

Comparison of termination methods for SSA40

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Introduction

Five different termination methods were considered:

1. Single termination at receiving end of transmission line, 75 ohms to Vdd.
2. Termination at both driver and receiver both 75 ohms to Vdd (dc coupled).
3. As above but with driver termination connected to Vdd via a capacitor.
4. Termination at both driver and receiver, driver terminated with 150 ohms across the differential lines.
5. Driver and receiver termination resistor connected directly to VDD with transmission line ac coupled.

See circuit diagrams that follow.

For each option dv/dt was modified by adding capacitance directly to the driver output to VDD, the following values of dv/dt were considered.

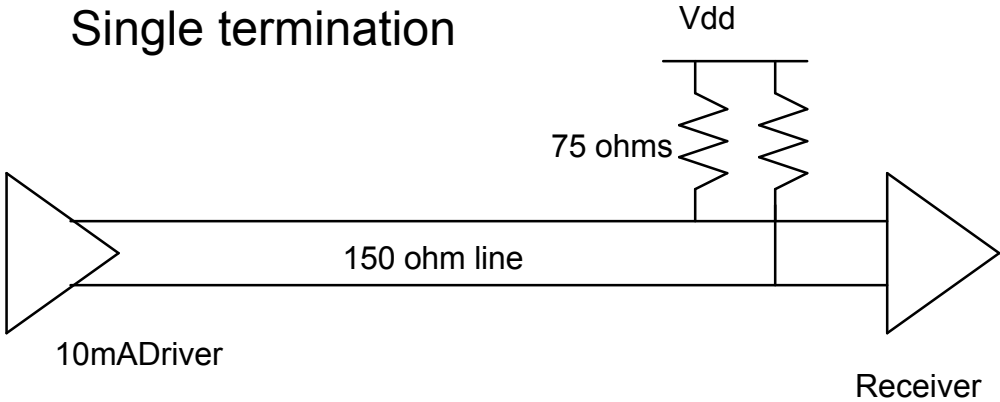
1. No restriction
2. $2v/ns^*$
3. $1Vns^*$

* These values were not achieved exactly because of the restricted values of capacitance that are available.

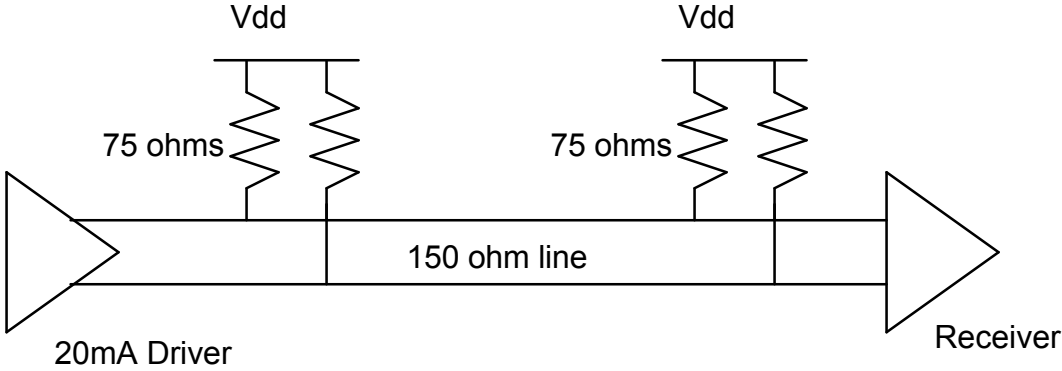
The card segment impedance was also measured and recorded along with plots of driver rise time.

All graphs of impedance and dv/dt are included in the appendix

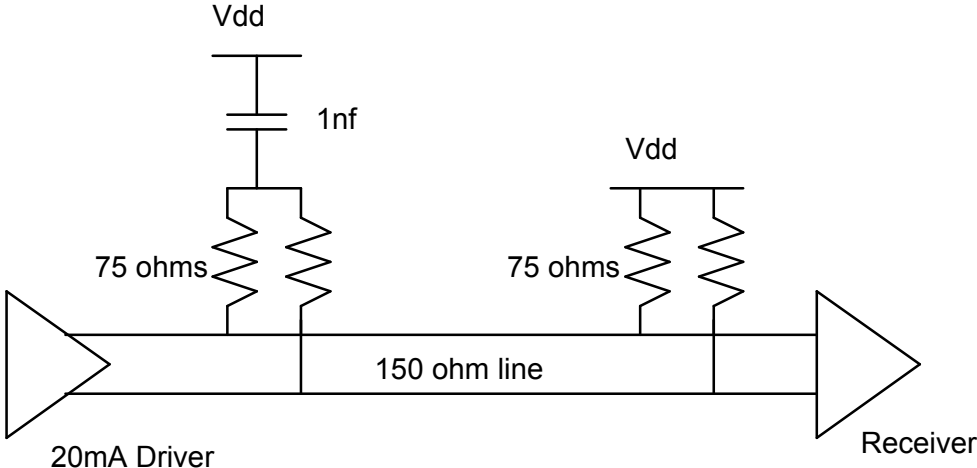
Single termination



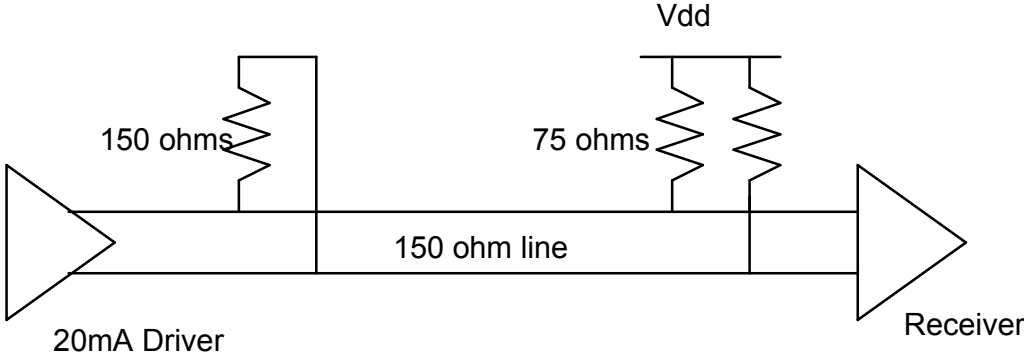
Double DC coupled termination



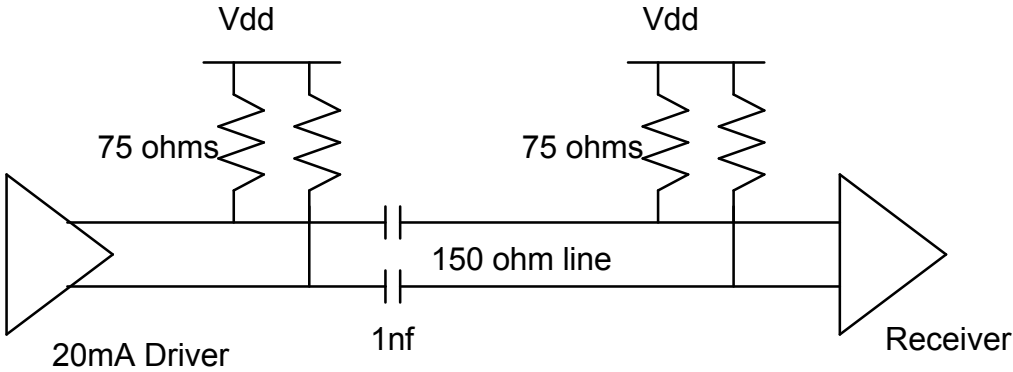
Double AC coupled termination



Double differential termination



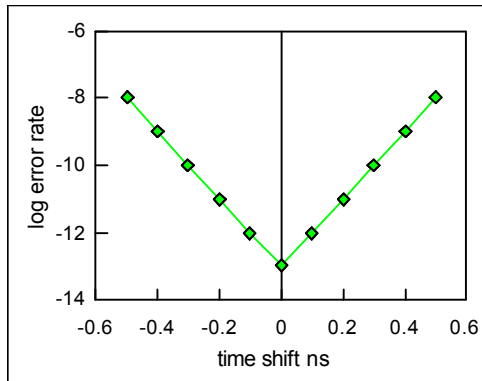
Data AC coupled termination



Error rate measurements

Comparisons in performance in this document are done using error rates. All measurements are done with a 20 metre 26 gauge cable. Absolute error rates are not of prime importance but the comparative rates between various methods. Error rates in the order of $1e-13$ are so low that direct measurement of error rate would take a very long time, each measurement would take days. Therefore some form of error rate acceleration is required to enable error rate to be measured in a practical time.

The method employed during this evaluation was to force the deserialiser to sample the incoming data at a point that is shifted in time from the optimum point, and plotting this shift in sample point against error rate. Theoretically this will yield a graph of the following form.



Not all the graphs have their minimum error rate at zero time shift, it is assumed that this means the optimum position for sampling is not in the centre of the bit.

At very high error rates above $1e-6$ errors/bit the graphs deviated from the theoretical line, this is believed to be due to the inability of the test cards to accurately measure high error rates. The cards spend a significantly large part of the time recovering from error conditions rather than sending data.

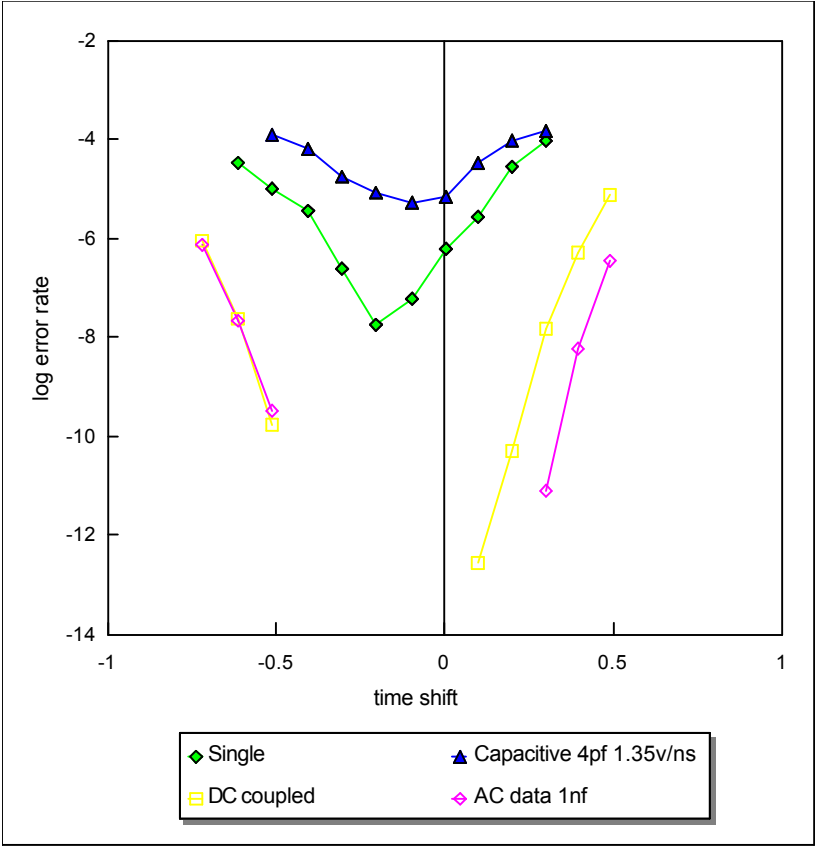
At all times the hardware was unchanged apart from switching the driver into double current mode and adding the necessary external termination/coupling components. The same micro strips and connectors were used for all the tests.

Conclusion

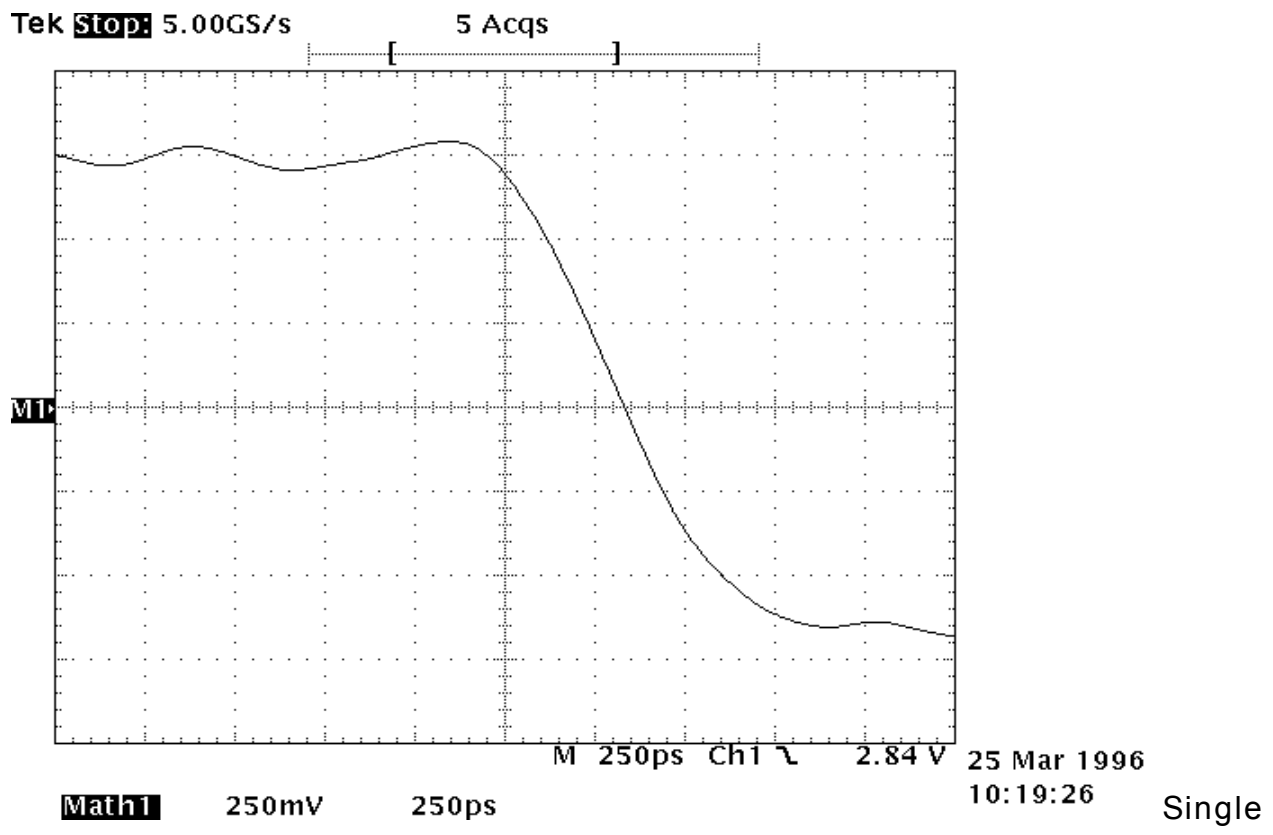
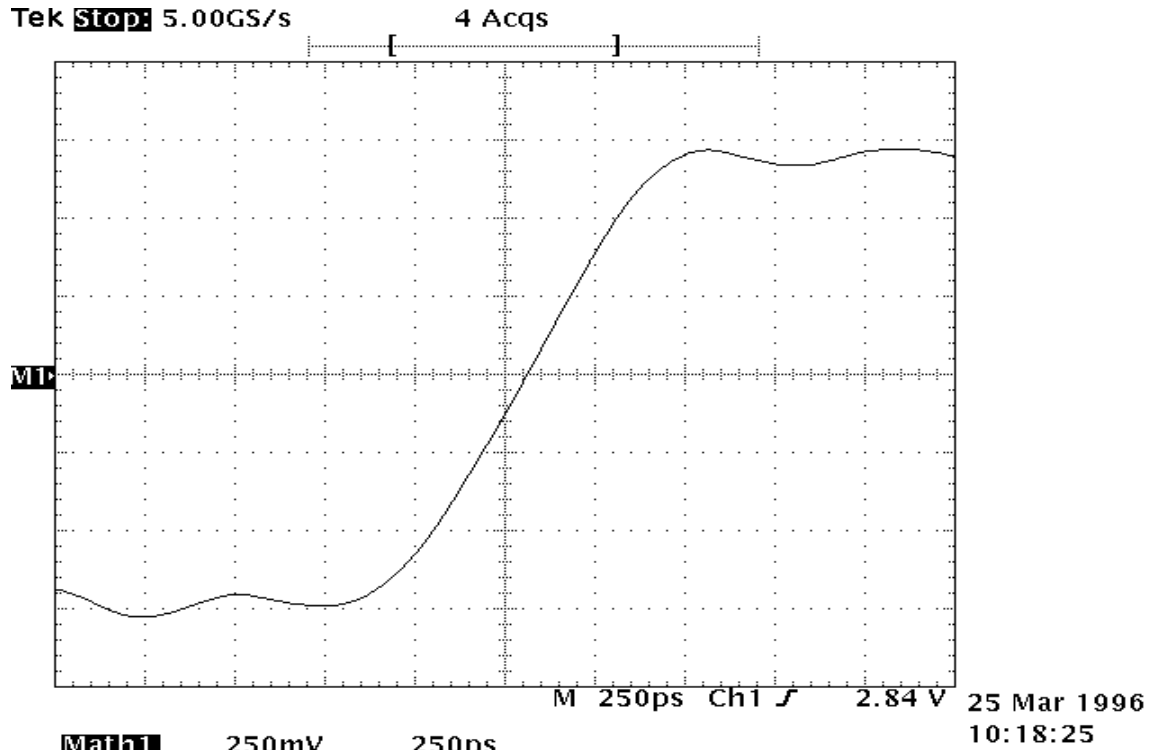
As a result of this work the following conclusions have been made for the evaluation cards under the test conditions.

