

NEW LOW COST MEDIA FOR DEVICENET™

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Presented at the ODVA
2007 CIP Networks Conference & 12th Annual Meeting
September 18-20, 2007
Englewood, Colorado USA

Abstract

In keeping DeviceNet competitive with other low level networks in the market place, a new media option has been released for DeviceNet. This low cost media provides a whole new approach to installing DeviceNet networks saving both time and money through Insulation Displacement Contact (IDC) technology. This paper will describe the technical merits of the media including topologies and connectorization options. In addition this paper will provide time studies on installation time savings over the traditional DeviceNet media options.

Keywords

IDC, competitive

Introduction

DeviceNet has been a successful industrial device level network for over 10 years. In phase one of the release of DeviceNet the media was constructed as a 2 shielded pairs with one overall shield plus 1 drain wire. One of the short falls of this network was the complexity and time associated with the installation of the cabling system. The Thick and Thin cables were difficult and time consuming to prepare and terminate into connectors. DeviceNet supports three connector families in the original release, 1) Mini, 2) Micro and 3) open style. All of these connectors are 5 circuit type connectors designed to support Thick, Thin and variants of the round shielded type cables.

Phase II media was developed to address the installation time and complexity associated with connector installation. Studies showed that the installation time could be significantly reduced and simplified if the cable preparation phase could be eliminated. This was only possible by eliminating the shielding and changing the cable to a common access type cable whereby IDC termination technology can be employed. Installation of the IDC assemblies had to be capable of being installed anywhere along the trunk line. It was found during the investigation that a specific order of conductors was required to reduce and cancel the coupling of transients between the power conductors and the signal conductors within the cable. Further it was found that shunt capacitors were needed across the power conductors to quench transient that would otherwise couple into the data pair and disrupt communications (cross talk). The system was modeled, simulated, built, tested and released. This new media was compatible with UV, oil resistant, sealed environments while addressing the NFPA and UL Class II power limitation of the predecessor cables. The IDC cabling and connector system met its goal by reducing the installation time and complexity. However due to the environmental requirements imposed on this design the solution is relatively expensive.

Phase III

The Phase II media was successful in reducing the installation time. The fast termination and sealing added cost that is not always needed for many installations. Phase II (Flat) DeviceNet addressed the installation labor costs, however is still viewed by the industry to be high in material costs on a per node basis. Now Phase III is designed to reduce materials and labor. Sealing traditionally adds cost and complexity to the components. In addition connectivity of nodes to the drop cables and trunk line adds cost in layers of IDC and connectors. By removing these requirements from the design, it is possible to further reduce the component costs and installation labor. Keeping with the IDC technology provides a cost effective installation solution. A simple tool installation system, helps to reduce the installation costs to below flat cable where power screwdrivers are needed to install a base module on flat 600 V flat wire. The Type II flat cabling system (Phase III) connectors install with a pair of pliers.

This report is the results and methods for analyzing the Omron CompoBus cable for use with DeviceNet. The original CompoBuss system is a 100 Ω , 4 conductor system. The cable was redesigned in attempts to meet the cabling electrical performance requirements of DeviceNet media.

The redesigned CompoBus cable was evaluated. The electrical characteristics have been determined by standard lab measurement techniques by measuring the phase and magnitude of the cable in an open and short state. The electrical parameters obtained from the tests were inserted the margins calculation tool to determine the new network lengths. Since DeviceNet is a Delay, Amplitude (attenuation) limited network, delay, attenuation, DCR and capacitance parameters are measured. The theoretical maximum length verses data rate is in table 1. Included in the table are the limiting factors. For this analysis, the maximum drop length for any individual drop cable was held to 6 meters max.

Data rate	ODVA specification (Thick/Flat)	Type II theoretical trunk length	Cumulative drop length	Limiting parameter
125Kb/s	500/420 Meters	350 meters	159meters	Amplitude margin
250Kb/s	250/200 Meters	150 meters	78 meters	Amplitude margin
500Kb/s	100/75 Meters	55 meters	39 meters	Reflected delay margin

Table 1: Initial Theoretical Trunk Lengths

Connector Design

IDC Contacts

The IDC contacts were cross sectioned to determine the quality and reliability of the IDC contacts. It is desirable to be able to terminate DeviceNet Thin cable into the type II system. DeviceNet Thin signal conductors are 24 AWG stranded wires. The original IDC contacts did not support the 24 AWG Thin cable conductors. The connector wire entry and the IDC contacts were modified to support 24 gauge conductors and the flat Type II CompoBus conductors.

As in the current Flat connector system, each IDC tap must provide a 0.2uf/50V capacitor across V+ and V-, to reduce the transients from being coupled into the signal pair. The cross talk of the cable is high enough to cause noise in the signal pair due to changing loads in the power bus. It is convenient to provide the capacitor in the tap as each node requires a tap and therefore for each tap there will be one transient suppression capacitor.

Cable Tests

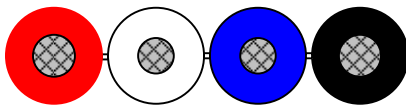
To maximize the trunk and drop budgets the cable must have the following electrical properties;

120 Ohms
High Velocity
Low capacitance
Low insertion loss

The original CompoNet cable was tested and found to have that the impedance and velocity was too low while the capacitance was too high. The cable was redesigned to meet the minimum requirements for DeviceNet. Because the frequencies are relatively low, cable electrical parameters can be determined by measuring the phase and amplitude of a small sample in an open and short mode. The impedance is then found by the following basic relationship;

$$Z_o = \sqrt{\frac{Z_{open}}{Z_{short}}}$$

The parameters were measured from 0.1MHz to 1 MHz. The following mechanical values were used to determine if the cable design would be close to the impedance needed for DeviceNet. They also provided a cross check for impedance for the electrical measurements. The dielectric constant for PVC can be as high as 5.0. However this cable is similar in construction to a lamp cord. The dielectric is partially air around the conductors which produces an effective dielectric of roughly 2.8



Using 20AWG wire, find the characteristic impedance

$$d := 0.031693 \quad D := .1 \quad \epsilon_r := 2.8$$

$$Z_0 := \frac{120}{\sqrt{\epsilon_r}} \cdot \operatorname{acosh} \left(\frac{D}{d} \right)$$

Equation (1)

$$Z_0 = 130.24$$

The Redesigned cable was tested and found to meet the minimum requirements of DeviceNet. The following graphs detail the frequency versus impedance, velocity, attenuation and capacitance of the redesigned cable, see Figure 1, Figure 2, Figure 3, and Figure 5 respectively.

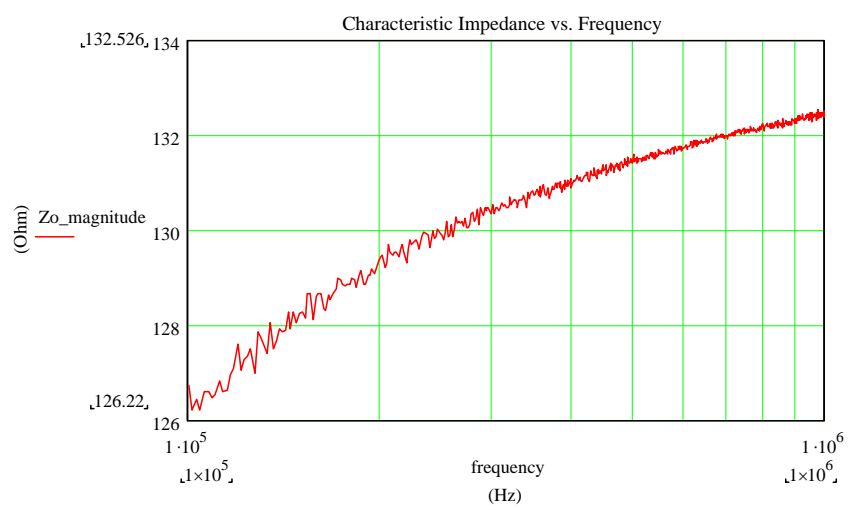


Figure 1: E2 Cable Impedance (100ft)

The impedance meets the limits of $120 \Omega \pm 10\%$ for DeviceNet cables.

The velocity was extracted from the open short phase and magnitude data and graphed

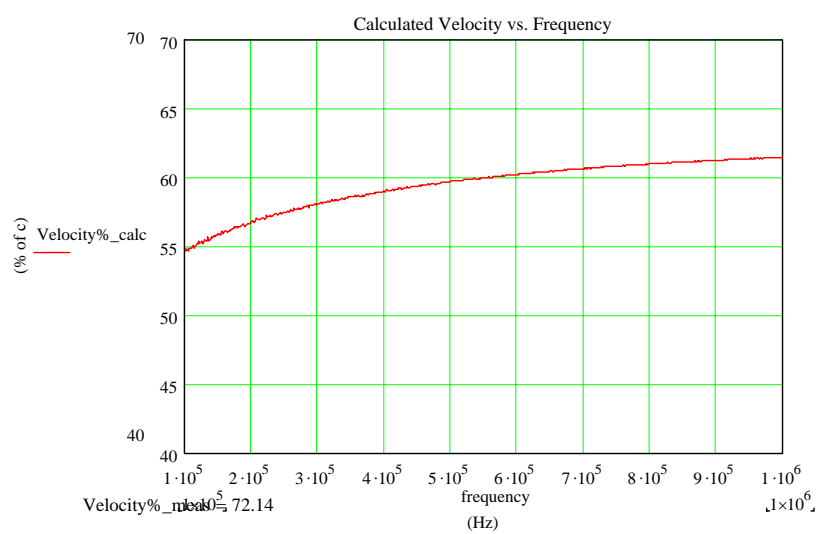


Figure 2 E2 Cable Velocity (100ft)

The velocity was found to be low compared to DeviceNet Thick and Thin cable profiles. However it is compatible to the Flat cable. Therefore the topology limits to be less than equal to the current Flat Type I cable

The attenuation was determined by two methods. 1) direct S21 NWA measurements and 2) by extracting the attenuation from the open short phase magnitude data. Both results are provided below.

