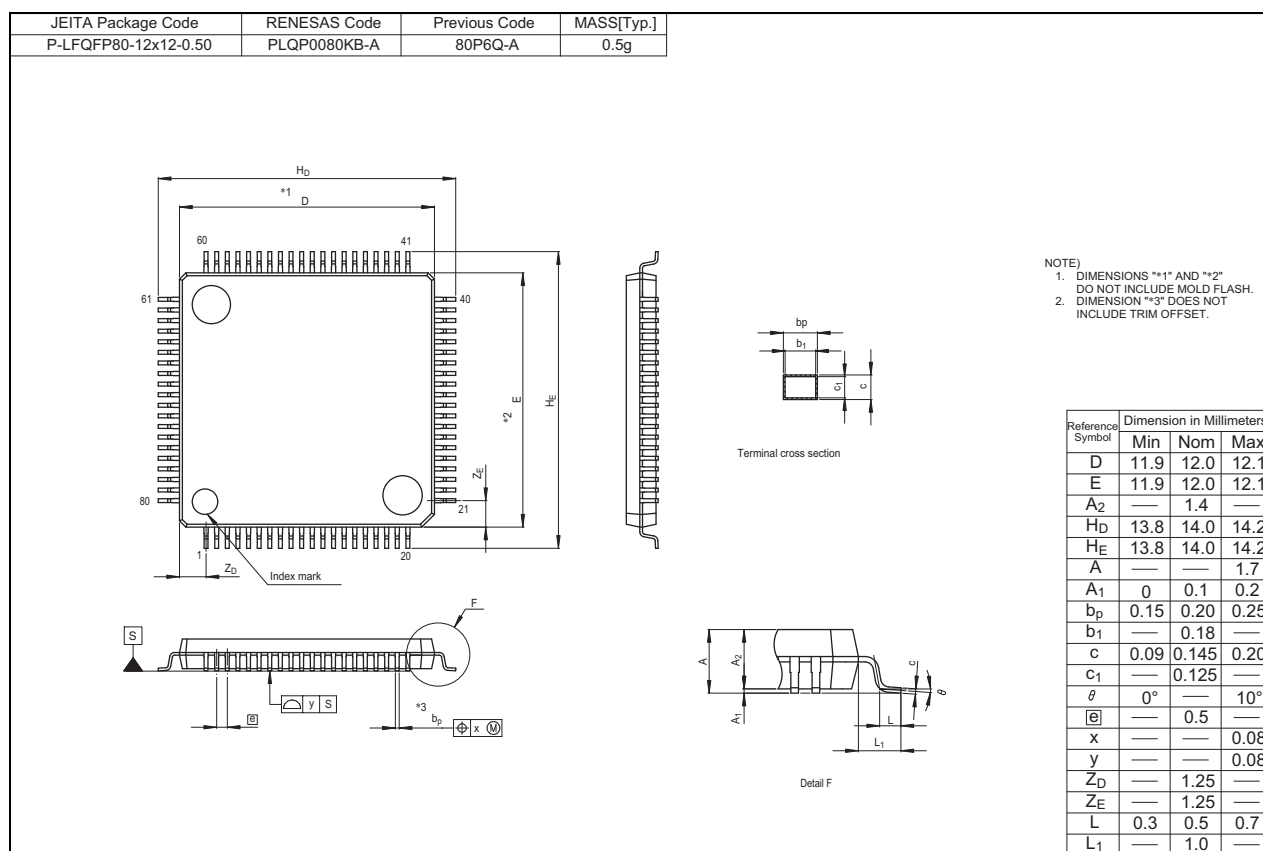
tsu: How long from when the TOOL0 pin is placed at the low level until a external reset ends

