

Low Voltage / Low Power CMOS 16-bit Microcontrollers

TMP93CW40DF / TMP93CW41DF

1. Outline and Device Characteristics

TMP93CW40/W41 are high-speed advanced 16-bit microcontrollers developed for controlling medium to large-scale equipment. The TMP93CW40/CW41 enable low-voltage and low consumption power operation.

The TMP93CW40/W41 are housed in 100-pin flat package.

The device characteristics are as follows:

(1) Original 16-bit CPU (900/L CPU)

- TLCS-90 instruction mnemonic upward compatible
- 16M-byte linear address space
- General-purpose registers and register bank system
- 16-bit multiplication / division and bit transfer / arithmetic instructions
- High-speed micro DMA : 4 channels (1.6 μ s / 2 bytes at 20 MHz)

(2) Minimum instruction execution time : 200 ns at 20 MHz

(3) Internal RAM : 4 Kbyte

Internal ROM :

TMP93CW40	128 K-byte ROM
TMP93CW41	None

(4) External memory expansion

- Can be expanded up to 16M bytes (for both programs and data).
- AM8 / $\overline{16}$ pin (select the external data bus width)
- Can mix 8- and 16-bit external data buses.
...Dynamic data bus sizing

(5) 8-bit timer : 2 channels

(6) 8-bit PWM timer : 2 channels

000707EBP1

- For a discussion of how the reliability of microcontrollers can be predicted, please refer to Section 1.3 of the chapter entitled Quality and Reliability Assurance / Handling Precautions.
- TOSHIBA is continually working to improve the quality and reliability of its products. Nevertheless, semiconductor devices in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing TOSHIBA products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such TOSHIBA products could cause loss of human life, bodily injury or damage to property.
In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the "Handling Guide for Semiconductor Devices," or "TOSHIBA Semiconductor Reliability Handbook" etc..
- The TOSHIBA products listed in this document are intended for usage in general electronics applications (computer, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). These TOSHIBA products are neither intended nor warranted for usage in equipment that requires extraordinarily high quality and/or reliability or a malfunction or failure of which may cause loss of human life or bodily injury ("Unintended Usage"). Unintended Usage include atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc.. Unintended Usage of TOSHIBA products listed in this document shall be made at the customer's own risk.
- The products described in this document are subject to the foreign exchange and foreign trade laws.
- The information contained herein is presented only as a guide for the applications of our products. No responsibility is assumed by TOSHIBA CORPORATION for any infringements of intellectual property or other rights of the third parties which may result from its use. No license is granted by implication or otherwise under any intellectual property or other rights of TOSHIBA CORPORATION or others.
- The information contained herein is subject to change without notice.

- (7) 16-bit timer : 2 channels
- (8) 4-bit pattern generator : 2 channels
- (9) Serial interface : 2 channels
- (10) 10-bit AD converter : 8 channels
- (11) Watchdog timer
- (12) Chip select / wait controller : 3 blocks
- (13) Interrupt functions
 - 2 CPU interrupts SWI instruction, and Illegal instruction
 - 14 internal interrupts
 - 6 external interrupts7-level priority can be set.
- (14) I/O ports
79 pins for TMP93CW40 and 61 pins for TMP93CW41
- (15) Standby function : 4 halt modes (Run, Idle2, Idle1, Stop)
- (16) Clock Gear Function
 - Dual clock Operation
 - Clock gear : High-frequency clock can be changed f_c to $f_c / 16$.
- (17) Wide Operating Voltage
 - $V_{cc} = 2.7$ to 5.5 V
- (18) Package

