# Troubleshooting communications problems in building control systems

## Application Note

More and more buildings are implementing control systems, as a means to increase energy efficiency and reduce operational costs. At the same time, these systems are becoming both more powerful and more complex to troubleshoot. The pneumatic controls that were nearly universal prior to the 1970s provided fewer capabilities, but at least technicians only had to learn a single platform.

The advent of electromechanical controls in the 1970s, analog controls in the 1980s, Direct Digital Control (DDC) in the 1990s and complete building control integration in the 2000s have offered powerful new options for reducing energy cost and improving comfort. But these blessings are mixed.

Multiple generations of pneumatic, electromechanical, digital, and integrated controls are often layered on top of each other, resulting in a complex hierarchy and in communications problems that are difficult to identify and troubleshoot.
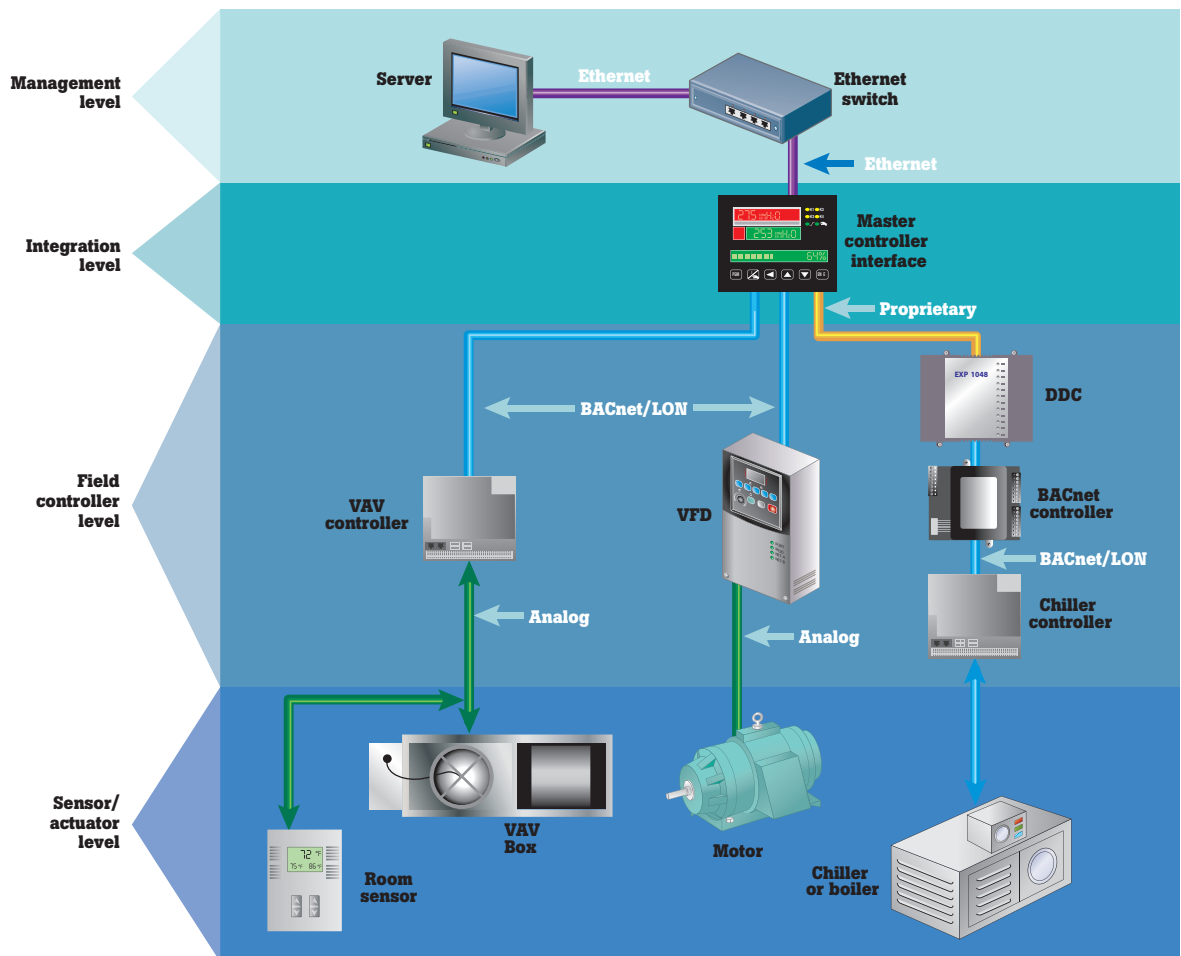


**Figure 1.** Adjust your troubleshooting to the particular digital or analog network controlling that level of the system.

