256Mbit GDDR SDRAM

2M x 32Bit x 4 Banks
Graphic Double Data Rate
Synchronous DRAM
with Bi-directional Data Strobe
(144-Ball FBGA)

Revision 1.1

May 2004

Revision History

Revision 1.1 (May 21, 2004)
- Changed ICC5. Refer to the DC characteristics table.
- Changed ICC6 from 5mA to 8mA

Revision 1.0 (March 29, 2004)
- tCK(max) changes : Refer to the AC characteristics of page 14.

Revision 0.7 (March 18, 2004) - *Preliminary*
- Added "Dummy MRS" command during the power-up sequence.

Revision 0.6 (February 21, 2004) - *Preliminary*
- DC changes : Refer to the DC characteristics of page 12

Revision 0.5 (January 31, 2004) - *Preliminary*
- Changed tCDLR for all the frequency from 2tCK to 3tCK
- Changed CL of -GC22/GC25 from 5tCK to 6tCK
- Changed CL of -GC2A/33/36 from 4tCK to 5tCK

Revision 0.4 (November 29, 2003) - *Target Spec*
- Corrected typo

Revision 0.3 (November 24, 2003) - *Target Spec*
- Added DC spec value

Revision 0.2 (November 13, 2003) - *Target Spec*
- Remove "Read interrupted by Read" and "Write interrupted by Write" from the spec. Accordingly, all interrupt functions are not supported.
- Removed BL2 option from the spec. Only BL4 without interrupt supported. Accordingly changed tCCD from 1tCK to 2tCK.
- Changed tCK(max) from 4ns to 6ns
- Changed DLL locking time from 20000tCK to 3000tCK
- Changed tRCD of K4D55323QF-GC33 from 4tCK to 5tCK.
- Changed tWR (Refer to the spec table)
- Added K4D55323QF-GC36

Revision 0.1 (September 15, 2003) - *Target Spec*
- "Read interrupted by precharge" and "write interrupted by precharge" functions are not supported.
- "Read interrupted by a burst stop" and " write and write interrupted by a read and DM fucntions " are not supported
- "Burst stop function" is not supported

  Only read interrupted by a read and write interrupted by a write are supported
- BL2 and BL4 supported (No BL8 supported) - the starting column address should be always a even number in this case.
- Power down mode :After issuing "power down mode", NOP or DESEL commands should be issued for more than 8ns.

  Also, during the tPDEX, only NOP or DESEL commands are available.

2M x 32Bit x 4 Banks Graphic Double Data Rate Synchronous DRAM with Bi-directional Data Strobe and DLL

FEATURES

- 1.8V ± 0.1V power supply for device operation
- 1.8V ± 0.1V power supply for I/O interface
- SSTL_2 compatible inputs/outputs
- 4 banks operation
- MRS cycle with address key programs
  - -. Read latency 3, 4, 5,6
  - **- Burst length 4 only**
    Starting column address : Even address only
  - -. Burst type (sequential only)
- All inputs except data & DM are sampled at the positive going edge of the system clock
- Differential clock input
- **No burst stop**
- **No interrupt function**
- 4 DQS's (1DQS / Byte)
- Data I/O transactions on both edges of Data strobe
- DLL aligns DQ and DQS transitions with Clock transition
- Edge aligned data & data strobe output
- Center aligned data & data strobe input
- DM for write masking only
- Auto & Self refresh
- 32ms refresh period (4K cycle)
- 144-Ball FBGA
- Maximum clock frequency up to 450MHz
- Maximum data rate up to 900Mbps/pin

ORDERING INFORMATION

Part NO.	Max Freq.	Max Data Rate	Interface	Package
K4D55323QF-GC22	450MHz	900Mbps/pin	SSTL	144-Ball FBGA
K4D55323QF-GC25	400MHz	800Mbps/pin		
K4D55323QF-GC2A	350MHz	700Mbps/pin		
K4D55323QF-GC33	300MHz	600Mbps/pin		
K4D55323QF-GC36	275MHz	550Mbps/pin		

K4D55323QF-VC is the Lead Free package part number

GENERAL DESCRIPTION

FOR 2M x 32Bit x 4 Bank GDDR SDRAM

The K4D55323QF is 268,435,456 bits of hyper synchronous data rate Dynamic RAM organized as 4 x 2,097,152 words by 32 bits, fabricated with SAMSUNG's high performance CMOS technology. Synchronous features with Data Strobe allow extremely high performance up to 4.0GB/s/chip. I/O transactions are possible on both edges of the clock cycle. Range of operating frequencies, programmable burst length and programmable latencies allow the device to be useful for a variety of high performance memory system applications.

PIN CONFIGURATION (Top View)

	2	3	4	5	6	7	8	9	10	11	12	13
B	DQS0	DM0	VSSQ	DQ3	DQ2	DQ0	DQ31	DQ29	DQ28	VSSQ	DM3	DQS3
C	DQ4	VDDQ	NC	VDDQ	DQ1	VDDQ	VDDQ	DQ30	VDDQ	NC	VDDQ	DQ27
D	DQ6	DQ5	VSSQ	VSSQ	VSSQ	VDD	VDD	VSSQ	VSSQ	VSSQ	DQ26	DQ25
E	DQ7	VDDQ	VDD	VSS	VSSQ	VSS	VSS	VSSQ	VSS	VDD	VDDQ	DQ24
F	DQ17	DQ16	VDDQ	VSSQ	VSS Thermal	VSS Thermal	VSS Thermal	VSS Thermal	VSSQ	VDDQ	DQ15	DQ14
G	DQ19	DQ18	VDDQ	VSSQ	VSS Thermal	VSS Thermal	VSS Thermal	VSS Thermal	VSSQ	VDDQ	DQ13	DQ12
H	DQS2	DM2	NC	VSSQ	VSS Thermal	VSS Thermal	VSS Thermal	VSS Thermal	VSSQ	NC	DM1	DQS1
J	DQ21	DQ20	VDDQ	VSSQ	VSS Thermal	VSS Thermal	VSS Thermal	VSS Thermal	VSSQ	VDDQ	DQ11	DQ10
K	DQ22	DQ23	VDDQ	VSSQ	VSS	VSS	VSS	VSS	VSSQ	VDDQ	DQ9	DQ8
L	$\overline{CAS}$	$\overline{WE}$	VDD	VSS	A10	VDD	VDD	RFU1	VSS	VDD	NC	NC
M	$\overline{RAS}$	NC	NC	BA1	A2	A11	A9	A5	RFU2	CK	$\overline{CK}$	MCL
N	$\overline{CS}$	NC	BA0	A0	A1	A3	A4	A6	A7	A8/AP	CKE	VREF

