

2M x 36 SigmaQuad-II ECCRAM—Top View

	1	2	3	4	5	6	7	8	9	10	11
A	$\overline{\text{CQ}}$	NC (288Mb)	SA	$\overline{\text{W}}$	$\overline{\text{BW2}}$	$\overline{\text{K}}$	$\overline{\text{BW1}}$	$\overline{\text{R}}$	SA	NF (144Mb)	CQ
B	Q27	Q18	D18	SA	$\overline{\text{BW3}}$	K	$\overline{\text{BW0}}$	SA	Q17	Q17	Q8
C	D27	Q28	D19	V _{SS}	SA	NF	SA	V _{SS}	D16	Q7	D8
D	D28	D20	Q19	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	Q16	D15	D7
E	Q29	D29	Q20	V _{DDQ}	V _{SS}	V _{SS}	V _{SS}	V _{DDQ}	Q15	D6	Q6
F	Q30	Q21	D21	V _{DDQ}	V _{DD}	V _{SS}	V _{DDQ}	V _{DDQ}	D14	Q14	Q5
G	D30	D22	Q22	V _{DDQ}	V _{DD}	V _{SS}	V _{DD}	V _{DDQ}	Q13	D13	D5
H	$\overline{\text{Doff}}$	V _{REF}	V _{DDQ}	V _{DDQ}	V _{DD}	V _{SS}	V _{DD}	V _{DDQ}	V _{DDQ}	V _{REF}	ZQ
J	D31	Q31	D23	V _{DDQ}	V _{DD}	V _{SS}	V _{DD}	V _{DDQ}	D12	Q4	D4
K	Q32	D32	Q23	V _{DDQ}	V _{DD}	V _{SS}	V _{DD}	V _{DDQ}	Q12	D3	Q3
L	Q33	Q24	D24	V _{DDQ}	V _{SS}	V _{SS}	V _{SS}	V _{DDQ}	D11	Q11	Q2
M	D33	Q34	D25	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	D10	Q1	D2
N	D34	D26	Q25	V _{SS}	SA	SA	SA	V _{SS}	Q10	D9	D1
P	Q35	D35	Q26	SA	SA	QVLD	SA	SA	Q9	D0	Q0
R	TDO	TCK	SA	SA	SA	ODT	SA	SA	SA	TMS	TDI

 11 x 15 Bump BGA—15 x 17 mm² Body—1 mm Bump Pitch

Note:

 BW0 controls writes to D0:D8; $\overline{\text{BW1}}$ controls writes to D9:D17; $\overline{\text{BW2}}$ controls writes to D18:D26; $\overline{\text{BW3}}$ controls writes to D27:D35.

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4M x 18 SigmaQuad-II ECCRAM—Top View

	1	2	3	4	5	6	7	8	9	10	11
A	$\overline{\text{CQ}}$	NC (144Mb)	SA	$\overline{\text{W}}$	$\overline{\text{BW1}}$	$\overline{\text{K}}$	NF	$\overline{\text{R}}$	SA	SA	CQ
B	NC	Q9	D9	SA	NF	K	$\overline{\text{BW0}}$	SA	NC	NC	Q8
C	NC	NC	D10	V_{SS}	SA	NF	SA	V_{SS}	NC	Q7	D8
D	NC	D11	Q10	V_{SS}	V_{SS}	V_{SS}	V_{SS}	V_{SS}	NC	NC	D7
E	NC	NC	Q11	V_{DDQ}	V_{SS}	V_{SS}	V_{SS}	V_{DDQ}	NC	D6	Q6
F	NC	Q12	D12	V_{DDQ}	V_{DD}	V_{SS}	V_{DD}	V_{DDQ}	NC	NC	Q5
G	NC	D13	Q13	V_{DDQ}	V_{DD}	V_{SS}	V_{DD}	V_{DDQ}	NC	NC	D5
H	$\overline{\text{Doff}}$	V_{REF}	V_{DDQ}	V_{DDQ}	V_{DD}	V_{SS}	V_{DD}	V_{DDQ}	V_{DDQ}	V_{REF}	ZQ
J	NC	NC	D14	V_{DDQ}	V_{DD}	V_{SS}	V_{DD}	V_{DDQ}	NC	Q4	D4
K	NC	NC	Q14	V_{DDQ}	V_{DD}	V_{SS}	V_{DD}	V_{DDQ}	NC	D3	Q3
L	NC	Q15	D15	V_{DDQ}	V_{SS}	V_{SS}	V_{SS}	V_{DDQ}	NC	NC	Q2
M	NC	NC	D16	V_{SS}	V_{SS}	V_{SS}	V_{SS}	V_{SS}	NC	Q1	D2
N	NC	D17	Q16	V_{SS}	SA	SA	SA	V_{SS}	NC	NC	D1
P	NC	NC	Q17	SA	SA	QVLD	SA	SA	NC	D0	Q0
R	TDO	TCK	SA	SA	SA	ODT	SA	SA	SA	TMS	TDI

 15 x 15 Bump BGA—15 x 17 mm² Body—1 mm Bump Pitch

Note:

BW0 controls writes to D0:D8. BW1 controls writes to D9:D17.

