

## RL78/L1A

R01DS0280EJ0100

### RENESAS MCU

Rev. 1.00

Aug 12, 2016

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  $\mu$ A/MHz, and 0.68  $\mu$ A 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  $\mu$ s: @ 24 MHz operation with high-speed on-chip oscillator clock) to ultra-low speed (30.5  $\mu$ s: @ 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  $\times$  8)  $\times$  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:  $\pm 1.0\%$  ( $V_{DD} = 1.8$  to 3.6 V,  $T_A = -20$  to  $+85$   $^{\circ}$ C)

#### Operating ambient temperature

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

#### 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<sup>2</sup>C/simplified I<sup>2</sup>C: 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) <sup>Note 1</sup>
- Common signal output: 4 (8) <sup>Note 1</sup>

#### A/D converter

- 12-bit resolution A/D converter ( $1.8$  V  $\leq V_{DD} \leq V_{DD} \leq 3.6$  V)
- Analog input: 10 to 14 channels
- Internal reference voltage (TYP. 1.45 V) and temperature sensor <sup>Note 2</sup>

#### D/A converter

- 12-bit resolution D/A converter ( $1.8$  V  $\leq V_{DD} \leq V_{DD} \leq 3.6$  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.

**Note 3.** The functions mounted depend on the product. See 1.6 Outline of Functions.

○ ROM, RAM capacities

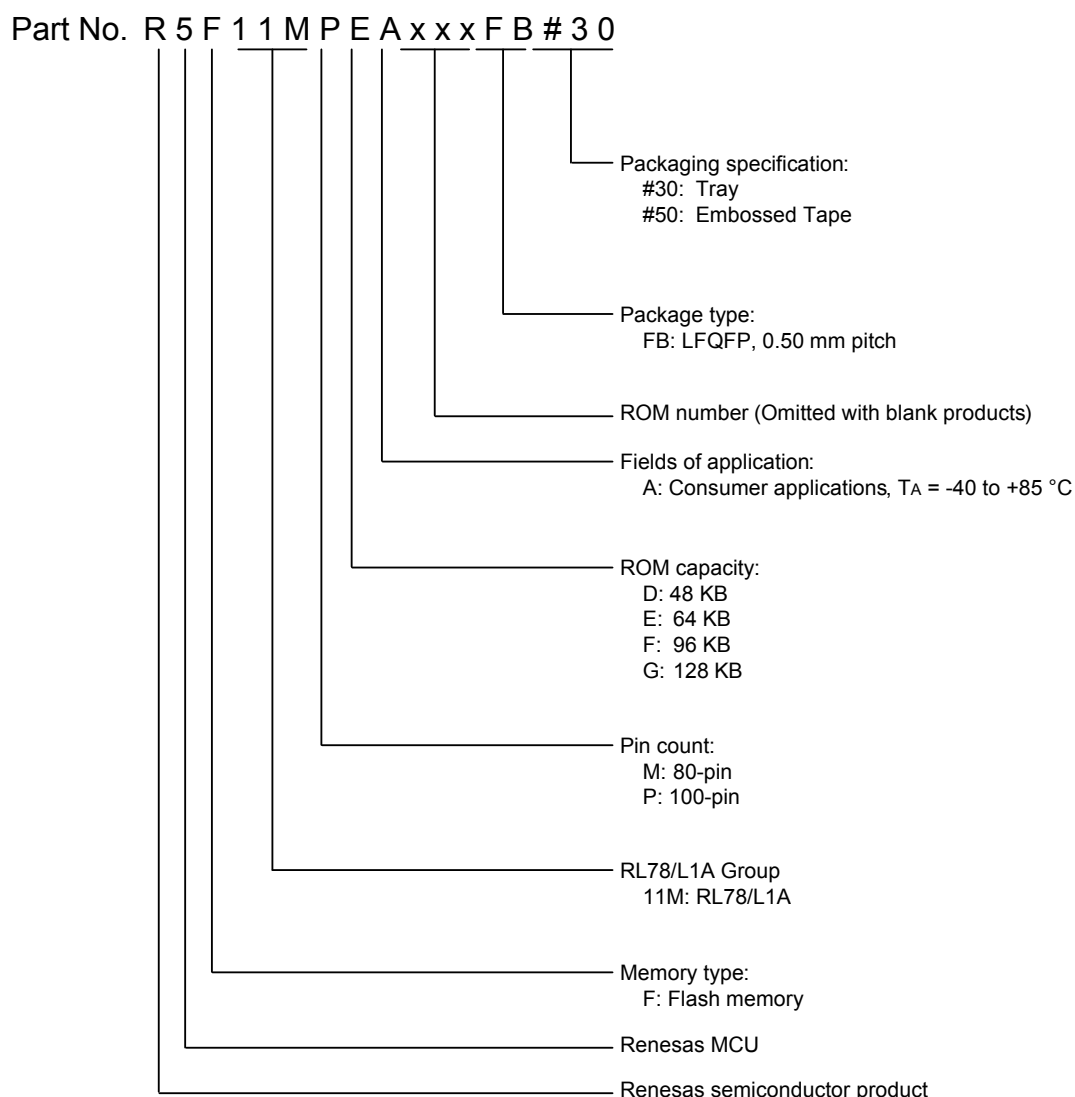
**Products with USB**

Flash ROM	Data Flash	RAM	RL78/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, R5F11MMFAFB#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

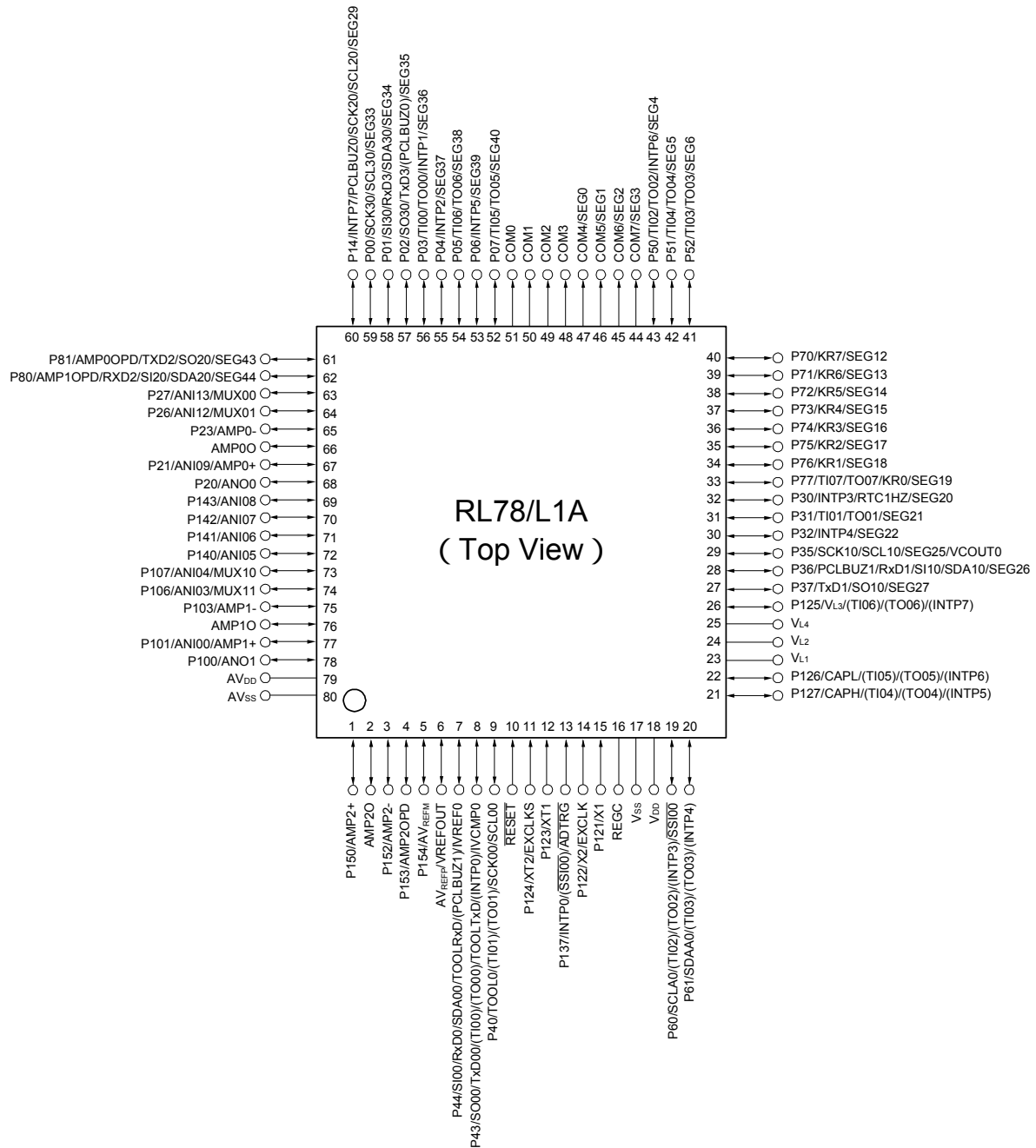


**Caution** Orderable part numbers are current as of when this manual was published.  
Please make sure to refer to the relevant product page on the Renesas website for the latest part numbers.

### 1.3 Pin Configuration (Top View)

#### 1.3.1 80-pin products

- 80-pin plastic LQFP (fine pitch) (12 ´ 12 mm, 0.5 mm pitch)



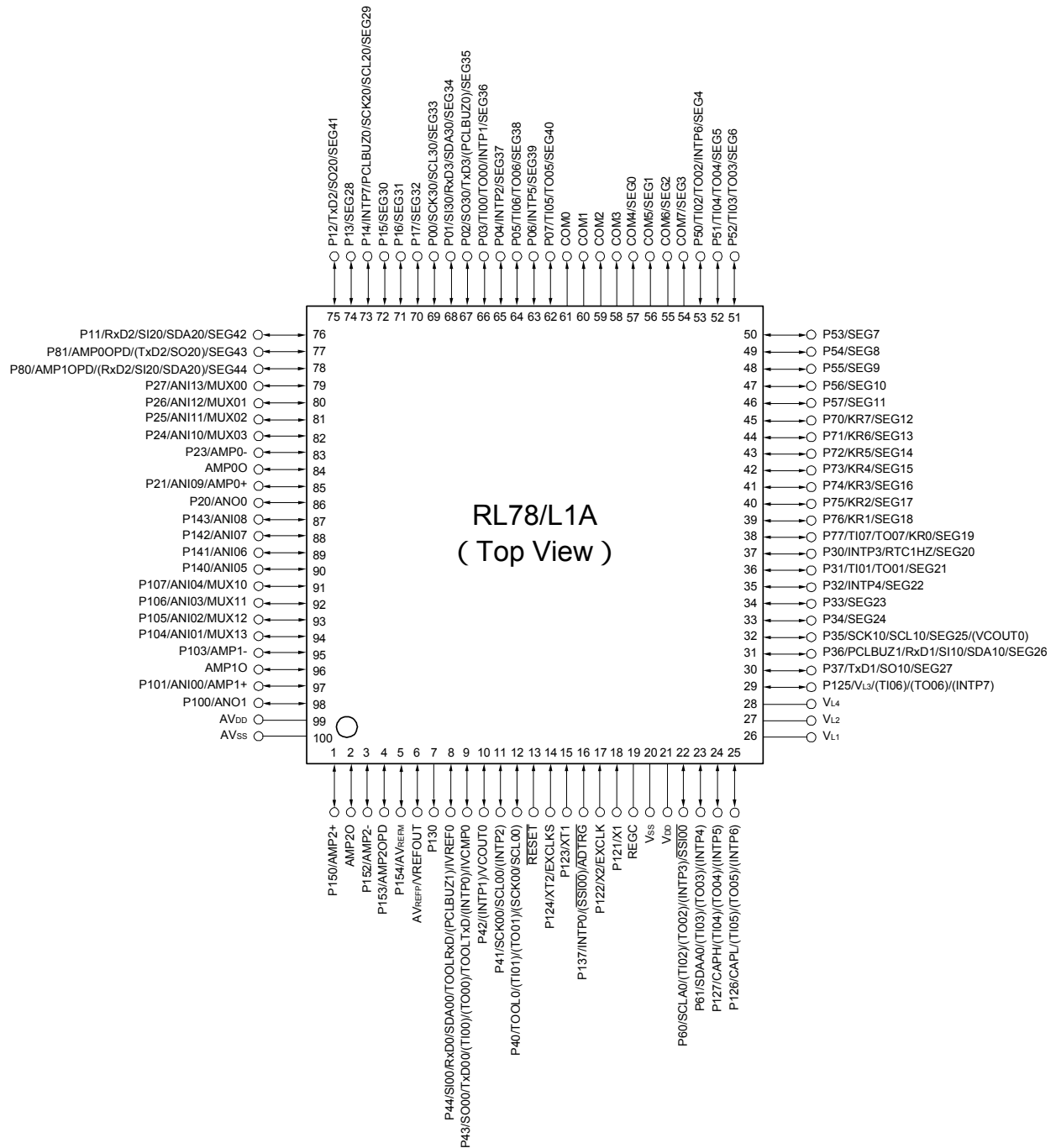
**Caution** Connect the REGC pin to VSS pin via a capacitor (0.47 to 1 µF).

**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.

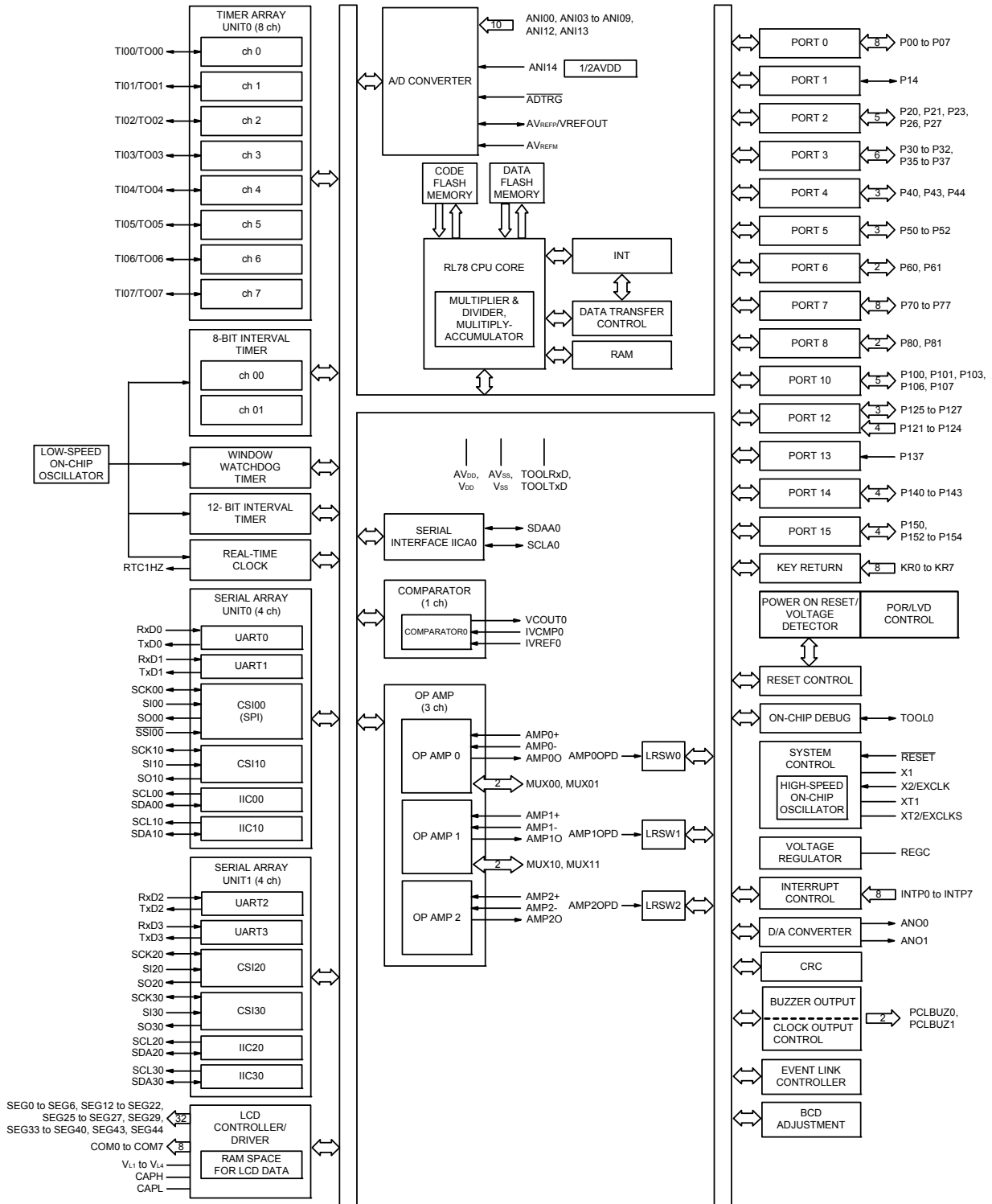
**Remark 2.** Functions in parentheses in the above figure can be assigned via settings in the peripheral I/O redirection register (PIOR).

