HEWLETT PACKARD

AMP SCSI-2 Cable Comparisons

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1. OBJECTIVES

The following tests were conducted to detect *differences* in system data integrity when using SCSI-1 (.050-center) flat ribbon cables and SCSI-2 high-density (.025-center) cables provided by AMP.

2. TEST CONFIGURATION

Four cable configurations were tested (Figure 1):

A. A 7-device asymetrical system being driven from one end. A five-device cluster and a 2-device cluster are separated by 4 meters of shielded cable. The signal under test is driven from the first device in the chain.

B. The same system as (A), but driven from a device in the middle of the chain.

C. A 5-device symmetrical system consisting of two shielded segments, driven from one end. Once device is in the middle, with two at each end.

D. The same system as (C), but driven from the middle of the cable.

The device breadboards were designed to duplicate transceiver circuitry on a real SCSI device. The hardware for each device breadboard is shown in Figure 2. Standard off-the-shelf TTL receivers were used (74LS240) to receive the SCSI bus signals. A .1 meter stub was used with a load capacitor which brought the total capacitance to 24-26 pF, measured at the SCSI-1 connector. SCSI-2 to SCSI-1 adapter boards provided by AMP were used to adapt the SCSI-2 cables to the breadboards.

Each "receiver" breadboard contained counters which recorded the number of positive and negative edges received, and communicated the result back to the transmitter.

A single "transmitter" breadboard was built with all the receiver components, plus a state machine and open-collector driver to transmit pulses down the cable. If the number of transmitted edges did not match the number of received edges for any one breadboard, an error was noted.

Each terminating breadboard had adjustable potentiometers for the termination resistors. Five combinations were tested across all four cable configurations, resulting in 20 test cases. The five termination resistor combinations consisted of:

1. 220/330-ohm terminations, representing the nominal case. The equivalent termination resistance of this combination is 132 ohms.
2. 231/347-ohm terminations, representing the case where the pullup resistance is high by 5%, and the pulldown resistance is also high by 5%. The equivalent termination resistance of this combination is 139 ohms (the highest recommended by the SCSI-2 spec). Since the impedance mismatch between cable and terminator is *greater* than the nominal, one would expect poorer signal quality for this case.
3. 209/347-ohm terminations, representing a -5%/+5% case. This results in a 130-ohm termination, the lowest permitted by the 5% recommendation. Since the impedance mismatch is *less* than the nominal, one would expect *better* signal quality for this case.

4. 231/314-ohm terminations, representing a +5%/-5% case. This results in only a slightly higher impedance of 133 ohms, but also represents the lowest DC bias point for deasserted signals. A nominal signal at TERMPWR=5.0 rests at 3.0V when deasserted. With this combination, the signal rests 120 mV lower. One would expect *poorer* signal quality with this configuration.
5. 110-ohm terminations, with TERMPWR lowered to simulate local regulation near 2.85V. One would expect *better* signal quality with this configuration.

3. TEST STRATEGY

Since low TERMPWR has been a common factor in all the failing systems tested thus far, it was decided to evaluate each cable by the amount of additional TERMPWR over the nominal case required to prevent failures - a "TERMPWR budget" perspective.

The strategy consisted of, for each of the 20 combinations of 4 topologies and 5 termination networks, slowly lowering TERMPWR until an error occurred. The voltage at the error was noted, along with the position of the failing device on the cable. This was repeated until two and three devices failed, but only the results pertaining to the first error are of general interest.

3.1 PRECISION

- Termpower voltage of first error: to nearest 5 millivolts. This is an objective measurement made by monitoring a logic analyzer and high-precision digital multimeter.
- Termpower voltage to guarantee strict SCSI-2 compliance (no spurious transitions across the 0.8/2.0V thresholds: to nearest 100 millivolts. This is a subjective measurement made by visual observation of the oscilloscope.
- Termination resistance adjustment: to nearest 0.5 ohms, using multi-turn 0-500 ohm potentiometers, measured with high precision digital multimeter.

3.2 ACCURACY

None of the instruments used were calibrated to a certified standard recently. However, all have shown consistent precision and ability to take comparative measurements. Many of the instruments were cross-checked with other instruments and were found to agree within the precision specified in this report.

3.3 REPEATABILITY

The measurements made were repeatable to within 10 mV. The same set of instruments were used throughout the measurements to help ensure accurate comparisons between various configurations. Test boards were labeled and always used in the same positions in the test fixture for each configuration across all cables.

4. CONCLUSIONS

The findings were remarkably consistent with theory: the lower impedance cables, the higher impedance resistor combinations, and the worst-case bus topologies all resulted in poorer signal quality.

Figures 3,4, and 5 show the raw data. In almost every case, the SCSI-1 (105-ohm) cables outperformed the AMP (93-ohm) cables which in turn outperformed the AMP (75-ohm) cables.

Figure 6 shows the comparison from two different perspectives: percentage TERMPWR increase over SCSI-1 as a function of topology, and as a function of the termination network. Overall, AMP(93) cables were 3.8% worse, AMP(75) cables were 5.5% worse.

Some other general observations:

1. Driving from the center of a cable is a much more stringent test of the cabling system than driving from one end. The driver is actually seeing the two halves of the cable in *parallel* (half the characteristic impedance). Signals arrive at the two terminators at approximately the same time, sending two sets of reflections back to compound at the center.

2. The same device positions failed first in the same topologies, regardless of cable type. Typically, the devices *closest* to the signal source were the most susceptible to failure.

   a. Device 2 was the first to fail in Configuration A (followed by device 1).
   b. Device 3 was the first to fail in Configuration B (followed by 6).
   c. Device 3 was the first to fail in Configuration C (followed by 5 and 2).
   d. Device 2 was the first to fail in Configuration D (followed by 3 and 1).

   The nominal case did not perform the best. The worst 5-volt termination network was +5%/+5% (0.25V worst than nominal). The best case was -5%/+5% (0.25V *better* than nominal). Thus a difference of 0.5 volts was observed due to resistor tolerances alone in some configurations.

3. The most reliable termination configuration was the 2.85V/110 ohm scheme. The terminating voltage required to induce an error was 2.63V in the worst case (AMP/75 cables in Configuration B). 5% regulation of 2.85V will be sufficient to ensure signal quality under these conditions.

4. A somewhat alarming observation was that all of the Configuration B systems and most of the Configuration C systems failed to meet the SCSI-2 requirement of 4.25V. Keep in mind that worst-case capacitive loads and stubs were being used, that testing was not performed in a shielded environment, and that TERMPWR supply cabling may not be typical of real systems. SPICE simulations will be performed to correlate the bench data.

