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DDR5 SERIAL PRESENCE DETECT (SPD) CONTENTS

From JEDEC Board Ballot JCB-22-40, formulated under the cognizance of JC-45, DRAM modules, item 2260-01N. This standard is broken down into various clauses with their respective revision numbers below.

- DDR5 SPD Document Release 1.1
- Beta Release 0
- Base SPD revision 1.1
- Soldered down annex revision 1.0
- UDIMM annex revision 1.0
- RDIMM/LRDIMM annex revision 1.0
- MRDIMM annex revision 1.0
- DDIMM annex revision 1.0
- NVDIMM-N annex revision 0.1
- NVDIMM-P annex revision 1.0

1 Introduction / Scope

This publication describes the serial presence detect (SPD) values for all DDR5 memory modules. In this context, “modules” applies to memory modules like traditional Dual In-line Memory Modules (DIMMs) or solder-down motherboard applications. The SPD data provides critical information about all modules on the memory channel and is intended to be use by the system's BIOS in order to properly initialize and optimize the system memory channels. The storage capacity of the SPD non-volatile memory is limited, so a number of techniques are employed to optimize the use of these bytes, including overlays and run length limited coding.

All unused entries will be coded as 0x00. All unused bits in defined bytes will be coded as 0 except where noted.

Timing parameters in the SPD represent the operation of the module including all DRAMs and support devices at the lowest supported supply voltages (see SPD bytes 16 through 18), and are valid from $t_{CKAVGmin}$ to $t_{CKAVGmax}$ (see SPD bytes 20 through 23).

To allow for maximum flexibility as devices evolve, SPD fields described in this document may support device configuration and timing options that are not included in the JEDEC DDR5 SDRAM data sheet (JESD79-5). Please refer to DRAM supplier data sheets or JESD79-5 to determine the compatibility of components.

2 History

Computer main memory buses have traditionally been defined by the generation of memory attached to the bus, e.g., EDO, SDRAM, DDR1, etc. The bus interface protocol and characteristics have largely been defined by the memory type. Clock frequency, CAS latencies, refresh recovery times and similar parameters defined the timing of signals between memory controller and the memory, and parameters such as number of ranks installed and device widths allowed system software to determine the memory capacity and similar high level characteristics of each module.

Over time, the memory bus has been extended to include additional features for application specific requirements. Registered DIMMs, for example, increased total capacity by buffering the loading of the address bus signals, allowing more DRAM to be installed. Similarly, Load Reduced DIMMs buffered the data bus as well, allowing even more ranks of memory to be supported. As each new extension to the function of the memory bus was introduced, system software combined knowledge of those extensions with information programmed into the non-volatile memory in the SPD to determine how to use and optimize the new features. Using the RDIMM as an example, systems understood that an additional clock of latency needed to be added to the DRAM latency to accommodate propagation delay through the register.

In later generations, the DRAM to host interface is completely virtualized. A memory module may have no DRAM at all, yet may use the DRAM bus to communicate with the host by emulating the DRAM channel interface. These virtual interfaces must appear to the system as one of the base module types, i.e., UDIMM, RDIMM, LRDIMM, or DDIMM. Modules that incorporate at least one non-DRAM media type for the purpose of main memory data storage are called “hybrid”, they act like a DRAM but on the other side of the interface protocol are some other memory type(s).

3 SPD Architecture

The SPD contents architecture must support the many variations of module types while remaining efficient. A system of overlay information selected through the use of “key bytes”, or selectors for the type of information to load has been implemented. The following DDR5 module SPD address map describes where the individual lookup table entries will be held in the serial non-volatile memory.

Consistent with the definition of DDR5 generation SPD devices (SPD5118) which have 16 individual write protection blocks of 64 bytes in length each, the SPD contents are aligned with these blocks as follows:

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	Reserved for future use
3	192~239	0x0C0~0x0EF	Common Module Parameters -- See annex A.0 for details
	240~255	0x0D0~0x0FF	Standard Module Parameters -- See annexes A.x for details
4	256~319	0x100~0x13F	Standard Module Parameters -- See annexes A.x for details
5	320~383	0x140~0x17F	Standard Module Parameters -- See annexes A.x for details
6	384~447	0x180~0x1BF	Standard Module Parameters -- See annexes A.x for details
7	448~509	0x1C0~0x1FD	Reserved for future use
	510~511	0x1FE~0x1FF	CRC for SPD bytes 0~509
8	512~575	0x200~0x23F	Manufacturing information
9	576~639	0x240~0x27F	Manufacturing information
10	640~703	0x280~0x2BF	End User Programmable
11	704~767	0x2C0~0x2FF	End User Programmable
12	768~831	0x300~0x33F	End User Programmable
13	832~895	0x340~0x37F	End User Programmable
14	896~959	0x380~0x3BF	End User Programmable
15	960~1023	0x3C0~0x3FF	End User Programmable

Operating parameters for the different module types are defined in the following Annexes and will reside in the appropriate address ranges of the SPD address map depending on the module type. Please see Overlay Schema for further detail.

- Annex A.0: Common SPD Bytes for All Module Types
- Annex A.1: Solder down memory applications
- Annex A.2: UDIMMs
- Annex A.3: RDIMM and LRDIMM
- Annex A.4: MRDIMM
- Annex A.5: DDIMM
- Annex A.6: NVDIMM-N
- Annex A.7: NVDIMM-P

4 Overlay Schema

The following Schema exemplifies the manner in which the base configuration information along with the Annexes are to be overlaid onto the appropriate address spaces in order to provide a complete definition of the module.

4.1 Solder Down Overlay Schema

Key Byte 3 contains any of the following values:

- 0x0B, Solder Down

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.1: Solder Down
4	256~319	0x100~0x13F	Insert Annex A.1: Solder Down
5	320~383	0x140~0x17F	Insert Annex A.1: Solder Down
6	384~447	0x180~0x1BF	Insert Annex A.1: Solder Down
7~15	448~1023	0x180~0x3FF	...

4.2 UDIMM Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0x02, UDIMM
- 0x03, SODIMM

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.2: Unbuffered Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.2: Unbuffered Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.2: Unbuffered Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.2: Unbuffered Memory Module Types
7~15	448~1023	0x180~0x3FF	...

4.3 RDIMM and LRDIMM Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0x01, RDIMM
- 0x04, LRDIMM

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.3: Registered and Load Reduced Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.3: Registered and Load Reduced Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.3: Registered and Load Reduced Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.3: Registered and Load Reduced Memory Module Types
7~15	448~1023	0x180~0x3FF	...

4.4 MRDIMM Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0x07, MRDIMM

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.4: Multiplexed Rank Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.4: Multiplexed Rank Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.4: Multiplexed Rank Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.4: Multiplexed Rank Memory Module Types
7~15	448~1023	0x180~0x3FF	...

4.5 DDIMM Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0x07, DDIMM

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.5: Differential Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.5: Differential Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.5: Differential Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.5: Differential Memory Module Types
7~15	448~1023	0x180~0x3FF	...

4.6 NVDIMM-N Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0x9X, NVDIMM-N Hybrid

where X refers to the base memory architecture

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.6: NVDIMM-N Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.6: NVDIMM-N Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.6: NVDIMM-N Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.6: NVDIMM-N Memory Module Types
7~15	448~1023	0x180~0x3FF	...

4.7 NVDIMM-P Overlay Schema

Key Byte 2 contains value 0x12 (DDR5)

Key Byte 3 contains any of the following values:

- 0xAX, NVDIMM-P Hybrid

where X refers to the base memory architecture

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	...
3	192~239	0x0C0~0x0EF	Insert Annex A.0: Common
	240~255	0x0D0~0x0FF	Insert Annex A.7: NVDIMM-P Memory Module Types
4	256~319	0x100~0x13F	Insert Annex A.7: NVDIMM-P Memory Module Types
5	320~383	0x140~0x17F	Insert Annex A.7: NVDIMM-P Memory Module Types
6	384~447	0x180~0x1BF	Insert Annex A.7: NVDIMM-P Memory Module Types
7~15	448~1023	0x180~0x3FF	...

5 Parsing the SPD

Some Relevant SPD Bytes for Parsing	
SPD Byte(s)	Definition
1	SPD revision for the base section of the SPD
2	DRAM interface type presented or emulated
3	Memory module interface type
0~125	Base configuration and DRAM parameters
192	SPD revision for the module specific annex
192~239	Common module parameters
240~445	Module specific parameters
510~511	CRC for bytes 0~509

The system BIOS will acquire information from the SPD in order to properly configure the system's memory controller. It is assumed the BIOS will parse the SPD data in the order listed below.

Step 1: Parse Byte 1 - Verify the SPD contents.

The first step is to verify the validity of the contents of the SPD. Calculate and verify that the 16-bit cyclic redundancy check (CRC) for bytes 0~509 matches the CRC stored in bytes 510~511.

Step 2: Parse Byte 2 - Verify the installed DRAM type is supported.

The first step in parsing the SPD is to verify that the DRAM type installed is supported by looking at DRAM device type byte 2. While it is usually not possible to physically plug in the wrong memory type, for example a DDR3 module size or key location should prevent insertion into a DDR5 system, there are cases where byte 2 is used to prevent accidental use of an incompatible memory type.

Step 3: Parse Byte 1 - Verify SPD compatibility. See Section 6 - SPD Revision Progression

The SPD revision byte 1 "encoding" nibble may be used to force legacy systems to reject newer modules. This would typically only occur if a critical error were found in SPD encoding that would require a "fix". In this case, as in the case of an unsupported DRAM type, system initialization must be halted immediately.

The SPD revision stored in Byte 1 applies to all information for the module, including base information and module specific information. Each SPD revision exactly defines how many bytes are valid in all other SPD blocks. The number of supported bytes (or bits) may increase from one SPD revision to another within each block as indicated by the "additions" nibble of the SPD revision. For example, an SPD revision 1.3 has more bytes or bits defined than SPD revision 1.2.

This progression of SPD contents is important for the BIOS to DIMM compatibility model. An older system may have a BIOS that only understands SPD revision 1.2 encoding, so if a module is installed that contains revision 1.3 information, the system can accurately interpret all of the historical revision 1.2 information retained in the module that is the subset of the revision 1.3 specification. Similarly, if a module with SPD revision 1.1 information is installed, that same BIOS can interpret all information that was current at the time that SPD 1.1 was defined. Therefore, BIOSes must maintain a knowledge of the active information for each historical SPD revision in order to support older modules.

5 Parsing the SPD (cont'd)

New in DDR5 SPD contents definition is a separate revision byte for sections of the contents. For example, the revision byte 1 covers only the base configuration information blocks, bytes 0 to 127. There is a separate revision byte for other sections such as the standard module parameters in bytes 192-447. The same scheme of contents and additions nibbles is used in each of these sections to allow forward and backward compatibility. Having separate revision levels in various sections of the SPD contents allows those sections to change independently.

Step 4: Parse Byte 3 - Determine module type and appropriate overlays.

Key byte 3 for module type determines the subsequent use of overlay information. Byte 3 defines the host to module interface style: unbuffered, registered, load reduced, differential, or hybrid. Standard module types are defined in Annexes A.x.

Step 5: Parse Bytes 0~127 - Make base configuration settings to memory interface based on these bytes.

All module types are required to read and interpret this block of data to set up the DRAM type, maximum operating frequency, the number of row, column, bank bits, write recovery time, etc. While these bytes primarily describe the timing of the DRAMs, timing represents the capabilities of the module and it may be necessary to downgrade the timing based on other factors including layout or support components on the module, such as registers.

Step 6: Parse Byte 192 - Module-specific annex SPD revision.

This byte determines the encoding level and additions level of the module specific bytes of the SPD. Separating the base section of the SPD and module specific section prevents unnecessary churn; for example, if the UDIMM annex changes, the SPD for RDIMM/LRDIMM module need not change.

Step 7: Parse Bytes 193~447 - Configure standard module memory interface.

These bytes will be referenced and used by the system as needed based on the Standard module type that was determined after Byte 3 was parsed as indicated in Step 2. Bytes 192~239 are common byte definitions for all module types as defined in Annex A.0. Bytes 240~447 are coded differently for each standard module type as defined in Annex A.x.

6 SPD Revision Progression

SPD Contents sections have a revision code for that section of the specification. This allows each section to evolve over time independently as much as possible. For example a system may need to parse one revision level for the Base Configuration section (bytes 0~127) and a different revision level for the Standard Module Parameters section (bytes 192-447).

Hypothetical SPD Revision Progression Showing Revision Relationships		
Section	Bytes	Revision Byte
Base Configuration and SDRAM Parameters	0~127	1
Standard Module Parameters	192~447	192

The Additions Level is never reduced even after an increment of the Encoding Level. For example, if the current SPD revision level were 1.2 and a change in Encoding Level were approved, the next revision level would be 2.2. If additions to revision 2.2 were approved, the next revision would be 2.3. Changes in the Encoding Level are extremely rare, however, since they can create incompatibilities with older systems.

The exceptions to the above rule are the SPD revision levels used during development prior to the Revision 1.0 release. Revisions 0.0 through 0.9 are used to indicate sequential pre-production SPD revision levels, however the first production release will be Revision 1.0.

6 SPD Revision Progression (cont'd)

A hypothetical progression is shown to illustrate the relationship between feature updates, typographical error corrections, specification revisions, and dates. In order to reduce the number of module requalifications, policy is to issue SPD releases once per year, typically in June (publication to the JEDEC public site typically takes an additional 3 months from committee approval).

Year	Description	Document	Release Date	SPD Byte 1	SPD Byte 192						
				Base	Solder Down	UDIMM	RDIMM/ LRDIMM	MRDIMM	DDIMM	NVDIMM-N	NVDIMM-P
0	Initial SPD document release	JESD400-5	June 2021	1.0	1.0	1.0	1.0	N/A	1.0	0.1	0.1
0	Typographical fixes	JESD400-5	September 2021	1.0	1.0	1.0	1.0	N/A	1.0	0.1	0.1
0	Typographical fixes	JESD400-5	December 2021	1.0	1.0	1.0	1.0	N/A	1.0	0.1	0.1
1	Additions to base, RDIMM Add MRDIMM First release NVDIMM-P Pre-production additions to NVDIMM-N	JESD400-5A	June 2022	1.1	1.0	1.0	1.1	1.0	1.0	0.2	1.0
1	Typographical fixes	JESD400-5A	September 2022	1.1	1.0	1.0	1.1	1.0	1.0	0.2	1.0
1	Typographical fixes	JESD400-5A	March 2023	1.1	1.0	1.0	1.1	1.0	1.0	0.2	1.0
2	Additions to base, RDIMM, DDIMM Additions to NVDIMM-P First release NVDIMM-N	JESD400-5B	June 2023	1.2	1.0	1.0	1.2	1.0	1.1	1.0	1.1
3	Additions to base	JESD400-5C	June 2024	1.3	1.0	1.0	1.2	1.0	1.1	1.0	1.1
3	Typographical fixes	JESD400-5C	March 2025	1.3	1.0	1.0	1.2	1.0	1.1	1.0	1.1
4	Additions to base, NVDIMM-N	JESD400-5D	June 2025	1.4	1.0	1.0	1.2	1.0	1.1	1.1	1.1

7 Address Map

The following is the SPD address map for all DDR5 modules. It describes where the individual lookup table entries will be held in the serial non-volatile memory. Consistent with the definition of DDR5 generation SPD devices which have 16 individual write protection blocks of 64 bytes in length each, the SPD contents are aligned with these blocks as follows:

Block	Range		Description
0	0~63	0x000~0x03F	Base Configuration and DRAM Parameters
1	64~127	0x040~0x07F	Base Configuration and DRAM Parameters
2	128~191	0x080~0x0BF	Reserved for future use
3	192~239	0x0C0~0x0EF	Common Module Parameters -- See Annex A.0 for details
	240~255	0x0D0~0x0FF	Standard Module Parameters -- See annexes A.x for details
4	256~319	0x100~0x13F	Standard Module Parameters -- See annexes A.x for details
5	320~383	0x140~0x17F	Standard Module Parameters -- See annexes A.x for details
6	384~447	0x180~0x1BF	Standard Module Parameters -- See annexes A.x for details
7	448~509	0x1C0~0x1FD	Reserved for future use
	510~511	0x1FE~0x1FF	CRC for bytes 0~509
8	512~575	0x200~0x23F	Manufacturing Information
9	576~639	0x240~0x27F	Manufacturing Information
10	640~703	0x280~0x2BF	End User Programmable
11	704~767	0x2C0~0x2FF	End User Programmable
12	768~831	0x300~0x33F	End User Programmable
13	832~895	0x340~0x37F	End User Programmable
14	896~959	0x380~0x3BF	End User Programmable
15	960~1023	0x3C0~0x3FF	End User Programmable

After programming the SPD contents, suppliers of JEDEC compliant modules must set the write protect bits for SPD device blocks 0 through 7. See the SPD5xx8 Device Specification for details on the block protect command protocol.

Beginning with modules supporting JESD400-5 DDR5 SPD Contents Specification Revision 1.1 or higher, write protect must also be asserted after programming on block 8 in addition to write protect on blocks 0 through 7.

7 Address Map (cont'd)

7.1 Blocks 0~1: Base Configuration and DRAM Parameters

Table 1 details the location of each byte in this block.

Table 1 — Blocks 0~1: Base Configuration and DRAM Parameters

Byte Number		Function Described	Notes
0	0x000	Number of Bytes in SPD Device and Beta Level	
1	0x001	SPD Revision for Base Configuration Parameters	
2	0x002	Key Byte / Host Bus Command Protocol Type	
3	0x003	Key Byte / Module Type	
4	0x004	First SDRAM Density and Package	1
5	0x005	First SDRAM Addressing	1
6	0x006	First SDRAM I/O Width	1
7	0x007	First SDRAM Bank Groups and Banks Per Bank Group	1
8	0x008	Second SDRAM Density and Package	1
9	0x009	Second SDRAM Addressing	1
10	0x00A	Second SDRAM I/O Width	1
11	0x00B	Second SDRAM Bank Groups and Banks Per Bank Group	1
12	0x00C	SDRAM BL32 and Post Package Repair	1
13	0x00D	SDRAM Duty Cycle Adjuster and Partial Array Self Refresh	1
14	0x00E	SDRAM Fault Handling	1
15	0x00F	Reserved	
16	0x010	SDRAM Nominal Voltage, VDD	1
17	0x011	SDRAM Nominal Voltage, VDDQ	1
18	0x012	SDRAM Nominal Voltage, VPP	1
19	0x013	SDRAM Timing	1
20	0x014	SDRAM Minimum Cycle Time ($t_{CKAVGmin}$), Least Significant Byte	1
21	0x015	SDRAM Minimum Cycle Time ($t_{CKAVGmin}$), Most Significant Byte	1
22	0x016	SDRAM Maximum Cycle Time ($t_{CKAVGmax}$), Least Significant Byte	1
23	0x017	SDRAM Maximum Cycle Time ($t_{CKAVGmax}$), Most Significant Byte	1
24	0x018	CAS Latencies Supported, First Byte	1
25	0x019	CAS Latencies Supported, Second Byte	1
26	0x01A	CAS Latencies Supported, Third Byte	1
27	0x01B	CAS Latencies Supported, Fourth Byte	1
28	0x01C	CAS Latencies Supported, Fifth Byte	1
29	0x01D	Reserved	1
30	0x01E	SDRAM Minimum CAS Latency Time (t_{AAmin}), Least Significant Byte	1
31	0x01F	SDRAM Minimum CAS Latency Time (t_{AAmin}), Most Significant Byte	1
32	0x020	SDRAM Minimum RAS to CAS Delay Time (t_{RCDmin}), Least Significant Byte	1
33	0x021	SDRAM Minimum RAS to CAS Delay Time (t_{RCDmin}), Most Significant Byte	1
NOTE 1 From DDR5 SDRAM datasheet.			

Table 1 — Blocks 0~1: Base Configuration and DRAM Parameters (cont'd)

Byte Number		Function Described	Notes
34	0x022	SDRAM Minimum Row Precharge Delay Time (t_{RPmin}), Least Significant Byte	1
35	0x023	SDRAM Minimum Row Precharge Delay Time (t_{RPmin}), Most Significant Byte	1
36	0x024	SDRAM Minimum Active to Precharge Delay Time (t_{RASmin}), Least Significant Byte	1
37	0x025	SDRAM Minimum Active to Precharge Delay Time (t_{RASmin}), Most Significant Byte	1
38	0x026	SDRAM Minimum Active to Active/Refresh Delay Time (t_{RCmin}), Least Significant Byte	1
39	0x027	SDRAM Minimum Active to Active/Refresh Delay Time (t_{RCmin}), Most Significant Byte	1
40	0x28	SDRAM Minimum Write Recovery Time (t_{WRmin}), Least Significant Byte	1
41	0x29	SDRAM Minimum Write Recovery Time (t_{WRmin}), Most Significant Byte	1
42	0x2A	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFC1min}$, $t_{RFC1slrmin}$), Least Significant Byte	1
43	0x2B	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFC1min}$, $t_{RFC1slrmin}$), Most Significant Byte	1
44	0x02C	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFC2min}$, $t_{RFC2slrmin}$), Least Significant Byte	1
45	0x02D	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFC2min}$, $t_{RFC2slrmin}$), Most Significant Byte	1
46	0x02E	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFCsbmin}$, $t_{RFCsbslrmin}$), Least Significant Byte	1
47	0x02F	SDRAM Minimum Refresh Recovery Delay Time ($t_{RFCsbdlrmin}$), Most Significant Byte	1
48	0x030	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFC1dlrmin}$), Least Significant Byte	1
49	0x031	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFC1dlrmin}$), Most Significant Byte	1
50	0x032	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFC2dlrmin}$), Least Significant Byte	1
51	0x033	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFC2dlrmin}$), Most Significant Byte	1
52	0x034	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFCsbdlrmin}$), Least Significant Byte	1
53	0x035	SDRAM Minimum Refresh Recovery Delay Time, 3DS Different Logical Rank ($t_{RFCsbdlrmin}$), Most Significant Byte	1
54	0x036	SDRAM Refresh Management, First Byte, First SDRAM	1
55	0x037	SDRAM Refresh Management, Second Byte, First SDRAM	1
56	0x038	SDRAM Refresh Management, First Byte, Second SDRAM	1
57	0x039	SDRAM Refresh Management, Second Byte, Second SDRAM	1
58	0x03A	SDRAM Adaptive Refresh Management Level A, First Byte, First SDRAM	1
59	0x03B	SDRAM Adaptive Refresh Management Level A, Second Byte, First SDRAM	1
60	0x03C	SDRAM Adaptive Refresh Management Level A, First Byte, Second SDRAM	1
61	0x03D	SDRAM Adaptive Refresh Management Level A, Second Byte, Second SDRAM	1
62	0x03E	SDRAM Adaptive Refresh Management Level B, First Byte, First SDRAM	1
63	0x03F	SDRAM Adaptive Refresh Management Level B, Second Byte, First SDRAM	1
64	0x040	SDRAM Adaptive Refresh Management Level B, First Byte, Second SDRAM	1
65	0x041	SDRAM Adaptive Refresh Management Level B, Second Byte, Second SDRAM	1
NOTE 1 From DDR5 SDRAM datasheet.			

Table 1 — Blocks 0~1: Base Configuration and DRAM Parameters (cont'd)

Byte Number		Function Described	Notes
66	0x042	SDRAM Adaptive Refresh Management Level C, First Byte, First SDRAM	1
67	0x043	SDRAM Adaptive Refresh Management Level C, Second Byte, First SDRAM	1
68	0x044	SDRAM Adaptive Refresh Management Level C, First Byte, Second SDRAM	1
69	0x045	SDRAM Adaptive Refresh Management Level C, Second Byte, Second SDRAM	1
70	0x046	SDRAM Minimum Active to Active Command Delay Time, Same Bank Group (t_{RRD_Lmin}), Least Significant Byte	1
71	0x047	SDRAM Minimum Active to Active Command Delay Time, Same Bank Group (t_{RRD_Lmin}), Most Significant Byte	1
72	0x048	SDRAM Minimum Active to Active Command Delay Time, Same Bank Group (t_{RRD_Lmin}), Lower Clock Limit	1
73	0x049	SDRAM Minimum Read to Read Command Delay Time, Same Bank Group (t_{CCD_Lmin}), Least Significant Byte	1
74	0x04A	SDRAM Minimum Read to Read Command Delay Time, Same Bank Group (t_{CCD_Lmin}), Most Significant Byte	1
75	0x04B	SDRAM Minimum Read to Read Command Delay Time, Same Bank Group (t_{CCD_Lmin}), Lower Clock Limit	1
76	0x04C	SDRAM Minimum Write to Write Command Delay Time, Same Bank Group ($t_{CCD_L_WRmin}$), Least Significant Byte	1
77	0x04D	SDRAM Minimum Write to Write Command Delay Time, Same Bank Group ($t_{CCD_L_WRmin}$), Most Significant Byte	1
78	0x04E	SDRAM Minimum Write to Write Command Delay Time, Same Bank Group ($t_{CCD_L_WRmin}$), Lower Clock Limit	1
79	0x04F	SDRAM Minimum Write to Write Command Delay Time, Second Write not RMW, Same Bank Group ($t_{CCD_L_WR2min}$), Least Significant Byte	1
80	0x050	SDRAM Minimum Write to Write Command Delay Time, Second Write not RMW, Same Bank Group ($t_{CCD_L_WR2min}$), Most Significant Byte	1
81	0x051	SDRAM Minimum Write to Write Command Delay Time, Second Write not RMW, Same Bank Group ($t_{CCD_L_WR2min}$), Lower Clock Limit	1
82	0x052	SDRAM Minimum Four Activate Window (t_{FAWmin}), Least Significant Byte	1
83	0x053	SDRAM Minimum Four Activate Window (t_{FAWmin}), Most Significant Byte	1
84	0x054	SDRAM Minimum Four Activate Window (t_{FAWmin}), Lower Clock Limit	1
85	0x055	SDRAM Minimum Write to Read Command Delay Time, Same Bank Group, ($t_{CCD_L_WTRmin}$), Least Significant Byte	1
86	0x056	SDRAM Minimum Write to Read Command Delay Time, Same Bank Group, ($t_{CCD_L_WTRmin}$), Most Significant Byte	1
87	0x057	SDRAM Minimum Write to Read Command Delay Time, Same Bank Group, ($t_{CCD_L_WTRmin}$), Lower Clock Limit	1
88	0x058	SDRAM Minimum Write to Read Command Delay Time, Different Bank Group, ($t_{CCD_S_WTRmin}$), Least Significant Byte	1
89	0x059	SDRAM Minimum Write to Read Command Delay Time, Different Bank Group, ($t_{CCD_S_WTRmin}$), Most Significant Byte	1
90	0x05A	SDRAM Minimum Write to Read Command Delay Time, Different Bank Group, ($t_{CCD_S_WTRmin}$), Lower Clock Limit	1
91	0x05B	SDRAM Minimum Read to Precharge Command Delay Time, (t_{RTPmin}), Least Significant Byte	1
NOTE 1 From DDR5 SDRAM datasheet.			