## 1.4 Pin Identification

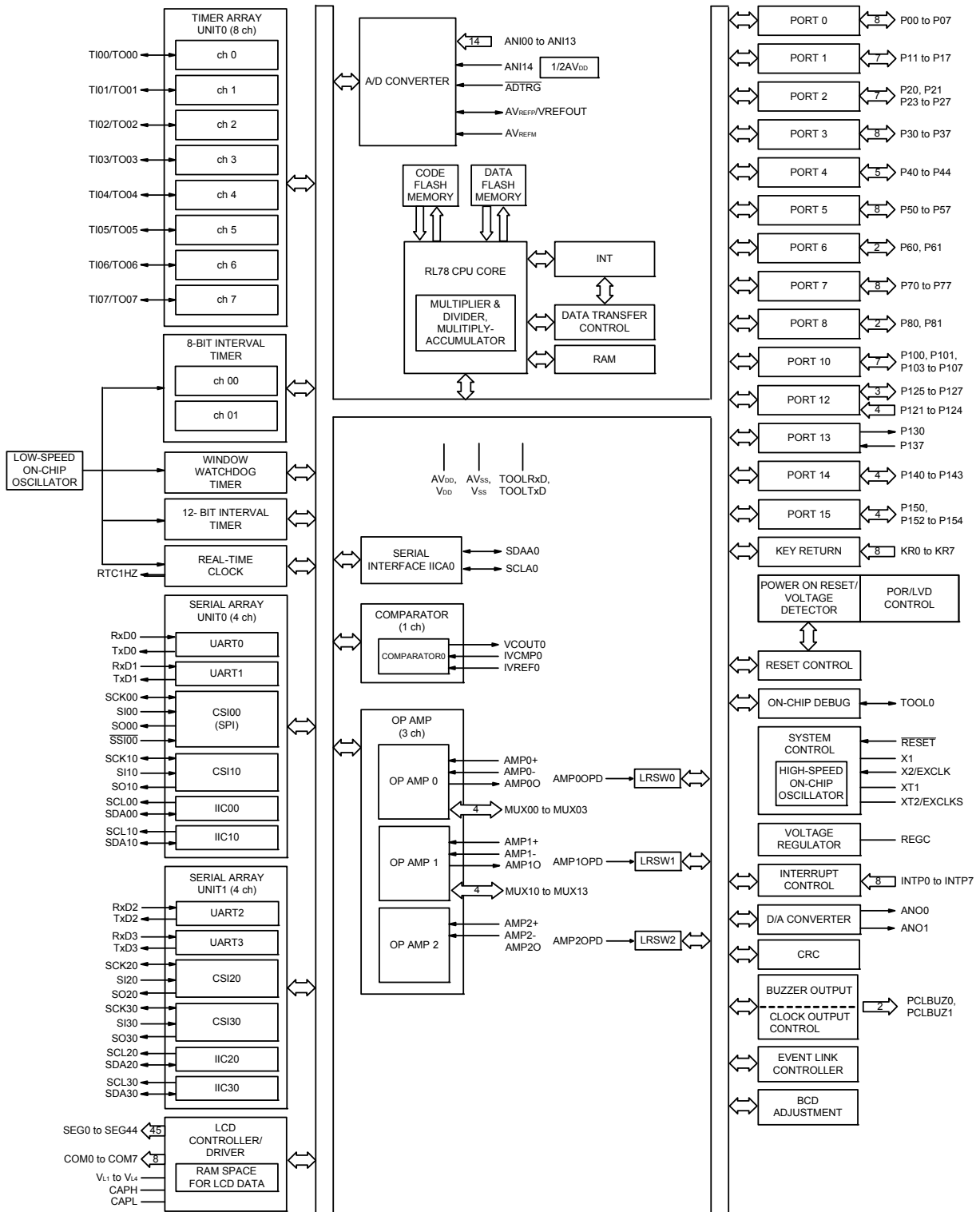
AMP0+ to AMP2+	: OP AMP + Input	PCLBUZ0, PCLBUZ1	: Programmable Clock Output/ Buzzer Output
AMP0- to AMP2+	: OP AMP - Input		
AMP0O to AMP2+	: OP AMP Output	REGC	: Regulator Capacitance
AMP0OPD to AMP2OPD	: Low Resistance Switch	$\overline{\text{RESET}}$	: Reset
$\overline{\text{ADTRG}}$	: A/D External Trigger Input	RTC1HZ	: Real-time Clock Correction
ANI0 to ANI14	: Analog Input	RxD0 to RxD3	: Receive Data
ANO0, ANO1	: Analog Output	SCK00, SCK10, SCK20, SCK30	: Serial Clock Input/Output
AVDD	: Analog Power Supply	SCLA0	: Serial Clock Input/Output
AV <sub>REFM</sub>	: Analog Reference Voltage Minus	SCL00, SCL10, SCL20, SCL30	: Serial Clock Output
AV <sub>REFP</sub>	: Analog Reference Voltage Plus	SDAA0, SDA00, SDA10, SDA20, SDA30	: Serial Data Input/Output
AV <sub>SS</sub>	: Analog Ground	SEG0 to SEG55	: LCD Segment Output
CAPH, CAPL	: Capacitor for LCD	SI00, SI10, SI20, SI30	: Serial Data Input
COM0 to COM7	: LCD Common Output	SO00, SO10, SO20, SO30	: Serial Data Output
EXCLK	: External Clock Input (Main System Clock)	$\overline{\text{SSIO0}}$	: Slave Select Input
EXCLKS	: External Clock Input (Sub System Clock)	TI00 to TI07	: Timer Input
INTP0 to INTP7	: External Interrupt Input	TO00 to TO07	: Timer Output
IVCMP0	: Comparator Input	TOOL0	: Data Input/Output for Tool
IVREF0	: Comparator Reference Input	TOOLRxD, TOOLTxD	: Data Input/Output for External Device
KR0 to KR7	: Key Return	TxD0 to TxD3	: Transmit Data
MUX00 to MUX03, MUX10 to MUX13	: OP AMP output analog MUX switch	VCOUT0	: Comparator Output
P00 to P07	: Port 0	V <sub>DD</sub>	: Power Supply
P11 to P17	: Port 1	V <sub>L1</sub> to V <sub>L4</sub>	: LCD Power Supply
P20, P21 P23 to P27	: Port 2	VREFOUT	: Analog Reference Voltage Output
P30 to P37	: Port 3	V <sub>SS</sub>	: Ground
P40 to P44	: Port 4	X1, X2	: Crystal Oscillator (Main System Clock)
P50 to P57	: Port 5	XT1, XT2	: Crystal Oscillator (Subsystem Clock)
P60, P61	: Port 6		
P70 to P77	: Port 7		
P80, P81	: Port 8		
P100, P101	: Port 10		
P103 to P107			
P121 to P127	: Port 12		
P130, P137	: Port 13		
P140 to P143	: Port 14		
P150, P152 to P154	: Port 15		

### 1.5 Block Diagram

#### 1.5.1 80-pin products



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: $V_{DD} = 2.7$ to $3.6$ V, 1 to 8 MHz: $V_{DD} = 1.8$ to $2.7$ V	
	High-speed on-chip oscillator clock	HS (high-speed main) operation mode: 1 to 24 MHz ( $V_{DD} = 2.7$ to $3.6$ V), HS (high-speed main) operation mode: 1 to 16 MHz ( $V_{DD} = 2.4$ to $3.6$ V), LS (low-speed main) operation mode: 1 to 8 MHz ( $V_{DD} = 1.8$ to $3.6$ V)	
Subsystem clock		XT1 (crystal) oscillation, external subsystem clock input (EXCLKS) 32.768 kHz (TYP.): $V_{DD} = 1.8$ to $3.6$ V	
Low-speed on-chip oscillator clock		15 kHz (TYP.): $V_{DD} = 1.8$ 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: $f_{HOCO} = f_{IH} = 24$ MHz operation)	
		0.05 μs (High-speed system clock: $f_{MX} = 20$ MHz operation)	
		30.5 μs (Subsystem clock: $f_{SUB} = 32.768$ kHz operation)	
Instruction set		<ul style="list-style-type: none"> <li>• Data transfer (8/16 bits)</li> <li>• Adder and subtractor/logical operation (8/16 bits)</li> <li>• Multiplication (8 bits × 8 bits, 16 bits × 16 bits), Division (16 bits ÷ 16 bits, 32 bits ÷ 32 bits)</li> <li>• Multiplication and Accumulation (16 bits × 16 bits + 32 bits)</li> <li>• Rotate, barrel shift, and bit manipulation (Set, reset, test, and Boolean operation), etc.</li> </ul>	
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 <sup>Note</sup> )	
	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: $f_{SUB} = 32.768$ 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
	<ul style="list-style-type: none"> <li>• 2.44 kHz, 4.88 kHz, 9.76 kHz, 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz (Main system clock: <math>f_{MAIN} = 20</math> MHz operation)</li> <li>• 256 Hz, 512 Hz, 1.024 kHz, 2.048 kHz, 4.096 kHz, 8.192 kHz, 16.384 kHz, 32.768 kHz (Subsystem clock: <math>f_{SUB} = 32.768</math> kHz operation)</li> </ul>	
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	<ul style="list-style-type: none"> <li>• CSI (SPI supported): 1 channel/UART (LIN-bus supported): 1 channel/simplified I<sup>2</sup>C: 1 channel</li> <li>• CSI: 1 channel/UART: 1 channel/simplified I<sup>2</sup>C: 1 channel</li> <li>• CSI: 1 channel/UART: 1 channel/simplified I<sup>2</sup>C: 1 channel</li> <li>• CSI: 1 channel/UART: 1 channel/simplified I<sup>2</sup>C: 1 channel</li> </ul>	
I <sup>2</sup> C bus	1 channel	1 channel
LCD controller/driver	Internal voltage boosting method, capacitor split method, and external resistance division method are switchable.	
Segment signal output	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
	External	9
Key interrupt	8	8
Reset	<ul style="list-style-type: none"> <li>• Reset by <math>\overline{RESET}</math> pin</li> <li>• Internal reset by watchdog timer</li> <li>• Internal reset by power-on-reset</li> <li>• Internal reset by voltage detector</li> <li>• Internal reset by illegal instruction execution Note 2</li> <li>• Internal reset by RAM parity error</li> <li>• Internal reset by illegal-memory access</li> </ul>	
Power-on-reset circuit	<ul style="list-style-type: none"> <li>• Power-on-reset: 1.51 <math>\pm</math>0.04 V</li> <li>• Power-down-reset: 1.50 <math>\pm</math>0.04 V</li> </ul>	
Voltage detector	<ul style="list-style-type: none"> <li>• Rising edge: 1.88 V to 3.13 V (10 stages)</li> <li>• Falling edge: 1.84 V to 3.06 V (10 stages)</li> </ul>	
On-chip debug function	Provided	
Power supply voltage	$V_{DD} = 1.8$ to 3.6 V	
Operating ambient temperature	$T_A = -40$ 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 electrical specifications for the products A: Consumer applications (TA = -40 to +85 °C).

**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 (TA = 25°C)

(1/3)

Parameter	Symbols	Conditions	Ratings	Unit
Supply voltage	V <sub>DD</sub>		-0.5 to +6.5	V
	AV <sub>DD</sub>	AV <sub>DD</sub> ≤ V <sub>DD</sub>	-0.5 to +4.6	V
REGC pin input voltage	V <sub>IREGC</sub>	REGC	-0.3 to +2.8 and -0.3 to V <sub>DD</sub> + 0.3 Note 1	V
Input voltage	V <sub>I1</sub>	P00 to P07, P11 to P17, P30 to P37, P40 to P44, P50 to P57, P70 to P77, P80, P81, P125 to P127, P137, EXCLK, EXCLKS, RESET	-0.3 to V <sub>DD</sub> + 0.3 Note 2	V
	V <sub>I2</sub>	P60, P61 (N-ch open-drain)	-0.3 to +6.5	V
	V <sub>I4</sub>	IVCMP0	-0.7 to V <sub>DD</sub> + 0.7	V
	V <sub>I5</sub>	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-0.3 to AV <sub>DD</sub> + 0.3 Note 3	V
Output voltage	V <sub>O1</sub>	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 <sub>DD</sub> + 0.3 Note 2	V
	V <sub>O2</sub>	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-0.3 to AV <sub>DD</sub> + 0.3 Note 3	V
Analog input voltage	V <sub>AI1</sub>	ANI0 to ANI3	-0.3 to AV <sub>DD</sub> + 0.3 and AV <sub>REF(+)</sub> + 0.3 Notes 2, 4	V

**Note 1.** Connect the REGC pin to V<sub>SS</sub> 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<sub>REF(+)</sub> + 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<sub>REF(+)</sub>: + side reference voltage of the A/D converter.

**Remark 3.** V<sub>SS</sub>: Reference voltage

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

Parameter	Symbols	Conditions	Ratings	Unit	
LCD voltage	VL11	VL1 input voltage <small>Note 1</small>	-0.3 to +2.8	V	
	VL12	VL2 input voltage <small>Note 1</small>	-0.3 to +6.5	V	
	VL13	VL3 input voltage <small>Note 1</small>	-0.3 to +6.5	V	
	VL14	VL4 input voltage <small>Note 1</small>	-0.3 to +6.5	V	
	VL15	CAPL, CAPH input voltage <small>Note 1</small>	-0.3 to +6.5	V	
	VLO1	VL1 output voltage	-0.3 to +2.8	V	
	VLO2	VL2 output voltage	-0.3 to +6.5	V	
	VLO3	VL3 output voltage	-0.3 to +6.5	V	
	VLO4	VL4 output voltage	-0.3 to +6.5	V	
	VLO5	CAPL, CAPH output voltage	-0.3 to +6.5	V	
	VLO6	COM0 to COM7 SEG0 to SEG44 output voltage	External resistance division method	-0.3 to VDD + 0.3 <small>Note 2</small>	V
			Capacitor split method	-0.3 to VDD + 0.3 <small>Note 2</small>	V
Internal voltage boosting method			-0.3 to VL14 + 0.3 <small>Note 2</small>	V	

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

**Note 2.** Must be 6.5 V or lower.

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

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

Parameter	Symbols	Conditions		Ratings	Unit
Output current, high	IOH1	Per pin		-40	mA
		Total of all pins	P40 to P44	-70	mA
	IOH2	Per pin	P00 to P07, P11 to P17, P30 to P37, P50 to P57, P70 to P77, P80, P81, P125 to P127, P130	-100	mA
		Total of all pins	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	-1.6 Note	mA
Output current, low	IOL1	Per pin		40	mA
		Total of all pins	P40 to P44	70	mA
	IOL2	Per pin	P00 to P07, P11 to P17, P30 to P37, P50 to P57, P60, P61, P70 to P77, P80, P81, P125 to P127, P130	100	mA
		Total of all pins	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	6.4 Note	mA
Operating ambient temperature	TA	In normal operation mode		-40 to +85	°C
		In flash memory programming mode			
Storage temperature	T <sub>stg</sub>			-65 to +150	°C

**Note** Do not exceed the rated values when outputting the current simultaneously 16 pins at maximum.

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

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

## 2.2 Oscillator Characteristics

### 2.2.1 X1 and XT1 oscillator characteristics

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

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

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

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

**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

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

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

**Note 1.** High-speed on-chip oscillator frequency is selected with bits 0 to 4 of the option byte (000C2H/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

### 2.3.1 Pin characteristics

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

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output current, high <sup>Note 1</sup>	IOH1	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% <sup>Note 3</sup> )	2.7 V ≤ AVDD ≤ VDD ≤ 3.6 V		-15.0	mA	
			1.8 V ≤ AVDD ≤ VDD < 2.7 V		-7.0	mA	
	IOH2	Per pin for P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ AVDD ≤ VDD ≤ 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% <sup>Note 3</sup> )	1.8 V ≤ AVDD ≤ VDD ≤ 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 VDD pin(IOH1), AVDD pin(IOH2) to an output pin.

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

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

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

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

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

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

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

**Caution** P00-P02, P11, P12, P14, P35-P37, P40, P41, P43, P44, P80, 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.

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

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output current, low Note 1	IOL1	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 (When duty = 70% Note 3)	2.7 V ≤ AVDD ≤ VDD ≤ 3.6 V			15.0	mA
			1.8 V ≤ AVDD ≤ VDD < 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, P130 (When duty = 70% Note 3)	2.7 V ≤ AVDD ≤ VDD ≤ 3.6 V			35.0	mA
			1.8 V ≤ AVDD ≤ VDD < 2.7 V			20.0	mA
	Total of all pins (When duty = 70% Note 3)				50.0	mA	
	IOL2	Per pin for P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ AVDD ≤ VDD ≤ 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 ≤ AVDD ≤ VDD ≤ 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 VSS pin (IOL1), AVSS pin (IOL2).

