SPI/QPI PSRAM

Specifications

- **Single Supply Voltage**
  - V_{DD}=2.7 to 3.6 V
- **Interface**: SPI/QPI with SDR mode
- **Performance**: Clock rate up to
  - 133MHz for Wrapped Burst operation at VDD=3.0V+/-10%
  - 109MHz for Wrapped Burst operation at VDD=3.3V+/-10%
  - 84MHz for Linear 512 Burst operation
- **Organization**: 16Mb, 2M x 8bits
- **Addressable Bit Range**: A[20:0]
- **Page Size**: 512 bytes
- **Refresh**: Self-managed
- **Operating Temperature Range**
  - T_{OPER}= -40°C to +85°C (standard range)
  - T_{OPER}= -40°C to +105°C (extended range)
- **Maximum Standby Current**:
  - 200µA @ 105°C
  - 150µA @ 85°C
- **Typical Standby Current**
  - 35µA @ 25°C

Features

- **Output Driver LVCMOS** with programmable drive strengths of 50, 100 and 200Ω
- **Dedicated Wrapped Burst** read and write commands
- **Linear 512 Length Burst** is supported up to 84MHz and can cross page boundary as long as tCEM is met
- **Register Configurable Wrap Lengths** of 16, 32, 64 and 512
- **Burst Length Toggle Command** to switch between configurable wrap length and 32 bytes wrap
- **Software Reset**

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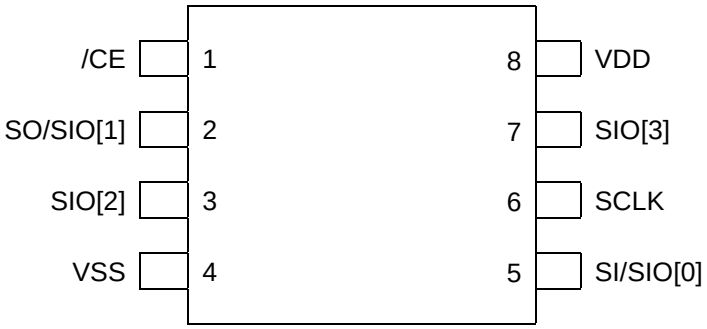
2 Introduction

This Pseudo-SRAM device features a high speed, low pin count interface. It has 4 I/O pins and operates in SPI(serial peripheral interface) or QPI (quad peripheral interface) mode with frequencies up to 133 MHz. The data input (A/DQ) to the memory relies on clock (CLK) to latch all instructions, addresses and data. It is most suitable for low-power and low cost portable applications. It incorporates a seamless self-managed refresh mechanism. Hence it does not require the support of DRAM refresh from system host. The self-refresh feature is a special design to maximize performance of memory read operation.

3 Package Information

The APS1604M-3SQR is available in standard package including 8-lead SOP-8L(150) and advanced package including 8-lead USON-8L 3x2mm.

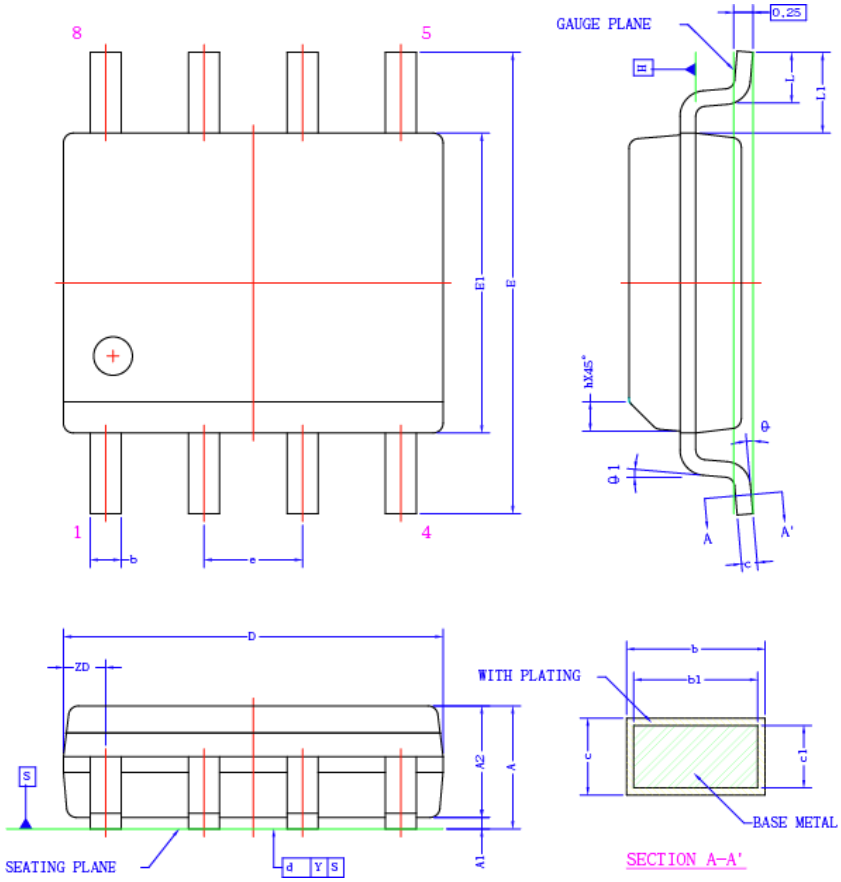
3.1 Package Types : SOP / USON (SN, ZR) , not to scale, Top view



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4 Package Outline Drawing

4.1 SOP-8L(150), package code SN



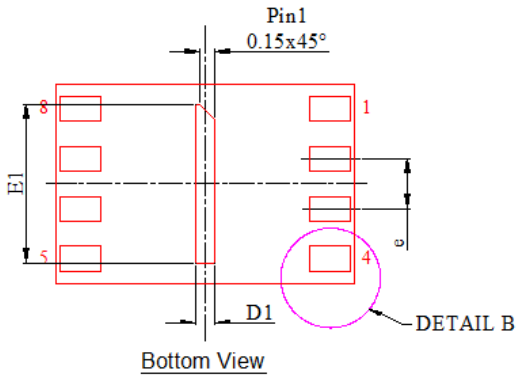
SYMBOL	DIMENSION (MM)			DIMENSION (MIL)		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	1.35	1.60	1.75	53	63	69
A1	0.10	0.15	0.25	4	6	10
A2	1.35	1.45	1.55	53	57	61
b	0.31	–	0.51	12	–	20
b1	0.28	0.40	0.48	11	16	19
c	0.17	–	0.25	7	–	10
c1	0.17	0.20	0.23	7	8	9
D	4.80	4.90	5.00	189	193	197
E	6.00 BSC			236 BSC		
E1	3.80	3.90	4.00	150	154	157
e	1.27 BSC			50 BSC		
L	0.40	0.66	1.27	16	26	50
L1	1.05 REF			41 REF		
ZD	0.55 REF			22 REF		
h	0.25	0.38	0.50	10	15	20
Y	–	–	0.10	–	–	4
θ	0°	–	8°	0°	–	8°
θ1	0°	–	–	0°	–	–

NOTE :

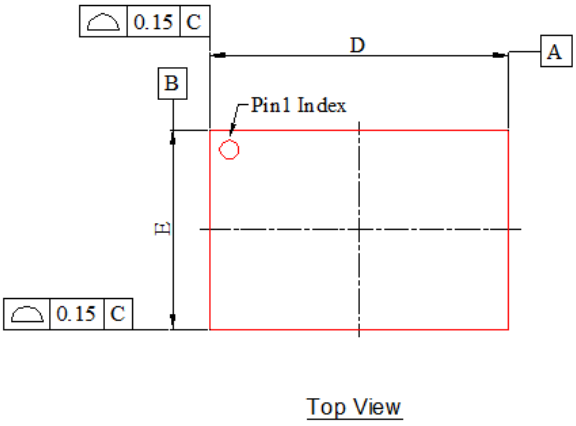
1. REFER TO JEDEC STD: MS-012 AA.
2. DIMENSION "D" DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURRS. MOLD FLASH, PROTRUSION AND GATE BURRS SHALL NOT EXCEED 0.15mm PER SIDE.
   DIMENSION "E1" DOES NOT INCLUDE INTERLEAD MOLD FLASH OR PROTRUSION. INTERLEAD MOLD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25mm PER SIDE.
   'D' AND 'E1' DIMENSIONS ARE DETERMIND AT DATUM H .
3. DIMENSION "b" DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.10mm TOTAL IN EXCESS OF THE 'b' DIMENSION AT MAXIMUM MATERIAL CONDITION. THE DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OF THE FOOT.

