SST™ Technical Note

Technical Aspects of Data Highway Plus

Overview

This technical note includes valuable information on the structure of the network, allowing you to troubleshoot and improve network performance. Illustrations are provided for clarity, but are not drawn to scale.

About this Technical Note

This technical note describes the following:

- Network Topology
- Topology of the Data Highway Plus Network
- Network Loading
- Network Tools
- Optimizing the Data Highway Plus Network
- Network Performance
- Transmission Line Examples
- Troubleshooting
- Glossary

This technical note assumes that:

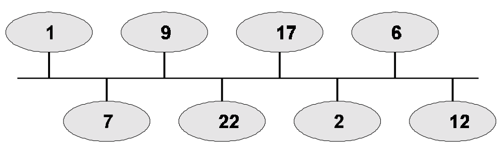
- you are troubleshooting an existing Data Highway Plus Network.
- you are setting up a Data Highway Plus Network.
- you are documenting operation of an existing Data Highway Plus Network.

Network Topology

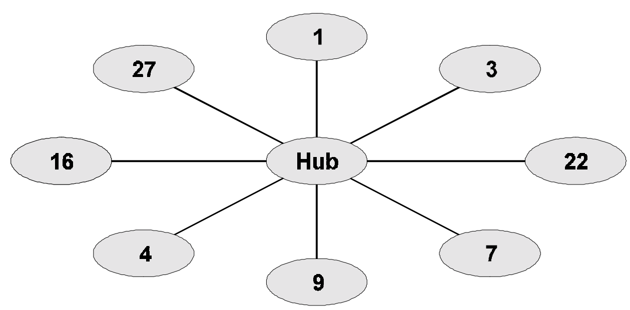
This section provides a description of the more common network types.

- Bus
- Star
- Token Ring

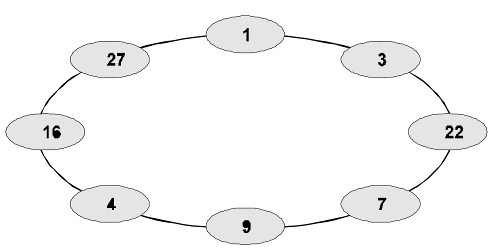
Bus Network



Star Network



Token Ring Network



Media Type

This refers to the physical medium used to carry the data.

Some common media types are:

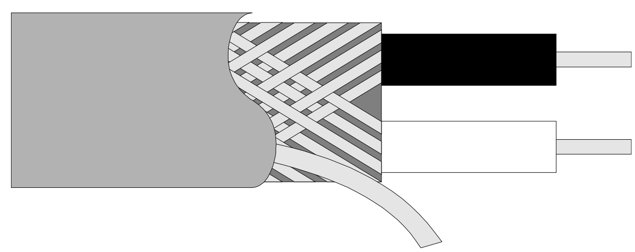
- Twisted Pair
- Coax
- Fiber Optic

Data on the given media may be one of the following:

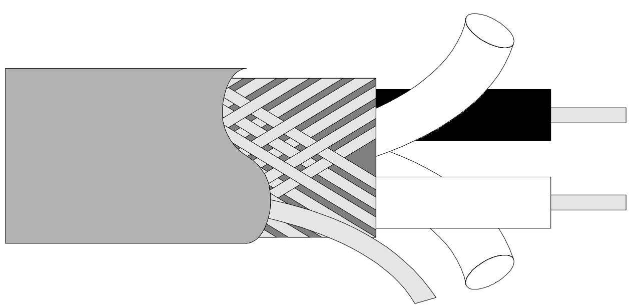
- Baseband - One channel of data (single lane highway)
- Broadband - Multiple channels of data, video, audio etc. (multilane super highway)

Twisted Pair Cable (Unshielded)

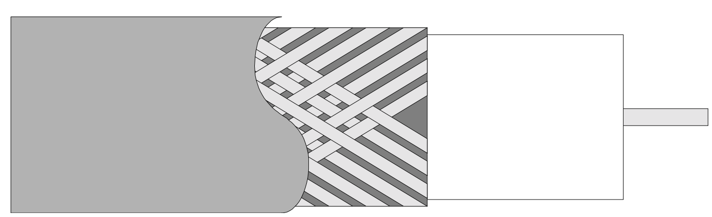
Twisted Pair Cable (Shielded)



Twin Axial Cable



Coaxial Cable



Media Access Method / Protocol

Since most media types are limited to half duplex signal (only one node can transmit at any time), a media access method is required to determine who gets to talk at any given time

Some common Media Access Methods are:

- Master / Slave (Remote I/O, Reliance DCS,)
- Token Passing (ArcNet, Data Highway Plus, RNET,)
- Carrier Sense, Multiple Access, with Collision Detection (CSMA/CD or Ethernet)
- Floating Master (Data Highway)

Topology of the Data Highway Plus Network

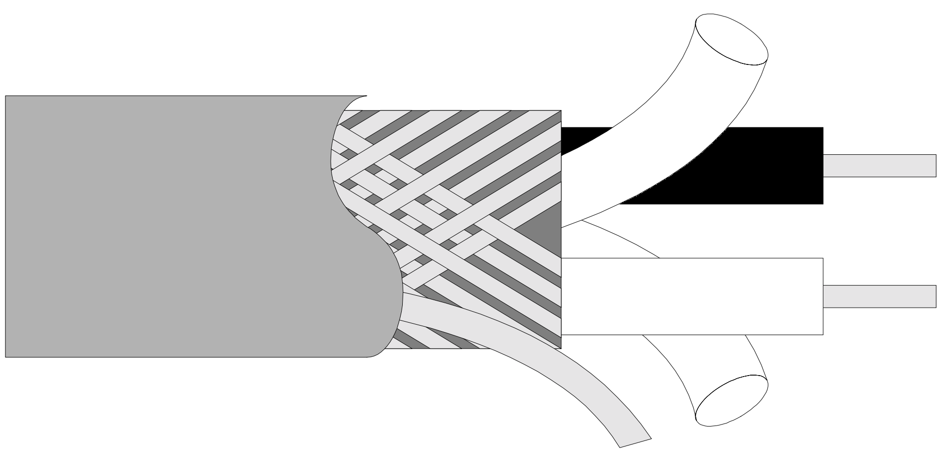
Nodes are connected in a BUS configuration (TrunkLine / DropLine). Refer to the diagram on page 2.

Media Type

Media Type is Baseband Shielded Twin Axial Cable

- Belden 9463..."Blue Hose"

Twin Axial Cable



Media Access Method / Protocol

Token Passing

- Proprietary Allen-Bradley token passing Protocol
- The node that has the right to transmit is said to have the Token.
- The node that has the token may send one or more messages, or pass the token on to the next node.
- A node should not hold the token for longer than 38 ms (many short messages, few long messages)
- In some situations AB PLCs may hold the token for as long as 100 ms.
- The token is always passed up to the next active node.
- The node numbers on a Data Highway Plus network range from 0-77 octal (0-63 decimal).
- A proprietary solicitation scheme is used to allow new nodes to join the network.

