



Industrial eMMC 5.1 Specification

(AXO Series, 3D TLC, 100ball)

V1.1

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1. GENERAL DESCRIPTION



1.1. Introduction

FLEXXON's AXO eMMC is fully comply with JEDEC eMMC5.1 Standard. It is combine of an embedded flash controller and standard 3D TLC NAND flash memory in one JEDEC standard package, 100Balls (14.0mm x 18.0mm).

FLEXXON eMMC provides high performance, good reliability and advanced power management. It is suitable for small, low power electronic devices.

1.2. Product Overview

FLEXXON AXO eMMC 5.1 includes the following features:

- Compliant with eMMC Specification Ver. 5.1
- Package of eMMC
 - 14.0 mm x 18.0 mm x 1.4 mm
- Temperature Range
 - Operation & Storage (Gold Grade): -25°C ~ 85°C
 - Operation & Storage (Diamond Grade): -40°C ~ 85°C
- Operating Voltage
 - VCC: 3.3V
 - VCCQ: 1.8V/3.3V
- Bus Mode
 - High-speed eMMC protocol
 - Clock frequency: 0 ~ 200MHz
- Supports three data bus widths: 1 bit (default), 4 bits, 8 bits
- Supports High Speed Mode HS400
- Supports Production State Awareness
- Supports Field Firmware Update
- RoHS compliant

2. PRODUCT SPECIFICATIONS



2.1. Performance

Table 2-1 eMMC Performance

Density	Sequential Read (MB/s)	Sequential Write (MB/s)
64GB	280	120
128GB	300	200
256GB	300	200
512GB	300	200

Notes:

1. 8-bit bus width; HS400 mode; $V_{cc} = 3.3V$, $V_{ccQ} = 1.8V$
2. Performance may differ according to flash configuration and platform.

2.2. Power Consumption

Table 2-2 eMMC Power Consumption

Capacity	Read (mA)		Write (mA)		Standby (mA)
	V_{ccQ}	V_{cc}	V_{ccQ}	V_{cc}	
64GB	110	90	95	90	0.5
128GB	175	110	100	115	0.5
256GB	175	115	110	115	0.5
512GB	175	115	110	115	0.5

Notes:

1. 8-bit bus width; clock frequency of 200MHz DDR mode; $V_{cc} = 3.3V$, $V_{ccQ} = 1.8V$
2. Standby current is measured at $V_{cc} = 3.3V$, 8-bit bus width without clock frequency.

3. INTERFACE DESCRIPTION



3.1. FLEXXON eMMC I/F Ball Array

	1	2	3	4	5	6	7	8	9	10	
A	NC	NC							NC	NC	A
B	NC									NC	B
C											C
D		RFU	RFU	RFU	RFU	RFU	RFU	NC	RFU		D
E		RFU	RFU	VDDI	RFU	RFU	RFU	RFU	RFU		E
F		VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		F
G		GND	GND	GND	GND	GND	GND	GND	GND		G
H		GND	VCCQ	RFU	RFU	RFU	RFU	VCCQ	GND		H
J		RFU	RFU	RFU	RFU/GND	RFU	RFU	RFU	RFU		J
K		DAT0	DAT2	RFU	RFU/DS	RFU	RFU	DAT5	DAT7		K
L		VCCQ	GND	VCCQ	RFU	RFU	VCCQ	GND	VCCQ		L
M		RFU	RFU	GND	RST_n	RFU	GND	RFU	RFU		M
N		DAT1	DAT3	RFU	RFU	RFU	RFU	DAT4	DAT6		N
P		GND	VCCQ	RFU	CMD	CLK	RFU	VCCQ	GND		P
R											R
T	NC									NC	T
U	NC	NC							NC	NC	U
	1	2	3	4	5	6	7	8	9	10	

Figure 3-1 eMMC interface in 100Balls Array (Top View)

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3.2. Pins and Signal Description

Table 3-1 Function Pin Assignment, 100 balls

eMMC Interface			
Ball No.	Ball Signal	Type	Description
K2	DAT0	I/O/PP	Data I/O: Bidirectional channel used for data transfer
N2	DAT1		
K3	DAT2		
N3	DAT3		
N8	DAT4		
K8	DAT5		
N9	DAT6		
K9	DAT7		
P5	CMD	I/O/PP	Command: A bidirectional channel used for device initialization and command transfers.
P6	CLK	Input	Clock: Each cycle directs a 1-bit transfer on the command and DAT lines
M5	RST_n	Input	Hardware Reset
F2	VCC	Supply	Supply Voltage for Core
F3	VCC		
F4	VCC		
F5	VCC		
F6	VCC		
F7	VCC		
F8	VCC		
F9	VCC		
H3	VCCQ	Supply	Supply Voltage for I/O
H8	VCCQ		
L2	VCCQ		
L4	VCCQ		
L7	VCCQ		
L9	VCCQ		
P3	VCCQ		
P8	VCCQ		
K5	DS	O/PP	Data strobe

4. EMMC REGISTERS



4.1. OCR Register

The 32-bit Operation Conditions Register (OCR) stores the VDD voltage profile of the Device and the access mode indication. The OCR register should be implemented by all Device.

