NEC Electronics Inc.

μPD8088
HIGH-PERFORMANCE 8-BIT MICROPROCESSOR

Description

The μPD8088 and μPD8088-2 are powerful 8-bit microprocessors that are software-compatible with the μPD8086. They have the same bus interface signals as μPD8085A, allowing them to interface directly with multiplexed bus peripherals. Both having a 20-bit address space which can be divided into four segments of up to 64K bytes each.

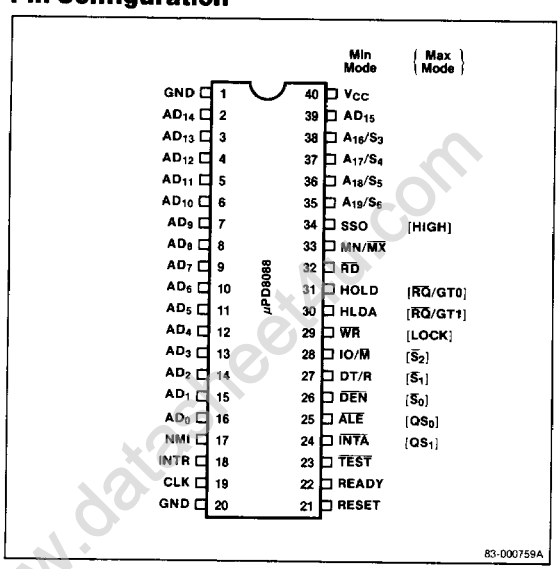
Features

- ☐ 8-bit data bus interface
- ☐ 16-bit internal architecture
- ☐ Addresses 1 Mbyte of memory
- ☐ Software-compatible with the 8086
- ☐ Provides byte, word, and block operations
- ☐ Performs 8- and 16-bit signed and unsigned arithmetic in binary and decimal
- ☐ Multiply and divide instruction
- ☐ Directly interfaces to 8155, 8355, and 8755A multiplexed peripherals

Ordering Information

Part Number	Package Type	Max Frequency of Operation
μPD8088D	40-pin ceramic DIP	5 MHz
μPD8088D-2	40-pin ceramic DIP	8 MHz

Pin Configuration



Pin Identification

No.	Symbol	Function
1, 20	GND	Ground
2-8, 35-39	A_{19}-A_8	Most significant address bits
9-16	AD_7-AD_0	Address/data bus
17	NMI	Non-maskable interrupt
18	INTR	Interrupt request
19	CLK	Clock
21	RESET	Reset
22	READY	Ready
23	$\overline{TEST}$	Test
24	$\overline{INTA}$	Interrupt acknowledge
25	$\overline{ALE}$	Address latch enable
24, 25	QS_1, QS_0	Queue status
26	$\overline{DEN}$	Data enable
27	DT/$\overline{R}$	Data transmit/receive
28	IO/$\overline{M}$	IO status/memory
29	$\overline{WR}$	Write
29	LOCK	Lock
30	HLDA	Hold acknowledge
31	HOLD	Hold
30, 31	$\overline{RQ}/GT_0$ $\overline{RQ}/GT_1$	Request/grant
32	$\overline{RD}$	Read
33	MN/$\overline{MX}$	Minimum/maximum
34	SS0	Status line
26-28	$\overline{S_0}$-$\overline{S_2}$	Status outputs
35-38	S_3-S_6	Status outputs
40	V_{CC}	Power supply

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Pin Function

Ground

Ground.

Most Significant Address Bits

Most significant bits for memory operations.

Address/Data Bus

Multiplexed address and data bus. 8-bit peripherals tied to these bits use A_0 to condition chip select functions. These lines are three-state during interrupt acknowledge and hold states.

Non-Maskable Interrupt

This edge-triggered input causes a type 2 interrupt. The processor uses a look-up table for vectoring information.

Interrupt Request

This is a level-triggered interrupt sampled on the last clock cycle of each instruction. A look-up table is used for vectoring. INTR can be masked in software by resetting the interrupt enable bit.

Clock

The clock input is a 1/3 duty cycle input providing basic timing for the processor and bus controller.

Reset

This active high signal must be high for 4 clock cycles. When it returns low, the processor restarts execution.

Ready

An acknowledgement from memory or I/O that data will be transferred. Synchronization is done by the μPD8284 clock generator.

Test

This input is examined by the "WAIT" instruction, and if low, execution continues. Otherwise the processor waits in an "Idle" state. Synchronized by the processor on the leading edge of CLK.

Interrupt Acknowledge

This is a read strobe for reading vectoring information. During T2, T3, and TW of each interrupt acknowledge cycle it is low.

