256 Mb HYPERRAM™ self-refresh DRAM (PSRAM)

HYPERBUS™ Extended-IO (x16) interface, 1.8 V

Features

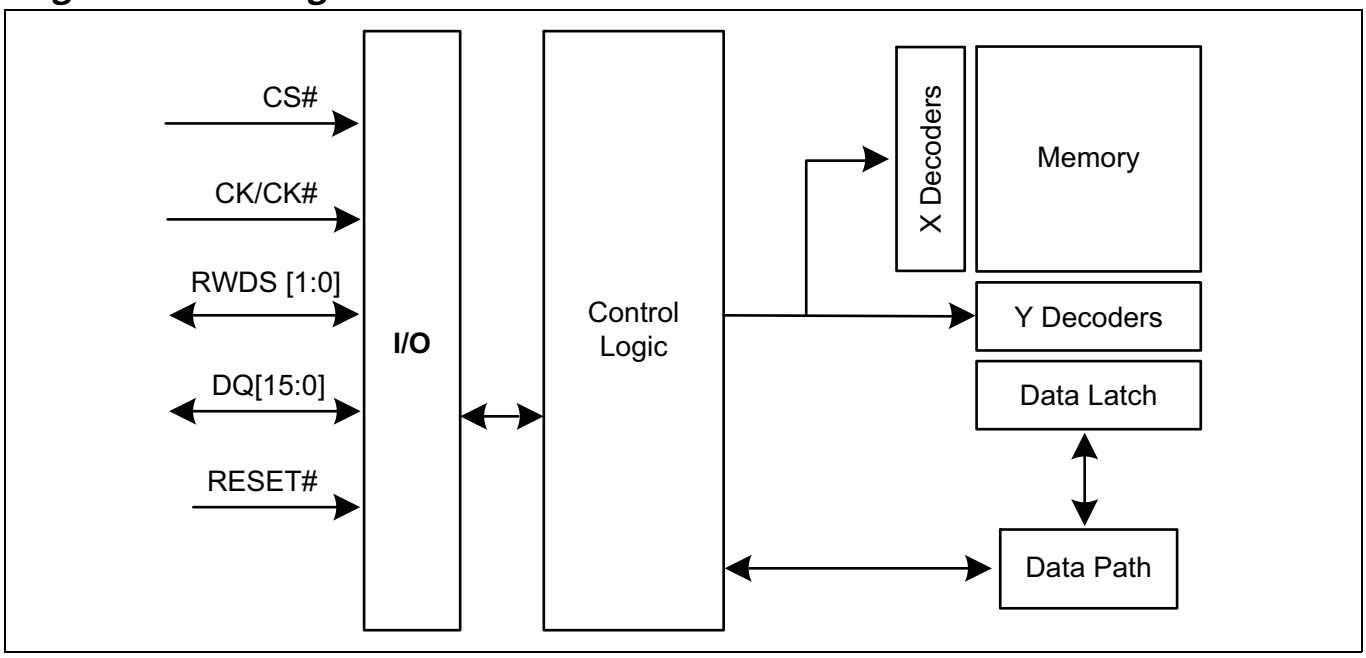
- Interface
  - HYPERBUS™ extended-IO
  - 1.7 to 2.0 V (1.8 typ.) interface support
    - Single-ended clock (CK) - 20 bus signals
    - Optional differential clock (CK, CK#) - 21 bus signals
  - Chip Select (CS#)
  - 16-bit data bus (DQ[15:0])
  - Hardware reset (RESET#)
  - Bidirectional read-write data strobe (RWDS [1:0])
    - Output at the start of all transactions to indicate refresh latency
    - Output during read transactions as read data strobe
    - Input during write transactions as write data mask
- Performance, power, and packages
  - 200 MHz maximum clock rate
  - DDR - transfers data on both edges of the clock
  - Data throughput up to 800 MBps (6,400 Mbps)
  - Configurable burst characteristics
    - Linear burst
    - Wrapped burst lengths:
      16 words (8 clocks)
      32 words (16 clocks)
      64 words (32 clocks)
      128 words (64 clocks)
    - Hybrid option - one wrapped burst followed by linear burst
  - Configurable output drive strength
  - Power modes
    - Hybrid Sleep mode
    - Deep Power Down
  - Memory array refresh
    - Partial array (1/8, 1/4, 1/2, and so on)
    - Full array
  - Package
    - 49-ball FBGA
  - Operating temperature range
    - Industrial (I): –40°C to +85°C
    - Industrial Plus (V): –40°C to +105°C
- Technology
  - 25 nm DRAM

Performance summary

Read transaction timings	Unit
Maximum clock rate at 1.8 V $V_{CC}/V_{CC}Q$	200 MHz
Maximum access time (t_{ACC})	35 ns

Maximum current consumption	Unit
Burst read or write (linear burst at 200 MHz)	20 mA/22 mA
Standby	1.55 µA
Deep power down	15 µA

Logic block diagram



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1 General description

The 256 Mb HYPERRAM™ device is a high-speed CMOS, self-refresh DRAM, with HYPERBUS™ extended-IO. The DRAM array uses dynamic cells that require periodic refresh. Refresh control logic within the device manages the refresh operations on the DRAM array when the memory is not being actively read or written by the HYPERBUS™ extended-IO interface master (host). Since the host is not required to manage any refresh operations, the DRAM array appears to the host as though the memory uses static cells that retain data without refresh. Hence, the memory is more accurately described as pseudo static RAM (PSRAM).

Since the DRAM cells cannot be refreshed during a read or write transaction, there is a requirement that the host limit read or write burst transfers lengths to allow internal logic refresh operations when they are needed. The host must confine the duration of transactions and allow additional initial access latency, at the beginning of a new transaction, if the memory indicates a refresh operation is needed.

1.1 HYPERBUS™ extended-IO interface

HYPERBUS™ extended-IO is a low signal count, DDR interface, that achieves high-speed read and write throughput. The DDR protocol transfers two 32-bit data word per clock cycle on the DQ[15:0] input/output signals. A read or write transaction on HYPERBUS™ extended-IO consists of a series of 16-bit wide, one clock cycle data transfers at the internal HYPERRAM™ array with two corresponding 16-bit wide, one-half-clock-cycle data transfers on the DQ signals. All inputs and outputs are LV-CMOS compatible. S80KS2564 or S80KS2564 devices are available as 1.8 V V_{CC}/(V_{CC}Q (nominal) for array (V_{CC}) and I/O buffer (V_{CCQ}) supplies, through different ordering part numbers (OPN).

Command, address, and data information is transferred over the 16 HYPERBUS™ extended-IO DQ[15:0] signals. The clock (CK#, CK) is used for information capture by a HYPERBUS™ extended-IO slave device when receiving command, address, or data on the DQ signals. Command or address values are center-aligned with clock transitions.

Every transaction begins with the assertion of CS# and command-address (CA) signals, followed by the start of clock transitions to transfer six CA bytes, followed by initial access latency and either read or write data transfers, until CS# is deasserted.

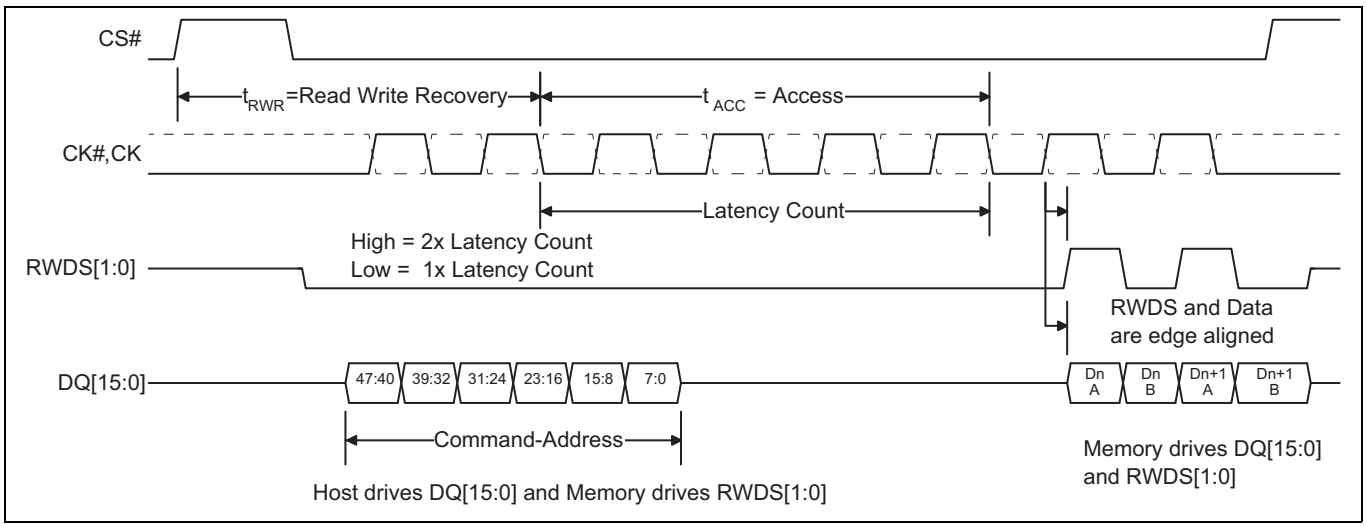


Figure 1 Read transaction, single initial latency count

The RWDS is a bidirectional signal that indicates:

- when data will start to transfer from a HYPERRAM™ device to the master device in read transactions (initial read latency)
- when data is being transferred from a HYPERRAM™ device to the master device during read transactions (as a source synchronous read data strobe)
- when data may start to transfer from the master device to a HYPERRAM™ device in write transactions (initial write latency)
- data masking during write data transfers

During the CA transfer portion of a read or write transaction, RWDS acts as an output from a HYPERRAM™ device to indicate whether additional initial access latency is needed in the transaction.

During read data transfers, RWDS is a read data strobe with data values edge-aligned with the transitions of RWDS.

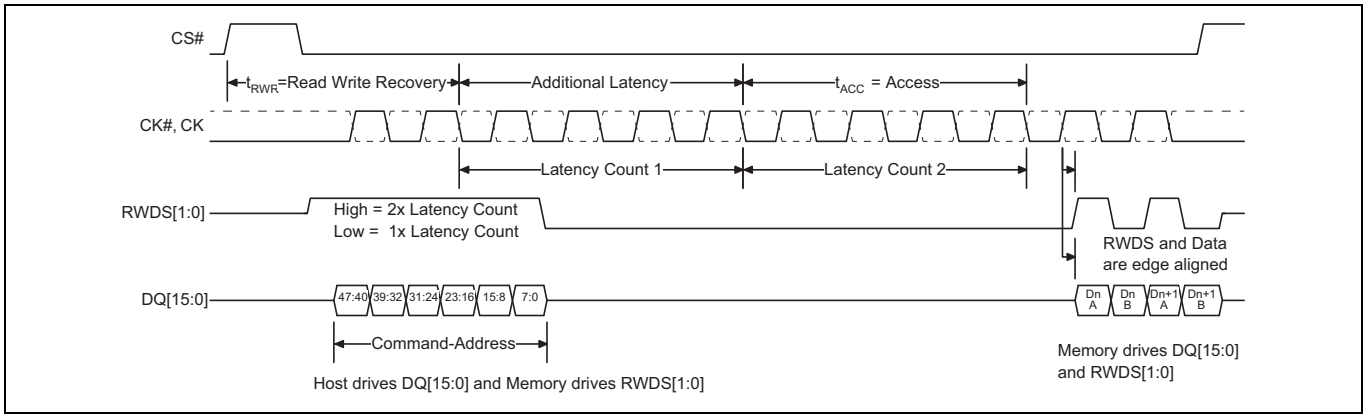


Figure 2 Read transaction, additional latency count

During write data transfers, RWDS indicates whether each data word transfer is masked with RWDS HIGH (invalid and prevented from changing the data word in a memory) or not masked with RWDS LOW (valid and written to a memory). Data masking may be used by the host to 16-bit word align write data within a memory or to enable merging of multiple non-word aligned writes in a single burst write. During write transactions, data is center-aligned with clock transitions.

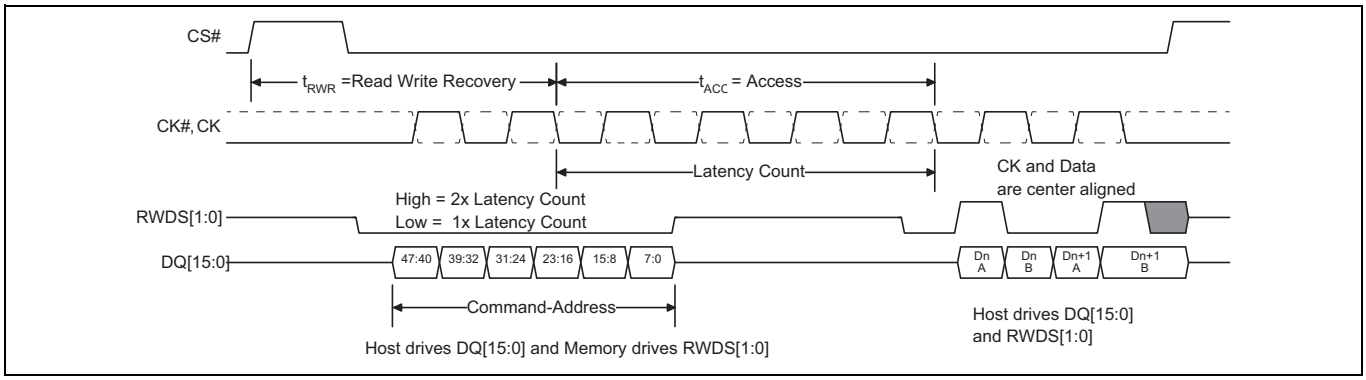


Figure 3 Write transaction, single initial latency count

Read and write transactions are burst oriented, transferring the next sequential word during each clock cycle. Each individual read or write transaction can use either a wrapped or linear burst sequence.

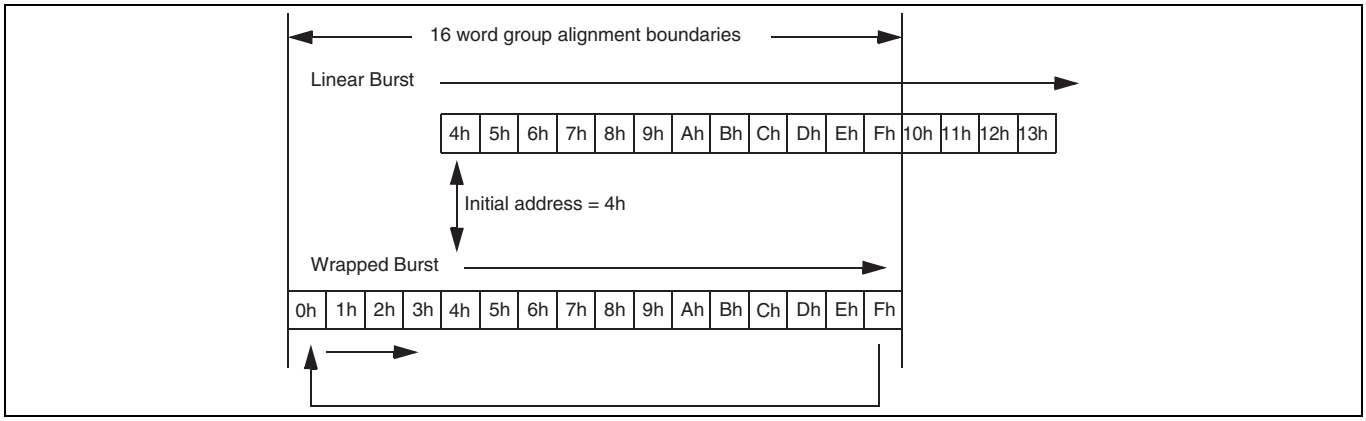


Figure 4 Linear versus wrapped burst sequence

During wrapped transactions, accesses start at a selected location and continue to the end of a configured word group aligned boundary, then wrap to the beginning location in the group, then continue back to the starting location. Wrapped bursts are generally used for critical word first cache line fill read transactions. During linear transactions, accesses start at a selected location and continue in a sequential manner until the transaction is terminated when CS# returns HIGH. Linear transactions are generally used for large contiguous data transfers such as graphic images. Since each transaction command selects the type of burst sequence for that transaction, wrapped and linear bursts transactions can be dynamically intermixed as needed.

2 Product overview

The 256 Mb HYPERRAM™ device is 1.8 V array and I/O, synchronous self-refresh DRAM. The HYPERRAM™ device provides a HYPERBUS™ extended-IO slave interface to the host system. The HYPERBUS™ extended-IO interface has an 16-bit wide DDR data bus and use only 32-bit double word address boundaries. Read transactions provide 16 bits of data during each clock cycle (8 bits on both clock edges). Write transactions take 32 bits of data from each clock cycle (16 bits on each clock edge).

