T10/02-163r0

Ultra640 SCSI Reduction of Crosstalk Errors During Timing Deskew

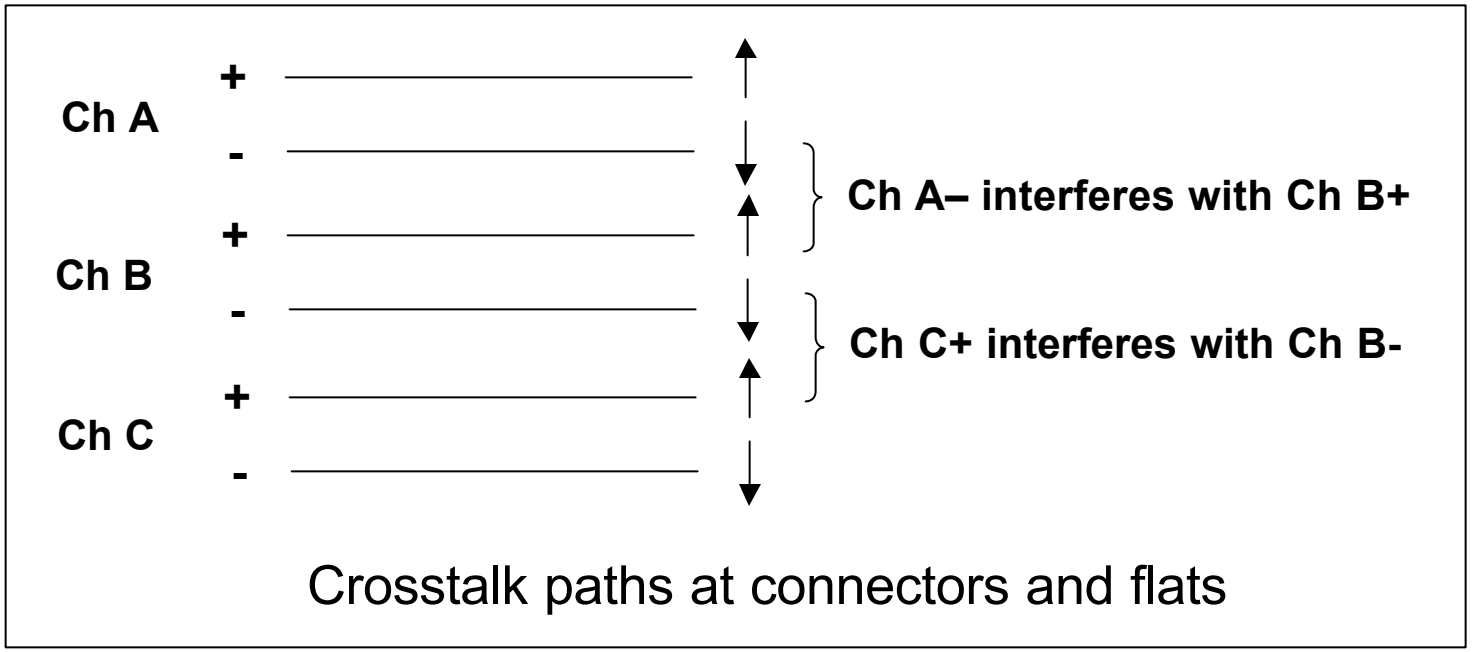
Russ Brown & Mehran Aliahmad
Maxtor Corporation
Parallel SCSI Working Group
29 April 2002
Nashua, NH

Introduction: crosstalk affects deskew in the training pattern

- The timing of a data signal in parallel SCSI can be shifted early or late by crosstalk from adjacent signals.
- Crosstalk interference from normal random data shifts the “victim” timing symmetrically early and late about the zero crosstalk timing.
- The training pattern for Ultra320 SCSI is applied to all signals in-phase. As a result, the training pattern on all data signals is delayed from its nominal (zero crosstalk) timing by about the maximum crosstalk shift.
- The ACK(REQ) timing reference signal is surrounded by quiet lines and is not affected by crosstalk.
- As a result, the deskew calibration point for all signals is offset (late) from ideal timing by approximately the maximum crosstalk shift.
- This is a small issue for Ultra320, but is significant for Ultra640 because of the shorter bit cell and higher crosstalk.
- Alternating training pattern polarities can significantly reduce the problem.

Crosstalk Interference

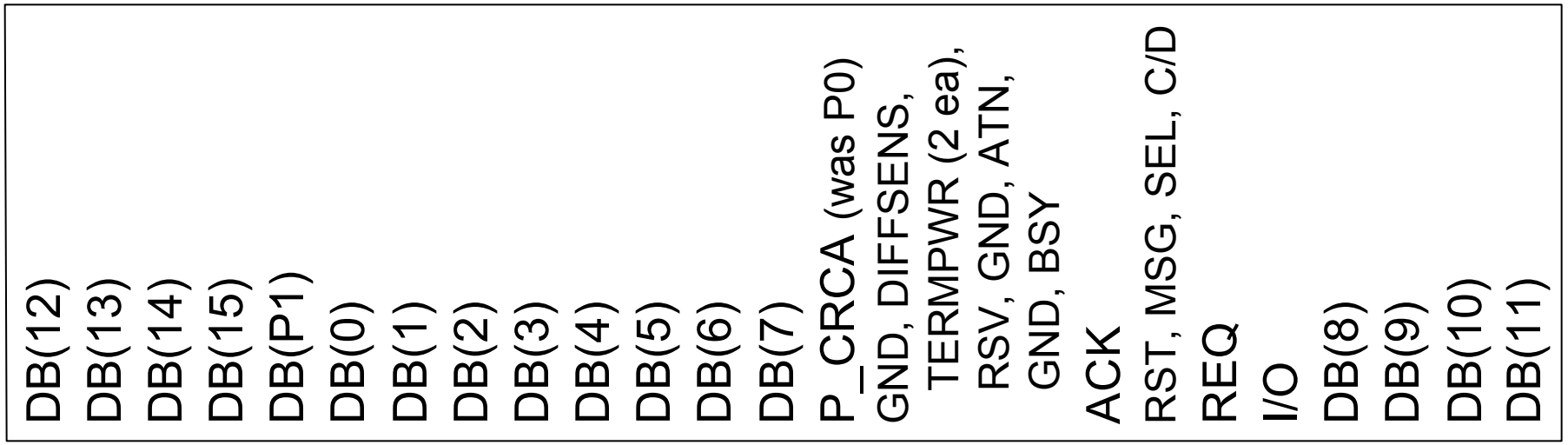
- With an in-phase pattern on all signals, nearest neighbors A and C interfere with the differential signal on B.
- If A and C were opposite phase, interference effects would be common mode on signal B and would not affect the differential signal.



