

Section 20 Electrical Characteristics

20.1 Absolute Maximum Ratings

Table 20-1 lists the absolute maximum ratings.

Table 20-1 Absolute Maximum Ratings

—Preliminary—

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	–0.3 to +7.0	V
Programming voltage	V_{PP}	–0.3 to +13.5	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.

20.2 Electrical Characteristics

20.2.1 DC Characteristics

Table 20-2 lists the DC characteristics. Table 20-3 lists the permissible output currents.

Table 20-2 DC Characteristics

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltages	Port A,	V_T^-	1.0	—	—	V	
	P8 ₀ to P8 ₂ ,	V_T^+	—	—	$V_{CC} \times 0.7$	V	
	PB ₀ to PB ₃	$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	RES, STBY, NMI, MD ₂ to 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 1, 2, 3, 4, 5, 6, 9, P8 ₃ , P8 ₄ , PB ₄ to PB ₇		2.0	—	$V_{CC} + 0.3$	V	
Input low voltage	RES, STBY, MD ₂ to MD ₀	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL, ports 1, 2, 3, 4, 5, 6, 7, 9, P8 ₃ , P8 ₄ , PB ₄ to PB ₇		-0.3	—	0.8	V	
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$

Note: * If the A/D and D/A converters are 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 20-2 DC Characteristics (cont)

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}^1$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	All output pins (except RESO)	V_{OL}	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1, 2, 5, and B	—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
	RESO	—	—	0.4	V	$I_{OL} = 2.6 \text{ mA}$
Input leakage current	STBY, NMI, RES, MD ₂ to MD ₀	$ I_{IN} $	—	1.0	μA	$V_{IN} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	Port 7	—	—	1.0	μA	$V_{IN} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$
Three-state leakage current (off state)	Ports 1, 2, 3, 4, 5, 6, 8 to B	$ I_{TS1} $	—	1.0	μA	$V_{IN} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	RESO	—	—	10.0	μA	$V_{IN} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
Input pull-up current	Ports 2, 4, and 5	$-I_p$	50	300	μA	$V_{IN} = 0 \text{ V}$
Input capacitance	NMI	C_{IN}	—	50	pF	$V_{IN} = 0 \text{ V}$ $f = 1 \text{ MHz}$ $T_a = 25^\circ\text{C}$
	All input pins except NMI	—	—	15		
Current dissipation*2	Normal operation	I_{CC}	—	35	55	mA $f = 10 \text{ MHz}$
			—	40	65	mA $f = 12 \text{ MHz}$
			—	50	80	mA $f = 16 \text{ MHz}$
	Sleep mode	—	—	25	40	mA $f = 10 \text{ MHz}$
			—	30	45	mA $f = 12 \text{ MHz}$
			—	35	60	mA $f = 16 \text{ MHz}$
	Standby mode*3	—	—	0.01	5.0	μA $T_a \leq 50^\circ\text{C}$
			—	—	20.0	μA $50^\circ\text{C} < T_a$

- Notes: 1. If the A/D and D/A converters are 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 $V_{IHmin} = V_{CC} - 0.5 \text{ V}$ and $V_{ILmax} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 4.5 \text{ V}$, $V_{IHmin} = V_{CC} \times 0.9$, and $V_{ILmax} = 0.3 \text{ V}$.

Table 20-2 DC Characteristics (cont)

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}^1$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (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	
	During A/D and D/A conversion		—	2.0	5.0	mA	
	Idle		—	0.01	5.0	μA	
Reference current	During A/D conversion	AI_{CC}	—	0.2	0.5	mA	$V_{REF} = 5.0 \text{ V}$
	During A/D and D/A conversion		—	0.5	1.0	mA	
	Idle		—	0.01	5.0	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

- Notes: 1. If the A/D and D/A converters are 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 $V_{IHmin} = V_{CC} - 0.5 \text{ V}$ and $V_{ILmax} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up transistors in the off state.
3. The values are for $V_{RAM} < V_{CC} < 4.5 \text{ V}$, $V_{IHmin} = V_{CC} \times 0.9$, and $V_{ILmax} = 0.3 \text{ V}$.

Table 20-2 DC Characteristics (cont)

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltages	Port A,	V_T^-	$V_{CC} \times 0.2$	—	—	V	
	P8 ₀ to P8 ₂ ,	V_T^+	—	—	$V_{CC} \times 0.7$	V	
	PB ₀ to PB ₃	$V_T^+ - V_T^-$	$V_{CC} \times 0.07$	—	—	V	
Input high voltage	RES, STBY, NMI, MD ₂ to 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 1, 2, 3, 4, 5, 6, 9, P8 ₃ , P8 ₄ , PB ₄ to PB ₇		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	RES, STBY, MD ₂ to MD ₀	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, ports 1, 2, 3, 4, 5, 6, 7, 9, P8 ₃ , P8 ₄ , PB ₄ to PB ₇		-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	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins (except RESO)	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Ports 1, 2, 5, and B		—	—	1.0	V	$V_{CC} \leq 4 \text{ V}$ $I_{OL} = 8 \text{ mA}$, $4 \text{ V} < V_{CC} \leq 5.5 \text{ V}$ $I_{OL} = 10 \text{ mA}$
	RESO		—	—	0.4	V	$I_{OL} = 2.6 \text{ m}$
Input leakage current	STBY, NMI, RES, MD ₂ to MD ₀	$ I_{IN} $	—	—	1.0	μA	$V_{IN} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
	Port 7		—	—	1.0	μA	$V_{IN} = 0.5 \text{ to } AV_{CC} - 0.5 \text{ V}$

Note: * If the A/D and D/A converters are 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 20-2 DC Characteristics (cont)

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Ports 1, 2, 3, 4, 5, 6, 8 to B	I_{TS1}	—	—	1.0	μA	$V_{IN} = 0.5$ to $V_{CC} - 0.5\text{ V}$
	$\overline{RES0}$		—	—	10.0	μA	$V_{IN} = 0.5$ to $V_{CC} - 0.5\text{ V}$
Input pull-up current	Ports 2, 4, and 5	$-I_p$	10	—	300	μA	$V_{CC} = 2.7\text{ V}$ to 5.5 V , $V_{IN} = 0\text{ V}$
Input capacitance	NMI	C_{IN}	—	—	50	pF	$V_{IN} = 0\text{ V}$
	All input pins except NMI		—	—	15		$f = 1\text{ MHz}$ $T_a = 25^\circ\text{C}$
Current dissipation*2	Normal operation	I_{CC}^{*4}	—	30 (5.0 V)	36.2 (5.5 V)	mA	$f = 8\text{ MHz}$
	Sleep mode		—	20 (5.0 V)	27.4 (5.5 V)	mA	$f = 8\text{ MHz}$
	Standby mode*3		—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
				—	—	20.0	μA
Analog power supply current	During A/D conversion	AI_{CC}	—	1.0	2.0	mA	$AV_{CC} = 3.0\text{ V}$
			—	1.2	—	mA	$AV_{CC} = 5.0\text{ V}$
	During A/D and D/A conversion		—	1.8	4.0	mA	$AV_{CC} = 3.0\text{ V}$
			—	2.0	—	mA	$AV_{CC} = 5.0\text{ V}$
	Idle			—	0.01	5.0	μA

- Notes: 1. If the A/D and D/A converters are 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 $V_{IHmin} = V_{CC} - 0.5 \text{ V}$ and $V_{ILmax} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up transistors in the off state.
3. The values are for $V_{RAM} \leq V_{CC} < 2.7 \text{ V}$, $V_{IHmin} = V_{CC} \times 0.9$, and $V_{ILmax} = 0.3 \text{ V}$.
4. I_{CC} depends on V_{CC} and f as follows:
 $I_{CCmax} = 1.0 \text{ (mA)} + 0.8 \text{ (mA/MHz} \cdot \text{V)} \times V_{CC} \times f$ [normal mode]
 $I_{CCmax} = 1.0 \text{ (mA)} + 0.6 \text{ (mA/MHz} \cdot \text{V)} \times V_{CC} \times f$ [sleep mode]

Table 20-2 DC Characteristics (cont)

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Reference current	During A/D conversion	I_{CC}	—	0.1	0.2	mA	$V_{REF} = 3.0\text{ V}$
			—	0.2	—	mA	$V_{REF} = 5.0\text{ V}$
	During A/D and D/A conversion		—	0.2	0.4	mA	$V_{REF} = 3.0\text{ V}$
			—	0.5	—	mA	$V_{REF} = 5.0\text{ V}$
	Idle		—	0.01	5.0	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Note: * If the A/D and D/A converters are 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 20-3 Permissible Output Currents

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

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Ports 1, 2, 5, and B	I_{OL}	—	—	10	mA
	Other output pins		—	—	2.0	mA
Permissible output low current (total)	Total of 28 pins in ports 1, 2, 5, and B	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 20-3.
2. When driving a darlington pair or LED, always insert a current-limiting resistor in the output line, as shown in figures 20-1 and 20-2.