- 1. Double termination is better than single termination by at least 6 orders
- 2. No improvement can be made to single termination by adding capacitance at the source.
- 3. No improvement can be made to any termination scheme by adding capacitance at the source to decrease dv/dt
- 4. AC coupling the data lines gave the best error rate of all the AC coupling methods tried.

The graph below shows the relative performance of the four methods.

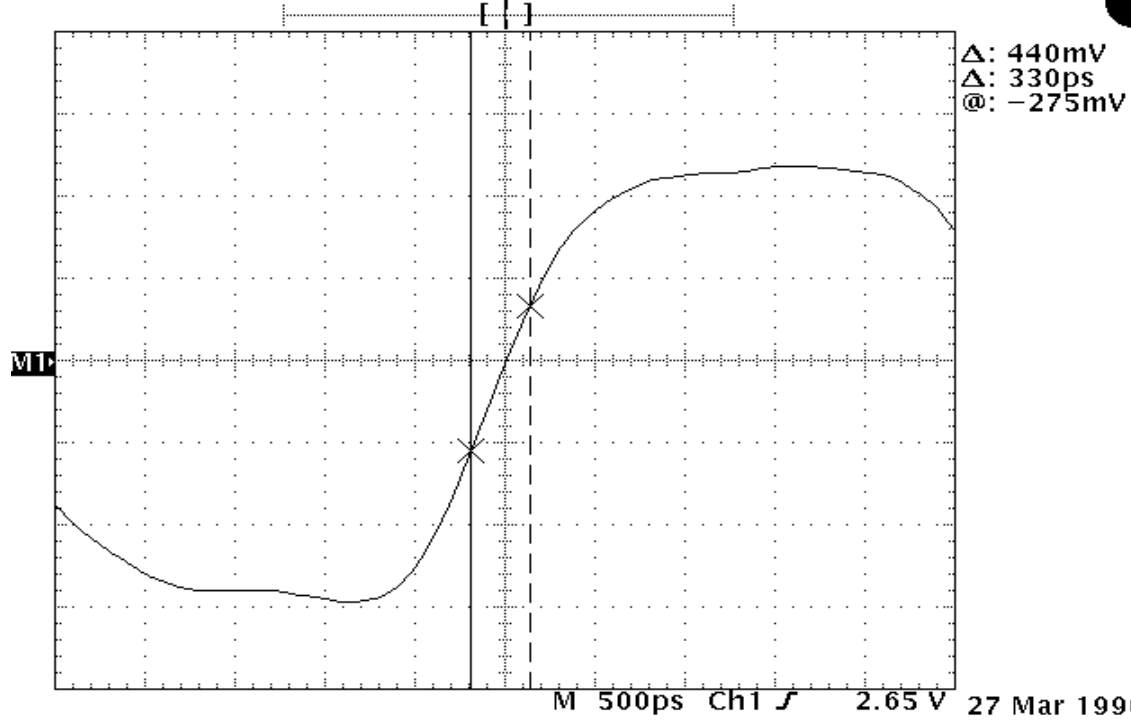


Appendix



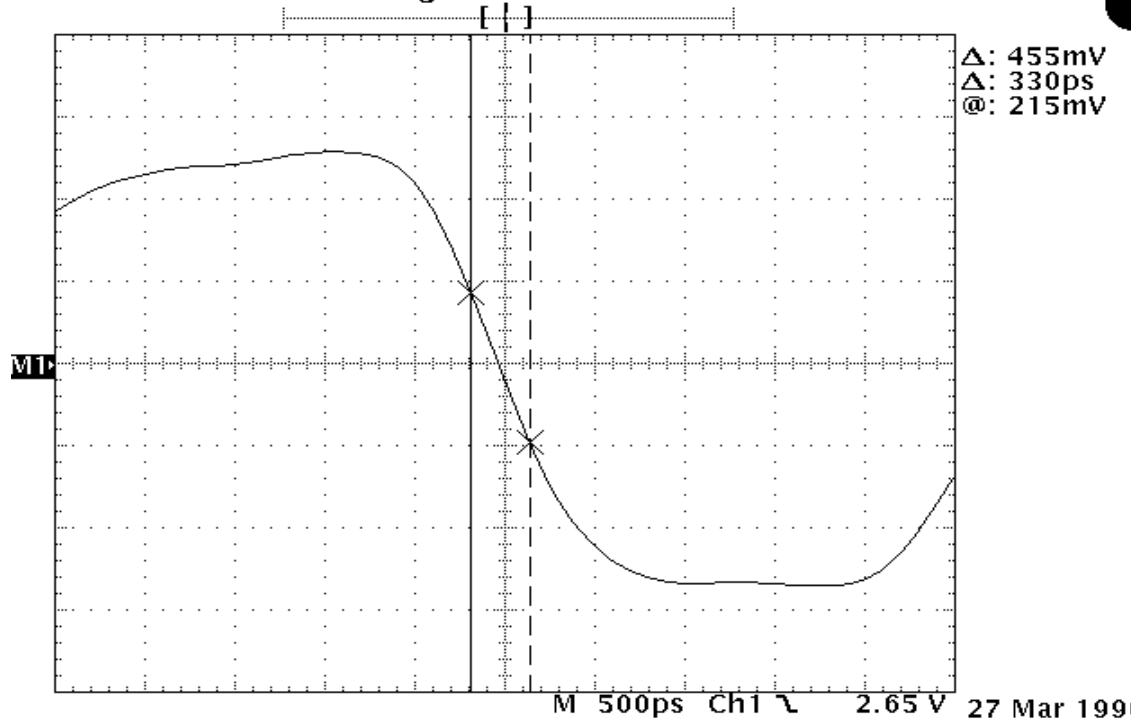
termination at receiver $dv/dt = 2v/ns$

Tek Run: 5.00GS/s Average



27 Mar 1996
09:35:08

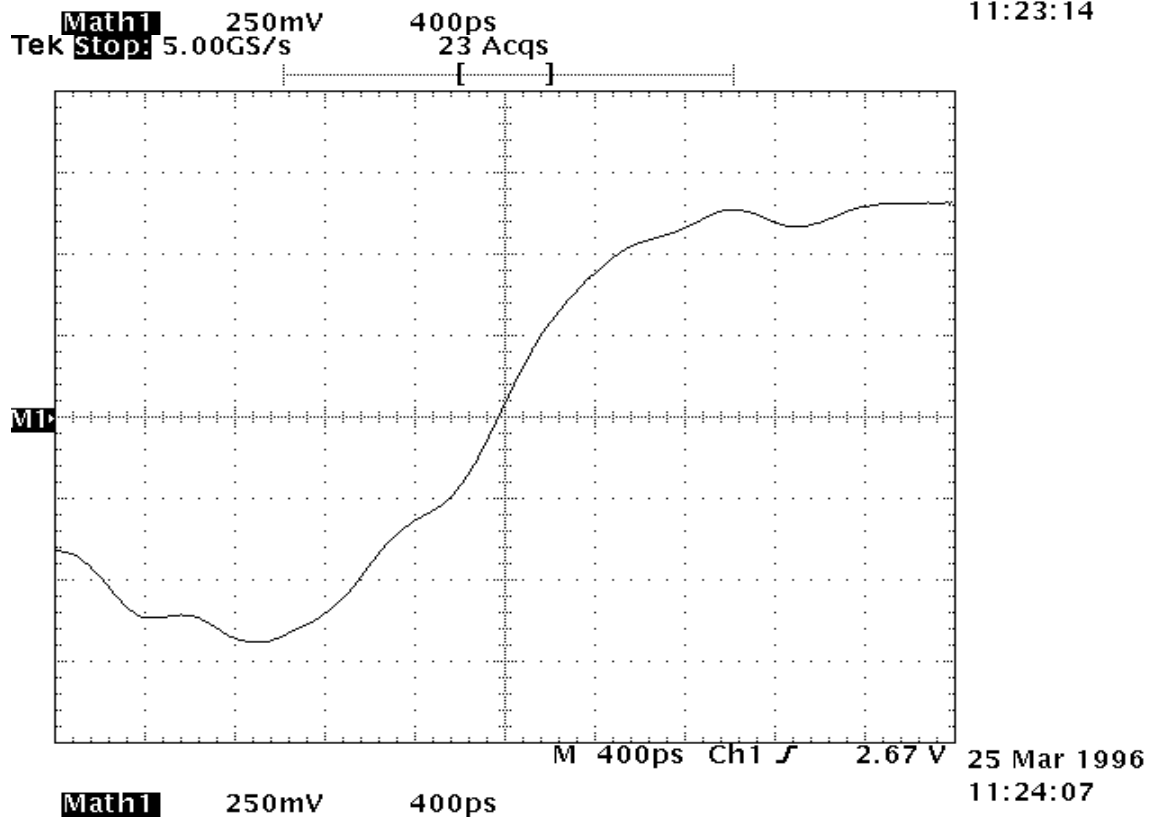
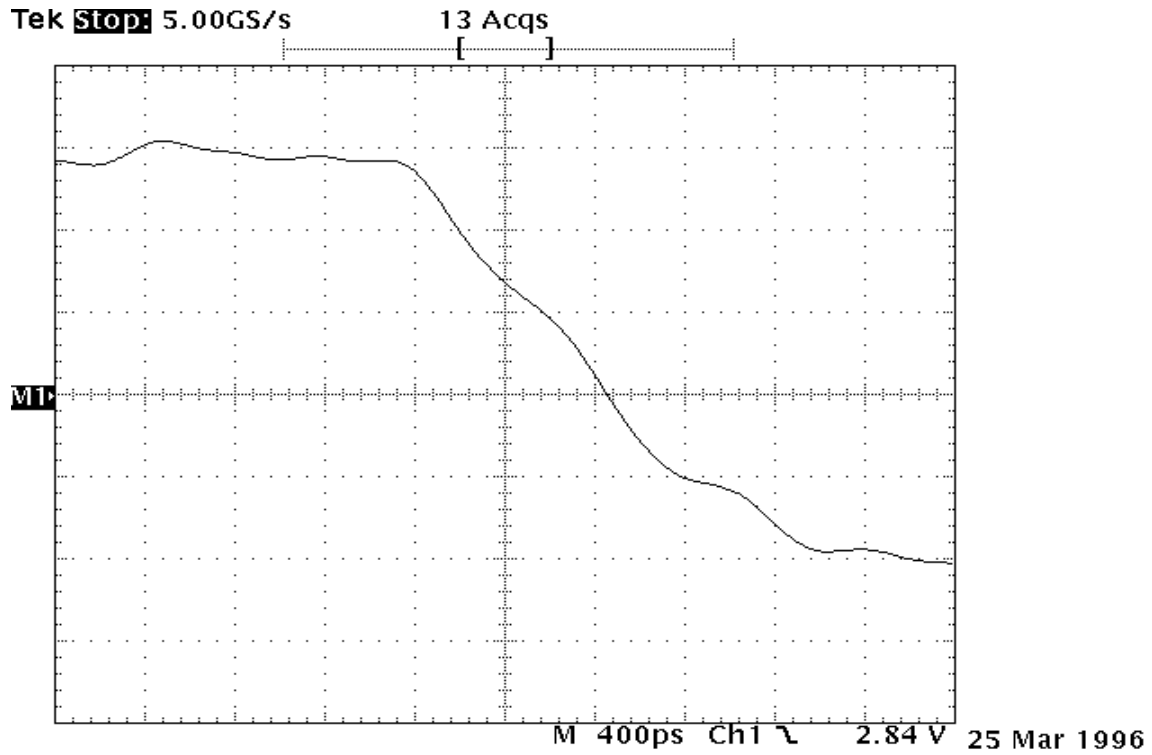
Math1 250mV 500ps
Tek Run: 5.00GS/s Average



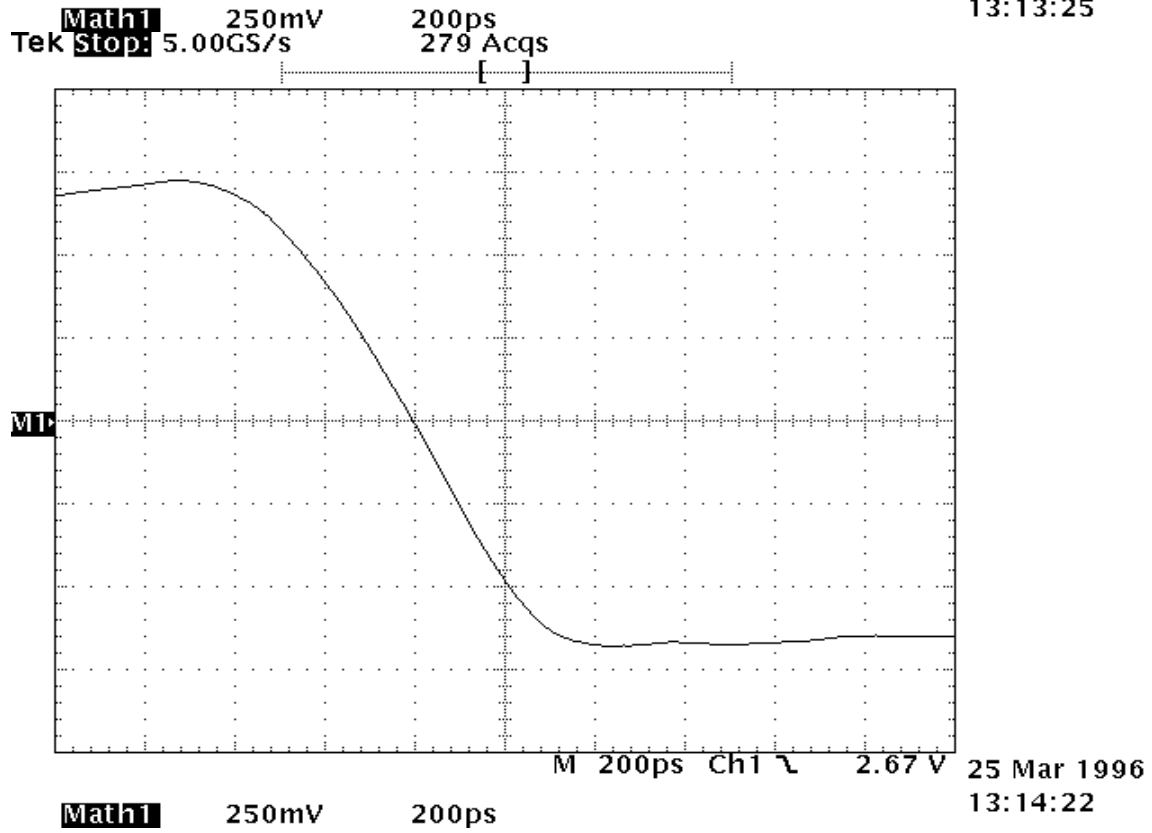
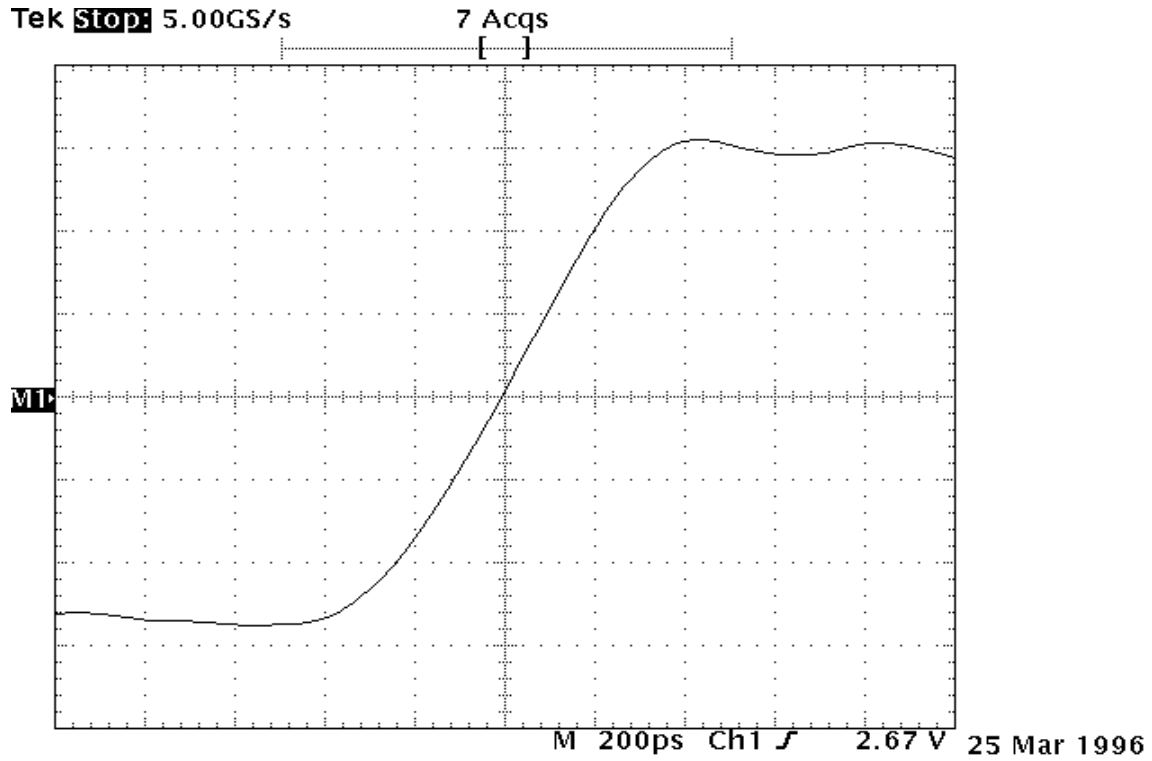
27 Mar 1996
09:35:38

