
Application Note for General PCB Design Guidelines for Mobile DRAM

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Purpose

Memory users frequently misuse the PCB design for Mobile DRAM, and many of those are related to line length, impedance matching and etc. In this application note, these will be explained in detail. This will be helpful for mobile system hardware (PCB design) engineers.

References

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1. Introduction

Mobile DRAM consists of mobile SDRAM, mobile DDR SDRAM and LPDDR2.

Items	Mobile SDR	Mobile DDR	LPDDR2
Max. Freq. (MHz)	133MHz	200MHz	400/533MHz
Max. Data Rate (Mbps)	133Mbps	400Mbps	800/1033Mbps
Differential Signals	none	Clock-{CK,/CK}	Clock-{CK,/CK} DQS-{DQS,/DQS}[0:3]
Vddq	1.8V	1.8V	1.2V
Vref.	none	none	being

LPDDR2 is fastest in mobile DRAM, and PCB design guidelines is written to use LPDDR2 signals. These guidelines cover Mobile SDR/DDR as well as LPDDR2.

2. PCB Design Guidelines for Signals

	DQ	Clock	CA & Control
Recommended Topology	Point to Point	Star	T-branch
Line Impedance (Zo)	Keep up same impedance - Recommended impedance : Single line = 50ohm Differential line = 80ohm		
Line Impedance Tolerance	Single line : +/- 10%, Differential line : +/- 15%		
Line to Line Space (min.)	3W*	3W*	3W*
Length Matching (Recommended range)	Target length +/- 0.1mm	+/- 0.1mm For CK to CK#	+/- 0.1mm For each net group
Signal Referencing	Keep up same reference - Recommended reference : DQ & CK nets are 'VSS' CA & Control nets are 'VDD'		

* W means signal line width

If one Mobile DRAM (1-package & 1-/CS) is designed in PCB, all topologies are same as "Point to Point" for all signals (DQ, Clock, CA & Control).

2.1 DQ net design guidelines

In LPDDR2, DQ net consists of Single line(DQs) and Differential line(DQSs, /DQSs).

In mobile SDR/DDR, DQ net consists of Single line(DQs, DQSs)

- P-to-P(Point to Point) topology is recommended for DQ net.
 - In two packages of DRAM, P-to-2P topology is recommended for DQ net
- Line Length & Impedance Matching
 - Check whether DQ line impedance is same for all signal layers.
Recommended DQ line impedance : 50 ohm +/- 10%
 - Spacing between DQ signals is recommended to 3W.
(W means signal line width)
 - Segments of DQS and /DQS should be in same layer.
Route most segments in inner layer. (if PCB has inner signal layers.)
Recommended differential impedance for DQS, /DQS : 80 ohm +/- 15%
cf.) In DDR, recommended DQS line impedance : 50 ohm +/- 10%
In mobile SDR, there is no DQS signal.
 - Lengths of DQ, DQS, /DQS and DM in a byte should be in target range.
Recommended range : target length +/- 0.1mm
Example)
 - Lengths of DQ[0:7], DQS0, /DQS0, DM0 : 2cm +/- 0.1mm*
 - Lengths of DQ[8:15], DQS1, /DQS1, DM1 : 2.5cm +/- 0.1mm*
 - Use same number of vias in DQ net or compensate length of vias.
- Signal Referencing
 - Signals of DQ net should keep up reference.
 - Check whether DQ net has reference
(Recommended reference is VSS plane)

2.2 Clock net design guidelines

DDR and LPDDR2 have Clock and Clock# signal, but SDR has only Clock signal.

DDR and LPDDR2 should follow these Clock net design guidelines.

- Star topology is recommended for clock net.
- Line Length & Impedance Matching
 - Check whether Clock line impedance is same for all signal layers.
Recommended differential impedance for clock net : 80 ohm +/- 15%
 - Spacing between Clock net and other net is recommended to 3W.
(W means signal line width)
 - Segments of Clock and Clock# should be in same layer.

Route most clock nets in inner layer

- Length of Clock is same as length of Clock#.
Recommended range : +/- 0.1mm for CK to /CK
- Minimize the branch length.

➤ Signal Referencing

- Signals of Clock net should keep up reference.
- Check whether Clock net has reference.
(Recommended reference is VSS plane)

2.3 CA & Control net design guidelines

In LPDDR2, CA net is DDR type (meaningful state is made by clock rising /falling edge) and Control net is SDR type (meaningful state is made by clock rising edge).

In SDR/DDR, Command, Address net and Control net are SDR type.

➤ T-Branch topology is recommended for Command, Address and Control net.

- CA net : CA[9:0]
- Control net : CKE, /CS

cf.) In SDR/DDR,

Command, Address net : A[15:0], BA[2:0], /RAS, /CAS, /WE

Control net : CKE, /CS

➤ Line Length & Impedance Matching

- Check whether CA & Control impedances are same for all signal layers.
Recommended C/A & Control line impedances : 50 ohm +/- 10%
- Do not route signals near high speed signals(CK,DQ net) or have enough spacing over 3W. (W means signal line width)
- Route most segments in inner layer. (if PCB has inner signal layers)
- Lengths of CA and Control in each net group should be in target range.
Recommended range : +/- 0.1mm for each net group
- Minimize the branch length.