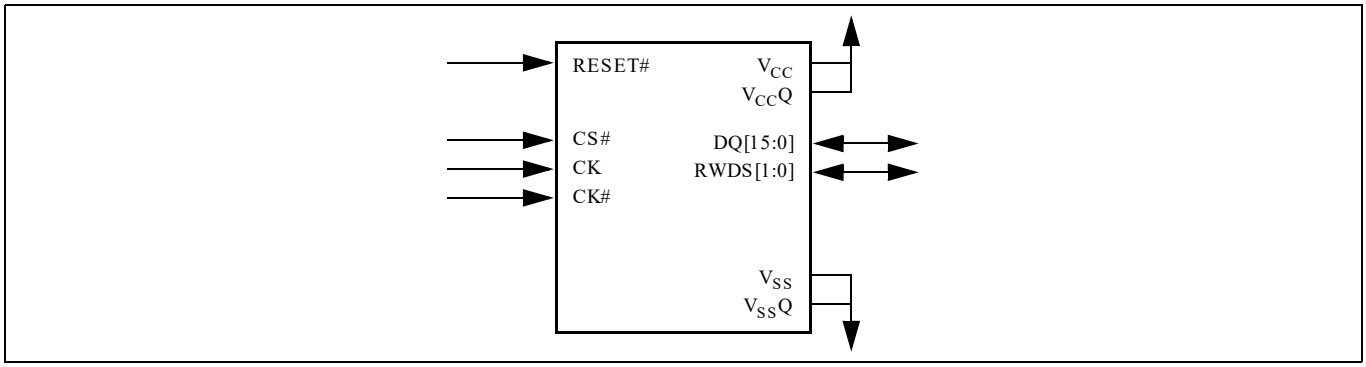


Figure 5 HYPERRAM™ interface[1]

2.1 HYPERBUS™ extended-IO interface

Read and write transactions require two clock cycles to define the target row address and burst type, then an initial access latency of t_{ACC}. During the CA part of a transaction, the memory will indicate whether an additional latency for a required refresh time (t_{RFH}) is added to the initial latency; by driving the RWDS signal to the HIGH state. During the CA period, the third clock cycle will specify the target word address within the target row. During a read (or write) transaction, after the initial data value has been output (or input), additional data can be read from (or written to) the row on subsequent clock cycles in either a wrapped or linear sequence. When configured in Linear Burst mode, the device will automatically fetch the next sequential row from the memory array to support a continuous linear burst. Simultaneously accessing the next row in the array while the read or write data transfer is in progress, allows for a linear sequential burst operation that can provide a sustained data rate of *800 MBps [1 word (16 bit data bus) * 2 (data clock edges) * 200 MHz = 800 MBps]*.

Note
1. CK# is used in Differential Clock mode, but optional.

3 Signal description

3.1 Input/output summary

HYPERRAM™ signals are shown in **Table 1**. Active Low signal names have a hash symbol (#) suffix.

Table 1 I/O summary

Symbol	Type	Description
CS#	Input	**Chip Select.** Bus transactions are initiated with a HIGH to LOW transition. Bus transactions are terminated with a LOW to HIGH transition. The master device has a separate CS# for each slave.
CK, CK#[2]		**Differential Clock.** Command, address, and data information is output with respect to the crossing of the CK and CK# signals. Use of differential clock is optional. Single ended clock. CK# is not used, only a single ended CK is used. The clock is not required to be free-running.
DQ[15:0]	Input/output	**Data Input/Output.** DQ[7:0] to transmit command and address during command/address (CA) period and lower byte of 16-bit data word during read and write transactions. DQ[15:8] to transmit upper byte of 16-bit data word during read and write transactions. Host has to drive DQ[15:8] all to “H” or “L” during the CA period. Floating is not allowed.
RWDS[1:0]		**Read-Write Data Strobe.** During the command/address portion of all bus transactions RWDS is a slave output and indicates whether additional initial latency is required. Slave output during read data transfer, data is edge aligned with RWDS. Slave input during data transfer in write transactions to function as a data mask. RWDS[0] corresponds to the data on DQ[7:0] RWDS[1] corresponds to the data on DQ[15:8] (High = Additional latency, Low = No additional latency).
RESET#	Input, internal pull-up	**Hardware RESET.** When LOW, the slave device will self initialize and return to the STANDBY state. RWDS[1:0] and DQ[15:0] are placed into the HIGH-Z state when RESET# is LOW. The slave RESET# input includes a weak pull-up, if RESET# is left unconnected it will be pulled up to the HIGH state.
V_{CC}	Power supply	**Array Power.**
$V_{CC}Q$		**Input/Output Power.**
V_{SS}		**Array Ground.**
$V_{SS}Q$		**Input/Output Ground.**
RFU	No connect	**Reserved for Future Use.** May or may not be connected internally, the signal/ball location should be left unconnected and unused by PCB routing channel for future compatibility. The signal/ball may be used by a signal in the future.

Note
2. CK# is used in differential clock mode, but optional connection. Tie the CK# input pin to either VccQ or VssQ if not connected to the host controller, but do not leave it floating.

4 HYPERBUS™ extended-IO transaction details

4.1 Command/address bit assignments

All HYPERRAM™ bus transactions can be classified as either read or write. A bus transaction is started with CS# going LOW with clock in idle state (CK = LOW and CK# = HIGH). The first three clock cycles transfer three words of command/address (CA0, CA1, CA2) information to define the transaction characteristics. The command/address words are presented with DDR timing, using the first six clock edges.

The following characteristics are defined by the Command/Address information:

- Read or write transaction
- Address space: memory array space or register space
  - Register space is used to access Device Identification (ID) registers and Configuration Registers (CR) that identify the device characteristics and determine the slave specific behavior of read and write transfers on the HYPERBUS™ extended-IO interface.
- Whether a transaction will use a linear or wrapped burst sequence.
- The target row (and half-page) address (upper order address)
- The target column (word within half-page) address (lower order address)

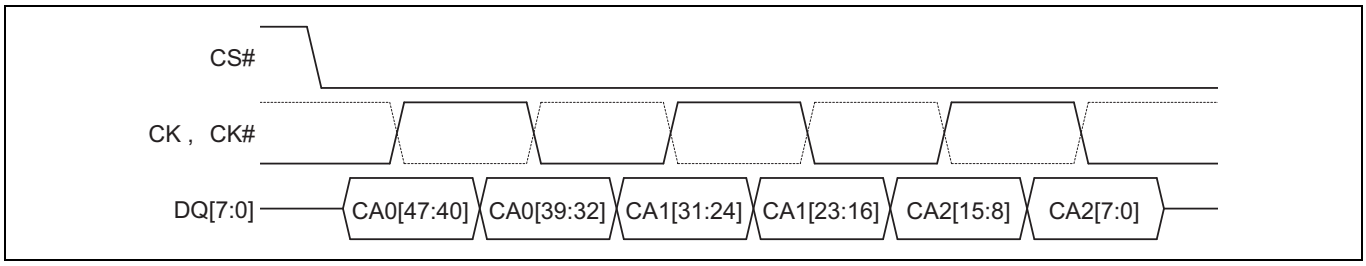


Figure 6 Command-address (CA) sequence[3–7]

Table 2 CA bit assignment to DQ signals

Signal	CA0[47:40]	CA0[39:32]	CA1[31:24]	CA1[23:16]	CA2[15:8]	CA2[7:0]
DQ[7]	CA[47]	CA[39]	CA[31]	CA[23]	CA[15]	CA[7]
DQ[6]	CA[46]	CA[38]	CA[30]	CA[22]	CA[14]	CA[6]
DQ[5]	CA[45]	CA[37]	CA[29]	CA[21]	CA[13]	CA[5]
DQ[4]	CA[44]	CA[36]	CA[28]	CA[20]	CA[12]	CA[4]
DQ[3]	CA[43]	CA[35]	CA[27]	CA[19]	CA[11]	CA[3]
DQ[2]	CA[42]	CA[34]	CA[26]	CA[18]	CA[10]	CA[2]
DQ[1]	CA[41]	CA[33]	CA[25]	CA[17]	CA[9]	CA[1]
DQ[0]	CA[40]	CA[32]	CA[24]	CA[16]	CA[8]	CA[0]

Notes
3. **Figure 6** shows the initial three clock cycles of all transactions on the HYPERBUS™ extended-IO.
4. CK# of differential clock is shown as dashed line waveform.
5. CA information is “center-aligned” with the clock during both read and write transactions.
6. Data bits in each byte are always in high to low order with bit 7 on DQ7 and bit 0 on DQ0.
7. DQ[15:8] should be Ignored during command/address phase but host has to drive them to “H” or “L”.

Table 3 Command/address bit assignments[8–11]

CA bit#	Bit name	Bit function
47	R/W#	Identifies the transaction as a read or write. R/W# = 1 indicates a read transaction R/W# = 0 indicates a write transaction
46	Address space (AS)	Indicates whether the read or write transaction accesses the memory or register space. AS = 0 indicates memory space AS = 1 indicates the register space The register space is used to access device ID and configuration registers.
45	Burst type	Indicates whether the burst will be linear or wrapped. Burst type = 0 indicates wrapped burst Burst type = 1 indicates linear burst
44–16	Row and upper column address	Row & Upper Column component of the target address: System word address bits A31–A3 Any upper row address bits not used by a particular device density should be set to '0' by the host controller master interface. The size of rows and therefore the address bit boundary between row and column address is slave device dependent.
15–3	Reserved	Reserved for future column address expansion. Reserved bits are don't care in current HYPERBUS™ extended-IO devices but should be set to '0' by the host controller master interface for future compatibility.
2–0	Lower column address	Lower column component of the target address: System word address bits A2–A0 selecting the starting word within a half-page.

Notes

8. A row is a group of words relevant to the internal memory array structure. The number of rows is also used in the calculation of a distributed refresh interval for HYPERRAM™ memory.
9. The column address selects the burst transaction starting word location within a row. The column address is split into an upper and lower portion. The upper portion selects an 8-word (32-byte) half-page and the lower portion selects the 32-bit double word within a half-page where a read or write transaction burst starts.
10. The initial read access time starts when the row and upper column (half-page) address bits are captured by a slave interface. Continuous linear read burst is enabled by memory devices internally interleaving access to 32 byte half-pages.
11. HYPERBUS™ extended-IO protocol address space limit, assuming:
    29 row and upper column address bits
    3 lower column address bits
    Each address selects a 32-bit wide data value
    29 + 3 = 32 address bits = 4G addresses supporting 8 GB (64 Gb) maximum address space
    Future expansion of the column address can allow for 29 row and upper column + 16 lower column address bits = 35 Tera-word = 70 Tera-byte address space.

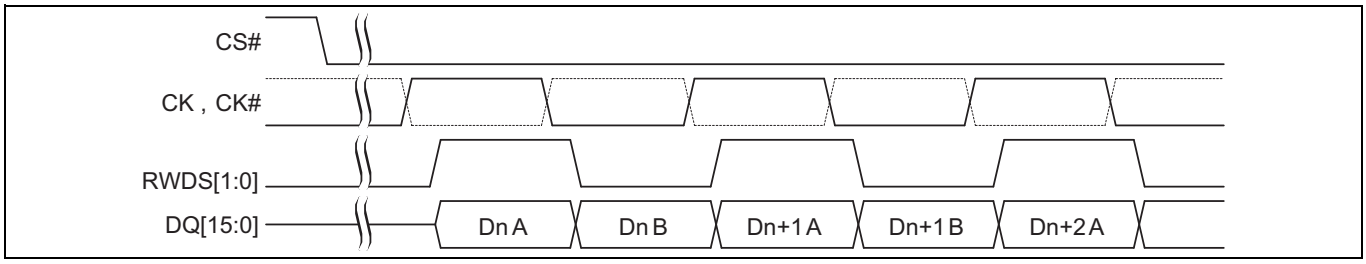


Figure 7 Data placement during a read transaction[12–16]

Data placement during memory read/write is dependent upon the host. The device will output data (read) as it was written in (write).

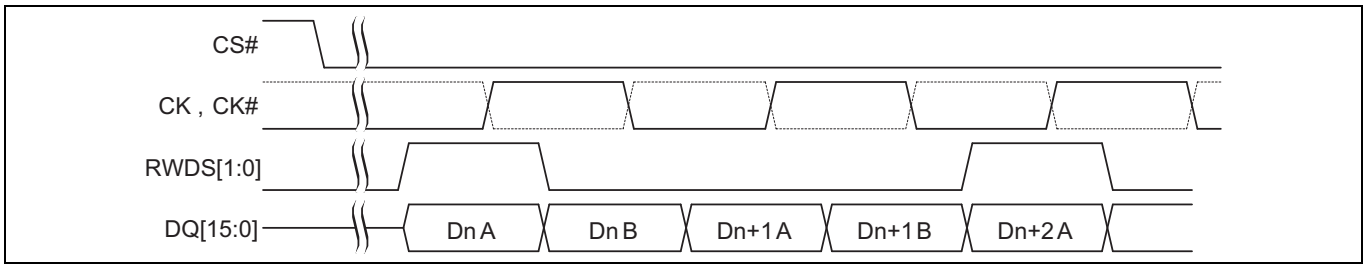


Figure 8 Data placement during a write transaction[12–20]

Notes

12. **Figure 7** shows a portion of a read transaction on the HYPERBUS™ extended-IO. CK# of differential clock is shown as dashed line waveform.
13. Data is “edge-aligned” with the RWDS serving as a read data strobe during read transactions.
14. Data is always transferred in full word increments (word granularity transfers).
15. Word address increments in each clock cycle. Byte A is between RWDS rising and falling edges and is followed by byte B between RWDS falling and rising edges, of each word.
16. Data bits in each 16-bit are always in high to low order with bit 15 on DQ15 and bit 0 on DQ0.
17. **Figure 8** shows a portion of a write transaction on the HYPERBUS™ extended-IO.
18. Data is “center-aligned” with the clock during a write transaction.
19. RWDS[1:0] functions as a data mask during write data transfers with initial latency.
    - RWDS[0] as a input data mask for the data on DQ0–7.
    - RWDS[1] as a input data mask for the data on DQ8–15.
20. RWDS is not driven by the master during write data transfers with zero initial latency. Full data words are always written in this case. RWDS may be driven LOW or left HIGH-Z by the slave in this case.

4.2 Read transactions (Memory array and registers)

The HYPERBUS™ extended-IO master begins a transaction by driving CS# LOW while clock is idle. The clock then begins toggling while CA words are transferred.

In CA0, CA[47] = 1 indicates that a read transaction is to be performed. CA[46] = 0 indicates the memory space is being read or CA[46] = 1 indicates the register space is being read. CA[45] indicates the burst type (wrapped or linear). Read transactions can begin the internal array access as soon as the row and upper column address has been presented in CA0 and CA1 (CA[47:16]). CA2 (CA(15:0]) identifies the target word address within the chosen row.

The HYPERBUS™ extended-IO master then continues clocking for a number of cycles defined by the latency count setting in configuration register 0. The initial latency count required for a particular clock frequency is based on RWDS. If RWDS is LOW during the CA cycles, one latency count is inserted. If RWDS is HIGH during the CA cycles, an additional latency count is inserted. Once these latency clocks have been completed the memory starts to simultaneously transition the RWDS and output the target data.

New data is output edge-aligned with every transition of RWDS. Data will continue to be output as long as the host continues to transition the clock while CS# is LOW. Note that burst transactions should not be so long as to prevent the memory from doing distributed refreshes.

Wrapped bursts will continue to wrap within the burst length and linear burst will output data in a sequential manner across row boundaries. When a linear burst read reaches the last address in the array, continuing the burst beyond the last address will provide data from the beginning of the address range. Read transfers can be ended at any time by bringing CS# HIGH when the clock is idle.

The clock is not required to be free-running. The clock may remain idle while CS# is HIGH.

