K1C5616BKB

256Mb B-die UtRAM2

Multiplexed Synchronous Burst Uni-Transistor Random Access Memory. (16M x16bit)

datasheet

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Revision History

Revision No.	History	Draft Date	Remark	Editor
0.0	- Preliminary Datasheet.	Jan. 21, 2010	Preliminnary	J.Y.Bae
0.1	- Corrected DC AND OPERATING CHARACTERISTICS. 1. I_{LI} : 5uA -> 2uA @ Max. 2. I_{LO} : 2uA -> -5uA @ Min.	Feb. 03, 2010	Preliminary	J.Y.Bae
0.5	- Corrected Ball Descriptions note. - Corrected Ball Descriptions for $\overline{ADV}$. - Corrected Power up Sequence.	Feb. 17, 2010	Preliminary	J.Y.Bae
0.6	- Corrected errata. - Deleted Hardware $\overline{RESET}$.	Mar. 19, 2010	Preliminary	J.Y.Bae
1.0	- Final datasheet. - Correct errata. - Revised DC AND OPERATING CHARACTERISTICS.	Apr. 17, 2010	Final	J.Y.Bae

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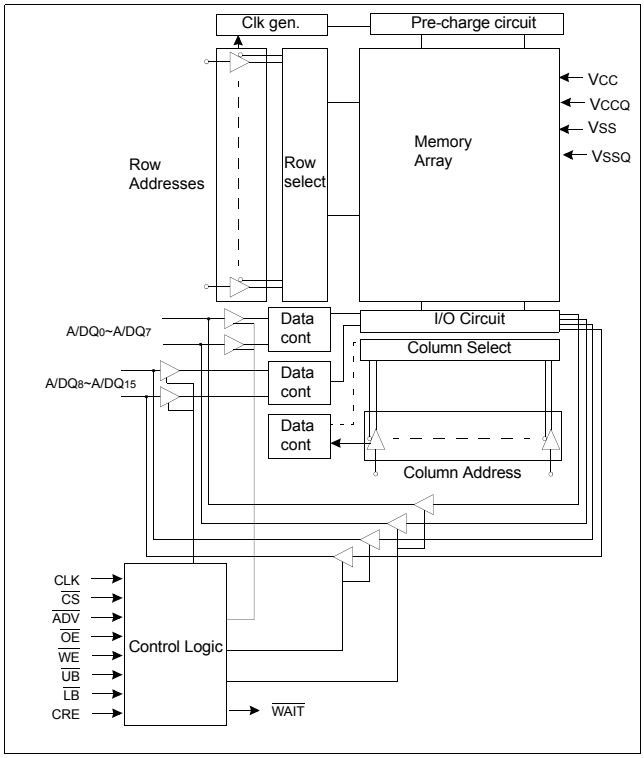
256Mb B-die UtRAM2

1.0 GENERAL DESCRIPTION

SAMSUNG's UtRAM products are designed to meet the request from the customers who want to cope with the fast growing mobile applications that need high-speed random access memory. UtRAM is the solution for the mobile market with its low cost, high density and high performance feature.
K1C5616BKB is fabricated by SAMSUNG's advanced CMOS technology using one transistor memory cell. The device supports the traditional SRAM like asynchronous operation (asynchronous read and asynchronous write), the fully synchronous operation (synchronous burst read and synchronous burst write). These operation modes are defined through the configuration register setting. It supports the special features for the standby power saving. Those are the PAR(Partial Array Refresh) mode, and internal TCSR(Temperature Compensated Self Refresh). It also supports variable and fixed latency, driver strength settings, Burst sequence (wrap or No-wrap) options and a device ID register (DIDR).

2.0 FEATURES & FUNCTION BLOCK DIAGRAM

- Process technology: CMOS
- Organization: 16M x 16 bit
- Power supply voltage: 1.7V~1.95V
- Three state outputs
- Supports Configuration Register Set
  - CRE pin set up
  - Software set up
- Supports power saving modes
  - PAR (Partial Array Refresh)
  - Internal TCSR (Temperature Compensated Self Refresh)
- Supports driver strength optimization
- Support 2 operation modes
  - Asynchronous mode
  - Synchronous mode
- Random access time:70ns
- Synchronous burst operation
  - Max. clock frequency : 108MHz
  - Fixed and Variable read latency
  - 4 / 8 / 16 / 32 and Continuous burst
  - Wrap / No-wrap
  - Latency :3(Variable) @ 108MHz
    3(Variable) @ 80MHz
    2(Variable) @ 66MHz
- Burst stop
- Burst read suspend
- Burst write data masking



3.0 PRODUCT FAMILY

Product Family	Operating Mode	Operating Temp.	Vcc / Vccq	CLK Freq. (Max.)	Current Consumption	
					Standby (ISB1, Max.)	Operating (ICC2, Max.)
K1C5616BKB-I	Asynch. Mode Synch. Mode	-25~85°C	1.7~1.95V	108MHz	350μA	35mA

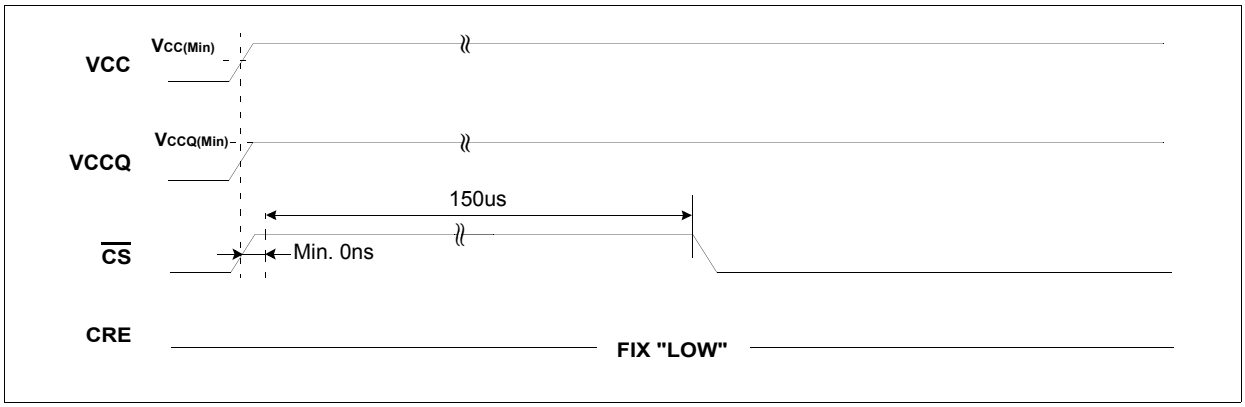
4.0 BALL DESCRIPTIONS

Symbol	Type	Description
A/DQ[15:0]	Input / Output	Address / Data I/Os: These pins are a multiplexed address/data bus. As inputs for addresses, these pins behave as A[15:0]; These lines are also used to define the value to be loaded into the BCR or the RCR.
A[23:16]	Input	Address Inputs for addresses during READ and WRITE operations.
CLK[1)]	Input	Clock: Synchronizes the memory to the system operating frequency during synchronous operations. When configured for synchronous operation, the address is latched on the first rising CLK edge when $\overline{ADV}$ is active. CLK is static LOW during asynchronous access READ and WRITE operations.
$\overline{ADV}$ [1)]	Input	Address valid: Indicates that a valid address is present on the address inputs. Addresses can be latched on the rising edge of $\overline{ADV}$ during asynchronous READ and WRITE operations.
CRE	Input	Control register enable: When CRE is HIGH, WRITE operations load the RCR or BCR, and READ operations access the RCR, BCR, or DIDR.
$\overline{CS}$	Input	Chip Select: Activates the device when LOW. When $\overline{CS}$ is HIGH, the device is disabled and goes into standby or deep power-down mode.
$\overline{OE}$	Input	Output enable: Enables the output buffers when LOW. When $\overline{OE}$ is HIGH, the output buffers are disabled.
$\overline{WE}$	Input	Write enable: Determines if a given cycle is a WRITE cycle. If $\overline{WE}$ is LOW, the cycle is a WRITE to either a configuration register or to the memory array.
$\overline{LB}$	Input	Lower byte enable. DQ[7:0]
$\overline{UB}$	Input	Upper byte enable. DQ[15:8]
$\overline{WAIT}$[1)]	Output	Wait: Provides data-valid feedback during burst READ and WRITE operations. The signal is gated by $\overline{CS}$. WAIT is used to arbitrate collisions between refresh and READ/WRITE operations. WAIT is also asserted during row boundary crossing within the burst length. WAIT is asserted and should be ignored during asynchronous operations. WAIT is High-Z when $\overline{CS}$ is HIGH.
RFU	-	Reserved for Future Use
VCC	Supply	Device power supply: (1.70V–1.95V) Power supply for device core operation.
VCCQ	Supply	I/O power supply: (1.70V–1.95V) Power supply for input/output buffers.
VSS	Supply	VSS must be connected to ground.
VSSQ	Supply	VSSQ must be connected to ground.

NOTE :
1) When using asynchronous mode exclusively, the CLK inputs can be tied to V_{SS}. WAIT will be asserted but should be ignored during asynchronous mode operations.

5.0 POWER UP SEQUENCE

After V_{CC} and V_{CCQ} reach minimum operating voltage(1.7V), drive $\overline{CS}$ High. Then the device gets into the Power Up mode. Wait for minimum 150μs to get into the normal operation mode. During the Power Up mode, the standby current can not be guaranteed. To get the appropriate device operation, be sure to keep the following power up sequence. Asynch. mode is default mode and is set up after power up.



6.0 ABSOLUTE MAXIMUM RATINGS

Item	Symbol	Ratings	Unit
Voltage on any pin relative to Vss	V_{IN}, V_{OUT}	-0.2 to VCCQ+0.3V	V
Power supply voltage relative to Vss	V_{CC}, V_{CCQ}	-0.2 to 2.5V	V
Power Dissipation	P_D	1.0	W
Storage temperature	T_{STG}	-55 to 150	°C
Operating Temperature	T_A	-25 to 85	°C

NOTE :
1) Stresses greater than "Absolute Maximum Ratings" may cause permanent damage to the device. Functional operation should be restricted to be used under recommended operating condition. Exposure to absolute maximum rating conditions longer than 1 second may affect reliability.

7.0 RECOMMENDED DC OPERATING CONDITIONS

Item	Symbol	Min	Typ	Max	Unit
Power supply voltage(Core)	V_{CC}	1.7	1.8	1.95	V
Power supply voltage(I/O)	V_{CCQ}	1.7	1.8	1.95	V
Ground	V_{SS}, V_{SSQ}	0	0	0	V
Input high voltage	V_{IH}	V_{CCQ}-0.4	-	V_{CCQ}+0.2[2)]	V
Input low voltage	V_{IL}	-0.2[3)]	-	0.4	V

NOTE :
1) T_A= -25 to 85°C, otherwise specified.
2) Overshoot: V_{CCQ} +1.0V in case of pulse width ≤20ns. Overshoot is sampled, not 100% tested.
3) Undershoot: -1.0V in case of pulse width ≤20ns. Undershoot is sampled, not 100% tested.

8.0 CAPACITANCE

Item	Symbol	Test Condition	Min	Max	Unit
Input capacitance	C_{IN}	V_{IN}=0V	-	6	pF
Input/Output capacitance	C_{IO}	V_{IO}=0V	-	6	pF

NOTE :
1) Freq.=1MHz, T_A=25°C
2) Capacitance is sampled, not 100% tested.

9.0 DC AND OPERATING CHARACTERISTICS

Item		Symbol	Test Conditions			Min	Typ	Max	Unit
Input Leakage Current		I_{LI}	V_{IN}=V_{SS} to V_{CCQ}			-2	-	2	μA
Output Leakage Current		I_{LO}	$\overline{CS}$=V_{IH}, CRE=V_{IL}, $\overline{OE}$=V_{IH} or $\overline{WE}$=V_{IL}, V_{IO}=V_{SS} to V_{CCQ}			-5	-	5	μA
Average Operating Current (Async)		I_{CC2} 6)	Cycle time=min t_{RC}/min t_{WC}, I_{IO}=0mA 4), 100% duty, $\overline{CS}$=V_{IL}, CRE=V_{IL}, V_{IN}=V_{IL} or V_{IH}			-	-	35	mA
Average Operating Current (Burst)	108Mhz	I_{CC3I}	V_{IN} = V_{CCQ} or 0V $\overline{CS}$=V_{IL}, I_{IO}=0mA 4)			-	-	35	mA
		I_{CC3R}				-	-	45	mA
		I_{CC3W}				-	-	40	mA
	80Mhz	I_{CC3I}				-	-	35	mA
		I_{CC3R}				-	-	45	mA
		I_{CC3W}				-	-	40	mA
	66Mhz	I_{CC3I}				-	-	35	mA
		I_{CC3R}				-	-	45	mA
		I_{CC3W}				-	-	40	mA
Output Low Voltage		V_{OL}	I_{OL}=0.2mA			-	-	0.2	V
Output High Voltage		V_{OH}	I_{OH}=-0.2mA			0.8xV_{CCQ}	-	-	V
Standby Current(CMOS)		I_{SB1} 1)	$\overline{CS}$ and $\overline{ADV}$=V_{CCQ}, CRE=0V, Other inputs=0V or V_{CCQ} (Toggle is not allowed) 5)	< 40°C		-	-	200	μA
				< 85°C		-	-	350	μA
Partial Refresh Current		I_{SBP} 2)	$\overline{CS}$ and $\overline{ADV}$=V_{CCQ}, CRE=0V, Other inputs=0V or V_{CCQ} (Toggle is not allowed) 5)	< 40°C	1/2 Block	-	-	190	μA
					1/4 Block	-	-	170	
					1/8 Block	-	-	170	
				< 85°C	1/2 Block	-	-	320	μA
					1/4 Block	-	-	300	
					1/8 Block	-	-	300	

NOTE :
1) I_{SB1} is measured after 500ms after $\overline{CS}$ high. CLK should be fixed at high or at Low.
2) Full Array Partial Refresh Current(I_{SBP}) is same as Standby Current(I_{SB1}).
3) Internal TCSR (Temperature Compensated Self Refresh) is used to optimize refresh cycle below 40°C.
4) I_{IO}=0mA; This parameter is specified with the outputs disabled to avoid external loading effects.
5) V_{IN}=0V; all inputs should not be toggle.
6) This parameter is for page disable mode, Clock should not be inserted between $\overline{ADV}$ low and $\overline{WE}$ low during Write operation.

10.0 CRE (CONTROL REGISTER ENABLE)

The configuration register values are written via A/DQ pins. In an asynchronous WRITE, the values are latched into the configuration register on the rising edge of $\overline{ADV}$, $\overline{CS}$, or $\overline{WE}$, whichever occurs first; $\overline{LB}$ and $\overline{UB}$ are “Don’t Care.” For reads, address inputs other than A[19:18] are “Don’t Care,” and register bits 15:0 are output as data ($\overline{ADV}$ HIGH) on A/DQ[15:0]. Immediately after performing a configuration register READ or WRITE operation, reading the memory array is highly recommended.

10.1 Bus Configuration Register

The BCR defines how the device interacts with the system memory bus. The BCR is accessed with CRE HIGH and A[19:18] = 10b, or through the register access software sequence with A/DQ = 0001h on the third cycle.

A19~A18	A/DQ15	A/DQ14	A/DQ13~A/DQ11	A/DQ10	A/DQ8	A/DQ5~A/DQ4	A/DQ3	A/DQ2~A/DQ0
RS	OM	IL	LC	WP	WC	DS	BW	BL

Register Select			Operating Mode		Initial Latency		Latency Count			
A19	A18	RS	A/DQ15	OM	A/DQ14	IL	A/DQ13	A/DQ12	A/DQ11	LC
0	0	RCR	0	Synch.	0	Variable (default)	0	0	0	Reserved
1	0	BCR	1	Asynch (default)	1	Fixed	0	0	1	Reserved
0	1	DIDR					0	1	0	2
							0	1	1	3 (default)
							1	0	0	4
							1	0	1	5
							1	1	0	6
							1	1	1	Reserved

Wait Polarity		Wait Config.		Driver Strength			Burst Wrap		Burst Length			
A/DQ10	WP	A/DQ8	WC	A/DQ5	A/DQ4	DS	A/DQ3	BW	A/DQ2	A/DQ1	A/DQ0	BL
0	Active Low	0	at data	0	0	Full Drive	0	Wrap	0	0	1	4 word
1	Active High (default)	1	1 CLK prior (default)	0	1	1/2 Drive (default)	1	No Wrap (default)	0	1	0	8 word
				1	0	1/4 Drive			0	1	1	16 word
				1	1	1/8 Drive			1	0	0	32 word
									1	1	1	Continuous (default)

NOTE :
1) A/DQ6, A/DQ7, A/DQ9, A16, A17, A20~A23 are reserved and should be ’0’
2) The registers are set automatically to default value.
3) Refresh command will be denied during continuous operation. $\overline{CS}$ low should not be longer than tBC(tCSM max. 2.5us)
4) If the register code is invalid, register will be set to default value.

10.2 Refresh Configuration Register

The refresh configuration register (RCR) defines how the device performs its self refresh. Altering the refresh parameters can reduce current consumption during standby mode. The RCR is accessed with CRE HIGH and A[19:18] = 00b; or through the register access software sequence with A/DQ = 0000h on the third cycle.

A19~A18	A/DQ2~A/DQ0
RS	PAR

Register Select			Partial Refresh			
A19	A18	RS	A/DQ2	A/DQ1	A/DQ0	PAR
0	0	RCR	0	0	0	Full Array (default)
1	0	BCR	0	0	1	Bottom 1/2 Array
0	1	DIDR	0	1	0	Bottom 1/4 Array
			0	1	1	Bottom 1/8 Array
			1	0	0	None of Array
			1	0	1	Top 1/2 Array
			1	1	0	Top 1/4 Array
			1	1	1	Top 1/8 Array

NOTE :
1) A/DQ3, A/DQ5~A/DQ15, A16, A17, A20~A23 are reserved and should be '0'
2) The registers are set automatically to default value.

10.3 Burst Length (BCR[2:0]) Default = Continuous Burst

Burst lengths define the number of words the device outputs during burst READ and WRITE operations. The device supports a burst length of 4, 8, 16, or 32 words or Continuous.

10.4 Burst Wrap (BCR[3]) Default = No Wrap

The burst-wrap option determines if a 4-, 8-, 16-, or 32-word READ or WRITE burst wraps within the burst length, or steps through sequential addresses.