NOTE:
1. RFU1 is reserved for A12
2. RFU2 is reserved for BA2
3. VSS Thermal balls are optional

PIN DESCRIPTION

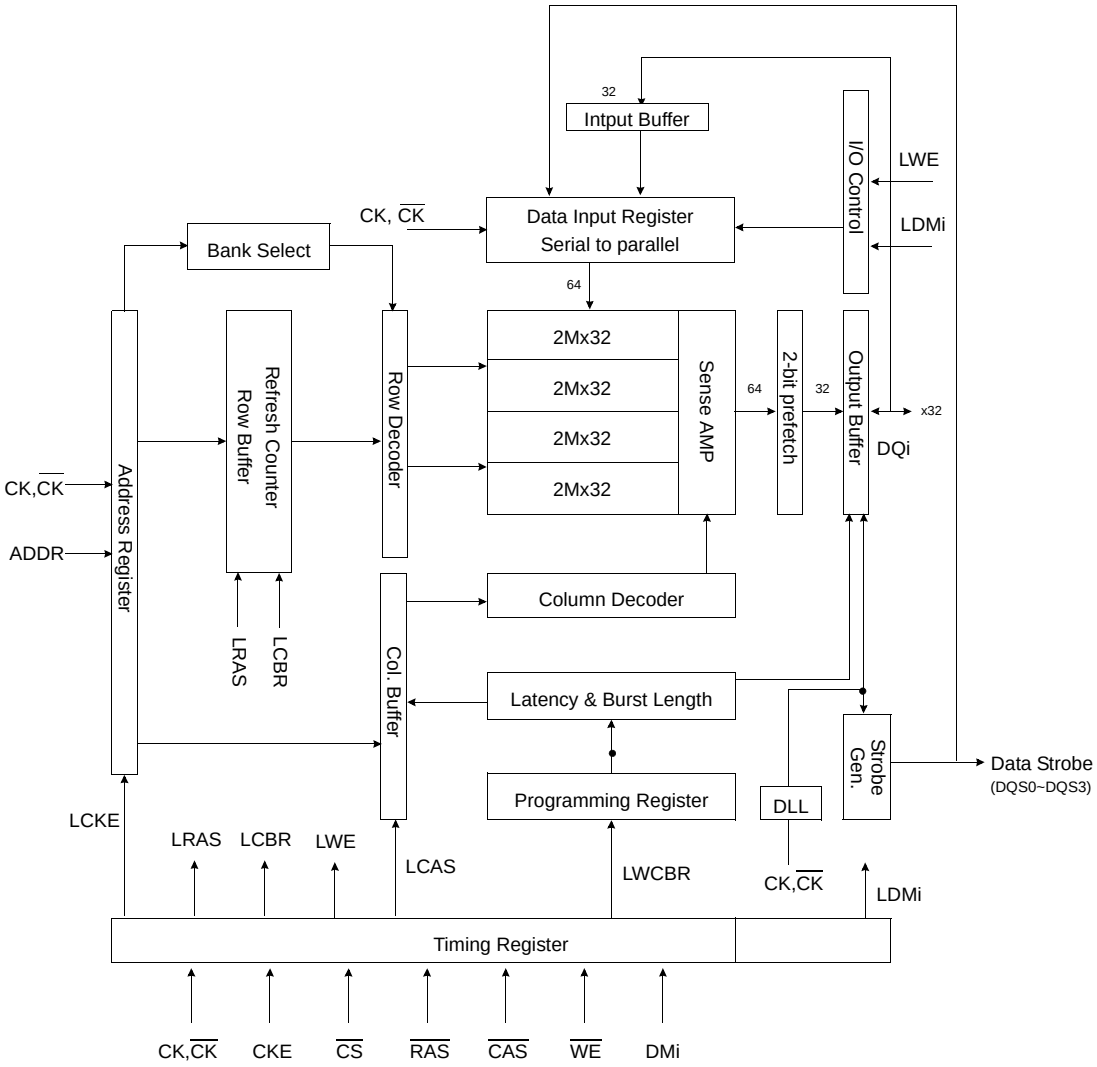
CK,$\overline{CK}$	Differential Clock Input	BA_0, BA_1	Bank Select Address
CKE	Clock Enable	A_0 ~A_{11}	Address Input
$\overline{CS}$	Chip Select	DQ_0 ~ DQ_{31}	Data Input/Output
$\overline{RAS}$	Row Address Strobe	V_{DD}	Power
$\overline{CAS}$	Column Address Strobe	V_{SS}	Ground
WE	Write Enable	V_{DDQ}	Power for DQ's
DQS	Data Strobe	V_{SSQ}	Ground for DQ's
DM	Data Mask	NC	No Connection
RFU	Reserved for Future Use	MCL	Must Connect Low

