To: T10 Membership
From: Greg Kapraun
Date: March 16, 1998
Re: 0.5 pF Balance Capacitance

- **Concern is with the ability to hold to 0.5pF LVD C1-C2 specification.**
- **Unitrode proposed increasing to 1pF Mid 1997.**
- **Multiple boards of empirical data**
- **Signal data with different C1-C2 deviation points**
- **Recommendation of C1-C2 specification change**

In order to protect the innocent and since everyone is buying or merging with everyone else, I'll just label each board as 1 Company. All measurements taken with an LCR Meter HP4285A.

1 Company - HBA

BOARD #	SIGNAL	C1 (pF)	C2 (pF)	C3 (pF)	|C1-C2| (pF)
1	DB12	45.36	45.24	19.52	0.12
	ACK	43.61	43.30	18.04	0.31
	REQ	41.62	41.18	16.84	0.44
SPI-2 SPEC Value		< 20	< 20	< 10	<0.5

1 Company - Disk Drive

BOARD #	SIGNAL	C1 (pF)	C2 (pF)	C3 (pF)	|C1-C2| (pF)
1	DB12	19.77	18.41	7.04	1.36
	ACK	19.94	18.65	6.87	1.29
	REQ	19.06	18.02	6.63	1.04
SPI-2 SPEC Value		< 20	< 20	< 10	<0.5

1 Company - 68-80pin adapter card

BOARD #	SIGNAL	C1 (pF)	C2 (pF)	C3 (pF)	|C1-C2| (pF)
1	DB12	8.51	8.12	3.14	0.39
	ACK	8.29	8.04	3.14	0.25
	REQ	9.10	8.41	3.12	0.69
SPI-2 SPEC Value		< 20	< 20	< 10	<0.5

1 Company - LVD-SE adapter card

BOARD #	SIGNAL	C1 (pF)	C2 (pF)	C3 (pF)	|C1-C2| (pF)
1	DB12	22.81	22.46	8.37	0.35
	ACK	20.74	20.44	7.24	0.30
	REQ	22.49	22.47	8.30	0.02
SPI-2 SPEC Value		< 20	< 20	< 10	<0.5

1 Company - HBA

BOARD #	SIGNAL	C1 (pF)	C2 (pF)	C3 (pF)	|C1-C2| (pF)
1	DB12	31.47	30.30	12.12	1.17
	ACK	32.44	31.10	12.73	1.34
	REQ	33.33	31.84	13.34	1.49
SPI-2 SPEC Value		< 20	< 20	< 10	<0.5

1 Company - Disk Drive

Signal	C1(pF)	C2(pF)	|C1-C2| (pF)
I/O	8.80	7.63	1.17
C/D	8.71	8.03	0.68
SEL	8.87	8.43	0.44
MSG	7.62	7.47	0.15
RST	8.30	7.62	0.68
BSY	7.77	7.42	0.35
ATN	8.25	8.01	0.24
REQ	7.98	7.81	0.17
ACK	7.91	7.66	0.25
DB0	8.47	8.31	0.16
DB1	9.83	9.57	0.26
DB2	8.47	8.09	0.38
DB3	8.39	8.03	0.36
DB4	8.62	8.29	0.33
DB5	8.56	7.81	0.75
DB6	8.12	7.80	0.32
DB7	9.64	8.31	1.33
DBP0	9.24	9.06	0.18
DB8	7.68	7.13	0.55
DB9	8.50	8.06	0.44
DB10	7.73	7.62	0.11
DB11	8.06	8.13	0.07
DB12	8.75	8.21	0.54
DB13	9.91	9.33	0.58
DB14	8.40	8.42	0.02
DB15	10.28	9.73	0.55
DBP1	8.47	8.06	0.41
SPEC	<20	<20	<0.5 (REQ, ACK, DATA and Parity) <3.0 (all other sigs)

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1 Company Disk Drive

Signal	C1(pF)	C2(pF)	|C1-C2| (pF)
SCSI0	18.960	17.97	0.99
SCSI1	19.280	17.98	1.3
SCSI2	19.240	18.55	0.69
SCSI3	19.620	19.07	0.55
SCSI4	20.870	19.7	1.17
SCSI5	19.390	18.48	0.91
SCSI6	19.790	18.03	1.76
SCSI7	20.150	19.3	0.85
SCSI8	21.200	20.11	1.09
SCSI9	20.170	18.74	1.43
SCSI10	19.750	18.84	0.91
SCSI11	19.560	19.22	0.34
SCSI12	19.740	18.43	1.31
SCSI13	19.770	18.65	1.12
SCSI14	19.640	18.99	0.65
SCSI15	19.670	18.38	1.29
SCSIP0	18.700	17.85	0.85
SCSIP1	18.940	17.86	1.08
ATN	19.550	18.33	1.22
BUSY	20.560	19.35	1.21
ACK	20.780	19.61	1.17
RST	26.580	21.66	4.92
MSG	20.730	19.49	1.24
SEL	21.230	19.79	1.44
C/D	19.700	18.55	1.15
REQ	19.760	18.75	1.01
Spec	< 20	< 20	< 0.5

For the next set of testing the following Cap measurements were made:

Approx. 0pF offset

	DB12			
BOARD #	C1	C2	C3	|C1-C2|
1	19.54	19.86	7.10	0.32
2	19.68	19.86	7.10	0.18
3	19.61	19.76	6.94	0.15
4	19.46	19.67	7.07	0.21
5	19.68	19.89	7.08	0.21
6	19.75	19.96	7.22	0.21
	19.68	19.94	7.15	0.26
8	19.88	20.01	7.24	0.13
9	19.90	20.10	7.36	0.20
10	19.71	19.90	7.13	0.19
11	19.58	19.76	7.14	0.18
12	19.55	19.85	7.15	0.30
13	19.60	19.73	7.02	0.13
14	19.60	19.76	7.03	0.16
15	19.80	20.00	7.14	0.20

Approx. 1pF offset

	DB12			
BOARD #	C1	C2	C3	|C1-C2|
1	19.45	20.37	7.14	0.92
2	19.65	20.52	7.23	0.87
3	19.57	20.51	7.00	0.94
4	19.45	20.40	6.76	0.95
5	19.66	20.65	6. 88	0.99
6	19.70	20.63	7.23	0.93
7	19.63	20.51	7.05	0.88
8	19.83	20.71	7.09	0.88
9	19.82	20.68	6.96	0.86
10	19.69	20.56	7.09	0.87
11	19.55	20.40	7.03	0.85
12	19.46	20.39	7.22	0.93
13	19.57	20.40	7.09	0.83
14	19.55	20.35	7.10	0.80
15	19.77	20.67	7.12	0.90

Approx. 2pF offset

	DB12			
BOARD #	C1	C2	C3	|C1-C2|
1	19.47	21.54	7.43	2.07
2	19.69	21.66	7.43	1.97
3	19.59	21.62	7.42	2.03
4	19.46	21.45	7.35	1.99
5	19.68	21.83	7.54	2.15
6	19.75	21.77	7.52	2.02
7	19.65	21.73	7.55	2.08
8	19.87	21.87	7.69	2.00
9	19.87	21.82	7.61	1.95
10	19.71	21.71	7.49	2.00
11	19.56	21.52	7.48	1.96
12	19.50	21.52	7.41	2.02
13	19.57	21.50	7.35	1.93
14	19.55	21.54	7.48	1.99
15	19.80	21.80	7.49	2.00

