Async/Page/Burst CellularRAM™ Memory

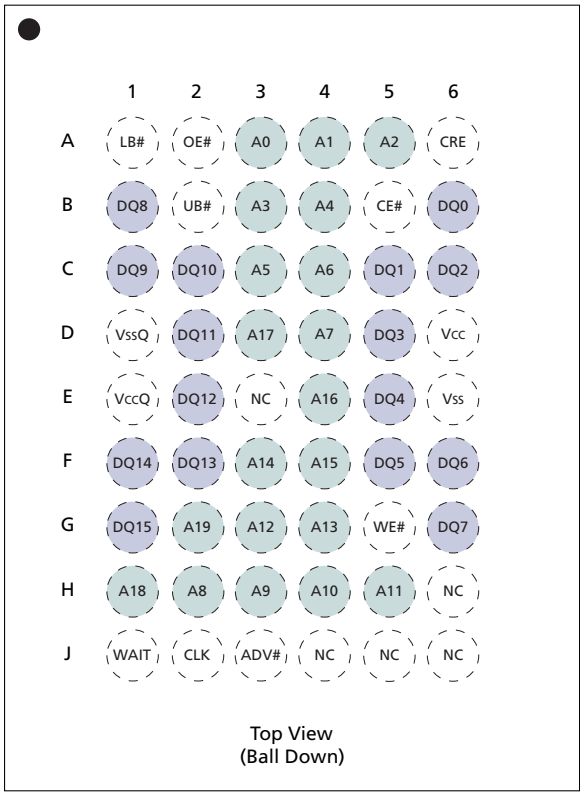
MT45W1MW16BDGB

Features

- Single device supports asynchronous, page, and burst operations
- Random access time: 70ns
- VCC, VCCQ voltages:
  - 1.7–1.95V VCC
  - 1.7–3.6V[1] VCCQ
- Page mode read access
  - Sixteen-word page size
  - Interpage read access: 70ns
  - Intrapage read access: 20ns
- Burst mode write access: continuous burst
- Burst mode read access:
  - 4, 8, or 16 words, or continuous burst
  - MAX clock rate: 104 MHz (^{t}CLK = 9.62ns)
  - Burst initial latency: 39ns (4 clocks) @ 104 MHz
  - ^{t}ACLK: 7ns @ 104 MHz
- Low power consumption
  - Asynchronous read: <20mA
  - Intrapage read: <15mA
  - Intrapage read initial access, burst read:
  - (39ns [4 clocks] @ 104 MHz) < 35mA
  - Continuous burst read: <28mA
  - Standby: 70µA
  - Deep power-down: <10µA (TYP @ 25°C)
- Low-power features
  - Temperature-compensated refresh (TCR)
  - On-chip temperature sensor
  - Partial-array refresh (PAR)
  - Deep power-down (DPD) mode

Options	Designator
• Configuration	
– 1 Meg x 16	MT45W1MW16BD
• Package	
– 54-ball VFBGA (“green”)	GB
• Access time	
– 70ns access	-70
• Frequency	
– 80 MHz	8
– 104 MHz	1

Figure 1: 54-Ball VFBGA



Options (continued)	Designator
• Standby power	
– Standard	None
• Operating temperature range	
– Wireless (–30°C to +85°C)	WT[1]
– Industrial (–40°C to +85°C)	IT[2]

Notes: 1. 3.6V I/O and –30°C exceed the CellularRAM Workgroup 1.0 specifications.
2. Contact factory.

Part Number Example:

MT45W1MW16BDGB-701WT

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General Description

Micron® CellularRAM™ is a high-speed, CMOS PSRAM memory device developed for low-power, portable applications. The MT45W1MW16BDGB is a 16Mb DRAM core device organized as 1 Meg x 16 bits. This device includes an industry-standard burst mode Flash interface that dramatically increases read/write bandwidth compared with other low-power SRAM or Pseudo SRAM offerings.

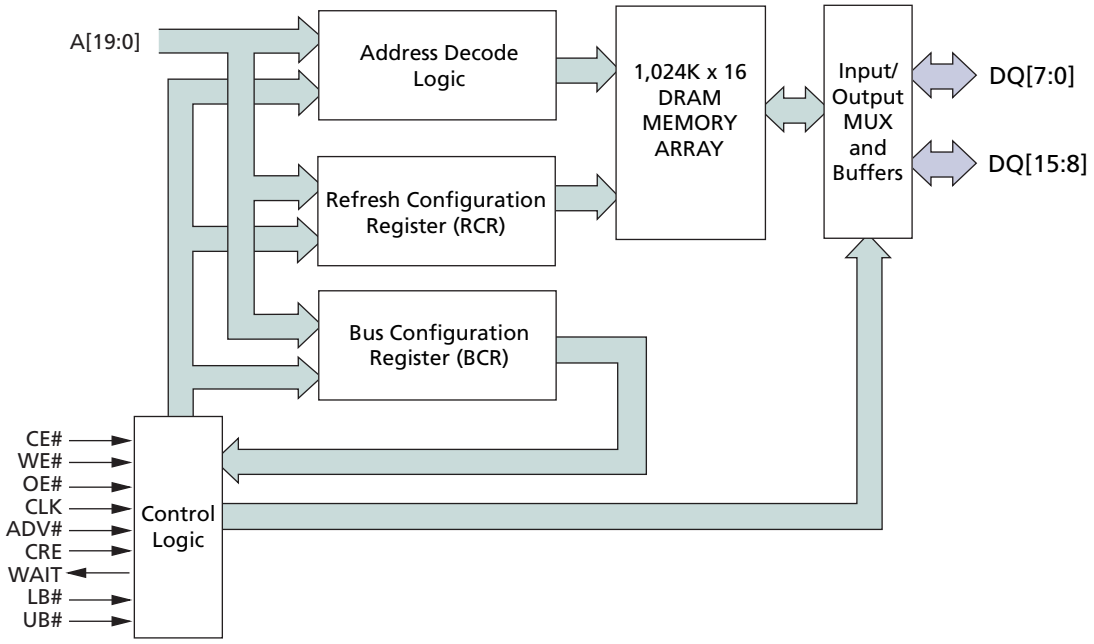
For seamless operation on a burst Flash bus, CellularRAM products incorporate a transparent self-refresh mechanism. The hidden refresh requires no additional support from the system memory controller and has no significant impact on device read/write performance.

Two user-accessible control registers define device operation. The bus configuration register (BCR) defines how the CellularRAM device interacts with the system memory bus and is nearly identical to its counterpart on burst mode Flash devices. The refresh configuration register (RCR) is used to control how refresh is performed on the DRAM array. These registers are automatically loaded with default settings during power-up and can be updated anytime during normal operation.

Special attention has been focused on standby current consumption during self refresh. CellularRAM products include three system-accessible mechanisms to minimize standby current. Partial-array refresh (PAR) limits refresh to only that part of the DRAM array that contains essential data. Temperature-compensated refresh (TCR) uses an on-chip sensor to adjust the refresh rate to match the device temperature. The refresh rate decreases at lower temperatures to minimize current consumption during standby. TCR can also be set by the system for maximum device temperatures of +85°C, +45°C, and +15°C. Deep power-down (DPD) halts the REFRESH operation altogether and is used when no vital information is stored in the device. These three refresh mechanisms are accessed through the RCR.

Functional Block Diagrams

Figure 2: Functional Block Diagram – 1 Meg x 16



Note: Functional block diagrams illustrate simplified device operation. See truth table, ball descriptions, and timing diagrams for detailed information.

Ball Descriptions

Table 1: VFBGA Ball Descriptions

VFBGA Assignment	Symbol	Type	Description
G2, H1, D3, E4, F4, F3, G4, G3, H5, H4, H3, H2, D4, C4, C3, B4, B3, A5, A4, A3	A[19:0]	Input	Address inputs: Inputs for addresses during READ and WRITE operations. Addresses are internally latched during READ and WRITE cycles. The address lines are also used to define the value to be loaded into the bus configuration register or the refresh configuration register.
J2	CLK	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 ADV# is active. CLK is static LOW or HIGH during asynchronous access READ and WRITE operations and during PAGE READ ACCESS operations.
J3	ADV#	Input	Address valid: Indicates that a valid address is present on the address inputs. Addresses can be latched on the rising edge of ADV# during asynchronous READ and WRITE operations. ADV# can be held LOW during asynchronous READ and WRITE operations.
A6	CRE	Input	Configuration register enable: When CRE is HIGH, WRITE operations load the refresh configuration register or bus configuration register.
B5	CE#	Input	Chip enable: Activates the device when LOW. When CE# is HIGH, the device is disabled and goes into standby or deep power-down mode.
A2	OE#	Input	Output enable: Enables the output buffers when LOW. When OE# is HIGH, the output buffers are disabled.
G5	WE#	Input	Write enable: Determines if a given cycle is a WRITE cycle. If WE# is LOW, the cycle is a WRITE to either a configuration register or to the memory array.
A1	LB#	Input	Lower byte enable: DQ[7:0].
B2	UB#	Input	Upper byte enable: DQ[15:8].
G1, F1, F2, E2, D2, C2, C1, B1, G6, F6, F5, E5, D5, C6, C5, B6	DQ[15:0]	Input/ Output	Data inputs/outputs.
J1	WAIT	Output	Wait: Provides data-valid feedback during burst READ and WRITE operations. The signal is gated by CE#. WAIT is used to arbitrate collisions between REFRESH and READ/WRITE operations. WAIT is asserted when a burst crosses a row boundary. WAIT is also used to mask the delay associated with opening a new internal page. WAIT is asserted and should be ignored during asynchronous and page mode operations. WAIT is High-Z when CE# is HIGH.
E3, H6, J4, J5, J6	NC	–	Not internally connected.
D6	V_{CC}	Supply	Device power supply (1.7–1.95V): Power supply for device core operation.
E1	V_{CCQ}	Supply	I/O power supply (1.7–3.6V): Power supply for input/output buffers.
E6	V_{SS}	Supply	V_{SS} must be connected to ground.
D1	V_{SSQ}	Supply	V_{SSQ} must be connected to ground.

Note: The CLK and ADV# inputs can be tied to V_{SS} if the device is always operating in asynchronous or page mode. WAIT will be asserted but should be ignored during asynchronous and page mode operations.

Bus Operations

Table 2: Bus Operations – Asynchronous Mode

Mode	Power	CLK[1]	ADV#	CE#	OE#	WE#	CRE	LB#/ UB#	WAIT[2]	DQ[15:0][3]	Notes
Read	Active	L	L	L	L	H	L	L	Low-Z	Data-Out	4
Write	Active	L	L	L	X	L	L	L	Low-Z	Data-In	4
Standby	Standby	L	X	H	X	X	L	X	High-Z	High-Z	5, 6
No operation	Idle	L	X	L	X	X	L	X	Low-Z	X	4, 6
Configuration Register	Active	L	L	L	H	L	H	X	Low-Z	High-Z	
DPD	Deep power-down	L	X	H	X	X	X	X	High-Z	High-Z	7

Table 3: Bus Operations – Burst Mode

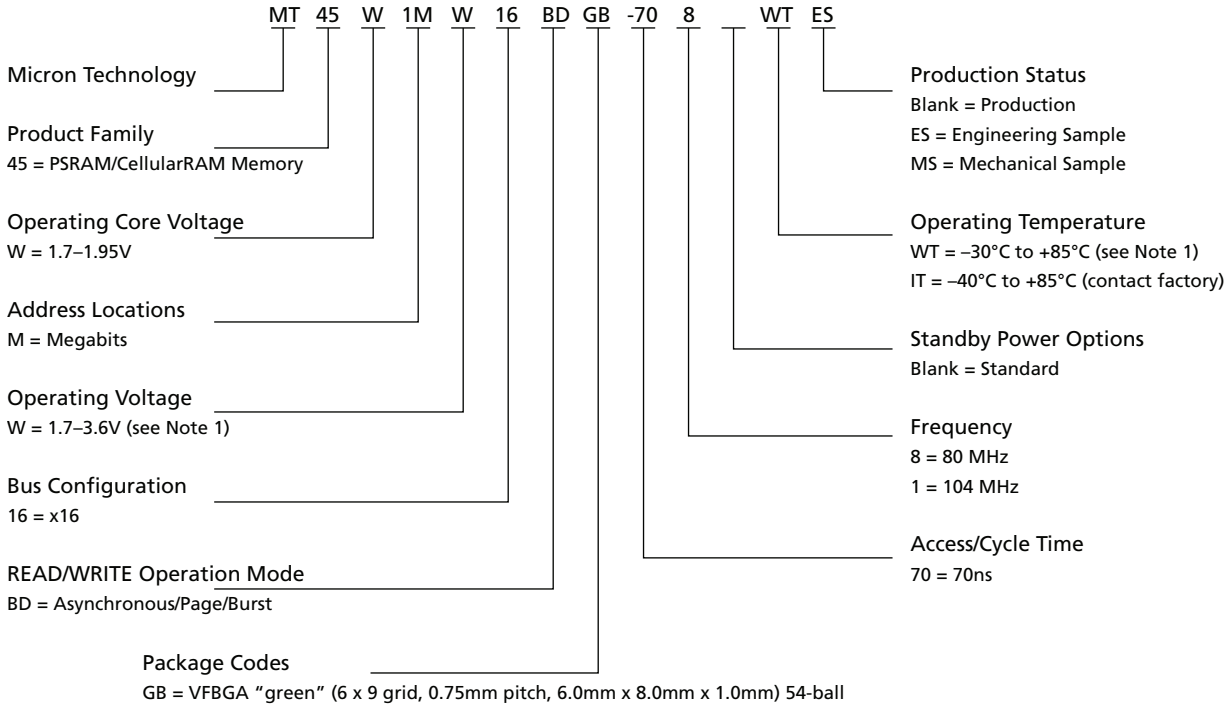
Mode	Power	CLK[1]	ADV#	CE#	OE#	WE#	CRE	LB#/ UB#	WAIT[2]	DQ[15:0][3]	Notes
Async read	Active	L	L	L	L	H	L	L	Low-Z	Data-Out	4
Async write	Active	L	L	L	X	L	L	L	Low-Z	Data-In	4
Standby	Standby	L	X	H	X	X	L	X	High-Z	High-Z	5, 6
No operation	Idle	L	X	L	X	X	L	X	Low-Z	X	4, 6
Initial burst read	Active		L	L	X	H	L	L	Low-Z	X	4, 8
Initial burst write	Active		L	L	H	L	L	X	Low-Z	X	4, 8
Burst continue	Active		H	L	X	X	X	L	Low-Z	Data-In or Data-Out	4, 8
Burst suspend	Active	X	X	L	H	X	L	X	Low-Z	High-Z	4, 8
Configuration register	Active		L	L	H	L	H	X	Low-Z	High-Z	8
DPD	Deep power-down	L	X	H	X	X	X	X	High-Z	High-Z	7

Notes:
1. CLK must be LOW during async read and async write modes, and to achieve standby power during standby and DPD modes. CLK must be static (HIGH or LOW) during burst suspend.
2. The WAIT polarity is configured through the bus configuration register (BCR[10]).
3. When LB# and UB# are in select mode (LOW), DQ[15:0] are affected. When only LB# is in select mode, DQ[7:0] are affected. When only UB# is in the select mode, DQ[15:8] are affected.
4. The device will consume active power in this mode whenever addresses are changed.
5. When the device is in standby mode, address inputs and data inputs/outputs are internally isolated from any external influence.
6. V_{IN} = V_{CCQ} or 0V; all device balls must be static (unswitched) in order to achieve standby current.
7. DPD is maintained until RCR is reconfigured.
8. Burst mode operation is initialized through the bus configuration register (BCR[15]).

Part Numbering Information

Micron CellularRAM devices are available in several different configurations and densities (see Figure 3).

Figure 3: Part Number Chart



Notes: 1. 3.6V I/O and –30°C exceed the CellularRAM Workgroup 1.0 specifications.

Valid Part Number Combinations

After building the part number from the part numbering chart above, visit to the Micron Part Marking Decoder Web site at www.micron.com/partsearch to verify that the part number is offered and valid. If the device required is not on this list, contact the factory.

Device Marking

Due to the size of the package, the Micron standard part number is not printed on the top of the device. Instead, an abbreviated device mark comprised of a five-digit alphanumeric code is used. The abbreviated device marks are cross-referenced to the Micron part numbers at www.micron.com/partsearch. To view the location of the abbreviated mark on the device, refer to customer service note, CSN-11, "Product Mark/Label" at www.micron.com/csn.

Functional Description

In general, the MT45W1MW16BDGB devices are high-density alternatives to SRAM and Pseudo SRAM products, popular in low-power, portable applications.

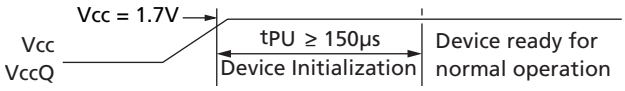
The MT45W1MW16BDGB contains a 16,777,216-bit DRAM core organized as 1,048,576 addresses by 16 bits. This device implements the same high-speed bus interface found on burst mode Flash products.

The CellularRAM bus interface supports both asynchronous and burst mode transfers. Page mode accesses are also included as a bandwidth-enhancing extension to the asynchronous read protocol.

Power-Up Initialization

CellularRAM products include an on-chip voltage sensor used to launch the power-up initialization process. Initialization will configure the BCR and the RCR with their default settings (see Figure 17 on page 23 and Figure 22 on page 27). VCC and VCCQ must be applied simultaneously. When they reach a stable level at or above 1.7V, the device will require 150µs to complete its self-initialization process. During the initialization period, CE# should remain HIGH. When initialization is complete, the device is ready for normal operation.

Figure 4: Power-Up Initialization Timing



Bus Operating Modes

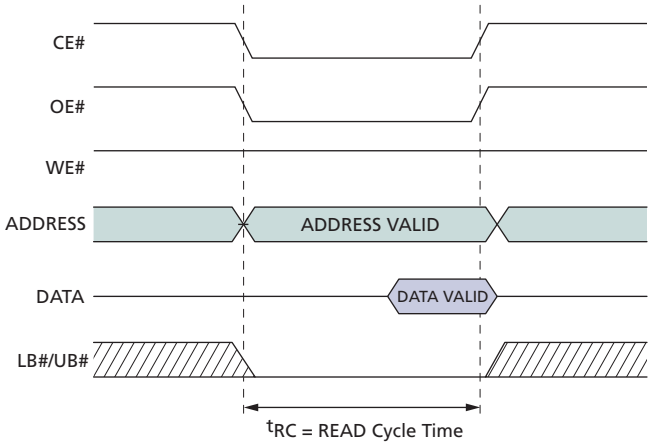
The MT45W1MW16BDGB CellularRAM products incorporate a burst mode interface found on Flash products targeting low-power, wireless applications. This bus interface supports asynchronous, page mode, and burst mode read and write transfers. The specific interface supported is defined by the value loaded into the bus configuration register. Page mode is controlled by the refresh configuration register (RCR[7]).

Asynchronous Mode

CellularRAM products power up in the asynchronous operating mode. This mode uses the industry-standard SRAM control bus (CE#, OE#, WE#, LB#/UB#). READ operations (Figure 5) are initiated by bringing CE#, OE#, and LB#/UB# LOW while keeping WE# HIGH. Valid data will be driven out of the I/Os after the specified access time has elapsed. WRITE operations (Figure 6 on page 11) occur when CE#, WE#, and LB#/UB# are driven LOW. During asynchronous WRITE operations, the OE# level is a “Don't Care,” and WE# will override OE#. The data to be written is latched on the rising edge of CE#, WE#, or LB#/UB# (whichever occurs first). Asynchronous operations (page mode disabled) can either use the ADV input to latch the address, or ADV can be driven LOW during the entire READ/WRITE operation.

