



Lighting Control Protocols

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Publication of this Technical Memorandum has been approved by the IES. Suggestions for revisions should be directed to the IES.

**Prepared by:
The IES Controls Protocol Committee**

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Contents

Foreword	1
1.0 Introduction	1
1.1 Scope	1
1.2 Document Structure	1
2.0 Core Definitions and Concepts	2
2.1 Ballast/Driver/Transformer	2
2.2 Bus	2
2.3 Controller	2
2.4 Gateway	2
2.5 Graphical User Interface (GUI)	2
2.6 Network	2
2.7 Physical Layer	2
2.8 Program	3
2.9 Protocol/Communication Mode/Method	3
2.10 Multiple Protocols in One System	3
2.11 Open vs. Proprietary Protocols	3
2.12 Topology	3
2.13 User	3
3.0 System Lighting Control Architectures	4
4.0 Technologies for Dimming Control of Light Sources	6
4.1 2-Wire Line Voltage Forward Phase Control for Dimming	6
4.2 2-Wire Line Voltage Reverse Phase Control for Dimming	6
4.3 3-Wire Line Voltage (Power or Class 1) for Fluorescent Dimming	7
4.4 4-Wire Low Voltage 0–10VDC (Class 2) for Fluorescent Dimming	7
4.5 DALI (Class 1 or 2) for Fluorescent Dimming	7
4.6 Pulse Width Modulation (PWM) for LED Dimming	7
5.0 Topology	7
5.1 Daisy Chain / Line	8
5.2 Bus	8
5.3 Star (Hub and Spoke)	8
5.4 Ring	8
5.5 Mesh	8
5.6 Free (Topology Free)	9
6.0 Physical Layer	9
6.1 RS232	9
6.2 RS485	9
6.3 Ethernet	9
6.4 USB	10

7.0	Protocols	
7.1	0-10VDC Front End (Current Source)	10
7.2	ACN	10
7.3	ASCII	10
7.4	BACnet	10
7.5	DALI	11
7.6	DMX512	11
7.7	EnOcean	11
7.8	Konnex	11
7.9	LonWorks	11
7.10	MIDI and MIDI Show Control	11
7.11	Modbus	12
7.12	RDM	12
7.13	SMPTE	12
7.14	TCP/IP	12
7.15	XML	12
7.16	ZigBee	13
7.17	Z-Wave	13
8.0	Commissioning	13
	Reference Standards	13
Appendix A	– Physical Layers	14
A.1	2-Wire Line Voltage Forward Phase Control for Dimming	14
A.2	2-Wire Line Voltage Reverse Phase Control for Dimming	16
A.3	3-Wire Line Voltage (Power or Class 1) Fluorescent Dimming	16
A.4	4-Wire Low Voltage 0–10VDC (Class 2) Fluorescent Dimming	16
A.5	DALI (Class 1 or 2) Fluorescent Dimming	17
A.6	Pulse Width Modulation (PWM) for LED Dimming	18
A.7	MIDI and MIDI Show Control	18
A.8	RS232	19
A.9	RS485	20
A.10	USB (Universal Serial Bus)	20
Appendix B	– Protocols	21
B.1	0-10VDC Front End (Current Source)	21
B.2	ACN	22
B.3	ASCII	22
B.4	BACnet	23
B.5	DALI	24
B.6	DMX512	24
B.7	EnOcean	26
B.8	Konnex	26
B.9	LonWorks	27
B.10	MIDI and MIDI Show Control	27
B.11	Modbus	28
B.12	RDM	29
B.13	SMPTE	29
B.14	TCP/IP	30
B.15	XML	31
B.16	ZigBee	32
B.17	Z-Wave	32

FOREWORD

This document is intended to serve as a technical resource for lighting specifiers integrating control into their projects. Lighting in commercial settings (and to some extent all places) can benefit from a coordinated control strategy for a number of reasons. Designers may wish to use control as a means of ensuring that their design intent for a given space is preserved. Security personnel may opt to use lighting control as a visual indicator of occupancy or to change lights in an emergency scenario. This can take the form of luminaires that energize on a schedule to indicate spaces where occupants are expected, or, in the converse, as an indication that people are in spaces where they are not expected.

As energy use codes have become more stringent, control has become a recognized means of reducing electrical consumption. Some form of control is now mandated in many state and local codes and ordinances. Control has been recognized as a component feature of overall energy efficiency by many certifying and accreditation agencies, e.g., Green Building Certification Institute (GBCI).

Lighting control can provide a means of giving workers input into their environment. This becomes increasingly necessary as specifiers are asked to consider the visual requirements for a work force that contains both aging and younger workers. The often conflicting visual needs throughout the demographic range of the North American corporate workforce require a solution that allows individuals to alter their visual environment to suit their physical needs as well as the requirements of a variety of tasks.

This Technical Memorandum seeks to provide unbiased information about the capabilities and shortcomings of the variety of technologies and approaches that exist and that may be appropriate for the lighting controls. More information on lighting controls, dimming technologies, and other considerations is available from the Illuminating Engineering Society.

1.0 INTRODUCTION

1.1 Scope

The goal of this Technical Memorandum is to increase the basic level of understanding among the various members of the lighting community about the possibilities of control as well as potential applications for those technologies. This increased baseline knowledge will encourage greater coordination

among disciplines and will allow the continued integration of lighting control with other major building systems. Greater integration will ultimately lead to more efficient and healthier buildings enhancing the experience of the built environment for more people.

For the purposes of this discussion, control refers to the systems or commands that regulate the intensity of electric luminaires in response to some stimulus or action on the part of the building occupants. The stimulus can be direct, as when the moving of a switch from one position to the other completes an electrical circuit and causes the luminaires to energize, or it can be less direct and can relate to a variety of states or conditions within or without the physical confines of the space. Among the most common of these types of less direct control stimuli are occupancy, time, motion, and the presence or absence of daylight.

A document cannot possibly serve as the final authority on any topic, especially one that is undergoing as much rapid development as lighting control. Readers are cautioned to use this Technical Memorandum as a starting point toward a greater understanding of the possibilities and limitations of currently available lighting control technologies. For further information or for more technically specific wiring diagrams and rules for implementation, the reader is encouraged to follow the references provided at various points throughout the document.

1.2 Document Structure

Lighting Control technology is constantly evolving. A byproduct of this evolution is that some confusion exists among even experienced professionals as to the specific meaning of certain terms. To allow lighting specifiers with a variety of professional experiences to take part in this discussion, core concepts and terms are defined in the first section of the body of this Technical Memorandum (**Section 2**). These definitions are not intended to restrict the usage or development of language to describe aspects and features of the subject at hand, but rather to provide a common starting point for subsequent discussions in this document.

Basic architecture and associated terms for additional aspects of control can be found in **Section 3**.

A discussion of the available technologies for controlling various light sources including those light sources that do not require a separate technology or interface to be controlled is in **Section 4**.

Topology is a major means of distinguishing types of systems from each other and is covered at some length in **Section 5**.

The Physical Layer, technologies through which system components are connected and communicate, is discussed in **Section 6**.

The various methods for enabling communication among controllable systems – Protocols - are briefly described in **Section 7**.

A discussion of Commissioning, the crucial and often overlooked final stage in the implementation of a lighting control strategy is provided in **Section 8**.

In **Appendix A**, more detailed descriptions of the Physical Layers from **Section 6** are provided.

In **Appendix B**, each type of control protocol is described in terms of its most typical applications, limits, and extents. Important, but sometimes overlooked data is included in a section entitled “Good To Know” at the end of many entries. Networks and other methods of combining systems are discussed in this section as well.

2.0 CORE DEFINITIONS AND CONCEPTS

This section provides key definitions for the understanding of the material in this document.

2.1 Ballast/Driver/Transformer

From the perspective of a control system, ballasts, LED drivers, and transformers all serve a similar function; as an interface between the light source being controlled and the current and voltage being used to power it. The reader should not make the mistake of assuming that all of these pieces of equipment function in the same manner, or even serve the same electrical purpose. Rather, it should be understood that in all cases, the interface serves to translate the effect of the control signal to the lamp electrically, causing it to alter the light level. In this sense, ballasts, transformers, and drivers can be collectively imagined as a “brick” either integral or remote to the luminaire.

2.2 Bus

In general terms, a bus is an electrical scheme to carry power or data. A bus refers to the wires over which control and communications signals are transmitted. A 0-10 VDC pair of wires is the simplest implementation of a bus; two wires carrying analog control currents. In lighting controls, the two wires that transmit the DALI protocol are an example of a digital bus. The different devices, sensors, and ballasts that are controlled by a bus are usually

connected in parallel with the bus so that any single point of failure will not disrupt communications to the other devices on the bus.

2.3 Controller

A Controller is the device that originates a command to execute a lighting change. Most commonly associated with a lighting control station or control console, a controller may also be a sensor or other automatic device operating without human interaction.

In lighting controls applications, the lighting controller usually contains all the instructions for operating all connected lighting fixtures based on information from sensors (occupancy and light, for example) and user switches and dimmers. Most digital controllers will implement one or more protocols that control the operation of fixtures, relays and other devices that are physically and electrically connected to a communications bus.

2.4 Gateway

A gateway is a device designed for interfacing between two communication networks that use different protocols, such as BACnet to DALI, or DMX512 to 0-10VDC. A gateway may contain devices such as protocol translators, impedance matching devices, rate converters, fault isolators, or signal translators as necessary to provide system interoperability. It also requires the establishment of mutually acceptable administrative procedures between both networks.

A protocol translation/mapping gateway interconnects networks with different network protocols by performing the required protocol conversions.

2.5 Graphical User Interface (GUI)

A Graphical User Interface is a screen-based, pictorial or diagrammatic representation of a system. In many lighting control systems, the GUI becomes one point of contact between the system and a user.

2.6 Network

A group of systems that function cooperatively and/or interdependently to provide a chain of command for lighting control.

2.7 Physical Layer

In the context of lighting control, the physical layer refers to the means by which command and communication signals are carried from one network node to another.

2.8 Program

A program is a command or set of commands which are executed according to a pre-defined algorithm. A program may function on a variety of levels but it is the basic command package that directs the lighting control system.

2.9 Protocol/Communication Mode/Method

A communications protocol is a set of standard rules - the syntax, semantics, and synchronization - for communicating over a computer network or a lighting control system or both. The protocol defines the methods for data representation, signaling, authentication and error detection to ensure control or enable the connection, communication, and data transfer between computing or control endpoints. Protocols may be implemented by hardware, software, or a combination of the two. At the lowest level, a protocol defines the behavior of a hardware connection.

Analog protocols are typically one-way (unidirectional) which don't allow for feedback from interfaces, luminaires, or devices.

Digital protocols may be either one-way or two-way. Two-way (bi-directional) protocols allow the luminaire or device to exchange data, reliability rules, or other communications.

Another attribute of protocols is whether they are a streaming (continuous or repetitive) scheme, or a command (command/response) scheme. In a streaming protocol, data is constantly sent, whether or not a change is needed. In a command scheme, the data is sent but not resent unless there is a change (e.g., a preset command), or in the case of bi-directional protocols, a response or request is received by the sender of the original command.

2.10 Multiple Protocols in One System

More than one protocol is commonly involved in the process of taking user (or sensor) input and providing the intended lighting response. In any large, integrated building controls project, multiple protocols may be used in different parts of the project. Even a standalone lighting control solution might combine, for example, DALI to implement addressable dimming at the individual fixture level with BACnet to provide integration with other building systems (such as HVAC). To ensure proper system operation, the specifier needs to be aware of which products use which protocols.

As a general rule, control protocols can be divided into two groups. Front End, which takes input directly from a user or sensor; and Back End, which executes the command electrically.

Front End - Commands originate from User Input in Front End protocols. The "user" may be a sensor or computer in addition to a human pressing a button or moving a slider. The Front End may also accept feedback for display to the user.

Back End - User Front End Commands are executed in Back End protocols. Normally, there is some interface between the Front End and the Back End - dimmers or other electronics. The Back End may also provide feedback which may be conveyed back to the user. An example of a Back End method is the phase control output of a dimmer to a load to change the level of light.

Front Ends and Back Ends may also employ different wiring and other physical characteristics.

2.11 Open vs. Proprietary Protocols

Open protocols are standards that are publicly available and are developed in an open consensus process under the auspices of a recognized (typically not for profit) organization. It is possible that some proprietary Intellectual Property may be associated with the standard, but usually it can be licensed for a reasonable royalty fee or other licensing agreement. Otherwise, such standards can be freely used - any costs are to cover development and administration.

Proprietary protocols may be freely available or may be only implemented through a contract. They are normally developed by manufacturers or individuals, and therefore not developed in an open consensus method.

2.12 Topology (see Section 5)

Topology is the physical or theoretical relationship among the network components. Topology can describe the physical routing of wire or cable from node to node, or the path of logic transmission.

2.13 User

For the purposes of this Technical Memorandum, "User" is either 1) a manual interaction with a control point such as a touch screen, preset station, computer or fader station, or 2) an indirect interaction such as an occupancy sensor, daylight sensor, time clock or other digital interface.

3.0 SYSTEM LIGHTING CONTROL ARCHITECTURES

There are multiple electrical/electronic methods for controlling the light output of a luminaire or light source, but there is a basic architecture that is common throughout. There is a user input – a device or computer command emulating a person or simply a person operating a controller. The controller then communicates to an interface. This interface may simply be a dimmer or may be a more sophisticated

device that communicates with dimmers or other load controlling devices. At the luminaire or light source, there may be a power regulation device (ballast, driver, transformer) or nothing at all. The following figures illustrate various common control architectures. **Figure 1** shows the basic architecture and the various types of control signals that may be present. Virtually any combination of the various elements is possible. When applying any of these elements, it is crucial to understand which technology is required by the specific make and model of the devices involved.

