Section 15 Electrical Characteristics

15.1 Absolute Maximum Ratings

Table 15-1 lists the absolute maximum ratings.

Table 15-1 Absolute Maximum Ratings

—Preliminary—

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	–0.3 to +7.0	V
Input voltage (except port 7)	V_{IN}	–0.3 to V_{CC} +0.3	V
Input voltage (port 7)	V_{IN}	–0.3 to AV_{CC} +0.3	V
Reference voltage	V_{REF}	–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.

15.2 Electrical Characteristics

15.2.1 DC Characteristics

Table 15-2 lists the DC characteristics. Table 15-3 lists the permissible output currents.

Table 15-2 DC Characteristics

Conditions: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V*, T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltages	Port A, $P8_0$ to $P8_2$, PB_0 to PB_3	V_T^-	1.0	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD_1, MD_0	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	
	Ports 6, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		2.0	—	$V_{CC} + 0.3$	V	
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD_1, MD_0	V_{IL}	–0.3	—	0.5	V	
	NMI, EXTAL, ports 6, 7, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		–0.3	—	0.8	V	
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH} = –200 µA
			3.5	—	—	V	I_{OH} = –1 mA

Note: * If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*1, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	All output pins (except $\overline{RESO}$)	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports B, A_{19} to A_0		—	—	1.0	V	I_{OL} = 10 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 2.6 mA
Input leakage current	$\overline{STBY}$, NMI, $\overline{RES}$, MD_1, MD_0	$\|I_{IN}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	Port 7		—	—	1.0	µA	V_{IN} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 6, 8 to B, A_{19} to A_0, D_7 to D_0	$\|I_{TSI}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	$\overline{RESO}$		—	—	10.0	µA	
Input capacitance	NMI	C_{IN}	—	—	50	pF	V_{IN} = 0 V, f = 1 MHz, T_a = 25°C
	All input pins except NMI		—	—	15		
Current dissipation*2	Normal operation	I_{CC}	—	45	60	mA	f = 16 MHz
	Sleep mode		—	32	45	mA	f = 16 MHz
	Standby mode*3		—	0.01	5.0	µA	$T_a \leq$ 50°C
			—	—	20.0	µA	50°C < T_a

Notes: 1. If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.
2. Current dissipation values are for $V_{IHmin} = V_{CC} - 0.5$ V and V_{ILmax} = 0.5 V with all output pins unloaded and the on-chip pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.5$ V, $V_{IHmin} = V_{CC} \times 0.9$, and V_{ILmax} = 0.3 V.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V*[1], T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Analog power supply current	During A/D conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	µA	
Reference current	During A/D conversion	AI_{CC}	—	0.3	0.6	mA	V_{REF} = 5.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.
2. Current dissipation values are for $V_{IHmin} = V_{CC} - 0.5$ V and V_{ILmax} = 0.5 V with all output pins unloaded and the on-chip pull-up transistors in the off state.
3. The values are for $V_{RAM} < V_{CC} < 4.5$ V, $V_{IHmin} = V_{CC} \times 0.9$, and V_{ILmax} = 0.3 V.

Conditions: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V*, T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltages	Port A, $P8_0$ to $P8_2$, PB_0 to PB_3	V_T^-	$V_{CC} \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.07$	—	—	V	
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD_1, MD_0	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	
	Ports 6, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	

Note: * If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD_1, MD_0	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, ports 6, 7, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		–0.3	—	$V_{CC} \times 0.2$	V	V_{CC} < 4.0 V
					0.8	V	V_{CC} = 4.0 to 5.5 V
Output high voltage	All output pins	V_{OH}	V_{CC} – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0	—	—	V	I_{OH} = –1 mA
Output low voltage	All output pins (except $\overline{RESO}$)	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports B, A_{19} to A_0		—	—	1.0	V	$V_{CC} \leq 4$ V, I_{OL} = 5 mA, 4 V ≤ V_{CC} ≤ 5.5 V, I_{OL} = 10 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 1.6 mA
Input leakage current	$\overline{STBY}$, NMI, $\overline{RES}$, MD_1, MD_0	$\|I_{IN}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	Port 7		—	—	1.0	µA	V_{IN} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 6, 8 to B, A_{19} to A_0, D_7 to D_0	$\|I_{TS1}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	$\overline{RESO}$		—	—	10.0	µA	

Note: * If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*1, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	NMI	C_{IN}	—	—	50	pF	V_{IN} = 0 V, f = 1 MHz, T_a = 25°C
	All input pins except NMI		—	—	15		
Current dissipation*2	Normal operation	I_{CC}*4	—	12 (3.0 V)	33.8 (5.5 V)	mA	f = 8 MHz
	Sleep mode		—	8 (3.0 V)	25.0 (5.5 V)	mA	f = 8 MHz
	Standby mode*3		—	0.01	5.0	µA	$T_a \leq$ 50°C
			—	—	20.0	µA	50°C < T_a
Analog power supply current	During A/D conversion	AI_{CC}	—	1.0	2.0	mA	AV_{CC} = 3.0 V
			—	1.2	—	mA	AV_{CC} = 5.0 V
	Idle		—	0.01	5.0	µA	
Reference current	During A/D conversion	AI_{CC}	—	0.2	0.4	mA	V_{REF} = 3.0 V
			—	0.3	—	mA	V_{REF} = 5.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.
2. Current dissipation values are for $V_{IHmin} = V_{CC} - 0.5$ V and V_{ILmax} = 0.5 V with all output pins unloaded.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7$ V, $V_{IHmin} = V_{CC} \times 0.9$, and V_{ILmax} = 0.3 V.
4. I_{CC} depends on V_{CC} and f as follows:
I_{CCmax} = 3.0 (mA) + 0.7 (mA/MHz · V) × V_{CC} × f [normal mode]
I_{CCmax} = 3.0 (mA) + 0.5 (mA/MHz · V) × V_{CC} × f [sleep mode]

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltages	Port A, $P8_0$ to $P8_2$, PB_0 to PB_3	V_T^-	$V_{CC} \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.07$	—	—	V	
Input high voltage	$\overline{RES}$, $\overline{STBY}$, NMI, MD_1, MD_0	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	
	Ports 6, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	$\overline{RES}$, $\overline{STBY}$, MD_1, MD_0	V_{IL}	–0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, ports 6, 7, 9, $P8_3$, PB_4 to PB_7, D_7 to D_0		–0.3	—	$V_{CC} \times 0.2$	V	V_{CC} < 4.0 V
					0.8	V	V_{CC} = 4.0 to 5.5 V
Output high voltage	All output pins	V_{OH}	V_{CC} – 0.5	—	—	V	I_{OH} = –200 µA
			V_{CC} – 1.0	—	—	V	I_{OH} = –1 mA