[Table 1] Sequence and Burst Length

Burst Wrap		Starting Address	4 word Burst Length	8 word Burst Length	16 word Burst Length	32 word Burst Length	Continuous Burst
BCR[3]	Wrap	Decimal	Linear	Linear	Linear	Linear	Linear
WRAP	Yes	0	0-1-2-3	0-1-2-3-4-5-6-7	0-1-2-3-4-5-6-7-8-9-10-11-12-13-14-15	0 - 1 - 2 ~ 29-30-31	0 - 1 - 2 - 3 - 4 - 5 ~
		1	1-2-3-0	1-2-3-4-5-6-7-0	1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-0	1 - 2 - 3 ~ 30-31 - 0	1 - 2 - 3 - 4 - 5 - 6 ~
		2	2-3-0-1	2-3-4-5-6-7-0-1	2-3-4-5-6-7-8-9-10-11-12-13-14-15-0-1	2 - 3 - 4 ~ 31 - 0 - 1	2 - 3 - 4 - 5 - 6 - 7 ~
		3	3-0-1-2	3-4-5-6-7-0-1-2	3-4-5-6-7-8-9-10-11-12-13-14-15-0-1-2	3 - 4 - 5 ~ 0 - 1 - 2	3 - 4 - 5 - 6 - 7 - 8 ~
		~		~	~	~	~
		7		7-0-1-2-3-4-5-6	7-8-9-10-11-12-13-14-15-0-1-2-3-4-5-6	7 - 8 - 9 ~ 4 - 5 - 6	7 - 8 - 9 - 10-11-12 ~
		~			~	~	~
		15			15-0-1-2-3-4-5-6-7-8-9-10-11-12-13-14	15-16-17 ~ 12- 13- 14	15-16-17-18-19-20 ~
		~				~	~
		31				31- 0 - 1 ~ 28-29-30	31-32-33-34-35-36 ~
No WRAP	No	0	0-1-2-3	0- 1- 2- 3- 4- 5- 6 -7	0- 1- 2- 3- 4- 5- 6- 7- 8- 9- 10- 11- 12-13-14-15	0 - 1 - 2 ~ 29-30-31	0 - 1 - 2 - 3 - 4 - 5 ~
		1	1-2-3-4	1- 2- 3- 4- 5- 6- 7- 8	1- 2- 3- 4- 5- 6- 7- 8- 9- 10- 11- 12-13-14-15-16	1 - 2 - 3 ~ 30-31-32	1 - 2 - 3 - 4 - 5 - 6 ~
		2	2-3-4-5	2- 3- 4- 5- 6- 7- 8- 9	2- 3- 4- 5- 6- 7- 8- 9- 10- 11- 12-13-14-15-16-17	2 - 3 - 4 ~ 31-32-33	2 - 3 - 4 - 5 - 6 - 7 ~
		3	3-4-5-6	3- 4- 5- 6- 7- 8- 9-10	3- 4- 5- 6- 7- 8- 9- 10- 11- 12-13-14-15-16-17-18	3 - 4 - 5 ~ 32-33-34	3 - 4 - 5 - 6 - 7 - 8 ~
		~		~	~	~	~
		7		7-8-9-10-11-12-13-14	7-8-9-10-11-12-13-14-15-16-17-18-19-20-21-22	7 - 8 - 9 ~ 36-37-38	7 - 8 - 9 - 10-11-12 ~
		~			~	~	~
		15			15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30	15-16-17 ~ 44-45-46	15-16-17-18-19-20 ~
		~				~	~
		31				31-32-33 ~ 60-61-62	31-32-33-34-35-36 ~

10.5 Drive Strength (BCR[5:4]) Default = 1/2 Drive Strength

The optimization of output driver strength is possible to adjust for the different data loadings. The device can minimize the noise generated on the data bus during read operation. The device supports full, 1/2 and 1/4 driver strength. The device's default mode is 1/2 driver strength. Outputs are configured at 1/2 drive strength during testing.

[Table 2] Drive Strength

Driver Strength	Full	1 / 2	1 / 4	1 / 8
Impedance(typ.)	25~30Ω	50Ω	100Ω	TBD
Recommendation	CL = 30pF to 50pF	CL = 15pF to 30pF 108 MHz at light load	CL = 15pF or lower	CL = 15pF or lower

NOTE :
1) Impedance values are typical values, not 100% tested.

10.6 WAIT Configuration (BCR[8]) Default = 1 CLK Prior.

The $\overline{WAIT}$ signal is output signal indicating the status of the data on the bus whether or not it is valid. $\overline{WAIT}$ configuration is to decide the timing when $\overline{WAIT}$ asserts or desserts. $\overline{WAIT}$ asserts (or desserts) one clock prior to the data when A/DQ8 is set to 1. ($\overline{WAIT}$ asserts (or desserts) at data clock when A/DQ8 is set to 0). $\overline{WAIT}$ polarity is to decide the $\overline{WAIT}$ signal level at which data is valid or invalid. Data is valid if $\overline{WAIT}$ signal is high when A/DQ10 is set to 0. (Data is valid if $\overline{WAIT}$ signal is low when A/DQ10 is set to 1). All the timing diagrams in this SPEC are illustrated based on following setup; A/DQ[10]:0 and A/DQ[8]:1.
Below timing shows $\overline{WAIT}$ signal's movement when word boundary crossing happens in No-wrap mode

10.7 WAIT Polarity (BCR[10]) Default = Active HIGH

The WAIT polarity bit indicates whether an asserted WAIT output should be HIGH or LOW. This bit will determine whether the WAIT signal requires a pull-up or pull-down resistor to maintain the de-asserted state.

No-Wrap. Word-line Crossing. LATENCY : 2. WP : Low Enable

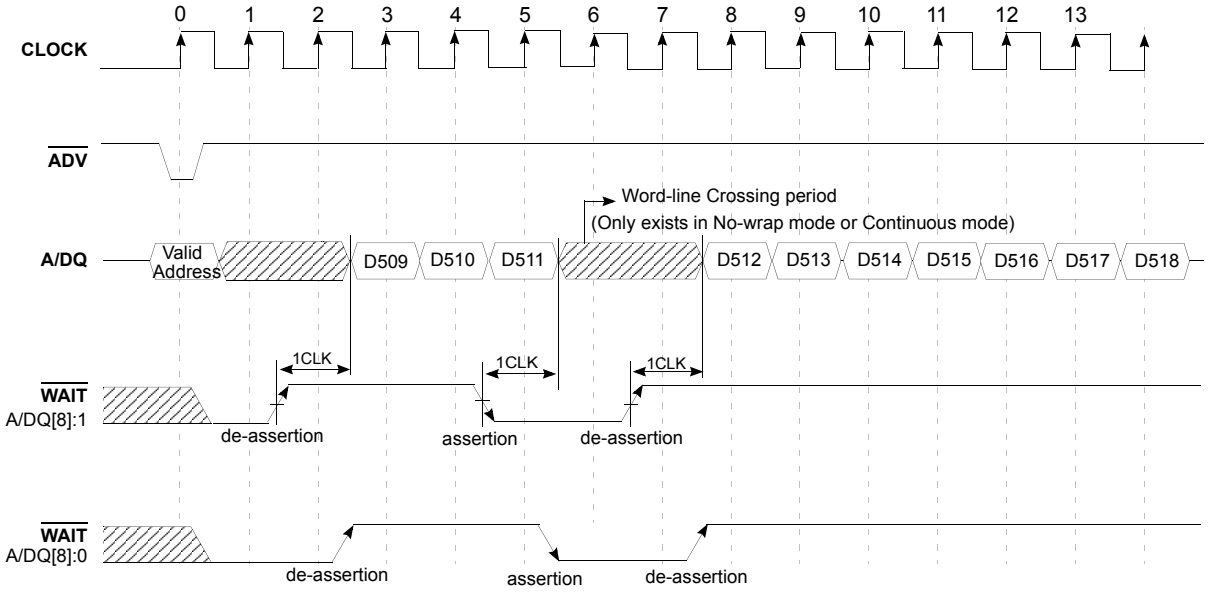


Figure 1. WAIT Configuration During Burst Operation

NOTE :
1)Non-default BCR setting: WAIT active LOW.

10.8 Operating Mode (BCR[15]) Default = Asynchronous Operation

The operating mode bit selects either synchronous burst operation or the default asynchronous mode of operation.

10.9 Latency Counter (BCR[13:11]) Default = 3 Clock Latency

The latency counter bits determine how many clocks occur between the beginning of a READ or WRITE operation and the first data value transferred. For allowable latency codes.

10.10 Initial Access Latency (BCR[14]) Default = Variable

Variable initial access latency outputs data after the number of clocks set by the latency counter. However, WAIT must be monitored to detect delays caused by collisions with refresh operations. Fixed initial access latency outputs the first data at a consistent time that allows for worst-case refresh collisions. The latency counter must be configured to match the initial latency and the clock frequency. It is not necessary to monitor WAIT with fixed initial latency. The burst begins after the number of clock cycles configured by the latency counter.

[Table 3] Variable Latency Configuration Codes

BCR[13:11]	Latency Configuration	Latency		Max Input CLK Frequency (MHz)		
		Normal	Refresh Collision	108	80	66
010	2(3 clocks)	2	4	66(15ns)	19,2ns	40(25ns)
011	3(4 clocks)-default	3	6	108(9.26ns)	80(12.5ns)	66(15ns)
Others	Reserved	-	-	-	-	-

[Table 4] Fixed Latency Configuration Codes

BCR[13:11]	Latency Configuration	Latency Count (N)	Max Input CLK Frequency (MHz)		
			108	80	66
010	2 (3 clocks)	2	33 (30ns)	20 (50ns)	20 (50ns)
011	3 (4 clocks)	3	52 (19.2ns)	40 (25ns)	33 (30ns)
100	4 (5 clocks)	4	66 (15ns)	52 (19.2ns)	40 (25ns)
101	5 (6 clocks)	5	80 (12.5ns)	66 (15ns)	52 (19.2ns)
110	6 (7 clocks)	6	108 (9.26ns)	80 (12.5ns)	66 (15ns)
Others	Reserved	-	-	-	-

NOTE :
1) Latency is the number of clock cycles from the initiation of a burst operation until data appears. Data is transferred on the next clock cycle.

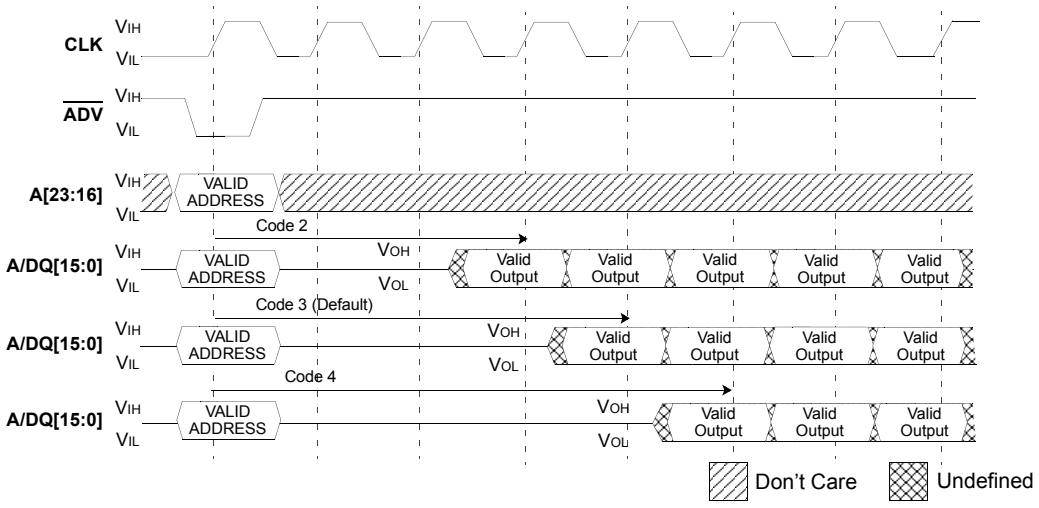


Figure 2. Latency Counter (Variable Initial Latency, No Refresh Collision)

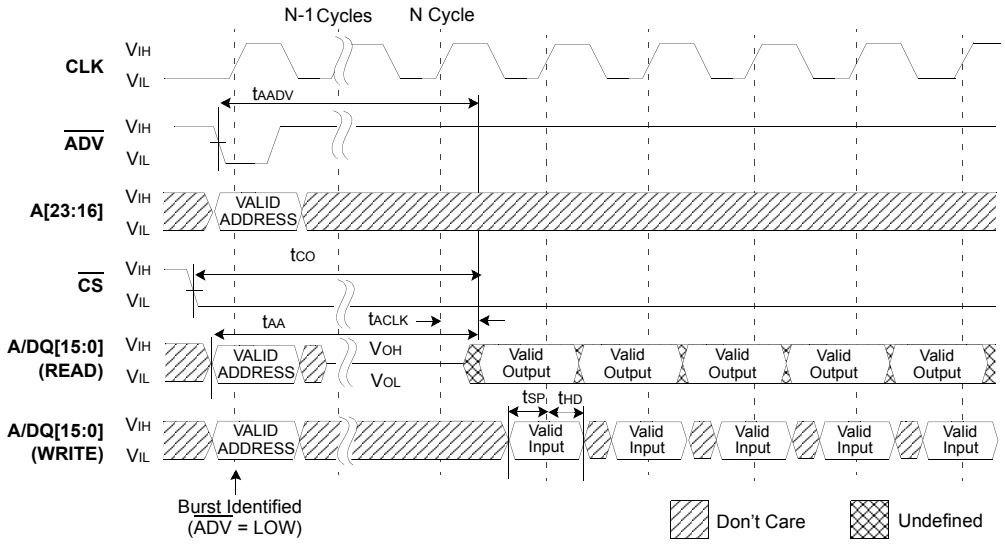


Figure 3. Latency Counter (Fixed Latency)

10.11 Partial Array Refresh (RCR[2:0] Default = Full Array Refresh

The PAR bits restrict refresh operation to a portion of the total memory array. This feature allows the device to reduce standby current by refreshing only that part of the memory array required by the host system. The refresh options are full array, one-half array, one-quarter array, one-eighth array, or none of the array. The mapping of these partitions can start at either the beginning or the end of the address map.

[Table 5] Address Patterns for PAR (RCR[4] = 1)

RCR[2]	RCR[1]	RCR[0]	Active Section	Address Space	Size	Density
0	0	0	Full Die	000000h-FFFFFFh	16 Meg x 16	256Mb
0	0	1	One-half die	000000h-7FFFFFh	8 Meg x 16	128Mb
0	1	0	One-quarter of die	000000h-3FFFFFh	4 Meg x 16	64Mb
0	1	1	One-eighth of die	000000h-1FFFFFh	2 Meg x 16	32Mb
1	0	0	None of die	0	0 Meg x 16	0Mb
1	0	1	One-half of die	800000h-FFFFFFh	8 Meg x 16	128Mb
1	1	0	One-quarter of die	C00000h-FFFFFFh	4 Meg x 16	64Mb
1	1	1	One-eighth of die	E00000h-FFFFFFh	2 Meg x 16	32Mb

10.12 Device Identification Register

The DIDR provides information on the device manufacturer, generation and the specific device configuration. This register is read-only. The DIDR is accessed with CRE HIGH and A[19:18] = 01b, or through the register access software sequence with A/DQ = 0002h on the third cycle.

[Table 6] Device Identification Register Mapping

Bit Field	DIDR[15]		DIDR[14:11]		DIDR[10:8])		DIDR[7:5]		DIDR[4:0]
Field name	Row Length		Device version		Device density		UtRAM generation		Vendor ID
	Length	Bit Setting	Version	Bit Setting	Density	Bit Setting	Generation	Bit Setting	Bit Setting
Options	512 words	1b	3rd	0110	256Mb	100b	UtRAM2	010b	01100

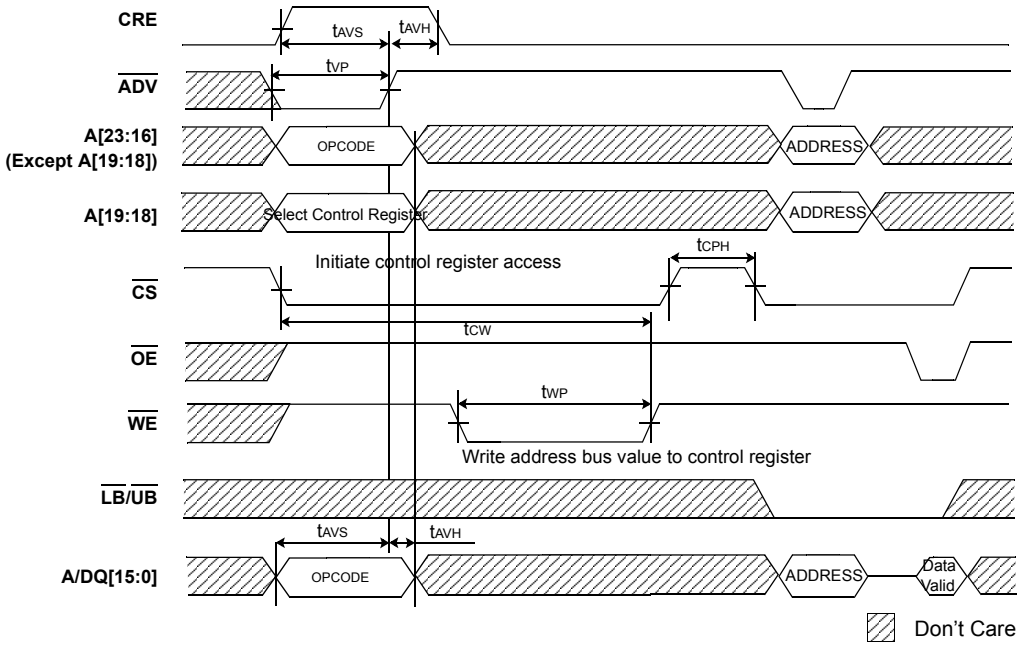


Figure 4. Configuration Register WRITE, Asynchronous Mode, Followed by READ ARRAY Operation

NOTE :
1) A[19:18] = 00b to load RCR, and 10b to load BCR.

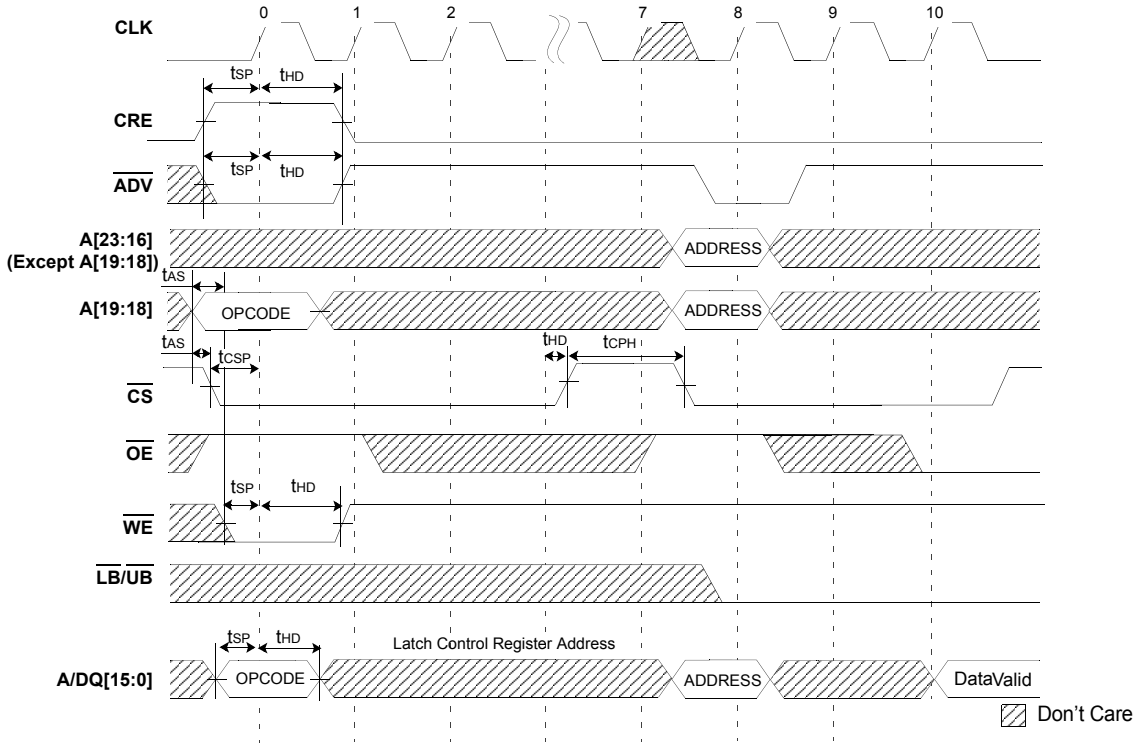


Figure 5. Configuration Register WRITE, Synchronous Mode Followed by READ ARRAY Operation

NOTE :
1) Non-default BCR settings for synchronous mode configuration register WRITE followed by READ ARRAY operation:
WAIT active LOW; WAIT asserted during delay.
2) A[19:18] = 00b to load RCR, and 10b to load BCR.
3) CS must remain LOW to complete a burst-of-one WRITE. WAIT must be monitored—additional WAIT cycles caused by refresh collisions require a corresponding number of additional CS LOW cycles.