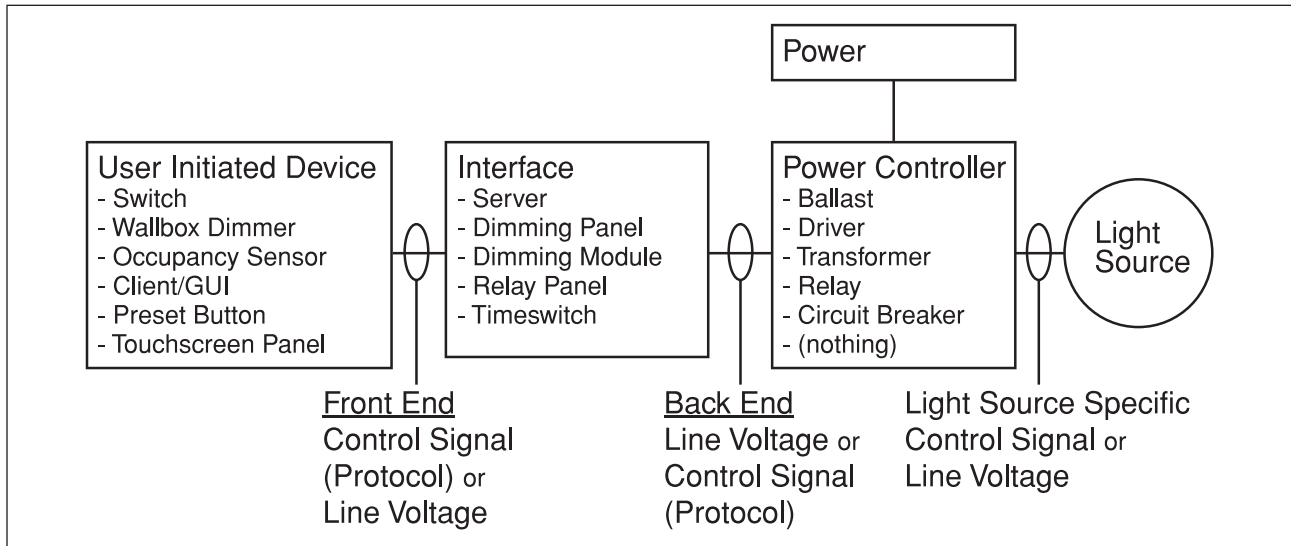


Figure 1. Basic Lighting Control Architecture

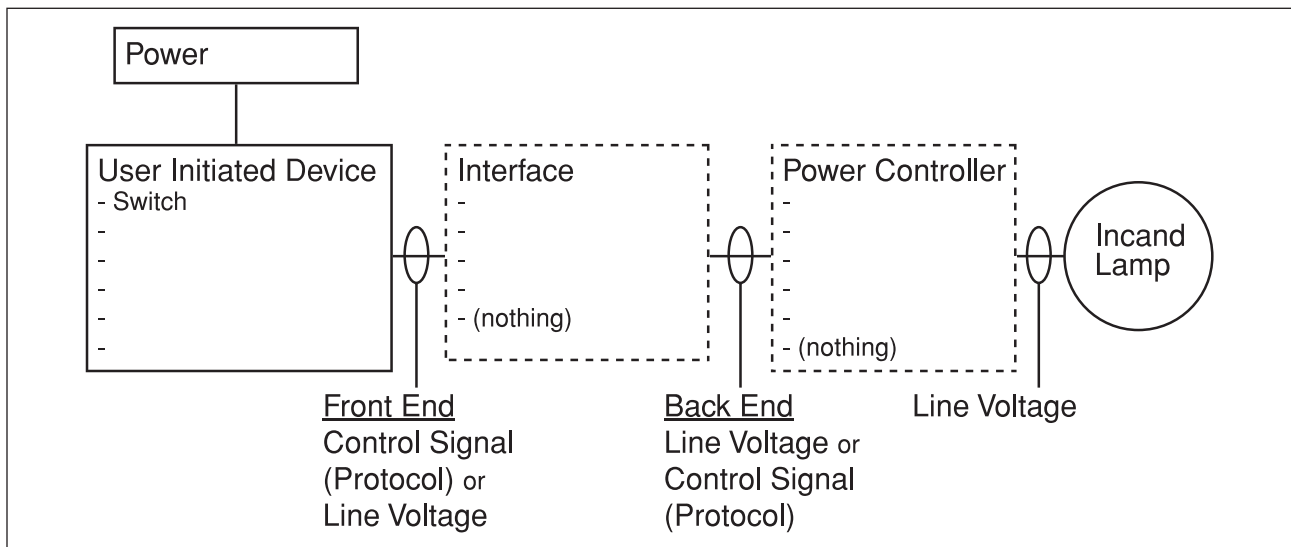


Figure 1a. Wall Switch for Line-Voltage Incandescent Lamp

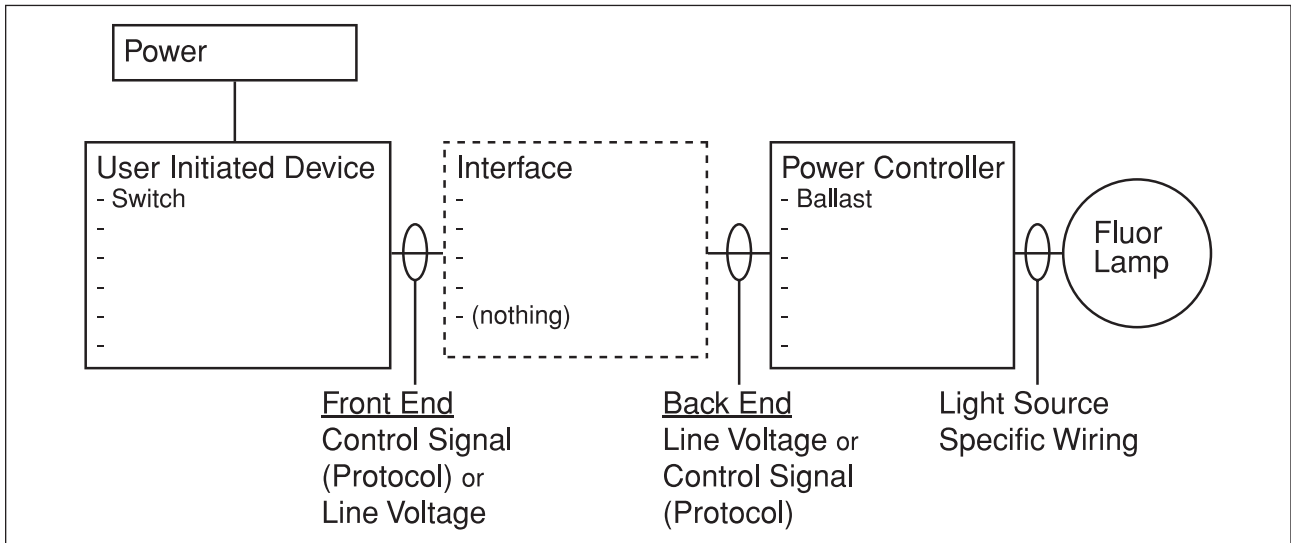


Figure 1b. Wall Switch for Fluorescent Lamp

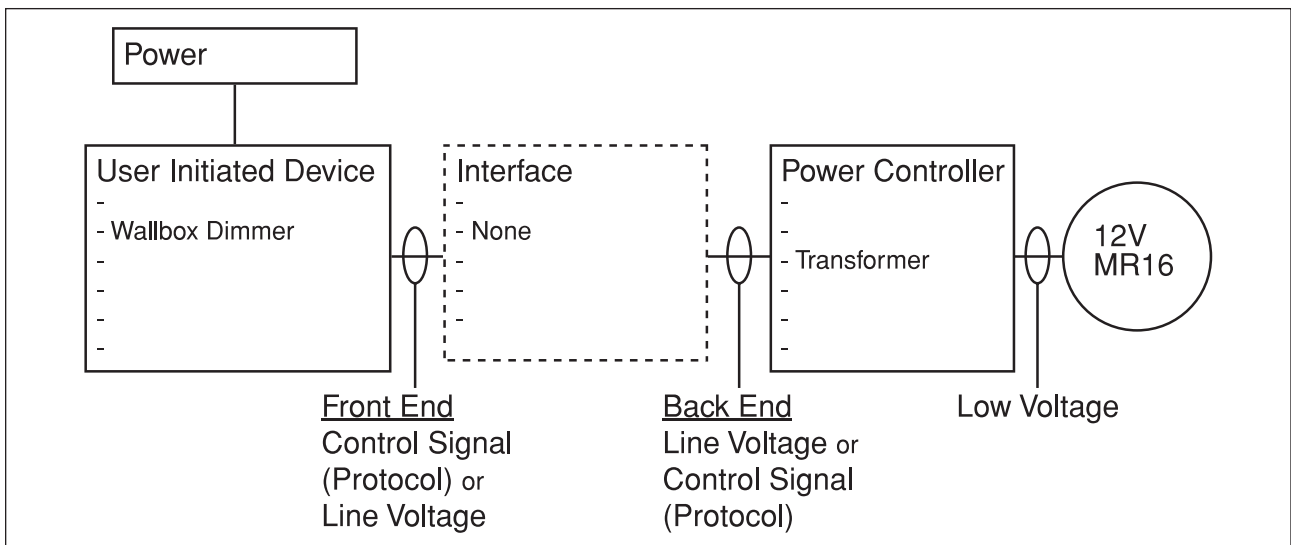


Figure 1c. Wallbox Dimmer for MR16 Lamp

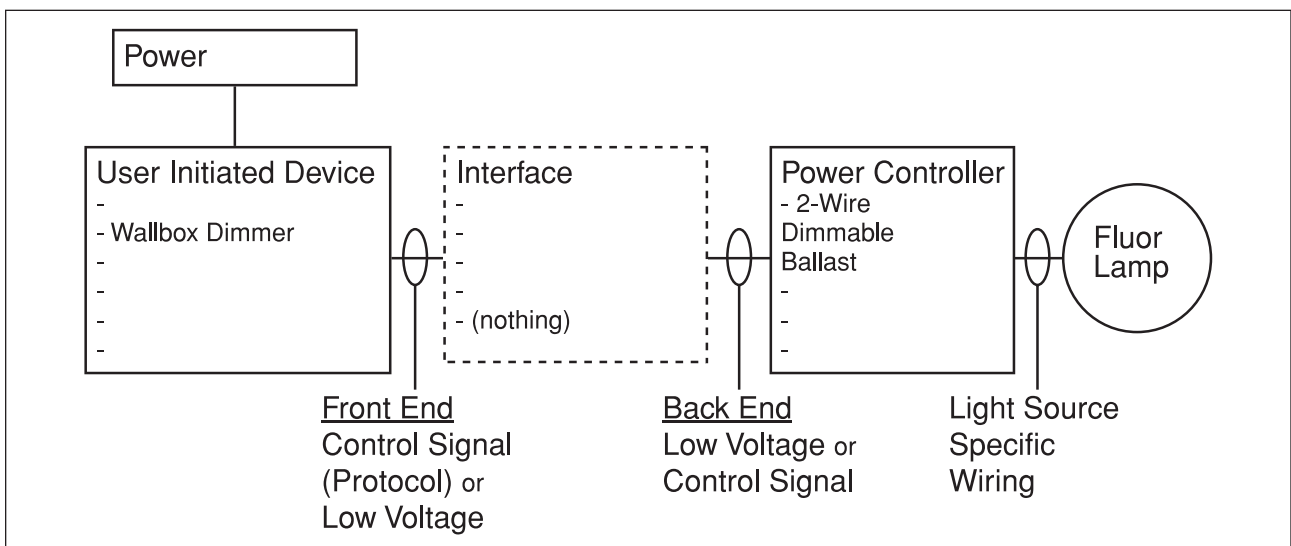


Figure 1d. Wallbox Dimmer for Fluorescent Lamp

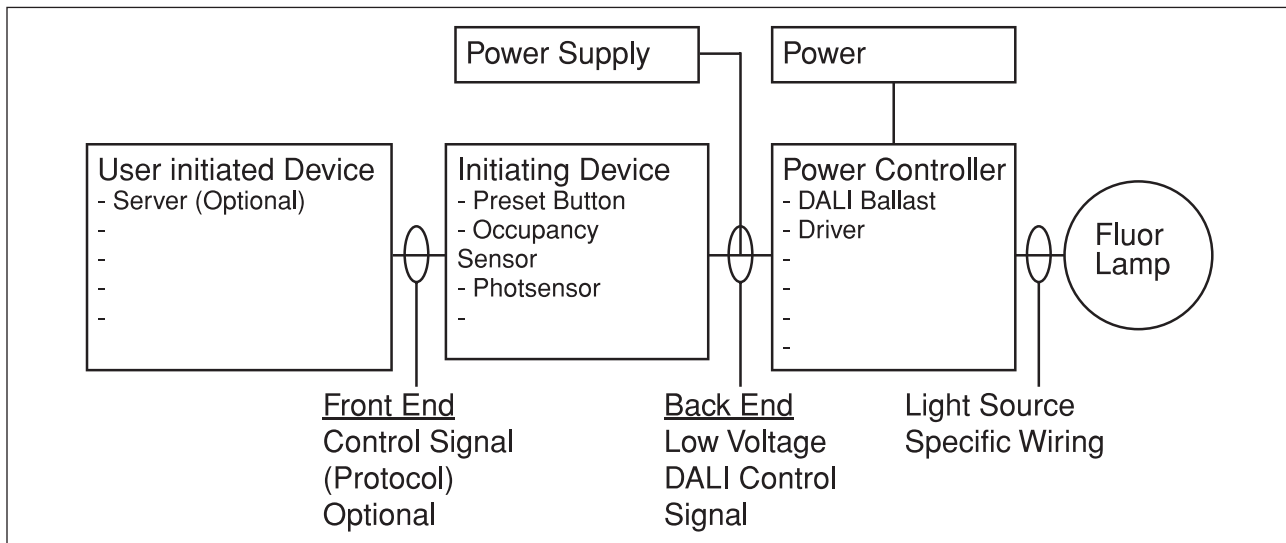


Figure 1e. DALI Dimming System for Fluorescent Lamp

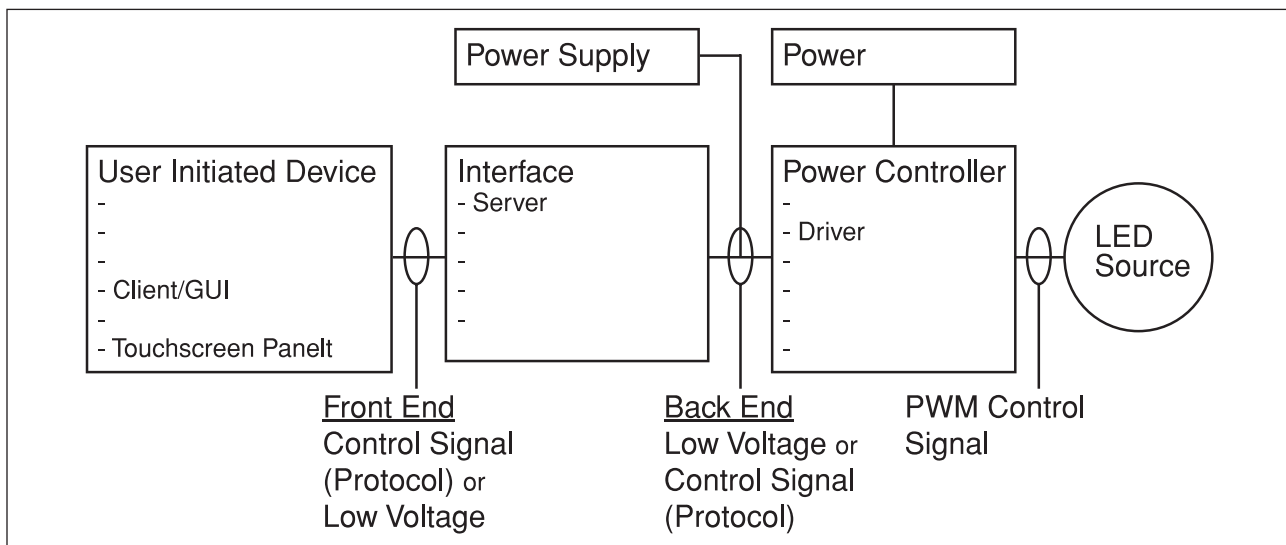


Figure 1f. Dimming System for LED Lamp

4.0 TECHNOLOGIES FOR DIMMING CONTROL OF LIGHT SOURCES

The technologies listed in this section are characterized by their prevailing use, or by their original intent. In actual use, these technologies are applied to different emerging lighting control situations. For example, all of these technologies are used to control various LED drivers.

4.1 2-Wire Line Voltage Forward Phase Control for Dimming

Forward Phase-control dimmers (also known as Leading Edge dimmers) control the amount of voltage available to a light source. The dimmer turns

off part of the leading edge of the AC sine wave for a preset amount of time, resulting in reduced lamp output (dimming). In systems where there is a transformer, ballast, or driver device, the device has to be specifically rated for this type of control. Because constant voltage is not maintained for the ballast or driver, the minimum dimming level will be compromised. This is due to regulation devices requiring a minimum voltage to keep the electronics working. (For more information see **Appendix A.1**).

4.2 2-Wire Line Voltage Reverse Phase Control for Dimming

Reverse Phase-control dimmers (also known as Trailing Edge dimmers) control the amount of voltage available to a light source. The dimmer turns off part

of the trailing edge of the AC sine wave for a preset amount of time, resulting in reduced lamp output (dimming). In systems where there is a transformer, ballast, or driver device, the device has to be specifically rated for this type of control. Because constant voltage is not maintained for the ballast or driver, the minimum dimming level will be compromised. This is due to regulation devices requiring a minimum voltage to keep the electronics working.

4.3 3-Wire Line Voltage (Power or Class 1) for Fluorescent Dimming

The switched hot in a 3 wire fluorescent dimming scheme insures constant voltage to the ballast for cathode heating. One method of 3 wire control dimmers uses forward-phase control dimming across the dimmed hot and neutral wires. Another method uses a Class 1 signal on the dimmed hot wire. In this case, the ballast electronics do the actual dimming. The ballast in each method has to be specifically rated for its particular 3-wire control scheme. Special dimming equipment is required to control these ballasts. (For more information see **Appendix A.2**).

4.4 4-Wire Low Voltage 0–10VDC (Class 2) for Fluorescent Dimming

The switched hot in a 4 wire fluorescent dimming scheme insures constant voltage to the ballast for cathode heating. In this method, the ballast is the current source for the DC signal. Since the dimmer is the point of reference, this Back End method is sometimes referred to as current sinking. In the 0-10 VDC 4 wire method (also known as 1-10 VDC 4 wire since 1 volt is the minimum level signal), the 2 low-voltage wires (violet & gray wires) must be kept separate from the power wiring in the system except at the ballast itself. The control wires are polarity sensitive so accuracy is important in wiring. If the ballast senses a loss of the control signal, the lamps go to full light output. This is described in NEMA ANSI C82.11-2002 High Frequency Fluorescent Lamp Ballasts - Annex A Low Voltage Control Interface for Controllable Ballasts. This protocol definition is also in IEC 60929 Annex E.2. Note that the switch in the dimmer for this application is required to turn off the ballast. In some cases, the 0-10VDC signal could be run as Class 1, but Class 2 is more prevalent. (For more information see **Appendix A.3**). This must not be confused with 0-10V current source applications, found in **Section 7.1**.