Messages

- When a node sends a message, the receiving node must send either an acknowledge (ACK) or a negative acknowledge (NAK).
- If the receiving node sends a NAK, the message is given an error status of 01h (destination could not buffer command). NAK'ed messages are not retried.
- If the sending node receives a packet that it does not recognize as an ACK or NAK, it retries the message. If the incorrect response persists after three tries, the message is given an error status of 03h (contention or duplicate node).
- If the node sending the message does not get an ACK or a NAK within a specified time, it retries the message.
- A message is retried up to two times (three tries in total).
- If no response is received after all retries are exhausted, the message is given an error status of 02h (destination did not respond).
- After a node has sent as many messages as it can, it must pass the token on to the next node.
- If an attempt is made to send a message while a node is not passing the token (it's the only node on the network), the message is given an error status of 04h (local port disconnected).

Data Highway Plus Network Loading

Why do you need to know about Loading?

- You may want to add another station, or more traffic to a network. You need to know how existing traffic will be affected.
- You may not be getting the performance you expect from the network. Before you split the network or put up with poor performance, you may want to get some facts so you can identify potential problem areas.
- After identifying and correcting problems, you need facts about network performance so you can determine how these changes affected the network.

There are two aspects of a token passing network that indicate its loading.

- The amount of time spent sending messages on the network (referred to as Traffic percentage).
- The volume of messages on the network (referred to as Busy Tokens percentage).

Traffic

Network time can be divided up into two categories:

- Overhead (token passes, solicit packets, ACKs, NAKs and spacing between packets)
- Messages going between nodes on the network

Traffic is expressed as a percentage of the total time available on a network.

For example, if during a 1 second sample period, 200 milliseconds were actually spent sending messages between nodes, the traffic is 20%. (The overhead is then 80%). A certain amount of overhead is necessary on any network, and throughput of the network is always less than actual baud rate. When there is little traffic, overhead is high; all idle time is spent passing the token. As traffic increases from a low percentage, overhead decreases and existing traffic is not greatly affected. As traffic continues to increase, the network starts to saturate, affecting the speed of existing traffic. If a network is totally saturated, any increase in traffic does not actually increase the traffic percentage, but slows down the existing traffic. The highest traffic percentage achievable on DH+ is approximately 75%. This means that the minimum overhead percentage is approximately 25%.

Busy Tokens

If the token goes to all the nodes on a network and none of the nodes have a message to send, this is considered an **Idle Token**. If any node sends a message when it has the token, this is considered a **Busy Token**. If a large number of short messages are used on a network, the Busy Token Percentage is high, but the actual data throughput is low. A high busy token percentage affects the throughput of a network, but its effect is not as serious as a high traffic percentage.

Network Tools

The following tools are provided to allow you to analyze and monitor your network. For more detailed information refer to the *Remote I/O Monitor* manual and the *Network Analyzer for Data Highway Plus* manual, that are included on the documentation CD.

The SST Data Highway Plus Network Analyzer

The Network Analyzer uses the 5136-SD card to collect information from the network.

A module on the card records each message on the network and reduces it to a brief summary that includes such information as source node, destination node, start and end times of the message, and whether the message is a command or a reply.

Front-end software running on your computer displays the statistics in either graphical or text form. The software can also log information to disk so that you can monitor the network for transient events.

Node by Node Information

Traffic %. This is made up of the network time the node is transmitting commands on the network and the time taken by the replies from other nodes to the commands this node sends. In other words, this is a measure of the traffic on the network originated by this node.

Replies %. This is the percentage of the network time taken up by replies by this node to commands from other nodes. This measures the loading on this node by other nodes.

Busy tokens %. If a node gets the token and has messages to send, it is considered a busy token. If the busy token rate reaches 90%, the node is approaching saturation and adding any more load degrades the performance of this node.

Duplicate Messages Transmitted or Received. This may help to identify nodes that are having trouble communicating on the network. DUP RX indicates receive errors by this node, DUP TX indicates another node has incorrectly received what this node transmitted. For every DUP TX on a particular node, there is a corresponding DUP RX on another node.

Reply Time. This is the average time it takes for a node to process a message. It is the time from the end of the receipt of a command to the start of the reply being sent. If a node has to process too many messages, reply time increases. To reduce reply time, decrease the rate of messages being sent to the node.

Total Network Information

Network Traffic. This is expressed as a percent and indicates to what extent you are using the bandwidth of the network. This can be used to estimate how much additional traffic you can add to the network without having a severe impact on the existing traffic. Since there is a certain amount of network overhead required for token passing, packet spacing etc., there is an upper limit of approximately 75% to total network traffic.

Busy Tokens. This gives an indication of the volume of messages that are being sent across the network. If the token goes to all the nodes on the network and none of them has a message to send, this is considered an idle token. If any node sends a message, this is considered a busy token.

Total Packets displays the number of actual packets used in the last network sample.

Bad Packets displays the number of packets in the last sample that were received incorrectly by the analyzer.

Total Messages displays the number of messages (including both commands and replies) that occurred during the last sample.

Message Retries displays the number of message retries that occurred in the last sample period. This corresponds to the DUP TX and DUP RX information displayed node by node.

Logging

All information can be logged to disk for later analysis or for documenting your network's characteristics under normal operation so that when a problem arises, you can quickly track it down.

The Data Highway Plus Network Monitor

The Network Analyzer package also includes a Network Monitor, which can be used to capture raw messages from the DH+ network. These messages use a proprietary Allen-Bradley format, which can be obtained from the AB document Data Highway / Data Highway Plus / DH-485 Communication Protocol and Command Set (1770-6.5.16)

The basic format for all DH+ messages is as follows:

```
dst src cmd sts tns fnc...
```

- `dst` destination station
- `src` source station
- `cmd` command code
- `sts` status
- `tns` message transaction number (two bytes, low byte / high byte)
- `fnc` function code (not always present)

All messages on DH+ are either a command or a reply. If bit 6 of the command byte is 0, the message is a command. If bit 6 of the command byte is 1, the message is a reply.

A Sample of the Network Monitor File Format is as follows:

```
Data Highway Plus Network Monitor Capture file

Created Mon Apr 05 09:54:32 1993

Line #   Time(ms) Destination    Source          Message...
------   -------- -----------    ------          ----------
    1 :         2 [ DRIVERS-002] (COMPUTER-062)  06 00 47 6f 01
00 01 23
    2 :         5 [COMPUTER-062] ( DRIVERS-002)  ACK
    3 :        22 [COMPUTER-062] ( DRIVERS-002)  46 00 47 6f 00
00 00 ....
    4 :        29 [ DRIVERS-002] (COMPUTER-062)  ACK
```

- Line 1 shows a command message from station 62 octal to station 2. The command is 06 (diagnostic command), the status is 0 (no error), the transaction number is 6f47 hex (tns is low byte / high byte), and the function is 01 (diagnostic read). The last three bytes are required parameters for the diagnostic read command.
- Lines 2 and 4 are ACKs.
- Line 3 shows the reply message from station 2 to station 62 octal. Note that bit 6 of the command byte is set, and the transaction number matches that of the command.

