RAW DATA. REFINED RESULTS.

OPERATIONS MANUAL

DATA ACQUISITION

STS4 4-CHANNEL INTELLIDUCER NODE

Document Revision History

Document	Rev.	Date	ECO	Changes
n/a	1.0	2/28/2012	n/a	Initial release document
n/a	1.1	6/7/2012	n/a	▪ Minor changes
n/a	1.2	4/2/2013	n/a	▪ Power ratings updated
201631	A	7/25/2019	n/a	▪ Updated content ▪ Minor changes to specifications ▪ New template and styles applied

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1. Introduction

1.1 Background

In the late 1980's, two bridge research projects were conducted at the University of Colorado in Boulder. The first was sponsored by the Pennsylvania Department of Transportation (PennDOT) and required the implementation of an efficient technique for developing highway bridge load ratings based on field test data. The second project was funded by the Federal Highway Administration (FHWA) and furthered this initial research to include recording the dynamic behavior of various bridge types. Approximately 50 highway bridges around the country were tested and evaluated during these two projects, and hardware and software delivered to each of the sponsors.

Based on the results of this extensive experience, the key personnel from the two projects founded Bridge Diagnostics, Inc. (BDI) in October 1989. Since that time, BDI has been providing field testing/monitoring, structural analysis, and data management services, in addition to manufacturing data acquisition systems (Structural Testing Systems, or STS). BDI supplies and supports customers all over the world that use STS systems to perform their own testing and evaluation.

1.2 About this Manual

This is a comprehensive document that explains the functions and features of the BDI STS4-IW3 node and includes references to other STS components such as the STS4 Wireless Base Station, STS4 Automatic Load Position Tracker, and STS-LIVE. However, this is NOT a comprehensive STS System Operation manual since that is available in the online BDI Video Library under the "Resources" tab at www.bditest.com. Other STS components are supplied with their own manuals that may be downloaded from the BDI website as well.

The following highlighted message blocks will appear throughout the manual and contain important information for the user:

STOP: This symbol and corresponding message represents information regarding the device that if not followed could lead to damaging the device! Pay close attention to this message.

WARNING: This symbol and corresponding message represents vital information and is critical for the device operation and/or the operational settings/configuration.

INFORMATION: This symbol and corresponding message represents general information and/or tips on successfully operating/configuring the device.

2. STS4-4-IW3 Intelliducer Node Overview

2.1 About the STS4-4-IW3 Nodes

The STS4-4-IW3 nodes are the fourth generation of our four-channel, Intelliducer-based distributed data acquisition devices designed to be used in harsh outdoor environments. Like the previous generations, the highlight of these nodes is the intelligent connector system that we developed nearly 30 years ago and have maintained in all versions of our STS systems. The STS4-4-IW3 nodes have also been upgraded to include the following features:

- Programmable excitation voltage
- Wider sensor input range
- Temperature sensor input on each channel
- Internal lithium-ion battery with integrated SMBus compliant changer
- More efficient power saving modes
- Up to 1,000 samples per second
- 8GB solid state internal storage
- IEEE 802.3af Power over Ethernet (PoE) port
- Weatherproof and rugged

2.2 Technical Specifications

Table 1: STS4-4-IW3 Specifications

MODEL	STS4-4-IW3
Measurement Types: **Analog Input** **Temperature Input**	 Analog Single-ended or Differential 3KΩ NTC Thermistor
Processor	Stellaris® Arm® Cortex™-M3
Maximum Sample Rate: **Analog Input** **Temperature Input**	 1,000 S/s ~1 S/s (non-user adjustable)
Sample Mode	Sequential
Node-to-Node Data Synchronization	+/-2.5 samples @ 1,000 S/s
Programmable Gain Stages	11
Analog to Digital Converter (ADC)	24-bit ADC (Sigma delta)
Voltage Reference System[1]	Ratiometric
ADC Temperature Tolerance	Gain drift 1 ppm/°C
Inputs	
Analog Inputs	4
Temperature Inputs (NTC Thermistor only)	4

Input Voltage Range Gain Stages[2]	
1: 0.25x single ended	+40.0 V_{dc}
2: 0.50x single ended	+20.0 V_{dc}
3: 1x differential	±5.00 V_{dc}
4: 2x differential	±2.50 V_{dc}
5: 4x differential	±1.25 V_{dc}
6: 8x differential	±625 mV
7: 16x differential	±312 mV
8: 32x differential	±156 mV
9: 64x differential	±78 mV
10: 128x differential	±39 mV
11: 256x differential	±19 mV
Input Impedance	> 1 MΩ
Protection	Surge, over-voltage, and isolated
Memory	
System Memory	16 MB (Operating System)
Internal Micro SD Card	8 GB
Excitation Voltages	
VX (programmable)	+1 to +5 V_{dc} @ 20 mA (per channel)
V+15	+15 V_{dc} @ 400 mA (combined)
Excitation Voltage Accuracy	
VX (programmable)	16-bit resolution, typ. 5ppm/°C
V+15	±5%
Power	
Li-Ion Battery	+10.8 V_{dc} (Nominal), 6.8 Ah, 73 Wh
DC Supply	+24 V_{dc} @ 3.0 Amp (max for charging)
Power over Ethernet	+48 V_{dc} (IEEE 802.3af)
Protection	over-voltage, reverse polarity, and ESD

Power Consumption[3]	
Base Consumption	1.6 W
Base Consumption (VX & V+15 on)	1.9 W
Typical Acquisition[4]	2.2 W
Standby Mode	1.20 W
Sleep Mode	< 0.01 W
Communication	
Wireless	802.11b/g/n (2.412 - 2.484 GHz)
Ethernet	10T-Base (Galvanically Isolated)
Sensor Interface	
Connector	10-Pin weatherproof Mil-Spec circular bayonet snap-lock.
Intelliducer Support[5]	Yes
Physical	
Enclosure	Combination aluminum extrusion and high strength molded parts.
Weather Protection	Splash-proof
Size	8.0 x 4.5 x 3.25 in (203 x 115 x 83 mm)
Weight	2.63 lb (1,200 g)
Temperature	
Battery & DC Supply Operation	-4° to +140 °F (-20 °C to +60 °C)
Battery Charging	32° to +104 °F (0 °C to +40 °C)
Storage Temperature	-4° to +140 °F (-20 °C to +60 °C)
Compliance & Warranty	
Wireless Module	FCC, IC, and CE Certified
Li-Ion Battery Pack	FCC Part 15 Class B, CE
Warranty	3 Years

1 Ratiometric: The system reference voltages are all derived from the same high precision ultra-stable source. Any residual drift would change excitation and ADC reference effectively canceling drift out.

2 Selectable through STS-LIVE, stated input voltage range ±10%.

3 Power consumption is based on wireless as the default communication mode.

4 Typical power drain is calculated with four 350Ω full bridge strain transducer connected to the system and collecting data at the highest sample rate possible. This does not include battery charging power consumption.

5 Intelliducer support refers to BDI's intelligent sensor connector interface. The intelligent sensor interface contains the sensor ID, calibration factor, gain setting, etc. within a memory chip inside the sensor connector.

2.3 Options & Accessories

Table 2: Options and Accessories

	**Ethernet Cable** – Industrial shielded CAT5e Ethernet cable with IP67 RJ45 connectors on one end and standard RJ45 on the other end. Supports PoE. Maximum length of 330 ft (100 m) per cable.
	**Power Supply (North America)** – 100-240 Vac to +24 V_{dc} power supply with M8 connectors. 3 ft (1 m) extension cable
	**Power Supply (European)** – 100-240 Vac to +24 V_{dc} power supply with M8 connector. 3 ft (1 m) extension cable
	**Shipping Case** – Rugged plastic travel & storage case, variable sizes

2.4 Applications

The STS4 has been successfully used in many field test applications such as those outlined in Table 3. It can be configured for many other applications as well.

Table 3: Some Typical Applications

Bridge Testing & Monitoring	▪ Highway & Rail

	▪ Steel, Concrete, Timber, FRP ▪ Movable Bridges ▪ Overload Detection
River Control Structures	▪ Mechanical Gates (Lift, Miter, Radial) ▪ Navigation Lock Gates and Valves ▪ Mechanical Drive Components ▪ Torque Shafts
Cable Forces	▪ In-Situ tension measurements with accelerometers ▪ Cable load balancing with in-place load cells
Laboratory	▪ Integration with existing NI hardware ▪ Customizable programming ▪ Ideal learning tool for students
Building Testing & Monitoring	▪ ASTM Standard Building Load Test Method ▪ Construction Monitoring ▪ Earthquake Monitoring
Stress/Strain Evaluation	▪ Simple to use system for quickly completing stress/strain analyses

3. SYSTEM CHARACTERISTICS

3.1 About The STS4 Data Acquisition System

Most data acquisition systems have been designed primarily for laboratory use which tends to make them relatively complex and difficult to use in tough field conditions. The STS4 is the fourth generation of our rugged field testing system that has been updated over time based on customer input and our extensive field testing experience. Every facet of the hardware and software has been optimized to allow fast system assembly, efficient sensor installation, and intuitive operation under stressful field-testing conditions.

STS4 System highlights include:

+ Short-term testing and long-term data logging capabilities
+ Intuitive and robust STS-LIVE data acquisition software
+ Sensor calibrations stored on board
+ Component names/IP addresses stored on board
+ Wide range of programmable excitations and input ranges
+ Temperature sensor/correction option for all channels
+ Internal batteries to provide days of continuous use
+ Integrated battery chargers and with status reporting
+ Several power conservation modes
+ Power over Ethernet (PoE) capability
+ Support for user-developed custom National Instruments (NI) LabView® programs

The STS4-4-IW3 nodes are fully equipped data acquisition systems operated through STS-LIVE.

3.2 Quality Assurance (Q/A)

Each STS4-4-IW3 node is designed and manufactured to exacting standards. The process of building a STS4-4-IW3 node involves individual verification for each circuit board for functionality before being used in a node. After manufacture, each node is run through a 24-point calibration process.

3.3 Shipping Requirements

BDI wants to ensure that our customers are aware that the internal Lithium-Ion battery (Li-Ion) units utilized in STS4-4-IW3 nodes are considered Dangerous Goods/Hazardous Materials for shipping purposes. There are certain strict rules governing the transportation of Li-Ion batteries and products powered by Li-Ion batteries. These rules, imposed by federal and international regulatory agencies, can be very complex and will vary depending on transport mode and battery type.

If you are uncertain on applicable lithium battery transport rules, BDI recommends you visit the DOT's website for further information: https://www.phmsa.dot.gov/lithiumbatteries

WARNING: Safety requirements for shipping Li-Ion batteries by both ground and air are continuously updated. Anyone handling shipments that involve Li-Ion batteries should receive the appropriate Dangerous Goods/Hazardous Materials shipping training which is offered by many vendors.

STOP: Significant criminal and civil penalties may be applied to ***individuals*** who improperly ship hazardous materials.

In addition to recommended training, three primary sources for shipping guidelines are:

+ **Ground:** In the United States, ground shipment regulations for Li-Ion batteries are provided by the U.S. Department of Transportation. Refer to phmsa.dot.gov/lithiumbatteries for further information.
+ **Air:** Air shipment requirements are provided by the International Air Transport Association (IATA) which the user should refer to at iata.org.
+ **Manufacturer:** Another excellent source for shipping information is provided by the battery manufacturer, Inspired Energy, LLC at inspired-energy.com.

BDI complies with the latest hazmat delivery guidelines when shipping STS4-4-IW3 nodes to and from our facilities and has developed recommended guidelines only for customers who are returning STS4 systems to BDI which are available at: https://bditest.com/resources/support/ under "Shipping Documents".

3.4 Custom Programming Capabilities

STS4 systems are controlled through the STS-LIVE application. However, users may develop their own custom application using programming environments such as National Instruments LabView® and C++. In these situations, BDI can supply the STS-CORE application with its corresponding control command set. Contact BDI for further information.

4. Power

4.1 Power On/Off

After the internal battery has been charged and/or one of the other sources is available, depress the Power button for just over two seconds. This action should cause the LED adjacent to the button to change colors in the following order: red, orange, then green (On). This LED will then turn off (to conserve power) but the node will still be on and the blue LED on the rear panel will. Similarly, the node is turned off by depressing the Power button for two seconds, or longer which causes the LED to light up in the opposite sequence: Green, Orange, Red, then Off.