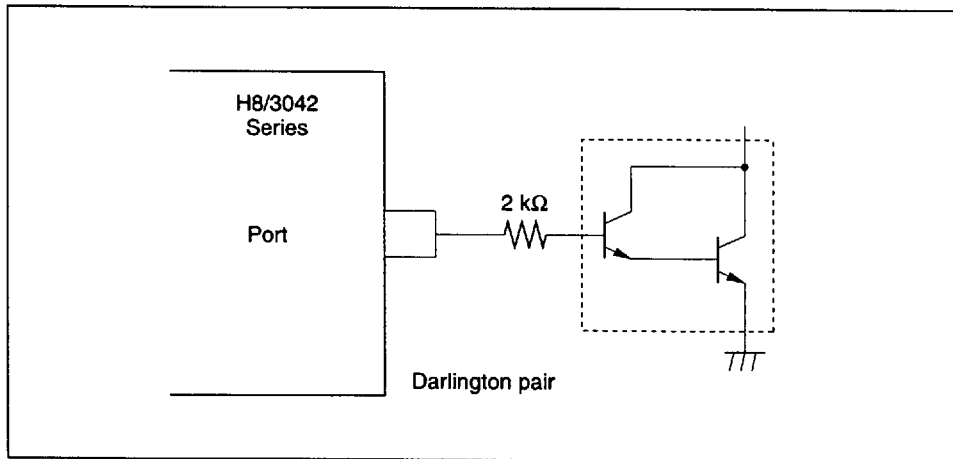


Figure 20-1 Darlington Pair Drive Circuit (Example)

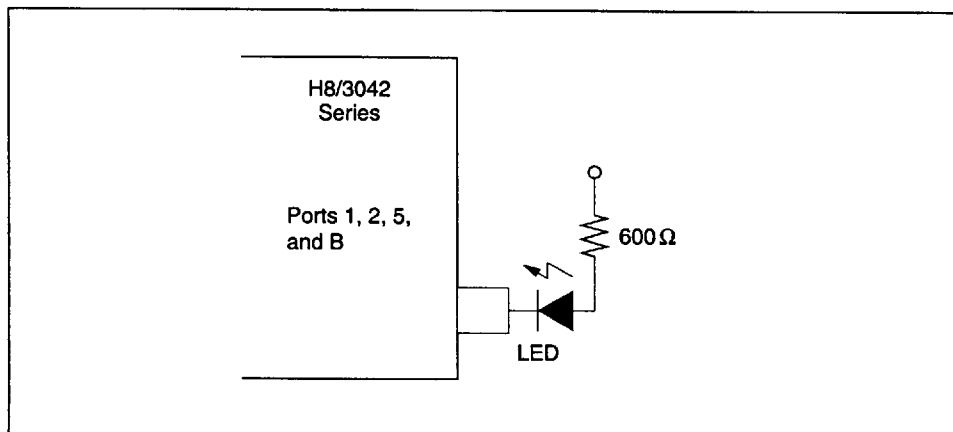


Figure 20-2 LED Drive Circuit (Example)

20.2.2 AC Characteristics

Bus timing parameters are listed in table 20-4. Refresh controller bus timing parameters are listed in table 20-5. Control signal timing parameters are listed in table 20-6. Timing parameters of the on-chip supporting modules are listed in table 20-7.

Table 20-4 Bus Timing (1)

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

Condition B: $V_{CC} = 5.0\text{ V} \pm 10\%$, $AV_{CC} = 5.0\text{ V} \pm 10\%$, $V_{REF} = 4.5\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to }16\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A				Condition B				Unit	Test Conditions
		8 MHz		10 MHz		12 MHz		16 MHz			
		Min	Max	Min	Max	Min	Max	Min	Max		
Clock cycle time	t _{CYC}	125	500	100	500	83.3	500	62.5	500	ns	Figure 20-4, Figure 20-5
Clock rise time	t _{CR}	—	20	—	10	—	10	—	10		
Clock fall time	t _{CF}	—	20	—	10	—	10	—	10		
Address delay time	t _{AD}	—	60	—	40	—	35	—	30		
Address hold time	t _{AH}	25	—	20	—	15	—	10	—		
Address strobe delay time	t _{ASD}	—	60	—	40	—	35	—	30		
Write strobe delay time	t _{WSD}	—	60	—	40	—	35	—	30		
Strobe delay time	t _{SD}	—	60	—	40	—	35	—	30		
Write data strobe pulse width 1	t _{WSW1} *	85	—	70	—	55	—	35	—		
Write data strobe pulse width 2	t _{WSW2} *	150	—	120	—	95	—	65	—		
Address setup time 1	t _{AS1}	20	—	15	—	10	—	10	—		
Address setup time 2	t _{AS2}	80	—	65	—	50	—	40	—		
Read data setup time	t _{RDS}	50	—	20	—	20	—	20	—		
Read data hold time	t _{RDH}	0	—	0	—	0	—	0	—		

Table 20-4 Bus Timing (cont)

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B				Test Conditions	
		8 MHz	10 MHz	12 MHz	16 MHz	Min	Max		
Write data delay time	t_{WDD}	—	75	—	65	—	60	—	ns
Write data setup time 1	t_{WDS1}	90	—	75	—	60	—	35	—
Write data setup time 2	t_{WDS2}	15	—	10	—	10	—	5	—
Write data hold time	t_{WDH}	25	—	20	—	20	—	20	—
Read data access time 1	t_{ACC1*}	—	110	—	100	—	80	—	55
Read data access time 2	t_{ACC2*}	—	230	—	200	—	160	—	115
Read data access time 3	t_{ACC3*}	—	55	—	50	—	40	—	25
Read data access time 4	t_{ACC4*}	—	160	—	150	—	120	—	85
Precharge time	t_{PCH*}	85	—	70	—	55	—	40	—
Wait setup time	t_{WTS}	40	—	35	—	25	—	25	—
Wait hold time	t_{WTH}	10	—	10	—	5	—	5	—
Bus request setup ime	t_{BRQS}	40	—	40	—	40	—	40	—
Bus acknowledge delay time 1	t_{BACD1}	—	60	—	50	—	40	—	30
Bus acknowledge delay time 2	t_{BACD2}	—	60	—	50	—	40	—	30
Bus-floating time	t_{BZD}	—	70	—	60	—	50	—	40

Note is on next page.

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

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

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

$$\begin{aligned}t_{ACC1} &= 1.5 \times t_{cyc} - 50 \text{ (ns)} & t_{WSW1} &= 1.0 \times t_{cyc} - 30 \text{ (ns)} \\t_{ACC2} &= 2.5 \times t_{cyc} - 50 \text{ (ns)} & t_{WSW2} &= 1.5 \times t_{cyc} - 30 \text{ (ns)} \\t_{ACC3} &= 1.0 \times t_{cyc} - 50 \text{ (ns)} & t_{PCH} &= 1.0 \times t_{cyc} - 30 \text{ (ns)} \\t_{ACC4} &= 2.0 \times t_{cyc} - 50 \text{ (ns)}\end{aligned}$$

At 12 MHz, the times below depend as indicated on the clock cycle time.

$$\begin{aligned}t_{ACC1} &= 1.5 \times t_{cyc} - 45 \text{ (ns)} & t_{WSW1} &= 1.0 \times t_{cyc} - 28 \text{ (ns)} \\t_{ACC2} &= 2.5 \times t_{cyc} - 48 \text{ (ns)} & t_{WSW2} &= 1.5 \times t_{cyc} - 30 \text{ (ns)} \\t_{ACC3} &= 1.0 \times t_{cyc} - 43 \text{ (ns)} & t_{PCH} &= 1.0 \times t_{cyc} - 28 \text{ (ns)} \\t_{ACC4} &= 2.0 \times t_{cyc} - 47 \text{ (ns)}\end{aligned}$$

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

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

Table 20-5 Refresh Controller Bus Timing

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B						Unit	Test Conditions
		8 MHz		10 MHz		12 MHz		16 MHz			
		Min	Max	Min	Max	Min	Max	Min	Max		
RAS delay time 1	t _{RAD1}	—	60	—	30	—	30	—	30	ns	Figure 20-7 to Figure 20-13
RAS delay time 2	t _{RAD2}	—	60	—	30	—	30	—	30		
RAS delay time 3	t _{RAD3}	—	60	—	30	—	30	—	30		
Row address hold time*	t _{RAH}	25	—	20	—	15	—	15	—		
RAS precharge time*	t _{RP}	85	—	70	—	55	—	40	—		
CAS to RAS precharge time*	t _{CRP}	85	—	70	—	55	—	40	—		
CAS pulse width	t _{CAS}	110	—	40	—	40	—	40	—		
RAS access time*	t _{RAC}	—	160	—	150	—	120	—	85		
Address access time	t _{AA}	—	105	—	55	—	55	—	55		
CAS access time*	t _{CAC}	—	50	—	50	—	40	—	25		
Write data setup time 3	t _{WDS3}	75	—	40	—	40	—	40	—		
CAS setup time*	t _{CSR}	20	—	15	—	15	—	15	—		
Read strobe delay time	t _{RSD}	—	60	—	30	—	30	—	30		