Approx. 3.4pF offset

	DB12			
BOARD #	C1	C2	C3	|C1-C2|
1	19.47	22.87	7.67	3.40
2	19.70	23.11	7.83	3.41
3	19.60	22.95	7.68	3.35
4	19.48	22.96	7.57	3.48
5	19.68	22.98	7.74	3.30
6	19.77	23.21	7.93	3.44
7	19.66	23.07	7.78	3.41
8	19.87	23.28	7.93	3.41
9	19.89	23.23	7.96	3.34
10	19.72	23.17	7.71	3.45
11	19.59	22.90	7.73	3.31
12	19.52	23.03	7.77	3.51
13	19.60	22.86	7.74	3.26
14	19.58	22.93	7.77	3.35
15	19.82	23.17	7.76	3.35

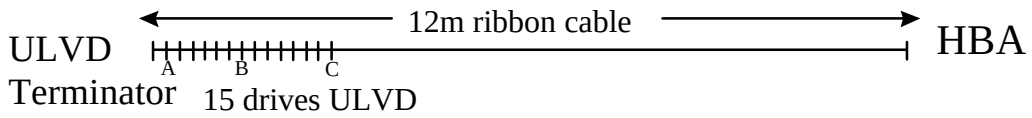
LVD Differential SKEW Testing
Test Environment
This data is on a pretty poor cabling environment.

15 Drives connected at 0.1m centers on 12m of Teflon unshielded ribbon cable (30AWG).

Termination at opposite end of HBA on ribbon cable

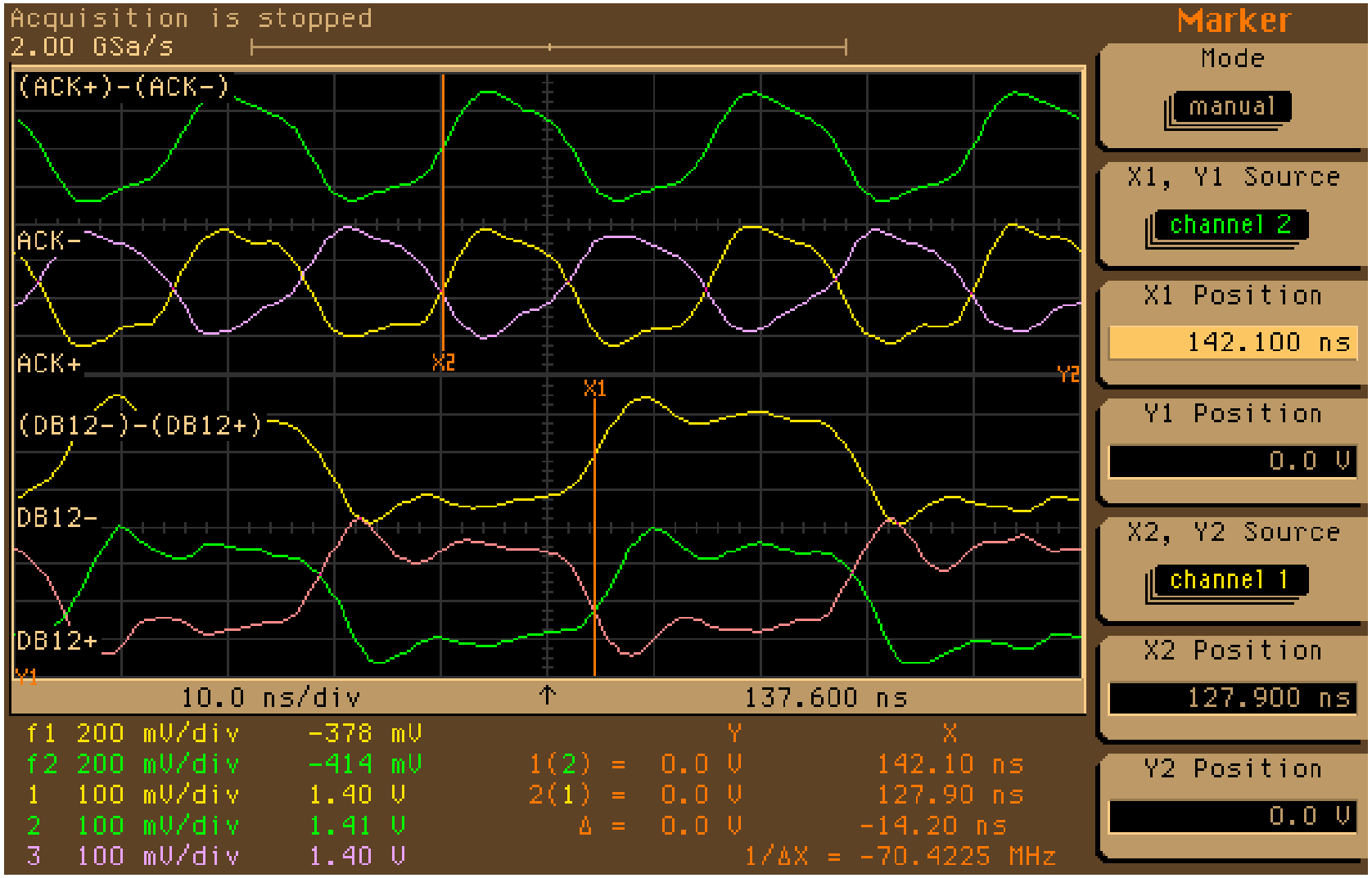
Scope used: HP5472D, with 2 Gs/sec resolution.
Probes used, HP 54701A 100K Ohm, 0.6pF 2.5GHz 200V

Test points included connector nearest terminator (A), connector in middle of 15 drives(B), and connector closest to HBA(C)