Figure 1: Power Status LED

4.2 Power Sources

The STS4-IW3 node utilizes an intelligent power management system that optimizes and balances internal energy requirements depending on the source and the sensor power load. Three possible power sources and corresponding system states are outlined in Table 4. Even though power for node operation takes priority over battery charging, both the 24 V_{dc} and PoE power sources are sufficient to supply the node base power and simultaneously charge the battery, allowing the system to run indefinitely.

Table 4: Power Sources & Configurations

Source	Power on State	Power Off State	Energy
+10.8 V_{dc} Internal Battery	Node Power Only	N/A	73 Watt-Hours
+24 V_{dc} External	Node Power + Charge Battery	Charge Battery	Indefinite
+48 V_{dc} 802.3af PoE	Node Power + Charge Battery	Charge Battery	Indefinite
+24 V_{dc} External & +48 V_{dc} PoE	PoE Ignored, Node Power + Charge Battery	PoE Ignored, +24 V_{dc} Charge Battery	Indefinite

4.2.1 Internal Lithium-Ion Battery

The internal battery pack consists of (6) internal Li-Ion cells assembled in a 3 series/2 parallel (3S-2P) configuration and packaged with an on-board Battery Management Module (BMM) as illustrated Figure 2.

Figure 2: Lithium Ion Battery Pack (Li-Ion) w/BMM (Courtesy Inspired Energy, LLC)

The self-contained unit complies with the following industry standards:

+ EMC Directive 2004/108/EC
+ Low Voltage Directive 2006/95/EC
+ Battery Recycling Directive 2006/66/EC as amended
+ RoHS Directive 2002/95/EC
+ CE Mark: [EN55022:2006 (ITE Class B) & EN55024:1998 (ITE)]
+ FCC Part 15 Class B
+ Transportation: UN Manual of tests and Criteria part III, subsection 38.3 (ST/SG/AC.10/11/Rev.3)

Table 5: Li-Ion Battery Technical Specifications

Manufacturer	Inspired Energy, LLC
Model	NF2040HD34
Chemistry	Lithium Ion
Equivalent Lithium Content	6g
Capacity/Energy	6.8 Ah / 73 Watt-Hours
Voltage Range	7.6 to 12.6 V_{dc}, (10.8 V_{dc} Nominal)
Maximum Continuous Discharge Current	6.0 Amps
Maximum Continuous Power	45 Watts
Communication	Fully SMBus 1.1 Compliant
Temperature Range	-4°F to 175°F (-20 °C to 80 °C)
Dimensions	5.9 x 2.4 x 0.9 in (150 x 58.9 x 22.3 mm)

Weight	0.77 lb (349 g)

4.2.2 Built-In Battery Protection

To optimize the battery performance and to extend its useful life, the built-in Battery Management Module (BMM) keeps the unit within its voltage, current, and temperature tolerances. The BMM also manages the battery's Discharge and Charging Operating Limits illustrated in Figure 3 and Figure 4.

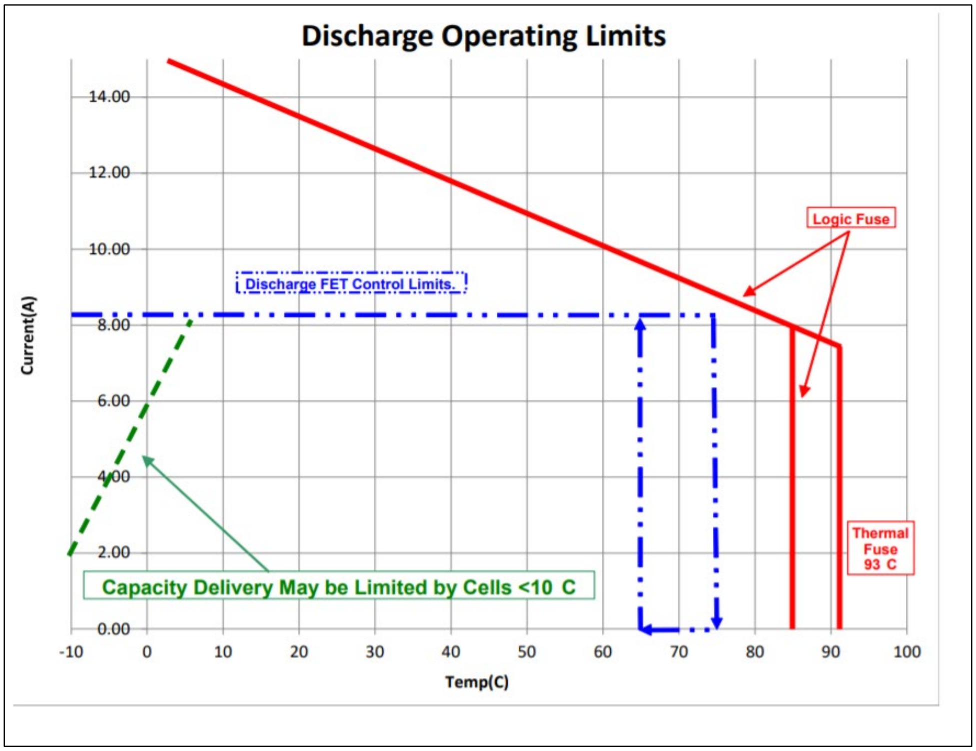


Figure 3: Battery Discharge Limits (Courtesy Inspired Energy, LLC)

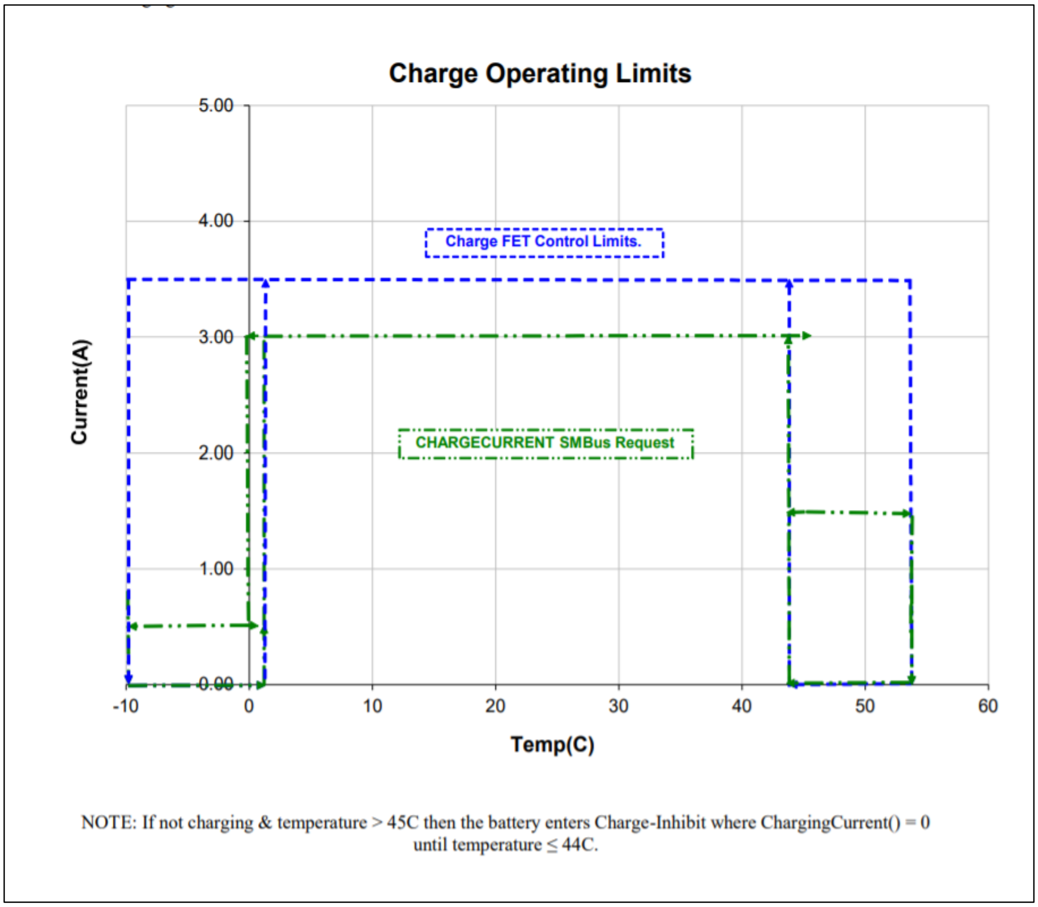


Figure 4: Battery Charging Operating Limits (Courtesy Inspired Energy, LLC)

4.2.3 Battery Status Test

The BMM also provides an on-board "fuel gage" that uses the five green LEDs shown in Figure 5 to indicate the approximate battery charge level. To activate the meter, momentarily depress the Power button (less than 2 seconds) and the LEDs should light up from left to right. Table 6 provides the percentage charge associated with each LED lighting sequence.

Figure 5: Battery Status LEDs

Table 6: Battery Status LED Functions for Remaining Charge

Battery Charge (Approximate)	LED 1 Red	LED 1 Green	LED 2	LED 3	LED 4	LED 5
100% - 81%	OFF	ON	ON	ON	ON	ON
80% - 61%	OFF	ON	ON	ON	ON	OFF
60% - 41%	OFF	ON	ON	ON	OFF	OFF
40% - 21%	OFF	ON	ON	OFF	OFF	OFF
20% - 6%	OFF	ON	OFF	OFF	OFF	OFF
5% - 0%	Flash	OFF	OFF	OFF	OFF	OFF

4.2.4 Battery Power Conservation Modes

Due to the nature of field testing where many variables can interrupt the data collection procedures, it is advantageous to manage battery power in wireless systems. To this end, the STS4 has been designed to require the least amount of power as possible while in "Active" mode (collecting and transmitting data) and by providing three energy conservation modes, outlined in the following sections.

STANDBY MODE

The sensors connected to the system can be one of the largest contributors to power consumption, depending on the sensor type. To help extend the operating time of the system we have added the option to turn off the power to the sensor, which is called Standby Mode. All other functions within the STS4-4-IW3 nodes will remain active.

SNOOZE MODE

Snooze mode allows the users to select a time interval for the system to enter into its low power state to be followed by a "wake up" to attempt to establish a connection to STS-LIVE. For example, if a user selects a Snooze period of 10 minutes, all nodes will enter the low power state for 10 minutes, after which time they will wake up and begin attempt to connect to the STS-LIVE. The communication attempt time has a default period of two minutes and, if unsuccessful, will enter back into its low power state for another 10-minute Snooze cycle. The Snooze cycle is automatically repeated until communication is established with the STS-LIVE application or the power button has been pressed for approximately two seconds (the same as turning the node on or off).

WARNING: Communication **CANNOT** be established with any STS4 node during a Snooze until the STS4 node "wakes up" and attempts to connect. The default setting for the Snooze mode is two minutes in low power mode followed by two minutes of "awake" attempting to connect to STS-LIVE. The STS4 nodes will revert to the default settings any time the device is power cycled.

When turning on the STS4 node, if the node cannot establish a connection to the STS-LIVE application, it will automatically enter into the default Snooze cycle.

SLEEP MODE

Sleep mode allows the user to put the node into its low power state until a specified date and time at which time it will "wake up" and attempt to establish a connection to STS-LIVE for the default two-minute cycle. If a connection is not established, it will transfer into the user defined Snooze mode as described above. For example, if the Sleep mode is set for the following day at 7:00 AM, the STS4-4-IW3 nodes will remain in its low power state overnight and begin attempting to connect to STS-LIVE at approximately 7:00 AM that morning.

The STS4 node's internal clock is automatically updated to the PC's timestamp when Sleep mode is activated. In cases where several nodes are being utilized simultaneously, there may some variation in their Sleep times, meaning some will begin to attempt connecting slightly sooner than others. One additional setting in the Sleep mode is the ability to customize the Snooze mode cycle time after the Sleep time period has elapsed.

STOP: When the STS4 node is in its low power state, it is not possible to establish a communication link to the STS4 node. The only way to reestablish a connection prior to the selected Sleep period is to wait for the next "wake up" sequence or to depress the power button, or approximately two seconds (same as turning the STS4 node on/off).

MAINTENANCE & LIFE EXPECTANCY

STS4-IW3 nodes are shipped from BDI with the batteries charged to approximately 60% to 100% of their capacity. Assuming that the battery has not exceeded the Voltage/Current/Temperature parameters and has undergone normal storage & usage, it should allow up to approximately 300 charge/discharge cycles, after which the expected power available should be ~2AHr.