Type No.	Package
TMP93CW40DF TMP93CW41DF	P-LQFP100-1414-0.50D

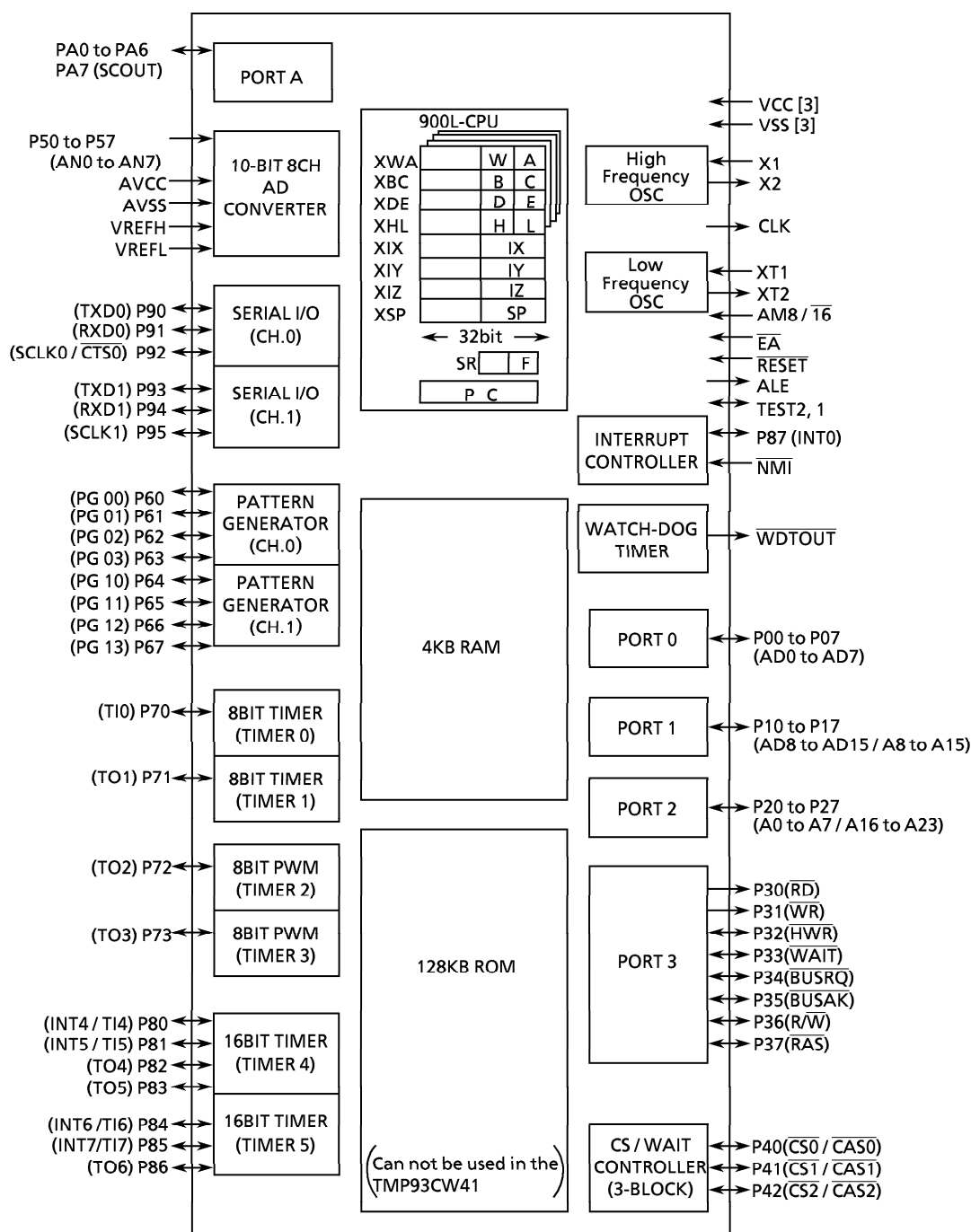


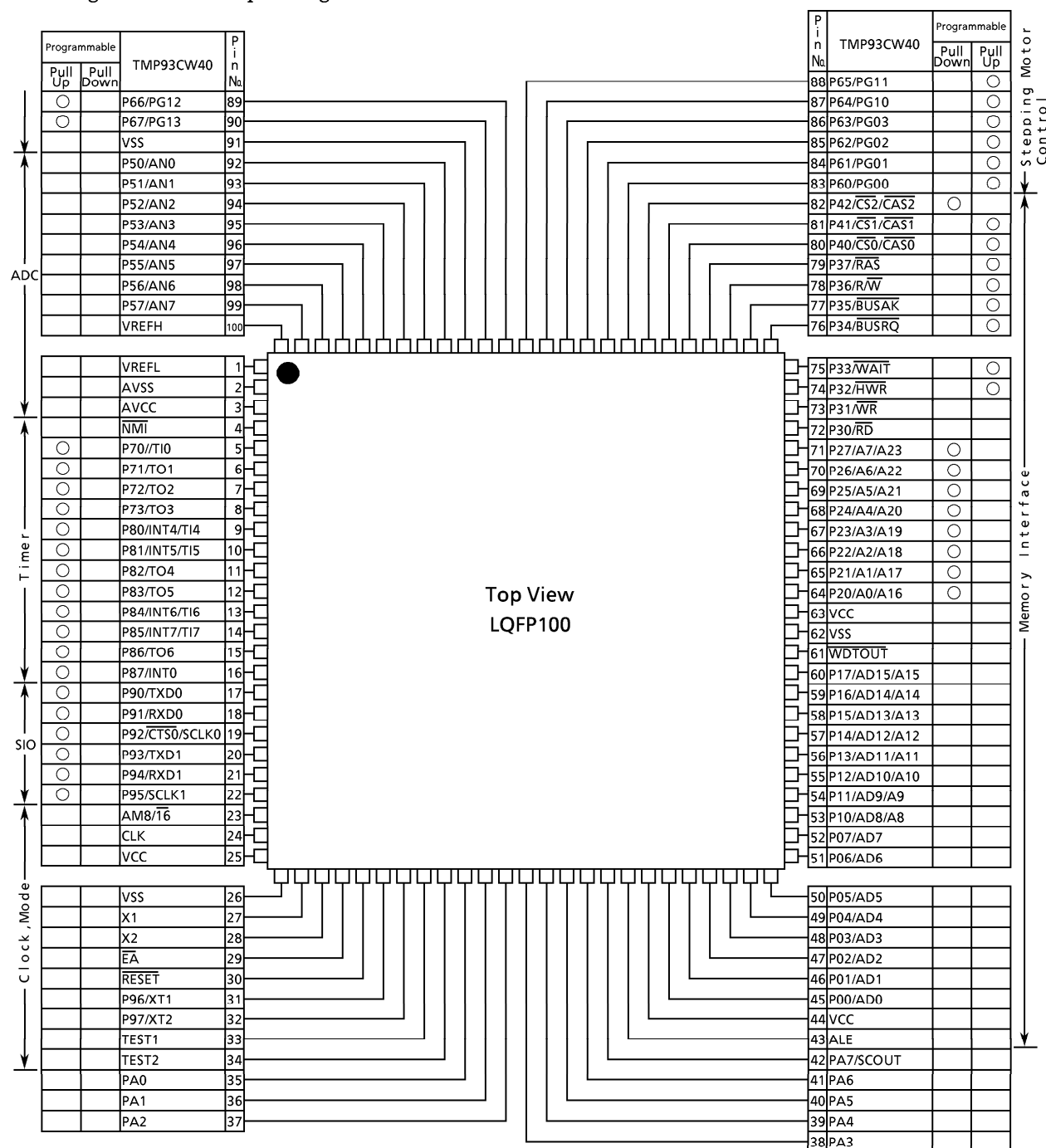
Figure 1.1 TMP93CW40/TMP93CW41 Block Diagram

2. Pin Assignment and Functions

The assignment of input / output pins for the TMP93CW40/W41, their name and outline functions are described below.

2.1 Pin Assignment

Figure 2.1.1 shows pin assignment of TMP93CW40DF/W41DF.



Note: Because the TMP93CW41 does not have an internal ROM, P00 to P17 pins are fixed to AD0 to AD15 (the case of AM8 / T6 = 0), or to AD0 to AD7, A8 to A15 (the case of AM8 / T6 = 1); P30 to RD; and P31 to WR.

Figure 2.1.1 Pin Assignment (100-pin LQFP)

2.2 Pin Names and Functions

The names of input / output pins and their functions are described below.

Table 2.2.1 Pin Names and Functions.

Table 2.2.1 Pin Names and Functions (1/4)

Pin name	Number of pins	I/O	Functions
P00 to P07 AD0 to AD7	8	I/O 3-state	Port 0: I/O port that allows I/O to be selected on a bit basis Address/data (lower): 0 to 7 for address/data bus
P10 to P17 AD8 to AD15 A8 to A15	8	I/O 3-state Output	Port 1: I/O port that allows I/O to be selected on a bit basis Address data (upper): 8 to 15 for address/data bus Address: 8 to 15 for address bus
P20 to P27 A0 to A7 A16 to A23	8	I/O Output Output	Port 2: I/O port that allows selection of I/O on a bit basis (with pull-down resistor) Address: 0 to 7 for address bus Address: 16 to 23 for address bus
P30 $\overline{RD}$	1	Output Output	Port 30: Output port Read: Strobe signal for reading external memory
P31 $\overline{WR}$	1	Output Output	Port 31: Output port Write: Strobe signal for writing data on pins AD0 to 7
P32 $\overline{HWR}$	1	I/O Output	Port 32: I/O port (with pull-up resistor) High write: Strobe signal for writing data on pins AD8 to 15
P33 $\overline{WAIT}$	1	I/O Input	Port 33: I/O port (with pull-up resistor) Wait: Pin used to request CPU bus wait
P34 $\overline{BUSRQ}$	1	I/O Input	Port34: I/O port (with pull-up resistor) Bus request: Signal used to request high impedance for AD0 to 15, A0 to 23, $\overline{RD}$, $\overline{WR}$, $\overline{HWR}$, $\overline{R/W}$, $\overline{RAS}$, $\overline{CS0}$, $\overline{CS1}$, and $\overline{CS2}$ pins. (For external DMAC)
P35 $\overline{BUSAK}$	1	I/O Output	Port 35: I/O port (with pull-up resistor) Bus acknowledge: Signal indicating that AD0 to 15, A0 to 23, $\overline{RD}$, $\overline{WR}$, $\overline{HWR}$, $\overline{R/W}$, $\overline{RAS}$, $\overline{CS0}$, $\overline{CS1}$, and $\overline{CS2}$ pins are at high impedance after receiving $\overline{BUSRQ}$. (For external DMAC)
P36 $\overline{R/W}$	1	I/O Output	Port 36: I/O port (with pull-up resistor) Read/write: 1 represents read or dummy cycle; 0, write cycle.
P37 $\overline{RAS}$	1	I/O Output	Port 37: I/O port (with pull-up resistor) Row address strobe: Outputs RAS strobe for DRAM.
P40 $\overline{CS0}$ $\overline{CAS0}$	1	I/O Output Output	Port 40: I/O port (with pull-up resistor) Chip select 0: Outputs 0 when address is within specified address area. Column address strobe 0: Outputs CAS strobe for DRAM when address is within specified address area.

Note : With the external DMA controller, this device's built-in memory or built-in I/O cannot be accessed using the $\overline{BUSRQ}$ and $\overline{BUSAK}$ pins.