Table 1 — Blocks 0~1: Base Configuration and DRAM Parameters (cont'd)

Byte Number		Function Described	Notes
92	0x05C	SDRAM Minimum Read to Precharge Command Delay Time, (t_{RTPmin}), Most Significant Byte	1
93	0x05D	SDRAM Minimum Read to Precharge Command Delay Time, (t_{RTPmin}), Lower Clock Limit	1
94~127	0x05E~0x07F	Reserved -- must be coded as 0x00	
NOTE 1 From DDR5 SDRAM datasheet.			

7.2 Block 2: Reserved for Future Use

7.3 Blocks 3~6: Module Specific Parameters

Bytes 192~447 (0x0C0~0x1BF) parameters in this block are specific to the module type as selected by the contents of SPD Key Byte 3 bits 3~0. Refer to the appropriate annex for detailed byte descriptions.

7.4 Block 7: Reserved for Future Use

Bytes 192~509 are reserved and must be programmed as 0.

Byte 510 (0x1FE): Cyclical Redundancy Code (CRC) for SPD Bytes 0~509, Least Significant Byte

Byte 511 (0x1FF): Cyclical Redundancy Code (CRC) for SPD Bytes 0~509, Most Significant Byte

This two-byte field contains the calculated CRC for bytes 0~509 (0x000~0x1FD) in the SPD. The following algorithm and data structures (shown in C) are to be followed in calculating and checking the code.

```
int Crc16 (char *ptr, int count)
{
    int crc, i;

    crc = 0;
    while (--count >= 0) {
        crc = crc ^ (int)*ptr++ << 8;
        for (i = 0; i < 8; ++i)
            if (crc & 0x8000)
                crc = crc << 1 ^ 0x1021;
            else
                crc = crc << 1;
    }
    return (crc & 0xFFFF);
}

char spdBytes[] = { SPD_byte_0, SPD_byte_1, ..., SPD_byte_N-1 };
int data16;

data16 = Crc16 (spdBytes, sizeof(spdBytes));
SPD_byte_510 = (char) (data16 & 0xFF);
SPD_byte_511 = (char) (data16 >> 8);
```

7.5 Blocks 8~9: Manufacturing Information

Bytes 512~639 (0x200~0x27F). **Table 2** details the location of each byte in this block.

Table 2 — Blocks 8~9 Byte Location

Byte Number		Function Described	Notes
512	0x200	Module Manufacturer's ID Code, First Byte	1
513	0x201	Module Manufacturer's ID Code, Second Byte	1
514	0x202	Module Manufacturing Location	1
515~516	0x203~0x204	Module Manufacturing Date	1
517~520	0x205~0x208	Module Serial Number	1
521~550	0x209~0x226	Module Part Number	1
551	0x227	Module Revision Code	
552	0x228	DRAM Manufacturer's ID Code, First Byte	1
553	0x229	DRAM Manufacturer's ID Code, Second Byte	1
554	0x22A	DRAM Stepping	
555~637	0x22B~0x27D	Module Manufacturer's Specific Data	
NOTE1 Required byte.			

7.6 Blocks 10~15: End User Programmable

Bytes 640~1023 (0x280~0x3FF) Bytes in these blocks are reserved for use by end users. Module manufacturers should not assert write protect on blocks 10~15 unless requested to do so by customers.

7.7 ASCII Decode Matrix for SPDs

Table 3 is a subset of the full ASCII standard which is used for coding bytes in the Serial Presence Detect EEPROM that require ASCII characters:

Table 3 — Subset of Full ASCII Standard

	Second Hex Digit in Pair															
First Hex Digit in Pair	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
2	Blank Space								()				- Dash	.	Period
3	0	1	2	3	4	5	6	7	8	9						
4		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z					_ Underscore
6		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z					

Examples:

- 0x20 = Blank Space
- 0x34 = '4'
- 0x41 = 'A'

SPD Bytes 521~550	
Manufacturer's PN	Coded in ASCII
13M32734BCD-260Y	31334D333237333344243442D323630592020

8 Details of Each Byte

8.1 Blocks 0 and 1: General Configuration Section: Bytes 0~127 (0x000~0x07F)

This clause contains defined parameters that are common to all DDR5 module types with DDR5 SDRAM as the media type, and provides “key bytes” to allow overlay of module specific information. These bytes are defined when Key Byte 2 contains 18 (0x12), DDR5 SDRAM.

8.1.1 Byte 0 (0x000): Number of Bytes in SPD Device and Beta Level

The least significant nibble of this byte describes the total number of bytes used by the module manufacturer for the SPD data and any (optional) specific supplier information. The byte count includes the fields for all required and optional data. Bits 6~4 describe the total size of the serial memory used to hold the Serial Presence Detect data. Bits 7,3~0 define the Beta Level of the SPD encoding.

Number of Bytes in SPD Device		
Bit 7	Bits 6~4	Bits 3~0
Beta Level 4	SPD Bytes Total	Beta Level 3~0
See bits 3~0	000: Undefined 001: 256 010: 512 011: 1024 (e.g., SPD5118) 100: 2048 (e.g., ESPD5216) All others reserved	Bits 7, 3~0: Beta Level Values 0 to 31
NOTE The 5-bit Beta Level field (bit 7 and bits 3~0) is the incremental documentation release level to track changes between major external publications of the SPD Contents specification, typically done once per year. This value shall be reset to 00000 upon each external release and will be visible only to JEDEC members between releases. The Beta Level applies to all sections of the document, including DRAM and module annex sections.		

8.1.2 Byte 1 (0x001): SPD Revision for Base Configuration Parameters

This byte describes the compatibility level of the encoding of the bytes contained in the SPD EEPROM, and the current collection of valid defined bytes. Software should examine the upper nibble (Encoding Level) to determine if it can correctly interpret the contents of the module SPD. The lower nibble (Additions Level) can optionally be used to determine which additional bytes or attribute bits have been defined; however, since any undefined additional byte must be encoded as 0x00 or undefined attribute bit must be defined as 0, software can safely detect additional bytes and use safe defaults if a zero encoding is read for these bytes.

8.1.2 Byte 1 (0x001): SPD Revision for Base Configuration Parameters (cont'd)

SPD Revision for Base Configuration Parameters										
Production Status	SPD Revision	Encoding Level				Additions Level				Hex
		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
Pre-production	Revision 0.0	0	0	0	0	0	0	0	0	00
	Revision 0.1	0	0	0	0	0	0	0	1	01

	Revision 0.9	0	0	0	0	1	0	0	1	09
Production	Revision 1.0	0	0	0	1	0	0	0	0	10
	Revision 1.1	0	0	0	1	0	0	0	1	11

Undefined	Undefined	1	1	1	1	1	1	1	1	FF

The Additions Level is never reduced even after an increment of the Encoding Level. For example, if the current SPD revision level were 1.2 and a change in Encoding Level were approved, the next revision level would be 2.2. If additions to revision 2.2 were approved, the next revision would be 2.3. Changes in the Encoding Level are extremely rare, however, since they can create incompatibilities with older systems.

The exceptions to the above rule are the SPD revision levels used during development prior to the Revision 1.0 release. Revisions 0.0 through 0.9 are used to indicate sequential pre-production SPD revision levels, however the first production release will be Revision 1.0.

Revisions for each module specific overlay are coded in the same format so that each module type can evolve over time independent of the base configuration parameters section.

The Beta Level (SPD byte 0, bits 7,3~0) may also be used to decode changes made since the last external publication of the SPD Contents.

8.1.3 Byte 2 (0x002): Key Byte / Host Bus Command Protocol Type

This byte is the key byte used by the system BIOS to determine how to interpret all other bytes in the SPD EEPROM. The BIOS must check this byte first to ensure that the EEPROM data is interpreted correctly. This command protocol is often based on the interface parameters for a specific memory device such as a DDR5 SDRAM, however may also be a general media interface protocol such as DDR5 NVDIMM-P. Protocol extensions such as the use of registers or data buffers must be documented in Byte 3, the Module Type byte, and such differences comprehended and accounted for by the system and memory controller. Some non-DRAM solutions called “Hybrid” use an extension of a DRAM bus protocol, such as NVDIMM-N, and use the code for the emulated DRAM protocol in this byte, such as DDR4 SDRAM.

Table 4 — Key Byte / Host Bus Command Protocol Type

Key Byte / Host Bus Command Protocol Type		
Line #	Hex	SDRAM / Module Type Corresponding to Key Byte
0	00	Reserved
1	01	Fast Page Mode
2	02	EDO
3	03	Pipelined Nibble
4	04	SDRAM
5	05	ROM
6	06	DDR SGRAM
7	07	DDR SDRAM
8	08	DDR2 SDRAM
9	09	DDR2 SDRAM FB-DIMM
10	0A	DDR2 SDRAM FB-DIMM PROBE
11	0B	DDR3 SDRAM
12	0C	DDR4 SDRAM
13	0D	Reserved
14	0E	DDR4E SDRAM
15	0F	LPDDR3 SDRAM
16	10	LPDDR4 SDRAM
17	11	LPDDR4X SDRAM
18	12	DDR5 SDRAM
19	13	LPDDR5 SDRAM
20	14	DDR5 NVDIMM-P
21	15	LPDDR5X SDRAM
-	-	-
253	FD	Reserved
254	FE	Reserved
255	FF	Reserved

8.1.4 Byte 3 (0x003): Key Byte / Module Type

This byte is a Key Byte used to index the module specific section of the SPD from bytes 512~639. Byte 3 bits 3~0 identifies the SDRAM memory module type, and bits 7~4 describe hybrid memory extensions.

Some modules may have no base memory, but will have only a secondary memory type. For example, a Flash-only memory module. These are classified as “hybrid” for the purposes of interpreting the SPD. Where base memory parameters apply to this class of hybrid module, these will be documented with those bytes in the base section.

Key Byte / Module Type		
Bit 7	Bits 6~4	Bits 3~0
Hybrid	Hybrid Media	Base Module Type
0: Not hybrid (Module is DRAM only) 1: Hybrid module (See bits 6~4 for hybrid type)	000: Not hybrid 001: NVDIMM-N Hybrid 010: NVDIMM-P Hybrid All other codes reserved	0000: Reserved 0001: RDIMM 0010: UDIMM 0011: SODIMM 0100: LRDIMM 0101: Reserved 0110: Reserved 0111: MRDIMM 1000: Reserved 1001: Reserved 1010: DDIMM 1011: Solder down 1100: Reserved 1101: Reserved 1110: Reserved 1111: Reserved
Base Module Type Definitions: Solder down: Direct attachment to memory controller RDIMM: Registered Dual In-Line Memory Module UDIMM: Unbuffered Dual In-Line Memory Module SODIMM: Unbuffered Small Outline Dual In-Line Memory Module LRDIMM: Load Reduced Dual In-Line Memory Module MRDIMM: Multiplexed Rank Dual In-Line Memory Module DDIMM: Differential Dual In-Line Memory Module Hybrid Memory Type Definitions: NVDIMM-N: Non-Volatile Dual In-Line Memory Module, Hybrid module with a DDR5 SDRAM interface with one or more non-DRAM components for data storage NVDIMM-P: Non-Volatile Dual In-Line Memory Module, Hybrid module with a DDR5 NVDIMM-P interface with one or more non-DRAM components for data storage		

Examples:

0x01: RDIMM, no hybrid memory present

0x91: RDIMM, NVDIMM-N hybrid memory present

0x94: LRDIMM, NVDIMM-N hybrid memory present

0x0B = soldered down memory, no hybrid memory present

8.1.5 Byte 4 (0x004): First SDRAM Density and Package

This byte describes the SDRAM package type, loading as seen by the system, and device density in Gbits. These values comes from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the even rank SDRAMs for asymmetrical memory configurations, or for all SDRAMs for symmetrical configurations.

First SDRAM Density and Package	
Bits 7~5	Bits 4~0
Die Per Package	SDRAM Density Per Die
000: 1 die; Monolithic SDRAM 001: 2 die; Dual-die package (DDP) 010: 2 die; 2H 3DS 011: 4 die; 4H 3DS 100: 8 die; 8H 3DS 101: 16 die; 16H 3DS All others reserved	00000: No memory; not defined 00001: 4 Gb 00010: 8 Gb 00011: 12 Gb 00100: 16 Gb 00101: 24 Gb 00110: 32 Gb 00111: 48 Gb 01000: 64 Gb All others reserved

8.1.6 Byte 5 (0x005): First SDRAM Addressing

This byte describes the number SDRAM column and row address bits. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the even rank SDRAMs for asymmetrical memory configurations, or for all SDRAMs for symmetrical configurations.

First SDRAM Addressing	
Bits 7~5	Bits 4~0
First SDRAM Column Address Bits	First SDRAM Row Address Bits
000: 10 columns 001: 11 columns All others reserved	00000: 16 rows 00001: 17 rows 00010: 18 rows All others reserved

8.1.7 Byte 6 (0x006): First SDRAM I/O Width

This byte describes the number SDRAM I/O bits (DQ) and the number of bank groups. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the even rank SDRAMs for asymmetrical memory configurations, or for all SDRAMs for symmetrical configurations.

First SDRAM I/O Width	
Bits 7~5	Bits 4~0
SDRAM I/O Width	Reserved
000: x4 001: x8 010: x16 011: x32 All others reserved	Reserved; must be coded as 00000

8.1.8 Byte 7 (0x007): First SDRAM Bank Groups and Banks Per Bank Group

This byte describes the number SDRAM banks per bank group. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the even rank SDRAMs for asymmetrical memory configurations, or for all SDRAMs for symmetrical configurations.

First SDRAM Bank Groups and Banks Per Bank Group		
Bits 7~5	Bits 4~3	Bits 2~0
First SDRAM Bank Groups	Reserved	First SDRAM Banks Per Bank Group
000: 1 bank group 001: 2 bank groups 010: 4 bank groups 011: 8 bank groups All others reserved	Reserved; must be coded as 00	000: 1 bank per bank group 001: 2 banks per bank group 010: 4 banks per bank group All others reserved

8.1.9 Byte 8 (0x008): Second SDRAM Density and Package

This byte describes the SDRAM package type, loading as seen by the system, and device density in Gbits. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the odd rank SDRAMs for asymmetrical memory configurations only.

Second SDRAM Density and Package	
Bits 7~5	Bits 4~0
Die Per Package	SDRAM Density Per Die
000: 1 die; Monolithic SDRAM 001: 2 die; Dual-die package (DDP) 010: 2 die; 2H 3DS 011: 4 die; 4H 3DS 100: 8 die; 8H 3DS 101: 16 die; 16H 3DS All others reserved	00000: No memory; not defined 00001: 4 Gb 00010: 8 Gb 00011: 12 Gb 00100: 16 Gb 00101: 24 Gb 00110: 32 Gb 00111: 48 Gb 01000: 64 Gb All others reserved
NOTE This byte is defined only for asymmetrical memory systems; for symmetrical systems this byte must be coded as 0x00.	

8.1.10 Byte 9 (0x009): Second SDRAM Addressing

This byte describes the number SDRAM column and row address bits. This byte describes the number SDRAM bank groups. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the odd rank SDRAMs for asymmetrical memory configurations only.

Second SDRAM Addressing	
Bits 7~5	Bits 4~0
Second SDRAM Column Address Bits	Second SDRAM Row Address Bits
000: 10 columns 001: 11 columns All others reserved	00000: 16 rows 00001: 17 rows 00010: 18 rows All others reserved
NOTE This byte is defined only for asymmetrical memory systems; for symmetrical systems this byte must be coded as 0x00.	

8.1.11 Byte 10 (0x00A): Secondary SDRAM I/O Width

This byte describes the number SDRAM I/O bits (DQ) and the number of bank groups. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the odd rank SDRAMs for asymmetrical memory configurations only.

Second SDRAM I/O Width	
Bits 7~5	Bits 4~0
SDRAM I/O Width	Reserved
000: x4 001: x8 010: x16 011: x32 All others reserved	Reserved; must be coded as 00000
NOTE This byte is defined only for asymmetrical memory systems; for symmetrical systems this byte must be coded as 0x00.	

8.1.12 Byte 11 (0x00B): Second SDRAM Bank Groups and Banks Per Bank Group

This byte describes the number SDRAM banks per bank group. These values come from the DDR5 SDRAM data sheet, JESD79-5. This byte applies to the odd rank SDRAMs for asymmetrical memory configurations only.

Second SDRAM Bank Groups and Banks Per Bank Group		
Bits 7~5	Bits 4~3	Bits 2~0
Second SDRAM Bank Groups	Reserved	Second SDRAM Banks Per Bank Group
000: 1 bank group 001: 2 bank groups 010: 4 bank groups 011: 8 bank groups All others reserved	Reserved; must be coded as 00	000: 1 bank per bank group 001: 2 banks per bank group 010: 4 banks per bank group All others reserved
NOTE This byte is defined only for asymmetrical memory systems; for symmetrical systems this byte must be coded as 0x00.		

8.1.13 Byte 12 (0x00C): SDRAM BL32 and Post Package Repair

This byte defines support for SDRAM features for burst length 32 (BL32) support and post package repair (PPR). These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM BL32 and Post Package Repair Features			
Bit 7	Bit 6	Bit 5	Bit 4
sPPR Granularity	Reserved	sPPR Undo/Lock	BL32
0 = One repair element per bank group 1 = One repair element per bank	Reserved; must be coded as 0	0: sPPR Undo/Lock not supported 1: sPPR Undo/Lock supported	0: Burst length 32 not supported 1: Burst length 32 supported
Bits 3~2		Bit 1	Bit 0
Reserved		MBIST/mPPR	Reserved
Reserved; must be coded as 00		0: MBIST/mPPR not supported 1: MBIST/mPPR supported	Reserved; must be coded as 0
ACRONYMS: MBIST = Memory Built-In Self Test PPR = Post Package Repair hPPR = Hard PPR sPPR = Soft PPR mPPR = MBIST PPR			

8.1.14 Byte 13 (0x00D): SDRAM Duty Cycle Adjuster and Partial Array Self Refresh

This byte describes the options for the DDR5 SDRAM duty cycle adjuster (DCA).

SDRAM Duty Cycle Adjuster			
Bits 7~5	Bit 4	Bits 3~2	Bits 1~0
Reserved	PASR	Reserved	DCA Types Supported
Reserved; must be coded as 0000	0: PASR not supported 1: PASR supported	Reserved; must be coded as 00	00 = Device does not support DCA 01 = Device supports DCA for single/2-phase internal clock(s) 10 = Device supports DCA for 4-phase internal clock(s) 11 = Reserved
ACRONYMS: PASR = Partial Array Self Refresh DCA = Duty Cycle Adjuster			

8.1.15 Byte 14 (0x00E): SDRAM Fault Handling and Temperature Sense

This byte defines support for SDRAM fault handling features and for wide on-die temperature sensing range (see MR4). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Fault Handling Features and Temperature Sense			
Bits 7~4			
Reserved; must be coded as 0000			
Bit 3	Bit 2	Bit 1	Bit 0
Wide Temperature Sense	x4 RMW/ECS Writeback Suppression	x4 RMW/ECS Writeback Suppression MR Selector	Bounded Fault
0: Wide temperature sense and reporting not supported 1: Wide temperature sense and reporting supported	0: Writeback suppression not supported 1: Writeback suppression supported	0: Writeback suppression control in MR9 1: Writeback suppression control in MR15	0: Bounded Fault not supported 1: Bounded Fault supported
ACRONYMS: ECS = Error Check Scrub RMW = Read-Modify-Write MR = Mode Register			

8.1.16 Byte 15 (0x00F): Reserved

Reserved - must be coded as 0x00.

8.1.17 Byte 16 (0x010): SDRAM Nominal Voltage, VDD

This byte describes the voltage levels for the SDRAM VDD supply only.

'Operable' is defined as the VDD voltage at which module operation is allowed using the performance values programmed in the SPD.

'Endurant' is defined as the VDD voltage at which the module may be powered without adversely affecting the life expectancy or reliability. Operation is not supported at this voltage.

SDRAM Nominal Voltage, VDD		
Nominal	Operable	Endurant
Bits 7~4	Bits 3~2	Bits 1~0
0000: 1.1 V All others reserved	00: 1.1 V All others reserved	00: 1.1 V All others reserved

8.1.18 Byte 17 (0x011): SDRAM Nominal Voltage, VDDQ

This byte describes the voltage levels for the SDRAM VDDQ supply only.

'Operable', 'Endurant': See Byte 16.

SDRAM Nominal Voltage, VDDQ		
Nominal	Operable	Endurant
Bits 7~4	Bits 3~2	Bits 1~0
0000: 1.1 V All others reserved	00: 1.1 V All others reserved	00: 1.1 V All others reserved

8.1.19 Byte 18 (0x012): SDRAM Nominal Voltage, VPP

This byte describes the voltage levels for the SDRAM VPP supply only.

'Operable', 'Endurant': See Byte 16.

SDRAM Nominal Voltage, VPP		
Nominal	Operable	Endurant
Bits 7~4	Bits 3~2	Bits 1~0
0000: 1.8 V All others reserved	00: 1.8 V All others reserved	00: 1.8 V All others reserved

8.1.20 Byte 19 (0x013): SDRAM Timing

This byte describes whether the SDRAM uses only standard core timings per JESD79-5, or non-standard timings for markets, such as overclocking systems. Core timings refer to tCKmin, tAAmin, tRCDmin, and tRPmin. This information assists in determining the most robust algorithm for calculating valid CAS latency settings.

SDRAM Timing	
Reserved	Non-Standard Core Timing
Bits 7~1	Bit 0
Reserved; must be coded as 0000000	0 = SDRAM uses standard core timings per JESD79-5 1 = SDRAM supports non-standard core timings

8.2 Timebases

Timebases in the DDR5 SPD are simplified compared to previous generations. Timing for parameters is expressed in either picosecond (ps) or nanosecond (ns) units. When programming memory controllers, it is often necessary to convert these timings to integer numbers of clocks (nCK) units. The algorithm for this conversion is described next.

8.3 Algorithms For Converting Time-based Parameters to Clock Counts

DDR5 SDRAM timing parameters are typically expressed in time units such as ns or ps, however digital logic design requires that these parameters be converted to a fixed number of clock periods “nCK” at the application frequency. The primary algorithm for this conversion is called the Rounding Algorithm, and it accounts for factors including errors caused by rounding and by digital integer expression or math calculation accuracy. The Rounding Algorithm is used for most parameters such as tRCDmin, tRCmin, tRFCmin, etc. A separate conversion called the CL Algorithm is defined specifically for determination of valid CAS Latency settings and accounts for factors including even latency requirements and unsupported CL settings.

The DDR5 SDRAM data sheet, JESD79-5, defines a baseline setting for timing that is common across vendors. However, specific devices in the industry may exceed the baseline timings for target markets such as point-to-point or overclocker systems. For these devices, the CL Algorithm may not apply, so specific rules are defined for determining valid CL settings. For non-standard SDRAMs, the memory supplier is expected to test for the additional boundary conditions created.

The guidelines for calculating CAS Latency are as follows:

- If Non-Standard Core Timing (SPD byte 19 bit 0) = 0 (i.e., the DRAM supports all JEDEC standard core timings), the preferred method for calculating valid CAS Latency settings is to use the CL Algorithm as it accounts for operation across a broad range of data rates including full speed or downbinning.
- Systems may prefer to use other methods to calculate CAS Latency settings, including applying the Rounding Algorithm on tAAmin (SPD bytes 30~31) to determine the desired CL setting, rounding up if necessary to ensure that only even nCK values are used, and applying the CAS Latency Mask (SPD bytes 24~28) to find a supported CL setting. If Non-Standard Core Timing (SPD byte 19 bit 0) = 1, the DRAM may support one or more exceptions or extensions of JEDEC standard core timings in which case other methods such as the Rounding Algorithm method described here are preferred to the CL Algorithm. Contact the memory supplier for details on supported CAS Latency conditions and recommended practices.