If there is reason to believe that the battery pack is malfunctioning, the STS4-IW3 node should be returned to BDI for evaluation and repair/replacement.

4.2.5 External Power Supply

The external power supply as illustrated in Figure 6 converts 110-240 VAC to $+24V_{dc}$ for the main purpose of charging the internal Li-Ion battery pack. The power supply is delivered with a USA AC outlet adapter; however, a wide range of optional AC adapters are available depending on the country in which the system is being utilized.

Figure 6: External Power Supply

Table 7: Power supply specifications (varies slightly by manufacturer)

Max Output Power	60 W
Input	90~264 VAC, 47-63 Hz
Output	+24 V_{dc}, 2.7 A
Safety Approvals	UL/cUL (UL 60950-1), EN 60950-1/IEC 60950-1, PSE
EMI/EMC	FCC part 15, subpart b, class B; CE; CISPR 22, class B; ICES-003; ANSI C63.4; EN 61204-3; EN 55022; EN 55024; EN 61000-(2, 3); IEC 61000-4-(2, 3, 4, 5, 6, 8, 11)
RoHS	Yes
Leakage Current	0.25 mA
Operating Temp.	32 to 104 °F (0 to 40°C)
Storage Temp.	14 to 158 °F (-10 to 70°C)
Dimensions	4.5 x 1.85 x 1.28 in (114 x 47 x 32 mm)
Weight	0.5 lb (230 g)

The 3-pin connector end of the power supply shown in Figure 7 threads into the receptacle on the back of the STS4-4-IW3 node shown in Figure 8. Since this scenario requires AC power at each STS4-4-IW3 node location, it is primarily used for charging the internal Li-Ion battery pack or used when the data collection time may exceed the battery capacity.

The power supply does provide the power to both operate the STS4-4-IW3 node and simultaneously charge the battery whose charging status is provided by the LEDs as described in Table 6. If an alternate +24 V_{dc} source is being utilized, the connector pinout is provided in Table 8 BDI can provide 3-pin connectors so the user can fabricate custom power cables.

Figure 7: +24 V_{dc} Power Adapter Connector

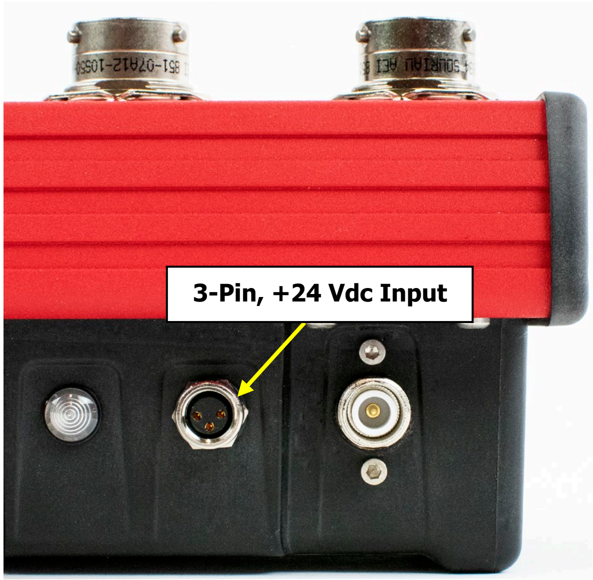


Figure 8: +24 V_{dc} Power Input Receptacle

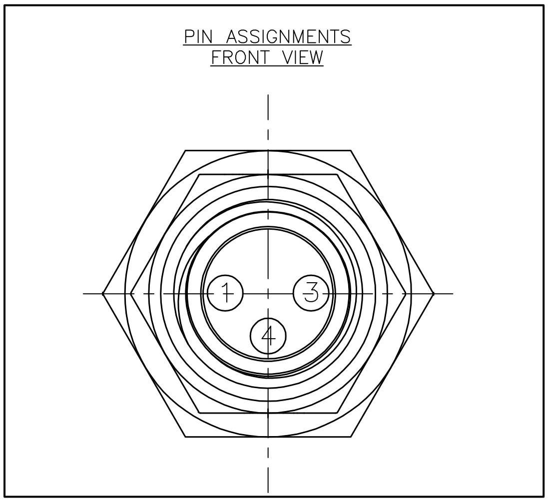


Figure 9: Pinout for +24 V_{dc} Adapter

Table 8: Power Connector Pin-Out

Pin	Signal
1	+24 V_{dc}
3	GND
4	n/a

4.2.6 Power Over Ethernet (PoE)

In certain testing scenarios, it is advantageous to utilize Ethernet cable to supply both communications and power (referred to as Power-over-Ethernet, or PoE). STS4 systems support IEEE 802.3af (2003) PoE (Alternative A and/or Alternative B) using either Endspan and/or Midspan configurations. Note that BDI does not manufacture the network hardware since it is available off-the-shelf from many commercial sources. It is recommended that high-quality shielded CAT5e or better cable be utilized to reduce potential communication degradation in "noisy" environments.

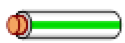
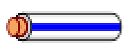
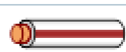
Specifications for STS4 PoE support are provided in Table 9 and

Table 10, and the node connection point is illustrated in Figure 10. For further information on PoE, please refer to IEEE Standards Section regarding IEEE 802.3af Power Over Ethernet. Significant on-line resources are available as well.

Table 9: Specifications for STS4 Power over Ethernet (PoE) Support

Standard	IEEE 802.3af
Power Available at STS4 node	12.95 W
Max Power delivered by PoE Injector	15.40 W
Voltage range (at STS4 node)	44.0-57.0 V_{dc}
Voltage range (at PoE Injector)	37.0-57.0 V_{dc}
Maximum current	350 mA
Maximum cable resistance	20Ω
Power management	Three power class levels negotiated at initial connection
Supported cabling	Cat5e (or better)
Supported Injection Configurations	Alternative A (End span), Alternative B (Mid span)

Table 10: 802.3af CAT5e Standards for Power over Ethernet

Pins on Switch	T568B Color (BDI Standard)	10/100 DC on Spares (Alternative B)
Pin 1		Transmit +
Pin 2		Transmit –
Pin 3		Receive +
Pin 4		DC + (+48 V_{dc})
Pin 5		DC + (+48 V_{dc})
Pin 6		Receive –
Pin 7		DC – (GND)
Pin 8		DC – (GND)

The +24 V_{dc} external power supply will override the PoE if both sources happen to be simultaneously connected to the STS4 node.

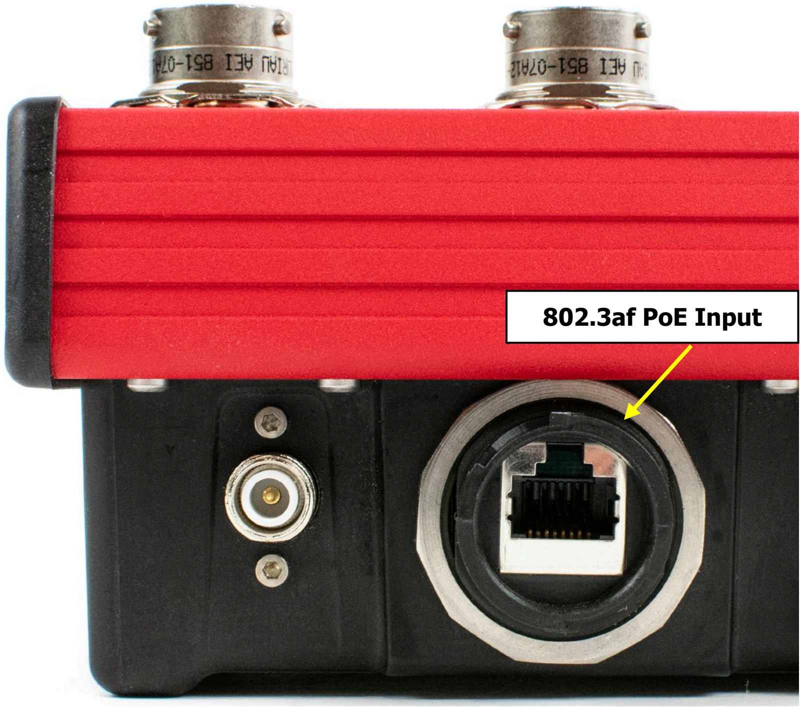


Figure 10: +48 V_{dc} PoE Ethernet Input Connector

4.2.7 Grounding and Electrostatic Discharge (ESD) Protection

It is assumed that each node operates in an "isolated" environment, meaning they can be located large distances from each other. One possible source of electronic noise can be a variation between the node and sensor's ground potential such as that can occur with railway bridges carrying electrified trains. If this is a suspected issue, the grounding lug shown in Figure 11 is provided to provide a route for the node ground to stabilize to the sensors placed nearby.

Figure 11: Location of ground screw on STS4-4

STS4-4-IW3 nodes are also equipped with on-board gas discharge tube arrestors to protect from over-voltages caused by lightning, power switching issues, and other fault conditions. Transient voltage suppressors are also built in which meet ESD requirements as described in IEC 61000-4-2, Level 4 (+/-15 kV air, +/-8 kV contact discharge.) In case these components are activated by overvoltage, they will be damaged and must be replaced by BDI.

4.2.8 Sensor Power Considerations

The amount of power required to operate the STS4-4-IW3 node and sensor combination varies with the type of sensors being utilized. Table 11 summarizes the available power to operate sensors as a function of the excitation power source. Simply add up the power requirements for an individual sensor or all four sensors and determine if it remains within the limits described in Table 11. Refer to the specifications for the specific sensors to be used to determine the total power requirements.

Table 11: Available Power for Sensors

Excitation Source	Available Current
V_{+15}	400mA (Shared between all four channels)
V_X	20mA (per channel)

5. COMMUNICATION

5.1 INTRODUCTION

The STS4 system has been expressly designed to be adaptable to a large range of field test variables such as:

- Physical access to structure
- Length of test
- Proximity of PC to installed system
- Allowable time for installation and/or removal
- Available power sources
- Temperature changes
- Environmental issues
- Electronically noisy applications
- Wireless communication interference
- Sensor types
- Number of channels

To provide maximum flexibility to adapt to these and other field conditions, various hardware configurations can be utilized. For example, for most short-term testing cases in which all nodes will be placed within several hundred feet of the Base Station, the wireless option is usually the most efficient. However, for applications where nodes are spaced significantly far apart or longer-term data collection is required, meaning that battery life would become an issue, STS4 systems can be operated in "wired" mode. This option not only ensures high-quality communication over longer distances but provides the PoE feature that allows the system to operate indefinitely. In still other situations, it may be advantageous to use a combination of both wireless and wired configurations.

The flexibility to combine wireless and wired modes stem from the use of the two-layered Transmission Control Protocol (TCP)/Internet Protocol (IP) (TCP/IP) in which the TCP handles data transmission and the IP guides it to the correct IP address. STS4 systems rely on a completed fixed IP network, meaning that all components have been preconfigured with fixed IP addresses. To operate in this environment, the user's PC must first be configured with a fixed address as described in Section 5.3

One significant advantage of TCP/IP technology is that it treats the communications links as "transparent", meaning that wireless and wired links can be interchanged with no effect on operation.

5.2 Computer Requirements & Network Settings

5.2.1 Personal Computer Requirements

BDI recommends that a personal computer (PC) equipped with a minimum of a Dual Core Intel i5 processor supported with 8GB RAM and Windows® 10 Pro be used for operating STS4 systems consisting of 100 data channels or less. For higher channel count STS4 systems, please contact BDI for recommended PC capabilities. It is also highly recommended to dedicate one PC for running the STS4 rather than having to configure the Windows® Firewall and other third-party internet security applications that often block the STS-LIVE application on various computer operating systems.

5.3 Configuring Network Settings

Prior to initiating communication with STS4 systems, the PC will need to be configured to act as the control point for the STS4 network. Due to the wide variety of available PCs and operating systems, it is not feasible to provide detailed configuration instructions for all. However, the two communication issues that must be addressed are:

+ IP Address and Subnet Mask under IPv4 Protocol
+ Windows Firewall and other Security Applications

WARNING: It is important that the computer Network Settings are correct before launching the STS-LIVE application and attempting to establish connections with STS4 components. This is often the first suspect in case a connection cannot be established. Please ensure the TCP/IPv4 settings are as follows:

IP address: 192.168.10.2
Subnet mask: 255.255.0.0
Default gateway: Blank
DNS Settings: Blank

In most cases Windows® Firewall will be alerted when a new application (STS-LIVE) is executed for the first time. There will likely be a warning message and it is important that the user select "Allow Access" to avoid blocking STS-LIVE from utilizing the network(s).