A time stamp in milliseconds is shown for each message. This may be useful for determining update and response times of specific pieces of data.

Message retries are shown as identical messages on consecutive lines. The transaction number will be the same, and no ACK will exist between the two lines.

The Monitor may be configured for **Triggered Start** or **Triggered Stop**. Triggered Start is useful for capturing events that are predictable and about to happen. Triggered Stop is useful for capturing events that are less predictable and just happened.

The Monitor may also be filtered. Use it to capture messages to and from a specific station.

Summary of Network Monitor

- Observing messages on the network is not for everybody.

  It is time consuming and requires knowledge of DH+ messages.
- The Monitor is especially useful when developing applications that generate messages on DH+.

  You can easily see what you are sending and what you are getting back.

Optimizing A DH+ Network

The bandwidth of the DH+ network is fixed, so there are only a limited number of ways to affect the throughput and response time of the network. Some of these are:

- Eliminate any unneeded messages.
- Decide how often you need each piece of data, try to group data based on how often updates are needed.
- Group data so that there are no gaps with unused data in messages.
- Group data so that fewer, larger, messages can be used.
- Decide which nodes are less critical; reduce poll times on these nodes.
- If possible use unsolicited messages, especially for alarms.

If your network has throughput problems, something somewhere has to give. Some things to look for when analyzing a network are:

- PLCs that have a high "REPLIES %" (all nodes trying to talk to the same PLC).
- Observe "TRAFFIC %" for all screens of any MMIs on the network. Different screens generate different amounts of traffic.
- Use the Max/Min indicators to detect surges in traffic.
- Beware of programming software; depending on what you are doing, it can generate a lot of traffic.

Summary of Network Optimization

After any unnecessary traffic has been eliminated, and data has been grouped as efficiently as possible in the PLC, network optimization is a matter of give and take.

By improving performance of one node, traffic will be affected, and the performance of other nodes will go down.

If the required performance cannot be achieved, the network may need to be split.

- This can often be costly as bridges must be purchased.
- This may not be practical depending on required data paths.

Network Performance

This section describes how the network works, when it is operating properly. You may compare this data with actual data from your network to determine what problems (if any) that you are experiencing.

Hardware

Transformer Coupled Differential Signal

- Transformer Coupling means that stations do not have to be at the same ground potential (Reduces grounding loops etc.)

Two wires carry data; data is represented by voltage differences between the two wires, not by the absolute voltage on the wires.

- This means that noise that is common to both wires is ignored. (Limitations apply).

Signal Level is typically 8-12 volts peak to peak.

Half Duplex (one transmitter at a time, other nodes receive)

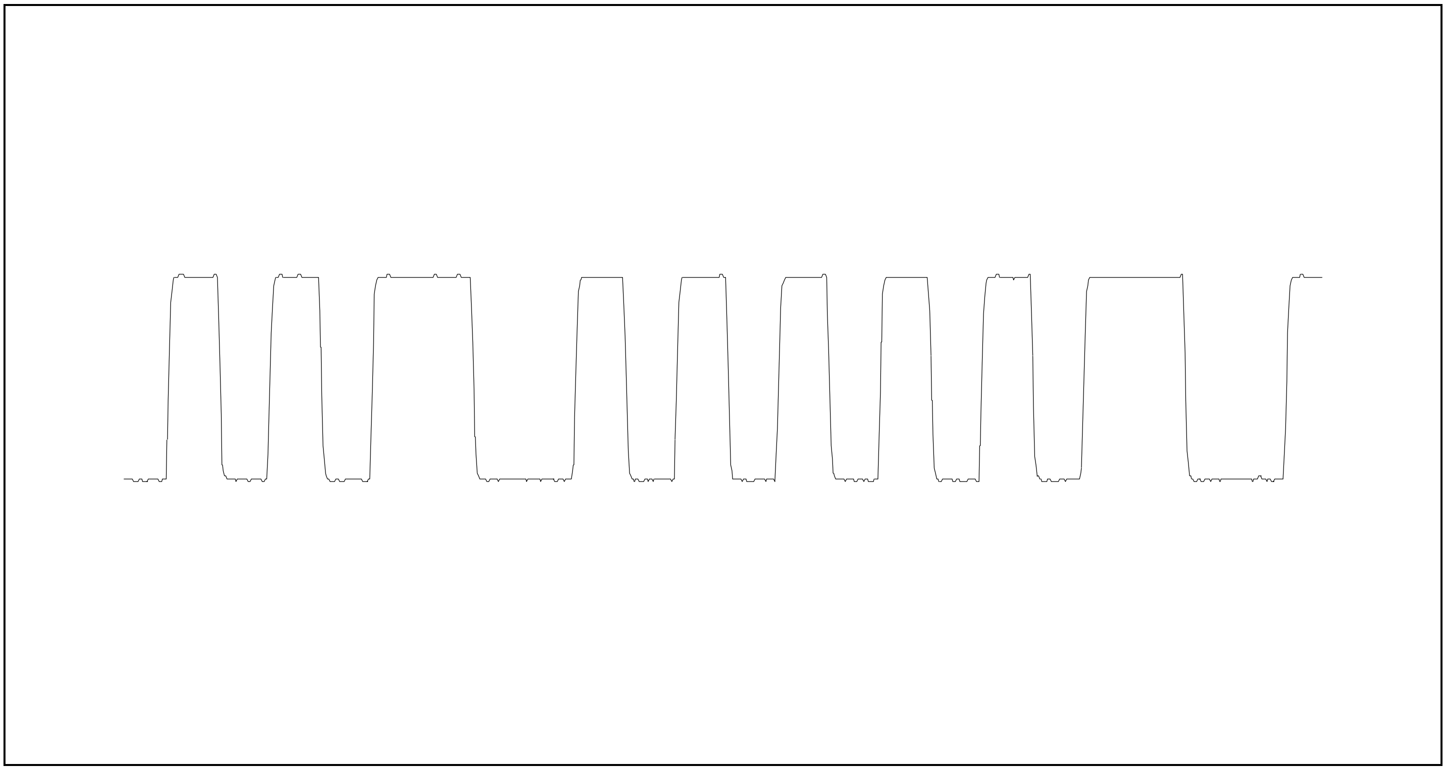
Baud Rate 57.6 kilobaud. (115.2/230.4 kilobaud optional on some PLCs etc.)

