RL78/L1A

RENESAS MCU

R01DS0280EJ0110
Rev.1.10
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Integrated LCD controller/driver, 12-bit resolution A/D Converter, 12-bit resolution D/A Converter, Operational amplifier, Internal reference voltage for A/D and D/A converters. True Low Power Platform (as low as 70.8 µA/MHz, and 0.68 µA in Halt mode(RTC2 + LVD)), 1.8 V to 3.6 V operation, 48 to 128 Kbyte Flash, 33 DMIPS at 24 MHz, for All LCD Based Applications.

1. OUTLINE

1.1 Features

○ Ultra-low power consumption technology
- V_{DD} = single power supply voltage of 1.8 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 µs: @ 24 MHz operation with high-speed on-chip oscillator clock) to ultra-low speed (30.5 µs: @ 32.768 kHz operation with subsystem clock)
- Multiply/divide and multiply/accumulate instructions are supported.
- Address space: 1 MB
- General-purpose registers: (8-bit register × 8) × 4 banks
- On-chip RAM: 5.5 KB

○ Code flash memory
- Code flash memory: 48 to 128 KB
- Block size: 1 KB
- Prohibition of block erase and rewriting (security function)
- On-chip debug function
- Self-programming (with boot swap function/flash shield window function)

○ 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 24 MHz, 16 MHz, 12 MHz, 8 MHz, 6 MHz, 4 MHz, 3 MHz, 2 MHz, and 1 MHz
- High accuracy: ±1.0% (V_{DD} = 1.8 to 3.6 V, T_A = -20 to +85°C)

○ Operating ambient temperature
- T_A = -40 to +85°C (A: Consumer applications)

○ Power management and reset function
- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 10 levels)

○ Data transfer controller (DTC)
- Transfer modes: Normal transfer mode, repeat transfer mode, block transfer mode
- Activation sources: Activated by interrupt sources (30 sources).
- Chain transfer function

○ Event link controller (ELC)
- Event signals of 22 types can be linked to the specified peripheral function.

○ Serial interfaces
- CSI/CSI (SPI supported): 4 channels
- UART: 4 channels
- I^2C/simplified I^2C: 5 channels

○ Timers
- 16-bit timer: 8 channels
- 8-bit timer: 2 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: 32 (28) to 45 (41) Note 1
- Common signal output: 4 (8) Note 1

○ A/D converter
- 12-bit resolution A/D converter (1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V)
- Analog input: 10 to 15 channels (including a dedicated one for internal 1/2 AV_{DD})
- Internal reference voltage (TYP. 1.45 V) and temperature sensor Note 2

<R>

○ D/A converter
- 12-bit resolution D/A converter (1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V)
- Analog output: 2 channels
- Output voltage: 0.35 V to AV_{DD} – 0.47 V

○ Voltage reference
- The output voltage can be selected from among 1.5 V (typ.), 1.8 V (typ.), 2.048 V (typ.), and 2.5 V (typ.).
- Can be used as the internal reference voltage for A/D and D/A converters.

○ Comparator
- 1 channel
- 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.

○ Operational amplifier
- General-purpose operational amplifier: 1 channel
- Rail-to-rail operational amplifier with analog MUX: 2 channels

○ I/O ports
- I/O ports: 59 to 79 (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**.

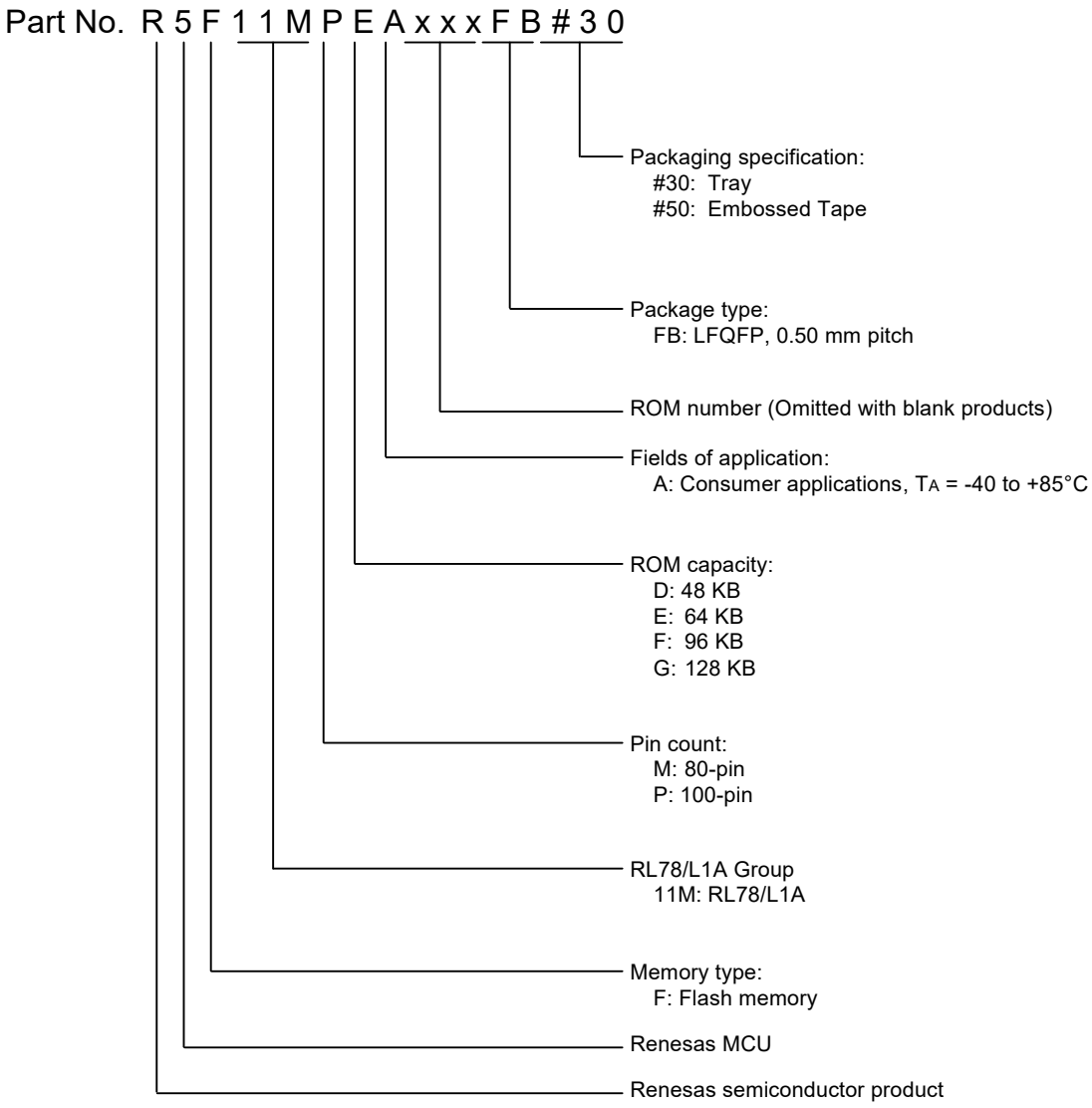
○ ROM, RAM capacities

Flash ROM	Data Flash	RAM	RL78/L1A	
			80 pins	100 pins
128 KB	8 KB	5.5 KB	—	R5F11MPG
96 KB	8 KB	5.5 KB	R5F11MMF	R5F11MPF
64 KB	8 KB	5.5 KB	R5F11MME	R5F11MPE
48 KB	8 KB	5.5 KB	R5F11MMD	—

1.2 Ordering Information

Pin Count	Package	Fields of Application	Orderable Part Number
80 pins	80-pin plastic LFQFP (12 × 12 mm, 0.5 mm pitch)	A	R5F11MMDAFB#30, R5F11MMEAFB#30, R5F111MFAFB#30 R5F11MMDAFB#50, R5F11MMEAFB#50, R5F11MMFAFB#50
100 pins	100-pin plastic LFQFP (14 × 14 mm, 0.5 mm pitch)	A	R5F11MPEAFB#30, R5F11MPFAFB#30, R5F11MPGAFB#30 R5F11MPEAFB#50, R5F11MPFAFB#50, R5F11MPGAFB#50

Figure 1 - 1 Part Number, Memory Size, and Package of RL78/L1A

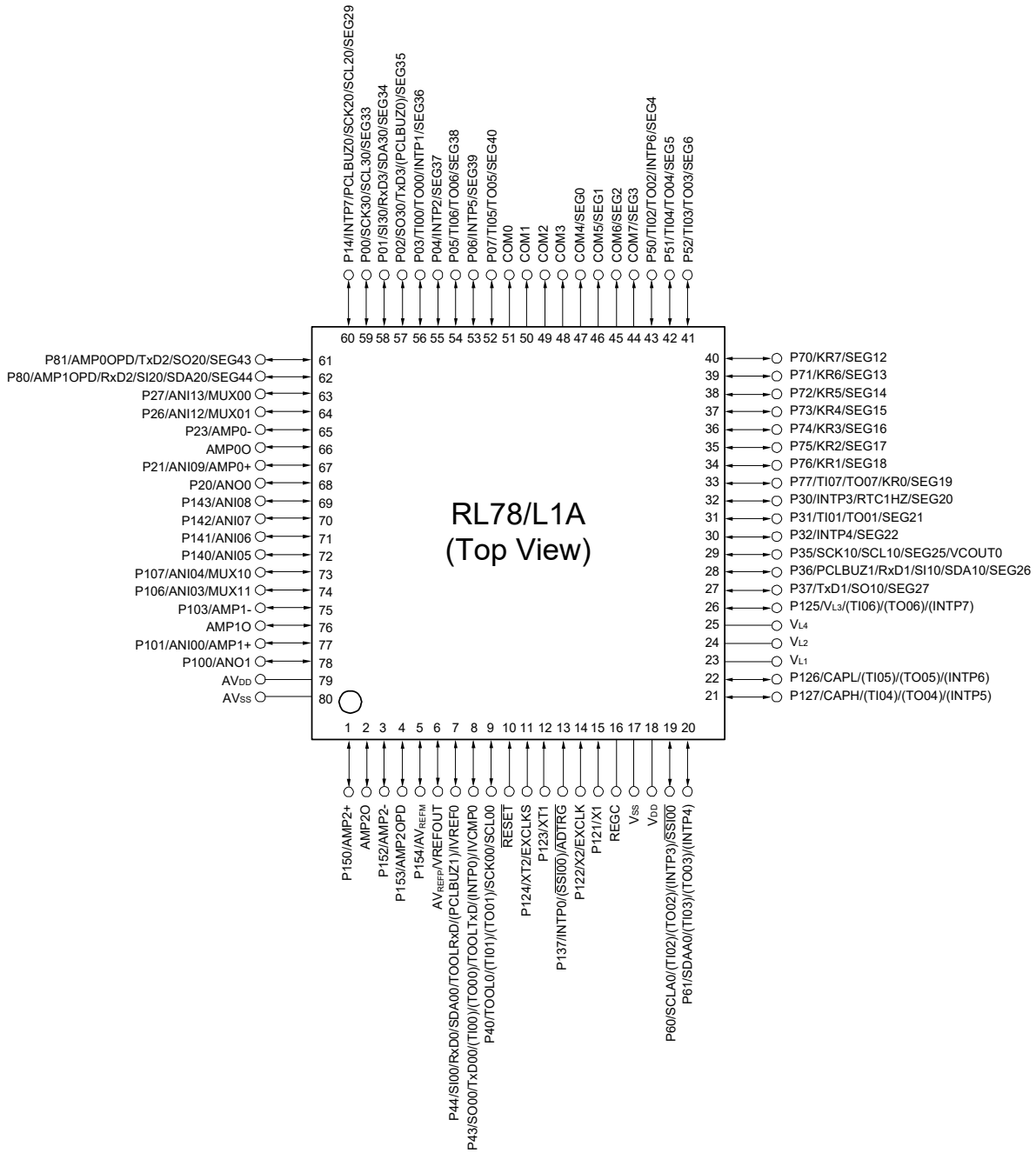


Caution Orderable part numbers are current as of when this manual was published.
Please make sure to refer to the relevant product page on the Renesas website for the latest part numbers.

1.3 Pin Configuration (Top View)

1.3.1 80-pin products

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



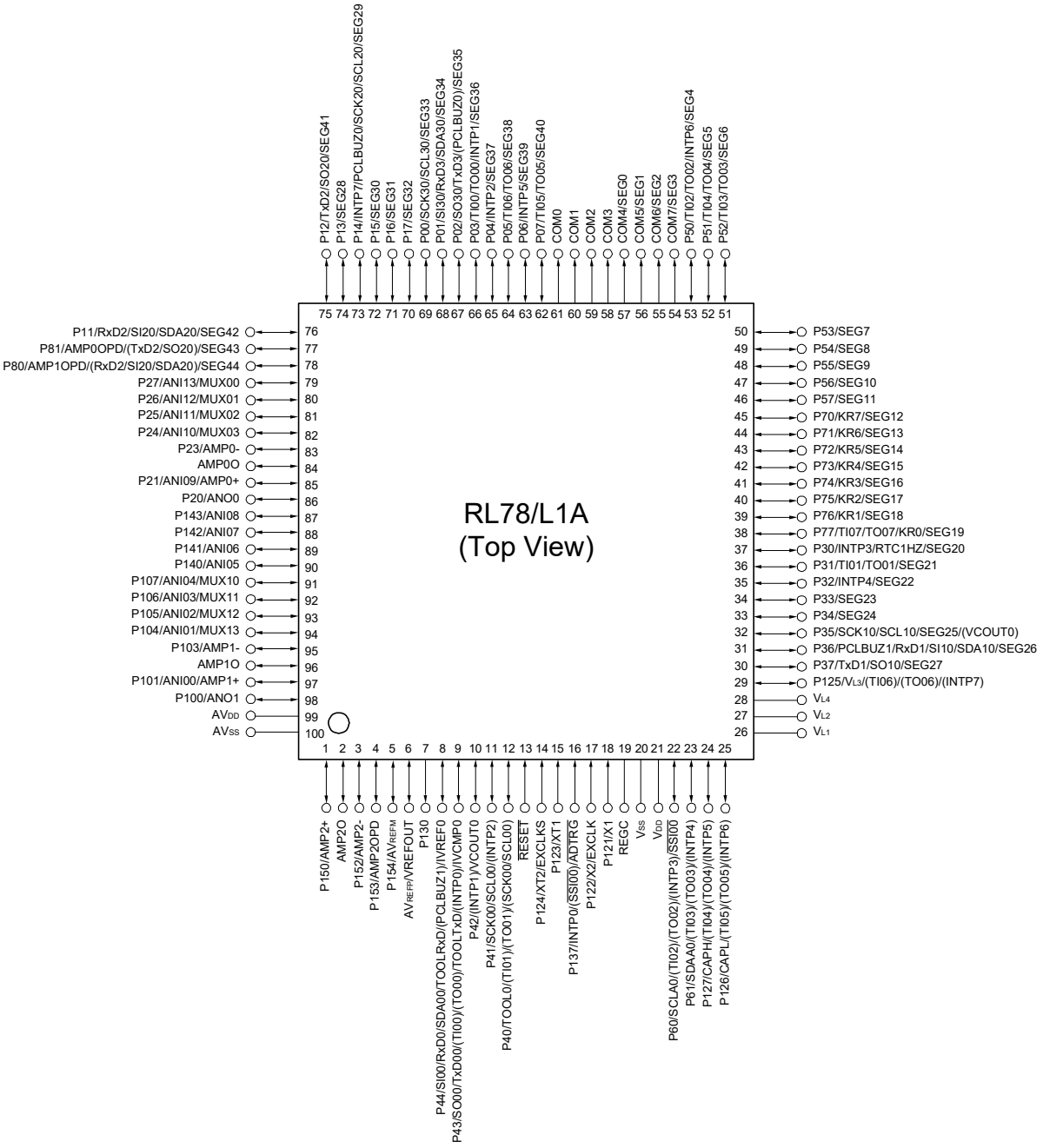
Caution Connect the REGC pin to VSS pin via a capacitor (0.47 to 1 μF).

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).

1.3.2 100-pin products

• 100-pin plastic LFQFP (fine pitch) (14 × 14 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**.