8.3.1 Rounding Algorithm

Software algorithms for calculation of timing parameters are subject to rounding errors from many sources. For example, a system may use a memory clock with a nominal frequency of 2200 MHz (4400 MT/s) for the DDR5-4400 speed bin, which mathematically yields a nominal clock period tCK(AVG) of 0.454545... ns. In most cases, it is impossible to express all digits after the decimal point exactly, and rounding must be used. The DDR5 SDRAM standard establishes a minimum granularity for timing parameters of 1 ps.

Rules for rounding must be defined to allow optimization of device performance without violating device parameters. All timing parameters specified in the time domain (ns, ps, etc.) which must then be converted to the clock domain (nCK units) shall be defined to align with these rules. The key point is, minimum and maximum timing parameter values shall generally use the same rounding rules used to define tCK(AVG)min and tCK(AVG)max. The resulting rounding algorithms rely on results that are within correction factors of device testing and specification to avoid losing performance due to rounding errors. These rules are:

8.3.1 Rounding Algorithm (cont'd)

- **DEFINING TIMING PARAMETER VALUES:** Minimum and maximum timing parameter values, including tCK(AVG)min and tCK(AVG)max, are to be rounded down and defined to 1 ps of accuracy in the DDR5 SDRAM specification based on the non-rounded nominal tCK(AVG) for a given speed bin. If the nominal timing parameter values require more than 1 ps of accuracy, they can be rounded down (faster) to the next 1 ps according to the rounding algorithms, and the DDR5SDRAM is responsible for absorbing this the resulting small parameter extensions. In other words, the DDR5 SDRAM specification only lists the nominal parameter values rounded down to the next 1 ps. For example, this extends the DDR5-4400 tCK(AVG)min definition to be exactly 0.454 ns, which is slightly smaller (faster) than the nominal memory clock period of 0.454545... ns by less than 1 ps.
- **CALCULATING THE REAL MINIMUM TIMING PARAMETER VALUES:** For minimum timing parameters, other than tCK(AVG)min, to avoid losing performance due to additional erroneous nCKs and to calculate the true real minimum values, their nominal values listed in the DDR5 SDRAM specification must be reduced (faster) by the maximum % error (correction factor) used to define tCK(AVG)min. The DDR5 SDRAM is responsible for absorbing the resulting small parameter extensions. For example, tWRmin has a nominal value of 30.000 ns, however, applying the 0.30% correction factor allows a more aggressive timing (for example, 29.910 ns) to be supported, which allows the intended smaller (faster) nCK value to be maintained when rounding tCK(AVG)min down to the next 1 ps. Note, parameter values defined to be 0 ps do not need to be reduced by a correction factor, and therefore do not require these rounding algorithms.
- **CALCULATING THE REAL MAXIMUM TIMING PARAMETER VALUES:** For maximum timing parameters, including tCK(AVG)max, to avoid losing performance due to excluding erroneous nCKs and to calculate the true real maximum values, their nominal values listed in the DDR5SDRAM specification must be increased (slower) by the maximum % error caused by rounding tCK(AVG) down to the next 1 ps. The DDR5 SDRAM is responsible for absorbing the resulting small parameter extensions. For example, tREFImax has a nominal value of 3.9 μ s; and the DDR5-8400 speed bin mathematically yields a nominal clock period tCK(AVG) of 0.238095... ns, resulting in a theoretical maximum % error of 0.42% (0.239 ns/0.238 ns-100%). So the true real tREFImax value is 3.916386... μ s (3.9 μ s*0.239 ns/0.238 ns) for the DDR5-8400 speed bin.
- **ROUNDING ALGORITHM FOR MINIMUM TIMING PARAMETER VALUES:** Round down only integer number math is commonly used in the industry to calculate nCK values. This rounding algorithm for minimum timing parameters uses scaling by 1000 to allow use of integer math. Nominal minimum timing parameters like tWRmin, tRCDmin, etc. which are programmed in systems in numbers of clocks (nCK) but expressed in units of time (ps), are rounded down to the next 1 ps, multiplied by the scaled inverse correction factor (1000 - 3 = 997) prior to division by the application memory clock period rounded down to the next 1 ps, and adding 1 scaled by 1000 to that result effectively adds 1 nCK. Division by 1000 undoes the scaling effects, resulting in a number of clocks as the final answer which has been effectively rounded up to the next 1 nCK by adding 1 nCK in the previous step and then rounding down to the next 1 nCK. The caveat is, effectively adding 1 prior to rounding down is mostly equivalent to rounding up except when the result is equal to an integer in which case the result won't be rounded down as intended, and therefore performance would be lost. To address this, the maximum 0.28% correction factor needed for 3600 MHz (0.277ns/0.277777...ns-100%) operation has been increased slightly to 0.30% in this rounding algorithm. This accounts for all integer boundary conditions, except for the specific case when the nominal minimum timing parameter value is defined to be 0 ps. No rounding is required for parameter values equal to 0 ps. This rounding algorithm is not optimized for parameter values that are less than or equal to 0 ps, and may result in unintended lost performance if used for parameter values that are less than or equal to 0 ps.

8.3.1 Rounding Algorithm (cont'd)

$$nCK[\text{min_parameter}] = \text{truncate} \left(\frac{\left(\frac{\text{truncate}[\text{nominal_min_parameter_in_ps}] \times 997}{\text{truncate}[\text{tCK(AVG)real_in_ps}]} + 1000 \right)}{1000} \right)$$

- **ROUNDING ALGORITHM FOR MAXIMUM TIMING PARAMETER VALUES:** Round down only integer number math is commonly used in the industry to calculate nCK values. This rounding algorithm is used for maximum timing parameters. Nominal maximum timing parameters like tREFImax, etc. which are programmed in systems in numbers of clocks (nCK) but expressed in units of time (ps), are rounded down to the next 1 ps prior to division by the application memory clock period rounded down to the next 1 ps, resulting in a number of clocks as the final answer which is rounded down to the next 1 nCK. No rounding is required for parameter values equal to 0 ps, but this rounding algorithm can still be used for parameter values equal to 0ps and no performance will be lost. This rounding algorithm is not optimized for parameter values that are less than 0 ps (negative parameter values), and may result in violating the parameter specification if used for parameter values that are less than 0 ps.

$$nCK[\text{max_parameter}] = \text{truncate} \left(\frac{\text{truncate}[\text{nominal_max_parameter_in_ps}]}{\text{truncate}[\text{tCK(AVG)real_in_ps}]} \right)$$

- **CL ALGORITHM FOR STANDARD SPEED BINS:** The rounding algorithms shall be used for all timing parameters when converting from the time domain (ns, ps, etc.) to the clock domain (nCK units), except for when converting tAA to CL. If these rounding algorithms are used to convert tAA to CL, they'll return invalid CL's for some cases when down clocking (and the DIMM SPD CL Mask does not protect against all of these cases). The proper setting of CL shall be determined by the memory controller, either by using the speed bin tables, or by using the CL algorithm, or by some other means. Refer to the Speed Bins and Operations section for more information. Note, the CL algorithm replaces the need to use the DIMM SPD CL Mask.
- **CL ALGORITHM FOR CUSTOM SPEED BINS:** If the DDR5 SDRAM supports non-standard tCK, tAA, tRCD, and tRP speed bin timings, the CL algorithm will still only return valid CL's as defined in the speed bin tables, which may not be the intended CL's for non-standard speed bins. In these cases, the rounding algorithms may need to be used to convert tAA to CL, instead of the CL algorithm. The CL returned by the rounding algorithms shall be incremented up to the next supported CL according to the DIMM SPD CL Mask. Consult the memory vendor for more information.

8.3.1 Rounding Algorithm (cont'd)

Example: Using round down only integer number math to convert $t_{WR(min)}$ from ps to nCK:

// This algorithm reduces the nominal minimum timing parameter value by a 0.30% correction factor,
// rounds tCK(AVG) down, calculates nCK, adds 1 nCK, and rounds nCK down to the next integer value

```
int TwrMin, Correction, ClockPeriod, TempTwr, TempNck, TwrInNck;
```

```
TwrMin      = 30000;                // tWRmin in ps
Correction   = 3;                   // 0.30% per the rounding algorithm
ClockPeriod = ApplicationTck;       // Clock period in ps is application specific
TempTwr     = TwrMin * (1000 - Correction); // Apply correction factor, scaled by 1000
TempNck     = TempTwr / ClockPeriod; // Initial nCK calculation, scaled by 1000
TempNck     = TempNck + 1000;       // Add 1, scaled by 1000, to effectively round up
TwrInNck    = (int)(TempNck / 1000); // Round down to next integer
```

Table 5 — Example 2, Using Round Down Only Integer Number Math

DDR5 Device Operating at Standard Application Frequencies Timing Parameter: $t_{WR(min)} = 30.000 \text{ ns} = 30000 \text{ ps}$					
Application Speed Grade	Device t_{WR}	Application tCK	Device t_{WR} / Application tCK	Device $t_{WR} * (1000 -$ Correction) / Application tCK + 1000	Truncate Corrected nCK / 1000
MT/s	ps	ps	nCK (real)	scaled nCK (corrected)	nCK (integer)
3200	30000	625	48.00	48856	48
3600	30000	555	54.05	54891	54
4000	30000	500	60.00	60820	60
4400	30000	454	66.08	66881	66
4800	30000	416	72.12	72899	72

8.3.2 CL Algorithm

The CL Algorithm specifically determines the valid CAS latency settings for SDRAMs with standard core timing values. This includes “downbinning”, i.e., operating the SDRAMs at data rates below the maximum data rate supported by a specific device bin. This algorithm selects up to four valid CAS Latency values based on the combination of the t_{Amin} value for the installed SDRAM, the actual clock period t_{CKreal} for the application data rate, and the valid CAS Latencies for standard JEDEC speeds. Some returned values may be RESERVED in which case a higher CAS Latency returned must be used – typically, the next higher CL value returned, though other values may be used to coordinate timing among various modules or memory channels. If no valid CL values are returned, i.e., all values are RESERVED, the algorithm has failed and other means must be used to determine a CAS Latency setting; contact your memory supplier for guidance. Similarly, if the four values returned are not sufficient for coordinating inter-module timings, other methods such as the CL Mask (SPD bytes 24~28) must be used to determine a common CL setting.

8.3.2 CL Algorithm (cont'd)

In pseudocode, the CL Algorithm is:

```
// Variables defined in the DDR5 SDRAM specification, JESD79-5
CorrFact = 0.30 // (%) Rounding Algorithm correction factor
ScaledCorrFact = 997 // Scaled correction factor (1000*(1-0.30%))
tCKreal = 1011-952, 682-238 // (ps) Real application tCK(AVG) (1980-2100MT/s, 2933-8400MT/s)
tAAmin MONO=14000-17500, 3DS=16000-20000 // (ps) From Speed Bin Tables and DIMM SPD bytes 30-31
tRCDtRPmin MONO=14000-17500, 3DS=14000-17500 // (ps) From Speed Bin Tables and DIMM SPD bytes 32-33 (tRCD=tRP)
tAAcorr = TRUNC(tAAmin*ScaledCorrFactor/1000) // (ps) Corrected tAA(min) per the Rounding Algorithm rules
tRCDtRPcorr = TRUNC(tRCDtRPmin*ScaledCorrFactor/1000) // (ps) Corrected tRCD(min), tRP(min) per the Rounding Algorithm
FUNC RA(targ) = TRUNC((targ*ScaledCorrFact/tCKstd+1000)/1000) // (nCK) Use Rounding Algorithm to convert bin target timing to nCK

// Round tCKreal down to the next faster standard frequency (tCK in ps)
IF (TRUNC(2000000/(2000*99%))>=TRUNC(tCKreal)>=TRUNC(2000000/(2000*105%))) // Check for 1980-2100 nominal data rates
    tCKstd=TRUNC(2000000/2000) // Assign standard 2000 tCK (ps)
ELSE IF (TRUNC(2000000/(2000*7*(133+(1/3))))>=TRUNC(tCKreal)>=TRUNC(2000000/3200)) // Check for 2933-3200 nominal data rates
    tCKstd=TRUNC(2000000/3200) // Assign standard 3200 tCK (ps)
ELSE
    FOR (DataRateNom=3200; DataRateNom<=8400; DataRateNom=DataRateNom+400) // Check for >3200-8400 nominal data rates
        IF (TRUNC(2000000/DataRateNom)>TRUNC(tCKreal)>=TRUNC(2000000/(DataRateNom+400)))
            tCKstd=TRUNC(2000000/(DataRateNom+400)) // Assign standard 3600-8800 tCK (ps)
        ELSE
            tCKstd=RESERVED // No valid data rate found

// Timing targets (ps) that have been used to define the Speed Bin Tables
// MONO targets // 3DS targets
BinAN_tAAtarg = 14000 BinAN_tAAtarg = 16000 // tAA target for AN bins
BinB__tAAtarg = 16000 BinB__tAAtarg = 18500 // tAA target for AN, B bins
BinBN_tAAtarg = 16000 BinBN_tAAtarg = 18500 // tAA target for AN, B, BN bins
BinC__tAAtarg = 17500 BinC__tAAtarg = 20000 // tAA target for AN, B, BN, C bins
BinAN_tRCDtRPtarg = 14000 BinAN_tRCDtRPtarg = 14000 // tRCD, tRP target for AN bins
BinBN_tRCDtRPtarg = 16000 BinBN_tRCDtRPtarg = 16000 // tRCD, tRP target for AN, B, BN bins
BinC__tRCDtRPtarg = 17500 BinC__tRCDtRPtarg = 17500 // tRCD, tRP target for AN, B, BN, C bins
IF (TRUNC(2000000/3600)>tCKstd) // tRCD, tRP target for B bins is frequency dependent
    BinB__tRCDtRPtarg = 16000 BinB__tRCDtRPtarg = 16000 // tRCD, tRP target for AN, B bins data rates faster than 3600
ELSE
    // 16250=(2000000/3200)*EVEN(TRUNC((BinB__tRCDtRPtarg*ScaledCorrFact/(2000000/3200)+1000)/1000))
    BinB__tRCDtRPtarg = 16250 BinB__tRCDtRPtarg = 16250 // tRCD, tRP target for AN, B bins for data rates 3600 and slower

// CL Algorithm using variables defined above
// Up to four valid CL's can be returned for a specific freq: CL(AN), CL(B), CL(BN), CL(C), depending on tAAmin, tRCDmin, tRPmin
// The B and BN bins return the same CL
// Only even CL's (not odd CL's) are valid per the DDR5 SDRAM specification
// nRCD, nRP are only even at standard native frequencies for the AN, BN bins (can be even or odd at intermediate frequencies)
// nRCD, nRP may be even or odd at standard native frequencies for the B, C bins (can be even or odd at intermediate frequencies)
IF (TRUNC(2000000/2000)=tCKstd) // CL22 is the only valid CL for 1980-2100 data rates
    CL(AN)=22 // Valid even CL for AN bins
    CL(B)=22 // Valid even CL for AN, B, bins
    CL(BN)=22 // Valid even CL for AN, B, BN bins
    CL(C)=22 // Valid even CL for AN, B, BN, C bins
ELSE IF (TRUNC(2000000/3200)>=tCKstd>=TRUNC(2000000/8800)) // Valid CL for 2933-8800 data rates
    IF ((EVEN(RA(BinAN_tAAtarg))*tCKstd>=tAAcorr)AND(EVEN(RA(BinAN_tRCDtRPtarg))*tCKstd>=tRCDtRPcorr)) // nRCD, nRP even only
        CL(AN)=EVEN(RA(BinAN_tAAtarg)) // Valid even CL for AN bins
        CL(B)=EVEN(RA(BinB__tAAtarg)) // Valid even CL for AN, B bins
        CL(BN)=EVEN(RA(BinBN_tAAtarg)) // Valid even CL for AN, B, BN bins
        CL(C)=EVEN(RA(BinC__tAAtarg)) // Valid even CL for AN, B, BN, C bins
    ELSE IF ((EVEN(RA(BinB__tAAtarg))*tCKstd>=tAAcorr)AND((RA(BinB__tRCDtRPtarg))*tCKstd>=tRCDtRPcorr)) // nRCD, nRP even, odd
        CL(AN)=RESERVED // Valid even CL for AN bins
        CL(B)=EVEN(RA(BinB__tAAtarg)) // Valid even CL for AN, B bins
        CL(BN)=EVEN(RA(BinBN_tAAtarg)) // Valid even CL for AN, B, BN bins
        CL(C)=EVEN(RA(BinC__tAAtarg)) // Valid even CL for AN, B, BN, C bins
    ELSE IF ((EVEN(RA(BinBN_tAAtarg))*tCKstd>=tAAcorr)AND(EVEN(RA(BinBN_tRCDtRPtarg))*tCKstd>=tRCDtRPcorr)) // nRCD, nRP even only
        CL(AN)=RESERVED // Valid even CL for AN bins
        CL(B)=RESERVED // Valid even CL for AN, B bins
        CL(BN)=EVEN(RA(BinBN_tAAtarg)) // Valid even CL for AN, B, BN bins
        CL(C)=EVEN(RA(BinC__tAAtarg)) // Valid even CL for AN, B, BN, C bins
    ELSE IF ((EVEN(RA(BinC__tAAtarg))*tCKstd>=tAAcorr)AND((RA(BinC__tRCDtRPtarg))*tCKstd>=tRCDtRPcorr)) // nRCD, nRP even, odd
        CL(AN)=RESERVED // Valid even CL for AN bins
        CL(B)=RESERVED // Valid even CL for AN, B bins
        CL(BN)=RESERVED // Valid even CL for AN, B, BN bins
        CL(C)=EVEN(RA(BinC__tAAtarg)) // Valid even CL for AN, B, BN, C bins
```

8.3.2 CL Algorithm (cont'd)

```

ELSE
    CL(AN)=RESERVED
    CL(B )=RESERVED
    CL(BN)=RESERVED
    CL(C )=RESERVED
ELSE
    CL(AN)=RESERVED
    CL(B )=RESERVED
    CL(BN)=RESERVED
    CL(C )=RESERVED

```

// No valid CL found (tAAmin, tRCDmin, tRPmin are too slow)
// Valid even CL for AN bins
// Valid even CL for AN, B bins
// Valid even CL for AN, B, BN bins
// Valid even CL for AN, B, BN, C bins
// No valid data rate found
// Valid even CL for AN bins
// Valid even CL for AN, B bins
// Valid even CL for AN, B, BN bins
// Valid even CL for AN, B, BN, C bins

8.4 SDRAM Minimum Cycle Time ($t_{CKAVGmin}$)

8.4.1 Byte 20 (0x014): Least Significant Byte

Byte 21 (0x015): Most Significant Byte

This 16-bit word defines the minimum cycle time for the SDRAM module, in picoseconds (ps). This number applies to all applicable components on the module. This byte applies to SDRAM and support components as well as the overall capability of the DIMM. This value comes from the DDR5 SDRAM data sheet, JESD79-5, and supports component data sheets.

SDRAM Minimum Cycle Time ($t_{CKAVGmin}$)	
ps	
Byte 21	Byte 20
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.5 SDRAM Maximum Cycle Time ($t_{CKAVGmax}$)

8.5.1 Byte 22 (0x016): Least Significant Byte

Byte 23 (0x017): Most Significant Byte

This 16-bit word defines the minimum cycle time for the SDRAM module, in picoseconds (ps). This number applies to all applicable components on the module. This byte applies to SDRAM and support components as well as the overall capability of the DIMM. This value comes from the DDR5 SDRAM data sheet, JESD79-5, and supports component data sheets.

SDRAM Maximum Cycle Time ($t_{CKAVGmax}$)	
ps	
Byte 23	Byte 22
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps. 0x0000: Reserved	

8.6 SDRAM CAS Latencies Supported

8.6.1 Byte 24 (0x018): First Byte

Byte 25 (0x019): Second Byte

Byte 26 (0x01A): Third Byte

Byte 27 (0x01B): Fourth Byte

Byte 28 (0x01C): Fifth Byte

These bytes define which CAS Latency (CL) values are supported with one bit per possible CAS Latency. A 1 in a bit position means that CL is supported, a 0 in that bit position means it is not supported. These values come from the DDR5 SDRAM, JESD79-5. CAS Latency Mask covers both DBI and non-DBI modes of operation.

SDRAM CAS Latencies Supported								
Byte 24	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CL =	34	32	30	28	26	24	22	20
Byte 25	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CL =	50	48	46	44	42	40	38	36
Byte 26	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CL =	66	64	62	60	58	56	54	52
Byte 27	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CL =	82	80	78	76	74	72	70	68
Byte 28	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CL =	98	96	94	92	90	88	86	84
NOTE For each bit position, 0 means this CAS Latency is not supported, 1 means this CAS Latency is supported.								

Example 1: DDR5-4400A SDRAM

CAS latencies supported: 22, 26, 28, 30, 32, 36, 40

SPD Byte	Bit	7	6	5	4	3	2	1	0	Hex Code
Byte 24	CAS Latencies	34	32	30	28	26	24	22	20	
	CL Mask	0	1	1	1	1	0	1	0	0x7A
Byte 25	CAS Latencies	50	48	46	44	42	40	38	36	
	CL Mask	0	0	0	0	0	1	0	1	0x05
Byte 26	CAS Latencies	66	64	62	60	58	56	54	52	
	CL Mask	0	0	0	0	0	0	0	0	0x00
Byte 27	CAS Latencies	82	80	78	76	74	72	70	68	
	CL Mask	0	0	0	0	0	0	0	0	0x00
Byte 28	CAS Latencies	98	96	94	92	90	88	86	84	
	CL Mask	0	0	0	0	0	0	0	0	0x00

8.6.2 Byte 29 (0x01D)

Reserved - must be coded as 0x00.

8.7 SDRAM Read Command to First Data (t_{AA})**8.7.1 Byte 30 (0x01E): Least Significant Byte****Byte 31 (0x01F): Most Significant Byte**

This 16-bit word defines the minimum SDRAM Read command to first data (CAS Latency) in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Read Command to First Data (t_{AA})	
ps	
Byte 31	Byte 30
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.8 SDRAM Activate to Read or Write Command Delay (t_{RCD})**8.8.1 Byte 32 (0x020): Least Significant Byte****Byte 33 (0x021): Most Significant Byte**

This 16-bit word defines the minimum SDRAM Activate to Read or Write command delay in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Activate to Read or Write Command Delay (t_{RCD})	
ps	
Byte 33	Byte 32
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.9 SDRAM Row Precharge Time (t_{RP})**8.9.1 Byte 34 (0x022): Least Significant Byte****Byte 35 (0x023): Most Significant Byte**

This 16-bit word defines the minimum SDRAM Row Precharge Time in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Row Precharge Time (t_{RP})	
ps	
Byte 35	Byte 34
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.10 SDRAM Activate to Precharge Command Period (t_{RAS})

8.10.1 Byte 36 (0x024): Least Significant Byte

Byte 37 (0x025): Most Significant Byte

This 16-bit word defines the minimum SDRAM Activate to Precharge command period in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Activate to Precharge Command Period (t_{RAS})	
ps	
Byte 37	Byte 36
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.11 SDRAM Activate to Activate or Refresh Command Period (t_{RC})

8.11.1 Byte 38 (0x026): Least Significant Byte

Byte 39 (0x027): Most Significant Byte

This 16-bit word defines the minimum SDRAM Activate to Activate/Refresh command period in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Activate to Activate or Refresh Command Period (t_{RC})	
ps	
Byte 39	Byte 38
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps. 0x0000: Reserved	

By DDR5 device design, t_{RCmin} must always be greater than or equal to $t_{RASmin} + t_{RPmin}$. When converting time in ns to nCK units using the appropriate rounding algorithms for these three parameters, systems must account for the overall design requirement and choose the larger of t_{RCmin} or ($t_{RASmin} + t_{RPmin}$) as a minimum setting.

8.12 SDRAM Write Recovery Time (t_{WR})

8.12.1 Byte 40 (0x028): Least Significant Byte

Byte 41 (0x029): Most Significant Byte

This 16-bit word defines the minimum SDRAM Write Recovery Time in picoseconds (ps). This value comes from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Write Recovery Time (t_{WR})	
ps	
Byte 41	Byte 40
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ps 0x0000: Reserved	

8.13 SDRAM Normal Refresh Recovery Time (t_{RFC1} , t_{RFC1_slr})

8.13.1 Byte 42 (0x02A): Least Significant Byte

Byte 43 (0x02B): Most Significant Byte

This 16-bit word defines the SDRAM Normal Refresh recovery time in nanoseconds (ns). t_{RFC1} relates to monolithic SDRAMs, t_{RFC1_slr} to 3DS SDRAMs. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Normal Refresh Recovery Time (t_{RFC1} , t_{RFC1_slr})	
ns	
Byte 43	Byte 42
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000 = Reserved	
NOTE $t_{RFC1min}$ relates to monolithic SDRAMs, $t_{RFC1_slr min}$ relates to 3DS SDRAMs.	