Synchronous Data, Manchester encoded.

- Rising edge = 1, Falling edge = 0. Timing of edges is critical.
- Receiver Sensitive to ±200mV, signals should pass through this range quickly.
- Clock information is sent along with data (inherent with Manchester encoding)
- Subset of HDLC/SDLC low level Frame synchronous protocol
- Flags (01111110) to start and end packets
- 16 bit CRC included before closing flag of every packet.

Typical Manchester Encoded Signal

When the network is running properly this is the signal that you see:



Transmission Lines

Blue Hose, Coax, and other kinds of wire have many properties associated with them, such as inductance, capacitance, impedance, and attenuation. When a significant length of any type of wire is being used to carry a signal, it is considered to be a transmission line.

Because transmission line analysis can get very complicated, consider a few basic properties that may help you to understand and troubleshoot DH+ networks.

Signal Propagation

Signals propagate along a transmission line at a fixed rate, usually expressed as a percentage of the speed of light. For Blue Hose the nominal velocity of propagation is 66%. Light travels at 299,800,000 meters per second, so light goes one meter in ~3.3356 nanoseconds (~1 nanosecond per foot). A signal would then propagate through one meter of Blue Hose in ~5 nanoseconds (~1.5 nanoseconds per foot).

As a signal propagates along a transmission line, it encounters the characteristic impedance of the wire, as if the wire was an infinite set of resistors (78 ohm resistors in the case of blue hose). When the signal reaches the end of the line, it must be absorbed by a terminator. The impedance of the terminator must match the impedance of the wire.

Any mismatch between the impedance in the line and the impedance of the terminator causes a reflection back down the cable. If the impedance of the terminator is higher than the line, a constructive reflection bounces back. If the impedance of the terminator is lower than the line, a destructive reflection bounces back.

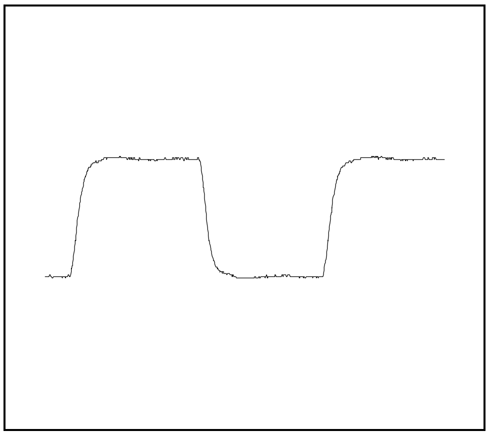
Transmission Line Examples

These examples are provided to assist you in troubleshooting your network. Note that several examples of each case are given to show how the signal can change, depending on the length of cable.

