SPI/QPI PSRAM

Specifications

- **Single Supply Voltage**
  - VDD=1.62 to 1.98V
- **Interface**: SPI/QPI with SDR mode
- **Performance**: Clock rate up to 84MHz
- **Organization**: 64Mb, 8M x 8bits
- **Addressable Bit Range**: A[22:0]
- **Page Size**: 1024 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**
  - 300µA @ 105°C
  - 200µA @ 85°C
- **Typical HalfSleep™ Mode with data retained**
  - 20µA @ 25°C

Features

- **50Ω Output Drive Strength LVCMOS**.
- **Linear Burst** is supported up to 84MHz and can cross page boundary as long as tCEM is met.
- **Software Reset**
- **Ultra Low Power HalfSleep™ Mode** with data retention.

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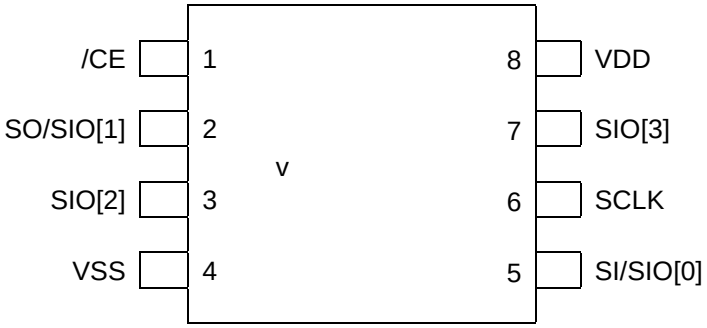
2 Introduction

This Pseudo-SRAM device features a high speed, low pin count interface. It has 4 SDR I/O pins and operates in SPI(serial peripheral interface) or QPI (quad peripheral interface) mode with frequencies up to 84 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 APS6404L-SQRH is available in standard package including 8-lead SOP-8L(150) and advanced package including 8-lead , USON-8L 3x2mm.

- **Package Type: SOP/USON (SN, ZR)**



Top View

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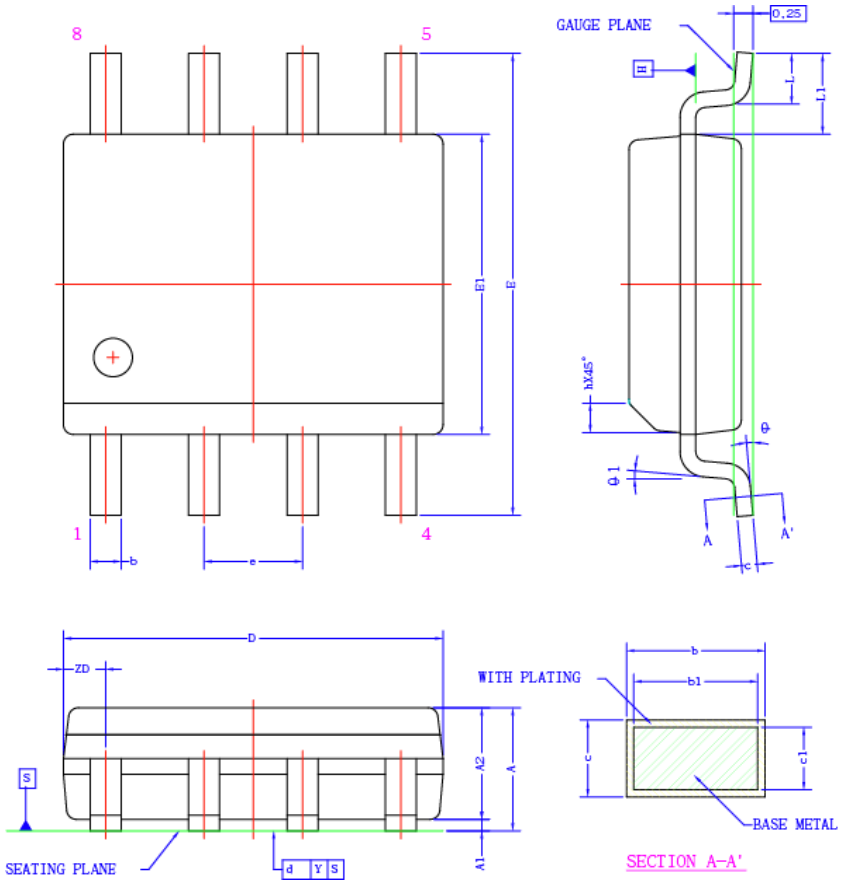
4 Package Outline Drawing

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 PLASH, PROTRUSION OR GATE BURRS. MOLD PLASH, PROTRUSION AND GATE BURRS SHALL NOT EXCEED 0.15mm PER SIDE.
   DIMENSION "E1" DOES NOT INCLUDE INTERLEAD MOLD PLASH OR PROTRUSION. INTERLEAD MOLD PLASH 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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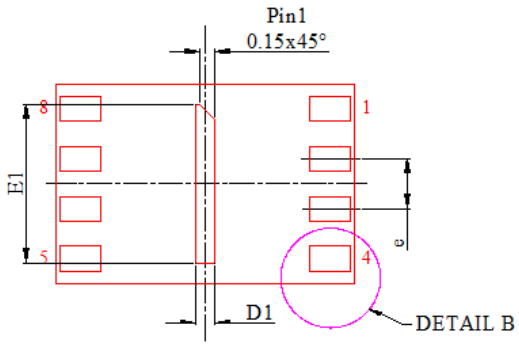
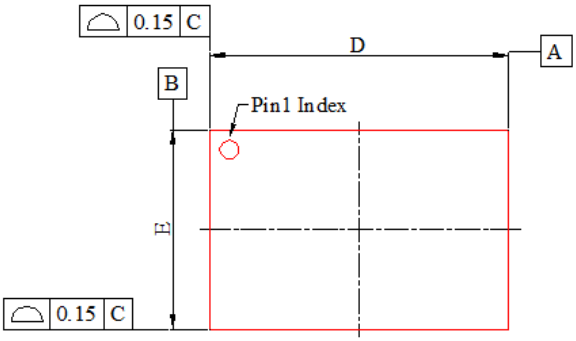
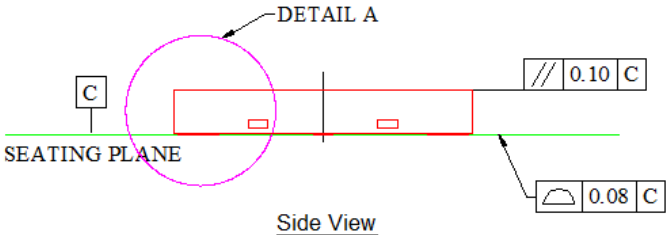
4.2 USON-8L 3x2mm, package code ZR



