slipstream

Building systems

Networked lighting controls and HVAC integration

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2024

1

Learning Objectives

- Introduce interior lighting types and controls.
- Explain networked lighting controls: capabilities and architecture.
- Discuss luminaire-level lighting controls: components and capabilities.
- Discuss the integration of HVAC controls with networked lighting controls.

2

Outline

Interior lighting types and controls
- Interior lighting fixture types
- Lighting controls

Networked Lighting Controls (NLC)
- Capabilities
- NLC architecture
- Luminaire-level lighting controls(LLLC) components, operations, pros and cons

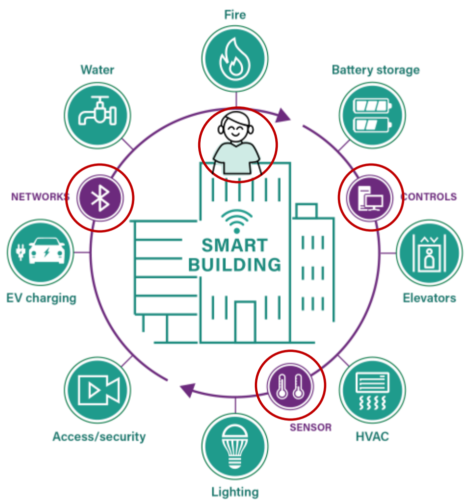
NLC integration with HVAC controls
- Benefits
- Integration basics
- HVAC control sequences
- Lessons learned

3

Interior Lighting Types

4

Smart Building Elements



1) Building systems
    1) Envelope
    2) HVAC
    3) Lighting
    4) Water
    5) Solar PV + battery energy storage
    6) EV charging
    7) Other (elevator, fire, access/security)
2) Sensors
3) Controls
    1) Platform
    2) Control methods
4) Networks
5) Occupants!

Lighting Fixture Types

Incandescent lamps

Compact fluorescent

Fluorescent tubes

High intensity discharge

Metal halide

Halogen lamps

Efficiency Comparison of Different Lighting Types

Lighting Type	Luminous Efficacy (lm/W)
Incandescent	10-17
Compact Fluorescent (CFL)	50-70
Halogen	16-29
High-Intensity Discharge	60-130
Fluorescent Tube	50-100+
Metal Halide	65-115

Source: https://blog.arcadia.com/led-vs-regular-lightbulbs-do-they-really-make-a-difference/

Light Emitting Diodes

All can be replaced/retrofitted with…

Advantages of LED

- High luminous efficacy
- Durability
- Energy efficiency
- Quality and control
- Low heat emission
- Eco-Friendly

Lighting Controls

Why Lighting Controls

Occupant visual comfort

- Light level
- Light color

Energy savings

- Turn on only when it is needed
- Only output the light level needed

Cost saving

- Energy cost savings
- Demand charge savings
- O&M savings (prolong lifespan)

Building management

- Monitoring
- Reporting
- Integration with other building systems

Lighting Control Methods

Code-Required Lighting Controls
- Manual switch
- Occupancy / vacancy sensing
- Daylight harvesting
- Timeclock scheduling
- Bi-level control
- Dimming

Advanced Lighting Controls
- Task tuning/ high-end trim
- Networked lighting systems
- Luminaire level control
- Load shedding
- Demand response

See ASHRAE 90.1 Chapter 9 or IECC Section 405 for energy code requirements

Lighting Controls with LEDs

LEDs are ideal for digital controls

1-for-1 retrofit of fluorescent to LED may result in lighting “too bright” and require dimming/task tuning controls

Additional energy savings
- Higher efficiency
- Up to 38% from various control strategies (LBNL study)
- Up to 47% from various control strategies (Design Lights Consortium study)

Better occupant visual comfort
- Easy to change light color

Lighting Controls for Smart Buildings

Integration with other building controls: Smart buildings

- HVAC systems
- Automated window treatments
- Life safety systems
- Automated demand response
- Asset management and asset tracking

Networked Lighting Controls (NLC)

Networked Lighting Controls (NLC)

- Components are connected through digital communication networks
- Combine luminaires (lamp, fixture or bulb), controls, connectivity for changes to lighting operations.
- One sensor can control many luminaires, or one luminaire for luminaire-level lighting controls (LLLC).
- Lighting controls functions at the level of zones, or for each individual luminaire (LLLC).

