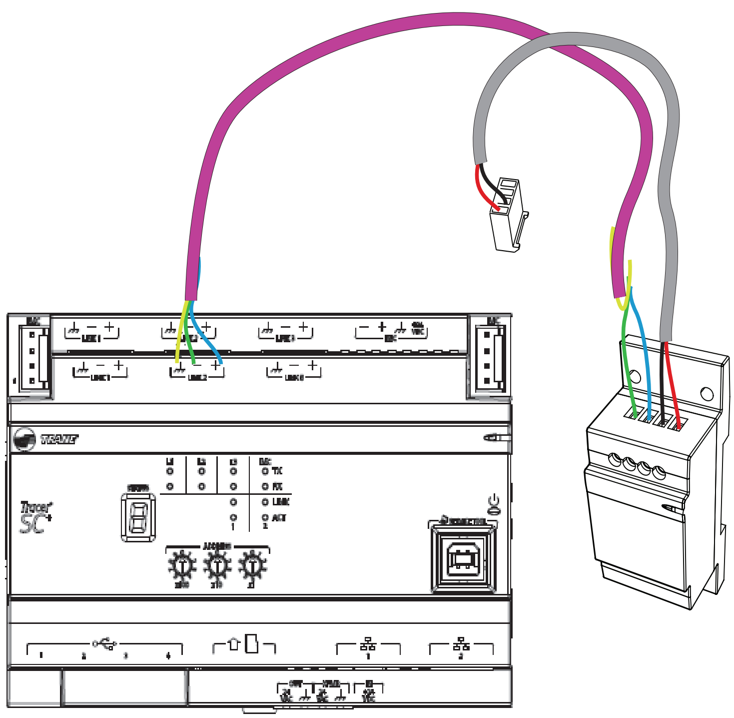
Installation, Operation, and Maintenance

# BACnet® MS/TP Wiring and Link Performance

## Best Practices and Troubleshooting



**SAFETY WARNING**

**Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.**

April 2024

**BAS-SVX51N-EN**

TRANE TECHNOLOGIES

# Introduction

## Warnings, Cautions, and Notices

Safety advisories appear throughout this manual as required. Your personal safety and the proper operation of this machine depend upon the strict observance of these precautions.

The three types of advisories are defined as follows:

| | |
|---|---|
| **WARNING** | Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury. |
| **CAUTION** | Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It could also be used to alert against unsafe practices. |
| ***NOTICE*** | Indicates a situation that could result in equipment or property-damage only accidents. |

### Important Environmental Concerns

Scientific research has shown that certain man-made chemicals can affect the earth's naturally occurring stratospheric ozone layer when released to the atmosphere. In particular, several of the identified chemicals that may affect the ozone layer are refrigerants that contain Chlorine, Fluorine and Carbon (CFCs) and those containing Hydrogen, Chlorine, Fluorine and Carbon (HCFCs). Not all refrigerants containing these compounds have the same potential impact to the environment. Trane advocates the responsible handling of all refrigerants.

### Important Responsible Refrigerant Practices

Trane believes that responsible refrigerant practices are important to the environment, our customers, and the air conditioning industry. All technicians who handle refrigerants must be certified according to local rules. For the USA, the Federal Clean Air Act (Section 608) sets forth the requirements for handling, reclaiming, recovering and recycling of certain refrigerants and the equipment that is used in these service procedures. In addition, some states or municipalities may have additional requirements that must also be adhered to for responsible management of refrigerants. Know the applicable laws and follow them.

**WARNING**

**Proper Field Wiring and Grounding Required!**

**Failure to follow code could result in death or serious injury. All field wiring MUST be performed by qualified personnel. Improperly installed and grounded field wiring poses FIRE and ELECTROCUTION hazards. To avoid these hazards, you MUST follow requirements for field wiring installation and grounding as described in NEC and your local/state/national electrical codes.**

**⚠WARNING**

**Personal Protective Equipment (PPE) Required!**

**Failure to wear proper PPE for the job being undertaken could result in death or serious injury. Technicians, in order to protect themselves from potential electrical, mechanical, and chemical hazards, MUST follow precautions in this manual and on the tags, stickers, and labels, as well as the instructions below:**

- **Before installing/servicing this unit, technicians MUST put on all PPE required for the work being undertaken (Examples; cut resistant gloves/sleeves, butyl gloves, safety glasses, hard hat/bump cap, fall protection, electrical PPE and arc flash clothing). ALWAYS refer to appropriate Safety Data Sheets (SDS) and OSHA guidelines for proper PPE.**
- **When working with or around hazardous chemicals, ALWAYS refer to the appropriate SDS and OSHA/GHS (Global Harmonized System of Classification and Labeling of Chemicals) guidelines for information on allowable personal exposure levels, proper respiratory protection and handling instructions.**
- **If there is a risk of energized electrical contact, arc, or flash, technicians MUST put on all PPE in accordance with OSHA, NFPA 70E, or other country-specific requirements for arc flash protection, PRIOR to servicing the unit. NEVER PERFORM ANY SWITCHING, DISCONNECTING, OR VOLTAGE TESTING WITHOUT PROPER ELECTRICAL PPE AND ARC FLASH CLOTHING. ENSURE ELECTRICAL METERS AND EQUIPMENT ARE PROPERLY RATED FOR INTENDED VOLTAGE.**

**⚠WARNING**

**Follow EHS Policies!**

**Failure to follow instructions below could result in death or serious injury.**

- **All Trane personnel must follow the company's Environmental, Health and Safety (EHS) policies when performing work such as hot work, electrical, fall protection, lockout/tagout, refrigerant handling, etc. Where local regulations are more stringent than these policies, those regulations supersede these policies.**
- **Non-Trane personnel should always follow local regulations.**

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# Trademarks



# Revision History

- Protocol Capture File content added.
- Updated content and images in "Trane SerialSpy Protocol Analyzer Software," p. 24

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# Table of Contents

# Summary List of Best Practices

Use the following summary list of best practices to quickly locate a specific topic.

# Overview

This guide contains best practices for configuring and wiring a BACnet® Multidrop Serial Bus/Token Passing (MS/TP) link for Trane and non-Trane devices.

## How a BACnet® MS/TP Link Works

A Multidrop Serial Bus/Token Passing (MS/TP) link is a type of Local Area Network (LAN) with a set of rules that control communication traffic. To initiate communications on the network, a device must have the electronic "token" (a small packet), passed from one device to another around the network. Manager devices are allowed to have the token, whereas subordinate devices are allowed only to respond to requests from manager devices. Trane's BACnet® MS/TP links only support manager devices so each device can send data when it has the token. Each device on the link has a unique physical network address (rotary switch address). Communication between devices is established within a few seconds of power-up after all the devices on the link discover other devices.

Each device attempts to locate a successor device at the next highest address by sending a polling message. If there is no response from the next highest address, the device will poll for one higher address. It will continue to do so until another device is found that the token can be passed to, or when all 127 possible addresses have been tested.

When a device has the token, it has control of the network and can request data from or write data to other devices on the link. When it is finished it passes the token to the device at the next address on the link in sequential order. If the next device has data to send, it does so and then passes the token on. The token passes from device to device very quickly; it completes the circuit several times per second.

The Trane SerialSpy Protocol Analyzer software looks at all the messages and activity on the BACnet® MS/TP link. The ability to view the token passing is very useful for discovering link problems.

## Symptoms of Poor Performance

Symptoms of poor BACnet® MS/TP performance include, but are not limited to:

- Slow Tracer® Synchrony screen data fill
- Comm loss alarms in the alarm log
- Delayed alarm enunciation between unit controllers and Tracer® SC+
- Slow Tracer® TU service tool performance when connected through the SC+ or using TU
- Degradation of building control
- Slow Tracer® Ensemble screen data fill

## Common Problems

The most frequently encountered problems that can cause poor performance, or non-performance, on a BACnet® MS/TP link are:

- An open circuit
- A short circuit
- The link has not been installed using a daisy-chain topology
- The wire used for the link does not meet the BACnet® standard specification
- Too many devices on the link
- Tracer BACnet® terminators are not installed at each end of the link
- Wiring polarity is reversed on the comm link
- When devices are sharing a 24Vac power supply, electrical polarity is not the same for all devices
- Two or more devices on the network with the same rotary switch address

## Considerations

Before troubleshooting the link, or contacting Trane Technical Support, it is helpful to have the following information at hand.

- A valid set of prints for the project that illustrates how the devices are wired on the link (including rotary addresses.
- The type of wire used to install the devices on the link
- Whether there are BACnet® terminators installed at each end of the BACnet® link
- Whether the link is configured in a daisy-chain topology
- Whether there are non-Trane devices on the link
- Firmware versions loaded on controllers with an MS/TP issue
- Tracer® SC+ rotary switches: (valid range is 1 to 419)
- Device rotary switches: (valid range is 1 to 127)

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# Best Practices

The following sections contain the best practices for various elements of the BACnet® MS/TP link.

## Configuring and Wiring the BACnet® MS/TP Link

This section describes the best practices for configuring and wiring a BACnet® MS/TP link. Follow these recommendations and techniques to get the best results.

### Wire and Network Characteristics

Does the wire that has been strung through the building have the correct physical characteristics? All wire is not created equal and is designed to fulfill a specific application. In this case, the wire is being used to convey information via small changes in voltage that occur at specific time intervals. Wire that has the wrong characteristics may result in failure of the network. The wire used should have the following physical characteristics. This information is typically marked on the label of the wire spool or contact the supplier for this information.

- Style—Braid or foil shielded, twisted pair wire.
- Impedance—100 to 130 ohms[1].
- Capacitance—between any two conductors, less than 100 pF per meter.
- Capacitance—between any conductor and shield wire, less than 200 pF per meter.
- Maximum Length—4000 feet with 18 AWG conductor wires.
- Maximum Length—2000 feet with 22 AWG conductor wires.

### Understanding Non-isolated and Isolated MS/TP Device Types

All BACnet® MS/TP devices are designed to communicate via either a two-wire (plus shield) or three-wire (plus shield) communication cable. A device that requires two wires is a non-isolated device. A device that requires three wires is an isolated device. The terms isolated and three-wire, or non-isolated and two-wire are used interchangeably in the field. Trane BACnet® MS/TP devices are largely non-isolated.

The term isolation refers to the electrical design of the EIA-485 transceiver on the device. With an isolated device design, the input signal circuitry is completely separate from the rest of the circuitry on the device. Power and ground are not shared and the transceiver input "floats" at some unknown voltage. In order to guarantee that two or more isolated devices can communicate, a common reference voltage is needed between the input circuitry of all devices. The third wire of a 3-wire cable is used to provide this voltage reference. The reference wire is not grounded anywhere in the system. See Figure 2, p. 10.

A non-isolated device design shares the power and ground between the input signal circuitry and the rest of the circuitry on the device. In this case, the reference voltage is provided by grounding the device to the enclosure. The ground wire of each enclosure will run back to a common, earth ground elsewhere in the building.

**Table 1. Trane non-isolated and isolated devices**

| Non-isolated Trane Devices | Isolated Trane Devices |
|---|---|
| • Tracer® UC210<br>• Tracer® UC400<br>• Tracer® UC600<br>• Tracer® UC800<br>• Tracer® SC+<br>• BCI-I, BCI-R, BCI-C<br>• Symbio™ 210<br>• Symbio™ 510<br>• Symbio™ 700<br>• Symbio™ 800 | • Trane Communicating Thermostats.<br>• TR200. |

1 The electrical impedance value of Trane purple wire is less than the specified range. Trane has tested this wire and authorizes its use for BACnet® MS/TP networks.

## Network Wiring Configurations

To ensure proper network communication, the selection of the appropriate cable and length limitations must be considered. The following figures describe network wiring configurations that are acceptable, depending on the type and number of devices that are being connected together on an MS/TP link.

***Do not mix isolated and non-isolated device types on a single link.***

Trane recommends that isolated and non-isolated device types are not mixed on a single link. Run separate 2-wire and 3-wire MS/TP links. Figure 1 and Figure 2 describe the correct method to wire each network type.

***Note:*** *End of link terminators have been omitted from the drawings. End of link terminators are required.*

**Figure 1. 2-Wire MS/TP network**

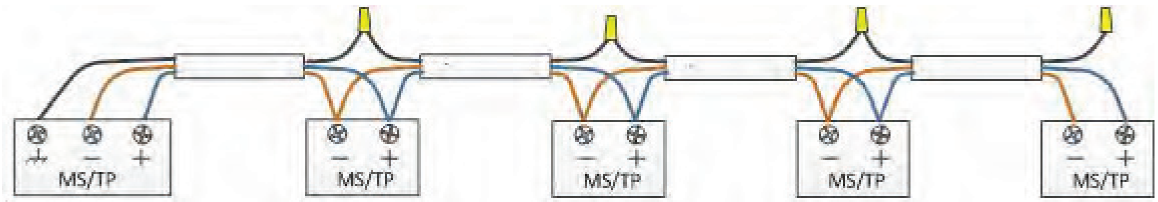
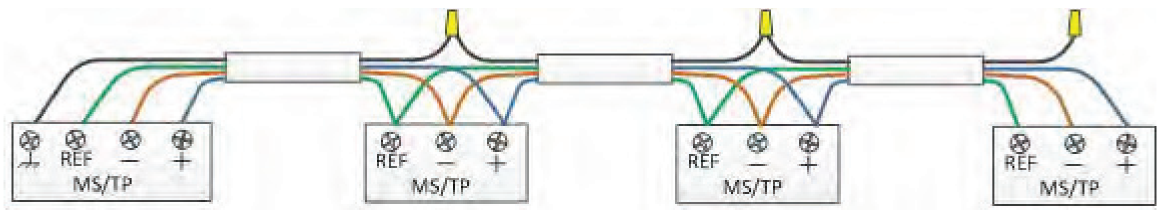



**Figure 2. 3-Wire MS/TP network**




## 2-Wire Mixed Device Networks

There are cases where it is not practical to separate isolated and non isolated devices to separate links. Typical cases include retrofit or system expansion applications where existing wiring will be used. Figure 3 describes the method for connecting one isolated device to a 2-wire link. Figure 4, p. 11 describes the method for connecting two or more isolated devices to a 2-wire link.