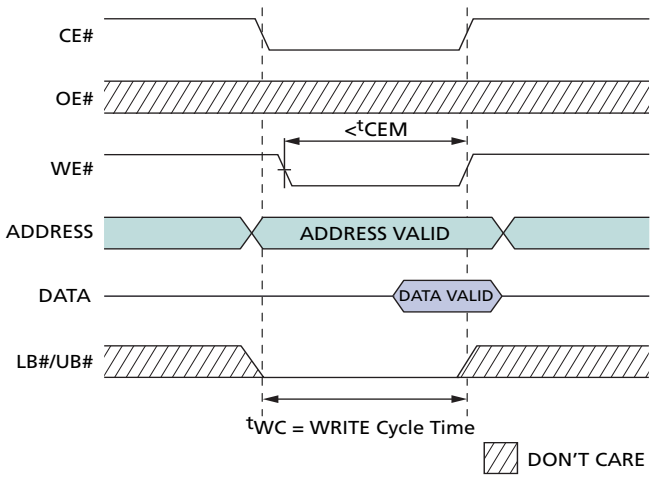
During asynchronous operation, the CLK input must be held static LOW or HIGH. WAIT will be driven while the device is enabled and its state should be ignored. WE# LOW time must be limited to ^{t}CEM.

Figure 5: READ Operation (ADV = LOW)



Note: ADV must remain LOW for page mode operation.

Figure 6: WRITE Operation (ADV = LOW)



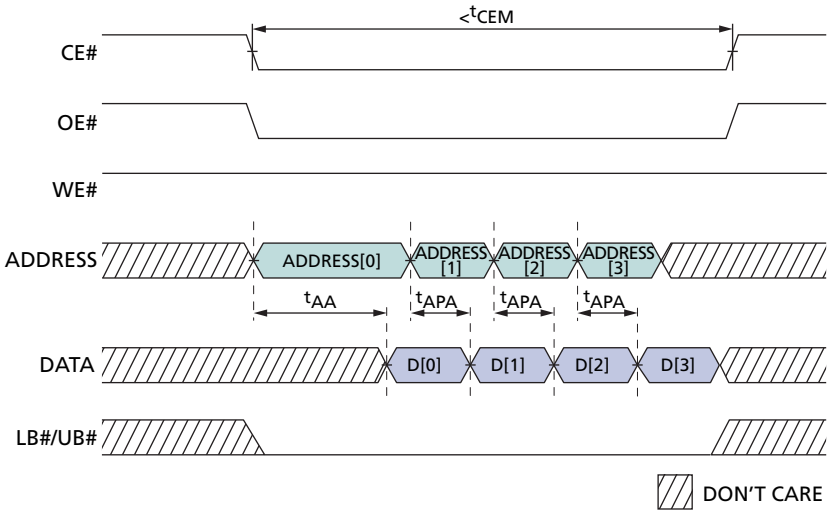
Page Mode READ Operation

Page mode is a performance-enhancing extension to the legacy asynchronous READ operation. In page-mode-capable products, an initial asynchronous read access is performed, then adjacent addresses can be read quickly by simply changing the low-order address. Addresses A[3:0] are used to determine the members of the 16-address CellularRAM page. Any change in addresses A[4] or higher will initiate a new ^{t}AA access time. Figure 7 shows the timing for a page mode access. Page mode takes advantage of the fact that adjacent addresses can be read in a shorter period of time than random addresses. WRITE operations do not include comparable page mode functionality.

During asynchronous page mode operation, the CLK input must be held static LOW or HIGH. CE# must be driven HIGH upon completion of a page mode access. WAIT will be driven while the device is enabled and its state should be ignored. Page mode is enabled by setting RCR[7] to HIGH. ADV must be driven LOW during all page mode read accesses.

The CE# LOW time is limited by refresh considerations. CE# must not stay LOW longer than ^{t}CEM.

Figure 7: Page Mode READ Operation (ADV = LOW)



Burst Mode Operation

Burst mode operations enable high-speed synchronous READ and WRITE operations. Burst operations consist of a multi-clock sequence that must be performed in an ordered fashion. After CE# goes LOW, the address to access is latched on the next rising edge of CLK that ADV# is LOW. During this first clock rising edge, WE# indicates whether the operation is going to be a READ (WE# = HIGH, Figure 8 on page 13) or WRITE (WE# = LOW, Figure 9 on page 14).

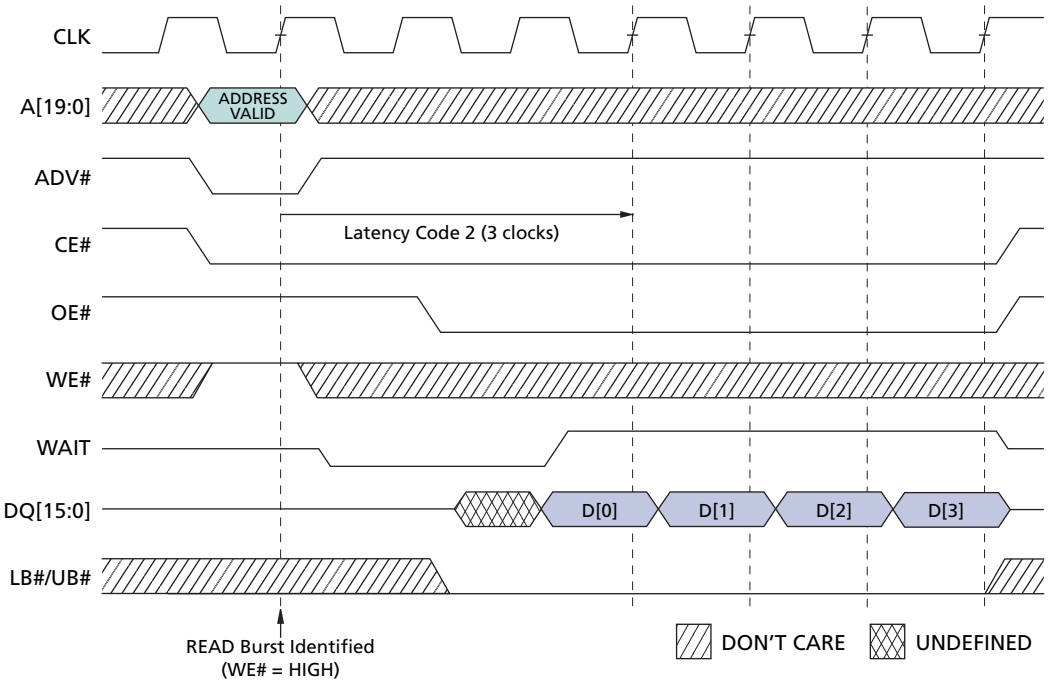
The size of a burst can be specified in the BCR as either fixed-length or continuous. Fixed-length bursts consist of four, eight, or sixteen words. Continuous bursts have the ability to start at a specified address and burst through the entire memory. The latency count stored in the BCR defines the number of clock cycles that elapse before the initial data value is transferred between the processor and CellularRAM device.

The WAIT output will be asserted as soon as CE# goes LOW and will be de-asserted to indicate when data is to be transferred into (or out of) the memory. WAIT will again be asserted if the burst crosses the boundary between 128-word rows. Once the CellularRAM device has restored the previous row's data and accessed the next row, WAIT will be de-asserted and the burst can continue (see Figure 33 on page 43).

The processor can access other devices without incurring the timing penalty of the initial latency for a new burst by suspending burst mode. 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, OE# should be taken HIGH to disable the CellularRAM outputs; otherwise, 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, OE# is taken LOW, then CLK is restarted after valid data is available on the bus.

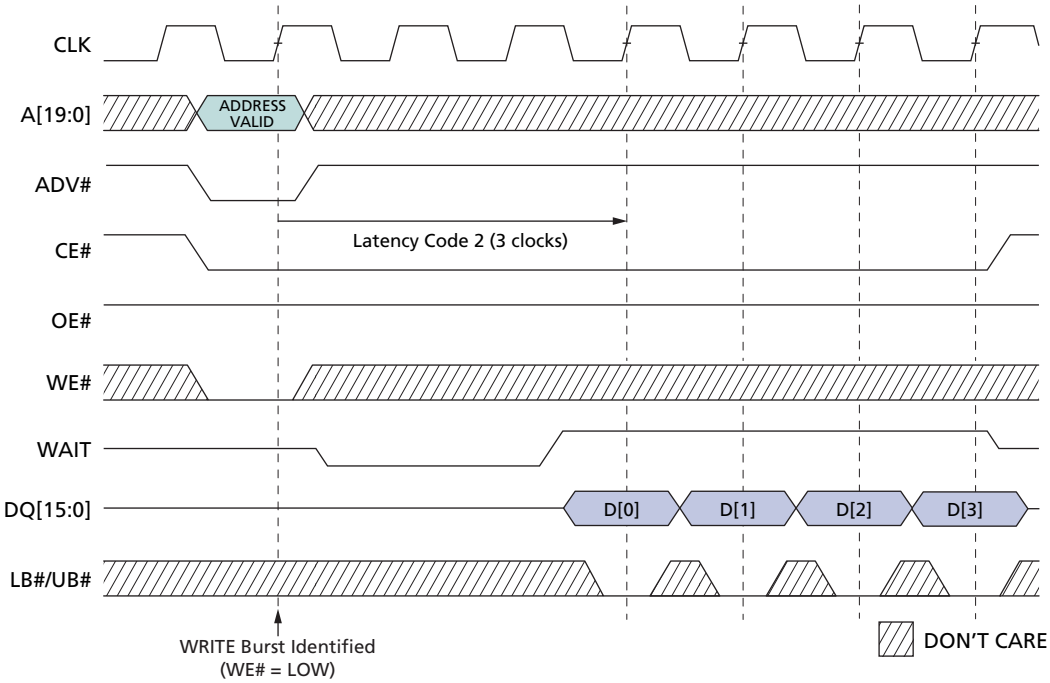
The CE# LOW time is limited by refresh considerations. CE# must not stay LOW longer than ^{t}CEM unless row boundaries are crossed at least every ^{t}CEM. If a burst suspension will cause CE# to remain LOW for longer than ^{t}CEM, CE# should be taken HIGH and the burst restarted with a new CE# LOW/ADV# LOW cycle.

Figure 8: Burst Mode READ (4-word Burst)



Note: Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Figure 9: Burst Mode WRITE (4-word Burst)



Note: Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

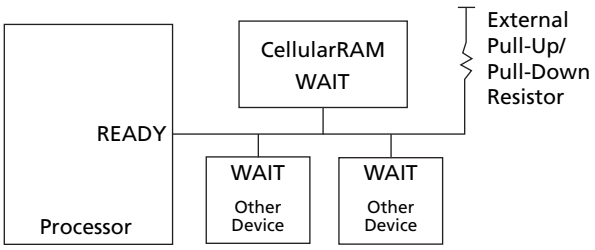
Mixed-Mode Operation

The device can support a combination of synchronous READ and asynchronous WRITE operations when the BCR is configured for synchronous operation. The asynchronous WRITE operation requires that the clock (CLK) be held static LOW or HIGH during the entire sequence. The ADV# signal can be used to latch the target address, or it can remain LOW during the entire WRITE operation. CE# must return HIGH when transitioning between mixed-mode operations. Note that the ^{t}CKA period is the same as a READ or WRITE cycle. This time is required to ensure adequate refresh. Mixed-mode operation facilitates a seamless interface to legacy burst mode Flash memory controllers. See Figure 41 on page 51.

WAIT Operation

The WAIT output on a CellularRAM device is typically connected to a shared, system-level WAIT signal (see Figure 10). The shared WAIT signal is used by the processor to coordinate transactions with multiple memories on the synchronous bus.

Figure 10: Wired-OR WAIT Configuration



Once a READ or WRITE operation has been initiated, WAIT goes active to indicate that the CellularRAM device requires additional time 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 the CellularRAM device. When WAIT transitions to an inactive state, the data burst will progress on successive clock edges.

During a Burst cycle, CE# must remain asserted until the first data is valid. Bringing CE# HIGH during this initial latency may cause data corruption.

The WAIT output also performs an arbitration role when a READ or WRITE operation is 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 (see Figures 11 and 12 on page 17). When the refresh operation has completed, the READ or WRITE operation will continue normally.

WAIT is also asserted when a continuous READ or WRITE burst crosses a row boundary. The WAIT assertion allows time for the new row to be accessed and permits any pending refresh operations to be performed.

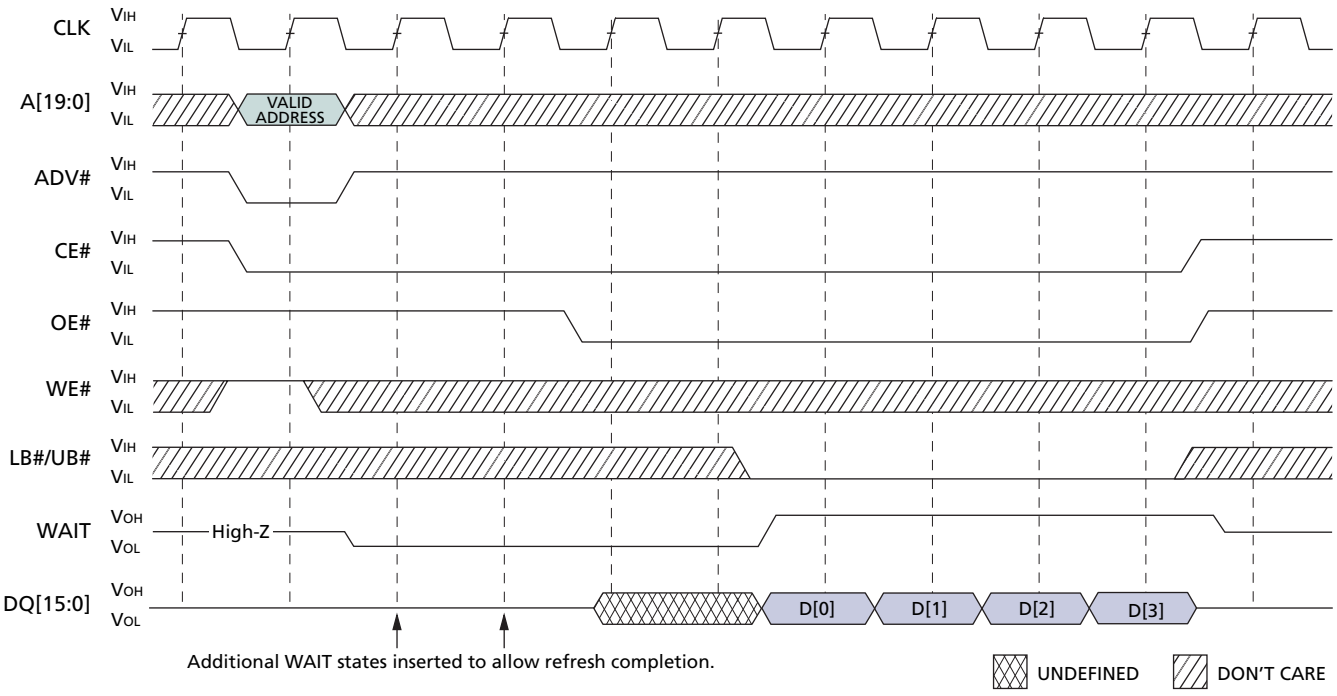
LB#/UB# Operation

The LB# enable and UB# enable signals support byte-wide data transfers. During READ operations, the enabled byte(s) are driven onto the DQ. The DQ associated with a disabled byte are put into a High-Z state during a READ operation. During WRITE opera-

tions, 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 CE#, WE#, LB#, or UB#, whichever occurs first.

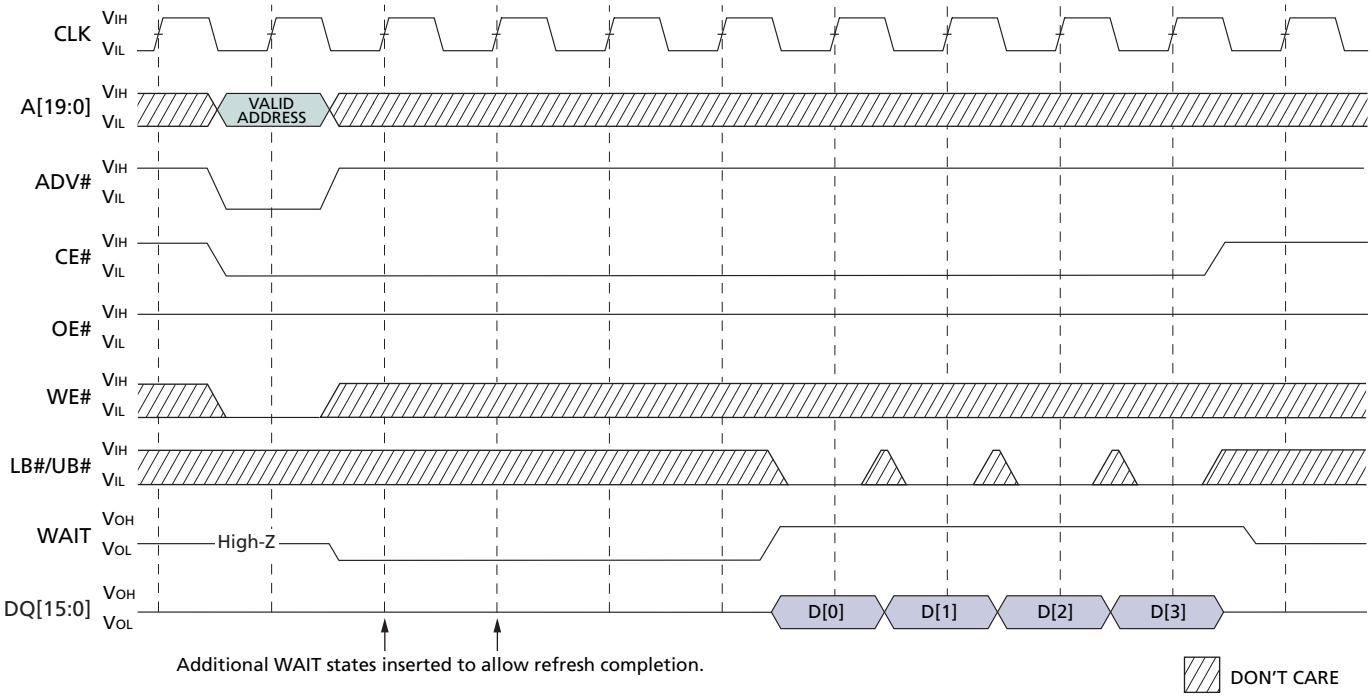
When both the LB# and UB# are disabled (HIGH) during an operation, the device will disable the data bus from receiving or transmitting data. Although the device will seem to be deselected, it remains in an active mode as long as CE# remains LOW.

Figure 11: Refresh Collision During READ Operation



Note: Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Figure 12: Refresh Collision During WRITE Operation



Note: Non-default BCR settings: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Low-Power Operation

Standby Mode Operation

During standby, the device current consumption is reduced to the level necessary to perform the DRAM refresh operation. Standby operation occurs when CE# is HIGH.

The device will enter a reduced power state upon completion of a READ or WRITE operation or when the address and control inputs remain static for an extended period of time. This mode will continue until a change occurs to the address or control inputs.

Temperature-Compensated Refresh

Temperature-compensated refresh (TCR) allows for adequate refresh at different temperatures. This CellularRAM device includes an on-chip temperature sensor. When the sensor is enabled, it continually adjusts the refresh rate according to the operating temperature. The on-chip sensor is enabled by default.

Three fixed refresh rates are also available, corresponding to temperature thresholds of +15°C, +45°C, and +85°C. The setting selected must be for a temperature higher than the case temperature of the CellularRAM device. If the case temperature is +35°C, the system can minimize self refresh current consumption by selecting the +45°C setting. The +15°C setting would result in inadequate refreshing and cause data corruption.

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 (see Table 6 on page 28). 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.