Table 4-1 OCR Register Table

OCR slice	Description	Value	Width
[31]	Card power up status bit (busy) ¹		
[30:29]	Access mode	00b (byte mode) 10b (sector mode)	2
[28:24]	Reserved	0 0000b	5
[23:15]	2.7 – 3.6V	1 1111 1111b	9
[14:8]	2.0 – 2.6V	000 0000b	7
[7]	1.7 – 1.95V	1b	1
[6:0]	Reserved	000 0000b	7

Note ¹: This bit is set to Low if the Device has not finished the power up routine

4.2. CID Register

The Card Identification (CID) register is 128 bits wide. It contains the Device identification information used during the Device identification phase. For details, refer to JEDEC Standard Specification No. JESD84-B51.

Table 4-2 CID Register Table

Name	Field	CID Slice	Value	Width
Manufacturer ID	MID	[127:120]	Ebh	8
Reserved	-	[119:114]	0h	6
Device/BGA	CBX	[113:112]	1h	2
OEM/ Application ID	OID	[111:104]	0Dh	8
Product Name	PNM	[103:56]	eMMC	48
Product Revision	PRV	[55:48]	51h	8
Product Serial Number	PSN	[47:16]	Random by Production	32
Manufacturing Date	MDT	[15:8]	Month, Year	8
CRC7 Checksum	CRC	[7:1]	-	7
Not used, always "1"	-	[0:0]	1h	1

4.3. CSD Register

The Device-Specific Data (CSD) register provides information on how to access the contents. The CSD defines the data format, error correction type, maximum data access time, data transfer speed, etc. For details, refer to JEDEC Standard Specification No. JESD84-B51.

Table 4-3 CSD Register Table

Name	Field	Width	Type	CSD Slice	Value
CSD structure	CSD_STRUCTURE	2	R	[127:126]	3h
System specification version	SPEC_VERS	4	R	[125:122]	4h
Reserved	-	2	R	[121:120]	0h
Data read access-time 1	TAAC	8	R	[119:112]	27h
Data read access-time 2 in CLK cycles (NSAC*100)	NSAC	8	R	[111:104]	1h
Max. bus clock frequency	TRAN_SPEED	8	R	[103:96]	32h
Device command classes	CCC	12	R	[95:84]	0F5h
Max. read data block length	READ_BL_LEN	4	R	[83:80]	9h
Partial blocks for read allowed	READ_BL_PARTIAL	1	R	[79:79]	0h
Write block misalignment	WRITE_BLK_MISALIGN	1	R	[78:78]	0h
Read block misalignment	READ_BLK_MISALIGN	1	R	[77:77]	0h
DSR implemented	DSR_IMP	1	R	[76:76]	0h
Reserved	-	2	R	[75:74]	0h
Device size	C_SIZE	12	R	[73:62]	FFFh
Max. read current @ VDD min	VDD_R_CURR_MIN	3	R	[61:59]	7h
Max. read current @ VDD max	VDD_R_CURR_MAX	3	R	[58:56]	7h
Max. write current @ VDD min	VDD_W_CURR_MIN	3	R	[55:53]	7h
Max. write current @ VDD max	VDD_W_CURR_MAX	3	R	[52:50]	7h
Device size multiplier	C_SIZE_MULT	3	R	[49:47]	7h
Erase group size	ERASE_GRP_SIZE	5	R	[46:42]	1Fh
Erase group size multiplier	ERASE_GRP_MULT	5	R	[41:37]	1Fh
Write protect group size	WP_GRP_SIZE	5	R	[36:32]	64GB:0Fh 128~512GB: 1Fh
Write protect group enable	WP_GRP_ENABLE	1	R	[31:31]	1h
Manufacturer default ECC	DEFAULT_ECC	2	R	[30:29]	0h
Write speed factor	R2W_FACTOR	3	R	[28:26]	2h
Max. write data block length	WRITE_BL_LEN	4	R	[25:22]	9h
Partial blocks for write allowed	WRITE_BL_PARTIAL	1	R	[21:21]	0h
Reserved	-	4	R	[20:17]	0h
Content protection application	CONTENT_PROT_APP	1	R	[16:16]	0h
File format group	FILE_FORMAT_GRP	1	R/W	[15:15]	0h
Copy flag (OTP)	COPY	1	R/W	[14:14]	1h
Permanent write protection	PERM_WRITE_PROTECT	1	R/W	[13:13]	0h
Temporary write protection	TMP_WRITE_PROTECT	1	R/W/E	[12:12]	0h
File format	FILE_FORMAT	2	R/W	[11:10]	0h
ECC code	ECC	2	R/W/E	[9:8]	0h

CRC	CRC	7	R/W/E	[7:1]	-
Not used, always '1'	-	1	-	[0:0]	1h

4.4. Extended CSD Register

The Extended CSD register defines the Device properties and selected modes. It is 512 bytes long. The most significant 320 bytes are the Properties segment, which defines the Device capabilities and cannot be modified by the host. The lower 192 bytes are the Modes segment, which defines the configuration the Device is working in. These modes can be changed by the host by means of the SWITCH command. For details, refer to JEDEC Standard Specification No. JESD84-B51.

