

TMS320C6455/C6454 DSP DDR2 Memory Controller

User's Guide



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Read This First

About This Manual

This document describes the DDR2 memory controller in the TMS320C6455/C6454 digital signal processors (DSPs).

Notational Conventions

This document uses the following conventions.

- Hexadecimal numbers are shown with the suffix h. For example, the following number is 40 hexadecimal (decimal 64): 40h.
- Registers in this document are shown in figures and described in tables.
 - Each register figure shows a rectangle divided into fields that represent the fields of the register. Each field is labeled with its bit name, its beginning and ending bit numbers above, and its read/write properties below. A legend explains the notation used for the properties.
 - Reserved bits in a register figure designate a bit that is used for future device expansion.

Related Documentation From Texas Instruments

The following documents describe the C6000™ devices and related support tools. Copies of these documents are available on the Internet. *Tip:* Enter the literature number in the search box provided at www.ti.com.

[SPRU189](#) — *TMS320C6000 DSP CPU and Instruction Set Reference Guide*. Describes the CPU architecture, pipeline, instruction set, and interrupts for the TMS320C6000 digital signal processors (DSPs).

[SPRU198](#) — *TMS320C6000 Programmer's Guide*. Describes ways to optimize C and assembly code for the TMS320C6000™ DSPs and includes application program examples.

[SPRU301](#) — *TMS320C6000 Code Composer Studio Tutorial*. Introduces the Code Composer Studio™ integrated development environment and software tools.

[SPRU321](#) — *Code Composer Studio Application Programming Interface Reference Guide*. Describes the Code Composer Studio™ application programming interface (API), which allows you to program custom plug-ins for Code Composer.

[SPRU871](#) — *TMS320C64x+ Megamodule Reference Guide*. Describes the TMS320C64x+ digital signal processor (DSP) megamodule. Included is a discussion on the internal direct memory access (IDMA) controller, the interrupt controller, the power-down controller, memory protection, bandwidth management, and the memory and cache.

C6455/C6454 DDR2 Memory Controller

1 Introduction

1.1 Purpose of the Peripheral

The DDR2 memory controller is used to interface with JESD79-2B standard compliant DDR2 SDRAM devices. Memory types such as DDR1 SDRAM, SDR SDRAM, SBSRAM, and asynchronous memories are not supported. The DDR2 memory controller SDRAM can be used for program and data storage.

1.2 Features

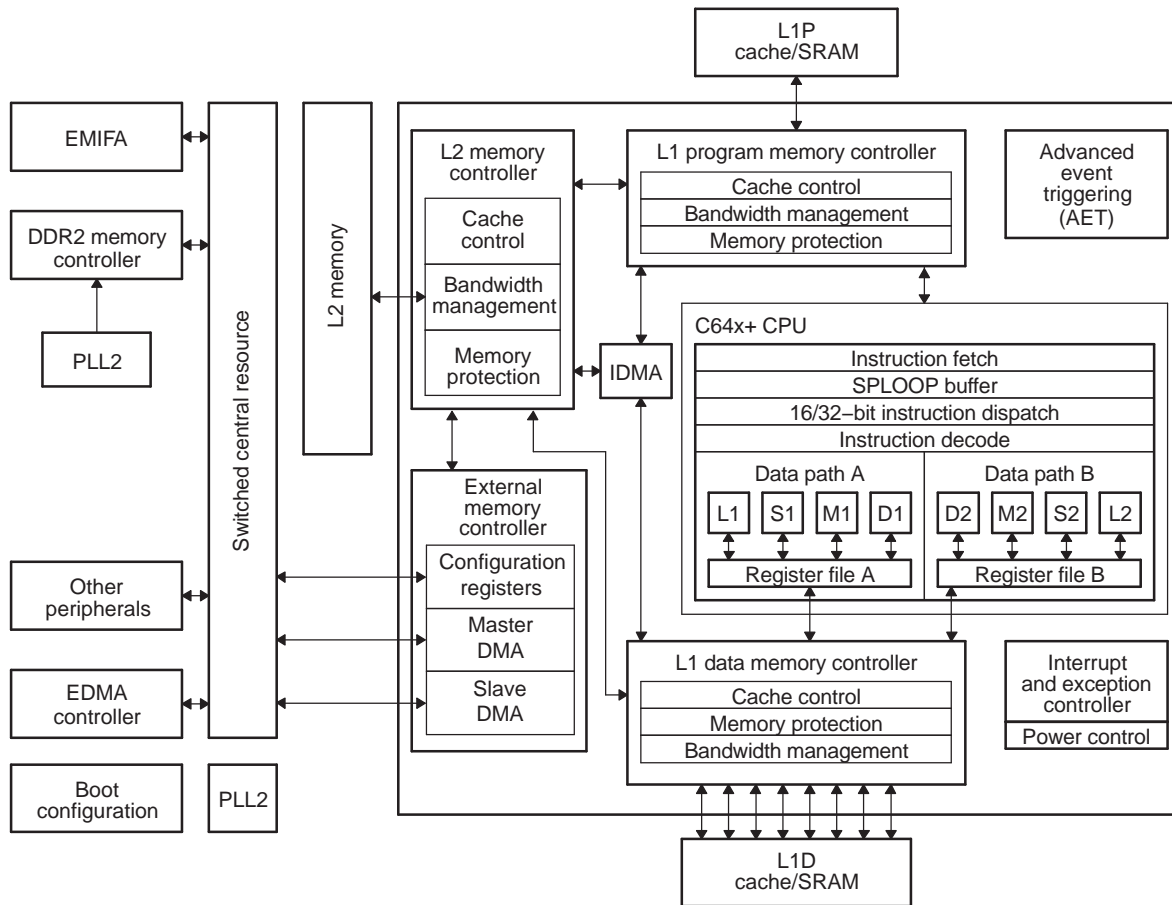
The DDR2 memory controller supports the following features:

- JESD79-2B standard compliant DDR2 SDRAM
- 512M byte memory space
- Data bus width of 32 or 16 bits
- CAS latencies: 2, 3, 4, and 5
- Internal banks: 1, 2, 4, and 8
- Burst length: 8
- Burst type: sequential
- 1 CE signal
- Page sizes: 256, 512, 1024, and 2048
- SDRAM autoinitialization
- Self-refresh mode
- Prioritized refresh
- Programmable refresh rate and backlog counter
- Programmable timing parameters
- Little endian and big endian transfers

1.3 Functional Block Diagram

The DDR2 memory controller is the main interface to external DDR2 memory (see [Figure 1](#)). Master peripherals, such as the EDMA controller and the CPU can access the DDR2 memory controller through the switched central resource (SCR). The DDR2 memory controller performs all memory-related background tasks such as opening and closing banks, refreshes, and command arbitration.

Figure 1. Device Block Diagram



1.4 Industry Standard(s) Compliance Statement

The DDR2 memory controller is compliant with the JESD79-2B DDR2 SDRAM.

2 Peripheral Architecture

The DDR2 memory controller can gluelessly interface to most standard DDR2 SDRAM devices and supports such features as self-refresh mode and prioritized refresh. In addition, it provides flexibility through programmable parameters such as the refresh rate, CAS latency, and many SDRAM timing parameters.

The following sections describe the architecture of the DDR2 memory controller as well as how to interface and configure it to perform read and write operations to DDR2 SDRAM devices. Also, [Section 3](#) provides a detailed example of interfacing the DDR2 memory controller to a common DDR2 SDRAM device.

2.1 Clock Control

The DDR2 memory controller is clocked directly from the output of the second phase-locked loop (PLL2) of C6455/C6454 devices. The PLL2 multiplies its input clock by 20. This clock is divided by 2 to generate DDR2CLKOUT. The frequency of DDR2CLKOUT can be determined by using the following formula:

$$\text{DDR2CLKOUT frequency} = (\text{PLL2 input clock frequency} \times 20) / 2 = \text{PLL2 input clock frequency} \times 10$$

The second output clock of the DDR2 memory controller, $\overline{\text{DDR2CLKOUT}}$, is the inverse of DDR2CLKOUT. For more information on the PLL2, see the device-specific data manual.

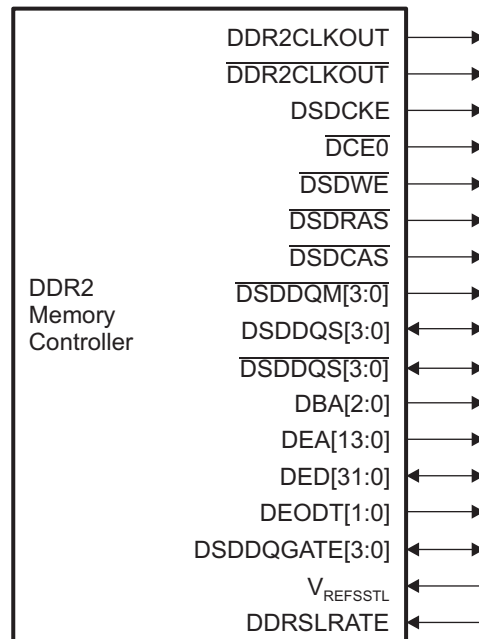
2.2 Memory Map

For information describing the device memory map, see the device-specific data manual.

2.3 Signal Descriptions

The DDR2 memory controller signals are shown in [Figure 2](#) and described in [Table 1](#). The following features are included:

- The maximum width for the data bus (DED[31:0]) is 32-bits.
- The address bus (DEA[13:0]) is 14-bits wide with an additional 3 bank address pins (DBA[2:0]).
- Two differential output clocks (DDR2CLKOUT and $\overline{\text{DDR2CLKOUT}}$) driven by internal clock sources.
- Command signals: Row and column address strobe (DSDRAS and DSDCAS), write enable strobe (DSDWE), data strobe (DSDDQS[3:0] and $\overline{\text{DSDDQS}}[3:0]$), and data mask (DSDDQM[3:0]).
- One chip select signal ($\overline{\text{DCE0}}$).
- One clock enable signal (DSDCKE).
- Two on-die termination output signals (DEODT[1:0]). (These pins are reserved for future use.)

Figure 2. DDR2 Memory Controller Signals

Table 1. DDR2 Memory Controller Signal Descriptions

Pin	Description
DED[31:0]	Bidirectional data bus. Input for data reads and output for data writes.
DEA[13:0]	External address output.
DCE0	Active-low chip enable for memory space CE0. $\overline{DCE0}$ is used to enable the DDR2 SDRAM memory device during external memory accesses. The $\overline{DCE0}$ pin stays low throughout the operation of the DDR2 memory controller; it never goes high. Note that this behavior does not affect the ability of the DDR2 memory controller to access DDR2 SDRAM memory devices.
\overline{DSDDQM} [3:0]	Active-low output data mask.
DDR2CLKOUT $\overline{DDR2CLKOUT}$	Differential clock outputs.
DSDCKE	Clock enable (used for self-refresh mode).
\overline{DSDCAS}	Active-low column address strobe.
\overline{DSDRAS}	Active-low row address strobe.
\overline{DSDWE}	Active-low write enable.
DSDDQS[3:0]/ \overline{DSDDQS} [3:0]	Differential data strobe bidirectional signals.
DEODT[1:0]	On-die termination signals to external DDR2 SDRAM. These pins are reserved for future use and should not be connected to the DDR2 SDRAM.
DBA[2:0]	Bank-address control outputs.
DSDDQGATE[3:0]	Data strobe gate pins. These pins are used as a timing reference during memory reads. The DSDDQGATE0 and DSDDQGATE2 pins should be routed out and connected to the DSDDQGATE1 and DSDDQGATE3 pins, respectively. For more routing requirements on these pins, see the device-specific data manual.
V _{REFSSTL}	DDR2 Memory Controller reference voltage. This voltage must be supplied externally. For more details, see the device-specific data manual.
DDRSLRATE	Pulling the DDRSLRATE input pin low selects the normal slew rate. If pulled high, the slew rate is reduced by 33%. For normal full-speed operation, the DDRSLRATE should be pulled low. This pin needs to be pulled low or high at all times (it is not latched).

2.4 Protocol Description(s)

The DDR2 memory controller supports the DDR2 SDRAM commands listed in [Table 2](#). [Table 3](#) shows the signal truth table for the DDR2 SDRAM commands.

Table 2. DDR2 SDRAM Commands

Command	Function
ACTV	Activates the selected bank and row.
DCAB	Precharge all command. Deactivates (precharges) all banks.
DEAC	Precharge single command. Deactivates (precharges) a single bank.
DESEL	Device Deselect.
EMRS	Extended Mode Register set. Allows altering the contents of the mode register.
MRS	Mode register set. Allows altering the contents of the mode register.
NOP	No operation.
Power Down	Power down mode.
READ	Inputs the starting column address and begins the read operation.
READ with autoprecharge	Inputs the starting column address and begins the read operation. The read operation is followed by a precharge.
REFR	Autorefresh cycle.
SLFREFR	Self-refresh mode.
WRT	Inputs the starting column address and begins the write operation.
WRT with autoprecharge	Inputs the starting column address and begins the write operation. The write operation is followed by a precharge.