Address Latch Enable

This is used in conjunction with the μPD8282/8283 latches to latch the address, during T1 of any bus cycle.

Queue Status

(Max mode) tracks the internal μPD8088 instruction queue.

Data Enable

This is the output enable for the μPD8286/8287 transceivers. It is active low during memory and I/O access and $\overline{INTA}$ cycles.

Data Transmit/Receive

Controls the direction of data flow through the transceivers.

IO Status/Memory

Separates memory access from I/O access.

Write

Depending on the state of the IO/$\overline{M}$ line, the processor is either writing to I/O or memory.

Lock

(Max mode) this output is set by the "LOCK" instruction to prevent other system bus masters from gaining control.

Hold Acknowledge

A response to the HOLD input, causing the processor to three-state the local bus. The bus becomes active one cycle after HOLD returns low.

Hold

When another device requests the local bus, HOLD is driven high, causing the μPD8088 to issue a HLDA.

Request/Grant

(Max mode) other local bus masters can force the processor to rebase the local bus at the end of the current bus cycle.

Read

Depending on the state of the IO/$\overline{M}$ line, the processor is reading from either memory or I/O.

Minimum/Maximum

This input tells the processor in which mode it is to be used. This affects some of the pin descriptions.

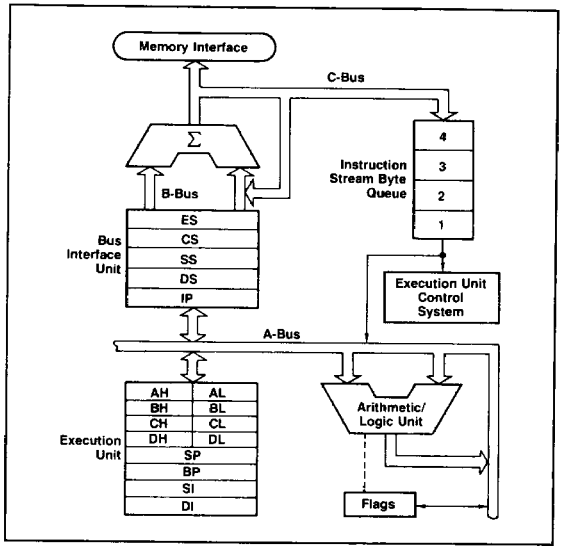
Status Outputs

(Max mode) These are the status outputs from the processor. They are used by the μPD8288 to generate bus control signals.

V_{CC}

5 V power supply input.

Block Diagram



Absolute Maximum Ratings

$T_A = 25°C$, Tentative

Power supply voltage, V_{DD}	−0.5 V to +7 V
Input voltage, V_I	−0.5 V to +7 V
Output voltage, V_O	−0.5 V to +7 V
Operating temperature, T_{OPT}	0°C to +70°C
Storage temperature, T_{STG}	−65°C to +150°C
Power dissipation, P_D	2.5 W

Comment: Exposing the device to stresses above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational sections of the specification. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

DC Characteristics

$T_A = 0°C$ to +70°C, $V_{CC} = +5\,V \pm 10\%$

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input voltage low	V_{IL}	−0.5		+0.8	V	
Input voltage high	V_{IH}	2.0		V_{CC}+0.5	V	
Output voltage low	V_{OL}			+0.45	V	$I_{OL} = 2.0\,mA$
Output voltage high	V_{OH}	2.4			V	$I_{OH} = -400\,\mu A$
Input clock voltage low	V_{CL}	−0.5		+0.6	V	
Input clock voltage high	V_{CH}	3.9		V_{CC}+1.0	V	
Input leakage current	I_{LI}			±10	μA	$0\,V < V_I < V_{CC}$
Output leakage current	I_{LO}			±10	μA	$0.45\,V \leq V_O \leq V_{CC}$
Power supply current	I_{CC}					
μPD8088/				340	mA	$T_A = 25°C$
μPD8088-2				350	mA	$T_A = 25°C$

Capacitance

Parameter	Symbol	Limits Min	Typ	Max	Unit	Test Conditions
Input capacitance	C_I			15	pF	(Note 1)
I/O capacitance	C_{IO}			15	pF	(Note 2)

Note:

(1) All input pins except AD_0-AD_7 and RQ/GT.

(2) Only input pins AD_0-AD_7 and RQ/GT.