Note: * If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	All output pins (except $\overline{RESO}$)	V_{OL}	—	—	0.4	V	I_{OL} = 1.6 mA
	Ports B, A_{19} to A_0		—	—	1.0	V	$V_{CC} \leq 4$ V, I_{OL} = 5 mA, 4 V < $V_{CC} \leq$ 5.5 V, I_{OL} = 10 mA
	$\overline{RESO}$		—	—	0.4	V	I_{OL} = 1.6 mA
Input leakage current	$\overline{STBY}$, NMI, $\overline{RES}$, MD_1, MD_0	$\|I_{IN}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	Port 7		—	—	1.0	µA	V_{IN} = 0.5 to AV_{CC} – 0.5 V
Three-state leakage current (off state)	Ports 6, 8 to B, A_{19} to A_0, D_7 to D_0	$\|I_{TSI}\|$	—	—	1.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V
	$\overline{RESO}$		—	—	10.0	µA	V_{IN} = 0.5 to V_{CC} – 0.5 V

Note: * If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.

Table 15-2 DC Characteristics (cont)

Conditions: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V*1, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Input capacitance	NMI	C_{IN}	—	—	50	pF	V_{IN} = 0 V, f = 1 MHz, T_a = 25°C
	All input pins except NMI		—	—	15		
Current dissipation*2	Normal operation	I_{CC}*4	—	15 (3.0 V)	41.5 (5.5 V)	mA	f = 10 MHz
	Sleep mode		—	10 (3.0 V)	30.5 (5.5 V)	mA	f = 10 MHz
	Standby mode*3		—	0.01	5.0	µA	$T_a \leq 50°C$
			—	—	20.0	µA	50°C < T_a
Analog power supply current	During A/D conversion	AI_{CC}	—	1.0	2.0	mA	AV_{CC} = 3.0 V
			—	1.2	—	mA	AV_{CC} = 5.0 V
	Idle		—	0.01	5.0	µA	
Reference current	During A/D conversion	AI_{CC}	—	0.2	0.4	mA	V_{REF} = 3.0 V
			—	0.3	—	mA	V_{REF} = 5.0 V
	Idle		—	0.01	5.0	µA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes:
1. If the A/D converter is not used, do not leave the AV_{CC}, AV_{SS}, and V_{REF} pins open. Connect AV_{CC} and V_{REF} to V_{CC}, and connect AV_{SS} to V_{SS}.
2. Current dissipation values are for $V_{IHmin} = V_{CC} - 0.5$ V and V_{ILmax} = 0.5 V with all output pins unloaded.
3. The values are for $V_{RAM} \leq V_{CC} < 3.0$ V, $V_{IHmin} = V_{CC} \times 0.9$, and V_{ILmax} = 0.3 V.
4. I_{CC} depends on V_{CC} and f as follows:
   I_{CCmax} = 3.0 (mA) + 0.7 (mA/MHz · V) × V_{CC} × f [normal mode]
   I_{CCmax} = 3.0 (mA) + 0.5 (mA/MHz · V) × V_{CC} × f [sleep mode]

Table 15-3 Permissible Output Currents

Conditions: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC},
$V_{SS} = AV_{SS}$ = 0 V, T_a = –20°C to +75°C (regular specifications),
T_a = –40°C to +85°C (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Ports B, A_{19} to A_0	I_{OL}	—	—	10	mA
	Other output pins		—	—	2.0	mA
Permissible output low current (total)	Total of 28 pins including ports B, A_{19} to A_0	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}	—	—	2.0	mA
Permissible output high current (total)	Total of all output pins	ΣI_{OH}	—	—	40	mA

Notes: 1. To protect chip reliability, do not exceed the output current values in table 15-3.
2. When driving a darlington pair or LED, always insert a current-limiting resistor in the output line, as shown in figures 15-1 and 15-2.

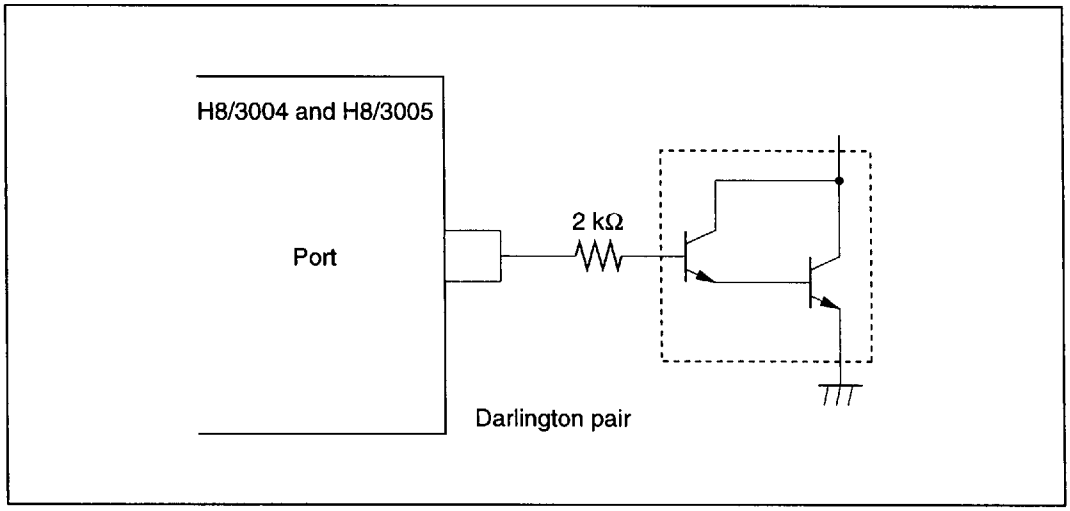

Figure 15-1 Darlington Pair Drive Circuit (Example)