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

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

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

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

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

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

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

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

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

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Input voltage, high	VIH1	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 VDD		VDD	V
	VIH2	For TTL mode supported ports	TTL input buffer 3.3 V ≤ VDD ≤ 3.6 V	2.0		VDD	V
			TTL input buffer 1.8 V ≤ VDD < 3.3 V	1.50		VDD	V
	VIH3	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154		0.7 AVDD		AVDD	V
	VIH4	P60, P61		0.7 VDD		6.0	V
	VIH5	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$		0.8 VDD		VDD	V
Input voltage, low	VIL1	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 VDD	V
	VIL2	For TTL mode supported ports	TTL input buffer 3.3 V ≤ VDD ≤ 3.6 V	0		0.5	V
			TTL input buffer 1.8 V ≤ VDD < 3.3 V	0		0.32	V
	VIL3	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154		0		0.3 AVDD	V
	VIL4	P60, P61		0		0.3 VDD	V
	VIL5	P121 to P124, P137, EXCLK, EXCLKS, $\overline{\text{RESET}}$		0		0.2 VDD	V

**Caution** The maximum value of VIH of pins P00 to P02, P11, P12, P14, P35 to P37, P40, P41, P43, P44, P80, P81 is VDD, even in the N-ch open-drain mode.

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

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

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Output voltage, high	VOH1	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 ≤ AVDD ≤ VDD ≤ 3.6 V, IOH = -2.0 mA	VDD - 0.6			V
			1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOH = -1.5 mA	VDD - 0.5			V
	VOH2	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOH = -100 μA	AVDD - 0.5			V
Output voltage, low	VOL1	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 ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 3.0 mA			0.6	V
			2.7 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 1.5 mA			0.4	V
			1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 0.6 mA			0.4	V
	VOL2	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 400 μA			0.4	V
	VOL3	P60, P61	2.7 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 3.0 mA			0.4	V
			1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, IOL = 2.0 mA			0.4	V

**Caution** P00 to P02, P11, P12, P14, P35 to P37, P40, P41. P43, P44, P80, 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.

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

Items	Symbol	Conditions	MIN.	TYP.	MAX.	Unit		
Input leakage current, high	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,_RESET	Vi = VDD			1	μA	
	LIH3	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	Vi = VDD	In input port or external clock input		1	μA	
				In resonator connection		10	μA	
	LIH4	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	Vi = AVDD			1	μA	
Input leakage current, low	LI L1	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,_RESET	Vi = VSS			-1	μA	
	LI L3	P121 to P124 (X1, X2, EXCLK, XT1, XT2, EXCLKS)	Vi = VSS	In input port or external clock input		-1	μA	
				In resonator connection		-10	μA	
	LI L4	P20, P21, P23 to P27, P100, P101, P103 to P107, P140 to P143, P150, P152 to P154	Vi = AVSS			-1	μA	
On-chip pull-up resistance	RU1	P00 to P07, P11 to P17, P30 to P37, P50 to P57, P70 to P77, P80, P81, P125 to P127	Vi = VSS	2.4 V ≤ VDD ≤ 3.6 V	10	20	100	kΩ
				1.8 V ≤ VDD < 2.4 V	10	30	100	
	RU2	P40 to P44	Vi = VSS		10	20	100	kΩ

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

### 2.3.2 Supply current characteristics

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

(1/2)

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit			
Supply current Note 1	IDD1	Operating mode	HS (high-speed main) mode Note 5	f <sub>IH</sub> = 24 MHz Note 3	Basic operation	V <sub>DD</sub> = 3.6 V		1.7		mA		
						V <sub>DD</sub> = 3.0 V		1.7				
					Normal operation	V <sub>DD</sub> = 3.6 V		3.6	6.1			
					V <sub>DD</sub> = 3.0 V		3.6	6.1				
					V <sub>DD</sub> = 3.6 V		2.7	4.7				
					V <sub>DD</sub> = 3.0 V		2.7	4.7				
				f <sub>IH</sub> = 16 MHz Note 3	Normal operation	V <sub>DD</sub> = 3.6 V		2.7	4.7			
						V <sub>DD</sub> = 3.0 V		2.7	4.7			
				LS (low-speed main) mode Note 5	f <sub>IH</sub> = 8 MHz Note 3	Normal operation	V <sub>DD</sub> = 3.6 V		1.2	2.1	mA	
						V <sub>DD</sub> = 3.0 V		1.2	2.1			
					HS (high-speed main) mode Note 5	f <sub>MX</sub> = 20 MHz Note 2, V <sub>DD</sub> = 3.6 V	Normal operation	Square wave input		3.0	5.1	mA
				Resonator connection					3.2	5.2		
			Normal operation	Square wave input				2.9	5.1			
				Resonator connection				3.2	5.2			
			Normal operation	f <sub>MX</sub> = 16 MHz Note 2, V <sub>DD</sub> = 3.6 V			Square wave input		2.5	4.4		
				Resonator connection				2.7	4.5			
			Normal operation	f <sub>MX</sub> = 16 MHz Note 2, V <sub>DD</sub> = 3.0 V		Square wave input		2.5	4.4			
				Resonator connection			2.7	4.5				
			Normal operation	f <sub>MX</sub> = 10 MHz Note 2, V <sub>DD</sub> = 3.6 V		Square wave input		1.9	3.0			
				Resonator connection			1.9	3.0				
			Normal operation	f <sub>MX</sub> = 10 MHz Note 2, V <sub>DD</sub> = 3.0 V		Square wave input		1.9	3.0			
				Resonator connection			1.9	3.0				
			LS (low-speed main) mode Note 5	f <sub>MX</sub> = 8 MHz Note 2, V <sub>DD</sub> = 3.6 V	Normal operation	Square wave input		1.1	2.0	mA		
						Resonator connection		1.1	2.0			
	Normal operation	f <sub>MX</sub> = 8 MHz Note 2, V <sub>DD</sub> = 3.0 V		Square wave input		1.1	2.0					
		Resonator connection			1.1	2.0						
	Subsystem clock operation	f <sub>SUB</sub> = 32.768 kHz Note 4 TA = -40°C	Normal operation	Square wave input		4.0	5.4	μA				
				Resonator connection		4.3	5.4					
		f <sub>SUB</sub> = 32.768 kHz Note 4 TA = +25°C	Normal operation	Square wave input		4.0	5.4					
				Resonator connection		4.3	5.4					
		f <sub>SUB</sub> = 32.768 kHz Note 4 TA = +50°C	Normal operation	Square wave input		4.1	7.1					
				Resonator connection		4.4	7.1					
		f <sub>SUB</sub> = 32.768 kHz Note 4 TA = +70°C	Normal operation	Square wave input		4.3	8.7					
				Resonator connection		4.7	8.7					
		f <sub>SUB</sub> = 32.768 kHz Note 4 TA = +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<sub>DD</sub>, including the input leakage current flowing when the level of the input pin is fixed to V<sub>DD</sub>, or V<sub>SS</sub>. 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 OPA(with analog MUX), General-purpose OPA, 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: | $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }24\text{ MHz}$ |
|                            | $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$ |
| LS (low-speed main) mode:  | $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$  |
- Remark 1.** f<sub>MX</sub>: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f<sub>IH</sub>: Frequency when the high-speed on-chip oscillator (24 MHz max.)
- Remark 3.** f<sub>SUB</sub>: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 4.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

(2/2)

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit				
Supply current Note 1	IDD2 Note 2	HALT mode	HS (high-speed main) mode Note 7	f <sub>IH</sub> = 24 MHz Note 4	V <sub>DD</sub> = 3.6 V		0.42	1.83	mA		
					V <sub>DD</sub> = 3.0 V		0.42	1.83			
				f <sub>IH</sub> = 16 MHz Note 4	V <sub>DD</sub> = 5.0 V		0.39	1.38			
					V <sub>DD</sub> = 3.0 V		0.39	1.38			
				LS (low-speed main) mode Note 7	f <sub>IH</sub> = 8 MHz Note 4	V <sub>DD</sub> = 3.0 V		0.25		0.71	mA
						V <sub>DD</sub> = 2.0 V		0.25		0.71	
			HS (high-speed main) mode Note 7	f <sub>MX</sub> = 20 MHz Note 3, V <sub>DD</sub> = 3.6 V	Square wave input		0.26	1.55	mA		
					Resonator connection		0.4	1.68			
				f <sub>MX</sub> = 20 MHz Note 3, V <sub>DD</sub> = 3.0 V	Square wave input		0.25	1.55			
					Resonator connection		0.4	1.68			
				f <sub>MX</sub> = 16 MHz Note 3, V <sub>DD</sub> = 3.6 V	Square wave input		0.23	1.22			
					Resonator connection		0.36	1.39			
				f <sub>MX</sub> = 16 MHz Note 3, V <sub>DD</sub> = 3.0 V	Square wave input		0.22	1.22			
					Resonator connection		0.35	1.39			
				f <sub>MX</sub> = 10 MHz Note 3, V <sub>DD</sub> = 3.0 V	Square wave input		0.18	0.82			
					Resonator connection		0.28	0.90			
				f <sub>MX</sub> = 10 MHz Note 3, V <sub>DD</sub> = 2.0 V	Square wave input		0.18	0.81			
					Resonator connection		0.28	0.89			
		LS (low-speed main) mode Note 7	f <sub>MX</sub> = 8 MHz Note 3, V <sub>DD</sub> = 3.0 V	Square wave input		0.09	0.51	mA			
				Resonator connection		0.15	0.56				
			f <sub>MX</sub> = 8 MHz Note 3, V <sub>DD</sub> = 2.0 V	Square wave input		0.10	0.52				
				Resonator connection		0.15	0.57				
		Subsystem clock operation	f <sub>SUB</sub> = 32.768 kHz Note 5 TA = -40°C	Square wave input		0.32	0.75	μA			
				Resonator connection		0.51	0.83				
			f <sub>SUB</sub> = 32.768 kHz Note 5 TA = +25°C	Square wave input		0.41	0.83				
				Resonator connection		0.62	1.00				
			f <sub>SUB</sub> = 32.768 kHz Note 5 TA = +50°C	Square wave input		0.52	1.17				
Resonator connection				0.75	1.36						
f <sub>SUB</sub> = 32.768 kHz Note 5 TA = +70°C	Square wave input			0.82	1.97						
	Resonator connection			1.08	2.16						
f <sub>SUB</sub> = 32.768 kHz Note 5 TA = +85°C	Square wave input			1.38	3.37						
	Resonator connection			1.62	3.56						
IDD3 Note 6	STOP mode Note 8	TA = -40°C			0.16	0.51	μA				
		TA = +25°C			0.22	0.51					
		TA = +50°C			0.27	1.10					
		TA = +70°C			0.37	1.90					
		TA = +85°C			0.6	3.30					

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



- Note 1.** Total current flowing into V<sub>DD</sub>, including the input leakage current flowing when the level of the input pin is fixed to V<sub>DD</sub> or V<sub>SS</sub>. 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 OPA(with analog MUX), General-purpose OPA, 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:  $2.7\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }24\text{ MHz}$   
 $2.4\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }16\text{ MHz}$   
 LS (low-speed main) mode:  $1.8\text{ V} \leq V_{DD} \leq 3.6\text{ V}@1\text{ MHz to }8\text{ MHz}$
- Note 8.** Regarding the value for current to operate the subsystem clock in STOP mode, refer to that in HALT mode.
- Remark 1.** f<sub>MX</sub>: High-speed system clock frequency (X1 clock oscillation frequency or external main system clock frequency)
- Remark 2.** f<sub>IH</sub>: Frequency when the high-speed on-chip oscillator (24 MHz max.)
- Remark 3.** f<sub>SUB</sub>: Subsystem clock frequency (XT1 clock oscillation frequency)
- Remark 4.** Except subsystem clock operation, temperature condition of the TYP. value is TA = 25°C

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Low-speed on-chip oscillator operating current	IFIL Note 1				0.20		μA
RTC2 operating current	IRTC Notes 1, 3	fSUB = 32.768 kHz			0.02		μA
12-bit interval timer operating current	ITMKA Notes 1, 2, 4	fSUB = 32.768 kHz			0.02		μA
8-bit interval timer operating current	ITMRT Notes 1, 20	fSUB = 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	IWDT Notes 1, 5	fIL = 15 kHz			0.22		μA
A/D converter operating current	IADC Notes 6, 7	AVDD = 3.0 V, when conversion at maximum speed			0.7	1.7	mA
A/D converter AVREF(+) current	IAVREF Note 8	AVDD = 3.0 V, HVSEL[1:0] = 00B Note 7			40	80	μA
		AVDD = 3.0 V, HVSEL[1:0] = 01B Note 10			40	80	μA
Internal reference voltage (1.45 V) current	IADREF Notes 1, 9				85		μA
Temperature sensor operating current	ITMPS Note 1				85		μA
D/A converter operating current	IDAC Notes 7, 11	Per D/A converter channel			0.4	0.8	mA
D/A converter AVREF(+) current	IDAREF Note 10	AVREFP = 3.0 V, REF[2:0] = 110B, Per channel			35	80	μA
Comparator operating current	ICMP Notes 1, 12	VDD = 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
		VDD = 3.6 V, Regulator output voltage = 1.8 V	Window mode		4.10		μA
			Comparator high-speed mode		1.5		μA
			Comparator low-speed mode		0.9		μA
General-purpose operational amplifier operating current (for 1 unit)	IAMP1 Notes 7, 19	AVDD = 3.0	Low-power consumption mode		2	4	μA
			High-speed mode		140	280	μA
Rail to rail operational amplifier operating current (for 1 unit)	IAMP2 Notes 7, 19	AVDD = 3.0	Low-power consumption mode		10	16	μA
			High-speed mode		210	350	μA
LVD operating current	ILVI Notes 1, 13				0.06		μA
Self-programming operating current	IFSP Notes 1, 14				2.0	12.2	mA
BGO operating current	IBGO Notes 1, 15				2.0	12.2	mA
SNOOZE operating current	ISNOZ Note 1	CSI/UART operation			0.70	0.84	mA
Voltage reference	IVREF	AVDD = VDD = 3.0 V				40	μA

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

Parameter	Symbol	Conditions				MIN.	TYP.	MAX.	Unit
LCD operating current	ILCD1 Notes 17, 18	External resistance division method	f <sub>LCD</sub> = f <sub>SUB</sub> LCD clock = 128 Hz	1/3 bias 4-time slice	V <sub>DD</sub> = 3.6 V, V <sub>L4</sub> = 3.6 V		0.14		μA
	ILCD2 Note 17	Internal voltage boosting method	f <sub>LCD</sub> = f <sub>SUB</sub> LCD clock = 128 Hz	1/3 bias 4-time slice	V <sub>DD</sub> = 3.0 V, V <sub>L4</sub> = 3.0 V (V <sub>LCD</sub> = 04H)		0.61		μA
	ILCD3 Note 17	Capacitor split method	f <sub>LCD</sub> = f <sub>SUB</sub> LCD clock = 128 Hz	1/3 bias 4-time slice	V <sub>DD</sub> = 3.0 V, V <sub>L4</sub> = 3.0 V		0.12		μA

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

- Note 1.** Current flowing to V<sub>DD</sub>.
- 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<sub>DD1</sub> or I<sub>DD2</sub>, and I<sub>RTC</sub>, when the real-time clock 2 operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I<sub>FIL</sub> should be added. I<sub>DD2</sub> 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<sub>DD1</sub> or I<sub>DD2</sub>, and I<sub>TMKA</sub>, when the 12-bit interval timer operates in operation mode or HALT mode. When the low-speed on-chip oscillator is selected, I<sub>FIL</sub> should be added. I<sub>DD2</sub> 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<sub>DD1</sub>, I<sub>DD2</sub> or I<sub>DD3</sub> and I<sub>WDT</sub> 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<sub>DD1</sub> or I<sub>DD2</sub> and I<sub>ADC</sub>, I<sub>AVREF</sub>, I<sub>ADREF</sub> when the A/D converter operates in an operation mode or the HALT mode.
- Note 7.** Current flowing to the AV<sub>DD</sub>.
- 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<sub>REFP</sub>.
- Note 11.** Current flowing only to the D/A converter. The current value of the RL78 microcontrollers is the sum of I<sub>DD1</sub> or I<sub>DD2</sub> and I<sub>DA</sub> 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<sub>DD1</sub>, I<sub>DD2</sub> or I<sub>DD3</sub> and I<sub>COMP</sub> 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<sub>DD1</sub>, I<sub>DD2</sub> or I<sub>DD3</sub> and I<sub>LVI</sub> when the LVD circuit operates in the Operating, HALT or STOP mode.
- Note 14.** Current flowing only during self-programming.
- Note 15.** Current flowing only during data flash rewrite.
- Note 16.** For shift time to the SNOOZE mode, see **24.3.3 SNOOZE mode** in the RL78/L1A User's Manual. RL78 microcontrollers
- Note 17.** Current flowing only to the LCD controller/driver (V<sub>DD</sub> pin). The current value of the RL78 microcontrollers is the sum of the LCD operating current (I<sub>LCD1</sub>, I<sub>LCD2</sub> or I<sub>LCD3</sub>) to the supply current (I<sub>DD1</sub>, or I<sub>DD2</sub>) when the LCD controller/driver operates in an operation mode or HALT mode. Not including the current that flows through the LCD panel.
- Note 18.** Not including the current that flows through the external divider resistor divider resistor.
- Note 19.** Current flowing only to the operational amplifier. The current value of the RL78 microcontrollers is the sum of I<sub>DD1</sub>, I<sub>DD2</sub> or I<sub>DD3</sub> and I<sub>AMP</sub> when the operational amplifier operates in the operating mode, HALT mode, or STOP mode.
- Note 20.** 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<sub>DD1</sub> or I<sub>DD2</sub>, and I<sub>IT</sub>, when the 8-bit interval timer operates in the operating mode or HALT mode. When the low-speed on-chip oscillator is selected, I<sub>FIL</sub> should be added.