Crosstalk paths at connectors and flats

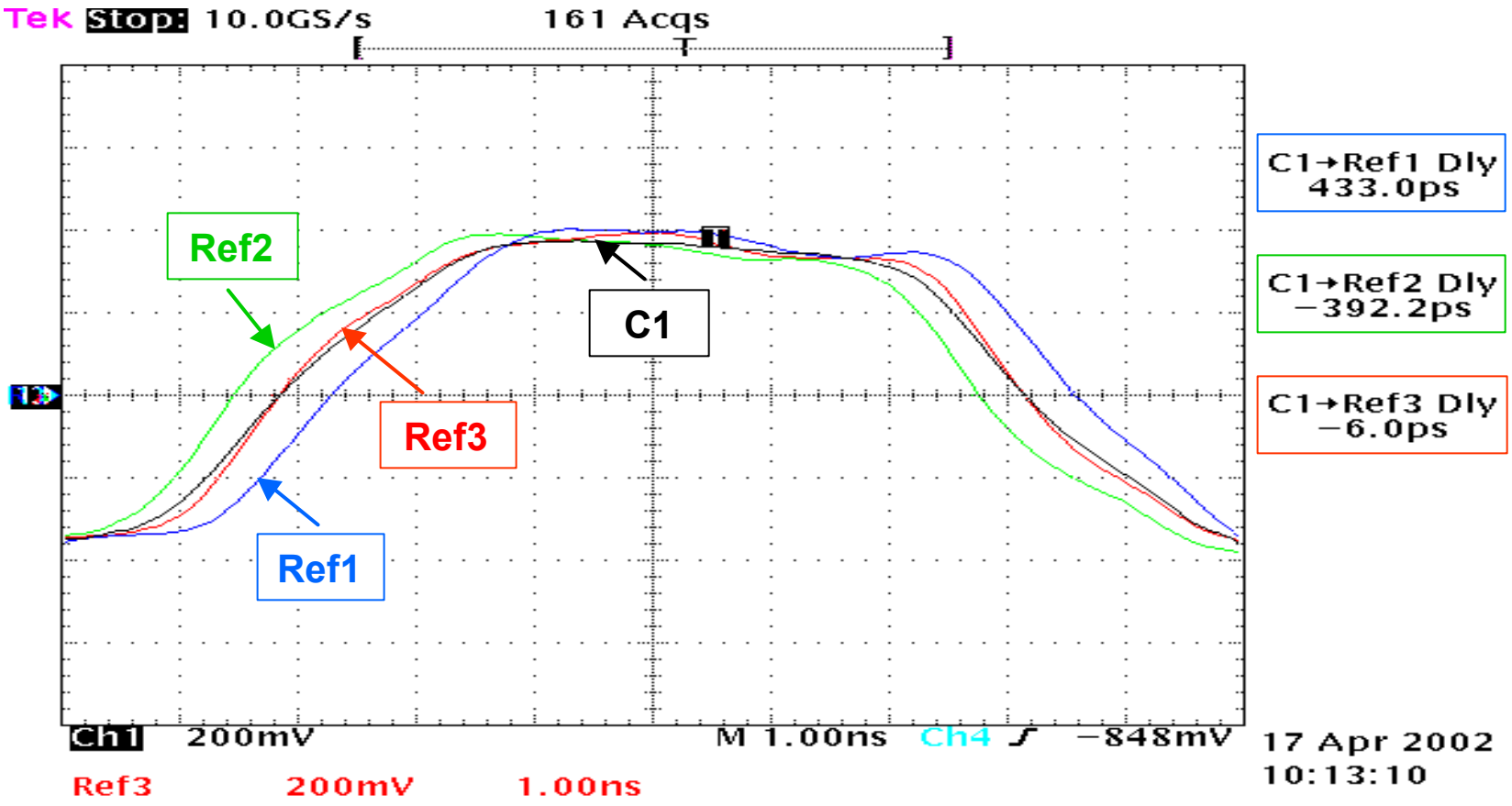
Test Description

- The data in the following slides shows the effect on crosstalk of changing signal polarities.
- The data was measured as follows:
  - 6-channel TEK HFS 9003 with trise/fall = 1 ns used as a 100 ohm differential signal source
  - 100 ohm termination on cable receive end
  - Receive signal captured with TEK P6247 differential probe and TEK TDS694C oscilloscope
- For the data in the tables “N” indicates “normal” phase of the training pattern, “I” indicates “inverted” phase, and “0” indicates not changing.
- The following is the order of signals in a 68-conductor “P” cable:



2.6 m Twisted-Flat Cable, “Middle” Pair (DB15)

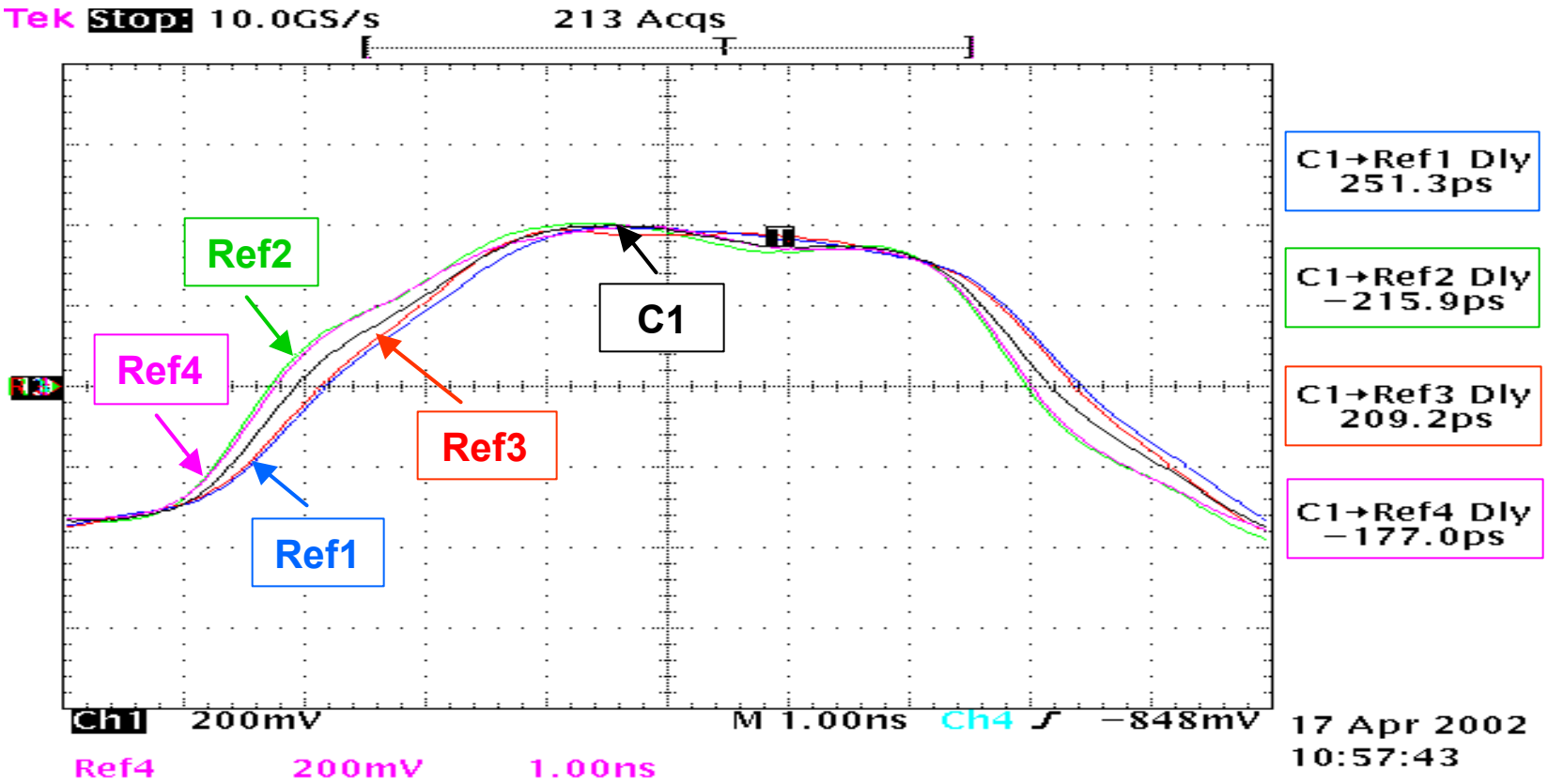
(1.75” flat, 9.85” pitch)



DB	12	13	14	15	P1	0	
C1:	0	0	0	N	0	0	- timing with no xtalk
Ref1:	N	N	N	N	N	N	- xtalk in phase: 433 ps late
Ref2:	I	I	I	N	I	I	- xtalk out of phase: 392 ps early
Ref3:	N	I	I	N	N	I	- alternating phases: 6 ps early, about = w/no xtalk

2.6 m Twisted-Flat Cable, "Outside End" Pair (DB12)

