

Fieldbus Physical Layer Troubleshooting Guide

1 Introduction

Foundation Fieldbus combines a reliable physical layer with a robust protocol. Even so, it isn't uncommon to encounter a few problems due to simple wiring errors while commissioning a new plant. In addition, environmental conditions can cause deterioration, impacting the physical layer over time. Problems are infrequent. However, when problems do occur determining the cause can be challenging. A fieldbus may appear to be functioning fine, even with multiple problems. Eliminating these problems before they lead to plant down-time saves time and money.

The purpose of this guide is to help identify the symptoms a fieldbus segment is exhibiting, point to possible causes, and then help correct the problems. This guide only addresses problems with the physical layer of the fieldbus: cable, wiring blocks, terminators, and power conditioners. Problems setting up control loops, configuring devices, and other higher level issues are beyond the scope of this document.

For a basic introduction to Foundation Fieldbus, see the Fieldbus Wiring Guide, available for viewing or download at www.relcominc.com.

If symptoms of a problem are known and data from the troubled segment is available from an FBT-3, FBT-6, F809F, or oscilloscope, see Appendix A for a list of possible causes and recommended actions.

2 Avoiding Physical Layer Problems

Prevention is the key to a reliable fieldbus network: proper training, tools, and supervision during installation and maintenance. Use quality cable and certified products from reputable companies. Save a set of segment data as a baseline when the fieldbus is operating properly. When problems are encountered take a new set of data and compare it to the baseline.

For more information, see the Preventing Fieldbus Physical Layer Problems application note at www.relcominc.com.

For guidance on troubleshooting a fieldbus physical layer problem, read on.

3 Troubleshooting Tools

Many tools are available to help determine the health of a fieldbus. Here is a list of the more important ones:

3.1 *Digital Multimeter (DMM)*

A good DMM can take resistance, voltage, current, and capacitance measurements. Measurements of bus voltage and shield resistance to ground (continuity) can be taken any time. Resistance between wires and shield can only be made when the network is without power, so they are only used when the segment is initially setup or down for maintenance.

3.2 *Oscilloscope*

An oscilloscope (scope) displays what the signals on the fieldbus look like. The information gleaned from a waveform can be useful to a person experienced with fieldbus waveforms. CAUTION: oscilloscopes are fairly complicated to operate and can disrupt fieldbus communications if not used properly. Once a signal is captured, it must be interpreted by an experienced and knowledgeable person. Using an oscilloscope is not recommended without such a person available.

Oscilloscope settings should start at: 200mV/div, 40usec/div, AC coupling, 50mV rising edge trigger level. This will capture the first few bits of a fieldbus frame to look at. Each frame is from one device, but the frame must be manually decoded to determine which device it is from (beyond the scope of this document). Look at many frames and identify any that look unusual. If noise is present on the bus, the oscilloscope may trigger on the noise instead of the signals. Raise the trigger level until fieldbus data is consistently captured. Oscilloscope settings may be adjusted to look at more of the waveform or look at the signal in closer detail as desired.

See Appendix B for more details on using oscilloscopes and sample oscilloscope captures.

3.3 FBT-3 Fieldbus Monitor

The FBT-3 is a hand-held electronic device specifically made to help determine the health of fieldbus segments and troubleshoot segments with problems. The bus powered FBT-3 passively listens to the device communications when connected to the fieldbus. It measures bus voltage, noise, and indicates the lowest device signal level detected as well as the signal level of the Link Active Scheduler (LAS). It also indicates when devices are added or removed from a network, indicates the number of devices on the segment, and more. Note that the FBT-3 will add a 10mA load to the bus. This should not be an issue on a fieldbus spur with a 59mA current limit and the typical device current of 20mA. However, Megablocks (device couplers) used in intrinsically safe or increased safety applications have a 40mA current limit and are more likely to be a concern.

3.4 FBT-6 Fieldbus Monitor

The FBT-6 is the follow-on to the FBT-3. It is hand-held, measures bus voltage, noise, the number of devices on the segment, and indicates when devices are added or removed from a network like the FBT-3. The noise measurement is split into 3 bands: the fieldbus frequency band (9kHz to 40kHz), below it (50Hz to 4kHz) and above it (90kHz to 350kHz). In addition, it counts retransmissions to devices (resent pass token frames), checks for the presence of shield shorts to the (+) or (-) fieldbus wire, specifies the address and signal level of each device, and identifies which device is the Link Active Scheduler (LAS). The data collected from a segment can be saved in memory, and then downloaded to a PC via a USB port. Note that the FBT-6 will add a 10mA load to the bus. This should not be an issue on a fieldbus spur with a 59mA current limit and the typical device current of 20mA. However, Megablocks (device couplers) used in intrinsically safe or increased safety applications have a 40mA current limit and are more likely to be a concern.

3.5 F809F Fieldbus Diagnostic Module

The F809F is essentially a permanently mounted FBT-6 that continuously collects diagnostic information on up to 8 segments.

3.6 Torque Screwdriver

To make sure screw terminals are adequately tightened, use a torque screwdriver. The amount of force that should be applied to the screw terminals surprises most people. Without a torque screw driver, screw terminals are often under- or over-torqued. Relcom products use screw terminals that should be tightened to 5 in-lbs (0.57 Nm) of torque. The Wiha TorqueFix 28503 screwdriver and replaceable 28537 3.0mm slotted blade is an example. Torque screwdrivers are expensive (~\$85) but much cheaper than plant down-time.

4 Troubleshooting

The network is powered and not functioning as expected. The basic troubleshooting approach is:

- List the symptoms
- Collect data
- Look up likely causes
- Inspect the physical layer for the problem

4.1 *List the Symptoms*

Gather all of the information on the symptoms the network is showing and write them down. During the course of listing the symptoms a pattern may be noticed or clues revealed that lead to the problem. Does the network get flaky at 4:13PM every day? If so, what happens in the plant at 4:13PM? Does a particular pump turn on? Does Joe start his shift then? Is it the same device always causing the problem? Are the devices that have the problem all in the same area?

4.2 Collect Data

A number of measurements can easily be made to help identify the problem. Five very useful measurements are:

- Voltage
- Signal Level
- Noise
- Retransmits
- Shield Shorts

These measurements are discussed in detail in the following paragraphs. The easiest way to make these measurements is with an FBT-3 or FBT-6. An oscilloscope or DMM can also be used to collect some of the same data. As measurements are collected, write them down (save the data in memory when using an FBT-6 then download it to a PC later). Make sure to note at what point on the segment the data was taken (at the fieldbus power supply, wiring block, a specific device, etc.).

Where the data is collected is important. The questions below help determine the best location to take the data and pinpoint the source of the problem.

- Is it one device, multiple devices, or all devices on a segment that are exhibiting the problem?
- What is common to the devices that exhibit the problem?

The idea behind these questions is to divide and conquer. Try to split the network into a part that is working fine and a part that is not, isolating the problem area so further investigation and corrective efforts are focused and more productive.

If one device exhibits the problem, take data on the spur that the problem device is on and another set at the trunk port of the wiring block the device is on. If multiple devices exhibit the problem, take measurements on either side of equipment, cabling, etc. that the devices share. If all devices exhibit the problem, take data at the control room end of the trunk and on one of the spurs. Compare the two sets of measurements and try to identify a specific part of the segment exhibiting the problem. Based on the results of the comparison, take additional measurements to further isolate the location of the problem.

4.2.1 Voltage

A device with inadequate power (voltage) can exhibit a variety of behaviors. Retransmissions, devices repeatedly dropping from and adding to the network, or not being seen on the network are all possible symptoms.

The expected DC voltage measurement on the fieldbus varies with the bulk DC power supply used, the fieldbus power supply used, and where on the fieldbus network the measurement is taken. Resistance in cable, wire terminations, and wiring blocks causes the voltage to drop. Voltage is highest at the fieldbus power supply and lowest at the fieldbus devices. The voltages elsewhere on the network should be lower than those at the fieldbus power supply. Voltage should never be less than 9 VDC or greater than 32VDC. The FBT-3 and FBT-6 both display DC voltage in the VOLTAGE function. Voltage measurement guidelines are listed in the table below.