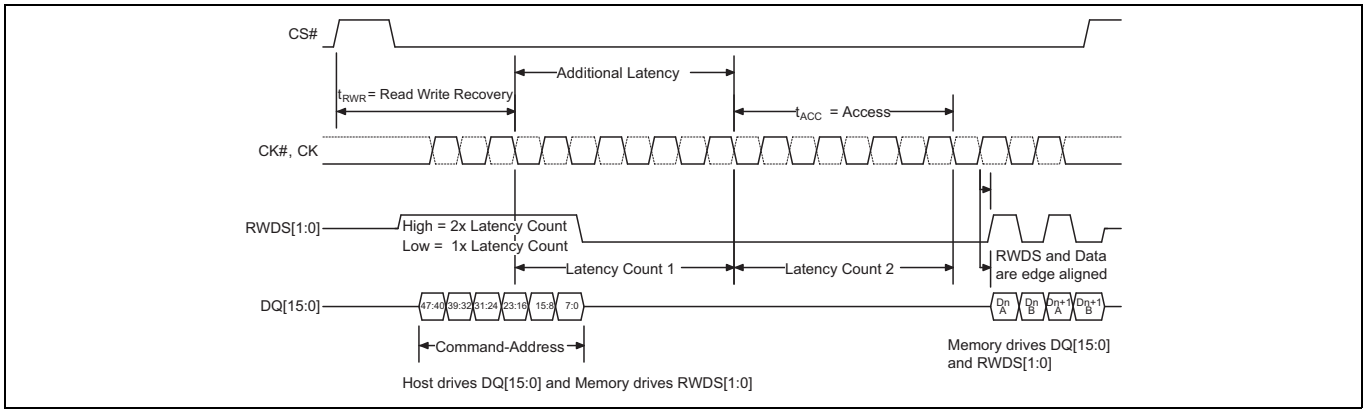


Figure 9 Read transaction with additional initial latency[21–30]

Notes

21. Transactions are initiated with CS# falling while CK = LOW and CK# = HIGH.
22. CS# must return HIGH before a new transaction is initiated.
23. CK# is the complement of the CK signal.CK# of a differential clock is shown as a dashed line waveform.
24. Read access array starts once CA[23:16] is captured.
25. The read latency is defined by the initial latency value in a configuration register.
26. In this read transaction example the initial latency count was set to four clocks.
27. In this read transaction a RWDS HIGH indication during CA delays output of target data by an additional four clocks.
28. The memory device drives RWDS during read transactions.
29. For register read, the output data Dn A[7:0] is RG[15:8], Dn B[7:0] is RG[7:0], Dn+1 A[7:0] is RG[15:8], Dn+1 B[7:0] is RG[7:0].
30. DQ[15:8] is Ignored during Command/Address phase but host has to drive them to “H” or “L”.

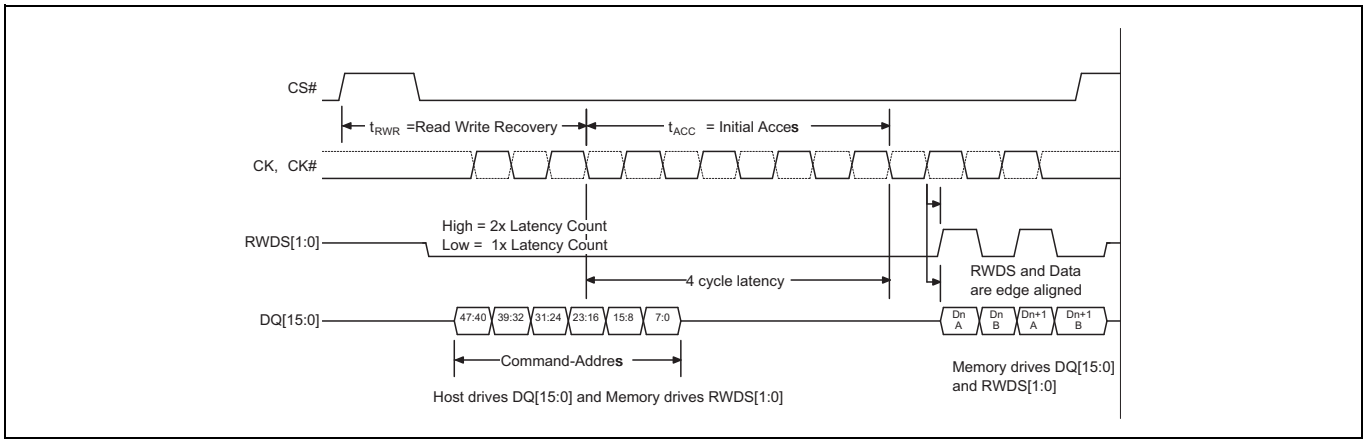


Figure 10 Read transaction without additional initial latency[31-32]

4.3 Write transactions (memory array write)

The HYPERBUS™ extended-IO master begins a transaction by driving CS# LOW while clock is idle. Then the clock begins toggling while CA words are transferred.

In CA0, CA[47] = 0 indicates that a write transaction is to be performed. CA[46] = 0 indicates the memory space is being written. CA[45] indicates the burst type (wrapped or linear). Write transactions can begin the internal array access as soon as the row and upper column address has been presented in CA0 and CA1 (CA[47:16]). CA2 (CA(15:0]) identifies the target word address within the chosen row.

The HYPERBUS™ extended-IO master then continues clocking for a number of cycles defined by the latency count setting in Configuration Register 0. The initial latency count required for a particular clock frequency is based on RWDS. If RWDS is LOW during the CA cycles, one latency count is inserted. If RWDS is HIGH during the CA cycles, an additional latency count is inserted.

Once these latency clocks have been completed, the HYPERBUS™ extended-IO master starts to output the target data. Write data is center-aligned with the clock edges. The first 16-bit data is captured by the memory on the rising edge of CK and the second 16-bit data is captured on the falling edge of CK.

During the CA clock cycles, RWDS is driven by the memory.

During the write data transfers, RWDS is driven by the host master interface as a data mask. When data is being written and RWDS is HIGH, the 16-bit will be masked and the array will not be altered. When data is being written and RWDS is LOW, the data will be placed into the array. Because the master is driving RWDS during write data transfers, neither the master nor the HYPERRAM™ device are able to indicate a need for latency within the data transfer portion of a write transaction. The acceptable write data burst length setting is also shown in Configuration Register 0.

Data will continue to be transferred as long as the HYPERBUS™ extended-IO master continues to transition the clock while CS# is LOW. Note that burst transactions should not be so long as to prevent the memory from doing distributed refreshes. Legacy format wrapped bursts will continue to wrap within the burst length. Hybrid wrap will wrap once then switch to linear burst starting at the next wrap boundary. Linear burst accepts data in a sequential manner across page boundaries. Write transfers can be ended at any time by bringing CS# HIGH when the clock is idle.

When a linear burst write reaches the last address in the memory array space, continuing the burst will write to the beginning of the address range.

The clock is not required to be free-running. The clock may remain idle while CS# is HIGH.

Notes

31. RWDS is LOW during the CA cycles. In this Read Transaction, there is a single initial latency count for read data access because, this read transaction does not begin at a time when additional latency is required by the slave.
32. DQ[15:8] should be Ignored during Command/Address phase but host has to drive them to “H” or “L”.

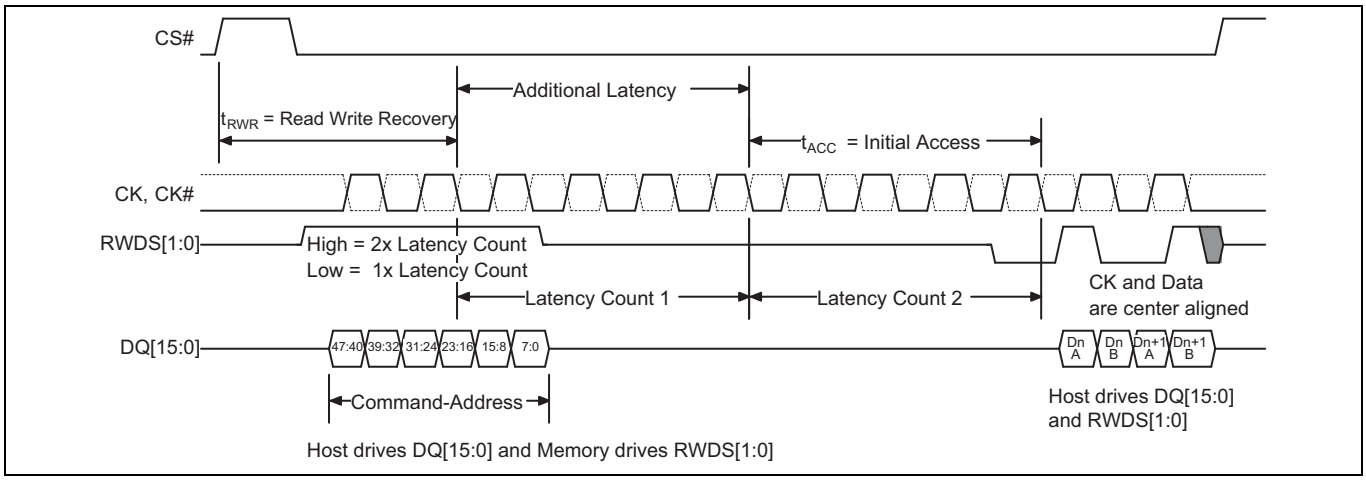


Figure 11 Write transaction with additional initial latency[33–36]

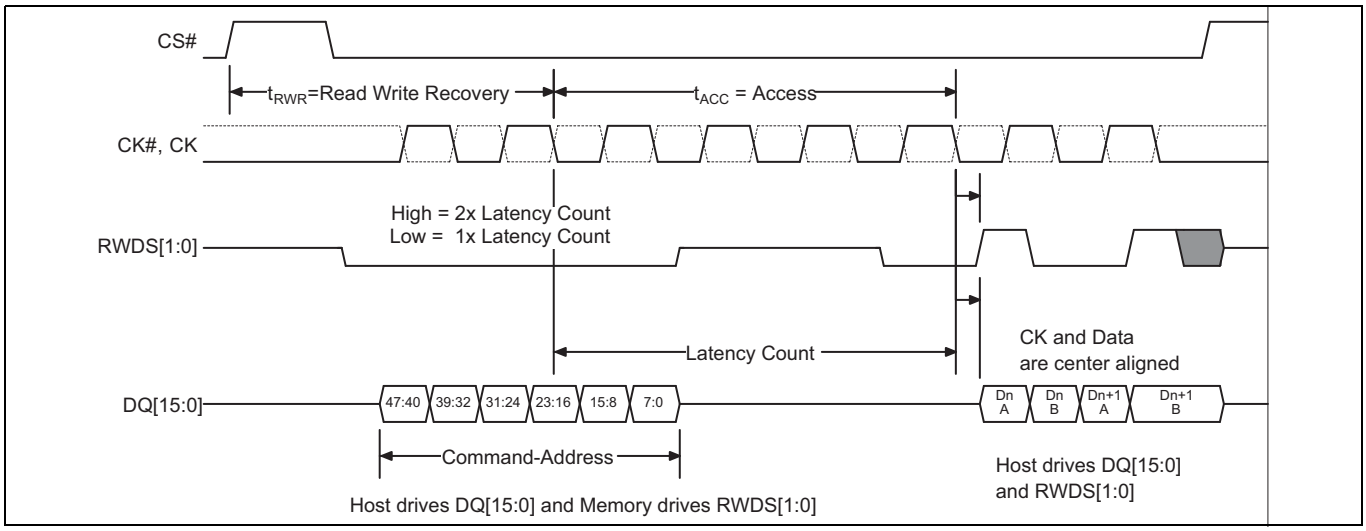


Figure 12 Write transaction without additional initial latency[37–40]

Notes

33. Transactions must be initiated with CK = LOW and CK# = HIGH.
34. CS# must return HIGH before a new transaction is initiated.
35. During CA, RWDS is driven by the memory and indicates whether additional latency cycles are required.
36. In this example, RWDS indicates that additional initial latency cycles are required.
37. At the end of CA cycles the memory stops driving RWDS to allow the host HYPERBUS™ extended-IO master to begin driving RWDS. The master must drive RWDS to a valid LOW before the end of the initial latency to provide a data mask preamble period to the slave.
38. During data transfer, RWDS is driven by the host to indicate which 16-bit data should be either masked or loaded into the array.
39. The figure shows RWDS masking 16-bit word Dn A and 16-bit Dn+1 B.
40. DQ[15:8] should be Ignored during command/address phase but host has to drive them to “H” or “L”.

4.4 Write transactions without initial latency (register write)

A write transaction starts with the first three clock cycles providing the command/address information indicating the transaction characteristics. CA0 may indicate that a write transaction is to be performed and also indicates the address space and burst type (wrapped or linear).

Writes without initial latency are used for register space writes. HYPERRAM™ device write transactions with zero latency mean that the CA cycles are followed by write data transfers. Writes with zero initial latency, do not have a turn around period for RWDS. The HYPERRAM™ device will always drive RWDS during the CA period to indicate whether extended latency is required for a transaction that has initial latency. However, the RWDS is driven before the HYPERRAM™ device has received the first byte of CA i.e., before the HYPERRAM™ device knows whether the transaction is a read or write to register space. In the case of a write with zero latency, the RWDS state during the CA period does not affect the initial latency of zero. Since master write data immediately follows the CA period in this case, the HYPERRAM™ device may continue to drive RWDS LOW or may take RWDS to HIGH-Z during write data transfer. The master must not drive RWDS during Writes with zero latency. Writes with zero latency do not use RWDS as a data mask function.

The first 16-bit data is presented on the rising edge of CK and the second 16-bit is presented on the falling edge of CK. DQ[7:0] transmits RG[15:8] on the rising edge of the CK while DQ[7:0] transmits RG[7:0] on the falling edge of the CK. DQ[15:8] should be ignored during CA cycle but host has to drive them to either “H” or “L”. Write data is center-aligned with the clock inputs. Write transfers can be ended at any time by bringing CS# HIGH when clock is idle. The clock is not required to be free-running.

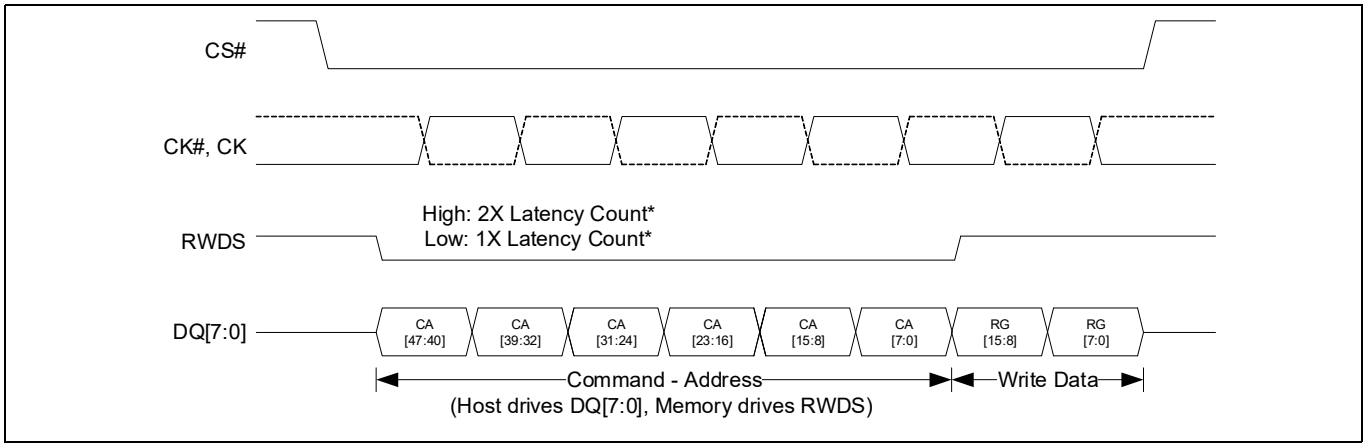


Figure 13 Register write operations[41–42]

Notes

41. Latency is not applicable during the Register Write. The RWDS driven LOW or HIGH after the CS# LOW should be ignored by the host. The register write data byte immediately follows the last CA byte (zero clock latency).
42. RWDS is not driven by the host during register write. The HYPERRAM™ ignores the RWDS status and always writes full data. RWDS may be driven Low or left High-Z by the slave during write data transfer.

5 Memory space

5.1 HYPERBUS™ extended-IO interface

Table 4 Memory space address map (double word based - 32 bits)

Unit type	Count	System word address bits	CA bits	Notes
Rows within 256 Mb device	32768 (Rows)	A22–A8	35–21	–
Row	32 (Half-pages)	A7–A3	20–16	Each row has 32 Half-pages. Each Half-page has eight 32-bit words. Therefore, each row has 256 double words (32-bit) or 1 KB.
Half-page	8 (32-bit, double word)	A2–A0	2–0	Half-Page (HP) address is also referenced as upper column address. A word within a Half-Page address is also referred to as lower column address.

6 Register space

6.1 HYPERBUS™ extended-IO interface

When CA[46] is '1', a read or write transaction accesses the register space.

Table 5 Register space address map

Register	System address	—	—	—	31–27	26–19	18–11	10–3	—	2–0
	CA bits	47	46	45[43]	44–40	39–32	31–24	23–16	15–8	7–0
Identification Register 0 Read[44]		C0h or E0h				00h	00h	00h	00h	00h
Identification Register 1 Read[44]		C0h or E0h				00h	00h	00h	00h	01h
Configuration Register 0 Read		C0h or E0h				00h	01h	00h	00h	00h
Configuration Register 0 Write		60h				00h	01h	00h	00h	00h
Configuration Register 1 Read		C0h or E0h				00h	01h	00h	00h	01h
Configuration Register 1 Write		60h				00h	01h	00h	00h	01h

6.2 Device Identification registers

There are two read only, non-volatile word registers, that provide information on the device selected when CS# is LOW.