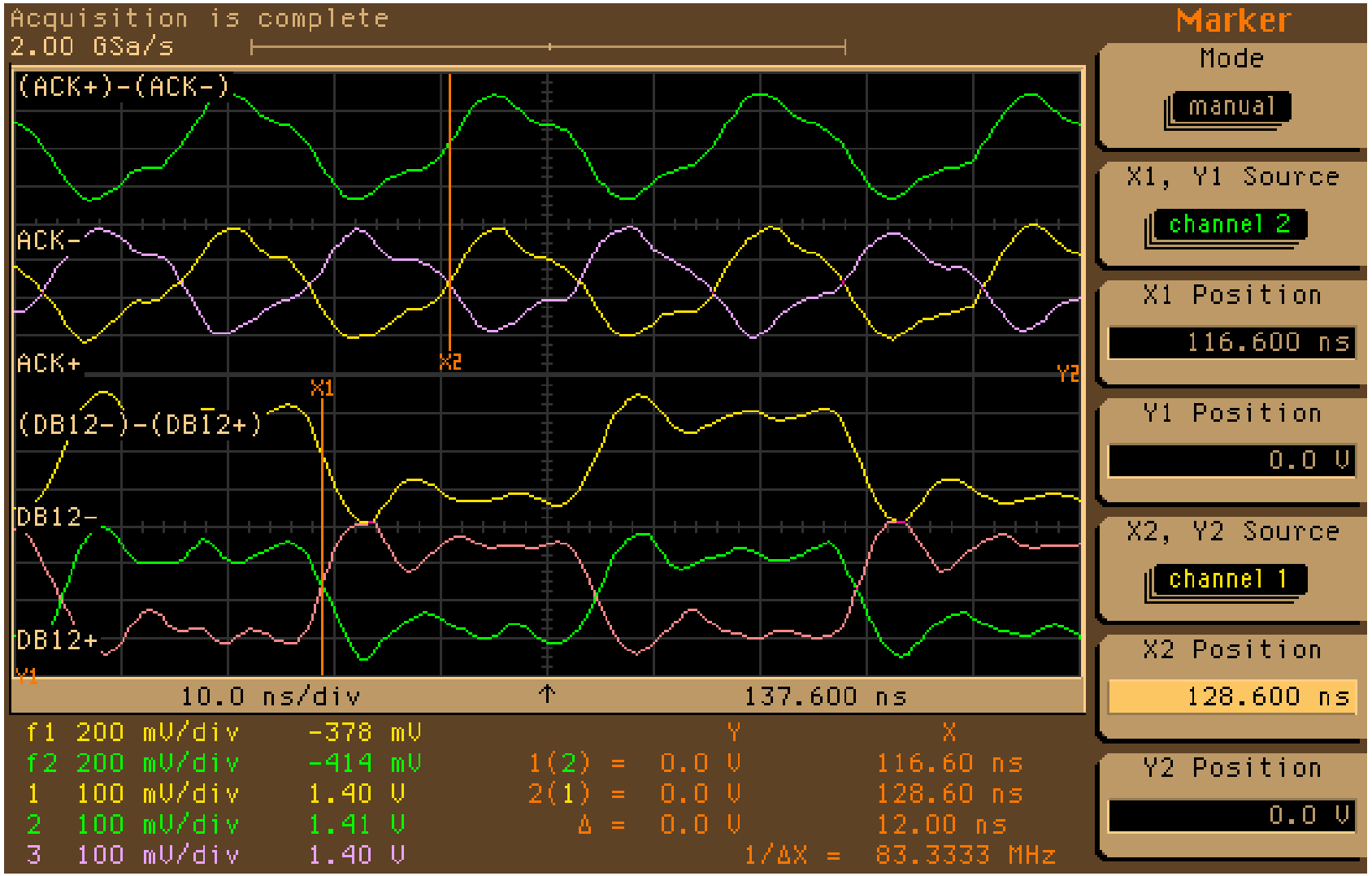


Experiment attempted to place 0pF, 1pF, 2pf and 3.4pF on one side of differential pair and then examine effects at A, B and C for Reads, Writes, setup, hold, and transitions.

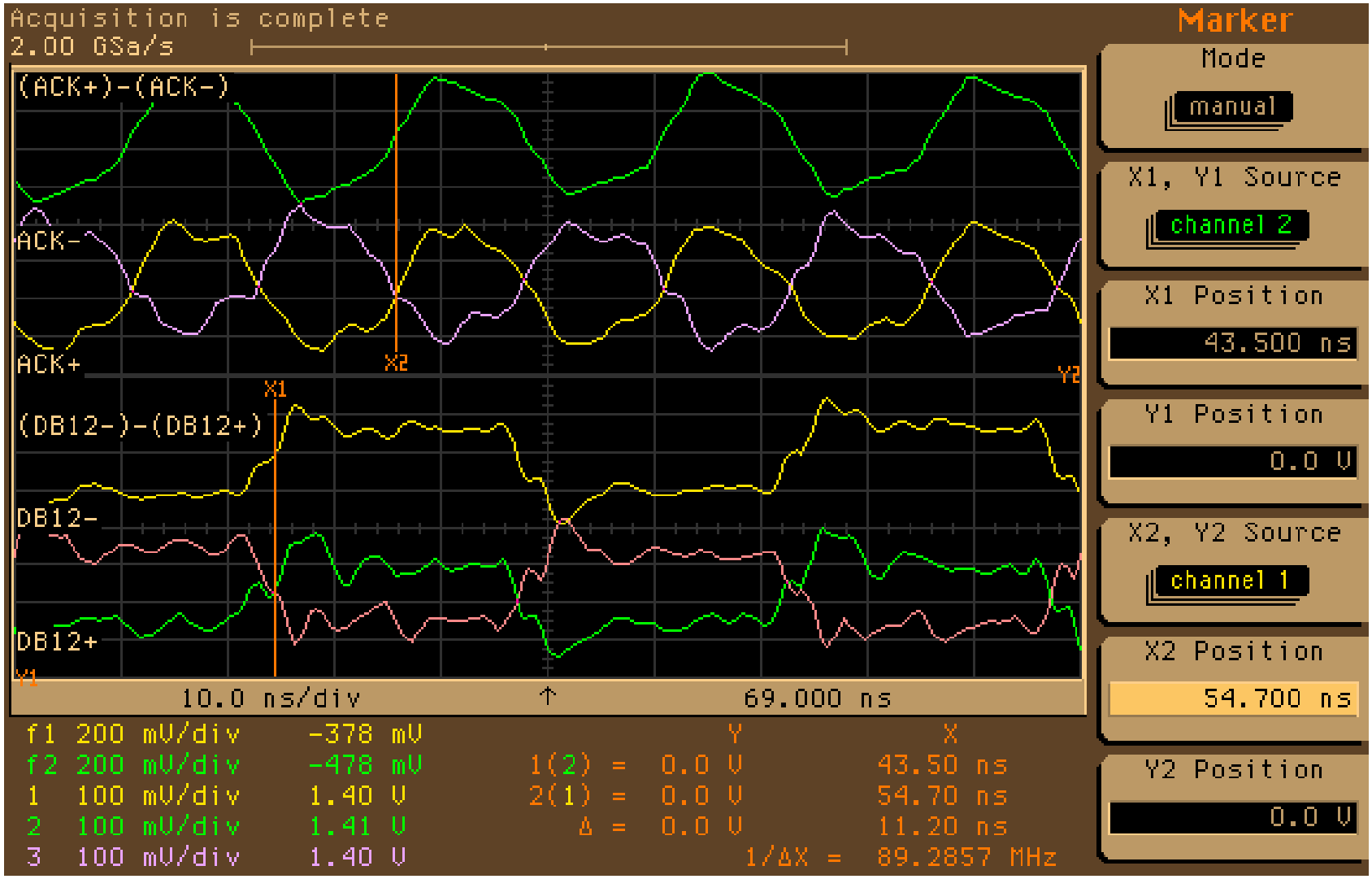
Pattern during reads and writes is alternating AAAA and 5555 pattern.