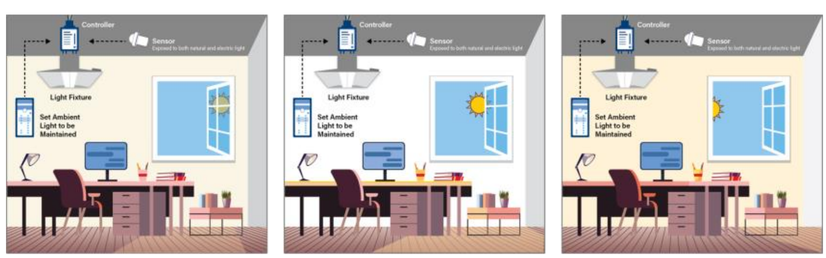
NLC Capabilities

Daylight harvesting

Automatically affect operation of lighting based on daylight or ambient light present

Occupancy sensing

Affect lighting operation based on detection of people in a space.



Morning until 10 am | Between 10 am and 4 pm | After 4 pm

NLC Capabilities

Scheduling

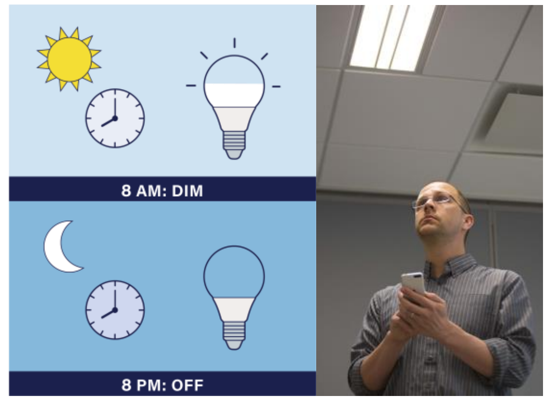
Based on time of day, week, month, or year.

Personal control

Adjust lighting in a task area to their preference.

High-end trim

Setting the maximum light output to a lesser output for one or a group of luminaires via the control software at commissioning.

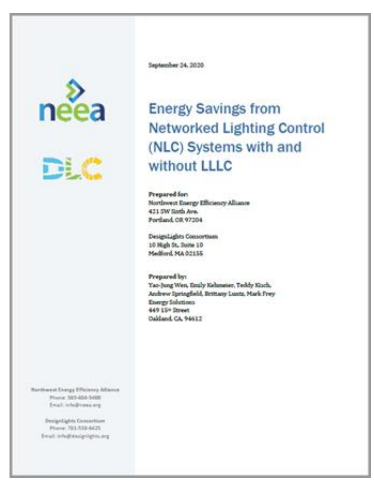


17

17

Energy Savings in NLC Applications

- Average lighting energy savings of 49%
- Range of energy savings
  - Office: 64%
  - Warehouse: 68%
  - Assembly: 28%
- Variations due to differences in commissioning, controls implemented and occupancy patterns.
- Lighting accounts for 10% of commercial building energy consumption



September 24, 2020

Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC

Prepared for:
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18

18

NLC Architecture

Lighting fixtures

- Lamp
- Drive
- Embedded networking and control components

Sensors

- Occupancy, daylight, ambient light, temperature, motion, etc.

