

# the EXTENSION

A Technical Supplement to Control Network

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## Specifying a Direct Digital Control (DDC) System

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### Introduction

Direct Digital Control System (DDC) is a term frequently found in building automation specifications. According to Levenhagen and Spethmann, “Direct Digital Control is the use of computers or microprocessors in conjunction with sensors and actuators to provide closed-loop control.” Over the last sixty years, control systems have evolved from pneumatic to electronic to micro-processor-based controls while reducing costs and improving performance. In order to ensure successful installations while bringing discipline to the process of specifying the new generation of controls, guidelines have been developed in the industry to assist owners, engineers, contractors and subcontractors in the specifying process. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) have produced an interesting guideline which will be explored.

### ASHRAE Guideline 13-2000

ASHRAE developed a guideline in 2000 entitled Specifying Direct Digital Control Systems. They have a slightly different definition of a DDC:

*A DDC system is composed of both hardware and software combined to produce a seamless architecture that provides complete integration of a building’s HVAC systems and may include control over or monitoring of lighting, security, and fire systems in the building. The DDC system can continuously and automatically monitor and—through control of the HVAC mechanical and refrigeration systems—maintain desired ambient temperature, static pressure, relative*

*humidity, indoor air quality, and energy management.*

ASHRAE has widened the definition of a DDC to encompass the complete building automation system. A DDC is not just one controller but a combination of controllers and other devices within a building. They refer to this model as a distributed control system supervising the actions of several individual HVAC control systems that process data close to the location of their inputs and controlled outputs. In fact, these subsystems may not be HVAC-centric since the guideline mentions other systems such as fire, lighting and security. This may not be so surprising since ASHRAE developed its 135 standard entitled *A Data Communications Protocol for Building Automation and Control Networks*. This standard is known as BACnet and was revised in 2004 and will continue to be revised. With this standard, all BACnet compliant devices can participate within one large control system even though these devices can attach to individual controllers within the system.

Unlike ASHRAE standard 135-2004, ASHRAE Guideline 13-2000 is just a *guideline* and not a *standard*. However, it provides good reading for those

who want to understand how building automation systems are specified among owners, engineers, contractors and subcontractors. The guideline is not restricted to only BACnet systems since proprietary control systems and networks are addressed as well.

### DDC Components

The guideline is under 100 pages long and introduces some definitions that are used throughout the document. The DDC system as defined by ASHRAE is actually a distributed control system with several distributed control components as shown in Figure 1 below. The list of components is as follows:

#### Distributed Control Components

- Building Controller (BC)
- Custom Application Controller (CAC)
- Application Specific Controller (ASC)
- Other Communication Devices
- Operator Interface (OWS)
- Input/Output (I/O) Devices

Although Ethernet is shown at the top, it is probably better represented as Ethernet TCP/IP since this is the network of choice at the highest level.

This level is called the supervisory or information level. Earlier BACnet implementations supported Ethernet but not TCP/IP. Later versions of BACnet now support the IP protocol. This top network connects all the building controllers together allowing for the coordination of clusters of control and the sharing of sensor data. Operator workstations reside at this level. The building controllers could have a lower-level network

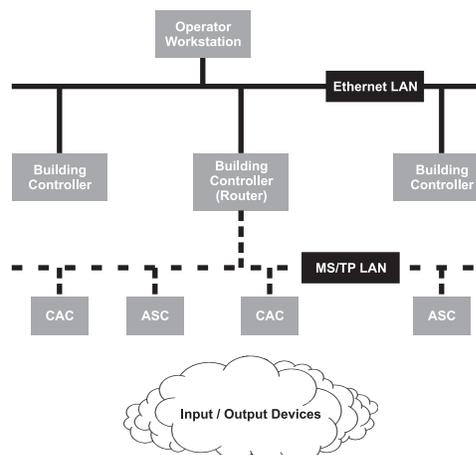


Figure 1 – Distributed Control Components

attached which is called a controller-level network. These control networks can be open such as BACnet's MS/TP and LON, semi-open as Johnson Control's N2, or closed with the equipment vendor providing a proprietary network. If BACnet compliance existed at both the supervisory and control levels, a router would be needed to pass data between the two networks since the two networks use the same protocol. Figure 1 shows an internal router as part of the building controller. An external router is also a possibility. If the supervisory network and control network did not use the same protocol, a gateway would replace the router in Figure 1. Like routers, gateways can be built into the building controller or standalone. Routers and gateways are considered communication devices.