Table 3. Truth Table for DDR2 SDRAM Commands

DDR2 SDRAM Signals	CKE		CS	RAS	CAS	WE	BA[2:0]	A[13:11, 9:0]	A10
	DSDCKE								
DDR2 Memory Controller Signals	Previous Cycles	Current Cycle	DCE0	DSDRAS	DSDCAS	DSDWE	DBA[2:0]	DEA[13:11, 9:0]	DEA[10]
ACTV	H ⁽¹⁾	H	L	L	H	H	Bank	Row Address	
DCAB	H	H	L	L	H	L	X	X	H
DEAC	H	H	L	L	H	L	Bank	X	L
MRS	H	H	L	L	L	L	BA ⁽²⁾	OP Code	
EMRS	H	H	L	L	L	L	BA	OP Code	
READ	H	H	L	H	L	H	BA	Column Address	L
READ with precharge	H	H	L	H	L	H	BA	Column Address	H
WRT	H	H	L	H	L	L	BA	Column Address	L
WRT with precharge	H	H	L	H	L	L	BA	Column Address	L
REFR	H	H	L	L	L	H	X	X	X
SLFREFR entry	H	L	L	L	L	H	X	X	X
SLFREFR exit	L	H	H	X	X	X	X	X	X
			L	H	H	H	X	X	X
NOP	H	X	L	H	H	H	X	X	X
DESEL	H	X	H	X	X	X	X	X	X
Power-down entry	H	L	H	X	X	X	X	X	X
			L	H	H	H	X	X	X
Power-down exit	L	H	H	X	X	X	X	X	X
			L	H	H	H	X	X	X

⁽¹⁾ LEGEND: H = logic high; L = logic low; X = don't care (either H or L).

⁽²⁾ BA refers to the bank address pins (BA[2:0]).

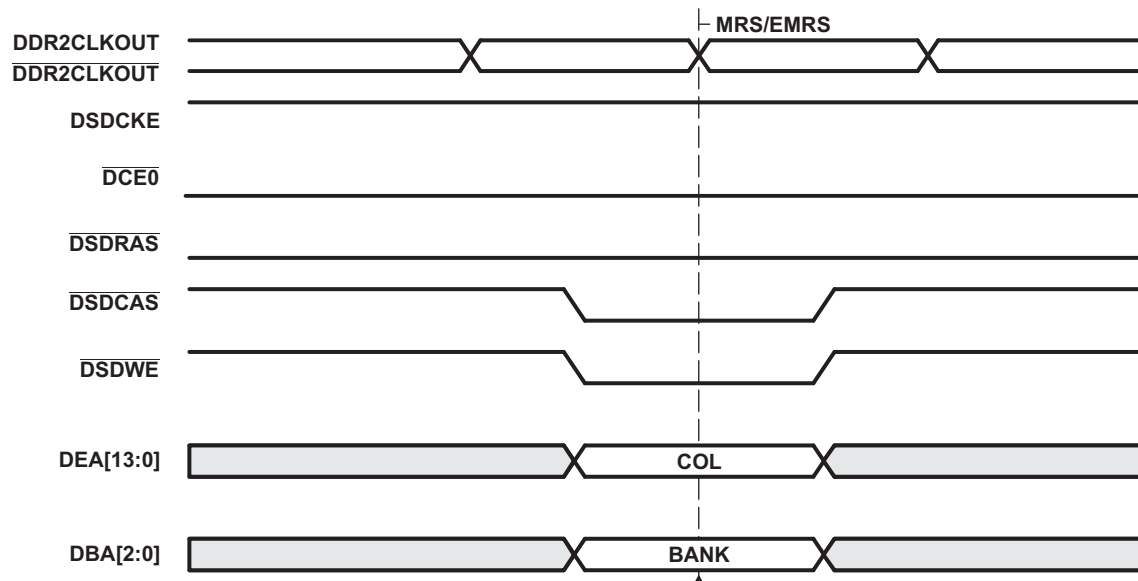
2.4.1 Mode Register Set (MRS and EMRS)

DDR2 SDRAM contains mode and extended mode registers that configure the DDR2 memory for operation. These registers control burst type, burst length, CAS latency, DLL enable/disable, single-ended strobe, etc.

The DDR2 memory controller programs the mode and extended mode registers of the DDR2 memory by issuing MRS and EMRS commands. When the MRS or EMRS command is executed, the value on DBA[1:0] selects the mode register to be written and the data on DEA[12:0] is loaded into the register. [Figure 3](#) shows the timing for an MRS and EMRS command.

The DDR2 memory controller only issues MRS and EMRS commands during the DDR2 memory controller initialization sequence. For more information, see [Section 2.11](#).

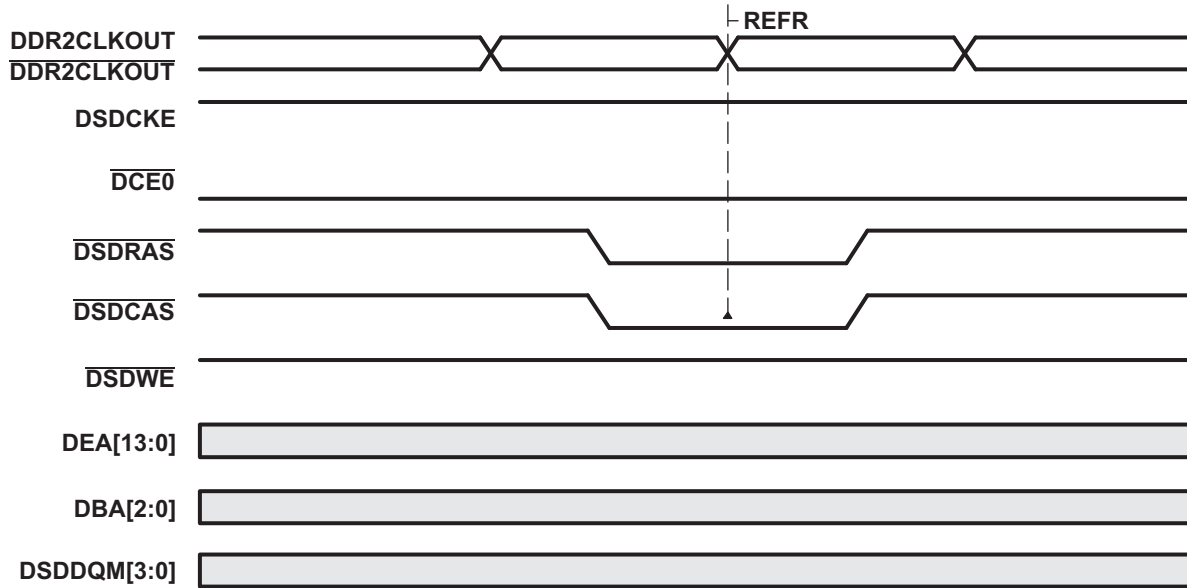
Figure 3. DDR2 MRS and EMRS Command



2.4.2 Refresh Mode

The DDR2 memory controller issues refresh commands to the DDR2 SDRAM device (Figure 4). REFR is automatically preceded by a DCAB command, ensuring the deactivation of all CE spaces and banks selected. Following the DCAB command, the DDR2 memory controller begins performing refreshes at a rate defined by the refresh rate (REFRESH_RATE) bit in the SDRAM refresh control register (SDRFC). Page information is always invalid before and after a REFR command; thus, a refresh cycle always forces a page miss. This type of refresh cycle is often called autorefresh. Autorefresh commands may not be disabled within the DDR2 memory controller. See Section 2.8 for more details on REFR command scheduling.

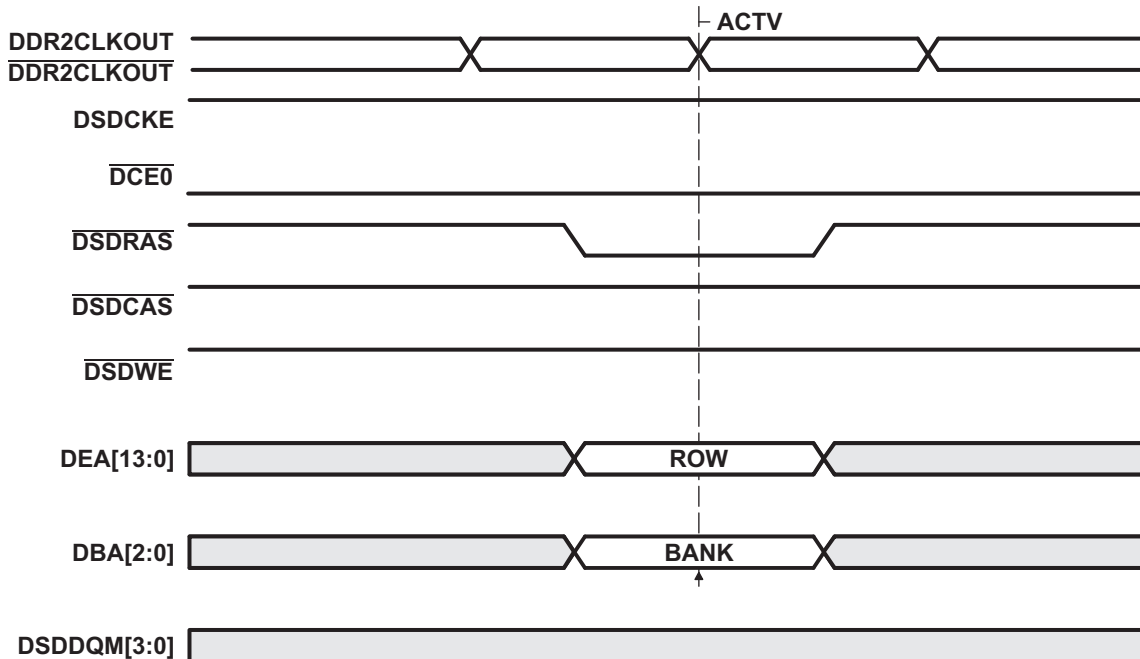
Figure 4. Refresh Command



2.4.3 Activation (ACTV)

The DDR2 memory controller automatically issues the activate (ACTV) command before a read or write to a closed row of memory. The ACTV command opens a row of memory, allowing future accesses (reads or writes) with minimum latency. The value of DBA[2:0] selects the bank and the value of A[12:0] selects the row. When the DDR2 memory controller issues an ACTV command, a delay of t_{RCD} is incurred before a read or write command is issued. Figure 5 shows an example of an ACTV command. Reads or writes to the currently active row and bank of memory can achieve much higher throughput than reads or writes to random areas because every time a new row is accessed, the ACTV command must be issued and a delay of t_{RCD} incurred.