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

4. PACKAGE DRAWINGS

4.1 80-pin products

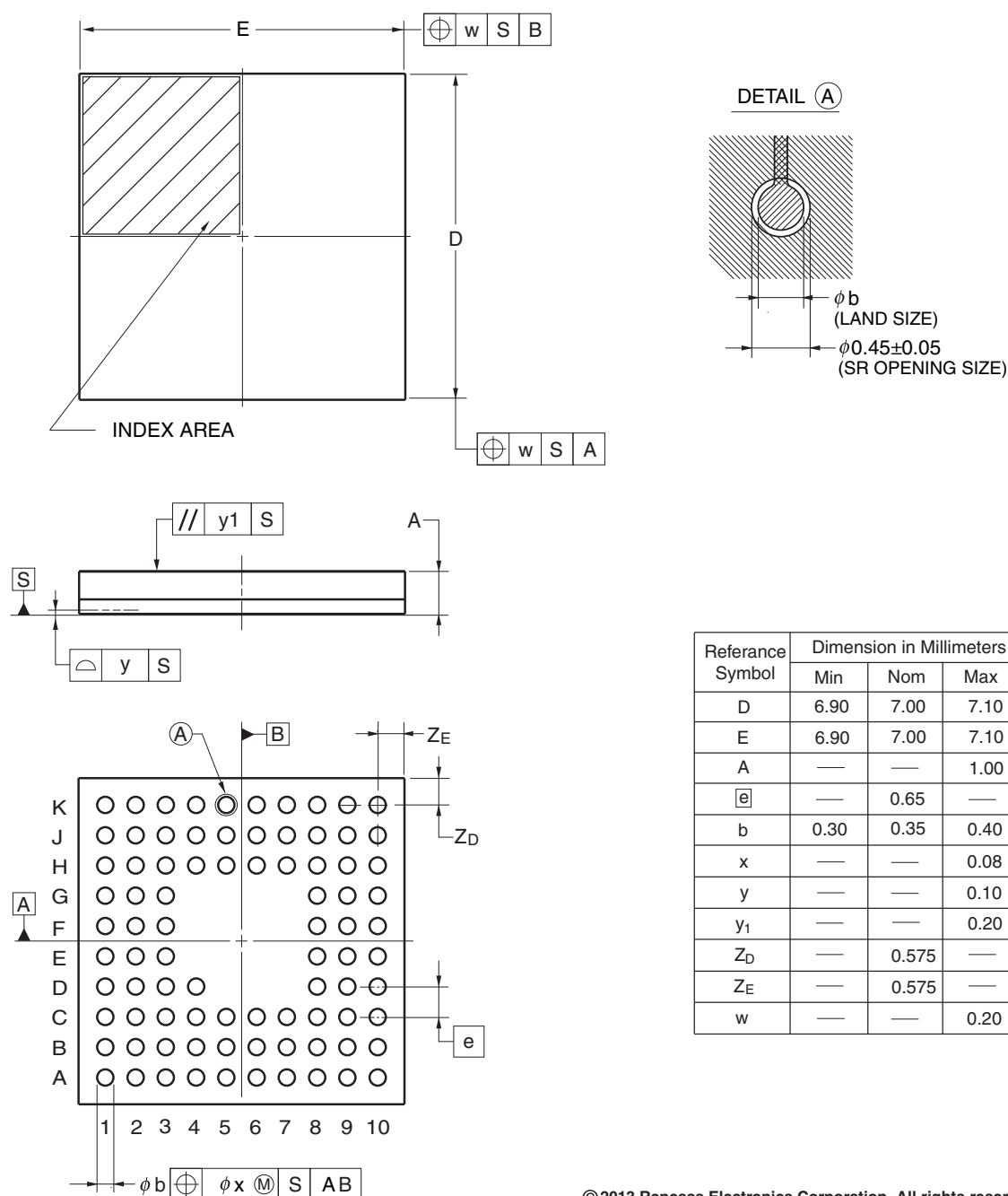
R5F110MEAFB, R5F110MFAFB, R5F110MGAFB, R5F110MHAFB, R5F110MJAFB
 R5F111MEAFB, R5F111MFAFB, R5F111MGAFB, R5F111MHAFB, R5F111MJAFB
 R5F110MEGFB, R5F110MFGFB, R5F110MGGFB, R5F110MHGFB, R5F110MJGFB
 R5F111MEGFB, R5F111MFGFB, R5F111MGGFB, R5F111MHGFB, R5F111MJGFB



4.2 85-pin products

R5F110NEALA, R5F110NFALA, R5F110NGALA, R5F110NHALA, R5F110NJALA
 R5F111NEALA, R5F111NFALA, R5F111NGALA, R5F111NHALA, R5F111NJALA
 R5F110NEGLA, R5F110NFGLA, R5F110NGGLA, R5F110NHGLA, R5F110NJGLA
 R5F111NEGLA, R5F111NFGLA, R5F111NGGLA, R5F111NHGLA, R5F111NJGLA