Figure 1 shows several custom application controllers and application specific controllers all sharing a common—in this case, Master Slave/Token Passing (MS/TP) control network. This is not always the case. There could be several separate control networks each connected to individual building controllers. The networks may not even be MS/TP.

The remaining piece of the puzzle is the input/output devices that can reside anywhere within the network. These devices can connect as individual points on the BC, CAC or ASC. They can also attach as a proprietary fieldbus sharing a two-wire network to any of these controllers.

What Figure 1 does not show is the potential flattening of the network. It is possible to eliminate the control network by putting all controllers and I/O devices on the Ethernet network. Currently, the cost of this approach plus the concerns for network security has limited the use of this option.

### Building Controller

The building controller is key to making everything happen. It has several attributes.

- Functions as a general purpose programmable controller
- May or may not have input/output points

- Can connect to control network of custom application controllers or application specific controllers
- Reside on the same information or supervisory network as PCs, operator workstations, and other building controllers
- Coordinates the activities of other controllers on its attached supervisory network through scheduling, alarm processing, trending and sequencing.

It is not common to find industrial automation programmable logic controllers (PLC) used in building automation even though their functions are similar. The building controller must provide graphics to the operator, must be programmable, must sequence actions, must implement control loops, must report alarms, and must schedule operations and trend data if necessary. Some building controllers have no local I/O but usually have an option for attaching local I/O.

### Custom Application Controller

The ASHRAE guideline introduces another controller with characteristics that differ from that of a building controller. This controller usually comes with mechanical equipment that is being installed as a sub-system on the job site. Its characteristics are as follows:

- A device that normally controls specific pieces of complex, custom equipment, such as an air-handling unit (AHU) or cooling tower
- Controller usually comes from the equipment manufacturer and can be programmed in the equipment manufacturer's language
- Usually resides on the control network but sometimes can be attached to the supervisory network
- Although it can operate its mechanical equipment stand-alone, it usually receives commands and instructions from the building controller

A custom application controller may not have an open-systems interface such as LON or BACnet so a gateway may be required for interfacing it

to the building controller. This type of controller is intended to control a sub-system and not the complete building.

### Application Specific Controller

The last controller is the application specific controller. At first we may think it is the same as the custom application controller, but its functionality is more restricted as seen below.

- A device that controls a single piece of equipment such as a variable-air-volume (VAV) box, chiller, rooftop units (RTU), or heat pump
- The controller comes with pre-programmed control algorithm and can only be configured—usually in the field
- More economical than a custom application controller but less flexible

The application specific controller is a bit different. It usually comes with a *canned* program or control algorithm suitable for a single application. There is no programming required, just configuration. Sometimes these controllers are called *unitary* controllers since they do a single function. These are OEM products that are mass produced.

With all sub-systems having their own proprietary controls, other controllers are needed to command them on and off or to modulate them. This type of control strategy is called *supervisory control*. Some people would call it Supervisory Control and Data Acquisition (SCADA). With a SCADA system, failure of the supervisory control will not render the sub-systems useless. They can continue to operate at last set point or at a minimum level of performance. In this way we do not have runaway boilers or frozen pipes in the event of a building controller failure or network failure.

### Other Communication Devices

Besides controllers, there could be other equipment simply used to facilitate communication networks. This is a catch-all category for non-controller and non-I/O items.

- Usually referred to as a communications gateway or router
- Used to connect legacy equipment with proprietary protocols to open protocols
- Could be used to interface packaged chillers and boilers to the main system
- Sometimes it is a router between two different data links
- Router/gateway functionality could reside in building controllers

The “other communications devices” could include infrastructure items such as Ethernet switches. However, the intent of this category is to identify routers and gateways.