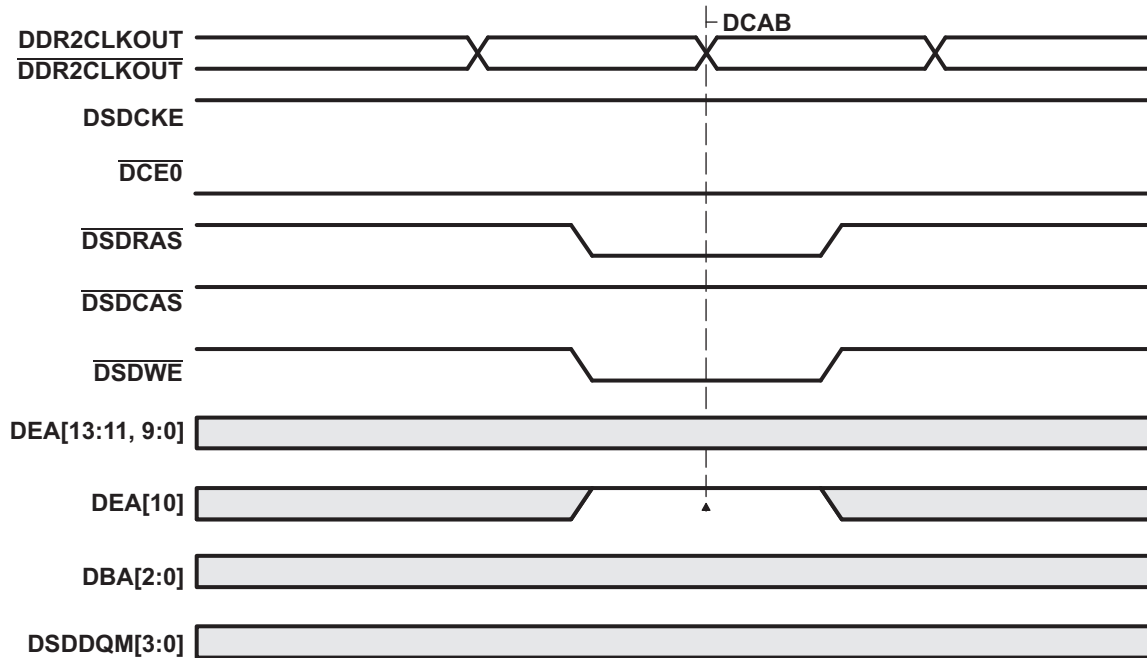
Figure 5. ACTV Command



2.4.4 Deactivation (DCAB and DEAC)

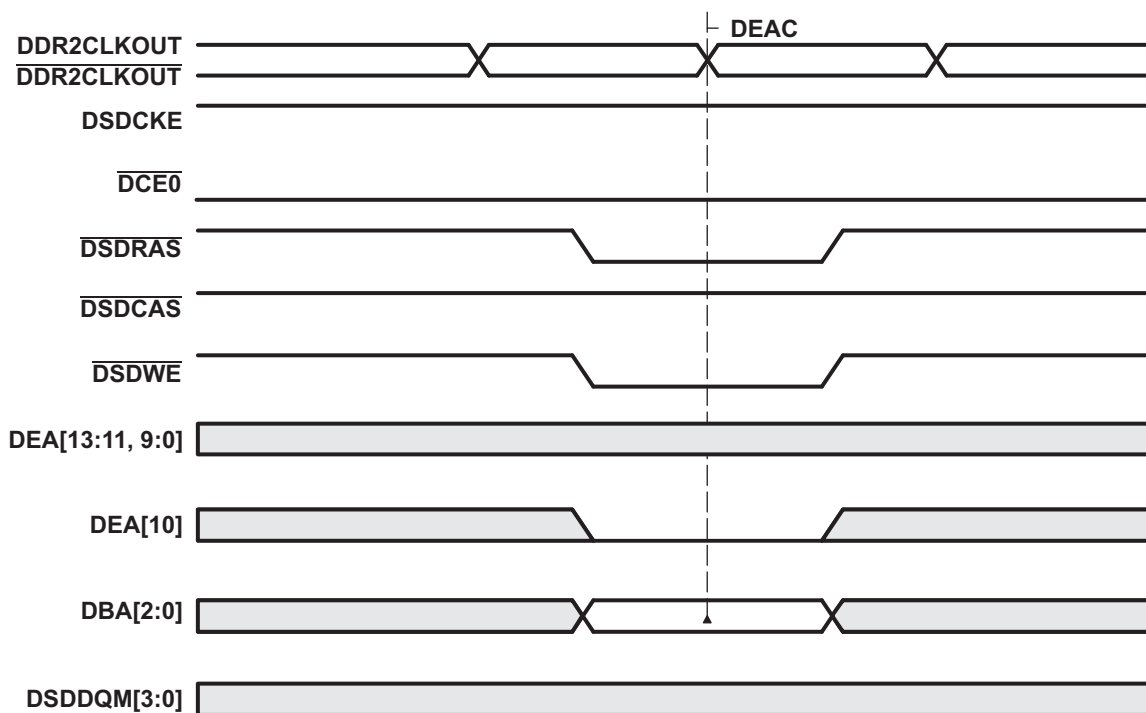
The precharge all banks command (DCAB) is performed after a reset to the DDR2 memory controller or following the initialization sequence. DDR2 SDRAMs also require this cycle prior to a refresh (REFR) and mode set register commands (MRS and EMRS). During a DCAB command, DEA10 is driven high to ensure the deactivation of all banks. [Figure 6](#) shows the timing diagram for a DCAB command.

Figure 6. DCAB Command



The DEAC command closes a single bank of memory specified by the bank select signals. Figure 7 shows the timings diagram for a DEAC command.

Figure 7. DEAC Command

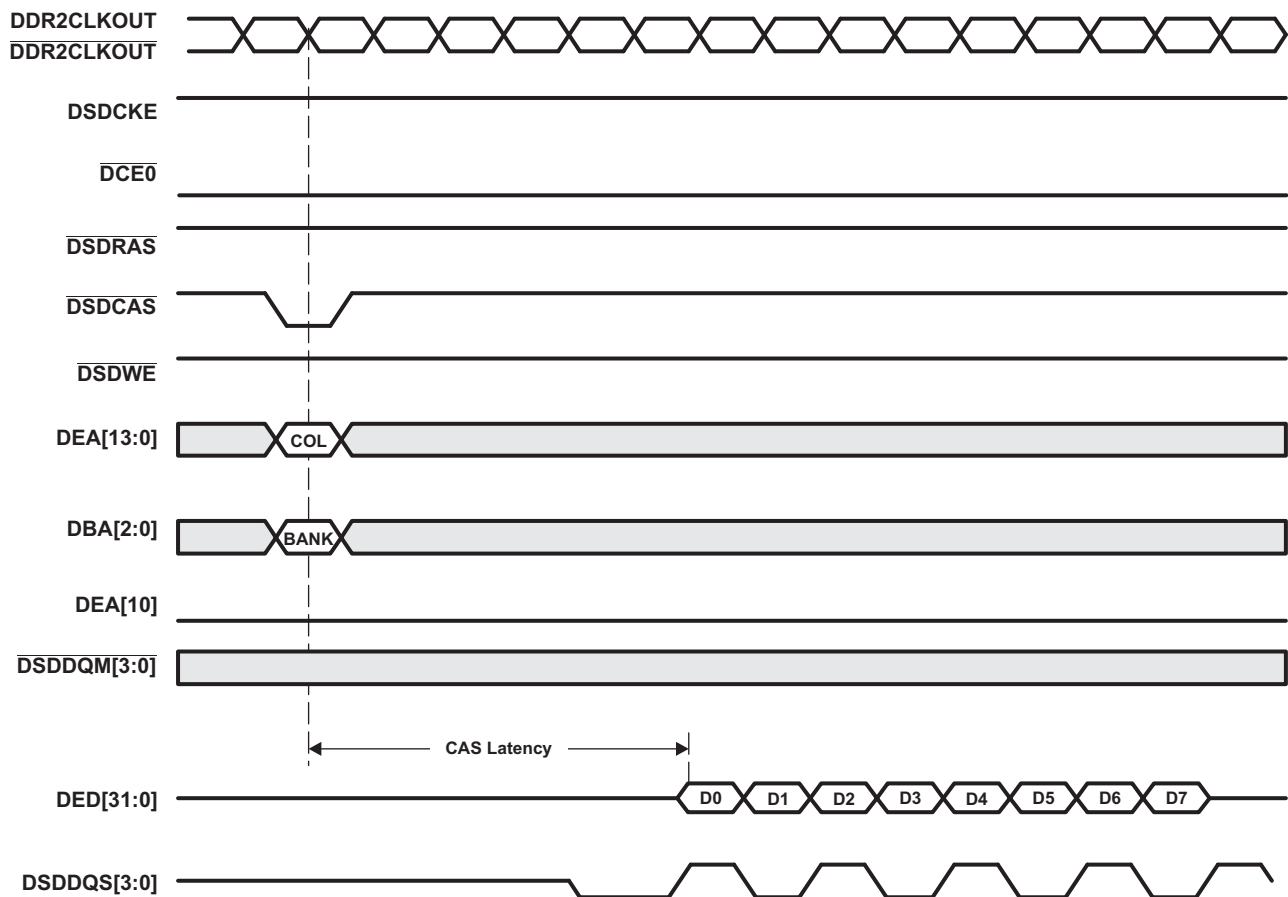


2.4.5 READ Command

Figure 8 shows the DDR2 memory controller performing a read burst from DDR2 SDRAM. The READ command initiates a burst read operation to an active row. During the READ command, $\overline{\text{DSDCAS}}$ drives low, $\overline{\text{DSDWE}}$ and $\overline{\text{DSDRAS}}$ remain high, the column address is driven on $\text{DEA}[12:0]$, and the bank address is driven on $\text{DBA}[2:0]$.

The DDR2 memory controller uses a burst length of 8, and has a programmable CAS latency of 2, 3, 4, or 5. The CAS latency is three cycles in Figure 8. Read latency is equal to CAS latency plus additive latency. The DDR2 memory controller always configures the memory to have an additive latency of 0, so read latency equals CAS latency. Since the default burst size is 8, the DDR2 memory controller returns 8 pieces of data for every read command. If additional accesses are not pending to the DDR2 memory controller, the read burst completes and the unneeded data is disregarded. If additional accesses are pending, depending on the scheduling result, the DDR2 memory controller can terminate the read burst and start a new read burst. Furthermore, the DDR2 memory controller does not issue a DCAB/DEAC command until page information becomes invalid.

Figure 8. DDR2 READ Command



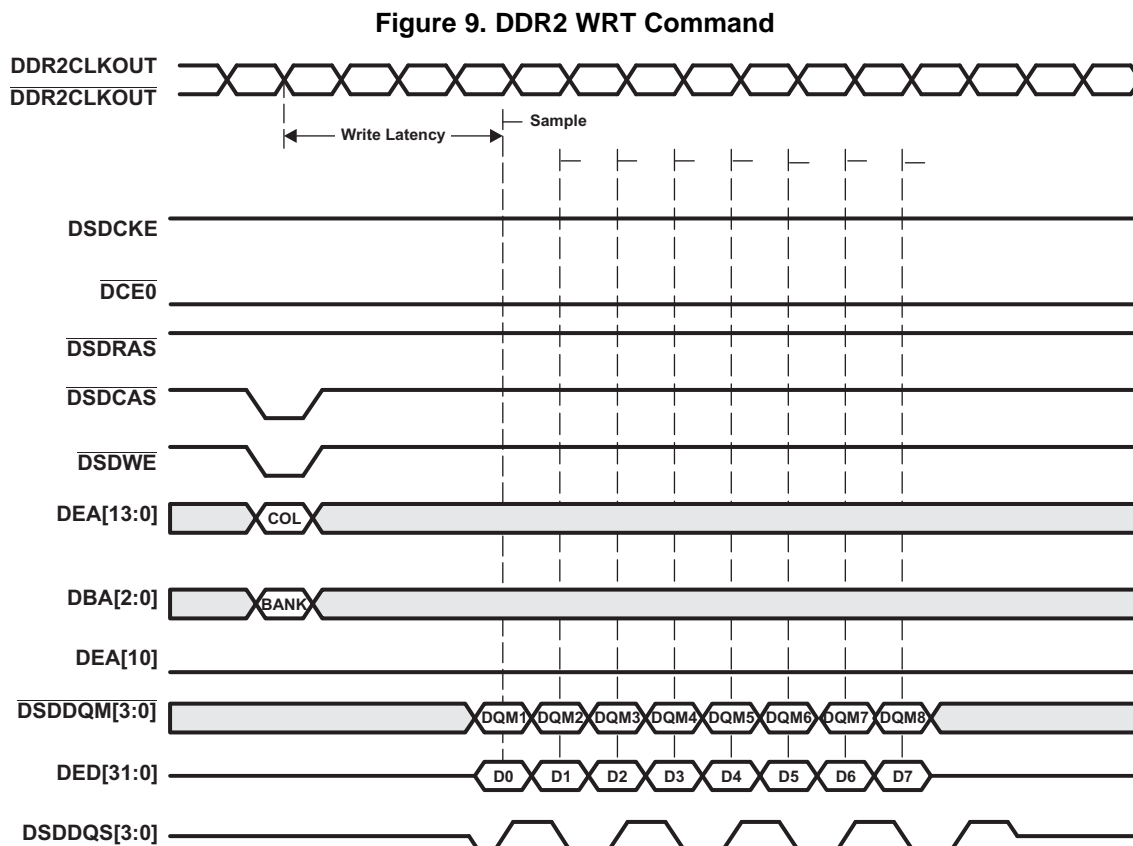
2.4.6 Write (WRT) Command

Prior to a WRT command, the desired bank and row are activated by the ACTV command. Following the WRT command, a write latency is incurred. Write latency is equal to CAS latency minus 1. All writes have a burst length of 8. The use of the DSDDQM outputs allows byte and halfword writes to be executed. [Figure 9](#) shows the timing for a write on the DDR2 memory controller.

If the transfer request is for less than 8 words, depending on the scheduling result and the pending commands, the DDR2 memory controller can:

- Mask out the additional data using DSDDQM outputs
- Terminate the write burst and start a new write burst

The DDR2 memory controller does not perform the DEAC command until page information becomes invalid.



2.5 Memory Width, Byte Alignment, and Endianness

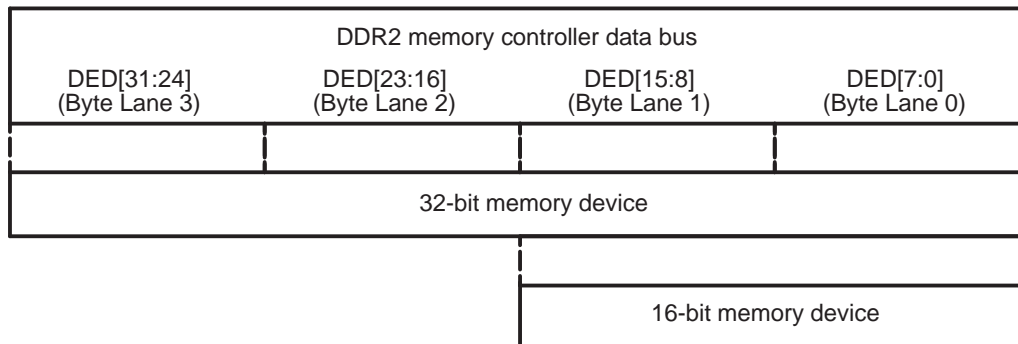
The DDR2 memory controller supports memory widths of 16 bits and 32 bits. [Table 4](#) summarizes the addressable memory ranges on the DDR2 memory controller.

Table 4. Addressable Memory Ranges

Memory Width	Maximum Addressable Bytes	Address Type Generated by DDR2 Memory Controller
×16	256M bytes	Halfword address
×32	512M bytes	Word address

Figure 10 shows the byte lanes used on the DDR2 memory controller. The external memory is always right aligned on the data bus.

Figure 10. Byte Alignment



The DDR2 memory controller supports both little endian and big endian formats. The endianness mode determines whether byte lane 0 (DED[7:0]) is accessed as byte address 0 (little endian) or as byte address N (big endian), where 2^n is the memory width in bytes. Similarly, byte lane N is addresses as either byte address 0 (big endian) or as byte address N (little endian).