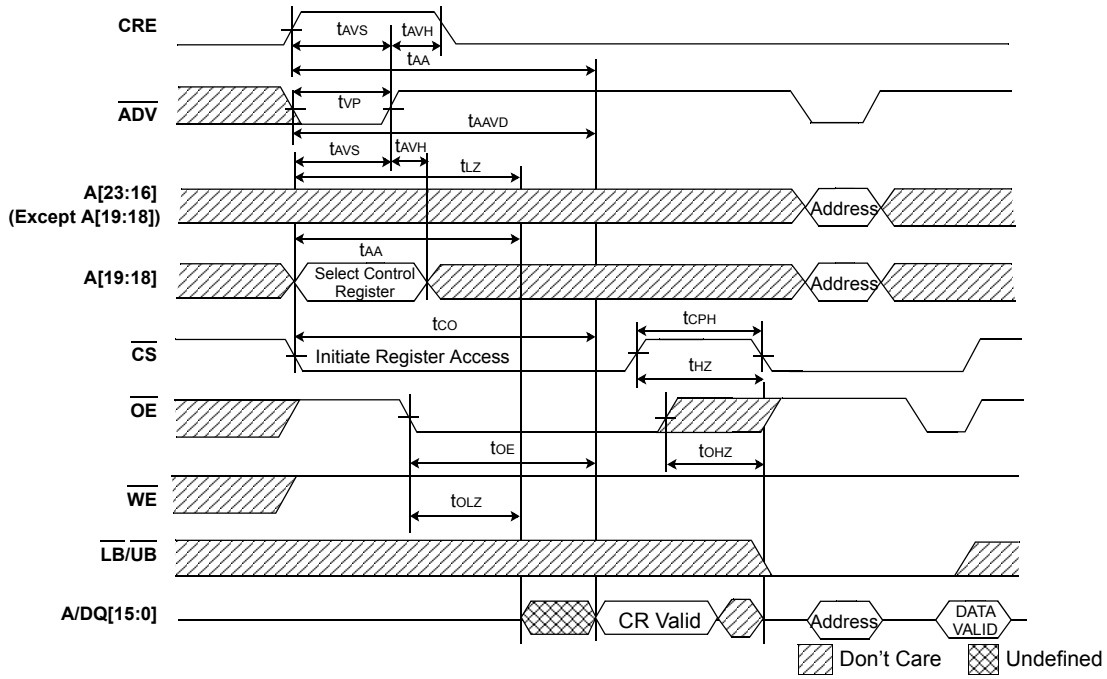


Figure 6. Register READ, Asynchronous Mode Followed by READ ARRAY Operation

NOTE :
1) A[19:18] = 00b to read RCR, 10b to read BCR, and 01b to read DIDR.

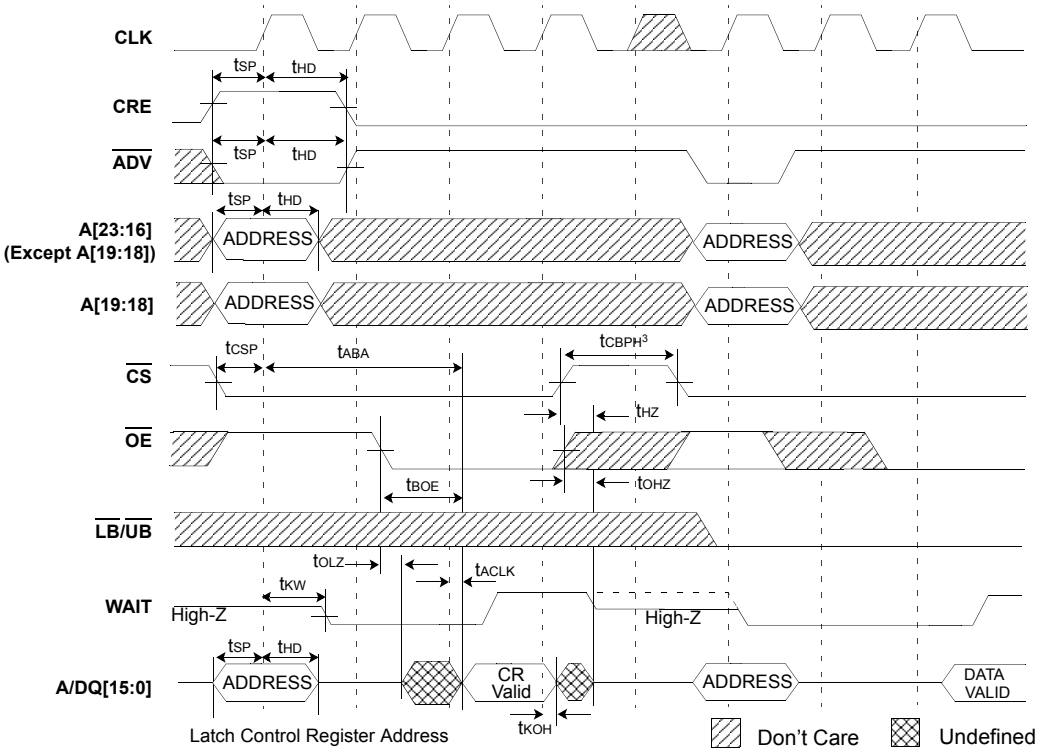


Figure 7. Register READ, Synchronous Mode Followed by READ ARRAY Operation

NOTE :
1) Non-default BCR settings for synchronous mode register READ followed by READ ARRAY operation: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) A[19:18] = 00b to read RCR, 10b to read BCR, and 01b to read DIDR.
3) $\overline{CS}$ must remain LOW to complete a burst-of-one WRITE. WAIT must be monitored—additional WAIT cycles caused by refresh collisions require a corresponding number of additional $\overline{CS}$ LOW cycles.

10.13 Software Access

Software access of the registers uses a sequence of asynchronous READ and asynchronous WRITE operations. The contents of the configuration registers can be modified and all registers can be read using the software sequence. The configuration registers are loaded using a four-step sequence consisting of two asynchronous READ operations followed by two asynchronous WRITE operations. The read sequence is virtually identical except that an asynchronous READ is performed during the fourth operation. The address used during all READ and WRITE operations is the highest address of the device being accessed (3FFFFF); the contents of this address are not changed by using this sequence. The data value presented during the third operation (WRITE) in the sequence defines whether the BCR, RCR, or the DIDR is to be accessed. If the data is 0000h, the sequence will access the RCR; if the data is 0001h, the sequence will access the BCR; if the data is 0002h, the sequence will access the DIDR. During the fourth operation, A/DQ[15:0] transfer data in to or out of bits 15–0 of the registers. The use of the software sequence does not affect the ability to perform the standard (CRE-controlled) method of loading the configuration registers. However, the software nature of this access mechanism eliminates the need for CRE. If the software mechanism is used, CRE can simply be tied to VSS. The port line often used for CRE control purposes is no longer required.

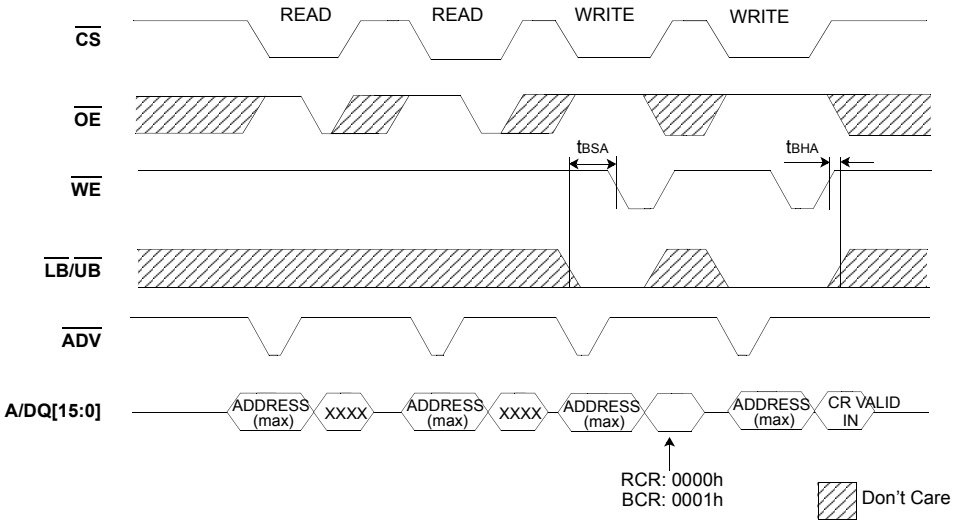


Figure 8. Load Configuration Register

NOTE :
1) /WE should be deasserted before /CS deasserting.

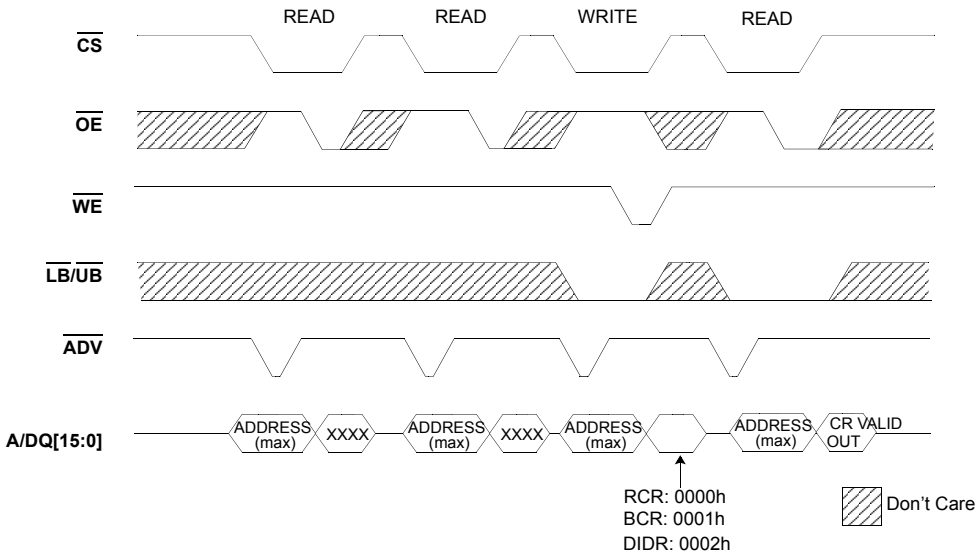


Figure 9. Read Configuration Register

NOTE :
1) /WE should be deasserted before /CS deasserting.
2) ALL Write Operation have tBSA, tBHA.

11.0 BUS OPERATING MODES

The bus interface supports asynchronous and burst mode read and write transfers. The specific interface supported is defined by the value loaded into the BCR.

11.1 Asynchronous Mode (default mode)

11.1.1 Asynchronous read operation

Asynchronous read operation starts when $\overline{CS}$, $\overline{OE}$ and $\overline{UB}$ or $\overline{LB}$ are asserted. $\overline{ADV}$ can be taken HIGH to capture the address. First data will be driven out of the A/DQ bus after random access time(tAA). $\overline{WE}$ should be de-asserted during read operation. The CLK input must be held static LOW during read operation. WAIT will be driven while the device is enabled and its state should be ignored.

11.1.2 Asynchronous write operation

Asynchronous write operation starts when $\overline{CS}$, $\overline{WE}$ and $\overline{UB}$ or $\overline{LB}$ are asserted. The data to be written is latched on the rising edge of $\overline{CS}$, $\overline{WE}$, or $\overline{LB}$/$\overline{UB}$ (whichever occurs first). $\overline{OE}$ is High during write operation. $\overline{WE}$ LOW time must be limited to tCSM. The CLK input must be held static LOW during write operation. $\overline{WAIT}$ signal is Hi-Z.

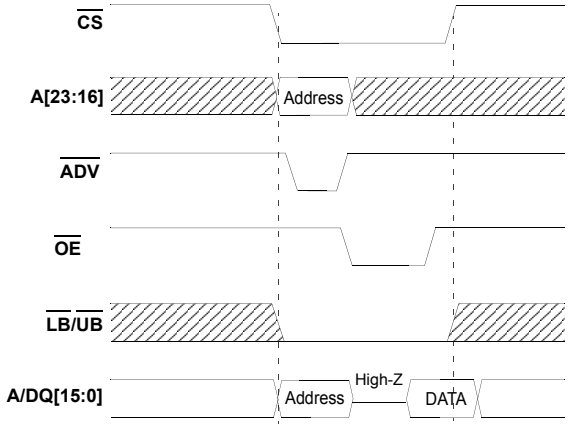


Figure 10. READ Operation $\overline{WE}$ = HIGH).

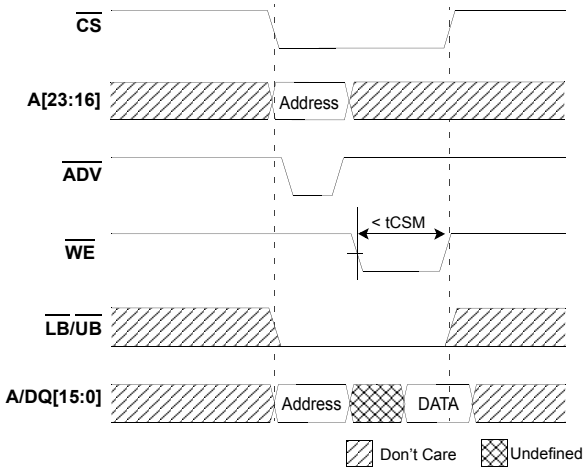


Figure 11. WRITE Operation $\overline{OE}$ = HIGH)

11.2 Functional Description (Asynch. mode)

Asynchfonous Mode BCR[15] = 1	Power	CLK	$\overline{ADV}$	$\overline{CS}$	$\overline{OE}$	$\overline{WE}$	CRE	UB / LB	WAIT	A/DQ[15:0]	Notes
Read	Active	L	⊓	L	L	H	L	L	Low-Z	Data out	1
Write	Active	L	⊓	L	H	L	L	L	Low-Z	Data in	1
Standby	Standby	L	H	H	X	X	L	X	High-Z	High-Z	2
No operation	Idle	L	X	L	X	X	L	X	Low-Z	X	1
Configuration register write	Active	L	L	L	H	L	H	X	Low-Z	High-Z	
Configuration register read	Active	L	⊓	L	L	H	H	L	Low-Z	Config. Reg.out	

NOTE :
1) The device will consume active power in this mode whenever addresses are changed.
2) When the device is in standby mode, address inputs and data inputs/outputs are internally isolated from any external influence.

12.0 Burst Mode Operation

12.1 synchronous Mode

12.1.1 Synchronous Burst Read Operation

Burst Read command is implemented when $\overline{ADV}$ is detected low at clock rising edge. $\overline{WE}$ should be de-asserted. Burst operation re-starts whenever $\overline{ADV}$ is detected low at clock rising edge even in the middle of operation.

12.1.2 Synchronous Burst Write Operation

Burst Write command is implemented when $\overline{ADV}$ & $\overline{WE}$ are detected low at clock rising edge. Burst Write operation re-starts whenever $\overline{ADV}$ is detected low at clock rising edge even in the middle of Burst Write operation.

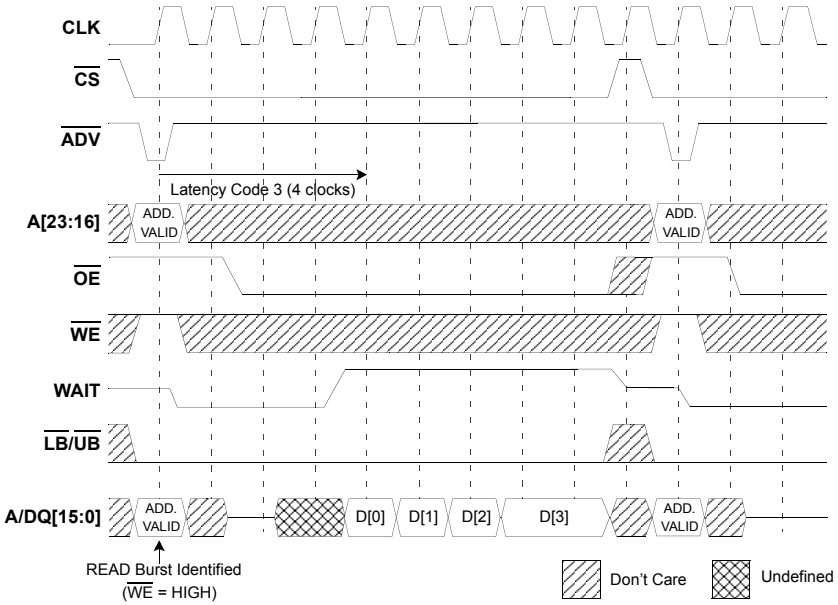


Figure 12. Burst Mode READ (4-word burst)

NOTE :
1) Non-default BCR settings for burst mode READ (4-word burst): Fixed or variable latency;
2) Latency code 3 (4 clocks); WAIT active LOW; WAIT asserted during delay.
3) Diagram in the figure above is representative of variable latency with no refresh collision or fixed-latency access.

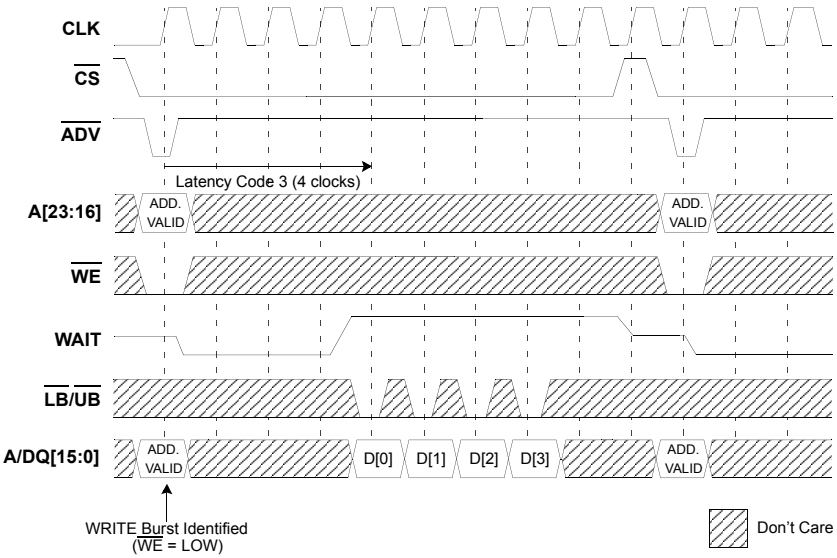


Figure 13. Burst Mode WRITE (4-word burst)

NOTE :
1) Non-default BCR settings for burst mode WRITE (4-word burst): Fixed or variable latency;
2) Latency code 3 (4 clocks); WAIT active LOW; WAIT asserted during delay.
3) tAS is need to Burst Write Operation.