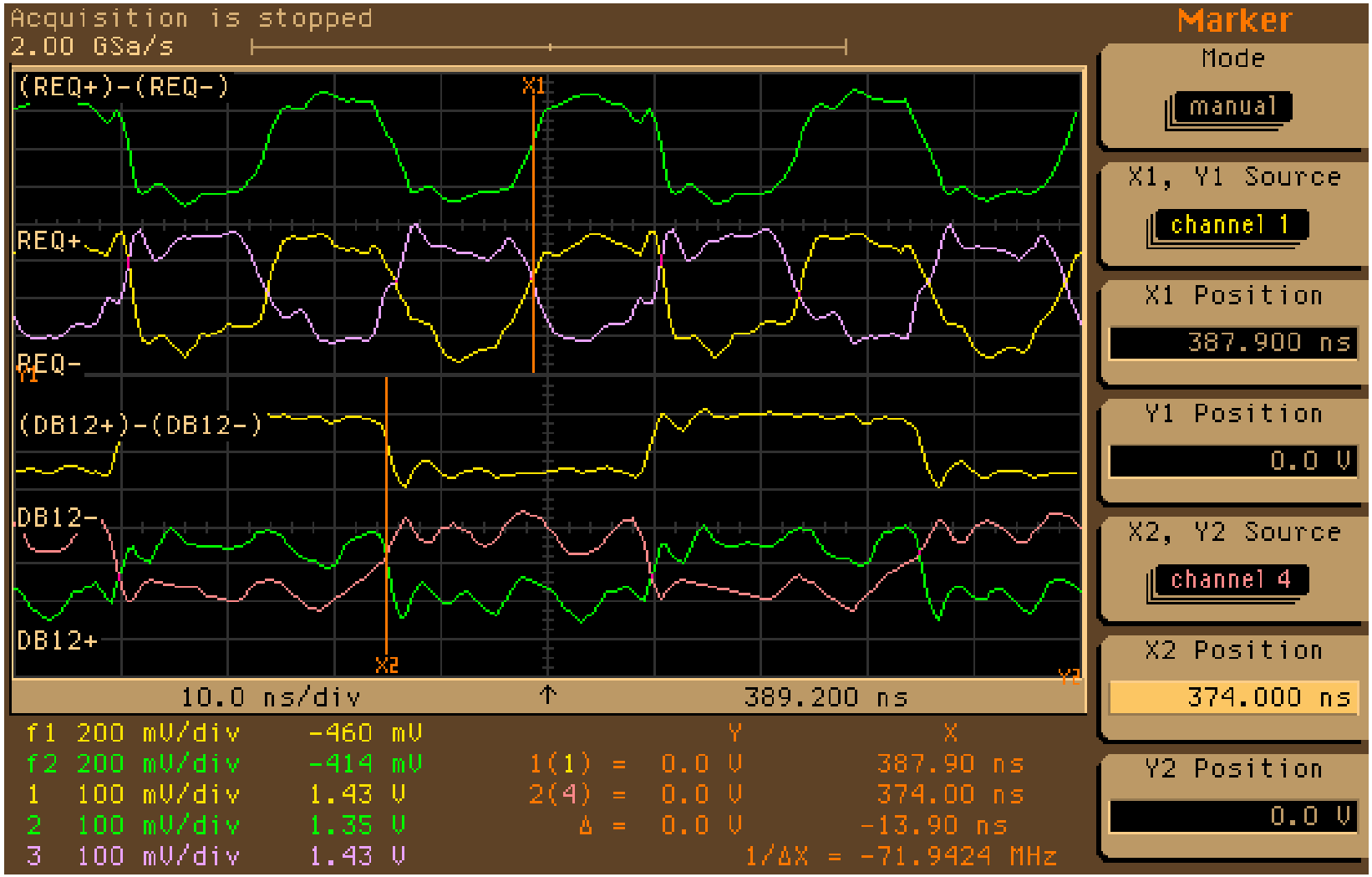
0pF graph, Write, data taken at the drive, position A



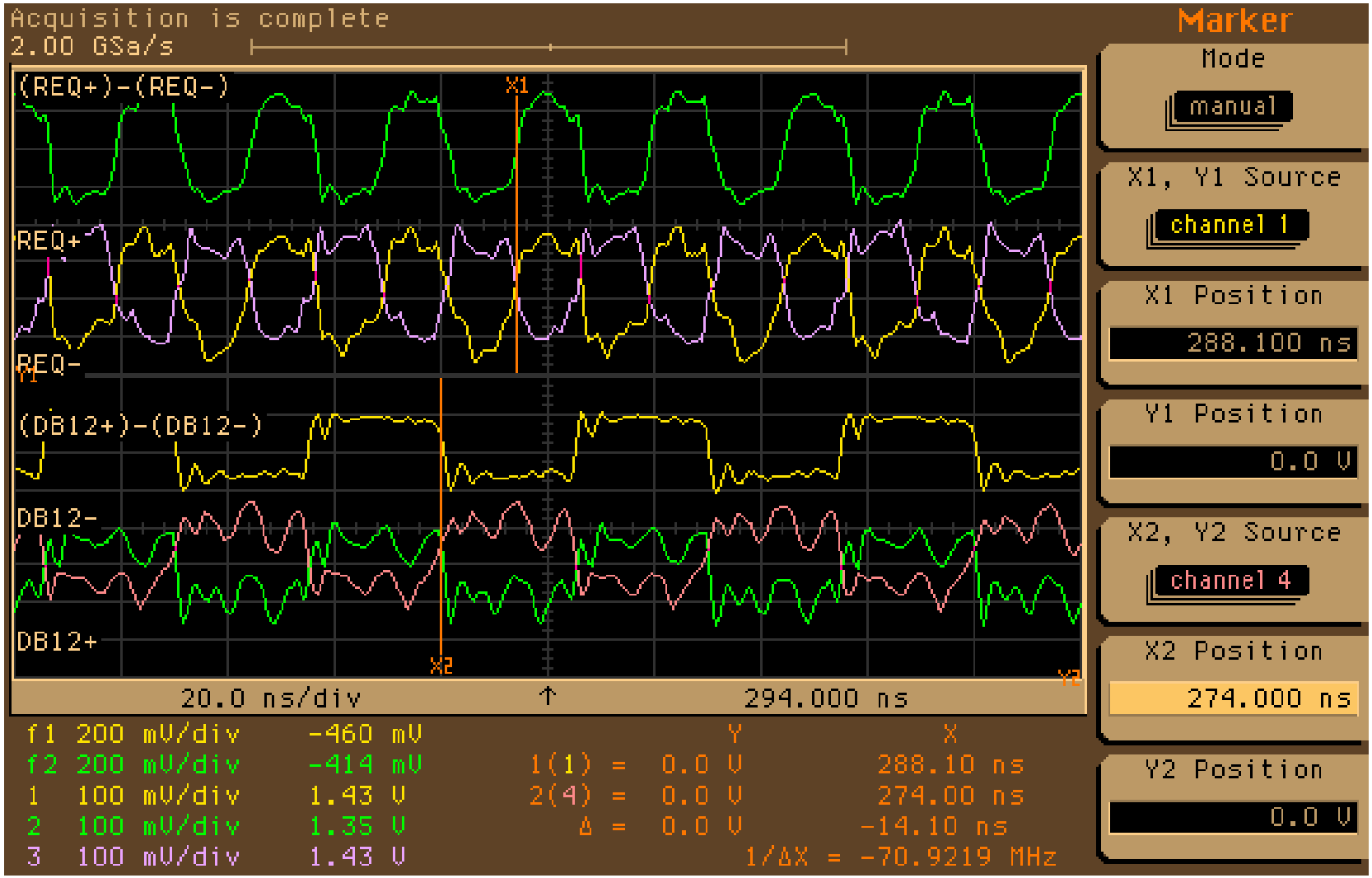
0pF graph, Write, data taken at the drive, position B