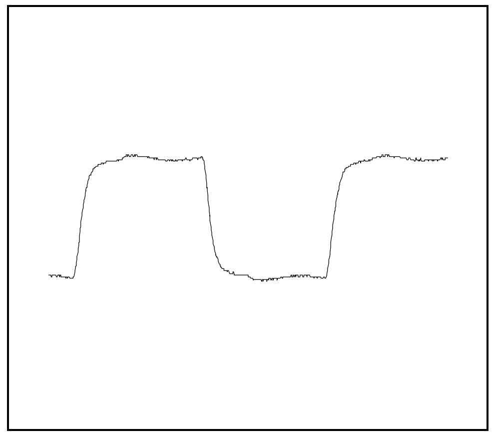
Proper Termination

78 ohm cable, 75 ohm terminator

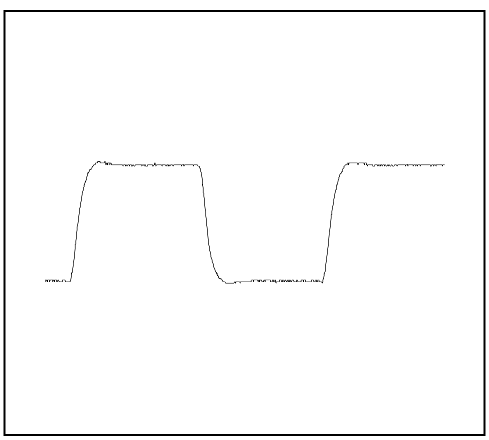
25 Feet of Cable



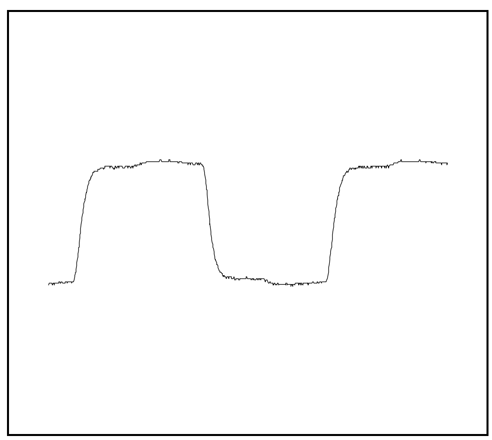
75 Feet of Cable



50 Feet of Cable



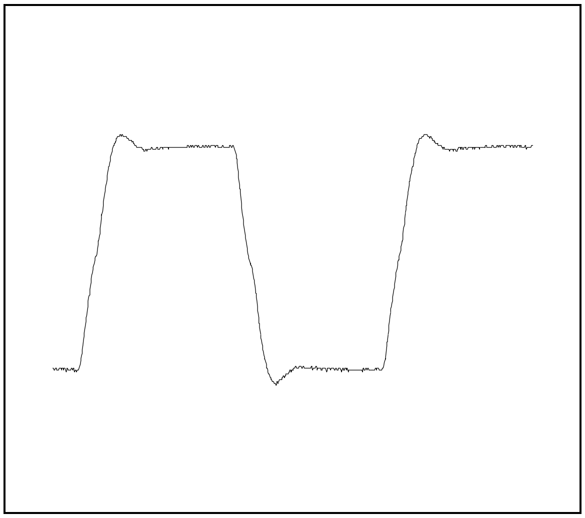
100 Feet of Cable



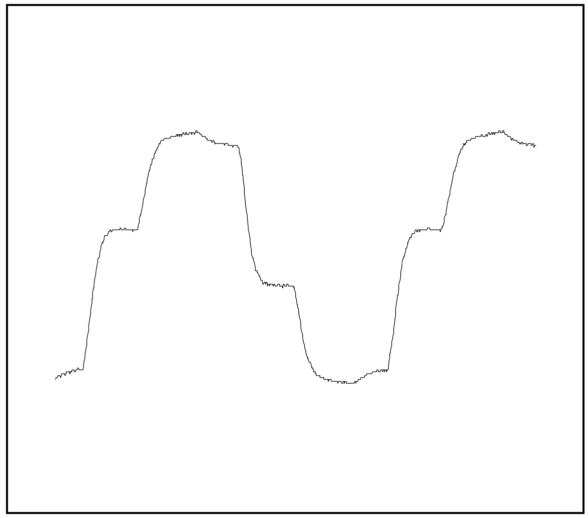
No Termination

78 ohm cable, No terminator

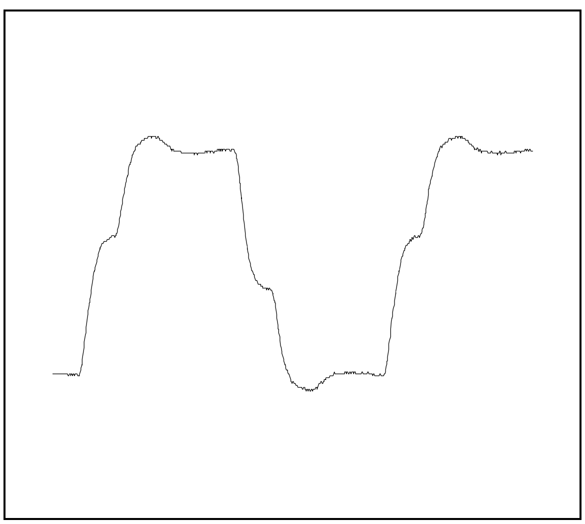
25 Feet of Cable



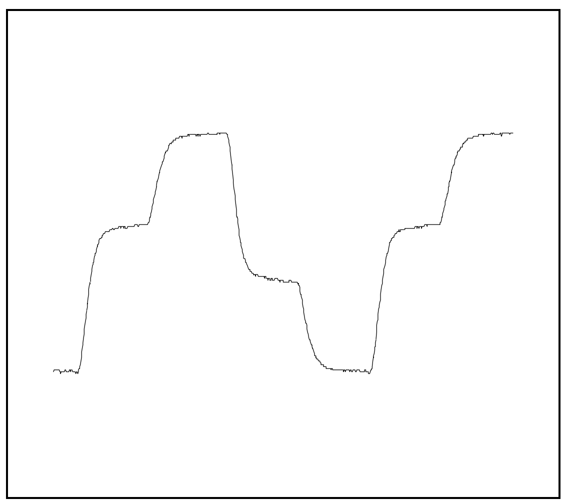
75 Feet of Cable



50 Feet of Cable



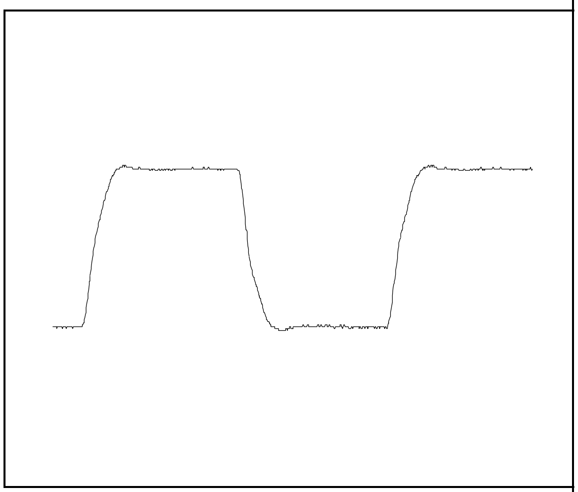
100 Feet of Cable



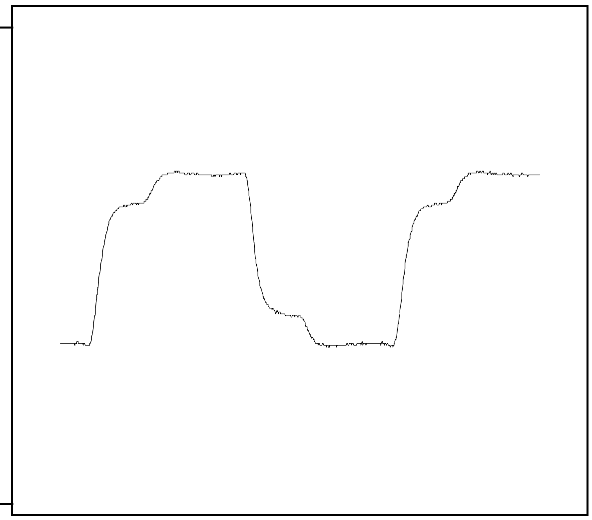
Terminator Too Large