AC Characteristics

Minimum Complexity Systems

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
CLK high time	t_{CHCL}	$(1/3\ t_{CLCL}) + 2$		$(1/3\ t_{CLCL}) + 2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8088	t_{RYHCH}	$(2/3\ t_{CLCL}) - 15$		$(2/3\ t_{CLCL}) - 15$		ns	
READY hold time into μPD8088	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 3)
HOLD setup time	t_{HVCH}	35		20		ns	
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V, except clock
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V, except clock

Timing Responses

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
ALE width	t_{LHLL}	$t_{CLCH} - 20$		$t_{CLCH} - 10$		ns	(Note 4)
ALE active delay	t_{CLLH}		80		50	ns	(Note 4)
ALE inactive delay	t_{CHLL}		85		55	ns	(Note 4)
Address hold time to ALE inactive	t_{LLAX}	$t_{CHCL} - 10$		$t_{CHCL} - 10$		ns	(Note 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Data hold time after $\overline{WR}$	t_{WHDX}	$t_{CLCH} - 30$		$t_{CLCH} - 30$		ns	(Note 4)
Control active delay 1	t_{CVCTV}	10	110	10	70	ns	(Note 4)
Control active delay 2	t_{CHCTV}	10	110	10	70	ns	(Note 4)
Control inactive delay	t_{CVCTX}	10	110	10	70	ns	(Note 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	80	ns	(Note 4)

AC Characteristics (cont)

Timing Responses (cont)

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL}-45$		$t_{CLCL}-40$		ns	(Note 4)
HLDA valid delay	t_{CLHAV}	10	160	10	100	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL}-75$		$2t_{CLCL}-50$		ns	(Note 4)
$\overline{WR}$ width	t_{WLWH}	$2t_{CLCL}-60$		$2t_{CLCL}-40$		ns	(Note 4)
Address valid to ALE low	t_{AVAL}	$t_{CLCH}-60$		$t_{CLCH}-40$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPD8284 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

(3) Applies only to T2 state. (8 ns into T3)

(4) $C_L = 20$–100 pF for all μPD8088 outputs (in addition to μPD8088 self-load).

Maximum Mode System with μPB8288 Bus Controller

$T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
CLK cycle period	t_{CLCL}	200	500	125	500	ns	
CLK low time	t_{CLCH}	$(2/3\ t_{CLCL})-15$		$(2/3\ t_{CLCL})-15$		ns	
CLK high time	t_{CHCL}	$(1/3\ t_{CLCL})+2$		$(1/3\ t_{CLCL})+2$		ns	
CLK rise time	t_{CH1CH2}		10		10	ns	From 1.0 V to 3.5 V
CLK fall time	t_{CL2CL1}		10		10	ns	From 3.5 V to 1.0 V
Data in setup time	t_{DVCL}	30		20		ns	
Data in hold time	t_{CLDX}	10		10		ns	
READY setup time into μPD8284	t_{R1VCL}	35		35		ns	(Notes 1 & 2)
READY hold time into μPD8284	t_{CLR1X}	0		0		ns	(Notes 1 & 2)
READY setup time into μPD8088	t_{RYHCH}	$(2/3\ t_{CLCL})-15$		$(2/3\ t_{CLCL})-15$		ns	
READY hold time into μPD8088	t_{CHRYX}	30		20		ns	
READY inactive to CLK	t_{RYLCL}	−8		−8		ns	(Note 5)
INTR, NMI, $\overline{TEST}$ setup time	t_{INVCH}	30		15		ns	(Note 2)
RQ / $\overline{GT}$ setup time	t_{GVCH}	30		15		ns	
RQ hold time into μPD8088	t_{CHGX}	40		30		ns	
Input rise time	t_{ILIH}		20		20	ns	From 0.8 V to 2.0 V, except clock
Input fall time	t_{IHIL}		12		12	ns	From 2.0 V to 0.8 V, except clock

AC Characteristics (cont)