### *Input/Output Devices*

There can be no system without input/output devices. The DDC equipment must be able to convert physical measurements into data with sufficient resolution and accuracy in order to make reliable control decisions. Likewise, the DDC must output data with adequate precision to affect control. I/O devices do the following:

- Make connections to real-world input sensors and output actuators
- Input sensors can sense temperature, pressure, humidity, air and water flow, equipment status, utility metering data, and alarms
- Outputs include the start/stop of equipment, modulation of dampers, valves, pumps, and fans

The guideline lumps all the real-world inputs and outputs into one category. These field devices must connect to the various controllers either directly as local I/O, through a proprietary fieldbus, or through either the control or supervisory control network.

### *Operator Interface*

When the guideline talks about “single seat,” it means that it is possible to view all equipment from one operator interface. With different proprietary systems in the building, this is not always possible. The drive

for BACnet was to correct this one deficiency. Operators want to see all the various processes from any operator interface on the network. Vendors have charged for “seats,” but the web browser has discouraged this practice. Customers want to see any process from any browser. A PC running a browser has become the operator workstation.

### **Developing a Specification**

The guideline includes a sample specification following the format determined by the Construction Specifications Institute (CSI). This format is commonly used in the construction industry.

#### *Construction Specifications Institute*

According to CSI’s web site ([www.csinet.org](http://www.csinet.org)), CSI is a national association dedicated to creating standards and formats to improve construction documents and project delivery. With MasterFormat, CSI™ has provided a common system of organizing and presenting construction documents. MasterFormat 1995 provided 16 Divisions of construction information with building automation equipment usually specified in Division 15. Each division has sub-divisions for more refined specifying.

In 2004, MasterFormat was extensively expanded into 50 divisions, but the industry has not fully embraced the expanded scope and still uses the older format. In fact, ASHRAE 13-2000 is based upon MasterFormat 1995 and there is currently no intention to reprint the standard using the newer categories. Go to the CSI web site to locate the relevant divisions and sub-divisions for building automation.

#### *Specification Format*

By using the CSI format, the specification provides a consistent organization and appearance. There are several sections to the specification, but they are all organized in a similar manner. The guideline suggests that the author answer three questions when developing a section.

- What interrelationships exist between the work of this section and the remainder of the project?
- What materials and products are involved?

- How are they incorporated into the work?

The answers to these questions should be grouped into three parts under each section.

- Part 1: General
- Part 2: Products
- Part 3: Execution

Using the above format, the guideline develops the relevant sections and provides recommendations for the various parts. Part 1 discusses codes and standards, system performance (in terms of measurement accuracy and controllability), drawing submittals, quality and warranty. Part 2 provides detailed specifications for the various types of distributed control components, sequence of operation, alarm requirements, and the type of cabling used. Part 3 talks about workmanship, wiring practice, tagging and labeling, system checkout and acceptance. There is plenty to specify and the guideline does a good job of identifying all the issues.

### **CtrlSpecBuilder™**

Developing a specification from the guideline is still a daunting task, but an extremely useful tool can be found on the Internet at [www.CtrlSpecBuilder.com](http://www.CtrlSpecBuilder.com). This site, administered by Automated Logic Corporation (ALC), allows anyone to write a building automation specification based upon ASHRAE 13-2000. Instead of doing tedious editing, the user just needs to fill in the blanks. The result is a Microsoft® Word compliant specification along with either an Autocad® or Microsoft Visio schematic drawing. If necessary, all the documents can be edited once they are downloaded from the site. What is even better is that it is all free!

You can become a ASHRAE 13-2000 expert without ever reading the guideline.

The control system being specified does not need to be BACnet, but it was clearly developed to support BACnet systems. Your detailed specifications can be stored on the site, but there is no necessity to do so. Specifications are not shared unless the user allows for sharing. ALC added some technologies that

either did not exist or were not popular when the guideline was written in 2000. However, the site is vendor neutral. No bias is given to any particular equipment vendor.