➤ Signal Referencing

- Signals of CA & Control net should keep up reference.
- Check whether C/A & Clock net have reference.
(Recommended reference is VDD plane)

3. PCB Design Guidelines for Power

	Decoupling Cap. Placement	Pattern/Plane Routing
Vref	Near Vref generation Point and DRAM	Vref to other net space is more than 3W*.
	One more de-cap for Vref per DRAM	Vref line Width $\geq 0.3\text{mm}$
Power (VDD/VSS)	Near DRAM	Use Solid VDD/VSS plane
	Two more de-caps for Power net per DRAM - Recommend De-cap value : Over 100nF	VDD/VSS line width $\geq 0.3\text{mm}$

* W means signal line width

3.1 Vref

LPDDR2 has Vref, but mobile SDR/DDR have no Vref.

- De-coupling capacitor Placement
 - Place de-cap near Vref generation point and DRAM.
 - Check whether Vref net has one more de-cap per DRAM.
- Pattern/Plane Routing
 - Do not route near high speed signals(CK,DQ net) or have enough spacing over 3W. (W means signal line width)
 - Vref line Width $\geq 0.3\text{mm}$

3.2 Power (VDD/VSS)

- De-coupling capacitor Placement
 - Place de-cap near DRAM.
 - Check whether VDD net have two more de-cap per DRAM.
Recommended De-cap value is over 100nF.
Recommended De-caps are only for DRAM.
- Pattern/Plane Routing
 - Use Solid VDD/VSS plane.
 - VDD/VSS line Width $\geq 0.3\text{mm}$

4. Examples of Channel Simulation

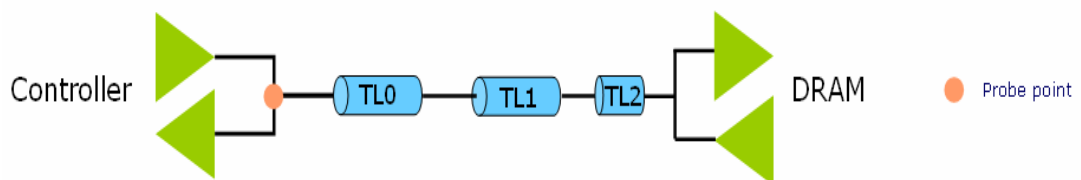
Channel Simulation is performed with change of line length and driver strength and result waveforms express the tendency along each variation. These examples will be very useful to check the dependency of line length and driver strength and will be helpful to do PCB design and signal testing. Comparing each waveform, it is necessary to focus the signal skew, overshoot/undershoot and aperture size.

4.1 DQ channel simulation

< Channel Condition for DQ >

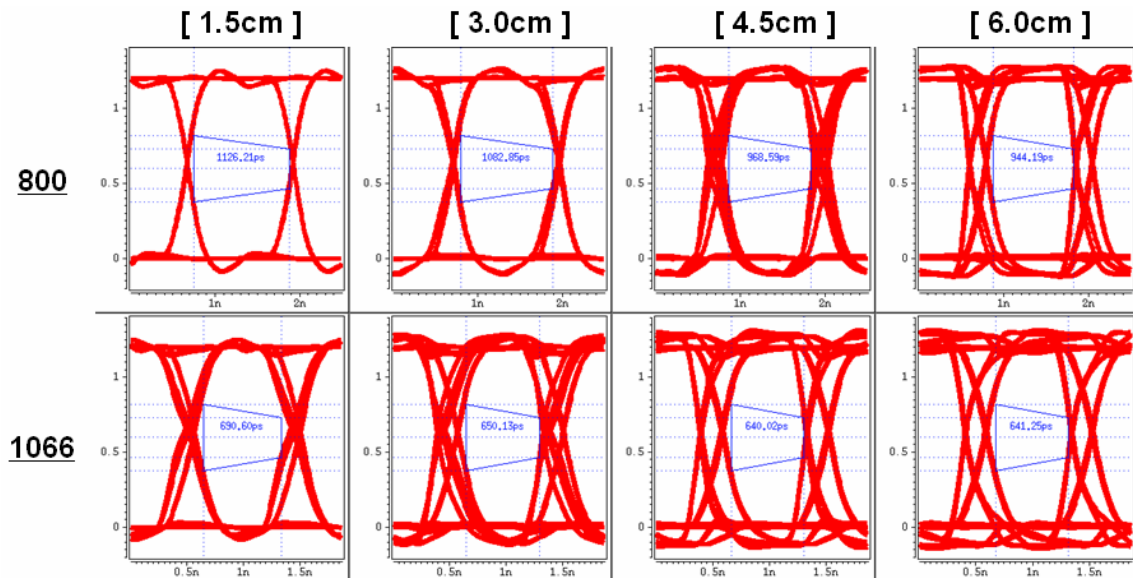
- DQ Read
 - Vddq : 1.2V
 - Impedance of Single line : 50ohm +/- 10%
 - DRAM model : LPDDR2
 - Operation Frequency : 800 / 1066Mbps
 - Driver strength (Ron) : 34.3 / 40 / 48 / 60ohm
 - Channel length : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm
- TL0 & TL2 is u-Strip line and each length is 4mm. TL1 (Strip line) is variable.

