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Hitachi 16-Bit Single-Chip Microcomputer

H8S/2128 Series, H8S/2124 Series

H8S/2128F-ZTAT™

Hardware Manual
— Supplement —



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Hitachi, Ltd.

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Announcement of Changes to Hardware Manual Contents

This is to announce that, with the addition of H8S/2128S and H8S/2127S products, a Supplement has been prepared for the following sections of the Hitachi single-chip microcomputer H8S/2128 Series and H8S/2124 Series Hardware Manual.

Applicable Manual:

H8S/2128 Series, H8S/2124 Series, H8S/2128F-ZTAT Hardware Manual, 2nd Edition
(ADE-602-114A), published September 1999

Applicable Sections:

Section 16, I²C Bus Interface → Replaced with “Supplement, Section 16”

Sections 22–23, Electrical Characteristics → Replaced with “Supplement, Section 22”

Appendix F, Product Code Lineup → Replaced with “Supplement, Appendix F”

Semiconductor & Integrated Circuits
Hitachi, Ltd.

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Section 16 I²C Bus Interface [Option]

A two-channel I²C bus interface is available as an option in the H8S/2128 Series. The I²C bus interface is not available for the H8S/2124 Series. Observe the following notes when using this option.

1. For mask-ROM versions, a W is added to the part number in products in which this optional function is used.

Examples: HD6432127SWFA

2. The product number is identical for F-ZTAT versions. However, be sure to inform your Hitachi sales representative if you will be using this option.

16.1 Overview

A two-channel I²C bus interface is available for the H8S/2128 Series as an option. The I²C bus interface conforms to and provides a subset of the Philips I²C bus (inter-IC bus) interface functions. The register configuration that controls the I²C bus differs partly from the Philips configuration, however.

Each I²C bus interface channel uses only one data line (SDA) and one clock line (SCL) to transfer data, saving board and connector space.

16.1.1 Features

- Selection of addressing format or non-addressing format
 - I²C bus format: addressing format with acknowledge bit, for master/slave operation
 - Serial format: non-addressing format without acknowledge bit, for master operation only
- Conforms to Philips I²C bus interface (I²C bus format)
- Two ways of setting slave address (I²C bus format)
- Start and stop conditions generated automatically in master mode (I²C bus format)
- Selection of acknowledge output levels when receiving (I²C bus format)
- Automatic loading of acknowledge bit when transmitting (I²C bus format)
- Wait function in master mode (I²C bus format)

A wait can be inserted by driving the SCL pin low after data transfer, excluding acknowledgement. The wait can be cleared by clearing the interrupt flag.

- Wait function in slave mode (I²C bus format)
A wait request can be generated by driving the SCL pin low after data transfer, excluding acknowledgement. The wait request is cleared when the next transfer becomes possible.
- Three interrupt sources
 - Data transfer end (including transmission mode transition with I²C bus format and address reception after loss of master arbitration)
 - Address match: when any slave address matches or the general call address is received in slave receive mode (I²C bus format)
 - Stop condition detection
- Selection of 16 internal clocks (in master mode)
- Direct bus drive (with SCL and SDA pins)
 - Two pins—P52/SCL0 and P47/SDA0—(normally NMOS push-pull outputs) function as NMOS open-drain outputs when the bus drive function is selected.
 - Two pins—P24/SCL1 and P23/SDA1—(normally CMOS pins) function as NMOS-only outputs when the bus drive function is selected.
- Automatic switching from formatless mode to I²C bus format (channel 0 only)
 - Slave mode addressless (no start condition/end condition, non-addressing) operation
 - Operation using common data pin (SDA) and independent clock pin (VSYNCI, SCL) pin configuration
 - Automatic switching from formatless mode to I²C bus format on fall of SCL

16.1.2 Block Diagram

Figure 16.1 shows a block diagram of the I²C bus interface.

Figure 16.2 shows an example of I/O pin connections to external circuits. Channel 0 I/O pins and channel 1 I/O pins differ in structure, and have different specifications for permissible applied voltages. For details, see section 22, Electrical Characteristics.

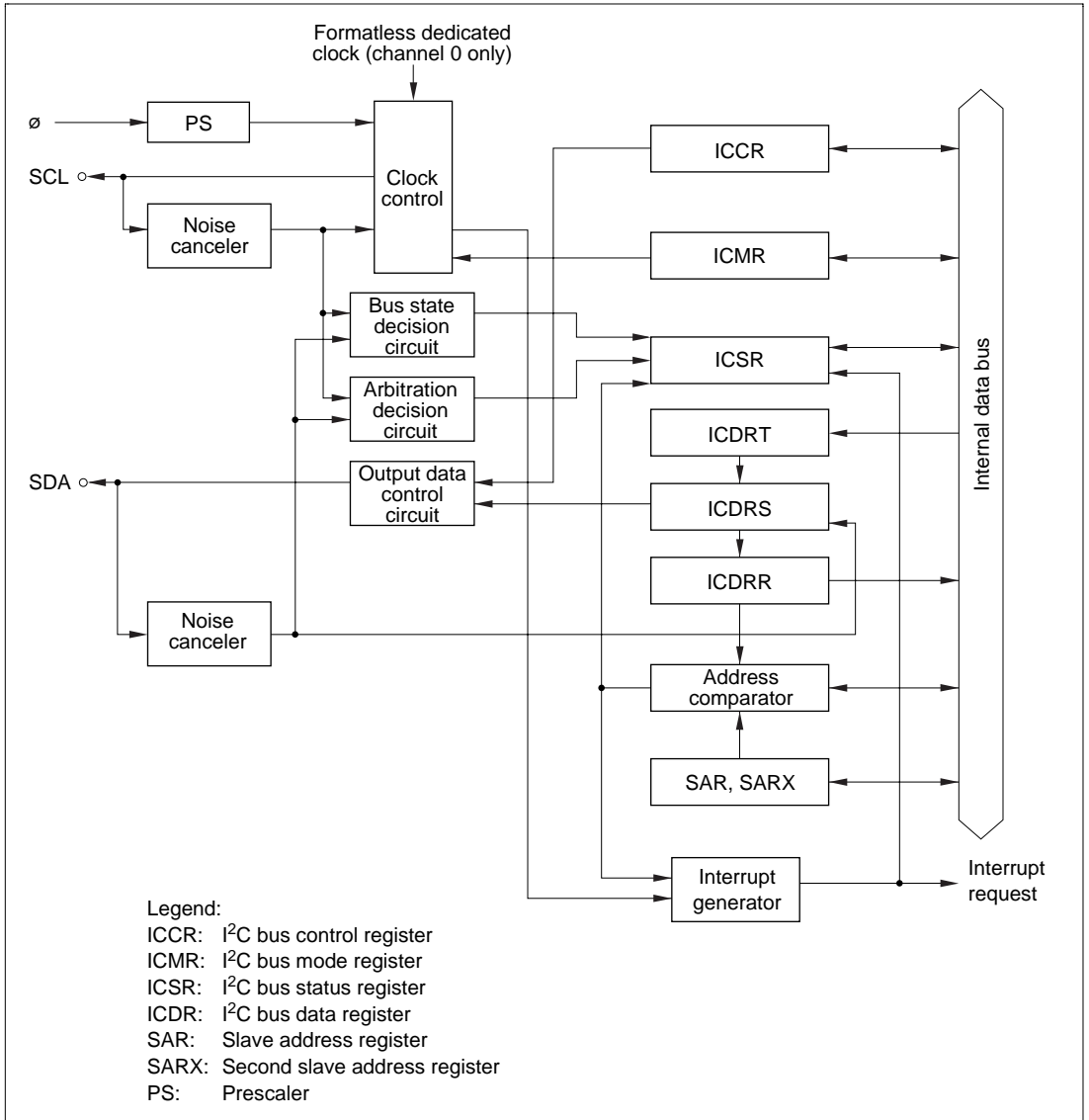
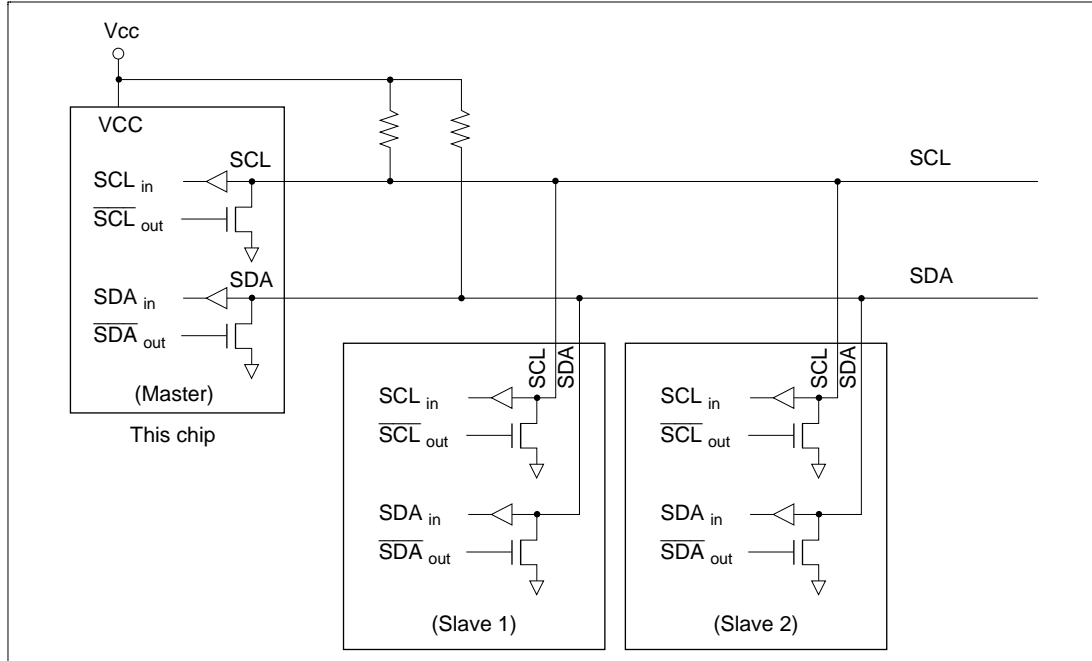


Figure 16.1 Block Diagram of I²C Bus Interface



**Figure 16.2 I²C Bus Interface Connections
(Example: This Chip as Master)**

16.1.3 Input/Output Pins

Table 16.1 summarizes the input/output pins used by the I²C bus interface.

Table 16.1 I²C Bus Interface Pins

Channel	Name	Abbreviation*	I/O	Function
0	Serial clock	SCL0	I/O	IIC0 serial clock input/output
	Serial data	SDA0	I/O	IIC0 serial data input/output
	Formatless serial clock	VSYNCl	Input	IIC0 formatless serial clock input
1	Serial clock	SCL1	I/O	IIC1 serial clock input/output
	Serial data	SDA1	I/O	IIC1 serial data input/output

Note: * In the text, the channel subscript is omitted, and only SCL and SDA are used.

16.1.4 Register Configuration

Table 16.2 summarizes the registers of the I²C bus interface.

Table 16.2 Register Configuration

Channel	Name	Abbreviation	R/W	Initial Value	Address ^{*1}
0	I ² C bus control register	ICCR0	R/W	H'01	H'FFD8
	I ² C bus status register	ICSR0	R/W	H'00	H'FFD9
	I ² C bus data register	ICDR0	R/W	—	H'FFDE ^{*2}
	I ² C bus mode register	ICMR0	R/W	H'00	H'FFDF ^{*2}
	Slave address register	SAR0	R/W	H'00	H'FFDF ^{*2}
	Second slave address register	SARX0	R/W	H'01	H'FFDE ^{*2}
1	I ² C bus control register	ICCR1	R/W	H'01	H'FF88
	I ² C bus status register	ICSR1	R/W	H'00	H'FF89
	I ² C bus data register	ICDR1	R/W	—	H'FF8E ^{*2}
	I ² C bus mode register	ICMR1	R/W	H'00	H'FF8F ^{*2}
	Slave address register	SAR1	R/W	H'00	H'FF8F ^{*2}
	Second slave address register	SARX1	R/W	H'01	H'FF8E ^{*2}
Common	Serial/timer control register	STCR	R/W	H'00	H'FFC3
	DDC switch register	DDCSWR	R/W	H'0F	H'FEE6
	Module stop control register	MSTPCRH	R/W	H'3F	H'FF86
		MSTPCRL	R/W	H'FF	H'FF87

Notes: ^{*1} Lower 16 bits of the address.

^{*2} The register that can be written or read depends on the ICE bit in the I²C bus control register. The slave address register can be accessed when ICE = 0, and the I²C bus mode register can be accessed when ICE = 1.

The I²C bus interface registers are assigned to the same addresses as other registers. Register selection is performed by means of the IICE bit in the serial/timer control register (STCR).

16.2 Register Descriptions

16.2.1 I²C Bus Data Register (ICDR)

Bit	7	6	5	4	3	2	1	0
	ICDR7	ICDR6	ICDR5	ICDR4	ICDR3	ICDR2	ICDR1	ICDR0
Initial value	—	—	—	—	—	—	—	—
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

- ICDRR

Bit	7	6	5	4	3	2	1	0
	ICDRR7	ICDRR6	ICDRR5	ICDRR4	ICDRR3	ICDRR2	ICDRR1	ICDRR0
Initial value	—	—	—	—	—	—	—	—
Read/Write	R	R	R	R	R	R	R	R

- ICDRS

Bit	7	6	5	4	3	2	1	0
	ICDRS7	ICDRS6	ICDRR5	ICDRS4	ICDRS3	ICDRS2	ICDRS1	ICDRS0
Initial value	—	—	—	—	—	—	—	—
Read/Write	—	—	—	—	—	—	—	—

- ICDRT

Bit	7	6	5	4	3	2	1	0
	ICDRT7	ICDRT6	ICDRT5	ICDRT4	ICDRT3	ICDRT2	ICDRT1	ICDRT0
Initial value	—	—	—	—	—	—	—	—
Read/Write	W	W	W	W	W	W	W	W

- TDRE, RDRF (internal flags)

Bit	—	—
	TDRE	RDRF
Initial value	0	0
Read/Write	—	—

ICDR is an 8-bit readable/writable register that is used as a transmit data register when transmitting and a receive data register when receiving. ICDR is divided internally into a shift register (ICDRS), receive buffer (ICDRR), and transmit buffer (ICDRT). ICDRS cannot be read or written by the CPU, ICDRR is read-only, and ICDRT is write-only. Data transfers among the three registers are performed automatically in coordination with changes in the bus state, and affect the status of internal flags such as TDRE and RDRF.

If IIC is in transmit mode and the next data is in ICDRT (the TDRE flag is 0) following transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRT to ICDRS. If IIC is in receive mode and no previous data remains in ICDRR (the RDRF flag is 0) following transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRS to ICDRR.

If the number of bits in a frame, excluding the acknowledge bit, is less than 8, transmit data and receive data are stored differently. Transmit data should be written justified toward the MSB side when $MLS = 0$, and toward the LSB side when $MLS = 1$. Receive data bits read from the LSB side should be treated as valid when $MLS = 0$, and bits read from the MSB side when $MLS = 1$.

ICDR is assigned to the same address as SARX, and can be written and read only when the ICE bit is set to 1 in ICCR.

The value of ICDR is undefined after a reset.

The TDRE and RDRF flags are set and cleared under the conditions shown below. Setting the TDRE and RDRF flags affects the status of the interrupt flags.

TDRE	Description
0	<p>The next transmit data is in ICDR (ICDRT), or transmission cannot be started (Initial value)</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> • When transmit data is written in ICDR (ICDRT) in transmit mode (TRS = 1) • When a stop condition is detected in the bus line state after a stop condition is issued with the I²C bus format or serial format selected • When a stop condition is detected with the I²C bus format selected • In receive mode (TRS = 0) (A 0 write to TRS during transfer is valid after reception of a frame containing an acknowledge bit)
1	<p>The next transmit data can be written in ICDR (ICDRT)</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> • In transmit mode (TRS = 1), when a start condition is detected in the bus line state after a start condition is issued in master mode with the I²C bus format or serial format selected • At the first transmit mode setting (TRS = 1) (first transmit mode setting only) after the mode is switched from I²C bus mode to formatless mode • When data is transferred from ICDRT to ICDRS (Data transfer from ICDRT to ICDRS when TRS = 1 and TDRE = 0, and ICDRS is empty) • When detecting a start condition and then switching from slave receive mode (TRS = 0) state to transmit mode (TRS = 1) (first transmit mode switching only).

RDRF	Description
0	<p>The data in ICDR (ICDRR) is invalid (Initial value)</p> <p>[Clearing condition]</p> <p>When ICDR (ICDRR) receive data is read in receive mode</p>
1	<p>The ICDR (ICDRR) receive data can be read</p> <p>[Setting condition]</p> <p>When data is transferred from ICDRS to ICDRR (Data transfer from ICDRS to ICDRR in case of normal termination with TRS = 0 and RDRF = 0)</p>

16.2.2 Slave Address Register (SAR)

Bit	7	6	5	4	3	2	1	0
	SVA6	SVA5	SVA4	SVA3	SVA2	SVA1	SVA0	FS
Initial value	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

SAR is an 8-bit readable/writable register that stores the slave address and selects the communication format. When the chip is in slave mode (and the addressing format is selected), if the upper 7 bits of SAR match the upper 7 bits of the first frame received after a start condition, the chip operates as the slave device specified by the master device. SAR is assigned to the same address as ICMR, and can be written and read only when the ICE bit is cleared to 0 in ICCR.

SAR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 1—Slave Address (SVA6 to SVA0): Set a unique address in bits SVA6 to SVA0, differing from the addresses of other slave devices connected to the I²C bus.

Bit 0—Format Select (FS): Used together with the FSX bit in SARX and the SW bit in DDCSWR to select the communication format.

- I²C bus format: addressing format with acknowledge bit
- Synchronous serial format: non-addressing format without acknowledge bit, for master mode only
- Formatless mode (channel 0 only): non-addressing format with or without acknowledge bit, slave mode only, start/stop conditions not detected

The FS bit also specifies whether or not SAR slave address recognition is performed in slave mode.

DDCSWR Bit 6	SAR Bit 0	SARX Bit 0	
SW	FS	FSX	Operating Mode
0	0	0	I ² C bus format <ul style="list-style-type: none"> SAR and SARX slave addresses recognized
		1	I ² C bus format (Initial value) <ul style="list-style-type: none"> SAR slave address recognized SARX slave address ignored
	1	0	I ² C bus format <ul style="list-style-type: none"> SAR slave address ignored SARX slave address recognized
		1	Synchronous serial format <ul style="list-style-type: none"> SAR and SARX slave addresses ignored
1	0	0	Formatless mode (start/stop conditions not detected)
	0	1	<ul style="list-style-type: none"> Acknowledge bit used
	1	0	
	1	1	Formatless mode* (start/stop conditions not detected) <ul style="list-style-type: none"> No acknowledge bit

Note: * Do not set this mode when automatic switching to the I²C bus format is performed by means of the DDCSWR setting.

16.2.3 Second Slave Address Register (SARX)

Bit	7	6	5	4	3	2	1	0
	SVAX6	SVAX5	SVAX4	SVAX3	SVAX2	SVAX1	SVAX0	FSX
Initial value	0	0	0	0	0	0	0	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

SARX is an 8-bit readable/writable register that stores the second slave address and selects the communication format. When the chip is in slave mode (and the addressing format is selected), if the upper 7 bits of SARX match the upper 7 bits of the first frame received after a start condition, the chip operates as the slave device specified by the master device. SARX is assigned to the same address as ICDR, and can be written and read only when the ICE bit is cleared to 0 in ICCR.

SARX is initialized to H'01 by a reset and in hardware standby mode.

Bits 7 to 1—Second Slave Address (SVAX6 to SVAX0): Set a unique address in bits SVAX6 to SVAX0, differing from the addresses of other slave devices connected to the I²C bus.

Bit 0—Format Select X (FSX): Used together with the FS bit in SAR and the SW bit in DDCCSWR to select the communication format.

- I²C bus format: addressing format with acknowledge bit
- Synchronous serial format: non-addressing format without acknowledge bit, for master mode only
- Formatless mode: non-addressing format with or without acknowledge bit, slave mode only, start/stop conditions not detected

The FSX bit also specifies whether or not SARX slave address recognition is performed in slave mode. For details, see the description of the FS bit in SAR.

16.2.4 I²C Bus Mode Register (ICMR)

Bit	7	6	5	4	3	2	1	0
	MLS	WAIT	CKS2	CKS1	CKS0	BC2	BC1	BC0
Initial value	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ICMR is an 8-bit readable/writable register that selects whether the MSB or LSB is transferred first, performs master mode wait control, and selects the master mode transfer clock frequency and the transfer bit count. ICMR is assigned to the same address as SAR. ICMR can be written and read only when the ICE bit is set to 1 in ICCR.

ICMR is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—MSB-First/LSB-First Select (MLS): Selects whether data is transferred MSB-first or LSB-first.

If the number of bits in a frame, excluding the acknowledge bit, is less than 8, transmit data and receive data are stored differently. Transmit data should be written justified toward the MSB side when MLS = 0, and toward the LSB side when MLS = 1. Receive data bits read from the LSB side should be treated as valid when MLS = 0, and bits read from the MSB side when MLS = 1.

Do not set this bit to 1 when the I²C bus format is used.

Bit 7

MLS	Description
0	MSB-first (Initial value)
1	LSB-first

Bit 6—Wait Insertion Bit (WAIT): Selects whether to insert a wait between the transfer of data and the acknowledge bit, in master mode with the I²C bus format. When WAIT is set to 1, after the fall of the clock for the final data bit, the IRIC flag is set to 1 in ICCR, and a wait state begins (with SCL at the low level). When the IRIC flag is cleared to 0 in ICCR, the wait ends and the acknowledge bit is transferred. If WAIT is cleared to 0, data and acknowledge bits are transferred consecutively with no wait inserted.

The IRIC flag in ICCR is set to 1 on completion of the acknowledge bit transfer, regardless of the WAIT setting.

The setting of this bit is invalid in slave mode.

Bit 6

WAIT	Description
0	Data and acknowledge bits transferred consecutively (Initial value)
1	Wait inserted between data and acknowledge bits

Bits 5 to 3—Serial Clock Select (CKS2 to CKS0): These bits, together with the IICX1 (channel 1) or IICX0 (channel 0) bit in the STCR register, select the serial clock frequency in master mode. They should be set according to the required transfer rate.

STCR

Bit 5 or 6 Bit 5 Bit 4 Bit 3					Transfer Rate				
IICX	CKS2	CKS1	CKS0	Clock	$\phi =$ 5 MHz	$\phi =$ 8 MHz	$\phi =$ 10 MHz	$\phi =$ 16 MHz	$\phi =$ 20 MHz
0	0	0	0	$\phi/28$	179 kHz	286 kHz	357 kHz	571 kHz*	714 kHz*
			1	$\phi/40$	125 kHz	200 kHz	250 kHz	400 kHz	500 kHz*
		1	0	$\phi/48$	104 kHz	167 kHz	208 kHz	333 kHz	417 kHz*
			1	$\phi/64$	78.1 kHz	125 kHz	156 kHz	250 kHz	313 kHz
	1	0	0	$\phi/80$	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
			1	$\phi/100$	50.0 kHz	80.0 kHz	100 kHz	160 kHz	200 kHz
		1	0	$\phi/112$	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz	179 kHz
			1	$\phi/128$	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
1	0	0	0	$\phi/56$	89.3 kHz	143 kHz	179 kHz	286 kHz	357 kHz
			1	$\phi/80$	62.5 kHz	100 kHz	125 kHz	200 kHz	250 kHz
		1	0	$\phi/96$	52.1 kHz	83.3 kHz	104 kHz	167 kHz	208 kHz
			1	$\phi/128$	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz	156 kHz
	1	0	0	$\phi/160$	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz	125 kHz
			1	$\phi/200$	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz	100 kHz
		1	0	$\phi/224$	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz	89.3 kHz
			1	$\phi/256$	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz	78.1 kHz

Note: * Outside the I²C bus interface specification range (normal mode: max. 100 kHz; high-speed mode: max. 400 kHz).

Bits 2 to 0—Bit Counter (BC2 to BC0): Bits BC2 to BC0 specify the number of bits to be transferred next. With the I²C bus format (when the FS bit in SAR or the FSX bit in SARX is 0), the data is transferred with one addition acknowledge bit. Bit BC2 to BC0 settings should be made during an interval between transfer frames. If bits BC2 to BC0 are set to a value other than 000, the setting should be made while the SCL line is low.

The bit counter is initialized to 000 by a reset and when a start condition is detected. The value returns to 000 at the end of a data transfer, including the acknowledge bit.

Bit 2	Bit 1	Bit 0	Bits/Frame	
BC2	BC1	BC0	Synchronous Serial Format	I ² C Bus Format
0	0	0	8	9 (Initial value)
		1	1	2
	1	0	2	3
		1	3	4
1	0	0	4	5
		1	5	6
	1	0	6	7
		1	7	8

16.2.5 I²C Bus Control Register (ICCR)

Bit	7	6	5	4	3	2	1	0
	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP
Initial value	0	0	0	0	0	0	0	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/(W)*	W

Note: * Only 0 can be written, to clear the flag.

ICCR is an 8-bit readable/writable register that enables or disables the I²C bus interface, enables or disables interrupts, selects master or slave mode and transmission or reception, enables or disables acknowledgement, confirms the I²C bus interface bus status, issues start/stop conditions, and performs interrupt flag confirmation.

ICCR is initialized to H'01 by a reset and in hardware standby mode.

Bit 7—I²C Bus Interface Enable (ICE): Selects whether or not the I²C bus interface is to be used. When ICE is set to 1, port pins function as SCL and SDA input/output pins and transfer operations are enabled. When ICE is cleared to 0, the I²C bus interface module is halted and its internal states are cleared.

The SAR and SARX registers can be accessed when ICE is 0. The ICMR and ICDR registers can be accessed when ICE is 1.

Bit 7

ICE	Description
0	I ² C bus interface module disabled, with SCL and SDA signal pins set to port function I ² C bus interface module internal states initialized SAR and SARX can be accessed
1	I ² C bus interface module enabled for transfer operations (pins SCL and SCA are driving the bus) ICMR and ICDR can be accessed

Bit 6—I²C Bus Interface Interrupt Enable (IEIC): Enables or disables interrupts from the I²C bus interface to the CPU.

Bit 6

IEIC	Description
0	Interrupts disabled (Initial value)
1	Interrupts enabled

Bit 5—Master/Slave Select (MST)

Bit 4—Transmit/Receive Select (TRS)

MST selects whether the I²C bus interface operates in master mode or slave mode.

TRS selects whether the I²C bus interface operates in transmit mode or receive mode.

In master mode with the I²C bus format, when arbitration is lost, MST and TRS are both reset by hardware, causing a transition to slave receive mode. In slave receive mode with the addressing format (FS = 0 or FSX = 0), hardware automatically selects transmit or receive mode according to the R/W bit in the first frame after a start condition.

Modification of the TRS bit during transfer is deferred until transfer of the frame containing the acknowledge bit is completed, and the changeover is made after completion of the transfer.

MST and TRS select the operating mode as follows.

Bit 5		Bit 4	
MST	TRs	Operating Mode	
0	0	Slave receive mode (Initial value)	
	1	Slave transmit mode	
1	0	Master receive mode	
	1	Master transmit mode	

Bit 5

MST	Description	
0	Slave mode (Initial value) [Clearing conditions] 1. When 0 is written by software 2. When bus arbitration is lost after transmission is started in I ² C bus format master mode	
1	Master mode [Setting conditions] 1. When 1 is written by software (in cases other than clearing condition 2) 2. When 1 is written in MST after reading MST = 0 (in case of clearing condition 2)	

Bit 4

TRs	Description	
0	Receive mode (Initial value) [Clearing conditions] 1. When 0 is written by software (in cases other than setting condition 3) 2. When 0 is written in TRs after reading TRs = 1 (in case of clearing condition 3) 3. When bus arbitration is lost after transmission is started in I ² C bus format master mode 4. When the SW bit in DDcSWR changes from 1 to 0	
1	Transmit mode [Setting conditions] 1. When 1 is written by software (in cases other than clearing conditions 3 and 4) 2. When 1 is written in TRs after reading TRs = 0 (in case of clearing conditions 3 and 4) 3. When a 1 is received as the R/W bit of the first frame in I ² C bus format slave mode	

Bit 3—Acknowledge Bit Judgement Selection (ACKE): Specifies whether the value of the acknowledge bit returned from the receiving device when using the I²C bus format is to be ignored and continuous transfer is performed, or transfer is to be aborted and error handling, etc., performed if the acknowledge bit is 1. When the ACKE bit is 0, the value of the received acknowledge bit is not indicated by the ACKB bit, which is always 0.

In the H8S/2128 Series, the DTC can be used to perform continuous transfer. The DTC is activated when the IRTR interrupt flag is set to 1 (IRTR is one of two interrupt flags, the other being IRIC). When the ACKE bit is 0, the TDRE, IRIC, and IRTR flags are set on completion of data transmission, regardless of the value of the acknowledge bit. When the ACKE bit is 1, the TDRE, IRIC, and IRTR flags are set on completion of data transmission when the acknowledge bit is 0, and the IRIC flag alone is set on completion of data transmission when the acknowledge bit is 1.

When the DTC is activated, the TDRE, IRIC, and IRTR flags are cleared to 0 after the specified number of data transfers have been executed. Consequently, interrupts are not generated during continuous data transfer, but if data transmission is completed with a 1 acknowledge bit when the ACKE bit is set to 1, the DTC is not activated and an interrupt is generated, if enabled.

Depending on the receiving device, the acknowledge bit may be significant, in indicating completion of processing of the received data, for instance, or may be fixed at 1 and have no significance.

Bit 3

ACKE	Description
0	The value of the acknowledge bit is ignored, and continuous transfer is performed (Initial value)
1	If the acknowledge bit is 1, continuous transfer is interrupted

Bit 2—Bus Busy (BBSY): The BBSY flag can be read to check whether the I²C bus (SCL, SDA) is busy or free. In master mode, this bit is also used to issue start and stop conditions.

A high-to-low transition of SDA while SCL is high is recognized as a start condition, setting BBSY to 1. A low-to-high transition of SDA while SCL is high is recognized as a stop condition, clearing BBSY to 0.

To issue a start condition, use a MOV instruction to write 1 in BBSY and 0 in SCP. A retransmit start condition is issued in the same way. To issue a stop condition, use a MOV instruction to write 0 in BBSY and 0 in SCP. It is not possible to write to BBSY in slave mode; the I²C bus interface must be set to master transmit mode before issuing a start condition. MST and TRS should both be set to 1 before writing 1 in BBSY and 0 in SCP.

Bit 2

BBSY	Description
0	Bus is free (Initial value) [Clearing condition] When a stop condition is detected
1	Bus is busy [Setting condition] When a start condition is detected

Bit 1—I²C Bus Interface Interrupt Request Flag (IRIC): Indicates that the I²C bus interface has issued an interrupt request to the CPU. IRIC is set to 1 at the end of a data transfer, when a slave address or general call address is detected in slave receive mode, when bus arbitration is lost in master transmit mode, and when a stop condition is detected. IRIC is set at different times depending on the FS bit in SAR and the WAIT bit in ICMR. See section 16.3.6, IRIC Setting Timing and SCL Control. The conditions under which IRIC is set also differ depending on the setting of the ACKEN bit in ICCR.

IRIC is cleared by reading IRIC after it has been set to 1, then writing 0 in IRIC.

When the DTC is used, IRIC is cleared automatically and transfer can be performed continuously without CPU intervention.

IRIC	Description
0	<p>Waiting for transfer, or transfer in progress (Initial value)</p> <p>[Clearing conditions]</p> <ol style="list-style-type: none"> When 0 is written in IRIC after reading IRIC = 1 When ICDR is written or read by the DTC (When the TDRE or RDRF flag is cleared to 0) (This is not always a clearing condition; see the description of DTC operation for details)
1	<p>Interrupt requested</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> I²C bus format master mode <ol style="list-style-type: none"> When a start condition is detected in the bus line state after a start condition is issued (when the TDRE flag is set to 1 because of first frame transmission) When a wait is inserted between the data and acknowledge bit when WAIT = 1 At the end of data transfer (at the rise of the 9th transmit/receive clock pulse when no wait is inserted, (WAIT=0) and, when a wait is inserted (WAIT=1), at the fall of the 8th transmit/receive clock pulse) When a slave address is received after bus arbitration is lost (when the AL flag is set to 1) When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1) I²C bus format slave mode <ol style="list-style-type: none"> When the slave address (SVA, SVAX) matches (when the AAS and AASX flags are set to 1) and at the end of data transfer up to the subsequent retransmission start condition or stop condition detection (when the TDRE or RDRF flag is set to 1) When the general call address is detected (when FS = 0 and the ADZ flag is set to 1) and at the end of data transfer up to the subsequent retransmission start condition or stop condition detection (when the TDRE or RDRF flag is set to 1) When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1) When a stop condition is detected (when the STOP or ESTP flag is set to 1) Synchronous serial format, and formatless mode <ol style="list-style-type: none"> At the end of data transfer (when the TDRE or RDRF flag is set to 1) When a start condition is detected with serial format selected When the SW bit is set to 1 in DDCSWR <p>Except the above, when the conditions to set the TDRE or RDRF internal flag to 1 is generated</p>

When, with the I²C bus format selected, IRIC is set to 1 and an interrupt is generated, other flags must be checked in order to identify the source that set IRIC to 1. Although each source has a corresponding flag, caution is needed at the end of a transfer.

When the TDRE or RDRF internal flag is set, the readable IRTR flag may or may not be set. The IRTR flag (the DTC start request flag) is not set at the end of a data transfer up to detection of a retransmission start condition or stop condition after a slave address (SVA) or general call address match in I²C bus format slave mode.

Even when the IRIC flag and IRTR flag are set, the TDRE or RDRF internal flag may not be set. The IRIC and IRTR flags are not cleared at the end of the specified number of transfers in continuous transfer using the DTC. The TDRE or RDRF flag is cleared, however, since the specified number of ICDR reads or writes have been completed.

Table 16.3 shows the relationship between the flags and the transfer states.

Table 16.3 Flags and Transfer States

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	State
1/0	1/0	0	0	0	0	0	0	0	0	0	Idle state (flag clearing required)
1	1	0	0	0	0	0	0	0	0	0	Start condition issuance
1	1	1	0	0	1	0	0	0	0	0	Start condition established
1	1/0	1	0	0	0	0	0	0	0	0/1	Master mode wait
1	1/0	1	0	0	1	0	0	0	0	0/1	Master mode transmit/receive end
0	0	1	0	0	0	1/0	1	1/0	1/0	0	Arbitration lost
0	0	1	0	0	0	0	0	1	0	0	SAR match by first frame in slave mode
0	0	1	0	0	0	0	0	1	1	0	General call address match
0	0	1	0	0	0	1	0	0	0	0	SARX match
0	1/0	1	0	0	0	0	0	0	0	0/1	Slave mode transmit/receive end (except after SARX match)
0	1/0	1	0	0	1	1	0	0	0	0	Slave mode transmit/receive end (after SARX match)
0	1	1	0	0	0	1	0	0	0	1	Slave mode transmit/receive end (after SARX match)
0	1/0	0	1/0	1/0	0	0	0	0	0	0/1	Stop condition detected

Bit 0—Start Condition/Stop Condition Prohibit (SCP): Controls the issuing of start and stop conditions in master mode. To issue a start condition, write 1 in BBSY and 0 in SCP. A retransmit start condition is issued in the same way. To issue a stop condition, write 0 in BBSY and 0 in SCP. This bit is always read as 1. If 1 is written, the data is not stored.

Bit 0

SCP	Description
0	Writing 0 issues a start or stop condition, in combination with the BBSY flag
1	Reading always returns a value of 1 (Initial value) Writing is ignored

16.2.6 I²C Bus Status Register (ICSR)

Bit	7	6	5	4	3	2	1	0
	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB
Initial value	0	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/W

Note: * Only 0 can be written, to clear the flags.

ICSR is an 8-bit readable/writable register that performs flag confirmation and acknowledge confirmation and control.

ICSR is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—Error Stop Condition Detection Flag (ESTP): Indicates that a stop condition has been detected during frame transfer in I²C bus format slave mode.

Bit 7

ESTP	Description
0	No error stop condition (Initial value) [Clearing conditions] 1. When 0 is written in ESTP after reading ESTP = 1 2. When the IRIC flag is cleared to 0
1	<ul style="list-style-type: none"> In I²C bus format slave mode Error stop condition detected [Setting condition] When a stop condition is detected during frame transfer In other modes No meaning

Bit 6—Normal Stop Condition Detection Flag (STOP): Indicates that a stop condition has been detected after completion of frame transfer in I²C bus format slave mode.