The size of a burst can be specified in the BCR either as a fixed length or continuous. Fixed-length bursts consist of four, eight, sixteen, or thirty-two words. The initial latency for READ operations can be configured as fixed or variable (WRITE operations always use fixed latency). Variable latency allows minimum latency at high clock frequencies, but the controller must monitor WAIT to detect any conflict with refresh cycles. Fixed latency outputs the first data word after the worst-case access delay, including allowance for refresh collisions. The initial latency time and clock speed determine the latency count setting. Fixed latency is used when the controller cannot monitor WAIT. Fixed latency also provides improved performance at lower clock frequencies.

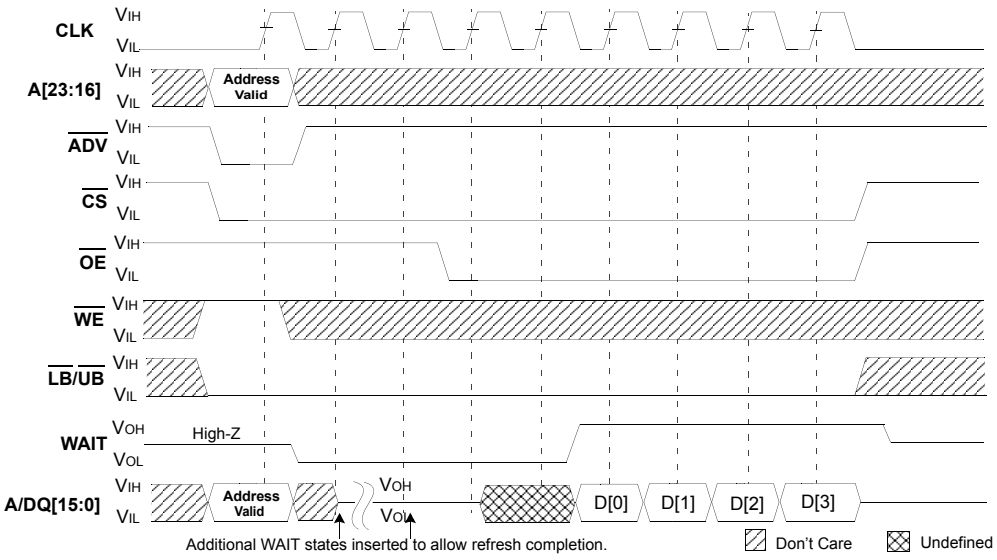


Figure 14. Refresh Collision During Variable-Latency READ Operation

NOTE :
1) Non-default BCR settings for refresh collision during variable-latency READ operation:
2) Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

12.2 Functional Description (Synch. mode)

Burst Mode BCR[15] = 0	Power	CLK	$\overline{ADV}$	$\overline{CS}$	$\overline{OE}$	$\overline{WE}$	CRE	$\overline{UB}$ / $\overline{LB}$	WAIT	A/DQ[15:0]	Notes
Standby	Standby	L	H	H	X	X	L	X	High-Z	High-Z	4
No operation	Idle	L	X	L	X	X	L	X	Low-Z	X	4
Initial burst read	Active	↑	L	L	X	H	L	L	Low-Z	Address	
Initial burst write	Active	↑	L	L	H	L	L	X	Low-Z	Address	
Burst continue	Active	↑	H	L	X	X	X	L	Low-Z	Data in or Data out	3
Burst suspend	Active	X	X	L	H	X	X	X	Low-Z	High-Z	3
Configuration register write	Active	↑	L	L	H	L	H	X	Low-Z	High-Z	
Configuration register read	Active	↑	L	L	L	H	H	L	Low-Z	Config. reg.out	

NOTE :
1) CLK must be LOW during async read and async write modes.
2) When $\overline{LB}$ and $\overline{UB}$ are in select mode (LOW), A/DQ[15:0] are affected. When only $\overline{LB}$ is in select mode, A/DQ[7:0] are affected. When only $\overline{UB}$ is in the select mode, A/DQ[15:8] are affected.
3) The device will consume active power in this mode whenever addresses are changed.
4) When the device is in standby mode, address inputs and data inputs/outputs are internally isolated from any external influence.

12.3 Burst Suspend

To access other devices on the same bus without the timing penalty of the initial latency for a new burst, burst mode can be suspended. Bursts are suspended by stopping CLK. CLK can be stopped HIGH or LOW. If another device will use the data bus while the burst is suspended, $\overline{OE}$ should be taken HIGH to disable the outputs. otherwise, $\overline{OE}$ can remain LOW. Note that the WAIT output will continue to be active, and as a result no other devices should directly share the WAIT connection to the controller. To continue the burst sequence, $\overline{OE}$ is taken LOW, then CLK is restarted after valid data is available on the bus. The $\overline{CS}$ LOW time is limited by refresh considerations. $\overline{CS}$ must not stay LOW longer than tCSM. If a burst suspension will cause $\overline{CS}$ to remain LOW for longer than tCSM, $\overline{CS}$ should be taken HIGH and the burst restarted with a new $\overline{CS}$ LOW/$\overline{ADV}$ LOW cycle.

12.4 Boundary Crossing

Continuous bursts or No wrap burst have the ability to start at a specified address and burst to the end of the address. It goes back to the first address and continues the burst operation. WAIT will be asserted at the boundary of the row and be desserted after crossing boundary of the row. There is no limitation for CS high time during Row Boundary Crossing.

12.5 WAIT Operation

The WAIT output is typically connected to a shared systemlevel WAIT signal. The shared WAIT signal is used by the processor to coordinate transactions with multiple memories on the synchronous bus. Once a READ or WRITE operation has been initiated, WAIT goes active to indicate that additional time is required before data can be transferred. For READ operations, WAIT will remain active until valid data is output from the device. For WRITE operations, WAIT will indicate to the memory controller when data will be accepted into this device. When WAIT transitions to an inactive state, the data burst will progress on successive clock edges. $\overline{CS}$ must remain asserted during WAIT cycles (WAIT asserted and WAIT configuration BCR[8] = 1). Bringing $\overline{CS}$ HIGH during WAIT cycles may cause data corruption. (Note that for BCR[8] = 0, the actual WAIT cycles end one cycle after WAIT de-asserts. When using variable initial access latency (BCR[14] = 0), the WAIT output performs an arbitration role for READ operations launched while an on-chip refresh is in progress. If a collision occurs, WAIT is asserted for additional clock cycles until the refresh has completed. When the refresh operation has completed, the READ operation will continue normally. WAIT will be asserted but should be ignored during asynchronous READ and WRITE operations. By using fixed initial latency (BCR[14] = 1), this device can be used in burst mode without monitoring the WAIT signal. However, WAIT can still be used to determine when valid data is available at the start of the burst.

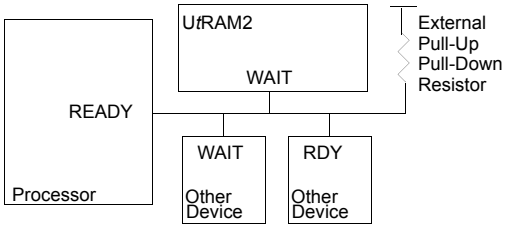


Figure 15. Wired or WAIT Configuration

12.6 LB / UB Operation

The $\overline{LB}$ enable and $\overline{UB}$ enable signals support byte-wide data WRITEs. During WRITE operations, any disabled bytes will not be transferred to the RAM array and the internal value will remain unchanged. During an asynchronous WRITE cycle. The data to be written is latched on the rising edge of $\overline{CS}$, $\overline{WE}$ whichever occurs first and $\overline{LB}$, $\overline{UB}$ must have rising edge after $\overline{CS}$ or $\overline{WE}$ go high. $\overline{LB}$ and $\overline{UB}$ must be LOW during READ cycles. When both the $\overline{LB}$ and $\overline{UB}$ are disabled (HIGH) during an operation, the device will disable the data bus from receiving or transmitting data. Although the device will seem to be deselected, it remains in an active mode as long as $\overline{CS}$ remains LOW.

13.0 LOW-POWER OPERATION

13.1 Temperature Compensated Self Refresh

Temperature compensated self refresh (TCSR) allows for adequate refresh at different temperatures. This U*t*RAM2 device includes an on-chip temperature sensor that automatically adjusts the refresh rate according to the operating temperature. The device continually adjusts the refresh rate to match that temperature.

13.2 Partial Array Refresh

Partial array refresh (PAR) restricts refresh operation to a portion of the total memory array. This feature enables the device to reduce standby current by refreshing only that part of the memory array required by the host system. The refresh options are full array, one-half array, one-quarter array, one-eighth array, or none of the array. The mapping of these partitions can start at either the beginning or the end of the address map. READ and WRITE operations to address ranges receiving refresh will not be affected. Data stored in addresses not receiving refresh will become corrupted. When re-enabling additional portions of the array, the new portions are available immediately upon writing to the RCR.

13.3 AC Input/Output Reference Waveform & AC Output Load Circuit

NOTE :
1) AC test inputs are driven at VCCQ for a logic 1 and VSSQ for a logic 0. Input rise and fall times (10% to 90%) <1.6ns.
2) Input timing begins at VCCQ/2 and Output timing ends at VCCQ/2.
3) All tests are performed with the outputs configured for default setting of half drive strength (BCR[5:4] = 01b)

14.0 TIMING REQUIREMENTS

14.1 Asynchronous READ Cycle Timing Requirements

Parameter	Symbol	Min	Max	Unit	Notes
Address access time	t_{AA}		70	ns	
$\overline{ADV}$ access time	t_{AADV}		70	ns	
Address setup to $\overline{ADV}$ HIGH	t_{AVS}	5		ns	
Address hold from $\overline{ADV}$ HIGH	t_{AVH}	2		ns	
$\overline{LB}$/$\overline{UB}$ access time	t_{BA}		70	ns	
$\overline{LB}$/$\overline{UB}$ disable to DQ High-Z output	t_{BHZ}		8	ns	1
Maximum $\overline{CS}$ Pulse Width	t_{CSM}		2.5	us	4
$\overline{CS}$ or $\overline{ADV}$ LOW to WAIT valid	t_{CSW}	1	7.5	ns	
$\overline{CS}$ HIGH between subsequent Async Operations	t_{CPH}	15		ns	4
Chip select access time	t_{CO}		70	ns	
$\overline{CS}$ LOW to $\overline{ADV}$ HIGH	t_{CVS}	7		ns	
Chip disable to DQ and WAIT High-Z output	t_{HZ}		8	ns	1
Output enable to valid output	t_{OE}		20	ns	
Output disable to DQ High-Z output	t_{OHZ}		8	ns	1
Output ebable to Low-Z output	t_{OLZ}	5		ns	2
READ cycle time	t_{RC}	80		ns	
$\overline{ADV}$ pulse width LOW	t_{VP}	5		ns	

14.2 Asynchronous WRITE Cycle Timing Requirements

Parameter	Symbol	Min	Max	Unit	Notes
Address setup to $\overline{ADV}$ going HIGH	t_{AVS}	5		ns	
Address hold from $\overline{ADV}$ HIGH	t_{AVH}	2		ns	
Address valid to end of WRITE	t_{AW}	70		ns	
$\overline{LB}$/$\overline{UB}$ select to end of WRITE	t_{BW}	70		ns	
$\overline{CS}$ HIGH between subsequent async operations	t_{CPH}	15		ns	1
$\overline{CS}$ LOW to $\overline{ADV}$ HIGH	t_{CVS}	7		ns	2
Chip enable to end of WRITE	t_{CW}	70		ns	3
Data HOLD from WRITE time	t_{DH}	0		ns	
Data WRITE setup time	t_{DW}	20		ns	
Chip disable to WAIT High-Z output	t_{HZ}		8	ns	
End WRITE to Low-Z output	t_{OW}	5		ns	2
$\overline{ADV}$ pulse width	t_{VP}	5		ns	
$\overline{ADV}$ setup to end of WRITE	t_{VS}	70		ns	
WRITE to DQ High-Z output	t_{WHZ}		8	ns	2
$\overline{CS}$ or $\overline{ADV}$ LOW to WAIT valid	t_{CSW}	1	7.5	ns	
WRITE pulse width	t_{WP}	55		ns	3
WRITE recovery time	t_{WR}	0		ns	
/UB, /LB valid or mask setup time to beginning of write	t_{BSA}	0	-	ns	
/UB, /LB valid or mask hold time to end of write	t_{BHA}	0	-	ns	
Address Skew	t_{SKEW}	-	10	ns	

NOTE :
1) The High-Z timings measure a 100mV transition from either VOH or VOL toward VCCQ/2.
2) The Low-Z timings measure a 100mV transition away from the High-Z (VCCQ/2) level toward either VOH or VOL.
3) $\overline{WE}$ LOW time must be limited to tCSM (2.5μs).
4) A refresh opportunity must be provided every tCSM. $\overline{CS}$ must not remain LOW longer than tCSM.

14.3 Burst READ Cycle Timing Requirements

Parameter	Symbol	108MHz		80MHz		66MHz		Unit	Notes
		Min	Max	Min	Max	Min	Max		
Address access time (fixed latency)	t_{AA}		70		70		70	ns	4
$\overline{ADV}$ access time (fixed latency)	t_{AADV}		70		70		70	ns	4
CLK to output delay	t_{ACLK}		7		9		11	ns	
Burst $\overline{OE}$ LOW to output delay	t_{BOE}		20		20		20	ns	
$\overline{CS}$ HIGH between subsequent burst or operations	t_{CBPH}	15		15		15		ns	3
Maximum $\overline{CS}$ pulse width LOW	t_{CSM}		2.5		2.5		2.5	us	3
$\overline{CS}$ or $\overline{ADV}$ LOW to WAIT valid	t_{CSW}	1	7.5	1	7.5	1	7.5	ns	
CLK period	t_{CLK}	9.26		12.5		15		ns	
Chip select access time (fixed latency)	t_{CO}		70		70		70	ns	4
$\overline{CS}$ setup time to active CLK edge	t_{CSP}	3		4		5		ns	
Hold time from active CLK edge	t_{HD}	2		2		2		ns	
Chip desable to DQ and WAIT High-Z output	t_{HZ}		8		8		8	ns	1
CLK rise or fall time	t_{KHKL}		1.6		1.8		2.0	ns	
CLK to WAIT valid	t_{KHTL}	2	7	2	9	2	11	ns	
Output HOLD from CLK	t_{KOH}	2		2		2		ns	
CLK HIGH or LOW time	t_{KP}	3		4		5		ns	
Output disable to DQ High-Z output	t_{OHZ}		8		8		8	ns	1
Output enable to Low-Z output	t_{OLZ}	5		5		5		ns	2
Setup time to active CLK edge	t_{SP}	3		3		3		ns	
$\overline{ADV}$ HIGH to $\overline{OE}$ LOW	t_{ADVO}	3		4		5		ns	
Address setup to $\overline{ADV}$ HIGH	t_{AVH}	2		2		2		ns	
$\overline{ADV}$ HIGH to CLK Rising	t_{AHCR}	2		2		2		ns	

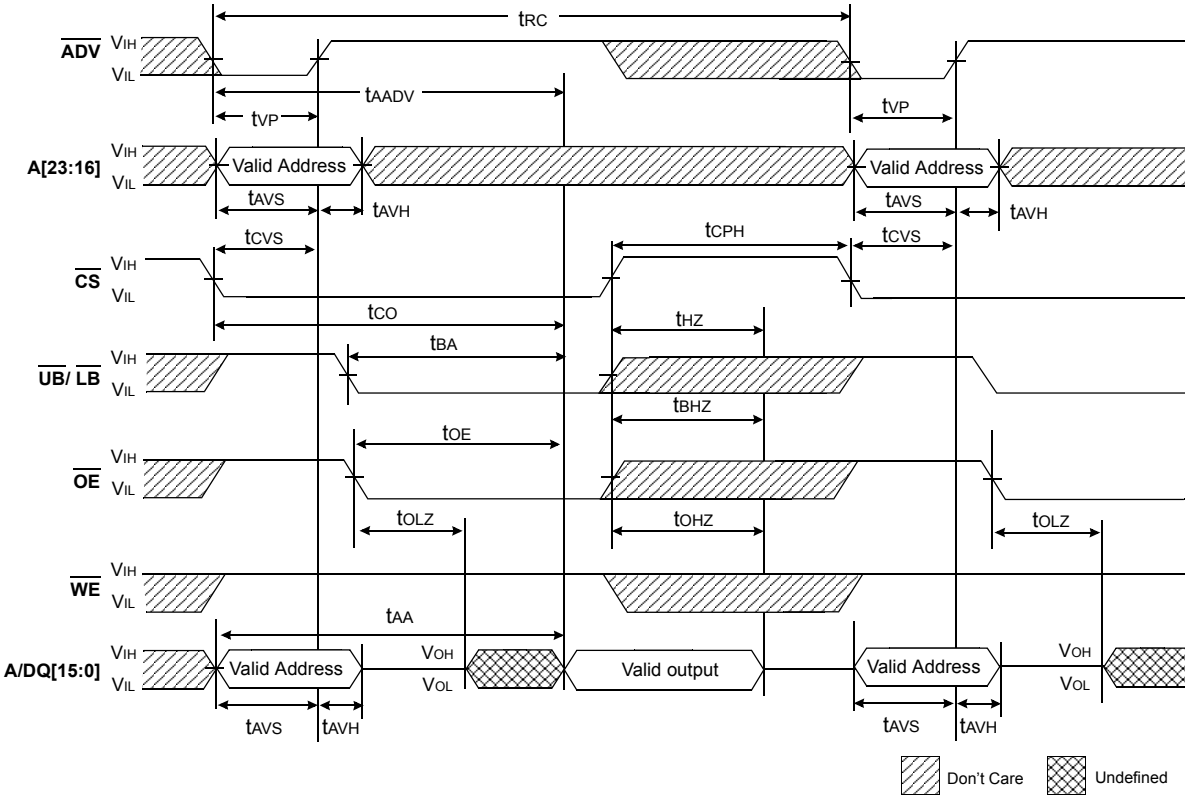
14.4 Burst WRITE Cycle Timing Requirements

Parameter	Symbol	108MHz		80MHz		66MHz		Unit	Notes
		Min	Max	Min	Max	Min	Max		
$\overline{CS}$ HIGH between subseuent burst or mixed mode operations	t_{CBPH}	15		15		15		ns	3
Maximum $\overline{CS}$ pulse width LOW	t_{CSM}		2.5		2.5		2.5	us	3
$\overline{CS}$ LOW to WAIT valid	t_{CSW}	1	7.5	1	7.5	1	7.5	ns	
Clock period	t_{CLK}	9.26		12.5		15		ns	
$\overline{CS}$ setup to CLK active edge	t_{CSP}	3		4		5		ns	
Hold time from active CLK edge	t_{HD}	2		2		2		ns	
Chip disable to WAIT High-Z output	t_{HZ}		8		8		8	ns	1
Last clock to $\overline{ADV}$ LOW (fixed latency)	t_{KADV}	15		15		15		ns	
CLK rise or fall time	t_{KHKL}		1.6		1.8		2.0	ns	
Clock to WAIT valid	t_{KHTL}	2	7	2	9	2	11	ns	
CLK HIGH or LOW time	t_{KP}	3		4		5		ns	
Setup time to activate CLK edge	t_{SP}	3		3		3		ns	
Address Hold from $\overline{ADV}$ HIGH	t_{AVH}	2		2		2		ns	
$\overline{ADV}$ HIGH to CLK Rising	t_{AHCR}	2		2		2		ns	

NOTE :
1) The High-Z timings measure a 100mV transition from either VOH or VOL toward VCCQ/2.
2) The Low-Z timings measure a 100mV transition away from the High-Z (VCCQ/2) level toward either VOH or VOL.
3) A refresh opportunity must be provided every tCSM. $\overline{CS}$ must not remain LOW longer than tCSM.
4) tAA, tAADV, tCO guarantee at min set-up time.