4.5. RCA Register

The writable 16-bit Relative Device Address (RCA) register carries the Device address assigned by the host during the Device identification. This address is used for the addressed host-Device communication after the Device identification procedure. The default value of the RCA register is 0x0001. The value 0x0000 is reserved to set all Devices into the *Stand-by State* with CMD7.

4.6. DSR Register

The 16-bit driver stage register (DSR) is described in detail in JEDEC Standard Specification, JESD84-B51 Section 7.6. It can be optionally used to improve the bus performance for extended operating conditions (depending on parameters like bus length, transfer rate or number of Devices). The CSD register carries the information about the DSR register usage. The default value of the DSR register is 0x404.

5. ELECTRICAL CHARACTERISTICS



5.1. Power Supply

Table 5-1 eMMC power supply

Parameter	Symbol	Min	Max	Unit
Supply voltage (NAND)	Vcc	2.7	3.6	V
Supply voltage (I/O)	Vccq	2.7	3.6	V
		1.7	1.95	V
Supply Power-Up for 1.8V	tPRUL		25	ms
Supply Power-Up for 3.3V	tPRUH		35	Ms

5.2. Bus Signal Levels

Figure 5-1 Bus Signal Levels

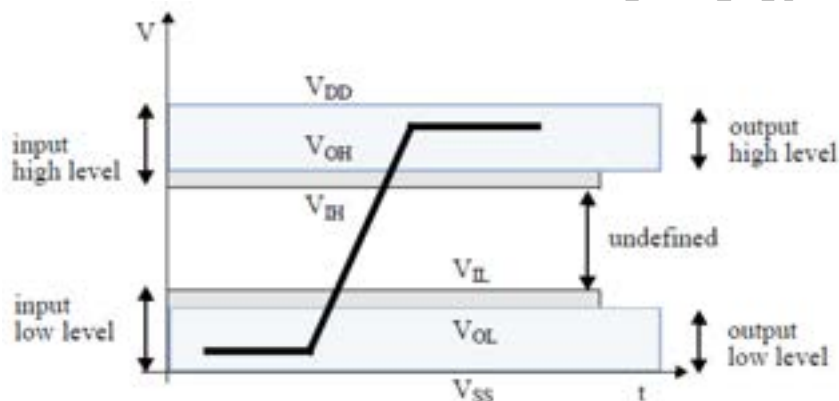
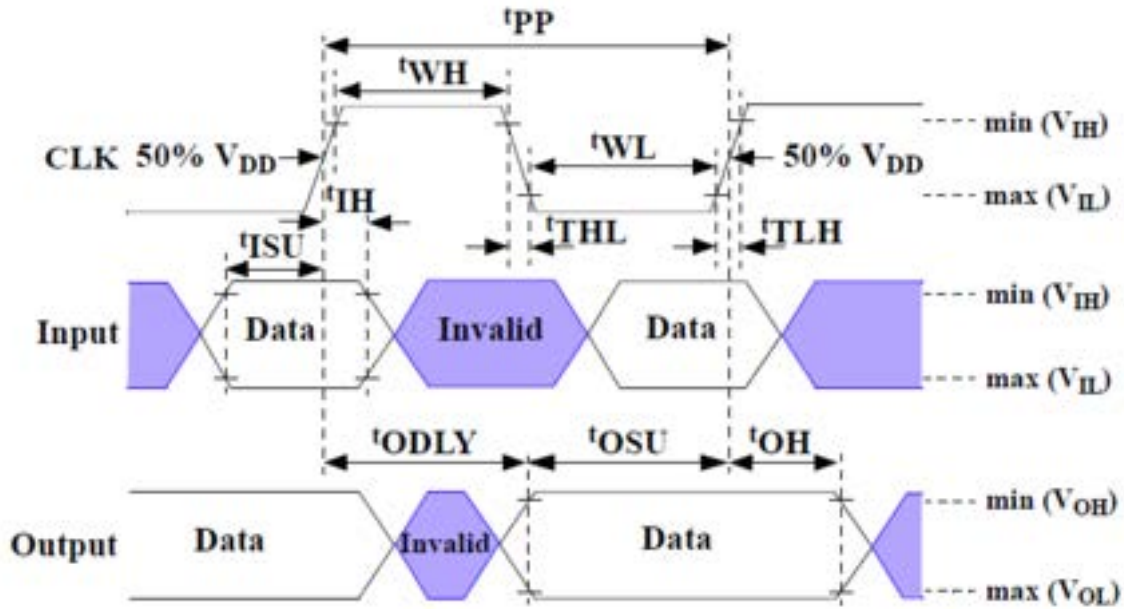


Table 5-2 Bus Signals Levels

Parameter	Symbol	Min	Max	Unit	Remark
Open-Drain Bus Signal Level					
Output High Voltage	VOH	VDD - 0.2	-	V	IOH = -100 uA
Output Low Voltage	VOL	-	0.3	V	IOL = 2 mA
Push-pull bus signal level (2.7V~3.6V)					
Output High Voltage	VOH	0.75 * VCCQ	-	V	IOH = -100 uA @ Vccq min
Output Low Voltage	VOL	-	0.125 * VCCQ	V	IOL = 100 uA @ Vccq min
Input High Voltage	VIH	0.625 * VCCQ	VCCQ + 0.3	V	
Input Low Voltage	VIL	VSS - 0.3	0.25 * VCCQ	V	
Push-pull bus signal level (1.7V~1.95V)					
Output High Voltage	VOH	VCCQ - 0.45V	-	V	IOH = -2 mA
Output Low Voltage	VOL	-	0.45V	V	IOL = 2 mA
Input High Voltage	VIH	0.65 * VCCQ	VCCQ + 0.3	V	
Input Low Voltage	VIL	VSS - 0.3	0.35 * VDD	V	

5.3. Bus Timing

Figure 5-2 Bus Timing in Single Data Rate Mode



Data must always be sampled on the rising edge of the clock.

