DATA SHEET

NEC

MOS INTEGRATED CIRCUIT

μPD4516421, 4516821, 4516161

16M-bit Synchronous DRAM

Description

The μPD4516421, 4516821, 4516161 are high-speed 16,777,216-bit synchronous dynamic random-access memories, organized as 2,097,152×4×2, 1,048,576×8×2 and 524,288×16×2 (word×bit×bank), respectively.

The synchronous DRAMs achieve high-speed data transfer using the pipeline architecture.

All inputs and outputs are synchronized with the positive edge of the clock.

The synchronous DRAMs compatible with Low Voltage TTL (LVTTL).

The synchronous DRAMs are packaged in 44-pin TSOP (II) (×4, ×8) and 50-pin TSOP (II) (×16).

Features

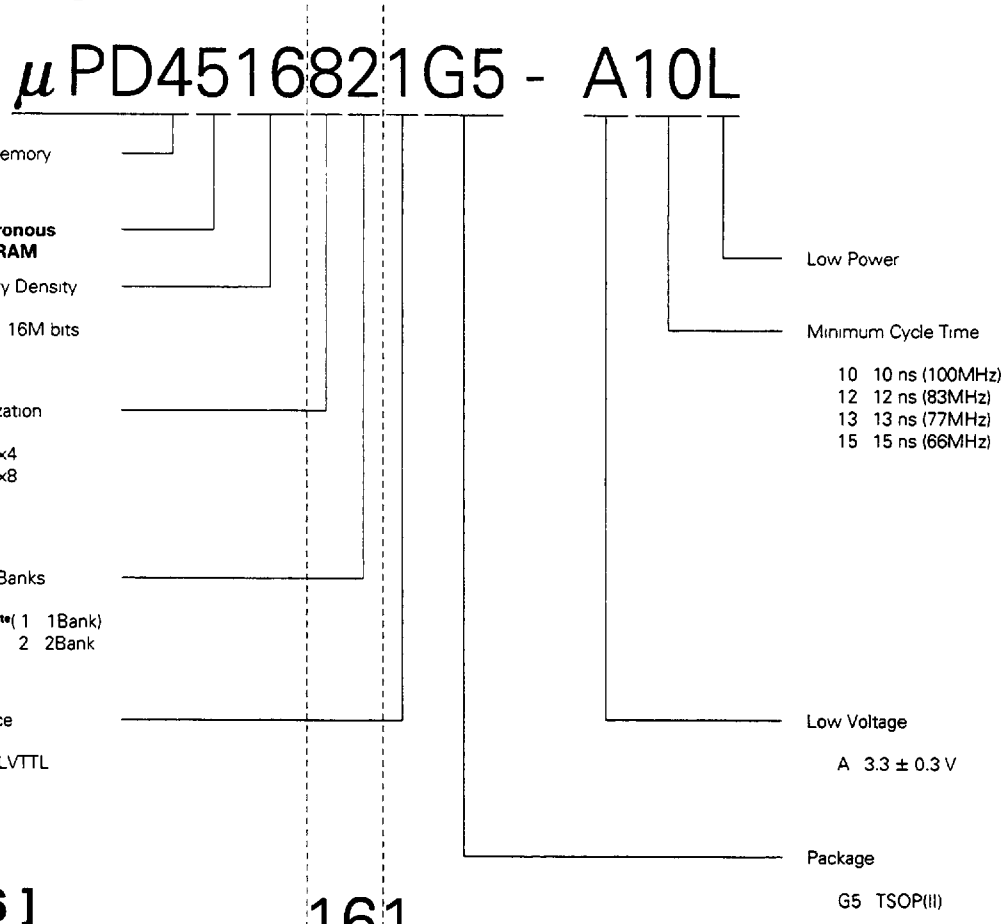
- Fully Synchronous Dynamic RAM, with all signals referenced to a positive clock edge
- Pulsed interface
- Possible to assert random column address in every cycle
- Dual internal banks controlled by A11 (Bank Select)
- Programmable burst-length (1, 2, 4, 8 Full Page)
- Programmable wrap sequence (Sequential/Interleave)
- Programmable $\overline{\text{CAS}}$ latency (1, 2, 3)
- Automatic precharge and controlled precharge
- CBR (Auto) refresh and self refresh
- ×4, ×8, ×16 organization
- Single +3.3±0.3 V power supply
- LVTTL compatible
- Byte control (×16) by LDQM and UDQM
- 2,048 refresh cycles/32ms
- Burst termination by Burst Stop command and Precharge command

Ordering Information

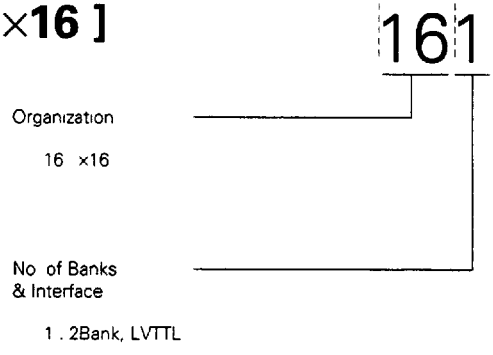
Part number	Organization (word × bit × bank)	Clock frequency MHz (MAX.)	Package
μPD4516421G5-A10	2M×4×2	100	44-pin Plastic TSOP(II) (400mil)
μPD4516421G5-A12		83	
μPD4516421G5-A13		77	
μPD4516421G5-A15		66	
μPD4516821G5-A10	1M×8×2	100	44-pin Plastic TSOP(II) (400mil)
μPD4516821G5-A12		83	
μPD4516821G5-A13		77	
μPD4516821G5-A15		66	
μPD4516161G5-A10	512K×16×2	100	50-pin Plastic TSOP(II) (400mil)
μPD4516161G5-A12		83	
μPD4516161G5-A13		77	
μPD4516161G5-A15		66	

Part Number

[×4, ×8]



[×16]

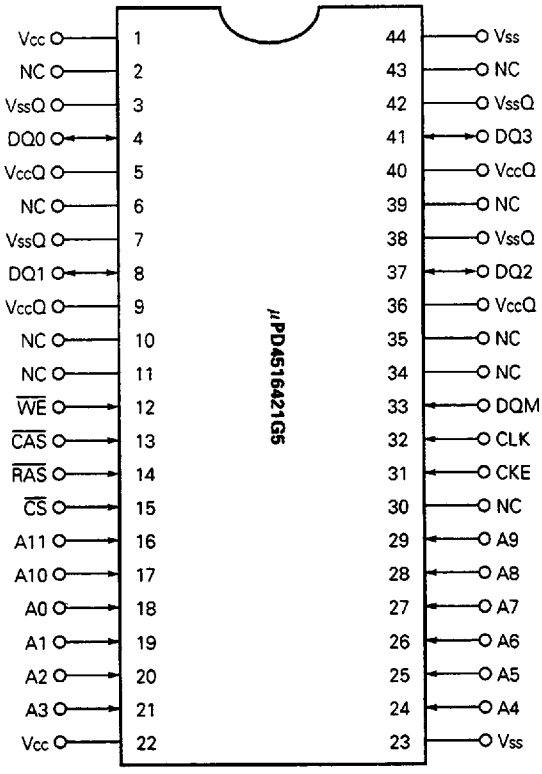


Note R: Reserved

Pin Configurations

[μPD4516421]

44-pin Plastic TSOP(II) (400 mil)

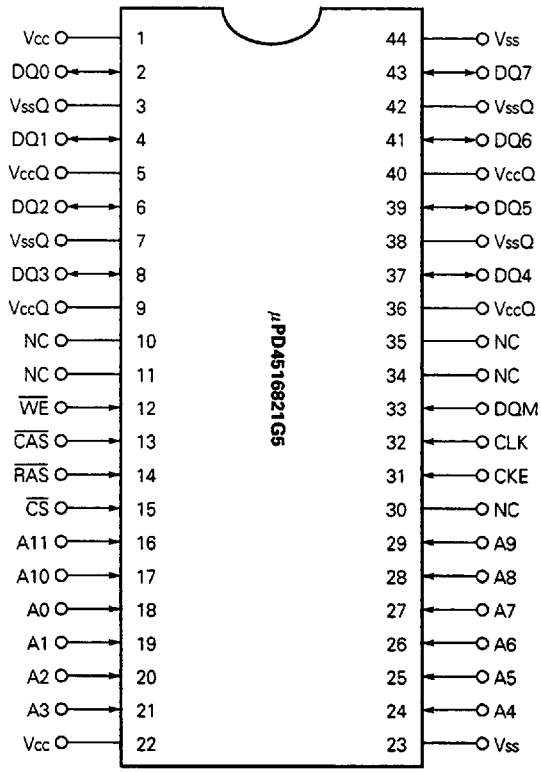


A0 to A11[Note] : Address inputs
DQ0 to DQ3 : Data inputs/outputs
CLK : System clock input
CKE : Clock enable
$\overline{CS}$: Chip select
$\overline{RAS}$: Row address strobe
$\overline{CAS}$: Column address strobe
$\overline{WE}$: Write enable
DQM : DQ mask enable
Vcc : Supply voltage
Vss : Ground
VccQ : Supply voltage for DQ
VssQ : Ground for DQ
NC : No connection

Note A0 to A10 : Row address inputs
A0 to A9 : Column address inputs
A11 : Bank select

[μPD4516821]

44-pin Plastic TSOP(II) (400 mil)

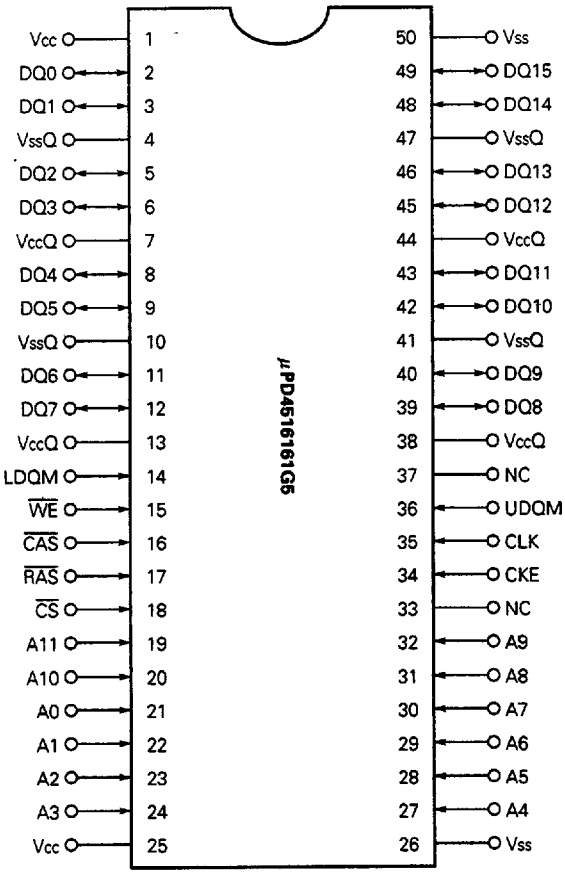


A0 to A11 **Note**	: Address inputs
DQ0 to DQ7	: Data inputs/outputs
CLK	: System clock input
CKE	: Clock enable
$\overline{CS}$	: Chip select
$\overline{RAS}$	: Row address strobe
$\overline{CAS}$	: Column address strobe
$\overline{WE}$	: Write enable
DQM	: DQ mask enable
Vcc	: Supply voltage
Vss	: Ground
VccQ	: Supply voltage for DQ
VssQ	: Ground for DQ
NC	: No connection

Note A0 to A10 : Row address inputs
A0 to A8 : Column address inputs
A11 : Bank select

[μPD4516161]

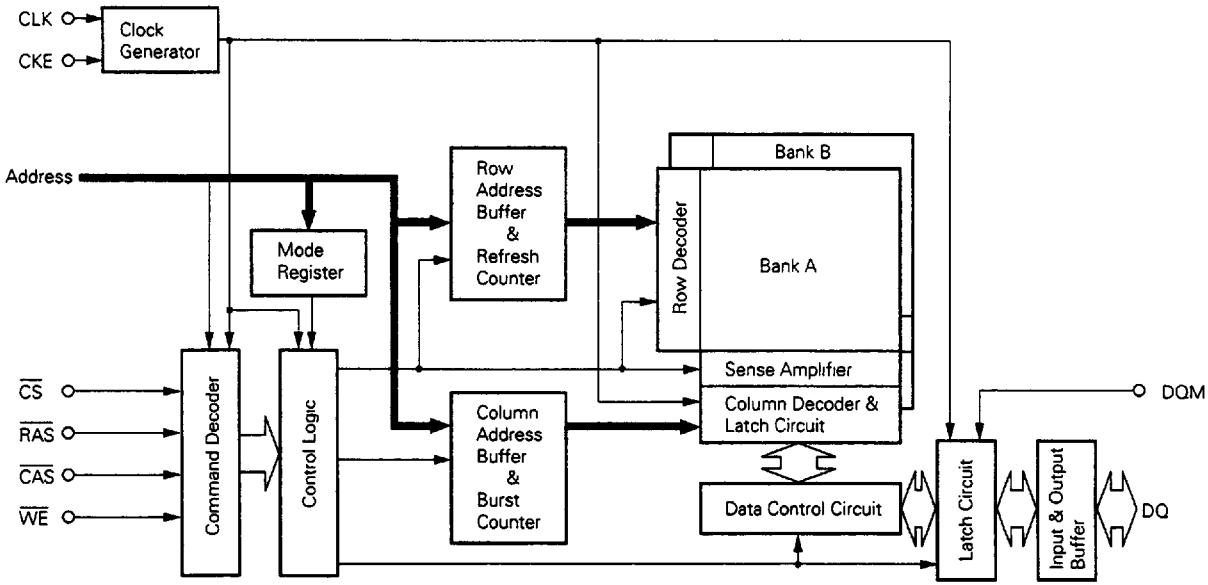
50-pin Plastic TSOP(II) (400 mil)



A0 to A11 [Note]	: Address inputs
DQ0 to DQ15	: Data inputs/outputs
CLK	: System clock input
CKE	: Clock enable
$\overline{CS}$	: Chip select
$\overline{RAS}$	: Row address strobe
$\overline{CAS}$	: Column address strobe
$\overline{WE}$	: Write enable
UDQM	: Upper DQ mask enable
LDQM	: Lower DQ mask enable
Vcc	: Supply voltage
Vss	: Ground
VccQ	: Supply voltage for DQ
VssQ	: Ground for DQ
NC	: No connection

Note A0 to A10 : Row address inputs
A0 to A7 : Column address inputs
A11 : Bank select

Block Diagram



1. Input/Output Pin Function

Pin name	Input/Output	Function
CLK	Input	CLK is the master clock input. Other inputs signals are referenced to the CLK rising edge.
CKE	Input	CKE determine validity of the next CLK (clock). If CKE is high, the next CLK rising edge is valid; otherwise it is invalid. If the CLK rising edge is invalid, the internal clock is not asserted and the μPD4516xxx suspends operation. When the μPD4516xxx is not in burst mode and CKE is negated, the device enters power down mode. During power down mode, CKE must remain low.
$\overline{CS}$	Input	$\overline{CS}$ low starts the command input cycle. When $\overline{CS}$ is high, commands are ignored but operations continue.
$\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$	Input	$\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$ have the same symbols on conventional DRAM but different functions. For details, refer to the command table.
A0 - A11	Input	Row Address is determined by A0 - A10 at the CLK (clock) rising edge in the activate command cycle. It does not depend on the bit organization. Column Address is determined by A0 - A9 at the CLK rising edge in the read or write command cycle. It depends on the bit organization: A0 - A9 for ×4 device, A0 - A8 for ×8 device and A0 - A7 for ×16 device. A11 is the bank select signal (BS). In command cycle, A11 low selects bank A and A11 high selects bank B. A10 defines the precharge mode. When A10 is high in the precharge command cycle, both banks are precharged; when A10 is low, only the bank selected by A11 is precharged. When A10 high in read or write command cycle, the precharge start automatically after the burst access.
DQM UDQM LDQM	Input	DQM controls I/O buffers. In ×16 products, UDQM and LDQM control upper byte and lower byte I/O buffers, respectively. In read mode, DQM controls the output buffers like a conventional $\overline{OE}$ pin. DQM high and DQM low turn the output buffers off and on, respectively. The DQM latency for the read is two clocks. In write mode, DQM controls the word mask. Input data is written to the memory cell if DQM is low but not if DQM is high. The DQM latency for the write is zero.
DQ0 - DQ15	Input/Output	DQ pins have the same function as I/O pins on a conventional DRAM.
V_{CC} V_{SS} V_{CCQ} V_{SSQ}	(Power supply)	V_{CC} and V_{SS} are power supply pins for internal circuits. V_{CCQ} and V_{SSQ} are power supply pins for the output buffers.

2. Commands

Mode register set command

($\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$ = Low)

The μPD4516×××has a mode register that defines how the device operates. In this command, A0 through A11 are the data input pins. After power on, the mode register set command must be executed to initialize the device.

The mode register can be set only when both banks are in idle state.

During 20 ns (t_{RSC}) following this command, the μPD4516××× cannot accept any other commands.

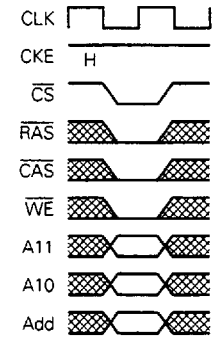


Fig. 1 Mode register set command

Activate command

($\overline{CS}$, $\overline{RAS}$ = Low, $\overline{CAS}$, $\overline{WE}$ = High)

The μPD4516××× has two banks, each with 2,048 rows.

This command activates the bank selected by A11 (BS) and a row address selected by A0 through A10.

This command corresponds to a conventional DRAM's $\overline{RAS}$ falling.

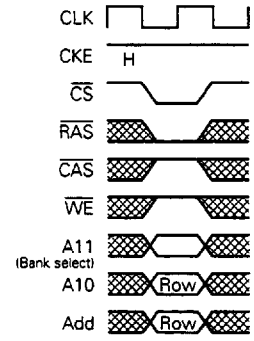


Fig. 2 Row address strobe and bank active command

Precharge command

($\overline{CS}$, $\overline{RAS}$, $\overline{WE}$ = Low, $\overline{CAS}$ = High)

This command begins precharge operation of the bank selected by A11 (BS). When A10 is High, both banks are precharged, regardless of A11. When A10 is Low, only the bank selected by A11 is precharged. A11 low selects bank A and A11 high selects bank B.

After this command, the μPD4516××× can't accept the activate command to the precharging bank during t_{RP} (precharge to activate command period).

This command corresponds to a conventional DRAM's $\overline{RAS}$ rising.

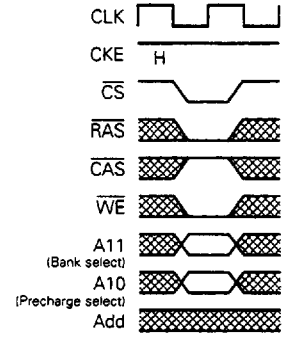


Fig. 3 Precharge command

Write command

($\overline{CS}$, $\overline{CAS}$, $\overline{WE}$ = Low, $\overline{RAS}$ = High)

If the mode register is in the burst write mode, this command sets the burst start address given by the column address to begin the burst write operation. The first write data in burst can be input with this command with subsequent data on following clocks.

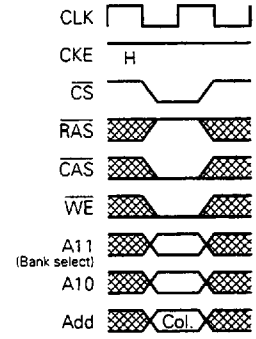


Fig. 4 Column address and write command

Read command

($\overline{CS}$, $\overline{CAS}$ = Low, $\overline{RAS}$, $\overline{WE}$ = High)

Read data is available after $\overline{CAS}$ latency requirements have been met.

This command sets the burst start address given by the column address.

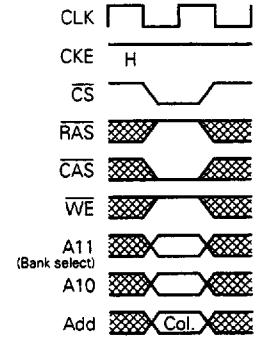


Fig. 5 Column address and read command

CBR (auto) refresh command

($\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$= Low, $\overline{WE}$, CKE = High)

This command is a request to begin the CBR refresh operation. The refresh address is generated internally.

Before executing CBR refresh, both banks must be precharged.

After this cycle, both banks will be in the idle (precharged) state and ready for a row activate command.

During t_{RC} period (from refresh command to refresh or activate command), the μPD4516×××cannot accept any other command.

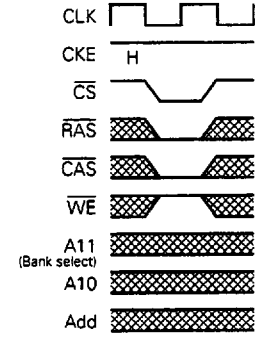


Fig. 6 Auto refresh command

Self refresh entry command

($\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, CKE = Low, $\overline{WE}$ = High)

After the command execution, self refresh operation continues while CKE remains low. When CKE goes to high, the μPD4516××× exits the self refresh mode.

During self refresh mode, refresh interval and refresh operation are performed internally, so there is no need for external control.

Before executing self refresh, both banks must be precharged.

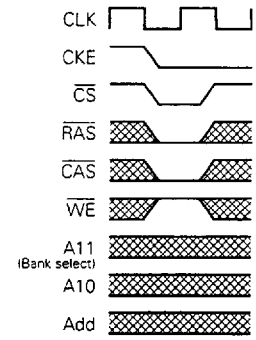


Fig. 7 Self refresh entry command

Burst stop command

($\overline{CS}$, $\overline{WE}$ = Low, $\overline{RAS}$, $\overline{CAS}$ = High)

This command terminates the current burst operation.

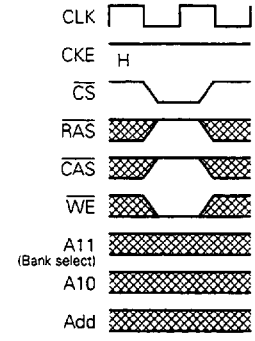


Fig. 8 Burst stop command in Full Page mode

No operation

($\overline{CS}$ = Low, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$ = High)

This command is not a execution command. No operations begin or terminate by this command.

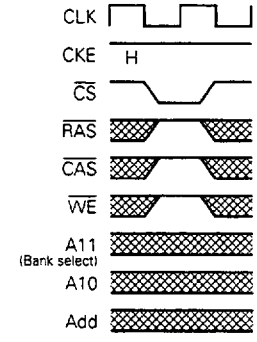
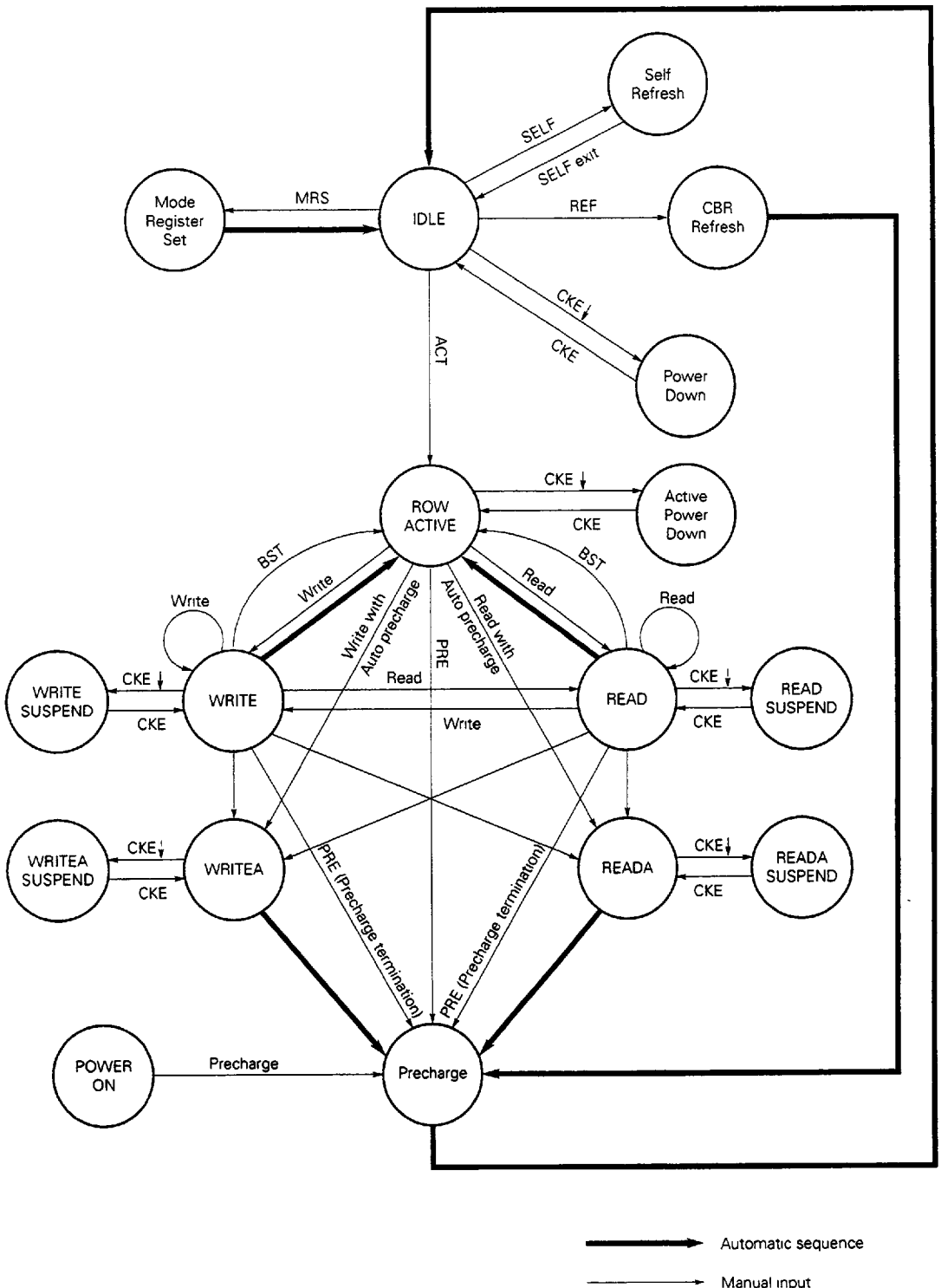


Fig. 9 No operation

3. Simplified State Diagram



4. Truth Table

4.1 Command Truth Table

Function	Symbol	CKE		$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	A11	A10	A9-A0
		n-1	n							
Device deselect	DESL	H	×	H	×	×	×	×	×	×
No operation	NOP	H	×	L	H	H	H	×	×	×
Burst stop	BST	H	×	L	H	H	L	×	×	×
Read	READ	H	×	L	H	L	H	V	L	V
Read with auto precharge	READA	H	×	L	H	L	H	V	H	V
Write	WRIT	H	×	L	H	L	L	V	L	V
Write with auto precharge	WRITA	H	×	L	H	L	L	V	H	V
Bank activate	ACT	H	×	L	L	H	H	V	V	V
Precharge select bank	PRE	H	×	L	L	H	L	V	L	×
Precharge all banks	PALL	H	×	L	L	H	L	×	H	×
Mode register set	MRS	H	×	L	L	L	L	L	L	V

4.2 DQM Truth Table

Function	Symbol	CKE		DQM	
		n-1	n	U	L
Data write/output enable	ENB	H	×	L	
Data mask/output disable	MASK	H	×	H	
Upper byte write enable/output enable	ENBU	H	×	L	×
Lower byte write enable/output enable	ENBL	H	×	×	L
Upper byte write inhibit/output disable	MASKU	H	×	H	×
Lower byte write inhibit/output disable	MASKL	H	×	×	H

4.3 CKE Truth Table

Current state	Function	Symbol	CKE		$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	Address
			n-1	n					
Activating	Clock suspend mode entry		H	L	×	×	×	×	×
Any	Clock suspend		L	L	×	×	×	×	×
Clock suspend	Clock suspend mode exit		L	H	×	×	×	×	×
Idle	CBR refresh command	REF	H	H	L	L	L	H	×
Idle	Self refresh entry	SELF	H	L	L	L	L	H	×
Self refresh	Self refresh exit		L	H	L	H	H	H	×
			L	H	H	×	×	×	×
Idle	Power down entry		H	L	×	×	×	×	×
Power down	Power down exit		L	H	×	×	×	×	×

H: High level, L: Low level

×: High or Low level (Don't care), V: Valid Data input

4.4 Operative Command Table[Notes1, 2]

(1/3)

Current state	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	Address	Command	Action	Notes
Idle	H	×	×	×	×	DESL	Nop or Power down	3
	L	H	H	×	×	NOP or BST	Nop or Power down	3
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	4
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	4
	L	L	H	H	BA, RA	ACT	Row active	
	L	L	H	L	BA, A10	PRE/PALL	Nop	
	L	L	L	H	×	REF/SELF	Refresh or Self refresh	5
	L	L	L	L	Op-Code	MRS	Mode register access	
Row active	H	×	×	×	×	DESL	Nop	
	L	H	H	×	×	NOP or BST	Nop	
	L	H	L	H	BA, CA, A10	READ/READA	Begin read:Determine AP	6
	L	H	L	L	BA, CA, A10	WRIT/WRITA	Begin write:Determine AP	6
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	Precharge	7
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Read	H	×	×	×	×	DESL	Continue burst to end → Row active	
	L	H	H	H	×	NOP	Continue burst to end → Row active	
	L	H	H	L	×	BST	Burst stop → Row active	
	L	H	L	H	BA, CA, A10	READ/READA	Term burst, new read:Determine AP	8
	L	H	L	L	BA, CA, A10	WRIT/WRITA	Term burst, start write:Determine AP	8, 9
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	Term burst, precharging	
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Write	H	×	×	×	×	DESL	Continue burst to end → Write recovering	
	L	H	H	H	×	NOP	Continue burst to end → Write recovering	
	L	H	H	L	×	BST	Burst stop → Row active	
	L	H	L	H	BA, CA, A10	READ/READA	Term burst, start read:Determine AP	8, 9
	L	H	L	L	BA, CA, A10	WRIT/WRITA	Term burst, new write:Determine AP	8
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	Term burst precharging	10
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	

(2/3)

Current state	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	Address	Command	Action	Notes
Read with auto precharge	H	×	×	×	×	DESL	Continue burst to end → Precharging	
	L	H	H	H	×	NOP	Continue burst to end → Precharging	
	L	H	H	L	×	BST	ILLEGAL	
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	ILLEGAL	4
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Write with auto precharge	H	×	×	×	×	DESL	Continue burst to end → Write recovering with auto precharge	
	L	H	H	H	×	NOP	Continue burst to end → Write recovering with auto precharge	
	L	H	H	L	×	BST	ILLEGAL	
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	ILLEGAL	4
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Precharging	H	×	×	×	×	DESL	Nop → Enter idle after t_{RP}	
	L	H	H	H	×	NOP	Nop → Enter idle after t_{RP}	
	L	H	H	L	×	BST	Nop → Enter idle after t_{RP}	
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	4
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	4
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	Nop → Enter idle after t_{RP}	
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Row activating	H	×	×	×	×	DESL	Nop → Enter row active after t_{RCD}	
	L	H	H	H	×	NOP	Nop → Enter row active after t_{RCD}	
	L	H	H	L	×	BST	Nop → Enter row active after t_{RCD}	
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	4
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	4
	L	L	H	H	BA, RA	ACT	ILLEGAL	4, 11
	L	L	H	L	BA, A10	PRE/PALL	ILLEGAL	4
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	

(3/3)

Current state	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	Address	Command	Action	Notes
Write recovering	H	×	×	×	×	DESL	Nop → Enter row active after t_{DPL}	
	L	H	H	H	×	NOP	Nop → Enter row active after t_{DPL}	
	L	H	H	L	×	BST	Nop → Enter row active after t_{DPL}	
	L	H	L	H	BA, CA, A10	READ/READA	Start read, Determine AP	9
	L	H	L	L	BA, CA, A10	WRIT/WRITA	New write, Determine AP	
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	ILLEGAL	4
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Write recovering with auto precharge	H	×	×	×	×	DESL	Nop → Enter precharge after t_{DPL}	
	L	H	H	H	×	NOP	Nop → Enter precharge after t_{DPL}	
	L	H	H	L	×	BST	Nop → Enter precharge after t_{DPL}	
	L	H	L	H	BA, CA, A10	READ/READA	ILLEGAL	4, 9
	L	H	L	L	BA, CA, A10	WRIT/WRITA	ILLEGAL	4
	L	L	H	H	BA, RA	ACT	ILLEGAL	4
	L	L	H	L	BA, A10	PRE/PALL	ILLEGAL	4
	L	L	L	H	×	REF/SELF	ILLEGAL	
	L	L	L	L	Op-Code	MRS	ILLEGAL	
Refreshing	H	×	×	×	×	DESL	Nop → Enter idle after t_{RC}	
	L	H	H	×	×	NOP/BST	Nop → Enter idle after t_{RC}	
	L	H	L	×	×	READ/WRIT	ILLEGAL	
	L	L	H	×	×	ACT/PRE/PALL	ILLEGAL	
	L	L	L	×	×	REF/SELF/MRS	ILLEGAL	
Mode register accessing	H	×	×	×	×	DESL	Nop → Enter idle after t_{RSC}	
	L	H	H	H	×	NOP	Nop → Enter idle after t_{RSC}	
	L	H	H	L	×	BST	ILLEGAL	
	L	H	L	×	×	READ/WRITE	ILLEGAL	
	L	L	×	×	×	ACT/PRE/PALL/ REF/SELF/MRS	ILLEGAL	

Notes 1. H: High level, L: Low level, ×: High or Low level (Don't care), V: Valid data input

2. All entries assume that CKE was active (High level) during the preceding clock cycle.
3. If both banks are idle, and CKE is inactive (Low level), μPD4516×××× will enter Power down mode. All input buffers except CKE will be disabled.
4. Illegal to bank in specified states; Function may be legal in the bank indicated by Bank Address (BA), depending on the state of that bank.
5. If both banks are idle, and CKE is inactive (Low level), μPD4516×××× will enter Self refresh mode. All input buffers except CKE will be disabled.
6. Illegal if t_{RCD} is not satisfied.
7. Illegal if t_{RAS} is not satisfied.
8. Must satisfy burst interrupt condition.
9. Must satisfy bus contention, bus turn around, and/or write recovery requirements.
10. Must mask preceding data which don't satisfy t_{DPL}.
11. Illegal if t_{RRD} is not satisfied.

4.5 Command Truth Table for CKE[Note 1]

Current state	CKE n-1	CKE n	$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	Address	Action	Notes
Self refresh (S.R.)	H	×	×	×	×	×	×	INVALID, CLK(n-1) would exit S.R.	
	L	H	H	×	×	×	×	S.R. Recovery	2
	L	H	L	H	H	×	×	S.R. Recovery	2
	L	H	L	H	L	×	×	ILLEGAL	2
	L	H	L	L	×	×	×	ILLEGAL	2
	L	L	×	×	×	×	×	Maintain S.R	
Self refresh recovery	H	H	H	×	×	×	×	Idle after t_{RC}	
	H	H	L	H	H	×	×	Idle after t_{RC}	
	H	H	L	H	L	×	×	ILLEGAL	
	H	H	L	L	×	×	×	ILLEGAL	
	H	L	H	×	×	×	×	ILLEGAL	
	H	L	L	H	H	×	×	ILLEGAL	
	H	L	L	H	L	×	×	ILLEGAL	
	H	L	L	L	×	×	×	ILLEGAL	
	L	H	×	×	×	×	×	Exit clock suspend next cycle	2
	L	L	×	×	×	×	×	Maintain clock suspend	
Power down (P.D.)	H	×	×	×	×	×		INVALID, CLK(n-1) would exit P.D.	
	L	H	×	×	×	×	×	EXIT P.D. → Idle	2
	L	L	×	×	×	×	×	Maintain power down mode	
Both banks idle	H	H	H	×	×	×		Refer to operations in Operative Command Table	
	H	H	L	H	×	×		Refer to operations in Operative Command Table	
	H	H	L	L	H	×		Refer to operations in Operative Command Table	
	H	H	L	L	L	H	×	Refresh	
	H	H	L	L	L	L	Op-Code	Refer to operations in Operative Command Table	
	H	L	H	×	×	×		Refer to operations in Operative Command Table	
	H	L	L	H	×	×		Refer to operations in Operative Command Table	
	H	L	L	L	H	×		Refer to operations in Operative Command Table	
	H	L	L	L	L	H	×	Self refresh	3
	H	L	L	L	L	L	Op-Code	Refer to operations in Operative Command Table	
	L	×	×	×	×	×	×	Power down	3
Any state other than listed above	H	H	×	×	×	×	×	Refer to operations in Operative Command Table	
	H	L	×	×	×	×	×	Begin clock suspend next cycle	4
	L	H	×	×	×	×	×	Exit clock suspend next cycle	
	L	L	×	×	×	×	×	Maintain clock suspend	

Notes 1. H: High level, L: Low level, X: High or low level (Don't care)

2. CKE Low to High transition will re-enable CLK and other inputs asynchronously. A minimum setup time must be satisfied before any command other than EXIT.

3. Power down and Self refresh can be entered only from the both banks idle state.

4. Must be legal command as defined in Operative Command Table.

4.6 Command Truth Table for Two Banks Operation [Notes 1, 2]

$\overline{CS}$	$\overline{RAS}$	$\overline{CAS}$	$\overline{WE}$	BA	A10	A9 - A0	Action	"FROM" State [Note 3]	"TO" State [Note 4]
H	×	×	×	×	×	×	NOP	Any	Any
L	H	H	H	×	×	×	NOP	Any	Any
L	H	H	L	×	×	×	BST	(R/W/A)0(I/A)1	A0(I/A)1
								I0(I/A)1	I0(I/A)1
								(R/W/A)1(I/A)0	A1(I/A)0
								I1(I/A)0	I1(I/A)0
L	H	L	H	H	H	CA	Read	(R/W/A)1(I/A)0	RP1(I/A)0
				H	H	CA		A1(R/W)0	RP1A0
				H	L	CA		(R/W/A)1(I/A)0	R1(I/A)0
				H	L	CA		A1(R/W)0	R1A0
				L	H	CA		(R/W/A)0(I/A)1	RP0(I/A)1
				L	H	CA		A0(R/W)1	RP0A1
				L	L	CA		(R/W/A)0(I/A)1	R0(I/A)1
				L	L	CA		A0(R/W)1	R0A1
L	H	L	L	H	H	CA	Write	(R/W/A)1(I/A)0	WP1(I/A)0
				H	H	CA		A1(R/W)0	WP1A0
				H	L	CA		(R/W/A)1(I/A)0	W1(I/A)0
				H	L	CA		A1(R/W)0	W1A0
				L	H	CA		(R/W/A)0(I/A)1	WP0(I/A)1
				L	H	CA		A0(R/W)1	WP0A1
				L	L	CA		(R/W/A)0(I/A)1	W0(I/A)1
				L	L	CA		A0(R/W)1	W0A1
L	L	H	H	H	RA		Activate Row	I1Any0	A1Any0
				L	RA			I0Any1	A0Any1
L	L	H	L	×	H	×	Precharge	(R/W/A/I)0(I/A)1	I0I1
				×	H	×		(R/W/A/I)1(I/A)0	I1I0
				H	L	×		(R/W/A/I)1(I/A)0	I1(I/A)0
				H	L	×		(I/A)1(R/W/A/I)0	I1(R/W/A/I)0
				L	L	×		(R/W/A/I)0(I/A)1	I0(I/A)1
				L	L	×		(I/A)0(R/W/A/I)1	I0(R/W/A/I)1
L	L	L	H	×	×	×	Refresh	I0I1	I0I1
L	L	L	L	Op-Code			Mode Register Access	I0I1	I0I1

Notes 1. Logic level abbreviations

H: High level, L: Low level, ×: High or low level (Don't care)

Pin name abbreviation

BA: Bank address (A11)

2. State abbreviations
   - I = Idle
   - A = Row active
   - R = Read with No precharge (No precharge is posted)
   - W = Write with No precharge (No precharge is posted)
   - RP = Read with auto precharge (Precharge is posted)
   - WP = Write with auto precharge (Precharge is posted)
   - Any = Any State
   - X0Y1 = Y1X0 = Bank A is in state "X", Bank B is in state "Y"
   - (X/Y)0Z1 = Z1(X/Y)0 = Bank A is in state "X" or "Y", Bank B is in state "Z"
3. If the μPD4516××× is in a state other than above listed in the "From State" column, the command is illegal.
4. The states listed under "To" might not be entered on the next clock cycle. Timing restrictions apply.