Math1 250mV 500ps

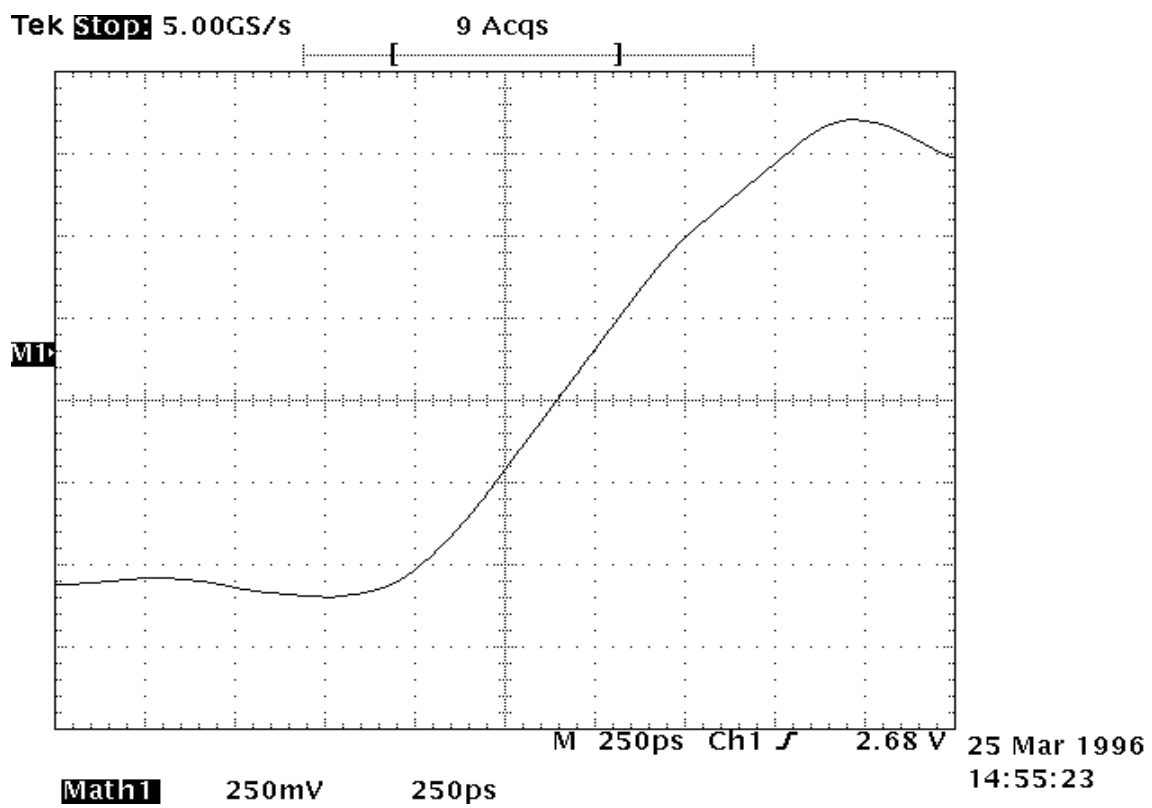
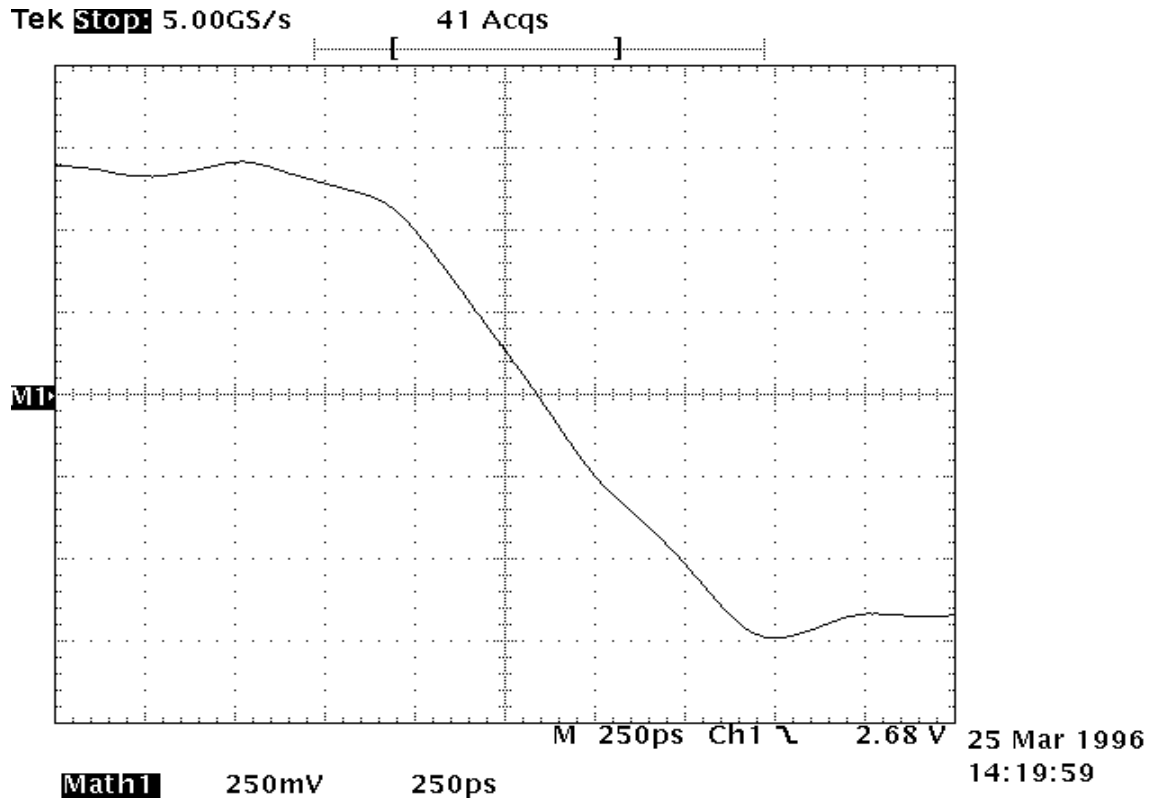
Single termination at receiver $dv/dt = 1.35v/ns$



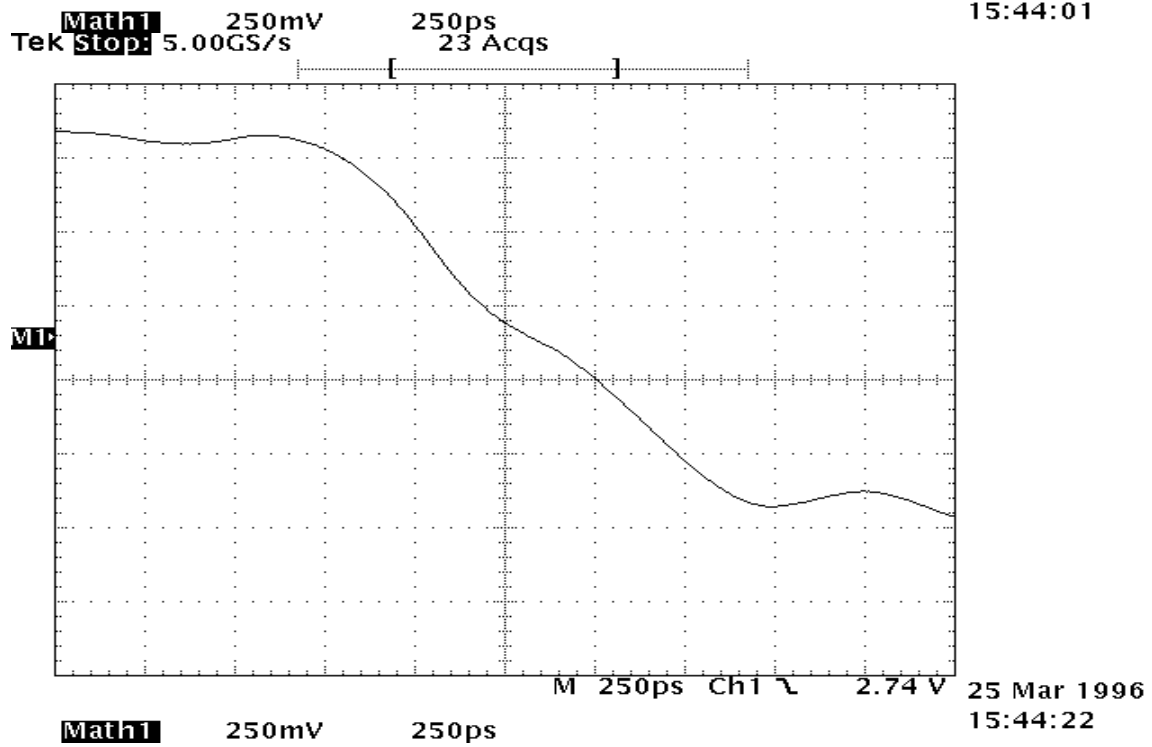
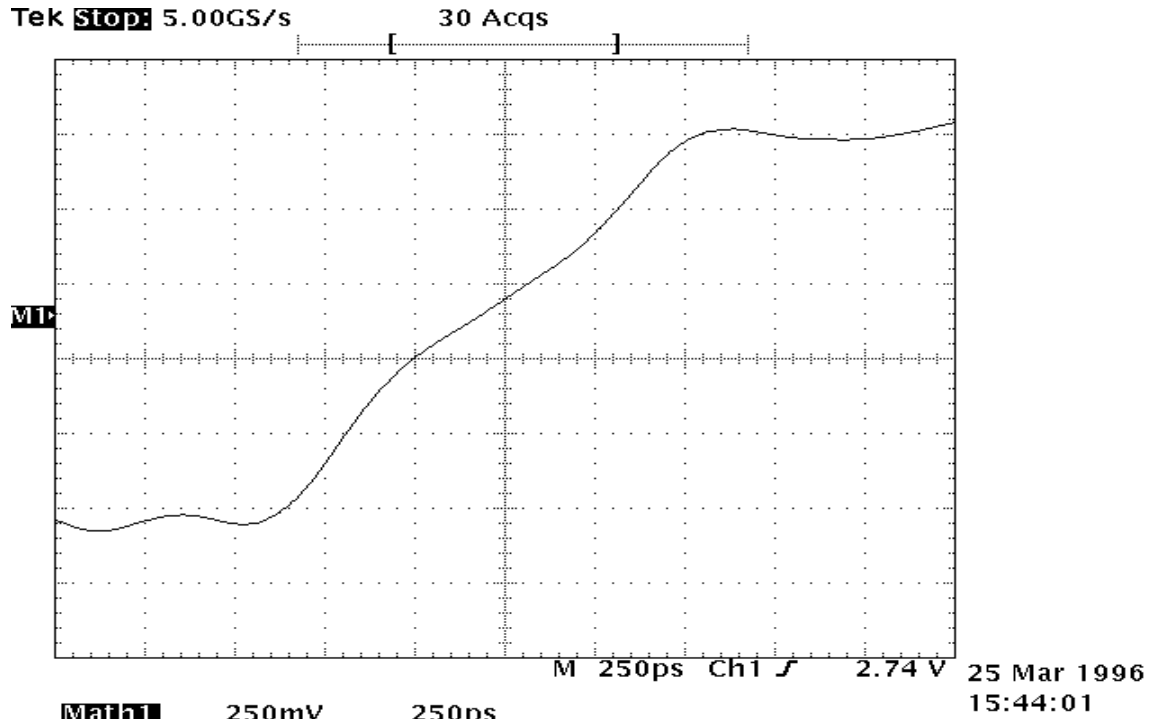
Single termination at receiver = 1v/ns



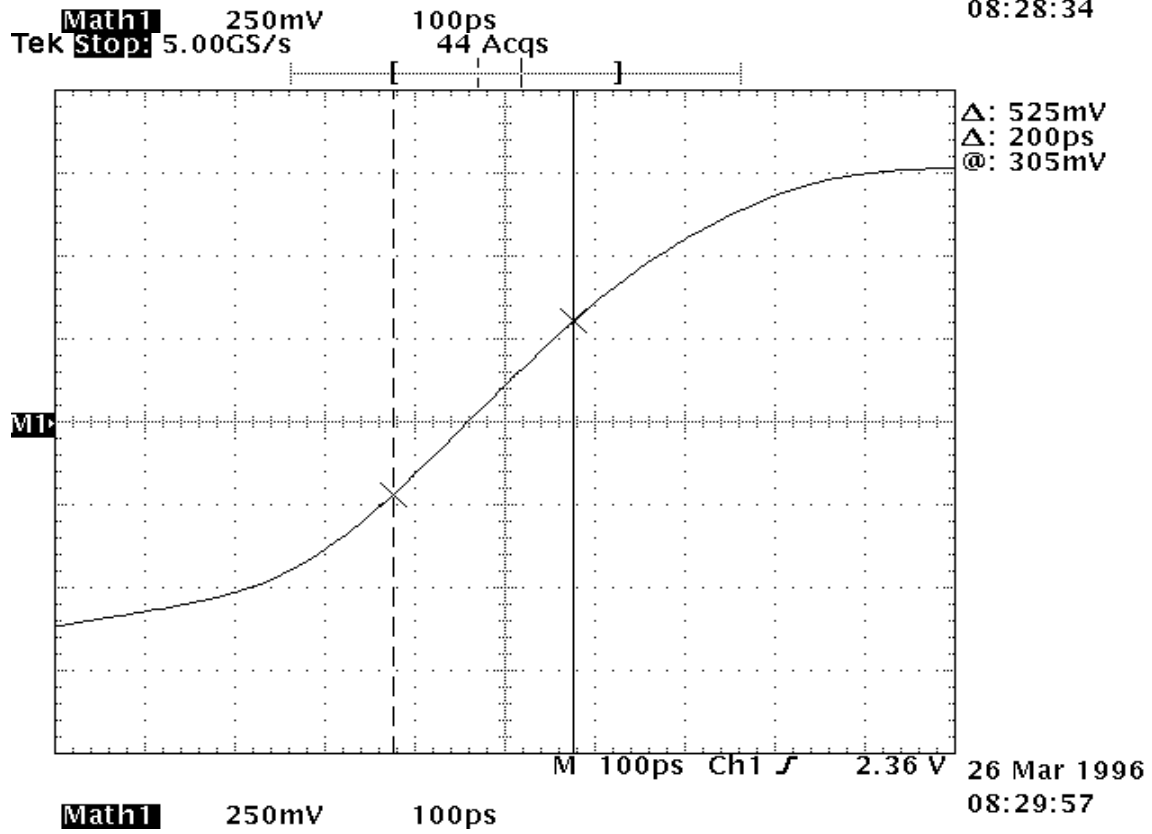
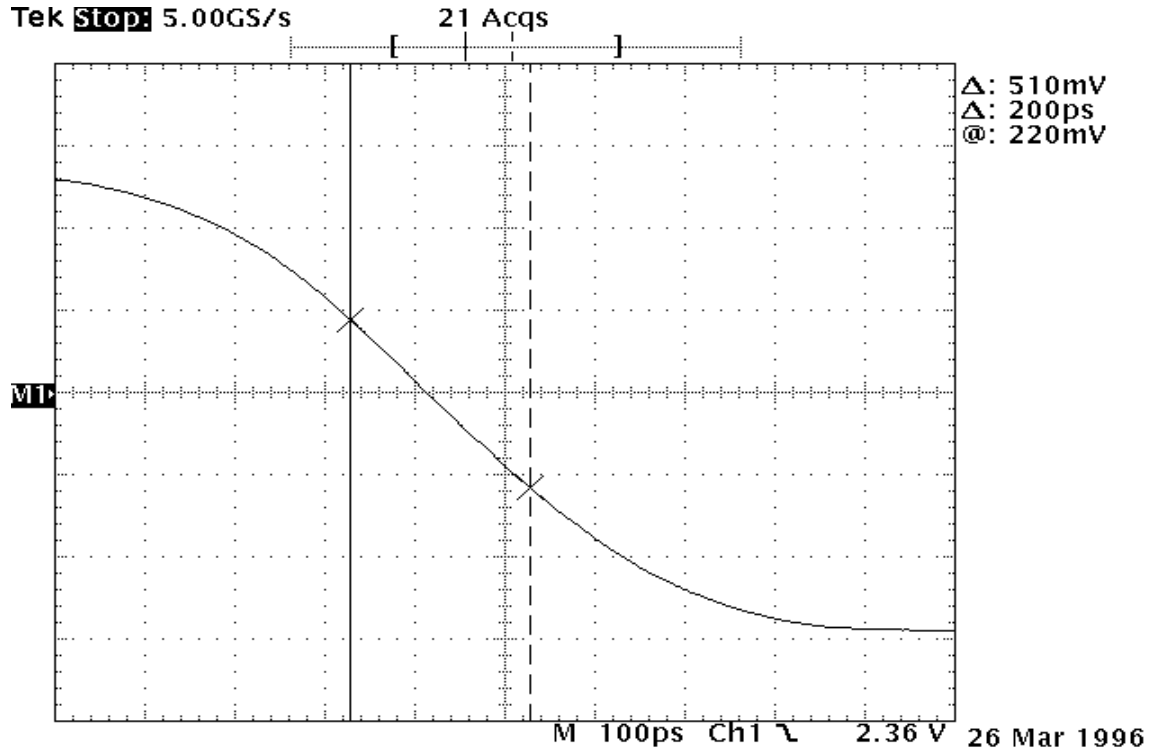
Double termination DC coupled $dv/dt=2.5v/ns$