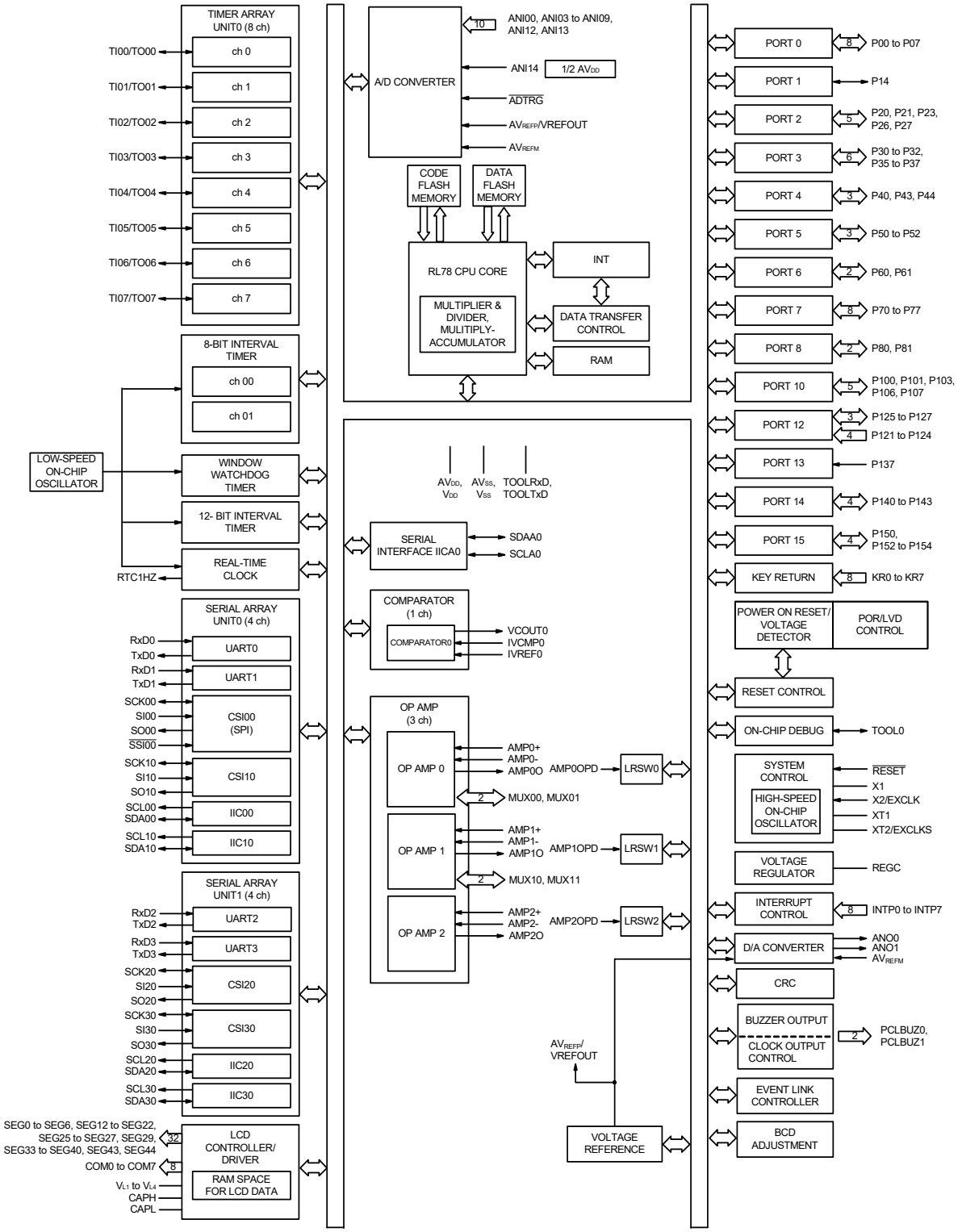
Remark 2. Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).

<R> 1.4 Pin Identification

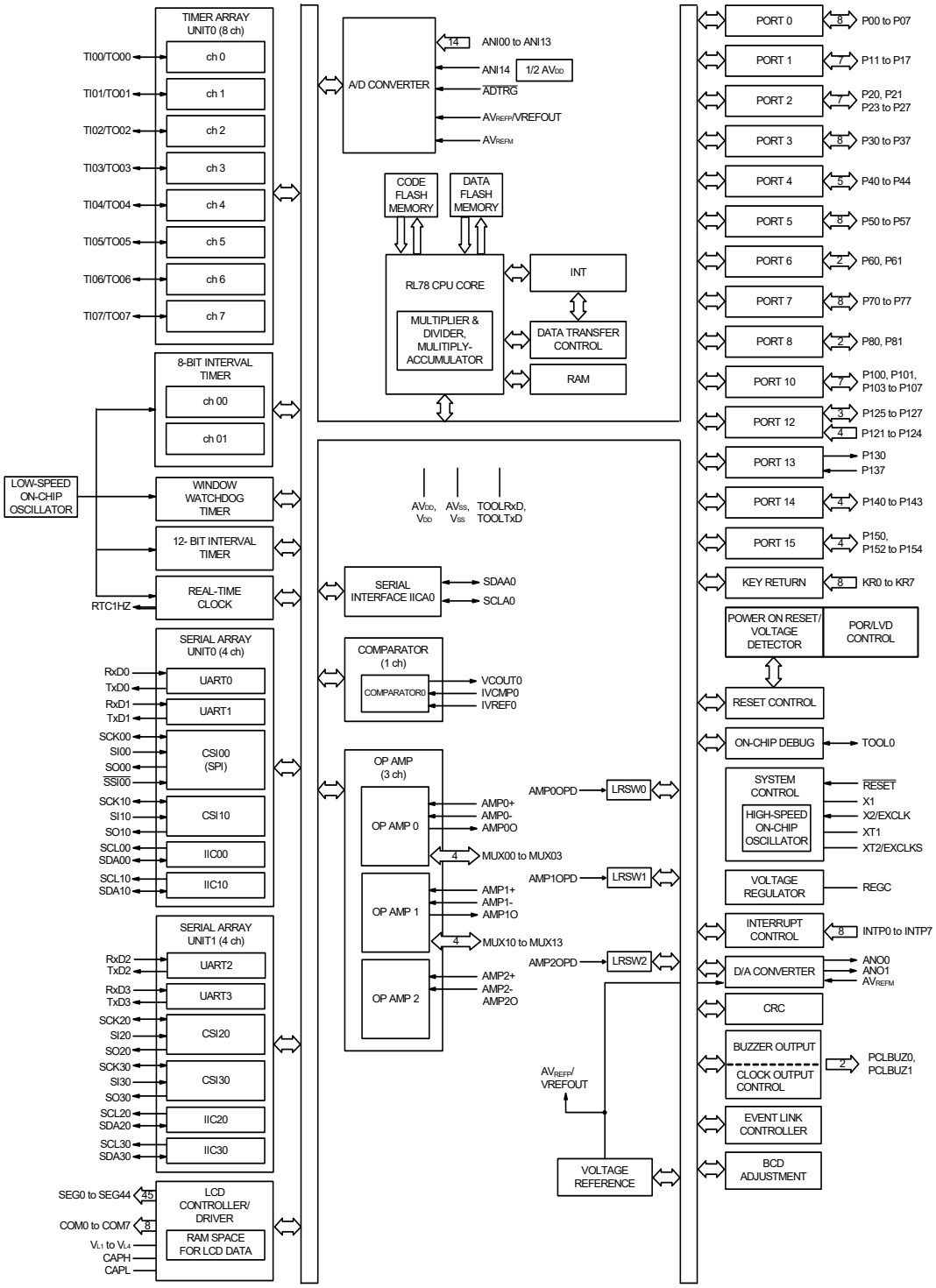
AMP0+ to AMP2+ : OP AMP + Input
AMP0- to AMP2- : OP AMP - Input
AMP0O to AMP2O : OP AMP Output
AMP0OPD to AMP2OPD : Low Resistance Switch
$\overline{\text{ADTRG}}$: A/D External Trigger Input
ANI00 to ANI13 : Analog Input
ANO0, ANO1 : Analog Output
AVDD : Analog Power Supply
AVREFM : Analog Reference Voltage Minus
AVREFP : Analog Reference Voltage Plus
AVSS : Analog Ground
CAPH, CAPL : Capacitor for LCD
COM0 to COM7 : LCD Common Output
EXCLK : External Clock Input (Main System Clock)
EXCLKS : External Clock Input (Sub System Clock)
INTP0 to INTP7 : External Interrupt Input
IVCMP0 : Comparator Input
IVREF0 : Comparator Reference Input
KR0 to KR7 : Key Return
MUX00 to MUX03, MUX10 to MUX13 : OP AMP output analog MUX switch
P00 to P07 : Port 0
P11 to P17 : Port 1
P20, P21 P23 to P27 : Port 2
P30 to P37 : Port 3
P40 to P44 : Port 4
P50 to P57 : Port 5
P60, P61 : Port 6
P70 to P77 : Port 7
P80, P81 : Port 8
P100, P101 P103 to P107 : Port 10
P121 to P127 : Port 12
P130, P137 : Port 13
P140 to P143 : Port 14
P150, P152 to P154 : Port 15
PCLBUZ0, PCLBUZ1 : Programmable Clock Output/ Buzzer Output
REGC : Regulator Capacitance
$\overline{\text{RESET}}$: Reset
RTC1HZ : Real-time Clock Correction
RxD0 to RxD3 : Receive Data
SCK00, SCK10, SCK20, SCK30 : Serial Clock Input/Output
SCLA0 : Serial Clock Input/Output
SCL00, SCL10, SCL20, SCL30 : Serial Clock Output
SDAA0, SDA00, SDA10, SDA20, SDA30 : Serial Data Input/Output
SEG0 to SEG44 : LCD Segment Output
SI00, SI10, SI20, SI30 : Serial Data Input
SO00, SO10, SO20, SO30 : Serial Data Output
$\overline{\text{SSI00}}$: Slave Select Input
TI00 to TI07 : Timer Input
TO00 to TO07 : Timer Output
TOOL0 : Data Input/Output for Tool
TOOLRxD, TOOLTxD : Data Input/Output for External Device
TxD0 to TxD3 : Transmit Data
VCOUT0 : Comparator Output
VDD : Power Supply
VL1 to VL4 : LCD Power Supply
VREFOUT : Analog Reference Voltage Output
VSS : Ground
X1, X2 : Crystal Oscillator (Main System Clock)
XT1, XT2 : Crystal Oscillator (Subsystem Clock)

1.5 Block Diagram

<R> 1.5.1 80-pin products



<R> 1.5.2 100-pin products



1.6 Outline of Functions

[80-pin, 100-pin products] **(1/2)**

Item		80-pin	100-pin
		R5F11MMx (x = D to F)	R5F11MPx (x = E to G)
Code flash memory (KB)		48 to 96	64 to 128
Data flash memory (KB)		8	8
RAM (KB)		5.5	5.5
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: VDD = 2.7 to 3.6 V, 1 to 8 MHz: VDD = 1.8 to 2.7 V	
	High-speed on-chip oscillator clock	HS (high-speed main) operation mode: 1 to 24 MHz (VDD = 2.7 to 3.6 V), HS (high-speed main) operation mode: 1 to 16 MHz (VDD = 2.4 to 3.6 V), LS (low-speed main) operation mode: 1 to 8 MHz (VDD = 1.8 to 3.6 V)	
Subsystem clock		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.): VDD = 1.8 to 3.6 V	
Low-speed on-chip oscillator clock		15 kHz (TYP.): VDD = 1.8 to 3.6 V	
General-purpose register		8 bits × 32 registers (8 bits × 8 registers × 4 banks)	
Minimum instruction execution time		0.04167 μs (High-speed on-chip oscillator clock: fHOCO = fIH = 24 MHz operation)	
		0.05 μs (High-speed system clock: fMX = 20 MHz operation)	
		30.5 μs (Subsystem clock: fSUB = 32.768 kHz operation)	
Instruction set		• Data transfer (8/16 bits) • Adder and subtractor/logical operation (8/16 bits) • Multiplication (8 bits × 8 bits, 16 bits × 16 bits), Division (16 bits ÷ 16 bits, 32 bits ÷ 32 bits) • Multiplication and Accumulation (16 bits × 16 bits + 32 bits) • Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc.	
I/O port	Total	59	79
	CMOS I/O	52	71
	CMOS input	5	5
	CMOS output	0	1
	N-ch open-drain I/O (6 V tolerance)	2	2
Timer	16-bit timer TAU	8 channels (Timer outputs: 8, PWM outputs: 7 Note)	
	8-bit or 16-bit interval timer	2 channels (8 bits) / 1 channel (16 bits)	
	Watchdog timer	1 channel	
	12-bit interval timer	1 channel	
	Real-time clock 2	1 channel	
	RTC output	1 1 Hz (subsystem clock: fSUB = 32.768 kHz)	

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

(2/2)

Item			80-pin	100-pin
			R5F11MMx (x = D to F)	R5F11MPx (x = E to G)
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: fMAIN = 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: fSUB = 32.768 kHz operation)	
12-bit resolution A/D converter			10 channels	14 channels
12-bit resolution D/A converter			2 channels	2 channels
VREFOUT (voltage reference)			2.5 V/2.048 V/1.8 V/1.5 V	
Operational amplifier			3 channels	3 channels
	AMPnO with analog MUX switch		2 channels (2 in-out/channel)	2 channels (4 in-out/channel)
Comparator			1 channel	1 channel
Serial interface			• CSI (SPI supported): 1 channel/UART (LIN-bus supported): 1 channel/simplified I^2C: 1 channel • CSI: 1 channel/UART: 1 channel/simplified I^2C: 1 channel • CSI: 1 channel/UART: 1 channel/simplified I^2C: 1 channel • CSI: 1 channel/UART: 1 channel/simplified I^2C: 1 channel	
	I^2C 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		32 (28) Note 1	45 (41) Note 1
	Common signal output		4 (8) Note 1	
Data transfer controller (DTC)			30 sources	30 sources
Event link controller (ELC)			Event input: 22, Event trigger output: 8	Event input: 22, Event trigger output: 8
Vectored interrupt sources		Internal	31	31
		External	9	9
Key interrupt			8	8
Reset			• Reset by $\overline{\text{RESET}}$ pin • Internal reset by watchdog timer • Internal reset by power-on-reset • Internal reset by voltage detector • Internal reset by illegal instruction execution Note 2 • Internal reset by RAM parity error • Internal reset by illegal-memory access	
Power-on-reset circuit			• Power-on-reset: 1.51 ±0.04 V • Power-down-reset: 1.50 ±0.04 V	
Voltage detector			• Rising edge: 1.88 V to 3.13 V (10 stages) • Falling edge: 1.84 V to 3.06 V (10 stages)	
On-chip debug function			Provided	
Power supply voltage			VDD = 1.8 to 3.6 V	
Operating ambient temperature			TA = -40 to +85°C (A: Consumer 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.

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

This chapter describes the following electrical specifications.

Target products A: Consumer applications (TA = -40 to +85°C)
R5F11MxxAFB

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. The pins mounted depend on the product. Refer to 2.1 Port Function to 2.2.1 With functions for each product in the RL78/L1A User's Manual.

2.1 Absolute Maximum Ratings

Absolute Maximum Ratings (T_A = 25°C) **(1/3)**

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V_{DD}		-0.5 to +6.5	V
	AV_{DD}	$AV_{DD} \leq V_{DD}$	-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
<R> Input voltage	V_{I1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P121 to P127, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$	-0.3 to V_{DD} + 0.3 Note 2	V
	V_{I2}	P60, P61 (N-ch open-drain)	-0.3 to +6.5	V
	V_{I4}	IVCMP0	-0.7 to V_{DD} + 0.7	V
	V_{I5}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-0.3 to AV_{DD} + 0.3 Note 3	V
Output voltage	V_{O1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127, P130	-0.3 to V_{DD} + 0.3 Note 2	V
	V_{O2}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-0.3 to AV_{DD} + 0.3 Note 3	V
<R> Analog input voltage	V_{AI2}	ANI00 to ANI13	-0.3 to AV_{DD} + 0.3 and $AV_{REF(+)}$ + 0.3 Notes 2, 4	V

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

Note 2. Must be 6.5 V or lower.

Note 3. Must be 4.6 V or lower.

Note 4. Do not exceed $AV_{REF(+)}$ + 0.3 V in case of A/D conversion target pin.

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

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

Remark 2. $AV_{REF(+)}$: Positive 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	V_{LI1}	V_{L1} input voltage Note 1		-0.3 to +2.8	V
	V_{LI2}	V_{L2} input voltage Note 1		-0.3 to +6.5	V
	V_{LI3}	V_{L3} input voltage Note 1		-0.3 to +6.5	V
	V_{LI4}	V_{L4} input voltage Note 1		-0.3 to +6.5	V
	V_{LI5}	CAPL, CAPH input voltage Note 1		-0.3 to +6.5	V
	V_{LO1}	V_{L1} output voltage		-0.3 to +2.8	V
	V_{LO2}	V_{L2} output voltage		-0.3 to +6.5	V
	V_{LO3}	V_{L3} output voltage		-0.3 to +6.5	V
	V_{LO4}	V_{L4} output voltage		-0.3 to +6.5	V
	V_{LO5}	CAPL, CAPH output voltage		-0.3 to +6.5	V
	V_{LO6}	COM0 to COM7 SEG0 to SEG44 output voltage	External resistance division method	-0.3 to V_{DD} + 0.3 Note 2	V
			Capacitor split method	-0.3 to V_{DD} + 0.3 Note 2	V
			Internal voltage boosting method	-0.3 to V_{LI4} + 0.3 Note 2	V

Note 1. This value only indicates the absolute maximum ratings when applying voltage to the V_{L1}, V_{L2}, V_{L3}, and V_{L4} pins; it does not mean that applying voltage to these pins is recommended. When using the internal voltage boosting method or capacitance split method, connect these pins to V_{SS} via a capacitor (0.47 ± 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	I_{OH1}	Per pin		-40	mA
<R>		Total of all pins -170 mA	P40 to P44, P130	-70	mA
<R>			P00 to P07, P11 to P17, P30 to P37, P50 to P57, P70 to P77, P80, P81, P125 to P127	-100	mA
	I_{OH2}	Per pin	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-0.1	mA
		Total of all pins		-1.6 Note	mA
Output current, low	I_{OL1}	Per pin		40	mA
<R>		Total of all pins 170 mA	P40 to P44, P130	70	mA
<R>			P00 to P07, P11 to P17, P30 to P37, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127	100	mA
	I_{OL2}	Per pin	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	0.4	mA
		Total of all pins		6.4 Note	mA
Operating ambient temperature	T_A	In normal operation mode		-40 to +85	°C
		In flash memory programming mode			
Storage temperature	T_{stg}			-65 to +150	°C

Note Do not exceed the rated value of current even in simultaneous output from the maximum of 16 AV_{DD}-group pins.