a) Point to Point Topology



< Channel Length Variation for DQ >

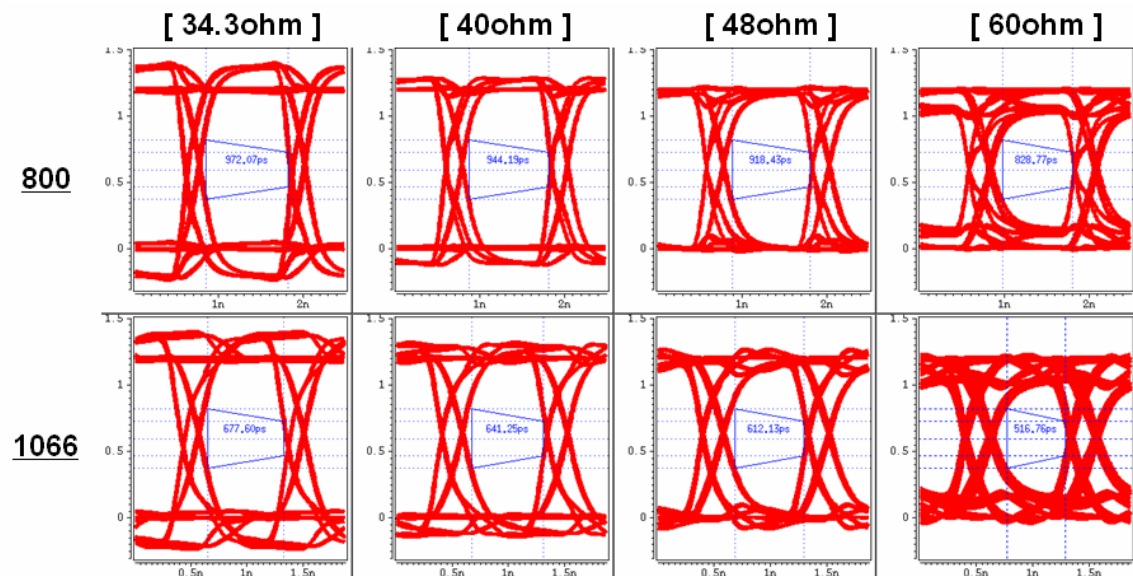
- Fixed Driver strength (Ron) : 40ohm
- Operation Freq. 800 / 1066Mbps
- Channel length variation : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm



When the channel length is increased, signal skew is increased, and it makes aperture reduced. There is increased over/under-shoot along increased length.

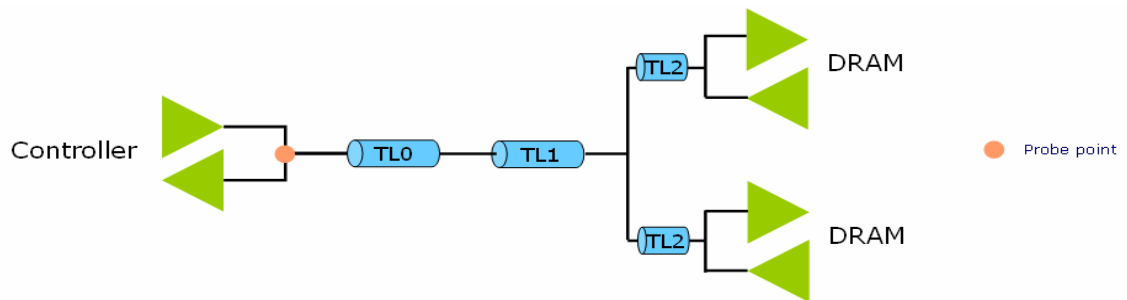
< Driver Strength Variation for DQ >

- Fixed Channel Length : 'TL0 + TL1 + TL2' = 6.0cm
- Operation Freq. 800 / 1066Mbps
- Driver strength(Ron) variation : 34.3 / 40 / 48 / 60ohm