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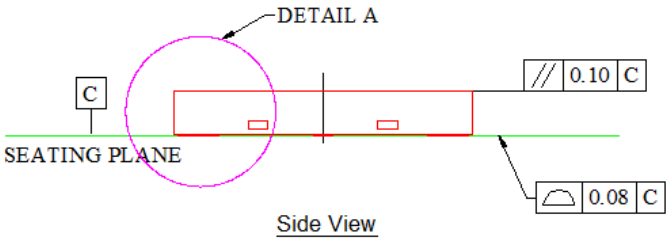
4.2 USON-8L 3x2mm, package code ZR



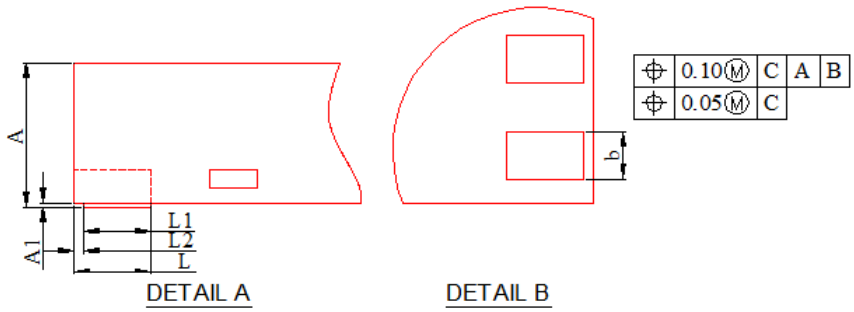
Bottom View



Top View



Side View



DETAIL A DETAIL B

Symbol	MILLIMETERS		
	MIN.	NOM.	MAX.
A	0.40	0.45	0.50
A1	0.00	---	0.05
D	2.90	3.00	3.10
D1	0.10	0.20	0.30
E	1.90	2.00	2.10
E1	1.50	1.60	1.70
L	0.40	0.45	0.50
L1	0.30	---	---
L2	---	---	0.15
b	0.20	0.25	0.30
e	0.50 BSC		

NOTE:
1. Scale 1:4
2. ALL DIMENSIONS AND TOLERANCES TAKE REFERANCE TO JEDEC MO-229
3. DIMENSION "b" APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15MM AND 0.30MM FROM THE TERMINAL TIP. IF THE TERMINAL HAS OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION B SHOULD NOT BE MEASURED IN THAT RADIUS AREA.

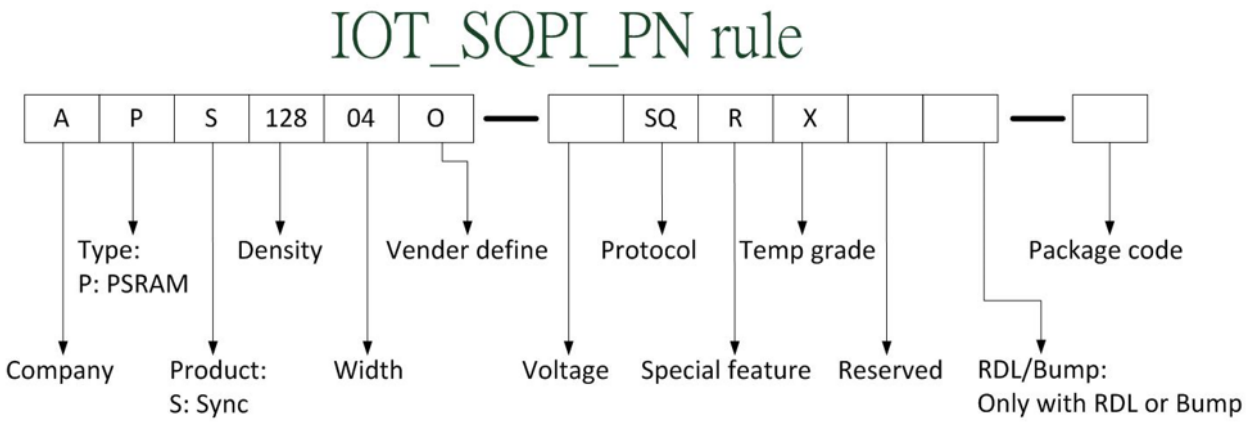
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5 Ordering Information

Table 1: Ordering Information

Part Number	*Temperature Range*	*Max Frequency*	*Note*
APS1604M-3SQR	Tj = -40°C to +85°C	133 MHz*	Bare die, SIP
APS1604M-3SQRX	Tj = -40°C to +105°C	133 MHz*	Bare die, SIP
APS1604M-3SQR-ZR	Tc=-40°C to +85°C	133 MHz*	USON-8
APS1604M-3SQR-SN	Tc=-40°C to +85°C	133 MHz*	SOP-8
APS1604M-3SQRX-SN	Tc=-40°C to +105°C	133 MHz*	SOP-8

Note *: 133MHz for Wrapped Burst operation at VDD=3.0V+/-10%
109MHz for Wrapped Burst operation at VDD=3.3V+/-10%
84MHz for Linear 512 Burst operation with RBX (row boundary crossing)



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6 Signal Table

All signals are listed in Table 2.

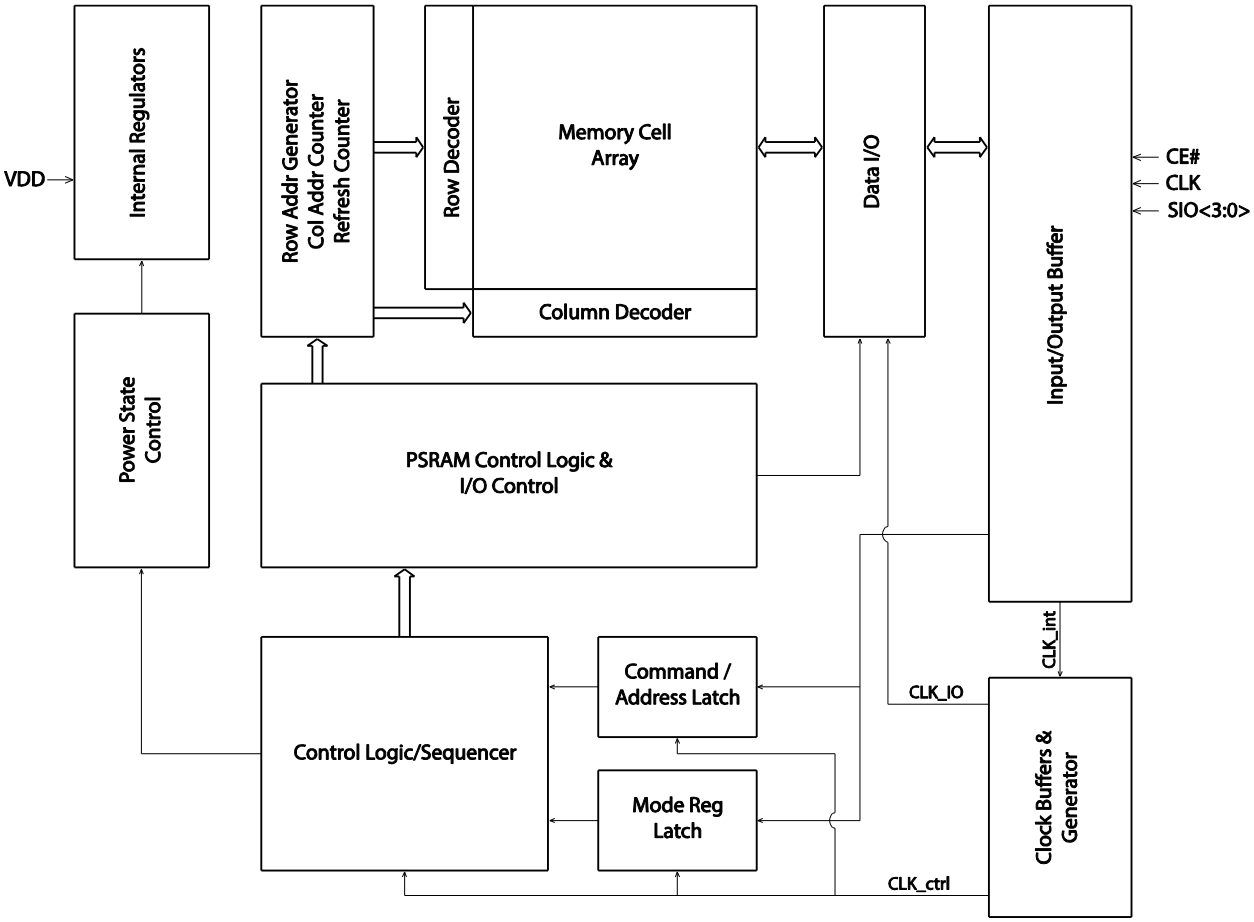
Table 2: Signals Table

Symbol	*Type*	*SPI Mode Function*		*QPI Mode Function*	*Comments*
VDD	Power	Core supply			
VSS	Ground	Core supply ground			
CE#	Input	Chip select, active low. When CE#=1, chip is in standby state			
CLK	Input	Clock Signal			
SI/SIO[0]	IO	Serial Input	IO[0]*	IO[0]	
SO/SIO[1]	IO	Serial Output	IO[1] *	IO[1]	
SIO[2]	IO	--	IO[2] *	IO[2]	
SIO[3]	IO	--	IO[3] *	IO[3]	

Note *: SPI Quad mode

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7 Block Diagram



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8 Power-Up Initialization

SPI/QPI products include an on-chip voltage sensor used to start the self-initialization process. When VDD reaches a stable level at or above minimum VDD, the device will require 150µs and user-issued RESET Operation (see section 17) to complete its self-initialization process. From the beginning of power ramp to the end of the 150µs period, CLK should remain LOW, CE# should remain HIGH (track VDD within 200mV) and SI/SO/SIO[3:0] should remain LOW.

After the Device Reset tRST≧50ns period the device is ready for normal operation.