Control devices

- Wall switches and controllers

Communication network

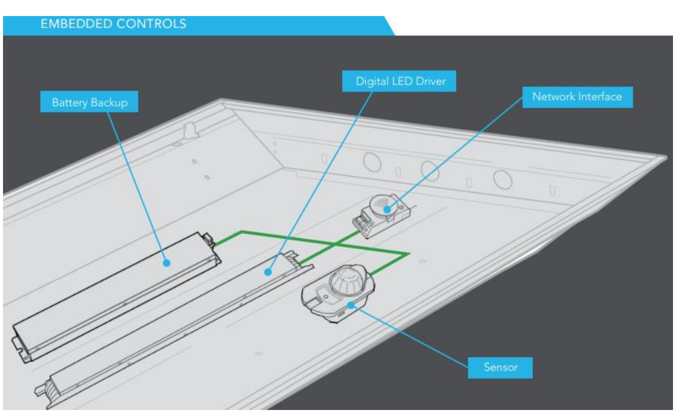
- Wired or wireless
- Protocols: Ethernet/IP, DALI, Zigbee, BACnet, Modbus, Bluetooth, etc.
- Gateway/bridge/router

Software

- Control, monitoring, and management

NLC Architecture – Lighting Fixture

A lighting fixture with embedded networking and control components



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LED driver

- Controls the power to the luminaire including dimming.
- Maintains a consistent temperature to the LEDs.

Network interface

- Communicate with other components

NLC Architecture – Sensors

Sensors

- Occupancy/motion
- Daylight/photosensor
- LLLC - integrated or embedded in each luminaire, usually factory-installed.

Occupancy sensor

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Photosensor

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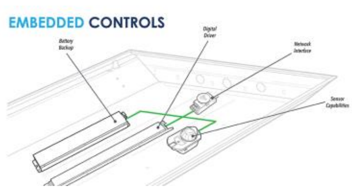

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Infrared receiver

Image used by permission from Everlight

Occupancy sensor

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NLC Architecture – Control Devices

Control devices

- Wall switches - dimmers, timers, on/off
  - RF signal – battery operated
  - Low voltage
- Programmable lighting controllers - integral to driver or may be separate.

Smart dimmer, Bluetooth

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Wall control – timer

Image used by permission from Lutron

Programmable lighting controller

Image used by permission from nLight® Controls – Acuity Brands

Touchscreen wall control

Image used by permission from nLight® Controls – Acuity Brands

Wall control

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NLC Architecture – Communication Network

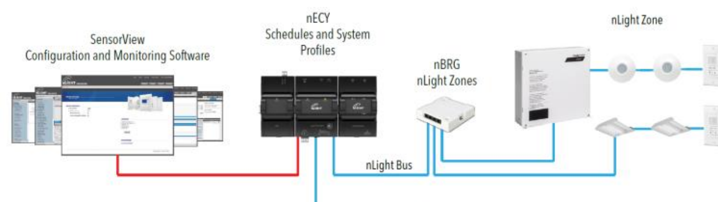
Wireless or wired connectivity

- Ethernet cable is the most common
- Common protocols: Ethernet/IP, DALI, Zigbee, BACnet, Modbus, Bluetooth. Or proprietary.

Network interface

- Gateway/router/bridge
- LLLC - each luminaire is addressable, resulting in more sensing granularity.

A wired networked lighting control system



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Wireless network gateway

NLC Architecture – Software

Functions and capabilities

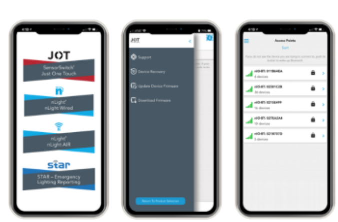
- Real-time monitoring
- Energy reporting
- Assist O&M through alerts
- Identify occupancy patterns – space utilization
- Automated demand response

Mobile app

- Individual control
- Configuration and commissioning

Lighting control software

Image used by permission from Lutron



Lighting control mobile app

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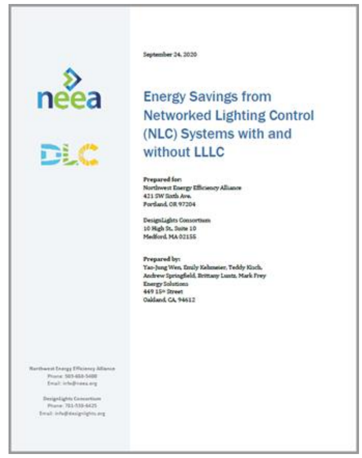
Luminaire Level Lighting Controls (LLLC)

