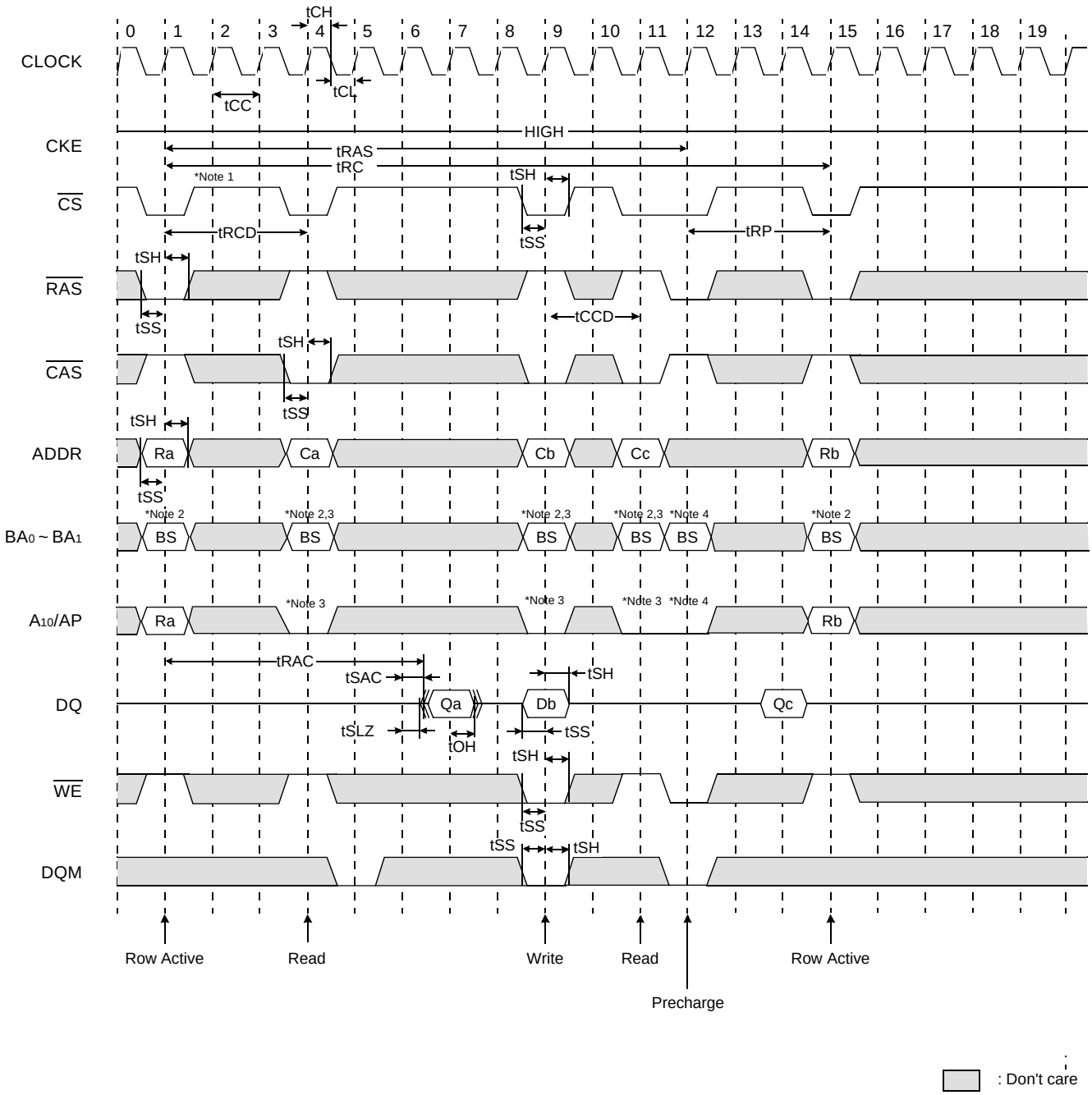
Single Bit Read-Write-Read Cycle(Same Page) @CAS Latency=3, Burst Length=1



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***Note :** 1. All input except CKE & DQM can be don't care when $\overline{CS}$ is high at the CLK high going edge.
2. Bank active & read/write are controlled by BA0~BA1.

BA0	BA1	Active & Read/Write
0	0	Bank A
0	1	Bank B
1	0	Bank C
1	1	Bank D

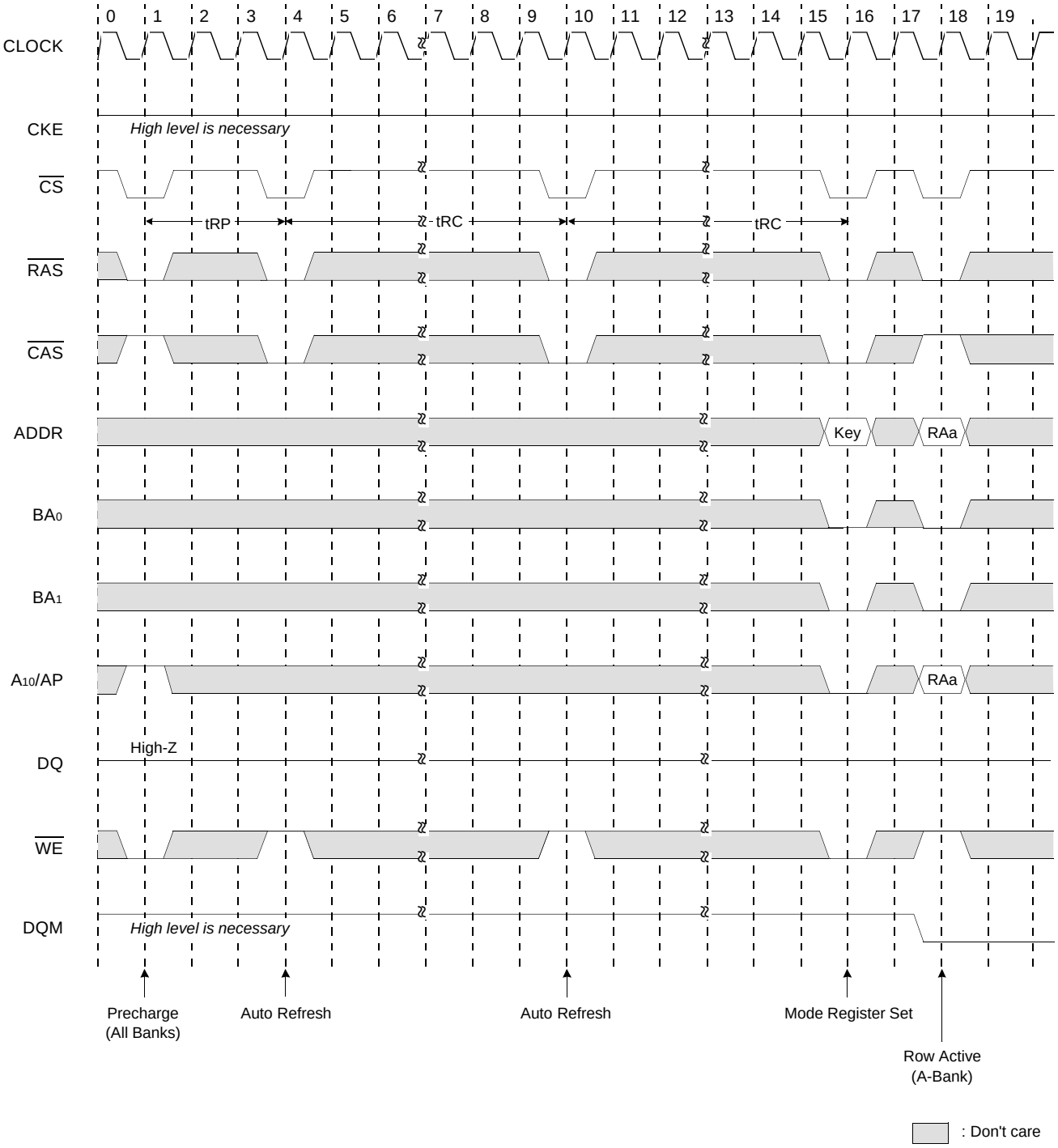
3. Enable and disable auto precharge function are controlled by A10/AP in read/write command

A10/AP	BA0	BA1	Operation
0	0	0	Disable auto precharge, leave bank A active at end of burst.
	0	1	Disable auto precharge, leave bank B active at end of burst.
	1	0	Disable auto precharge, leave bank C active at end of burst.
	1	1	Disable auto precharge, leave bank D active at end of burst.
1	0	0	Enable auto precharge, precharge bank A at end of burst.
	0	1	Enable auto precharge, precharge bank B at end of burst.
	1	0	Enable auto precharge, precharge bank C at end of burst.
	1	1	Enable auto precharge, precharge bank D at end of burst.