5. Initialization

The synchronous DRAM is initialized in the power-on sequence according to the following.

(1) To stabilize internal circuits, when power is applied, a 100-μs or longer pause must precede any signal toggling.

(2) After the pause, both banks must be precharged using the Precharge command (The Precharge all banks command is convenient).

(3) Once the precharge is completed and the minimum t_{RP} is satisfied, the mode register can be programmed.
After the mode register set cycle, t_{RSC} (20 ns minimum) pause must be satisfied as well.

(4) Two or more CBR (Auto) refresh must be performed.

Remarks 1. The sequence of Mode register programming and Refresh above may be transposed.

2. CKE and DQM may be held high until the Precharge command is asserted to ensure data-bus Hi-Z.

6. Programming the Mode Register

The mode register is programmed by the Mode register set command using address bits A11 through A0 as data inputs. The register retains data until it is reprogrammed or the device loses power.

The mode register has four fields;

Options : A11 through A7
$\overline{\text{CAS}}$ latency: A6 through A4
Wrap type : A3
Burst length: A2 through A0

Following mode register programming, no command can be asserted before at least 20 ns have elapsed.

$\overline{\text{CAS}}$ Latency

$\overline{\text{CAS}}$ latency is the most critical of the parameters being set. It tells the device how many clocks must elapse before the data will be available.

The value is determined by the frequency of the clock and the speed grade of the device. The table on page 45 shows the relationship of $\overline{\text{CAS}}$ latency to the clock period and the speed grade of the device.

Burst Length

Burst Length is the number of words that will be output or input in a read or write cycle. After a read burst is completed, the output bus will become Hi-Z.

The burst length is programmable as 1, 2, 4, 8 or full page.

Wrap Type (Burst Sequence)

The wrap type specifies the order in which the burst data will be addressed. This order is programmable as either "Sequential" or "Interleave". The method chosen will depend on the type of CPU in the system.

Some microprocessor cache system are optimized for sequential addressing and others for interleaved addressing. The table on the page 24 shows the addressing sequence for each burst length using them. Both sequences support bursts of 1, 2, 4 and 8. Additionally, sequential sequence supports the full page length.

7. Mode Register

11	10	9	8	7	6	5	4	3	2	1	0	
0	0	0	0	1								JEDEC Standard Test Set (refresh counter test)
×	×	1	0	0	LTMODE			WT		BL		Burst Read and Single Write (for Write Through Cache)
			1	0								Use in future
×	×	×	1	1	V	V	V	V	V	V	V	Vender Specific
0	0	0	0	0	LTMODE			WT		BL		Mode Register Set

V = Valid
× = Don't care

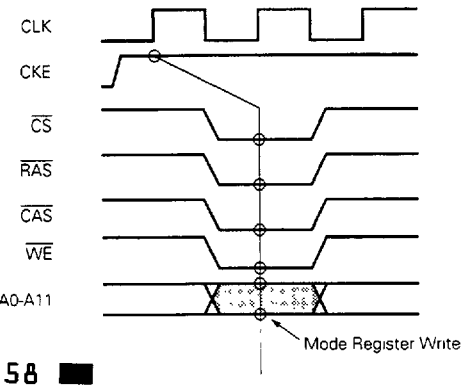
	Bits2-0	WT = 0	WT = 1
Burst length	000	1	1
	001	2	2
	010	4	4
	011	8	8
	100	R	R
	101	R	R
	110	R	R
	111	Full page	R

Wrap type	0	Sequential
	1	Interleave

	Bits6-4	$\overline{CAS}$ latency
Latency mode	000	R
	001	1
	010	2
	011	3
	100	R
	101	R
	110	R
	111	R

Remark R: Reserved

Mode Register Write Timing



7.1 Burst Length and Sequence

[Burst of Two]

Starting Address (column address A0, binary)	Sequential Addressing Sequence (decimal)	Interleave Addressing Sequence (decimal)
0	0, 1	0, 1
1	1, 0	1, 0

[Burst of Four]

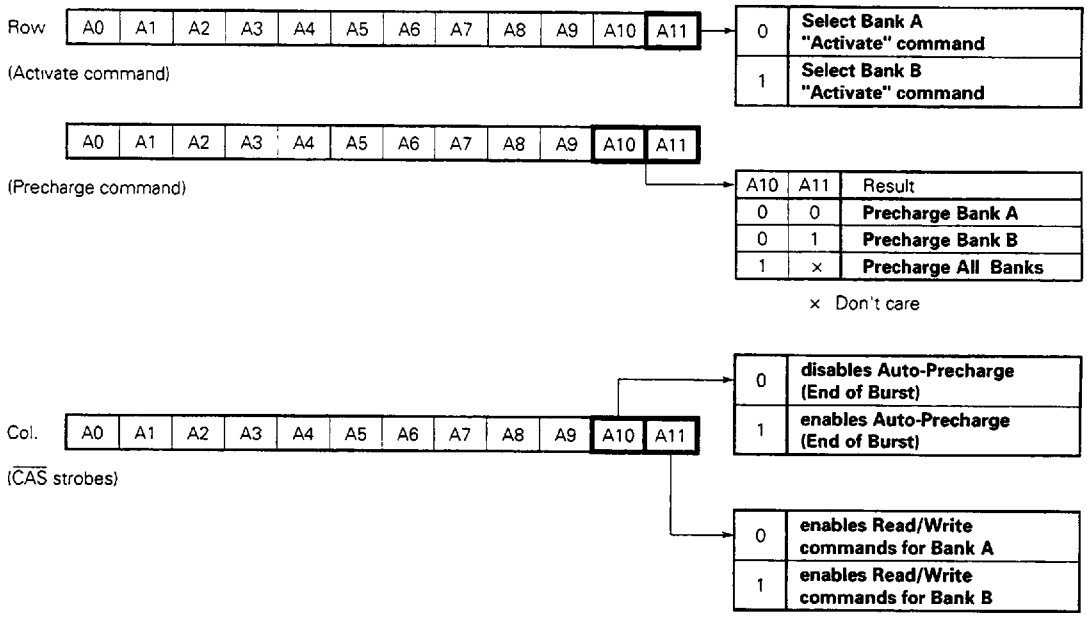
Starting Address (column address A1 - A0, binary)	Sequential Addressing Sequence (decimal)	Interleave Addressing Sequence (decimal)
00	0, 1, 2, 3	0, 1, 2, 3
01	1, 2, 3, 0	1, 0, 3, 2
10	2, 3, 0, 1	2, 3, 0, 1
11	3, 0, 1, 2	3, 2, 1, 0

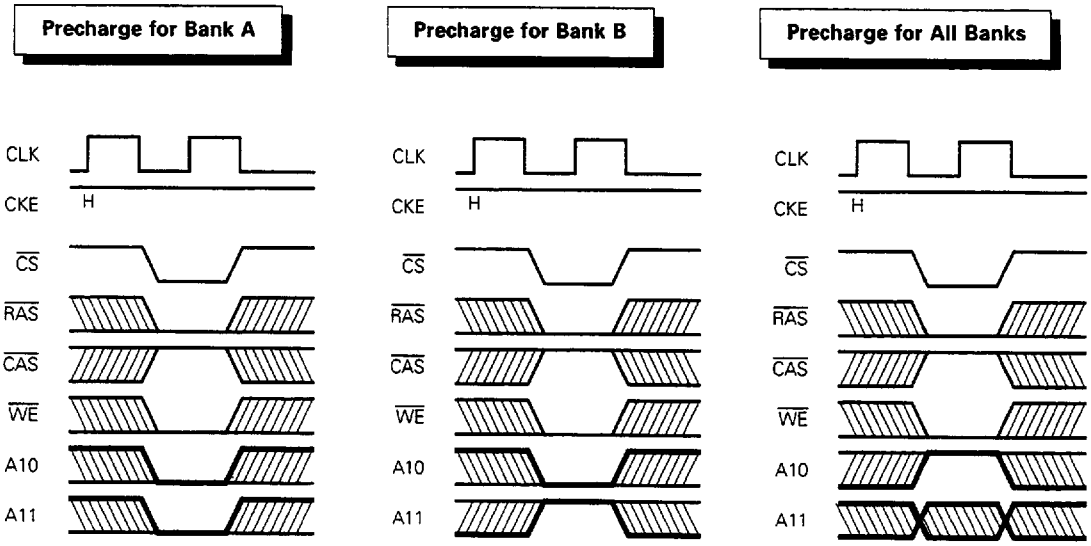
[Burst of Eight]

Starting Address (column address A2 - A0, binary)	Sequential Addressing Sequence (decimal)	Interleave Addressing Sequence (decimal)
000	0, 1, 2, 3, 4, 5, 6, 7	0, 1, 2, 3, 4, 5, 6, 7
001	1, 2, 3, 4, 5, 6, 7, 0	1, 0, 3, 2, 5, 4, 7, 6
010	2, 3, 4, 5, 6, 7, 0, 1	2, 3, 0, 1, 6, 7, 4, 5
011	3, 4, 5, 6, 7, 0, 1, 2	3, 2, 1, 0, 7, 6, 5, 4
100	4, 5, 6, 7, 0, 1, 2, 3	4, 5, 6, 7, 0, 1, 2, 3
101	5, 6, 7, 0, 1, 2, 3, 4	5, 4, 7, 6, 1, 0, 3, 2
110	6, 7, 0, 1, 2, 3, 4, 5	6, 7, 4, 5, 2, 3, 0, 1
111	7, 0, 1, 2, 3, 4, 5, 6	7, 6, 5, 4, 3, 2, 1, 0

Full page burst is an extension of the above tables of Sequential Addressing, with the length being 512 (for 2M ×8 device), 1,024 (for 4M ×4 device) and 256 (for 1M ×16 device).

8. Address Bits of Bank-Select and Precharge





9. Precharge

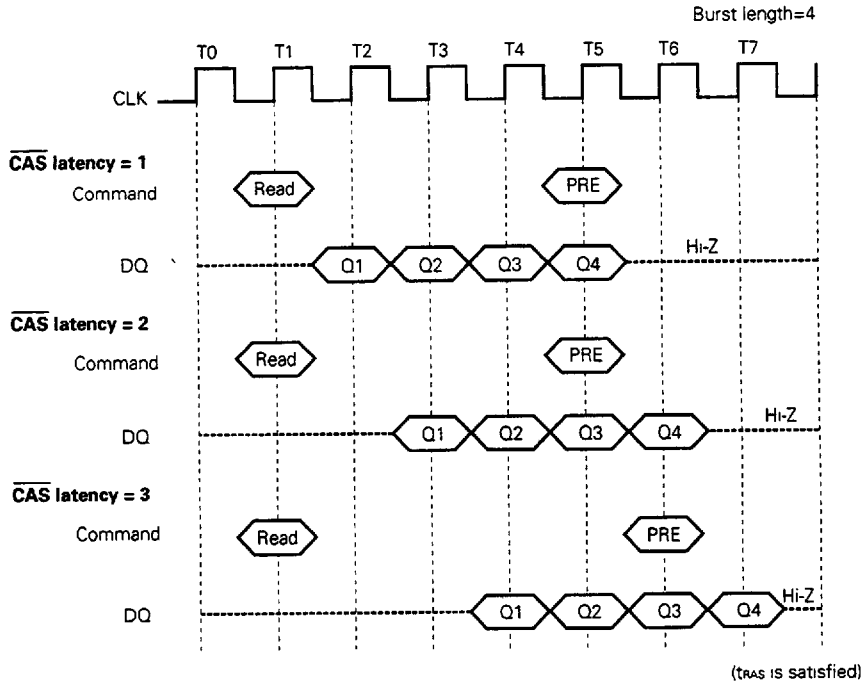
The precharge command can be asserted anytime after $t_{RAS(MIN.)}$ is satisfied.

Soon after the precharge command is asserted, precharge operation performed and the synchronous DRAM enters the idle state after t_{RP} is satisfied. The parameter t_{RP} is the time required to perform the precharge.

The earliest timing in a read cycle that a precharge command can be asserted without losing any data in the burst is as follows.

It is depending on the $\overline{CAS}$ latency.

$\overline{CAS}$ latency = 1 : At the same clock as the last read data.
$\overline{CAS}$ latency = 2 or 3 : One clock earlier than the last read data.



In order to write all data to the memory cell correctly, the asynchronous parameter "t_{DPL}" must be satisfied. The $t_{DPL(MIN.)}$ specification defines the earliest time that a precharge command can be asserted. Minimum number of clocks are calculated by dividing $t_{DPL\ (MIN.)}$ with clock cycle time.

In summary, the precharge command can be asserted relative to reference clock that indicates the last data word is valid. In the following table, minus means clocks before the reference; plus means time after the reference.

$\overline{CAS}$ latency	Read	Write
1	0	+$t_{DPL\ (MIN.)}$
2	-1	+$t_{DPL\ (MIN.)}$
3	-1	+$t_{DPL\ (MIN.)}$

10. Auto Precharge

During a read or write command cycle, A10 controls whether auto precharge is selected. A10 high in the read or write command (Read with Auto precharge command or Write with Auto precharge command), auto precharge is selected and begins automatically after the burst access.

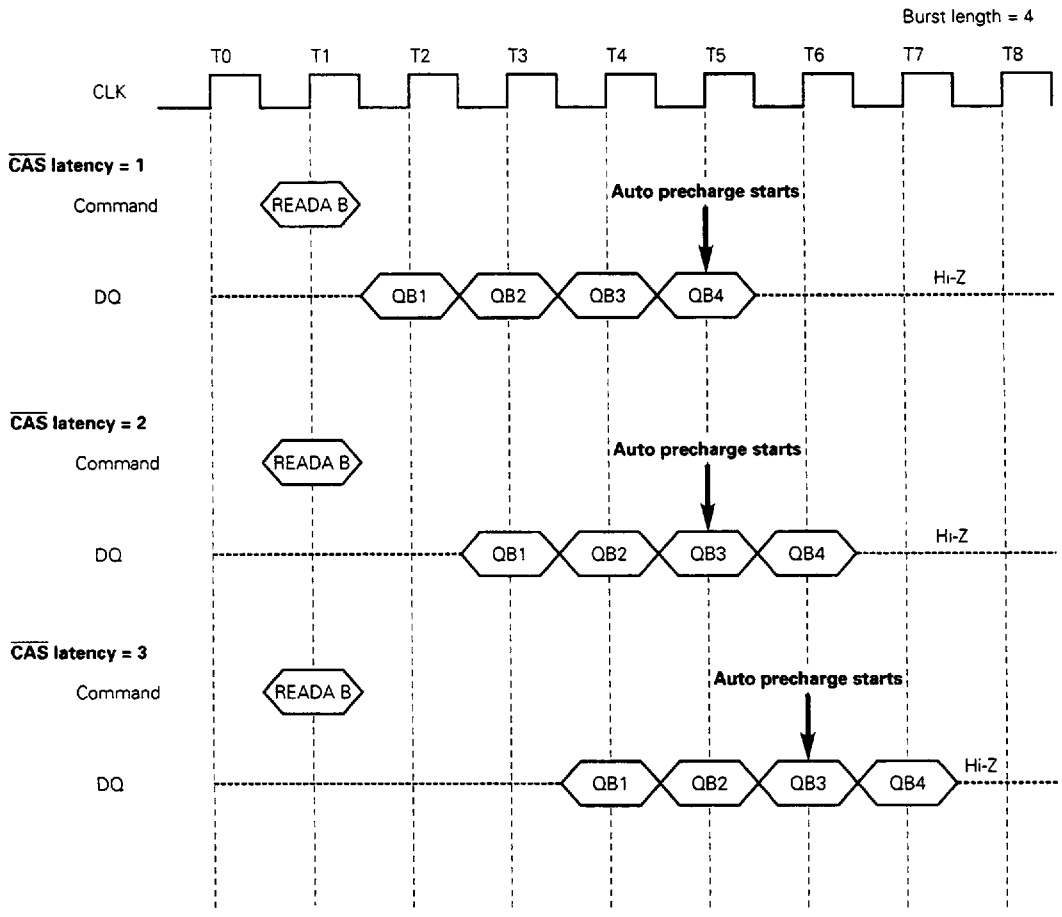
In write cycle, the t_{DAL} must be satisfied to assert the next activate command to the bank being precharged. It is not necessary to know when the precharge starts.

When using auto precharge in READ cycle, knowing when the precharge starts is important because the next activate command to the bank being precharged cannot be executed until the precharge cycle ends. Once auto precharge has started, an activate command to the bank can be asserted after t_{RP} has been satisfied.

The timing that begins the auto precharge cycle is depend on both the $\overline{CAS}$ latency programmed into the mode register and whether READ or WRITE cycle.

10.1 Read with Auto Precharge

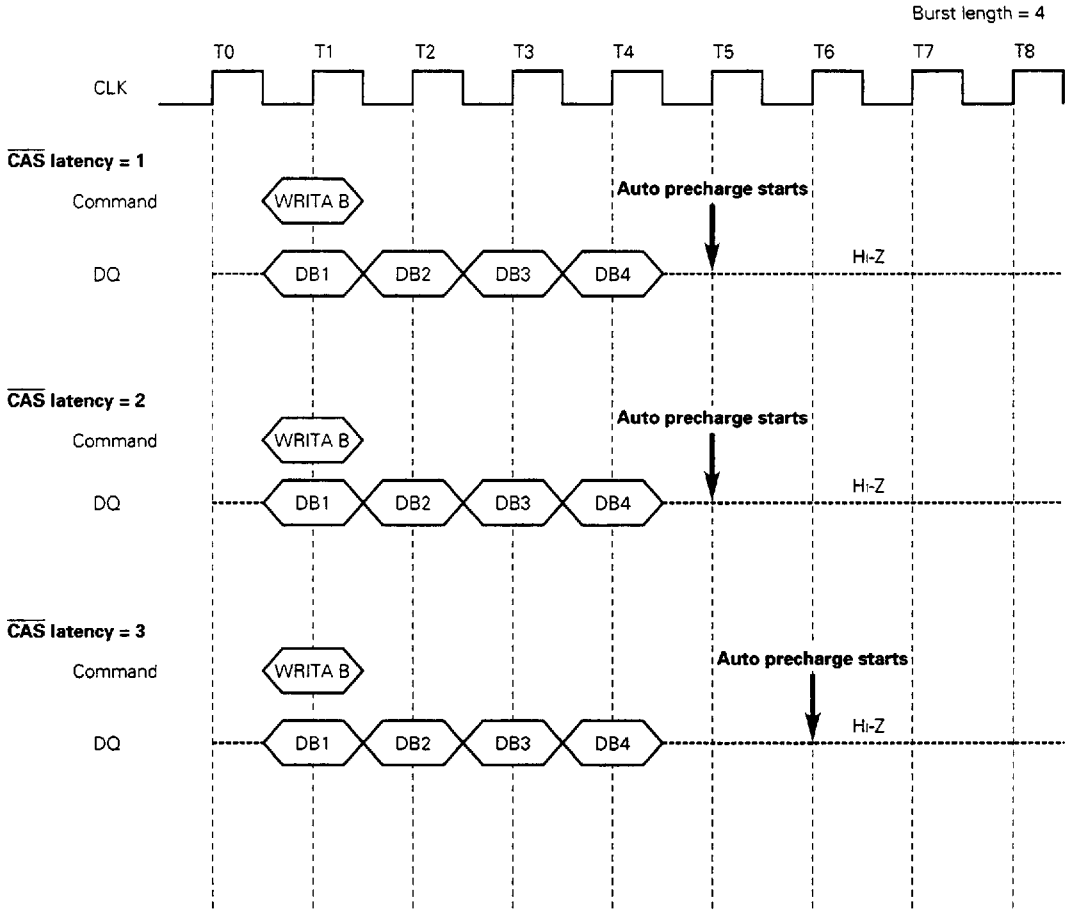
During READ cycle, the auto precharge begins on the clock that indicates the last data word output during the burst is valid ($\overline{CAS}$ latency of 1) or one clock earlier ($\overline{CAS}$ latency of 2 or 3).



Remark READA means Read with Auto precharge

10.2 Write with Auto Precharge

During WRITE cycle, the auto precharge begins one clock after the last data word input to the device ($\overline{CAS}$ latency of 1 or 2) or two clocks after ($\overline{CAS}$ latency of 3).



Remark WRITA means Write with Auto precharge

In summary, the auto precharge cycle begins relative to a reference clock that indicates the last data word is valid.

In the table below, minus means clocks before the reference; plus means clocks after the reference.

$\overline{CAS}$ latency	Read	Write
1	0	+1
2	−1	+1
3	−1	+2

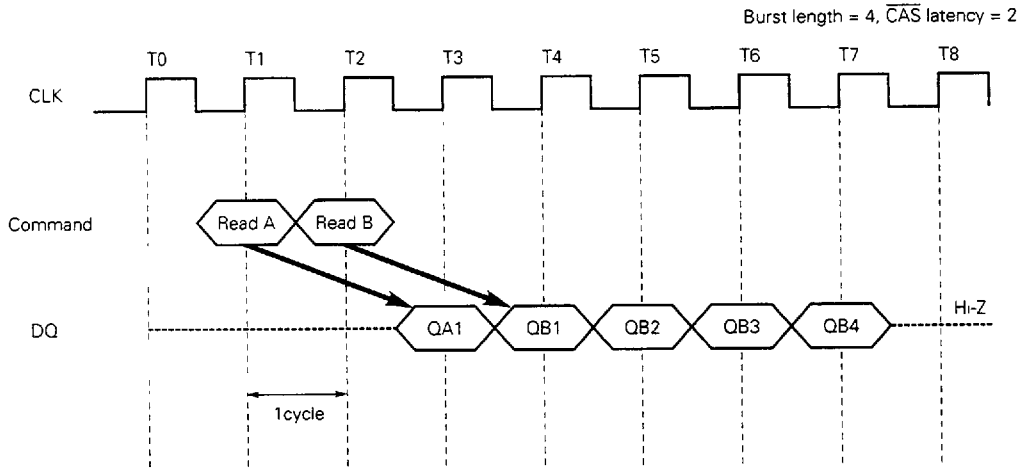
When the t_{RAS} is not satisfied, the precharge does not start at above timing. And the precharge will start when the t_{RAS} is satisfied.

11. Read/Write Command Interval

11.1 Read to Read Command Interval

During READ cycle, when new Read command is asserted, it will be effective after $\overline{CAS}$ latency, even if the previous READ operation does not completed. READ will be interrupted by another READ.

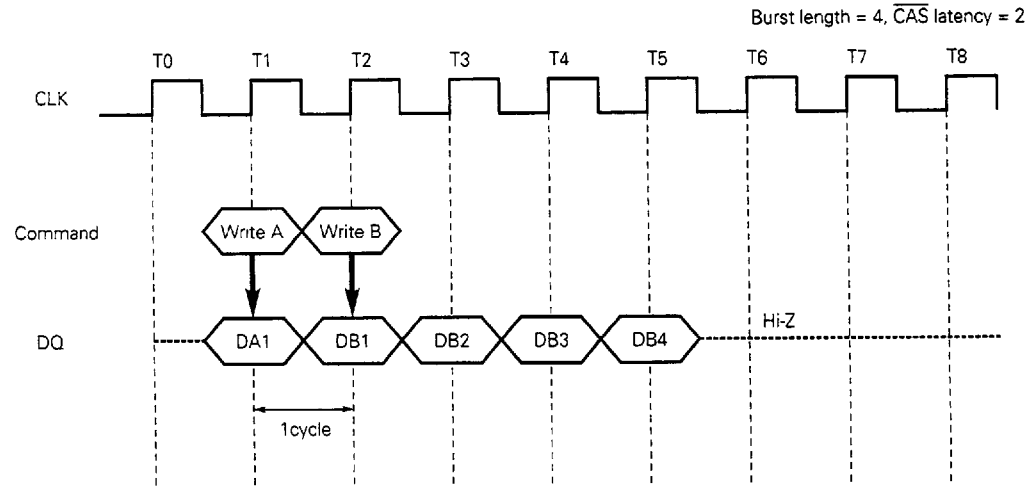
The interval between the commands is 1 cycle minimum. Each Read command can be asserted in every clock without any restriction.



11.2 Write to Write Command Interval

During WRITE cycle, when new Write command is asserted, the previous burst will terminate and the new burst will begin with a new Write commnad. WRITE will be interrupted by another WRITE.

The interval between the commands is minimum 1. Each Write command can be asserted in every clock without any restriction.

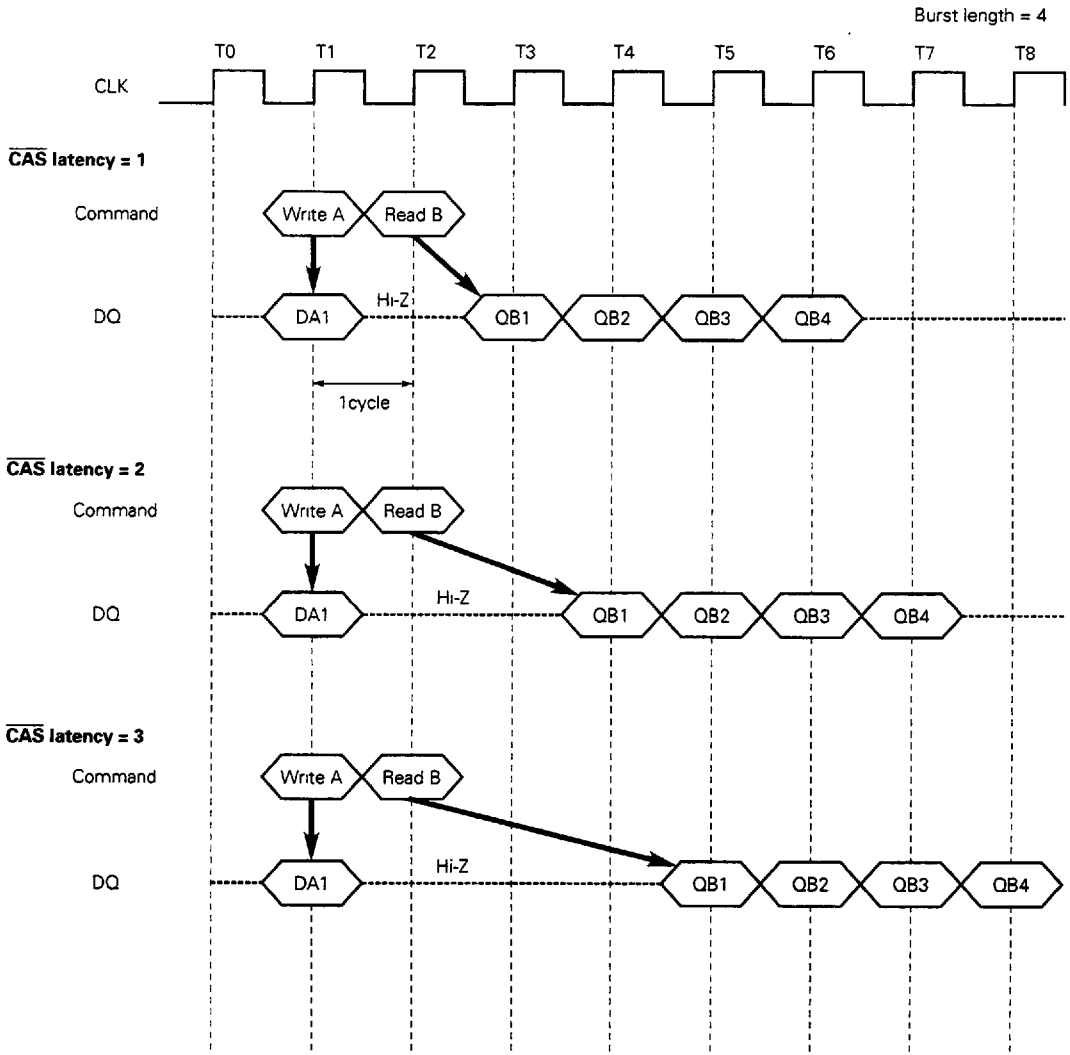


11.3 Write to Read Command Interval

Write command and Read command interval is also 1 cycle.

Only the write data before Read command will be written.

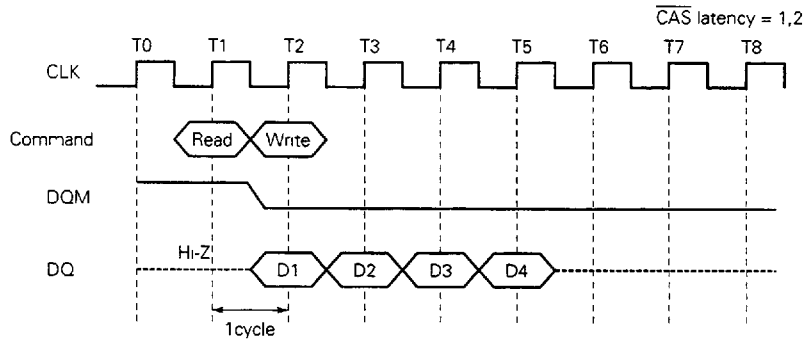
The data bus must be Hi-Z at least one cycle prior to the first DOUT.



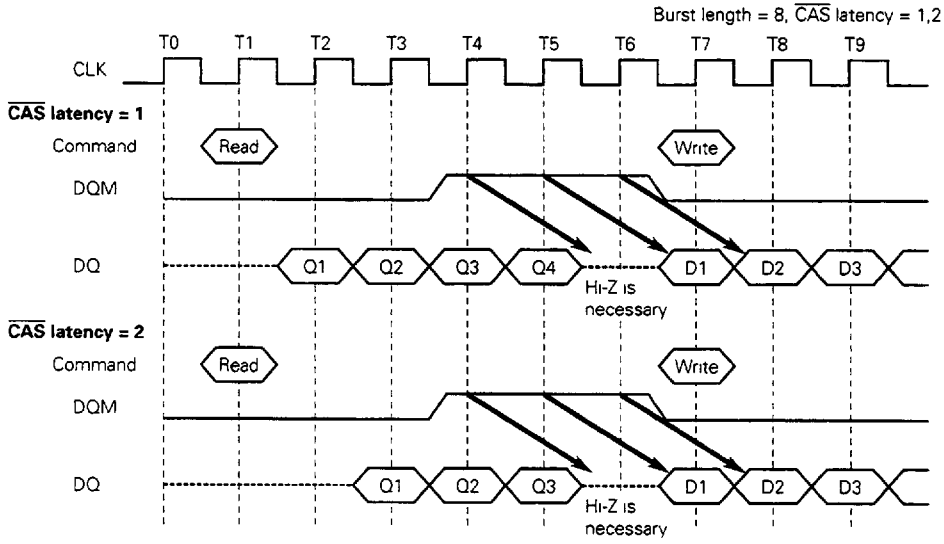
11.4 Read to Write Command Interval

During READ cycle, READ can be interrupted by WRITE. When the $\overline{CAS}$ latency is 3 and then the burst length is Full page, the burst read cannot be interrupted by WRITE (A Burst Stop command (BST) or a Precharge command can interrupt).

When the $\overline{CAS}$ latency is 1 or 2, the Read and Write command interval is 1 cycle minimum. There is a restriction to avoid data conflict. The data bus must be Hi-Z using DQM before WRITE.

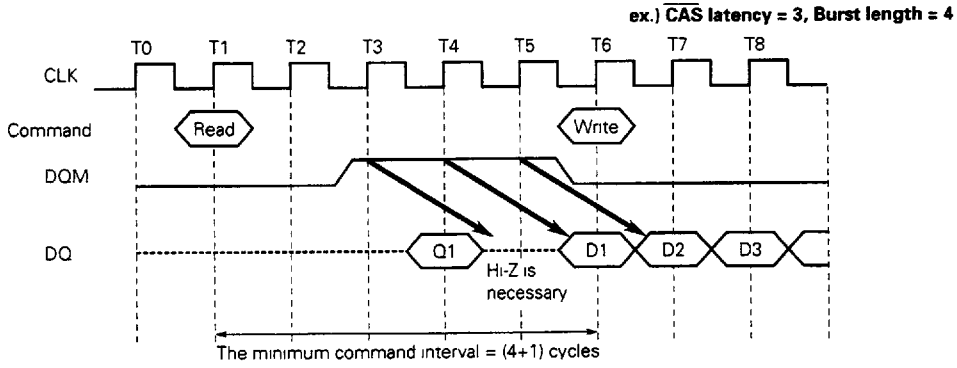


In case $\overline{CAS}$ latency is 1 or 2, READ can be interrupted by WRITE. DQM must be High at least 3 clocks prior to the Write command.



In case $\overline{CAS}$ latency is 3 (burst length is not Full page), READ can be interrupted by WRITE.

The minimum command interval is [burst length +1] cycles. DQM must be High at least 3 clocks prior to the Write command.

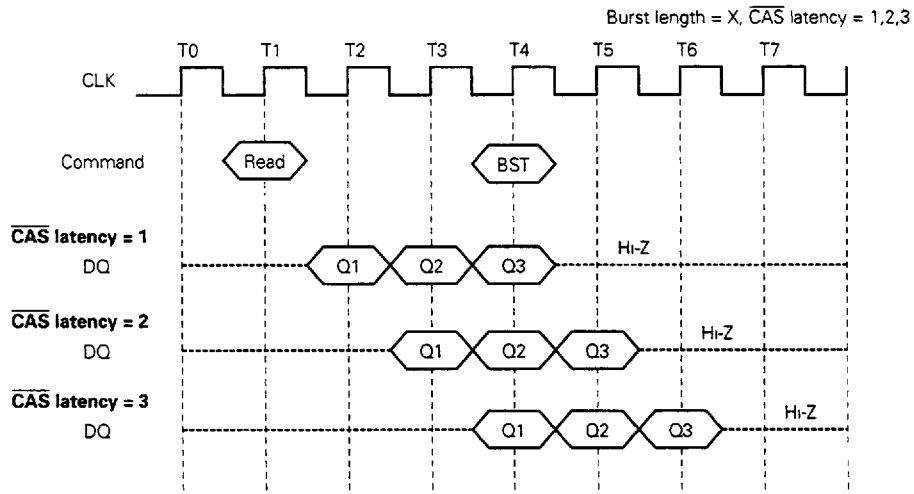


12. Burst Termination

There are two methods to terminate a burst operation other than using a read or a write command. One is the burst stop command and the other is the precharge command.

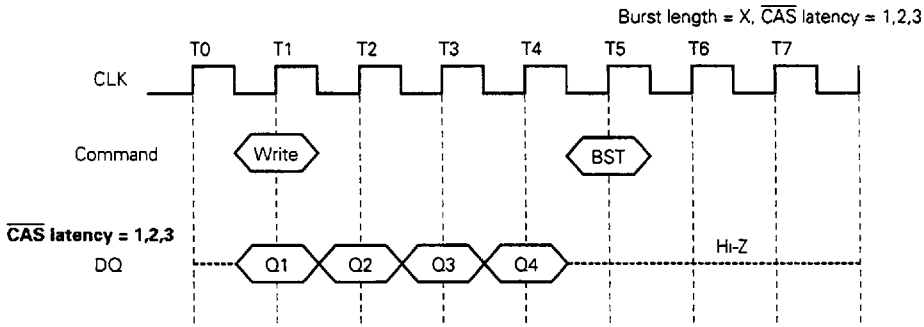
12.1 Burst Stop Command

During READ cycle, when the burst stop command is asserted, the burst read data are terminated and the data bus goes to Hi-Z after the $\overline{CAS}$ latency from the burst stop command.



Remark BST: Burst stop command

During WRITE cycle, when the burst stop command is asserted, the burst write data are terminated and data bus goes to Hi-Z at the same clock with the burst stop command.



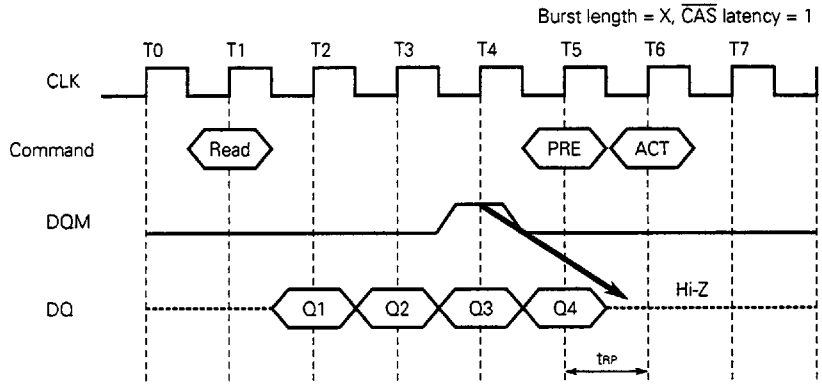
Remark BST: Burst stop command

12.2 Precharge Termination

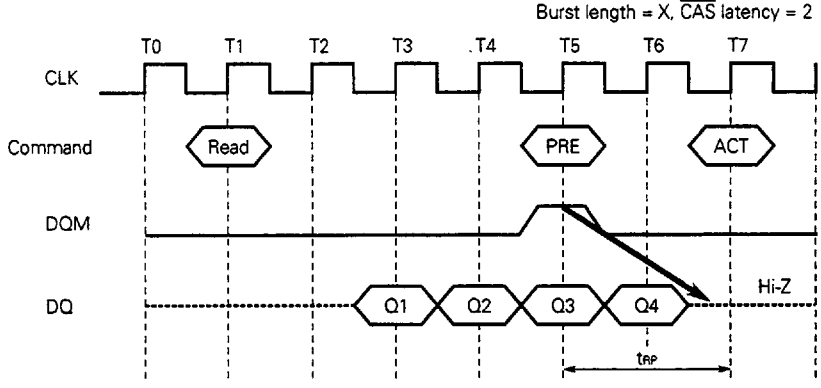
12.2.1 Precharge Termination in READ Cycle

During READ cycle, the burst read operation is terminated by a precharge command.
When the precharge command is asserted, the burst read operation is terminated and precharge starts.
The same bank can be activated again after t_{RP} from the precharge command.
The DQM must be high to mask the invalid data.

When $\overline{CAS}$ latency is 1, the read data will remain valid until the precharge command is asserted.
Invalid data may appear one clock after valid data out.
The DQM may be high to mask the invalid data.