Bit 6

STOP	Description
0	No normal stop condition (Initial value) [Clearing conditions] 1. When 0 is written in STOP after reading STOP = 1 2. When the IRIC flag is cleared to 0
1	<ul style="list-style-type: none"> In I²C bus format slave mode Normal stop condition detected [Setting condition] When a stop condition is detected after completion of frame transfer In other modes No meaning

Bit 5—I²C Bus Interface Continuous Transmission/Reception Interrupt Request Flag

(IRTR): Indicates that the I²C bus interface has issued an interrupt request to the CPU, and the source is completion of reception/transmission of one frame in continuous transmission/reception for which DTC activation is possible. When the IRTR flag is set to 1, the IRIC flag is also set to 1 at the same time.

IRTR flag setting is performed when the TDRE or RDRF flag is set to 1. IRTR is cleared by reading IRTR after it has been set to 1, then writing 0 in IRTR. IRTR is also cleared automatically when the IRIC flag is cleared to 0.

Bit 5

IRTR	Description
0	Waiting for transfer, or transfer in progress (Initial value) [Clearing conditions] 1. When 0 is written in IRTR after reading IRTR = 1 2. When the IRIC flag is cleared to 0
1	Continuous transfer state [Setting condition] <ul style="list-style-type: none"> In I²C bus interface slave mode When the TDRE or RDRF flag is set to 1 when AASX = 1 In other modes When the TDRE or RDRF flag is set to 1

Bit 4—Second Slave Address Recognition Flag (AASX): In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVAX6 to SVAX0 in SARX.

AASX is cleared by reading AASX after it has been set to 1, then writing 0 in AASX. AASX is also cleared automatically when a start condition is detected.

Bit 4

AASX	Description
0	Second slave address not recognized (Initial value) [Clearing conditions] 1. When 0 is written in AASX after reading AASX = 1 2. When a start condition is detected 3. In master mode
1	Second slave address recognized [Setting condition] When the second slave address is detected in slave receive mode while FSX = 0

Bit 3—Arbitration Lost (AL): This flag indicates that arbitration was lost in master mode. The I²C bus interface monitors the bus. When two or more master devices attempt to seize the bus at nearly the same time, if the I²C bus interface detects data differing from the data it sent, it sets AL to 1 to indicate that the bus has been taken by another master.

AL is cleared by reading AL after it has been set to 1, then writing 0 in AL. In addition, AL is reset automatically by write access to ICDR in transmit mode, or read access to ICDR in receive mode.

Bit 3

AL	Description
0	Bus arbitration won (Initial value) [Clearing conditions] 1. When ICDR data is written (transmit mode) or read (receive mode) 2. When 0 is written in AL after reading AL = 1
1	Arbitration lost [Setting conditions] 1. If the internal SDA and SDA pin disagree at the rise of SCL in master transmit mode 2. If the internal SCL line is high at the fall of SCL in master transmit mode

Bit 2—Slave Address Recognition Flag (AAS): In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVA6 to SVA0 in SAR, or if the general call address (H'00) is detected.

AAS is cleared by reading AAS after it has been set to 1, then writing 0 in AAS. In addition, AAS is reset automatically by write access to ICDR in transmit mode, or read access to ICDR in receive mode.

Bit 2

AAS	Description
0	Slave address or general call address not recognized (Initial value) [Clearing conditions] 1. When ICDR data is written (transmit mode) or read (receive mode) 2. When 0 is written in AAS after reading AAS = 1 3. In master mode
1	Slave address or general call address recognized [Setting condition] When the slave address or general call address is detected in slave receive mode while FS = 0

Bit 1—General Call Address Recognition Flag (ADZ): In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition is the general call address (H'00).

ADZ is cleared by reading ADZ after it has been set to 1, then writing 0 in ADZ. In addition, ADZ is reset automatically by write access to ICDR in transmit mode, or read access to ICDR in receive mode.

Bit 1

ADZ	Description
0	General call address not recognized (Initial value) [Clearing conditions] 1. When ICDR data is written (transmit mode) or read (receive mode) 2. When 0 is written in ADZ after reading ADZ = 1 3. In master mode
1	General call address recognized [Setting condition] When the general call address is detected in slave receive mode while FSX = 0 or FS = 0

Bit 0—Acknowledge Bit (ACKB): Stores acknowledge data. In transmit mode, after the receiving device receives data, it returns acknowledge data, and this data is loaded into ACKB. In receive mode, after data has been received, the acknowledge data set in this bit is sent to the transmitting device.

When this bit is read, in transmission (when TRS = 1), the value loaded from the bus line (returned by the receiving device) is read. In reception (when TRS = 0), the value set by internal software is read.

When this bit is written to, the acknowledge data transmitted at the receipt is rewritten regardless of the TRS value. The data loaded from the receiving device is retained, therefore take care of using bit-manipulation instructions.

Bit 0

ACKB	Description
0	Receive mode: 0 is output at acknowledge output timing (Initial value) Transmit mode: Indicates that the receiving device has acknowledged the data (signal is 0)
1	Receive mode: 1 is output at acknowledge output timing Transmit mode: Indicates that the receiving device has not acknowledged the data (signal is 1)

16.2.7 Serial/Timer Control Register (STCR)

Bit	7	6	5	4	3	2	1	0
	—	IICX1	IICX0	IICE	FLSHE	—	ICKS1	ICKS0
Initial value	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

STCR is an 8-bit readable/writable register that controls register access, the I²C interface operating mode (when the on-chip IIC option is included), and on-chip flash memory (F-ZTAT versions), and selects the TCNT input clock source. For details of functions not related to the I²C bus interface, see section 3.2.4, Serial/Timer Control Register (STCR), and the descriptions of the relevant modules. If a module controlled by STCR is not used, do not write 1 to the corresponding bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—Reserved: Do not write 1 to this bit.

Bit 6 and 5—I²C Transfer Select 1 and 0 (IICX1 and 0): This bit, together with bits CKS2 to CKS0 in ICMR, selects the transfer rate in master mode. For details, see section 16.2.4, I²C Bus Mode Register (ICMR).

Bit 4—I²C Master Enable (IICE): Controls CPU access to the I²C bus interface data and control registers (ICCR, ICSR, ICDR/SARX, ICMR/SAR), PWMX data and control registers, and SCI control registers.

Bit 4

IICE	Description
0	CPU access to I ² C bus interface data and control registers is disabled (Initial value) CPU access to SCI control registers is enabled
1	CPU access to I ² C bus interface data and control registers is enabled CPU access to PWMX data and control registers is enabled

Bit 3—Flash Memory Control Register Enable (FLSHE): Controls CPU access to the flash memory control registers, the power-down mode control registers, and the supporting module control registers. See section 3.2.4, Serial Timer Control Register (STCR), for details.

Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Source Select 1 and 0 (ICKS1, ICKS0): These bits, together with bits CKS2 to CKS0 in TCR, select the clock input to the timer counters (TCNT). For details, see section 12.2.4, Timer Control Register (TCR).

16.2.8 DDC Switch Register (DDCSWR)

Bit	7	6	5	4	3	2	1	0
	SWE	SW	IE	IF	CLR3	CLR2	CLR1	CLR0
Initial value	0	0	0	0	1	1	1	1
Read/Write	R/W	R/W	R/W	R/(W)*1	W*2	W*2	W*2	W*2

Notes: *1 Only 0 can be written, to clear the flag.

*2 Always read as 1.

DDCSWR is an 8-bit readable/writable register that is used to initialize IIC and controls IIC internal latch clearance.

DDCSWR is initialized to H'0F by a reset and in hardware standby mode.

Bits 7—DDC Mode Switch Enable (SWE): Selects the function for automatically switching IIC channel 0 from formatless mode to the I²C bus format.

Bit 7

SWE	Description
0	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format is disabled (Initial value)
1	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format is enabled

Bits 6—DDC Mode Switch (SW): Selects either formatless mode or the I²C bus format for IIC channel 0.

Bit 6

SW	Description
0	IIC channel 0 is used with the I ² C bus format (Initial value) [Clearing conditions] 1. When 0 is written by software 2. When a falling edge is detected on the SCL pin when SWE = 1
1	IIC channel 0 is used in formatless mode [Setting condition] When 1 is written in SW after reading SW = 0

Bits 5—DDC Mode Switch Interrupt Enable Bit (IE): Enables or disables an interrupt request to the CPU when automatic format switching is executed for IIC channel 0.

Bit 5

IE	Description
0	Interrupt when automatic format switching is executed is disabled (Initial value)
1	Interrupt when automatic format switching is executed is enabled

Bits 4—DDC Mode Switch Interrupt Flag (IF): Flag that indicates an interrupt request to the CPU when automatic format switching is executed for IIC channel 0.

Bit 4

IF	Description
0	No interrupt is requested when automatic format switching is executed (Initial value) [Clearing condition] When 0 is written in IF after reading IF = 1
1	An interrupt is requested when automatic format switching is executed [setting condition] When a falling edge is detected on the SCL pin when SWE = 1

Bits 3 to 0—IIC Clear 3 to 0 (CLR3 to CLR0): These bits control initialization of the internal state of IIC0 and IIC1.

These bits can only be written to; if read they will always return a value of 1.

When a write operation is performed on these bits, a clear signal is generated for the internal latch circuit of the corresponding module(s), and the internal state of the IIC module(s) is initialized.

The write data for these bits is not retained. To perform IIC clearance, bits CLR3 to CLR0 must be written to simultaneously using an MOV instruction. Do not use a bit manipulation instruction such as BCLR.

When clearing is required again, all the bits must be written to in accordance with the setting.

Bit 3	Bit 2	Bit 1	Bit 0	
CLR3	CLR2	CLR1	CLR0	Description
0	0	—	—	Setting prohibited
	1	0	0	Setting prohibited
			1	IIC0 internal latch cleared
			0	IIC1 internal latch cleared
		1	1	IIC0 and IIC1 internal latches cleared
1	—	—	—	Invalid setting

16.2.9 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2	MSTP1	MSTP0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

MSTPCR comprises two 8-bit readable/writable registers, and is used to perform module stop mode control.

When the MSTP4 or MSTP3 bit is set to 1, operation of the corresponding IIC channel is halted at the end of the bus cycle, and a transition is made to module stop mode. For details, see section 21.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRL Bit 4—Module Stop (MSTP4): Specifies IIC channel 0 module stop mode.

MSTPCRL

Bit 4

MSTP4	Description
0	IIC channel 0 module stop mode is cleared
1	IIC channel 0 module stop mode is set (Initial value)

MSTPCRL Bit 3—Module Stop (MSTP3): Specifies IIC channel 1 module stop mode.

MSTPCRL

Bit 3

MSTP3	Description
0	IIC channel 1 module stop mode is cleared
1	IIC channel 1 module stop mode is set (Initial value)

16.3 Operation

16.3.1 I²C Bus Data Format

The I²C bus interface has serial and I²C bus formats.

The I²C bus formats are addressing formats with an acknowledge bit. These are shown in figures 16.3 (a) and (b). The first frame following a start condition always consists of 8 bits.

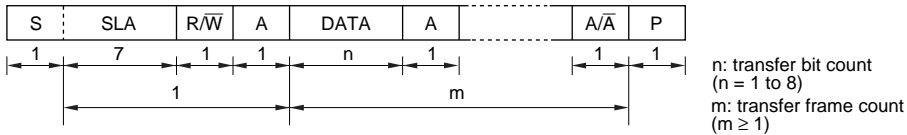
IIC channel 0 only is capable of formatless operation, as shown in figure 16.4.

The serial format is a non-addressing format with no acknowledge bit. Although start and stop conditions must be issued, this format can be used as a synchronous serial format. This is shown in figure 16.5.

Figure 16.6 shows the I²C bus timing.

The symbols used in figures 16.3 to 16.6 are explained in table 16.4.

(a) I²C bus format (FS = 0 or FSX = 0)



(b) I²C bus format (start condition retransmission, FS = 0 or FSX = 0)

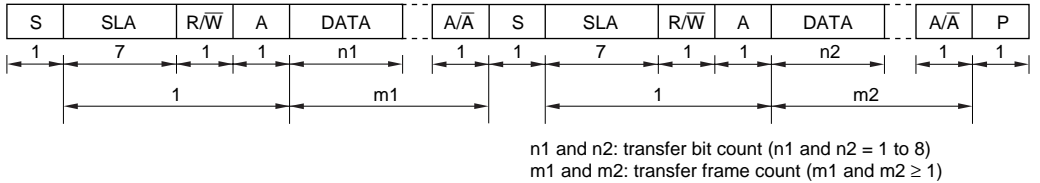


Figure 16.3 I²C Bus Data Formats (I²C Bus Formats)

IIC0 only, FS = 0 or FSX = 0

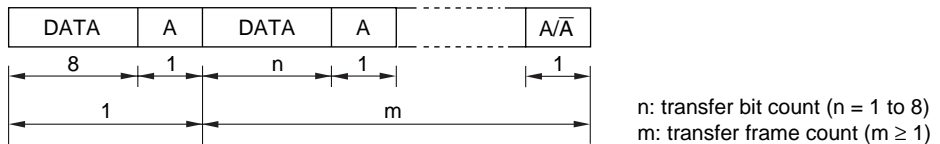


Figure 16.4 Formatless

FS = 1 and FSX = 1

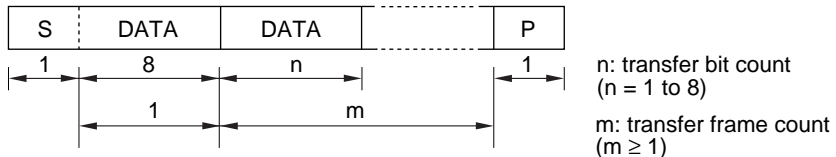


Figure 16.5 I²C Bus Data Format (Serial Format)

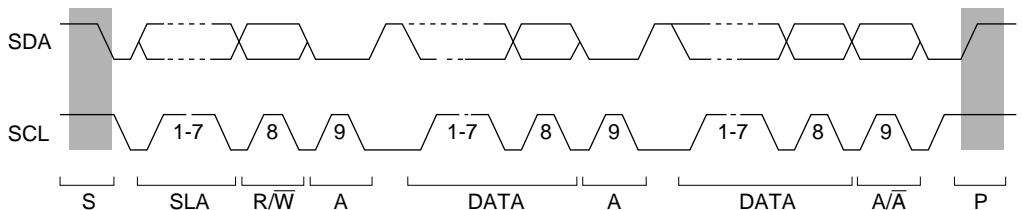


Figure 16.6 I²C Bus Timing

Table 16.4 I²C Bus Data Format Symbols**Legend**

S	Start condition. The master device drives SDA from high to low while SCL is high
SLA	Slave address, by which the master device selects a slave device
R/ \overline{W}	Indicates the direction of data transfer: from the slave device to the master device when R/ \overline{W} is 1, or from the master device to the slave device when R/ \overline{W} is 0
A	Acknowledge. The receiving device (the slave in master transmit mode, or the master in master receive mode) drives SDA low to acknowledge a transfer
DATA	Transferred data. The bit length is set by bits BC2 to BC0 in ICMR. The MSB-first or LSB-first format is selected by bit MLS in ICMR
P	Stop condition. The master device drives SDA from low to high while SCL is high

16.3.2 Master Transmit Operation

In I²C bus format master transmit mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal.

The transmission procedure and operations by which data is sequentially transmitted in synchronization with ICDR write operations, are described below.

- (1) Set the ICE bit in ICCR to 1. Set bits MLS, WAIT, and CKS2 to CKS0 in ICMR, and bit IICX in STCR, according to the operation mode.
- (2) Read the BBSY flag to confirm that the bus is free.
- (3) Set the MST and TRS bits to 1 in ICCR to select master transmit mode.
- (4) Write 1 to BBSY and 0 to SCP. This switches SDA from high to low when SCL is high, and generates the start condition.
- (5) When the start condition is generated, the IRIC and IRTR flags are set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU.
- (6) Write data to ICDR (slave address + R/ \overline{W})

With the I²C bus format (when the FS bit in SAR or the FSX bit in SARX is 0), the first frame data following the start condition indicates the 7-bit slave address and transmit/receive direction.

Then clear the IRIC flag to indicate the end of transfer.

Writing to ICDR and clearing of the IRIC flag must be executed continuously, so that no interrupt is inserted.

If a period of time that is equal to transfer one byte has elapsed by the time the IRIC flag is cleared, the end of transfer cannot be identified.

The master device sequentially sends the transmit clock and the data written to ICDR with the timing shown in figure 16.7. The selected slave device (i.e., the slave device with the matching slave address) drives SDA low at the 9th transmit clock pulse and returns an acknowledge signal.

- (7) When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the 9th transmit clock pulse. After one frame has been transmitted, SCL is automatically fixed low in synchronization with the internal clock until the next transmit data is written.
- (8) Read the ACKB bit to confirm that ACKB is 0. When the slave device has not returned an acknowledge signal and ACKB remains 1, execute the transmit end processing described in step (12) and perform transmit operation again.
- (9) Write the next data to be transmitted in ICDR. To indicate the end of data transfer, clear the IRIC flag to 0.

As described in step (6) above, writing to ICDR and clearing of the IRIC flag must be executed continuously so that no interrupt is inserted.

The next frame is transmitted in synchronization with the internal clock.

- (10) When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the 9th transmit clock pulse. After one frame has been transmitted, SCL is automatically fixed low in synchronization with the internal clock until the next transmit data is written.
- (11) Read the ACKB bit of ICSR. Confirm that the slave device has returned an acknowledge signal and ACKB is 0. When more data is to be transmitted, return to step (9) to execute next transmit operation. If the slave device has not returned an acknowledge signal and ACKB is 1, execute the transmit end processing described in step (12).
- (12) Clear the IRIC flag to 0. Write BBSY and SCP of ICCR to 0. By doing so, SDA is changed from low to high while SCL is high and the transmit stop condition is generated.

- (3) The IRIC flag is set to 1 at the fall of the 8th clock of a one-frame reception clock. At this point, if the IEIC bit of ICCR is set to 1, an interrupt request is generated to the CPU. SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag is cleared. If the first frame is the final reception frame, execute the end processing as described in (10).
- (4) Clear the IRIC flag to 0 to release from the wait state.
The master device outputs the 9th receive clock pulse, sets SDA to low, and returns an acknowledge signal.
- (5) When one frame of data has been transmitted, the IRIC and IRTR flags are set to 1 at the rise of the 9th transmit clock pulse.
The master device continues to output the receive clock for the next receive data.
- (6) Read the ICDR receive data.
- (7) Clear the IRIC flag to indicate the next wait.
From clearing of the IRIC flag to completion of data transmission as described in steps (5), (6), and (7), must be performed within the time taken to transfer one byte, because releasing of the wait state as described in step (4) (or (9)).
- (8) The IRIC flag is set to 1 at the fall of the 8th one-frame reception clock pulse. SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag is cleared. If this frame is the final reception frame, execute the end processing as described in (10).
- (9) Clear the IRIC flag to 0 to release from the wait state. The master device outputs the 9th reception clock pulse, sets SDA to low, and returns an acknowledge signal.
By repeating steps (5) to (9) above, more data can be received.
- (10) Set the ACKB bit of ICSR to 1 and set the acknowledge data for the final reception.
Set the TRS bit of ICCR to 1 to change receive mode to transmit mode.
- (11) Clear the IRIC flag to release from the wait state.
- (12) When one frame of data has been received, the IRIC flag is set to 1 at the rise of the 9th reception clock pulse.
- (13) Clear the WAIT bit of ICMR to 0 to cancel wait mode. Read the ICDR receive data and clear the IRIC flag to 0.
Clear the IRIC flag only when WAIT = 0.
(If the stop-condition generation command is executed after clearing the IRIC flag to 0 and then clearing the WAIT bit to 0, the SDA line is fixed low and the stop condition cannot be generated.)
- (14) Write 0 to BBSY and SCP. This changes SDA from low to high when SCL is high, and generates the stop condition.

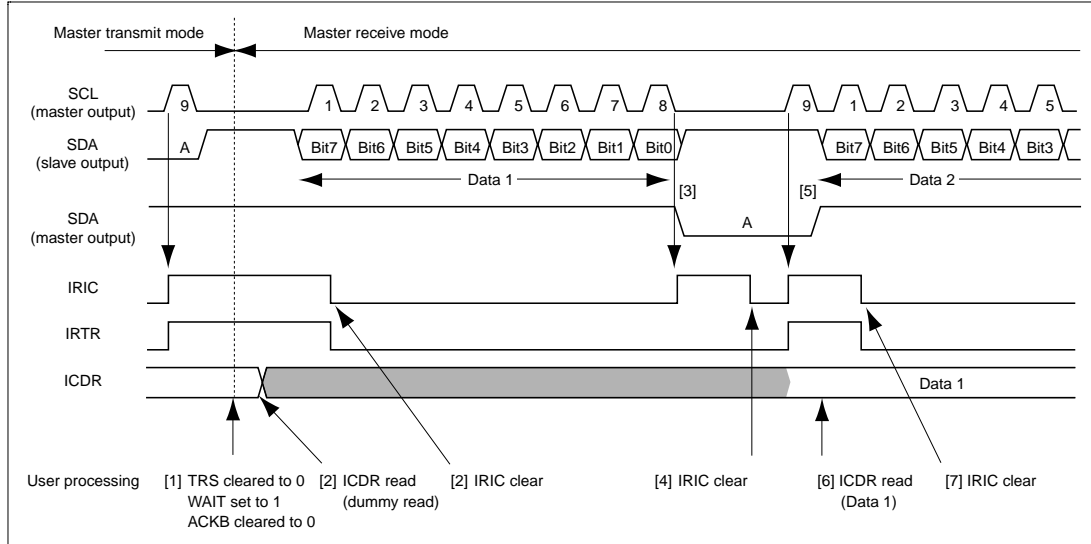


Figure 16.8 (a) Example of Master Receive Mode Operation Timing
(MLS = ACKB = 0, WAIT = 1)

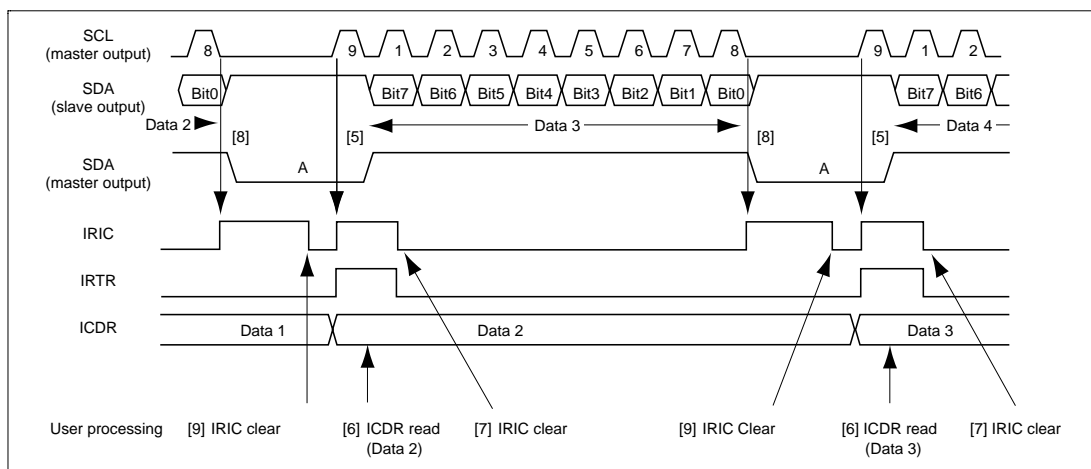


Figure 16.8 (b) Example of Master Receive Mode Operation Timing
(MLS = ACKB = 0, WAIT = 1)

16.3.4 Slave Receive Operation

In slave receive mode, the master device outputs the transmit clock and transmit data, and the slave device returns an acknowledge signal. The reception procedure and operations in slave receive mode are described below.

- [1] Set the ICE bit in ICCR to 1. Set the MLS bit in ICMR and the MST and TRS bits in ICCR according to the operating mode.
- [2] When the start condition output by the master device is detected, the BBSY flag in ICCR is set to 1.
- [3] When the slave address matches in the first frame following the start condition, the device operates as the slave device specified by the master device. If the 8th data bit (R/\overline{W}) is 0, the TRS bit in ICCR remains cleared to 0, and slave receive operation is performed.
- [4] At the 9th clock pulse of the receive frame, the slave device drives SDA low and returns an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. If the RDRF internal flag has been cleared to 0, it is set to 1, and the receive operation continues. If the RDRF internal flag has been set to 1, the slave device drives SCL low from the fall of the receive clock until data is read into ICDR.
- [5] Read ICDR and clear the IRIC flag in ICCR to 0. The RDRF flag is cleared to 0.

Receive operations can be performed continuously by repeating steps [4] and [5]. When SDA is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICCR is cleared to 0.

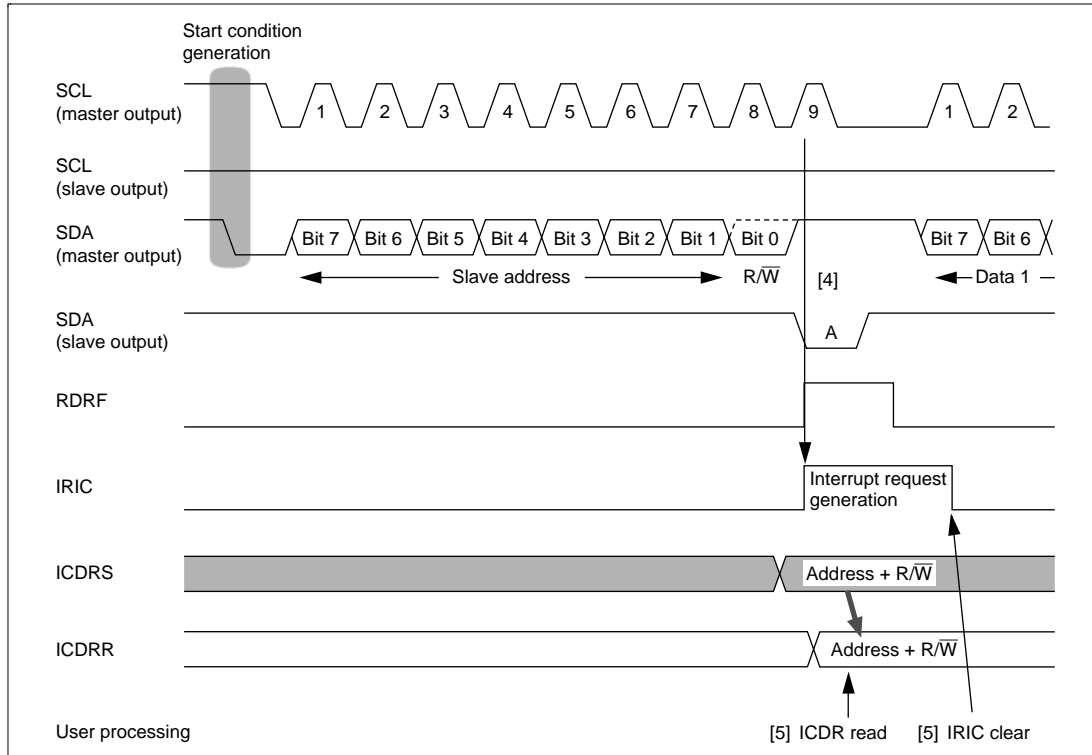


Figure 16.9 Example of Slave Receive Mode Operation Timing (1) ($MLS = ACKB = 0$)

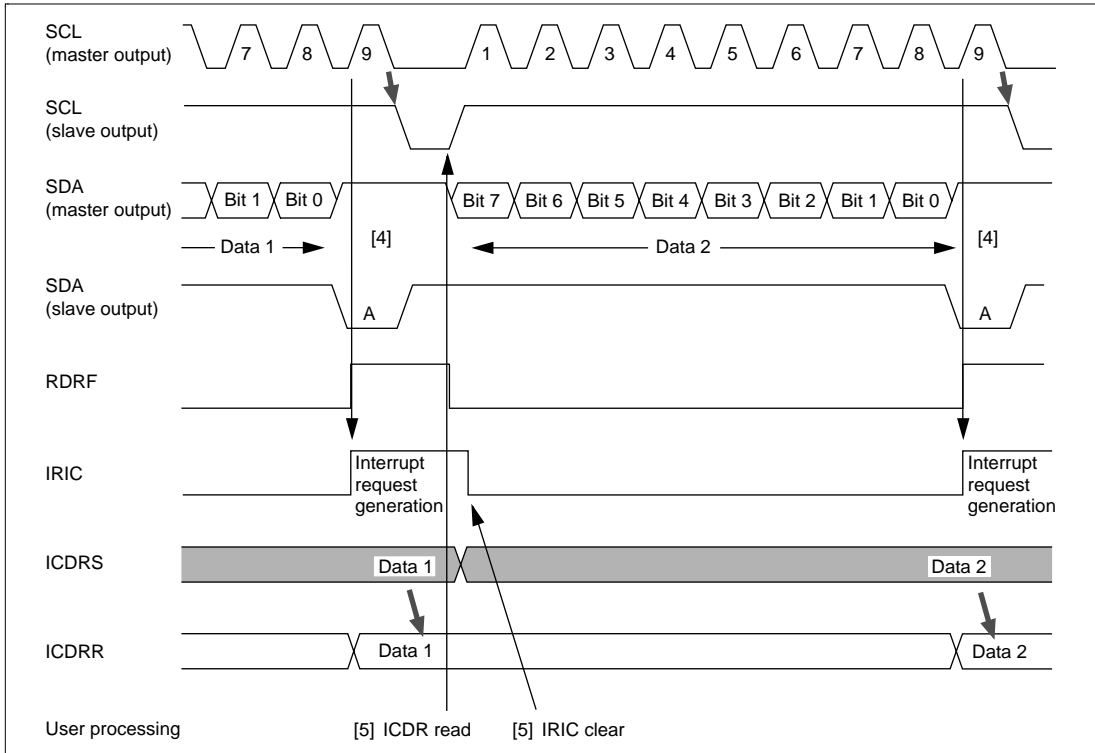


Figure 16.10 Example of Slave Receive Mode Operation Timing (2) ($MLS = ACKB = 0$)

16.3.5 Slave Transmit Operation

In slave transmit mode, the slave device outputs the transmit data, while the master device outputs the receive clock and returns an acknowledge signal. The transmission procedure and operations in slave transmit mode are described below.

- [1] Set the ICE bit in ICCR to 1. Set the MLS bit in ICMR and the MST and TRS bits in ICCR according to the operating mode.
- [2] When the slave address matches in the first frame following detection of the start condition, the slave device drives SDA low at the 9th clock pulse and returns an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. If the 8th data bit (R/\overline{W}) is 1, the TRS bit in ICCR is set to 1, and the mode changes to slave transmit mode automatically. The TDRE internal flag is set to 1. The slave device drives SCL low from the fall of the transmit clock until ICDR data is written.
- [3] After clearing the IRIC flag to 0, write data to ICDR. The TDRE internal flag is cleared to 0. The written data is transferred to ICDRS, and the TDRE internal flag and the IRIC and IRTR

flags are set to 1 again. After clearing the IRIC flag to 0, write the next data to ICDR. The slave device sequentially sends the data written into ICDR in accordance with the clock output by the master device at the timing shown in figure 16.11.

- [4] When one frame of data has been transmitted, the IRIC flag in ICCR is set to 1 at the rise of the 9th transmit clock pulse. If the TDRE internal flag has been set to 1, this slave device drives SCL low from the fall of the transmit clock until data is written to ICDR. The master device drives SDA low at the 9th clock pulse, and returns an acknowledge signal. As this acknowledge signal is stored in the ACKB bit in ICSR, this bit can be used to determine whether the transfer operation was performed normally. When the TDRE internal flag is 0, the data written into ICDR is transferred to ICDRS, transmission is started, and the TDRE internal flag and the IRIC and IRTR flags are set to 1 again.
- [5] To continue transmission, clear the IRIC flag to 0, then write the next data to be transmitted into ICDR. The TDRE internal flag is cleared to 0.

Transmit operations can be performed continuously by repeating steps [4] and [5]. To end transmission, write H'FF to ICDR to release SDA on the slave side. When SDA is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICCR is cleared to 0.

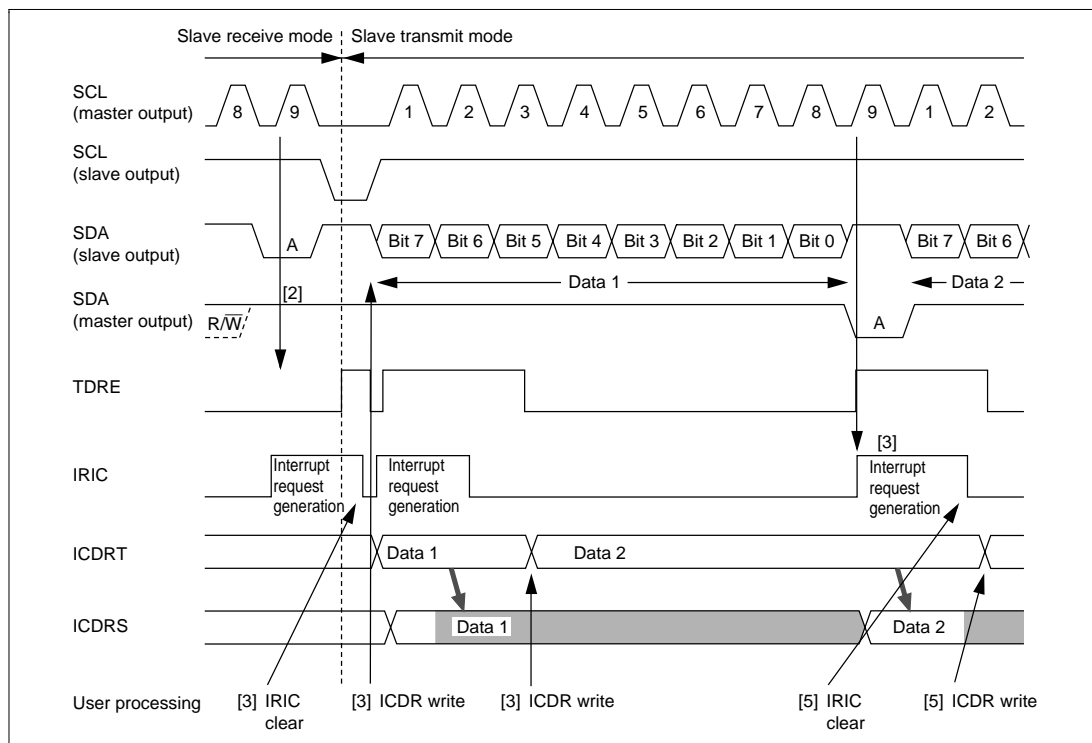
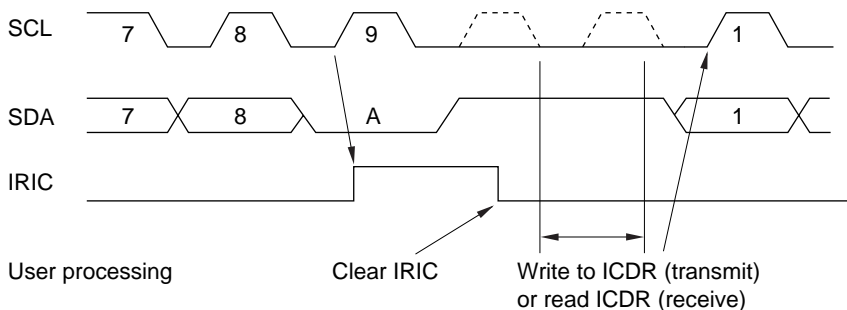


Figure 16.11 Example of Slave Transmit Mode Operation Timing (MLS = 0)

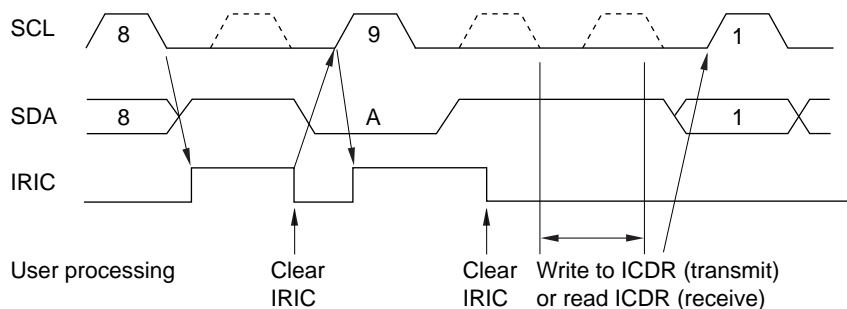
16.3.6 I2C Setting Timing and SCL Control

The interrupt request flag (IRIC) is set at different times depending on the WAIT bit in ICMR, the FS bit in SAR, and the FSX bit in SARX. If the TDRE or RDRF internal flag is set to 1, SCL is automatically held low after one frame has been transferred; this timing is synchronized with the internal clock. Figure 16.12 shows the IRIC set timing and SCL control.

