ANSI X3T9.2 SCSI COMMITTEE PLENARY MEETING
AUSTIN, TEXAS 2/20-21/89

SCSI-2 CABLE TESTING SUMMARY REPORT

Preliminary results as of 2/18/89

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ABSTRACT

At last October's Plenary, Sun, DEC, and HP were charged with the task of testing the various SCSI-2 cable and connector proposals put forward by AMP, Stewart Stamping, and 3M. This report details the tests that Sun has performed for the committee.

The intent of the tests were to determine, as completely as possible, whether the samples of cable interconnect from the various manufacturers would function satisfactorily in a SCSI system environment, and to determine any prerequisites to meet or exceed current SCSI-1 cable system performance. If possible, testing up to 10 MHz was to be performed.

To accomplish these goals, Sun has utilized three separate test platforms: 1) a function generator, 2) Adaptec SDS-3 Sync SCSI Test system, and 3) Sun's own systems, some with synchronous capability. The approach was to first utilize the function generator to inject controlled input signals into the cables and monitor the resulting characteristics of the signal at max distance on the bus. Second, the Adaptec test system was used to verify that sync transfers could be performed on the SCSI bus with consistency. Finally, tests were performed on Sun systems themselves to verify operations in an actual multi-user, multi-tasking environment with various peripheral devices.

During the testing with the Adaptec, it was decided that varying the applied voltage to TERMPWR could provide some form of margin characterization across the different sets of cables tested. The voltage supplied at the initiator node (one end of the bus) was dropped from 5.25 volts until failure. Initially, only one end's termination voltage was margined. Later tests margined the power on both bus terminators.

The results were tabulated, data were compared for the various configurations tested, and the final conclusions and recommendations were drafted. See Section IV.

TEST OUTLINE

The following is a list of test equipment used during this period.

1) Tektronix C-30B scope camera
2) Tektronix 2430A digital storage Oscilloscope
3) Tektronix 2445 150 MHz Oscilloscope
4) Wavetek 166 function generator
5) Hewlett Packard 6023A power supply
6) Peripherals - CDC Wren IV disk drive
   Quantum P105S disk drive
   CDC Wren III disk drive
   Archive/Emulex tape combination
   Maxtor 8760 disk drive
7) Adaptec SDS-3 synchronous SCSI test system
8) Sun systems, Emulex VH-01 host adapter

Cable configurations tested:

i) One piece, single impedance, 21 foot cable with one connector every foot
ii) Combination cable with 100 ohm SCSI-1 external twisted-pair and "brand X" internal cable to form worst-case system length.
iii) External shielded SCSI-2 cable for system testing section only.

TEST STRUCTURE:

The testing was grouped into three tests - a) function generator, b) Adaptec tests, and c) System tests. All tests with a particular impedance cable were run with cable configurations i) and ii) to determine the effects of cable impedance mismatch on signal quality and thus on system performance. Clustering of devices was performed in parts b) and c) only.

a) Function generator test:

The function generator's 50 ohm output stage was used to inject square waves of 1.5, 5.0, and 10.0 MHz into one end of the cable assembly through pin 1, using pin 2 as a return. Signal quality at the other end of the bus was photographed and compared to the incident signal. Propagation delay, rise time, peak time, settle time, overshoot, fall time, and undershoot were all characterized from this test.
The bus length was terminated at each end with characteristic 132 ohm Thevenin equivalent termination networks, with TERMPWR supplied at 5.0 volts.
While the bus length was maintained at 21 feet or 6.4 meters, the distance between source and destination nodes was 18 feet.

b) Adaptec tests:

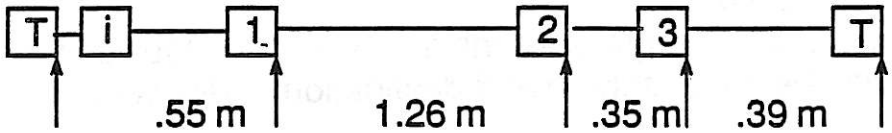
This test consisted of running the Adaptec SDS-3 with a stand-alone test program written to perform both async and sync data transfers at up to 5 MHz on the SCSI bus. The target drives were CDC (Imprimis) 5.25" Wren IV and Quantum 3.5" P105S devices, each with synchronous transfer capability. The Adaptec was programmed for a maximum offset of 7 and a transfer period of 200 ns to negotiate with during sync data transfers. The Imprimis drive very nearly matched the negotiation, while the Quantum drive negotiated to 4.0 MHz data transfers. The Adaptec uses their AIC-6250 SCSI protocol controller in the SDS-3.

One device was placed at the second node from the end of each of the cable configurations (last node for termination) while the initiator was maintained at the other end. The Adaptec has its own built in termination.

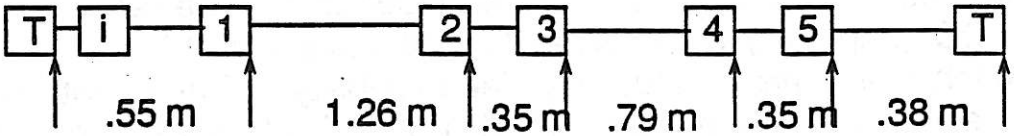
Term power was varied from 5.25 Volts down to failure of the SCSI bus. Upon failure, the voltage was raised again and operated for 20 minutes error free prior to reducing it back to the error level and reverifying the same SCSI bus error conditions. The voltage at the farthest device was checked to determine total line loss for the test.

FOR CLUSTER TESTING, three separate cluster arrangements were implemented, described in figure 1-1. Measurements were made at each cluster of nodes during the test, with scope shots taken of the worst case signals. The tests were performed using both cable configurations, that is, 6 meter, single impedance cable, and the combination internal/external cable set.

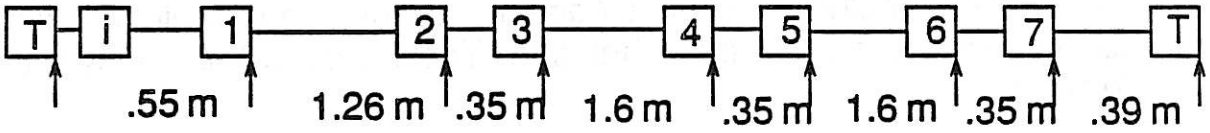
i=initiator T=SCSI 220/330 ohm termination network
1, 2, etc= node number connected to SCSI bus



CLUSTER CONFIGURATION #1



CLUSTER CONFIGURATION #2



CLUSTER CONFIGURATION #3

FIGURE 1: CLUSTERING CONFIGURATIONS

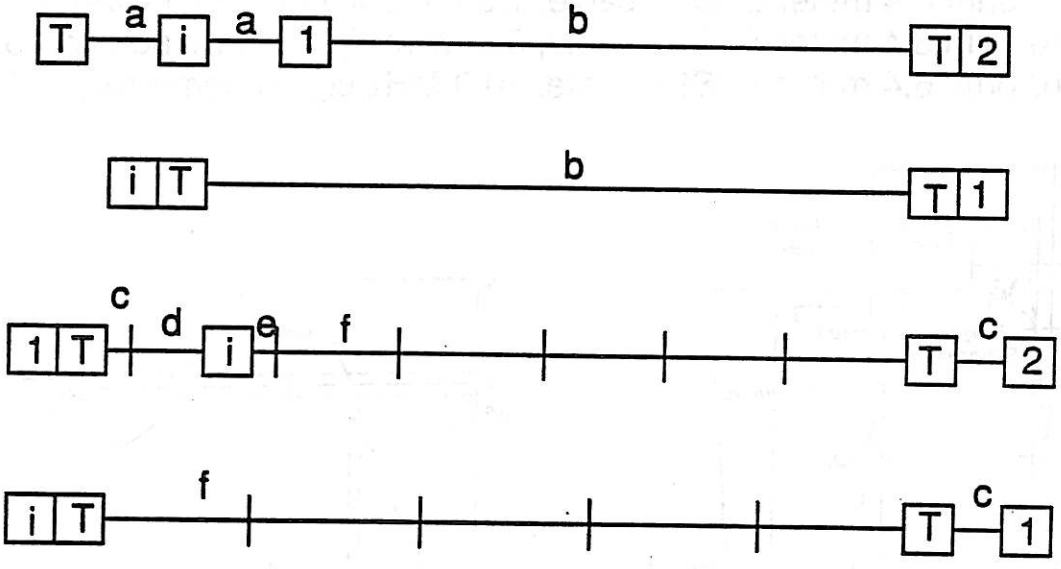
c) System testing:

System testing was performed a) with shell scripts and b) with a system exerciser running on Sun test systems. Both the shell scripts and the system exerciser issued commands to all devices on the bus in multi-tasking mode. Any errors that occurred during the test were recorded into a log file.

The cabling configuration for the 386i testing was identical to that used in the cluster tests. All three clusters were tested with each singular cable impedance and with a combination cable. SCSI asynchronous data transfers were used with the Western Digital 33C93 SCSI protocol controller as a host adapter.

Testing at Sun's West Coast facilities was performed using the external version of SCSI-2 cable at 70, 100, 105, 110, and 120 ohm impedances. A 53C90 host adapter chip and an Emulex VH-01 host adapter were used in the test systems. The configuration is as follows:

a=.2m etch b=6.4m SCSI-1 cable c=.1m SCSI-1 cable
d=.3m etch e=.05m etch f=1.2m SCSI-2 cable



i=initiator T=220/330 termination network
1,2 = target devices

III. DATA

A. Function generator testing

SCOPE SHOTS:

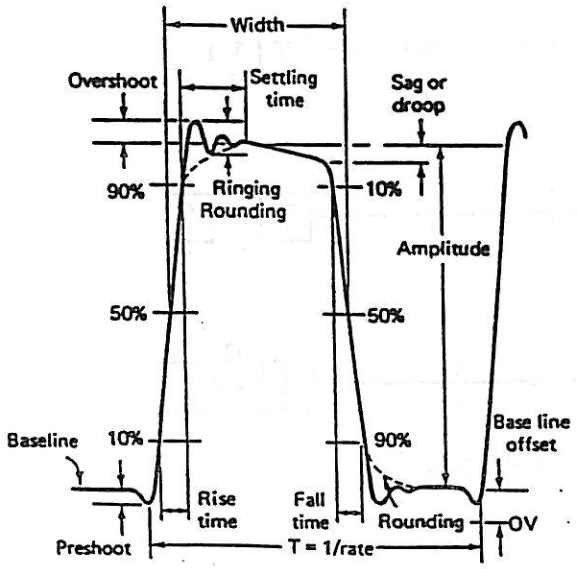
1) 93/100 ohm 6.3 meter cable, 1.5 MHz signal, term power = 5.0 V.
2) 93/100 ohm 6.3 meter cable, 5.0 MHz signal, term power = 5.0 V.
3) 93/100 ohm 6.3 meter cable, 10.0 MHz signal, term power = 5.0 V.

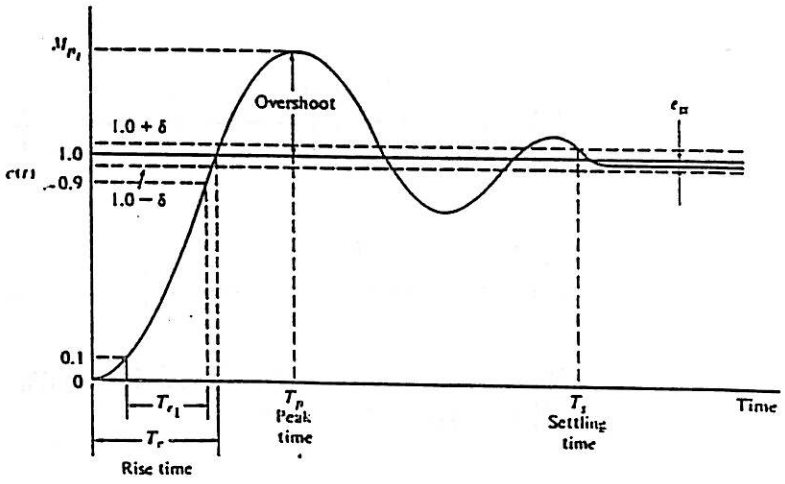
4) 75/100 ohm 6.3 meter cable, 1.5 MHz signal, term power = 5.0 V.
5) 75/100 ohm 6.3 meter cable, 5.0 MHz signal, term power = 5.0 V.
6) 75/100 ohm 6.3 meter cable, 10.0 MHz signal, term power = 5.0 V.

7) 75 ohm 6.4 meter cable, 1.5 MHz signal, term power = 5.0 V.
8) 75 ohm 6.4 meter cable, 5.0 MHz signal, term power = 5.0 V.
9) 75 ohm 6.4 meter cable, 10.0 MHz signal, term power = 5.0 V.

10) 93 ohm 6.4 meter cable, 1.5 MHz signal, term power = 5.0 V.
11) 93 ohm 6.4 meter cable, 5.0 MHz signal, term power = 5.0 V.
12) 93 ohm 6.4 meter cable, 10.0 MHz signal, term power = 5.0 V.

13) 110 ohm 6.4 meter SCSI-1 cable, 1.5 MHz signal, term power = 5.0 V.
14) 110 ohm 6.4 meter SCSI-1 cable, 5.0 MHz signal, term power = 5.0 V.
15) 110 ohm 6.4 meter SCSI-1 cable, 10.0 MHz signal, termpower =5.0 V.