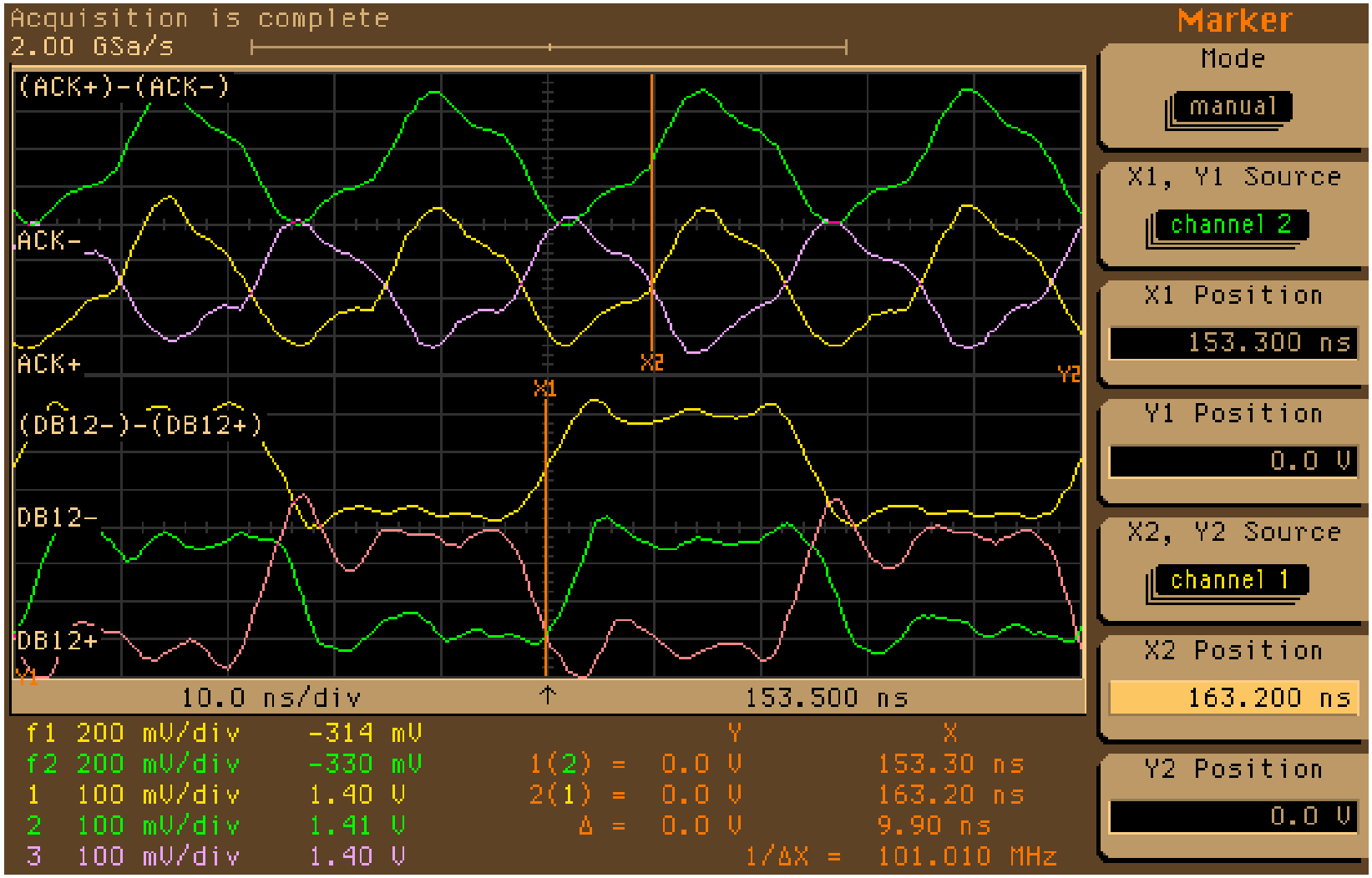
0pF graph, Write, data taken at the drive, position C



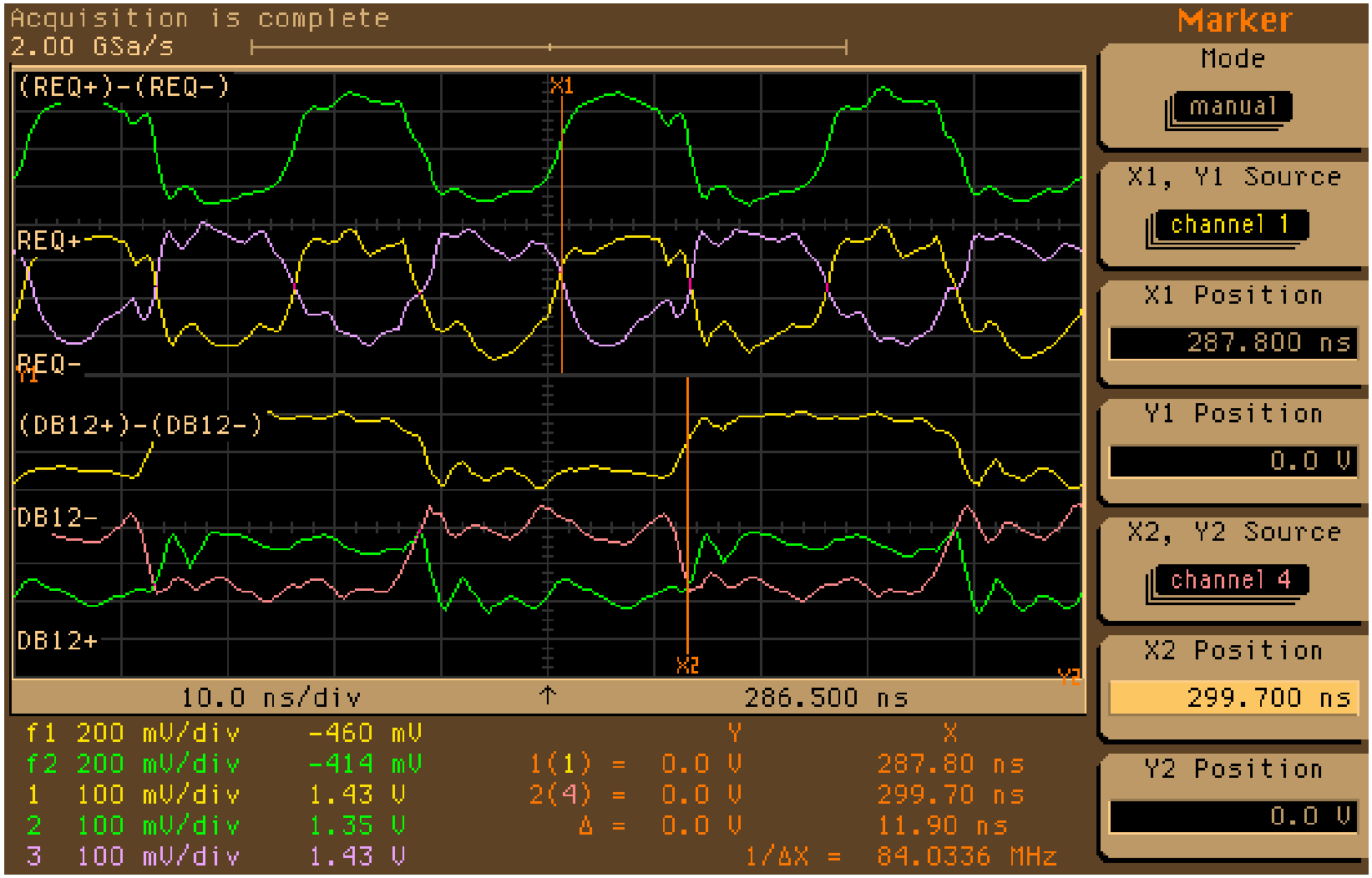
0pF graph, Read, data taken at the HBA, reading from position C