Timing Responses

μPD8088: $T_A = 0°C$ to $+70°C$, $V_{CC} = 5\ V \pm 10\%$

Parameter	Symbol	Limits μPD8088 Min	Limits μPD8088 Max	Limits μPD8088-2 Min	Limits μPD8088-2 Max	Unit	Test Conditions
Command active delay	t_{CLML}	10	35	10	35	ns	(Notes 1 & 4)
Command inactive delay	t_{CLMH}	10	35	10	35	ns	(Notes 1 & 4)
READY active to status passive	t_{RYHSH}		110		65	ns	(Notes 3 & 4)
Status active delay	t_{CHSV}	10	110	10	60	ns	(Note 4)
Status inactive delay	t_{CLSH}	10	130	10	70	ns	(Note 4)
Address valid delay	t_{CLAV}	10	110	10	60	ns	(Note 4)
Address hold time	t_{CLAX}	10		10		ns	(Note 4)
Address float delay	t_{CLAZ}	t_{CLAX}	80	t_{CLAX}	50	ns	(Note 4)
Status valid to ALE high	t_{SVLH}		15		15	ns	(Notes 1 & 4)
Status valid to MCE high	t_{SVMCH}		15		15	ns	(Notes 1 & 4)
CLK low to ALE valid	t_{CLLH}		15		15	ns	(Notes 1 & 4)
CLK low to MCE high	t_{CLMCH}		15		15	ns	(Notes 1 & 4)
ALE inactive delay	t_{CHLL}		15		15	ns	(Notes 1 & 4)
MCE inactive delay	t_{CLMCL}		15		15	ns	(Notes 1 & 4)
Data valid delay	t_{CLDV}	10	110	10	60	ns	(Note 4)
Data hold time	t_{CHDX}	10		10		ns	(Note 4)
Control active delay	t_{CVNV}	5	45	5	45	ns	(Notes 1 & 4)
Control inactive delay	t_{CVNX}	10	45	10	45	ns	(Notes 1 & 4)
Address float to READ active	t_{AZRL}	0		0		ns	(Note 4)
$\overline{RD}$ active delay	t_{CLRL}	10	165	10	100	ns	(Note 4)
$\overline{RD}$ inactive delay	t_{CLRH}	10	150	10	80	ns	(Note 4)
$\overline{RD}$ inactive to next address active	t_{RHAV}	$t_{CLCL} - 45$		$t_{CLCL} - 40$		ns	(Note 4)
Direction control active delay	t_{CHDTL}		50		50	ns	(Notes 1 & 4)
Direction control inactive delay	t_{CHDTH}		30		30	ns	(Notes 1 & 4)
$\overline{GT}$ active delay	t_{CLGL}	0	85	0	50	ns	(Note 4)
$\overline{GT}$ inactive delay	t_{CLGH}	0	85	0	50	ns	(Note 4)
$\overline{RD}$ width	t_{RLRH}	$2t_{CLCL} - 75$		$2t_{CLCL} - 50$		ns	(Note 4)
Output rise time	t_{OLOH}		20		20	ns	From 0.8 V to 2.0 V
Output fall time	t_{OHOL}		12		12	ns	From 2.0 V to 0.8 V

Note:

(1) Signal at μPB8284 or μPB8288 shown for reference only.

(2) Setup requirement for asynchronous signal only to guarantee recognition at next CLK.

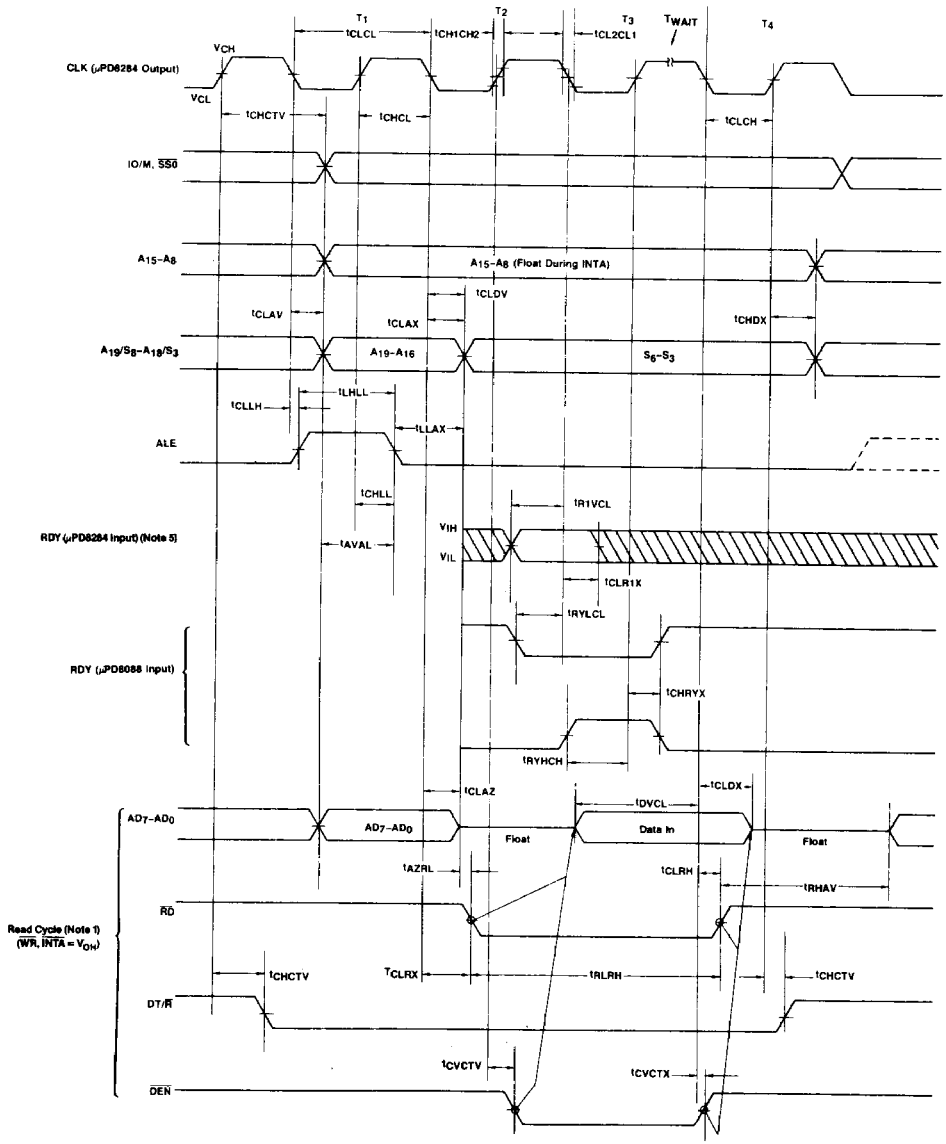
(3) Applies only to T3 and wait states.

