MindShare DRAM Quick Reference Guide (Rev 6)

DRAM Quick Reference Guide Rev 6
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3DS	3 Dimensional Silicon or Stack
ab, AB	All Banks (LPDDRs), AP in PC DDRs
ACT	Active aka Activate command
AL	Additive Latency, 0 to 5 for DDR2, 0, CL-1, or CL-2 for DDR3 & 4, RL = AL + CL + PL
AMB	Advanced Memory Buffer
AMBA	Advanced Microcontroller Bus Architecture
AP	Auto Precharge, Precharge All, A10
ASR	Auto Self Refresh, auto temp., not Auto Refresh
AXI	Advanced eXtensible Interface
BA	Bank Address
BC	Burst Chop
BC#	Burst Chop pin, A12
BC4	Burst Chop 4
BG	Bank Group
BGA	Ball Grid Array
BL	Burst Length
BL4	DDR2 Burst Length 4 UI, inappropriate term for DDR3/4 BC4
BL8	Burst Length 8, 8 UI of DQ
BL9	Inappropriate term for BL8 + CRC x8,x16
BL10	Inappropriate term for BL8 + CRC x4
BL16, BL32	Burst Lengths for LPDDR4
C	Chip ID, like CS# but for 3DS
C	Column Address (LPDDR3/4)
CA	Column Address (DDR3/4)
CA	Command and Address (LPDDRs)
CAS	Column Address Strobe
CB	Check Bit
CDIMM	Clocked 72-bit Mini DIMM
CK	Clock
CKE	Clock Enable
CL	CAS Latency (in MR0)=RL–AL–PL
CRC	Cyclic Redundancy Check
CS#	Chip Select, Rank, S# in 21C spec
CTT	Center Tap Termination
CWL	CAS Write Latency (in MR2)
DBI#	Data Bus Inverted
DDP	Dual-Die Package
DES	Device Deselect (pseudo command)
DLL	Delay-Locked Loop
DDR	Double Data Rate, DDR1
DDR1	Double Data Rate, DDR
DDR2	Double Data Rate 2
DDR3	Double Data Rate 3
DIMM	Dual In-line Memory Module
DM	Data Mask
DMI	LPDDR4 Data Mask/Inversion not inverted data mask
DMI	Intel's Direct Media Interface
DNU	Do Not Use, NF, connected on die
DQ	Data; Data-in, Query Output
DQS	Data Strobe
DRAM	Dynamic Random Access Memory
ECC	Error Checking and Correcting
eMMC	Embedded Multi-Media Card
EMRS	Extended MRS command
FBDIMM	Fully-Buffered DIMM
FBGA	Fine-pitch BGA
FSP	LPDDR4 Frequency Setpoint
GDDR	Graphics DDR SGRAM, not JEDEC DDR1, 2, 3
HBM	High Bandwidth Memory JESD235
HBM	Human Body Model JESD22-A114F
HS_LLVCMOS	High-Speed Lower Low Voltage CMOS
HSUL	High-Speed Unterminated Logic High-Speed Undermanaged Logic
IDD	I_{DD} current
I2C	Philips Inter-Integrated Circuit, I squared C
ICH	Intel IO Controller Hub
ISM	Internal Stacked Module
JEDEC	Solid State Technology Association, was Joint Electron Device Engineering Council
LDM	Lower Data Mask
LDQS	Lower Data Strobe
LP3	LPDDR3, informally
LP4	LPDDR4, informally
LPDDR	Low-Power DDR, LPDDR1
LPDDR2	Low-Power DDR2
LPDDR3	Low-Power DDR3
LPDDR4	Low-Power DDR4
LRDIMM	Load-Reduced DIMM
LVSTL	Low Voltage Swing Terminated Logic
MA	MR Address, Mode Register number
MAC	LPDDR4 Maximum Activate Count between tREFW*2 refresh period
MCH	Intel Memory Controller Hub
MCP	Multi-Chip Package
MIPI	Mobile Industry Processor Interface
MO	Microelectronic Outline
MoBo	Motherboard
MPC	LPDDR4 Multi-Purpose Command
M-PHY	MIPI PHY
MPR	Multi Purpose Register, NOT a MR
MR	Mode Register
MRR	Mode Register Read command
MRS	Mode Register Set command (set is verb, not noun)
MRW	Mode Register Write command
n	Width of device's data bus (for prefetch)
N	1N, 2N, 3N, etc. timing, 1T, 2T, etc.
nCK	One tick of CK as dimensionless number
NC	No Connect, not connected on die
NF	No Function, DNU,connected on die
OCD	Off-Chip Driver
ODT	On-Die Termination
OP[n]	Bit n of MR opcode, MR data
OTF	On The Fly
PASR	Partial Array Self Refresh
pb	LPDDRs per bank
PC3	DDR3, informally
PC4	DDR4, informally
PCH	Intel Platform Controller Hub
PDA	Per-DRAM Addressability
PEC	SMB Packet Error Checking
PHY	Physical Layer
PL	Parity Latency
PLL	Phase-Locked Loop
POD	Pseudo Open Drain
PoP	Package on Package
PPR	Post-Package Repair Fail Row Repair
PRE	Precharge command
Q	Query Output (Sept. 2007 DDR3)
QDP	Quad-Die Package
R	Row Address (LPDDR3/4)
RA	Row Address (DDR3/4)
RAS	Row Address Strobe
RAS	Reliability, Availability, Servicability
RCD	RAS-to-CAS Delay
RCD	Registering Clock Driver
RDIMM	Registered DIMM
RDTR	GDDR5 Read Training LPDDR4 MPC [RD-FIFO]
RDQS	Redundant DQS
REF	Refresh command
RFU	Reserved for Future Use
RL	Read Latency = CL + AL + PL
RLDRAM	Reduced-Latency DRAM
QERR#	RCD parity error pin
S#	CS# in 21C spec
S3	Suspend to DRAM pwr mgmt state
S4EC D4ED	Single 4-bit Error Correction, Double 4-bit Error Detection
SA	SMB hardwired DIMM addr., not bused
SCL	SMB clock pin, DIMM pin
SDA	SMB address and data pin, DIMM pin
SDR	Single Data Rate
SDRAM	Synchronous DRAM
SECDED	Single bit Error Correction, Double bit Error Detection
SGRAM	Synchronous Graphics RAM
SIMM	Single In-line Memory Module
SMB	System Management Bus
SMBus	System Management Bus
SO-DIMM	Small Outline DIMM
SPD	Serial Presence Device or Detect
SPD ROM	SPD ROM
SRAM	Static Random Access Memory
SRT	Self Refresh Temperature, see ASR
SSTL	Stub Series-Terminated Logic
T	1T, 2T, 3T, etc. timing, as 1N, 2N, etc.
t_{CK}	Time for one tick of CK
t_{XXX}	JEDEC timing spec XXX
T_{XXX}	JEDEC Temperature spec XXX
TDQS	Termination DQS, not RDQS
TRn	Target Row number
TRR	Target or Targeted Row Refresh
TSOP	Thin Small Outline Package
TSV	Through Silicon Via
TUF	Temperature Update Flag
UDIMM	Unbuffered DIMM
UDM	Upper Data Mask
UDQS	Upper Data Strobe
UFS	Universal Flash Storage
UFSA	Universal Flash Storage Association
UI	Unit Interval, single half-clock bit time
V_{CC}	Power (not for DRAM)
V_{DD}, V_{DD1}, V_{DD2}	Core Power
V_{DDCA}	Input Buffer Power (LPDDRs)
V_{DDQ}	IO Buffer Power
V_{REF}	Reference Voltage
V_{PP}	Voltage Pump Replacement Power
V_{SS}	Ground
V_{TT}	Termination Voltage
VLP	Very Low Profile
VRCG	LPDDR4 Vref Current Generator
WCL	Write Command Latency (*not* CWL) Added to WL if both CRC & DM enabled
WL	Write Latency 1 for DDR1; RL - 1 for DDR2; variable for DDR3 & DDR4 WL = CWL + AL + PL
WRTR	GDDR5 Write Training LPDDR4 MPC [WR-FIFO]
XDR	Rambus DRAM, improperly 'XDRAM'
ZQ	Data Source Impedance: Q=data out or query, Z=impedance