In addition, some third-party applications (ex. Norton Internet Security, McAfee, etc.) may require the user to manually add the STS-LIVE application to the trusted program list. Please consult the application's operations manual on how to add STS-LIVE to the trusted program list.

5.4 Wireless Communications

5.4.1 Wireless System Architecture

The typical wireless testing scenario involves the use the STS4 Wireless Base Station (STS4-WBS) as the central point of communication between the STS4-4-IW3 nodes and the PC as illustrated in Figure 12. The network protocol is all preconfigured (with the exception of the user's PC) to a fixed IP network. This configuration can support up to 128 STS4-4-IW3 nodes with a single STS4-WBS. Adding additional STS4-WBS's will expand the wireless network range and increase the overall STS4-4-IW3 node count.

100% WIRELESS MODE CONFIGURATION

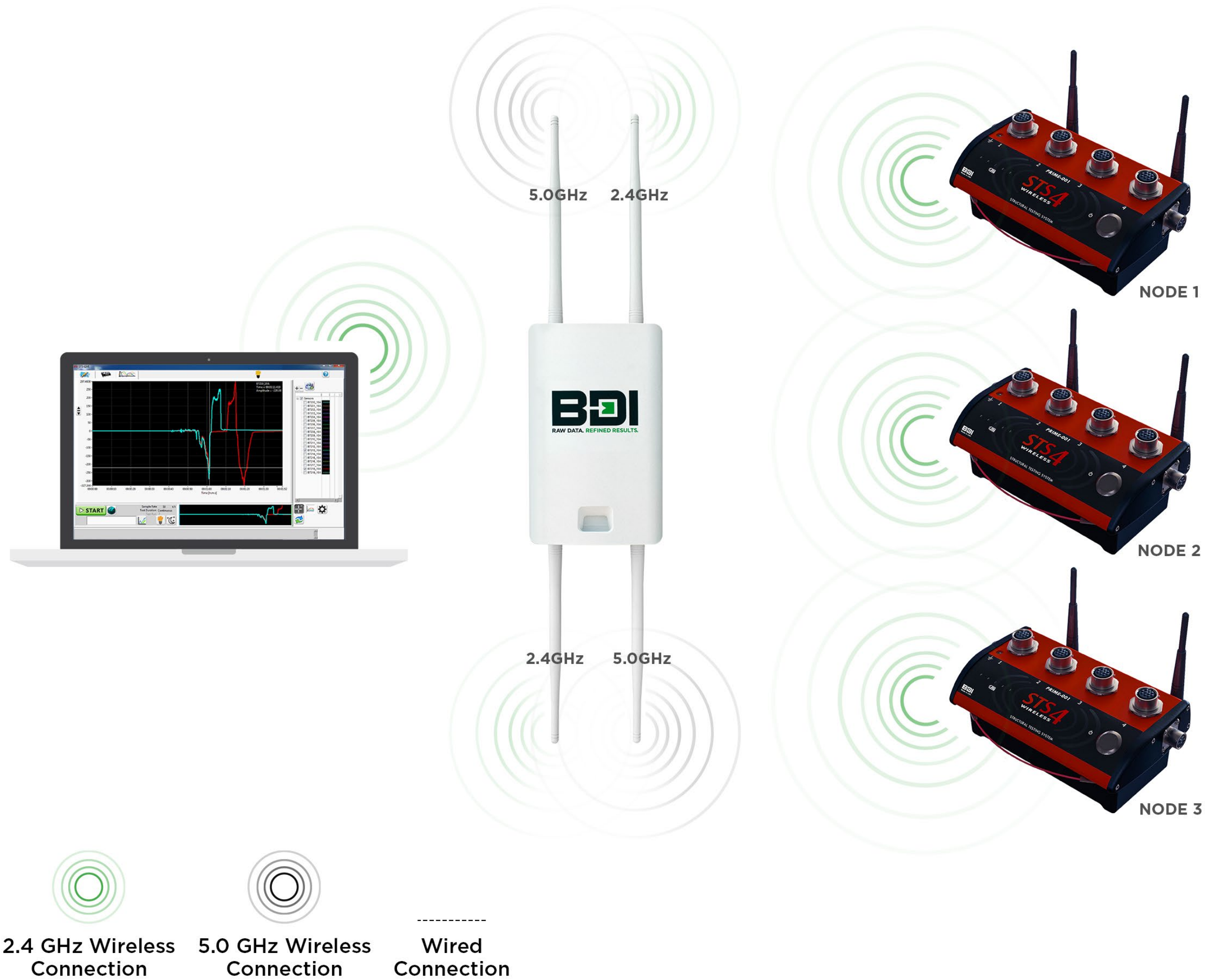


Figure 12: Typical wireless communication protocol

5.4.2 Wireless Communication Protocol

The wireless protocol used in the STS4-4-IW3 nodes is a standard Wireless Local Area Network (WLAN) using IEEE 802.11b/g/n protocol operating on the 2.4 GHz Industrial, Scientific and Medical (ISM) frequency band. See Table 12 for specifications.

Table 12: Wireless Communication Specifications (STS4 nodes)

Feature	Description
Frequency Band	2.400 – 2.500 GHz (2.4 GHz ISM Band)
Antennas:	
Gain	7 dBi
Radiation	Omni-Directional
Polarization	Vertical
Impedance	50Ω

Horizontal Beam Width **Vertical Beam Width** **VSRW**	360° 20° ±5° < 2.0
Frequency Reference	40 MHz
Modulation	OFDM with BPSK, QPSK, 16-QAM, and 64-QAM 802.11b with CCK and DSSS
Supported Data Rates: **802.11n** **802.11g** **802.11b**	 6.5, 13, 19.5, 26, 39, 52, 58.5, 65 Mbps 6, 9, 12, 18, 24, 36, 48, 54 Mbps 1, 2, 5.5, 11 Mbps
802.11n Features	MCS 0-7, STBC, RIFS, Grenfield Protection A-MPDU, A-MSDU Aggregation with Clock-ack, PSMP, and MTBA
Typical Transmit Power (±2 dBm)	17 dBm for 802.11b DSSS 17 dBm for 802.11b CCK 15 dBm for 802.11g/n OFDM
Transmitting Range (line-of-sight)	~500 ft (150 m)

5.4.3 Node to Base Station Communications

The communications capability of the STS4-WBS is provided by an Access Point (AP) that broadcasts the wireless local area network (WLAN) and manages all incoming and outgoing traffic between the STS4-4-IW3 nodes and the PC (STS-LIVE). STS4-WBS units supplied by BDI are preconfigured with the "STS" network name (SSID) and should be visible to the computer's wireless network tool/application when configuring network settings. Please refer to the STS4-WBS Operations Manual for further details on network configurations.

5.4.4 Antenna Positioning

All STS4 components antennas should be oriented such that the wireless radiation pattern between the STS4-WBS and the STS4-4-IW3 nodes and PC overlap. Figure 13 shows the typical radiation pattern for the omni direction antenna types that are used in the STS4-WBS and STS4-4-IW3 nodes. What this typical radiation pattern shows is that the primary direction of the wireless signal radiates outward from the antenna in a "donut" pattern meaning that the antenna positions should always be parallel to each other and aligned so that the radiation pattern overlaps. Figure 14 illustrates correct and incorrect antenna positioning.

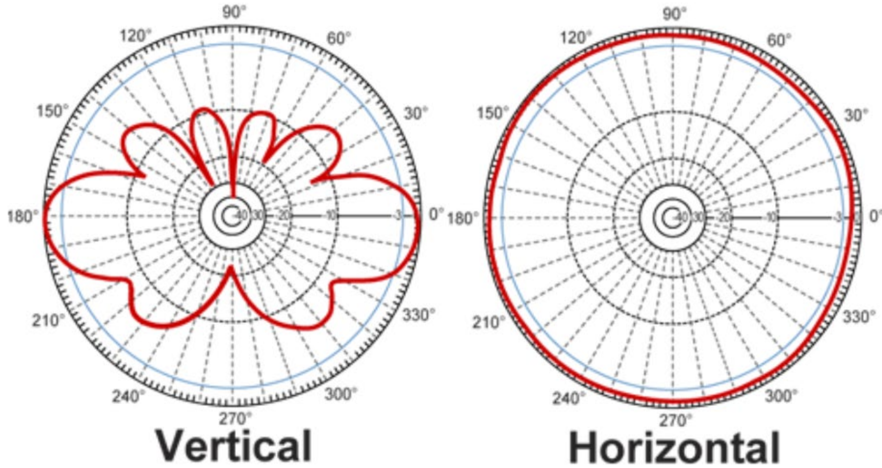


Figure 13: Wireless radiation pattern for typical omni direction antennas

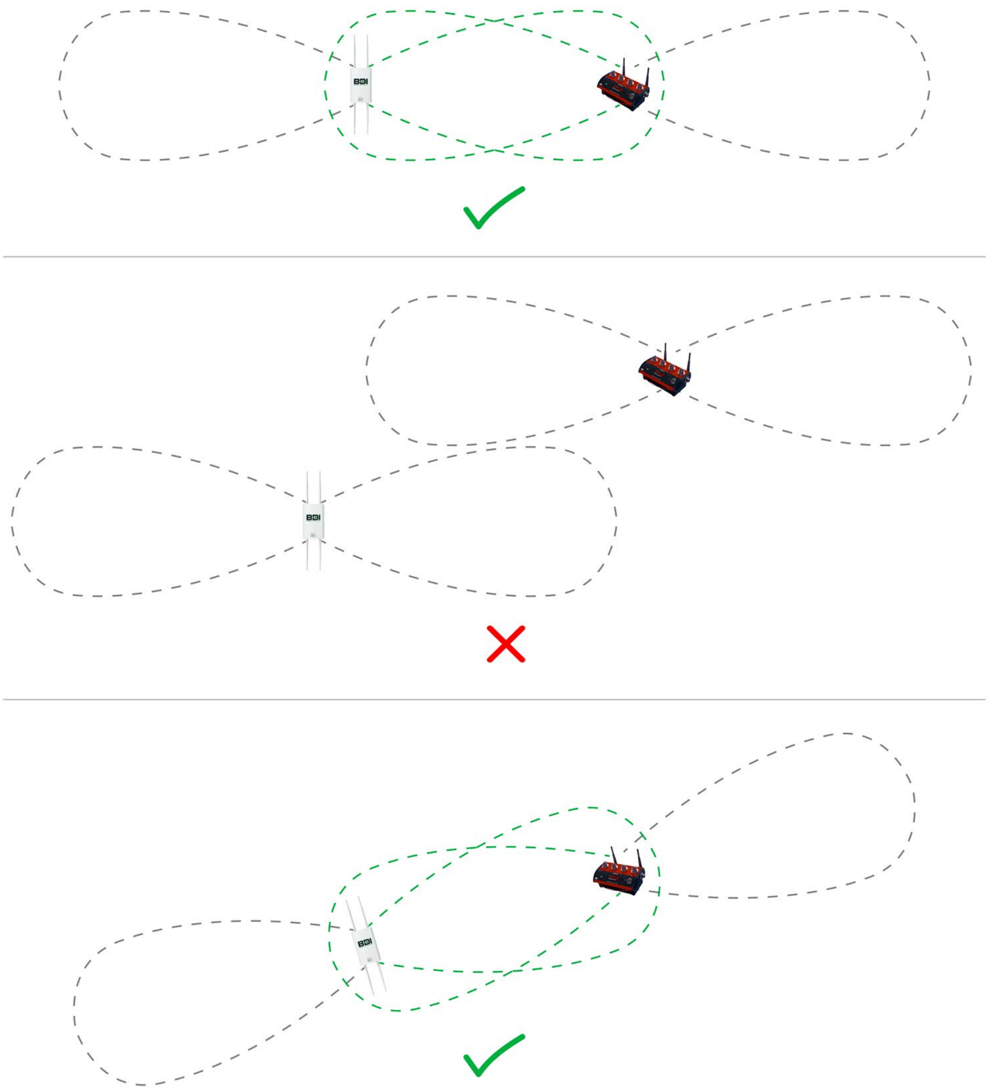


Figure 14: Correct and incorrect antenna positioning

5.5 Wired Communications

In some scenarios (either because of power or communication issues), it is advantageous to use STS4-4-IW3 nodes in a wired mode, meaning that communication is facilitated through standard Ethernet protocol and connected as outlined in Section 5.5.1 .