The device information fields identify:

- Manufacturer
- Type
- Density
- Row address bit count
- Column address bit count

Table 6 Identification Register 0 (ID0) bit assignments

Bits	Function	Settings (binary)
[15:14]	MCP die address	00 - Default
[13]	Reserved	0 - Default
[12:8]	Row address bit count	01110b - 256 Mb; fifteen row address bits (256 Mb)
[7:4]	Column address bit count	0111b - Eight column address bits (default)
[3:0]	Manufacturer	0110b

Table 7 Identification Register 1 (ID1) bit assignments

Bits	Function	Settings (binary)
[15:4]	Reserved	0000_0000_0000b (default)
[3:0]	Device type	1001 - HYPERRAM™ extended-IO

Notes

43. CA45 may be either 0 or 1 for either wrapped or linear read. CA45 must be 1 as only linear single word register writes are supported.
44. The burst type (wrapped/linear) definition is not supported in register reads. Hence C0h/E0h have the same effect.

Register space

6.2.1 Density and row boundaries

The DRAM array size (density) of the device can be determined from the total number of system address bits used for the row and column addresses as indicated by the row address bit count and column address bit count fields in the ID0 register. For example: a 256 Mb HYPERRAM™ device has 8 column address bits and 15 row address bits for a total of 23 word address bits = 2^{23} = 8M × 32-bit or 256 Mb. The 8 column address bits indicate that each row holds 2^8 = 256 × 32-bit or 8192 bits. The row address bit count indicates there are 32,784 rows to be refreshed within each array refresh interval. The row count is used in calculating the refresh interval.

ID0 value for the 256 Mb HYPERRAM™ is 0xE76.

6.3 Register space access

Register default values are loaded upon power-up or hardware reset. The registers can be altered at any time while the device is in the STANDBY state.

Loading a register is accomplished with write transaction without initial latency using a single 16-bit word write transaction.

Each register is written with a separate single word write transaction. Register write transactions have zero latency, the single word of data immediately follows the CA. RWDS is not driven by the host during the write because RWDS is always driven by the memory during the CA cycles to indicate whether a memory array refresh is in progress. Because a register space write goes directly to a register, rather than the memory array, there is no initial write latency, related to an array refresh that may be in progress. In a register write, RWDS is also not used as a data mask because both bytes of a register are always written and never masked.

Reserved register fields must be written with their default value. Writing reserved fields with other than default values may produce undefined results.

Notes

- The host must not drive RWDS during a write to register space.
- The RWDS signal is driven by the memory during the CA period based on whether the memory array is being refreshed. This refresh indication does not affect the writing of register data.
- The RWDS signal returns to high impedance after the CA period. Register data is never masked. Both data bytes of the register data are loaded into the selected register.

Reading of a register is accomplished with read transaction with single or double initial latency using a single 16 bit read transaction. If more than one word is read, the output becomes indeterminate. The contents of the register is returned in the same manner as reading the memory array, as shown in **Figure 9**, with one or two latency counts, based on the state of RWDS during the CA period. The latency count is defined in the Configuration Register 0 read latency field (CR0[7:4]).

6.3.1 Configuration register 0

Configuration Register 0 (CR0) is used to define the power state and access protocol operating conditions for the HYPERRAM™ device. Configurable characteristics include:

- Wrapped burst length (16, 32, 64 or 128 16-bit word aligned and length data group)
- Wrapped burst type
  - Legacy wrap (Sequential access with wrap around within a selected length and aligned group)
  - Hybrid wrap (Legacy wrap once then linear burst at start of the next sequential group)
- Initial latency
- Variable latency
  - Whether an array read or write transaction will use fixed or variable latency. If fixed latency is selected the memory will always indicate a refresh latency and delay the read data transfer accordingly. If variable latency is selected, latency for a refresh is only added when a refresh is required at the same time a new transaction is starting.
- Output drive strength
- Deep power down (DPD) mode

Register space

Table 8 Configuration Register 0 (CR0) bit assignments

CR0 bit	Function	Settings (binary)
[15]	Deep power down enable	1 - Normal operation (default). HYPERRAM™ will automatically set this value to '1' after DPD exit 0 - Writing 0 causes the device to enter deep power down
[14:12]	Drive strength	000 - 34 Ω (default) 001 - 115 Ω 010 - 67 Ω 011 - 46 Ω 100 - 34 Ω 101 - 27 Ω 110 - 22 Ω 111 - 19 Ω
[11:8]	Reserved	1 - Reserved (default) Reserved for future use. When writing this register, these bits should be set to '1' for future compatibility.
[7:4]	Initial latency	0000 - 5 clock latency @ 133 MHz Max frequency 0001 - 6 clock latency @ 166 MHz Max frequency 0010 - 7 clock latency @ 200 MHz Max frequency (default) 0011 - Reserved 0100 - Reserved ... 1101 - Reserved 1110 - 3 clock latency @ 85 MHz Max frequency 1111 - 4 clock latency @ 104 MHz Max frequency
[3]	Fixed latency enable	0 - Variable latency - 1 or 2 times initial latency depending on RWDS during CA cycles. 1 - Fixed 2 times initial latency (default)
[2]	Hybrid burst enable	0: Wrapped burst sequence to follow hybrid burst sequencing 1: Wrapped burst sequence in legacy wrapped burst manner (default) This bit setting is effective only when the "Burst Type" bit in the command/address register is set to '0', i.e. CA[45] = 0; otherwise, it is ignored.
[1:0]	Burst length	00 - 128 words 01 - 64 words 10- 16 words 11 - 32 words (default)

Wrapped burst

A wrapped burst transaction accesses memory within a group of words aligned on a word boundary matching the length of the configured group. Wrapped access groups can be configured as 16, 32, 64, or 128 16-bit word alignment and length. During wrapped transactions, access starts at the CA selected location within the group, continues to the end of the configured word group aligned boundary, then wraps around to the beginning location in the group, then continues back to the starting location. Wrapped bursts are generally used for critical word first instruction or data cache line fill read accesses.

Hybrid burst

The beginning of a hybrid burst will wrap within the target address wrapped burst group length before continuing to the next half-page of data beyond the end of the wrap group. Continued access is in linear burst order until the transfer is ended by returning CS# HIGH. This hybrid of a wrapped burst followed by a linear burst starting at the beginning of the next burst group, allows multiple sequential address cache lines to be filled in a single access. The first cache line is filled starting at the critical word. Then the next sequential line in memory can be read in to the cache while the first line is being processed.

Table 9 CR0[2] control of wrapped burst sequence

Bit	Default value	Name
2	1	Hybrid burst enable CR0[2] = 0: Wrapped burst sequence to follow hybrid burst sequencing CR0[2] = 1: Wrapped burst sequence in legacy wrapped burst manner

Table 10 Example wrapped burst sequences (HYPERBUS™ extended-IO addressing)

Burst type	Wrap boundary (16-bit)	Start address (Hex)	Sequence of word addresses (Hex) of data words
Hybrid 128	128 wrap once then linear	XXXXXX03	03, 04, 05, 06, 07, 08, 09, 0A, 0B, 0C, 0D, 0E, 0F, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, 1B, 1C, 1D, 1E, 1F, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C, 2D, 2E, 2F, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 3A, 3B, 3C, 3D, 3E, 3F, 00, 01, 02 (wrap complete, now linear beyond the end of the initial 128 wrap group) 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 4A, 4B, 4C, 4D, 4E, 4F, 50, 51, ...
Hybrid 64	64 wrap once then linear	XXXXXX03	03, 04, 05, 06, 07, 08, 09, 0A, 0B, 0C, 0D, 0E, 0F, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, 1B, 1C, 1D, 1E, 1F, 00, 01, 02 (wrap complete, now linear beyond the end of the initial 64 wrap group) 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C, 2D, 2E, 2F, 30, 31, ...
Hybrid 64	64 wrap once then linear	XXXXXX2E	2E, 2F, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 3A, 3B, 3C, 3D, 3E, 3F, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C, 2D (wrap complete, now linear beyond the end of the initial 64 wrap group) 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 4A, 4B, 4C, 4D, 4E, 4F, 50, 51, ...
Hybrid 16	16 wrap once then linear	XXXXXX02	02, 03, 04, 05, 06, 07, 00, 01 (wrap complete, now linear beyond the end of the initial 16 wrap group) 08, 09, 0A, 0B, 0C, 0D, 0E, 0F, 10, 11, 12, ...
Hybrid 16	16 wrap once then linear	XXXXXX0C	0C, 0D, 0E, 0F, 08, 09, 0A, 0B (wrap complete, now linear beyond the end of the initial 16 wrap group) 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, ...
Hybrid 32	32 wrap once then linear	XXXXXX0A	0A, 0B, 0C, 0D, 0E, 0F, 00, 01, 02, 03, 04, 05, 06, 07, 08, 09 (wrap complete, now linear beyond the end of the initial 32 wrap group) 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, ...
Wrap 64	64	XXXXXX03	03, 04, 05, 06, 07, 08, 09, 0A, 0B, 0C, 0D, 0E, 0F, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, 1B, 1C, 1D, 1E, 1F, 00, 01, 02, ...
Wrap 64	64	XXXXXX2E	2E, 2F, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 3A, 3B, 3C, 3D, 3E, 3F, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C, 2D, ...
Wrap 16	16	XXXXXX02	02, 03, 04, 05, 06, 07, 00, 01, ...
Wrap 16	16	XXXXXX0C	0C, 0D, 0E, 0F, 08, 09, 0A, 0B, ...
Wrap 32	32	XXXXXX0A	0A, 0B, 0C, 0D, 0E, 0F, 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, ...
Linear	Linear burst	XXXXXX03	03, 04, 05, 06, 07, 08, 09, 0A, 0B, 0C, 0D, 0E, 0F, 10, 11, 12, 13, 14, 15, 16, 17, 18, ...

Register space

Initial latency

Memory space read and write transactions or register space read transactions require some initial latency to open the row selected by the CA. This initial latency is t_{ACC}. The number of latency clocks needed to satisfy t_{ACC} depends on the HYPERBUS™ extended-IO frequency can vary from 3 to 7 clocks. The value in CR0[7:4] selects the number of clocks for initial latency. The default value is 7 clocks, allowing for operation up to a maximum frequency of 200 MHz prior to the host system setting a lower initial latency value that may be more optimal for the system.

In the event a distributed refresh is required at the time a memory space read or write transaction or register space read transaction begins, the RWDS signal goes HIGH during the CA to indicate that an additional initial latency is being inserted to allow a refresh operation to complete before opening the selected row.

Register space write transactions always have zero initial latency. RWDS may be HIGH or LOW during the CA period. The level of RWDS during the CA period does not affect the placement of register data immediately after the CA, as there is no initial latency needed to capture the register data. A refresh operation may be performed in the memory array in parallel with the capture of register data.

Fixed latency

A Configuration Register Option bit CR0[3] is provided to make all memory space read and write transactions or register space read transactions require the same initial latency by always driving RWDS HIGH during the CA to indicate that two initial latency periods are required. This fixed initial latency is independent of any need for a distributed refresh, it simply provides a fixed (deterministic) initial latency for all of these transaction types. The fixed latency option may simplify the design of some HYPERBUS™ extended-IO memory controllers or ensure deterministic transaction performance. Fixed latency is the default POR or reset configuration. The system may clear this configuration bit to disable fixed latency and allow variable initial latency with RWDS driven HIGH only when additional latency for a refresh is required.

Drive strength

DQ and RWDS signal line loading, length, and impedance vary depending on each system design. Configuration Register bits CR0[14:12] provide a means to adjust the DQ[15:0] and RWDS[1:0] signal output impedance to customize the DQ and RWDS signal impedance to the system conditions to minimize high speed signal behaviors such as overshoot, undershoot, and ringing. The default POR or reset configuration value is 000b to select the mid point of the available output impedance options.

The impedance values shown are typical for both pull-up and pull-down drivers at typical silicon process conditions, nominal operating voltage (1.8 V) and 50°C. The impedance values may vary from the typical values depending on the process, voltage, and temperature (PVT) conditions. Impedance will increase with slower process, lower voltage, or higher temperature. Impedance will decrease with faster process, higher voltage, or lower temperature.

Each system design should evaluate the data signal integrity across the operating voltage and temperature ranges to select the best drive strength settings for the operating conditions.

Deep power down

When the HYPERRAM™ device is not needed for system operation, it may be placed in a very low power consuming state called deep power down (DPD), by writing ‘0’ to CR0[15]. When CR0[15] is cleared to ‘0’, the device enters the DPD state within t_{DPDIN} time and all refresh operations stop. The data in RAM is lost, (becomes invalid without refresh) during DPD state. Exiting DPD requires driving CS# LOW then HIGH, POR, or a reset. Only CS# and RESET# signals are monitored during DPD mode. For additional details, see **“Deep power down”** on page 28.

Register space

6.3.2 Configuration Register 1

Configuration Register 1 (CR1) is used to define the refresh array size, refresh rate and hybrid sleep for the HYPERRAM™ device. Configurable characteristics include:

- Partial array refresh
- Hybrid sleep state
- Refresh rate

Table 11 Configuration Register 1 (CR1) bit assignments

CR1 bit	Function	Setting (binary)
[15:7]	Reserved	111111111 - Reserved (default) When writing this register, these bits should keep 111111111 for future compatibility.
[6]	Master clock type	1 - Single-ended - CK (default) 0 - Differential - CK#, CK
[5]	Hybrid sleep	1 - Causes the device to enter hybrid sleep state 0 - Normal operation (default)
[4:2]	Partial array refresh	000 - Full array (default) 001 - Bottom 1/2 array 010 - Bottom 1/4 array 011 - Bottom 1/8 array 100 - None 101 - Top 1/2 array 110 - Top 1/4 array 111 - Top 1/8 array
[1:0]	Distributed refresh interval (read only)	10 - 1 µs t_{CSM} (Industrial Plus temperature range devices) 11 - Reserved 00 - Reserved 01 - 4 µs t_{CSM} (Industrial temperature range devices)

Master clock type

Two clock types, namely single ended and differential, are supported. CR1[6] selects which type to use.

- In the single ended clock mode (by default), CK# input is not enabled; hence it may be left either floating or biased to HIGH or LOW.
- In the differential clock mode (when enabled), the CK# input can't be left floating. It must be either driven by the host, or biased to HIGH or LOW.

Partial array refresh

The partial array refresh configuration restricts the refresh operation in HYPERRAM™ to a portion of the memory array specified by CR1[5:3]. This reduces the standby current. The default configuration refreshes the whole array.

Hybrid sleep (HS)

When the HYPERRAM™ is not needed for system operation but data in the device needs to be retained, it may be placed in hybrid sleep state to save more power. Enter hybrid sleep state by writing 1 to CR1[5]. Bringing CS# LOW will cause the device to exit HS state and reset CR1[5] to '0'. Also, POR or a hardware reset will cause the device to exit hybrid sleep state. Note that a POR or a hardware reset disables refresh where the memory core data can potentially get lost.

Distributed refresh interval

The HYPERRAM™ device is built with volatile DRAM array which requires periodic refresh of all bits in it. The refresh operation can be done by an internal self-refresh logic that will evenly refresh the memory array automatically. The automatic refresh operation can only be done when the memory array is not actively read or written by the host system. The refresh logic waits for the end of any active read or write before doing a refresh, if a refresh is needed at that time. If a new read or write begins before the refresh is completed, the memory will drive RWDS high during the CA period to indicate that an additional initial latency time is required at the start of the new access in order to allow the refresh operation to complete before starting the new access. The evenly distributed refresh operations require a maximum refresh interval between two adjacent refresh operations. The maximum distributed refresh interval varies with temperature as shown in **Table 12**.

Table 12 Array refresh interval per temperature

Operating temperature	Refresh interval t_{CSM}	CR1[1:0]
TA ≤ 85°C	4 µs	01b
85°C < TA ≤ 105°C	1 µs	10b

The distributed refresh operation requires that the host does not perform burst transactions longer than the distributed refresh interval to prevent the memory from unable doing the distributed refreshes operation when it is needed. This sets an upper limit on the length of read and write transactions so that the automatic distributed refresh operation can be done between transactions. This limit is called the CS# LOW maximum time (t_{CSM}) and the t_{CSM} will be equal to the maximum distributed refresh interval. The host system is required to respect the t_{CSM} value by terminating each transaction before violating t_{CSM}. This can be done by host memory controller splitting long transactions when reaching the t_{CSM} limit, or by host system hardware or software not performing a single burst read or write transaction that would be longer than t_{CSM}.

As noted in **Table 12**, the maximum refresh interval is longer at lower temperatures such that t_{CSM} could be increased to allow longer transactions. The host may determine the operating temperature from a temperature sensor in the system and use the t_{CSM} value from the table accordingly, or it may determine dynamically by reading the read only CR1[1:0] bits in order to set the distributed refresh interval prior to the HYPERRAM™ access.

7 Interface states

Table 13 describes the required value of each signal for each interface state.