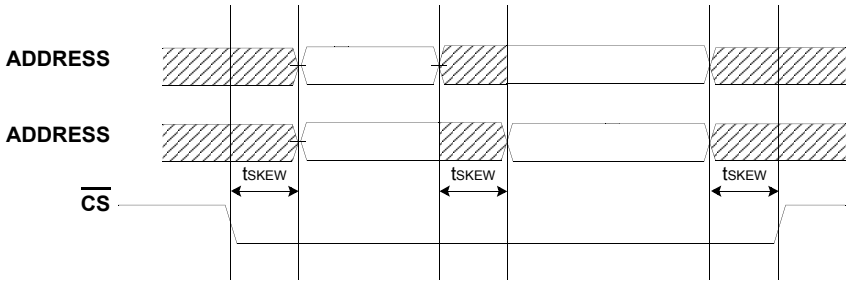
15.0 TIMING DIAGRAMS

15.1 Asynchronous READ ($\overline{CS}$ controlled)

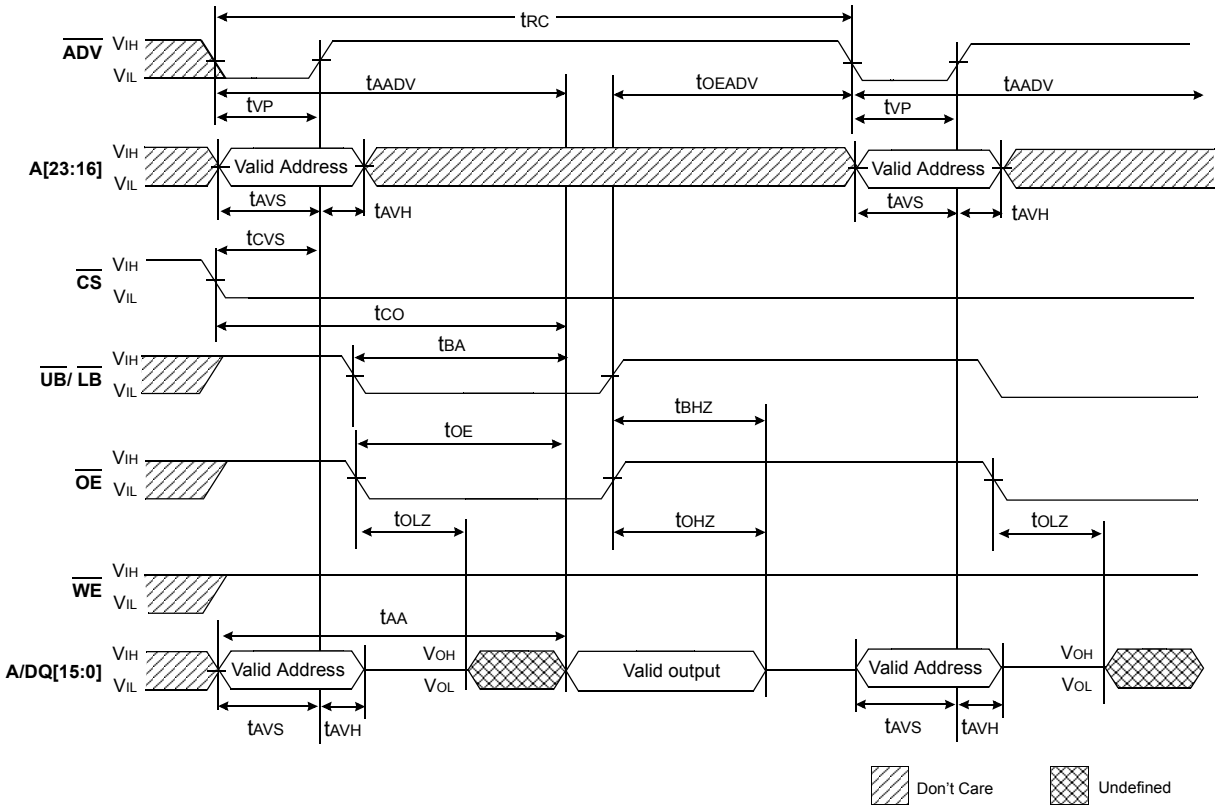


NOTE :
1) Don't care must be in VIL or VIH.
2) tHZ and tOHZ are defined as the time at which the outputs achieve the open circuit conditions and are not referenced to output voltage levels.
3) At any given temperature and voltage condition, tHZ(Max.) is less than tLZ(Min.) both for a given device and from device to device interconnection.
4) tOE(max) is met only when $\overline{OE}$ becomes enabled after tAA(max).
5) If invalid address signals shorter than min. tRC are continuously repeated for over 2.5us, the device needs a normal read timing(tRC) or needs to sustain standby state for min. tRC at least once in every 2.5us.

15.1.1 Address Skew for Asynchronous Operation

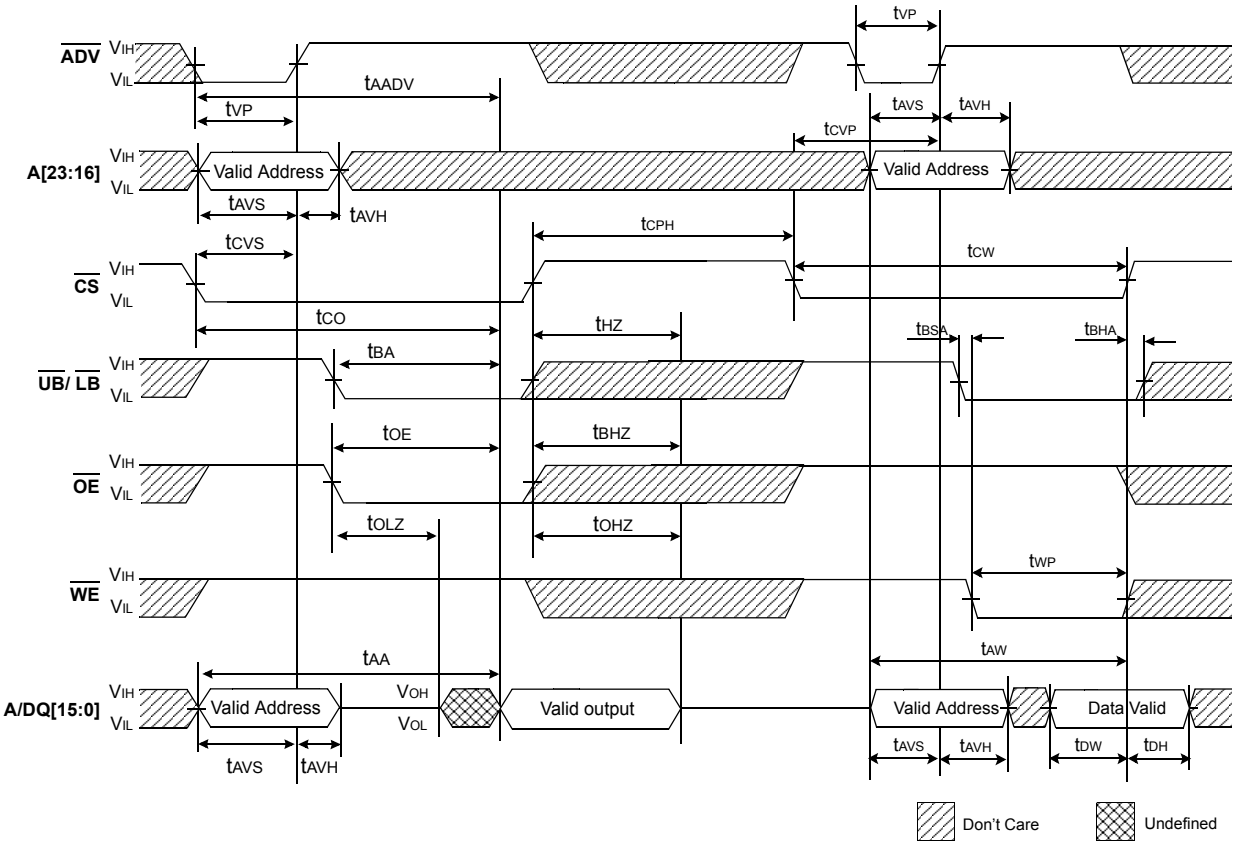


15.2 Asynchronous READ ($\overline{OE}$ controlled)

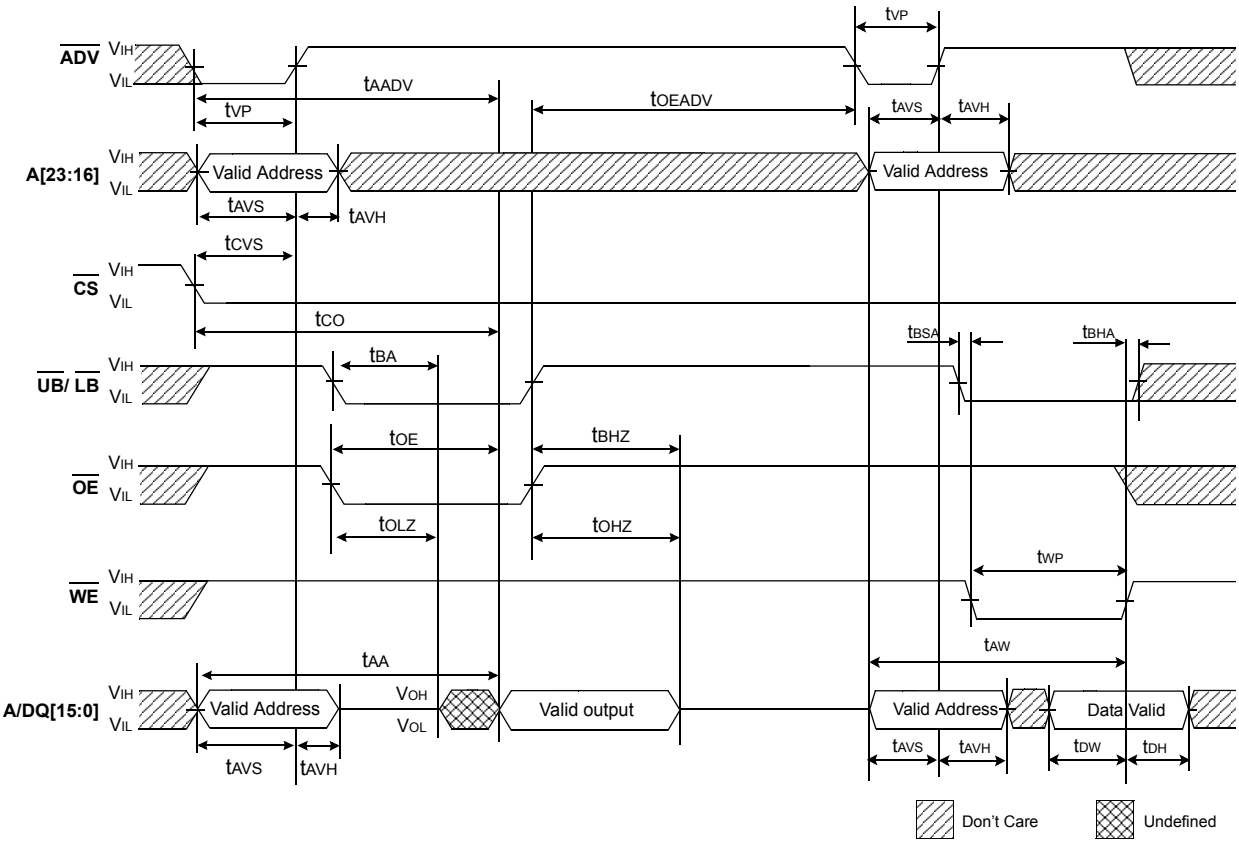


NOTE :
1) Don't care must be in V_{IL} or V_{IH}.
2) t_{HZ} and t_{OHZ} are defined as the time at which the outputs achieve the open circuit conditions and are not referenced to output voltage levels.
3) At any given temperature and voltage condition, t_{HZ}(Max.) is less than t_{LZ}(Min.) both for a given device and from device to device interconnection.
4) t_{OE}(max) is met only when $\overline{OE}$ becomes enabled after t_{AA}(max).
5) If invalid address signals shorter than min. t_{RC} are continuously repeated for over 2.5us, the device needs a normal read timing(t_{RC}) or needs to sustain standby state for min. t_{RC} at least once in every 2.5us.

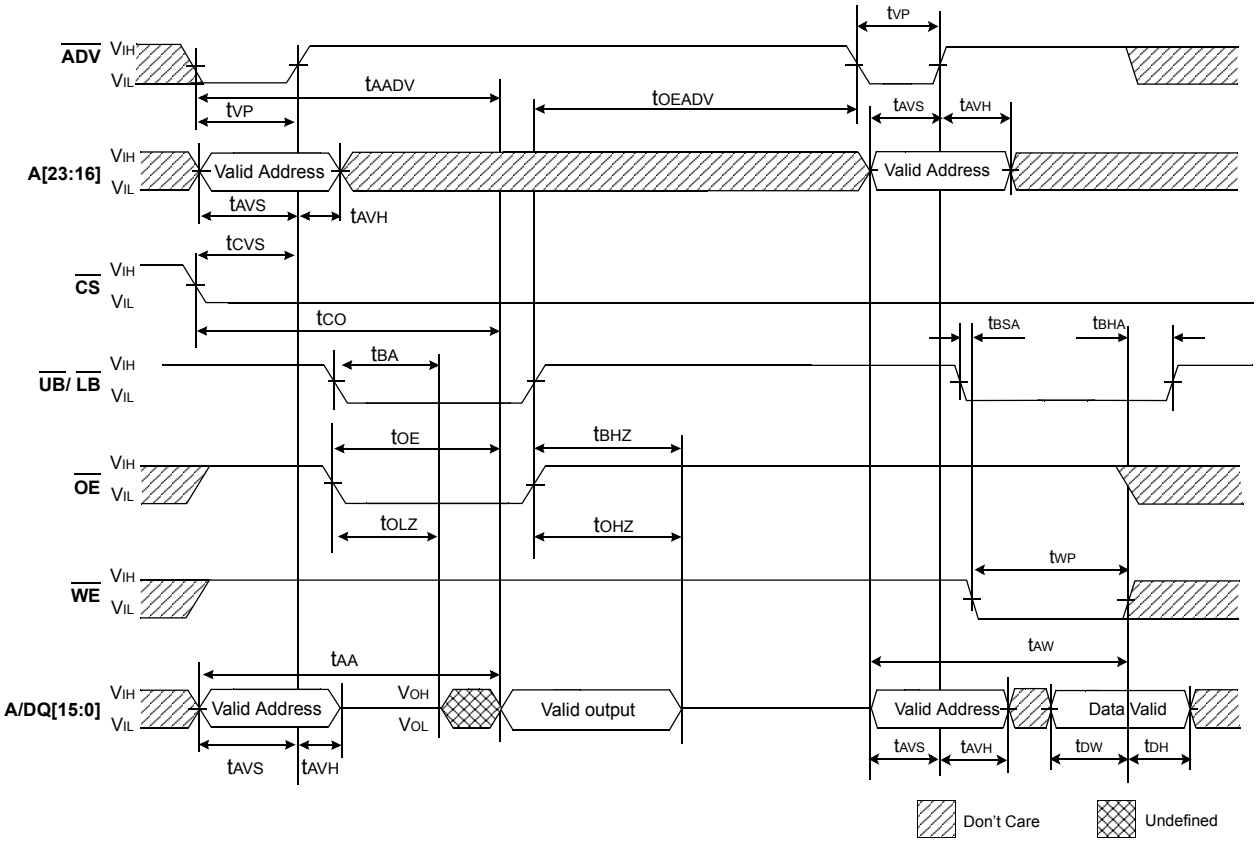
15.3 Asynchronous READ Followed by Asynchronous WRITE ($\overline{CS}$ Controlled)



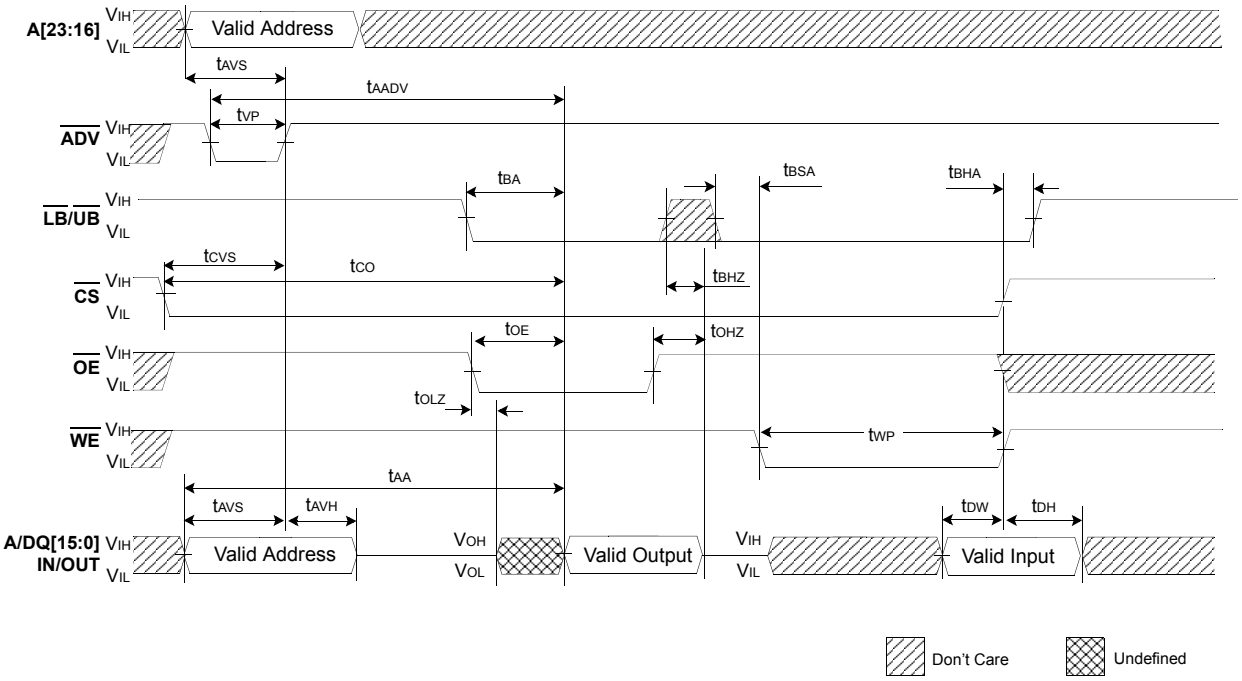
15.4 Asynchronous READ Followed by Asynchronous WRITE ($\overline{OE}$, $\overline{WE}$ Controlled)