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

$$t_{RAH} = 0.5 \times t_{cyc} - 38 \text{ (ns)} \quad t_{CAC} = 1.0 \times t_{cyc} - 75 \text{ (ns)}$$

$$t_{RAC} = 2.0 \times t_{cyc} - 90 \text{ (ns)} \quad t_{CSR} = 0.5 \times t_{cyc} - 43 \text{ (ns)}$$

$$t_{RP} = t_{CRP} = 1.0 \times t_{cyc} - 40 \text{ (ns)}$$

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

$$t_{RAH} = 0.5 \times t_{cyc} - 30 \text{ (ns)} \quad t_{CAC} = 1.0 \times t_{cyc} - 50 \text{ (ns)}$$

$$t_{RAC} = 2.0 \times t_{cyc} - 50 \text{ (ns)} \quad t_{CSR} = 0.5 \times t_{cyc} - 35 \text{ (ns)}$$

$$t_{RP} = t_{CRP} = 1.0 \times t_{cyc} - 30 \text{ (ns)}$$

At 12 MHz, the times below depend as indicated on the clock cycle time.

$$t_{RAH} = 0.5 \times t_{cyc} - 27 \text{ (ns)} \quad t_{CAC} = 1.0 \times t_{cyc} - 43 \text{ (ns)}$$

$$t_{RAC} = 2.0 \times t_{cyc} - 47 \text{ (ns)} \quad t_{CSR} = 0.5 \times t_{cyc} - 27 \text{ (ns)}$$

$$t_{RP} = t_{CRP} = 1.0 \times t_{cyc} - 28 \text{ (ns)}$$

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

$$t_{RAH} = 0.5 \times t_{cyc} - 16 \text{ (ns)} \quad t_{CAC} = 1.0 \times t_{cyc} - 38 \text{ (ns)}$$

$$t_{RAC} = 2.0 \times t_{cyc} - 40 \text{ (ns)} \quad t_{CSR} = 0.5 \times t_{cyc} - 16 \text{ (ns)}$$

$$t_{RP} = t_{CRP} = 1.0 \times t_{cyc} - 23 \text{ (ns)}$$

Table 20-6 Control Signal Timing

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B				Test Conditions	
		8 MHz	10 MHz	12 MHz	16 MHz	Min	Max		
RES setup time	t_{RESS}	200	—	200	—	200	—	ns	Figure 20-15
RES pulse width	t_{RESW}	10	—	10	—	10	—	t_{CYC}	
RESO output delay time	t_{RESO}	—	100	—	100	—	100	ns	Figure 20-16
RESO output pulse width	t_{RESOW}	132	—	132	—	132	—	t_{CYC}	
NMI setup time (NMI, $\overline{IRQ_5}$ to $\overline{IRQ_0}$)	t_{NMIS}	150	—	150	—	150	—	ns	Figure 20-17
NMI hold time (NMI, $\overline{IRQ_5}$ to $\overline{IRQ_0}$)	t_{NMIH}	10	—	10	—	10	—		
Interrupt pulse width (NMI, $\overline{IRQ_2}$ 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 20-19
Clock oscillator settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms	Figure 19-1

Table 20-7 Timing of On-Chip Supporting Modules

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

			Condition A				Condition B						
			8 MHz		10 MHz		12 MHz		16 MHz				
Item	Symbol		Min	Max	Min	Max	Min	Max	Min	Max	Unit	Test Conditions	
DMAC	$\overline{\text{DREQ}}$ setup time	t_{DRQS}	40	—	30	—	30	—	30	—	ns	Figure 20-27	
	$\overline{\text{DREQ}}$ hold time	t_{DRQH}	10	—	10	—	10	—	10	—			
	$\overline{\text{TEND}}$ delay time 1	t_{TED1}	—	100	—	50	—	50	—	50		Figure 20-25, Figure 20-26	
	$\overline{\text{TEND}}$ delay time 2	t_{TED2}	—	100	—	50	—	50	—	50			
ITU	Timer output delay time	t_{TOCD}	—	100	—	100	—	100	—	100	ns	Figure 20-21	
	Timer input setup time	t_{TICS}	50	—	50	—	50	—	50	—			
	Timer clock input setup time	t_{TCKS}	50	—	50	—	50	—	50	—		Figure 20-22	
	Timer clock pulse width	Single edge	t_{TCKWH}	1.5	—	1.5	—	1.5	—	1.5	—	t_{CYC}	
		Both edges	t_{TCKWL}	2.5	—	2.5	—	2.5	—	2.5	—		
SCI	Input clock cycle	Asynchronous	t_{SCYC}	4	—	4	—	4	—	4	—	t_{CYC}	Figure 20-23
		Synchronous	t_{SCYC}	6	—	6	—	6	—	6	—		
	Input clock rise time	t_{SCKr}	—	1.5	—	1.5	—	1.5	—	1.5	t_{SCYC}		
	Input clock fall time	t_{SCKf}	—	1.5	—	1.5	—	1.5	—	1.5			
	Input clock pulse width	t_{SCKW}	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6			

Table 20-7 Timing of On-Chip Supporting Modules (cont)

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

		Symbol	Condition A				Condition B				Unit	Test Conditions	
			8 MHz		10 MHz		12 MHz		16 MHz				
SCI	Transmit data delay time	t _{TXD}	—	100	—	100	—	100	—	100	ns	Figure 20-24	
	Receive data setup time (synchronous)	t _{RXS}	100	—	100	—	100	—	100	—			
	Receive data hold time (synchronous)	Clock input	t _{RXH}	100	—	100	—	100	—	100	—		
		Clock output		0	—	0	—	0	—	0	—		
	Ports and TPC	Output data delay time	t _{PWD}	—	100	—	100	—	100	—	100		ns
	Input data setup time	t _{PRS}	50	—	50	—	50	—	50	—			
	Input data hold time	t _{PRH}	50	—	50	—	50	—	50	—			

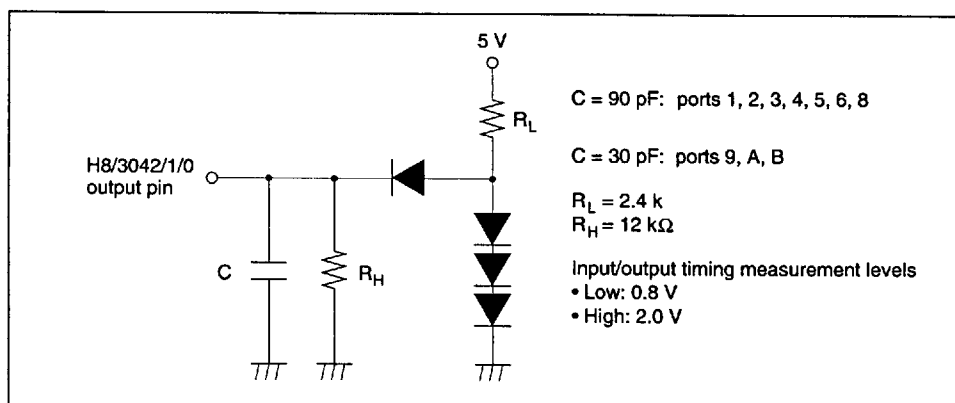


Figure 20-3 Output Load Circuit

20.2.3 A/D Conversion Characteristics

Table 20-8 lists the A/D conversion characteristics.

Table 20-8 A/D Converter Characteristics

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

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{REF} = 4.5 \text{ V to } AV_{CC}$,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } 16 \text{ MHz}$, $T_a = -20^\circ\text{C to } +75^\circ\text{C}$ (regular
specifications), $T_a = -40^\circ\text{C to } +85^\circ\text{C}$ (wide-range specifications)

Item	Condition A			Condition B										Unit
	8 MHz			10 MHz			12 MHz			16 MHz				
Resolution	10	10	10	10	10	10	10	10	10	10	10	10	10	bits
Conversion time	—	—	16.8	—	—	13.4	—	—	11.2	—	—	8.4	—	μs
Analog input capacitance	—	—	20	—	—	20	—	—	20	—	—	20	—	pF
Permissible signal-source impedance	—	—	10 ^{*1}	—	—	10	—	—	10	—	—	10 ^{*3}	—	kΩ
	—	—	5 ^{*2}	—	—	—	—	—	—	—	—	5 ^{*4}	—	—
Nonlinearity error	—	—	±6.0	—	—	±3.0	—	—	±3.0	—	—	±3.0	—	LSB
Offset error	—	—	±4.0	—	—	±2.0	—	—	±2.0	—	—	±2.0	—	LSB
Full-scale error	—	—	±4.0	—	—	±2.0	—	—	±2.0	—	—	±2.0	—	LSB
Quantization error	—	—	±0.5	—	—	±0.5	—	—	±0.5	—	—	±0.5	—	LSB
Absolute accuracy	—	—	±8.0	—	—	±4.0	—	—	±4.0	—	—	±4.0	—	LSB

Notes: 1. The value is for $4.0 \leq AV_{CC} \leq 5.5$.