4.5 DALI (Class 1 or 2) for Fluorescent Dimming

In a DALI dimming system, two wires provide a constant voltage to the ballast for cathode heating and

to energize the internal electronics. The other two wires, operating at approximately 16VDC, carry a digital signal from controller devices to the ballasts. As a digital device, DALI ballasts have 254 dimming intensity levels with a greater number of its levels in the lower range which better matches the behavior of the human eye. See **Section 7** for additional discussion on DALI as a control protocol. The ballast responds to digital commands on the DALI control wires. The control wires may be installed as Class 1 or as Class 2. If Class 2, the DALI wiring must be run separate from power wiring. If Class 1, the DALI wiring may be run in the same raceway with the lighting branch circuit conductors. Check the National Electrical Code® or applicable local electrical codes for wiring rules. (For more information see **Appendix A.5**).

Note—DALI is a trademark belonging to ZVEI: Zentralverband Elektrotechnik- und Elektronikindustrie e.V.; Stresemannallee 19; D-60596 Frankfurt am Main.

4.6 Pulse Width Modulation (PWM) for LED Dimming

Pulse-width modulation (PWM) dimming is a common method for controlling the brightness of an LED. The LED current level is set and then turned on and off faster than is perceptible by the human eye. The dimming of the LED is approximately proportional to the amount of on time to the amount of off time; for example, the more time the current is on, the brighter the LED appears to be.

The European market has a PWM protocol for the dimming of fluorescent lamps using a PWM dimmable ballast. The control signal is inverse to the dimming, for example, the more time the voltage is on, the dimmer the lamp, and the lesser the time the voltage is on, the brighter the lamp. This dimming protocol is defined in IEC 60929 Annex E.3.

5.0 TOPOLOGY

Topology describes the interconnections of elements in a network (devices, links, nodes etc) that are linked together for communication. A topology can be termed as either physical or logical. Physical topologies represent the wiring of elements. The graphic mapping of the wires between the nodes in a given topology produces a geometrical shape that may be used to describe the physical topology of the network. Logical topologies are used to model data flow between elements. The mapping of the data flows between the nodes in the network determines

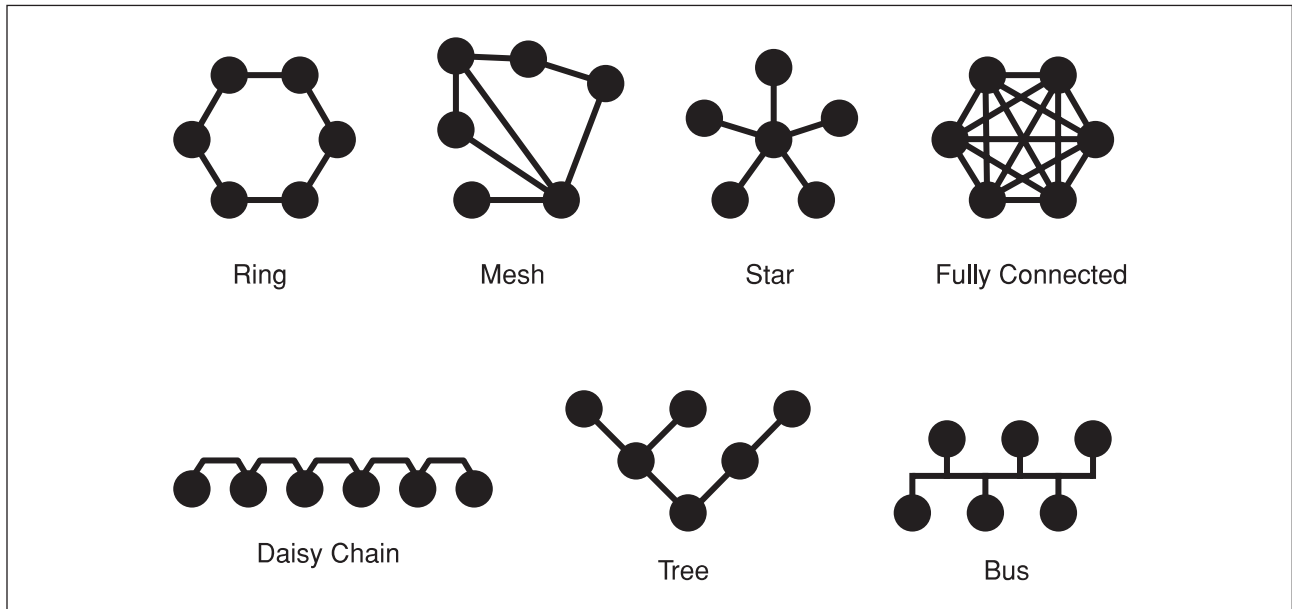


Figure 2. Some examples of topologies

the logical topology of the network. The physical and logical topologies may or may not be identical in any particular network. Distances between nodes, physical interconnections, transmission rates, and/or signal types may differ in two networks and yet their topologies may be identical.

5.1 Daisy Chain

In electrical and electronic engineering, a daisy chain is a wiring scheme in which device A is wired to device B, device B is wired to device C, device C is wired to device D, etc. Connections do not form webs and the communication must pass through each successive node. In the preceding example, device C cannot be directly connected to device A, nor do they loop back from the last device to the first. For example, A-B-C-D-E is a daisy chain, A-B-C-D-E & C-M-N-O (branched at C) is a tree, and A-B-C-D-E-A is a loop or ring. Daisy chains may be used for power, analog signals, digital data, or a combination thereof.

5.2 Bus

In a bus topology, nodes are connected to a single, central data or control source. Information does not need to pass through successive nodes, although all nodes are fed by a common signal.

5.3 Star (a.k.a. Hub and Spoke)

Star networks are one of the most common computer network topologies. In its simplest form, a star network consists of one central switch, hub or computer, which acts as a conduit to transmit messages. Thus, the central and peripheral nodes, and

the physical transmission lines between them, form a graph with the topology of a star (sometimes referred to as hub and spoke).

The star topology reduces the chance of network failure by connecting all of the systems to a central node. When applied to a logical bus-based network, this central hub rebroadcasts all transmissions received from any peripheral node to all peripheral nodes on the network, sometimes including the originating node. All peripheral nodes may thus communicate with all others by transmitting to, and receiving from, the central node only. The failure of a transmission line linking any peripheral node to the central node will result in the isolation of that peripheral node from all others, but the rest of the systems will be unaffected.

5.4 Ring

In a ring network topology each node connects to exactly two other nodes, forming a single continuous pathway for signals through each node - a ring. Data travels from node to node, with each node along the way handling every packet.

Because a ring topology provides only one pathway between any two nodes, ring networks may be disrupted by the failure of a single link. A node failure or cable break might isolate every node attached to the ring. However, several ring network protocols employ methods to overcome this weakness.

5.5 Mesh

Mesh networking is a type of networking wherein each node in the network may act as an independ-

dent router, regardless of whether it is connected to another network or not. It allows for continuous connections and reconfiguration around broken or blocked paths by “hopping” from node to node until the destination is reached. A mesh network whose nodes are all connected to each other is a fully connected network. Mesh networks differ from other networks in that the component parts can all connect to each other via multiple hops. Mesh networks are self-healing: the network can still operate when one node breaks down or a connection goes bad. As a result, the network may typically be very reliable, as there is often more than one path between a source and a destination in the network. Although mostly used in wireless scenarios, this concept is also applicable to wired networks and software interaction.

5.6 Free (Topology Free)

Free topology allows any combination of stars, “T”s, daisy chain, or mesh wiring.

6.0 PHYSICAL LAYER

A network is a group of systems that function cooperatively and/or interdependently to provide a chain of command, in this case, for lighting control. The components of a network can be linked together using cable, a wireless communication device, or other means forming an intricately connected system of devices.

It is common in networking to describe various aspects of communications using a Layer model. There are many different layers in the communications model, as defined in the Open Systems Interconnection (OSI) model. The Physical Layer (PHY) consists of the basic hardware transmission technologies of a network. It is the fundamental layer underlying the logical data structures of the higher level functions in a network. It is, in essence, the road along which data will travel. The physical network is the copper wires, the fiber cable, the satellite signals, or the cellular wireless network signal. The Physical Layer defines the means of transmitting voice or data but does not affect the language spoken by the parties (English, French, etc). The languages themselves are separate from the Physical Layer.

The descriptions that follow refer to the common shapes of the electrical connectors and the cable or wiring requirements they imply. Wireless schemes, which substitute radio transmission rules for physical wiring, are also described. Given the plethora of available technologies and combinations, this can be the most complex part of a networked system. Note

that the higher layer protocol in lighting control may define the Physical Layer. Readers are reminded that, by definition, the physical layer only describes the electrical characteristics of the control signals. It does not describe the informational content of the communication.

6.1 RS232 (Currently TIA-232)

Recommended Standard 232 (RS232) now managed by the Telecommunications Industry Association (TIA), defines the electrical characteristics and timing of signals, and the physical size and pinout of connectors for serial binary single-ended data and control signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). RS232 is commonly used in computer serial ports.

The Standard was originally developed to provide a means of communication between electromechanical typewriters and modems. RS232 is most often used as a baseline level of electronic data exchange between two individual components of a system at a local level.

It must be remembered that RS232 only describes the electrical characteristics of the signal. It does not describe the informational content of the communication. (For more information see **Appendix A.8**).

6.2 RS485 (Currently TIA-485)

Recommended Standard 485 (RS485), currently managed by the Telecommunications Industry Association (TIA), is a network, designed to handle a need for fast communication to a series of devices in a system over a short distance, or slower communication over a long distance. RS485 can be used to communicate among several devices.

It must be remembered that RS485 only describes the electrical characteristics of the signal. It does not describe the informational content of the communication. For example, TIA-485 is the electrical standard behind the protocol DMX512 A, covered elsewhere in this document. (For more information see **Appendix A.9**).

6.3 Ethernet

Ethernet is network technology on which data may be sent and received from each connected unit (frequently called a node). It defines wiring and connection methods as well as basic communication rules for carrying data, but not the final form or meaning of the data. Therefore, Ethernet is always combined with other protocols in order to complete a network.

6.4 USB (Universal Serial Bus)

Universal Serial Bus (USB) was developed by a consortium of computer manufacturers to establish communication between devices and a host controller (such as personal computers). The technology was intended to replace a variety of serial and parallel ports that were being used to connect computer peripherals such as mice, keyboards, digital cameras, printers, personal media players, flash drives, and external hard drives. For many of these devices, USB has become the standard connection method. USB was designed for personal computers, but it has become commonplace on other devices such as smartphones, PDAs and video game consoles. USB can also serve as the power connection between a device and an AC adapter plugged into a wall receptacle, or for a computer or hub to supply power to a remote peripheral.

It must be remembered that USB only describes the electrical characteristics of the signal. It does not describe the informational content of the communication. (For more information see **Appendix A.10**).

7.0 PROTOCOLS

A protocol is a set of rules or guidelines for communication between two or more devices.

7.1 COMMON NAME: 0-10 VDC Front End (Current Source)

FULL NAME/STANDARD TITLE: ANSI E1.3 Entertainment Technology - Lighting Control Systems 0 to 10V Analog Control Specification.

The standard describes a front end/user driven method of controlling equipment by means of a current source analog control voltage in the nominal range from 0 to 10 volts positive. It is often seen in theatrical/entertainment applications (and until the advent of various digital protocols, was one of the most prevalent protocols), as well as in architectural systems.

0-10VDC Current Source is primarily intended for lighting control equipment, i.e., controllers and dimmers, typically found in theatrical control applications.

This must not be confused with 0-10VDC current sink applications typically used in many fluorescent dimming ballasts and some solid state lighting drivers. The current sink method is considered a back-end protocol and is described in **Section 4.4** of this document. (For more information see **Appendix B.1**).

7.2 COMMON NAME: ACN

FULL NAME/STANDARD TITLE: ANSI E1.17 Entertainment Technology - Architecture for Control Networks.

ACN is a suite of protocols that is most commonly used to control theatrical lighting, audio and effects. The standard is maintained by ESTA (Entertainment Services & Technology Association). ACN can be combined and configured with other standard protocols. It can be implemented on a variety of networks, typically using Ethernet. ACN is bidirectional with sequencing and reliability; meaning that ACN equipment advertises itself and is dynamically discovered by controllers. Reliability is achieved by detection and resend of lost or out of sequence packets. ACN equipment exposes "properties" that may have values read or written to. Upon the receipt of a subscription request, ACN equipment will publish changes to "properties" back to the subscriber. ACN contains the definition of an XML based language (DDL) for describing the "properties" of equipment. Any ACN device will give out its DDL file upon request so that a controller can always find out how to control a device it hasn't seen before. (For more information see **Appendix B.2**).

7.3 COMMON NAME: ASCII

FULL NAME/STANDARD TITLE: Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)

ASCII code is the numerical representation of a character such as 'a' or '@' or an action of some sort. It was originally developed in 1963 for use with teletype machines to allow computers to understand and interpret non-numerical characters and instructions. Notepad.exe creates ASCII text, (and MS Word allows you to save a file as 'text only') so that a document or control sequence can be supplied in the raw format which any computer can understand. This is an important means of avoiding compatibility issues when importing files from one application to another. (For more information see **Appendix B.3**)

7.4 COMMON NAME: BACnet

FULL NAME/STANDARD TITLE: ANSI/ASHRAE135 / ISO Standard 16484-5 2003, BACnet® A Data Communication Protocol for Building Automation and Control Networks

BACnet is a communication protocol that is specifically designed to meet the communication needs of building automation and control systems. Applications for this communication include HVAC control, lighting

control, access control, security, and fire detection systems. Development of BACnet began in 1987 and the first standard was published in 1995. ANSI/ASHRAE standard 135 / ISO Standard 16484-5:2003 was developed through a consensus process and is currently under maintenance by an ASHRAE standing project committee. (For more information see **Appendix B.4**).

7.5 COMMON NAME: DALI

FULL NAME/STANDARD TITLE: Digital Addressable Lighting Interface IEC 60929 Annex E - soon to be replaced with IEC 62386 Parts 101 and 102

DALI (Digital Addressable Lighting Interface) is a non-proprietary lighting control protocol standardized by IEC 60929 Annex E, soon to be replaced with IEC 62386 Parts 101 and 102. Under this protocol, two wires which can be installed with the lighting branch circuit conductors are connected to DALI ballasts and DALI controllers. Digital commands (such as On, Off, Dim Up, Go to Scene, etc.) are sent from the controllers over the two communication wires to the ballasts. The protocol is bi-directional, in that commands can query individual ballasts and the specific ballast replies with the requested information such as lamp status or ballast status. Each DALI ballast has a non-volatile memory which contains its own settings, such as address, group assignments, scene levels, and fade rate. This capability allows DALI systems to operate without a mandatory central control unit. (For more information see **Appendix B.5**).

Note—DALI is a trademark belonging to ZVEI: Zentralverband Elektrotechnik- und Elektronikindustrie e.V.; Stresemannallee 19; D-60596 Frankfurt am Main.

7.6 COMMON NAME: DMX512

FULL NAME/STANDARD TITLE: ANSI E1.11 Entertainment Technology - USITT DMX512-A, Asynchronous Serial Data Transmission Standard for Controlling Lighting Equipment and Accessories

DMX512, originally developed in 1986 by USITT (United States Institute for Theatre Technology, Inc.) is a standard that describes a method of digital data transmission between controllers and lighting equipment and accessories, and is considered a Front End method for most applications. It covers electrical characteristics (based on the EIA/TIA 485 A standard), data format, data protocol, and connector type. The standard is intended to provide for interoperability at both communication and mechanical levels with equipment made by different manufacturers.

It also serves in a Back End method for many Solid State Lighting luminaires. (For more information see **Appendix B.6**).

7.7 COMMON NAME: EnOcean

FULL NAME/STANDARD TITLE: EnOcean.