15.5 Asynchronous READ Followed by Asynchrous WRITE ($\overline{UB}$, $\overline{LB}$ Controlled)

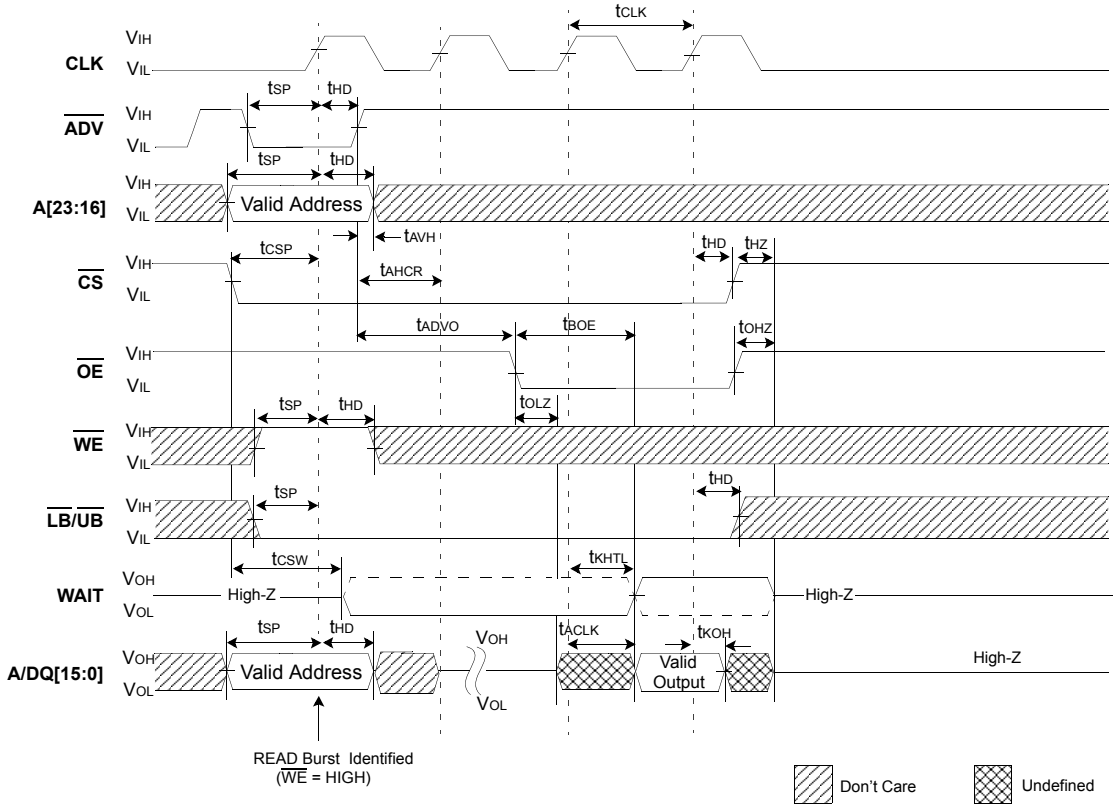


15.6 Asynchronous READ Followed by WRITE at the Same Address ($\overline{UB}$/$\overline{LB}$ Controlled)



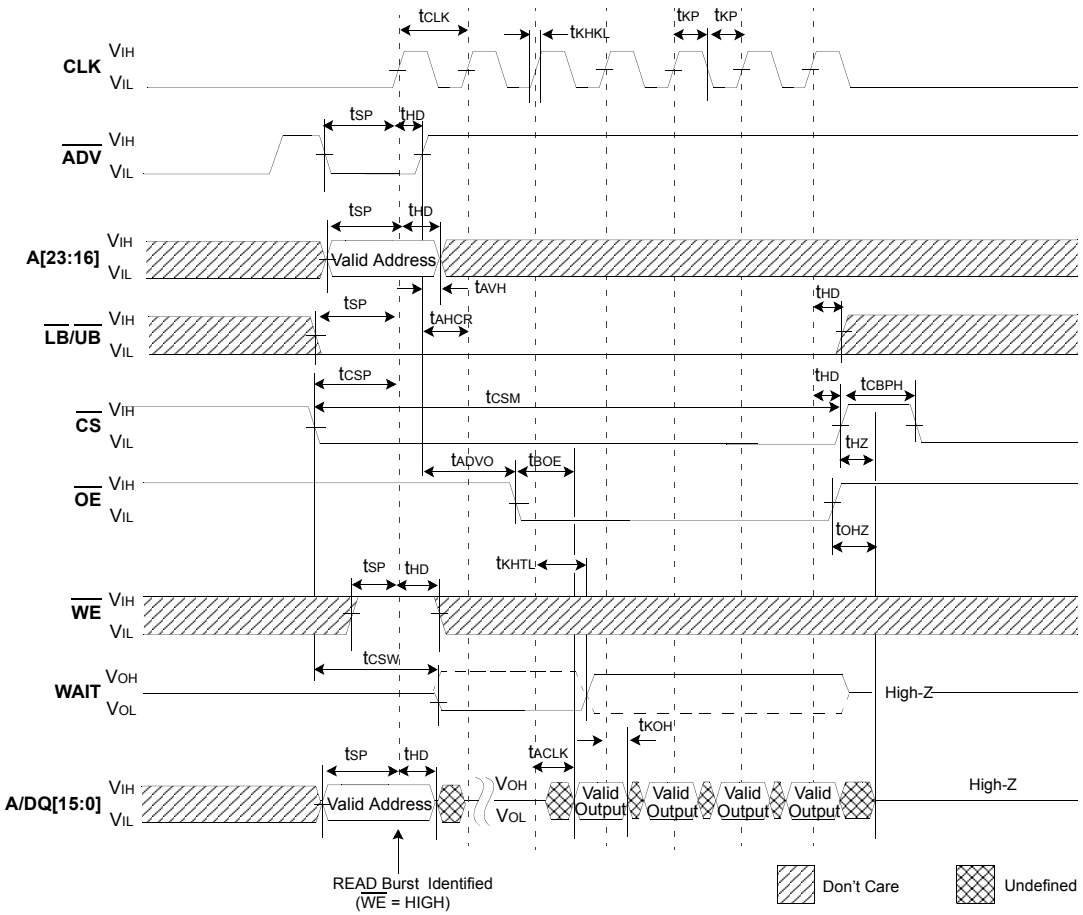
NOTE :
1) Don't care must be in VIL or VIH.

15.7 Single-Access Burst READ Operation—Variable Latency



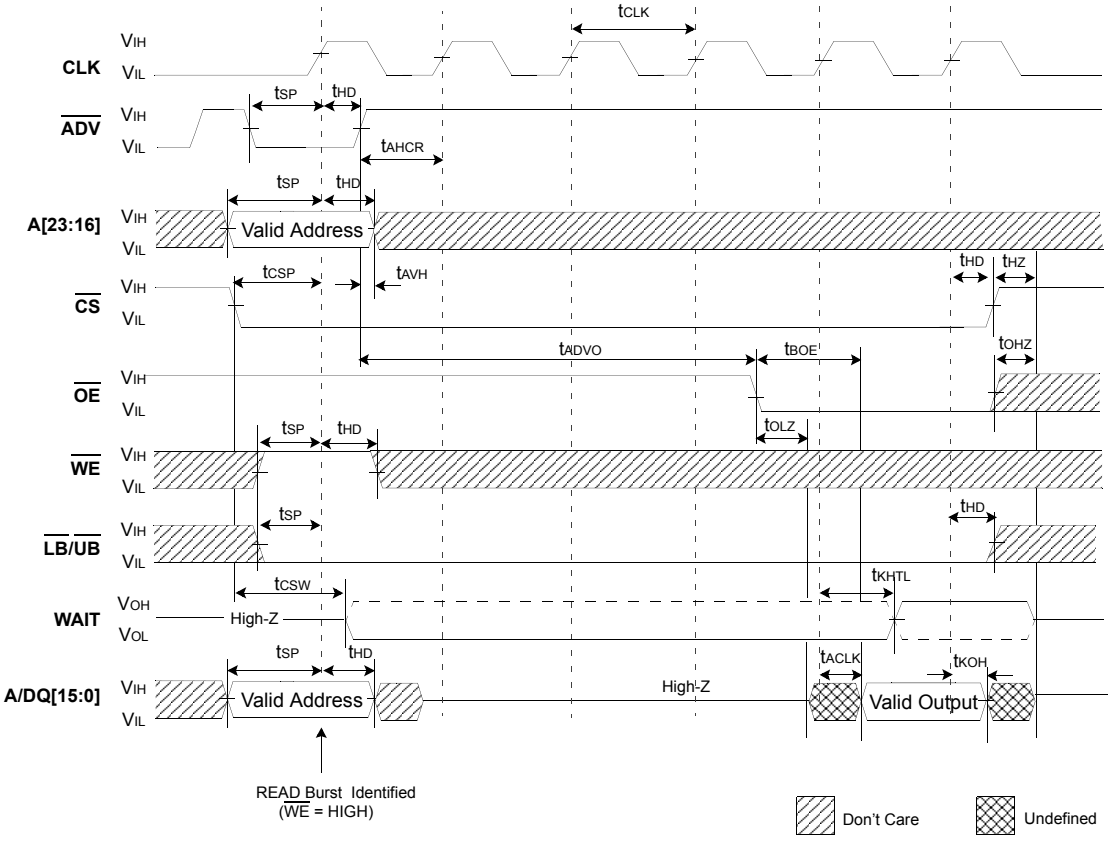
NOTE :
1) Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.

15.8 4-Word Burst READ Operation—Variable Latency



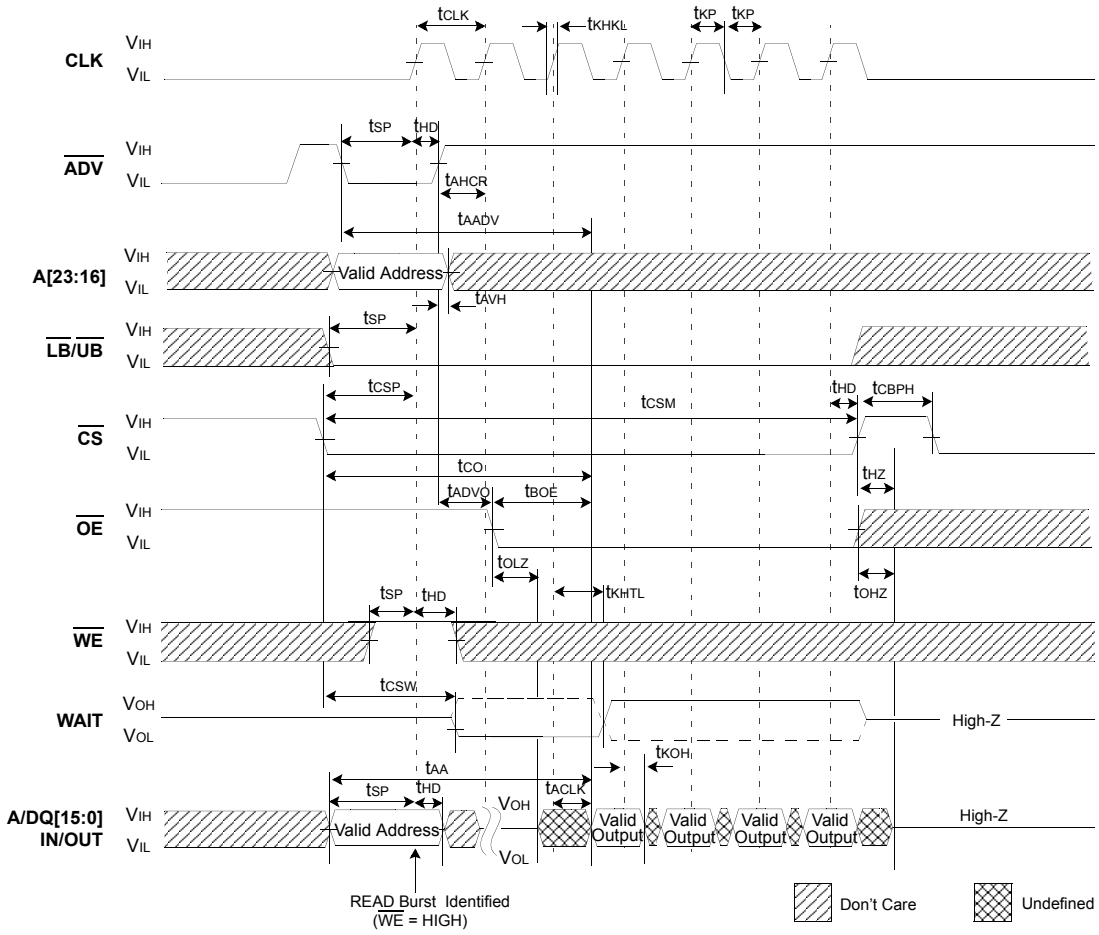
NOTE :
1) Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.

15.9 Single-Access Burst READ Operation—Fixed Latency



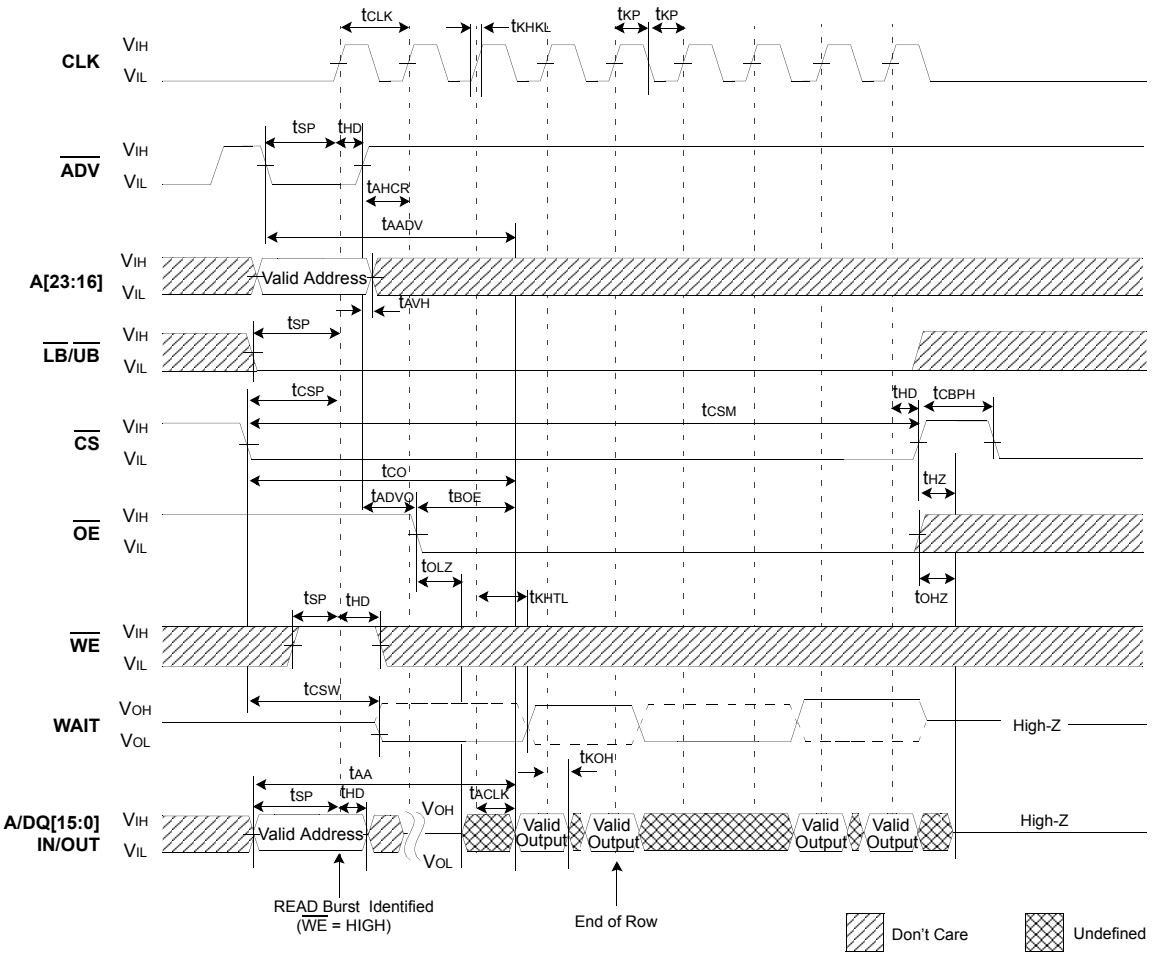
NOTE :
1) Non-default BCR settings: Fixed latency; latency code four (five clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.

15.10 4-Word Burst READ Operation—Fixed Latency



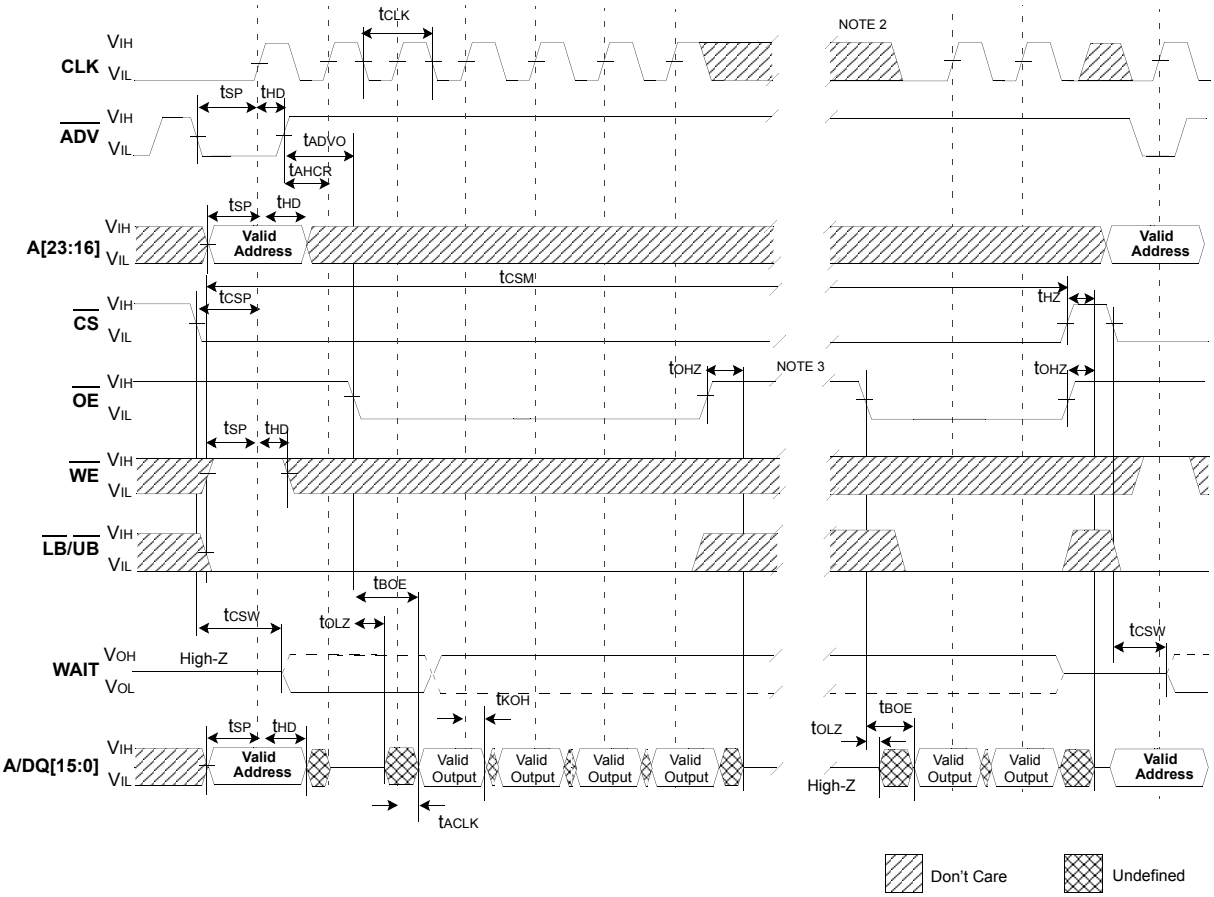
NOTE :
1) Non-default BCR settings: Fixed latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.