**Remark 1.** f<sub>IL</sub>: Low-speed on-chip oscillator clock frequency

**Remark 2.** f<sub>SUB</sub>: Subsystem clock frequency (XT1 clock oscillation frequency)

**Remark 3.** f<sub>CLK</sub>: CPU/peripheral hardware clock frequency

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

## 2.4 AC Characteristics

### 2.4.1 Basic operation

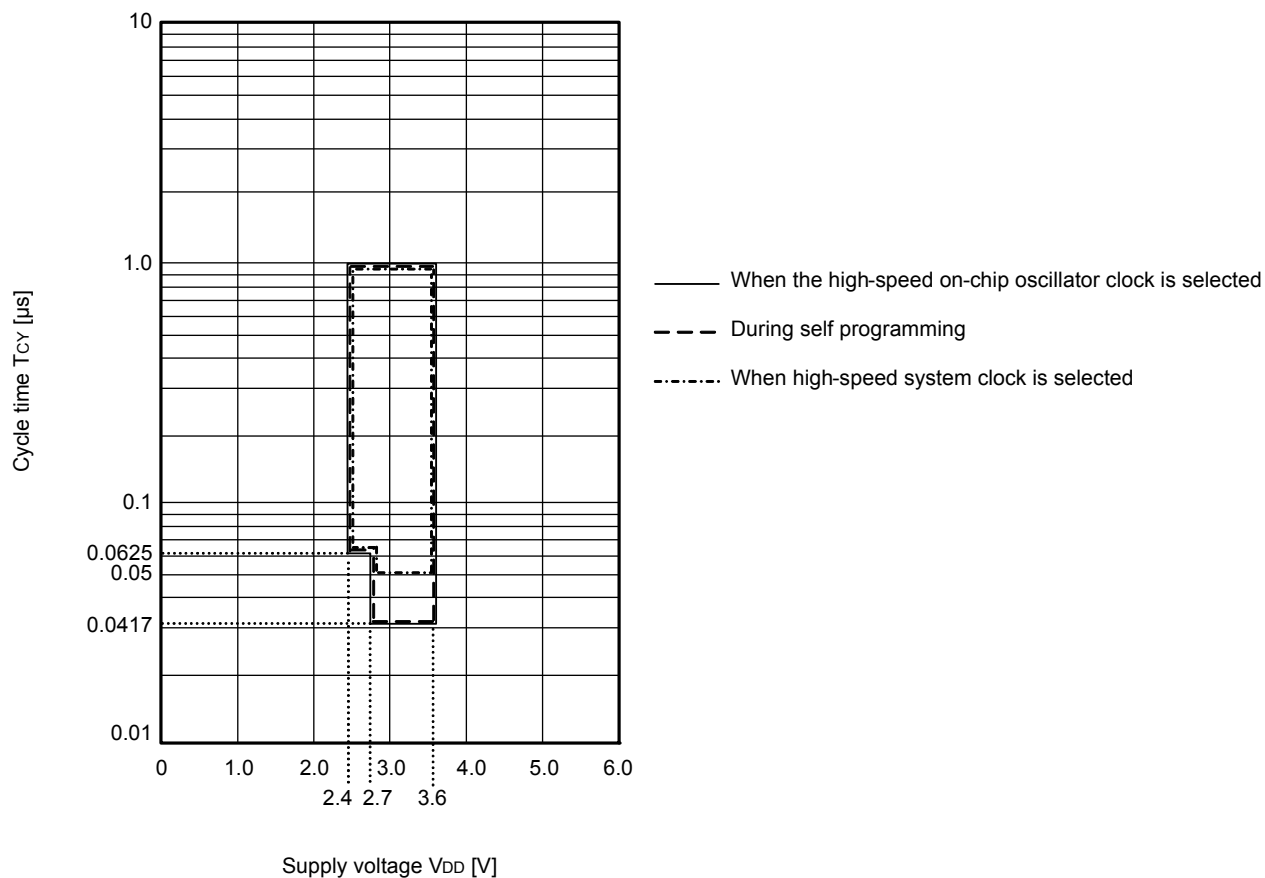
(TA = -40 to +85 °C, 1.8 V ≤ AVDD ≤ VDD ≤ 3.6 V, VSS = 0 V)

Items	Symbol	Conditions		MIN.	TYP.	MAX.	Unit	
Instruction cycle (minimum instruction execution time)	TCY	Main system clock (fMAIN) operation	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V	0.0417	1	μs	
				2.4 V ≤ VDD < 2.7 V	0.0625	1	μs	
			LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V	0.125	1	μs	
		Subsystem clock (fSUB) operation		1.8 V ≤ VDD ≤ 3.6 V	28.5	30.5	31.3	μs
		In the self-programming mode	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V	0.0417	1	μs	
				2.4 V ≤ VDD < 2.7 V	0.0625	1	μs	
	LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V	0.125	1	μs			
External main system clock frequency	fEX	EXCLK		2.7 V ≤ VDD ≤ 3.6 V	1.0	20.0	MHz	
				2.4 V ≤ VDD < 2.7 V	1.0	16.0	MHz	
				1.8 V ≤ VDD < 2.7 V	1.0	8.0	MHz	
	fEXT	EXCLKS			32	35	kHz	
External main system clock input high-level width, low-level width	tEXH, tEXL	EXCLK		2.7 V ≤ VDD ≤ 3.6 V	24		ns	
				2.4 V ≤ VDD < 2.7 V	30		ns	
				1.8 V ≤ VDD < 2.7 V	60		ns	
	tEXHS, tEXLS	EXCLKS			13.7		μs	
Timer input high-level width, low-level width	tTIH, tTIL	TI00 to TI07			1/fMCK + 10		ns	
Timer output frequency	fTO	TO00 to TO07	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V		8	MHz	
				2.4 V ≤ VDD < 2.7 V		8	MHz	
		LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V		4	MHz		
Buzzer output frequency	fPCL	PCLBUZ0, PCLBUZ1	HS (high-speed main) mode	2.7 V ≤ VDD ≤ 3.6 V		8	MHz	
				2.4 V ≤ VDD < 2.7 V		8	MHz	
		LS (low-speed main) mode	1.8 V ≤ VDD ≤ 3.6 V		4	MHz		
Interrupt input high-level width, low-level width	tINTH, tINTL	INTP0 to INTP7		1.8 V ≤ VDD ≤ 3.6 V	1		μs	
Key interrupt input low-level width	tKR	KR0 to KR7		1.8 V ≤ VDD ≤ 3.6 V	250		ns	
RESET low-level width	tRSL	RESET			10		μs	

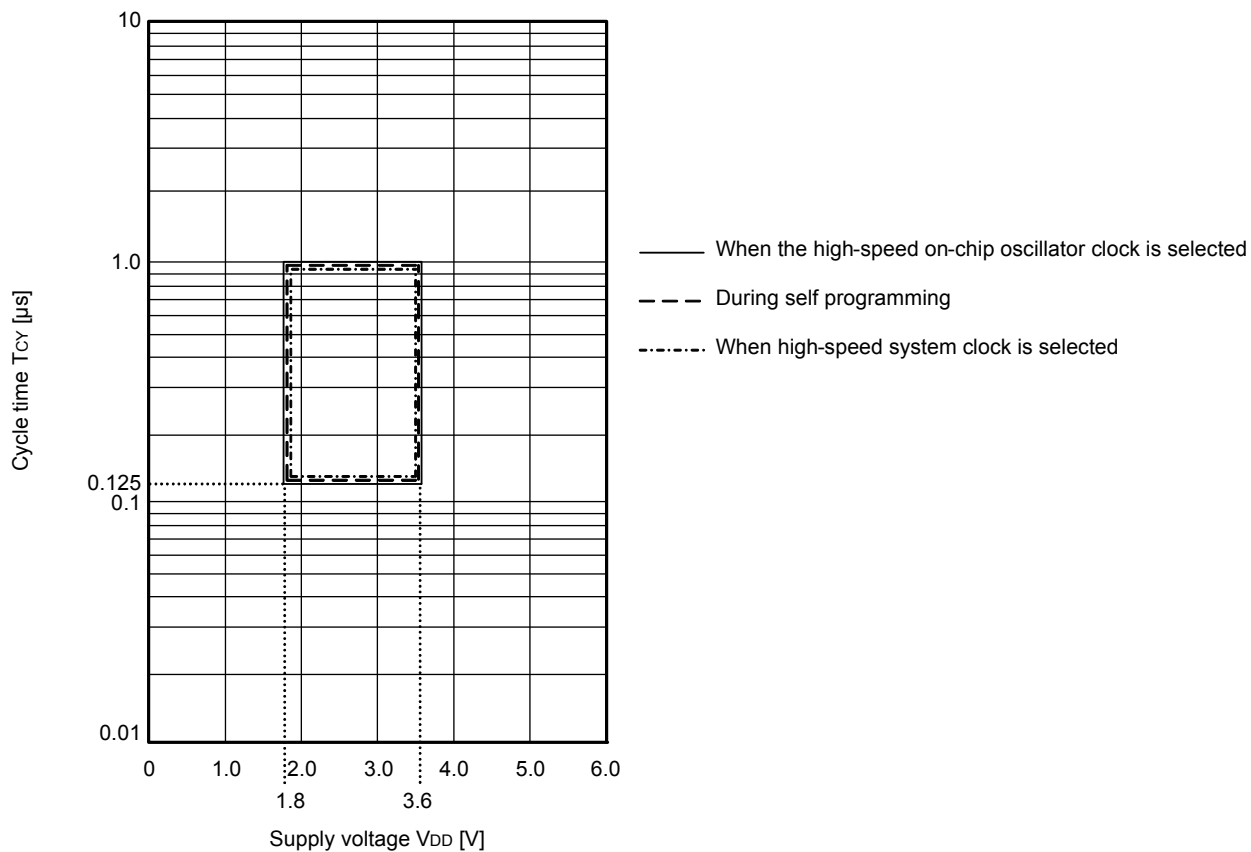
**Remark** fMCK: Timer array unit operation clock frequency  
 (Operation clock to be set by the CKSmn bit of timer mode register mn (TMRmn). m: Unit number (m = 0),  
 n: Channel number (n = 0 to 7))

Minimum Instruction Execution Time during Main System Clock Operation

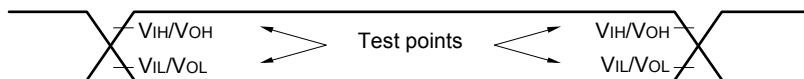
T<sub>cy</sub> vs V<sub>DD</sub> (HS (high-speed main) mode)



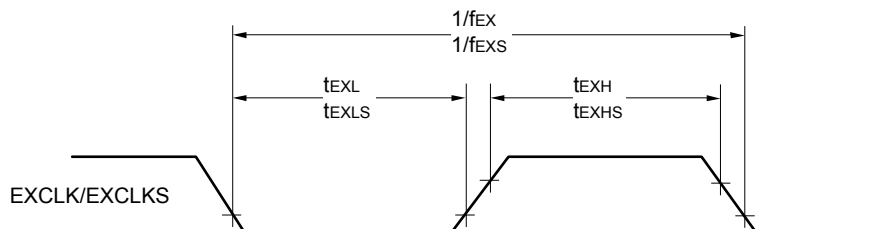
Tcy vs VDD (LS (low-speed main) mode)



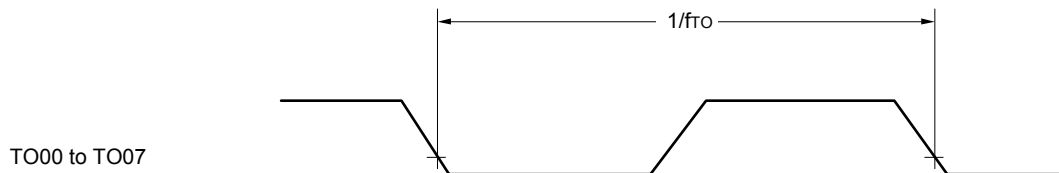
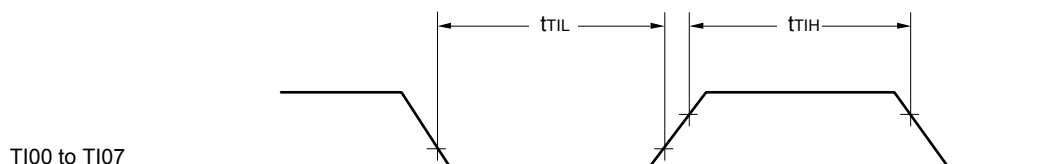
AC Timing Test Points



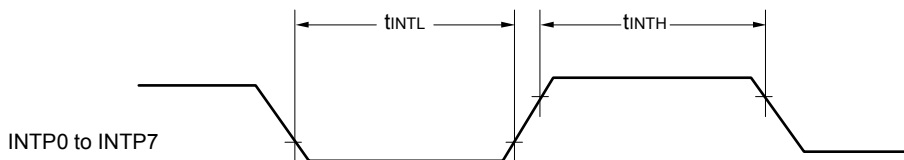
External System Clock Timing



TI/TO Timing

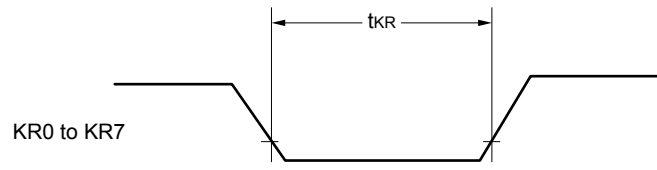


Interrupt Request Input Timing

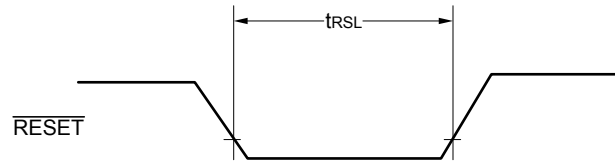




Key Interrupt Input Timing

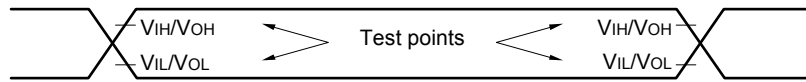


$\overline{\text{RESET}}$  Input Timing



## 2.5 Peripheral Functions Characteristics

### AC Timing Test Points



### 2.5.1 Serial array unit

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

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

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
Transfer rate Note 1		2.7 V ≤ VDD ≤ 3.6 V		fMCK/6 Note 2		fMCK/6	bps
		Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		4.0		1.3	Mbps
		2.4 V ≤ VDD ≤ 3.6 V		fMCK/6 Note 2		fMCK/6	bps
		Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		2.6		1.3	Mbps
		1.8 V ≤ VDD ≤ 3.6 V		—		fMCK/6 Note 2	bps
		Theoretical value of the maximum transfer rate fMCK = fCLK Note 3		—		1.3	Mbps

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

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

2.4 V ≤ VDD < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ VDD < 2.4 V: MAX. 1.3 Mbps

**Note 3.** The maximum operating frequencies of the CPU/peripheral hardware clock (fCLK) are:

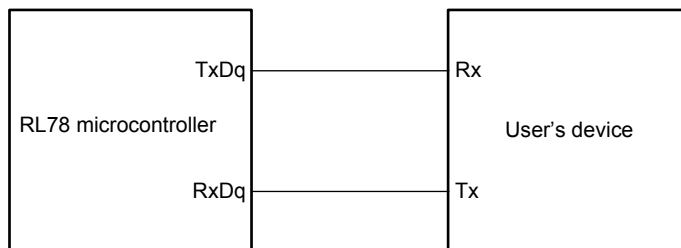
HS (high-speed main) mode: 24 MHz (2.7 V ≤ VDD ≤ 3.6 V)

16 MHz (2.4 V ≤ VDD ≤ 3.6 V)

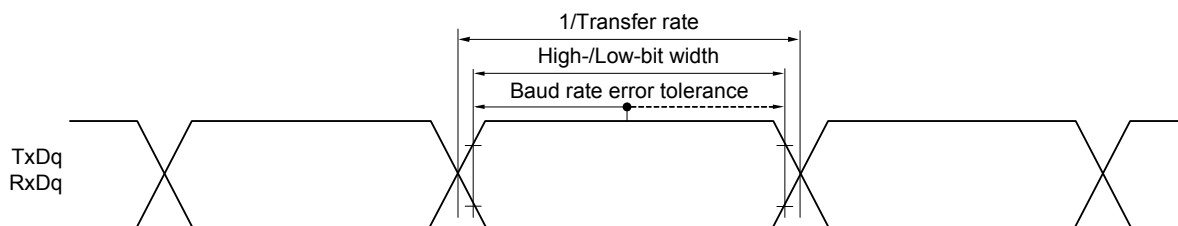
LS (low-speed main) mode: 8 MHz (1.8 V ≤ VDD ≤ 3.6 V)

**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.** f<sub>MCK</sub>: Serial array unit operation clock frequency  
 (Operation clock to be set by the CKSmn bit of serial mode register mn (SMRmn). m: Unit number, n: Channel number (mn = 00 to 03, 10 to 13))

**(2) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)****(TA = -40 to +85 °C, 2.7 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 0 V)**

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

**Note 1.** When DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 0, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 1. The Slp setup time becomes “to SCKp↓” when DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 1, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 0.