EnOcean is a technology supplier of self-powered modules (transmitters, receivers, transceivers, energy converters) to OEM manufacturers that develop and manufacture products used in building automation (light, shading, HVAC), industrial automation, and automotive industry.

The EnOcean Alliance is a recently-formed industry alliance with responsibility for assuring product interoperability. The EnOcean Alliance has the formal purpose of initially developing the specifications for the interoperability of the sensor profiles for the wireless products operating in unlicensed frequency bands. (For more information see **Appendix B.7**).

7.8 COMMON NAME: Konnex (KNX)

FULL NAME/STANDARD TITLE: Konnex.

The Konnex KNX (standard) was developed as a result of the convergence between the European Installation Bus (EIB), and EHS (European Home Standards Association). KNX claims to be "the world's only open standard for Home & Building control". KNX fully complies with the EN 50090 series, the European Standard for Home and Building Electronic Systems and ISO/IEC 14543. KNX is common in Europe and there are multiple control manufacturers that market systems in the US that use KNX. (For more information see **Appendix B.8**).

7.9 COMMON NAME: LonWorks

FULL NAME/STANDARD TITLE: ISO/IEC 14908-2.

LonWorks is a platform created by Echelon Corporation that is used for the automation of building systems including HVAC and lighting. It includes the protocol and all devices required to control the system. (For more information see **Appendix B.9**).

7.10 COMMON NAME: MIDI & MIDI Show Control

FULL NAME/STANDARD TITLE: Musical Instrument Digital Interface

MIDI 1.0 Detailed Specification ("MIDI") and MMA/AMEI Recommended Practice RP-002 ("MIDI Show Control")

MIDI is an entertainment industry standard protocol that enables electronic musical instruments, computers and other equipment to communicate, control and synchronize with each other. MIDI does not transmit an audio signal or media — it simply transmits digital data "event messages" such as the pitch and intensity of musical notes to play, control signals for parameters such as volume, cues and clock signals to set the tempo. As an electronic protocol, it is notable for its success, both in its widespread adoption throughout the music industry, and in remaining essentially unchanged in the face of technological developments since its introduction in 1983. The MIDI Manufacturers Association (MMA) was formed as an industry user group, and now manages the standard. (For more information see **Appendix B.10**).

MIDI Show Control, or MSC, was developed through a joint venture between the United States Institute for Theatre Technology (USITT) and the MIDI group (MMA). MSC is a significant Real Time System Exclusive extension of the MIDI standard. The MIDI Show Control protocol was ratified as an industry standard by the MIDI Manufacturers Association in 1991. It allows all types of entertainment control devices to talk with each other and with computers to perform show control functions in live and pre-recorded entertainment applications. Just like musical MIDI, MSC does not transmit the actual show media. It simply transmits digital information about a multimedia performance.

(For more information see **Appendix B.10**).

7.11 COMMON NAME: Modbus

FULL NAME/STANDARD TITLE: Modbus

Modbus is an industrial control protocol developed by Modicon (now Schneider Automation) in 1979 for use in its industrial process controllers, and programmable logic controllers (PLC's). The original implementation of Modbus used serial physical layers such as RS232 and RS485, now known as Modbus RTU. Additions to the protocol include Modbus ASCII, using text strings for more complex control messages, and Modbus TCP, using Ethernet networks to send serial-like messages to and from devices. The protocol is now managed by the Modbus-IDA organization. (For more information see **Appendix B.11**).

7.12 COMMON NAME: RDM

FULL NAME/STANDARD TITLE: ANSI E1.20 Entertainment Technology - Remote Device Management over USITT DMX512 Networks

RDM is an extension of USITT DMX512 that describes a method of bi-directional communication over a DMX512/1990 or DMX512-A network. RDM permits a console or other controlling device to discover and then configure, monitor, and manage intermediate and end-devices connected through a DMX512 network, providing for improved control of devices. Since DMX512 is unidirectional and RDM is bidirectional, there are some hardware differences that must be examined if retrofitting RDM into an existing DMX512 system. (For more information see **Appendix B.12**).

7.13 COMMON NAME: SMPTE (Society of Motion Picture and Television Engineers)

FULL NAME/STANDARD TITLE: SMPTE 12M

SMPTE (pronounced "simp-tee") is a time code synchronization protocol originally developed for use in the television and motion picture industry to deal with changing technologies. In lighting control systems, the protocol is typically used to synchronize lighting with video (or film) displays. (For more information see **Appendix B.13**).

7.14 COMMON NAME: TCP/IP

FULL NAME/STANDARD TITLE: Transmission Control Protocol (TCP) and the Internet Protocol (IP).

TCP/IP is the ubiquitous protocol suite used by the Internet, the World Wide Web, and most networked computers for exchanging data. The name, TCP/IP, is a concatenation of two major data communications protocols. TCP/IP includes a set of standards that specify how computers should communicate. In addition, the TCP/IP suite defines conventions for connecting different networks and routing traffic through routers, bridges and other types of connections. It is useful for the layperson to think of TCP/IP as being the operating system that underlies the Internet and the "web". TCP/IP is a mature protocol and virtually all computers capable of operating in a networked environment support it because of its reliability and universality. (For more information see **Appendix B.14**).

7.15 COMMON NAME: XML

FULL NAME/STANDARD TITLE: Extensible Markup Language (XML)

XML or Extensible Markup Language is a standard for document markup endorsed by the World Wide Web Consortium (W3C). It defines a generic syntax used to mark up data with simple, human-readable language. It provides a standard format for computer documents, although this format is flexible enough to be customized to fit web sites, electronic data

interchange, remote procedure calls, lighting controls or voice mail systems. Readers should refer to Internet Engineering Task Force (IETF) RFC 3023 for more information about the use of XML in interchanging data over the internet. (For more information see **Appendix B.15**).

7.16 COMMON NAME: ZigBee

FULL NAME/STANDARD TITLE: ZigBee

ZigBee is a suite of specifications for high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). Development of this standard was undertaken to provide a means of connecting lighting fixtures, sensors and switches into a wireless communication network, without adding expensive cabling to existing buildings. (For more information see **Appendix B.16**).

7.17 COMMON NAME: Z-Wave

FULL NAME/STANDARD TITLE: Z-Wave

Z-Wave is an interoperable wireless communication protocol developed by Danish company Zensys and the Z-Wave Alliance. It is designed for low-power and low-bandwidth appliances, such as home automation and sensor and control networks. Z-Wave networks are 2-way RF with meshing capabilities for powered nodes. The meshing capability routes 2-way command signals from one Z-Wave device to another around obstacles or radio dead spots that might occur. (For more information see **Appendix B.17**).

8.0 COMMISSIONING

Commissioning, in the context of lighting controls, refers to all those activities undertaken to ensure that the building lighting performs and operates according to design intent and Owner Project Requirements. The Commissioning process imposes itself from the development of the early design documents (OPR-Owner's Project Requirements and BOD-Basis of Design) and continues through contract documentation, equipment installation, and through the long-term operation of the building lighting. A distinction should be made between the calibration and adjustment activities which take place immediately after equipment installation and the commissioning of the lighting system as performed by a commissioning agent.

All systems depend upon proper commissioning to function. An occupancy sensor that is not appropriately aimed may respond to movement in hallways,

or in adjacent rooms that can be "seen" through windows; thus negating any practical energy savings. The importance of proper commissioning increases exponentially with system complexity and with the number of building systems that are responding with or to each other. Readers are urged to consider commissioning as a vital part of specification writing and an important expression of the Basis of Design. For further information, see **IES DG-29 – The Commissioning Process Applied to Lighting and Control Systems**. General information concerning the overall commissioning process can be found in ASHRAE Guideline 0-2005 "The Commissioning Process".

Regardless of whether a system functions on a digital or analog network, the same basic functions need to be addressed. Lamps must be matched to each other and seasoned prior to dimming operation, sensors must be properly located and aimed, and pre-set routines must be programmed. Perhaps the most significant difference in commissioning digital systems stems from the inherent 2-way communication abilities of the digital system. Each digital component must be assigned a unique identity which must be integrated into the control system data base. This allows the system to identify not only which component is operating, but the parameters defining the components' operation. Several lighting control companies offer software that accomplishes most of the functionality required to efficiently commission these systems as well as automating other tasks, such as diagnostics, energy monitoring, demand response, etc.

Currently, some LEED (Leadership in Energy and Environmental Design) rating systems require commissioning of lighting control systems including daylighting controls as a prerequisite for certification.

REFERENCE STANDARDS

1. ANSI E1.3 Entertainment Technology - Lighting Control Systems 0 to 10V Analog Control Specification
2. ANSI E1.11 Entertainment Technology - USITT DMX512-A, Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories
3. ANSI E1.17 Entertainment Technology - Architecture for Control Networks
4. ANSI E1.20 Entertainment Technology - Remote Device Management over USITT DMX512 Networks
5. ANSI E1.31 Entertainment Technology - Lightweight Streaming Protocol for Transport of DMX512 using ACN

6. ANSI INCITS 4 - Information Systems – Coded Character Sets – 7-bit American National Standard Code for Information Interchange (7-Bit ASCII)
7. ANSI/ASHRAE 135 BACnet® - A Data Communication Protocol for Building Automation and Control Networks
8. ISO/IEC 14543 - Home Electronic Systems (HES) Architecture
9. ISO/IEC DIS 14908 Parts 1, 2, 3 and 4 - Open Data Communication in Building Automation, Controls and Building Management -- Control Network Protocol (commonly referred to as LonWorks)
10. IEC 60929 Annex E - Digital Addressable Lighting Interface
11. IEC 60929 AC-supplied electronic ballasts for tubular fluorescent lamps - Performance requirements
12. IEC 62386-101 Digital addressable lighting interface - Part 101: General requirements - System
13. IEC 62386-102 Digital addressable lighting interface - Part 102: General requirements - Control gear
14. IEEE 802.15.4 - Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)
15. ISO 16484– Building Automation and Control Systems – Part 5: Data communication protocol
16. MIDI 1.0 Detailed Specification (“MIDI”) and MMA/AMEI Recommended Practice RP-002 (“MIDI Show Control”)
17. NEMA ANSI C82.11- High Frequency Fluorescent Lamp Ballasts - Annex A Low Voltage Control Interface for Controllable Ballasts
18. NEMA LSD 53-2010 Proposal for Digital Protocol for Lighting Control Devices
19. SMPTE 12M- Television - Time and Control Code
20. TIA-232-F - Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.
21. TIA-485-A - Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems.

APPENDIX A – PHYSICAL LAYERS

A.1 2-wire Line Voltage Forward Phase Control for Dimming

Phase control dimmers control the amount of voltage and current to the dimming ballast. The dimmer turns off part of the AC sine wave for a preset amount of time, resulting in reduced lamp output (dimming). This method uses semiconductors that once they are in conduction mode, the natural zero crossing of the sine wave is used to turn the conduction off. This is

the most common method of dimming. A contactor (switch) is not required in all systems. The ballast has to be specifically rated for this type of control. Because consistent voltage is not maintained for the ballast or driver, the lower limit of dimming capability is compromised as a byproduct of failing to ensure correct cathode heating.

As control is effectively created without a separate communication link, Forward Phase Control Dimming can often be used in retrofit applications where pulling new or additional branch circuit wiring or back end control wiring can be complicated and expensive.

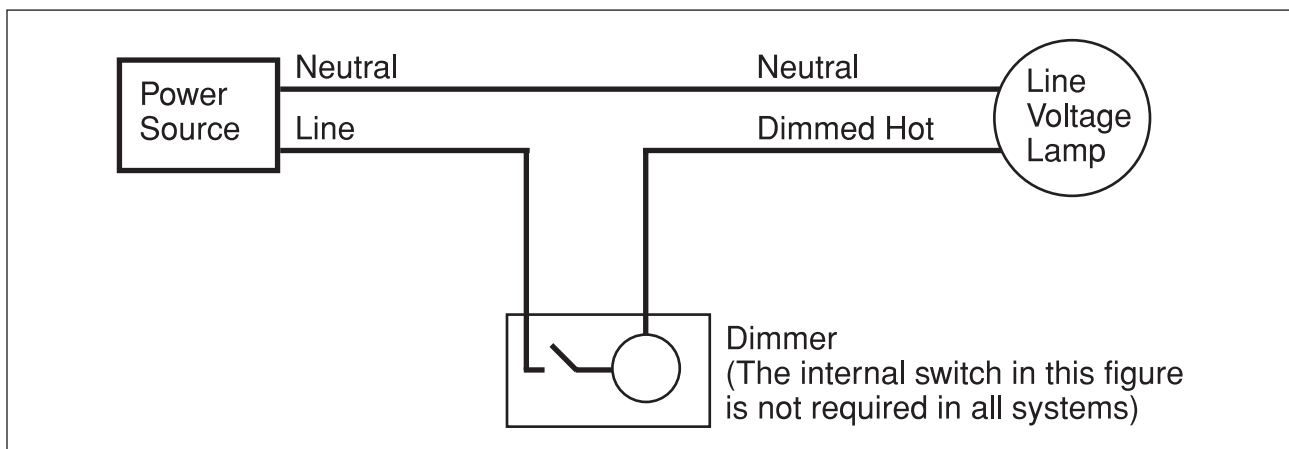


Figure A1. Wiring Diagram for 2 Wire Line Voltage Phase Control 120V Incandescent Dimming

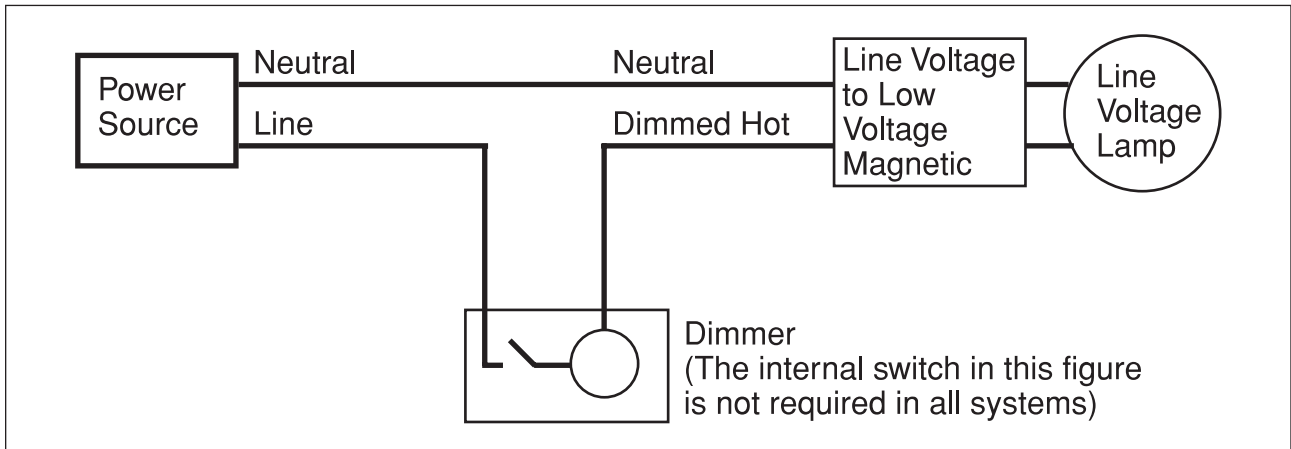


Figure A2. Wiring Diagram for 2 Wire Line Voltage Phase Control Low Voltage Incandescent Dimming

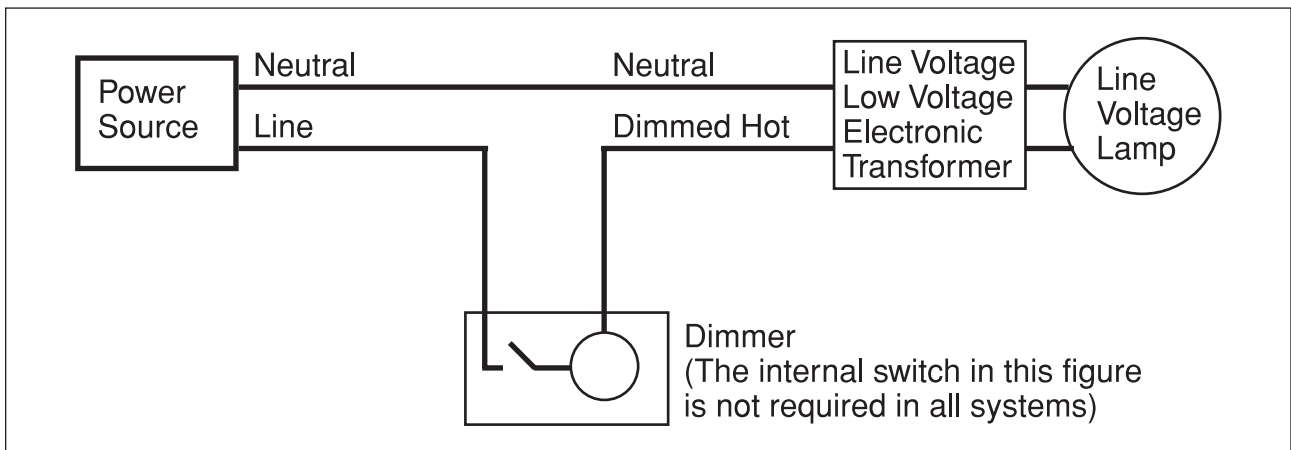


Figure A3. Wiring Diagram for 2 Wire Line Voltage Forward Phase Control (Leading Edge) 12V Incandescent Dimming. Electronic Transformer must be specifically rated for Forward Phase Control.*

* A significant percentage, but not all, electronic low voltage transformers require a Reverse Phase Control dimmer. The installer must be diligent in matching the controller to the requirements of the transformer.