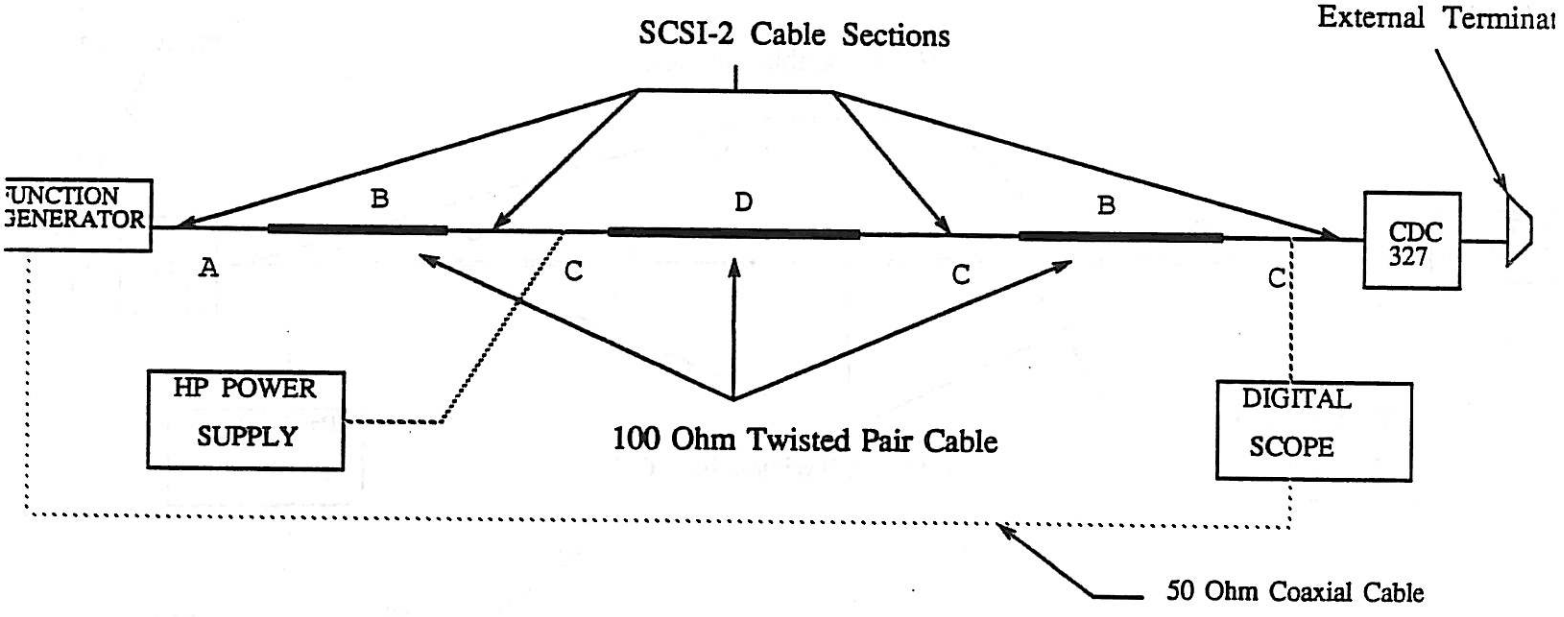
CABLE LENGTHS

1. Section A	0.940	Meters	SCSI-2 93 Ohm cable
2. Section B	0.419	Meters	SCSI-1 100 Ohm cable
3. Section C	1.118	Meters	SCSI-2 93 Ohm cable
4. Section D	1.270	Meters	SCSI-1 100 Ohm cable
5. Total Length	6.4	Meters	Combined 95.34 Ohm Cable

POINT	FREQUENCY	RISE TIME	PEAK TIME	SETTLE TIME	OVERSHOOT	FALL TIME	UNDERSHOOT
SOURCE	1.5 MHz.	6.0 nS	19.5 nS	79 nS	20 mV	4.3 nS	130 mV
LOAD	1.5 MHz.	8.0 nS	70.0 nS	128.0 nS	440 mV	15.8 nS	260 mV
SOURCE	5.0 MHz.	5.0 nS	19.0 nS	35.6 nS	none	4.3 nS	380 mV
LOAD	5.0 MHz.	26.5 nS	42.2 nS	41.5 nS	none	16.0 nS	none
SOURCE	10.0 MHz.	3.75 nS	6.8 nS	22.8 nS	180 mV	4.8 nS	380 mV
LOAD	10.0 MHz.	6.0 nS	12.2 nS	25.0 nS	110 mV	4.6 nS	none

Propagation delay approximately 35 ns.

TEST CONFIGURATION



*Note: The Hewlett Packard power supply was used for TERM POWER on the SCSI bus at +5 Volts.

PERFORMANCE INDICES FOR SCSI-2 CABLE

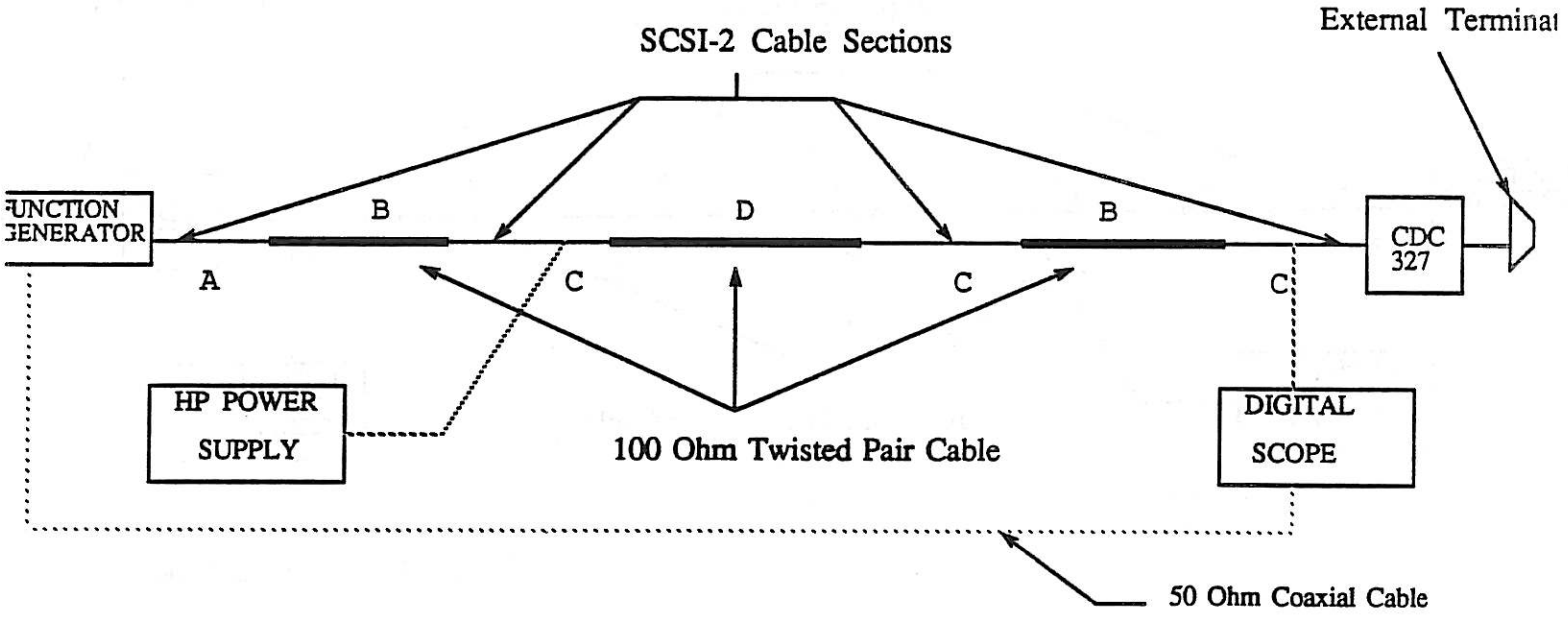
CABLE LENGTHS

1. Section A	0.940	Meters	SCSI-2 75 Ohm cable
2. Section B	0.419	Meters	SCSI-1 100 Ohm cable
3. Section C	1.118	Meters	SCSI-2 75 Ohm cable
4. Section D	1.270	Meters	SCSI-1 100 Ohm cable
5. Total Length	6.4	Meters	

POINT	FREQUENCY	RISE TIME	PEAK TIME	SETTLE TIME	OVERSHOOT	FALL TIME	UNDERSHOOT
SOURCE	1.5 MHz.	9.0 nS	14.5 nS	79.0 nS	460 mV	9.5 nS	220 mV
LOAD	1.5 MHz.	12.5 nS	69.0 nS	102.0 nS	500 mV	12.5 nS	320 mV
SOURCE	5.0 MHz.	4.1 nS	7.9 nS	21.0 nS	none	4.2 nS	200 mV
LOAD	5.0 MHz.	22.0 nS	37.0 nS	39.5 nS	none	19.0 nS	none
SOURCE	10.0 MHz.	4.7 nS	18.8 nS	19.6 nS	280 mV	4.5 nS	120 mV
LOAD	10.0 MHz.	9.0 nS	20.0 nS	18.2 nS	140 mV	10.0 nS	none

Propagation delay average 35 ns.
Vpp at source = 3.18 Volts.

TEST CONFIGURATION



*Note: The Hewlett Packard power supply was used for TERM POWER on the SCSI bus at +5 Volts.

PERFORMANCE INDICES FOR SCSI-2 CABLE

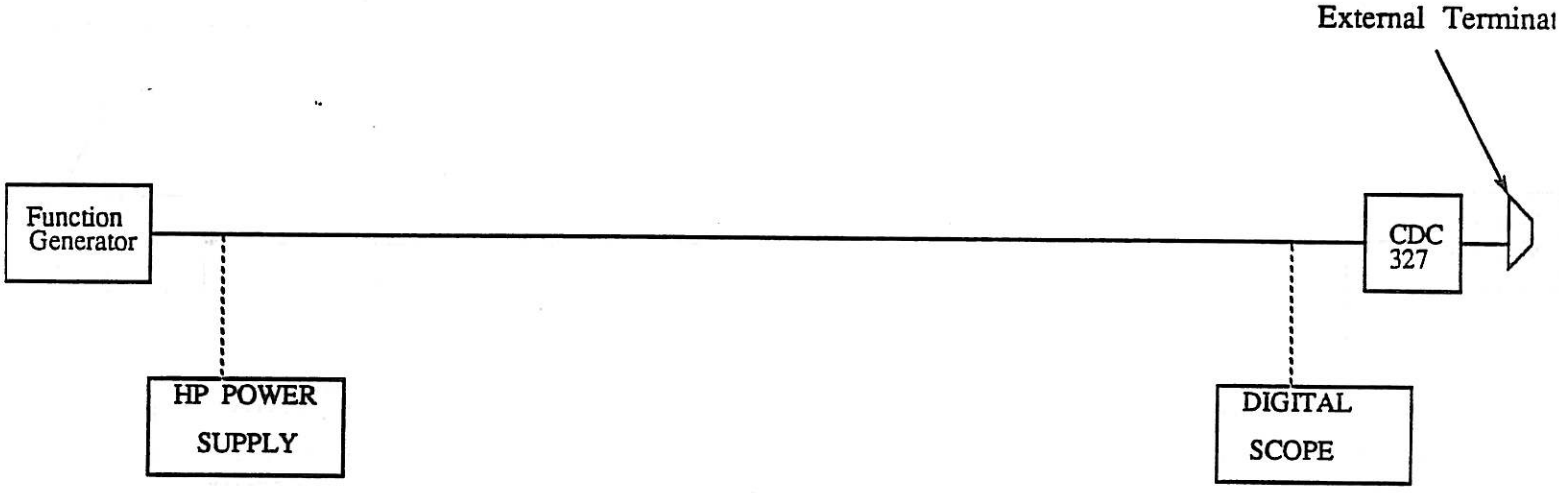
CABLE LENGTH

1. Section A 6.46 Meters SCSI-2 75 Ohm cable

POINT	FREQUENCY	RISE TIME	PEAK TIME	SETTLE TIME	OVERSHOOT	FALL TIME	UNDERSHOOT
SOURCE	1.5 MHz.	5.0 nS	13.0 nS	11.7 nS	none	5.0 nS	none
LOAD	1.5 MHz.	11.0 nS	37.0 nS	87 nS	270 mV	9.1 nS	160 mV
SOURCE	5.0 MHz.	4.2 nS	10.4 nS	11.4 nS	none	3.8 nS	270 mV
LOAD	5.0 MHz.	9.0 nS	28.2 nS	19.4 nS	none	9.2 nS	none
SOURCE	10.0 MHz.	4.0 nS	7.8 nS	20.4 nS	170 mV	4.3 nS	390 mV
LOAD	10.0 MHz.	15.0 nS	23.2 nS	18.0 nS	none	14.7 nS	none

Propagation delay of approximately 33 ns.
Source signal at 3.24 Volts, 3.14 Volts, and 3.2 Volts respectively.

TEST CONFIGURATION



*Note: The Hewlett Packard power supply was used for TERM POWER on the SCSI bus at +5 Volts.