8.14 SDRAM Fine Granularity Refresh Recovery Time (t_{RFC2} , t_{RFC2_slr})

8.14.1 Byte 44 (0x02C): Least Significant Byte

Byte 45 (0x02D): Most Significant Byte

This 16-bit word defines the SDRAM Fine Granularity Refresh recovery time in nanoseconds (ns). t_{RFC2} relates to monolithic SDRAMs, t_{RFC2_slr} to 3DS SDRAMs. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Fine Granularity Refresh Recovery Time (t_{RFC2} , t_{RFC2_slr}) ns	
Byte 45	Byte 44
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000 = Reserved	
NOTE t_{RFC2} relates to monolithic SDRAMs, t_{RFC2_slr} relates to 3DS SDRAMs.	

8.15 SDRAM Same Bank Refresh Recovery Time (t_{RFCsb} , t_{RFCsb_slr})

8.15.1 Byte 46 (0x02E): Least Significant Byte

Byte 47 (0x02F): Most Significant Byte

This 16-bit word defines the SDRAM Same Bank Refresh recovery time in nanoseconds (ns). t_{RFCsb} relates to monolithic SDRAMs, t_{RFCsb_slr} to 3DS SDRAMs. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Same Bank Refresh Recovery Time (t_{RFCsb} , t_{RFCsb_slr}) ns	
Byte 47	Byte 46
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000: Reserved	
NOTE t_{RFCsb} relates to monolithic SDRAMs, t_{RFCsb_slr} relates to 3DS SDRAMs.	

8.16 SDRAM Normal Refresh Recovery Time, 3DS Different Logical Rank (t_{RFC1_dlr})

8.16.1 Byte 48 (0x030): Least Significant Byte

Byte 49 (0x031): Most Significant Byte

This 16-bit word defines the SDRAM Normal Refresh recovery time in nanoseconds (ns). t_{RFC1_dlr} relates to 3DS SDRAMs only. For monolithic SDRAMs, these bytes must be encoded as 0x0000. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Normal Refresh Recovery Time, 3DS Different Logical Rank (t_{RFC1_dlr}) ns	
Byte 49	Byte 48
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000 = Reserved	
NOTE These bytes are defined for 3DS only; for monolithic SDRAMs, code as 0x0000.	

8.17 SDRAM Fine Granularity Refresh Recovery Time, 3DS Different Logical Rank (t_{RFC2_dlr})

8.17.1 Byte 50 (0x032): Least Significant Byte

Byte 51 (0x033): Most Significant Byte

This 16-bit word defines the SDRAM Fine Granularity Refresh recovery time in nanoseconds (ns). t_{RFC2_dlr} relates to 3DS SDRAMs only. For monolithic SDRAMs, these bytes must be encoded as 0x0000. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Fine Granularity Refresh Recovery Time (t_{RFC2_dlr}) ns	
Byte 51	Byte 50
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000 = Reserved	
NOTE These bytes are defined for 3DS only; for monolithic SDRAMs, code as 0x0000.	

8.18 SDRAM Same Bank Refresh Recovery Time, 3DS Different Logical Rank
(t_{RFCsb_dlr})

8.18.1 Byte 52 (0x034): Least Significant Byte
Byte 53 (0x035): Most Significant Byte

This 16-bit word defines the SDRAM Same Bank Refresh recovery time for different logical ranks in nanoseconds (ns). t_{RFCsb_dlr} relates to 3DS SDRAMs only. For monolithic SDRAMs, these bytes must be encoded as 0x0000. These values come from the DDR5 SDRAM data sheet, JESD79-5.

SDRAM Same Bank Refresh Recovery Time (t _{RFCsb_dlr}) ns	
Byte 53	Byte 52
Bits 15~8	Bits 7~0
Values defined from 1 to 65535 ns 0x0000 = Reserved	
NOTE These bytes are defined for 3DS only; for monolithic SDRAMs, code as 0x0000	

8.19 Byte 54 (0x036): SDRAM Refresh Management, First Byte, First SDRAM Byte 55 (0x037): SDRAM Refresh Management, Second Byte, First SDRAM

These bytes represent the refresh management (RFM) settings for the SDRAMs used on this module. These are identical to the contents of the DDR5 SDRAM mode registers MR58 and MR59. These values come from the DDR5 SDRAM data sheet, JESD79-5. If all devices in a group (i.e., First or Second) are not matched, the value coded must represent the worst case for any device in the group.

SDRAM Refresh Management (RFM), First Byte Byte 54 (First SDRAM)				
Bits 7~5 (MR58:OP[7:5])		Bits 4~1 (MR58:OP[4:1])		Bit 0 (MR58:OP[0])
RAAMMT		RAAIMT		RFM Required
Normal	FGR	Normal	FGR	
000~010: Reserved 011: 3X 100: 4X 101: 5X 110: 6X 111: Reserved	000~010: Reserved 011: 6X 100: 8X 101: 10X 110: 12X 111: Reserved	0000-0011: Reserved 0100: 32 0101: 40 ... 1001: 72 1010: 80 All other codings reserved	0000-0011: Reserved 0100: 16 0101: 20 ... 1001: 36 1010: 40 All other codings reserved	0: Refresh management not required 1: Refresh management required
Notes: RFM = Refresh Management RAAMMT = Rolling Accumulated ACT Maximum Management Threshold RAAIMT = Rolling Accumulated ACT Initial Management Threshold Normal = Normal refresh mode FGR = Fine granularity refresh mode First SDRAM applies to all package ranks of SDRAMs in symmetrical configurations or even ranks in asymmetrical configurations Second SDRAM applies to odd ranks in asymmetrical configurations only				

8.19 Byte 54 (0x036): SDRAM Refresh Management, First Byte, First SDRAM (cont'd)

SDRAM Refresh Management (RFM), Second Byte Byte 55 (First SDRAM)				
Bits 7~6 (MR59:OP[7:6])	Bits 5~4 (MR59:OP[5:4])	Bit 3 (MR59:OP[3])	Bits 2~1 (MR59:OP[2:1])	Bit 0 (MR59:OP[0])
RFM RAA Counter Decrement per REF command	ARFM Level	BRC Support Level	Recommended Bounded Refresh Configuration	DRFM Supported
00: RAAIMT 01: RAAIMT ÷ 2 Other codes reserved	Reserved; must be coded in the SPD as 00; modified by the host controller via MRW to select ARFM Level	0: BRC2, 3, 4 (default) 1: BRC2 only	00: BRC2 = always +/- 1, ratio +/- 2 01: BRC3 = always +/- 1, +/- 2, ratio +/- 3 10: BRC4 = always +/- 1, +/- 2, +/- 3, ratio +/- 4 11: Reserved	0 = DRFM not supported 1 = DRFM supported
<p>Notes:</p> <p>ARFM = Adaptive Refresh Management.</p> <p>BRC = Bounded Refresh Configuration. The SPD field bits 2~1 define the module supplier's recommended value, however the host may program other values into the SDRAM mode register based on system policy. BRC values define how many rows are refreshed.</p> <p>DRFM = Directed Refresh Management. SPD bit 0 defines whether the SDRAM supports the DRFM feature, the host must still program 1 into the SDRAM mode register bit to enable the feature.</p> <p>BRC Support Level = indicates how many BRC options the DRAM can support which is set by the DRAM vendor in the read only MR59:OP[3]. The module supplier is required to program the value in DDR5 SDRAM MR59:OP[3] into SPD bit 3.</p> <p>MRW = mode register write SDRAM command.</p> <p>RAA = Rolling Accumulated ACT.</p> <p>RAAIMT = Rolling Accumulated ACT Initial Management Threshold.</p> <p>First SDRAM applies to all package ranks of SDRAMs in symmetrical configurations or even ranks in asymmetrical configurations.</p> <p>Second SDRAM applies to odd ranks in asymmetrical configurations only.</p> <p>Selection of ARFM level is managed by writing to SDRAM mode register bits MR59:OP[5:4].</p>				

8.20 Byte 56 (0x038): SDRAM Refresh Management, First Byte, Second SDRAM
Byte 57 (0x039): SDRAM Refresh Management, Second Byte, Second SDRAM

These bytes represent the refresh management (RFM) settings for the Second SDRAMs used on this module for odd ranks in asymmetrical assemblies.

SDRAM Refresh Management (RFM), First Byte Byte 56 (Second SDRAM)		
Bits 7~5 (MR58:OP[7:5])	Bits 4~1 (MR58:OP[4:1])	Bit 0 (MR58:OP[0])
RAAMMT	RAAIMT	RFM Required
See byte 54 for details. For symmetrical assemblies (all ranks use identical SDRAMs), must be coded as 0x00.		

8.20 Byte 56 (0x038): SDRAM Refresh Management, First Byte, Second SDRAM (cont'd)

SDRAM Refresh Management (RFM), Second Byte Byte 57 (Second SDRAM)				
Bits 7~6 (MR59:OP[7:6])	Bits 5~4 (MR59:OP[5:4])	Bit 3 (MR59:OP[3])	Bits 2~1 (MR59:OP[2:1])	Bit 0 (MR59:OP[0])
RFM RAA Counter Decrement per REF command	ARFM Level	BRC Support Level	Recommended Bounded Refresh Configuration	DRFM Supported
See byte 55 for details. For symmetrical assemblies (all ranks use identical SDRAMs), must be coded as 0x00.				

8.21 Bytes 58~69 (0x03A~0x045): SDRAM Adaptive Refresh Management

These bytes represent the adaptive refresh management (ARFM) settings for the SDRAMs used on this module. These values are vendor specific and come from the vendor's DDR5 SDRAM data sheet.

SDRAM Adaptive Refresh Management (ARFM)				
ARFM Level	First SDRAM		Second SDRAM	
	First Byte	Second Byte	First Byte	Second Byte
A	SPD Byte 58 (0x03A)	SPD Byte 59 (0x03B)	SPD Byte 60 (0x03C)	SPD Byte 61 (0x03D)
B	SPD Byte 62 (0x03E)	SPD Byte 63 (0x03F)	SPD Byte 64 (0x040)	SPD Byte 65 (0x041)
C	SPD Byte 66 (0x042)	SPD Byte 67 (0x043)	SPD Byte 68 (0x044)	SPD Byte 69 (0x045)
NOTES: ARFM = Adaptive Refresh Management These bytes use similar encoding to the RFM bytes 54~55, with the difference that bit 0 of all First Bytes is to be decoded as "ARFM Level Supported"				

SDRAM Adaptive Refresh Management (ARFM), First Bytes		
Bits 7~5 (MR58:OP[7:5])	Bits 4~1 (MR58:OP[4:1])	Bit 0 (MR58:OP[0])
RAAMMT	RAAIMT	ARFM Level
See byte 54 for details.		0: ARFM Level not supported 1: ARFM Level supported

SDRAM Adaptive Refresh Management (ARFM), Second Bytes				
Bits 7~6 (MR59:OP[7:6])	Bits 5~4 (MR59:OP[5:4])	Bit 3 (MR59:OP[3])	Bits 2~1 (MR59:OP[2:1])	Bit 0 (MR59:OP[0])
RFM RAA Counter Decrement per REF command	ARFM Level	BRC Support Level	Recommended Bounded Refresh Configuration	DRFM Supported
See byte 55 for details.				

8.22 SDRAM Activate to Activate Command Delay for Same Bank Group (t_{RRD_L})

8.22.1 Byte 70 (0x046): Least Significant Byte

Byte 71 (0x047): Most Significant Byte

Byte 72 (0x048): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum SDRAM Activate to Activate command delay in picoseconds (ps) when accessing the same bank group. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{RRD_L}(1K)$ min or $t_{RRD_L}(2K)$ min; for 3DS devices, this parameter is $t_{RRD_L_slr}(1K)$ min. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target t_{RRD_L} clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application t_{RRD_L} in nCK units to the greater of the target t_{RRD_L} or the Lower Clock Limit.

SDRAM Activate to Activate Command Delay for Same Bank Group (t_{RRD_L})		
nCK	ps	
Byte 72	Byte 71	Byte 70
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.23 SDRAM Read to Read Command Delay for Same Bank Group (t_{CCD_L})

8.23.1 Byte 73 (0x049): Least Significant Byte

Byte 74 (0x04A): Most Significant Byte

Byte 75 (0x04B): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum SDRAM Read to Read Command Delay in picoseconds (ps) when accessing the same bank group. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is t_{CCD_L} min; for 3DS devices, this parameter is $t_{CCD_L_slr}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target t_{CCD_L} clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application t_{CCD_L} in nCK units to the greater of the target t_{CCD_L} or the lower clock limit.

SDRAM Read to Read Command Delay for Same Bank Group (t_{CCD_L})		
nCK	ps	
Byte 75	Byte 74	Byte 73
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.24 SDRAM Write to Write Command Delay for Same Bank Group ($t_{\text{CCD_L_WR}}$)

8.24.1 Byte 76 (0x04C): Least Significant Byte

Byte 77 (0x04D): Most Significant Byte

Byte 78 (0x04E): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum SDRAM Write to Write Command Delay in picoseconds (ps) when accessing the same bank group. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{\text{CCD_L_WR}}$; for 3DS devices, this parameter is $t_{\text{CCD_L_WR_slr}}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target $t_{\text{CCD_L_WR}}$ clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application $t_{\text{CCD_L_WR}}$ in nCK units to the greater of the target $t_{\text{CCD_L_WR}}$ or the lower clock limit.

SDRAM Write to Write Command Delay for Same Bank Group ($t_{\text{CCD_L_WR}}$)		
nCK	ps	
Byte 78	Byte 77	Byte 76
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.25 SDRAM Write to Write Command Delay for Same Bank Group, Second Write not RMW ($t_{\text{CCD_L_WR2}}$)

8.25.1 Byte 79 (0x04F): Least Significant Byte

Byte 80 (0x050): Most Significant Byte

Byte 81 (0x051): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum SDRAM Write to Write Command Delay in picoseconds (ps) when accessing the same bank group and the second write is not a read-modify-write. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{\text{CCD_L_WR2}}$; for 3DS devices, this parameter is $t_{\text{CCD_L_WR2_slr}}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target $t_{\text{CCD_L_WR2}}$ clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application $t_{\text{CCD_L_WR2}}$ in nCK units to the greater of the target $t_{\text{CCD_L_WR2}}$ or the lower clock limit.

SDRAM Write to Write Command Delay for Same Bank Group, Second Write not RMW ($t_{\text{CCD_L_WR2}}$)		
nCK	ps	
Byte 81	Byte 80	Byte 79
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.26 SDRAM Four Activate Window (t_{FAW})

8.26.1 Byte 82 (0x052): Least Significant Byte

Byte 83 (0x053): Most Significant Byte

Byte 84 (0x054): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum SDRAM Four Activate Window in picoseconds (ps). The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{FAW}(1K)$ or $t_{FAW}(2K)$; for 3DS devices, this parameter is $t_{FAW_slr}(1K)$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target t_{FAW} clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application t_{FAW} in nCK units to the greater of the target t_{FAW} or the lower clock limit.

SDRAM Four Activate Window (t_{FAW})		
nCK	ps	
Byte 84	Byte 83	Byte 82
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.27 SDRAM Write to Read Command Delay for Same Bank Group ($t_{CCD_L_WTR}$)

8.27.1 Byte 85 (0x055): Least Significant Byte

Byte 86 (0x056): Most Significant Byte

Byte 87 (0x057): Lower Clock Limit

The 16-bit word in the lower two bytes defines the analog portion (WTR(L)) of the minimum Write to Read command delay in picoseconds (ps) when accessing the same bank group. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{CCD_L_WTR}$; for 3DS devices, this parameter is $t_{CCD_L_WTR_slr}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the command time in clocks for CAS Write Latency (CWL) plus Write Burst Length divided by 2.
- Calculate the target WTR(L) clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application WTR(L) in nCK units to the greater of the target WTR(L) or the lower clock limit.
- Set the application $t_{CCD_L_WTR}$ to the sum of command time and WTR(L):

$$t_{CCD_L_WTR} = CWL + WBL/2 + WTR(L)$$

SDRAM Write to Read Command Delay Time for Same Bank Group ($t_{CCD_L_WTR}$)		
nCK	ps	
Byte 87	Byte 86	Byte 85
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.28 SDRAM Write to Read Command Delay for Different Bank Group ($t_{\text{CCD_S_WTR}}$)

8.28.1 Byte 88 (0x058): Least Significant Byte

Byte 89 (0x059): Most Significant Byte

Byte 90 (0x05A): Lower Clock Limit

The 16-bit word in the lower two bytes defines the analog portion (WTR(S)) of the minimum Write to Read command delay in picoseconds (ps) when accessing different bank groups. The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is $t_{\text{WTR_S}}$; for 3DS devices, this parameter is $t_{\text{WTR_S_slr}}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the command time in clocks for CAS Write Latency (CWL) plus Write Burst Length divided by 2.
- Calculate the target WTR(S) clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application WTR(S) in nCK units to the greater of the target WTR(S) or the lower clock limit.
- Set the application $t_{\text{CCD_L_WTR}}$ to the sum of command time and WTR(S):
 $t_{\text{CCD_S_WTR}} = \text{CWL} + \text{WBL}/2 + \text{WTR(S)}$.

SDRAM Write to Read Command Delay for Different Bank Group ($t_{\text{CCD_S_WTR}}$)		
nCK	ps	
Byte 90	Byte 89	Byte 89
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.29 SDRAM Read to Precharge Command Delay (t_{RTP} , $t_{\text{RTP_slr}}$)

8.29.1 Byte 91 (0x05B): Least Significant Byte

Byte 92 (0x05C): Most Significant Byte

Byte 93 (0x05D): Lower Clock Limit

The 16-bit word in the lower two bytes defines the minimum Read to Precharge command delay in picoseconds (ps). The third byte defines the minimum number of clocks (nCK) required. For monolithic SDRAMs, this parameter is t_{RTP} ; for 3DS devices, this parameter is $t_{\text{RTP_slr}}$. These values come from the DDR5 SDRAM data sheet, JESD79-5. The general algorithm is:

- Calculate the target t_{RTP} clock count by applying the standard rounding algorithm to the 16-bit ps value and the application clock period in ps.
- Set the application t_{RTP} in nCK units to the greater of the target t_{RTP} or the lower clock limit.

Parameter $t_{\text{CCD_WTRA}}$ (write to read with autoprecharge command delay) is calculated as $t_{\text{CCD_WTRA}} = t_{\text{WR}} - t_{\text{RTP}}$. This calculation must be maintained when using the rounding algorithm on each parameter individually, or rounding on the result of the subtraction, and the higher number of resulting clocks must be used.

8.29 SDRAM Read to Precharge Command Delay (t_{RTP} , t_{RTP_slr}) (cont'd)

SDRAM Minimum Write to Read Command Delay Time (t_{RTPmin}), Different Bank Group		
nCK	ps	
Byte 87	Byte 86	Byte 85
Bits 7~0	Bits 15~8	Bits 7~0
Values defined from 1 to 255 clocks (nCK) 0x00: Reserved	Values defined from 1 to 65535 ps 0x0000: Reserved	

8.30 Bytes 94~127 (0x05E~0x07F): Reserved, Base Configuration Section

Must be coded as 0x00

9 Example SPD Codes

Table 6 through **Table 9** show example codes for the SPD contents. These calculations account for the 0.3% correction factor allowed for digital math inaccuracies. The clock periods for each standard speed grade used for these calculations are:

tCK		
Grade	tCKmin	tCKmax
3200	0.625	1.010
3600	0.555	1.010
4000	0.500	1.010
4400	0.454	1.010
4800	0.416	1.010
5200	0.384	1.010
5600	0.357	1.010
6000	0.333	1.010
6400	0.312	1.010
6800	0.294	1.010
7200	0.277	1.010

9.1 Core Parameters, DDR5 Monolithic Single Die Package (SDP) SDRAMs

Table 6 — Example #1, Codes for SPD Contents

	3200AN Mono	3200B Mono	3200BN Mono	3200C Mono	3600AN Mono	3600B Mono	3600BN Mono	3600C Mono	4000AN Mono	4000B Mono	4000BN Mono	4000C Mono	
tCKmin	0.625	0.625	0.625	0.625	0.555	0.555	0.555	0.555	0.500	0.500	0.500	0.500	
tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	
tAA	15.000	16.250	16.250	17.500	14.444	16.250	16.666	17.500	14.000	16.000	16.000	17.500	
tRCD	15.000	16.250	16.250	17.500	14.444	16.250	16.666	17.500	14.000	16.000	16.000	17.500	
tRP	15.000	16.250	16.250	17.500	14.444	16.250	16.666	17.500	14.000	16.000	16.000	17.500	
tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	
tRC	47.000	48.250	48.250	49.500	46.444	48.250	48.666	49.500	46.000	48.000	48.000	49.500	
tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	
SPD #	tCKmin (ps)	625	625	625	625	555	555	555	555	500	500	500	500
20	tCKmin low	0x71	0x71	0x71	0x71	0x2B	0x2B	0x2B	0x2B	0xF4	0xF4	0xF4	0xF4
21	tCKmin high	0x02	0x02	0x02	0x02	0x02	0x02	0x02	0x02	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	15000	16250	16250	17500	14444	16250	16666	17500	14000	16000	16000	17500
30	tAA low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
31	tAA high	0x3A	0x3F	0x3F	0x44	0x38	0x3F	0x41	0x44	0x36	0x3E	0x3E	0x44
SPD #	tRCD (ps)	15000	16250	16250	17500	14444	16250	16666	17500	14000	16000	16000	17500
32	tRCD low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
33	tRCD high	0x3A	0x3F	0x3F	0x44	0x38	0x3F	0x41	0x44	0x36	0x3E	0x3E	0x44
SPD #	tRP (ps)	15000	16250	16250	17500	14444	16250	16666	17500	14000	16000	16000	17500
34	tRP low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
35	tRP high	0x3A	0x3F	0x3F	0x44	0x38	0x3F	0x41	0x44	0x36	0x3E	0x3E	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	47000	48250	48250	49500	46444	48250	48666	49500	46000	48000	48000	49500
38	tRC low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
39	tRC high	0xB7	0xBC	0xBC	0xC1	0xB5	0xBC	0xBE	0xC1	0xB3	0xBB	0xBB	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.1 Core Parameters, DDR5 Monolithic Single Die Package (SDP) SDRAMs (cont'd)

Table 7 — Example #2, Codes for SPD Contents

		4400AN Mono	4400B Mono	4400BN Mono	4400C Mono	4800AN Mono	4800B Mono	4800BN Mono	4800C Mono	5200AN Mono	5200B Mono	5200BN Mono	5200C Mono
	tCKmin	0.454	0.454	0.454	0.454	0.416	0.416	0.416	0.416	0.384	0.384	0.384	0.384
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	14.545	16.000	16.363	17.500	14.166	16.000	16.666	17.500	14.615	16.000	16.153	17.500
	tRCD	14.545	16.000	16.363	17.500	14.166	16.000	16.666	17.500	14.615	16.000	16.153	17.500
	tRP	14.545	16.000	16.363	17.500	14.166	16.000	16.666	17.500	14.615	16.000	16.153	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	46.545	48.000	48.363	49.500	46.166	48.000	48.666	49.500	46.615	48.000	48.153	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	454	454	454	454	416	416	416	416	384	384	384	384
20	tCKmin low	0xC6	0xC6	0xC6	0xC6	0xA0	0xA0	0xA0	0xA0	0x80	0x80	0x80	0x80
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	14545	16000	16363	17500	14166	16000	16666	17500	14615	16000	16153	17500
30	tAA low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x18	0x5C
31	tAA high	0x38	0x3E	0x3F	0x44	0x37	0x3E	0x41	0x44	0x39	0x3E	0x3F	0x44
SPD #	tRCD (ps)	14545	16000	16363	17500	14166	16000	16666	17500	14615	16000	16153	17500
32	tRCD low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x18	0x5C
33	tRCD high	0x38	0x3E	0x3F	0x44	0x37	0x3E	0x41	0x44	0x39	0x3E	0x3F	0x44
SPD #	tRP (ps)	14545	16000	16363	17500	14166	16000	16666	17500	14615	16000	16153	17500
34	tRP low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x18	0x5C
35	tRP high	0x38	0x3E	0x3F	0x44	0x37	0x3E	0x41	0x44	0x39	0x3E	0x3F	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46545	48000	48363	49500	46166	48000	48666	49500	46615	48000	48153	49500
38	tRC low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x19	0x5C
39	tRC high	0xB5	0xBB	0xBC	0xC1	0xB4	0xBB	0xBE	0xC1	0xB6	0xBB	0xBC	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.1 Core Parameters, DDR5 Monolithic Single Die Package (SDP) SDRAMs (cont'd)