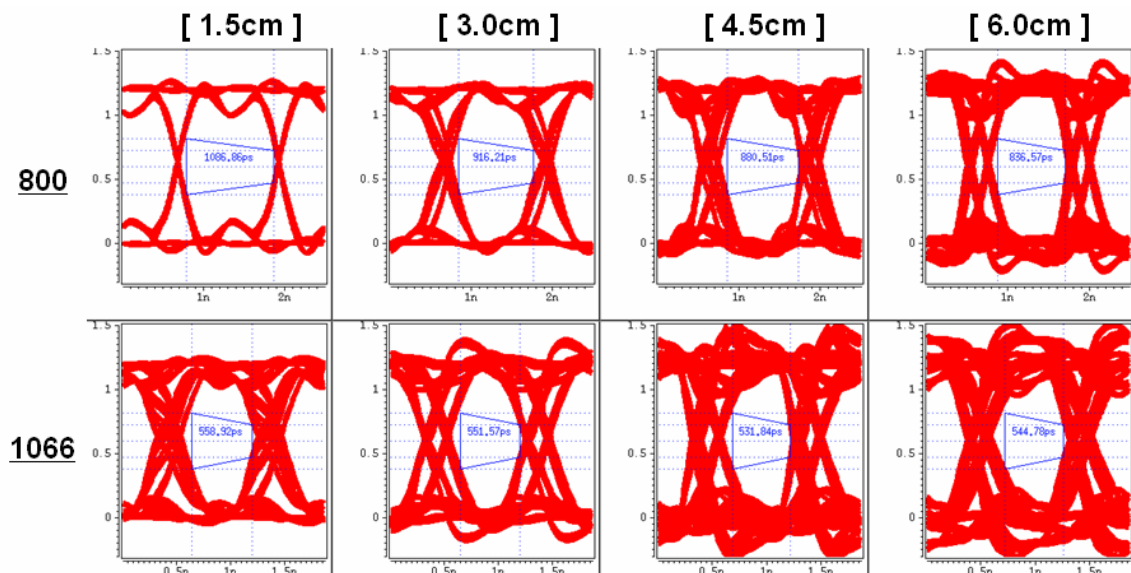
Small Ron value means large driver strength. Driver strength affects over/under-shoot and aperture size. It is necessary to select appropriate driver strength.

b) Point to 2-Point Topology



< Channel Length Variation for DQ with P-to-2P >

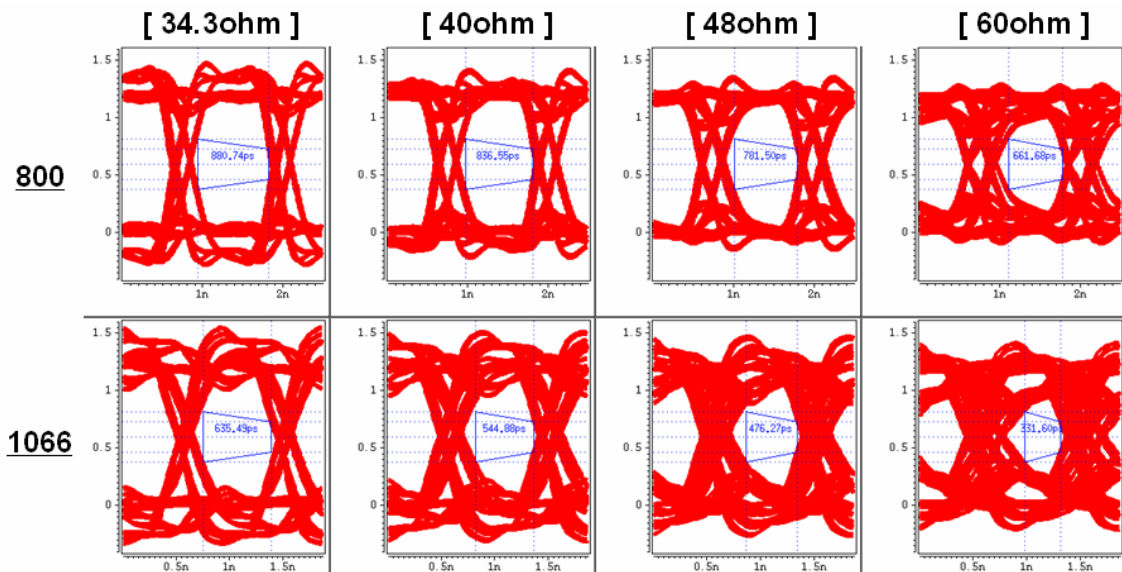
- Fixed Driver strength (R_{on}) : 40ohm
- Operation Freq. 800 / 1066Mbps
- Channel length variation : ' $TL0 + TL1 + TL2$ ' = 1.5 / 3.0 / 4.5 / 6.0cm



When the channel length is increased, signal skew is increased, and it makes aperture reduced. There is increased over/under-shoot along increased length.

< Driver Strength Variation for DQ with P-to-2P >

- Fixed Channel Length : ' $TL0 + TL1 + TL2$ ' = 6.0cm
- Operation Freq. 800 / 1066Mbps
- Driver strength(R_{on}) variation : 34.3 / 40 / 48 / 60ohm