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Table 5-3 High Speed Device Interface Timing

Parameter	Symbol	Min	Max	Unit	Remark
Clock CLK¹					
Clock Frequency Data Transfer Mode (PP) ²	f _{PP}	0	52 ³	MHz	CL ≤30 pF Tolerance:+ 100 KHz
Clock Frequency Identification Mode (OD)	f _{OD}	0	400	kHz	Tolerance: +20 KHz
Clock high time	t _{WH}	6.5	-	ns	CL ≤30 pF
Clock low time	t _{WL}	6.5	-	ns	CL ≤30 pF
Clock rise time ⁴	t _{TLH}	-	3	ns	CL ≤30 pF
Clock fall time	t _{THL}	-	3	ns	CL ≤30 pF
Inputs /Outputs CMD, DAT (Referenced to CLK)					
Input set-up time	t _{ISU}	3	-	ns	CL ≤30 pF
Input hold time	t _{IH}	3	-	ns	CL ≤30 pF
Output delay time during data transfer	t _{ODLY}	-	13.7	ns	CL ≤30 pF
Output hold time	t _{OH}	2.5	-	ns	CL ≤30 pF
Signal rise time ⁵	t _{RISE}	-	3	ns	CL ≤30 pF

Note ¹: CLK timing is measured at 50% of VDD.
 Note ²: eMMC shall support the full frequency range from 0-26Mhz, or 0-52MHz
 Note ³: Device can operate as high-speed Device interface timing at 26 MHz clock frequency.
 Note ⁴: CLK rise and fall times are measured by min (VIH) and max (VIL).
 Note ⁵: Inputs CMD, DAT rise and fall times are measured by min (VIH) and max (VIL), and output CMD, DAT rise and fall times are measured by min (VOH) and max (VOL).

Figure 5-3 Bus Timing in Dual Data Rate Mode

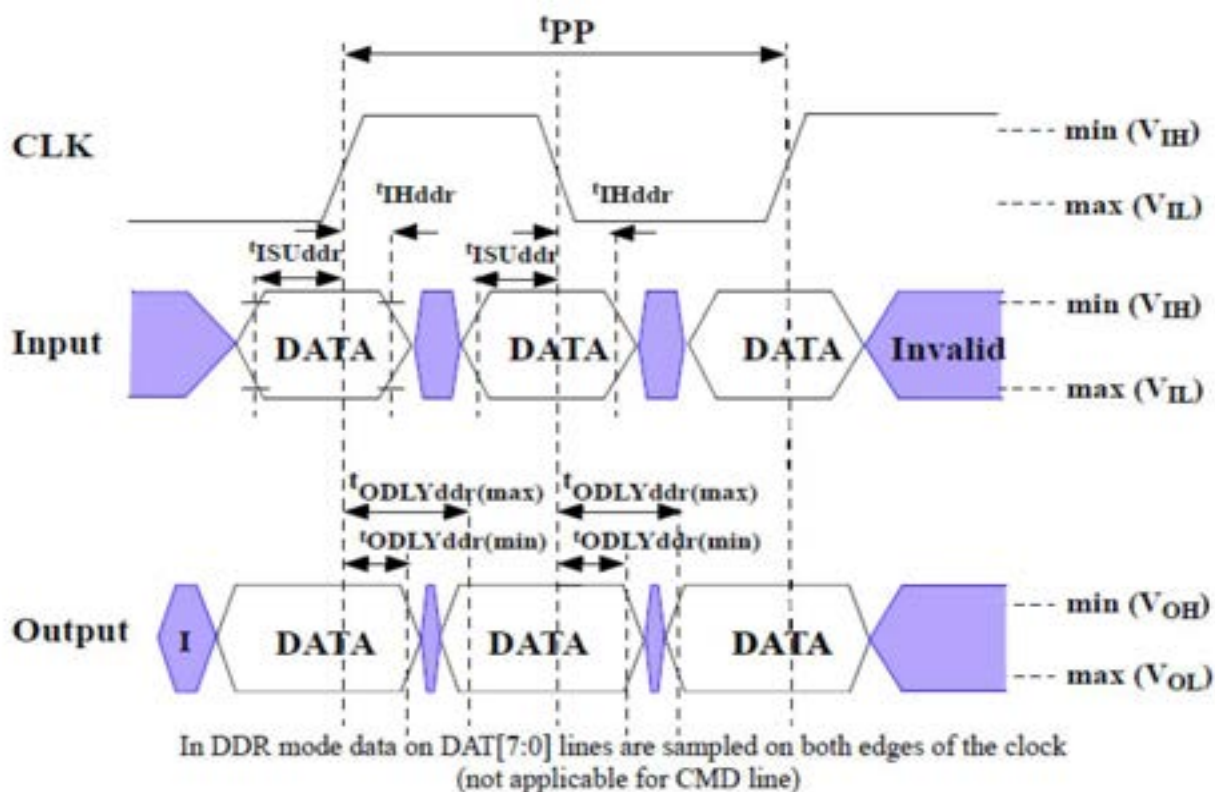
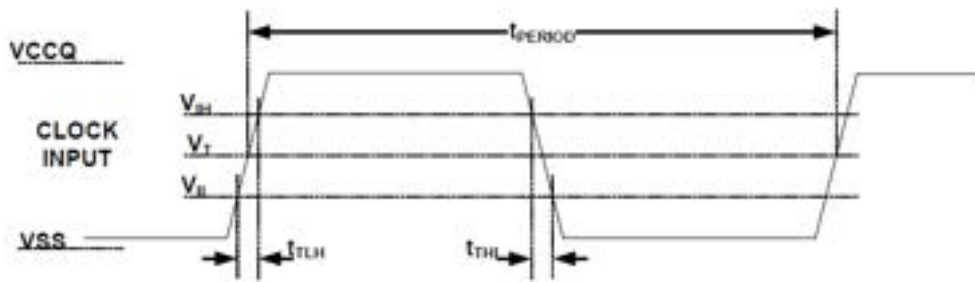


