

Termination & Testing

This section presents guidelines for network layout, termination and testing. It replaces Appendix B of the StarBus User's Guide.

If you will be using StarBus for control applications rather than peripheral sharing, the User's Guide will serve only as occasional reference (basic commands on black-edged pages). Your main resource will be the programming notes for your controller and 'Advanced Features: Programming Series C StarBus'. It explains embedded commands in your controls applications notes.

Quick Intro: Initializing new Busdrivers

Before laying out or testing the integrity of your network wires, it is a good idea to become familiar with the basic process of talking to a StarBus Busdriver, and setting its configuration parameters.

Each Busdriver requires a unique station number. Once given, you can connect or configure any Busdriver by number or by a name that you assign. You may also broadcast to a GROUP ADDRESS, or - if you don't care to wait for a target station that may be in use by someone else - you may send one-way DATAGRAMS. These will arrive at the selected target when it becomes free (Advanced Features, pg.14). Finally, if you want a full connection with any one of several Busdrivers serving in similar capacities, you can assign names that begin with the same characters. If you specify only the matching first letters when issuing your connect command, a connection is made with the next available unit (User's Guide, p46).

Instructions for first time initialization appear on the top cover of each unit. A more detailed discussion is found in Chapter 2 of the User's Guide. Set only the station number and name for now. Other parameters can be configured later from any station on the network.

The initialization technique described on the top cover of each Busdriver tells you to press and hold the spacebar while powering the attached Busdriver. This causes it to boot into the INITIALIZE PARAMETERS menu. But you may not realize that you are also preparing to reset the APPLICATIONS SEQUENCE which is used as a prefix for embedded StarBus commands. Therefore, the spacebar-initialize method should only be used on a new Busdriver, or when recycling a Busdriver from one job and moving it to a Busdriver to a new application. If you choose to reconfigure parameters of a Busdriver that has previously been initialized for its current application, simply awaken it (press the DISCONNECT CHARACTER three times), and enter the Initialize command I or I/S followed by the name or number, if configuring a remote unit. This conventional technique does not prepare reset the Applications Sequence, unless you explicitly press a reset character for a particular brand of controls equipment. For example, pressing Ctrl-A from within either INITIALIZE PARAMETERS menu, will pre-

configures the local Application Sequence to the one recommended by Andover Controls (*Using StarBus with Andover Controls*, pg. 7).

The spacebar method described on the top cover is intended primarily for first time installations. It erases all parameters, including the embedded command applications sequence that you may have previously set for use with programmed equipment.

Once StarBus is installed and tested and the stations configured, you will be ready to customize the applications for which it was purchased. Industrial control installers must program the controllers and front end script files (Andover dealers, see "*Using StarBus with Andover Controls*"). Peripheral sharing users will probably want to install HotKey (Chapters 7 and 5 of User's Guide).

The section is divided into three parts. Most installers need refer only to Part 1. Part 2 requires use of a digital volt/ohm meter.

Contents of This Section:

1. Before Attaching Busdrivers...
Plan Wire Layout, Check Wires and Select Termination

Some layout decisions can be made even when using previously installed wiring. Then, select termination resistance and bias.

2. After Attaching Busdrivers, Run a Simple Test

Perform ten NETWORK MAPS from several stations. If there are problems, this section presents several quick tests to verify wiring and isolate problems.

3. Advanced Test Techniques for use at Problem Sites

PART 1. Check Wires; Select Termination Resistors

Appendix B of the User's Guide contains general guidelines for determining whether your site topology is suited for layout as a BUS, STAR or TREE.

A bus is most desirable, because it covers the greatest distance. Use a long multidrop wire pair, trying to minimize side runs further than 50~100 feet from the bus.* Total wire length, including side runs should not exceed 4000 feet.

A combination of factors may permit operation up to 4800 feet without the use of repeaters. (1) when using low capacitance wire (under 40 pF/ft); and/or (2) when a majority of Busdrivers are situated near the bus ends; and/or (3) if 18 or 20 gauge wire is used (instead of a higher gauge). This document will help you determine if you have such a configuration.