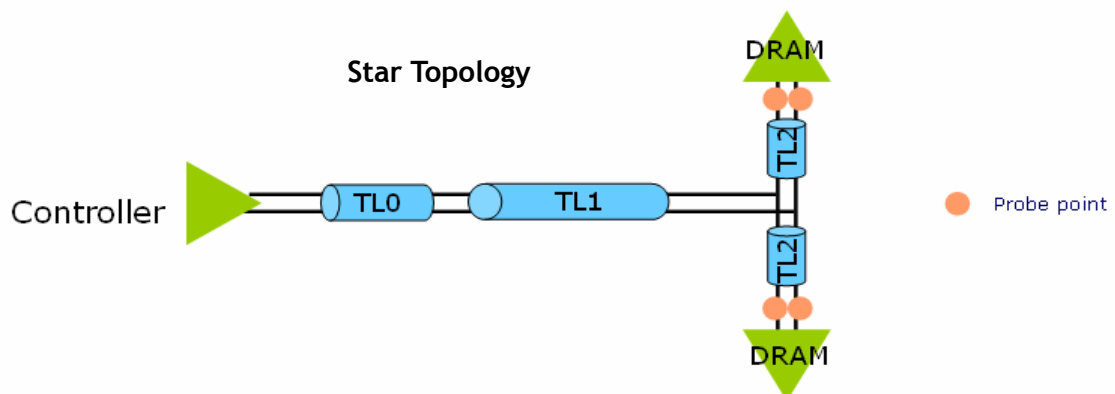


Small Ron value means large driver strength. Driver strength affects over/under-shoot and aperture size. It is necessary to select appropriate driver strength.

4.2 CK channel simulation

< Channel Condition for CK >

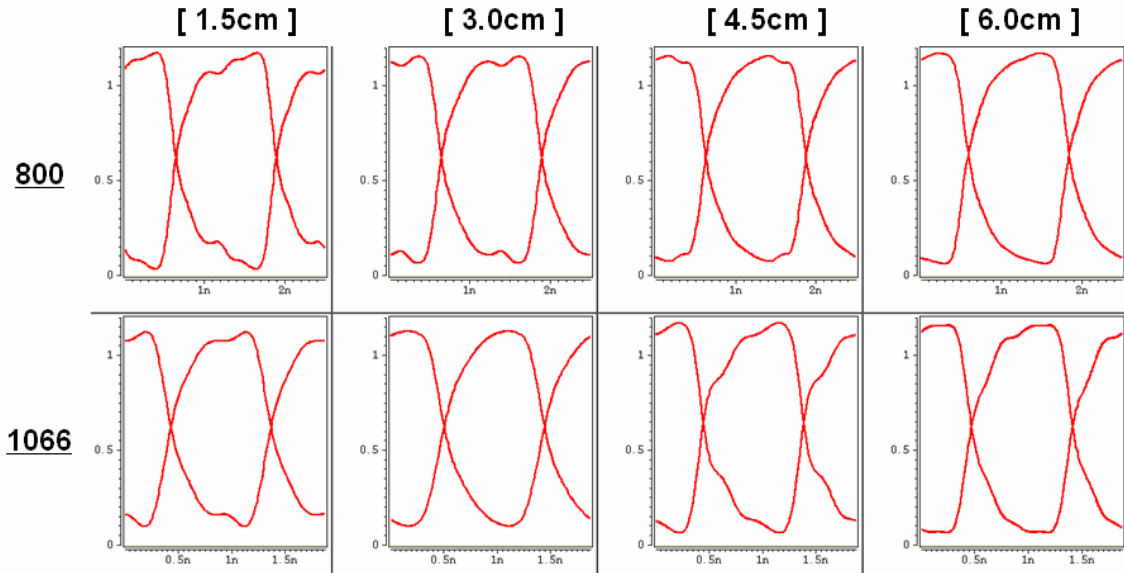
- Vddq : 1.2V
 - Impedance of Single line : 80ohm +/- 15%
 - DRAM model : LPDDR2
 - Operation Frequency : 800 / 1066Mbps
 - Driver strength (Ron) : 34.3 / 40 / 48 / 60ohm
 - Channel length : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm
- TL0 & TL2 is u-Strip line and each length is 4mm. TL1 (Strip line) is variable.



Star topology is used for CK net when two or more DRAMs are designed. When a DRAM is designed, the topology for CK net is Point-to-Point.