78 ohm cable, 150 ohm terminator

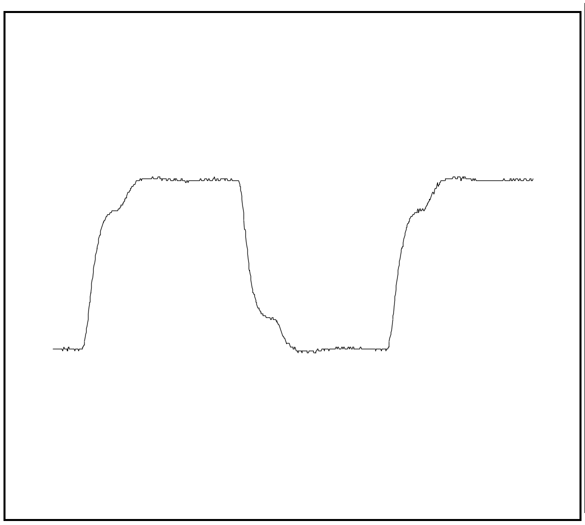
25 Feet of Cable



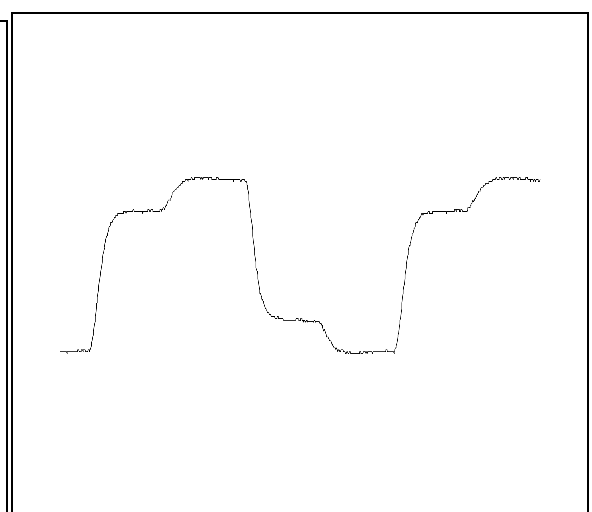
75 Feet of Cable



50 Feet of Cable



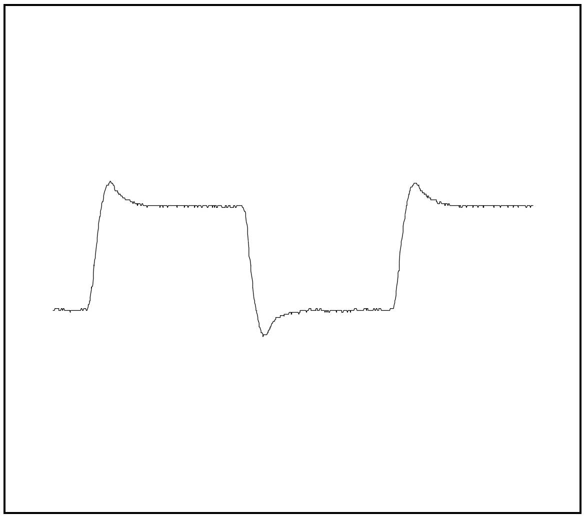
100 Feet of Cable



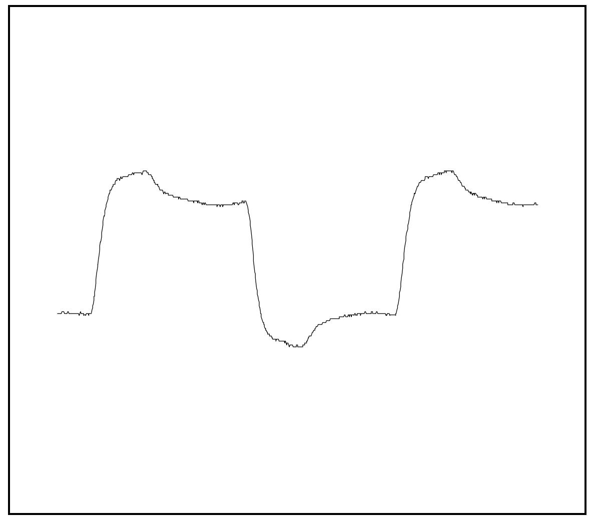
Terminator Too Small

78 ohm cable, 41 ohm terminator

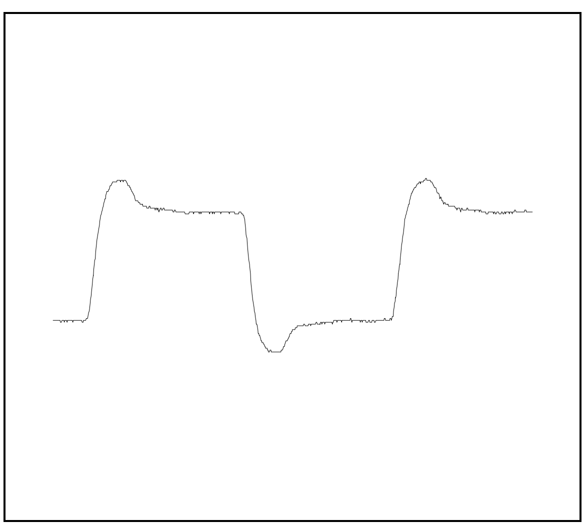
25 Feet of Cable



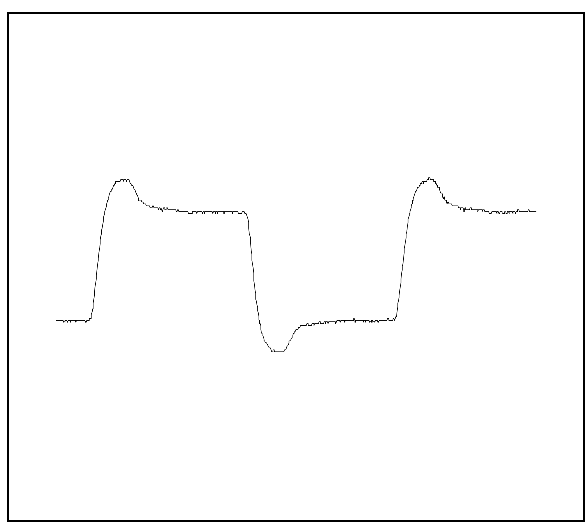
75 Feet of Cable



50 Feet of Cable



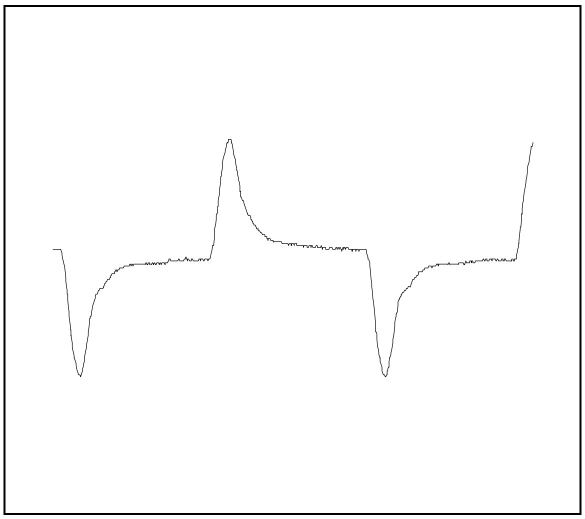
100 Feet of Cable



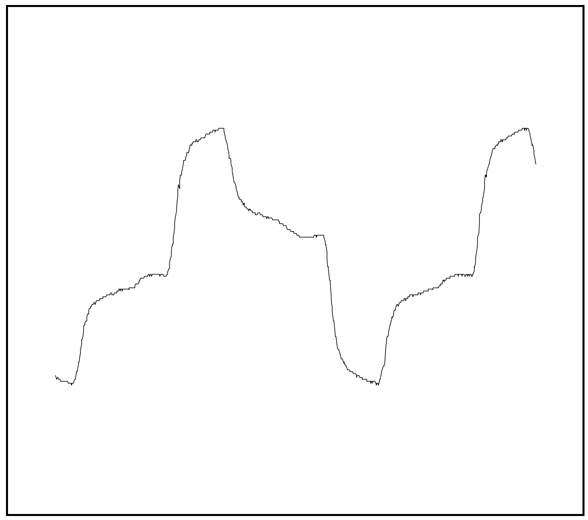
End of line Shorted

78 ohm cable, 0 ohm terminator (ends shorted)