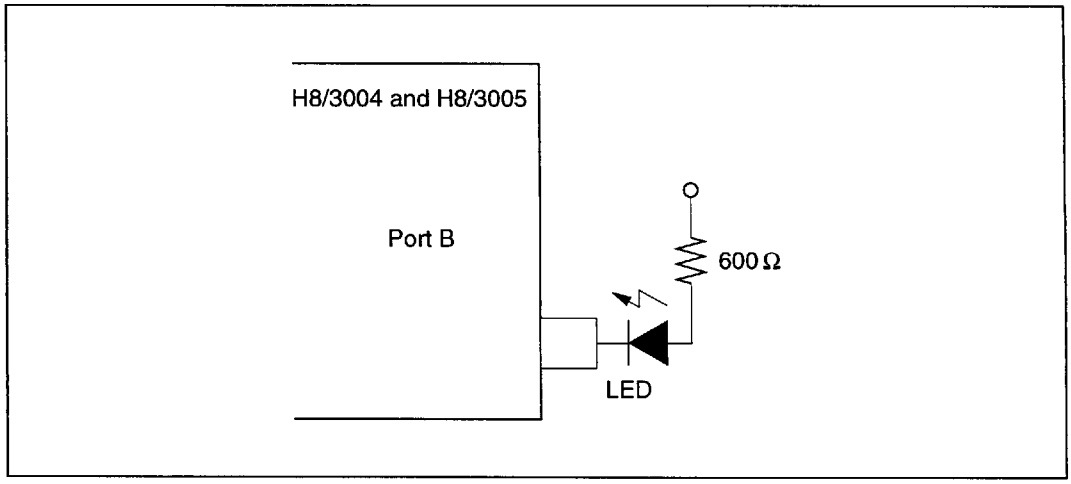

Figure 15-2 LED Drive Circuit (Example)

15.2.2 AC Characteristics

Bus timing parameters are listed in table 15-4. Control signal timing parameters are listed in table 15-5. Timing parameters of the on-chip supporting modules are listed in table 15-6.

Table 15-4 Bus Timing

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B		Condition C			
		8 MHz		10 MHz		16 MHz			
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
Clock cycle time	t_{CYC}	125	500	100	500	62.5	500	ns	Figure 15-4, Figure 15-5
Clock low pulse width	t_{CL}	40	—	30	—	20	—		
Clock high pulse width	t_{CH}	40	—	30	—	20	—		
Clock rise time	t_{CR}	—	20	—	15	—	10		
Clock fall time	t_{CF}	—	20	—	15	—	10		
Address delay time	t_{AD}	—	60	—	50	—	30		
Address hold time	t_{AH}	25	—	20	—	10	—		
Address strobe delay time	t_{ASD}	—	60	—	40	—	30		
Write strobe delay time	t_{WSD}	—	60	—	50	—	30		
Strobe delay time	t_{SD}	—	60	—	50	—	30		
Write data strobe pulse width 1	t_{WSW1}*	85	—	60	—	35	—		
Write data strobe pulse width 2	t_{WSW2}*	150	—	110	—	65	—		
Address setup time 1	t_{AS1}	20	—	15	—	10	—		
Address setup time 2	t_{AS2}	80	—	65	—	40	—		
Read data setup time	t_{RDS}	50	—	35	—	20	—		
Read data hold time	t_{RDH}	0	—	0	—	0	—		

Table 15-4 Bus Timing (cont)

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B		Condition C			
		8 MHz		10 MHz		16 MHz			
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
Write data delay time	t_{WDD}	—	75	—	75	—	60	ns	Figure 15-4, Figure 15-5
Write data setup time 1	t_{WDS1}	60	—	40	—	15	—		
Write data setup time 2	t_{WDS2}	5	—	–10	—	–5	—		
Write data hold time	t_{WDH}	25	—	20	—	20	—		
Read data access time 1	t_{ACC1}*	—	110	—	100	—	55		
Read data access time 2	t_{ACC2}*	—	230	—	200	—	115		
Read data access time 3	t_{ACC3}*	—	55	—	50	—	25		
Read data access time 4	t_{ACC4}*	—	160	—	150	—	85		
Precharge time	t_{PCH}*	85	—	60	—	40	—		
Wait setup time	t_{WTS}	40	—	40	—	25	—	ns	Figure 15-6
Wait hold time	t_{WTH}	10	—	10	—	5	—		

Note is on next page.

Note: At 8 MHz, the times below depend as indicated on the clock cycle time.

$t_{ACC1} = 1.5 \times t_{cyc} - 78$ (ns) $t_{WSW1} = 1.0 \times t_{cyc} - 40$ (ns)
$t_{ACC2} = 2.5 \times t_{cyc} - 83$ (ns) $t_{WSW2} = 1.5 \times t_{cyc} - 38$ (ns)
$t_{ACC3} = 1.0 \times t_{cyc} - 70$ (ns) $t_{PCH} = 1.0 \times t_{cyc} - 40$ (ns)
$t_{ACC4} = 2.0 \times t_{cyc} - 90$ (ns)

At 10 MHz, the times below depend as indicated on the clock cycle time.

$t_{ACC1} = 1.5 \times t_{cyc} - 50$ (ns) $t_{WSW1} = 1.0 \times t_{cyc} - 40$ (ns)
$t_{ACC2} = 2.5 \times t_{cyc} - 50$ (ns) $t_{WSW2} = 1.5 \times t_{cyc} - 40$ (ns)
$t_{ACC3} = 1.0 \times t_{cyc} - 50$ (ns) $t_{PCH} = 1.0 \times t_{cyc} - 40$ (ns)
$t_{ACC4} = 2.0 \times t_{cyc} - 50$ (ns)

At 16 MHz, the times below depend as indicated on the clock cycle time.

$t_{ACC1} = 1.5 \times t_{cyc} - 39$ (ns) $t_{WSW1} = 1.0 \times t_{cyc} - 28$ (ns)
$t_{ACC2} = 2.5 \times t_{cyc} - 41$ (ns) $t_{WSW2} = 1.5 \times t_{cyc} - 28$ (ns)
$t_{ACC3} = 1.0 \times t_{cyc} - 38$ (ns) $t_{PCH} = 1.0 \times t_{cyc} - 23$ (ns)
$t_{ACC4} = 2.0 \times t_{cyc} - 40$ (ns)

Table 15-5 Control Signal Timing

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, V_{SS} = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