**Figure 3. 2-Wire network with isolated device**

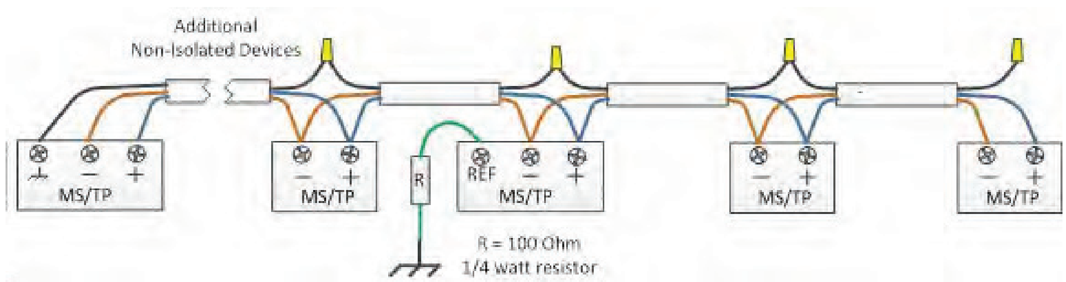
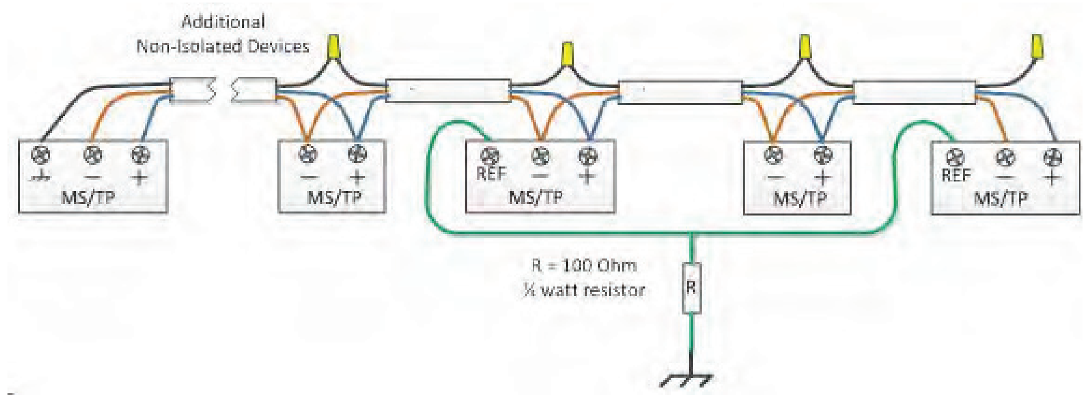


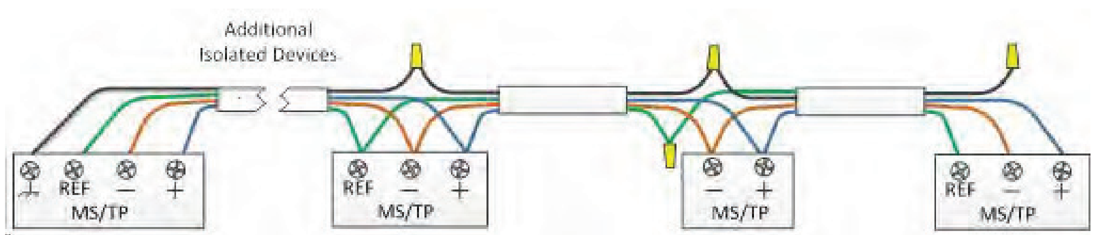
Figure 4. 2-Wire network with multiple isolated devices




## 3-Wire Mixed Device Networks

Figure 5 describes the method for connecting one or more non-isolated devices to a 3-wire link. Notice that the reference wire is not connected to any terminal of the non-isolated device.

Figure 5. 3-Wire network with non-isolated device




## Network Wiring Details

***BACnet® wiring must use a daisy-chain configuration.***

Follow these steps to connect communication wiring as shown in Figure 6.

1. Review the wiring diagram and determine which BACnet® MS/TP link is being wired.

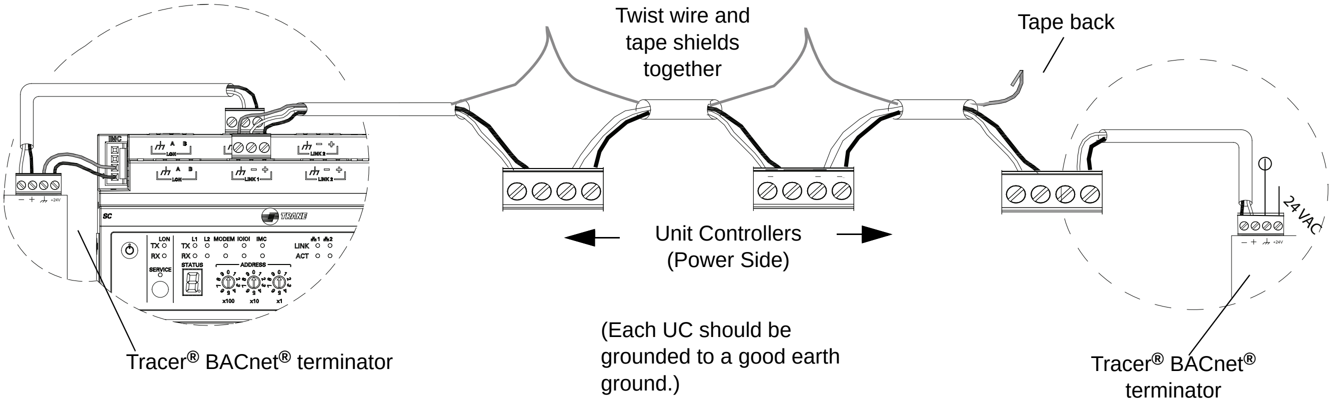
   **Note:** *It is not necessary to place the Tracer® SC+ at the end of the of the communication link. However, a Tracer® BACnet® Terminator must be wired at each end of the link.*

2. Attach the communication wire between two adjacent devices on the link and verify that polarity of the wires is maintained.
3. At each unit controller, join the shield wires together and insulate the connection with electrical tape to prevent accidental shorting of the wire.
4. Repeat steps 2 and 3 for each unit controller on the link.

**Note:** *For more information about the specific unit controller you are wiring, see the installation guide for the specific controller.*

**Important:** *Tracer® unit controllers are not grounded on the DIN rail. It is necessary to ground each controller to a good earth ground.*

**Figure 6. Daisy-chain configuration for BACnet® wiring**




***Note:*** *The Tracer® UC800 cannot power a BACnet® terminator.*

### *Observe the maximum link length recommendation*

The maximum length of a 18 AWG network wire is 4,000 feet. The maximum lenght of a 22 AWG network wire is 2,000 feet. Wire runs longer than recommended may experience communication issues.

***Note:*** *There is no support for repeaters on BACnet® MS/TP links.*

### *Use a Tracer® BACnet® terminator at each end of the link.*

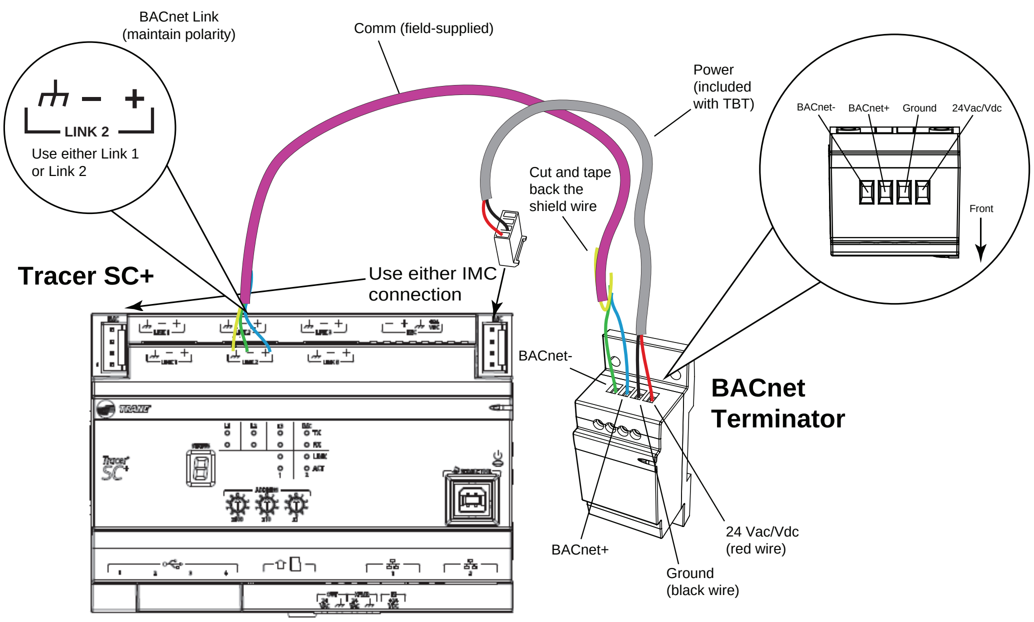
Because the amount of communication signal degradation increases as the length of communication wire increases toward the maximum of 4,000 ft. (1,219 m), Trane requires that a Tracer® BACnet® Terminator (TBT) module (PN: X13651524-01) be connected at each end point of the network. For correct termination placement, follow these guidelines:

- All BACnet® MS/TP links must be properly terminated. Use a Tracer® BACnet® terminator at each end of the link.
- Connect the communication wire shield to the ground terminal of the link termination block at the Tracer® SC+ as shown in Figure 7. The Tracer® SC+ provides the ground for the BACnet® MS/TP link. This is the only place on the link that the shield wire should be grounded.
- Tape back the shield at each of the Tracer® BACnet® terminators to prevent accidental contact with metal components.

  ***Note:*** *If a Tracer® UC400 is at the end of the link, the process is the same. The Tracer® SC+ provides the ground wherever it resides on the link.*
- During installation, compile a set of as-built drawings or a map of the communication wire layout. Sketches of the communication layout should feature the Tracer® BACnet® terminators.
- The Tracer® BACnet® Terminator is a powered device and it will not work without a power source. Connect TBT power terminals to a 24 Vac/Vdc power supply.

***Note:*** *Some third-party devices have a network terminator built into the device. The use of the terminator is usually controlled by a jumper or switch on the device itself. Verify that the terminators on each device are disabled, so that only the TBT are biasing the network.*

**Figure 7. Terminating BACnet® links using BACnet® terminators**




### *Use the built-in terminator on the BCI-R when the BCI-R is the last node in the network.*

The Trane BCI-R has a built in BACnet® terminator. If a BCI-R is the last node on the network, this terminator should be installed as shown in the BCI-R installation guide (RF-SVN03*-EN). For other BCI-R devices that are not the last node on the link, verify that the terminator has not been wired to the network.

***Note:*** *The new BCI2-R does not have a built in terminator. If a new BCI2-R is the last node on the link, an external BACnet® terminator must be added.*

### *Maintain consistent wiring polarity between devices.*

BACnet® links are polarity sensitive. Mixing plus and minus terminals between devices will cause network communication failure. Designate one color as positive and consistently use this color for all positive link terminals on the site.

### *Observe network cable and conductor termination best practices during installation.*

The following wiring practices are recommended:

- Trane purple wire is acceptable 2-conductor cable and it is best practice to use this wire for non-isolated device network communications. 3-conductor cable is required for isolated device network communication. See Table 1, p. 9 for a list of non-isolated and isolated Trane devices.
- Connect the shield portion of the communication wire to the ground terminal of the link termination block at the Tracer® SC+. The Tracer® SC+ provides the ground for the BACnet® MS/TP link.
- Splice and tape the shield between wire segments at each unit controller connection point in order to maintain a continuous shield and avoid connection to ground.
- Consider labeling the communication links at each device to make servicing easier. For example, when at device #10, the two comm wires could be labeled “From device 39”, and “To device #11”.
- Do not run BACnet® MS/TP cable:
  – in the same conduit as 24 Vac power.
  – alongside 24 VAC power, which is not contained in a conduit.
  – alongside conductors being driven by binary outputs.
  – in the same conduit as conductors be driven by binary outputs.
  – near electrical motors or variable frequency drive modules.
- Strip no more than 2 in. (5 cm) of the outer conductor of shielded wire.

### *Avoid sharing 24 Vac power between unit controllers.*

***Important:*** *If sharing a transformer with multiple controllers is necessary, verify that polarity has not been mixed. 24 Vac hot/ground polarity must be maintained.*

### *Ensure that 24 Vac power supplies are consistently grounded.*

If grounds are not maintained, intermittent or failed communication could result.

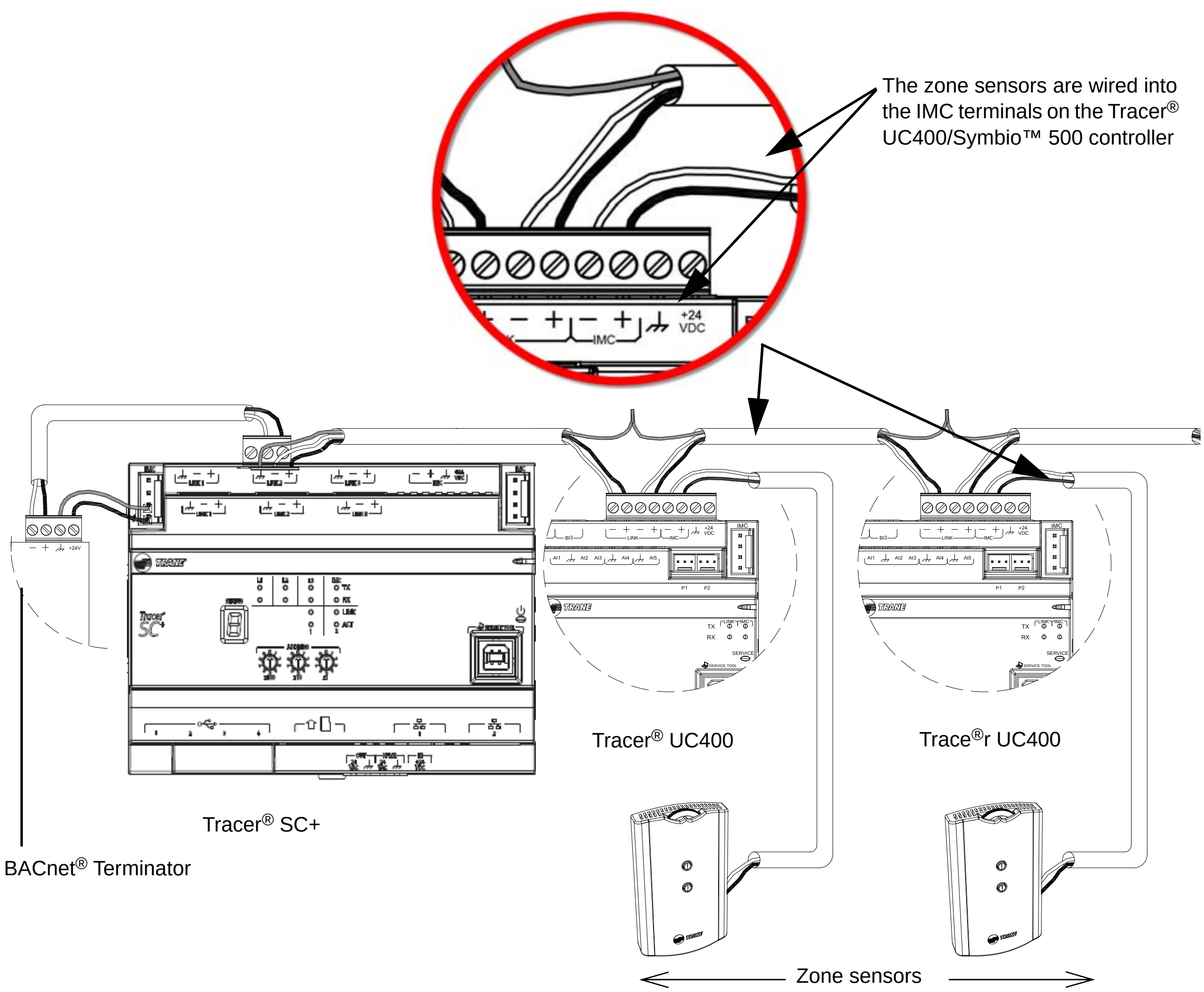
### *Meet requirements when adding zone sensor communication stubs to a Tracer® UC400/Symbio™ 500.*

The wire that runs from a zone sensor to a unit controller is commonly referred to as a communication stub. Figure 8 shows an example of communication stub-wiring to a BACnet® device. The stub is not part of the BACnet® link; it is a wire that runs from the Tracer® UC400 IMC link down to the zone sensor. Ensure that the zone sensor includes the optional communication module.