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

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

Parameter	Resonator	Conditions	MIN.	TYP.	MAX.	Unit
X1 clock oscillation frequency (f_X) Note	Ceramic resonator/crystal resonator	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	
		1.8 V ≤ V_{DD} < 2.4 V	1.0		8.0	
XT1 clock oscillation frequency (f_{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.**

Remark When using the X1 and XT1 oscillator, refer to **5.4 System Clock Oscillator in the RL78/L1A User's Manual**.

2.2.2 On-chip oscillator characteristics

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

Oscillators	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
High-speed on-chip oscillator clock frequency Notes 1, 2	f_{HOCO}	2.7 V ≤ V_{DD} ≤ 3.6 V		1		24	MHz
		2.4 V ≤ V_{DD} ≤ 3.6 V		1		16	MHz
		1.8 V ≤ V_{DD} ≤ 3.6 V		1		8	MHz
High-speed on-chip oscillator clock frequency accuracy		-20 to +85°C	1.8 V ≤ V_{DD} ≤ 3.6 V	-1.0		+1.0	%
		-40 to -20°C	1.8 V ≤ V_{DD} ≤ 3.6 V	-1.5		+1.5	%
Low-speed on-chip oscillator clock frequency	f_{IL}				15		kHz
Low-speed on-chip oscillator clock frequency accuracy				-15		+15	%

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

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

2.3 DC Characteristics

<R> 2.3.1 Pin characteristics

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

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output current, high Note 1	I_{OH1}	Per pin for P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130				-10.0 Note 2	mA
		Total of P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130 (When duty = 70% Note 3)	2.7 V ≤ V_{DD} ≤ 3.6 V			-15.0	mA
			1.8 V ≤ V_{DD} < 2.7 V			-7.0	mA
	I_{OH2}	Per pin for P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ V_{DD} ≤ 3.6 V			-0.1 Note 2	mA
		Total of P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154 (When duty = 70% Note 3)	1.8 V ≤ V_{DD} ≤ 3.6 V			-1.6	mA

Note 1. Value of current at which the device operation is guaranteed even if the current flows from the V_{DD} pin (I_{OH1}) and AV_{DD} pin (I_{OH2}) 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 = (I_{OH} × 0.7)/(n × 0.01)

<Example> Where n = 50% and I_{OH} = -10.0 mA
Total output current of pins = (-10.0 × 0.7)/(50 × 0.01) = -14.0 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, P11, P12, P14, P35 to P37, P40, P41, P43, P44, P80, and P81 do not output high level in N-ch open-drain mode.

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

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

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output current, low Note 1	I_{OL1}	Per pin for P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130				20.0 Note 2	mA
		Per pin for P60 and P61				15.0 Note 2	mA
		Total of P40 to P44, P130 (When duty = 70% Note 3)	2.7 V ≤ V_{DD} ≤ 3.6 V			15.0	mA
			1.8 V ≤ V_{DD} < 2.7 V			9.0	mA
		Total of P00 to P07, P11 to P17, P30 to P37, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127 (When duty = 70% Note 3)	2.7 V ≤ V_{DD} ≤ 3.6 V			35.0	mA
			1.8 V ≤ V_{DD} < 2.7 V			20.0	mA
		Total of all pins (When duty = 70% Note 3)				50.0	mA
	I_{OL2}	Per pin for P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ V_{DD} ≤ 3.6 V			0.4 Note 2	mA
		Total of P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154 (When duty = 70% Note 3)	1.8 V ≤ V_{DD} ≤ 3.6 V			6.4	mA

Note 1. Value of current at which the device operation is guaranteed even if the current flows from an output pin to the V_{SS} pin (I_{OL1}) and AV_{SS} pin (I_{OL2}).

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 = (I_{OL} × 0.7)/(n × 0.01)

<Example> Where n = 50% and I_{OL} = 10.0 mA
Total output current of pins = (10.0 × 0.7)/(50 × 0.01) = 14.0 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.

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

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Input voltage, high	V_{IH1}	Port P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P81, P125 to P127	Normal input buffer	0.8 V_{DD}		V_{DD}	V
	V_{IH2}	P00, P01, P11, P14, P35, P36, P40, P41, P44, P80	TTL input buffer 3.3 V ≤ V_{DD} ≤ 3.6 V	2.0		V_{DD}	V
			TTL input buffer 1.8 V ≤ V_{DD} < 3.3 V	1.50		V_{DD}	V
	V_{IH3}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154		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}	Port P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80 to P81, P125 to P127	Normal input buffer	0		0.2 V_{DD}	V
	V_{IL2}	P00, P01, P11, P14 ,P35, P36, P40, P41, P44, P80	TTL input buffer 3.3 V ≤ V_{DD} ≤ 3.6 V	0		0.5	V
			TTL input buffer 1.8 V ≤ V_{DD} < 3.3 V	0		0.32	V
	V_{IL3}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154		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, P11, P12, P14, P35 to P37, P40, P41. P43, P44, P80, and P81 is V_{DD}, even in the N-ch open-drain mode.

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

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

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Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Output voltage, high	V_{OH1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130	2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -2.0 mA	V_{DD} - 0.6			V
			1.8 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -1.5 mA	V_{DD} - 0.5			V
	V_{OH2}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ V_{DD} ≤ 3.6 V, I_{OH} = -100 μA	AV_{DD} - 0.5			V
Output voltage, low	V_{OL1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130	2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 3.0 mA			0.6	V
			2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 1.5 mA			0.4	V
			1.8 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 0.6 mA			0.4	V
	V_{OL2}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 400 μA			0.4	V
	V_{OL3}	P60, P61	2.7 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 3.0 mA			0.4	V
			1.8 V ≤ V_{DD} ≤ 3.6 V, I_{OL} = 2.0 mA			0.4	V

Caution **P00 to P02, P11, P12, P14, P35 to P37, P40, P41. P43, P44, P80, and P81 do not output high level in N-ch open-drain mode.**

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

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

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Input leakage current, high	I_{LIH1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127, P137, $\overline{RESET}$	V_I = V_{DD}				1	μA
	I_{LIH3}	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
	I_{LIH4}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	V_I = AV_{DD}				1	μA
Input leakage current, low	I_{LIL1}	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127, P137, $\overline{RESET}$	V_I = V_{SS}				-1	μA
	I_{LIL3}	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
	I_{LIL4}	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	V_I = AV_{SS}				-1	μA
On-chip pull-up resistance	R_{U1}	P00 to P07, P11 to P17, P30 to P37, P50 to P57, P70 to P77, P80, P81, P125 to P127	V_I = V_{SS}	2.4 V ≤ V_{DD} ≤ 3.6 V	10	20	100	kΩ
				1.8 V ≤ V_{DD} < 2.4 V	10	30	100	
	R_{U2}	P40 to P44	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

(T_A = -40 to +85°C, 1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 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_{IH} = 24 MHz Note 3	Basic operation	V_{DD} = 3.6 V			1.7		mA
						V_{DD} = 3.0 V			1.7		
					Normal operation	V_{DD} = 3.6 V			3.6	6.1	
						V_{DD} = 3.0 V			3.6	6.1	
				f_{IH} = 16 MHz Note 3	Normal operation	V_{DD} = 3.6 V			2.7	4.7	
						V_{DD} = 3.0 V			2.7	4.7	
			LS (low-speed main) mode Note 5	f_{IH} = 8 MHz Note 3	Normal operation	V_{DD} = 3.6 V			1.2	2.1	mA
						V_{DD} = 3.0 V			1.2	2.1	
			HS (high-speed main) mode Note 5	f_{MX} = 20 MHz Note 2, V_{DD} = 3.6 V	Normal operation	Square wave input			3.0	5.1	mA
						Resonator connection			3.2	5.2	
				f_{MX} = 20 MHz Note 2, V_{DD} = 3.0 V	Normal operation	Square wave input			2.9	5.1	
						Resonator connection			3.2	5.2	
				f_{MX} = 16 MHz Note 2, V_{DD} = 3.6 V	Normal operation	Square wave input			2.5	4.4	
						Resonator connection			2.7	4.5	
				f_{MX} = 16 MHz Note 2, V_{DD} = 3.0 V	Normal operation	Square wave input			2.5	4.4	
						Resonator connection			2.7	4.5	
				f_{MX} = 10 MHz Note 2, V_{DD} = 3.6 V	Normal operation	Square wave input			1.9	3.0	
						Resonator connection			1.9	3.0	
				f_{MX} = 10 MHz Note 2, V_{DD} = 3.0 V	Normal operation	Square wave input			1.9	3.0	
						Resonator connection			1.9	3.0	
			LS (low-speed main) mode Note 5	f_{MX} = 8 MHz Note 2, V_{DD} = 3.6 V	Normal operation	Square wave input			1.1	2.0	mA
						Resonator connection			1.1	2.0	
				f_{MX} = 8 MHz Note 2, V_{DD} = 3.0 V	Normal operation	Square wave input			1.1	2.0	
						Resonator connection			1.1	2.0	
			Subsystem clock operation	f_{SUB} = 32.768 kHz Note 4 T_A = -40°C	Normal operation	Square wave input			4.0	5.4	μA
						Resonator connection			4.3	5.4	
				f_{SUB} = 32.768 kHz Note 4 T_A = +25°C	Normal operation	Square wave input			4.0	5.4	
						Resonator connection			4.3	5.4	
				f_{SUB} = 32.768 kHz Note 4 T_A = +50°C	Normal operation	Square wave input			4.1	7.1	
						Resonator connection			4.4	7.1	
				f_{SUB} = 32.768 kHz Note 4 T_A = +70°C	Normal operation	Square wave input			4.3	8.7	
						Resonator connection			4.7	8.7	
				f_{SUB} = 32.768 kHz Note 4 T_A = +85°C	Normal operation	Square wave input			4.7	12.0	
						Resonator connection			5.2	12.0	

(**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, rail to rail operational amplifier (with analog multiplexer), general-purpose operational amplifier, voltage reference, low-resistance switch, comparator, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

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

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

Note 4. When high-speed on-chip oscillator and high-speed system clock are stopped. When AMPHS1 = 1 (ultra-low power consumption oscillation). However, not including the current flowing into the real-time clock 2, 12-bit interval timer, 8-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

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

Remark 2. f_{IH}: Frequency when the high-speed on-chip oscillator (24 MHz max.)

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

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

(T_A = -40 to +85°C, 1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 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_{IH} = 24 MHz Note 4	V_{DD} = 3.6 V		0.42	1.83	mA
					V_{DD} = 3.0 V		0.42	1.83	
				f_{IH} = 16 MHz Note 4	V_{DD} = 5.0 V		0.39	1.38	
					V_{DD} = 3.0 V		0.39	1.38	
			LS (low-speed main) mode Note 7	f_{IH} = 8 MHz Note 4	V_{DD} = 3.0 V		0.25	0.71	mA
					V_{DD} = 2.0 V		0.25	0.71	
			HS (high-speed main) mode Note 7	f_{MX} = 20 MHz Note 3, V_{DD} = 3.6 V	Square wave input		0.26	1.55	mA
					Resonator connection		0.4	1.68	
				f_{MX} = 20 MHz Note 3, V_{DD} = 3.0 V	Square wave input		0.25	1.55	
					Resonator connection		0.4	1.68	
				f_{MX} = 16 MHz Note 3, V_{DD} = 3.6 V	Square wave input		0.23	1.22	
					Resonator connection		0.36	1.39	
				f_{MX} = 16 MHz Note 3, V_{DD} = 3.0 V	Square wave input		0.22	1.22	
					Resonator connection		0.35	1.39	
				f_{MX} = 10 MHz Note 3, V_{DD} = 3.0 V	Square wave input		0.18	0.82	
					Resonator connection		0.28	0.90	
				f_{MX} = 10 MHz Note 3, V_{DD} = 2.0 V	Square wave input		0.18	0.81	
					Resonator connection		0.28	0.89	
			LS (low-speed main) mode Note 7	f_{MX} = 8 MHz Note 3, V_{DD} = 3.0 V	Square wave input		0.09	0.51	mA
					Resonator connection		0.15	0.56	
				f_{MX} = 8 MHz Note 3, V_{DD} = 2.0 V	Square wave input		0.10	0.52	
					Resonator connection		0.15	0.57	
			Subsystem clock operation	f_{SUB} = 32.768 kHz Note 5 T_A = -40°C	Square wave input		0.32	0.75	μA
					Resonator connection		0.51	0.83	
				f_{SUB} = 32.768 kHz Note 5 T_A = +25°C	Square wave input		0.41	0.83	
					Resonator connection		0.62	1.00	
				f_{SUB} = 32.768 kHz Note 5 T_A = +50°C	Square wave input		0.52	1.17	
					Resonator connection		0.75	1.36	
				f_{SUB} = 32.768 kHz Note 5 T_A = +70°C	Square wave input		0.82	1.97	
					Resonator connection		1.08	2.16	
				f_{SUB} = 32.768 kHz Note 5 T_A = +85°C	Square wave input		1.38	3.37	
					Resonator connection		1.62	3.56	
	I_{DD3} Note 6	STOP mode Note 8	T_A = -40°C				0.16	0.51	μA
			T_A = +25°C				0.22	0.51	
			T_A = +50°C				0.27	1.10	
			T_A = +70°C				0.37	1.90	
			T_A = +85°C				0.6	3.30	

(**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, ail to rail operational amplifier (with analog multiplexer), general-purpose operational amplifier, voltage reference, low-resistance switch, comparator, LVD circuit, I/O port, and on-chip pull-up/pull-down resistors and the current flowing during data flash rewrite.

Note 2. During HALT instruction execution by flash memory.

Note 3. When high-speed on-chip oscillator and subsystem clock are stopped.

Note 4. When high-speed system clock and subsystem clock are stopped.

Note 5. When high-speed on-chip oscillator and high-speed system clock are stopped. When RTCLPC = 1 and setting ultra-low current consumption (AMPHS1 = 1). The current flowing into the real-time clock 2 is included. However, not including the current flowing into the 12-bit interval timer, 8-bit interval timer, and watchdog timer.

Note 6. Not including the current flowing into the real-time clock 2, 12-bit interval timer, 8-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

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. fIH: Frequency when the high-speed on-chip oscillator (24 MHz max.)

Remark 3. fSUB: Subsystem clock frequency (XT1 clock oscillation frequency)

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

(T_A = -40 to +85°C, 1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 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	f_{SUB} = 32.768 kHz			0.02		μA
12-bit interval timer operating current	I_{TMKA} Notes 1, 2, 4	f_{SUB} = 32.768 kHz			0.02		μA
8-bit interval timer operating current	I_{TMRT} Notes 1, 19	f_{SUB} = 32.768 kHz	8-bit counter mode × 2-channel operation		0.12		μA
			16-bit counter mode operation		0.10		μA
Watchdog timer operating current	I_{WDT} Notes 1, 5	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			0.7	1.7	mA
A/D converter AVREF(+) current	I_{AVREF} Note 8	AV_{DD} = 3.0 V, HVSEL[1:0] = 00B Note 7			40	80	μA
		AV_{DD} = 3.0 V, HVSEL[1:0] = 01B Note 10			40	80	
Internal reference voltage (1.45 V) current	I_{ADREF} Notes 1, 9				85		μA
Temperature sensor operating current	I_{TMPS} Note 1				85		μA
D/A converter operating current	I_{DAC} Notes 7, 11	Per D/A converter channel			0.4	0.8	mA
D/A converter AVREF(+) current	I_{DAREF} Note 10	AV_{REFP} = 3.0 V, REF[2:0] = 110B, Per channel			35	80	μA
Comparator operating current	I_{CMP} Notes 1, 12	V_{DD} = 3.6 V, Regulator output voltage = 2.1 V	Window mode		7.0		μA
			Comparator high-speed mode		2.6		μA
			Comparator low-speed mode		1.2		μA
		V_{DD} = 3.6 V, Regulator output voltage = 1.8 V	Window mode		4.1		μA
			Comparator high-speed mode		1.5		μA
			Comparator low-speed mode		0.9		μA
General-purpose operational amplifier operating current (for 1 unit)	I_{AMP1} Notes 7, 18	AV_{DD} = 3.0 V	Low-power consumption mode		2	4	μA
			High-speed mode		140	280	μA
Rail to rail operational amplifier operating current (for 1 unit)	I_{AMP2} Notes 7, 18	AV_{DD} = 3.0 V	Low-power consumption mode		10	16	μA
			High-speed mode		210	350	μA
LVD operating current	I_{LVI} Notes 1, 13				0.06		μA
Self-programming operating current	I_{FSP} Notes 1, 14				2.0	12.2	mA
BGO operating current	I_{BGO} Notes 1, 15				2.0	12.2	mA
SNOOZE operating current	I_{SNOZ} Note 1	CSI/UART operation			0.70	0.84	mA
Voltage reference operating current	I_{VREF}	AV_{DD} = V_{DD} = 3.0 V				40	μA

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

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
LCD operating current	I_{LCD1} Notes 16, 17	External resistance division method	f_{LCD} = f_{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V_{DD} = 3.6 V, V_{L4} = 3.6 V		0.14		μA
	I_{LCD2} Note 16	Internal voltage boosting method	f_{LCD} = f_{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V_{DD} = 3.0 V, V_{L4} = 3.0 V (VLCD = 04H)		0.61		μA
	I_{LCD3} Note 16	Capacitor split method	f_{LCD} = f_{SUB} LCD clock = 128 Hz	1/3 bias 4-time slice	V_{DD} = 3.0 V, V_{L4} = 3.0 V		0.12		μA

(**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_{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.