Deep Power-Down Operation

Deep power-down (DPD) operation disables all refresh-related activity. This mode is used if the system does not require the storage provided by the CellularRAM device. Any stored data will become corrupted when DPD is enabled. When refresh activity has been re-enabled by rewriting the RCR, the CellularRAM device will require 150µs to perform an initialization procedure before normal operations can resume. During this 150µs period, the current consumption will be higher than the specified standby levels, but considerably lower than the active current specification.

DPD cannot be enabled or disabled by writing to the RCR using the software access sequence; the RCR should be accessed using CRE instead.

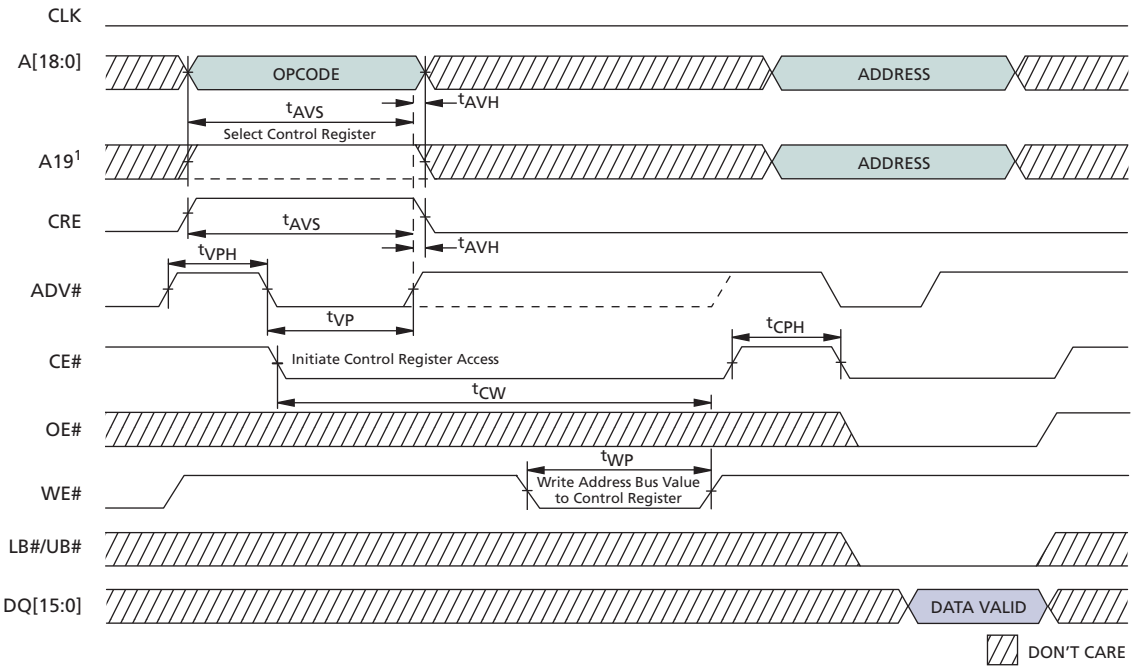
Configuration Registers

Two user-accessible configuration registers define the device operation. The bus configuration register (BCR) defines how the CellularRAM interacts with the system memory bus and is nearly identical to its counterpart on burst mode Flash devices. The refresh configuration register (RCR) is used to control how refresh is performed on the DRAM array. These registers are automatically loaded with default settings during power-up and can be updated any time the devices are operating in a standby state.

Access Using CRE

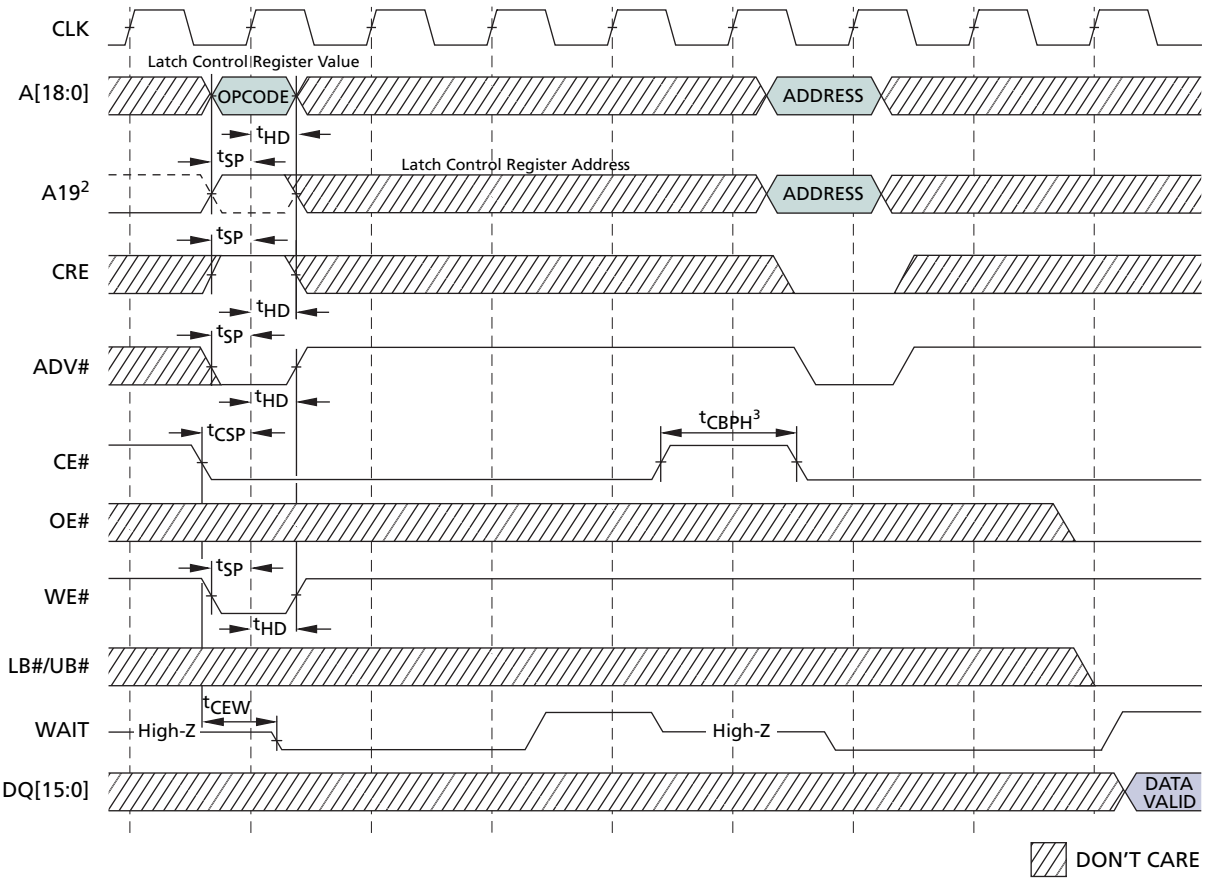
The configuration registers are loaded using either a synchronous or an asynchronous WRITE operation when the configuration register enable (CRE) input is HIGH (see Figure 13 on page 19 and Figure 14 on page 20). When CRE is LOW, a READ or WRITE operation will access the memory array. The register values are placed on address pins A[19:0]. In an asynchronous WRITE, the values are latched into the configuration register on the rising edge of ADV#, CE#, or WE#, whichever occurs first; LB# and UB# are "Don't Care." Access using CRE is WRITE only. The BCR is accessed when A[19] is HIGH; the RCR is accessed when A[19] is LOW.

Figure 13: Configuration Register WRITE in Asynchronous Mode Followed by READ ARRAY Operation



Note: A[19] = LOW to load RCR; A[19] = HIGH to load BCR.

Figure 14: Configuration Register WRITE in Synchronous Mode Followed by READ ARRAY Operation



Notes:
1. Non-default BCR settings for CR WRITE in synchronous mode followed by READ ARRAY operation: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2. A[19] = LOW to load RCR; A[19] = HIGH to load BCR.
3. CE# 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 CE# LOW cycles.

Software Access

Software access of the configuration registers uses a sequence of asynchronous READ and asynchronous WRITE operations. The contents of the configuration registers can be read or modified 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 (see Figure 15). The read sequence is virtually identical except that an asynchronous READ is performed during the fourth operation (see Figure 16). Note that a third READ cycle of the highest address will cancel the access sequence until a different address is read.

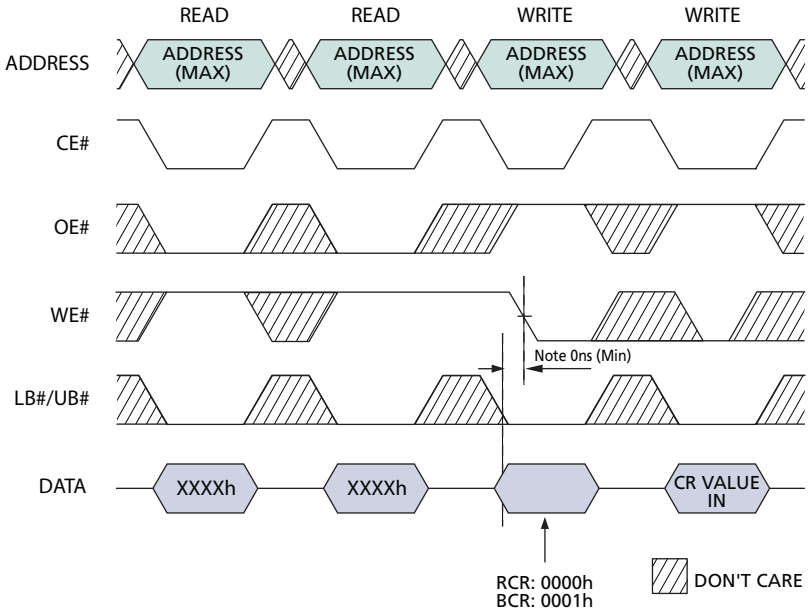
The address used during all READ and WRITE operations is the highest address of the CellularRAM device being accessed (FFFFFh for 16Mb); the content at this address is not changed by using this sequence.

The data value presented during the third operation (WRITE) in the sequence defines whether the BCR or the RCR 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. During the fourth operation, DQ[15:0] transfer data into or out of bits 15–0 of the configuration 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 the control register enable (CRE) pin. If the software mechanism is used, the CRE pin can simply be tied to Vss. The port line often used for CRE control purposes is no longer required.

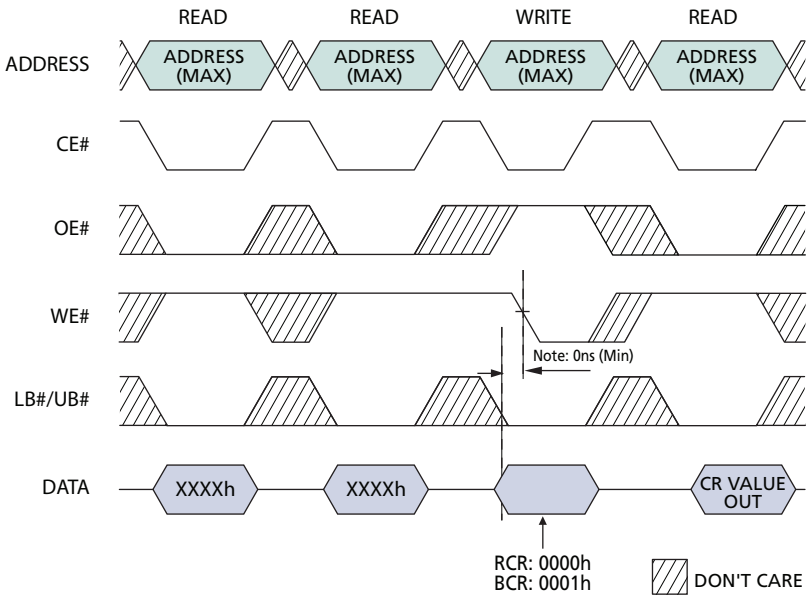
Software access of the RCR should not be used to enter or exit DPD.

Figure 15: Load Configuration Register



Note: If the data present when WE# falls is not 0000h or 0001h, it is possible that the maximum address will be overwritten.

Figure 16: Read Configuration Register



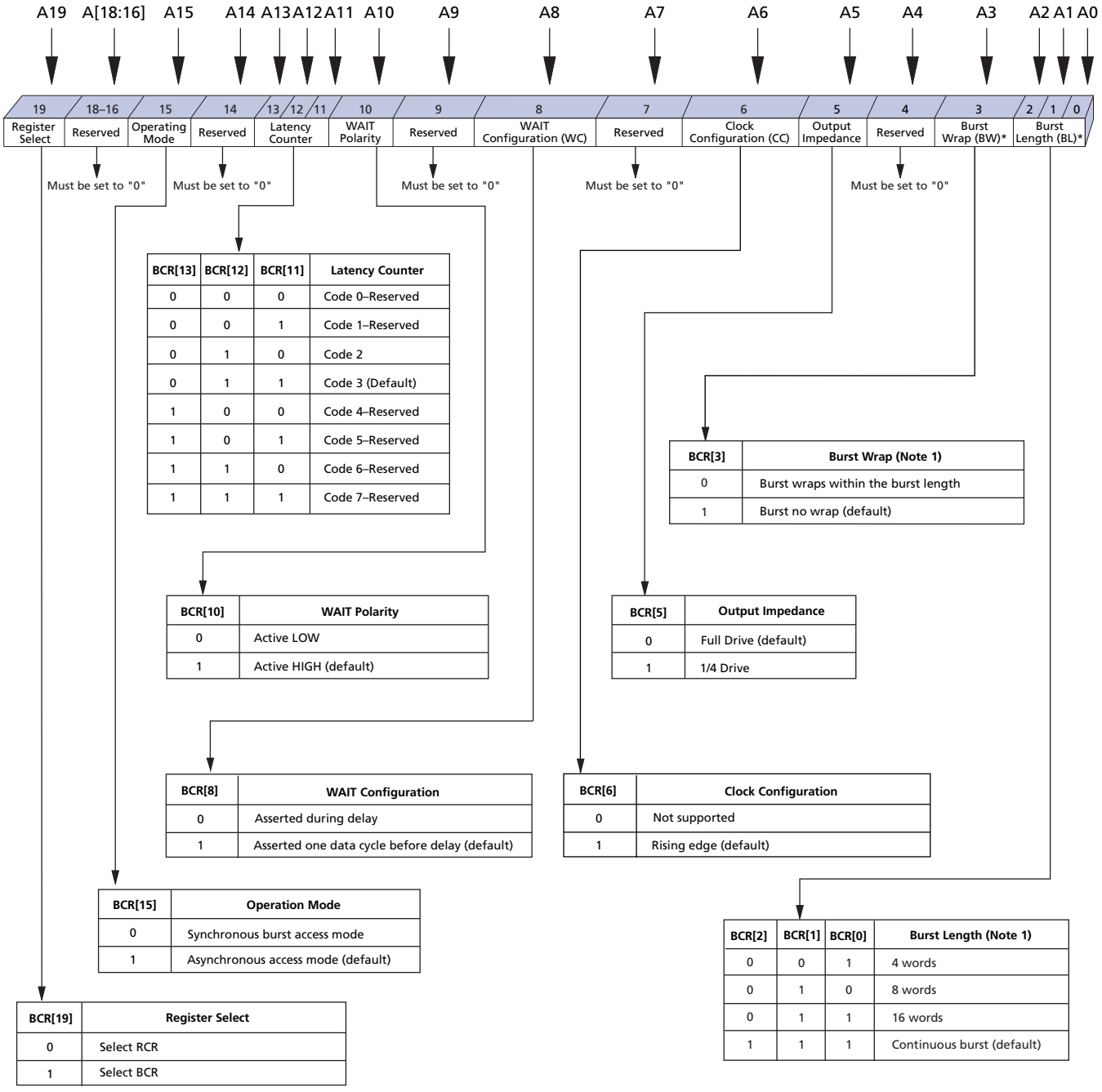
Note: If the data present when WE# falls is not 0000h or 0001h, it is possible that the maximum address will be overwritten.

Bus Configuration Register

The BCR defines how the CellularRAM device interacts with the system memory bus. Page mode operation is enabled by a bit contained in the RCR. Figure 17 describes the control bits in the BCR. At power-up, the BCR is set to 9D4Fh.

The BCR is accessed using CRE and A[19] HIGH or through the configuration register software sequence with DQ = 0001h on the third cycle.

Figure 17: Bus Configuration Register Definition



BCR[13]	BCR[12]	BCR[11]	Latency Counter
0	0	0	Code 0–Reserved
0	0	1	Code 1–Reserved
0	1	0	Code 2
0	1	1	Code 3 (Default)
1	0	0	Code 4–Reserved
1	0	1	Code 5–Reserved
1	1	0	Code 6–Reserved
1	1	1	Code 7–Reserved

BCR[3]	Burst Wrap (Note 1)
0	Burst wraps within the burst length
1	Burst no wrap (default)

BCR[10]	WAIT Polarity
0	Active LOW
1	Active HIGH (default)

BCR[5]	Output Impedance
0	Full Drive (default)
1	1/4 Drive

BCR[8]	WAIT Configuration
0	Asserted during delay
1	Asserted one data cycle before delay (default)

BCR[6]	Clock Configuration
0	Not supported
1	Rising edge (default)

BCR[15]	Operation Mode
0	Synchronous burst access mode
1	Asynchronous access mode (default)

BCR[2]	BCR[1]	BCR[0]	Burst Length (Note 1)
0	0	1	4 words
0	1	0	8 words
0	1	1	16 words
1	1	1	Continuous burst (default)

BCR[19]	Register Select
0	Select RCR
1	Select BCR

Note: All burst WRITEs are continuous.

Table 4: Sequence and Burst Length

Burst Wrap		Starting Address	4-Word Burst Length	8-Word Burst Length	16-Word Burst length	Continuous Burst
BCR[3]	Wrap	(Decimal)	Linear	Linear	Linear	Linear
0	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	0-1-2-3-4-5-6-…
		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	1-2-3-4-5-6-7-…
		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	2-3-4-5-6-7-8-…
		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	3-4-5-6-7-8-9-…
		4		4-5-6-7-0-1-2-3	4-5-6-7-8-9-10-11-12-13-14-15-0-1-2-3	4-5-6-7-8-9-10-…
		5		5-6-7-0-1-2-3-4	5-6-7-8-9-10-11-12-13-14-15-0-1-2-3-4	5-6-7-8-9-10-11-…
		6		6-7-0-1-2-3-4-5	6-7-8-9-10-11-12-13-14-15-0-1-2-3-4-5	6-7-8-9-10-11-12-
		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	7-8-9-10-11-12-13-…
		…			…	…
		14			14-15-0-1-2-3-4-5-6-7-8-9-10-11-12-13	14-15-16-17-18-19-20-…
		15			15-0-1-2-3-4-5-6-7-8-9-10-11-12-13-14	15-16-17-18-19-20-21…
1	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	0-1-2-3-4-5-6-…
		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	1-2-3-4-5-6-7-…
		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	2-3-4-5-6-7-8-…
		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	3-4-5-6-7-8-9-…
		4		4-5-6-7-8-9-10-11	4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19	4-5-6-7-8-9-10-…
		5		5-6-7-8-9-10-11-12	5-6-7-8-9-10-11-12-13-…-15-16-17-18-19-20	5-6-7-8-9-10-11…
		6		6-7-8-9-10-11-12-13	6-7-8-9-10-11-12-13-14-…-16-17-18-19-20-21	6-7-8-9-10-11-12…
		7		7-8-9-10-11-12-13-14	7-8-9-10-11-12-13-14-…-17-18-19-20-21-22	7-8-9-10-11-12-13…
		…			…	…
		14			14-15-16-17-18-19-…-23-24-25-26-27-28-29	14-15-16-17-18-19-20-…
		15			15-16-17-18-19-20-…-24-25-26-27-28-29-30	15-16-17-18-19-20-21-…

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

Burst lengths define the number of words the device outputs during a burst READ operation. The device supports a burst length of 4, 8, or 16 words. The device can also be set in continuous burst mode where data is output sequentially without regard to address boundaries; the internal address wraps to 000000h if the device is read past the last address. WRITE bursts are always performed using continuous burst mode.