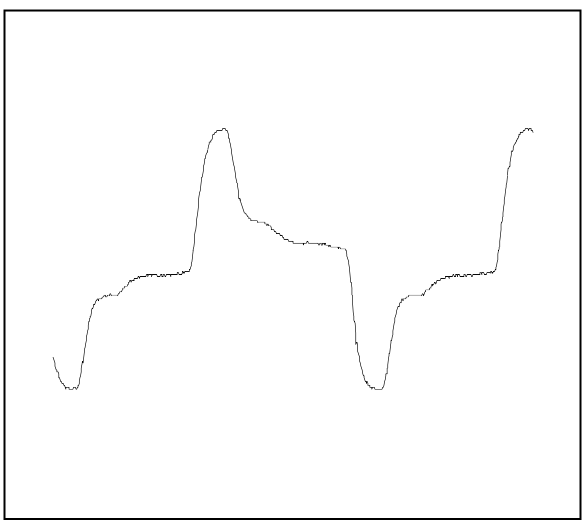
25 Feet of Cable



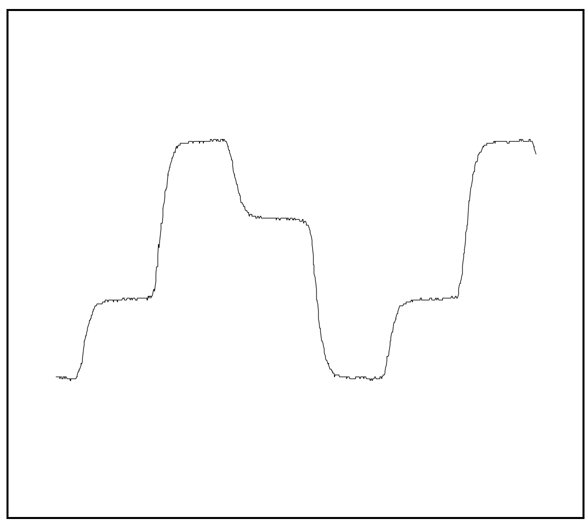
75 Feet of Cable



50 Feet of Cable



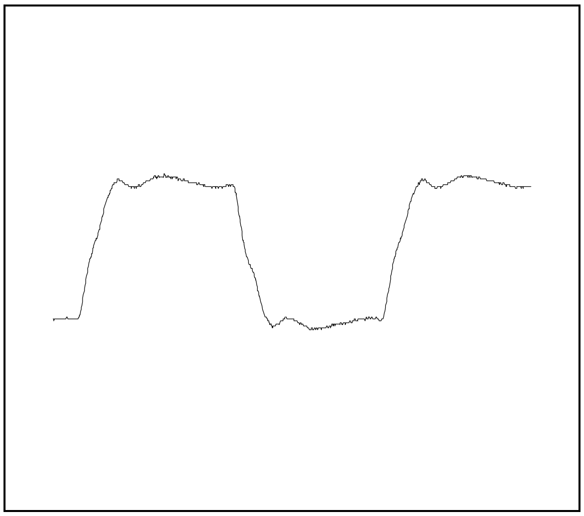
100 Feet of Cable



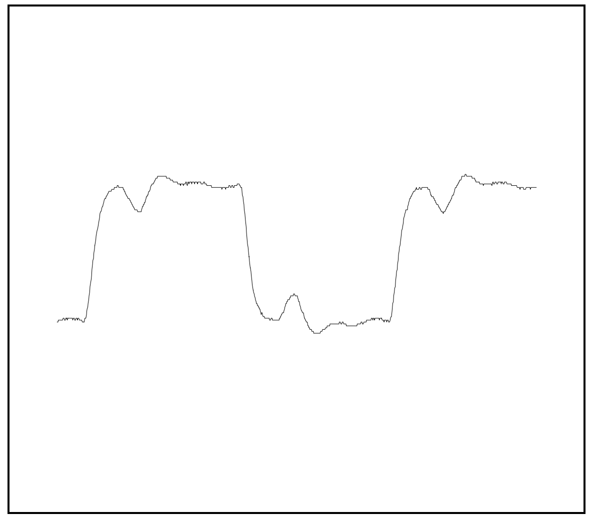
Properly Terminated Network with Drop

78 ohm cable, 75 ohm terminator, 75 foot "trunk", drop "tapped" at various points.

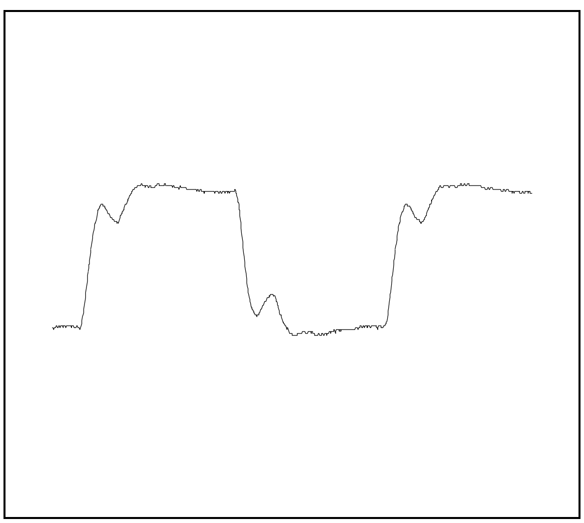
Tap at start of Cable



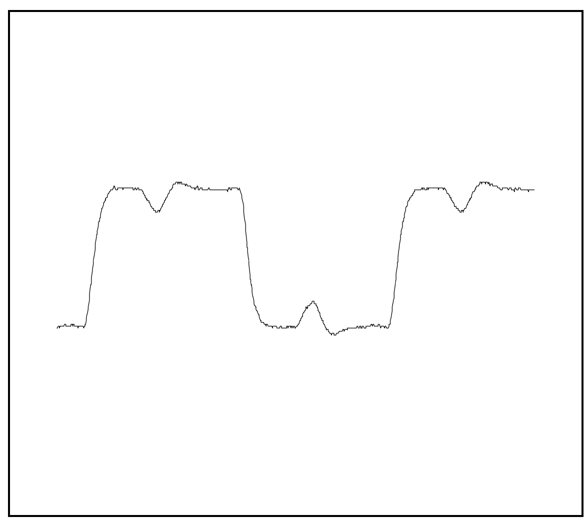
Tap at 50 feet



Tap at 25 feet



Tap at end of cable



Transmission Line Summary

Using propagation delay can be very useful:

- You can determine quite accurately how far down a line a break or short exists.
- Commercially available Time Delay Reflectometers (TDR) are available.

By understanding transmission lines, you may be able to recognize network problems by looking at the waveforms on a network.

Troubleshooting on a DH+ Network

Hardware Problems

Hardware problems are usually indicated by a high rate of CRC errors on one or more nodes on the network. The only other things that can cause CRC errors are low-level protocol errors or duplicate stations (which causes two stations to transmit at the same time). Usually CRC errors cause various other errors on the network such as token pass time out, message retries etc.

The CRC error count for nodes on DH+ can be monitored using programming software, or diagnostic programs such as DHPD.EXE etc. to monitor the DH+ diagnostic counters. If possible, it is best to monitor the error counters on the local node so that extra traffic is not generated by reading back the diagnostic counters from other nodes.

The network analyzer also shows the number of CRC errors it encounters while monitoring the network. This is unobtrusive since no extra traffic is being generated.

CRC errors can be caused by problems with a specific node, or by problems with the network in general.