2. The value is for $2.7 \leq AV_{CC} \leq 4.0$.

3. The value is for $\phi \leq 12 \text{ MHz}$.

4. The value is for $\phi > 12 \text{ MHz}$.

20.2.4 D/A Conversion Characteristics

Table 20-9 lists the D/A conversion characteristics.

Table 20-9 D/A Converter Characteristics

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

Condition B: $V_{CC} = 5.0\text{ V} \pm 10\%$, $AV_{CC} = 5.0\text{ V} \pm 10\%$, $V_{REF} = 4.5\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to }16\text{ MHz}$, $T_a = -20^\circ\text{C to }+75^\circ\text{C}$
(regular specifications), $T_a = -40^\circ\text{C to }+85^\circ\text{C}$ (wide-range specifications)

Item	Condition A			Condition B									Test Conditions	
	8 MHz			10 MHz			12 MHz			16 MHz				
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Unit	
Resolution	8	8	8	8	8	8	8	8	8	8	8	8	Bits	
Conversion time	—	—	10	—	—	10	—	—	10	—	—	10	μS	20-pF capacitive load
Absolute accuracy	—	±2.0	±3.0	—	±1.0	±1.5	—	±1.0	±1.5	—	±1.0	±1.5	LSB	2-MΩ resistive load
	—	—	±2.0	—	—	±1.0	—	—	±1.0	—	—	±1.0	LSB	4-MΩ resistive load

20.3 Operational Timing

This section shows timing diagrams.

20.3.1 Bus Timing

Bus timing is shown as follows:

- Basic bus cycle: two-state access

Figure 20-4 shows the timing of the external two-state access cycle.

- Basic bus cycle: three-state access

Figure 20-5 shows the timing of the external three-state access cycle.

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

Figure 20-6 shows the timing of the external three-state access cycle with one wait state inserted.

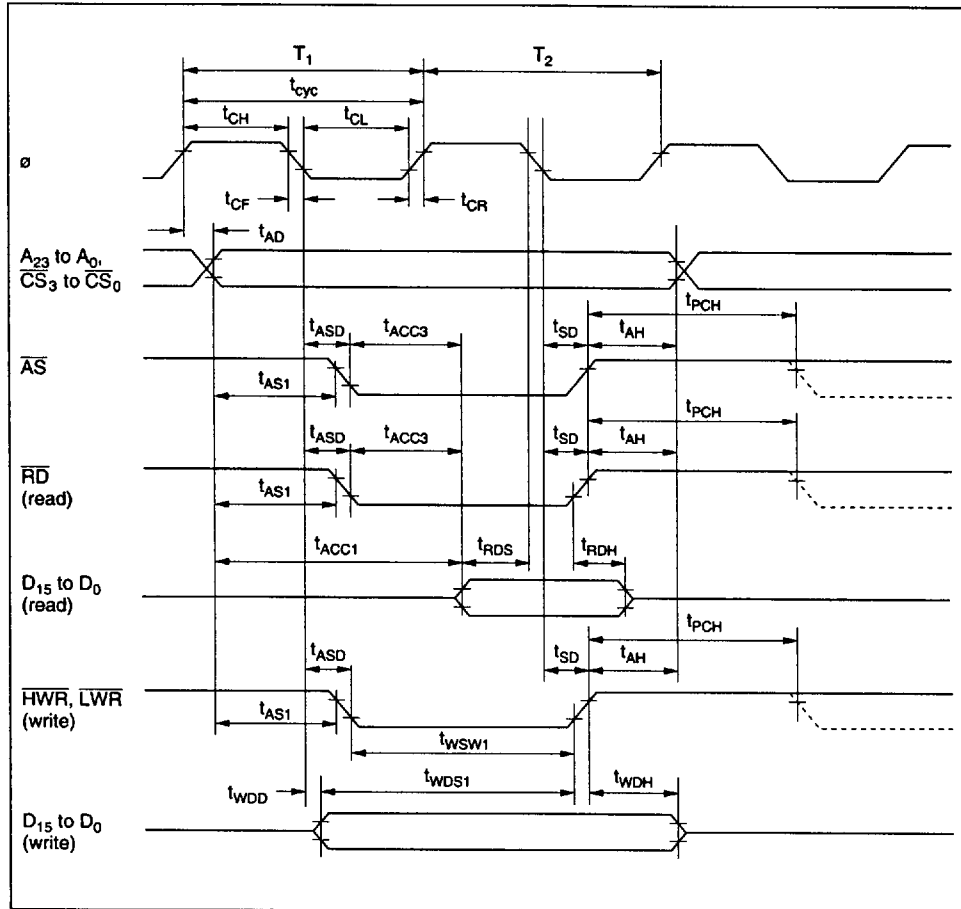


Figure 20-4 Basic Bus Cycle: Two-State Access

to D

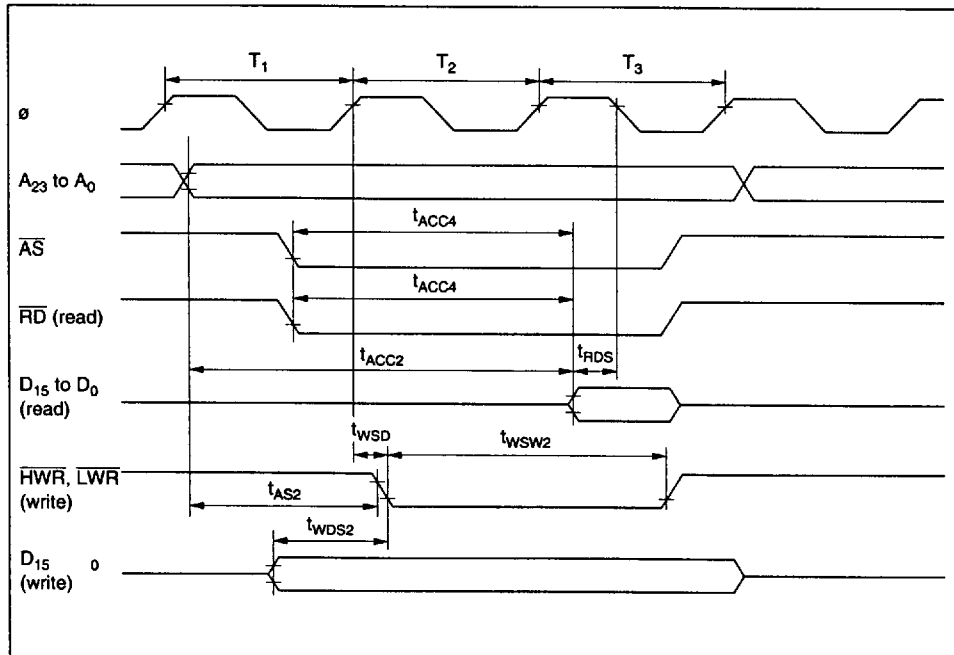


Figure 20-5 Basic Bus Cycle: Three-State Access

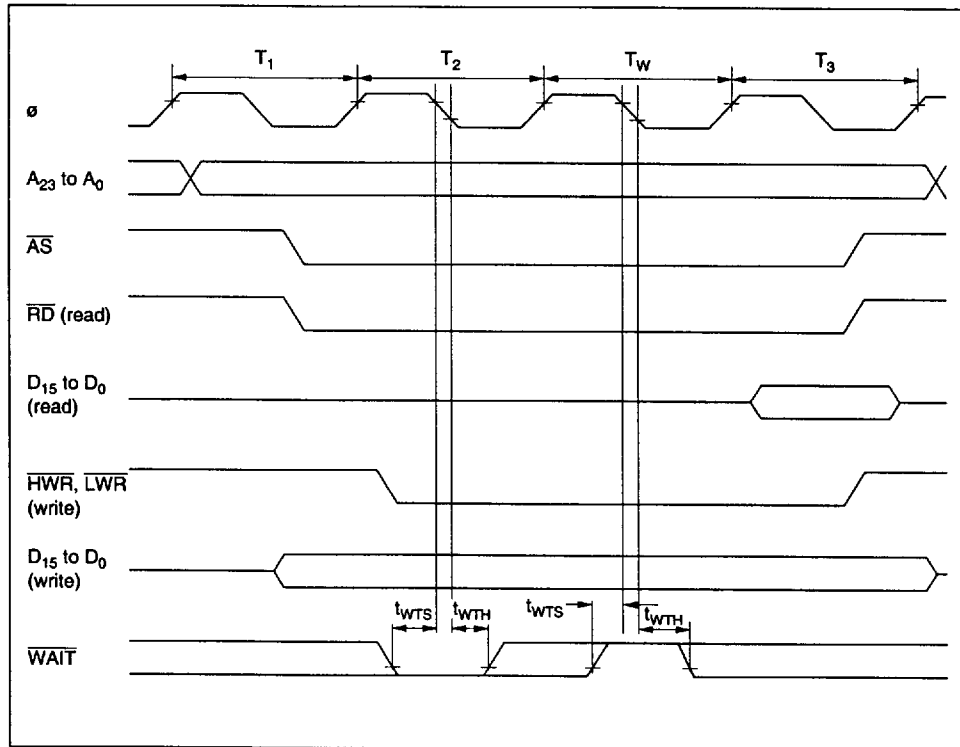


Figure 20-6 Basic Bus Cycle: Three-State Access with One Wait State

20.3.2 Refresh Controller Bus Timing

Refresh controller bus timing is shown as follows:

- DRAM bus timing

Figures 20-7 to 20-12 show the DRAM bus timing in each operating mode.