**Note 2.** When DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 0, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 1. The Slp hold time becomes “from SCKp↓” when DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 1, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 0.

**Note 3.** When DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 0, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 1. The delay time to SOp output becomes “from SCKp↑” when DAP<sub>mn</sub> = 0 and CKP<sub>mn</sub> = 1, or DAP<sub>mn</sub> = 1 and CKP<sub>mn</sub> = 0.

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

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

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

**Remark 2.** f<sub>MCK</sub>: Serial array unit operation clock frequency  
(Operation clock to be set by the CKS<sub>mn</sub> bit of serial mode register mn (SMR<sub>mn</sub>). m: Unit number, n: Channel number (mn = 00))

**(3) During communication at same potential (CSI mode) (master mode, SCKp... internal clock output)**  
**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	t <sub>KCY1</sub>	t <sub>KCY1</sub> ≥ f <sub>CLK</sub> /4	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	167		500	ns
			2.4 V ≤ V <sub>DD</sub> ≤ 3.6 V	250		500	ns
			1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		500	ns
SCKp high-/low-level width	t <sub>KH1</sub> , t <sub>KL1</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	t <sub>KCY1</sub> /2 - 18		t <sub>KCY1</sub> /2 - 50	ns	
		2.4 V ≤ V <sub>DD</sub> ≤ 3.6 V	t <sub>KCY1</sub> /2 - 38		t <sub>KCY1</sub> /2 - 50	ns	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		t <sub>KCY1</sub> /2 - 50	ns	
Slp setup time (to SCKp↑) Note 1	t <sub>SIK1</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	44		110	ns	
		2.4 V ≤ V <sub>DD</sub> ≤ 3.6 V	75		110	ns	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		110	ns	
Slp hold time (from SCKp↑) Note 2	t <sub>KSI1</sub>	2.4 V ≤ V <sub>DD</sub> ≤ 3.6 V	19		19	ns	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		19	ns	
Delay time from SCKp↓ to SOp output Note 3	t <sub>KSO1</sub>	C = 30 pF Note 4	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V		25	50	ns
			2.4 V ≤ V <sub>DD</sub> ≤ 3.6 V		25	50	ns
			1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	50	ns

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

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

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

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

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

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

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

**(4) During communication at same potential (CSI mode) (slave mode, SCKp... external clock input)**  
**(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 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	tkCY2	2.7 V ≤ VDD ≤ 3.6 V	fMCK > 16 MHz	8/fMCK		—	ns	
			fMCK ≤ 16 MHz	6/fMCK		6/fMCK	ns	
		2.4 V ≤ VDD ≤ 3.6 V		6/fMCK and 500		6/fMCK and 500	ns	
			1.8 V ≤ VDD ≤ 3.6 V	—		6/fMCK and 750	ns	
SCKp high-/low-level width	tkH2, tkL2	2.7 V ≤ VDD ≤ 3.6 V		tkCY2/2 - 8		tkCY2/2 - 8	ns	
		1.8 V ≤ VDD ≤ 3.6 V	—		tkCY2/2 - 18	ns		
Slp setup time (to SCKp↑) Note 1	tsIK2	2.7 V ≤ VDD ≤ 3.6 V		1/fMCK + 20		1/fMCK + 30	ns	
		2.4 V ≤ VDD ≤ 3.6 V		1/fMCK + 30		1/fMCK + 30	ns	
		1.8 V ≤ VDD ≤ 3.6 V	—		1/fMCK + 30	ns		
Slp hold time (from SCKp↑) Note 2	tkSI2	2.4 V ≤ VDD ≤ 3.6 V		1/fMCK + 31		1/fMCK + 31	ns	
		1.8 V ≤ VDD ≤ 3.6 V	—		1/fMCK + 31	ns		
Delay time from SCKp↓ to SOp output Note 3	tkSO2	C = 30 pF Note 4	2.7 V ≤ VDD ≤ 3.6 V		2/fMCK + 44		2/fMCK + 110	ns
			2.4 V ≤ VDD ≤ 3.6 V		2/fMCK + 75		2/fMCK + 110	ns
			1.8 V ≤ VDD ≤ 3.6 V	—			2/fMCK + 110	ns

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

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

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

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

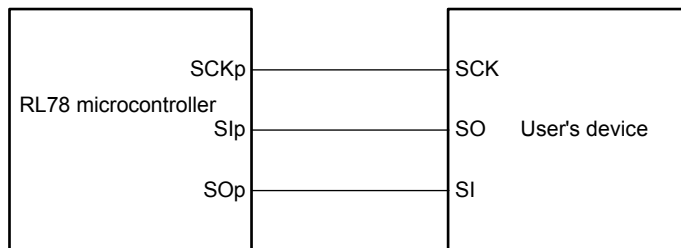
**Note 5.** The maximum transfer rate when using the SNOOZE mode is 1 Mbps.

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

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

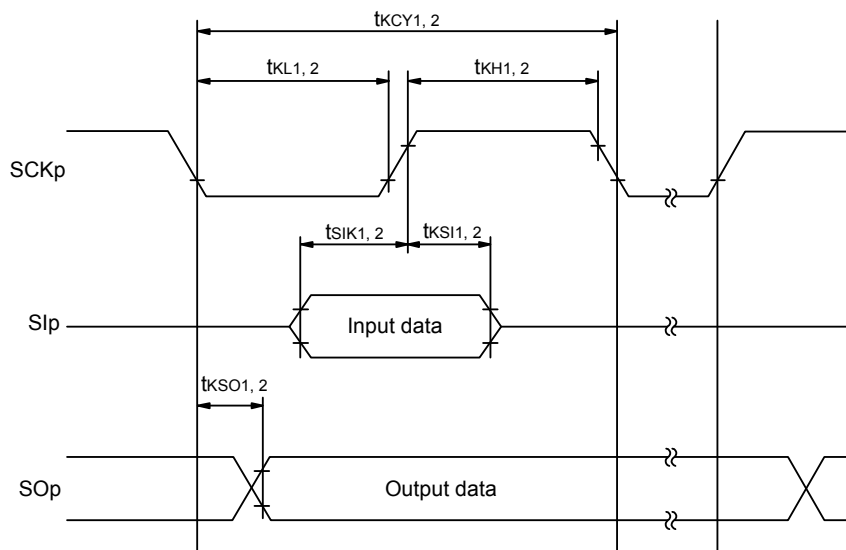
**CSI mode connection diagram (during communication at same potential)**



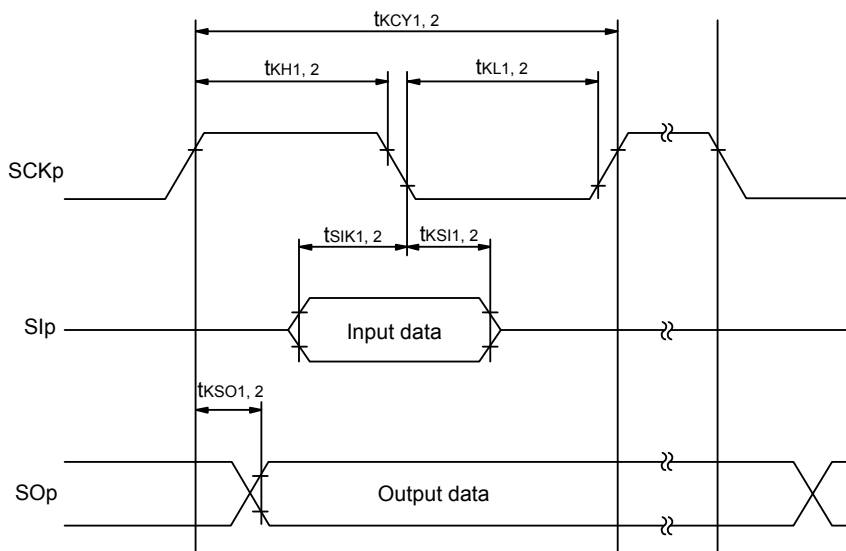
**Remark 1.** p: CSI number (p = 00, 10, 20, 30)

**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)

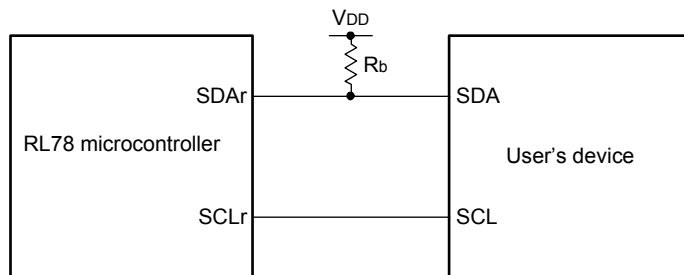


**(5) During communication at same potential (simplified I<sup>2</sup>C mode)****(TA = -40 to +85 °C, 1.8 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 0 V)**

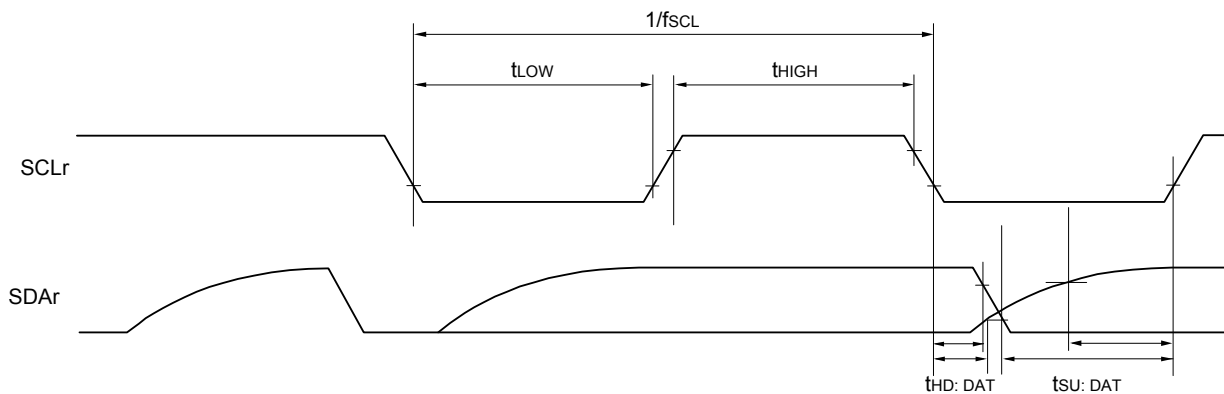
Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f <sub>SCL</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V, C <sub>b</sub> = 50 pF, R <sub>b</sub> = 2.7 kΩ		1000 Note 1		400 Note 1	kHz
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V, C <sub>b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

**Note 1.** The value must also be equal to or less than f<sub>MCK</sub>/4.**Note 2.** Set the f<sub>MCK</sub> 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<sub>DD</sub> 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 I<sup>2</sup>C mode connection diagram (during communication at same potential)**



**Simplified I<sup>2</sup>C mode serial transfer timing (during communication at same potential)**



- Remark 1.** R<sub>b</sub>[Ω]: Communication line (SDAr) pull-up resistance, C<sub>b</sub>[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),  
h: POM number (h = 0 to 3)
- Remark 3.** f<sub>mck</sub>: 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 to 03, 10 to 13)

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

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

**Note 1.** Transfer rate in the SNOOZE mode is 4,800 bps only.

**Note 2.** Use it with VDD ≥ Vb.

**Note 3.** The following conditions are required for low voltage interface.

2.4 V ≤ VDD < 2.7 V: MAX. 2.6 Mbps

1.8 V ≤ VDD < 2.4 V: MAX. 1.3 Mbps

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

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

16 MHz (2.4 V ≤ VDD ≤ 3.6 V)

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

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

**Remark 1.** Vb[V]: Communication line voltage

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

**(6) Communication at different potential (1.8 V, 2.5 V) (UART mode)****(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)(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 ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V		Note 1		Note 1	bps
					1.2 Note 2		1.2 Note 2	Mbps
			1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V		Notes 3, 4		Notes 3, 4	bps
					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  $2.7 V \leq V_{DD} \leq 3.6 V$  and  $2.3 V \leq V_b \leq 2.7 V$

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

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

\* 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  $1.8 V \leq V_{DD} < 3.3 V$  and  $1.6 V \leq V_b \leq 2.0 V$

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

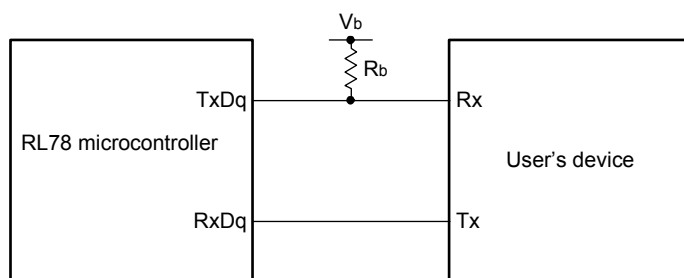
$$\text{Baud rate error (theoretical value)} = \frac{\frac{1}{\text{Transfer rate} \times 2} - \{-C_b \times R_b \times \ln(1 - \frac{1.5}{V_b})\}}{(\frac{1}{\text{Transfer rate}}) \times \text{Number of transferred bits}} \times 100 \text{ [%]}$$

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

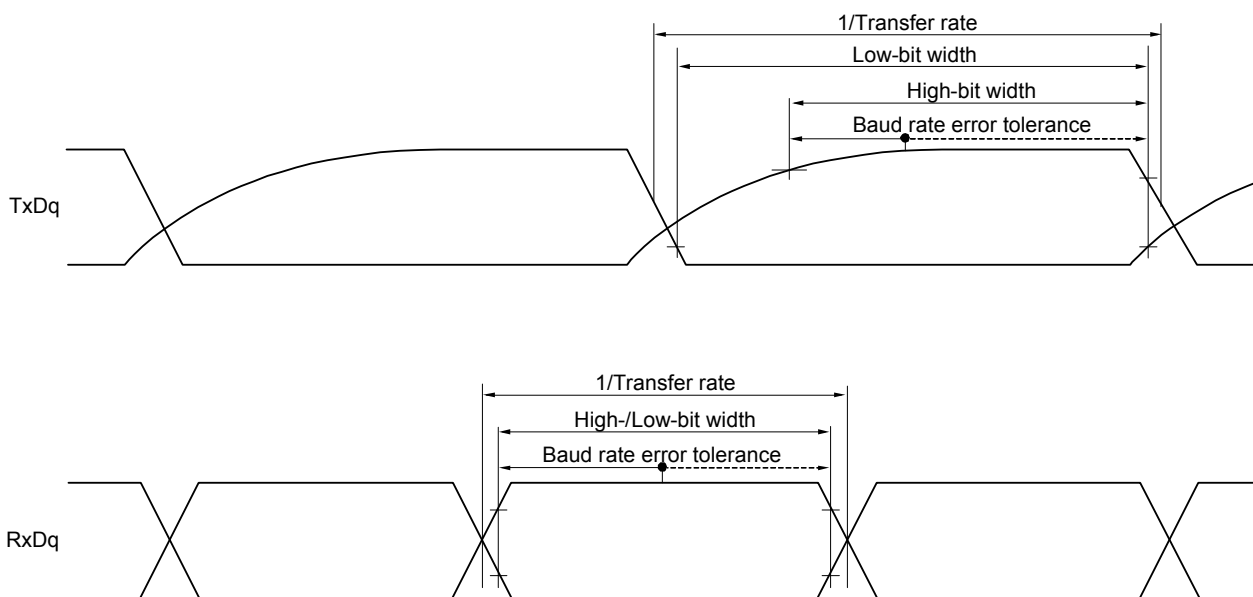
**Note 5.** This value as an example is calculated when the conditions described in the "Conditions" column are met. Refer to Note 4 above to calculate the maximum transfer rate under conditions of the customer.