(4) $C_L = 20$–100 pF for all μPD8088 outputs (in addition to μPD8088 self-load).

(5) Applies only to T2 state. (8 ns into T3).

Timing Waveforms

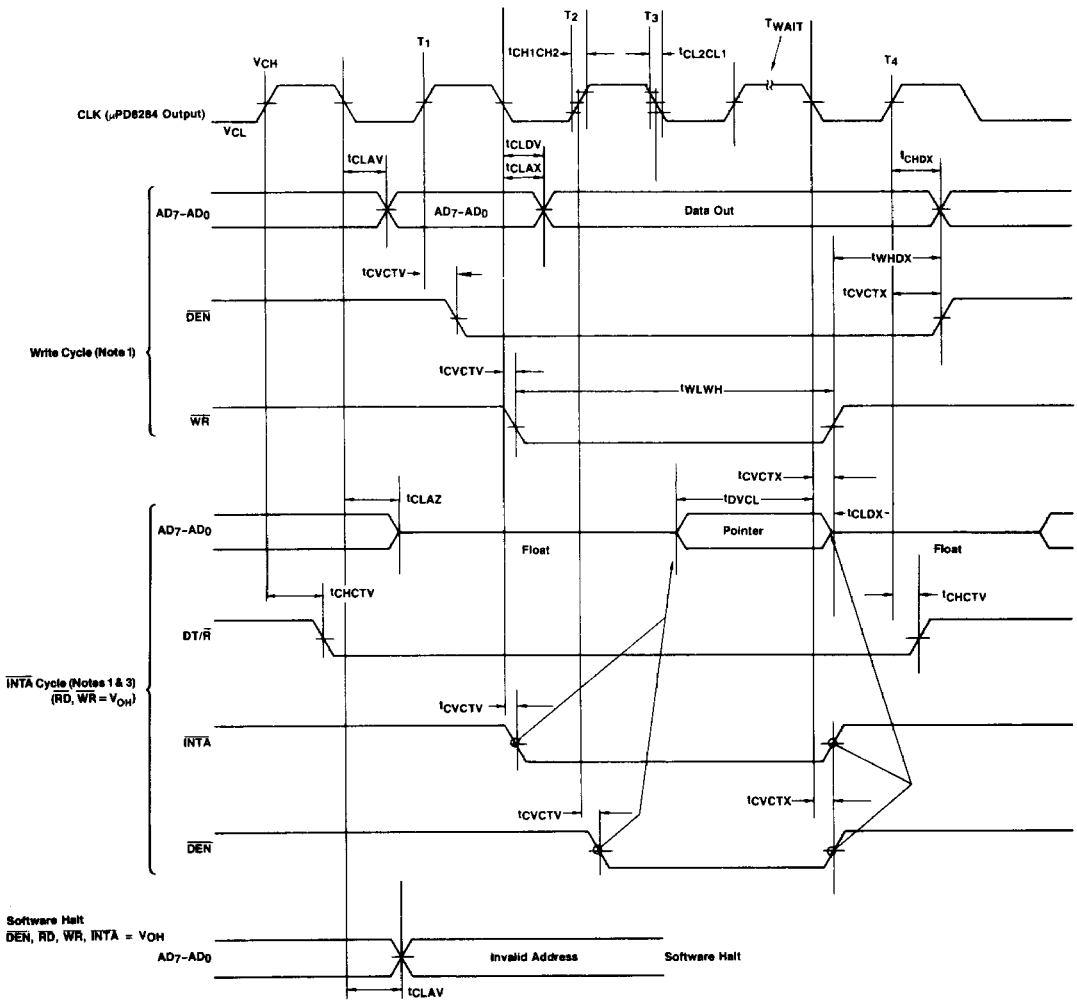
Minimum Complexity Systems (Note 5)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.
(3) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.
(4) Signals at the μPD8284 are shown for reference.
(5) All timing measurements are taken at 1.5 V unless otherwise specified.