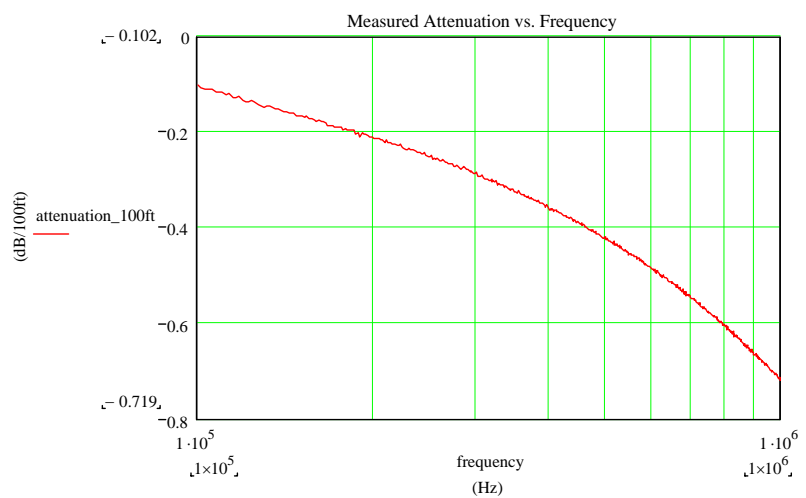


Figure 3 E2 Cable Measured Attenuation (100ft)

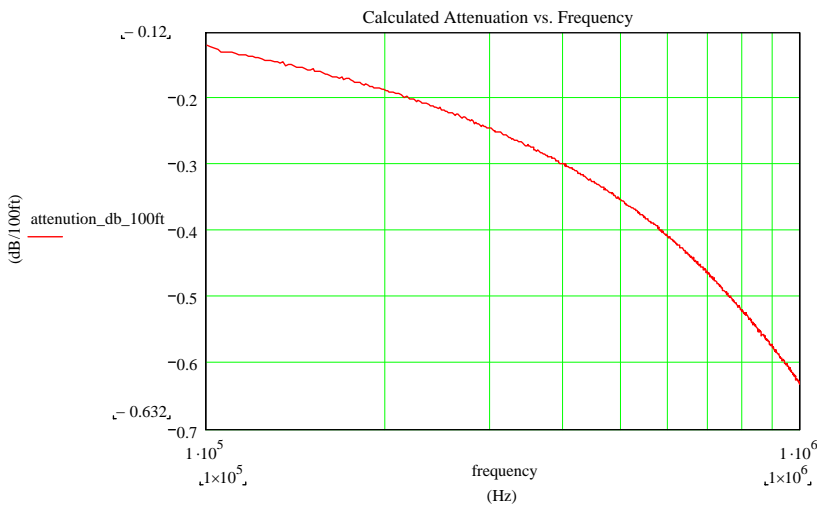


Figure 4: E2 Cable Calculated Attenuation (100ft)

Note that the measured attenuation and the calculated attenuation are within a small percentage of each other. The attenuation is compatible with DeviceNet Thick cable profile.

The capacitance was extracted from the open short phase and magnitude measurements and was found to be compatible with DeviceNet Flat cable profile.

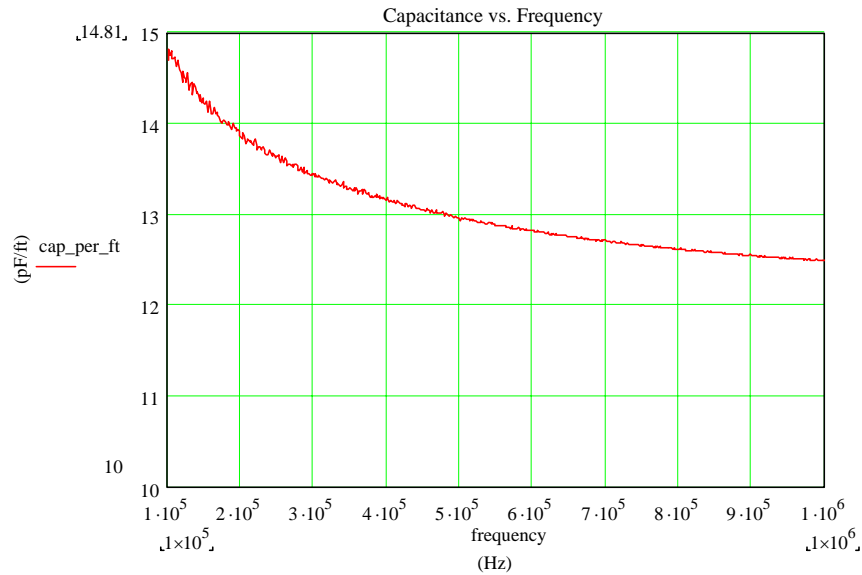


Figure 5: E2 Cable Capacitance (100ft)

The impedance, velocity, capacitance and attenuation values are used later in this report to predict the cabling length versus data rate.

Summary of electrical data from the calculations and measurements are detailed in Table 2 for the three data rate frequencies and 100KHz and 1 MHz.

Parameter	100KHz	125KHz	250KHz	500KHz	1MHz
100 ft sample					
Zo	126	127.5	129.8	131.6	132.47
VP	54.8	55	57.5	59.7	61.4
Atten Calc	0.12235	0.14	0.21809	0.35592	0.631
Atten Mea	0.1025	0.1378	0.25	0.4223	0.7185
CO	14.81	14.37	13.658	12.967	12.485
10 ft sample					
Zo	123	124.6	129.68	132	134
VP	52	54.6	56.3	58.8	61
Atten Calc	0.067	0.096	0.19229	0.3472	0.531
Atten Mea	0.10383	0.13563	0.232	0.4211	0.71835
CO	15.8	15	13.94	12.9	12.5

Table 2 : Summary of Cable Data

The cable DCR was directly measured and then calculated from the copper cross-sectional area of the conductors as a check. Table 3 lists the DCR for two different production runs of the cable.

Conductor	Spool 3	New Spool	Calculated based on copper area.
Black	2.343	2.260	2.2603
Red	2.345	2.263	2.2603
White	3.527	3.412	3.3876
Blue	3.526	3.401	3.3876

Table 3 : Conductor DCR at 20 degrees C

The measurements and calculations were found to be consistent with each other.

Topology Calculations

The margins are calculated using a proven tool that was created several years ago for DeviceNet. The calculations are based on an engineering report generated by Allen Bradley (Rockwell Automation) ER-500/009/01. This tool considers the impedance, velocity, DC resistance and AC resistance of the trunk and drop cables. In addition the accumulated connector contact resistance is factored into the losses. The minimum and maximum delays for device that have an affect on the CAN timing at the physical layer are factored into the calculations. The delay margin is simply the PHY delays + cable delay. The delay is required to be less than 511ns at 500kb/s and 2948ns at 125kb/s. The reflection margin considers the magnitude of the discontinuity when all but 2 nodes are located at one end of the cable with the maximum drop. The reflected voltage is then compared to the sampling point as defined by the CAN spec. If the reflection is delayed enough and the magnitude is greater than 0.46 volts then a CAN receiver may detect the reflection as an incorrect state. The ac resistance and dc resistance is also used to determine the reflection amplitude and finally the amplitude margin for the system. From this information topology limits can be predicted. The tool yields Delay margin, Reflection margin and Amplitude margins for each data rate based on trunk and drop length and cable electrical parameters.

Table 4 represents the predicted trunk and drop lengths for the cable. At 250 Kb/s and 500 Kb/s data rates the reflection margin is predicted to be the limiting factor. At the lower data rate 125kbps, the amplitude margin is low.

Data rate	Amplitude margin %	Delay margin %	Reflection delay margin %	Trunk (meters)	Drop (meters)
125kbps	1.04	25.5	8.25	325	156
250kbps	1.98	10.1	1.40	175	50
500kbps	2.7	6.99	1.53	65	25

Table 4 : Predicted Trunk/Drop Lengths

Topology Measurements

Each data rate will be evaluated by constructing the worst case system. The reflection margin, delay margin and amplitude margin can be measured and compared to the analysis in the previous section of this report.

The network was assembled with CompoNet Type I cable. Nodes were replaced with lumped elements. The lumped element equivalents were constructed of resistor and capacitors to maximize the reflections. A second set of loads were built to simulate worst case loading for attenuation measurements.

Worst Case Topology

Delay Margin

The worst case delay margin occurs when the cable is at maximum length.

Reflection Margin

Worst case reflection occurs when the largest mismatch is located at one end of the cable system and when the maximum allowable drop cable is connected to the remote nodes. The magnitude of the reflection will be a function of the mismatch located at the remote end. To maximize the miss match, the analysis will assume that the node input resistance is at max and the node capacitance is at maximum and the maximum capacitance from the drop cable is present. Therefore this model assumes that 62 nodes are at the opposite end of the cable system and the system is loaded with the maximum capacitance (nodes and drop cables) and maximum (100K) node resistance. The number of loads used is dependant on the drop budget and number of 6 meter drops. Each drop was terminated into the equivalent of 62 nodes/number of drops.

Amplitude Margin

Worst case Amplitude occurs when the maximum network capacitance (nodes and drop cables) and minimum node resistance is applied to the network. A set of loads was determined depending on the number of 6 meter drops and the equivalent parallel resistance of 62 nodes.

Test Procedure

The cable systems were constructed with the calculated cable lengths based on topology calculations. Test loads were calculated based on the number of drops available and the maximum node capacitance and min/max node resistance. The allowable cable delays were calculated for each data rate base on the CAN specs for recommended delay, the optical isolators, transceiver and CAN controller delays and sample point. The delays were measured by applying a CAN signal to the cable and measuring the delay at the receiver end. The reflection delay is based on the reflected voltage at the sample point. The reflected voltage must be below 0.46V at the sample point. The reflected voltage was measured for the under conditions that would cause the worst case reflected voltage. The amplitude margin was determined by measuring the amplitude at the farthest distance from the source under maximum loaded conditions.

125Kbps Testing

Load #1 Maximum R and Maximum C for Reflection delay - 61 nodes @ 20k each 25pf/node 5.38K ohm in parallel with a 221pf for 7 loads

Load#2 Minimum R and Maximum C for amplitude margin 322 ohms in parallel 1550pf capacitor

Recommended delay(max) 6500ns

Sample point 7000ns

Fixed delays (31ns+40ns+80ns+80ns+40ns+31ns)*2 = 604ns

Maximum allowable cable delay (6500ns-604ns)/2 = 2948ns

Cable Delay spec = 6ns/m = 491m

Calculated Delay 5.36ns/m = 550m

Use 325m for trunk tests,

Delay Margin 2948- 2.619ns = 329ns margin or 11.15% margin

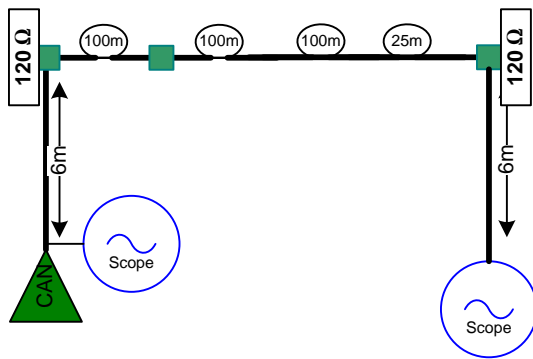


Figure 6 : 125 kbps Delay Margin Test

The delay measurement for the configuration in Figure 6 is below in Figure 7.