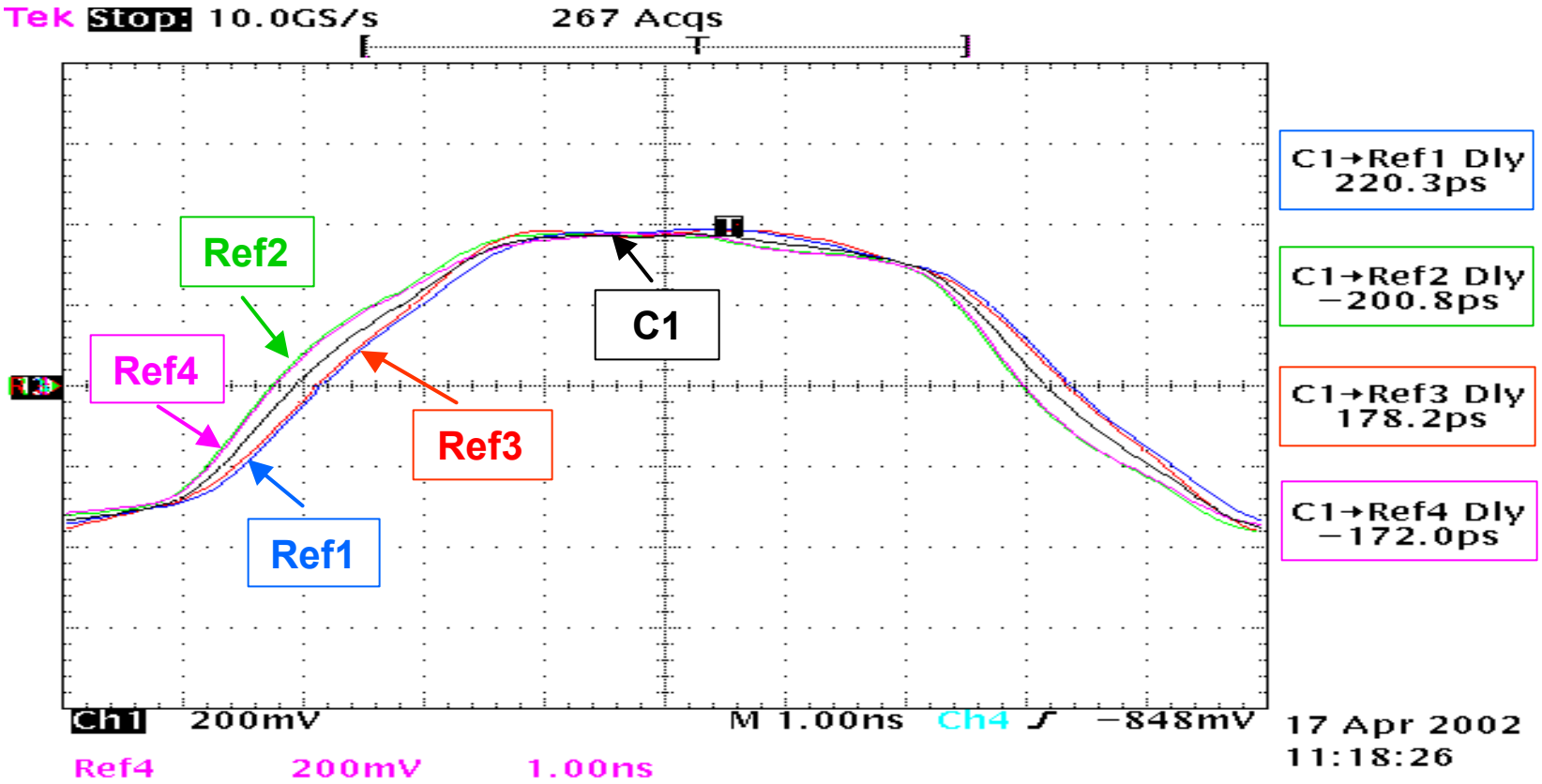
(1.75" flat, 9.85" pitch)



DB	12	13	14	15	P1	0	
C1:	N	0	0	0	0	0	- timing with no xtalk
Ref1:	N	N	N	N	N	N	- xtalk in phase: 251 ps late
Ref2:	N	I	I	I	I	I	- xtalk out of phase: 216 ps early
Ref3:	N	N	I	I	N	N	- alternation1: 209 ps late
Ref4:	N	I	I	N	N	I	- alternation2: 177 ps early

2.6 m Twisted-Flat Cable, “Inside End” Pair (DB7)

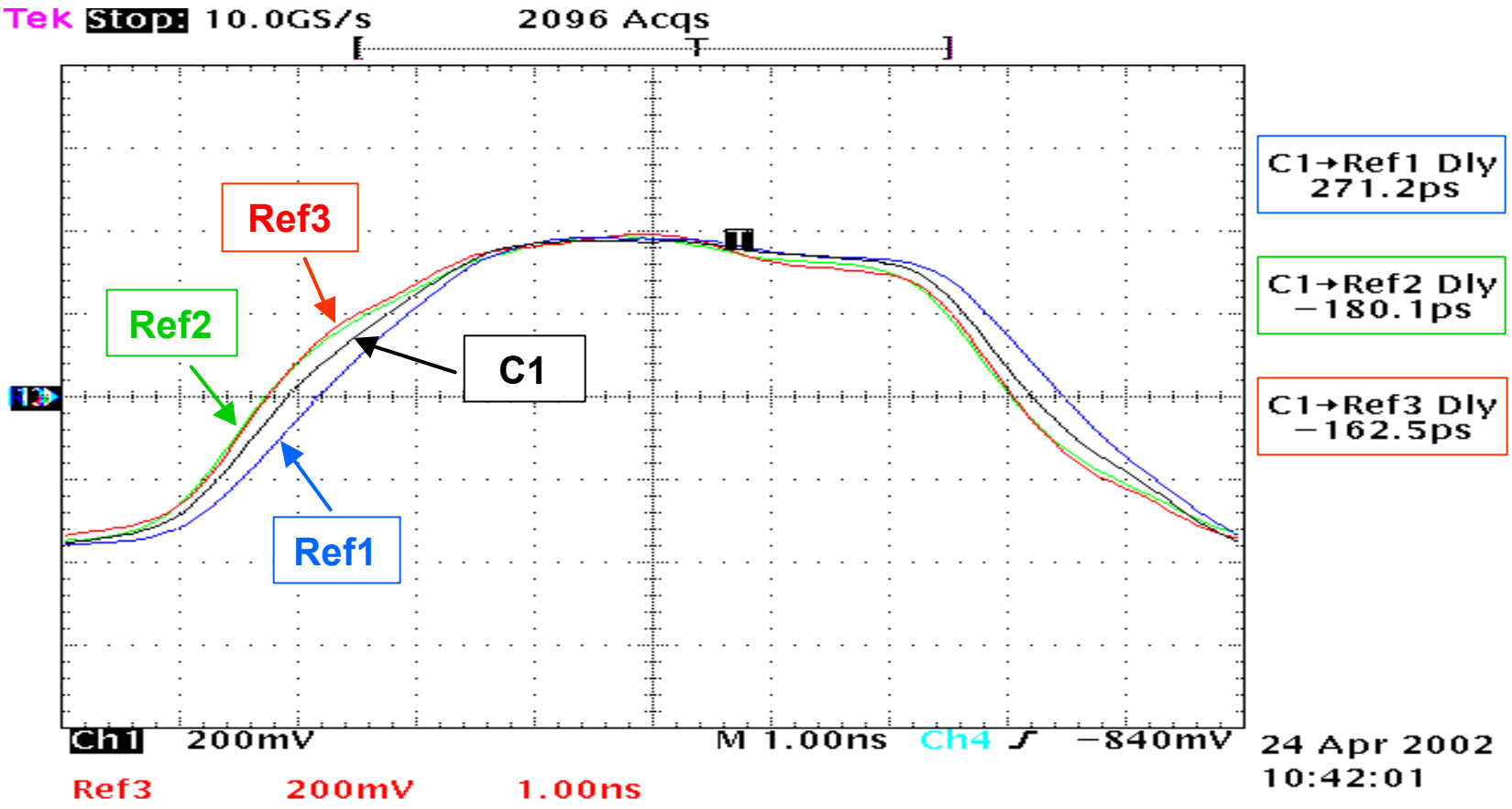
(1.75” flat, 9.85” pitch)