The DDR2 memory controller uses the endianness mode being used by the rest of the DSP. The endianness mode of the DSP is set during device reset (for more details, see the device-specific data manual. The endianness mode of the DDR2 memory controller is shown on the BE bit of the DDR2 memory controller status register (DMCSTAT); BE = 1 indicates big endian mode and BE = 0 indicates little endian mode.

2.6 Address Mapping

The DDR2 memory controller views external DDR2 SDRAM as one continuous block of memory. This statement is true regardless of the number of memory devices located on the chip select space. The DDR2 memory controller receives DDR2 memory access requests along with a 32-bit logical address from the rest of the system. In turn, DDR2 memory controller uses the logical address to generate a row/page, column, bank address, and chip selects for the DDR2 SDRAM. The number of column and bank address bits used is determined by the IBANK and PAGESIZE fields. The chip selection pins used are determined by the DCE0 field (see Table 5). The DDR2 memory controller uses up to 14 bits for the row/page address.

Table 5. Bank Configuration Register Fields for Address Mapping

Bit Field	Bit Value	Bit Description
IBANK		Defines the number of internal banks on the external DDR2 memory.
	0	1 bank
	1h	2 banks
	2h	4 banks
PAGESIZE		Defines the page size of each page of the external DDR2 memory.
	0	256 words (requires 8 column address bits)
	1h	512 words (requires 9 column address bits)
	2h	1024 words (requires 10 column address bits)
	3h	2048 words (requires 11 column address bits)

Figure 11 and Figure 12 show how the logical address bits map to the row, column, bank, and chip select bits all combinations of IBANK and PAGESIZE values. Note that the upper three bits of the logical address cannot be used for memory addressing, as the DDR2 memory controller has a maximum addressable memory range of 512M bytes.

The DDR2 memory controller address pins provide the row and column address to the DDR2 SDRAM, thus the DDR2 memory controller appropriately shifts the logical address during row and column address selection. The bank address is driven to the DDR2 SDRAM using the bank address pins. The two lower bits of the logical address decode the value of the byte enable pins (only used for accesses less than the width of the DDR2 memory controller data bus).

Figure 11. Logical Address-to-DDR2 SDRAM Address Map for 32-Bit SDRAM

SDCFG Bit		Logical Address															
IBANK	PAGESIZE	31:29	28	27	26	25	24	23	22:17	16	15	14	13	12	11	10	9:2
0	0	X	X	X	X	X	X	X	nrb=14								ncb=8
1	0	X	X	X	X	X	X	nrb=14								nbb=1	ncb=8
2	0	X	X	X	X	nrb=14								nbb=2	ncb=8		
3	0	X	X	X	nrb=14								nbb=3	ncb=8			
0	1	X	X	X	X	X	nrb=14								ncb=9		
1	1	X	X	X	X	nrb=14								nbb=1	ncb=9		
2	1	X	X	X	nrb=14								nbb=2	ncb=9			
3	1	X	X	nrb=14								nbb=3	ncb=9				
0	2	X	X	X	X	nrb=14								ncb=10			
1	2	X	X	X	nrb=14								nbb=1	ncb=10			
2	2	X	X	nrb=14								nbb=2	ncb=10				
3	2	X	nrb=14								nbb=3	ncb=10					
0	3	X	X	X	nrb=14								ncb=11				
1	3	X	X	nrb=14								nbb=1	ncb=11				
2	3	X	nrb=14								nbb=2	ncb=11					
3	3	X	nrb=13								nbb=3	ncb=11					

LEGEND: nrb = number of row address bits; ncb = number of column address bits; nbb = number of bank address bits.

Figure 12. Logical Address-to-DDR2 SDRAM Address Map for 16-bit SDRAM

SDCFG Bit		Logical Address																
IBANK	PAGESIZE	31:29	28	27	26	25	24	23	22	21:16	15	14	13	12	11	10	9	8:1
0	0	X	X	X	X	X	X	X	nrb=14								ncb=8	
1	0	X	X	X	X	X	X	nrb=14								nbb=1	ncb=8	
2	0	X	X	X	X	X	nrb=14								nbb=2	ncb=8		
3	0	X	X	X	X	nrb=14								nbb=3	ncb=8			
0	1	X	X	X	X	X	X	nrb=14								ncb=9		
1	1	X	X	X	X	X	nrb=14								nbb=1	ncb=9		
2	1	X	X	X	X	nrb=14								nbb=2	ncb=9			
3	1	X	X	X	nrb=14								nbb=3	ncb=9				
0	2	X	X	X	X	X	nrb=14								ncb=10			
1	2	X	X	X	X	nrb=14								nbb=1	ncb=10			
2	2	X	X	X	nrb=14								nbb=2	ncb=10				
3	2	X	X	nrb=14								nbb=3	ncb=10					
0	3	X	X	X	X	nrb=14								ncb=11				
1	3	X	X	X	nrb=14								nbb=1	ncb=11				
2	3	X	X	nrb=14								nbb=2	ncb=11					
3	3	X	nrb=14								nbb=3	ncb=11						

LEGEND: nrb = number of row address bits; ncb = number of column address bits; nbb = number of bank address bits.

Figure 11 shows how the DSP memory map is partitioned into columns, rows, and banks. Note that during a linear access, the DDR2 memory controller increments the column address as the logical address increments. When the DDR2 memory controller reaches a page/row boundary, it moves onto the same page/row in the next bank. This movement continues until the same page has been accessed in all banks. To the DDR2 SDRAM, this process looks as shown on Figure 14.

By traversing across banks while remaining on the same row/page, the DDR2 memory controller maximizes the number of activated banks for a linear access. This results in the maximum number of open pages when performing a linear access being equal to the number of banks. Note that the DDR2 memory controller never opens more than one page per bank.

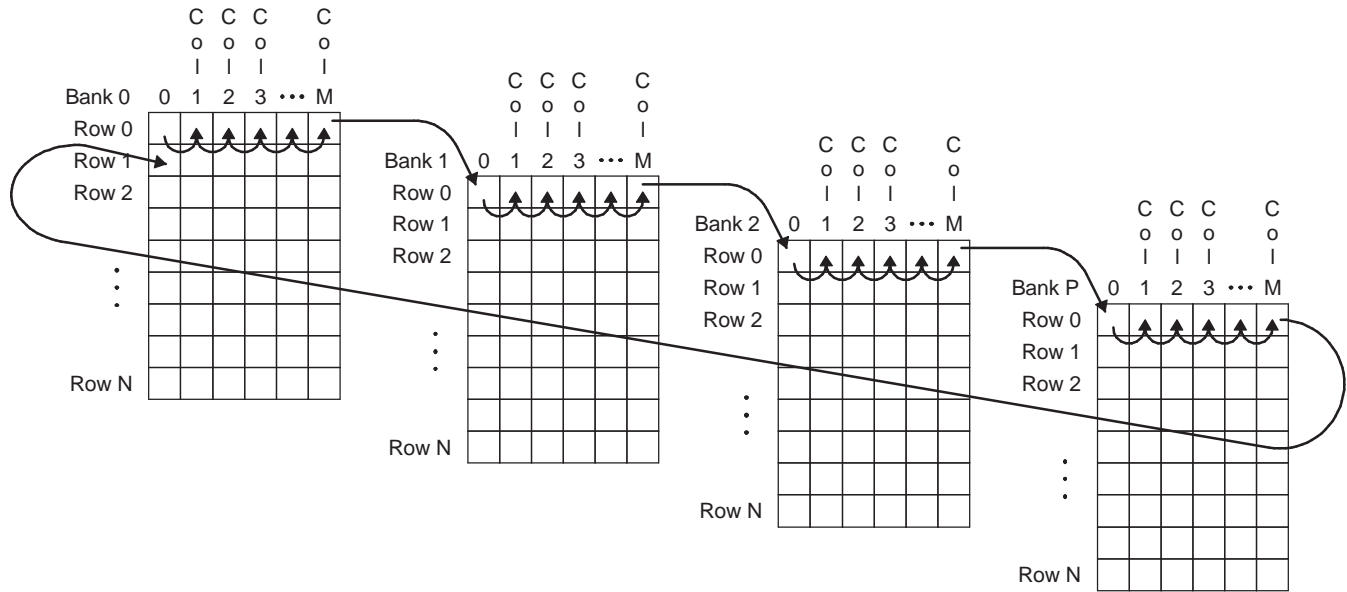
Ending the current access is not a condition that forces the active DDR2 SDRAM row/page to be closed. The DDR2 memory controller leaves the active row open until it becomes necessary to close it. This decreases the deactivate-reactivate overhead.

Figure 13. Logical Address-to-DDR2 SDRAM Address Map

Col. 0	Col. 1	Col. 2	Col. 3	Col. 4	...	Col. M-1	Col. M	
					...			Row 0, bank 0
					...			Row 0, bank 1
					...			Row 0, bank 2
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
					...			Row 0, bank P
					...			Row 1, bank 0
					...			Row 1, bank 1
					...			Row 1, bank 2
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
					...			Row 1, bank P
					...			•
					...			•
					...			•
					...			Row N, bank 0
					...			Row N, bank 1
					...			Row N, bank 2
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
•	•	•	•	•	...	•	•	•
					...			Row N, bank P

A M is number of columns (as determined by PAGESIZE) minus 1, P is number of banks (as determined by IBANK) minus 1, and N is number of rows (as determined by both PAGESIZE and IBANK) minus 1.

Figure 14. DDR2 SDRAM Column, Row, and Bank Access



A M is number of columns (as determined by PAGESIZE) minus 1, P is number of banks (as determined by IBANK) minus 1, and N is number of rows (as determined by both PAGESIZE and IBANK) minus 1.

2.7 DDR2 Memory Controller Interface

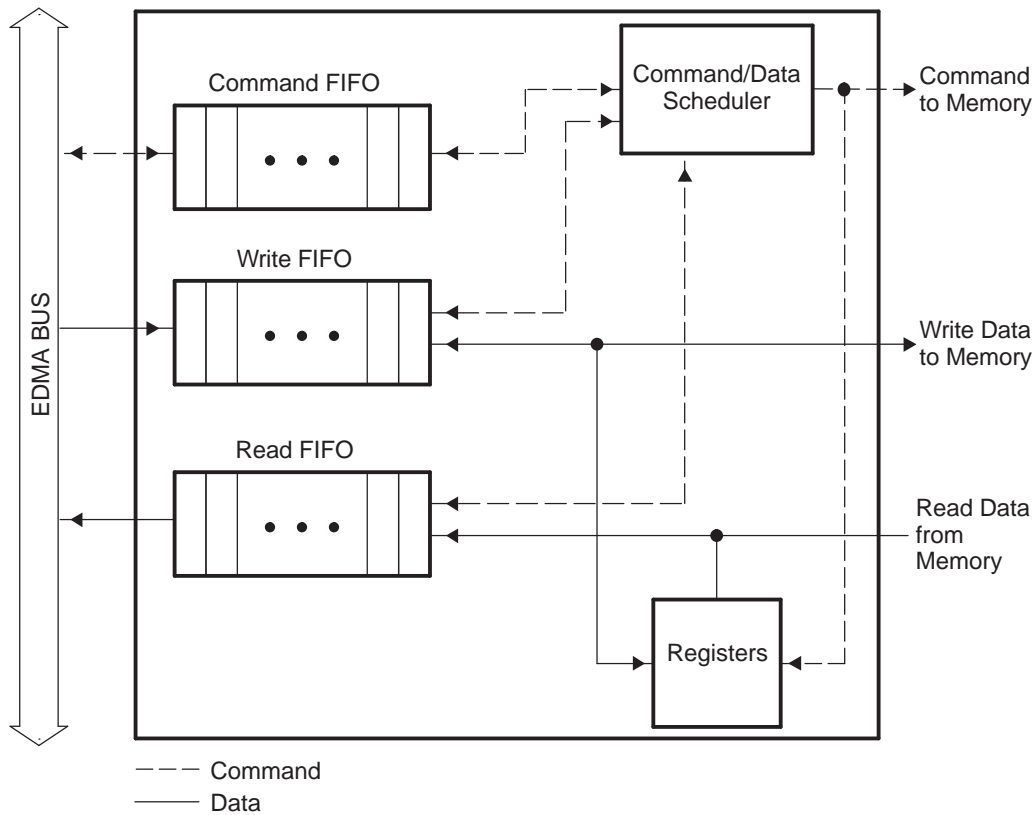
To move data efficiently from on-chip resources to external DDR2 SDRAM device, the DDR2 memory controller makes use of a command FIFO, a write FIFO, and command and data schedulers. [Table 6](#) describes the purpose of each FIFO.

[Figure 15](#) shows the block diagram of the DDR2 memory controller FIFOs. Commands, write data, and read data arrive at the DDR2 memory controller parallel to each other. The same peripheral bus is used to write and read data from external memory as well as internal memory-mapped registers.

Table 6. DDR2 Memory Controller FIFO Description

FIFO	Description	Depth (64-Bit Doublewords)
Command	Stores all commands coming from on-chip requestors	7
Write	Stores write data coming from on-chip requestors to memory	11
Read	Stores read data coming from memory to on-chip requestors	17

Figure 15. DDR2 Memory Controller FIFO Block Diagram



2.7.1 Command Ordering and Scheduling, Advanced Concept

The DDR2 memory controller performs command re-ordering and scheduling in an attempt to achieve efficient transfers with maximum throughput. The goal is to maximize the utilization of the data, address, and command buses while hiding the overhead of opening and closing DDR2 SDRAM rows. Command re-ordering takes place within the command FIFO.