General Guidelines for Voltage Measurements

Voltage (VDC)	Condition
>32	Too High
10 - 32	OK
<10	Too Low

It is important to emphasize that the numbers in the table are GUIDELINES. Every fieldbus segment is different. The fieldbus power supply, cable length, where the measurement is taken, and other factors can drastically affect the actual measurements on the network. Engineers familiar with fieldbus can calculate what values to expect at various points on a network. The Fieldbus Segment Calculator software tool available as a free download at the MTL website can help with such calculations.

http://www.mtl-inst.com/products/soft-tools/soft_tools.htm

As an example, consider an FPS-I fieldbus power supply that outputs 28V. The output voltage varies little (~3V) from no load to full load. At the FPS-I a voltage measurement of 28V +0/-3V is expected. The voltage at the end of a 2000ft trunk cable with 10 devices drawing 0.02A each is another matter. Standard fieldbus cable has a resistance of 7.32ohms/1000ft (24ohms/Km). The voltage at this point (V_{field}) can be estimated by using Ohms Law ($V=I*R$) to calculate the voltage loss due to the cable from the fieldbus power supply output (V_{loss}) and subtracting it from the power supply output voltage (V_{supply}).

$$V_{loss} = I * R$$

Where I is the current in the trunk cable and R is the resistance of the trunk cable.

$$V_{loss} = (10 \text{ devices} * 0.02A) * ((7.32\text{ohms}/1000\text{ft}) * 2000\text{ft})$$

$$V_{loss} = 2.9V$$

$$V_{field} = V_{supply} - V_{loss} = 28V - 2.9V = 25.1V +0/-3V$$

4.2.2 Signal Level

The signal level of a device indicates how loudly it is talking to other devices. If a device talks too quietly or the bus is too noisy the other devices cannot hear it.

Signal level is measured from the top of one signal peak to the bottom of the next peak (peak-to-peak). Signal level is impacted by the number of terminators attached to the segment, trunk and spur cable lengths, and series resistance of current limiting devices (such as Megablock SpurGuards). Each fieldbus segment should have 2 terminators installed. An extra terminator typically results in a signal level reduction of 30%. A missing terminator typically results in a signal level increase of 70%.

The FBT-3 LAS function displays the signal level of the LAS. The FBT-3 and FBT-6 both have a LOW function that displays the lowest detected signal level from a device. The FBT-6 DEVICE function displays the signal level of each device. Signal level measurement guidelines are listed below.

General Guidelines for Signal Level Measurements

Signal Level (mVpp)	Condition
>1000	Too High – Missing Terminator
250-1000	OK
<250	Too Low

Again, it is important to emphasize that the numbers in the table are GUIDELINES. Every fieldbus segment is different. The specific device, cable length, where the measurement is taken, and other factors can drastically affect the actual measurement results. Certain devices, such as fieldbus barriers, have a high series resistance and can result in signal levels of up to 2000mVpp. Megablock SpurGuard circuits have a series resistance that can result in signal levels of up to 1400mVpp on a spur. These situations are unusual, but keep them in mind. A measurement that doesn't meet the above guidelines may be fine.

4.2.3 Noise

Noise can interfere with the fieldbus signal causing communications to be corrupted or missed. Ungrounded or improperly grounded shield wires and routing fieldbus cables near other cables (particularly high power cables) are typical sources of fieldbus noise. Noise can be constant or come in bursts.

Fieldbus communicates within a frequency band of 7.8KHz to 39.1KHz. The closer the noise frequency is to the fieldbus frequency band, the lower the noise signal strength must be to impact communications on the fieldbus. Fieldbus devices are required to reject signals within the fieldbus frequency band that are less than 75mVpp.

The FBT-3 and FBT-6 both measure average and peak noise. High average noise indicates the noise source is constantly present. Common causes of high average noise include a poorly grounded shield and routing of fieldbus cables near and parallel with other signal carrying cables or AC power cables.

Peak noise indicates the highest noise level detected by the tester. High peak noise with low average noise indicates the network is experiencing noise spikes. Common causes of noise spikes are nearby high-powered equipment turning on and off (i.e. welders, large pumps, motors, etc.) and loose fieldbus wire terminations.

The FBT-6 breaks noise measurements into 3 frequency bands: the fieldbus frequency band (FF), low frequencies below the fieldbus frequency band (LF), and high frequencies above the fieldbus frequency band (HF). Identifying the frequency band of the noise can help identify the source. Low frequency noise is often caused by coupling of signals from 50-60Hz power lines to the fieldbus cable. High frequency noise is often caused by variable speed drives.

Frequency Band	Common Noise Sources
<7.8KHz	AC power cables near the fieldbus cables, bad connections (loose/broken wires etc.)
7.8KHz – 39.1KHz	
>39.1KHz	Variable frequency drives, high-powered equipment turned on/off

Noise level measurement guidelines are listed below.

General Guidelines for Noise Level Measurements with the FBT-3

Noise Level (mV)	Condition
<25	Excellent
25-50	OK
50-100	Marginal
>100	Poor

General Guidelines for Noise Level Measurements with the FBT-6

Noise Level in FF Noise Band (mV)	Noise Level in LF Noise Band (mV)	Noise Level in HF Noise Band (mV)	Condition
<30	<50	<50	Good
30-75	50-150	50-150	Marginal
>75	>150	>150	Too High

4.2.4 Retransmits

Foundation Fieldbus devices talk one at a time on the bus by sending messages back and forth to each other. Some messages sent from one device (the source) to another device (the destination) require a response from the destination device. If the destination device does not respond, the source device sends the message again. Messages that must be sent again are referred to as Retransmits.

Retransmits are a very good indicator of overall network health. They can occur with many different potential physical layer problems, including high bus noise level, low signal level, and low bus voltage level. An ideal fieldbus setup would have no retransmits, but a network with very few retransmissions is likely in good shape.

The FBT-3 and the FBT-6 both monitor for Retransmits. The FBT-3 indicates Retransmits in the DEVICE function. When a Retransmit occurs, the device is dropped from the FBT-3's internal "live list" then quickly added back to the list. This causes the device count displayed on the DEVICE screen to momentarily drop by one then return to normal. In addition, a + or – symbol will appear then disappear on the screen.

The FBT-6 shows the same behavior on its DEVICE COUNT screen. In addition, the RETRANSMIT function keeps track of the total number of Retransmits detected for each device on the network (up to a maximum of 250 Retransmits).

4.2.5 Shield Shorts

Foundation Fieldbus is an ungrounded (galvanically isolated) system meaning that neither the positive nor the negative wires are directly connected to ground. Ungrounded systems have the advantage that if the positive wire is grounded, the network can continue operating. However, grounding signal wires can cause problems, including increased noise susceptibility, bypassing of short-circuit protection, and disruption of communications on multiple segments.

Because the shield in the fieldbus cable is connected to ground, it is easy to see how a damaged cable, water-logged cable, or loose wire strands can create contact between the shield and either of the two signal wires causing a short to ground. The FBT-6 WIRING function detects shorts between the fieldbus positive or negative wire and ground.

Shorts can also be detected by measuring the resistance between wires with a DMM. This procedure can be performed when the fieldbus segment is un-powered, but not while operating. Refer to the table below for resistance measurement guidelines.

General Guidelines for Resistance Measurements

Measure Resistance from the:	Acceptable Result
+ signal wire to – signal wire	>50 Kohms (1)
+ signal wire to shield wire	>20 Mohms (1)
- signal wire to shield wire	>20 Mohms (1)

(1) Results can vary with the meter used to measure resistance. Some may show a constantly increasing value. Some may show a value that increases for several seconds then levels off. Get experience with a particular meter to see how it behaves. In general, if the meter resistance displayed rises above the value in the table the resistance measurement is OK.

4.3 Look up Likely Causes

Examine the collected data and look for any measurements that are outside of the expected ranges given above. A baseline of data collected while the segment was operating properly is a great help. If a baseline doesn't exist, compare the same data from different points on the network to help identify data that is suspicious.

Use the symptoms and data collected to enter the table in Appendix A. The table lists a variety of symptoms, the possible causes, and recommended actions to either further isolate or eliminate the problem.

4.4 Inspect the Physical Layer for the Problem

Once the likely problem is identified take one or more of the actions recommended in the table in Appendix A. These actions usually consist of inspecting the cabling and connections associated with the problem device(s). Walk the cable run and check the cable and connections for the following problems:

- Connectors not securely plugged in
- Loose wires
- Damaged cable or wires
- Stray wire strands at wire terminations
- Screw terminals and hold-down screws are not tight (use a torque screwdriver)
- Cable shield grounded at more than one location or not grounded
- Cable bend radius too small
- Tie wraps too tight

The torque screwdriver will ensure the screws are not over- or under-tightened – both very common causes of physical layer problems (see the Tools section for more information). Check cabling and connectors to each device, including the power supply/conditioner, terminators, DC power supply, and ground. Verify LEDs are appropriately lit on the wiring blocks and fieldbus power supply.