DB	Gnd	P0	7	6	5	4	3	2	
C1:	0	0	N	0	0	0	0	0	- timing with no xtalk
Ref1:	0	0	N	N	N	N	N	N	- xtalk in phase: 220 ps late
Ref2:	0	0	N	I	I	I	I	I	- xtalk out of phase: 201 ps early
Ref3:	0	0	N	N	I	I	N	N	- alternation1: 178 ps late
Ref4:	0	0	N	I	I	N	N	I	- alternation2: 172 ps early

2.6 m Twisted-Flat Cable, “Inside End” Pair (DB8)

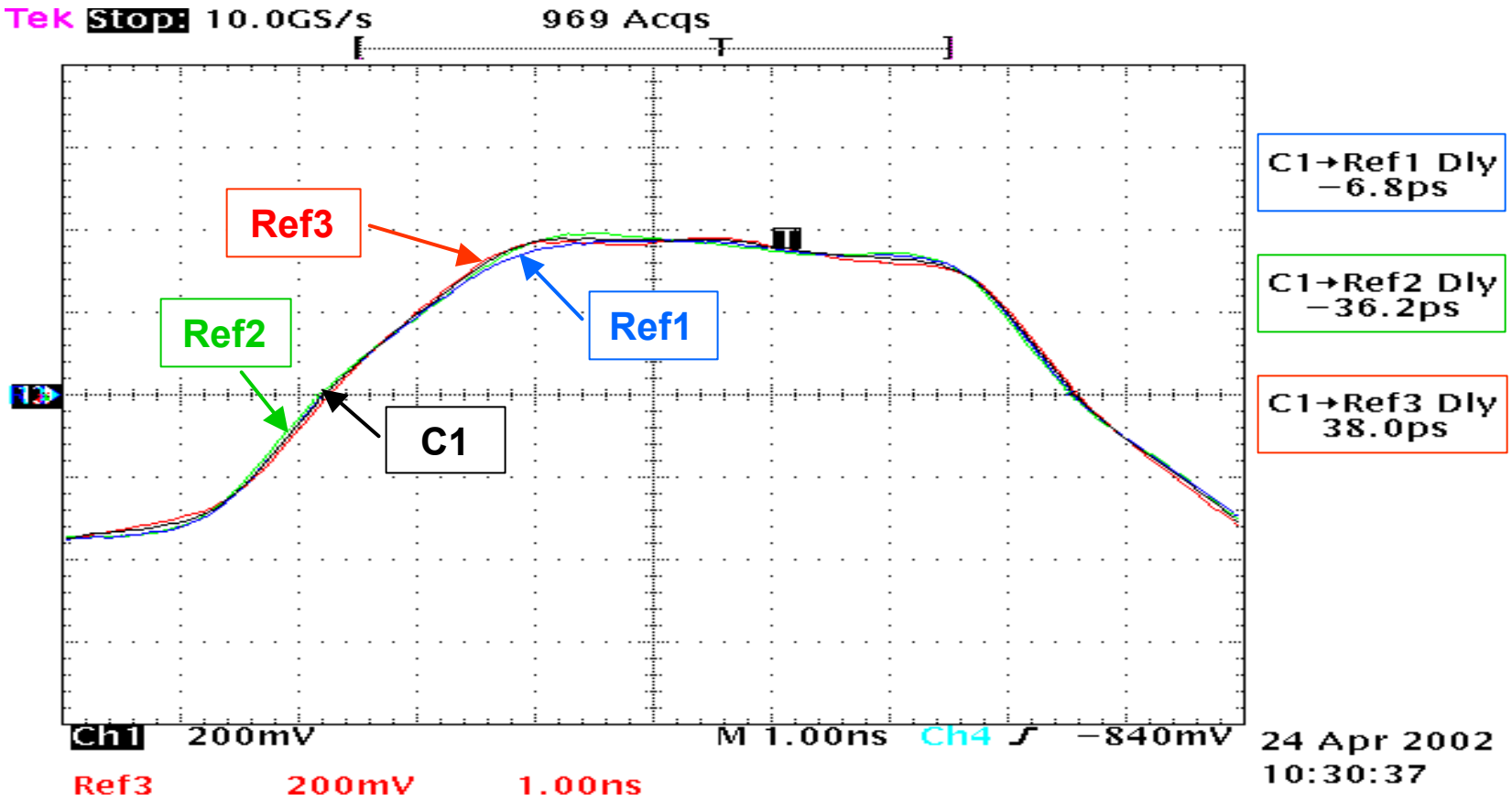
(1.75” flat, 9.85” pitch)



DB	C/D	REQ	I/O	8	9	10	11	
C1:	0	0	0	N	0	0	0	- timing with no xtalk
Ref1:	0	N	0	N	N	N	N	- xtalk in phase: 271 ps late
Ref2:	0	N	0	N	I	I	N	- alternation1: 180 ps early
Ref3:	0	I	0	N	I	I	N	- alternation2: 163 ps early

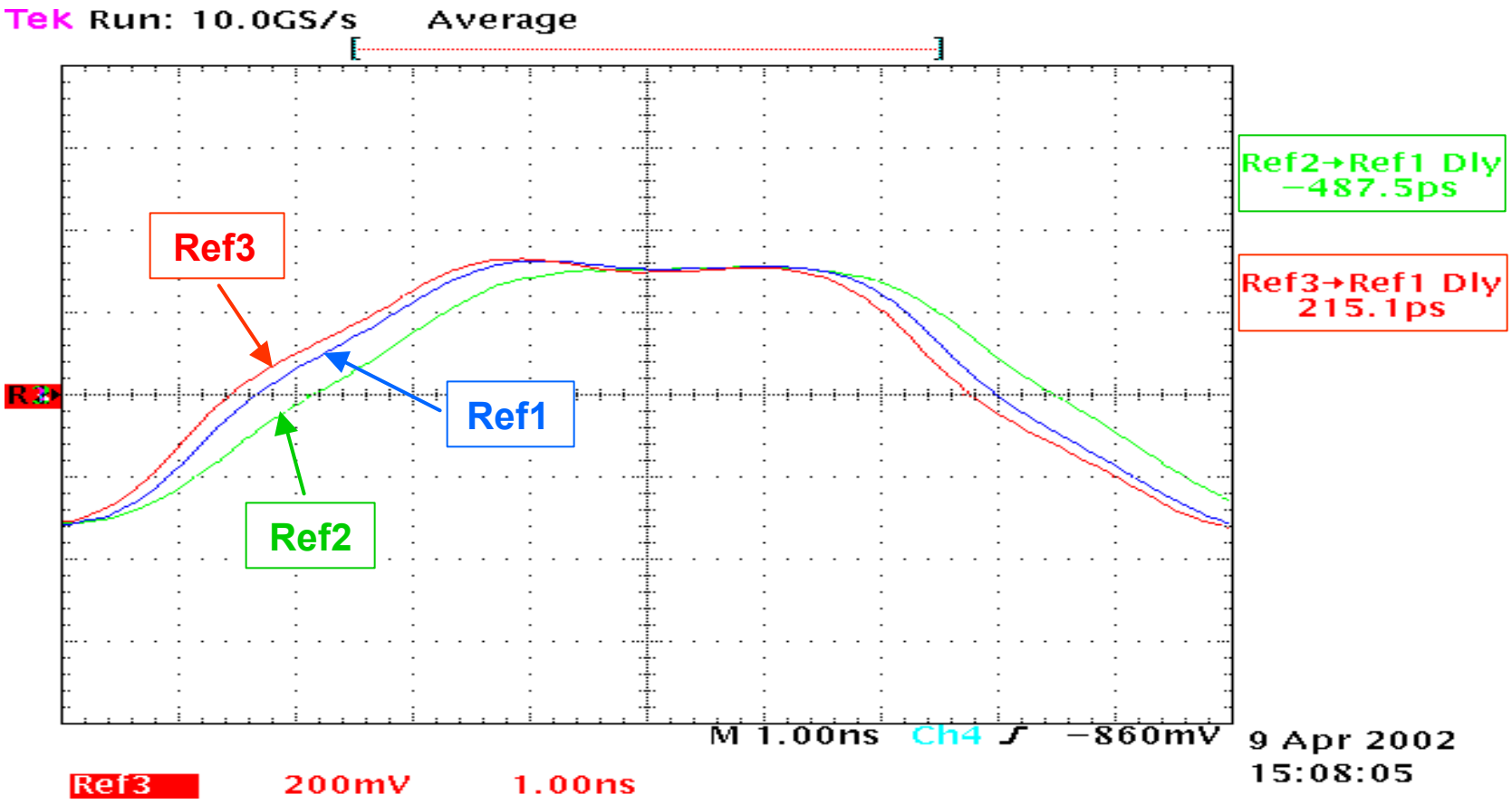
2.6 m Twisted-Flat Cable, REQ Pair

(1.75” flat, 9.85” pitch)