Double termination DC coupled $dv/dt=1.6v/ns$

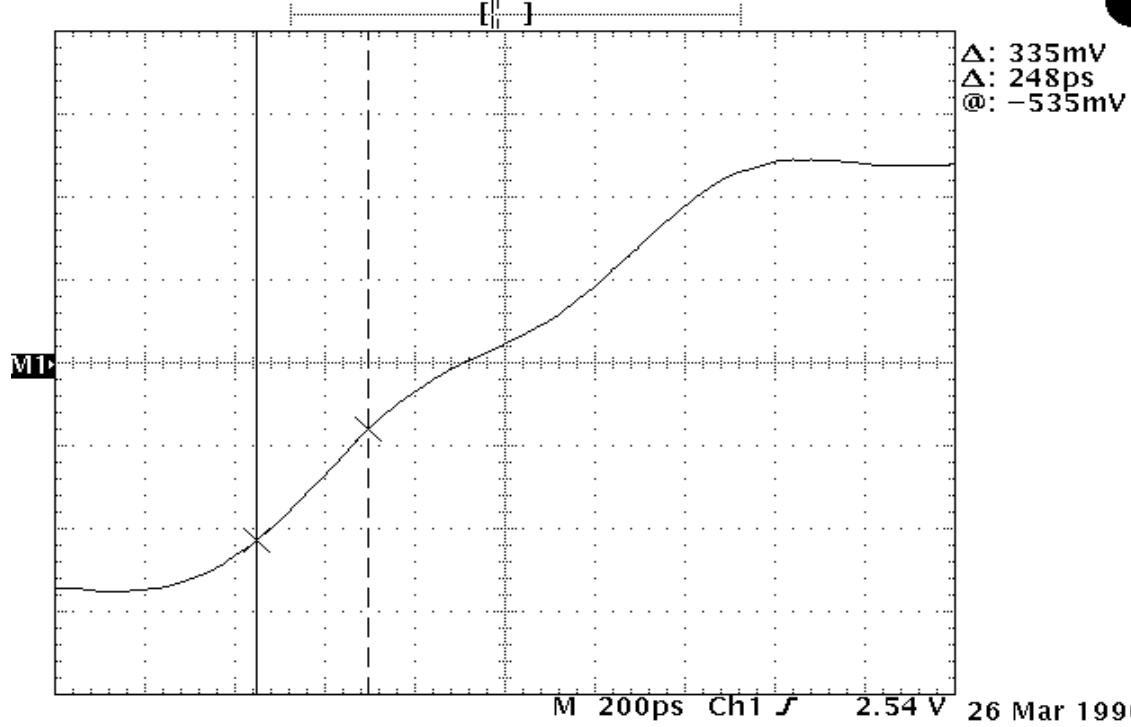


Double termination DC coupled $dv/dt=1.0v/ns$

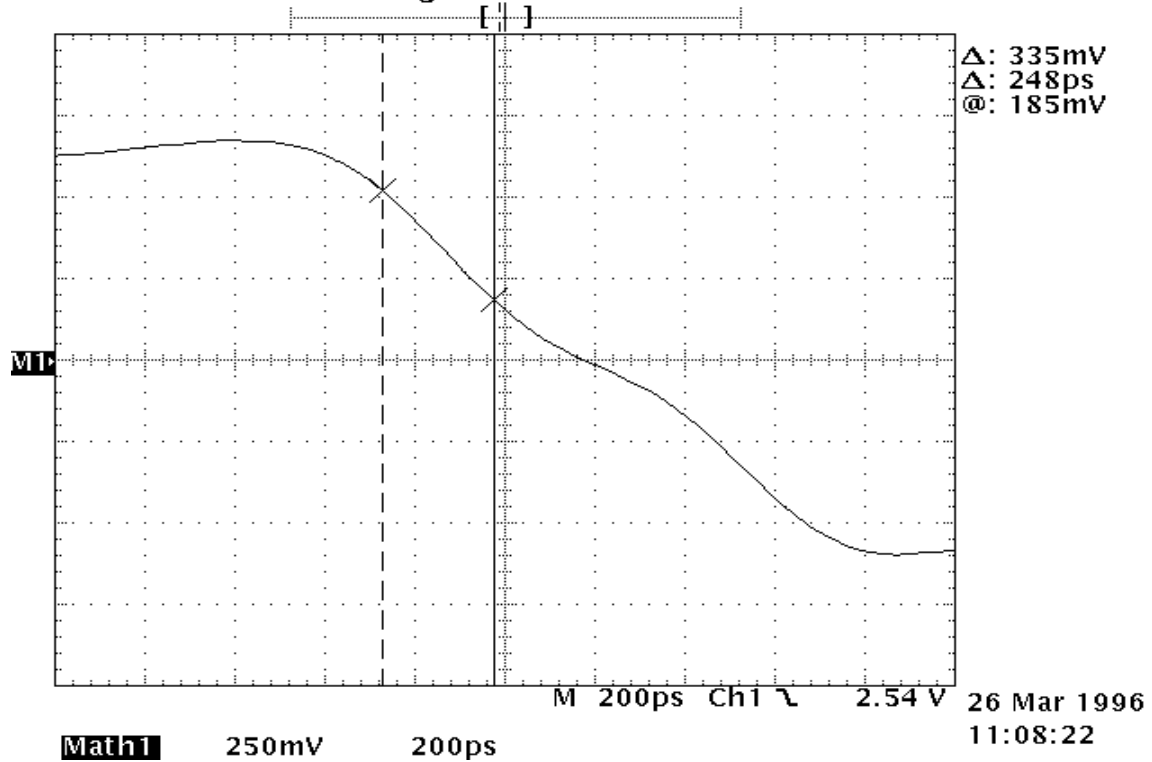


Double terminated , termination AC coupled $dv/dt=2.6v/ns$

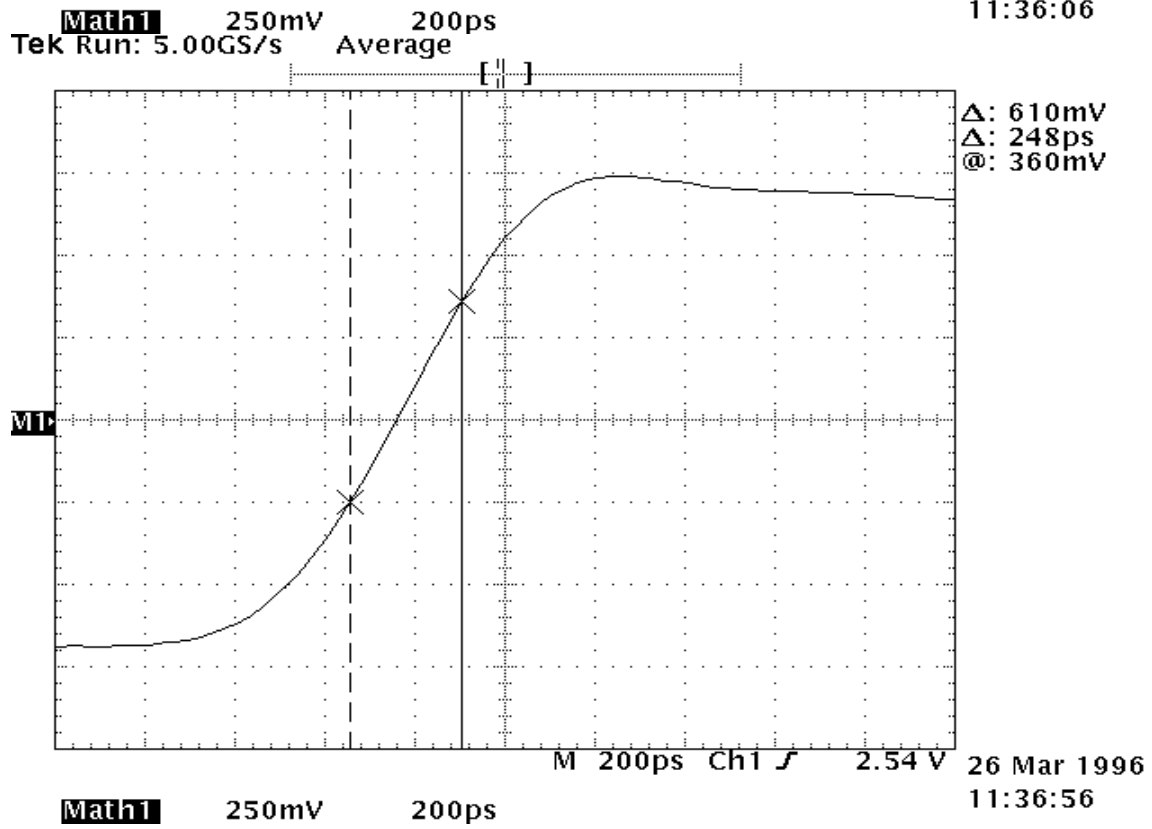
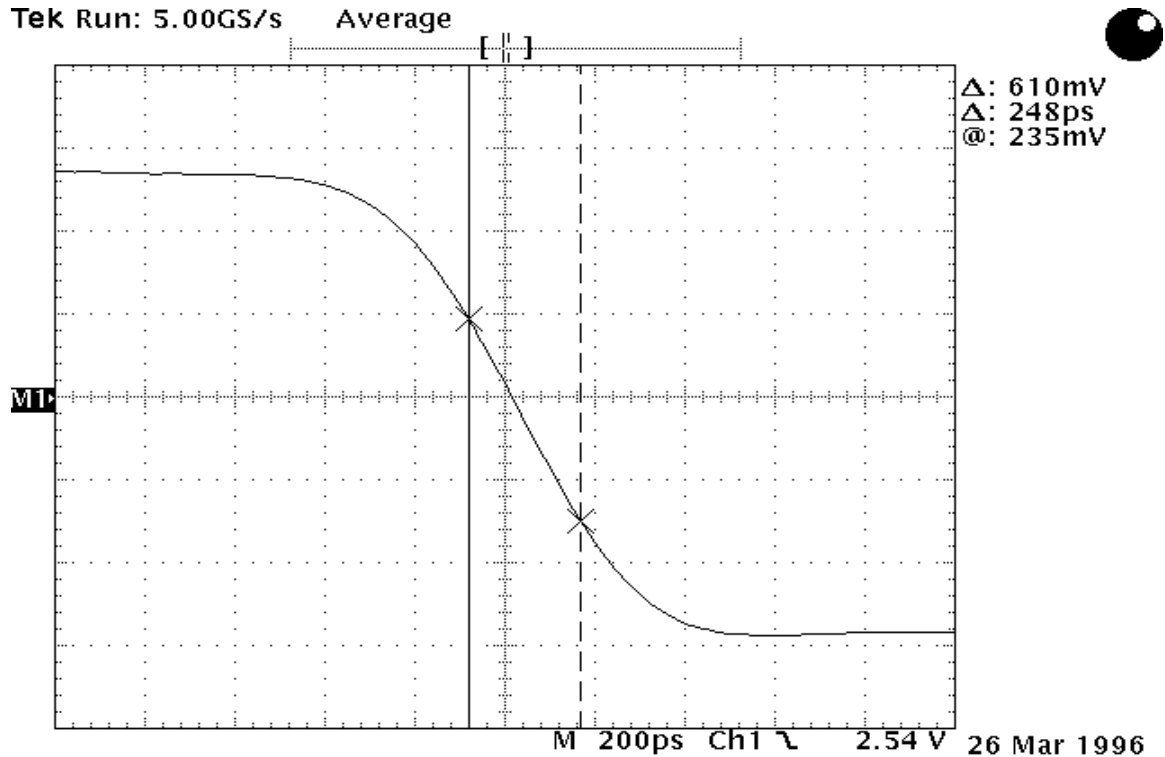
Tek Run: 5.00GS/s Average



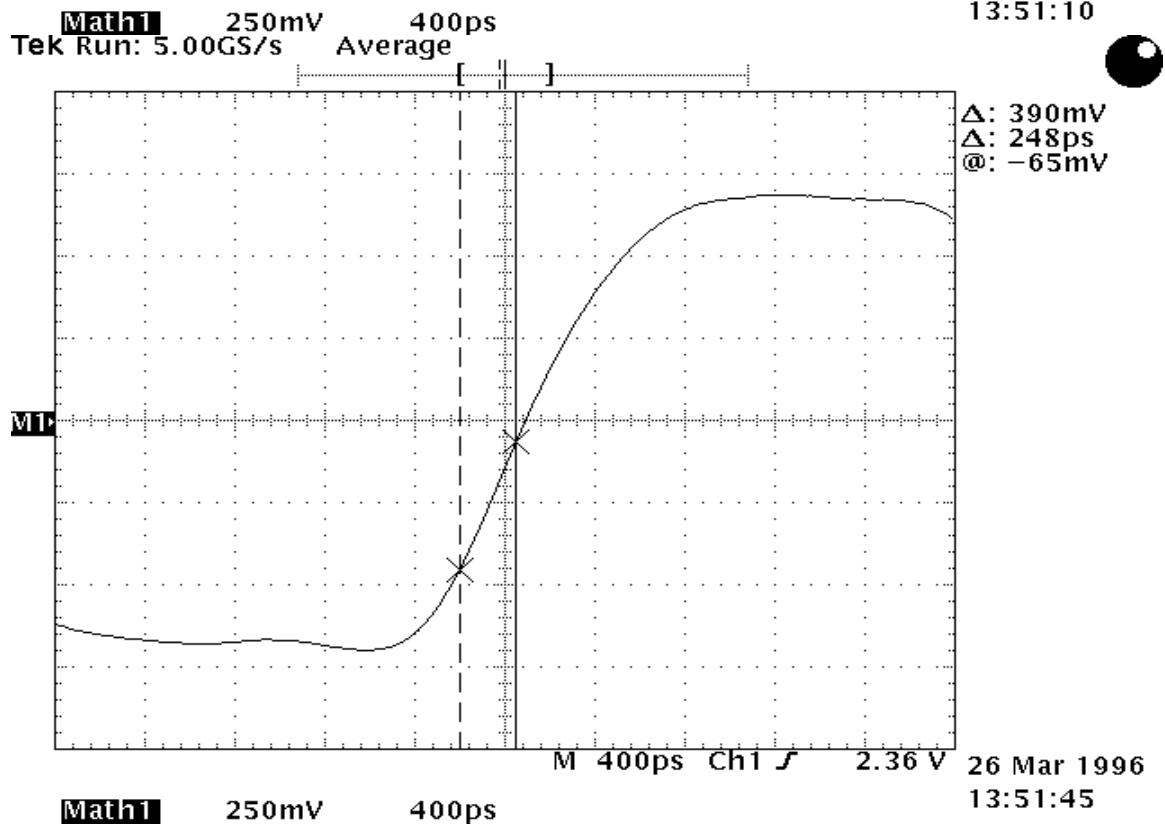
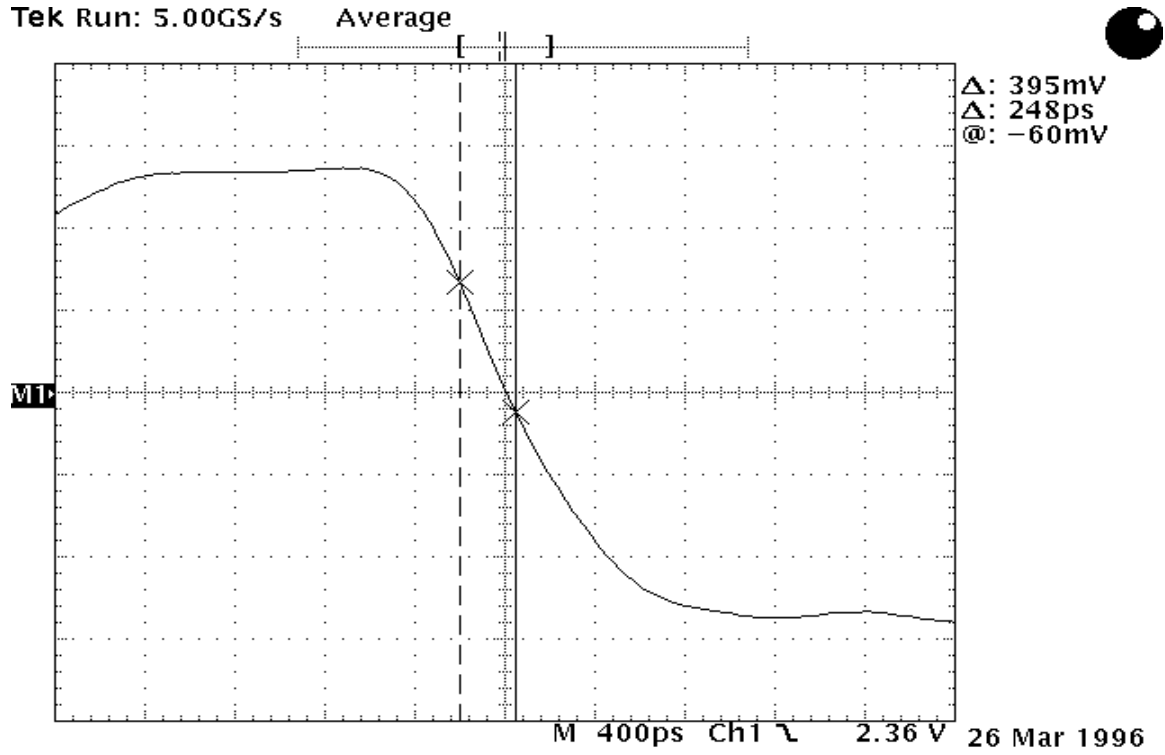
Math1 250mV 200ps
Tek Run: 5.00GS/s Average