Table 8 — Example #3, Codes for SPD Contents

		5600AN Mono	5600B Mono	5600BN Mono	5600C Mono	6000AN Mono	6000B Mono	6000BN Mono	6000C Mono	6400AN Mono	6400B Mono	6400BN Mono	6400C Mono
tCKmin		0.357	0.357	0.357	0.357	0.333	0.333	0.333	0.333	0.312	0.312	0.312	0.312
tCKmax		1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
tAA		14.285	16.000	16.428	17.500	14.000	16.000	16.000	17.500	14.375	16.000	16.250	17.500
tRCD		14.285	16.000	16.428	17.500	14.000	16.000	16.000	17.500	14.375	16.000	16.250	17.500
tRP		14.285	16.000	16.428	17.500	14.000	16.000	16.000	17.500	14.375	16.000	16.250	17.500
tRAS		32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
tRC		46.285	48.000	48.428	49.500	46.000	48.000	48.000	49.500	46.375	48.000	48.250	49.500
tWR		30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	357	357	357	357	333	333	333	333	312	312	312	312
20	tCKmin low	0x65	0x65	0x65	0x65	0x4D	0x4D	0x4D	0x4D	0x38	0x38	0x38	0x38
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	14285	16000	16428	17500	14000	16000	16000	17500	14375	16000	16250	17500
30	tAA low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
31	tAA high	0x37	0x3E	0x40	0x44	0x36	0x3E	0x3E	0x44	0x38	0x3E	0x3F	0x44
SPD #	tRCD (ps)	14285	16000	16428	17500	14000	16000	16000	17500	14375	16000	16250	17500
32	tRCD low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
33	tRCD high	0x37	0x3E	0x40	0x44	0x36	0x3E	0x3E	0x44	0x38	0x3E	0x3F	0x44
SPD #	tRP (ps)	14285	16000	16428	17500	14000	16000	16000	17500	14375	16000	16250	17500
34	tRP low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
35	tRP high	0x37	0x3E	0x40	0x44	0x36	0x3E	0x3E	0x44	0x38	0x3E	0x3F	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46285	48000	48428	49500	46000	48000	48000	49500	46375	48000	48250	49500
38	tRC low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
39	tRC high	0xB4	0xBB	0xBD	0xC1	0xB3	0xBB	0xBB	0xC1	0xB5	0xBB	0xBC	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.1 Core Parameters, DDR5 Monolithic Single Die Package (SDP) SDRAMs (cont'd)

Table 9 — Example #4, Codes for SPD Contents

		6800AN Mono	6800B Mono	6800BN Mono	6800C Mono	7200AN Mono	7200B Mono	7200BN Mono	7200C Mono
	tCKmin	0.294	0.294	0.294	0.294	0.277	0.277	0.277	0.277
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	14.117	16.000	16.470	17.500	14.444	16.000	16.111	17.500
	tRCD	14.117	16.000	16.470	17.500	14.444	16.000	16.111	17.500
	tRP	14.117	16.000	16.470	17.500	14.444	16.000	16.111	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	46.117	48.000	48.000	49.500	46.444	48.000	48.111	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	294	294	294	294	277	277	277	277
20	tCKmin low	0x26	0x26	0x26	0x26	0x15	0x15	0x15	0x15
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	14117	16000	16470	17500	14444	16000	16111	17500
30	tAA low	0x25	0x80	0x56	0x5C	0x6C	0x80	0xEF	0x5C
31	tAA high	0x37	0x3E	0x40	0x44	0x38	0x3E	0x3E	0x44
SPD #	tRCD (ps)	14117	16000	16470	17500	14444	16000	16111	17500
32	tRCD low	0x25	0x80	0x56	0x5C	0x6C	0x80	0xEF	0x5C
33	tRCD high	0x37	0x3E	0x40	0x44	0x38	0x3E	0x3E	0x44
SPD #	tRP (ps)	14117	16000	16470	17500	14444	16000	16111	17500
34	tRP low	0x25	0x80	0x56	0x5C	0x6C	0x80	0xEF	0x5C
35	tRP high	0x37	0x3E	0x40	0x44	0x38	0x3E	0x3E	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46117	48000	48000	49500	46444	48000	48111	49500
38	tRC low	0x25	0x80	0x80	0x5C	0x6C	0x80	0xEF	0x5C
39	tRC high	0xB4	0xBB	0xBB	0xC1	0xB5	0xBB	0xBB	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.2 Parameters with Lower nCK Limits, DDR5 Monolithic Single Die Package SDRAMs

		DDR5-3200 Mono	DDR5-3600 Mono	DDR5-4000 Mono	DDR5-4400 Mono	DDR5-4800 Mono	DDR5-5200 Mono	DDR5-5600 Mono	DDR5-6000 Mono	DDR5-6400 Mono
tRRD_L (2K)	ps	5000	5000	5000	5000	5000	5000	5000	5000	5000
tRRD_L (2K)	nCK	8	8	8	8	8	8	8	8	8
tRRD_L (1K)	ps	5000	5000	5000	5000	5000	5000	5000	5000	5000
tRRD_L (1K)	nCK	8	8	8	8	8	8	8	8	8
tCCD_L	ps	5000	5000	5000	5000	5000	5000	5000	5000	5000
tCCD_L	nCK	8	8	8	8	8	8	8	8	8
tCCD_L_WR	ps	20000	20000	20000	20000	20000	20000	20000	20000	20000
tCCD_L_WR	nCK	32	32	32	32	32	32	32	32	32
tCCD_L_WR2	ps	10000	10000	10000	10000	10000	10000	10000	10000	10000
tCCD_L_WR2	nCK	16	16	16	16	16	16	16	16	16
tFAW (2K)	ps	25000	22222	20000	18181	16666	15384	14285	13333	12500
tFAW (2K)	nCK	40	40	40	40	40	40	40	40	40
tFAW (1K)	ps	20000	17777	16000	14545	13333	12307	11428	10666	10000
tFAW (1K)	nCK	32	32	32	32	32	32	32	32	32
tCCD_L_WTR	ps	10000	10000	10000	10000	10000	10000	10000	10000	10000
tCCD_L_WTR	nCK	16	16	16	16	16	16	16	16	16
tCCD_S_WTR	ps	2500	2500	2500	2500	2500	2500	2500	2500	2500
tCCD_S_WTR	nCK	4	4	4	4	4	4	4	4	4
tRTP	ps	7500	7500	7500	7500	7500	7500	7500	7500	7500
tRTP	nCK	12	12	12	12	12	12	12	12	12

SPD#			DDR5-3200 Mono	DDR5-3600 Mono	DDR5-4000 Mono	DDR5-4400 Mono	DDR5-4800 Mono	DDR5-5200 Mono	DDR5-5600 Mono	DDR5-6000 Mono	DDR5-6400 Mono
71, 70	tRRD_L (2K)	MSB, LSB	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88
72	tRRD_L (2K)	nCK	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08
71, 70	tRRD_L (1K)	MSB, LSB	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88
72	tRRD_L (1K)	nCK	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08
74, 73	tCCD_L	MSB, LSB	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88
75	tCCD_L	nCK	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08
77, 76	tCCD_L_WR	MSB, LSB	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20
78	tCCD_L_WR	nCK	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20
80, 79	tCCD_L_WR2	MSB, LSB	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10
81	tCCD_L_WR2	nCK	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10
83, 82	tFAW (2K)	MSB, LSB	0x61, 0xA8	0x56, 0xCE	0x4E, 0x20	0x47, 0x05	0x41, 0x1A	0x3C, 0x18	0x37, 0xCD	0x34, 0x15	0x30, 0xD4
84	tFAW (2K)	nCK	0x28	0x28	0x28	0x28	0x28	0x28	0x28	0x28	0x28
83, 82	tFAW (1K)	MSB, LSB	0x4E, 0x20	0x45, 0x71	0x3E, 0x80	0x38, 0xD1	0x34, 0x15	0x30, 0x13	0x2C, 0xA4	0x29, 0xAA	0x27, 0x10
84	tFAW (1K)	nCK	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20
86, 85	tCCD_L_WTR	MSB, LSB	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10
87	tCCD_L_WTR	nCK	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10
89, 88	tCCD_S_WTR	MSB, LSB	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4
90	tCCD_S_WTR	nCK	0x04	0x04	0x04	0x04	0x04	0x04	0x04	0x04	0x04
92, 91	tRTP	MSB, LSB	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C
93	tRTP	nCK	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C

9.2 Parameters with Lower nCK Limits, DDR5 Monolithic Single Die Package SDRAMs (cont'd)

		DDR5-6800 Mono	DDR5-7200 Mono
tRRD_L (2K)	ps	5000	5000
tRRD_L (2K)	nCK	8	8
tRRD_L (1K)	ps	5000	5000
tRRD_L (1K)	nCK	8	8
tCCD_L	ps	5000	5000
tCCD_L	nCK	8	8
tCCD_L_WR	ps	20000	20000
tCCD_L_WR	nCK	32	32
tCCD_L_WR2	ps	10000	10000
tCCD_L_WR2	nCK	16	16
tFAW (2K)	ps	11764	11111
tFAW (2K)	nCK	40	40
tFAW (1K)	ps	9411	8888
tFAW (1K)	nCK	32	32
tCCD_L_WTR	ps	10000	10000
tCCD_L_WTR	nCK	16	16
tCCD_S_WTR	ps	2352	2222
tCCD_S_WTR	nCK	4	4
tRTP	ps	7500	7500
tRTP	nCK	12	12

SPD#			DDR5-6800 Mono	DDR5-7200 Mono
71, 70	tRRD_L (2K)	MSB, LSB	0x13, 0x88	0x13, 0x88
72	tRRD_L (2K)	nCK	0x08	0x08
71, 70	tRRD_L (1K)	MSB, LSB	0x13, 0x88	0x13, 0x88
72	tRRD_L (1K)	nCK	0x08	0x08
74, 73	tCCD_L	MSB, LSB	0x13, 0x88	0x13, 0x88
75	tCCD_L	nCK	0x08	0x08
77, 76	tCCD_L_WR	MSB, LSB	0x4E, 0x20	0x4E, 0x20
78	tCCD_L_WR	nCK	0x20	0x20
80, 79	tCCD_L_WR2	MSB, LSB	0x27, 0x10	0x27, 0x10
81	tCCD_L_WR2	nCK	0x10	0x10
83, 82	tFAW (2K)	MSB, LSB	0x2D, 0xF4	0x2B, 0x67
84	tFAW (2K)	nCK	0x28	0x28
83, 82	tFAW (1K)	MSB, LSB	0x24, 0xC3	0x22, 0xB8
84	tFAW (1K)	nCK	0x20	0x20
86, 85	tCCD_L_WTR	MSB, LSB	0x27, 0x10	0x27, 0x10
87	tCCD_L_WTR	nCK	0x10	0x10
89, 88	tCCD_S_WTR	MSB, LSB	0x09, 0x30	0x08, 0xAE
90	tCCD_S_WTR	nCK	0x04	0x04
92, 91	tRTP	MSB, LSB	0x1D, 0x4C	0x1D, 0x4C
93	tRTP	nCK	0x0C	0x0C

9.3 CAS Latency Masks, DDR5 Monolithic Single Die Package SDRAMs

Optional downbins are included. Optional CAS latencies are not included.

Mono Speed Bin	SPD[24]	SPD[25]	SPD[26]	SPD[27]	SPD[28]
3200AN	0x1E	0x00	0x00	0x00	0x00
3200B	0x1A	0x00	0x00	0x00	0x00
3200BN	0x1A	0x00	0x00	0x00	0x00
3200C	0x12	0x00	0x00	0x00	0x00
3600AN	0x7E	0x00	0x00	0x00	0x00
3600B	0x7A	0x00	0x00	0x00	0x00
3600BN	0x72	0x00	0x00	0x00	0x00
3600C	0x52	0x00	0x00	0x00	0x00
4000AN	0x7E	0x01	0x00	0x00	0x00
4000B	0x7A	0x01	0x00	0x00	0x00
4000BN	0x7A	0x01	0x00	0x00	0x00
4000C	0x52	0x01	0x00	0x00	0x00
4400AN	0x7E	0x05	0x00	0x00	0x00
4400B	0x7A	0x05	0x00	0x00	0x00
4400BN	0x72	0x05	0x00	0x00	0x00
4400C	0x52	0x05	0x00	0x00	0x00
4800AN	0xFE	0x0D	0x00	0x00	0x00
4800B	0x7A	0x0D	0x00	0x00	0x00
4800BN	0x72	0x0D	0x00	0x00	0x00
4800C	0x52	0x0D	0x00	0x00	0x00
5200AN	0x7E	0x2F	0x00	0x00	0x00
5200B	0x7A	0x2D	0x00	0x00	0x00
5200BN	0x7A	0x2D	0x00	0x00	0x00
5200C	0x52	0x2D	0x00	0x00	0x00
5600AN	0x7E	0xAF	0x00	0x00	0x00
5600B	0x7A	0xAD	0x00	0x00	0x00
5600BN	0x72	0xAD	0x00	0x00	0x00
5600C	0x52	0xAD	0x00	0x00	0x00
6000AN	0xFE	0xEF	0x02	0x00	0x00
6000B	0x7A	0xED	0x02	0x00	0x00
6000BN	0x7A	0xED	0x02	0x00	0x00
6000C	0x52	0xAD	0x02	0x00	0x00
6400AN	0x7E	0xEF	0x07	0x00	0x00
6400B	0x7A	0xED	0x07	0x00	0x00
6400BN	0x7A	0xED	0x07	0x00	0x00
6400C	0x52	0xAD	0x06	0x00	0x00
6800AN	0xFE	0xEF	0xF7	0x00	0x00
6800B	0x7A	0xED	0x17	0x00	0x00
6800BN	0x72	0xAD	0x16	0x00	0x00
6800C	0x52	0xAD	0x16	0x00	0x00
7200AN	0x7E	0xEF	0x5F	0x00	0x00
7200B	0x7A	0xED	0x5F	0x00	0x00
7200BN	0x7A	0xAD	0x5F	0x00	0x00
7200C	0x52	0xAD	0x56	0x00	0x00

9.4 Parameters Defined by Device Density, DDR5 Monolithic Single Die Package (SDP) SDRAMs

		SPD[43]	SPD[42]
	ns	MSB	LSB
tRFC1, 8 Gb	195	0x00	0xC3
tRFC1, 16 Gb	295	0x01	0x27
tRFC1, 24 Gb	410	0x01	0x9A
tRFC1, 32 Gb	410	0x01	0x9A

		SPD[45]	SPD[44]
	ns	MSB	LSB
tRFC2, 8 Gb	130	0x00	0x82
tRFC2, 16 Gb	160	0x00	0xA0
tRFC2, 24 Gb	220	0x00	0xDC
tRFC2, 32 Gb	220	0x00	0xDC

		SPD[47]	SPD[46]
	ns	MSB	LSB
tRFCsb, 8 Gb	115	0x00	0x73
tRFCsb, 16 Gb	130	0x00	0x82
tRFCsb, 24 Gb	190	0x00	0xBE
tRFCsb, 32 Gb	190	0x00	0xBE

9.5 Core Parameters, DDR5 Multi-Die Packages (3DS) SDRAMs

		3200AN 3DS	3200B 3DS	3200BN 3DS	3200C 3DS	3600AN 3DS	3600B 3DS	3600BN 3DS	3600C 3DS	4000AN 3DS	4000B 3DS	4000BN 3DS	4000C 3DS
	tCKmin	0.625	0.625	0.625	0.625	0.555	0.555	0.555	0.555	0.500	0.500	0.500	0.500
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	16.250	18.750	18.750	20.000	16.666	18.750	18.888	20.000	16.000	18.750	19.000	20.000
	tRCD	15.000	16.250	16.250	17.500	14.444	16.250	16.666	17.500	14.000	16.000	16.000	17.500
	tRP	15.000	16.250	16.250	17.500	14.444	16.250	16.666	17.500	14.000	16.000	16.000	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	45.750	48.250	48.250	49.500	46.444	48.250	48.666	49.500	46.000	48.000	48.000	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	625	625	625	625	555	555	555	555	500	500	500	500
20	tCKmin low	0x71	0x71	0x71	0x71	0x2B	0x2B	0x2B	0x2B	0xF4	0xF4	0xF4	0xF4
21	tCKmin high	0x02	0x02	0x02	0x02	0x02	0x02	0x02	0x02	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	16250	18750	18750	20000	16666	18750	18888	20000	16000	18750	19000	20000
30	tAA low	0x7A	0x3E	0x3E	0x20	0x1A	0x3E	0xC8	0x20	0x80	0x3E	0x38	0x20
31	tAA high	0x3F	0x49	0x49	0x4E	0x41	0x49	0x49	0x4E	0x3E	0x49	0x4A	0x4E
SPD #	tRCD (ps)	15000	16250	16250	17500	14444	16250	16666	17500	14000	16000	16000	17500
32	tRCD low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
33	tRCD high	0x3A	0x3F	0x3F	0x44	0x38	0x3F	0x41	0x44	0x36	0x3E	0x3E	0x44
SPD #	tRP (ps)	15000	16250	16250	17500	14444	16250	16666	17500	14000	16000	16000	17500
34	tRP low	0x98	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
35	tRP high	0x3A	0x3F	0x3F	0x44	0x38	0x3F	0x41	0x44	0x36	0x3E	0x3E	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	45750	48250	48250	49500	46444	48250	48666	49500	46000	48000	48000	49500
38	tRC low	0xB6	0x7A	0x7A	0x5C	0x6C	0x7A	0x1A	0x5C	0xB0	0x80	0x80	0x5C
39	tRC high	0xB2	0xBC	0xBC	0xC1	0xB5	0xBC	0xBE	0xC1	0xB3	0xBB	0xBB	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.5 Core parameters, DDR5 Multi-Die Packages (3DS) SDRAMs (cont'd)

		4400AN 3DS	4400B 3DS	4400BN 3DS	4400C 3DS	4800AN 3DS	4800B 3DS	4800BN 3DS	4800C 3DS	5200AN 3DS	5200B 3DS	5200BN 3DS	5200C 3DS
	tCKmin	0.454	0.454	0.454	0.454	0.416	0.416	0.416	0.416	0.384	0.384	0.384	0.384
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	16.363	18.750	19.090	20.000	16.666	18.750	19.166	20.000	16.153	18.750	19.230	20.000
	tRCD	14.545	16.000	16.363	17.500	14.166	16.000	16.666	17.500	14.615	16.000	16.153	17.500
	tRP	14.545	16.000	16.363	17.500	14.166	16.000	16.666	17.500	14.615	16.000	16.153	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	46.545	48.000	48.363	49.500	46.166	48.000	48.666	49.500	46.615	48.000	49.500	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	454	454	454	454	416	416	416	416	384	384	384	384
20	tCKmin low	0xC6	0xC6	0xC6	0xC6	0xA0	0xA0	0xA0	0xA0	0x80	0x80	0x80	0x80
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	16363	18750	19090	20000	16666	18750	19166	20000	16153	18750	19230	20000
30	tAA low	0xEB	0x3E	0x92	0x20	0x1A	0x3E	0xDE	0x20	0x18	0x3E	0x1E	0x20
31	tAA high	0x3F	0x49	0x4A	0x4E	0x41	0x49	0x4A	0x4E	0x3F	0x49	0x4B	0x4E
SPD #	tRCD (ps)	14545	16000	16363	17500	14166	16000	16666	17500	14615	16000	16153	17500
32	tRCD low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x18	0x5C
33	tRCD high	0x38	0x3E	0x3F	0x44	0x37	0x3E	0x41	0x44	0x39	0x3E	0x3F	0x44
SPD #	tRP (ps)	14545	16000	16363	17500	14166	16000	16666	17500	14615	16000	16153	17500
34	tRP low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x18	0x5C
35	tRP high	0x38	0x3E	0x3F	0x44	0x37	0x3E	0x41	0x44	0x39	0x3E	0x3F	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46545	48000	48363	49500	46166	48000	48666	49500	46615	48000	49500	49500
38	tRC low	0xD1	0x80	0xEB	0x5C	0x56	0x80	0x1A	0x5C	0x17	0x80	0x5C	0x5C
39	tRC high	0xB5	0xBB	0xBC	0xC1	0xB4	0xBB	0xBE	0xC1	0xB6	0xBB	0xC1	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.5 Core parameters, DDR5 Multi-Die Packages (3DS) SDRAMs (cont'd)

		6800AN 3DS	6800B 3DS	6800BN 3DS	6800C 3DS	7200AN 3DS	7200B 3DS	7200BN 3DS	7200C 3DS
	tCKmin	0.294	0.294	0.294	0.294	0.277	0.277	0.277	0.277
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	16.470	18.571	18.823	20.000	16.111	18.571	18.888	20.000
	tRCD	14.117	16.000	16.470	17.500	14.444	16.000	16.111	17.500
	tRP	14.117	16.000	16.470	17.500	14.444	16.000	16.111	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	46.117	48.000	48.000	49.500	46.444	48.000	48.111	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	294	294	294	294	277	277	277	277
20	tCKmin low	0x26	0x26	0x26	0x26	0x15	0x15	0x15	0x15
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	16470	18571	18823	20000	16111	18571	18888	20000
30	tAA low	0x56	0x8B	0x87	0x20	0xEF	0x8B	0xC8	0x20
31	tAA high	0x40	0x48	0x49	0x4E	0x3E	0x48	0x49	0x4E
SPD #	tRCD (ps)	14117	16000	16470	17500	14444	16000	16111	17500
32	tRCD low	0x25	0x80	0x56	0x5C	0x6C	0x80	0xEF	0x5C
33	tRCD high	0x37	0x3E	0x40	0x44	0x38	0x3E	0x3E	0x44
SPD #	tRP (ps)	14117	16000	16470	17500	14444	16000	16111	17500
34	tRP low	0x25	0x80	0x56	0x5C	0x6C	0x80	0xEF	0x5C
35	tRP high	0x37	0x3E	0x40	0x44	0x38	0x3E	0x3E	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46117	48000	48000	49500	46444	48000	48111	49500
38	tRC low	0x25	0x80	0x80	0x5C	0x6C	0x80	0xEF	0x5C
39	tRC high	0xB4	0xBB	0xBB	0xC1	0xB5	0xBB	0xBB	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.5 Core parameters, DDR5 Multi-Die Packages (3DS) SDRAMs (cont'd)

		5600AN 3DS	5600B 3DS	5600BN 3DS	5600C 3DS	6000AN 3DS	6000B 3DS	6000BN 3DS	6000C 3DS	6400AN 3DS	6400B 3DS	6400BN 3DS	6400C 3DS
	tCKmin	0.357	0.357	0.357	0.357	0.333	0.333	0.333	0.333	0.312	0.312	0.312	0.312
	tCKmax	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
	tAA	16.428	18.571	18.571	20.000	16.000	18.571	18.666	20.000	16.250	18.571	18.750	20.000
	tRCD	14.285	16.000	16.428	17.500	14.000	16.000	16.000	17.500	14.375	16.000	16.250	17.500
	tRP	14.285	16.000	16.428	17.500	14.000	16.000	16.000	17.500	14.375	16.000	16.250	17.500
	tRAS	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000	32.000
	tRC	46.285	48.000	48.428	49.500	46.000	48.000	48.000	49.500	46.375	48.000	48.250	49.500
	tWR	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
SPD #	tCKmin (ps)	357	357	357	357	333	333	333	333	312	312	312	312
20	tCKmin low	0x65	0x65	0x65	0x65	0x4D	0x4D	0x4D	0x4D	0x38	0x38	0x38	0x38
21	tCKmin high	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01	0x01
SPD #	tCKmax (ps)	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010	1010
22	tCKmax low	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2	0xF2
23	tCKmax high	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03	0x03
SPD #	tAA (ps)	16428	18571	18571	20000	16000	18571	18666	20000	16250	18571	18750	20000
30	tAA low	0x2C	0x8B	0x8B	0x20	0x80	0x8B	0xEA	0x20	0x7A	0x8B	0x3E	0x20
31	tAA high	0x40	0x48	0x48	0x4E	0x3E	0x48	0x48	0x4E	0x3F	0x48	0x49	0x4E
SPD #	tRCD (ps)	14285	16000	16428	17500	14000	16000	16000	17500	14375	16000	16250	17500
32	tRCD low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
33	tRCD high	0x37	0x3E	0x40	0x44	0x36	0x3E	0x3E	0x44	0x38	0x3E	0x3F	0x44
SPD #	tRP (ps)	14285	16000	16428	17500	14000	16000	16000	17500	14375	16000	16250	17500
34	tRP low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
35	tRP high	0x37	0x3E	0x40	0x44	0x36	0x3E	0x3E	0x44	0x38	0x3E	0x3F	0x44
SPD #	tRAS (ps)	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000	32000
36	tRAS low	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00
37	tRAS high	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D	0x7D
SPD #	tRC (ps)	46285	48000	48428	49500	46000	48000	48000	49500	46375	48000	48250	49500
38	tRC low	0xCD	0x80	0x2C	0x5C	0xB0	0x80	0x80	0x5C	0x27	0x80	0x7A	0x5C
39	tRC high	0xB4	0xBB	0xBD	0xC1	0xB3	0xBB	0xBB	0xC1	0xB5	0xBB	0xBC	0xC1
SPD #	tWR (ps)	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000
40	tWR low	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30	0x30
41	tWR high	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75	0x75

9.6 Parameters with Lower nCK Limits, DDR5 Multi-Die Packages (3DS) SDRAMs

		DDR5-3200 3DS	DDR5-3600 3DS	DDR5-4000 3DS	DDR5-4400 3DS	DDR5-4800 3DS	DDR5-5200 3DS	DDR5-5600 3DS	DDR5-6000 3DS	DDR5-6400 3DS
tRRD_L_slr (1K)	ps	5000	5000	5000	5000	5000	5000	5000	5000	5000
tRRD_L_slr (1K)	nCK	8	8	8	8	8	8	8	8	8
tCCD_L_slr	ps	5000	5000	5000	5000	5000	5000	5000	5000	5000
tCCD_L_slr	nCK	8	8	8	8	8	8	8	8	8
tCCD_L_WR_slr	ps	20000	20000	20000	20000	20000	20000	20000	20000	20000
tCCD_L_WR_slr	nCK	32	32	32	32	32	32	32	32	32
tCCD_L_WR2_slr	ps	10000	10000	10000	10000	10000	10000	10000	10000	10000
tCCD_L_WR2_slr	nCK	16	16	16	16	16	16	16	16	16
tFAW_slr (1K)	ps	20000	17777	16000	14545	13333	12307	11428	10666	10000
tFAW_slr (1K)	nCK	32	32	32	32	32	32	32	32	32
tCCD_L_WTR_slr	ps	10000	10000	10000	10000	10000	10000	10000	10000	10000
tCCD_L_WTR_slr	nCK	16	16	16	16	16	16	16	16	16
tCCD_S_WTR_slr	ps	2500	2500	2500	2500	2500	2500	2500	2500	2500
tCCD_S_WTR_slr	nCK	4	4	4	4	4	4	4	4	4
tRTP_slr	ps	7500	7500	7500	7500	7500	7500	7500	7500	7500
tRTP_slr	nCK	12	12	12	12	12	12	12	12	12