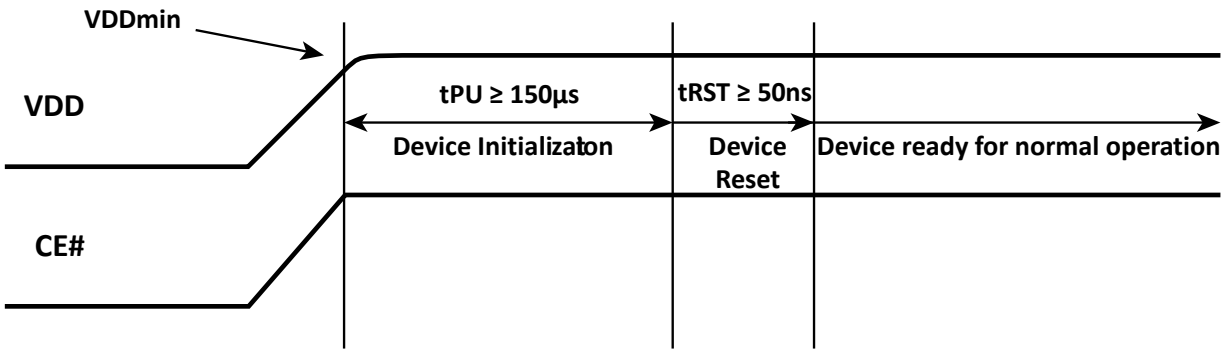


Figure 1. Power-Up Initialization Timing

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9 Interface Description

9.1 Address Space

SPI/QPI PSRAM device is byte-addressable. 16M device is addressed with A[20:0].

9.2 Page Length

Read and write operations are default page size of 512 bytes.

9.3 Drive Strength

The device powers up in 50Ω.

9.4 Power-on Status

The device powers up in SPI Mode. It is required to have CE# high before beginning any operations.

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10 Mode Register Definition

Table 3: Mode Register Table

MR No.	MA[3:0]	Access	OP7	OP6	OP5	OP4	OP3	OP2	OP1	OP0
0	`h0	R/W	rsvd.	Wrap		rsvd.			DQ Zout	

Table 4: Wrap Codes MR0[6:5]

Wrap Burst Settings		Page Boundary Crossing	
MR0[6:5]	Wrapped Length	Non-Wrap CMDs ('h03,'h0B,`hEB,'h02,'h38)	Wrap CMDs('h8B,'h82)
00	16	Wrap 16, no cross page boundary	
01	32	Wrap 32, no cross page boundary	
10	64	Wrap 64, no cross page boundary	
11 (default)	512 (page size)	Linear, can cross page boundary	Wrap 512, no cross page boundary

Table 5: DQ Output Drive Strength Codes MR0[1:0]

DQ Output Drive Strength	
MR0[1:0]	Impedance
00 (default)	50Ω
01	100Ω
10	200Ω
Others	reserved

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11 Command/Address Latching Truth Table

The device recognizes the following commands specified by the various input methods.

		SPI Mode (QE=0)					QPI Mode (QE=1)					
Command	**Code**	**Cmd**	**Addr**	**Wait Cycle**	**DIO**	**Max Freq.**	**Cmd**	**Addr**	**Wait Cycle**	**DIO**	**DIO**	**Max Freq.**
Read	'h03	S	S	0	S	33	N/A					
Fast Read	'h0B	S	S	8	S	133/84*	Q	Q	4	Q	Q	66
Fast Read Quad	'hEB	S	Q	6	Q	133/84*	Q	Q	6	Q	Q	133/84*
Write	'h02	S	S	0	S	133/84*	Q	Q	0	Q	Q	133/84*
Quad Write	'h38	S	Q	0	Q	133/84*	same as 'h02					
Wrapped Read	h8B	S	S	8	S	133	Q	Q	6	Q	Q	133
Wrapped Write	h82	S	S	0	S	133	Q	Q	0	Q	Q	133
Mode Register Read	hB5	S	S	8	S	133	Q	Q	6	Q	Q	133
Mode Register Write	hB1	S	S	0	S	133	Q	Q	0	Q	Q	133
Enter Quad Mode	'h35	S	-	-	-	133	N/A					
Exit Quad Mode	'hF5	N/A					Q	-	-	-	-	133
Reset Enable	'h66	S	-	-	-	133	Q	-	-	-	-	133
Reset	'h99	S	-	-	-	133	Q	-	-	-	-	133
Burst Length Toggle	'hC0	S	-	-	-	133	Q	-	-	-	-	133
Read ID	'h9F	S	S	0	S	33	N/A					

Remark: S = Serial IO, Q = Quad IO

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11.1 Command Termination

All Reads & Writes must be completed by raising CE# high immediately afterwards in order to terminate the active command and set the device into standby. Not doing so will block internal refresh operations and cause memory failure.

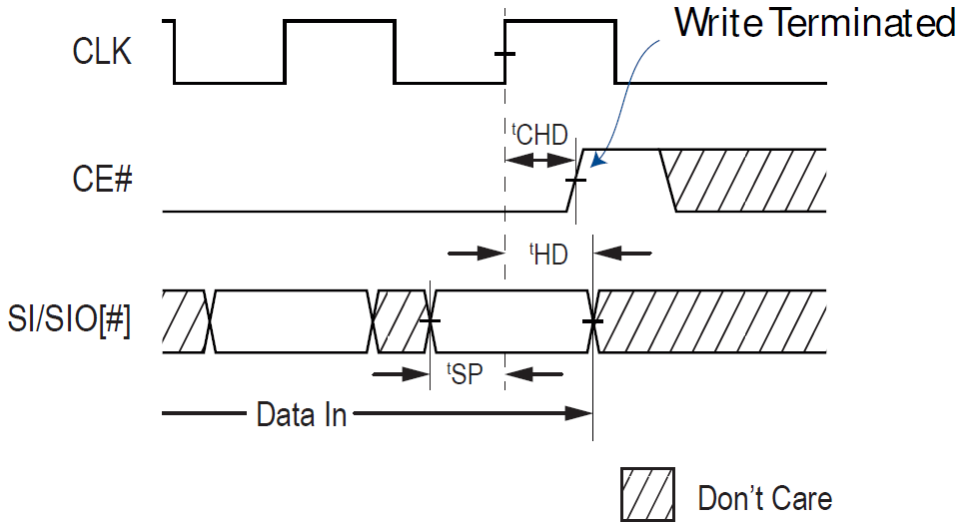


Figure 2: Write Command Termination

For a memory controller to correctly latch the last piece of data prior to read termination, it is recommended to provide a longer CE# hold time (^{t}CHD > ^{t}ACLK+^{t}CLK) for a sufficient data window.

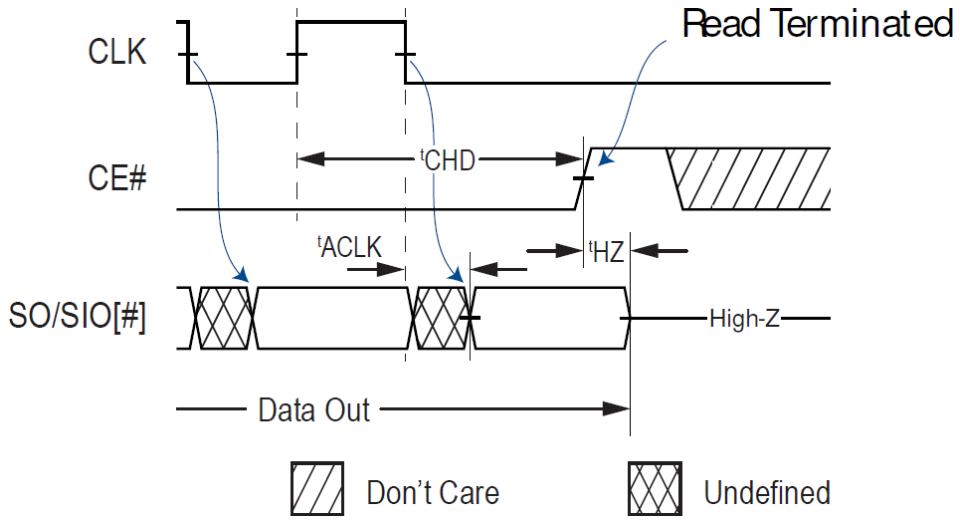


Figure 3: Read Command Termination

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12 Mode Register Operations

12.1 SPI MR Read Operation

For all reads, MR data will be available ^{t}ACLK after the falling edge of CLK.