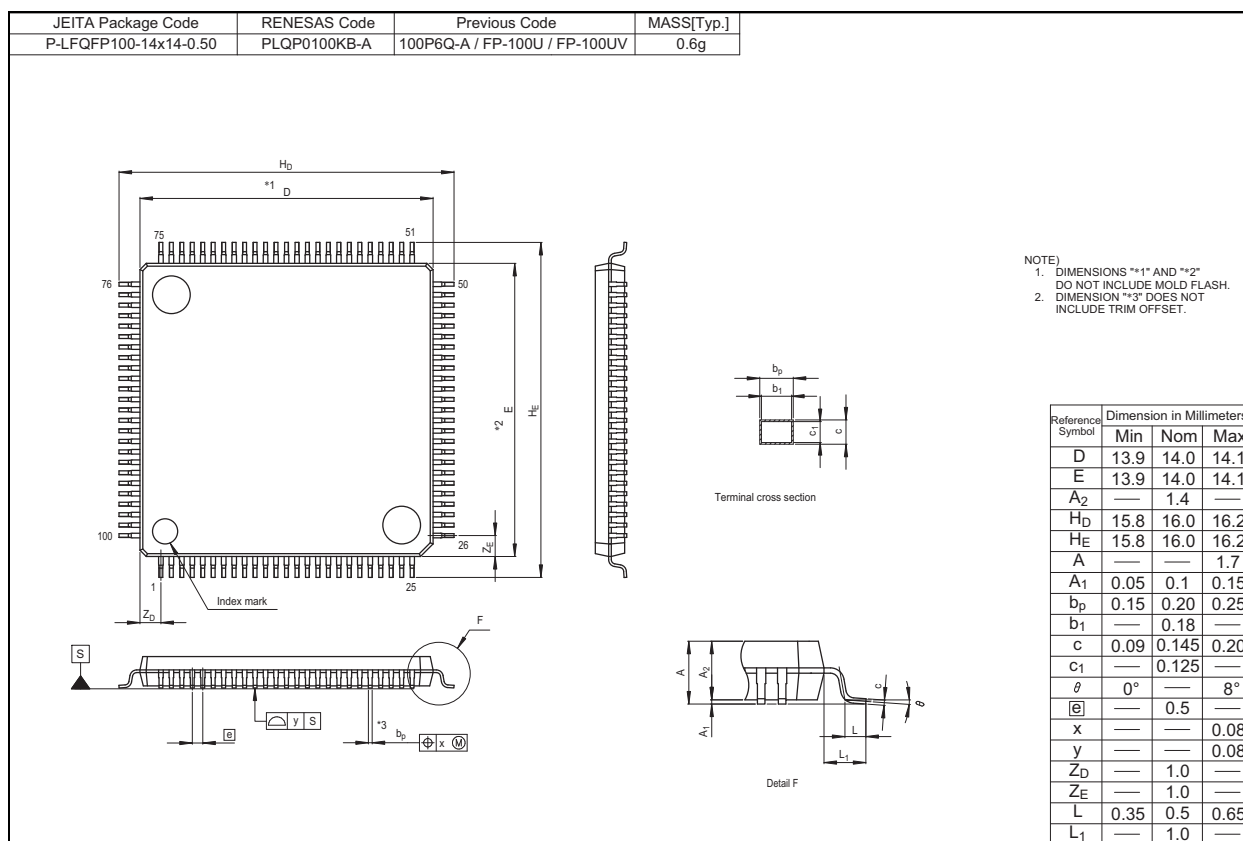
JEITA Package code	RENESAS code	Previous code	MASS(TYP.)[g]
P-VFLGA85-7x7-0.65	PVLG0085JA-A	P85FC-65-BN4	0.1



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4.3 100-pin products

R5F110PEAFB, R5F110PFAFB, R5F110PGAFA, R5F110PHAFA, R5F110PJAFB
 R5F111PEAFB, R5F111PFAFB, R5F111PGAFA, R5F111PHAFA, R5F111PJAFB
 R5F110PEGFB, R5F110PFGFB, R5F110PGGFB, R5F110PHGFB, R5F110PJGFB
 R5F111PEGFB, R5F111PFGFB, R5F111PGGFB, R5F111PHGFB, R5F111PJGFB