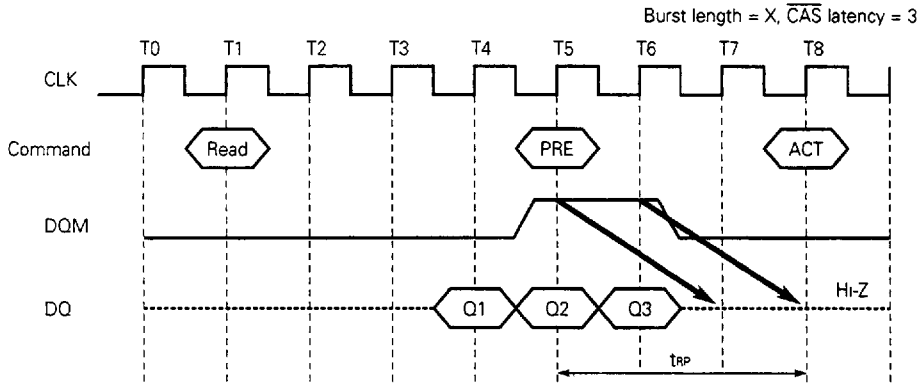


When $\overline{CAS}$ latency is 2, the read data will remain valid until one clock after the precharge command. Invalid data may appear one clock after valid data out.
The DQM may be high to mask the invalid data.



When $\overline{CAS}$ latency is 3, the read data will remain valid until one clock after the precharge command. Invalid data may appear one and two clocks after valid data out.

The DQM may be high to mask the invalid data.



12.2.2 Precharge Termination in WRITE Cycle

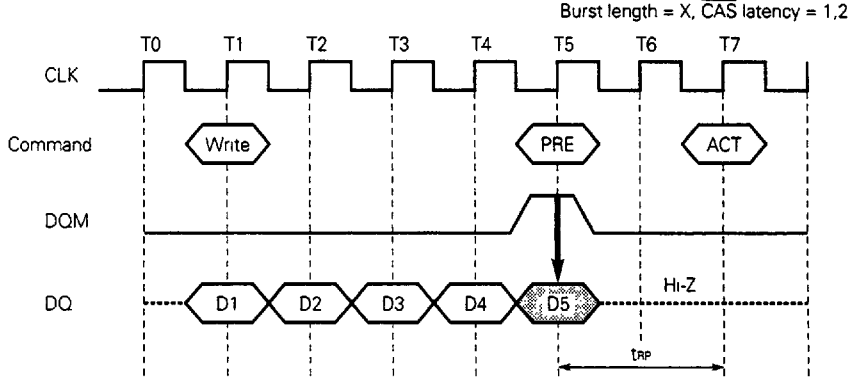
During WRITE cycle, the burst write operation is terminated by a precharge command.

When the precharge command is asserted, the burst write operation is terminated and precharge starts.

The same bank can be activated again after t_{RP} from the precharge command.

The DQM must be high to mask invalid data in.

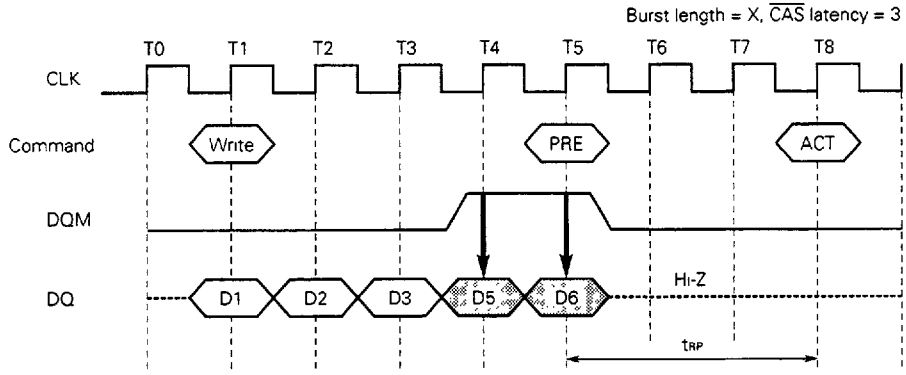
When $\overline{CAS}$ latency is 1 or 2, the write data written prior to the precharge command will be correctly stored. However, invalid data may be written at the same clock as the precharge command. To prevent this from happening, DQM must be high at the same clock as the precharge command. This will mask the invalid data.



When $\overline{CAS}$ latency is 3, the write data written more than one clock prior to the precharge command will be correctly stored.

However, invalid data may be written at one clock before and the same clock as the precharge command.

To prevent this from happening, DQM must be high from one clock prior to the precharge command until the precharge command. This will mask the invalid data.



13. Electrical Specifications

- All voltage are referenced to Vss (GND).
- After power up, wait more than 100 μs and then, execute **Power on sequence and Auto Refresh** before proper device operation is achived.

Absolute Maximum Ratings

Parameter	Symbol	Condition	Rating	Unit
Voltage on power supply pin relative to GND	V_T		−1.0 to +4.6	V
Voltage on input pin relative to GND	V_{CC}, $V_{CC}Q$		−1.0 to +4.6	V
Short circuit output current	I_O		50	mA
Power dissipation	P_D		1	W
Operating ambient temperature	T_A		0 to +70	°C
Storage temperature	T_{stg}		−55 to +125	°C

Caution Exposing the device to stress above those listed in Absolute Maximum Ratings could cause permanent damage. The device is not meant to be operated under conditions outside the limits described in the operational section of this specification. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

Recommended Operating Conditions

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Supply voltage	V_{CC}		3.0	3.3	3.6	V
High level input voltage	V_{IH}		2.0		4.6	V
Low level input voltage	V_{IL}		−0.3		+0.8	V
Operating ambient temperature	T_A		0		70	°C

Capacitance (T_A=25°C, f=1MHz)

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
Input capacitance	C_{I1}	A0 to A11	2		4	pF
	C_{I2}	CLK, CKE, $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, DQM, UDQM, LDQM	2		4	pF
Data input/output capacitance	$C_{I/O}$	DQ0 to DQ15	2		5	pF

DC Characteristics 1 (Recommended Operating Conditions unless otherwise noted) (1/2)

Parameter	Symbol	Test condition	$\overline{CAS}$ latency	Grade	Maximum ×4	Maximum ×8	Maximum ×16	Unit	Notes
Operating current	I_{CC1}	Burst length=1 $t_{RC} \geq t_{RC\ (MIN.)}$ I_O=0mA	CL=1	-10	70	75	80	mA	1
				-12	65	70	75		
				-13	60	65	70		
				-15	60	65	70		
			CL=2	-10	75	80	85	mA	1
				-12	70	75	80		
				-13	65	70	75		
				-15	65	70	75		
			CL=3	-10	80	85	90	mA	1
				-12	75	80	85		
				-13	70	75	80		
				-15	65	70	75		
Precharge standby current in Power down mode	I_{CC2P}	CKE ≤ $V_{IL\ (MAX.)}$ t_{CK}=15ns			3	3	3	mA	
	I_{CC2PS}	CKE ≤ $V_{IL\ (MAX.)}$ t_{CK}=∞			2	2	2		
Precharge standby current in Non power down mode	I_{CC2N}	CKE ≥ $V_{IH\ (MIN.)}$ t_{CK}=15ns $\overline{CS}$ ≥ $V_{IH\ (MIN.)}$ Input signals are changed one time during 30ns.			20	20	20	mA	
	I_{CC2NS}	CKE ≥ $V_{IH\ (MIN.)}$ t_{CK}=∞ Input signals are stable.			6	6	6		
Active standby current in Power down mode	I_{CC3P}	CKE ≤ $V_{IL\ (MAX.)}$ t_{CK}=15ns			3	3	3	mA	
	I_{CC3PS}	CKE ≤ $V_{IL\ (MAX.)}$ t_{CK}=∞			2	2	2		
Active standby current in Non power down mode	I_{CC3N}	CKE ≥ $V_{IH\ (MIN.)}$ t_{CK}=15ns $\overline{CS}$ ≥ $V_{IH\ (MIN.)}$ Input signals are changed one time during 30 ns.		-10	28	28	30	mA	
				-12	28	28	30		
				-13	28	28	30		
				-15	25	25	25		
	I_{CC3NS}	CKE ≥ $V_{IH\ (MIN.)}$ t_{CK}=∞ Input signals are stable.			10	10	10		
Operating current (Burst mode)	I_{CC4}	$t_{CK} \geq t_{CK\ (MIN.)}$ I_O=0mA	CL=1	-10	70	75	90	mA	2
				-12	60	65	80		
				-13	55	60	75		
				-15	55	60	75		
			CL=2	-10	110	120	150		
				-12	90	100	125		
				-13	85	95	115		
				-15	85	95	115		
			CL=3	-10	150	165	210		
				-12	130	145	180		
				-13	120	130	160		
				-15	100	110	140		

DC Characteristics 1 (Recommended Operating Conditions unless otherwise noted) (2/2)

Parameter	Symbol	Test condition	$\overline{CAS}$ latency	Grade	Maximum ×4	Maximum ×8	Maximum ×16	Unit	Notes
Refresh current	I_{CC5}	$t_{RC} \geq t_{RC(MIN.)}$	CL=1	-10	90	90	90	mA	3
				-12	80	80	80		
				-13	75	75	75		
				-15	75	75	75		
			CL=2	-10	95	95	95		
				-12	85	85	85		
				-13	80	80	80		
				-15	80	80	80		
			CL=3	-10	100	100	100		
				-12	90	90	90		
				-13	85	85	85		
				-15	80	80	80		
Self refresh Current	I_{CC6}	CKE ≤ 0.2V		-**	2	2	2	mA	
				-**L	100	100	100	μA	

Notes 1. I_{CC1} depends on output loading and cycle rates. Specified values are obtained with the output open. In addition to this, I_{CC1} is measured on condition that addresses are changed only one time during $t_{CK(MIN.)}$.

2. I_{CC4} depends on output loading and cycle rates. Specified values are obtained with the output open. In addition to this, I_{CC4} is measured on condition that addresses are changed only one time during $t_{CK(MIN.)}$.

3. I_{CC5} is measured on condition that addresses are changed only one time during $t_{CK(MIN.)}$.

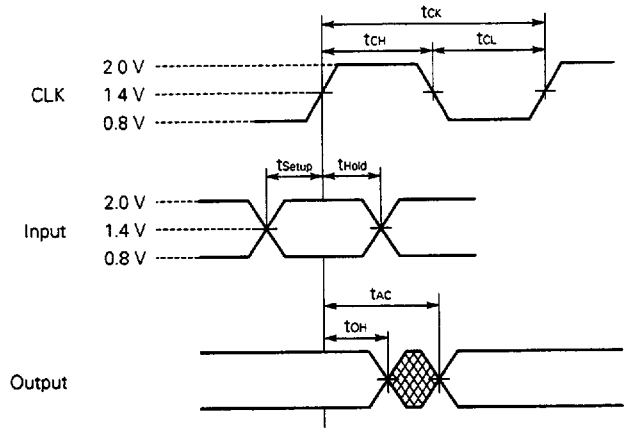
DC Characteristics 2 (Recommended Operating Conditions unless otherwise noted)

Parameter	Symbol	Test condition	MIN.	TYP.	MAX.	Unit
Input leakage current	$I_{I(L)}$	V_I=0 to 3.6V, all other pins not under test =0V	−1.0		+1.0	μA
Output leakage current	$I_{O(L)}$	D_{OUT} is disabled, V_O=0 to 3.6V	−1.0		+1.0	μA
High level output voltage	V_{OH}	I_O=−2mA	2.4			V
Low level output voltage	V_{OL}	I_O=+2mA			0.4	V

AC Characteristics (Recommended Operating Conditions unless otherwise noted)

Test Conditions

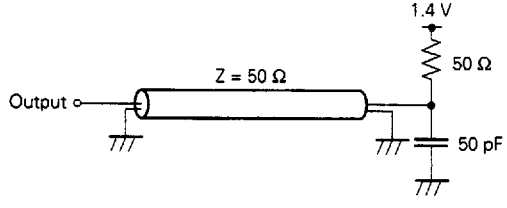
- AC measurements assume t_T=1ns.
- Reference level for measuring timing of input signals is 1.4V. Transition times are measured between V_{IH} and V_{IL}.
- If t_T is longer than 1 ns, reference level for measuring timing of input signals is $V_{IH\,(MIN.)}$ and $V_{IL\,(MAX.)}$.
- An access time is measured at 1.4V.



Synchronous Characteristics

Parameter		Symbol	-10		-12		-13		-15		Unit	Note
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
Clock cycle time	$\overline{CAS}$ latency=3	t_{CK3}	10	(100MHz)	12	(83MHz)	13	(77MHz)	15	(66MHz)	ns	
	$\overline{CAS}$ latency=2	t_{CK2}	15	(66MHz)	18	(55MHz)	19.5	(50MHz)	19.5	(50MHz)	ns	
	$\overline{CAS}$ latency=1	t_{CK1}	30	(33MHz)	36	(28MHz)	39	(25MHz)	39	(25MHz)	ns	
Access time from CLK	$\overline{CAS}$ latency=3	t_{AC3}		8		10		12		14	ns	1
	$\overline{CAS}$ latency=2	t_{AC2}		11		14		16.5		16.5	ns	1
	$\overline{CAS}$ latency=1	t_{AC1}		27		33		36		36	ns	1
CLK high level width		t_{CH}	3.5		4		5		5		ns	
CLK low level width		t_{CL}	3.5		4		5		5		ns	
Data-out hold time		t_{OH}	4		4		4		4		ns	
Data-out low-impedance time		t_{LZ}	0		0		0		0		ns	
Data-out high-impedance time	$\overline{CAS}$ latency=3	t_{HZ3}	4	8	4	8	4	10	4	10	ns	
	$\overline{CAS}$ latency=2	t_{HZ2}	4	11	4	11	4	11	4	11	ns	
	$\overline{CAS}$ latency=1	t_{HZ1}	4	27	4	27	4	27	4	27	ns	
Data-in setup time		t_{DS}	2.5		3.0		3.5		3.5		ns	
Data-in hold time		t_{DH}	1.0		1.5		1.5		1.5		ns	
Address setup time		t_{AS}	2.5		3.0		3.5		3.5		ns	
Address hold time		t_{AH}	1.0		1.5		1.5		1.5		ns	
CKE setup time		t_{CKS}	2.5		3.0		3.5		3.5		ns	
CKE hold time		t_{CKH}	1.0		1.5		1.5		1.5		ns	
CKE setup time (Power down exit)		t_{CKSP}	2.5		3.0		3.5		3.5		ns	
Command ($\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, DQM) setup time		t_{CMS}	2.5		3.0		3.5		3.5		ns	
Command ($\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$, DQM) hold time		t_{CMH}	1.0		1.5		1.5		1.5		ns	

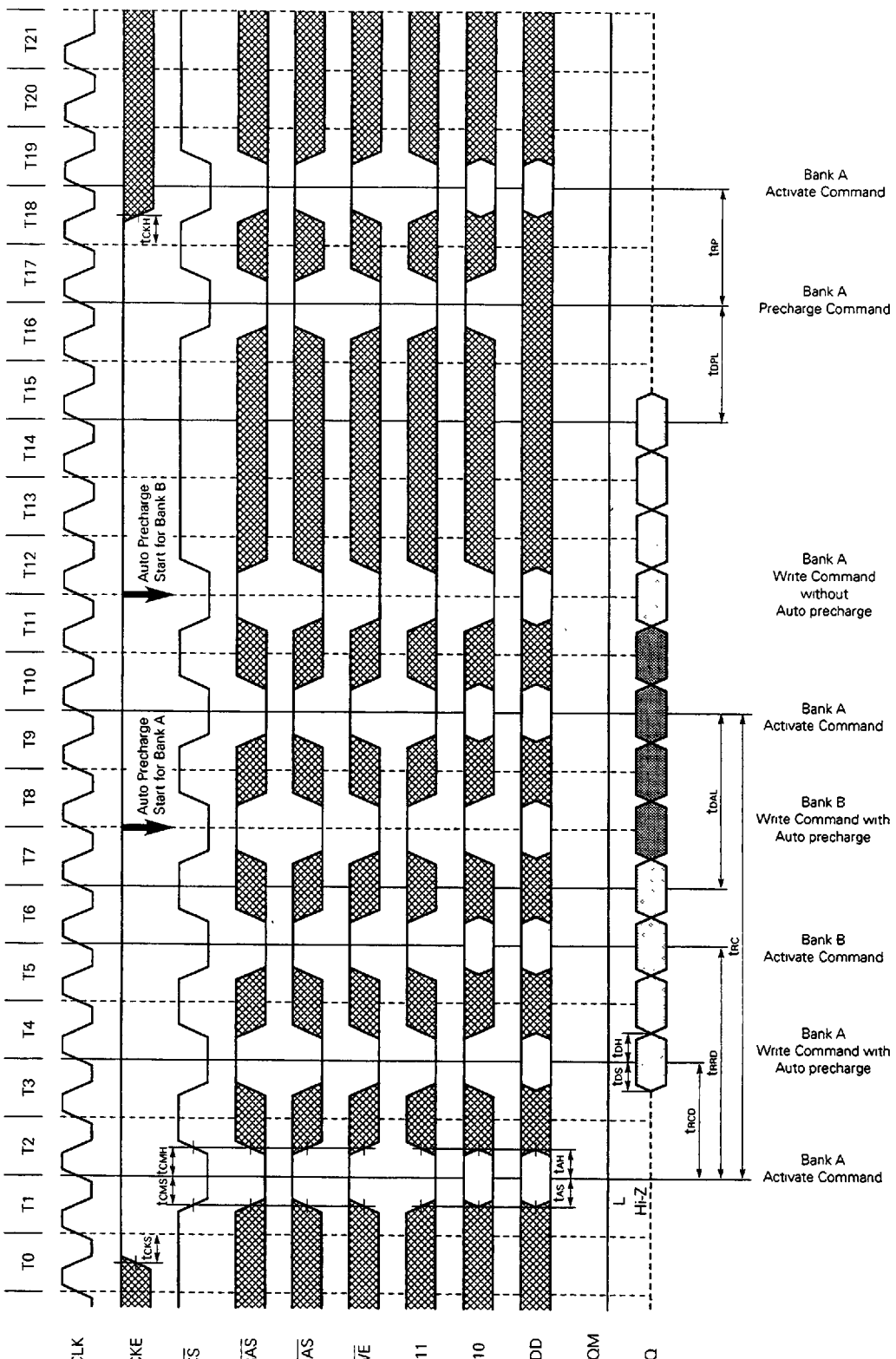
Note 1. Output load



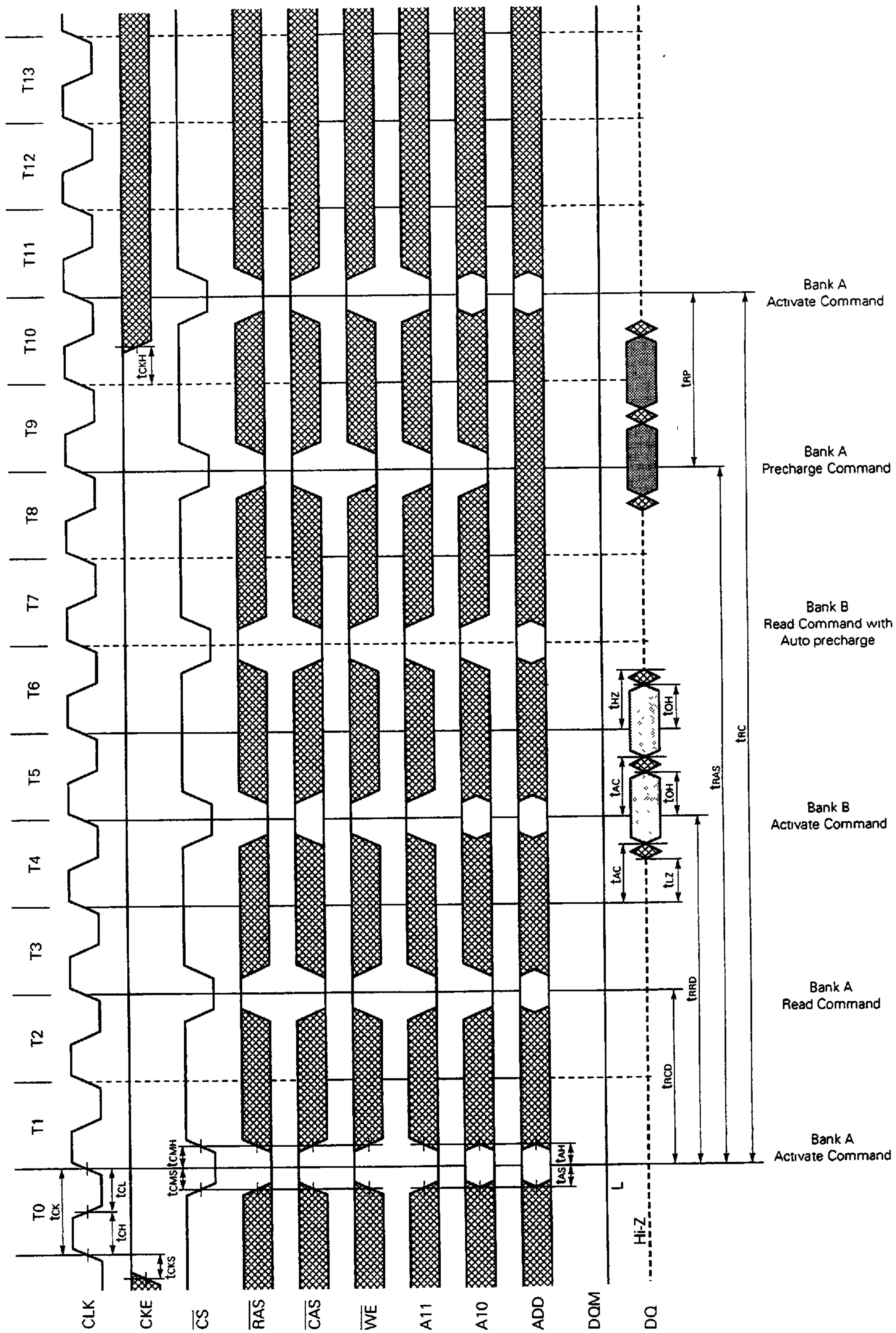
Asynchronous Characteristics

Parameter		Symbol	-10		-12		-13		-15		Unit	Note
			MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.		
REF to REF/ACT Command period		t_{RC}	100		120		130		130		ns	
ACT to PRE Command period		t_{RAS}	70	120,000	84	120,000	91	120,000	91	120,000	ns	
PRE to ACT Command period		t_{RP}	30		36		39		39		ns	
Delay time ACT to READ/ WRITE Command		t_{RCD}	30		36		39		39		ns	
ACT(0) to ACT(1) Command period		t_{RRD}	30		36		39		39		ns	
Data-in to PRE Command period	$\overline{CAS}$ latency=3	t_{DPL3}	15		18		1CLK+13		1CLK+15		ns	
	$\overline{CAS}$ latency=2	t_{DPL2}	15		18		19.5		19.5		ns	
	$\overline{CAS}$ latency=1	t_{DPL1}	15		18		19.5		19.5		ns	
Data-in to ACT (REF) Command period (Auto precharge)	$\overline{CAS}$ latency=3	t_{DAL3}	2CLK+30		2CLK+36		2CLK+39		2CLK+45		ns	
	$\overline{CAS}$ latency=2	t_{DAL2}	1CLK+30		1CLK+36		1CLK+39		1CLK+39		ns	
	$\overline{CAS}$ latency=1	t_{DAL1}	1CLK+30		1CLK+36		1CLK+39		1CLK+39		ns	
Mode register set cycle time		t_{RSC}	20		20		20		20		ns	
Transition time		t_T	1	30	1	30	1	30	1	30	ns	
Refresh time		t_{REF}		32		32		32		32	ms	

13.1 AC Parameters for Write Timing (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



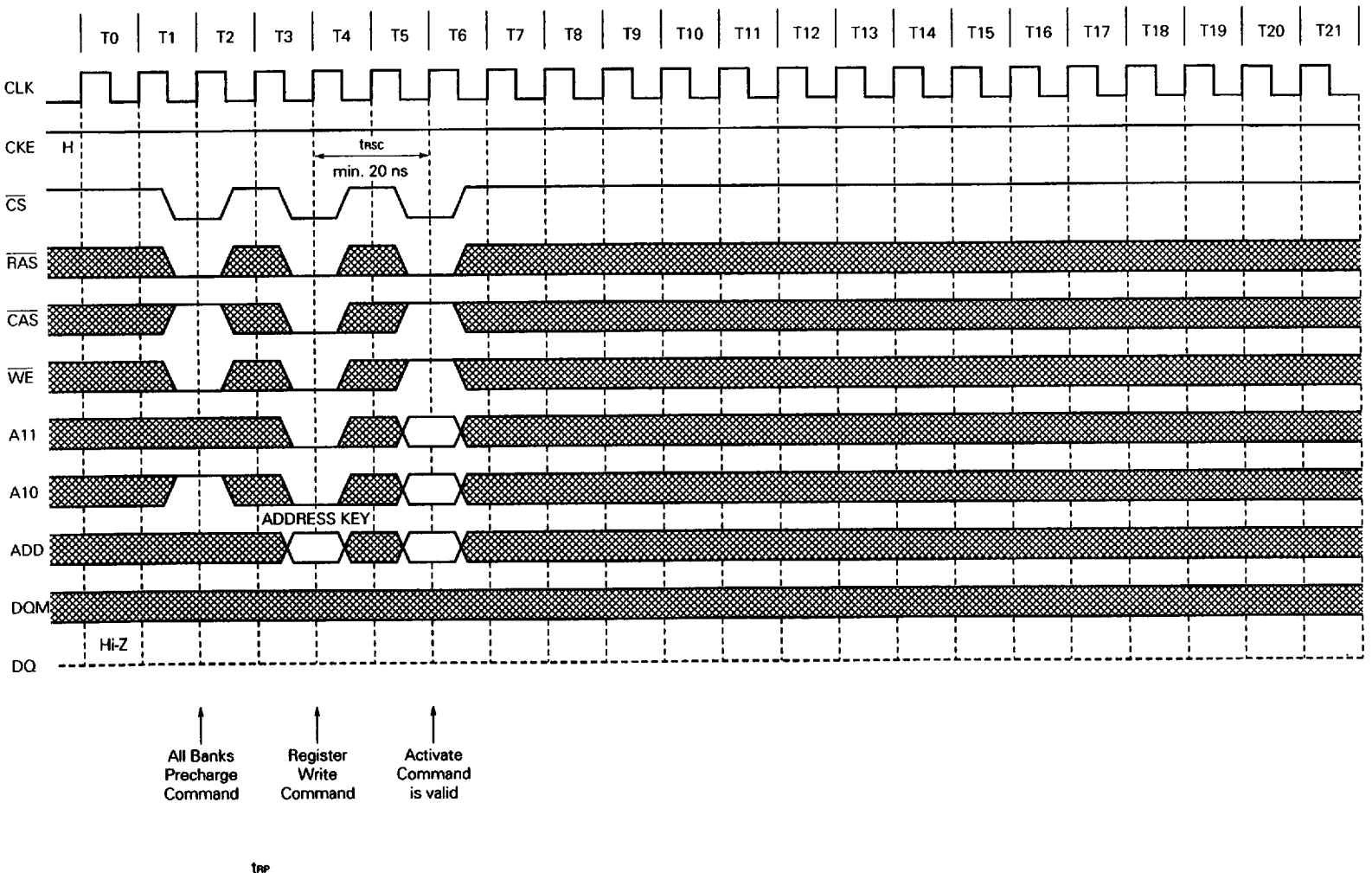
13.2 AC Parameters for Read Timing (Burst length = 2, $\overline{CAS}$ latency = 2)



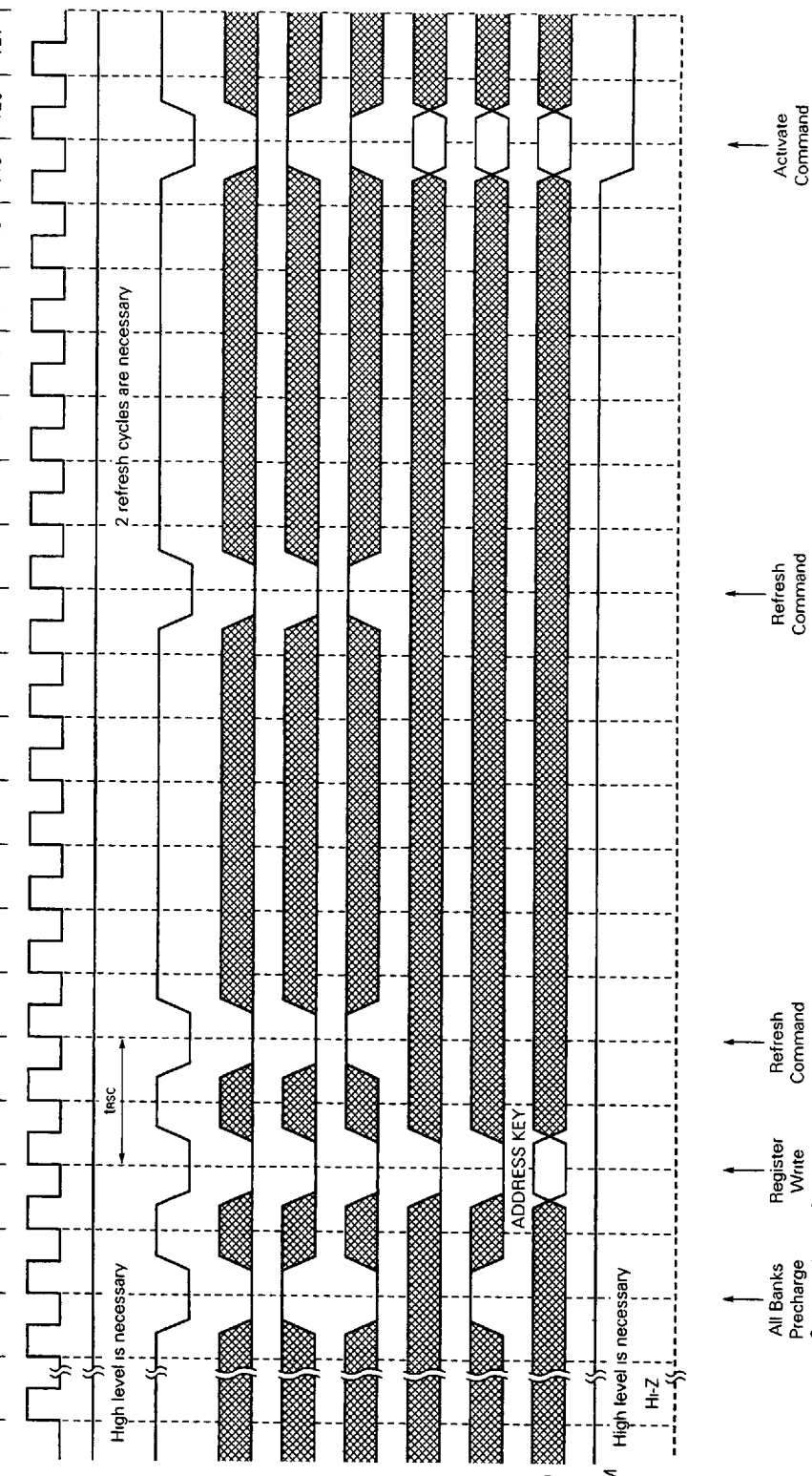
13.3 Relationship between Frequency and Latency

Speed version	-10			-12			-13			-15		
Clock cycle time [ns]	10	15	30	12	18	36	13	19.5	39	15	19.5	39
Frequency [MHz]	100	66	33	83	55	28	77	50	25	66	50	25
$\overline{CAS}$ latency	3	2	1	3	2	1	3	2	1	3	2	1
[t_{RCD}]	3	2	1	3	2	1	3	2	1	3	2	1
$\overline{RAS}$ latency ($\overline{CAS}$ latency + [t_{RCD}])	6	4	2	6	4	2	6	4	2	6	4	2
[t_{RC}]	10	7	4	10	7	4	10	7	4	10	7	4
[t_{RAS}]	7	5	3	7	5	3	7	5	3	7	5	3
[t_{RRD}]	3	2	1	3	2	1	3	2	1	3	2	1
[t_{RP}]	3	2	1	3	2	1	3	2	1	3	2	1
[t_{DPL}]	2	1	1	2	1	1	2	1	1	2	1	1
[t_{DAL}]	5	3	2	5	3	2	5	3	2	5	3	2
[t_{SREX}]	2	2	1	2	2	1	2	2	1	2	2	1

13.4 Mode Register Write (Burst length = 4, $\overline{CAS}$ latency = 2)

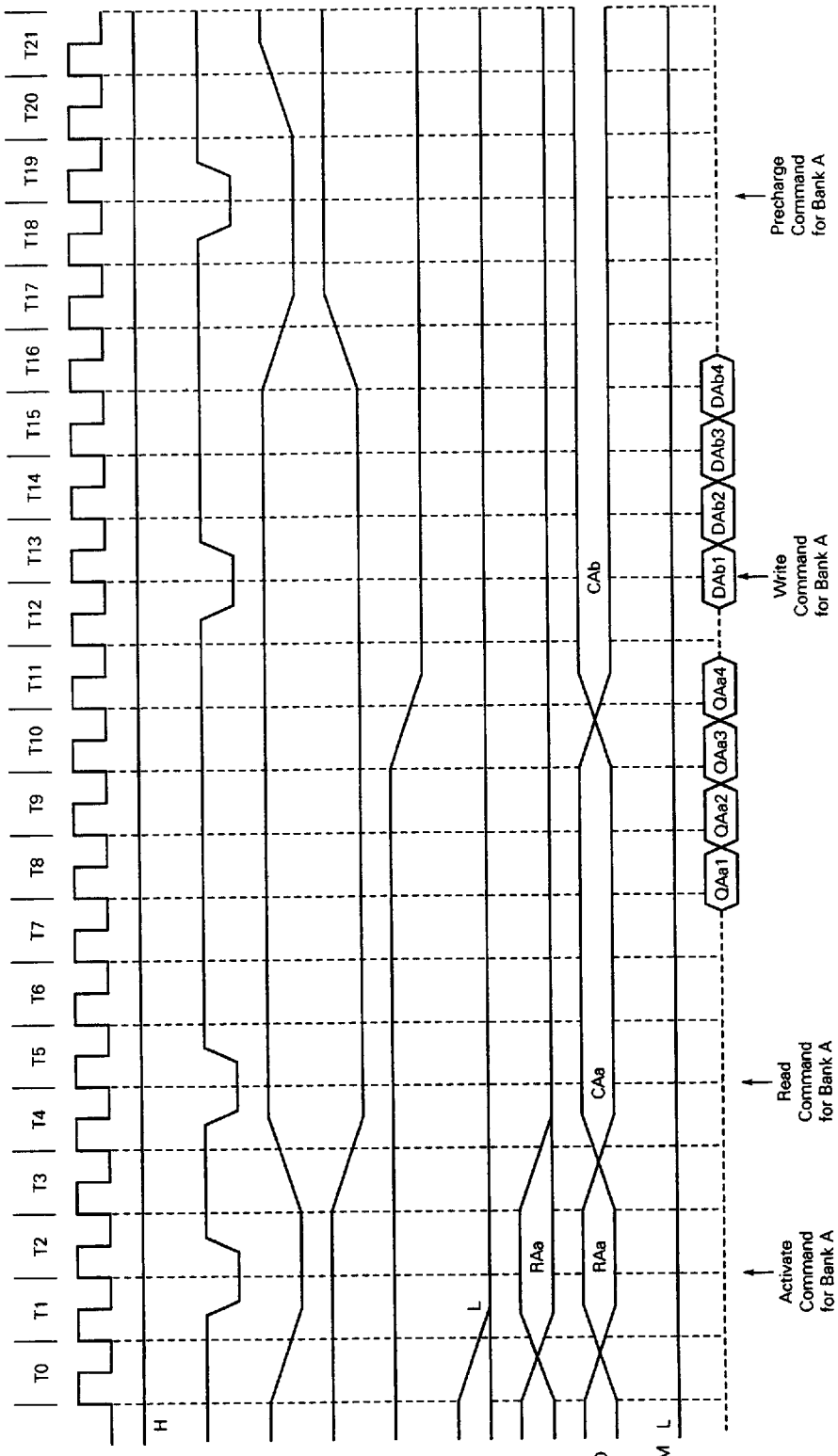


13.5 Power on Sequence and Auto Refresh

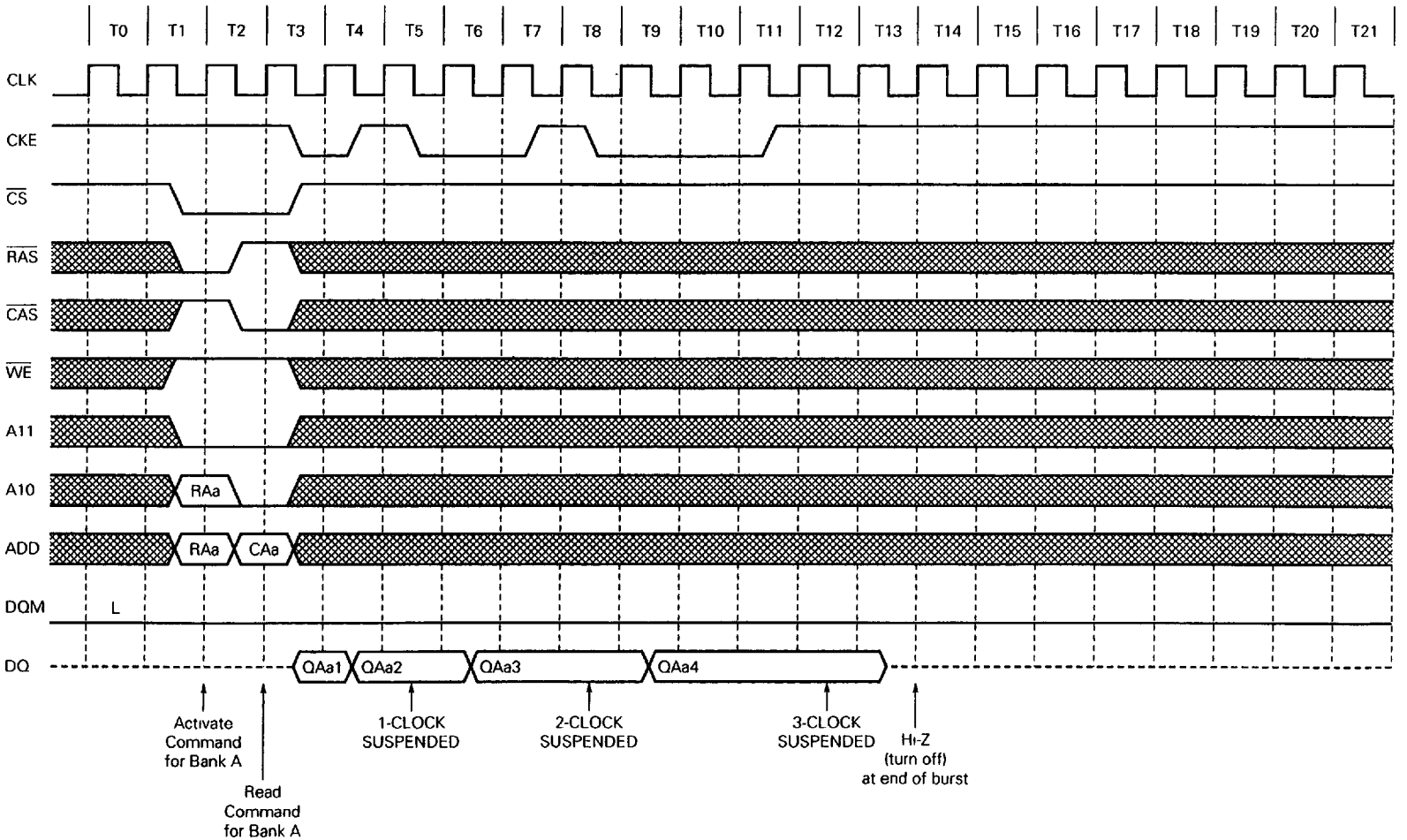


13.6 $\overline{CS}$ Function (at 100 MHz, Burst length = 4, $\overline{CAS}$ latency = 3)