4. A10/AP and BA0~BA1 control bank precharge when precharge command is asserted.

A10/AP	BA0	BA1	Precharge
0	0	0	Bank A
0	0	1	Bank B
0	1	0	Bank C
0	1	1	Bank D
1	x	x	All Banks

Power Up Sequence



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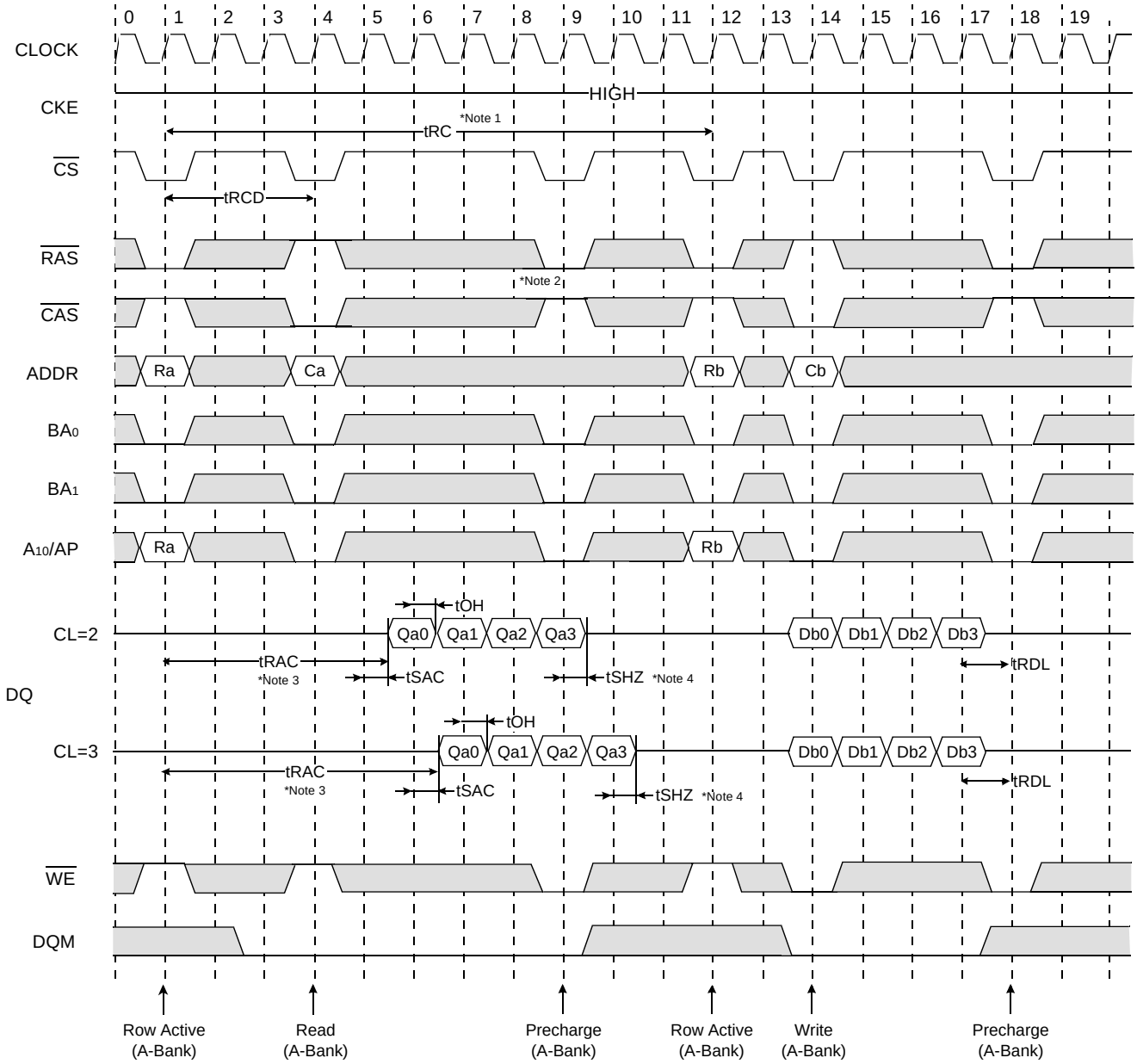
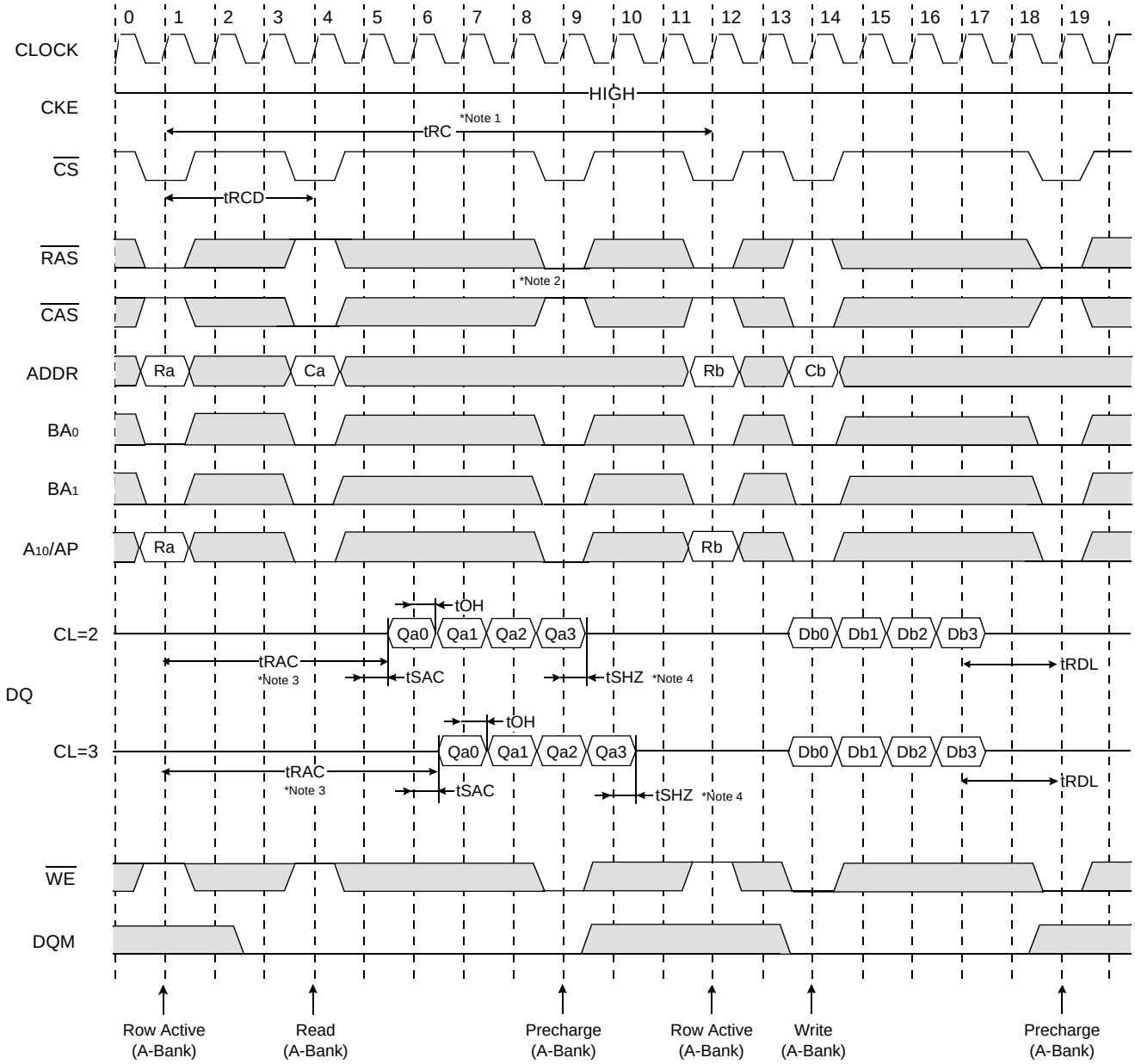
Read & Write Cycle at Same Bank @Burst Length=4, tRDL=1CLK



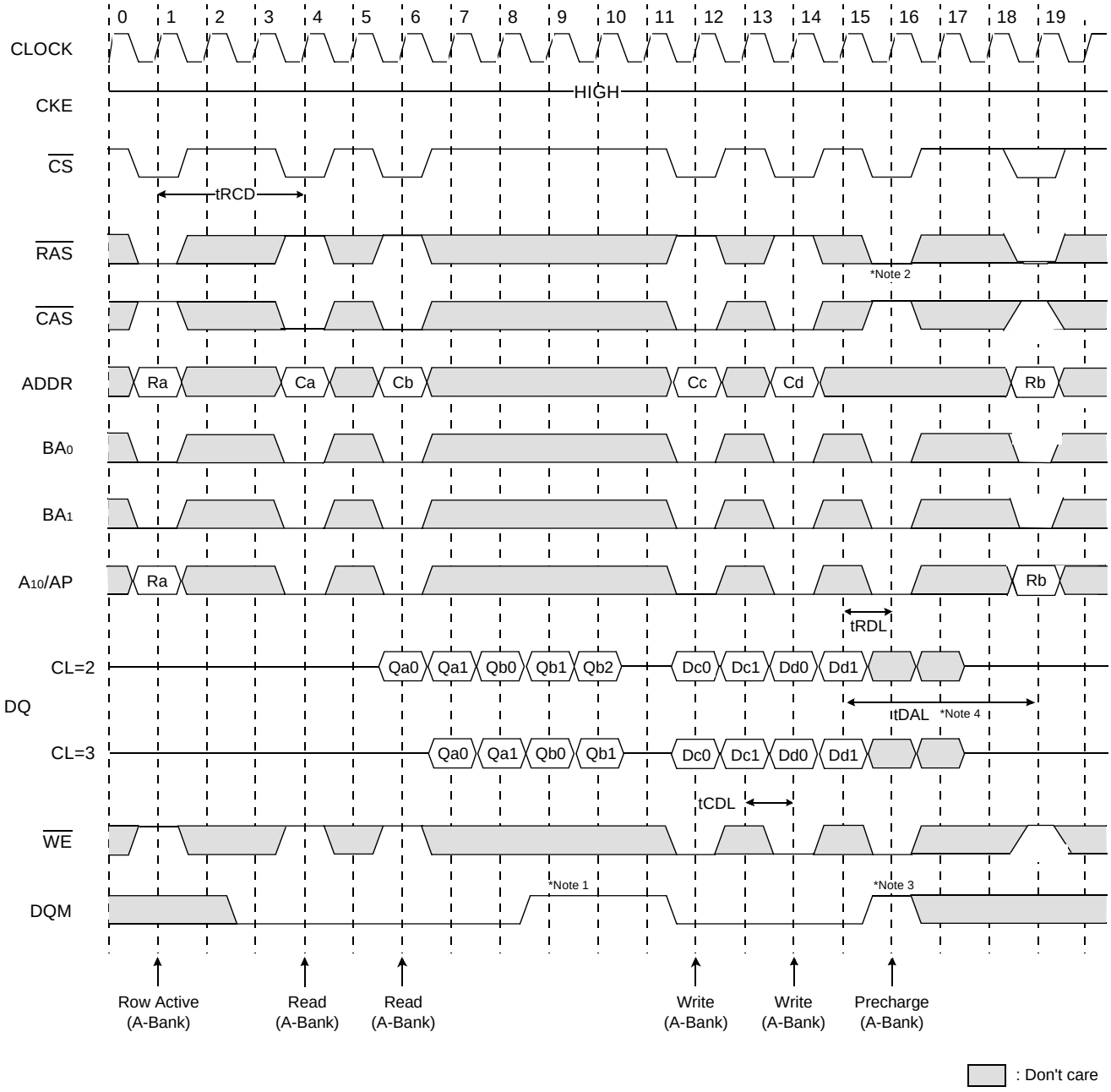
***Note :** 1. Minimum row cycle times is required to complete internal DRAM operation.
2. Row precharge can interrupt burst on any cycle. [CAS Latency - 1] number of valid output data is available after Row precharge. Last valid output will be Hi-Z(t_{SHZ}) after the clcok.
3. Access time from Row active command. t_{CC} *(t_{RCD} + CAS latency - 1) + t_{SAC}
4. Ouput will be Hi-Z after the end of burst. (1, 2, 4, 8 & Full page bit burst)