Table 2.2.1 Pin Names and Functions (2/4)

Pin name	Number of pins	I/O	Functions
P41 $\overline{CS1}$ $\overline{CAS1}$	1	I/O Output Output	Port 41: I/O port (with pull-up resistor) Chip select 1: Outputs 0 if address is within specified address area. Column address strobe 1: Outputs $\overline{CAS}$ strobe for DRAM if address is within specified address area.
P42 $\overline{CS2}$ $\overline{CAS2}$	1	I/O Output Output	Port 42: I/O port (with pull-down resistor) Chip select 2: Outputs 0 if address is within specified address area. Column address strobe 2: Outputs $\overline{CAS}$ strobe for DRAM if address is within specified address area.
P50 to P57 AN0 to AN7	8	Input Input	Port 5: Input port Analog input: Input to AD converter
VREFH	1	Input	Pin for reference voltage input to AD converter (H)
VREFL	1	Input	Pin for reference voltage input to AD converter (L)
P60 to P63 PG00 to PG03	4	I/O Output	Ports 60 to 63: I/O ports that allow selection of I/O on a bit basis (with pull-up resistor) Pattern generator ports: 00 to 03
P64 to P67 PG10 to PG13	4	I/O Output	Ports 64 to 67: I/O ports that allow selection of I/O on a bit basis (with pull-up resistor) Pattern generator ports: 10 to 13
P70 TI0	1	I/O Input	Port 70: I/O port (with pull-up resistor) Timer input 0: Timer 0 input
P71 TO1	1	I/O Output	Port 71: I/O port (with pull-up resistor) Timer output 1: Timer 0 or 1 output
P72 TO2	1	I/O Output	Port 72: I/O port (with pull-up resistor) PWM output 2: 8-bit PWM timer 2 output
P73 TO3	1	I/O Output	Port 73: I/O port (with pull-up resistor) PWM output 3: 8-bit PWM timer 3 output
P80 TI4 INT4	1	I/O Input Input	Port 80: I/O port (with pull-up resistor) Timer input 4: Timer 4 count / capture trigger signal input Interrupt request pin 4: Interrupt request pin with programmable rising / falling edge
P81 TI5 INT5	1	I/O Input Input	Port 81: I/O port (with pull-up resistor) Timer input 5: Timer 4 count / capture trigger signal input Interrupt request pin 5: Interrupt request pin with rising edge
P82 TO4	1	I/O Output	Port 82: I/O port (with pull-up resistor) Timer output 4: Timer 4 output pin
P83 TO5	1	I/O Output	Port 83: I/O port (with pull-up resistor) Timer output 5: Timer 4 output pin

Table 2.2.1 Pin Names and Functions (3/4)

Pin name	Number of pins	I/O	Functions
P84 TI6 INT6	1	I/O Input Input	Port 84: I/O port (with pull-up resistor) Timer input 6: Timer 5 count / capture trigger signal input Interrupt request pin 6: Interrupt request pin with programmable rising / falling edge
P85 TI7 INT7	1	I/O Input Input	Port 85: I/O port (with pull-up resistor) Timer input 7: Timer 5 count / capture trigger signal input Interrupt request pin 7: Interrupt request pin with rising edge
P86 TO6	1	I/O Output	Port 86: I/O port (with pull-up resistor) Timer output 6: Timer 5 output pin
P87 INT0	1	I/O Input	Port 87: I/O port (with pull-up resistor) Interrupt request pin 0: Interrupt request pin with programmable level / rising edge
P90 TXD0	1	I/O Output	Port 90: I/O port (with pull-up resistor) Serial send data 0
P91 RXD0	1	I/O Input	Port 91: I/O port (with pull-up resistor) Serial receive data 0
P92 CTS0 SCLK0	1	I/O Input I/O	Port 92: I/O port (with pull-up resistor) Serial data send enable 0 (Clear to Send) Serial Clock I/O 0
P93 TXD1	1	I/O Output	Port 93: I/O port (with pull-up resistor) Serial send data 1
P94 RXD1	1	I/O Input	Port 94: I/O port (with pull-up resistor) Serial receive data 1
P95 SCLK1	1	I/O I/O	Port 95: I/O port (with pull-up resistor) Serial clock I/O 1
PA0 to PA6	7	I/O	Port A: I/O ports
PA7 SCOUT	1	I/O Output	Port A7: I/O port System Clock Output: Outputs system clock or 1/2 oscillation clock for synchronizing to external circuit.
WDTOUT	1	Output	Watchdog timer output pin
NMI	1	Input	Non-maskable interrupt request pin: Interrupt request pin with falling edge. Can also be operated at rising edge by program.
CLK	1	Output	Clock output: Outputs $\lceil \text{System Clock} \div 2 \rceil$ Clock. Pulled-up during reset. can be set to Output Disable for reducing noise.
EA	1	Input	External access: "0" should be inputted with TMP93CW41. "1" should be inputted with TMP93CW40.

Table 2.2.1 Pin Names and Functions (4/4)

Pin name	Number of pins	I/O	Functions
AM8 / $\overline{16}$	1	Input	Address Mode: Selects external Data Bus width. (the case of TMP93CW40) "1" should be inputted. The Data Bus Width for external access is set by Chip Select / WAIT Control register, Port 1 Control register. (the case of TMP93CW41) "0" should be inputted with fixed 16bit Bus Width or 16bit Bus interlarded with 8bit Bus. "1" should be inputted with fixed 8bit Bus Width.
ALE	1	Output	Address Latch Enable Can be set to Output Disable for reducing noise.
$\overline{\text{RESET}}$	1	Input	Reset: Initializes LSI. (With pull-up resistor)
X1/X2	2	I/O	High Frequency Oscillator connecting pin
XT1 P96	1	Input I/O	Low Frequency Oscillator connecting pin Port 96: I/O port (Open Drain Output)
XT2 P97	1	Output I/O	Low Frequency Oscillator connecting pin Port 97: I/O port (Open Drain Output)
TEST1 / TEST2	2	Output / Input	TEST1 Should be connected with TEST2 pin.
VCC	3		Power supply pin
VSS	3		GND pin (0 V)
AVCC	1		Power supply pin for AD converter
AVSS	1		GND pin for AD converter (0 V)

Note : Pull-up / pull-down resistor can be released from the pin by software.