Luminaire Level Lighting Controls

- Luminaire Level Lighting Controls are a type of Networked Lighting Controls.
- Lighting controls function at the level of each luminaire and may also control more than one luminaire.
- Integrated in each fixture:
  - Occupancy or Vacancy sensor
  - Photosensor
  - Controller

NLC vs. LLLC Energy Savings

- Average savings for all NLC systems 49%
- Savings are more site specific than they are based on building types
- Savings for NLCs not using LLLC – 35%
- Savings for NLCs using LLLC – 63%
    - More granular control available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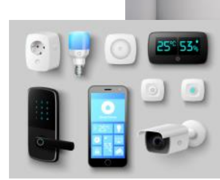
Luminaire Level Lighting Controls Pros and Cons

- Individualized control
- Labor savings in installation
- Connectivity
- Integrate with other building systems for granular monitoring and control
- Space utilization and assets tracking
- Higher initial capital costs
- Smart systems may be more difficult to program



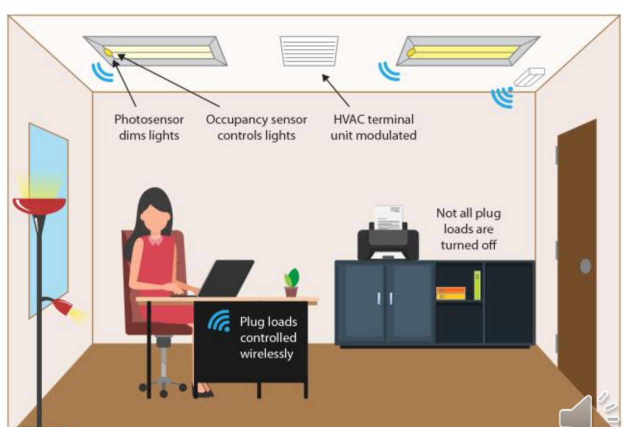
NLC Integration with HVAC Controls

29

29

NLC Integration with HVAC Controls

- Lighting + HVAC account for more than 50% of building energy.
- Lighting is ubiquitous in buildings.
- Networked lighting may include occupancy data that can be used by HVAC control systems.
- "HVAC Integration" involves communication between the lighting and HVAC system for information sharing and control purposes.



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NLC Integration with HVAC Controls

- Use occupancy data to control the lighting and the HVAC through one system for additional savings.
- Aggregate HVAC and lighting energy reporting into a single dashboard.
- Deploy demand response signals to both HVAC and lighting system during an event.

32

Integration Benefits – Energy Savings

Type	Measure
Traditional Lighting Retrofit	Efficient LED Lighting
Advanced Lighting Control	Task Tuning
	Daylighting
	Occupancy / Vacancy
	Personal Tuning
Integrated Control - HVAC	Thermostat Setback (Airside, Waterside, Baseboard)
	VAV Box Turndown (including off)
	Aggressive Pressure/Temperature Reset
	Ventilation Reset
	Demand Control Ventilation

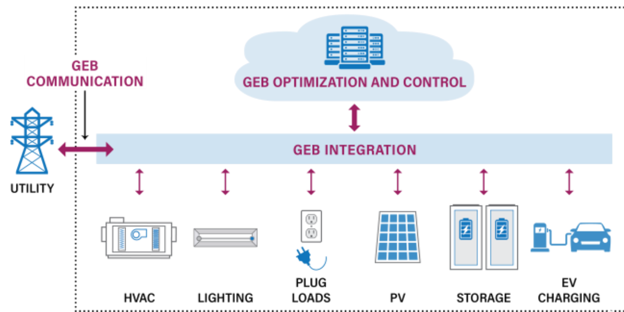
HVAC energy savings through real-time occupancy signals from LLLC.