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

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



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



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

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

**(7) Communication at different potential (2.5 V) (CSI mode) (master mode, SCKp... internal clock output, corresponding CSI00 only)****(TA = -40 to +85 °C, 2.7 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCKp cycle time	tkCY1	tkCY1 ≥ 2/fCLK 2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 1.4 kΩ	300		1150		ns
SCKp high-level width	tkH1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	tkCY1/2 - 120		tkCY1/2 - 120		ns
SCKp low-level width	tkL1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 1.4 kΩ	tkCY1/2 - 10		tkCY1/2 - 50		ns
Slp setup time (to SCKp↑) Note 1	tsIK1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	121		479		ns
Slp hold time (from SCKp↑) Note 1	tkSI1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 1.4 kΩ	10		10		ns
Delay time from SCKp↓ to SOp output Note 1	tkSO1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 1.4 kΩ		130		130	ns
Slp setup time (to SCKp↓) Note 2	tsIK1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	33		110		ns
Slp hold time (from SCKp↓) Note 2	tkSI1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 2.7 kΩ	10		10		ns
Delay time from SCKp↑ to SOp output Note 2	tkSO1	2.7 V ≤ VDD < 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V, Cb = 20 pF, Rb = 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 Slp pin and the N-ch open drain output (VDD tolerance) mode for the SOp pin and SCKp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

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

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

**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))

**(8) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (master mode, SCKp... internal clock output)****(TA = -40 to +85 °C, 1.8 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 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	tkCY1	tkCY1 ≥ 4/fCLK 2.7 V ≤ V <sub>DD</sub> < 3.6 V, 2.3 V ≤ V <sub>b</sub> ≤ 2.7 V, C <sub>b</sub> = 30 pF, R <sub>b</sub> = 2.7 kΩ	500 Note		1150		ns
			1150 Note		1150		ns
SCKp high-level width	tkH1	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V, 2.3 V ≤ V <sub>b</sub> ≤ 2.7 V, C <sub>b</sub> = 30 pF, R <sub>b</sub> = 2.7 kΩ	tkCY1/2 - 170		tkCY1/2 - 170		ns
		1.8 V ≤ V <sub>DD</sub> < 3.3 V, 1.6 V ≤ V <sub>b</sub> ≤ 2.0 V, C <sub>b</sub> = 30 pF, R <sub>b</sub> = 5.5 kΩ	tkCY1/2 - 458		tkCY1/2 - 458		ns
SCKp low-level width	tkL1	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V, 2.3 V ≤ V <sub>b</sub> ≤ 2.7 V, C <sub>b</sub> = 30 pF, R <sub>b</sub> = 2.7 kΩ	tkCY1/2 - 18		tkCY1/2 - 50		ns
		1.8 V ≤ V <sub>DD</sub> < 3.3 V, 1.6 V ≤ V <sub>b</sub> ≤ 2.0 V, C <sub>b</sub> = 30 pF, R <sub>b</sub> = 5.5 kΩ	tkCY1/2 - 50		tkCY1/2 - 50		ns

**Note** Use it with V<sub>DD</sub> ≥ V<sub>b</sub>.**Caution** Select the TTL input buffer for the SIp pin and the N-ch open drain output (V<sub>DD</sub> 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<sub>IH</sub> and V<sub>IL</sub>, see the DC characteristics with TTL input buffer selected.

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

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

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

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

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

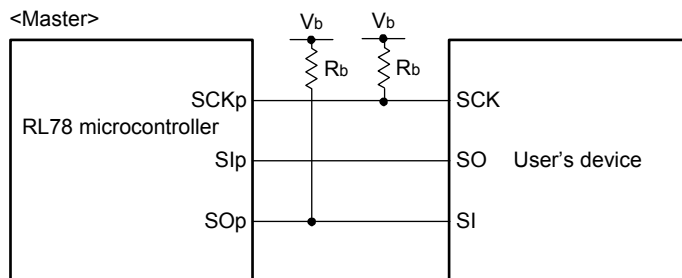
**Note 3.** Use it with VDD ≥ Vb.

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

(Remarks are listed on the next page.)



**CSI mode connection diagram (during communication at different potential)**

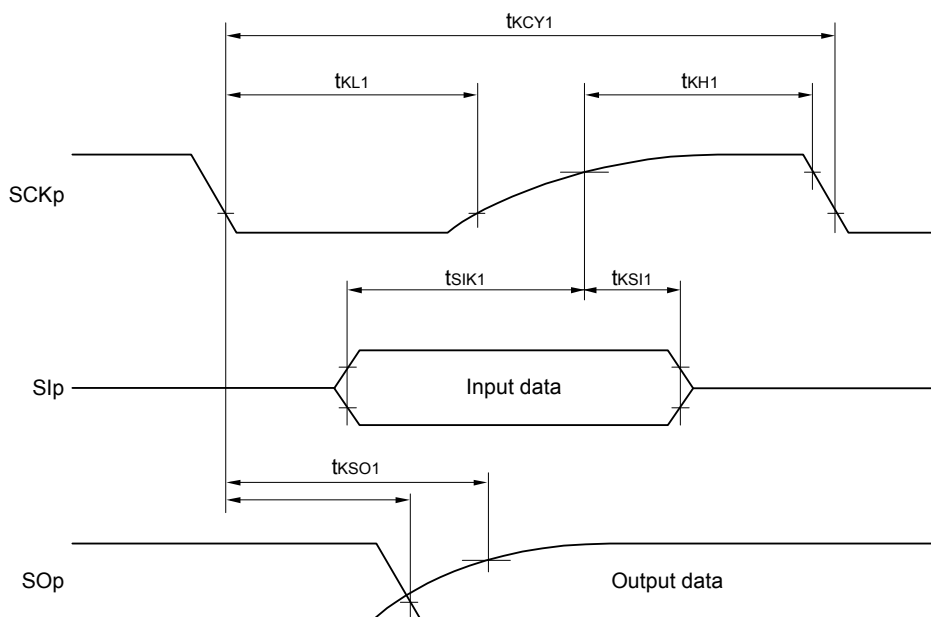


**Remark 1.**  $R_b[\Omega]$ : Communication line (SCKp, SOp) pull-up resistance,  $C_b[F]$ : Communication line (SCKp, SOp) load capacitance,  $V_b[V]$ : Communication line voltage

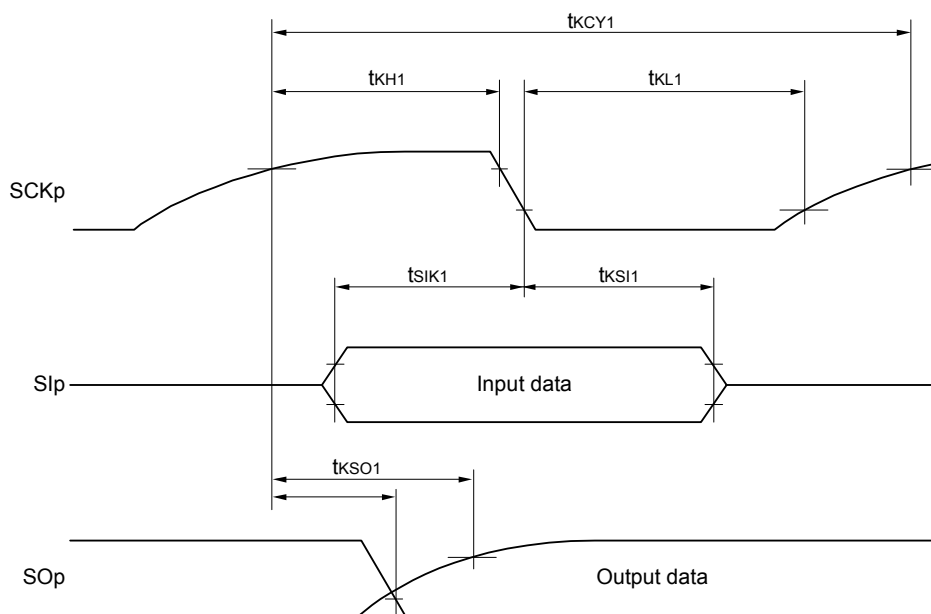
**Remark 2.** p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 4, 8)

**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 (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)

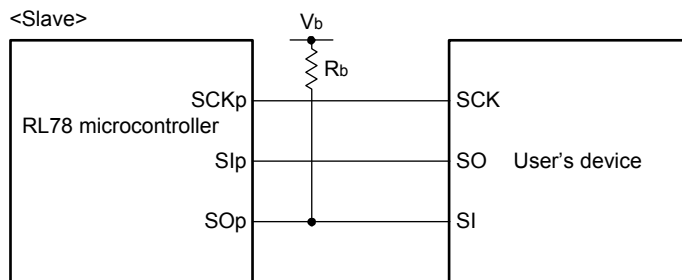
**(9) Communication at different potential (1.8 V, 2.5 V) (CSI mode) (slave mode, SCKp... external clock input)****(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, VSS = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCKp cycle time <sup>Note 1</sup>	tkCY2	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V	20 MHz < fMCK ≤ 24 MHz	16/fMCK		—	ns
			16 MHz < fMCK ≤ 20 MHz	14/fMCK		—	ns
			8 MHz < fMCK ≤ 16 MHz	12/fMCK		—	ns
			4 MHz < fMCK ≤ 8 MHz	8/fMCK		16/fMCK	ns
			fMCK ≤ 4 MHz	6/fMCK		10/fMCK	ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V <sup>Note 2</sup>	20 MHz < fMCK ≤ 24 MHz	36/fMCK		—	ns
			16 MHz < fMCK ≤ 20 MHz	32/fMCK		—	ns
			8 MHz < fMCK ≤ 16 MHz	26/fMCK		—	ns
			4 MHz < fMCK ≤ 8 MHz	16/fMCK		16/fMCK	ns
			fMCK ≤ 4 MHz	10/fMCK		10/fMCK	ns
SCKp high-/low-level width	tkH2, tkL2	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V	tkCY2/2 - 18		tkCY2/2 - 50	ns	
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V <sup>Note 2</sup>	tkCY2/2 - 50		tkCY2/2 - 50	ns	
Slp setup time (to SCKp↑) <sup>Note 3</sup>	tSIK2	2.7 V ≤ VDD ≤ 3.6 V	1/fMCK + 20		1/fMCK + 30	ns	
		1.8 V ≤ VDD < 3.3 V	1/fMCK + 30		1/fMCK + 30	ns	
Slp hold time (from SCKp↑) <sup>Note 4</sup>	tKSI2		1/fMCK + 31		1/fMCK + 31	ns	
Delay time from SCKp↓ to SOp output <sup>Note 5</sup>	tkSO2	2.7 V ≤ VDD ≤ 3.6 V, 2.3 V ≤ Vb ≤ 2.7 V Cb = 30 pF, Rb = 2.7 kΩ		2/fMCK + 214		2/fMCK + 573	ns
		1.8 V ≤ VDD < 3.3 V, 1.6 V ≤ Vb ≤ 2.0 V <sup>Note 2</sup> Cb = 30 pF, Rb = 5.5 kΩ		2/fMCK + 573		2/fMCK + 573	ns

**Note 1.** Transfer rate in the SNOOZE mode: MAX. 1 Mbps**Note 2.** Use it with VDD ≥ Vb.**Note 3.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp setup time becomes “to SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Note 4.** When DAPmn = 0 and CKPmn = 0, or DAPmn = 1 and CKPmn = 1. The Slp hold time becomes “from SCKp↓” when DAPmn = 0 and CKPmn = 1, or DAPmn = 1 and CKPmn = 0.**Note 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 Slp pin and SCKp pin and the N-ch open drain output (VDD tolerance) mode for the SOp pin by using port input mode register g (PIMg) and port output mode register g (POMg). For VIH and VIL, see the DC characteristics with TTL input buffer selected.

(Remarks are listed on the next page.)

**CSI mode connection diagram (during communication at different potential)**

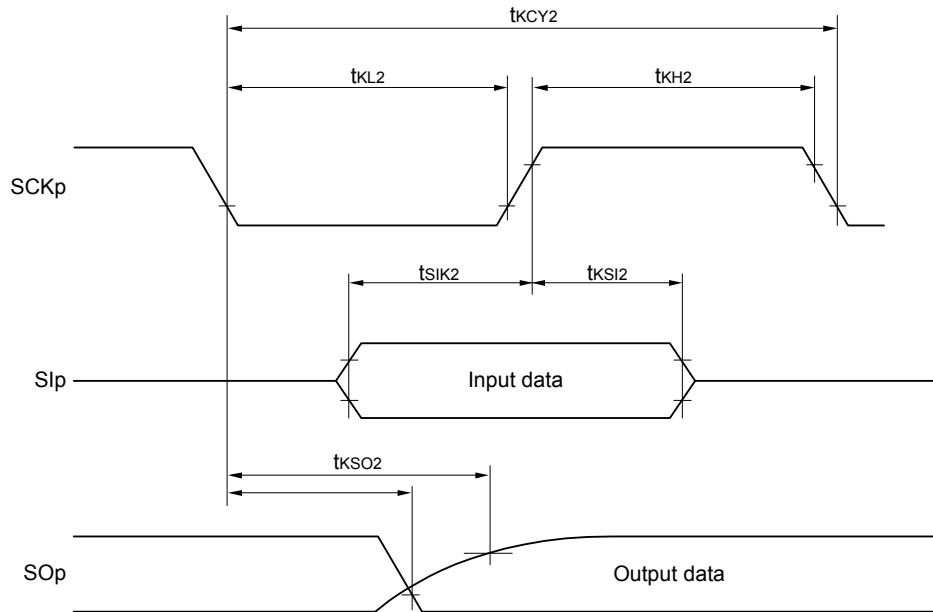


**Remark 1.** R<sub>b</sub>[Ω]: Communication line (SO<sub>p</sub>) pull-up resistance, C<sub>b</sub>[F]: Communication line (SO<sub>p</sub>) load capacitance, V<sub>b</sub>[V]: Communication line voltage

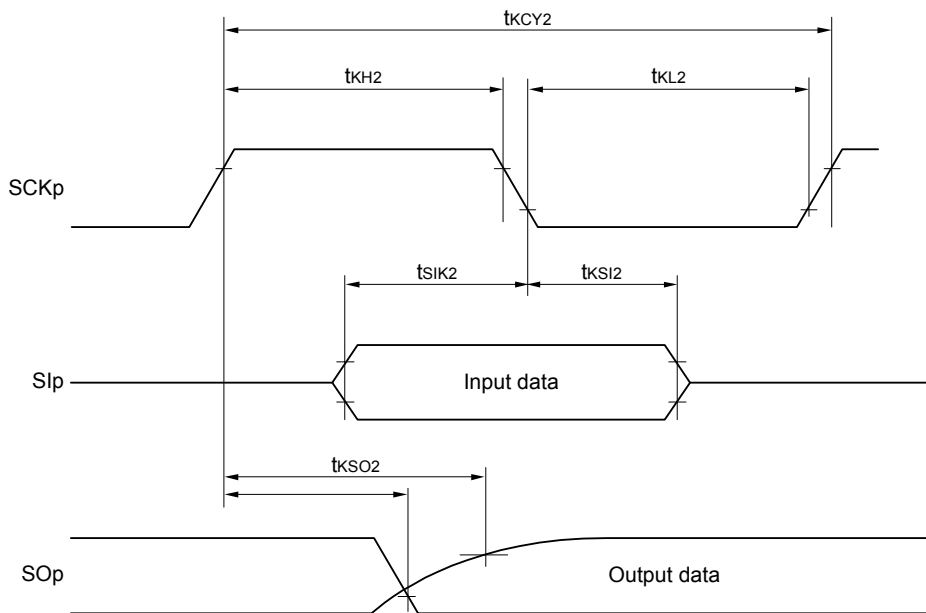
**Remark 2.** p: CSI number (p = 00, 10, 20, 30), m: Unit number (m = 0, 1), n: Channel number (n = 0 to 3), g: PIM and POM number (g = 0, 1, 3, 4, 8)

**Remark 3.** f<sub>MCK</sub>: 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<sup>2</sup>C mode)****(TA = -40 to +85 °C, 1.8 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 0 V)**

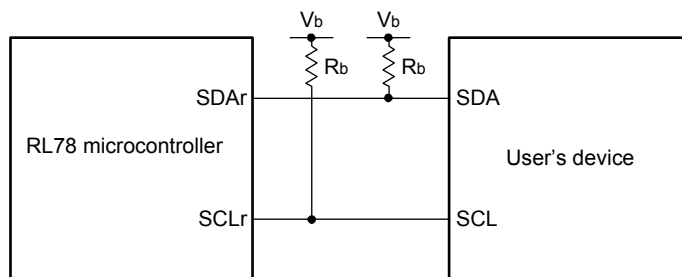
Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
			MIN.	MAX.	MIN.	MAX.	
SCLr clock frequency	f <sub>SCL</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V, 2.3 V ≤ V <sub>b</sub> < 2.7 V, C <sub>b</sub> = 50 pF, R <sub>b</sub> = 2.7 kΩ		1000 Note 1		300 Note 1	kHz
		2.7 V ≤ V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

**Note 1.** The value must also be equal to or less than f<sub>MCK</sub>/4.**Note 2.** Use it with V<sub>DD</sub> ≥ V<sub>b</sub>.**Note 3.** Set the f<sub>MCK</sub> value to keep the hold time of SCLr = "L" and SCLr = "H".