PERFORMANCE INDICES FOR SCSI-2 CABLE

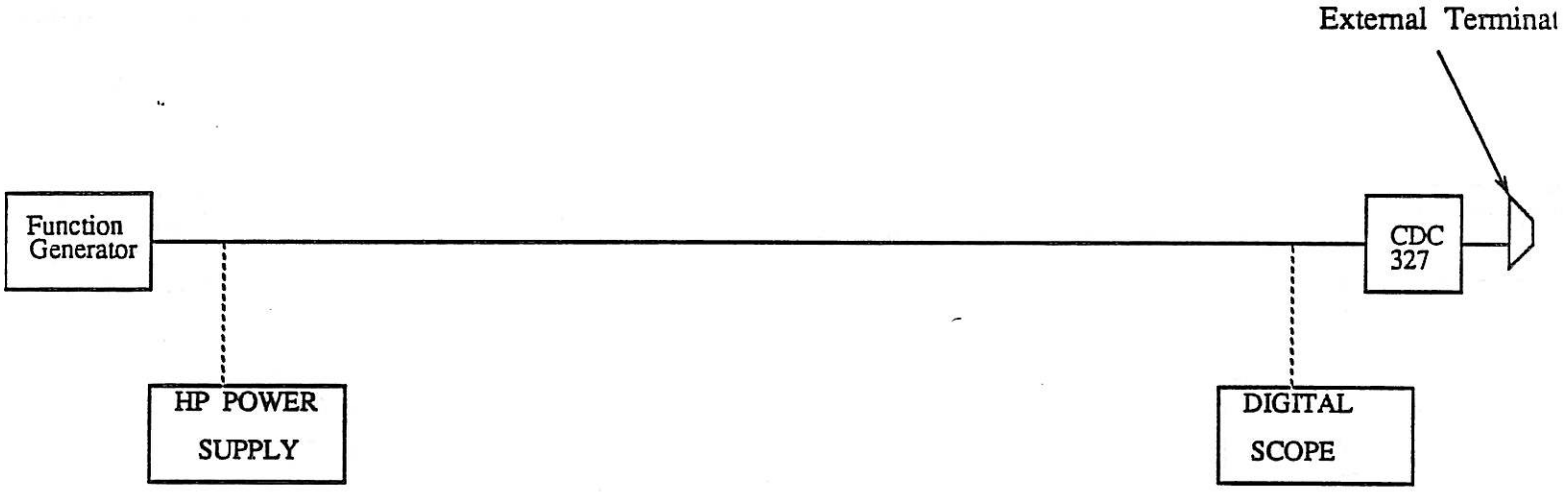
CABLE LENGTH

1. Section A 6.46 Meters SCSI-2 93 Ohm cable

POINT	FREQUENCY	RISE TIME	PEAK TIME	SETTLE TIME	OVERSHOOT	FALL TIME	UNDERSHOOT
SOURCE	1.5 MHz.	7.0 nS	8.6 nS	113 nS	400 mV	5.3 nS	240 mV
LOAD	1.5 MHz.	16.1 nS	20.6 nS	142 nS	500 mV	16.4 nS	500 mV
SOURCE	5.0 MHz.	5.8 nS	7.8 nS	35.4 nS	240 mV	4.5 nS	320 mV
LOAD	5.0 MHz.	25.8 nS	37.0 nS	53.0 nS	520 mV	13.8 nS	540 mV
SOURCE	10.0 MHz.	4.85 nS	6.55 nS	25 nS	320 mV	4.7 nS	460 mV
LOAD	10.0 MHz.	17.1 nS	20.9 nS	32.9 nS	240 mV	14.5 nS	380 mV

Propagation delay of approximately 33 ns.
Vpp of square wave = 3.12 Volts

TEST CONFIGURATION



*Note: The Hewlett Packard power supply was used for TERM POWER on the SCSI bus at +5 Volts.

PERFORMANCE INDICES FOR SCSI-2 CABLE

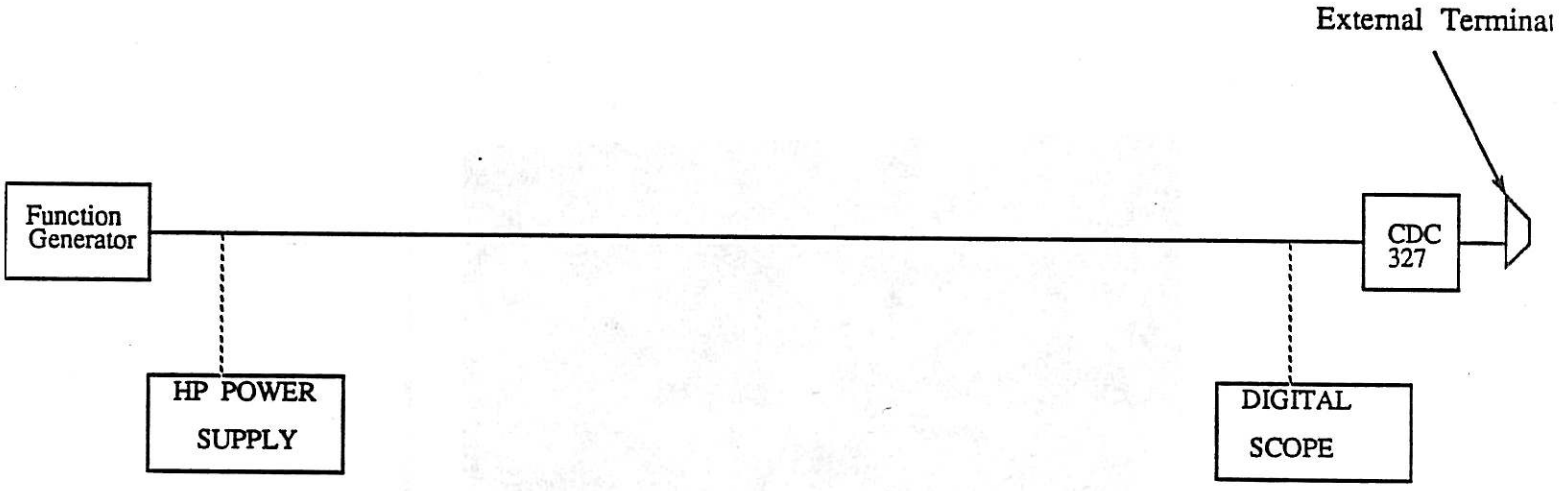
CABLE LENGTH

. Section A 6.46 Meters SCSI-1 110 ohm ribbon cable

POINT	FREQUENCY	RISE TIME	PEAK TIME	SETTLE TIME	OVERSHOOT	FALL TIME	UNDERSHOOT
SOURCE	1.5 MHz.	5.45 nS	8.2 nS	20.5 nS	220 mV	5.35 nS	none
LOAD	1.5 MHz.	16.5 nS	20.5 nS	86.5 nS	540 mV	11.9 nS	340 mV
SOURCE	5.0 MHz.	4.5 nS	6.2 nS	19 nS	220 mV	3.95 nS	260 mV
LOAD	5.0 MHz.	16.3 nS	18.3 nS	43 nS	200 mV	13.3 nS	440 mV
SOURCE	10.0 MHz.	4.95 nS	6.7 nS	21 nS	320 mV	5.2 nS	600 mV
LOAD	10.0 MHz.	13.4 nS	20.2 nS	27.5 nS	none	12.4 nS	none

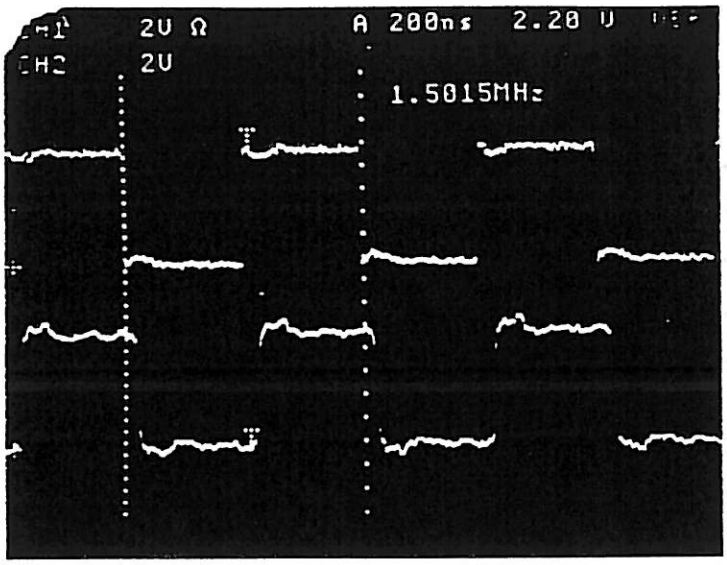
Propagation delay approximately 30 ns.
Vpp of square wave = 3.2 Volts.

TEST CONFIGURATION



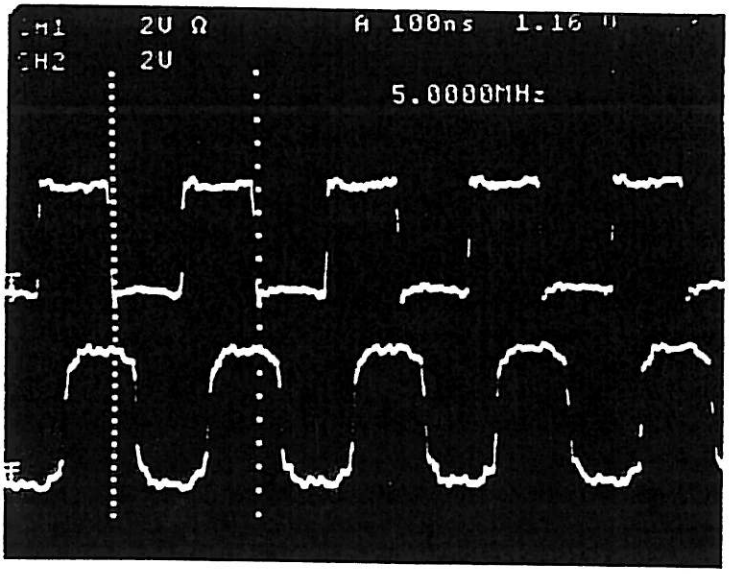
*Note: The Hewlett Packard power supply was used for TERM POWER on the SCSI bus at +5 Volts.

SECTION A SCOPE SHOT #1



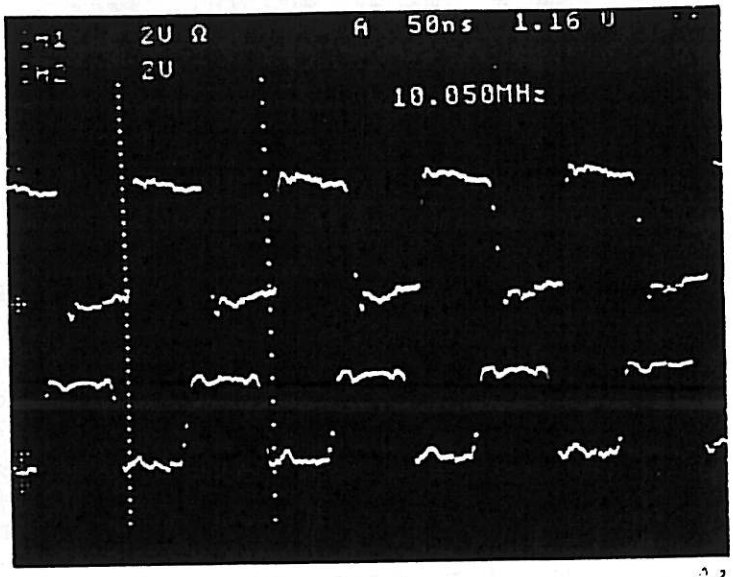
A1

SECTION A SCOPE SHOT #2



A2

SECTION A SCOPE SHOT #3



A3

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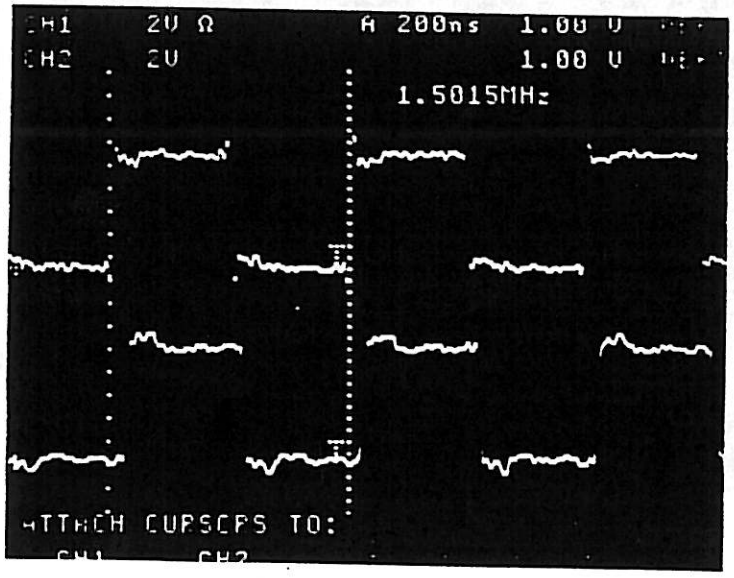

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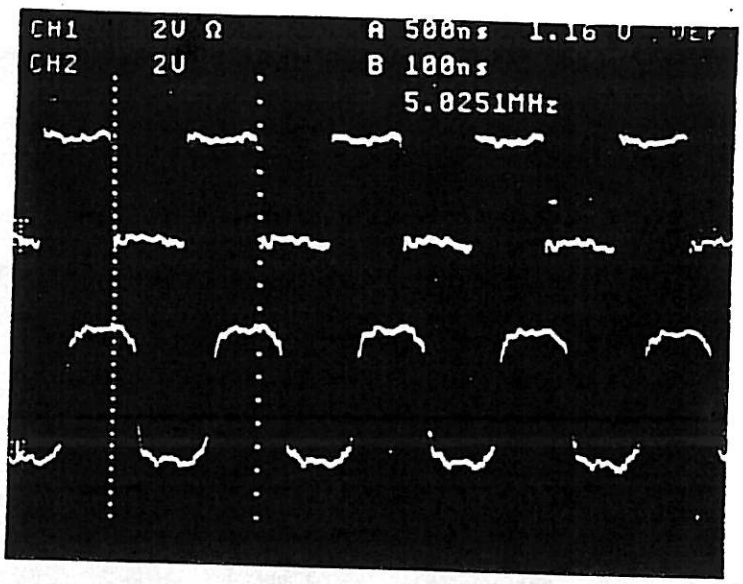