17-Mar-06
14:07:16

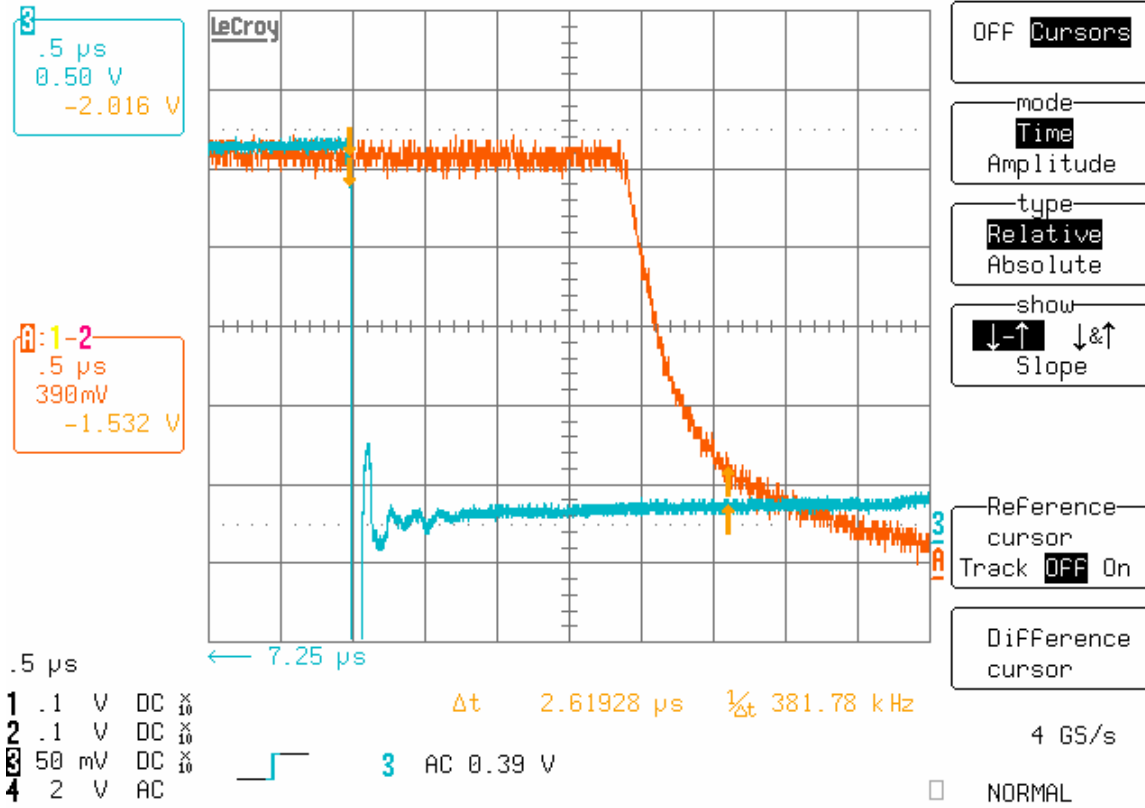


Figure 7 : 125 kbps Delay

Reflection $7000\text{ns} - 6568\text{ns} = 432\text{ns}$ margin or 6.33% margin. A system was constructed as shown in Figure 7 to represent worst case reflection.

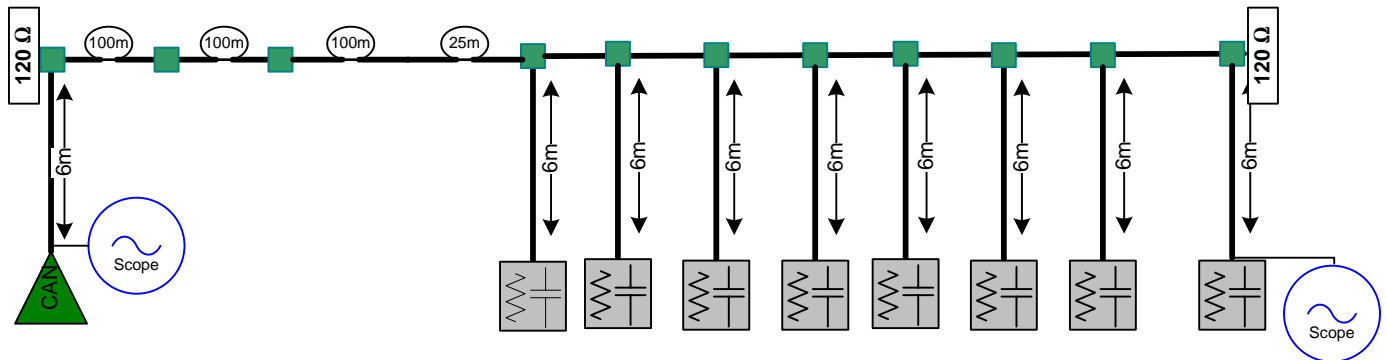


Figure 8 : 125 kbps Reflection and Amplitude Margin Test

Reflection margin measurement is in Figure 8 below.

17-Mar-06
14:27:20

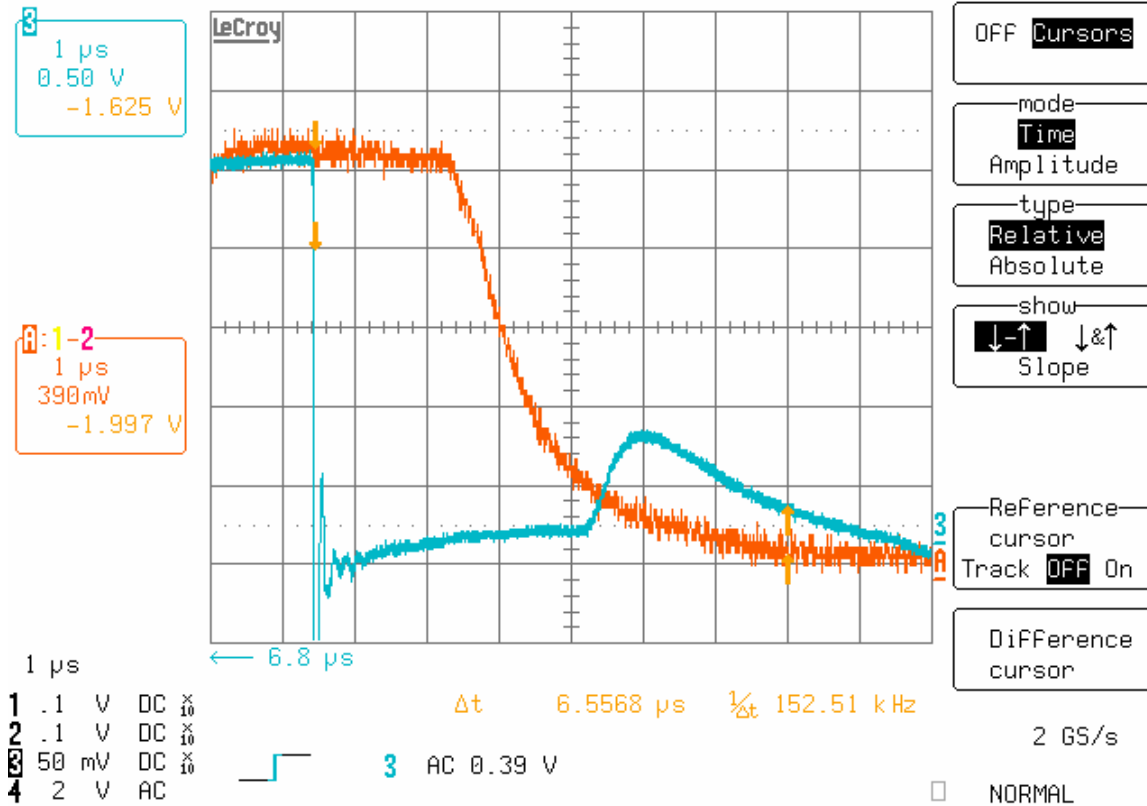


Figure 9 : 125kbps Reflection Time t at 0.46V

Amplitude 5.6dB margin is determined by measuring the input amplitude at one end of the cable and output amplitude at the far end of the cable as shown in Figure 10. The margin was determined by comparing the measured amplitude at the far end to the minimum allowable signal level for CAN and dividing by 2.

$$\text{Amplitude_margin} = \frac{20 \cdot \log\left(\frac{V_{\text{out}}}{V_{\text{min}}}\right)}{2} \quad \text{Equation (2)}$$

V_{out} = 1.91V
V_{min} = 0.46
6 dB margin

17-Mar-06
14:34:50

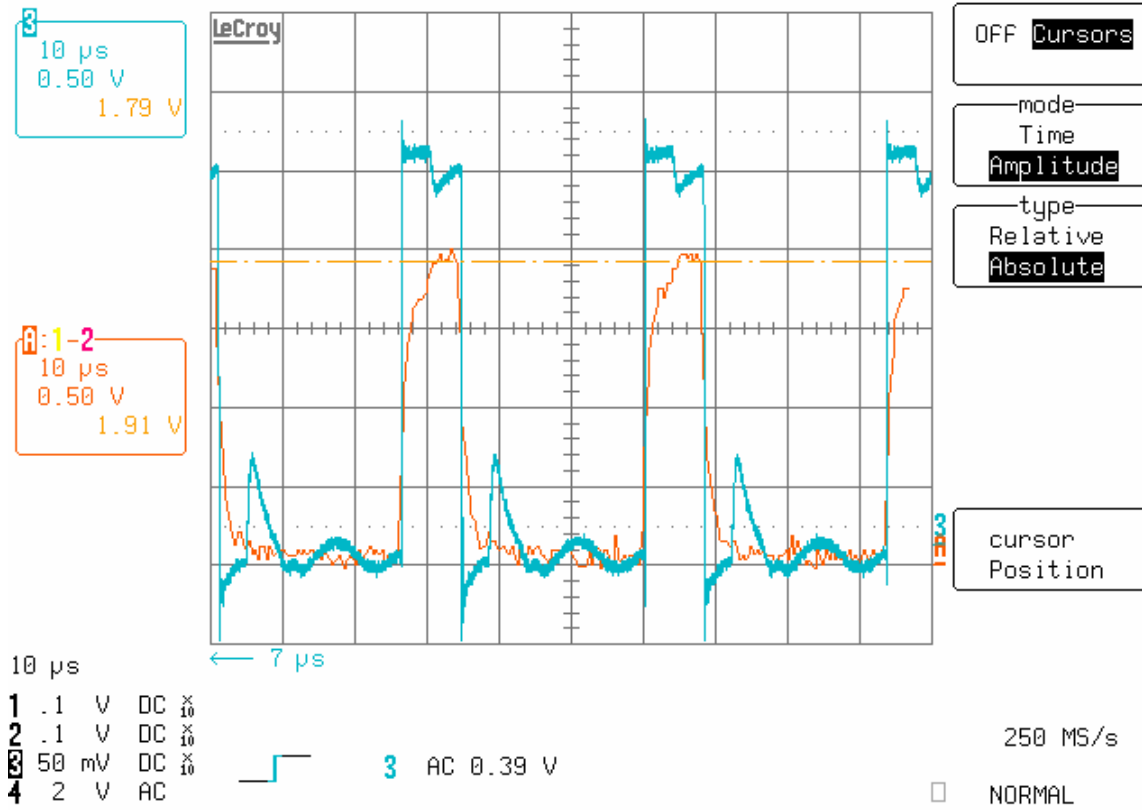


Figure 10 : 125kbps Amplitude Margin

Summary of Test Results

Trunk 319m (predicted 325 m)
Drop 156m

250Kbps Testing

Load #1 Maximum resistance and Maximum capacitance reflection delay - 61 nodes @ 20k each 25pf/node 5.38K ohm in parallel with a 221pf for 7 loads

Load#2 m=Minimum R and Maximum C for amplitude margin 322 ohms in parallel 1550pf capacitor

Recommended delay (max) 3250ns

Sample point 3500ns

Fixed delays (31ns+40ns+80ns+80ns+40ns+31ns)*2 = 604ns

Maximum allowable cable delay is (3250ns-604)/2 = 1323ns one way

Cable Delay spec = 6ns/m = 220.5 meters

Calculated delay 5.36ns/m = 246.8 meters

200 meters of trunk measured delay = 1285ns

Delay margin 1323ns - 1285ns = 38ns or 2.87% margin

The system as in Figure 11 was constructed to represent the maximum delay.