Burst Wrap (BCR[3]) Default = Burst No Wrap (Within Burst Length)

The burst wrap option determines if a 4-, 8-, or 16-word burst READ wraps within the burst length or steps through sequential addresses. If the wrap option is not enabled, the device outputs data from sequential addresses without regard to burst boundaries; the internal address wraps to 000000h if the device is read past the last address.

Output Impedance (BCR[5]) Default = Outputs Use Full Drive Strength

The output driver strength can be altered to adjust for different data bus loading scenarios. The reduced-strength option should be more than adequate in stacked chip (Flash + CellularRAM) environments when there is a dedicated memory bus. The reduced-drive-strength option is included to minimize noise generated on the data bus during READ operations. Normal output impedance should be selected when using a discrete CellularRAM device in a more heavily loaded data bus environment. Partial drive is approximately one-quarter full drive strength. Outputs are configured at full drive strength during testing.

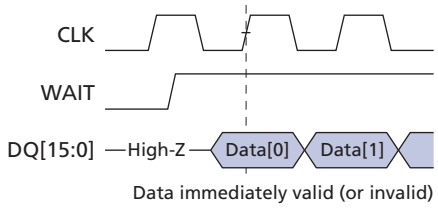
WAIT Configuration (BCR[8]) Default = WAIT Transitions One Clock Before Data Valid/Invalid

The WAIT configuration bit is used to determine when WAIT transitions between the asserted and the de-asserted state with respect to valid data presented on the data bus. The memory controller will use the WAIT signal to coordinate data transfer during synchronous READ and WRITE operations. When BCR[8] = 0, data will be valid or invalid on the clock edge immediately after WAIT transitions to the de-asserted or asserted state, respectively (see Figures 18 and 20). When BCR[8] = 1, the WAIT signal transitions one clock period prior to the data bus going valid or invalid (see Figures 19 and 20).

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

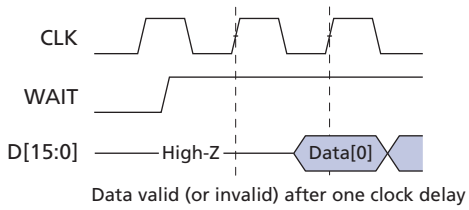
The WAIT polarity bit indicates whether an asserted WAIT output should be HIGH or LOW. This bit will determine whether the WAIT signal requires a pull-up or pull-down resistor to maintain the de-asserted state.

Figure 18: WAIT Configuration (BCR[8] = 0)



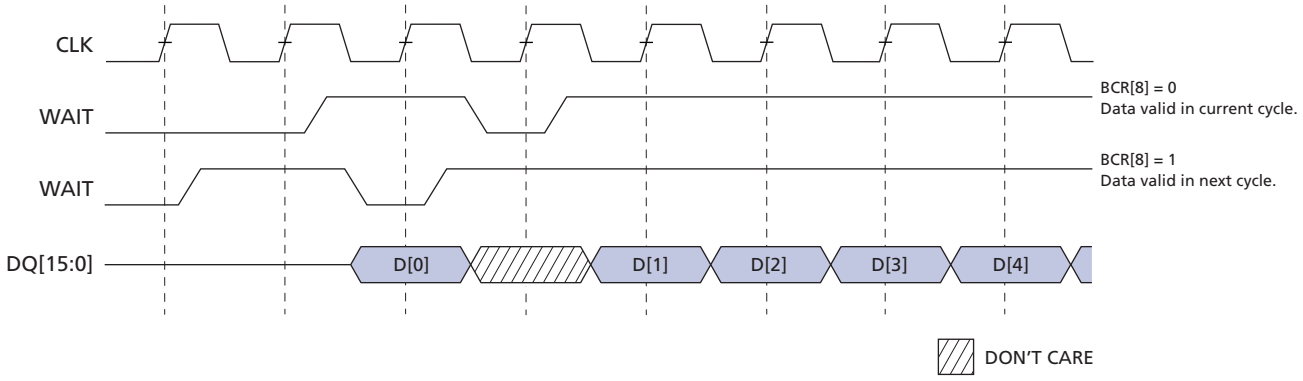
Note: Data valid/invalid immediately after WAIT transitions (BCR[8] = 0). See Figure 20 on page 26.

Figure 19: WAIT Configuration (BCR[8] = 1)



Note: Valid/invalid data delayed for one clock after WAIT transitions (BCR[8] = 1). See Figure 20 on page 26.

Figure 20: WAIT Configuration During Burst Operation



Note: Non-default BCR setting for WAIT during BURST operation: WAIT active LOW.

Latency Counter (BCR[13:11]) Default = Three-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. Only latency code two (three clocks) or latency code three (four clocks) is allowed (see Table 5 and Figure 21).

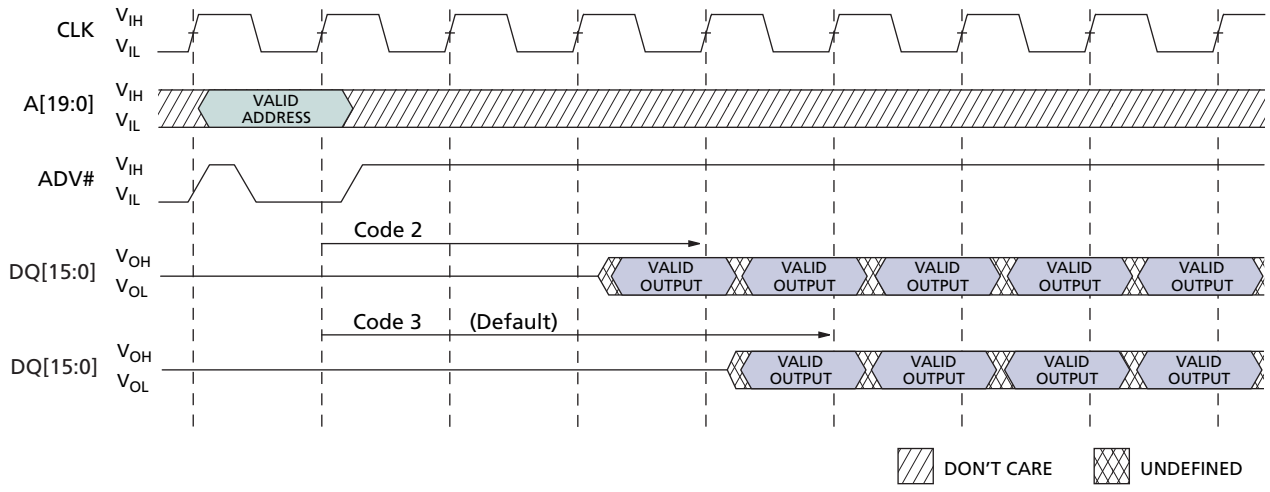
Operating Mode (BCR[15]) Default = Asynchronous Operation

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

Table 5: Latency Configuration

Latency Configuration Code	Max Input CLK Frequency (MHz)	
	104 MHz	80 MHz
2 (3 clocks)	66 (15ns)	53 (18.75ns)
3 (4 clocks) – default	104 (9.62ns)	80 (12.50ns)

Figure 21: Latency Counter



Refresh Configuration Register

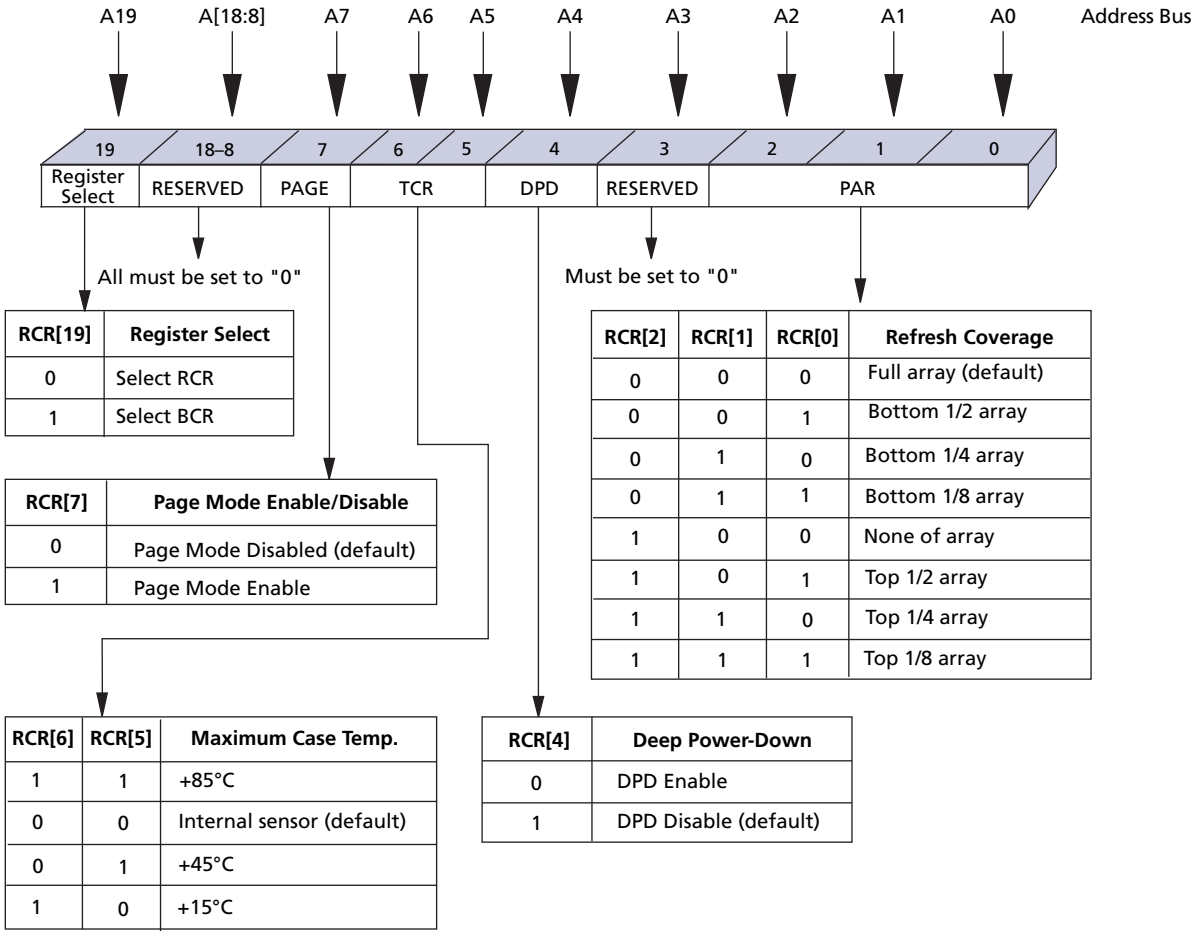
The refresh configuration register (RCR) defines how the CellularRAM device performs its transparent self refresh. Altering the refresh parameters can dramatically reduce current consumption during standby mode. Page mode control is also embedded into the RCR. Figure 22 describes the control bits used in the RCR. At power-up, the RCR is set to 0010h.

The RCR is accessed using CRE and A[19] LOW; or through the configuration register software access sequence with DQ = 0000h on the third cycle (see "Configuration Registers" on page 19.)

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 (see Table 6 on page 28).

Figure 22: Refresh Configuration Register Mapping



RCR[19]	Register Select
0	Select RCR
1	Select BCR

RCR[7]	Page Mode Enable/Disable
0	Page Mode Disabled (default)
1	Page Mode Enable

RCR[6]	RCR[5]	Maximum Case Temp.
1	1	+85°C
0	0	Internal sensor (default)
0	1	+45°C
1	0	+15°C

RCR[4]	Deep Power-Down
0	DPD Enable
1	DPD Disable (default)

RCR[2]	RCR[1]	RCR[0]	Refresh Coverage
0	0	0	Full array (default)
0	0	1	Bottom 1/2 array
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

Table 6: 16Mb 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–0FFFFFh	1 Meg x 16	16Mb
0	0	1	One-half of die	000000h–07FFFFh	512K x 16	8Mb
0	1	0	One-quarter of die	000000h–03FFFFh	256K x 16	4Mb
0	1	1	One-eighth of die	000000h–01FFFFh	128K x 16	2Mb
1	0	0	None of die	0	0 Meg x 16	0Mb
1	0	1	One-half of die	80000h–0FFFFFh	512K x 16	8Mb
1	1	0	One-quarter of die	C0000h–0FFFFFh	256K x 16	4Mb
1	1	1	One-eighth of die	E0000h–0FFFFFh	128K x 16	2Mb

Deep Power-Down (RCR[4]) Default = DPD Disabled

The deep power-down bit enables and disables all refresh-related activity. This mode is used if the system does not require the storage provided by the CellularRAM device. Any stored data will become corrupted when DPD is enabled. When refresh activity has been re-enabled, the CellularRAM device will require 150µs to perform an initialization procedure before normal operations can resume.

Deep power-down is enabled when RCR[4] = 0, and remains enabled until RCR[4] is set to "1." DPD should not be enabled or disabled with the software access sequence; instead, use CRE to access the RCR.

Temperature-Compensated Refresh (RCR[6:5]) Default = On-Chip Temperature Sensor

This CellularRAM device includes an on-chip temperature sensor that automatically adjusts the refresh rate according to the operating temperature. The on-chip TCR is enabled by clearing both of the TCR bits in the refresh configuration register (RCR[6:5] = 00b). Any other TCR setting enables a fixed refresh rate. When the on-chip temperature sensor is enabled, the device continually adjusts the refresh rate according to the operating temperature.

The TCR bits also allow for adequate fixed-rate refresh at three different temperature thresholds (+15°C, +45°C, and +85°C). The setting selected must be for a temperature higher than the case temperature of the CellularRAM device. If the case temperature is +35°C, the system can minimize self refresh current consumption by selecting the +45°C setting. The +15°C setting would result in inadequate refreshing and cause data corruption.

Page Mode Operation (RCR[7]) Default = Disabled

The page mode operation bit determines whether page mode is enabled for asynchronous READ operations. In the power-up default state, page mode is disabled.

Electrical Characteristics

Table 7: Absolute Maximum Ratings

Parameter	Rating
Voltage to any ball except V_{CC}, V_{CCQ} relative to V_{SS}	–0.5V to (4.0V or V_{CCQ} + 0.3V, whichever is less)
Voltage on V_{CC} supply relative to V_{SS}	–0.2V to +2.45V
Voltage on V_{CCQ} supply relative to V_{SS}	–0.2V to +4.0V
Storage temperature (plastic)	–55°C to +150°C
Operating temperature (case) Wireless[1] Industrial	 –30°C to +85°C –40°C to +85°C
Soldering temperature and time 10 seconds (solder ball only)	 +260°C

Notes: 1. –30°C exceeds the CellularRAM Workgroup 1.0 specification of –25°C.

Stresses greater than those listed may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Table 8: Electrical Characteristics and Operating Conditions

Wireless temperature[1] (–30°C < T_C < +85°C); Industrial temperature (–40°C < T_C < +85°C)

Description	Conditions	Symbol		Min	Max	Units	Notes
Supply voltage		VCC		1.7	1.95	V	
I/O supply voltage		VCCQ		1.7	3.6	V	1
Input high voltage		VIH		1.4	VCCQ + 0.2	V	2, 3
Input low voltage		VIL		–0.2	0.4	V	4
Output high voltage	IOH = –0.2mA	VOH		0.8 VCCQ		V	5
Output low voltage	IOL = +0.2mA	VOL			0.2 VCCQ	V	5
Input leakage current	VIN = 0 to VCCQ	ILI			1	µA	
Output leakage current	OE# = VIH or Chip disabled	ILO			1	µA	
Operating Current							
Asynchronous random READ/WRITE	VIN = VCCQ or 0V Chip enabled, IOUT = 0	ICC1	–70		20	mA	6
Asynchronous page READ		ICC1P	–70		15	mA	6
Initial access, burst READ/WRITE		ICC2	104 MHz		35	mA	6
			80 MHz		30		
Continuous burst READ		ICC3R	104 MHz		28	mA	6
			80 MHz		22		
Continuous burst WRITE		ICC3W	104 MHz		33	mA	6
			80 MHz		25		
Standby current	VIN = VCCQ or 0V CE# = VCCQ	ISB	Standard		70	µA	7

Notes:
1. –30°C and 3.6V I/O exceed the CellularRAM Workgroup 1.0 specifications.
2. Input signals may overshoot to VCCQ + 1.0V for periods less than 2ns during transitions.
3. VIH (MIN) value is not aligned with CellularRAM work group 1.0 specification of VCCQ - 0.4V.
4. Input signals may undershoot to VSS - 1.0V for periods less than 2ns during transitions.
5. BCR[5] = 0b.
6. This parameter is specified with the outputs disabled to avoid external loading effects. The user must add the current required to drive output capacitance expected in the actual system.
7. ISB (MAX) values measured with PAR set to FULL ARRAY and TCR set to +85°C. In order to achieve low standby current, all inputs must be driven to either VCCQ or VSS. ISB might be slightly higher for up to 500ms after power-up, after changes to the PAR array partition, or when entering standby mode.

Maximum and Typical Standby Currents

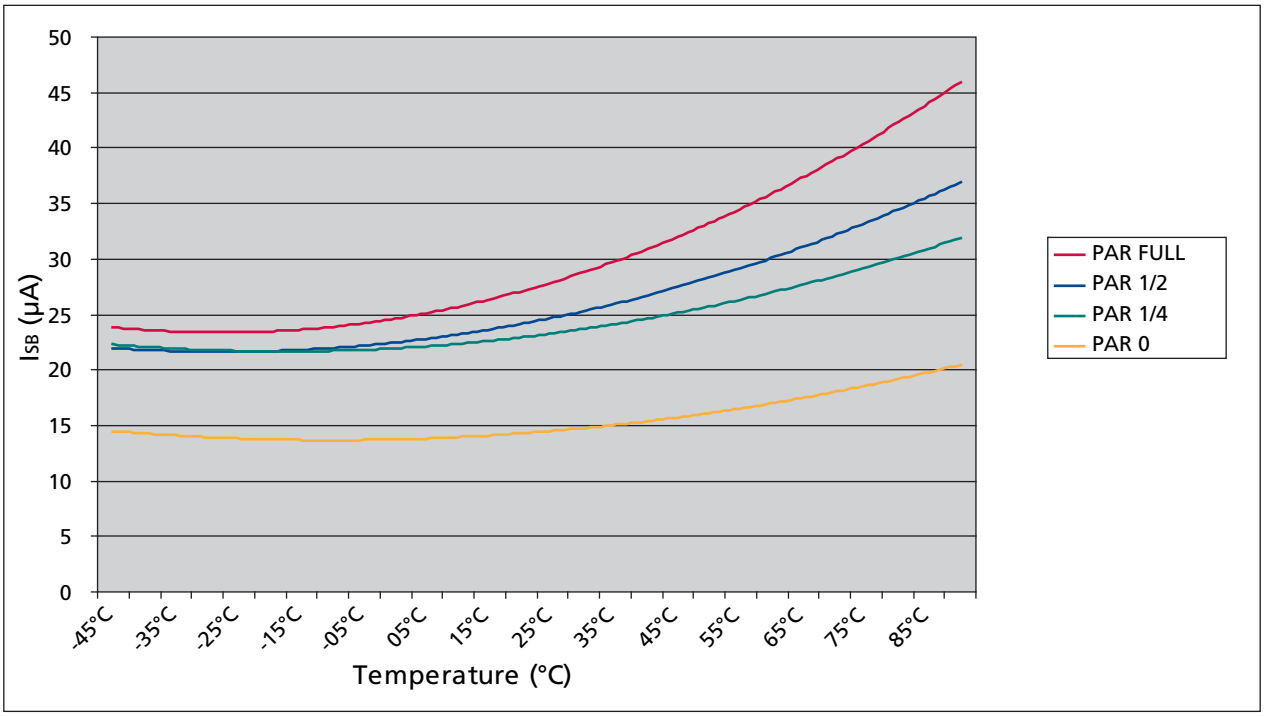
The following table and figure refer to the maximum and typical standby currents for the MT45W1MW16BDGB device. The typical values shown in Figure 23 are measured with the default on-chip temperature sensor control enabled. The maximum values shown in Table 9 are measured with the relevant TCR bits set in the configuration register.