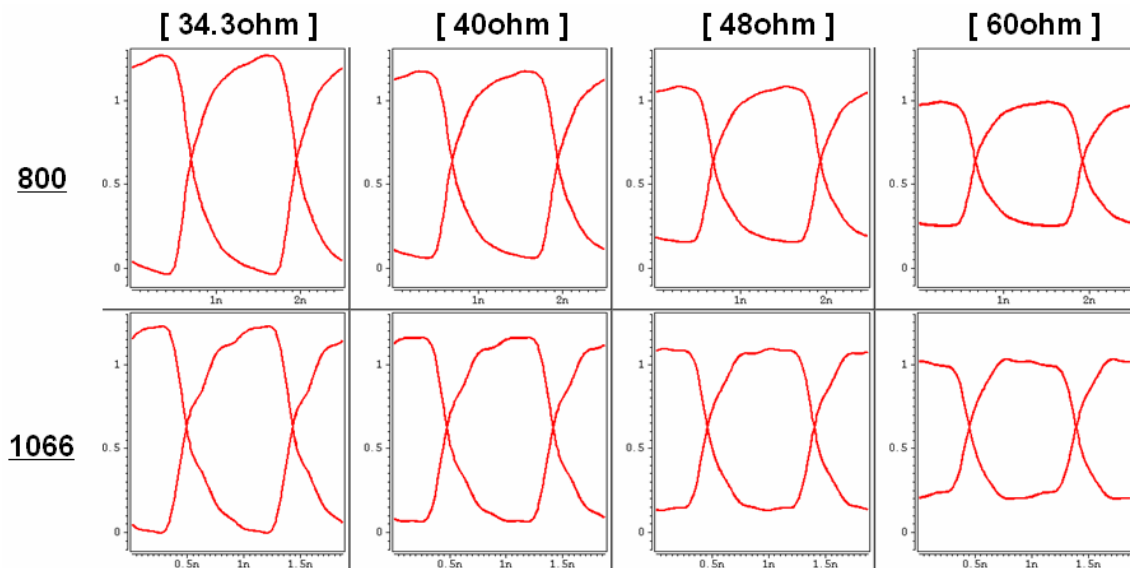
< Channel Length Variation for CK >

- Fixed Driver strength (Ron) : 40ohm
- Operation Freq. 800 / 1066Mbps
- Channel length variation : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm



< Driver Strength Variation for CK >

- Fixed Channel Length : 'TL0 + TL1 + TL2' = 6.0cm
- Operation Freq. 800 / 1066Mbps
- Driver strength(Ron) variation : 34.3 / 40 / 48 / 60ohm

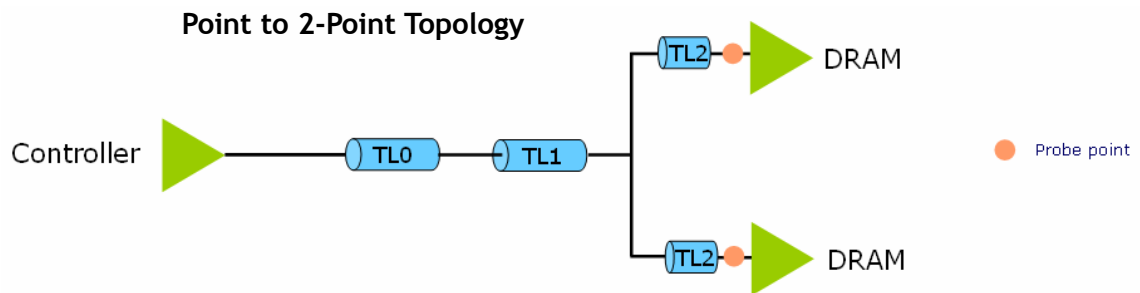


4.3 CA & Control channel simulation

a) CA channel simulation

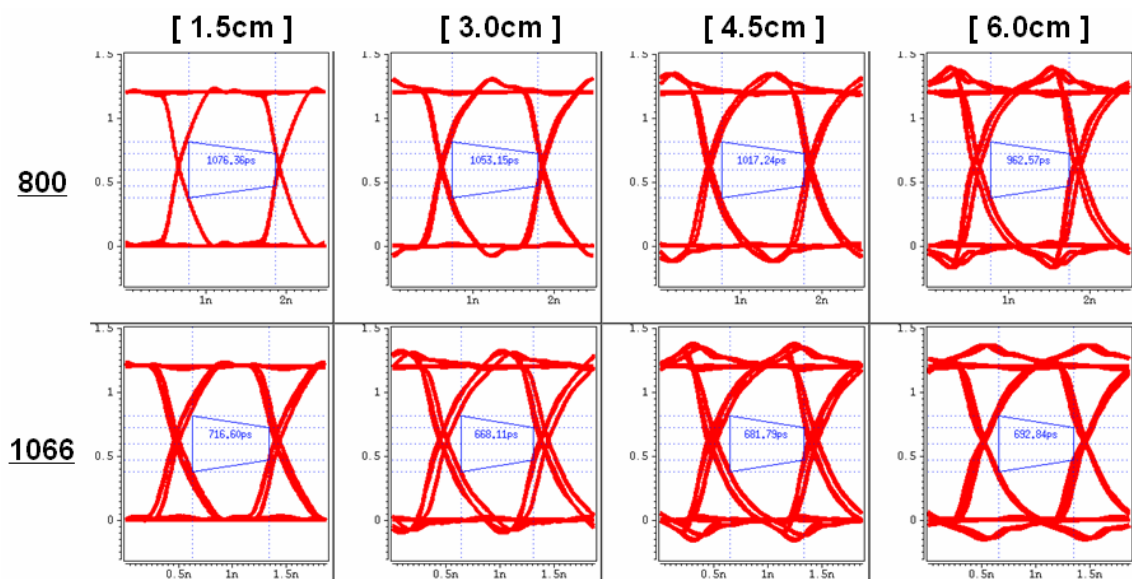
< Channel Condition for CA >

- Vddq : 1.2V
 - Impedance of Single line : 50ohm +/- 10%
 - DRAM model : LPDDR2
 - Operation Frequency : 800 / 1033Mbps
 - Driver strength (Ron) : 34.3 / 40 / 48 / 60ohm
 - Channel length : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm
- TL0 & TL2 is u-Strip line and each length is 4mm. TL1(Strip line) is variable.