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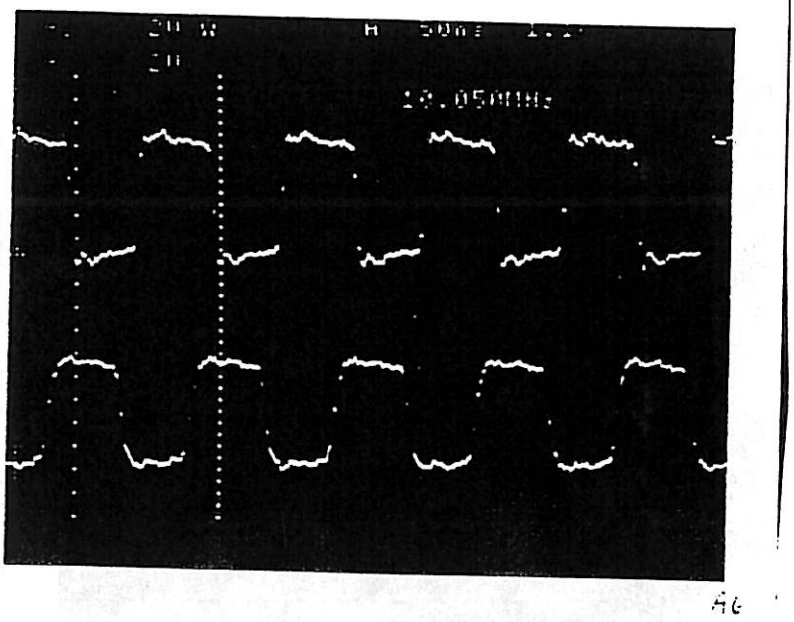
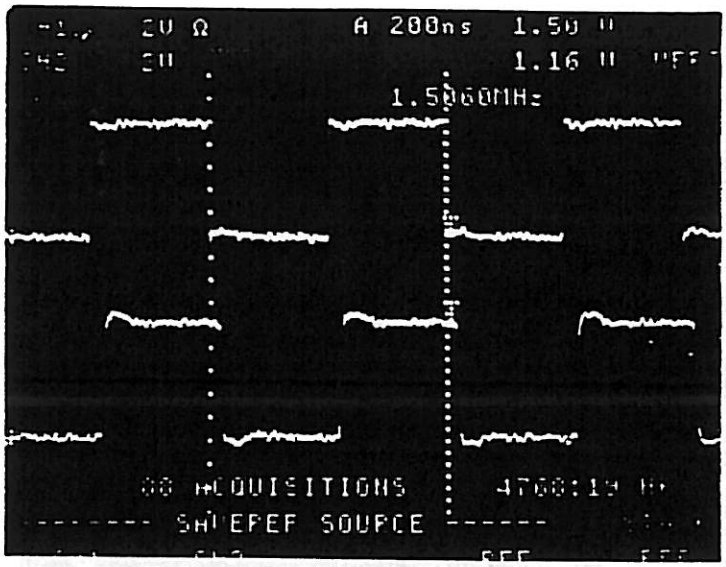
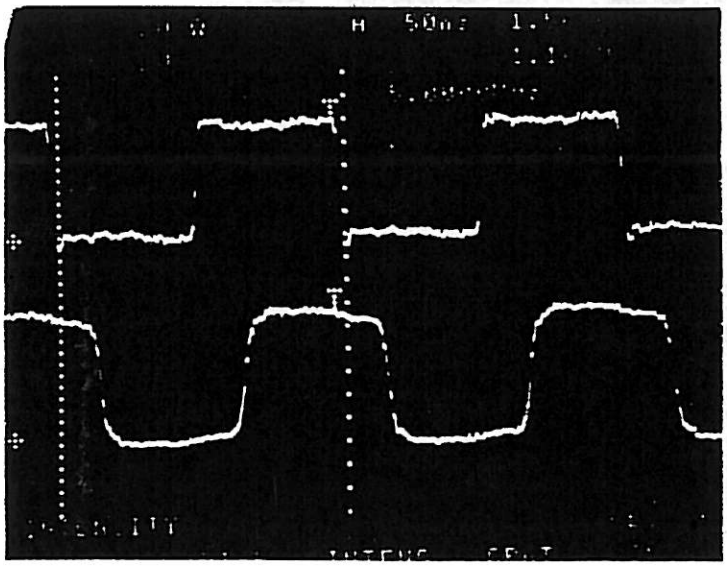


SECTION A SCOPE SHOT #7

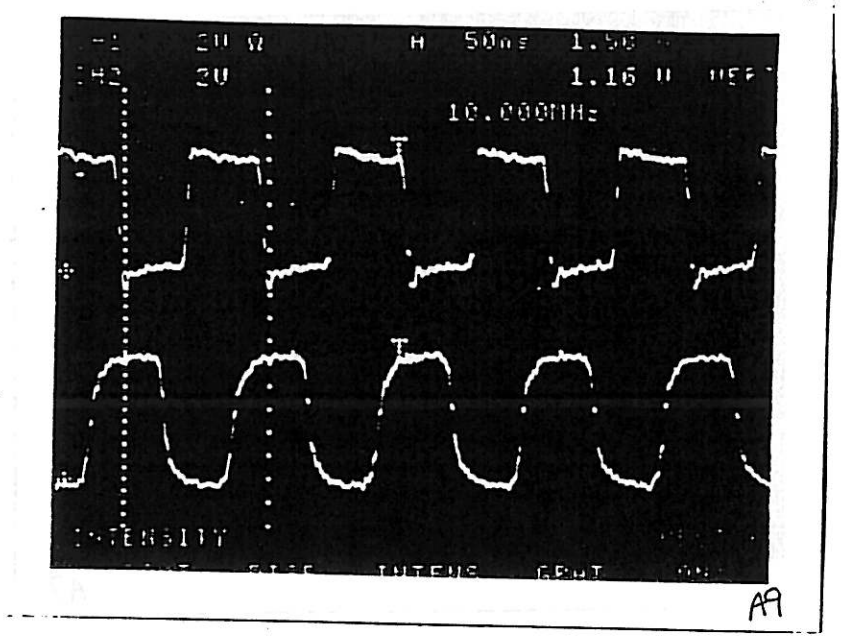


A7

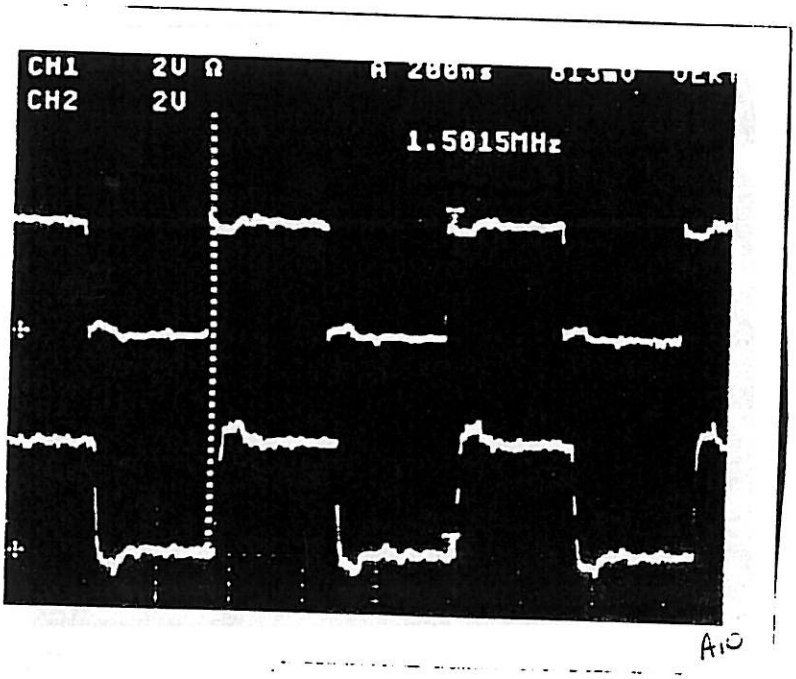
SECTION A SCOPE SHOT #8



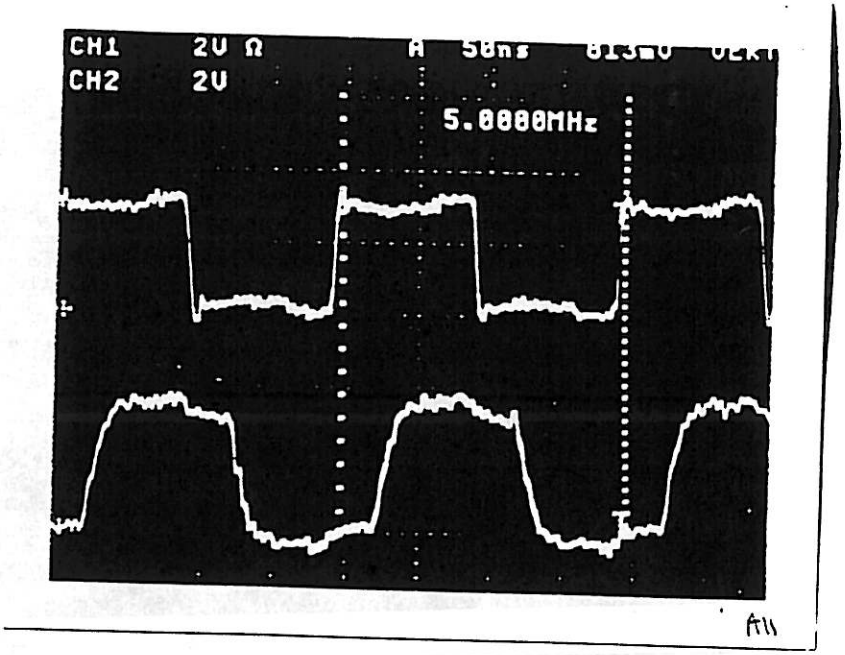
SECTION A SCOPE SHOT #9



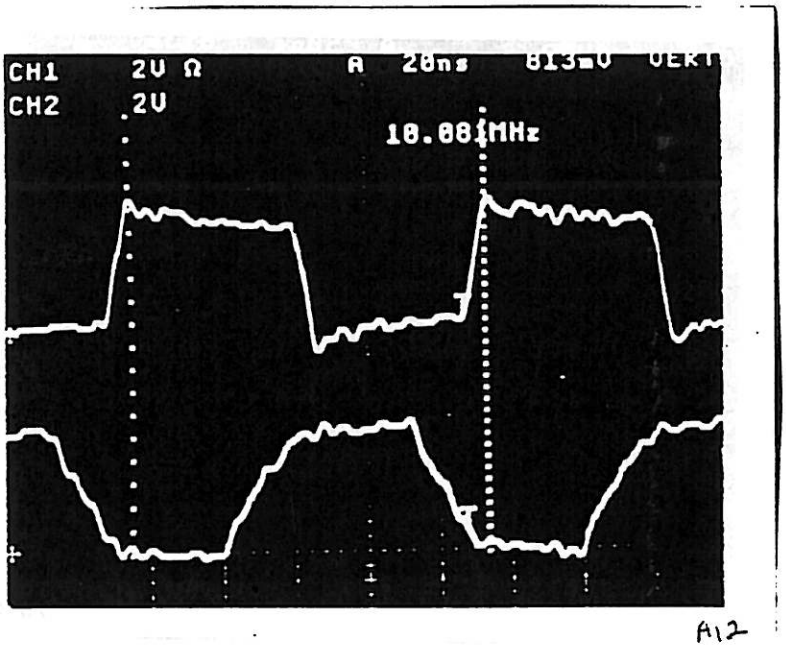
SECTION A SCOPE SHOT #10



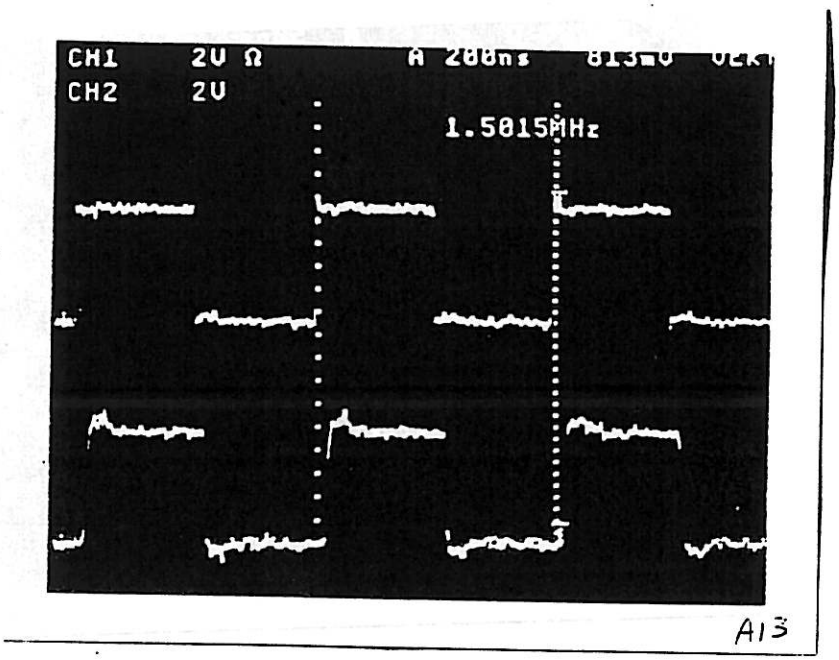
SECTION A SCOPE SHOT #11



SECTION A SCOPE SHOT #12



SECTION A SCOPE SHOT #13



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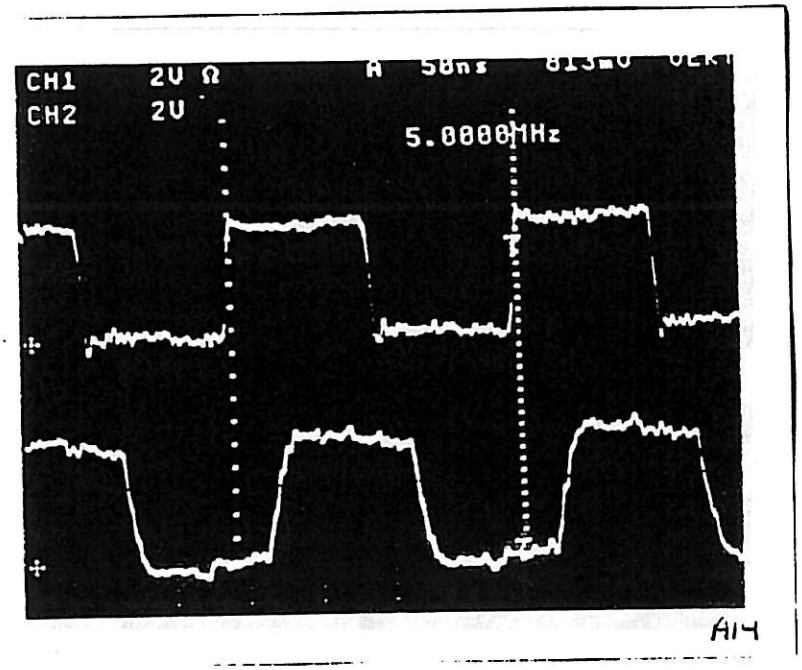
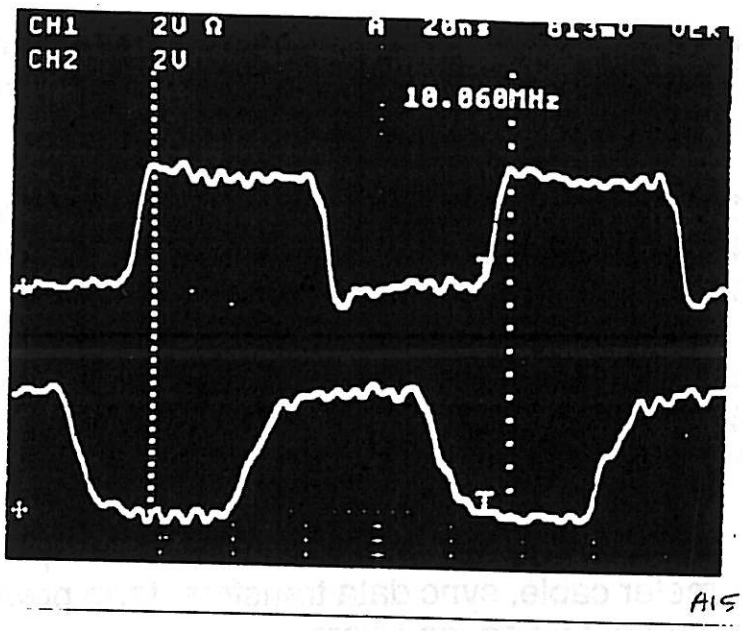


SECTION A SCOPE SHOT #15



B. Adaptec Testing

SCOPE SHOTS - two node version:

1) 93 ohm 6.4 meter cable, async data transfers, term power=5.25 V.
2) 93 ohm 6.4 meter cable, sync data transfers, term power=5.25 V.
   Over 8 hours of testing, no errors.