Any or all unit controllers on a link can be wired with a communication stub. Unlike LonTalk® links, there is no limit on the number of unit controller communication stubs. Polarity must be maintained and the length limit is 600 ft (183 m).

For ease of use, the wire for the communication stub can be the same as that used for BACnet® communication link wiring as described in "Configuring and Wiring the BACnet® MS/TP Link," p. 9.

**Figure 8. Zone sensor communication stubs on Tracer® UC400/Symbio™ 500**




***Note:*** *UC400 is shown, but this applies to Symbio™ 500 as well.*

# Setting the BACnet® Device Addresses

This section describes the best practices for setting the rotary switch values on a BACnet® MS/TP link.

## Rotary Switch Values and BACnet® Device ID

### Rotary Switch Values

The rotary switch value is the physical address of a device on a network. It is often referred to as the MAC address. The term is generic and is used to denote the physical address of many types of networks. For example, the rotary switch address of a BACnet® MS/TP network has a valid range of zero (0) to 255 and can be represented by a single byte. The MAC address of an Ethernet network is six bytes in length. Each device must be assigned a unique rotary switch address. Failure to assign a unique value to each device will result in communication errors.

### BACnet® Device ID

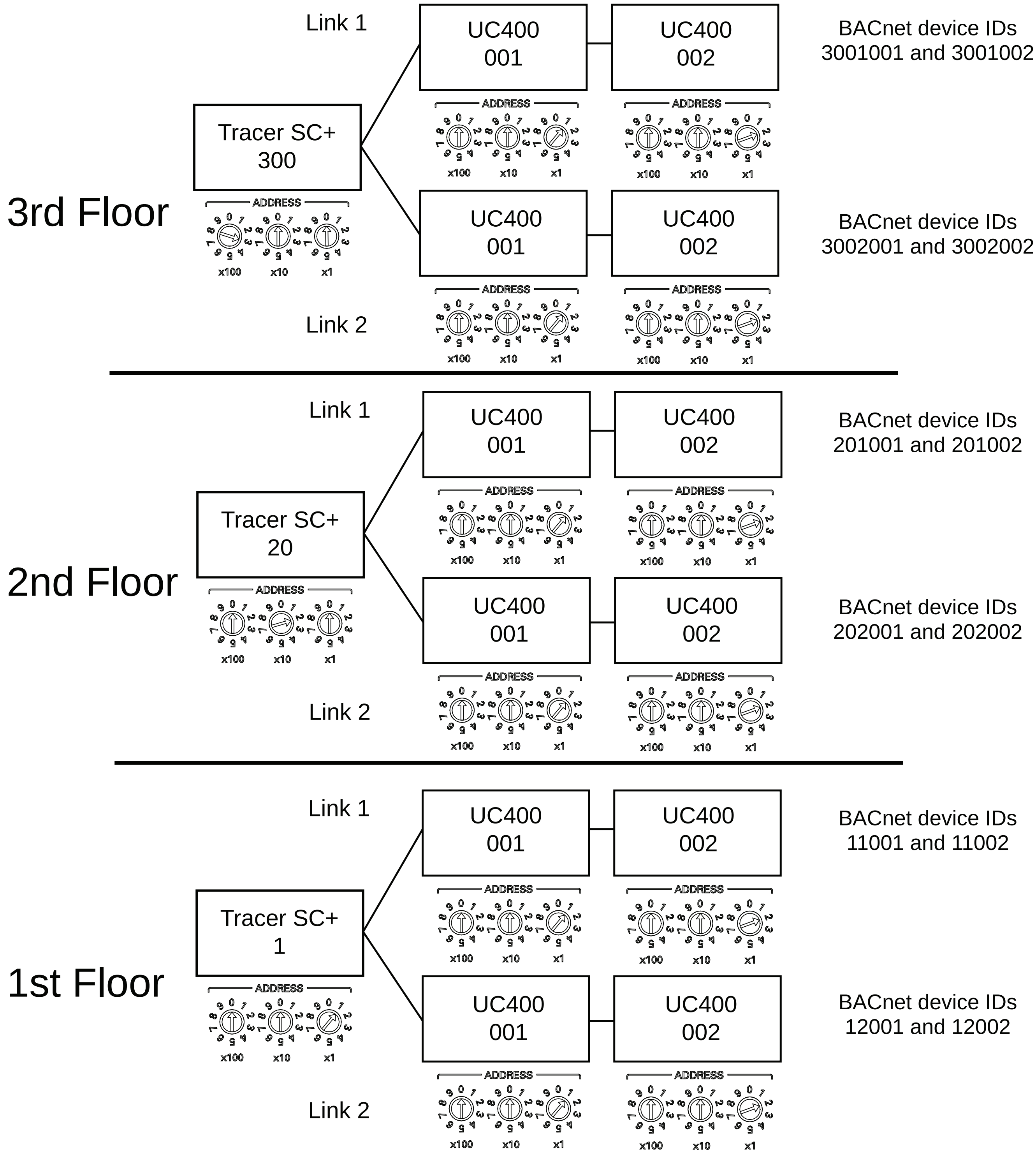
The BACnet® Device ID uniquely identifies each BACnet® device as a logical address. The valid range of this address is 0 to 4194302 (see BACnet® standard 2016 sections: 22.1.5 and 24.2.4). For example, the logical address in an Internet Protocol (IP) network is the IP address, which is four bytes in length and is typically written in the format of 192.168.1.125. Failure to assign unique address to each device will result in communication errors.

### How Rotary Switch Addresses and BACnet® Devices IDs Work Together

When rotary switch addresses and BACnet® Device IDs are configured as shown in Figure 9, p. 17 the result is a unique BACnet® Device ID for each device.

- In a three-story building, there is a Tracer® SC+ installed on each floor.
  - The rotary dial setting on the Tracer® SC+ on the first floor is set to 001.
  - The rotary dial setting on the Tracer® SC+ on the second floor is set to 020.
  - The rotary dial setting on the Tracer® SC+ on the third floor is set to 300.
- Each Tracer® SC+ has two BACnet® links with two UC400 controllers wired to each link (four UC400s total on each floor). The rotary dials on the UC400 controllers are set to 001 and 002.

**Figure 9. Rotary switch addresses and BACnet® device ID example**



# Setting Rotary Addresses on the Tracer® SC+ System Controller

The Tracer® SC+ has a set of three rotary switches on the front of the device, which are used to set the BACnet® Device ID. The rotary switch range is 1 to 419. Zero (0) cannot be used because it is the default value assigned to the device at the factory.

***Note:*** *If you set the rotary switch values to a number between 001 and 419, the Tracer® SC+ device ID and the BACnet® MS/TP numbers will be calculated from that number.*

To set the rotary switch values, use a small screwdriver to turn the three rotary switches on the Tracer® SC+ to a unique number between 001 and 419.

## BACnet® MS/TP Device ID Assignment

Each unit controller must have a unique BACnet® device ID. Tracer® SC+ automates the process by calculating a unique device ID for each unit controller and then saving the device ID to memory in each device.

For Tracer® SC and SC+ prior to version 5.4, BACnet® MS/TP device IDs are calculated using the following three sets of values:

- The Tracer® SC+ rotary switch value (1 to 419).
- The Tracer® SC+ BACnet MS/TP link number (1 to 3).
- The unit controller rotary switch value (1 to 127).

The three values are joined together to form the BACnet® device ID for the unit controller.

The following example in Table 2 illustrates this process.

**Table 2. Calculating the BACnet® device ID**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Tracer® SC+ rotary switch value (21)** | **0** | **2** | **1** | | | | |
| **Tracer® SC+ BACnet® MS/TP link number (1)** | | | | **1** | | | |
| **Unit controller rotary switch value (38)** | | | | | **0** | **3** | **8** |
| **BACnet® Device ID: 211038** | **0** | **2** | **1** | **1** | **0** | **3** | **8** |

For Tracer® SC+ version 5.4 and higher, BACnet® MS/TP device IDs are calculated using only two sets of values:

- The network number.
- The unit controller 3 digit rotary switch.

## Device ID Assignment for BACnet IP Devices

For devices connecting over BACnet® IP, Tracer® SC+ calculates the device ID using the following:

- The BACnet® network number for Ethernet 1. (This number can be changed by the user).
- The unit controller rotary switch value. (The Tracer® SC rotary address is not used to calculate BACnet® IP device IDs).

The following example in Table 3 illustrates this process using a Tracer® UC600 controller.

**Table 3. Calculating the BACnet® IP device ID**

| | | | | | |
|---|---|---|---|---|---|
| **BACnet® network number Eth port 1 (1)** | | **1** | | | |
| **Unit controller rotary address (42)** | | | **0** | **4** | **2** |
| **BACnet® IP Device ID: 01042** | **0** | **1** | **0** | **4** | **2** |

## Device ID Assignment for Base Tracer® SC+s

For unit controllers installed using a Base Tracer® SC+, the Application Tracer® SC+ calculates the device ID using the BACnet® network number of the Base Tracer® SC+ MS/TP link and the rotary switch value of the unit controller.

The following example in Table 4 illustrates this process.

**Table 4. Calculating the base Tracer® SC device ID**

| | | | | | |
|---|---|---|---|---|---|
| BACnet® network number of Base SC MS/TP link 1 (22) | 2 | 2 | | | |
| Unit controller rotary switch value (001) | | | 0 | 0 | 1 |
| Unit controller device ID set by Application SC: 22001 | 2 | 2 | 0 | 0 | 1 |

## Device ID Assignment for Wireless Devices

For devices connecting over a wireless network, Tracer® SC+ calculates the device ID using the BACnet® network number and the rotary switch value of the wireless device.

The following example in Table 5 illustrates this process.

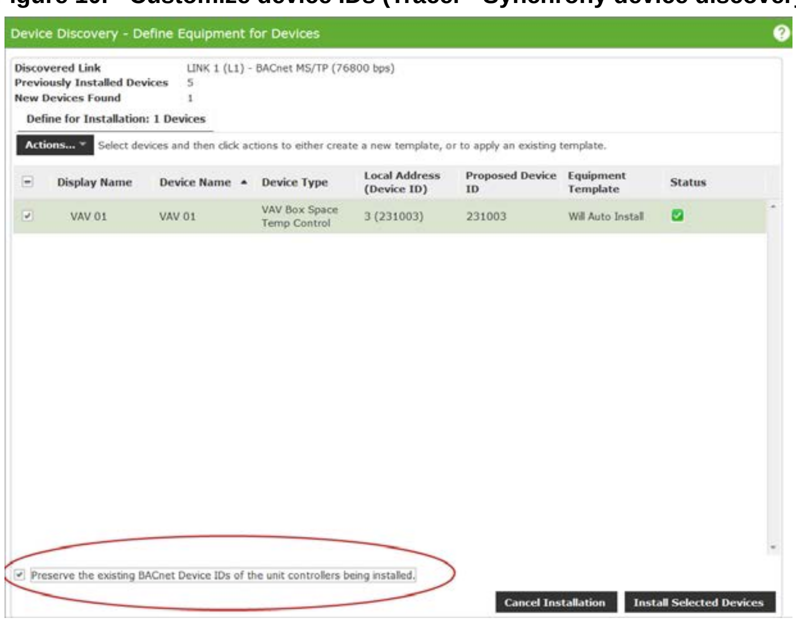
**Table 5. Calculating the wireless device ID**

| | | | | | |
|---|---|---|---|---|---|
| BACnet® network number of Tracer SC+ wireless network (13) | 1 | 3 | | | |
| Wireless unit controller rotary switch value (001) | | | 0 | 0 | 1 |
| Wireless unit controller Device ID set by Application SC: 13001 | 1 | 3 | 0 | 0 | 1 |

## Customizing Device IDs

For complex BACnet® addressing schemes or prescribed job specifications, custom device IDs may be required. You can customize the device IDs of Tracer® unit controllers by using the Tracer® TU service tool. During the device installation process in Tracer® SC+, select the “Preserve the predefined BACnet® device ID of the unit controllers being installed” checkbox (Figure 10, p. 19). As a result, the installed devices will retain their device IDs. This feature applies to Trane and non-Trane BACnet® devices.

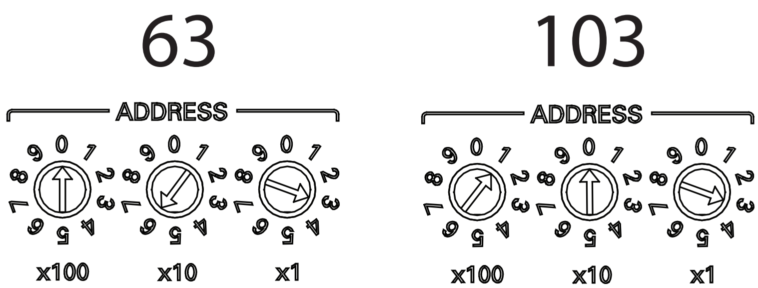
**Figure 10. Customize device IDs (Tracer® Synchrony device discovery page)**



### *Set the rotary switch address on all unit controllers.*

All Trane BACnet® unit controllers use the same method to set the rotary switch address of the device. On the front of the unit controller are three decimal rotary dials labeled with the word ADDRESS. Rotate the dial and position the arrow of each dial to point at the preferred number. Figure 11, p. 20 shows two examples how to set a rotary switch address for preferred address of 63 and 103.