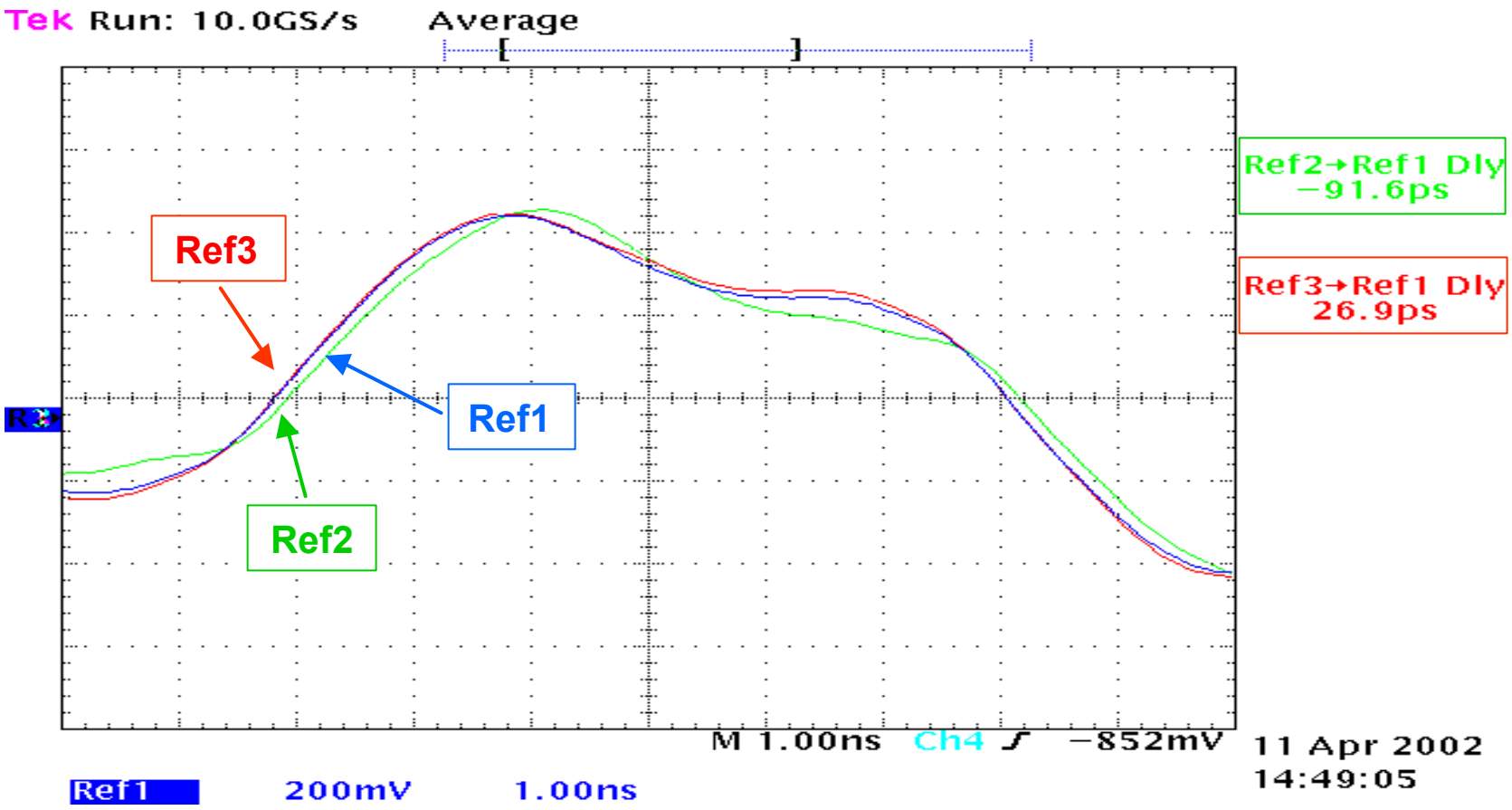
DB	CD	REQ	I/O	8	9	10	11	
C1:	0	N	0	0	0	0	0	- timing with no xtalk
ref1:	0	N	0	N	N	N	N	- xtalk in-phase: 7 ps early
ref2:	0	N	0	N	I	I	N	- xtalk out of phase: 36 ps early
ref3:	0	N	0	I	N	N	I	- alternation: 38 ps late

10 m Round Cable, Pair (DB15)



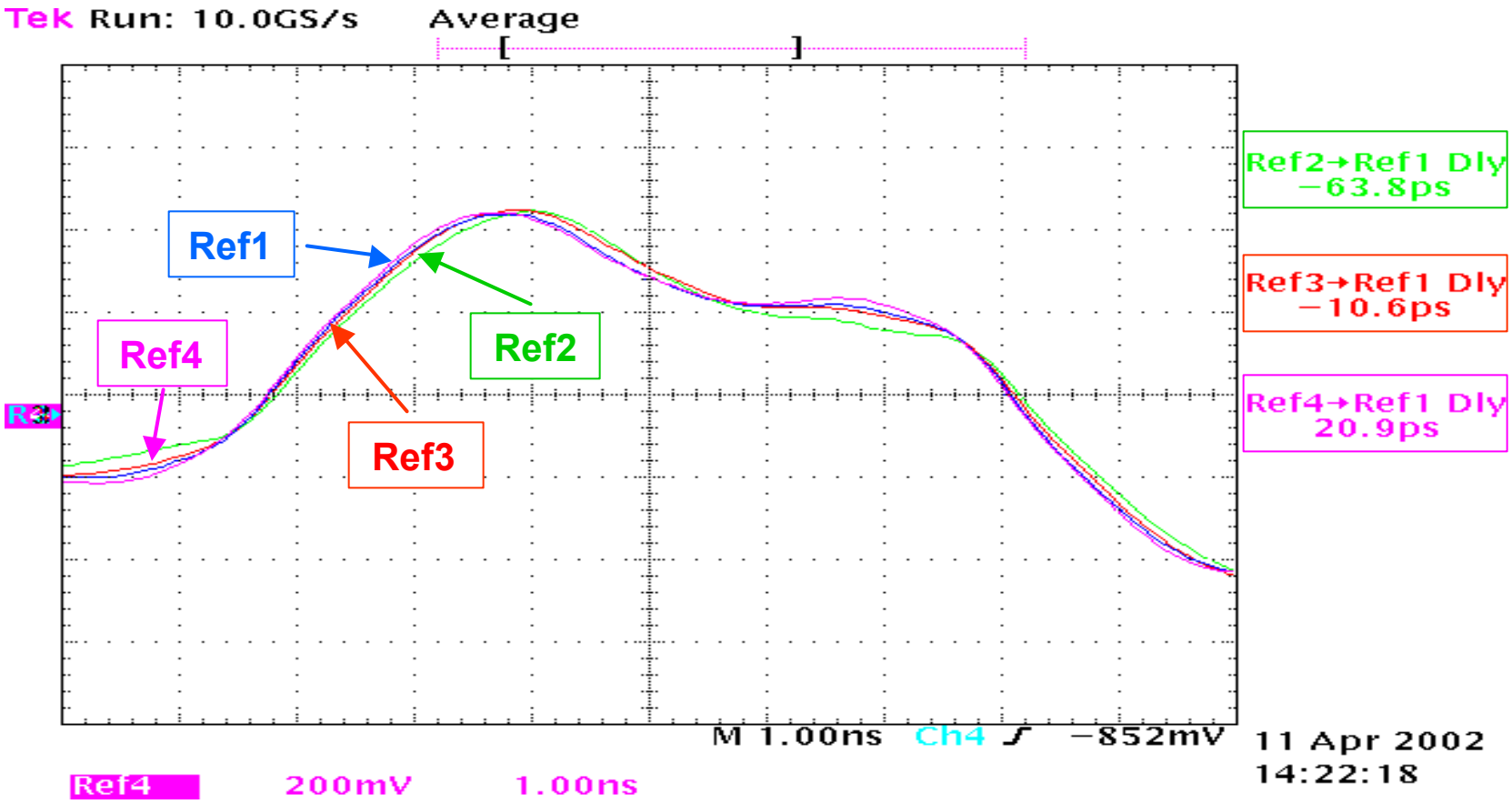
DB	12	13	14	15	P1	0	
Ref1:	0	0	0	N	0	0	- timing with no xtalk
Ref2:	N	N	N	N	N	N	- xtalk in phase: 488 ps late
Ref3:	N	I	I	N	N	I	- alternating phases: 215 ps early