Table 5-4 Dual Data Rate Interface Timing

Parameter	Symbol	Min	Max	Unit	Remark
Input CLK¹					
Clock Duty Cycle	-	45	55	%	Include jitter, phase noise
Input/Output DAT (Referenced to CLK-DDR Mode)					
Input set-up time	tISUddr	2.5	-	ns	CL ≤20 pF
Input hold time	tIHddr	2.5	-	ns	CL ≤20 pF
Output delay time	tODLYddr	1.5	7	ns	CL ≤20 pF
Signal rise time (DAT0-7) ²	tRISE	-	2	ns	CL ≤20 pF
Signal fall time (DAT0-7)	tFALL	-	2	ns	CL ≤20 pF

Note ¹: CLK timing is measured at 50% of VDD.
 Note ²: Inputs DAT rise and fall times are measured by min (VIH) and max (VIL), and outputs DAT rise and fall times are measured by min (VOH) and max (VOL).

Figure 5-4 HS200 Clock Signal Timing



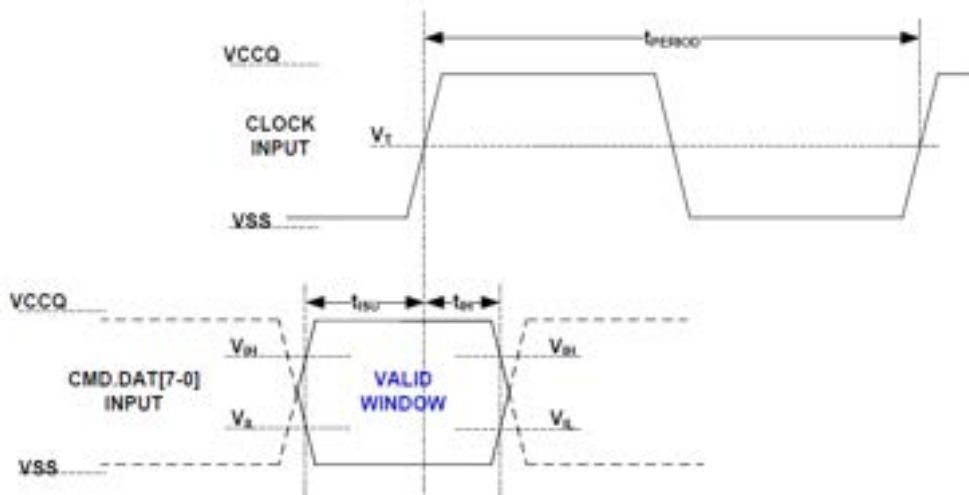
Notes:

1. VIH denote VIH(min.) and VIL denotes VIL(max.).
2. VT=0.975V – Clock Threshold, indicates clock reference point for timing measurements.

Table 5-3 HS200 Clock Signal Timing

Symbol	Min	Max	Unit	Remark
tPERIOD	5	-	ns	200MHz (Max.), between rising edges
tTLH, tTHL	-	0.2* tPERIOD	ns	tTLH, tTHL < 1ns (max.) at 200MHz, CDEVICE=6pF, The absolute maximum value of tTLH, tTHL is 10ns regardless of clock frequency.
Duty Cycle	30	70	%	