Many HVAC service and controls technicians are familiar with troubleshooting Direct Digital Control (DDC) Input and Output (I/O) 4 mA to 20 mA and 0 V dc to 10 V dc (or 1 V to 5 V) analog signals. But as systems become integrated over digital networks, many other problems are occurring, between field controllers, between DDCs, from field controllers to DDCs, from sensors to DDCs, etc.

The reality is that many technicians are increasing their skills to cover both network and signal troubleshooting. This article outlines communications problems that crop up in today's multilayered building control system and provides a high-level guide to identifying their source.

## Building controls overview

Let's quickly review the four-level architecture found in most modern building control systems and shown in Figure 1. Starting from the bottom, at the sensor/actuator level, present control systems commonly use fully-electronic, two-way, three-way and Pressure Independently Characterized Control Valves (PICCVs).

Variable frequency drives (VFDs) are used as standard equipment on towers, variable air volume (VAV) fans, pumps and chillers.

Typical sensors include humidity and temperature transmitters, $CO_2$ sensors for indoor air quality, power meters, branch circuit monitors and energy meters.

Field level controllers talk to sensors and actuators, often using 4 mA to 20 mA or 0 V dc to 10 V dc analog signals.

Field level controllers are typically connected together using a BACnet master/remote over local area networks (LAN) or a proprietary network. The BACnet MS/TP LAN may be linked through a BACtalk Integrator (BTI) to a BACnet/IP or BACnet/Ethernet

wide area network (WAN) that links multiple DDCs to the management level controller.

## Overview of common problems

Here's a short list of problems that can pop up in building control systems.

- At the lowest level, a sensor or actuator may fail due to aging, stress or inadvertent physical damage. Some setups fail as a result of communication cabling or downstream devices. These failures are typically signaled by a flashing LED.
- Yellow or red alarms frequently flash on workstations in the management control room, indicating that a field controller is not receiving an acceptable value from a sensor.
- Individual DDCs may generate alarms if a certain panel or a certain building is not communicating.
- Similarly, the management-level workstation may generate error messages if it becomes disconnected from one or many buildings.
- In other cases, problems may be randomly called in by occupants—a room is too hot or too cold.

With all these different alarm indicators and potential problems, how do you solve them? Where do you start?

## Problem sources and categories

These problems may arise from a wide range of sources. Starting at the lowest level, there may be a failure in the equipment or the sensor or actuator. There could be a problem with the cabling running from the sensor to the field controller. Something may have gone wrong in the control loop, such as that the process feedback is going to the wrong panel because it was never wired properly and commissioned on startup. Or a field

controller panel may have failed and the DDC controller itself may have failed.

There could also be problems in the network communications between the field controller and the Ethernet/IP backbone. Communications problems usually fall into one of three categories: cabling infrastructure, signal transmission and networking protocols. Communications problems also occur in the Ethernet/IP backbone.

Besides the three basic network problems mentioned above, backbones are also prone to configuration errors that usually fall into the information technology (IT) domain. Finally, the management level controller may experience configuration or other problems.



Using the automatic network-test function on the Fluke 125 ScopeMeter® Test Tool.

## How to narrow it down

Modern building control systems are often so complex, the first challenge a troubleshooter faces is determining specifically where the problem is at. If applicable, a good starting point is to log into the central management controller to get a bird's eye view of the problem.

**Controller checks.** The controller might show you that communications are cut off from a section of the building, or the whole building or the complete campus. If it's isolated to a section of the building, the most likely source is the field controller panel, analog circuitry or the sensor or actuator itself. If the entire building is dark, then the network communications between the management level controller and the DDC, network routers or switches should be the first suspects. On the other hand, if you can't see the entire campus, you should immediately suspect a problem on the Ethernet or IP backbone.

**Ethernet checks.** If it looks like a building-level or campus-level communications problem, take a look at the Ethernet network. A good first step is to verify operation by checking the network connectivity icons or Ethernet port link status LED's. Next use a network troubleshooting tool like a Fluke Networks EtherScope. The EtherScope can connect to a copper, fiber or wireless Ethernet network and quickly give you a broad overview of critical network performance parameters, including protocol alarms and errors, visibility of all switches and VLANs, routers, access points and IP devices. The alarms, errors and protocol information can help localize the problem down to a subnet, port, even part or controller or particular device.
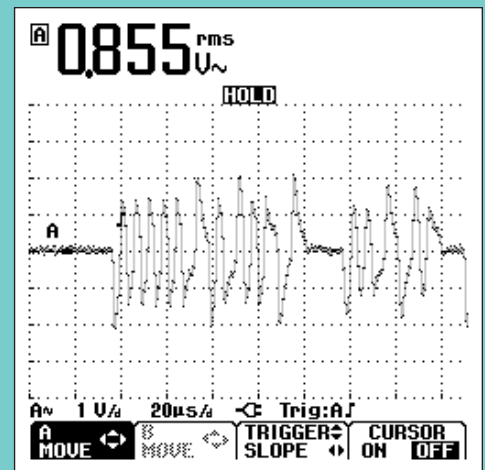