INPUT/OUTPUT FUNCTIONAL DESCRIPTION

Symbol	Type	Function
CK, $\overline{CK}$*1	Input	The differential system clock Input. All of the inputs are sampled on the rising edge of the clock except DQ's and DM's that are sampled on both edges of the DQS.
CKE	Input	Activates the CK signal when high and deactivates the $\overline{CK}$ signal when low. By deactivating the clock, CKE low indicates the Power down mode or Self refresh mode.
$\overline{CS}$	Input	$\overline{CS}$ enables the command decoder when low and disabled the command decoder when high. When the command decoder is disabled, new commands are ignored but previous operations continue.
$\overline{RAS}$	Input	Latches row addresses on the positive going edge of the CK with $\overline{RAS}$ low. Enables row access & precharge.
$\overline{CAS}$	Input	Latches column addresses on the positive going edge of the CK with $\overline{CAS}$ low. Enables column access.
$\overline{WE}$	Input	Enables write operation and row precharge. Latches data in starting from $\overline{CAS}$, $\overline{WE}$ active.
DQS_0 ~ DQS_3	Input/Output	Data input and output are synchronized with both edge of DQS. DQS_0 for DQ_0 ~ DQ_7, DQS_1 for DQ_8 ~ DQ_{15}, DQS_2 for DQ_{16} ~ DQ_{23}, DQS_3 for DQ_{24} ~ DQ_{31}.
DM_0 ~ DM_3	Input	Data In mask. Data In is masked by DM Latency=0 when DM is high in burst write. DM_0 for DQ_0 ~ DQ_7, DM_1 for DQ_8 ~ DQ_{15}, DM_2 for DQ_{16} ~ DQ_{23}, DM_3 for DQ_{24} ~ DQ_{31}.
DQ_0 ~ DQ_{31}	Input/Output	Data inputs/Outputs are multiplexed on the same pins.
BA_0, BA_1	Input	Selects which bank is to be active.
A_0 ~ A_{11}	Input	Row/Column addresses are multiplexed on the same pins. Row addresses : RA_0 ~ RA_{11}, Column addresses : CA_0 ~ CA_7,CA_9 Column address CA_8 is used for auto precharge.
V_{DD}/V_{SS}	Power Supply	Power and ground for the input buffers and core logic.
V_{DDQ}/V_{SSQ}	Power Supply	Isolated power supply and ground for the output buffers to provide improved noise immunity.
V_{REF}	Power Supply	Reference voltage for inputs, used for SSTL interface.
NC/RFU	No connection/ Reserved for future use	This pin is recommended to be left "No connection" on the device
MCL	Must Connect Low	Must connect low

*1 : The timing reference point for the differential clocking is the cross point of CK and $\overline{CK}$.
For any applications using the single ended clocking, apply V_{REF} to $\overline{CK}$ pin.

BLOCK DIAGRAM (2Mbit x 32I/O x 4 Bank)



FUNCTIONAL DESCRIPTION

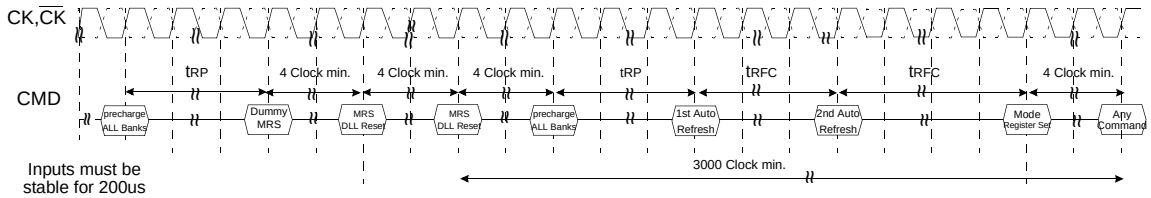
• Power-Up Sequence

GDDR SDRAMs must be powered up and initialized in a predefined manner to prevent undefined operations.

1. Apply power and keep CKE at low state (All other inputs may be undefined)
   - Apply VDD before VDDQ .
   - Apply VDDQ before VREF & VTT
2. Start clock and maintain stable condition for minimum 200us.
3. The minimum of 200us after stable power and clock(CK,$\overline{CK}$), apply NOP and take CKE to be high .
4. Issue precharge command for all banks of the device.
5. **Issue a dummy MRS command ("00001000100001")**
6. Issue a EMRS command to enable DLL
7. *1 Issue a MRS command to reset DLL. The additional 3000 clock cycles are required to lock the DLL.
8. *1,2 Issue precharge command for all banks of the device.
9. Issue at least 2 or more auto-refresh commands.
10. Issue a mode register set command with A8 to low to initialize the mode register.

*1 The additional 3000 cycles of clock input is required to lock the DLL after enabling DLL.
*2 Sequence of 6&7 is regardless of the order.

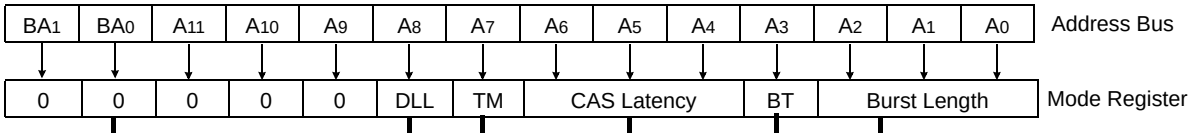
Power up & Initialization Sequence



*** When the operating frequency is changed, DLL reset should be required again.**
After DLL reset again, the minimum 3000 cycles of clock input is needed to lock the DLL.

MODE REGISTER SET(MRS)

The mode register stores the data for controlling the various operating modes of GDDR SDRAM. It programs CAS latency, addressing mode, burst length, test mode, DLL reset and various vendor specific options to make GDDR SDRAM useful for variety of different applications. The default value of the mode register is not defined, therefore the mode register must be written after EMRS setting for proper operation. The mode register is written by asserting low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$(The GDDR SDRAM should be in active mode with CKE already high prior to writing into the mode register). The state of address pins A_0 ~ A_{11} and BA_0, BA_1 in the same cycle as $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$ going low is written in the mode register. Minimum four clock cycles are requested to complete the write operation in the mode register. The mode register contents can be changed using the same command and clock cycle requirements during operation as long as all banks are in the idle state. The mode register is divided into various fields depending on functionality. The burst length uses A_0 ~ A_2, addressing mode uses A_3, CAS latency(read latency from column address) uses A_4 ~ A_6. A_7 is used for test mode. A_8 is used for DLL reset. A_7,A_8, BA_0 and BA_1 must be set to low for normal MRS operation. Refer to the table for specific codes for various burst length, addressing modes and CAS latencies.



DLL

A_8	DLL Reset
0	No
1	Yes

Test Mode

A_7	mode
0	Normal
1	Test

Burst Type

A_3	Type
0	Sequential
1	Reserved

0

BA_0	A_n ~ A_0
0	MRS
1	EMRS

* RFU(Reserved for future use) should stay "0" during MRS cycle.