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Note 16. 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 17. Not including the current that flows through the external divider resistor divider resistor.

Note 18. Current flowing only to the operational amplifier. The current value of the RL78 microcontrollers is the sum of I_{DD1}, I_{DD2} or I_{DD3} and I_{AMP} when the operational amplifier operates in the operating mode, HALT mode, or STOP mode.

Note 19. Current flowing only to the 8-bit interval timer (excluding the operating current of the low-speed on-chip oscillator and the XT1 oscillator). The supply current of the RL78 microcontrollers is the sum of the values of either I_{DD1} or I_{DD2}, and I_{IT}, when the 8-bit interval timer operates in the operating mode or HALT mode. When the low-speed on-chip oscillator is selected, I_{FIL} should be added.

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

2.4 AC Characteristics

2.4.1 Basic operation

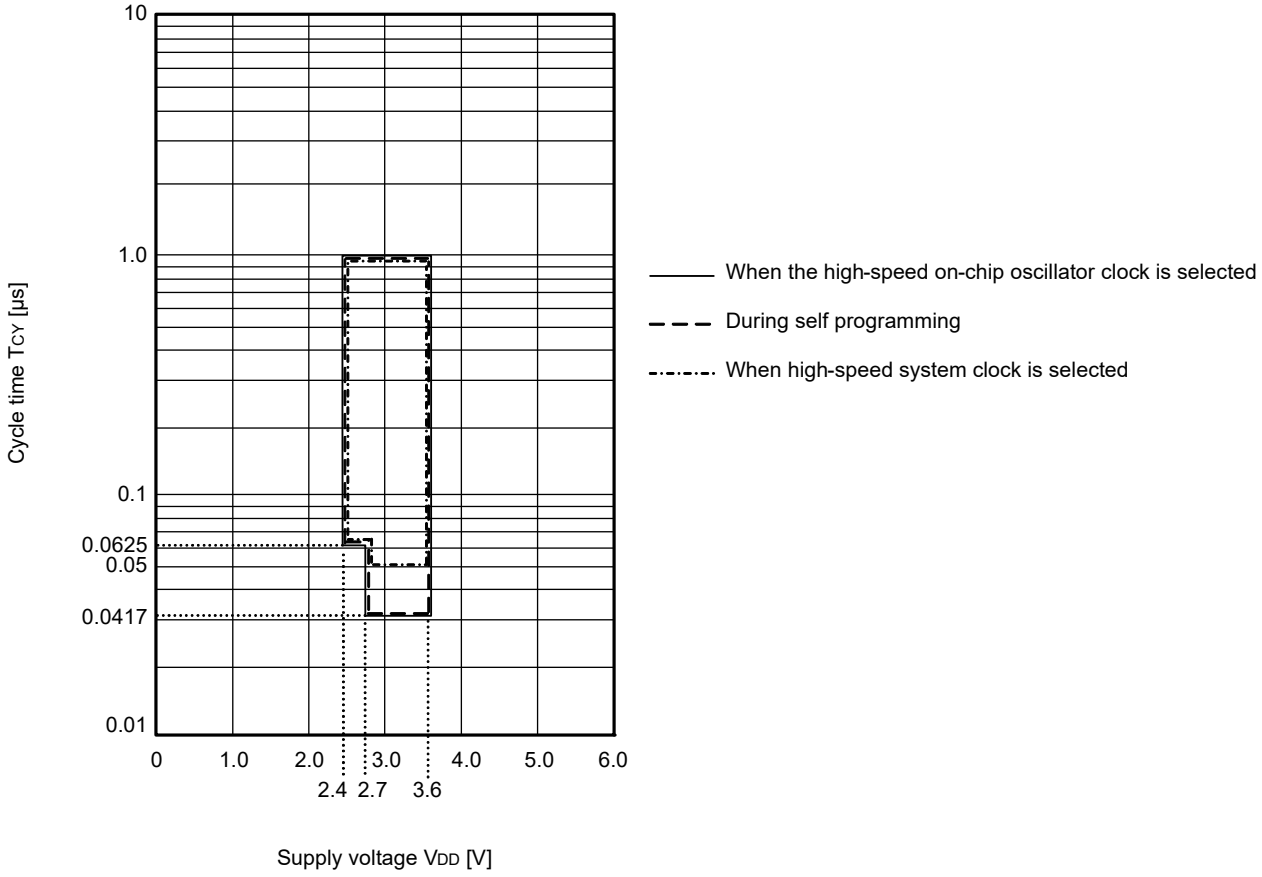
(T_A = -40 to +85°C, 1.8 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Items	Symbol	Conditions			MIN.	TYP.	MAX.	Unit
Instruction cycle (minimum instruction execution time)	T_{CY}	Main system clock (f_{MAIN}) operation	HS (high-speed main) mode	2.7 V ≤ V_{DD} ≤ 3.6 V	0.0417		1	μs
				2.4 V ≤ V_{DD} < 2.7 V	0.0625		1	μs
			LS (low-speed main) mode	1.8 V ≤ V_{DD} ≤ 3.6 V	0.125		1	μs
		Subsystem clock (f_{SUB}) operation		1.8 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
			LS (low-speed main) mode	1.8 V ≤ V_{DD} ≤ 3.6 V	0.125		1	μs
External main system clock frequency	f_{EX}	EXCLK		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
				1.8 V ≤ V_{DD} < 2.7 V	1.0		8.0	MHz
	f_{EXT}	EXCLKS			32		35	kHz
External main system clock input high-level width, low-level width	t_{EXH}, t_{EXL}	EXCLK		2.7 V ≤ V_{DD} ≤ 3.6 V	24			ns
				2.4 V ≤ V_{DD} < 2.7 V	30			ns
				1.8 V ≤ V_{DD} < 2.7 V	60			ns
	t_{EXHS}, t_{EXLS}	EXCLKS			13.7			μs
Timer input high-level width, low-level width	t_{TIH}, t_{TIL}	TI00 to TI07			1/f_{MCK} + 10			ns
Timer output frequency	f_{TO}	TO00 to TO07	HS (high-speed main) mode	2.7 V ≤ V_{DD} ≤ 3.6 V			8	MHz
				2.4 V ≤ V_{DD} < 2.7 V			8	MHz
			LS (low-speed main) mode	1.8 V ≤ V_{DD} ≤ 3.6 V			4	MHz
Buzzer output frequency	f_{PCL}	PCLBUZ0, PCLBUZ1	HS (high-speed main) mode	2.7 V ≤ V_{DD} ≤ 3.6 V			8	MHz
				2.4 V ≤ V_{DD} < 2.7 V			8	MHz
			LS (low-speed main) mode	1.8 V ≤ V_{DD} ≤ 3.6 V			4	MHz
Interrupt input high-level width, low-level width	t_{INTH}, t_{INTL}	INTP0 to INTP7		1.8 V ≤ V_{DD} ≤ 3.6 V	1			μs
Key interrupt input low-level width	t_{KR}	KR0 to KR7		1.8 V ≤ V_{DD} ≤ 3.6 V	250			ns
$\overline{RESET}$ low-level width	t_{RSL}	$\overline{RESET}$			10			μs

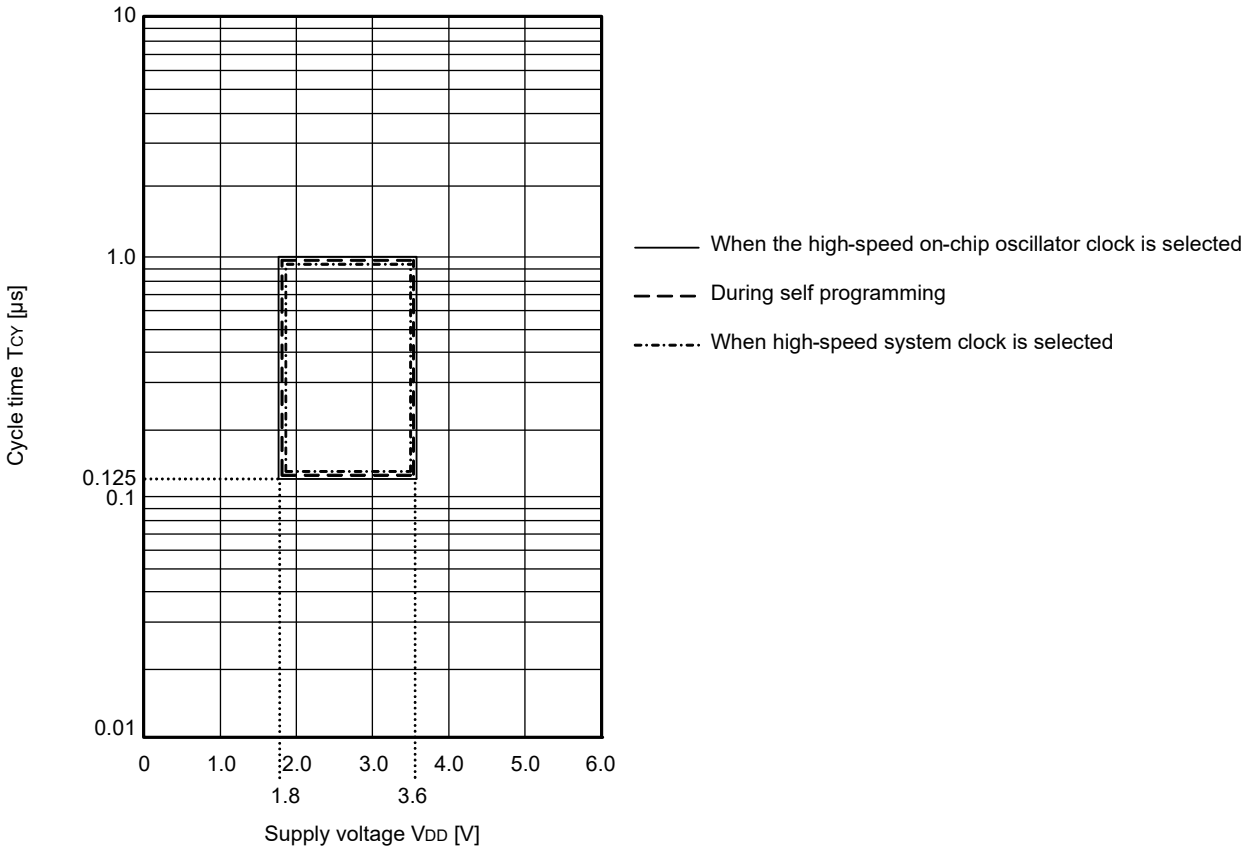
Remark f_{MCK}: Timer array unit operation clock frequency
(Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0), n: Channel number (n = 0 to 7))

Minimum Instruction Execution Time during Main System Clock Operation

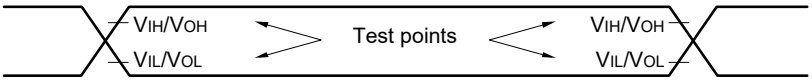
TCY vs VDD (HS (high-speed main) mode)



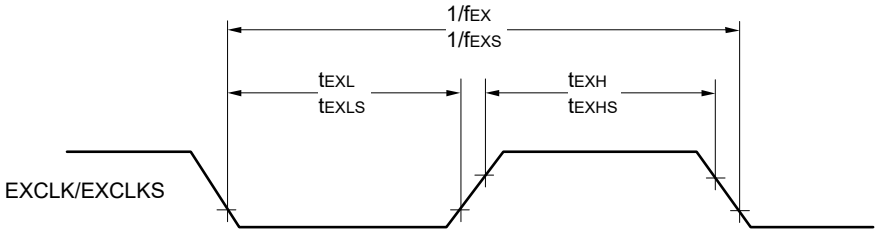
TCY vs VDD (LS (low-speed main) mode)



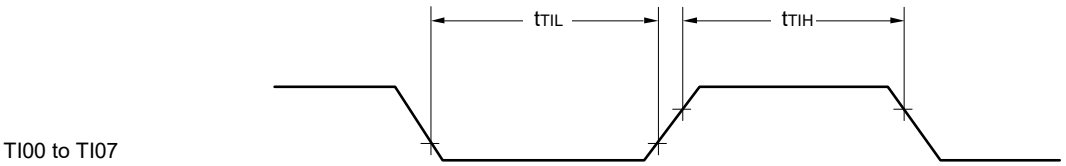
AC Timing Test Points

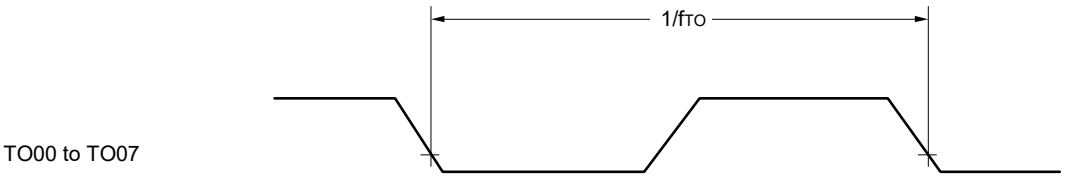


External System Clock Timing

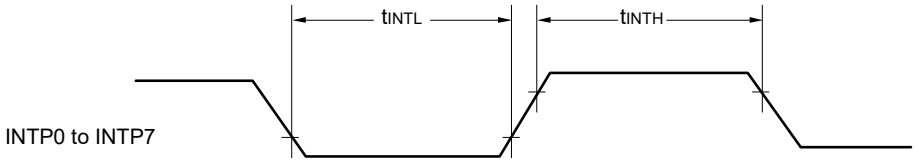


TI/TO Timing

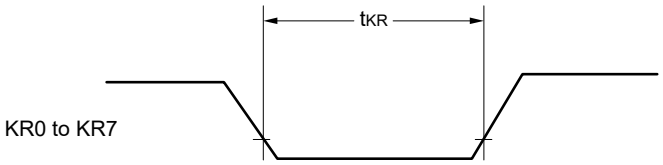




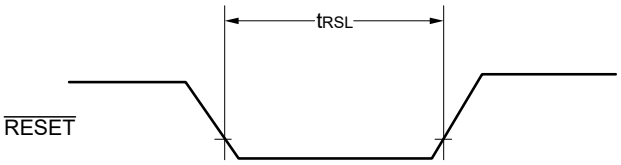
Interrupt Request Input Timing



Key Interrupt Input Timing

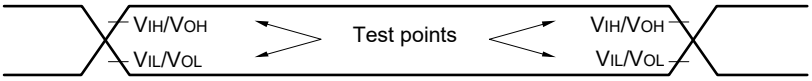


$\overline{\text{RESET}}$ Input Timing



2.5 Peripheral Functions Characteristics

AC Timing Test Points



2.5.1 Serial array unit

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

(T_A = -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		Unit
			MIN.	MAX.	MIN.	MAX.	
Transfer rate Note 1		2.7 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		4.0		1.3	Mbps
		2.4 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		2.6		1.3	Mbps
		1.8 V ≤ V_{DD} ≤ 3.6 V	—			f_{MCK}/6 Note 2	bps
		Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} Note 3	—			1.3	Mbps

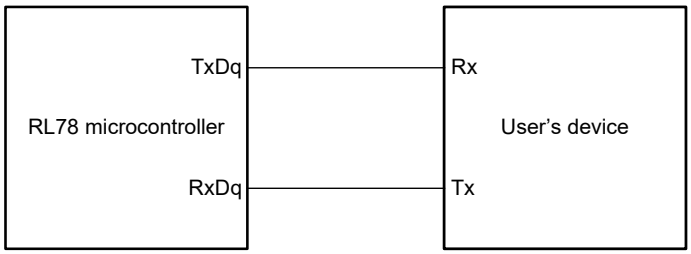
Note 1. Transfer rate in the SNOOZE mode is 4800 bps only.