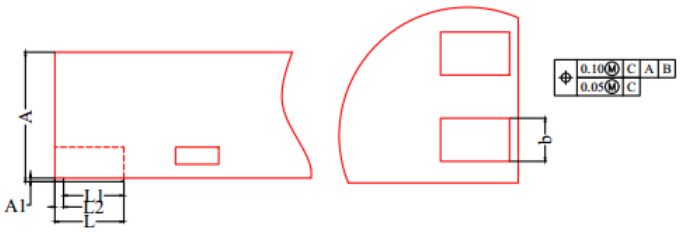
Bottom View



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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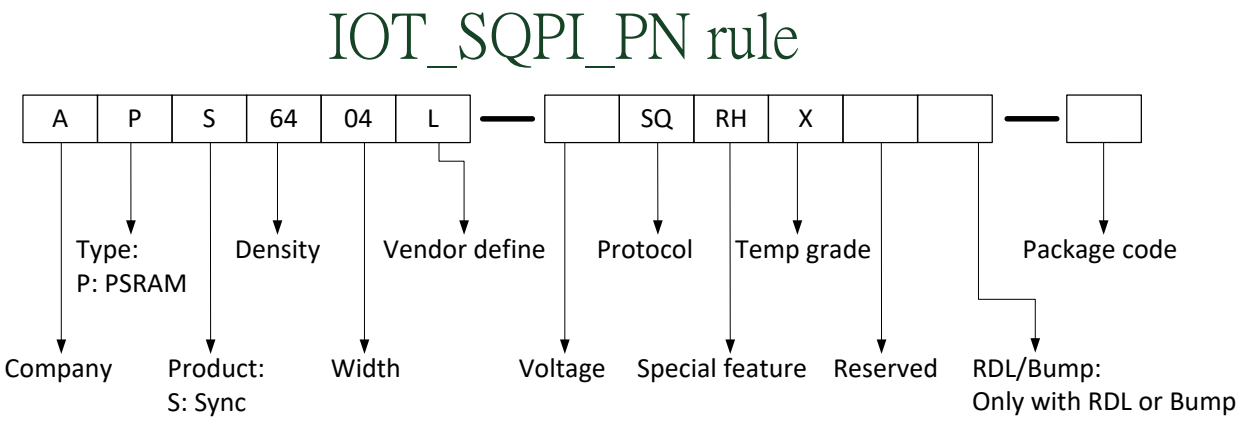
5 Ordering Information

Table 1: Ordering Information

Part Number	*Temperature Range*	*Max Frequency*	*Note*
APS6404L-SQRH	Tj = -40°C to +85°C	84 MHz	Bare die, SIP
APS6404L-SQRHX	Tj = -40°C to +105°C	84 MHz	Bare die, SIP
APS6404L-SQRH-ZR	Tc = -40°C to +85°C	84 MHz	USON-8
APS6404L-SQRH-SN	Tc = -40°C to +85°C	84 MHz	SOP-8
APS6404L-SQRHX-SN	Tc = -40°C to +105°C	84 MHz	SOP-8



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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 1.8V			
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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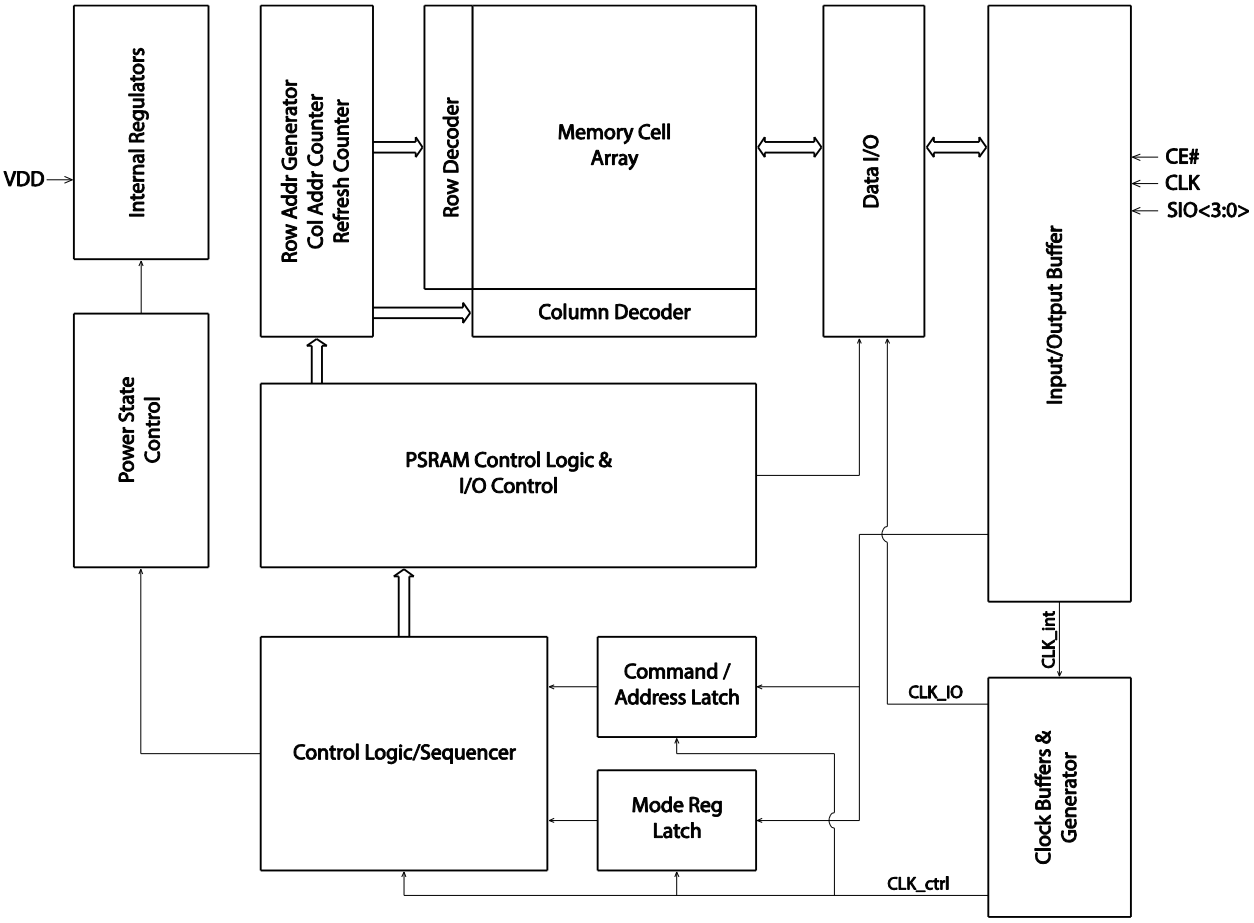
7 Block Diagram



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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 14) 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.