Read & Write Cycle at Same Bank @Burst Length=4, tRDL=2CLK



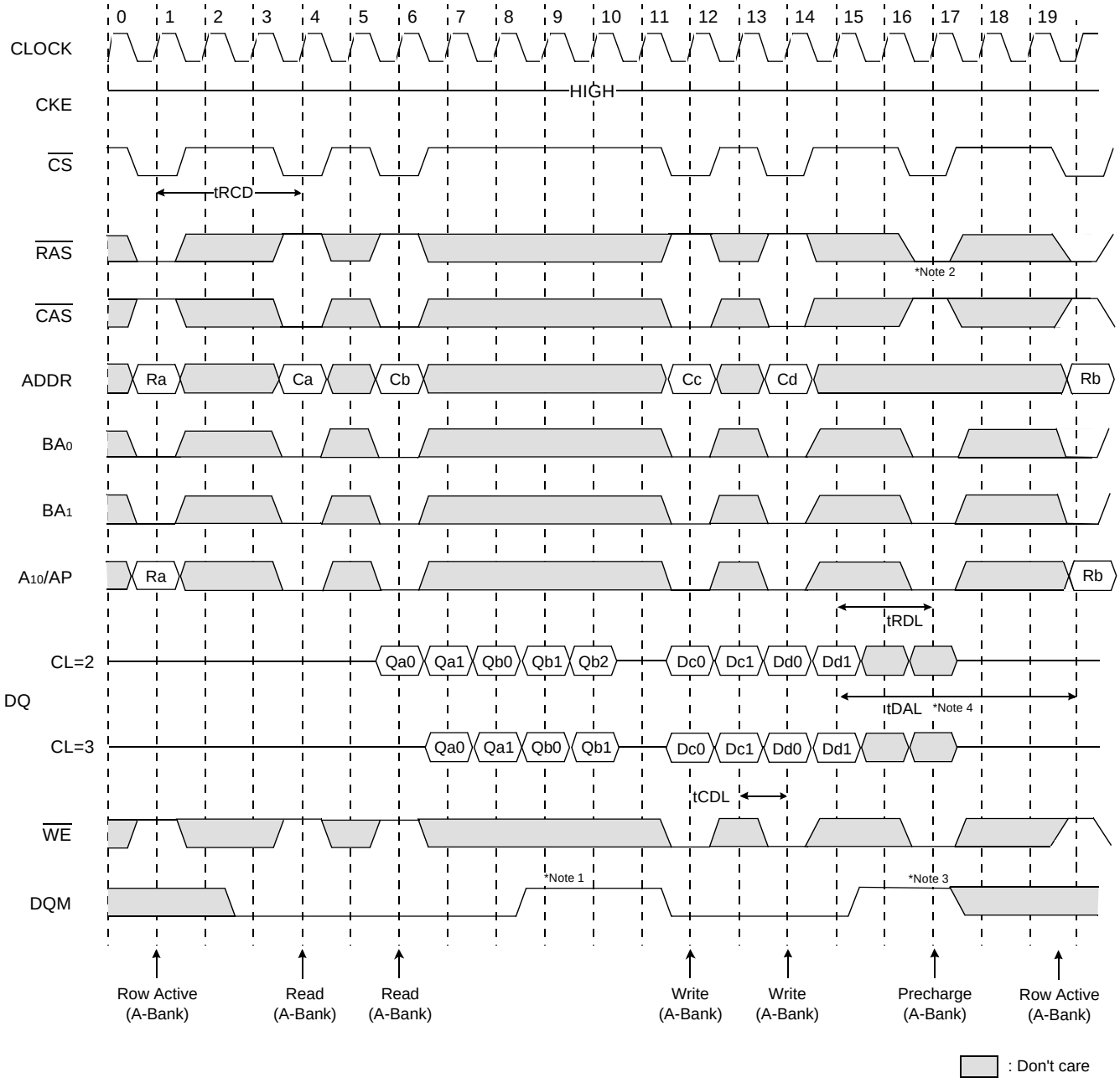
***Note :** 1. Minimum row cycle times is required to complete internal DRAM operation.
2. Row precharge can interrupt burst on any cycle. [CAS Latency - 1] number of valid output data is available after Row precharge. Last valid output will be Hi-Z(t_{SHZ}) after the clcok.
3. Access time from Row active command. t_{CC} *(t_{RCD} + CAS latency - 1) + t_{SAC}
4. Ouput will be Hi-Z after the end of burst. (1, 2, 4, 8 & Full page bit burst)

Page Read & Write Cycle at Same Bank @Burst Length=4, tRDL=1CLK



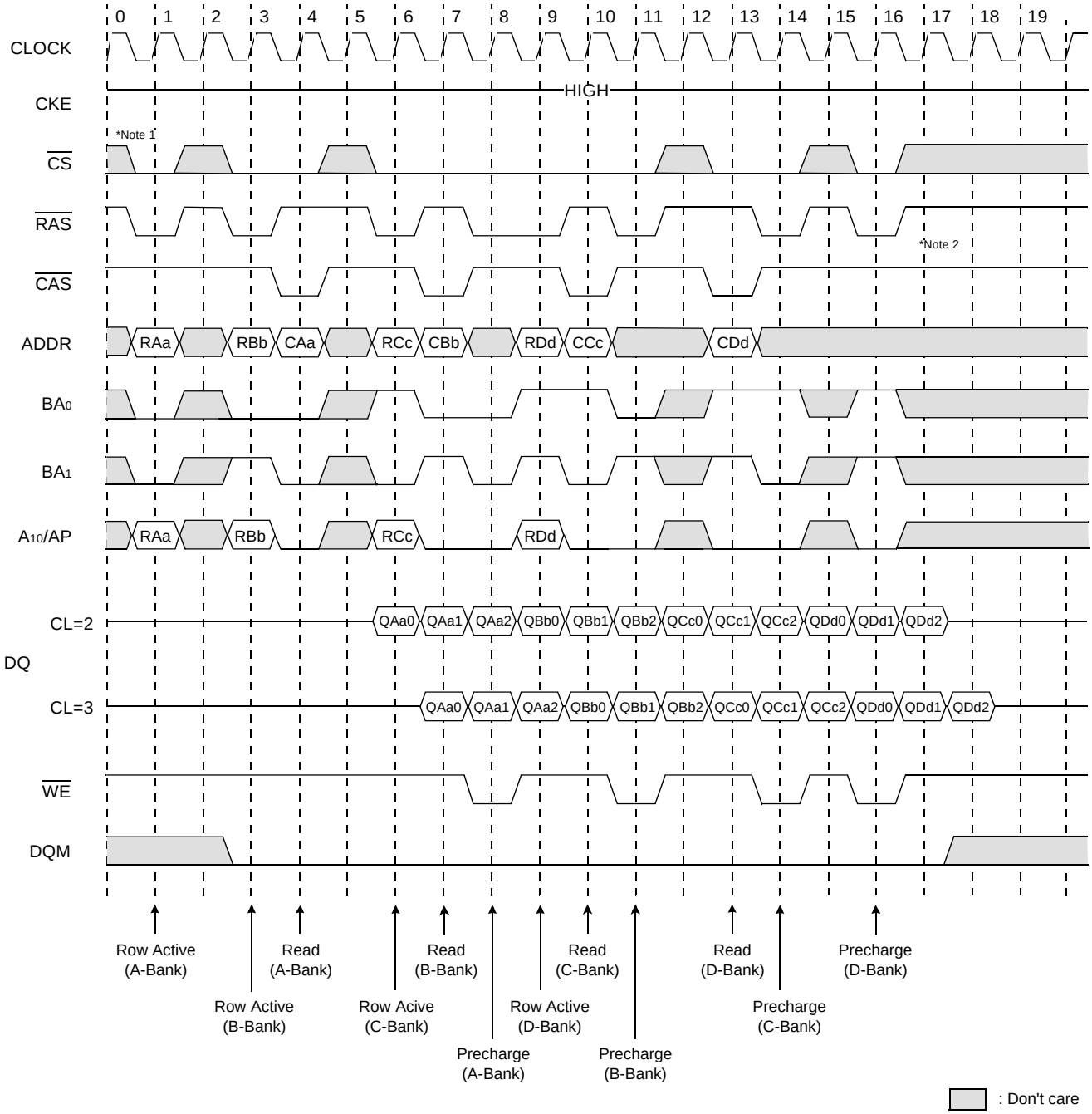
***Note :** 1. To write data before burst read ends, DQM should be asserted three cycle prior to write command to avoid bus contention.
2. Row precharge will interrupt writing. Last data input, t_{RDL} before Row precharge, will be written.
3. DQM should mask invalid input data on precharge command cycle when asserting precharge before end of burst. Input data after Row precharge cycle will be masked internally.
4. tDAL, last data in to active delay, is 1CLK + 20ns