**Figure 11. Rotary switch address settings**




All devices regardless of manufacturer must have a rotary switch address. Third-party BACnet® manufacturers can use a different method to set the address. Consult the appropriate documentation to determine how to set the address on third-party devices.

### *Ensure no duplicate rotary switch addresses exist on a BACnet® MS/TP link.*

All BACnet® devices on the same MS/TP network must have a unique rotary switch address.

### *Sequentially address BACnet® MS/TP devices; leave no gaps.*

***Important:*** *When there are two links used on a Tracer® SC+, each link should start with controller rotary address 1.*

Sequential rotary addressing is very important for BACnet® MS/TP links. The BACnet® MS/TP communications mechanism polls devices at each address between the lowest and the highest address found. If a device rotary address is skipped, additional, unnecessary messages will be sent, which will consume additional bandwidth.

***Note:*** *BACnet® MS/TP controllers can be addressed independent of where they are located on a link, as long as all devices wired on a link are addressed sequentially without gaps. For example, a link of devices could be addressed "1, 3, 5, 2, 4, 6" where all addresses sequentially from 1 to 6 exist despite their physical location. Conversely, addressing devices "1, 3, 5, 7, 9, 11" would have 5 skipped addresses which would adversely impact link performance unnecessarily.*

When multiple Tracer® SC+s are used on a project, each Tracer SC+ must have its rotary switch address set to a unique address. The valid rotary switch address range for the SC+ is 1 to 419.This is critical to avoid duplicate BACnet® Device IDs and network numbers on a site.

***Note:*** *Max Manager is an MS/TP configuration property that may be used to define the highest rotary switch address that is currently in use on the network. For most devices this value is fixed at 127, which is the highest rotary switch address that may be set on the network. Some third-party devices allow this value to be modified.*

*A situation can exist where a device is being added to the MS/TP network at a rotary switch address that is higher than the Max Manager value set in the device with the highest rotary switch address currently on the link. If this is the case, the token will not get passed to the new device until the Max Manager property of the other device is increased equal to or greater than the rotary switch address of the new device.*

# Total Number of Trane and Non-Trane Devices on a BACnet® Link

This section describes the best practices when there are only Trane devices on a BACnet® link, and when there are both Trane and non-Trane devices on a BACnet® link.

***Important:*** *In an all-Trane device network, the maximum number of devices on a BACnet® MS/TP link is 60. Each Tracer® SC+ supports three BACnet® MS/TP links.*

### *Limit the quantity of devices on a link when there are both Trane and non-Trane devices on the link.*

BACnet® MS/TP is not implemented consistently amongst controller manufacturers. When possible, verify that the third-party device has BTL certification.

- **Baud Rate**: BACnet® MS/TP link baud rate must be set to the same value for all controllers on the link, which is defined by the device with the slowest baud rate. For example, a third-party device that is capable of only 19.2k baud will require all BACnet® MS/TP devices on the same link be set to 19.2k baud. Baud rates that are lower than the Trane default of 76.8k baud will adversely affect the performance of the entire BACnet® MS/TP link.

  ***Note:*** *Third-party devices may support auto baud functionality. Trane recommends that the auto baud feature of a device not be used and the baud rate be manually set to the appropriate value. Consult the appropriate documentation to determine how to verify and modify the baud rate as needed.*

- Best practice is to place slower devices on a separate MS/TP network.
- **Object Lists**: The BACnet® 2008 standard specifies that an object list is required for all BACnet® devices. Some non-Trane controllers do not contain a BACnet® Object List. Tracer® SC+ requires an object list to exist in a BACnet® controller in order to discover the points that reside in the BACnet® MS/TP device.
- **Impedance**: Trane controllers allow for more controllers (60) to reside on a link, compared to the BACnet® MS/TP standard (32). The addition of non-Trane controllers to a BACnet® MS/TP link may reduce the number of devices below the Trane limitation (60). Some non-Trane controllers may be limited to a quantity of 32 based on their device impedance.
- Integrating non-Trane devices may require a separate link, potentially limited to 30 devices.

### *Populate BACnet® links evenly when 30+ devices are present.*

Split BACnet® MS/TP links of more than 30 devices equally among the three links on the Tracer® SC+. Table 6, p. 21 contains some criteria to use. The fewer devices there are per link, the better the communication performance will be. For example, if link 1 has 45 devices, link 2 has 15 devices, and link 3 has 30 devices, we recommend moving 15 devices from link 1 to link 2 so that each link has 30. The quantity does not have to be exactly the same; an equal amount is optimum but not always practical.

***Notes:***

- *It is not necessary to change links that contain less than 30 devices. Doing so will not significantly improve performance and may result in unnecessary wiring.*
- *When possible, place non-Trane devices on their own link.*

**Table 6. Criteria useful in determining when to divide a link**

| When to divide the link | |
|---|---|
| Baud rate | Placing devices that do not support the 76.8K baud rate on a separate link is preferred to reducing the baud rate of Trane unit controllers |
| Critical devices | • Isolate critical devices to their own link<br>• A critical device is performing intense data logging or TGP2, or displaying lots of data on Tracer ES graphics |

Table 6. Criteria useful in determining when to divide a link

| When to divide the link | |
|---|---|
| Non-Trane devices | Isolate non-Trane devices to contain possible performance issues |
| Device count greater than 30 | • Equally load non-critical links<br>• There is less value in dividing links when there are fewer than 30 devices<br>• Performance is proportional to number of devices |

### *Place Trane Communicating Thermostats on a separate link.*

Trane Communicating Thermostats (TCTs) may have communication issues when mixed on a link with Trane UC devices that use the 76,800 baud rate. To prevent this, place all TCTs on a separate link with a baud rate of 76,800.

If the TCTs cannot be isolated on a separate link, reduce the baud rate of all devices on the mixed network to 38,400 baud to eliminate this issue. Although the slower baud rate will affect the bandwidth, in most cases the slower rate will have no significant effect on performance. Data intensive operations such as harvesting trend logs will experience some slower performance.

**Note:** *The Tracer® SC+ has a default baud rate at 76,800 baud. If using TCTs, the Tracer® SC+ and all MS/TP devices on the same physical MS/TP link must be set to the 38,400 baud rate.*

## Custom Programming

### *Limit Tracer® SC+ TGP2 run frequency.*

Very few supervisory control routines require calculations or updates more frequently than once per minute - and often can be run at a much slower rate (such as every 5, 10 or 15 minutes). Tracer® SC+ TGP2 routines that read values from controllers on BACnet® MS/TP links will load the MS/TP link with their requests and impact performance. Therefore, if it is possible to accomplish the required control function without reading data directly from unit controllers, it will improve overall performance. (See below for suggestions.) If it is necessary to read data from unit controllers in TGP2, choose the slowest possible run frequency to optimize performance.

### *Use event triggered TGP2 to reduce run frequency.*

### *Use Tracer® SC+ System Applications for common calculations.*

Tracer® SC+ System Applications (Area, VAS, Chiller Plant Control) perform calculations using data from their controller members. These calculated values are available to TGP2 as “properties” of the TGP2 Applications Blocks. Using the already calculated values will avoid additional unnecessary link loading. For example, Area performs group calculations for min, max, and average space temperatures. VAS also has a number of group calculations for all of its member VAV controllers.

## Custom Graphics

### *Limit number of points displayed on a Tracer® SC+ Custom Graphic.*

Custom graphics with many point values from unit controllers on a BACnet® MS/TP link will take time to load and present the data on the screen. Use these data points wisely. If a graphic is loading slower than desired, consider reducing the number of data points, or use multiple graphics to distribute the data points. For example, instead of a single floor plan graphic with 40 space temperature values, two floor plans (east wing and west wing) each with 20 space temperatures will give better performance. In any case, Trane recommends an upper limit of 90 data points.

# Controller Software

### *Update all UC400 controllers to Version 4.15 firmware (or higher).*

The latest Tracer® UC400 Firmware Version 4.15 (or higher) includes changes that improve BACnet® MS/TP performance. UC400 firmware is the same regardless of application (VAV, Field Programmable, etc.). UC400 firmware can be updated with any of the following methods:

- Tracer® TU direct connect (USB) - individual controller update
- Tracer® TU Single Link connection - individual controller update
- Tracer® TU via Tracer SC+ Pass through connection - multiple controller update

**Note:** *See the Tools section of this guide for details on service tools for BACnet® MS/TP controllers.*

### *Always run the latest Tracer® SC+ software (v5.5 or higher).*

The latest Tracer® SC+ software updates include improvements that affect the performance of the BACnet® MS/TP links. Ensure that you are running the latest Tracer® SC+ software at the time of the installation.

# Tools

The following software and hardware tools are available to help you troubleshoot your BACnet® MS/TP link.

### *Trane SerialSpy Protocol Analyzer Software to troubleshoot communication links.*

This software is available on the Controls Download page.

### *High-performance volt meter.*

If possible, use a high-performance meter for best results.

# Trane SerialSpy Protocol Analyzer Software

The SerialSpy Protocol Analyzer software was developed internally at Trane and is designed specifically for troubleshooting communication links. The interface between the communication link and the SerialSpy software is a USB adapter equipped with wires and alligator clips, which allow you to tap into the link at the wire terminals of any device. Tracer® SC controllers (not SC+) allowed for the use of Serial Capture; Tracer® SC+ controllers do not require Serial Capture.

Tracer® SC+ captures BACnet® traffic during BACnet® discovery and installation. Log output goes into a comm.log file, which can be viewed and exported from Tools/System Logs on the Tracer® SC+. In SC+ v5.7 or later, you can also capture data using the built-in BACnet® Capture Tool (see “Tracer® SC+ Protocol Capture File,” p. 27). BACnet® Capture Tool stores data into a bacnetCapture.log file.

***Note:*** *Starting with Tracer SC+ v6.0, the Protocol Capture Tool can capture token passing data. Capture is done within the Synchrony UI; therefore, it is not required that users be on-site to use the Comm4 adapter.*

The comm.log files and bacnetCapture.log files can be imported into Serial Spy 3.6.1 or later for decoding.

This section explains how to use SerialSpy with the Rover Service Tool Comm4 USB Adapter.

## Using SerialSpy With the Comm4 USB Adapter

SerialSpy works with the Rover Service Tool Comm4 USB adapter. There are a set of dip switches on the adapter. Leave the dip switches in the Comm4 position (switches 1 and 4 ON, and switches 2 and 3 OFF).

### Set Up the USB Adapter and Serial Port

1. Plug the adapter into a USB port on your laptop.
2. Select **Start**>**Control Panel**>**System**. The System Properties dialog appears.
3. Click on the **Hardware** tab and click **Device Manager**.
4. Navigate to Ports in the tree and check to see what comm port the adapter is using.

   ***Note:*** *The adapter will only read the link every 16 Ms at the default setting. Adjust this setting to increase the accuracy of the time stamp given to the MS/TP messages.*

   a. Right click on USB Serial Port in Device Manager navigation tree. The USB Serial Port properties dialog appears.
   b. Click the **Port Settings** tab and click **Advanced**.
   c. Change the Latency Timer to **2 Ms**. Adjusting the timing to this level of detail might be critical to troubleshooting.
5. Use the alligator clips, provided with the Rover Service Tool Comm4 USB adapter, to connect the laptop to the MS/TP link.

   ***Notes:***

   *•Ensure that you are not connected to a live link when you plug in the USB adapter; the laptop might recognize it as a mouse device.*

   *•The connection is polarity sensitive; ensure that you connect the appropriate terminals.*

### Install and Start Serial Spy Protocol Analyzer Software

The application is available to Trane technicians on the Trane Commercial Downloads page under Tracer® SC+ (https://tranetechnologies.sharepoint.com/sites/softwaredownloads/SitePages/Home.aspx). If you have the Trane Updater Tool running on your PC, you can also use it to install Serial Spy.

***Important:*** *If you have licensing issues with running SerialSpy on your PC, contact Technical Support. You may want to install the software in your office to verify before taking it to a job site.*

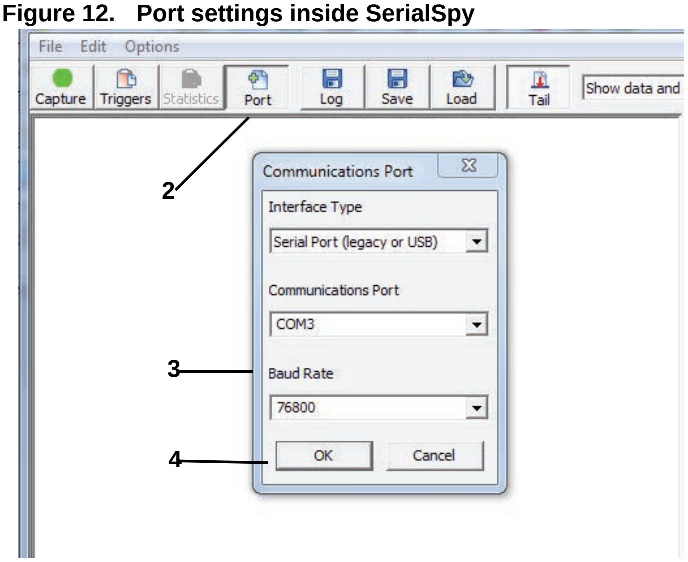
Once the SerialSpy software is installed, you can start it as follows:

1. From the **Start** menu, choose **All Programs**>**Trane**>**Serial Spy**.

***Note:*** *SerialSpy might not work if your laptop is running on battery power, because BACnet® signals require a ground reference. You can run on AC power or attach a ground wire to terminal 3 on the USB dongle.*

2. Click **Port** (see Figure 12, p. 25).
3. From the Communications Port list, click the comm port to match that for the COMM 4 USB Adapter.
4. From the Baud Rate list, choose the baud rate for the MS/TP link. Trane devices have a default baud rate of 76800. Ensure that you choose the rate used by the controllers or you will not obtain a quality capture.

**Figure 12. Port settings inside SerialSpy**

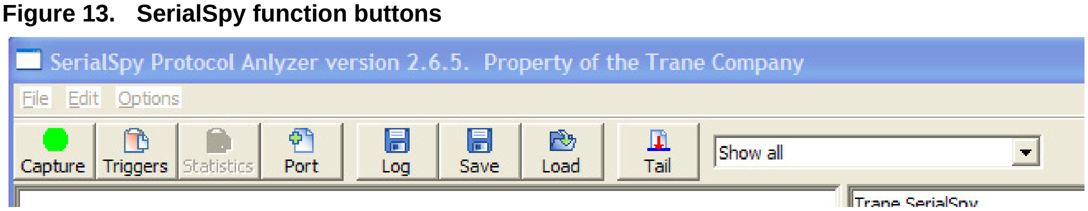



# Use SerialSpy to Capture Link Messages

Figure 13, p. 25 shows the buttons available on SerialSpy. Follow the steps below to initiate a capture. The descriptions following Figure 13, p. 25 explain what will appear as you monitor the MS/TP link, and the function of the buttons on the user interface in relation to the capture.