Table 13 Interface states

Interface state	V_{CC} / $V_{CC}Q$	CS#	CK, CK#	DQ[15:0]	RWDS[1:0]	RESET#
Power-off	< V_{LKO}	X	X	HIGH-Z	HIGH-Z	X
Power-on (cold) reset	≥ V_{CC} / $V_{CC}Q$ min					
Hardware (warm) reset						L
Interface standby		H				H
CA		L	T	Master output valid	Y	
Read initial access latency (data bus turn around period)			T	HIGH-Z	L	
Write initial access latency (RWDS turn around period)			T		HIGH-Z	
Read data transfer			T	Slave output valid	Slave output valid Z or T	
Write data transfer with Initial latency			T	Master output valid	Master output valid X or T	
Write data transfer without Initial latency[45]			T		Slave output L or HIGH-Z	
Active clock stop[46]			Idle	Master or slave output valid or HIGH-Z	Y	
Deep power down		H	X or T	HIGH-Z	HIGH-Z	
Hybrid sleep						

Legend

L = V_{IL}
H = V_{IH}
X = Either V_{IL} or V_{IH}
Y= Either V_{IL} or V_{IH} or V_{OL} or V_{OH}
Z = Either V_{OL} or V_{OH}
L/H = Rising edge
H/L = Falling edge
T = Toggling during information transfer
Idle = CK is LOW and CK# is HIGH.
Valid = All bus signals have stable L or H level

Notes

45. Writes without initial latency (with zero initial latency), do not have a turn around period for RWDS[1:0]. The HYPERRAM™ device will always drive RWDS[1:0] during the CA period to indicate whether extended latency is required. Since master write data immediately follows the CA period the HYPERRAM™ device may continue to drive RWDS[1:0] LOW or may take RWDS[1:0] to HIGH-Z. The master must not drive RWDS[1:0] during Writes with zero latency. Writes with zero latency do not use RWDS[1:0] as a data mask function. All write data are written.
46. Active Clock Stop is described in **"Active clock stop"** on page 26. DPD is described in **"Deep power down"** on page 28.

8 Power conservation modes

8.1 Interface standby

STANDBY is the default, low power, state for the interface while the device is not selected by the host for data transfer (CS# = HIGH). All inputs, and outputs other than CS# and RESET# are ignored in this state.

8.2 Active clock stop

The active clock stop state reduces device interface energy consumption to the I_{CC6} level during the data transfer portion of a read or write operation. The device automatically enables this state when clock remains stable for t_{ACC} + 30 ns. While in active clock stop state, read data is latched and always driven onto the data bus. I_{CC6} shown in **"DC characteristics"** on page 31.

Active clock stop state helps reduce current consumption when the host system clock has stopped to pause the data transfer. Even though CS# may be LOW throughout these extended data transfer cycles, the memory device host interface will go into the active clock stop current level at t_{ACC} + 30 ns. This allows the device to transition into a lower current state if the data transfer is stalled. Active read or write current will resume once the data transfer is restarted with a toggling clock. The active clock stop state must not be used in violation of the t_{CSM} limit. CS# must go HIGH before t_{CSM} is violated. Clock can be stopped during any portion of the active transaction as long as it is in the LOW state. Note that it is recommended to avoid stopping the clock during register access.

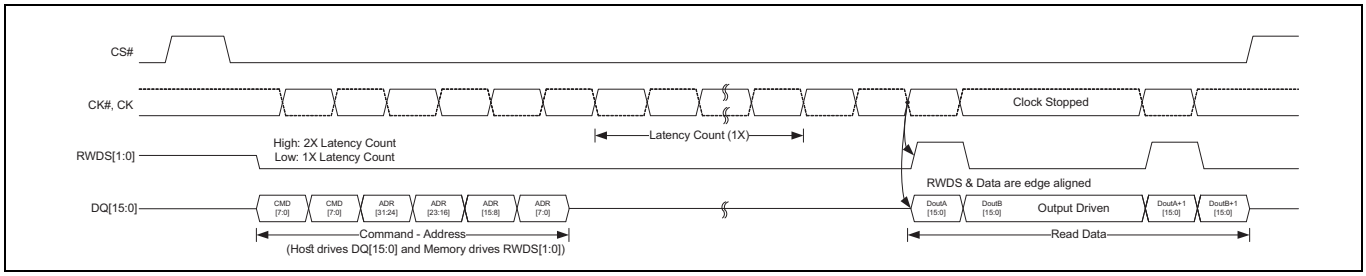


Figure 14 Active clock stop during read transaction (DDR)[47, 48]

Notes

47. DQ[15:8] should be ignored during command/address phase but host has to drive them to "H" or "L".
48. RWDS is LOW during the CA cycles. In this read transaction, there is a single initial latency count for read data access because, this read transaction does not begin at a time when additional latency is required by the slave.

8.3 Hybrid sleep

In the hybrid sleep (HS) state, the current consumption is reduced (i_{HS}). HS state is entered by writing a '1' to CR1[5]. The device reduces power within t_{HSIN} time. The data in memory space and register space is retained during HS state. Bringing CS# LOW will cause the device to exit HS state and reset CR1[5] to '0'. Also, POR or a hardware reset will cause the device to exit hybrid sleep state. Note that a POR or a hardware reset disables refresh where the memory core data can potentially get lost. Returning to STANDBY state requires t_{EXITHS} time. Following the exit from HS due to any of these events, the device is in the same state as entering hybrid sleep.

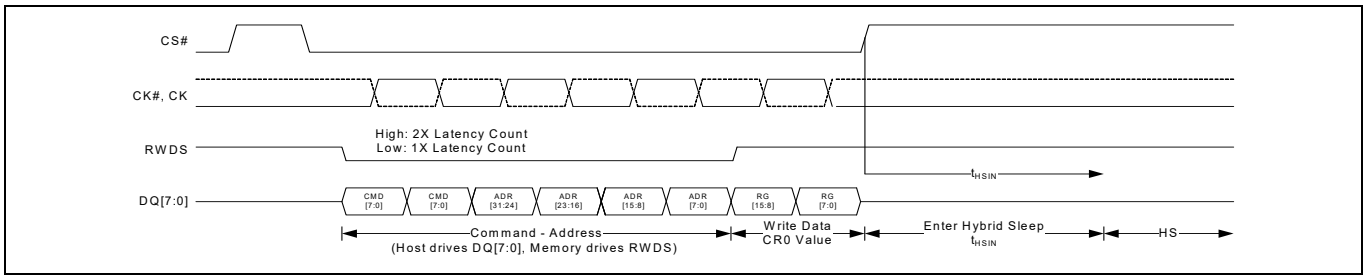


Figure 15 Enter HS transaction

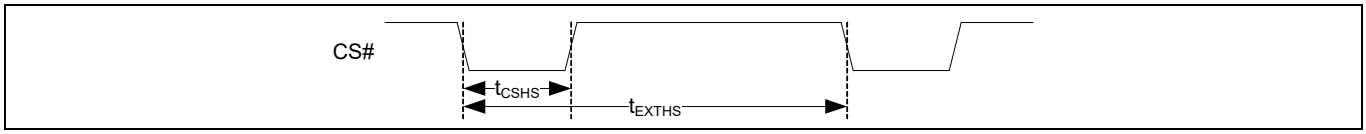


Figure 16 Exit HS transaction

Table 14 Hybrid sleep timing parameters

Parameter	Description	Min	Max	Unit
t_{HSIN}	Hybrid sleep CR1[5] = 0 register write to DPD power level	–	3	µs
t_{CSHS}	CS# pulse width to exit HS	60	3000	ns
t_{EXTHS}	CS# exit hybrid sleep to standby wakeup time	–	100	µs

8.4 Deep power down

In the deep power down (DPD) state, current consumption is driven to the lowest possible level (I_{DPD}). DPD state is entered by writing a '0' to CR0[15]. The device reduces power within t_{DPDIN} time and all refresh operations stop. The data in memory space is lost, (becomes invalid without refresh) during DPD state. Driving CS# LOW then HIGH will cause the device to exit DPD state. Also, POR or a hardware reset will cause the device to exit DPD state. Returning to STANDBY state requires t_{EXTDPD} time. Returning to STANDBY state following a POR requires t_{VCS} time, as with any other POR. Following the exit from DPD due to any of these events, the device is in the same state as following POR.

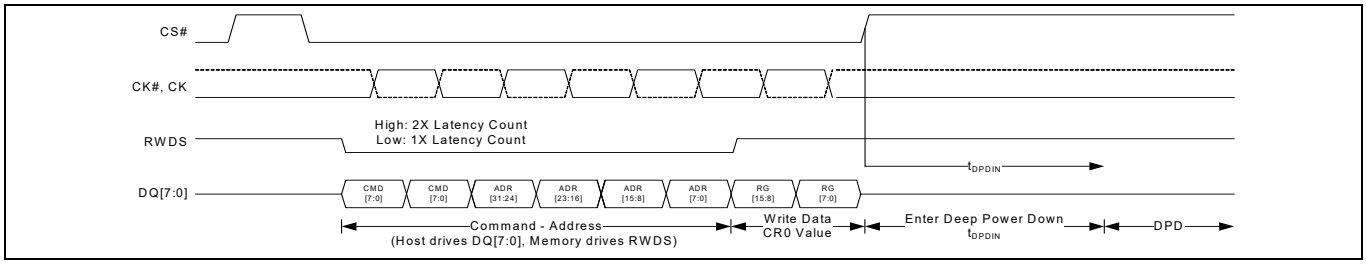


Figure 17 Enter DPD transaction[49]

Figure 18 Exit DPD transaction

Table 15 Deep power down timing parameters

Parameter	Description	Min	Max	Unit
t_{DPDIN}	Deep power down CR0[15] = 0 register write to DPD power level	–	3	µs
t_{CSDPD}	CS# pulse width to exit DPD	200	3000	ns
t_{EXTDPD}	CS# exit deep power down to standby wakeup time	–	150	µs

Note
49. DQ[15:8] should be ignored during command/address phase but host has to drive them to "H" or "L".

9 Electrical specifications

9.1 Absolute maximum ratings[50]

Parameter	Description
Storage temperature plastic packages	-65°C to +150°C
Ambient temperature with power applied	-65°C to +135°C
Voltage with respect to ground All signals[51]	-0.5 V to +(V_{CC} + 0.5 V)
Output short circuit current[52]	100 mA
Voltage on V_{CC}, $V_{CC}Q$ pins relative to V_{SS}	-0.5 V to +2.5 V
Electrostatic discharge voltage: Human body model (JEDEC Std JESD22-A114-B)	2000 V
Charged device model (JEDEC Std JESD22-C101-A)	500 V

9.2 Input signal overshoot

During DC conditions, input or I/O signals should remain equal to or between V_{SS} and V_{CC}. During voltage transitions, inputs or I/Os may negative overshoot V_{SS} to –1.0 V or positive overshoot to V_{CC} + 1.0 V, for periods up to 20 ns.

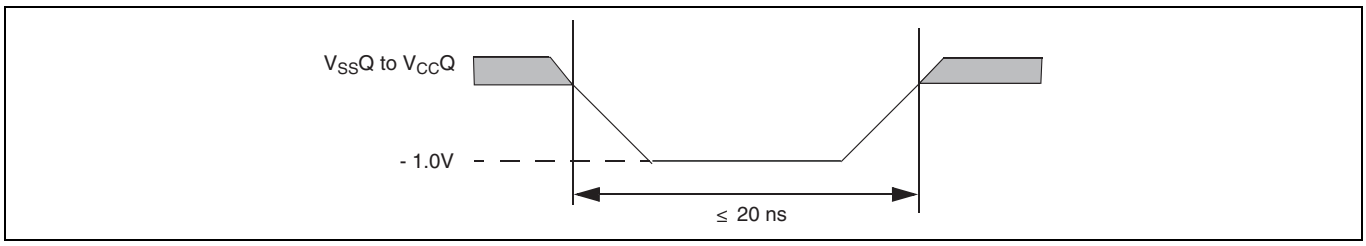


Figure 19 Maximum negative overshoot waveform

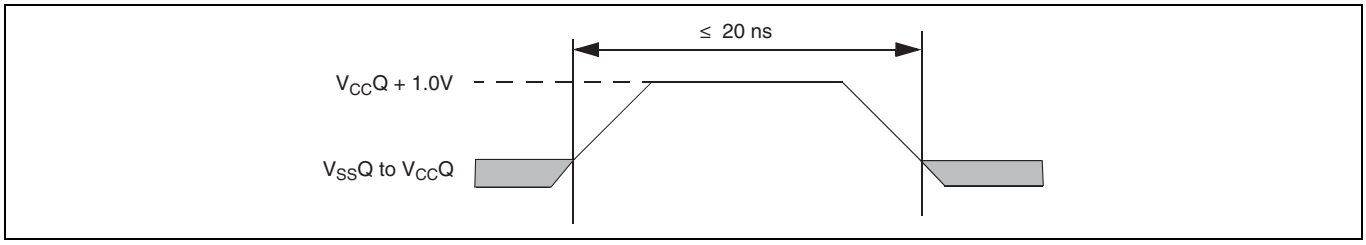


Figure 20 Maximum positive overshoot waveform

Notes

50. Stresses above those listed under **"Absolute maximum ratings[50]"** on page 29 may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational sections of this data sheet is not implied. Exposure of the device to absolute maximum rating conditions for extended periods may affect device reliability.
51. Minimum DC voltage on input or I/O signal is –1.0 V. During voltage transitions, input or I/O signals may undershoot V_{SS} to –1.0 V for periods of up to 20 ns. See **Figure 19**. Maximum DC voltage on input or I/O signals is V_{CC} +1.0 V. During voltage transitions, input or I/O signals may overshoot to V_{CC} + 1.0 V for periods up to 20 ns. See **Figure 20**.
52. No more than one output may be shorted to ground at a time. Duration of the short circuit should not be greater than one second.

9.3 Latch-up characteristics

9.3.1 Latch-up specification

Table 16 Latch-up specification[53]

Description	Min	Max	Unit
Input voltage with respect to $V_{SS}Q$ on all input only connections	–1.0	$V_{CC}Q$ + 1.0	V
Input voltage with respect to $V_{SS}Q$ on all I/O connections			
$V_{CC}Q$ current	–100	+100	mA

9.4 Operating ranges

Operating ranges define those limits between which the functionality of the device is guaranteed.

9.4.1 Temperature ranges

Table 17 Temperature ranges

Parameter	Symbol	Device	Spec		Unit
			Min	Max	
Ambient temperature	T_A	Industrial (I)	–40	85	°C
		Industrial Plus (V)		105	

9.4.2 Power supply voltages

Table 18 Power supply voltages

Description	Min	Max	Unit
1.8 V V_{CC} power supply	1.7	2.0	V

Note
53. Excludes power supplies $V_{CC}/V_{CC}Q$. Test conditions: $V_{CC} = V_{CC}Q$, one connection at a time tested, connections not being tested are at V_{SS}.

9.5 DC characteristics

Table 19 DC characteristics (CMOS compatible)

Parameter	Description	Test Conditions	Value			Unit
			Min	Typ[54]	Max	
I_{LI2}	Input leakage current device reset signal HIGH	$V_{IN} = V_{SS}$ to V_{CC}, $V_{CC} = V_{CC}$ max	–	–	2	µA
I_{LI4}	Input leakage current device reset signal LOW[55]	$V_{IN} = V_{SS}$ to V_{CC}, $V_{CC} = V_{CC}$ max			15	
I_{CC1}	V_{CC} active read current operating temperature range	CS# = V_{SS}, CK@200 MHz, $V_{CC} = V_{CC}$ max		14	20	mA
I_{CC2}	V_{CC} active write current operating temperature range	CS# = V_{SS}, CK@200 MHz, $V_{CC} = V_{CC}$ max		16	22	
I_{CC4}	V_{CC} standby current (-40°C to +85°C)	CS# = V_{CC}, $V_{CC} = V_{CC}$ max; full Array		470	1200	µA
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/2 array		–	850	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/4 array			700	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/8 array			600	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/2 array			850	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/4 array			700	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/8 array			600	
	VCC standby current (-40°C to +105°C)	CS# = V_{CC}, $V_{CC} = V_{CC}$ max; full array		470	1550	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/2 array		–	1150	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/4 array			950	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; bottom 1/8 array			850	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/2 array			1150	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/4 array			950	
		CS# = V_{CC}, $V_{CC} = V_{CC}$ max; top 1/8 array			850	
I_{CC5}	Reset current (-40°C to +85°C)	CS# = V_{CC}, RESET# = VSS, $V_{CC} = V_{CC}$ max			0.55	mA
	Reset current (-40°C to +105°C)				0.75	

Notes
54. Not 100% tested.
55. RESET# LOW initiates exits from hybrid sleep state and initiates the draw of I_{CC5} reset current, making I_{LI} during RESET# LOW insignificant.