Timing Waveforms (cont)

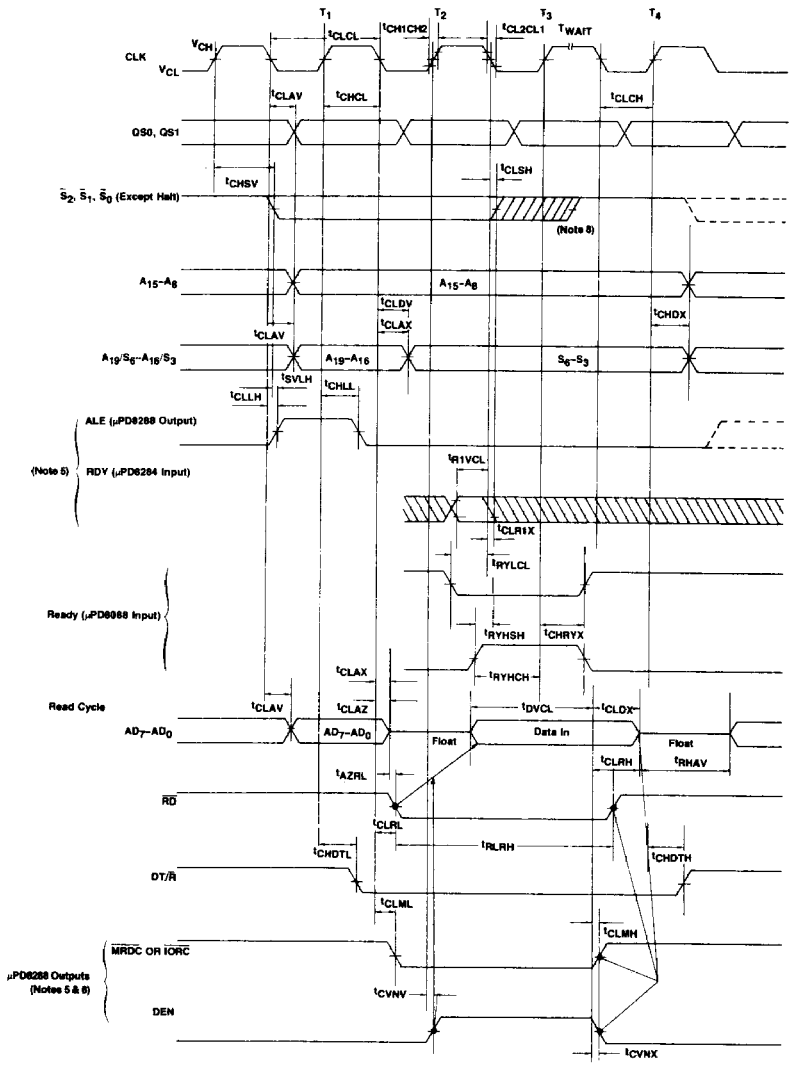
Minimum Complexity Systems (Note 5)



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.
(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.
(3) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.
(4) Signals at the μPD8284 are shown for reference.
(5) All timing measurements are taken at 1.5 V unless otherwise specified.

Timing Waveforms (cont)

Maximum Mode System Bus Timing Using μPB8288 Bus Controller (Note 7)



Note:

(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.

(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.

(3) The cascade address is valid between the first and second $\overline{INTA}$ cycles.

(4) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.

(5) Signals at the μPD8284 are shown for reference.