5.5.1 Wired Communications Protocol

In addition to the built-in wireless capabilities, the STS4 hardware is equipped with on-board support for standard IEEE 802.3af Ethernet Local Area Network (LAN) protocol. As illustrated in Figure 15 an off-the-shelf network switch is utilized. The network can be supported by any switch or combinations of switches that support the IEEE 802.3af protocol.

BDI does not manufacture or support the Ethernet switching components. If additional support is required for configuring switching components, please contact your IT Support Department. We recommend utilizing unmanaged Ethernet switches as they are typically plug-and-play.

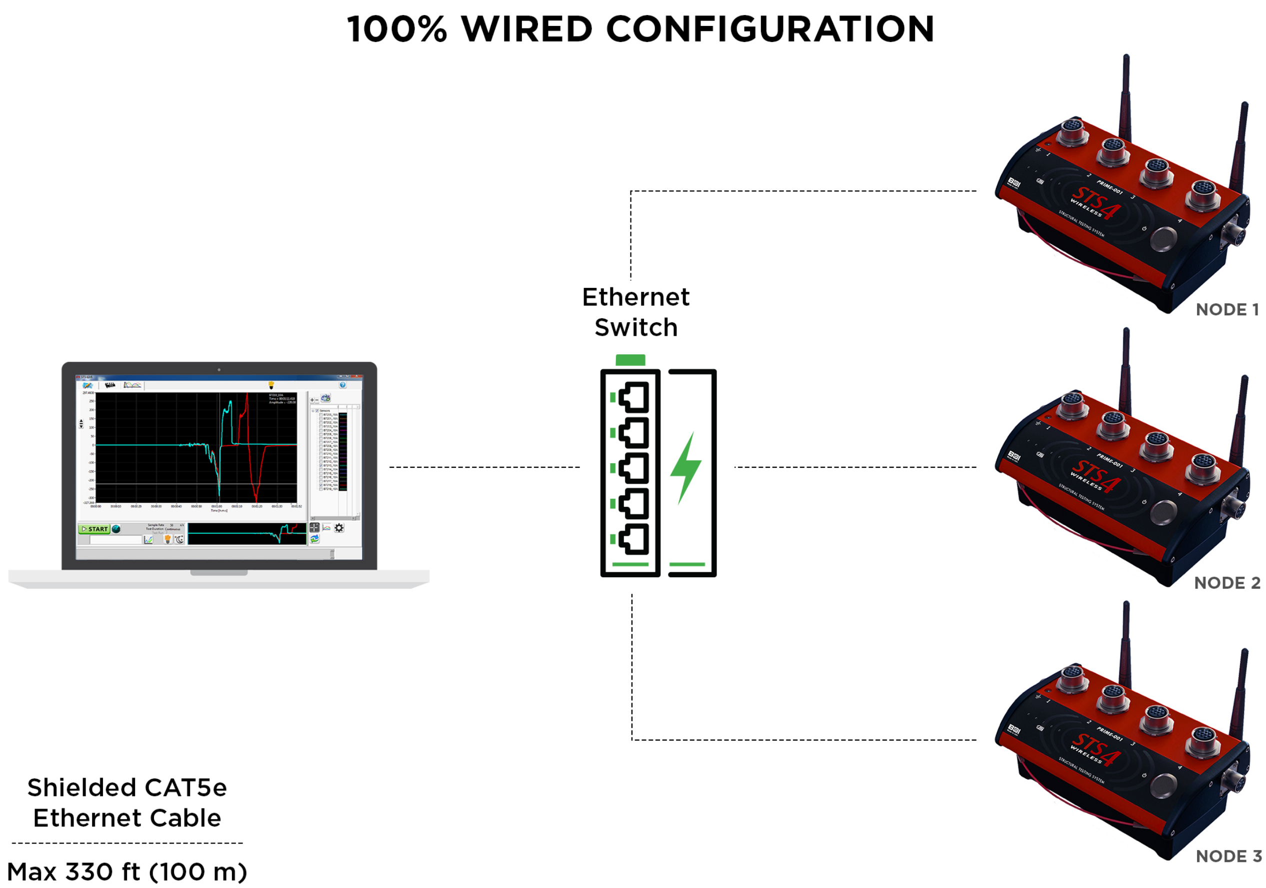


Figure 15: Wired Ethernet communication configuration

5.6 Wireless-Wired (Mixed -Mode) Communications

The wired TCP/IP LAN protocol dovetails with the wireless IEEE 802.11b/g/n TCP/IP network protocol, meaning that both communication links are essentially transparent to all STS4 components. This design feature allows full interchangeability between wired and wireless links.

In the case where the entire system is to be wired, an unmanaged Ethernet switch is required to replace or work in conjunction with the STS4-WBS as illustrated in Figure 16. A single STS4-4-IW3 node can also be connected directly to the PC's Ethernet adapter as shown in Figure 17.

MIXED MODE CONFIGURATION

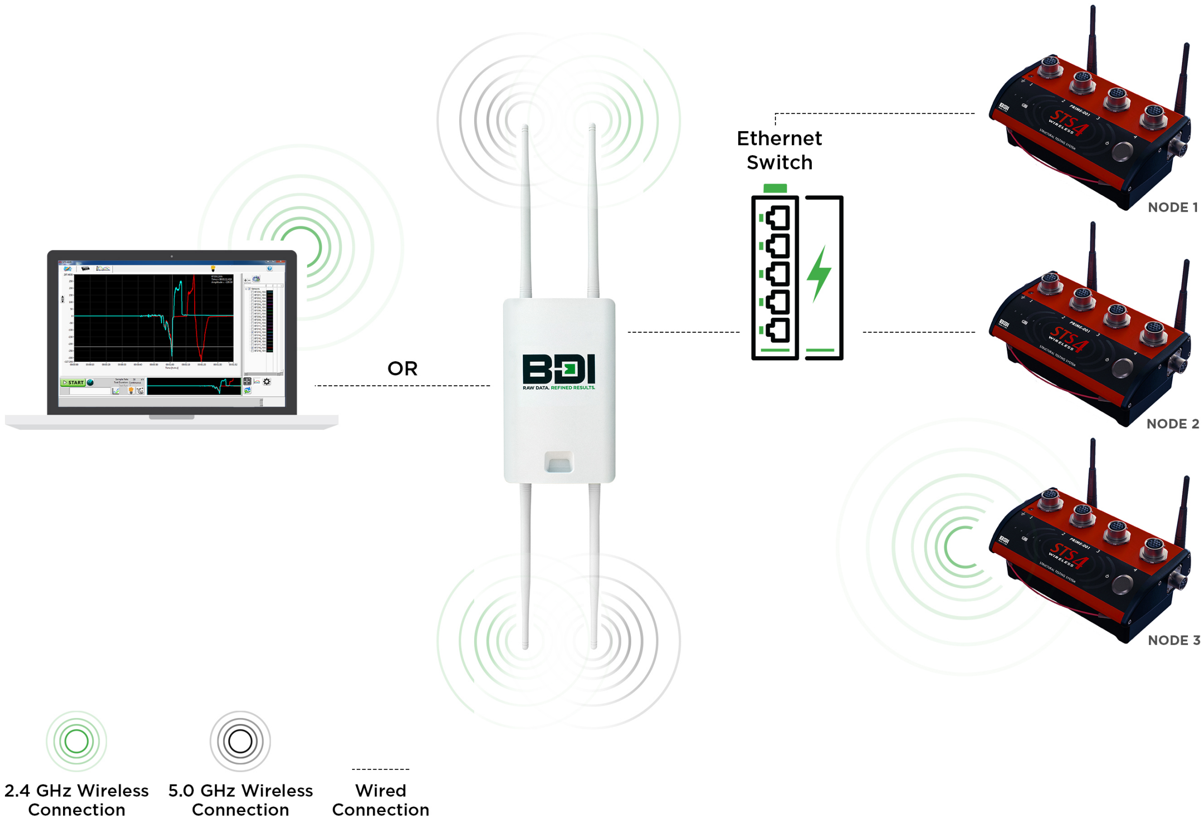


Figure 16: Multiple Node Communication using Ethernet Cable and Ethernet Switch

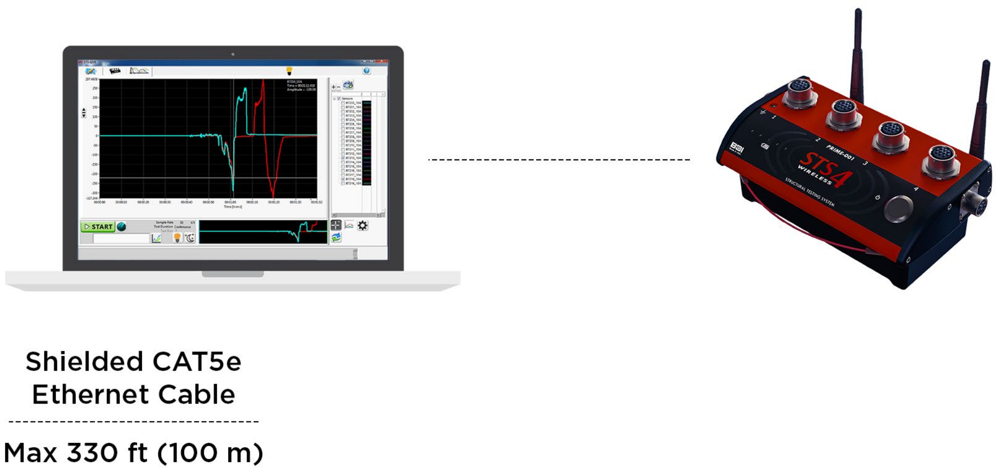


Figure 17: Communication with one node with Ethernet cable

6. Data Acquisition

6.1 Data Flow

The data collection sequence begins with four sensors capturing continuous physical quantities such as strain, displacement, acceleration, or rotations. Each sensor's analog response signal is directed to the STS4-4-IW3 nodes on-board analog-to-digital converter (ADC) where it is converted to discrete digital values according to the selected sample rate. The digitized data is then buffered into the on-board memory while simultaneously being transmitted to the PC. The basic data flow scheme through a full STS system is illustrated in Figure 18.

During the downloading sequence, selected sensors can be graphically displayed to allow immediate evaluation. Once the download sequence has completed and all data has been stored to the PC, STS-LIVE allows more detailed graphing of each sensor's output which allows for a quick data quality check.