Page Read & Write Cycle at Same Bank @Burst Length=4, tRDL=2CLK



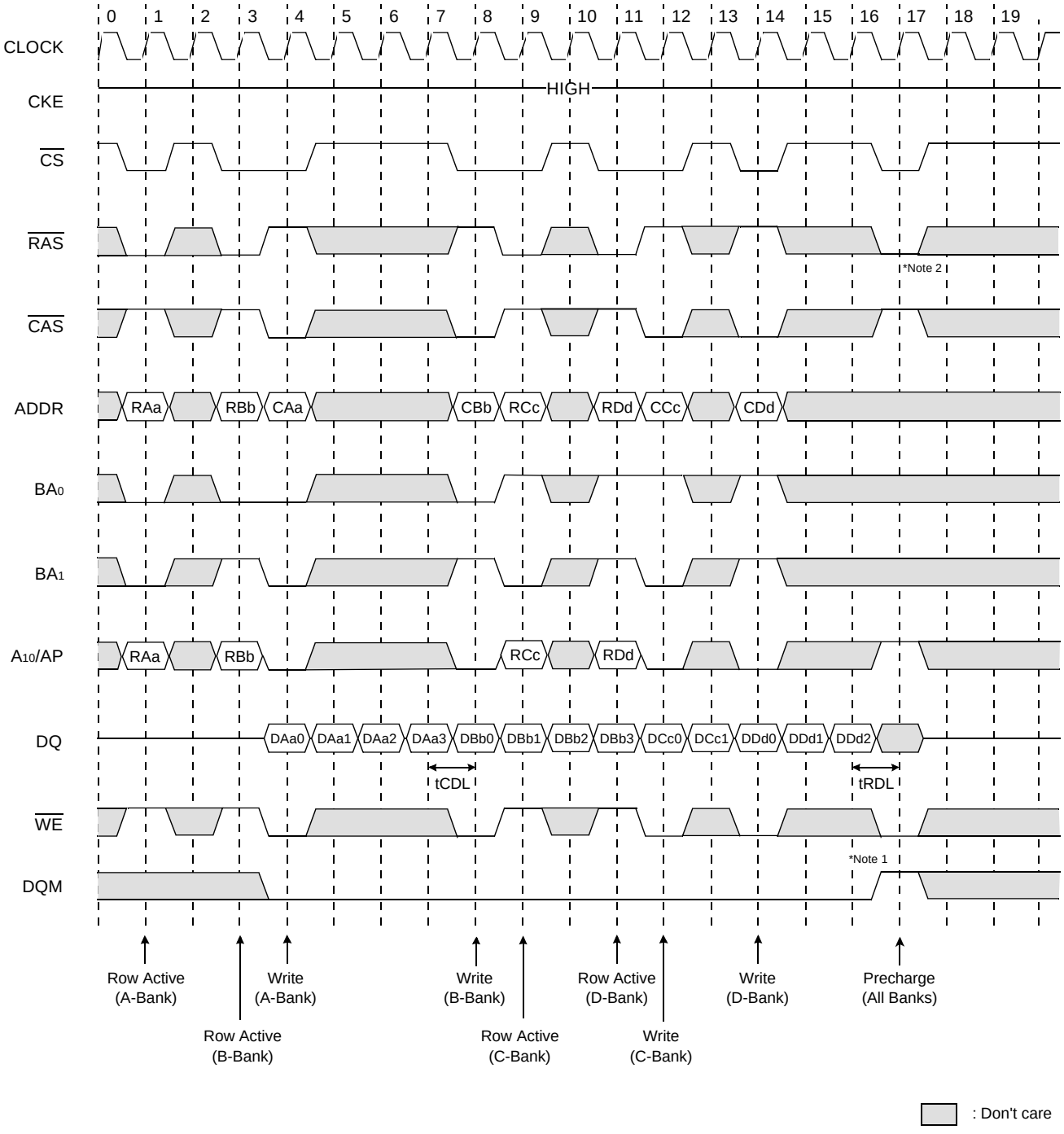
***Note :** 1. To write data before burst read ends, DQM should be asserted three cycle prior to write command to avoid bus contention.
2. Row precharge will interrupt writing. Last data input, t_{RDL} before Row precharge, will be written.
3. DQM should mask invalid input data on precharge command cycle when asserting precharge before end of burst. Input data after Row precharge cycle will be masked internally.
4. tDAL ,last data in to active delay, is 2CLK + 20ns.

Page Read Cycle at Different Bank @Burst Length=4



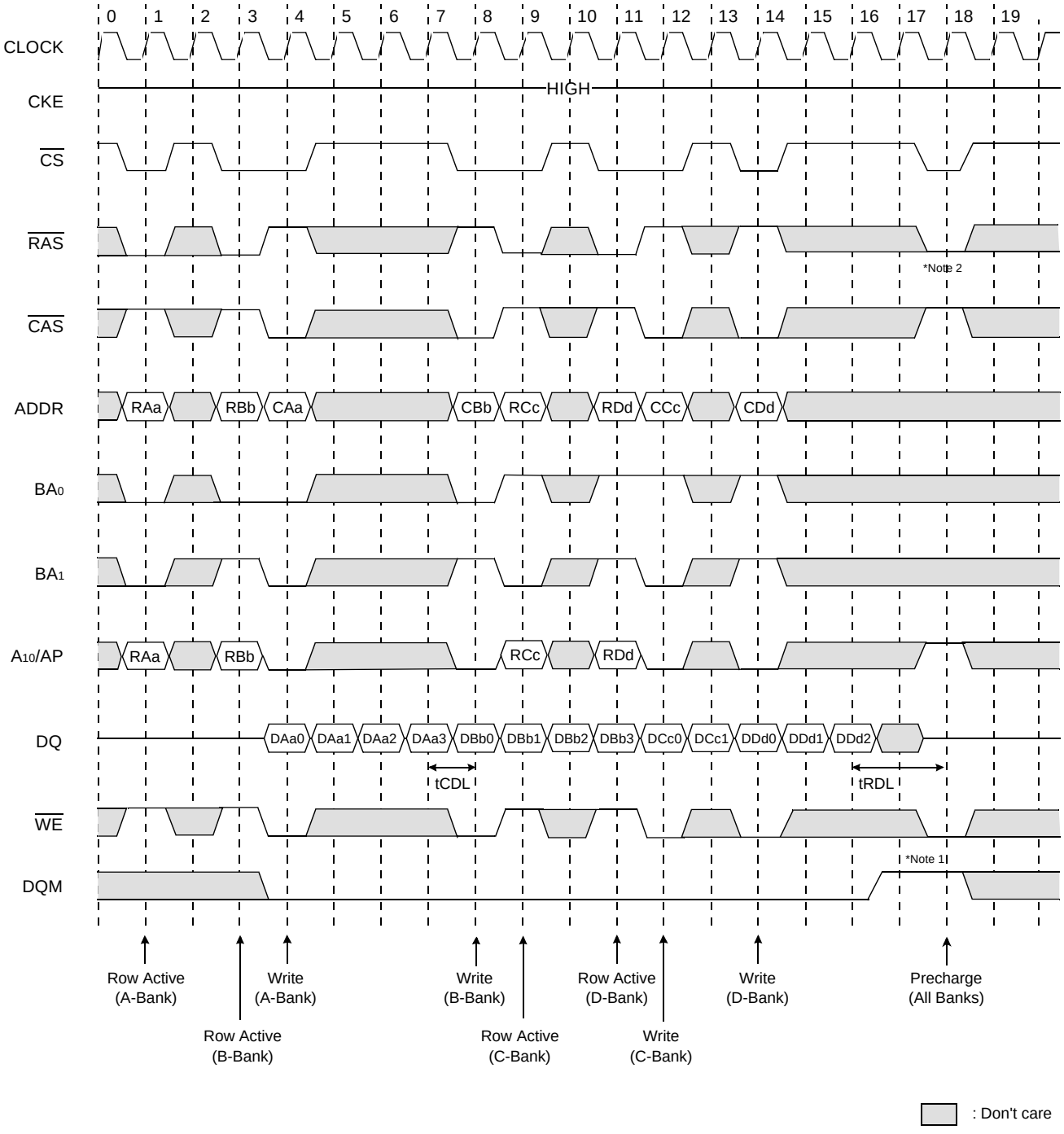
***Note :** 1. $\overline{CS}$ can be don't cared when $\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$ are high at the clock high going dege.
2. To interrupt a burst read by row precharge, both the read and the precharge banks must be the same.

Page Write Cycle at Different Bank @Burst Length=4, tRDL=1CLK



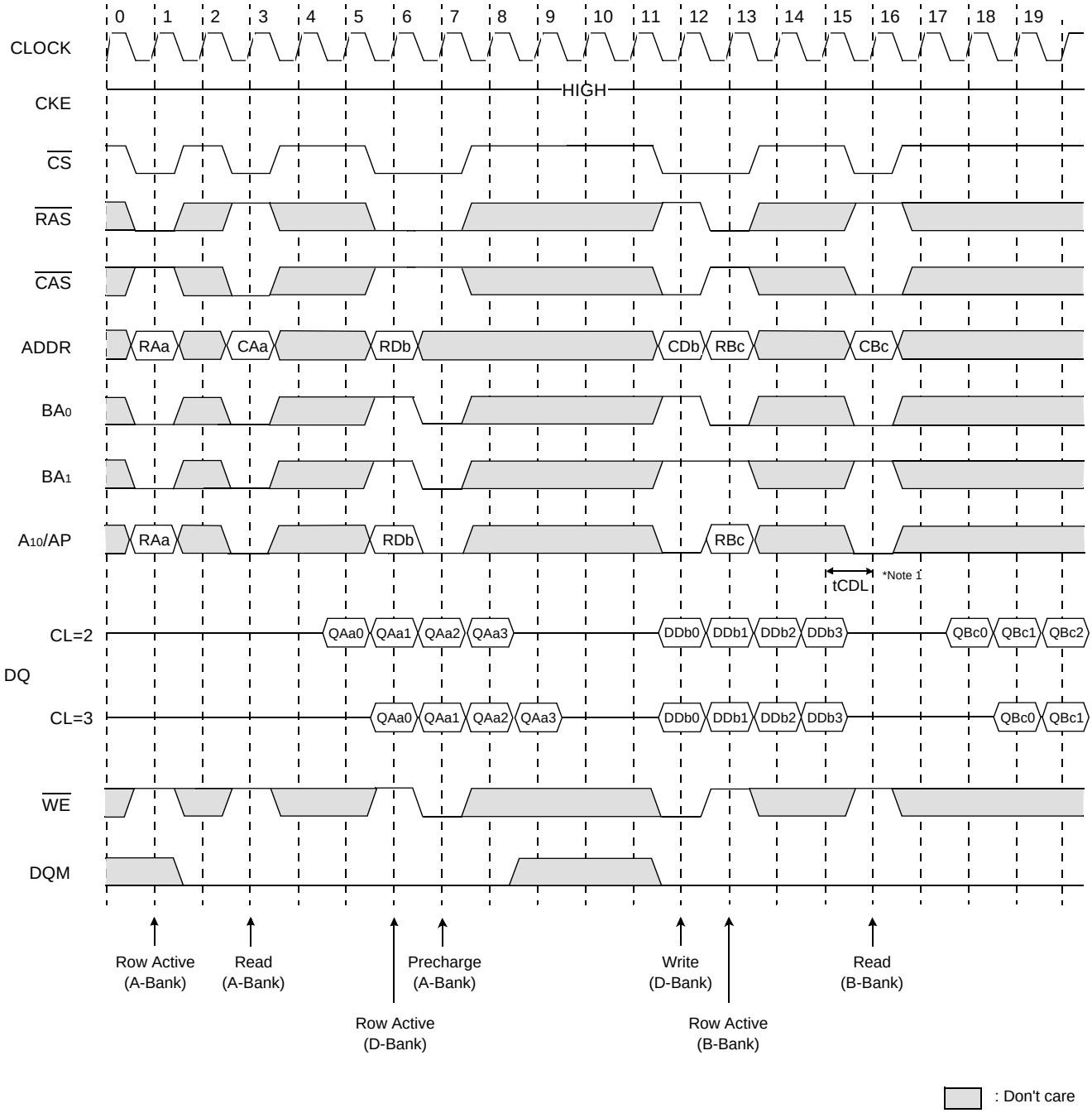
***Note :** 1. To interrupt burst write by Row precharge, DQM should be asserted to mask invalid input data.
2. To interrupt burst write by Row precharge, both the write and the precharge banks must be the same.