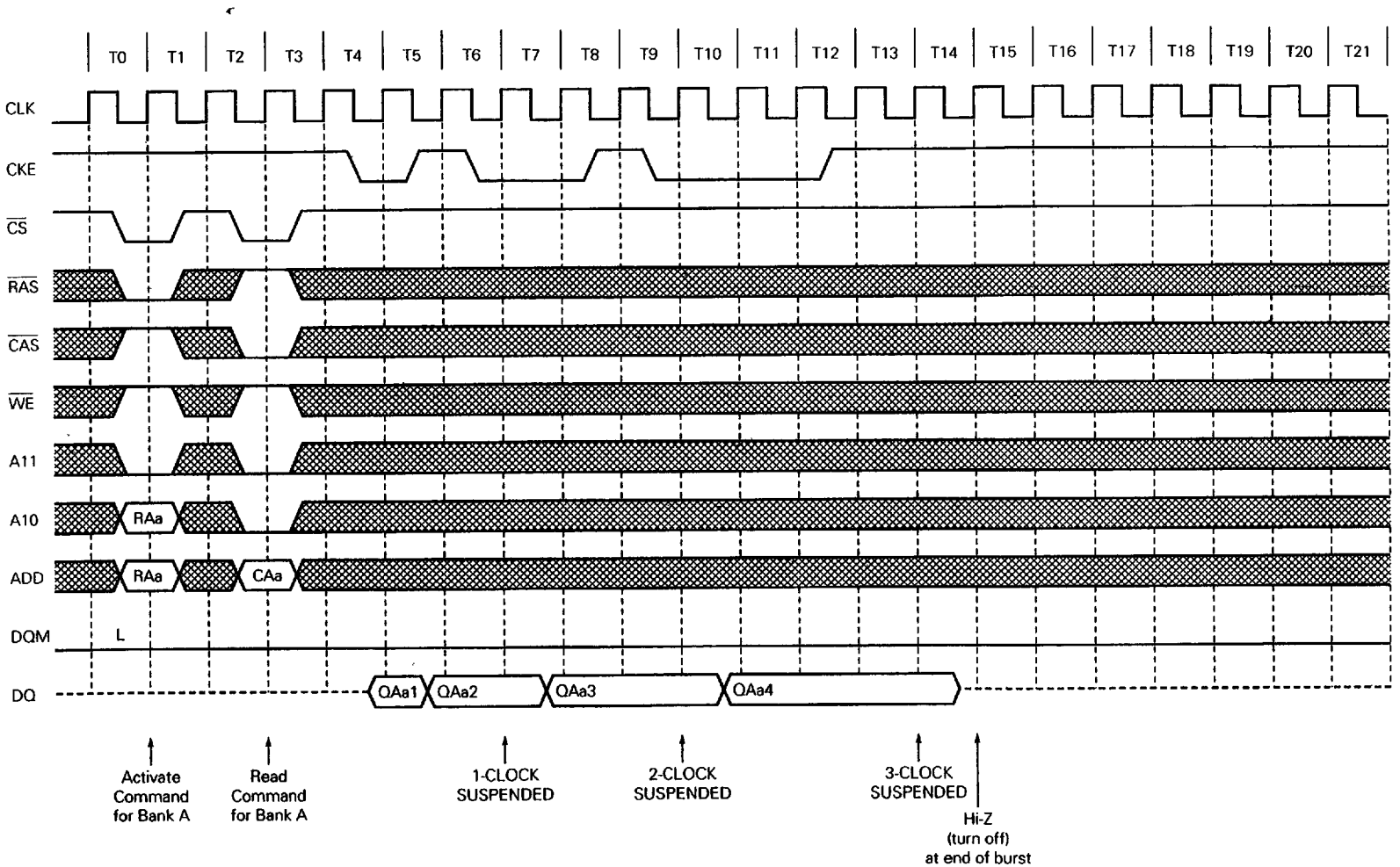
Only $\overline{CS}$ signal needs to be asserted at minimum rate



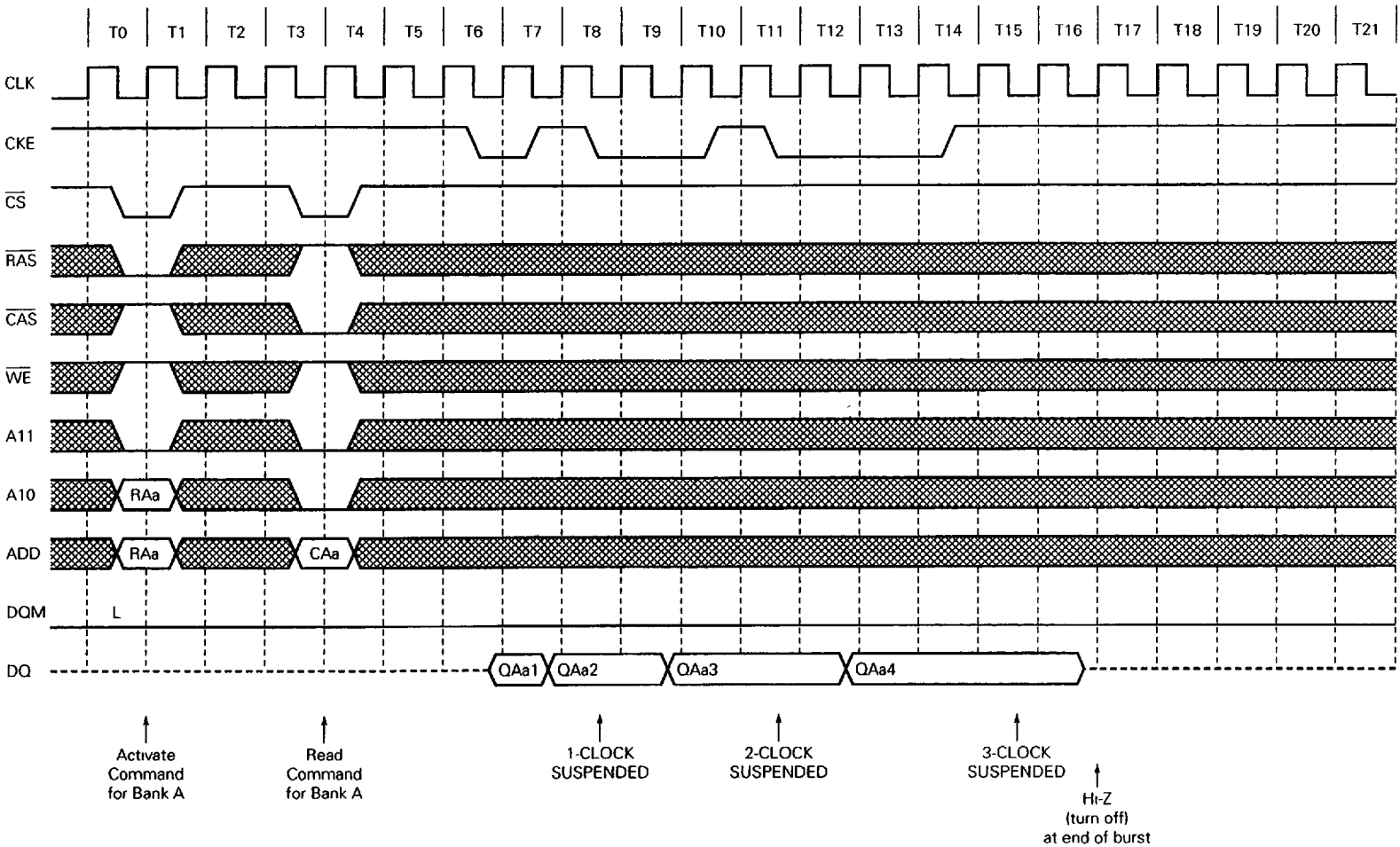
13.7 Clock Suspension during Burst Read (using CKE Function) (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



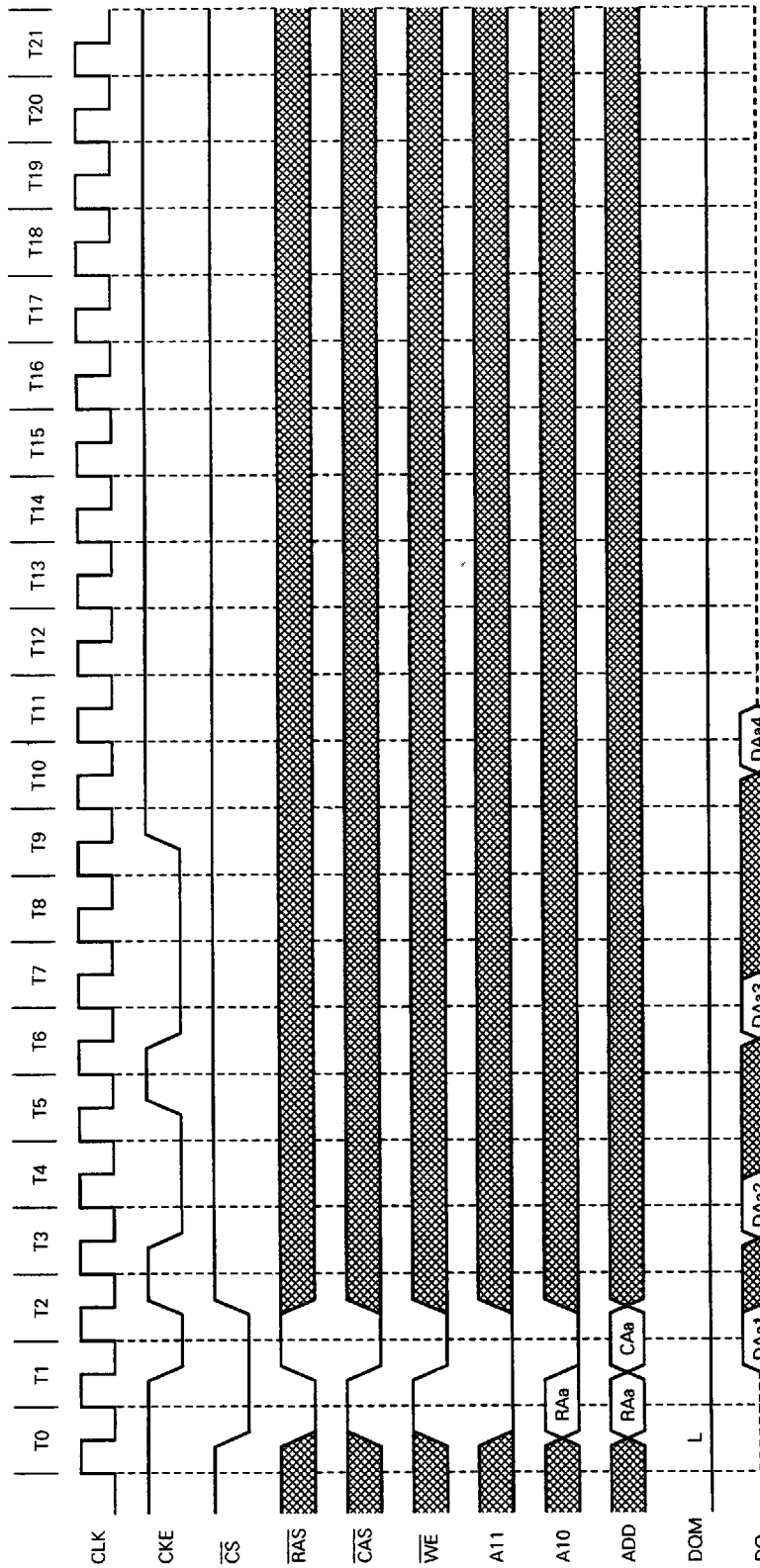
Clock Suspension during Burst Read (using CKE Function) (2/3) (Burst length = 4, $\overline{CAS}$ latency = 2)



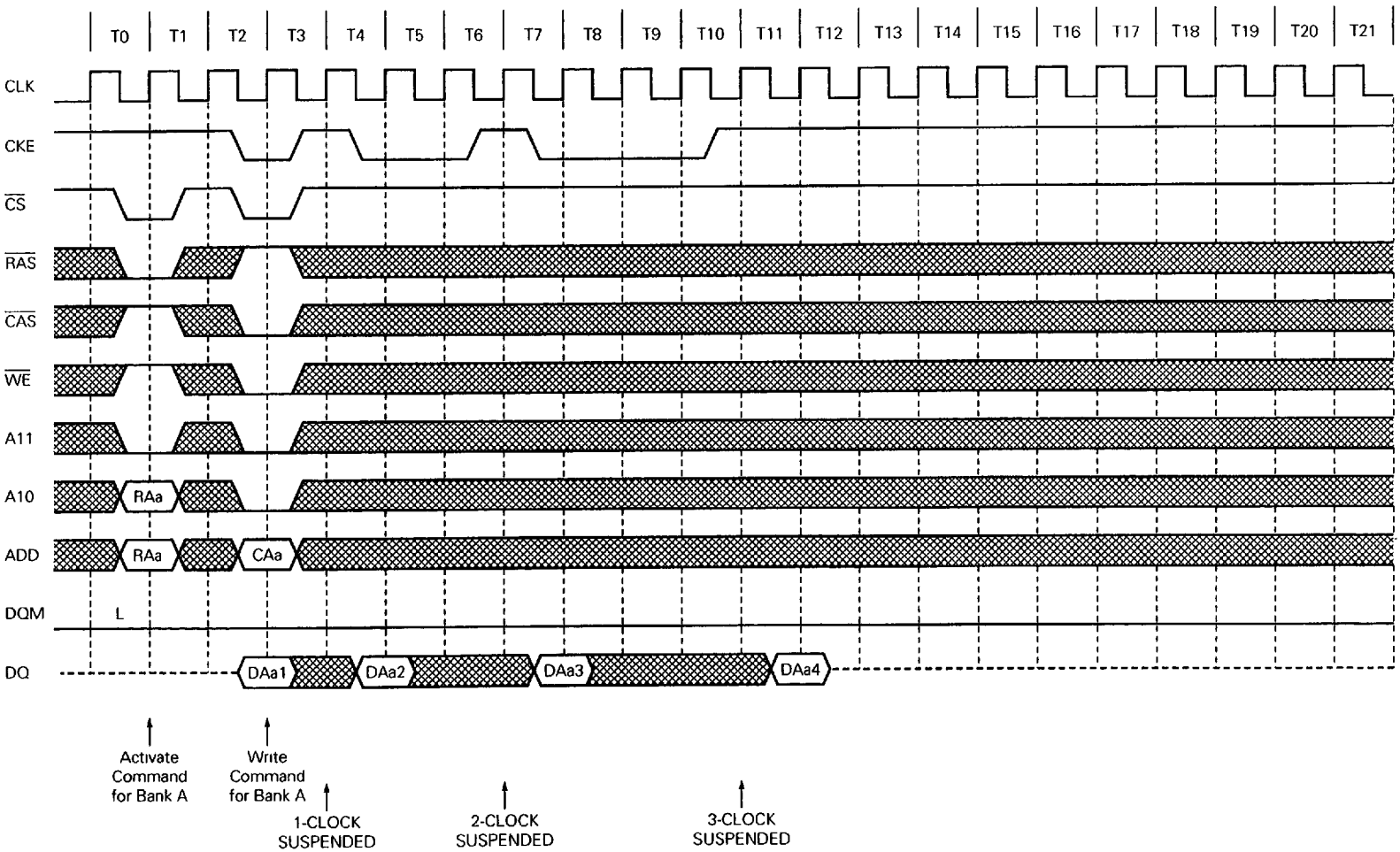
Clock Suspension during Burst Read (using CKE Function) (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



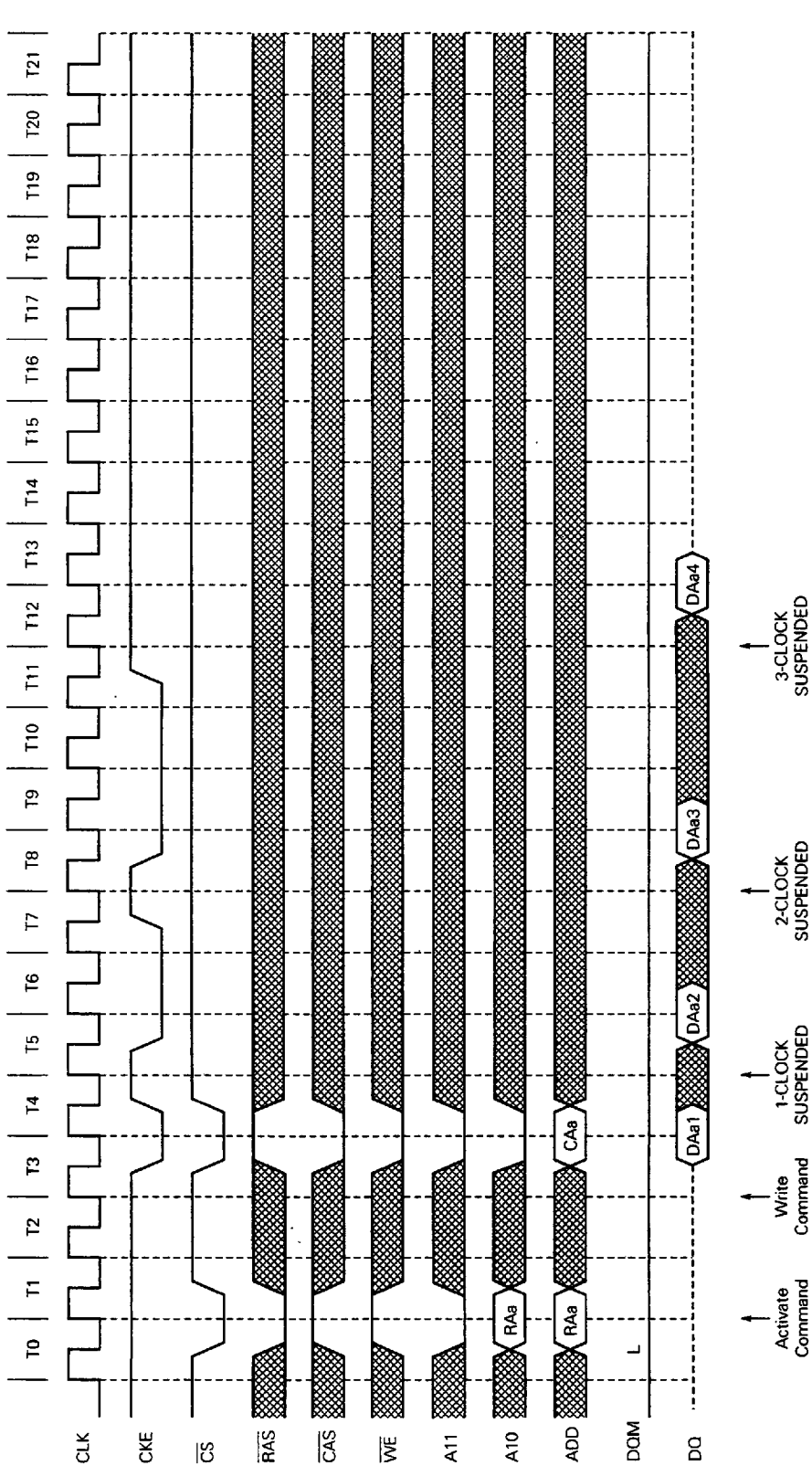
13.8 Clock Suspension during Burst Write (using CKE Function) (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



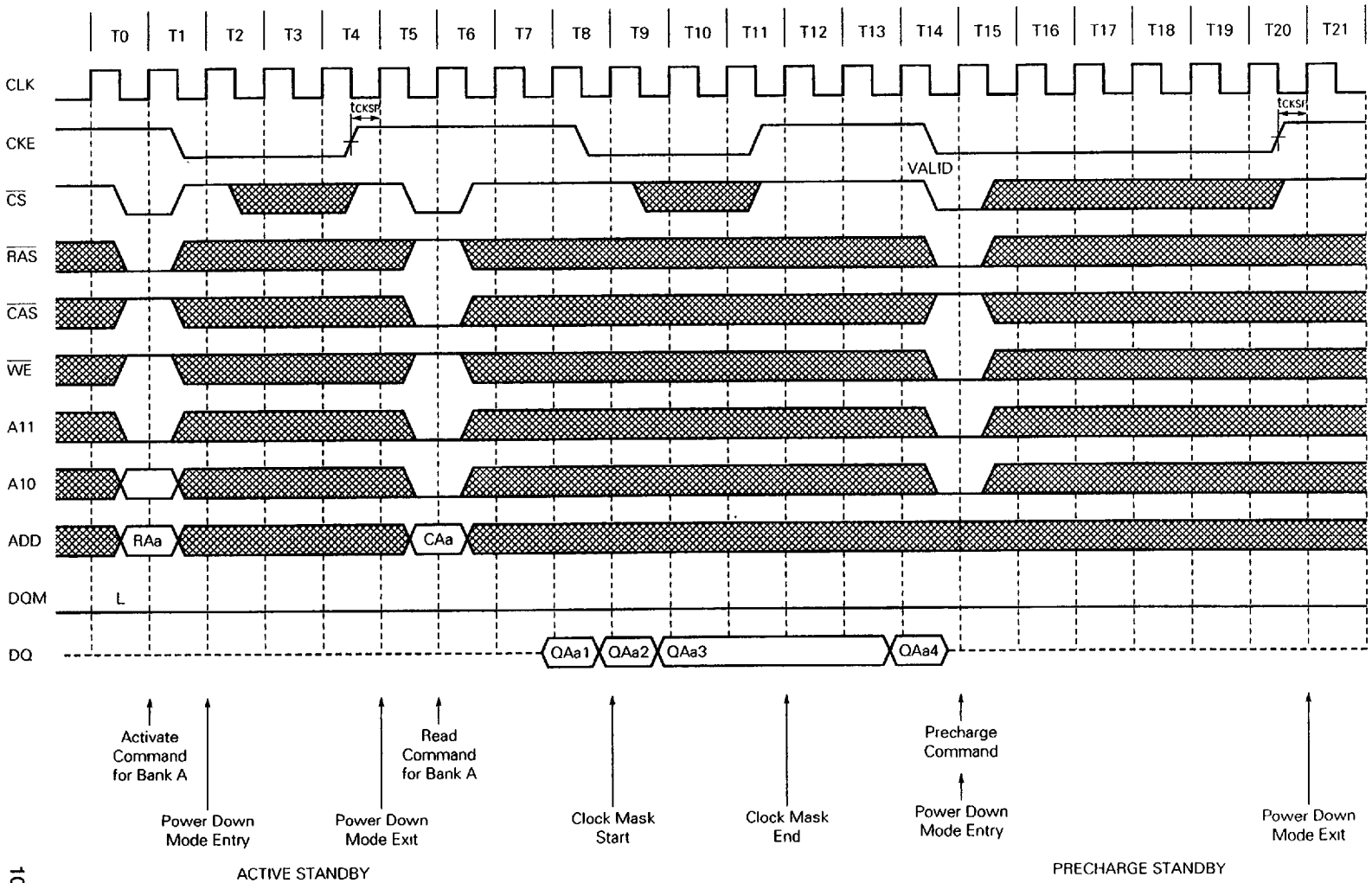
Clock Suspension during Burst Write (using CKE Function) (2/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



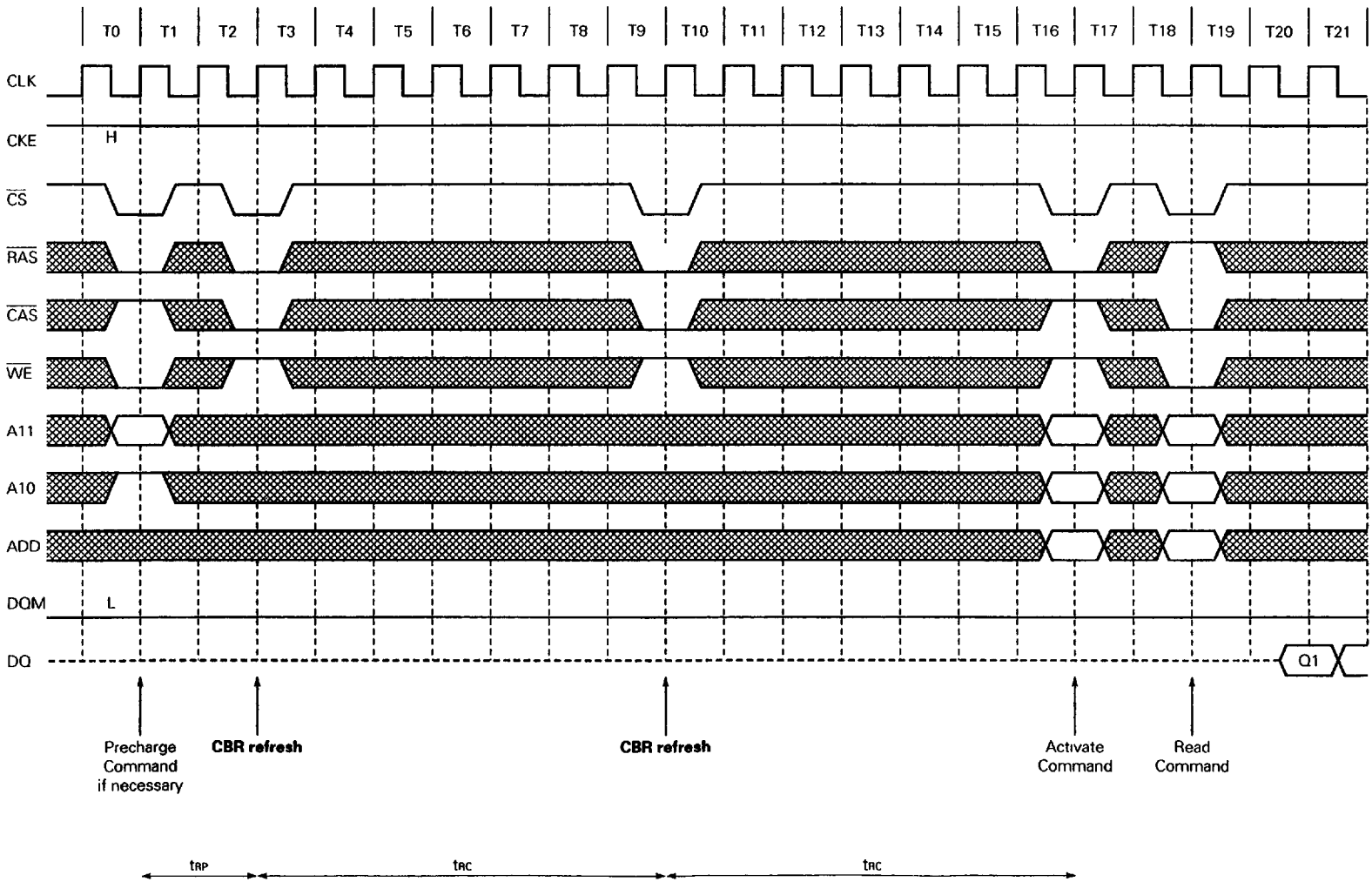
Clock Suspension during Burst Write (using CKE Function) (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



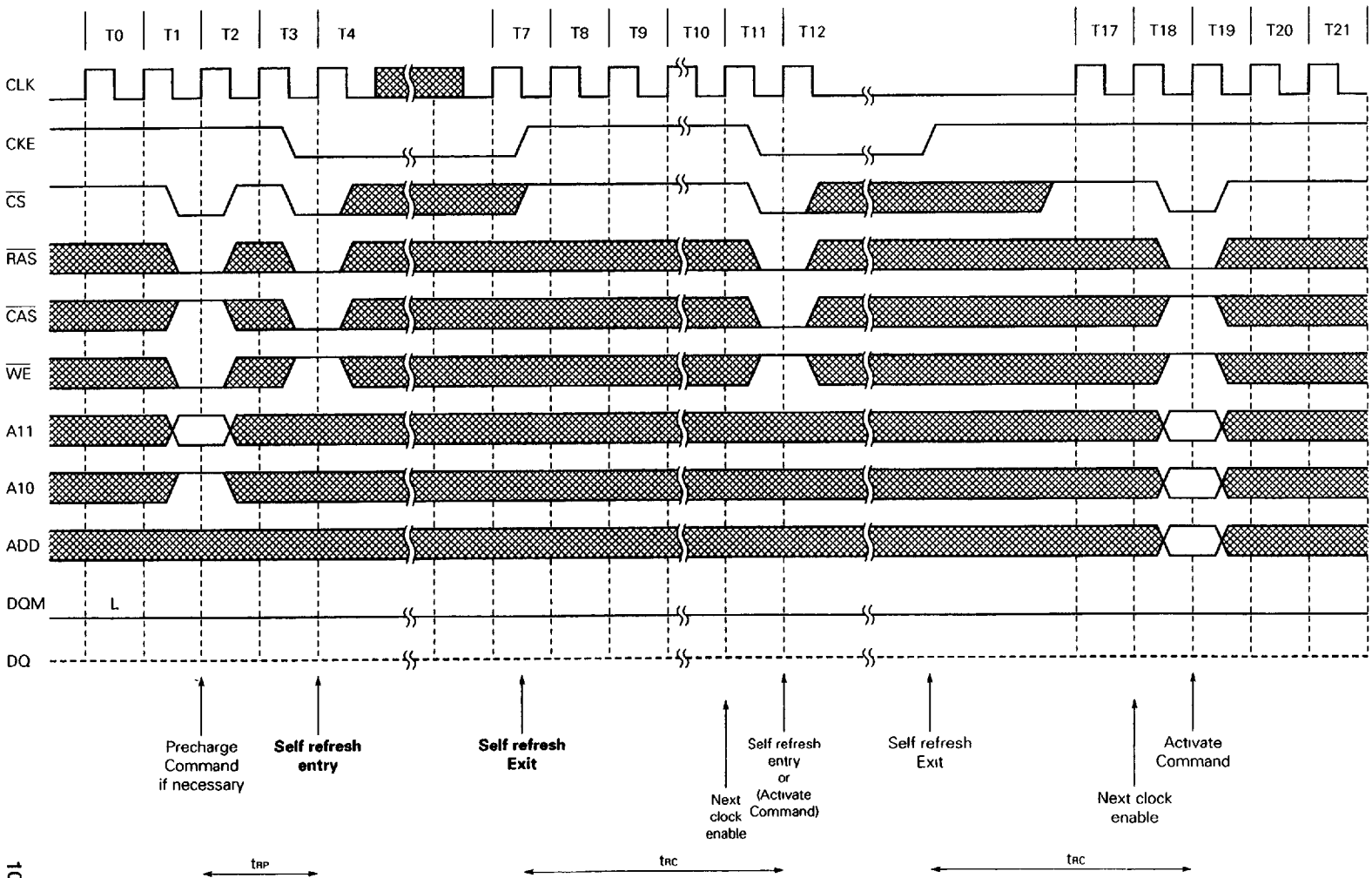
13.9 Power Down Mode and Clock Mask (Burst length = 4, $\overline{CAS}$ latency = 2)



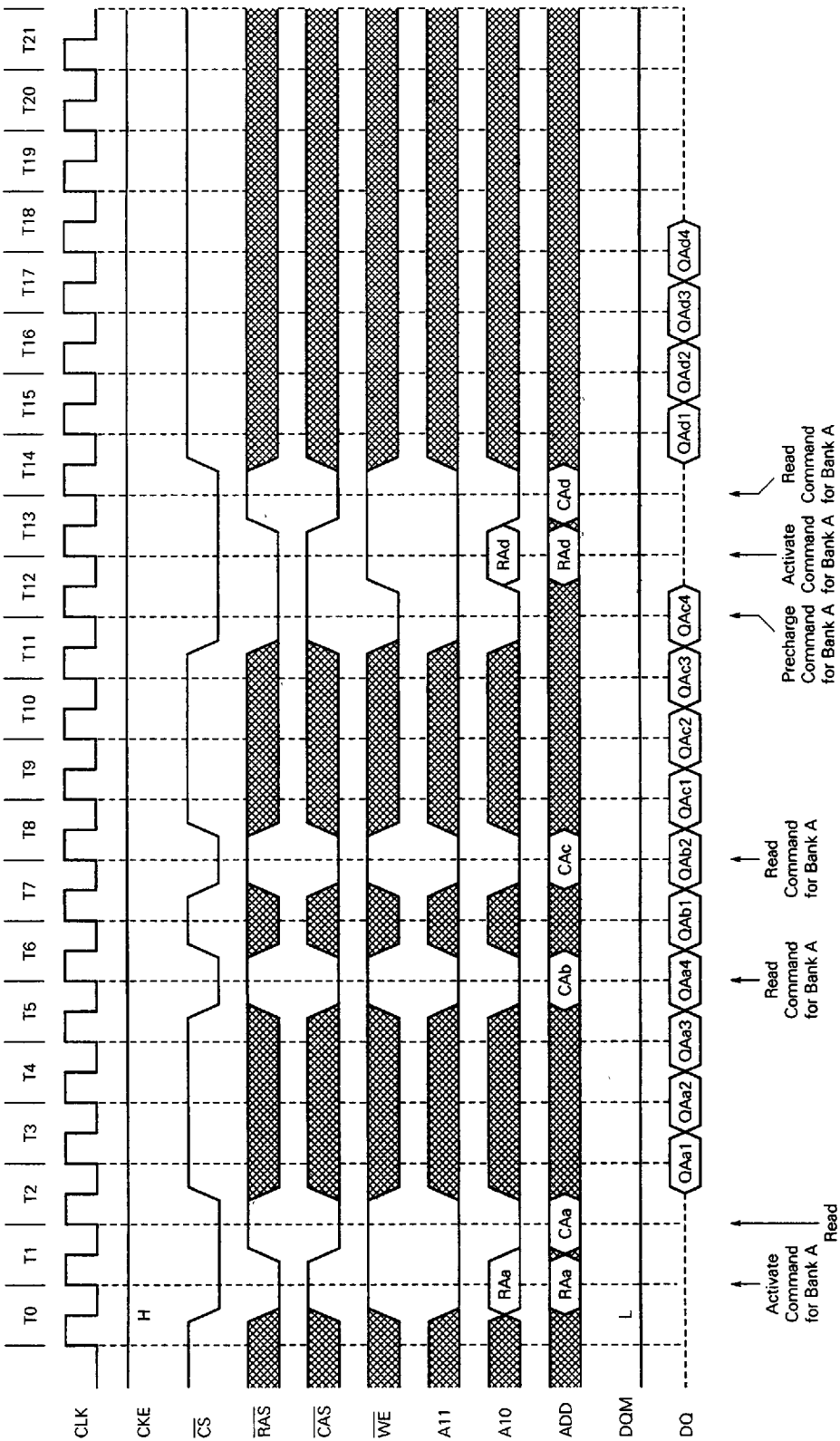
13.10 CBR Refresh



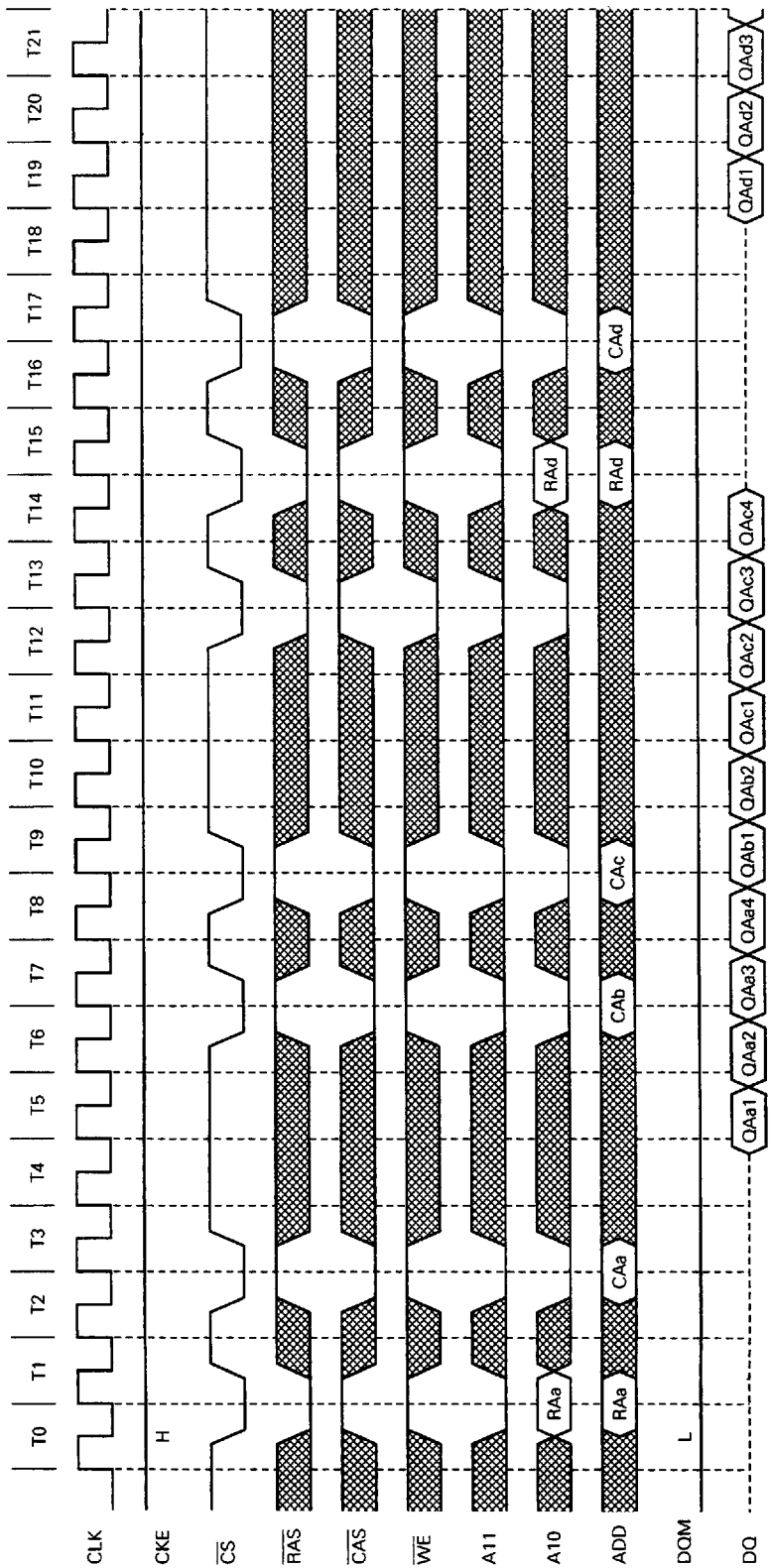
13.11 Self Refresh (entry and exit)