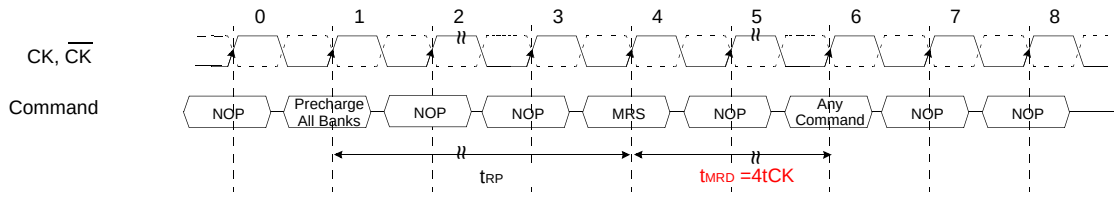
CAS Latency

A_6	A_5	A_4	Latency
0	0	0	Reserved
0	0	1	Reserved
0	1	0	Reserved
0	1	1	Reserved
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	Reserved

Burst Length

A_2	A_1	A_0	Burst Type
0	0	0	Reserved
0	0	1	Reserved
0	1	0	4
0	1	1	Reserved
1	0	0	Reserved
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

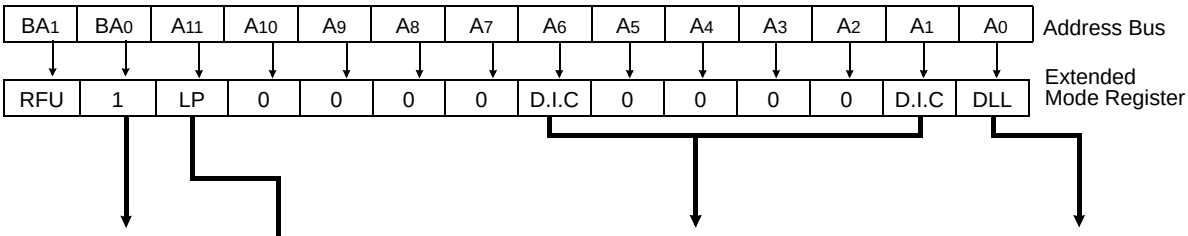
MRS Cycle



*1 : MRS can be issued only at all banks precharge state.
*2 : Minimum t_{RP} is required to issue MRS command.

EXTENDED MODE REGISTER SET(EMRS)

The extended mode register stores the data for enabling or disabling DLL and selecting output driver strength. The default value of the extended mode register is not defined, therefore the extened mode register must be written after power up for enabling or disabling DLL. The extended mode register is written by asserting low on $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{WE}$ and high on BA0(The GDDR SDRAM should be in all bank precharge with CKE already high prior to writing into the extended mode register). The state of address pins A0, A2 ~ A5, A7 ~ A11 and BA1 in the same cycle as $\overline{CS}$, $\overline{RAS}$, $\overline{CAS}$ and $\overline{WE}$ going low are written in the extended mode register. A1 and A6 are used for setting driver strength to normal, weak or matched impedance. The minimum four clock cycles are required to complete the write operation in the extended mode register. The mode register contents can be changed using the same command and clock cycle requirements during operation as long as all banks are in the idle state. A0 is used for DLL enable or disable. "High" on BA0 is used for EMRS. A11 is used for low power enable or disable. All the other address pins except A0,A1,A6,A11 and BA0 must be set to low for proper EMRS operation. Refer to the table for specific codes.



BA0	An ~ A0
0	MRS
1	EMRS

A6	A1	Output Driver Impedence Control
0	0	20 Ω
0	1	30 Ω
1	0	45 Ω
1	1	60 Ω

A0	DLL Enable
0	Enable
1	Disable

A11	Low Power
0	Disable
1	Enable

Low Power Mode

Low power mode can be enabled by A11="H" during the EMRS command and in this case, Precharge Power Down command activates LP mode1 and Self Refresh command activates LP mode2. In case that A11 set to "L" during the EMRS, Low Power mode is disabled and Precharge Power Down command and Self Refresh command will do normal operation.

If a Precharge Power Down command issued under the condition of Low Power mode enabled, a device enters the LP mode1 and it can reduce Precharge Power Down current significantly by disabling DLL during the Precharge Power Down, however it takes more time to exit Power Down. If the power down duration is less than 20us, the required tPDEX is 100tCK. Otherwise, 3000tCK required for the tPDEX.

If a Self Refresh command issued under the condition of Low Power mode enabled, a device enters the LP mode2 and it can reduce tXSR while slightly increase the Self Refresh current. If the Self Refresh duration is less than 20us, the required tXSR is 100tCK. Otherwise, 3000tCK required for the tXSR.

Low Power / Command	Disabled (A11="L" @ EMRS)	Enabled (A11="H" @ EMRS)	Comments
Precharge Power Down	Precharge Power Down	LP Mode1	. DLL disabled for the purpose of current saving (ICC2P minimized) . tPDEX increased - 100tCK@ power down exit within 20us - 3KtCK@ power down exit after 20us
Self Refresh	Self Refresh	LP Mode2	. Short tXSR - 100tCK@ Self refresh exit within 20us - 3KtCK@ Self refresh exit after 20us

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Unit
Voltage on any pin relative to Vss	V_{IN}, V_{OUT}	-0.5 ~ 2.5	V
Voltage on V_{DD} supply relative to Vss	V_{DD}	-1.0 ~ 2.5	V
Voltage on V_{DD} supply relative to Vss	V_{DDQ}	-0.5 ~ 2.5	V
Storage temperature	T_{STG}	-55 ~ +150	°C
Power dissipation	P_D	2.0	W
Short circuit current	I_{OS}	50	mA

Note : Permanent device damage may occur if ABSOLUTE MAXIMUM RATINGS are exceeded.
Functional operation should be restricted to recommended operating condition.
Exposure to higher than recommended voltage for extended periods of time could affect device reliability.