Table 9: Maximum Standby Currents for Applying PAR and TCR Settings

PAR	TCR			Units
	+15°C (RCR[6:5] = 10b)	+45°C (RCR[6:5] = 01b)	+85°C (RCR[6:5] = 11b)	
Full array	45	60	70	µA
1/2 array	40	55	65	µA
1/4 array	37	50	60	µA
1/8 array	37	50	60	µA
0 array	35	45	55	µA

Notes:
1. For RCR[6:5] = 00b (default) refer to Figure 23, Typical Refresh Current vs. Temperature (I_{TCR}) for typical values.
2. In order to achieve low standby current, all inputs must be driven to V_{CCQ} or V_{SS}. I_{SB} might be slightly higher for up to 500ms after power-up, after changes to the PAR array portion, or when entering standby mode.
3. TCR values for 85°C are 100 percent tested. TCR values for 15°C and 45°C are sampled only.
4. Typical I_{SB} currents for each PAR setting with the appropriate TCR selected, or temperature sensor enabled.

Figure 23: Typical Refresh Current vs. Temperature (I_{TCR})



Note: Typical I_{SB} currents for each PAR setting with the appropriate TCR selected, or temperature sensor enabled.

Table 10: Deep Power-Down Specifications

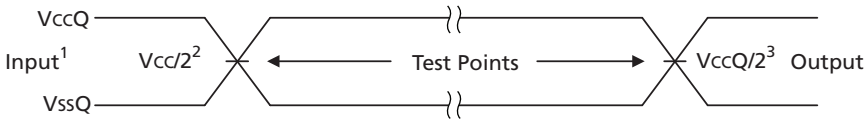
Description	Conditions	Symbol	Typ	Units
Deep power-down	V_{IN} = V_{CCQ} or 0V; +25°C	Izz	10	µA

Table 11: Capacitance

Description	Conditions	Symbol	Min	Max	Units	Notes
Input capacitance	T_C = +25°C; f = 1 MHz; V_{IN} = 0V	C_{IN}	2.0	6.5	pF	1
Input/output capacitance (DQ)		C_{IO}	3.0	6.5	pF	1

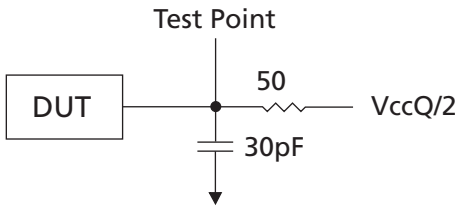
Notes: 1. These parameters are verified in device characterization and are not 100 percent tested.

Figure 24: AC Input/Output Reference Waveform



Notes: 1. AC test inputs are driven at V_{CCQ} for a logic 1 and V_{SSQ} for a logic 0. Input rise and fall times (10% to 90%) < 1.6ns.
2. Input timing begins at V_{CC}/2. Due to the possibility of a difference between V_{CC} and V_{CCQ}, the input test point may not be shown to scale.
3. Output timing ends at V_{CCQ}/2.

Figure 25: Output Load Circuit



Notes: 1. All tests are performed with the outputs configured for full drive strength (BCR[5] = 0b).

Timing Requirements

Table 12: Asynchronous READ Cycle Timing Requirements

Parameter[1]	Symbol	70ns		Units	Notes
		Min	Max		
Address access time	tAA		70	ns	
ADV# access time	tAADV		70	ns	
Page access time	tAPA		20	ns	
Address hold from ADV# HIGH	tAVH	5		ns	
Address setup to ADV# HIGH	tAVS	10		ns	
LB#/UB# access time	tBA		70	ns	
LB#/UB# disable to DQ High-Z output	tBHZ		8	ns	4
LB#/UB# enable to Low-Z output	tBLZ	10		ns	3
Maximum CE# pulse width	tCEM		8	µs	2
CE# LOW to WAIT valid	tCEW	1	7.5	ns	
Chip select access time	tCO		70	ns	
CE# LOW to ADV# HIGH	tCVS	10		ns	
Chip disable to DQ and WAIT High-Z output	tHZ		8	ns	4
Chip enable to Low-Z output	tLZ	10		ns	3
Output enable to valid output	tOE		20	ns	
Output hold from address change	tOH	5		ns	
Output disable to DQ High-Z output	tOHZ		8	ns	4
Output enable to Low-Z output	tOLZ	3		ns	3
Page cycle time	tPC	20		ns	
READ cycle time	tRC	70		ns	
ADV# pulse width LOW	tVP	10		ns	
ADV# pulse width HIGH	tVPH	10		ns	

Notes:
1. All tests are performed with the outputs configured for full drive strength (BCR[5] = 0b).
2. Low-Z to High-Z timings are tested with the circuit shown in Figure 25 on page 32. The High-Z timings measure a 100mV transition from either V_{OH} or V_{OL} toward $V_{CCQ}/2$.
3. High-Z to Low-Z timings are tested with the circuit shown in Figure 25 on page 32. The Low-Z timings measure a 100mV transition away from the High-Z ($V_{CCQ}/2$) level toward either V_{OH} or V_{OL}.
4. Page mode enabled only.

Table 13: Burst READ Cycle Timing Requirements

Parameter[1]	Symbol	104 MHz		80 MHz		Units	Notes
		Min	Max	Min	Max		
Burst to READ access time	^{t}ABA		35		46.5	ns	
CLK to output delay	^{t}ACLK		7		9	ns	
Burst OE# LOW to output delay	^{t}BOE		20		20	ns	
CE# HIGH between subsequent burst and mixed-mode operations	^{t}CBPH	5		5		ns	2
Maximum CE# pulse width	^{t}CEM		8		8	µs	
CE# LOW to WAIT valid	^{t}CEW	1	7.5	1	7.5	ns	
CLK period	^{t}CLK	9.62	20	12.5	20	ns	
CE# setup time to active CLK edge	^{t}CSP	3	20	4.5	20	ns	
Hold time from active CLK edge	^{t}HD	2		2		ns	
Chip disable to DQ and WAIT High-Z output	^{t}HZ		8		8	ns	3
CLK rise or fall time	^{t}KHKL		1.6		1.8	ns	
CLK to WAIT valid	^{t}KHTL		7		9	ns	
Output HOLD from CLK	^{t}KOH	2		2		ns	
CLK HIGH or LOW time	^{t}KP	3		4		ns	
Output disable to DQ High-Z output	^{t}OHZ		8		8	ns	3
Output enable to Low-Z output	^{t}OLZ	3		3		ns	4
Setup time to active CLK edge	^{t}SP	3		3		ns	

Notes:
1. All tests are performed with the outputs configured for full drive strength (BCR[5] = 0b).
2. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns.
3. Low-Z to High-Z timings are tested with the circuit shown in Figure 25 on page 32. The High-Z timings measure a 100mV transition from either V_{OH} or V_{OL} toward $V_{CCQ}/2$.
4. High-Z to Low-Z timings are tested with the circuit shown in Figure 25 on page 32. The Low-Z timings measure a 100mV transition away from the High-Z ($V_{CCQ}/2$) level toward either V_{OH} or V_{OL}.

Table 14: Asynchronous WRITE Cycle Timing Requirements

Parameter	Symbol	70ns		Units	Notes
		Min	Max		
Address and ADV# LOW setup time	^{t}AS	0		ns	
Address hold from ADV# going HIGH	^{t}AVH	5		ns	
Address setup to ADV# going HIGH	^{t}AVS	10		ns	
Address valid to end of WRITE	^{t}AW	70		ns	
LB#/UB# select to end of WRITE	^{t}BW	70		ns	
CE# LOW to WAIT valid	^{t}CEW	1	7.5	ns	
Async address-to-burst transition time	^{t}CKA	70		ns	
CE# HIGH between subsequent asynchronous operations	^{t}CPH	5		ns	
CE# LOW to ADV# HIGH	^{t}CVS	10		ns	
Chip enable to end of WRITE	^{t}CW	70		ns	
Data hold from WRITE time	^{t}DH	0		ns	
Data WRITE setup time	^{t}DW	23		ns	
Chip disable to WAIT High-Z output	^{t}HZ		8	ns	
Chip enable to Low-Z output	^{t}LZ	10		ns	1
End WRITE to Low-Z output	^{t}OW	5		ns	1
ADV# pulse width	^{t}VP	10		ns	
ADV# pulse width HIGH	^{t}VPH	10		ns	
ADV# setup to End of WRITE	^{t}VS	70		ns	
WRITE cycle time	^{t}WC	70		ns	
WRITE to DQ High-Z output	^{t}WHZ		8	ns	2
WRITE pulse width	^{t}WP	46		ns	3
WRITE pulse width HIGH	^{t}WPH	10		ns	
WRITE recovery time	^{t}WR	0		ns	

Notes:
1. High-Z to Low-Z timings are tested with the circuit shown in Figure 25 on page 32. The Low-Z timings measure a 100mV transition away from the High-Z ($V_{CC}Q/2$) level toward either V_{OH} or V_{OL}.
2. Low-Z to High-Z timings are tested with the circuit shown in Figure 25 on page 32. The High-Z timings measure a 100mV transition from either V_{OH} or V_{OL} toward $V_{CC}Q/2$.
3. WE# LOW time must be limited to ^{t}CEM (8µs).

Table 15: Burst WRITE Cycle Timing Requirements

Parameter	Symbol	104 MHz		80 MHz		Units	Notes
		Min	Max	Min	Max		
CE# HIGH between subsequent burst and mixed-mode operations	^{t}CBPH	5		5		ns	1
Maximum CE# pulse width	^{t}CEM		8		8	µs	1
CE# LOW to WAIT valid	^{t}CEW	1	7.5	1	7.5	ns	
Clock period	^{t}CLK	9.62	20	12.5	20	ns	
CE# setup to CLK active edge	^{t}CSP	3	20	4.5	20	ns	
Hold time from active CLK edge	^{t}HD	2		2		ns	
Chip disable to WAIT High-Z output	^{t}HZ		8		8	ns	
CLK rise or fall time	^{t}KHKL		1.6		1.8	ns	
Clock to WAIT valid	^{t}KHTL		7		9	ns	
CLK HIGH or LOW time	^{t}KP	3		4		ns	
Setup time to active CLK edge	^{t}SP	3		3		ns	

Notes: 1. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns.

Figure 26: Initialization Period

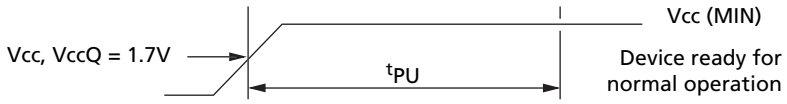


Table 16: Initialization Timing Parameters

Parameter	Symbol	-70		Units
		Min	Max	
Initialization period (required before normal operations)	^{t}PU		150	µs