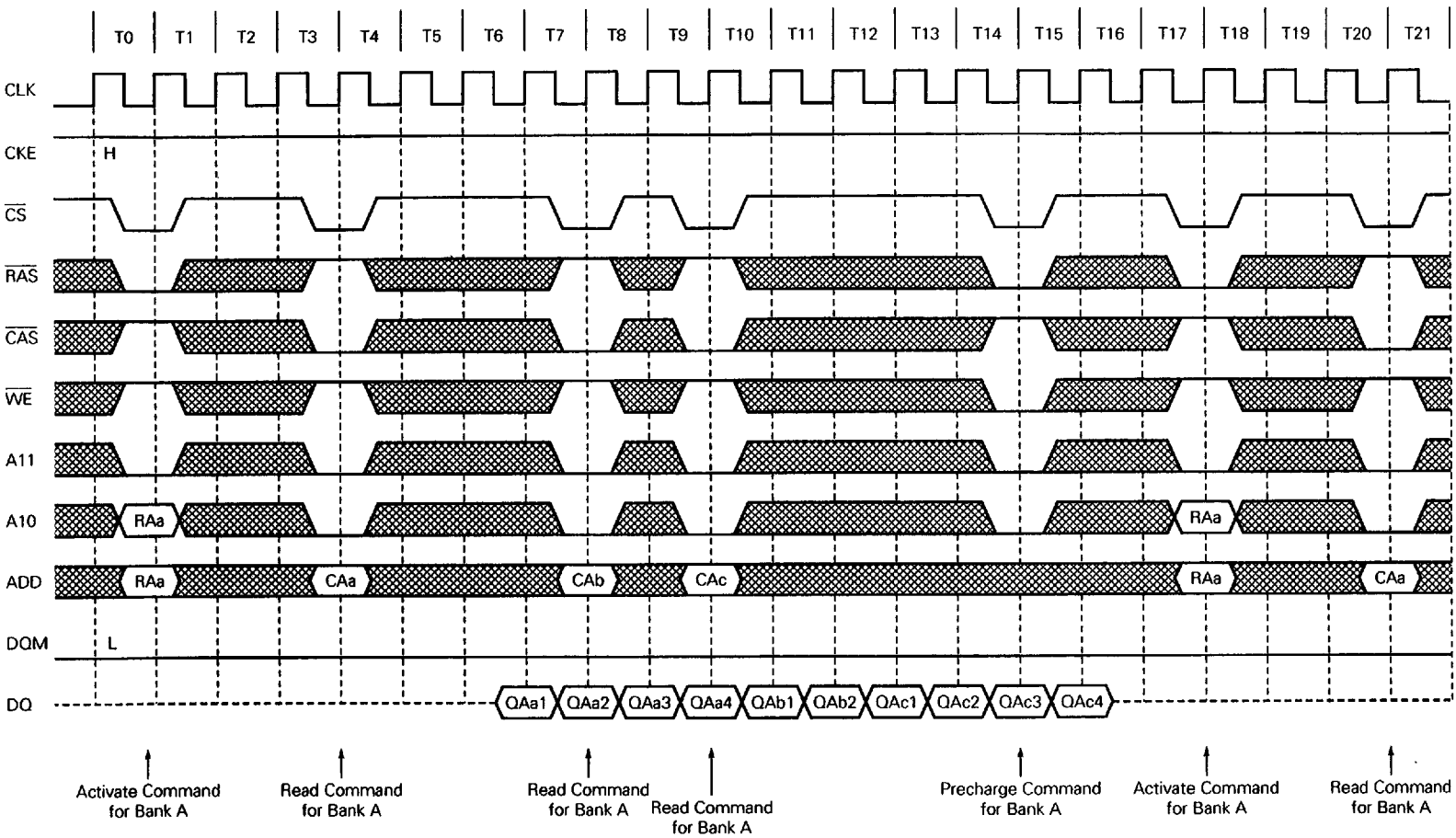
13.12 Random Column Read (Page with same bank) (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



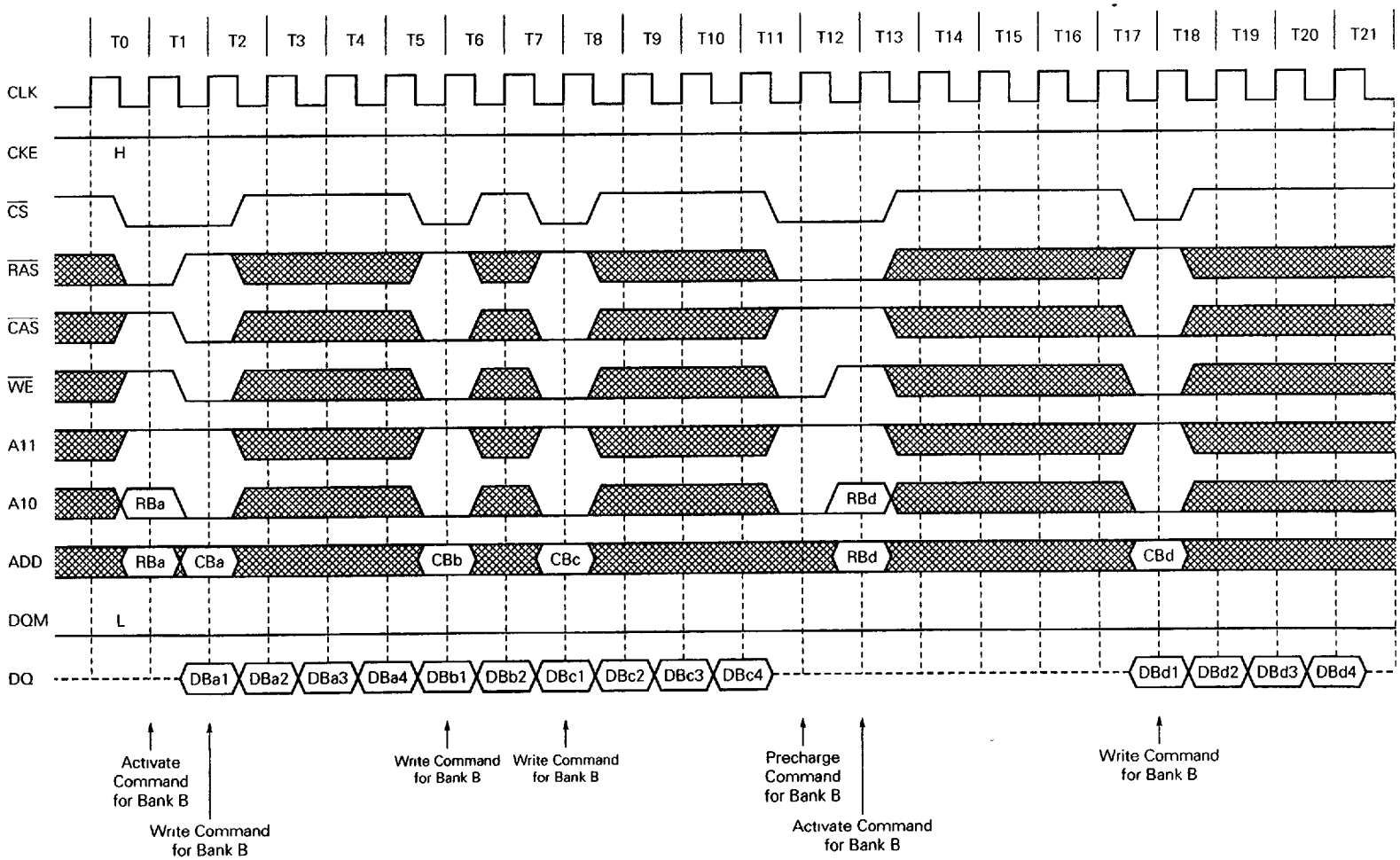
Random Column Read (Page with same bank) (2/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



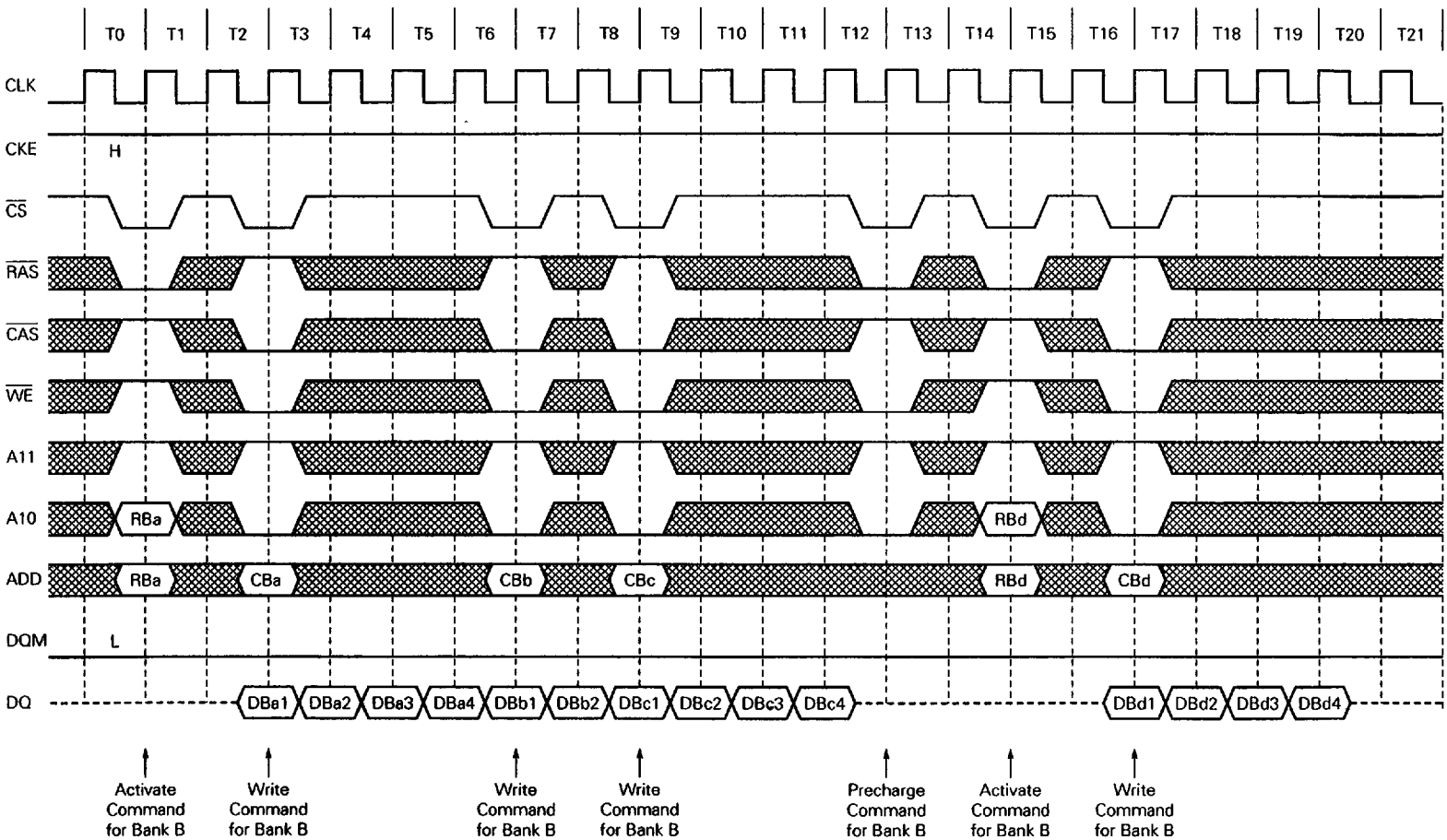
Random Column Read (Page with same bank) (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



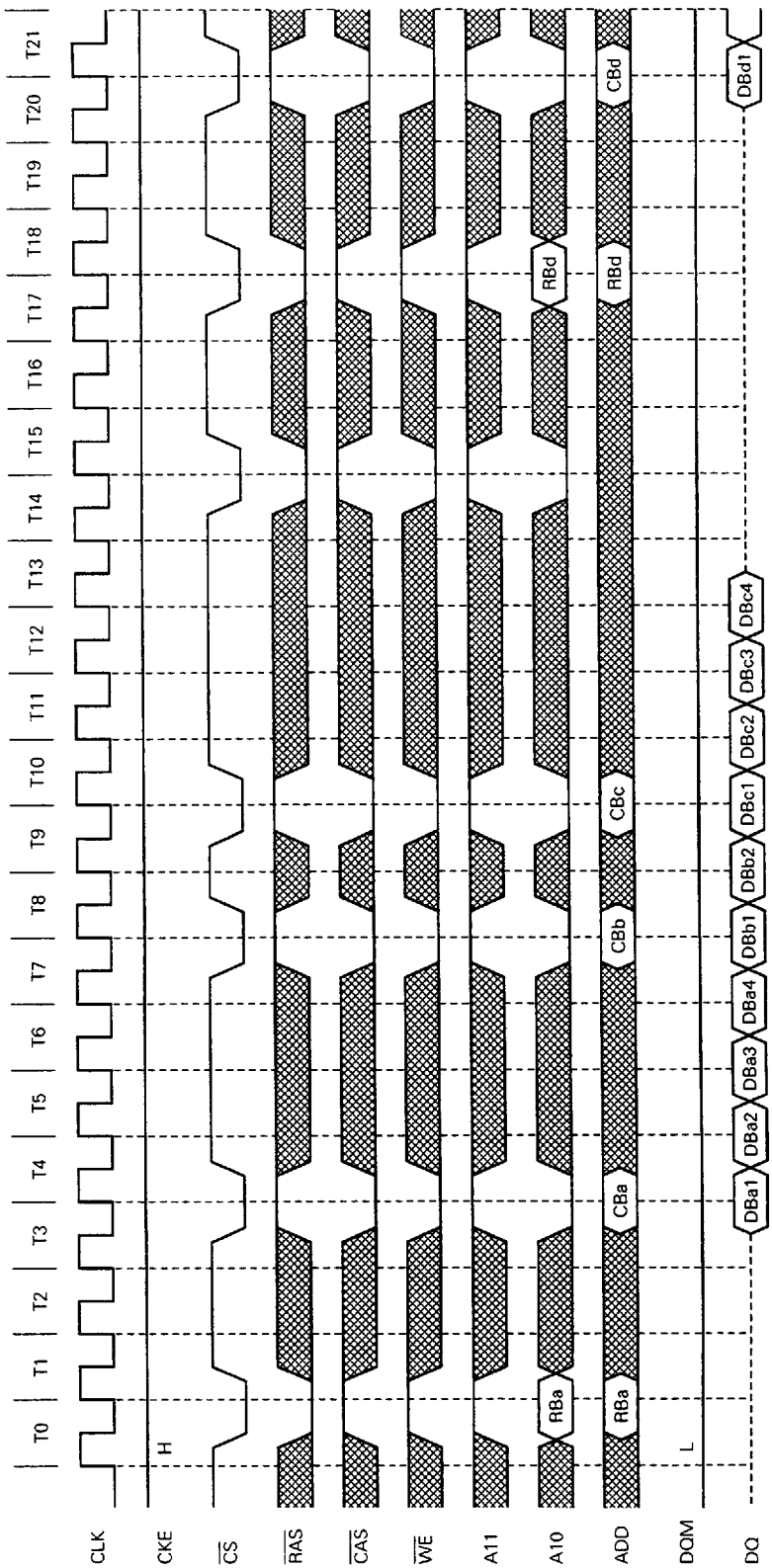
13.13 Random Column Write (Page with same bank) (1/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 1)



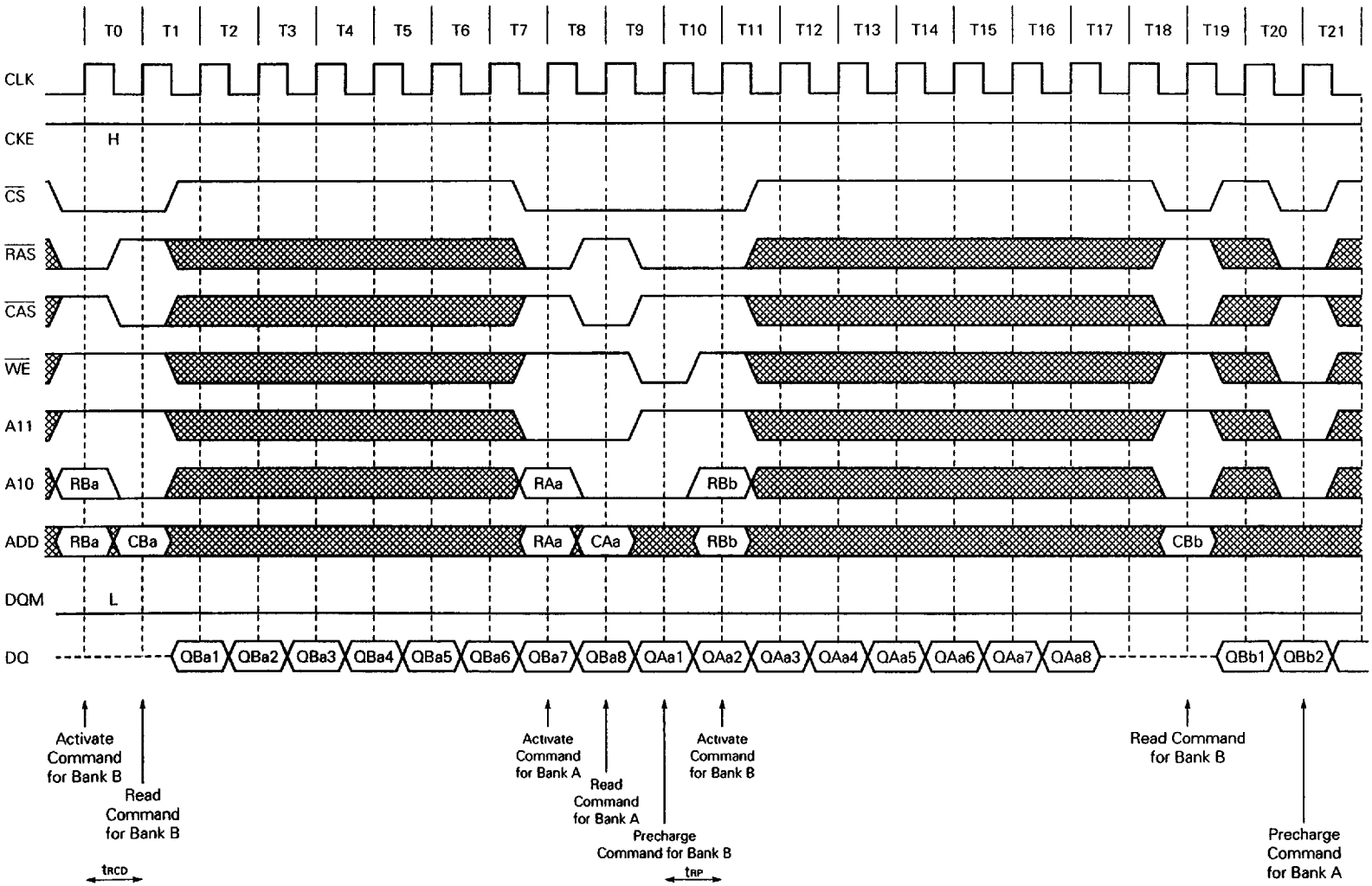
Random Column Write (Page with same bank) (2/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



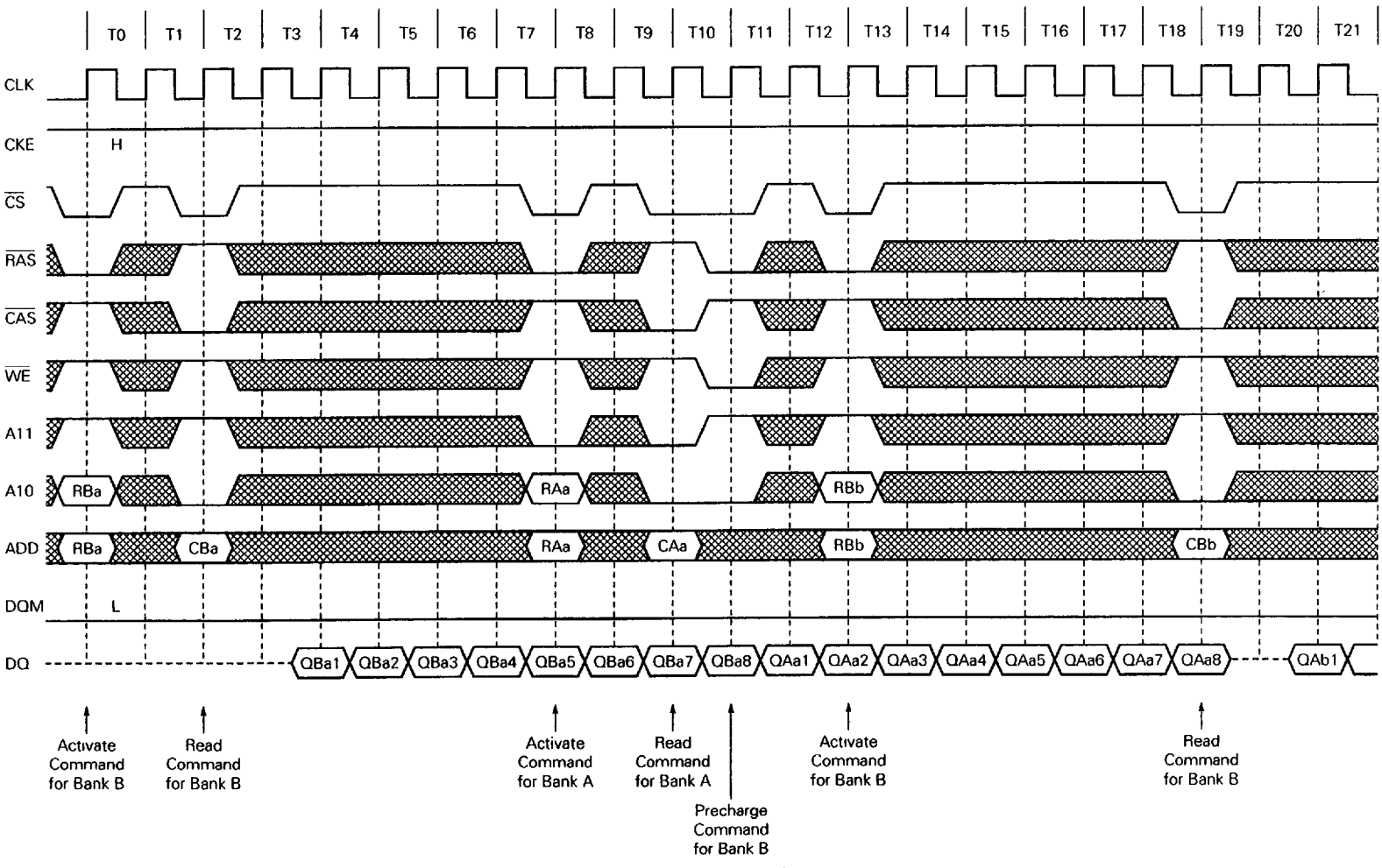
Random Column Write (Page with same bank) (3/3) (Burst length = 4, $\overline{CAS}$ latency = 3)



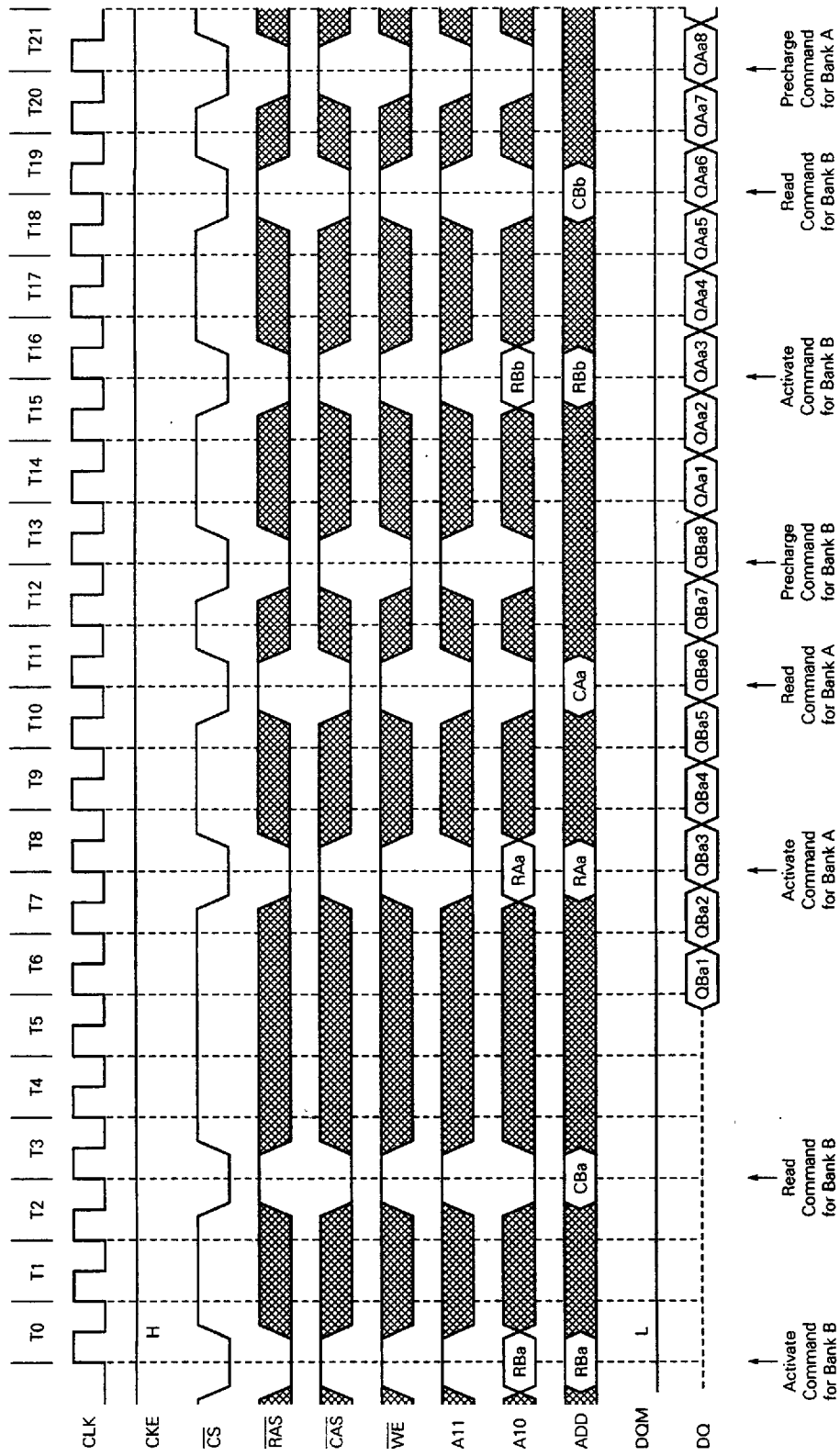
13.14 Random Row READ (Pingpong banks) (1/3) (Burst length = 8, $\overline{CAS}$ latency = 1)



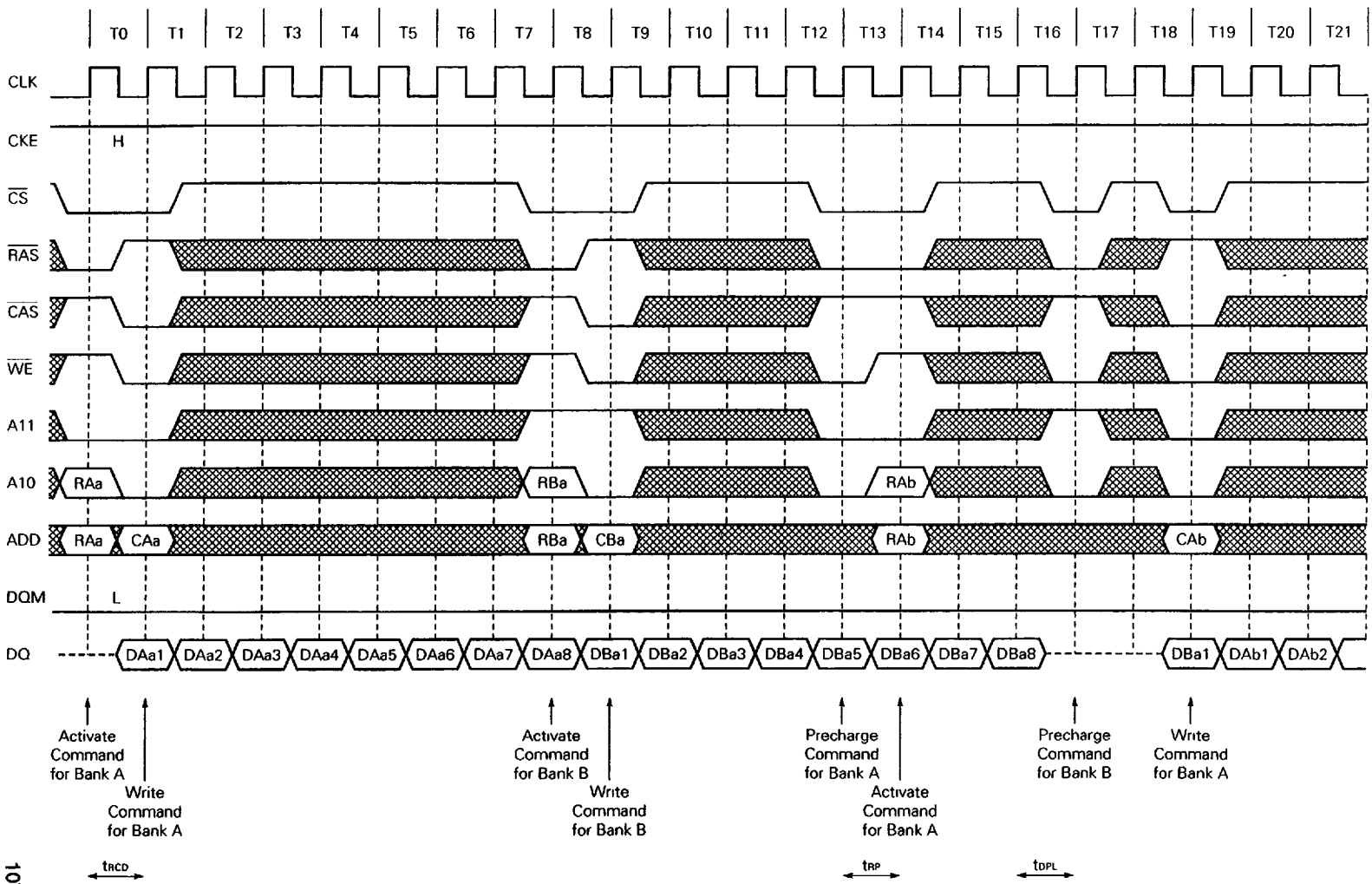
Random Row READ (Pingpong banks) (2/3) (Burst length = 8, $\overline{CAS}$ latency = 2)



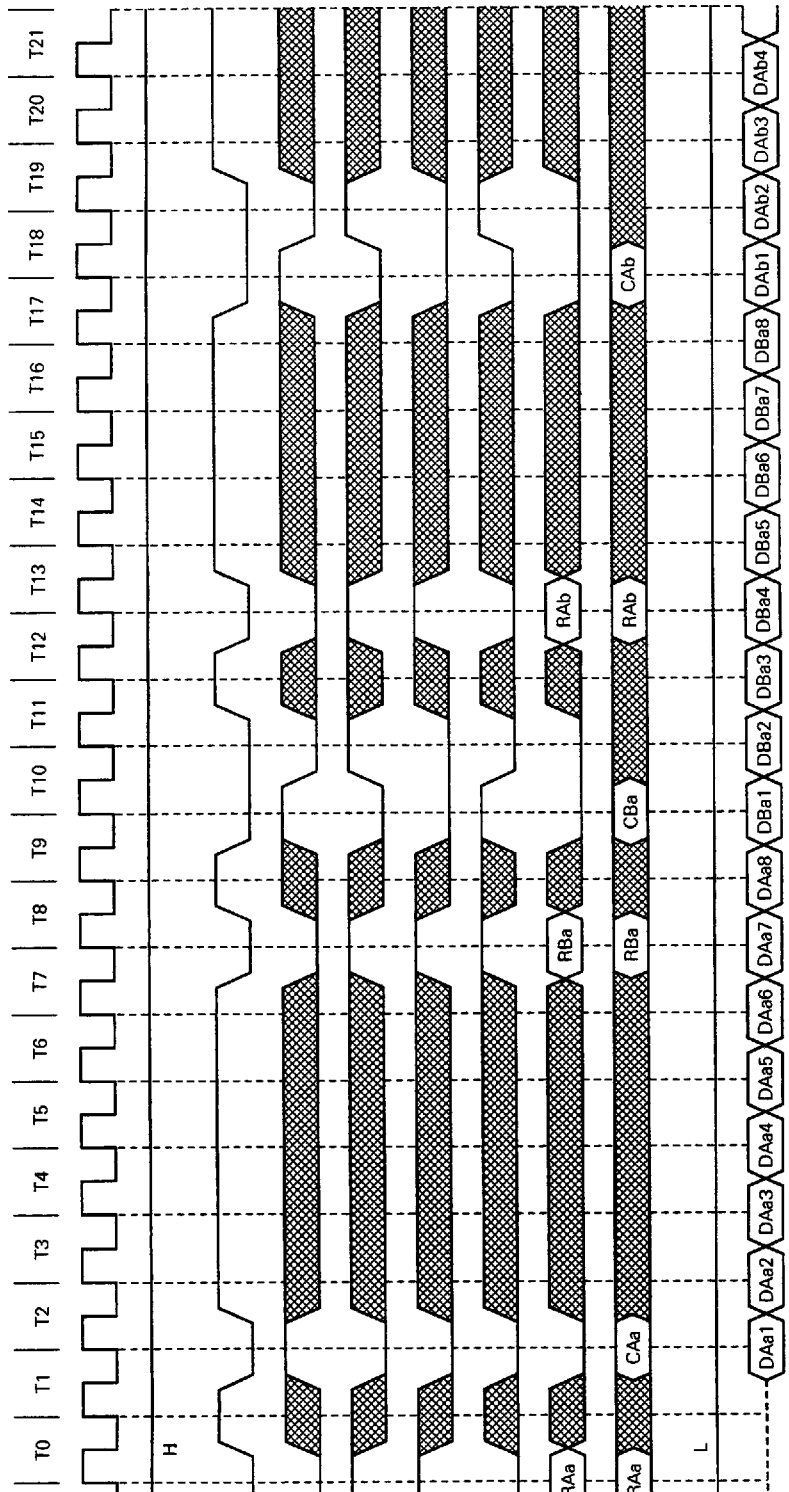
Random Row READ (Pingpong banks) (3/3) (Burst length = 8, $\overline{CAS}$ latency = 3)



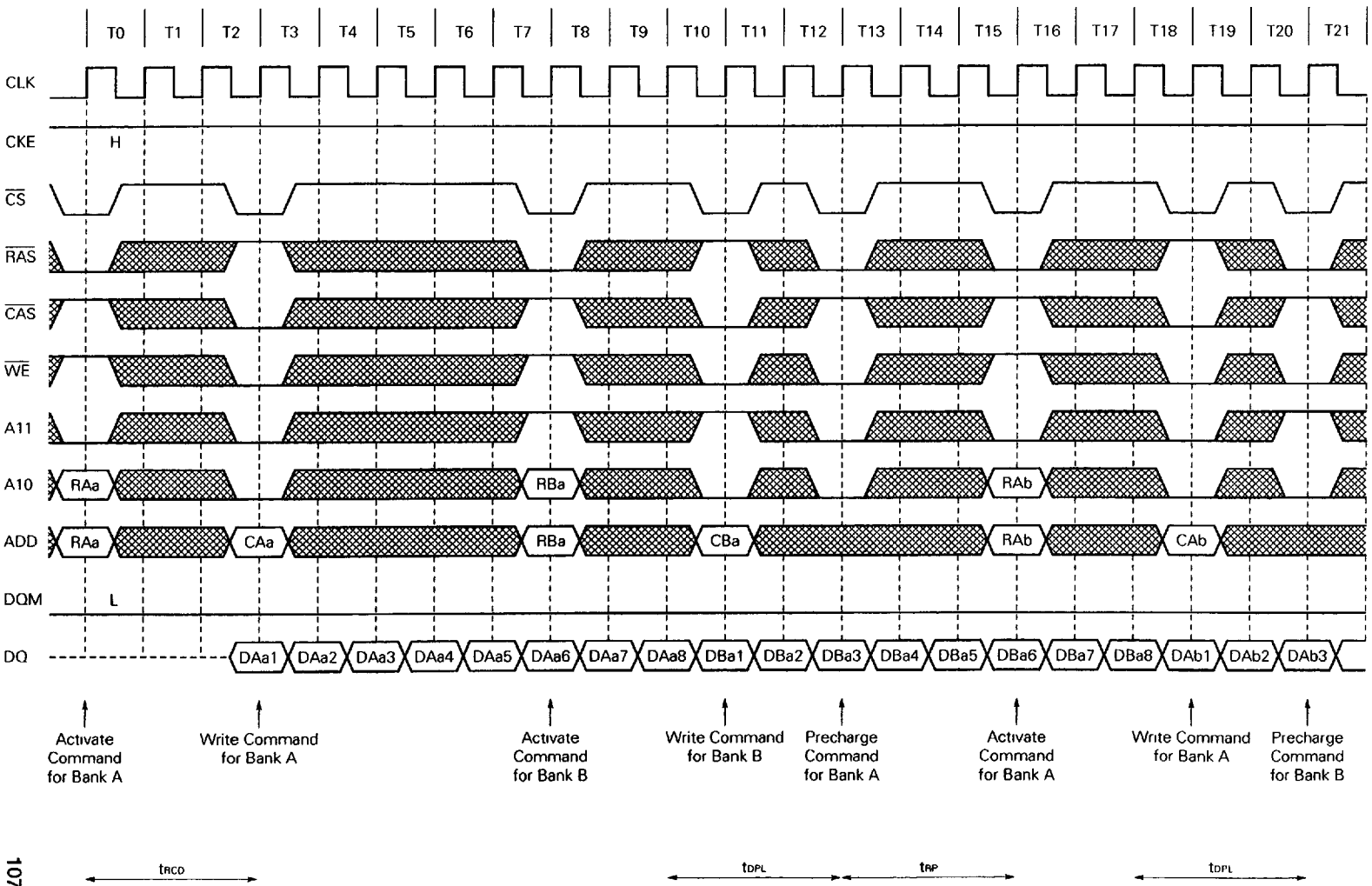
13.15 Random Row Write (Pingpong banks) (1/3) (Burst length = 8, $\overline{CAS}$ latency = 1)