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Numbering

1n, 2n, 4n, 8n, 16n	Prefetch widths
1T, 1N	New command every clock
2T, 2N	New command every other clock
4T, 6T	SRAM (not SDRAM) cell technology
DDRn-mmm	n=2,3,4 mmm=MT/s Example: DDR2-800 = 400MHz CK
PC 97, PC 99	Microsoft PC requirements, not DRAM
PC 100	Early SDRAM DIMM bandwidth
PCn-xxxx	xxxx=DIMM KB/sec bandwidth =MT/s × DIMM data width / 8
x-x-x	CL-t_{RCD}-t_{RP} (older standards) CL-nRCD-nRP (newer standards)
x-x-x-x	CL-t_{RCD}-t_{RP}-t_{RAS}
n × n	Device density × data width
n × n × n	Array density × data width × #banks

Specifications

JESD8-8	SSTL_3 3.3 volt spec
JESD8-9B	SSTL_2 2.5 volt spec
JESD8-15A	SSTL_18 1.8 volt spec
JESD8-18A	FBDIMM signals (not SSTL_18)
?	SSTL_15 1.5 volt spec
JESD8-22	HSUL spec
JESD8-24	1.2v POD spec
JESD21C	DIMM (and thus SPD) spec
JESD22-A114F	Human Body Model
JESD79F	DDR SDRAM standard
JESD79-2F	DDR2 SDRAM standard
JESD79-3F	DDR3 SDRAM standard
JESD79-3-1	DDR3L SDRAM standard
JESD79-3-2	DDR3U SDRAM standard
JESD79-4	DDR4 SDRAM standard
JESD209B	LPDDR1 SDRAM standard
JESD209-2E	LPDDR2 SDRAM standard
JESD209-3B	LPDDR3 SDRAM standard
JESD209-4	LPDDR4 SDRAM standard
JESD229	WideIO SDRAM standard
JESD229-2	WideIO2 SDRAM standard
JESD235	High Bandwidth Memory
MO-207	BGA package spec
MO-309A	DDR4 DIMM spec