- PSRAM bus timing

Figures 20-13 and 20-14 show the pseudo-static RAM bus timing in each operating mode.

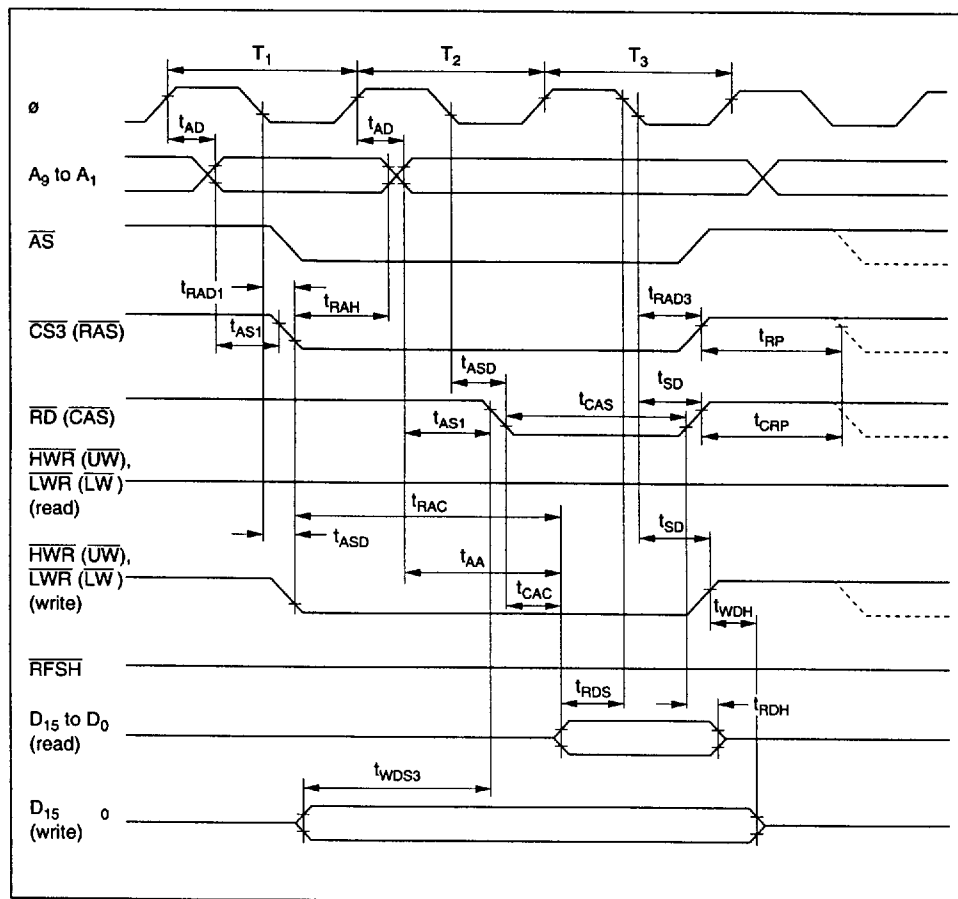


Figure 20-7 DRAM Bus Timing (Read/Write): Three-State Access
— 2WE Mode —

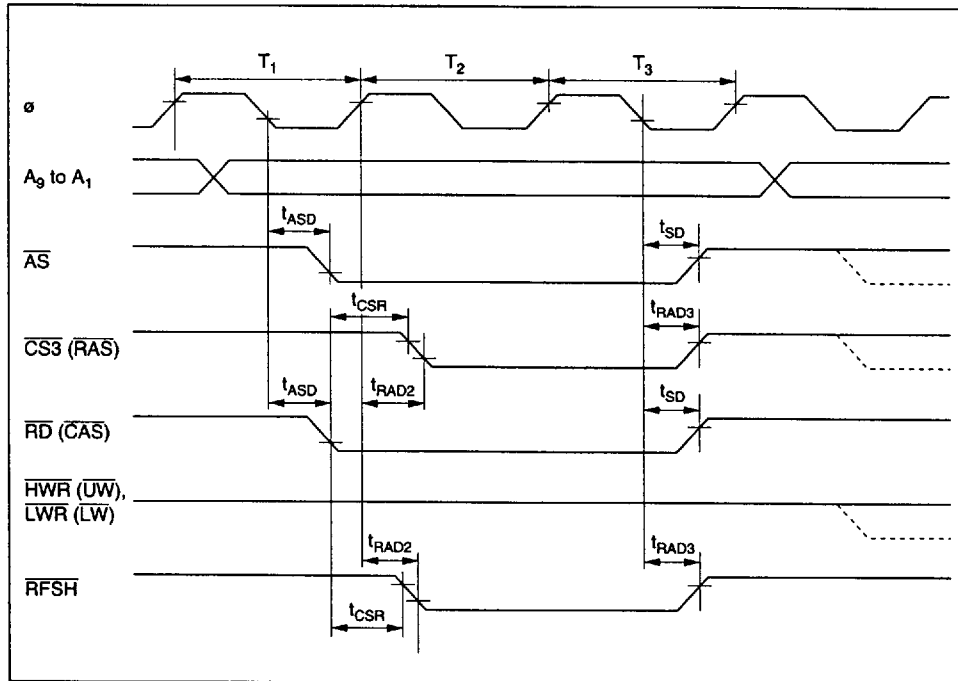


Figure 20-8 DRAM Bus Timing (Refresh Cycle): Three-State Access
— $2\overline{WE}$ Mode —