Page Write Cycle at Different Bank @Burst Length=4, tRDL=2CLK



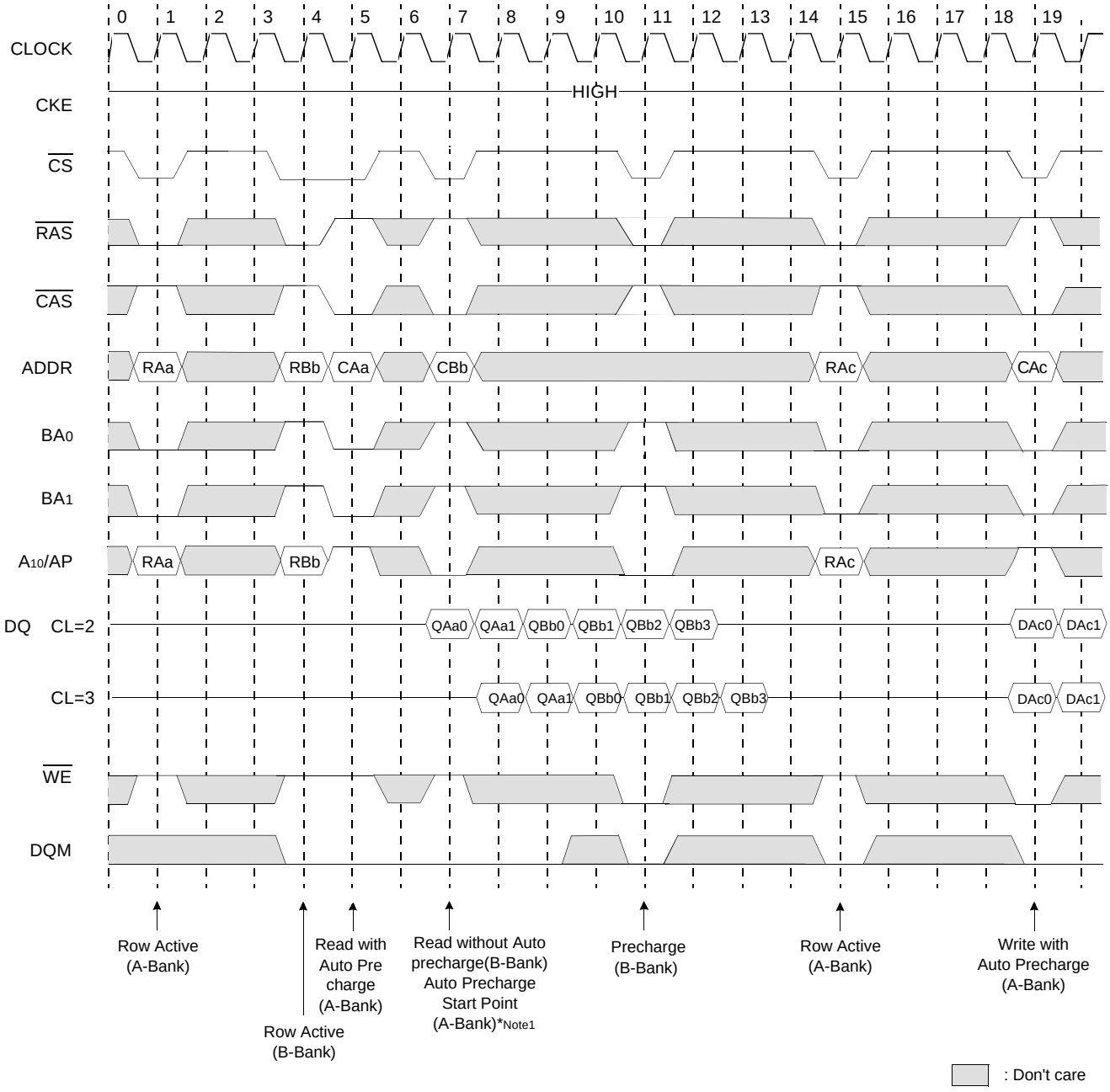
***Note :** 1. To interrupt burst write by Row precharge, DQM should be asserted to mask invalid input data.
2. To interrupt burst write by Row precharge, both the write and the precharge banks must be the same.

Read & Write Cycle at Different Bank @Burst Length=4



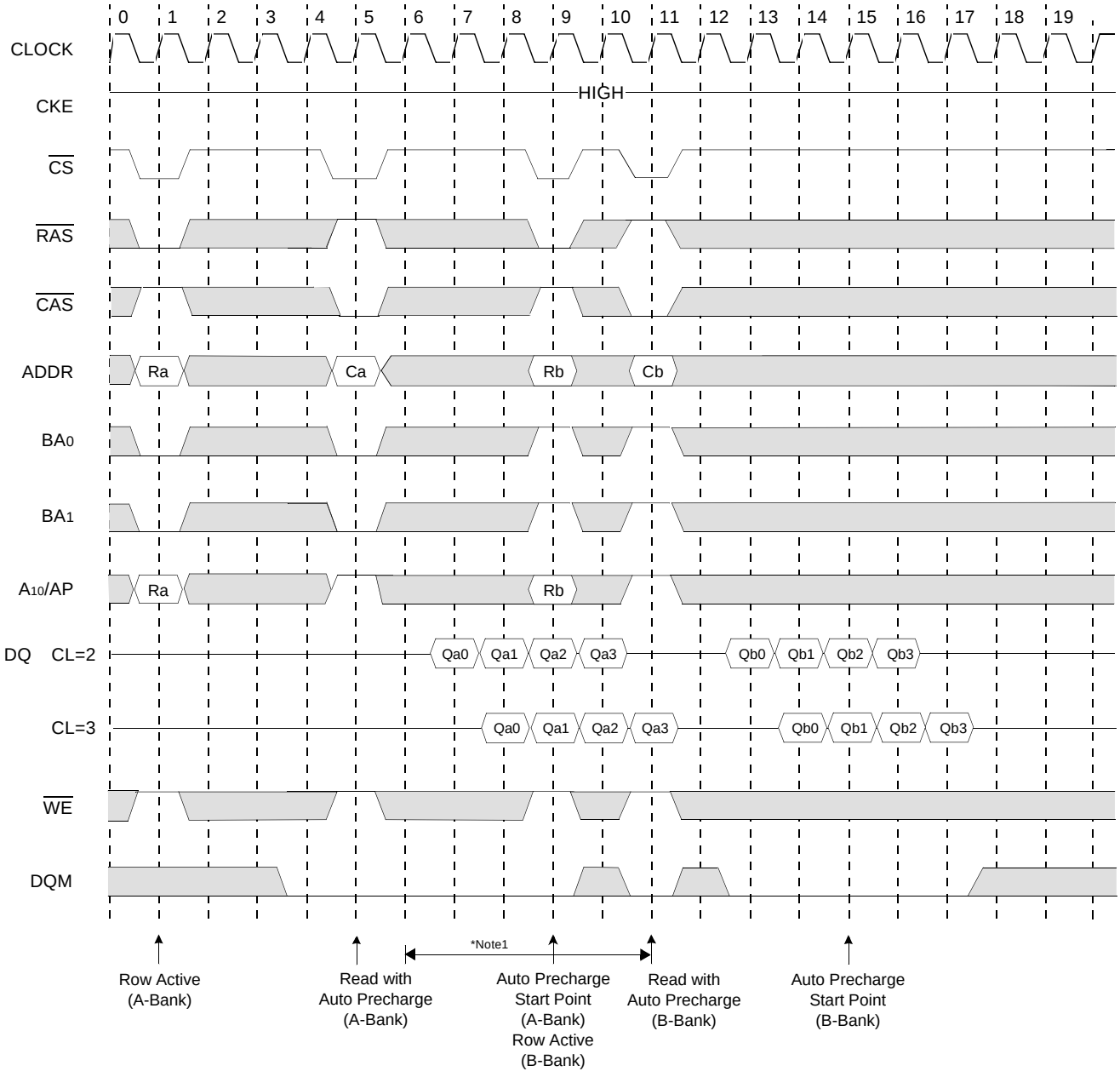
***Note :** 1. t_{CDL} should be met to complete write.

Read & Write Cycle with Auto Precharge I @Burst Length=4



***Note1:** When Read(Write) command with auto precharge is issued at A-Bank after A and B Bank activation.
- if Read(Write) command without auto precharge is issued at B-Bank before A-Bank auto precharge starts, A-Bank auto precharge will start at B-Bank read command input point .
- any command can not be issued at A-Bank during tRP after A-Bank auto precharge starts.