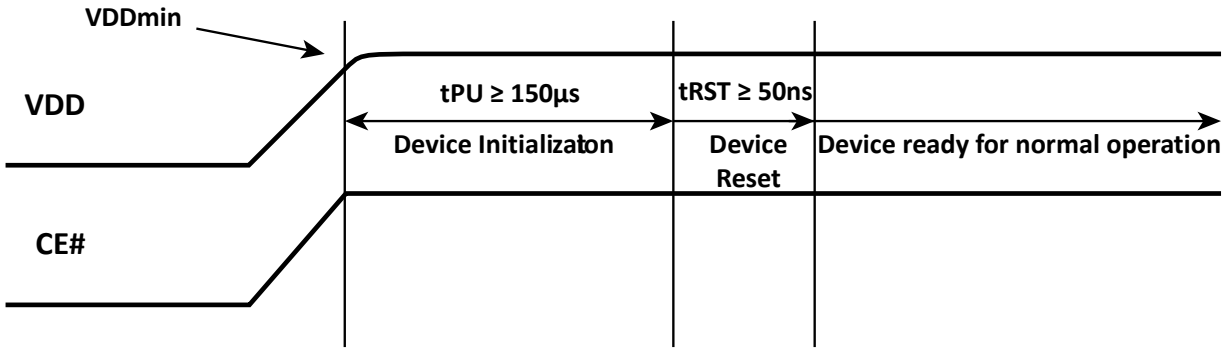

Figure 1. Power-Up Initialization Timing

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9 Interface Description

9.1 Address Space

SPI/QPI PSRAM device is byte-addressable. 64M device is addressed with A[22:0].

9.2 Page Size

Page size is 1K (CA[9:0]). The device operates in a linear bursting address sequence that crosses page boundary in a continuous manner. Note however that burst operations which cross page boundary have a lower max input clock frequency limit of 84MHz, and it can cross page boundary one time only in a burst.

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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9.5 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**	**Max Freq.**
Read	'h03	S	S	0	S	33	N/A				
Fast Read	'h0B	S	S	8	S	84	Q	Q	4	Q	66
Fast Read Quad	'hEB	S	Q	6	Q	84	Q	Q	6	Q	84
Write	'h02	S	S	0	S	84	Q	Q	0	Q	84
Quad Write	'h38	S	Q	0	Q	84	same as 'h02				
Enter Quad Mode	'h35	S	-	-	-	84	N/A				
Exit Quad Mode	'hF5	N/A					Q	-	-	-	84
Reset Enable	'h66	S	-	-	-	84	Q	-	-	-	84
Reset	'h99	S	-	-	-	84	Q	-	-	-	84
Halfsleep™ Entry	'hC0	S	-	-	-	84	Q	-	-	-	84
Read ID	'h9F	S	S	0	S	33	N/A				

Remark: S = Serial IO, Q = Quad IO

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9.6 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.

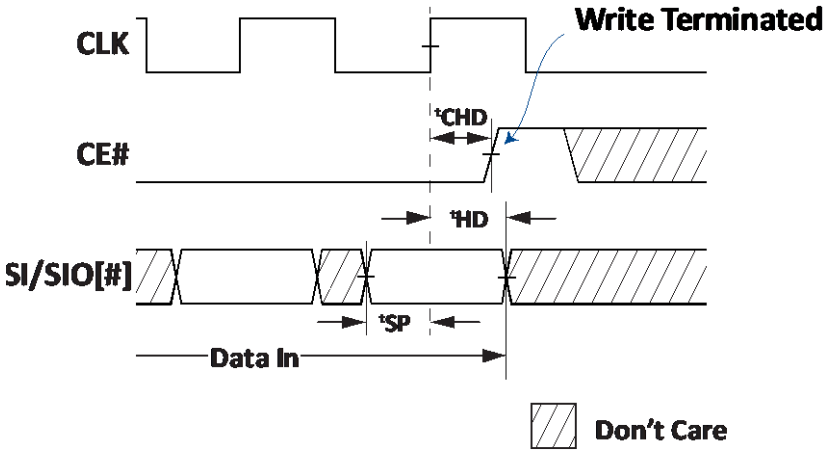

Figure 2: Write Command Termination

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.

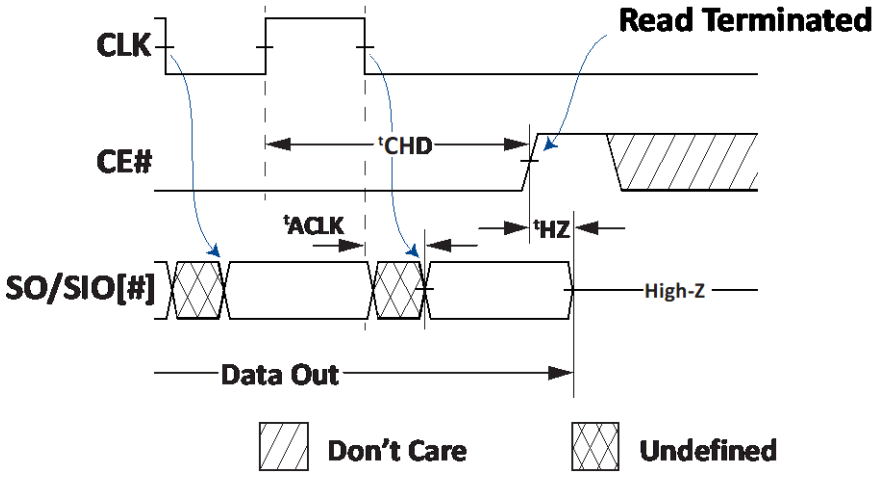

Figure 3: Read Command Termination

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10 Halfsleep™ mode Operation

Halfsleep™ Mode is a feature which puts the device in an ultra-low power state, while the stored data is retained. Halfsleep™ Mode Entry can be entered by issuing a command 'hC0 in SPI modes. CE# going high initiates the Halfsleep™ mode and must be maintained for the minimum duration of ^{t}HS. The Halfsleep™ Entry command sequences are shown below.