		Condition A		Condition B		Condition C			
		8 MHz		10 MHz		16 MHz			Test
Item	Symbol	Min	Max	Min	Max	Min	Max	Unit	Conditions
$\overline{RES}$ setup time	t_{RESS}	200	—	200	—	200	—	ns	Figure 15-7
$\overline{RES}$ pulse width	t_{RESW}	10	—	10	—	10	—	t_{CYC}	
$\overline{RESO}$ output delay time	t_{RESD}	—	100	—	100	—	100	ns	Figure 15-8
$\overline{RESO}$ output pulse width	t_{RESOW}	132	—	132	—	132	—	t_{CYC}	
NMI setup time (NMI, $\overline{IRQ_4}$ to $\overline{IRQ_0}$)	t_{NMIS}	200	—	200	—	150	—	ns	Figure 15-9
NMI hold time (NMI, $\overline{IRQ_4}$ to $\overline{IRQ_0}$)	t_{NMIH}	10	—	10	—	10	—		
Interrupt pulse width (NMI, $\overline{IRQ_4}$ to $\overline{IRQ_0}$ when exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—		
Clock oscillator settling time at reset (crystal)	t_{OSC1}	20	—	20	—	20	—	ms	Figure 15-10
Clock oscillator settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms	Figure 14-1

Table 15-6 Timing of On-Chip Supporting Modules

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, V_{SS} = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, $V_{SS} = AV_{SS}$ = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

				Condition A		Condition B		Condition C			
				8 MHz		10 MHz		16 MHz			
Item			Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
ITU	Timer output delay time		t_{TOCD}	—	100	—	100	—	100	ns	Figure 15-12
	Timer input setup time		t_{TICS}	50	—	50	—	50	—		
	Timer clock input setup time		t_{TCKS}	50	—	50	—	50	—		Figure 15-13
	Timer clock pulse width	Single edge	t_{TCKWH}	1.5	—	1.5	—	1.5	—	t_{CYC}	
		Both edges	t_{TCKWL}	2.5	—	2.5	—	2.5	—		
SCI	Input clock cycle	Asynchronous	t_{SCYC}	4	—	4	—	4	—		Figure 15-14
		Synchronous	t_{SCYC}	6	—	6	—	6	—		
	Input clock rise time		t_{SCKr}	—	1.5	—	1.5	—	1.5		
	Input clock fall time		t_{SCKf}	—	1.5	—	1.5	—	1.5		
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	t_{SCYC}	

Table 15-6 Timing of On-Chip Supporting Modules (cont)

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, V_{SS} = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

			Condition A		Condition B		Condition C			
			8 MHz		10 MHz		16 MHz			
Item		Symbol	Min	Max	Min	Max	Min	Max	Unit	Test Conditions
SCI	Transmit data delay time	t_{TXD}	—	100	—	100	—	100	ns	Figure 15-15
	Receive data setup time (synchronous)	t_{RXS}	100	—	100	—	100	—		
	Receive data hold time (synchronous clock input)	t_{RXH}	100	—	100	—	100	—		
	Receive data hold time (synchronous clock output)	t_{RXH}	0	—	0	—	0	—		
Ports	Output data delay time	t_{PWD}	—	100	—	100	—	100	ns	Figure 15-11
	Input data setup time (synchronous)	t_{PRS}	50	—	50	—	50	—		
	Input data hold time (synchronous)	t_{PRH}	50	—	50	—	50	—		

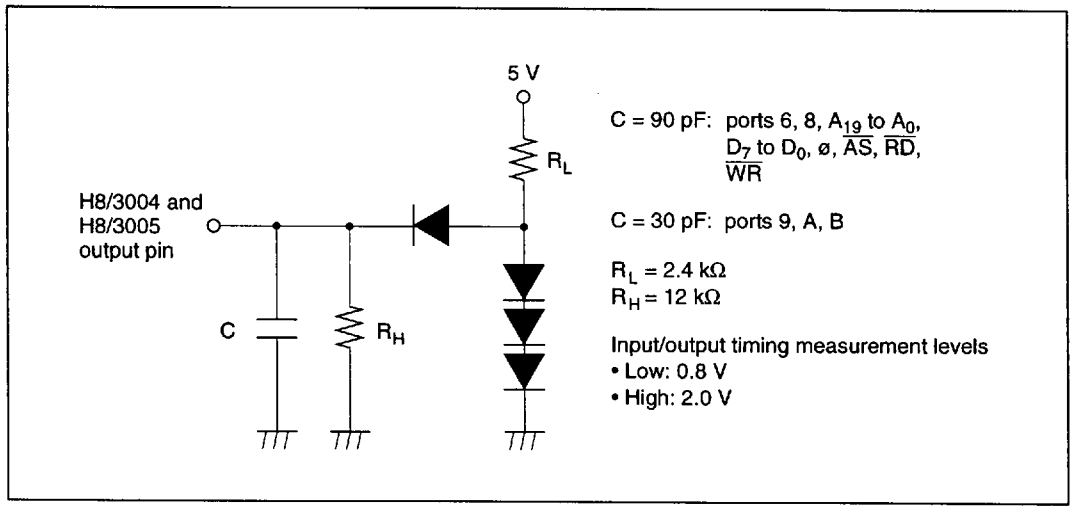

Figure 15-3 Output Load Circuit

15.2.3 A/D Conversion Characteristics

Table 15-7 lists the A/D conversion characteristics.

Table 15-7 A/D Converter Characteristics

Condition A: V_{CC} = 2.7 V to 5.5 V, AV_{CC} = 2.7 V to 5.5 V, V_{REF} = 2.7 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 8 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition B: V_{CC} = 3.0 V to 5.5 V, AV_{CC} = 3.0 V to 5.5 V, V_{REF} = 3.0 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 10 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

Condition C: V_{CC} = 5.0 V ± 10%, AV_{CC} = 5.0 V ± 10%, V_{REF} = 4.5 V to AV_{CC}, V_{SS} = AV_{SS} = 0 V, ø = 2 MHz to 16 MHz, T_a = –20°C to +75°C (regular specifications), T_a = –40°C to +85°C (wide-range specifications)

	Condition A			Condition B			Condition C			
	8 MHz			10 MHz			16 MHz			
Item	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Unit
Resolution	10	10	10	10	10	10	10	10	10	bits
Conversion time	—	—	16.8	—	—	13.4	—	—	8.4	µs
Analog input capacitance	—	—	20	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10*1	—	—	10*1	—	—	10*4	kΩ
	—	—	5*2			5*3	—	—	5*5	
Nonlinearity error	—	—	±6.0	—	—	±6.0	—	—	±3.0	LSB
Offset error	—	—	±4.0	—	—	±4.0	—	—	±2.0	LSB
Full-scale error	—	—	±4.0	—	—	±4.0	—	—	±2.0	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	LSB
Absolute accuracy	—	—	±8.0	—	—	±8.0	—	—	±4.0	LSB

Notes: 1. The value is for $4.0 \leq AV_{CC} \leq 5.5$.
2. The value is for $2.7 \leq AV_{CC} < 4.0$.
3. The value is for $3.0 \leq AV_{CC} < 4.0$.
4. The value is for ø ≤ 12 MHz.
5. The value is for ø > 12 MHz.