In addition, take a resistance measurement from the shield to ground with a DMM. It should be less than 100 ohms. If it is high or fluctuating, check the location of the shield ground connection. Verify it is connected to a good ground, not a noisy one used by many high powered pieces of equipment. Once a good grounding point is identified, verify the connection to it is secure.

If it is convenient, the physical layer inspection can be done without even taking any data. Many problems present themselves just by visual inspection or tugging on wires.

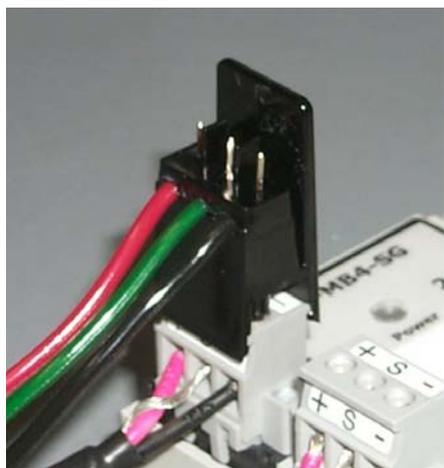
Lastly, keep in mind that more than one problem may exist.

5 Connecting to the fieldbus

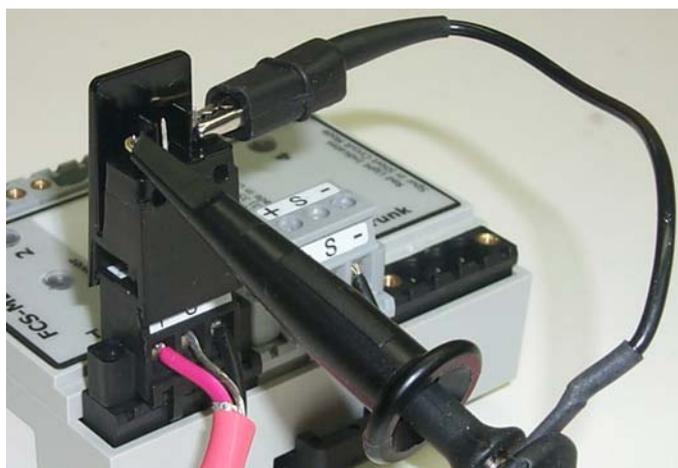
Electrically connecting diagnostic devices like the FBT-3, FBT-6, or an oscilloscope to the fieldbus wires can be difficult. Exposed wires are undesirable because of susceptibility to corrosion and shorts.

Wiring blocks like the Relcom Megablocks have wire terminations with screw terminals or cage clamps for the individual wires. If enough insulation is stripped away, hook a probe tip around the bare wire to make contact.

The FBT-6 includes a cable with a clip-on probe that easily snaps on and off pluggable terminations and makes electrical contact by touching the screws of the screw terminals. The clip-on probe is available as a separate part and has posts sticking out of the top separated by plastic barriers. These posts allow easier connection of an oscilloscope or other device. If connecting the clip-on probe to a spare connector, make sure the screw terminals are tightened down to get good electrical contact.



Relcom FBT-A63 Cable
Attached to a Megablock



Relcom FBT-A64 Clip-on Probe with
Oscilloscope Probe Attached

If clip-on probes are not an option, insulation displacement type probes are available from companies like E-Z-Hook and Pomona. These probes have sharp points that poke through wire insulation to make contact with the wire. Stripping the wire is not necessary, but some of the cable jacket and shield foil may need to be removed. A custom-made cable may be necessary to connect these probes to the test device.

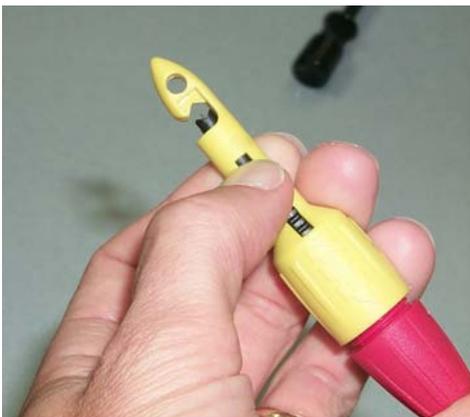
Some insulation displacement probe options are shown below.



E-Z-Hook
XJ Series
www.e-z-hook.com



E-Z-Hook
XEL Series
www.e-z-hook.com



Pomona
Model 6405
www.pomonaelectronics.com

6 Glossary

Communications (Comm) Error	In general, a failed attempt by the DCS to communicate. Comm errors can occur when the DCS cannot communicate with a single device, all devices on a segment or with a card or module within itself.
DLL Retry	An event in which data or a command is sent to a device requiring the receiving device to respond but it does not.
Drop	A cable between the trunk cable and a fieldbus device. Also called a “Spur”
Fieldbus Power Supply	The device providing isolated and conditioned power to a fieldbus segment.
Home Run	The main cable between the control room and a junction box in the field. Also called “Trunk”.
Link Active Scheduler (LAS)	A device that tells other devices on the network when they are allowed to transmit.
Power Conditioner	The filter between a power supply and fieldbus wiring.
Retransmit	A repeated Pass Token frame. The LAS resends Pass Token frames if it does not detect a response from the device the Pass Token frame was sent to. Same as a Token Passing Timeout (TPTO).
Segment	A fieldbus network that is separately powered and has its own terminators.
Spur	A cable between the trunk cable and a fieldbus device. Also called a “Drop”
Terminator	A device on a segment that shapes the transmitted signals and prevents signal distortion.
Trunk	The main cable between the control room and a junction box in the field. Also called “Home Run”.
Wiring Block	A device attached to the trunk cable to provide connections for multiple devices. Wiring blocks often provide short-circuit protection for each device also.

7 References

AG-181 Foundation Fieldbus System Engineering Guidelines Revision 2.0 August 2004.

Appendix A: Troubleshooting Table

Symptom	Possible Causes	Recommendations
High peak or average noise	Water/condensation in wiring, improperly connected shield, bad fieldbus device, bad physical layer component (power supply, terminator, wiring block), segment is not isolated from ground, fieldbus cable is located near noise producing cable, loose wire termination.	Inspect the network cable and connections. Tighten screw terminals and connector hold-down screws. Look for waterlogged cables, condensation in junction boxes, loose wires, FF cable routed near other signaling cables or AC power cables, loose strands of wire shorting to other wires/conductive objects. Use FBT-6 to determine if a shield short to + or - fieldbus wire exists. Verify the segment is powered by an isolated fieldbus power supply or that the bulk supply for the fieldbus power supply is isolated and only powers one segment. Take noise measurements at multiple locations on the network to identify where noise is highest and most likely located. Measure resistance from shield to ground with a DMM and verify it is <100Ω. Disconnect devices one at a time to see if noise disappears. Replace terminators, fieldbus power supplies, and wiring blocks.
Excessive retransmissions or communications errors (on one device) OR One device is being added and dropped repeatedly	Bad cable or spur wiring connection to device, not enough power to the device, bad device, bad port on the wiring block, noise on the spur	Use the FBT-3/6 to check for high noise levels and check the voltage at the device is >9VDC. If the wiring block has a current limiting (SpurGuard) feature, check the associated LED to make sure it isn't constantly or intermittently lit. Inspect the wiring and connections from the wiring block to the device looking for waterlogged cables, condensation in junction boxes, loose wires, FF cable routed near other signaling cables or AC power cables, loose strands of wire shorting to other wires/conductive objects. Try putting the device on a different spur from the wiring block. Replace the device.
Excessive retransmissions or communications errors (on all or multiple devices) OR Multiple devices are being added and dropped repeatedly	Wiring/cable problem, not enough power to the devices, bad physical layer device (power supply, terminator, wiring block), noise on the bus	Determine if the entire network is affected or just part of it. Focus on the part of the network with problems. Use the FBT-3/6 to check for high noise levels and check the bus voltage is >9VDC at the fieldbus power supply and the device furthest from the power supply. Inspect the network looking for waterlogged cables, condensation in junction boxes, loose wires, FF cable routed near other signaling cables or AC power cables, loose strands of wire shorting to other wires/conductive objects. Replace the terminators, power supply/conditioner.