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Pin Description Table

Symbol	Description	Type	Comments
SA	Synchronous Address Inputs	Input	—
\bar{R}	Synchronous Read	Input	Active Low
\bar{W}	Synchronous Write	Input	Active Low
$\overline{BW0-BW3}$	Synchronous Byte Writes	Input	Active Low
K	Input Clock	Input	Active High
\bar{K}	Input Clock	Input	Active Low
TMS	Test Mode Select	Input	—
TDI	Test Data Input	Input	—
TCK	Test Clock Input	Input	—
TDO	Test Data Output	Output	—
V _{REF}	HSTL Input Reference Voltage	Input	—
ZQ	Output Impedance Matching Input	Input	—
Qn	Synchronous Data Outputs	Output	—
Dn	Synchronous Data Inputs	Input	—
\overline{Doff}	Disable DLL when low	Input	Active Low
CQ	Output Echo Clock	Output	—
\bar{CQ}	Output Echo Clock	Output	—
V _{DD}	Power Supply	Supply	1.8 V Nominal
V _{DDQ}	Isolated Output Buffer Supply	Supply	1.5 V Nominal
V _{SS}	Power Supply: Ground	Supply	—
QVLD	Q Valid Output	Output	—
ODT	On-Die Termination	Input	—
NC	No Connect	—	—
NF	No Function	—	—

Notes:

1. NC = Not Connected to die or any other pin
2. NF= No Function. There is an electrical connection to this input pin, but the signal has no function in the device. It can be left unconnected, or tied to V_{SS} or V_{DDQ}.
3. K, or \bar{K} cannot be set to V_{REF} Voltage.

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Background

Separate I/O SRAMs, from a system architecture point of view, are attractive in applications where alternating reads and writes are needed. Therefore, the SigmaQuad-II+ ECCRAM interface and truth table are optimized for alternating reads and writes. Separate I/O SRAMs are unpopular in applications where multiple reads or multiple writes are needed because burst read or write transfers from Separate I/O ECCRAMs can cut the RAM's bandwidth in half.

SigmaQuad-II+ B4 ECCRAM DDR Read

The status of the Address Input, \overline{W} , and \overline{R} pins are sampled by the rising edges of K. \overline{W} and \overline{R} high causes chip disable. A low on the Read Enable pin, \overline{R} , begins a read cycle. \overline{R} is always ignored if the previous command loaded was a read command. Clocking in a high on the Read Enable pin, \overline{R} , begins a read port deselect cycle.

SigmaQuad-II+ B4 ECCRAM DDR Write

The status of the Address Input, \overline{W} , and \overline{R} pins are sampled by the rising edges of K. \overline{W} and \overline{R} high causes chip disable. A low on the Write Enable pin, \overline{W} , and a high on the Read Enable pin, \overline{R} , begins a write cycle. \overline{W} is always ignored if the previous command was a write command. Data is clocked in by the next rising edge of K, the rising edge of \overline{K} after that, the next rising edge of K, and finally by the next rising edge of \overline{K} .

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Power-Up Sequence for SigmaQuad-II+ ECCRAMs

SigmaQuad-II+ ECCRAMs must be powered-up in a specific sequence in order to avoid undefined operations.

1. After power supplies power-up and clocks (K , \bar{K}) are stabilized, 163,840 cycles are required to set Output Driver Impedance.
2. Thereafter, an additional 65,536 clock cycles are required to lock the DLL after it has been enabled.
3. Begin Read and Write operations.

For more information, read **AN1021 SigmaQuad and SigmaDDR Power-Up**.

On-Chip Error Correction

SigmaQuad-II ECCRAMs implement a single-bit error detection and correction algorithm (specifically, a Hamming Code) on each DDR data word (comprising two 9-bit data bytes) transmitted on each 9-bit data bus (i.e., transmitted on D/Q[8:0], D/Q[17:9], D/Q[26:18], or D/Q[35:27]). To accomplish this, 5 ECC parity bits (invisible to the user) are utilized per every 18 data bits (visible to the user).

The ECC algorithm neither corrects nor detects multi-bit errors. However, GSI ECCRAMs are architected in such a way that a single SER event very rarely causes a multi-bit error across any given "transmitted data unit", where a "transmitted data unit" represents the data transmitted as the result of a single read or write operation to a particular address. The extreme rarity of multi-bit errors results in the SER mentioned previously (i.e., <0.002 FITs/Mb measured at sea level).

Not only does the on-chip ECC significantly improve SER performance, but it also frees up the entire memory array for data storage. Very often SRAM applications allocate 1/9th of the memory array (i.e., one "error bit" per eight "data bits", in any 9-bit "data byte") for error detection (either simple parity error detection, or system-level ECC error detection and correction). Such error-bit allocation is unnecessary with ECCRAMs—the entire memory array can be utilized for data storage, effectively providing 12.5% greater storage capacity compared to SRAMs of the same density not equipped with on-chip ECC.

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Special Functions

Byte Write Control

Byte Write Enable pins are sampled at the same time that Data In is sampled. A High on the Byte Write Enable pin associated with a particular byte (e.g., $\overline{BW0}$ controls D0–D8 inputs) will inhibit the storage of that particular byte, leaving whatever data may be stored at the current address at that byte location undisturbed. Any or all of the Byte Write Enable pins may be driven High or Low during the data in sample times in a write sequence.

Each write enable command and write address loaded into the RAM provides the base address for a 4-beat data transfer. The x18 version of the RAM, for example, may write 72 bits in association with each address loaded. Any 9-bit byte may be masked in any write sequence.

Note: If “Half Write” operations (i.e., write operations in which a \overline{BWn} pin is asserted for only half of a DDR write data transfer on the associated 9-bit data bus, causing only 9 bits of the 18-bit DDR data word to be written), are initiated, the on-chip ECC will be disabled for as long as the SRAM remains powered up thereafter. This must be done because ECC is implemented across entire 18-bit data words, rather than across individual 9-bit data bytes.

Byte Write Truth Table

The truth table below applies to write operations to Address "m", where Address "m" is the 18-bit memory location comprising the 2 beats of DDR write data associated with each \overline{BWn} pin in a given clock cycle.