1. In the drop-down list, select **Show all**.
2. Click **Capture** (when clicked, the Capture button becomes the Stop button).
3. Allow the capture to run 3-5 minutes.
4. Click **Stop**.

**Figure 13. SerialSpy function buttons**



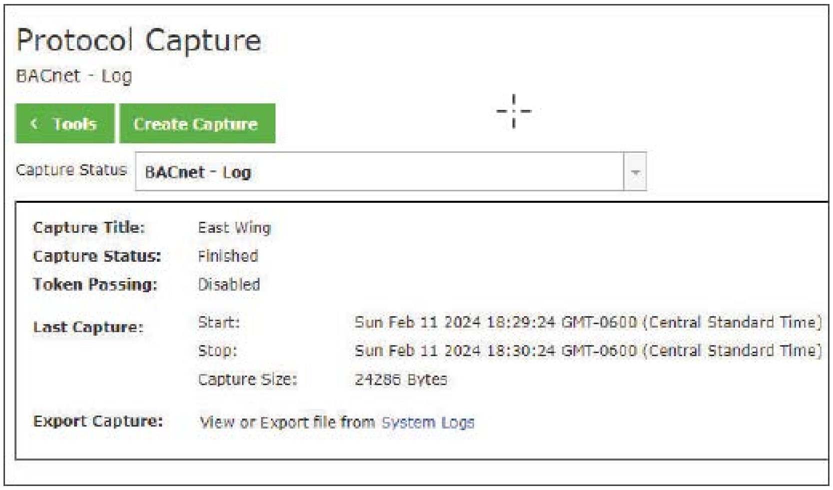

- **Blue lines** — You will probably see a couple of lines in blue. These are diagnostics and are normal every time you start SerialSpy. If the link has problems you will see lots of diagnostics shown in blue. A typical 5-minute capture of a clean link has 85,000 messages with six blue diagnostics. The error rate is incredibly low. The same link with a problem, such as a duplicate address for example, has 9,000 blue diagnostics with 82,000 messages. Problems like these are not subtle or difficult to detect. Unless you are dealing with an intermittent problem, a 5-minute capture is usually enough for troubleshooting.

- **Gray lines/token passing** — You should then see an orderly series of token passing messages, which are gray. These should be error-free (uninterrupted by blue lines), and there should be thousands of them every minute. You should be able to see every address on the link passing the token along in order by address
- **Black lines** — There should be occasional larger messages in black if there is a Tracer® SC+ or other front end on the link. These are data requests or data writes.
- **Capture** button — Clicking this initiates a capture on the BACnet® MS/TP link.
- **Triggers** button — Use this button to initiate or end a capture based on an event or circumstance occurring on the link.
- **Statistics** button — Refer to "Statistics Summary," p. 38 for details on how this button is used.
- **Port** button — Refer to "Trane SerialSpy Protocol Analyzer Software," p. 24 for details on how this button is used.
- **Log** button — The Log button allows you to continuously save a capture to a specified file location.
- **Save** button — The Save button saves the current capture to a specified file. These saved files can be emailed to Tech Support. Longer saved captures of an hour or more make very large files that are difficult to email.
- **Load** button — The Load button allows you to open a previously saved capture file.
- **Tail** button — When you click the Tail button, you see a very fast scroll of messages flashing by. When viewing the tail you can begin to get some notion of how fast the token is being passed from device to device, and how many thousands of times this happens in just a few minutes. Click the Tail button again to stop the scrolling and look more carefully at the messages.
- **Show Diagnostics Only** — To filter the messages, click the pull-down list and select **Show diagnostics only** or **Show data and diagnostics**. Because of the continuous token-passing activity on the link, diagnostics will often reveal a problem.

# Tracer® SC+ Protocol Capture File

Protocol Capture tool can be found under **Tools** > **Protocol Capture**

**Figure 14. Protocol capture**




The page shows the status of the last capture.

**Capture Status selection** – Multiple Capture Status windows. Use the selection window to select the appropriate one. Settings of the Capture Status window will automatically filter to appropriate protocol when Create Capture is used.

**Capture Title** — Name of the last capture to be run or name of the one currently running or scheduled.

**Capture Status**:

- Idle - The capture has not yet begun running.
- Running - The capture is currently running.
- Finished - The capture is completed; a download file is available.
- Scheduled - The capture has been scheduled to run at a specific time.

**Token Passing** – When applicable it will show if it was Enabled for Capture.

**Last Capture**:

- If the status is Scheduled or Running, it will show the Start time and planned capture duration.
- If the status is Idle or Finished, it will show the previous capture's start/stop time and the size of the
- capture.

**Export Capture**: Two options will be displayed based off Protocol Link. Log files will have a link to navigate to System Logs. Pcap files will have a link to download the file.

In System Logs, two file structures are used to store captures and are named according to their Protocol (bacnetCapture, modbusCapture). Logs file can be viewed or exported to view with Serial Spy.

# How to Create New Protocol Capture

To create a new capture, click **Create Capture**. The Create Capture dialog box opens.

**Capture Title**: Text box in which the user needs to give title of the capture.

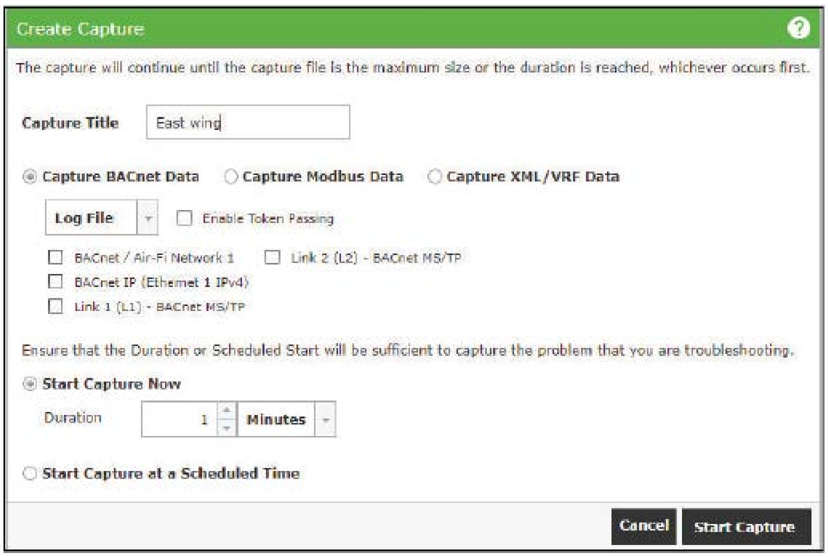
**Link Selection**: All active BACnet/Modbus/VRF links on the Tracer SC+ are shown here. Select one Protocol and one or more of its links.

**File Selection** – Applicable for BACnet only. Use Log File to capture Link data and Pcap for IP traffic.

**Enable Token Passing** – Applicable for BACnet only. Enabling this option will limit link selection only to MS/TP and only one link at a time. Capture will include Token passing data for that particular link.

Users can either start the capture now or schedule the capture, by selecting the preferred radio button.
**Start capture now**: Allows the user to capture the network now. Users are required to provide the duration of the capture (default it is 1 hour or 60 minutes) and the maximum limit is 12 hours or 720 minutes.
**Schedule the Capture**: Users can schedule the capture by providing the start date and time duration of the capture (default it is 1 hour or 60 minutes) and the maximum limit is 12 hours or 720 Minutes.
Once the required fields are filled, users must click **Start Capture** to begin the capture or click **Schedule Capture** in the event of scheduling a capture.

**Figure 15. Create capture**

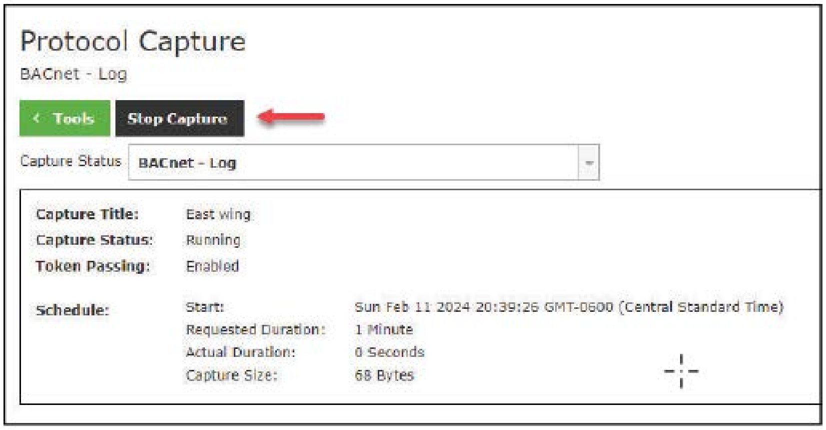



***Note:*** *Once the capture has been created, users will not be allowed to create another capture until the current capture completes the activity.*

## Stop Capture

Click **Stop Capture** to stop the capture while it is in running status. Once stopped, the capture status shows **Finished** and displays the **Create Capture** button.

**Figure 16. Stop capture**

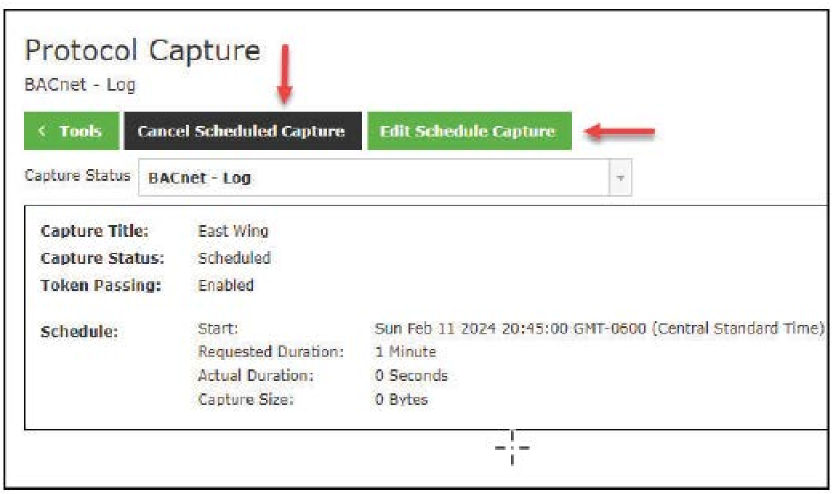



## Cancel/Edit Scheduled Capture

To cancel a scheduled capture, click **Cancel Scheduled Capture**. Once cancelled, the capture status shows **Idle** and displays the **Create Capture** button.

To edit a scheduled capture, click **Edit Schedule Capture** which opens the edit dialog box (same as create).

**Figure 17. Cancel/edit scheduled capture**



# Export Capture

View or export the capture through **System Logs** in tools or download file from appropriate link.

**Figure 18. System logs**

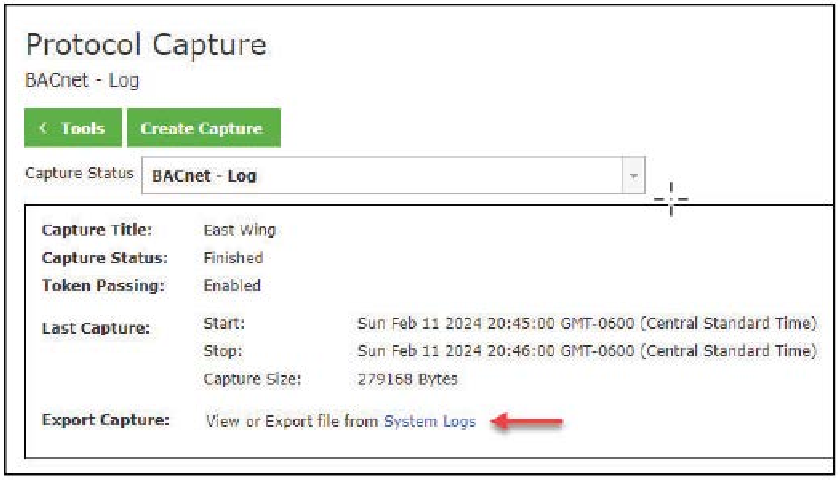
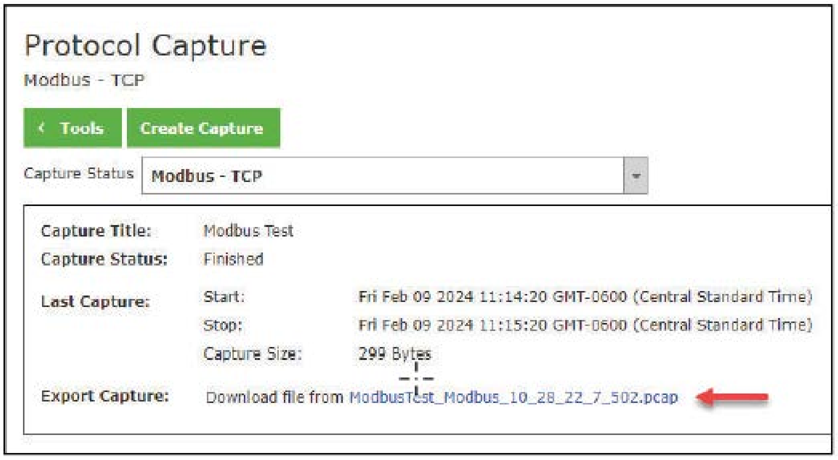



**Figure 19. Download file**




# Log Files

When a capture is finished, follow link on the status page to **System Logs** or navigate to **Tools** > **System Logs**.

- Protocol Capture tool uses the same file format as hydra, comm, and other log files. As the main .logfile fills, the data is then pushed to.log.1, which pushes to .log.2 and so forth.
- Protocol Capture tool BACnet log files are saved as bacnetCapture.log, bacnetCapture.log.1 through 4. Modbus log files are saved as modbusCapture.log, modbustCapture.log.1 through 4.

***Note:*** *New data will be stored in the bacnetCapture.log file.*

- Each capture log file holds 2 MB data, with a total maximum of 10 MB spread across all five log files.

***Note:*** *Captures larger than 10 MB will be missing the data from the beginning of the Capture.*

## Viewing a Log File

Best practice is to export the log file and view it with Serial Spy.