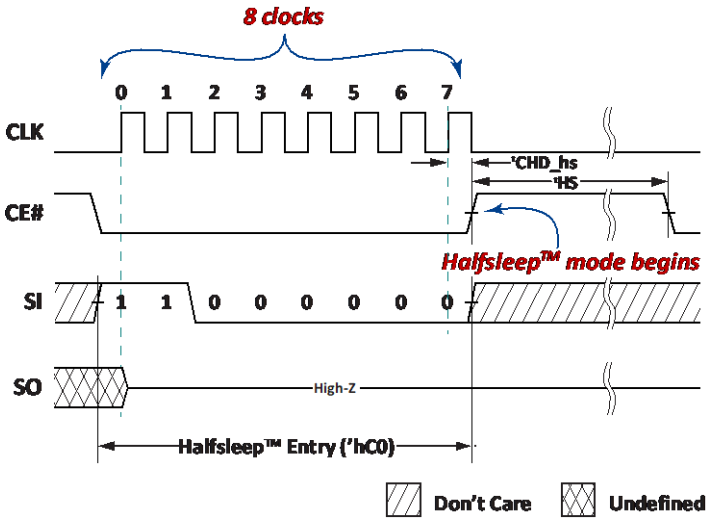

Figure 4: SPI Halfsleep™ Entry 'hC0, SPI only command.

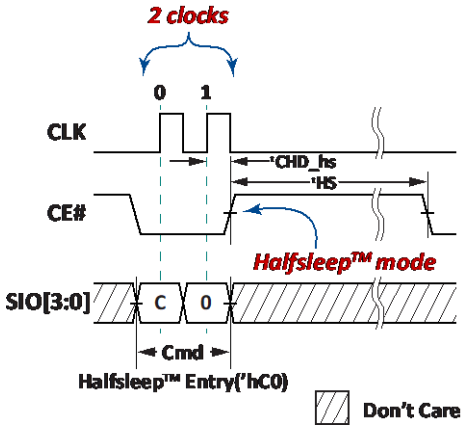

Figure 5: QPI Halfsleep™ Entry 'hC0.

Halfsleep™ Exit is initiated by a low pulsed CE#. Afterwards, CE# can be held high with or without clock toggling until the first operation begins (observing minimum tXHS).

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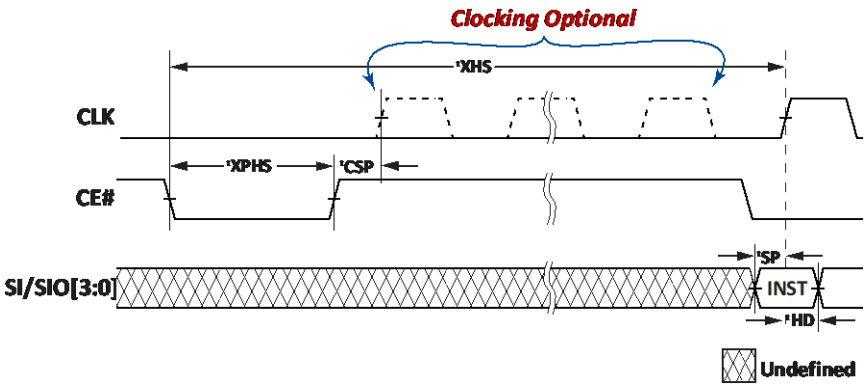

Figure 6: Halfsleep™ Exit

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11 SPI Mode Operations

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

11.1 SPI Read Operations

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

SPI Reads can be done in three ways:

1. ‘h03: Serial CMD, Serial Addr/IO, slow frequency.
2. ‘h0B: Serial CMD, Serial Addr/IO, fast frequency.
3. ‘hEB: Serial CMD, Quad Addr/IO, fast frequency.

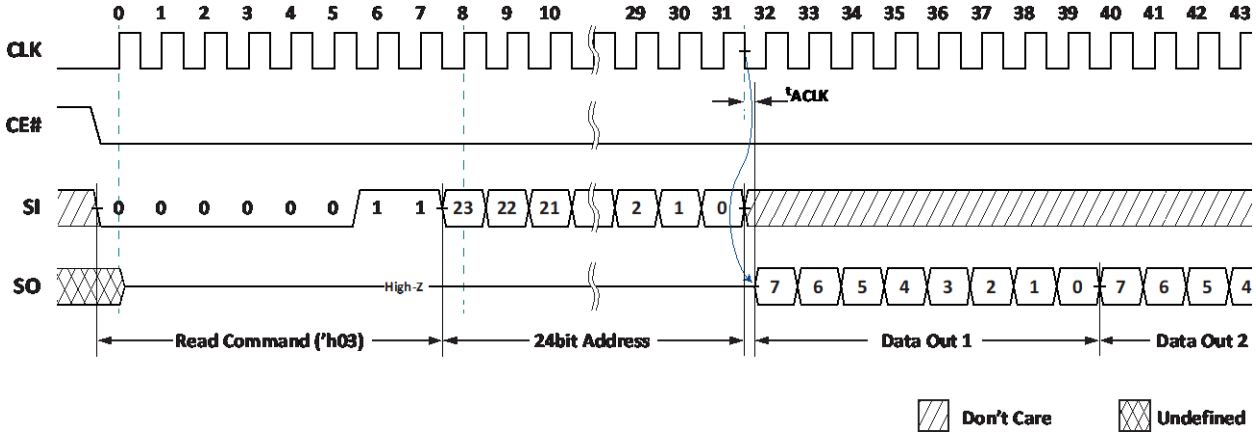

Figure 7: SPI Read ‘h03 (max freq 33MHz)

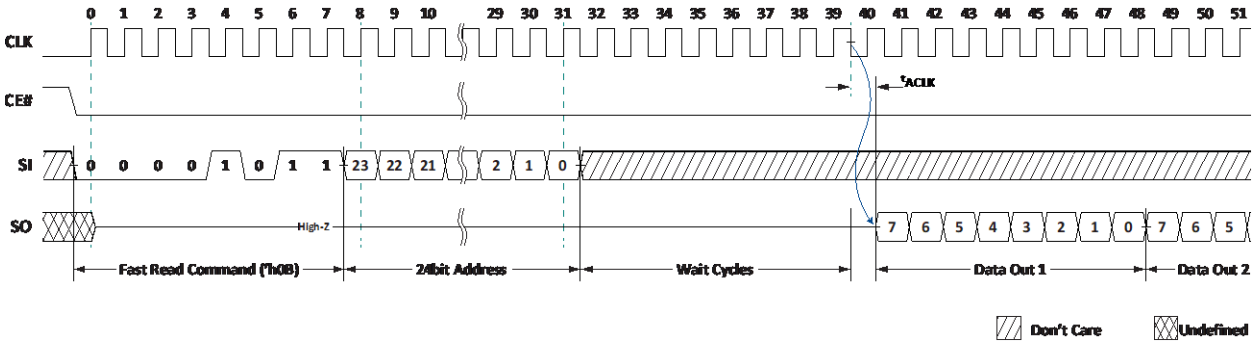

Figure 8: SPI Fast Read ‘h0B (max freq 84 MHz)