3) 93 ohm 6.4 meter cable, async data transfers, term power=5.0 V.
4) 93 ohm 6.4 meter cable, sync data transfers, term power=5.0 V.
   Over 10 hours of testing, no errors.

5) 93 ohm 6.4 meter cable, async data transfers, term power=4.75 V.
6) 93 ohm 6.4 meter cable, sync data transfers, term power=4.75 V.
   Over 11 hours of testing, no errors.

7) 93 ohm 6.4 meter cable, async data transfers, term power=4.5 V.
8) 93 ohm 6.4 meter cable, sync data transfers, term power=4.5 V.
   Over 8 hours of testing, no errors.

9) 93 ohm 6.4 meter cable, async data transfers, term power=4.25 V.
10) 93 ohm 6.4 meter cable, sync data transfers, term power=4.25 V.
   SCSI miscompares immediately.

11) 93 ohm 6.4 meter cable, async data transfers, term power=4.40 V.
12) 93 ohm 6.4 meter cable, sync data transfers, term power=4.40 V.
   Over 11 hours of testing, no errors.

13) 93 ohm 6.4 meter cable, async data transfers, term power=4.30 V.
14) 93 ohm 6.4 meter cable, sync data transfers, term power=4.30 V.
   Miscompares and timeouts after 40 minutes of testing.

Note: All errors occurred during synchronous portions of testing.

SCOPE SHOTS - two node version:

15) 75 ohm 6.4 meter cable, async data transfers, term power=5.25 V.
16) 75 ohm 6.4 meter cable, sync data transfers, term power=5.25 V.
No errors in over 2 hours of testing.

17) 75 ohm 6.4 meter cable, async data transfers, term power=5.0 V.
18) 75 ohm 6.4 meter cable, sync data transfers, term power=5.0 V.
No errors in over 2 hours of testing.

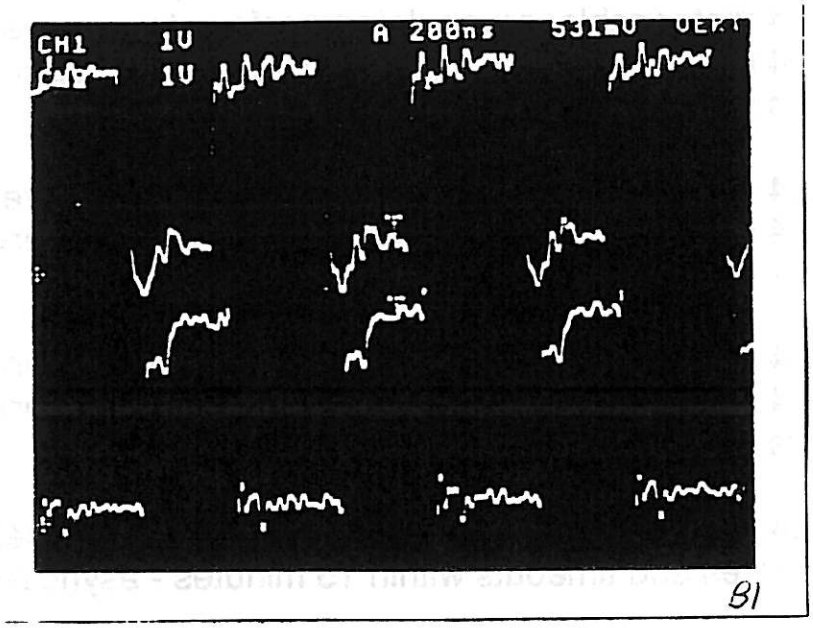
19) 75 ohm 6.4 meter cable, async data transfers, term power=4.5 V.
20) 75 ohm 6.4 meter cable, sync data transfers, term power=4.5 V.
No errors in over 15 hours of testing.

21) 75 ohm 6.4 meter cable, async data transfers, term power=4.25 V.
Miscompares and timeouts within 15 minutes - async reads.

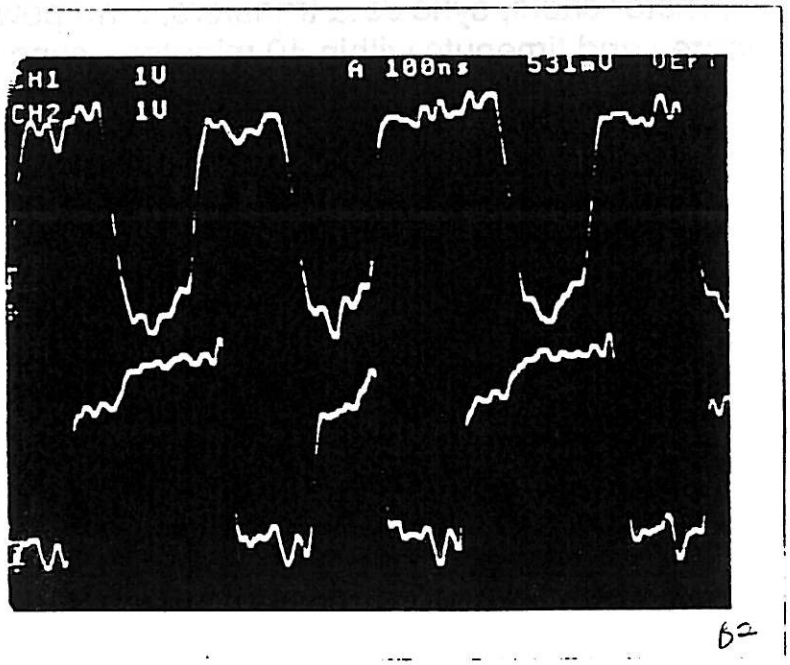
22) 75 ohm 6.4 meter cable, async data transfers, term power=4.30 V.
23) 75 ohm 6.4 meter cable, sync data transfers, term power=4.30 V.
Miscompares and timeouts within 20 minutes - sync reads.

24) 75 ohm 6.4 meter cable, async data transfers, term power=4.40 V.
25) 75 ohm 6.4 meter cable, sync data transfers, term power=4.40 V.
Miscompares and timeouts within 40 minutes - sync reads.