(a) When WAIT = 0, and FS = 0 or FSX = 0 (I²C bus format, no wait)



(b) When WAIT = 1, and FS = 0 or FSX = 0 (I²C bus format, wait inserted)



(c) When FS = 1 and FSX = 1 (synchronous serial format)

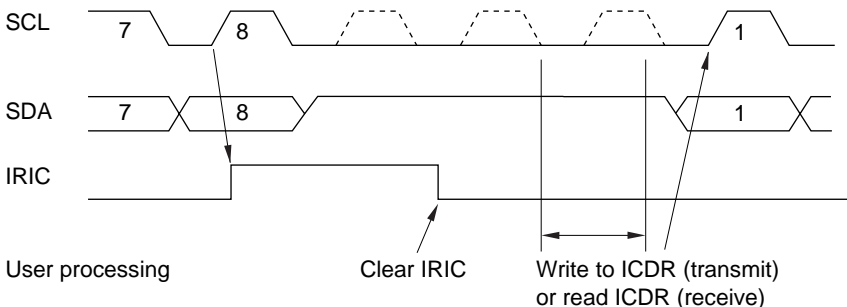


Figure 16.12 IRIC Setting Timing and SCL Control

16.3.7 Automatic Switching from Formatless Mode to I²C Bus Format

Setting the SW bit to 1 in DDCSWR enables formatless mode to be selected as the IIC0 operating mode. Switching from formatless mode to the I²C bus format (slave mode) is performed automatically when a falling edge is detected on the SCL pin.

The following four preconditions are necessary for this operation:

- A common data pin (SDA) for formatless and I²C bus format operation
- Separate clock pins for formatless operation (VSYNCl) and I²C bus format operation (SCL)
- A fixed 1 level for the SCL pin during formatless operation (the SCL pin does not output a low level)
- Settings of bits other than TRS in ICCR that allow I²C bus format operation

Automatic switching is performed from formatless mode to the I²C bus format when the SW bit in DDCSWR is automatically cleared to 0 on detection of a falling edge on the SCL pin. Switching from the I²C bus format to formatless mode is achieved by having software set the SW bit in DDCSWR to 1.

In formatless mode, bits (such as MSL and TRS) that control the I²C bus interface operating mode must not be modified. When switching from the I²C bus format to formatless mode, set the TRS bit to 1 or clear it to 0 according to the transmit data (transmission or reception) in formatless mode, then set the SW bit to 1. After automatic switching from formatless mode to the I²C bus format (slave mode), in order to wait for slave address reception, the TRS bit is automatically cleared to 0.

If a falling edge is detected on the SCL pin during formatless operation, the I²C bus interface operating mode is switched to the I²C bus format without waiting for a stop condition to be detected.

16.3.8 Operation Using the DTC

The I²C bus format provides for selection of the slave device and transfer direction by means of the slave address and the R/ \overline{W} bit, confirmation of reception with the acknowledge bit, indication of the last frame, and so on. Therefore, continuous data transfer using the DTC must be carried out in conjunction with CPU processing by means of interrupts.

Table 16.5 shows some examples of processing using the DTC. These examples assume that the number of transfer data bytes is known in slave mode.

Table 16.5 Examples of Operation Using the DTC

Item	Master Transmit Mode	Master Receive Mode	Slave Transmit Mode	Slave Receive Mode
Slave address + R/ \overline{W} bit transmission/reception	Transmission by DTC (ICDR write)	Transmission by CPU (ICDR write)	Reception by CPU (ICDR read)	Reception by CPU (ICDR read)
Dummy data read	—	Processing by CPU (ICDR read)	—	—
Actual data transmission/reception	Transmission by DTC (ICDR write)	Reception by DTC (ICDR read)	Transmission by DTC (ICDR write)	Reception by DTC (ICDR read)
Dummy data (H'FF) write	—	—	Processing by DTC (ICDR write)	—
Last frame processing	Not necessary	Reception by CPU (ICDR read)	Not necessary	Reception by CPU (ICDR read)
Transfer request processing after last frame processing	1st time: Clearing by CPU 2nd time: End condition issuance by CPU	Not necessary	Automatic clearing on detection of end condition during transmission of dummy data (H'FF)	Not necessary
Setting of number of DTC transfer data frames	Transmission: Actual data count + 1 (+1 equivalent to slave address + R/ \overline{W} bits)	Reception: Actual data count	Transmission: Actual data count + 1 (+1 equivalent to dummy data (H'FF))	Reception: Actual data count

16.3.9 Noise Canceled

The logic levels at the SCL and SDA pins are routed through noise cancelers before being latched internally. Figure 16.13 shows a block diagram of the noise canceler circuit.

The noise canceler consists of two cascaded latches and a match detector. The SCL (or SDA) input signal is sampled on the system clock, but is not passed forward to the next circuit unless the outputs of both latches agree. If they do not agree, the previous value is held.

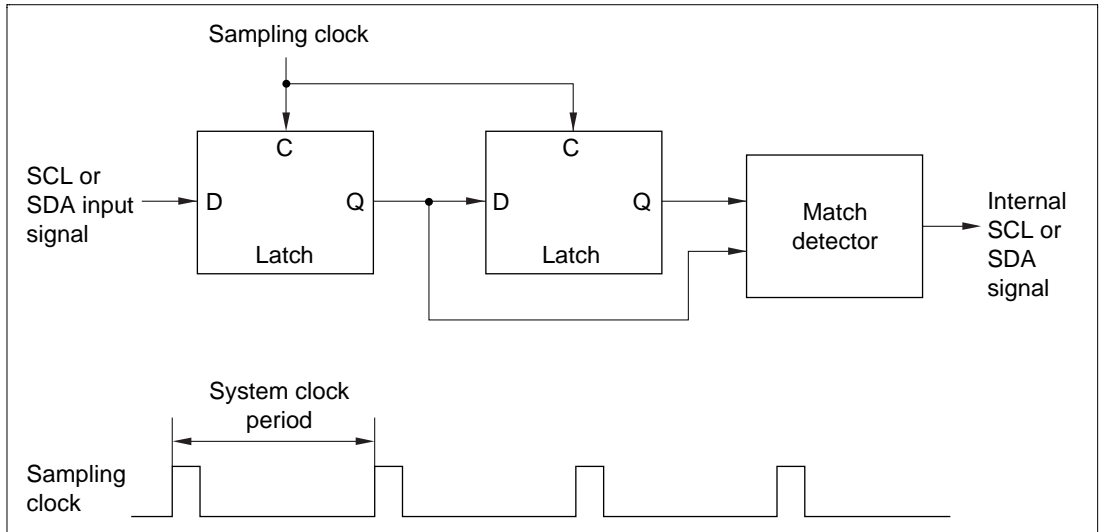


Figure 16.13 Block Diagram of Noise Canceled

16.3.10 Sample Flowcharts

Figures 16.14 to 16.17 show sample flowcharts for using the I²C bus interface in each mode.

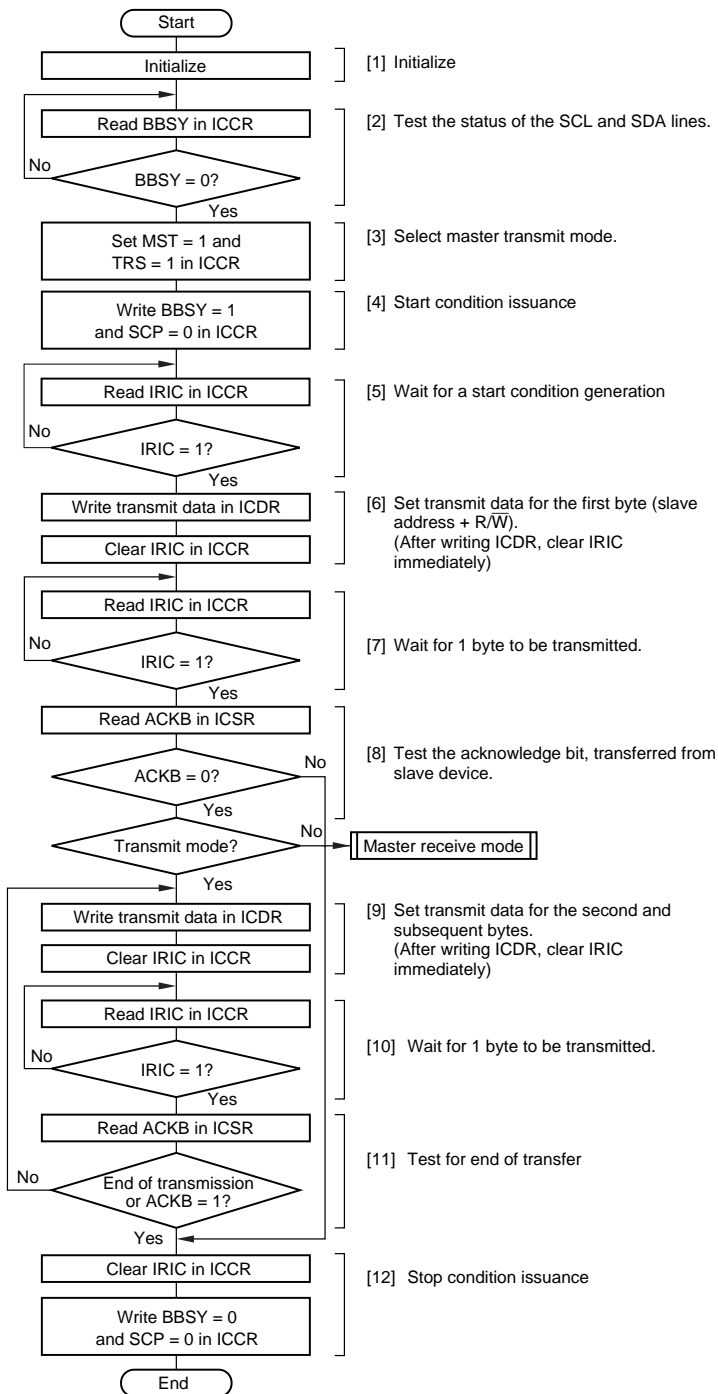


Figure 16.14 Flowchart for Master Transmit Mode (Example)

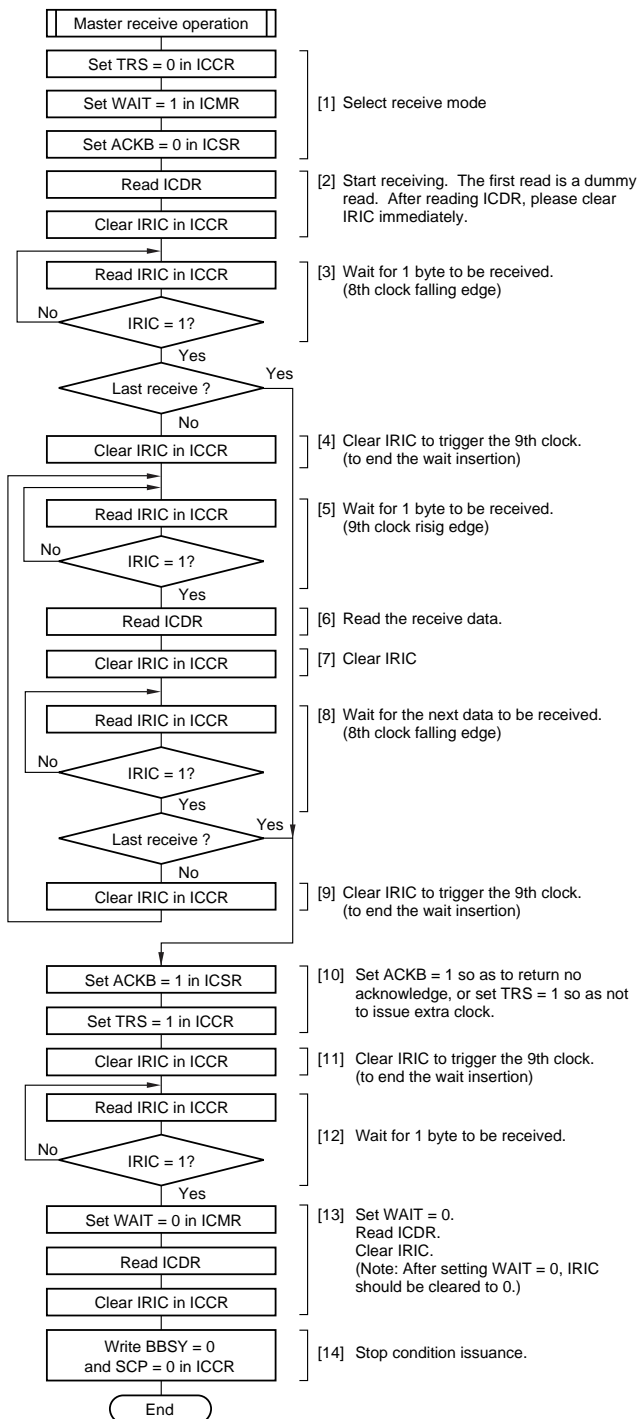
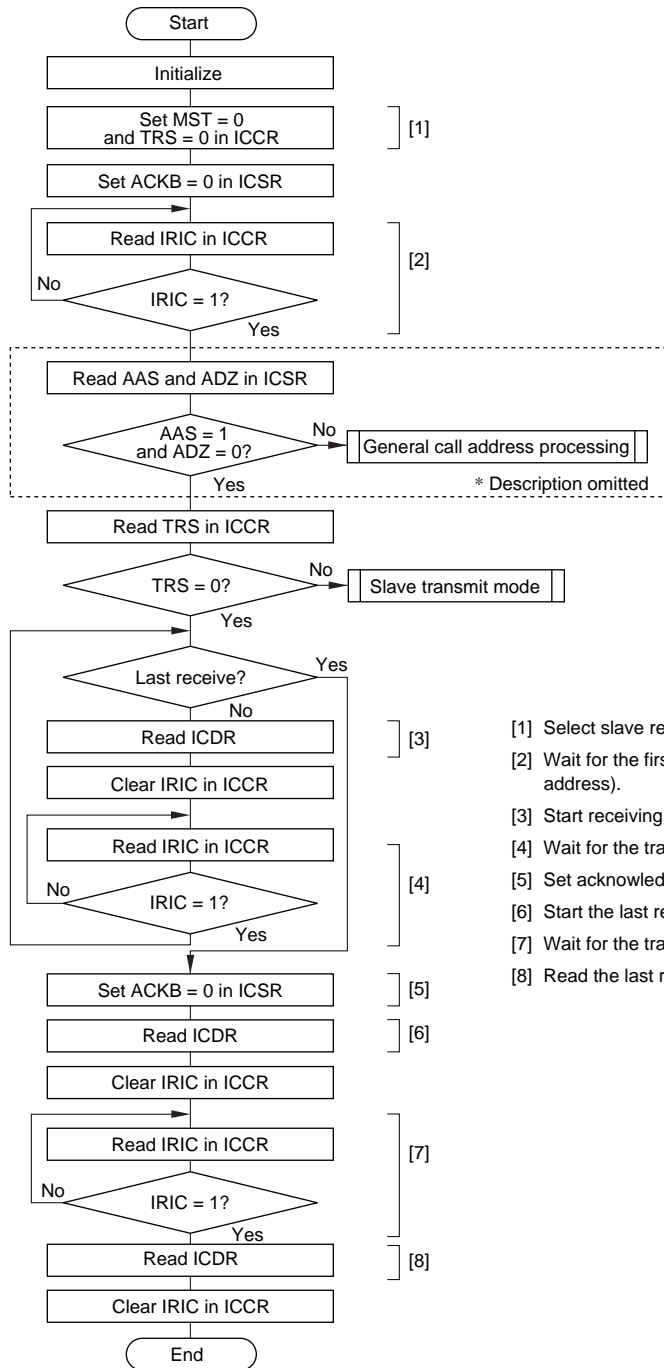


Figure 16.15 Flowchart for Master Receive Mode (Example)



- [1] Select slave receive mode.
- [2] Wait for the first byte to be received (slave address).
- [3] Start receiving. The first read is a dummy read.
- [4] Wait for the transfer to end.
- [5] Set acknowledge data for the last receive.
- [6] Start the last receive.
- [7] Wait for the transfer to end.
- [8] Read the last receive data.

Figure 16.16 Flowchart for Slave Receive Mode (Example)

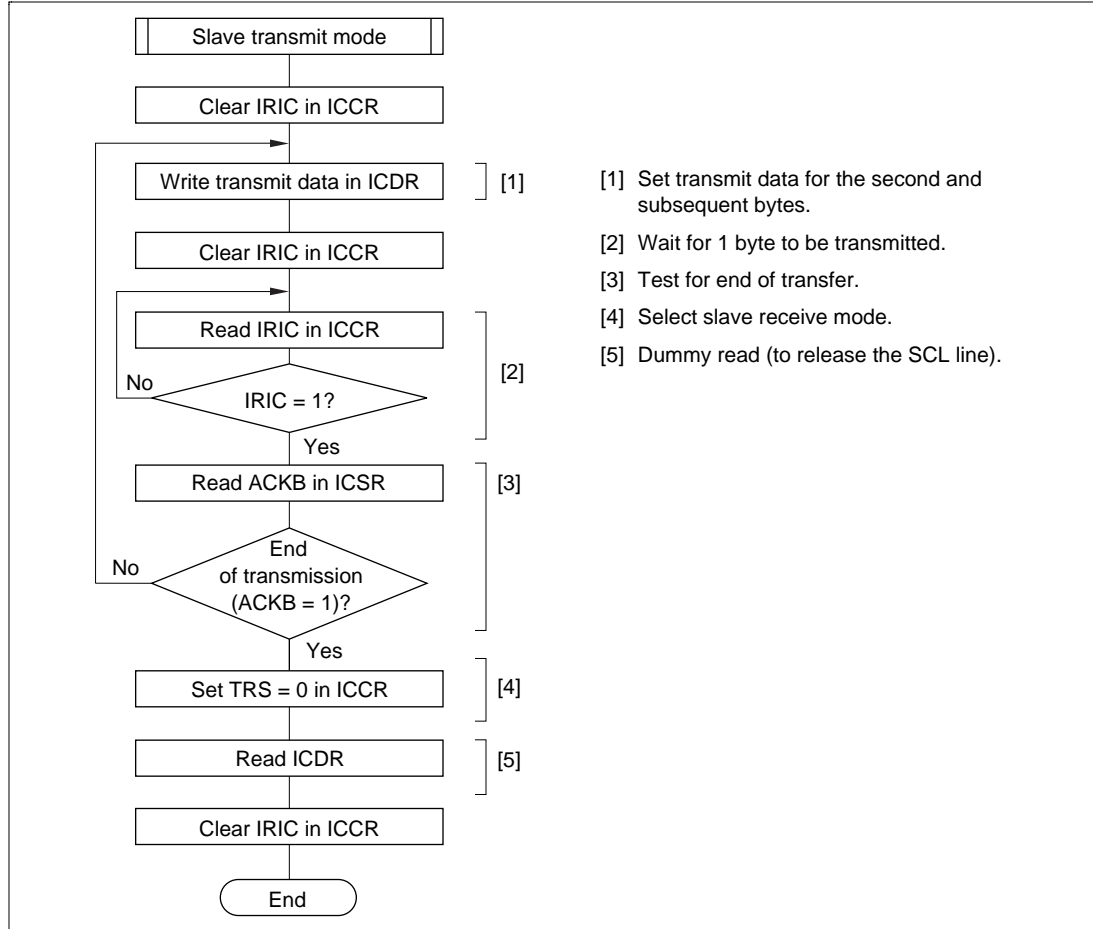


Figure 16.17 Flowchart for Slave Transmit Mode (Example)

16.3.11 Initialization of Internal State

The IIC has a function for forcible initialization of its internal state if a deadlock occurs during communication.

Initialization is executed by (1) setting bits CLR3 to CLR0 in the DDCSWR register or (2) clearing the ICE bit. For details of settings for bits CLR3 to CLR0, see section 16.2.8, DDC Switch Register (DDCSWR).

Scope of Initialization: The initialization executed by this function covers the following items:

- TDRE and RDRF internal flags
- Transmit/receive sequencer and internal operating clock counter

- Internal latches for retaining the output state of the SCL and SDA pins (wait, clock, data output, etc.)

The following items are not initialized:

- Actual register values (ICDR, SAR, SARX, ICMR, ICCR, ICSR, DDCCSWR, STCR)
- Internal latches used to retain register read information for setting/clearing flags in the ICMR, ICCR, ICSR, and DDCCSWR registers
- The value of the ICMR register bit counter (BC2 to BC0)
- Generated interrupt sources (interrupt sources transferred to the interrupt controller)

Notes on Initialization:

- Interrupt flags and interrupt sources are not cleared, and so flag clearing measures must be taken as necessary.
- Basically, other register flags are not cleared either, and so flag clearing measures must be taken as necessary.
- When initialization is performed by means of the DDCCSWR register, the write data for bits CLR3 to CLR0 is not retained. To perform IIC clearance, bits CLR3 to CLR0 must be written to simultaneously using an MOV instruction. Do not use a bit manipulation instruction such as BCLR. Similarly, when clearing is required again, all the bits must be written to simultaneously in accordance with the setting.
- If a flag clearing setting is made during transmission/reception, the IIC module will stop transmitting/receiving at that point and the SCL and SDA pins will be released. When transmission/reception is started again, register initialization, etc., must be carried out as necessary to enable correct communication as a system.

The value of the BBSY bit cannot be modified directly by this module clear function, but since the stop condition pin waveform is generated according to the state and release timing of the SCL and SDA pins, the BBSY bit may be cleared as a result. Similarly, state switching of other bits and flags may also have an effect.

To prevent problems caused by these factors, the following procedure should be used when initializing the IIC state.

1. Execute initialization of the internal state by setting of bit CLR3 to CLR0 or by clearing ICE bit.
2. Execute a stop condition issuance instruction (write 0 to BBSY and SCP) to clear the BBSY bit to 0, and wait for two transfer rate clock cycles.
3. Re-execute initialization of the internal state by setting of bit CLR3 to CLR0 or by clearing ICE bit.
4. Initialize (re-set) the IIC registers.

16.4 Usage Notes

- In master mode, if an instruction to generate a start condition is immediately followed by an instruction to generate a stop condition, neither condition will be output correctly. To output consecutive start and stop conditions, after issuing the instruction that generates the start condition, read the relevant ports, check that SCL and SDA are both low, then issue the instruction that generates the stop condition. Note that SCL may not yet have gone low when BBSY is cleared to 0.
- Either of the following two conditions will start the next transfer. Pay attention to these conditions when reading or writing to ICDR.
 - Write access to ICDR when ICE = 1 and TRS = 1 (including automatic transfer from ICDRT to ICDRS)
 - Read access to ICDR when ICE = 1 and TRS = 0 (including automatic transfer from ICDRS to ICDRR)
- Table 16.6 shows the timing of SCL and SDA output in synchronization with the internal clock. Timings on the bus are determined by the rise and fall times of signals affected by the bus load capacitance, series resistance, and parallel resistance.

Table 16.6 I²C Bus Timing (SCL and SDA Output)

Item	Symbol	Output Timing	Unit	Notes
SCL output cycle time	t_{SCLC}	$28t_{\text{cyc}}$ to $256t_{\text{cyc}}$	ns	Figure 22.24 (reference)
SCL output high pulse width	t_{SCLH}	$0.5t_{\text{SCLC}}$	ns	
SCL output low pulse width	t_{SCLL}	$0.5t_{\text{SCLC}}$	ns	
SDA output bus free time	t_{BUFO}	$0.5t_{\text{SCLC}} - 1t_{\text{cyc}}$	ns	
Start condition output hold time	t_{STAHO}	$0.5t_{\text{SCLC}} - 1t_{\text{cyc}}$	ns	
Retransmission start condition output setup time	t_{STASO}	$1t_{\text{SCLC}}$	ns	
Stop condition output setup time	t_{STOSO}	$0.5t_{\text{SCLC}} + 2t_{\text{cyc}}$	ns	
Data output setup time (master)	t_{SDASO}	$1t_{\text{SCLL}} - 3t_{\text{cyc}}$	ns	
Data output setup time (slave)		$1t_{\text{SCLL}} - (6t_{\text{cyc}} \text{ or } 12t_{\text{cyc}}^*)$		
Data output hold time	t_{SDAHO}	$3t_{\text{cyc}}$	ns	

Note: * $6t_{\text{cyc}}$ when IICX is 0, $12t_{\text{cyc}}$ when 1.

- SCL and SDA input is sampled in synchronization with the internal clock. The AC timing therefore depends on the system clock cycle t_{cyc} , as shown in I²C Bus Timing in section 22, Electrical Characteristics. Note that the I²C bus interface AC timing specifications will not be met with a system clock frequency of less than 5 MHz.

- The I²C bus interface specification for the SCL rise time t_{sr} is under 1000 ns (300 ns for high-speed mode). In master mode, the I²C bus interface monitors the SCL line and synchronizes one bit at a time during communication. If t_{sr} (the time for SCL to go from low to V_{IH}) exceeds the time determined by the input clock of the I²C bus interface, the high period of SCL is extended. The SCL rise time is determined by the pull-up resistance and load capacitance of the SCL line. To insure proper operation at the set transfer rate, adjust the pull-up resistance and load capacitance so that the SCL rise time does not exceed the values given in the table below.

Table 16.7 Permissible SCL Rise Time (t_{sr}) Values

		Time Indication						
IICX	t_{cyc} Indication	I ² C Bus Specification (Max.)		$\phi =$ 5 MHz	$\phi =$ 8 MHz	$\phi =$ 10 MHz	$\phi =$ 16 MHz	$\phi =$ 20 MHz
0	7.5 t_{cyc}	Standard mode	1000 ns	1000 ns	937 ns	750 ns	468 ns	375 ns
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns	300 ns
1	17.5 t_{cyc}	Standard mode	1000 ns	1000 ns	1000 ns	1000 ns	1000 ns	875 ns
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns	300 ns

- The I²C bus interface specifications for the SCL and SDA rise and fall times are under 1000 ns and 300 ns. The I²C bus interface SCL and SDA output timing is prescribed by t_{cyc} , as shown in table 16.6. However, because of the rise and fall times, the I²C bus interface specifications may not be satisfied at the maximum transfer rate. Table 16.8 shows output timing calculations for different operating frequencies, including the worst-case influence of rise and fall times.

t_{BUFO} fails to meet the I²C bus interface specifications at any frequency. The solution is either (a) to provide coding to secure the necessary interval (approximately 1 μ s) between issuance of a stop condition and issuance of a start condition, or (b) to select devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

t_{SCLLO} in high-speed mode and t_{STASO} in standard mode fail to satisfy the I²C bus interface specifications for worst-case calculations of t_{sr}/t_{sf} . Possible solutions that should be investigated include (a) adjusting the rise and fall times by means of a pull-up resistor and capacitive load, (b) reducing the transfer rate to meet the specifications, or (c) selecting devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

Table 16.8 I²C Bus Timing (with Maximum Influence of t_{Sr}/t_{Sf})

		Time Indication (at Maximum Transfer Rate) [ns]							
Item	t_{cyc} Indication		t_{Sr}/t_{Sf} Influence (Max.)	I ² C Bus Specifi- cation (Min.)	I ² C Bus				
					$\phi =$ 5 MHz	$\phi =$ 8 MHz	$\phi =$ 10 MHz	$\phi =$ 16 MHz	$\phi =$ 20 MHz
t_{SCLHO}	$0.5t_{SCLO}$ ($-t_{Sr}$)	Standard mode	-1000	4000	4000	4000	4000	4000	4000
		High-speed mode	-300	600	950	950	950	950	950
t_{SCLLO}	$0.5t_{SCLO}$ ($-t_{Sf}$)	Standard mode	-250	4700	4750	4750	4750	4750	4750
		High-speed mode	-250	1300	1000 ^{*1}	1000 ^{*1}	1000 ^{*1}	1000 ^{*1}	1000 ^{*1}
t_{BUFO}	$0.5t_{SCLO} - 1t_{cyc}$ ($-t_{Sr}$)	Standard mode	-1000	4700	3800 ^{*1}	3875 ^{*1}	3900 ^{*1}	3938 ^{*1}	3950 ^{*1}
		High-speed mode	-300	1300	750 ^{*1}	825 ^{*1}	850 ^{*1}	888 ^{*1}	900 ^{*1}
t_{STAH0}	$0.5t_{SCLO} - 1t_{cyc}$ ($-t_{Sf}$)	Standard mode	-250	4000	4550	4625	4650	4688	4700
		High-speed mode	-250	600	800	875	900	938	950
t_{STAS0}	$1t_{SCLO}$ ($-t_{Sr}$)	Standard mode	-1000	4700	9000	9000	9000	9000	9000
		High-speed mode	-300	600	2200	2200	2200	2200	2200
t_{STOSO}	$0.5t_{SCLO} + 2t_{cyc}$ ($-t_{Sr}$)	Standard mode	-1000	4000	4400	4250	4200	4125	4100
		High-speed mode	-300	600	1350	1200	1150	1075	1050
t_{SDAS0} (master)	$1t_{SCLLO}^{*3} - 3t_{cyc}$ ($-t_{Sr}$)	Standard mode	-1000	250	3100	3325	3400	3513	3550
		High-speed mode	-300	100	400	625	700	813	850
t_{SDAS0} (slave)	$1t_{SCLL}^{*3} - 12t_{cyc}^{*2}$ ($-t_{Sr}$)	Standard mode	-1000	250	1300	2200	2500	2950	3100
		High-speed mode	-300	100	-1400 ^{*1}	-500 ^{*1}	-200 ^{*1}	250	400

Time Indication (at Maximum Transfer Rate) [ns]

Item	t_{cyc} Indication	t_{SI}/t_{SF} Influence (Max.)	t_{SI}/t_{SF} I ² C Bus Specifi- cation (Min.)	$\phi =$ 5 MHz	$\phi =$ 8 MHz	$\phi =$ 10 MHz	$\phi =$ 16 MHz	$\phi =$ 20 MHz	
t_{SDAHO}	$3t_{cyc}$	Standard mode	0	0	600	375	300	188	150
		High-speed mode	0	0	600	375	300	188	150

Notes: *1 Does not meet the I²C bus interface specification. Remedial action such as the following is necessary: (a) secure a start/stop condition issuance interval; (b) adjust the rise and fall times by means of a pull-up resistor and capacitive load; (c) reduce the transfer rate; (d) select slave devices whose input timing permits this output timing.

The values in the above table will vary depending on the settings of the IICX bit and bits CKS0 to CKS2. Depending on the frequency it may not be possible to achieve the maximum transfer rate; therefore whether or not the I²C bus interface specifications are met must be determined in accordance with the actual setting conditions.

*2 Value when the IICX bit is set to 1. When the IICX bit is cleared to 0, the value is ($t_{SCLL} - 6t_{cyc}$).

*3 Calculated using the I²C bus specification values (standard mode: 4700 ns min.; high-speed mode: 1300 ns min.).

• Note on ICDR Read at End of Master Reception

To halt reception at the end of a receive operation in master receive mode, set the TRS bit to 1 and write 0 to BBSY and SCP in ICCR. This changes SDA from low to high when SCL is high, and generates the stop condition. After this, receive data can be read by means of an ICDR read, but if data remains in the buffer the ICDRS receive data will not be transferred to ICDR, and so it will not be possible to read the second byte of data.

If it is necessary to read the second byte of data, issue the stop condition in master receive mode (i.e. with the TRS bit cleared to 0). When reading the receive data, first confirm that the BBSY bit in the ICCR register is cleared to 0, the stop condition has been generated, and the bus has been released, then read the ICDR register with TRS cleared to 0.

Note that if the receive data (ICDR data) is read in the interval between execution of the instruction for issuance of the stop condition (writing of 0 to BBSY and SCP in ICCR) and the actual generation of the stop condition, the clock may not be output correctly in subsequent master transmission.

Clearing of the MST bit after completion of master transmission/reception, or other modifications of IIC control bits to change the transmit/receive operating mode or settings, must be carried out during interval (a) in figure 16.18 (after confirming that the BBSY bit has been cleared to 0 in the ICCR register).

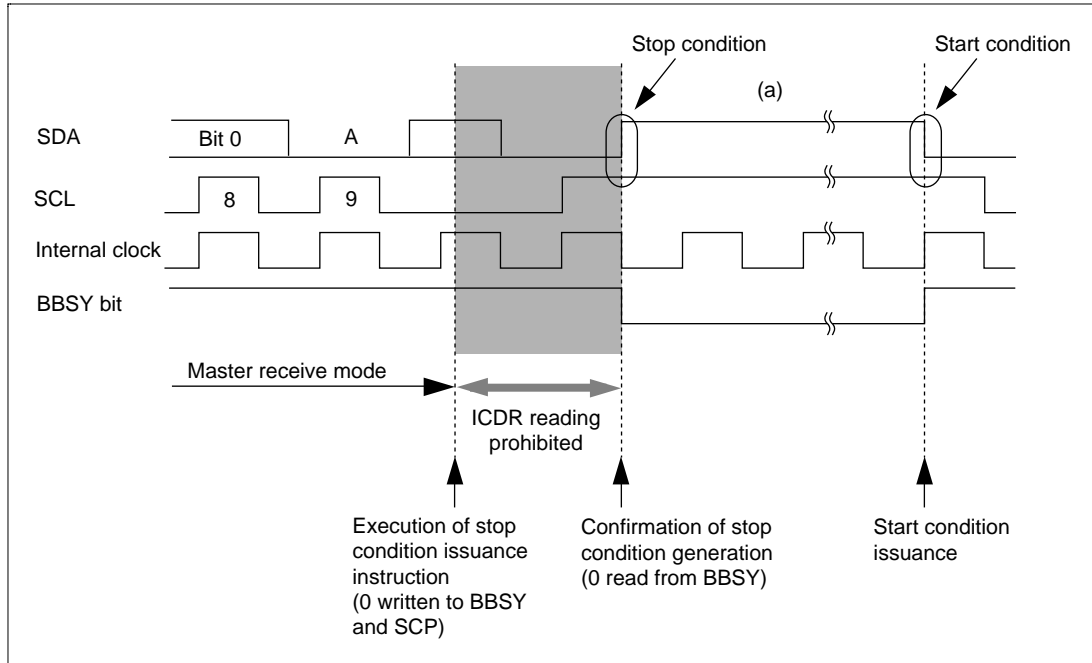


Figure 16.18 Points for Attention Concerning Reading of Master Receive Data

- Notes on Start Condition Issuance for Retransmission

Figure 16-19 shows the timing of start condition issuance for retransmission, and the timing for subsequently writing data to ICDR, together with the corresponding flowchart. After start condition issuance is done and determined the start condition, write the transmit data to ICDR, as shown below.

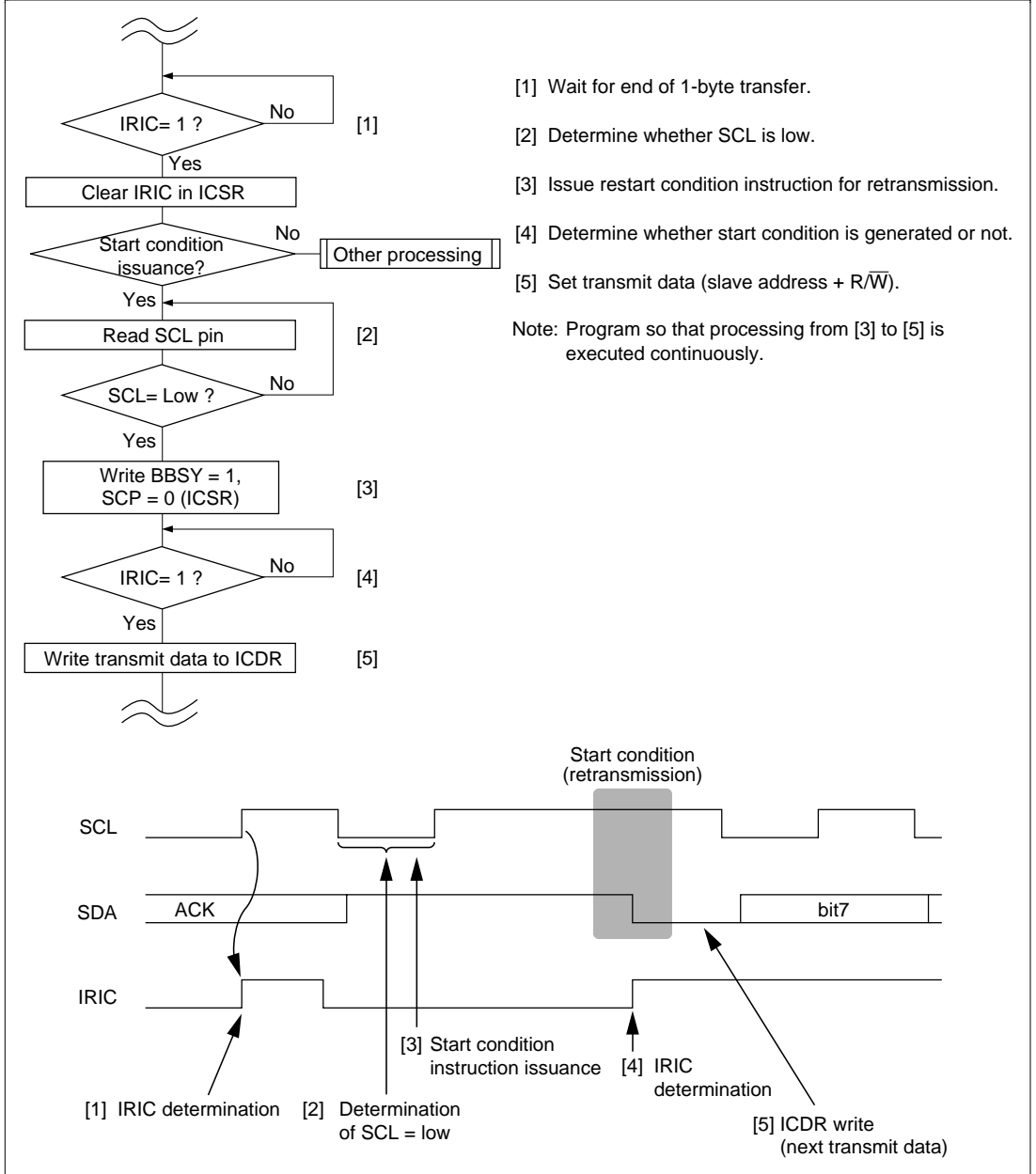


Figure 16.19 Flowchart and Timing of Start Condition Instruction Issuance for Retransmission

- Notes on I²C Bus Interface Stop Condition Instruction Issuance

If the rise time of the 9th SCL clock exceeds the specification because the bus load capacitance is large, or if there is a slave device of the type that drives SCL low to effect a wait, after rising of the 9th SCL clock, issue the stop condition instruction after reading SCL and determining it to be low, as shown below.