\overline{BWn}		Input Data Byte n		Operation	Result
$\uparrow K$ (Beat 1)	$\uparrow \overline{K}$ (Beat 2)	$\uparrow K$ (Beat 1)	$\uparrow \overline{K}$ (Beat 2)		
0	0	D0	D1	Full Write	D0 and D1 written to Address m
0	1	D0	X	Half Write	Only D0 written to Address m
1	0	X	D1	Half Write	Only D1 written to Address m
1	1	X	X	Abort	Address m unchanged

Notes:

- $\overline{BW0}$ is associated with Input Data Byte D[8:0].
- $\overline{BW1}$ is associated with Input Data Byte D[17:9].
- $\overline{BW2}$ is associated with Input Data Byte D[26:18] (in x36 only).
- $\overline{BW3}$ is associated with Input Data Byte D[35:27] (in x36 only).
- ECC is disabled if a “Half Write” operation is initiated.
- Although these devices execute Burst of 4 (i.e., 4-beat) write operations, for the purposes of this table they should be viewed as a pair of Burst of 2 (i.e., 2-beat) write operations. As such, valid/allowable Burst of 4 write operations only comprise (any combination of) Burst of 2 Full Write and/or Abort Write operations, as defined above.

FLXDrive-II Output Driver Impedance Control

HSTL I/O SigmaQuad-II+ ECCRAMs are supplied with programmable impedance output drivers. The ZQ pin must be connected to V_{SS} via an external resistor, RQ, to allow the SRAM to monitor and adjust its output driver impedance. The value of RQ must be 5X the value of the desired RAM output impedance. The allowable range of RQ to guarantee impedance matching continuously is between 175Ω and 275Ω . Periodic readjustment of the output driver impedance is necessary as the impedance is affected by drifts in supply voltage and temperature. The SRAM's output impedance circuitry compensates for drifts in supply voltage and temperature. A clock cycle counter periodically triggers an impedance evaluation, resets and counts again. Each impedance evaluation may move the output driver impedance level one step at a time towards the optimum level. The output driver is implemented with discrete binary weighted impedance steps.

Input Termination Impedance Control

These SigmaQuad-II+ ECCRAMs are supplied with programmable input termination on Data (D), Byte Write (\overline{BW}), and Clock (K/ \overline{K}) input receivers. Input termination can be enabled or disabled via the ODT pin (6R). When the ODT pin is tied Low (or left floating -the pin has a small pull-down resistor), input termination is disabled. When the ODT pin is tied High, input termination is enabled. Termination impedance is programmed via the same RQ resistor (connected between the ZQ pin and V_{SS}) used to program output driver impedance, and is nominally $RQ \cdot 0.6$ Thevenin-equivalent when RQ is between 175Ω and 250Ω . Periodic readjustment of the termination impedance occurs to compensate for drifts in supply voltage and temperature, in the same manner as for driver impedance (see above).

Note:

When $ODT = 1$, Data (D), Byte Write (\overline{BW}), and Clock (K, \overline{K}) input termination is always enabled. Consequently, D, \overline{BW} , K, \overline{K} inputs should always be driven High or Low; they should never be tri-stated (i.e., in a High-Z state). If the inputs are tri-stated, the input termination will pull the signal to $V_{DDQ}/2$ (i.e., to the switch point of the diff-amp receiver), which could cause the receiver to enter a meta-stable state, resulting in the receiver consuming more power than it normally would. This could result in the device's operating currents being higher.

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Separate I/O SigmaQuad II+ B4 ECCRAM Truth Table

Previous Operation	A	\bar{R}	\bar{W}	Current Operation	D	D	D	D	Q	Q	Q	Q
$K \uparrow$ (t_{n-1})	$K \uparrow$ (t_n)	$K \uparrow$ (t_n)	$K \uparrow$ (t_n)	$K \uparrow$ (t_n)	$K \uparrow$ (t_{n+1})	$\bar{K} \uparrow$ ($t_{n+1\frac{1}{2}}$)	$K \uparrow$ (t_{n+2})	$\bar{K} \uparrow$ ($t_{n+2\frac{1}{2}}$)	$\bar{K} \uparrow$ ($t_{n+2\frac{1}{2}}$)	$K \uparrow$ (t_{n+3})	$\bar{K} \uparrow$ ($t_{n+3\frac{1}{2}}$)	$K \uparrow$ (t_{n+4})
Deselect	X	1	1	Deselect	X	X	—	—	Hi-Z/0	Hi-Z/0	—	—
Write	X	1	X	Deselect	D2	D3	—	—	Hi-Z/0	Hi-Z/0	—	—
Read	X	X	1	Deselect	X	X	—	—	Q2	Q3	—	—
Deselect	V	1	0	Write	D0	D1	D2	D3	Hi-Z/0	Hi-Z/0	—	—
Deselect	V	0	X	Read	X	X	—	—	Q0	Q1	Q2	Q3
Read	V	X	0	Write	D0	D1	D2	D3	Q2	Q3	—	—
Write	V	0	X	Read	D2	D3	—	—	Q0	Q1	Q2	Q3

Notes:

1. "1" = input "high"; "0" = input "low"; "V" = input "valid"; "X" = input "don't care"
2. "—" indicates that the input requirement or output state is determined by the next operation.
3. Q0, Q1, Q2, and Q3 indicate the first, second, third, and fourth pieces of output data transferred during Read operations.
4. D0, D1, D2, and D3 indicate the first, second, third, and fourth pieces of input data transferred during Write operations.
5. Users should not clock in metastable addresses.
6. When On-Die Termination is disabled (ODT = 0), Q drivers are disabled (i.e., Q pins are tri-stated) for one cycle in response to NOP and Write commands, 2.5 cycles after the command is sampled, except when preceded by a Read command.
7. When On-Die Termination is enabled (ODT = 1), Q drivers are enabled Low (i.e., Q pins are driven Low) for one cycle in response to NOP and Write commands, 2.5 cycles after the command is sampled, except when preceded by a Read command. This is done so that the ASIC/Controller can enable On-Die Termination on its data inputs without having to cope with the termination pulling tri-stated data inputs to $V_{DD}/2$ (i.e., to the switch point of the data input receivers).