6-slot Backplane, no Cable, Slot 4 (DB15)



DB	12	13	14	15	P1	0	
Ref1:	0	0	0	N	0	0	- timing with no xtalk
Ref2:	N	N	N	N	N	N	- xtalk in phase: 92 ps late
Ref3:	N	I	I	N	N	I	- alternating phases: 27 ps early

6-slot Backplane, no Cable, Slot 4 (DB12)



DB	12	13	14	15	P1	0	
Ref1:	N	0	0	0	0	0	- timing with no xtalk
Ref2:	N	N	N	N	N	N	- xtalk in phase: 64 ps late
Ref3:	N	N	I	I	N	N	- alternation1: 11 ps late
Ref4:	N	I	I	N	N	I	- alternation1: 21 ps early

Summary of Data

The table below shows data from testing the 2.6 m twisted-flat cable:

	"Middle" pairs e.g., DB15	"Outside End" pairs, e.g., DB12	"Inside End" pair DB7	"Inside End" pair DB8
Error with present in-phase pattern	**433 ps late (= ERRmax)**	**251 ps late**	**220 ps late**	**271 ps late**
Error with alternating pattern	**6 ps early**	**177 ps early**	**178 ps late**	**180 ps early**
| Alternating / ERRmax |	**1 / 72**	**1 / 2.4**	**1 / 2.4**	**1 / 2.4**

- For the 2.6 m Twisted-Flat cable cases, an alternating polarity training pattern reduces the worst skew error from 433 ps to 180 ps.
- This residual error is comparable to other deskew residual errors.
- The alternating polarity pattern also decreases error in the 10 m cable and in the backplanes tested.

Proposed Training Pattern Polarity Map for Decreasing Deskew Error: Data In Phase

In the following, “N” indicates “normal” phase of the training pattern, “I” indicates “inverted” phase, and “0” indicates not changing.

DB12	DB13	DB14	DB15	DBP1	DB0	DB1	DB2	DB3	DB4	DB5	DB6	DB7	P_CRCA
N	I	I	N	N	I	I	N	N	I	I	N	N	I

GND	DSNS	GND	BSY	ACK	RST	MSG	SEL	CD	REQ	I/O	DB8	DB9	DB10	DB11
0	0	0	0	0	0	0	0	0	N	0	N	I	I	N

- All signals except for the end ones (DB12, P_CRCA, DB8, and DB11) have adjacent interfering signals with opposite polarity training patterns to cancel crosstalk.
- The four “end” signals (DB12, P_CRCA, DB8, and DB11) have less crosstalk (aggressors on one side only).
- Data for the twisted-flat cable cases shows that the N-I-I and N-N-I configurations are comparable on these signals.
- For Data In training, the ACK training pattern from the host (800 ns duration) will finish before the “1100” deskew pattern from the target begins, and so is indicated as “0” (not changing).

Proposed Training Pattern Polarity Map for Decreasing Deskew Error: Data Out Phase

In the following, “N” indicates “normal” phase of the training pattern, “I” indicates “inverted” phase, and “0” indicates not changing.

DB12	DB13	DB14	DB15	DBP1	DB0	DB1	DB2	DB3	DB4	DB5	DB6	DB7	P_CRCA
N	I	I	N	N	I	I	N	N	I	I	N	N	0

GND	DSNS	GND	BSY	ACK	RST	MSG	SEL	CD	REQ	I/O	DB8	DB9	DB10	DB11
0	0	0	0	N	0	0	0	0	0	0	N	I	I	N

- All signals except for the end ones (DB12, DB7, DB8, and DB11) have adjacent interfering signals with opposite polarity training patterns to cancel crosstalk.
- The four “end” signals (DB12, DB7, DB8, and DB11) have less crosstalk (aggressors on one side only).
- Data for twisted-flat cable cases shows that the N-I-I and N-N-I configurations are comparable on these signals.
- For Data Out training, the REQ and PCRCA training patterns from the target (800 ns duration) will finish before the “1100” deskew pattern from the host begins, and so are indicated as “0” (not changing).