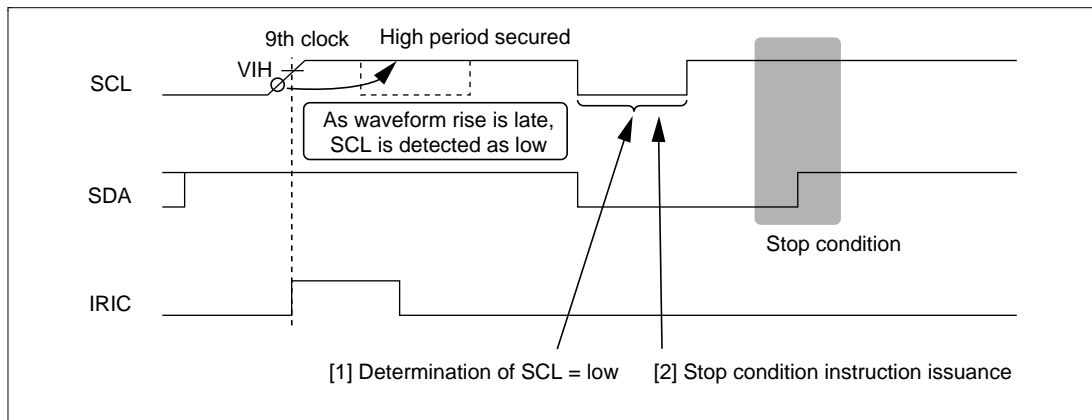


Figure 16.20 Timing of Stop Condition Issuance

22.1 Voltage of Power Supply and Operating Range

The power supply voltage and operating range (shaded part) for each product are shown in table 22.1.

Table 22.1 Power Supply Voltage and Operating Range (1)

(F-ZTAT Products)

Product/ Power supply	5 V version	Product/ Power supply	3 V version
HD64F2128	<p>Graph for HD64F2128 5V version: V_{cc} vs fop. Shaded region: 4.0 V to 5.5 V V_{cc}, 2 MHz to 20 MHz fop. Note: Select 5.0 V ± 0.5 V for programming condition in PROM programmer. Flash Memory Programming.</p>	HD64F2128V	<p>Graph for HD64F2128V 3V version: V_{cc} vs fop. Shaded region: 3.0 V to 5.5 V V_{cc}, 2 MHz to 10 MHz fop. Note: Select 5.0 V ± 0.5 V for programming condition in PROM programmer. Flash Memory Programming.</p>
VCC1 pin VCC2 pin	V _{cc} = 5.0 V ± 10% (fop = 2 to 20 MHz) V _{cc} = 4.0 V to 5.5 V (fop = 2 to 16 MHz)	VCC1 pin VCC2 pin	V _{cc} = 3.0 V to 5.5 V (fop = 2 to 10 MHz)
AVCC pin	AV _{cc} = 5.0 V ± 10% (fop = 2 to 20 MHz) AV _{cc} = 4.0 V to 5.5 V (fop = 2 to 16 MHz)	AVCC pin	AV _{cc} = 3.0 V to 5.5 V (fop = 2 to 10 MHz)

Table 22.1 Power Supply Voltage and Operating Range (2)
(Mask ROM Products)

Product/ Power supply	5 V version	4 V version	3 V version
HD6432128S HD6432128SW HD6432127S HD6432127SW	<p>A graph showing the operating range for the 5V version. The vertical axis is labeled V_{CC} with values 4.5 V and 5.5 V. The horizontal axis is labeled f_{op} with values 2 MHz and 20 MHz. A shaded rectangular region represents the operating range from 4.5 V to 5.5 V and 2 MHz to 20 MHz.</p>	<p>A graph showing the operating range for the 4V version. The vertical axis is labeled V_{CC} with values 4.0 V and 5.5 V. The horizontal axis is labeled f_{op} with values 2 MHz and 16 MHz. A shaded rectangular region represents the operating range from 4.0 V to 5.5 V and 2 MHz to 16 MHz.</p>	<p>A graph showing the operating range for the 3V version. The vertical axis is labeled V_{CC} with values 2.7 V and 3.6 V. The horizontal axis is labeled f_{op} with values 2 MHz and 10 MHz. A shaded rectangular region represents the operating range from 2.7 V to 3.6 V and 2 MHz to 10 MHz.</p>
VCC1 pin	V _{CC} = 5.0 V ± 10%	V _{CC} = 4.0 V to 5.5 V	V _{CC} = 2.7 V to 3.6 V (When using CIN input, V _{CC} = 3.0 V to 3.6 V)
VCL pin (VCC2)	V _{CL} = C connection	V _{CL} = C connection	V _{CL} = V _{CC} connection
AVCC pin	AV _{CC} = 5.0 V ± 10%	AV _{CC} = 4.0 V to 5.5 V	AV _{CC} = 2.7 V to 3.6 V (When using CIN input, AV _{CC} = 3.0 V to 3.6 V)

Table 22.1 Power Supply Voltage and Operating Range (3)
(Mask ROM Products)

Product/ Power supply	5 V version	4 V version	3 V version
HD6432127R HD6432127RW HD6432126R HD6432126RW HD6432122 HD6432120	<p>A graph showing the operating range for the 5V version. The vertical axis is labeled V_{CC} with values 4.5 V and 5.5 V. The horizontal axis is labeled f_{op} with values 2 MHz and 20 MHz. A shaded rectangular region represents the operating range from 4.5 V to 5.5 V and 2 MHz to 20 MHz.</p>	<p>A graph showing the operating range for the 4V version. The vertical axis is labeled V_{CC} with values 4.0 V and 5.5 V. The horizontal axis is labeled f_{op} with values 2 MHz and 16 MHz. A shaded rectangular region represents the operating range from 4.0 V to 5.5 V and 2 MHz to 16 MHz.</p>	<p>A graph showing the operating range for the 3V version. The vertical axis is labeled V_{CC} with values 2.7 V and 5.5 V. The horizontal axis is labeled f_{op} with values 2 MHz and 10 MHz. A shaded rectangular region represents the operating range from 2.7 V to 5.5 V and 2 MHz to 10 MHz.</p>
VCC1 pin VCC2 pin	V _{CC} = 5.0 V ± 10%	V _{CC} = 4.0 V to 5.5 V	V _{CC} = 2.7 V to 5.5 V
AVCC pin	AV _{CC} = 5.0 V ± 10%	AV _{CC} = 4.0 V to 5.5 V	AV _{CC} = 2.7 V to 5.5 V

22.2 Electrical Characteristics [H8S/2128 Series, H8S/2128 F-ZTAT]

22.2.1 Absolute Maximum Ratings

Table 22.2 lists the absolute maximum ratings.

Table 22.2 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	−0.3 to +7.0	V
Input voltage (except ports 6, and 7)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input not selected for port 6)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input selected for port 6)	V_{in}	Lower voltage of −0.3 to $V_{CC} + 0.3$ and $AV_{CC} + 0.3$	V
Input voltage (port 7)	V_{in}	−0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	−0.3 to +7.0	V
Analog input voltage	V_{AN}	−0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: −20 to +75	°C
		Wide-range specifications: −40 to +85	°C
Operating temperature (Flash memory programming/erasing)	T_{opr}	Regular specifications: 0 to +75	°C
		Wide-range specifications: 0 to +85	°C
Storage temperature	T_{stg}	−55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

22.2.2 DC Characteristics

Table 22.3 lists the DC characteristics. Table 22.4 lists the permissible output currents.

Table 22.3 DC Characteristics (1)

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC}^{*1} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$,

$T_a = -20 \text{ to } +75^\circ\text{C}^{*8}$ (regular specifications),

$T_a = -40 \text{ to } +85^\circ\text{C}^{*8}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *5} , (1) IRQ2 to IRQ0 ^{*3}	V_T^-	1.0	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	RES, STBY, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		2.0	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		2.0	—	$V_{CC} + 0.3$	V	
Input low voltage	RES, STBY, (3) MD1, MD0	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V	
Output high voltage	All output pins (except P47, and P52 ^{*4})	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$
	P47, P52 ^{*4}		2.5	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	STBY, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5 V$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	50	—	300	μA	$V_{in} = 0 V$
Input capacitance	\overline{RES}	(4) C_{in}	—	—	80	pF	$V_{in} = 0 V$ $f = 1 MHz$ $T_a = 25^\circ C$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{CC}	—	70	90	mA	$f = 20 MHz$
	Sleep mode		—	55	75	mA	$f = 20 MHz$
	Standby mode* ⁷		—	0.01	5.0	μA	$T_a \leq 50^\circ C$
			—	—	20.0	μA	$50^\circ C < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0 V$ to $5.5 V$
Analog power supply voltage* ¹		AV_{CC}	4.5	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

- Notes: *¹ Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.
- *² P67 to P60 include supporting module inputs multiplexed on those pins.
- *³ $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.
- *⁴ In the H8S/2128 Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.
An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 ($ICE = 1$).
In the H8S/2128 Series, P52/SCK0 and P47 ($ICE = 0$) high levels are driven by NMOS.

- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 4.5 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.
- *8 For flash memory program/erase operations, the applicable range is $T_a = 0 \text{ to } +75^\circ\text{C}$ (regular specifications) or $T_a = 0 \text{ to } +85^\circ\text{C}$ (wide-range specifications).

Table 22.3 DC Characteristics (2)

Conditions: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}^{*8}$, $AV_{CC}^{*1} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$,

$T_a = -20 \text{ to } +75^\circ\text{C}^{*8}$ (regular specifications),

$T_a = -40 \text{ to } +85^\circ\text{C}^{*8}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *5} , (1) IRQ2 to IRQ0 ^{*3}	V_T^-	1.0	—	—	V	$V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
		V_T^-	0.8	—	—	V	$V_{CC} < 4.5 \text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.3	—	—	V	
Input high voltage	RES, STBY, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		2.0	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		2.0	—	$V_{CC} + 0.3$	V	
Input low voltage	RES, STBY, (3) MD1, MD0	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V	
Output high voltage	All output pins (except P47, and P52 ^{*4})	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$, $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$
			3.0	—	—	V	$I_{OH} = -1 \text{ mA}$, $V_{CC} < 4.5 \text{ V}$
	P47, P52 ^{*4}		2.0	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	STBY, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6		$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5$ V
Input pull-up MOS current	Ports 1 to 3		$-I_P$	50	—	300	μA	$V_{in} = 0$ V, $V_{CC} = 4.5$ V to 5.5 V
				30	—	200	μA	$V_{in} = 0$ V, $V_{CC} < 4.5$ V
Input capacitance	RES	(4)	C_{in}	—	—	80	pF	$V_{in} = 0$ V, $f = 1$ MHz, $T_a = 25^\circ\text{C}$
	NMI	—		—	50	pF		
	P52, P47, P24, P23	—		—	20	pF		
	Input pins except (4) above	—		—	15	pF		
Current dissipation* ⁶	Normal operation		I_{CC}	—	55	75	mA	$f = 16$ MHz
	Sleep mode			—	42	62	mA	$f = 16$ MHz
	Standby mode* ⁷			—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
				—	—	20.0	μA	$50^\circ\text{C} < T_a$
Analog power supply current	During A/D conversion		AI_{CC}	—	1.5	3.0	mA	$AV_{CC} = 2.0$ V to 5.5 V
	Idle			—	0.01	5.0	μA	
Analog power supply voltage* ¹			AV_{CC}	4.0	—	5.5	V	Operating
				2.0	—	5.5	V	Idle/not used
RAM standby voltage			V_{RAM}	2.0	—	—	V	

- Notes: *1 Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.
- *2 P67 to P60 include supporting module inputs multiplexed on those pins.
- *3 $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.
- *4 In the H8S/2128 Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.
An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 ($\text{ICE} = 1$).
In the H8S/2128 Series, P52/SCK0 and P47 ($\text{ICE} = 0$) high levels are driven by NMOS.
- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3$ V when CIN input is not selected, and the lower of $V_{CC} + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected.
When a pin is in output mode, the output voltage is equivalent to the applied voltage.

- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 4.0 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.
- *8 For flash memory program/erase operations, the applicable ranges are $V_{CC} = 4.5 \text{ V}$ to 5.5 V and $T_a = 0$ to $+75^\circ\text{C}$ (regular specifications) or $T_a = 0$ to $+85^\circ\text{C}$ (wide-range specifications).

Table 22.3 DC Characteristics (3)

Conditions (Mask ROM version): $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC}^{*1} = 2.7 \text{ V to } 5.5 \text{ V}$,
 $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

(Flash memory version): $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC}^{*1} = 3.0 \text{ V to } 5.5 \text{ V}$,
 $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$, $T_a = -20 \text{ to } +75^\circ\text{C}^{*8}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *5} , (1) $\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}^{*3}$	V_T^-	$V_{CC} \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	$\overline{\text{RES}}$, $\overline{\text{STBY}}$, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	$\overline{\text{RES}}$, $\overline{\text{STBY}}$, (3) MD1, MD0	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V	$V_{CC} < 4.0 \text{ V}$
					0.8	V	$V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$
Output high voltage	All output pins (except P47, and P52 ^{*4})	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = -1 \text{ mA}$ ($V_{CC} < 4.0 \text{ V}$)
	P47, P52 ^{*4}		1.0	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 5 \text{ mA}$ ($V_{CC} < 4.0 \text{ V}$), $I_{OL} = 10 \text{ mA}$ ($4.0 \text{ V} \leq V_{CC} \leq 5.5 \text{ V}$)
Input leakage current	$\overline{\text{RES}}$	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	$\overline{\text{STBY}}$, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5 V$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	10	—	150	μA	$V_{in} = 0 V$, $V_{CC} = 2.7 V$ to $3.6 V$
Input capacitance	\overline{RES}	(4) C_{in}	—	—	80	pF	$V_{in} = 0 V$, $f = 1 MHz$, $T_a = 25^\circ C$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{CC}	—	40	52	mA	$f = 10 MHz$
	Sleep mode		—	30	42	mA	$f = 10 MHz$
	Standby mode* ⁷		—	0.01	5.0	μA	$T_a \leq 50^\circ C$
			—	—	20.0	μA	$50^\circ C < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0 V$ to $5.5 V$
Analog power supply voltage* ¹		AV_{CC}	2.7	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *1 Do not leave the AV_{CC} and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*2 P67 to P60 include supporting module inputs multiplexed on those pins.

*3 $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.

*4 In the H8S/2128 Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.
An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 ($ICE = 1$).
In the H8S/2128 Series, P52/SCK0 and P47 ($ICE = 0$) high levels are driven by NMOS.

- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 2.7 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.
- *8 For flash memory program/erase operations, the applicable range is $V_{CC} = 3.0 \text{ V}$ to 3.6 V and $T_a = 0$ to $+75^\circ\text{C}$.

Table 22.4 Permissible Output Currents

Conditions: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $T_a = -20\text{ to }+75^{\circ}\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^{\circ}\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0	I_{OL}	—	—	20	mA
	Ports 1, 2, 3		—	—	10	mA
	Other output pins		—	—	2	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	80	mA
	Total of all output pins, including the above		—	—	120	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	40	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.4.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.1 and 22.2.

Table 22.4 Permissible Output Currents (cont)

Conditions: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $T_a = -20\text{ to }+75^{\circ}\text{C}$

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0	I_{OL}	—	—	10	mA
	Ports 1, 2, 3		—	—	2	mA
	Other output pins		—	—	1	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	40	mA
	Total of all output pins, including the above		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	30	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.4.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.1 and 22.2.

Table 22.5 Bus Drive Characteristics

Conditions: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$

Applicable Pins: SCL1, SCL0, SDA1, SDA0 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	V_T^-	$V_{CC} \times 0.3$	—	—	V	$V_{CC} = 2.7\text{ V to }5.5\text{ V}$
	V_T^+	—	—	$V_{CC} \times 0.7$		$V_{CC} = 2.7\text{ V to }5.5\text{ V}$
	$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—		$V_{CC} = 2.7\text{ V to }5.5\text{ V}$
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	$V_{CC} = 2.7\text{ V to }5.5\text{ V}$
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$		$V_{CC} = 2.7\text{ V to }5.5\text{ V}$
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16\text{ mA}$, $V_{CC} = 4.5\text{ V to }5.5\text{ V}$
		—	—	0.5		$I_{OL} = 8\text{ mA}$
		—	—	0.4		$I_{OL} = 3\text{ mA}$
Input capacitance	C_{in}	—	—	20	pF	$V_{in} = 0\text{ V}$, $f = 1\text{ MHz}$, $T_a = 25^\circ\text{C}$
Three-state leakage current (off state)	$ I_{TSL} $	—	—	1.0	μA	$V_{in} = 0.5\text{ to }V_{CC} - 0.5\text{ V}$
SCL, SDA output fall time	t_{Of}	$20 + 0.1Cb$	—	250	ns	$V_{CC} = 2.7\text{ V to }5.5\text{ V}$

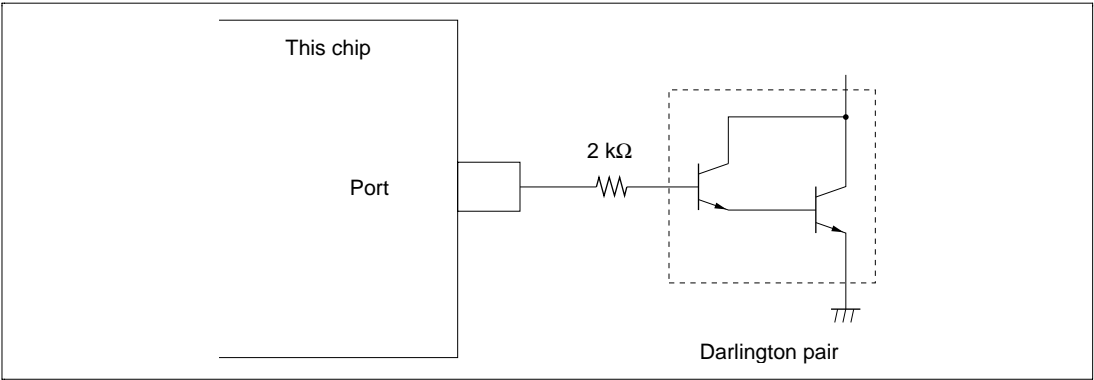


Figure 22.1 Darlington Pair Drive Circuit (Example)

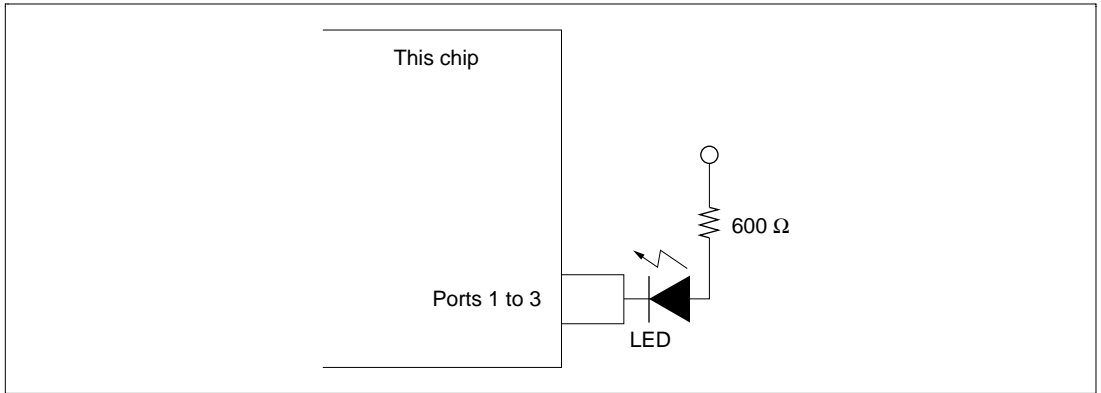


Figure 22.2 LED Drive Circuit (Example)

22.2.3 AC Characteristics

Figure 22.3 shows the test conditions for the AC characteristics.

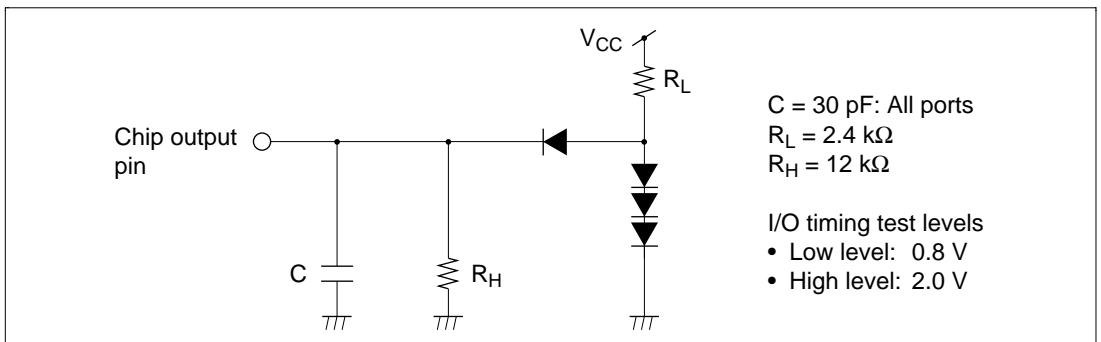


Figure 22.3 Output Load Circuit

(1) Clock Timing

Table 22.6 shows the clock timing. The clock timing specified here covers clock (ϕ) output and clock pulse generator (crystal) and external clock input (EXTAL pin) oscillation settling times. For details of external clock input (EXTAL pin and EXCL pin) timing, see section 20, Clock Pulse Generator.

Table 22.6 Clock Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V^* , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Clock cycle time	t _{cyc}	50	500	62.5	500	100	500	ns	Figure 22.4
Clock high pulse width	t _{CH}	17	—	20	—	30	—	ns	Figure 22.4
Clock low pulse width	t _{CL}	17	—	20	—	30	—	ns	
Clock rise time	t _{Cr}	—	8	—	10	—	20	ns	
Clock fall time	t _{Cf}	—	8	—	10	—	20	ns	
Oscillation settling time at reset (crystal)	t _{OSC1}	10	—	10	—	20	—	ms	Figure 22.5 Figure 22.6
Oscillation settling time in software standby (crystal)	t _{OSC2}	8	—	8	—	8	—	ms	
External clock output stabilization delay time	t _{DEXT}	500	—	500	—	500	—	μs	

Note: * For the low-voltage F-ZTAT version, $V_{CC} = 3.0 \text{ V}$ to 5.5 V .

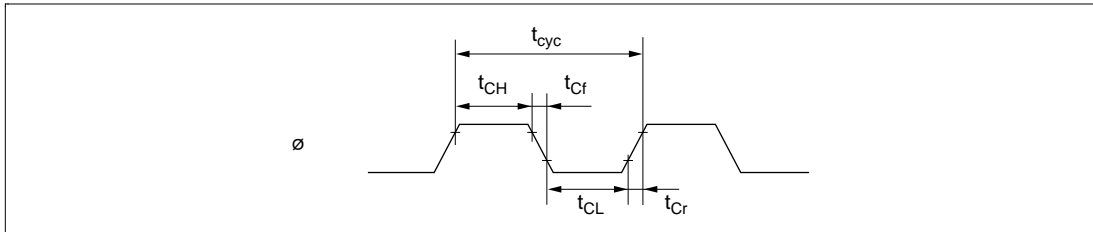


Figure 22.4 System Clock Timing

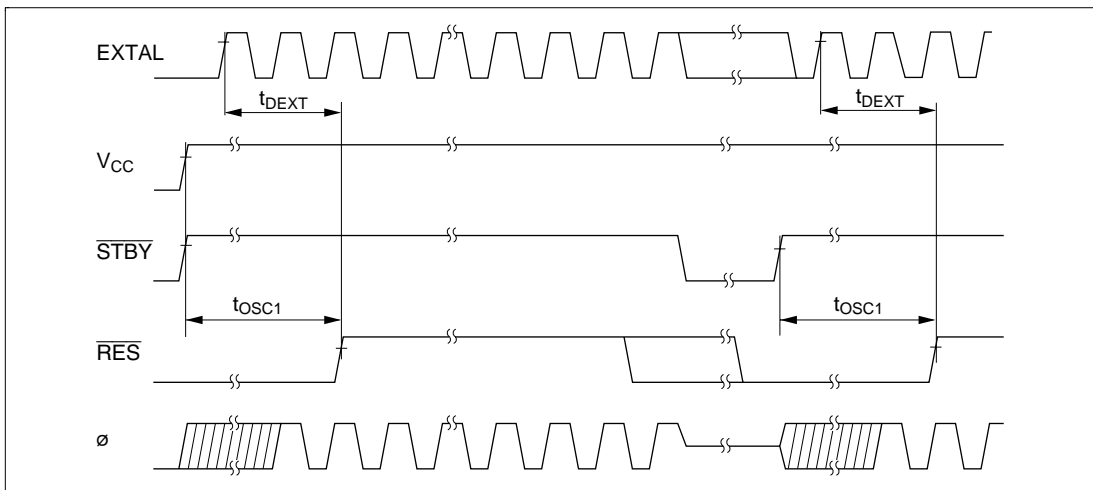


Figure 22.5 Oscillation Settling Timing

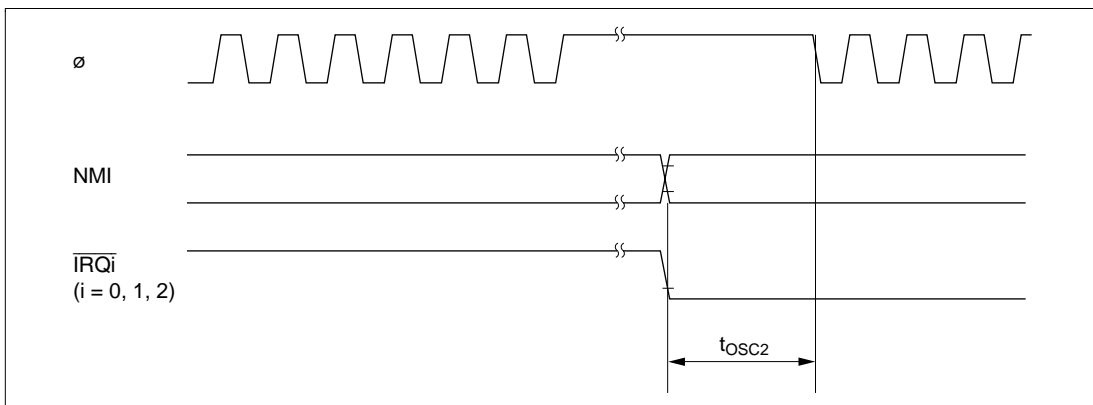


Figure 22.6 Oscillation Setting Timing (Exiting Software Standby Mode)

(2) Control Signal Timing

Table 22.7 shows the control signal timing. The only external interrupts that can operate on the subclock ($\phi = 32.768$ kHz) are NMI and IRQ0, 1, and IRQ2.

Table 22.7 Control Signal Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V^* , $V_{SS} = 0 \text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
$\overline{\text{RES}}$ setup time	t_{RESS}	200	—	200	—	300	—	ns	Figure 22.7
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Figure 22.8
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time ($\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time ($\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width ($\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

Note: * For the low-voltage F-ZTAT version, $V_{CC} = 3.0 \text{ V}$ to 5.5 V .

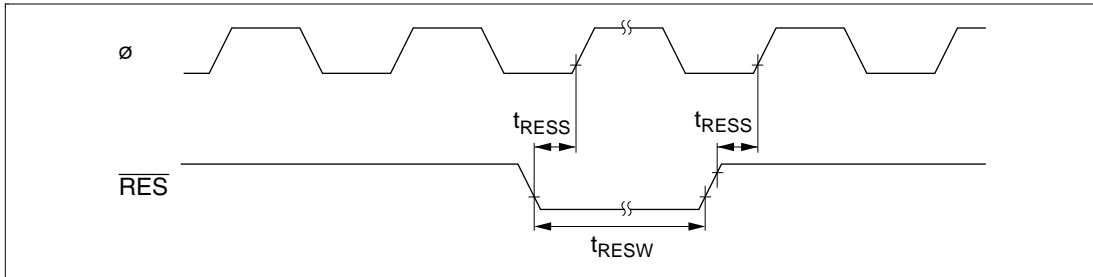


Figure 22.7 Reset Input Timing

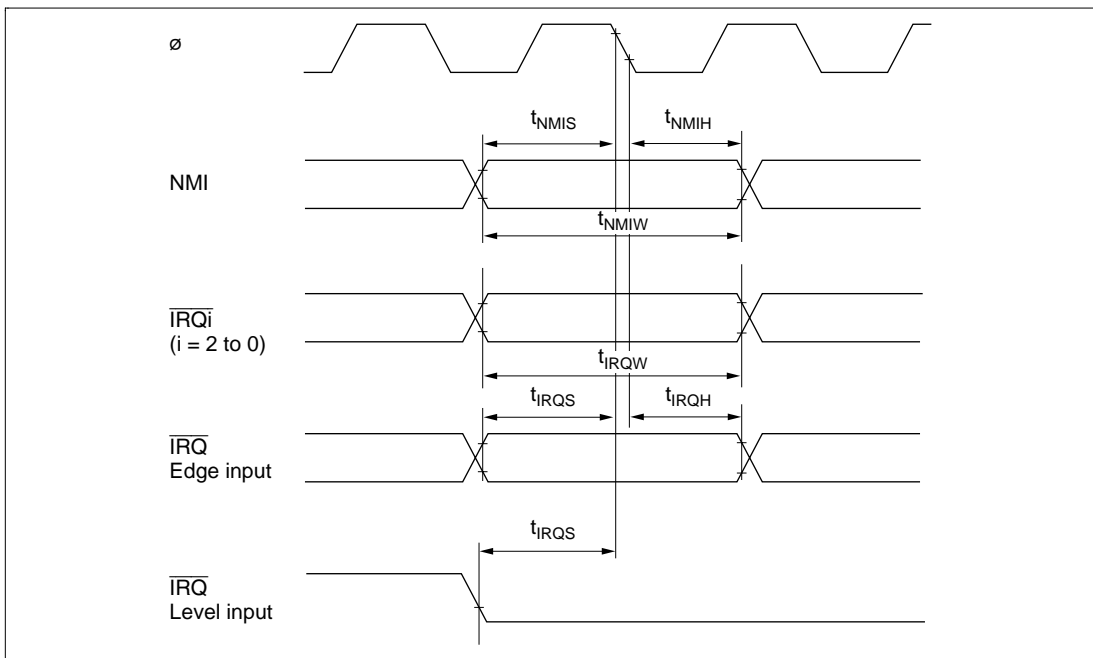


Figure 22.8 Interrupt Input Timing

(3) Bus Timing

Table 22.8 shows the bus timing. Operation in external expansion mode is not guaranteed when operating on the subclock ($\phi = 32.768$ kHz).

Table 22.8 Bus Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

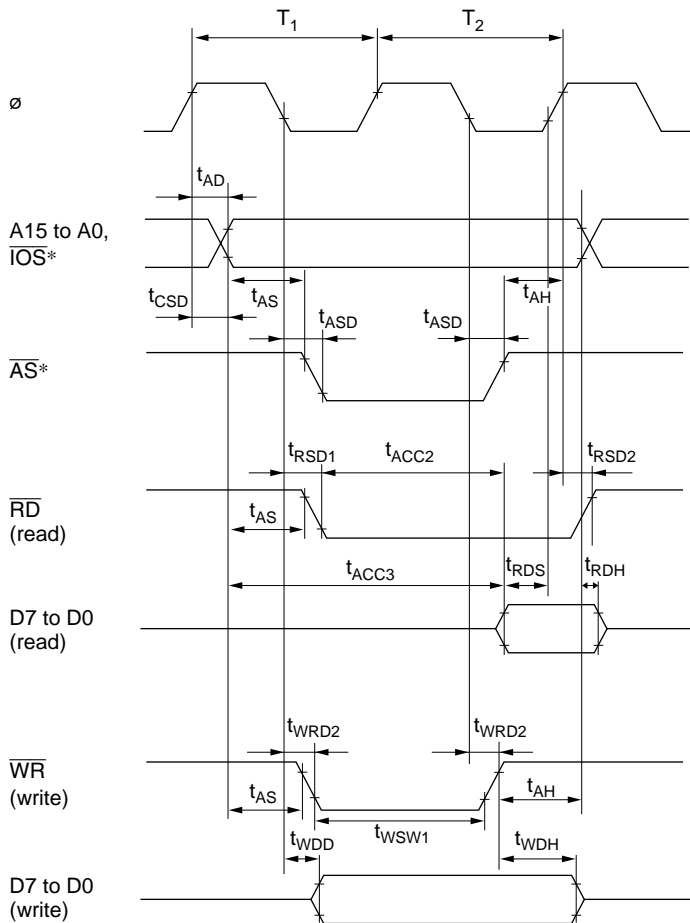
Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V^* , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Address delay time	t _{AD}	—	20	—	30	—	40	ns	Figure 22.9 to figure 22.13
Address setup time	t _{AS}	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	0.5 × t _{cyc} – 30	—	ns	
Address hold time	t _{AH}	0.5 × t _{cyc} – 10	—	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	ns	
\overline{CS} delay time (IOS)	t _{CSD}	—	20	—	30	—	40	ns	
\overline{AS} delay time	t _{ASD}	—	30	—	45	—	60	ns	
\overline{RD} delay time 1	t _{RSD1}	—	30	—	45	—	60	ns	
\overline{RD} delay time 2	t _{RSD2}	—	30	—	45	—	60	ns	
Read data setup time	t _{RDS}	15	—	20	—	35	—	ns	
Read data hold time	t _{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t _{ACC1}	—	1.0 × t _{cyc} – 30	—	1.0 × t _{cyc} – 40	—	1.0 × t _{cyc} – 60	ns	
Read data access time 2	t _{ACC2}	—	1.5 × t _{cyc} – 25	—	1.5 × t _{cyc} – 35	—	1.5 × t _{cyc} – 50	ns	

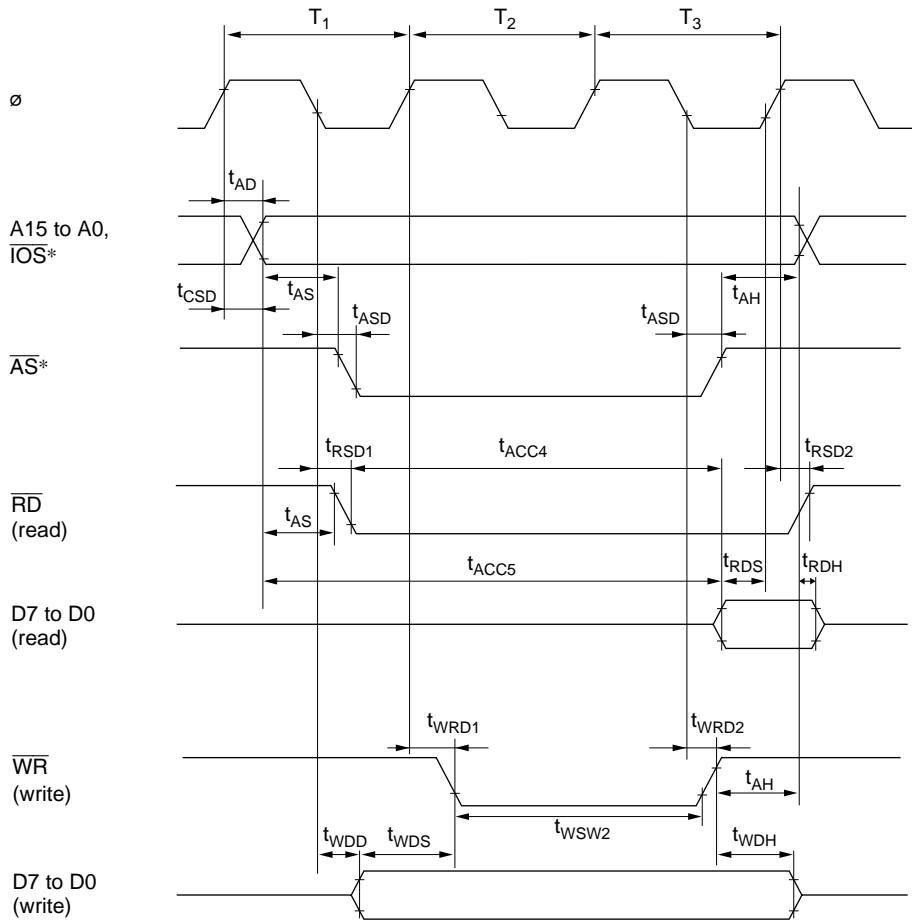
Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		Min	Max	Min	Max	Min	Max		
Read data access time 3	t_{ACC3}	—	$2.0 \times t_{cyc} - 30$	—	$2.0 \times t_{cyc} - 40$	—	$2.0 \times t_{cyc} - 60$	ns	Figure 22.9 to figure 22.13
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 25$	—	$2.5 \times t_{cyc} - 35$	—	$2.5 \times t_{cyc} - 50$	ns	
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 30$	—	$3.0 \times t_{cyc} - 40$	—	$3.0 \times t_{cyc} - 60$	ns	
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns	
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns	
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 20$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 40$	—	ns	
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 20$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 40$	—	ns	
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns	
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns	
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns	
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns	
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns	

Note: * For the low-voltage F-ZTAT version, $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$.