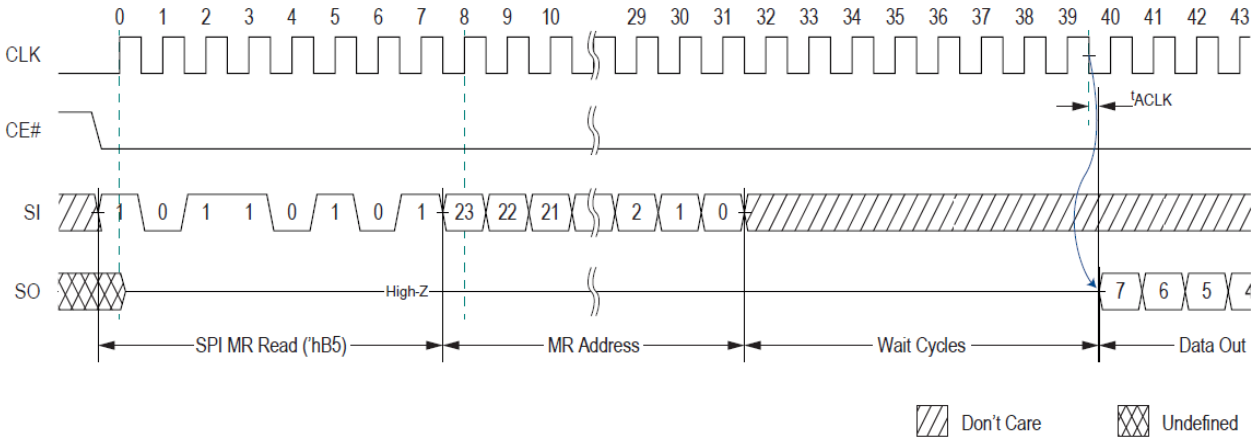


Figure 4: SPI MR Read 'hB5

12.2 SPI MR Write Operation

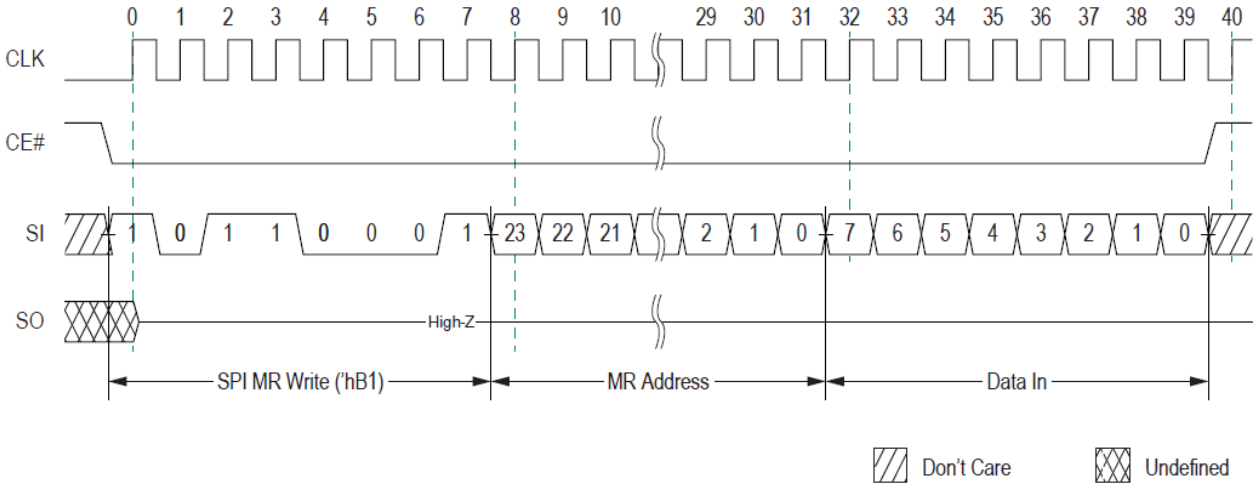


Figure 5: SPI MR Write 'hB1

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12.3 QPI MR Read Operation

For all reads, MR data will be available ^{t}ACLK after the falling edge of CLK.

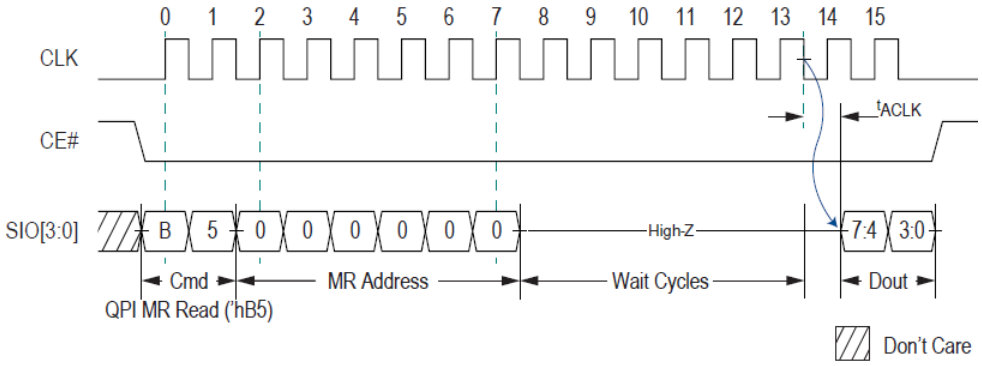


Figure 6: QPI MR Read 'hB5

12.4 QPI MR Write Operation

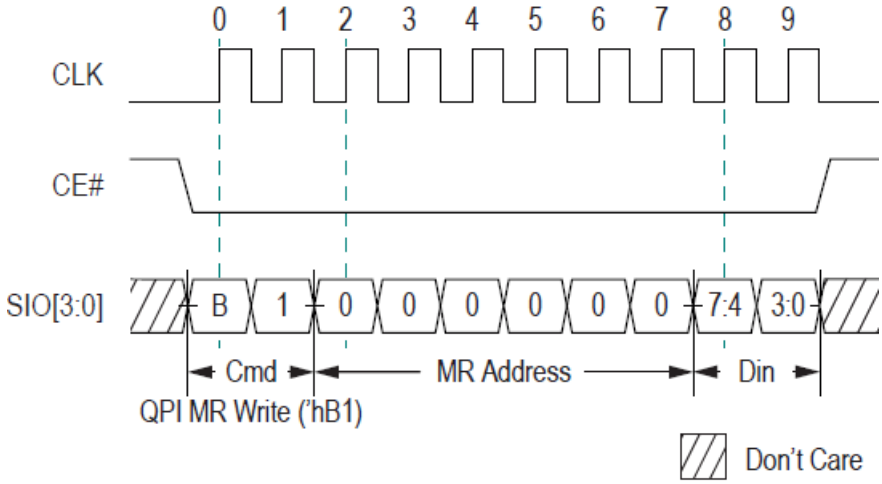


Figure 7: QPI MR Write 'hB1

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13 Read ID

Read ID command provides information of vendor ID, known-good-die, device density, and manufacturing ID. Note that Read ID command can be used ONLY as Power up initialization after the device Reset tRST≧ 50ns right after Global Reset command.



Figure 12: Pre-condition of EID Read

13.1 SPI Read ID Operation

This command is similar to Fast Read, but without the wait cycles and the device outputs EID value instead of data.

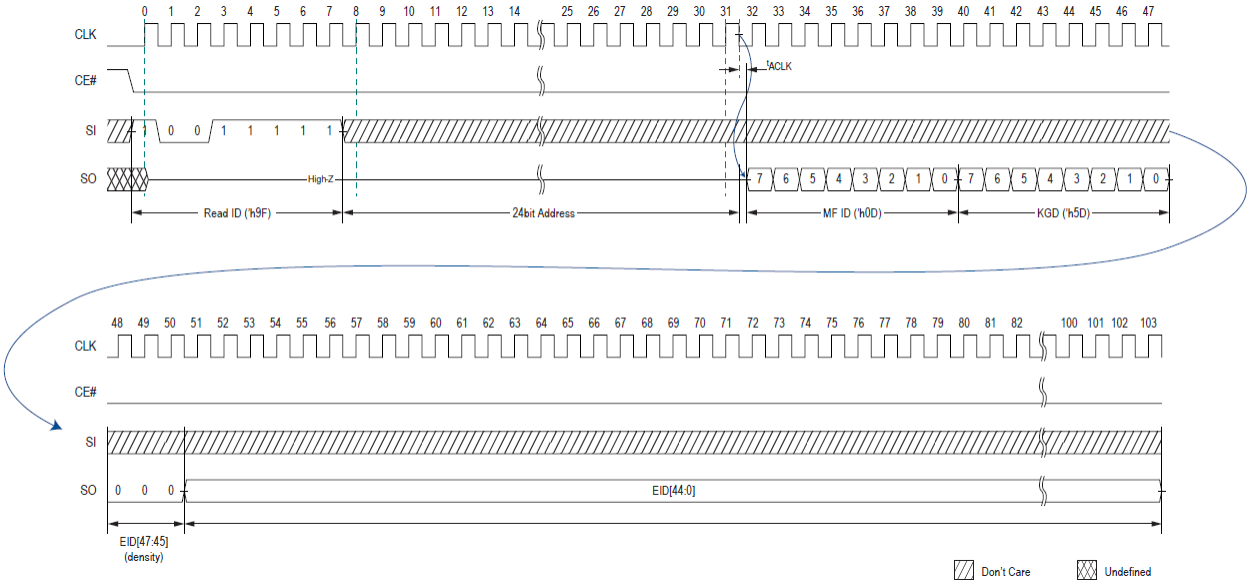


Figure 8: SPI Read ID 'h9F (available only in SPI mode)

14 Toggle Burst Length Operation

The Toggle Burst Length Operation switches the device's wrapped burst boundary between the Mode Register setting MR0[6:5] and a fixed value of 32 bytes.

Commands other than Wrapped Read ('h8B) and Wrapped Write ('h82) are linear type bursts which allow the

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device to burst through page boundaries. A page boundary crossing is only available when the Burst Length Toggle is set to use MR settings (default) **AND** Burst Wrap setting is set to full page size MR0[6:5] = 11 (default). The page boundary crossing is invisible to the memory controller and limited to a lower max CLK frequency of 84MHz.