Read & Write Cycle with Auto Precharge II @Burst Length=4

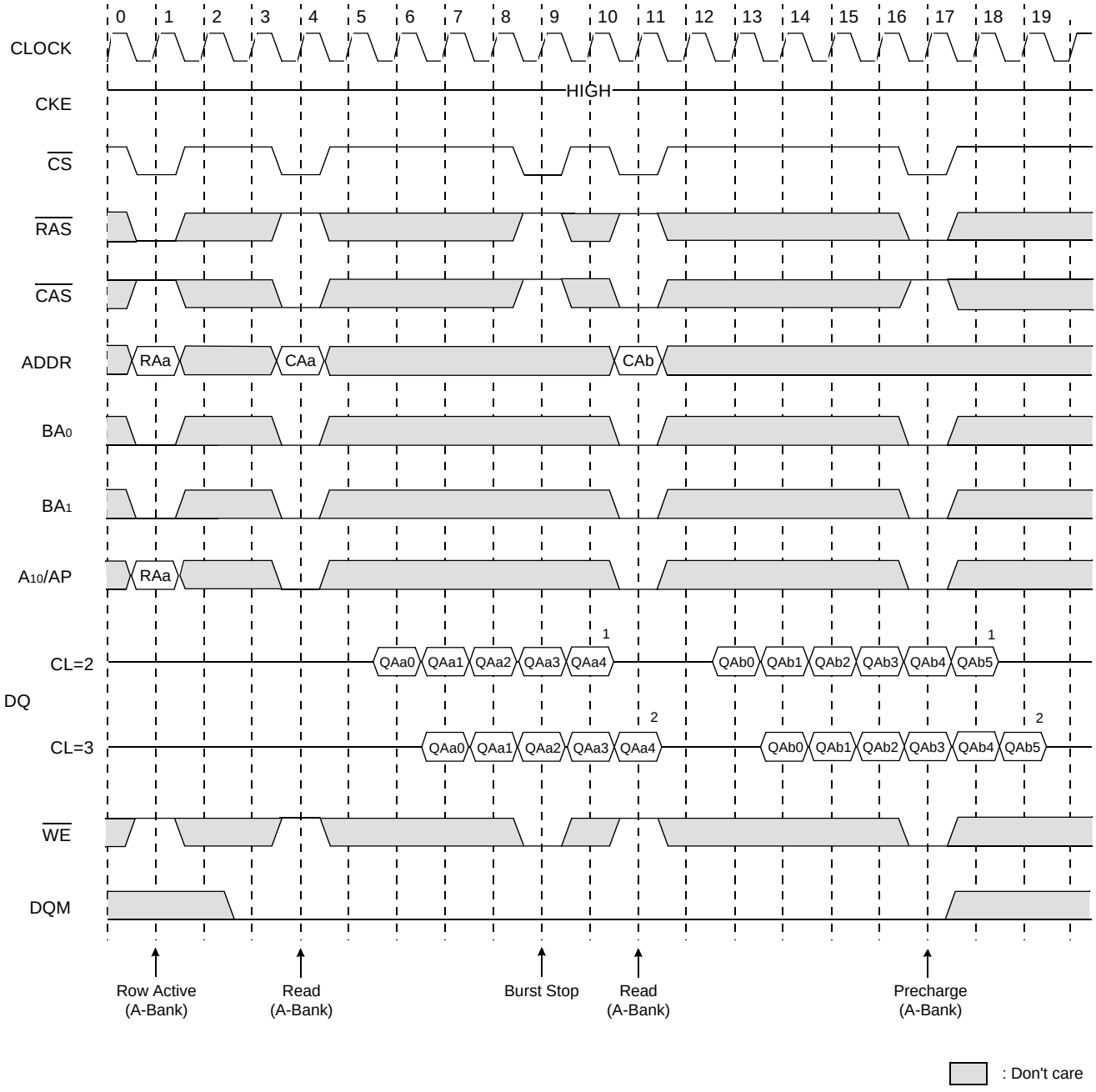


***Note 1:** Any command to A-bank is not allowed in this period.
tRP is determined from at auto precharge start point

Clock Suspension & DQM Operation Cycle @CAS Latency=2, Burst Length=4

***Note1 :** DQM is needed to prevent bus contention.

Read Interrupted by Precharge Command & Read Burst Stop Cycle @ Full Page Burst

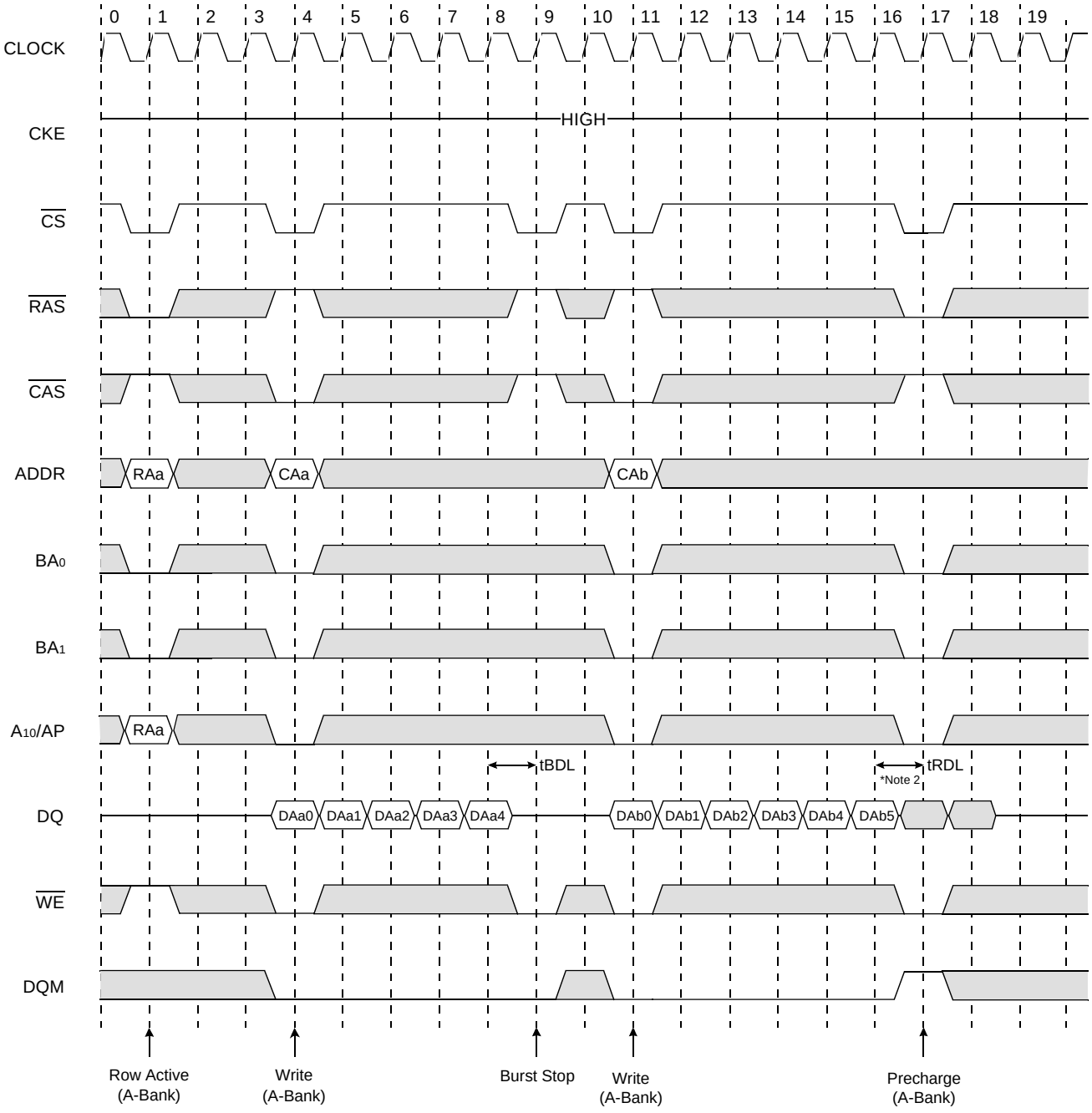


***Note :** 1. At full page mode, burst is end at the end of burst. So auto precharge is possible.

2. About the valid DQs after burst stop, it is same as the case of $\overline{RAS}$ interrupt.
   Both cases are illustrated above timing diagram. See the label 1, 2 on them.
   But at burst write, Burst stop and $\overline{RAS}$ interrupt should be compared carefully.
   Refer the timing diagram of "Full page write burst stop cycle".