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Byte Write Clock Truth Table

\overline{BW}	\overline{BW}	\overline{BW}	\overline{BW}	Current Operation	D	D	D	D
$K \uparrow$ (t_{n+1})	$\overline{K} \uparrow$ ($t_{n+1\frac{1}{2}}$)	$K \uparrow$ (t_{n+2})	$\overline{K} \uparrow$ ($t_{n+2\frac{1}{2}}$)	$K \uparrow$ (t_n)	$K \uparrow$ (t_{n+1})	$\overline{K} \uparrow$ ($t_{n+1\frac{1}{2}}$)	$K \uparrow$ (t_{n+2})	$\overline{K} \uparrow$ ($t_{n+2\frac{1}{2}}$)
T	T	T	T	Write Dx stored if $\overline{BWn} = 0$ in all four data transfers	D0	D1	D2	D3
T	F	F	F	Write Dx stored if $\overline{BWn} = 0$ in 1st data transfer only	D0	X	X	X
F	T	F	F	Write Dx stored if $\overline{BWn} = 0$ in 2nd data transfer only	X	D1	X	X
F	F	T	F	Write Dx stored if $\overline{BWn} = 0$ in 3rd data transfer only	X	X	D2	X
F	F	F	T	Write Dx stored if $\overline{BWn} = 0$ in 4th data transfer only	X	X	X	D3
F	F	F	F	Write Abort No Dx stored in any of the four data transfers	X	X	X	X

Notes:

1. "1" = input "high"; "0" = input "low"; "X" = input "don't care"; "T" = input "true"; "F" = input "false".
2. If one or more $\overline{BWn} = 0$, then $\overline{BW} = "T"$, else $\overline{BW} = "F"$.

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x36 Byte Write Enable (\overline{BWn}) Truth Table

$\overline{BW0}$	$\overline{BW1}$	$\overline{BW2}$	$\overline{BW3}$	D0–D8	D9–D17	D18–D26	D27–D35
1	1	1	1	Don't Care	Don't Care	Don't Care	Don't Care
0	1	1	1	Data In	Don't Care	Don't Care	Don't Care
1	0	1	1	Don't Care	Data In	Don't Care	Don't Care
0	0	1	1	Data In	Data In	Don't Care	Don't Care
1	1	0	1	Don't Care	Don't Care	Data In	Don't Care
0	1	0	1	Data In	Don't Care	Data In	Don't Care
1	0	0	1	Don't Care	Data In	Data In	Don't Care
0	0	0	1	Data In	Data In	Data In	Don't Care
1	1	1	0	Don't Care	Don't Care	Don't Care	Data In
0	1	1	0	Data In	Don't Care	Don't Care	Data In
1	0	1	0	Don't Care	Data In	Don't Care	Data In
0	0	1	0	Data In	Data In	Don't Care	Data In
1	1	0	0	Don't Care	Don't Care	Data In	Data In
0	1	0	0	Data In	Don't Care	Data In	Data In
1	0	0	0	Don't Care	Data In	Data In	Data In
0	0	0	0	Data In	Data In	Data In	Data In

 x18 Byte Write Enable (\overline{BWn}) Truth Table

$\overline{BW0}$	$\overline{BW1}$	D0–D8	D9–D17
1	1	Don't Care	Don't Care
0	1	Data In	Don't Care
1	0	Don't Care	Data In
0	0	Data In	Data In

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Absolute Maximum Ratings

(All voltages reference to V_{SS})

Symbol	Description	Value	Unit
V_{DD}	Voltage on V_{DD} Pins	-0.5 to 2.4	V
V_{DDQ}	Voltage in V_{DDQ} Pins	-0.5 to V_{DD}	V
V_{REF}	Voltage in V_{REF} Pins	-0.5 to V_{DDQ}	V
$V_{I/O}$	Voltage on I/O Pins	-0.5 to $V_{DDQ} + 0.5$ (≤ 2.4 V max.)	V
V_{IN}	Voltage on Other Input Pins	-0.5 to $V_{DDQ} + 0.5$ (≤ 2.4 V max.)	V
I_{IN}	Input Current on Any Pin	+200	mA dc
I_{OUT}	Output Current on Any I/O Pin	+/-100	mA dc
T_J	Maximum Junction Temperature	120	$^{\circ}\text{C}$
T_{STG}	Storage Temperature	-55 to 125	$^{\circ}\text{C}$

Note:

Permanent damage to the device may occur if the Absolute Maximum Ratings are exceeded. Operation should be restricted to Recommended Operating Conditions. Exposure to conditions exceeding the Recommended Operating Conditions, for an extended period of time, may affect reliability of this component.

Recommended Operating Conditions

Power Supplies

Parameter	Symbol	Min.	Typ.	Max.	Unit
Supply Voltage	V_{DD}	1.7	1.8	1.9	V
I/O Supply Voltage	V_{DDQ}	1.4	—	1.6	V
Reference Voltage	V_{REF}	$V_{DDQ}/2 - 0.05$	—	$V_{DDQ}/2 + 0.05$	V

Note:

The power supplies need to be powered up simultaneously or in the following sequence: V_{DD} , V_{DDQ} , V_{REF} , followed by signal inputs. The power down sequence must be the reverse. V_{DDQ} must not exceed V_{DD} . For more information, read **AN1021 SigmaQuad and SigmaDDR Power-Up**.

Operating Temperature

Parameter	Symbol	Min.	Typ.	Max.	Unit
Junction Temperature (Commercial Range Versions)	T_J	0	25	85	$^{\circ}\text{C}$
Junction Temperature (Industrial Range Versions)*	T_J	-40	25	100	$^{\circ}\text{C}$

Note:

* The part numbers of Industrial Temperature Range versions end with the character "I". Unless otherwise noted, all performance specifications quoted are evaluated for worst case in the temperature range marked on the device.

Thermal Impedance

Package	Test PCB Substrate	θ_{JA} (C°/W) Airflow = 0 m/s	θ_{JA} (C°/W) Airflow = 1 m/s	θ_{JA} (C°/W) Airflow = 2 m/s	θ_{JB} (C°/W)	θ_{JC} (C°/W)
165 BGA	4-layer	15.25	12.38	11.41	7.79	1.31

Notes:

1. Thermal Impedance data is based on a number of samples from multiple lots and should be viewed as a typical number.
2. Please refer to JEDEC standard JESD51-6.
3. The characteristics of the test fixture PCB influence reported thermal characteristics of the device. Be advised that a good thermal path to the PCB can result in cooling or heating of the RAM depending on PCB temperature.