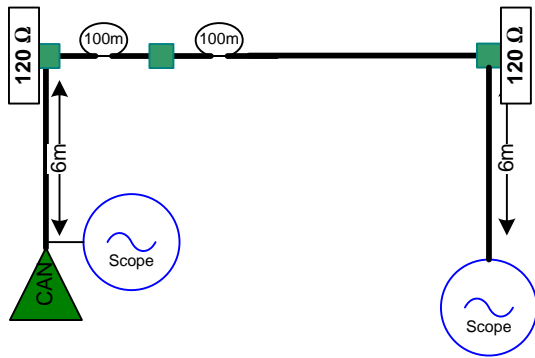


Figure 11: 250 Kbps Delay Test

The measured delay is determined by measuring the propagation delay from the initial pulse front to the resulting pulse front at the far end of the cable when loaded, see Figure 12.

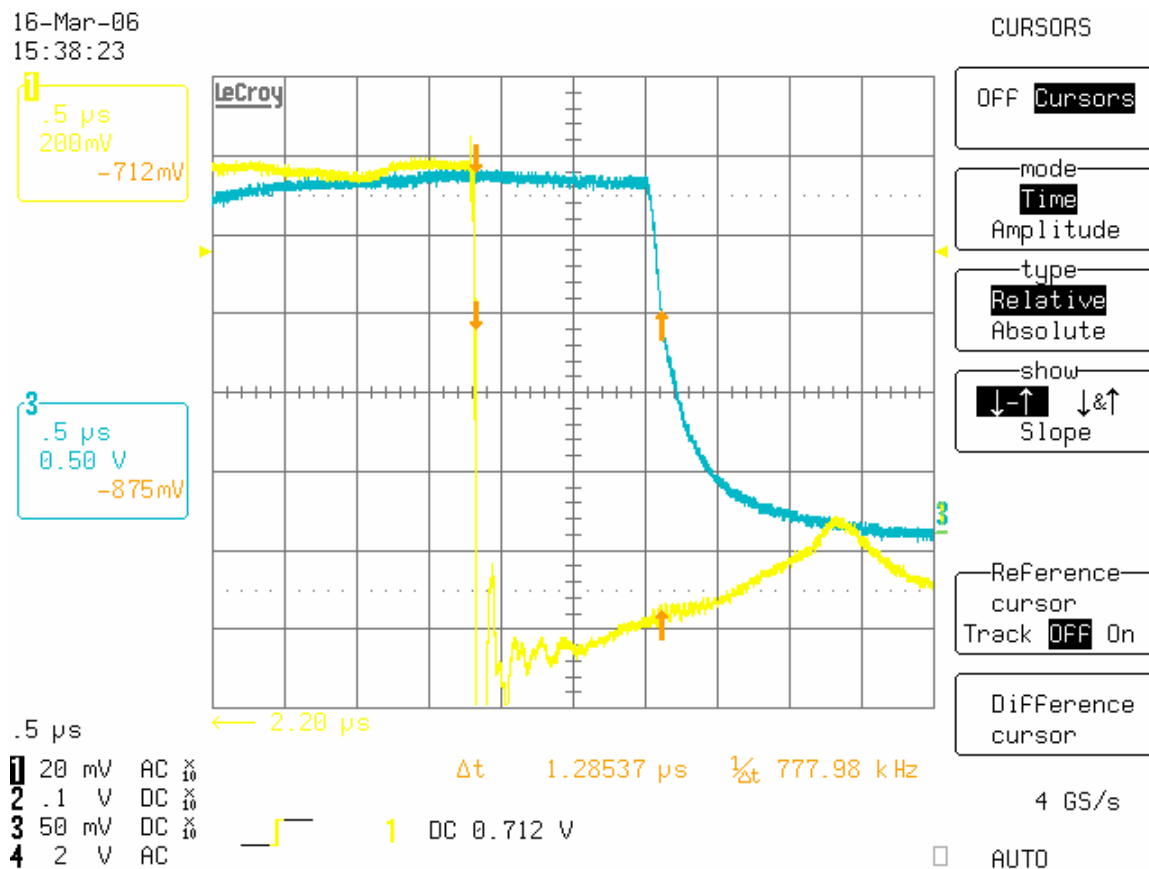
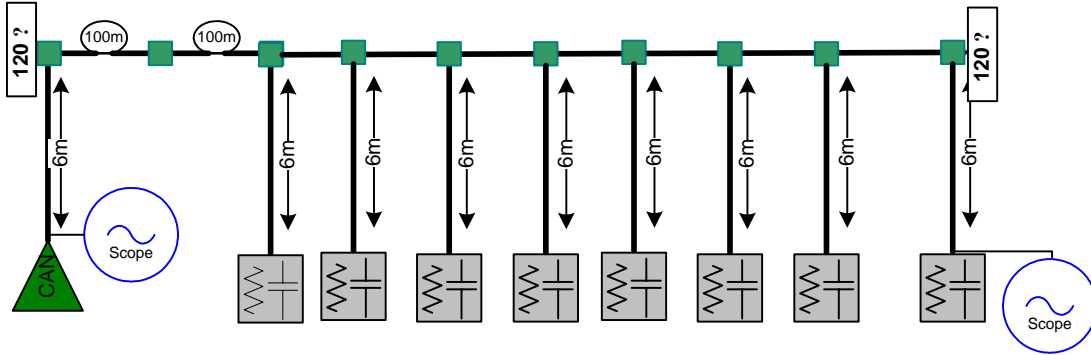


Figure 12: 250kbps Delay Margin

The reflection margin was determined by measuring the amplitude and position of the reflection under a worst case configuration shown in



The scope measurement shows the amplitude at the measurement point in Figure 14.

Reflection margin 3032ns. 3500ns is allowed. 468ns or 13.4% margin

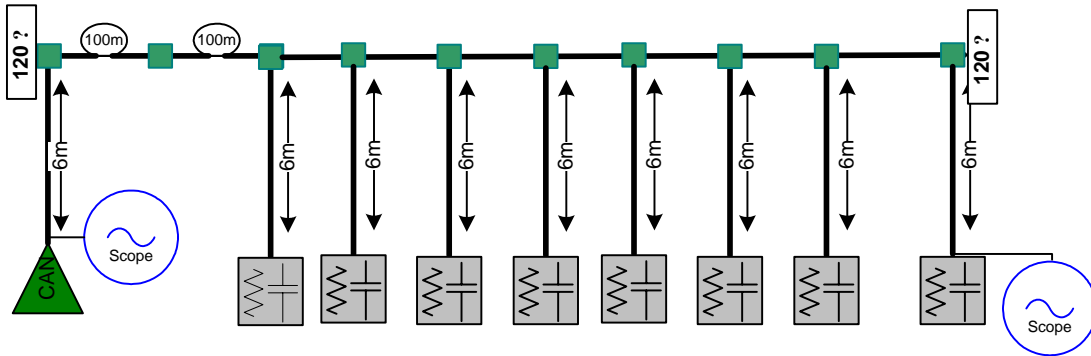


Figure 13 250 kbps Reflection and Amplitude Margin Test

17-Mar-06
13:33:21

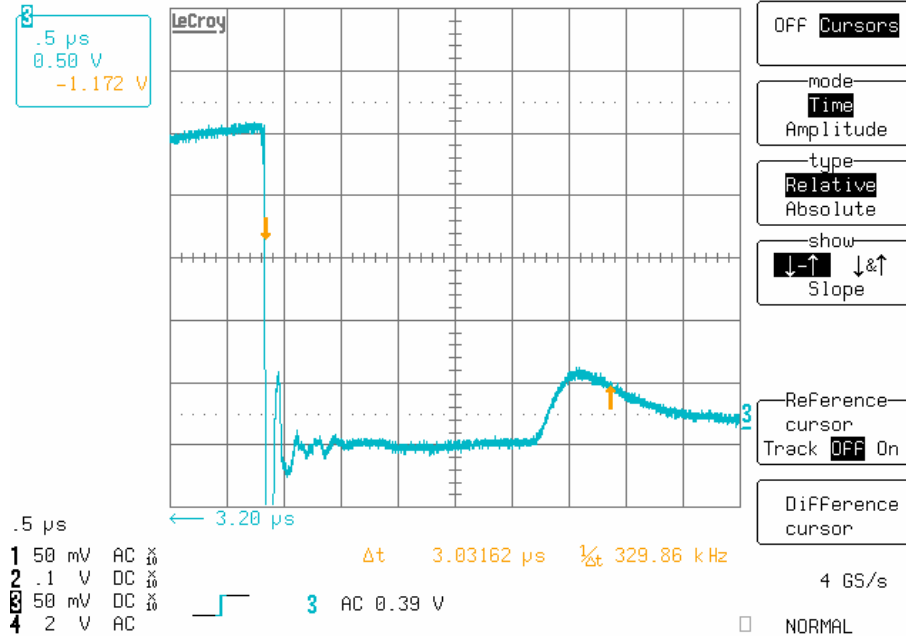


Figure 14 : 250kbps Reflection time t at 0.46V

The amplitude margin is determined using the equation below and comparing to the minimum allowable amplitude to the minimum voltage measured on the cable and dividing by 2. The measured amplitude as shown in Figure 15 is 1.8 volts

$$\text{Amplitude_margin} = \frac{20 \cdot \log\left(\frac{V_{\text{out}}}{V_{\text{min}}}\right)}{2} \quad \text{Equation (2)}$$