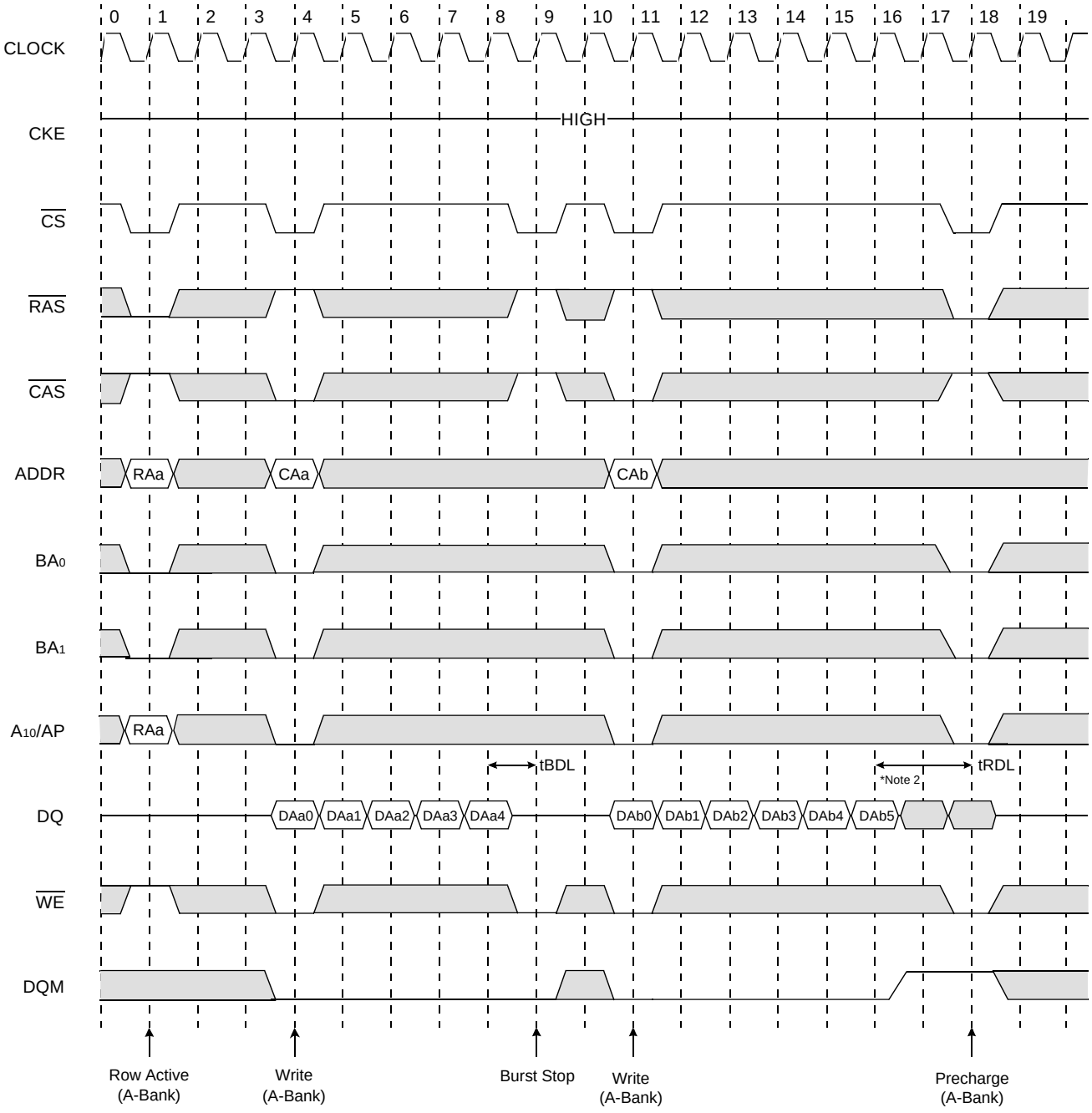
3. Burst stop is valid at every burst length.

Write Interrupted by Precharge Command & Write Burst Stop Cycle @ Full Page Burst, tRDL=1CLK



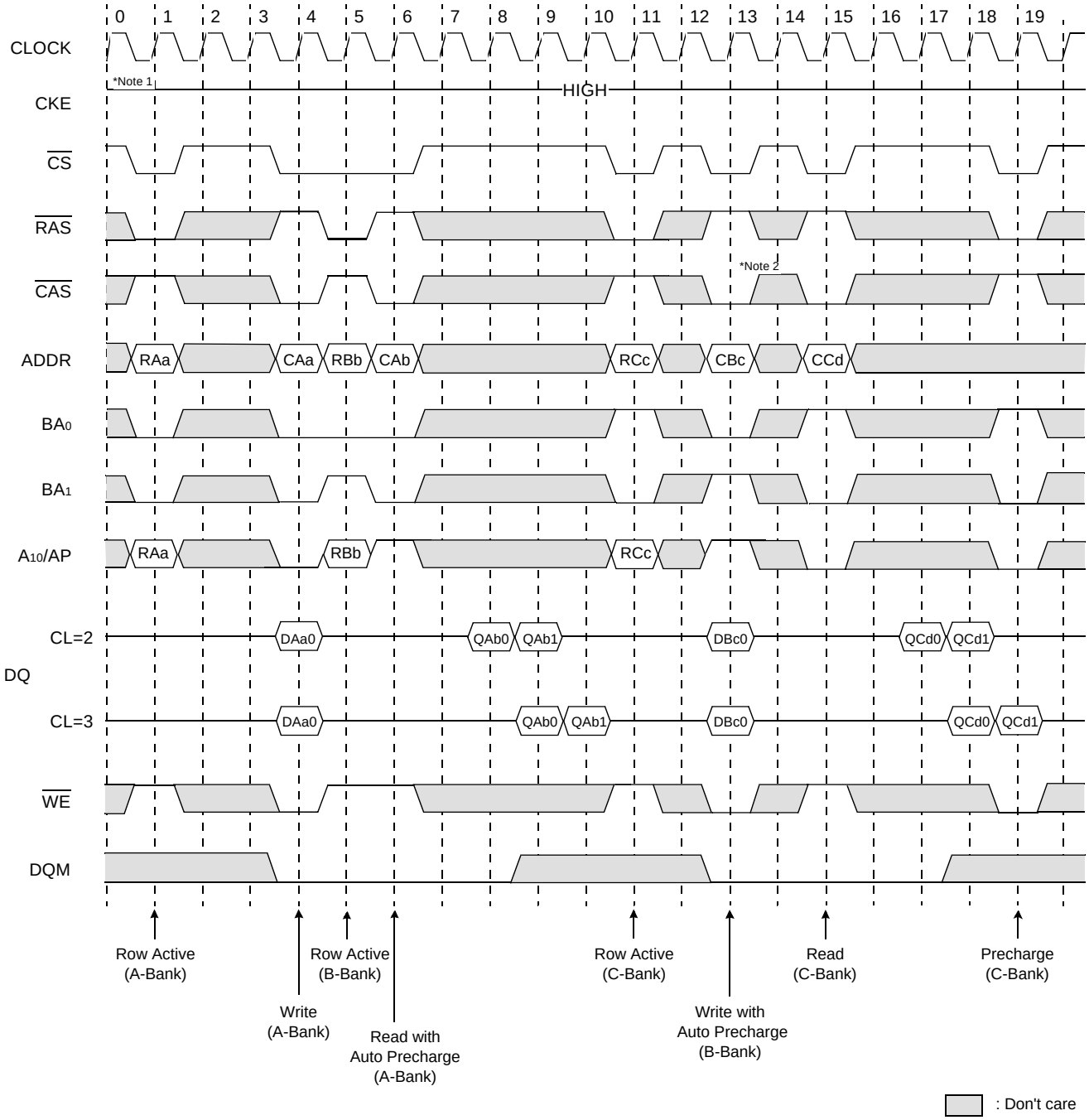
***Note :** 1. At full page mode, burst is end at the end of burst. So auto precharge is possible.
2. Data-in at the cycle of interrupted by precharge can not be written into the corresponding memory cell. It is defined by AC parameter of t_{RDL}.
DQM at write interrupted by precharge command is needed to prevent invalid write.
DQM should mask invalid input data on precharge command cycle when asserting precharge before end of burst. Input data after Row precharge cycle will be masked internally.
3. Burst stop is valid at every burst length.

Write Interrupted by Precharge Command & Write Burst Stop Cycle @ Full Page Burst, tRDL=2CLK



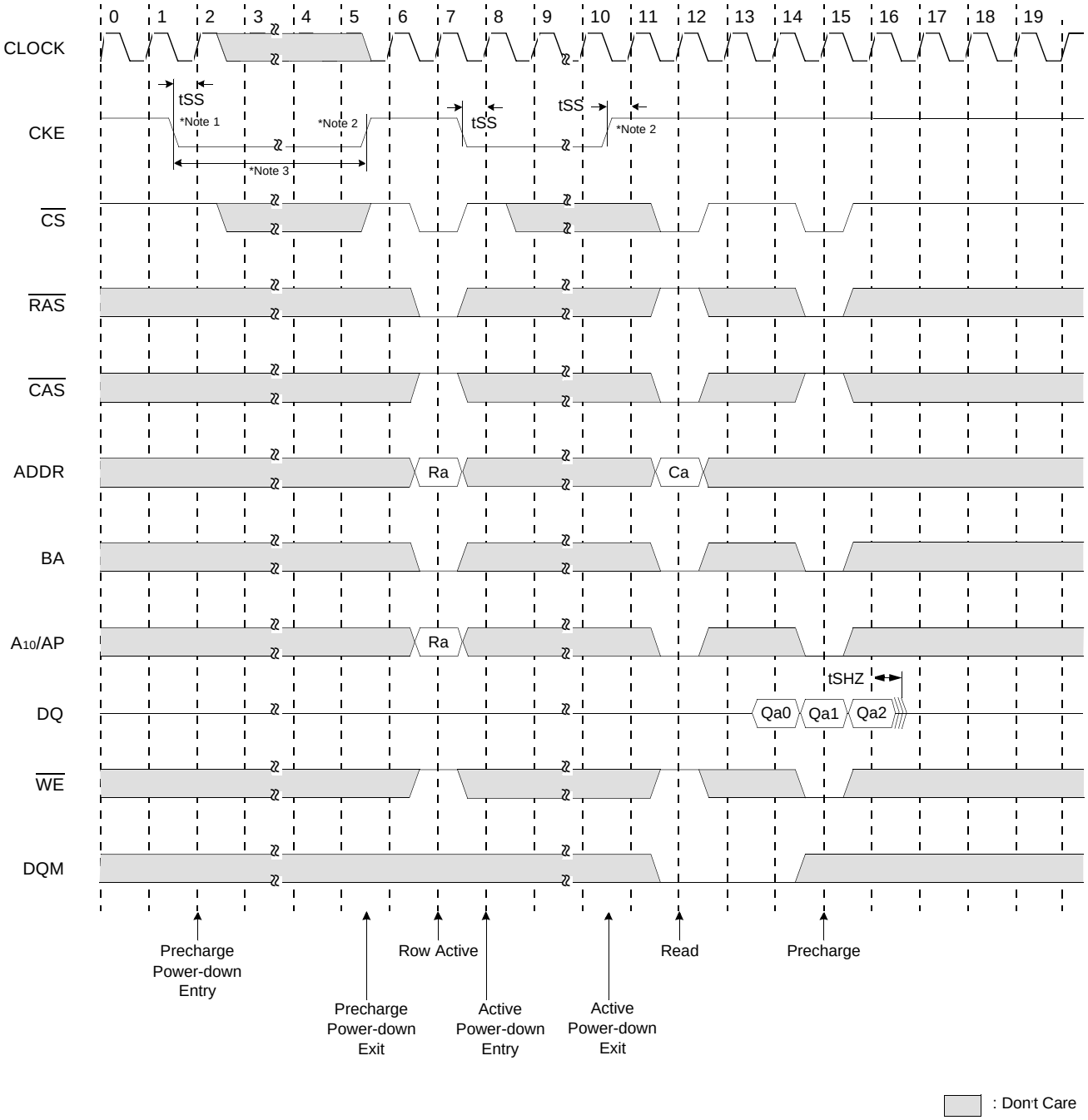
***Note :** 1. At full page mode, burst is end at the end of burst. So auto precharge is possible.
2. Data-in at the cycle of interrupted by precharge can not be written into the corresponding memory cell. It is defined by AC parameter of t_{RDL}.
DQM at write interrupted by precharge command is needed to prevent invalid write.
DQM should mask invalid input data on precharge command cycle when asserting precharge before end of burst. Input data after Row precharge cycle will be masked internally.
3. Burst stop is valid at every burst length.