Figure 5-5 HS200 Device Input Timing



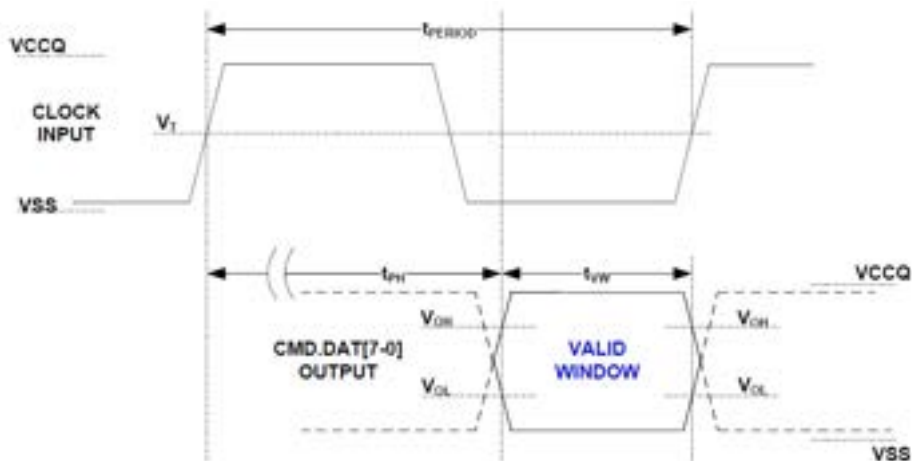
Note 1: t_{SU} and t_{H} are measured at V_{IL} (max) and V_{IH} (min).

Note 2: V_{IH} denote V_{IH} (min) and V_{IL} (max) denotes V_{IL} (max).

Table 5-6 HS200 Device Input Timing

Symbol	Min	Max	Unit	Remark
t_{SU}	1.40	-	ns	$C_{DEVICE} \leq 6pF$
t_{H}	0.8	-	ns	$C_{DEVICE} \leq 6pF$

Figure 5-6 HS200 Device Output Timing



NOTE V_{OH} denotes $V_{OH(min)}$ and V_{OL} denotes $V_{OL(max)}$.

Table 5-7 HS200 Device Output Timing

Symbol	Min	Max	Unit	Remark
t_{PH}	0	2	UI	Device output momentary phase from CLK input to CMD or DAT lines output. Does not include a long term temperature drift.
ΔT_{PH}	-350 ($\Delta T = -20^\circ C$)	+1550 ($\Delta T = 90^\circ C$)	ps	Delay variation due to temperature change after tuning. Total allowable shift of output valid window (TVW) from last system Tuning procedure ΔT_{PH} is 2600ps for ΔT from $-25^\circ C$ to $125^\circ C$ during operation.
T_{VW}	0.575	-	UI	$t_{VW} = 2.88ns$ at 200MHz Using test circuit including skew among CMD and DAT lines created by the Device. Host path may add Signal Integrity induced noise, skews, etc. Expected TVW at Host input is larger than 0.475UI.

Note: Unit Interval (UI) is one bit nominal time. For example, UI=5ns at 200MHz.