$V_{\text{out}} = 1.8\text{V}$

$V_{\text{min}} = 0.46$

5.9 dB margin

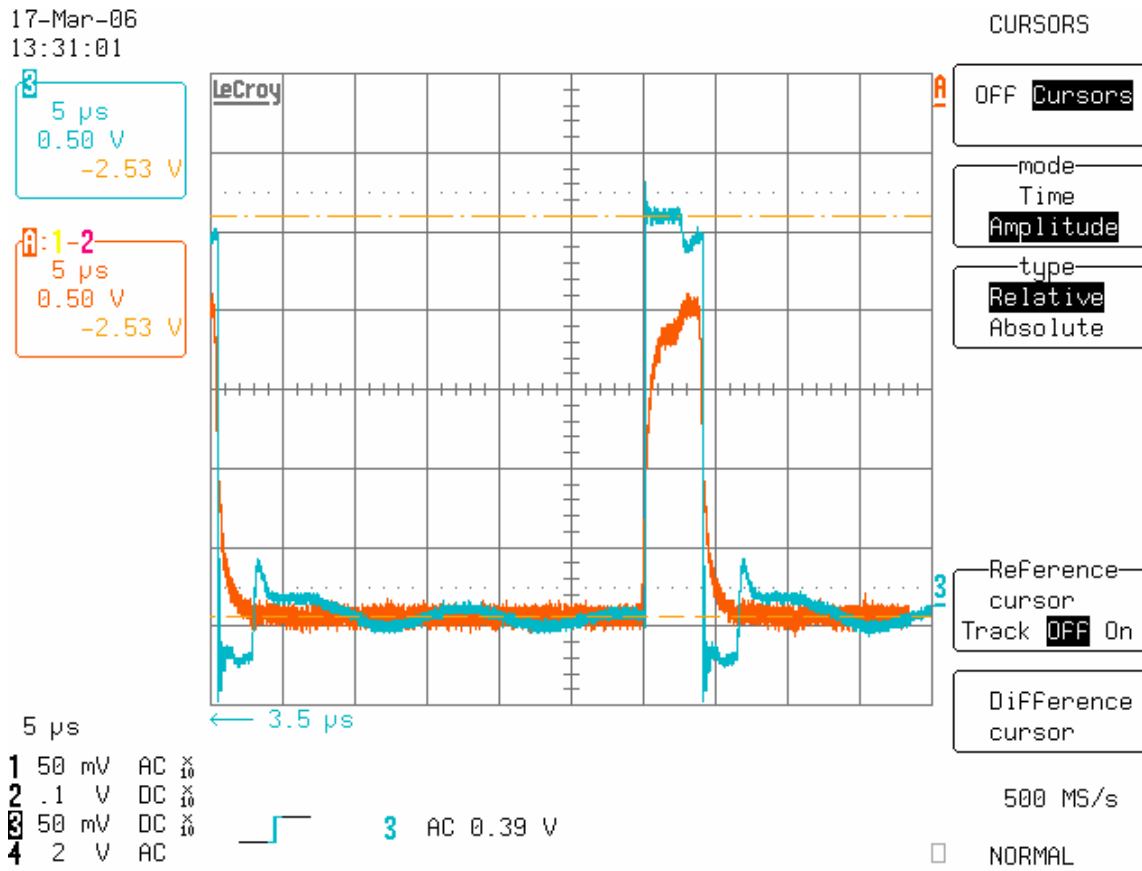


Figure 15 : 250kbps Amplitude Margin

Summary of Test Results

Trunk 212 meters (predicted 175 meters)
Drop 48 meters

500Kbps Testing

Load #1 Maximum R and max C for reflection margin tests 20nodes @ 100K each 25 pf/node 4.7K in parallel with 470pf (3 places)

Load #2 Minimum R Maximum C for amplitude margin 20nodes @ 20K each 25 pf/node 1k in parallel with 470pf

The recommended delay (max) is 1626ns.

Sample point 1750ns

Fixed delays $(31\text{ns}+40\text{ns}+80\text{ns}+80\text{ns}+40\text{ns}+31\text{ns}) \times 2 = 604\text{ns}$

Max allowable cable delay is $(1626\text{ns}-604\text{ns})/2$ one way

511ns one way

The worst case delay configuration was constructed as shown in Figure 16.

Cable Delay spec 6.0ns/m = 85meters

Measured cable delay 5.36ns/m = 95meters

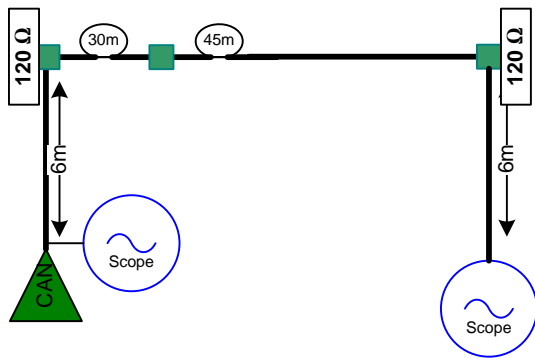


Figure 16 : 500 kbps Delay Test

Max reflected delay for sample point is 1750ns. The reflected voltage must decay to less than 0.46volts by this point. The reflection was measured as shown in Figure 17.

Delay Margin -- 478.25ns = 6.4% margin

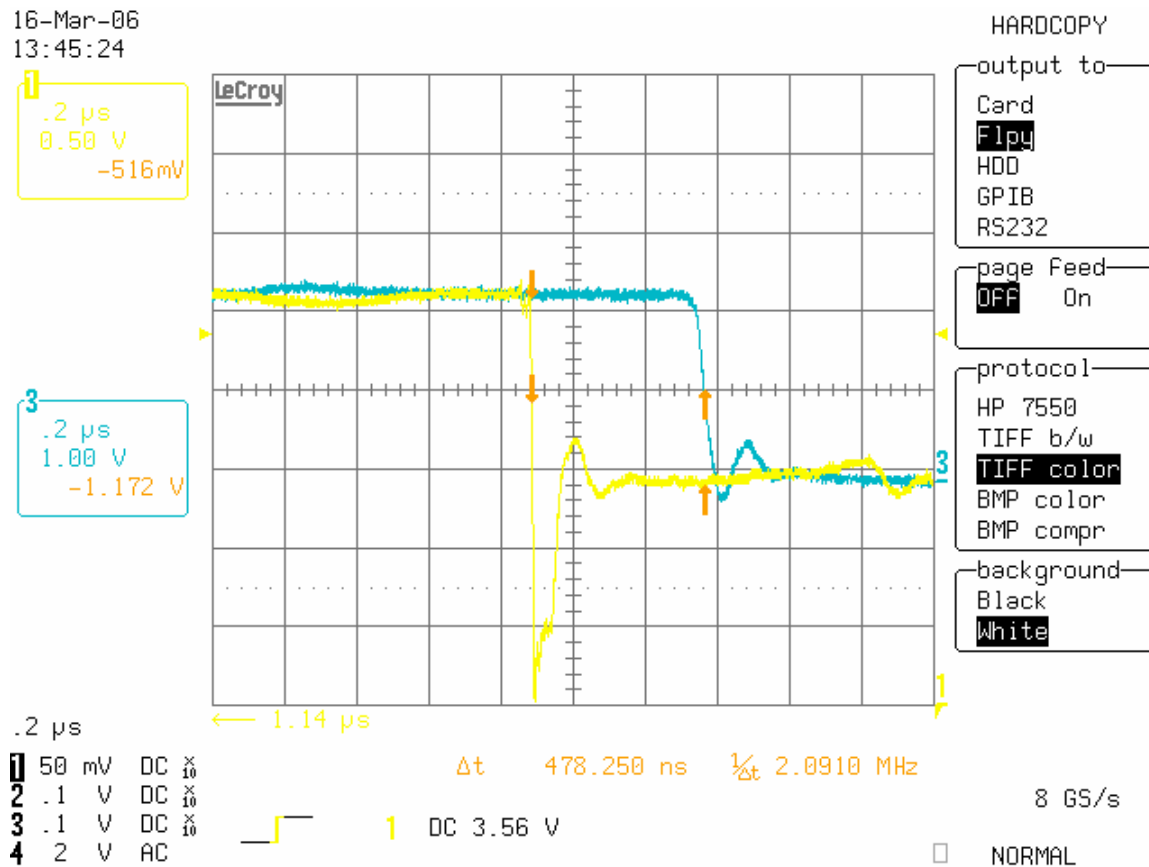


Figure 17 : 500kbps Delay Margin

Max reflected delay for sample point is 1750ns. The reflected voltage must decay to less than 0.46volts by this point. The reflection was measured as shown in Figure 18
Reflection

The reflection delay was measured at 1.172us for 500 Kb/s as shown in Figure 19 for the worst case configuration in Figure 18.

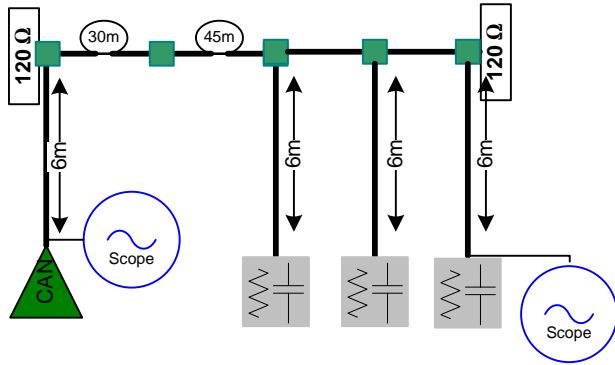


Figure 18 : 500 Kbps Reflection Delay and Amplitude Margin Test

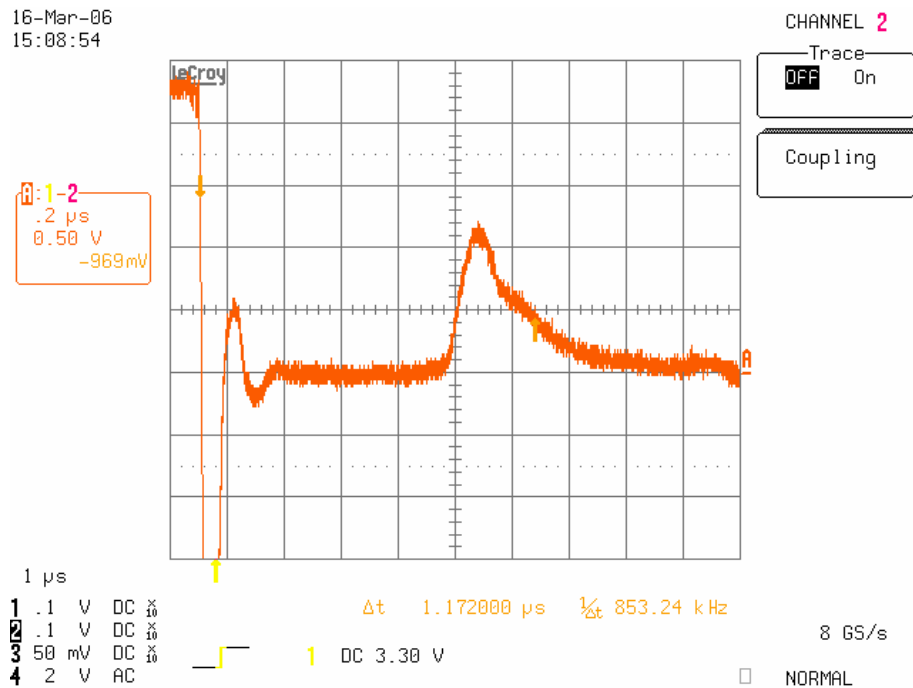


Figure 19 : 500kbps Reflection Time t at 0.46V

The reflection delay was calculated at 33% margin.