Table 19 DC characteristics (CMOS compatible) (Continued)

Parameter	Description	Test Conditions	Value			Unit
			Min	Typ[54]	Max	
I_{CC6}	Active clock stop current (-40°C to +85°C)	CS# = V_{SS}, RESET# = V_{CC}, V_{CC} = V_{CC} max		17	25	mA
	Active clock stop current (-40°C to +105°C)				30	
I_{CC7}	VCC current during power up	CS# = V_{CC}, V_{CC} = V_{CC} max, V_{CCQ} = V_{CC}		–	35	
I_{DPD}	Deep power down current (-40°C to +85°C)	CS# = V_{CC}, V_{CC} = V_{CC} max			12	µA
	Deep power down current (-40°C to +105°C)				15	
I_{HS}[55]	Hybrid sleep current (-40°C to +85°C)	CS# = V_{CC}, V_{CC} = V_{CC} max; full array	–	140	1100	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/2 array		–	800	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/4 array			600	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/8 array			500	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/2 array			800	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/4 array			600	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/8 array			500	
	Hybrid sleep current (-40°C to +105°C)	CS# = V_{CC}, V_{CC} = V_{CC} max; full array		140	1250	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/2 array		–	850	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/4 array			650	
		CS# = V_{CC}, V_{CC} = V_{CC} max; bottom 1/8 array			550	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/2 array			850	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/4 array			650	
		CS# = V_{CC}, V_{CC} = V_{CC} max; top 1/8 array			550	
V_{IL}	Input low voltage	–	-0.15 × V_{CCQ}		0.30 × V_{CCQ}	V
V_{IH}	Input high voltage		0.70 × V_{CCQ}		1.15 × V_{CCQ}	
V_{OL}	Output low voltage	I_{OL} = 100 µA for DQ[7:0]	–		0.2	
V_{OH}	Output high voltage	I_{OL} = 100 µA for DQ[7:0]	V_{CCQ} - 0.20		–	

Notes
54. Not 100% tested.
55. RESET# LOW initiates exits from hybrid sleep state and initiates the draw of I_{CC5} reset current, making I_{LI} during RESET# LOW insignificant.

9.5.1 Capacitance characteristics

Table 20 1.8 V capacitive characteristics[56–58]

Description	Parameter	256-Mb	Unit
		Max	
Input capacitance (CK, CK#, CS#)	CI	3.0	pF
Delta input capacitance (CK, CK#)	CID	0.25	
Output capacitance (RWDS)	CO	3.0	
IO capacitance (DQx)	CIO	3.0	
IO capacitance delta (DQx)	CIOD	0.25	

Table 21 Thermal resistance

Parameter[59]	Description	Test conditions	49-ball FBGA package	Unit
θ_{JA}	Thermal resistance (junction to ambient)	Test conditions follow standard test methods and procedures for measuring thermal impedance, per EIA/JESD51.	56.6	°C/W
θ_{JC}	Thermal resistance (junction to case)		20.4	

Notes
56. These values are guaranteed by design and are tested on a sample basis only.
57. Contact capacitance is measured according to JEP147 procedure for measuring capacitance using a vector network analyzer. V_{CC}, $V_{CC}Q$ are applied and all other signals (except the signal under test) floating. DQ's should be in the high impedance state.
58. Note that the capacitance values for the CK, CK#, RWDS and DQx signals must have similar capacitance values to allow for signal propagation time matching in the system. The capacitance value for CS# is not as critical because there are no critical timings between CS# going active (LOW) and data being presented on the DQs bus.
59. This parameter is guaranteed by characterization; not tested in production.

9.6 Power-up initialization

HYPERRAM™ products include an on-chip voltage sensor used to launch the power-up initialization process. V_{CC} and $V_{CC}Q$ must be applied simultaneously. When the power supply reaches a stable level at or above V_{CC}(min), the device will require t_{VCS} time to complete its self-initialization process.

The device must not be selected during power-up. CS# must follow the voltage applied on $V_{CC}Q$ until V_{CC} (min) is reached during power-up, and then CS# must remain HIGH for a further delay of t_{VCS}. A simple pull-up resistor from $V_{CC}Q$ to Chip Select (CS#) can be used to insure safe and proper power-up.

If RESET# is LOW during power up, the device delays start of the t_{VCS} period until RESET# is HIGH. The t_{VCS} period is used primarily to perform refresh operations on the DRAM array to initialize it.

When initialization is complete, the device is ready for normal operation.

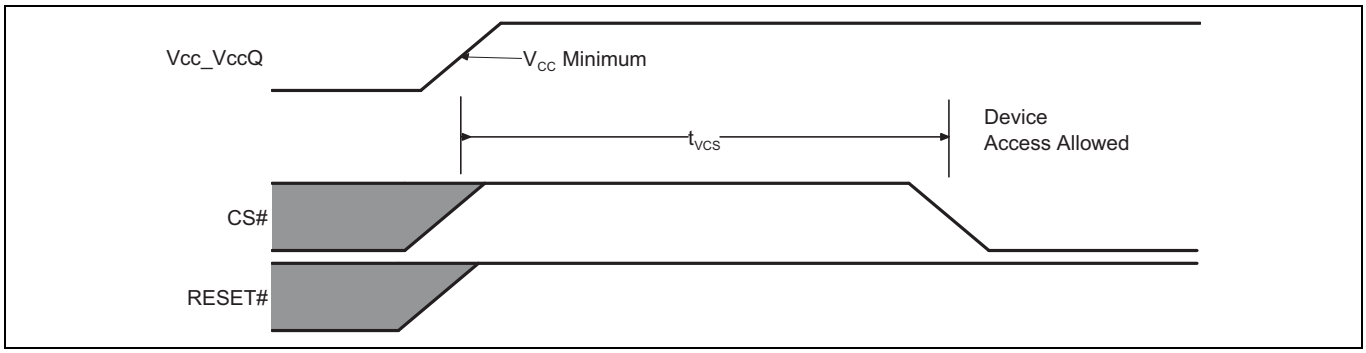


Figure 21 Power-up with RESET# HIGH

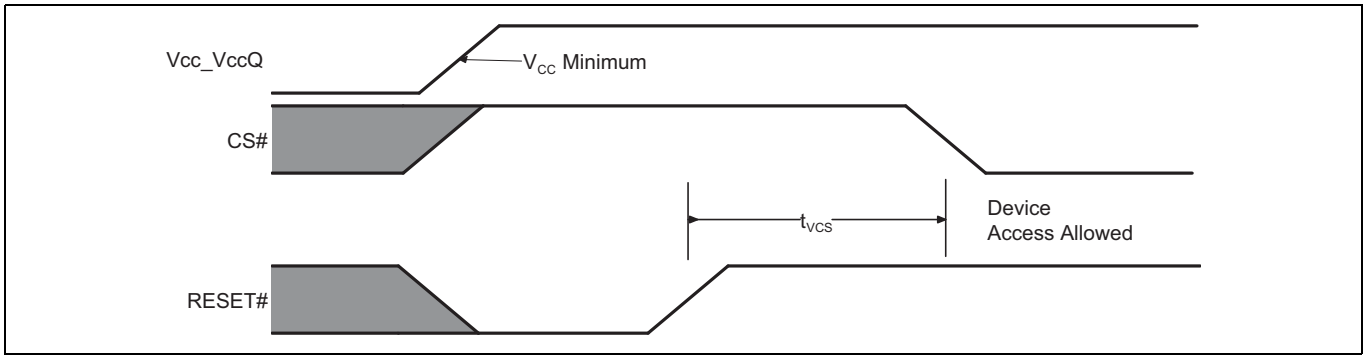


Figure 22 Power-up with RESET# LOW

Table 22 Power-up and reset parameters[60–62]

Parameter	Description	Min	Max	Unit
V_{CC}	1.8 V V_{CC} power supply	1.7	2.0	V
t_{VCS}	V_{CC} and $V_{CC}Q \geq$ minimum and RESET# HIGH to first access	–	150	µs

Notes
60. Bus transactions (read and write) are not allowed during the power-up reset time (t_{VCS}).
61. $V_{CC}Q$ must be the same voltage as V_{CC}.
62. V_{CC} ramp rate may be non-linear.

9.7 Power down

HYPERRAM™ devices are considered to be powered-off when the array power supply (V_{CC}) drops below the V_{CC} lock-out voltage (V_{LKO}). During a power supply transition down to the V_{SS} level, $V_{CC}Q$ should remain less than or equal to V_{CC}. At the V_{LKO} level, the HYPERRAM™ device will have lost configuration or array data.

V_{CC} must always be greater than or equal to $V_{CC}Q$ ($V_{CC} \geq V_{CC}Q$).

During power-down or voltage drops below V_{LKO}, the array power supply voltages must also drop below V_{CC} Reset (V_{RST}) for a power down period (t_{PD}) for the part to initialize correctly when the power supply again rises to V_{CC} minimum. See **Figure 23**.

If during a voltage drop the V_{CC} stays above V_{LKO} the part will stay initialized and will work correctly when V_{CC} is again above V_{CC} minimum. If V_{CC} does not go below and remain below V_{RST} for greater than t_{PD}, then there is no assurance that the POR process will be performed. In this case, a hardware reset will be required ensure the HYPERBUS™ extended-IO device is properly initialized.

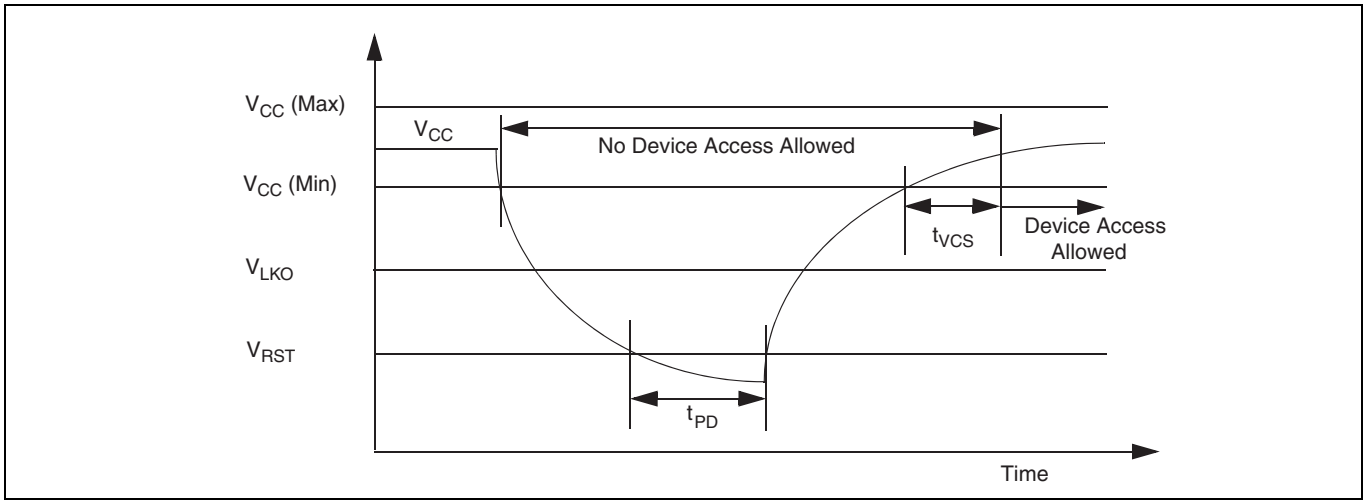


Figure 23 Power down or voltage drop

Table 23 describes the HYPERRAM™ device-dependent aspects of power down specifications.

Table 23 1.8 V power-down voltage and timing[63]

Symbol	Parameter	Min	Max	Unit
V_{CC}	V_{CC} power supply	1.7	2.0	V
V_{LKO}	V_{CC} lock-out below which re-initialization is required	1.5	–	
V_{RST}	V_{CC} low Voltage needed to ensure initialization will occur	0.7		
t_{PD}	Duration of $V_{CC} \leq V_{RST}$	50		µs

Note
63. V_{CC} ramp rate may be non-linear.

9.8 Hardware reset

The RESET# input provides a hardware method of returning the device to the STANDBY state.

During t_{RPH} the device will draw I_{CC5} current. If RESET# continues to be held LOW beyond t_{RPH}, the device draws CMOS standby current (I_{CC4}). While RESET# is LOW (during t_{RP}), and during t_{RPH}, bus transactions are not allowed.

A hardware reset will do the following:

- Cause the configuration registers to return to their default values
- Halt self-refresh operation while RESET# is LOW - memory array data is considered as invalid
- Force the device to exit the hybrid sleep state
- Force the device to exit the deep power down state

After RESET# returns HIGH, the self-refresh operation will resume. Because self-refresh operation is stopped during RESET# LOW, and the self-refresh row counter is reset to its default value, some rows may not be refreshed within the required array refresh interval per **Table 12**. This may result in the loss of DRAM array data during or immediately following a hardware reset. The host system should assume DRAM array data is lost after a hardware reset and reload any required data.

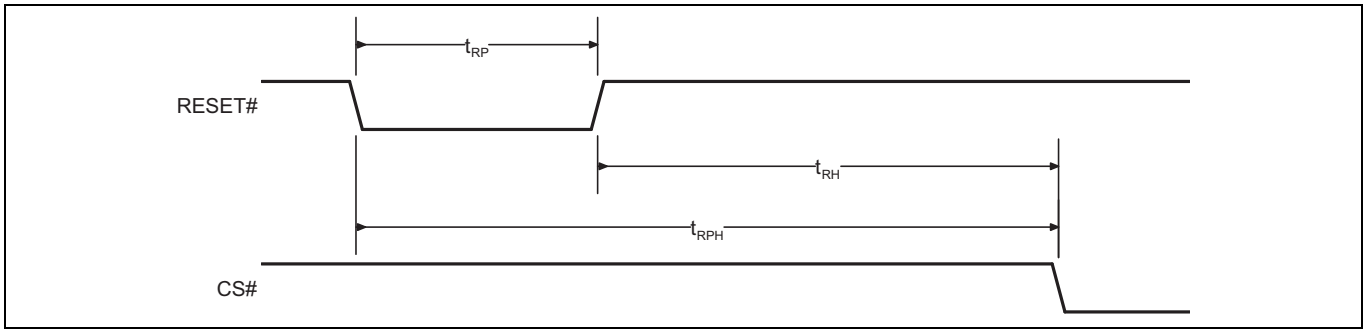


Figure 24 Hardware reset timing diagram

Table 24 Power-up and reset parameters

Parameter	Description	Min	Max	Unit
t_{RP}	RESET# pulse width	200	–	ns
t_{RH}	Time between RESET# (HIGH) and CS# (LOW)			
t_{RPH}	RESET# LOW to CS# LOW	400		

10 Timing specifications

The following section describes HYPERRAM™ device dependent aspects of timing specifications.

10.1 Key to switching waveforms

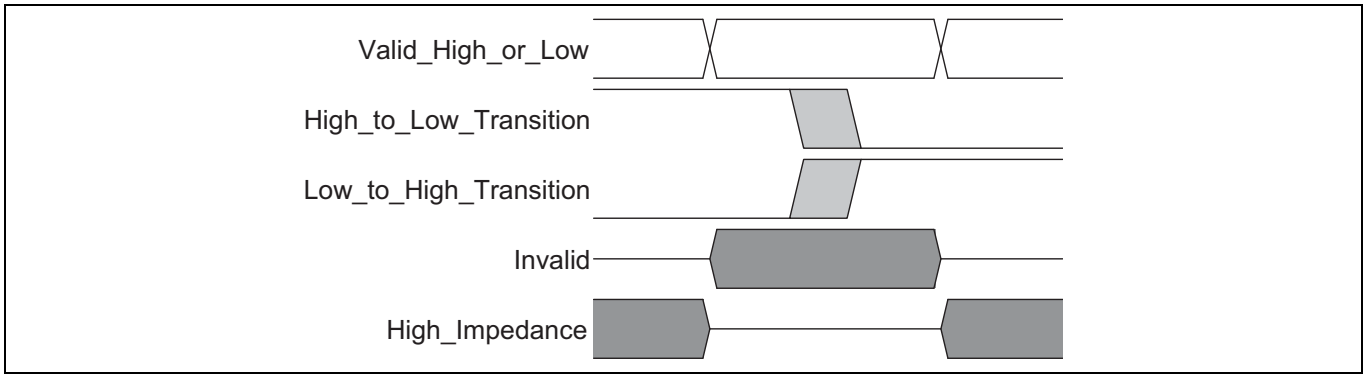


Figure 25 Key to switching waveforms

10.2 AC test conditions

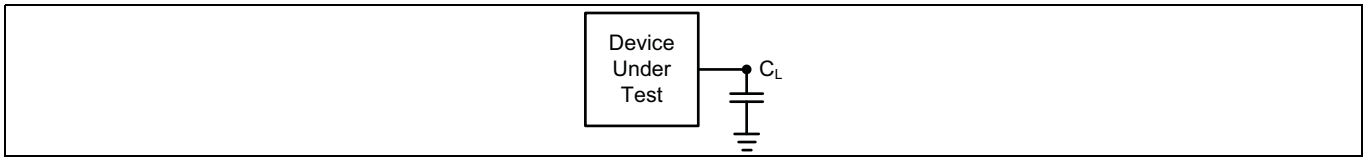


Figure 26 Test setup

Table 25 Test specification[64]

Parameter	All speeds	Unit
Output load capacitance, C_L	15	pF
Minimum input rise and fall slew rates (1.8 V)[65]	1.13	V/ns
Input pulse levels	0.0–$V_{CC}Q$	V
Input timing measurement reference levels	$V_{CC}Q/2$	
Output timing measurement reference levels	$V_{CC}Q/2$	

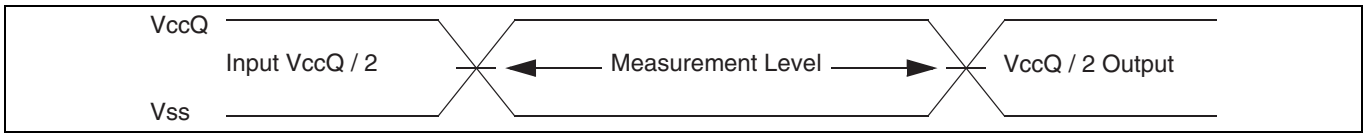


Figure 27 Input waveforms and measurement levels[66]

Notes
64. Input and output timing is referenced to $V_{CC}Q/2$ or to the crossing of CK/CK#.
65. All AC timings assume this input slew rate.
66. Input timings for the differential CK/CK# pair are measured from clock crossings.