Double terminated, termination AC coupled $dv/dt=1.33v/ns$

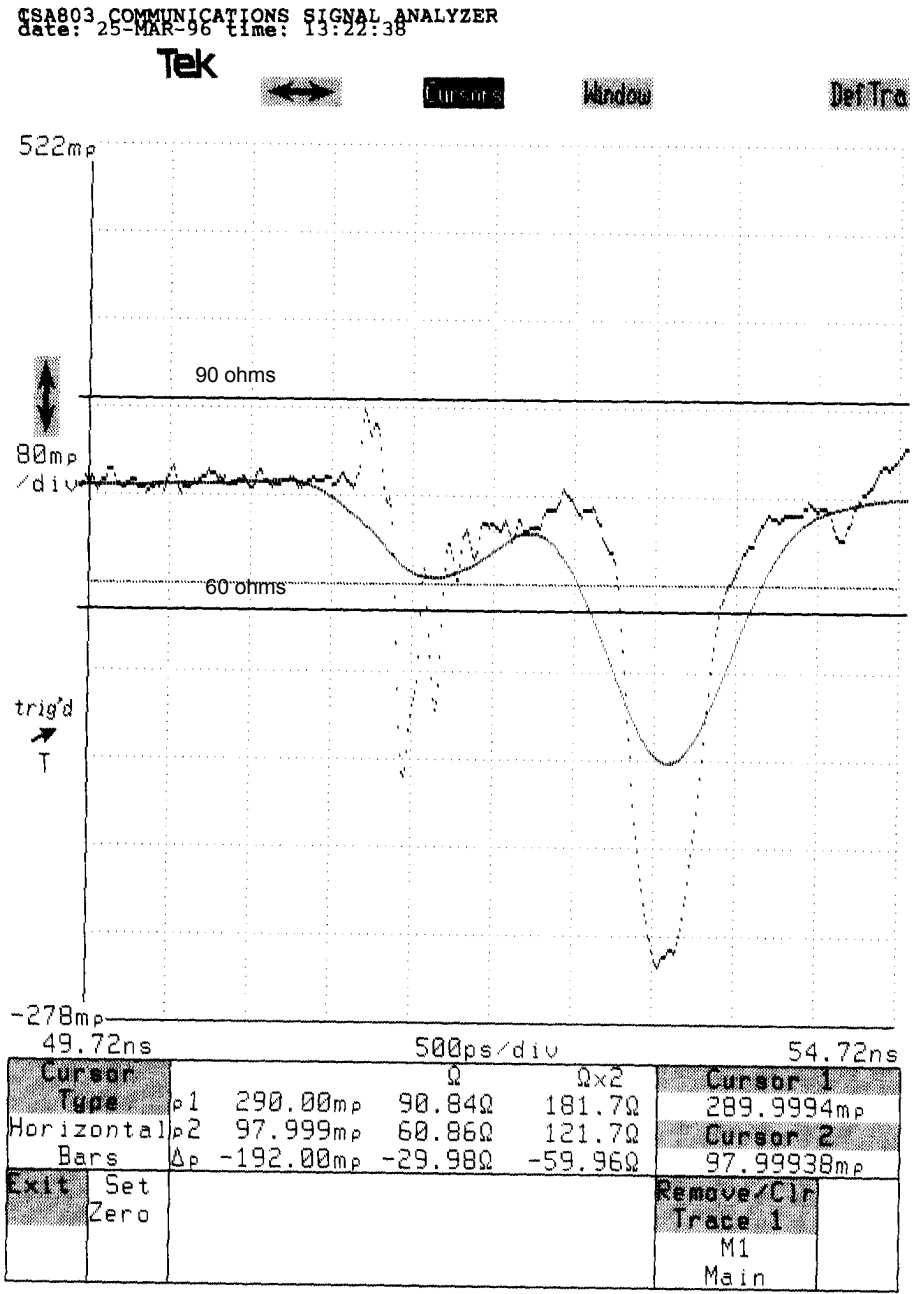


Double terminated, source terminated differentially $dv/dt=2.4v/ns$

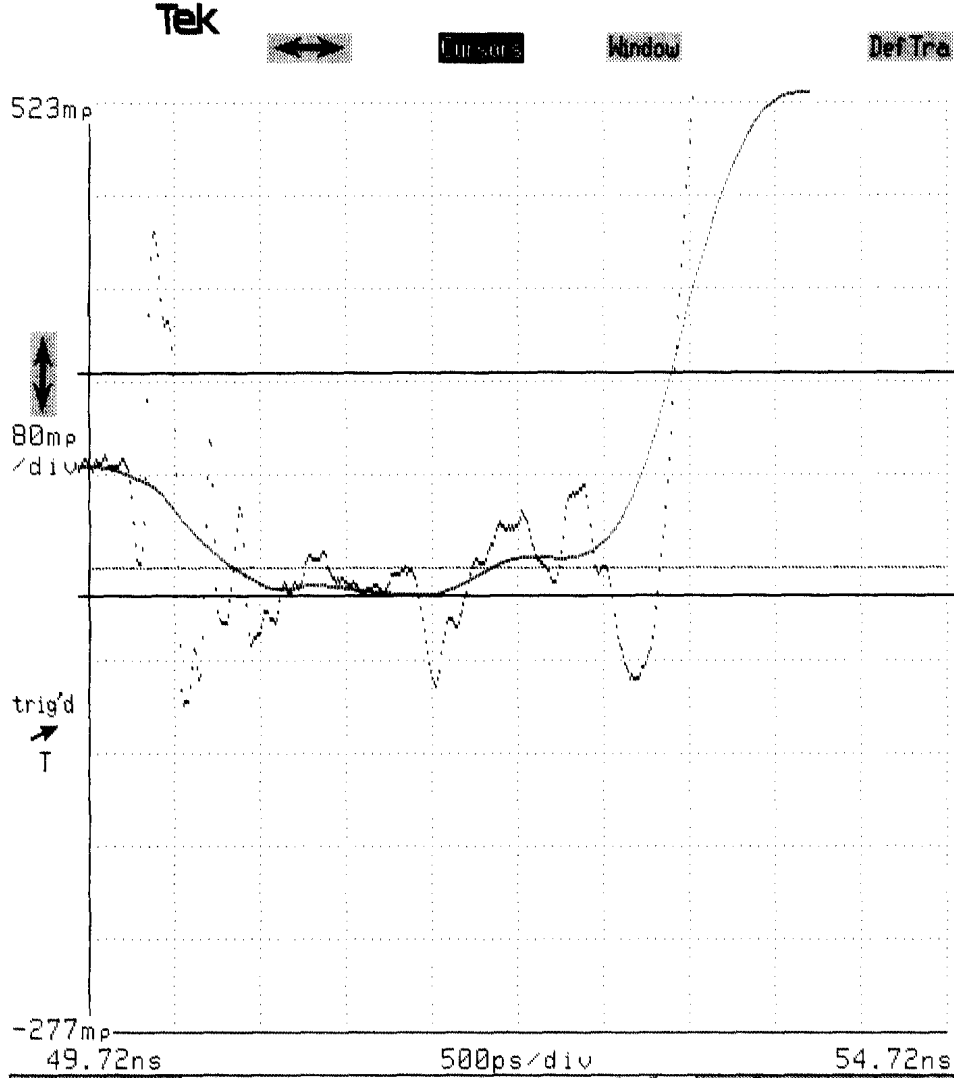


Double termination, source terminated differentially $dv/dt=1.6v/ns$

LINE SEGMENT IMPEDANCE



CSA803 COMMUNICATIONS SIGNAL ANALYZER
 date: 25-MAR-96 time: 13:14:59



Cursor		Ω			Ωx2	
Type	p1	291.00mp	91.04Ω	182.1Ω	Cursor 1	290.9998mp
Horizontal	p2	99.000mp	60.99Ω	122.0Ω	Cursor 2	
Bars	Δp	-192.00mp	-30.06Ω	-60.11Ω	Cursor 2	98.99986mp
Exit	Set				Remove/Clr	
	Zero				Trace 1	
					M1	
					Main	

terminated driver no capacitance

Single

CSA803 COMMUNICATIONS SIGNAL ANALYZER
 date: 25-MAR-96 time: 13:10:35

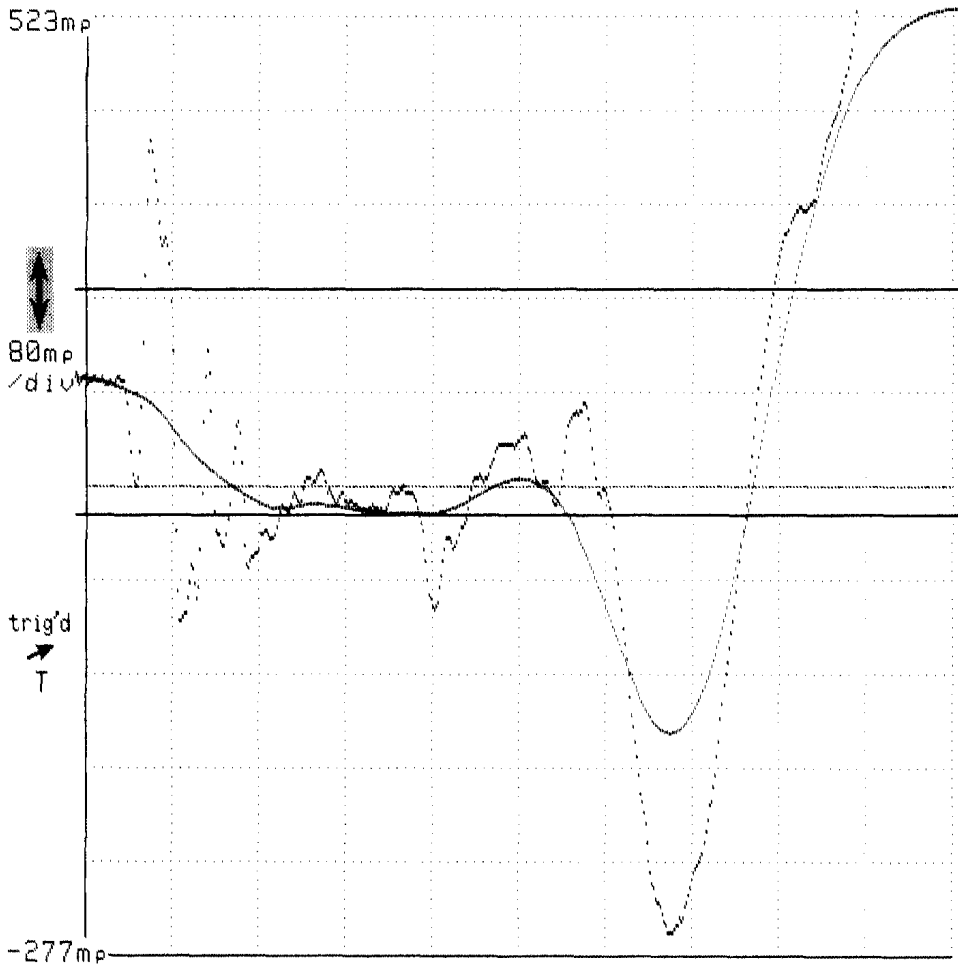
Tek



Cursors

Window

DefTra

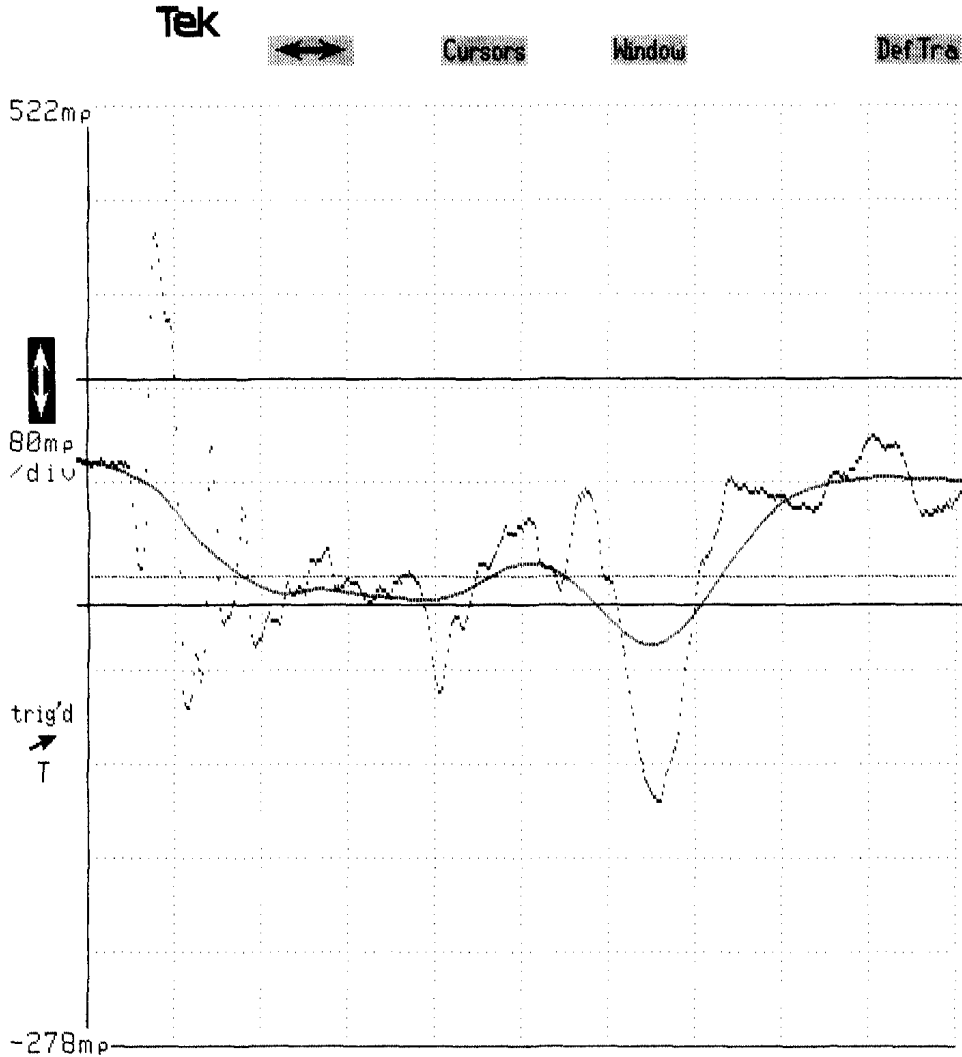


Cursor		Ω			Cursor 1	
Type	p1	291.00mp	91.04 Ω	182.1 Ω	290.9998mp	
Horizontal	p2	99.000mp	60.99 Ω	122.0 Ω	Cursor 2	
Bars	Δp	-192.00mp	-30.06 Ω	-60.11 Ω	98.99986mp	
Exit	Set				Remove/Clr	
	Zero				Trace 1	
						M1
						Main

terminated driver plus 10pf to Vdd

Single

CSA803 COMMUNICATIONS SIGNAL ANALYZER
 date: 25-MAR-96 time: 14:58:37



49.72ns		500ps/div		54.72ns	
Cursor		Ω	$\Omega \times 2$	Vert Size: M1	
Type	p1	290.00mp	90.84 Ω	181.7 Ω	80mp/div
Horizontal	p2	97.998mp	60.86 Ω	121.7 Ω	Vert Offset: M1
Bars	Δp	-192.00mp	-29.98 Ω	-59.96 Ω	122mp
Exit	Set			Remove/ClrChan	
	Zero			Trace 1	Sel
				M1	M1
				Main	