33

Integration Benefits – Demand Response

- Respond to Demand Response (DR) signals by directly reducing lighting loads through NLC
- Coordinate HVAC controls to directly or indirectly reduce electric load
- Occupancy-driven strategies
- Automated Demand Response (ADR)
- Grid-interactive Efficient Building (GEB)

A GEB Control Platform Illustration



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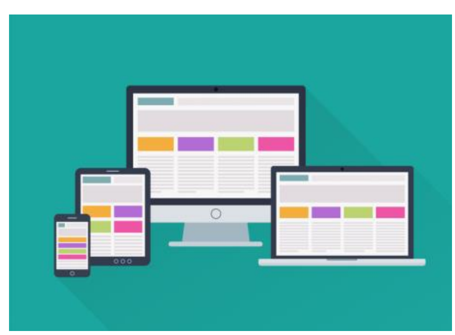
Integration Benefits – Beyond Energy

- Consistent user experience: Multiple manufacturers and platforms on one interface
- Improved user experience and easier O&M and reporting
- Individualized occupant comfort
- Better space utilization with historical data and analytics



Integration provides analytics capability for over 50% of building energy consumption.

Integration Basics – Protocols

Most Common Networked Lighting Communication Protocols

- 0-10VDC Front End (Current Source)
- DALI
- BACnet
- LonWorks
- Modbus
- Zigbee
- Others

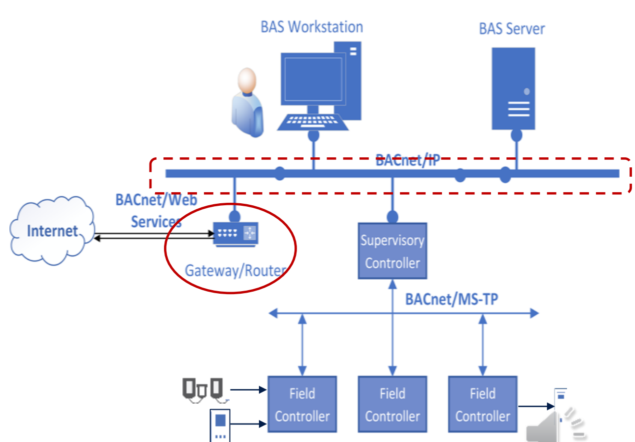
Most Common BAS Communication Protocols

	Open System	Closed System
Proprietary	**LonWorks (Echelon)**	**Many BAS Manufacturers**
Non-proprietary	**BACnet (ASHRAE)**	-

Source: IES TM-23-11 *Lighting Control Protocols* by Illuminating Engineering Society

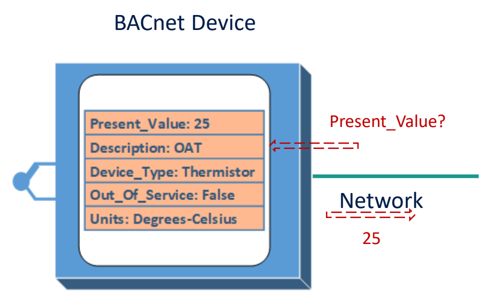
Integration Basics – Protocols - BACnet

- Developed by ASHRAE since 1987
- Supported by ASHRAE Standing Standard Project Committee SSPC 135 – ASHRAE/ANSI Standard 135
- BACnet/IP
- CAT5, 5e, or 6 Ethernet cable
- Wiring: daisy-chain, star or bus
- Maximum devices: 254 per segment
- Network speeds: 100~1000 Mbps (Megabits or 1,000 kilobits, per second)



Integration Basics – Protocols - BACnet

- BACnet/IP
- MAC address: xx:xx:xx:xx:xx:xx
- IP address: e.g., 192.168.1.1 (IPV4)
- Client-Server Peer-to-peer communication



- BACnet Object
- 54 different standard object types
- Properties: define capabilities, operation and related data

NLC BACnet Objects

Lighting system BACnet objects available for HVAC integration

- Px = Indicates device pole.
- BV = Binary Value
- BI = Binary Input
- AV = Analog Value
- AI = Analog Input
- COV = Change of Value

The following chart provides the available BACnet object types and description of each object.