HSTL I/O DC Input Characteristics

Parameter	Symbol	Min	Max	Units	Notes
Input Reference Voltage	V_{REF}	$V_{DDQ}/2 - 0.05$	$V_{DDQ}/2 + 0.05$	V	—
Input High Voltage	V_{IH1}	$V_{REF} + 0.1$	$V_{DDQ} + 0.3$	V	1
Input Low Voltage	V_{IL1}	-0.3	$V_{REF} - 0.1$	V	1
Input High Voltage	V_{IH2}	$0.7 * V_{DDQ}$	$V_{DDQ} + 0.3$	V	2,3
Input Low Voltage	V_{IL2}	-0.3	$0.3 * V_{DDQ}$	V	2,3

Notes:

1. Parameters apply to \bar{K} , \bar{K} , SA, D, \bar{R} , \bar{W} , $\bar{B}\bar{W}$ during normal operation and JTAG boundary scan testing.
2. Parameters apply to $\bar{D}\bar{o}\bar{f}\bar{f}$, ODT during normal operation and JTAG boundary scan testing.
3. Parameters apply to ZQ during JTAG boundary scan testing only.

HSTL I/O AC Input Characteristics

Parameter	Symbol	Min	Max	Units	Notes
Input Reference Voltage	V_{REF}	$V_{DDQ}/2 - 0.08$	$V_{DDQ}/2 + 0.08$	V	—
Input High Voltage	V_{IH1}	$V_{REF} + 0.2$	$V_{DDQ} + 0.5$	V	1,2,3
Input Low Voltage	V_{IL1}	-0.5	$V_{REF} - 0.2$	V	1,2,3
Input High Voltage	V_{IH2}	$V_{DDQ} - 0.2$	$V_{DDQ} + 0.5$	V	4,5
Input Low Voltage	V_{IL2}	-0.5	0.2	V	4,5

Notes:

1. $V_{IH(MAX)}$ and $V_{IL(MIN)}$ apply for pulse widths less than one-quarter of the cycle time.
2. Input rise and fall times must be a minimum of 1 V/ns, and within 10% of each other.
3. Parameters apply to \bar{K} , \bar{K} , SA, D, \bar{R} , \bar{W} , $\bar{B}\bar{W}$ during normal operation and JTAG boundary scan testing.
4. Parameters apply to $\bar{D}\bar{o}\bar{f}\bar{f}$, ODT during normal operation and JTAG boundary scan testing.

Capacitance

($T_A = 25^\circ\text{C}$, $f = 1\text{ MHz}$, $V_{DD} = 1.8\text{ V}$)

Parameter	Symbol	Test conditions	Typ.	Max.	Unit
Input Capacitance	C_{IN}	$V_{IN} = 0\text{ V}$	4	5	pF
Output Capacitance	C_{OUT}	$V_{OUT} = 0\text{ V}$	4.5	5.5	pF

Note:

This parameter is sample tested.

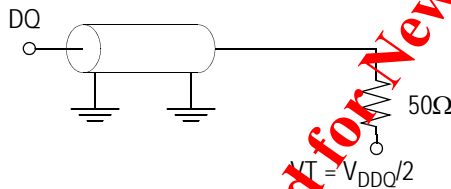
AC Test Conditions

Parameter	Conditions
Input high level	1.25 V
Input low level	0.25 V
Max. input slew rate	2 V/ns
Input reference level	0.75 V
Output reference level	$V_{DDQ}/2$

Note:

Test conditions as specified with output loading as shown unless otherwise noted.

AC Test Load Diagram



$$R_Q = 250\ \Omega \text{ (HSTL I/O)}$$

$$V_{REF} = 0.75\text{ V}$$

Input and Output Leakage Characteristics

Parameter	Symbol	Test Conditions	Min.	Max
Input Leakage Current (except mode pins)	I_{IL}	$V_{IN} = 0\text{ to }V_{DDQ}$	-2 μA	2 μA
$\overline{\text{Doff}}$	$I_{IL\overline{\text{DOFF}}}$	$V_{IN} = 0\text{ to }V_{DDQ}$	-100 μA	2 μA
ODT	$I_{IL\text{ ODT}}$	$V_{IN} = 0\text{ to }V_{DDQ}$	-2 μA	100 μA
Output Leakage Current	I_{OL}	Output Disable, $V_{OUT} = 0\text{ to }V_{DDQ}$	-2 μA	2 μA

Programmable Impedance HSTL Output Driver DC Electrical Characteristics

Parameter	Symbol	Min.	Max.	Units	Notes
Output High Voltage	V_{OH1}	$V_{DDQ}/2 - 0.12$	$V_{DDQ}/2 + 0.12$	V	1
Output Low Voltage	V_{OL1}	$V_{DDQ}/2 - 0.12$	$V_{DDQ}/2 + 0.12$	V	2
Output High Voltage	V_{OH2}	$V_{DDQ} - 0.2$	V_{DDQ}	V	3, 4
Output Low Voltage	V_{OL2}	V_{SS}	0.2	V	3, 5
Output Driver Impedance	R_{OUT}	$(RQ/5) * 0.88$	$(RQ/5) * 1.12$	Ω	6, 7

Notes:

- $I_{OH} = (V_{DDQ}/2) / (RQ/5) \pm 15\%$ @ $V_{OH} = V_{DDQ}/2$ (for: $175\Omega \leq RQ \leq 275\Omega$)
- $I_{OL} = (V_{DDQ}/2) / (RQ/5) \pm 15\%$ @ $V_{OL} = V_{DDQ}/2$ (for: $175\Omega \leq RQ \leq 275\Omega$)
- $0\Omega \leq RQ \leq \infty\Omega$
- $I_{OH} = -1.0$ mA
- $I_{OL} = 1.0$ mA
- Parameter applies when $175\Omega \leq RQ \leq 275\Omega$
- Tested at $V_{OUT} = V_{DDQ} * 0.2$ and $V_{DDQ} * 0.8$