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

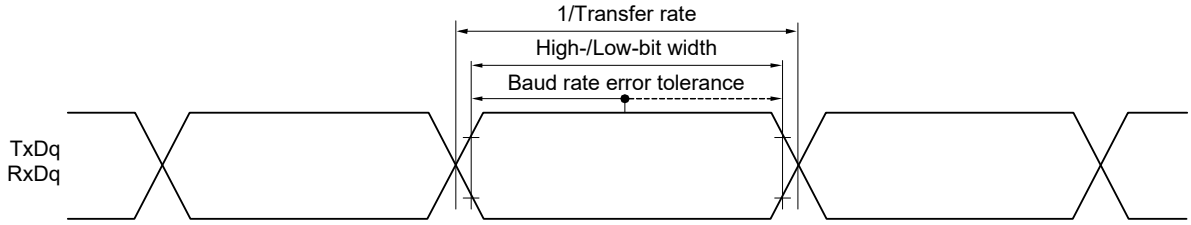
Note 3. The maximum operating frequencies of the CPU/peripheral hardware clock (f_{CLK}) are:
HS (high-speed main) mode: 24 MHz (2.7 V ≤ V_{DD} ≤ 3.6 V)
16 MHz (2.4 V ≤ V_{DD} ≤ 3.6 V)
LS (low-speed main) mode: 8 MHz (1.8 V ≤ V_{DD} ≤ 3.6 V)

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, 1, 3, 4, 8)

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))

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

(T_A = -40 to +85°C, 2.7 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

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Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq f_{CLK}/2$	2.7 V ≤ V_{DD} ≤ 3.6 V	167		250		ns
SCKp high-/low-level width	t_{KH1}, t_{KL1}	2.7 V ≤ V_{DD} ≤ 3.6 V		t_{KCY1}/2 - 10		t_{KCY1}/2 - 50		ns
SIp setup time (to SCKp↑) Note 1	t_{SIK1}	2.7 V ≤ V_{DD} ≤ 3.6 V		33		110		ns
SIp hold time (from SCKp↑) Note 2	t_{KSI1}	2.7 V ≤ V_{DD} ≤ 3.6 V		10		10		ns
Delay time from SCKp↓ to SOp output Note 3	t_{KSO1}	C = 20 pF Note 4			10		10	ns

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

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

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

Remark 1. p: CSI number (p = 00), m: Unit number (m = 0), n: Channel number (n = 0), g: PIM and POM number (g = 4)

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)

(T_A = -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		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq f_{CLK}/4$	2.7 V ≤ V_{DD} ≤ 3.6 V	167		500		ns
			2.4 V ≤ V_{DD} ≤ 3.6 V	250		500		ns
			1.8 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 - 18		t_{KCY1}/2 - 50		ns
		2.4 V ≤ V_{DD} ≤ 3.6 V		t_{KCY1}/2 - 38		t_{KCY1}/2 - 50		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		t_{KCY1}/2 - 50		ns
SIp setup time (to SCKp↑) Note 1	t_{SIK1}	2.7 V ≤ V_{DD} ≤ 3.6 V		44		110		ns
		2.4 V ≤ V_{DD} ≤ 3.6 V		75		110		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		110		ns
SIp hold time (from SCKp↑) Note 2	t_{KSI1}	2.4 V ≤ V_{DD} ≤ 3.6 V		19		19		ns
		1.8 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	ns
			2.4 V ≤ V_{DD} ≤ 3.6 V		25		50	ns
			1.8 V ≤ V_{DD} ≤ 3.6 V		—		50	ns

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

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

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

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 and POM number (g = 0, 1, 3, 4, 8)

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)

(T_A = -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		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time Note 5	t_{KCY2}	2.7 V ≤ V_{DD} ≤ 3.6 V	f_{MCK} > 16 MHz	8/f_{MCK}		—		ns
			f_{MCK} ≤ 16 MHz	6/f_{MCK}		6/f_{MCK}		ns
		2.4 V ≤ V_{DD} ≤ 3.6 V		6/f_{MCK} and 500		6/f_{MCK} and 500		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		6/f_{MCK} and 750		ns
SCKp high-/low-level width	t_{KH2}, t_{KL2}	2.7 V ≤ V_{DD} ≤ 3.6 V		t_{KCY2}/2 - 8		t_{KCY2}/2 - 8		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		t_{KCY2}/2 - 18		ns
SIp setup time (to SCKp↑) Note 1	t_{SIK2}	2.7 V ≤ V_{DD} ≤ 3.6 V		1/f_{MCK} + 20		1/f_{MCK} + 30		ns
		2.4 V ≤ V_{DD} ≤ 3.6 V		1/f_{MCK} + 30		1/f_{MCK} + 30		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		1/f_{MCK} + 30		ns
SIp hold time (from SCKp↑) Note 2	t_{KSI2}	2.4 V ≤ V_{DD} ≤ 3.6 V		1/f_{MCK} + 31		1/f_{MCK} + 31		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		1/f_{MCK} + 31		ns
Delay time from SCKp↓ to SOp output Note 3	t_{KSO2}	C = 30 pF Note 4	2.7 V ≤ V_{DD} ≤ 3.6 V		2/f_{MCK} + 44		2/f_{MCK} + 110	ns
			2.4 V ≤ V_{DD} ≤ 3.6 V		2/f_{MCK} + 75		2/f_{MCK} + 110	ns
			1.8 V ≤ V_{DD} ≤ 3.6 V		—		2/f_{MCK} + 110	ns

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

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

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.

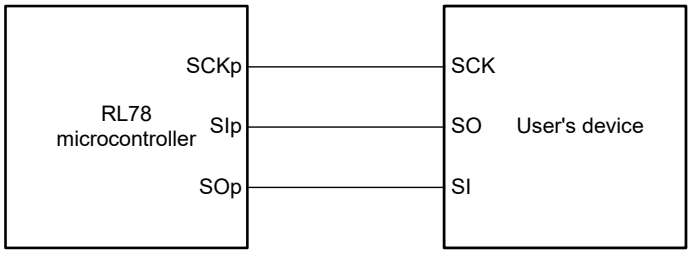
Note 5. The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

Caution Select the normal input buffer for the SIp 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 and POM number (g = 0, 1, 3, 4, 8)

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))

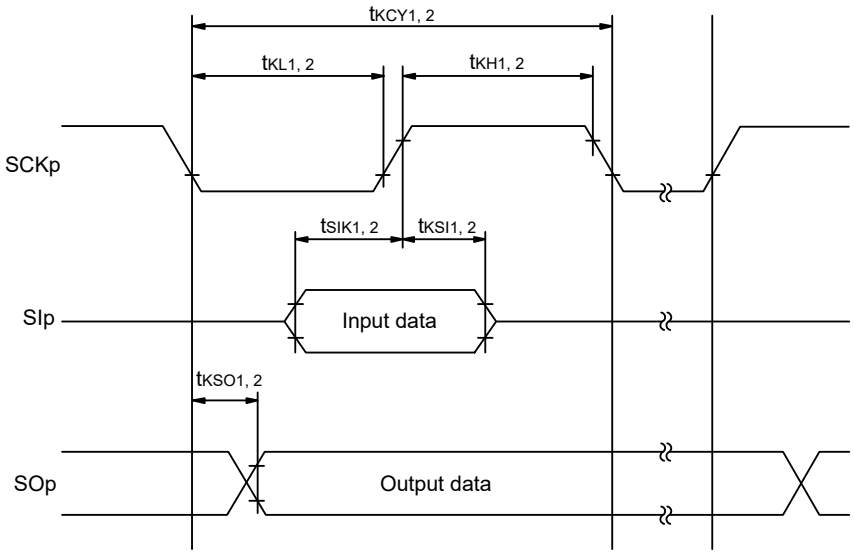
CSI mode connection diagram (during communication at same potential)



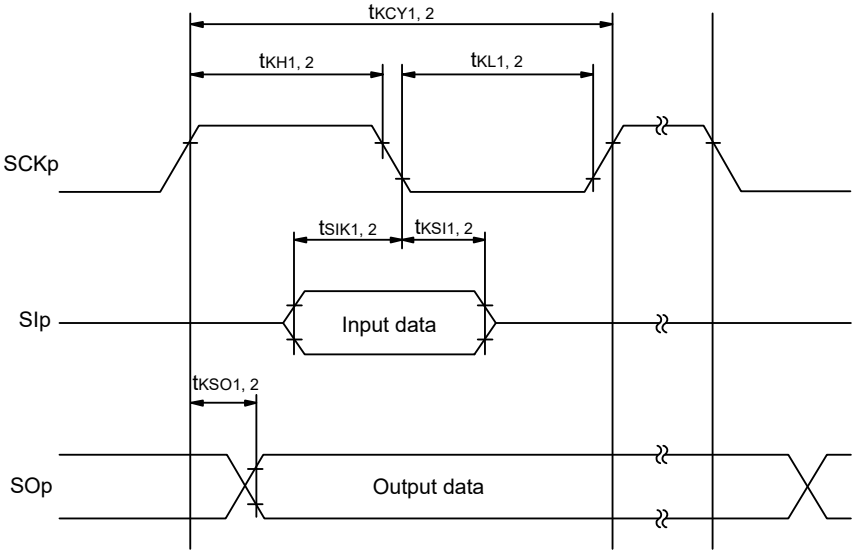
Remark 1. p: CSI number (p = 00, 10, 20, 30)

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)

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

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

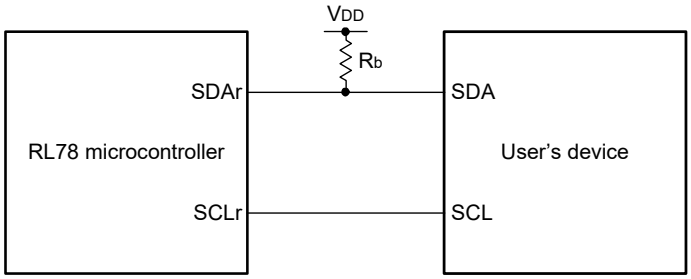
Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f_{SCL}	2.7 V ≤ V_{DD} ≤ 3.6 V, C_b = 50 pF, R_b = 2.7 kΩ		1000 Note 1		400 Note 1	kHz
		1.8 V ≤ V_{DD} ≤ 3.6 V, C_b = 100 pF, R_b = 3 kΩ		400 Note 1		400 Note 1	kHz
		1.8 V ≤ V_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ		300 Note 1		300 Note 1	kHz
Hold time when SCLr = "L"	t_{LOW}	2.7 V ≤ V_{DD} ≤ 3.6 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1150		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V, C_b = 100 pF, R_b = 3 kΩ	1150		1150		ns
		1.8 V ≤ V_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	1550		1550		ns
Hold time when SCLr = "H"	t_{HIGH}	2.7 V ≤ V_{DD} ≤ 3.6 V, C_b = 50 pF, R_b = 2.7 kΩ	475		1150		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V, C_b = 100 pF, R_b = 3 kΩ	1150		1150		ns
		1.8 V ≤ V_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	1550		1550		ns
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V, C_b = 50 pF, R_b = 2.7 kΩ	1/f_{MCK} + 85 Note 2		1/f_{MCK} + 145 Note 2		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V, C_b = 100 pF, R_b = 3 kΩ	1/f_{MCK} + 145 Note 2		1/f_{MCK} + 145 Note 2		ns
		1.8 V ≤ V_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	1/f_{MCK} + 230 Note 2		1/f_{MCK} + 230 Note 2		ns
Data hold time (transmission)	$t_{HD:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V, C_b = 50 pF, R_b = 2.7 kΩ	0	305	0	305	ns
		1.8 V ≤ V_{DD} ≤ 3.6 V, C_b = 100 pF, R_b = 3 kΩ	0	355	0	355	ns
		1.8 V ≤ V_{DD} < 2.7 V, C_b = 100 pF, R_b = 5 kΩ	0	405	0	405	ns

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

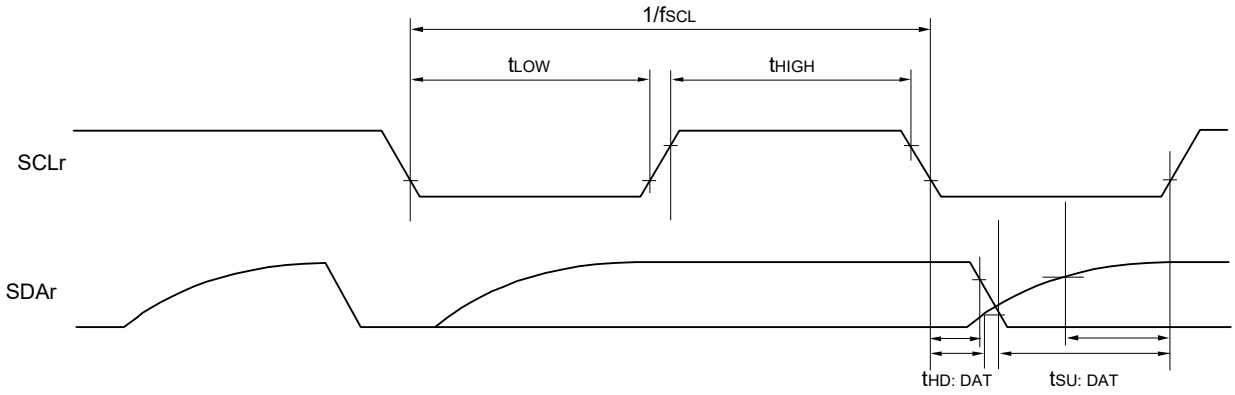
Note 2. Set the f_{MCK} value to keep the hold time of SCLr = "L" and SCLr = "H".

Caution Select the normal input buffer and the N-ch open drain output (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. Rb[Ω]: Communication line (SDAr) pull-up resistance, Cb[F]: Communication line (SCLr, SDAr) load capacitance

Remark 2. r: IIC number (r = 00, 10, 20, 30), g: PIM number (g = 0, 1, 3, 4, 8),
<R> h: POM number (h = 0, 1, 3, 4, 8)

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

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

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)(1/2)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
Transfer rate Notes 1, 2		reception	2.7 V ≤ V_{DD} ≤ 3.6 V, 2.3 V ≤ V_b ≤ 2.7 V		f_{MCK}/6 Note 1		f_{MCK}/6 Note 1	bps
			Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} Note 4		4.0		1.3	Mbps
			1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V		f_{MCK}/6 Notes 1, 2, 3		f_{MCK}/6 Notes 1, 2, 3	bps
			Theoretical value of the maximum transfer rate f_{MCK} = f_{CLK} 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 $V_{DD} \geq V_b$.

Note 3. 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

Note 4. 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)

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, 1, 3, 4, 8)

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) (UART mode)

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)(2/2)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	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		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		1.2 Note 2	Mbps
			1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V		Notes 3, 4		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		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 $V_{DD} \geq V_b$.

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 V ≤ V_{DD} < 3.3 V and 1.6 V ≤ V_b ≤ 2.0 V

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

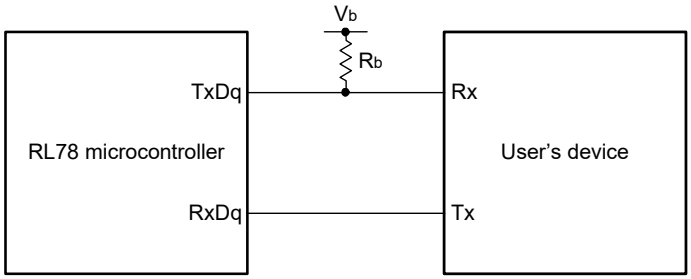
$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [\%]}$$

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

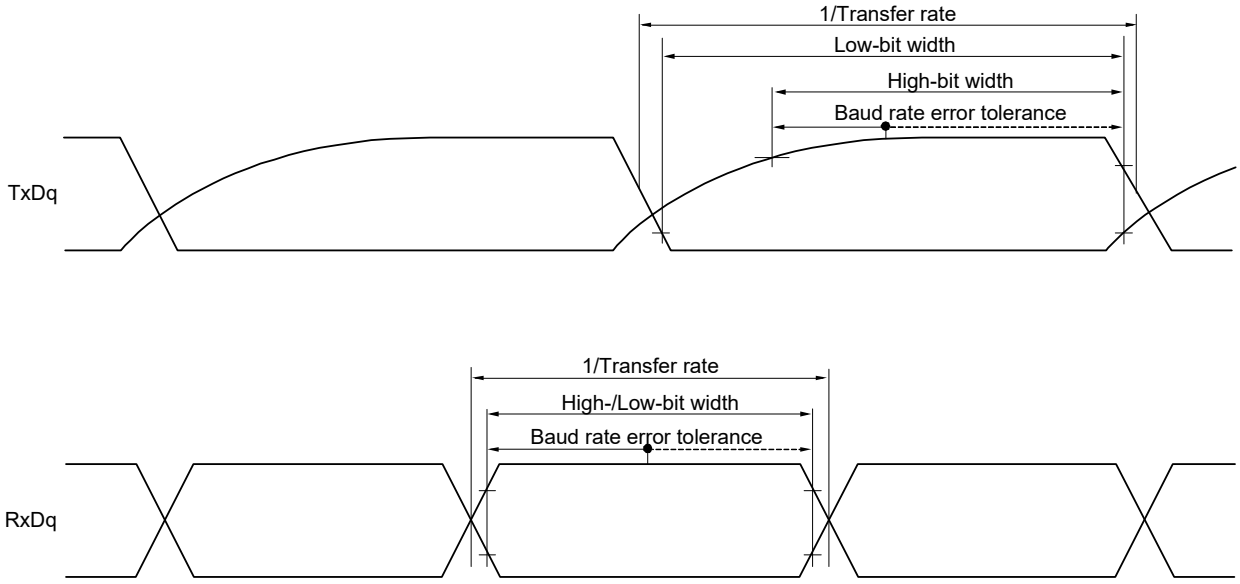
Note 5. This value as an example is calculated when the conditions described in the “Conditions” column are met.
Refer to Note 4 above to calculate the maximum transfer rate under conditions of the customer.

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

Remark 2. q: UART number (q = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 4, 8)

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))

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

(T_A = -40 to +85°C, 2.7 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq 2/f_{CLK}$	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	300		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		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		ns
SIp 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		ns
SIp 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		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	ns
SIp 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		ns
SIp 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		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	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 SIp pin and the N-ch open drain output (V_{DD} tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics with TTL input buffer selected.

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

Remark 2. p: CSI number (p = 00), m: Unit number (m = 0),
n: Channel number (n = 0), g: PIM and POM number (g = 4)

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))

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

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)(1/2)

Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t_{KCY1}	$t_{KCY1} \geq 4/f_{CLK}$	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		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		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		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		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		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		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.)