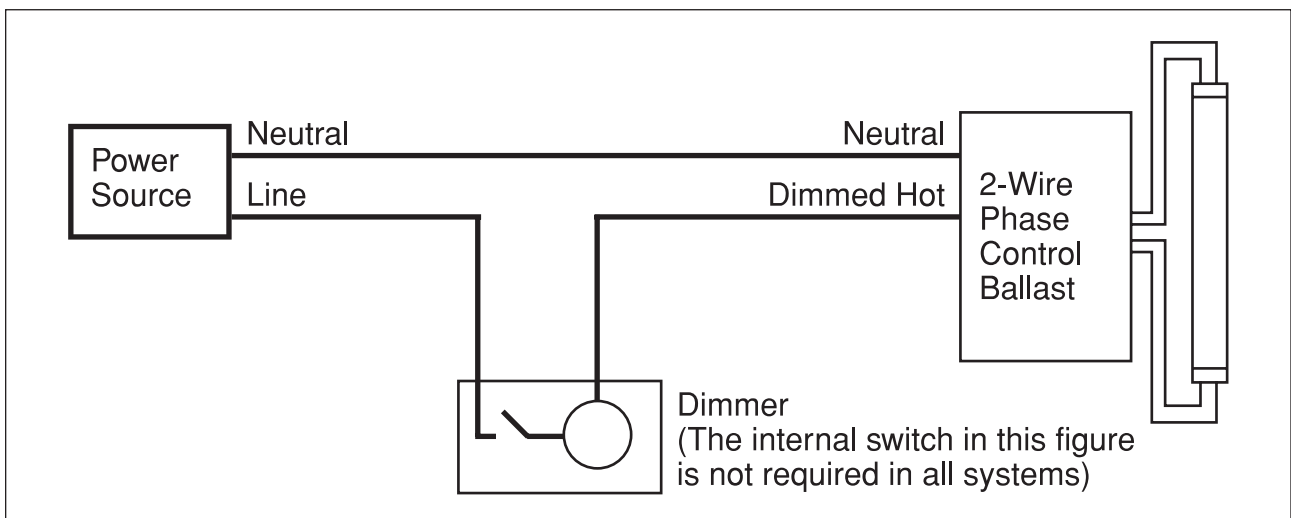


Figure A4. Wiring Diagram for 2 Wire Line Voltage Forward Phase Control (Leading Edge) Fluorescent Dimming

A.2 2-Wire Line Voltage Reverse Phase Control for Incandescent Dimming

Reverse Phase control dimmers (also known as Trailing Edge dimmers) control the amount of voltage and current to a light source. The dimmer turns off part of the trailing edge of the AC sine wave for a preset amount of time, resulting in reduced lamp output (dimming). This method uses semiconductors that can be turned off when the desired voltage is reached. This method is also used when the load device requires close synchronization with the sine wave leading edge. In systems where there is a transformer, ballast, or driver device, the device has to be specifically rated for this type of control. Because constant voltage is not maintained for the ballast or driver, the minimum dimming level will be compromised. This is because regulating devices require a minimum voltage to keep the electronics working.

A.3 3-Wire Line Voltage (Power or Class 1) Fluorescent Dimming

The switched hot in a 3 wire fluorescent dimming scheme insures constant voltage to the ballast for correct cathode heating thus allowing a greater dimming range. Each lamp socket must be of the rapid start type. One method of 3 wire control dimmers uses forward-phase-control dimming across the dimmed hot and neutral wires. Another method uses a Class 1 signal on the dimmed hot. In this case, the ballast electronics do the actual dimming. The ballast in each method has to be specifically rated for its particular 3 wire control scheme.

A.4 4-Wire Low Voltage 0–10VDC (Class 2) Fluorescent Dimming

Standard: NEMA ANSI C82.11 American National Standard for High Frequency Fluorescent Lamp

Ballasts - Annex A Low Voltage Control Interface for Controllable Ballasts Supplements.

Description:

A topology free, two wire, polarity sensitive, parallel bus is connected to all the controllable ballasts and to the controller. Typically, the ballast is capable of withstanding a voltage range of -15V to +15V. 10VDC produces maximum light output, while 1VDC produces minimum light output. Ballasts are protected from reverse polarity. If the control terminals of the ballast experience reverse polarity, the ballast produces minimum light output. If the control unit is not connected, as in an open circuit or control equipment failure, the ballast produces maximum light output. Ballasts are the source of the control current. Controllers for this method are variable resistors or an electronic equivalent capable of handling a range from 0.01ma - 2ma and are hardwired to a ballast or group of ballasts. Typical applications include architectural dimming and daylight harvesting.

The switched hot in a 4 wire fluorescent dimming scheme insures constant voltage to the ballast for correct cathode heating allowing greater dimming range. Each lamp socket must be of the rapid start type. In the 0-10 VDC 4 wire method, the 2 low-voltage wires (violet & gray wires) must be kept separate from the power wiring in the system except at the ballast itself. The control wires are polarity sensitive. In this case, the ballast electronics do the actual dimming. The ballast in each case has to be specifically rated for the 4 wire control method. If the ballast senses a loss of the control signal, the lamps produce full light output.

Good To Know:

The Standard does not define or address the value of the minimum light output nor does it address the shape of the dimming curve. As a result, products

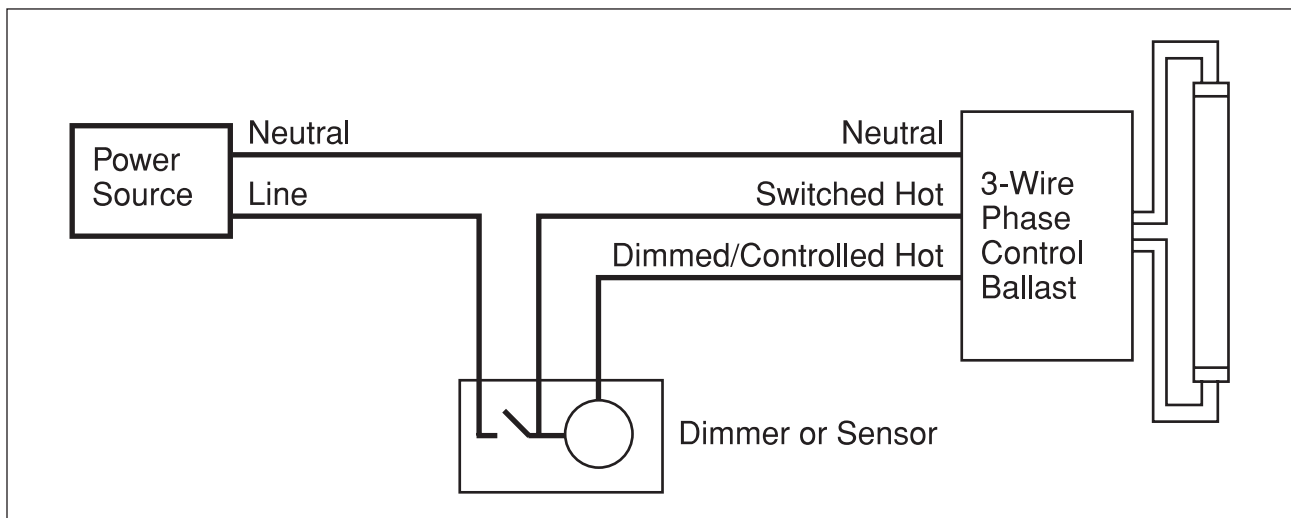


Figure A5. Wiring Diagram for 3 Wire Line Voltage Phase Control Fluorescent Dimming

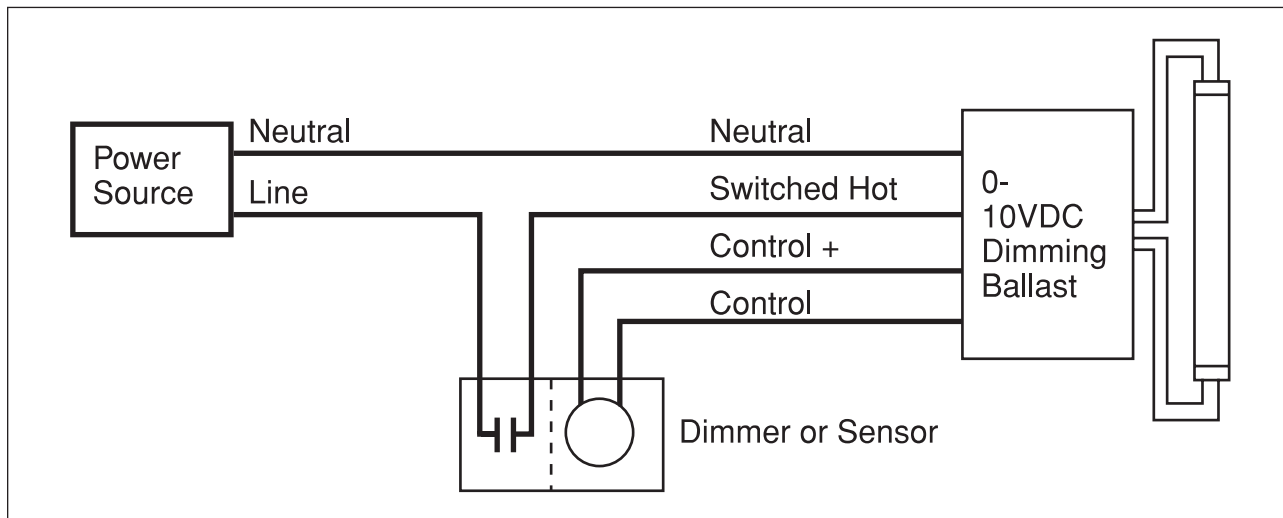


Figure A6. Wiring Diagram for 0-10VDC Fluorescent Dimming

from different manufacturers or even different models from the same manufacturer are not necessarily interchangeable with respect to their lighting response.

This method provides large dimming range and it is common and generally well understood. Since control groups are hardwired, they are defined prior to installation. This generally means that there is reliable documentation regarding which controllers affect which luminaires. The control circuit is self powered by the ballasts. Control wires are Class 2 (although they can be Class 1 in some cases) and must be routed separately from branch circuit wiring. This is more difficult in retrofit installations if control wires do not exist. The hardwired nature of 0-10V control means that zoning changes can be difficult to make and expensive to achieve after installation. Dimming response is dependent on the quantity of ballasts in each group, and the installed controller must be compatible with the specified ballasts. Voltage drop can be a factor. This is most noticeable in a long line of fixtures with the first fixture significantly closer to the controller than the last fixture.

A.5 DALI (Class 1 or 2) Fluorescent Dimming

Standard: IEC 60929 Annex E soon to be replaced with IEC 62386 Parts 101, 102 and 103

Description:

DALI stands for Digital Addressable Lighting Interface. Dimming is achieved through proper cathode heating via the lamp leads and control of the arc current. Each lamp socket must be of the rapid start type in order to allow for cathode heating. As a digital ballast, DALI has 254 dimming intensity levels with a greater number of its levels in the lower range which better matches the behavior of the human eye. See **Section B.5** for additional discussion on DALI

as a control protocol. The ballast responds to digital commands on the DALI control wires. The control wires may be installed as Class 1 or as Class 2. If Class 2, the DALI wiring must be run separate from the power wiring. If Class 1, the DALI wiring may be run in the same raceway with the lighting branch circuit conductors as allowed by NEC 300.3 (C)(1) and 725.26. Check the National Electrical Code® or applicable local electrical codes for wiring rules. Similar rules apply under the Canadian Electrical Code (CSA C22.2 No. 166).

Digital data is sent over a pair of conductors at 1200 bits per second. The protocol specifies the rise time of the signal to minimize possible interference to or from other systems.

DALI ballasts by themselves are not a control system. As with other ballasts, they are a back-end technology and require a front-end controller to realize their full potential. See Appendix B.5 for more information on the front-end aspects of DALI.

The DALI control wires may be installed as a combination of star, daisy-chain and tree. Loops are prohibited. The total wire length per DALI bus must not exceed 300 meters (1000 feet). There must be no more than 64 control points (ballasts, dimmers, relays) on a control bus. Each DALI bus requires a power supply at 16VDC and current limited to no greater than 250ma. The power supply may also incorporate a bridge for communicating with another DALI bus or a gateway for communicating with other protocols.

As a consensus-based international standard, DALI ensures interoperability of ballasts from different manufacturers. It must be noted that devices that do not match IEC standards and testing requirements may not bear the DALI logo or trademark.

Good To Know:

DALI ballasts are available from all major ballast manufacturers. The low bandwidth of DALI limits its practical real-time continuous polling of individual ballasts. The designer needs to specify digital addressable ballasts not just digital lighting controls, and must specify DALI if interoperability is desired. DALI-based relays or dimmers may be used to control other load types.

A.6 Pulse Width Modulation (PWM) for LED Dimming

Description

Pulse-width modulation (PWM) dimming is a common method for controlling the intensity of an LED source or sources. LED brightness (lumen output) is determined by the average forward LED current. The relationship between forward current and lumen output is effectively linear at lower forward current levels, and becomes nonlinear as forward current increases. Source efficacy (lumens per watt) begins to decrease in the nonlinear segment of the range, because an increasing percentage of output power is converted to heat.

Pulse-width modulation (PWM) controls the time-averaged current through an LED, and therefore, the brightness of the LED source or sources. In the PWM method, LED current level is set and then turned on and off very quickly, typically faster than is perceptible by the human eye. The dimming of the LED is proportional to the duty cycle of the PWM waveform.

Typical Use

Pulse-width modulation (PWM) dimming is commonly used for both static and dynamic dimming. It is also used with white light sources and for light sources designed for color mixing, such as RGB sources, where the brightness of the individual colors are adjusted to deliver the desired color.

Good To Know

Because it keeps forward current constant, PWM dimming is often preferred over analog dimming methods for LEDs, since it prevents color-shifting (changes in dominant wavelength) that occur with changes in drive current. Such changes are especially noticeable in white-light LED applications, where even small shifts in the CCT of adjacent LED nodes may be readily perceptible.

A.7 MIDI and MIDI Show Control

Standard: MIDI 1.0 Detailed Specification (“MIDI”) and MMA/AMEI Recommended Practice RP-002 (“MIDI Show Control”)

Description

MIDI (Musical Instrument Digital Interface) is a standard protocol that enables electronic musical instruments, computers and other equipment to communicate, control and synchronize with each other. MIDI does not transmit an audio signal or media — it simply transmits digital data "event messages" such as the pitch and intensity of musical notes to play, control signals for parameters such as volume, cues and clock signals to set the tempo. As an electronic protocol, it is notable for its success, both in its widespread adoption throughout the music industry, and in remaining essentially unchanged in the face of technological developments since its introduction in 1983. The MIDI Manufacturers Association was formed as an industry user group and now manages the standard.