3. Operation

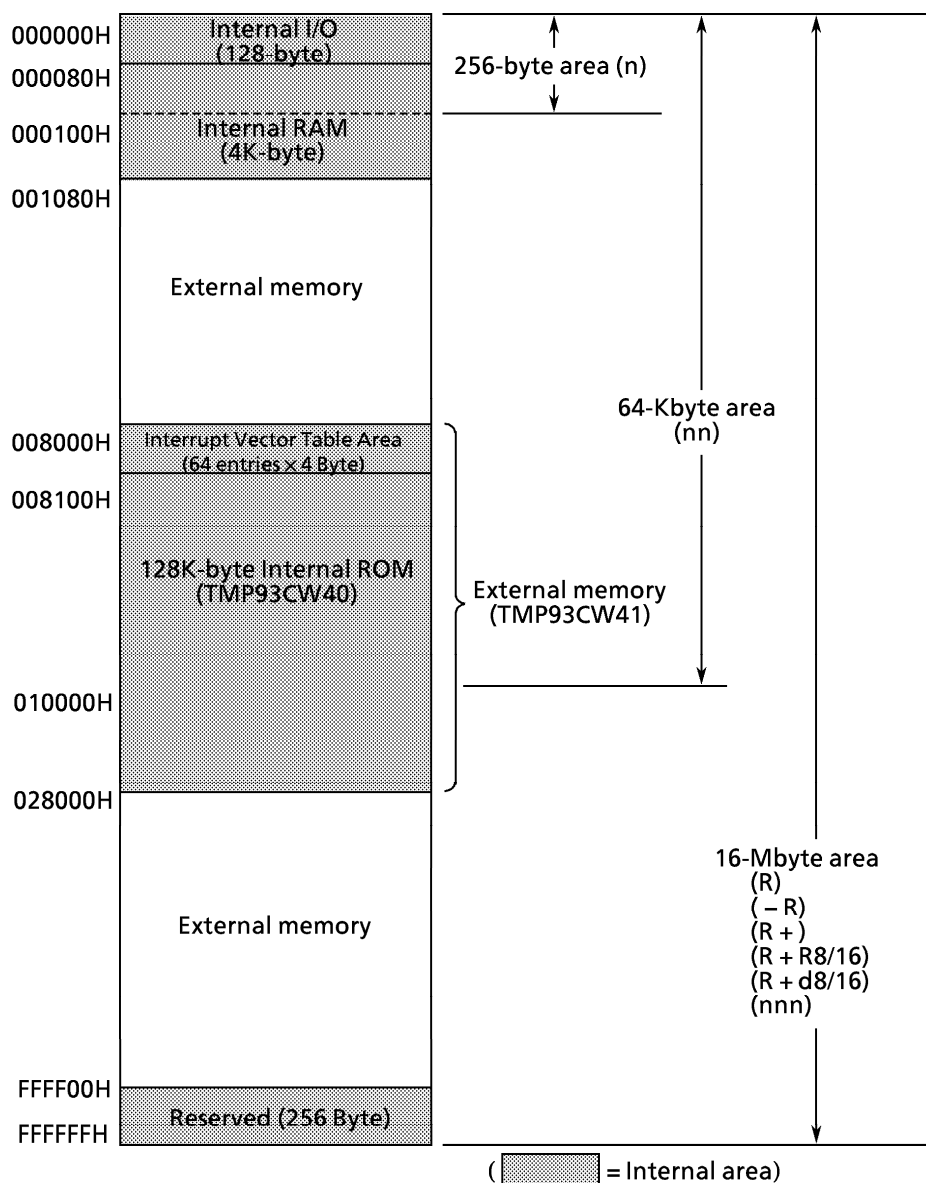
This section describes in blocks the functions and basic operations of TMP93CW40/ W41 devices.

3.1 CPU

The TMP93CW40/W41 devices have a built-in high-performance 16-bit CPU (900/L_CPU). (For CPU operation, see TLCS-900/L CPU in the previous section).

3.2 Memory Map

Figure 3.2.1 is a memory map of the TMP93CW40/W41.



Note : Resetting sets the stack pointer (XSP) to 100H.

The 256 Byte Area from FFFF00H to FFFFFFFH can not be used.

Figure 3.2.1 Memory map

4. ELECTRICAL CHARACTERISTICS

4.1 Absolute Maximum Ratings

(TMP93CW40DF, TMP93CW41DF)

"X" used in an expression shows a frequency of clock f_{PPH} selected by $SYSCR1 < SYSCK >$. If a clock gear or a low speed oscillator is selected, a value of "X" is different. The value in an example is calculated at f_c , $gear = 1/f_c$ ($SYSCR1 < SYSCK$, GEAR 2 to 0) = "0000".

Parameter	Symbol	Rating	Unit
Power Supply Voltage	V_{CC}	- 0.5 to 6.5	V
Input Voltage	V_{IN}	- 0.5 to $V_{CC} + 0.5$	V
Output Current (total)	ΣI_{OL}	120	mA
Output Current (total)	ΣI_{OH}	- 80	mA
Power Dissipation ($T_a = 85^\circ\text{C}$)	P_D	600	mW
Soldering Temperature (10 s)	T_{SOLDER}	260	$^\circ\text{C}$
Storage Temperature	T_{STG}	- 65 to 150	$^\circ\text{C}$
Operating Temperature	T_{OPR}	- 40 to 85	$^\circ\text{C}$

Note : The absolute maximum ratings are rated values which must not be exceeded during operation, even for an instant. Any one of the ratings must not be exceeded. If any absolute maximum rating is exceeded, a device may break down or its performance may be degraded, causing it to catch fire or explode resulting in injury to the user. Thus, when designing products which include this device, ensure that no absolute maximum rating value will ever be exceeded.

4.2 DC Characteristics (1/2)

 $T_a = -40$ to 85°C

Parameter		Symbol	Condition	Min	Typ. (Note)	Max	Unit
Power Supply Voltage ($AV_{CC} = V_{CC}$ $AV_{CC} = V_{SS} = 0V$)		V_{CC}	$f_c = 4$ to 20 MHz $f_s = 30$ to 34 kHz	4.5		5.5	V
Input Low Voltage	AD0 to 15	V_{IL}	$V_{CC} \geq 4.5\text{ V}$ $V_{CC} < 4.5\text{ V}$			0.8 0.6	V
	Port 2 to A (except P87)	V_{IL1}	$V_{CC} = 2.7$ to 5.5 V	-0.3		$0.3 V_{CC}$	
	RESET, NMI, INT0	V_{IL2}				$0.25 V_{CC}$	
	EA, AM8/16	V_{IL3}				0.3	
	X1	V_{IL4}				$0.2 V_{CC}$	
Input High Voltage	AD0 to 15	V_{IH}	$V_{CC} \geq 4.5\text{ V}$ $V_{CC} < 4.5\text{ V}$	2.2 2.0		$V_{CC} + 0.3$	V
	Port 2 to A (except P87)	V_{IH1}	$V_{CC} = 2.7$ to 5.5 V	$0.7 V_{CC}$			
	RESET, NMI, INT0	V_{IH2}		$0.75 V_{CC}$			
	EA, AM8/16	V_{IH3}		$V_{CC} - 0.3$			
	X1	V_{IH4}		$0.8 V_{CC}$			
Output Low Voltage		V_{OL}	$I_{OL} = 1.6\text{ mA}$ ($V_{CC} = 2.7$ to 5.5 V)			0.45	V
Output High Voltage		V_{OH1}	$I_{OH} = -400\text{ }\mu\text{A}$ ($V_{CC} = 3\text{ V} \pm 10\%$)	2.4			
		V_{OH2}	$I_{OH} = -400\text{ }\mu\text{A}$ ($V_{CC} = 5\text{ V} \pm 10\%$)	4.2			

Note: Typical values are for $T_a = 25^\circ\text{C}$ and $V_{CC} = 5\text{ V}$ unless otherwise noted.