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

(T_A = -40 to +85°C, 1.8 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)(2/2)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SIp setup time (to SCKp↑) Note 1	t_{SIK1}	2.7 V ≤ V_{DD} ≤ 3.6 V, 2.3 V ≤ V_b ≤ 2.7 V, C_b = 30 pF, R_b = 2.7 kΩ	177		479		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ	479		479		ns
SIp 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 = 30 pF, R_b = 2.7 kΩ	19		19		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ	19		19		ns
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 = 30 pF, R_b = 2.7 kΩ		195		195	ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ		483		483	ns
SIp 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 = 30 pF, R_b = 2.7 kΩ	44		110		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ	110		110		ns
SIp 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 = 30 pF, R_b = 2.7 kΩ	19		19		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ	19		19		ns
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 = 30 pF, R_b = 2.7 kΩ		25		25	ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 3, C_b = 30 pF, R_b = 5.5 kΩ		25		25	ns

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

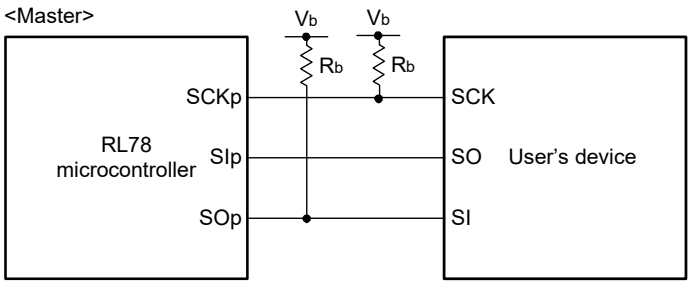
Note 2. When DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

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

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 next page.)

CSI mode connection diagram (during communication at different potential)

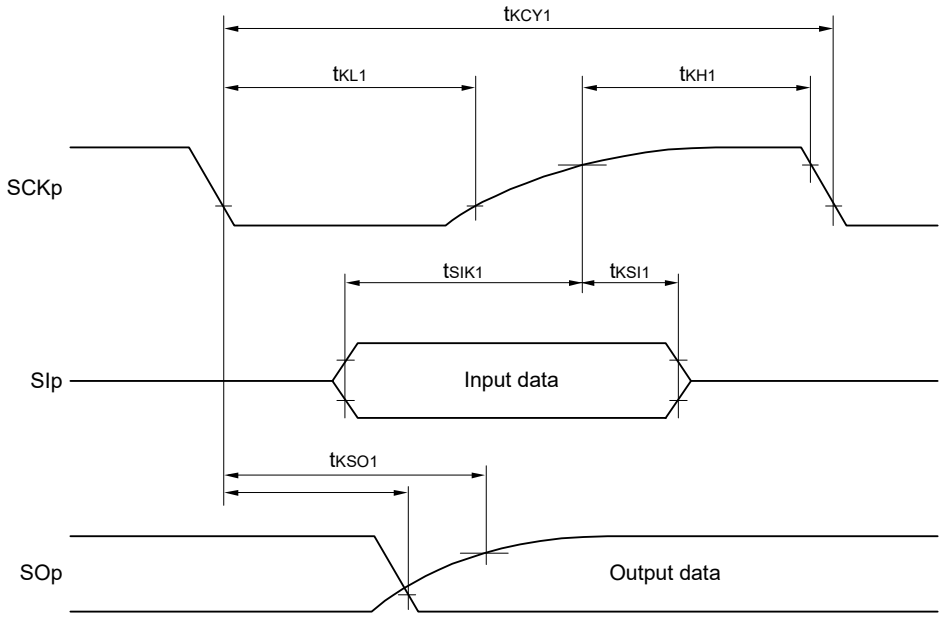


Remark 1. Rb[Ω]: Communication line (SCKp, SOp) pull-up resistance, Cb[F]: Communication line (SCKp, SOp) load capacitance, Vb[V]: Communication line voltage

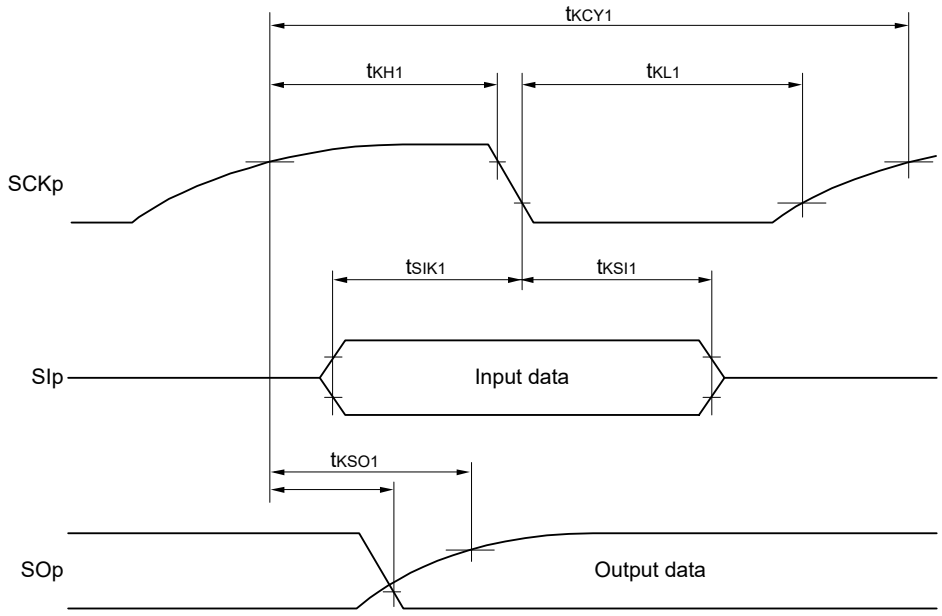
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 4, 8)

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, 02, 10, 12))

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, 2),
g: PIM and POM number (g = 0, 1, 3, 4, 8)

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

(T_A = -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		Unit
				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}		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}		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		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2		t_{KCY2}/2 - 50		t_{KCY2}/2 - 50		ns
SIp setup time (to SCKp↑) Note 3	t_{SIK2}	2.7 V ≤ V_{DD} ≤ 3.6 V		1/f_{MCK} + 20		1/f_{MCK} + 30		ns
		1.8 V ≤ V_{DD} < 3.3 V		1/f_{MCK} + 30		1/f_{MCK} + 30		ns
SIp hold time (from SCKp↑) Note 4	t_{KSI2}			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	ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2 C_b = 30 pF, R_b = 5.5 kΩ			2/f_{MCK} + 573		2/f_{MCK} + 573	ns

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

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

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.

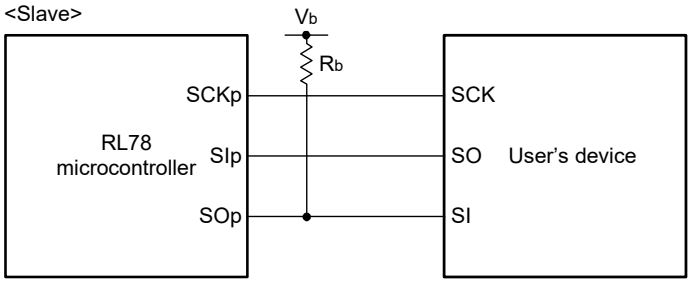
Note 4. When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The SIp hold time becomes "from SCKp↓" when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.

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)

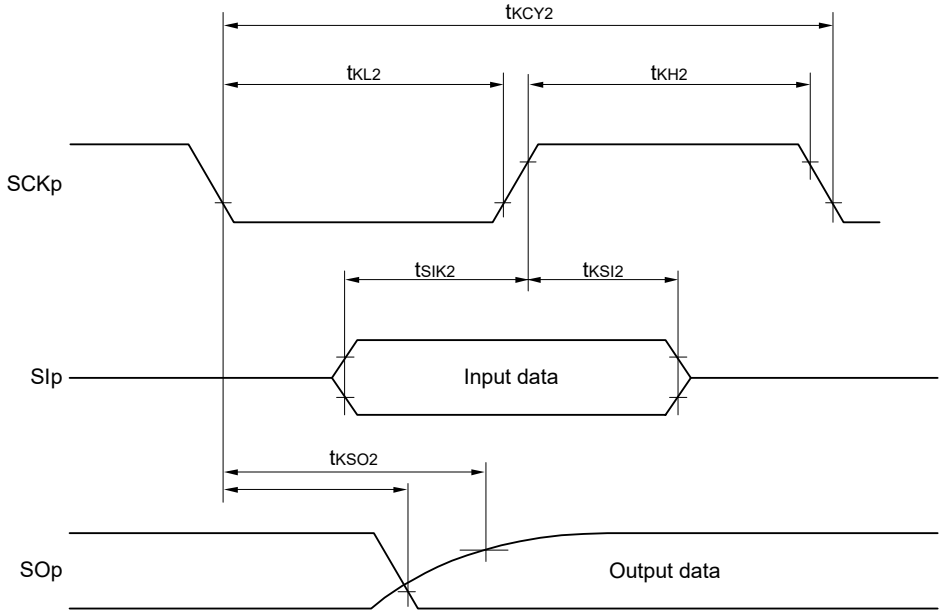


Remark 1. R_b[Ω]: Communication line (SOp) pull-up resistance, C_b[F]: Communication line (SOp) load capacitance, V_b[V]: Communication line voltage

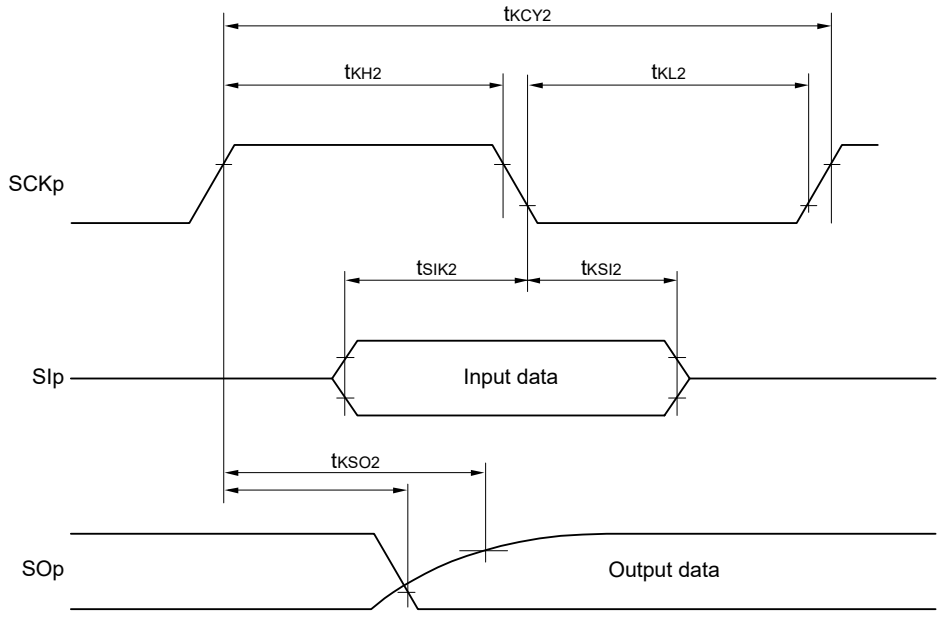
Remark 2. p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 4, 8)

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, 1, 3, 4, 8)

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

(T_A = -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		Unit
			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	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	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	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		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		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2, C_b = 100 pF, R_b = 5.5 kΩ	1550		1550		ns
Hold time when SCLr = "H"	t_{HIGH}	2.7 V ≤ V_{DD} ≤ 3.6 V, 2.3 V ≤ V_b < 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	200		610		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		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2, C_b = 100 pF, R_b = 5.5 kΩ	610		610		ns
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V, 2.3 V ≤ V_b < 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	1/f_{MCK} + 135 Note 3		1/f_{MCK} + 190 Note 3		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		ns
		1.8 V ≤ V_{DD} < 3.3 V, 1.6 V ≤ V_b ≤ 2.0 V Note 2, C_b = 100 pF, R_b = 5.5 kΩ	1/f_{MCK} + 190 Note 3		1/f_{MCK} + 190 Note 3		ns
Data hold time (transmission)	$t_{HD:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V, 2.3 V ≤ V_b < 2.7 V, C_b = 50 pF, R_b = 2.7 kΩ	0	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	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	ns

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

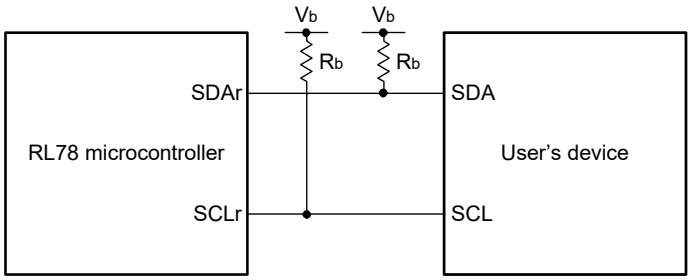
Note 2. Use it with V_{DD} ≥ V_b.

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

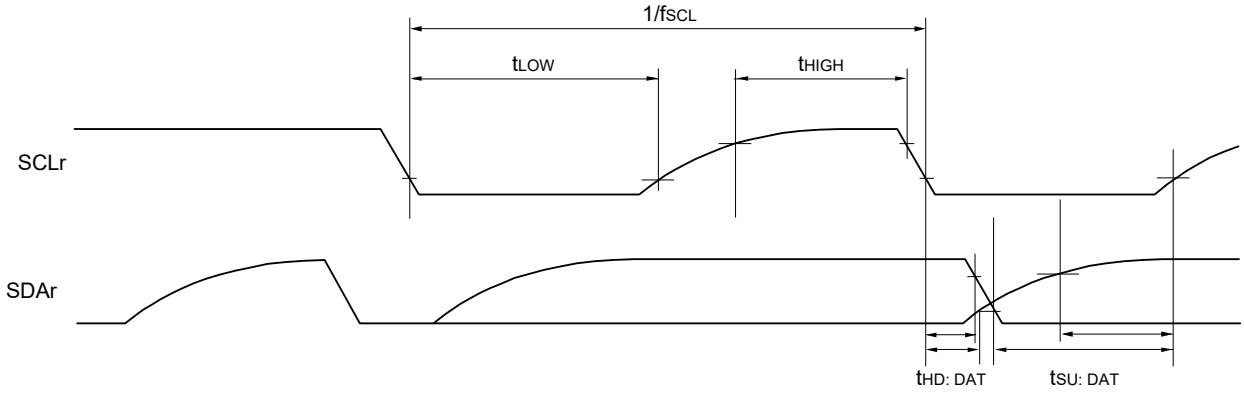
Caution Select the TTL input buffer and the N-ch open drain output (V_{DD} tolerance) mode for the SDAr pin and the N-ch open drain output (V_{DD} tolerance) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V_{IH} and V_{IL}, see the DC characteristics 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. Rb[Ω]: Communication line (SDAr, SCLr) pull-up resistance, Cb[F]: Communication line (SDAr, SCLr) load capacitance, Vb[V]: Communication line voltage

Remark 2. r: IIC number (r = 00, 10, 20, 30), g: PIM, POM number (g = 0, 1, 3, 4, 8)

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

2.5.2 Serial interface IICA

(1) I²C standard mode

(T_A = -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		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Standard mode: f_{CLK} ≥ 1 MHz	2.7 V ≤ V_{DD} ≤ 3.6 V	0	100	0	100	kHz
			1.8 V ≤ V_{DD} ≤ 3.6 V	—	—	0	100	kHz
Setup time of restart condition	$t_{SU:STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		4.7		4.7		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		4.7		µs
Hold time Note 1	$t_{HD:STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		4.0		4.0		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		4.0		µs
Hold time when SCLA0 = “L”	t_{LOW}	2.7 V ≤ V_{DD} ≤ 3.6 V		4.7		4.7		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		4.7		µs
Hold time when SCLA0 = “H”	t_{HIGH}	2.7 V ≤ V_{DD} ≤ 3.6 V		4.0		4.0		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		4.0		µs
Data setup time (reception)	$t_{SU:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		250		250		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		250		ns
Data hold time (transmission) Note 2	$t_{HD:DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0	3.45	0	3.45	µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0	3.45	µs
Setup time of stop condition	$t_{SU:STO}$	2.7 V ≤ V_{DD} ≤ 3.6 V		4.0		4.0		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		4.0		µs
Bus-free time	t_{BUF}	2.7 V ≤ V_{DD} ≤ 3.6 V		4.7		4.7		µs
		1.8 V ≤ V_{DD} ≤ 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) I^2C fast mode

(T_A = -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		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Fast mode: f_{CLK} ≥ 3.5 MHz	2.7 V ≤ V_{DD} ≤ 3.6 V	0	400	0	400	kHz
			1.8 V ≤ V_{DD} ≤ 3.6 V	0	400	0	400	kHz
Setup time of restart condition	$t_{SU: STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.6		0.6		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0.6		µs
Hold time Note 1	$t_{HD: STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.6		0.6		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0.6		µs
Hold time when SCLA0 = “L”	t_{LOW}	2.7 V ≤ V_{DD} ≤ 3.6 V		1.3		1.3		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		1.3		µs
Hold time when SCLA0 = “H”	t_{HIGH}	2.7 V ≤ V_{DD} ≤ 3.6 V		0.6		0.6		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0.6		µs
Data setup time (reception)	$t_{SU: DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		100		100		ns
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		100		ns
Data hold time (transmission) Note 2	$t_{HD: DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0	0.9	0	0.9	µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0	0.9	µs
Setup time of stop condition	$t_{SU: STO}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.6		0.6		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		0.6		µs
Bus-free time	t_{BUF}	2.7 V ≤ V_{DD} ≤ 3.6 V		1.3		1.3		µs
		1.8 V ≤ V_{DD} ≤ 3.6 V		—		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.
Fast mode: C_b = 320 pF, R_b = 1.1 kΩ