SPD#			DDR5-3200 3DS	DDR5-3600 3DS	DDR5-4000 3DS	DDR5-4400 3DS	DDR5-4800 3DS	DDR5-5200 3DS	DDR5-5600 3DS	DDR5-6000 3DS	DDR5-6400 3DS
71, 70	tRRD_L_slr (1K)	MSB, LSB	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88
72	tRRD_L_slr (1K)	nCK	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08
74, 73	tCCD_L_slr	MSB, LSB	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88	0x13, 0x88
75	tCCD_L_slr	nCK	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08	0x08
77, 76	tCCD_L_WR_slr	MSB, LSB	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20	0x4E, 0x20
78	tCCD_L_WR_slr	nCK	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20
80, 79	tCCD_L_WR2_slr	MSB, LSB	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10
81	tCCD_L_WR2_slr	nCK	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10
83, 82	tFAW_slr (1K)	MSB, LSB	0x4E, 0x20	0x45, 0x71	0x3E, 0x80	0x38, 0xD1	0x34, 0x15	0x30, 0x13	0x2C, 0xA4	0x29, 0xAA	0x27, 0x10
84	tFAW_slr (1K)	nCK	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20	0x20
86, 85	tCCD_L_WTR_slr	MSB, LSB	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10	0x27, 0x10
87	tCCD_L_WTR_slr	nCK	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10	0x10
89, 88	tCCD_S_WTR_slr	MSB, LSB	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4	0x09, 0xC4
90	tCCD_S_WTR_slr	nCK	0x04	0x04	0x04	0x04	0x04	0x04	0x04	0x04	0x04
92, 91	tRTP_slr	MSB, LSB	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C	0x1D, 0x4C
93	tRTP_slr	nCK	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C	0x0C

9.6 Parameters with Lower nCK Limits, DDR5 Multi-Die Packages (3DS) SDRAMs (cont'd)

		DDR5-6800 3DS	DDR5-7200 3DS
tRRD_L_slr (1K)	ps	4705	4444
tRRD_L_slr (1K)	nCK	8	8
tCCD_L_slr	ps	5000	5000
tCCD_L_slr	nCK	8	8
tCCD_L_WR_slr	ps	20000	20000
tCCD_L_WR_slr	nCK	32	32
tCCD_L_WR2_slr	ps	10000	10000
tCCD_L_WR2_slr	nCK	16	16
tFAW_slr (1K)	ps	9411	8888
tFAW_slr (1K)	nCK	32	32
tCCD_L_WTR_slr	ps	10000	10000
tCCD_L_WTR_slr	nCK	16	16
tCCD_S_WTR_slr	ps	2352	2222
tCCD_S_WTR_slr	nCK	4	4
tRTP_slr	ps	7500	7500
tRTP_slr	nCK	12	12

SPD#			DDR5-6400 3DS	DDR5-6400 3DS
71, 70	tRRD_L_slr (1K)	MSB, LSB	0x12, 0x61	0x11, 0x5C
72	tRRD_L_slr (1K)	nCK	0x08	0x08
74, 73	tCCD_L_slr	MSB, LSB	0x13, 0x88	0x13, 0x88
75	tCCD_L_slr	nCK	0x08	0x08
77, 76	tCCD_L_WR_slr	MSB, LSB	0x4E, 0x20	0x4E, 0x20
78	tCCD_L_WR_slr	nCK	0x20	0x20
80, 79	tCCD_L_WR2_slr	MSB, LSB	0x27, 0x10	0x27, 0x10
81	tCCD_L_WR2_slr	nCK	0x10	0x10
83, 82	tFAW_slr (1K)	MSB, LSB	0x24, 0xC3	0x22, 0xB8
84	tFAW_slr (1K)	nCK	0x20	0x20
86, 85	tCCD_L_WTR_slr	MSB, LSB	0x27, 0x10	0x27, 0x10
87	tCCD_L_WTR_slr	nCK	0x10	0x10
89, 88	tCCD_S_WTR_slr	MSB, LSB	0x09, 0x30	0x08, 0xAE
90	tCCD_S_WTR_slr	nCK	0x04	0x04
92, 91	tRTP_slr	MSB, LSB	0x1D, 0x4C	0x1D, 0x4C
93	tRTP_slr	nCK	0x0C	0x0C

9.7 CAS Latency Masks, DDR5 Multi-Die Packages (3DS) SDRAMs

Optional downbins are included. Optional CAS latencies are not included.

3DS Speed Bin	SPD[24]	SPD[25]	SPD[26]	SPD[27]	SPD[28]
3200AN 3DS	0x6A	0x00	0x00	0x00	0x00
3200B 3DS	0x62	0x00	0x00	0x00	0x00
3200BN 3DS	0x62	0x00	0x00	0x00	0x00
3200C 3DS	0x42	0x00	0x00	0x00	0x00
3600AN 3DS	0xE2	0x01	0x00	0x00	0x00
3600B 3DS	0xE2	0x01	0x00	0x00	0x00
3600BN 3DS	0xC2	0x01	0x00	0x00	0x00
3600C 3DS	0x42	0x01	0x00	0x00	0x00
4000AN 3DS	0xEA	0x07	0x00	0x00	0x00
4000B 3DS	0xE2	0x07	0x00	0x00	0x00
4000BN 3DS	0x42	0x07	0x00	0x00	0x00
4000C 3DS	0x42	0x05	0x00	0x00	0x00
4400AN 3DS	0xE2	0x1F	0x00	0x00	0x00
4400B 3DS	0xE2	0x1F	0x00	0x00	0x00
4400BN 3DS	0x42	0x1D	0x00	0x00	0x00
4400C 3DS	0x42	0x15	0x00	0x00	0x00
4800AN 3DS	0xE2	0x7F	0x00	0x00	0x00
4800B 3DS	0xE2	0x7F	0x00	0x00	0x00
4800BN 3DS	0x42	0x75	0x00	0x00	0x00
4800C 3DS	0x42	0x55	0x00	0x00	0x00
5200AN 3DS	0xEA	0xFF	0x01	0x00	0x00
5200B 3DS	0xE2	0xFF	0x01	0x00	0x00
5200BN 3DS	0x42	0xD5	0x01	0x00	0x00
5200C 3DS	0x42	0x55	0x01	0x00	0x00
5600AN 3DS	0xE2	0xFF	0x05	0x00	0x00
5600B 3DS	0xE2	0xFF	0x05	0x00	0x00
5600BN 3DS	0xC2	0x75	0x05	0x00	0x00
5600C 3DS	0x42	0x55	0x05	0x00	0x00
6000AN 3DS	0xEA	0xFF	0x15	0x00	0x00
6000B 3DS	0xE2	0xFF	0x15	0x00	0x00
6000BN 3DS	0xE2	0xFF	0x15	0x00	0x00
6000C 3DS	0x42	0x55	0x15	0x00	0x00
6400AN 3DS	0xEA	0xFF	0x55	0x00	0x00
6400B 3DS	0xE2	0xFF	0x5F	0x00	0x00
6400BN 3DS	0xE2	0x7D	0x55	0x00	0x00
6400C 3DS	0x42	0x55	0x55	0x00	0x00
6800AN 3DS	0xE2	0xFF	0x5D	0x01	0x00
6800B 3DS	0xE2	0xFF	0x55	0x01	0x00
6800BN 3DS	0xC2	0xFD	0x54	0x01	0x00
6800C 3DS	0x42	0x55	0x55	0x01	0x00
7200AN 3DS	0xEA	0xFF	0x5D	0x05	0x00
7200B 3DS	0xE2	0xFF	0x55	0x05	0x00
7200BN 3DS	0xC2	0xFD	0x55	0x05	0x00
7200C 3DS	0x42	0x55	0x55	0x05	0x00

9.8 Parameters Defined by Device Density, DDR5 Multi-Die Packages (3DS) SDRAMs

		SPD[43]	SPD[42]
	ns	MSB	LSB
tRFC1_slr 3DS, 8Gb	195	0x00	0xC3
tRFC1_slr 3DS, 16Gb	295	0x01	0x27
tRFC1_slr 3DS, 24Gb	410	0x01	0x9A
tRFC1_slr 3DS, 32Gb	410	0x01	0x9A

		SPD[45]	SPD[44]
	ns	MSB	LSB
tRFC2_slr 3DS, 8Gb	130	0x00	0x82
tRFC2_slr 3DS, 16Gb	160	0x00	0xA0
tRFC2_slr 3DS, 24Gb	220	0x00	0xDC
tRFC2_slr 3DS, 32Gb	220	0x00	0xDC

		SPD[47]	SPD[46]
	ns	MSB	LSB
tRFCsb_slr 3DS, 8Gb	115	0x00	0x73
tRFCsb_slr 3DS, 16Gb	130	0x00	0x82
tRFCsb_slr 3DS, 24Gb	190	0x00	0xBE
tRFCsb_slr 3DS, 32Gb	190	0x00	0xBE

		SPD[49]	SPD[48]
	ns	MSB	LSB
tRFC1_dlr 3DS, 8Gb	65	0x00	0x41
tRFC1_dlr 3DS, 16Gb	99	0x00	0x63
tRFC1_dlr 3DS, 24Gb	137	0x00	0x89
tRFC1_dlr 3DS, 32Gb	137	0x00	0x89

		SPD[51]	SPD[50]
	ns	MSB	LSB
tRFC2_dlr 3DS, 8Gb	44	0x00	0x2C
tRFC2_dlr 3DS, 16Gb	54	0x00	0x36
tRFC2_dlr 3DS, 24Gb	74	0x00	0x4A
tRFC2_dlr 3DS, 32Gb	74	0x00	0x4A

		SPD[53]	SPD[52]
	ns	MSB	LSB
tRFCsb_dlr 3DS, 8Gb	39	0x00	0x27
tRFCsb_dlr 3DS, 16Gb	44	0x00	0x2C
tRFCsb_dlr 3DS, 24Gb	64	0x00	0x40
tRFCsb_dlr 3DS, 32Gb	64	0x00	0x40

9.9 Blocks 3~6: Module-Specific Section: Bytes 192~447 (0x0C0~0x1BF)

This clause contains SPD bytes which are specific to families DDR5 module families. Module Type Key Byte 3 is used as an index for the encoding of bytes 192~447. The content of bytes 192~447 are described in multiple annexes, one for each memory module family. These bytes are write protected.

9.10 Blocks 8~9: Module Supplier's Data: Bytes 512~639 (0x200~0x27F)

These blocks of the SPD contain information specific to the memory module assembly including module manufacturer ID, manufacturing location, and module part number.

9.11 Blocks 10~15: End User Programmable, Bytes 640~1023 (0x280~0x3FF)

These blocks of the SPD are not write protected so that end users may program any values into these bytes during system runtime or for system management.

10 Annex A — (Informative) Differences Between Revisions

This version incorporated ballots passed at June 2022 meeting as follows:

1. JC-45-136: MRDIMM (changed editorially to MRDIMM after tally)
2. JC-45-137: Add DDP back in
3. JC-45-138: Expanded rounding algorithm
4. JC-45-139: Example tables through 7200
5. Editorial changes per TG45_1^20220816a and approved by the BOD
 - Added support for RCD03, DB03 to RDIMM/LRDIMM annex
 - Clarified definition of “ranks”
 - Cleanup, clarifications for MRDIMM, sub-channels

Detailed changes as follows:

Clause	Changes
Page 1	Changed DDR5 SPD Document Release 1.1, Beta release 0 Changed Base SPD revision 1.1 Added MRDIMM annex revision 1.0
4.4	Added MRDIMM Overlay Schema
8.1.4	Changed 0111:Reserved to 0111:MRDIMM in Key Byte/Module Type Table for Byte 3 (0x003)
8.1.5	Changed 001:Reserved to 001:2 die; Dual-die package (DDP) in First SDRAM Density and Package Table for Byte 4 (0x004)
8.1.9	Changed 001:Reserved to 001:Reserved to 001:2 die; Dual-die package (DDP) in Second SDRAM Density and Package Table for Byte 8 (0x008)
8.3.1	Changed Rounding Algorithm section and added MT/s header in first column of Table 5
8.3.2	Modified pseudocode of CVL Algorithm
9	Added 6800 and 7200 speed grades in the clock period table (tCK)
9.1	Added new Table 9 Example #4, Codes for SPD Contents
9.2	Added new table for DDR5-6800 Mono and DDR5-7200 Mono parameters with Lower nCK Limits
9.3	Added Mono Sped Bins for 6800AN through 7200C in CAS Latency Masks table
9.5	Added new table for 6800AN through 7200C 3DS Core Parameters, DDR5 Multi-die Packages (3DS) SDRAMs
9.6	Added new table for DDR5-6800 through DDR5-7200 3DS Parameters with Lower nCK Limits, DDR5 3DS SDRAMs
9.7	Added 6800AN 3DS through 7200C 3DS speed bins in the CAS Latency Masks, DDR5 3DS SDRAM table
10	Changed from A4:Reserved to A4:Multiplexed Rank DIMMs (MRDIMM) Annex
10.2	Changed RCDs and DBs in the Hashing Sequence Table for Bits 2~0
15	Changed Annex A.4 from Reserved to Module Specific Bytes for Multiplexed Rank (MRDIMM) Memory Module Types
Sec. 6	SPD Revision Progression table revision
Sec. 8.1.4	Modified table for Byte 3 to add MRDIMM
Sec. 11.9	Annex A0:Common SPD Bytes for All Module Types, table modified
Sec. 11.10	Annex A0:Common SPD Bytes for All Module Types, table modified
Sec. 11.10.1	Annex A0:Common SPD Bytes for All Module Types, calculating Module DRAM Capacity
Sec. 14.2	Annex A3:Module Specific Bytes for Registered (RDIMM) and Load Reduced (LRDIMM) Memory Module Types, modified table

11 Annex A.0: Common SPD Bytes for All Module Types (Bytes 192~447, 0x0C0~0x1BF)

This clause describes SPD bytes that are common to all module types. Some bytes, as indicated in **Table 10**, are documented in separate annexes for each module type:

- A.1: Solder Down
- A.2: Unbuffered DIMMs (UDIMM)
- A.3: Registered DIMMs (RDIMM) and Load Reduced DIMMs (LRDIMM)
- A.4: Multiplexed Rank DIMMs (MRDIMM)
- A.5: Differential DIMMs (DDIMM)
- A.6: Non-Volatile DIMMs, -N (NVDIMM-N)
- A.7: Non-Volatile DIMMs, -P (NVDIMM-P)

Table 10 — Common SPD Bytes for All Module Types

SPD Bytes Common to All Module Types		
Byte Number		Function Described
192	0x0C0	SPD Revision for SPD bytes 192~447
193	0x0C1	Hashing Sequence
194	0x0C2	SPD Manufacturer ID Code, First Byte
195	0x0C3	SPD Manufacturer ID Code, Second Byte
196	0x0C4	SPD Device Type
197	0x0C5	SPD Device Revision Number
198	0x0C6	PMIC 0 Manufacturer ID Code, First Byte
199	0x0C7	PMIC 0 Manufacturer ID Code, Second Byte
200	0x0C8	PMIC 0 Device Type
201	0x0C9	PMIC 0 Revision Number
202	0x0CA	PMIC 1 Manufacturer ID Code, First Byte
203	0x0CB	PMIC 1 Manufacturer ID Code, Second Byte
204	0x0CC	PMIC 1 Device Type
205	0x0CD	PMIC 1 Revision Number
206	0x0CE	PMIC 2 Manufacturer ID Code, First Byte
207	0x0CF	PMIC 2 Manufacturer ID Code, Second Byte
208	0x0D0	PMIC 2 Device Type
209	0x0D1	PMIC 2 Revision Number
210	0x0D2	Thermal Sensor Manufacturer ID Code, First Byte
211	0x0D3	Thermal Sensor Manufacturer ID Code, Second Byte
212	0x0D4	Thermal Sensor Device Type
213	0x0D5	Thermal Sensor Revision Number
214~229	0x0D6~0x0E5	Reserved
230	0x0E6	Module Nominal Height
231	0x0E7	Module Maximum Thickness
232	0x0E8	Reference Raw Card Used
233	0x0E9	DIMM Attributes
234	0x0EA	Module Organization
235	0x0EB	Memory Channel Bus Width
236~239	0x0EC~0x0EF	Reserved
240~447	0x0F0~0x1BF	Module Type Specific Information. These SPD bytes are unique to each module type. See the appropriate annex for the module.

11.1 (Common): SPD Revision for Module Information**Byte 192 (0x0C0)**

This byte defines the SPD revision for bytes 192~447. See SPD byte 1 for details.

11.2 (Common): Hashing Sequence**Byte 193 (0x0C1)**

This byte defines the sequence of device serial numbers used in the hashing of an attribute certificate for the authentication of a memory solution. See JESD316-5 Enhanced Serial Presence Detect Device Specification for details. If authentication is not supported, code as 0x00.

Hashing Sequence	
Bits 7~3	Bits 2~0
Reserved	Serial Number Hashing Sequence
Reserved; must be coded as 00000	000 = No authentication 001 = Algorithm 1 ESPDs DRAMs PMICs RCDs/MRCDs TSs DBs/MDBs All other codes reserved

11.3 (Common): Module Device Information**Bytes 194~213 (0x0C2~0x0D5)**

Table 11 lists the SPD byte addresses for the key components on this assembly.

Table 11 — SPD Byte Addresses for Key Components

Module Generic Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
SPD	194	0x0C2	195	0x0C3	196	0x0C4	197	0x0C5
PMIC 0	198	0x0C6	199	0x0C7	200	0x0C8	201	0x0C9
PMIC 1	202	0x0CA	203	0x0CB	204	0x0CC	205	0x0CD
PMIC 2	206	0x0CE	207	0x0CF	208	0x0D0	209	0x0D1
Thermal Sensors (TS)	210	0x0D2	211	0x0D3	212	0x0D4	213	0x0D5
Notes: SPD = Serial Presence Detect PMIC = Power Management Integrated Circuit								

11.3 (Common): Module Device Information (Bytes 194~213 (0x0C2~0x0D5) (cont'd)

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
SPD	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: SPD5118 (see JESD300-5) 0001: ESPD5216 (see JESD316-5) All other codes reserved
PMIC 0	0 = Not installed 1 = Installed			0000: PMIC5000 (see JESD301-1) 0001: PMIC5010 (see JESD301-1) 0010: PMIC5100 (see JESD301-2) All other codes reserved
PMIC 1	0 = Not installed 1 = Installed			
PMIC 2	0 = Not installed 1 = Installed			
Thermal Sensors	0 = TS0 Not installed 1 = TS0 Installed	0 = TS1 Not installed 1 = TS1 Installed		0000: TS5111 (see JESD302-1) 0001: TS5110 (see JESD302-1) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

11.4 (Common): Reserved Bytes 214~229 (0x0D6~0x0E5)

11.5 (Common): Module Nominal Height

Byte 230 (0x0E6)

This byte defines the nominal height (A dimension) in millimeters of the fully assembled module including heat spreaders or other added components. Refer to the relevant JEDEC JC-11 module outline (MO) documents for dimension definitions.

Module Nominal Height	
Bits 7~5	Bits 4~0
Reserved	Module Nominal Height max, in mm (baseline height = 15 mm)
Reserved; must be coded as 000	00000 = height \leq 15 mm 00001 = 15 < height \leq 16 mm 00010 = 16 < height \leq 17 mm 00011 = 17 < height \leq 18 mm 00100 = 18 < height \leq 19 mm ... 01010 = 24 < height \leq 25 mm 01011 = 25 < height \leq 26 mm ... 01111 = 29 < height \leq 30 mm 10000 = 30 < height \leq 31 mm 10001 = 31 < height \leq 32 mm ... 11111 = 45 mm < height

Examples:

Nominal Module Height	Coding, bits 4 ~ 0	Meaning
mm	Binary	mm
18.75	00100	18 < height \leq 19 mm
25.40	01011	25 < height \leq 26 mm
30.00	01111	29 < height \leq 30 mm
30.25	10000	30 < height \leq 31 mm
31.25	10001	31 < height \leq 32 mm

11.6 (Common): Module Maximum Thickness
Byte 231 (0x0E7)

This byte defines the maximum thickness in millimeters of the fully assembled module including heat spreaders or other added components above the module circuit board surface, rounding up to the next integer. Refer to the relevant JEDEC JC-11 module outline (MO) documents for dimension definitions.

Module Maximum Thickness	
Bits 7 ~ 4	Bits 3 ~ 0
Module Maximum Thickness max, Back, in mm (baseline thickness = 1 mm)	Module Maximum Thickness max, Front, in mm (baseline thickness = 1 mm)
0000 = thickness ≤ 1 mm 0001 = 1 < thickness ≤ 2 mm 0010 = 2 < thickness ≤ 3 mm 0011 = 3 < thickness ≤ 4 mm ... 1110 = 14 < thickness ≤ 15 mm 1111 = 15 < thickness	0000 = thickness ≤ 1 mm 0001 = 1 < thickness ≤ 2 mm 0010 = 2 < thickness ≤ 3 mm 0011 = 3 < thickness ≤ 4 mm ... 1110 = 14 < thickness ≤ 15 mm 1111 = 15 < thickness

11.7 (Common): Reference Raw Card Used

Byte 232 (0x0E8)

This byte indicates which JEDEC reference design raw card was used as the basis for the module assembly, if any. Special reference raw card indicator, ZZ, is used when no JEDEC standard raw card reference design was used as the basis for the module design. Pre-production modules should be encoded as revision 0 in bits 7~5.

Reference Raw Card Used	
Bit 7~5	Bits 4~0
Design Revision	Reference Design
000 = Revision 0	00000 = A
001 = Revision 1	00001 = B
010 = Revision 2	00010 = C
011 = Revision 3	00011 = D
100 = Revision 4	00100 = E
101 = Revision 5	00101 = F
110 = Revision 6	00110 = G
	00111 = H
	01000 = J
	01001 = K
	01010 = L
	01011 = M
	01100 = N
	01101 = P
	01110 = R
	01111 = T
	10000 = U
	10001 = V
	10010 = W
	10011 = Y
	10100 = AA
	10101 = AB
	10110 = AC
	10111 = AD
	11000 = AE
	11001 = AF
	11010 = AG
	11011 = AH
	11100 = AJ
	11101 = AK
	11110 = Reserved
	11111 = ZZ (No reference used)
11111111 = ZZ (no JEDEC reference raw card design used)	

11.8 (Common): DIMM Attributes

Byte 233 (0x0E9)

This byte indicates the number of rows of DRAM packages (monolithic or 3D stacked) parallel to edge connector (independent of DRAM orientation) on each side of the printed circuit board, and whether the assembly is covered in a heat spreader. The temperature range applies to the SDRAM components on the module. All other support components on the module must remain within their respective operating temperature ranges when the case temperature of the SDRAMs are at the minimum and maximum values.

DIMM Attributes			
Bits 7~4	Bit 3	Bit 2	Bits 1~0
Operating Temperature Range ¹	Reserved	Heat Spreader	# of rows of DRAMs on Module
0000 = A1T (-40 to +125 °C) 0001 = A2T (-40 to +105 °C) 0010 = A3T (-40 to +85 °C) 0011 = IT (-40 to +95 °C) 0100 = ST (-25 to +85 °C) 0101 = ET (-25 to +105 °C) 0110 = RT (0 to +45 °C) 0111 = NT (0 to +85 °C) 1000 = XT (0 to +95 °C) ² All other codings reserved	Reserved; must be coded as 0	0 = Not installed 1 = Installed	00 = Undefined 01 = 1 row 10 = 2 rows 11 = Reserved
NOTE 1 See JESD402-1 for details NOTE 2 Typical DDR5 SDRAM thermal specification is XT, 0 to +95 °C, code 1000 in bits 7~4			

11.9 (Common): Module Organization

Byte 234 (0x0EA)

This byte describes the organization of the SDRAM module. Bits 5~3 encode the number of package ranks on the module. Bit 6 describes whether the assembly has the same SDRAM density on all ranks or has different SDRAM densities on even and odd ranks.