Symptom	Possible Causes	Recommendations
Low device signal level (one device)	Bad spur wiring connection to device, not enough power to the device, bad device, bad port on the wiring block	Check the voltage at the device is >9VDC. If the wiring block has a current limiting (SpurGuard) feature, check the associated LED to make sure it isn't constantly or intermittently triggered. Inspect the wiring and connections from the wiring block to the device looking for waterlogged cable, condensation, loose wires, loose strands of wire shorting to other wires/conductive objects. Verify the total length of cable (trunk length + length of all spurs) does not exceed 1900m and the length of individual spurs does not exceed 120m. Try putting the device on a different spur from the wiring block. Replace the device.
Low device signal level (all devices)	Too many terminators, wiring problem, not enough power to the devices, bad physical layer device (power supply, terminator, wiring block)	Verify that only 2 terminators are installed on the segment. Check the voltage at the fieldbus power supply and the device furthest from it is >9VDC. Check the power LEDs on the wiring blocks are steadily lit. Inspect the wiring and connections (especially at the parts common to all devices such as power supply/conditioner, terminators, trunk cable, etc.) looking for waterlogged cable, condensation, loose wires, loose strands of wire shorting to other wires/conductive objects. Replace suspect physical layer components (power supply/conditioner, terminators, wiring blocks).
High device signal level (one device)	Excessive cable/connector resistance on a spur or spur connections, bad device. Wiring block or fieldbus barrier with high series resistance.	Inspect the wiring and connections on the spur looking for waterlogged/damaged cable, condensation, loose wires. Replace the device. High signal levels may be expected at a device connected to a fieldbus barrier or spur of a wiring block with short-circuit protection.
High device signal level (all devices)	Missing terminator, failed terminator, improperly connected terminator, failed fieldbus power supply	Verify two terminators are installed (note that some terminators are built-in to power supplies/conditioners and wiring blocks, some are turned on/off with a switch and some are automatic). Check wiring to the terminators. Replace suspect terminators or the products that contain them. Replace the fieldbus power supply.
Shield short to (-) wire	Wiring problem, grounded device connected to the fieldbus, power conditioner is not isolated, water in a cable/device/wiring block	Check for damaged cable, make sure all devices are properly connected. Verify that fieldbus (-) wire is not connected to a ground at the power supply, to a device case, or through other equipment (such as an oscilloscope). Look for shield connections to the fieldbus (-) cable including stray strands of shield wire at wire terminations or un-insulated shield wire loose at the device. Disconnect portions of cable and check if the short goes away. Verify the fieldbus power supply is isolated from ground.

Symptom	Possible Causes	Recommendations
Shield short to (+) wire	Wiring problem, water in a cable/device/wiring block	Check for damaged cable, make sure all devices are properly connected. Look for shield connections to the fieldbus (+) cable including stray strands of shield wire at wire terminations or un-insulated shield wire loose at the device. Disconnect portions of cable and check if the short goes away.
DC bus voltage is low at one device	Bad spur wiring connection to device, not enough power to the device, bad device, bad port on the wiring device, cable too long	If the wiring block the device is connected to has a current limiting (SpurGuard) feature, check the associated LED to make sure it isn't constantly or intermittently triggered. Inspect the wiring and connections from the wiring block to the device looking for waterlogged cable, condensation, loose wires, loose strands of wire shorting to other wires/conductive objects. Try putting the device on a different spur from the wiring block. Verify the spur length does not exceed 120m. Verify the longest cable length between the problem device and any other does not exceed 1900m. Use a fieldbus segment calculator to check segment design. Replace the device.
DC bus voltage is low everywhere on the network	Wiring problem, not enough power to the devices, bad physical layer device (power supply, terminator, wiring block), cable too long	Check the power LEDs on the wiring blocks are steadily lit. Inspect the wiring and connections (especially at the parts common to all devices such as power supply/conditioner, terminators, trunk cable, etc.) looking for waterlogged cable, condensation, loose wires, loose strands of wire shorting to other wires/conductive objects. Unplug each device one at a time while watching bus voltage. Replace suspect physical layer components (power supply/conditioner, terminators, wiring blocks). Verify the longest cable length between the problem device and any other does not exceed 1900m.
Device is not "seen" on the bus/not communicating	Bad spur wiring connection to device, not enough power to the device, bad device, bad port on the wiring block, excessive noise	Check DC voltage at the device is >9VDC. If the wiring block the device is connected to has a current limiting (SpurGuard) feature, check the associated LED to make sure it isn't constantly or intermittently triggered. Inspect the wiring and connections from the wiring block to the device looking for waterlogged cable, condensation, loose wires, loose strands of wire shorting to other wires/conductive objects. Try putting the device on a different spur from the wiring block. Verify noise level is low. Replace the device.
FBT-6 never leaves segment check mode	Low frequency noise is high enough in amplitude and frequency to look like a Fieldbus signal to the FBT-6.	See the recommendations for high peak or average noise.

Appendix B: Oscilloscope Captures

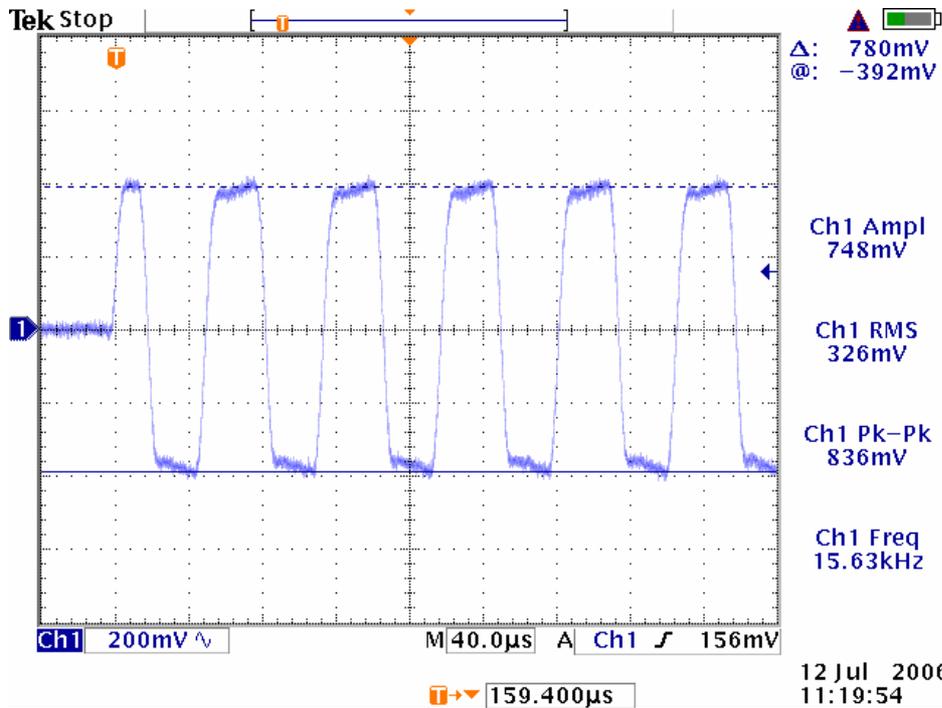
OSCILLOSCOPE USE IS NOT RECOMMENDED FOR PEOPLE UNFAMILIAR WITH THEIR OPERATION OR PEOPLE INEXPERIENCED WITH INTERPRETING FIELDBUS WAVEFORMS. NETWORK COMMUNICATION PROBLEMS AND PROCESS INTERRUPTION CAN RESULT FROM IMPROPER USE OF AN OSCILLOSCOPE.

This appendix contains a set of oscilloscope captures. The purpose is to give a general idea of what fieldbus signals might look like under normal and abnormal conditions. THE OSCILLOSCOPE CAPTURES IN THIS APPENDIX ARE FOR GUIDANCE ONLY.

Under some conditions, a fieldbus signal may not conform to the guidelines in this document or look like the “good” waveform captures in this appendix, yet the segment may be set up and operating properly. It is very important to keep in mind that every fieldbus segment is different. The specific devices, cable type, cable lengths, where the measurement is taken, and other factors can drastically affect the actual results seen on the oscilloscope.

CAUTION: Use an oscilloscope that is isolated from ground. Using a grounded oscilloscope will connect the negative fieldbus wire to ground. This may have no noticeable effect, add noise to the network, or (if an existing short to ground exists) could take down one or more segments. Be careful when using an oscilloscope! A battery powered oscilloscope with no ground connection can be used. The Tektronix TPS2000 Series oscilloscopes have isolated channel inputs and can also be used. The Fluke 123 ScopeMeter is battery powered, portable and has DMM features as well. Another option is to use an isolated differential probe with the oscilloscope.