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Operating Currents

Parameter	Symbol	Test Conditions	-633		-550		-500		-450		-400		Notes
			0° to 70°C	-40° to 85°C	0° to 70°C	-40° to 85°C	0° to 70°C	-40° to 85°C	0° to 70°C	-40° to 85°C	0° to 70°C	-40° to 85°C	
Operating Current (x36): DDR	I_{DD}	$V_{DD} = \text{Max}, I_{OUT} = 0 \text{ mA}$ Cycle Time $\geq t_{KHKH} \text{ Min}$	2740 mA	2760 mA	2440 mA	2460 mA	2230 mA	2250 mA	2050 mA	2070 mA	1860 mA	1880 mA	2, 3
Operating Current (x18): DDR	I_{DD}	$V_{DD} = \text{Max}, I_{OUT} = 0 \text{ mA}$ Cycle Time $\geq t_{KHKH} \text{ Min}$	1950 mA	1970 mA	1750 mA	1770 mA	1610 mA	1630 mA	1490 mA	1510 mA	1360 mA	1380 mA	2, 3

Notes:

1. Power measured with output pins floating.
2. Minimum cycle, $I_{OUT} = 0 \text{ mA}$
3. Operating current is calculated with 50% read cycles and 50% write cycles.

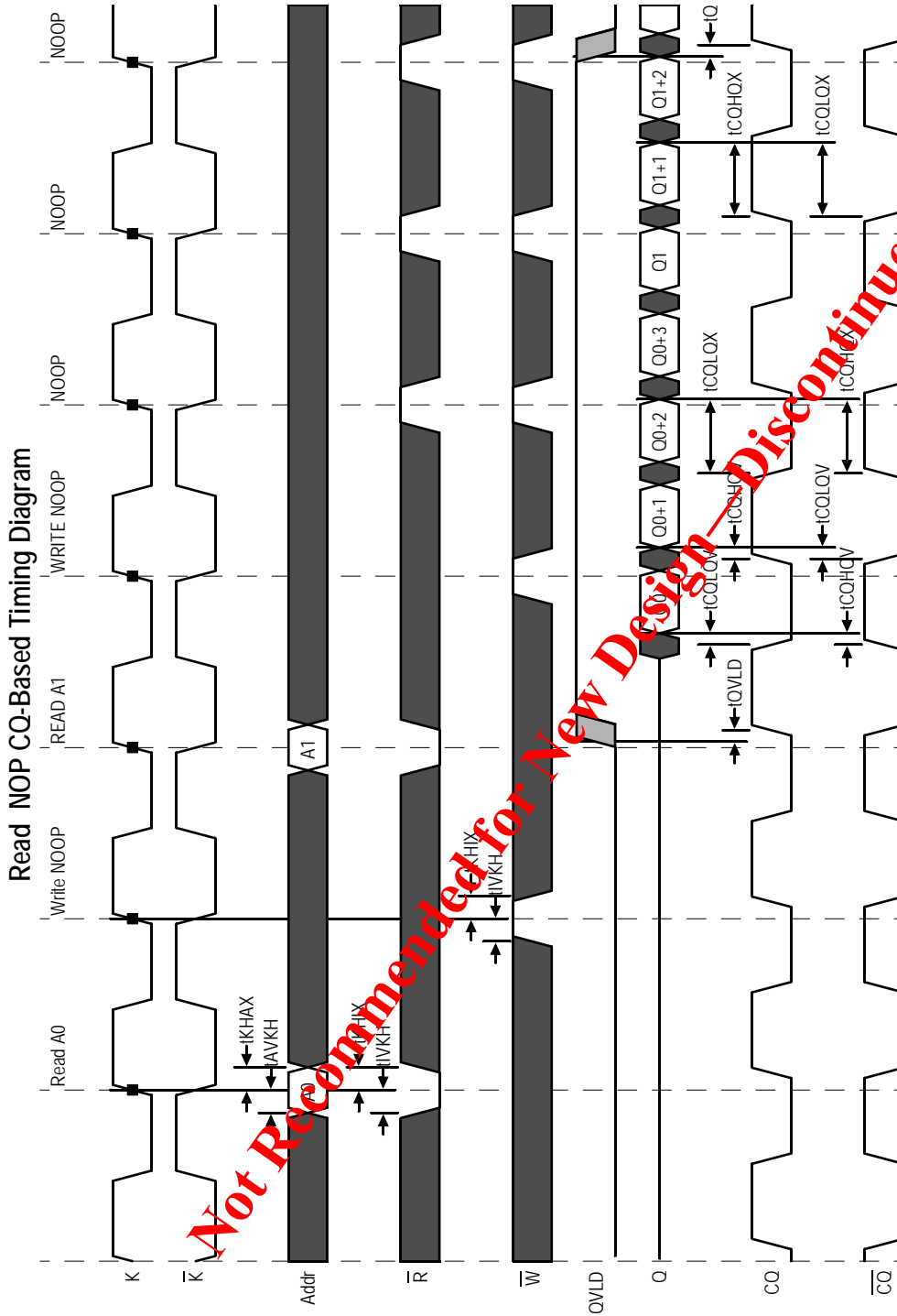
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AC Electrical Characteristics