with source termination and no capacitance

Driver

CSA803 COMMUNICATIONS SIGNAL ANALYZER
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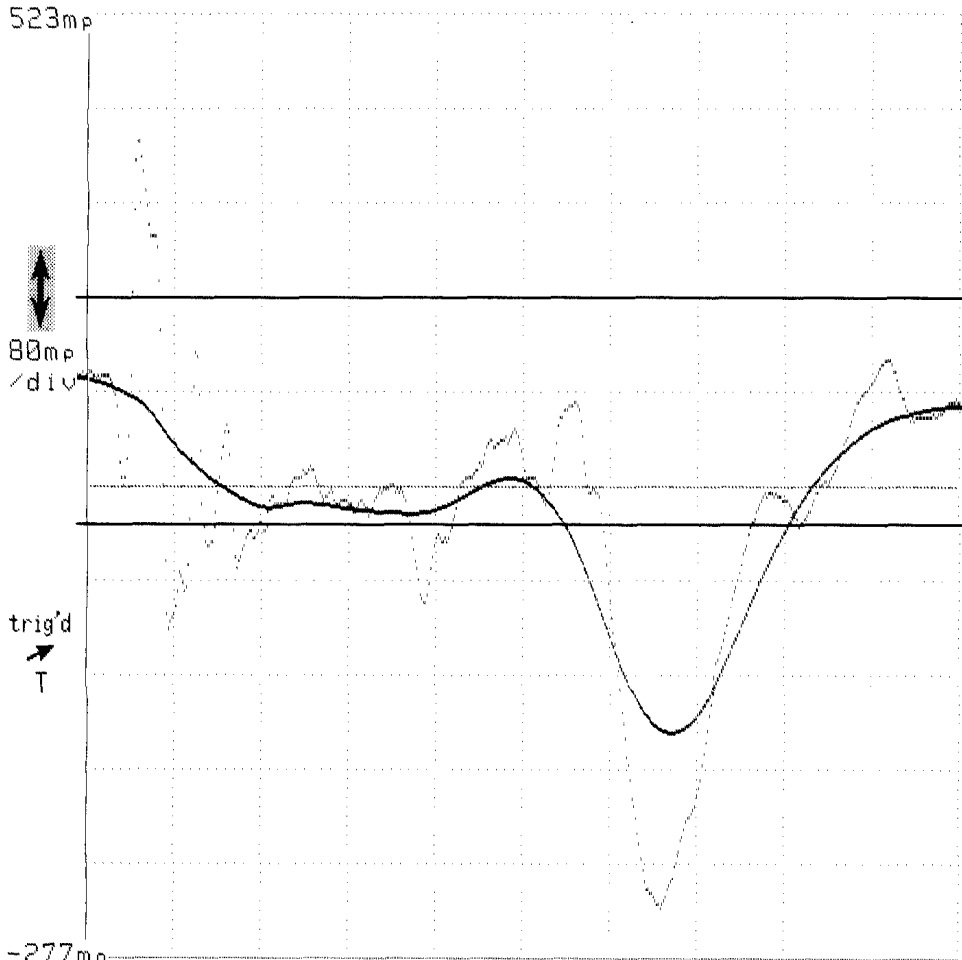
Tek



Cursors

Window

Def Tra



49.82ns 500ps/div 54.82ns

Cursor	Type	p1	283.00mp	Q	89.47Ω	Qx2	178.9Ω	Cursor 1	282.9996mp
Horizontal	Bars	p2	91.000mp	Δp	-192.00mp			Cursor 2	90.99963mp
					-29.46Ω		-58.92Ω		
Exit	Set							Remove/Clr	
	Zero							Trace 2	
								Filter (M1...	
								Main	

with source termination and 5pf capacitance

Driver

CSA803 COMMUNICATIONS SIGNAL ANALYZER
 date: 25-MAR-96 time: 18:22:14

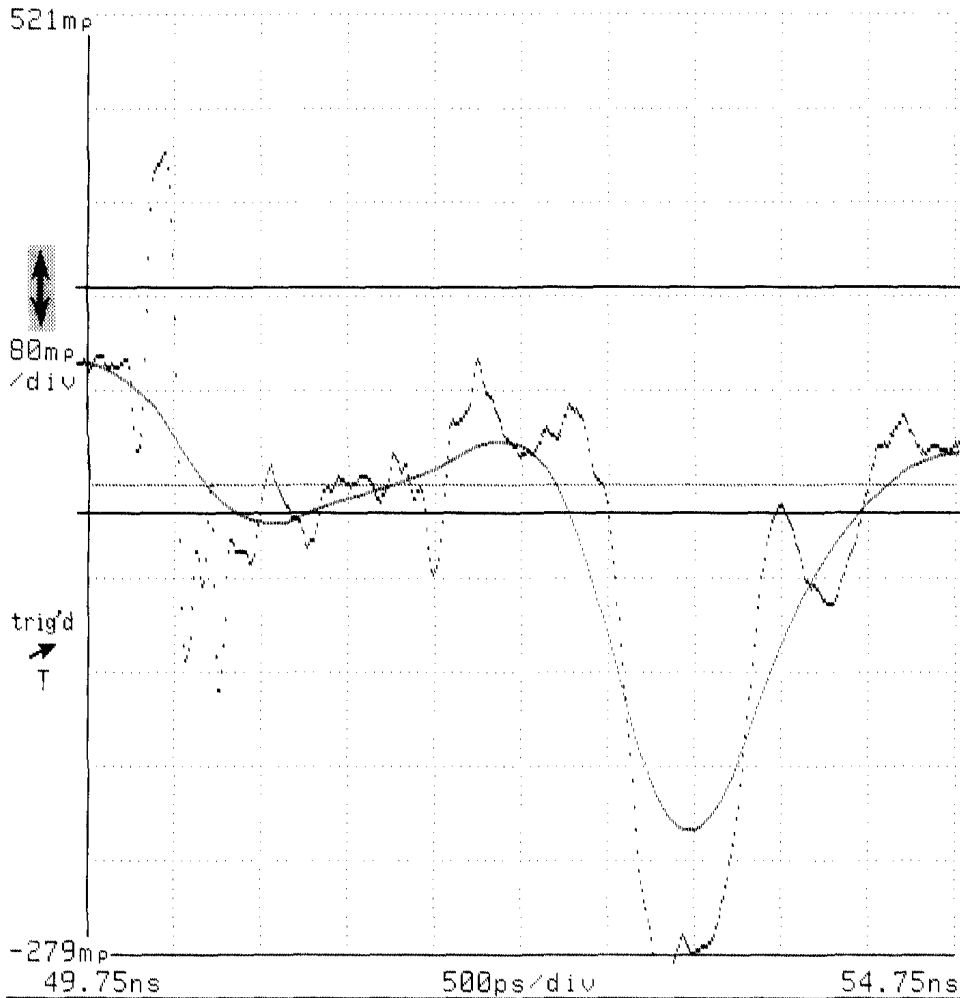
Tek



Cursors

Window

Def Tra

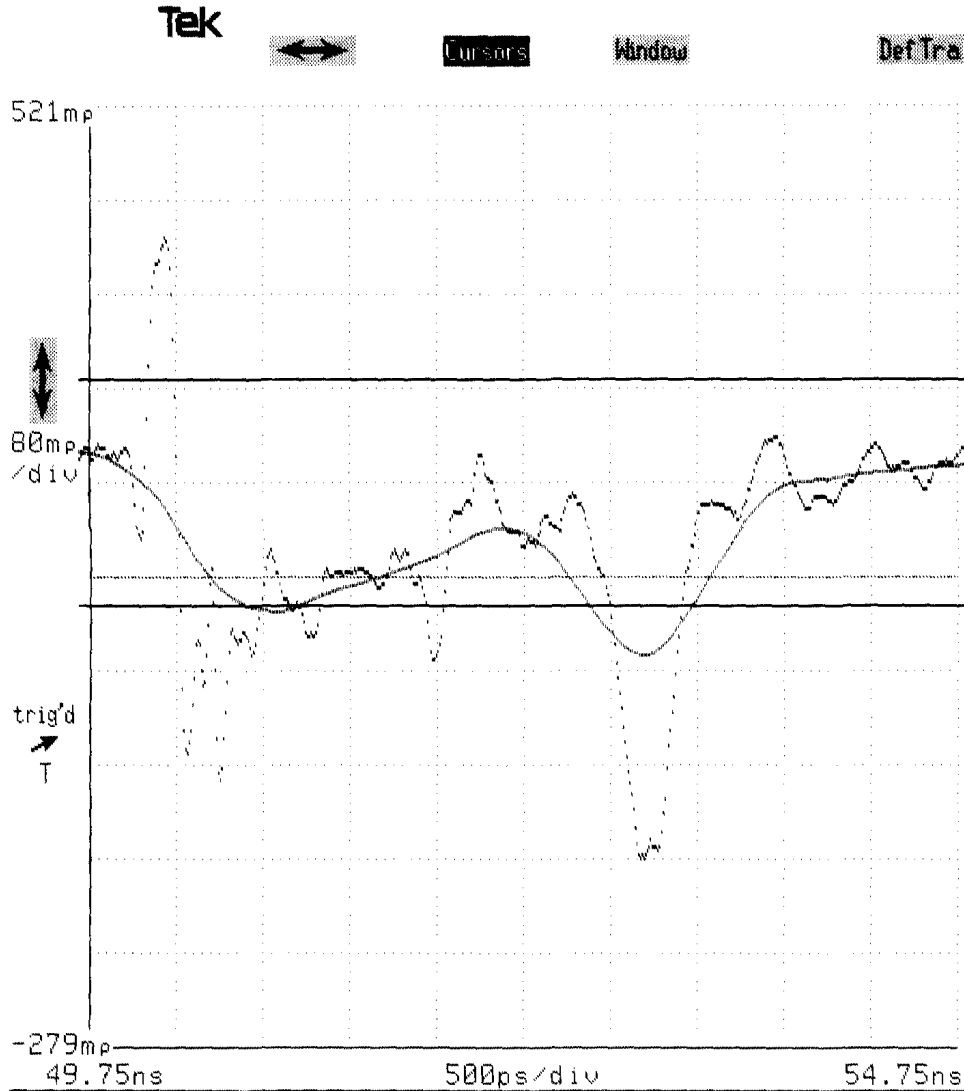


Cursor	Type	p1	289.00mp	90.65Ω	181.30	Cursor 1	288.9996mp
Horizontal	Bars	p2	97.000mp	60.74Ω	121.50	Cursor 2	96.99963mp
		Δp	-192.00mp	-29.90Ω	-59.81Ω		
Exit	Set					Remove/Clr	
	Zero					Trace 1	
						M1	
						Main	

with source termination and 10pf capacitance

Driver

CSA803 COMMUNICATIONS SIGNAL ANALYZER
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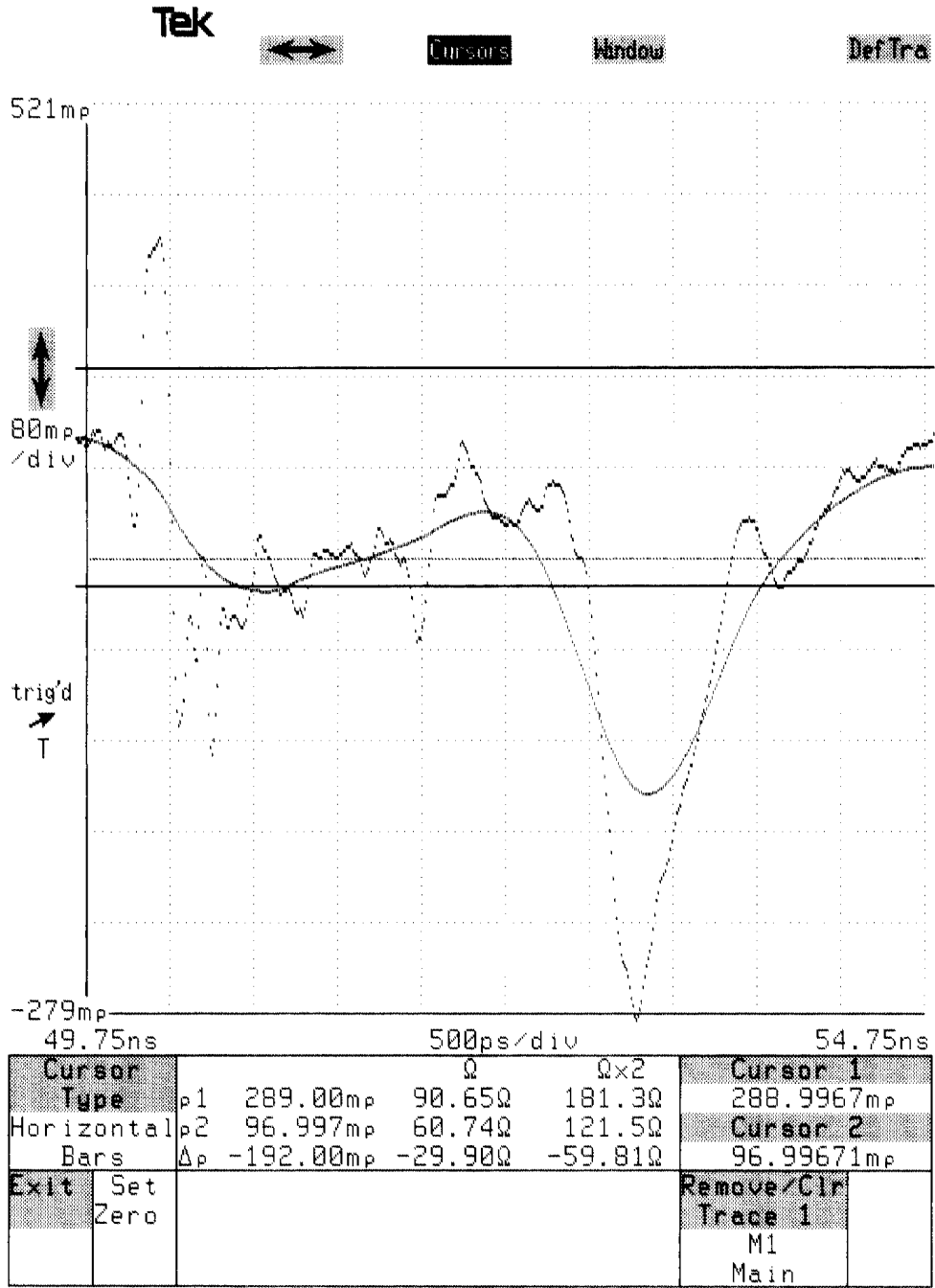


		500ps/div			54.75ns	
Cursor			Ω	$\Omega \times 2$	Cursor 1	
Type	p1	289.00mp	90.65 Ω	181.30	288.9960mp	
Horizontal	p2	96.996mp	60.74 Ω	121.5 Ω	Cursor 2	
Bars	Δp	-192.00mp	-29.90 Ω	-59.81 Ω	96.99599mp	
Exit	Set				Remove/Clr	
	Zero				Trace 1	
					M1	
					Main	

with differential source termination (150 ohms)

Driver

CSA803 COMMUNICATIONS SIGNAL ANALYZER
 date: 26-MAR-96 time: 15:38:51



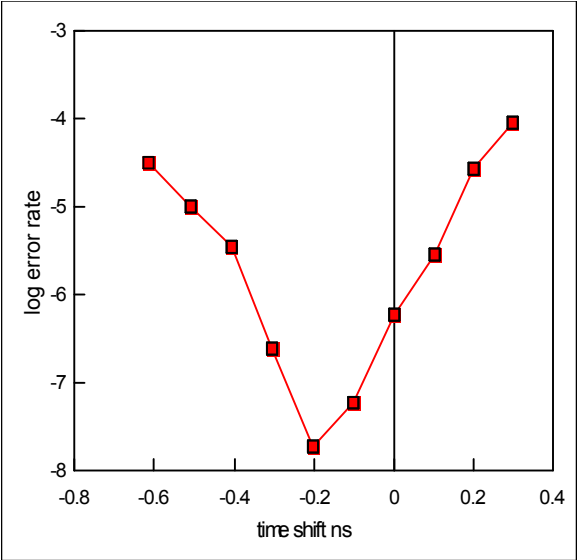
with differential source termination plus 3p

Driver

Single termination

20 metres 26gauge 2v/ns

Minutes	Errors	Mhz Freq	ns shift	log err/bit
		24.3	-0.72	
0.25	196473	24.4	-0.615	-4.485
0.25	59106	24.5	-0.51	-5.007
0.167	14399	24.6	-0.407	-5.444
0.5	2956	24.7	-0.304	-6.608
1	450	24.8	-0.202	-7.727
0.667	967	24.9	-0.1	-7.219
0.667	9673	25	0	-6.219
0.333	22969	25.1	0.0996	-5.542
0.333	224192	25.2	0.1984	-4.552
0.167	368431	25.3	0.2964	-4.036