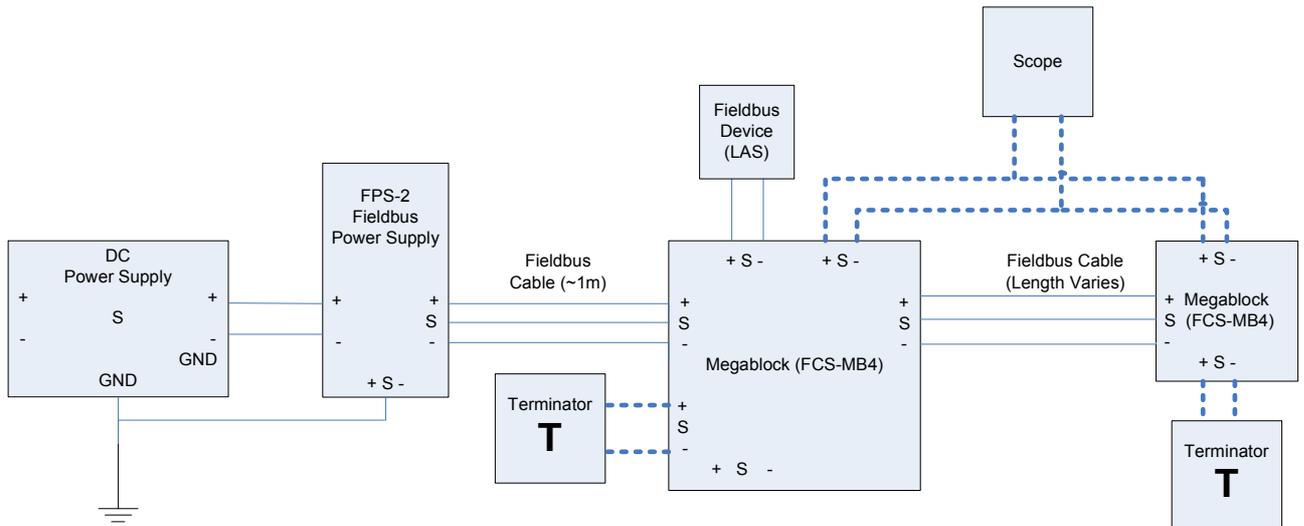
Below is an example of a “good” fieldbus waveform taken from a 1m long segment. The signal is basically trapezoidal, about 800mVpp, and shows very little noise. The tops and bottoms of the waveforms are slightly slanted.



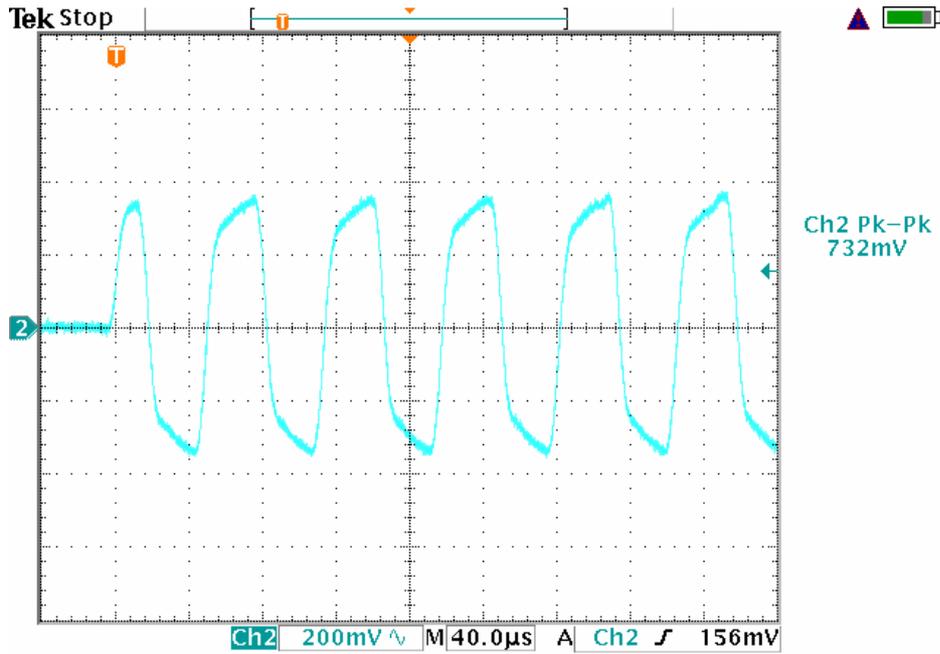
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
1	MB4	1	Both	Near ideal waveform

Various forces can impact the shape of this waveform. The signal level may be lower, the signals may become more rounded or triangular, noise may be present etc.

The remainder of the oscilloscope captures that follow were made using the setup below.



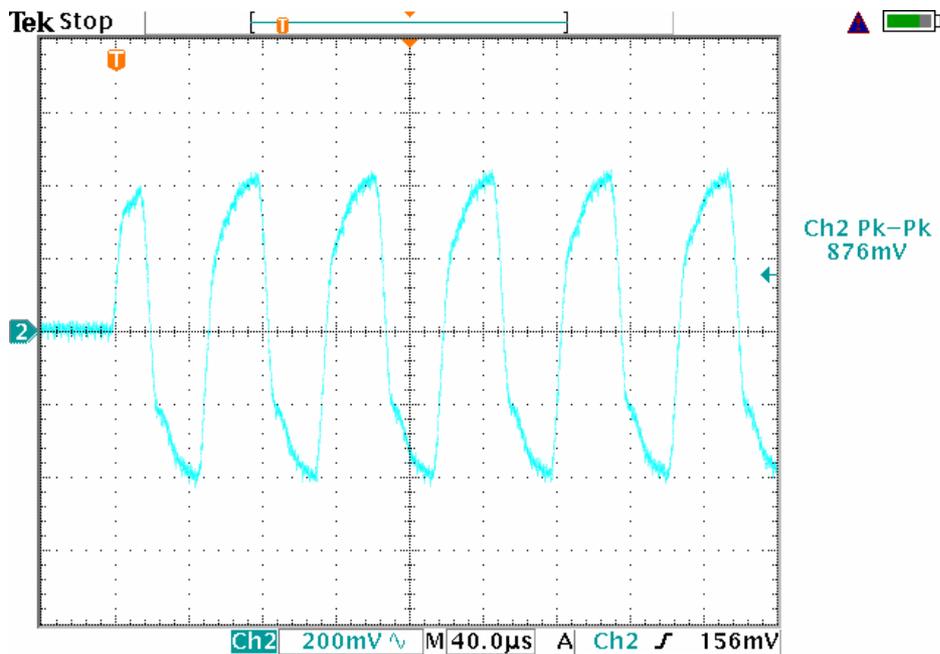
The next two captures represent “typical” fieldbus signals for the segment that is properly constructed with two terminators and a 610m trunk. The captures following the typical ones show what happened to the segment when various problems were introduced to the segment. Effects from missing terminators, extra terminators, and different noise frequencies can be observed.



1 Sep 2006
08:49:18

158.800µs

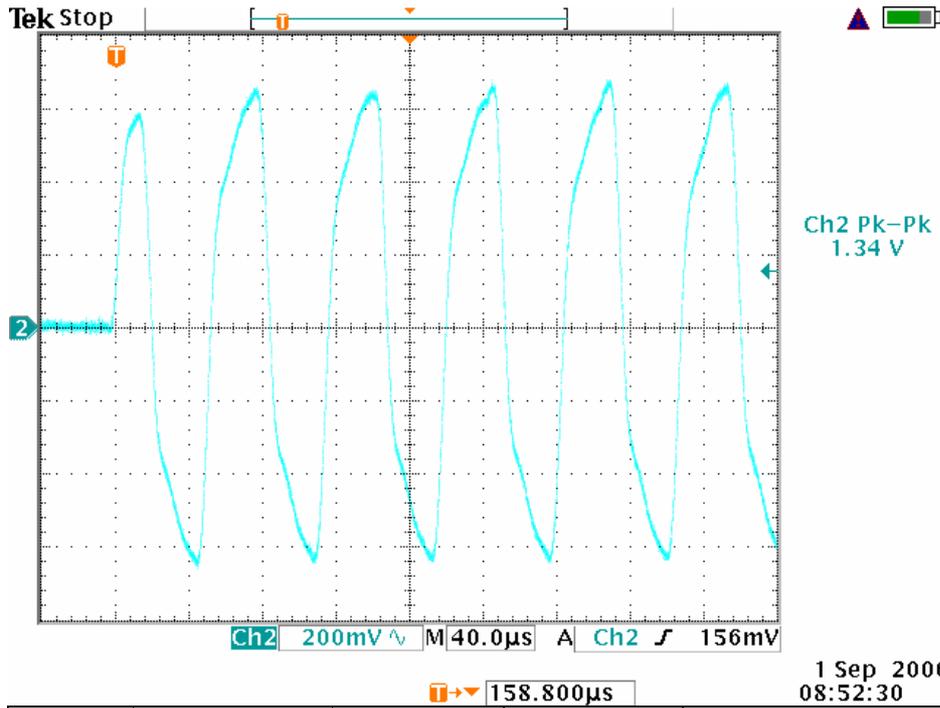
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
42	Field End of Trunk	610	Both	"Typical" signal on a properly constructed segment.