5. Errors were observed on Configuration B when TERMPWR was *above* or beyond 5.0V (Figure 7). The higher voltage caused a step in the middle of the rising edge to rise into the threshold of the receivers. The error voltage varied with termination resistance from 4.97 to 5.24 volts for the SCSI-1 cable, and was higher for the others. This reminds us that keeping TERMPWR as high as possible is only a makeshift solution: the better remedy is to more closely match impedances, as the 110-ohm results indicate.

6. Errors occurred in voltage *bands*. Generally, when a device detected an error, it would function error-free a few tenths of a volt lower; errors were not strictly cumulative as voltage decreased, down to a certain point where no edges are detected. This effect was not explored in detail.

7. Using the strict interpretation of the SCSI-2 standard (2.0 and 0.8V) by looking at oscilloscope traces showed much worse performance than the "typical" TTL transceivers used would indicate. A system that is error-free may or may not meet the SCSI-2 specification. If a "worst-case" receiver were designed (as we have done) it would fail (as we have observed) in most of these cases.

5. FUTURE INVESTIGATION

The next phase of testing will involve the following:

a. Combine 2.85/110 termination networks with conventional terminators.
b. Use SPICE to try to correlate the results of this testing
c. Investigation into the transmission line behavior of the TERMPWR wire itself.
d. Measurement of crosstalk in the above cables.
e. Comparison of the above cables with Stewart cables.