MIDI Show Control, or MSC, was developed through a joint venture between the United States Institute for Theatre Technology (USITT) and the MIDI group (MMA). MSC is a significant Real Time System Exclusive extension of the MIDI standard. MSC enables all types of entertainment equipment to

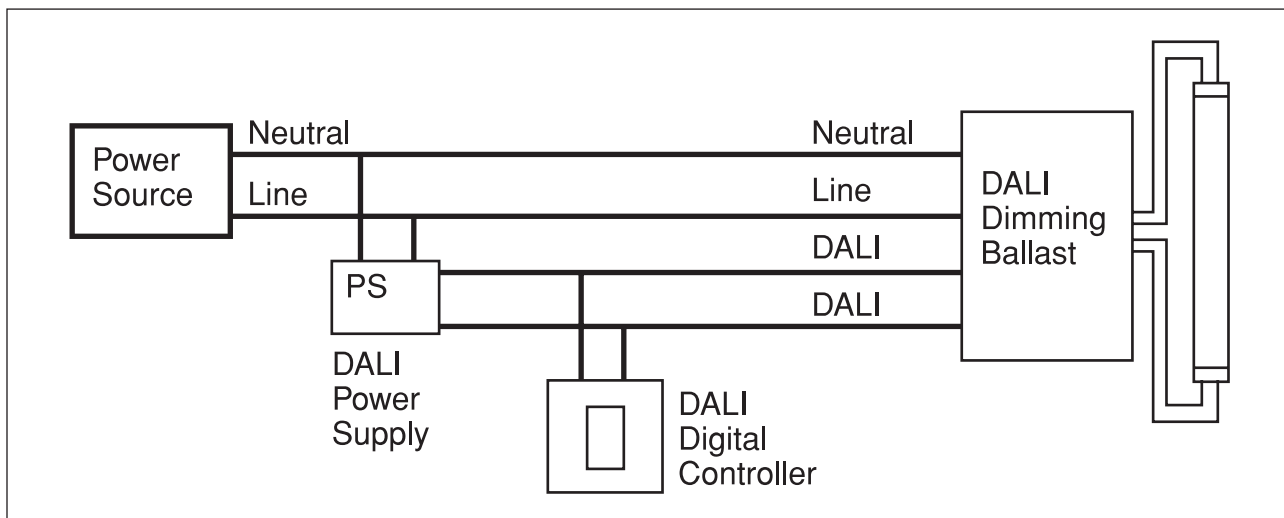


Figure A7. Wiring Diagram for DALI Fluorescent Dimming

easily communicate with each other through the process of show control. The MIDI Show Control protocol is an industry standard ratified by the MIDI Manufacturers Association in 1991 which allows all types of entertainment control devices to talk with each other and with computers to perform show control functions in live and pre-recorded entertainment applications. Just like musical MIDI, MSC does not transmit the actual show media - it simply transmits digital information about a multimedia performance.

Typical Use

The MIDI protocol is used primarily to allow music devices to control one another, and exchange time data (synchronizing). Most music recordings today use MIDI devices to produce and record the information.

The MIDI Show Control extensions are used to synchronize music with other systems for various effects and cues. For example, a lighting display can be set to music using MIDI Show Control, provided that the music contains the cues in MIDI.

Topology

The original specification for MIDI defined a physical connector, the 5-pin DIN (or MIDI DIN 5/180), that is still in use today. The MIDI DIN connector has a male and female version, and most devices have one of each, allowing a daisy-chain of "in" and "through" ports. Recent MIDI devices also allow communication over USB, Firewire, and Ethernet Networking, however, there are no standards for these methods of connection, and therefore are manufacturer specific (proprietary).

Limits/Extents

The standard MIDI DIN specification allows a maximum cable length of 50 ft. (15m). MIDI DIN hubs are available to distribute data locally. Gateways are available to convert the MIDI physical layer to other formats, typically TIA-422 (similar to TIA-485) and Ethernet.

Interoperation with other protocols

MIDI has several extensions allowing interoperation with similar protocols (see SMPTE Time Code). The well established physical layer and standard message formats allow other devices to interpret and use MIDI and MIDI SC data.

Designer responsibilities/Spec recommendations

MIDI and MIDI Show Control are well established standards. Typically, products claiming use of MIDI and MIDI SC have implemented the standard fully, and there are few known caveats. MIDI SC is a reliable and inexpensive method for synchronizing music and other media with lighting systems.

A.8 RS232 (currently TIA-232)

Standard: TIA-232-F Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange

Description

RS232 is the common use name for a data communications standard used by electronic equipment. The original standards were developed by the Electronics Industry Association (EIA) beginning in 1962, and were assigned the prefix "RS" to indicate Recommended Standard. The protocol is also known under the name of EIA-232 and as 232. The protocol standards are now maintained by the Telecommunications Industry Association (TIA).

RS232 was originally developed to facilitate communication between electromechanical typewriters and modems. As a result of its adoption by an extremely broad array of devices, there are many differences in the implementation of the data protocol exchanged over the standard, but all of the electrical characteristics and limitations are similar. RS232 is most often used as a baseline level of electronic data exchange between two individual components of a system at a local level. The physical standard described by RS232 has largely been supplanted by the Universal Serial Bus (USB) standard in computers, and by various Ethernet network standards in most other devices.

Topology

For TIA-232, there can be one sender, and one receiver, with a typical distance limitation of 50 feet. The cable and connector vary widely by implementation, but the most common connectors are DB9 (9-pins) and DB25 (25 pins). The electrical characteristics of the protocol depend heavily on the length, type, and quality of the wire and connector.

Limits/Extents

TIA-232 is limited to 50 feet, between two devices. Repeaters and special data cables are available for longer distances.

Interoperation with other protocols

Use of RS232 is typically focused on the interoperation between products from different manufacturers. Interoperation between any one serial protocol and another or between serial and a different protocol requires the use of a gateway, or translator, to convert the electrical signals.

Good To Know

RS232 permits no more than two devices to interconnect and they must be within 50' of each other.

As a standard, RS232 is specifically concerned with the electrical and physical, format of the information exchanged among networked devices. It does not cover information content. The standard assumes that connected devices are capable of exchanging data that is useful to one or both parties. Care should be taken to confirm that connected devices can transmit and receive information in commonly useful formats at the same data rate (speed) and that the physical characteristics of each device's connection (plug and cable) mechanism are compatible.

A.9 RS485 (currently TIA-485)

Standard: TIA-485-A Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems

Description

Recommended Standard 485 (RS485), currently managed by the Telecommunications Industry Association (TIA) is a protocol, designed to handle a need for fast communication to a series of devices in a system over a short distance, or slower communication over a long distance. RS485 can be used to communicate among several devices. RS485 is the electrical standard behind DMX512-A, covered elsewhere in this document. The current standard for "RS485" is *TIA-485-A Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems* issued in 1998.

Typical Use

The RS485 protocol is a multipoint protocol, typically allowing a master device to send data to or receive data from many slave devices at once. RS485 has been supplanted in many cases by Ethernet standards.

Topology

RS485, can accommodate multiple senders and receivers on a cable, in a multi-drop bus topology commonly called a daisy chain. At the end of the chain of devices the cable is terminated with a resistor that matches the impedance of the cable. The cable and connector vary widely by implementation, but the most common use is with 2-, 3- or 5-wire cables with twisted pairs ending in DB9, DB25, or modular connectors.

Limits/Extents

RS485 protocol has the electrical characteristics of a communication link. By itself, it does not contain informational content or data.

RS485 is specified to an ideal limit of 4000 ft. (1200m) between 32 drivers and 32 receivers per run, but is often limited in practice to 1500 ft. (500m).

Interoperation with other protocols

Use of RS485 is typically focused on the interoperation between products from different manufacturers. Interoperation between any one serial protocol and another or between serial and a different protocol requires the use of a gateway, or translator, to convert the electrical signals.

Designer responsibilities/Spec recommendations

The standard does not dictate the data format that is sent between devices. Each device must have the ability to send and receive data that is useful to the other device. Each device must also share the same baud rate (speed) and possess compatible physical connections.

RS485 also does not dictate how devices are addressed, but the standard generally requires addresses for target devices. The daisy-chain topology does not allow insertions of new devices at any location but the end of the chain. Lastly care should be given to properly terminate the transmission cable. Some devices offer an ability to apply a termination resistance on their own.

A.10 USB (Universal Serial Bus)

Standard: USB Implementers Forum, Inc.

Description

USB (Universal Serial Bus) is a specification to establish communication between devices and a host controller (usually personal computers). USB is managed by the USB Implementers Forum, Inc. USB was intended to replace the many varieties of serial and parallel ports in current usage at its inception. USB can connect computer peripherals such as mice, keyboards, digital cameras, printers, personal media players, flash drives, and external hard drives. For many of those devices, USB has become the standard connection method. USB was designed for personal computers, but it has become commonplace on other devices such as smartphones, PDAs and video game consoles, and as a power cord between a device and an AC adapter plugged into a wall receptacle for charging.

As a serial communication bus, USB sends one bit (binary digit) of data at a time. Eight bits (b) equals one byte (B). Since its original introduction, the USB specification has been continually updated to allow for faster data transmission. Currently, devices are in circulation which rely on 4 versions of the standard:

USB 1.0, low-bandwidth rate of 1.5 Mbit/s
(~183 KB/s)

USB1.1, full-bandwidth rate of 12 Mbit/s
(~1.43 MB/s)

USB 2, hi-speed (USB 2.0) rate of 480 Mbit/s
(~57 MB/s)

USB 3, SuperSpeed (USB 3.0) rate of 4.8 Gbit/s
(~572 MB/s)

Power over USB operates at 5V, 500mA for USB
1.0, 1.1 and 2.0, and at 5V, 900mA for USB 3.0.

Typical Use

USB is typically used for temporary connections between a lighting system controller and a personal computer (PC) during programming and commissioning. Long-term connections may exist if the PC is a permanent part of the lighting system function. Another use is the temporary output of another protocol (serial, LonWorks, DMX/RDM) from a PC, where a

USB device translates the incoming computer data into another protocol for direct control of a lighting system.

Topology

USB is a serial protocol and follows either a daisy-chain or star topology using a hub. When found in a lighting system, there is typically a point-to-point connection (line) from the PC to the target device, although the data could pass through a hub, or another device, following standard USB practice.

Limits/Extents

USB protocol covers the electrical characteristics and bit construction of a communication link. Typical use allows up to 16 feet from point to point (PC to device), with extensions provided by a hub.

Interoperation with other protocols

By itself, USB does not contain informational content or data.

APPENDIX B – PROTOCOLS

B.1

Common Name: 0-10 VDC Front End (Current Source)

Standard Title: ANSI E1.3 Entertainment Technology - Lighting Control Systems - 0 to 10V Analog Control Specification.

Responsible Body: ESTA (Entertainment Services & Technology Association)

Description

The standard describes a front end/user driven method of controlling equipment by means of a current source analog control voltage in the nominal range from 0 to 10 volts positive. It is often seen in theatrical/entertainment applications - and until the advent of various digital protocols - was one of the most prevalent protocols in architectural systems as well.

Typical Use

0-10VDC protocol is primarily intended for lighting control equipment (controllers and dimmers), but any equipment that might be controlled by a lighting controller (automated luminaires, strobe lights, fog machines, etc.) could also use this control method. ESTA publishes a free downloadable application guide for ANSI E1.3 which explains some of the design implications and offers some troubleshooting

guidance for users of analog control equipment. This document does not add or remove any requirements to the E1.3 standard. It is advisory only.

Topology

A free-topology, two wire, polarity sensitive parallel bus. Two parallel wires are connected to all the controllable devices and to the controller(s).

Limits/Extents

Control conductor size and current consumption will limit distance due to voltage drop. Voltage drop can affect the results, e.g., if the output of the controller is set for 90% (9 volts) and the voltage drop is such that only 8 volts is presented to the controller, then the controlled device may not act as expected.

Inter-operation with other protocols

Numerous converters are available to convert 0-10V signals to other protocols and vice-versa.

Designer's responsibilities/Spec recommendations

ESTA provides recommended specification "boilerplate" language that reads:

Products utilizing a "0 – 10V" control protocol shall comply with the rules and recommendations of the following standard: Entertainment Services & Technology Association (ESTA) ANSI E1.3 - 2001 (R2006) Entertainment Technology - Lighting Control Systems - 0 to 10V Analog Control Specification.

Good To Know

Some 0-10V controlled devices such as fluorescent dimming ballasts and some solid state lighting drivers require current-sink controllers. The current sink method is considered a back-end protocol and is described elsewhere in this document.

B.2

Common Name: ACN

Full Name: Architecture for Control Networks

Standard Title: ANSI E1.17 Entertainment Technology - Architecture for Control Networks.

Responsible Body: ESTA (Entertainment Services & Technology Association).

Description

ACN is a suite of protocols that is most commonly used to control theatrical lighting, audio and effects. The standard is maintained by ESTA (Entertainment Service and Technology Association). ACN can be combined and configured with other standard protocols. It can be implemented on a variety of networks, including, but not limited to Ethernet. ACN is bidirectional with sequencing and reliability; meaning that ACN equipment advertises itself and is dynamically discovered by controllers. Reliability is achieved by detection and resend of lost or out of sequence packets. ACN equipment exposes "properties" that may have values read or written to. Upon the receipt of a subscription request, ACN equipment will publish changes to "properties" back to the subscriber. ACN contains the definition of an XML based language (DDL) for describing the "properties" of equipment. Any ACN device will give out its DDL file upon request so that a controller can always find out how to control a device it hasn't seen before.

Typical Use

Controllers discover equipment and send reliable packets of property values as needed. The values instruct the equipment to perform the desired action or output.

Topology

Topology is dependent upon the physical transport to which ACN is applied. Ethernet is the most common method, following a star topology. The protocol allows for other transport methods where ACN is carried on top of UDP/IP, and can be "one to one or one to many".

Limits/Extents

There are no limits on the number of ACN devices or the number of properties each may have.

Inter-operation with other protocols

Inter-operation between ACN and other protocols is achieved via gateways that translate between ACN and other protocols. Gateways are known to exist for MIDI, SMPTE, DMX512-A, RDM, RS232, Analog Input, and Contact Closure Output.

E1.31 – Lightweight streaming protocol for transport of DMX512 – is an extension of ACN and describes a way of transporting DMX512-type data over ACN's Session Data Transport mechanism, and most often via Ethernet.

Good To Know

Structured cabling standards should be followed depending on the physical transport medium used. In the case of Ethernet, Category 5e or better cable should be specified. 100BASE-T, or 10/100BASE-T should be the minimum speed of Ethernet specified. Ethernet over Fiber may also be used for longer distances.

ESTA's recommended specification "boilerplate" language reads:

"Products utilizing the "ACN" control protocol shall comply with the rules and recommendations of the following standard: Entertainment Services & Technology Association (ESTA) ANSI E1.17 – 2006 - Entertainment Technology - Architecture for Control Networks."

B.3

Common Name: ASCII

Full Name: Information Systems – Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII)

Standard Title: ANSI INCITS 4

Description

Computers can only understand numbers, so ASCII code was developed to provide a numerical representation of a non-numerical character or action such as 'a' or '@'. The code was originally developed in 1963 for use with teletype machines. Over time, the meanings of the original, 32 non-printing characters have become somewhat obscure as they are rarely used for their original purpose.

Notepad.exe creates ASCII text, (and MS Word allows you to save a file as 'text only') so that a document or control sequence can be supplied in the raw format any computer can understand. This is an important means of avoiding compatibility issues when importing files from one application to another.

As people gradually required computers to understand additional characters and non-printing characters the ASCII set became restrictive. As with most technology, it took a while to get a single standard for these extra characters and hence there are few varying 'extended' sets.

Limits/Extents

ASCII is only a numeric representation of characters. By itself, it does not contain informational content or data.

B.4

Common Name: BACnet

Full Name: Building Automation and Control Network

Standard Title: ANSI/ASHRAE -135 - BACnet®
A Data Communication Protocol for Building Automation and Control Networks

Responsible Body: ASHRAE

Description

BACnet is a communication protocol that is specifically designed to meet the communication needs of building automation and control systems. Applications for this communication include HVAC control, lighting control, access control, security, and fire detection systems. Development of BACnet began in 1987 and the first standard was published in 1995. An ASHRAE, ANSI, and ISO standard, it was developed through a consensus process and is currently under continuous maintenance by an ASHRAE standing project committee.

The BACnet standard defines a set of objects and services that are used to generically model building control systems. Objects typically used for lighting control include the Binary Output Object (BO) used to represent a relay or a group of relays and the Analog Output Object (AO) used to represent a dimmed lighting load. Currently under development by ASHRAE is a new Lighting Output Object that will be tailored specifically to the control of lighting.