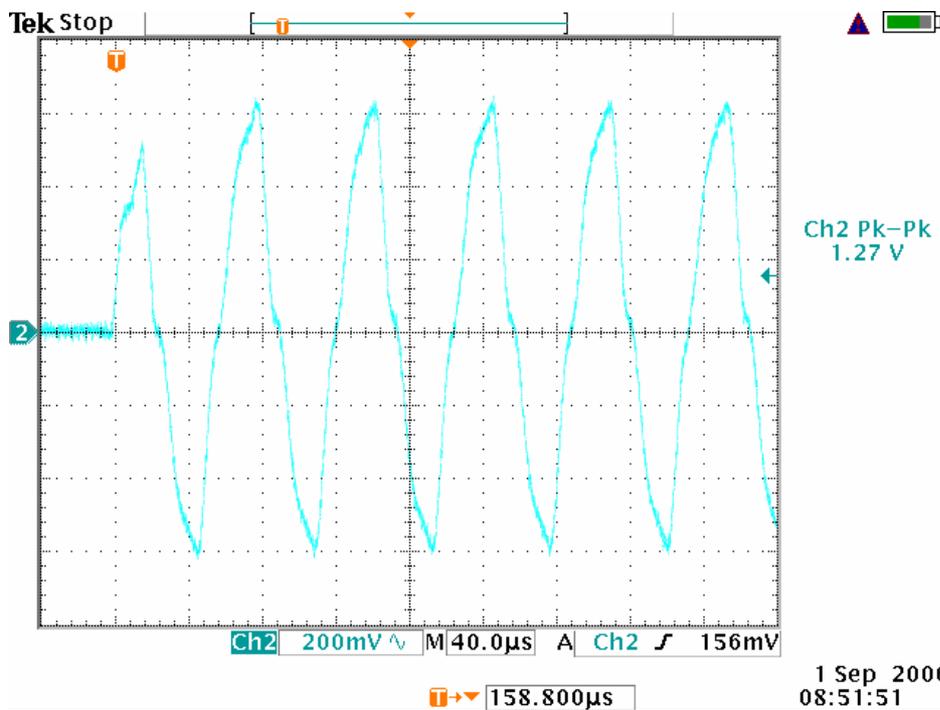
1 Sep 2006
08:50:27

158.800µs

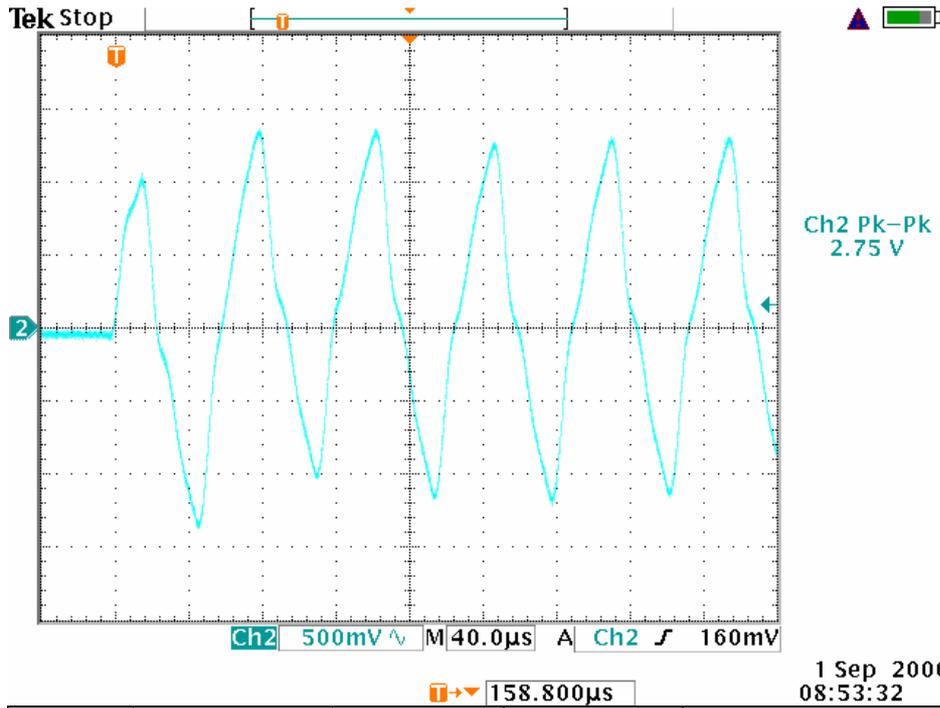
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
43	Control Room End of Trunk	610	Both	A bit more noise from the power supply near the power supply end of the trunk.



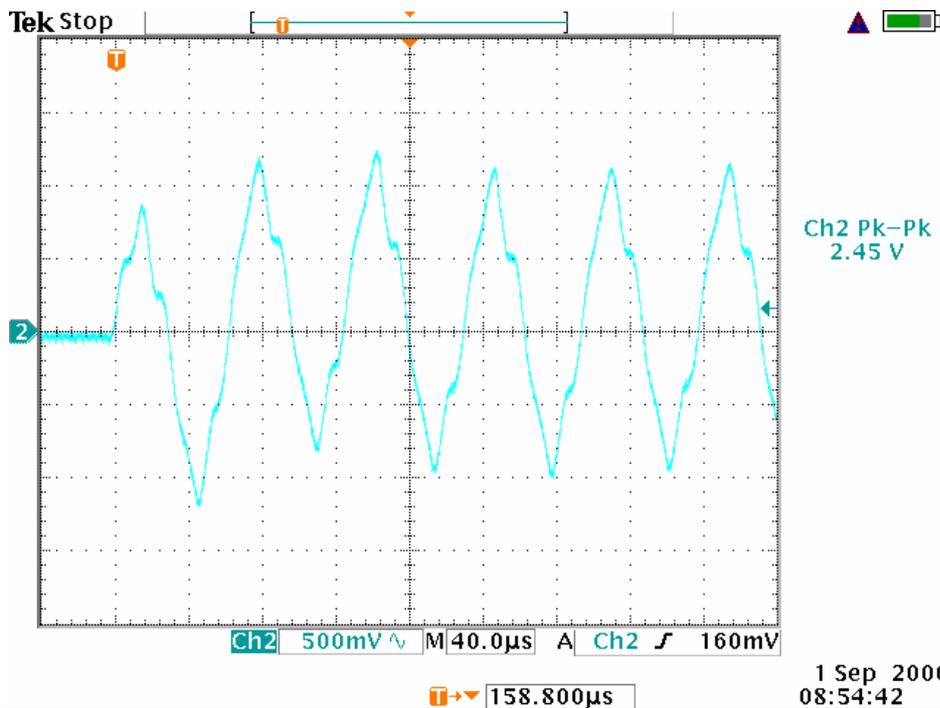
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
45	Field End of Trunk	610	Control Room End of Trunk	Signal level increased 80% with terminator in the field missing.



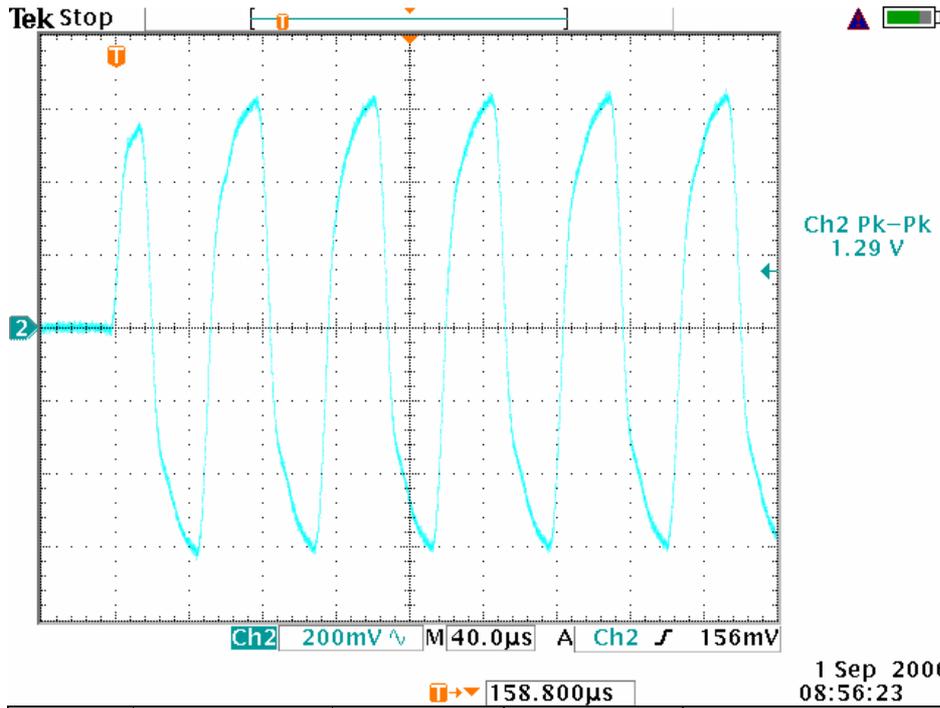
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
44	Control Room End of Trunk	610	Control Room End of Trunk	Signal level increased 45% with terminator in the field missing.