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.9 Basic Bus Timing (Two-State Access)



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.10 Basic Bus Timing (Three-State Access)

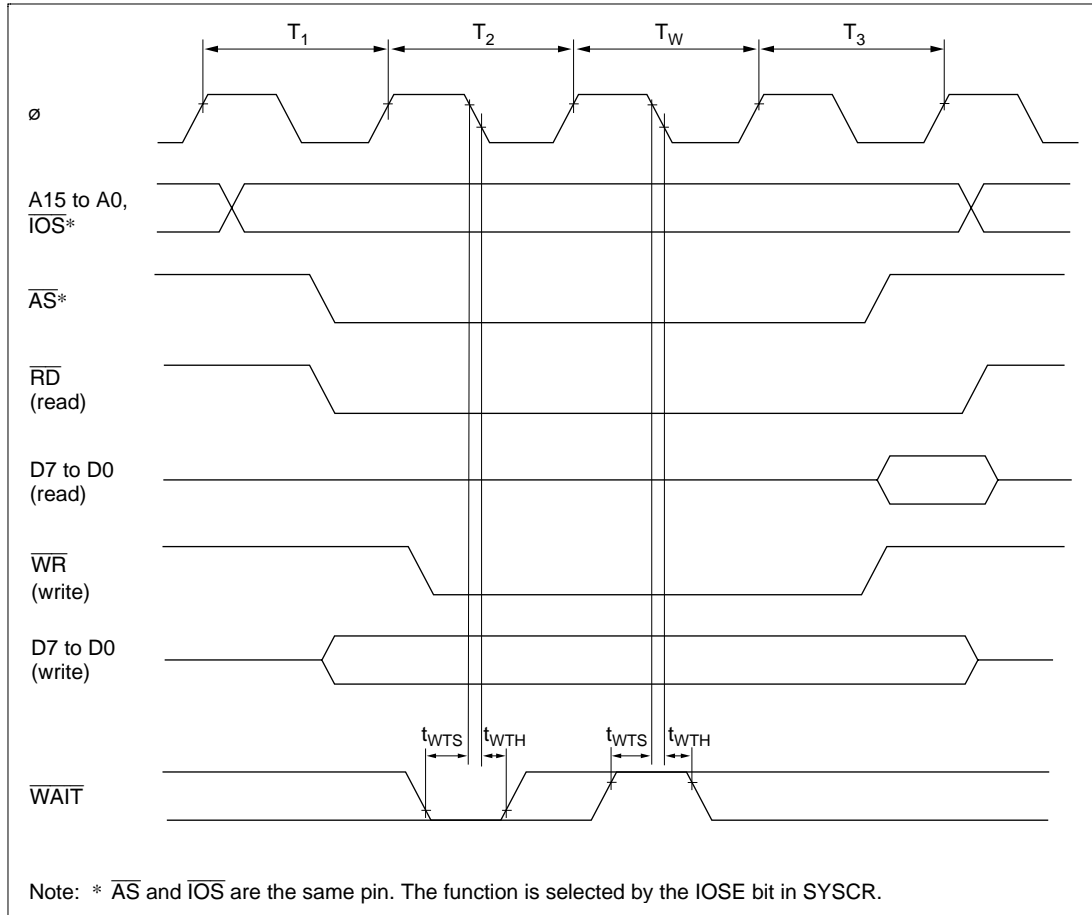


Figure 22.11 Basic Bus Timing (Three-State Access with One Wait State)

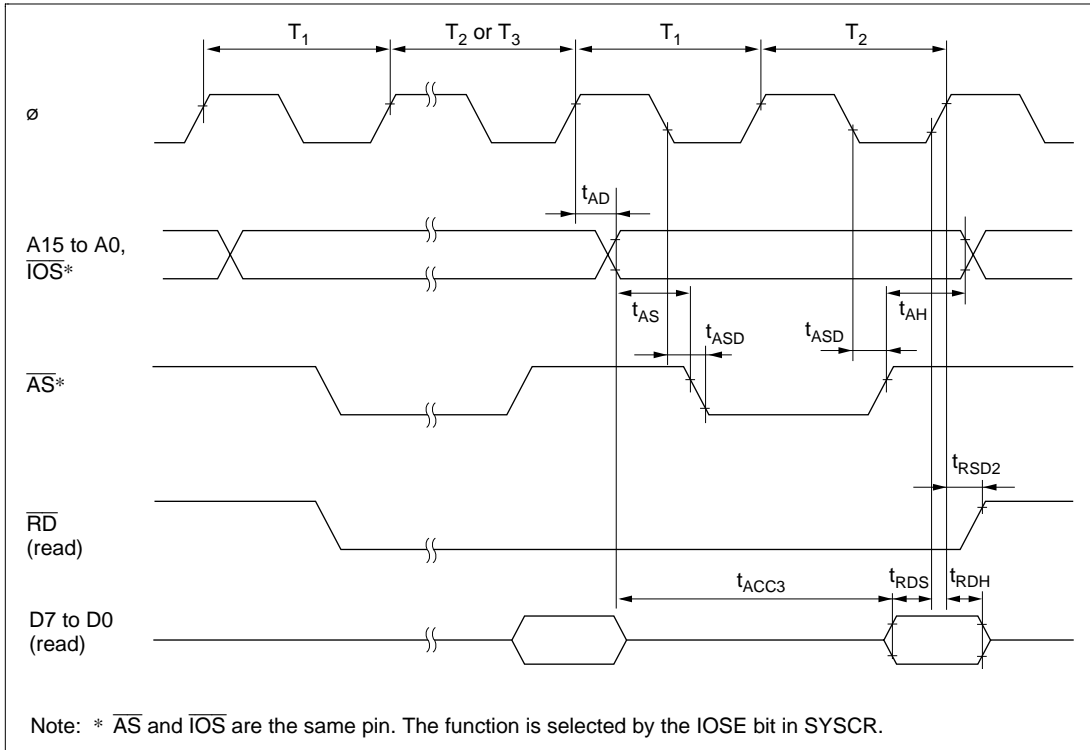
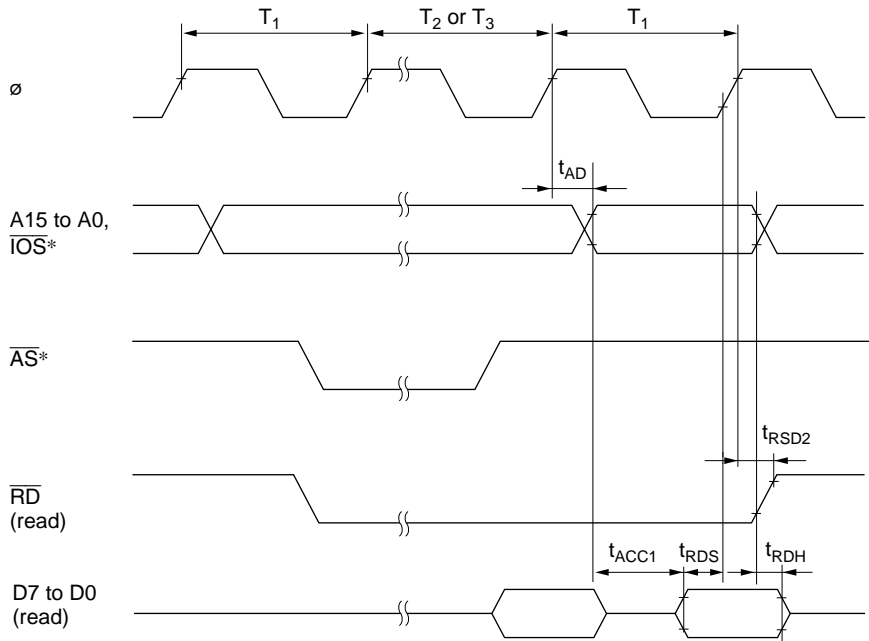


Figure 22.12 Burst ROM Access Timing (Two-State Access)



Note: * \overline{AS} and $\overline{I/O}$ are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.13 Burst ROM Access Timing (One-State Access)

(4) Timing of On-Chip Supporting Modules

Tables 22.9 and 22.10 show the on-chip supporting module timing. The only on-chip supporting modules that can operate in subclock operation ($\phi = 32.768 \text{ kHz}$) are the I/O ports, external interrupts (NMI and IRQ0, 1, and IRQ2), the watchdog timer, and the 8-bit timer (channels 0 and 1).

Table 22.9 Timing of On-Chip Supporting Modules

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^{*1}$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^{*1}$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}^{*2}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^{*1}$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item		Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions	
			20 MHz		16 MHz		10 MHz				
			Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	t _{PWD}	—	50	—	50	—	100	ns	Figure 22.14	
	Input data setup time	t _{PRS}	30	—	30	—	50	—			
	Input data hold time	t _{PRH}	30	—	30	—	50	—			
FRT	Timer output delay time	t _{FTOD}	—	50	—	50	—	100	ns	Figure 22.15	
	Timer input setup time	t _{FTIS}	30	—	30	—	50	—			
	Timer clock input setup time	t _{FTCS}	30	—	30	—	50	—		Figure 22.16	
	Timer clock pulse width	Single edge	t _{FTCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	
		Both edges	t _{FTCWL}	2.5	—	2.5	—	2.5	—		

Item		Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions	
			Min	Max	Min	Max	Min	Max			
											20 MHz
TMR	Timer output delay time	t _{TMOD}	—	50	—	50	—	100	ns	Figure 22.17	
	Timer reset input setup time	t _{TMRs}	30	—	30	—	50	—		Figure 22.19	
	Timer clock input setup time	t _{TMCs}	30	—	30	—	50	—		Figure 22.18	
	Timer clock pulse width	Single edge	t _{TMCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	
		Both edges	t _{TMCWL}	2.5	—	2.5	—	2.5	—		
PWM, PWMX	Pulse output delay time	t _{PWOD}	—	50	—	50	—	100	ns	Figure 22.20	
SCI	Input clock cycle	Asynchronous	t _{Scyc}	4	—	4	—	4	—	t _{cyc}	Figure 22.21
		Synchronous		6	—	6	—	6	—		
	Input clock pulse width	t _{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	t _{Scyc}		
	Input clock rise time	t _{SCKr}	—	1.5	—	1.5	—	1.5	t _{cyc}		
	Input clock fall time	t _{SCKf}	—	1.5	—	1.5	—	1.5			
	Transmit data delay time (synchronous)	t _{TXD}	—	50	—	50	—	100	ns	Figure 22.22	
	Receive data setup time (synchronous)	t _{RXS}	50	—	50	—	100	—	ns		
	Receive data hold time (synchronous)	t _{RXH}	50	—	50	—	100	—	ns		
A/D converter	Trigger input setup time	t _{TRGS}	30	—	30	—	50	—	ns	Figure 22.23	

- Notes: 1. Only supporting modules that can be used in subclock operation
2. For the low-voltage F-ZTAT version, $V_{CC} = 3.0\text{ V}$ to 5.5 V

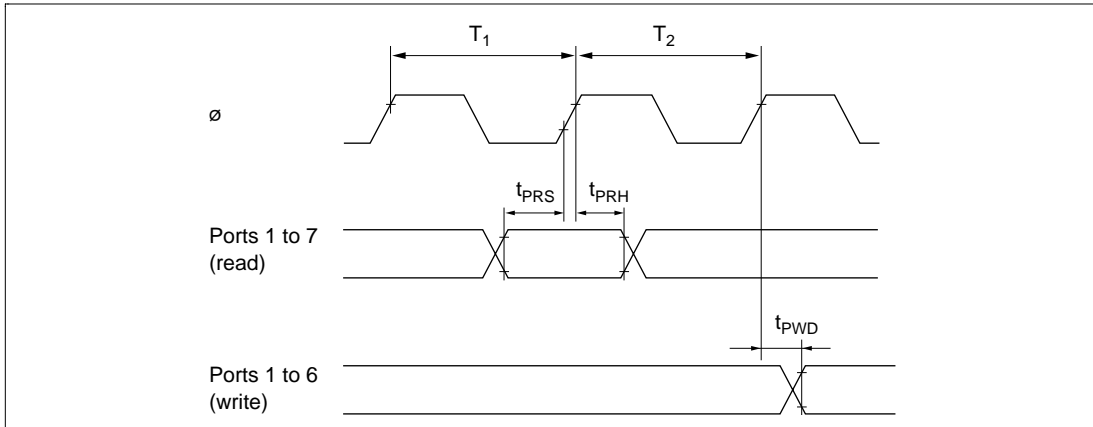


Figure 22.14 I/O Port Input/Output Timing

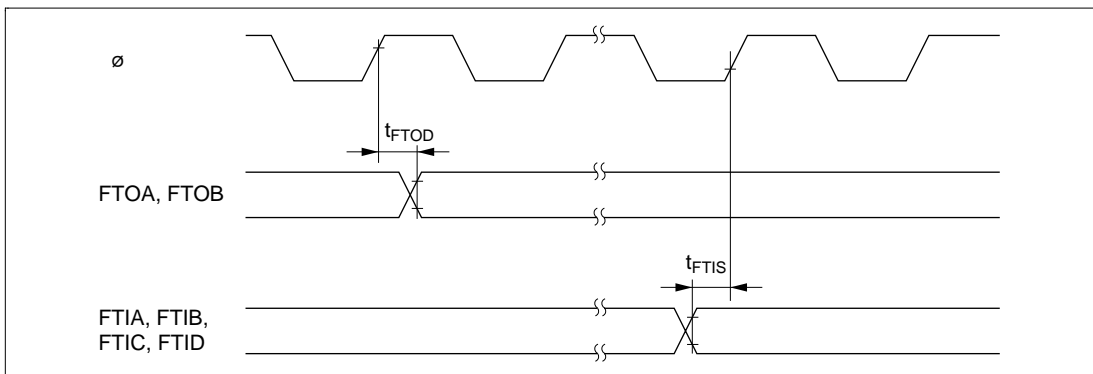


Figure 22.15 FRT Input/Output Timing

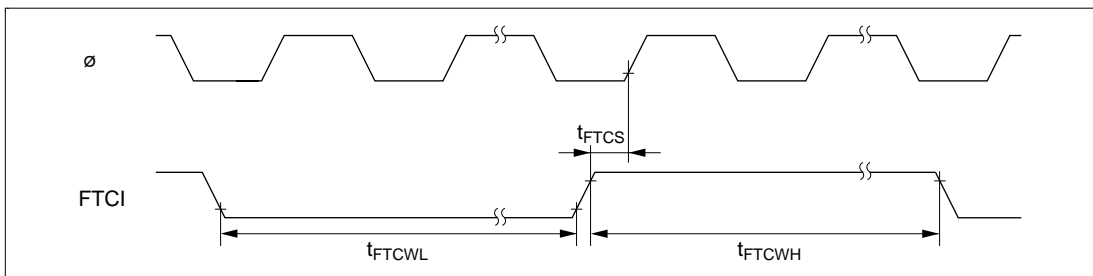


Figure 22.16 FRT Clock Input Timing

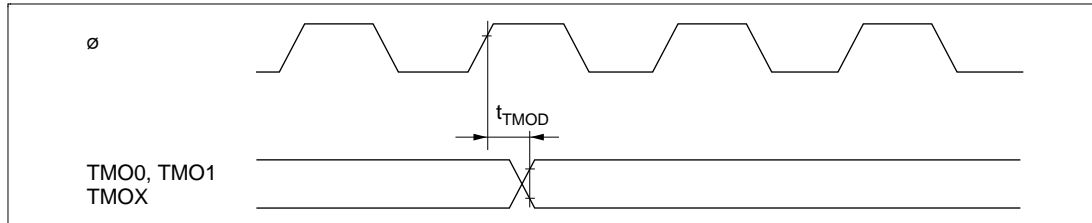


Figure 22.17 8-Bit Timer Output Timing

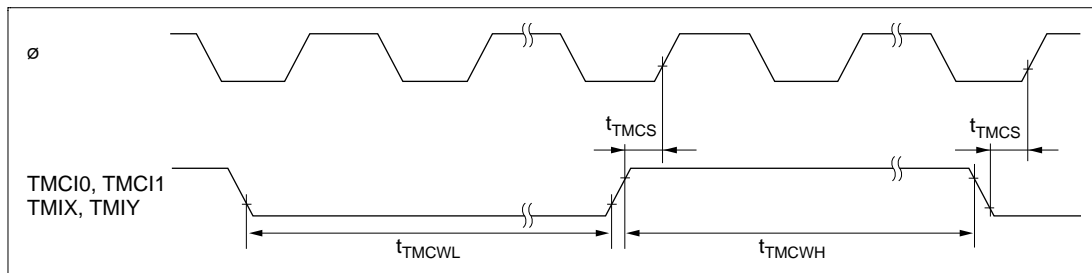


Figure 22.18 8-Bit Timer Clock Input Timing

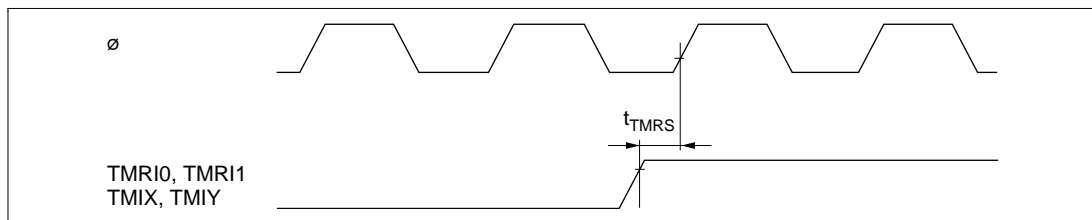


Figure 22.19 8-Bit Timer Reset Input Timing

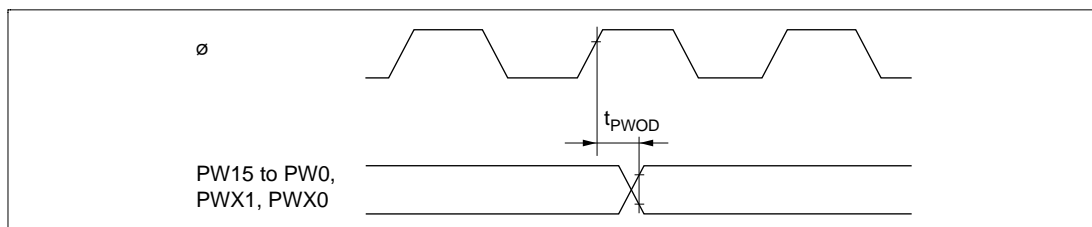


Figure 22.20 PWM, PWMX Output Timing

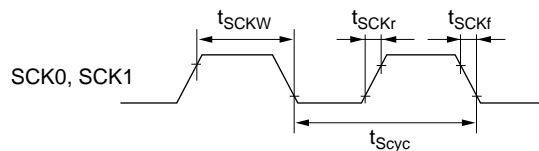


Figure 22.21 SCK Clock Input Timing

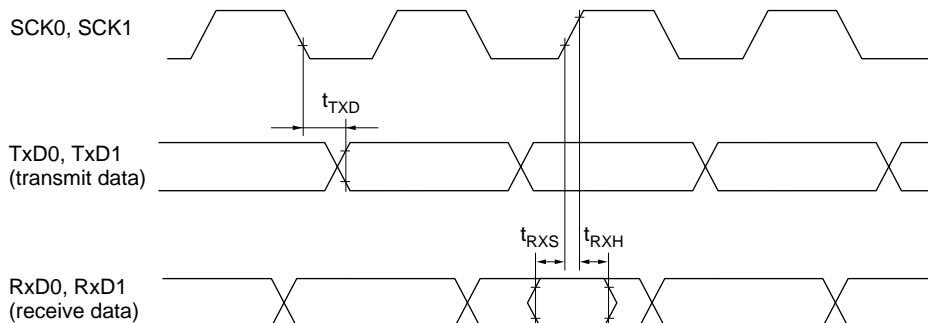


Figure 22.22 SCI Input/Output Timing (Synchronous Mode)

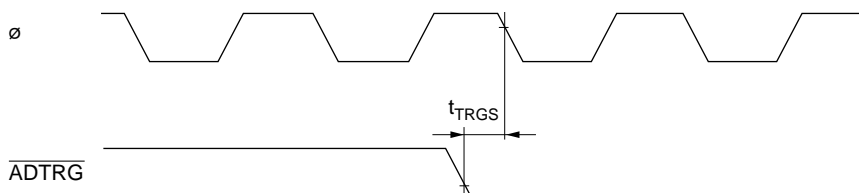


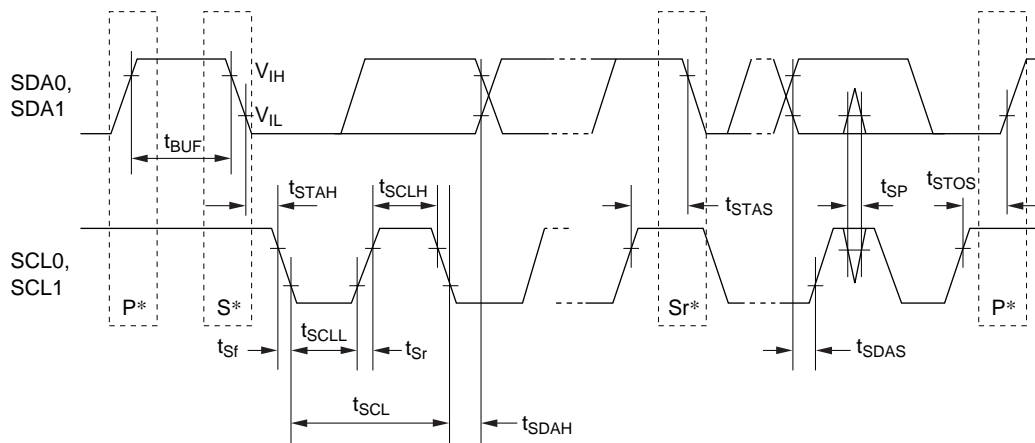
Figure 22.23 A/D Converter External Trigger Input Timing

Table 22.10 I²C Bus Timing

Conditions: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 5\text{ MHz}$ to maximum operating frequency,
 $T_a = -20\text{ to }+75^{\circ}\text{C}$

Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Notes
SCL clock cycle time	t_{SCL}	12	—	—	t_{cyc}		Figure 22.24
SCL clock high pulse width	t_{SCLH}	3	—	—	t_{cyc}		
SCL clock low pulse width	t_{SCLL}	5	—	—	t_{cyc}		
SCL, SDA input rise time	t_{Sr}	—	—	7.5*	t_{cyc}		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	t_{SP}	—	—	1	t_{cyc}		
SDA input bus free time	t_{BUF}	5	—	—	t_{cyc}		
Start condition input hold time	t_{STAH}	3	—	—	t_{cyc}		
Retransmission start condition input setup time	t_{STAS}	3	—	—	t_{cyc}		
Stop condition input setup time	t_{STOS}	3	—	—	t_{cyc}		
Data input setup time	t_{SDAS}	0.5	—	—	t_{cyc}		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitive load	C_b	—	—	400	pF		

Note: * $17.5t_{cyc}$ can be set according to the clock selected for use by the I²C module. For details, see section 16.4, Usage Notes.



Note: * S, P, and Sr indicate the following conditions.

S: Start condition

P: Stop condition

Sr: Retransmission start condition

Figure 22.24 I²C Bus Interface Input/Output Timing (Option)

22.2.4 A/D Conversion Characteristics

Tables 22.11 and 22.12 list the A/D conversion characteristics.

Table 22.11 A/D Conversion Characteristics
(AN7 to AN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $AV_{CC} = 4.0 \text{ V}$ to 5.5 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V^{*5} , $AV_{CC} = 2.7 \text{ V}$ to 5.5 V^{*5}
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*6	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*3	—	—	10*3	—	—	10*1	kΩ
			5*4			5*4			5*2	
Nonlinearity error	—	—	±3.0	—	—	±3.0	—	—	±7.0	LSB
Offset error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Full-scale error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±4.0	—	—	±4.0	—	—	±8.0	LSB

Notes: *1 When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$

*2 When $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$

*3 When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)

*4 When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)

*5 For the low-voltage F-ZTAT version, $V_{CC} = 3.0 \text{ V}$ to 5.5 V and $AV_{CC} = 3.0 \text{ V}$ to 5.5 V .

*6 At the maximum operating frequency in single mode

Table 22.12 A/D Conversion Characteristics
(CIN7 to CIN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}^{*5}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}^{*5}$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*6	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*3	—	—	10*3	—	—	10*1	kΩ
			5*4			5*4			5*2	
Nonlinearity error	—	—	±5.0	—	—	±5.0	—	—	±11.0	LSB
Offset error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Full-scale error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±6.0	—	—	±6.0	—	—	±12.0	LSB

Notes: *1 When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$

*2 When $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$

*3 When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)

*4 When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)

*5 For the low-voltage F-ZTAT version, $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$ and $AV_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$.

*6 At the maximum operating frequency in single mode

22.2.5 Flash Memory Characteristics

Table 22.13 shows the flash memory characteristics.

Table 22.13 Flash Memory Characteristics

Conditions (5 V version): $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $T_a = 0 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = 0 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Conditions for low-voltage version: $V_{CC} = 3.0 \text{ V to } 3.6 \text{ V}$, $V_{SS} = 0 \text{ V}$, $T_a = 0 \text{ to } +75^\circ\text{C}$
 (Programming/erasing operating temperature)

Item	Symbol	Min	Typ	Max	Unit	Test Condition
Programming time ^{*1 *2 *4}	tP	—	10	200	ms/ 32 bytes	
Erase time ^{*1 *3 *5}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	—	—	100	Times	
Programming	Wait time after SWE-bit setting ^{*1}	x	10	—	μs	
	Wait time after PSU-bit setting ^{*1}	y	50	—	μs	
	Wait time after P-bit setting ^{*1 *4}	z	150	—	μs	
	Wait time after P-bit clear ^{*1}	α	10	—	μs	
	Wait time after PSU-bit clear ^{*1}	β	10	—	μs	
	Wait time after PV-bit setting ^{*1}	γ	4	—	μs	
	Wait time after dummy write ^{*1}	ε	2	—	μs	
	Wait time after PV-bit clear ^{*1}	η	4	—	μs	
	Maximum programming count ^{*1 *4 *5}	N	—	—	1000	Times z = 200 μs

Item		Symbol	Min	Typ	Max	Unit	Test Condition
Erase	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs	
	Wait time after ESU-bit setting ^{*1}	y	200	—	—	μs	
	Wait time after E-bit setting ^{*1 *6}	z	5	—	10	ms	
	Wait time after E-bit clear ^{*1}	α	10	—	—	μs	
	Wait time after ESU-bit clear ^{*1}	β	10	—	—	μs	
	Wait time after EV-bit setting ^{*1}	γ	20	—	—	μs	
	Wait time after dummy write ^{*1}	ε	2	—	—	μs	
	Wait time after EV-bit clear ^{*1}	η	5	—	—	μs	
	Maximum erase count ^{*1 *6 *7}	N	—	—	120	Times	z = 10 ms

Notes: ^{*1} Set the times according to the program/erase algorithms.

^{*2} Programming time per 32 bytes (Shows the total period for which the P-bit in the flash memory control register (FLMCR1) is set. It does not include the programming verification time.)

^{*3} Block erase time (Shows the total period for which the E-bit in FLMCR1 is set. It does not include the erase verification time.)

^{*4} Maximum programming time (t_P (max)) = wait time after P-bit setting (z) × maximum programming count (N))

^{*5} Number of times when the wait time after P-bit setting (z) = 200 μs.

The number of writes should be set according to the actual set value of z to allow programming within the maximum programming time (t_P).

^{*6} Maximum erase time (t_E (max)) = Wait time after E-bit setting (z) × maximum erase count (N))

^{*7} Number of times when the wait time after E-bit setting (z) = 10 ms.

The number of erases should be set according to the actual set value of z to allow erasing within the maximum erase time (t_E).

22.2.6 Usage Note

The F-ZTAT and mask ROM versions have been confirmed as fully meeting the reference values for electrical characteristics shown in this manual. However, actual performance figures, operating margins, noise margins, and other properties may vary due to differences in the manufacturing process, on-chip ROM, layout patterns, etc.

When system evaluation testing is carried out using the F-ZTAT version, the same evaluation tests should also be conducted for the mask ROM version when changing over to that version.

22.3 Electrical Characteristics [H8S/2128S Series]

22.3.1 Absolute Maximum Ratings

Table 22.14 lists the absolute maximum ratings.

Table 22.14 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage ^{*1}	V_{CC}	−0.3 to +7.0	V
Power supply voltage ^{*1} (3 V version)	V_{CC}	−0.3 to +4.3	V
Power supply voltage ^{*2} (V_{CL} version)	V_{CL}	−0.3 to +4.3	V
Input voltage (except ports 6, 7)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input not selected for port 6)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input selected for port 6)	V_{in}	−0.3 V to lower of voltages $V_{CC} + 0.3$ and $AV_{CC} + 0.3$	V
Input voltage (port 7)	V_{in}	−0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	−0.3 to +7.0	V
Analog power supply voltage (3 V version)	AV_{CC}	−0.3 to +4.3	V
Analog input voltage	V_{AN}	−0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: −20 to +75	°C
		Wide-range specifications: −40 to +85	°C
Storage temperature	T_{stg}	−55 to +125	°C

Cautions: 1. Permanent damage to the chip may result if absolute maximum ratings are exceeded.

2. Never apply more than 7.0 V to any of the pins of the 5 V or 4 V version or 4.3 V to any of the pins of the 3 V version.

Notes: ^{*1} Power supply voltage for V_{CC1} pin

Never exceed the maximum rating of V_{CL} in the low-power version (3 V version) because both the V_{CC1} and V_{CL} pins are connected to the V_{CC} power supply.

^{*2} It is an operating power supply voltage pin on the chip.

Never apply power supply voltage to the V_{CL} pin in the 5 V or 4 V version.

Always connect an external capacitor between the V_{CL} pin and ground for internal voltage stabilization.

22.3.2 DC Characteristics

Table 22.15 lists the DC characteristics. Table 22.16 lists the permissible output currents.

Table 22.15 DC Characteristics (1)

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC}^{*1} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$,

$T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),

$T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60*2*5, (1) IRQ2 to IRQ0*3*8	V_T^-	1.0	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	RES, STBY, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	RES, STBY, (3) MD1, MD0	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL		-0.3	—	0.8	V	
	Input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins (except P47, and P52*4)	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$
	P47, P52*4		2.0	—	—	V	$I_{OH} = -200 \mu\text{A}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	STBY, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5$ V
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	μA	$V_{in} = 0$ V
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF	$V_{in} = 0$ V $f = 1$ MHz $T_a = 25^\circ\text{C}$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{CC}	—	45	55	mA	$f = 20$ MHz
	Sleep mode		—	30	41	mA	$f = 20$ MHz
	Standby mode* ⁷		—	1.0	5.0	μA	$T_a \leq 50^\circ\text{C}$
			—	—	20.0	μA	$50^\circ\text{C} < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0$ V to 5.5 V
Analog power supply voltage* ¹		AV_{CC}	4.5	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *¹ Do not leave the AV_{CC} and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*² P67 to P60 include supporting module inputs multiplexed on those pins.

*³ $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.

*⁴ In the H8S/2128S Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.

An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 ($\text{ICE} = 1$).

In the H8S/2128S Series, P52/SCK0 and P47 ($\text{ICE} = 0$) high levels are driven by NMOS.

- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$ and $V_{IL} \text{ max} = 0.2 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 4.5 \text{ V}$, $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$, and $V_{IL} \text{ max} = 0.2 \text{ V}$.
- *8 The V_T^+ to V_T^- specification does not apply to $\overline{IRQ2}$ (\overline{ADTRG}) to $\overline{IRQ0}$.

Table 22.15 DC Characteristics (2)

Conditions: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC}^{*1} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$,

$T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),

$T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *5} , (1) IRQ2 to IRQ0 ^{*3 *8}	V_T^-	1.0	—	—	V	$V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
		V_T^-	0.8	—	—	V	$V_{CC} < 4.5 \text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.3	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , (2) NMI, MD1, MD0	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	\overline{RES} , \overline{STBY} , (3) MD1, MD0	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL		-0.3	—	0.8	V	
	Input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins (except P47, and P52 ^{*4})	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$, $V_{CC} = 4.5 \text{ V to } 5.5 \text{ V}$
			3.0	—	—	V	$I_{OH} = -1 \text{ mA}$, $V_{CC} < 4.5 \text{ V}$
	P47, P52 ^{*4}		1.5	—	—	V	$I_{OH} = -200 \mu\text{A}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5 V$
	STBY, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5$ to $AV_{CC} - 0.5 V$
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5 V$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	μA	$V_{in} = 0 V$, $V_{CC} = 4.5 V$ to $5.5 V$
			20	—	200	μA	$V_{in} = 0 V$, $V_{CC} < 4.5 V$
Input capacitance	RES	(4) C_{in}	—	—	80	pF	$V_{in} = 0 V$, $f = 1 MHz$, $T_a = 25^\circ C$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation ^{*6}	Normal operation	I_{CC}	—	35	44	mA	$f = 16 MHz$
	Sleep mode		—	25	34	mA	$f = 16 MHz$
	Standby mode ^{*7}		—	1.0	5.0	μA	$T_a \leq 50^\circ C$
			—	—	20.0	μA	$50^\circ C < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0 V$ to $5.5 V$
Analog power supply voltage ^{*1}		AV_{CC}	4.0	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *1 Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used. Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*2 P67 to P60 include supporting module inputs multiplexed on those pins.

*3 $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.

*4 In the H8S/2128S Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.

An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 (ICE = 1).

In the H8S/2128S Series, P52/SCK0 and P47 (ICE = 0) high levels are driven by NMOS.

- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$ and $V_{IL} \text{ max} = 0.2 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 4.0 \text{ V}$, $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$, and $V_{IL} \text{ max} = 0.2 \text{ V}$.
- *8 The V_T^+ to V_T^- specification does not apply to $\overline{IRQ2}$ (\overline{ADTRG}) to $\overline{IRQ0}$.

Table 22.15 DC Characteristics (3)

Conditions (Mask ROM version): $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$, $AV_{CC}^{*1} = 2.7 \text{ V to } 3.6 \text{ V}$,
 $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60*2*5, (1) IRQ2 to IRQ0*3*8	V_T^-	$V_{CC} \times 0.2$	—	V	
		V_T^+	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	V	
Input high voltage	RES, STBY, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
	Port 7		$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V
	Input pins except (1) and (2) above		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
Input low voltage	RES, STBY, (3) MD1, MD0	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V
Output high voltage	All output pins (except P47, and P52*4)	V_{OH}	$V_{CC} - 0.5$	—	V	$I_{OH} = -200 \mu\text{A}$
			$V_{CC} - 1.0$	—	V	$I_{OH} = -1 \text{ mA}$
	P47, P52*4		0.5	—	V	$I_{OH} = -200 \mu\text{A}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V $I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V $I_{OL} = 5 \text{ mA}$
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA $V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	STBY, NMI, MD1, MD0		—	—	1.0	μA
	Port 7		—	—	1.0	μA $V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5 V$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	5	—	150	μA	$V_{in} = 0 V$, $V_{CC} = 2.7 V$ to $3.6 V$
Input capacitance	\overline{RES}	(4) C_{in}	—	—	80	pF	$V_{in} = 0 V$, $f = 1 MHz$, $T_a = 25^\circ C$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{CC}	—	24	30	mA	$f = 10 MHz$
	Sleep mode		—	15	23	mA	$f = 10 MHz$
	Standby mode* ⁷		—	1.0	5.0	μA	$T_a \leq 50^\circ C$
			—	—	20.0	μA	$50^\circ C < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0 V$ to $3.6 V$
Analog power supply voltage* ¹		AV_{CC}	2.7	—	3.6	V	Operating
			2.0	—	3.6	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *¹ Do not leave the AV_{CC} and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 3.6 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*² P67 to P60 include supporting module inputs multiplexed on those pins.