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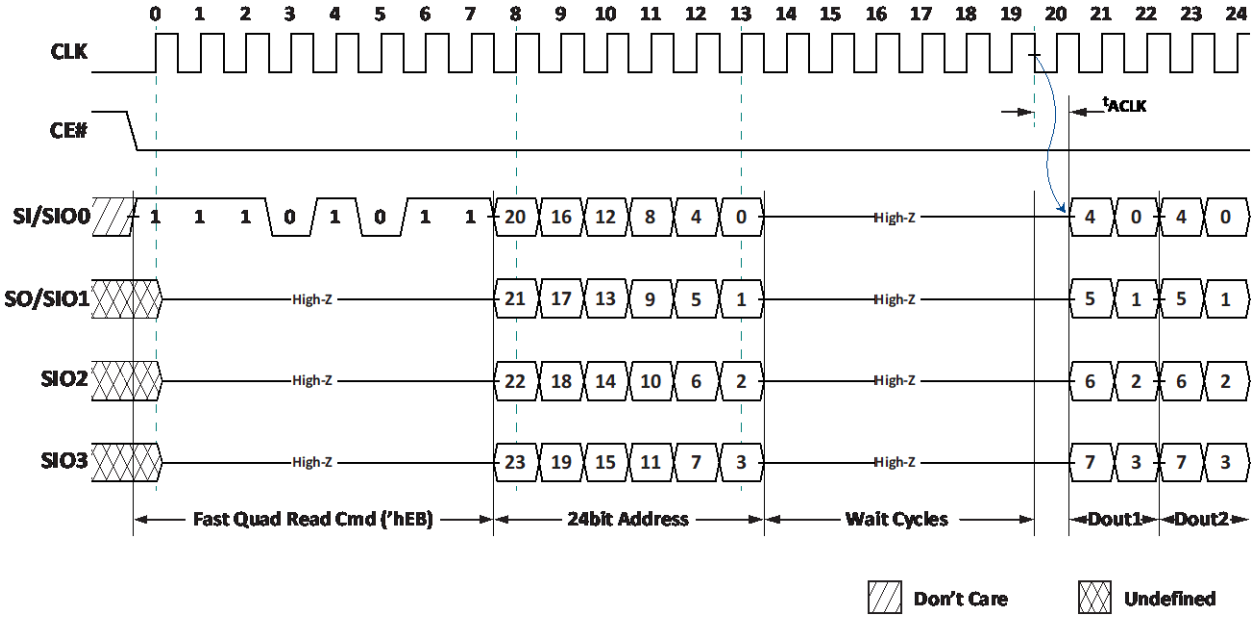

Figure 9: SPI Fast Quad Read 'hEB (max freq 84 MHz)

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11.2 SPI Write Operations

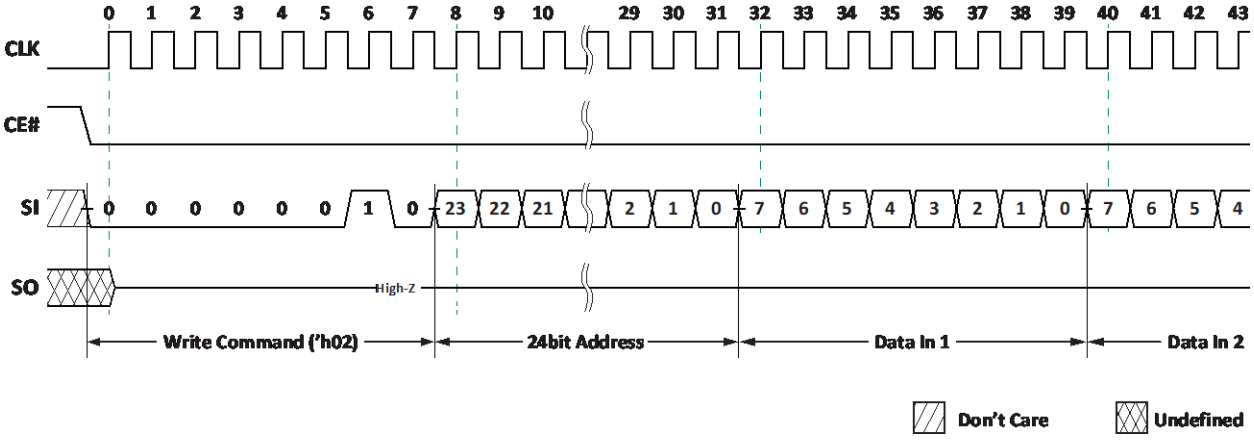

Figure 10: SPI Write 'h02

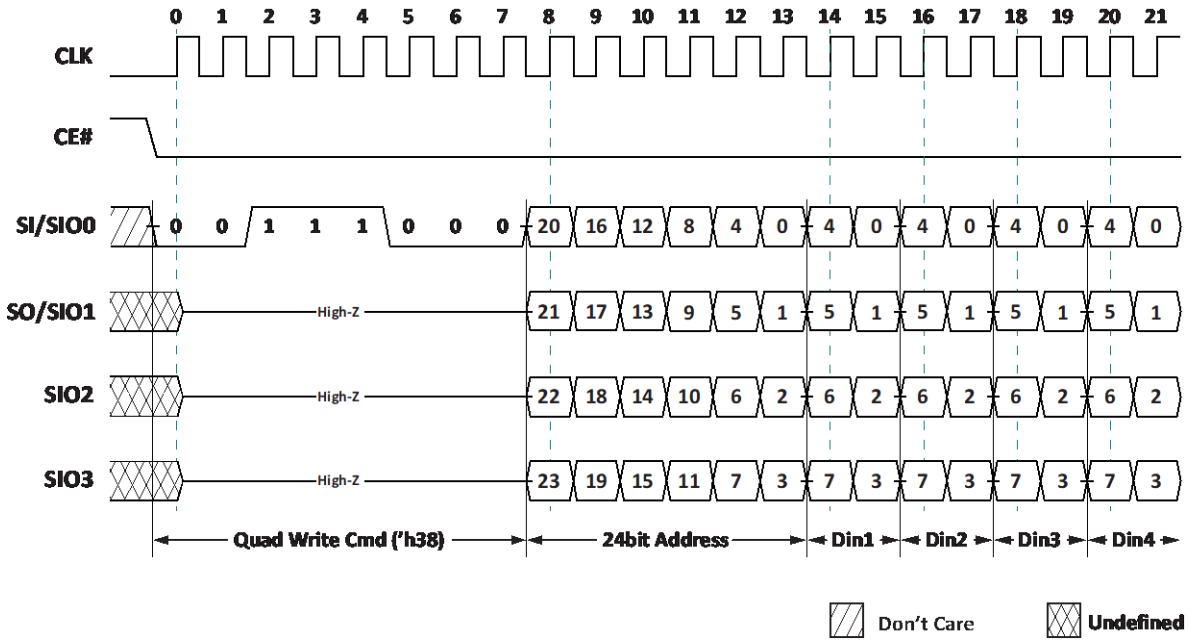

Figure 11: SPI Quad Write 'h38

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11.3 SPI Quad Mode Enable Operation

This command switches the device into quad IO mode.