**Figure 2.** Bus test screen and distorted waveform screen from a Fluke 125 ScopeMeter® Test Tool.

**Cabling checks.** Once the problem is isolated, start by checking the cabling connecting the problematic devices. For twisted pair cabling (UTP), use a cable analyzer such as the Fluke Networks Cable IQ or DTX CableAnalyzer series. These tools will find common problems like opens or shorts and will verify the cable's electrical performance. If the network is built on standard AWG cabling, use a precision low ohms digital multimeter to check for basic cable opens and shorts and impedance problems.

**Signal checks.** If the cabling checks out OK, then check the quality of the communication signals traveling on the network by using an oscilloscope to capture the waveforms. The Fluke 125 ScopeMeter® test tool, an easy-to-use oscilloscope with automatic Connect-and-View™ mode to capture waveforms, now has a network bus health, physical layer test function. The scope will help you determine whether signals are getting through at all, and if they are, whether they are attenuated or too distorted to be read clearly, in which case, something is disturbing the line.

**Intermittent problems.** Intermittent problems are usually the most difficult to troubleshoot, because techs can't just stand around hoping to catch the error when it randomly happens. They need a logging multimeter or oscilloscope that they can connect to the circuit in question, leave to monitor, and then when the problem surfaces, if there was an analog or network component the logger will have caught it. Turning to digital multimeters or oscilloscopes with recording or trend capture modes can save many hours and frustration, waiting for a problem to occur.

Problems like these are sometimes caused by degradation of equipment, controls or cabling due to vibration or environmental changes. Another possible cause is installation errors, most commonly during tenant improvements. Such errors include running unshielded network cabling near a high voltage source or an inductive load, using incorrect cable type or installing an excessively long cable run.

**Figure 3.** The Fluke 773 Milliamp Clamp includes both milliamp and low voltage measurement and sourcing.

**Power problems.** Power issues can also cause devices to intermittently trip or fail altogether. If there has been a building or system upgrade recently, the old power supply may be overloaded or unbalanced. Or, the new controls may either require cleaner power than the old electrical distribution system can deliver, or, new electronic equipment may be introducing harmonic disturbances into the power supply. In some cases, retrofits will take a while to cause failures, making the cause less obvious. If you suspect power supply problems, use a power quality analyzer to measure and log voltage, current, dips, swells, interruptions, harmonics, inter-harmonics, flicker, power, energy, transients, frequency, unbalance, inrush, etc.

**Analog checks.** Troubleshooting analog problems is also a frequent step, given the multi-layered control system. Again—localize the problem before you start. If the problem is only occurring in only one segment of the building, it's far more likely to have an analog component since that's the most local part of the building control architecture (Figure 1).

Sensors communicate by converting their output signal to a 4–20 mA dc current, with 4 mA representing the sensor's zero-level output and 20 mA representing the sensor's full-scale output. Other systems use 1 V dc to 5 V dc or 0 V to 10 V dc circuits in a similar fashion. Occasionally, the 4–20 mA signal is converted to a 2 V dc to 10 V dc signal by adding a 500 ohm resistor across the load.

The fastest troubleshooting route here is to use a milliamp clamp meter to measure the current or voltage between the sensor or actuator and the field controller and a voltage and current sourcing tool to simulate control signals back into the controller. The technician will need to know what the circuit should read, based on the desired control operations.

The Fluke 773 Process Milliamp Clamp Meter can both measure the milliamp signal as well as source the 4–20 mA and 1–5 or 0–10 V signals.

If the problem lies within the circuit, use a mA or voltage sourcing tool to further test the line. If the problem traces back to the sensor, use humidity, temperature, pressure, or other measurement devices to verify the accuracy of the sensor reading. Other possible problems include bad I/O cards, isolators, power supplies, and transmitters.

## Conclusion

As building control systems become more powerful and complex, technicians need to broaden their troubleshooting scope and skills. Move beyond electrical and mechanical solutions to consider communications. This is an opportunity for both in-house staff, as well as specialty contractors to expand on their troubleshooting skills with the proper test tools.

The best reason for bringing these skills onto your team is to solve conflicts between equipment from multiple manufacturers. When systems collide, it leads to extra costs, finger-pointing, and extended resolution time. The best solution is for the primary technicians to upgrade their skills and be prepared to find and solve problems at any point in the building control system.