4.2 DC Characteristics (2/2)

Parameter	Symbol	Condition	Min	Typ. (Note 1)	Max	Unit
Darlington Drive Current (8 Output Pins Max)	I_{DAR} (Note 2)	$V_{EXT} = 1.5\text{ V}$ $R_{EXT} = 1.1\text{ k}\Omega$ (when $V_{CC} = 5\text{ V} \pm 10\%$)	- 1.0		- 3.5	mA
Input Leakage Current	I_{LI}	$0.0 \leq V_{IN} \leq V_{CC}$		0.02	± 5	μA
Output Leakage Current	I_{LO}	$0.2 \leq V_{IN} \leq V_{CC} - 0.2$		0.05	± 10	
Powerdown Voltage (at Stop, RAM Back-up)	V_{STOP}	$V_{IL2} = 0.2V_{CC}$, $V_{IH2} = 0.8V_{CC}$	2.0		6.0	V
RESET Pull-up Resistor	R_{RST}	$V_{CC} = 5\text{ V} \pm 10\%$ $V_{CC} = 3\text{ V} \pm 10\%$	50 80		150 200	$\text{k}\Omega$
Pin Capacitance	C_{IO}	$f_c = 1\text{ MHz}$			10	pF
Schmitt Width RESET, NMI, INT0	V_{TH}		0.4	1.0		V
Programmable Pull-down Resistor	R_{KL}	$V_{CC} = 5\text{ V} \pm 10\%$ $V_{CC} = 3\text{ V} \pm 10\%$	10 30		80 150	$\text{k}\Omega$
Programmable Pull-up Resistor	R_{KH}	$V_{CC} = 5\text{ V} \pm 10\%$ $V_{CC} = 3\text{ V} \pm 10\%$	50 100		150 300	
Normal (Note 3)	I_{CC}	$V_{CC} = 5\text{ V} \pm 10\%$ $f_c = 20\text{ MHz}$		19	25	mA
Normal2 (Note 4)				24	30	
Run				17	25	
Idle2				10	15	
Idle1				3.5	5	
Normal (Note 3)		$V_{CC} = 3\text{ V} \pm 10\%$ $f_c = 12.5\text{ MHz}$ (Typ: $V_{CC} = 3.0\text{ V}$)		6.5	10	mA
Normal2 (Note 4)				9.5	13	
Run				5.0	9	
Idle2				3.0	5	
Idle1				0.8	1.5	
Slow (Note 3)		$V_{CC} = 3\text{ V} \pm 10\%$ $f_s = 32.768\text{ kHz}$ (Typ: $V_{CC} = 3.0\text{ V}$)		20	45	μA
Run				16	40	
Idle2				10	30	
Idle1				5	25	
Stop				0.2	10	
		$T_a \leq 50^\circ\text{C}$			20	μA
		$T_a \leq 70^\circ\text{C}$			50	
		$T_a \leq 85^\circ\text{C}$				

Note1: Typical values are for $T_a = 25^\circ\text{C}$ and $V_{CC} = 5\text{ V}$ unless otherwise Noted.

Note2: I_{DAR} is guranteed for total of up to 8 ports.

Note3: The condition of measurement of I_{CC} (Normal / Slow).

Only CPU operates. Output ports are open and input ports fixed.

Note 4: The condition of measurement of I_{CC} (Normal 2).

CPU and all peripherals operate. Output ports are open and input ports fixed.

4.3 AC Characteristics

(1) $V_{CC} = 5\text{ V} \pm 10\%$

No.	Parameter	Symbol	Variable		16 MHz		20 MHz		Unit
			Min	Max	Min	Max	Min	Max	
1	Osc. Period (= x)	t_{OSC}	50	31250	62.5		50		ns
2	CLK pulse Width	t_{CLK}	$2x - 40$		85		60		ns
3	A0 to A23 Valid $\rightarrow$ CLK Hold	t_{AK}	$0.5x - 20$		11		5		ns
4	CLK Valid $\rightarrow$ A0 to A23 Hold	t_{KA}	$1.5x - 70$		24		5		ns
5	A0 to A15 Valid $\rightarrow$ ALE Fall	t_{AL}	$0.5x - 15$		16		10		ns
6	ALE Fall $\rightarrow$ A0 to A15 Hold	t_{LA}	$0.5x - 20$		11		5		ns
7	ALE High pulse Width	t_{LL}	$x - 40$		23		10		ns
8	ALE Fall $\rightarrow$ $\overline{RD}/\overline{WR}$ Fall	t_{LC}	$0.5x - 25$		6		0		ns
9	$\overline{RD}/\overline{WR}$ Rise $\rightarrow$ ALE Rise	t_{CL}	$0.5x - 20$		11		5		ns
10	A0 to A15 Valid $\rightarrow$ $\overline{RD}/\overline{WR}$ Fall	t_{ACL}	$x - 25$		38		25		ns
11	A0 to A23 Valid $\rightarrow$ $\overline{RD}/\overline{WR}$ Fall	t_{ACH}	$1.5x - 50$		44		25		ns
12	$\overline{RD}/\overline{WR}$ Rise $\rightarrow$ A0 to A23 Hold	t_{CA}	$0.5x - 25$		6		0		ns
13	A0 to A15 Valid $\rightarrow$ D0 to D15 Input	t_{ADL}		$3.0x - 55$		133		95	ns
14	A0 to A23 Valid $\rightarrow$ D0 to D15 Input	t_{ADH}		$3.5x - 65$		154		110	ns
15	$\overline{RDFall} \rightarrow$ D0 to D15 Input	t_{RD}		$2.0x - 60$		65		40	ns
16	$\overline{RD}$ Low Pulse Width	t_{RR}	$2.0x - 40$		85		60		ns
17	$\overline{RDRise} \rightarrow$ D0 to D15 Hold	t_{HR}	0		0		0		ns
18	$\overline{RDRise} \rightarrow$ A0 to A15 Output	t_{RAE}	$x - 15$		48		35		ns
19	$\overline{WR}$ Low Pulse Width	t_{WW}	$2.0x - 40$		85		60		ns
20	D0 to D15 Valid $\rightarrow$ $\overline{WR}$ Rise	t_{DW}	$2.0x - 55$		70		45		ns
21	$\overline{WR}$ Rise $\rightarrow$ D0 to D15 Hold	t_{WD}	$0.5x - 15$		16		10		ns
22	A0 to A23 Valid $\rightarrow$ $\overline{WAIT}$ Input	t_{AWH}		$3.5x - 90$		129		85	ns
23	A0 to A15 Valid $\rightarrow$ $\overline{WAIT}$ Input	t_{AWL}		$3.0x - 80$		108		70	ns
24	$\overline{RD}/\overline{WR}$ Fall $\rightarrow$ $\overline{WAIT}$ Hold	t_{CW}	$2.0x + 0$		125		100		ns
25	A0 to A23 Valid $\rightarrow$ PORT Input	t_{APH}		$2.5x - 120$		36		5	ns
26	A0 to A23 Valid $\rightarrow$ PORT Hold	t_{APH2}	$2.5x + 50$		206		175		ns
27	$\overline{WR}$ Rise $\rightarrow$ PORT Valid	t_{CP}		200		200		200	ns
28	A0 to A23 Valid $\rightarrow$ $\overline{RAS}$ Fall	t_{ASRH}	$1.0x - 40$		23		10		ns
29	A0 to A15 Valid $\rightarrow$ $\overline{RAS}$ Fall	t_{ASRL}	$0.5x - 15$		16		10		ns
30	$\overline{RAS}$ Fall $\rightarrow$ D0 to D15 Input	t_{RAC}		$2.5x - 70$		86		55	ns
31	$\overline{RAS}$ Fall $\rightarrow$ A0 to A15 Hold	t_{RAH}	$0.5x - 15$		16		10		ns
32	$\overline{RAS}$ Low Pulse Width	t_{RAS}	$2.0x - 40$		85		60		ns
33	$\overline{RAS}$ High Pulse Width	t_{RP}	$2.0x - 40$		85		60		ns
34	$\overline{CAS}$ Fall $\rightarrow$ $\overline{RAS}$ Rise	t_{RSH}	$1.0x - 40$		23		10		ns
35	$\overline{RAS}$ Rise $\rightarrow$ $\overline{CAS}$ Rise	t_{RSC}	$0.5x - 25$		6		0		ns
36	$\overline{RAS}$ Fall $\rightarrow$ $\overline{CAS}$ Fall	t_{RCD}	$1.0x - 40$		23		10		ns
37	$\overline{CAS}$ Fall $\rightarrow$ D0 to D15 Input	t_{CAC}		$1.5x - 65$		29		10	ns
38	$\overline{CAS}$ Low Pulse Width	t_{CAS}	$1.5x - 30$		64		40		ns