Module Organization			
Bit 7	Bit 6	Bits 5~3	Bits 2~0
Reserved	Rank Mix	Number of Package Ranks per Sub-Channel	Reserved
Reserved; must be coded as 0	0 = Symmetrical 1 = Asymmetrical	Bit [5, 4, 3] : 000 = 1 Package Rank 001 = 2 Package Ranks 010 = 3 Package Ranks 011 = 4 Package Ranks 100 = 5 Package Ranks 101 = 6 Package Ranks 110 = 7 Package Ranks 111 = 8 Package Ranks	Reserved; must be coded as 000

11.9 (Common): Module Organization (Byte 234 (0x0EA) (cont'd)

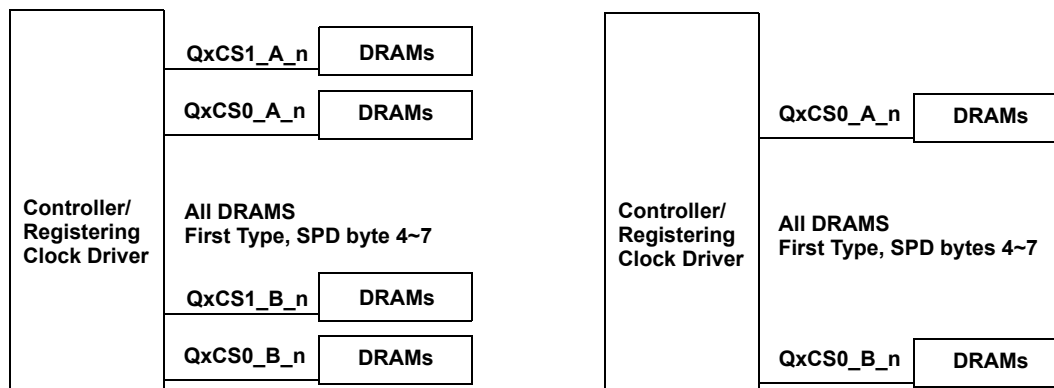
“Package ranks per DIMM” refers to the collections of devices on the module sharing common chip select signals or copy of a chip select (across the data width of the DIMM sub-channel), either from the edge connector for unbuffered modules or from the outputs of a registering clock driver for RDIMMs and LRDIMMs.

“Logical rank” refers the individually addressable die in a 3DS stack and has no meaning for monolithic SDRAMs, however, for purposes of calculating the capacity of the module, one should treat monolithic SDRAMs as having one logical rank per package rank.

“Channel” to the data interface at the DIMM edge connector, and “Sub-channel” refers to the inter-face to the separately addressable groups of SDRAMs. For example, DDR5 DIMMs with an 80-bit channel width are addressable as two 40-bit sub-channels, often referred to as “left” and “right” or “Sub-channel A” and “Sub-channel B”

Byte 242 Bit 6 = 0 defines a memory module as being “symmetrical” where all SDRAM devices on the module are “First SDRAM” type per SPD bytes 4~7.

Examples shown cover 1 and 2 rank modules, i.e., codes 000 or 001 in SPD byte 234 bits 5~3; for higher package rank counts, apply the same logic.



Symmetrical Configurations (byte 234 Bit 6 = 0)

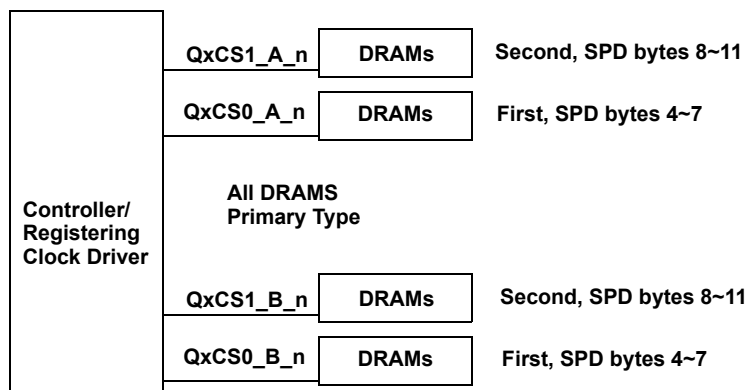
Rank Matrix for Symmetrical Modules (Byte 234 Bit 6 = 0)		
SDRAM Package Type	# Package Ranks per Channel	# Logical Ranks per Channel
SPD Byte 4 Bits 7~5	SPD Byte 234 Bits 5~3	Calculated
SDP	1	1
	2	2
2H 3DS	1	2
	2	4
4H 3DS	1	4
	2	8
8H 3DS	1	8
	2	16
16H 3DS	1	16
	2	32
Logical Ranks per Channel = # Package Ranks per Channel * # Logical Ranks per Package Rank		
Bytes 8~10 coded as 0x00 for all symmetrical configurations		

11.9 (Common): Module Organization (Byte 234 (0x0EA) (cont'd)

Byte 234 Bit 6 = 1 defines a memory module as being “asymmetrical”, where all DRAMs in even package ranks (0, 2, 4, 6) are of “First SDRAM” type per SPD bytes 4~7, and all DRAMs in odd package ranks (1, 3, 5, 7) are of “Second SDRAM” type as described in SPD bytes 8~11.

The example shown covers the case of a 2 rank module, i.e., code 001 in SPD byte 234 bits 5~3; for higher package rank counts, apply the same logic for even (Primary) and odd (Secondary) ranks.

The I/O width of all ranks (SPD byte 6 bits 7~5 and SPD byte 10 bits 7~5) in an asymmetrical assembly must be the same, e.g., all x4 or all x8.



Asymmetrical Configurations (byte 234 Bit 6 = 1)

Rank Mix for Asymmetrical Modules (Byte 242 Bit 6 = 1)			
First SDRAM Package Type	Second SDRAM Package Type	# Package Ranks per Channel	# Logical Ranks per Channel
SPD Byte 4 Bits 7~5	SPD Byte 8 Bits 7~5	SPD Byte 234 Bits 5~3	Calculated
SDP	2H 3DS	2	3
2H 3DS	SDP	2	3
SDP	4H 3DS	2	5
4H 3DS	SDP	2	5
...
8H 3DS	16H 3DS	2	24
16H 3DS	8H 3DS	2	24
Logical Ranks per DIMM = # Logical Ranks in Primary SDRAM type + # Logical Ranks in Secondary SDRAM type			

11.10 (Common): Memory Channel Bus Width

Byte 235 (0x0EB)

This byte describes the width of the SDRAM memory bus on the module. Bits 2~0 encode the primary bus width. Bits 4~3 encode the bus extensions such as parity or ECC. Bits 6~5 defines the number of channels on each module.

Memory Channel Bus Width			
Bit 7	Bits 6~5	Bits 4~3	Bits 2~0
Reserved	Number of Sub-Channels per DIMM	Bus width extension per Sub-Channel, in bits	Primary bus width per Sub-Channel, in bits
Reserved; must be coded as 0	Bit [6, 5] : 00 = 1 channel 01 = 2 channels All others reserved	Bit [4, 3] : 00 = 0 bits (no extension) 01 = 4 bits 10 = 8 bits All others reserved	Bit [2, 1, 0] : 000 = 8 bits 001 = 16 bits 010 = 32 bits 011 = 64 bits All others reserved

Examples:

Number of Sub-Channels Per DIMM	Primary Bus Width per Sub-Channel	Bus Width Extension Per Sub-Channel	Byte 235 Coding	Total Data Width per DIMM	Standard Usage
2	32	0	0 01 00 010	64	SODIMM, UDIMM
2	32	4	0 01 01 010	72	ECC SODIMM, ECC UDIMM
2	32	8	0 01 10 010	80	EC8 RDIMM, LRDIMM, NVDIMM MRDIMM
2	32	4	0 01 01 010	72	EC4 RDIMM

11.10.1 Calculating Module DRAM Capacity

The total memory capacity of the DRAM on a DIMM may be calculated from SPD values. **Table 12** details the SPD bytes needed for the calculation.

Table 12 — SPD Bytes Needed for Total Memory Capacity Calculation

Symmetry	Package Ranks per Sub-Channel	SDRAM Density per Die	Die per Package	SDRAM I/O Width	Primary Bus Width per Sub-Channel	Number of Sub-Channels per DIMM
0 = Symmetrical	All	SPD byte 4 Bits 4~0	SPD byte 4 Bits 7~5	SPD byte 6 Bits 7~5	SPD byte 235 Bits 2~0	SPD byte 235 Bits 6~5
1 = Asymmetrical	Even (0, 2, 4, 6)	SPD byte 4 Bits 4~0	SPD byte 4 Bits 7~5	SPD byte 6 Bits 7~5	SPD byte 235 Bits 2~0	SPD byte 235 Bits 6~5
	Odd (1, 3, 5, 7)	SPD byte 8 Bits 4~0	SPD byte 8 Bits 7~5	SPD byte 10 Bits 7~5	SPD byte 235 Bits 2~0	SPD byte 235 Bits 6~5

11.10.1 Calculating Module DRAM Capacity (cont'd)

To calculate the total capacity in bytes for a symmetric module, the following math applies:

$$\begin{aligned} \text{Capacity in bytes} = & \\ & \text{Number of sub-channels per DIMM} * \\ & \text{Primary bus width per sub-channel / SDRAM I/O Width} * \\ & \text{Die per package} * \\ & \text{SDRAM density per die / 8} * \\ & \text{Package ranks per sub-channel} \end{aligned}$$

To calculate the total capacity in bytes for an asymmetric module, the following math applies:

$$\begin{aligned} \text{Capacity in bytes} = & \\ & \text{Capacity of even ranks (first SDRAM type)} + \\ & \text{Capacity of odd ranks (second SDRAM type)} \end{aligned}$$

Commonly, parity or ECC are not counted in total module capacity, though they can also be included by adding the bus width extension in SPD byte 235 bits 4~3 to the primary bus width in the previous examples.

11.11 (Common): Reserved Bytes 236~239 (0x0EC~0EF)

Reserved - must be coded as 0x00

11.12 (Common): Module Type Specific Information Bytes 240~447 (0x0F0~0x1BF)

These bytes are specific to each module type. See the appropriate annex for definition.

12 Annex A.1: Module Specific Bytes for Solder Down (Bytes 192~447, 0x0C0~0x1BF)

12.1 Revision 1.0: Byte 192 Coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Memory Technology Key Byte 2 contains the value 0x12 and Module Type Key Byte 3 contains any of the following:

- 0xHB, Solder Down
- where H refers to the hybrid memory architecture, if any present

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0xEF).

Module Specific SPD Bytes for Solder Down Memory		
Byte Number		Function Described
240~447	0x0F0~0x1BF	Reserved

12.2 Bytes 240~447 (0x0F8~0x1BF) (Solder Down):

Reserved - must be coded as 0x00.

13 Annex A.2: Module Specific Bytes for Unbuffered Memory Module Types (Bytes 192~447, 0x0C0~0x1BF)

13.1 Revision 1.0: Byte 192 Coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Memory Technology Key Byte 2 contains the value 0x12 and Module Type Key Byte 3 contains any of the following:

- 0x02, UDIMM
- 0x03, SODIMM

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0EF).

Module Specific SPD Bytes for Unbuffered Module Types		
Byte Number		Function Described
240	0x0F0	Clock Driver Manufacturer ID Code, First Byte
241	0x0F1	Clock Driver Manufacturer ID Code, Second Byte
242	0x0F2	Clock Driver Device Type
243	0x0F3	Clock Driver Revision Number
244~445	0x0F4~0x1BD	Reserved

13.2 (Unbuffered): Module Specific Device Information Bytes 240~243 (0x0F0~0x0F3)

Table 13 lists the SPD byte addresses for the key components on this assembly.

Table 13 — SPD Byte Addresses for Unbuffered Memory Module Types

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Clock Driver (CK)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3

13.2 (Unbuffered): Module Specific Device Information (cont'd)

Bytes 240~243 (0x0F0~0x0F3)

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Clock Driver (CK)	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DDR5CK01 (see JESD82-531) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

13.3 (Unbuffered): Reserved

Bytes 244~447 (0x0F4~0x1BF)

Reserved - must be coded as 0x00.

14 Annex A.3: Module Specific Bytes for Registered (RDIMM) and Load Reduced (LRDIMM) Memory Module Types

14.1 (Bytes 192~447, 0x0C0~0x1BF)

Revision 1.0: Byte 192 Coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Memory Technology Key Byte 2 contains the value 0x12 and Module Type Key Byte 3 contains any of the following:

- 0xH1, RDIMM
- 0xH4, LRDIMM
- where H refers to the hybrid memory architecture, if any present on the module.

Table entries highlighted in light blue are LRDIMM specific.

The ECC data width for RDIMMs may vary from design to design. Some RDIMMs support 8-bit ECC per channel (EC8: 2 channels of 40 bits wide each) while other RDIMMs support 4-bit ECC per channel (EC4: 2 channels of 36 bits wide each). To determine which configuration of ECC is supported by this module design, look to the following SPD bytes:

- SPD byte 232: Reference Raw Card Used
- SPD byte 235: Memory Channel Bus Width, especially bits 4~3, bus width extension

RDIMMs and LRDIMMs may support symmetrical or asymmetrical memory ranks. Symmetrical means that all ranks on the DIMM are identical. Asymmetrical means that even ranks and odd ranks may contain SDRAMs of different per-device capacity. This rule applies across both A and B channels; all devices on both A and B channels within any rank must be identical. See Annex A.0 Common SPD Bytes for details. In particular, symmetry is defined by the following SPD byte:

- SPD byte 234: Module Organization, especially bit 6, Rank Mix

All note that other SDRAM characteristics may vary between even and odd ranks in asymmetrical designs, such as Refresh Management (RFM) settings.

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0xEF).

14.1 (Bytes 192~447, 0x0C0~0x1BF), Revision 1.0: Byte 192 Coded as 0x10 (cont'd)

Module Specific SPD Bytes for Registered and Load Reduced Module Types		
Byte Number		Function Described
240	0x0F0	Registering Clock Driver Manufacturer ID Code, First Byte
241	0x0F1	Registering Clock Driver Manufacturer ID Code, Second Byte
242	0x0F2	Register Device Type
243	0x0F3	Register Revision Number
244	0x0F4	Data Buffer Manufacturer ID Code, First Byte
245	0x0F5	Data Buffer Manufacturer ID Code, Second Byte
246	0x0F6	Data Buffer Device Type
247	0x0F7	Data Buffer Revision Number
248	0x0F8	RCD-RW08 Clock Driver Enable
249	0x0F9	RCD-RW09 Output Address and Control Enable
250	0x0FA	RCD-RW0A QCK Driver Characteristics
251	0x0FB	RCD-RW0B
252	0x0FC	RCD-RW0C QxCA and QxCS_n Driver Characteristics
253	0x0FD	RCD-RW0D Data Buffer Interface Driver Characteristics
254	0x0FE	RCD-RW0E QCK, QCA and QCS Output Slew Rate
255	0x0FF	RCD-RW0F BCK, BCOM, and BCS Output Slew Rate
256	0x100	DB-RW86 DQS RTT Park Termination
257~447	0x101~0x1BF	Reserved

**14.2 (RDIMM/LRDIMM): Module Specific Device Information
Bytes 240~247 (0x0F0~0x0F7)**

Table 14 lists the SPD byte addresses for the key components on this assembly.

Table 14 — SPD Byte Addresses for RDIMM / LRDIMM

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Registering Clock Driver (RCD)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3
Data Buffers (DB)	244	0x0F4	245	0x0F5	246	0x0F6	247	0x0F7

14.2 (RDIMM/LRDIMM): Module Specific Device Information (cont'd)

Bytes 240~247 (0x0F0~0x0F7)

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Registering Clock Driver (RCD)	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DDR5RCD01 (see JESD82-511) 0001: DDR5RCD02 (see JESD82-512) 0010: DDR5RCD03 (see JESD82-513) All other codes reserved
Data Buffers (DB)	0 = Not installed (RDIMM) 1 = Installed (LRDIMM)			0000: DDR5DB01 (see JESD82-521) 0001: DDR5DB02 (see JESD82-522) All other codes reserved RDIMM: code as 0000

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

14.3 (RDIMM/LRDIMM): RCD-RW08 Clock Driver Enable

Byte 248 (0x0F8)

Byte defined as per JESD82-511 DDR5RCD01 standard.

RCD-RW08: Clock Driver Enable						
Bits 7~6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	BCK_t/ BCK_c	Reserved	QDCK_t/ QDCK_c	QCCK_t/ QCCK_c	QBCK_t/ QBCK_c	QACK_t/ QACK_c
Reserved; must be coded as 00	0 = Enabled 1 = Disabled	Reserved; must be coded as 0	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled

14.4 (RDIMM/LRDIMM): RCD-RW09 Output Address and Control Enable Byte 249 (0x0F9)

Byte defined as per JESD82-511 DDR5RCD01 standard.

RCD-RW09: Output Address and Control Enables			
Bit 7	Bit 6	Bit 5	Bit 4
Reserved	QBCS[1:0]_n output	QACS[1:0]_n output	Q[B:A]CA13 output driver
Reserved; must be coded as 0	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled
Bit 3	Bit 2	Bit 1	Bit 0
BCS_n, BCOM[2:0] and BRST_n outputs	DCS1_n input buffer and QxCS1_n outputs	QBCA outputs	QACA outputs
0 = Enabled (LRDIMM) 1 = Disabled (RDIMM)	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled	0 = Enabled 1 = Disabled

14.5 (RDIMM/LRDIMM): RCD-RW0A QCK Driver Characteristics Byte 250 (0x0FA)

Byte defined as per JESD82-511 DDR5RCD01 standard.

RCD-RW0A: QCK Driver Characteristics			
Bits 7~6	Bits 5~4	Bits 3~2	Bits 1~0
QDCK_t/QDCK_c	QCCK_t/QCCK_c	QBCK_t/QBCK_c	QACK_t/QACK_c
00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved

14.6 (RDIMM/LRDIMM): RCD-RW0B Byte 251 (0x0FB)

RCD-RW0B:
Bits 7~0
Reserved
Reserved. Must be coded as 0x00.

14.7 (RDIMM/LRDIMM): RCD-RW0C QxCA and QxCS_n Driver Characteristics Byte 252 (0x0FC)

Byte defined as per JESD82-511 DDR5RCD01 standard.

RCD-RW0C: QxCA and QxCS _n Driver Characteristics			
Bits 7~6	Bits 5~4	Bits 3~2	Bits 1~0
Reserved	Driver Strength QxCS0 _n , QxCS1 _n	Reserved	Driver Strength Address/Command for both A and B outputs
Reserved. Must be coded as 00	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved	Reserved. Must be coded as 00	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved

14.8 (RDIMM/LRDIMM): RCD-RW0D Data Buffer Interface Driver Characteristics Byte 253 (0x0FD)

Byte defined as per JESD82-511 DDR5RCD01 standard. These values are LRDIMM specific; RDIMMs shall encode as 0x00.

RCD-RW0D: Data Buffer Interface Driver Characteristics			
Bits 7~5	Bits 4~3	Bit 2	Bits 1~0
Reserved	Driver Strength BCK _t /BCK _c	Reserved	Driver Strength BCOM[2:0], BCS _n
Reserved. Must be coded as 000	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = RZQ/24 (10 Ω) 11 = Reserved	Reserved. Must be coded as 0	00 = RZQ/12 (20 Ω) 01 = RZQ/17 (14 Ω) 10 = Reserved 11 = Reserved

14.9 (RDIMM/LRDIMM): RCD-RW0E QCK, QCA, and QCS Output Slew Rate Byte 254 (0x0FE)

Byte defined as per JESD82-511 DDR5RCD01 standard.

RCD-RW0E: QCK, QCA, and QCS Output Slew Rate			
Bits 7~6	Bits 5~4	Bits 3~2	Bits 1~0
Reserved	Q[B:A]CS[1:0] _n Single Ended Slew Rate	Q[B:A]CA[13:0] Single Ended Slew Rate	QCK[D:A] _t /QCK[D:A] _c Differential Slew Rate
Reserved. Must be coded as 00	00 = Moderate (4-7 V/ns) 01 = Fast (6-10 V/ns) 10 = Slow (2.7-4.5 V/ns) 11 = Reserved	00 = Moderate (4-7 V/ns) 01 = Fast (6-10 V/ns) 10 = Slow (2.7-4.5 V/ns) 11 = Reserved	00 = Moderate (12-20 V/ns) 01 = Fast (14-27 V/ns) 10 = Reserved 11 = Reserved

14.10 (RDIMM/LRDIMM): RCD-RW0F BCK, BCOM, and BCS Output Slew Rate Byte 255 (0x0FF)

Byte defined as per JESD82-511 DDR5RCD01 standard. These values are LRDIMM specific; RDIMMs shall encode as 0x00.

RCD-RW0F: BCK, BCOM, and BCS Output Slew Rate		
Bits 7~4	Bits 3~2	Bits 1~0
Reserved	BCK_t/BCK_c Differential Slew Rate	BCOM[2:0], BCS_n Single Ended slew rate
Reserved. Must be coded as 0000	00 = Moderate (12-20 V/ns) 01 = Fast (14-27 V/ns) 10 = Reserved 11 = Reserved	00 = Moderate (3.7-6.7 V/ns) 01 = Fast (5.2-9.2 V/ns) 10 = Slow (2.5-4.3 V/ns) 11 = Reserved

14.11 (RDIMM/LRDIMM): DB-RW86 DQS RTT Park Termination Byte 256 (0x100)

Byte defined as per JESD82-521 DDR5DB01 standard. These values are LRDIMM specific; RDIMMs shall encode as 0x00.

DB-RW86: DQS RTT Park Termination	
Bits 7~3	Bits 2~0
Reserved	DQS RTT Park Termination
Reserved. Must be coded as 00000	000 = RTT_OFF (default) 001 = RZQ/1 (240 Ω) 010 = RZQ/2 (120 Ω) 011 = RZQ/3 (80 Ω) 100 = RZQ/4 (60 Ω) 101 = RZQ/5 (48 Ω) 110 = RZQ/6 (40 Ω) 111 = RZQ/7 (34 Ω)

14.12 (RDIMM/LRDIMM): Reserved Bytes 257~447 (0x101~0x1BF)

Reserved - must be coded as 0x00.

15 Annex A.4: Module Specific Bytes for Multiplexed Rank (MRDIMM) Memory Module Types

15.1 (Bytes 192~447 (0x0C0~1BF))

Revision 1.0: byte 192 coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Memory Technology Key Byte 2 contains the value 0x12 and Module Type Key Byte 3 contains any of the following:

- 0x07, MRDIMM

The ECC data width for MRDIMMs may vary from design to design. Some MRDIMMs support 8-bit ECC per channel / pseudo-channel (EC8: 2 channels each with 2 pseudo channels of 40 bits wide each) while other MRDIMMs support 4-bit ECC per channel / Pseudo-channel (EC4: 2 channels each with 2 pseudo channels of 36 bits wide each). To determine which configuration of ECC is supported by this module design, look to the following SPD bytes:

- SPD byte 232: Reference Raw Card Used
- SPD byte 235: Memory Channel Bus Width, especially bits 4~3, bus width extension

MRDIMMs may support symmetrical or asymmetrical memory ranks. Symmetrical means that all ranks on the DIMM are identical. Asymmetrical means that even ranks and odd ranks may contain SDRAMs of different per-device capacities. This rule applies across both A and B channels and across both pseudo-channels of a channel; all devices on both A and B channels within any rank must be identical and all devices on both pseudo-channels within a rank must be identical. See Annex A.0 Common SPD Bytes for details. In particular, symmetry is defined by the following SPD byte:

- SPD byte 234: Module Organization, especially bit 6, Rank Mix

All note that other SDRAM characteristics may vary between even and odd ranks in asymmetrical designs, such as Refresh Management (RFM) settings.

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0EF).

Module Specific SPD Bytes for Multiplexed Rank Module Types		
Byte Number		Function Described
240	0x0F0	Multiplex Registering Clock Driver Manufacturer ID Code, First Byte
241	0x0F1	Multiplex Registering Clock Driver Manufacturer ID Code, Second Byte
242	0x0F2	Register Device Type
243	0x0F3	Register Revision Number
244	0x0F4	Multiplex Data Buffer Manufacturer ID Code, First Byte
245	0x0F5	Multiplex Data Buffer Manufacturer ID Code, Second Byte
246	0x0F6	Data Buffer Device Type
247	0x0F7	Data Buffer Revision Number
248~447	0x0F8~0x1BF	Reserved

15.2 (MRDIMM): Module Specific Device Information

Bytes 240~247 (0x0F0~0x0F7)

Table 15 lists the SPD byte addresses for the key components on this assembly.

Table 15 — SPD Byte Addresses for MRDIMM Key Components

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Multiplex Registering Clock Driver (MRCD)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3
Multiplex Data Buffers (MDB)	244	0x0F4	245	0x0F5	246	0x0F6	247	0x0F7

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Multiplex Registering Clock Driver (MRCD)	Must be coded as 1 (installed)	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DDR5MRCD01 (see JESD82-541) All other codes reserved
Multiplex Data Buffers (MDB)	Must be coded as 1 (installed)			0000: DDR5MDB01 (see JESD82-551) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

16 Annex A.5: Module Specific Bytes for Differential Memory Module Types (Bytes 192~447, 0x0C0~0x1BF)

16.1 Revision 1.0: Byte 192 Coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Memory Technology Key Byte 2 contains the value 0x0C and Module Type Key Byte 3 contains any of the following:

- 0xHA, DDIMM
- where H refers to the hybrid memory architecture, if any present on the module

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0EF).

Module Specific SPD Bytes for Differential Module Types		
Byte Number		Function Described
240	0x0F0	Differential Memory Buffer Manufacturer ID Code, First Byte
241	0x0F1	Differential Memory Buffer Manufacturer ID Code, Second Byte
242	0x0F2	Differential Memory Buffer Device Type
243	0x0F3	Differential Memory Buffer Revision Number
244~447	0x0F6~0x1BF	Reserved

16.2 (Differential): Module Specific Device Information Bytes 240~243 (0x0F0~0x0F3)

Table 16 lists the SPD byte addresses for the key components on this assembly.