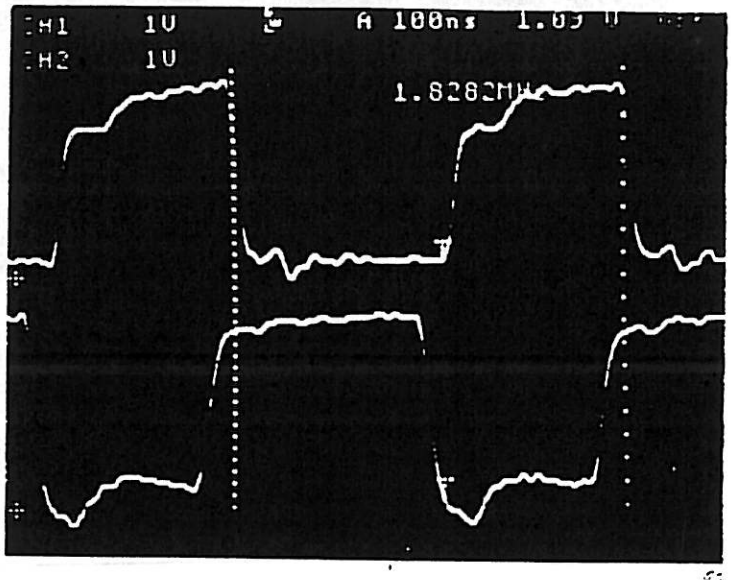
SECTION B SCOPE SHOT #1



SECTION B SCOPE SHOT #2

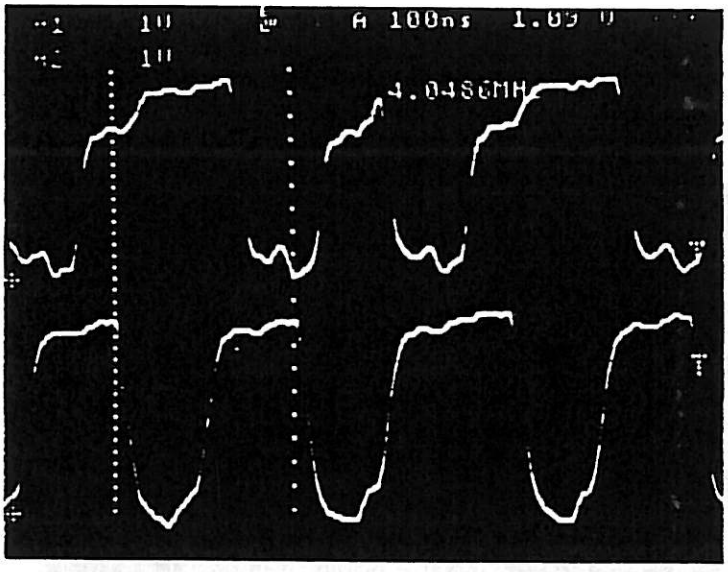


SECTION B SCOPE SHOT #3



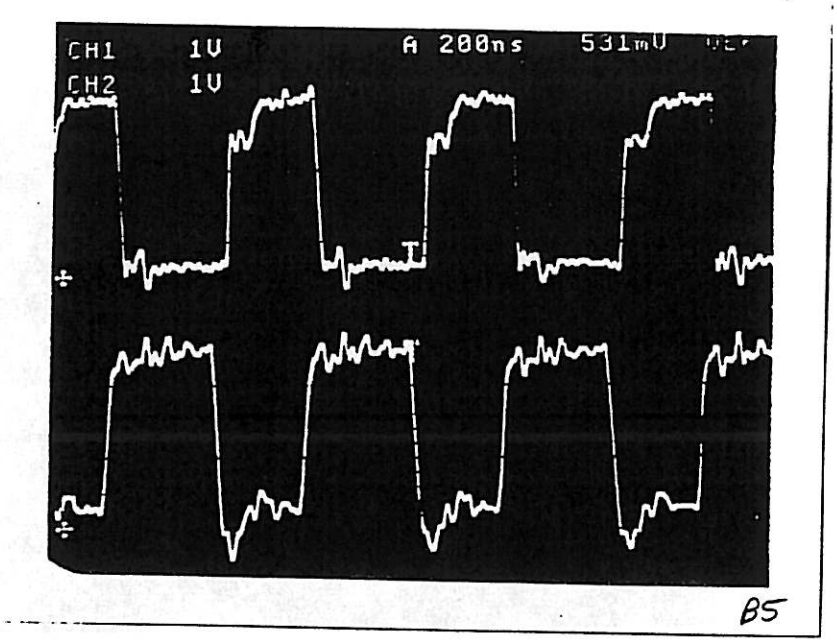
B3

SECTION B SCOPE SHOT #4

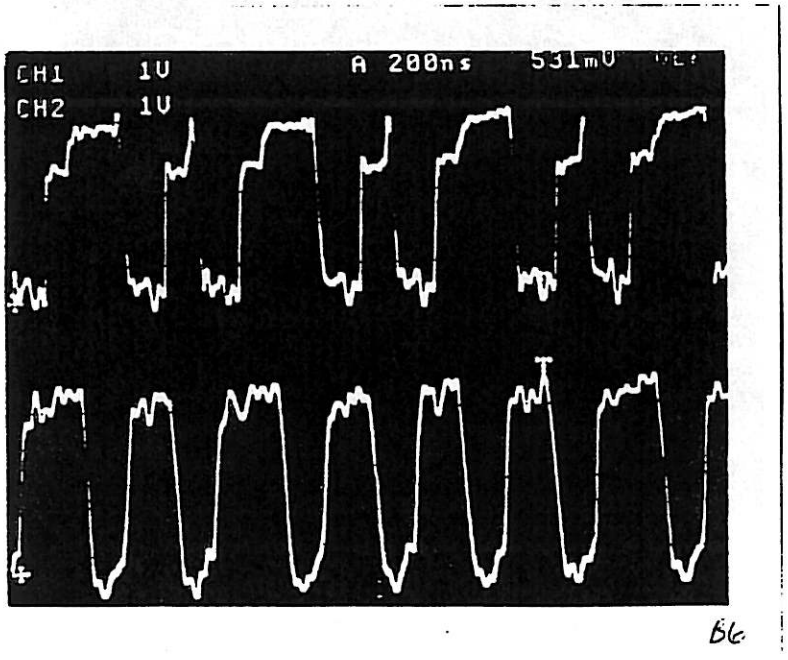


B4

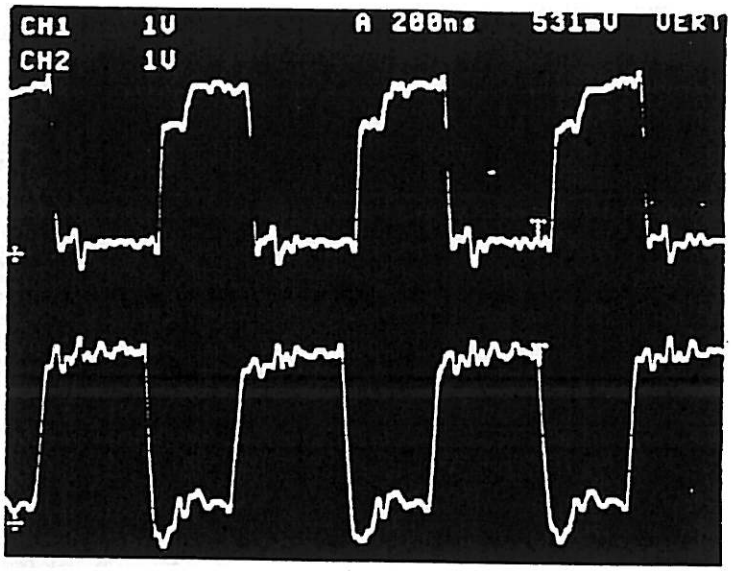
SECTION B SCOPE SHOT #5



SECTION B SCOPE SHOT #6

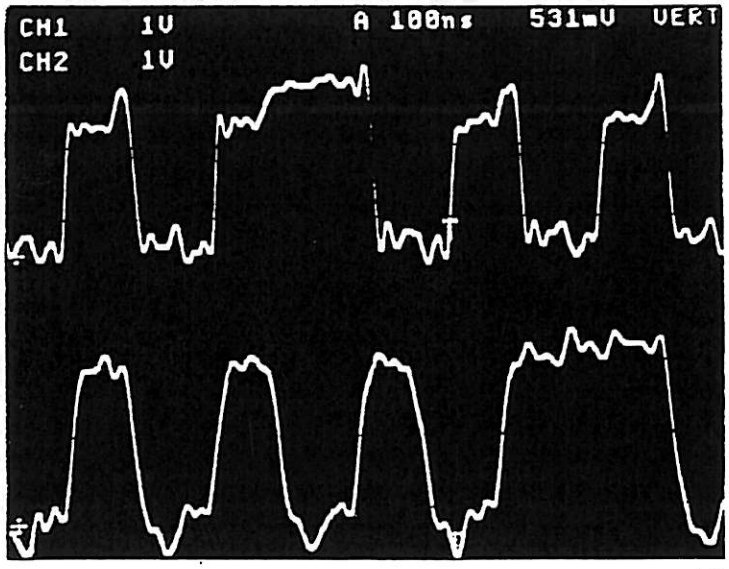


SECTION B SCOPE SHOT #7



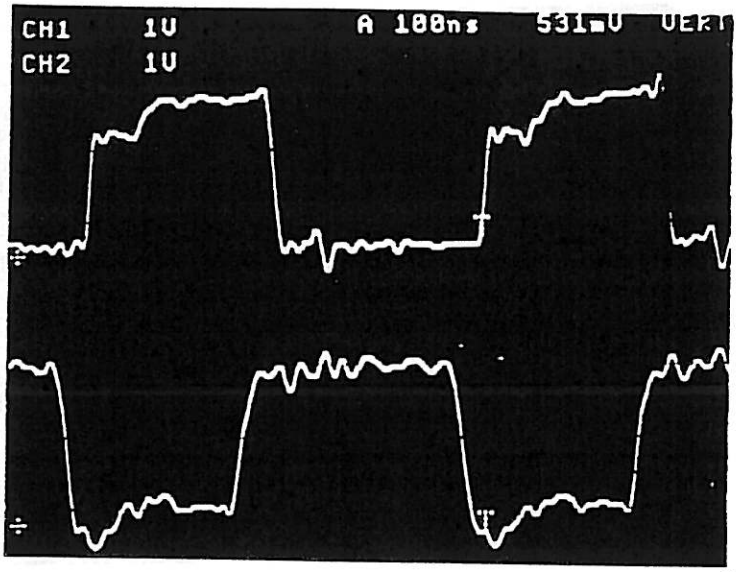
B7

SECTION B SCOPE SHOT #8

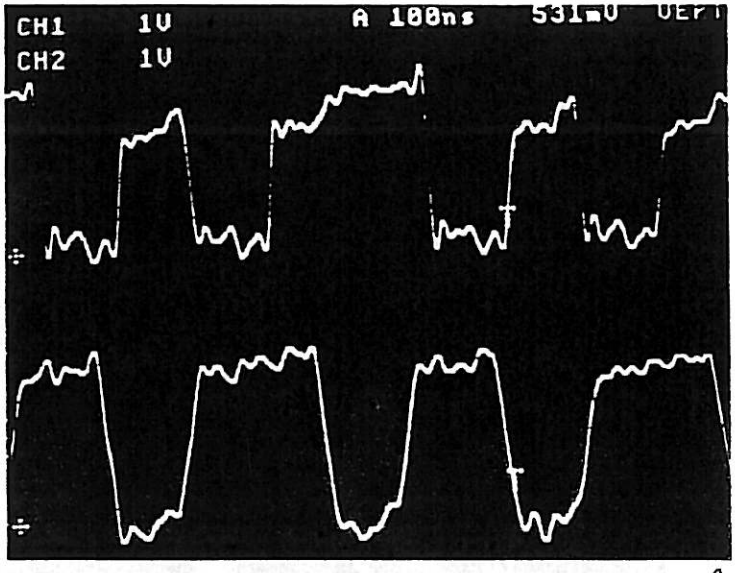


B8

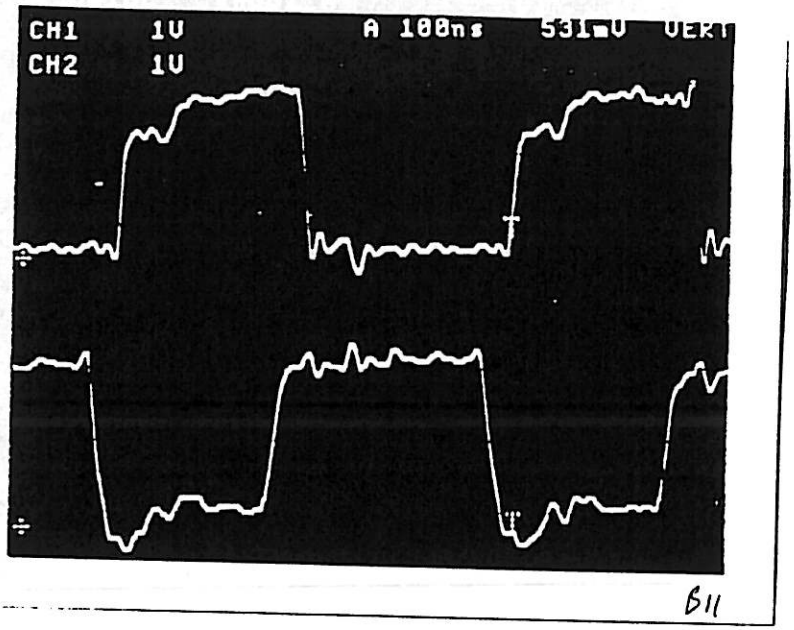
SECTION B SCOPE SHOT #9



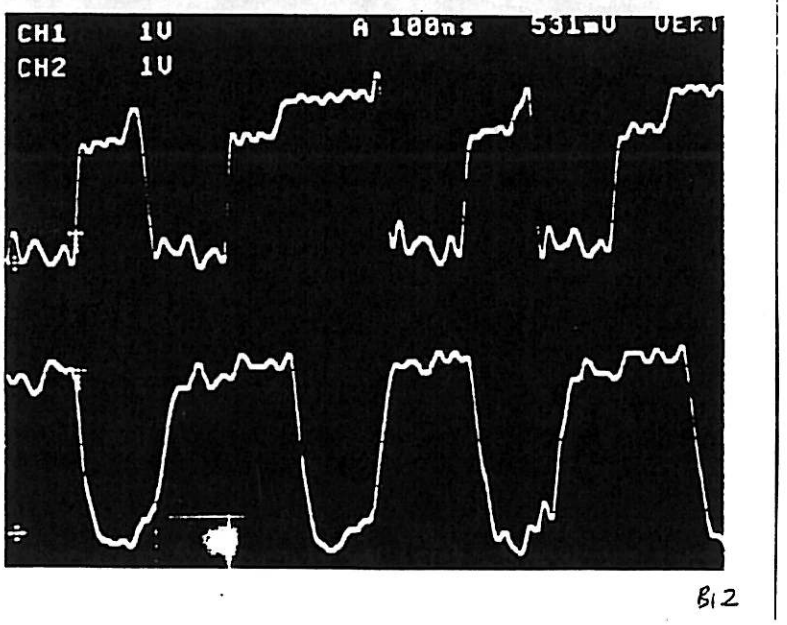
SECTION B SCOPE SHOT #10



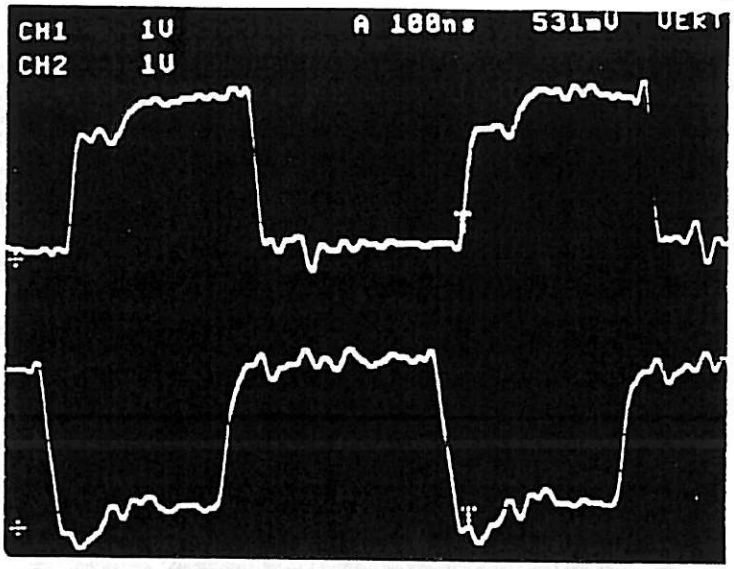
SECTION B SCOPE SHOT #11



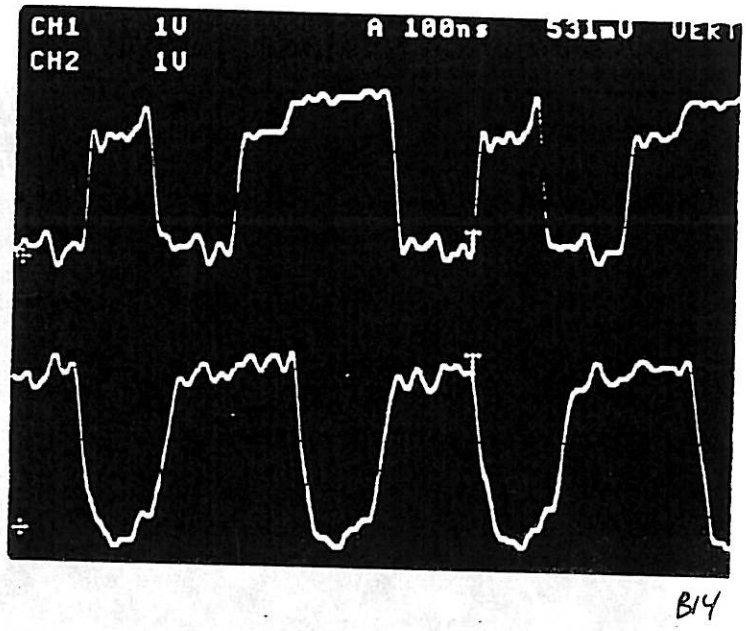
SECTION B SCOPE SHOT #12



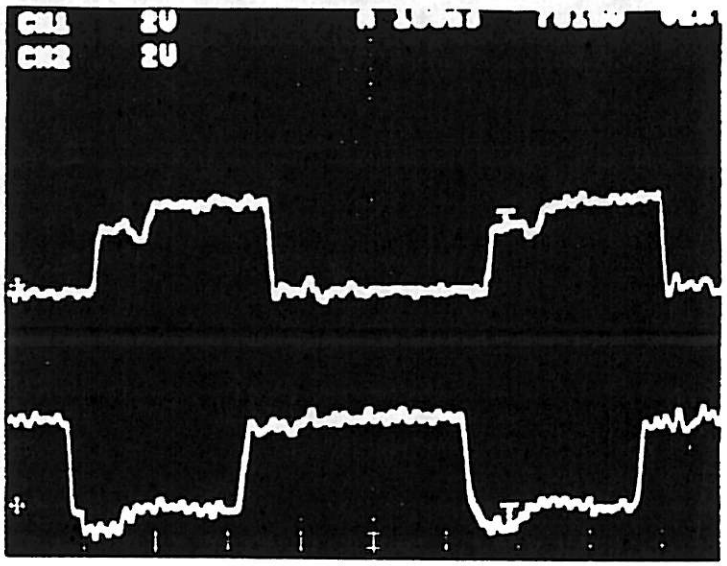
SECTION B SCOPE SHOT #13



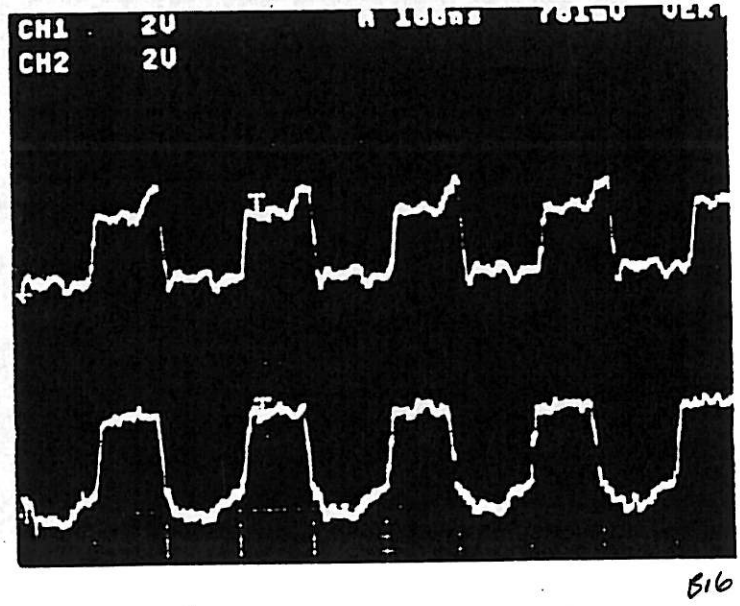
SECTION B SCOPE SHOT #14



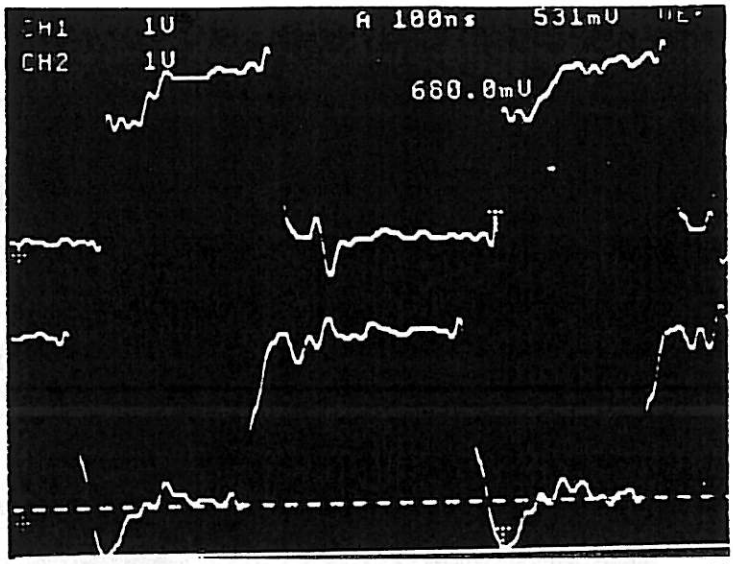