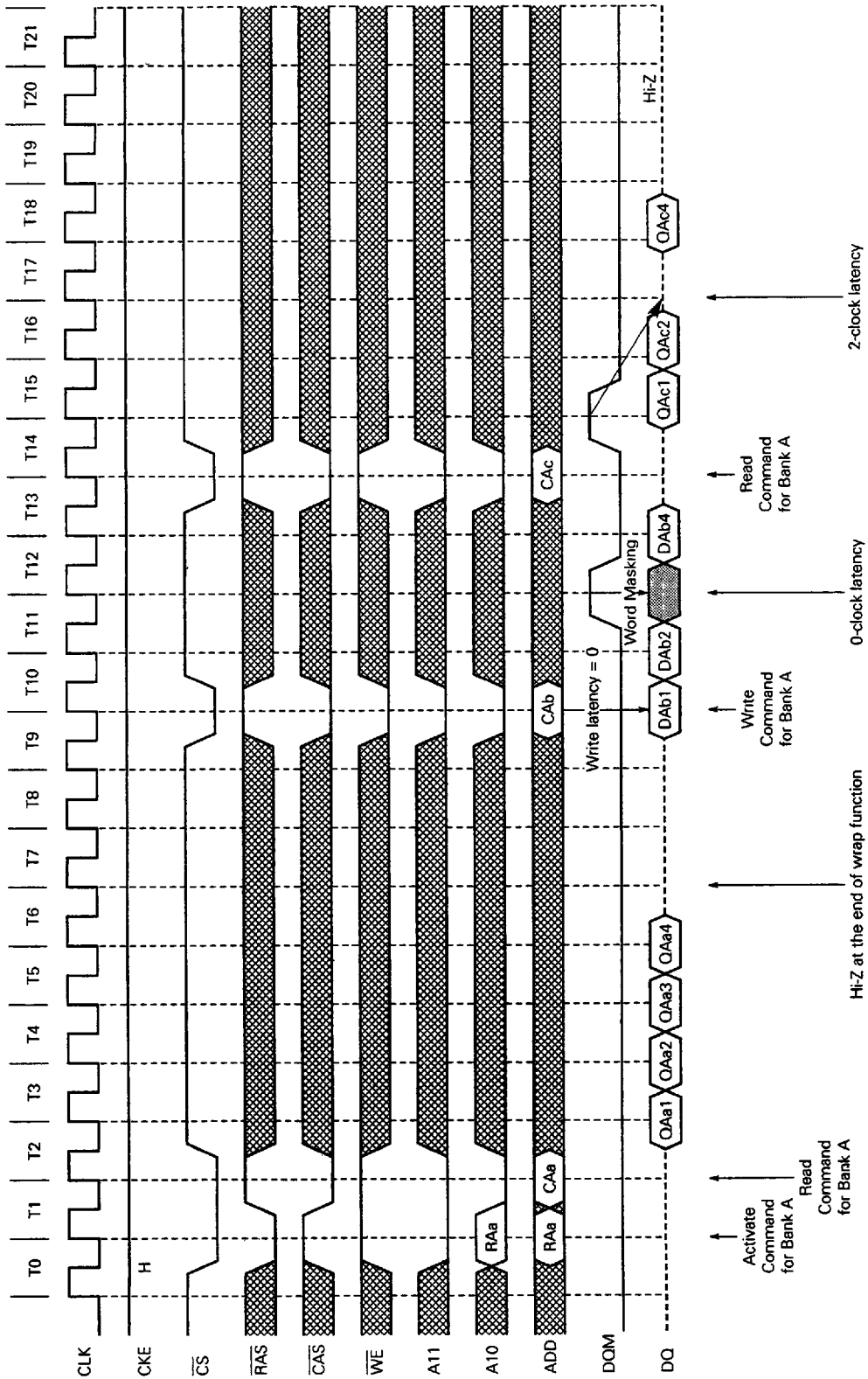
Random Row Write (Pingpong banks) (2/3) (Burst length = 8, $\overline{CAS}$ latency = 2)



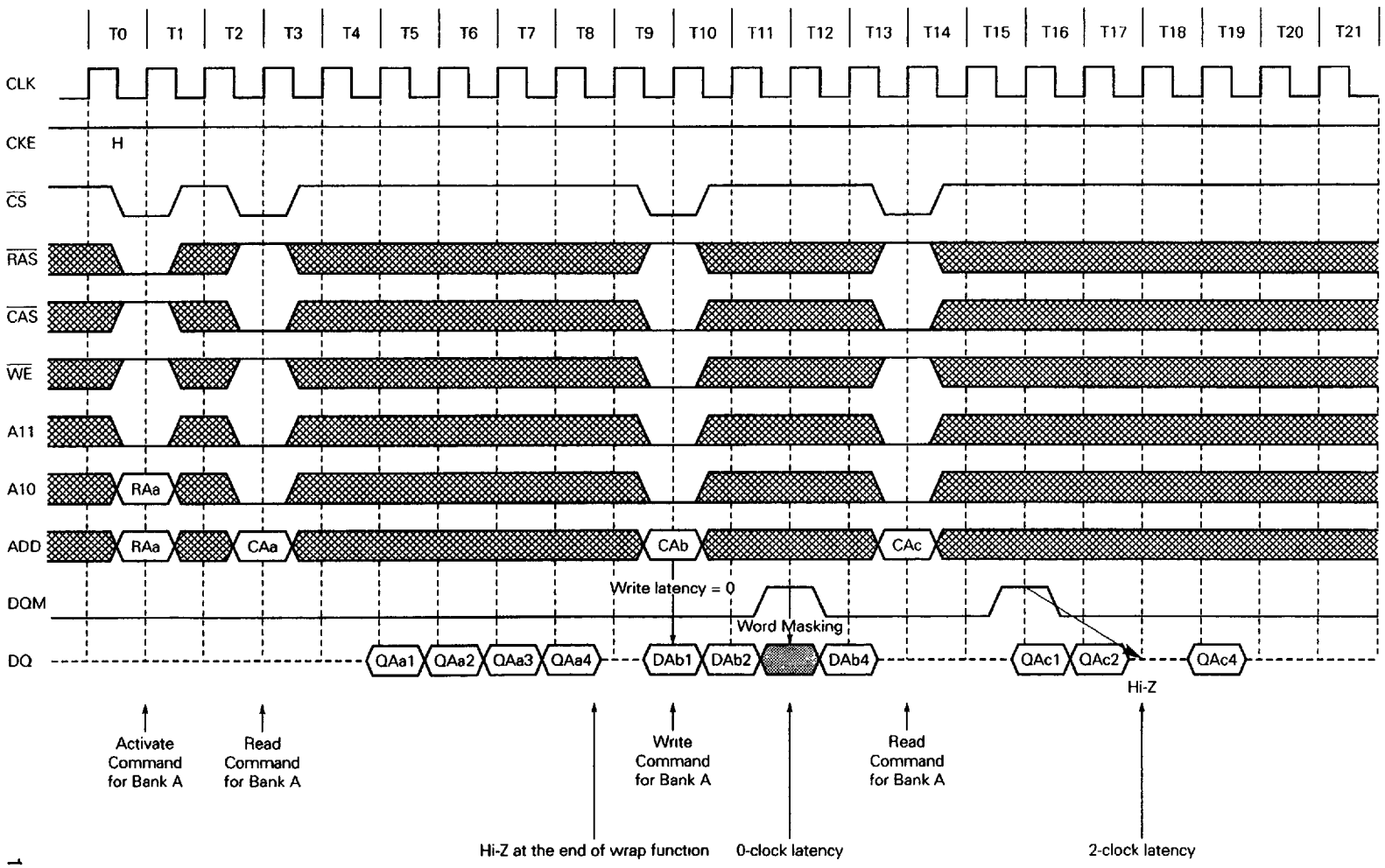
Random Row Write (Pingpong banks) (3/3) (Burst length = 8, $\overline{CAS}$ latency = 3)



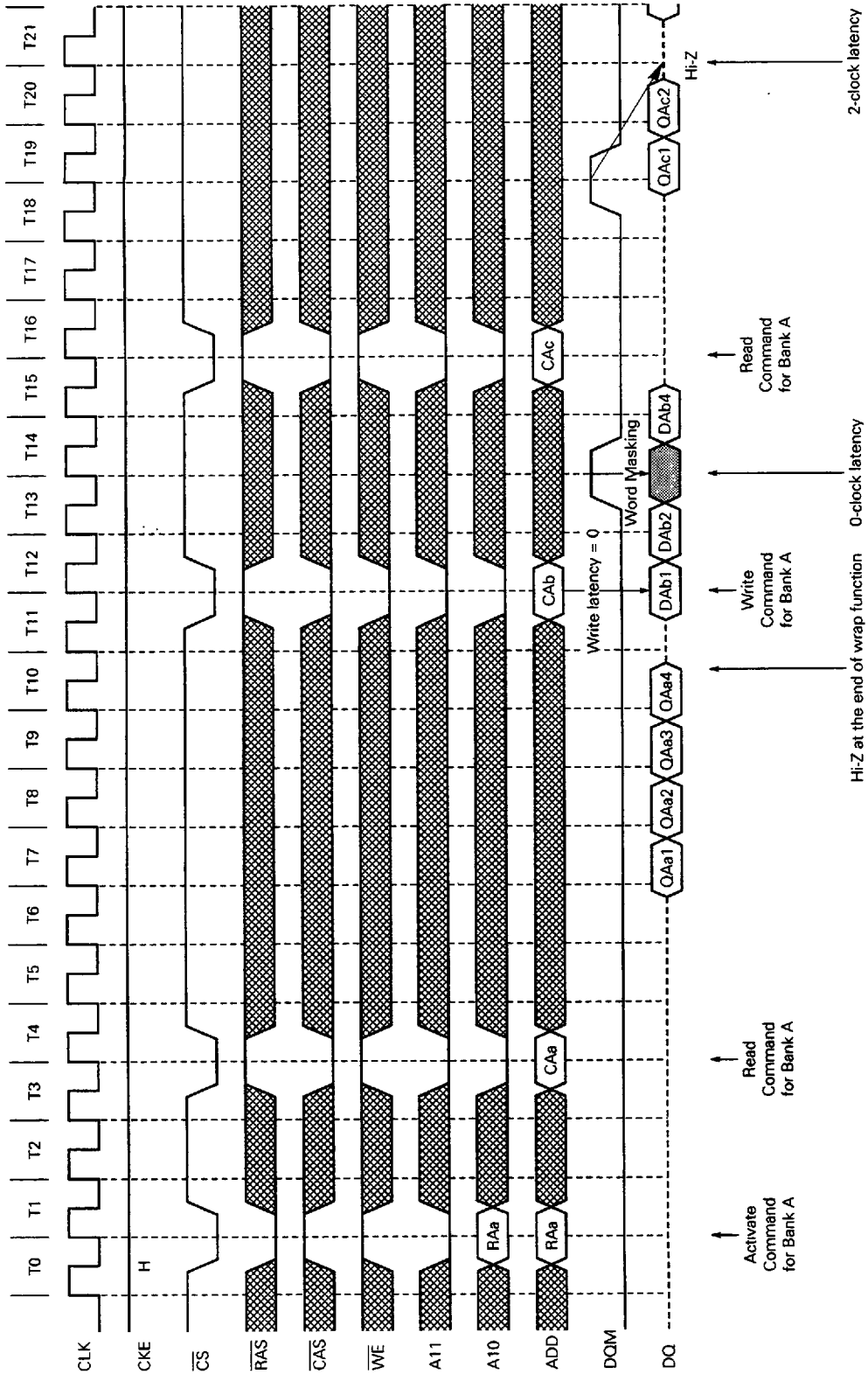
13.16 READ and WRITE (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



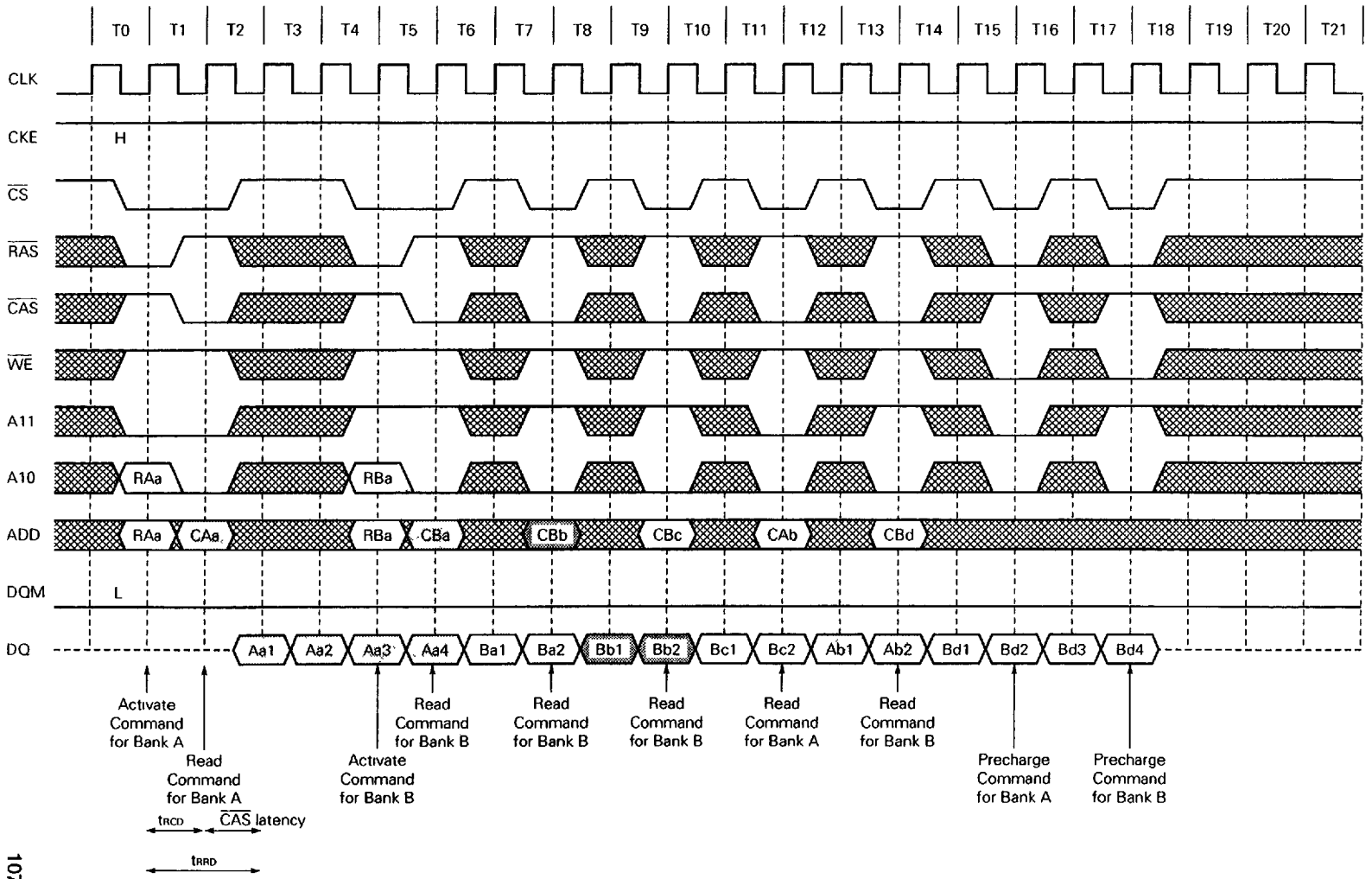
READ and WRITE (2/3) (Burst length = 4, $\overline{CAS}$ latency = 2)



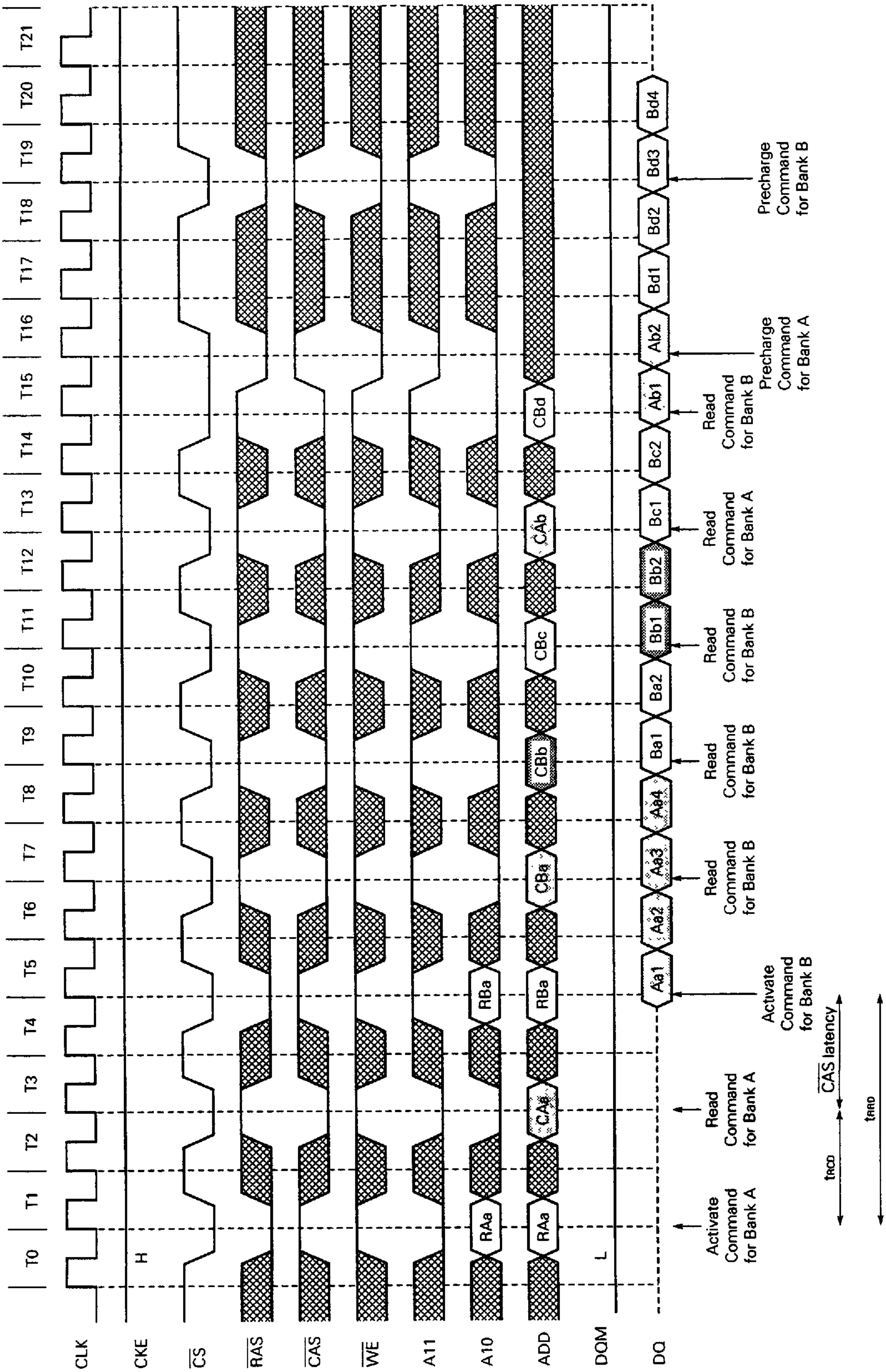
READ and WRITE (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



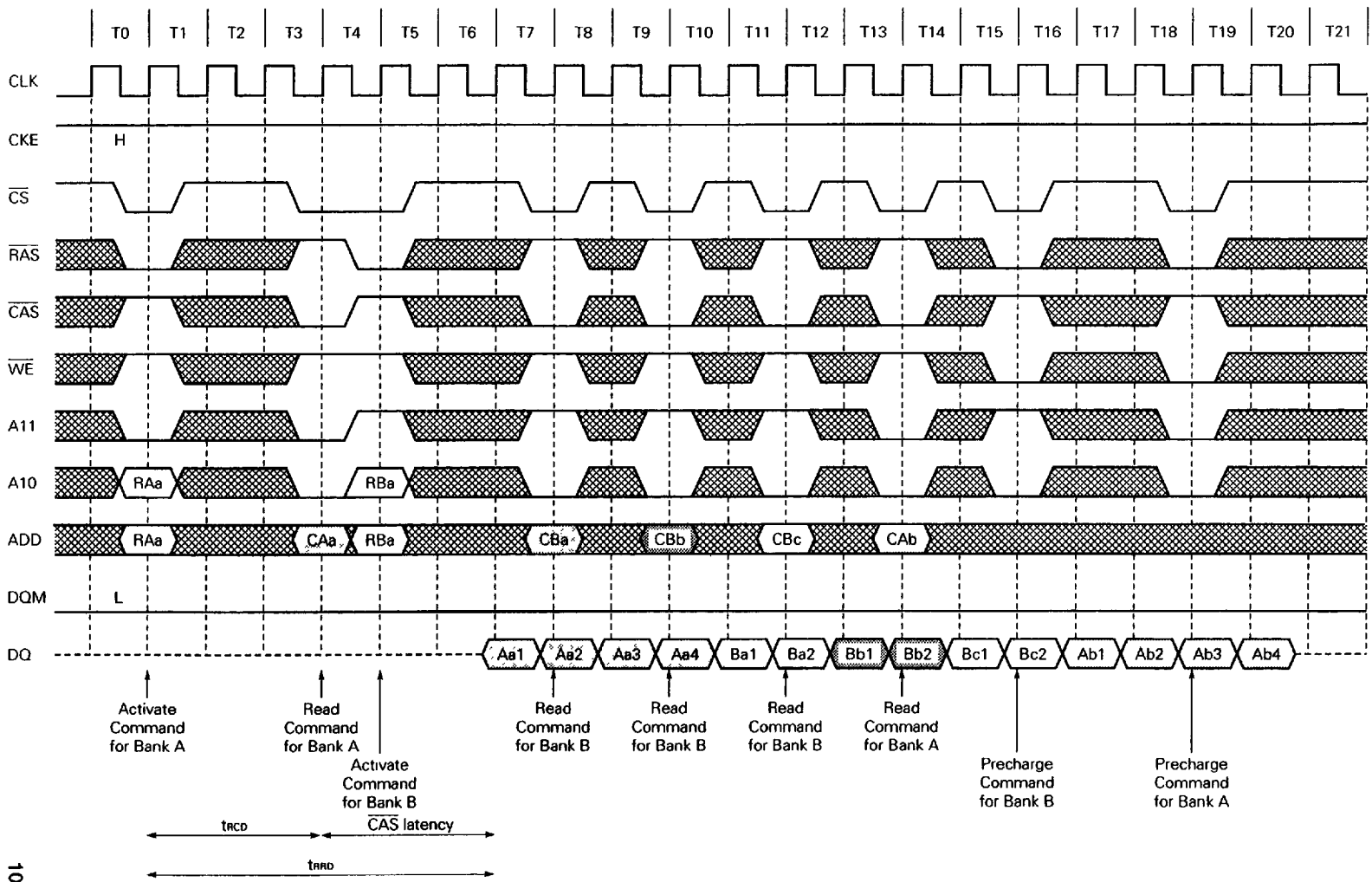
13.17 Interleaved Column READ Cycle (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



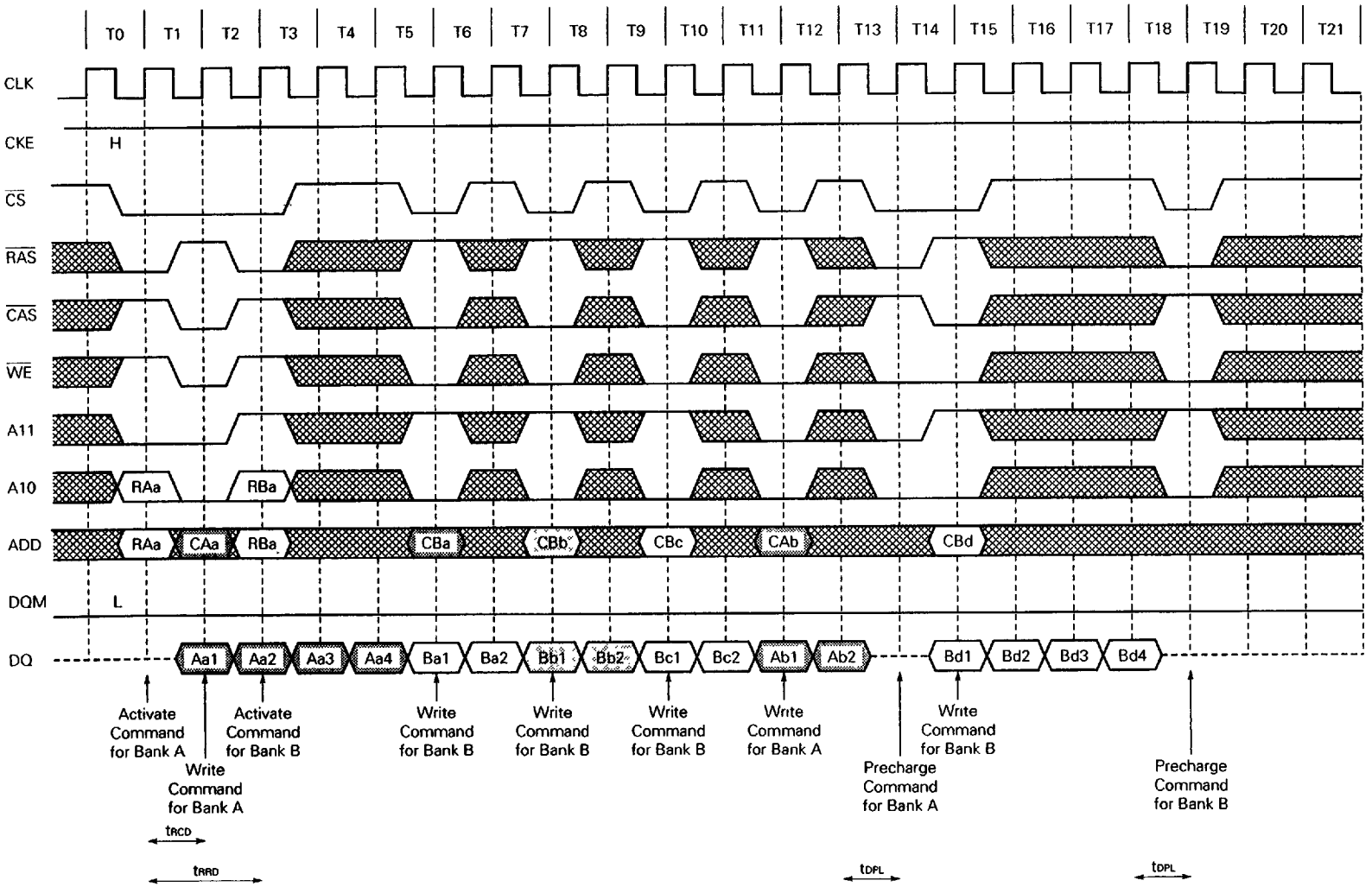
Interleaved Column READ Cycle (2/3) (Burst length = 4, $\overline{CAS}$ latency = 2)



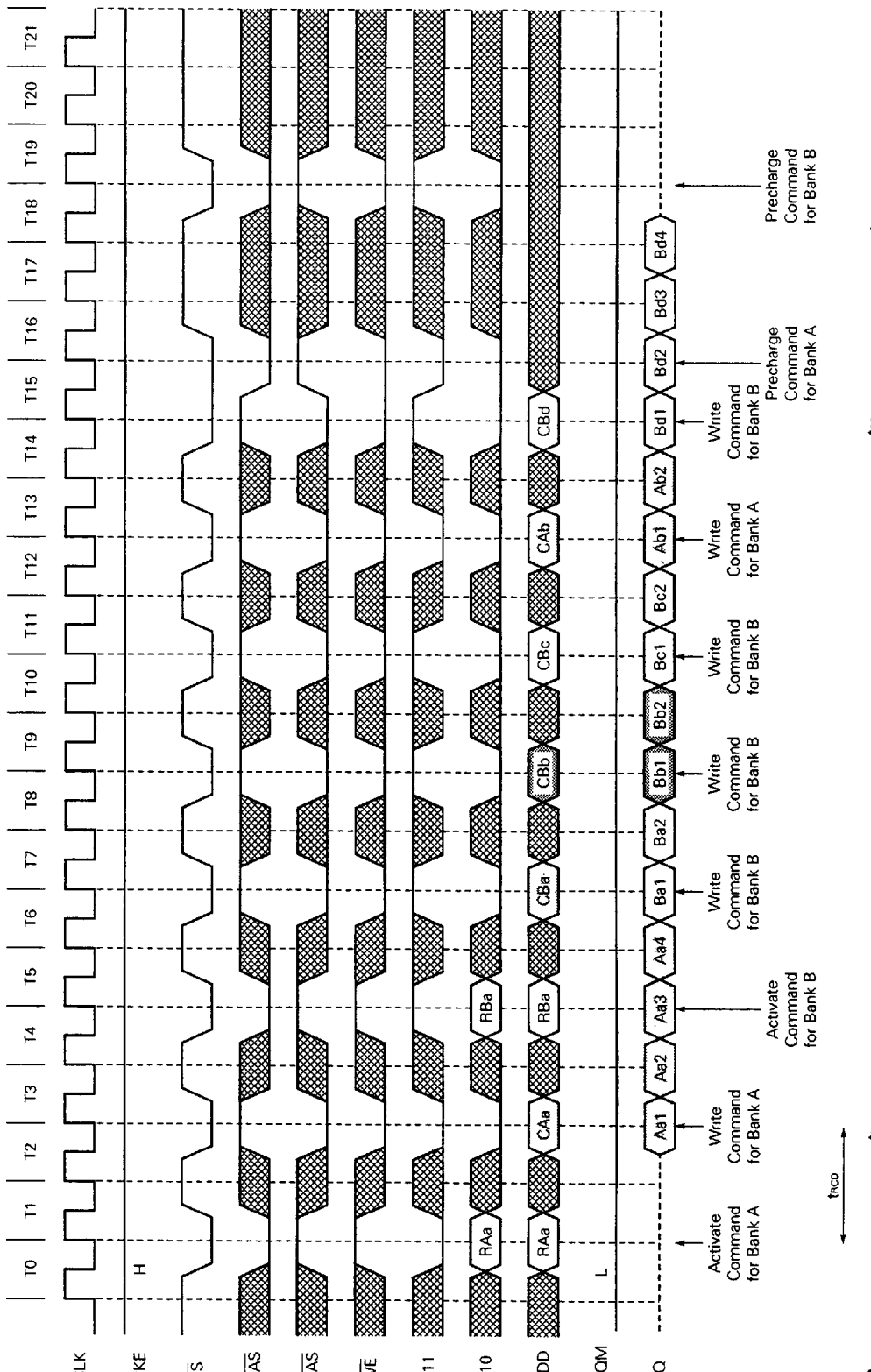
Interleaved Column READ Cycle (3/3) (Burst length = 4, $\overline{CAS}$ latency = 3)



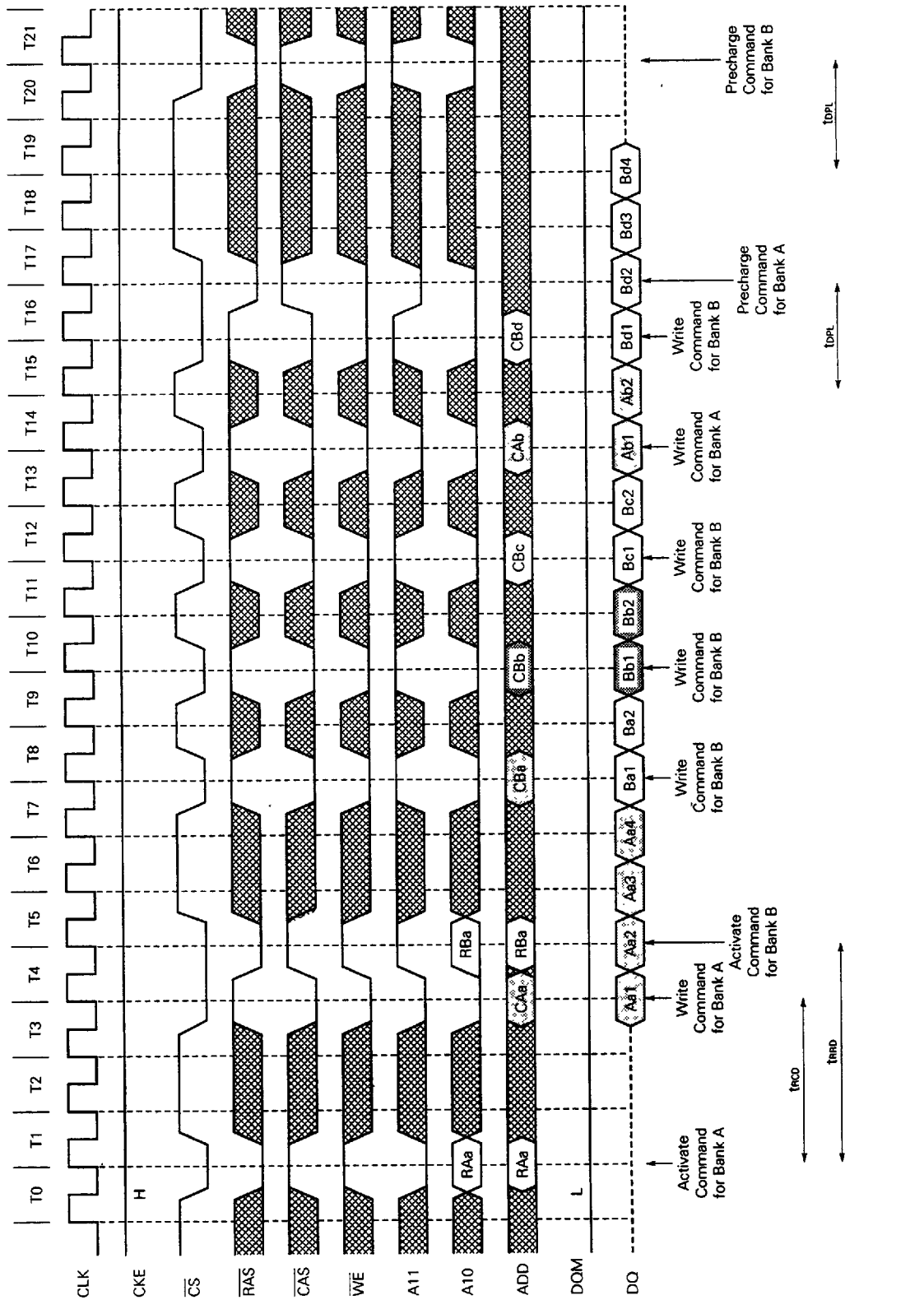
13.18 Interleaved Column WRITE Cycle (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



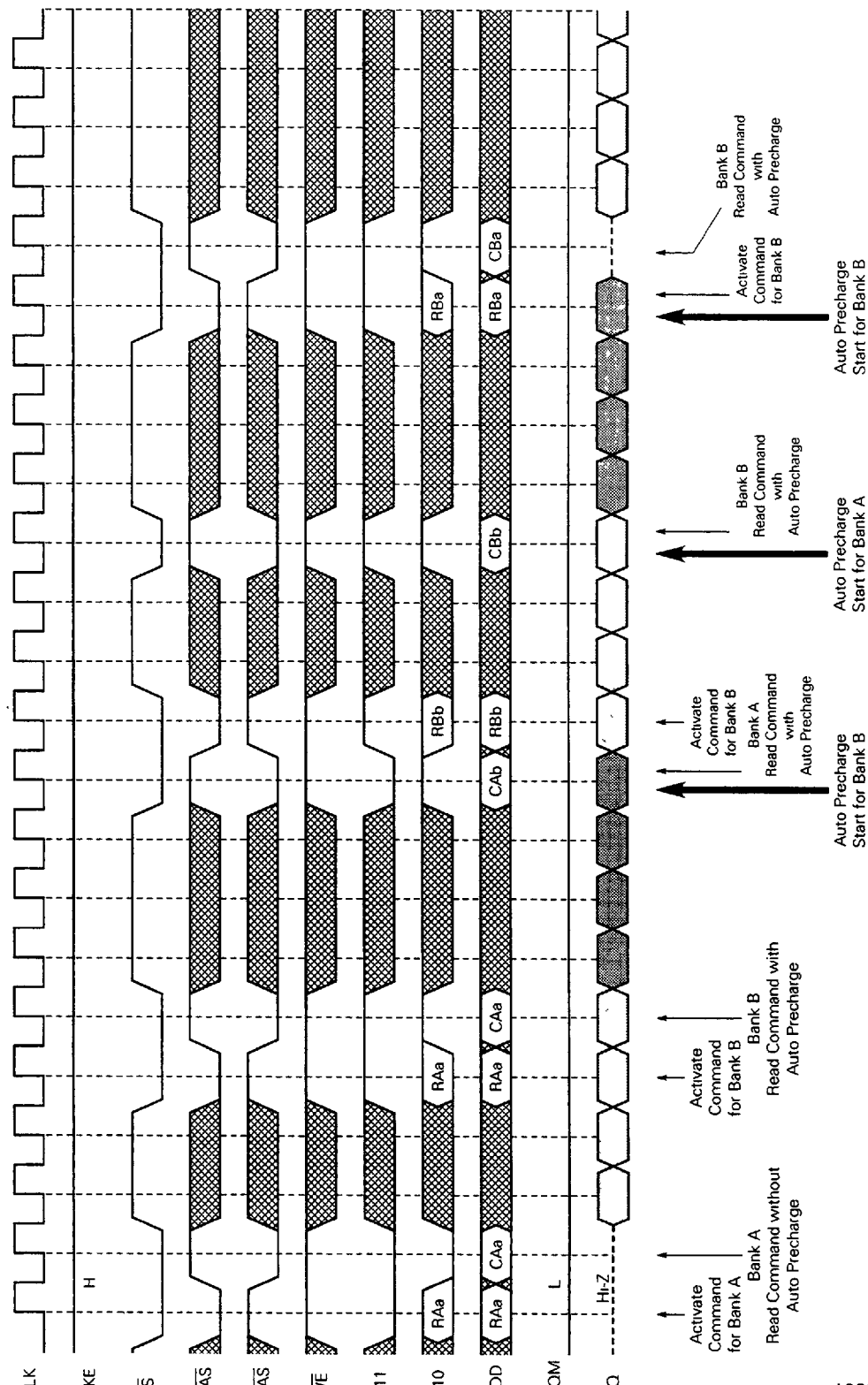
Interleaved Column WRITE Cycle (2/3) (Burst length = 4, $\overline{CAS}$ latency = 2)



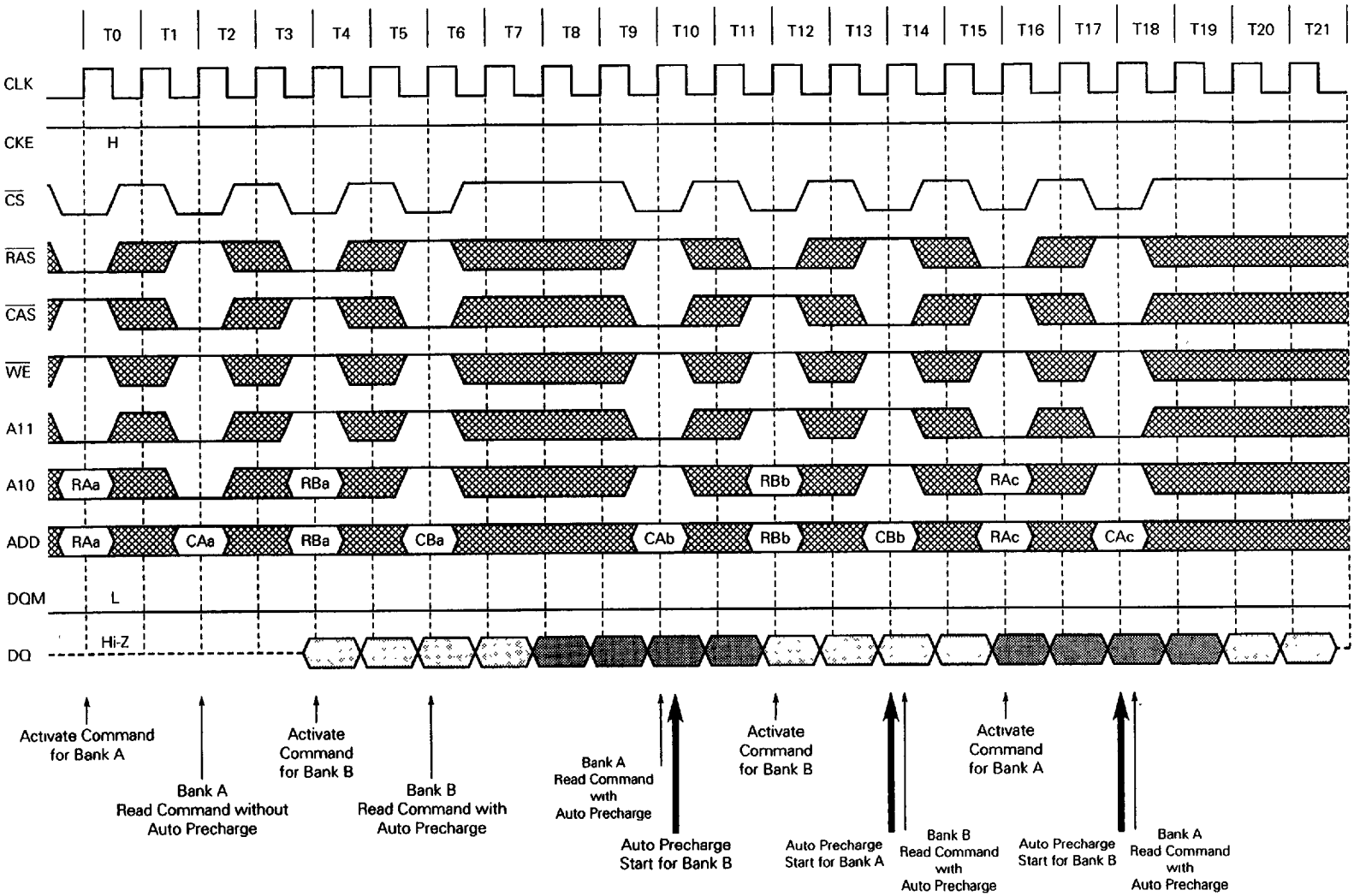
Interleaved Column WRITE Cycle (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