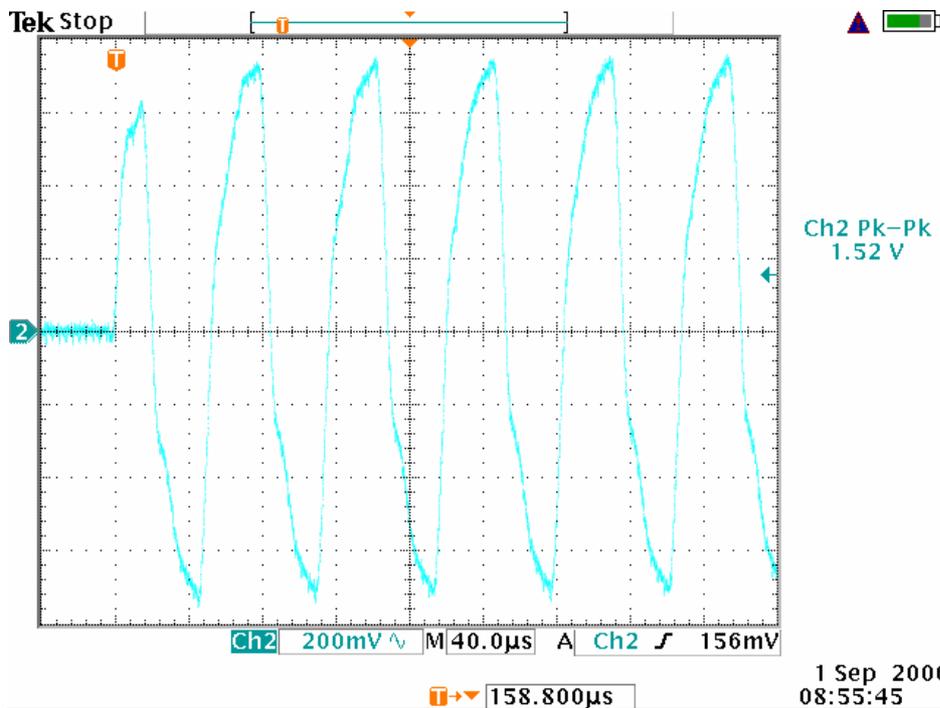
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
46	Field End of Trunk	610	None	No terminators, a lot of distortion, signal level up 275%.



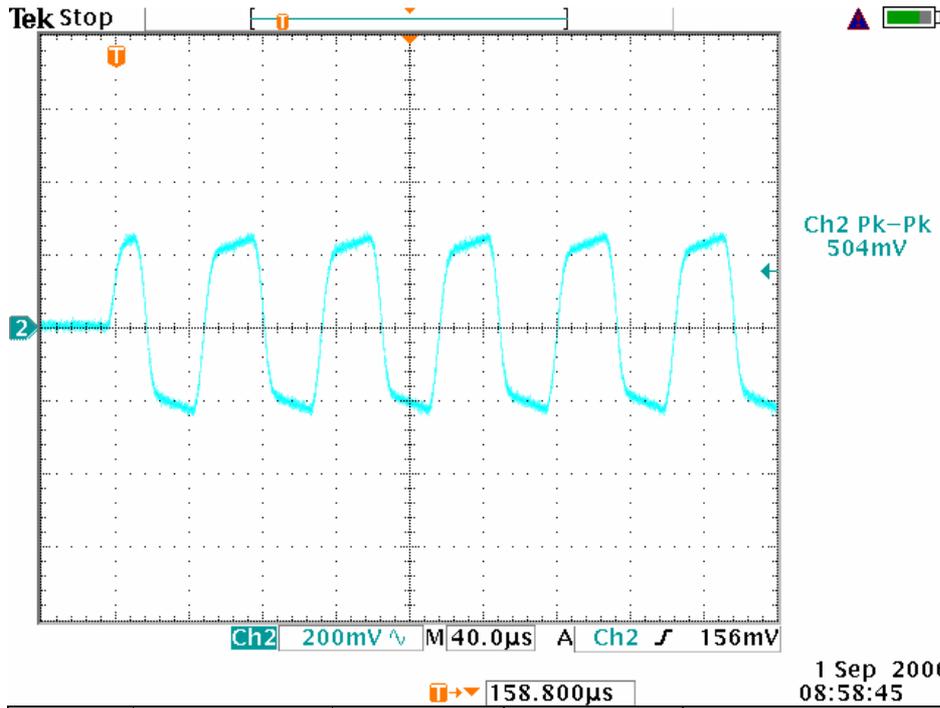
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
47	Control Room End of Trunk	610	None	No terminators, a lot of distortion, signal level up 180%.



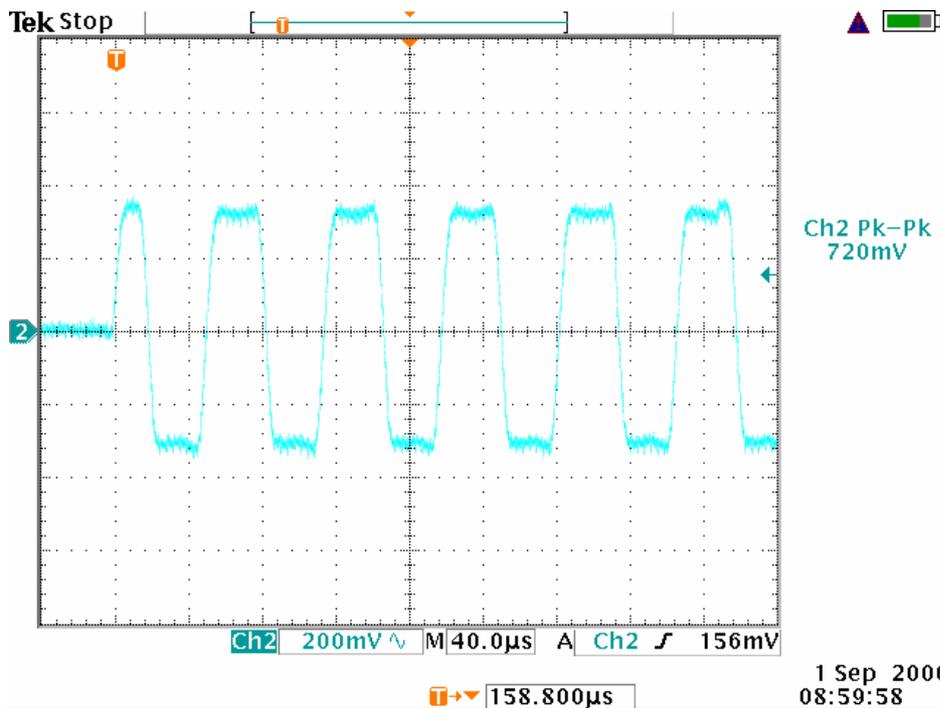
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
49	Field End of Trunk	610	Field End of Trunk	Signal level increased 75% with missing terminator in the control room.