The amplitude measurement was performed using the same method as the previous two data rates using the worst case configuration of Figure 18. Figure 20 shows not measure able difference between the input and output when measured at opposite ends of the cable system.

Amplitude Margin no measurable attenuation
 > 6dB margin

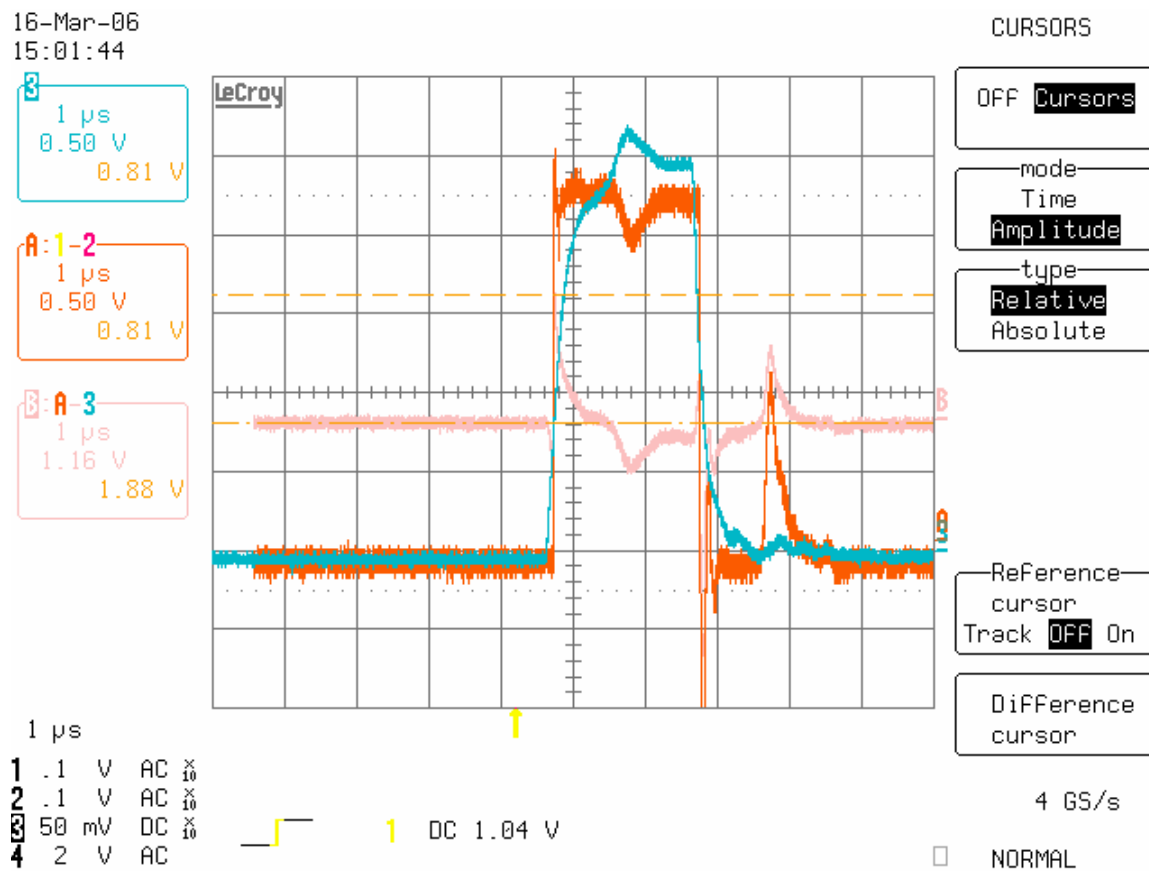


Figure 20 : 500kbps Amplitude Margin

Summary of test results

The following summary is based on the predicted lengths which is based on the measured cabling parameters. The measured lengths are based on using lumped elements for the loads. This does not take into consideration BER that can occur in a actual network with operational communication devices. Table 5 details the predicted lengths and the measured. The topologies must be verified using actual communications devices.

Trunk length: 74.67 m (predicted 65 meters)
 Drop cable length: 25 m

Data Rate	Trunk Length		Drop Cable	
	Predicted	Measured	Predicted	Measured
125kbps	325	319	156	156
250kbps	175	212	50	48
500kbps	65	75m	25	25

Table 5 : Summary of Measurements and Calculations

Topology Verification

During the KwikLink™ development a Flexible Topology Test Stand was constructed, see Figure 21 . The Flexible Topology Test Stand will be referred to “the test stand” throughout this report. The test stand allowed quick manipulation of the cable topology for testing of various network constraints. Validation of the test stand can be found in RA engineering report “Topology Testing”. The test stand was rewired with flat type II cabling. The original flat cable connectors were left in place (disconnected) for future support of the flat cabling system. Both cabling systems (flat and flat type II are shown).

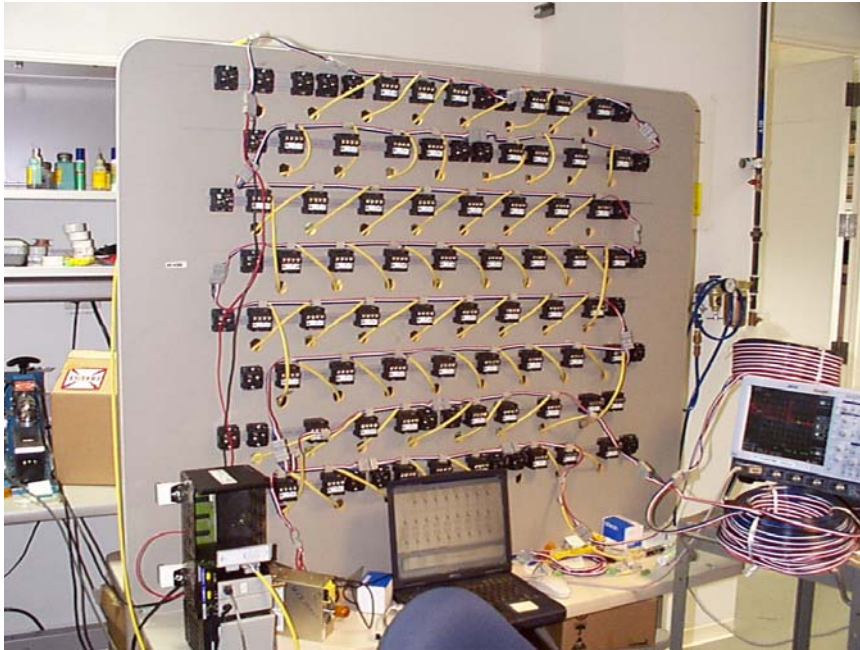


Figure 21: Flexible Topology Test Stand

The same test stand was used for the CompoNet cabling system. The test stand consists of 64 node positions. The active devices on the test stand are shown in Figure 22. The devices are a mixture of DeviceNet DeviceLinks and Photo Eyes. This provide a reasonable representation of DeviceNet node interfaces while keeping the size of the test stand to a minimum.

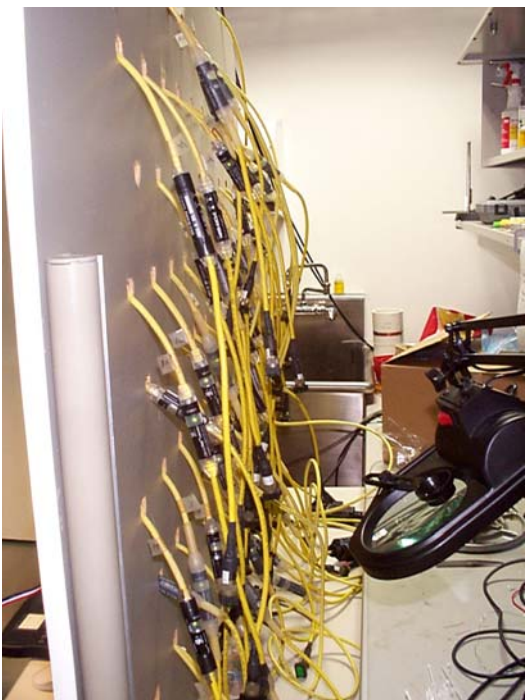


Figure 22: Device Side of Test Stand

The following testing was performed in the Rockwell Automation Development Media Development Lab in Mayfield Heights OH. By Bob Lounsbury. The purpose of the testing was to help establish the maximum topology parameter for the CompoNet Type I DeviceNet cabling system.

Worst Case Topology

Previous testing has shown the worst case topology to be as follows:

- Maximum trunk length (for delay)
- A maximum length drop on each end of the trunk (for delay)
- Maximum node count (for reflection from capacitance)
- Maximum total drop (for reflection from capacitance)
- The power supply, along with two or more nodes on one end of the network (two nodes allows internal clock drift)
- The rest of the nodes on the opposite end of the trunk (maximum capacitance on one end)
- In some configurations the worse case topology was with 8-16 nodes at the PLC SCNR end and the balance at the remote end.

Test Procedure

1. Testing was performed at three data rates - 125kbps, 250kbps, and 500kbps.
2. A test stand was used to assemble a test configuration for each data rate.
3. The goal was to generate as close to a worst case topology as possible, given the test stand and media limitations.
 - Maximum of 64 nodes
 - Maximum total drop length
 - Maximum single drop length of 20 ft
4. Each configuration was then used to determine the maximum reliable trunk length. The trunk cable was adjusted in 5m increments to find the maximum length where the nodes operated reliably. A 1756 DNB was

used to communicate with the devices by configuring scan lists. A DeviceNet Detective was used to monitor the network for errors. When the cable was too long, node dropout was experienced.

5. Oscilloscope measurements were taken, at each end of the trunk, for data transmission initiated from each end of the trunk.