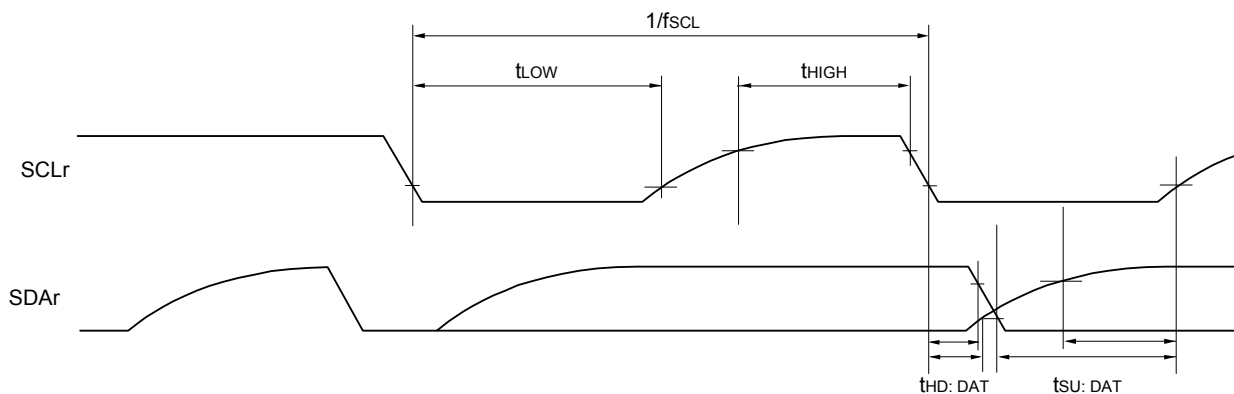
**Caution** Select the TTL input buffer and the N-ch open drain output (V<sub>DD</sub> tolerance) mode for the SDAr pin and the N-ch open drain output (V<sub>DD</sub> tolerance) mode for the SCLr pin by using port input mode register g (PIMg) and port output mode register g (POMg). For V<sub>IH</sub>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

(Remarks are listed on the next page.)

**Simplified I<sup>2</sup>C mode connection diagram (during communication at different potential)**



**Simplified I<sup>2</sup>C mode serial transfer timing (during communication at different potential)**



- Remark 1.** R<sub>b</sub>[Ω]: Communication line (SDAr, SCLr) pull-up resistance, C<sub>b</sub>[F]: Communication line (SDAr, SCLr) load capacitance, V<sub>b</sub>[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.** f<sub>MCK</sub>: 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) I<sup>2</sup>C standard mode

(TA = -40 to +85 °C, 1.8 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 0 V)

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit	
			MIN.	MAX.	MIN.	MAX.		
SCLA0 clock frequency	f <sub>SCL</sub>	Standard mode: f <sub>CLK</sub> ≥ 1 MHz	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0	100	0	100	kHz
			1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—	—	0	100	kHz
Setup time of restart condition	t <sub>SU: STA</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.7		4.7		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	4.7		μs	
Hold time <sup>Note 1</sup>	t <sub>HD: STA</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.0		4.0		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	4.0		μs	
Hold time when SCLA0 = "L"	t <sub>LOW</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.7		4.7		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	4.7		μs	
Hold time when SCLA0 = "H"	t <sub>HIGH</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.0		4.0		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	4.0		μs	
Data setup time (reception)	t <sub>SU: DAT</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	250		250		ns	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	250		ns	
Data hold time (transmission) <sup>Note 2</sup>	t <sub>HD: DAT</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0	3.45	0	3.45	μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	0	3.45	μs	
Setup time of stop condition	t <sub>SU: STO</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.0		4.0		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V		—	4.0		μs	
Bus-free time	t <sub>BUF</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	4.7		4.7		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 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<sub>HD:DAT</sub> is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**Remark** The maximum value of C<sub>b</sub> (communication line capacitance) and the value of R<sub>b</sub> (communication line pull-up resistor) at that time in each mode are as follows.

Standard mode: C<sub>b</sub> = 400 pF, R<sub>b</sub> = 2.7 kΩ



**(2) I<sup>2</sup>C fast mode****(TA = -40 to +85 °C, 1.8 V ≤ V<sub>DD</sub> ≤ 3.6 V, V<sub>SS</sub> = 0 V)**

Parameter	Symbol	Conditions	HS (high-speed main) Mode		LS (low-speed main) Mode		Unit	
			MIN.	MAX.	MIN.	MAX.		
SCLA0 clock frequency	f <sub>SCL</sub>	Fast mode: f <sub>CLK</sub> ≥ 3.5 MHz	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0	400	0	400	kHz
			1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	0	400	0	400	kHz
Setup time of restart condition	t <sub>SU: STA</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0.6		0.6		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		0.6		μs	
Hold time <sup>Note 1</sup>	t <sub>HD: STA</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0.6		0.6		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		0.6		μs	
Hold time when SCLA0 = "L"	t <sub>LOW</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	1.3		1.3		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		1.3		μs	
Hold time when SCLA0 = "H"	t <sub>HIGH</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0.6		0.6		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		0.6		μs	
Data setup time (reception)	t <sub>SU: DAT</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	100		100		ns	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		100		ns	
Data hold time (transmission) <sup>Note 2</sup>	t <sub>HD: DAT</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0	0.9	0	0.9	μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		0	0.9	μs	
Setup time of stop condition	t <sub>SU: STO</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	0.6		0.6		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 3.6 V	—		0.6		μs	
Bus-free time	t <sub>BUF</sub>	2.7 V ≤ V <sub>DD</sub> ≤ 3.6 V	1.3		1.3		μs	
		1.8 V ≤ V <sub>DD</sub> ≤ 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<sub>HD: DAT</sub> is during normal transfer and a wait state is inserted in the ACK (acknowledge) timing.

**Remark** The maximum value of C<sub>b</sub> (communication line capacitance) and the value of R<sub>b</sub> (communication line pull-up resistor) at that time in each mode are as follows.

Fast mode: C<sub>b</sub> = 320 pF, R<sub>b</sub> = 1.1 kΩ

**(3) I<sup>2</sup>C fast mode plus**

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

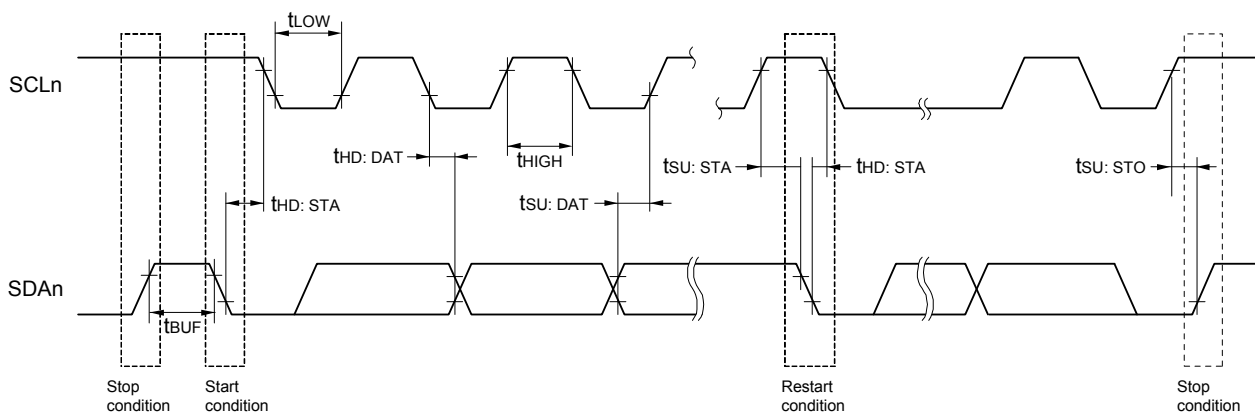
Parameter	Symbol	Conditions		HS (high-speed main) Mode		LS (low-speed main) Mode		Unit
				MIN.	MAX.	MIN.	MAX.	
SCLA0 clock frequency	fSCL	Fast mode plus: fCLK ≥ 10 MHz	2.7 V ≤ VDD ≤ 3.6 V	0	1000	—		kHz
Setup time of restart condition	tSU: STA	2.7 V ≤ VDD ≤ 3.6 V		0.26		—		μs
Hold time Note 1	tHD: STA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

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

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

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

**I<sup>2</sup>C serial transfer timing**



## 2.6 Analog Characteristics

### 2.6.1 A/D converter characteristics

TA = -40 to +85°C, 1.8 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V, VSS = AVSS = 0 V, reference voltage(+) = AVREFP, reference voltage(-) = AVREFM = 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	
Frequency	f <sub>CLK</sub>	High-speed mode	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	1	—	24	MHz
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	1	—	16	MHz
		Normal mode	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	1	—	24	MHz
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	1	—	16	MHz
			1.8 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	1	—	8	MHz
Conversion time	T <sub>conv</sub>	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V Permissible signal source impedance max = 0.3 kΩ ADCLK = 24 MHz	3	—	—	μs
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 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 ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V Permissible signal source impedance max = 1.1 kΩ ADCLK = 24 MHz	3.4	—	—	μs
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V Permissible signal source impedance max = 2.2 kΩ ADCLK = 16 MHz	5.1	—	—	μs
			1.8 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 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 ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±1.25	±5.0	LSB
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±1.25	±5.0	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±1.25	±5.0	LSB
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±1.25	±5.0	LSB
			1.8 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±3.0	±8.0	LSB
Zero-scale error	EZS	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±0.5	±4.5	LSB
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±0.5	±4.5	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±0.5	±4.5	LSB
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±0.5	±4.5	LSB
			1.8 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	±1	±7.5	LSB

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit	
Full-scale error	EFS	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±0.75	±4.5	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±0.75	±4.5	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±0.75	±4.5	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±0.75	±4.5	LSB
Differential linearity error	DLE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	—	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	—	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	—	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	—	LSB
Integral linearity error	ILE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	±3.0	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	±4.5	LSB
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	±3.0	LSB
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	±3.0	LSB
		$1.8\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—	±1.0	±3.0	LSB	

**Note** 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.

TA = 0 to +50°C,  $2.0\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$ ,  $V_{SS} = AV_{SS} = 0\text{ V}$ , reference voltage(+) =  $AV_{REFP}$ , reference voltage(-) =  $AV_{REFM} = 0\text{ V}$

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit	
Resolution	RES		—	—	—Note 3	bit	
Analog capacitance	Cs		—	—	—Note 3	pF	
Analog input resistance	Rs		—	—	—Note 3	kΩ	
Frequency	fCLK	High-speed mode	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—Note 3	—	—Note 3	MHz
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—Note 3	—	—Note 3	MHz
		Normal mode	$2.7\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—Note 3	—	—Note 3	MHz
			$2.4\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—Note 3	—	—Note 3	MHz
			$2.0\text{ V} \leq AV_{REFP} \leq AV_{DD} \leq V_{DD} \leq 3.6\text{ V}$	—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 ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—Note 3	—	—	μs	
			Permissible signal source impedance max = 0.3 kΩ ADCLK = 24 MHz					
				2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—Note 3	—	—	μs
				Permissible signal source impedance max = 1.3 kΩ ADCLK = 16 MHz				
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—Note 3	—	—	μs	
			Permissible signal source impedance max = 1.1 kΩ ADCLK = 24 MHz					
2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—Note 3		—	—	μs			
		2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—Note 3	—	—	μs		
		Permissible signal source impedance max = 5 kΩ ADCLK = 8 MHz						
Overall error	AINL	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
Zero-scale error Note 1, Note 2	Ezs	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	±4.5	LSB	
Full-scale error Note 1, Note 2	EFS	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	±4.5	LSB	
Differential linearity error	DLE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—	LSB	
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—	LSB	
			2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—	LSB	
Integral linearity error	ILE	High-speed mode ADCSR.ADHSC = 0 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
		Normal mode ADCSR.ADHSC = 1 ADSSTRn = 28H	2.7 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.4 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	
			2.0 V ≤ AVREFP ≤ AVDD ≤ VDD ≤ 3.6 V	—	—Note 3	—Note 3	LSB	

- Note** 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.
- Note 1.** MAX. value is the average value  $\pm 3\sigma$  at normalized distribution.
- Note 2.** These values are the results of characteristic evaluation.
- Note 3.** The reference value is not available.

## 2.6.2 Temperature sensor, internal reference voltage output characteristics

(TA = -40 to +85 °C, 2.4 V  $\leq$  VDD  $\leq$  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 $\leq$ VDD $\leq$ 3.6 V	5			$\mu$ s

### 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	RO		30			kΩ
Load capacitance	CO				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	RO		30			kΩ
Load capacitance	CO				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	High-speed comparator mode, standard mode			1.2	μs
			High-speed comparator mode, window mode			2.0	μs
			Low-speed comparator mode, standard mode		3	5.0	μs
High-electric-potential judgment voltage	VTW+	High-speed comparator mode, window mode		0.76 VDD		V	
Low-electric-potential judgment voltage	VTW-	High-speed comparator mode, window mode		0.24 VDD		V	
Operation stabilization wait time	tcMP		100			μs	
Internal reference voltage <small>Note</small>	VBGR		1.38	1.45	1.50	V	

**Note** Not usable in LS (low-speed main) mode, sub-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	CMPR			—	90	—	dB
Operation stabilization wait time	Tturn1	CL = 20 pF	Low-power consumption mode	—	110	300	μs
	Tturn2	CL = 20 pF	High-speed mode	—	5	14	μs
Settling time	Tset1	CL = 20 pF	Low-power consumption mode	—	100	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.

(TA = 0 to 50°C, 2.0 V ≤ AVDD ≤ VDD ≤ 3.6 V, AVSS = VSS = 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	CMPR			—	—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

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

Parameter	Symbol	Conditions		MIN.	TYP.	MAX.	Unit
Circuit current	Icc1	Low-power consumption mode			2	4	μA
	Icc2	High-speed mode			140	280	μA
Common mode input range	Vicm1	Low-power consumption mode		0.2		AVDD-0.5	V
	Vicm2	High-speed mode		0.3		AVDD-0.6	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	3σ		-10		+10	mV
Open gain	Av			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	PSRP				90		dB
Common mode signal reduction ratio	CMPR				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

## 2.6.7 Voltage reference

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Reference voltage output	VREF1	VSEL = 00, 2.65 V ≤ AVDD ≤ 3.6V	2.425	2.5	2.575	V
	VREF2	VSEL = 01, 2.2 V ≤ AVDD ≤ 3.6V	1.987	2.048	2.109	V
	VREF3	VSEL = 10, 2.0 V ≤ AVDD ≤ 3.6V	1.746	1.8	1.854	V
	VREF4	VSEL = 11, 1.8 V ≤ AVDD ≤ 3.6V	1.455	1.5	1.545	V
Settling time		From power-on to AVDD set			50	ms
Load current of the VREFOUT pin	I <sub>Load</sub>				200	μA

**Note 1.** Connect AVREFP/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 VREFOUT is in use for the on-chip A/D converter and D/A converter reference potential.

When VREFOUT is in use for the on-chip A/D converter load reference, the maximum load current is 55 μA.

When VREFOUT is in use for the on-chip D/A converter (channel 1), the maximum load current is 55 μA.

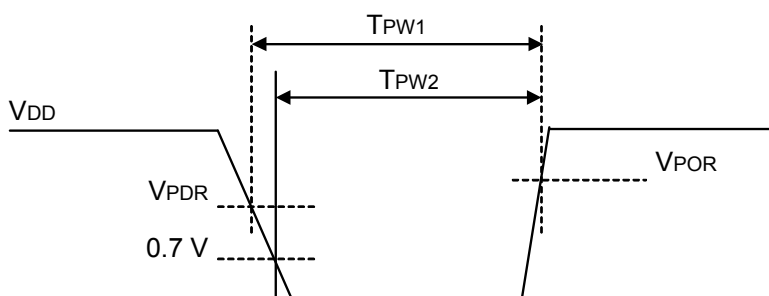
### 2.6.8 POR circuit characteristics

(TA = -40 to +85 °C, Vss = 0 V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Detection voltage	V <sub>POR</sub>	Power supply rise time	1.47	1.51	1.55	V
	V <sub>PDR</sub>	Power supply fall time <sup>Note 1</sup>	1.46	1.50	1.54	V
Minimum pulse width <sup>Note 2</sup>	T <sub>PW1</sub>	Other than STOP/SUB HALT/SUB RUN	300			μs
	T <sub>PW2</sub>	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 V<sub>DD</sub> exceeds below V<sub>PDR</sub>. This is also the minimum time required for a POR reset from when V<sub>DD</sub> exceeds below 0.7 V to when V<sub>DD</sub> exceeds V<sub>POR</sub> while STOP mode is entered or the main system clock is stopped through setting bit 0 (HIOSSTOP) and bit 7 (MSTOP) in the clock operation status control register (CSC).