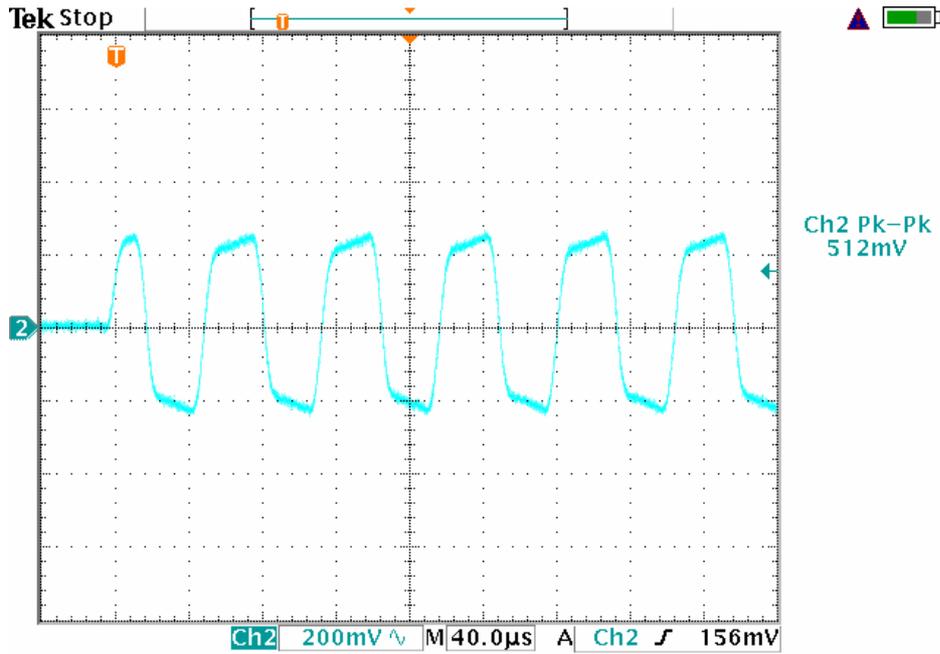
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
48	Control Room End of Trunk	610	Field End of Trunk	Signal level increased 70% with missing terminator in the control room.



Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
50	Field End of Trunk	610	Both + Extra at Field End	Signal level dropped 30% with extra terminator at field end.

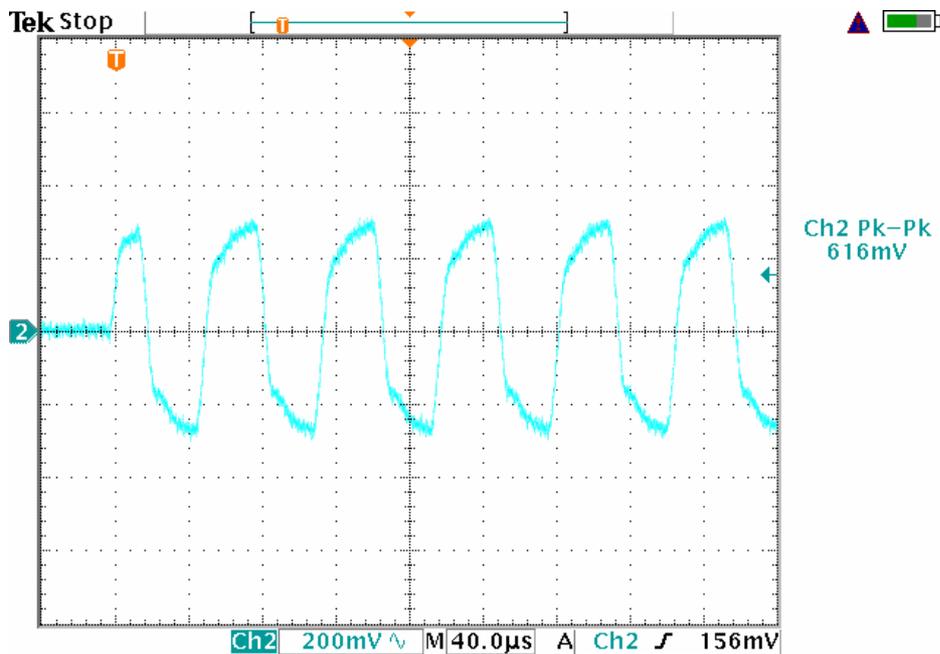


Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
51	Control Room End of Trunk	610	Both + Extra at Field End	Signal level dropped 18% with extra terminator at field end.



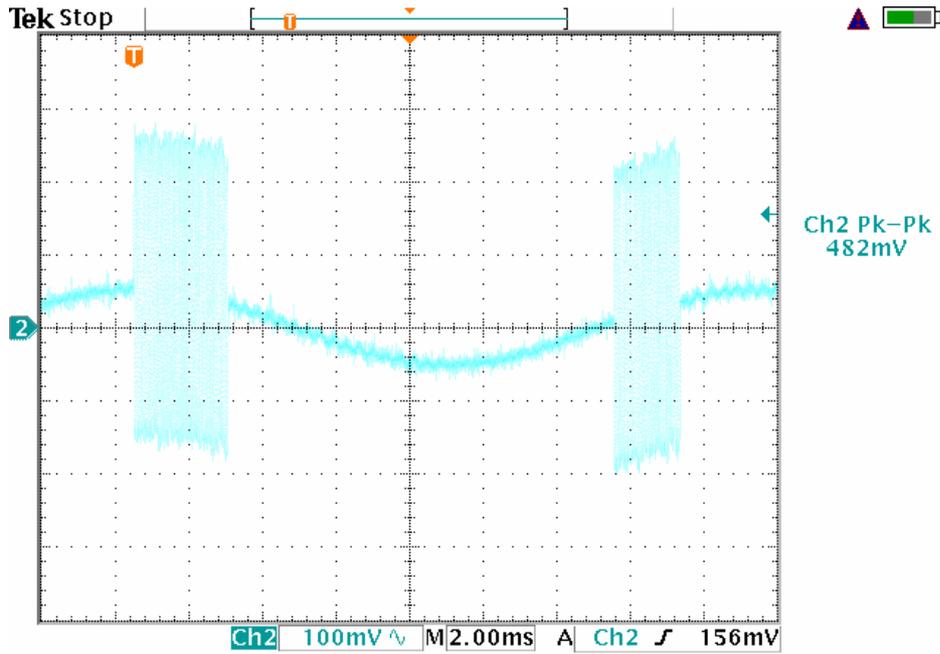
1 Sep 2006
09:07:21

Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
53	Field End of Trunk	610	Both + Extra at Ctrl Rm	Signal level dropped 30% with extra terminator at control room end.



1 Sep 2006
09:06:41

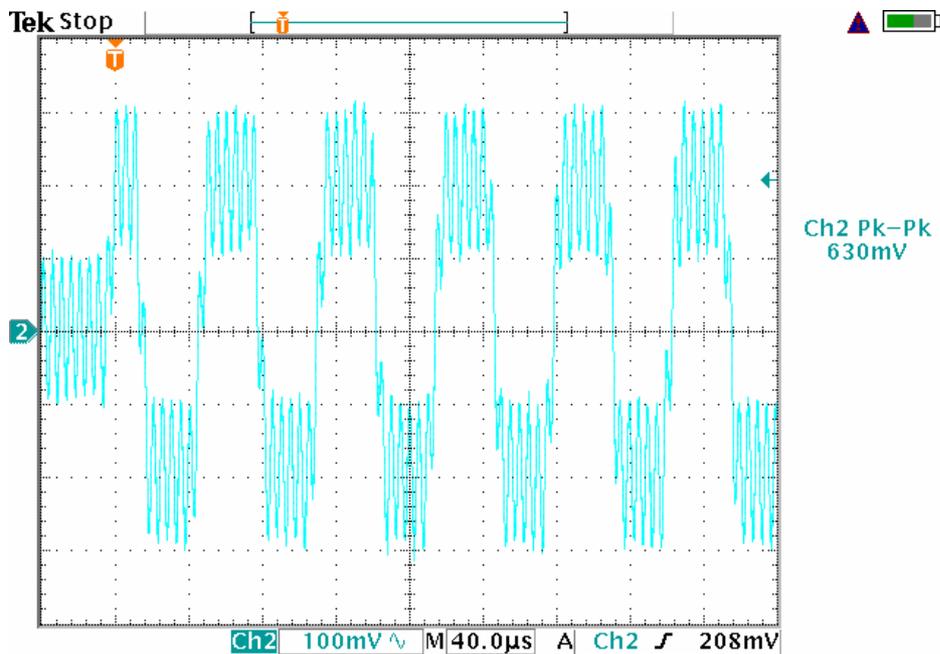
Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
52	Control Room End of Trunk	610	Both + Extra at Ctrl Rm	Signal level dropped 30% with extra terminator at control room end.



1 Sep 2006
09:19:27

7.47800ms

Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
54	Field End of Trunk	1	Both	FF signal riding 100mVpp 60Hz low frequency noise.



1 Sep 2006
09:22:28

10.00 %

Scope Trace #	Scope connected at	Trunk Length (m)	Terminators Connected	Comments
55	Field End of Trunk	1	Both	FF signal with 200mVpp 200KHz high frequency noise.