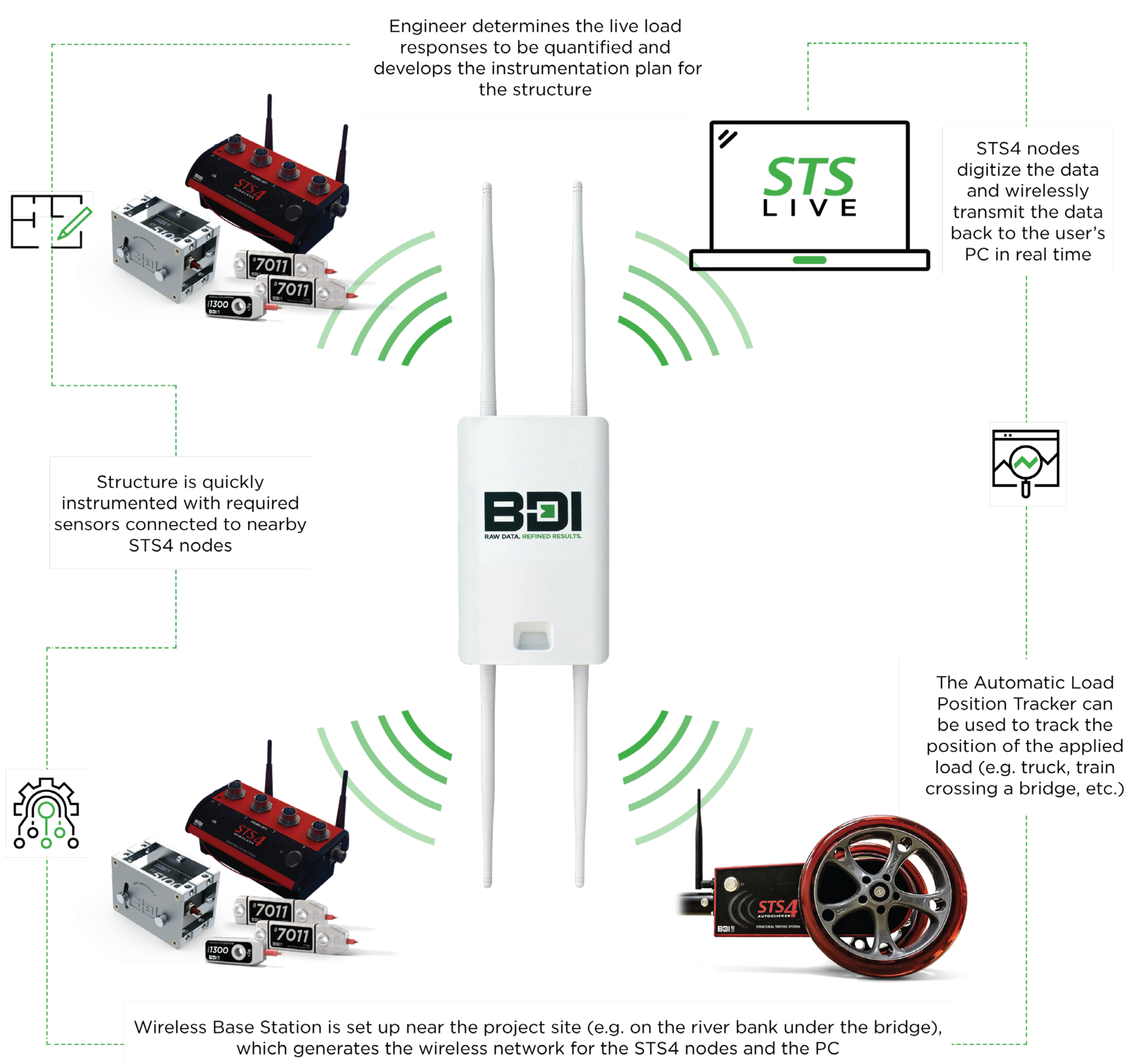


Figure 18: STS4 System Architecture

6.2 Embedded Hardware Information

6.2.1 Node Information

Prior to shipment, all STS4-4-IW3 nodes are programmed with calibration and general system information that is automatically retrieved by STS-LIVE. Table 13 outlines the information stored in each node during the manufacturing process.

Table 13: Embedded Node Information

Information Stored	Description
Node Name	Labeled on the front of each node
Calibration Constants	Calibration constants for the gain stages
Wireless Network Name (SSID)	Network name (default: STS)
IP Address	Pre-programmed unique IP address
MAC Address	Unique MAC address

6.3 Analog-to-Digital Converter (ADC)

The STS4-4-IW3 node uses a single 24-bit, sigma-delta ADC that allows the data channels to be sampled at a maximum rate of 1,000 S/s per channel and additional auxiliary channels (temperature, battery information, etc.) at approximately 1 S/s.

Table 14: ADC Specifications

Specification	Description
Resolution	24-bit (No missing codes)
Max Sample Rate: **Sensors** **Auxiliary Data**	 1,000 S/s ~1 S/s
Full Scale Input Range[1]	±5.0 V_{dc} (differential) +40 V_{dc} (single-ended)
Input Gain Stages: **0.25** **0.50** **1** **2** **4** **8** **16** **32** **64** **128** **256**	Input Range +40.0 V_{dc} (single-ended) +10.00 V_{dc} (single-ended) ±5,000 mV (differential) ±2,500 mV (differential) ±1,250 mV (differential) ±625 mV (differential) ±312 mV (differential) ±156 mV (differential) ±78.1 mV (differential) ±39.0 mV (differential) ±19.5 mV (differential)
Gain Drift	0.4 PPM/°C (typical) – 2.0 PPM/°C (max)

[1] Input range ±10%

6.4 Calibration Data

Each node channel has been calibrated and corresponding parameters are stored in on-board non-volatile memory and is not accessible by user.

6.5 Sample Rates

The STS4-4-IW3 node is capable of sampling as low as 1 S/s and as high as 1,000 S/s. Table 15 outlines the selectable sample rate options within the STS-LIVE application.

Table 15: Sample Rates

Selectable Sample Rates (S/s)
1,000
500
250
200
100
50
20
10
5
2
1

6.6 System Memory/Data Storage

The STS4-4-IW3 nodes contain three memory types for storing system information, firmware, and test data. The following sections outline each of the three types of memory and their function.

6.6.1 Volatile System Storage (SDRAM)

The STS4-4-IW3 hardware contains 16Mb of Synchronous Dynamic Random-Access Memory (SDRAM). This memory is reserved for:

+ 4Mb reserved for general firmware task handling and non-critical information regarding the test parameters that have been set by STS-LIVE
+ 12Mb reserved for a circular memory buffer for incoming data (approximately 750,000 data points per node)

If power is suddenly lost or the hardware is manually rebooted, the data stored in the circular memory will be lost and the test parameters will need to be set up again through STS-LIVE.

6.6.2 Non-Volatile System Storage (NVM)

The STS4-4-IW3 hardware contains 256Kb of non-volatile flash memory. This memory is reserved for:

- Node Name & Type
- Serial Number
- Calibration Data
- Programmed IP Address

6.6.3 Non-Volatile Data Storage (Internal Micro SD Card)[1]

The micro SD card is internally mounted in the STS4-4-IW3 hardware and not physically accessible by the user. Test data is stored on the micro SD card for disaster recovery purposes only and not designed to be a user defined backup tool. Data retrieved through the STS-LIVE application.

Table 16: Micro SD Card Characteristics

Storage Capacity	8 GB
Number of Records	316 x 106
Approximate Backup Time at 1,000 S/s [DD:HH:MM:SS]	03:15:46:40
Allocation: Hardware & Error Logging	100 MB

6.7 Internal Temperature Sensor

The STS4-4-IW3 hardware contains an internal temperature sensor. While the data for the internal temperature sensor is available, it's primary use it to track the temperature with respect to the battery operational limits.

6.8 Lithium Ion Battery Reporting

The Li-Ion battery, or Smart Battery System (SBS) pack is Smart Management Bus (SMBus) Rev 1.1 compliant, which means that the battery pack contains an integrated circuit board that monitors and reports information through an industry standard protocol. The STS4-4-IW3 nodes interfaces with the SBS and reports the information outlined in Table 17 approximately every 10 seconds. Not all items are reported in the STS-LIVE application.

Table 17: Li-Ion Battery Pack Reporting

Battery Information	Units
Battery ID	Serial Number
Battery Voltage	V_{dc}
Battery Capacity	% of full
Current Draw	mA
Run Time to Empty[1]	Minutes
Charging Voltage	V_{dc}

[1] Micro SD card support to be released 2019.

Time to Full Charge	Minutes
Charge Cycles	Number of Charge/discharge cycles
Temperature	°F
Low Capacity Alarm	Warning to indicate the battery is near the empty state (Minutes Remaining)
Critical Alarm	Critical warning message

1 The reported time to empty is predicted time based on the battery discharging at the current state of usage.

6.9 Time Synchronization Between Nodes

A major consideration for distributed data acquisition systems is to ensure data is accurately synchronized between all STS4-4-IW3 nodes. Due to the large number of possible STS4 field testing scenarios such as system size (number of channels), sample rates, and potential wireless and wired communication quality issues it is important that the synchronization routine can be implemented in any scenario. In order to provide accurate time synchronization, the PC is designated as the "parent" clock and all STS4-4-IW3 node clocks are "child's". This is possible because the STS4-4-IW3 node clocks have variable frequencies that can be varied or "re-set" as necessary.

The syncing of the STS4-4-IW3 node clocks takes place in two distinct states. The initial state happens when a STS4-4-IW3 node is connected to an instance of STS-LIVE for the first time. After a node establishes a valid connection to the STS-LIVE, STS-LIVE pings the STS4-4-IW3 node multiple times to open a low latency TCP/IP connection. Once a low latency TCP/IP connection is established, the core sends a time reference to the STS4-4-IW3 node and the STS4-4-IW3 node sets its time to the reference time from STS-LIVE. Since the amount of time it takes for the reference to arrive at the STS4-4-IW3 node is unknown a baseline difference in time (delta T) between STS-LIVE and the STS4-4-IW3 node must be established. To establish a known offset between the STS-LIVE and the STS4-4-IW3 node, the STS-LIVE pings the STS4-4-IW3 node 64 times and tracks the delta T of each ping. This process happens within 5 seconds of a STS4-4-IW3 node connection to STS-LIVE. Generally, delta T is a noisy signal so it must be filtered then put through an algorithm that determines the actual difference in time between the STS-LIVE and the STS4-4-IW3 nodes.

After STS-LIVE has established a delta T for each STS4-4-IW3 node, a test can be started in which all STS4-4-IW3 nodes will start recording data within +/- 2.5 milliseconds of each other. This means that for the sample rates of 1 S/s to 1,000 S/s STS-LIVE will now have sampled an accurate start time sync between all STS4-4-IW3 nodes. For the following sample rates the maximum deviation of samples between nodes at the start of a test are as follows:

+ 250 S/s +/- 0.6 samples
+ 500 S/s +/- 1.25 samples
+ 1000 S/s +/- 2.5 samples

In order to sync the start time of all the STS4-4-IW3 nodes, a time in the future must be used as the start time for the test. STS-LIVE determines the best time in the future to start the test based on the connection quality of all STS4-4-IW3 nodes. The test start offset time can vary between 1,000ms to 2,500ms in the future.

The process of establishing a valid delta T value between the STS4-4-IW3 nodes and STS-LIVE takes place only once for each time STS-LIVE is started, and an STS4-4-IW3 node connects. If an STS4-4-IW3 node disconnects from STS-LIVE and re-connects the established delta T is used and the clock on the STS4-4-IW3 node is not reset. If the clock has drifted in the time that a STS4-4-IW3 node was disconnected the slow loop correction, as described below, will re-align the clock in the STS4-4-IW3 node to STS-LIVE. The only way to force a re-sync (reset the nodes clock) after a node has checked in is to either put the nodes to sleep or restart the core. Putting the STS4-4-IW3 nodes to sleep turns off the internal clock so there is no way to maintain Time Sync when an STS4-4-IW3 node is asleep. When an STS4-4-IW3 node wakes up, it goes through the initial Time Sync just as if it was being connected to the system for the first time.

The second state of time synchronization is a slow control loop that ensures the clock on the STS4-4-IW3 node does not drift out of sync from the clock on the PC. The control loop is implemented in STS-LIVE. Once a STS4-4-IW3 node has established a baseline delta T as described above, it switches to the slow control loop. This process happens in the background if a STS4-4-IW3 node is connected, including when a STS4-4-IW3 node is idle or testing. Each time a test is started a test offset time is calculated and sent to the STS4-4-IW3 nodes. The slow control loop uses this test start offset time as the reference point for the clock in each STS4-4-IW3 node. The slow control loop will force the clock on the STS4-4-IW3 nodes to maintain the same delta T value that was calculated at the beginning of the test thus keeping all nodes synced to the same sample accuracy that was obtained at the beginning of the test.

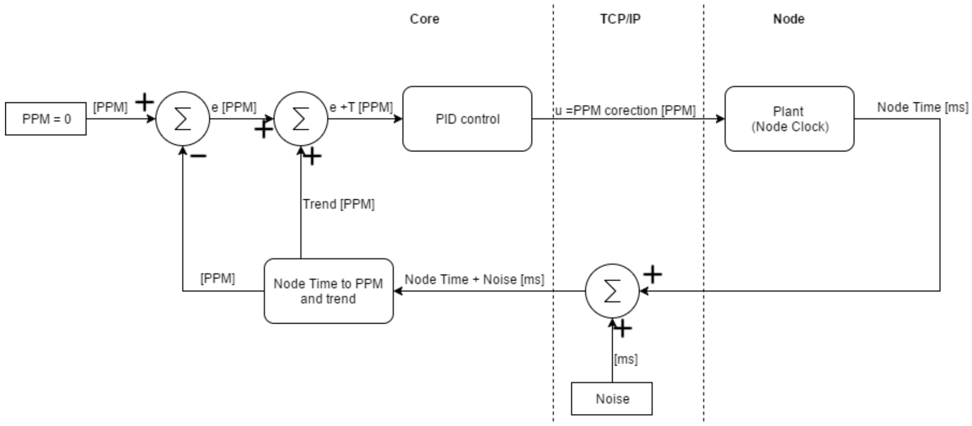


Figure 19: Simplified block diagram of the node and STS-LIVE control loop

A significant part of Time Sync is the ability at the start of a test to determine if a STS4-4-IW3 node is in sync or not. STS-LIVE checks and determines if a STS4-4-IW3 node is not in sync at the start of a test. This detection and warning system will require the user to either stop the test and wait for the node to sync, or, ignore the warning and continue the test with a node that is not in sync.