Table 16 — SPD Byte Addresses for (Differential) Module Specific Device Information

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Differential Memory Buffer (DMB)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3

16.2 (Differential): Module Specific Device Information

Bytes 240~243 (0x0F0~0x0F3) (cont'd)

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Differential Memory Buffer (DMB)	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DMB501 (see JESD303-1) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

16.3 (Differential): Reserved

Bytes 204~447 (0x0F4~0x1BF)

Reserved - must be coded as 0x00.

17 Annex A.6: Non-Volatile (NVDIMM-N) Hybrid Memory Parameters (Bytes 192~447, 0x0C0~0x1BF)

17.1 Revision 0.1: Byte 192 Coded as 0x01

This clause defines the encoding of SPD bytes 192~447 when Module Type Key Byte 3 contains the following:

- 0x9M, NVDIMM-N
- where M refers to the base memory architecture

NVDIMM types defined at this time are:

NVDIMM-N	Persistent DRAM using NAND flash
----------	----------------------------------

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0EF).

Module Specific SPD Bytes for NVDIMM-N Module Types		
Byte Number		Function Described
240	0x0F0	Registering Clock Driver Manufacturer ID Code, First Byte
241	0x0F1	Registering Clock Driver Manufacturer ID Code, Second Byte
242	0x0F2	Register Device Type
243	0x0F3	Register Revision Number
244	0x0F4	Data Buffer Manufacturer ID Code, First Byte
245	0x0F5	Data Buffer Manufacturer ID Code, Second Byte
246	0x0F6	Data Buffer Device Type
247	0x0F7	Data Buffer Revision Number
248~447	0x0F8~0x1BF	Reserved

17.2 (NVDIMM-N): Module Specific Device Information

Bytes 240~247 (0x0F0~0x0F7)

Table 17 lists the SPD byte addresses for the key components on this assembly.

Table 17 — SPD Byte Addresses for NVDIMM-N Assembly

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Registering Clock Driver (RCD)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3
Data Buffers (DB)	244	0x0F4	245	0x0F5	246	0x0F6	247	0x0F7

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Registering Clock Driver (RCD)	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DDR5RCD01 (see JESD82-511) All other codes reserved
Data Buffers (DB)	0 = Not installed 1 = Installed			0000: DDR5DB01 (see JESD82-521) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

17.3 (NVDIMM-N): Reserved

Bytes 248~447 (0x0F8~0x1BF)

Reserved - must be coded as 0x00.

18 Annex A.7: Non-Volatile (NVDIMM-P) Hybrid Memory Parameters

18.1 (Bytes 192~447, 0x0C0~0x1BF)

Revision 1.0: Byte 192 Coded as 0x10

This clause defines the encoding of SPD bytes 192~447 when Module Type Key Byte 3 contains the following:

- 0xAM, NVDIMM-P
- where M refers to the base memory architecture

NVDIMM types defined at this time are:

Type	Definition	Specification
NVDIMM-P	Transactional credit based memory module	JESD304-5

See Annex A.0 for common SPD bytes 192~239 (0x0C0~0xEF).

Module Specific SPD Bytes for NVDIMM-P Module Types		
Byte Number		Function Described
240	0x0F0	Registering Clock Driver Manufacturer ID Code, First Byte
241	0x0F1	Registering Clock Driver Manufacturer ID Code, Second Byte
242	0x0F2	Register Device Type
243	0x0F3	Register Revision Number
244	0x0F4	Data Buffer Manufacturer ID Code, First Byte
245	0x0F5	Data Buffer Manufacturer ID Code, Second Byte
246	0x0F6	Data Buffer Device Type
247	0x0F7	Data Buffer Revision Number
248	0x0F8	Module Storage Capacity, Least Significant Byte
249	0x0F9	Module Storage Capacity, Most Significant Byte
250	0x0FA	Protocol Profile
251~447	0x0FB~0x1BF	Reserved

18.2 (NVDIMM-P): Module Specific Device Information

Bytes 240~247 (0x0F0~0x0F7)

Table 18 lists the SPD byte addresses for the key components on this assembly.

Table 18 — SPD Byte Addresses for NVDIMM-P Assembly

Module Specific Device Information								
Device	Manufacturer ID Code, First Byte		Manufacturer ID Code, Second Byte		Device Type		Device Revision	
	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
Registering Clock Driver (RCD)	240	0x0F0	241	0x0F1	242	0x0F2	243	0x0F3
Data Buffers (DB)	244	0x0F4	245	0x0F5	246	0x0F6	247	0x0F7

Manufacturer ID Code: Per JEP106. See SPD bytes 512~513 for an example.

Device types:

Module Specific Device Types				
	Bit 7	Bit 6	Bits 5 ~ 4	Bits 3 ~ 0
Device	Devices Installed		Reserved	Device Type
Registering Clock Driver (RCD)	0 = Not installed 1 = Installed	Reserved; must be coded as 0	Reserved. Must be coded as 00	0000: DDR5RCD01 (see JESD82-511) All other codes reserved
Data Buffers (DB)	0 = Not installed 1 = Installed			0000: DDR5DB01 (see JESD82-521) All other codes reserved

Device revision: This byte is coded as a major revision in bits 7~4 and minor revision in bits 3~0, each nibble expressed in BCD. For example, device stepping 3.2 would be coded as 0x32.

18.3 (NVDIMM-P): Module Storage Capacity

Bytes 248~249 (0x0F8~0x0F9)

These bytes form a 16-bit word which defines the capacity of the non-volatile storage on the NVDIMM-P accessible via the transactional protocol.

Module Storage Capacity		
Byte 249		Byte 248
Bits 15~14	Bits 13~4	Bits 3~0
Capacity, Base	Capacity, Digits	Capacity, Tenths
00 = Megabytes 01 = Gigabytes 10 = Terabytes 11 = Petabytes	Values from 0 to 999 All other values reserved	0000 = 0 0001 = 0.1 0010 = 0.2 0011 = 0.3 0100 = 0.4 0101 = 0.5 0110 = 0.6 0111 = 0.7 1000 = 0.8 1001 = 0.9 All other codes reserved

Examples:

Module Storage Capacity		
Code	Hex	Meaning
01 00 1000 0000 0000	0x2800	Module storage capacity = 128 GB
10 00 0000 0001 0000	0x8010	Module storage capacity = 1 TB
10 00 0000 0001 0101	0x8015	Module storage capacity = 1.5 TB
00 11 0010 0000 0000	0x3200	Module storage capacity = 800 MB

18.4 (NVDIMM-P): Protocol Profile

Byte 250 (0x0FA)

This byte defines the NVDIMM-P profile for the interface protocol. See JESD304-5 for details on profile characteristics.

Protocol Profile	
Bits 7~4	Bits 3~0
Reserved	Protocol Profile
Reserved; must be coded as 0000	0000 = NVDIMM-P Profile 0 0001 = NVDIMM-P Profile 1 All other codes reserved

18.5 (NVDIMM-P): Reserved

Bytes 251~447 (0x0FB~0x1BF)

Reserved - must be coded as 0x00.

18.6 Application Notes for Transactional Credit Based NVDIMMs:

When programming an SPD for use in an NVDIMM supporting this function, the following guidelines must be followed for programming SPD Block 0 to represent the NVDIMM. All other bytes in block 0 are Reserved and must be programmed to 0x00 for use in an NVDIMM.

Byte	Description	Transactional Credit Based NVDIMM Definition
0	Number of bytes in SPD device	Standard programming
1	SPD Revision	Standard programming
2	Key Byte / Host Bus Command Protocol Type	Must be programmed as 20 (0x14), DDR5 NVDIMM-P
3	Key Byte / Module Type	NVDIMM-P based on RDIMM interface: Programmed as 0xA1 NVDIMM-P based on LRDIMM interface: Programmed as 0xA4
12	SDRAM BL32 and Post Package Repair	Must be programmed as 0x00, Burst length of 16, no PPR support
16	SDRAM Nominal Voltage, VDD	Standard programming
17	SDRAM Nominal Voltage, VDDQ	Standard programming
20	SDRAM Minimum Cycle Time ($t_{CKAVGmin}$ Least Significant Byte)	Standard programming
21	SDRAM Minimum Cycle Time ($t_{CKAVGmin}$ Most Significant Byte)	Standard programming
22	SDRAM Maximum Cycle Time ($t_{CKAVGmax}$ Least Significant Byte)	Standard programming
23	SDRAM Maximum Cycle Time ($t_{CKAVGmax}$ Most Significant Byte)	Standard programming
24	CAS Latencies Supported, First Byte	Standard programming
25	CAS Latencies Supported, Second Byte	Standard programming
26	CAS Latencies Supported, Third Byte	Standard programming
27	CAS Latencies Supported, Fourth Byte	Standard programming
28	CAS Latencies Supported, Fifth Byte	Standard programming
30	Minimum CAS Latency Time (t_{AAmin}) Least Significant Byte	Minimum READ SEND time, t_{SEND_RDmin} . Used to calculate t_{SEND_RDmin} , t_{SEND_WRmin} , t_{SEND_SRDmin} .
31	Minimum CAS Latency Time (t_{AAmin}) Most Significant Byte	

Table 19 documents bytes in SPD block 3, Standard Module Parameters – Common SPD Bytes, that must be programmed to specific values to represent the NVDIMM. All other bytes are programmed with standard programming values.

Table 19 — Bytes in SPD Block 3, Standard Module Parameters

Byte	Description	Transactional Credit Based NVDIMM Definition
235	Memory Channel Bus Width	Must be 8-bit extension, 32-bits primary data bus Bits[4~3] = 10 Bits[2~0] = 010

Error logging in the End User blocks of the SPD is not supported in release 1.0 of the NVDIMM-P.

19 Blocks 8-9: Manufacturing Information: (Bytes 512~639, 0x200~0x27F)

19.1 Byte 512 (0x200): Module Manufacturer ID Code, First Byte Byte 513 (0x201): Module Manufacturer ID Code, Second Byte

This two-byte field indicates the manufacturer of the module, and shall be encoded as follows: the first byte is the number of continuation bytes indicated in JEP-106; the second byte is the last non-zero byte of the manufacturer's ID code, again as indicated in JEP-106.

Byte 513, Bits 7~0	Byte 512, Bit 7	Byte 512, Bits 6~0
Last non-zero byte, Module Manufacturer	Odd Parity for Byte 512, bits 6~0	Number of continuation codes, Module Manufacturer
See JEP-106		See JEP-106

Examples:

Company	JEP-106		# continuation codes	SPD	
	Bank	Code		Byte 512	Byte 513
Fujitsu	1	04	0	0x80	0x04
US Modular	5	A8	4	0x04	0xA8

19.2 Byte 514 (0x202): Module Manufacturing Location

The module manufacturer shall include an identifier that uniquely defines the manufacturing location of the memory module. While the SPD specification will not attempt to present a decode table for manufacturing sites, the individual manufacturer must keep track of manufacturing location and its appropriate decode represented in this byte.

19.3 Bytes 515~516 (0x203~0x204): Module Manufacturing Date

The module manufacturer shall include a date code for the module. The JEDEC definitions for bytes 515 and 516 are year and week respectively. These bytes must be represented in Binary Coded Decimal (BCD). For example, week 47 in year 2014 would be coded as 0x14 (0001 0100) in byte 515 and 0x47 (0100 0111) in byte 516.

19.4 Bytes 517~520 (0x205~0x208): Module Serial Number

The supplier shall include a unique serial number for the module. The supplier may use whatever decode method desired to maintain a unique serial number for each module.

One method of achieving this is by assigning a byte in the field from 517~520 as a tester ID byte and using the remaining bytes as a sequential serial number. Bytes 512~520 will then result in a nine-byte unique module identifier. Note that part number is not included in this identifier: the supplier may not give the same value for Bytes 517~520 to more than one DIMM even if the DIMMs have different part numbers.

19.5 Bytes 521~550 (0x209~0x226): Module Part Number

The manufacturer's part number shall be included and is written in ASCII format within these bytes. Unused digits are coded as ASCII blanks (0x20).

19.6 Byte 551 (0x227): Module Revision Code

This refers to the module revision code. While the SPD specification will not attempt to define the format for this information, the individual manufacturer may keep track of the revision code and its appropriate decode represented in this byte. This revision code refers to the manufacturer's assembly revision level and may be different than the raw card revision in SPD byte 232.

19.7 Byte 552 (0x228): DRAM Manufacturer ID Code, First Byte Byte 553 (0x229): DRAM Manufacturer ID Code, Second Byte

This two-byte field indicates the manufacturer of the DRAM on the module, and shall be encoded as follows: the first byte is the number of continuation bytes indicated in JEP-106; the second byte is the last non-zero byte of the manufacturer's ID code, again as indicated in JEP-106.

Byte 553, Bits 7~0	Byte 552, Bit 7	Byte 552, Bits 6~0
Last non-zero byte, DRAM Manufacturer	Odd Parity for Byte 552, bits 6~0	Number of continuation codes, DRAM Manufacturer
See JEP-106		See JEP-106

Example: See bytes 512~513 for example manufacturer codes.

19.8 Byte 554 (0x22A): DRAM Stepping

This byte defines the vendor die revision level (often called the “stepping”) of the DRAMs on the module. This byte is optional. For modules without DRAM stepping information, this byte should be programmed to 0xFF. For DRAM suppliers who use a single letter (“A”, “B”, etc.) for the stepping indicator, the coding shall be the uppercase ASCII code for that letter.

Bits 7~0
DRAM Stepping
Programmed in straight Hex format - no conversion needed. 00 - Valid 01 - Valid .. FE - Valid FF - Undefined (No Stepping Number Provided)

Examples:

Code	Meaning
0x00	Stepping 0
0x01	Stepping 1
0x31	Stepping 3.1
0xA3	Stepping A3
0xB1	Stepping B1
0x41	Stepping A
0x4A	Stepping J
0xFF	Stepping information not provided

19.9 Bytes 555~639 (0x22B~27F): Manufacturer’s Specific Data

The module manufacturer may include any additional information desired into the module within these locations.

20 Blocks 10~15: End User Programmable, Bytes 640~1023 (0x280~0x3FF)

These blocks of the SPD are not write protected so that end users may program any values into these bytes during system runtime or for system management.

Optionally, end users may choose to save error logging information in these blocks. If so, the standard error logging format is described below.

20.1 Bytes n~n+23: Error Logging Data

Zero or more error logs may appear anywhere in any End User Programmable blocks of the SPD, including over SPD Block boundaries. They may be found by searching for a four byte anchor string. The 20 bytes after the anchor contain information about the error captured. If more than one error log is stored, it is not required to be stored sequentially, nor necessarily at a higher address. The timestamp in the error log may be used to determine the relative order of errors captured.

System BIOSes establish the policy to determine what error types are to be logged, such as only uncorrectable, only correctable, or any error type, and also whether it is the first error found or having exceeding some system specific error count threshold.

Care must be taken not to exceed the write limitations of the SPD device; see JESD300-5 for details.

Error Logging Data format is as follows:

Bytes	Field	Meaning
n ~ n+3	Anchor	Anchor String to identify the beginning of an error log
n + 4	Header	Error Type
n+5 ~ n+13	Address	Error Location
n+14~n+17	Location	Timestamp
n+18	Refresh	Highest DRAM Refresh Settings on the Module
n+19 ~ n+20	Temperature	Module Measured Temperature
n+21 ~ n+23	Reserved	Reserved for future use

Encoding details, by byte:

20.2 Bytes n~n+3: Anchor String to Indicate Valid Error Log

Bytes n~n+3 contain the string “_FL_”, hex codes 0x5F, 0x46, 0x4C, 0x5F. Parsing the following bytes of the error log and using a “reasonableness” check on the contents may help avoid a false hit on error log data. For example, if the Month field decodes to an invalid Month 15 or the Day field decodes to an invalid Day 0, that indicates a likely false hit on the anchor string.

20.3 Byte n+4: Header to Indicate Error Type

Byte n+4 defines the type(s) of errors detected. For DRAM errors, the host system may interrogate the error logging information in each DRAM in the rank where the error occurred to determine the error type(s), and multiple error types may be possible. Other (non-DRAM) errors may be logged in future releases of the SPD document; all other bytes in the error log may be different depending on the coding of byte n+4 bits 7~6.

Error Type Header	
Bits 7~6	Bits 5~0
Error Log Type	Errors Found(s)
00 = DRAM error log type has been written	Bit code 0 = False, 1 = True Bit 0: At least one DRAM uncorrectable error Bit 1: At least one DRAM correctable error Bit 2: At least one DRAM ECS error Bit 3: An error occurred that required an hPPR Bit 4: At least one Post Package Repair (PPR) resource error Bit 5: Reserved; must be coded as 0
Other codes reserved	Coding dependent on Bits 7~6
NOTE 1 ECS errors may be caused by the row or code word error count (DDR5 SDRAM MR20) or errors per row count (MR19) exceeding an OEM-defined limit. NOTE 2 Bits 3 and 4 may be used conjunctively to indicate that an hPPR was necessary and that the required resource was or was not available. NOTE 3 PPR Resource error may indicate that the system detected that a row repair was required using sPPR, hPPR, or mPPR, but insufficient PPR resources remained to complete the repair, or that a device dropped below an OEM-defined minimum resource count. This error could also be caused by a guard key error that prevented a requested repair from completing.	

20.3.1 DRAM Error Log Byte Definitions

The following error log bytes are defined when the Error Log Type is 00 (DRAM error log).

It is important to note that conditions described in the DRAM error log capture the state of the memory module at the time that the error log is written. For many reasons, these conditions may or may not apply to the conditions at the time the memory error occurred, such as the difference between when the data was written versus when the data was read. As noted above, users may set error count thresholds before logging, so the log may only represent the last error that occurred. Additional processing is likely required to associate correlation and causation.

20.4 Bytes n+5~n+12 (DRAM Error): Error Location

These bytes identify the location(s) where the errors occurred. The error log may only contain information regarding one specific address, however different devices may report different error types regarding that address. The erring devices are identified by a bit map of devices connected on data strobe (DQS) lines.

Error Location								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
n+5	Reserved	Reserved	CPU2	CPU1	CPU0	Reserved	CPUMC3	CPUMC2
n+6	CPUMC1	CPUMC0	Reserved	DIMM	CS0_A_n	CS1_A_n	CS0_B_n	CS1_B_n
n+7	Reserved	PAR	CID3/R17	CID2	CID1	CID0	BG2	BG1
n+8	BG0	BA1	BA0	R16	R15	R14	R13	R12
n+9	R11	R10	R9	R8	R7	R6	R5	R4
n+10	R3	R2	R1	R0	C10	C9	C8	C7
n+11	C6	C5	C4	C3	DQS9A_n	DQS8A_n	DQS7A_n	DQS6A_n
n+12	DQS54_n	DQS4A_n	DQS3A_n	DQS2A_n	DQS1A_n	DQS0A_n	DQS9B_n	DQS8B_n
n+13	DQS7B_n	DQS6B_n	DQS54_n	DQS4B_n	DQS3B_n	DQS2B_n	DQS1B_n	DQS0B_n

The following data select the location of the SDRAMs and address information for the operation. Note that some signals that are active low (n) are indicated as active with a 0, inactive with a 1.

Reserved: Must be coded as 0

CPU[2~0]: Identifies the CPU that initiated the operation (0-7)

CPUMC[3~0]: Identifies the memory controller on the CPU that initiated the operation (0-15)

DIMM: Identifies the memory module on the identified memory controller interface (0-1)

0 = DIMM 0 selected

1 = DIMM 1 selected

CS[1~0]_A_n: Rank selected on sub-channel A (0-1)

CS[1~0]_B_n: Rank selected on sub-channel B (0-1)

0 = Rank selected

1 = Rank not selected

PAR: Parity

CID3/R17: Chip identifier or row address

CID[2~0]: Chip identifier

BG[2~0]: Bank group

BA[1~0]: Bank address

R[16~0]: Row address

C[10:3]: Column address

The following signals are a bit map for every device exhibiting an error for the logged operation, as selected by the data strobes for each device.

DQS[9~0]A_n: Device select (data strobes) on sub-channel A

DQS[9~0]B_n: Device select (data strobes) on sub-channel B

0 = Device selected

1 = Device not selected

20.5 Bytes n+14~n+17 (DRAM Error): Timestamp

These bytes identify the time at which the error occurred which triggered error logging. The date is per the Gregorian calendar.

Timestamp								
Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
n+14	Year						Month MSb	
n+15	Month LSb		Day					Hour MSb
n+16	Hour LSb				Minute MSb			
n+17	Minute LSb		Second					
NOTES: Year is coded as [year - 2020], i.e., the range is from 2020 to 2083 on the Gregorian calendar Month is 1 to 12 Day is 1 to 31 Hour is 0 to 23 Minute is 0 to 59 Second is 0 to 59								

Example:

Error logged on March 16, 2025 at 20:15:44

Year = 000101, Month = 0011, Day = 10000, Hour = 10100, Minute = 001111, Second = 101100

Code byte n+14 = 000101 00 (0x14)

Code byte n+15 = 11 10000 1 (0xE1)

Code byte n+16 = 0100 0011 (0x43)

Code byte n+17 = 11 101100 (0xEC)

20.6 Byte n+18 (DRAM Error): Highest DRAM Refresh Settings on the Module

This byte saves the state of the highest refresh rate settings of all DRAMs on the module at the time of error log entry, where “highest” is defined by the value of bits OP[2~0] in DRAM mode register MR4. This byte is coded as 0x00 if this information is not being logged. This MR4 information may or may not come from a DRAM reporting an error as indicated in byte n+5 through n+12.

Highest DRAM Refresh Settings on the Module			
Bit 7	Bit 6	Bit 5	Bit 4
Temperature Update Flag (TUF)	Reserved	Wide Range	Refresh tRFC Mode
0 = No change in OP[2~0] since last MR4 read 1 = Change in OP[2~0] since last MR4 read	Reserved; must be coded as 0	0 = Wide temperature sense range not supported 1 = Wide temperature sense range supported	0 = Normal (tRFC1) 1 = Fine granularity (tRFC2)
Bit 3	Bits 2~0		
Refresh Interval Rate Indicator	Minimum Refresh Rate		
0 = Not implemented 1 = Implemented	If bit 5 = 0 000 = Reserved 001 = tREFI x1 (1x Refresh Rate), t ≤ 80 °C 010 = tREFI x1 (1x Refresh Rate), 80 °C < t ≤ 85 °C 011 = tREFI /2 (2x Refresh Rate), 85 °C < t ≤ 90 °C 100 = tREFI /2 (2x Refresh Rate), 90 °C < t ≤ 95 °C 101 = tREFI /2 (2x Refresh Rate), t > °95 C Other codes reserved	If bit 5 = 1 000 = tREFI x1 (1x Refresh Rate), t ≤ 75 °C 001 = tREFI x1 (1x Refresh Rate), 75 °C < t ≤ 80 °C 010 = tREFI x1 (1x Refresh Rate), 80 °C < t ≤ 85 °C 011 = tREFI /2 (2x Refresh Rate), 85 °C < t ≤ 90 °C 100 = tREFI /2 (2x Refresh Rate), 90 °C < t ≤ 95 °C 101 = tREFI /2 (2x Refresh Rate), 95 °C < t ≤ 100 °C 110 = tREFI /2 (2x Refresh Rate), t > °100 C 111 = Reserved	
NOTE 1 See the JESD79-5 DDR5 SDRAM definition for mode register MR4.			
NOTE 2 Bit 5, Wide Range, is the same as SPD byte 14 bit 3, included here for simplicity of copying MR4 contents into the error log.			

20.7 Byte n+19~20 (DRAM Error): Module Measured Temperature

These bytes store the module temperature measured at the SPD (or ESPD) and external thermal sensors when the error log is created.

Module Measured Temperature		
Byte n+19		
Bits 7~5	Bits 4~0	
TS0 Temperature, LSB ^{1,2,4}	SPD/ESPD Temperature ^{1,3,4}	
Byte n+20		
Bit 7	Bits 6~2	Bits 1~0
Reserved; code as 0	TS1 Temperature ^{1,2,4}	TS0 Temperature, MSb ^{1,2,4}
<div>NOTE 1 All thermal sensors are coded as: 00000 = Not specified or not installed 00001 = 74 °C + 1 = 75 °C or lower 00010 = 74 °C + 2 = 76 °C ... 11110 = 74 °C + 30 = 104 °C 11111 = 74 °C + 31 = 105 °C or higher</div> <div>NOTE 2 See the JESD302-1 TS511X Thermal Sensor Specification for mode registers MR49 and MR50: TS temperatures are calculated from TS MR49 and MR50</div> <div>NOTE 3 See the JESD300-5 SPD5118 or JESD316-5 ESPD5216 Device Standards for mode registers MR49 and MR50: SPD temperature is calculated from (E)SPD MR49 and MR50</div> <div>NOTE 4 Devices not installed shall be reported as 00000</div>		

20.8 Bytes n+21~n+23 (DRAM Error): Reserved

Must be coded as 0x00 if an error log is stored.

Annex B — (Informative) Differences between JESD400-5A.01 and JESD400-5A

Task Group editorial correction from the JC-45 module committee meeting # 77:

- Clause 9.1, Table 6 “Example #1, Codes for SPD Contents”: tRC, tRC(ps), tRC low, and tRC high values under the “3600B Mono” column.



Standard Improvement Form**JEDEC Standard JESD400-5A.01, Release 1.1**

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