POWER & DC OPERATING CONDITIONS(SSTL In/Out)

Recommended operating conditions(Voltage referenced to V_{SS}=0V, T_A=0 to 65°C)

Parameter	Symbol	Min	Typ	Max	Unit	Note
Device Supply voltage	V_{DD}	1.7	1.8	1.9	V	1
Output Supply voltage	V_{DDQ}	1.7	1.8	1.9	V	1
Reference voltage	V_{REF}	0.49*V_{DDQ}	-	0.51*V_{DDQ}	V	2
Termination voltage	Vtt	V_{REF}-0.04	V_{REF}	V_{REF}+0.04	V	3
Input logic high voltage	$V_{IH(DC)}$	V_{REF}+0.15	-	V_{DDQ}+0.30	V	4
Input logic low voltage	$V_{IL(DC)}$	-0.30	-	V_{REF}-0.15	V	5
Output logic high voltage	V_{OH}	Vtt+0.4	-	-	V	I_{OH}=-15.2mA
Output logic low voltage	V_{OL}	-	-	Vtt-0.4	V	I_{OL}=+15.2mA
Input leakage current	I_{IL}	-5	-	5	uA	6
Output leakage current	I_{OL}	-5	-	5	uA	6

Note :
1. Under all conditions V_{DDQ} must be less than or equal to V_{DD}.
2. V_{REF} is expected to equal 0.50*V_{DDQ} of the transmitting device and to track variations in the DC level of the same. Peak to peak noise on the V_{REF} may not exceed + 2% of the DC value.
3. V_{tt} of the transmitting device must track V_{REF} of the receiving device.
4. V_{IH}(max.)= V_{DDQ} +1.5V for a pulse width and it can not be greater than 1/3 of the cycle rate.
5. V_{IL}(min.)= -1.5V for a pulse width and it can not be greater than 1/3 of the cycle rate.
6. For any pin under test input of 0V $\leq$ V_{IN} $\leq$ V_{DD} is acceptable. For all other pins that are not under test V_{IN}=0V.

DC CHARACTERISTICS

Recommended operating conditions Unless Otherwise Noted, T_A=0 to 65°C)

Parameter	Symbol	Test Condition	Version					Unit	Note
			-22	-25	-2A	-33	-36		
Operating Current (One Bank Active)	I_{CC1}	Burst Lenth=2 $t_{RC} \geq t_{RC}$(min) I_{OL}=0mA, t_{CC}= t_{CC}(min)	360	350	310	300	290	mA	1
Precharge Standby Current in Power-down mode	I_{CC2P}	CKE ≤ V_{IL}(max), t_{CC}= t_{CC}(min)	60	60	50	50	45	mA	
Precharge Standby Current in Non Power-down mode	I_{CC2N}	CKE ≥ V_{IH}(min), CS ≥ V_{IH}(min), t_{CC}= t_{CC}(min)	130	120	110	100	95	mA	
Active Standby Current power-down mode	I_{CC3P}	CKE ≤ V_{IL}(max), t_{CC}= t_{CC}(min)	95	90	80	75	70	mA	
Active Standby Current in in Non Power-down mode	I_{CC3N}	CKE ≥ VIH(min), CS ≥ VIH(min), t_{CC}= t_{CC}(min)	230	210	190	170	160	mA	
Operating Current (Burst Mode)	I_{CC4}	I_{OL}=0mA ,t_{CC}= t_{CC}(min), Page Burst, All Banks activated.	470	430	400	380	360	mA	
Refresh Current	I_{CC5}	$t_{RC} \geq t_{RFC}$(min)	420	400	385	350	325	mA	2
Self Refresh Current	I_{CC6}	CKE ≤ 0.2V	8					mA	
Operating Current (4Bank interleaving)	I_{CC7}	Burst Length=4 $t_{RC} \geq t_{RC}$(min) I_{OL}=0mA, t_{CC}= t_{CC}(min)	670	600	550	520	510	mA	

Note : 1. Measured with outputs open.
2. Refresh period is 32ms.

AC INPUT OPERATING CONDITIONS

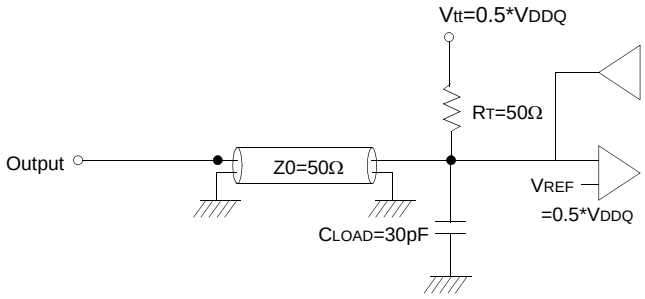
Recommended operating conditions(Voltage referenced to V_{SS}=0V, V_{DD}=1.8V± 0.1V, V_{DDQ}=1.8V± 0.1V,T_A=0 to 65°C)

Parameter	Symbol	Min	Typ	Max	Unit	Note
Input High (Logic 1) Voltage; DQ	V_{IH}	V_{REF}+0.35	-	-	V	
Input Low (Logic 0) Voltage; DQ	V_{IL}	-	-	V_{REF}-0.35	V	
Clock Input Differential Voltage; CK and $\overline{CK}$	V_{ID}	0.7	-	V_{DDQ}+0.6	V	1
Clock Input Crossing Point Voltage; CK and $\overline{CK}$	V_{IX}	0.5*V_{DDQ}-0.2	-	0.5*V_{DDQ}+0.2	V	2

Note : 1. V_{ID} is the magnitude of the difference between the input level on CK and the input level on $\overline{CK}$
2. The value of V_{IX} is expected to equal 0.5*V_{DDQ} of the transmitting device and must track variations in the DC level of the same

AC OPERATING TEST CONDITIONS (V_{DD}=1.8V±0.1V, T_A= 0 to 65°C)

Parameter	Value	Unit	Note
Input reference voltage for CK(for single ended)	0.50*V_{DDQ}	V	
CK and $\overline{CK}$ signal maximum peak swing	1.5	V	
CK signal minimum slew rate	1.0	V/ns	
Input Levels(V_{IH}/V_{IL})	V_{REF}+0.35/V_{REF}-0.35	V	
Input timing measurement reference level	V_{REF}	V	
Output timing measurement reference level	V_{tt}	V	
Output load condition	See Fig.1		