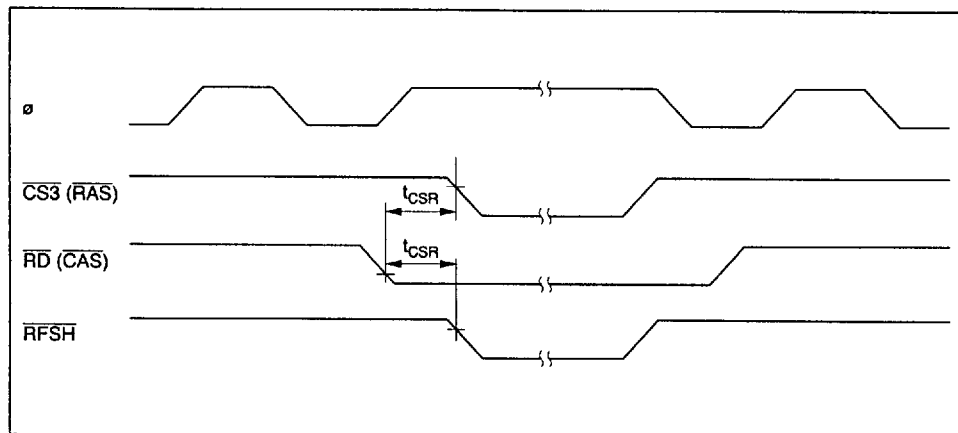


Figure 20-9 DRAM Bus Timing (Self-Refresh Mode)
— $2\overline{WE}$ Mode —

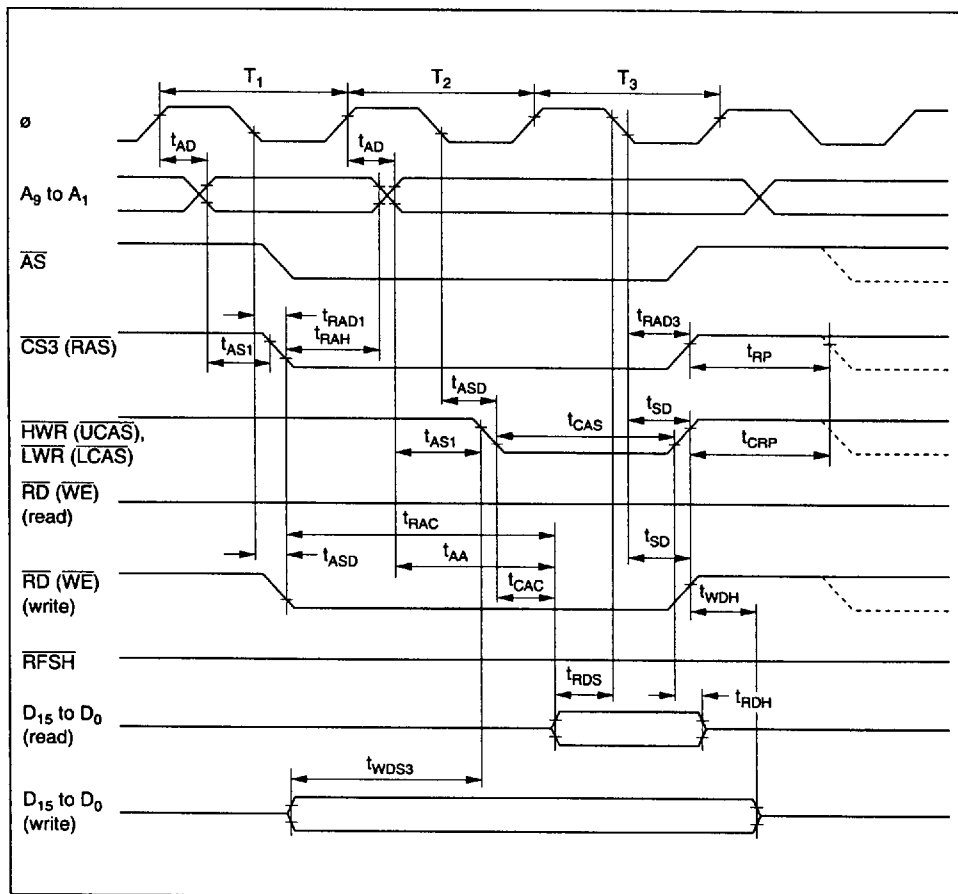


Figure 20-10 DRAM Bus Timing (Read/Write): Three-State Access
— 2CAS Mode —

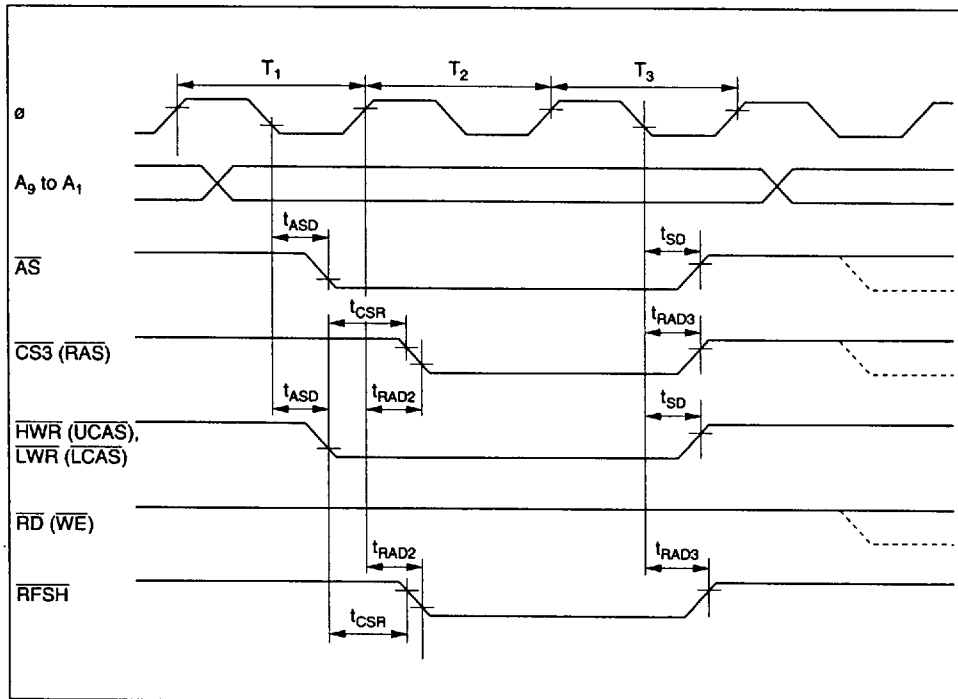


Figure 20-11 DRAM Bus Timing (Refresh Cycle): Three-State Access
— 2CAS Mode —

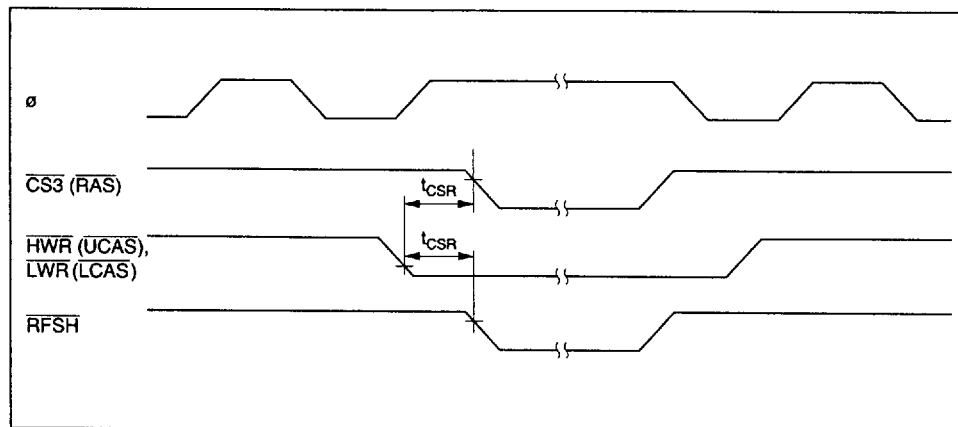


Figure 20-12 DRAM Bus Timing (Self-Refresh Mode)
— 2CAS Mode —

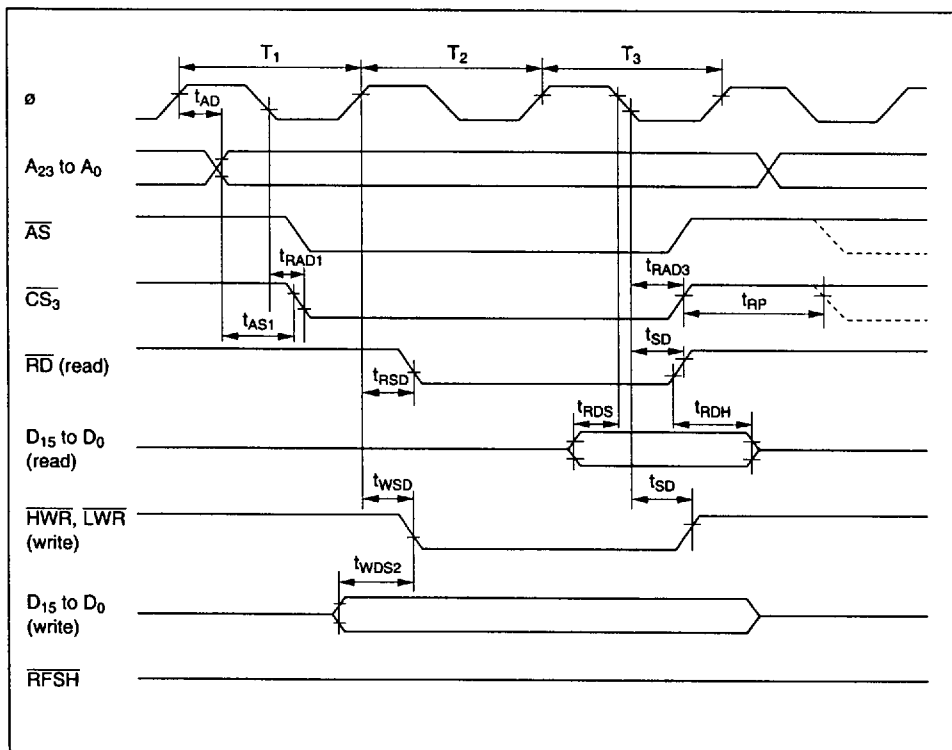


Figure 20-13 PSRAM Bus Timing (Read/Write): Three-State Access

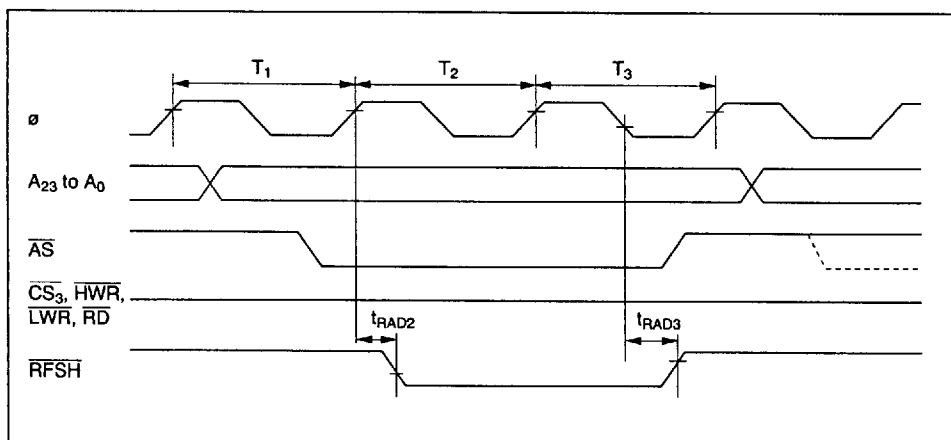


Figure 20-14 PSRAM Bus Timing (Refresh Cycle): Three-State Access

20.3.3 Control Signal Timing

Control signal timing is shown as follows:

- Reset input timing

Figure 20-15 shows the reset input timing.

- Reset output timing

Figure 20-16 shows the reset output timing.

- Interrupt input timing

Figure 20-17 shows the input timing for NMI and $\overline{\text{IRQ}}_5$ to $\overline{\text{IRQ}}_0$.

- Bus-release mode timing

Figure 20-18 shows the bus-release mode timing.