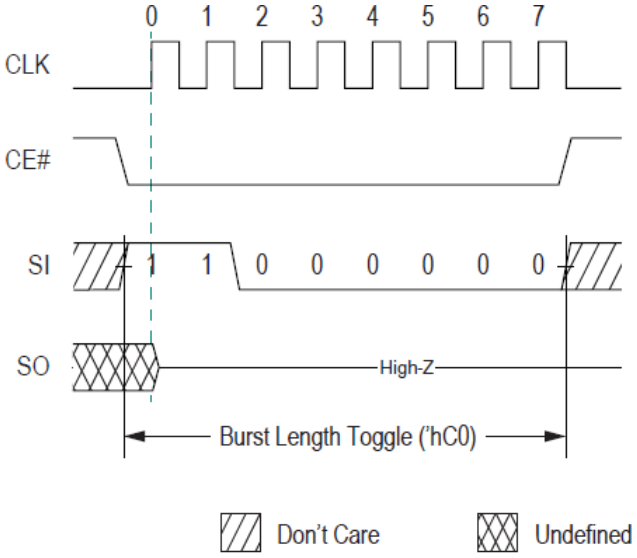


Figure 9: SPI Burst Length Toggle 'hC0

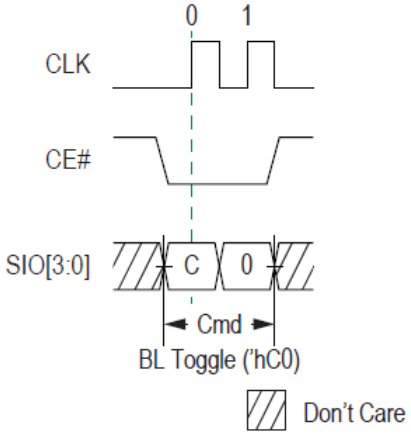


Figure 10: QPI Burst Length Toggle 'hC0

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15 SPI Mode Operations

The device powers up into SPI mode by default but can also be switched into QPI mode.

15.1 SPI Read Operations

For all reads, data will be available ^{t}ACLK after the falling edge of CLK.

SPI Reads can be done in four ways:

1. 'h03: Serial CMD, Serial Addr/IO, slow frequency, with wrap or linear bursting.
2. 'h0B: Serial CMD, Serial Addr/IO, fast frequency, with wrap or linear bursting.
3. 'hEB: Serial CMD, Quad Addr/IO, fast frequency, with wrap or linear bursting.
4. 'h8B: Serial CMD, Serial Addr/IO, fast frequency, with forced wrap (toggle & register configurable lengths).

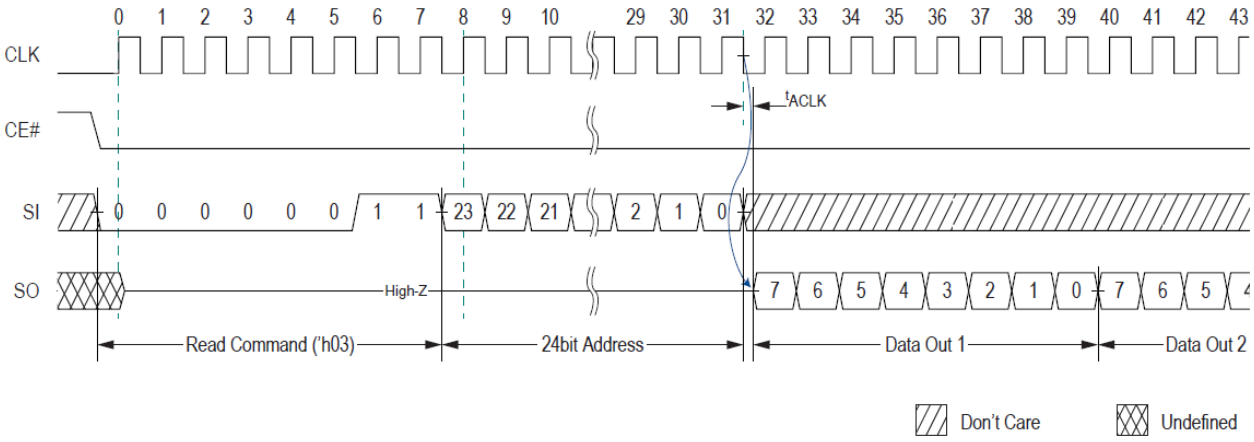


Figure 11: SPI Read 'h03 (max freq 33 MHz)

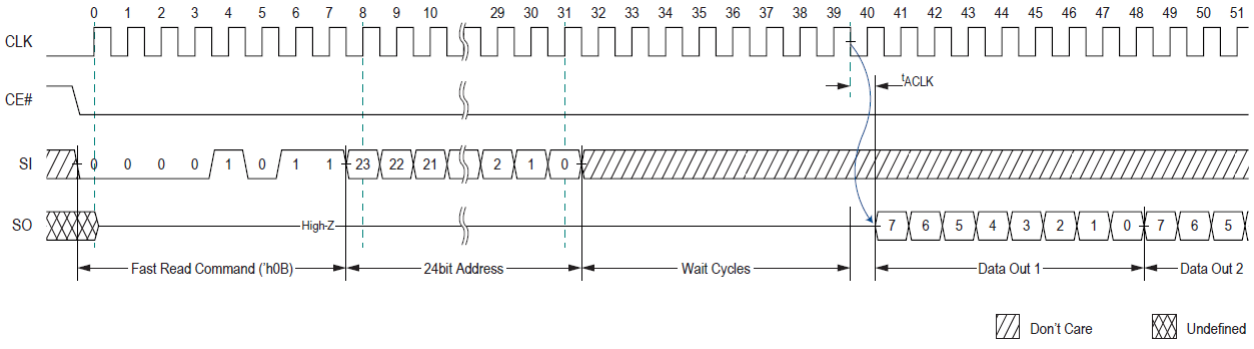


Figure 12: SPI Fast Read 'h0B (max freq 133/84 MHz)

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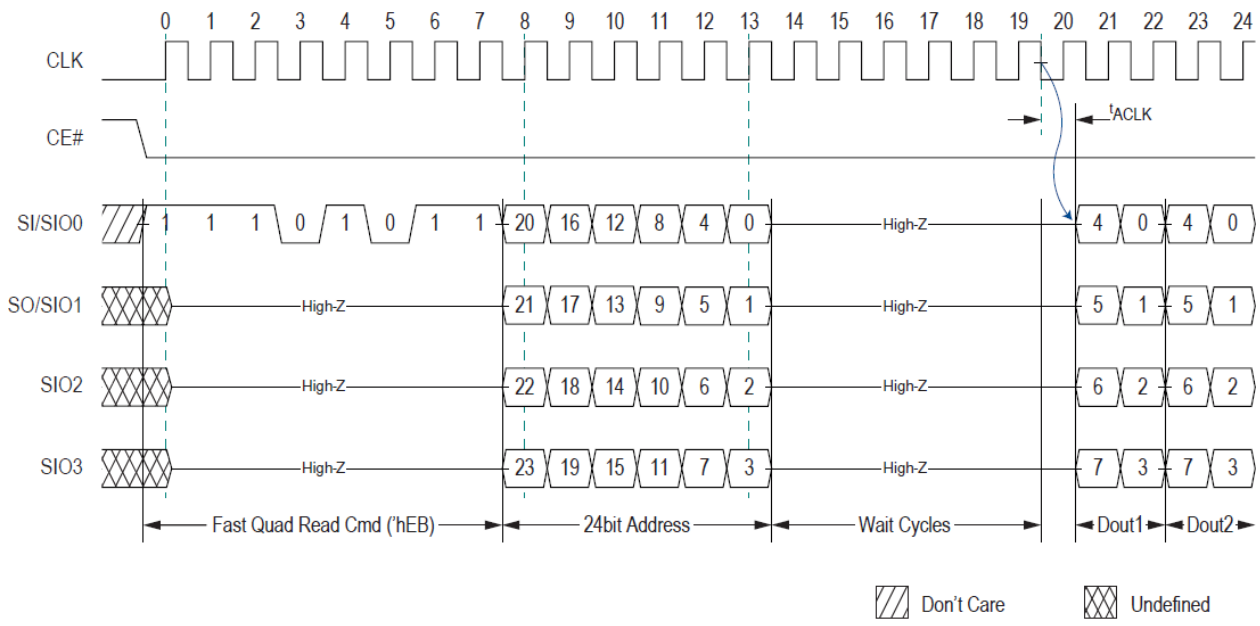


Figure 13: SPI Fast Quad Read 'hEB (max freq 133/84 MHz)