SCSI-2 CABLE EVALUATION

CONFIGURATIONS

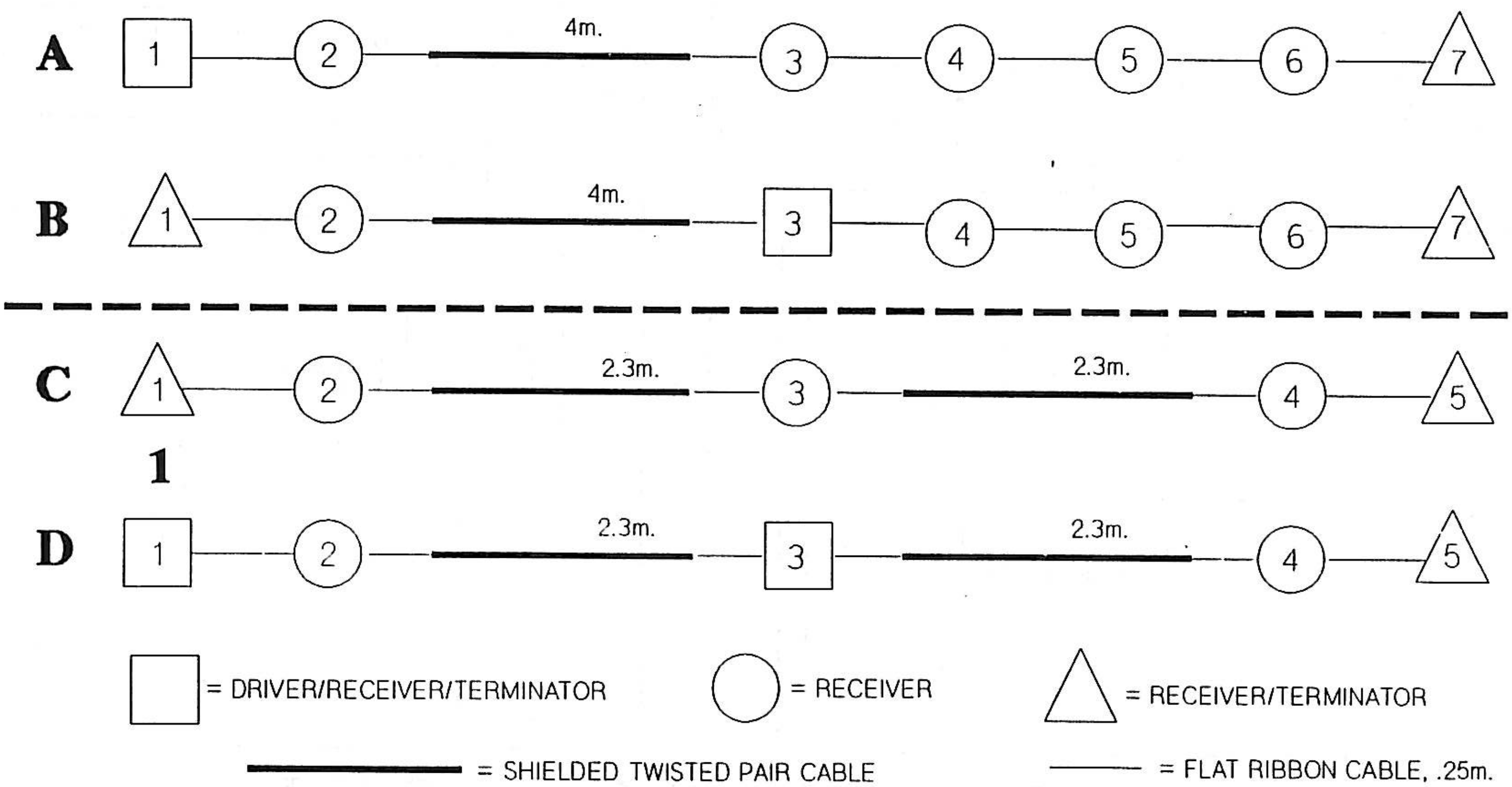

FIGURE 1

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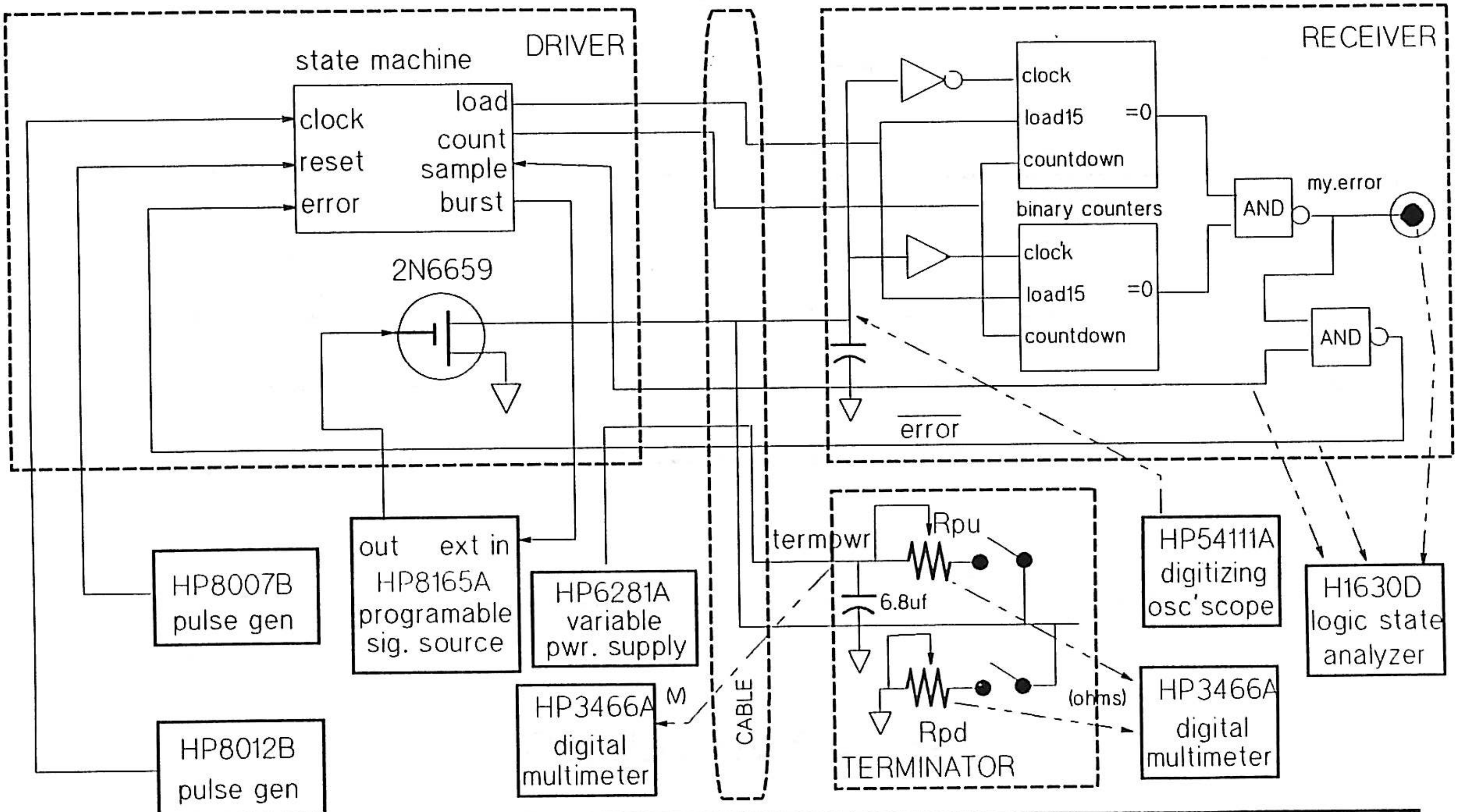
SCSI-2 CABLE EVALUATION

BENCH TEST COMPONENTS



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FIGU 2

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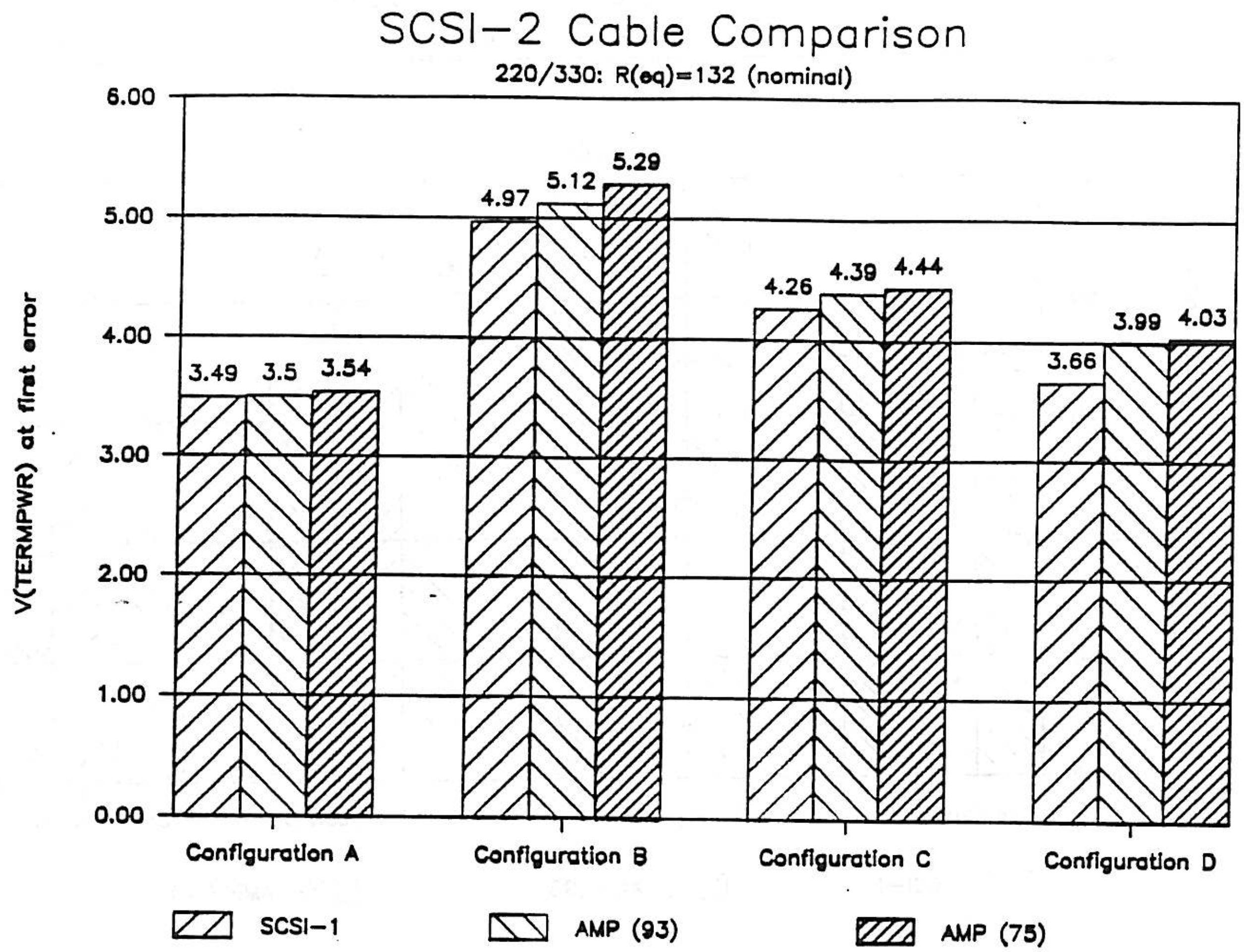
SCSI-2 Cable Comparison
220/330: R(eq)=132 (nominal)
V(TERMPWR) at first error
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.49
3.5
3.54
4.97
5.12
5.29
4.26
4.39
4.44
3.66
3.99
4.03
Configuration A
Configuration B
Configuration C
Configuration D
SCSI-1
AMP (93)
AMP (75)