Signal Suffixes

#	asserted low, negative logic
#	complementary signal in differential pair
_n	asserted low, negative logic
_t	true signal in differential pair
_c	complementary signal in differential pair
r	rising
f	falling

Terms

Access time	CK to DQS. Formerly RAS# to valid data
Activate	ACT Active Command
Active	ACT Active Command, Open
Array	One bank of the device
Auto Precharge	Precharge after read/write w/o explicit PRE cmd.
Auto Refresh	Just Refresh, not ASR nor Self Refresh
Bank	Formerly rank. Internal to DRAM device.
Bank Group	Four banks in DDR4
Bit Line	Several per column
Burst	Sequential or interleaved
Channel	Interface between controller's PHY and a rank of DRAM; SMB & SPD are not on the channel.
Column	In Read/Write command
Command	RAS#, CAS#, and WE#
Control	CS#, CKE, and ODT
Data Group	DQ, DQS, DM/DBI
Dynamic ODT	ODT when written to.
Fast CKE Power Down	Power Down w/ DLL Enabled
Idle	Closed, Precharged
Open	Active, Activated
Page	Row
Page size	Row size expressed as bytes not bits
Postamble	DQS after read/write
Preactive	NVM term, NOT DRAM
Preamble	DQS before read/write
Precharge	PRE/PREA command
Prefetch width	1n, 2n, 4n, 8n, 16n
Rank	CS#
Raw Card	JESD21C DIMMs
Refresh	Auto Refresh
Registered	Sampled, latched
Row	In ACT command
Self Refresh	Rest of system powered off
Word Line	One per row
Write Leveling	Write DQS calibration
Write Levelization	Write Leveling

Commands

ACT	Bank ACTive aka ACTivate
ACT-1, -2	Parts of LPDDR4 ACT command
BST	Burst Terminate, Burst STop
CAS-2	CAS Command follows some '-1' carries LPDDR4 column address
DES	Device DESelect, CS# false
DPD	Deep Power Down entry
DPDX	Deep Power Down eXit
EMRS	Extended Mode Register Set
MPC	Multi-Purpose Command
MRR	Mode Register Read
MRS	Mode Register Set
MRW	Mode Register Write
MWR	Masked Write
MWRA	Masked Write with Auto-precharge
NOP	No Operation
PD	Power-Down entry
PDE	Power-Down Entry
PDX	Power-Down eXit
PR	Per-bank Precharge
PRA	All-bank Precharge
PRE	Single-bank PREcharge
PREA	PREcharge All banks
RD	ReaD fixed BL8 or BC4
RDA	RD w/Auto-precharge
RDAS4	RDA BC4, OTF
RDAS8	RDA BL8, OTF
RDS4	RD BC4, OTF
RDS8	RD BL8, OTF
REF	REFresh
REFpb	Per-bank Refresh
REFab	All-bank Refresh
SRE	Self-Refresh Entry
SREF	Self-REFresh entry
SREFX	Self-REFresh eXit
SRX	Self-Refresh eXit
WR	WRite fixed BL8 or BC4
WRA	WR w/Auto-precharge
WRAS4	WRA BC4, OTF
WRAS8	WRA BL8, OTF
WRS4	WR BC4, OTF
WRS8	WR BL8, OTF
ZQCL	ZQ Calibration Long
ZQCS	ZQ Calibration Short

Timings

t_{AA}	Time internal read to first data
t_{AC}	Time CK to DQS, access
t_{CH}	Time CK high
t_{CK}	Time CK period
t_{CL}	Time CK low, NOT CAS Latency CL
t_{DQSCK}	Time CK to DQS
t_{FAW}	Time Four Activate Window
t_{MOD}	Time MRS to any command (PC DDRs)
t_{MRD}	Time MRS to MRS command (PC DDRs)
t_{MRD}	Time MRW to any command (LPDDR3/4)
t_{MRW}	Time MRW to MRW command (LPDDR3/4)
t_{RAS}	Time Active to Precharge, ACT to PRE max 9 x t_{REFI}, min by speed bin
t_{RC}	Time Row Cycle Time ACT to ACT or ACT to REF, no PRE in-between
t_{RCD}	Time RAS-to-CAS delay, ACT to RD/WR
t_{REFI}	Time Refresh Interval 1.95, 3.9, or 7.8uS
t_{RFC}	Time Refresh Command 72 to 350nS
t_{RP}	Time Precharge, Recovery Period
t_{RRD}	Time ACT to ACT, different banks, no PRE between
t_{RTP}	Time Read to Precharge

t_{XX} as in t_{CK}, time period, inconsistently used as in t_{CCD_S}=5 which is 5 ticks, not 5ns.

nXX as in nRCD, number of CK ticks, inconsistently used as in t_{AA}+2nCK which should be t_{AA}+2t_{CK}.

CL = ticks for CAS Latency, never shown as nCL.