15.3 Operational Timing

This section shows timing diagrams.

15.3.1 Bus Timing

Bus timing is shown as follows:

- Basic bus cycle: two-state access

  Figure 15-4 shows the timing of the external two-state access cycle.

- Basic bus cycle: three-state access

  Figure 15-5 shows the timing of the external three-state access cycle.

- Basic bus cycle: three-state access with one wait state

  Figure 15-6 shows the timing of the external three-state access cycle with one wait state inserted.

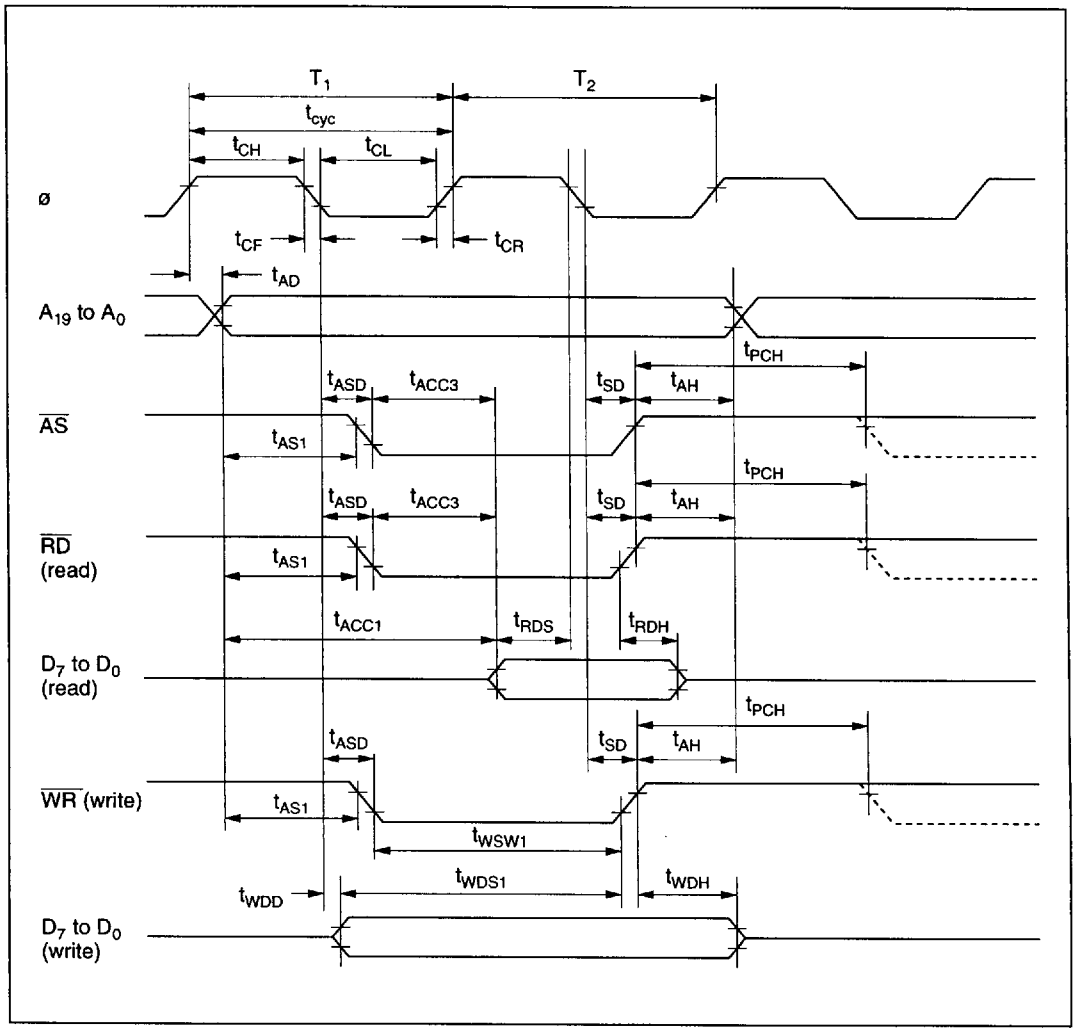