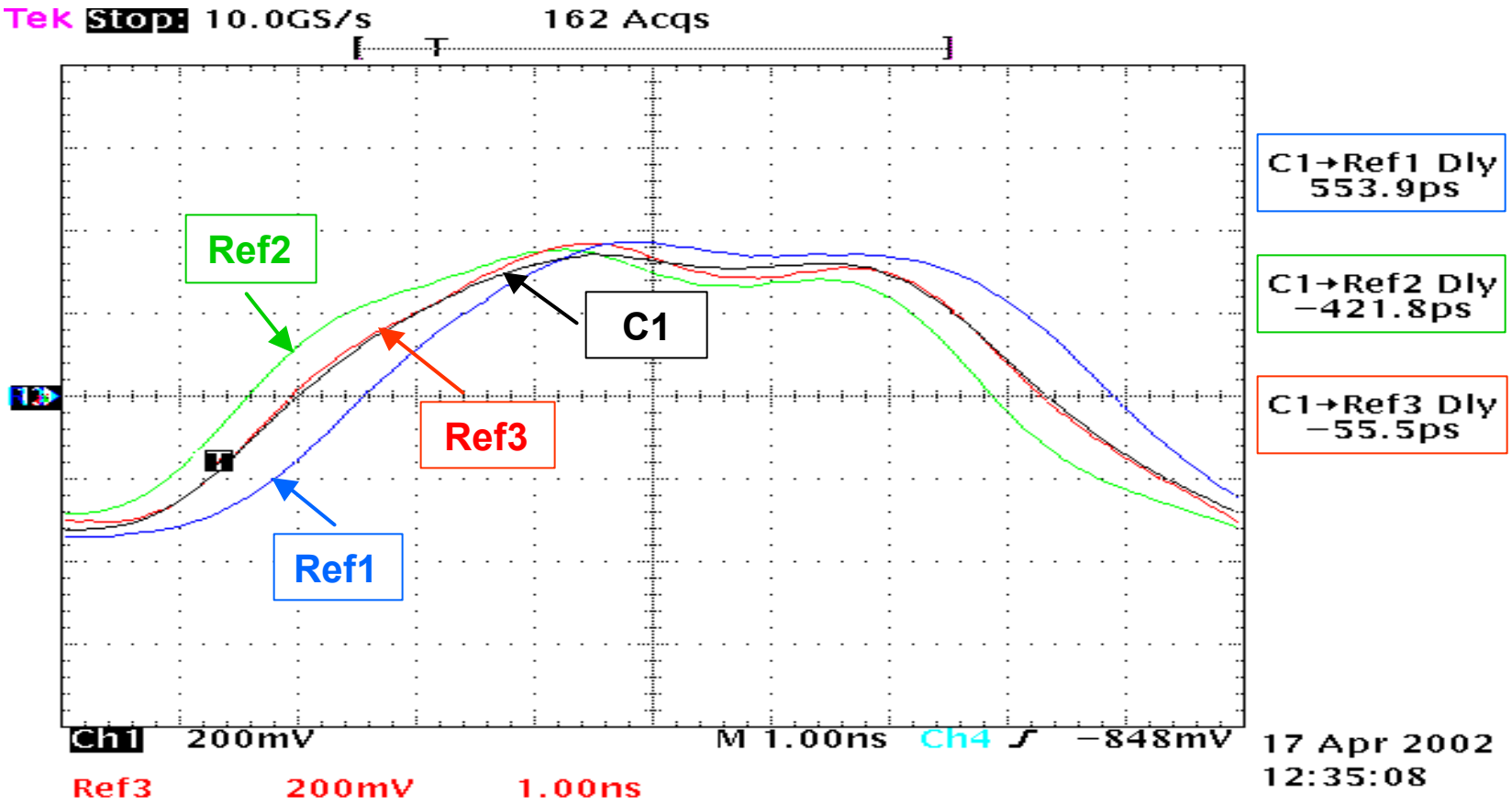
Conclusions

- **Crosstalk from adjacent signals offsets the deskew calibration point from its ideal timing.**
- **Cable is the major source of this effect, and timing shift due to backplane crosstalk is small.**
- **The "all in-phase" training pattern defined for Ultra320 SCSI maximizes this error.**
- **The data presented here shows that this effect can be reduced by two to three times by simply alternating the polarities of adjacent signals in pairs.**
- **Round cable and backplane data also shows that the proposed alternating polarity training pattern reduces the deskew error.**
- **The proposed solution is easy to implement and does not affect training time or ACK(REQ) and DBP1 signals.**

(supplemental test data follows this slide)

1.25 m Twisted-Flat Cable, “Middle” Pair (DB15)

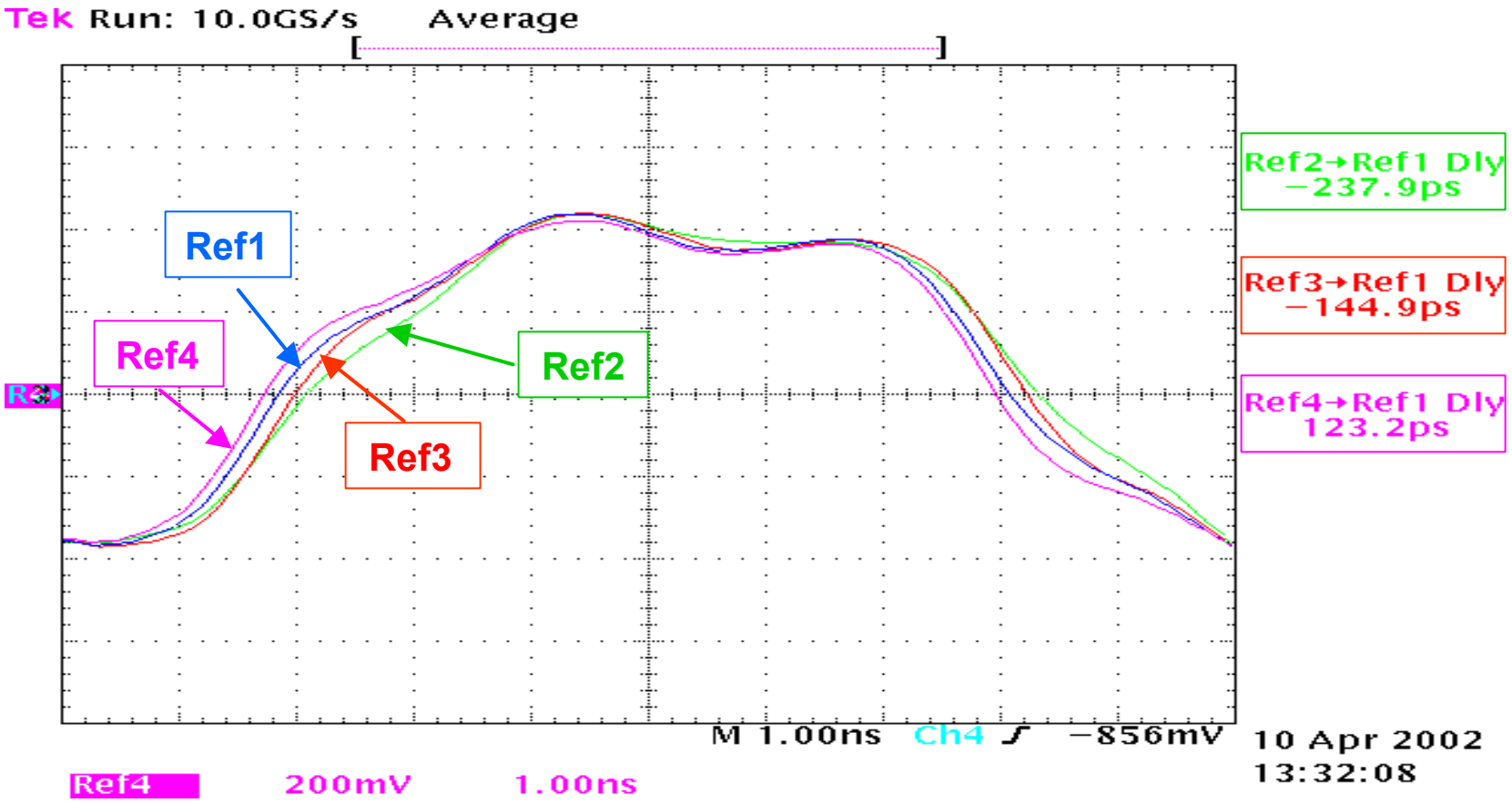
(1.75” flat, 5.25” pitch)



DB	12	13	14	15	P1	0	
C1:	0	0	0	N	0	0	- timing with no xtalk
Ref1:	N	N	N	N	N	N	- xtalk in phase: 404 ps late
Ref2:	I	I	I	N	I	I	- xtalk out of phase: 244 ps early
Ref3:	N	I	I	N	N	I	- alternating phases: 21 ps early

1.25 m Twisted-Flat Cable, “Outside End” Pair (DB12)