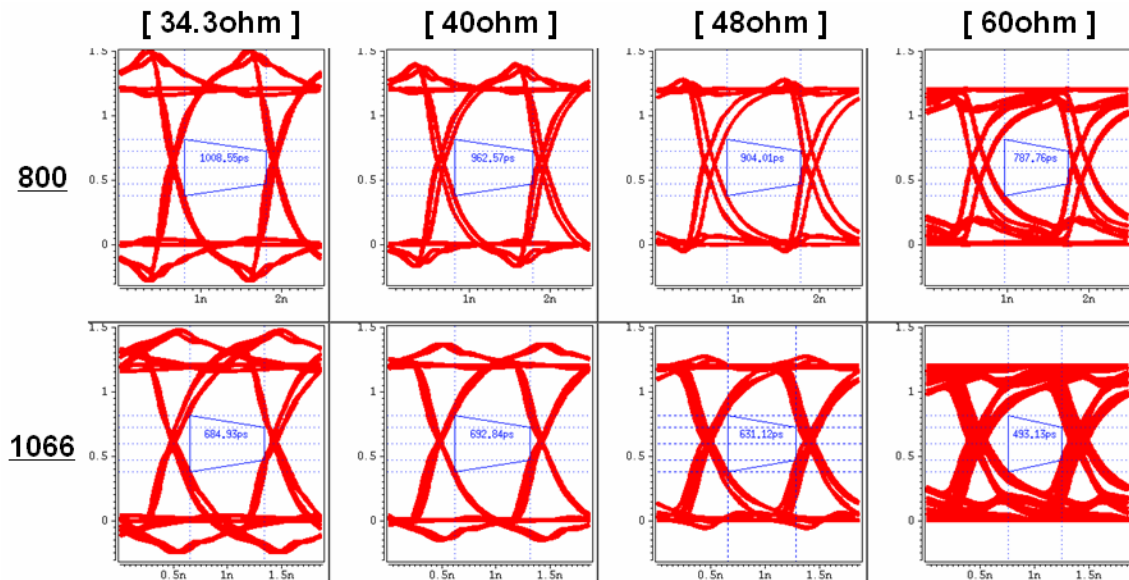
< Channel Length Variation for CA >

- Fixed Driver strength (Ron) : 40ohm
- Operation Freq. 800 / 1066Mbps
- Channel length variation : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm



< Driver Strength Variation for CA >

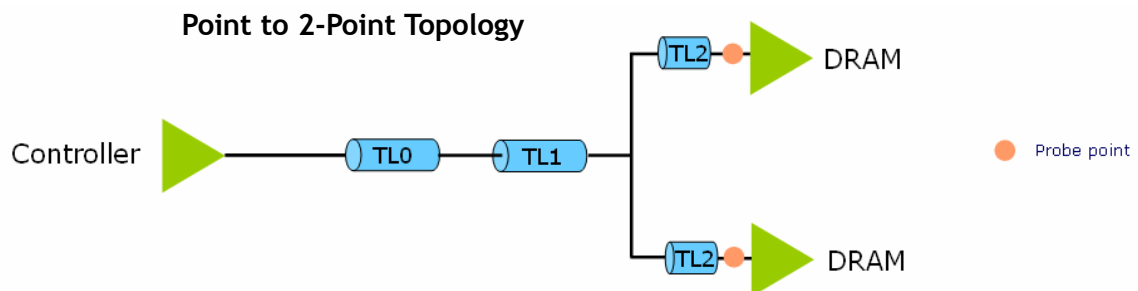
- Fixed Channel Length : 'TL0 + TL1 + TL2' = 6.0cm
- Operation Freq. 800 / 1066Mbps
- Driver strength(Ron) variation : 34.3 / 40 / 48 / 60ohm