(Fig. 1) Output Load Circuit

CAPACITANCE (V_{DD}=1.8V, T_A= 25°C, f=1MHz)

Parameter	Symbol	Min	Max	Unit
Input capacitance(CK, $\overline{CK}$)	C_{IN1}	3.0	5.0	pF
Input capacitance(A_0~A_{11}, BA_0~BA_1)	C_{IN2}	3.0	5.0	pF
Input capacitance (CKE, $\overline{CS}$, $\overline{RAS}$,$\overline{CAS}$, $\overline{WE}$)	C_{IN3}	3.0	5.0	pF
Data & DQS input/output capacitance(DQ_0~DQ_{31})	C_{OUT}	3.0	5.0	pF
Input capacitance(DM0 ~ DM3)	C_{IN4}	3.0	5.0	pF

DECOUPLING CAPACITANCE GUIDE LINE

Recommended decoupling capacitance added to power line at board.

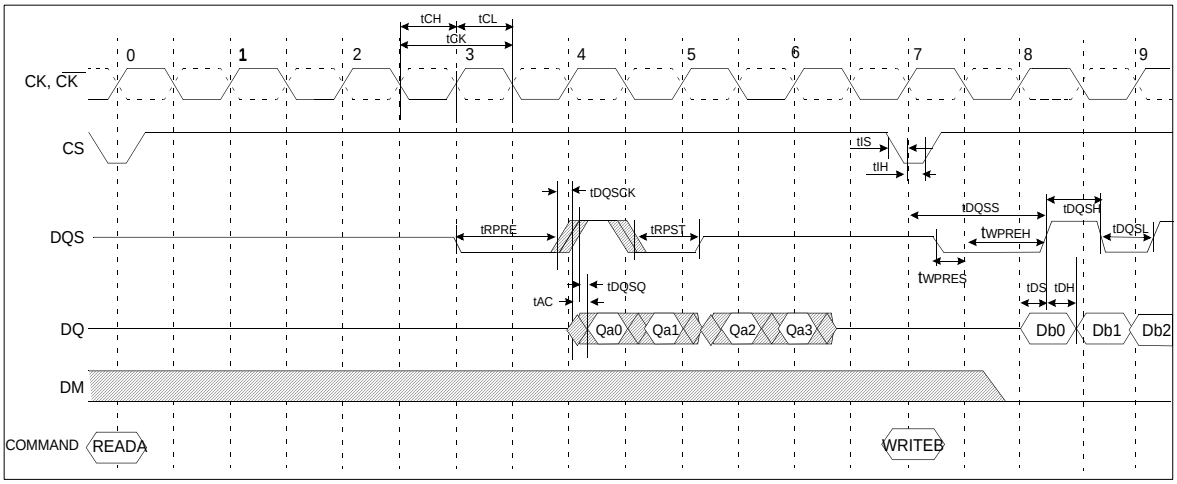
Parameter	Symbol	Value	Unit
Decoupling Capacitance between V_{DD} and V_{SS}	C_{DC1}	10	uF
Decoupling Capacitance between V_{DDQ} and V_{SSQ}	C_{DC2}	10	uF

Note : 1. V_{DD} and V_{DDQ} pins are separated each other.
All V_{DD} pins are connected in chip. All V_{DDQ} pins are connected in chip.
2. V_{SS} and V_{SSQ} pins are separated each other
All V_{SS} pins are connected in chip. All V_{SSQ} pins are connected in chip.

AC CHARACTERISTICS

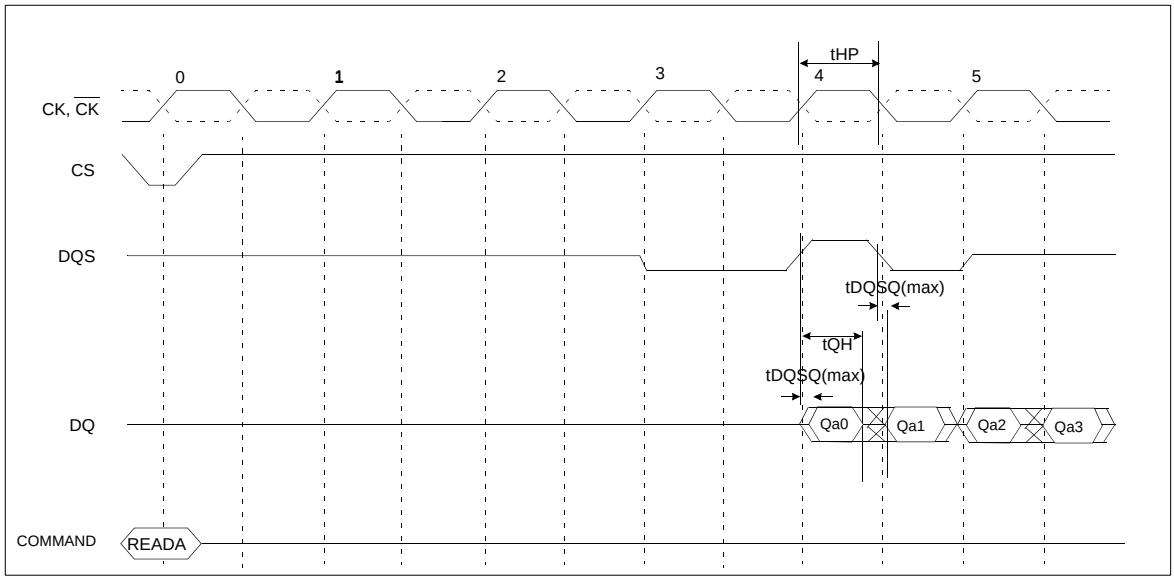
Parameter		Symbol	-22		-25		-2A		-33		-36		Unit	Note
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
CK cycle time	CL=4	tCK	-	6.0	-	6.0	-	6.0	-	6.0	-	6.0	ns	
	CL=5		2.86	4.0	3.3	4.0	2.86	4.0	3.3	4.0	3.6	4.0	ns	
	CL=6		2.2		2.5		-		-		-		ns	
CK high level width		tCH	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	tCK	
CK low level width		tCL	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	tCK	
DQS out access time from CK		tDQSCK	-0.45	0.45	-0.45	0.45	-0.55	0.55	-0.55	0.55	-0.6	0.6	ns	
Output access time from CK		tAC	-0.45	0.45	-0.45	0.45	-0.55	0.55	-0.55	0.55	-0.6	0.6	ns	
Data strobe edge to Dout edge		tDQSQ	-	0.28	-	0.28	-	0.35	-	0.35	-	0.4	ns	1
Read preamble		tRPRE	0.9	1.1	0.9	1.1	0.9	1.1	0.9	1.1	0.9	1.1	tCK	
Read postamble		tRPST	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	tCK	
CK to valid DQS-in		tDQSS	0.85	1.15	0.85	1.15	0.85	1.15	0.85	1.15	0.85	1.15	tCK	
DQS-In setup time		tWPRES	0	-	0	-	0	-	0	-	0	-	ns	
DQS-in hold time		tWPREH	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	tCK	
DQS write postamble		tWPST	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	0.4	0.6	tCK	
DQS-In high level width		tDQSH	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	tCK	
DQS-In low level width		tDQSL	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	tCK	
Address and Control input setup		tIS	0.55	-	0.6	-	0.8	-	0.8	-	0.9	-	ns	
Address and Control input hold		tIH	0.55	-	0.6	-	0.8	-	0.8	-	0.9	-	ns	
DQ and DM setup time to DQS		tDS	0.27	-	0.3	-	0.35	-	0.35	-	0.40	-	ns	
DQ and DM hold time to DQS		tDH	0.27	-	0.3	-	0.35	-	0.35	-	0.40	-	ns	
Clock half period		tHP	tCLmin or tCHmin	-	tCLmin or tCHmin	-	tCLmin or tCHmin	-	tCLmin or tCHmin	-	tCLmin or tCHmin	-	ns	
Data Hold skew factor		tQHS	-	0.4	-	0.4	-	0.4	-	0.4	-	0.45	ns	
Data output hold time from DQS		tQH	tHP-tQHS	-	tHP-tQHS	-	tHP-tQHS	-	tHP-tQHS	-	tHP-tQHS	-	ns	