REVISION HISTORY	RL78/L1C Datasheet
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Rev.	Date	Description	
		Page	Summary
0.01	Oct 15, 2012	—	First Edition issued
1.00	Nov 18, 2013	1, 2	Modification of 1.1 Features
		3, 4	Modification of 1.2 Ordering Information
		5 to 8	Modification of package type in 1.3 Pin Configuration (Top View)
		14 to 17	Modification of vectored interrupt sources in 1.6 Outline of Functions
		14 to 17	Modification of operating ambient temperature in 1.6 Outline of Functions
		19 to 21	Modification of description in tables in 2.1 Absolute Maximum Ratings
		22, 23	Modification of description in 2.2 Oscillator Characteristics
		25	Modification of low-level output current in 2.3.1 Pin characteristics
		26	Modification of error of high-level input voltage conditions in 2.3.1 Pin characteristics
		26	Modification of error of low-level input voltage conditions in 2.3.1 Pin characteristics
		27	Modification of low-level output voltage in 2.3.1 Pin characteristics
		28	Modification of error of internal pull-up resistor conditions in 2.3.1 Pin characteristics
		29 to 34	Modification of 2.3.2 Supply current characteristics
		35, 36	Modification of 2.4 AC Characteristics
		37, 38	Addition of minimum instruction execution time during main system clock operation
		41 to 63	Addition of LS mode and LV mode characteristics in 2.5.1 Serial array unit
		64 to 66	Addition of LS mode and LV mode characteristics in 2.5.2 Serial interface IICA
		67, 68	Modification of conditions in 2.5.3 USB
		69	Addition of (3) BC option standard in 2.5.3 USB
		70 to 75	Addition of characteristics about conversion of internal reference voltage and temperature sensor in 2.6.1 A/D converter characteristics
		76	Addition of characteristic in 2.6.4 Comparator
		76	Deletion of detection delay in 2.6.5 POR circuit characteristics
		78	Modification of 2.7 Power supply voltage rising slope characteristics
		79 to 82	Modification of 2.8 LCD Characteristics
2.00	Feb 21, 2014	83	Modification of 2.9 Data Memory STOP Mode Low Supply Voltage Data Retention Characteristics
		83	Modification of 2.10 Flash Memory Programming Characteristics
		84	Addition of 2.12 Timing Specs for Switching Modes
		85 to 144	Addition of 3. ELECTRICAL SPECIFICATIONS (G: TA = -40 to +105°C)
		All	Addition of 85-pin product information
		All	Modification from 80-pin to 80/85-pin
		All	Modification from x = M, P to x = M, N, P
		All	Modification from high-accuracy real-time clock to real-time clock 2
		All	Modification from RTC to RTC2
		1	Modification of 1.1 Features
		3	Modification of 1.2 Ordering Information

REVISION HISTORY	RL78/L1C Datasheet
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Rev.	Date	Description	
		Page	Summary
2.00	Feb 21, 2014	4	Modification of Figure 1 - 1 Part Number, Memory Size, and Package of RL78/L1C
		69	Modification of (1) Electrical specifications in 2.5.3 USB
		82	Modification of note 1 in (1) 1/3 bias method in 2.8.2 Internal voltage boosting method
		130	Modification of (1) Electrical specifications in 3.5.3 USB
		142	Modification of note 1 in (1) 1/3 bias method in 3.8.2 Internal voltage boosting method
2.10	Aug 12, 2016	5	Addition of product name (RL78/L1C) and description (Top View) in 1.3.1 80-pin products (with USB)
		6	Addition of product name (RL78/L1C) and description (Top View) in 1.3.2 80-pin products (without USB)
		9	Addition of product name (RL78/L1C) and description (Top View) in 1.3.5 100-pin products (with USB)
		10	Addition of product name (RL78/L1C) and description (Top View) in 1.3.6 100-pin products (without USB)
		17, 19	Modification of 1.6 Outline of Functions
		23	Modification of description in Absolute Maximum Ratings (TA = 25°C)
		26, 27	Modification of description in 2.3.1 Pin characteristics
		39, 40	Modification of the graph for Minimum Instruction Execution Time during Main System Clock Operation
		72	Modification of conditions in (1) of 2.6.1 A/D converter characteristics
		85	Modification of the title and note in 2.9 RAM Data Retention Characteristics
		85	Modification of conditions in 2.10 Flash Memory Programming Characteristics
		87	Modification of description in 3. ELECTRICAL SPECIFICATIONS (G: INDUSTRIAL APPLICATIONS TA = -40 to +105 °C)
		88, 90	Modification of description in Absolute Maximum Ratings (TA = 25°C)
		93, 94, 96	Modification of description in 3.3.1 Pin characteristics
		106	Modification of the graph for Minimum Instruction Execution Time during Main System Clock Operation
		144	Modification of the title and note in 3.9 RAM Data Retention Characteristics
		145	Modification of conditions and addition of note 4 in 3.10 Flash Memory Programming Characteristics

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

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