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15.2 SPI Write Operations

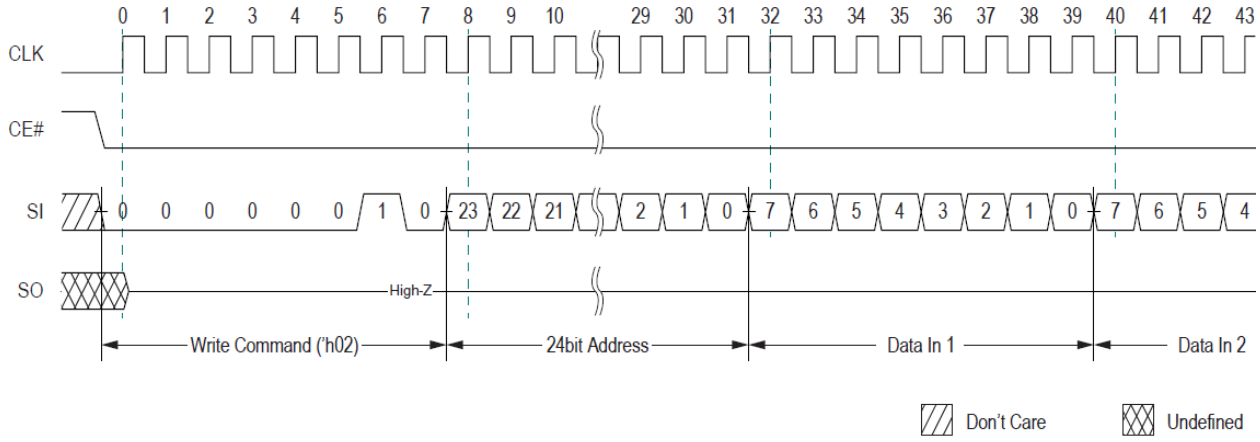


Figure 14: SPI Write 'h02

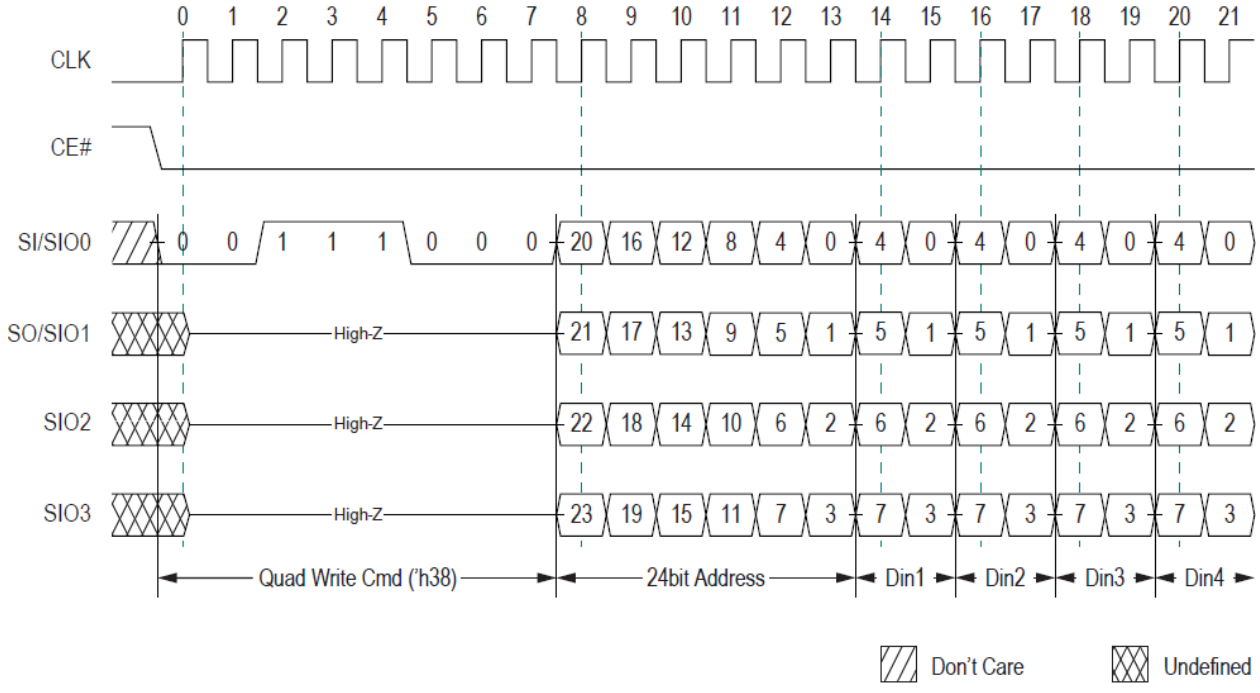


Figure 15: SPI Quad Write 'h38

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15.3 SPI Quad Mode Enable Operation

This command switches the device into quad IO mode.

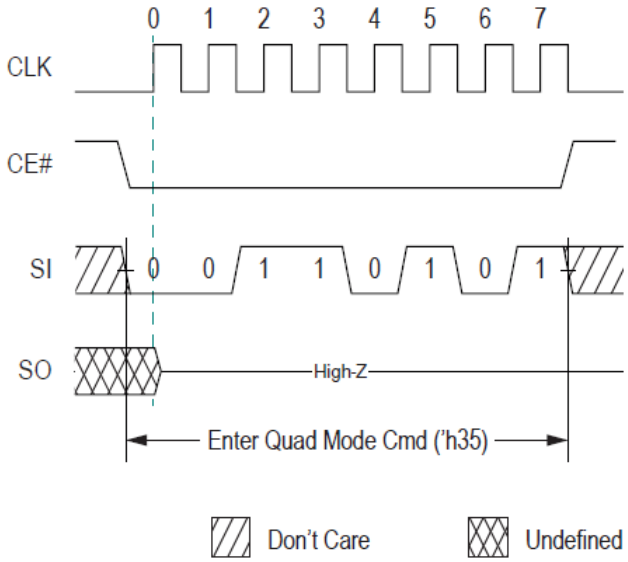


Figure 16: Quad Mode Enable 'h35 (available only in SPI mode)

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16 QPI Mode Operations

16.1 QPI Read Operations

For all reads, data will be available ^{t}ACLK after the falling edge of CLK.

QPI Reads can be done in one of three ways:

1. ‘h0B: Quad CMD, Addr & IO, slow frequency with wrap or linear bursting.
2. ‘hEB: Quad CMD, Addr & IO, fast frequency with wrap or linear bursting.
3. ‘h8B: Quad CMD, Addr & IO, fast frequency with forced wrap (toggle & register configurable lengths).

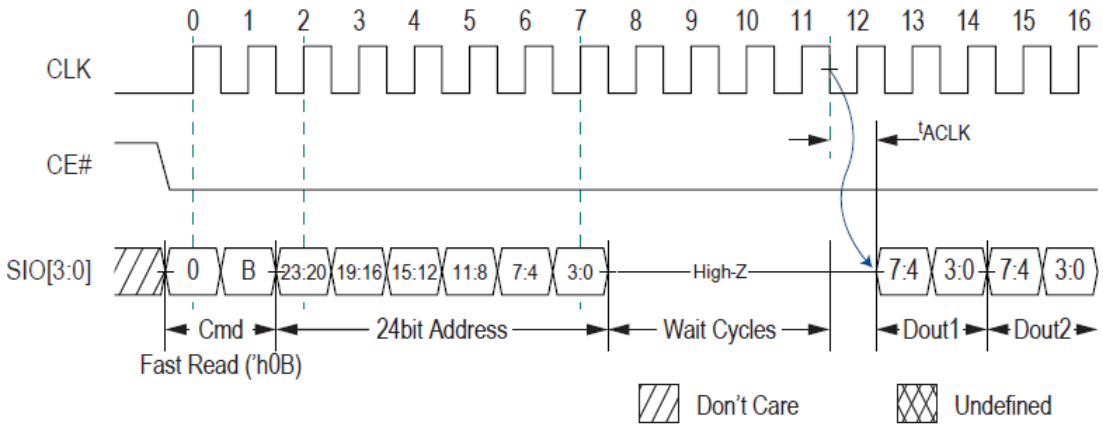


Figure 17: QPI Fast Read ‘h0B (max freq 66 MHz)

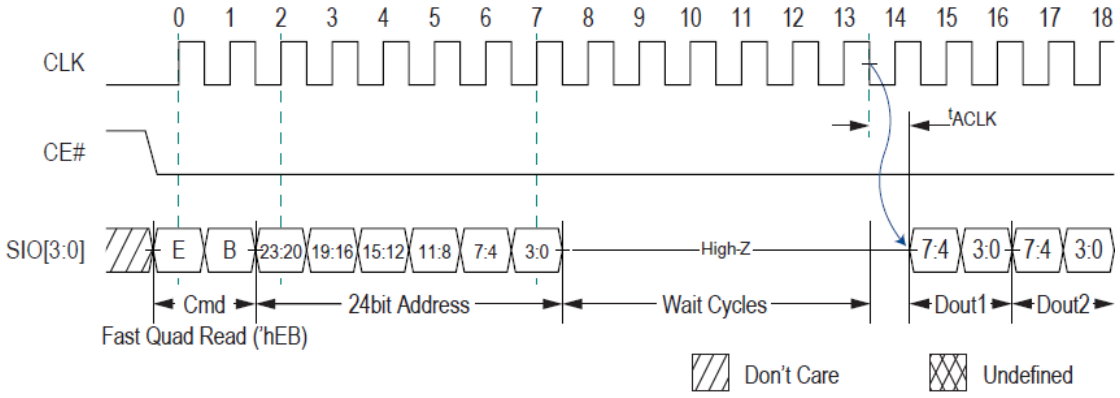


Figure 18: QPI Fast Quad Read ‘hEB (max freq 133/84 MHz)

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16.2 QPI Write Operation(s)

QPI write command can be done in one of two ways:

1. ‘h02 or ‘h38: Quad CMD, Addr & IO, with wrap or linear bursting.
2. ‘h82: Quad CMD, Addr & IO, with forced wrap (toggle & register configurable lengths).