### 2.6.9 1/2 AV<sub>DD</sub> voltage output

#### LVD Detection Voltage of Reset Mode and Interrupt Mode

(TA = -40 to +85 °C, 1.8 V ≤ AV<sub>DD</sub> ≤ V<sub>DD</sub> ≤ 3.6 V, AV<sub>SS</sub> = V<sub>SS</sub> = 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

## 2.6.10 LVD circuit characteristics

### LVD Detection Voltage of Reset Mode and Interrupt Mode (TA = -40 to +85 °C, VPDR ≤ VDD ≤ 3.6 V, VSS = 0 V)

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

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

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

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

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

**LVD Detection Voltage of Interrupt & Reset Mode**

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
Interrupt and reset mode	VLVDB0	VPOC0, VPOC1, VPOC2 = 0, 0, 1, falling reset voltage: 1.8 V	1.80	1.84	1.87	V	
	VLVDB1	LVIS0, LVIS1 = 1, 0	Rising release reset voltage	1.94	1.98	2.02	V
			Falling interrupt voltage	1.90	1.94	1.98	V
	VLVDB2	LVIS0, LVIS1 = 0, 1	Rising release reset voltage	2.05	2.09	2.13	V
			Falling interrupt voltage	2.00	2.04	2.08	V
	VLVDB3	LVIS0, LVIS1 = 0, 0	Rising release reset voltage	3.07	3.13	3.19	V
			Falling interrupt voltage	3.00	3.06	3.12	V
	VLVDC0	VPOC0, VPOC1, VPOC2 = 0, 1, 0, falling reset voltage: 2.4 V	2.40	2.45	2.50	V	
	VLVDC1	LVIS0, LVIS1 = 1, 0	Rising release reset voltage	2.56	2.61	2.66	V
			Falling interrupt voltage	2.50	2.55	2.60	V
	VLVDC2	LVIS0, LVIS1 = 0, 1	Rising release reset voltage	2.66	2.71	2.76	V
			Falling interrupt voltage	2.60	2.65	2.70	V
VLVDD0	VPOC0, VPOC1, VPOC2 = 0, 1, 1, falling reset voltage: 2.7 V	2.70	2.75	2.81	V		
VLVDD1	LVIS0, LVIS1 = 1, 0	Rising release reset voltage	2.86	2.92	2.97	V	
		Falling interrupt voltage	2.80	2.86	2.91	V	
VLVDD2	LVIS0, LVIS1 = 0, 1	Rising release reset voltage	2.96	3.02	3.08	V	
		Falling interrupt voltage	2.90	2.96	3.02	V	

**2.6.11 Low-resistance switch**

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

TA = 0 to +50 °C, 2.0 V ≤ AVDD ≤ VDD ≤ 3.6 V, AVSS = VSS = 0 V

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

(TA = -40 to +85 °C, Vss = 0 V)

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

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



## 2.8 LCD Characteristics

### 2.8.1 Resistance division method

#### (1) Static display mode

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

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

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

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

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

#### (3) 1/3 bias method

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

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

## 2.8.2 Internal voltage boosting method

### (1) 1/3 bias method

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
LCD output voltage variation range	VL1	C1 to C4 Note 1 = 0.47 μF Note 2	VLCD = 04H	0.90	1.00	1.08	V
			VLCD = 05H	0.95	1.05	1.13	V
			VLCD = 06H	1.00	1.10	1.18	V
			VLCD = 07H	1.05	1.15	1.23	V
			VLCD = 08H	1.10	1.20	1.28	V
			VLCD = 09H	1.15	1.25	1.33	V
			VLCD = 0AH	1.20	1.30	1.38	V
			VLCD = 0BH	1.25	1.35	1.43	V
			VLCD = 0CH	1.30	1.40	1.48	V
			VLCD = 0DH	1.35	1.45	1.53	V
			VLCD = 0EH	1.40	1.50	1.58	V
			VLCD = 0FH	1.45	1.55	1.63	V
			VLCD = 10H	1.50	1.60	1.68	V
			VLCD = 11H	1.55	1.65	1.73	V
VLCD = 12H	1.60	1.70	1.78	V			
VLCD = 13H	1.65	1.75	1.83	V			
Doubler output voltage	VL2	C1 to C4 Note 1 = 0.47 μF	2 VL1 - 0.1	2 VL1	2 VL1	V	
Tripler output voltage	VL4	C1 to C4 Note 1 = 0.47 μF	3 VL1 - 0.15	3 VL1	3 VL1	V	
Reference voltage setup time Note 2	tVWAIT1		5			ms	
Voltage boost wait time Note 3	tVWAIT2	C1 to C4 Note 1 = 0.47 μF	500			ms	

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

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between VL1 and GND

C3: A capacitor connected between VL2 and GND

C4: A capacitor connected between VL4 and GND

C1 = C2 = C3 = C4 = 0.47 μF±30%

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

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

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit	
LCD output voltage variation range	VL1	C1 to 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	VL2	C1 to C5 Note 1 = 0.47 μF	2 VL1 - 0.08	2 VL1	2 VL1	V	
Tripler output voltage	VL3	C1 to C5 Note 1 = 0.47 μF	3 VL1 - 0.12	3 VL1	3 VL1	V	
Quadruply output voltage	VL4	C1 to C5 Note 1 = 0.47 μF	4 VL1 - 0.16	4 VL1	4 VL1	V	
Reference voltage setup time Note 2	tVWAIT1		5			ms	
Voltage boost wait time Note 3	tVWAIT2	C1 to C5 Note 1 = 0.47 μF	500			ms	

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

C1: A capacitor connected between CAPH and CAPL

C2: A capacitor connected between VL1 and GND

C3: A capacitor connected between VL2 and GND

C4: A capacitor connected between VL3 and GND

C5: A capacitor connected between VL4 and GND

C1 = C2 = C3 = C4 = 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).

### 2.8.3 Capacitor split method

#### (1) 1/3 bias method

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

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
V <sub>L4</sub> voltage	V <sub>L4</sub>	C1 to C4 = 0.47 μF Note 2		V <sub>DD</sub>		V
V <sub>L2</sub> voltage	V <sub>L2</sub>	C1 to C4 = 0.47 μF Note 2	2/3 V <sub>L4</sub> - 0.1	2/3 V <sub>L4</sub>	2/3 V <sub>L4</sub> + 0.1	V
V <sub>L1</sub> voltage	V <sub>L1</sub>	C1 to C4 = 0.47 μF Note 2	1/3 V <sub>L4</sub> - 0.1	1/3 V <sub>L4</sub>	1/3 V <sub>L4</sub> + 0.1	V
Capacitor split wait time Note 1	t <sub>WAIT</sub>		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<sub>L1</sub> and GND

C3: A capacitor connected between V<sub>L2</sub> and GND

C4: A capacitor connected between V<sub>L4</sub> and GND

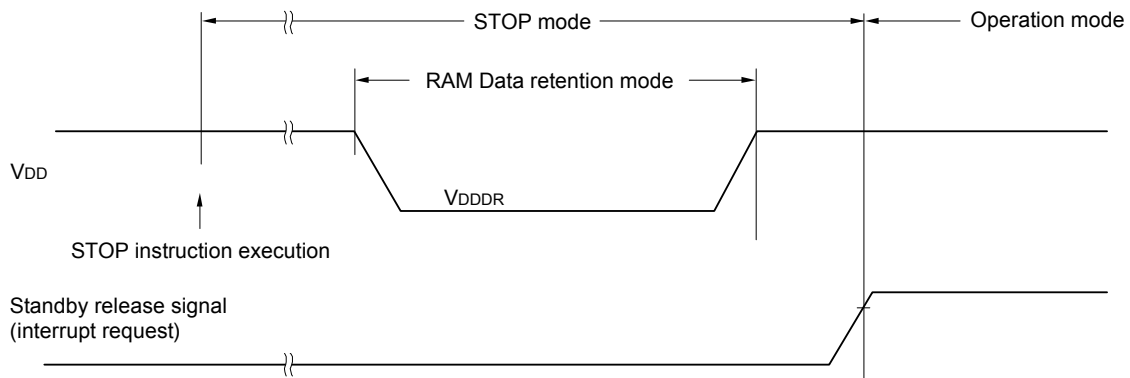
C1 = C2 = C3 = C4 = 0.47 μF±30%

### 2.9 RAM data retention characteristics

(TA = -40 to +85 °C, Vss = 0 V)

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

**Note** 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	C <sub>erwr</sub>	Retained for 20 years	TA = 85°C	1,000			Times
		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			
Number of data flash rewrites Notes 1, 2, 3							

- Note 1.** 1 erase + 1 write after the erase is regarded as 1 rewrite. The retaining years are until next rewrite after the rewrite.
- Note 2.** When using flash memory programmer and Renesas Electronics self programming library
- Note 3.** These are the characteristics of the flash memory and the results obtained from reliability testing by Renesas Electronics Corporation.

### 2.11 Dedicated Flash Memory Programmer Communication (UART)

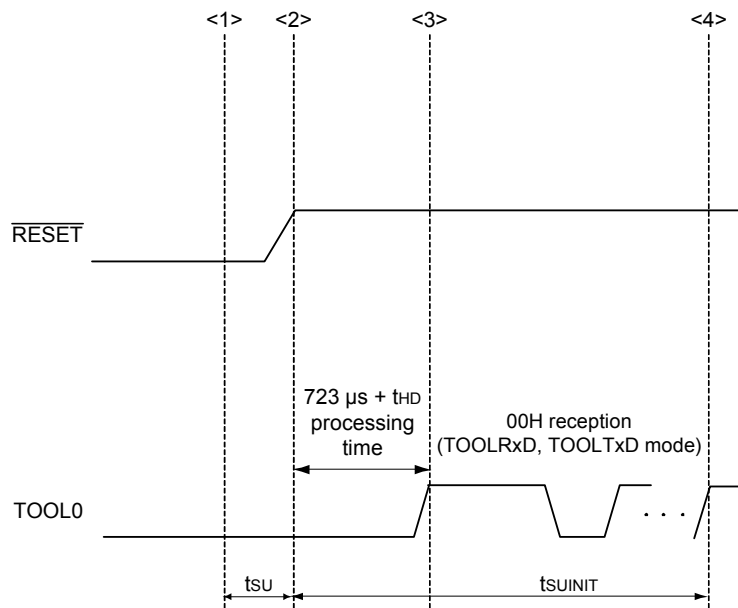
(TA = -40 to +85 °C, 1.8 V ≤ VDD ≤ 3.6 V, Vss = 0 V)

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

### 2.12 Timing Specs for Switching Modes

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

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



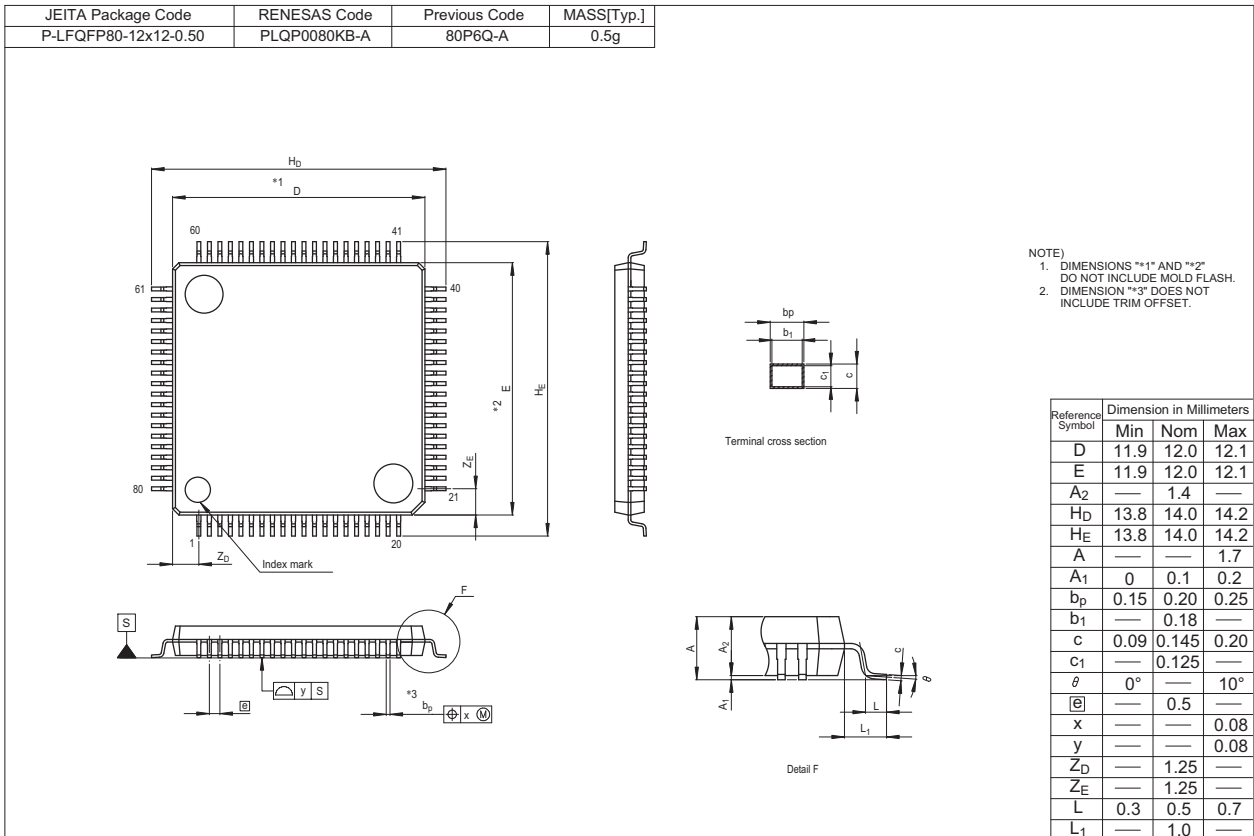
- <1> The low level is input to the TOOL0 pin.
- <2> The external reset ends (POR and LVD reset must end before the external reset ends.).
- <3> The TOOL0 pin is set to the high level.
- <4> Setting of the flash memory programming mode by UART reception and complete the baud rate setting.

**Remark** tsuINIT: The segment shows that it is necessary to finish specifying the initial communication settings within 100 ms from when the resets end.  
 tsu: How long from when the TOOL0 pin is placed at the low level until an external reset ends  
 tHD: 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

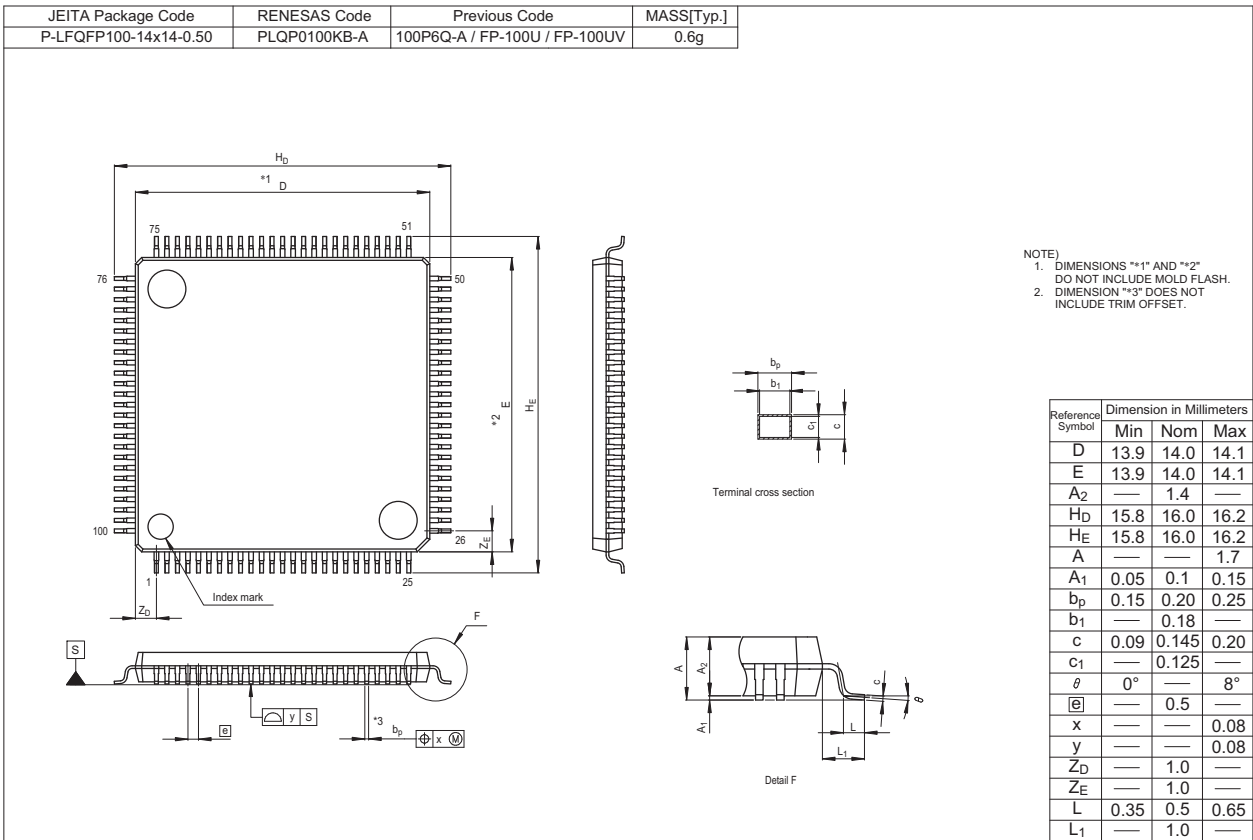
#### 3.1 80-pin products

R5F11MMDAFB, R5F11MMEAFB, R5F11MMFAFB



### 3.2 100-pin products

R5F11MPEAFB, R5F11MPFAFB, R5F11MPGAFB





REVISION HISTORY	RL78/L1A Datasheet
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Rev.	Date	Description	
		Page	Summary
1.00	Aug 12, 2016	—	First Edition issued

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## NOTES FOR CMOS DEVICES

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

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