(3) I^2C fast mode plus

(T_A = -40 to +85°C, 2.7 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

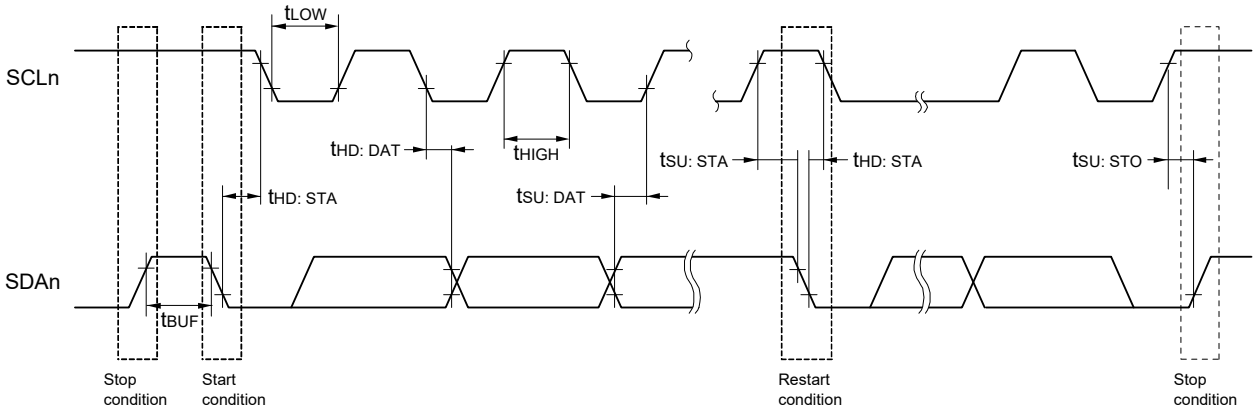
Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	f_{SCL}	Fast mode plus: f_{CLK} ≥ 10 MHz	2.7 V ≤ V_{DD} ≤ 3.6 V	0	1000	—		kHz
Setup time of restart condition	$t_{SU: STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.26		—		μs
Hold time Note 1	$t_{HD: STA}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.26		—		μs
Hold time when SCLA0 = "L"	t_{LOW}	2.7 V ≤ V_{DD} ≤ 3.6 V		0.5		—		μs
Hold time when SCLA0 = "H"	t_{HIGH}	2.7 V ≤ V_{DD} ≤ 3.6 V		0.26		—		μs
Data setup time (reception)	$t_{SU: DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		50		—		ns
Data hold time (transmission) Note 2	$t_{HD: DAT}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0	0.45	—		μs
Setup time of stop condition	$t_{SU: STO}$	2.7 V ≤ V_{DD} ≤ 3.6 V		0.26		—		μs
Bus-free time	t_{BUF}	2.7 V ≤ V_{DD} ≤ 3.6 V		0.5		—		μs

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

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.
Fast mode plus: C_b = 120 pF, R_b = 1.1 kΩ

IICA serial transfer timing



2.6 Analog Characteristics

2.6.1 A/D converter characteristics

(T_A = –40 to +85°C, 1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = AV_{SS} = 0 V, reference voltage(+) = AV_{REFP}, reference voltage(–) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			—	—	12	bit
Analog capacitance	Cs			—	—	15	pF
Analog input resistance	Rs			—	—	2.5	kΩ
<R> Frequency	ADCLK	High-speed mode	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	1	—	24	MHz
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	1	—	16	MHz
		Normal mode	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	1	—	24	MHz
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	1	—	16	MHz
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	1	—	8	MHz
Conversion time Note	Tconv	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 0.3 kΩ ADCLK = 24 MHz	3	—	—	μs
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 1.3 kΩ ADCLK = 16 MHz	4.5	—	—	μs
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 1.1 kΩ ADCLK = 24 MHz	3.4	—	—	μs
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 2.2 kΩ ADCLK = 16 MHz	5.1	—	—	μs
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 5 kΩ ADCLK = 8 MHz	10.1	—	—	μs
Overall error	AINL	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28 H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.25	±5.0	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.25	±5.0	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.25	±5.0	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.25	±5.0	LSB
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±3.0	±8.0	LSB
Zero-scale error	E_{ZS}	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.5	±4.5	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.5	±4.5	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.5	±4.5	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.5	±4.5	LSB
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1	±7.5	LSB

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Full-scale error	E_{FS}	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.75	±4.5	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.75	±4.5	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.75	±4.5	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±0.75	±4.5	LSB
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.5	±7.5	LSB
Differential linearity error	DLE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	—	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	—	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	—	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	—	LSB
			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	—	LSB
Integral linearity error	ILE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	±3.0	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	±4.5	LSB
		Normal mode ADCSR.ADHSC =1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	±3.0	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.0	±3.0	LSB
<R>			1.8 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	±1.25	±3.0	LSB

<R> **Note** The conversion time is the sum of sampling time and comparison time. The values indicated in the table are those in the case of 40 clock cycles of ADCLK per sampling state.

Caution The characteristics above only apply when pins other than those of the A/D converter are not in use. The overall error includes the quantization error. Each of the offset error, full-scale error, DNL differential non-linearity error, and INL integral non-linearity error does not include the quantization error.

[Reference value for design (not guaranteed)]

We can provide the design reference values for the A/D converter. Note, however, that these values are not guaranteed and can only be used as a reference when using this function. See below for details.

(T_A = 0 to +50°C, 2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, V_{SS} = AV_{SS} = 0 V, reference voltage(+) = AV_{REFP}, reference voltage(–) = AV_{REFM} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Resolution	RES			—	—	—Note 3	bit
Analog capacitance	Cs			—	—	—Note 3	pF
Analog input resistance	Rs			—	—	—Note 3	kΩ
Frequency	f_{CLK}	High-speed mode	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—Note 3	—	—Note 3	MHz
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—Note 3	—	—Note 3	MHz
		Normal mode	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—Note 3	—	—Note 3	MHz
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—Note 3	—	—Note 3	MHz
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—Note 3	—	—Note 3	MHz

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Conversion time	Tconv	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 0.3 kΩ ADCLK = 24 MHz	—Note 3	—	—	μs
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 1.3 kΩ ADCLK = 16 MHz	—Note 3	—	—	μs
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 1.1 kΩ ADCLK = 24 MHz	—Note 3	—	—	μs
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 2.2 kΩ ADCLK = 16 MHz	—Note 3	—	—	μs
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V Permissible signal source impedance max = 5 kΩ ADCLK = 8 MHz	—Note 3	—	—	μs
Overall error	AINL	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
Zero-scale error Notes 1, 2	E_{ZS}	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	±4.5	LSB
Full-scale error Notes 1, 2	E_{FS}	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	±4.5	LSB
Differential linearity error	DLE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—	LSB
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—	LSB
Integral linearity error	ILE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤3 .6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.4 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB
			2.0 V ≤ AV_{REFP} ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V	—	—Note 3	—Note 3	LSB

Note 1. MAX. value is the average value ±3σ at normalized distribution.

Note 2. These values are the results of characteristic evaluation.

Note 3. The reference value is not available.

Caution The characteristics above only apply when pins other than those of the A/D converter are not in use. The overall error includes the quantization error. Each of the offset error, full-scale error, DNL differential non-linearity error, and INL integral non-linearity error does not include the quantization error.

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	TA = +25°C	—	1.05	—	V
Internal reference voltage	VBGR		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	2.4 V ≤ VDD ≤ 3.6 V	5	—	—	μs

2.6.3 D/A converter characteristics

(1) When reference voltage = AVREFP, AVREFM

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES				12	bit
Load resistance	R0		30			kΩ
Load capacitance	C0				50	pF
Output voltage range	Tout		0.35		AVDD - 0.47	V
Differential linearity error	DNL			±0.5	±1.0	LSB
Integral linearity error	AINL			±0.4	±8.0	LSB
Zero-scale error	EZS				±20	mV
Full-scale error	EFS				±20	mV
Output resistance	RO			5		Ω
Conversion time	tcon				30	μs

(2) When reference voltage = AVDD, AVSS

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Resolution	RES				12	bit
Load resistance	R0		30			kΩ
Load capacitance	C0				50	pF
Output voltage range	Tout		0.35		AVDD - 0.47	V
Differential linearity error	DNL			±0.5	±2.0	LSB
Integral linearity error	AINL			±0.4	±8.0	LSB
Zero-scale error	EZS				±30	mV
Full-scale error	EFS				±30	mV
Output resistance	RO			5		Ω
Conversion time	tcon				30	μs

2.6.4 Comparator

(TA = -40 to +85°C, 1.8 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	Comparator high-speed mode, standard mode			1.2	μs
			Comparator high-speed mode, window mode			2.0	μs
			Comparator low-speed mode, standard mode		3	5.0	μs
High-electric-potential judgment voltage	VTW+	Comparator high-speed mode, window mode			0.76 VDD		V
Low-electric-potential judgment voltage	VTW-	Comparator high-speed mode, window mode			0.24 VDD		V
Operation stabilization wait time	tCMP			100			μs
<R> Internal reference voltage Note	VBGR	2.4 V ≤ VDD ≤ 3.6 V, HS (high-speed main) mode		1.38	1.45	1.50	V

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

2.6.5 Rail to rail operational amplifier characteristics

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Circuit current	Icc1	Low-power consumption mode		—	10	16	μA
	Icc2	High-speed mode		—	210	350	μA
Common mode input range	Vicm1	Low-power consumption mode		0.1	—	AVDD-0.1	V
	Vicm2	High-speed mode		0.1	—	AVDD-0.1	V
Output voltage range	Vo1	Low-power consumption mode		0.1	—	AVDD-0.1	V
	Vo2	High-speed mode		0.1	—	AVDD-0.1	V
Input offset voltage	Fioff	Low-power consumption mode		-10	—	10	mV
		High-speed mode		-5	—	5	mV
Open gain	Av			—	120	—	dB
Gain-bandwidth (GB) product	GBW1	Low-power consumption mode		—	0.06	—	MHz
	GBW2	High-speed mode		—	1	—	MHz
Phase margin	PM	CL = 22 pF		50	—	—	deg
Gain margin	GM	CL = 20 pF		10	—	—	dB
Equivalent input noise	Vnoise1	f = 1 kHz	Low-power consumption mode	—	900	—	nV/√Hz
	Vnoise2	f = 10 kHz		—	450	—	nV/√Hz
	Vnoise3	f = 1 kHz	High-speed mode	—	80	—	nV/√Hz
	Vnoise4	f = 2 kHz		—	50	—	nV/√Hz
Power supply reduction ratio	PSRR			—	90	—	dB
Common mode signal reduction ratio	CMRR			—	90	—	dB
<R> Operation stabilization wait time	Tstd1	CL = 20 pF	Low-power consumption mode	—	110	300	μs
	Tstd2	CL = 20 pF	High-speed mode	—	5	14	μs
<R> Settling time	Tset1	CL = 20 pF	Low-power consumption mode	—	110	300	μs
	Tset2	CL = 20 pF	High-speed mode	—	4	14	μs
Slew rate	Tselw1	CL = 20 pF	Low-power consumption mode	0.01	0.04	—	V/μs
	Tselw2	CL = 20 pF	High-speed mode	0.3	0.7	—	V/μs
Load current	Iload1	Low-power consumption mode		-110	—	110	μA
	Iload2	High-speed mode		-110	—	110	μA
Load capacitance	CL			—	—	22	pF
Analog MUX ON resistance	Ron	One channel		—	—	1	kΩ

[Reference value for design (not guaranteed)]

We can provide the design reference values for the rail-to-rail operational amplifier. Note, however, that these values are not guaranteed and can only be used as a reference when using this function. See below for details.

(T_A = 0 to 50°C, 2.0 V ≤ AV_{DD} ≤ V_{DD} ≤ 3.6 V, AV_{SS} = V_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Circuit current	Icc1	Low-power consumption mode		—	Note 3	Note 3	μA
	Icc2	High-speed mode		—	Note 3	Note 3	μA
Common mode input range	Vicm1	Low-power consumption mode		Note 3	—	Note 3	V
	Vicm2	High-speed mode		Note 3	—	Note 3	V
Output voltage range	Vo1	Low-power consumption mode		Note 3	—	Note 3	V
	Vo2	High-speed mode		Note 3	—	Note 3	V
Input offset voltage Note 1, Note 2	Fioff	Low-power consumption mode		–7	—	7	mV
		High-speed mode		Note 3	—	Note 3	mV
Open gain	Av			Note 3	Note 3	—	dB
Gain-bandwidth (GB) product	GBW1	Low-power consumption mode		—	Note 3	—	MHz
	GBW2	High-speed mode		—	Note 3	—	MHz
Phase margin	PM	CL = 22 pF		Note 3	—	—	deg
Gain margin	GM	CL = 20 pF		Note 3	—	—	dB
Equivalent input noise	Vnoise1	f = 1 kHz	Low-power consumption mode	—	Note 3	—	nV/√Hz
	Vnoise2	f = 10 kHz		—	Note 3	—	nV/√Hz
	Vnoise3	f = 1 kHz	High-speed mode	—	Note 3	—	nV/√Hz
	Vnoise4	f = 2 kHz		—	Note 3	—	nV/√Hz
Power supply reduction ratio	PSRR			—	Note 3	—	dB
Common mode signal reduction ratio	CMRR			—	Note 3	—	dB
Operation stabilization wait time	Tstd1	CL = 20 pF	Low-power consumption mode	—	Note 3	Note 3	μs
	Tstd2	CL = 20 pF	High-speed mode	—	Note 3	Note 3	μs
Settling time	Tset1	CL = 20 pF	Low-power consumption mode	—	Note 3	Note 3	μs
	Tset2	CL = 20 pF	High-speed mode	—	Note 3	Note 3	μs
Slew rate	Tselw1	CL = 20 pF	Low-power consumption mode	Note 3	Note 3	—	V/μs
	Tselw2	CL = 20 pF	High-speed mode	Note 3	Note 3	—	V/μs
Load current	Iload1	Low-power consumption mode		Note 3	—	Note 3	μA
	Iload2	High-speed mode		Note 3	—	Note 3	μA
Load capacitance	CL			—	—	Note 3	pF
Analog MUX ON resistance	Ron	One channel		—	—	Note 3	kΩ

Note 1. MAX. value is the average value ±3σ at normalized distribution.

Note 2. These values are the results of characteristic evaluation.

Note 3. The reference value is not available.

2.6.6 General purpose operational amplifier characteristics

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Circuit current	I_{CC1}	Low-power consumption mode			2	4	μA
	I_{CC2}	High-speed mode			140	280	μA
Common mode input range	V_{icm1}	Low-power consumption mode		0.2		AV_{DD}-0.5	V
	V_{icm2}	High-speed mode		0.3		AV_{DD}-0.6	V
Output voltage range	V_{o1}	Low-power consumption mode		0.1		AV_{DD}-0.1	V
	V_{o2}	High-speed mode		0.1		AV_{DD}-0.1	V
Input offset voltage	Fioff	3σ		-10		+10	mV
Open gain	A_V			60	120		dB
Gain-bandwidth (GB) product	GBW1	Low-power consumption mode			0.04		MHz
	GBW2	High-speed mode			1.7		MHz
Phase margin	PM	CL = 20 pF		50			deg
Gain margin	GM	CL = 20 pF		10			dB
Equivalent input noise	Vnoise1	f = 1 kHz	Low-power consumption mode		230		nV/√Hz
	Vnoise2	f = 10 kHz			200		nV/√Hz
	Vnoise3	f = 1 kHz	High-speed mode		90		nV/√Hz
	Vnoise4	f = 2 kHz			70		nV/√Hz
Power supply reduction ratio	PSRR				90		dB
Common mode signal reduction ratio	CMRR				90		dB
Operation stabilization wait time	Tstd1	CL = 20 pF	Low-power consumption mode			650	μs
	Tstd2	CL = 20 pF	High-speed mode			13	μs
Settling time	Tset1	CL = 20 pF	Low-power consumption mode			750	μs
	Tset2	CL = 20 pF	High-speed mode			13	μs
Slew rate	Tselw1	CL = 20 pF	Low-power consumption mode		0.02		V/μs
	Tselw2	CL = 20 pF	High-speed mode		1.1		V/μs
Load current	Iload1	Low-power consumption mode		-100		100	μA
	Iload2	High-speed mode		-100		100	μA
Load capacitance	CL					20	pF

<R> 2.6.7 Voltage reference

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Reference voltage output Note 2	V_{REF1}	VSEL = 00, 2.65 V ≤ AV_{DD} ≤ 3.6V	2.425	2.5	2.575	V
	V_{REF2}	VSEL = 01, 2.2 V ≤ AV_{DD} ≤ 3.6V	1.987	2.048	2.109	V
	V_{REF3}	VSEL = 10, 2.0 V ≤ AV_{DD} ≤ 3.6V	1.746	1.8	1.854	V
	V_{REF4}	VSEL = 11, 1.8 V ≤ AV_{DD} ≤ 3.6V	1.455	1.5	1.545	V
Settling time		From power-on to AV_{DD} settling (external capacitance: 10 μF)			50	ms
Load current of the AV_{REFP}/VREFOUT pin Notes 1, 3	I_{Load}				200	μA

Note 1. Connect AV_{REFP}/AVREFOUT pins to the ground via a tantalum capacitor (capacity: 10 μF ±30%, ESR: 2Ω (max.), ESL: 10 nH (max.)) and a ceramic capacitor (capacity: 0.1 μF ±30%, ESR: 2Ω (max.), ESL: 10nH (max.)).