b) Control channel simulation

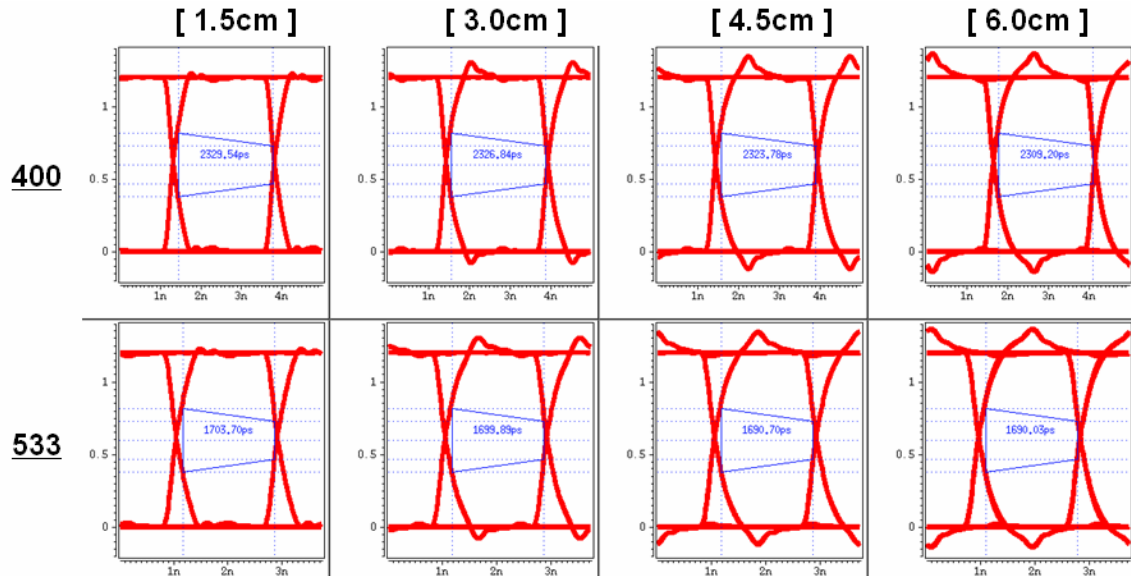
< Channel Condition for Control >

- Vddq : 1.2V
 - Impedance of Single line : 50ohm +/- 10%
 - DRAM model : LPDDR2
 - Operation Frequency : 400 / 533Mbps
 - Driver strength (Ron) : 34.3 / 40 / 48 / 60ohm
 - Channel length : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm
- TL0 & TL2 is u-Strip line and each length is 4mm. TL1(Strip line) is variable.



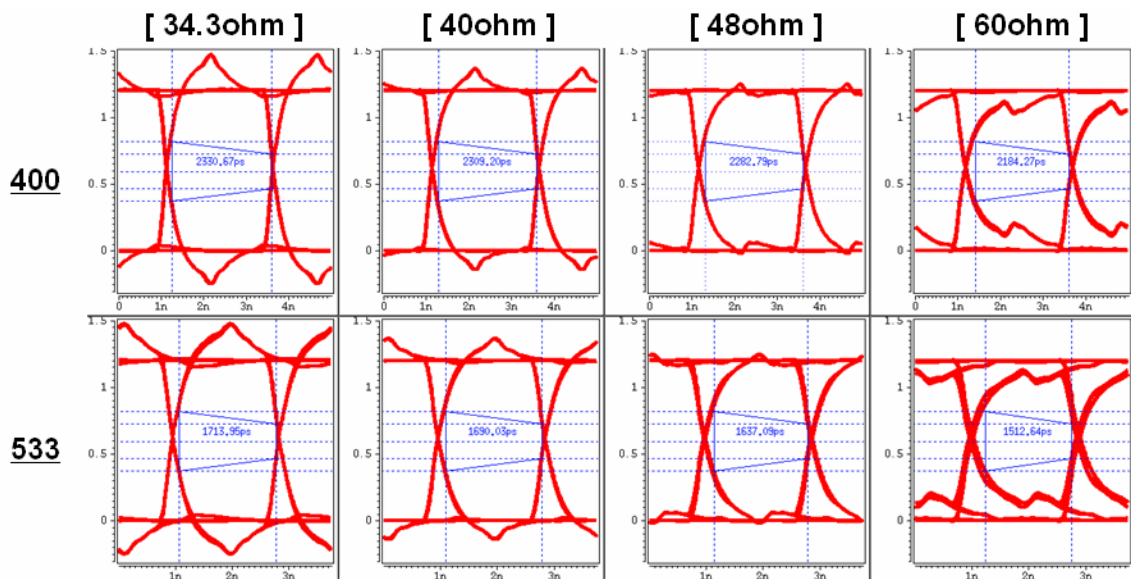
< Channel Length Variation for Control >

- Fixed Driver strength (Ron) : 40ohm
- Operation Freq. 400 / 533Mbps
- Channel length variation : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm



< Driver Strength Variation for Control >

- Fixed Driver strength (Ron) : 40ohm
- Operation Freq. 400 / 533Mbps
- Channel length variation : 'TL0 + TL1 + TL2' = 1.5 / 3.0 / 4.5 / 6.0cm



4.4 Channel Simulation Summary

Summary of DQ @800Mbps

- P-to-P(Point to Point) topology is recommended for DQ net.
- Minimize the trace between driver and receiver.
 - Shorter than 4.5cm to avoid overshoot/undershoot problem.
 - Longer length, Larger Skew and ISI.
- Appropriate Driver strength helps to reduce Overshoot/Undershoot appearance.
 - Appropriate Driver strength values are recommended by Simulation.
 - In case of total-length '6cm' , the best driver strength is 'Ron 40ohm' condition.

Summary of CA, Control & Clock @800Mbps

- Minimize the trace between driver and receiver.
 - Shorter than 3cm to avoid overshoot/undershoot problem.
- Appropriate Driver strength helps to reduce Overshoot/Undershoot appearance.
 - Appropriate Driver strength values are recommended by Simulation.
 - In case of total-length '6cm' , the best driver strength is 'Ron 48ohm' condition.