For the user, it is important to note that STS4-4-IW3 nodes must have time to sync when they are connected to a system. There is now an indicator on the nodes tab that will let you know when STS4-4-IW3 nodes are syncing. In general, it will take around 10 seconds for a node to connect and sync to STS-LIVE. See Figure 20 for details on syncing indicators.

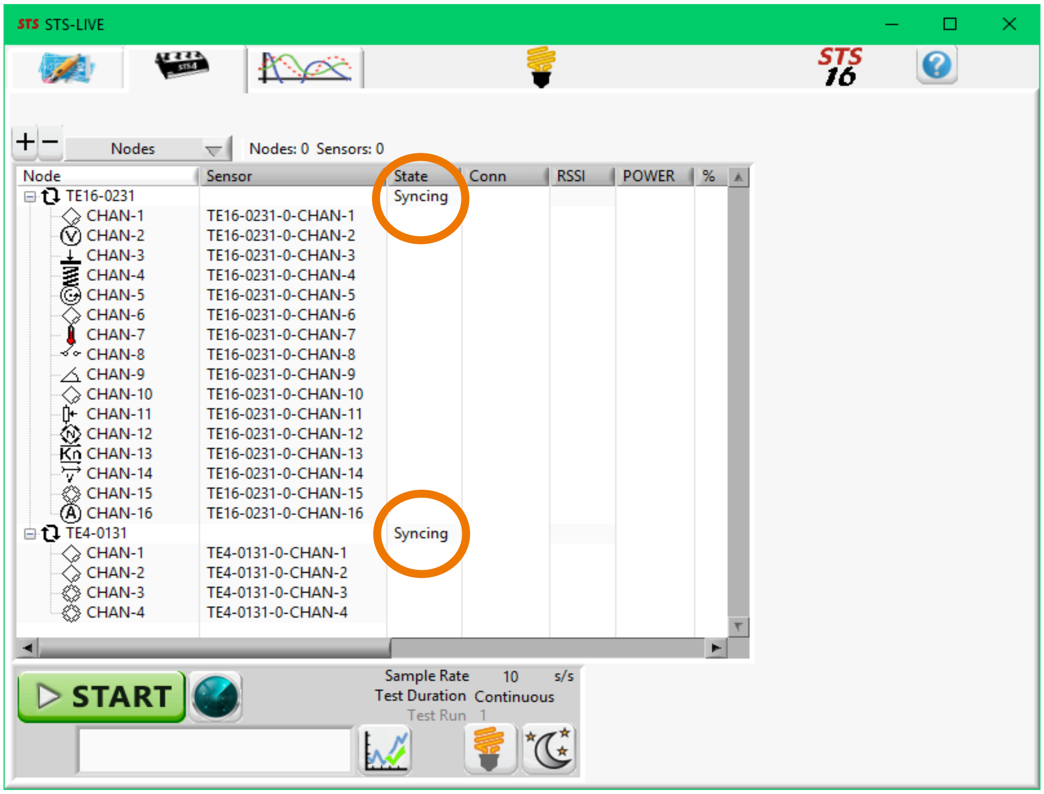


Figure 20: Syncing Indicator in STS-LIVE

INFORMATION: Syncing is indicated in STS-LIVE and when STS4-4-IW3 nodes are successfully connected, the icon will become green, indicating that the node is ready for testing.

6.10 Sensor Support

6.10.1 Excitation Voltages

The STS4-4-IW3 nodes have been designed to accommodate a large variety of sensors used for recording structural responses such as strains, displacements, rotations, and accelerations. To provide this flexibility, both regulated and unregulated excitation options are available.

PROGRAMMABLE REGULATED +1.0 V_{DC} TO +5.0 V_{DC}

Regulated power supplies are typically used for ratiometric sensors such as those based on a Wheatstone bridge. Pin G (see Table 19) provides a regulated excitation voltage and is programmable from +1.0 to +5.0 V_{dc} (16-bit resolution, typ. 5ppm/°C) with a current limit of 20mA per channel.

The primary reasons for modifying voltage levels are power savings and optimizing foil strain gage outputs. For power savings, one should consider that when four 350Ω Wheatstone bridge strain transducers are connected to a STS4-4-IW3 node at +5.0 V_{dc} excitation, the sensors are consuming nearly 30% of the system power. By simply lowering the excitation voltage to +2.5 V_{dc} a significant increase in operational time for STS4-4-IW3 is gained. More importantly though is measurement quality, higher excitation voltages will result in higher output, thus increasing the signal to noise ratio. This programmable feature allows the user to optimize the excitation voltage for is specific sensor/application. Please note that there are a lot of considerations when it comes to defining the proper excitation level for a given sensor/application, so please consult the sensors technical documents for guidance.

UNREGULATED +15 V_{DC}

Pin A (see Table 19) provides an unregulated +15 V_{dc} (±5%) excitation voltage. This excitation voltage is provided to handle the large family of sensors that generally have internal power conditioning such as LVDTs. The current limit for this excitation voltage is 400mA and is shared between all four data channels. Please note the difference between the available current on this power supply compared to the regulated excitation. Since this power supply is shared it can power a single sensor up to 400mA or be shared between all four channels with 125mA per channel or any combination between.

6.11 Voltage Measurements

6.11.1 Data Channel Input Range

The STS4-4-IW3 ADC input range (same as a sensor's output range) is limited to ±5.0 V_{dc} differential or +10 V_{dc} single-ended. If the sensor output exceeds the ±5.0 V_{dc} limit, the STS4-4-IW3 ADC unit saturates and "clips" the output, disabling it from converting data and outputting "NAN" (not a number). Then, once the sensor output is back in range, the ADC "releases" and the STS4-4-IW3 continues processing real data.

For sensors that may produce output voltages outside the acceptable range, a voltage divider can often be used to make the sensor compatible for the STS4-4-IW3. Please contact BDI for details.

SENSOR OFFSETS

Sensors may produce a reading when there is no strain, displacement, rotation, or acceleration taking place. Using STS-LIVE software, the sensors can be 'zeroed' to eliminate the sensor offset. Please note that this is a mathematical offset, NOT a bridge balancing routine; therefore, any offset in the sensor results in the loss of usable range in the direction of the offset.

STS4-4-IW3 GAIN STAGES

STS-LIVE has the ability to select the gain stage with respect to the range of the sensor in the units of the sensor as opposed to the input voltage range of the STS4-4-IW3 nodes. To utilize this feature, the user will need sensor type, calibration factor, and expected output in terms of your units. When you select the range, gain is automatically calculated to optimize to the range. STS4-4-IW3 nodes have the ability of providing sensor output gain factors of 0.25 to 0.5 for single-ended output sensors and 1 to 256 for differential output sensors. Gain factors are generally used to increase the signal to noise ratio of sensors that have output signals that are lower than the ADC input range (±5.0 V_{dc} differential or +40 V_{dc} single-ended). See Table 18 for the range of gain selections.

Table 18: Available Gain Settings

Gain Stage	Input Range1
0.25 (Single-Ended)	+40.0 V_{dc}
0.50 (Single-Ended)	+20.0 V_{dc}
1 (Differential)	±5.0 V_{dc}
2 (Differential)	±2.5 V_{dc}
4 (Differential)	±1.25 V_{dc}
8 (Differential)	±625 mV
16 (Differential)	±312 mV

32 (Differential)	±156 mV
64 (Differential)	±78 mV
128 (Differential)	±39 mV
256 (Differential)	±19 mV

[1] Input range ±10%

6.11.2 Calculating Gain Stages

The following examples show how to calculate the correct gain setting for a sensor:

1. The sensor is a 350Ω full bridge strain transducer with an output of 250με/mV differential output and a maximum range of ±5,000με.

   a. First calculate the maximum output range of the sensor:

   $$Maximum\ Sensor\ Output = \frac{\pm 5{,}000\mu\varepsilon}{250\ \mu\varepsilon/mV} = \pm 20mV$$

   b. Select the appropriate gain factor so that the Maximum Sensor Output is still within the range of the STS4-4 ADC:

   $$\pm 20mV\ \times\ 256 =\ \pm 5{,}120mV > \pm 5.0VDC$$ ✗

   $$\pm 20mV\ \times\ 128 =\ \pm 2{,}560mV < \pm 5.0VDC$$ ✓

   c. Correct gain factor is 128.

2. The sensor is displacement with a differential output of 50mm/V and a maximum range of ±100mm.

   a. First calculate the maximum output range of the sensor:

   $$Maximum\ Sensor\ Output = \frac{\pm 100mm}{50\ mm/V} = \pm 2V$$

   b. Select the appropriate gain factor so that the Maximum Sensor Output is still within the range of the STS4-4-IW3 ADC:

   $$\pm 2V\ \times\ 4 =\ \pm 8V > \pm 5.0VDC$$ ✗

   $$\pm 2V\ \times\ 2 =\ \pm 4V < \pm 5.0VDC$$ ✓

   c. Correct gain factor is 2.

6.11.3 Selecting Sensor Types

DIFFERENTIAL OUTPUT VOLTAGE

This input configuration is what STS4-4-IW3 node is designed for, simply match the signals as shown in Figure 21. In this configuration the ADC will have a maximum input range of ±5.0 V_{dc}.

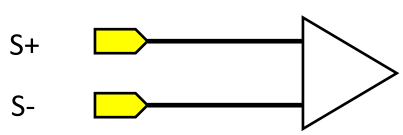


Figure 21: Differential signal input

SINGLE-ENDED OUTPUT VOLTAGE

Single-ended sensors are handled by jumping the excitation voltage ground to the Signal minus input on the Intelliducer connector as shown in Figure 22. In this configuration the ADC will have an input range of +40 V_{dc}. Note that if these sensors are ordered through BDI the modifications will be completed prior to delivery.

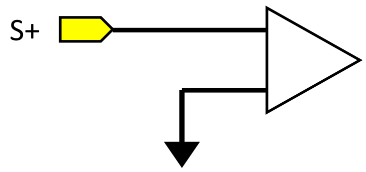


Figure 22: Single ended signal input

4-20 MA SENSOR SUPPORT

4-20 mA sensors require a resistor within the Intelliducer connector to convert the current signal to a voltage signal. As shown in Figure 23, this sensor type typically requires a 100Ω-350Ω (0.1% tolerance) resistor soldered between S+ and V_EXT as well as S- and V_EXT. Please verify the configuration, e.g. open collector, and the maximum load requirements per the sensor's manufacturer. Note that if these sensors are ordered through BDI the modifications will be completed prior to delivery.

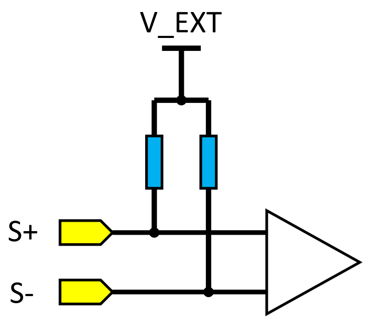


Figure 23: 4-20 mA signal input

6.12 Temperature Measurements

The STS4-4-IW3 nodes have been designed to acquire temperature data from sensors that are equipped with 3kΩ NTC-type thermistors. This feature is available on all four channels using the Intelliducer connector and is typically used to correct sensor outputs against changing ambient temperatures.

6.13 Intelliducer Connectors

Intelliducers are required to make sensors compatible with the STS4-4-IW3 nodes. These connectors are equipped with a memory chip that stores the sensor's designated name so that all related information can be retrieved from the calibration file. The intent of Intelliducers is threefold:

1. The entire STS4 system is completely plug-and-play. All relevant information about each sensor is automatically populated in STS-LIVE and retrieved upon detection of the sensor's name.
2. The sensor's location within the system is automatically mapped (which channel in which node) to allow easy comparison to the field notes.
3. High levels of weather resistance and ruggedness are achieved with the military specification (Mil-Spec) connectors and epoxy sealed (potted) back shells.