Timing Diagrams

Figure 27: Asynchronous READ

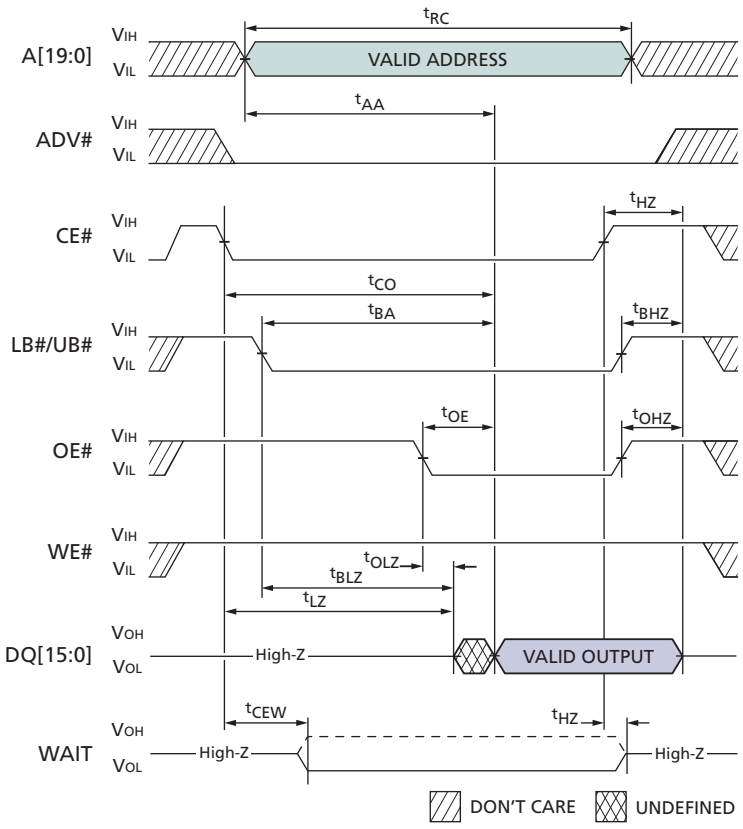


Figure 28: Asynchronous READ Using ADV#

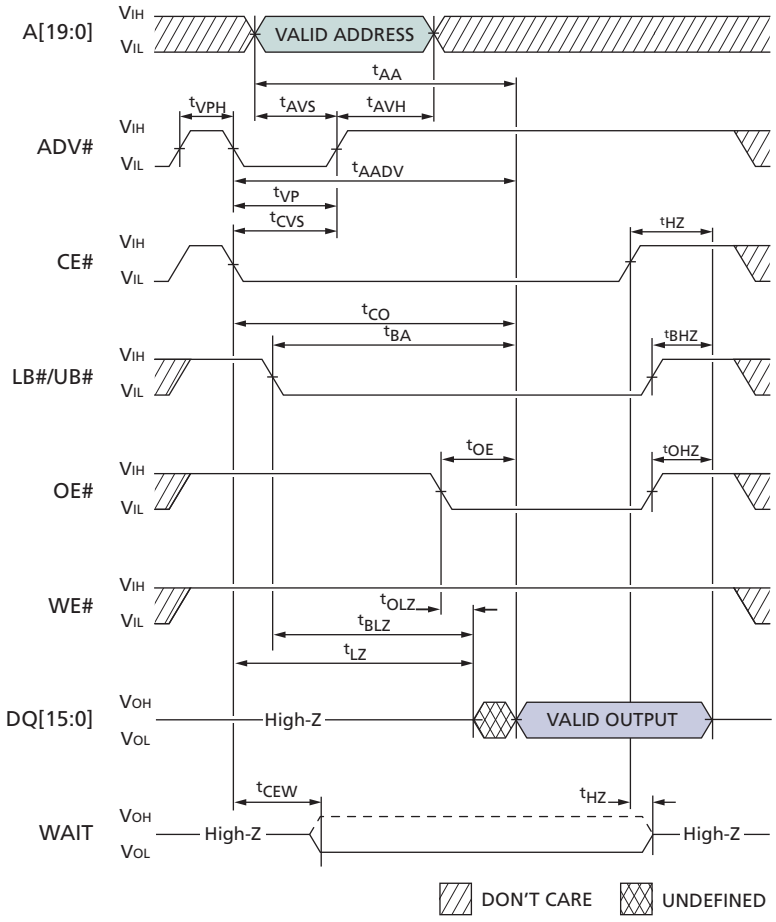


Figure 29: Page Mode READ

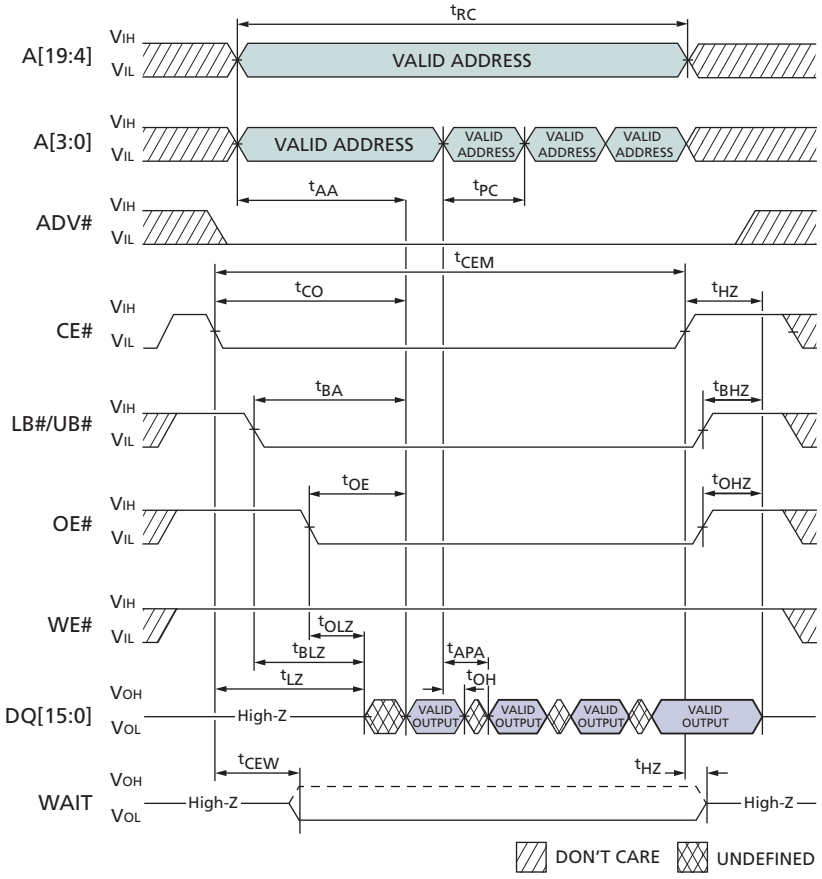
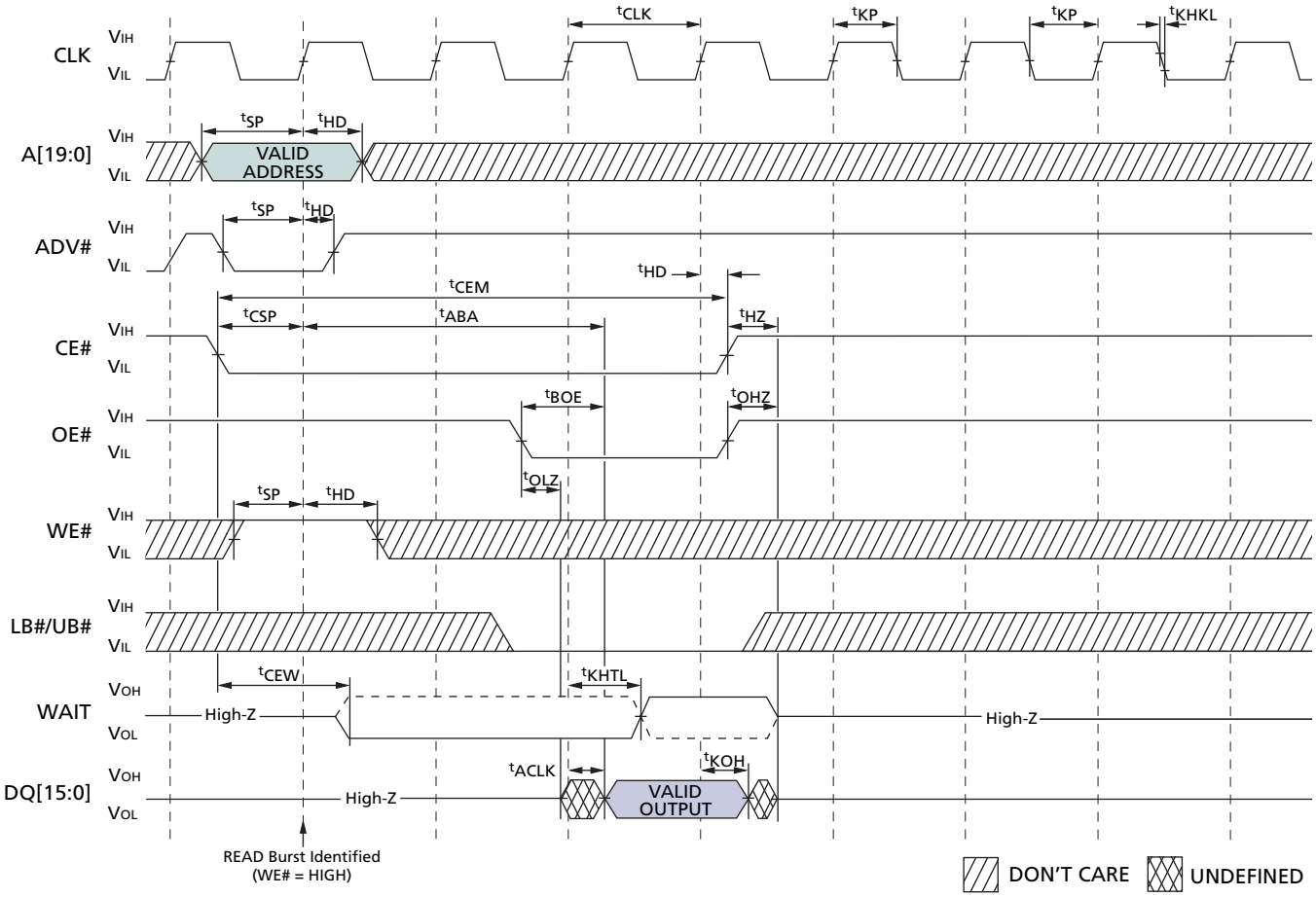
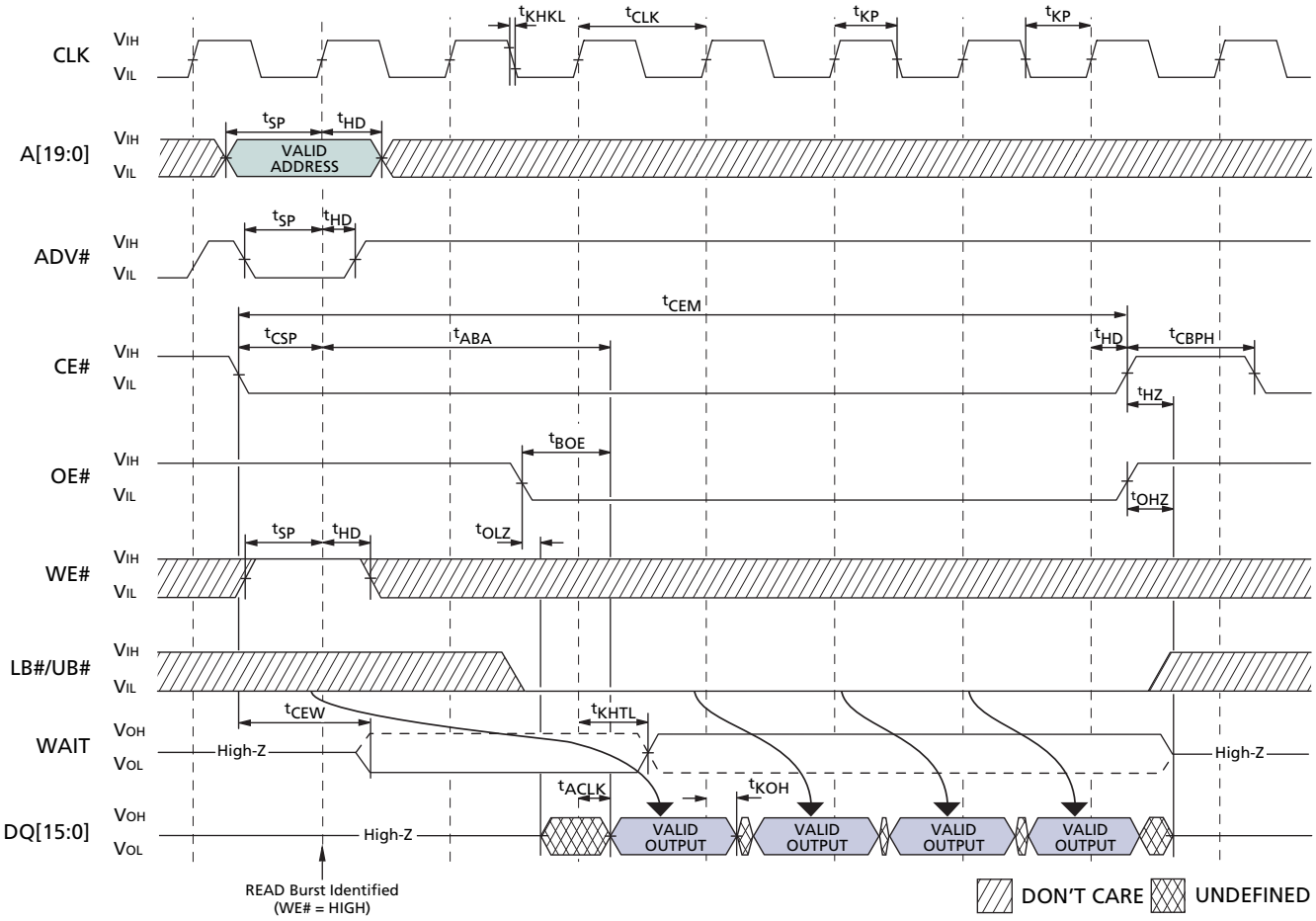


Figure 30: Single-Access Burst READ Operation



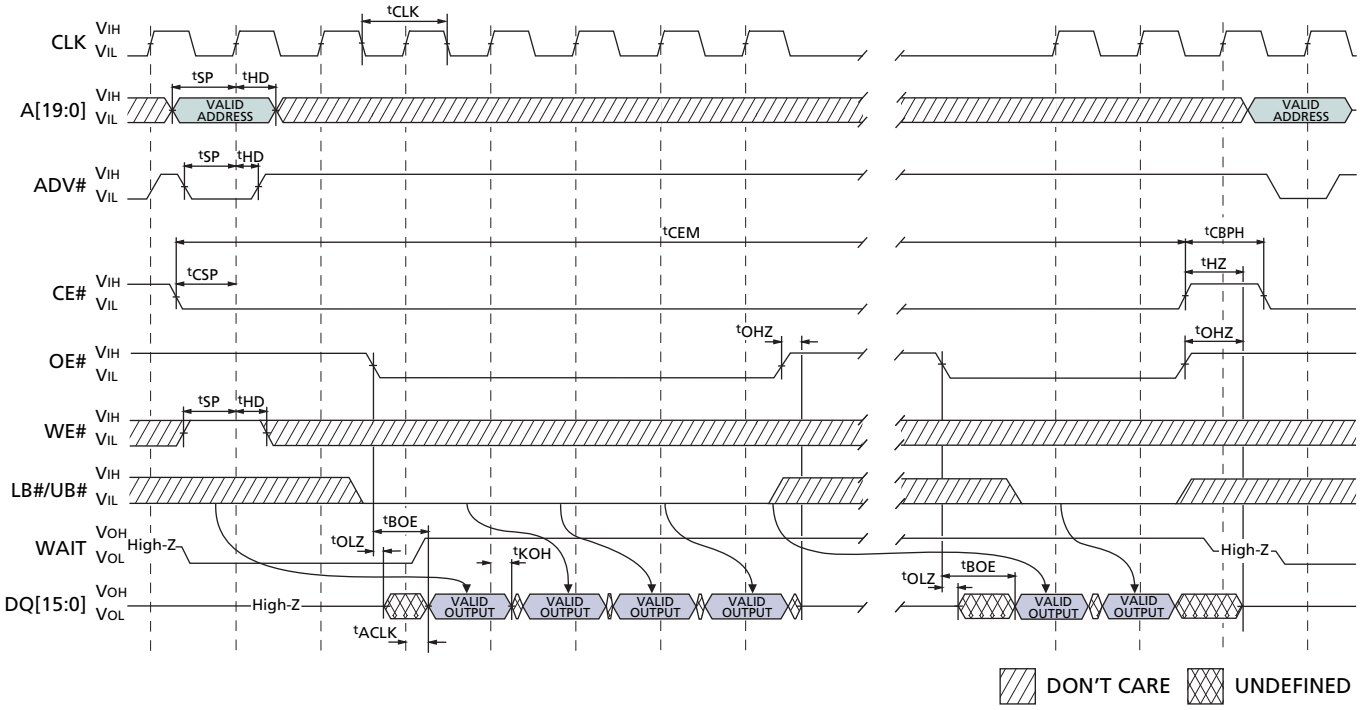
Notes: 1. Non-default BCR settings for single-access burst READ operation: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Figure 31: 4-Word Burst READ Operation



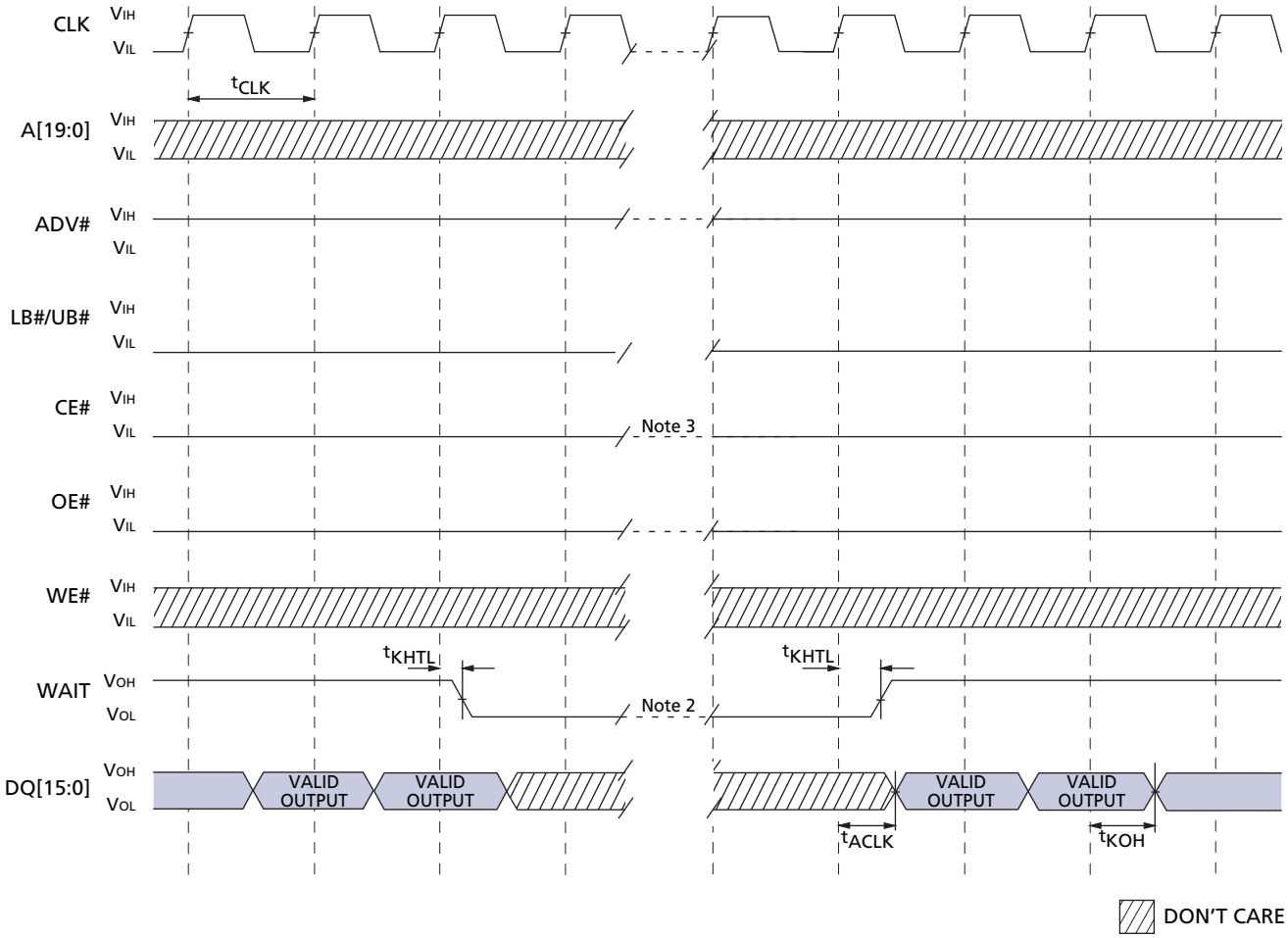
Note: Non-default BCR settings for 4-word burst READ operation: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Figure 32: READ Burst Suspend



Note: Non-default BCR settings for READ burst suspend: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.

Figure 33: Continuous Burst READ Showing an Output Delay with BCR[8] = 0 for End-of-Row Condition



Notes:
1. Non-default BCR settings for continuous burst READ showing an output delay, BCR[8] = 0 for end-of-row condition: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2. WAIT will be asserted a maximum of (2 × LC) cycles (BCR[8] = 0; WAIT asserted during delay). LC = latency code (BCR[13:11]).
3. CE# must not remain LOW longer than ^{t}CEM.