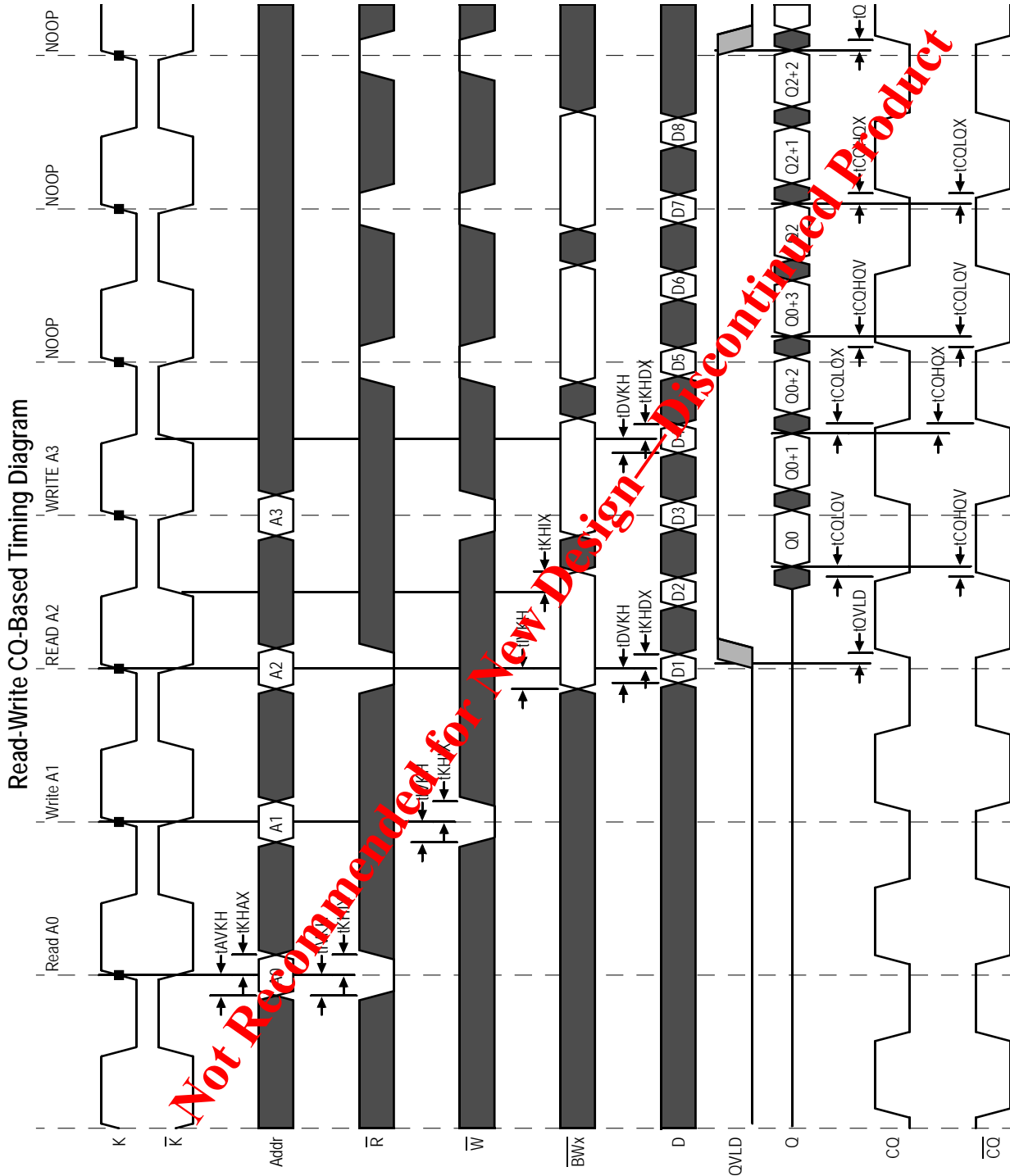
Parameter	Symbol	-633		-550		-500		-450		-400		Units	Notes
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
Clock													
K, \bar{K} Clock Cycle Time	t_{KHKL}	1.57	6.0	1.81	6.0	2.0	6.0	2.2	6.0	2.5	6.0	ns	
tK Variable	t_{KVar}	—	0.15	—	0.15	—	0.15	—	0.15	—	0.2	ns	4
K, \bar{K} Clock High Pulse Width	t_{KHKL}	0.4	—	0.4	—	0.4	—	0.4	—	0.4	—	cycle	
K, \bar{K} Clock Low Pulse Width	t_{KLKH}	0.4	—	0.4	—	0.4	—	0.4	—	0.4	—	cycle	
K to \bar{K} High	$t_{KH\bar{K}H}$	0.67	—	0.77	—	0.85	—	0.94	—	1.06	—	ns	
\bar{K} to K High	$t_{\bar{K}HKH}$	0.67	—	0.77	—	0.85	—	0.94	—	1.06	—	ns	
DLL Lock Time	t_{KLock}	64K	—	64K	—	64K	—	64K	—	64K	—	cycle	5
K Static to DLL reset	t_{KReset}	30	—	30	—	30	—	30	—	30	—	ns	
Output Times													
K, \bar{K} Clock High to Data Output Valid	t_{KHQV}	—	0.45	—	0.45	—	0.45	—	0.45	—	0.45	ns	
K, \bar{K} Clock High to Data Output Hold	t_{KHQX}	-0.45	—	-0.45	—	-0.45	—	-0.45	—	-0.45	—	ns	
K, \bar{K} Clock High to Echo Clock Valid	t_{KHCOV}	—	0.45	—	0.45	—	0.45	—	0.45	—	0.45	ns	
K, \bar{K} Clock High to Echo Clock Hold	t_{KHCOX}	-0.45	—	-0.45	—	-0.45	—	-0.45	—	-0.45	—	ns	
CQ, \bar{CQ} High Output Valid	t_{CQH0V}	—	0.15	—	0.15	—	0.15	—	0.15	—	0.2	ns	
CQ, \bar{CQ} High Output Hold	t_{CQH0X}	-0.15	—	-0.15	—	-0.15	—	-0.15	—	-0.2	—	ns	
CQ, \bar{CQ} High to QVLD	t_{QVLD}	-0.15	0.15	-0.15	0.15	-0.15	0.15	-0.15	0.15	-0.2	0.2	ns	
CQ Phase Distortion	$t_{CQH\bar{C}OH}$ $t_{\bar{C}OHCOH}$	0.55	—	0.65	—	0.75	—	0.85	—	1.0	—	ns	
K Clock High to Data Output High-Z	t_{KHQZ}	—	0.45	—	0.45	—	0.45	—	0.45	—	0.45	ns	5
K Clock High to Data Output Low-Z	t_{KHQX1}	-0.45	—	-0.45	—	-0.45	—	-0.45	—	-0.45	—	ns	5
Setup Times													
Address Input Setup Time	t_{AVKH}	0.23	—	0.23	—	0.25	—	0.275	—	0.4	—	ns	1
Control Input Setup Time (R, W)	t_{IVKH}	0.23	—	0.23	—	0.25	—	0.275	—	0.4	—	ns	2
Control Input Setup Time (BW _X)	t_{IVKH}	0.18	—	0.18	—	0.2	—	0.22	—	0.28	—	ns	3
Data Input Setup Time	t_{DVKH}	0.18	—	0.18	—	0.2	—	0.22	—	0.28	—	ns	
Hold Times													
Address Input Hold Time	t_{KH0H}	0.23	—	0.23	—	0.25	—	0.275	—	0.4	—	ns	1
Control Input Hold Time (R, W)	t_{KHIX}	0.23	—	0.23	—	0.25	—	0.275	—	0.4	—	ns	2
Control Input Hold Time (BW _X)	t_{KHIX}	0.18	—	0.18	—	0.2	—	0.22	—	0.28	—	ns	3
Data Input Hold Time	t_{KHDX}	0.18	—	0.18	—	0.2	—	0.22	—	0.28	—	ns	