# Evaluate the SerialSpy Output

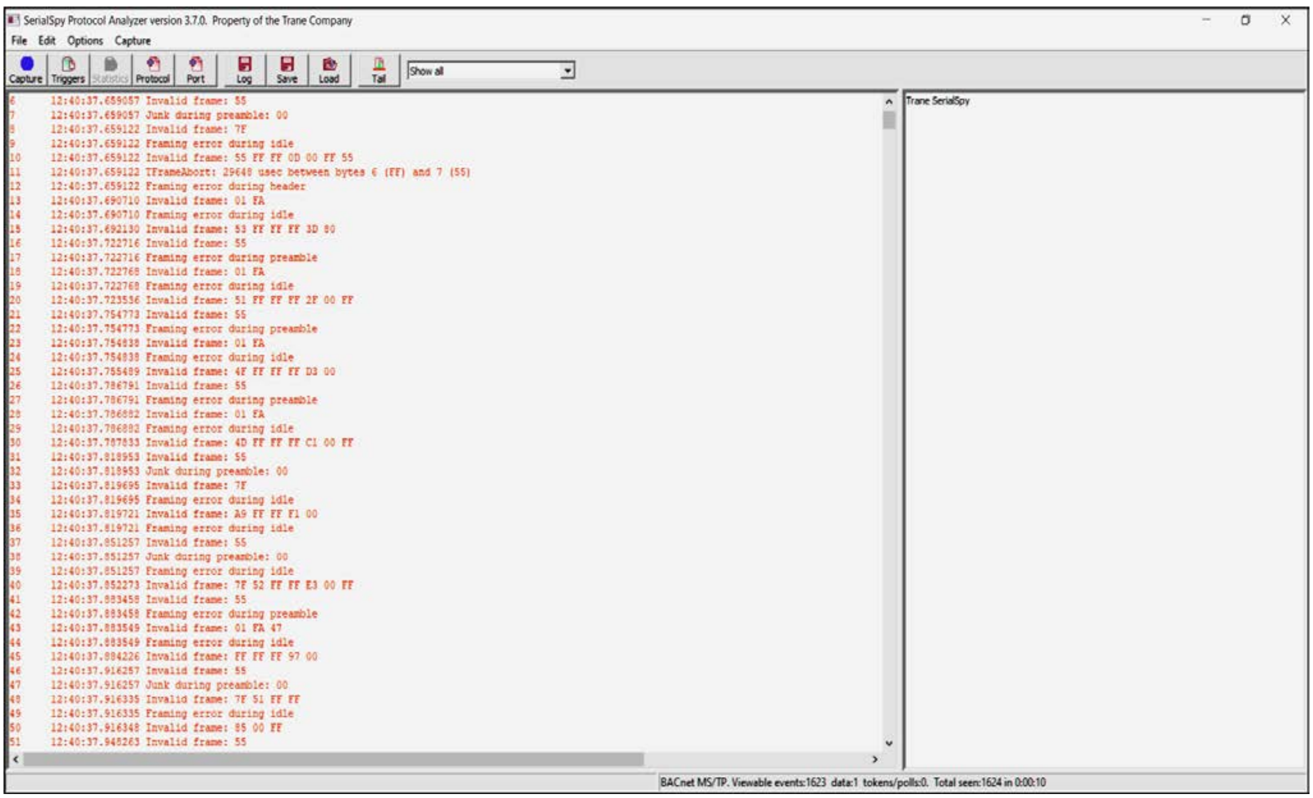
Typically, there are two types of BACnet® link problems:

- Total failure - there is no communication on the link.
- Partial failure - there is some communication on the link, but it is impeded.

## Total Communication Failure

Total communication failure can be caused by short circuits, shorts to ground, and reversed comm link polarity. In these cases, SerialSpy shows nothing but blue diagnostic messages or no messages at all (see Figure 20, p. 31).

**Figure 20. Typical SerialSpy output when connected to a link with a short circuit, short to ground, or reversed polarity**




Once you know there is a physical problem with the link, you can use two tools to help locate the problem:

- A voltmeter measuring dc volts
- The link LEDs on the Trane devices

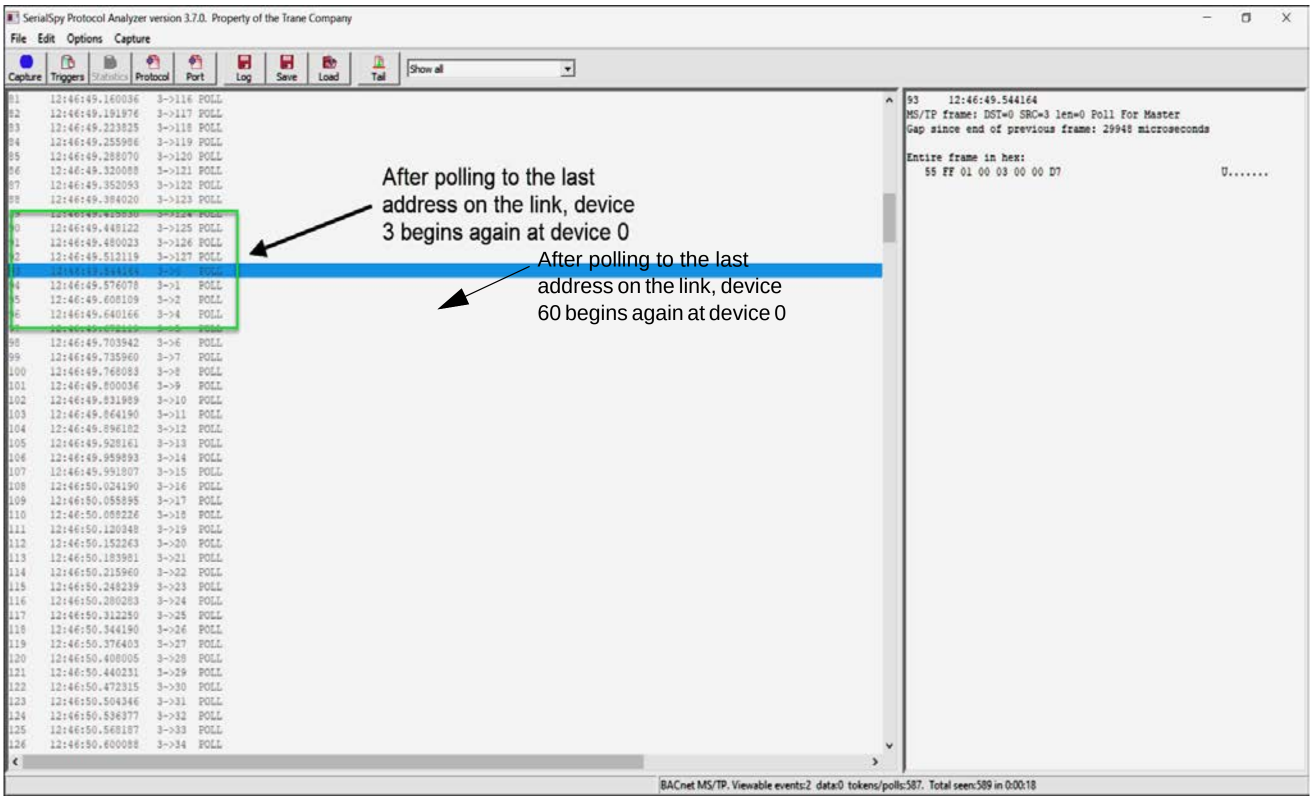
You can use the "Troubleshooting Technique (Isolation)," p. 41 to narrow the search for a bad segment of wire. Table 8, p. 42 shows some particular characteristics that will identify specific faults.

## Partial Communication Failure

In cases where there are some good messages getting through the comm link, you can use SerialSpy to help pinpoint communication problems. Observing the token-passing allows you to identify every device that is communicating on the link. SerialSpy can also help to find some common problems, such as duplicate addresses, and to determine which addresses are the likely source of trouble.

Figure 21, p. 32 shows an example of a capture with a single Trane BACnet® device on the link. You can see that even with only one device on the link, the device will eventually start polling and try to find other devices on the link.

**Figure 21. One device polling**

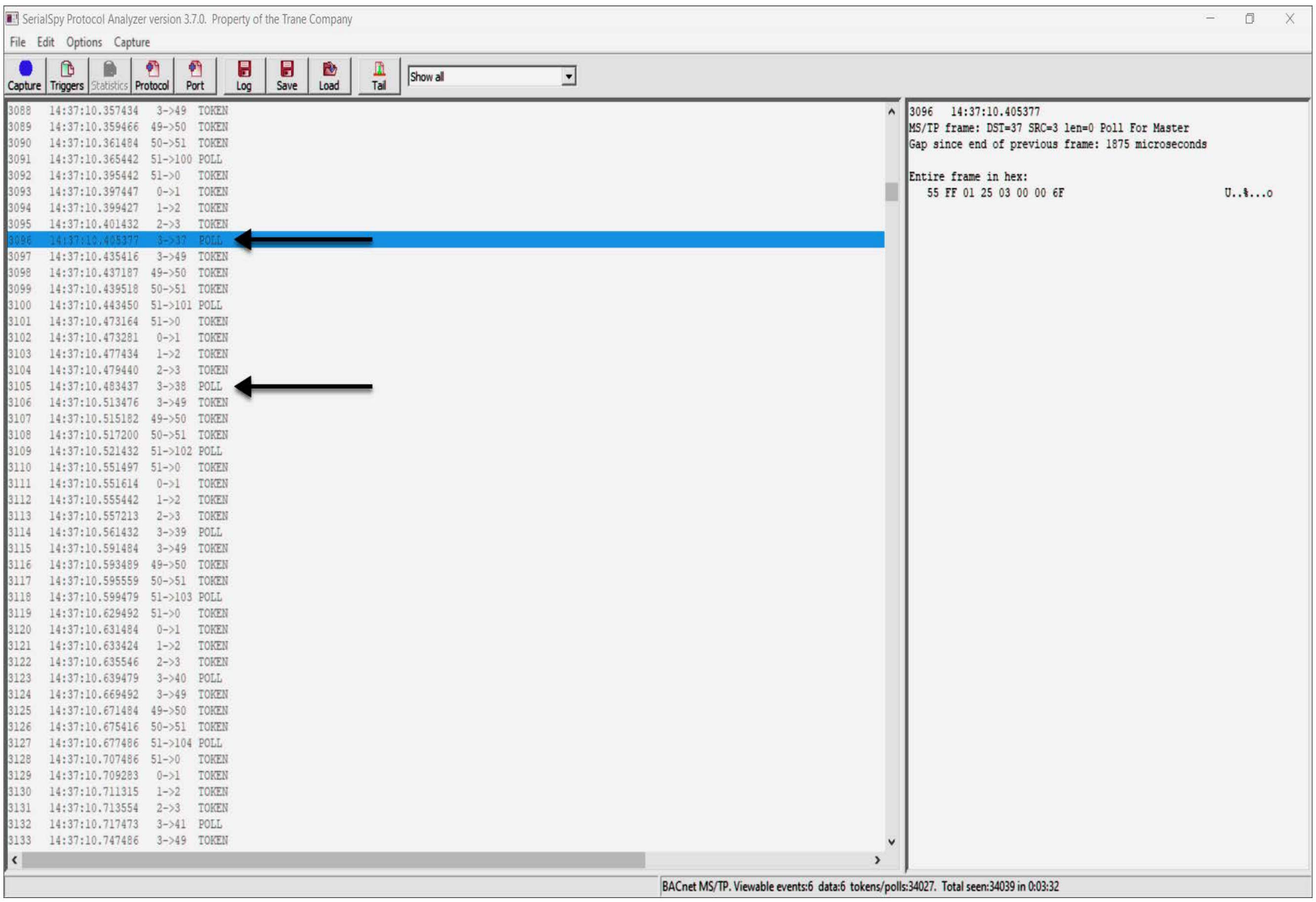


## Gaps in Rotary Switch Addressing

BACnet® devices use a set of token-passing rules that allow them to get organized within seconds of power-up. Figure 22, p. 33 shows token-passing and data requests on a clean link. Note that there is a gap between address 3 and address 49. The device at address 3 will poll each time it has the token. Each time it polls it will look for the next highest address. You can see the fist poll for address 37, the next for 38 and so on. Polling results in an unnecessary additional message on the link, which will reduce performance. For this reason, Trane recommends that addresses be set up sequentially when possible.

***Note:*** *Once the device has polled the last address in the gap, it will stop polling for new devices for the next 50 token cycles. After 50 cycles, it will try each address again.*

**Figure 22. Device 3 polling**

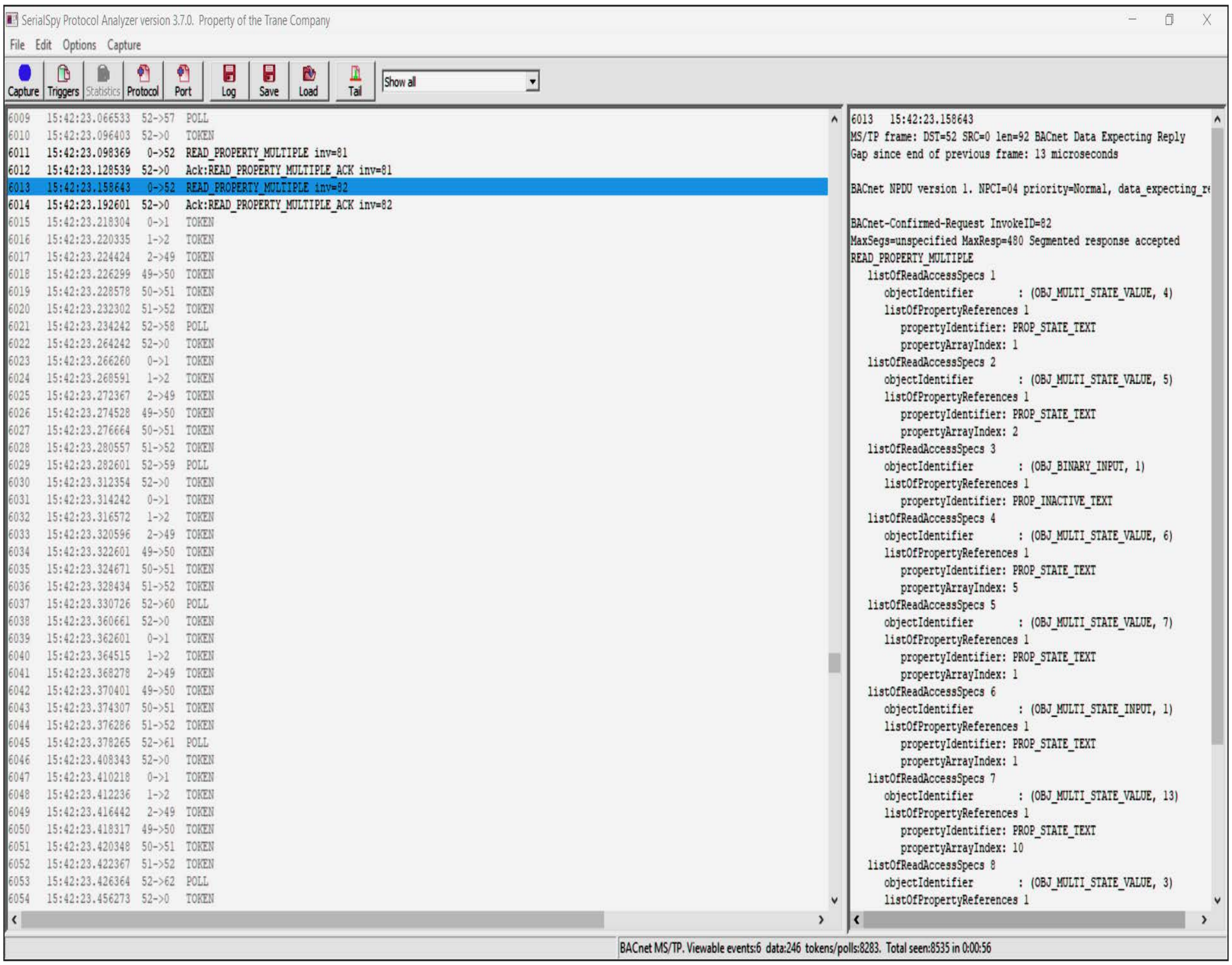


## Data Request Details

Serial Spy captures are most useful for determining which addresses are communicating and if there are specific patterns of diagnostics. So for the most part, that is what you will be looking for when you evaluate a SerialSpy capture. However, there may be occasions when you will want to look at data requests and replies in some detail.