Figure 34: CE#-Controlled Asynchronous WRITE

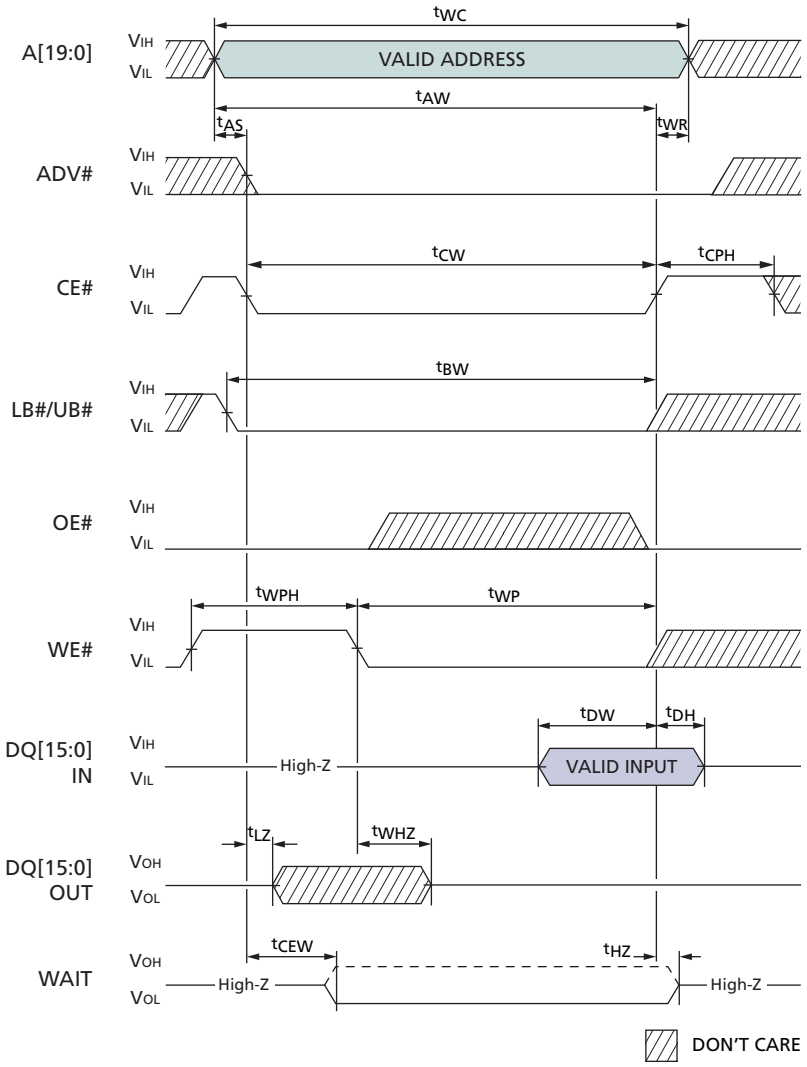


Figure 35: LB#/UB#-Controlled Asynchronous WRITE

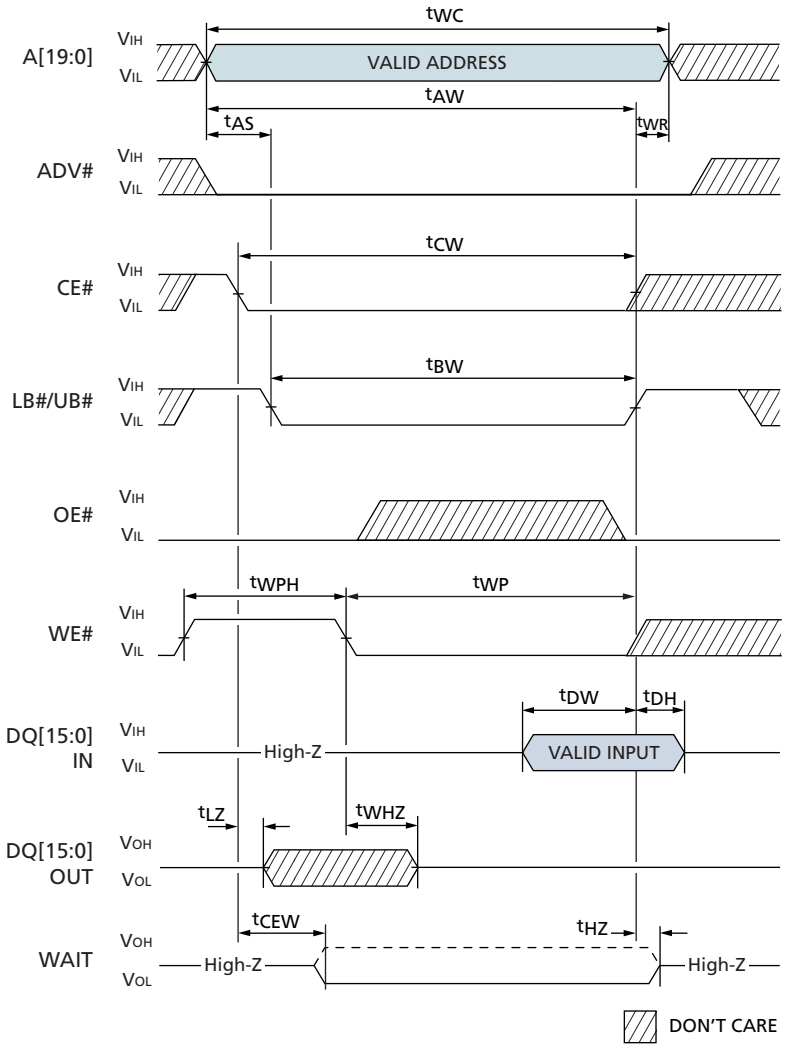


Figure 36: WE#-Controlled Asynchronous WRITE

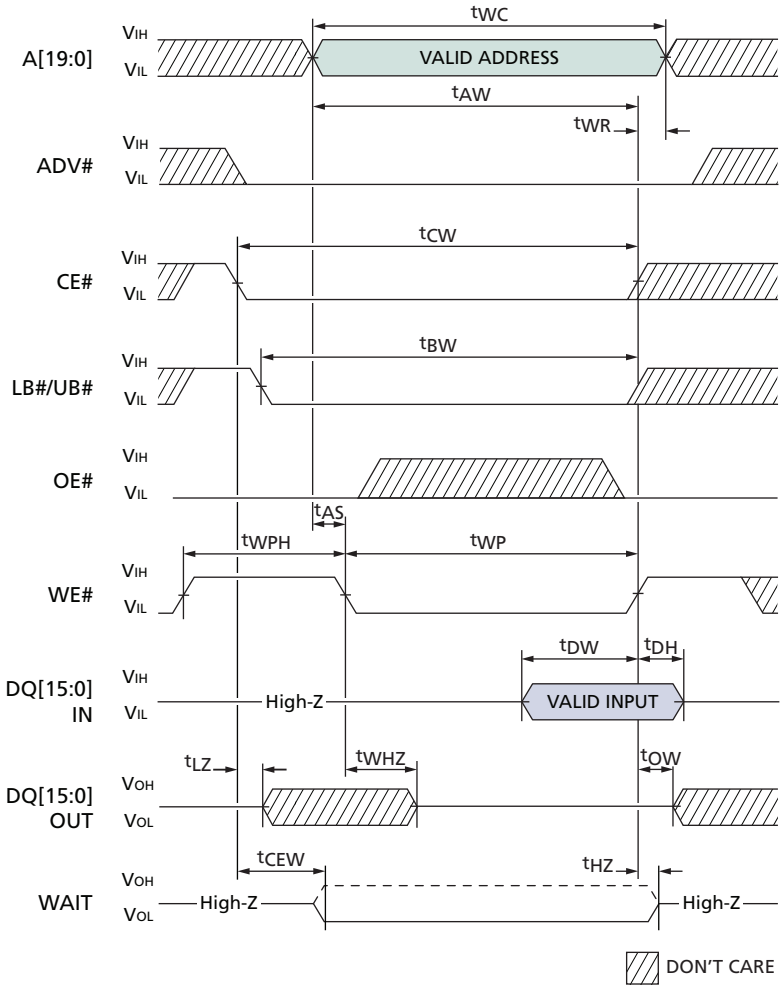


Figure 37: Asynchronous WRITE Using ADV#

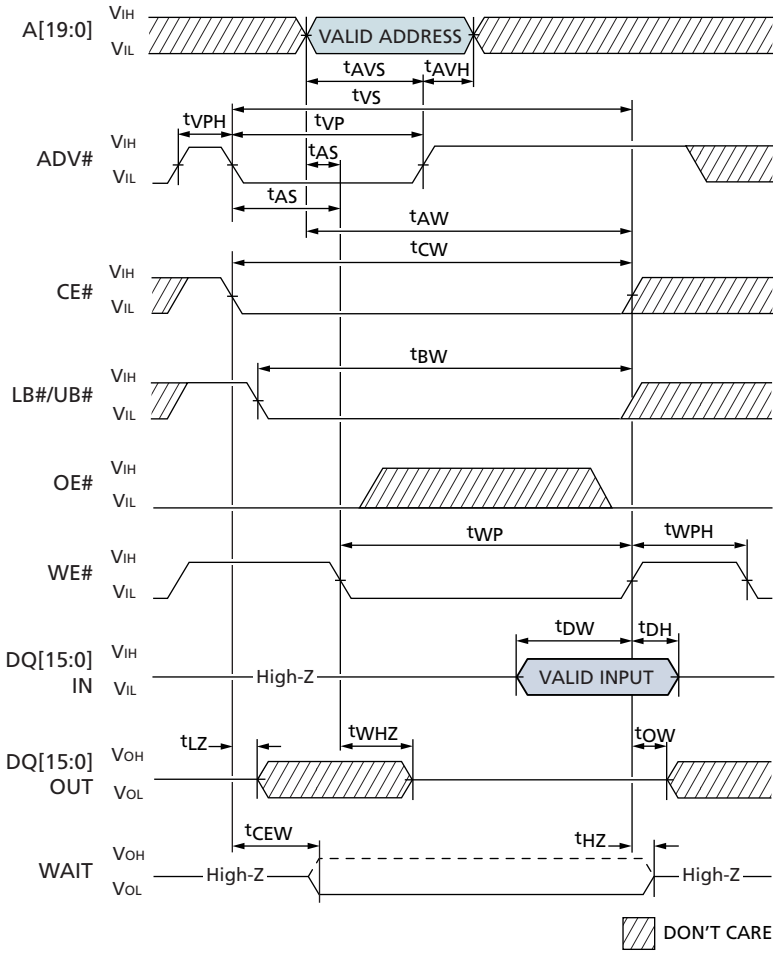
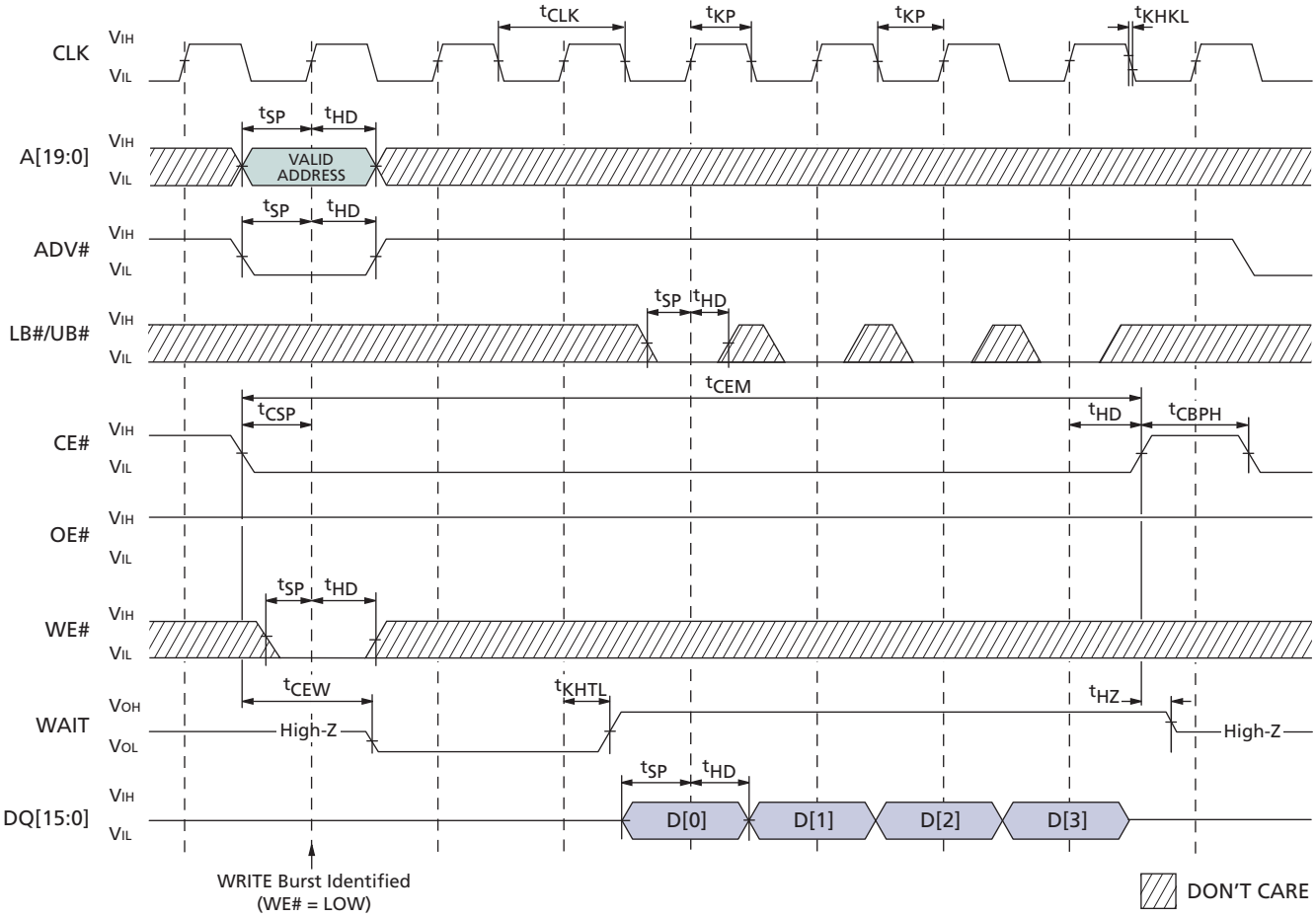
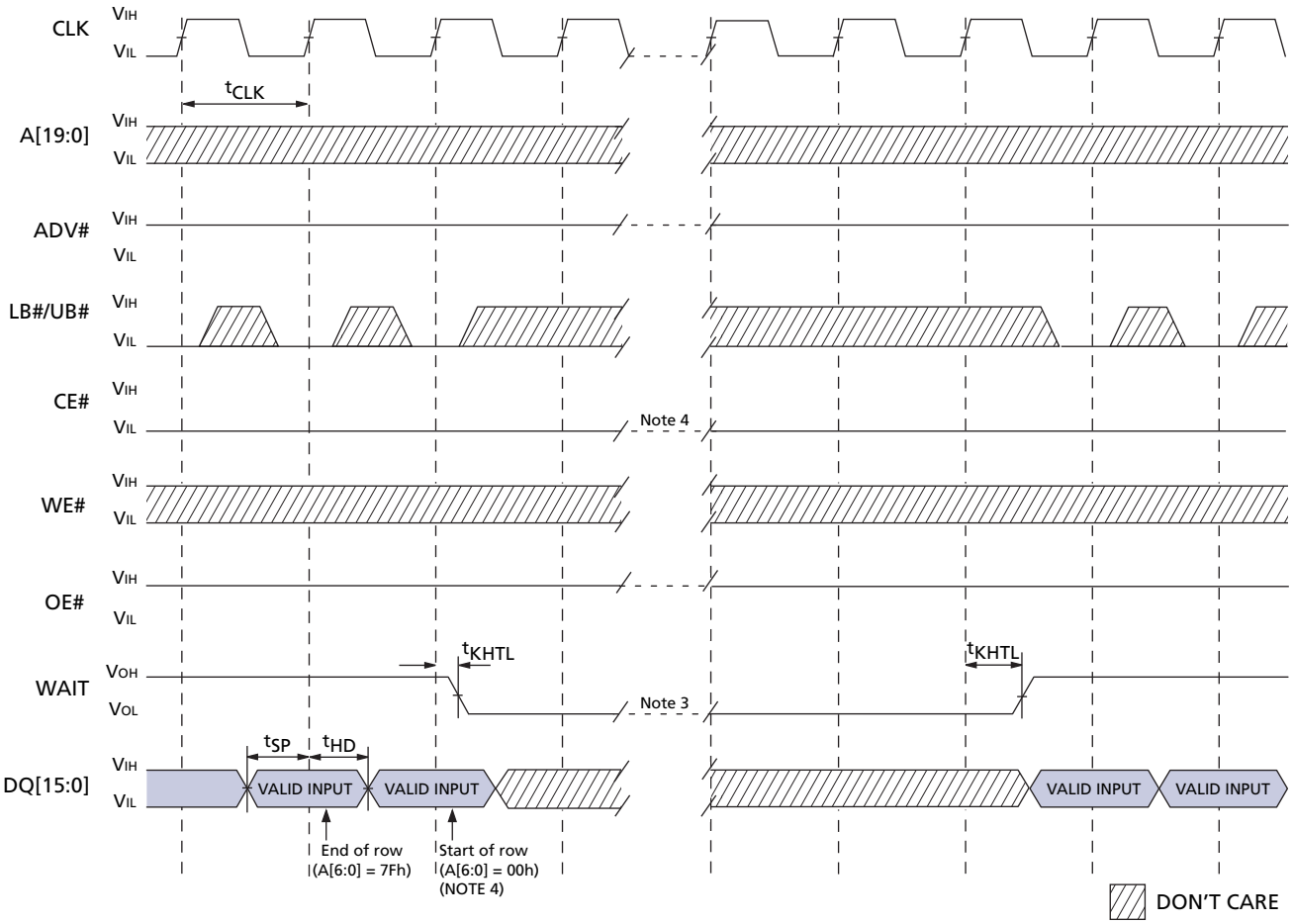


Figure 38: Burst WRITE Operation



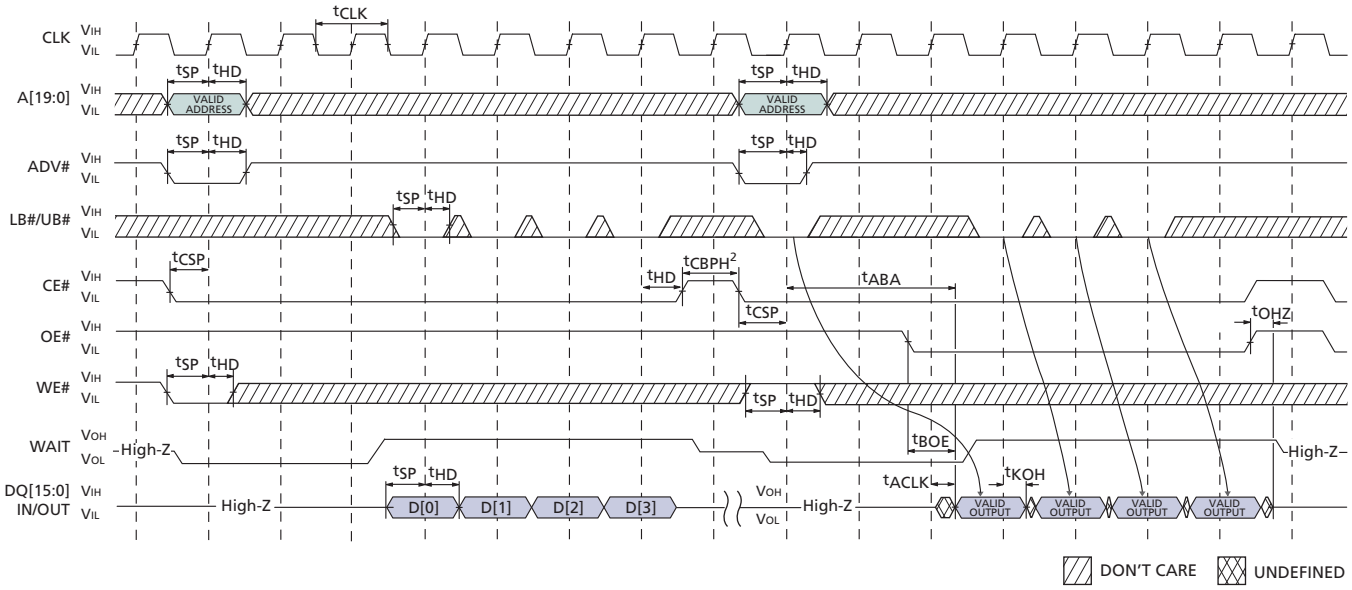
Note: Non-default BCR settings for burst WRITE operation: Latency code two (three clocks); WAIT active LOW; WAIT asserted.

Figure 39: Continuous Burst WRITE Showing an Output Delay with BCR[8] = 0 for End-of-Row Condition



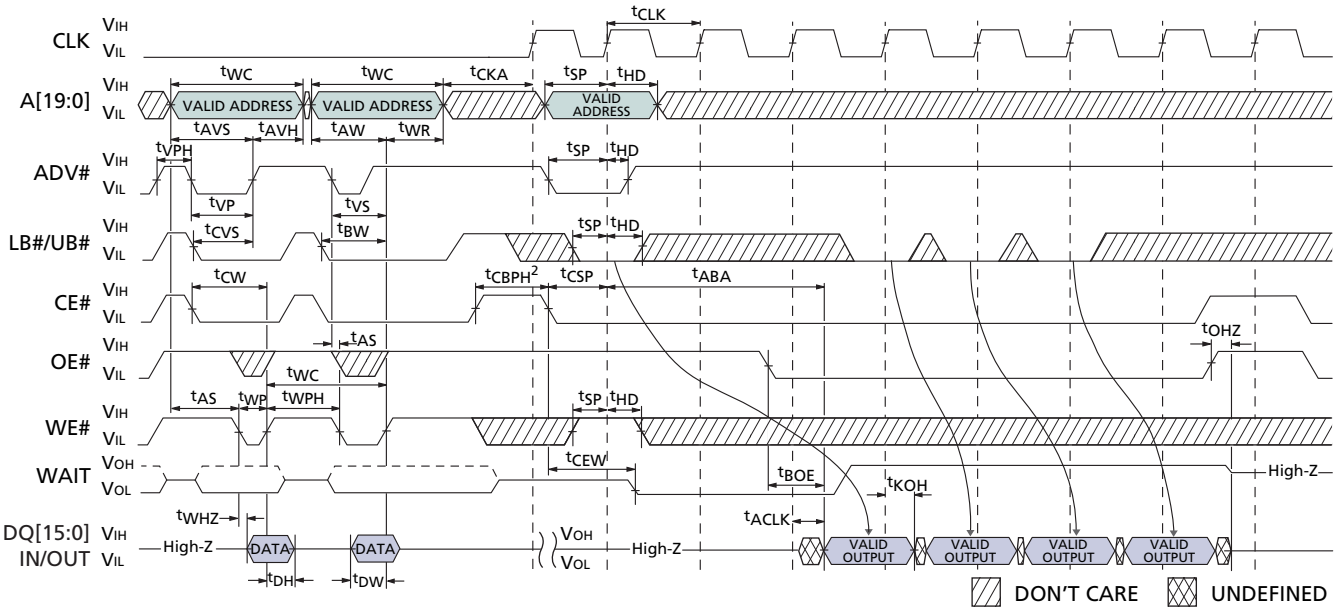
Notes:
1. Non-default BCR settings for continuous burst WRITE, BCR[8] = 0; WAIT active LOW; WAIT asserted during delay. Do not cross row boundaries with fixed latency.
2. CE# must not remain LOW longer than ^{t}CEM.
3. WAIT asserts for anywhere from LC to 2LC cycles. LC = latency code (BCR[13:11]).
4. Taking CE# HIGH or ADV# LOW on the start-of-row cycle will abort the burst and not write the start-of-row data. Devices from different CellularRAM vendors can assert WAIT so that the start-of-row data is input just before (as shown), or just after WAIT asserts. This difference in behavior will not be noticed by controllers that monitor WAIT, or that use WAIT to abort on the start-of-row input cycle.

Figure 40: Burst WRITE Followed by Burst READ



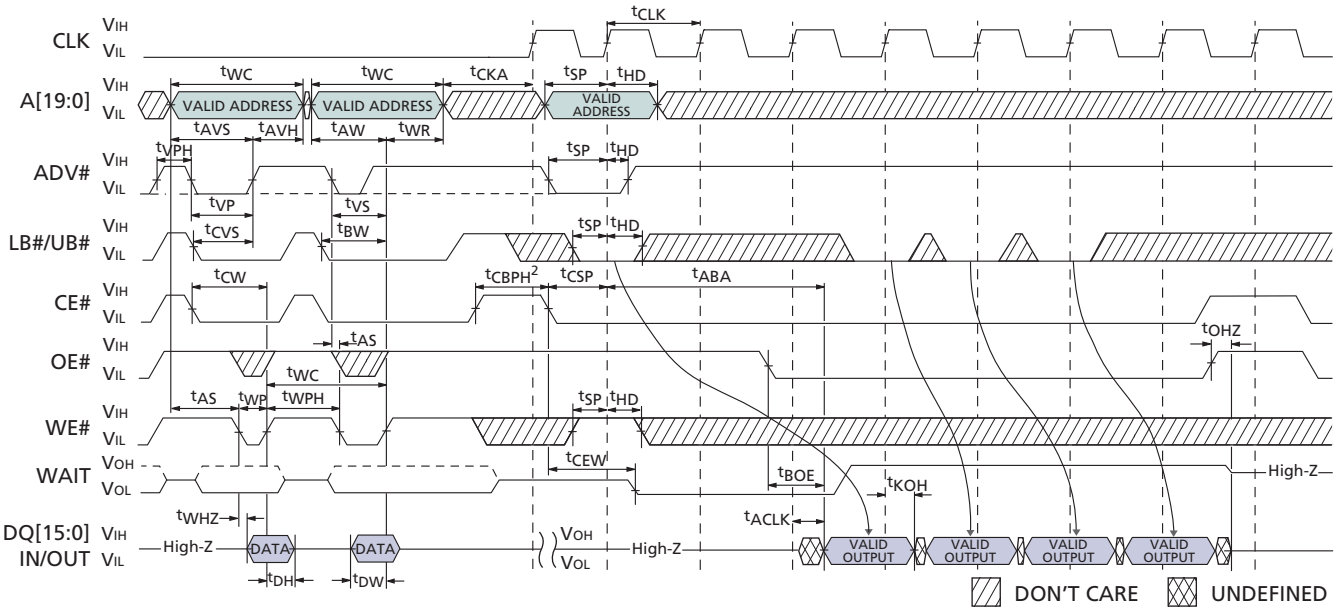
Notes:
1. Non-default BCR settings for burst WRITE followed by burst READ: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns. Note that the CellularRAM Workgroup 1.0 specification requires CE# to be clocked HIGH to terminate the burst.
3. Clock rates below 50 MHz (^{t}CLK > 20ns) are allowed as long as ^{t}CSP specifications are met.