Object Object Name Without Label Object Name With Label	Type	Units	Range	Permission	Inactive State (0)	Active State (1)
Occupied (Px) OccupiedPx_ABCD1234 label1_OccupiedPx_ABCD1234	BI			Read / COV	Unoccupied	Occupied
Relay State (Px) RelayStatePx_ABCD1234 label1_RelayStatePx_ABCD1234	BV			Read / Write / COV	Relay Open	Relay Closed
Dimming Output Level (Px) DimLevelPx_ABCD1234 label1_DimLevelPx_ABCD1234	AV	Percentage	0-100	Read / Write / COV		
Measured Light Level (Px) LightLevel_ABCD1234 label1_LightLevel_ABCD1234	AI	Foot-Candles	0-212	Read / COV		
Photocell Inhibiting (Px) PCellInhibitPx_ABCD1234 label1_PCellInhibitPx_ABCD1234	BI			Read / COV	Not Inhibiting	Inhibiting

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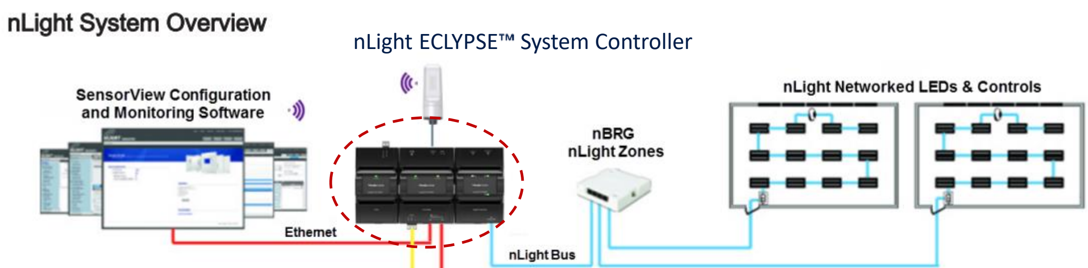
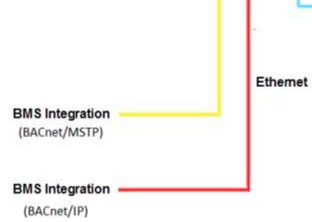
Integration Basics – Networking





- Same manufacturer's lighting control and BAS systems
- Integration through an nLight® ECLYPSE™ controller
- BACnet Testing Laboratories (BTL) listed as a BACnet Building Controller (B-BC)
- Browser-based nLight configuration using HTML5
- Wi-Fi client, access point and hot spot capabilities

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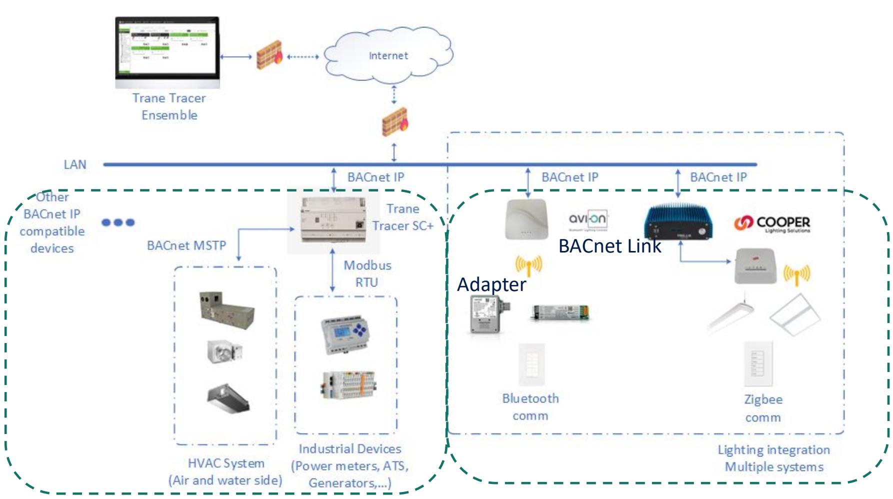
40