The test stand contains 62 nodes with permanently attached drop cable ranging from .3meters to 2 meters. In addition the modularity allows for additional drop cable to be added to any nodes that have less than 0.3m of permanently attached drop cable. For some data rates the permanently attached drop cable is greater than allowed. In this case nodes will have to be removed and replaced with capacitors to simulate the node capacitance without the drop cable.

The minimum fixed drop calculation for the flexible test stand is as follows

Group Address	Drop
1-7 + diagnostic device	7.79m
8-15	9.76m
16-23	11.46m
24-31	13.15m
32-29	8m
40-47	8m
48-55	6.37m
56-62 + 0 + diagnostic device	10.85m
Total Drop	75.38M

Results

Measured trunk length was as follows:

- 87m @ 500kbps
- 138m @ 250kbp
- 263m @ 125kbps

Measured drop length was as follows;

- 36m@500kbps
- 48m @ 250kbps
- 134m@125kbps

The trunk lengths achieved in this test include typical values for items such as the node impedance to its reference. Worst case calculations are necessary to generate end user limits, and may yield shorter lengths.

125Kbps Testing

The network was first built with 300m of trunk. The trunk length was reduced until the system was stable. Then the system was reconfigured (see the configurations below) and further reduced until stable again. Each box represents a group of nodes connected to the trunk via a drop cable. The drop length for each group of nodes was adjusted to achieve the maximum drop budget without exceeding the 20 meters per drop rule. The total drop was limited to 134m. There are three configuration for this data rate as shown in Figure 23, Figure 24 and Figure 25. The test node was moved from one location to another as designated by the "T". In addition the grouping of the nodes is moved to optimize the worse case network. The power supply is optimally placed to keep the power bus in specification ($\pm 5V$ common mode) and bus voltage $\geq 11Volts$.

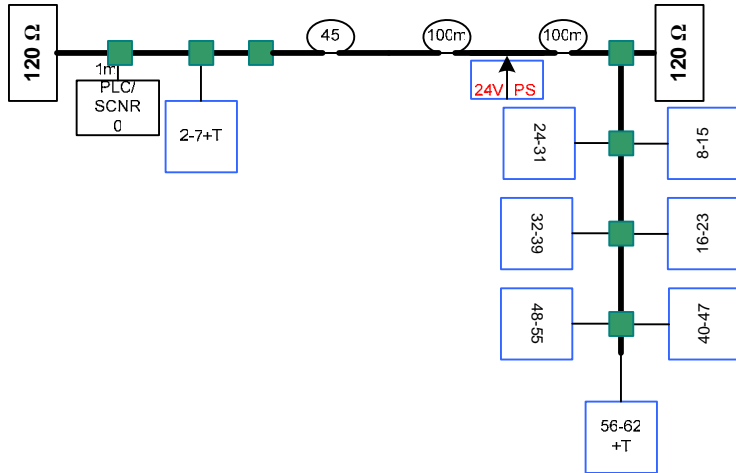


Figure 23: Worse Case Topology Configuration #1

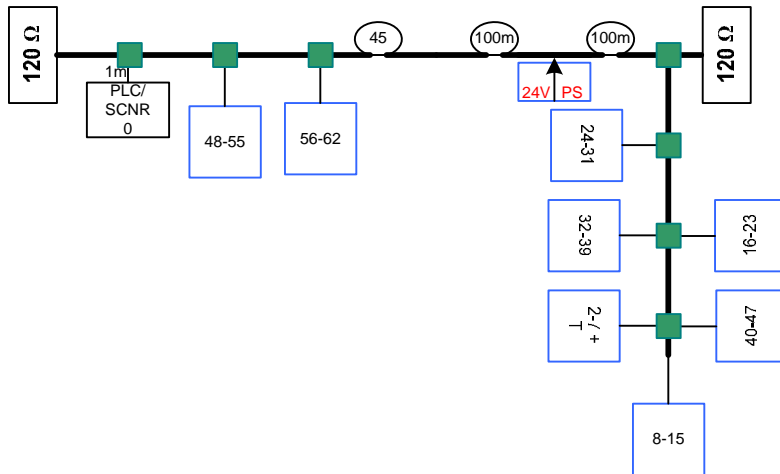


Figure 24: Configuration #2

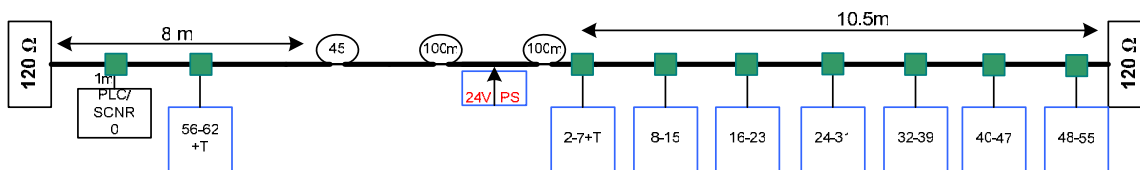


Figure 25 :Configuration #3

Test Results

At 125kbps the final length of 263 (245m + 18m) meters the network was stable. The lowest supply voltage measured was 11.9 Volts

Final configuration for data rate 125kbps

- Trunk 263m
- Drop length 134m
- Nodes 64

250Kbps Testing

The test stand was reconfigured for 212 meters of trunk and 48 meters of drop. This lengths were determined in the delay margin testing. The topology was multiple drops in groups of 8 nodes each at the remote end as shown in Figure 26.

Because the drop budget is over by 22 meters ($75.38\text{m} - 48\text{m}$), 52 meters of fixed drop cable was left in to produce margin. Several nodes were removed. A capacitor was added to simulate the node capacitance. Trunk was then added in until the cable system became unstable. The power supply was positioned to keep the power bus within specification of greater than or equal to 11V at the farthest node. Figure 27 represents the worst case reflection caused by nodes being lumped together at one end of the trunk. Additionally Figure 28 has added trunk between groups of nodes to optimize the reflection delays between the groups of nodes on drop cables.

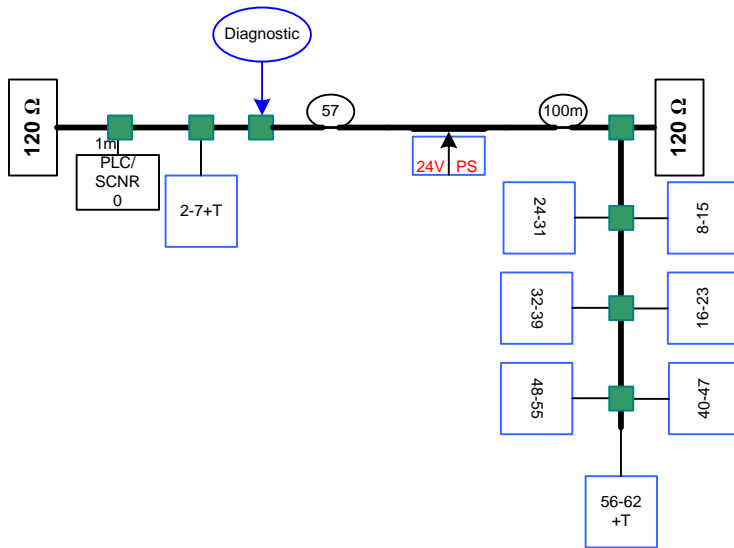


Figure 26 : Configuration #4

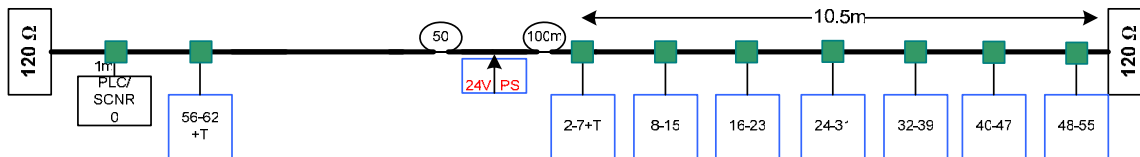


Figure 27 : Configuration #5

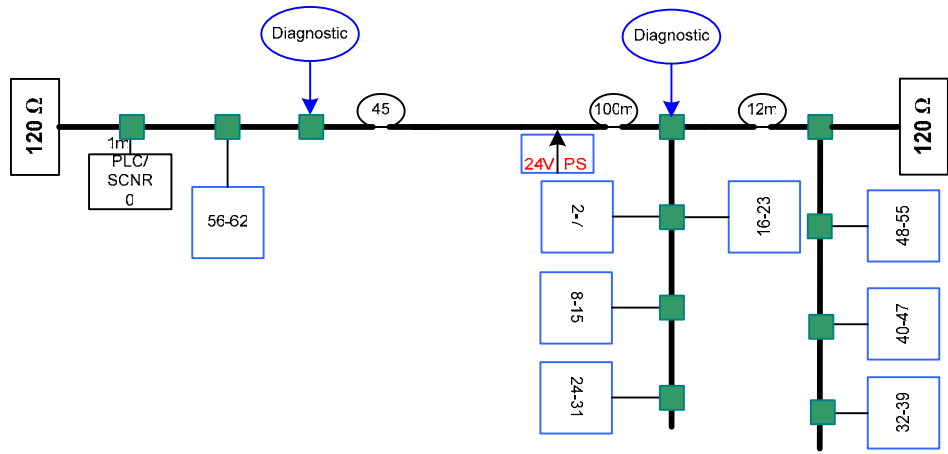


Figure 28 : Configuration #6

Configuration # 4 was the result of adding 6 meters in to the trunk until the network became unstable and then removing trunk until the network became stable again. The final trunk length was 157m with 52 meters of drop. The delay was the limiting factor measured 3163ns max allowed is 3250ns, see Figure 29.

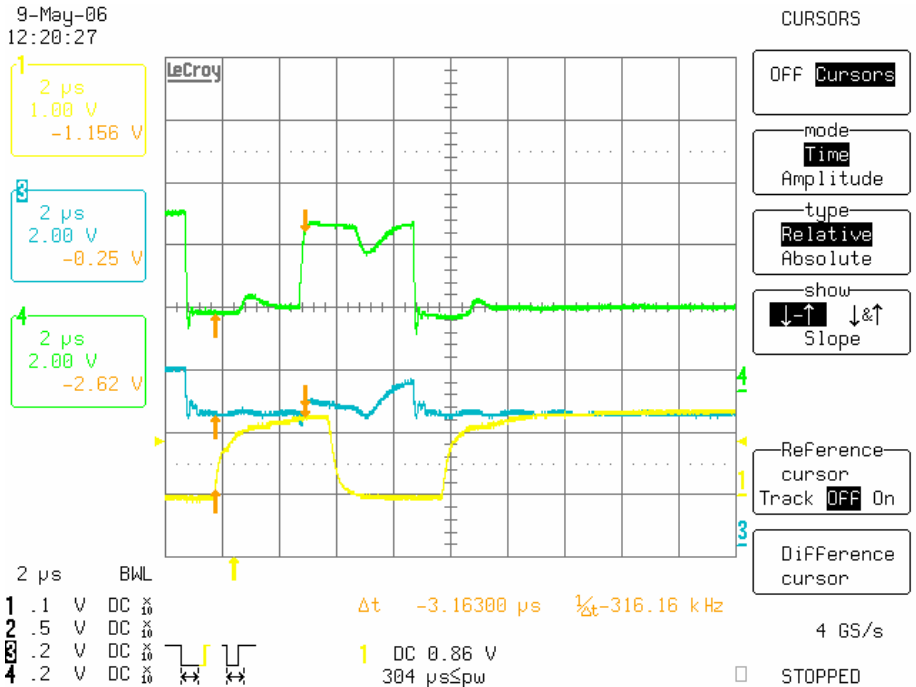


Figure 29 : Maximum Delay

Test Results

At 250kbps the final length of 157m meters the network was stable.