Figure 5-7 ΔT_{PH} consideration

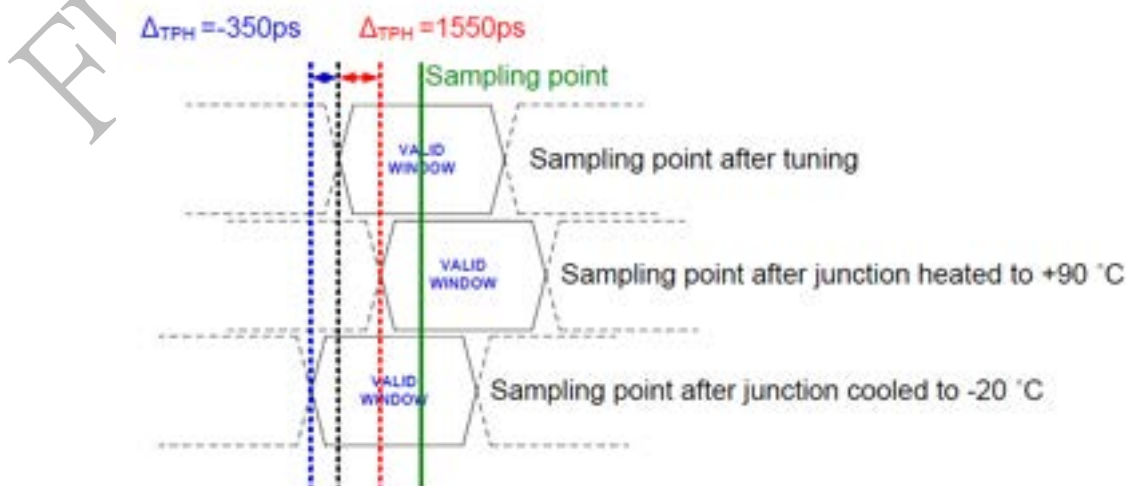


Figure 5-8 HS400 Device Input Timing

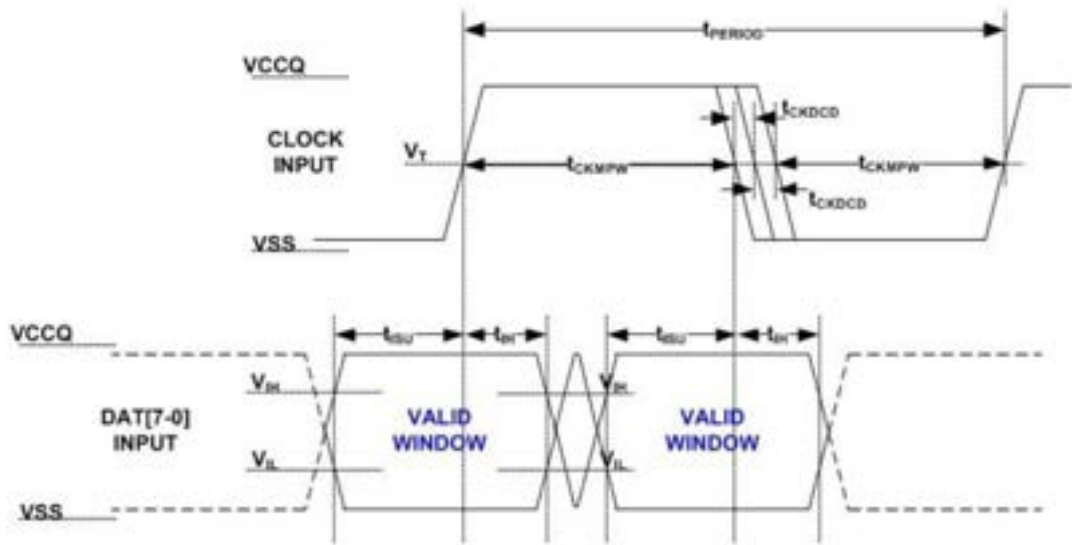


Table 5-4 HS400 Device Input Timing

Parameter	Symbol	Min	Max	Unit	Remark
Input CLK					
Cycle time data transfer mode	tPERIOD	5			200MHz (Max), between rising edges with respect to V_T .
Slew rate	SR	1.125		V/ns	With respect to V_{IH}/V_{IL} .
Duty cycle distortion	tCKDCD	0	0.3	ns	Allowable deviation from an ideal 50% duty cycle. With respect to V_T . Includes jitter, phase noise.
Minimum pulse width	tCKMPW	2.2		ns	With respect to V_T .
Input DAT (referenced to CLK)					
Input set-up time	tISUddr	0.4	-	ns	$C_{device} \leq 6pF$ with respect to V_{IH}/V_{IL} .
Input hold time	tIHddr	0.4	-	ns	$C_{device} \leq 6pF$ with respect to V_{IH}/V_{IL} .
Slew rate	SR	1.125		V/ns	with respect to V_{IH}/V_{IL} .

Figure 5-9 HS400 Device Output Timing

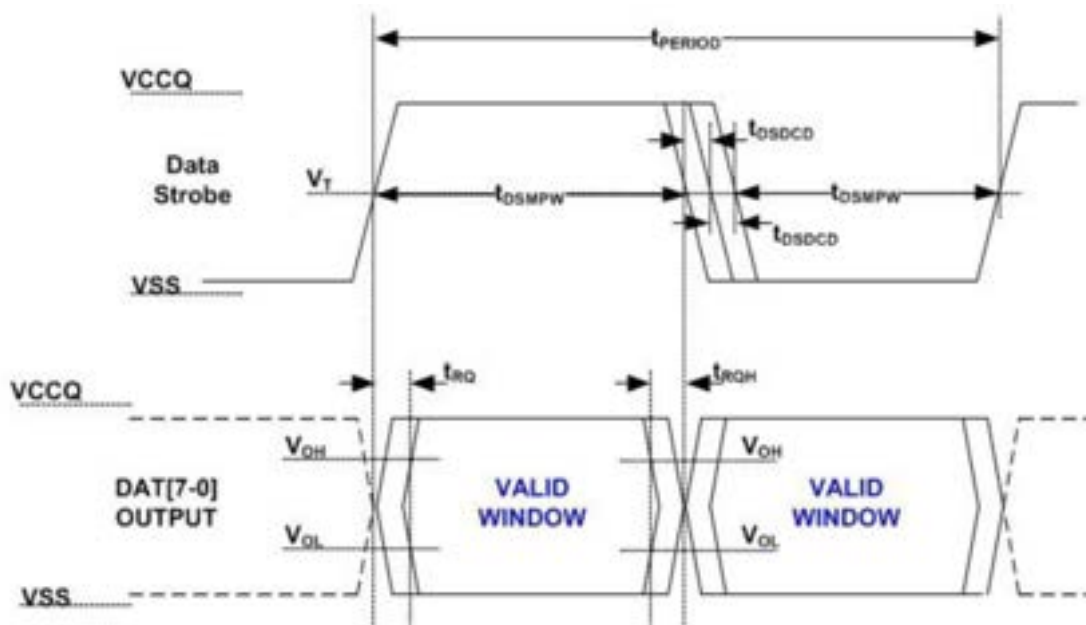


Table 5-5 HS400 Device Output Timing

Parameter	Symbol	Min	Max	Unit	Remark
Data Strobe					
Cycle time data transfer mode	t_{PERIOD}	5			200MHz(Max), between rising edges with respect to V_T .
Slew rate	SR	1.125		V/ns	With respect to V_{OH}/V_{OL} and HS400 reference load
Duty cycle distortion	t_{SDCD}	0	0.2	ns	Allowable deviation from an input CLK duty cycle distortion (t_{CKDCD}). With respect to V_T . Includes jitter, phase noise
Minimum pulse width	t_{SMPW}	2		ns	With respect to V_T .
Read pre-amble	t_{RPRE}	0.4		t_{PERIOD}	Max value is specified by manufacture. Value up to infinite is valid
Read post-amble	t_{RPST}	0.4		t_{PERIOD}	Max value is specified by manufacture. Value up to infinite is valid
Output DAT (Referenced to Data Strobe)					
Slew rate	SR	1.125		V/ns	With respect to V_{OH}/V_{OL} and HS400 reference load.