Simplified Timing @ BL=4, CL=4



Note 1 :
- The JEDEC GDDR specification currently defines the output data valid window(tDV) as the time period when the data strobe and all data associated with that data strobe are coincidentally valid.
- The previously used definition of tDV(=0.35tCK) artificially penalizes system timing budgets by assuming the worst case output vaild window even then the clock duty cycle applied to the device is better than 45/55%
- A new AC timing term, tQH which stands for data output hold time from DQS is difined to account for clock duty cycle variation and replaces tDV
- tQHmin = tHP-X where
  . tHP=Minimum half clock period for any given cycle and is defined by clock high or clock low time(tCH,tCL)
  . X=A frequency dependent timing allowance account for tDQSQmax

tQH Timing (CL4, BL4)



AC CHARACTERISTICS (I)

Parameter	Symbol	-22		-25		-2A		-33		-36		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
Row cycle time	tRC	20	-	17	-	15	-	13	-	13	-	tCK	
Refresh row cycle time	tRFC	22	-	19	-	17	-	15	-	15	-	tCK	
Row active time	tRAS	14	100K	12	100K	10	100K	9	100K	9	100K	tCK	
RAS to CAS delay for Read	tRCDRD	7	-	6	-	5	-	5	-	5	-	tCK	
RAS to CAS delay for Write	tRCDWR	5	-	4	-	3	-	3	-	3	-	tCK	
Row precharge time	tRP	6	-	5	-	5	-	4	-	4	-	tCK	
Row active to Row active	tRRD	5	-	4	-	4	-	3	-	3	-	tCK	
Last data in to Row precharge @Normal Precharge	tWR	6	-	5	-	5	-	4	-	4	-	tCK	1
Last data in to Row precharge @Auto Precharge	tWR_A	5	-	5	-	5	-	5	-	5	-	tCK	1
Last data in to Read command	tCDLR	3	-	3	-	3	-	3	-	3	-	tCK	1
Col. address to Col. address	tCCD	2	-	2	-	2	-	2	-	2	-	tCK	
Mode register set cycle time	tMRD	4	-	4	-	4	-	4	-	4	-	tCK	
Auto precharge write recovery + Precharge	tDAL	11	-	10	-	10	-	9	-	9	-	tCK	
Exit self refresh to read command	tXSR	3000	-	3000	-	3000	-	3000	-	3000	-	tCK	
Power down exit time	tPDEX	4tCK+ tIS	-	4tCK+ tIS	-	3tCK+ tIS	-	3tCK+ tIS	-	3tCK+ tIS	-	ns	2
Refresh interval time	tREF	7.8	-	7.8	-	7.8	-	7.8	-	7.8	-	us	

Note : 1. For normal write operation, even numbers of Din are to be written inside DRAM

2. During the tPDEX, only NOP or DESEL commands are available.
After entering "power down mode", NOP or DESEL commands should be issued during 8ns+tIS.

AC CHARACTERISTICS (II)

(Unit : Number of Clock)

K4D55323QF-GC22

Frequency	Cas Latency	tRC	tRFC	tRAS	tRCDRD	tRCDWR	tRP	tRRD	tDAL	Unit
450MHz (2.2ns)	6	20	22	14	7	5	6	5	11	tCK
400MHz (2.5ns)	6	17	19	12	6	4	5	4	10	tCK
350MHz (2.86ns)	5	15	17	10	5	3	5	4	10	tCK
300MHz (3.3ns)	5	13	15	9	5	2	4	3	9	tCK
275MHz (3.6ns)	5	13	15	9	5	2	4	3	9	tCK

K4D55323QF-GC25

Frequency	Cas Latency	tRC	tRFC	tRAS	tRCDRD	tRCDWR	tRP	tRRD	tDAL	Unit
400MHz (2.5ns)	6	17	19	12	6	4	5	4	10	tCK
350MHz (2.86ns)	5	15	17	10	5	3	5	4	10	tCK
300MHz (3.3ns)	5	13	15	9	5	2	4	3	9	tCK
275MHz (3.6ns)	5	13	15	9	5	2	4	3	9	tCK