The DDR2 memory controller examines all the commands stored in the command FIFO to schedule commands to the external memory. For each master, the DDR2 memory controller reorders the commands based on the following rules:

- Selects the oldest command
- A read command is advanced before an older write command if the read is to a different block address (2048 bytes) and the read priority is equal to or greater than the write priority.

NOTE: Most masters issue commands on a single priority level. Also, the EDMA transfer controller read and write ports are considered different masters, and thus, the above rule does not apply.

The second bullet above may be viewed as an exception to the first bullet. This means that for an individual master, all of its commands will complete from oldest to newest, with the exception that a read may be advanced ahead of an older, lower or equal priority write. Following this scheduling, each master may have one command ready for execution.

Next, the DDR2 memory controller examines each of the commands selected by the individual masters and performs the following reordering:

- Among all pending reads, selects reads to rows already open. Among all pending writes, selects writes to rows already open.
- Selects the highest priority command from pending reads and writes to open rows. If multiple commands have the highest priority, then the DDR2 memory controller selects the oldest command.

The DDR2 memory controller may now have a final read and write command. If the Read FIFO is not full, then the read command will be performed before the write command, otherwise the write command will be performed first.

Besides commands received from on-chip resources, the DDR2 memory controller also issues refresh commands. The DDR2 memory controller attempts to delay refresh commands as long as possible to maximize performance while meeting the SDRAM refresh requirements. As the DDR2 memory controller issues read, write, and refresh commands to DDR2 SDRAM device, it follows the following priority scheme:

1. (Highest) Refresh request resulting from the Refresh Must level of urgency (see [Section 2.8](#)) being reached
2. Read request without a higher priority write (selected from above reordering algorithm)
3. Refresh request resulting from the Refresh Need level of urgency (see [Section 2.8](#)) being reached
4. Write request (selected from above reordering algorithm)
5. Refresh request resulting from Refresh May level of urgency (see [Section 2.8](#)) being reached
6. (Lowest) Request to enter self-refresh mode

The following results from the above scheduling algorithm:

- All writes from a single master will complete in order
- All reads from a single master will complete in order
- From the same master, any read to the same location (or within 2048 bytes) as a previous write will complete in order

2.7.2 Command Starvation

The reordering and scheduling rules listed above may lead to command starvation, which is the prevention of certain commands from being processed by the DDR2 memory controller. Command starvation results from the following conditions:

- A continuous stream of high-priority read commands can block a low-priority write command
- A continuous stream of DDR2 SDRAM commands to a row in an open bank can block commands to the closed row in the same bank.

To avoid these conditions, the DDR2 memory controller can momentarily raise the priority of the oldest command in the command FIFO after a set number of transfers have been made. The PRIO_RAISE field in the Burst Priority Register (BPRIO) sets the number of the transfers that must be made before the DDR2 memory controller will raise the priority of the oldest command.

2.7.3 Possible Race Condition

A race condition may exist when certain masters write data to the DDR2 memory controller. For example, if master A passes a software message via a buffer in DDR2 memory and does not wait for indication that the write completes, when master B attempts to read the software message it may read stale data and therefore receive an incorrect message. In order to confirm that a write from master A has landed before a read from master B is performed, master A must wait for the write completion status from the DDR2 memory controller before indicating to master B that the data is ready to be read. If master A does not wait for indication that a write is complete, it must perform the following workaround:

1. Perform the required write.
2. Perform a dummy write to the DDR2 memory controller module ID and revision register.
3. Perform a dummy read to the DDR2 memory controller module ID and revision register.
4. Indicate to master B that the data is ready to be read after completion of the read in step 3. The completion of the read in step 3 ensures that the previous write was done.

For a list of the master peripherals that need this workaround, see the device-specific data manual.

2.8 Refresh Scheduling

The DDR2 memory controller issues autorefresh (REFR) commands to DDR2 SDRAM devices at a rate defined in the refresh rate (REFRESH_RATE) bit field in the SDRAM refresh control register (SDRFC). A refresh interval counter is loaded with the value of the REFRESH_RATE bit field and decrements by 1 each cycle until it reaches zero. Once the interval counter reaches zero, it reloads with the value of the REFRESH_RATE bit. Each time the interval counter expires, a refresh backlog counter increments by 1. Conversely, each time the DDR2 memory controller performs a REFR command, the backlog counter decrements by 1. This means the refresh backlog counter records the number of REFR commands the DDR2 memory controller currently has outstanding.

The DDR2 memory controller issues REFR commands based on the level of urgency. The level of urgency is defined in [Table 7](#). Whenever the refresh level of urgency is reached, the DDR2 memory controller issues a REFR command before servicing any new memory access requests. Following a REFR command, the DDR2 memory controller waits T_{RFC} cycles, defined in the SDRAM timing 1 register (SDTIM1), before rechecking the refresh urgency level.

In addition to the refresh counter previously mentioned, a separate backlog counter ensures the interval between two REFR commands does not exceed $8 \times$ the refresh rate. This backlog counter increments by 1 each time the interval counter expires and resets to zero when the DDR2 memory controller issues a REFR command. When this backlog counter is greater than 7, the DDR2 memory controller issues four REFR commands before servicing any new memory requests.

The refresh counters do not operate when the DDR2 memory is in self-refresh mode.

Table 7. Refresh Urgency Levels

Urgency Level	Description
Refresh May	Backlog count is greater than 0. Indicates there is a backlog of REFR commands, when the DDR2 memory controller is not busy it will issue the REFR command.
Refresh Release	Backlog count is greater than 3. Indicates the level at which enough REFR commands have been performed and the DDR2 memory controller may service new memory access requests.
Refresh Need	Backlog count is greater than 7. Indicates the DDR2 memory controller should raise the priority level of a REFR command above servicing a new memory access.
Refresh Must	Backlog count is greater than 11. Indicates the level at which the DDR2 memory controller should perform a REFR command before servicing new memory access requests.

2.9 Self-Refresh Mode

Setting the self refresh (SR) bit in the SDRAM refresh control register (SDRFC) to 1 forces the DDR2 memory controller to place the external DDR2 SDRAM in a low-power mode (self refresh), in which the DDR2 SDRAM maintains valid data while consuming a minimal amount of power. When the SR bit is asserted, the DDR2 memory controller continues normal operation until all outstanding memory access requests have been serviced and the refresh backlog has been cleared. At this point, all open pages of DDR2 SDRAM are closed and a self-refresh (SLFRFR) command (an autorefresh command with DSDCKE low) is issued.

The DDR2 memory controller exits the self-refresh state when a memory access is received or when the SR bit in SDRFC is cleared. While in the self-refresh state, if a request for a memory access is received, the DDR2 memory controller services the memory access request, returning to the self-refresh state upon completion.

The DDR2 memory controller will not exit the self-refresh state (whether from a memory access request or from clearing the SR bit) until $T_CKE + 1$ cycles have expired since the self-refresh command was issued. The value of T_CKE is defined in the SDRAM timing 2 register (SDTIM2).

After exiting from the self-refresh state, the DDR2 memory controller will not immediately start using commands. Instead, it will wait T_XSNR+1 clock cycles before issuing non-read commands and T_XSRD+1 clock cycles before issuing read commands. The SDRAM timing 2 register (SDTIM2) programs the values of T_XSNR+1 and T_XSRD+1 .

2.10 Reset Considerations

The DDR2 memory controller can be reset through a hard reset or a soft reset. A hard reset resets the state machine, the FIFOs, and the internal registers. A soft reset only resets the state machine and the FIFOs. A soft reset does not reset the internal registers except for the interrupt registers. Register accesses cannot be performed while either reset is asserted.

The DDR2 memory controller hard and soft reset are derived from device-level resets. C6455/C6454 devices have several types of device-level resets: power-on reset, warm reset, max reset, system reset, and CPU reset. [Table 8](#) shows the relationship between the device-level resets and the DDR2 memory controller resets.

Table 8. Device and DDR2 Memory Controller Reset Relationship

DDR2 Memory Controller Reset	Effect	Initiated by:
Hard reset	Resets control logic and all DDR2 memory controller registers	Power on reset Warm reset Max reset
Soft reset	Resets control logic and interrupt registers	System reset CPU reset

In case of a warm reset on the DSP, the DDR2 SDRAM memory content can be retained if the user places the DDR2 SDRAM in self-refresh mode before invoking the warm reset. However, the DDR2 memory controller registers will be reset and need to be reprogrammed to the required values after the warm reset. For more information on the device-level resets, see the device-specific data manual.

2.11 DDR2 SDRAM Memory Initialization

DDR2 SDRAM devices contain mode and extended mode registers that configure the mode of operation for the device. These registers control parameters such as burst type, burst length, and CAS latency. The DDR2 memory controller programs the mode and extended mode registers of the DDR2 memory by issuing MRS and EMRS commands during the initialization sequence described in [Section 2.11.2](#) and [Section 2.11.3](#). The initialization sequence performed by the DDR2 memory controller is compliant with the JESDEC79-2A specification.

The DDR2 memory controller performs the initialization sequence under the following conditions:

- Automatically following a hard or soft reset, see [Section 2.11.2](#).

- Following a write to the two least-significant bytes in the SDRAM configuration register (SDCFG); see [Section 2.11.3](#).

At the end of the initialization sequence, the DDR2 memory controller performs an auto-refresh cycle, leaving the DDR2 memory controller in an idle state with all banks deactivated.

When the initialization section is started automatically after a hard or soft reset, commands and data stored in the DDR2 memory controller FIFOs are lost. However, when the initialization sequence is initiated by a write to the two least-significant bytes in SDCFG, data and commands stored in the DDR2 memory controller FIFOs are not lost and the DDR2 memory controller ensures read and write commands are completed before starting the initialization sequence.

2.11.1 DDR2 SDRAM Device Mode Register Configuration Values

The DDR2 memory controller initializes the mode register and extended mode register 1 of the memory device with the values shown on [Table 9](#) and [Table 10](#). The DDR2 SDRAM extended mode registers 2 and 3 are configured with a value of 0h.

Table 9. DDR2 SDRAM Mode Register Configuration

Mode Register Bit	Mode Register Field	Init Value	Description
12	Power-down Mode	0	Active power-down exit time bit. Configured for Fast exit.
11-9	Write Recovery	SDTIM1.T_WR	Write recovery bits for auto-precharge. Initialized using the T_WR bits of the SDRAM timing 1 register (SDTIM1).
8	DLL Reset	0	DLL reset bits. DLL is not in reset.
7	Mode	0	Operating mode bit. Normal operating mode is always selected.
6-4	CAS Latency	SDCFG.CL	CAS latency bits. Initialized using the CL bits of the SDRAM configuration register (SDCFG).
3	Burst Type	0	Burst type bits. Sequential burst mode is always used.
2-0	Burst Length	3h	Burst length bits. A burst length of 8 is always used.

Table 10. DDR2 SDRAM Extended Mode Register 1 Configuration

Mode Register Bit	Mode Register Field	Init Value	Description
12	Output Buffer Enable	0	Output buffer enable bits. Output buffer is always enabled.
11	RDQS Enable	0	$\overline{\text{RDQS}}$ enable bits. Always initialized to 0 ($\overline{\text{RDQS}}$ signals disabled.)
10	$\overline{\text{DQS}}$ enable	0	$\overline{\text{DQS}}$ enable bit. Always initialized to 0 ($\overline{\text{DQS}}$ signals enabled.)
9-7	OCD Operation	0h	Off-chip driver impedance calibration bits. This bit is always initialized to 0h.
6	ODT Value (Rtt)	0	On-die termination effective resistance (Rtt) bit. This bit is reserved for future use.
5-3	Additive Latency	0h	Additive latency bits. Always initialized to 0h (no additive latency).
2	ODT Value (Rtt)	1	On-die termination effective resistance (Rtt) bit. This bit is reserved for future use.
1	Output Driver Impedance	SDCFG.DDR_DRIVE	Output driver impedance control bits. Initialized using the DDR_DRIVE bit of the SDRAM configuration register (SDCFG).
0	DLL Enable	0	DLL enable/disable bits. DLL is always enabled.

2.11.2 DDR2 SDRAM Initialization After Reset

After a hard or a soft reset, the DDR2 memory controller will automatically start the initialization sequence. The DDR2 memory controller will use the default values in the SDRAM timing 1 and timing 2 registers and the SDRAM configuration register to configure the mode registers of the DDR2 SDRAM device(s). Note that since a soft reset does not reset the DDR2 memory controller registers, an initialization sequence started by a soft reset would use the register values from a previous configuration.

2.11.3 DDR2 SDRAM Initialization After Register Configuration

The initialization sequence can also be initiated by performing a write to the two least-significant bytes in the SDRAM configuration register (SDCFG). Using this approach, data and commands stored in the DDR2 memory controller FIFOs are not lost and the DDR2 memory controller ensures read and write commands are completed before starting the initialization sequence.

Perform the following steps to start the initialization sequence:

1. Set the BOOT_UNLOCK bit in the SDRAM configuration register (SDCFG).
2. Write a 0 to the BOOT_UNLOCK bit along with the desired value for the DDR_DRIVE bit.
3. Program the rest of the SDCFG to the desired value with the TIMUNLOCK bit set (unlocked).
4. Program the SDRAM timing 1 register (SDTIM1) and SDRAM timing register 2 (SDTIM2) with the value needed to meet the DDR2 SDRAM device timings.
5. Program the REFRESH_RATE bits in the SDRAM refresh control register (SDRFC) to a value that meets the refresh requirements of the DDR2 SDRAM device.
6. Program SDCFG with the desired value and the TIMUNLOCK bit cleared (locked).
7. Program the read latency (RL) bit in the DDR2 memory controller control register (DMCCTL) to the desired value.