Figure 41: Asynchronous WRITE Followed by Burst READ



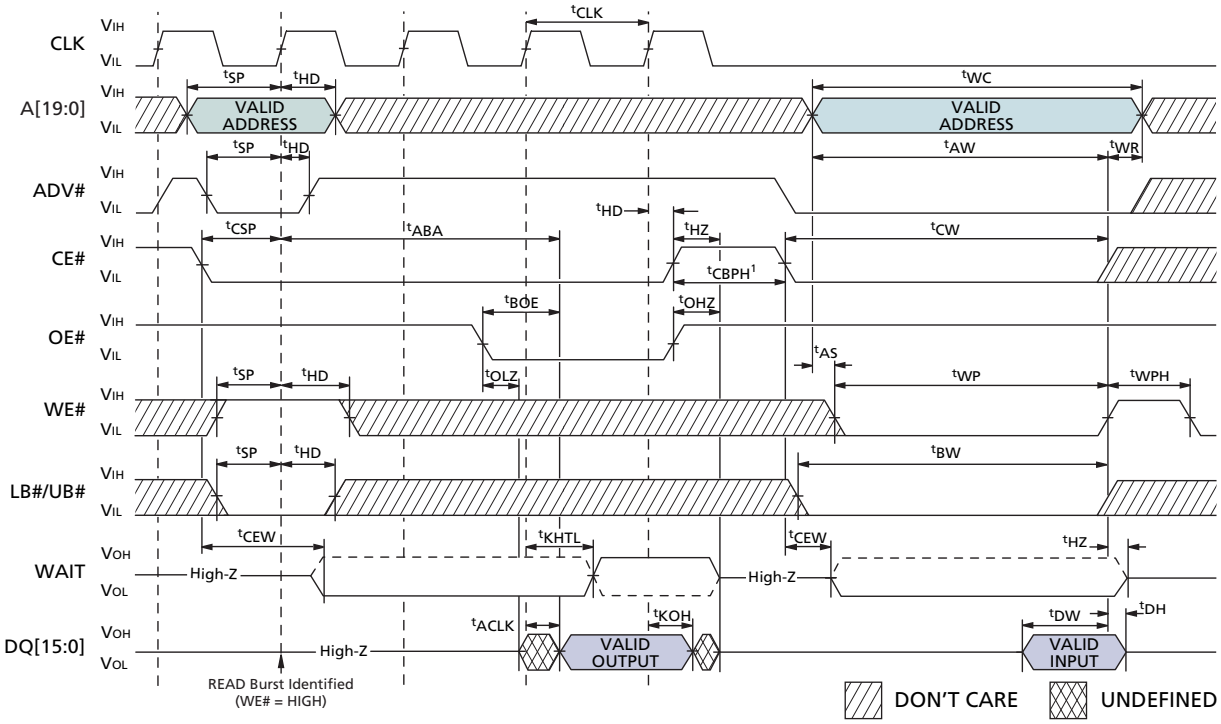
Notes:
1. Non-default BCR settings for asynchronous WRITE followed by burst READ: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns. Note that the CellularRAM Workgroup 1.0 specification requires CE# to be clocked HIGH to terminate the burst.
3. Clock rates below 50 MHz (^{t}CLK > 20ns) are allowed as long as ^{t}CSP specifications are met.

Figure 42: Asynchronous WRITE Followed by Burst READ – ADV# LOW



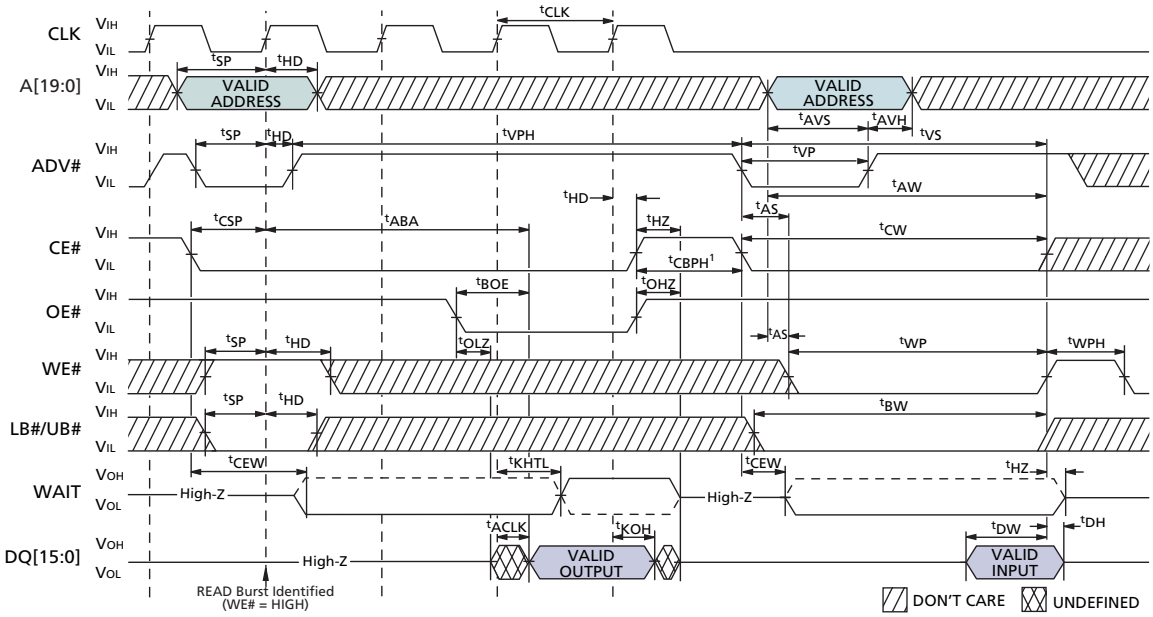
Notes:
1. Non-default BCR settings for asynchronous WRITE followed by burst READ: Latency code two (three clocks); WAIT active LOW; WAIT asserted during delay.
2. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of these conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns. Note that the CellularRAM Workgroup 1.0 specification requires CE# to be clocked HIGH to terminate the burst.
3. Clock rates below 50 MHz (^{t}CLK > 20ns) are allowed as long as ^{t}CSP specifications are met.

Figure 43: Burst READ Followed by Asynchronous WRITE (WE#-Controlled)



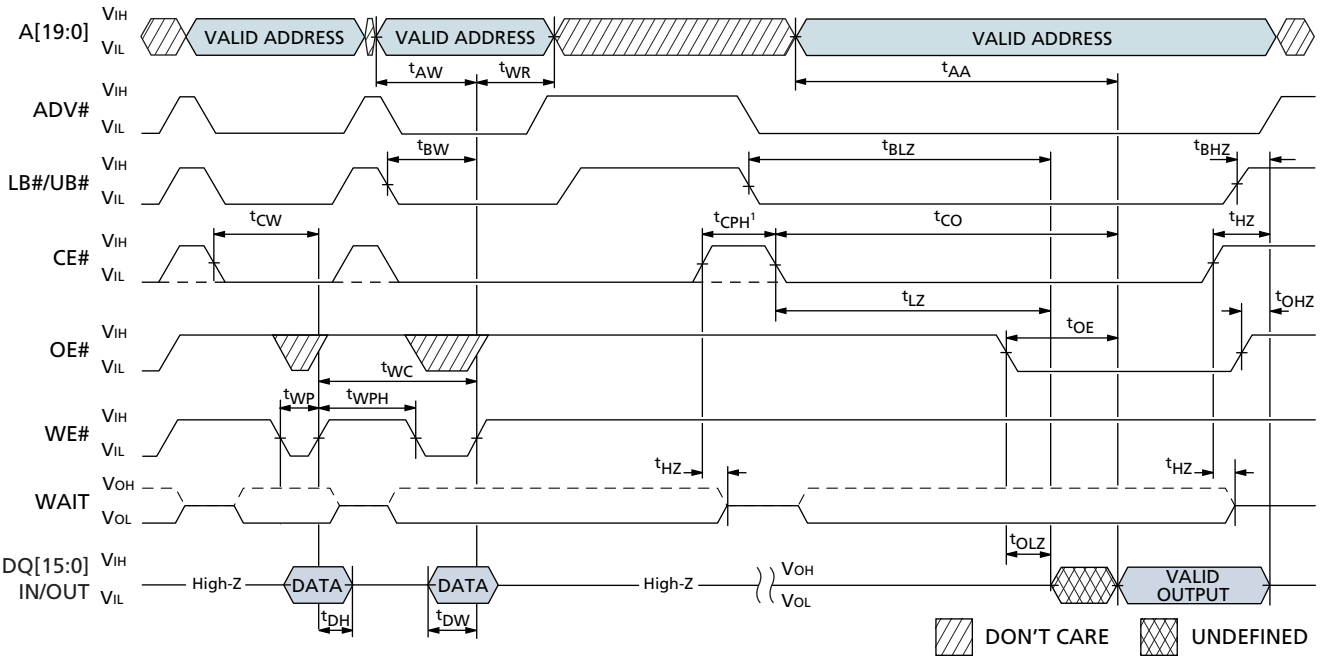
Notes: 1. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns. Note that CellularRAM Workgroup specification 1.0 requires CE# to be clocked HIGH to terminate the burst.

Figure 44: Burst READ Followed by Asynchronous WRITE Using ADV#



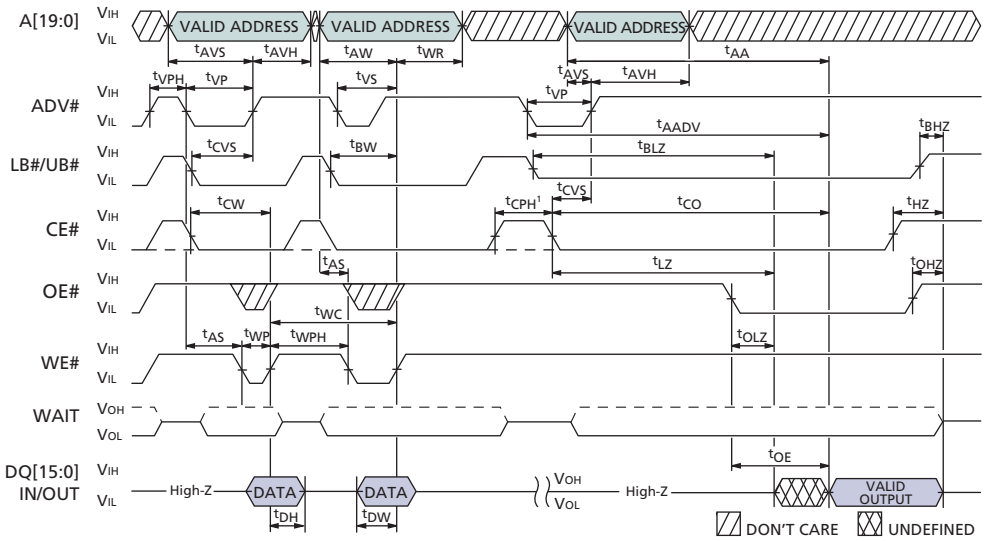
Notes: 1. When configured for synchronous mode (BCR[15] = 0), a refresh opportunity must be provided every ^{t}CEM. A refresh opportunity is satisfied by either of the following two conditions: a) clocked CE# HIGH, or b) CE# HIGH for greater than 15ns. Note that CellularRAM Workgroup specification 1.0 requires CE# to be clocked HIGH to terminate the burst.

Figure 45: Asynchronous WRITE Followed by Asynchronous READ – ADV# LOW



Notes: 1. When configured for synchronous mode (BCR[15] = 0), CE# must remain HIGH for at least 5ns (^{t}CPH) to schedule the appropriate internal refresh operation. Otherwise, ^{t}CPH is only required after CE#-controlled WRITEs.

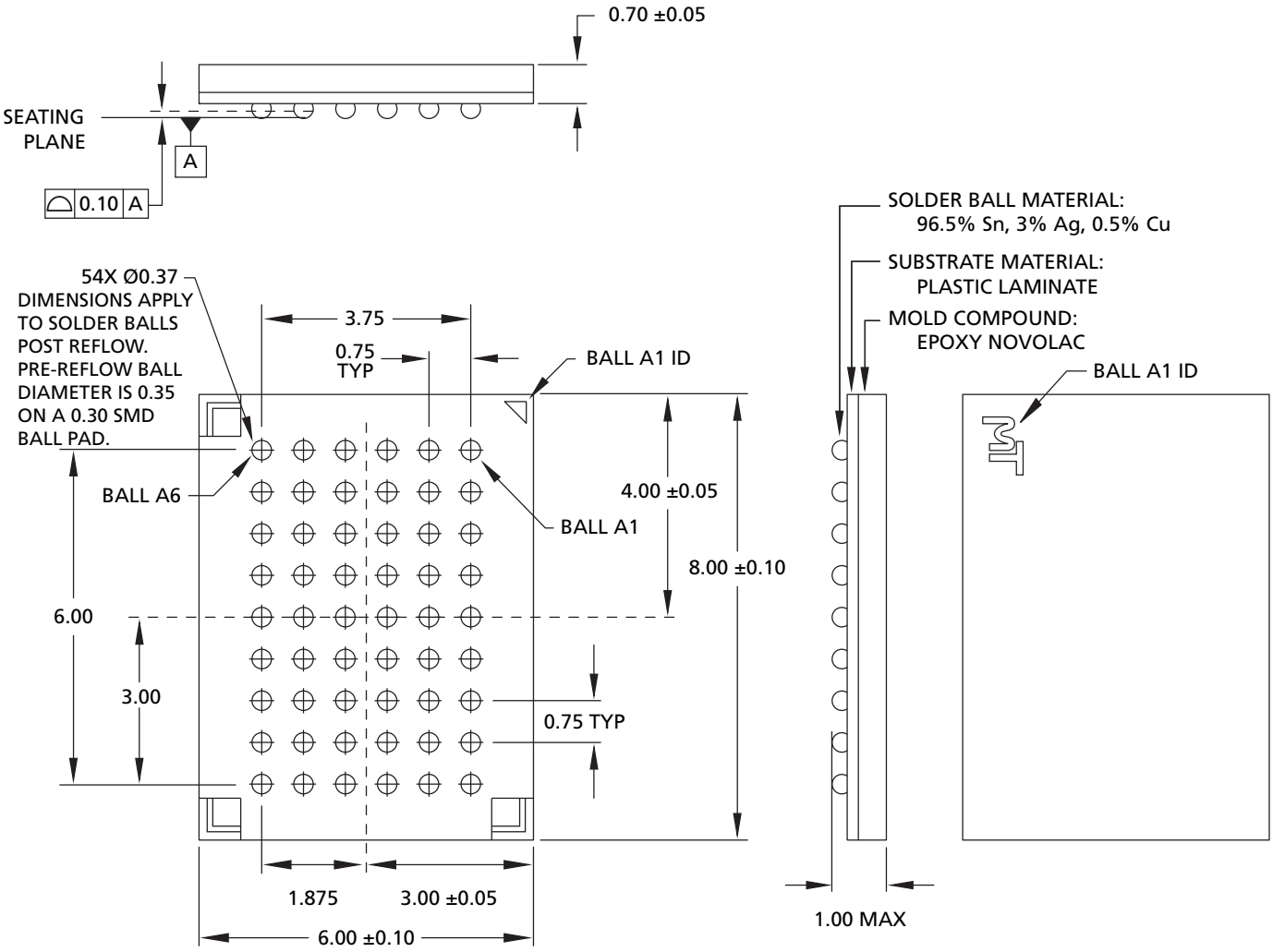
Figure 46: Asynchronous WRITE Followed by Asynchronous READ



Notes: 1. When configured for synchronous mode (BCR[15] = 0), CE# must remain HIGH for at least 5ns (^{t}CPH) to schedule the appropriate internal refresh operation. Otherwise, ^{t}CPH is only required after CE#-controlled WRITEs.

Package Dimensions

Figure 47: 54-Ball VFBGA



Notes:
1. All dimensions in millimeters; MAX/MIN or typical, as noted.
2. Package width and length do not include mold protrusion; allowable mold protrusion is 0.25mm per side.
3. The MT45W1MW16BDGB uses “green” packaging.

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Revision History

Rev. H, Production 04/08

- Updated the MAX I/O voltage from 3.3V to 3.6V.
- Updated Figure 15 on page 21 and Figure 16 on page 22 to include the 0ns MIN spec.
- Changed ^{t}PU in Table 16 on page 36 from a MIN to a MAX value.
- Updated Figure 42 on page 52 to include the correct drawing.

Rev. G, Production 11/07

- Table 15, "Burst WRITE Cycle Timing Requirements," on page 36: Corrected ^{t}CEM parameter label from minimum to maximum.

Rev. F, Production 11/06

- Updated Rev. letter to F

Rev. F, Production 06/06

- Changed the title of Figure 10 to "Wired-OR Wait Configuration"
- Updated wording in the third paragraph of "WAIT Operation" on page 15 to the following: "During a Burst cycle, CE# must remain asserted until the first data is valid. Bringing CE# HIGH during this initial latency may cause data corruption."
- Changed WAIT from "^{t}CW" to "^{t}CEW" in Figure 14
- Changed Min/Max columns from "-701" and "-708," to "104 MHz" and "80 MHz" in Table 5
- Changed "Output enable to Low-Z output" MIN value from 5 to 3 in Table 12
- Changed Min/Max columns from "-70" to "70ns" in Table 12
- Removed "CLK to DQ High-Z Output" and "CLK to Low-Z Output" rows from Table 13
- Changed "Output enable to Low-Z output" MIN value from 5 to 3 in Table 13
- Changed Min/Max columns from "-701" and "-708," to "104 MHz" and "80 MHz" in Table 13
- Changed Min/Max columns from "-70" to "70ns" in Table 14
- Changed Min/Max columns from "-701" and "-708," to "104 MHz" and "80 MHz" in Table 15
- Changed Min/Max columns from "-70" to "70ns" in Table 16
- Removed ^{t}WHZ lines and arrows in Figure 42
- Removed ^{t}WHZ lines and arrows in Figure 45
- Removed ^{t}WHZ lines and arrows in Figure 46

Rev. E, Production. 02/06

- Changed document status to Production.

Rev. D, Preliminary. 01/06

- Changed V_{IH} and V_{IL} to V_{OH} and V_{OL} in Figure 27, 28, 29, 34, 35, 36, 37
- Updated Continuous burst READ and Standby specifications in "Features" section
- Updated document designator to Preliminary
- Deleted Tables 17–43.

Rev. C 12/05

- Deleted "4-Word Burst READ Operation (with LB#/UB#)" timing diagram
- Changed file name to new standard: p23z16_b_cr1-0 to 16mb_burst_cr1_0_p23z

Rev. B 10/05

- Fixed exceptions to template (primarily minor formatting on page 1)

- Page 1, Figure 1: changed E3 ball color to white
- Page 1: changed multiple "-" to "–" for negative numbers (per style)
- Eliminated holdover references to dual parts (pgs. 10 and 30)
- Updated to state that "CLK must be held static LOW *or HIGH*" during async READ and WRITE (pgs. 7, 10, 11, 14)
- Updated note 4 in Table 8 to eliminate reference to dual part (was "BCR[5:4] = 00b")

Rev. A 08/05

- Initial release with "Advance" designation.

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