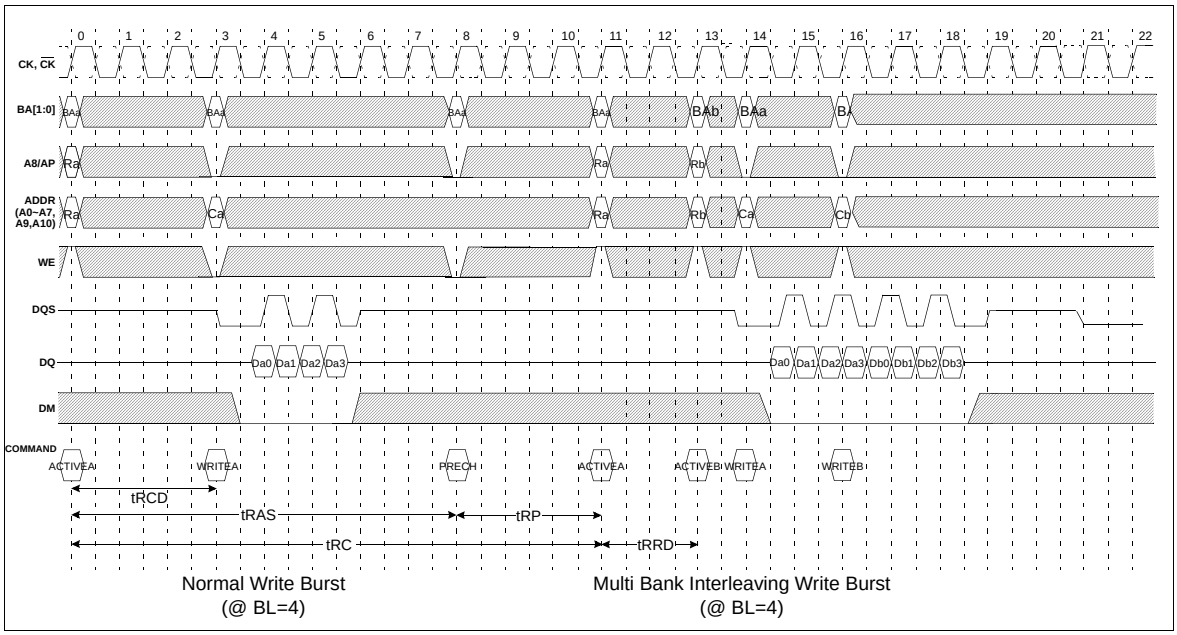
K4D55323QF-GC2A

Frequency	Cas Latency	tRC	tRFC	tRAS	tRCDRD	tRCDWR	tRP	tRRD	tDAL	Unit
350MHz (2.86ns)	5	15	17	10	5	3	5	4	10	tCK
300MHz (3.3ns)	5	13	15	9	5	2	4	3	9	tCK
275MHz (3.6ns)	5	13	15	9	5	2	4	3	9	tCK

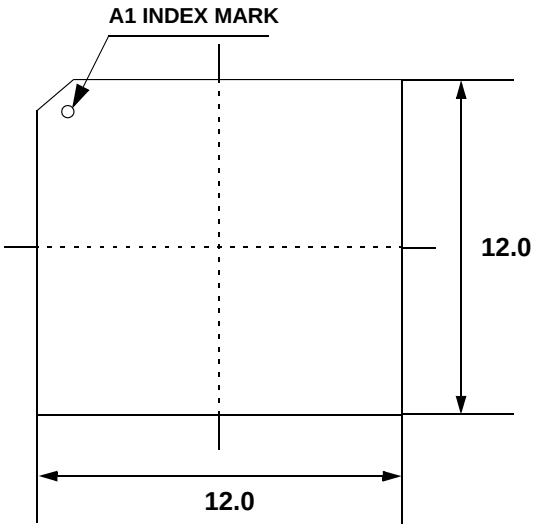
K4D55323QF-GC33

Frequency	Cas Latency	tRC	tRFC	tRAS	tRCDRD	tRCDWR	tRP	tRRD	tDAL	Unit
300MHz (3.3ns)	5	13	15	9	5	2	4	3	9	tCK
275MHz (3.6ns)	5	13	15	9	5	2	4	3	9	tCK

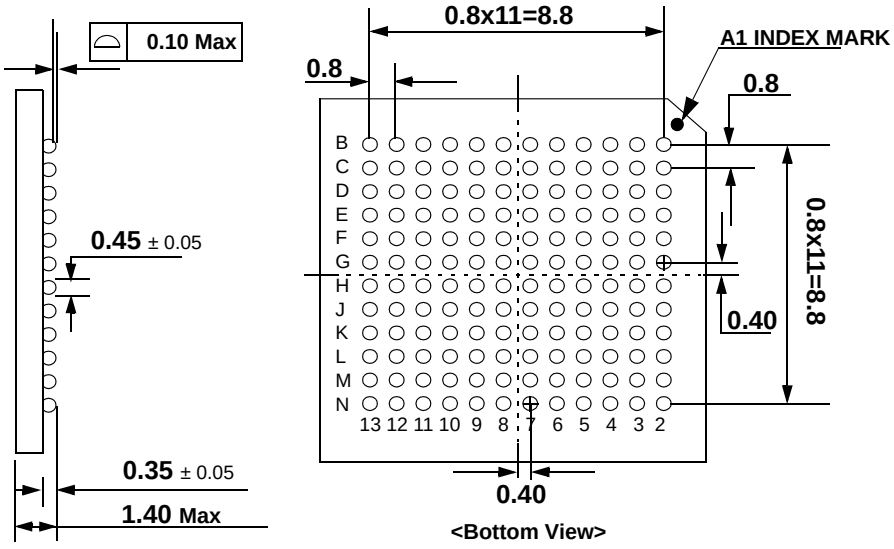
Simplified Timing(2) @ BL=4



PACKAGE DIMENSIONS (144-Ball FBGA)



<Top View>



<Bottom View>

Unit : mm