2.12 Interrupt Support

The DDR2 memory controller does not generate any interrupts.

2.13 EDMA Event Support

The DDR2 memory controller is a DMA slave peripheral and therefore does not generate EDMA events. Data read and write requests may be made directly by masters including the EDMA controller.

2.14 Emulation Considerations

The DDR2 memory controller will remain fully functional during emulation halts to allow emulation access to external memory.

3 Using the DDR2 Memory Controller

The following sections show various ways to connect the DDR2 memory controller to DDR2 memory devices. The steps required to configure the DDR2 memory controller for external memory access are also described.

3.1 *Connecting the DDR2 Memory Controller to DDR2 SDRAM*

[Figure 16](#), [Figure 17](#), and [Figure 18](#) show a high-level view of the three memory topologies

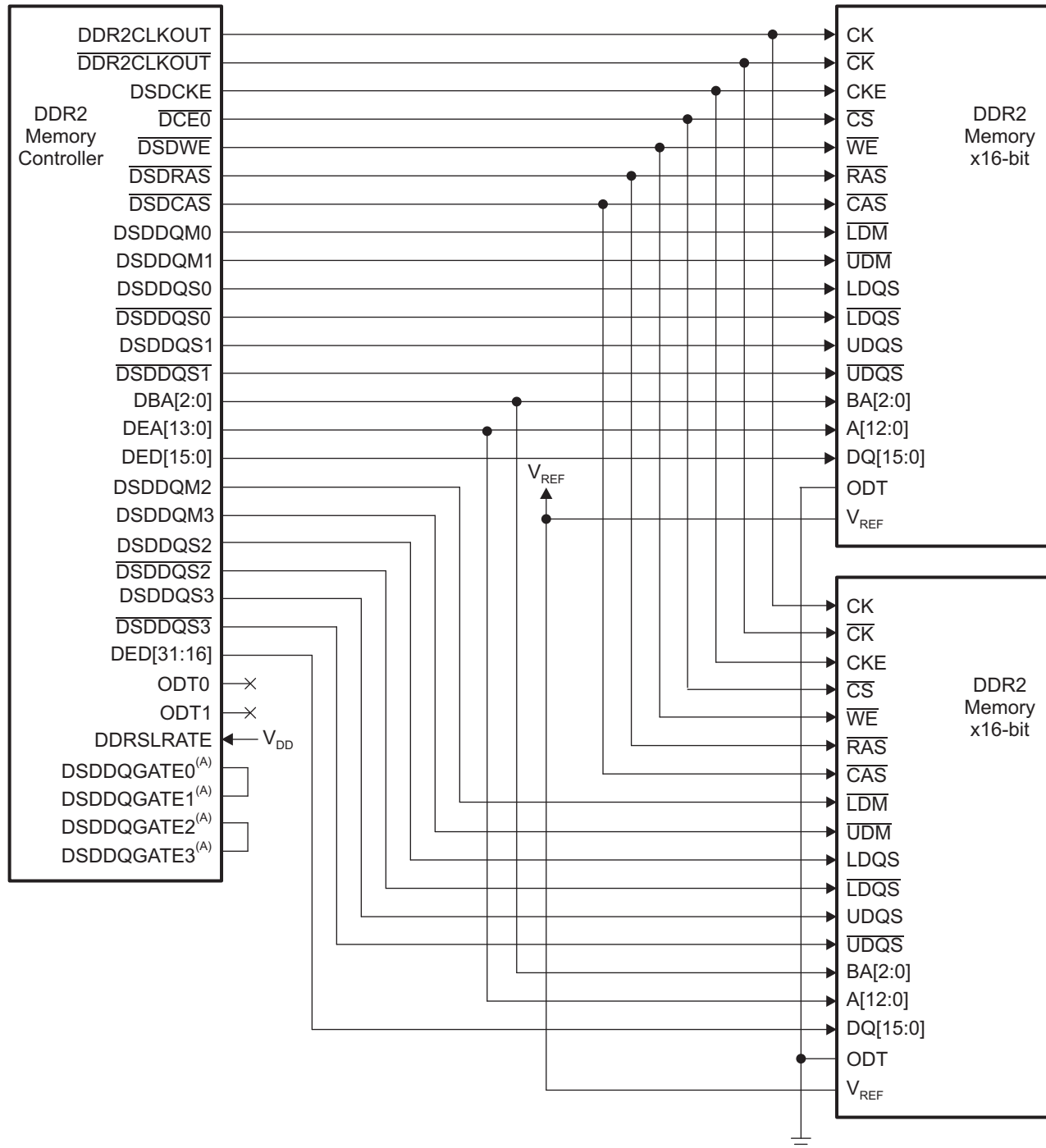
- A 32-bit wide configuration interfacing to two 16-bit wide DDR2 SDRAM devices
- A 16-bit wide configuration interfacing to a single 16-bit wide DDR2 SDRAM device
- A 16-bit wide configuration interfacing to two 8-bit wide DDR2 SDRAM devices

All DDR2 SDRAM devices must be compliant to the JESD79-2B standard.

Not all of the memory topologies shown may be supported by your device. For more information, see the device-specific data manual.

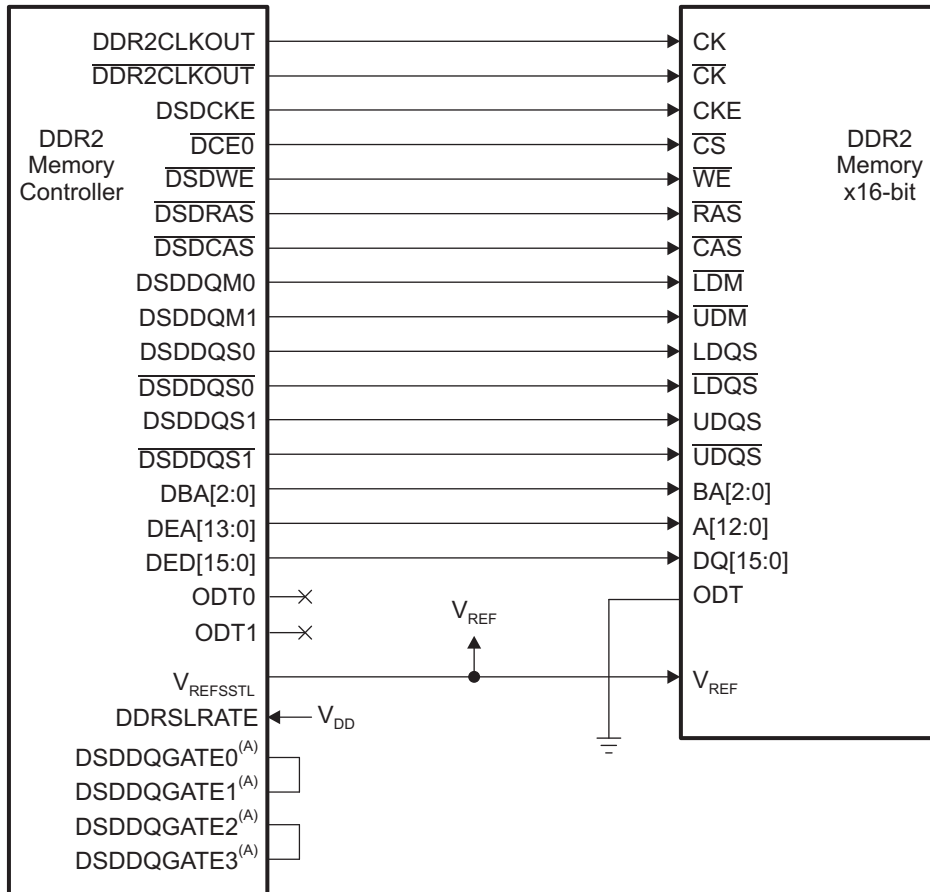
Printed circuit board (PCB) layout rules and connection requirements between the DSP and the memory device exist and are described in a separate document. For more information, see the device-specific data manual.

Figure 16. Connecting to Two 16-Bit DDR2 SDRAM Devices



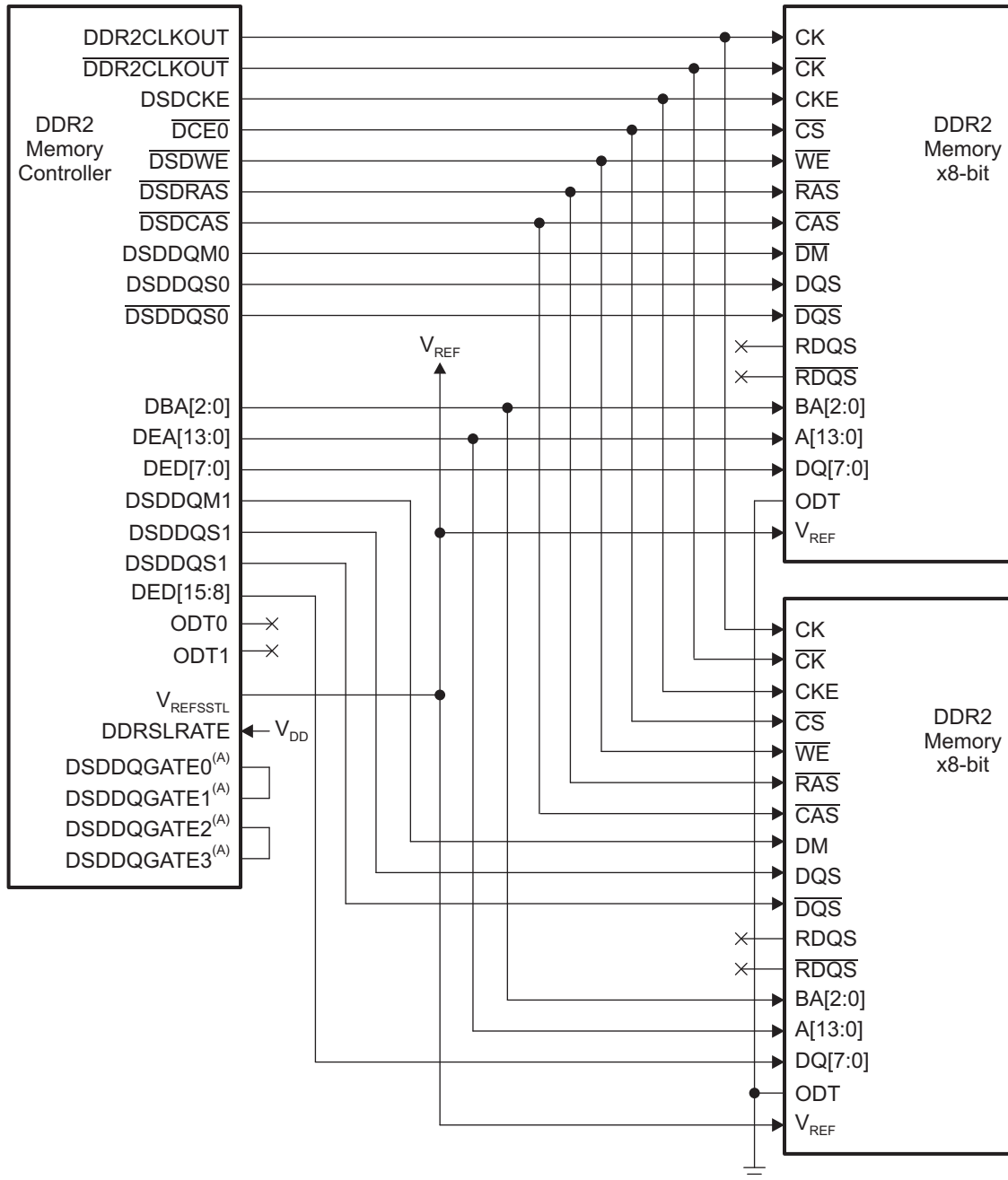
A These pins are used as a timing reference during memory reads. For routing rules, see the device-specific data manual.

Figure 17. Connecting to a Single 16-Bit DDR2 SDRAM Device



- A These pins are used as a timing reference during memory reads. For routing rules, see the device-specific data manual.

Figure 18. Connecting to Two 8-Bit DDR2 SDRAM Devices



A These pins are used as a timing reference during memory reads. For routing rules, see the device-specific data manual.

3.2 Configuring DDR2 Memory Controller Registers to Meet DDR2 SDRAM Specifications

The DDR2 memory controller allows a high degree of programmability for shaping DDR2 accesses. This provides the DDR2 memory controller with the flexibility to interface with a variety of DDR2 devices. By programming the SDRAM Configuration Register (SDCFG), SDRAM Refresh Control Register (SDRFC), SDRAM Timing 1 Register (SDTIM1), and SDRAM Timing 2 Register (SDTIM2), the DDR2 memory controller can be configured to meet the data sheet specification for JESD79-2B compliant DDR2 SDRAM devices.

As an example, the following sections describe how to configure each of these registers for access to two 1Gb, 16-bit wide DDR2 SDRAM devices connected as shown on [Figure 16](#), where each device has the following configuration:

- Maximum data rate: 533MHz
- Number of banks: 8
- Page size: 1024 words
- CAS latency: 4

It is assumed that the frequency of the DDR2 memory controller clock (DDR2CLKOUT) is set to 250MHz.