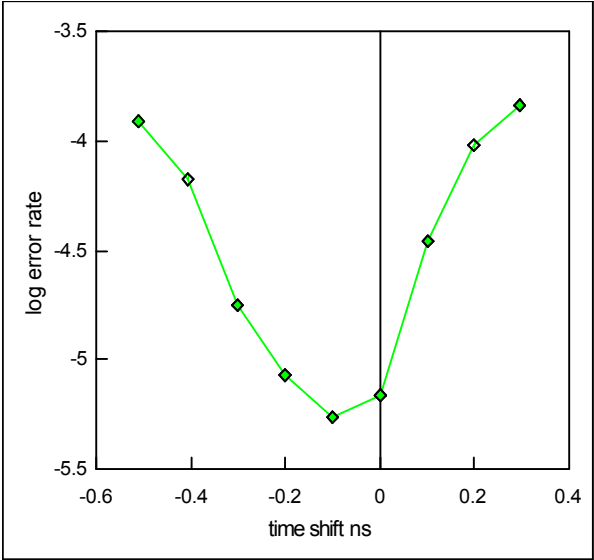
Single termination

+ capacitance or

Capacitive source termination

20 metres 26gauge
1.35v/ns 4pf source termination

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017	49365	24.5	-0.51	-3.909
0.017	26538	24.6	-0.407	-4.178
0.017	7124	24.7	-0.304	-4.749
0.017	3388	24.8	-0.202	-5.072
0.017	2203	24.9	-0.1	-5.259
0.017	2722	25	0	-5.167
0.017	13811	25.1	0.0996	-4.462
0.017	38459	25.2	0.1984	-4.017
0.017	57859	25.3	0.2964	-3.84



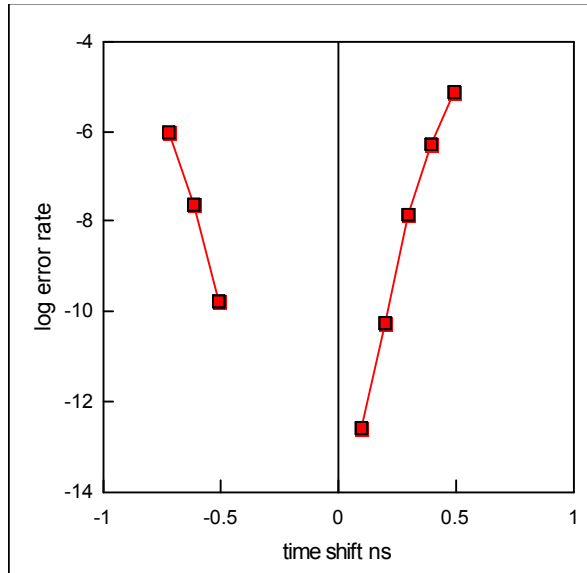
1v/ns 10pf source termination
Failed to run

Double termination

DC Coupled

20 metres 26gauge 2.5v/ns

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.333	7320	24.3	-0.72	-6.0386
0.667	373	24.4	-0.615	-7.6324
6.26	25	24.5	-0.51	-9.7788
		24.6	-0.407	
		24.7	-0.304	
		24.8	-0.202	
		24.9	-0.1	
		25	0	
915	6	25.1	0.0996	-12.563
7	9	25.2	0.1984	-10.271
0.017	5.79	25.3	0.2964	-7.8394
0.017	210	25.4	0.3937	-6.2798
0.017	3024	25.5	0.4902	-5.1215

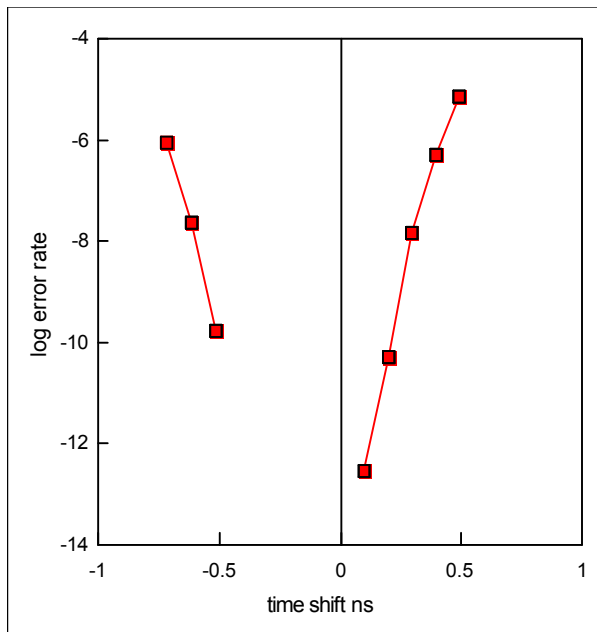


Double termination

DC Coupled

20 metres 26gauge 1.6v/ns

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.333	7320	24.3	-0.72	-6.0386
0.667	373	24.4	-0.615	-7.6324
6.26	25	24.5	-0.51	-9.7788
		24.6	-0.407	
		24.7	-0.304	
		24.8	-0.202	
		24.9	-0.1	
		25	0	
915	6	25.1	0.0996	-12.563
7	9	25.2	0.1984	-10.271
0.017	5.79	25.3	0.2964	-7.8394
0.017	210	25.4	0.3937	-6.2798
0.017	3024	25.5	0.4902	-5.1215

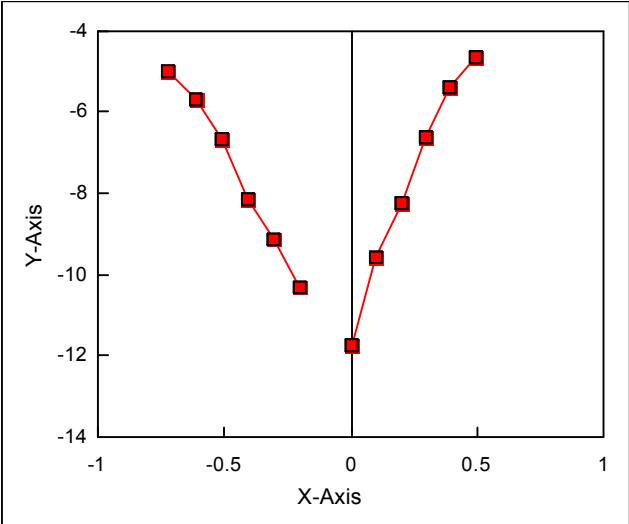


Double termination

DC Coupled

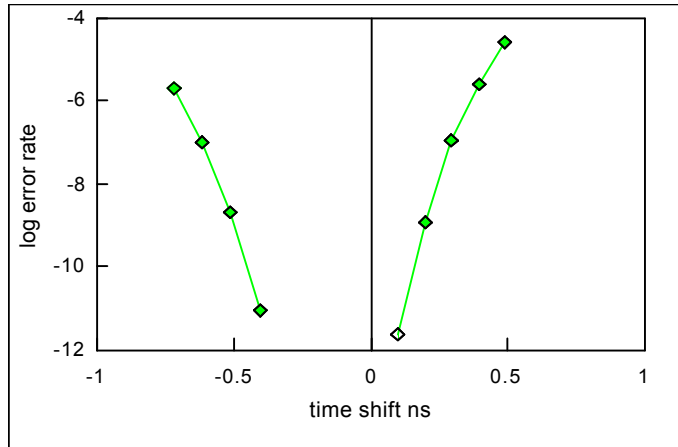
20 metres 26gauge 1.0v/ns

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017	4253	24.3	-0.72	-4.9734
0.017	813	24.4	-0.615	-5.692
0.017	88	24.5	-0.51	-6.6576
1	170	24.6	-0.407	-8.1498
2	34	24.7	-0.304	-9.1498
7	8	24.8	-0.202	-10.322
		24.9	-0.1	
70	3	25	0	-11.748
2	13	25.1	0.0996	-9.5673
0.017	2.42	25.2	0.1984	-8.2182
0.017	97.2	25.3	0.2964	-6.6144
0.017	1625	25.4	0.3937	-5.3912
0.017	9063	25.5	0.4902	-4.6448



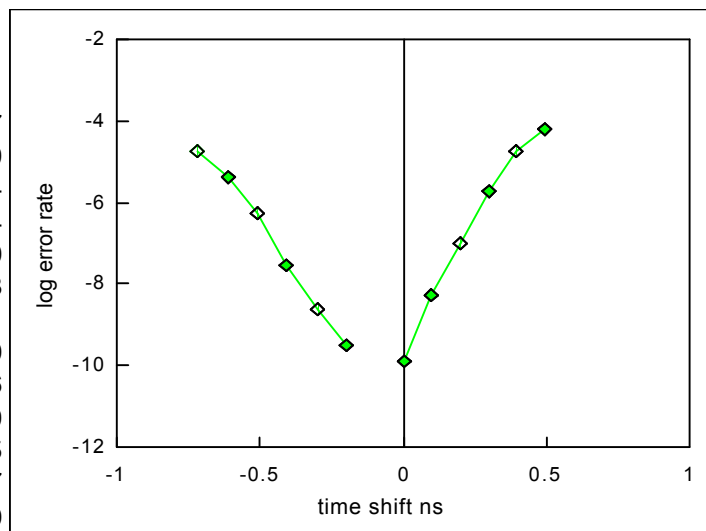
Double termination
 AC Coupled termination
 20 metres 26gauge 2.6v/ns

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.02	756.00	24.30	-0.72	-5.72
0.02	40.50	24.40	-0.61	-6.99
1.00	51.00	24.50	-0.51	-8.67
14.50	3.00	24.60	-0.41	-11.06
		24.70	-0.30	
		24.80	-0.20	
		24.90	-0.10	
		25.00	0.00	
50.00	3.00	25.10	0.10	-11.60
1.00	30.00	25.20	0.20	-8.90
0.02	47.00	25.30	0.30	-6.93
0.02	976.00	25.40	0.39	-5.61
0.02	9700.00	25.50	0.49	-4.62



Double termination
 AC Coupled termination
 20 metres 26gauge 1.33v/ns

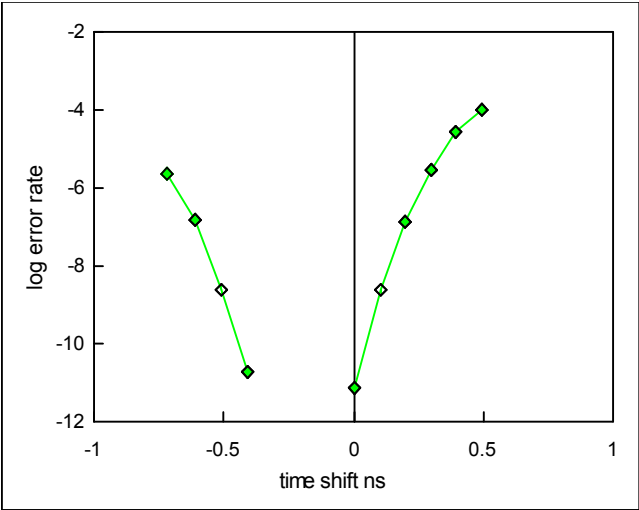
Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.02	6861.00	24.30	-0.72	-4.77
0.02	1614.00	24.40	-0.61	-5.39
0.02	229.00	24.50	-0.51	-6.24
0.02	14.00	24.60	-0.41	-7.54
0.75	45.00	24.70	-0.30	-8.60
2.00	16.00	24.80	-0.20	-9.48
		24.90	-0.10	
2.00	6.00	25.00	0.00	-9.90
0.02	2.18	25.10	0.10	-8.26
0.02	40.60	25.20	0.20	-6.99
0.02	715.00	25.30	0.30	-5.75
0.02	6776.00	25.40	0.39	-4.77
0.02	24966.00	25.50	0.49	-4.20



Double differential source

20 metres 26gauge 2.4v/ns

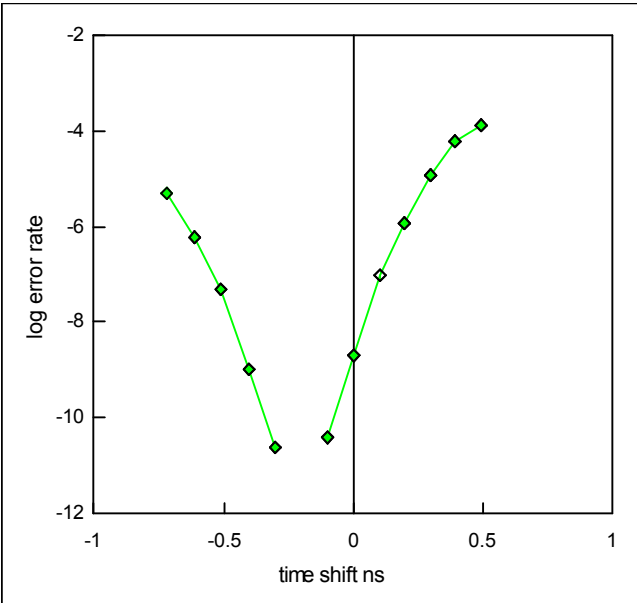
Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017	898	24.3	-0.72	-5.65
0.017	60	24.4	-0.61	-6.82
0.017	0.99	24.5	-0.51	-8.61
56.5	27	24.6	-0.41	-10.7
		24.7	-0.3	
		24.8	-0.2	
		24.9	-0.1	
16	3	25	0	-11.1
2	123	25.1	0.1	-8.59
0.017	52.8	25.2	0.198	-6.88
0.017	1188	25.3	0.296	-5.53
0.017	11069	25.4	0.394	-4.56
0.017	39539	25.5	0.49	-4.01



Double differential source

20 metres 26gauge 1.6v/ns

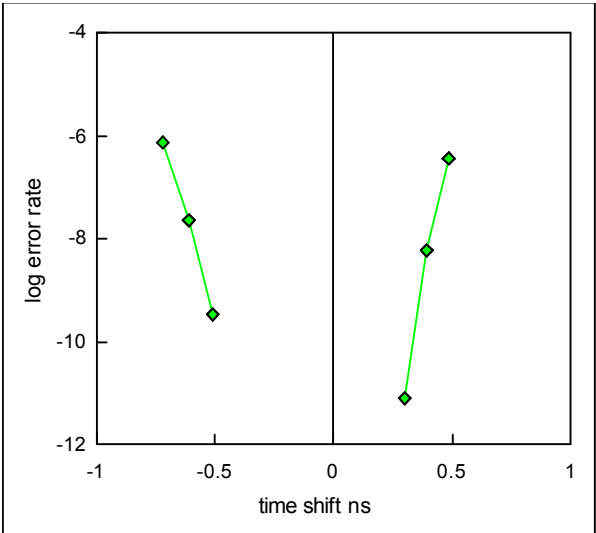
Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017	2016	24.3	-0.72	-5.3
0.017	249	24.4	-0.61	-6.21
0.017	20	24.5	-0.51	-7.3
2	52	24.6	-0.41	-8.97
9	5	24.7	-0.3	-10.6
		24.8	-0.2	
12	11	24.9	-0.1	-10.4
3.5	175	25	0	-8.68
0.017	37	25.1	0.1	-7.03
0.017	492	25.2	0.198	-5.91
0.017	4907	25.3	0.296	-4.91
0.017	25077	25.4	0.394	-4.2
0.017	50306	25.5	0.49	-3.9



Double termination data AC coupled

20 metres 26gauge 2.5v/ns
1nf capacitor

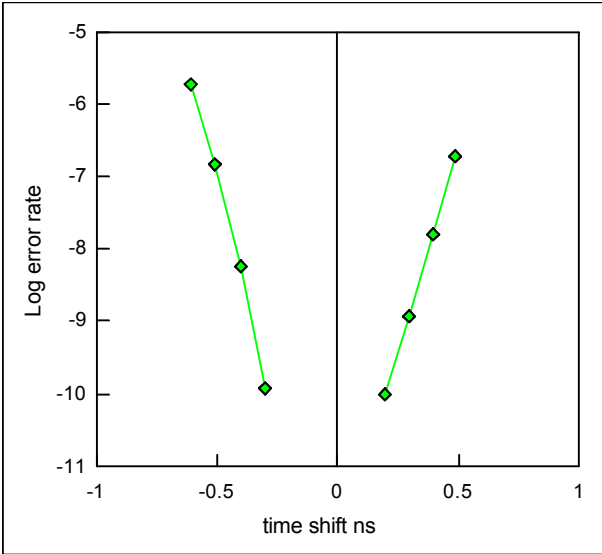
Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017	290	24.3	-0.72	-6.14
0.017	9	24.4	-0.615	-7.648
1	8	24.5	-0.51	-9.477
		24.6	-0.407	
		24.7	-0.304	
		24.8	-0.202	
		24.9	-0.1	
		25	0	
855		25.1	0.0996	
7		25.2	0.1984	
16	3	25.3	0.2964	-11.11
0.017	2.3	25.4	0.3937	-8.24
0.017	140	25.5	0.4902	-6.456