Final configuration for data rate 250kbps

- Trunk 157m
- Drop length 52m
- Nodes 64

500Kbps Testing

The test stand was configured with 75 meters of trunk and 57 meters of drop. This produced a repeatable bus-off condition. The trunk could be reduced to 69 meters to reduce the errors to a trickle.

The minimum drop cable of the test stand was 56.9m. Nodes were removed until the drop cable was 36m. A 220pf capacitor was added to simulate the node capacitance of the removed nodes.

The trunk length was increased in 6m increments until the network was unstable. Once the network was unstable then the maximum amount of trunk (when stable) was recorded. The configuration as shown in Figure 31 was constructed and tested to determine the worse case limiting configuration.

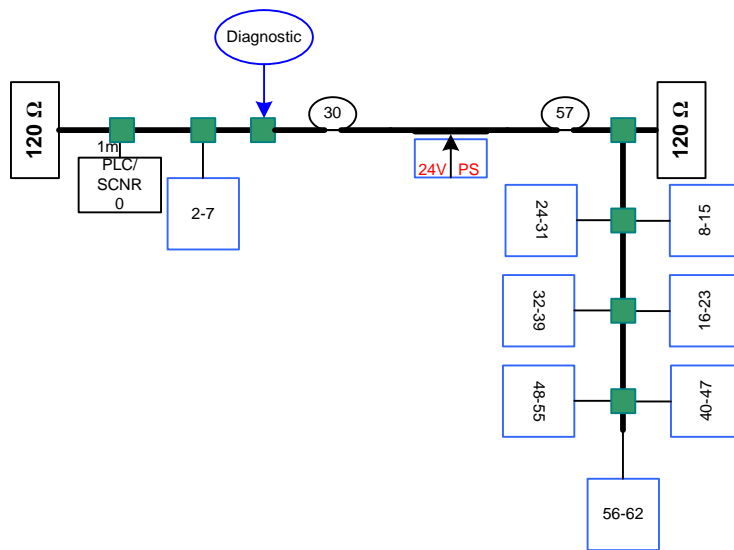


Figure 30 : Configuration #7

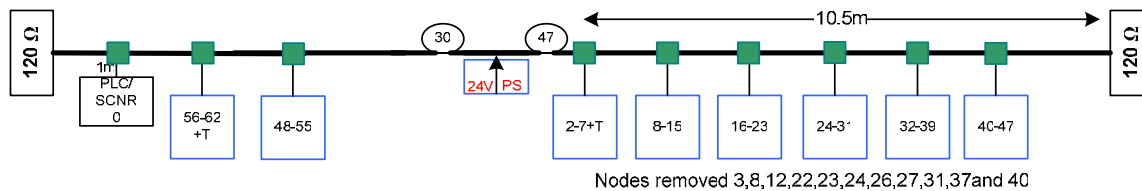


Figure 31: Configuration #8

Test Results

At 500kbps the final length of 87m meters the network was stable.

Final configuration for data rate 500kbps

- Trunk 87m
- Drop length 36m
- Nodes 64

Data Rate	Trunk Length (Meters)		Drop Cable (Meters)	
	Measured	Node Test	Measured	Node Tests
125kbps	319	263	156	134
250kbps	212	157	48	52
500kbps	75	87	25	36

Table 6 : Comparison of Test Results to Measurements

Installation Time Studies of Phase III Media

Time Comparisons

To effectively mount and install a DeviceNet KwikLink IDC module, a power screwdriver and drill is required. The time to install a KwikLink IDC module is approximately 3 to 10 minutes if the tap requires mounting to a back panel.

Installation of the XW7D-TR4 trunk cable connectors

8 approx 1 meter cables were cut and marked with a permanent marker to position a total of 64 IDC connectors (8 per cable).

The process took 55 minutes which included 2 skipped positions where the retainer had to be removed and repositioned. One cable was terminated with 7 connectors in reverse (black to V+ and Red to V-) and had to be remade. The total connectors installed was 71.

This is an average of 1 every 51 seconds as compared to roughly 3 minutes for KwikLink

The cables were cut and marked where the connector was to be crimped. The retainer clam shell was installed by folding over and pressing shut using the forefinger and thumb. This resulted in the breakage of 19 retainer locks (only one on each retainer never both) One retainer lock on each of the 8 incorrectly placed connectors were broken. After installing 65 retainers the IDC module was installed by clipping onto the retainer and then positioning over the mark using the visual slot located on the color code side of the retainer. The assembly was inserted into a bench model PanaVise and tightened down ¼ turn past two audible clicks was heard. This completed the installation of the cable side connector.

Conclusion

The CompoNet Type I (DeviceNet Flat II) cabling takes about 1/3rd the time to terminate as KwikLink IDC connectors. This represents a sizable savings in installation costs for the customer. The construction of the retainers allows precise placement of taps. The table vise used was helpful in limiting the amount of force placed on the assembly while crimping the IDC contacts. However the Vice will not be feasible in the field. A pair of pliers with a parallel jaw with travel limiting would be aid in the installation of the jack and plug onto the cables and further cut the installation time.

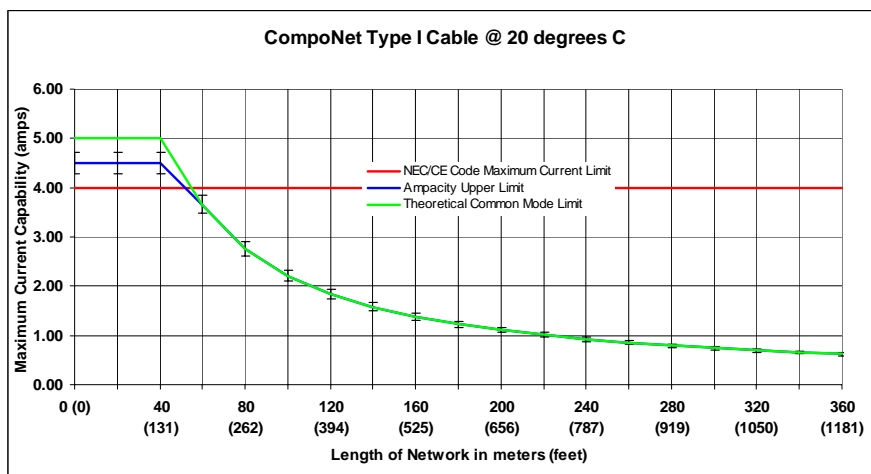
Topology Based on Ampacity of Cable

The DCR was obtained from a 100 foot and 100 meter sample. The values were obtained at 20degrees C. The values were then scaled to 60 degrees C using a standard Copper temperature coefficient of .0039349/degree C. The scaled and un-scaled DCR values was then used to calculate the current versus length graphs attached. Note that the 8 amps is only available at roughly a trunk length of 20 meters at 20 degrees C. From the CAN perspective, the current versus Trunk length is a graph is the Common Mode offset limit. Further analysis was then performed to determine the maximum current the conductors can safely handle. Due to the relative small gauge of the two power conductors (V+ and V-) the ampacity may place an additional limit the Common Mode graph below. The conductor gauge calculations are in Table 7 below. The Omron cable is approximately equivalent to an 19 AWG wire. Therefore the ampacity is approximately 4.5 Amps as shown on the graph. Note that this is above the NEC limits of 100VA. The trunk versus current takes into consideration the reduced number of series contacts that are required in the standard round DeviceNet system.

Conductor	Number of Strands	Strand Diameter (mm)	Calculated CMA	Calculated Gauge (AWG)	Calculated DCR @ 20 degrees C per foot	Measured DCR at 20 degrees C per foot
Wht/Blu	20	.18	1005	~20	0.01032515	.01084
Red/Blk	30	.18	1505	~18	0.0068893	.00688

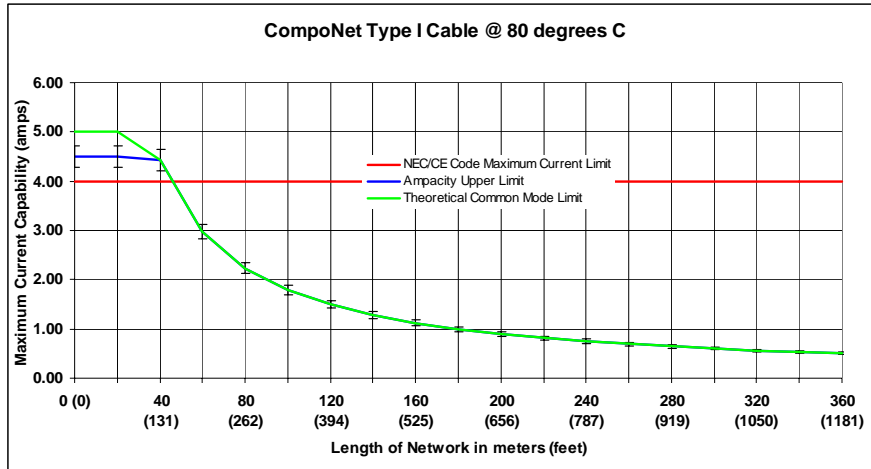
Table 7 : Conductor Physical Dimensions

Connectivity to the trunk is through IDC contacts without severing the trunk. Therefore the Common Mode offset is calculated based on two contacts. The following table represents the current versus length of the trunk cable at 20 deg C. The tables assume that all nodes are attached to the trunk cable via dedicated taps. All nodes are lumped together at the opposite end of the cable system from the power supply. The theoretical Common mode limits takes into consideration the maximum current capacity of the connectors (5A).



The following table and graph represent the limits at elevated temperature of 80 degrees C.

Conductor	Number of Strands	Strand Diameter (mm)	Calculated CMA	Calculated Gauge (AWG)	Calculated DCR @ 80 degrees C per foot	Measured DCR at 80 degrees C per foot
Wht/Blu	20	.18	1005	~20	.01275982	NA
Red/Blk	30	.18	1505	~18	0.0085138	NA



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