There is a five-point process involved before you are able to print out your custom specification. The five steps are as follows:

1. Enter basic project information.
2. Select equipment and options to generate control sequences and points list.
3. Select specifications options.
4. Preview the specifications online.
5. Download specifications in Microsoft Word and drawings in AutoCAD or Microsoft Visio.

Once you print out your project, you will have a title page customized to the job. The CSI sub-division is on top along with the name of the sub-division. You have a choice of using MasterFormat 1995 or 2004. We decided to use the 2004 format and noticed that the title to our specification was "23 09 00 Instrumentation and Control for HVAC." Also on the title page was the project name and number we assigned to our virtual project. Our name was included as the submitter.

The Table of Contents listed two sub-divisions. The first was 23 09 23 Direct Digital Control System for HVAC that had three parts—1: General, 2: Products and 3: Execution. Under each part were sub-parts consistent with ASHRAE 13-2000.

The second sub-division was "23 09 93 Sequence of Operations for HVAC Controls." This section only had Part 1: General.

Once you examine the body of the specification you will notice sections

Point Name	Hardware Points				Software Points				Show On Graphic	
	AI	AO	BI	BO	AV	BV	Sched	Trend		Alarm
Zone Temp	x							x		x
Zone Setpoint Adjust	x									x
Mixed Air Temp	x							x		x
Return Air Temp	x									x
Cooling Valve		x						x		x
Heating Valve		x						x		x
Mixed Air Dampers		x						x		x
Zone Override		x						x		x
Freeze/Stat		x						x	x	x
Supply Air Smoke Detector		x						x	x	x
Supply Fan Status		x						x		x
Supply Fan Start/Stop			x					x		x
Economizer Zone Temp Setpoint					x			x		x
Schedule								x		
Heating Setpoint								x		x
Cooling Setpoint								x		x
High Zone Temp									x	
Low Zone Temp									x	
Supply Fan Failure									x	
Supply Fan In Hand									x	
Supply Fan Runtime Exceeded									x	
High Mixed Air Temp									x	
Low Mixed Air Temp									x	
High Return Air Temp									x	
Low Return Air Temp									x	
<b>Totals</b>	<b>4</b>	<b>3</b>	<b>4</b>	<b>1</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>14</b>	<b>11</b>	<b>15</b>
Total Hardware ( 12 )		Total Software ( 27 )								

Table 1 – Point List example

that were left blank. These sections are specific to the job and must be filled in by the submitter. Other sections have been filled in for you by the program. For example, the reporting accuracy of measurements is right out of 13-2000. It is best to review this section to see if you agree with the accuracy requirements.

The section on operator interface was interesting. Although 13-2000 only mentions the requirement of PCs attached to the same network as the building controllers, CtrlSpecBuilder was much more specific in the performance of the PCs by specifying processor speed, memory and drive sizes. A browser was required to be installed on the PC. This section mentioned the latest BACnet standard which was not in existence during 2000, then discusses programming languages and operating systems. To some this may appear to be over-specifying, but it is an excellent opportunity to review the importance of these issues to the success of the project. You can always edit the document to suit your needs since you are given a Word compatible file.

The second sub-division is also very interesting. This is where you receive your point list and sequence of operation based upon the type of equipment you specified in the five-step process. A copy of the point list is shown in Table 1.

There is much to learn by going through the process of specifying a system. You can make changes to your system and rerun the job and then note what changes. This is a better way to learn 13-2000 then simply studying the guideline.

### Conclusion

Depending upon the size of a building automation system, specifying a DDC can become a complex chore. ASHRAE Guideline 13-2000 provides good guidance in what is required to ensure a successful project. However, CtrlSpecBuilder automates the process with an excellent online tool available at no cost.

### References

*HVAC Controls and Systems*, John I. Levenhagen and Donald H. Spethmann, McGraw-Hill, Inc. 1993

*Specifying Direct Digital Control Systems*, ASHRAE Guideline 13-2000

*BACnet—A Data Communications Protocol for Building Automation and Control Networks*, ASHRAE Standard 13-2004

MasterFormat, www.csinet.org, Construction Specifications Institute

CtrlSpecBuilder, www.CtrlSpecBuilder.com, Automated Logic Corporation



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