BACnet objects each have a set of properties that describe their purpose and functions. A particularly useful object property for lighting control is the description property that allows a text string to be stored with the object to describe the function of the load represented by the object such as the circuit number or room name where the lighting is located. BACnet services include functions such as read property, write property, and file transfer among others.

Lighting is typically controlled and monitored via BACnet through manipulation of the object property called Present Value. Reading the Present Value will return the on/off status of a switched lighting load or the level of a dimmed lighting load. To control the load it is only necessary to write to the present value of the object representing the lighting load.

BTL is a listing that is commonly used to show compliance with the BACnet protocol. It is achieved by having a product tested and approved by the BACnet Testing Laboratory. Many BMS manufacturers are recommending and requiring interfacing devices to have the BTL listing.

Typical Use

The most common application of BACnet for lighting is in providing the facility manager a "single seat" environment for building automation, where lighting control is combined with HVAC functions into a common set of operating schedules. Integration also allows lighting control devices such as occupancy sensors to trigger adjustments or setbacks in air comfort systems minimizing redundant equipment and enhancing system efficiency.

Topology

The BACnet standard defines a number of physical media over which BACnet messaging can be transported. Each of these has unique topology requirements. The most common media for BACnet are Ethernet (BACnet/IP) and MS/TP. MS/TP stands for master slave token passing and is a BACnet specific wired protocol using the industry standard RS485 specification. MS/TP uses shielded twisted pair wire in a daisy chain topology. BACnet IP is typically deployed over a wired or wireless Ethernet LAN. Each device on BACnet/IP has its own IP address or Ethernet MAC address that allows devices to communicate on a client's network. Devices are viewed as if there is a local area network. Unlike MS/TP, BACnet/IP is peer to peer. It is common for installations to use a backbone and rib topology where floor level devices (relays, thermostats, etc.) are connected via MS/TP to building control devices that are in turn aggregated using Ethernet.

Limits/Extents

BACnet devices each have a unique network identification known as the Device ID that is typically set during system commissioning. BACnet supports over 4 million Device ID instances allowing for the configuration of very large systems. There are different limitations for each of the two BACnet types.

BACnet/IP configurations are only limited by system bandwidth and amount of data that needs to be transmitted.

BACnet MS/TP segments may be several thousand feet in length but are limited by other factors. The standard allows 127 MAC addresses per segment and limits the number of devices to 32 units, based on power draw. Since many manufacturers use ½ power and ¼ power (low power) UART transceivers in modern device electronics it is possible to use more than 32 devices per segment. The maximum baud rate defined for MS/TP is 76,800 bits per second, but 38,400, 19,200, and 9600 are also used. Several MS/TP segments will typically be used for each BACnet installation.

Interoperation with Other Protocols

BACnet messaging can be translated to other protocols through a gateway. The transparency of gateway devices will vary greatly by manufacturer. Some gateways will be totally seamless while others will require additional commissioning or factory configuration to meet project requirements.

Good To Know

Typically, a lighting control system integrated with another BACnet system receives time-of-day information and preset triggers from another BACnet system. The lighting control system may also run autonomously, and then only need updates when system information changes.

An important consideration in specifying BACnet integrated lighting control systems is to properly define the scope of work expected in both the lighting and BAS sections of the project documents. The scope should include an enumeration of the lighting control points to be controlled and a complete sequence of operation that describes the expected operation.

More extensive guidelines are available in the form of a National Institute of Standards and Technology (NIST) document titled “GSA Guide to Specifying Interoperable Building Automation and Control Systems Using ANSI/ASHRAE Standard 135-1995, BACnet” that is available for download from the BACnet web site at www.bacnet.org.

B.5

Common Name: DALI

Full Name: Digital Addressable Lighting Interface

Standard: IEC 60929 Annex E (soon to be replaced with IEC 62386 Parts 101 and 102)

Responsible Body: IEC and DALI-AG

Description

DALI is an open, non-proprietary, international standard that ensures interchangeability between components from different manufacturers. Developed as a lighting control standard in Europe by DALI AG, the protocol is designed to allow two-way communication among fluorescent ballasts. There are efforts underway to include other devices and controllers. The bi-directional nature of the communication allows the system to query a specific component and receive a real-time answer. As a diagnostic tool, this is extremely useful as the system can self-identify some of the most common maintenance issues and report the status of its lamps and ballasts. The specificity of digital addressing allows DALI ballasts and components to maintain individual identities. DALI allows a ballast to be assigned to any combination of up to 16 control zones and each ballast can store 16 scenes or preset intensities.

DALI uses three types of addressing – broadcast, group, or individual, coupled with a command, to communicate specified actions.

Typical Use

DALI is typically used where the control strategy requires luminaires to respond to more than one controller (e.g., a button push and a daylight sensor), where luminaires need to be assigned to more than one control zone simultaneously, or when future reconfiguration is anticipated. Lighting systems can operate as stand alone control systems, or can be integrated as subsystems within a larger Building Management System.

Limits/Extents

Although groups of DALI buses can be combined into networks, the basic unit of control, the bus, is limited to 64 controlled devices (ballasts and relays). NEMA and IEC are working to develop another digital protocol that will operate concurrent with the DALI protocol to allow up to 64 controllers (switches, sensors, etc) to reside on the DALI bus.

Good To Know

Both the digital nature of the control signal and the ballasts need to be clearly identified in the specification documentation. While there are a number of digital ballast technologies available on the market, DALI is an open protocol and must be called out by name if interoperability among devices of different types (shades, sensors, etc) from different manufacturers is to be assured.

B.6

Common Name: DMX512

Full Name: Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories

Standard: ANSI E1.11 Entertainment Technology-USITT DMX512 A, Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories

AKA: DMX512/1990 (an older version), USITT DMX512 (generically covers all versions), DMX512-A

Responsible Body: ESTA (Entertainment Services & Technology Association)

Description

Originally developed in 1986 by USITT (United States Institute for Theatre Technology, Inc.) the DMX512 standard describes a method of digital data transmission between controllers and lighting equipment and accessories, and is considered a Front End method for most applications. It covers electrical characteristics (based on the EIA/TIA 485 A standard), data format, data protocol, and connector type. Communication on a DMX512 network is uni-directional and the standard provides neither error detection nor correction. Reliability is achieved by repeat sending of packets of information. The standard is intended to provide for interoperability among controllers made by different manufacturers, at both communication and mechanical levels. It also serves in a Back End method for many Solid State Lighting luminaires.

Typical Use

A DMX512 A controller sends packets containing between 24 and 512 single byte data values. All devices (lighting fixtures or other equipment) on the DMX512 cable receive all packets. These devices must be configured to know which data values apply to them. EIA-485-A limits the electrical load on a data link to 32 Unit Loads. As most devices are rated well under 1 unit load, it is possible to place more than 32 devices on one data link, but consideration must be given to system reliability and performance should one data link fail.

Topology

A DMX512 controller is connected to an EIA-485 rated cable (typically 100-120ohm) in a daisy chain. Category 5e unshielded twisted pair (UTP) cable is also permitted. At the end of the chain of devices the cable is terminated with a resistor that matches the impedance of the cable. In many cases, this termination is built into the receiving device. Plugged connections use 5-Pin XLR connectors. 3-Pin XLR connectors are specifically prohibited in the standard.

The standard excludes other topologies (e.g., stars, or trees). If the physical requirements of a system do not allow for a daisy chain, then DMX512 splitters (also called amplifiers or repeaters) are used.

Limits/Extents

The use of a high quality continuous EIA-485-A 120 ohm nominal impedance cable of minimal dc resistance theoretically allows for runs as long as 1 kilometer (3281 feet). In practice, runs are typically limited to $\leq 500\text{m}$ (1500 ft). If longer runs are required, a signal amplifier (repeater) should be used. ESTA also publishes documents to address cabling; ANSI E1.27-1 – 2006, Entertainment Technology-Standard for Portable Control Cables for Use with USITT DMX512/1990 and E1.11 (DMX512-A) Products and ANSI E1.27-2 – 2009, Entertainment Technology — Recommended Practice for Permanently Installed Control Cables for Use with ANSI E1.11 (DMX512-A) and USITT DMX512/1990 Products.

Interoperation with other protocols

Typically interoperation between DMX512-A and other protocols is handled by protocol converters (gateways). Proprietary and open protocols exist which allow DMX512 to be carried over networks, most commonly Ethernet-TCP/IP. ESTA recently published ANSI E1.31, Lightweight Streaming Protocol for Transport of DMX512 using ACN. E1.31 describes a method of transporting DMX512-type data over networks.

Good To Know

ESTA's recommended specification "boilerplate" language reads:

"Products utilizing the "DMX512" control protocol shall comply with the rules and recommendations of the following standard: Entertainment Services & Technology Association (ESTA), ANSI E1.11 – 2008 - Entertainment Technology - USITT DMX512 A, Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories"

ANSI E1.27-2 (referenced above) allows for the use of Category 5e Unshielded Twisted Pair (Cat5e UTP) cable for DMX512 wiring, as long the rules of DMX512-A are followed.

3-Pin XLR connectors are specifically prohibited even though used by some manufacturers (this non-compliant equipment causes compatibility problems with compliant equipment). The use of 3-Pin XLR connectors also leads some to use audio cable which has very different characteristics than EIA-485 rated or Cat 5e cables. RJ45 connectors are allowed under very specific restrictions including a specific pinout.

Recommended Practice for DMX512 2nd Edition is available from USITT on their website.

B.7**Common Name:** EnOcean**Full Name:** EnOcean**Description**

EnOcean is a technology supplier of self-powered modules (transmitters, receivers, transceivers, energy converters) to OEM manufacturers that develop and manufacture products used in building automation (light, shading, HVAC), industrial automation, and the automotive industry.

The EnOcean Alliance is a recently-formed industry alliance with responsibility for assuring product interoperability. The EnOcean Alliance has the formal purpose of initially developing the specifications for the interoperability of the sensor profiles for the wireless products operating in unlicensed frequency bands.

Typical Use

The first product stemming from this proprietary RF protocol is the battery-free wireless light switch. This product has gone to market under the premise that it requires less time and wire to install because no wire is required between the switch and the light fixture. It also avoids the need to run switched circuits as the actual power switching is performed locally at the load itself.

Switch signals and sensor information are reliably transmitted – interference from other signals can be excluded. Every device has a unique 32-bit serial number, so local interference is avoided by 'training' a receiver to its specific transmitters. Packets of data are transmitted at 120 kbit/s with the packet being 14 bytes long with a four byte data payload. Three packets are sent at pseudo-random intervals reducing the possibility of packet collisions. Push switches also transmit a further three data packets on release of the switch push-button, enabling other features such as light dimming to be implemented.

Topology

EnOcean devices can form a wireless community of battery-free sensors and actuators to connect to transceivers that are powered for continuous operation.

Limits/Extents

The frequency used for the majority of the devices is 868.3 MHz. In the US, 315 MHz is increasingly being used in EnOcean devices.

A license from EnOcean is needed to use this proprietary protocol.

Interoperation with other protocols

There is increasing availability of EnOcean based devices that are compatible with 0-10 VDC (sink) analog and DALI digital control protocols.

Good To Know

A group of companies in Europe and North America formed the EnOcean Alliance. Designers should consult the Alliance for more information.

B.8**Common Name:** Konnex, KNX**Full Name:** Konnex, KNX**Standard:** EN50090, ISO/IEC 14543-3, CEN EN 13321-1**Responsible Body:** KNX Association**Description**

The Konnex KNX protocol is used extensively for lighting controls in continental Europe, especially Germany, Austria, and Switzerland.

Typical Use

The Konnex protocol allows local system communication between user controls and power devices, and serves as a backbone between system-level devices. The standard supports three modes of operation, Automatic (A), Easy (E) and System (S). Automatic mode allows simple devices to connect and operate in a default mode, for basic use (on/off, presets). The Easy mode allows for a small amount of programming at an intelligent controller to set new commands in other devices, usually without external software. The System mode uses a software package to allow devices in a system to be customized, as well as providing communication between networked controllers.

Topology

KNX uses twisted pair wiring to connect user-devices (button stations and other controls) to dimming and switching panels. The twisted-pair typically is daisy-chained; running at 4800 to 9600 baud, and may also carry power to devices. Topology-free, segments can also be created using KNX, however they operate at a lower speed.

Power Line Carrier (PLC) communication and Radio Frequency (RF) allow communication between user-devices and panels or controllers either by using the existing power wiring to communicate between devices (PLC), or through wireless communication (RF). The PLC portion of the standard was drawn directly from the European Installation Bus (EIB) protocols that preceded KNX.

The KNX standard allows for use of wired and wireless Ethernet communication between networked controllers.

Limits/Extents

Twisted Pair installations are typically limited to 500 m per bus; manufacturers of PLC and RF systems place specific limitations on their products. Ethernet installations must follow Category 5 wiring (structured cabling) standards with 100m segment limits between switches, routers, hubs and devices.

Interoperation with other protocols

Interoperation is an integral part of the KNX specifications (Volume 3 Part 7 and Volume 7). Manufacturers wishing to align themselves and their products with the standard must follow a certification process administrated by the Konnex Organization.

Good To Know

Products certified for use with either KNX or EIB will work together, regardless of their manufacturer.

B.9

Common Name: LonWorks

Full Name: Local Operating Network

Standard: ISO/IEC 14908-1; ANSI/CEA-709.1-B-2000

Responsible Body: LonMark Association

Description

LonWorks is a peer to peer network in which all devices speak to each other. Each device or node contains a microprocessor to communicate the protocol to each other device. The microprocessors are called "neuron" cores or chips and contain three inline processors; two to communicate the protocol and one for the node's application.

Microprocessors typically used for LonWorks are 8-bit. However, 16, 32, and 64 bit microprocessors can be used for complicated projects. The different devices are connected either through twisted pair, Ethernet, power lines, radio frequency, coax cable, fiber, or TCP/IP.

Typical Use

Building Automation including HVAC and Lighting.

Limits/Extents

A domain is made up of devices that can communicate with each other. A domain can contain up to 256 groups. Groups are a collection of nodes within a domain and contain up to 64 nodes. Each node can

have up to two addresses which allows for a total of 32,000 devices on a system.

Good To Know

The system is completely de-centralized, allowing different nodes to speak to each other. This also provides for a system that does not suffer a communication interruption when a node malfunctions as all nodes are already communicating to all others. At the outset, nodes required a specific LonWorks Neuron Chip to be integrated into the network. Recent developments have allowed for general purpose micro-processors to connect to the system. While the acceptance of these generic micro-processors is growing, it is not fully realized.

B.10

Common Name: MIDI and MIDI Show Control

Full Name: Musical Instrument Digital Interface and Musical Instrument Digital Interface Show Control

Standard: MIDI 1.0 Detailed Specification ("MIDI") and MMA/AMEI Recommended Practice RP-002 ("MIDI Show Control")

Responsible Body: MIDI Manufacturers Association (MMA)

Description

MIDI (Musical Instrument Digital Interface) is a standard protocol that enables electronic musical instruments, computers and other equipment to communicate, control and synchronize with each other. MIDI does not transmit an audio signal or media — it simply transmits digital data "event messages" such as the pitch and intensity of musical notes to play, control signals for parameters such as volume, cues and clock signals to set the tempo. As an electronic protocol, it is notable for its success, both in its widespread adoption throughout the music industry, and in remaining essentially unchanged in the face of technological developments since its introduction in 1983. The MIDI Manufactures Association (MMA) was formed as an industry user group, and now manages the standard.

MIDI Show Control, or MSC, was developed through a joint venture between the United States Institute for Theatre Technology (USITT) and the MIDI group (MMA). MSC is a significant Real Time System Exclusive extension of the MIDI standard. MSC enables all types of entertainment equipment to easily communicate with each other through the process of show control. The MIDI Show Control protocol is an industry standard ratified by the MIDI Manufacturers Association in 1991 which allows all

types of entertainment control devices to talk with each other and with computers to perform show control functions in live and pre-recorded entertainment applications. Just like musical MIDI, MSC does not transmit the actual show media - it simply transmits digital information about a multimedia performance.

Typical Use

The MIDI protocol is used primarily to allow music devices to control one another, and exchange time data (synchronizing). Most music recordings today use MIDI devices to produce and record the information.

Basic MIDI messages are either 2 or 3 bytes long (16 or 24 bits), and enable addressing of 256 different controls (128 using "Note Number w/Velocity" messages and 128 using "Controller Number w/Value" messages) on 16 different devices (4096 controls). (Musical instruments are expected to use the defined MIDI messages according to their defined purpose, but other devices may use the same messages for other purposes.) Many simple lighting controllers accept Basic MIDI Messages for luminaire lamp selection and intensity adjustment.