1a) Accommodate Stations Far From the Bus

*Generally, a BUS-network should not have side runs which extend farther than 50 feet from the main bus. If a few such positions must be accommodated, there are two solutions...

- i. If the main backbone is not yet near the maximum distance specification (4000 ft for 22 ga wire or 2500 ft for 24 gauge wire), then these side runs can be avoided if the wire leading to the side station contains 2 pairs. Detour the main backbone out and back from the distant station.

Be sure to cut the original backbone so the signal is forced to detour out and back. This method adds twice the sideways distance to the bus length, but contains the total run within the much longer bus specification.

- ii. One or two spokes may extend as far as 400 feet from the backbone of a bus-configured network (up to three, if all spokes over 50 feet are under 150 feet). Terminate spokes over 300 feet with a 470 ohm resistor.

If StarBus uses one pair in a multiconductor cable (e.g. a telephone trunk) for more than 1000 ft on a thread with fewer than 10 Busdrivers (or a repeater plus fewer than 4 Busdrivers), then test for noise during command state and during connections. Connect and disconnect the Busdriver to various remote stations, observing the terminal screen for expected responses. Also run the LINE ANALYZER test shown at the end of this section. If noise appears, your network may require the addition of a BIAS module. A section on BIAS appears below.

1b) Check the Wires

Once a network is installed, it can be difficult to isolate wiring problems from a noise condition, a ground problem, or a piece of failed equipment.

A few simple tests on installed wiring before attaching StarBus can save a lot of time later. By performing these tests before attaching Busdrivers, you will know to look elsewhere for the source of post-installation symptoms.

These tests are for wires only. Do not yet install any resistors or Busdrivers.

- i. Short the network pair at one end.

Short one far end of the wires. If a repeater will be used later, treat each thread separately for this procedure and for all electrical tests (only the LINE ANALYZER test is performed after installation of repeaters).

Verify the expected wire impedance from two far points. A table appears in this chapter. Multiple the actual wire length by two, because current from your meter must pass through each wire.

For example, a 24 AWG wire pair of 2150 feet should show a resistance of approximately $2.15 \text{ kft} \times 25.7 \text{ ohm/kft} \times 2 = 110 \text{ ohms}$.

If individual Busdrivers are attached to the main bus with a separate jumper wire then this test must be performed from each location, to insure that none of the jumper segments contain an open circuit on one side. Individual port testing can be skipped only if the bus pair is physically brought to the rear of each unit.

- ii. With the wires still shorted at one location, check the impedance of the wire pair to ground. Use your meter's highest ohm setting. If any conductivity is apparent, remove the short and determine which wire is at fault. It may be necessary to separate the wire into shorter segments to locate the ground condition.
- iii. The above tests take only resistance into effect. StarBus is also sensitive to wire capacitance, but maximum wire capacitance is dependent on wire length, termination and number of stations. These variables can be summed up in the following rule of thumb. Total wire capacitance (wire-wire and wire-shield) should not exceed 0.2 uF for networks of 15 or fewer Busdrivers, and 0.15 uF for more than 15.

Since most 22 and 24 AWG wire is 50 pf/ft or less, capacitance is not usually a limiting factor.

1c) Select Termination Resistors

It's easy to overlook termination, because a network may seem to operate properly without it. However, when traffic increases, an unterminated network may exhibit poor performance due to the high number of rejected packets (these packets are repeated, thus reducing efficiency). Performance of an unterminated network may also deteriorate when repeaters are added to the network, or when Busdrivers are powered on and off.

When selecting termination resistors, treat each thread as a separate network. Threads are the long network segments bridged by one or more StarBus repeaters. In the absence of repeaters, a network contains one thread.

Termination flowcharts in previous editions of this Technical Reference are no longer required. For nearly all network installations, this simple termination guideline is satisfactory.

Terminate each network thread with one or two 330Ω resistors. For STAR networks or BUS networks of less than 1000 ft use one resistor, as close to the center as is practical. For bus networks which exceed 1000 ft, terminate each far end with 330Ω. If there are several

hundred feet of spurs near one of the bus-ends (heading to Busdrivers in various directions), place the 'bus-end' resistor nearest the junctions. This helps to dampen the signal reflection that junctions exhibit.