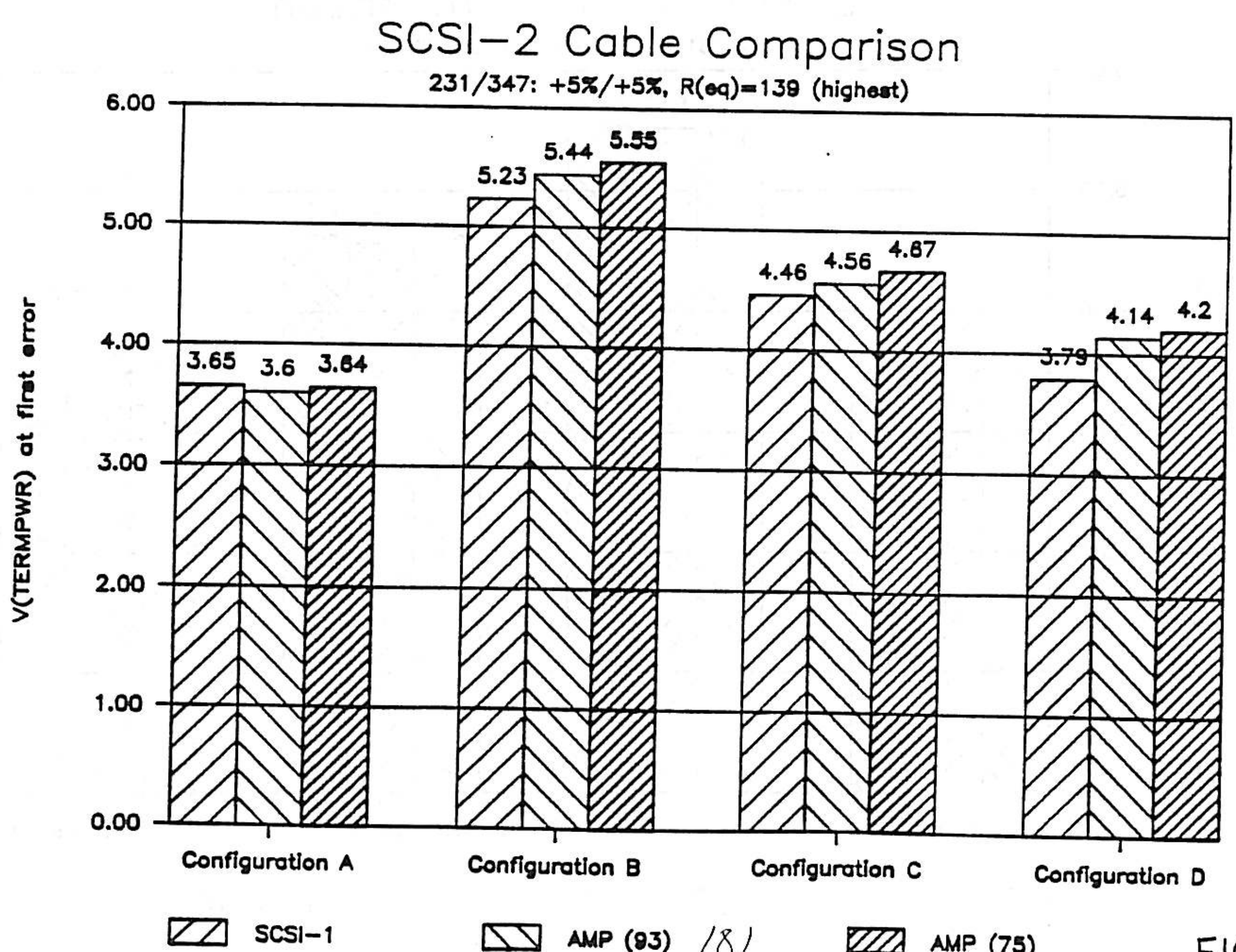
SCSI-2 Cable Comparison
231/347: +5%/+5%, R(eq)=139 (highest)
V(TERMPWR) at first error
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.65
3.6
3.64
5.23
5.44
5.55
4.46
4.56
4.67
3.79
4.14
4.2
Configuration A
Configuration B
Configuration C
Configuration D
SCSI-1
AMP (93)
AMP (75)

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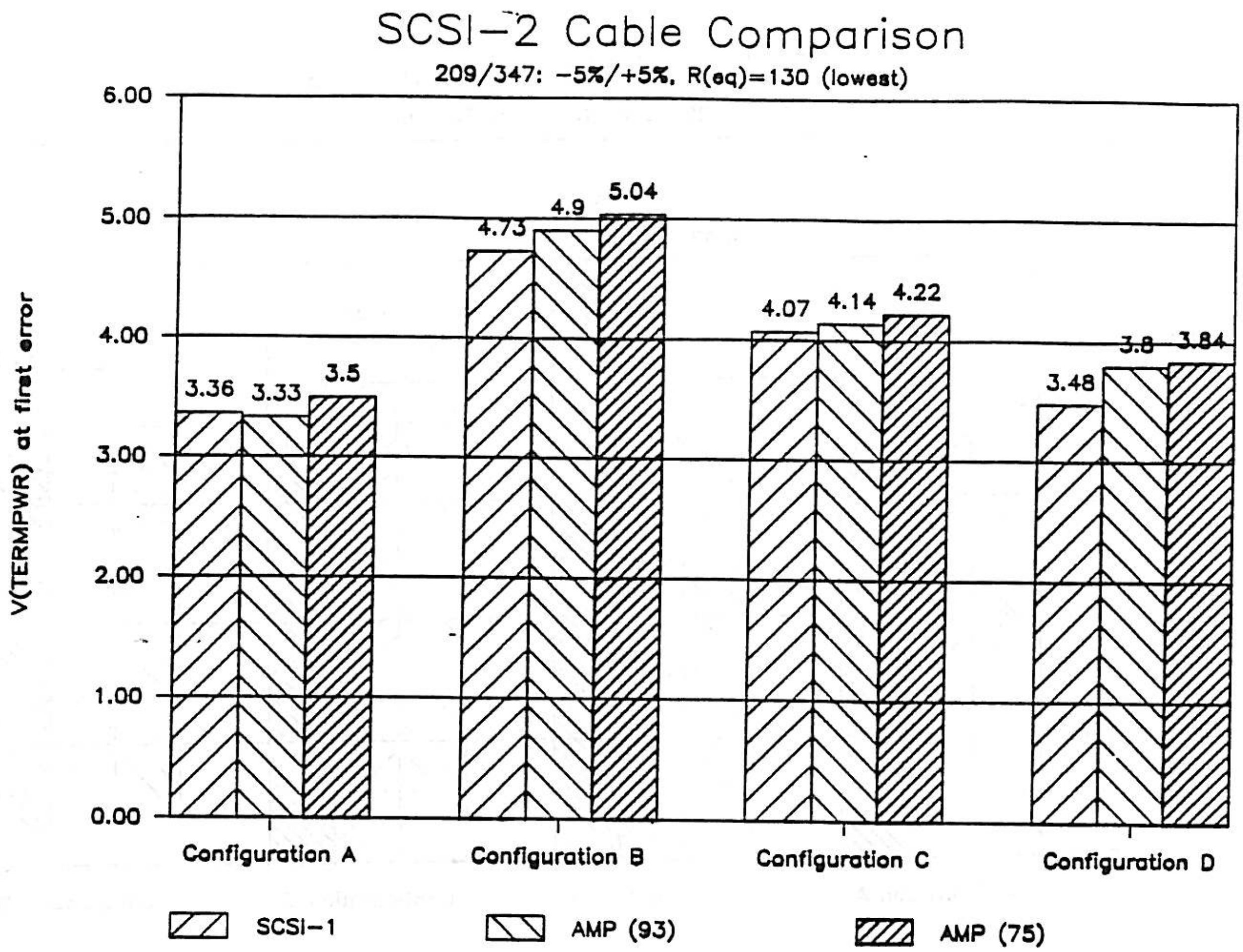
FIGURE 3