Figure 15-4 Basic Bus Cycle: Two-State Access

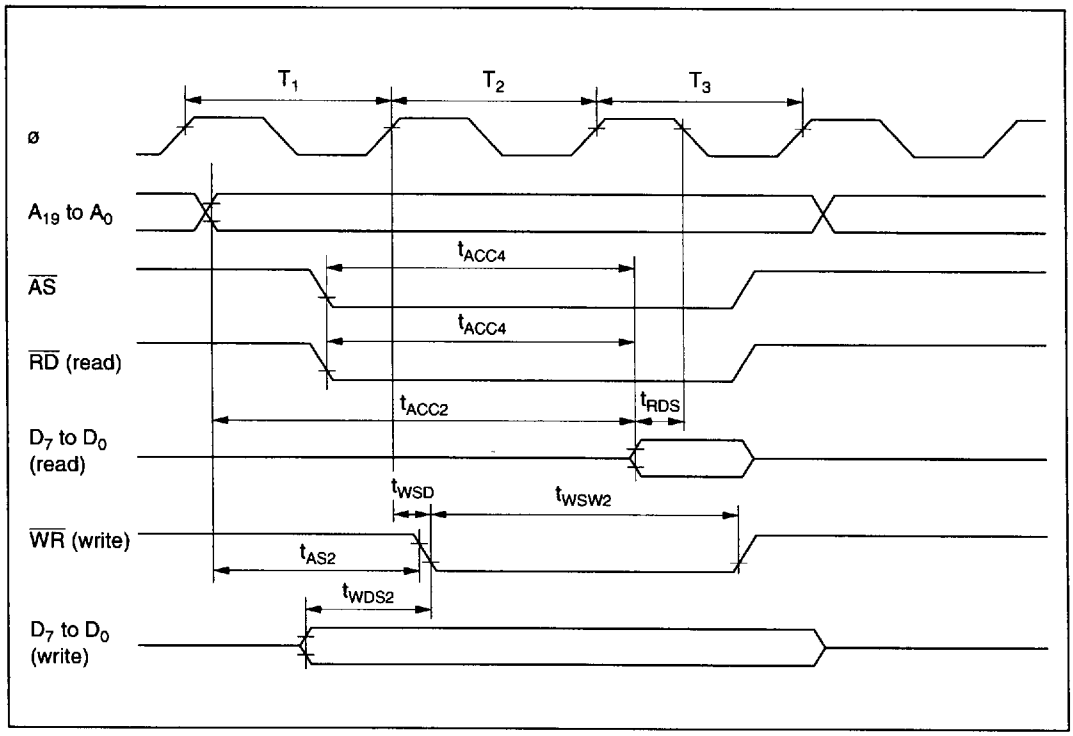

Figure 15-5 Basic Bus Cycle: Three-State Access

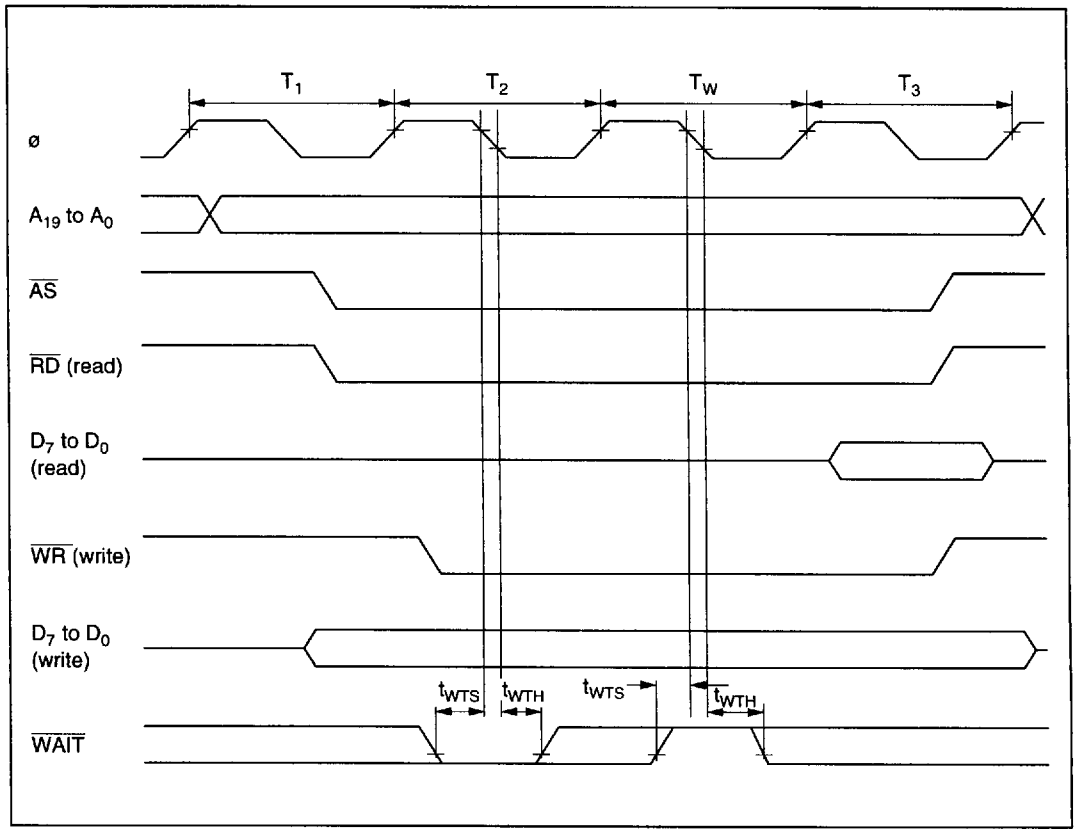

Figure 15-6 Basic Bus Cycle: Three-State Access with One Wait State

15.3.2 Control Signal Timing

Control signal timing is shown as follows:

- Reset input timing

  Figure 15-7 shows the reset input timing.

- Reset output timing

  Figure 15-8 shows the reset output timing.

- Interrupt input timing

  Figure 15-9 shows the input timing for NMI and $\overline{IRQ_4}$ to $\overline{IRQ_0}$.