15.11 4-Word Burst READ Operation - Row Boundary Crossing



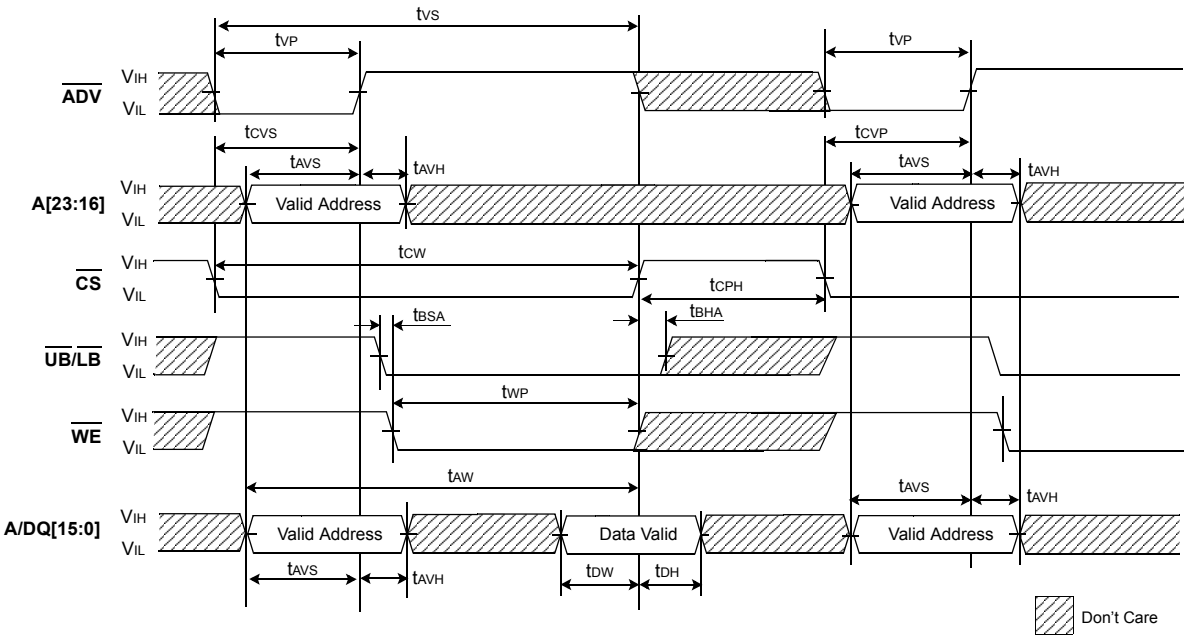
NOTE :
1) Non-default BCR settings: Fixed latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.
3) There is no limitation for CS high time during Row Boundary Crossing.
4) There is no $\overline{ADV}$ low during Row Boundary Crossing.

15.12 READ Burst Suspend



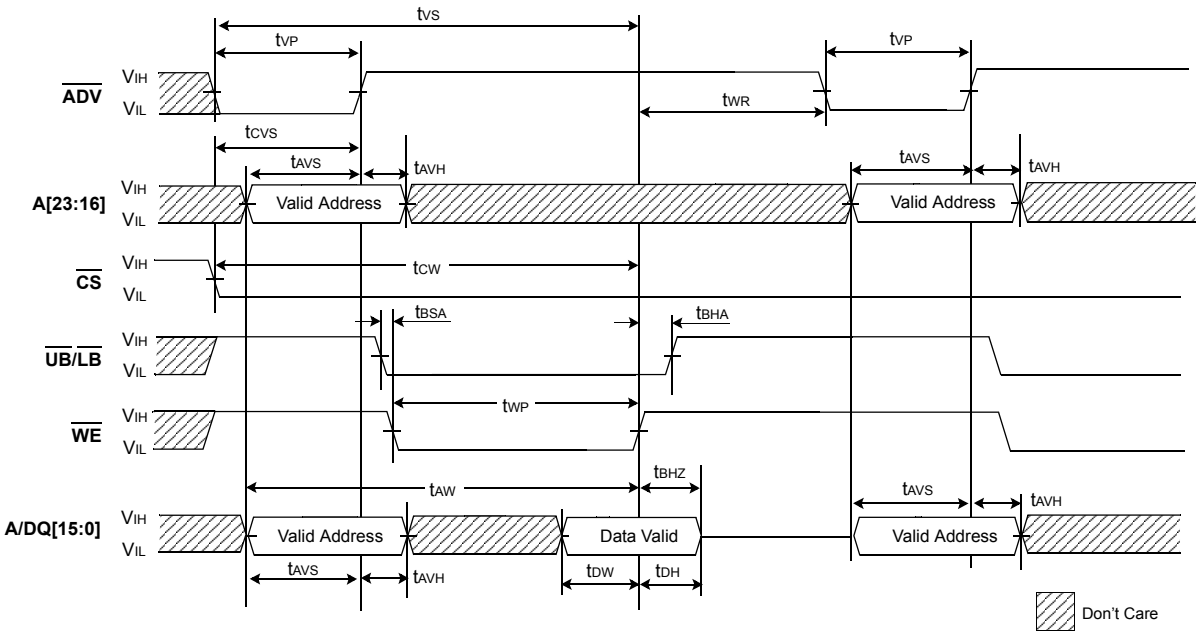
NOTE :
1) Non-default BCR settings for READ burst suspend: Fixed or variable latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) CLK can be stopped LOW or HIGH, but must be static, with no LOW-to-HIGH transitions during burst suspend.
3) $\overline{OE}$ can stay LOW during burst suspend. If $\overline{OE}$ is LOW, A/DQ[15:0] will continue to output valid data.
4) Don't care must be in VIL or VIH.

15.13 Asynchronous WRITE ($\overline{CS}$ Controlled)



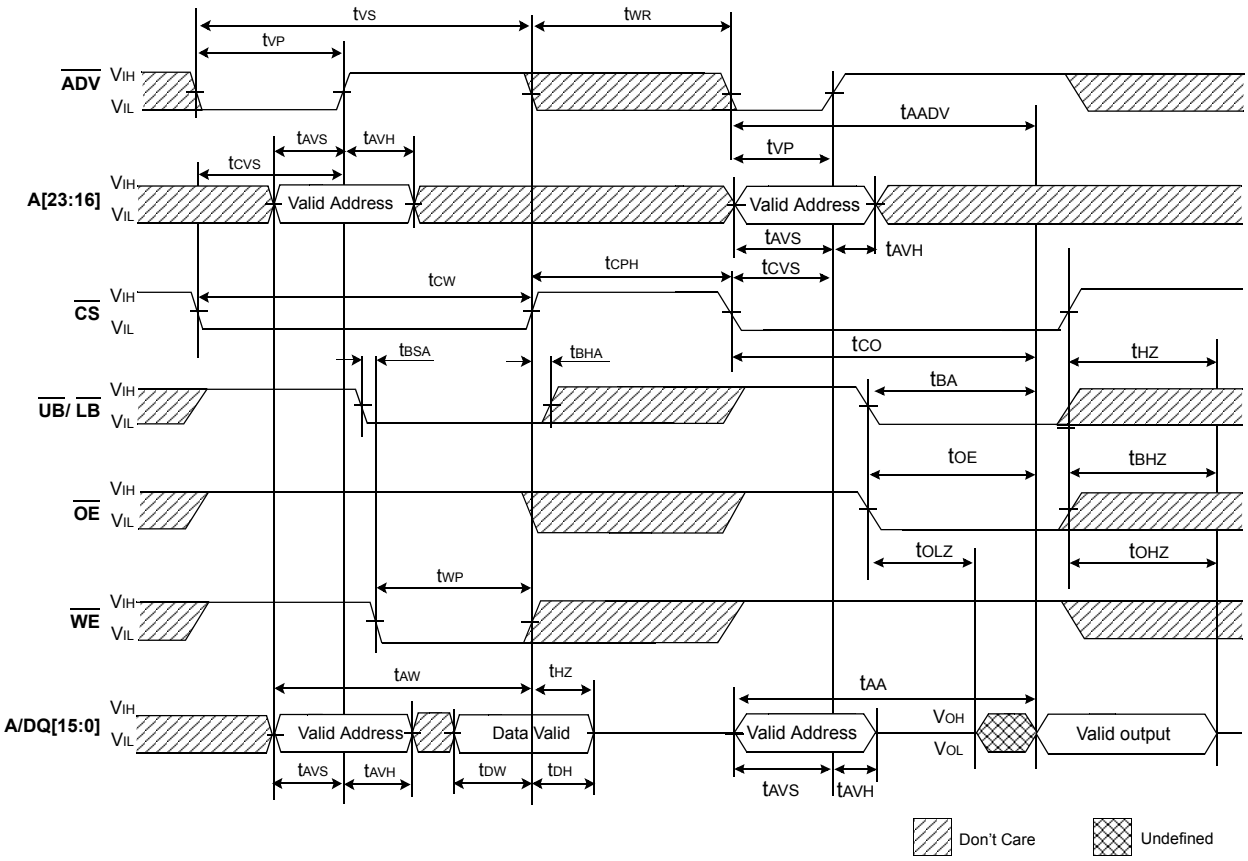
NOTE :
1) Don't care must be in VIL or VIH.
2) A write occurs during the overlap(tWP) of low $\overline{CS}$ and low $\overline{WE}$. A write begins when $\overline{CS}$ goes low and $\overline{WE}$ goes low with asserting $\overline{UB}$ or $\overline{LB}$ for single byte operation or simultaneously asserting $\overline{UB}$ and $\overline{LB}$ for double byte operation.
3) tCW is measured from the $\overline{CS}$ going low to the end of write.
4) tAS is measured from the address valid to the beginning of write.
5) tWR is measured from the end of write to the address change. tWR is applied in case a write ends with $\overline{CS}$ or $\overline{WE}$ going high.

15.14 Asynchronous WRITE ($\overline{WE}$, $\overline{UB}$/$\overline{LB}$ Controlled)

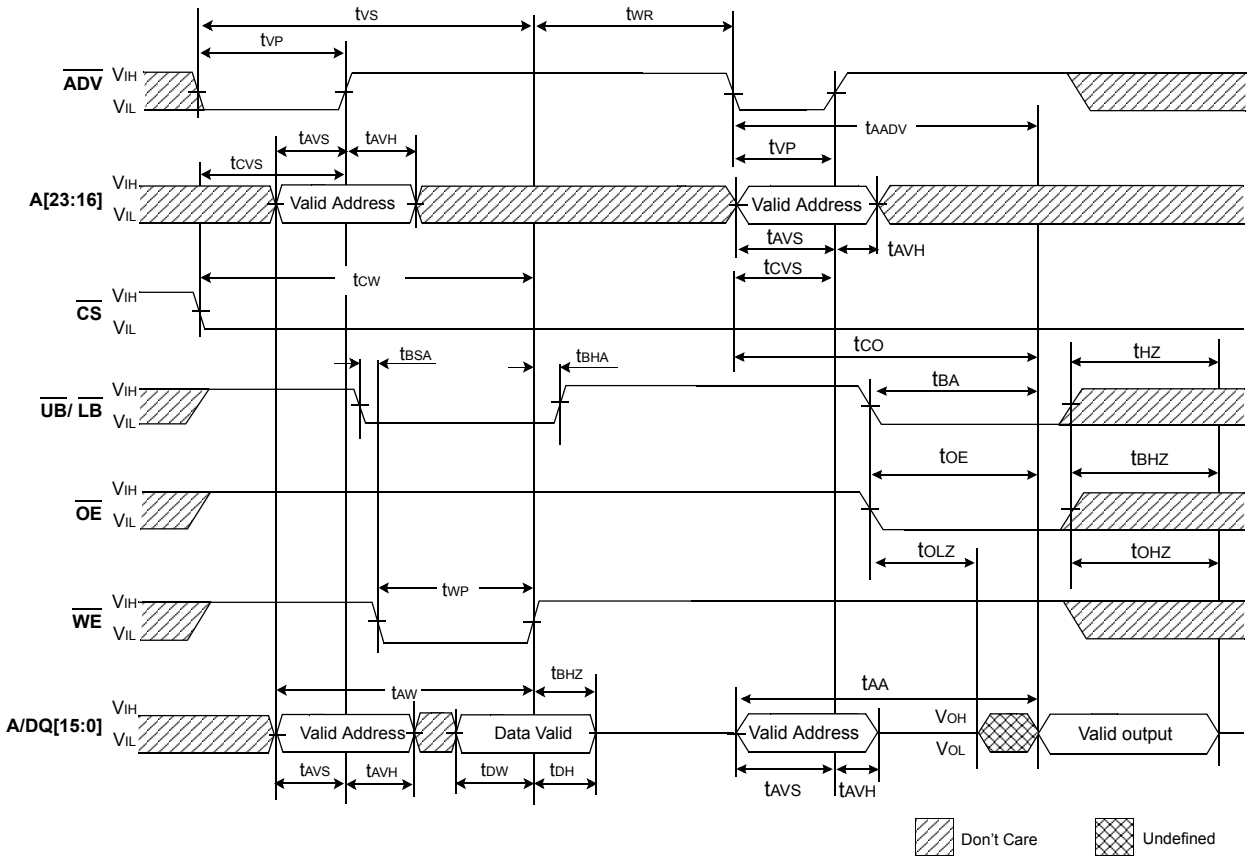


NOTE :
1) Don't care must be in VIL or VIH.
2) A write occurs during the overlap(tWP) of low $\overline{CS}$ and low $\overline{WE}$. A write begins when $\overline{CS}$ goes low and $\overline{WE}$ goes low with asserting $\overline{UB}$ or $\overline{LB}$ for single byte operation or simultaneously asserting $\overline{UB}$ and $\overline{LB}$ for double byte operation.
3) tCW is measured from the $\overline{CS}$ going low to the end of write.
4) tAS is measured from the address valid to the beginning of write.
5) tWR is measured from the end of write to the address change. tWR is applied in case a write ends with $\overline{CS}$ or $\overline{WE}$ going high.

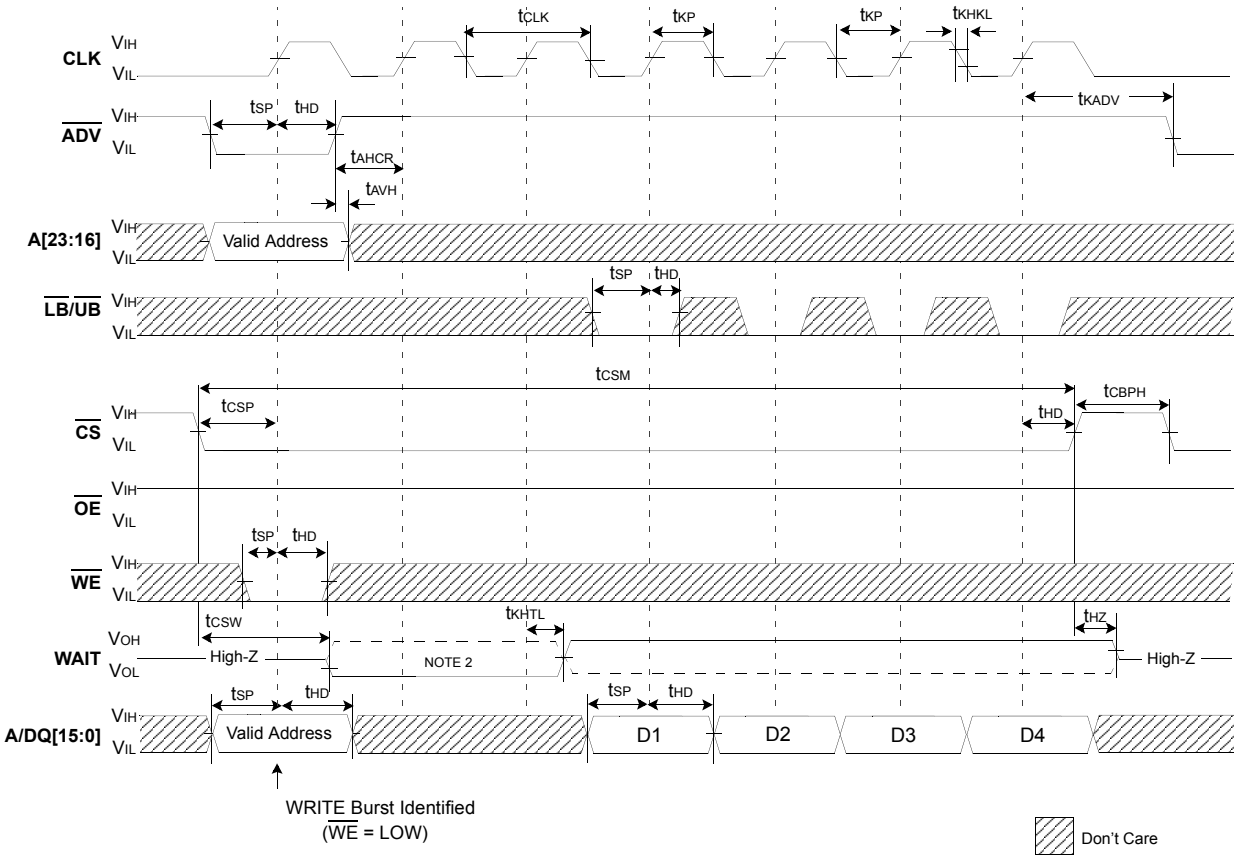
15.15 Asynchronous WRITE Followed by Asynchronous READ ($\overline{CS}$ Controlled)