SCSI-2 Cable Comparison
209/347: -5%/+5%, R(eq)=130 (lowest)
V(TERMPWR) at first error
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.36 3.33 3.5
4.73 4.9 5.04
4.07 4.14 4.22
3.48 3.8 3.84
Configuration A
Configuration B
Configuration C
Configuration D
SCSI-1
AMP (93)
AMP (75)

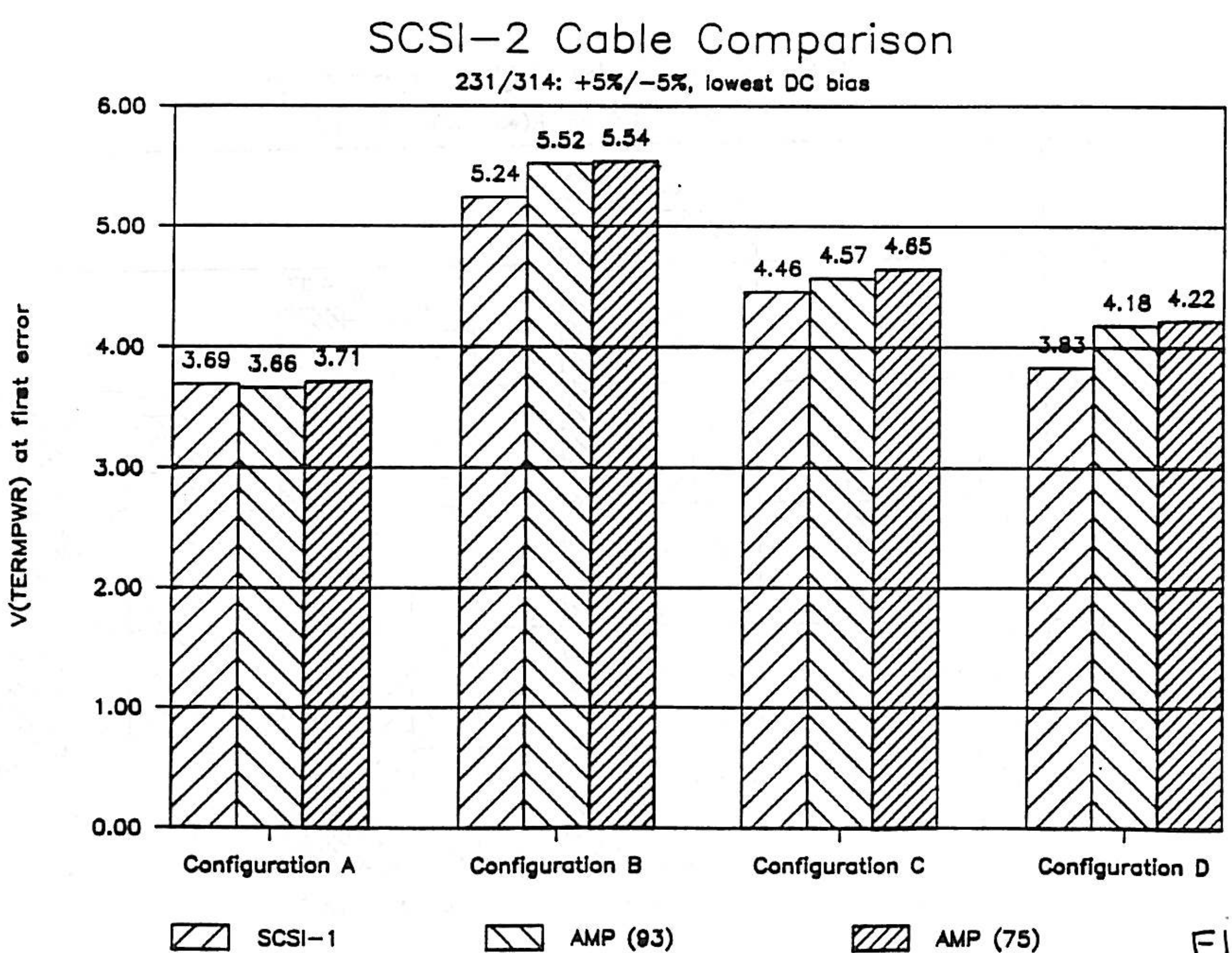

SCSI-2 Cable Comparison
231/314: +5%/-5%, lowest DC bias
V(TERMPWR) at first error
6.00
5.00
4.00
3.00
2.00
1.00
0.00
3.69 3.66 3.71
5.24 5.52 5.54
4.46 4.57 4.65
3.83 4.18 4.22
Configuration A
Configuration B
Configuration C
Configuration D
SCSI-1
AMP (93)
AMP (75)