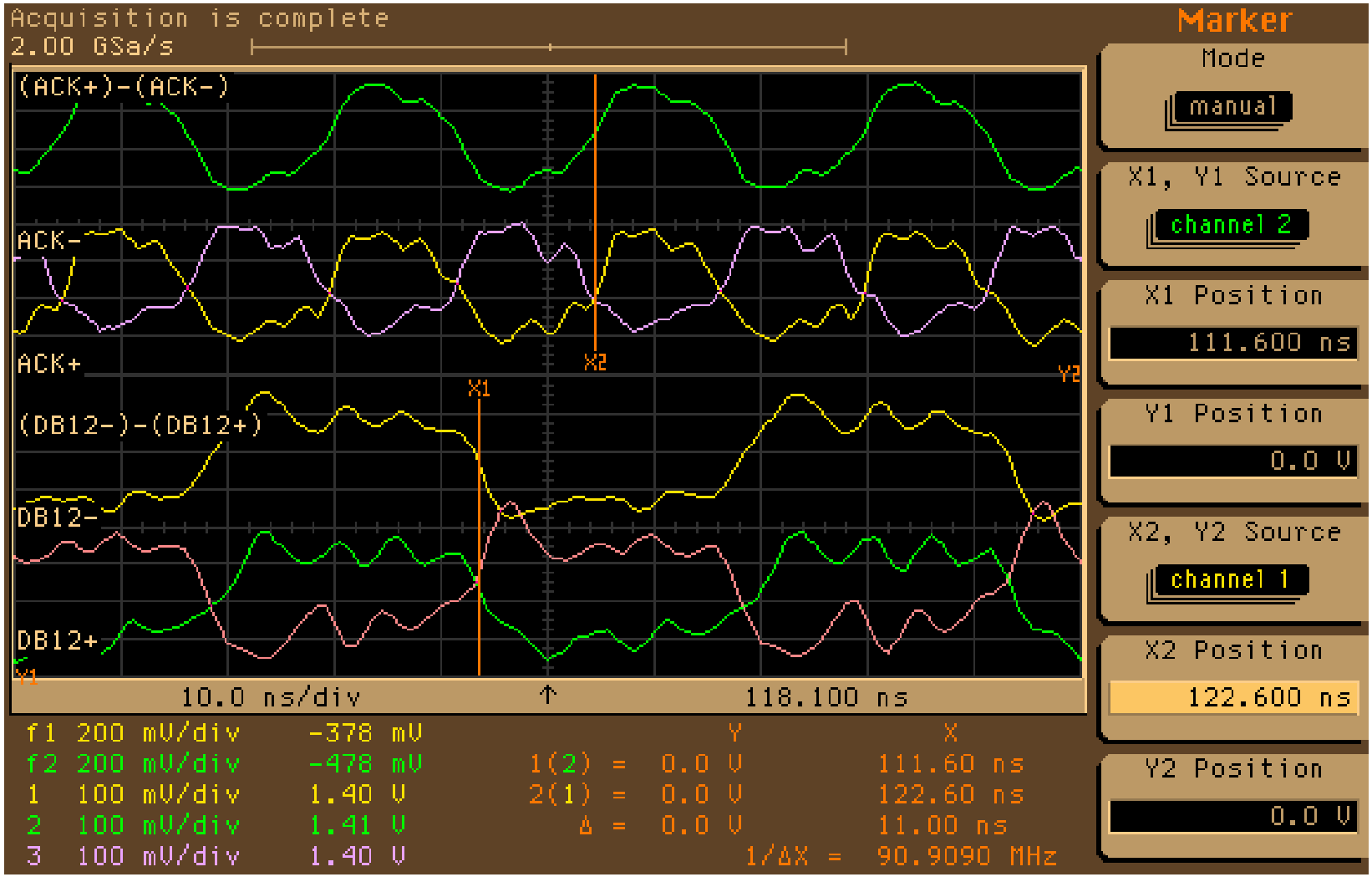
1pF graph, Read, data taken at the HBA, reading from position C