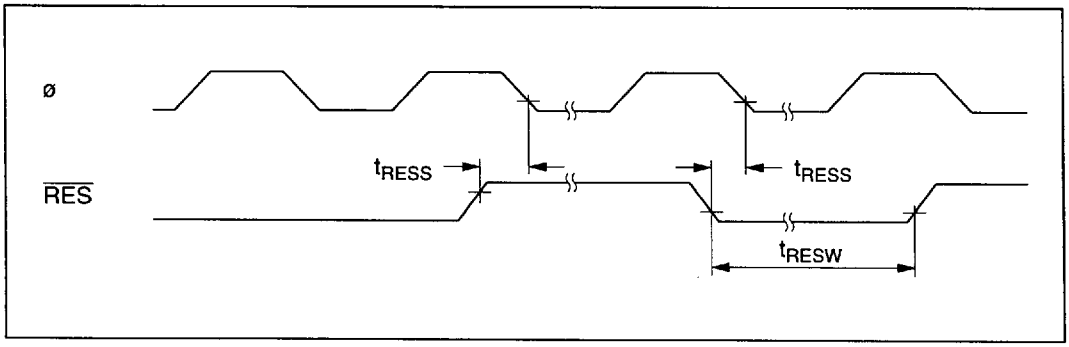

Figure 15-7 Reset Input Timing

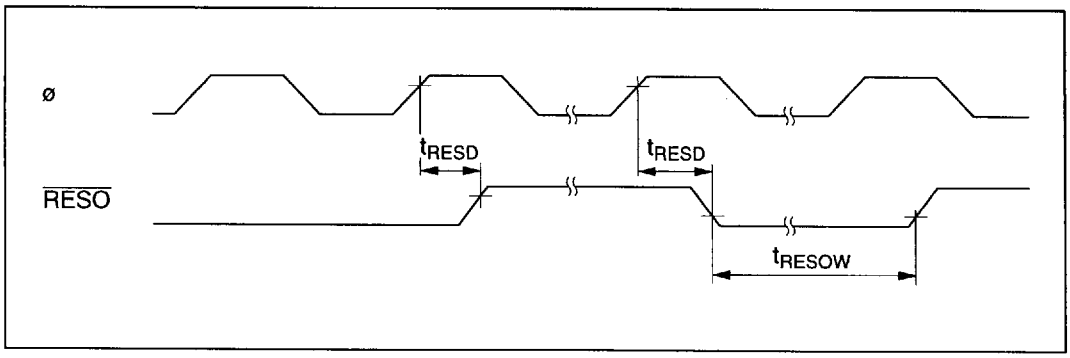

Figure 15-8 Reset Output Timing

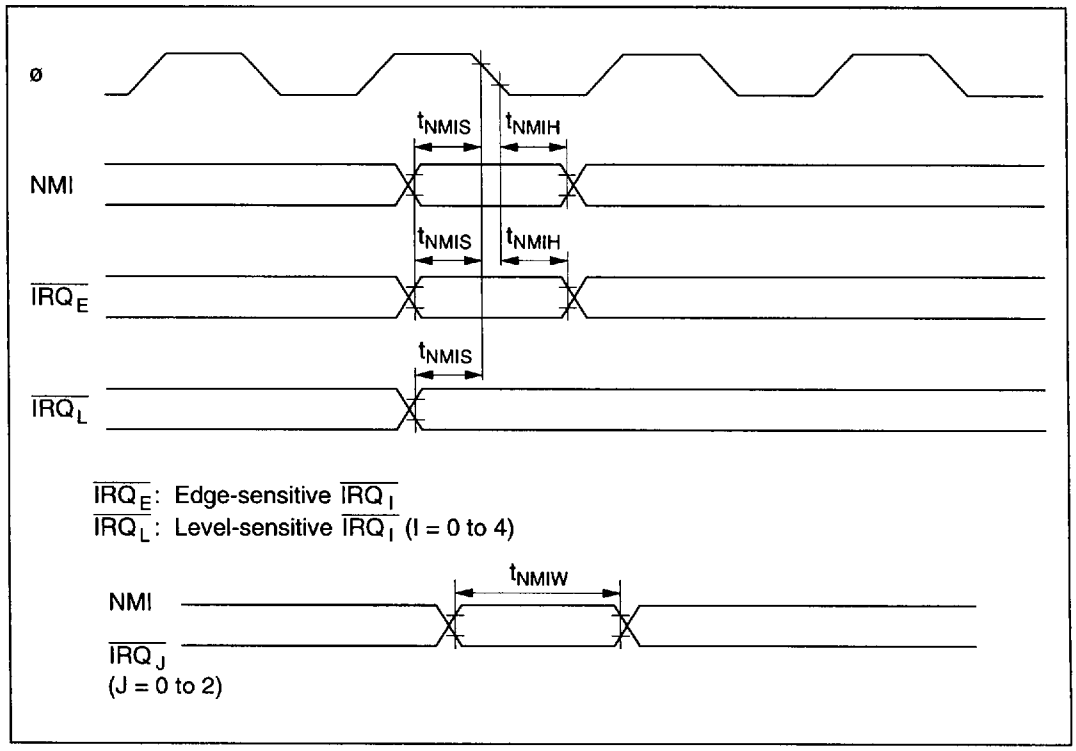

Figure 15-9 Interrupt Input Timing

15.3.3 Clock Timing

Clock timing is shown as follows:

- Oscillator settling timing

  Figure 15-10 shows the oscillator settling timing.

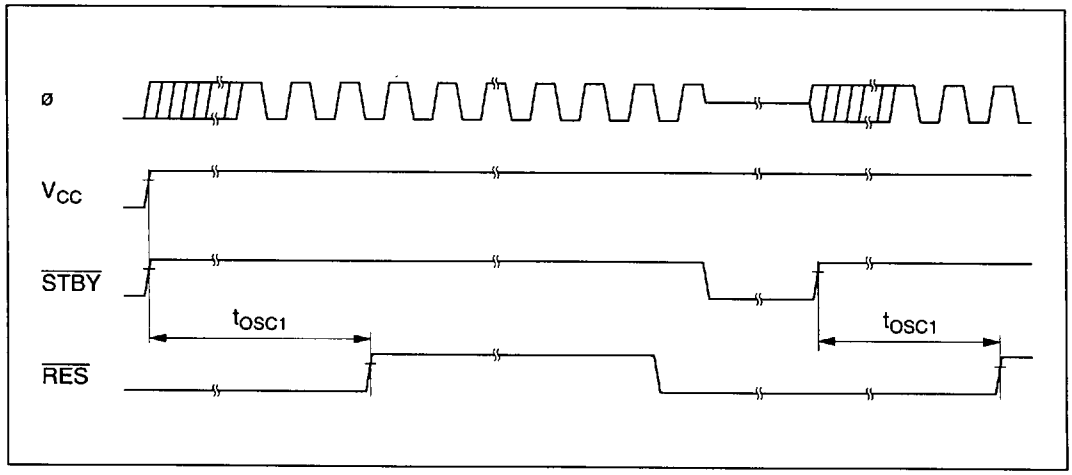

Figure 15-10 Oscillator Settling Timing

15.3.4 I/O Port Timing

I/O port timing is shown as follows.

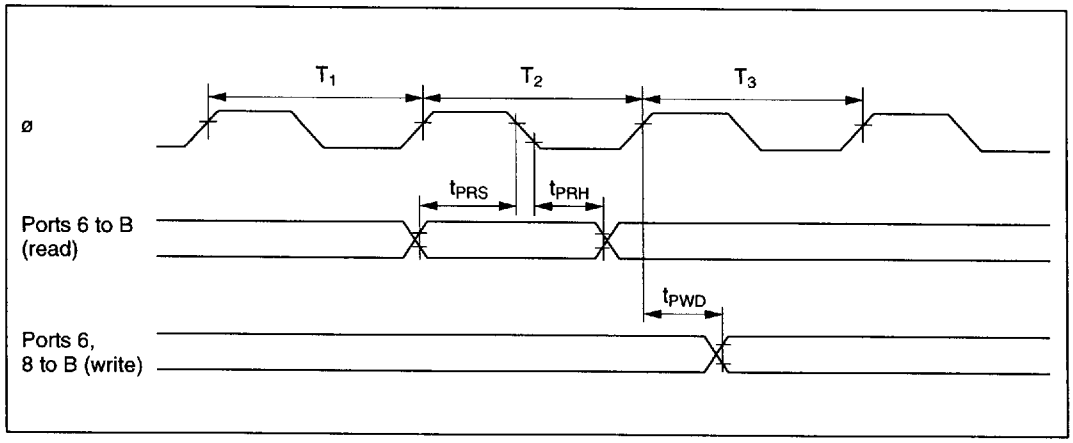

Figure 15-11 I/O Port Input/Output Timing

15.3.5 ITU Timing

ITU timing is shown as follows:

- ITU input/output timing

  Figure 15-12 shows the ITU input/output timing.