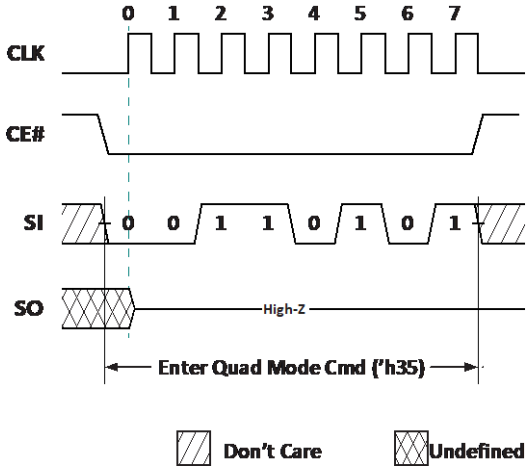

Figure 12: Quad Mode Enable 'h35 (available only in SPI mode)

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12 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 13: Pre-condition of EID Read

12.1 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.

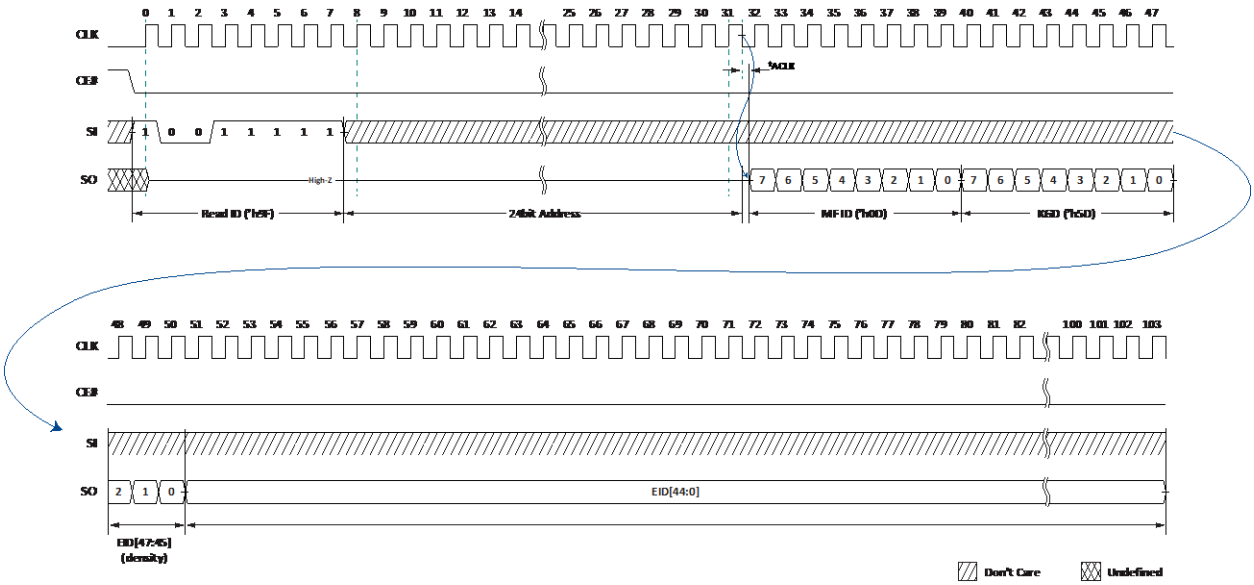

Figure 14: SPI Read ID 'h9F (available only in SPI mode)

Table 3: Known Good Die (KGD)

KGD[7:0]	*Known Good Die*
'b0101_0101	FAIL
'b0101_1101	PASS

*Note: Default is FAIL die, and only marked PASS after all tests passed.

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13 QPI Mode Operations

13.1 QPI Read Operation

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

QPI Reads can be done in one of two ways:

1. ‘h0B: Quad CMD, Quad Addr/IO, slow frequency
2. ‘hEB: Quad CMD, Quad Addr/IO, fast frequency

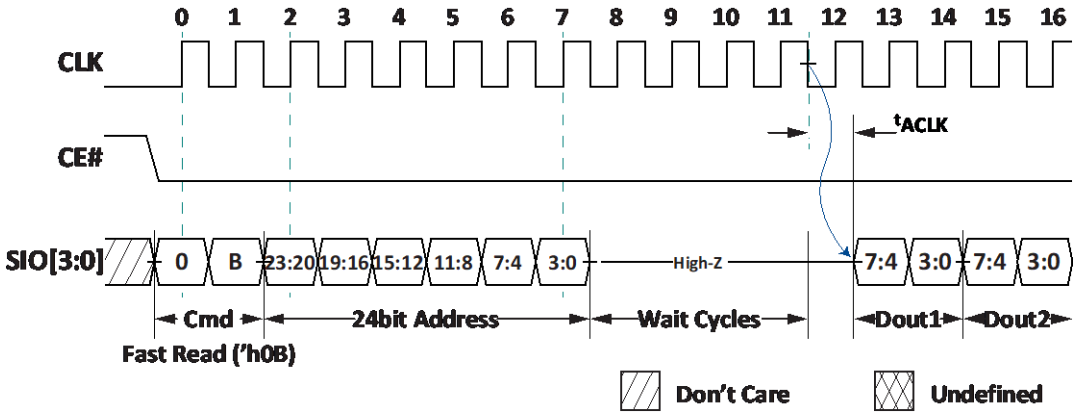

Figure 15: QPI Fast Read ‘h0B (max freq 66 MHz)