*³ $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.

*⁴ In the H8S/2128S Series, P52/SCK0/SCL0 and P47/SDA0 are NMOS push-pull outputs.

An external pull-up resistor is necessary to provide high-level output from SCL0 and SDA0 ($ICE = 1$).

In the H8S/2128S Series, P52/SCK0 and P47 ($ICE = 0$) high levels are driven by NMOS.

- *5 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
- *6 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$ and $V_{IL} \text{ max} = 0.2 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.
- *7 The values are for $V_{RAM} \leq V_{CC} < 2.7 \text{ V}$, $V_{IH} \text{ min} = V_{CC} - 0.2 \text{ V}$, and $V_{IL} \text{ max} = 0.2 \text{ V}$.
- *8 The V_T^+ to V_T^- specification does not apply to $\overline{IRQ2}$ (\overline{ADTRG}) to $\overline{IRQ0}$.

Table 22.16 Permissible Output Currents

Conditions: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0	I_{OL}	—	—	20	mA
	Ports 1, 2, 3		—	—	10	mA
	Other output pins		—	—	2	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	80	mA
	Total of all output pins, including the above		—	—	120	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	40	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.16.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.25 and 22.26.

Table 22.16 Permissible Output Currents (cont)

Conditions: $V_{CC} = 2.7 \text{ V}$ to 3.6 V , $V_{SS} = 0 \text{ V}$, $T_a = -20$ to $+75^\circ\text{C}$

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	SCL1, SCL0, SDA1, SDA0	I_{OL}	—	—	10	mA
	Ports 1, 2, 3		—	—	2	mA
	Other output pins		—	—	1	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	40	mA
	Total of all output pins, including the above		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	30	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.16.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.25 and 22.26.

Table 22.17 Bus Drive Characteristics

Conditions: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{CC} = 2.7\text{ to }3.6\text{ V}$ (3 V version), $V_{SS} = 0\text{ V}$

Applicable Pins: SCL1, SCL0, SDA1, SDA0 (bus drive function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	$V_{T^{-}}$	$V_{CC} \times 0.3$	—	—	V	
	$V_{T^{+}}$	—	—	$V_{CC} \times 0.7$		
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$		
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16\text{ mA}$, $V_{CC} = 4.5\text{ V to }5.5\text{ V}$
		—	—	0.5		$I_{OL} = 8\text{ mA}$
		—	—	0.4		$I_{OL} = 3\text{ mA}$
Input capacitance	C_{in}	—	—	20	pF	$V_{in} = 0\text{ V}$, $f = 1\text{ MHz}$, $T_a = 25^{\circ}\text{C}$
Three-state leakage current (off state)	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5\text{ to }V_{CC} - 0.5\text{ V}$
SCL, SDA output fall time	t_{Of}	$20 + 0.1Cb$	—	250	ns	

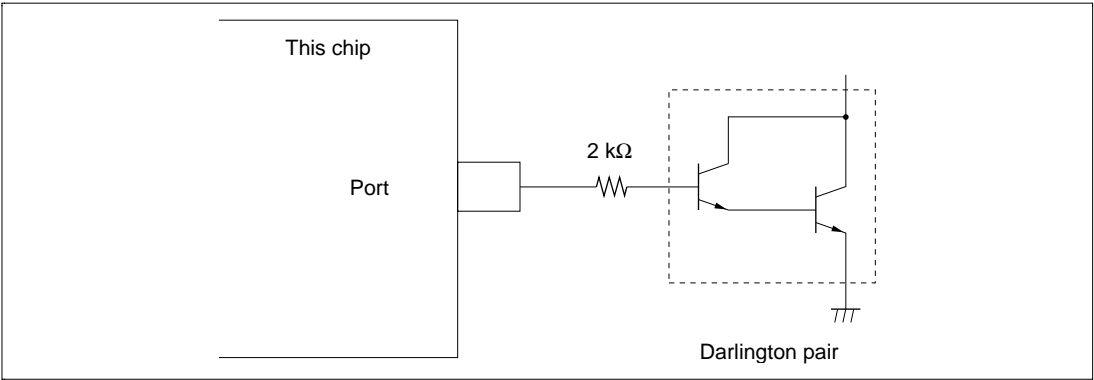


Figure 22.25 Darlington Pair Drive Circuit (Example)

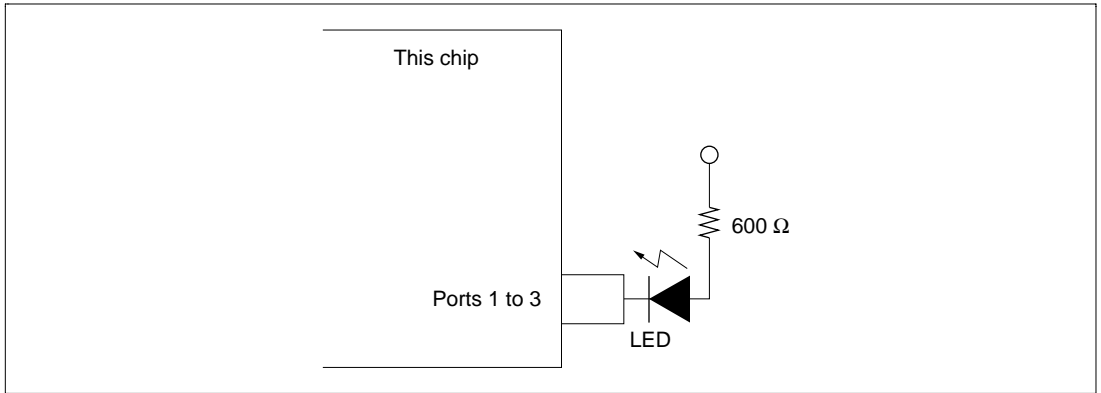


Figure 22.26 LED Drive Circuit (Example)

22.3.3 AC Characteristics

Figure 22.3 shows the test conditions for the AC characteristics.

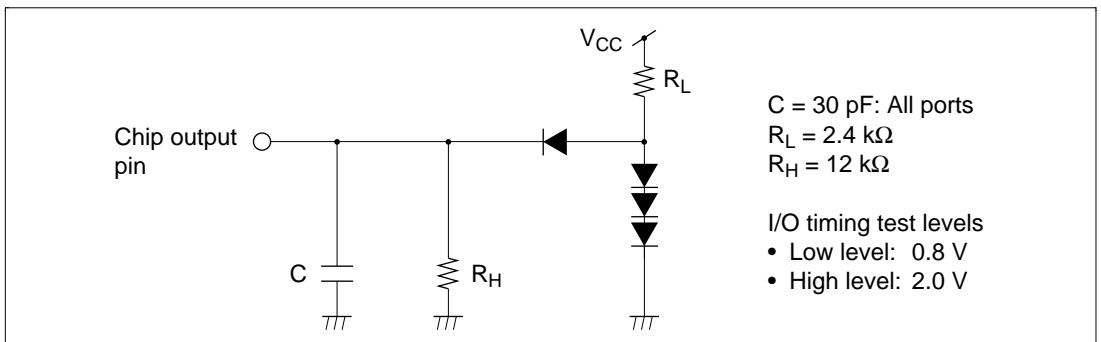


Figure 22.27 Output Load Circuit

(1) Clock Timing

Table 22.18 shows the clock timing. The clock timing specified here covers clock (ϕ) output and clock pulse generator (crystal) and external clock input (EXTAL pin) oscillation settling times. For details of external clock input (EXTAL pin and EXCL pin) timing, see section 20, Clock Pulse Generator.

Table 22.18 Clock Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 3.6 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Clock cycle time	t _{cyc}	50	500	62.5	500	100	500	ns	Figure 22.28
Clock high pulse width	t _{CH}	17	—	20	—	30	—	ns	Figure 22.28
Clock low pulse width	t _{CL}	17	—	20	—	30	—	ns	
Clock rise time	t _{Cr}	—	8	—	10	—	20	ns	
Clock fall time	t _{Cf}	—	8	—	10	—	20	ns	
Oscillation settling time at reset (crystal)	t _{OSC1}	10	—	10	—	20	—	ms	Figure 22.29 Figure 22.30
Oscillation settling time in software standby (crystal)	t _{OSC2}	8	—	8	—	8	—	ms	
External clock output stabilization delay time	t _{DEXT}	500	—	500	—	500	—	μs	

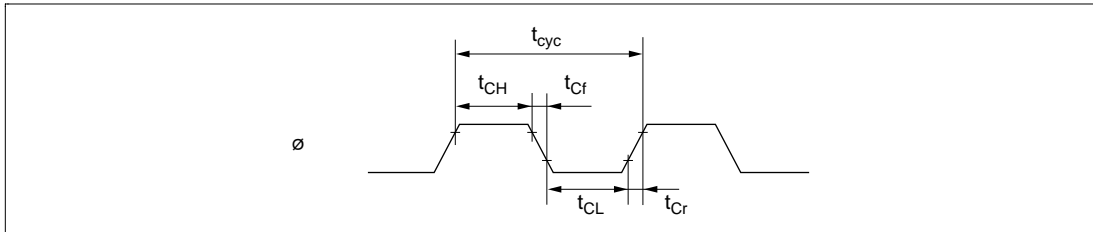


Figure 22.28 System Clock Timing

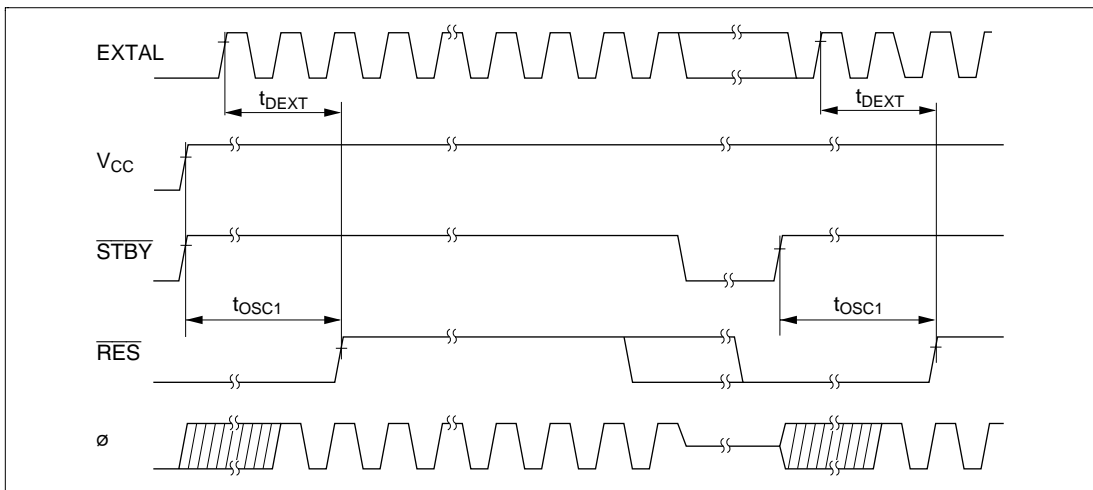


Figure 22.29 Oscillation Settling Timing

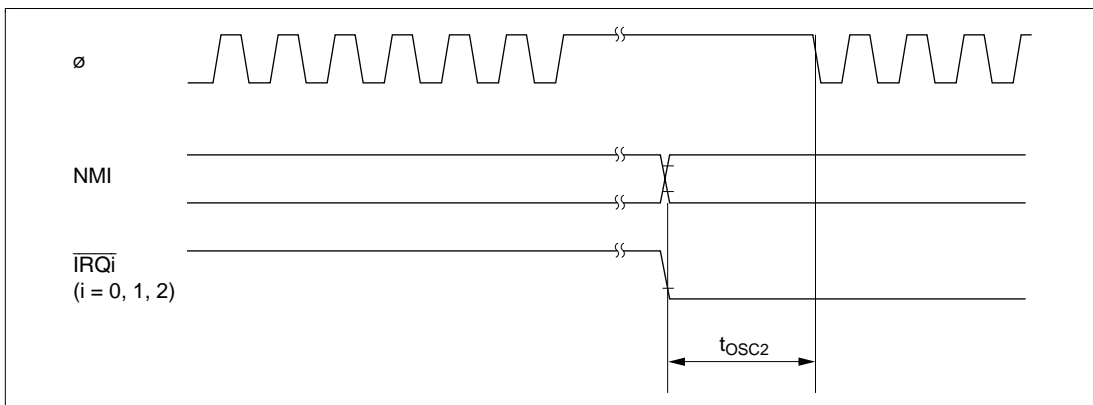


Figure 22.30 Oscillation Setting Timing (Exiting Software Standby Mode)

(2) Control Signal Timing

Table 22.19 shows the control signal timing. The only external interrupts that can operate on the subclock ($\phi = 32.768$ kHz) are NMI and IRQ0, 1, and IRQ2.

Table 22.19 Control Signal Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 3.6 V , $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
$\overline{\text{RES}}$ setup time	t_{RESS}	200	—	200	—	300	—	ns	Figure 22.31
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Figure 22.32
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time (IRQ2 to IRQ0)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ2 to IRQ0)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

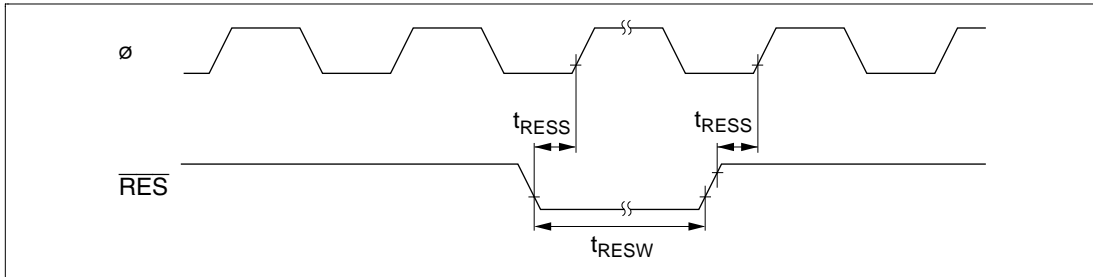


Figure 22.31 Reset Input Timing

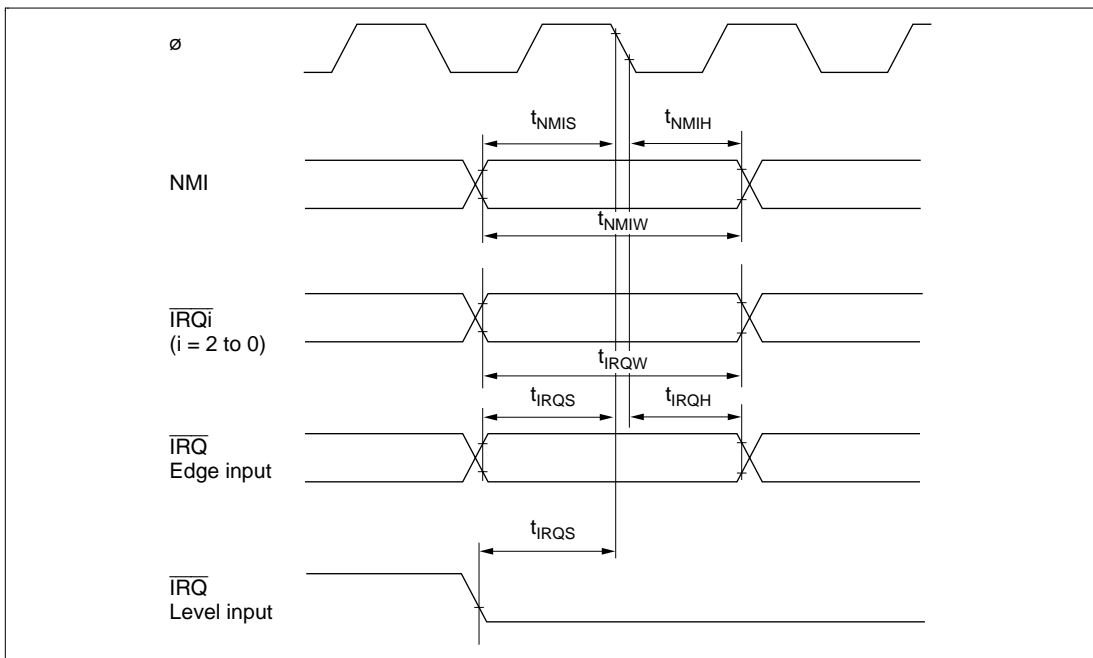


Figure 22.32 Interrupt Input Timing

(3) Bus Timing

Table 22.20 shows the bus timing. Operation in external expansion mode is not guaranteed when operating on the subclock ($\phi = 32.768$ kHz).

Table 22.20 Bus Timing

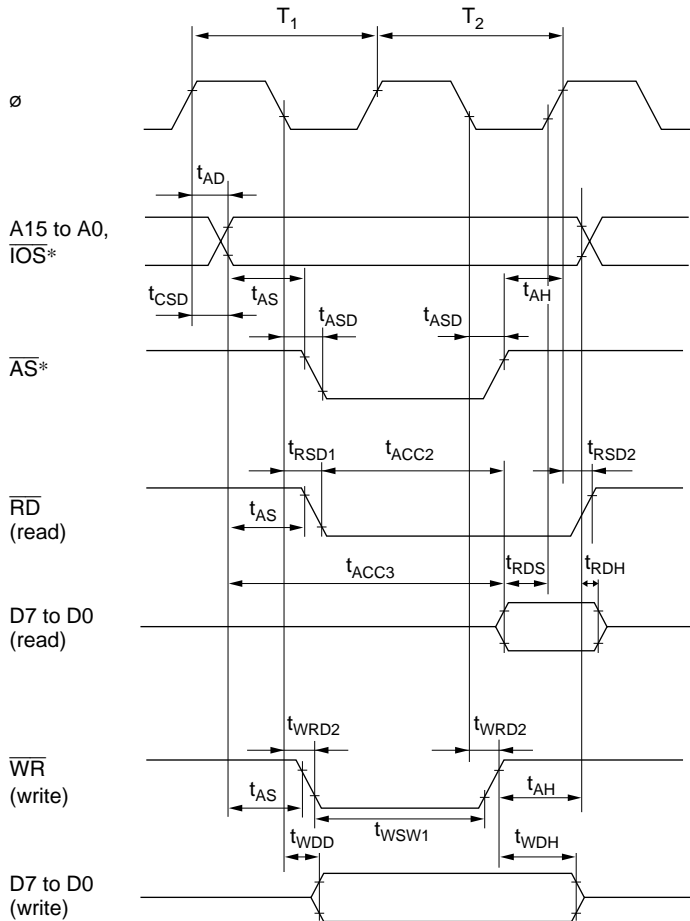
Condition A: $V_{CC} = 5.0\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V}$ to 3.6 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

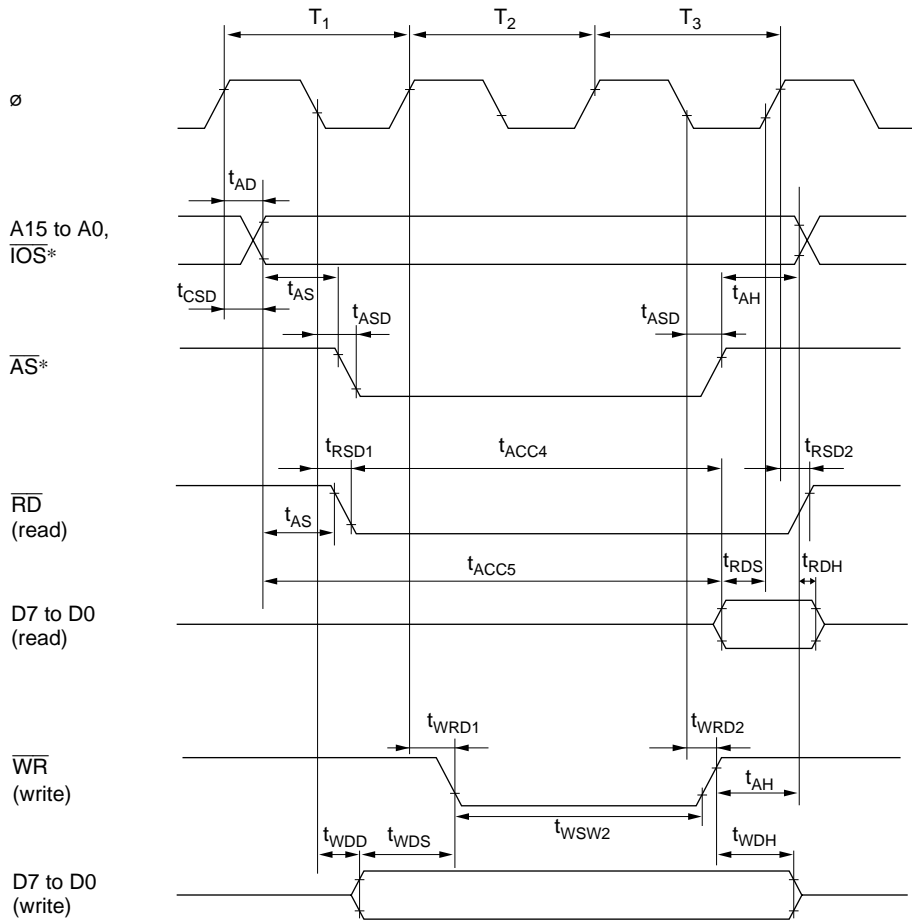
Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Address delay time	t _{AD}	—	20	—	30	—	40	ns	Figure 22.33 to figure 22.37
Address setup time	t _{AS}	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	0.5 × t _{cyc} – 30	—	ns	
Address hold time	t _{AH}	0.5 × t _{cyc} – 10	—	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	ns	
\overline{CS} delay time (IOS)	t _{CSD}	—	20	—	30	—	40	ns	
\overline{AS} delay time	t _{ASD}	—	30	—	45	—	60	ns	
\overline{RD} delay time 1	t _{RSD1}	—	30	—	45	—	60	ns	
\overline{RD} delay time 2	t _{RSD2}	—	30	—	45	—	60	ns	
Read data setup time	t _{RDS}	15	—	20	—	35	—	ns	
Read data hold time	t _{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t _{ACC1}	—	1.0 × t _{cyc} – 30	—	1.0 × t _{cyc} – 40	—	1.0 × t _{cyc} – 60	ns	
Read data access time 2	t _{ACC2}	—	1.5 × t _{cyc} – 25	—	1.5 × t _{cyc} – 35	—	1.5 × t _{cyc} – 50	ns	

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		Min	Max	Min	Max	Min	Max		
Read data access time 3	t _{ACC3}	—	2.0 × t _{cyc} – 30	—	2.0 × t _{cyc} – 40	—	2.0 × t _{cyc} – 60	ns	Figure 22.33 to figure 22.37
Read data access time 4	t _{ACC4}	—	2.5 × t _{cyc} – 25	—	2.5 × t _{cyc} – 35	—	2.5 × t _{cyc} – 50	ns	
Read data access time 5	t _{ACC5}	—	3.0 × t _{cyc} – 30	—	3.0 × t _{cyc} – 40	—	3.0 × t _{cyc} – 60	ns	
WR delay time 1	t _{WRD1}	—	30	—	45	—	60	ns	
WR delay time 2	t _{WRD2}	—	30	—	45	—	60	ns	
WR pulse width 1	t _{WSW1}	1.0 × t _{cyc} – 20	—	1.0 × t _{cyc} – 30	—	1.0 × t _{cyc} – 40	—	ns	
WR pulse width 2	t _{WSW2}	1.5 × t _{cyc} – 20	—	1.5 × t _{cyc} – 30	—	1.5 × t _{cyc} – 40	—	ns	
Write data delay time	t _{WDD}	—	30	—	45	—	60	ns	
Write data setup time	t _{WDS}	0	—	0	—	0	—	ns	
Write data hold time	t _{WDH}	10	—	15	—	20	—	ns	
WAIT setup time	t _{WTS}	30	—	45	—	60	—	ns	
WAIT hold time	t _{WTH}	5	—	5	—	10	—	ns	



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.33 Basic Bus Timing (Two-State Access)



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.34 Basic Bus Timing (Three-State Access)

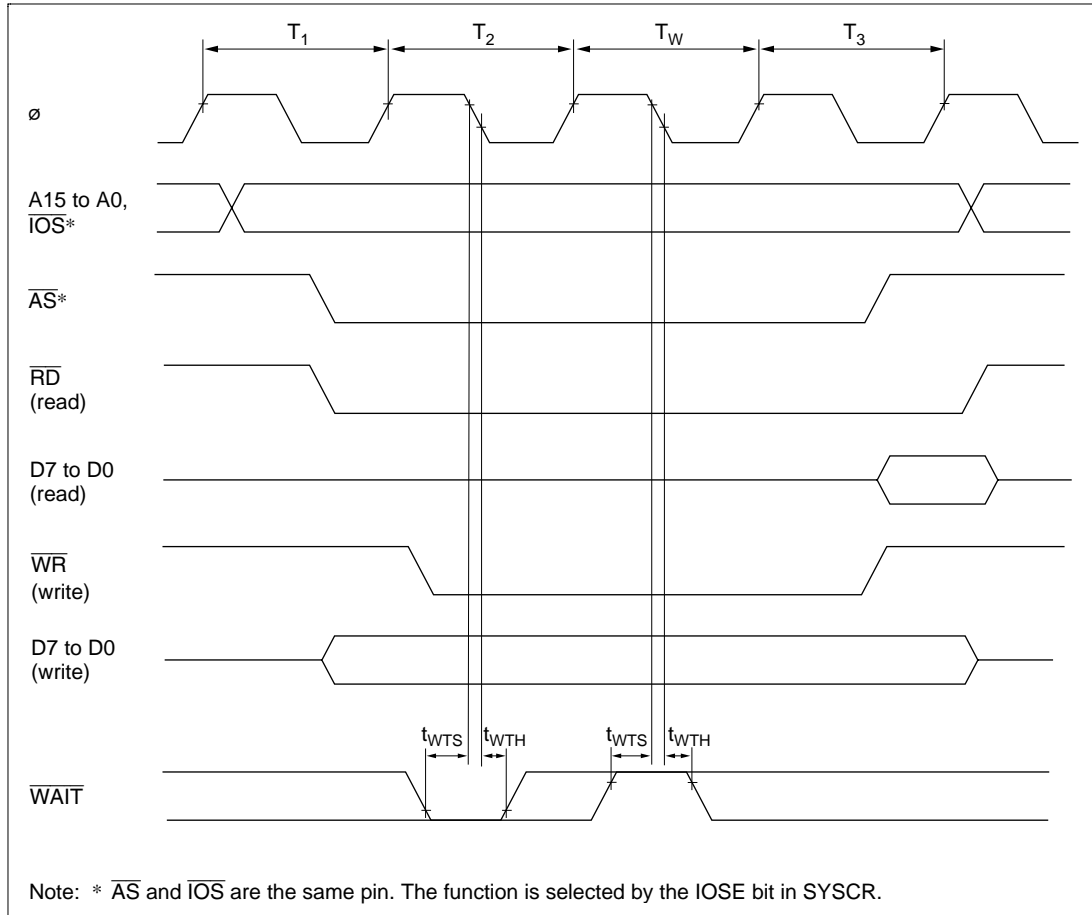


Figure 22.35 Basic Bus Timing (Three-State Access with One Wait State)

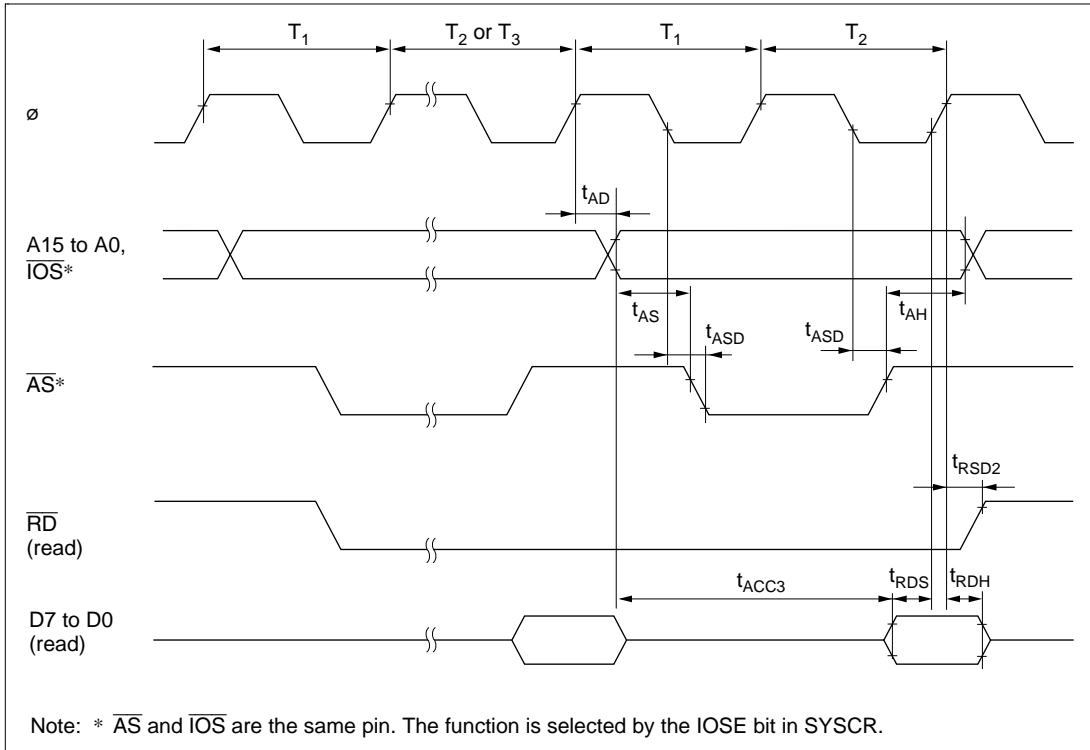
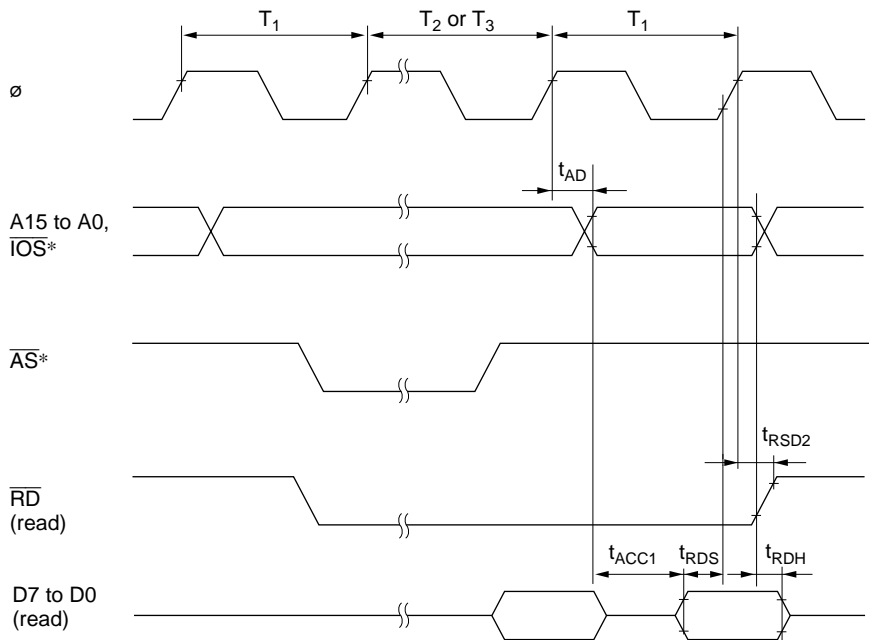


Figure 22.36 Burst ROM Access Timing (Two-State Access)



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.37 Burst ROM Access Timing (One-State Access)

(4) Timing of On-Chip Supporting Modules

Tables 22.21 and 22.22 show the on-chip supporting module timing. The only on-chip supporting modules that can operate in subclock operation ($\phi = 32.768 \text{ kHz}$) are the I/O ports, external interrupts (NMI and IRQ0, 1, and IRQ2), the watchdog timer, and the 8-bit timer (channels 0 and 1).