Table 5-6 HS400 Capacitance

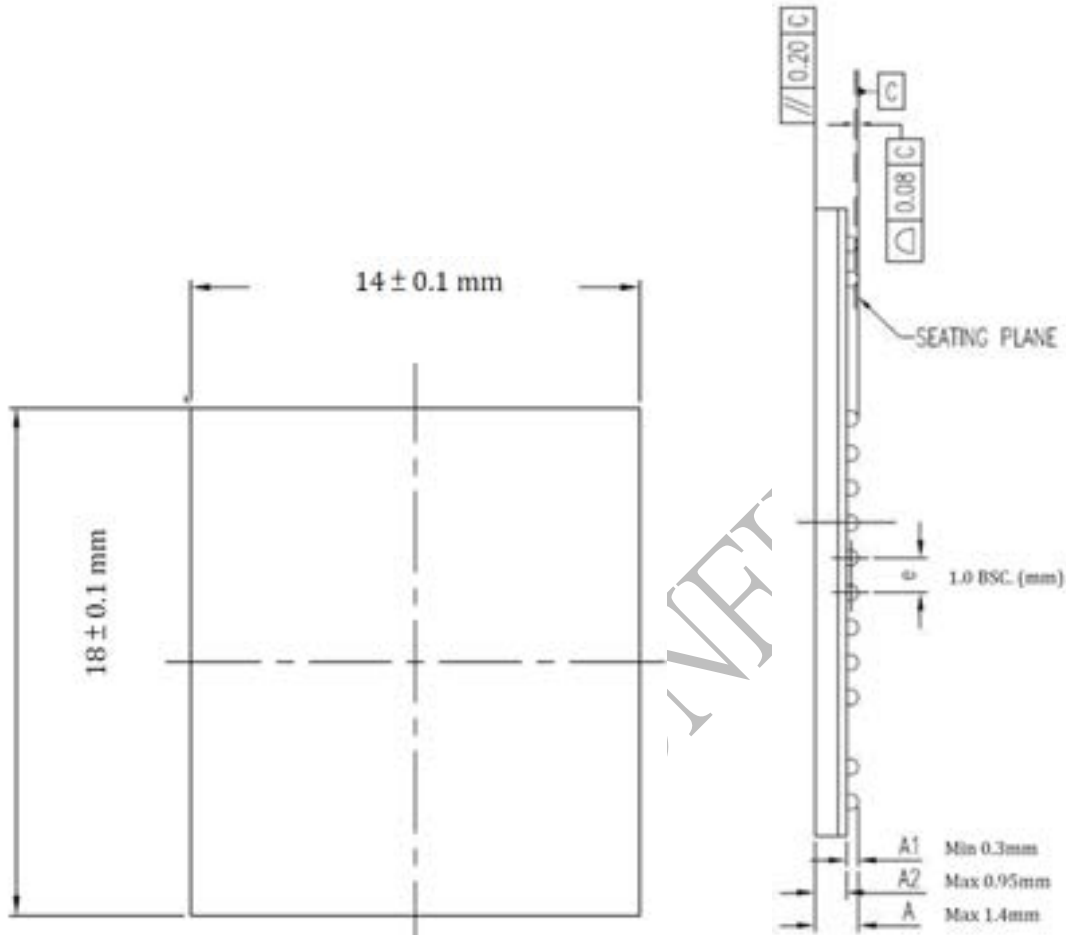
Parameter	Symbol	Min	Type	Max	Unit
Pull-up resistance for CMD	RCMD	4.7		50	Kohm
Pull-up resistance for DAT0-7	RDAT	10		50	Kohm
Pull-down resistance for Data Strobe	RDS	10		50	Kohm
Internal pull up resistance DAT1-DAT7	Rint	10		150	Kohm
Single Device capacitance	Cdevice			6	pF

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6. PACKAGE



Package Size: 14.0 x 18.0 x 1.4mm



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7. ORDERING INFORMATION



Capacity	MPN (Diamond Grade)	MPN (Gold Grade)	Power System	Pin Configuration	Package Size
64GB	FEMC064GBE-E530	FEMC064GBG-E530	VCCQ: 1.8V/3.3V VCC: 3.3V	100 FBGA	14x18x1.4 (mm)
128GB	FEMC128GBE-E530	FEMC128GBG-E530			
256GB	FEMC256GBE-E530	FEMC256GBG-E530			
512GB	FEMC512GBE-E530	FEMC512GBG-E530			

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Revision History

Revision	Release Date	History
1.0	2022/04	Preliminary Version
1.1	2022/04	Update Performance and Power consumption

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