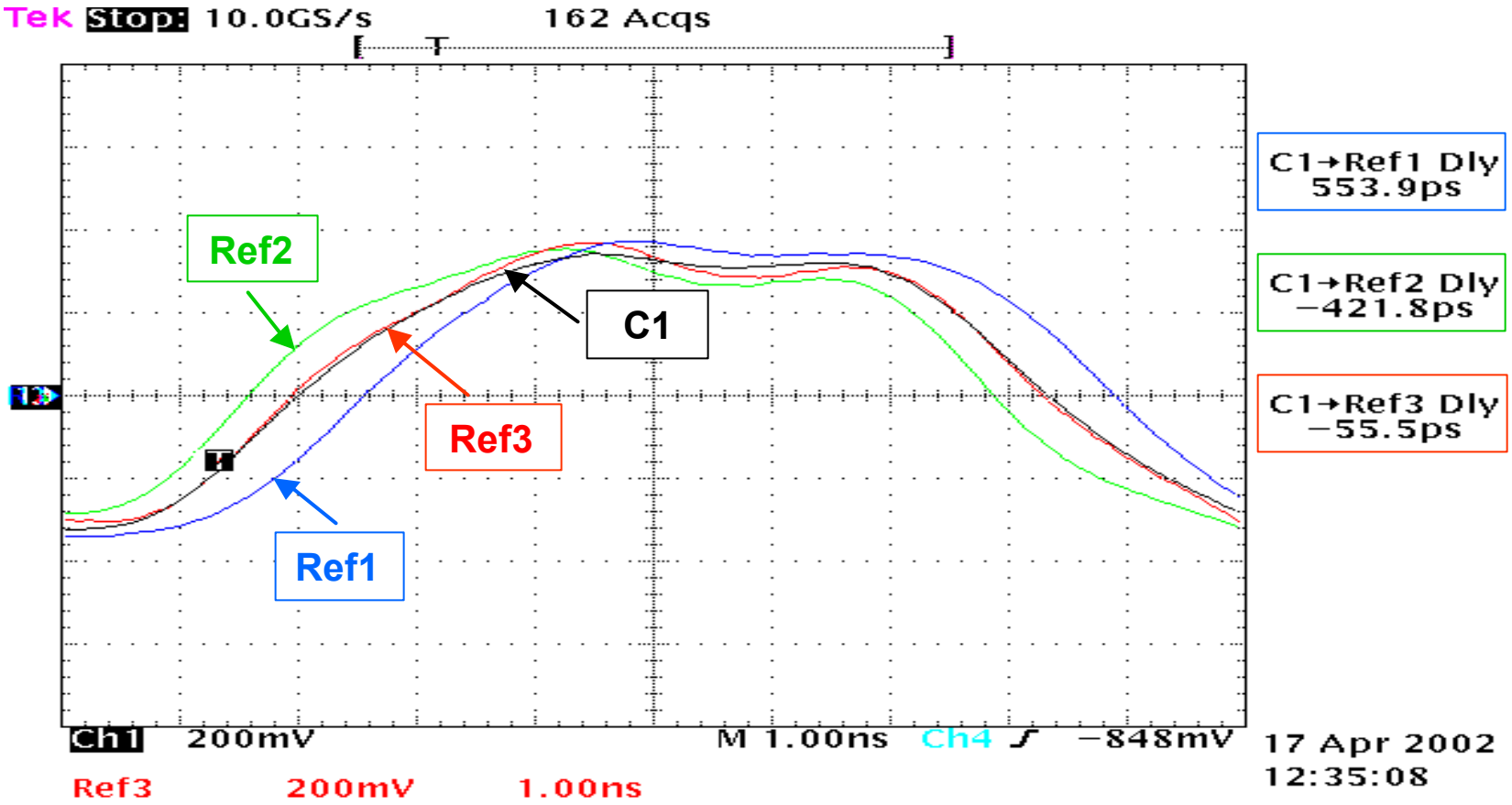
(1.75” flat, 5.25” pitch)



DB	12	13	14	15	P1	0	
Ref1:	N	0	0	0	0	0	- timing with no xtalk
Ref2:	N	N	N	N	N	N	- xtalk in phase: 237 ps late
Ref3:	N	I	I	I	I	I	- xtalk out of phase: 145 ps early
Ref3:	N	N	I	I	N	N	- alternation1: 123 ps late

6 m Twisted-Flat Cable, “Middle” Pair (DB15)

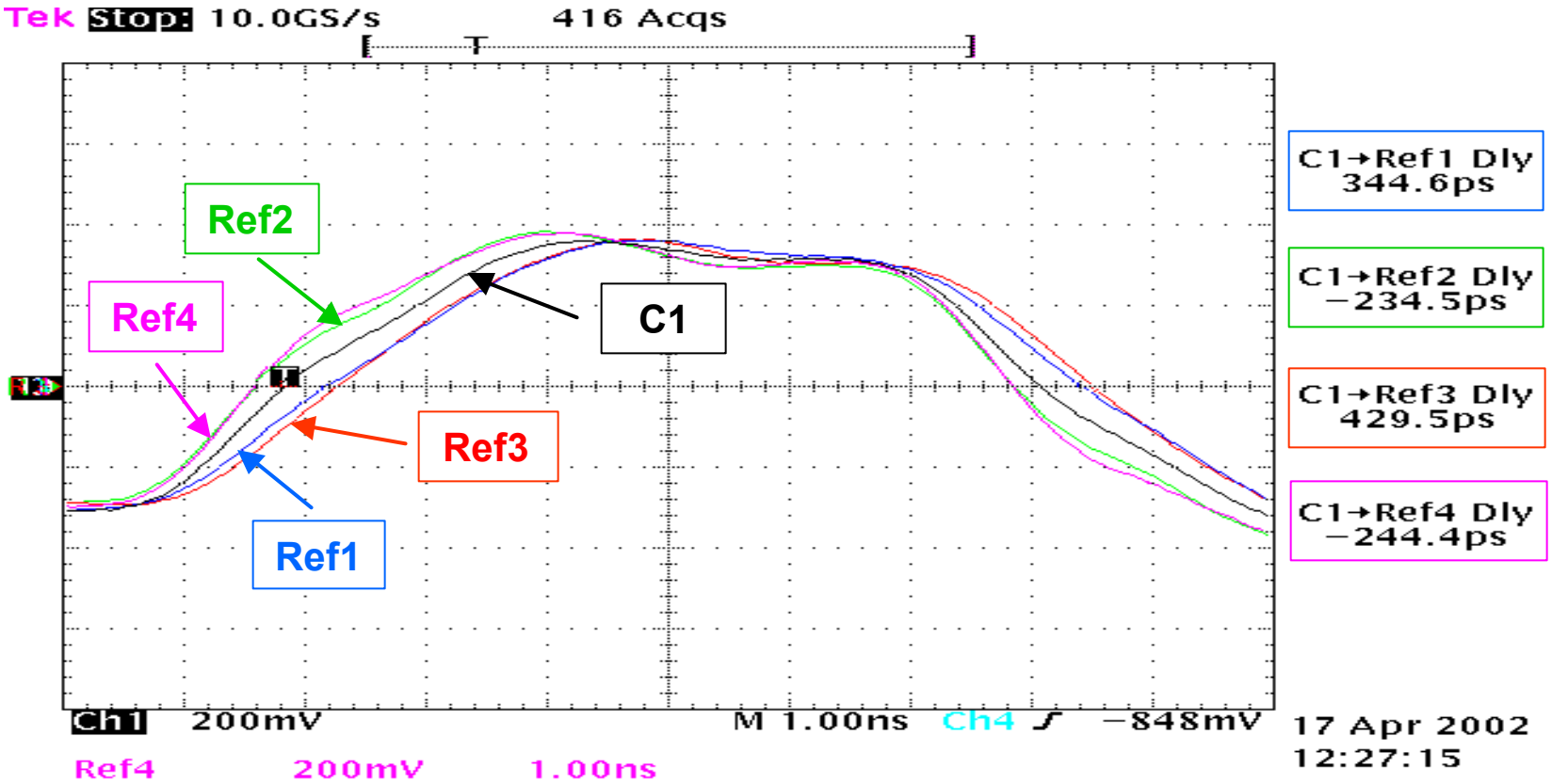
(1” flat, 5.25” pitch)



DB	12	13	14	15	P1	0	
C1:	0	0	0	N	0	0	- timing with no xtalk
Ref1:	N	N	N	N	N	N	- xtalk in phase: 544 ps late
Ref2:	I	I	I	N	I	I	- xtalk out of phase: 422 ps early
Ref3:	N	I	I	N	N	I	- alternating phases: 56 ps early

6 m Twisted-Flat Cable, "Outside End" Pair (DB12)

(1" flat, 5.25" pitch)



DB	12	13	14	15	P1	0	
C1:	N	0	0	0	0	0	- timing with no xtalk
Ref1:	N	N	N	N	N	N	- xtalk in phase: 345 ps late
Ref2:	N	I	I	I	I	I	- xtalk out of phase: 235 ps early
Ref3:	N	N	I	I	N	N	- alternation1: 430 ps late
Ref4:	N	I	I	N	N	I	- alternation1: 244 ps early