Figure 23, p. 34 shows the Tracer® SC+ (address 0) requesting data from device 52. When you highlight the line in the left panel of SerialSpy, you can see the details of the request listed in the right panel (which properties and which objects in the device are being read).

**Figure 23. Details of a data request from the Tracer® SC+**

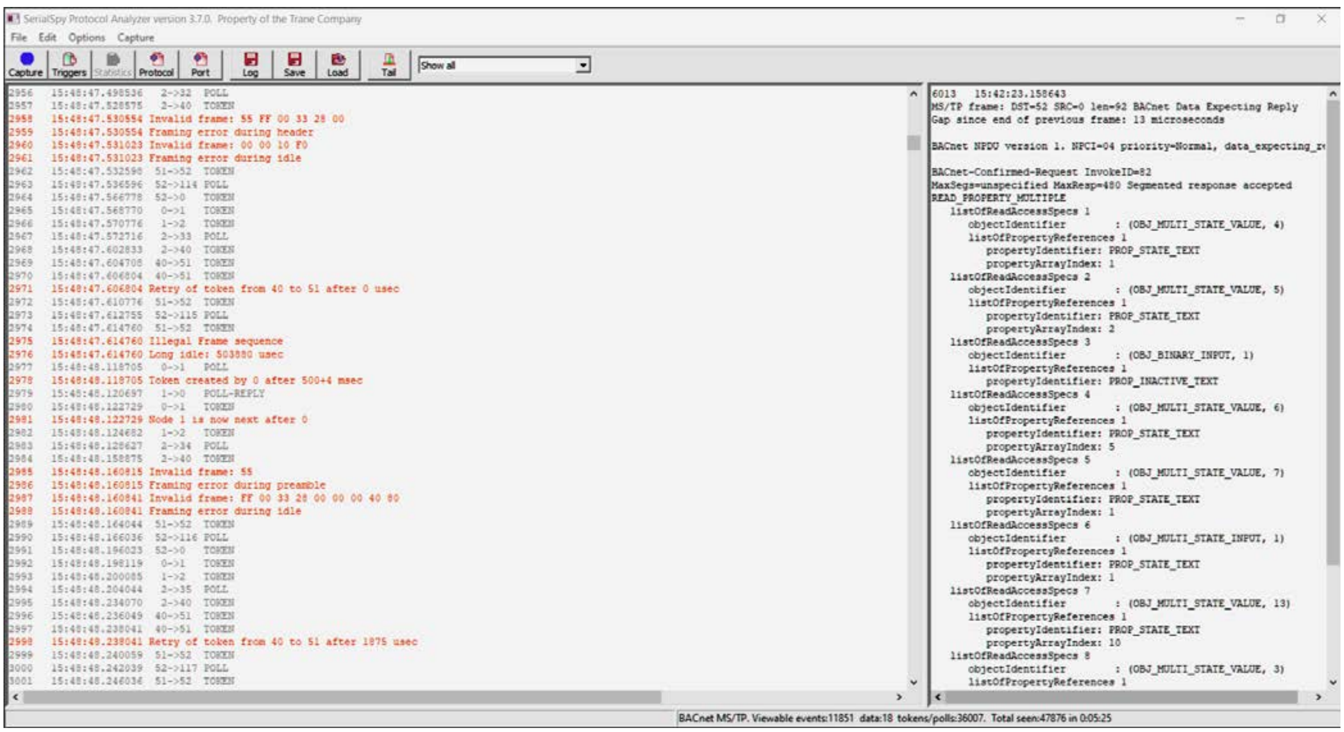


## Duplicate Addresses

A common problem is two devices on the network set to the same rotary switch address. At first glance, the SerialSpy capture appears populated blue diagnostics (see Figure 24, p. 35). However, one particular message repeats, “Retry of Token from 40 to 41”. This easier to see if you select “Show Diagnostics Only” in the list box (see Figure 25, p. 36). Inspection of the token passing messages around this error reveals that the device addresses are in sequential order. However, the device at address 39 is not present.

In this example the token is passing along normally until it reaches device 40. Because there are two devices addressed 40, they both respond by passing the token. This triggers a Retry diagnostic from SerialSpy. There are now two tokens bouncing down the link. This condition will not necessarily result in a comm down state at the Tracer® SC+, but communication will be very slow on the link and the Tracer® SC+ performance will suffer.

**Figure 24. Duplicate address at 40**



## Power Polarity Reversal

Many jobs have a single transformer powering multiple Tracer® UC400s. Strict polarity of the power wiring from the transformer to the Tracer UC400s must be observed in these cases. It is very easy to inadvertently switch power polarity by simply offsetting the power plug on the Tracer® UC400 by one position. This condition might result in a very chaotic SerialSpy capture.

Figure 26, p. 37 shows a very simple link with a Tracer® SC+ at address 0 and Tracer® UC400s at addresses 1, 2, and 3. The three Tracer® UC400s share a transformer. When power polarity is reversed on device 1, it begins polling and receives a reply from address 0 but continues polling as if unaware of the reply. Often when this happens, an entire group of devices that share a transformer will not communicate.

**Figure 25. Same capture with "Show diagnostics only" selected**

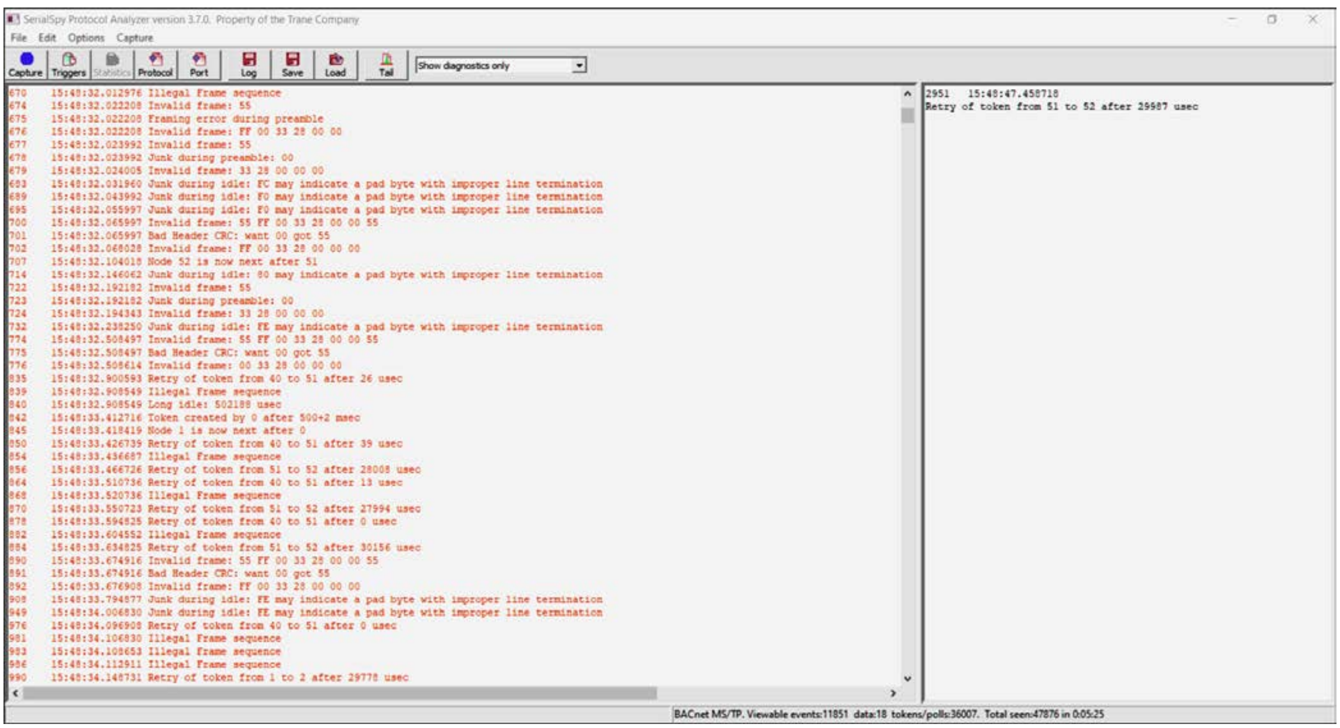
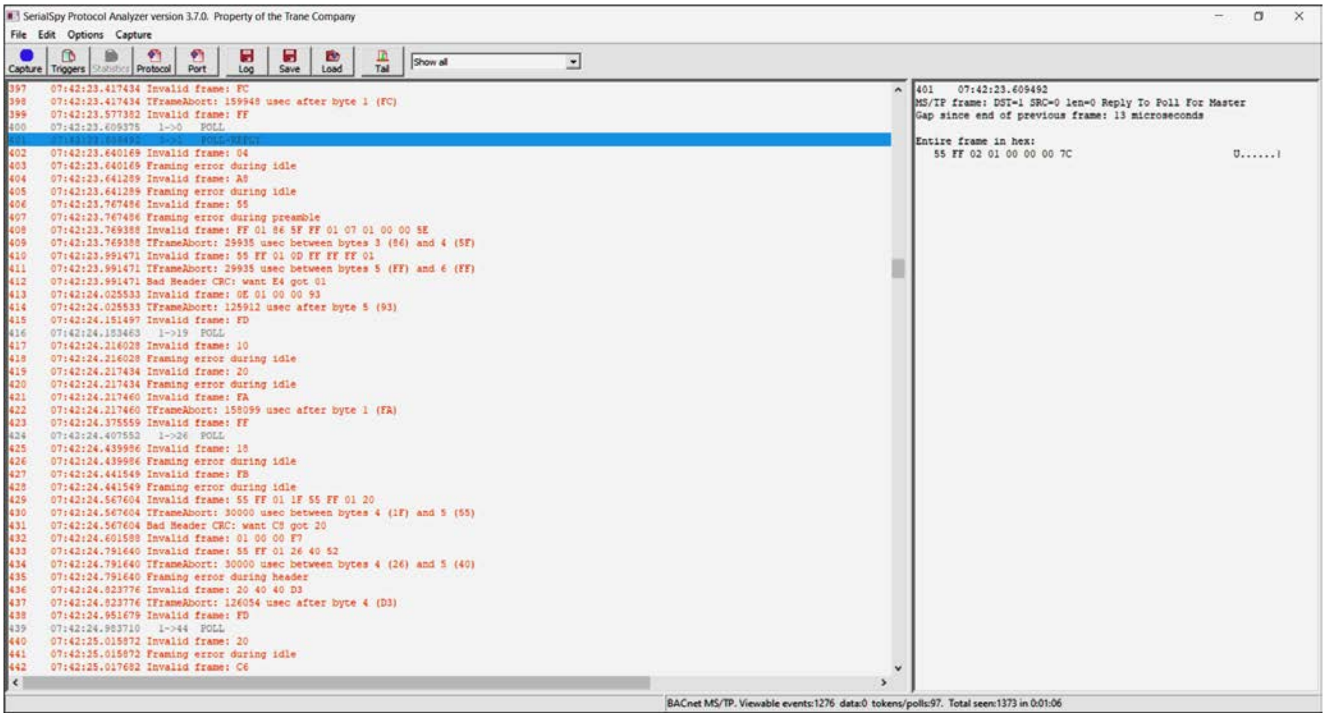


**Figure 26. Power polarity on device 1 reversed**

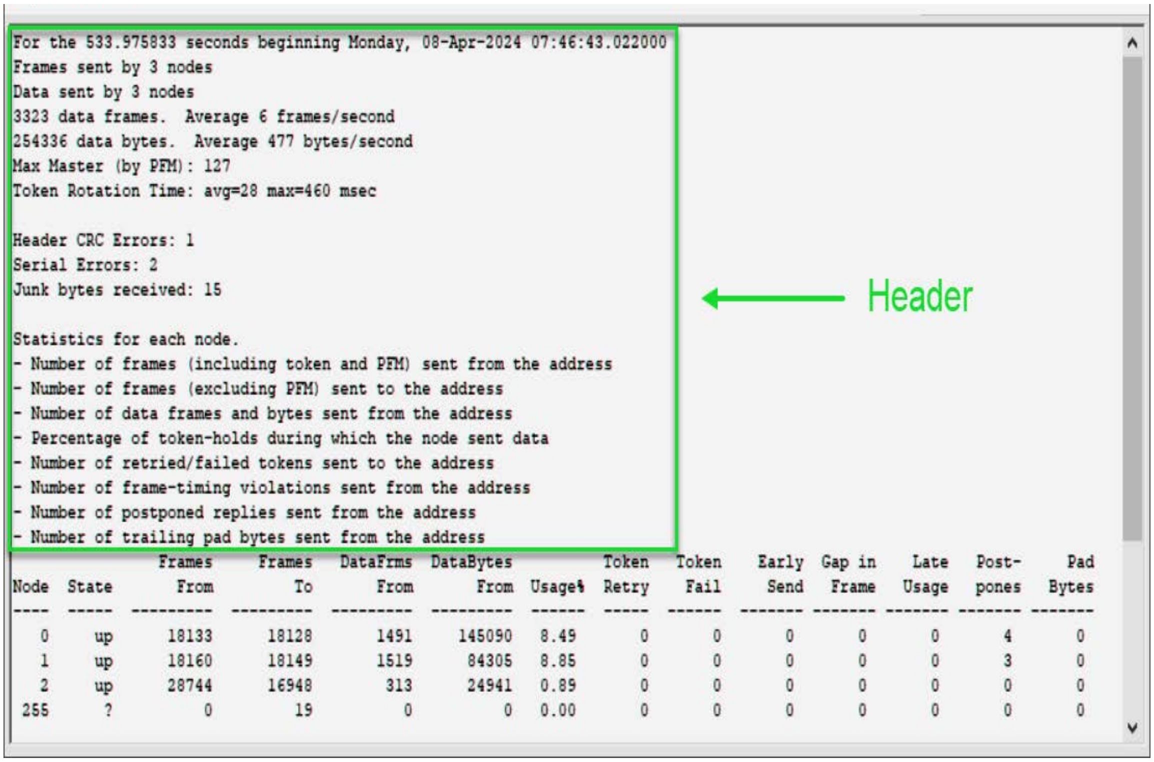


## Statistics Summary

There are two ways to view and gather statistics.The first is to use the Statistics button, which is useful for tracking stats during a live capture session. The second is to use the Stop button, which will append the statistics to the end of the captured file. You should always use the Stop button at the end of a session, particularly when you intend to send the file to Tech Support. The statistics report contains the following information.