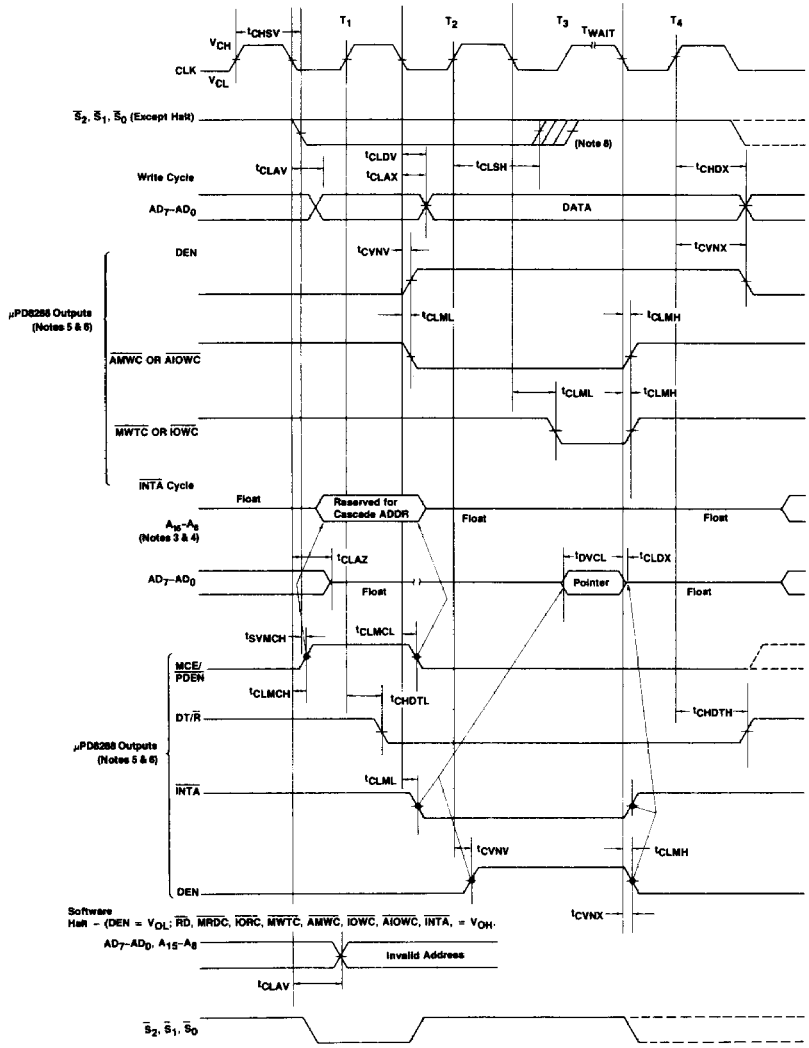
(6) The μPD8288 active-high CEN lags when the μPD8288 issues command and control signals ($\overline{MRDC}$, $\overline{MWTC}$, $\overline{AMWC}$, $\overline{IORC}$, $\overline{IOWC}$, $\overline{AIOWC}$, $\overline{INTA}$, and $\overline{DEN}$).

(7) All timing measurements are taken at 1.5 V unless otherwise specified.

(8) Status is inactive prior to T4.

Timing Waveforms (cont)

Maximum Mode System Bus Timing Using μPB8288 Bus Controller (cont) (Note 7)



Note:

(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.

(2) RDY is sampled near the end of T2, T3, TWAIT to determine if TWAIT machine states are inserted.

(3) The cascade address is valid between the first and second $\overline{INTA}$ cycles.

(4) Two $\overline{INTA}$ cycles run back-to-back. The μPD8088 local Address/Data bus floats during both $\overline{INTA}$ cycles. The control signals shown are for the second $\overline{INTA}$ cycle.

(5) Signals at the μPD8284 are shown for reference.

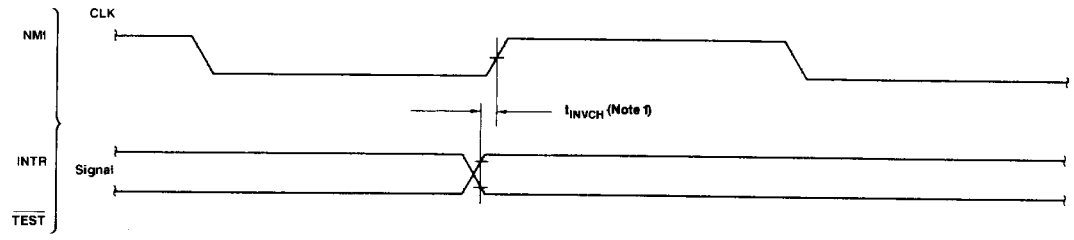
(6) The μPD8288 active-high CEN lags when the μPD8288 issues command and control signals ($\overline{MRDC}$, $\overline{MWTC}$, $\overline{AMWC}$, $\overline{IORC}$, $\overline{IOWC}$, $\overline{AIOWC}$, $\overline{INTA}$, and $\overline{DEN}$).