FIGURE 4

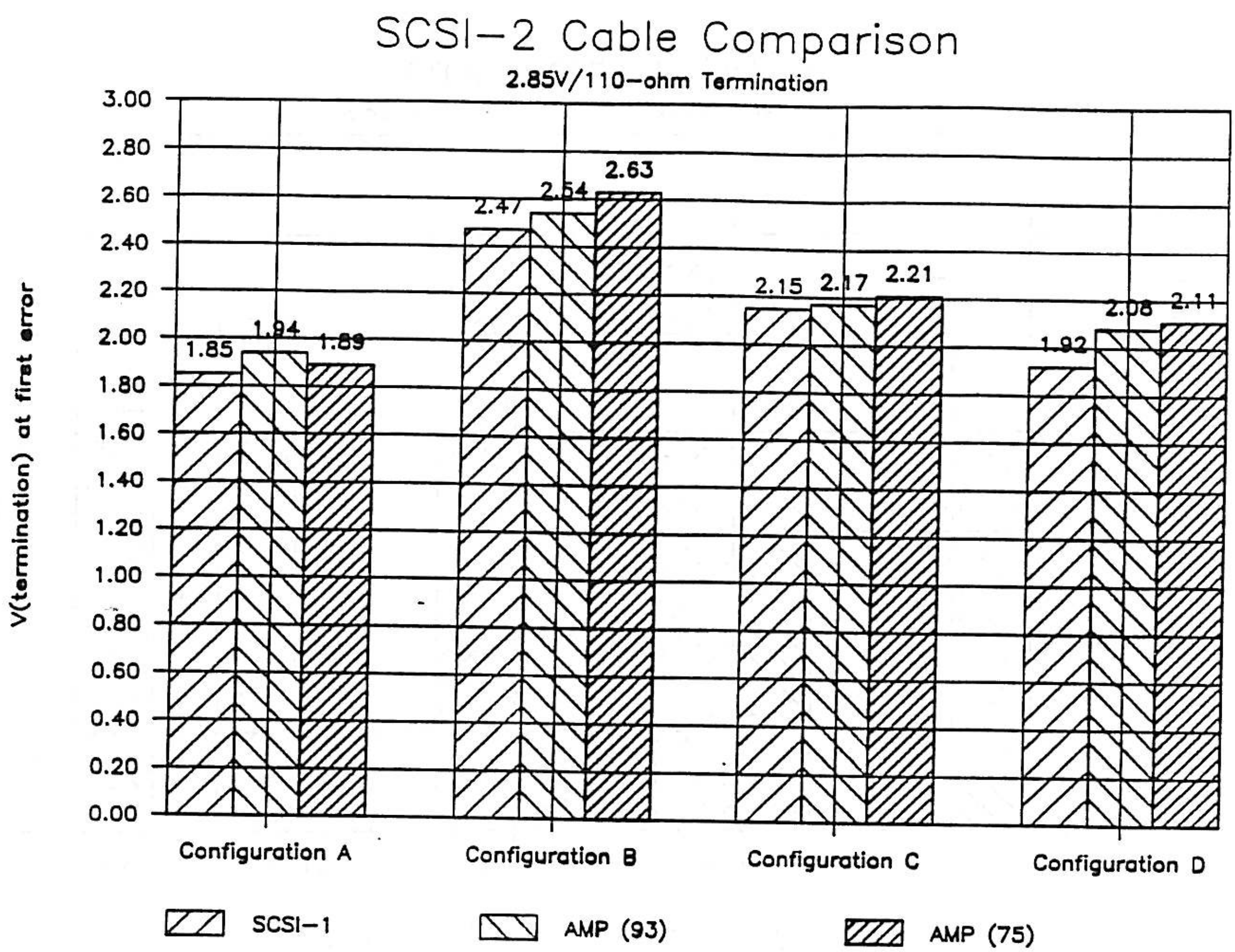
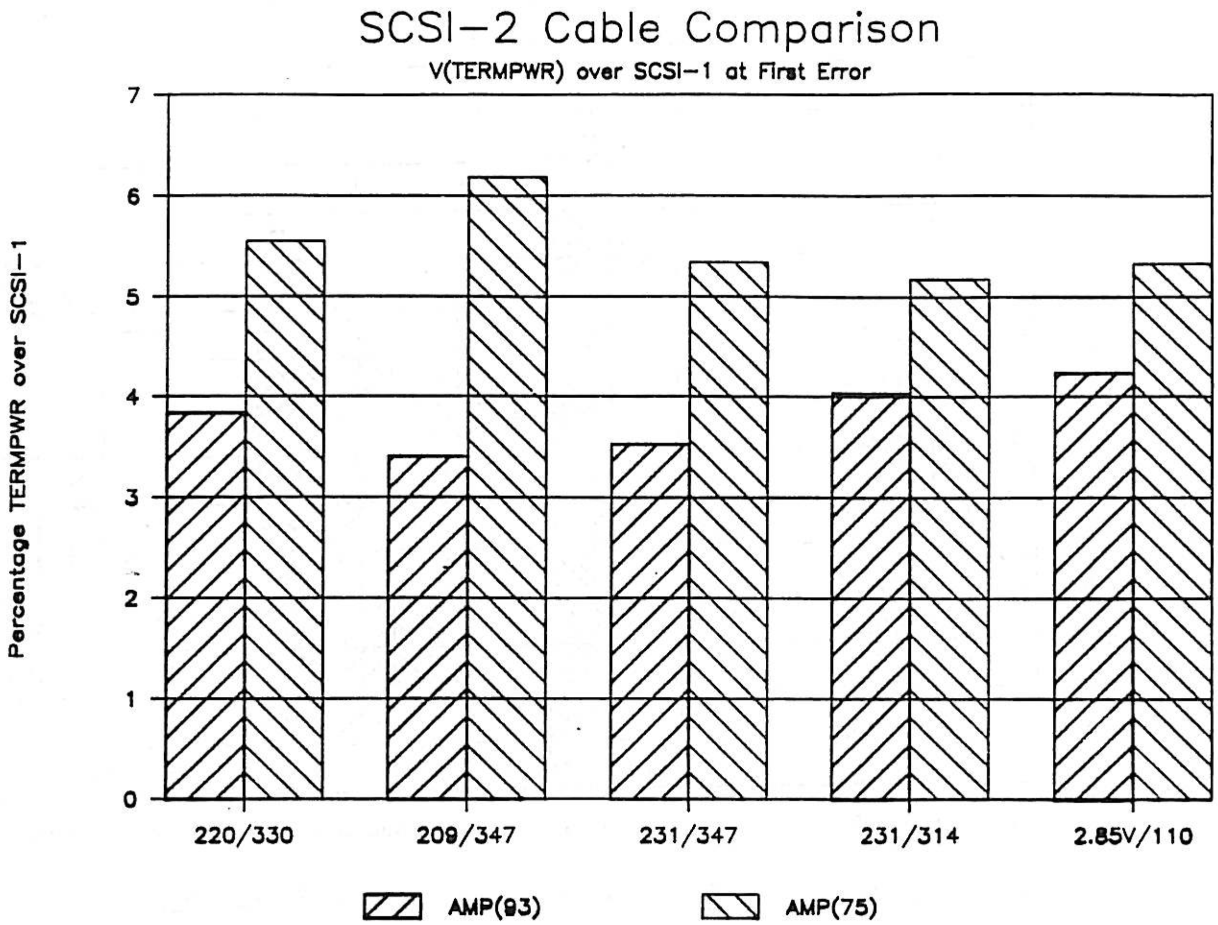