3.2.1 Programming the SDRAM Configuration Register (SDCFG)

The SDRAM configuration register (SDCFG) contains register fields that configure the DDR2 memory controller to match the data bus width, CAS latency, number of banks, and page size of the attached DDR2 memory.

[Table 11](#) shows the resulting SDCFG configuration. Note that the value of the TIMUNLOCK field is dependent on whether or not it is desirable to unlock SDTIM1 and SDTIM2. The TIMUNLOCK bit should only be set to 1 when the SDTIM1 and SDTIM2 needs to be updated.

Table 11. SDCFG Configuration

Field	Value	Function Selection
TIMUNLOCK	x	Set to 1 to unlock the SDRAM timing and timing 2 registers. Cleared to 0 to lock the SDRAM timing and timing 2 registers.
NM	0h	To configure the DDR2 memory controller for a 32-bit data bus width.
CL	4h	To select a CAS latency of 4.
IBANK	3h	To select 8 internal DDR2 banks.
PAGESIZE	2h	To select 1024-word page size.

3.2.2 Programming the SDRAM Refresh Control Register (SDRFC)

The SDRAM refresh control register (SDRFC) configures the DDR2 memory controller to meet the refresh requirements of the attached DDR2 device. SDRFC also allows the DDR2 memory controller to enter and exit self refresh. In this example, we assume that the DDR2 memory controller is not in self-refresh mode.

The REFRESH_RATE field in SDRFC is defined as the rate at which the attached DDR2 device is refreshed in DDR2 cycles. The value of this field may be calculated using the following equation:

$$REFRESH_RATE = DDR2CLKOUT \text{ frequency} \times \text{memory refresh period}$$

Table 12 displays the DDR2-533 refresh rate specification.

Table 12. DDR2 Memory Refresh Specification

Symbol	Description	Value
t_{REF}	Average Periodic Refresh Interval	7.8 μ s

Therefore, the value for the REFRESH-RATE can be calculated as follows:

$$\text{REFRESH_RATE} = 250 \text{ MHz} \times 7.8 \mu\text{s} = 1950 = 79\text{Eh}$$

Table 13 shows the resulting SDRFC configuration.

Table 13. SDRFC Configuration

Field	Value	Function Selection
SR	0	DDR2 memory controller is not in self-refresh mode.
REFRESH_RATE	79Eh	Set to 79Eh DDR2 clock cycles to meet the DDR2 memory refresh rate requirement.

3.2.3 Configuring SDRAM Timing Registers (SDTIM1 and SDTIM2)

The SDRAM timing 1 register (SDTIM1) and SDRAM timing 2 register (SDTIM2) configure the DDR2 memory controller to meet the data sheet timing parameters of the attached DDR2 device. Each field in SDTIM1 and SDTIM2 corresponds to a timing parameter in the DDR2 data sheet specification. Table 14 and Table 15 display the register field name and corresponding DDR2 data sheet parameter name along with the data sheet value. These tables also provide a formula to calculate the register field value and displays the resulting calculation. Each of the equations include a minus 1 because the register fields are defined in terms of DDR2 clock cycles minus 1. See Section 4.5 and Section 4.6 for more information.

Table 14. SDTIM1 Configuration

Register Field Name	DDR2 SDRAM Data Sheet Parameter Name	Description	Data Sheet Value (ns)	Formula (Register Field Must Be \geq)	Field Value
T_RFC	t_{RFC}	Refresh cycle time	127.5	$(t_{RFC} \times f_{DDR2_CLK}) - 1$	31
T_RP	t_{RP}	Precharge command to refresh or activate command	15	$(t_{RP} \times f_{DDR2_CLK}) - 1$	3
T_RCD	t_{RCD}	Activate command to read/write command	15	$(t_{RCD} \times f_{DDR2_CLK}) - 1$	3
T_WR	t_{WR}	Write recovery time	15	$(t_{WR} \times f_{DDR2_CLK}) - 1$	3
T_RAS	t_{RAS}	Active to precharge command	45	$(t_{RAS} \times f_{DDR2_CLK}) - 1$	11
T_RC	t_{RC}	Activate to Activate command in the same bank	60	$(t_{RC} \times f_{DDR2_CLK}) - 1$	14
T_RRD	t_{RRD}	Activate to Activate command in a different bank	10	$((4 * t_{rrd} + 2 * t_{ck}) / (4 * t_{ck})) - 1$	2
T_WTR	t_{WTR}	Write to read command delay	7.5	$(t_{WTR} \times f_{DDR2_CLK}) - 1$	1

Table 15. SDTIM2 Configuration

Register Field Name	DDR2 SDRAM Data Sheet Parameter Name	Description	Data Sheet Value	Formula (Register Field Must Be \geq)	Field Value
T_ODT	t_{AOND}	t_{AOND} specifies the ODT turn-on delay	2 (t_{CK} cycles)	t_{AOND}	2
T_XSNR	t_{XSNR}	Exit self refresh to a non-read command	137.5 ns	$(t_{XSNR} \times f_{DDR2_CLK}) - 1$	34
T_XSRD	t_{XSRD}	Exit self refresh to a read command	200 (t_{CK} cycles)	$(t_{XSRD}) - 1$	199
T_RTP	t_{RTP}	Read to precharge command delay	7.5 ns	$(t_{RTP} \times f_{DDR2_CLK}) - 1$	1
T_CKE	t_{CKE}	CKE minimum pulse width	3 (t_{CK} cycles)	$(t_{CKE}) - 1$	2

3.2.4 Configuring the DDR2 Memory Controller Control Register (DMCCTL)

The DDR2 memory controller control register (DMCCTL) contains a read latency (RL) field that helps the DDR2 memory controller determine when to sample read data. The RL field should be programmed to a value equal to CAS latency + 1. For example, if a CAS latency of 4 is used, then RL should be programmed to 5.

Table 16. DMCCTL Configuration

Register Field Name	Description	Register Value
IFRESET	Programmed to be out of reset.	0
RL	Read latency is equal to CAS latency + 1.	5

4 DDR2 Memory Controller Registers

[Table 17](#) lists the memory-mapped registers for the DDR2 memory controller. For the memory address of these registers, see the device-specific data manual.

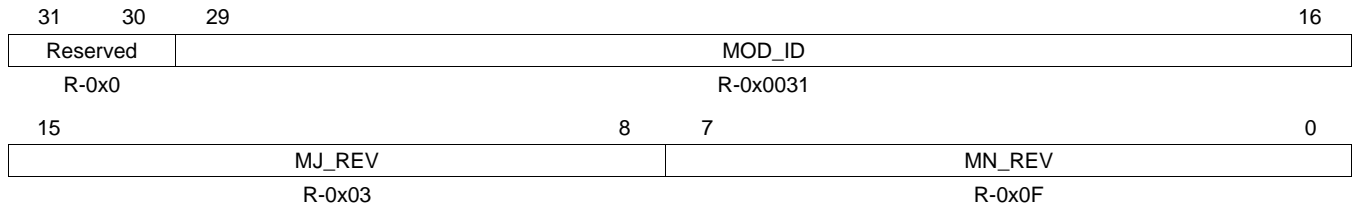
Table 17. DDR2 Memory Controller Registers

Offset	Acronym	Register Description	Section
00h	MIDR	Module ID and Revision Register	Section 4.1
04h	DMCSTAT	DDR2 Memory Controller Status Register	Section 4.2
08h	SDCFG	SDRAM Configuration Register	Section 4.3
0Ch	SDRFC	SDRAM Refresh Control Register	Section 4.4
10h	SDTIM1	SDRAM Timing 1 Register	Section 4.5
14h	SDTIM2	SDRAM Timing 2 Register	Section 4.6
20h	BPRI0	Burst Priority Register	Section 4.7
E4h	DMCCTL	DDR2 Memory Controller Control Register	Section 4.8

4.1 Module ID and Revision Register (MIDR)

The Module ID and Revision register (MIDR) is shown in [Figure 19](#) and described in [Table 18](#).

Figure 19. Module ID and Revision Register (MIDR)



LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

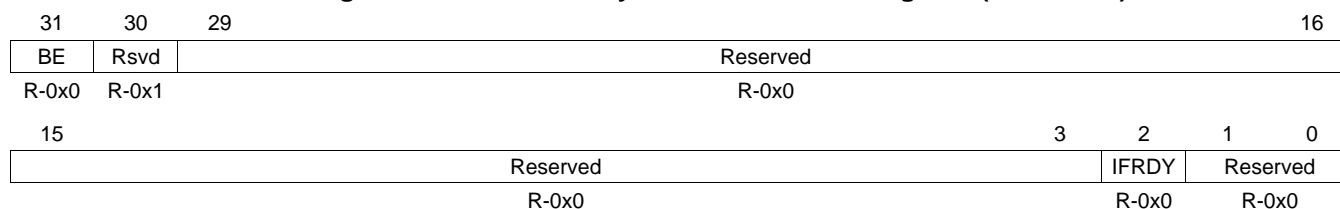
Table 18. Module ID and Revision Register (MIDR) Field Descriptions

Bit	Field	Value	Description
31-30	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
29-16	MOD_ID		Module ID bits.
15-8	MJ_REV		Major revision.
7-0	MN_REV		Minor revision.

4.2 DDR2 Memory Controller Status Register (DMCSTAT)

The DDR2 memory controller status register (DMCSTAT) is shown in [Figure 20](#)

Figure 20. DDR2 Memory Controller Status Register (DMCSTAT)



LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 19. DDR2 Memory Controller Status Register (DMCSTAT) Field Descriptions

Bit	Field	Value	Description
31	BE	0 1	Big endian bit. Reflects whether the DDR2 Memory Controller is configured for big- or little-endian mode. 0 DDR2 Memory Controller is configured for little-endian mode. 1 DDR2 Memory Controller is configured for big-endian mode.
30	Reserved		Reserved. The reserved bit location is always read as 1. A value written to this field has no effect.
29-3	Reserved	0	Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
2	IFRDY	0 1	DDR2 memory controller interface logic ready bit. The interface logic controls the signals used to communicate with DDR2 SDRAM devices. This bit displays the status of the interface logic. 0 Interface logic is not ready; either powered down, not ready, or not locked. 1 Interface logic is powered up, locked, and ready for operation.
1-0	Reserved	0	Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.

4.3 SDRAM Configuration Register (SDCFG)

The SDRAM configuration register (SDCFG) contains fields that program the DDR2 memory controller to meet the specification of the DDR2 memory. These fields configure the DDR2 memory controller to match the data bus width, CAS latency, number of internal banks, and page size of the external DDR2 memory. Bits 0-14 of the SDCFG register are only writeable when the TIMUNLOCK bit is set to 0 (unlocked). for more information on initializing the configuration registers of the DDR2 memory controller, see [Section 2.11.1](#). The SDCFG register is shown in [Figure 21](#) and described in [Table 20](#).

Figure 21. SDRAM Configuration Register (SDCFG)

Reserved										
R-0x0										
31									24	
23	22						19	18	17	16
BOOT_UNLOCK	Reserved					DDR_DRIVE	Reserved			
R/W-0	R/W-0xA					R-0	R-0x3			
15	14	13	12	11				9	8	
TIMUNLOCK	NM	Reserved			CL			Reserved		
R/W-0	R/W-0	R-0x0			R/W-0x5			R-0x0		
7	6				4	3	2	0		
Reserved	IBANK			Reserved	PAGESIZE					
R-0x0	R/W-0x2			R-0x0	R/W-0x0					

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 20. SDRAM Configuration Register (SDCFG) Field Descriptions

Bit	Field	Value	Description
31-24	Reserved		Reserved. Writes to this register must keep these bits at their default values.
23	BOOT_UNLOCK	0	Boot unlock bit. Controls write access to bits 16-22 and 27 of this register. Writes to bits 22:16 of this register are not permitted.
		1	Writes to bits 22:16 of this register are allowed.
22-19	Reserved		Reserved. Writes to this register must keep these bits at their default value.
18	DDR_DRIVE	0	DDR2 SDRAM drive strength. This bit is used to select the drive strength used by the DDR2 SDRAM. This bit is writeable only when BOOT_UNLOCK is unlocked (set to 1). Normal drive strength.
		1	Weak (60%) drive strength.
17-16	Reserved		Reserved. Writes to this register must keep these bits at their default value.
15	TIMUNLOCK	0	Timing unlock bit. Controls write access for the SDRAM Timing Register (SDTIM1) and SDRAM Timing Register 2 (SDTIM2). A write to this bit causes the DDR2 Memory Controller to start the SDRAM initialization sequence. Register fields in the SDTIM1 and SDTIM2 registers may not be changed.
		1	Register fields in the SDTIM1 and SDTIM2 registers may be changed.
14	NM	0	DDR2 data bus width. A write to this bit will cause the DDR2 Memory Controller to start the SDRAM initialization sequence. 32-bit bus width.
		1	16-bit bus width
13-12	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.