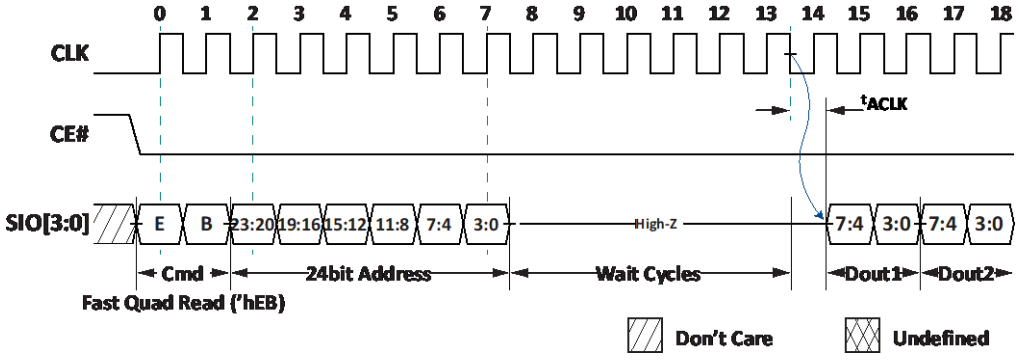

Figure 16: QPI Fast Quad Read ‘hEB (max freq 84 MHz)

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13.2 QPI Write Operation(s)

QPI write command can be input as ‘h02 or ‘h38.

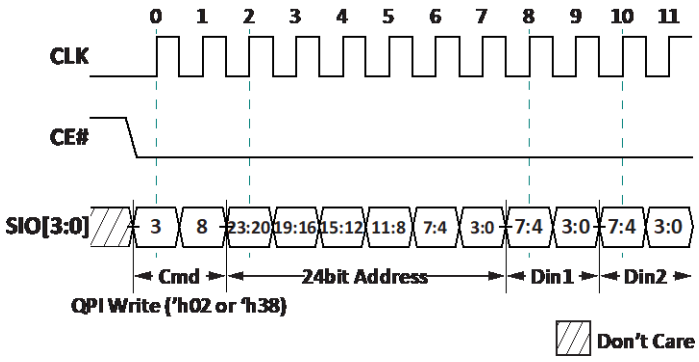

Figure 17: QPI Write ‘h02 or ‘h38

13.3 QPI Quad Mode Exit operation

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

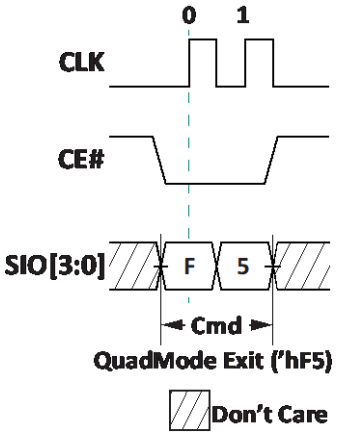

Figure 18: Quad Mode Exit ‘hF5 (only available in QPI mode)

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14 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).

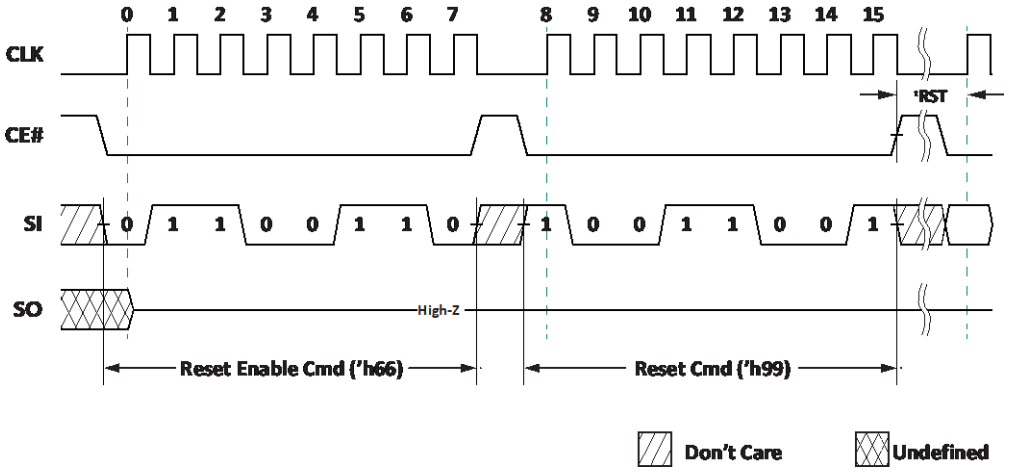

Figure 19: SPI Reset

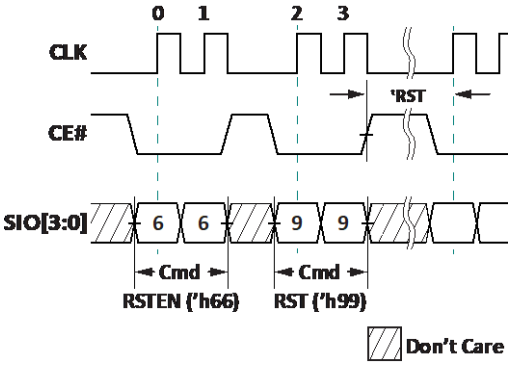

Figure 20: QPI Reset

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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15 Input/Output Timing