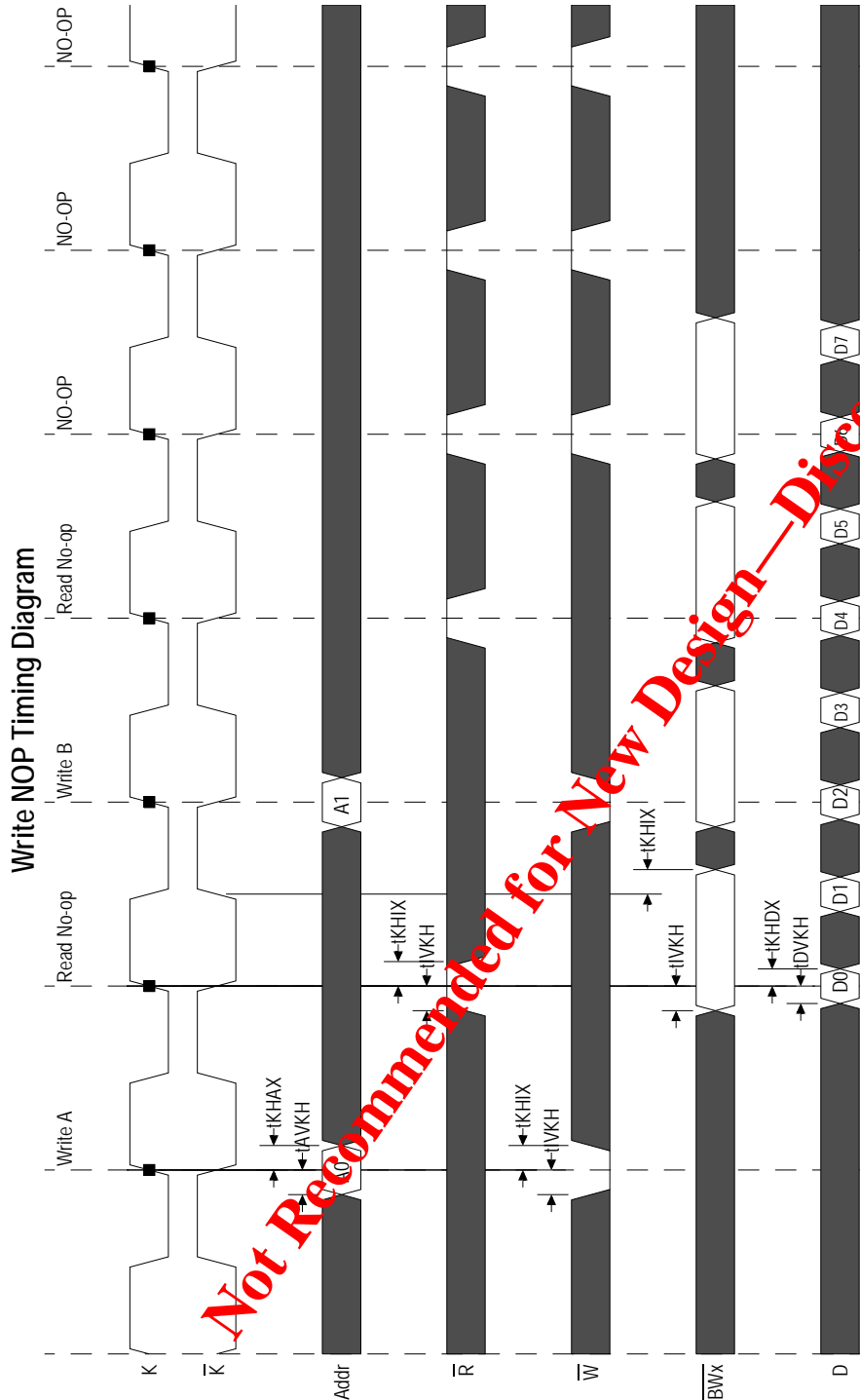
Notes:

- All Address inputs must meet the specified setup and hold times for all latching clock edges.
- Control signals are R, W.
- Control signals are BW₀, BW₁ and (BW₂, BW₃ for x36).
- Clock phase jitter is the variance from clock rising edge to the next expected clock rising edge.
- V_{DD} slew rate must be less than 0.1 V DC per 50 ns for DLL lock retention. DLL lock time begins once V_{DD} and input clock are stable.



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