SECTION B SCOPE SHOT #15



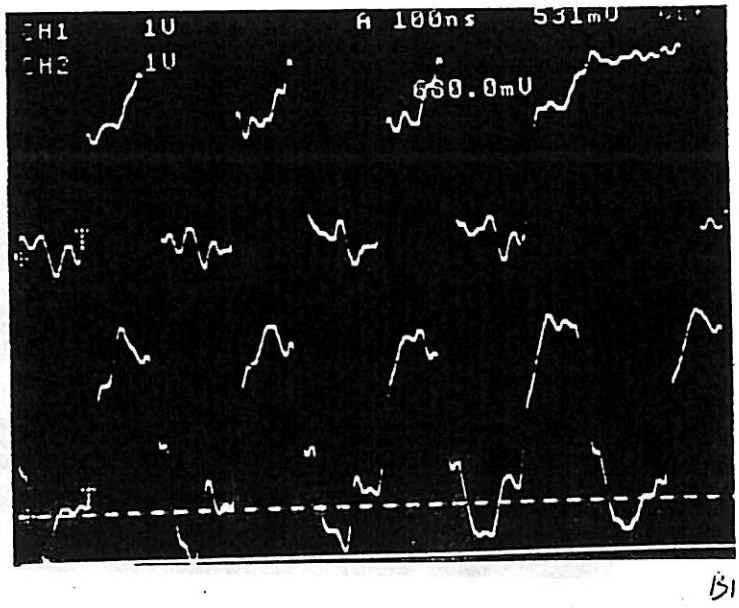
SECTION B SCOPE SHOT #16



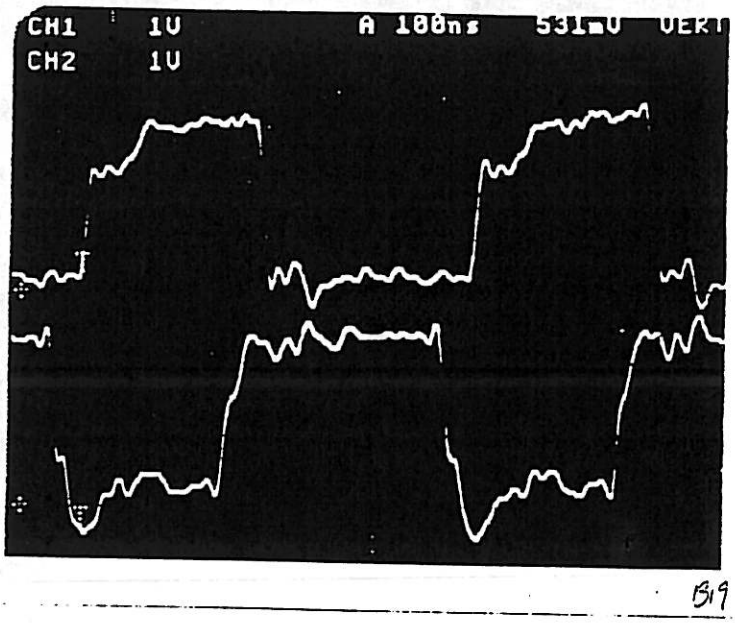
SECTION B SCOPE SHOT #17



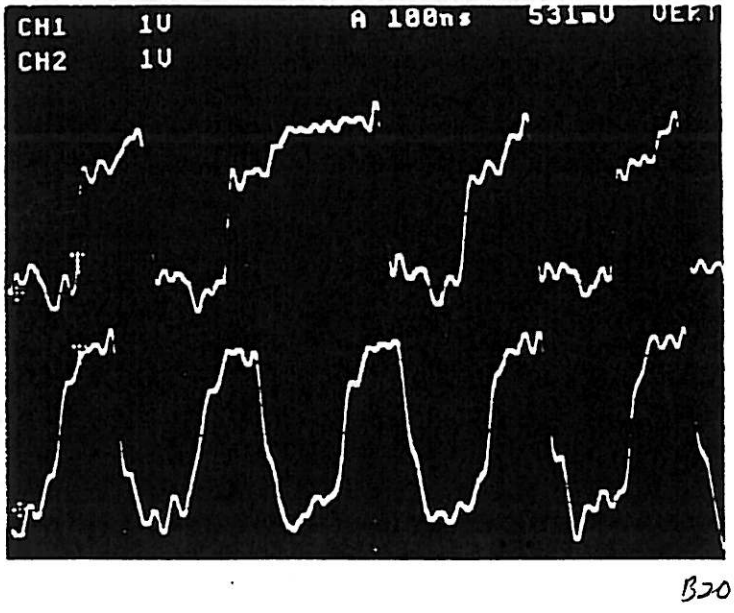
SECTION B SCOPE SHOT #18



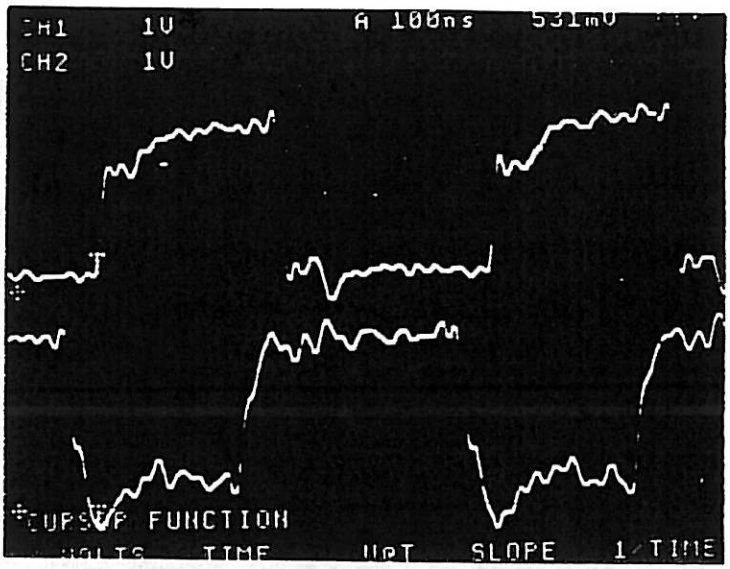
SECTION B SCOPE SHOT #19



SECTION B SCOPE SHOT #20

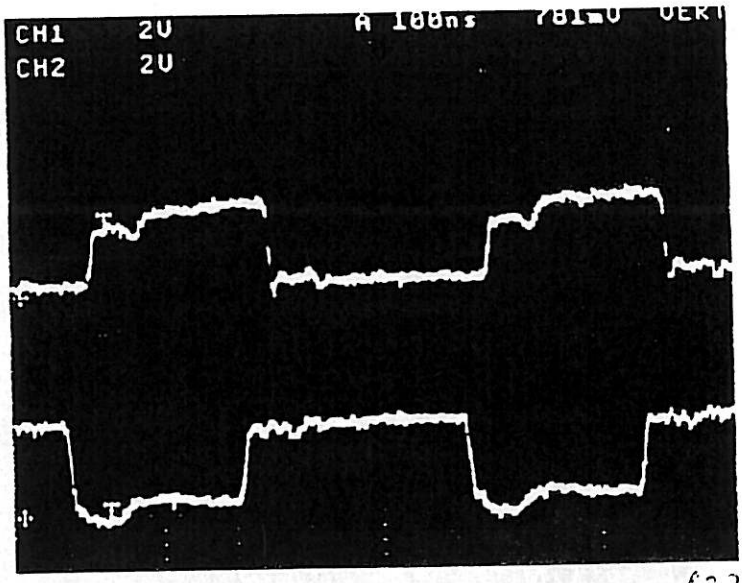


SECTION B SCOPE SHOT #21



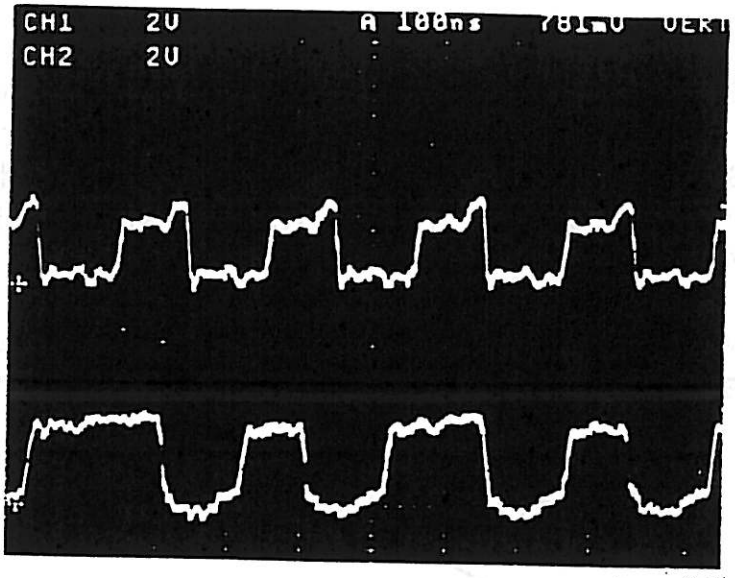
B21

SECTION B SCOPE SHOT #22



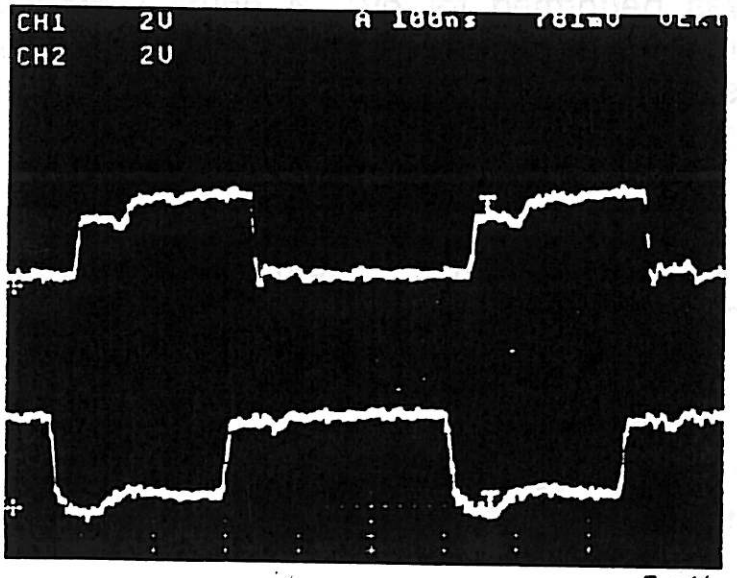
B22

SECTION B SCOPE SHOT #23



B23

SECTION B SCOPE SHOT #24



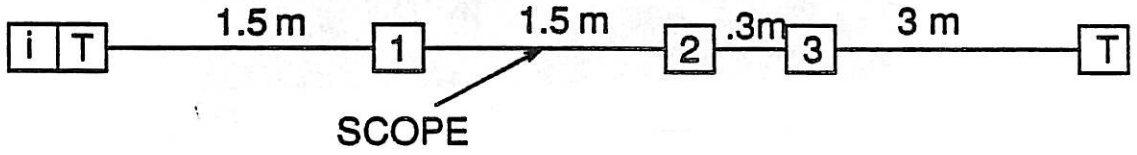
B24

SCOPE SHOTS - initial clustering:

Initial cluster testing was performed on the Adaptec using different drive clusters than the preferred configuration. Due to limited test time with the sample cables, the results of these tests are detailed here to show the observed effects of cluster loading with the 93 ohm impedance cable. Future reports will detail cluster testing more fully.