SCSI-2 Cable Comparison
2.85V/110-ohm Termination
V(termination) at first error
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.85
1.94
1.89
2.47
2.54
2.63
2.15
2.17
2.21
1.92
2.08
2.11
Configuration A
Configuration B
Configuration C
Configuration D
SCSI-1
AMP (93)
AMP (75)

FIGURE 5


SCSI−2 Cable Comparison
V(TERMPWR) over SCSI−1 at First Error
Percentage TERMPWR over SCSI−1
0
1
2
3
4
5
6
7
220/330
209/347
231/347
231/314
2.85V/110
AMP(93)
AMP(75)

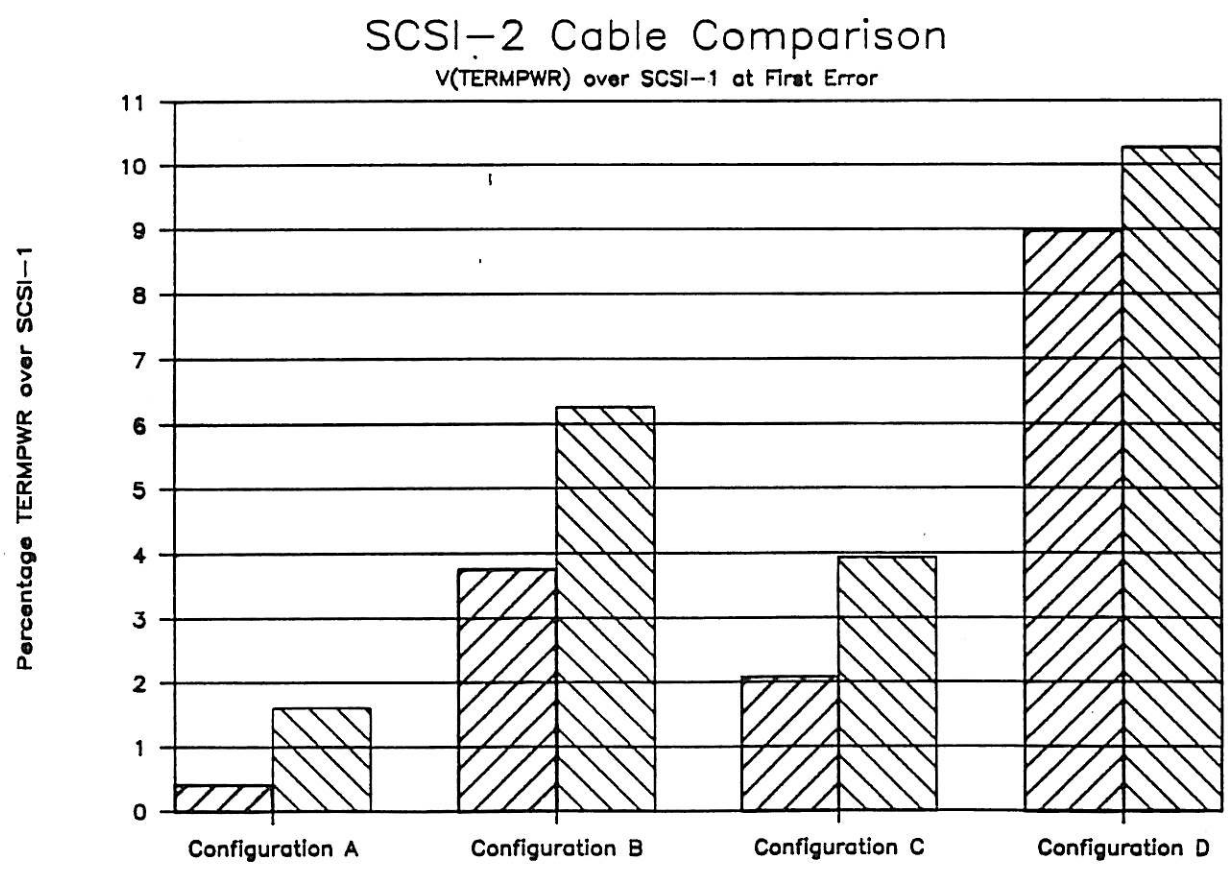

SCSI−2 Cable Comparison
V(TERMPWR) over SCSI−1 at First Error
Percentage TERMPWR over SCSI−1
0
1
2
3
4
5
6
7
8
9
10
11
Configuration A
Configuration B
Configuration C
Configuration D
AMP(93)
AMP(75)

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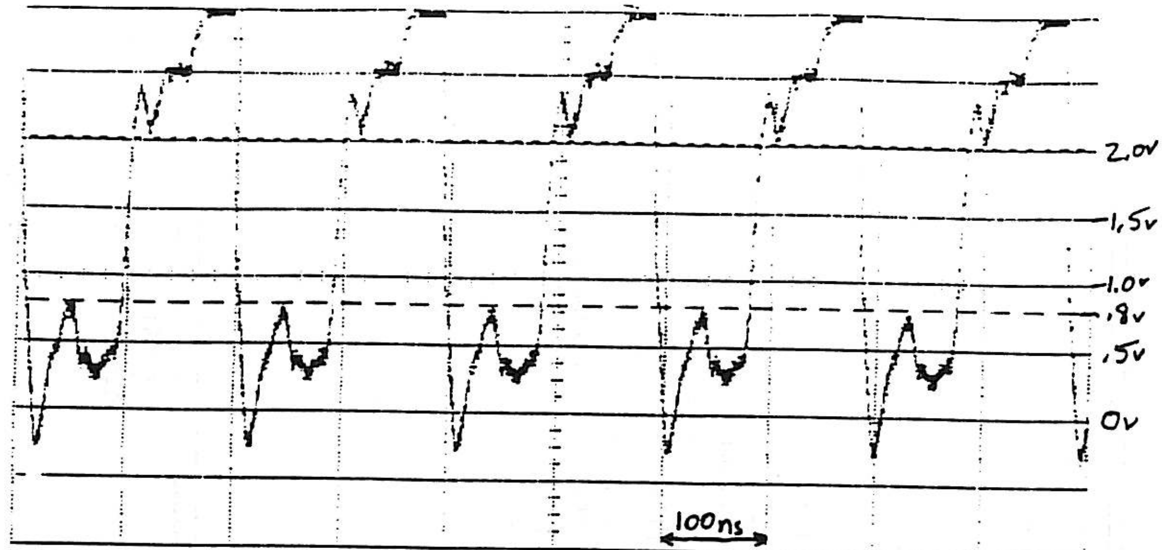
FIGURE 6



CONFIGURATION B
Terminators = 220/33
LOCATION #6
CABLES = 75-105-75
Termpower = 5.98 V.