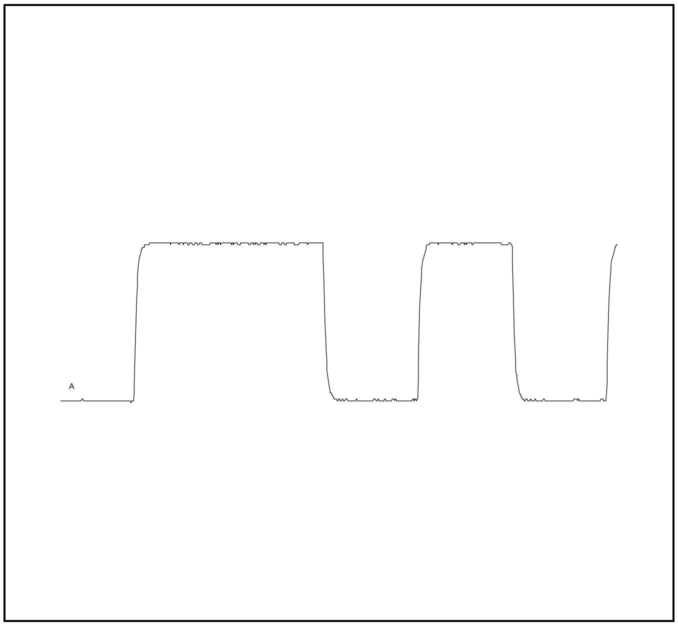
Observing Signals on DH+

The Scope should be connected with ground clip on shield, one probe on clear, other probe on blue. If possible, use an isolated ground adapter. Full wave can be seen with channel B on ADD INVERT.

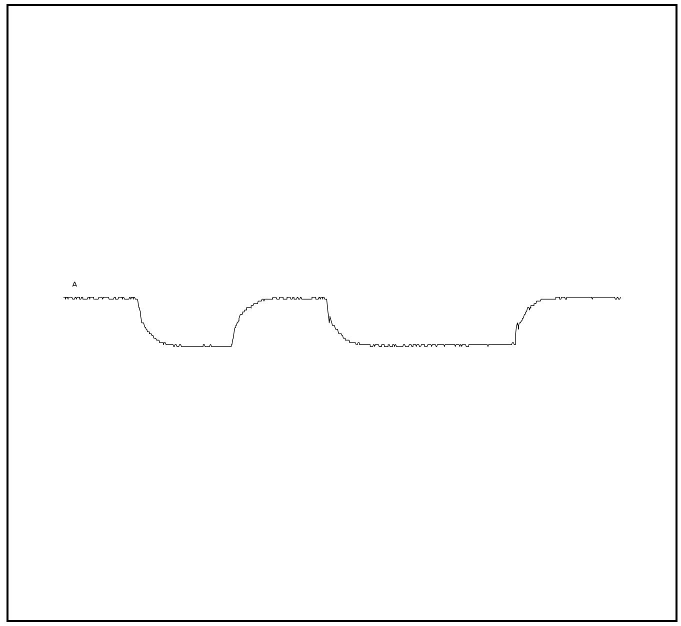
Spotting problems on DH+ by observing waveforms requires experience, and ideally printouts of samples taken when the network was working properly. This is often not possible or practical. Since edges are the most critical part of a Manchester signal, the most important part of the signal is the zero crossing. Any signal that does not go quickly through zero crossing can potentially cause problems on the network.

Try to apply transmission line principles to help track down problems.

Good DH+ Signal



Bad DH+ Signal



LED Triggering

Sometimes it is necessary to look at signals from specific nodes on the network. This is usually very hard to do, since there is usually nothing to trigger the scope when a particular node transmits. The LED-triggering feature on the network analyzer can be used to generate a scope trigger. In order to use this feature, use the test point labeled LEDT. On older cards you must solder a test point on the lower lead of the SD card's green LED. The analyzer module on the SD card can be configured to turn the LED on when a signal is received from any specific node on the network. This LED test point can be connected to the external trigger of the scope. This provides a convenient way to look at signals from specific nodes on the DH+ network.

Troubleshooting by Comparing Blue and Clear Phases.

Signals on A and B should be almost identical, but 180º out of phase. This fact can be useful for tracking down hardware problems.

Bad connections, shorts, or bad nodes often cause a difference between the two phases. Tracking down what is causing the difference often points us to what is causing the network problem.

To compare the signal on the clear and blue wires, connect one to channel A of the scope, the other to channel B of the scope. Set channel B to INV mode. Since the channels are 180º out of phase, the inverse of B should be the same as A. By placing the traces on top of each other, it is easy to spot differences.

The success of this method of troubleshooting is based on the fact that many error situations such as bad sections of wire, bad connections etc. affect one phase of the wire (blue or clear) differently than the other.

Narrowing in on the Problem

If the problem is found to be specific to the signal from a specific node, it is of course easy to find the specific problem. If the problem is network wide, it is more difficult to find the specific problem spot.

The only way to track down some problems is to methodically break up the network into sections. Care must be taken to ensure that each new subsection is properly terminated. Sometimes when a network is divided, problems seem to go away.

It is usually hard to duplicate the traffic etc. in each subsection. Whatever discrepancy you are looking for in signal should still exist in one of the sub-networks, even if the symptoms do not show.

Summary of DH+ Hardware Troubleshooting

- It is quite often very difficult to find specific problems on a network.
- The most important rule of thumb is "Never assume that any connection, terminator, wire, or any other aspect of the network is correct until you have checked it."
- Problems are often found where they are deemed to be impossible.

Glossary

ACK An "Acknowledge" packet from a node that has just received a message to the node that sent the message, indicating that the message was received correctly.

Busy Token If the token goes around the network to all active nodes and none of the nodes has a message to send, this is an idle token. If any node sends a message, this is a busy token.

Command A message initiated by a node, which must be responded to by the node to which the command is sent.

Message A packet containing a command, transaction number and data, the information we're trying to pass between nodes. A node may only send a message if it has the token. All messages on DH+ are either commands or replies.

NAK A "Negative Acknowledge" packet from a node that has just received a message to the node that sent the message, indicating that the receiving node was unable to process the message at the time it was sent (usually because it ran out of buffer space).

Node A point or "station" on a network (Node and Station are used interchangeably)

Packet Any data group on the network, could be a token pass, solicit packet, message, ACK or NAK.

Reply A message that is sent in response to a command sent by another node.

Solicit Checking for nodes entering the network (either being connected or turned on) by sending a "solicit" packet to a node that does not currently exist on the network. If the node responds, it is added to the network, and will receive the token.

Successor The Node with the next highest node number, which is active (The node to which the current token holder will pass the token).

Token The "right" to transmit on the network

Traffic Time used on the network by a node sending a command, and for the node to which the command is sent to send the reply.

Technical Support

Technical support is available during regular business hours by telephone, fax or email from any SST office, or from the company Web site at www.sstech.on.ca.

Documentation and software updates are available on our Web site.

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