Very few installations will require a third resistor or a special BIAS module. The remainder of this section will help you determine if this is the case for your configuration. By adhering to these guidelines, your StarBus network will continue to function properly as users add network devices, use telephone splitters, or extend the length of their Busdriver cables.

1d) Treat Separately Threads on Each Side of a Repeater

A repeater bridges 2 wire pairs - called threads - into a single StarBus network. Repeaters include a bias equal to 6 Busdrivers for the thread on each side. Therefore, a bias module is generally not required for network threads which are attached to a repeater. Repeaters are described in another chapter.

For the purpose of termination and bias, the thread to each side of a repeater is treated as a separate network. For example, if one side of the repeater is situated at the end of a BUS thread, a termination resistor is placed on that side of the repeater. But if the other side of the repeater is not located at the end of its thread, a resistor is not warranted on that side.

When counting the total number of Busdrivers on a thread, do not count units which will be unpowered at times when other units will be in use. That is, if a network contains 12 Busdrivers, but is partially shutdown at night, a bias module may be required to maintain the appearance of 6 powered units.

1e) Adding a Bias Module

Networks containing more than 1000 feet of wire, but only 6 or fewer Busdrivers are more susceptible to induced noise than other configurations. Such networks may exhibit slow performance (because the error correcting logic is refusing many incorrect data packets) and may display the NETWORK MAP with question marks, "NON-EXIST"s, or repeated entries. The network map provides an early warning of noise problems because information in this map is not subjected to the extensive error correction through which data must pass.

On such networks, it may be necessary to attach a bias module to one of the Busdrivers. This provides a high degree of noise immunity by simulating the DC contribution 6 Busdrivers. Part two describes several post-installation tests. They will help you determine whether additional bias is required. Bias can also be added by changing 2 resistors inside any Busdriver.

1f) Nonstandard Configurations

There are two ways of dealing with networks which do not satisfy STAR, BUS, or TREE configurations, described in Appendix B of the User's Guide.

i. Find one or more points in the network wiring which are accessible to an electric outlet, free of heavy pedestrian traffic, and which divides the network into threads which are each a legal configuration.

A StarBus repeater placed at these points will attach individual segments (network threads) into one large StarBus network. Each repeater bridges two threads, isolating their electrical characteristics from each other. Installation and usage guidelines are presented in Chapter 8.

ii. In some cases, a repeater may not be necessary. First, reexamine the way in which you look at network topology and your choice of where stations are attached to the network wire. By studying the wire plan on paper, it may become apparent that the termination point of a BUS or STAR might be more appropriately selected at a different location.

Many factors affect the performance of nonstandard topologies. To account for them all would require a polynomial equation and knowledge of the wire capacitance, reactance, tightness (or lack) of twist, insulation dielectric, etc. Educated trial and error provides a more efficacious technique for determining if a network repeater can be avoided.

Trials consist of varying termination and bias in accordance with these guidelines and errors are determined via the Network Map function and/or viewing the network signal on an oscilloscope. The NETWORK MAP provides an excellent acid test for network integrity, since it bypasses the error correction through which normal data must pass.

If the network has one or more illegal branches, begin by following the BUS or STAR flowchart which best matches your topology (ignore exceptional branches).

When accommodating one or more illegal branches, try to lessen the total number of branches by clustering Busdrivers if possible. Even two illegal branches may be viable, if the overall number of branches can be reduced.

A network which could be classified as a STAR or BUS except for one long branch may operate properly simply by adding a 470 ohm resistor to the end of the branch. Again, it may be necessary to add a BIAS module if any two stations are more than 1000 feet apart and it is likely that the network may operate with 6 or fewer powered Busdrivers. Part 2 of this section describes how to measure the bias of a network.

Two or more extended-distance branches lessen the chance of finding a non-repeater solution, because the network cannot support a fifth resistor.* In such a case, use 330Ω resistors only on the three longest branches, or alternatively use four 470Ω resistors.