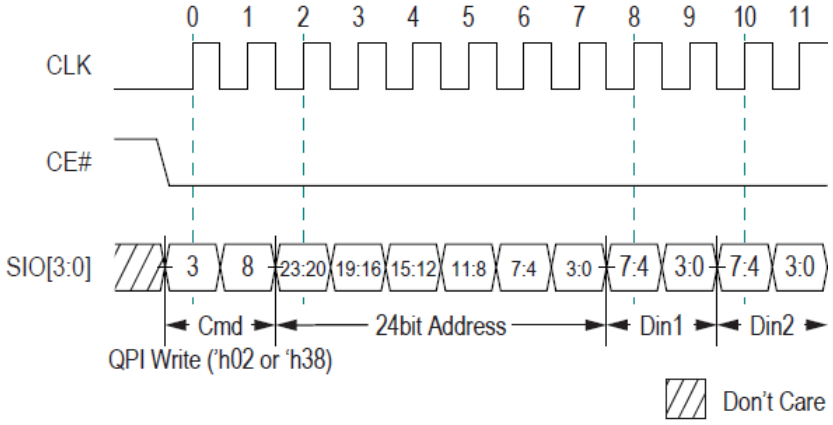


Figure 19: QPI Write

16.3 QPI Quad Mode Exit operation

This command will switch the device back into serial IO mode.

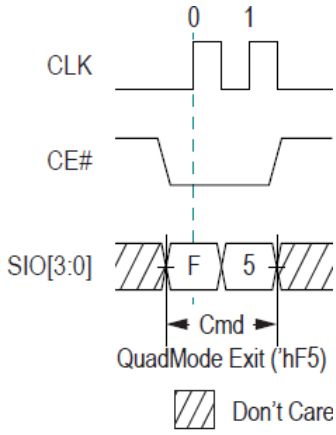


Figure 20: Quad Mode Exit ‘hF5 (only available in QPI mode)

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17 Reset Operation

The Reset operation is used as a system (software) reset that puts the device in SPI standby mode which is also the default mode after power-up. This operation consists of two commands: Reset-Enable (RSTEN) and Reset (RST).

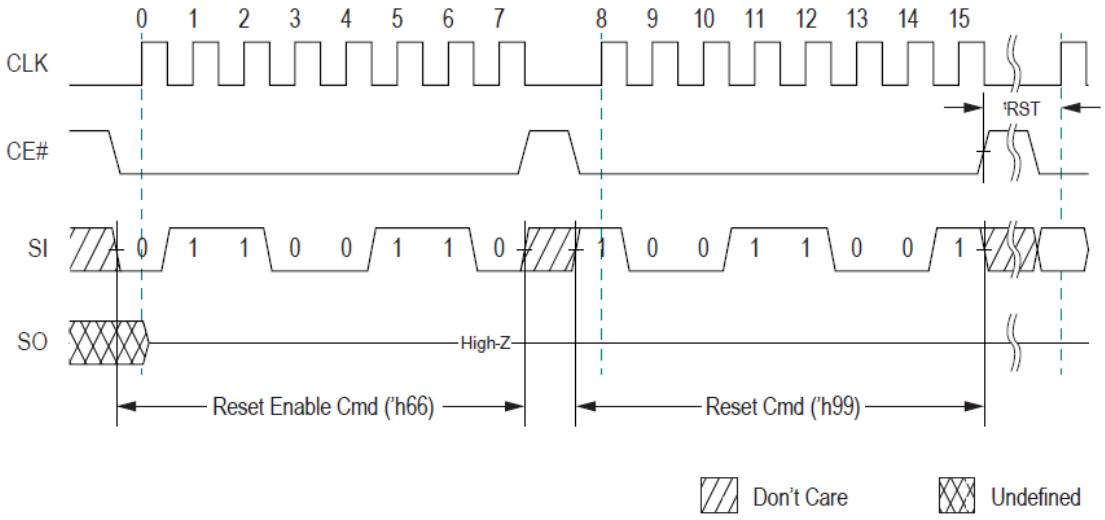


Figure 21: SPI Reset

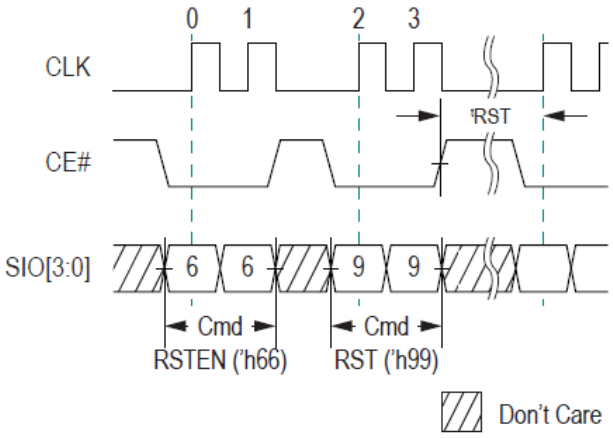


Figure 22: QPI Reset

Reset command has to immediately follow the Reset-Enable command in order for the reset operation to take effect. Any command other than the Reset command after the Reset-Enable command will cause the device to exit Reset-Enable state and abandon reset operation.

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18 Input/Output Timing

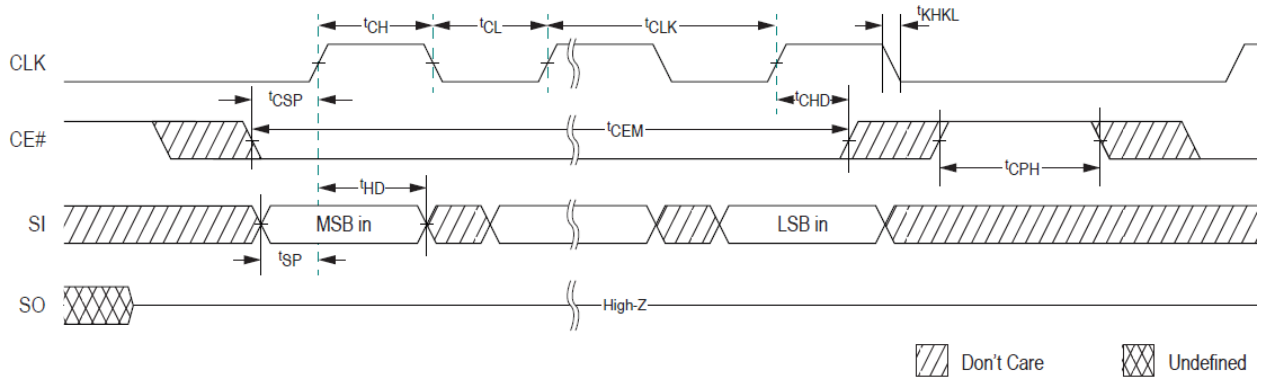


Figure 23: Input Timing

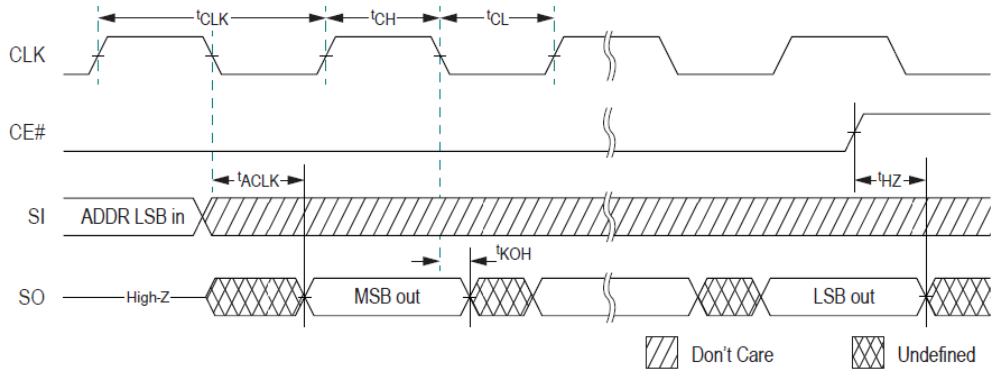


Figure 24: Output Timing

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19 Electrical Specifications:

19.1 Absolute Maximum Ratings

Table 6: Absolute Maximum Ratings

Parameter	*Symbol*	*Rating*	*Unit*	*Notes*
Voltage to any ball except V_{DD} relative to V_{SS}	VT	-0.4 to V_{DD}+0.4	V	
Voltage on V_{DD} supply relative to V_{SS}	V_{DD}	-0.4 to +4.0	V	
Storage Temperature	T_{STG}	-55 to +150	℃	1

Notes 1: Storage temperature refers to the case surface temperature on the center/top side of the PSRAM.

Caution:
Exposing the device to stress above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational section of this specification. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

19.2 Input Signal Overshoot

During DC conditions, input or I/O signals should remain equal to or between VSS and VDD. During voltage transitions, inputs or I/Os may negative overshoot VSS to -1.0V or positive overshoot to VDD +1.0V, for periods up to 20 ns.