- ITU external clock input timing

  Figure 15-13 shows the ITU external clock input timing.

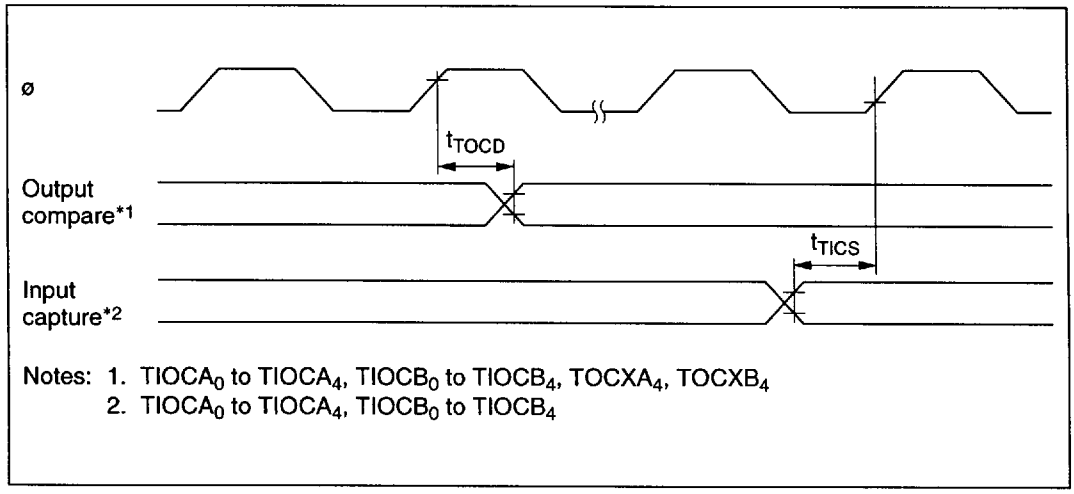

Figure 15-12 ITU Input/Output Timing

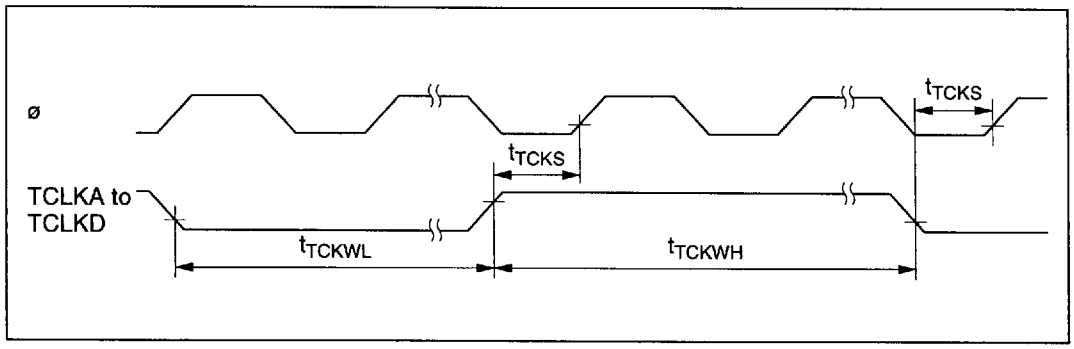

Figure 15-13 ITU Clock Input Timing

15.3.6 SCI Input/Output Timing

SCI timing is shown as follows:

- SCI input clock timing

  Figure 15-14 shows the SCI input clock timing.

- SCI input/output timing (synchronous mode)

  Figure 15-15 shows the SCI input/output timing in synchronous mode.

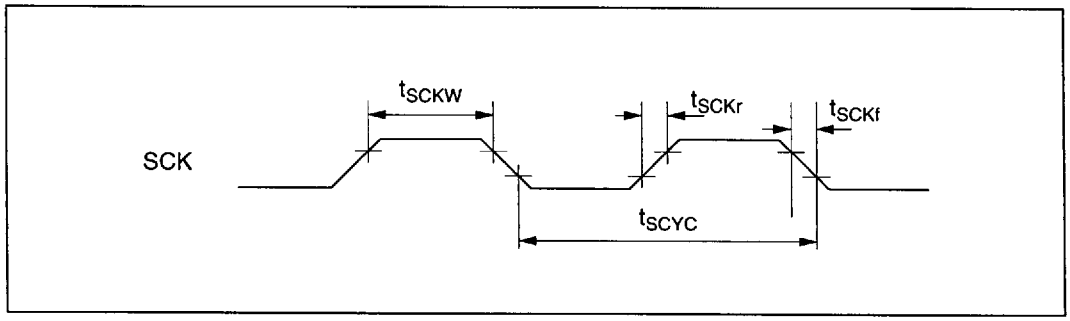

Figure 15-14 SCK Input Clock Timing

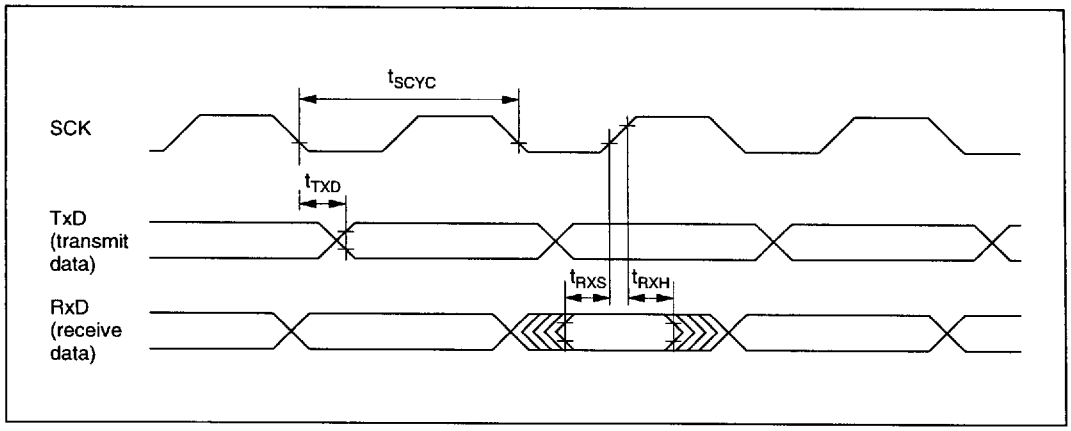

Figure 15-15 SCI Input/Output Timing in Synchronous Mode