A STAR topology should be used where "daisy chains" are not possible. STARS require all stations to be within a 500 foot radius of a common electrical point. But that point need not be the spot at which individual runs are connected. It is always acceptable to add stations to an existing STAR spoke, rather than adding a new wire to the central junction.

As above, minimize extended-distance branches by grouping stations onto existing spokes.

*1g) Net Resistance Calculation

Total termination impedance is calculated by adding the inverse of each termination resistor, and then taking the inverse of that quantity.

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots$$

Total impedance should not fall below 80 ohms. Thus, we may use a maximum of four 330Ω resistors. For 24 or 26 gauge wire, only three resistors might be tolerated due to the length and impedance of the wires themselves.

Resistance of Solid Copper Wire

(stranded wire slightly higher)

AWG	Ω/Kft
16	4.0
18	6.4
20	10.2
22	16.1
24	25.7
26	41.0
28	64.9
30	103.0

1h) Configure and Install

Determine if you will be configuring one of the Busdrivers as POLLER/1, instead of POLLER. The POLLER/1 causes a Busdriver to act as both network master and also as station #1, thus saving the cost of one Busdriver. But there are two restrictions when using this feature:

- i. The attached device can neither send or receive Datagrams - sometimes called alarms - are described in Chapter 6 and also in the special appendix for controls dealers.
- ii. POLLER/1 is not recommended for use with networks with more than 15 stations. Such use may interfere with the overall efficiency of the network.

Next configure and install each Busdriver. Controls dealers should follow the procedure outlined in the brochure “Using StarBus with Andover Controllers”.

A new Busdriver will flash its yellow led continuously until it is initialized. But once a Busdriver has been initialized, its yellow led will flash for only a few seconds on successive power ups.

If the POLLER or POLLER/1 is installed first, the yellow light of other Busdrivers will remain on after powerup. If they do not remain on, the Busdriver does not sense the poller on the network. This could be due to several things:

- i. The Busdriver (or the POLLER) was attached with the wrong polarity. Reverse the wires and observe the yellow LED.
- ii. The wires are shorted to each other or ground, or one wire is open circuit at some point. Review wire tests, above.

iii. The MAX POLLING ADDRESS is set for a number lower than the station being attached. Check this parameter at the poller. If using a POLLER/1, this parameter can be checked and reset from any station attached to a terminal or PC.

1i) Test Your Network

Enter a terminal session and awaken your Busdriver. Then perform the NETWORK MAP function 10 times (from the SCI> prompt, press N f).

If you see no irregularities (or the word NON-EXIST), you are done with StarBus installation and configuration. If you suspect you made an error, reread Appendix B of the StarBus User’s Guide and the above section. If you believe that your network contains exceptions to recommended wiring guidelines, continue with the next section of this appendix.

PART 2: Post Installation Testing

Perform the above continuity and ground-short tests described before connecting Busdrivers. Part 2 procedures verify Busdriver output levels and network wiring after StarBus units are already attached to the network wires.

2a) Measuring Network Bias (10 minutes)

For this test, leave all Busdrivers attached to network wire with power. But do not start controller communications. Observe the DC voltage from several points along the network. This voltage is called the network bias. With no termination resistors, bias will read 2 volts or higher, but when properly terminated it should fall in the ranges defined below:

Furthest Points (end-to-end)	Cable Type	Min Bias
< 2000 ft	up to 6 pairs	150 mv
< 1000 ft	many pairs	175
2000-4000	up to 6 pairs	200
1000-2000	many pairs	200
2000-4000	many pairs	225

2b) Effect of Termination and Number of Stations on Bias

Each resistor acts to lower the overall network bias. Each Busdriver increases this voltage. Typically, networks that include at least one termination resistor do not exceed 500 mv bias.

Typically, the best termination for a BUS-configured network is two 330Ω resistors. One across each far end of network pair. But for bus lengths shorter than 1000 feet, you may alternatively use a single 330Ω resistor located close to the center of the wire. A single resistor leaves a higher bias than does two resistors.