Table 22.21 Timing of On-Chip Supporting Modules

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item		Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions	
			20 MHz		16 MHz		10 MHz				
			Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	t _{PWD}	—	50	—	50	—	100	ns	Figure 22.38	
	Input data setup time	t _{PRS}	30	—	30	—	50	—			
	Input data hold time	t _{PRH}	30	—	30	—	50	—			
FRT	Timer output delay time	t _{FTOD}	—	50	—	50	—	100	ns	Figure 22.39	
	Timer input setup time	t _{FTIS}	30	—	30	—	50	—			
	Timer clock input setup time	t _{FTCS}	30	—	30	—	50	—		Figure 22.40	
	Timer clock pulse width	Single edge	t _{FTCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	
		Both edges	t _{FTCWL}	2.5	—	2.5	—	2.5	—		

			Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
				Min	Max	Min	Max	Min	Max		
TMR	Timer output delay time		t _{TMOD}	—	50	—	50	—	100	ns	Figure 22.41
	Timer reset input setup time		t _{TMRs}	30	—	30	—	50	—		Figure 22.43
	Timer clock input setup time		t _{TMCs}	30	—	30	—	50	—		Figure 22.42
	Timer clock pulse width	Single edge	t _{TMCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	
		Both edges	t _{TMCWL}	2.5	—	2.5	—	2.5	—		
PWM, PWMX	Pulse output delay time		t _{PWOD}	—	50	—	50	—	100	ns	Figure 22.44
SCI	Input clock cycle	Asynchronous	t _{Scyc}	4	—	4	—	4	—	t _{cyc}	Figure 22.45
		Synchronous		6	—	6	—	6	—		
	Input clock pulse width		t _{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	t _{Scyc}	
	Input clock rise time		t _{SCKr}	—	1.5	—	1.5	—	1.5	t _{cyc}	
	Input clock fall time		t _{SCKf}	—	1.5	—	1.5	—	1.5		
	Transmit data delay time (synchronous)		t _{TXD}	—	50	—	50	—	100	ns	Figure 22.46
	Receive data setup time (synchronous)		t _{RXS}	50	—	50	—	100	—	ns	
	Receive data hold time (synchronous)		t _{RXH}	50	—	50	—	100	—	ns	
A/D converter	Trigger input setup time		t _{TRGS}	30	—	30	—	50	—	ns	Figure 22.47

Note: * Only supporting modules that can be used in subclock operation

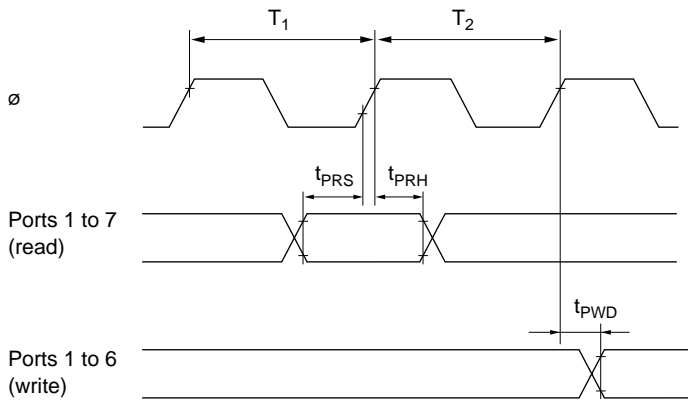


Figure 22.38 I/O Port Input/Output Timing

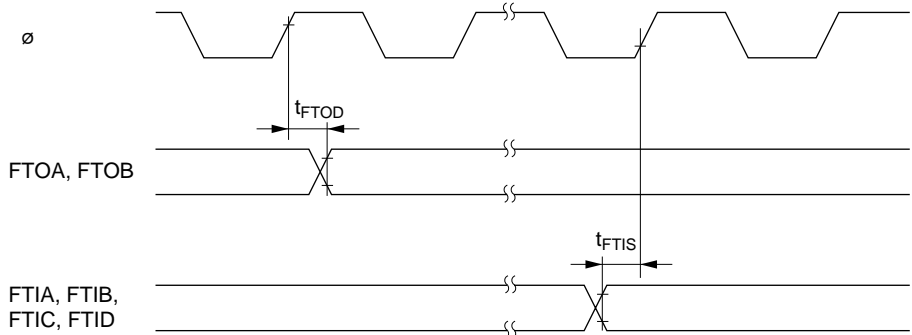


Figure 22.39 FRT Input/Output Timing

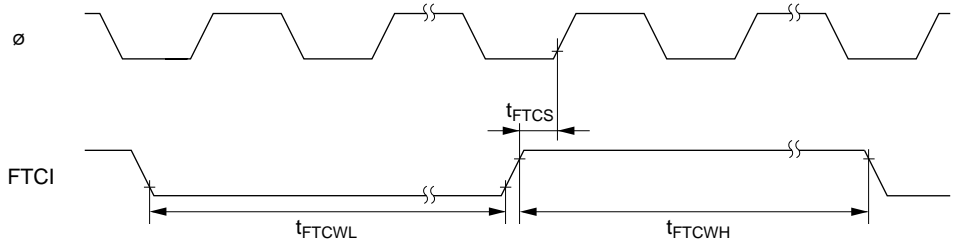


Figure 22.40 FRT Clock Input Timing

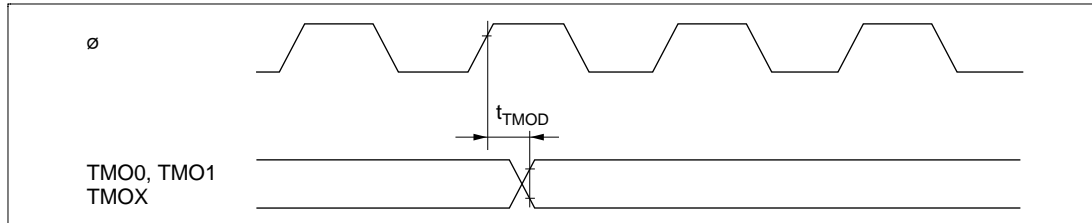


Figure 22.41 8-Bit Timer Output Timing

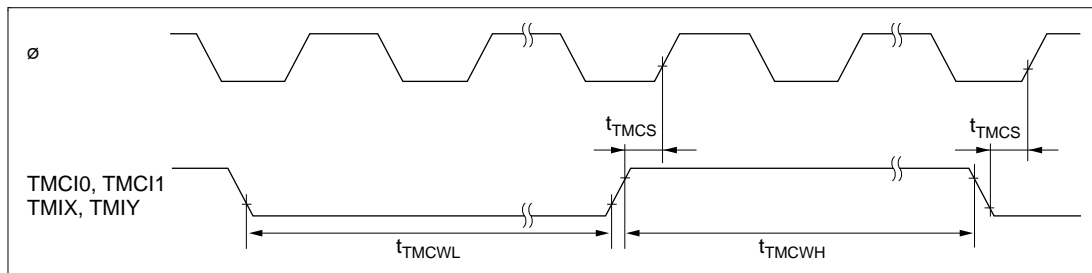


Figure 22.42 8-Bit Timer Clock Input Timing

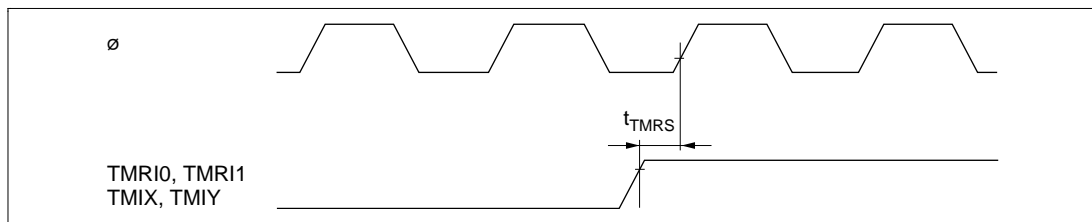


Figure 22.43 8-Bit Timer Reset Input Timing

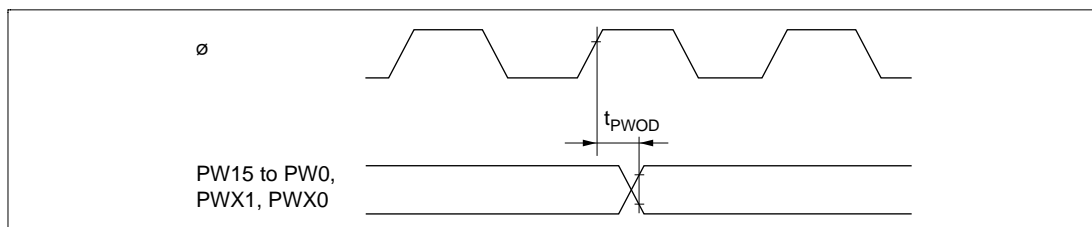


Figure 22.44 PWM, PWMX Output Timing

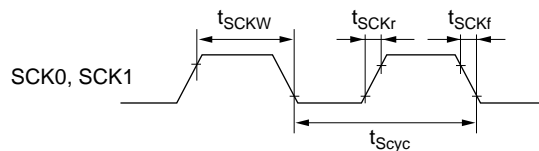


Figure 22.45 SCK Clock Input Timing

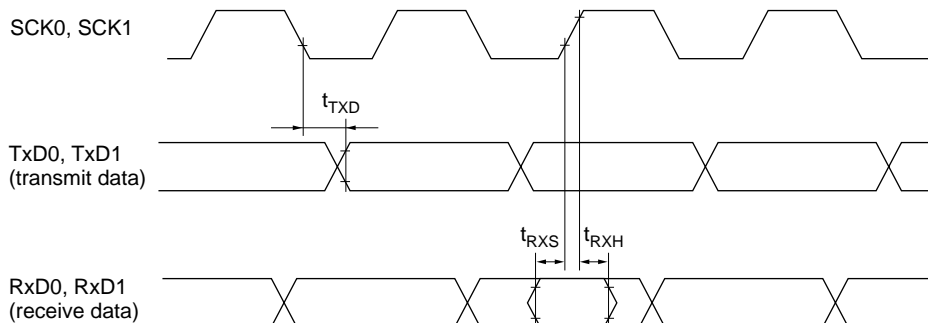


Figure 22.46 SCI Input/Output Timing (Synchronous Mode)

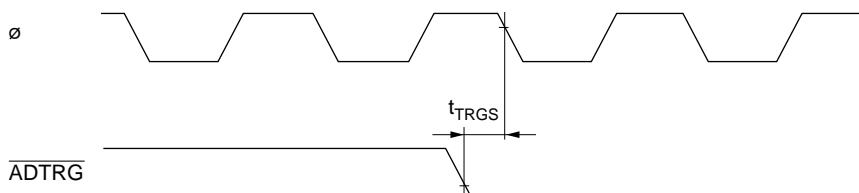


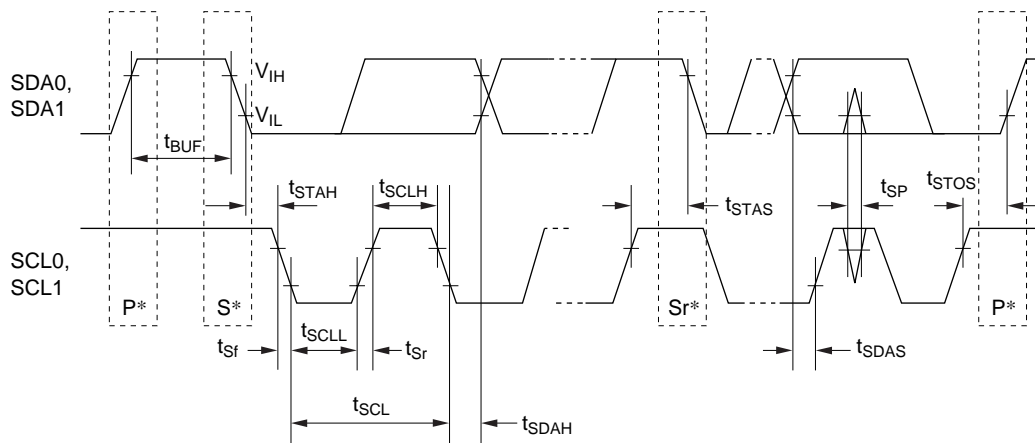
Figure 22.47 A/D Converter External Trigger Input Timing

Table 22.22 I²C Bus Timing

Conditions: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$ (3 V version), $V_{SS} = 0 \text{ V}$, $\phi = 5 \text{ MHz}$ to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Min	Typ	Max	Unit	Test Conditions	Notes
SCL clock cycle time	t_{SCL}	12	—	—	t_{cyc}		Figure 22.48
SCL clock high pulse width	t_{SCLH}	3	—	—	t_{cyc}		
SCL clock low pulse width	t_{SCLL}	5	—	—	t_{cyc}		
SCL, SDA input rise time	t_{Sr}	—	—	7.5*	t_{cyc}		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns		
SCL, SDA input spike pulse elimination time	t_{SP}	—	—	1	t_{cyc}		
SDA input bus free time	t_{BUF}	5	—	—	t_{cyc}		
Start condition input hold time	t_{STAH}	3	—	—	t_{cyc}		
Retransmission start condition input setup time	t_{STAS}	3	—	—	t_{cyc}		
Stop condition input setup time	t_{STOS}	3	—	—	t_{cyc}		
Data input setup time	t_{SDAS}	0.5	—	—	t_{cyc}		
Data input hold time	t_{SDAH}	0	—	—	ns		
SCL, SDA capacitive load	C_b	—	—	400	pF		

Note: * $17.5t_{cyc}$ can be set according to the clock selected for use by the I²C module. For details, see section 16.4, Usage Notes.



Note: * S, P, and Sr indicate the following conditions.

S: Start condition

P: Stop condition

Sr: Retransmission start condition

Figure 22.48 I²C Bus Interface Input/Output Timing (Option)

22.3.4 A/D Conversion Characteristics

Tables 22.23 and 22.24 list the A/D conversion characteristics.

Table 22.23 A/D Conversion Characteristics
(AN7 to AN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $AV_{CC} = 4.0 \text{ V}$ to 5.5 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 3.6 V , $AV_{CC} = 2.7 \text{ V}$ to 3.6 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*3	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*1	—	—	10*1	—	—	5	kΩ
			5*2			5*2				
Nonlinearity error	—	—	±3.0	—	—	±3.0	—	—	±7.0	LSB
Offset error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Full-scale error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±4.0	—	—	±4.0	—	—	±8.0	LSB

Notes: *1 When conversion time $\geq 11.17 \mu\text{s}$ ($\text{CKS} = 1$ and $\phi \leq 12 \text{ MHz}$, or $\text{CKS} = 0$)

*2 When conversion time $< 11.17 \mu\text{s}$ ($\text{CKS} = 1$ and $\phi > 12 \text{ MHz}$)

*3 At the maximum operating frequency in single mode

Table 22.24 A/D Conversion Characteristics
(CIN7 to CIN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $AV_{CC} = 4.0 \text{ V}$ to 5.5 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0 \text{ V}$ to 3.6 V^{*4} , $AV_{CC} = 3.0 \text{ V}$ to 3.6 V^{*4}
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*3	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*1	—	—	10*1	—	—	5	kΩ
			5*2			5*2				
Nonlinearity error	—	—	±5.0	—	—	±5.0	—	—	±11.0	LSB
Offset error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Full-scale error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±6.0	—	—	±6.0	—	—	±12.0	LSB

Notes: *1 When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)

*2 When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)

*3 At the maximum operating frequency in single mode

*4 When using CIN input, $V_{CC} = 3.0 \text{ V}$ to 3.6 V and $AV_{CC} = 3.0 \text{ V}$ to 3.6 V .

22.3.5 Usage Note

- (1) The F-ZTAT and mask ROM versions have been confirmed as fully meeting the reference values for electrical characteristics shown in this manual. However, actual performance figures, operating margins, noise margins, and other properties may vary due to differences in the manufacturing process, on-chip ROM, layout patterns, etc.

When system evaluation testing is carried out using the F-ZTAT version, the same evaluation tests should also be connected for the mask ROM version when changing over to that version.

- (2) On-chip power supply step-down circuit

The H8S/2128 F-ZTAT does not incorporate an internal power supply step-down circuit.

When changing over to F-ZTAT versions or mask ROM versions incorporating an internal step-down circuit, the V_{CC2} pin has the same pin location as the V_{CL} pin in a step-down circuit. Therefore, note that the circuit patterns differ between these two types of products.

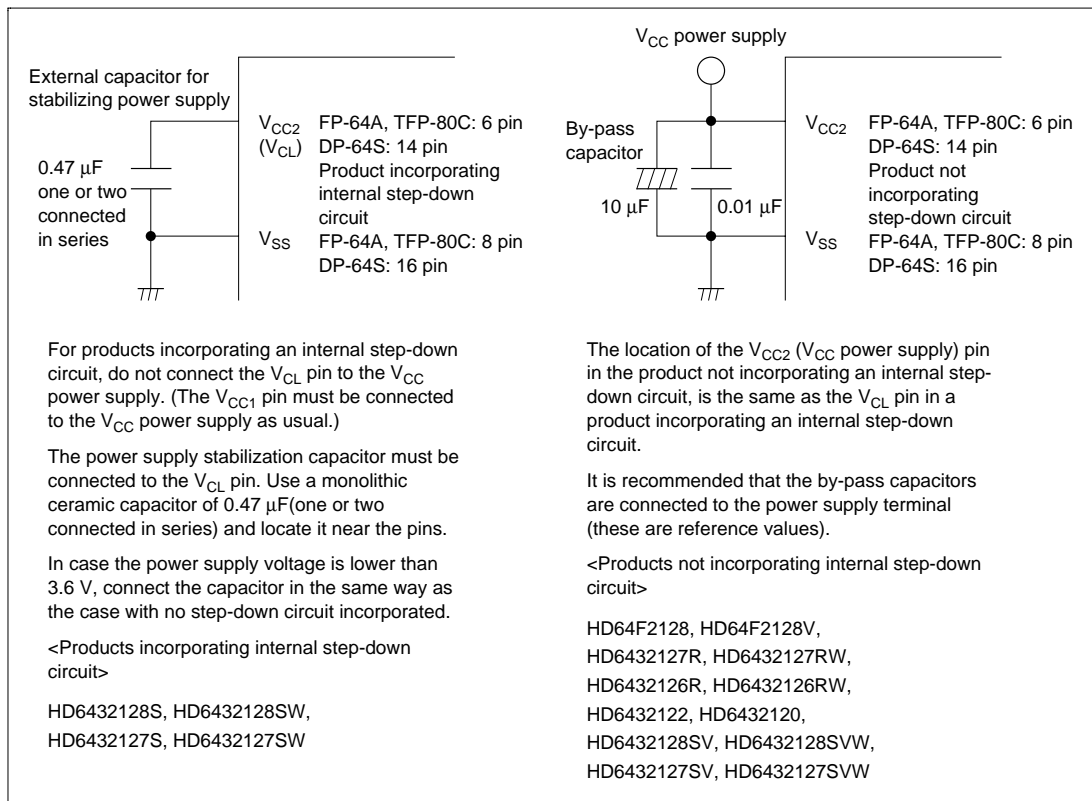


Figure 22.49 Connection of External Capacitor (mask ROM type incorporating step-down circuit and product not incorporating step-down circuit)

(3) Specification differences in internal I/O registers

Mask ROM version of H8S/2128S, H8S/2127S are different from the H8S/2128 Series and H8S/2124 Series in the specification of control registers for peripheral functions.

A/D converter: A/D Control Register (ADCR)

H8S/2128 Series, H8S/2124 Series	Bit	7	6	5	4	3	2	1	0
		TRGS1	TRGS0	—	—	—	—	—	—
	Initial value	0	0	1	1	1	1	1	1
	Read/Write	R/W	R/W	—	—	—	—	—	—

Bits 5 to 0—Reserved bits: These bits cannot be modified and are always read as 1.

H8S/2128S Series Mask ROM Version (internal step-down products)	Bits 5 to 0—Reserved bits: Should always be written 1.
--	--

Power-down state: Standby Control Register (SBYCR)

H8S/2128 Series, H8S/2124 Series	Bit 6	Bit 5	Bit 4	Description
	STS2	STS1	STS0	
	0	0	0	Standby time = 8,192 states (Initial value)
			1	Standby time = 16,384 states
		1	0	Standby time = 32,768 states
			1	Standby time = 65,536 states
	1	0	0	Standby time = 131,072 states
			1	Standby time = 262,144 states
		1	0	Reserved
			1	Standby time = 16 states*

Note: * This setting must not be used in the flash memory versions.

H8S/2128S Series Mask ROM Version (internal step-down products)	Bit 6	Bit 5	Bit 4	Description
	STS2	STS1	STS0	
	0	0	0	Standby time = 8,192 states (Initial value)
			1	Standby time = 16,384 states
		1	0	Standby time = 32,768 states
			1	Standby time = 65,536 states
	1	0	0	Standby time = 131,072 states
			1	Standby time = 262,144 states
		1	0	Reserved
			1	Standby time = 16 states*

Note: * This setting must not be used in the flash memory versions and H8S/2128S Series.

22.4 Electrical Characteristics [H8S/2124 Series]

22.4.1 Absolute Maximum Ratings

Table 22.25 lists the absolute maximum ratings.

Table 22.25 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	−0.3 to +7.0	V
Input voltage (except ports 6, and 7)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input not selected for port 6)	V_{in}	−0.3 to $V_{CC} + 0.3$	V
Input voltage (CIN input selected for port 6)	V_{in}	Lower voltage of −0.3 to $V_{CC} + 0.3$ and $AV_{CC} + 0.3$	V
Input voltage (port 7)	V_{in}	−0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	−0.3 to +7.0	V
Analog input voltage	V_{AN}	−0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: −20 to +75	°C
		Wide-range specifications: −40 to +85	°C
Storage temperature	T_{stg}	−55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

22.4.2 DC Characteristics

Table 22.26 lists the DC characteristics. Table 22.27 lists the permissible output currents.

Table 22.26 DC Characteristics (1)

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC}^{*1} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$,

$T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),

$T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *4} , (1)	V_T^-	1.0	—	—	V	
	IRQ2 to IRQ0 ^{*3}	V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , (2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	NMI, MD1, MD0						
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7		2.0	—	$AV_{CC} + 0.3$	V	
Input low voltage	Input pins except (1) and (2) above		2.0	—	$V_{CC} + 0.3$	V	
	\overline{RES} , \overline{STBY} , (3)	V_{IL}	-0.3	—	0.5	V	
	MD1, MD0						
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	50	—	300	μA	$V_{in} = 0 \text{ V}$
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF	$V_{in} = 0 \text{ V}$ $f = 1 \text{ MHz}$ $T_a = 25^\circ\text{C}$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation*5	Normal operation	I_{CC}	—	70	90	mA	$f = 20 \text{ MHz}$
	Sleep mode		—	55	75	mA	$f = 20 \text{ MHz}$
	Standby mode*6		—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
			—	—	20.0	μA	$50^\circ\text{C} < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} = 2.0 \text{ V to } 5.5 \text{ V}$
Analog power supply voltage*1			4.5	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *1 Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*2 P67 to P60 include supporting module inputs multiplexed on those pins.

*3 $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.

*4 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected.
When a pin is in output mode, the output voltage is equivalent to the applied voltage.

*5 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.

*6 The values are for $V_{RAM} \leq V_{CC} < 4.5 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.

Table 22.26 DC Characteristics (2)

Conditions: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $AV_{CC}^{*1} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = AV_{SS}^{*1} = 0\text{ V}$,

$T_a = -20\text{ to }+75^{\circ}\text{C}$ (regular specifications),

$T_a = -40\text{ to }+85^{\circ}\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2 *4} , (1) <u>IRQ2 to IRQ0^{*3}</u>	V_T^-	1.0	—	—	V	$V_{CC} = 4.5\text{ V to }5.5\text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
		V_T^-	0.8	—	—	V	$V_{CC} < 4.5\text{ V}$
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.3	—	—	V	
Input high voltage	<u>RES, STBY, NMI, MD1, MD0</u>	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	<u>EXTAL</u>		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	<u>Port 7</u>		2.0	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above		2.0	—	$V_{CC} + 0.3$	V	
Input low voltage	<u>RES, STBY, MD1, MD0</u>	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V	
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200\text{ }\mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1\text{ mA}$, $V_{CC} = 4.5\text{ V to }5.5\text{ V}$
			3.0	—	—	V	$I_{OH} = -1\text{ mA}$, $V_{CC} < 4.5\text{ V}$
Output low voltage	<u>All output pins</u>	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6\text{ mA}$
	<u>Ports 1 to 3</u>		—	—	1.0	V	$I_{OL} = 10\text{ mA}$
Input leakage current	<u>RES</u>	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5\text{ to }V_{CC} - 0.5\text{ V}$
	<u>STBY, NMI, MD1, MD0</u>		—	—	1.0	μA	
	<u>Port 7</u>		—	—	1.0	μA	$V_{in} = 0.5\text{ to }AV_{CC} - 0.5\text{ V}$

Item			Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6		$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to $V_{CC} - 0.5\text{ V}$
Input pull-up MOS current	Ports 1 to 3		$-I_P$	50	—	300	μA	$V_{in} = 0\text{ V}$, $V_{CC} = 4.5\text{ V}$ to 5.5 V
				30	—	200	μA	$V_{in} = 0\text{ V}$, $V_{CC} < 4.5\text{ V}$
Input capacitance	RES	(4)	C_{in}	—	—	80	pF	$V_{in} = 0\text{ V}$, $f = 1\text{ MHz}$, $T_a = 25^\circ\text{C}$
	NMI	—		—	50	pF		
	P52, P47, P24, P23	—		—	20	pF		
	Input pins except (4) above	—		—	15	pF		
Current dissipation*5	Normal operation		I_{CC}	—	55	75	mA	$f = 16\text{ MHz}$
	Sleep mode			—	42	62	mA	$f = 16\text{ MHz}$
	Standby mode*6			—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
				—	—	20.0	μA	$50^\circ\text{C} < T_a$
Analog power supply current	During A/D conversion		AI_{CC}	—	1.5	3.0	mA	$AV_{CC} = 2.0\text{ V}$ to 5.5 V
	Idle			—	0.01	5.0	μA	
Analog power supply voltage*1			AV_{CC}	4.0	—	5.5	V	Operating
				2.0	—	5.5	V	Idle/not used
RAM standby voltage			V_{RAM}	2.0	—	—	V	

Notes: *1 Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used.
Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*2 P67 to P60 include supporting module inputs multiplexed on those pins.

*3 $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.

*4 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3$ V when CIN input is not selected, and the lower of $V_{CC} + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected.
When a pin is in output mode, the output voltage is equivalent to the applied voltage.

*5 Current dissipation values are for V_{IH} min = $V_{CC} - 0.5$ V and V_{IL} max = 0.5 V with all output pins unloaded and the on-chip pull-up MOSs in the off state.

*6 The values are for $V_{RAM} \leq V_{CC} < 4.0$ V, V_{IH} min = $V_{CC} \times 0.9$, and V_{IL} max = 0.3 V.

Table 22.26 DC Characteristics (3)

Conditions : $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC}^{*1} = 2.7 \text{ V to } 5.5 \text{ V}$,
 $V_{SS} = AV_{SS}^{*1} = 0 \text{ V}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	P67 to P60 ^{*2*4} , (1) IRQ2 to IRQ0 ^{*3}	V_T^-	$V_{CC} \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , NMI, MD1, MD0	(2) V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	EXTAL				$V_{CC} + 0.3$	V	
	Port 7				$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above				$V_{CC} + 0.3$	V	
Input low voltage	\overline{RES} , \overline{STBY} , MD1, MD0	(3) V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, input pins except (1) and (3) above				$V_{CC} \times 0.2$	V	$V_{CC} < 4.0 \text{ V}$
					0.8	V	$V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = -1 \text{ mA}$ ($V_{CC} < 4.0 \text{ V}$)
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1 to 3		—	—	1.0	V	$I_{OL} = 5 \text{ mA}$ ($V_{CC} < 4.0 \text{ V}$), $I_{OL} = 10 \text{ mA}$ ($4.0 \text{ V} \leq V_{CC} \leq 5.5 \text{ V}$)
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	$V_{in} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1 to 6	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ V}$ $V_{CC} - 0.5 \text{ V}$
Input pull-up MOS current	Ports 1 to 3	$-I_P$	10	—	150	μA	$V_{in} = 0 \text{ V}$, $V_{CC} = 2.7 \text{ V}$ to 3.6 V
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF	$V_{in} = 0 \text{ V}$, $f = 1 \text{ MHz}$, $T_a = 25^\circ\text{C}$
	NMI		—	—	50	pF	
	P52, P47, P24, P23		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation ^{*5}	Normal operation	I_{CC}	—	40	52	mA	$f = 10 \text{ MHz}$
	Sleep mode		—	30	42	mA	$f = 10 \text{ MHz}$
	Standby mode ^{*6}		—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
			—	—	20.0	μA	$50^\circ\text{C} < T_a$
Analog power supply current	During A/D conversion	AI_{CC}	—	1.5	3.0	mA	
	Idle		—	0.01	5.0	μA	$AV_{CC} =$ 2.0 V to 5.5 V
Analog power supply voltage ^{*1}		AV_{CC}	2.7	—	5.5	V	Operating
			2.0	—	5.5	V	Idle/not used
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: *1 Do not leave the AV_{CC} , and AV_{SS} pins open even if the A/D converter is not used.

Even if the A/D converter is not used, apply a value in the range 2.0 V to 5.5 V to AV_{CC} by connection to the power supply (V_{CC}), or some other method.

*2 P67 to P60 include supporting module inputs multiplexed on those pins.

*3 $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.

*4 The upper limit of the port 6 applied voltage is $V_{CC} + 0.3 \text{ V}$ when CIN input is not selected, and the lower of $V_{CC} + 0.3 \text{ V}$ and $AV_{CC} + 0.3 \text{ V}$ when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.

*5 Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up MOSs in the off state.

*6 The values are for $V_{RAM} \leq V_{CC} < 2.7 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.

Table 22.27 Permissible Output Currents

Conditions: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Ports 1, 2, 3	I_{OL}	—	—	10	mA
	Other output pins		—	—	2	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	80	mA
	Total of all output pins, including the above		—	—	120	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	40	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.27.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.50 and 22.51.

Table 22.27 Permissible Output Currents (cont)**– Preliminary –**

Conditions: $V_{CC} = 2.7 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $T_a = -20$ to $+75^\circ\text{C}$

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Ports 1, 2, 3	I_{OL}	—	—	2	mA
	Other output pins		—	—	1	mA
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	40	mA
	Total of all output pins, including the above		—	—	60	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	30	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 22.27.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor in the output line, as show in figures 22.50 and 22.51.

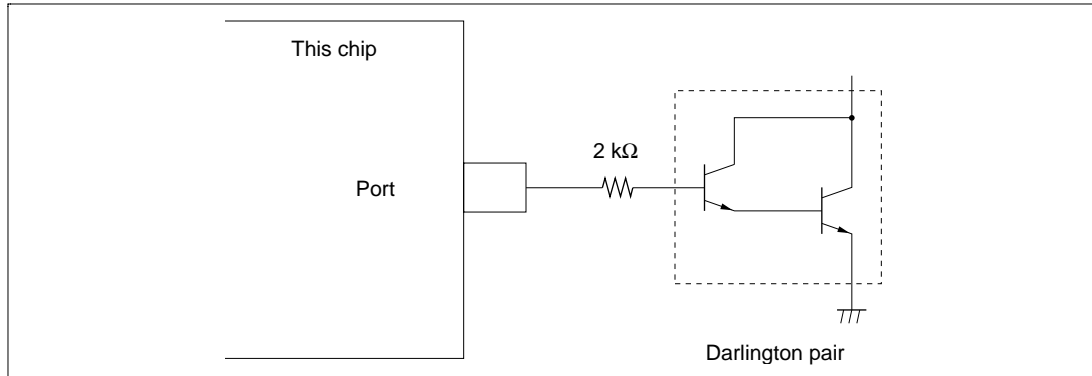


Figure 22.50 Darlington Pair Drive Circuit (Example)

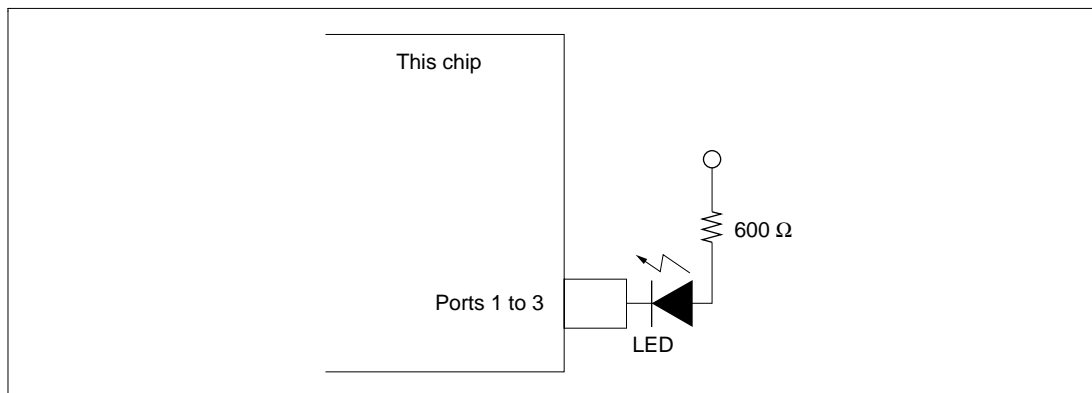


Figure 22.51 LED Drive Circuit (Example)

22.4.3 AC Characteristics

Figure 22.52 shows the test conditions for the AC characteristics.

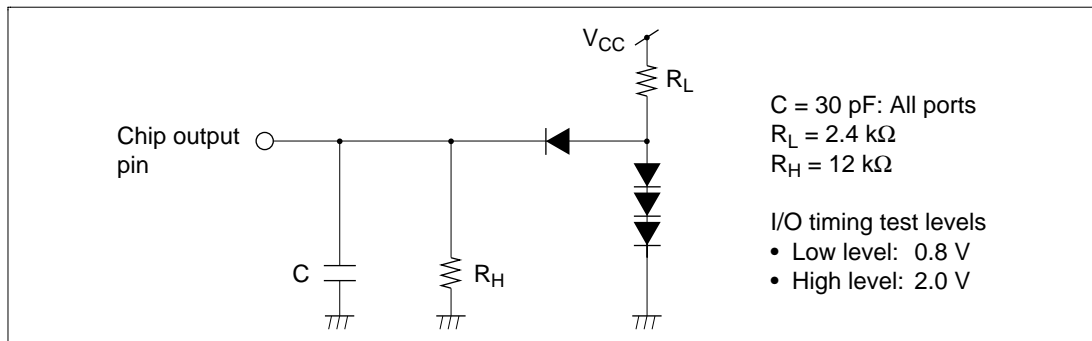


Figure 22.52 Output Load Circuit

(1) Clock Timing

Table 22.28 shows the clock timing. The clock timing specified here covers clock (ϕ) output and clock pulse generator (crystal) and external clock input (EXTAL pin) oscillation settling times. For details of external clock input (EXTAL pin and EXCL pin) timing, see section 20, Clock Pulse Generator.

Table 22.28 Clock Timing

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Clock cycle time	t _{cyc}	50	500	62.5	500	100	500	ns	Figure 22.53
Clock high pulse width	t _{CH}	17	—	20	—	30	—	ns	Figure 22.53
Clock low pulse width	t _{CL}	17	—	20	—	30	—	ns	
Clock rise time	t _{Cr}	—	8	—	10	—	20	ns	
Clock fall time	t _{Cf}	—	8	—	10	—	20	ns	
Oscillation settling time at reset (crystal)	t _{OSC1}	10	—	10	—	20	—	ms	Figure 22.54 Figure 22.55
Oscillation settling time in software standby (crystal)	t _{OSC2}	8	—	8	—	8	—	ms	
External clock output stabilization delay time	t _{DEXT}	500	—	500	—	500	—	μs	

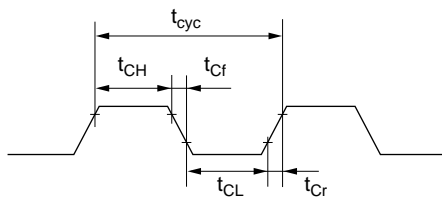


Figure 22.53 System Clock Timing

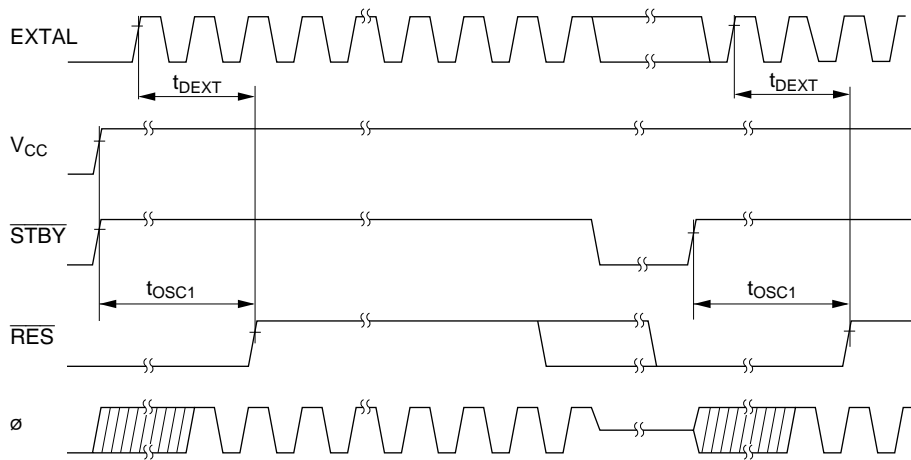


Figure 22.54 Oscillation Settling Timing

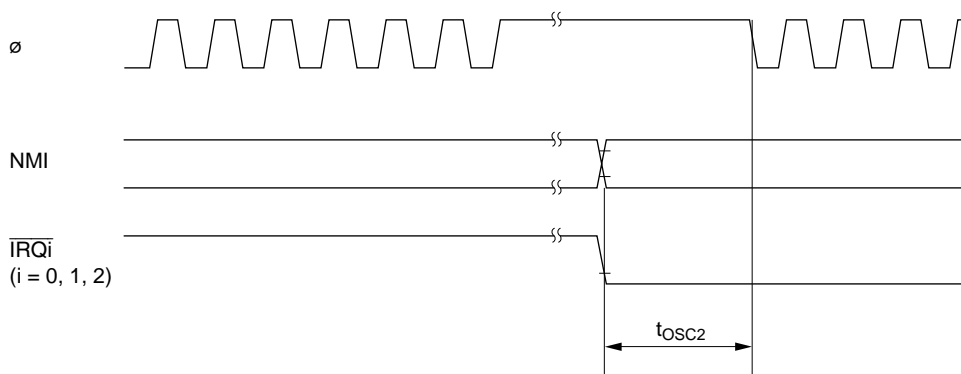


Figure 22.55 Oscillation Setting Timing (Exiting Software Standby Mode)

(2) Control Signal Timing

Table 22.29 shows the control signal timing. The only external interrupts that can operate on the subclock ($\phi = 32.768$ kHz) are NMI and IRQ0, 1, and IRQ2.

Table 22.29 Control Signal Timing

Condition A: $V_{CC} = 5.0\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 32.768$ kHz, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
$\overline{\text{RES}}$ setup time	t_{RESS}	200	—	200	—	300	—	ns	Figure 22.56
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Figure 22.57
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time (IRQ2 to $\overline{\text{IRQ0}}$)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ2 to $\overline{\text{IRQ0}}$)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ2 to $\overline{\text{IRQ0}}$) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

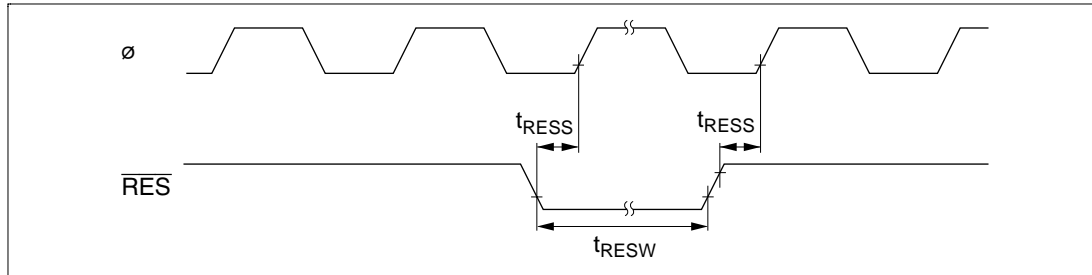


Figure 22.56 Reset Input Timing

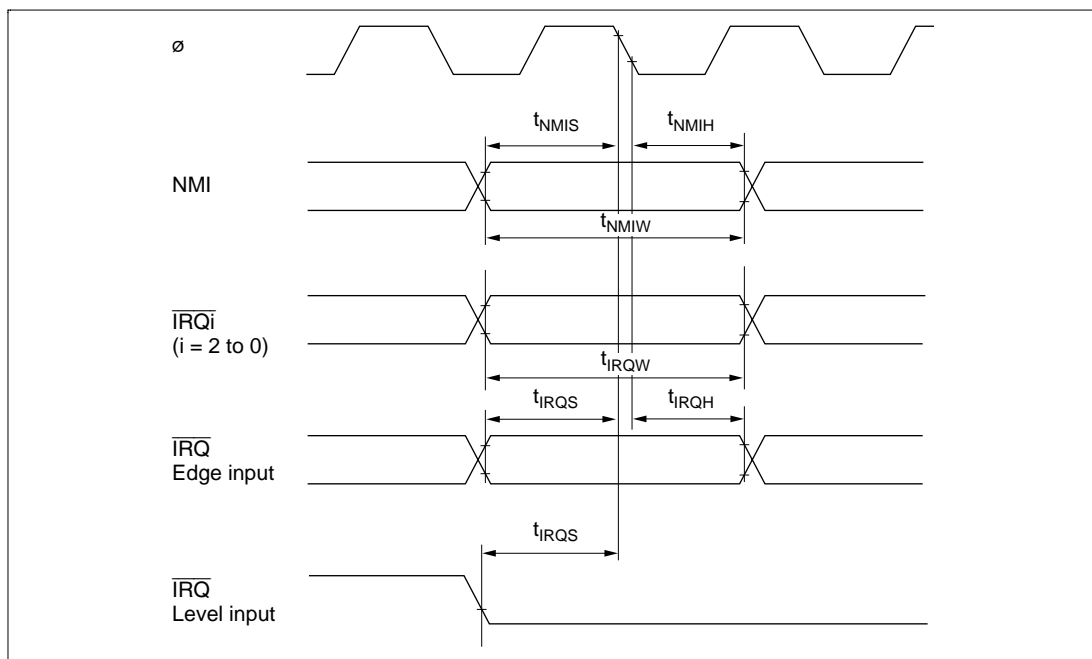


Figure 22.57 Interrupt Input Timing

(3) Bus Timing

Table 22.30 shows the bus timing. Operation in external expansion mode is not guaranteed when operating on the subclock ($\phi = 32.768$ kHz).