(7) All timing measurements are taken at 1.5 V unless otherwise specified.

(8) Status is inactive prior to T4.

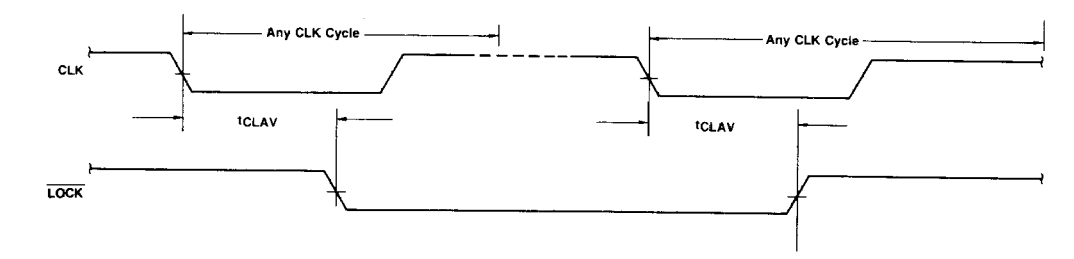
Timing Waveforms (cont)

Asynchronous Input Recognition

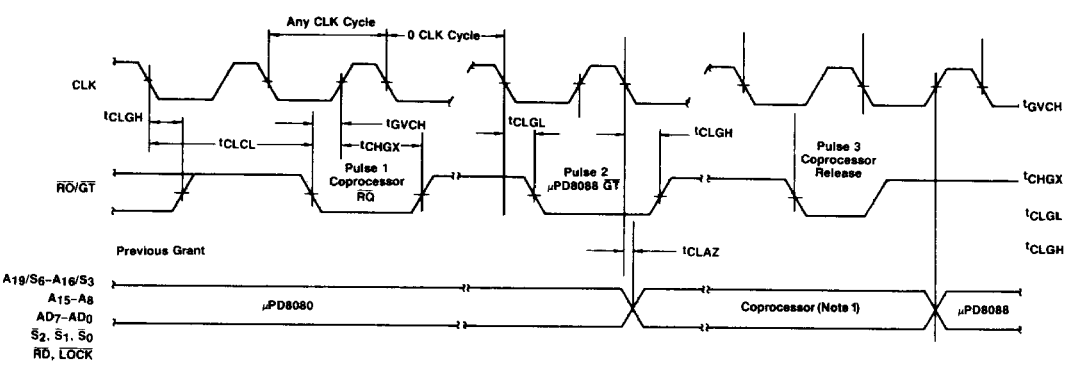


Note:
(1) Setup requirements for asynchronous signals guarantee recognition at next CLK.

Maximum Mode Bus Lock Signal Timing



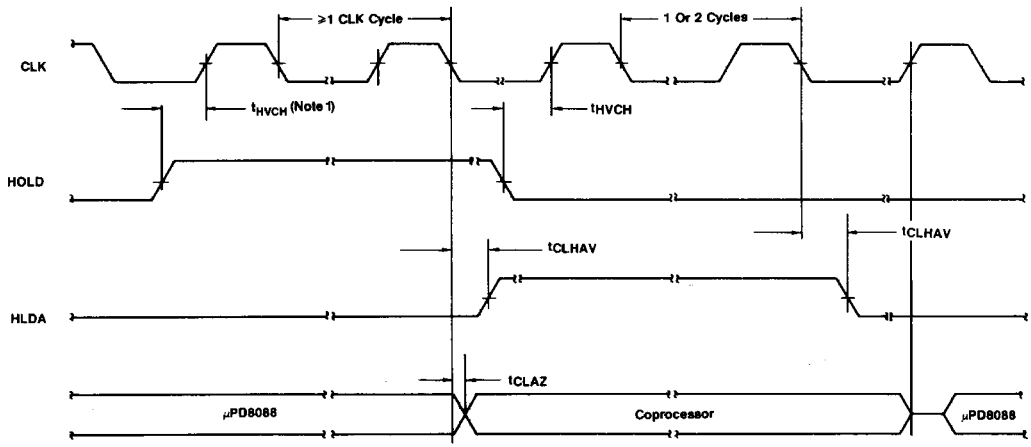
Maximum Mode Request/Grant Sequence Timing



Note:
(1) The coprocessor risks bus contention if it drives the buses outside the areas shown.

Timing Waveforms (cont)

Mimimum Mode Hold Acknowledge Timing



Note:
(1) All signals switch between V_{OH} and V_{OL} unless otherwise specified.