15.16 Asynchronous WRITE Followed by Asynchronous READ ($\overline{OE}$, $\overline{WE}$ Controlled)

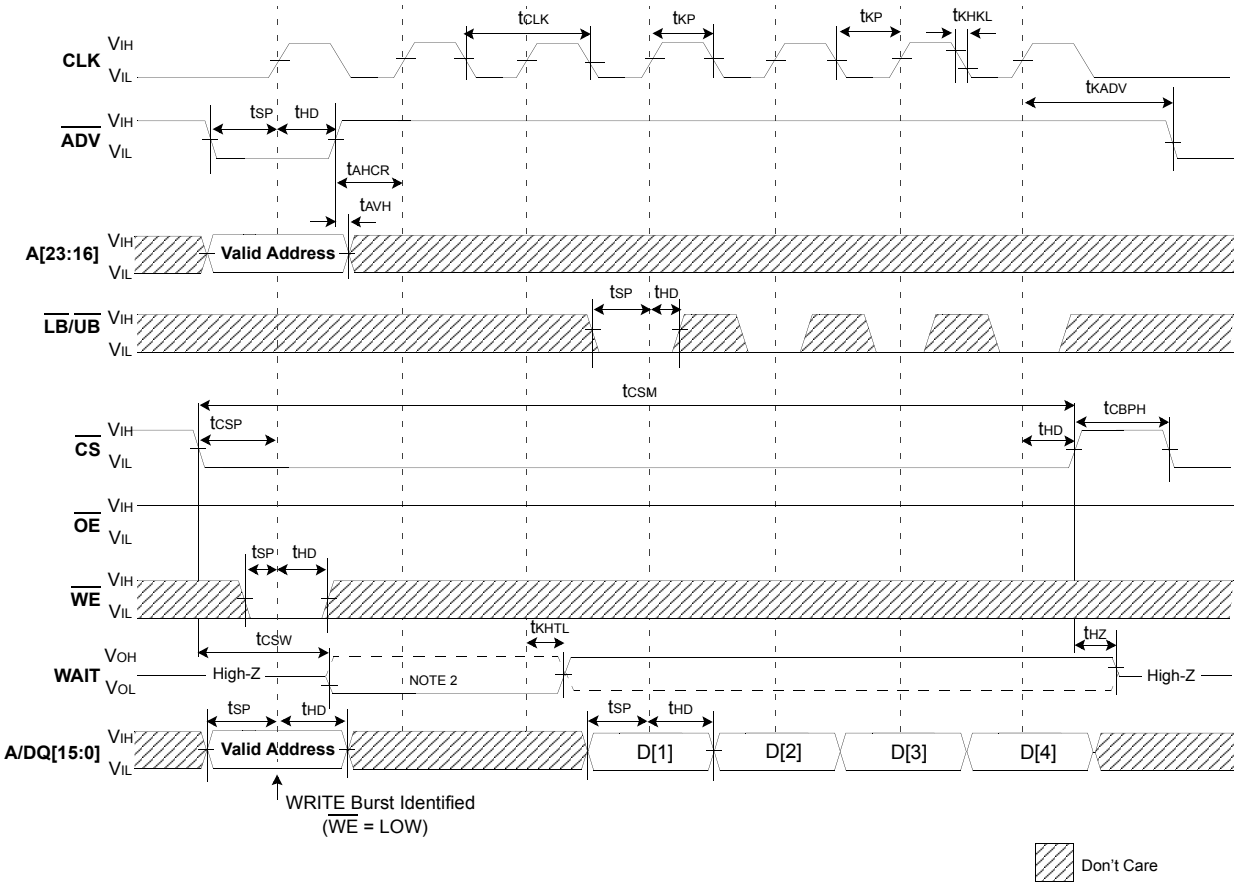


15.17 Burst WRITE Operation—Variable Latency Mode



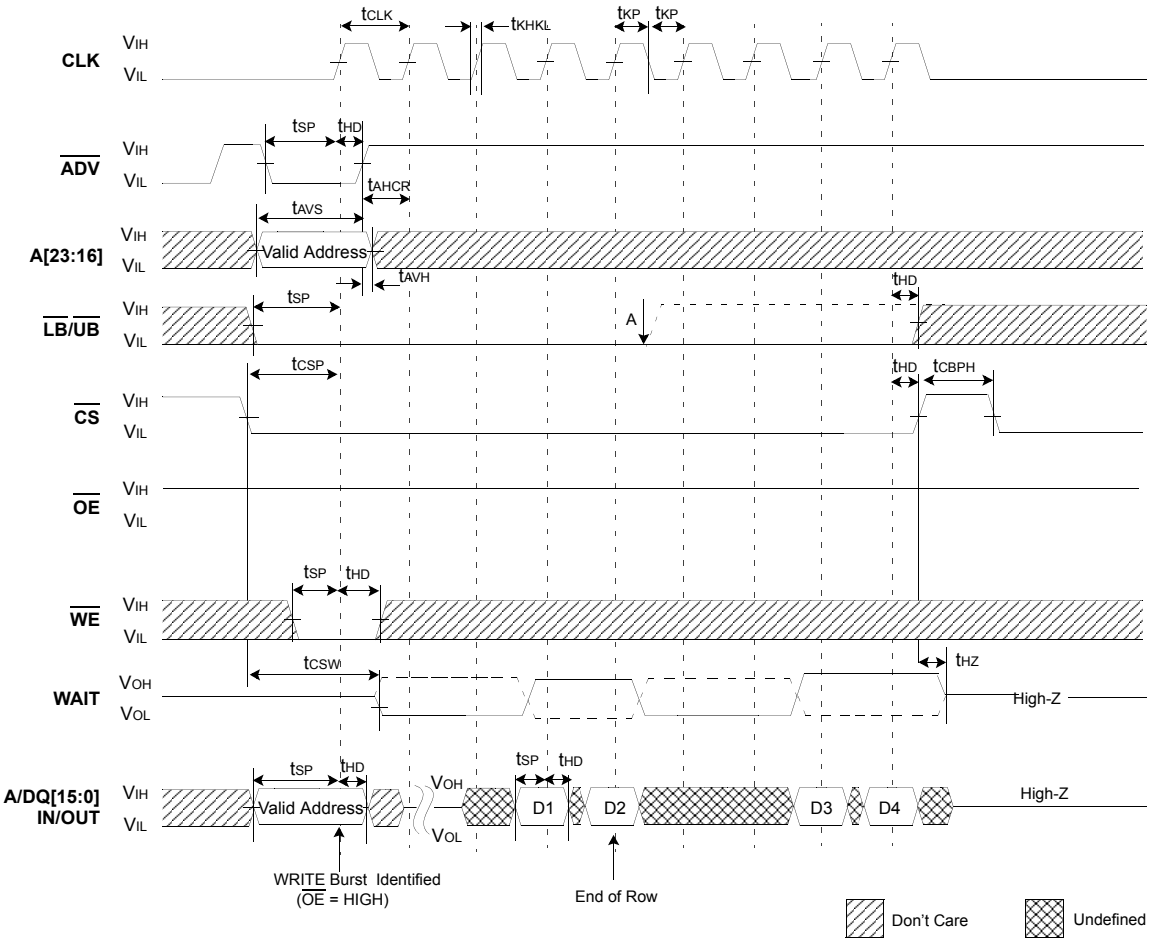
NOTE :
1) Non-default BCR settings for burst WRITE operation in variable latency mode: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay; burst length four; burst wrap enabled.
2) WAIT asserts for LC cycles for both fixed and variable latency. LC = Latency Code (BCR[13:11]).
3) Don't care must be in VIL or VIH.

15.18 Burst WRITE Operation—Fixed Latency Mode



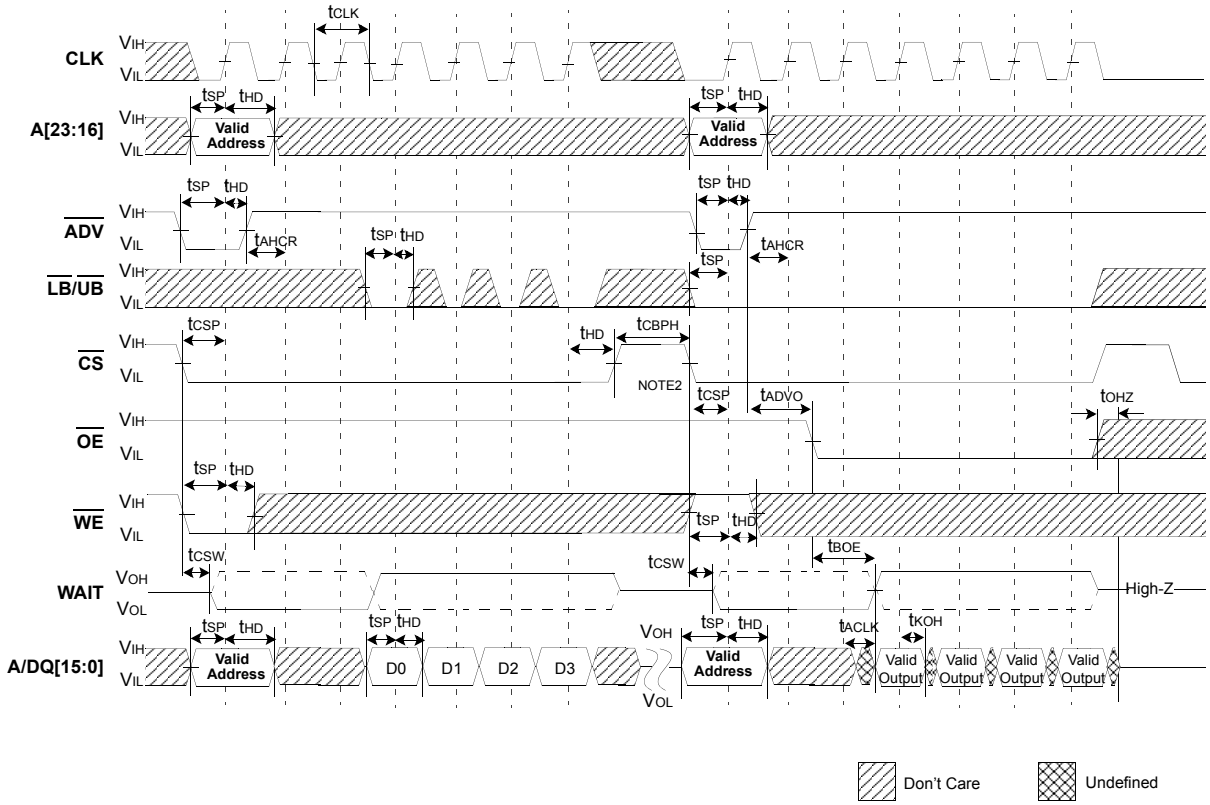
NOTE :
1) Non-default BCR settings for burst WRITE operation in fixed latency mode: Fixed latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay; burst length four; burst wrap enabled.
2) WAIT asserts for LC cycles for both fixed and variable latency. LC = Latency Code (BCR[13:11]).
3) Don't care must be in VIL or VIH.

15.19 4-Word Burst WRITE Operation - Row Boundary Crossing



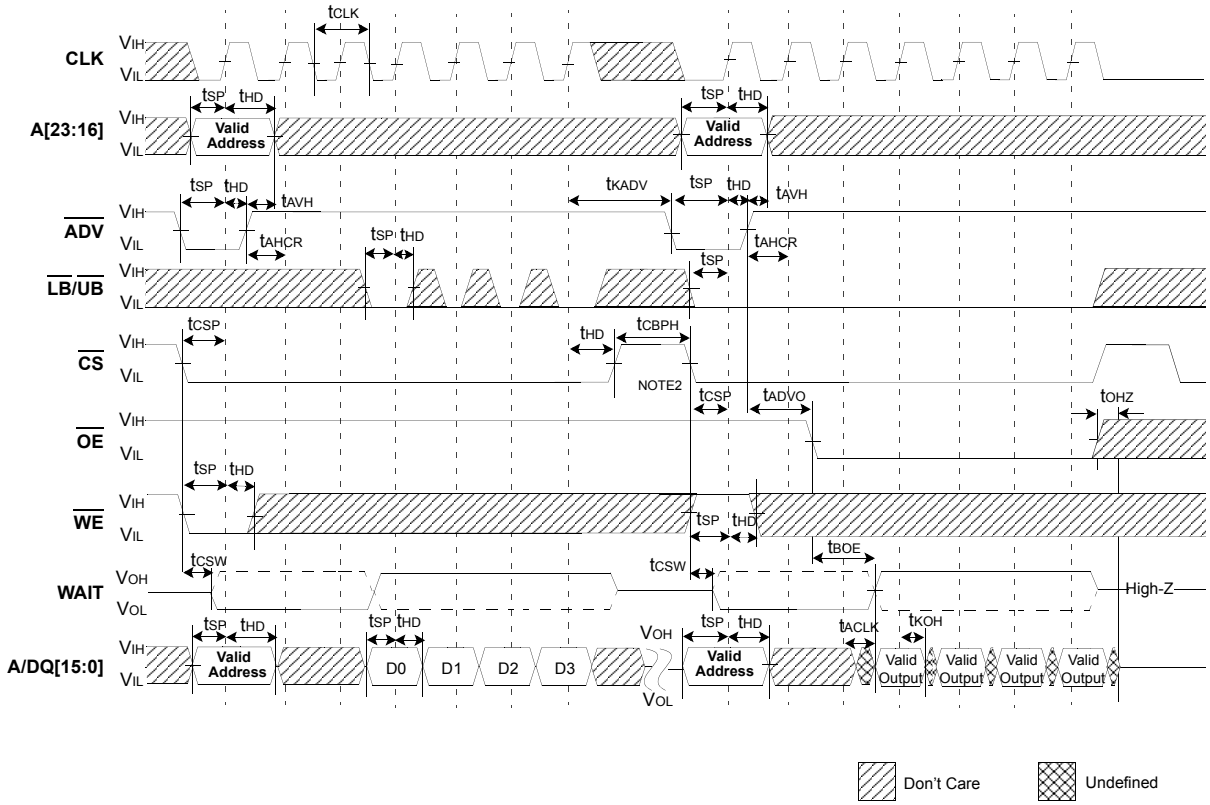
NOTE :
1) Non-default BCR settings: Fixed latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) Don't care must be in VIL or VIH.
3) D2 can be written when CS goes high at Point A.
4) There is no limitation for CS high time during Row Boundary Crossing.
6) There is no ADV low during Row Boundary Crossing.

15.20 Burst WRITE Followed by Burst READ, Variable Latency



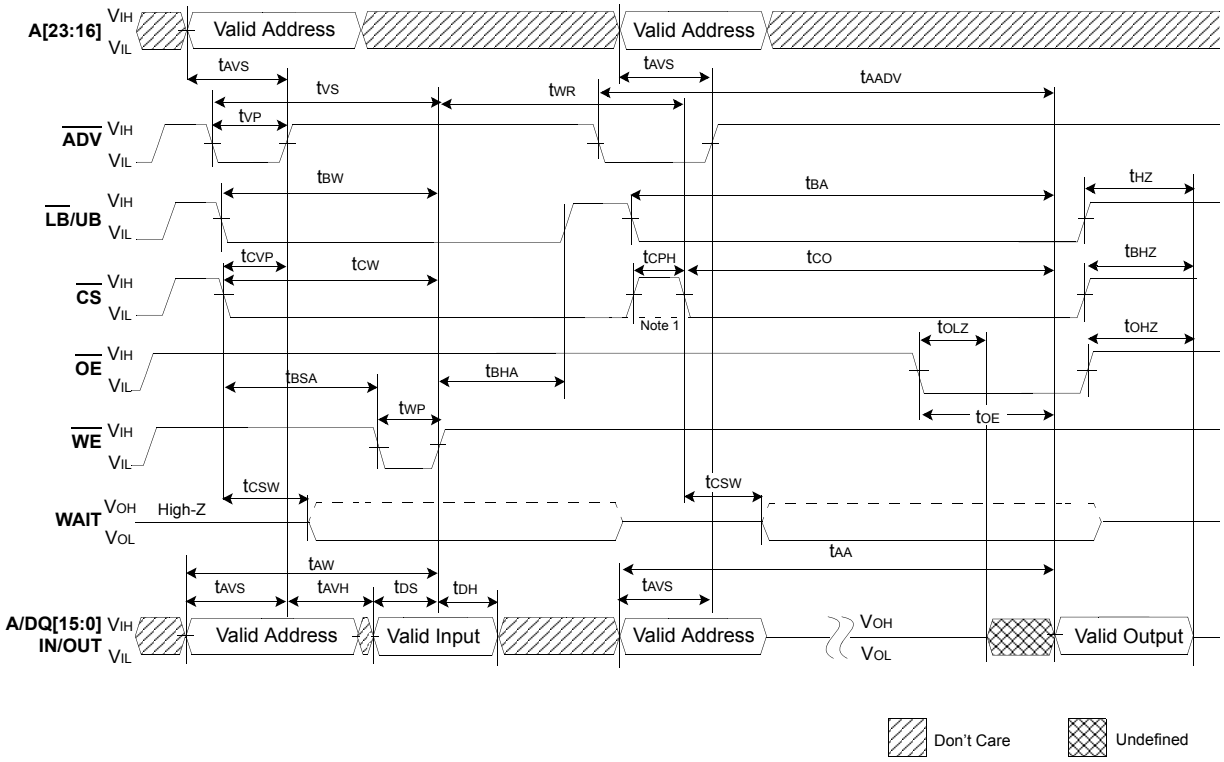
NOTE :
1) Non-default BCR settings for burst WRITE followed by burst READ: Variable latency; latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2) A refresh opportunity must be provided every tCSM by taking $\overline{CS}$ HIGH.
3) Don't care must be in VIL or VIH.

15.21 Burst WRITE Followed by Burst READ, Fixed Latency



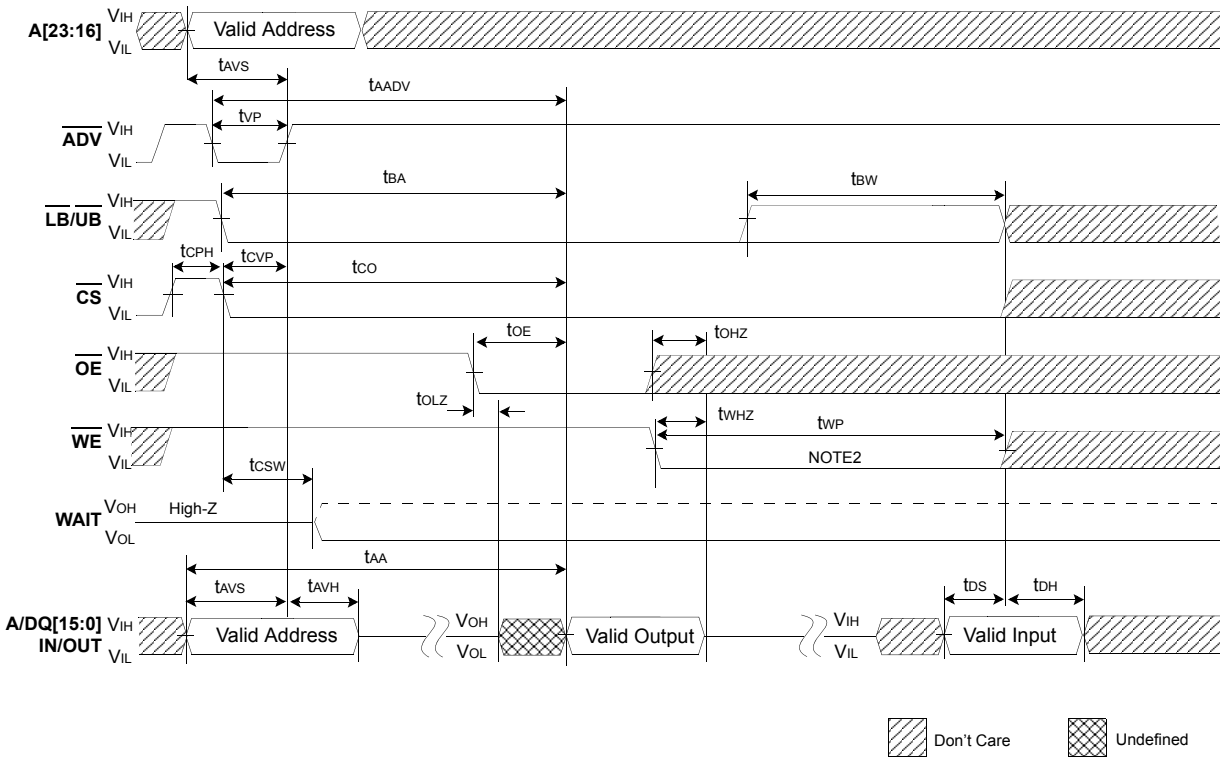
NOTE :
1) Non-default BCR settings for burst WRITE followed by burst READ: fixed latency; latency code two (three clocks); WAIT active LOW; WAIT asseted during delay.
2) A refresh opportunity must be provided every tCSM by taking $\overline{CS}$ HIGH.
3) Don't care must be in VIL or VIH.

15.22 Asynchronous WRITE Followed by Asynchronous READ



NOTE :
1) $\overline{CS}$ can stay LOW when transitioning between asynchronous operations. If $\overline{CS}$ goes HIGH, it must remain HIGH for at least tCPH to schedule the appropriate internal refresh operation.
2) Don't care must be in VIL or VIH.

15.23 Asynchronous READ Followed by WRITE at the Same Address



NOTE :
1) The end of the WRITE cycle is controlled by $\overline{CS}$, $\overline{LB}$/$\overline{UB}$, or $\overline{WE}$, whichever de-asserts first.
2) $\overline{WE}$ must not remain LOW longer than 2.5μs (tCSM) while the device is selected ($\overline{CS}$ LOW).
3) Don't care must be in VIL or VIH.