2pF graph, Write, data taken at the drive, position B

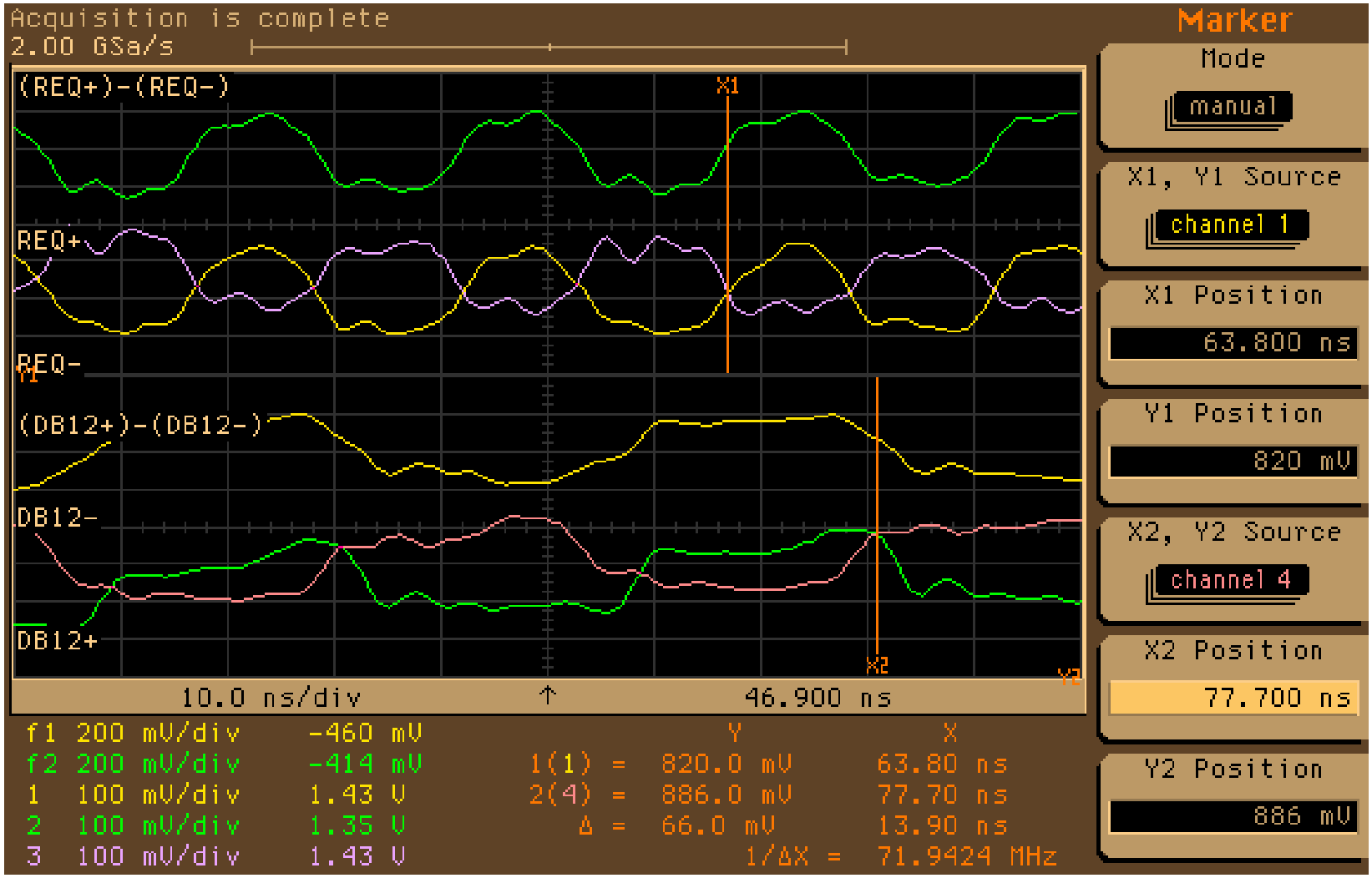


2pF graph, Read, data taken at the HBA, reading from position C



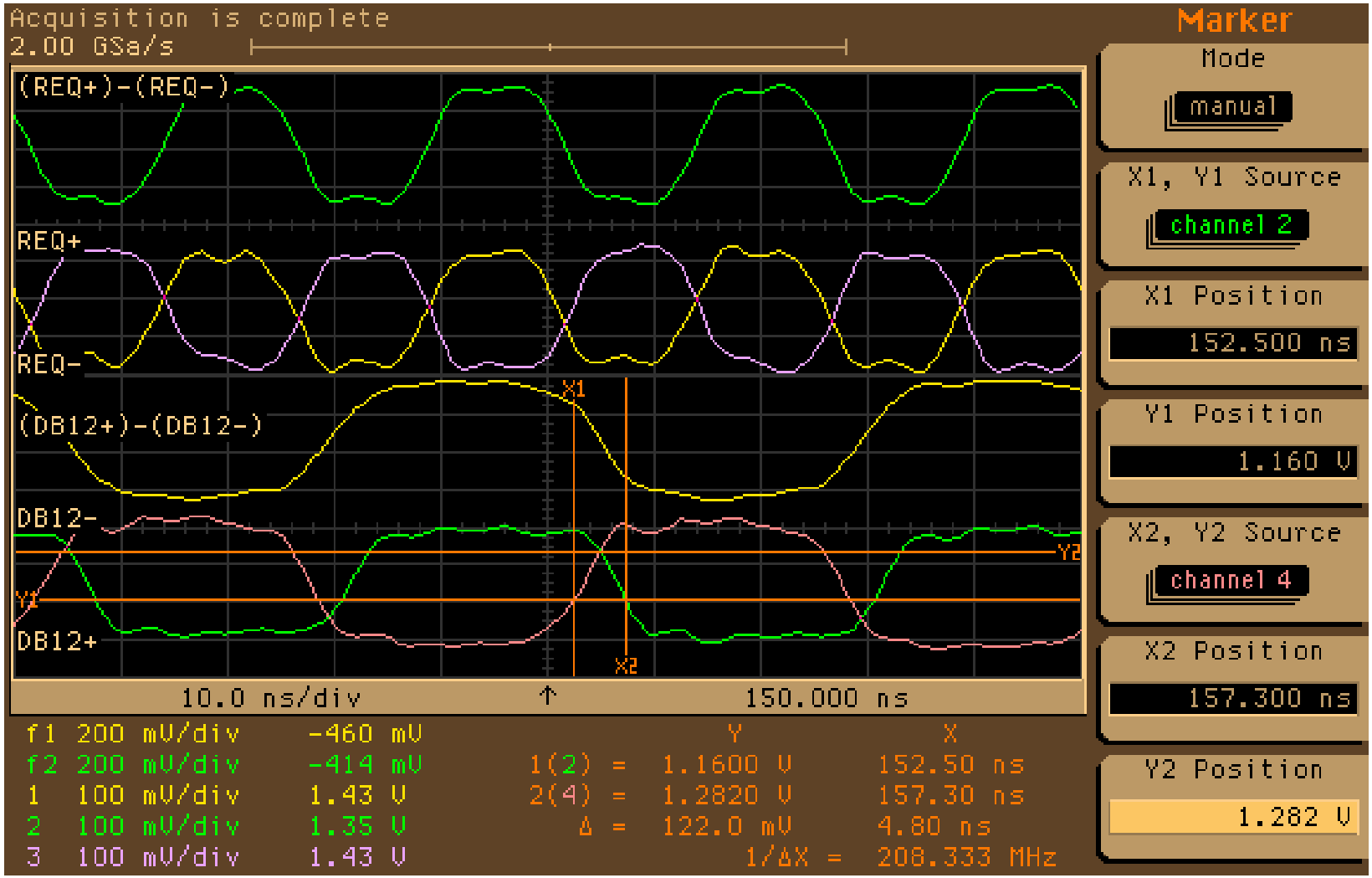
3.4pF graph, Write, data taken at the drive, position A