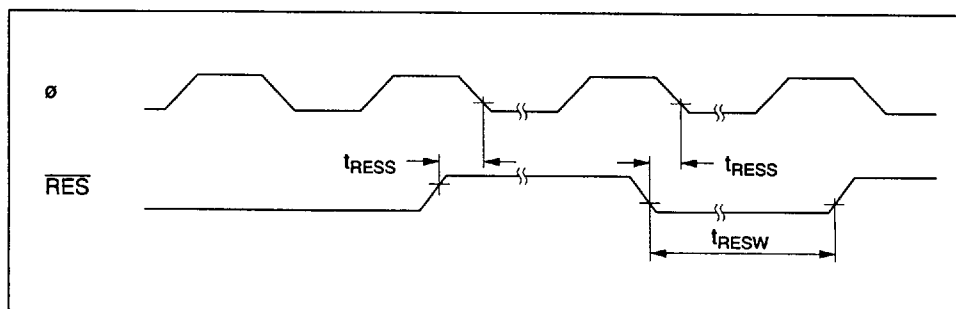


Figure 20-15 Reset Input Timing

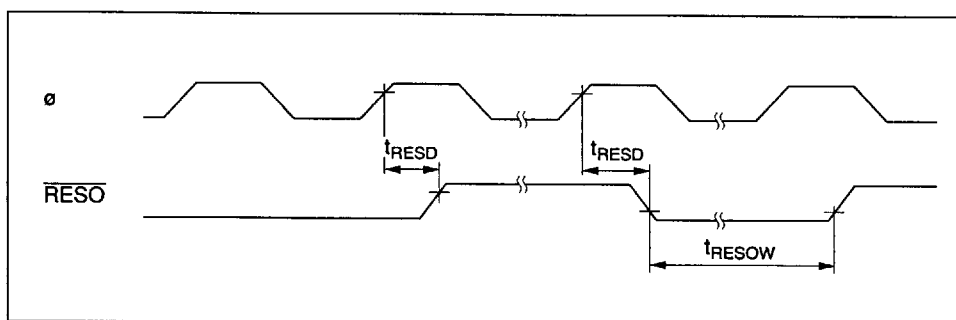


Figure 20-16 Reset Output Timing

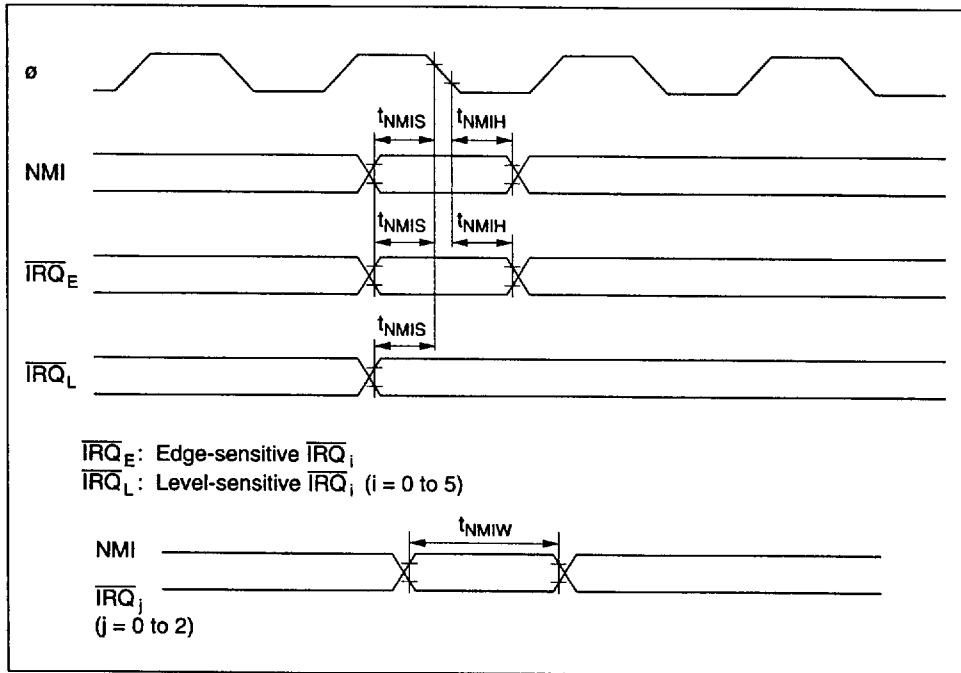


Figure 20-17 Interrupt Input Timing

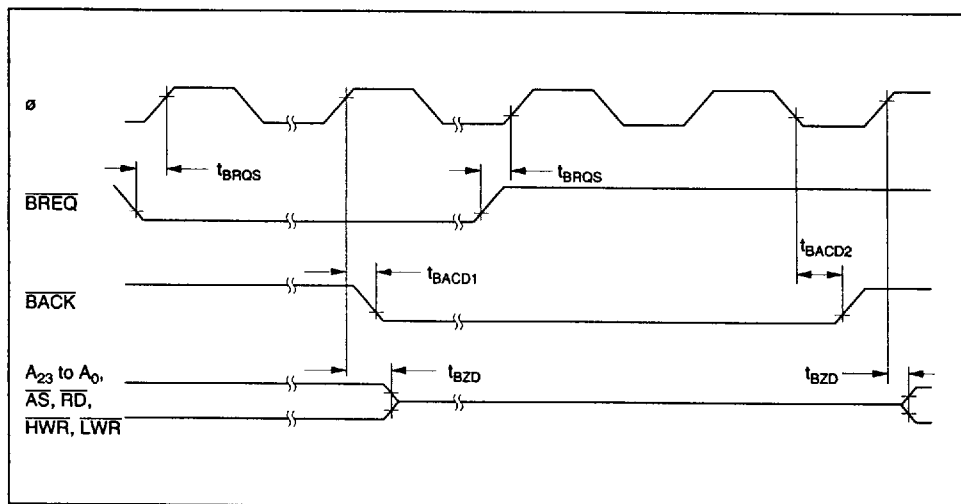


Figure 20-18 Bus-Release Mode Timing

20.3.4 Clock Timing

Clock timing is shown as follows:

- Oscillator settling timing

Figure 20-19 shows the oscillator settling timing.

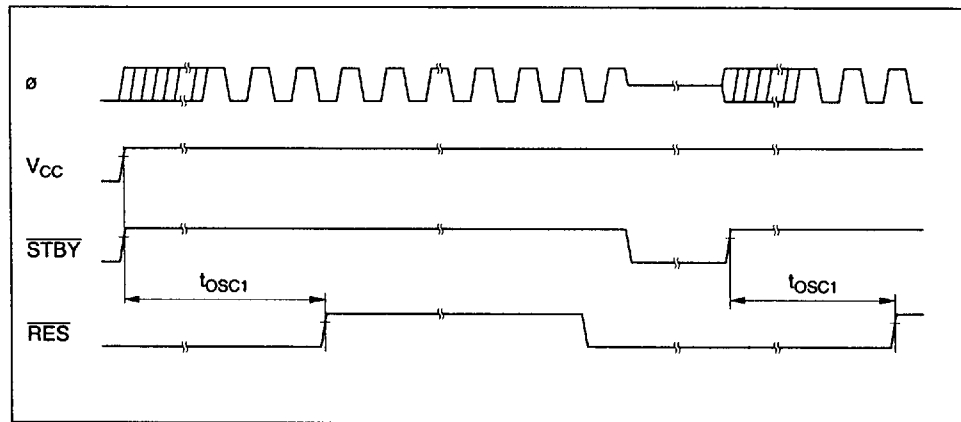


Figure 20-19 Oscillator Settling Timing

20.3.5 TPC and I/O Port Timing

TPC and I/O port timing is shown as follows.

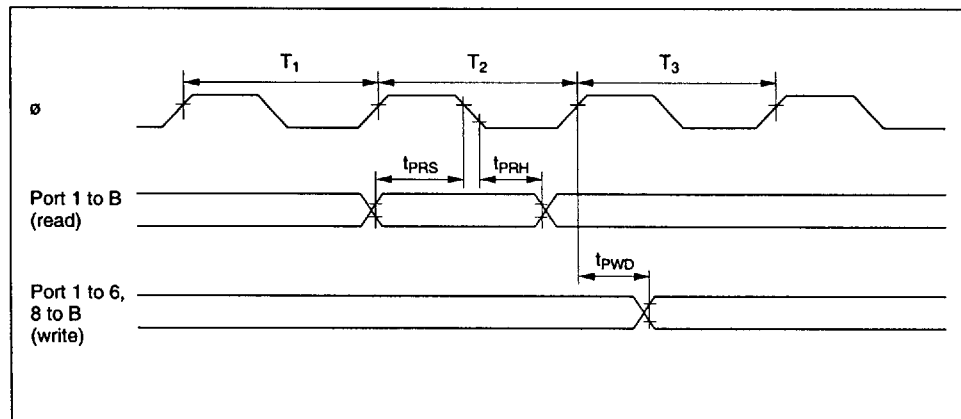


Figure 20-20 TPC and I/O Port Input/Output Timing

20.3.6 ITU Timing

ITU timing is shown as follows:

- ITU input/output timing

Figure 20-21 shows the ITU input/output timing.