40

Integration Basics – Networking



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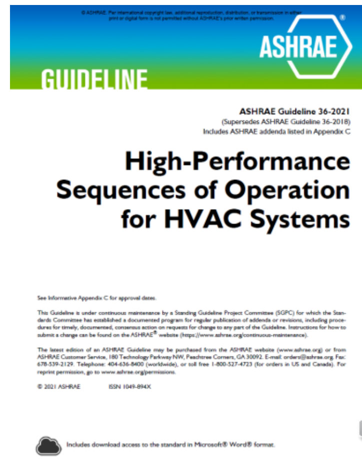
41

41

HVAC Control Sequences – ASHRAE Guideline 36

- High-performance Sequences of Operation for HVAC Systems
- Based on industry best practices
- ASHRAE standing committee with broad representation
- Consensus process
- Multiple rounds of public review
- First published in 2018, recently released the 2021 version
- Under continuous improvement
- Several occupancy- or demand-based strategies to save energy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ASHRAE

GUIDELINE

ASHRAE Guideline 36-2021
(Supersedes ASHRAE Guideline 36-2018)
Includes ASHRAE addenda listed in Appendix C

High-Performance Sequences of Operation for HVAC Systems

See Informative Appendix C for approval dates.

This Guideline is under continuous maintenance by a Standing Guideline Project Committee (SGPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Guideline. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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Includes download access to the standard in Microsoft® Word® format.

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HVAC Control Sequences – Zone Setpoint

Occupancy-based setpoint reset

- Occupied-standby mode: no occupant in the zone during "Occupied" period
- Occupancy sensor: -1°F (heating), +1°F (cooling) after the space has been unpopulated for 5 minutes continuously
- Restore the original values after the space has been populated for 1 minute continuously

Occupancy sensor

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Object Object Name Without Label Object Name With Label	Type	Units	Range	Permission	Inactive State (0)	Active State (1)
Occupied (Px) OccupiedPx_ABCD1234 label1_OccupiedPx_ABCD1234	BI			Read / COV	Unoccupied	Occupied

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Integration Lessons Learned

- The integrator must have detailed knowledge of the operation of the lighting and BAS systems.
  - Good documentation of both systems configuration is imperative.

- High rates of BACnet traffic can cause communication problems.
  - Limit the read/write commands as much as possible.

44

Integration Lessons Learned

- Bench tests to limit errors in the field.
- Pre-configure the lighting system as much as possible. Share the BACnet point list and site-specific zone names with the HVAC system integrator.
- The HVAC system integrator must have good communication with the lighting controls tech.
- Coordinate lighting system updates with the HVAC integrator.
  - New firmware/software versions may affect the amount and format of the data that is transmitted, and therefore may impact the integration.

45

Integration Lessons Learned

- Include all required hardware/software components for the integration. Some lighting systems require licensing for integration.
- Make sure both the HVAC and lighting integrators know the customer expectations.
  - For example: Partial integrations (only lighting occ sensors), dimming control capabilities integrations, and full lighting control from the BAS.
- Building business relationship between the lighting and HVAC vendors can greatly reduce risk.

46

More Information

Slipstream HVAC Integration Implementation Guide

https://slipstreaminc.org/sites/default/files/documents/research/us-department-energy-integrated-controls-study_2.pdf

Slipstream Lighting and HVAC Integrated Controls Savings Estimator

https://slipstream.shinyapps.io/int_ctrls_calc

47

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Office (BTO) Award Number DE-EE0009703.

Thank you!