The following configurations were used with the 6.4 meter 93 ohm SCSI-2 cable:

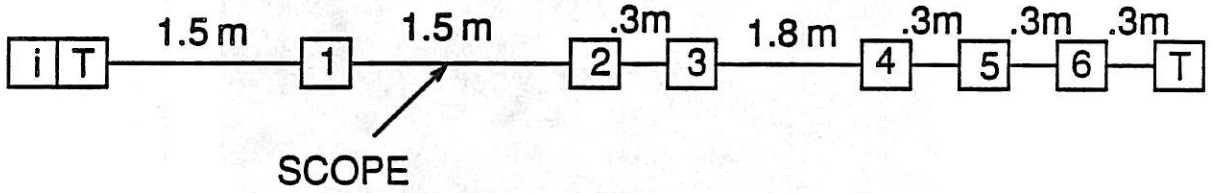
#1)



i=initiator T=220/330 ohm termination network
1=target test drive 2&3=cluster load drives

Term power was set at 5.01 volts at the initiator. Async and sync testing was performed for over 4 hours without errors on target number 1, while devices 2 and 3 were connected with power on but not accessed. See scope shots on next page for REQ/ACK signal quality, figure 26 and 27.

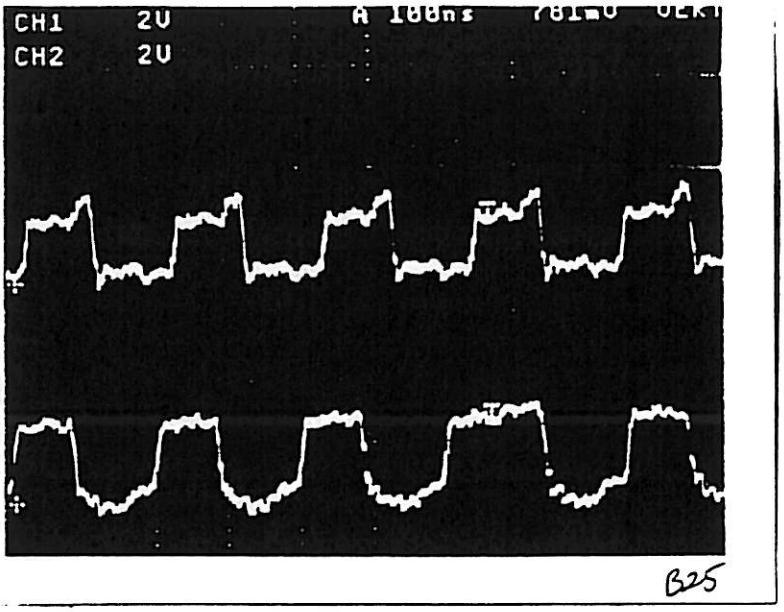
#2)



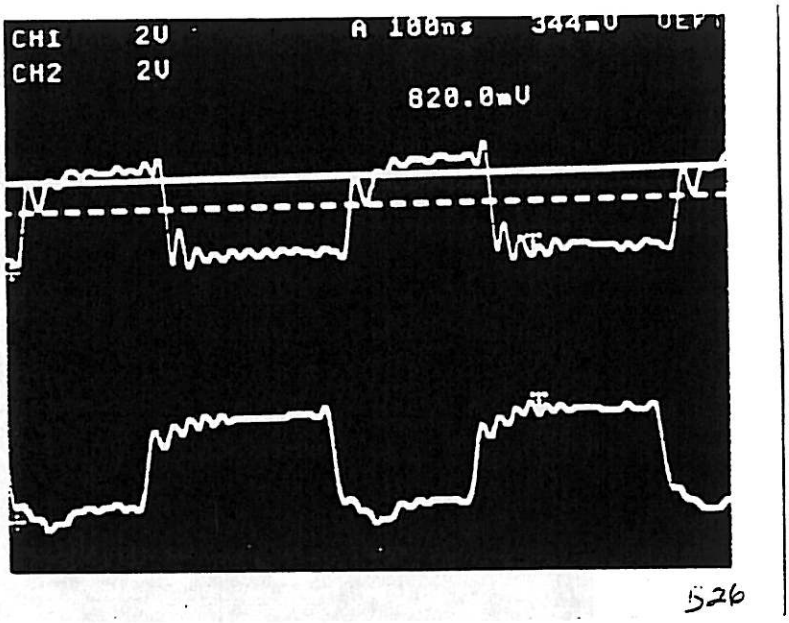
i=initiator T=220/330 ohm termination network
1=target test drive 2-6=cluster load drives

Again, term power was originated at the initiator at 5.0 V. Async and sync testing was performed for over 4 hours without errors on

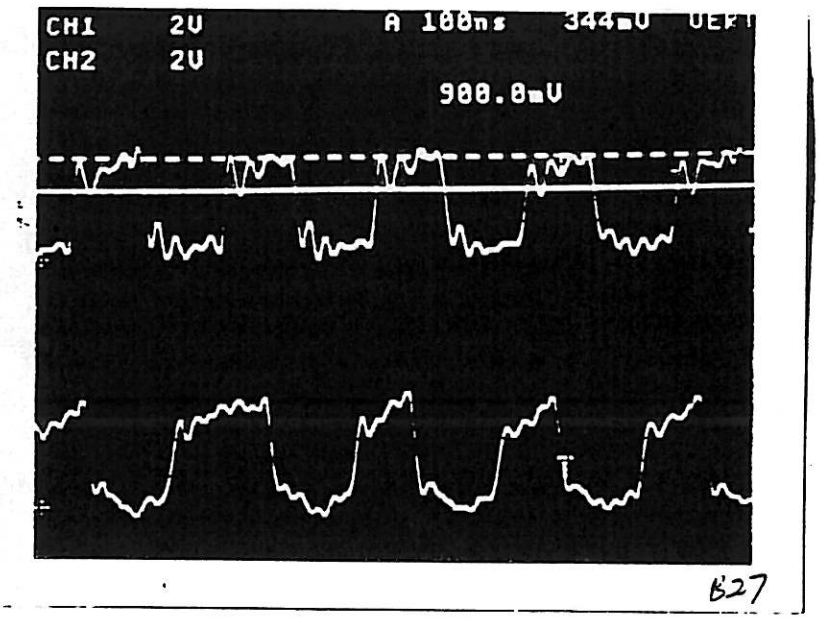
SECTION B SCOPE SHOT #25



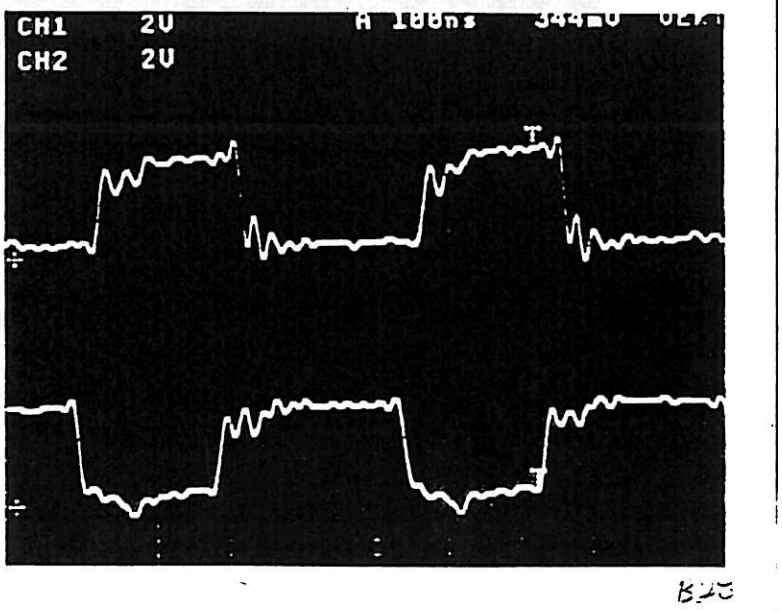
SECTION B SCOPE SHOT #26



SECTION B SCOPE SHOT #27

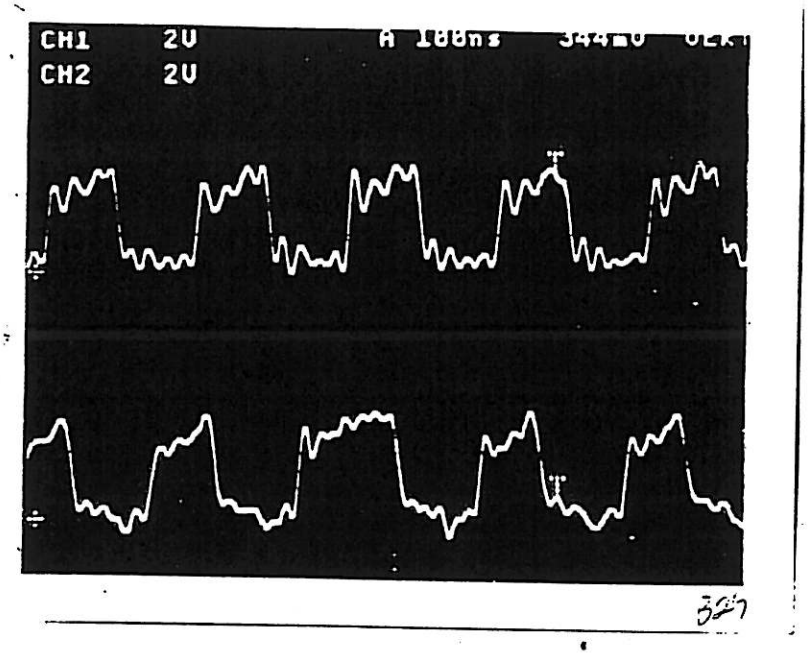


SECTION B SCOPE SHOT #28



target number 1, while devices 2 through 6 were connected with power on but not accessed. See scope shots on next page for REQ/ACK signal quality, figure 28 and 29.

SECTION B SCOPE SHOT #29



C. System Testing

The following companies have or will supply cable assemblies built to our assembly specifications: AMP Inc., Amphenol, Icontec and Quintec, 3M, and possibly Stewart/T&B. The cable vendors used are Astro, C&M, Furukawa, Madison Cable, 3M, and Hitachi. The connector vendors are AMP, Honda, Fujitsu, 3M, and Stewart. Terminators are being supplied by AMP, Amphenol, Fujitsu and Methode.

Typically, vendors supplied the following assemblies for testing at the Sun West Coast facility:

8 each 0.45 meter shielded SCSI-2 male-male cable
5 each 1.20 meter shielded SCSI-2 male-male cable
2 each 2.00 meter shielded SCSI-2 to Sun SCSI D-sub cable

Data rates to 5 MHz were observed with the VH-01 host adapter and the Maxtor 8760S disk drive. Term power drops up to 230 mV were observed on the combination cable tests. The termination power has as of this time not been margined, but is planned for future testing.
Test results will be available in a seperate handout.

Sun East Coast facility system testing has just been started. Test reports will be available in the next report.

Conclusions/Recommendations
Preliminary

All information assumes single-ended SCSI implemented with synchronous data transfers up to 5 MHz rates. No testing done with differential drivers/receivers.

Observations:

- voltage drops of up to 550 mv with 6.4 meter length cable
- lowest term power supplied that still worked >2hours - 4.5 Volts
- regardless of signal appearance, SCSI system is operational
- using 75 ohm cable resulted in lower signal quality, reduced term power error margins
- mixing high density cables with the higher 100 ohm impedance external cables improved performance and signal quality

Recommendations:

- maintain term power >4.75 Volts
- use a Schottky diode with fuse to supply power to bus
- certain devices at points along the bus could/should provide term power as above if long cables (near spec limit) are used
- SCSI-2 cables should be specified at as high a characteristic impedance as possible, > 93 ohms, preferably 100 ohms
- changing the termination Thevenin equivalent impedance and/or implementing an active network still needs testing in an attempt to improve upon design margins using low (<93 ohm) impedance cables (put into SCSI-2 as an alternate term network for long bus lengths when using single-ended drivers/receivers?)
- allow another 30-60 days for all vendors to supply cable samples, to test active SCSI termination networks, to verify further cluster testing, and to prepare a complete test report for the committee

APPENDIX A

VENDOR CONTACT LIST

For C&M 100 ohm shielded cable with AMP and Honda connectors, passive and active terminators:

Amphenol Corporation
Interconnect Products Division
Endicott, NY
Bill Sopchak, Product manager (607)786-4307

QuadRep, Inc.
Richard Somers, V.P. (408)432-3300

For Furukawa 70 ohm shielded cable with AMP connectors and for high density terminators, 75 and 93 ohm hi-density cable with Modu-50 and SCSI-2 connectors:

AMP Incorporated
Intercom Division
Harrisburg, PA
Robert Whiteman, Product Manager (717)780-7481
Charles Brill, Computer Standards, (717)561-6198

For 100 +/- 10 ohm shielded cable:

Astro Wire and Cable
Worcester, MA
Peter Blackford, Chief Engineer, (800)447-1128, (508)754-3281

For 110 ohm +/- 10 % differential cable
Icontec Incorporated
Manufacturing and Assembly,
Milpitas, CA
Allen Haigh, V.P. (408)945-7766

For connectors, terminators, and Furukawa cable contact:

Fujitsu Components of America, Inc.
Santa Clara, CA
Joel Urban, Marketing Manager, (408)562-1722
Bob Thornton, Product Engineer, (408)562-1735

For 105 +/- 7 ohm and 120 +/- 10 ohm shielded cable:

Madison Cable
Worcester, MA
John Osborne, Product Manager, (508)752-7320

For inline and end-of-line terminators:

Methode Electronics
Chicago, IL
John Cannon, Product Manager, (312)867-9600 x 371
Bob Masterson, Applications Engineering Manager,(303)695-1333
Roger Fontenot, Sales Engineer, (408)262-3812

For providing Astro or Madison cable:

Quintec Interconnect
San Jose, CA
Greg Sulger, Sales Engineer, (408)272-8000

For providing 75 and 93 ohm hi-density cables with private interconnect:

3M Company
Electronic Products Division
Austin, TX
Bob Herron, Product Manager, (512)984-6807