10.3 CLK characteristics

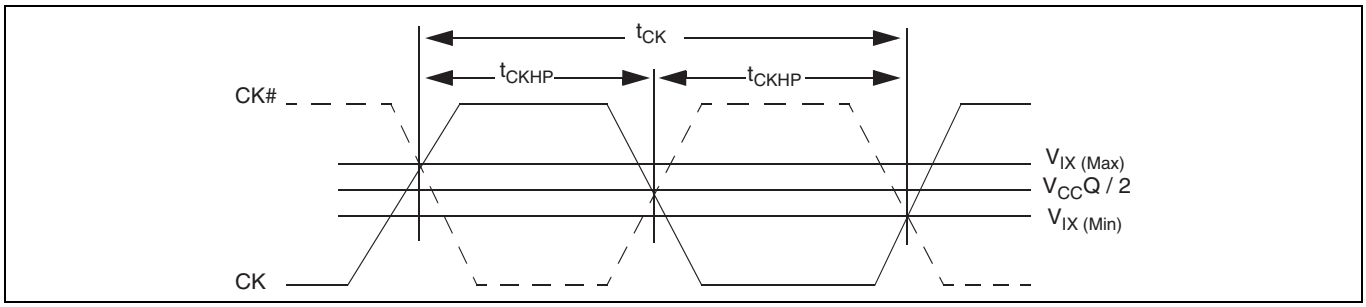


Figure 28 Clock characteristics

Table 26 Clock timings[67–69]

Parameter	Symbol	200 MHz	
		Min	Max
CK period	t_{CK}	5	–
CK half period - duty cycle	t_{CKHP}	0.45	0.55
CK half period at frequency Min = 0.45 t_{CK} Min Max = 0.55 t_{CK} Min	t_{CKHP}	2.25	2.75

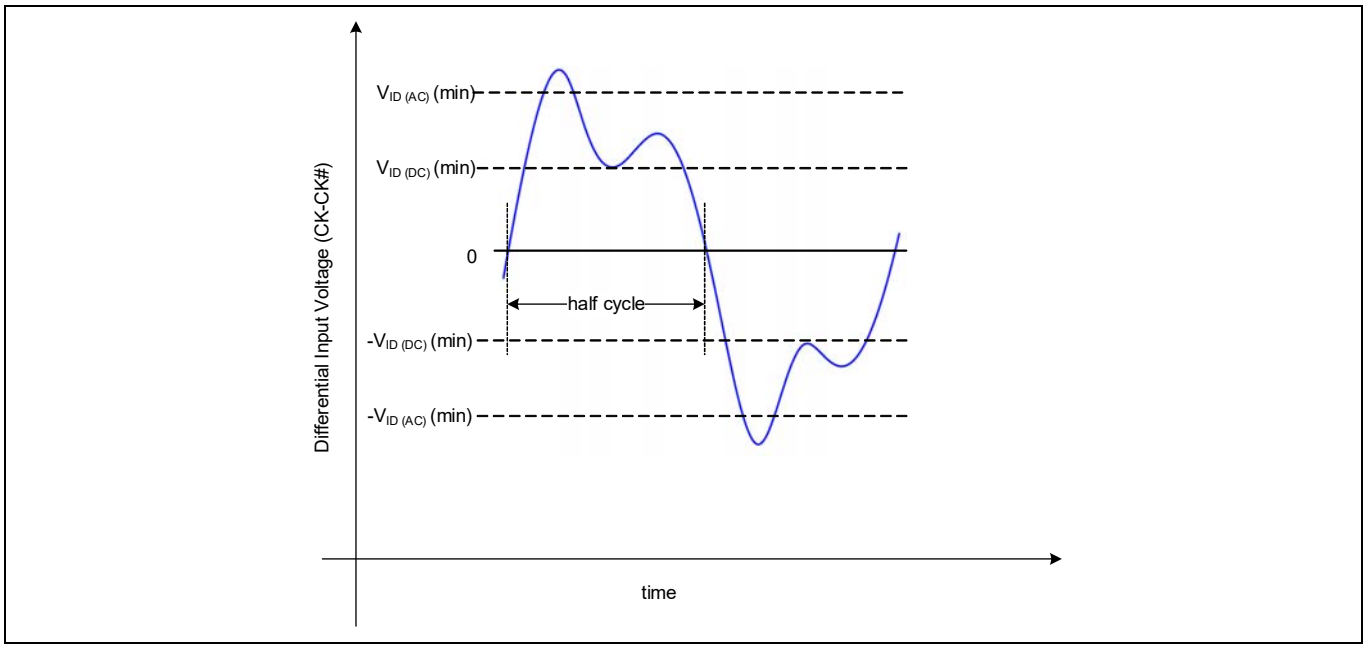


Figure 29 Differential clock (CK/CK#) input swing

Notes
67. Clock jitter of ±5% is permitted.
68. Minimum frequency (maximum t_{CK}) is dependent upon maximum CS# LOW time (t_{CSM}), initial latency and burst length.
69. CK and CK# input slew rate must be ≥1 V/ns (2 V/ns if measured differentially).

Table 27 Clock AC/DC electrical characteristics[70, 71]

Parameter	Symbol	Min	Max	Unit
DC input voltage	V_{IN}	–0.3	$V_{CC}Q + 0.3$	V
DC input differential voltage	$V_{ID(DC)}$	$V_{CC}Q \times 0.4$	$V_{CC}Q + 0.6$	
AC input differential voltage	$V_{ID(AC)}$	$V_{CC}Q \times 0.6$	$V_{CC}Q + 0.6$	
AC differential crossing voltage	V_{IX}	$V_{CC}Q \times 0.4$	$V_{CC}Q \times 0.6$	

10.4 AC characteristics

10.4.1 Read transactions

Table 28 HYPERRAM™ specific read timing parameters

Parameter	Symbol	200 MHz		Unit
		Min	Max	
Chip select high between transactions	t_{CSHI}	6	–	ns
HYPERRAM™ read-write recovery time	t_{RWR}	35		
Chip select setup to next CK rising edge	t_{CSS}	4		
Data strobe valid	t_{DSV}	–	5	
Input setup	t_{IS}	0.5	–	
Input hold	t_{IH}	0.5		
HYPERRAM™ read initial access time	t_{ACC}	35		
Clock to DQs low Z	t_{DQLZ}	0		
CK transition to DQ valid	t_{CKD}	1	5	
CK transition to DQ invalid	t_{CKDI}	0	4.2	
Data valid (t_{DV} min = the lesser of: (t_{CKHP} min – t_{CKD} max + t_{CKDI} max) or (t_{CKHP} min – t_{CKD} min + t_{CKDI} min)	t_{DV}[72, 73]	1.45	–	
CK transition to RWDS valid	t_{CKDS}	1	5	
RWDS transition to DQ valid	t_{DSS}	–0.4	+0.4	
RWDS transition to DQ invalid	t_{DSH}			
Chip select hold after CK falling edge	t_{CSH}	0	–	
Chip select inactive to RWDS High-Z	t_{DSZ}	–	5	
Chip select inactive to DQ High-Z	t_{OZ}			
Refresh time	t_{RFH}	35	–	
CK transition to RWDS low @ CA phase @ read	t_{CKDSR}	1	5.5	

Notes
70. V_{ID} is the magnitude of the difference between the input level on CK and the input level on CK#.
71. The value of V_{IX} is expected to equal $V_{CC}Q/2$ of the transmitting device and must track variations in the DC level of $V_{CC}Q$.
72. Refer to **Figure 32** for data valid timing.
73. The t_{DV} timing calculation is provided for reference only, not to determine the spec limit. The spec limit is guaranteed by testing.

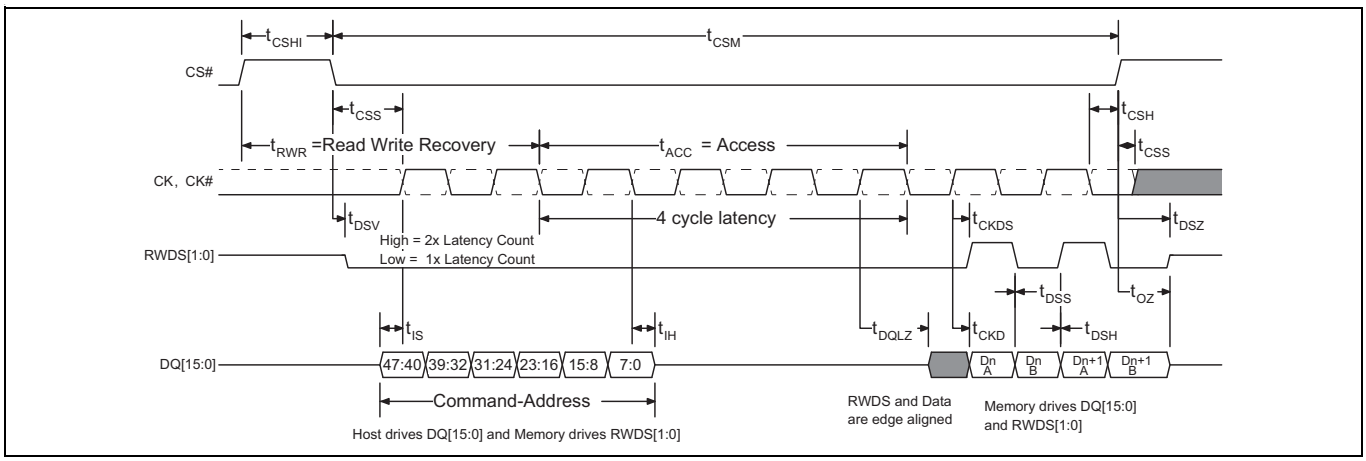


Figure 30 Read timing diagram — no additional latency required

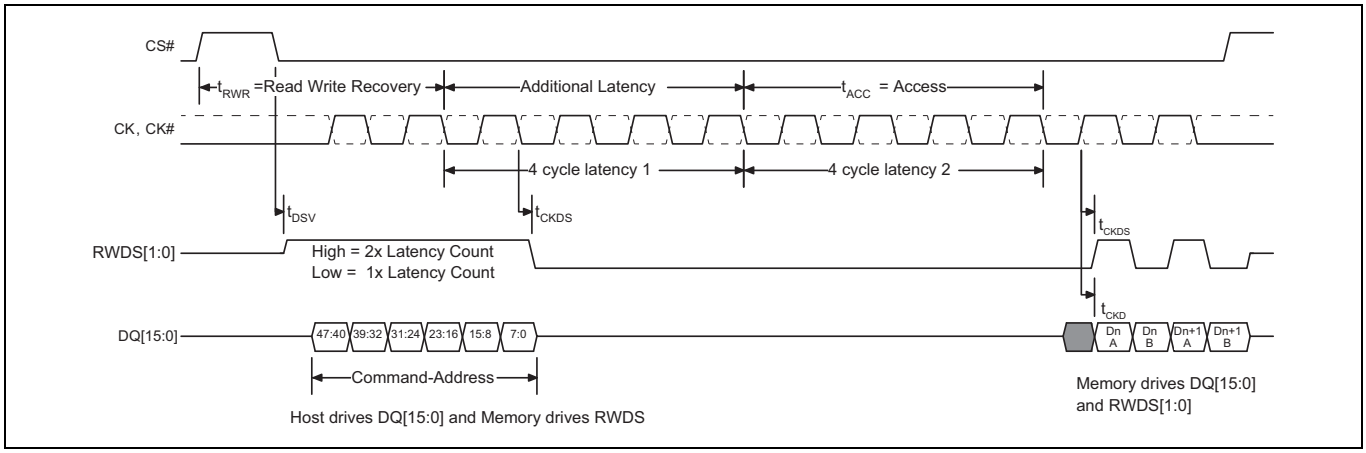


Figure 31 Read timing diagram — with additional latency required

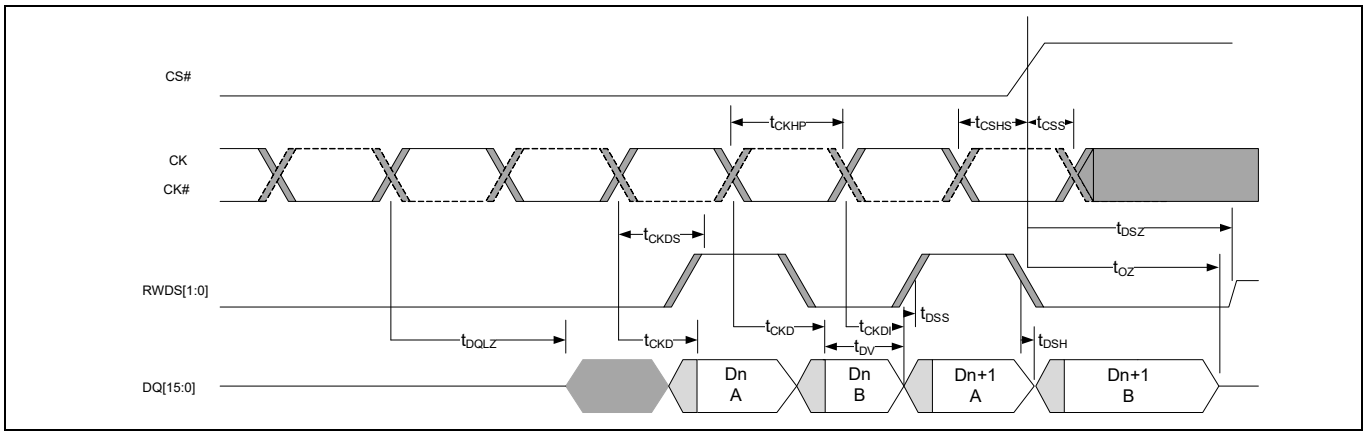


Figure 32 Data valid timing[74–76]

Notes

74. t_{CKD} and t_{CKDI} parameters define the beginning and end position of data valid period.
75. t_{DSS} and t_{DSH} define how early or late DQ may transition relative to RWDS. This is a potential skew between the CK to DQ delay t_{CKD} and CK to RWDS delay t_{CKDS}.
76. Since DQ and RWDS are the same output types, the t_{CKD}, t_{CKDI} and t_{CKDS} values track together (vary by the same ratio).