Double termination data AC coupled

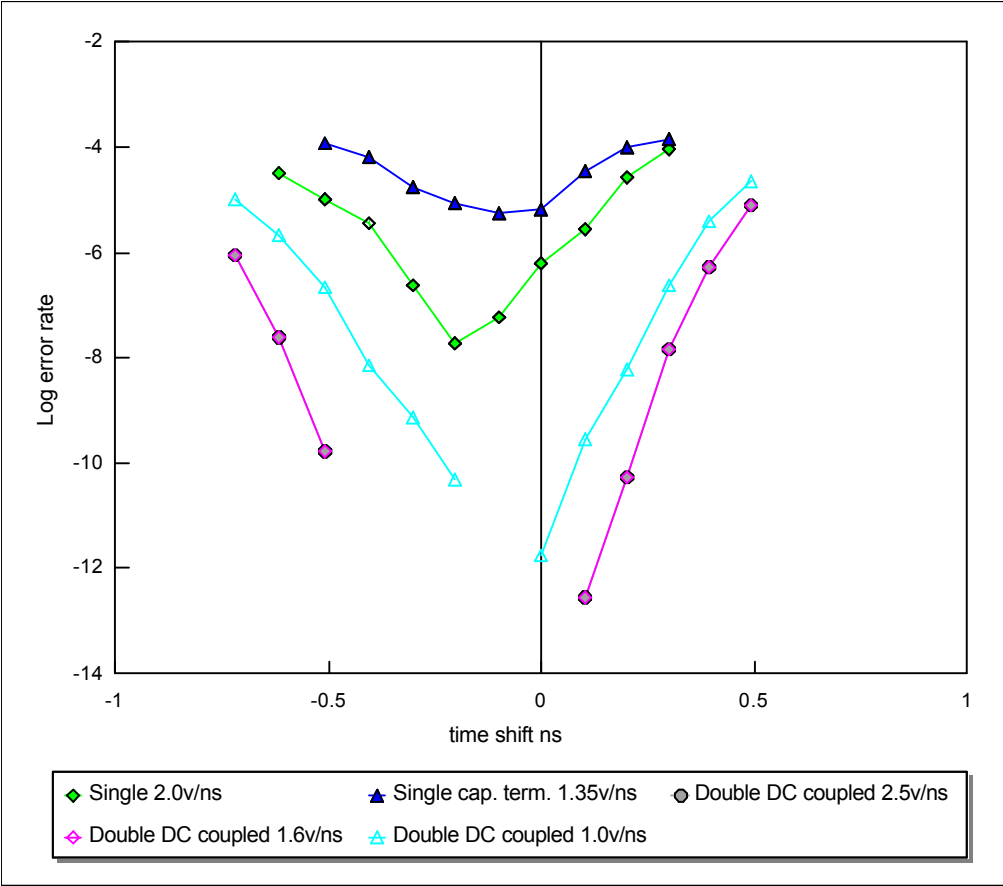
20 metres 26gauge 2.5v/ns
100pf capacitor

Minutes	Errors	Mhz Freq	ns shift	Log err/bit
0.017		24.3	-0.72	
0.017	772	24.4	-0.615	-5.714
0.017	59.6	24.5	-0.51	-6.827
1	135	24.6	-0.407	-8.25
5	14	24.7	-0.304	-9.933
		24.8	-0.202	
		24.9	-0.1	
		25	0	
855		25.1	0.0996	
3	7	25.2	0.1984	-10.01
1	29	25.3	0.2964	-8.918
0.017	6.5	25.4	0.3937	-7.789
0.017	76	25.5	0.4902	-6.721

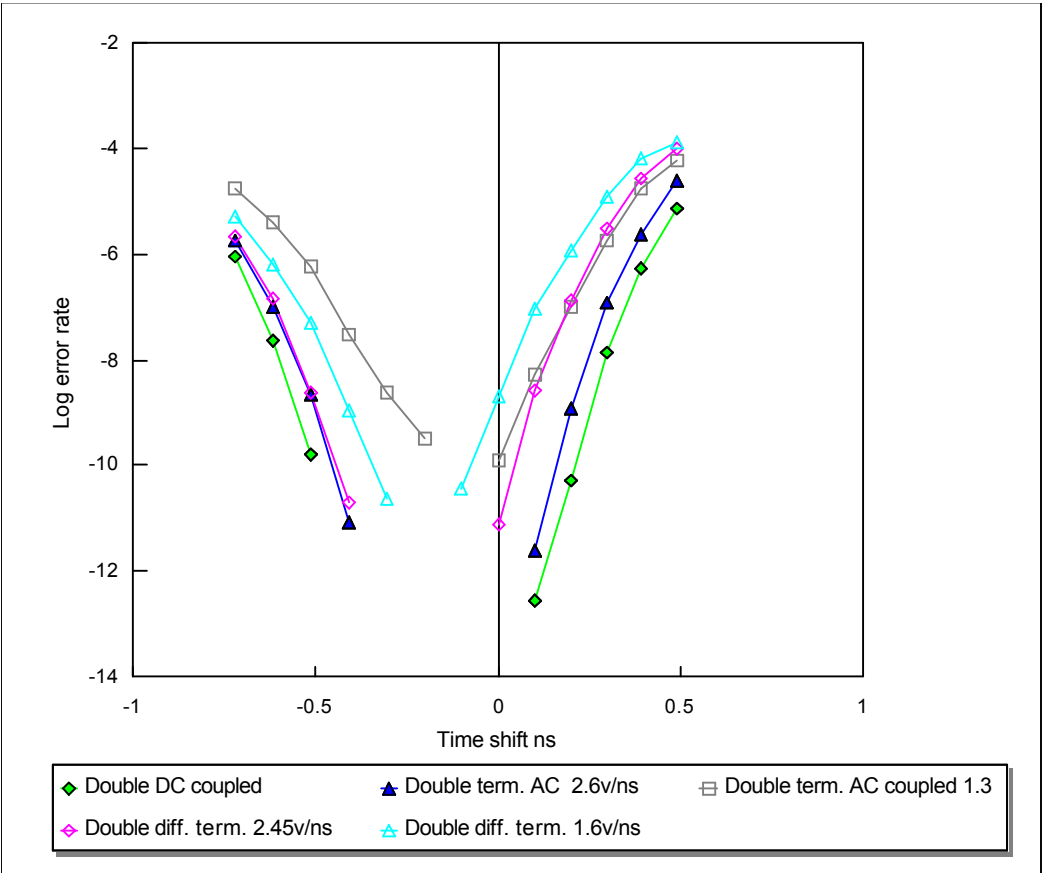


Comparison

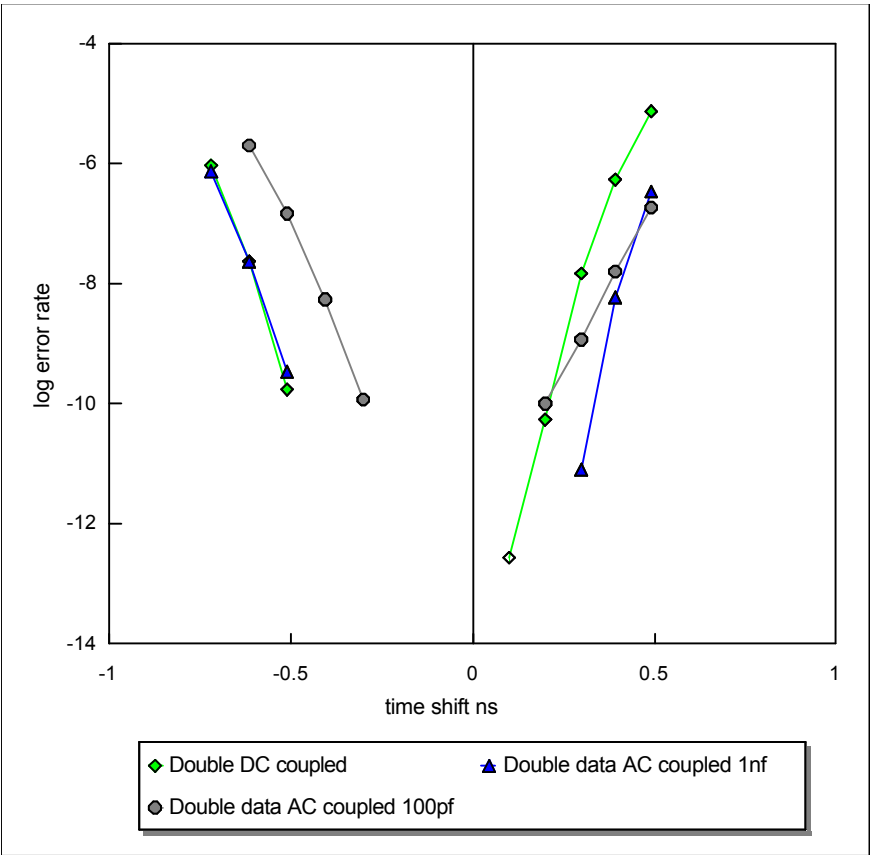
ns shift	Single		Double	Double	Double
	2.0v/ns single	Capacitive 1.35v/ns	DC coupled 2.5v/ns	DC coupled 1.6v/ns	DC coupled 1.0v/ns
-0.72			-6.0385789	-6.03858	-4.97336
-0.615	-4.48484837		-7.6324112	-7.63241	-5.69197
-0.51	-5.00651968	-3.908641	-9.7788456	-9.77885	-6.65758
-0.407	-5.44372766	-4.178192			-8.14976
-0.304	-6.60847682	-4.749336			-9.14976
-0.202	-7.72699873	-5.072117			-10.3222
-0.1	-7.21869351	-5.259045			
0	-6.21855879	-5.167172			-11.7482
0.0996	-5.5419479	-4.461835	-12.563481	-12.5635	-9.5673
0.1984	-4.55246988	-4.017062	-10.271067	-10.2711	-8.21824
0.2964	-4.03570383	-3.839689	-7.8393814	-7.83938	-6.61439
0.3937			-6.2798407	-6.27984	-5.39121
0.4902			-5.1214782	-5.12148	-4.64479



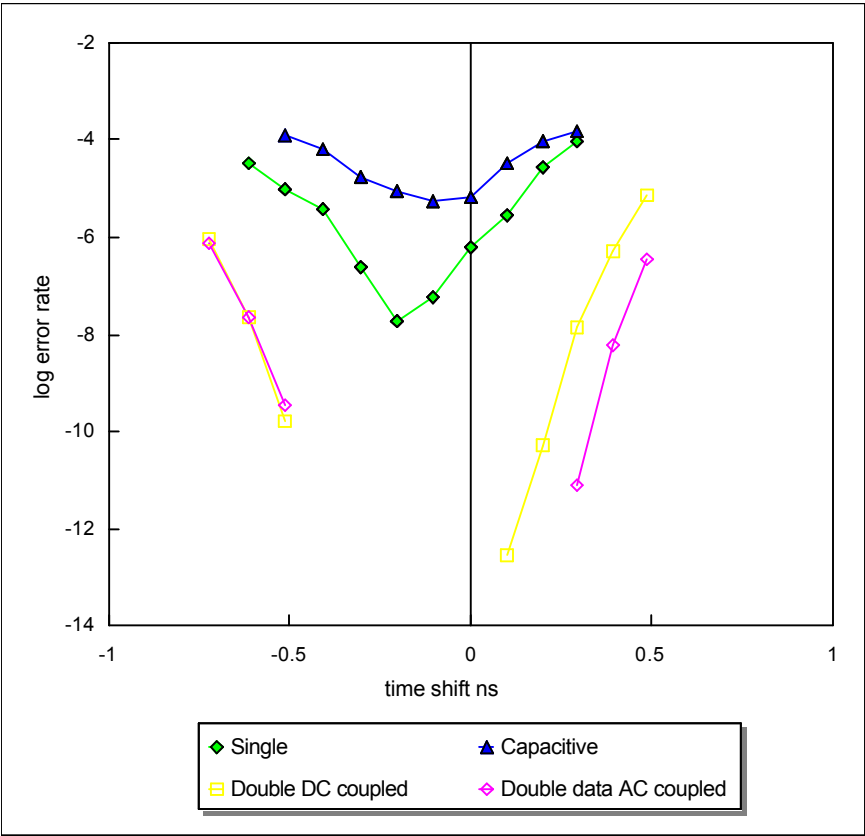
ns shift	DC coupled 2.5v/ns	AC coupled double 2.6v/ns	AC coupled 1.33v/ns	AC coupled Diff 2.45v/ns	Diff 1.6v/ns
-0.72	-6.0385789	-5.72354	-4.76567	-5.64878	-5.29757
-0.615	-7.6324112	-6.9946	-5.39416	-6.82391	-6.20586
-0.51	-9.7788456	-8.67264	-6.24222	-8.60642	-7.30103
-0.407		-11.0645	-7.53511	-10.7009	-8.96524
-0.304			-8.60206		-10.6355
-0.202			-9.47712		
-0.1					-10.418
0			-9.90309	-11.1072	-8.68124
0.0996	-12.563481	-11.6021	-8.2636	-8.59134	-7.03386
0.1984	-10.271067	-8.90309	-6.99353	-6.87943	-5.91009
0.2964	-7.8393814	-6.92996	-5.74775	-5.52724	-4.91124
0.3937	-6.2798407	-5.61261	-4.77109	-4.55795	-4.20278
0.4902	-5.1214782	-4.61529	-4.20471	-4.00503	-3.90044



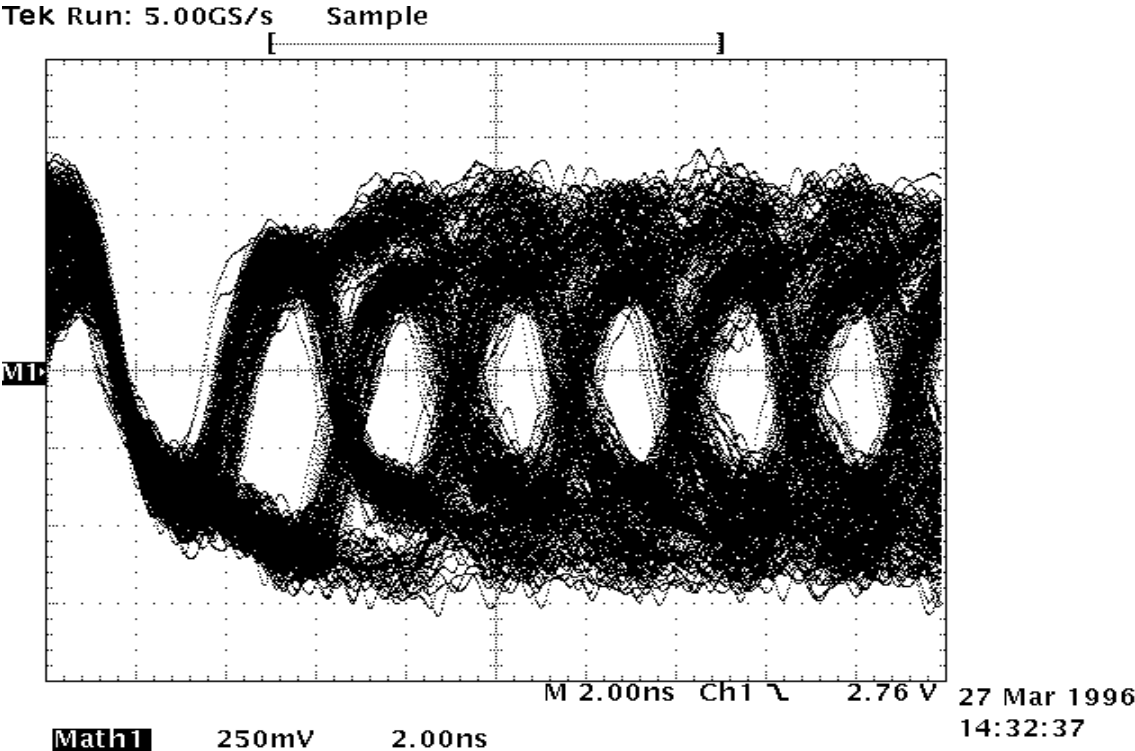
ns shift	DC coupled 2.5v/ns double	AC data 1nf 2.5v/ns	AC data 100pf
-0.72	-6.03857891	-6.139662	
-0.615	-7.63241115	-7.647817	-5.7144427
-0.51	-9.77884557	-9.477121	-6.8268137
-0.407			-8.2498775
-0.304			-9.9330532
-0.202			
-0.1			
0			
0.0996	-12.5634811		
0.1984	-10.2710668		-10.012234
0.2964	-7.83938143	-11.10721	-8.9178132
0.3937	-6.2798407	-8.240332	-7.7891466
0.4902	-5.1214782	-6.455932	-6.7212464



ns shift	Double			
	Single	Capacitive	DC coupled	AC data 1nf
-0.72			-6.03858	-6.13966
-0.615	-4.4848484		-7.63241	-7.64782
-0.51	-5.0065197	-3.90864	-9.77885	-9.47712
-0.407	-5.4437277	-4.17819		
-0.304	-6.6084768	-4.74934		
-0.202	-7.7269987	-5.07212		
-0.1	-7.2186935	-5.25905		
0	-6.2185588	-5.16717		
0.0996	-5.5419479	-4.46183	-12.5635	
0.1984	-4.5524699	-4.01706	-10.2711	
0.2964	-4.0357038	-3.83969	-7.83938	-11.1072
0.3937			-6.27984	-8.24033
0.4902			-5.12148	-6.45593



Eye diagram for 20 metre 26 gauge Single terminated



Eye diagram for 20 metre 26 gauge double terminated