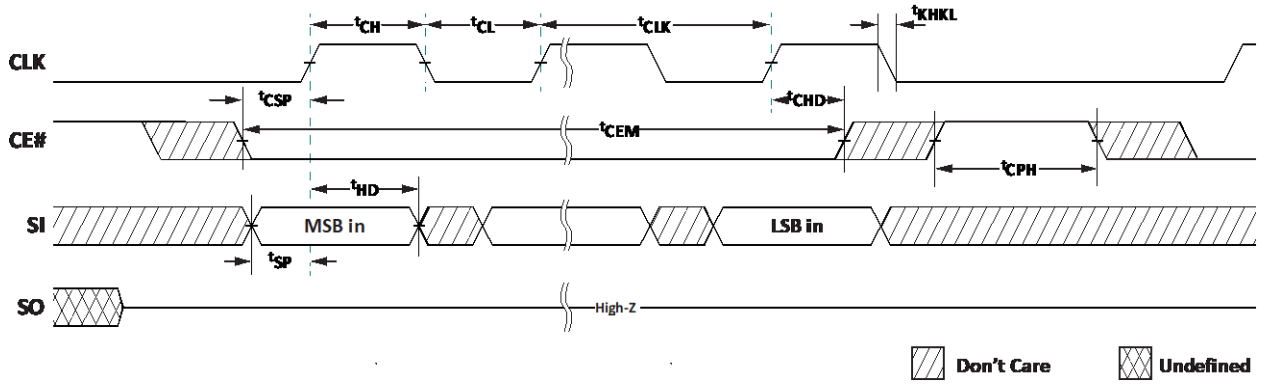

Figure 21: Input Timing

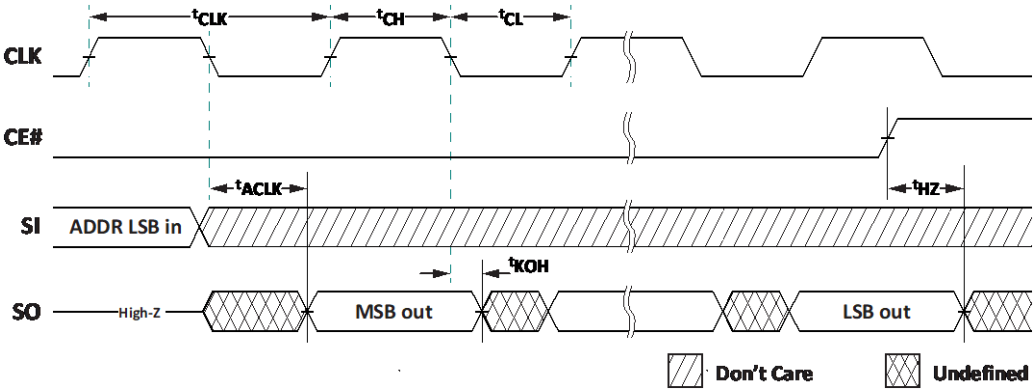

Figure 22: Output Timing

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16 Electrical Specifications:

16.1 Absolute Maximum Ratings

Table 4: 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 +2.45	V	
Storage Temperature	T_{STG}	-55 to +150	°C	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.

16.2 Pin Capacitance

Table 5: 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 6: 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 7: 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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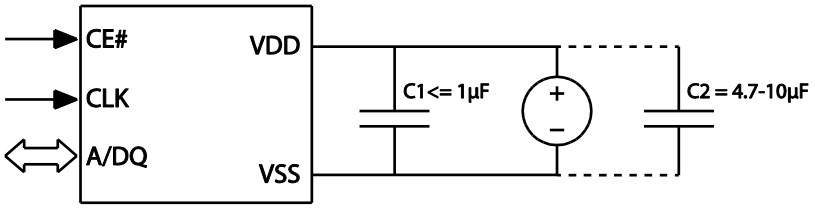
16.3 Decoupling Capacitor Requirement

System designers need to take care of power integrity considering voltage regulator response and the memory peak currents/usage modes.



16.3.1 Low ESR cap C1:

It is recommended to place a low ESR decoupling capacitor of <=1µF close to the device to absorb transient peaks.

16.3.2 Large cap C2:

During Half-sleep modes even though half-sleep average currents are very small (less than 100µA), device will internally have low duty cycle burst refresh for an extended period of time of a few tens of microseconds. These refresh current peaks are large. During this period if the system regulator cannot supply large peaks for several microseconds, it is important to place a 4.7µF-10µF cap to take care of burst refresh currents and replenish the charge before next burst of refreshes.

16.4 Operating Conditions

Table 8: Operating Characteristics

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

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16.5 DC Characteristics

Table 9: DC Characteristics

Symbol	*Parameter*	*Min*	*Max*	*Unit*	*Notes*
V_{DD}	Supply Voltage	1.62	1.98	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		7	mA	1,2
ISB_{EXT}	Standby current (105C)		300	µA	3
ISB_{STD}	Standby current (85C)		200	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 $ISB_{STDROOM}$ is 66uA.

5: Typical ISB_{STD_HS} is 20uA.

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16.6 AC Characteristics

Table 10: 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	7			84MHz*1,2
^{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	3
^{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	2
^{t}CHD_HS	CE# hold time from CLK rising edge for Halfsleep™ Entry command	6		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}HS	Minimum Half Sleep duration	150		us	
^{t}XHS	Halfsleep™ Exit CE# low to CLK setup time	150		us	
^{t}XPHS	Halfsleep™ Exit CE# low pulse width	60		ns	
			tCEM	us	Standard temp
				us	Extended temp
^{t}RST	Time between end of RST CMD to next	50		ns	

Note 1: Frequency limits are therefore:

84MHz max when burst commands cross page boundary

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

3: Measured from 20% to 80% of VDD

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17 Change Log

Version	Who	Date	Description
0.1		Dec 23, 2016	Initial Version
1.0		Mar 01, 2017	updated max frequency & standby current #
2.0		May 19, 2017	Reworded linear burst, renamed page toggle cmds; updated timing parameters for 144MHz; removed QPI Read 'h0B support; clarified termination section; added pin cap tables
2.1		Jul 10, 2017	Updated tCPH to 18ns
2.2		Jul 25, 2017	Updated tHZ, tACLK, package code and ordering information
2.3		Aug 24, 2017	Corrected package code; Added system max C_L for the use of package & related tCK and tCHD
2.5		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 ISBstdroom & USON package ZR, ISBstd@25C
2.6		Nov 13, 2017	Modified spec of ICC, ISB
2.7		Feb 1, 2018	Added Half Sleep support
2.8		Mar 8, 2018	changed tCLK requirement for Half Sleep command, added tCHD_hs spec
3.0		June 14, 2018	Revised part # for RBX. Temperature -40C, added WLCSP code "RA"
3.1		Aug 20, 2018	Revised WLCSP code "RA", max frequency for Read ID command, removed WSON
3.2		Nov 29, 2018	Revised POD of USON, code "ZR"
3.21		Mar 11, 2019	Removed 133MHz, modified ordering information and C Load
3.22		Mar 25, 2019	Removed HS entry of QPI mode
3.23		Jun 05, 2019	Updated tXHS spec
3.3		Sep 06, 2019	Updated Figure 12 and Table 9; Added table for Change Log; Noted in section 9.2; updated section 9.5 and 16.6; added section 16.3
3.4a		Oct 02, 2019	Updated header, page 1 and Table 1
3.5		Oct 30, 2019	Revised the typo in page 14, 16 and 21; updated Table 9 and Table 10, Figure 19 and Figure 20
3.6		Nov 21, 2019	Update Table 2, Figure 11 and Figure 17
3.7		Jan 09, 2021	Updated POD of USON-8L: marked pin numbers
3.8		Oct 08, 2021	Revised tCEM value from 4us to 3us @105C
3.9	Kim/ Gene/Eric	Jun 17, 2022	Typos correct

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4.0	Kim	Aug 17, 2022	Revise SPI read waveform and modified command truth table for QPI could let Halfsleep™ entry
4.1	Kim	Oct 28, 2022	Release USON temp. from -25~85 to -40~85

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