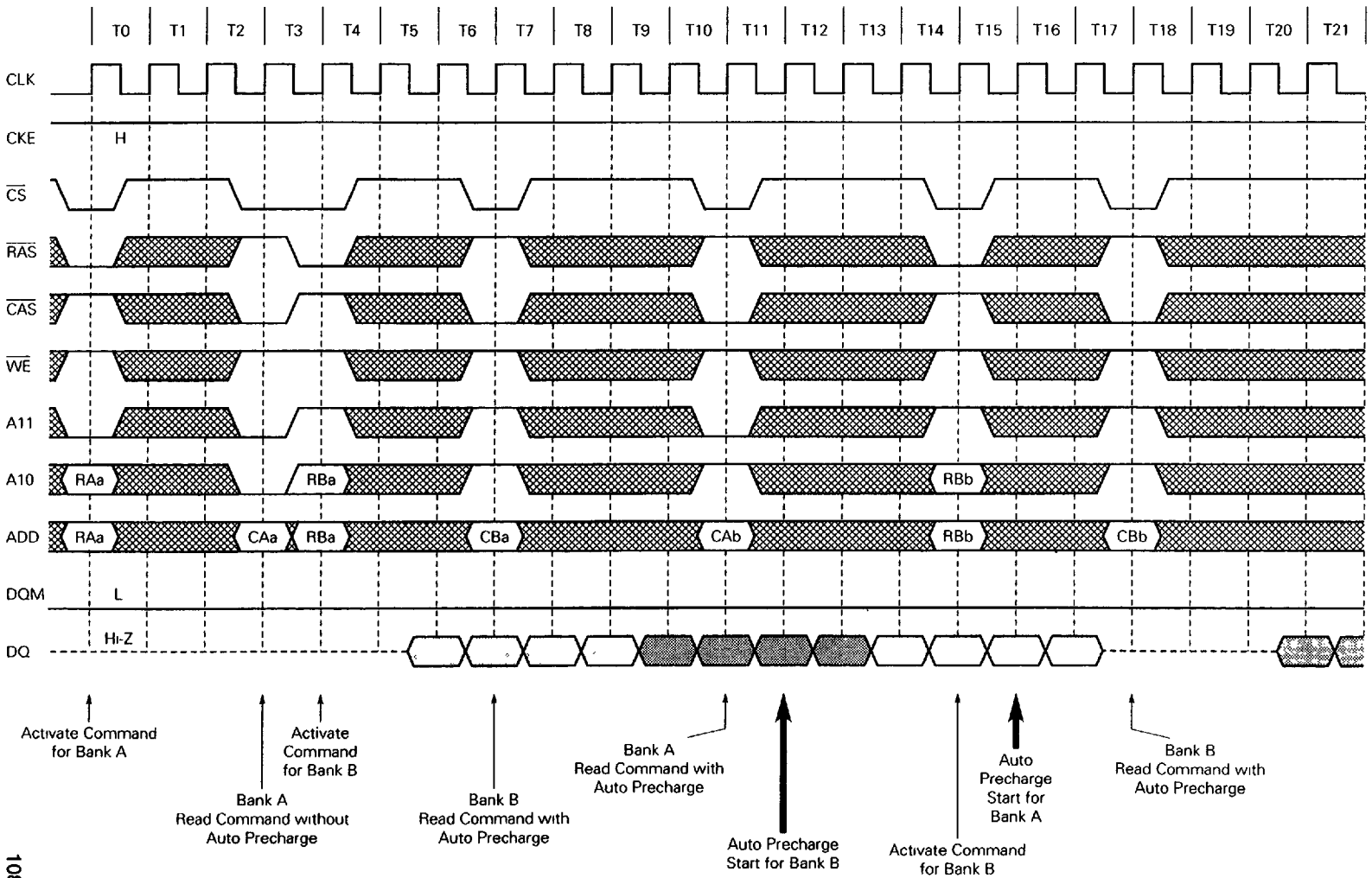
13.19 Auto Precharge after Read Burst (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



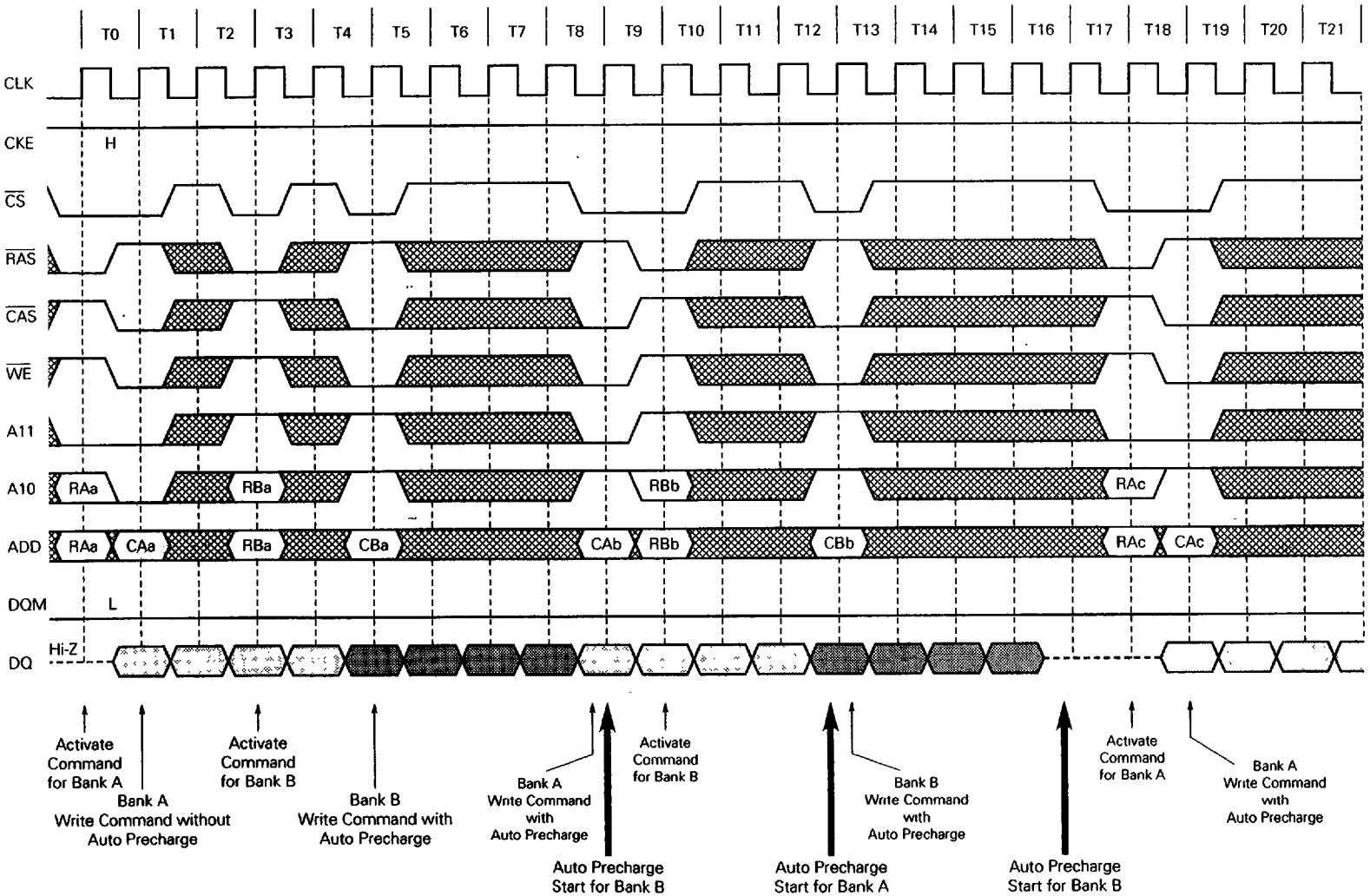
Auto Precharge after Read Burst (2/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



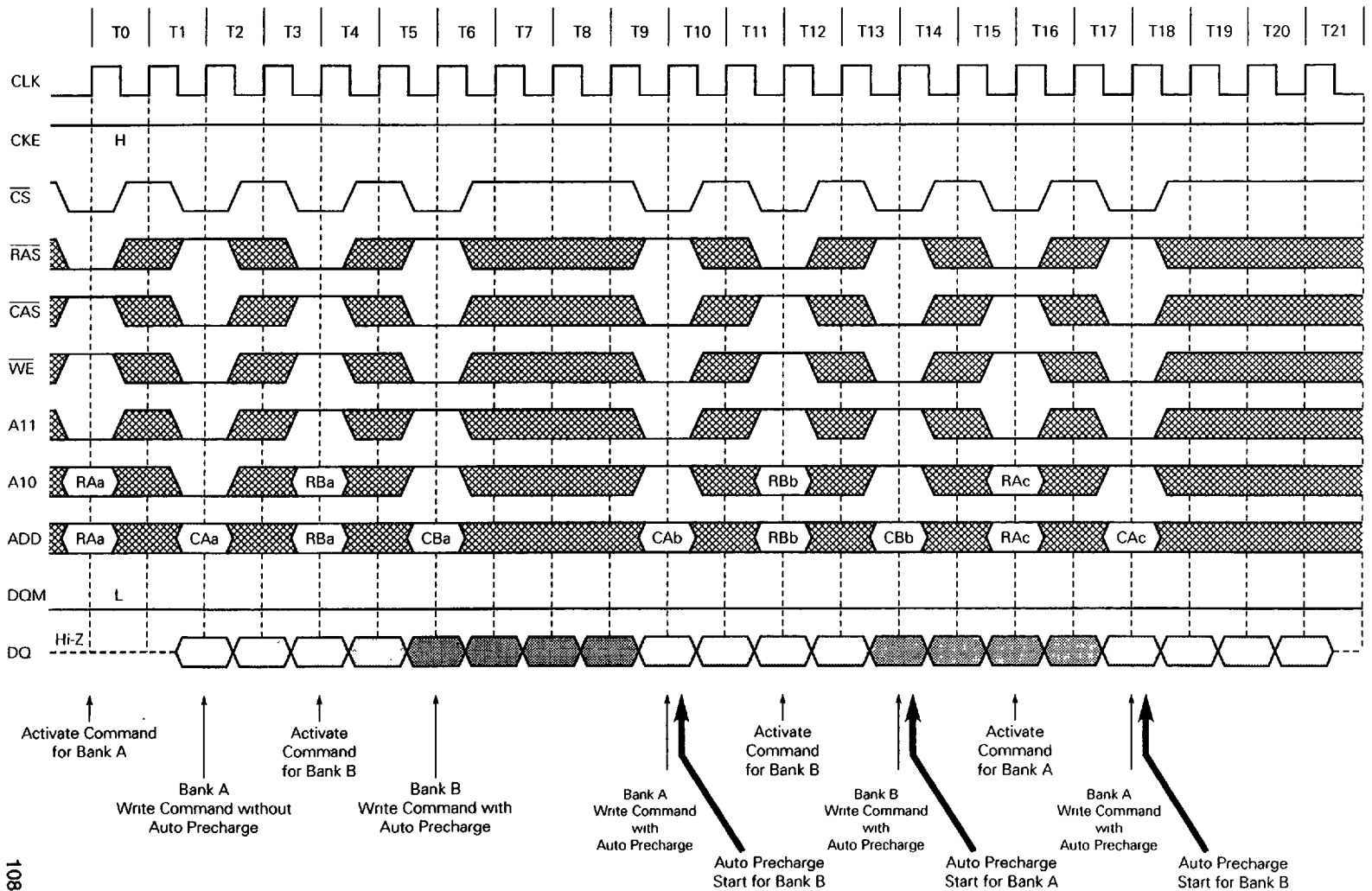
Auto Precharge after Read Burst (3/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 3)



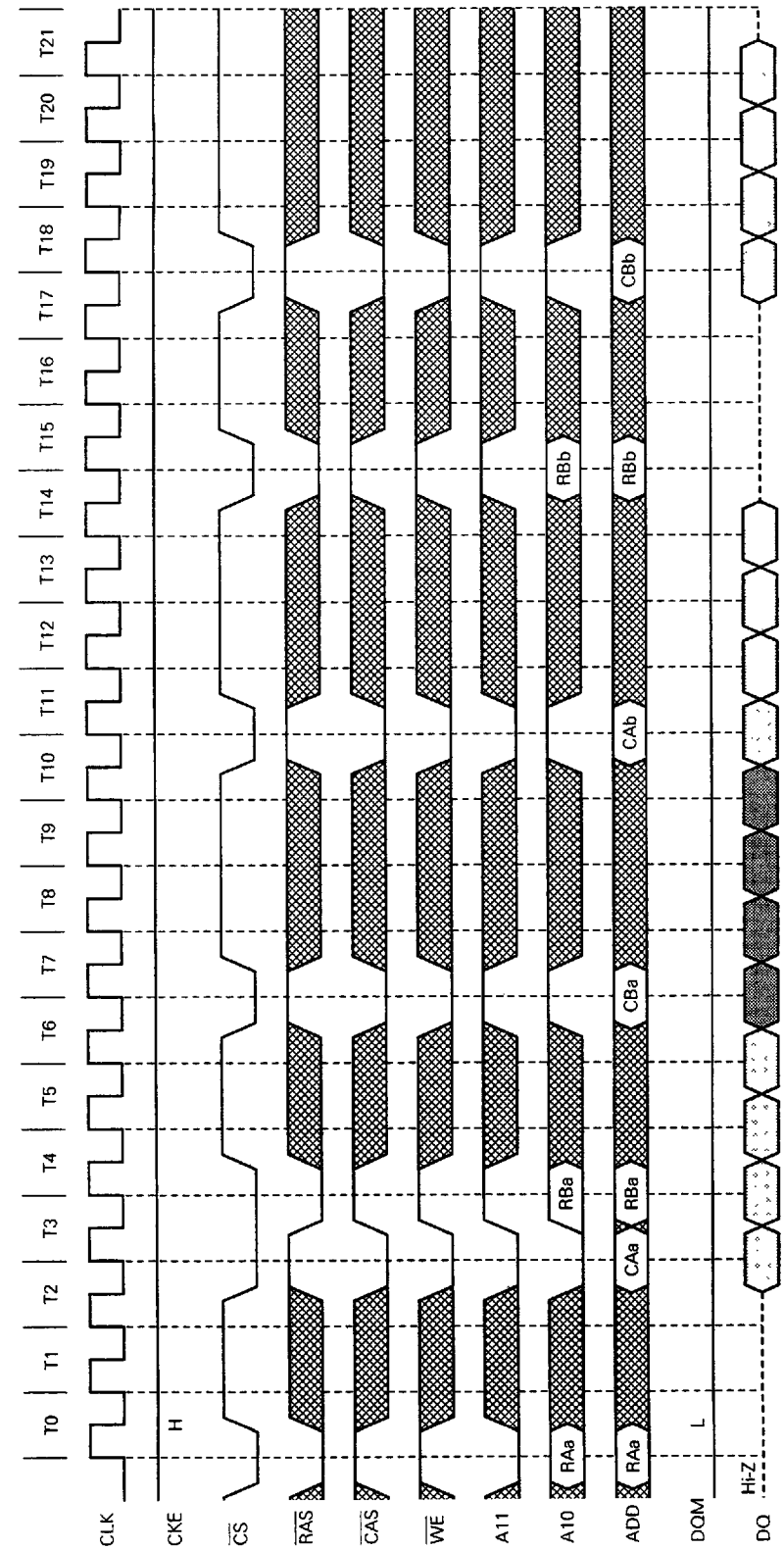
13.20 Auto Precharge after Write Burst (1/3) (Burst length = 4, $\overline{CAS}$ latency = 1)



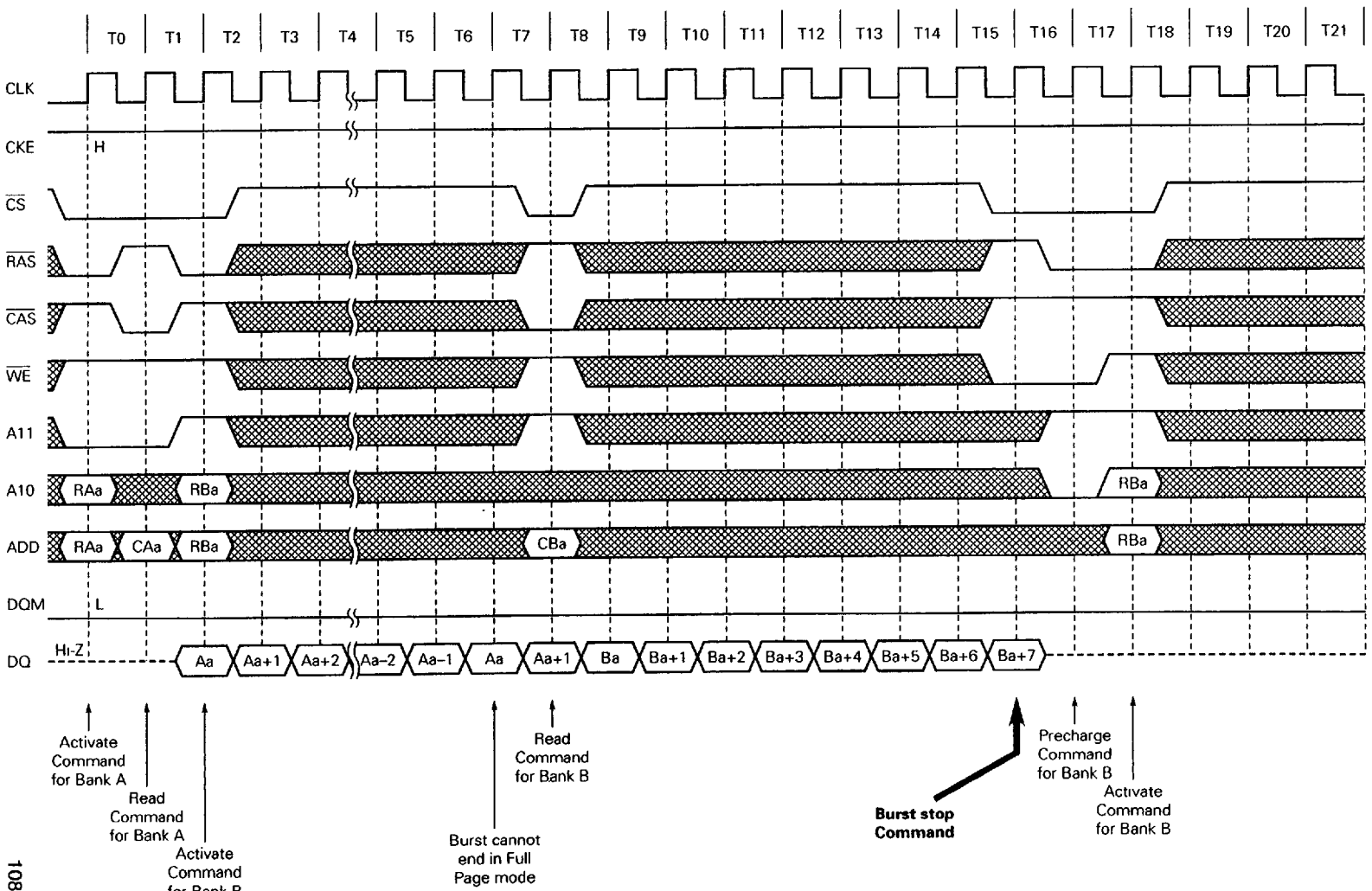
Auto Precharge after Write Burst (2/3) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



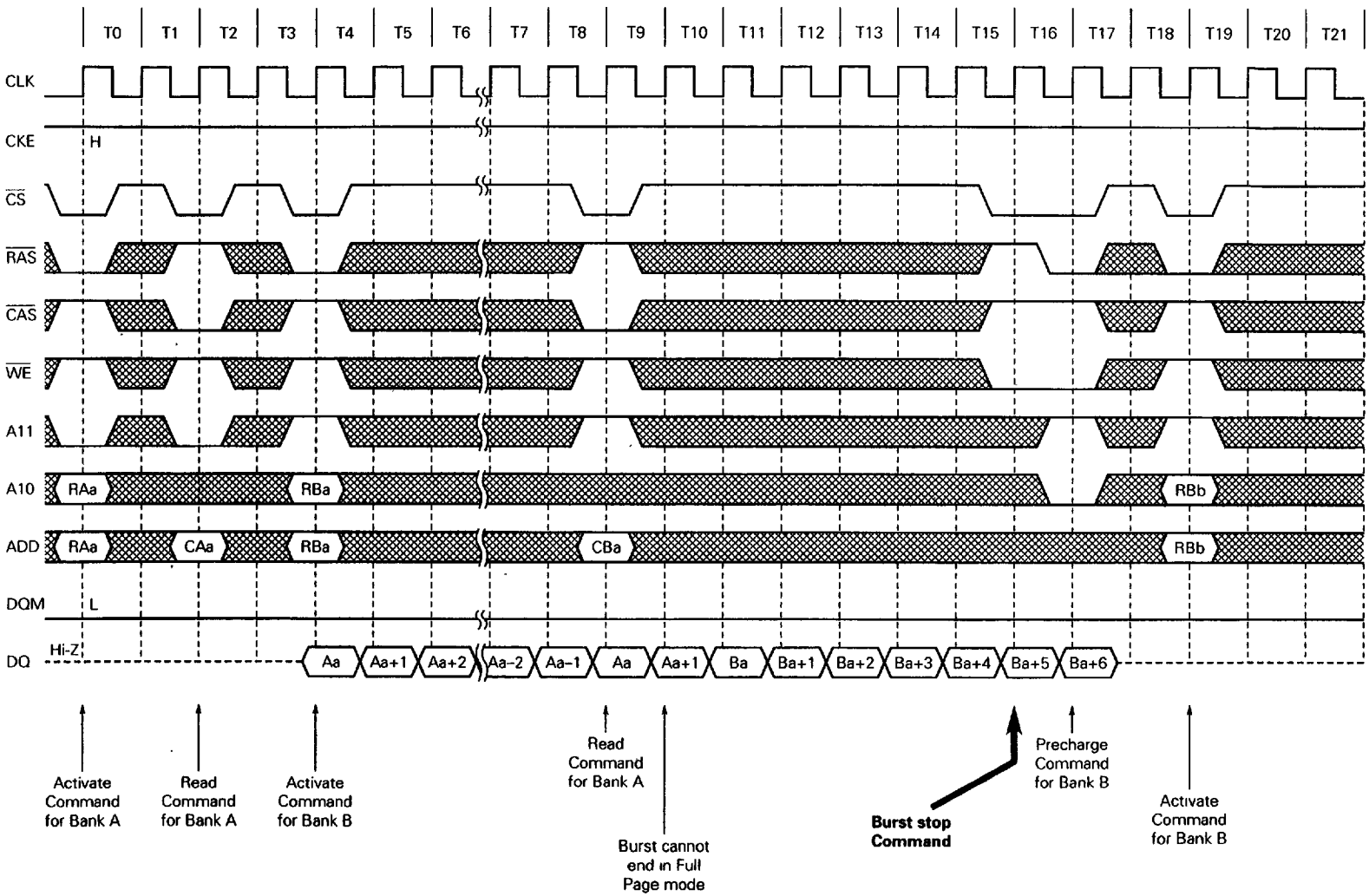
Auto Precharge after Write Burst (3/3) (Burst length = 4, $\overline{CAS}$ latency = 3)



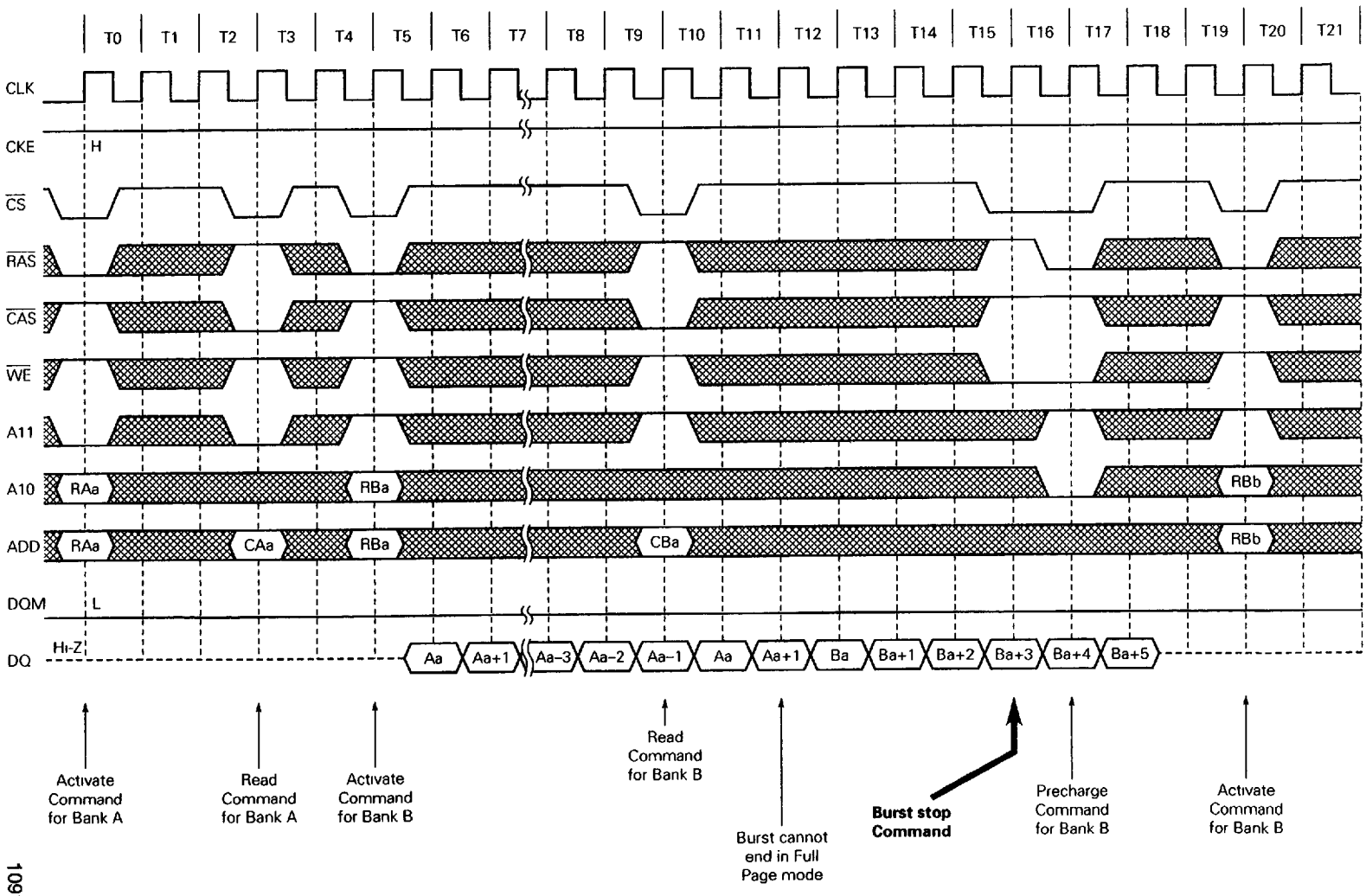
13.21 Full Page READ Cycle (1/3) ($\overline{CAS}$ latency = 1)



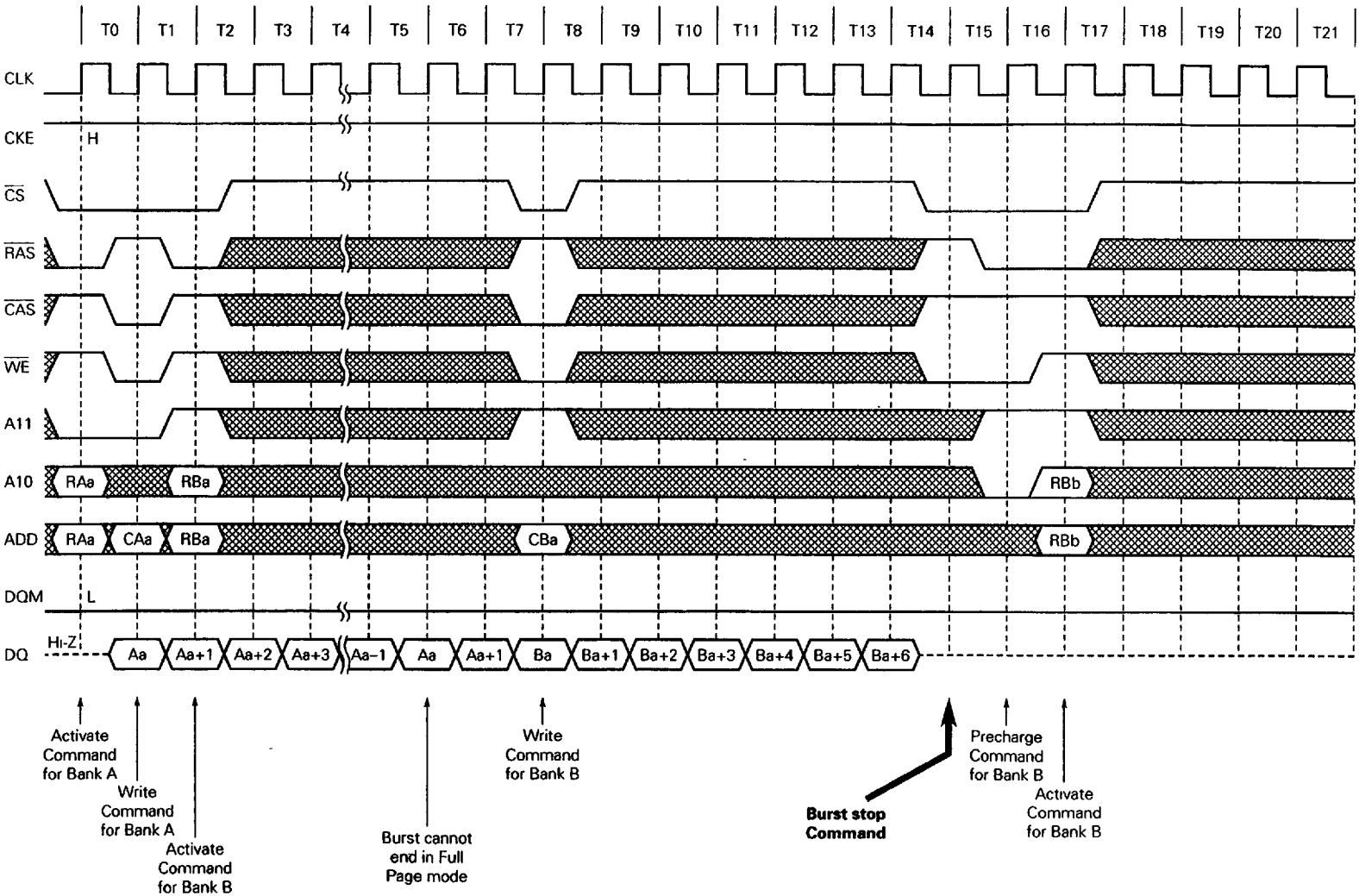
Full Page READ Cycle (2/3) ($\overline{CAS}$ latency = 2)



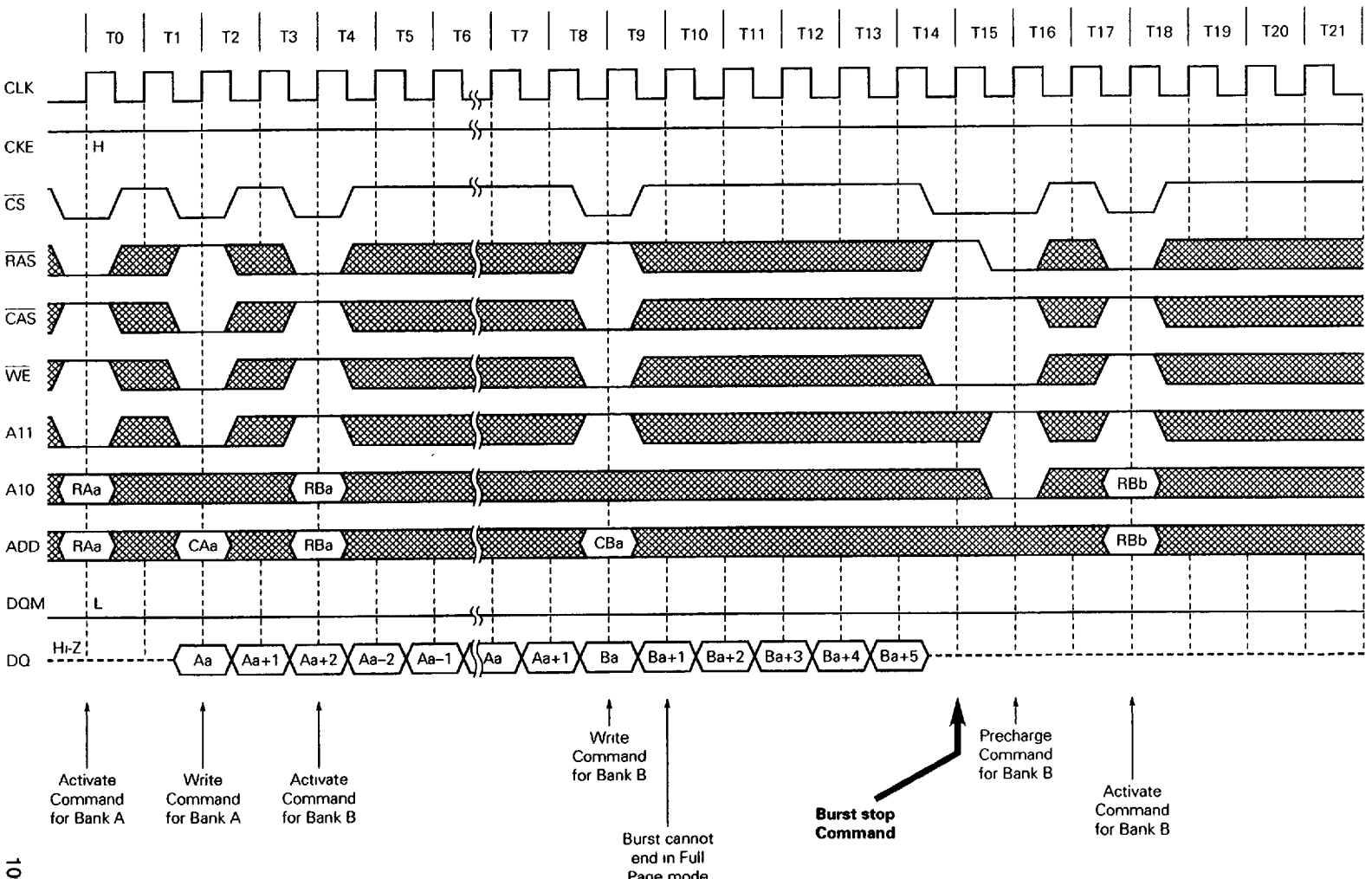
Full Page READ Cycle (3/3) ($\overline{CAS}$ latency = 3)



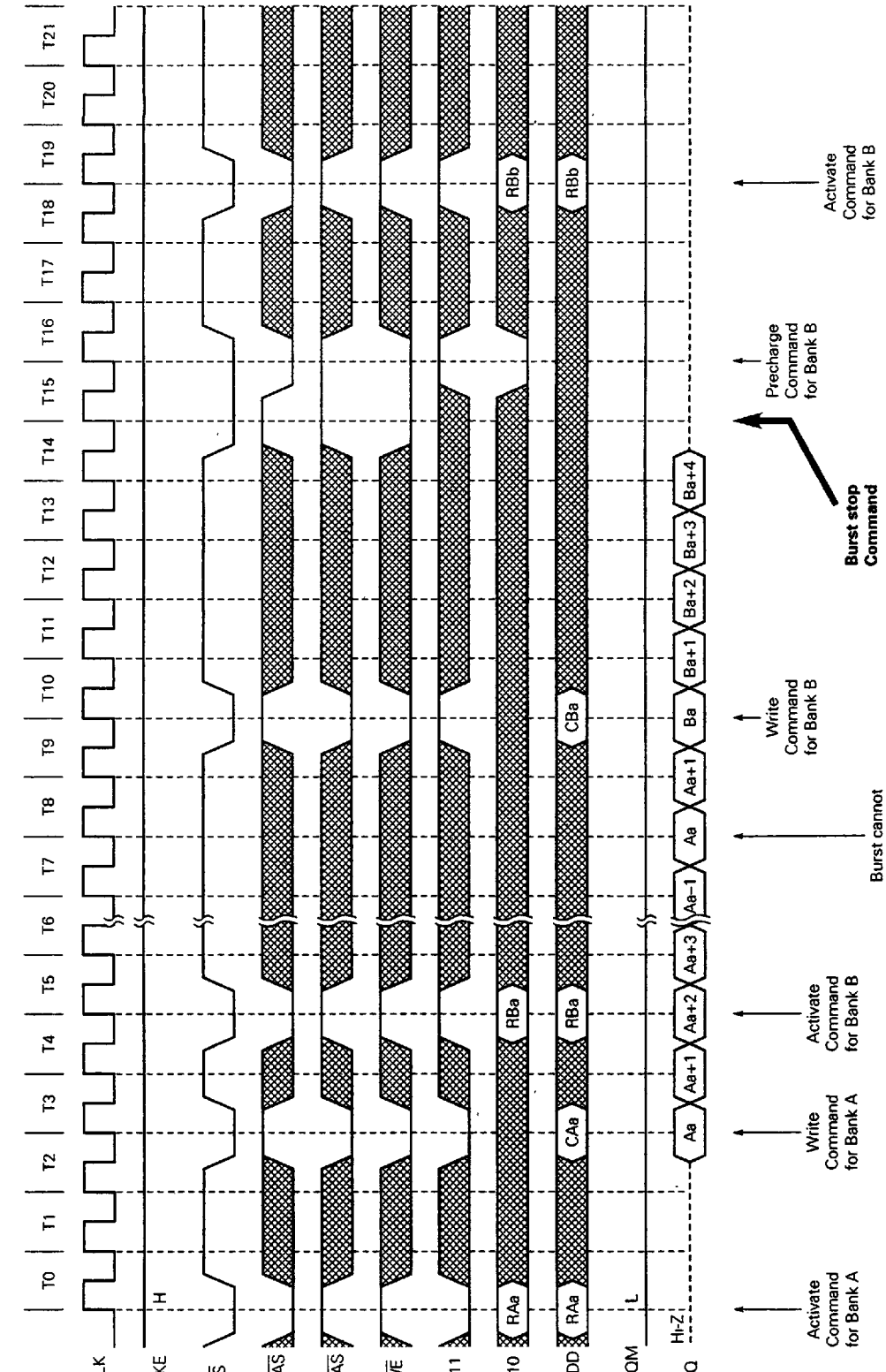
13.22 Full Page WRITE Cycle (1/3) ($\overline{CAS}$ latency = 1)