Table 22.30 Bus Timing

Condition A: $V_{CC} = 5.0\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,

$T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,

$T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),

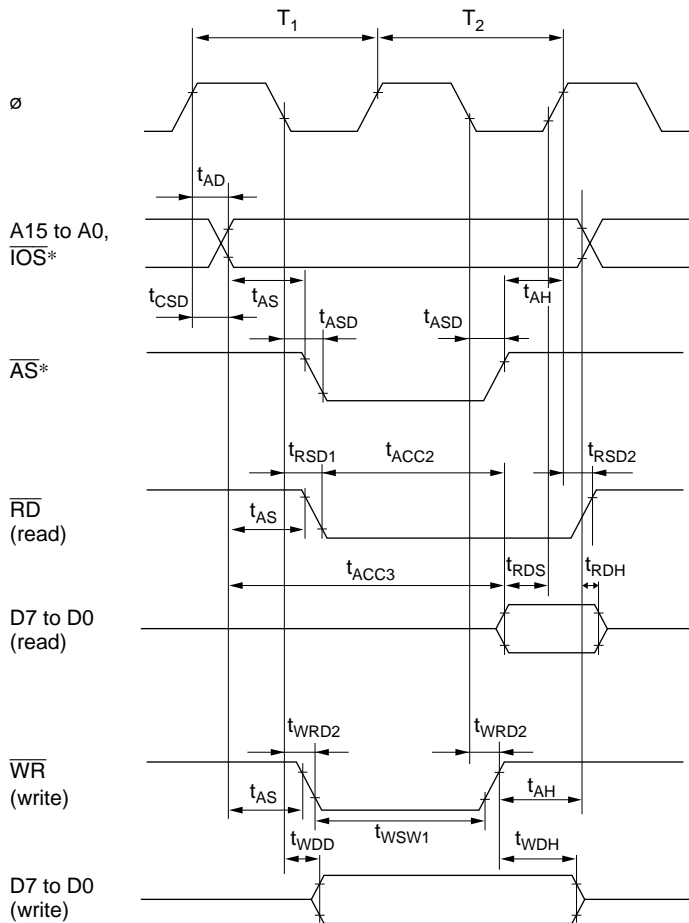
$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,

$T_a = -20$ to $+75^\circ\text{C}$

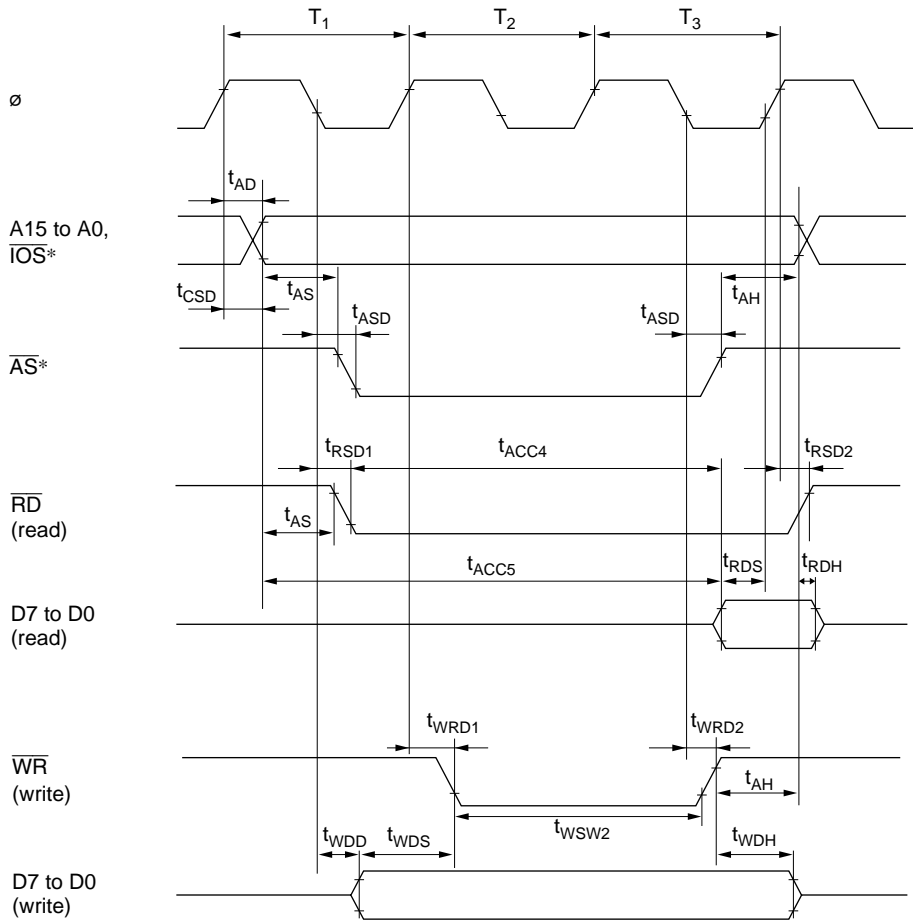
Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Address delay time	t _{AD}	—	20	—	30	—	40	ns	Figure 22.58 to figure 22.62
Address setup time	t _{AS}	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	0.5 × t _{cyc} – 30	—	ns	
Address hold time	t _{AH}	0.5 × t _{cyc} – 10	—	0.5 × t _{cyc} – 15	—	0.5 × t _{cyc} – 20	—	ns	
\overline{CS} delay time (IOS)	t _{CSD}	—	20	—	30	—	40	ns	
\overline{AS} delay time	t _{ASD}	—	30	—	45	—	60	ns	
\overline{RD} delay time 1	t _{RSD1}	—	30	—	45	—	60	ns	
\overline{RD} delay time 2	t _{RSD2}	—	30	—	45	—	60	ns	
Read data setup time	t _{RDS}	15	—	20	—	35	—	ns	
Read data hold time	t _{RDH}	0	—	0	—	0	—	ns	
Read data access time 1	t _{ACC1}	—	1.0 × t _{cyc} – 30	—	1.0 × t _{cyc} – 40	—	1.0 × t _{cyc} – 60	ns	
Read data access time 2	t _{ACC2}	—	1.5 × t _{cyc} – 25	—	1.5 × t _{cyc} – 35	—	1.5 × t _{cyc} – 50	ns	

Item	Symbol	Condition A		Condition B		Condition C		Unit	Test Conditions
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Read data access time 3	t _{ACC3}	—	2.0 × t _{cyc} – 30	—	2.0 × t _{cyc} – 40	—	2.0 × t _{cyc} – 60	ns	Figure 22.58 to figure 22.62
Read data access time 4	t _{ACC4}	—	2.5 × t _{cyc} – 25	—	2.5 × t _{cyc} – 35	—	2.5 × t _{cyc} – 50	ns	
Read data access time 5	t _{ACC5}	—	3.0 × t _{cyc} – 30	—	3.0 × t _{cyc} – 40	—	3.0 × t _{cyc} – 60	ns	
WR delay time 1	t _{WRD1}	—	30	—	45	—	60	ns	
WR delay time 2	t _{WRD2}	—	30	—	45	—	60	ns	
WR pulse width 1	t _{WSW1}	1.0 × t _{cyc} – 20	—	1.0 × t _{cyc} – 30	—	1.0 × t _{cyc} – 40	—	ns	
WR pulse width 2	t _{WSW2}	1.5 × t _{cyc} – 20	—	1.5 × t _{cyc} – 30	—	1.5 × t _{cyc} – 40	—	ns	
Write data delay time	t _{WDD}	—	30	—	45	—	60	ns	
Write data setup time	t _{WDS}	0	—	0	—	0	—	ns	
Write data hold time	t _{WDH}	10	—	15	—	20	—	ns	
WAIT setup time	t _{WTS}	30	—	45	—	60	—	ns	
WAIT hold time	t _{WTH}	5	—	5	—	10	—	ns	



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.58 Basic Bus Timing (Two-State Access)



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.59 Basic Bus Timing (Three-State Access)

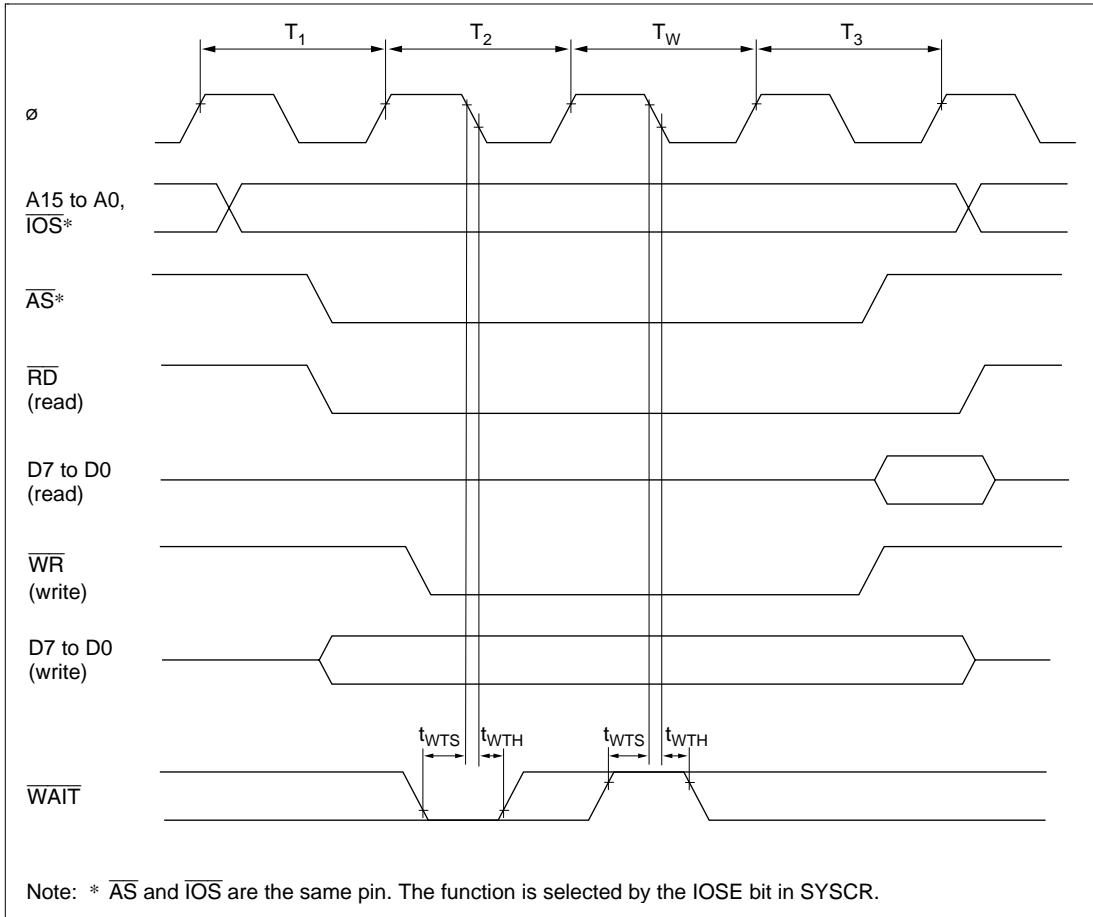
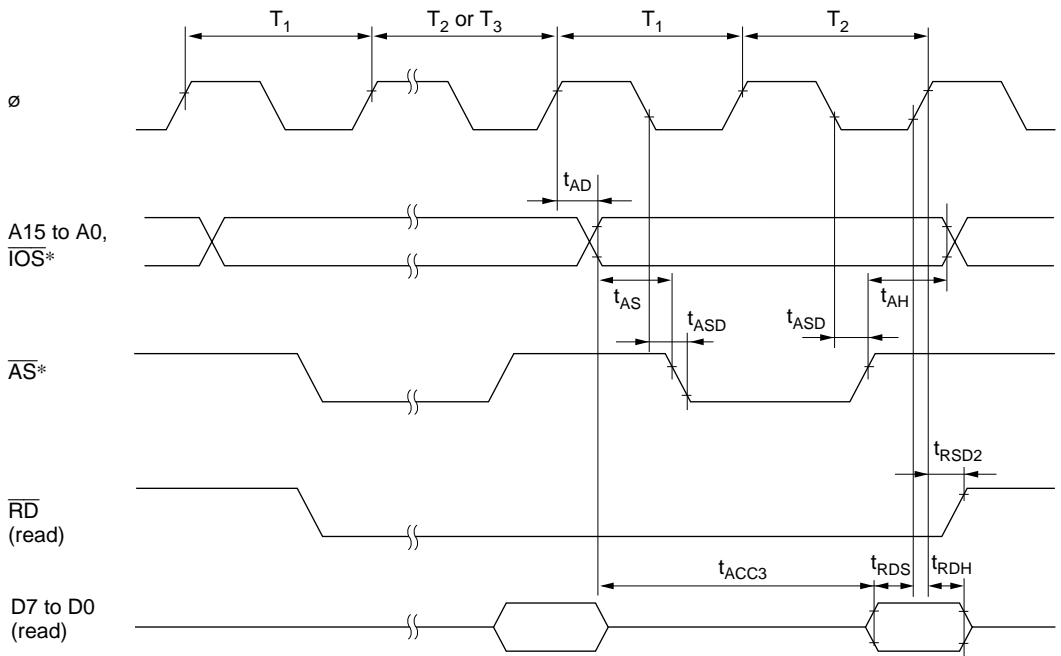
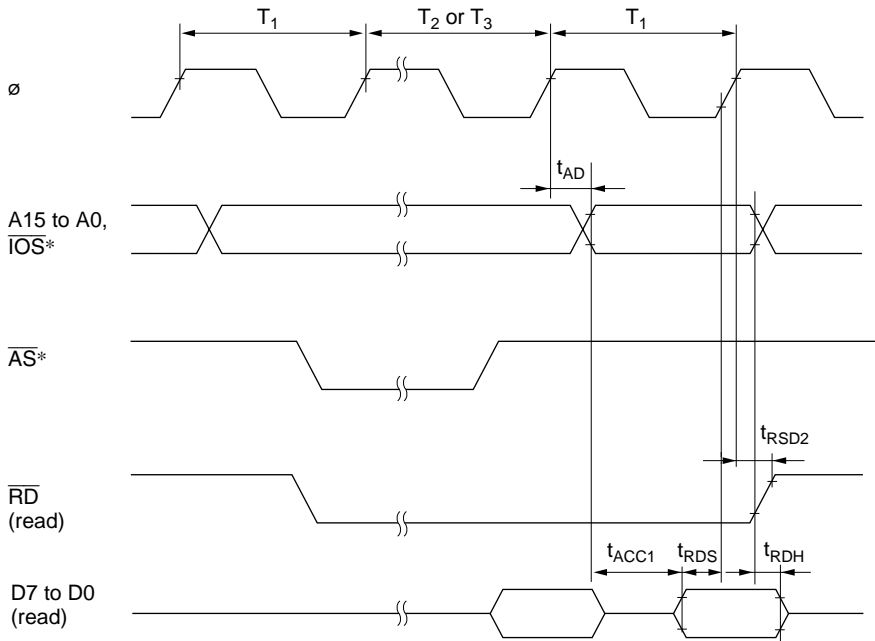


Figure 22.60 Basic Bus Timing (Three-State Access with One Wait State)



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.61 Burst ROM Access Timing (Two-State Access)



Note: * \overline{AS} and $\overline{I/O}$ are the same pin. The function is selected by the IOSE bit in SYSCR.

Figure 22.62 Burst ROM Access Timing (One-State Access)

(4) Timing of On-Chip Supporting Modules

Table 22.31 shows the on-chip supporting module timing. The only on-chip supporting modules that can operate in subclock operation ($\phi = 32.768$ kHz) are the I/O ports, external interrupts (NMI and IRQ0, 1, and IRQ2), the watchdog timer, and the 8-bit timer (channels 0 and 1).

Table 22.31 Timing of On-Chip Supporting Modules

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}^*$, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

			Condition A		Condition B		Condition C				
			20 MHz		16 MHz		10 MHz		Test		
Item		Symbol	Min	Max	Min	Max	Min	Max	Unit	Conditions	
I/O ports	Output data delay time	t _{PWD}	—	50	—	50	—	100	ns	Figure 22.63	
	Input data setup time	t _{PRS}	30	—	30	—	50	—			
	Input data hold time	t _{PRH}	30	—	30	—	50	—			
FRT	Timer output delay time	t _{FTOD}	—	50	—	50	—	100	ns	Figure 22.64	
	Timer input setup time	t _{FTIS}	30	—	30	—	50	—			
	Timer clock input setup time	t _{FTCS}	30	—	30	—	50	—			
	Timer clock pulse width	Single edge	t _{FTCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	Figure 22.65
		Both edges	t _{FTCWL}	2.5	—	2.5	—	2.5	—		

			Condition A		Condition B		Condition C		Test Conditions		
			Min	Max	Min	Max	Min	Max			
Item		Symbol	Min	Max	Min	Max	Min	Max	Unit		
TMR	Timer output delay time	t _{TMOD}	—	50	—	50	—	100	ns	Figure 22.66	
	Timer reset input setup time	t _{TMRS}	30	—	30	—	50	—		Figure 22.68	
	Timer clock input setup time	t _{TMCS}	30	—	30	—	50	—		Figure 22.67	
	Timer clock pulse width	Single edge	t _{TMCWH}	1.5	—	1.5	—	1.5	—	t _{cyc}	
		Both edges	t _{TMCWL}	2.5	—	2.5	—	2.5	—		
SCI	Input clock cycle	Asynchronous	t _{Scyc}	4	—	4	—	4	—	t _{cyc}	Figure 22.69
		Synchronous		6	—	6	—	6	—		
	Input clock pulse width	t _{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	t _{Scyc}		
	Input clock rise time	t _{SCKr}	—	1.5	—	1.5	—	1.5	t _{cyc}		
	Input clock fall time	t _{SCKf}	—	1.5	—	1.5	—	1.5			
	Transmit data delay time (synchronous)	t _{TXD}	—	50	—	50	—	100	ns	Figure 22.70	
	Receive data setup time (synchronous)	t _{RXS}	50	—	50	—	100	—	ns		
	Receive data hold time (synchronous)	t _{RXH}	50	—	50	—	100	—	ns		
A/D converter	Trigger input setup time	t _{TRGS}	30	—	30	—	50	—	ns	Figure 22.71	

Note: * Only supporting modules that can be used in subclock operation

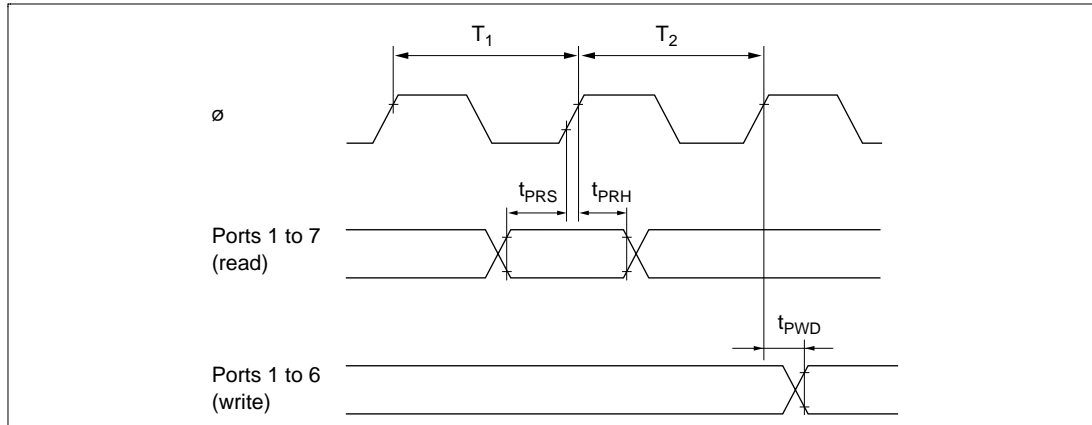


Figure 22.63 I/O Port Input/Output Timing

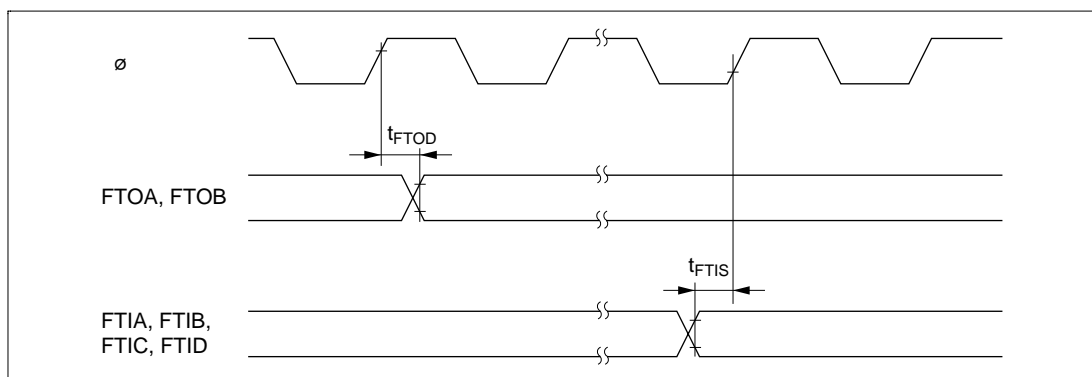


Figure 22.64 FRT Input/Output Timing

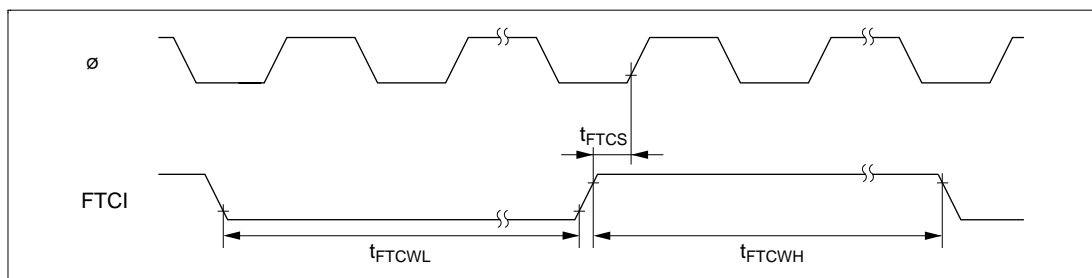


Figure 22.65 FRT Clock Input Timing

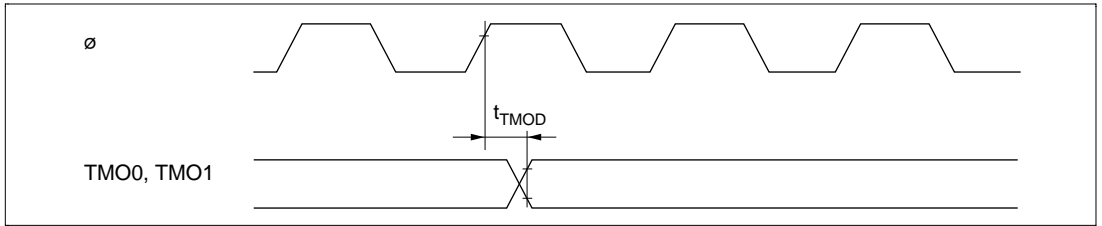


Figure 22.66 8-Bit Timer Output Timing

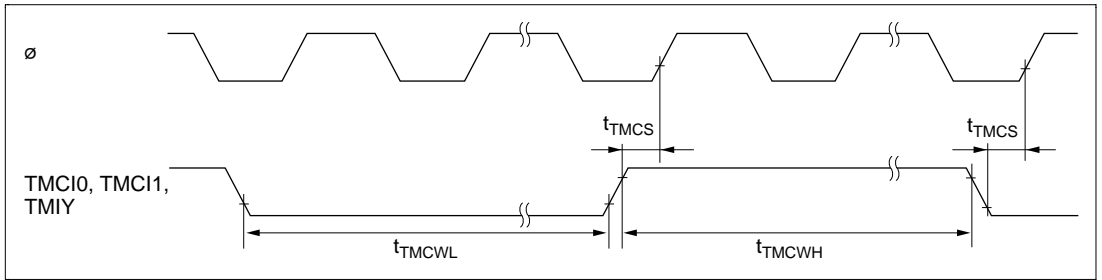


Figure 22.67 8-Bit Timer Clock Input Timing

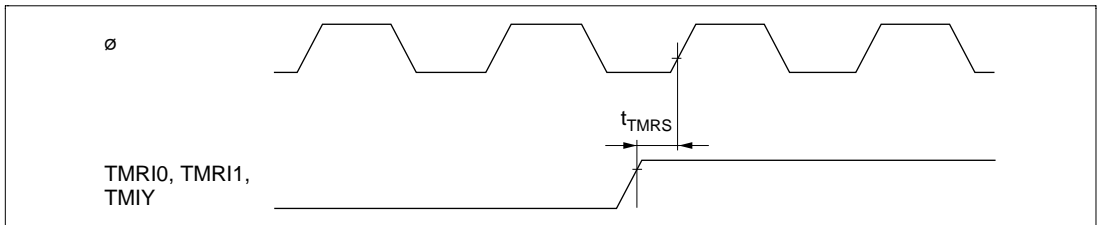


Figure 22.68 8-Bit Timer Reset Input Timing

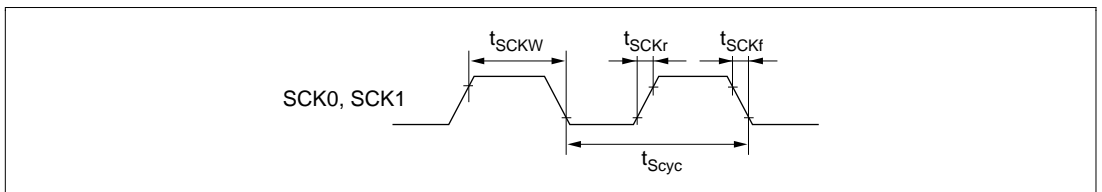


Figure 22.69 SCK Clock Input Timing

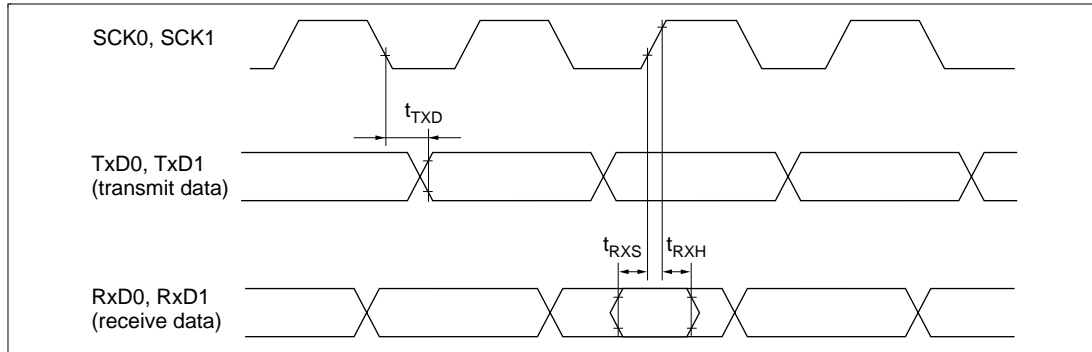


Figure 22.70 SCI Input/Output Timing (Synchronous Mode)

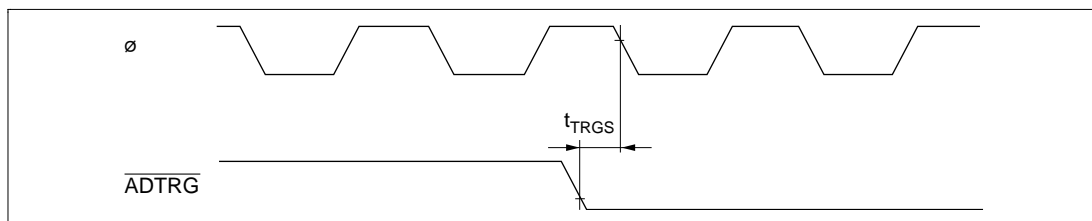


Figure 22.71 A/D Converter External Trigger Input Timing

22.4.4 A/D Conversion Characteristics

Tables 22.32 and 22.33 list the A/D conversion characteristics.

Table 22.32 A/D Conversion Characteristics
(AN7 to AN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*5	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*3	—	—	10*3	—	—	10*1	kΩ
			5*4			5*4			5*2	
Nonlinearity error	—	—	±3.0	—	—	±3.0	—	—	±7.0	LSB
Offset error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Full-scale error	—	—	±3.5	—	—	±3.5	—	—	±7.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±4.0	—	—	±4.0	—	—	±8.0	LSB

Notes: *1 When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$

*2 When $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$

*3 When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)

*4 When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)

*5 At the maximum operating frequency in single mode

Table 22.33 A/D Conversion Characteristics
(CIN7 to CIN0 Input: 134/266-State Conversion)

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $AV_{CC} = 4.0 \text{ V}$ to 5.5 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 5.5 V , $AV_{CC} = 2.7 \text{ V}$ to 5.5 V
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C			Unit
	20 MHz			16 MHz			10 MHz			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	10	10	10	Bits
Conversion time*5	—	—	6.7	—	—	8.4	—	—	13.4	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*3	—	—	10*3	—	—	10*1	kΩ
			5*4			5*4			5*2	
Nonlinearity error	—	—	±5.0	—	—	±5.0	—	—	±11.0	LSB
Offset error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Full-scale error	—	—	±5.5	—	—	±5.5	—	—	±11.5	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±6.0	—	—	±6.0	—	—	±12.0	LSB

Notes: *1 When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$

*2 When $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$

*3 When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)

*4 When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)

*5 At the maximum operating frequency in single mode

22.4.5 Usage Note

The specifications of the H8S/2128 F-ZTAT version and H8S/2124 Series mask ROM version differ in terms of on-chip module functions provided and port (P47, P52) output specifications. Also, while the F-ZTAT and mask ROM versions both satisfy the electrical characteristics shown in this manual, actual electrical characteristic values, operating margins, noise margins, and other properties may vary due to differences in manufacturing process, on-chip ROM, layout patterns, etc.

When system evaluation testing is carried out using the H8S/2128 F-ZTAT version, the above differences must be taken into consideration in system design, and the same evaluation testing should also be conducted for the mask ROM version when changing over to that version.

Appendix F Product Code Lineup

Table F.1 H8S/2128 Series and H8S/2124 Series Product Code Lineup — Preliminary —

Product Type				Product Code	Mark Code	Package (Hitachi Package Code)	Notes
H8S/2128 Series	H8S/2128 F-ZTAT version	Standard product (5 V/4 V version)	HD64F2128	HD64F2128PS20	HD64F2128PS20	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	
		Low-voltage version (3 V version)	HD64F2128V	HD64F2128VPS10	HD64F2128VPS10	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	
	H8S/2127 Mask ROM version	Standard product (5 V version, 4 V version, 3 V version)	HD6432127R	HD6432127R(***)PS	HD6432127R(***)PS	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	
		Version with on-chip I ² C bus interface (5 V version, 4 V version, 3 V version)	HD6432127RW	HD6432127RW(***)PS	HD6432127RW(***)PS	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	
H8S/2126	Mask ROM version	Standard product (5 V version, 4 V version, 3 V version)	HD6432126R	HD6432126R(***)PS	HD6432126R(***)PS	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	
		Version with on-chip I ² C bus interface (5 V version, 4 V version, 3 V version)	HD6432126RW	HD6432126RW(***)PS	HD6432126RW(***)PS	64-pin shrink DIP (DP-64S)	
						64-pin QFP (FP-64A)	
						80-pin TQFP (TFP-80C)	

Product Type				Product Code	Mark Code	Package (Hitachi Package Code)	Notes
H8S/2128S Series	H8S/2128S Mask ROM version	Standard product (5 V version, 4 V version)	HD6432128S	HD6432128S(***)PS	64-pin shrink DIP (DP-64S)		
				HD6432128S(***)FA	64-pin QFP (FP-64A)		
				HD6432128S(***)TF	80-pin TQFP (TFP-80C)		
	Low-voltage version (3 V version)		HD6432128SV	HD6432128SV(***)PS	64-pin shrink DIP (DP-64S)		Under planning
				HD6432128SV(***)FA	64-pin QFP (FP-64A)		
				HD6432128SV(***)TF	80-pin TQFP (TFP-80C)		
	Standard product with on-chip I ² C bus interface (5 V version, 4 V version)		HD6432128SW	HD6432128SW(***)PS	64-pin shrink DIP (DP-64S)		
				HD6432128SW(***)FA	64-pin QFP (FP-64A)		
				HD6432128SW(***)TF	80-pin TQFP (TFP-80C)		
	Low-voltage version with on-chip I ² C bus interface (3 V version)		HD6432128SVW	HD6432128SVW(***)PS	64-pin shrink DIP (DP-64S)		Under planning
				HD6432128SVW(***)FA	64-pin QFP (FP-64A)		
				HD6432128SVW(***)TF	80-pin TQFP (TFP-80C)		
H8S/2127S	Mask ROM version	Standard product (5 V version, 4 V version)	HD6432127S	HD6432127S(***)PS	64-pin shrink DIP (DP-64S)		
				HD6432127S(***)FA	64-pin QFP (FP-64A)		
				HD6432127S(***)TF	80-pin TQFP (TFP-80C)		
	Low-voltage version (3 V version)		HD6432127SV	HD6432127SV(***)PS	64-pin shrink DIP (DP-64S)		Under planning
				HD6432127SV(***)FA	64-pin QFP (FP-64A)		
				HD6432127SV(***)TF	80-pin TQFP (TFP-80C)		
	Standard product with on-chip I ² C bus interface (5 V version, 4 V version)		HD6432127SW	HD6432127SW(***)PS	64-pin shrink DIP (DP-64S)		
				HD6432127SW(***)FA	64-pin QFP (FP-64A)		
				HD6432127SW(***)TF	80-pin TQFP (TFP-80C)		
	Low-voltage version with on-chip I ² C bus interface (3 V version)		HD6432127SVW	HD6432127SVW(***)PS	64-pin shrink DIP (DP-64S)		Under planning
				HD6432127SVW(***)FA	64-pin QFP (FP-64A)		
				HD6432127SVW(***)TF	80-pin TQFP (TFP-80C)		

Product Type				Product Code	Mark Code	Package (Hitachi Package Code)	Notes
H8S/2124 Series	H8S/2122	Mask ROM version	Standard product (5 V version, 4 V version, 3 V version)	HD6432122	HD6432122(***)PS	64-pin shrink DIP (DP-64S)	
					HD6432122(***)FA	64-pin QFP (FP-64A)	
					HD6432122(***)TF	80-pin TQFP (TFP-80C)	
	H8S/2120	Mask ROM version	Standard product (5 V version, 4 V version, 3 V version)	HD6432120	HD6432120(***)PS	64-pin shrink DIP (DP-64S)	
					HD6432120(***)FA	64-pin QFP (FP-64A)	
					HD6432120(***)TF	80-pin TQFP (TFP-80C)	

Note: (***) is the ROM code.

The F-ZTAT version of the H8S/2128 has an on-chip I²C bus interface as standard.

The F-ZTAT 5 V/4 V version supports the operating ranges of the 5 V version and the 4 V version.

The operating range of the F-ZTAT low-voltage version will be decided later.

The above table includes products in the planning stage or under development. Information on the status of individual products can be obtained from Hitachi's sales offices.

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