AC Measuring Conditions

- Output Level : High 2.2 V / Low 0.8 V, $CL = 50\text{ pF}$
(However $CL = 100\text{ pF}$ for AD0 to AD15, A0 to A23, ALE, $\overline{RD}$, $\overline{WR}$, $\overline{HWR}$, $\overline{R/W}$, CLK, $\overline{RAS}$, $\overline{CAS0}$ to $\overline{CAS2}$)
- Input Level : High 2.4 V / Low 0.45 V (AD0 to AD15)
High $0.8 \times V_{CC}$ / Low $0.2 \times V_{CC}$ (Except for AD0 to AD15)

(2) $V_{CC} = 3\text{ V} \pm 10\%$

No.	Parameter	Symbol	Variable		12.5 MHz		Unit
			Min	Max	Min	Max	
1	Osc. Period (= x)	t_{OSC}	80	31250	80		ns
2	CLK pulse width	t_{CLK}	$2x - 40$		120		ns
3	A0 to 23 Valid → CLK Hold	t_{AK}	$0.5x - 30$		10		ns
4	CLK Valid → A0 to 23 Hold	t_{KA}	$1.5x - 80$		40		ns
5	A0 to 15 Valid → ALE fall	t_{AL}	$0.5x - 35$		5		ns
6	ALE fall → A0 to 15 Hold	t_{LA}	$0.5x - 35$		5		ns
7	ALE High pulse width	t_{LL}	$x - 60$		20		ns
8	ALE fall → RD/WR fall	t_{LC}	$0.5x - 35$		5		ns
9	RD/WR rise → ALE rise	t_{CL}	$0.5x - 40$		0		ns
10	A0 to 15 Valid → RD/WR fall	t_{ACL}	$x - 50$		30		ns
11	A0 to 23 Valid → RD/WR fall	t_{ACH}	$1.5x - 50$		70		ns
12	RD/WR rise → A0 to 23 Hold	t_{CA}	$0.5x - 40$		0		ns
13	A0 to 15 Valid → D0 to 15 input	t_{ADL}		$3.0x - 110$		130	ns
14	A0 to 23 Valid → D0 to 15 input	t_{ADH}		$3.5x - 125$		155	ns
15	RD fall → D0 to 15 input	t_{RD}		$2.0x - 115$		45	ns
16	RD Low pulse width	t_{RR}	$2.0x - 40$		120		ns
17	RD rise → D0 to 15 Hold	t_{HR}	0		0		ns
18	RD rise → A0 to 15 output	t_{RAE}	$x - 25$		55		ns
19	WR Low pulse width	t_{WW}	$2.0x - 40$		120		ns
20	D0 to 15 Valid → WR rise	t_{DW}	$2.0x - 120$		40		ns
21	WR rise → D0 to 15 Hold	t_{WD}	$0.5x - 40$		0		ns
22	A0 to 23 Valid → WAIT input (1 WAIT + n mode)	t_{AWH}		$3.5x - 130$		150	ns
23	A0 to 15 Valid → WAIT input (1 WAIT + n mode)	t_{AWL}		$3.0x - 100$		140	ns
24	RD/WR fall → WAIT Hold (1 WAIT + n mode)	t_{CW}	$2.0x + 0$		160		ns
25	A0 to 23 Valid → PORT input	t_{APH}		$2.5x - 195$		5	ns
26	A0 to 23 Valid → PORT Hold	t_{APH2}	$2.5x + 50$		250		ns
27	WR rise → PORT Valid	t_{CP}		200		200	ns
28	A0 to 23 Valid → RAS fall	t_{ASRH}	$1.0x - 60$		20		ns
29	A0 to 15 Valid → RAS fall	t_{ASRL}	$0.5x - 40$		0		ns
30	RAS fall → D0 to 15 input	t_{RAC}		$2.5x - 90$		110	ns
31	RAS fall → A0 to 15 Hold	t_{RAH}	$0.5x - 25$		15		ns
32	RAS Low pulse width	t_{RAS}	$2.0x - 40$		120		ns
33	RAS High pulse width	t_{RP}	$2.0x - 40$		120		ns
34	CAS fall → RAS rise	t_{RSH}	$1.0x - 55$		25		ns
35	RAS rise → CAS rise	t_{RSC}	$0.5x - 25$		15		ns
36	RAS fall → CAS fall	t_{RCD}	$1.0x - 40$		40		ns
37	CAS fall → D0 to 15 input	t_{CAC}		$1.5x - 120$		0	ns
38	CAS Low pulse width	t_{CAS}	$1.5x - 40$		80		ns

AC Measuring Conditions

- Output Level : High $0.7 \times V_{CC}$ / Low $0.3 \times V_{CC}$, $CL = 50\text{ pF}$
- Input Level : High $0.9 \times V_{CC}$ / Low $0.1 \times V_{CC}$

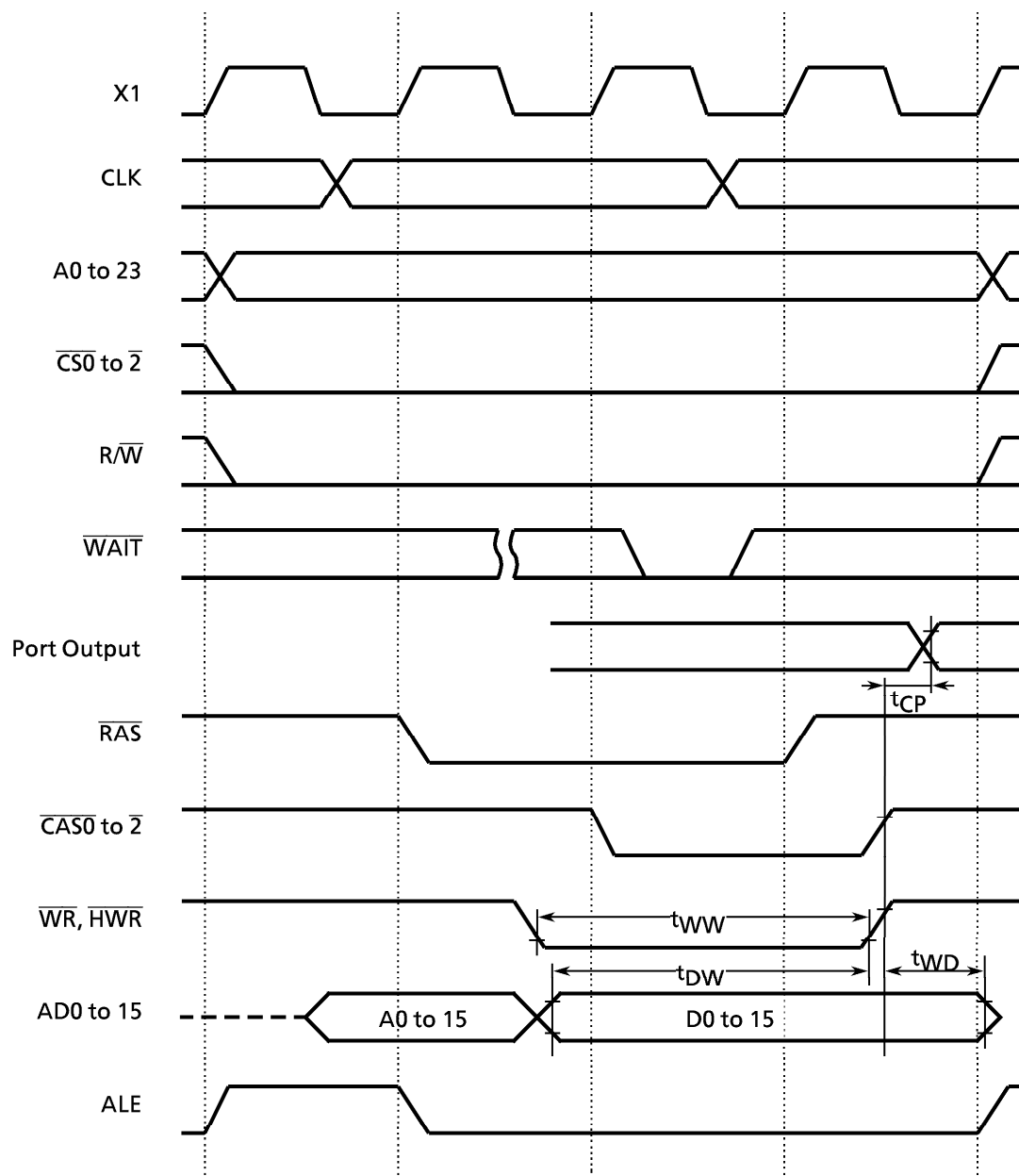
The diagram illustrates the timing relationships between the Intel 80386 microprocessor and its external components. The signals shown are:

- X1**: Oscillator input signal.
- CLK**: Clock signal.
- A0 to 23**: Address bus signal.
- CS₀ to 2**: Chip select signals.
- R/W**: Read/Write control signal.
- WAIT**: Wait state signal.
- Port Input**: Data bus signal during memory-mapped I/O.
- RAS**: Row Address Strobe signal.
- CAS₀ to 2**: Column Address Strobe signals.
- RD**: Read control signal.
- AD0 to 15**: Multiplexed address/data bus signal.
- ALE**: Active Low Enable signal.

Key timing parameters labeled include:

- t_{osc} : Oscillator period.
- t_{clk} : Clock period.
- t_{AK} : Address setup time before clock.
- t_{KA} : Address hold time after clock.
- t_{AWH} , t_{AWL} : Address valid high/low times relative to R/W.
- t_{CW} : Command valid time relative to R/W.
- t_{APH} , t_{APH2} : Port output pulse width and delay.
- t_{ASRH} : RAS setup time before address.
- t_{ASRL} : RAS setup time before column strobes.
- t_{RAH} , t_{RCD} : RAS hold time and row-to-column delay.
- t_{RSH} , t_{RAS} , t_{RSC} : RAS pulse width, period, and setup time before column strobe.
- t_{CAH} , t_{CAC} : Column strobe hold time and setup time before data.
- t_{ACH} , t_{ACL} : Address setup/hold times relative to RD.
- t_{RR} : Read refresh rate.
- t_{RD} , t_{ADL} : Read data setup/hold times relative to RD.
- t_{AL} , t_{LA} : ALE setup/hold times relative to address.
- t_{LL} : ALE low pulse width.
- t_{CL} : Data capture time relative to RD.
- t_{HR} : Hold time after RD.
- t_{RAE} : Read after enable time.
- t_{RP} : RAS precharge time.

(2) Write Cycle



4.4 AD Conversion Characteristics

$$AV_{CC} = V_{CC}, AV_{SS} = V_{SS}$$

Parameter	Symbol	Power Supply	Min	Typ.	Max	Unit
Analog reference voltage (+)	V_{REFH}	$V_{CC} = 5\text{ V} \pm 10\%$	$V_{CC} - 1.5\text{ V}$	V_{CC}	V_{CC}	V
		$V_{CC} = 3\text{ V} \pm 10\%$	$V_{CC} - 0.2\text{ V}$	V_{CC}	V_{CC}	
Analog reference voltage (-)	V_{REFL}	$V_{CC} = 5\text{ V} \pm 10\%$	V_{SS}	V_{SS}	$V_{SS} + 0.2\text{ V}$	
		$V_{CC} = 3\text{ V} \pm 10\%$	V_{SS}	V_{SS}	$V_{SS} + 0.2\text{ V}$	
Analog input voltage range	V_{AIN}		V_{REFL}		V_{REFH}	
Analog current for analog reference voltage <VREFON> = 1 <VREFON> = 0	I_{REF} ($V_{REFL} = 0\text{ V}$)	$V_{CC} = 5\text{ V} \pm 10\%$		0.5	1.5	mA
		$V_{CC} = 3\text{ V} \pm 10\%$		0.3	0.9	
		$V_{CC} = 2.7\text{ to }5.5\text{ V}$		0.02	5.0	μA
Error (excluding quantizing error)	-	$V_{CC} = 5\text{ V} \pm 10\%$		± 1.0	± 3.0	LSB
		$V_{CC} = 3\text{ V} \pm 10\%$		± 1.0	± 3.0	

Note 1 : $1\text{LSB} = (V_{REFH} - V_{REFL}) / 2^{10} [\text{V}]$

Note 2 : Minimum operation frequency

The operation of the AD converter is guaranteed only when f_c (high-frequency oscillator) is used. (It is not guaranteed when f_s is used.) Additionally, it is guaranteed when the clock frequency which is selected by the clock gear is 4 MHz or more.

Note 3 : The value I_{CC} includes the current which flows through the AV_{CC} pin.

4.5 Serial Channel Timing

(1) I/O Interface Mode

① SCLK Input Mode

Parameter	Symbol	Variable		32.768 MHz (Note)		12.5 MHz		20 MHz		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	
SCLK cycle	t_{SCY}	16X		488 μs		1.28		0.8		μs
Output Data → Rising edge or SCLK	t_{OSS}	$t_{SCY}/2 - 5X - 50$		91.5 μs		190		100		ns
SCLK rising edge → Output Data hold	t_{OHS}	$5X - 100$		152 μs		300		150		ns
SCLK rising edge → Input Data hold	t_{HSR}	0		0		0		0		ns
SCLK rising edge → effective data input	t_{SRD}		$t_{SCY} - 5X - 100$		336 μs		780		450	ns

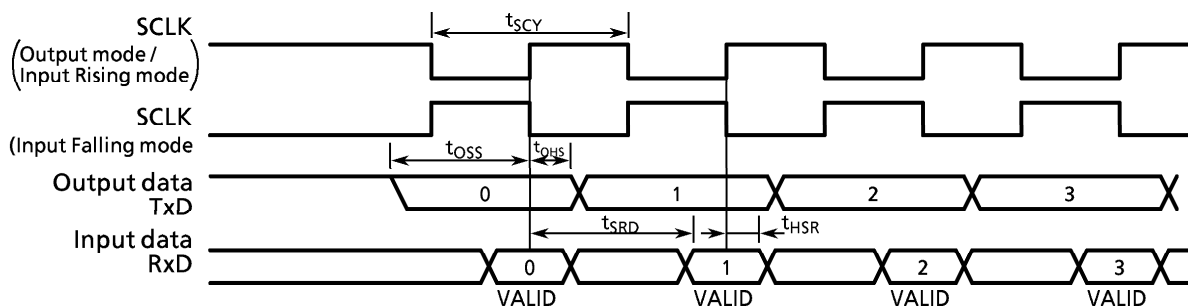
Note : When f_s is used as system clock (f_{SYS}) or f_s is used as input clock to prescaler.

*) SCLK rising / falling timing ... SCLK rising in the rising mode of SCLK, SCLK falling in the falling mode of SCLK.