Here's the catch and a solution: Longer networks generally have the most resistors (up to four resistors if there are 2 long side taps into a main bus). Additionally, networks over 2000 feet sometimes require 220Ω resistors to better reduce end reflection. Since these longer networks need a slightly higher bias, these extra resistors can be a problem. Networks with many Busdrivers exhibit sufficient voltage. But long networks with few Busdrivers may require the addition of a StarBus BIAS module. The BIAS module simulates the presence of 6 additional Busdrivers and by raising the bias voltage without the need to skimp on termination resistance.

The above tests check the DC continuity of the wires, but cannot ensure that a network is within the maximum distance limitation. Generally, total wire length must not exceed 4000 feet (18-22 AWG wire), including the length of stubs which tap out from the bus.

2c) Checking a Busdriver for Damage

A Busdriver can be checked for damage by measuring DC voltage at the rear posts with a digital volt meter. For this test, the unit must be powered, but not connected to the network, and must not set to address POLLER or POLLER/1.

Busdrivers produce between 2 and 2.5 volts DC (open circuit). The voltage must drop to 36-38 mv when a 330Ω resistor is placed across the posts.

Older repeaters (in Busdriver boxes) exhibit between 200-250 mv with a 330Ω across the side under test, while miniature repeaters yield 166±3 mv. A high or low reading typically indicates lightning damage to the RS-485 transceiver. The chip – marked SN75176 – is easily replaced.

A network affected by a damaged Busdriver will function when the offending station is removed, but swapping the position of two Busdrivers is a much more conclusive test. If the voltage of a suspect Busdriver is correct, swap it with one use on another piece of equipment. Exchange both units, including addresses and parameters so that they can communicate with their mated equipment. There are two INITIALIZE PARAMETERS menus in each unit: I (n) and I/S (n), where 'n' is the station number or name for times when configuring a remote unit.

You can determine if the problem is related to network wiring or to a bad Busdriver by observing if the communications problem moves with the suspect Busdriver or stays at the original port location.

It is difficult to overstate the importance of good lightning protection (covered in another chapter). All multi-building networks and any network over 350 feet must have low-capacitance protectors in the vicinity of each station.

2d) The Line Analyzer Test (1 minute + time for exciting reading)

A Busdriver has the ability to reconfigure into a digital line analyzer. This special mode allows you to peer directly onto the network bus from any PC or terminal. Error control is intentionally disabled at the inquiring station. This mode is "read only" and does not interfere with other stations.

Normally, the network bus carries data as well as StarBus polling and error control bytes. One option permits you to filter out the StarBus polling, displaying only user data surrounded by header and footer blocks.

But what if you see stray characters in this mode, even though the network is idle. These characters represent noise induced onto the network wires, and are usually a symptom of wiring which greatly violates the published specs for a proper TREE or BUS network. Because StarBus must repeat data which surrounds the noise, a noisy network may exhibit sluggish performance or faulty network maps.

The absence of noise induced traffic increases confidence in network integrity. You can leave a customer site without wondering if a wiring plan is potentially unstable. To enter LINE ANALYZER, use a PC or terminal which is attached to a Busdriver, but not the one which is set to POLLER or POLLER/1. If you are using a PC, enter the terminal mode of any communications software:

<u>You type</u>	<u>StarBus responds</u>
1. <SF> <SF> <CTRL>L	PASSWORD:
2. EUJAGADAPH	Invalid: XXXX.
3. <space bar>	<view packets>

where <SF> is the SPECIAL FUNCTION character selected in the PRIMARY PARAMETERS menu.

EUJAGADAPH is the master password for all Busdrivers. It also appears inside the front page of this manual. We suggest that you circle it for future reference. The last six letters of this word must be typed in less than 2 seconds. If you type it properly, StarBus will respond with the word INVALID, but will also reveal a unique 4-character password for use on that particular Busdriver (shown above as XXXX).

The next time you use the special LINE ANALYZER mode, you may use either the master password or the unique password. When using the unique password, it is not necessary to type fast. Do not write the unique password on the Busdriver itself, because the site manager may not wish casual users to have access to data packets sent between other stations.

Each time you press the space bar, you are viewing the activity on the network. You will see a counting sequence (the poller activity) separated by dots (timer ticks). The pattern should be regular and even. If the network uses a POLLER/1 (instead of POLLER), you will not see the number (1) and one dot will be missing where the number 1 would have been.