Note 2. The values specified in the Reference voltage output column apply when a load is stable. These values cannot be guaranteed when the load is variable.

Note 3. Total load current, including the load current when AV_{REFP}/VREFOUT is in use for the on-chip A/D converter and D/A converter reference potential.
When AV_{REFP}/VREFOUT is in use for the on-chip A/D converter load reference, the maximum load current is 55 μA.
When AV_{REFP}/VREFOUT is in use for the on-chip D/A converter (channel 1), the maximum load current is 55 μA.

<R> 2.6.8 1/2 AV_{DD} voltage output

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Output voltage accuracy			-4.0		+4.0	%
Sampling time for the corresponding channel			20.0			μs

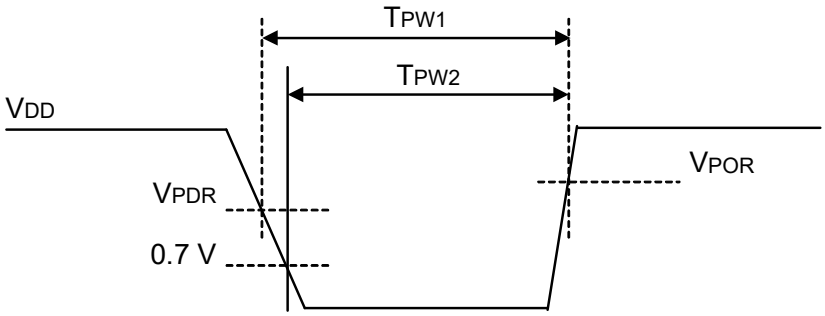
2.6.9 POR circuit characteristics

(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	1.46	1.50	1.54	V
Minimum pulse width Note 2	TPW1	Other than STOP/SUB HALT/SUB RUN	300			μs
	TPW2	STOP/SUB HALT/SUB RUN	300			μs

Note 1. If the power supply voltage falls while the voltage detector is off, be sure to either shift to STOP mode or execute a reset by using the voltage detector or external reset pin before the power supply voltage falls below the minimum operating voltage specified in 2.4 AC Characteristics.

Note 2. 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 (HIOSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).



2.6.10 LVD circuit characteristics

LVD Detection Voltage of Reset Mode and Interrupt Mode
(T_A = -40 to +85°C, $V_{PDR} \leq V_{DD} \leq$ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V_{LVD2}	Power supply rise time	3.07	3.13	3.19	V
		Power supply fall time	3.00	3.06	3.12	V
	V_{LVD3}	Power supply rise time	2.96	3.02	3.08	V
		Power supply fall time	2.90	2.96	3.02	V
	V_{LVD4}	Power supply rise time	2.86	2.92	2.97	V
		Power supply fall time	2.80	2.86	2.91	V
	V_{LVD5}	Power supply rise time	2.76	2.81	2.87	V
		Power supply fall time	2.70	2.75	2.81	V
	V_{LVD6}	Power supply rise time	2.66	2.71	2.76	V
		Power supply fall time	2.60	2.65	2.70	V
	V_{LVD7}	Power supply rise time	2.56	2.61	2.66	V
		Power supply fall time	2.50	2.55	2.60	V
	V_{LVD8}	Power supply rise time	2.45	2.50	2.55	V
		Power supply fall time	2.40	2.45	2.50	V
	V_{LVD9}	Power supply rise time	2.05	2.09	2.13	V
		Power supply fall time	2.00	2.04	2.08	V
	V_{LVD10}	Power supply rise time	1.94	1.98	2.02	V
		Power supply fall time	1.90	1.94	1.98	V
	V_{LVD11}	Power supply rise time	1.84	1.88	1.91	V
		Power supply fall time	1.80	1.84	1.87	V
Minimum pulse width	t_{LW}		300			μs
Detection delay time					300	μs

Caution Set the detection voltage (V_{LVD}) 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 @ 1 MHz to 24 MHz
V_{DD} = 2.4 to 3.6 V @ 1 MHz to 16 MHz
LS (low-speed main) mode: V_{DD} = 1.8 to 3.6 V @ 1 MHz to 8 MHz

LVD Detection Voltage of Interrupt & Reset Mode

(T_A = -40 to +85°C, $V_{PDR} \le V_{DD} \le$ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Detection voltage	V_{LVDB0}	V_{POC0}, V_{POC1}, V_{POC2} = 0, 0, 1, falling reset voltage: 1.8 V		1.80	1.84	1.87	V
	V_{LVDB1}	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
	V_{LVDB2}	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
	V_{LVDB3}	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
	V_{LVDC0}	V_{POC0}, V_{POC1}, V_{POC2} = 0, 1, 0, falling reset voltage: 2.4 V		2.40	2.45	2.50	V
	V_{LVDC1}	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
	V_{LVDC2}	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
	V_{LVDD0}	V_{POC0}, V_{POC1}, V_{POC2} = 0, 1, 1, falling reset voltage: 2.7 V		2.70	2.75	2.81	V
	V_{LVDD1}	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
	V_{LVDD2}	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

2.6.11 Low-resistance switch

(T_A = –40 to + 85°C, 1.8 V $\le AV_{DD} \le V_{DD} \le$ 3.6 V, $AV_{SS} = V_{SS}$ = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
ON resistance 1	Ron1	AMP0OPD, AMP1OPD Load current < 0.1 mA	—	16	50	Ω
ON resistance 2	Ron2	AMP2OPD Load current < 0.1 mA	—	10	30	
Load current	Icas	—	—	—	0.1	mA

[Reference value for design (not guaranteed)]

We can provide the design reference values for the low-resistance switch. Note, however, that these values are not guaranteed and can only be used as a reference when using this function. See below for details.

(T_A = 0 to + 50°C, 2.0 V $\le AV_{DD} \le V_{DD} \le$ 3.6 V, $AV_{SS} = V_{SS}$ = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
ON resistance 1 Note 1, Note 2	Ron1	AMP0OPD, AMP1OPD Load current < 0.1 mA	—	—Note 3	26	Ω
ON resistance 2 Note 1, Note 2	Ron2	AMP2OPD Load current < 0.1 mA	—	—Note 3	15	
Load current	Icas	—	—	—	—Note 3	mA

Note 1. MAX. value is the average value ±3σ at normalized distribution.

Note 2. These values are the results of characteristic evaluation.

Note 3. The reference value is not available.

2.7 Power supply voltage rising slope characteristics

(T_A = -40 to +85°C, V_{SS} = 0 V)

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

Caution 1. Make sure to keep the internal reset state by the LVD circuit or an external reset until V_{DD} reaches the operating voltage range shown in 2.4 AC Characteristics.

<R> **Caution 2. When the voltages for V_{DD} and AV_{DD} differ and they rise at different rates, if AV_{DD} is lower than 0.8 V at the time of the release from the internal reset state by the power-on reset (POR) circuit, the chip may not start normally. In such cases, apply either of the following countermeasures.**

- **Hold $AV_{DD} \geq 0.8$ V until $V_{DD} \geq 1.47$ V.**
- **Hold the $\overline{\text{RESET}}$ pin low until $V_{DD} \geq 1.47$ V and $AV_{DD} \geq 0.8$ V.**

2.8 LCD Characteristics

2.8.1 Resistance division method

(1) Static display mode

(T_A = -40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

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

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

(T_A = -40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

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

(3) 1/3 bias method

(T_A = -40 to +85°C, V_{L4} (MIN.) ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

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

2.8.2 Internal voltage boosting method

(1) 1/3 bias method

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
LCD output voltage variation range	V_{L1}	C1 to C4 Note 1 = 0.47 μF Note 2	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
			VLCD = 0BH	1.25	1.35	1.43	V
			VLCD = 0CH	1.30	1.40	1.48	V
			VLCD = 0DH	1.35	1.45	1.53	V
			VLCD = 0EH	1.40	1.50	1.58	V
			VLCD = 0FH	1.45	1.55	1.63	V
			VLCD = 10H	1.50	1.60	1.68	V
			VLCD = 11H	1.55	1.65	1.73	V
			VLCD = 12H	1.60	1.70	1.78	V
			VLCD = 13H	1.65	1.75	1.83	V
Doubler output voltage	V_{L2}	C1 to C4 Note 1 = 0.47 μF		2 V_{L1} - 0.1	2 V_{L1}	2 V_{L1}	V
Tripler output voltage	V_{L4}	C1 to C4 Note 1 = 0.47 μF		3 V_{L1} - 0.15	3 V_{L1}	3 V_{L1}	V
Reference voltage setup time Note 2	t_{VWAIT1}			5			ms
Voltage boost wait time Note 3	t_{VWAIT2}	C1 to C4 Note 1 = 0.47μF		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 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

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

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

<R>

2.8.3 Capacitor split method

(1) 1/3 bias method

(T_A = -40 to +85°C, 2.2 V ≤ V_{DD} ≤ 3.6 V, V_{SS} = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
V_{L4} voltage	V_{L4}	C1 to C3 = 0.47 μF Note 2		V_{DD}		V
V_{L2} voltage	V_{L2}	C1 to C3 = 0.47 μF Note 2	2/3 V_{L4} - 0.1	2/3 V_{L4}	2/3 V_{L4} + 0.1	V
V_{L1} voltage	V_{L1}	C1 to C3 = 0.47 μF Note 2	1/3 V_{L4} - 0.1	1/3 V_{L4}	1/3 V_{L4} + 0.1	V
Capacitor split wait time Note 1	t_{VWAIT}		100			ms

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

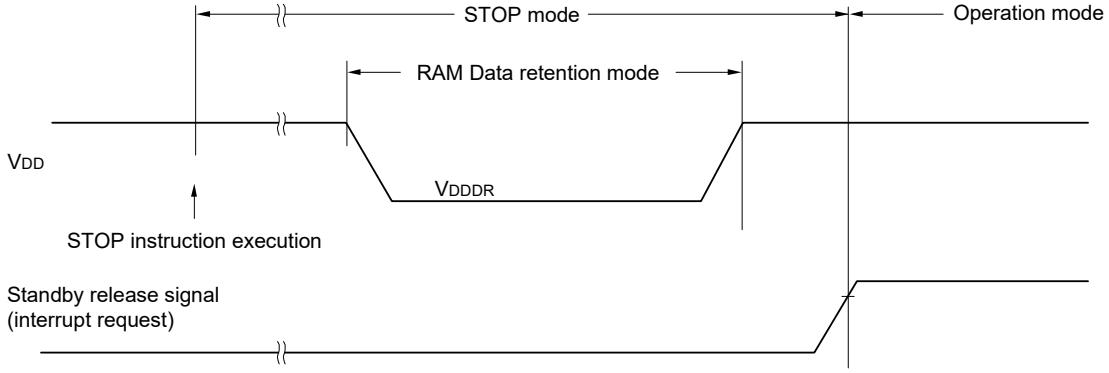
Note 2. This is a capacitor that is connected between voltage pins used to drive the LCD.
C1: A capacitor connected between CAPH and CAPL
C2: A capacitor connected between V_{L1} and GND
C3: A capacitor connected between V_{L2} and GND
C1 = C2 = C3 = 0.47 μF±30%

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



2.10 Flash Memory Programming Characteristics

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

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

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

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

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

2.11 Dedicated Flash Memory Programmer Communication (UART)

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

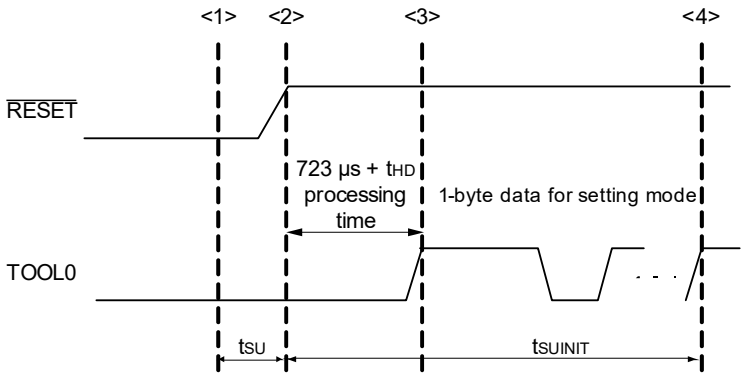
Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Transfer rate		During serial programming	115,200		1,000,000	bps

2.12 Timing Specs for Switching Modes

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
How long from when an external reset ends until the initial communication settings are specified	t_{SUINIT}	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	t_{SU}	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)	t_{HD}	POR and LVD reset must end before the external reset ends.	1			ms

<R>



<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.

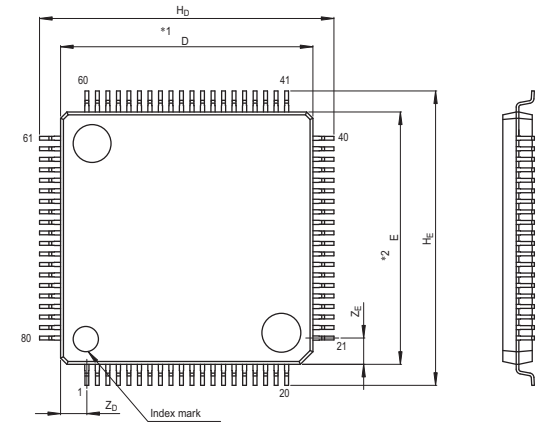
Remark t_{SUINIT}: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.
t_{SU}: How long from when the TOOL0 pin is placed at the low level until an external reset ends
t_{HD}: Time to hold the TOOL0 pin at the low level after an external reset is released (excluding the processing time of the firmware to control the flash memory)

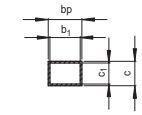
3. PACKAGE DRAWINGS

3.1 80-pin products

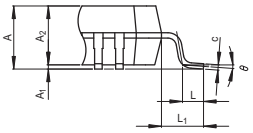
R5F11MMDAFB, R5F11MMEAFB, R5F11MMFAFB

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LFQFP80-12x12-0.50	PLQP0080KB-A	80P6Q-A	0.5g





Terminal cross section



Detail F

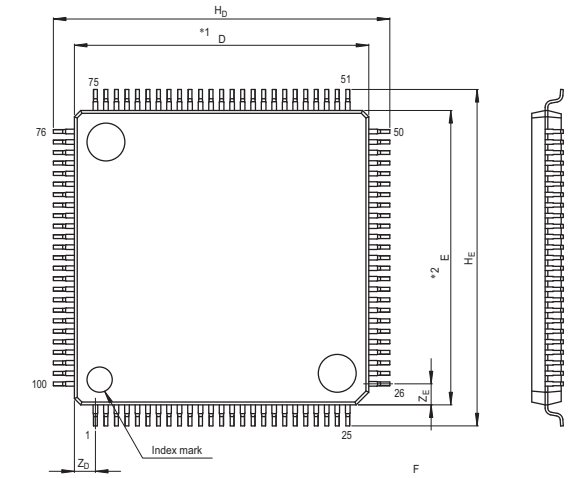
NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

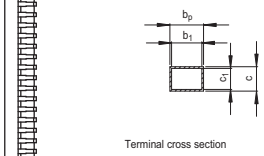
Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	11.9	12.0	12.1
E	11.9	12.0	12.1
A_2	—	1.4	—
H_D	13.8	14.0	14.2
H_E	13.8	14.0	14.2
A	—	—	1.7
A_1	0	0.1	0.2
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	10°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.25	—
Z_E	—	1.25	—
L	0.3	0.5	0.7
L_1	—	1.0	—

3.2 100-pin products

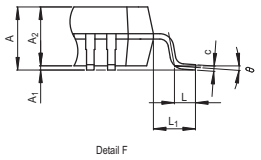
R5F11MPEAFB, R5F11MPFAFB, R5F11MPGAFB

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LFQFP100-14x14-0.50	PLQP0100KB-A	100P6Q-A / FP-100U / FP-100UV	0.6g





Terminal cross section



Detail F

NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.35	0.5	0.65
L_1	—	1.0	—

REVISION HISTORY	RL78/L1A Datasheet

Rev.	Date	Description	
		Page	Summary
1.00	Aug 12, 2016	—	First Edition issued
1.10	Sep 30, 2019	p.2	Modification of 1.1 Features
		p.6	Modification of description in 1.4 Pin Identification
		p.7	Modification of block diagram in 1.5.1 80-pin products
		p.8	Modification of block diagram in 1.5.2 100-pin products
		p.12, 14	Modification of 2.1 Absolute Maximum Ratings
		p.17 to 20	Modification of 2.3.1 Pin characteristics
		p.28	Deletion of note 16 in 2.3.2 Supply current characteristics
		p.36	Modification of 2.5.1 (2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)
		p.42	Modification of remarks 2 and 3 in 2.5.1 (5) During communication at same potential (simplified I^2C mode)
		p.59	Modification of 2.6.1 A/D converter characteristics
		p.60	Modification of table and addition of note in 2.6.1 A/D converter characteristics
		p.64	Addition of description in 2.6.4 Comparator
		p.65	Modification of 2.6.5 Rail to rail operational amplifier characteristics
		p.68	Modification of 2.6.7 Voltage reference
		p.68	Modification of 2.6.8 1/2 AV_{DD} voltage output, and the location of this chapter has been moved.
		p.72	Addition of caution 2 in 2.7 Power supply voltage rising slope characteristics
		p.75	Modification of note 2 in 2.8.3 Capacitor split method
		p.77	Modification of 2.12 Timing Specs for Switching Modes

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

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

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

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