The MIDI Show Control extensions are used to synchronize music with other systems for various effects and cues. For example, a lighting display can be set to music using MIDI Show Control, provided that the music contains the cues in MIDI.

MIDI Show Control (MSC) messages are not Basic MIDI messages, rather they use a second message format in MIDI called "Universal System Exclusive" (or "SysEx"). Unlike the basic MIDI messages, SysEx messages can be any length, and so there is no limit to the complexity of the messages. The MSC messages include commands such as Go, STOP, SET, RESUME, as well as command modifiers such as cue number, list, time values, and more. There are also specific commands appropriate to specific types of devices, such as Sound Commands, Lighting Commands, and Rigging Commands.

Where safety is an issue, the MSC Protocol includes a "Two Phase Commit" methodology to verify readiness before issuing specific commands (such as receiving a signal from a performer indicating he/she is on-mark before issuing the GO command to fire pyrotechnics).

Topology

The original specification for MIDI defined a physical connector, the 5-pin DIN (or MIDI DIN 5/180), still in use today. The MIDI DIN connector has a male and female version, and most devices have one of each, allowing a daisy-chain of "in" and "through" ports. Recent MIDI devices also allow communication over USB, Firewire, and Ethernet Networking, however,

there are no standards for these methods of connection, and therefore these devices are manufacturer specific (proprietary).

Limits/Extents

The standard MIDI DIN specification allows a maximum cable length of 50 ft. (15m). MIDI DIN hubs are available to distribute data locally. Gateways are available to convert the MIDI physical layer to other formats, typically TIA-422 (similar to TIA-485) and Ethernet.

Interoperation with other protocols

MIDI has several extensions allowing interoperation with similar protocols (see SMPTE Time Code). The well established physical layer and standard message formats allow other devices to interpret and use MIDI and MIDI Show Control data.

Good To Know

MIDI and MIDI Show Control are well established standards. Typically, products claiming use of MIDI and MIDI SC have implemented the standard fully, and there are few known caveats. MIDI SC is a reliable and inexpensive method for synchronizing music and other media with lighting systems.

B.11

Common Name: Modbus

Full Name: ModBus

Standard: Modbus Application Protocol Specification

Responsible Body: Modbus-IDA Organization

Description

Modbus is an industrial control protocol developed by Modicon (now Schneider Automation) in 1979 for use in its industrial process controllers, and programmable logic controllers (PLC's). The original implementation of Modbus used serial physical layers such as RS232 and RS485, now known as Modbus RTU. Additions to the protocol include Modbus ASCII, using text strings for more complex control messages, and Modbus TCP, using Ethernet networks to send serial-like messages to and from devices. There is also Modbus-MS/TP.

Typical Use

Modbus is a popular open protocol for industrial control equipment (factory production machines, robotic manufacturing, etc.). Many building automation and heating/ventilation/air conditioning (HVAC) products use Modbus as an integration protocol, allowing process engineers to have complete control of the production equipment and the surrounding building systems.

Topology

When Modbus RTU over RS485 is used, the topology must follow a daisy-chain serial format. For Modbus TCP over Ethernet networks, a star topology is used, following Ethernet standards.

Limits/Extents

The standard Modbus specification allows a maximum cable length of 50 ft. (15m) when using RS232 serial. Other formats utilizing Ethernet networks will follow those standards and equipment.

Interoperation with other protocols

Modbus gateways are available to convert the physical layer to other formats, typically TIA-422 (similar to TIA-485) and Ethernet. Some gateways also convert the Modbus data to other protocols, allowing interoperability with other common building automation and HVAC protocols.

Good To Know

Modbus, over all of its formats, is a well established standard in the industrial control market. Most interaction with a lighting controls system will be limited to time-based commands.

B.12

Common Name: RDM

Full Name: Remote Device Management

Standard: ANSI E1.20-2006 Entertainment Technology Remote Device Management over USITT DMX512 Networks

Responsible Body: ESTA

Description

RDM describes a method of bi-directional communications over a DMX512 data link between an RDM capable controller and one or more remotely controlled RDM capable DMX512 devices. It allows discovery of devices on a DMX512 network and the remote setting of DMX512 starting addresses, as well as status and fault reporting back to the control console. While basic DMX512 is a unidirectional protocol, RDM is a bi-directional protocol. RDM is most commonly used to configure and monitor the health of theatrical lighting equipment.

RDM is a half-duplex bi-directional serial protocol. RDM equipment is discovered by the controller searching for RDM devices. There is no inherent reliability, though some operations can be verified through the use of time-outs.

RDM equipment is configured by messages defined in the standard that manipulate a set of parameters.

Typical Use

A single RDM controller searches for devices. After finding a device, the controller may ask for any status the device has or set its configuration. RDM devices may not initiate communication, they may only respond when spoken to.

Topology

A DMX512 controller is connected to a TIA/EIA-485 rated cable (typically 100-120ohm) in a daisy chain. Category 5e unshielded twisted pair (UTP) cable is also permitted. At the end of the chain of devices the cable is terminated with a resistor that matches the impedance of the cable. In many cases, this termination is built into the receiving device. Plugged connections use 5-Pin XLR connectors.

Limits/Extents

The maximum number of RDM devices on a single daisy chain is limited to 32 unit loads (which may be more than 32 devices) by the DMX512-A standard.

Interoperation with other protocols

Interoperation between RDM and other protocols is achieved via gateways that translate between the protocols. Gateways are known to exist for ACN and some proprietary Ethernet protocols.

Good To Know

RDM runs on DMX512-A systems. A system specified to contain RDM equipment needs to contain software to gather and present the RDM status to the user.

ESTA's recommended specification "boilerplate" language reads:

"Products utilizing the "RDM" control protocol shall comply with the rules and recommendations of the following standard: Entertainment Services & Technology Association (ESTA) ANSI E1.20–2006 - Entertainment Technology-RDM Remote Device Management over USITT DMX512 Networks."

B.13

Common Name: SMPTE

Full Name: Society of Motion Picture & Television Engineers

Standard: SMPTE 0012M-1-2008 Television - Time and Control Code

Responsible Body: Society of Motion Picture & Television Engineers

Description

SMPTE (pronounced “Simp-tee”) was developed by the Motion Picture and Television industries as a method to provide a “frame-accurate” way to synchronize devices for video or sound-track editing. A number of methods were employed in the early days, but because of the inherent slippage and stretching properties of tape, frame accurate synchronization met with limited success. The introduction of SMPTE Longitudinal Time Code (LTC) provided this frame accuracy and incorporated additional functionality.

The Code is based on a 24 hour clock providing Hours, Minutes, Seconds, and frames format with frame timing to 1/24th, 1/25th, or 1/30th of a second.

Typical Use

The increasing sophistication of lighting and video integration has placed a greater demand on the synchronization of lighting control. Lighting systems are often required to work in concert with audio and video equipment in many modern landmark buildings. Because AV equipment is typically already set up for SMPTE time code, the logical choice was to embed a SMPTE reader into the lighting control system. There, the SMPTE LTC is used as an event signal to trigger lighting control system events.

Topology

American National Standard ANSI SMPTE 12M-1986 provides the industry specification for SMPTE LTC distribution. The standard does not define the transmission medium or distribution of LTC other than to say “...to be recorded on a longitudinal track of video and audio magnetic tape...” implying that the signal is what is commonly referred to as “Standard Audio”. In most cases, SMPTE can be handled just as though it were any other audio signal, and the SMPTE source will determine how devices are interconnected and whether or not additional equipment will be required to reduce noise. The interconnect cabling used is most commonly two-conductor, shielded audio cable and can be either Unbalanced (single ended) or Balanced (differential). It doesn't matter which is used, or even if it is mixed in a given installation, as long as proper termination and impedance matching is observed.

Limits/Extents

Most SMPTE reading devices support one input, while a source may support multiple outputs. The typical output will be +4 to +8 dBm, with a source impedance of 50 to 600 ohms. This is roughly a 1.2 to 2 volt, peak-to-peak signal. Total run length is difficult to determine because of the nature of

the signal, however audio compression/expansion, equalization, noise canceling and automatic gain control should be defeated and the original waveform maintained to optimize clean signal transfer. Signal conditioning may be required depending on the installation. Various conditioning techniques and devices are available.

Interoperation with other protocols

ANSI Standard SMPTE 12M-1986 does not operate with other protocols, and is typically a one-way transmission of time-code data.

Good To Know

In most cases the hardware required for SMPTE Time Code reading is optional and ordered as a separate item, either with the product initially or possibly as a field upgrade option. This usually involves the installation of some hardware within the given product. The SMPTE input itself consists of one or more audio cables with balanced or unbalanced signals. In most lighting control systems, the system software allows you to set up SMPTE on the given product, and provides a display mode for programming SMPTE times and events. The SMPTE event programming display provides full creation and editing capability for writing and testing SMPTE events. SMPTE optional settings are accessed through a system Setup display and provide a way to enable SMPTE, to configure such things as Frame rate, and chose whether a Cue List or Event List is displayed.

B.14

Common Name: TCP/IP

Full Name: Transmission Control Protocol (TCP) and the Internet Protocol (IP).

Standard: RFC-1122 & RFC-1123

Responsible Body: Internet Engineering Task Force

Description

TCP/IP is the ubiquitous protocol suite used by the Internet, the World Wide Web, and most networked computers for exchanging data. The name, TCP/IP, is a concatenation of two major data communications protocols: Transmission Control Protocol (TCP) and the Internet Protocol (IP). TCP/IP includes a set of standards that specify how computers should communicate. In addition, the TCP/IP suite defines conventions for connecting different networks and routing traffic through routers, bridges and other types of connections. It is useful for the layperson to think of TCP/IP as being the operating system that underlies the Internet and the WWW. TCP/IP is a mature protocol and virtually all computers capable

of operating in a networked environment support it because of its reliability and universality.

Typical Use

Because TCP/IP is widely available and supported, lighting controls systems already leverage the TCP/IP infrastructure to at least some degree. For example, large lighting energy management systems generally have Internet connectivity available as an option, allowing these systems to communicate with remote computers. Few analog lighting controllers have internet connectivity, but it is generally available for lighting controllers using digital protocols, such as DALI. Interfacing between TCP/IP and an application-specific network, such as DALI generally requires a router, an electronic device capable of translating and routing between two different network protocols.

The continued development of digital control systems is expected to rely on Internet connectivity as a means to monitor lighting power, commission and re-commission lighting control systems and for integrating disparate sensor data across other building sub-systems, such as HVAC and automated shading devices.

Topology

Connecting lighting controllers to the Internet generally requires access to an Ethernet port or a wireless network connection, such as WiFi. IT Departments often frown on connecting lighting (or building) controllers to the Internet because of security concerns. As a result, lighting control manufacturers must ensure that their products do not represent security threats. This may require that lighting control manufacturers supply an additional Ethernet backbone solely for carrying building automation data (including lighting data).

Limits/Extents

Since TCP/IP is the dominant system running on the Internet, and the Internet connects millions of computers worldwide, it is arguably limitless. But all the underlying physical means of transmission, whether by wires, optical cable or wireless have specific physical limits and requirements.

TCP/IP, by itself, does not contain informational content or data.

Interoperation with other protocols

The vast number of devices that operate within the context of internet connectivity assure that most protocols have a way of communicating via TCP/IP. Some, like BACnet are natively TCP/IP compliant. Others, like DALI, require a bridge.

Good To Know

Although the standard's ubiquity would seem to make TCP/IP compliance a given in the development of any control protocol, designers are encouraged to check with the manufacturer of the particular equipment being specified to assure that the necessary interfaces are available and that all networked components will be able to communicate as required by the design intent narrative.

B.15

Common Name: XML

Full Name: Extensible Markup Language (XML)

Standard: (None found)

Responsible Body: World Wide Web Consortium (W3C)

Description

XML or Extensible Markup Language is a standard for document markup endorsed by the World Wide Web Consortium (W3C). It defines a generic syntax used to mark up data with simple, human-readable language. It provides a standard format for computer documents, although this format is flexible enough to be customized to fit web sites, electronic data interchange, remote procedure calls, lighting controls or voice mail systems. Refer to RFC 3023 for more information about XML use in interchanging data over the Internet.

Typical Use

is a software tool that is used to provide truly cross-platform, long-term data formats. XML contains all information about the format and content of the data found within the document which makes it extremely easy to use and provides the ability to pass that data from one system to another. Typical uses today are found in software applications and web sites such as Microsoft Office® 2007 and many websites that transfer customer or user data.

Topology

XML has nothing to do with electrical signals, wiring or hardware.

Limits/Extents

An XML document is limited only by the detail and content of its definition and schema. The flexibility of the document allows developers to take information from the XML document and integrate it into various platforms using a variety of transport methods.

Interoperation with other protocols

XML is a standard for document and data exchange which makes the information easily portable between protocols and systems.

Good To Know

XML is relatively new and is primarily involved with software data and document management. Although some manufacturers are using XML to manage data, not all have adopted XML for various reasons.

B.16

Common Name: ZigBee

Full Name: ZigBee

Standard: IEEE 802.15.4

Responsible Body: ZigBee Alliance (<http://www.zigbee.org>)

Description

ZigBee is a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). The vision is for all lighting fixtures, sensors and switches to communicate wirelessly, without the need to add expensive cabling to buildings.

Typical Use

ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking. ZigBee's current focus is to define a general-purpose, inexpensive, self-organizing mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building and home automation (including lighting), etc. The resulting network will use very small amounts of power so individual devices might run for a year or two using the originally installed battery.

Topology

The ZigBee system can handle a variety of topologies including star and peer-to-peer. ZigBee is designed to support both full function devices (FFD) and reduced function devices (RFD). RFD's are intended for very simple devices such as light switches. While FFD's can perform communications routing and forwarding functions.

Limits/Extents

ZigBee nodes communicate wirelessly at relatively low power. Consequently their range is limited to about 75 meters outside, with a smaller range indoors.

Interoperation with other protocols

ZigBee can operate with the Internet using gateways and routers that are TCP/IP compatible.

Good To Know:

Products which conform to the specifications established by the ZigBee Alliance bear the ZigBee label.

B.17

Common Name: Z-Wave

Full name: Z-Wave

Standard: Proprietary

Responsible Body: Z-Wave Alliance

Description

Z-Wave is a proprietary interoperable wireless communication protocol developed by Danish company Zensys and the Z-Wave Alliance. It is designed for low-power and low-bandwidth appliances, such as home automation and sensor and control networks. Z-Wave networks are 2-way RF with meshing capabilities for powered nodes. The meshing capability routes 2-way command signals from one Z-Wave device to another around obstacles or radio dead spots that might occur.

Z-Wave is a registered trademark of Zensys, Inc.

The Z-Wave Alliance is a consortium of more than one hundred independent manufacturers who have agreed to build wireless home control products based on the Z-Wave standard.

Typical Use

Z-Wave is focused on the remote control and management of home automation devices and systems.

Topology

A Z-wave network can consist of up to 232 units with the option of bridging networks if more units are required. A Z-wave network has no master node. A message from node A to node C can be successfully delivered even if the two nodes are not within range providing that a third node B can communicate with nodes A and C. In order for Z-wave units to be able to route unsolicited messages, they cannot be in sleep mode. Therefore, most battery-operated devices cannot effectively function as repeater units (node B in the example above). This may limit the usefulness of a network of Z-Wave-enabled ballasts in situations where ballasts are not continually energized.

Limits/Extents

The restriction to 232 units per network limits the usefulness of the technology in large, commercial settings.

Z-wave units communicate at 9,600 bit/s or 40 Kbit/s, use GFSK Modulation, and have a range of approximately 30 meters assuming "open air" conditions, with reduced range indoors depending on building materials, etc.

Z-Wave radios use the 900 MHz ISM band; 908.42 MHz in the US. There are some advantages to 900 MHz (compared to 2.4 GHz, for example). 900 MHz tends to travel further than 2.4 GHz, and in buildings, which have RF-attenuating walls, floors and equipment, the lower frequencies penetrate RF barriers better. Additionally, the RF spectrum space at and above 2.4 GHz is becoming increasingly crowded with other RF devices.

Interoperation with other protocols

The computer controllers that interface to Z-wave systems speak a standardized, but proprietary, serial protocol.

Good To Know

To ensure proper performance, the specifier should consult the Z-Wave Alliance.



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