NOISE BAND IS CLEA ONLY AT THIS VOLTAGE ABOVE, LOWER END IS VIOLATED, BELOW, UPPER END IS VIOLATED.

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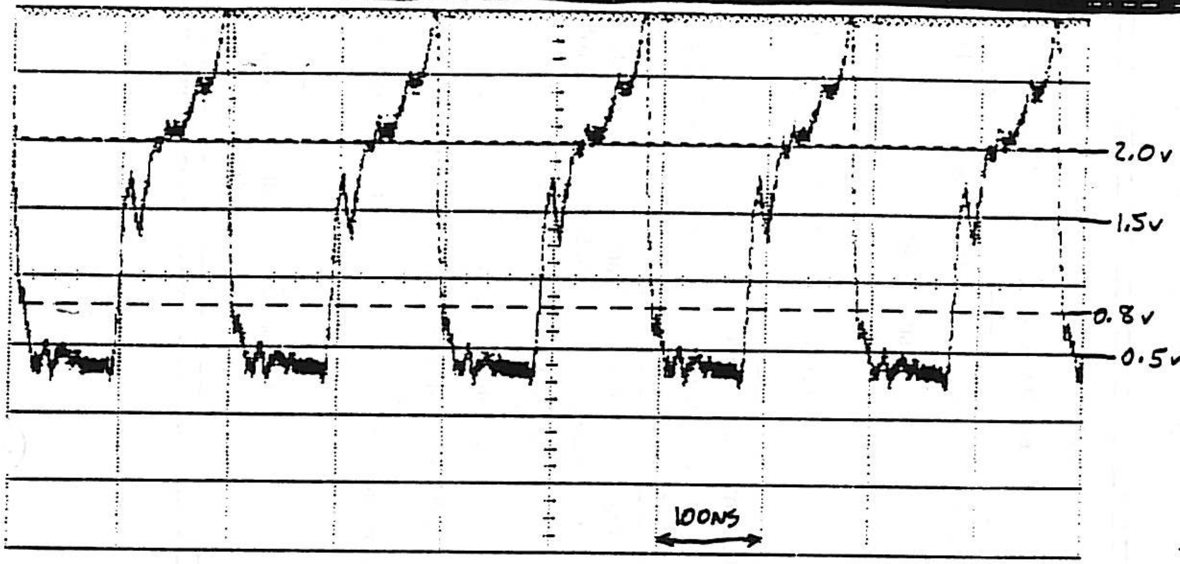
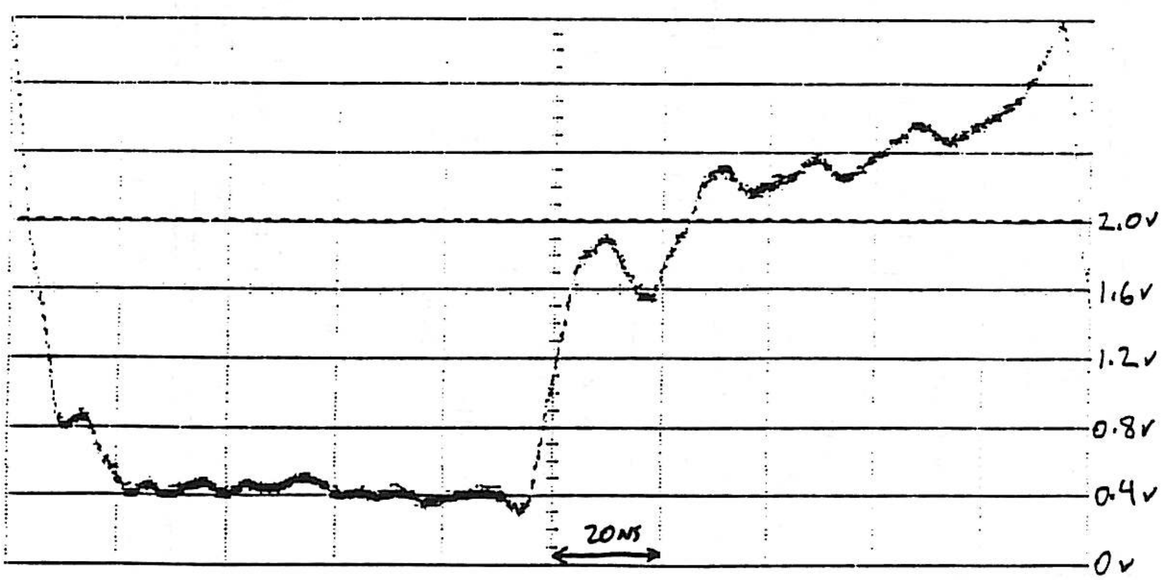


Configuration B
AMP 93 ohm short cables
Location #3
$V_{Termpwr} = 5.0v$

Error detected

890414
G Matheson



Termpower = 2.85v
Terminator = 110 Ω
CABLES = 75-105-75
CONFIGURATION #B
LOCATION #3

GLITCH IN NOISE BAND ON RISING EDGE

890413
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FIGURE 7

SCSI-2 CABLE EVALUATION
BENCH TEST INSTRUMENTATION SPECS

INSTRUMENT	PURPOSE	SPECIFICATIONS and ADJUSTMENTS
HP8007B Pulse Generator	Manual reset of state machine on driver board	Manual Trigger Amplitude = 0 to 4 v. rise/fall = minimum Positive Pulse 50usec pulse duration
HP8012B Pulse Generator	Square-wave clock for driver state machine	Square wave Amplitude = 0 to 3.0v. rise/fall=minimum Positive Pulse 10 usec period
HP6281A Variable Power Supply	Adjustable Termpower	0-7.5V 0-5amps millivolt vernier
HP8165A Programmable Signal Source	Generate pulse streams to drive test signal	Function=Square Wave Duty Cycle = 50% Amplitude = 4.0v. Offset = 1.0 v. Frequency = 5.0 Mhz. Burst= 15. Mode = External Trigger. External Input = 1Mohm 10:1 attenuating probe.
HP1630D Logic Analyzer	Monitor detected errors on receivers	Continuous trace. Start and store on state (SAMPLE * ERROR). Clock on rising edge of 8012B output. Probe MY.ERROR on every receiver. Observe LIST screen for trace activity to detect and pinpoint errors.
HP54111B Digitizing Oscilloscope	Examining waveforms & Adjusting Termpower	1 Megaohm, 7.5pf, 10:1 attenuating probes. Not to be attached while determining data errors.
Custom Receiver Circuit		0.1m wiring stubs. 25pf total capacitance, with capacitor added. 2 74LS240 inputs
HP3466A Digital Multimeters	Measure Termpower and termination resistors	Precision to 1 millivolt in 5 volts, 0.1 ohm in 500.

FIGURE 8

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