- **Header** — This is a summary of the link activity during the capture. The average frames and bytes per second indicate general bandwidth utilization. The average time, in milliseconds, required for the token to complete the circuit is the Token Rotation Time (TRT). TRT will increase on a bigger, busier link and a very large value might indicate bandwidth saturation.
- **Node** — These are the addresses of the devices on the link.
- **Frames From** — This is the total number of frames sent from the device for each node on the link. This total number includes token, poll for manager frames.
- **Frames To** — This is the total number of frames sent to the device for each node on the link. This total number excludes poll for manager messages on the link. Note that on a clean link like this one they are mostly uniform from one device to another.
- **DataFramesFrom** — This is the total number of data frames sent from the device for each node on the link. Data Frames are used to carry BACnet data. Some Data frames carry BACnet Confirmed Services, such as ReadProperty or WriteProperty, and expect to get a reply. Other Data frames carry BACnet Unconfirmed Services such as Time Synch or I-Am and do not expect to get a reply.
- **DataBytesFrom** — Similar to Data Frames above, this is the total number of data bytes sent from the device for each node on the link that have not been installed on the Tracer SC+, and therefore have much smaller values in this column.
- **Usage%** — This is the percentage of times that the device used the token to pass data for each node on the link. On a link with a Tracer SC+, it's common to see the node representing the Tracer SC+ with the highest percentage in this usage column.
- **TokenRetry** — This is a typical clean link with fewer or no retries. If duplicate addresses were present, there would be a very large number at the duplicate address.
- **TokenFail** — If device X on the link sends a token frame to device Y on the link, Serial Spy expects the next frame to be from device Y. If the next frame is a poll for manager from device X, Serial Spy will flag this as a token fail.
- **Early Send** —This indicates a potential timing violation for the node.
- **Gap in Frame** — BACnet defines the maximum allowable delay timing between any 2 bytes in the frame. This indicates how many times each node on the link exceeded this maximum timing delay.
- **Late Usage** — This indicates a potential timing violation for the node.
- **Postpones** — Indicates that a device intends to respond to a message but intends to defer its response to a later token pass.
- **Pad Bytes** — Indicates the number of trailing pad bytes for each node on the link. BACnet allows but does not require the use of pad bytes. Pad bytes are used to tell the sending device to disable its transmitter. Most devices, including Tracer SC+ and unit controllers, do not send pad bytes.

**Figure 27. Statistics summary**



For the 533.975833 seconds beginning Monday, 08-Apr-2024 07:46:43.022000
Frames sent by 3 nodes
Data sent by 3 nodes
3323 data frames. Average 6 frames/second
254336 data bytes. Average 477 bytes/second
Max Master (by PFM): 127
Token Rotation Time: avg=28 max=460 msec

Header CRC Errors: 1
Serial Errors: 2
Junk bytes received: 15

Statistics for each node.
- Number of frames (including token and PFM) sent from the address
- Number of frames (excluding PFM) sent to the address
- Number of data frames and bytes sent from the address
- Percentage of token-holds during which the node sent data
- Number of retried/failed tokens sent to the address
- Number of frame-timing violations sent from the address
- Number of postponed replies sent from the address
- Number of trailing pad bytes sent from the address

| Node | State | Frames From | Frames To | DataFrms From | DataBytes From | Usage% | Token Retry | Token Fail | Early Send | Gap in Frame | Late Usage | Post-pones | Pad Bytes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | up | 18133 | 18128 | 1491 | 145090 | 8.49 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| 1 | up | 18160 | 18149 | 1519 | 84305 | 8.85 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 2 | up | 28744 | 16948 | 313 | 24941 | 0.89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 255 | ? | 0 | 19 | 0 | 0 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Troubleshooting Options

Use Table 7, p. 40 to quickly identify the symptom and some possible causes, then refer to the best practices section of this document for information on fixing the problem.

**Table 7. Troubleshooting quick reference**

| Symptom | Possible Causes |
|---|---|
| Intermittent communication or communication is down | • Using the wrong type of wire.<br>• Wire run is too long.<br>• Too many devices on the link.<br>• Wrong wire topology.<br>• Problem with Terminators (i.e., missing, too few, too many, not powered, etc.).<br>• Improper wire connections at the terminals on the device.<br>• Bad ground connection at the device.<br>• Both ends of the shield wire not grounded.<br>• Open connection of shield wire.<br>• Short in communication wire to ground.<br>• Short between communication wires.<br>• Baud rate mismatch.<br>• Duplicate rotary switch address.<br>• External electrical interference. |
| Device not found | • Non-conforming third-party device, or device is not using BACnet® protocol.<br>• Reverse ground at a device (swapped 24 Vac wire with ground wire with a common power transformer) Transformer shared with device and other non-controller devices in an enclosure.<br>• Reverse ground at a device (swapped 24 Vac wire with ground wire with a common power transformer) Multiple unit controllers sharing a transformer.<br>• Bad ground connection at the device.<br>• Loose terminals.<br>• Device not configured for BACnet® communications.<br>• Rotary dial error (address set to “0” with dials).<br>• Trane rotary dial value set to zero.<br>• Max Manager property set to low.<br>• Device powered down. |
| Tracer® SC+ cannot install devices above 60 devices | • Too many devices on the link. |
| All down-stream devices not found | • Break in wire (both wires).<br>• Break in wire (one wire).<br>• Loose terminals.<br>• Bad wire connection at the device.<br>• Reverse polarity of +/- communication wires.<br>• Incorrect connector placement[(a)]. |
| Two devices not communicating | • Duplicate rotary switch Address. |
| Communication time-outs, slow data response to query | • Link data traffic overload.<br>• TGP2 data requests are too frequent.<br>• Data log requests are too frequent.<br>• Too many data logs gathering information. |

(a) In the UC400 and UC600 controller design, there is a pin terminal connector that the MS/TP and IMC communication buss share. It is common to miss-align the MS/TP connector and connect one line of the network to an IMC terminal.

# Troubleshooting Technique (Isolation)

Physical problems require some trial and error monitoring at various points on the link to isolate the location of the problem. Use this procedure, your volt meter, and Table 8, p. 42 to help you find the problem.

***Important:*** *Before troubleshooting the link, locate a valid set of prints for the project that show how the devices are wired on the link along with their addresses.*

The following steps define the isolation technique for troubleshooting BACnet® links.

1. From the Tracer® SC+, verify the following:
   a. The SC is grounded properly.
   b. Rotary address setting on the SC.

      ***Note:*** *Ensure that the rotary switches match the submittal documents. If you change the rotary switches, verify the Tracer® SC+ BACnet® configuration by navigating to (**Installation** > **Identification and Communication** > **BACnet® Configuration**) at the Tracer Synchrony user interface.*

   c. Shield wires are properly terminated.
   d. Communication wiring terminal is fully seated on the controller.
   e. Polarity of the comm link is maintained.
   f. Both the in and out wires are properly terminated (tug test each).
2. Verify that a Tracer® BACnet® Terminator is properly installed on each end of the comm link.
3. Go to the device in the middle of the link and check the following items:
   a. Rotary address setting on the unit controller.

      ***Note:*** *Make sure its rotary switches match the submittal documents. If you find switches set incorrectly, you must change the rotary address and then cycle power on the unit controller.*

   b. Shield wires are properly terminated.
   c. Communication wiring terminal is fully seated on the controller.
   d. Polarity of the comm link is maintained.
   e. Both the in and out wires are properly terminated (tug test each).

   If you find any of these items to be improperly installed, correct them and run a SerialSpy capture. If the problem persists, go to Step 4.
4. Disconnect the wire going to the outward part of the link (away from the Tracer® SC+). Connect the alligator clips from the USB Comm4 adapter to the plus (+) and minus (-) terminals on the device and run a SerialSpy capture.

   If all devices are communicating and passing the token properly with no errors or diagnostics shown, the problem exists on the outward side (away from the Tracer® SC+) of the broken link. If you see errors and diagnostics, go to Step 8.
5. Perform a voltage check. Voltage should be between 0.3 V and 0.5 V. See Table 8, p. 42 for more information.
6. Reconnect the link and move half-way farther out on the link and break the link there.
7. Disconnect the wire going to the outward part of the link (away from the Tracer® SC+). Connect the alligator clips from the USB Comm4 adapter to the plus (+) and minus (-) terminals on the device and run a SerialSpy capture.

   If all devices are discovered, the problem exists on the outward side (away from the Tracer® SC+) of the broken link.
8. Repeat Step 6 and Step 7 until the trouble is isolated.

9. If you see errors and diagnostics, it is likely that there is an issue with the BACnet® link on the inward side of the broken link.
10. Reconnect the link and move to the device that is half-way back toward the Tracer® SC+.
11. Disconnect the wire leading to the outward part of the link (away from the Tracer® SC+). Connect the alligator clips from the USB Comm4 adapter to the plus (+) and minus (-) terminals on the device and run a SerialSpy capture.
12. Repeat Step 4 and Step 5 until the problem is isolated.

## Network Voltage Measurement

The general procedure is to measure the dc voltage across the plus (+) and minus (-) communication terminals at any device on the network. With terminators, the normal operating range that provides adequate communication is 0.3V to 0.5V. Less than 0.2V is inadequate.

***Note:*** *You can obtain this voltage measurement with all devices on the link powered up and running.*

**Table 8. Characteristics associated with specific problems on the BACnet® MS/TP link**

| Condition | Vdc | LEDs | Serial Spy |
|---|---|---|---|
| Normal<br>Two powered Trane BACnet® terminators | Normal[(a)]<br>Min = 0.33<br>Max = 0.60<br>Avg = 0.45<br>(refer to Note [(b)]) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors [(c)] |
| One powered Trane BACnet® terminator | Min = 0.35<br>Max = 0.60<br>Avg = 0.45<br>(refer to Note [(b)]) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)] |
| Two unpowered Trane BACnet® terminator | Min = 0.003<br>Max = 0.45<br>Avg = 0.21<br>(refer to Note [(b)]) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)] |
| No Trane BACnet® terminators | Min = 1.1<br>Max = 2.2<br>Avg = 1.5 | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)] |
| Cut the minus (-) comm wire | Normal<br>Min = 0.33<br>Max = 0.60<br>Avg = 0.45<br>(refer to Note [(b)]) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)]<br>However, all units past the wire break stop communicating — looks like two separate links, each intact |
| Cut the plus (+) comm wire | Normal<br>Min = 0.33<br>Max = 0.60<br>Avg = 0.45<br>(refer to Note [(b)]) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)]<br>However, all units past the wire break stop communicating — looks like two separate links, each intact |
| Minus (-) comm wire grounded | Min = 0.54<br>Max = 0.64<br>Avg = 0.58<br>(voltage range is very flat) | For units on the same transformer<br>Tx = quick flash<br>Rx = almost solid on<br>Other units are unaffected | All units sharing a transformer with grounded units are comm down. The rest of the link is normal. |
| Plus (+) wire grounded | Min = –0.50<br>Max = 0.16<br>Avg = 0.20<br>(voltage goes negative) | Normal<br>Tx = quick flash<br>Rx = almost solid on | Normal<br>Clean token pass<br>No (or few) blue diagnostics or errors[(c)] |
| Comm polarity reversed | 0.60 V<br>(very steady, no fluctuation) | Tx = off<br>Rx = Weak flashing | Junk during idle — framing errors |
| Dead Short across the comm link | 0 V | Tx = weak solid on<br>Rx = off or very weak | Junk during idle — framing errors<br>Bad header, fast scrolling |

**Table 8. Characteristics associated with specific problems on the BACnet® MS/TP link (continued)**

| Condition | Vdc | LEDs | Serial Spy |
|---|---|---|---|
| Plug comm link into IMC | Min = 0.59<br>Max = 0.61<br>Avg = 0.59<br>(voltage range is very flat) | Tx = off<br>Rx = solid on | Junk during idle only. No other diagnostics |
| Duplicate rotary switch address | Normal<br>Min = 0.33<br>Max = 0.60<br>Avg = 0.45<br>(refer to Note [b]) | Units with duplicate addresses have a normal interval then:<br>Tx = off<br>Rx = flashing for several seconds, other units are normal | Junk during idle — framing errors<br>Bad Header<br>Retry of token from X > Z<br>X is the duplicate address<br>(refer to sample capture) |
| Mixed baud rate | Normal<br>Min = 0.33<br>Max =0.60<br>Avg = 0.45<br>(refer to Note [b]) | Dominant speed units normal<br>Tx = quick flash<br>Rx = almost solid on<br>Quiet units<br>Tx = off<br>Rx = almost solid on | The baud rate of the first units that power up will dominate communication on the link. SerialSpy shows a clean capture with no (or few) blue diagnostics or errors.[c] However, devices communicating at a different baud rate will be silent—no Tx. |
| Power polarity reversed on shared transformer | Min = 0.10<br>Max = 0.20<br>Avg = 0.13<br>(very low reading with an occasional spike to 0.60)<br>(refer to Note [b]) | Tx = inconsistent, sometimes normal flash, sometime off<br>Rx = almost solid on | Chaos. Sometimes you see one device or more that is constantly polling, but never finding another device.<br>It also might appear to be normal, but with all the devices on that shared transformer down. |

(a) A properly terminated and powered link typically shows voltage measurements between 0.30 and 0.60 with an average voltage of 0.45.
(b) These readings are typical for ordinary meters. Very good meters (Fluke) with Min/Max recording capability will detect very transitory spikes of much higher voltage.
(c) There may be one blue diagnostic message every 10,000 lines (12-30 in a 3-5 min capture). This would still represent a normally functioning link.

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