Table 20. SDRAM Configuration Register (SDCFG) Field Descriptions (continued)

Bit	Field	Value	Description
11-9	CL	<p>CAS latency. The value of this field defines the CAS latency, to be used when accessing connected SDRAM devices. A write to this field will cause the DDR2 Memory Controller to start the SDRAM initialization sequence. This field is writeable only when the TIMUNLOCK bit is unlocked. Values 0, 1, 6, and 7 are reserved for this field.</p> <p>2 CAS latency of 2.</p> <p>3 CAS latency of 3.</p> <p>4 CAS latency of 4.</p> <p>5 CAS latency of 5.</p>	
8-7	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
6-4	IBANK	<p>Internal SDRAM bank setup bits. Defines number of banks inside connected SDRAM devices. A write to this bit will cause the DDR2 Memory Controller to start the SDRAM initialization sequence. Values 4-7 are reserved for this field.</p> <p>0 One bank SDRAM devices.</p> <p>1 Two banks SDRAM devices.</p> <p>2 Four banks SDRAM devices.</p> <p>3 Eight banks SDRAM devices.</p>	
3	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
2-0	PAGESIZE	<p>Page size bits. Defines the internal page size of the external DDR2 memory. A write to this bit will cause the DDR2 Memory Controller to start the SDRAM initialization sequence. Values 4-7 are reserved for this field.</p> <p>0 256-word page requiring 8 column address bits.</p> <p>1 512-word page requiring 9 column address bits.</p> <p>2 1024-word page requiring 10 column address bits.</p> <p>3 2048-word page requiring 11 column address bits.</p>	

4.4 SDRAM Refresh Control Register (SDRFC)

The SDRAM refresh control register (SDRFC) is used to configure the DDR2 memory controller to:

- Enter and Exit the self-refresh state.
- Meet the refresh requirement of the attached DDR2 device by programming the rate at which the DDR2 memory controller issues autorefresh commands.

The SDRFC is shown in [Figure 22](#) and described in [Table 21](#).

Figure 22. SDRAM Refresh Control Register (SDRFC)

31	30	29	16
SR	Rsvd	Reserved	
R/W- 0x0	R/W- 0x0	R-0x0	
15			0
REFRESH_RATE			
R/W-0x753			

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 21. SDRAM Refresh Control Register (SDRFC) Field Descriptions

Bit	Field	Value	Description
31	SR	0 1	Self-refresh bit. Writing a 1 to this bit will cause connected SDRAM devices to be place into Self Refresh mode and the DDR2 Memory Controller to enter the Self Refresh state. Exit self-refresh mode. Enter self-refresh mode.
30-16	Reserved		Reserved. Writes to this register must keep this field at its default value.
15-0	REFRESH_RATE		Refresh rate bits. The value in this field is used to define the rate at which connected SDRAM devices will be refreshed as follows: $SDRAM\ refresh\ rate = DDR2CLKOUT\ clock\ rate / REFRESH_RATE$ Writing a value less than 0x0100 to this field will cause it to be loaded with $2 * T_RFC$ value from the SDRAM Timing 1 Register.

4.5 SDRAM Timing 1 Register (SDTIM1)

The SDRAM timing 1 register (SDTIM1) configures the DDR2 memory controller to meet many of the AC timing specification of the DDR2 memory. Note that DDR2CLKOUT is equal to the period of the DDR2CLKOUT signal. For information on the appropriate values to program each field, see the DDR2 memory section of the device-specific data manual. The bit fields in the SDTIM1 register are only writeable when the TIMUNLOCK bit of the SDRAM Configuration register (SDCFG) is unlocked. The SDTIM1 is shown in Figure 23 and described in Table 22.

Figure 23. SDRAM Timing 1 Register (SDTIM1)

31	25	24	22	21	19	18	16
T_RFC			T_RP		T_RCD		T_WR
R/W-0x3F			R/W-0x7		R/W-0x7		R/W-0x7
15	11	10	6	5	3	2	1 0
T_RAS		T_RC			T_RRD		Rsvd T_WTR
R/W-0x1F		R/W-0x1F			R/W-0x7		R-0 R/W-0x3

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 22. SDRAM Timing 1 Register (SDTIM1) Field Descriptions

Bit	Field	Value	Description
31-25	T_RFC		These bits specify the minimum number of DDR2CLKOUT cycles from a refresh or load mode command to a refresh or activate command, minus one. The value for these bits can be derived from the t_{rfc} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using this formula: $T_RFC = (t_{rfc}/DDR2CLKOUT) - 1$
24-22	T_RP		These bits specify the minimum number of DDR2CLKOUT cycles from a precharge command to a refresh or activate command, minus 1. The value for these bits can be derived from the t_p AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using the formula: $T_RP = (t_p/DDR2CLKOUT) - 1$
21-19	T_RCD		These bits specify the minimum number of DDR2CLKOUT cycles from an activate command to a read or write command, minus 1. The value for these bits can be derived from the t_{rcd} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using the formula: $T_RCD = (t_{rcd}/DDR2CLKOUT) - 1$
18-16	T_WR		These bits specify the minimum number of DDR2CLKOUT cycles from the last write transfer to a precharge command, minus 1. The value for these bits can be derived from the t_{wr} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using the formula: $T_WR = (t_{wr}/DDR2CLKOUT) - 1$ The SDRAM initialization sequence will be started when the value of this field is changed from the previous value and the DDR2_ENABLE in SDCFG is equal to 1.
15-11	T_RAS		These bits specify the minimum number of DDR2CLKOUT cycles from an activate command to a precharge command, minus 1. The value for these bits can be derived from the t_{ras} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using this formula: $T_RAS = (t_{ras}/DDR2CLKOUT) - 1$ T_RAS must be greater than or equal to T_RCD .
10-6	T_RC		These bits specify the minimum number of DDR2CLKOUT cycles from an activate command to an activate command, minus 1. The value for these bits can be derived from the t_{rc} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using this formula: $T_RC = (t_{rc}/DDR2CLKOUT) - 1$

Table 22. SDRAM Timing 1 Register (SDTIM1) Field Descriptions (continued)

Bit	Field	Value	Description
5-3	T_RRD		<p>These bits specify the minimum number of DDR2CLKOUT cycles from an activate command to an activate command in a different bank, minus 1. The value for these bits can be derived from the t_{rrd} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using this formula:</p> $T_RRD = (t_{rrd}/DDR2CLKOUT) - 1$ <p>When connecting to an 8-bank DDR2 SDRAM, this field must be equal to:</p> $T_RRD = ((4*t_{rrd} + 2*t_{ck}) / (4*t_{ck})) - 1$
2	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
1-0	T_WTR		<p>These bits specify the minimum number of DDR2CLKOUT cycles from the last write to a read command, minus 1. The value for these bits can be derived from the t_{wtr} AC timing parameter in the DDR2 memory section of the device-specific data manual. Calculate using this formula:</p> $T_WTR = (t_{wtr}/DDR2CLKOUT) - 1$

4.6 SDRAM Timing 2 Register (SDTIM2)

Like the SDRAM timing 1 register (SDTIM1), the SDRAM timing 2 register (SDTIM2) also configures the DDR2 memory controller to meet the AC timing specification of the DDR2 memory. For information on the appropriate values to program each field, see the DDR2 memory section of the device-specific data manual. The bit fields in the SDTIM2 register are only writeable when the TIMUNLOCK bit of the SDRAM Configuration register (SDCFG) is unlocked. SDTIM2 is shown in Figure 24 and described in Table 23.

Figure 24. SDRAM Timing 2 Register (SDTIM2)

31	25	24	23	22	16
Reserved		T_ODT		T_XSNR	
R-0x0		R/W-0x3		R/W-0x7F	
15	8	7	5	4	0
T_XSRD			T_RTP		T_CKE
R/W-0xFF			R/W-0x7		R/W-0x1F

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset; -x = value is indeterminate after reset

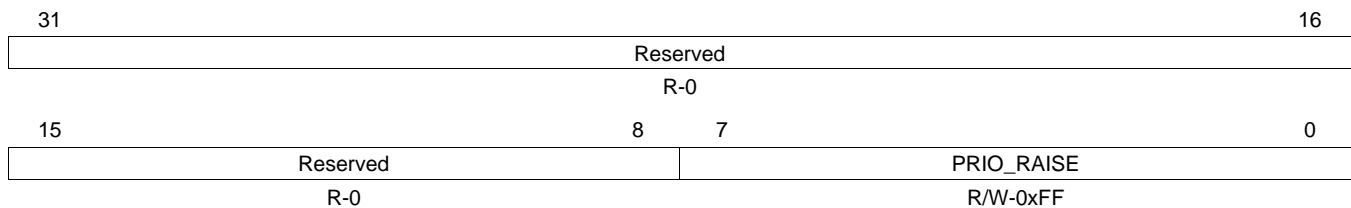
Table 23. SDRAM Timing 2 Register (SDTIM2) Field Descriptions

Bit	Field	Value	Description
31-25	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
24-23	T_ODT		Minimum number of DDR clock cycles from ODT enable to write data driven for DDR2 SDRAM. T_ODT must be equal to t_{AOND} . $T_ODT = t_{AOND}$
22-16	T_XSNR	0-7Fh	These bits specify the minimum number of DDR2CLKOUT cycles from a self_refresh exit to any other command except a read command, minus 1. The value for these bits can be derived from the t_{XSNR} AC timing parameter in the DDR2 section of the device-specific data manual. Calculate using this formula: $T_XSNR = t_{XSNR} - 1$
15-8	T_XSRD	0-FFh	These bits specify the minimum number of DDR2CLKOUT cycles from a self_refresh exit to a read command, minus 1. The value for these bits can be derived from the t_{XSRD} AC timing parameter in the DDR2 section of the device-specific data manual. Calculate using this formula: $T_XSRD = t_{XSRD} - 1$
7-5	T_RTP	0-7h	These bits specify the minimum number of DDR2CLKOUT cycles from a last read command to a precharge command, minus 1. The value for these bits can be derived from the t_{rtp} AC timing parameter in the DDR2 section of the device-specific data manual. Calculate using this formula: $T_RTP = (t_{rtp}/DDR2CLKOUT) - 1$
4-0	T_CKE	0-1Fh	These bits specify the minimum number of DDR2CLKOUT cycles between transitions on the DSDCKE pin, minus 1. The value for these bits can be derived from the t_{cke} AC timing parameter in the DDR2 section of the device-specific data manual. Calculate using this formula: $T_CKE = t_{cke} - 1$

4.7 Burst Priority Register (BPRIO)

The Burst Priority Register (BPRIO) helps prevent command starvation within the DDR2 memory controller. To avoid command starvation, the DDR2 memory controller momentarily raises the priority of the oldest command in the command FIFO after a set number of transfers have been made. The PRIO_RAISE bit sets the number of transfers that must be made before the DDR2 memory controller raises the priority of the oldest command. The BPRIO is shown in Figure 25 and described in Table 24. For more details on command starvation, see Section 2.7.2.

Figure 25. Burst Priority Register (BPRIO)



LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

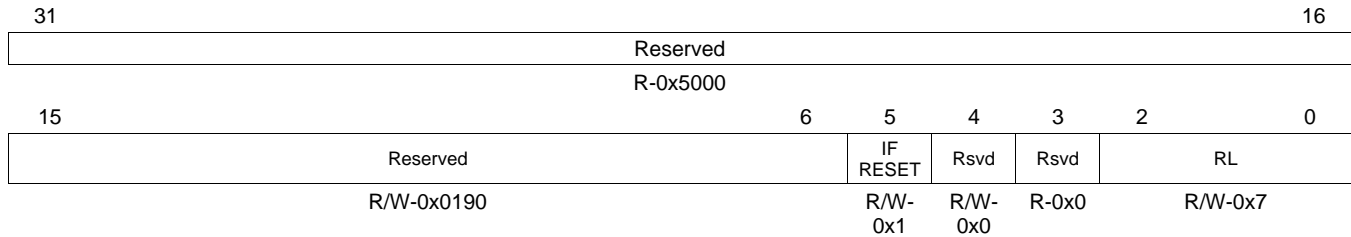
Table 24. Burst Priority Register (BPRIO) Field Descriptions

Bit	Field	Value	Description
31-8	Reserved	000h	Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
7-0	PRIO_RAISE	0h	1 memory transfer.
		1h	2 memory transfers.
		...	
		FEh	255 memory transfers.
		FFh	EMIF reorders commands based on its arbitration.

4.8 DDR2 Memory Controller Control Register (DMCCTL)

The DDR2 memory controller control register (DMCCTL) resets the interface logic of the DDR2 memory controller. The DMCCTL is shown in [Figure 26](#) and described in [Table 25](#).

Figure 26. DDR2 Memory Controller Control Register (DMCCTL)



LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 25. DDR2 Memory Controller Control Register (DMCCTL) Field Descriptions

Bit	Field	Value	Description
31-6	Reserved		Reserved. Writes to this register must keep this field at its default value.
5	IFRESET	0 1	DDR2 memory controller interface logic reset. The interface logic controls the signals used to communicate with DDR2 SDRAM devices. This bit resets the interface logic. The status of this interface logic is shown on the DDR2 memory controller status register. Release reset. Assert reset.
4	Reserved		Reserved. Writes to this register must keep this field at its default value.
3	Reserved		Reserved. The reserved bit location is always read as 0. A value written to this field has no effect.
2-0	RL		Read latency bits. These bits must be set equal to the CAS latency + 1.

Revision History

This revision history highlights the technical changes made to the document in this revision.

See	Additions/Modifications/Deletions
Table 1	Modified Description for DEODT[1:0] Pins
Table 10	Modified Descriptions for Bits 6 and 2
Figure 16	Modified ODT pins in figure
Figure 17	Modified ODT pins in figure
Figure 18	Modified ODT pins in figure

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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