Press M. Now tap the space bar again. This time you should see a blank screen, except possibly for the last one or two characters in the bottom corner. This mode suppresses viewing of the poller and timer ticks. It is possible to see much more activity, since only data (and noise) will be reported to the screen.

Continue pressing M to experiment with each of the three different viewing modes. The key to a noise-free network is a nearly blank screen in mode 2. Only the dashed line should rise to the top while the screen fills with blank spaces. If you see stray characters, the network has too much noise. This noise will eventually impact on network performance. The common sources of noise are presented below. Solutions are described earlier in this section.

- | | |
|-----------------------------------|---|
| 1. Open side, short or ground | <i>Verify wires without Busdrivers</i> |
| 2. Insufficient bias | <i>Measure DC level and add bias</i> |
| 3. Network wires are too long | <i>Reroute branches or add a repeater</i> |
| 4. Noise induced from other wires | <i>Break up long run at jumper block</i> |

To exit LINE ANALYZER, press <ctrl>^ (ctrl-shift-6). The Busdriver will reboot, as if you had reset the main power connector.

PART 3: The Scope Test (20 minutes)

There are hundreds of StarBus installations in more than 25 countries. As of this printing, an oscilloscope has been required at fewer than a dozen sites.

- 3a) The RS-485 network wires are partially referenced to the RS-232 ground. Therefore, it is best to use a 2-channel scope in differential mode without using the ground clips. In the absence of a 2-channel scope, disconnect computer equipment from each Busdriver being careful not to leave the RS-232 cable end where it may touch a conductive surface. Alternatively, a scope equipped with an isolation transformer will also function properly.
- 3b) Attach the poller and the smallest number of additional stations which might be expected to have power at a given time. If possible, locate the poller at one far end of the network wires for this test. Leave your best guess for termination resistance and bias in place. Observe the network signal from a point furthest from the poller.

Since the poller is broadcasting a sequence of 10 or more addresses, the scope is likely to trigger from various addresses, displaying a superimposed pattern. The symptom can be alleviated by uncalibrating the time base and setting a delayed alternate channel trigger. For the test, a stable pattern is not required.

- i. The RS-485 transceivers are remarkably immune to signal attenuation and to the ringing associated with edge transitions. But ringing must not dip within 0.25 v of the differential ground level. To establish the differential ground, use the scope ground locator and not the quiet level between polling addresses.

Termination resistors reduce ringing significantly. But don't add termination resulting in a total impedance of less than 80Ω.

- ii. The quiet level between polling must be at least 150 mv from the differential ground. For networks containing 1000 feet of wire or more, it should be at least 175-225 mv from ground.

If you believe that your network configuration does not account for the bias reading or waveform, try disconnecting and reattaching Busdrivers one at a time (a second person and a 2-way radio really help). If the removal of one Busdriver clears up the problem, you may wish to contact IMCO for service.

But always try a swap test first: It is the only technique that can rule out all other factors (e.g. problems with the wires, attached equipment, induced noise, AC voltage, or programming sequences). Simply swap the suspected unit with a Busdriver operating on another piece of equipment. Be sure to also swap the configuration parameters between the two units. It is important to not only test another unit at the network location in question, *but to also move the suspect unit to a known good location*. Now, simply determine if the problem moves with the Busdriver or stays at the first location.

A voltage of more than 500 mv may also indicate a problem with one Busdriver or the presence of some non-StarBus device on the wires.

This is the BIAS level, which can be increased with the addition of a BIAS module. The StarBus repeater also adds BIAS to both attached threads. Thus, BIAS modules are rarely required in the presence of a StarBus repeater.

Each powered Busdriver helps to bias the network, so perform this measurement with the fewest number of Busdrivers which might be powered at a time when the network is likely to be in use.

WHAT'S NEXT?

Your StarBus installation is complete. Next, you will want to configure the applications for which you purchased StarBus. Industrial control installers must program the controllers and front end script files. Peripheral sharing users may want to install HotKey pop-up communications software, although the HOME BASE feature in recent versions essentially renders HotKey and other communications packages an unnecessary step.