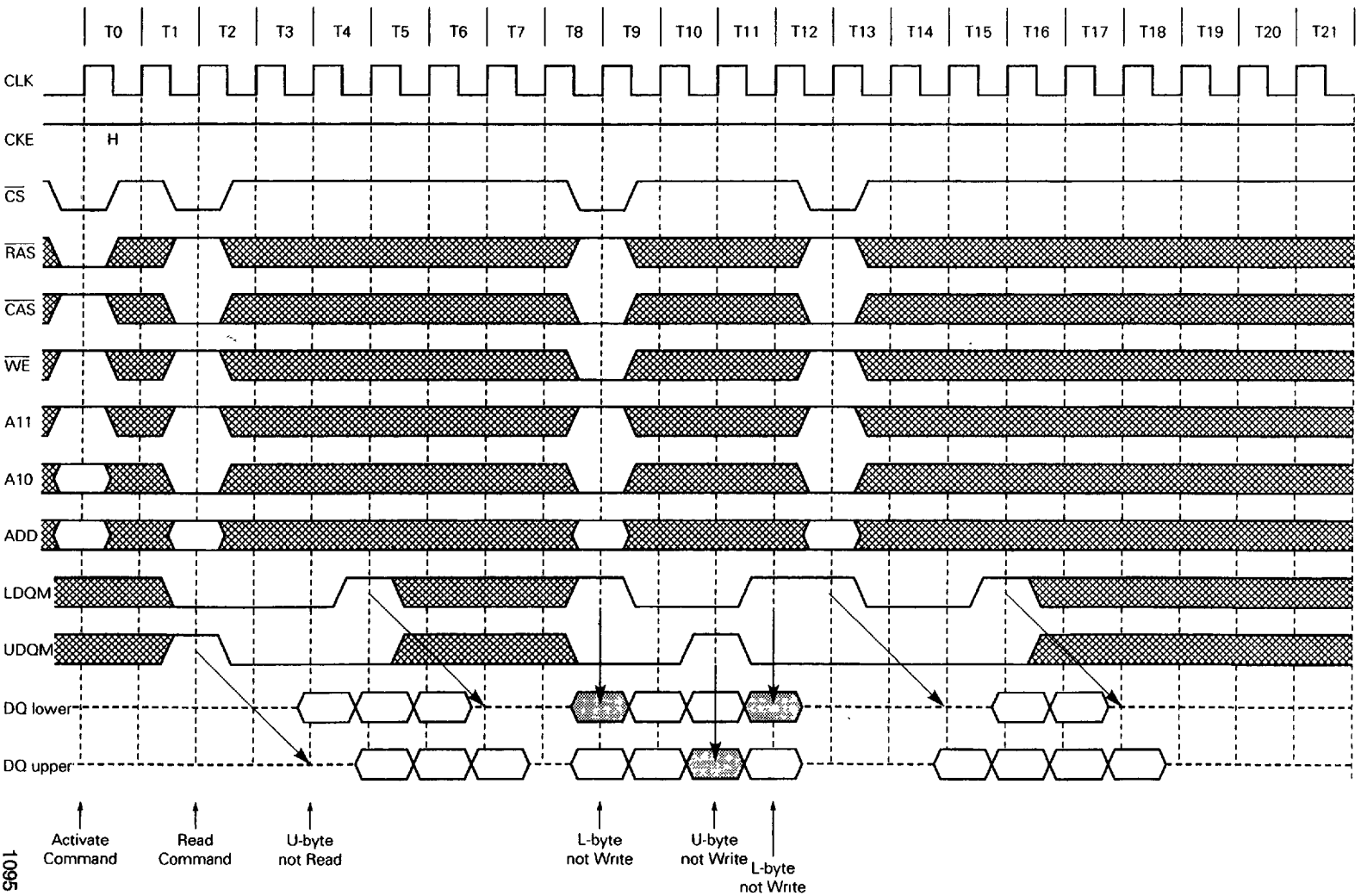
Full Page WRITE Cycle (2/3) ($\overline{CAS}$ latency = 2)



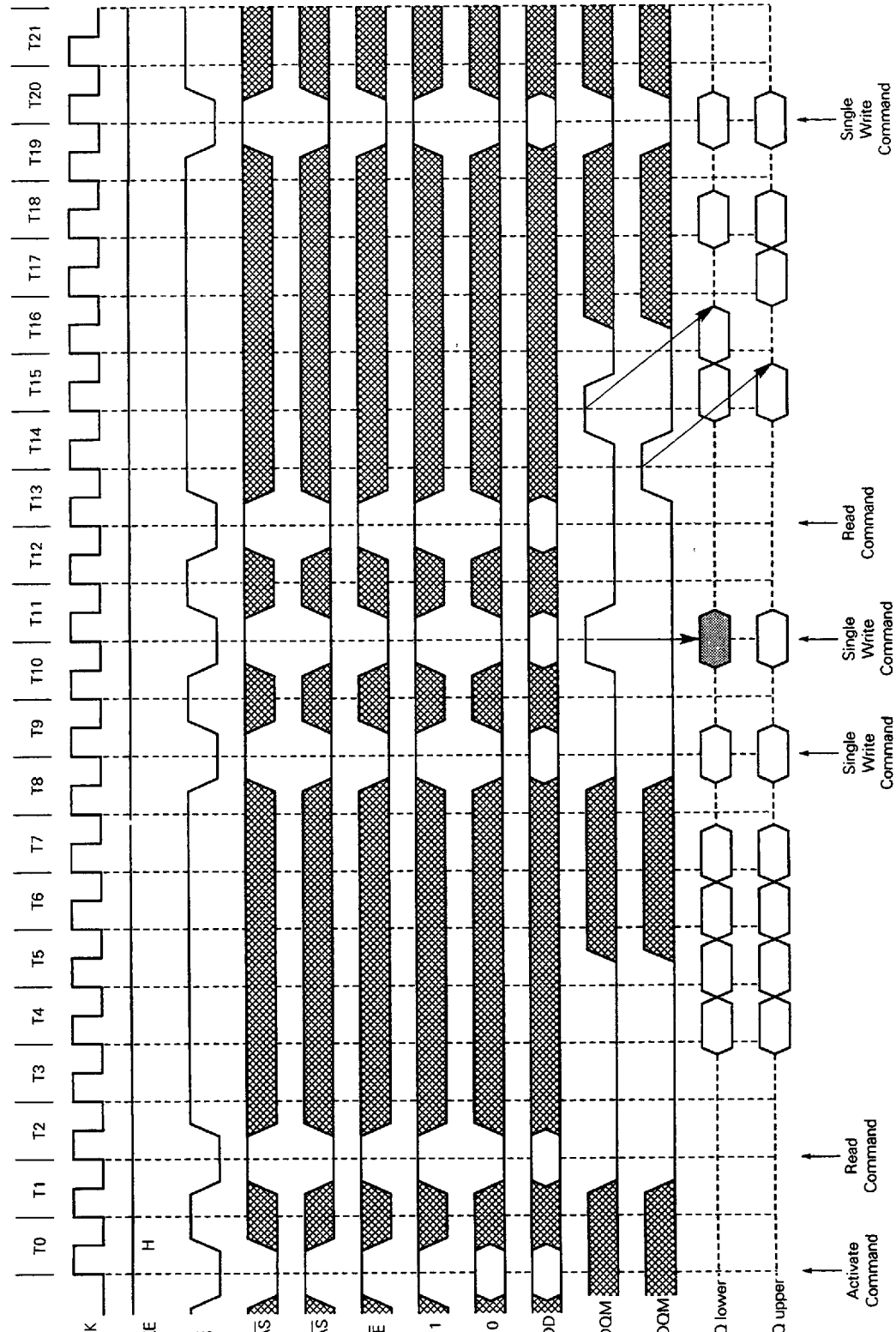
Full Page WRITE Cycle (3/3) ($\overline{CAS}$ latency = 3)



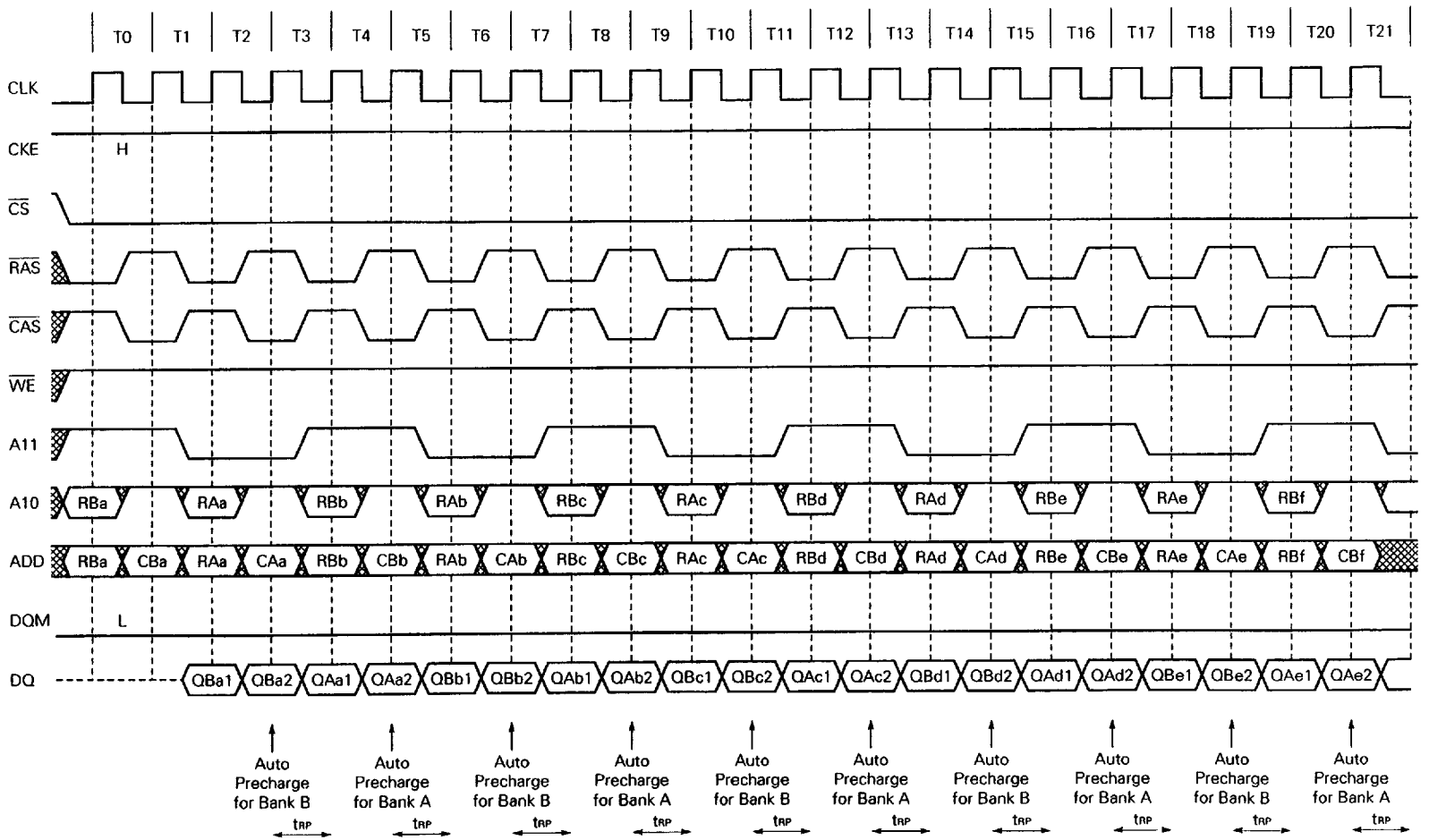
13.23 Byte Write Operation (Burst length = 4, $\overline{CAS}$ latency = 2)



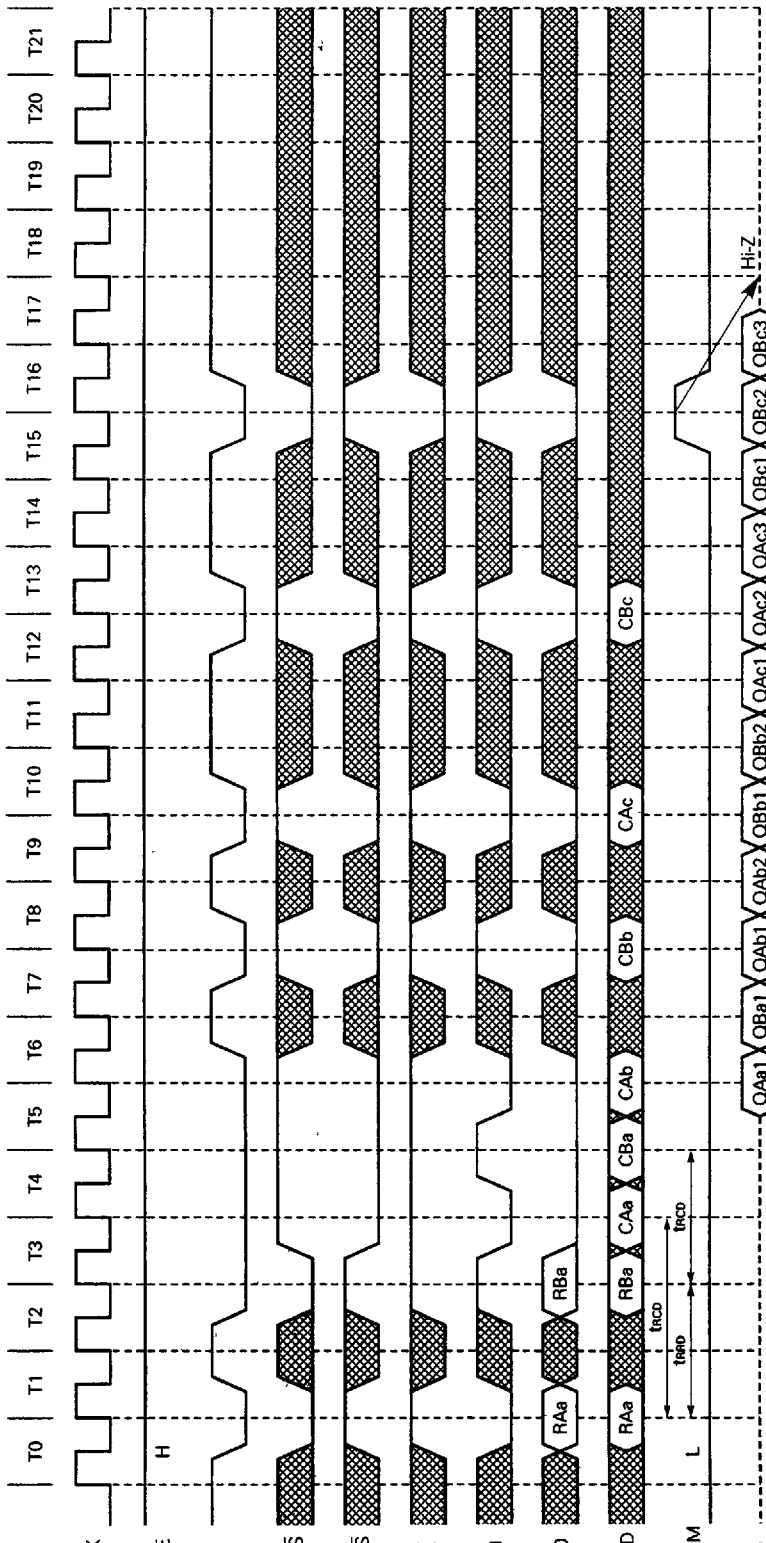
13.24 Burst Read and Single Write (Option) (Burst length = 4, $\overline{\text{CAS}}$ latency = 2)



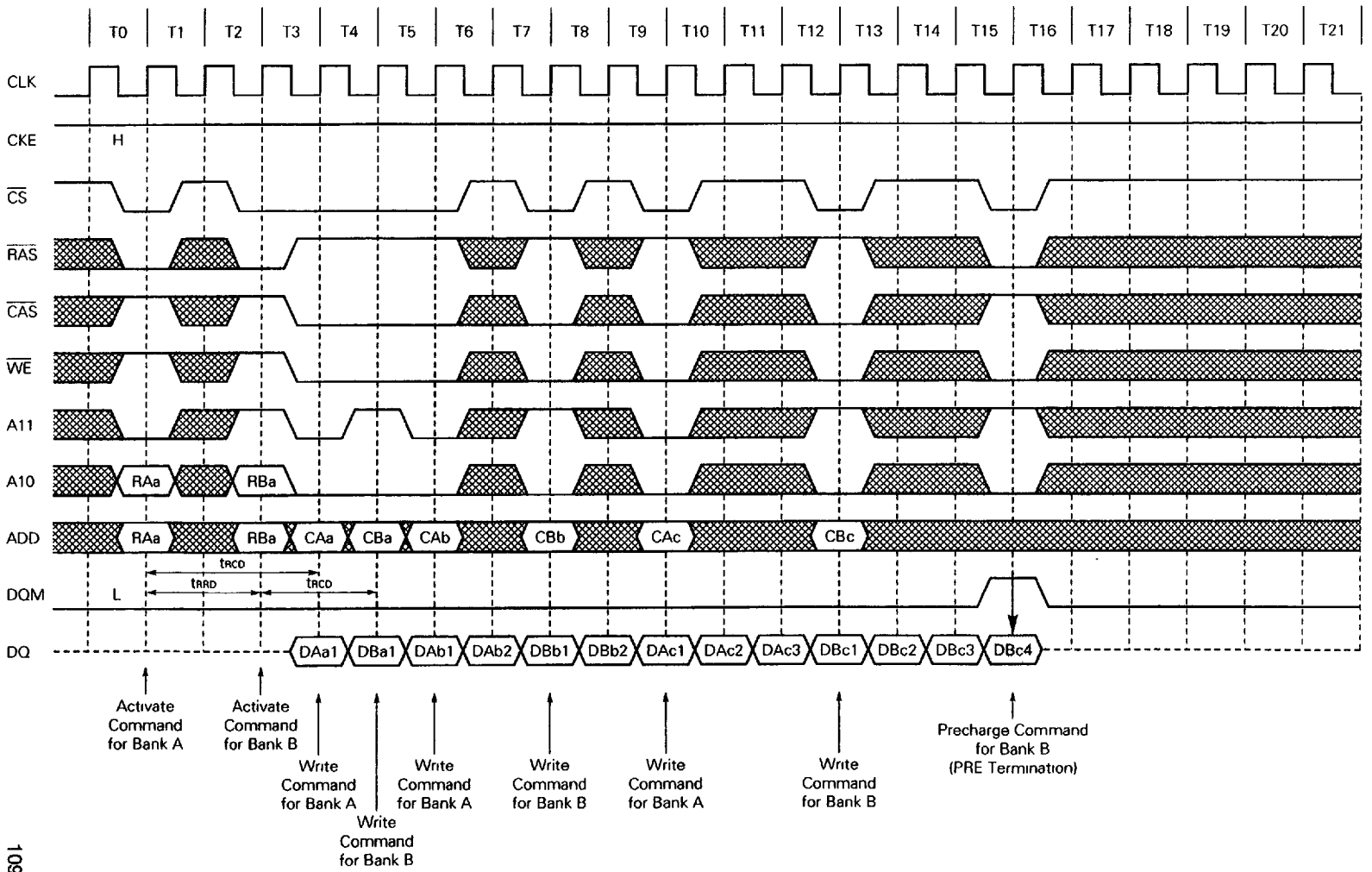
13.25 Random Row READ (Pingpong banks) (Burst length = 2, $\overline{CAS}$ latency = 1)



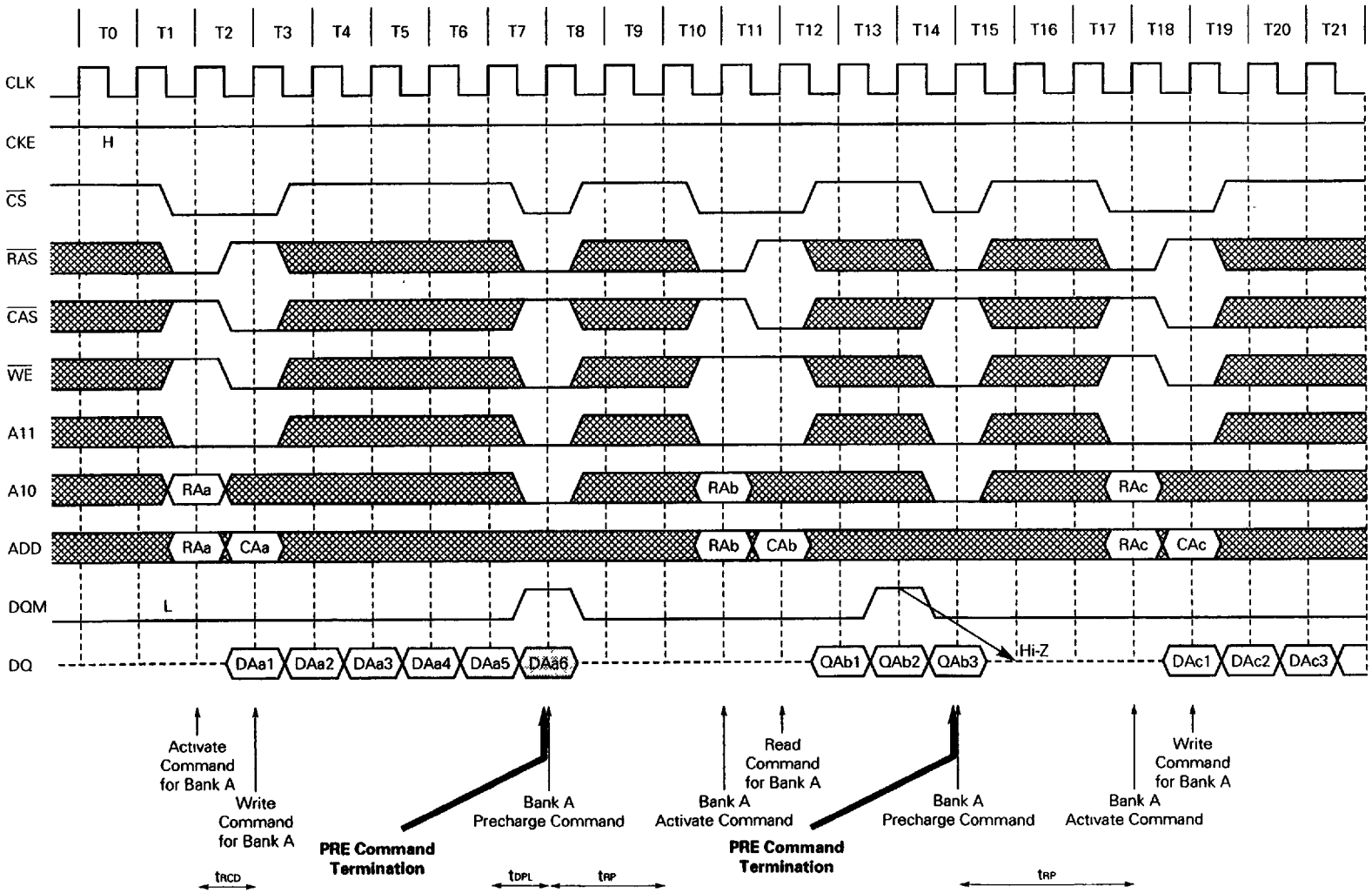
13.26 Full Page Random Column Read (Burst length = Full Page, $\overline{CAS}$ latency = 2)



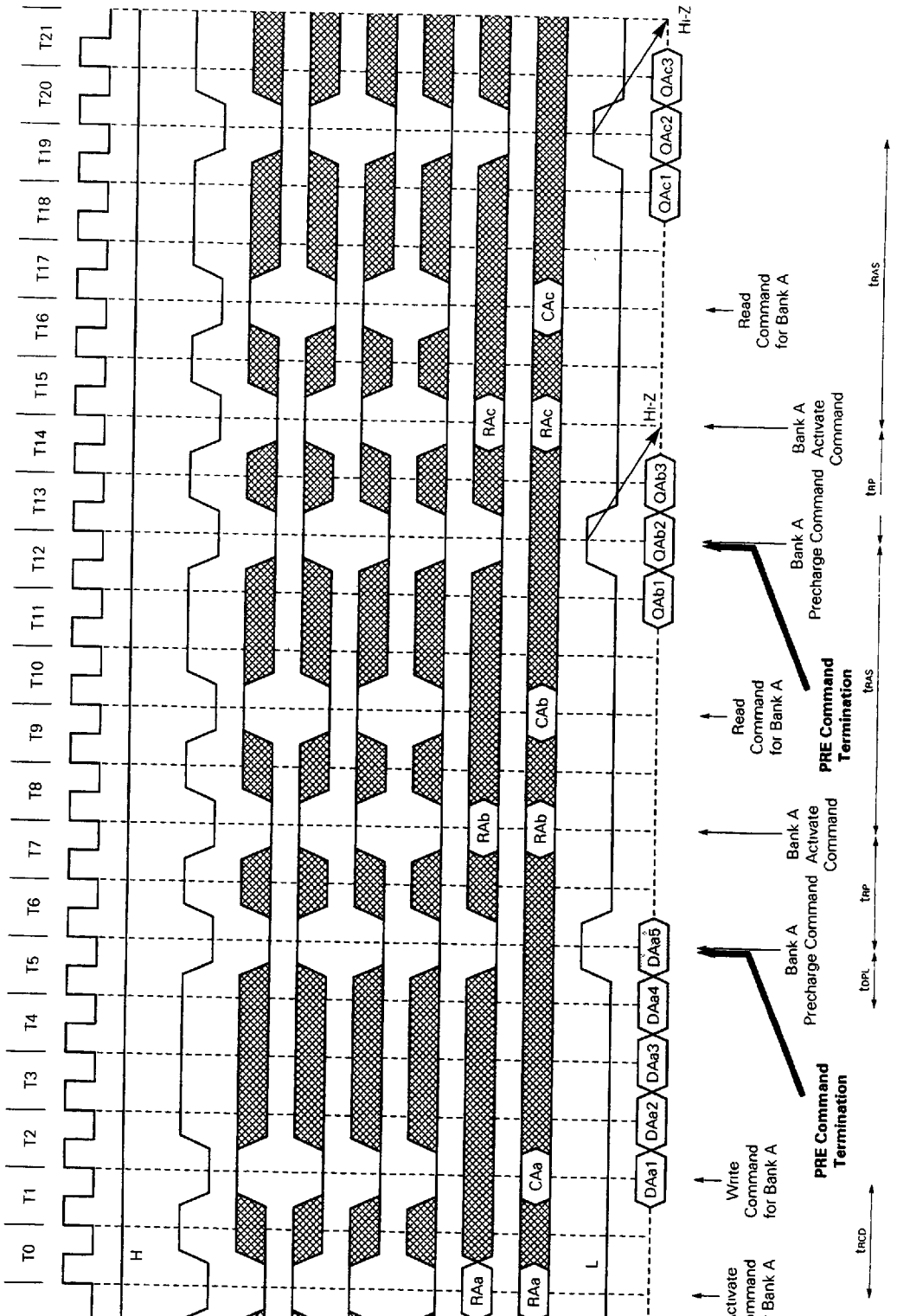
13.27 Full Page Random Column Write (Burst length = Full Page, $\overline{CAS}$ latency = 2)



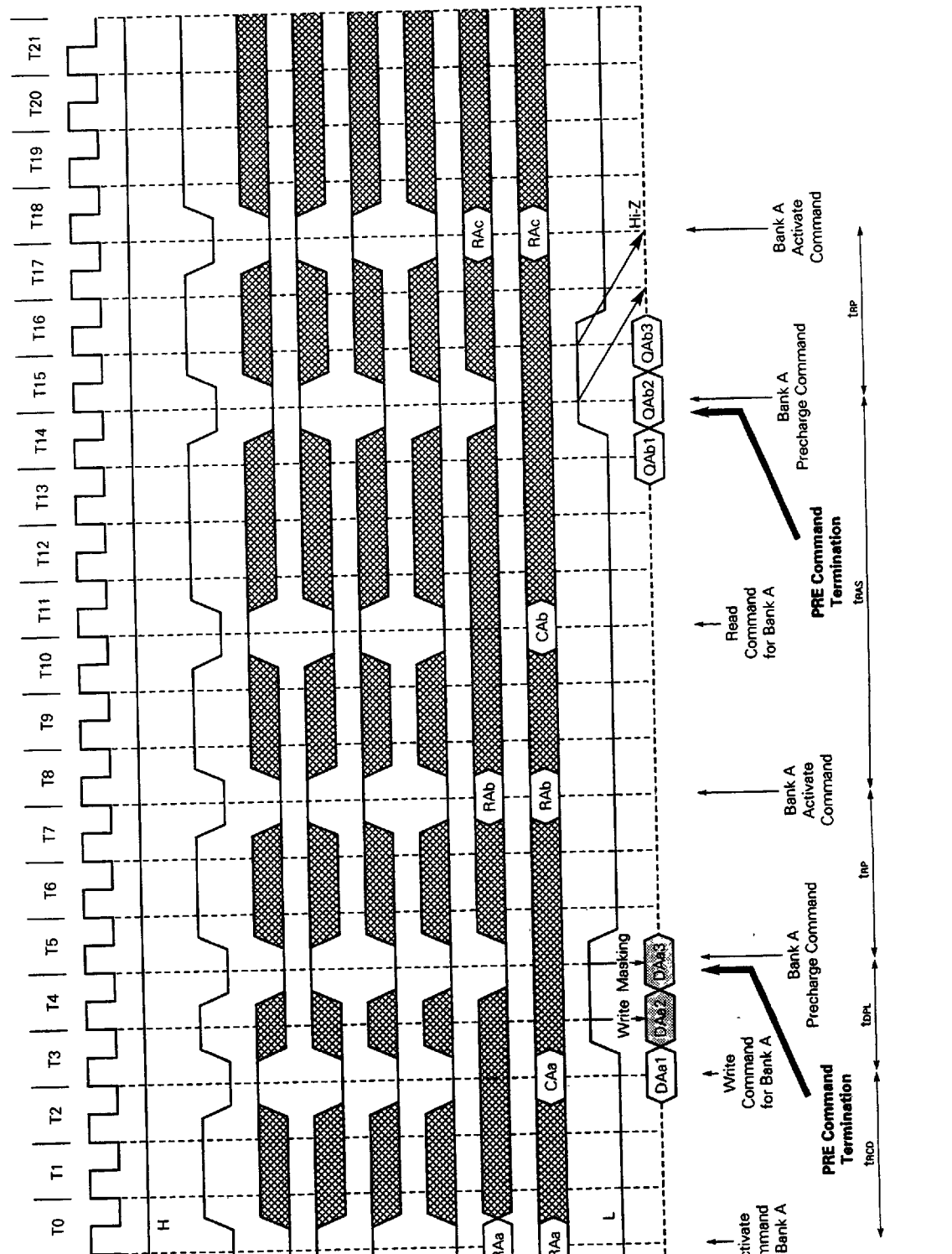
13.28 PRE(Precharge)Termination of Burst (1/3) (Burst length = 2, 4, 8, FULL, $\overline{CAS}$ latency = 1)



PRE(Precharge)Termination of Burst (2/3) (Burst length = 2, 4, 8, FULL, $\overline{CAS}$ latency = 2)

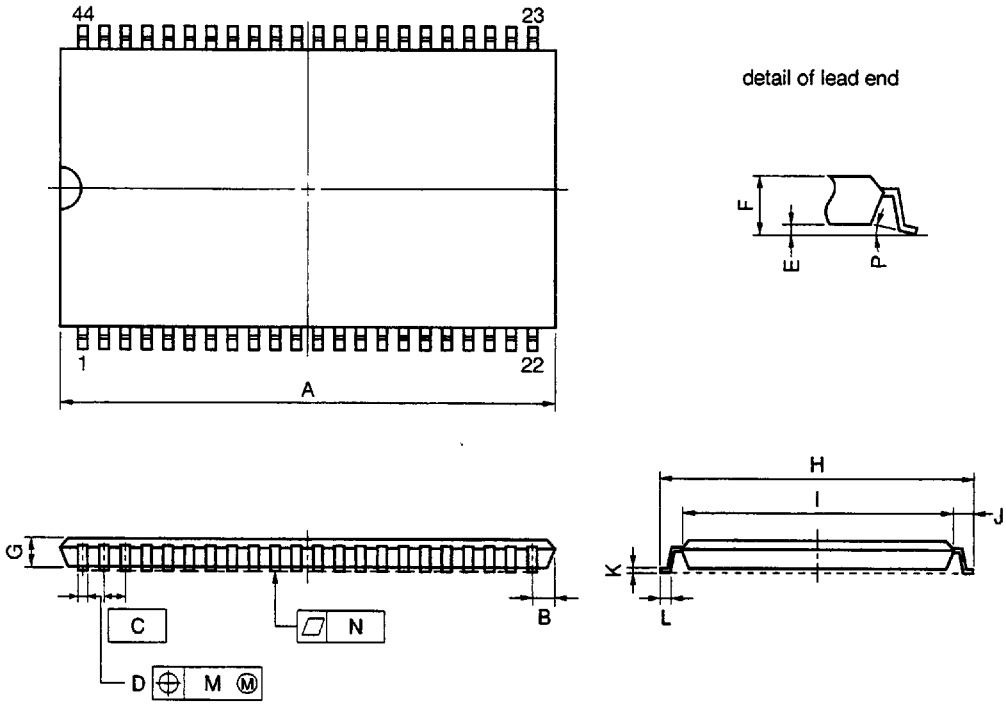


PRE(Precharge)Termination of Burst (3/3) (Burst length = 2, 4, 8, FULL, $\overline{CAS}$ latency = 3)



14. Package Drawings

44PIN PLASTIC TSOP(II) (400 mil)



NOTE

Each lead centerline is located within 0.13 mm (0.005 inch) of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS	INCHES
A	18.63 MAX.	0.734 MAX.
B	0.93 MAX.	0.037 MAX.
C	0.8 (T.P.)	0.031 (T.P.)
D	$0.32^{+0.08}_{-0.07}$	0.013±0.003
E	0.1±0.05	0.004±0.002
F	1.2 MAX.	0.048 MAX.
G	0.97	0.038
H	11.76±0.2	0.463±0.008
I	10.16±0.1	0.400±0.004
J	0.8±0.2	$0.031^{+0.009}_{-0.008}$
K	$0.145^{+0.025}_{-0.015}$	0.006±0.001
L	0.5±0.1	$0.020^{+0.004}_{-0.005}$
M	0.13	0.005
N	0.10	0.004
P	$3°^{+7°}_{-3°}$	$3°^{+7°}_{-3°}$

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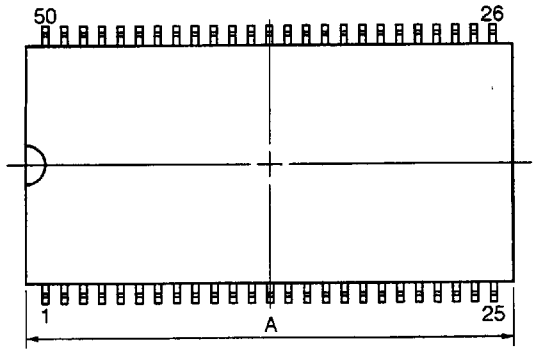
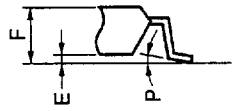
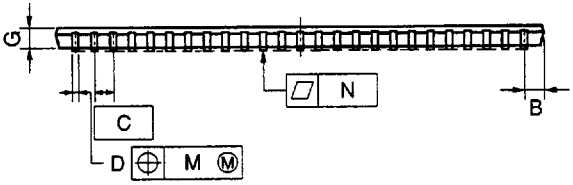
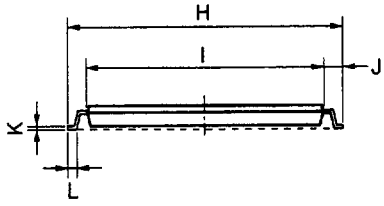
50PIN PLASTIC TSOP(II) (400 mil)



detail of lead end







NOTE

Each lead centerline is located within 0.13 mm (0.005 inch) of its true position (T.P.) at maximum material condition.

ITEM	MILLIMETERS	INCHES
A	21.17 MAX.	0.834 MAX.
B	1.0 MAX.	0.040 MAX.
C	0.8 (T.P.)	0.031 (T.P.)
D	$0.32^{+0.08}_{-0.07}$	0.013±0.003
E	0.1±0.05	0.004±0.002
F	1.2 MAX.	0.048 MAX.
G	0.97	0.038
H	11.76±0.2	0.463±0.008
I	10.16±0.1	0.400±0.004
J	0.8±0.2	$0.031^{+0.009}_{-0.008}$
K	$0.145^{+0.025}_{-0.015}$	0.006±0.001
L	0.5±0.1	$0.020^{+0.004}_{-0.005}$
M	0.13	0.005
N	0.10	0.004
P	$3°^{+7°}_{-3°}$	$3°^{+7°}_{-3°}$

S50G5-80-7JF3

15. Recommended Soldering Conditions

The following conditions must be met for soldering conditions of the μPD4516421, 4516821, 4516161.

For more details, refer to our document "SEMICONDUCTOR DEVICE MOUNTING TECHNOLOGY MANUAL" (IEI-1207).

Please consult with our sales offices in case other soldering process is used, or in case the soldering is done under different conditions.

Types of Surface Mount Device

μPD4516421G5, 4516821G5: 44-pin plastic TSOP (II) (400 mil)
μPD4516161G5: 50-pin plastic TSOP (II) (400 mil)

Soldering process	Soldering conditions	Symbol
Infrared ray reflow	Peak temperature of package surface: 235 °C or lower, Reflow time: 30 seconds or less (210 °C or higher), Number of reflow processes: MAX. 2 Exposure limit: 7 days[Note] (10 hours pre-baking is required at 125 °C afterwards) **Cautions** **1. After the first reflow process, cool the package down to room temperature, then start the second reflow process.** **2. After the first reflow process, do not use water to remove residual flux (water can be used in the second process).**	IR35-107-2
VPS	Peak temperature of package: 215 °C or lower, Reflow time: 40 seconds or less (200 °C or higher), Number of reflow processes: MAX. 2 Exposure limit :7 days[Note] (10 hours pre-baking is required at 125 °C afterwards) **Cautions** **1. After the first reflow process, cool the package down to room temperature, then start the second reflow process.** **2. After the first reflow process, do not use water to remove residual flux (water can be used in the second process).**	VP15-107-2
Partial heating method	Terminal temperature: 300 °C or lower, Time: 3 seconds or lower (Per side of the package).	———

Note Exposure limit before soldering after dry-pack package is opened.
Storage conditions: 25 °C and relative humidity at 65 % or less.

Caution Do not apply more than one soldering method at any one time, except for "Partial heating method".