② SCLK Output Mode

Parameter	Symbol	Variable		32.768 MHz (Note)		12.5 MHz		20 MHz		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	
SCLK cycle (programmable)	t_{SCY}	16X	8192X	488 μs	250 ms	1.28	655.36	0.8	409.6	μs
Output Data → SCLK rising edge	t_{OSS}	$t_{SCY} - 2X - 150$		427 μs		970		550		ns
SCLK rising edge → Output Data hold	t_{OHS}	$2X - 80$		60 μs		80		20		ns
SCLK rising edge → Input Data hold	t_{HSR}	0		0		0		0		ns
SCLK rising edge → effective data input	t_{SRD}		$t_{SCY} - 2X - 150$		428 μs		970		550	ns

Note : When f_s is used as system clock (f_{SYS}) or f_s is used as input clock to prescaler.



4.6 Timer/Counter Input Clock (TI0, TI4, TI5, TI6, TI7)

Parameter	Symbol	Variable		12.5 MHz		20 MHz		Unit
		Min	Max	Min	Max	Min	Max	
Clock Cycle	t_{VCK}	$8X + 100$		740		500		ns
Low level clock Pulse width	t_{VCKL}	$4X + 40$		360		240		ns
High level clock Pulse width	t_{VCKH}	$4X + 40$		360		240		ns

4.7 Interrupt and Capture

(1) $\overline{NMI}$, INT0 interrupts

Parameter	Symbol	Variable		12.5 MHz		20 MHz		Unit
		Min	Max	Min	Max	Min	Max	
$\overline{NMI}$, INT0 Low Level Pulse Width	t_{INTAL}	4X		320		200		ns
$\overline{NMI}$, INT0 High Level Pulse Width	t_{INTAH}	4X		320		200		ns

(2) INT4 to 7 interrupts, capture

Input pulse width of INT4 to 7 depends on the operation clock of CPU and Timer (9-bit prescaler). The following shows the pulse width in each clock.

System clock selected <SYSCK>	Prescaler clock selected <PRCK1 to 0>	t_{INTBL} (INT4 to 7 low level pulse width)		t_{INTBH} (INT4 to 7 high level pulse width)		Unit
		Variable	20 MHz	Variable	20 MHz	
		Min	Min	Min	Min	
0 (fc)	00 (f_{FPH})	$8X + 100$	500	$8X + 100$	500	ns
	01 (fs)	$8XT + 0.1$	244.3	$8XT + 0.1$	244.3	
	10 (fc/16)	$128X + 0.1$	6.5	$128X + 0.1$	6.5	
1 (fs) (Note 2)	00 (f_{FPH})	$8XT + 0.1$	244.3	$8XT + 0.1$	244.3	μs
	01 (fs)					

Note 1: XT represents the cycle of the low frequency clock fs. Calculated at $f_s = 32.768$ kHz.

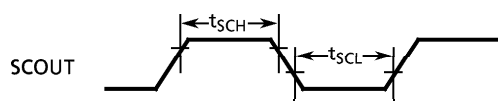
Note 2: When fs is used as the system clock, fc/16 can not be selected for the prescaler clock.

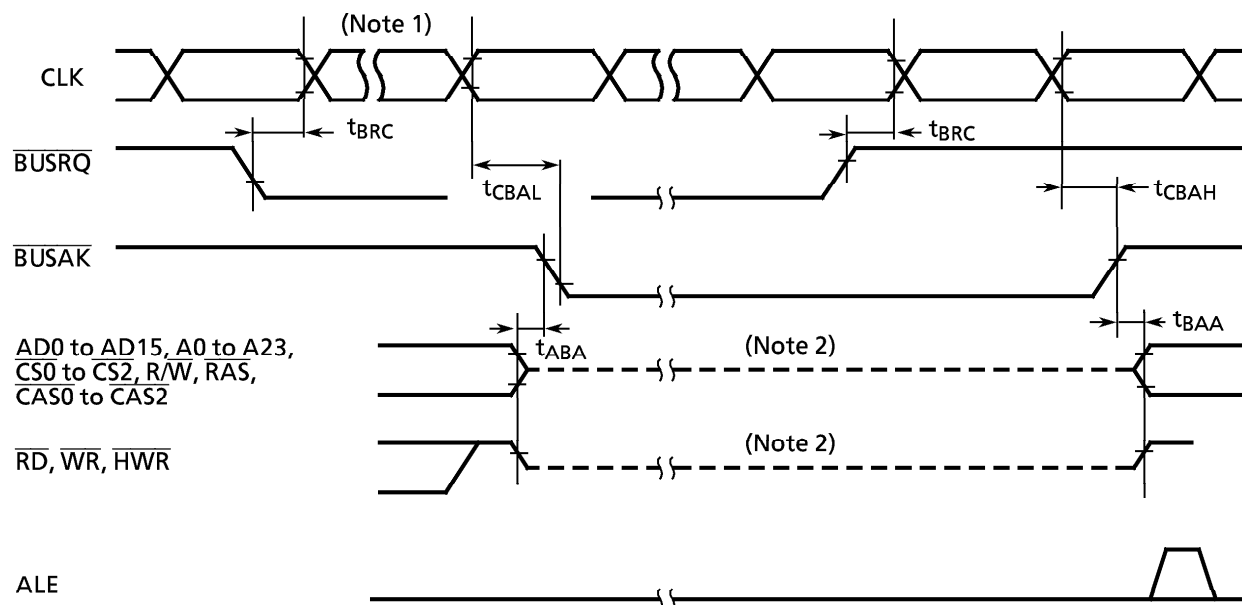
4.8 SCOUT pin AC characteristics

Parameter		Symbol	Variable		12.5 MHz		20 MHz		Unit
			Min	Max	Min	Max	Min	Max	
High-Level Pulse Width	$V_{CC} = 5\text{ V} \pm 10\%$	t_{SCH}	$0.5X - 10$		30		15		ns
	$V_{CC} = 3\text{ V} \pm 10\%$		$0.5X - 20$		20		–	–	
Low-Level Pulse Width	$V_{CC} = 5\text{ V} \pm 10\%$	t_{SCL}	$0.5X - 10$		30		15		ns
	$V_{CC} = 3\text{ V} \pm 10\%$		$0.5X - 20$		20		–	–	

Measurement condition

- Output level: High 2.2 V / Low 0.8 V, $C_L = 10$ pF



4.9 Timing Chart for Bus Request ($\overline{\text{BUSRQ}}$) / Bus Acknowledge ($\overline{\text{BUSAK}}$)

Parameter	Symbol	Variable		12.5 MHz		20 MHz		Unit
		Min	Max	Min	Max	Min	Max	
$\overline{\text{BUSRQ}}$ Set-up Time to CLK	t_{BRC}	120		120		120		ns
CLK $\rightarrow$ $\overline{\text{BUSAK}}$ Falling Edge	t_{CBAL}		$1.5X + 120$		270		195	ns
CLK $\rightarrow$ $\overline{\text{BUSAK}}$ Rising Edge	t_{CBAH}		$0.5X + 40$		80		65	ns
Output Buffer off to $\overline{\text{BUSAK}}$	t_{ABA}	0	80	0	80	0	80	ns
$\overline{\text{BUSAK}}$ to Output Buffer on	t_{BAA}	0	80	0	80	0	80	ns

Note 1 : The Bus will be released after the $\overline{\text{WAIT}}$ request is inactive, when the $\overline{\text{BUSRQ}}$ is set to "0" during "Wait" cycle.

Note 2 : This line only shows the output buffer is off-state.

It doesn't indicate the signal level is fixed.

Just after the bus is released, the signal level which is set before the bus is released is kept dynamically by the external capacitance. Therefore, to fix the signal level by an external resistor during bus releasing, designing is executed carefully because the level-fix will be delayed.

The internal programmable pull-up/pull-down resistor is switched active/non-active by an internal signal.