10.4.2 Write transactions

Table 29 Write timing parameters

Parameter	Symbol	200 MHz		Unit
		Min	Max	
Read-write recovery time	t_{RWR}	35	–	ns
Access time	t_{ACC}	35		
Refresh time	t_{RFH}	35		
Chip select maximum low time (85°C)	t_{CSM}	–	4	µs
Chip select maximum low time (105°C)	t_{CSM}		1	
RWDS data mask valid	t_{DMV}	0	–	

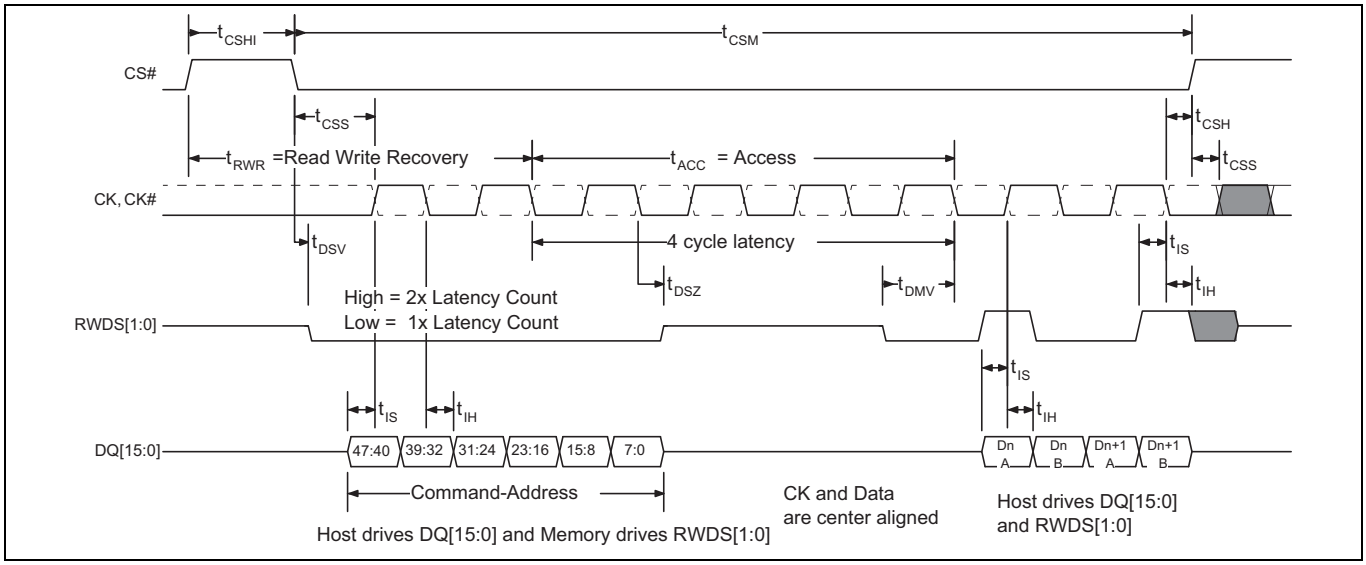


Figure 33 Write timing diagram — no additional latency

10.5 Timing reference levels

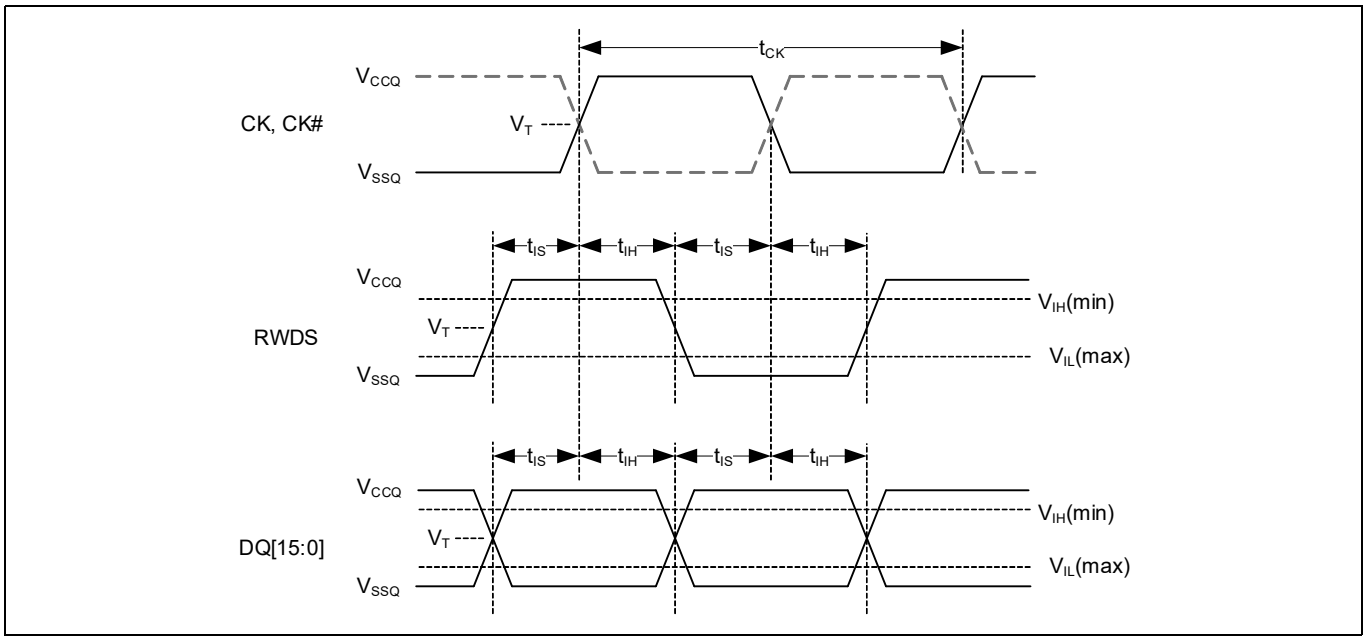


Figure 34 DDR input timing reference levels

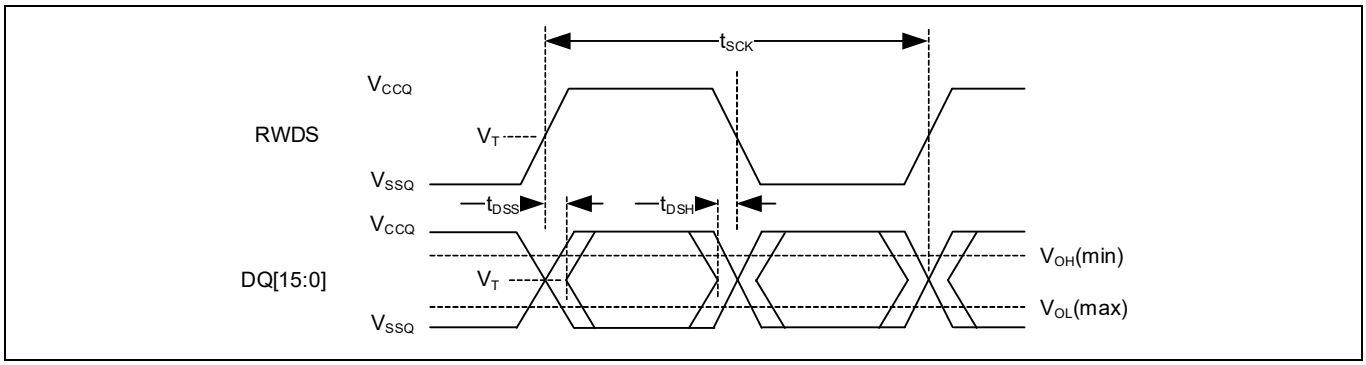


Figure 35 DDR output timing reference levels

11 Packaging

11.1 FBGA 49-ball 7 × 7 array footprint

HYPERBUS™ extended-IO HYPERRAM™ devices are provided in fortified ball grid array (FBGA), 1 mm pitch, 49-ball, 7 × 7 ball array footprint, with 8 mm × 8 mm body.

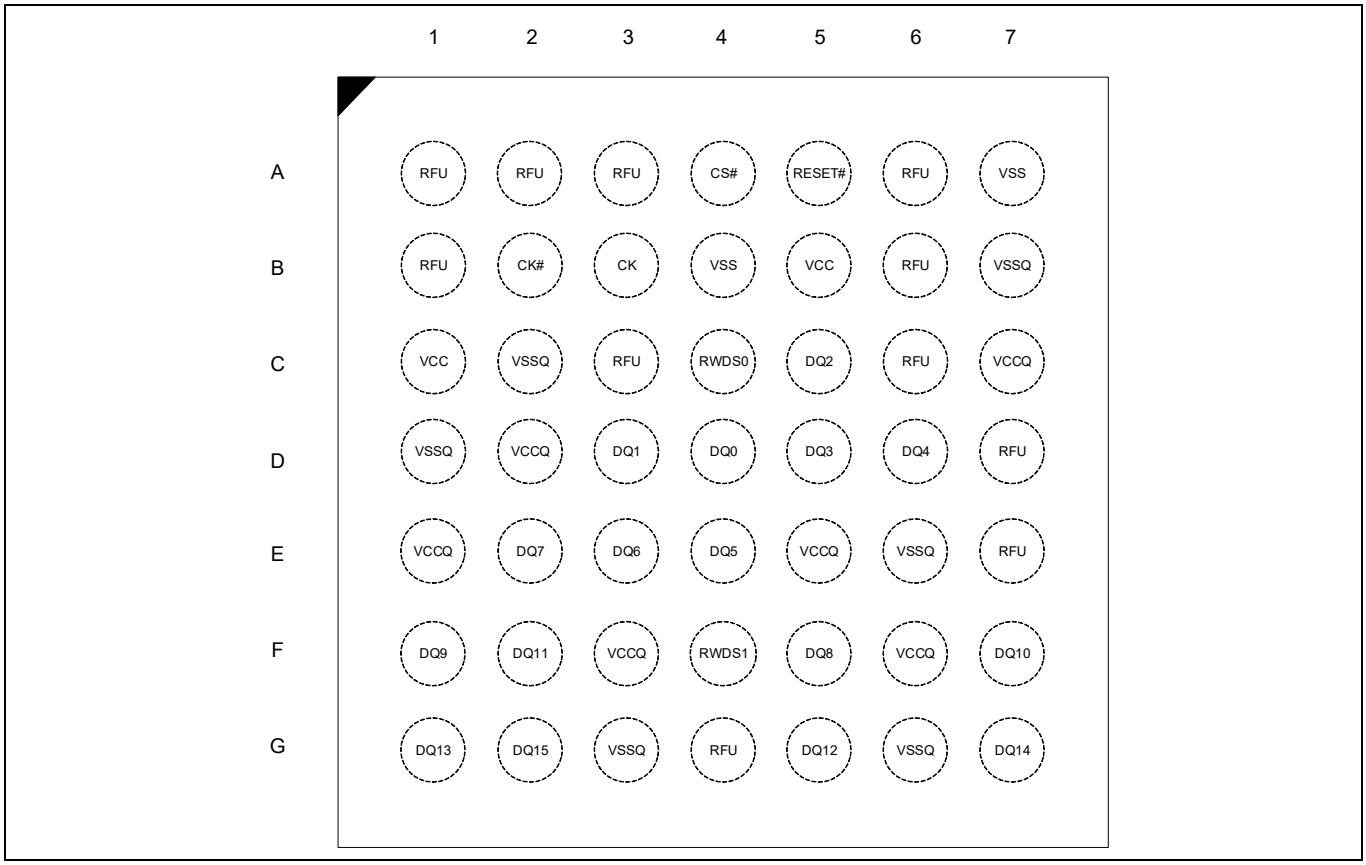
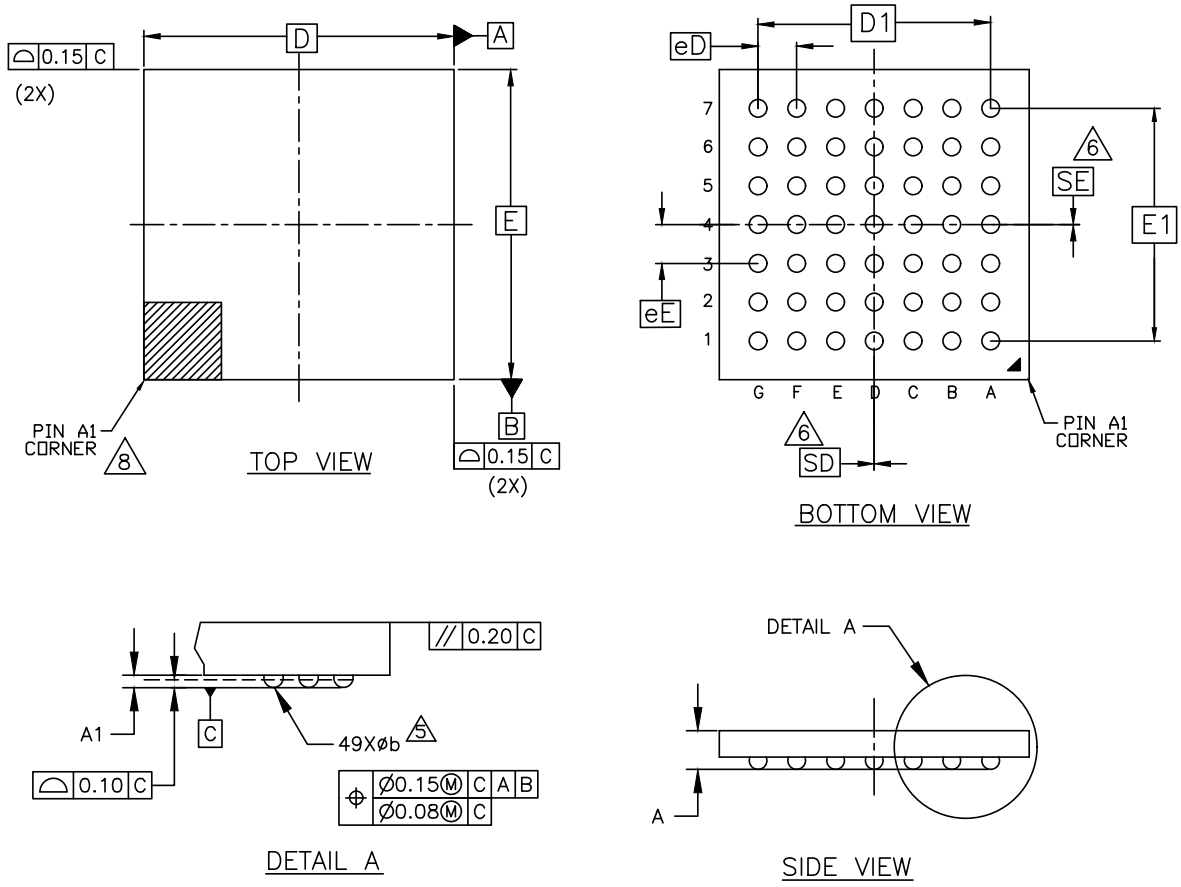


Figure 36 49-ball FBGA, 8 × 8 mm, 7 × 7 ball footprint, top view

11.2 Package diagram



SYMBOL	DIMENSIONS		
	MIN.	NOM.	MAX.
A	-	-	1.00
A1	0.20	-	-
D		8.00 BSC	
E		8.00 BSC	
D1		6.00 BSC	
E1		6.00 BSC	
MD		7	
ME		7	
N		49	
Ø b	0.35	0.40	0.45
eE		1.00 BSC	
eD		1.00 BSC	
SD		0.00 BSC	
SE		0.00 BSC	

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. BALL POSITION DESIGNATION PER JEP95, SECTION 3, SPP-020.
3. "e" REPRESENTS THE SOLDER BALL GRID PITCH.
4. SYMBOL "MD" IS THE BALL MATRIX SIZE IN THE "D" DIRECTION.
   SYMBOL "ME" IS THE BALL MATRIX SIZE IN THE "E" DIRECTION.
   N IS THE NUMBER OF POPULATED SOLDER BALL POSITIONS FOR MATRIX SIZE MD X ME.
5. DIMENSION "b" IS MEASURED AT THE MAXIMUM BALL DIAMETER IN A PLANE PARALLEL TO DATUM C.
6. "SD" AND "SE" ARE MEASURED WITH RESPECT TO DATUMS A AND B AND DEFINE THE POSITION OF THE CENTER SOLDER BALL IN THE OUTER ROW.
   WHEN THERE IS AN ODD NUMBER OF SOLDER BALLS IN THE OUTER ROW "SD" OR "SE" = 0.
   WHEN THERE IS AN EVEN NUMBER OF SOLDER BALLS IN THE OUTER ROW, "SD" = eD/2 AND "SE" = eE/2.
7. "+" INDICATES THE THEORETICAL CENTER OF DEPOPULATED BALLS.
8. A1 CORNER TO BE IDENTIFIED BY CHAMFER, LASER OR INK MARK, METALLIZED MARK INDENTATION OR OTHER MEANS.
9. JEDEC SPECIFICATION NO. REF: N/A

002-32552 **

Figure 37 Package outline, 49-ball BGA 8.0 mm × 8.0 mm × 1.0 mm VAD049

12 Ordering information

12.1 Ordering part number

The ordering part number is formed by a valid combination of the following:

S80KS 256 4 GA C H I 02 0

Packing type
0 = Tray
3 = 13” Tape and reel

Model number (Additional ordering options)
04 = 49-ball FBGA (JEDEC Std.)

Temperature range / Grade
I = Industrial (–40°C to + 85°C)
V = Industrial Plus (–40°C to + 105°C)

Package materials
H = Low-Halogen, Pb-free

Package type
C = 49-ball FBGA, 1.00 mm pitch (7 × 7 ball footprint)

Speed
GA = 200 MHz

Device technology
2 = HYPERBUS™
3 = Octal xSPI
4 = HYPERBUS™ extended-IO

Density
256 = 256 Mb

Device family
S80KS - 1.8 V-only, HYPERRAM™ self-refresh DRAM

12.2 Valid combinations

The recommended combinations table lists configurations planned to be available in volume. **Table 30** will be updated as new combinations are released. Contact your local sales representative to confirm availability of specific combinations and to check on newly released combinations.

Table 30 Valid combinations - standard

Device family	Density	Technology	Speed	Package, material, and temperature	Model number	Packing type	Ordering part number	Package marking
S80KS	256	4	GA	CHI	04	0	S80KS2564GACHI040	8KS2564GAHI04
				CHV			S80KS2564GACHV040	8KS2564GAHV04

Revision history

Document version	Date of release	Description of changes
*C	2022-04-18	Publish to web.

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