- ITU external clock input timing

Figure 20-22 shows the ITU external clock input timing.

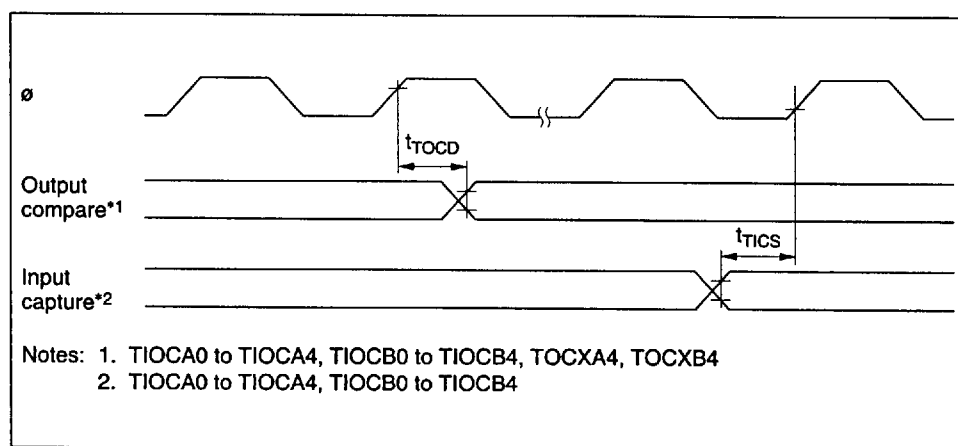


Figure 20-21 ITU Input/Output Timing

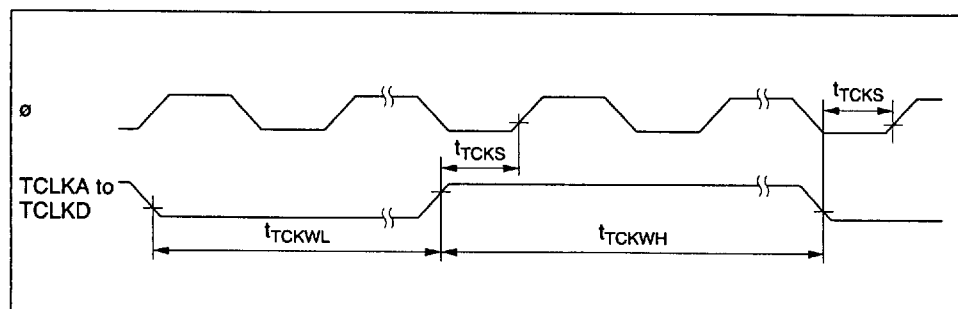


Figure 20-22 ITU Clock Input Timing

20.3.7 SCI Input/Output Timing

SCI timing is shown as follows:

- SCI input clock timing

Figure 20-23 shows the SCI input clock timing.

- SCI input/output timing (synchronous mode)

Figure 20-24 shows the SCI input/output timing in synchronous mode.

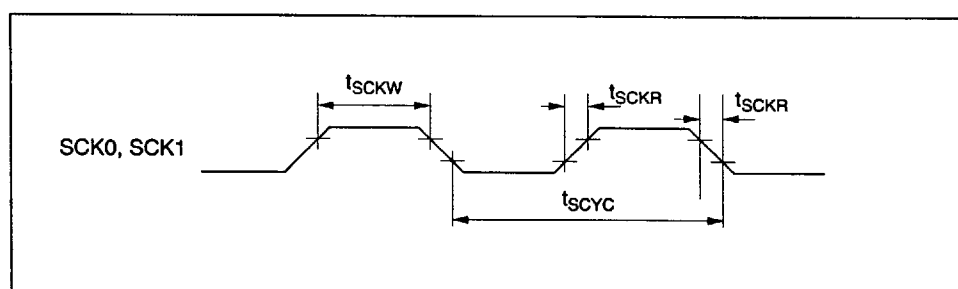


Figure 20-23 SCK Input Clock Timing

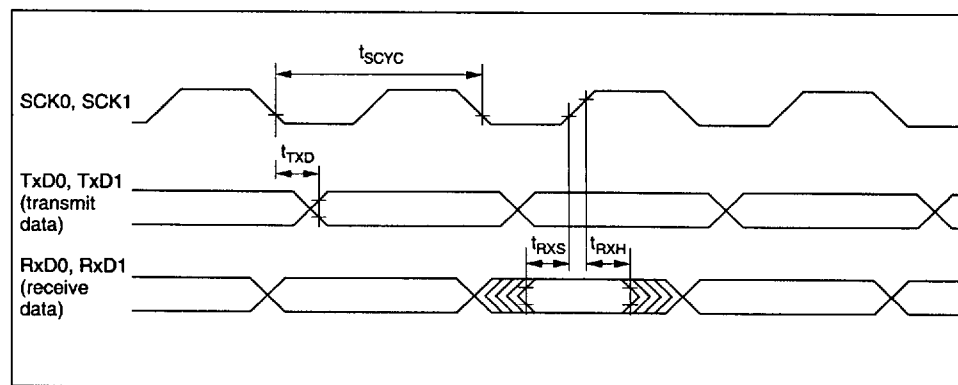


Figure 20-24 SCI Input/Output Timing in Synchronous Mode

20.3.8 DMAC Timing

DMAC timing is shown as follows.

- DMAC $\overline{\text{TEND}}$ output timing for 2 state access

Figure 20-25 shows the DMAC $\overline{\text{TEND}}$ output timing for 2 state access.

- DMAC $\overline{\text{TEND}}$ output timing for 3 state access

Figure 20-26 shows the DMAC $\overline{\text{TEND}}$ output timing for 3 state access.

- DMAC $\overline{\text{DREQ}}$ input timing

Figure 20-27 shows DMAC $\overline{\text{DREQ}}$ input timing.

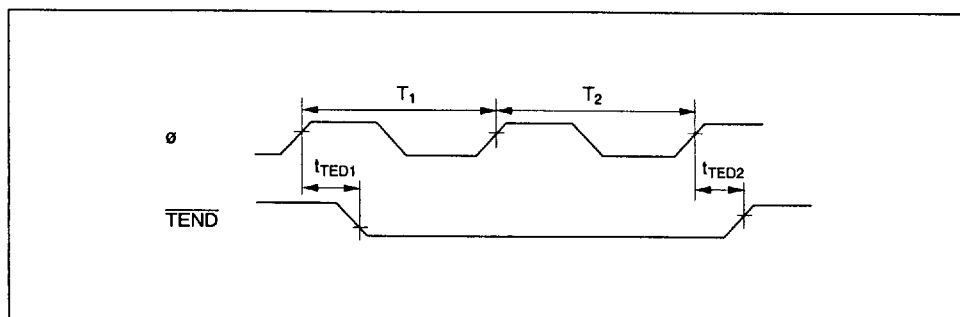


Figure 20-25 DMAC $\overline{\text{TEND}}$ Output Timing for 2 State Access

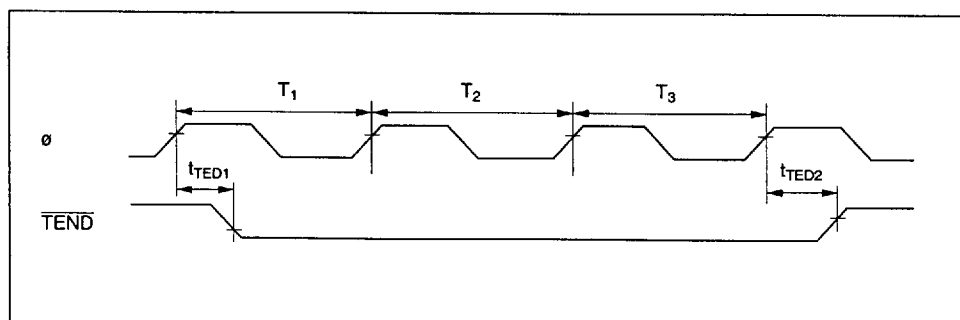


Figure 20-26 DMAC $\overline{\text{TEND}}$ Output Timing for 3 State Access

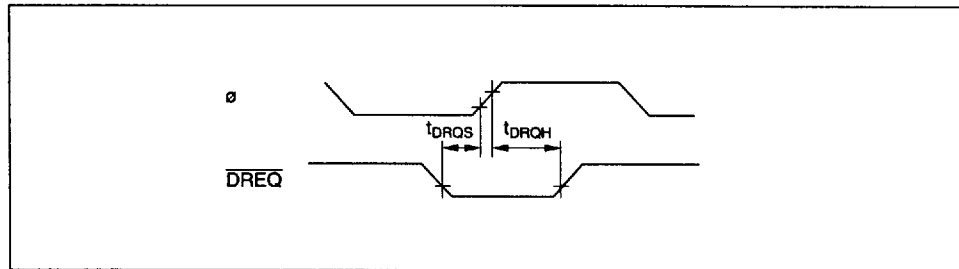


Figure 20-27 DMAC $\overline{\text{DREQ}}$ Input Timing