3.4pF graph, Write, data taken at the drive, position C

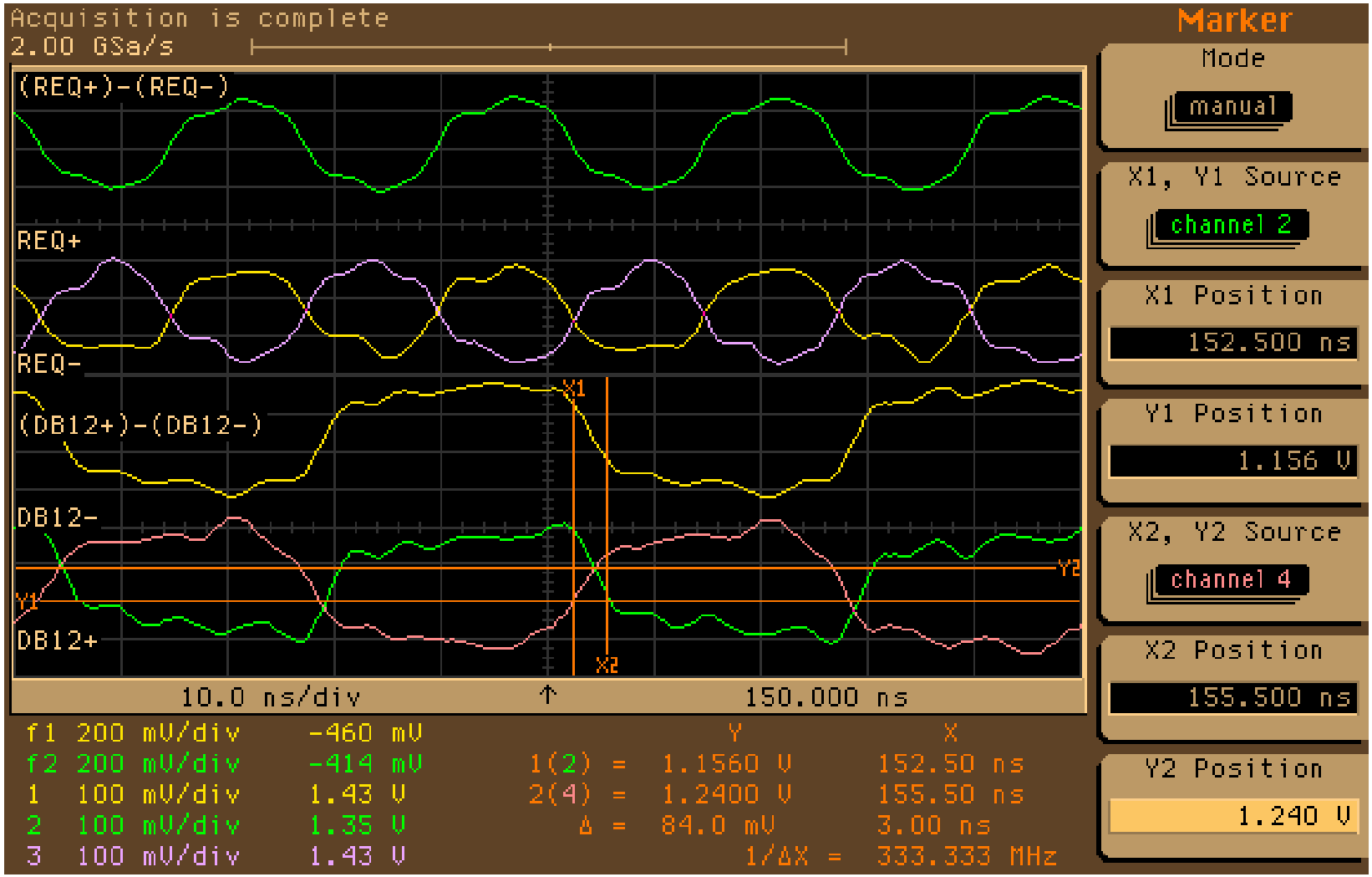


3.4pF graph, Read, data taken at the HBA, reading from position B

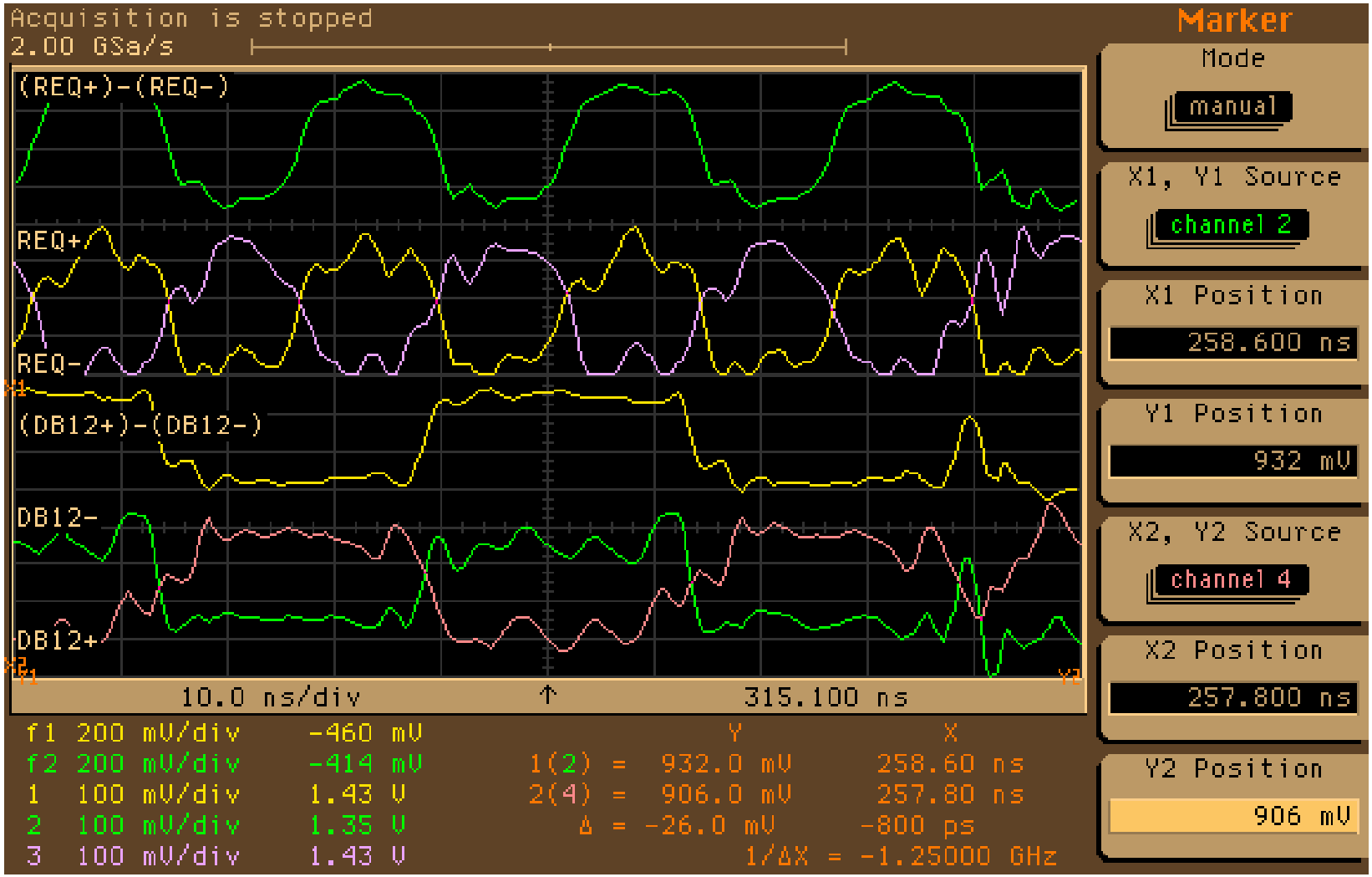
3.4pF graph, Read, data taken at the HBA, reading from position C



3.4pF graph, Read, data taken at the HBA, reading from position A, Competitor's drive



3.4pF graph, Read, data taken at the HBA, reading from position B, Competitor's drive



3.4pF graph, Read, data taken at the HBA, reading from position C, Competitor's drive (Note double clocking concern)

From all the data taken and the challenge to keep the capacitance within 0.5pF both at the device level and at the Silicon level it is Western Digital's recommendation that the SPI-2 specification be changed for C1-C2.

In order to maintain the advantages LVD SCSI now offers in the form of low cost implementations and in order to allow for high volume manufacturing variations, Western Digital recommends a 2pF specification.

It is also recommended that implementers be encouraged to keep the difference as low as possible.

Final note: As the Ultra-3 double clocking is looked at in the future and as Silicon and device suppliers engineer better solutions, this specification may need tightened to 1.5pF or 1pF. In any case the 1st device reflection problem needs to be addressed through some innovative techniques or bus architecture solutions.