These features dramatically improve the efficiency of field data collection and greatly reduces the potential for human data entry errors.

6.13.1 Intelliducer Compatibility

New Intelliducer connectors still use the same bayonet-lock style connectors as those used on all previous STS sensors, however, all units shipped after September 2013 have additional storage capabilities and therefore, creates three possible Intelliducer–STS combinations:

New Intelliducer with STS4-4-IW3 node: This takes full advantage of the additional stored data by first checking the date of the calibration against the date stored by STS-LIVE. Depending on which date is newest, either the internal STS-LIVE file or the Intelliducer will be automatically updated (User prompted!). New Intelliducers can be re-programmed with the software as discussed in the STS-LIVE manual.

Older Intelliducer with STS4-4-IW3 Node: In this case, STS-LIVE running on STS4-4-IW3 will recognize the older sensor and only rely on the calibration information that has previously been stored by the program. If no information is available, the user will be prompted to fill out information. Also, STS-LIVE can be used to update the name on older Intelliducers, but not their calibration factor.

6.13.2 Intelliducer Pinout

The user cannot modify the potted Intelliducer connectors, however, terminal versions that are easily configurable for non-BDI sensors.

Figure 24: Intelliducer Plug Pin Assignment

Table 19: Intelliducer Connector Pin-out

Intelliducer Pin	Signal
A	+ Excitation (+15 V_{dc})
B	Thermistor Input
C	+ Sensor Input Signal
D	SPI CS (Intelliducer Support)
E	SPI CLK (Intelliducer Support)
F	SPI DATA IN (Intelliducer Support)
G	+ Excitation (Programmable +1.0 V_{dc} to +5.0 V_{dc})
H	SPI DATA OUT (Intelliducer Support)

J	– Sensor Input Signal
K	– Excitation (Ground)

6.13.3 Storage Capabilities

All Intelliducer connectors shipped by BDI after July 2014 have additional internal storage capabilities. Currently, the only item stored on the Intelliducer plug is the serial number (Name) of the sensor along with an extension identifying the date of calibration. When this gage is connected to STS-LIVE is will now be displayed as:

B1391_[YY][Z]

Where B1391 is the serial number of the gage and _[YY][Z] is the date code. Where [YY] is the last two digits of the year that the gage was calibrated so for 2016, [YY] = 16. The [Z] placeholder is the reference for the number of times that the gage has been calibrated during the year. If the gage was calibrated once in 2016 it will have the date code _16A. If the gage has been calibrated 17 times in 2016 it will have the date code _16Q. Since this example gage was calibrated once in 2016 it will be displayed in STS-LIVE as:

B1391_16A

This Name will correspond to a record int eh calibration file that is supplied with the system or with any new sensor ordered through BDI.

6.13.4 Calibration File

All sensors supplied by BDI will be accompanied by a calibration file that can be uploaded to the STS-LIVE application. The calibration file contains all relevant information and settings for the sensor and will be automatically applied to the sensor in the STS-LIVE application.

Table 20: Calibration File Data

Column	Item
1	Name
2	Calibration Factor
3	Auto Zero
4	Intelliducer Connector
5	Sensor Type
6	Sensor Units
7	Gain Stage
8	Excitation Mode
9	Excitation Value
10	Sensor Upper Limit
11	Sensor Lower Limit
12	Sensor Native Units
13	Calibration Offset

14	Sensor Output Type
15	Shunt Capability
16	Shunt Visibility
17	Attributes Visibility
18	Ratiometric
19	Attributes
20	Temperature Visibility
21	Temperature Active

7. Maintenance and Troubleshooting

7.1 Maintenance

The STS4-4-IW3 hardware has been designed to be largely maintenance free. Aside from keeping the connector dust caps on and the Intelliducer receptacle clean, it is recommended that STS4-4-IW3 hardware be stored in the airtight transit cases that come with the system and that the hardware be stored with a minimum of 20-40% charge on the battery.

7.1.1 System Endurance

MOISTURE

The STS4-4-IW3 node hardware has been designed to be dust tight and to handle water spray from all angles without any as long as all connection points are sealed either with a mating connector or available cover. Generally, this is more than sufficient to protect the hardware from the worst-case rainstorm. Note that the unit is NOT to be submersed under any circumstances.

WARNING: The Node will be protected from dust and water intrusion ONLY when all connectors and/or caps are installed.

STOP: When the STS4 Node is in its Low Power state, it is not possible to establish a communication link to the Base Station. The only way to reestablish a connection prior to the selected Sleep period is to wait for the next "wake up" sequence or to quickly press the Power button (<2 sec.).

SUNLIGHT AND HEAT

The STS4-4-IW3 hardware contains two internal temperature sensors to monitor the temperature of the circuit boards and the internal battery. If either of the two sensors pass the high temperature threshold the STS4-4 hardware will shut down to prevent damaging any of the components. The shutdown limit of the Li Ion battery pack is approximately +85°C when it is in the discharge mode and approximately +55°C when charging. It is possible to reach either of these limits if the system is operating at full capacity outdoors in direct sunlight. If this occurs, the charging will shut down along with the power supply to the STS4-4-IW3 hardware as discussed in Section 4.2.2 . Depressing the power button momentarily to check the battery status, the battery LEDs simply show the first LED blinking, alternating between yellow and red.

It is good practice to locate the STS4-4-IW3 hardware in shaded areas whenever possible. If that is not possible and the temperature is reaching the operating limit, then an alternate solution is to cover the hardware with a cloth or similar to protect against direct sunlight. STS-LIVE will provide a warning when operating limits are reached.

7.1.2 Equipment Returns

If the STS4-4-IW3 node is experiencing technical problems that require internal maintenance, the node must be sent back to BDI for repairs. Please refer to Warranty information for returning equipment to BDI.

7.2 Troubleshooting

Best way to avoid equipment issues is to thoroughly test out the hardware in the office/laboratory before going to the field. The following sections represent typical "families" of issues that users may experience in the field along with a systematic series of steps to follow to isolate and resolve them as fast as possible.

7.2.1 Wireless Communication Issues

There are many variables that can disrupt communications and, unfortunately, they are not always easy to resolve. Similar to cell phone signals, WLAN connections can be disrupted by environmental conditions or other wireless interference. BDI has spent considerable effort during development of STS4 to mitigate wireless issues as much as possible. However, there can still be interference that decreases the wireless signal quality between the STS4-4-IW3 nodes and the STS4-WBS.

If issues are present, it is best to first determine if it is related only to a single STS4-4-IW3 to STS4-WBS communication link or more "global" where it involves several wireless links.

The following steps will often yield positive results:

1. Review the signal strengths provided in STS-LIVE and attempt to relocate node into range or within line-of-sight of the STS4-WSB.
2. Replace wireless link between WBS and node with CAT5 network cable.
3. Move node closer to STS4-WBS in case at edge of wireless ranges (see Section 5.4.4)
4. Move node if located behind large obstruction such as bridge pier.
5. Wireless speakers, cell phones, external video monitors, LCD displays, Bluetooth devices, and other signal sources that operate in the 2.4GHz or 5.0GHz bandwidth
6. Microwave ovens or microwave towers in the vicinity
7. High voltage power sources nearby (ex. power lines, catenary lines, third-rail power, power stations, etc.)

Some solutions to resolve the issues include:

1. If possible, relocate the STS4-4-IW3 node(s) to be further away from the source of interference.
2. Create a physical barrier between the interfering device and the STS4-4-IW3 hardware such as metal or concrete barriers. Less effective barriers are wood, plastic, or glass.

If the problem is more global, meaning that most of the STS4-4-IW3 nodes continue to drop connections, then the problem is either with the wireless access point (STS4-WBS) or the PC's wireless connection. The first step would be to relocate the STS4-WBS to see if the connectivity issues gets better. Within the STS-LIVE application, the signal strength's (RSSI) of each STS4-4-IW3 nodes are reported, so when the location of the STS4-WBS is changed, the signal strength's will be updated. If that doesn't solve the problem then it is likely the connection between the computer and the base station, which is a very common problem due to the variety of wireless network cards that are preinstalled in computers. Since the variety and quality of network cards is impossible to quantify, if purchasing a new computer, be sure to purchase a good quality network card! Another option is to purchase a good quality USB wireless network adapter and dedicate that adapter for communication with the STS4-4-IW3 hardware. One method for testing is the computers network card is failing is to hard wire the computer to the base station and see if the connectivity of the STS4-4-IW3 node improves. Generally, this fixes most global connectivity issues!

7.2.2 Power Issues

There is not much that can go wrong with the internal battery packs. The following represents the most common issues that can occur with the Li-Ion battery packs:

1. Overheated Battery: Battery LEDs will flash alternating yellow/red when the battery is overheated. The STS4-4-IW3 node should be taken to a location where it can cool down sufficiently before attempting to power up or charge the node again.
2. Damaged Battery: If the battery circuitry is damaged the battery status LED will simply flash red. Damage can occur if the battery overheats too much, or if simply one of the internal components is damaged. The STS4-4-IW3 node will need to be returned to BDI for replacement.
3. Loss in Capacity: After many (>300) battery charge/discharge cycles the capacity of the battery will begin to diminish. If the charge to the battery has lost significant capacity after a full charge, then it is likely time to replace the battery. The STS4-4-IW3 node will need to be returned to BDI for replacement.

7.2.3 Wired Communication Issues

Very little can go wrong with a wired connection to the STS4-4-IW3 hardware. If a connection to the hardware cannot be established, even after rebooting the hardware, there are only a few items that could potentially cause the problem:

1. **Damaged Ethernet Cable:** Inspect the length of the cable for any damage and also inspect the RJ45 connectors for wires that are disconnected or damage to the connector. Try swapping the cable that is not working with a cable that is known to work properly to verify that the problem is with the cable.
2. **Poor Quality Ethernet Cable:** Not all Ethernet cable is manufactured the same. Good quality shielded CAT5e or better should be used and purchased from a company with a good reputation for quality.
3. **Verify the Connections:** Double check that the RJ45 connectors are properly plugged into the STS4-4-IW3 hardware and the computer/Ethernet Switch/Base Station.
4. **STS4-4 Node Damage:** The RJ45 connector on the STS4-4-IW3 node is only waterproof when a cable is connected (with the correct mating connector) or the dust cap is installed correctly. Any water intrusion could cause damage to the Ethernet connection, which would result in the connection not working correctly. There is always a chance that something else is damaged inside the STS4-4-IW3 hardware; in either of these cases the STS4-4-IW3 hardware will need to be returned to BDI for inspection.

7.2.4 Data Acquisition Section

See our instruction videos on STS-LIVE:

https://bditest.com/training-support-videos/

7.2.5 Additional Help

Go to Contact Us page on our website or call us for support at +1.303.494.3230.

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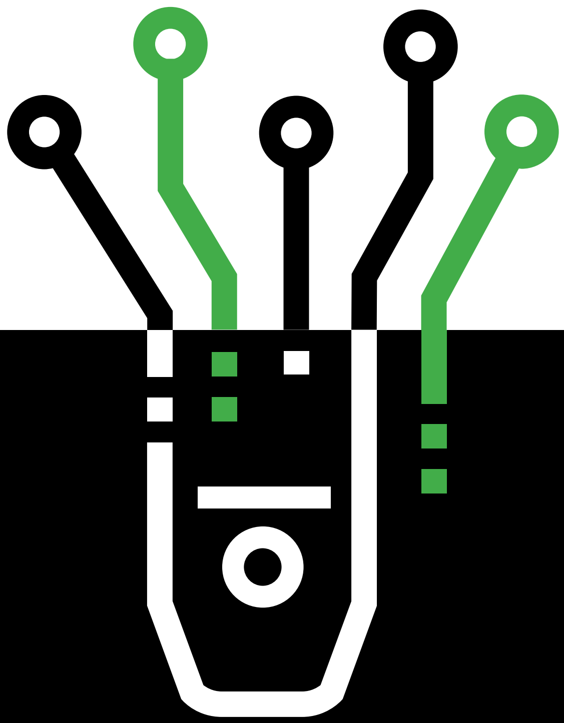

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