Burst Read Single bit Write Cycle @Burst Length=2



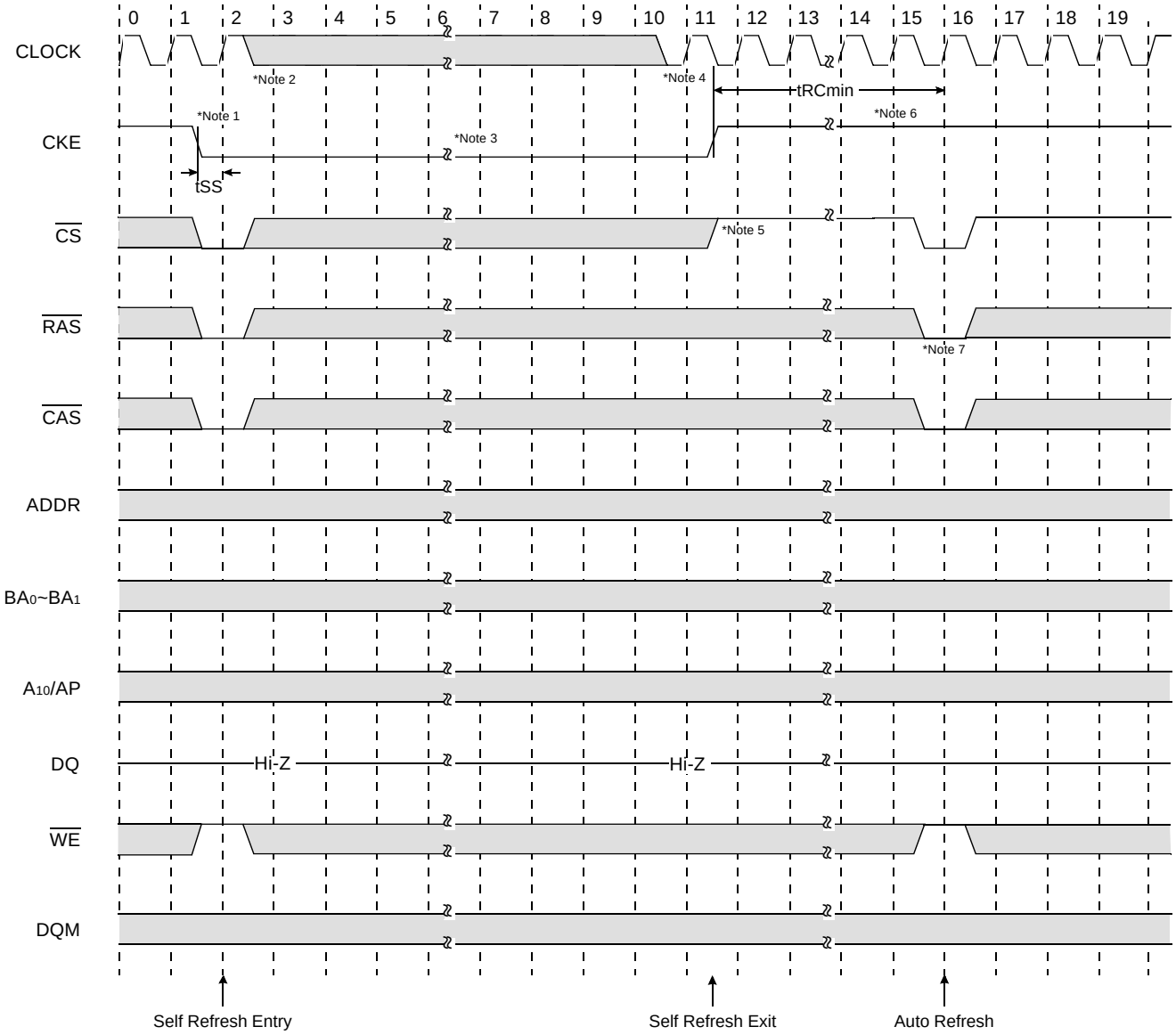
***Note :** 1. BRSW modes is enabled by setting A_9 "High" at MRS (Mode Register Set).
At the BRSW Mode, the burst length at write is fixed to "1" regardless of programmed burst length.
2. When BRSW write command with auto precharge is executed, keep it in mind that t_{RAS} should not be violated.
Auto precharge is executed at the burst-end cycle, so in the case of BRSW write command,
the next cycle starts the precharge.

Active/Precharge Power Down Mode @CAS Latency=2, Burst Length=4



***Note :** 1. Both banks should be in idle state prior to entering precharge power down mode.
2. CKE should be set high at least 1CLK + tss prior to Row active command.
3. Can not violate minimum refresh specification. (64ms)

Self Refresh Entry & Exit Cycle



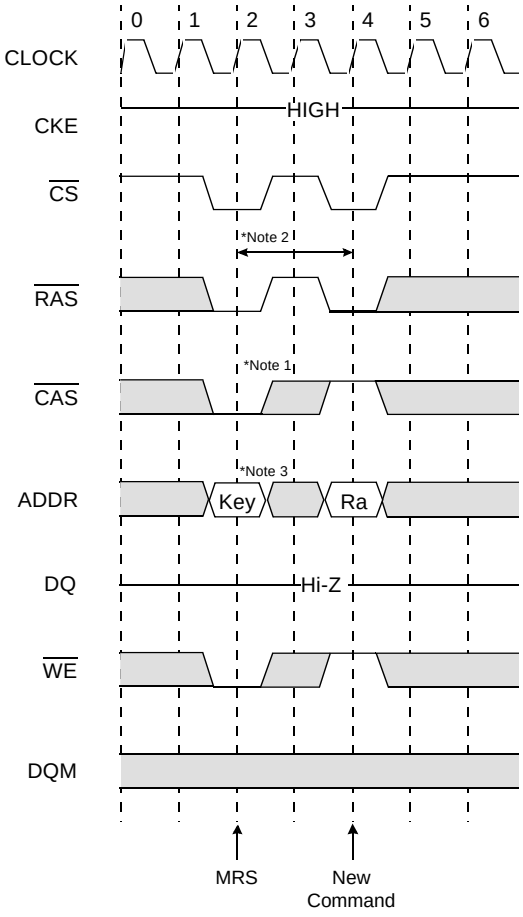
***Note : TO ENTER SELF REFRESH MODE**

1. $\overline{CS}$, $\overline{RAS}$ & $\overline{CAS}$ with CKE should be low at the same clcok cycle.
2. After 1 clock cycle, all the inputs including the system clock can be don't care except for CKE.
3. The device remains in self refresh mode as long as CKE stays "Low".
   cf.) Once the device enters self refresh mode, minimum t_{RAS} is required before exit from self refresh.

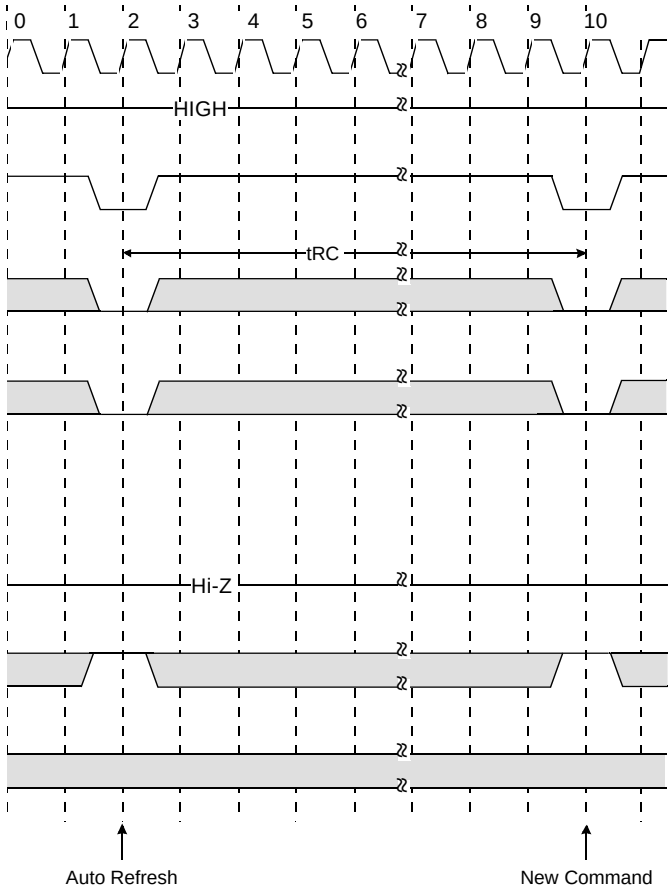
TO EXIT SELF REFRESH MODE

4. System colck restart and be stable before returning CKE high.
5. $\overline{CS}$ starts from high.
6. Minimum t_{RC} is required after CKE going high to complete self refresh exit.
7. 4K cycle(64Mb 5th, 128Mb 2nd/3rd) or 8K cycle(256Mb 2nd) of burst auto refresh is required before self refresh entry and after self refresh exit if the system uses burst refresh.

Mode Register Set Cycle



Auto Refresh Cycle



: Don't care

* All banks precharge should be completed before Mode Register Set cycle and auto refresh cycle.

MODE REGISTER SET CYCLE

***Note :** 1. $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, & $\overline{WE}$ activation at the same clock cycle with address key will set internal mode register.
2. Minimum 2 clock cycles should be met before new $\overline{RAS}$ activation.
3. Please refer to Mode Register Set table.