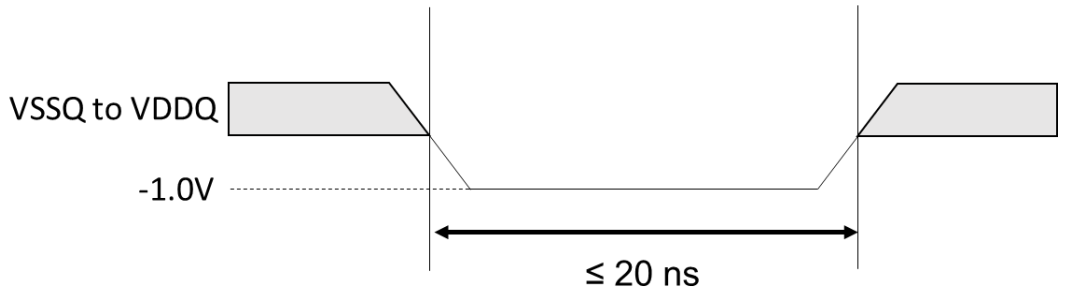


Figure 25 Maximum Negative Overshoot Waveform

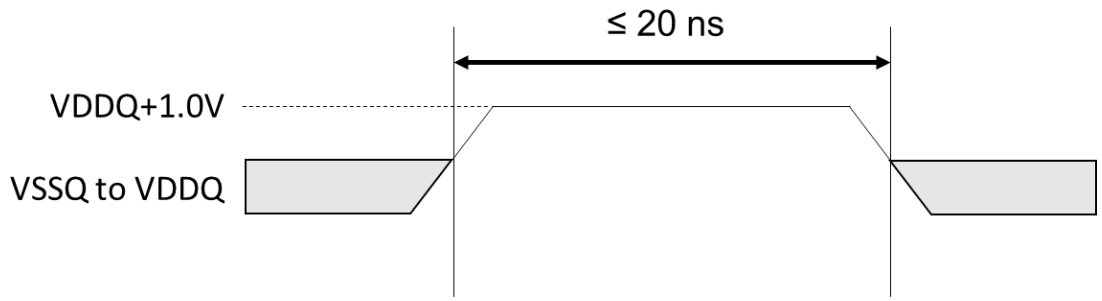


Figure 26 Maximum Positive Overshoot Waveform

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19.3 Pin Capacitance

Table 7: Bare Die Pin Capacitance

Parameter	*Symbol*	*Min*	*Max*	*Unit*	*Notes*
Input Pin Capacitance	CIN		2	pF	VIN=0V
Output Pin Capacitance	COUT		3	pF	VOUT=0V

Note: spec'd at 25°C.

Table 8: Package Pin Capacitance

Parameter	*Symbol*	*Min*	*Max*	*Unit*	*Notes*
Input Pin Capacitance	CIN		6	pF	VIN=0V
Output Pin Capacitance	COUT		8	pF	VOUT=0V

Note: spec'd at 25°C.

Table 9: Load Capacitance

Parameter	*Symbol*	*Min*	*Max*	*Unit*	*Notes*
Load Capacitance	C_L		15	pF	

Note: System C_L for the use of package

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19.4 Decoupling Capacitor Requirement

It is required to have a decoupling capacitor on VDD pin for IO switchings and psram internal transient events. A low ESR 1µF ceramic cap is recommended. To minimize parasitic inductance, place the cap as close to VDD pin as possible. An optional 0.1µF can further improve high frequency transient response.

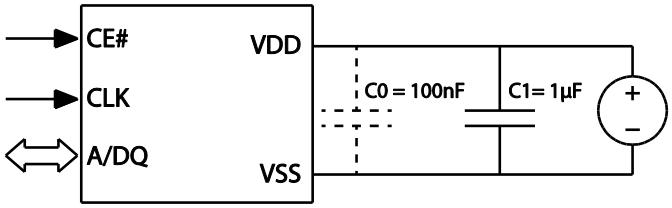


Figure 27: Decoupling Capacitor

Note that the length of grounding connection between PSRAM and PCB must be as short as possible. Having **ground plane on PCB** and **multipoint ground** would be preferred (to avoid single-point grounding topology). The width of VDD and VSS traces would be suggested more than 20mil.

19.5 Operating Conditions

Table 10: Operating Characteristics

Parameter	*Min*	*Max*	*Unit*	*Notes*
Operating Temperature (extended)	-40	105	°C	
Operating Temperature (standard)	-40	85	°C	

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19.6 DC Characteristics

Table 11: DC Characteristics

Symbol	*Parameter*	*Min*	*Max*	*Unit*	*Notes*
V_{DD}	Supply Voltage	2.7	3.6	V	
V_{IH}	Input high voltage	V_{DD}-0.4	V_{DD}+0.2	V	
V_{IL}	Input low voltage	-0.2	0.4	V	
V_{OH}	Output high voltage (I_{OH}=-0.2mA)	0.8 V_{DD}		V	
V_{OL}	Output low voltage (I_{OL}=+0.2mA)		0.2 V_{DD}	V	
I_{LI}	Input leakage current		1	µA	
I_{LO}	Output leakage current		1	µA	
I_{CC}	Read/Write (133MHz)		7	mA	1,2
	Read/Write (66MHz)		6	mA	1,2
	Read/Write (13MHz)		5	mA	1,2
ISB_{EXT}	Standby current (105C)		200	µA	3
ISB_{STD}	Standby current (85C)		150	µA	3

Note 1: Output load current not included
2: 50% bus toggling rate.
3: Standby current is measured when CLK is in DC low state.
4: Typical ISBSTD 35µA at 25°C

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19.7 AC Characteristics

Table 12: READ/WRITE Timing

Symbol	Parameter	Min	Max	Unit	Notes
^{t}CLK	CLK period - SPI Read (‘h03)	30.3		ns	33MHz
	CLK period - QPI Read (‘h0B)	15.1			66MHz
	CLK period - all other operations PKG 3V	7.5			133MHz*1,2,3
	CLK period - all other operations PKG 3.3V	9.17			109MHz*1,2,3
	CLK period - all other operations	11.9			84MHz*1
^{t}CH/^{t}CL	Clock high/low width	0.45	0.55	^{t}CLK(min)	
^{t}KHKL	CLK rise or fall time		1.5	ns	4
^{t}CPH	CE# HIGH between subsequent burst operations	18		ns	
^{t}CEM	CE# low pulse width		3	µs	Extended
			8		Standard grade
^{t}CSP	CE# setup time to CLK rising edge PKG	2.5		ns	
^{t}CHD	CE# hold time from CLK rising edge PKG	3.0		ns	
^{t}SP	Setup time to active CLK edge	2		ns	
^{t}HD	Hold time from active CLK edge	2		ns	
^{t}HZ	Chip disable to DQ output high-Z		5.5	ns	
^{t}ACLK	CLK to output delay	2	5.5	ns	
^{t}KOH	Data hold time from clock falling edge	1.5		ns	
^{t}RST	Time between end of RST CMD to next valid CMD	50		ns	

Note 1: Only Linear 512 Burst allows page boundary crossing. Frequency limits are therefore 133MHz max for Wrapped Burst operation at VDD=3.0V+/-10%, 109MHz for Wrapped Burst operation at VDD=3.3V+/-10%, 84MHz max when Linear 512 Burst commands cross page boundary

2: System max C_L 15pF for the use of package.

3: For operating frequencies >84MHz, it is highly recommended to utilize CLK falling edge to sample read data or align sampling clock via data pattern tuning (refer to JEDEC JESD84-B50 for an example).

4: Measured from 20% to 80% of VDD

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20 Change Log

Version	Who	Date	Description
1.0		Aug 01, 2017	Officially released
1.1		Aug 24, 2017	Added system max C_L for the use of package & related tCK and tCHD; relaxed tCSP/tHD, removed drive strength setting '11, changed tACLK, tKHKL, tCPH; added ISBstdroom
1.5		Oct 30, 2017	Enabled QPI Read 'h0B support; changed Min/Max absolute voltage, Vil_min and Vih_max,; defined tCEM for different temperature grade; corrected speed typo. Added USON package ZR
1.6		Nov 10, 2017	Modified spec of ISB, ICC
1.7		Feb 26, 2018	Typo corrected in Fig.12, 17
1.8		Mar 29, 2018	Revised part # for RBX
1.9		Oct 03, 2018	added SPI MRW/MRR waves, elaborated on boundary crossing conditions and table, QPI EID Read, updated package information & corrected some wording
2.0		Oct 03, 2018	Revised speed for linear read & Read ID
2.1		Dec. 13, 2018	Added tRST parameter, Block Diagram, updated POD of USON, ball map of WLCSP, temperature grade, Typo corrected
2.2		Jul 19, 2019	Update section 13 from –SQR v2.16, and min frequency of truth table in section 11 from –SQQ v2.43
2.3		Sep 06, 2019	Updated Page 1, Section 5 and **錯誤! 找不到參照來源。**; updated Table 9 and Table 11
2.4a		Oct 02, 2019	Updated header, footer and Page 1
2.5		Oct 24, 2019	Revised typo in **錯誤! 找不到參照來源。** and Table 12; updated notes in 19.4
2.6		Nov 21, 2019	Updated Table 2
2.7		Apr 30, 2020	Modify VDD's description of Table 2
2.8		Oct 12, 2021	Revised tCEM value from 4us to 3us @105C
2.8a		Dec 13, 2021	Revised some figure can't display grid (ex: Don't care/Undefined) when conversion to PDF.
2.8b	Alan	Jan 25, 2022	Update Table of Contents page number.
2.9	Kim/ Gene/ Eric	Jun 16, 2022	Typos correct
3.0	Kim	Oct 28, 2022	Release USON temp. from -25~85 to -40~85
3.1	Kim	Nov 21, 2023	Add chapter 19.2 Input signal overshoot

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