Advanced Lighting Control Systems for Specifiers

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IEEE PES Cal Poly Student Branch

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Learning Objectives

- Define functionality and scope of a lighting control system.
- Review lighting control strategies
- Learn how to write control narratives, and develop schedules and drawings for lighting control systems.
- Explore differences between hardwired analog and “plug-and-play” digital systems.

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History of this Seminar

- CALCTP – 40 hours for electricians.
- Electricians install only what is in the contract.
- Need to teach designers and specifiers.
- Lighting Control Components Workshop
- Lighting Control Systems for Specifiers
- Development of this seminar was cofunded by PG&E and SCE.

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This Seminar

- From Concept
- To Construction

  of lighting control systems

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This Seminar is NOT

- A review of the Electrical Code
- A course on LEED®
- A primer on Title 24
- A tutorial on dimmer electronics

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Agenda

- Factors To Consider
- Lighting Control Strategies
- Design Process
- Lighting Control Components
- Dimming Technologies
- Control Narratives
- Hardware, Protocols, Systems
- Research , Incentives
- How to Convey the Control System Design

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Factors To Consider When Specifying A Control System

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Factors to Consider

- Control Theory
- Lighting Control Strategies
- Design Process
- Lighting Control Components
- Dimming Technologies

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Control Theory

- Sensor (Input) - e.g. Pushbutton
  - Provides information to logic circuit
- Controller (Algorithm/Process) - e.g Relay
  - Decides On/Off or how much
- Actuator (Output) - e.g. Lamp
  - The output changes

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Control Theory

- Open Loop
- Closed Loop

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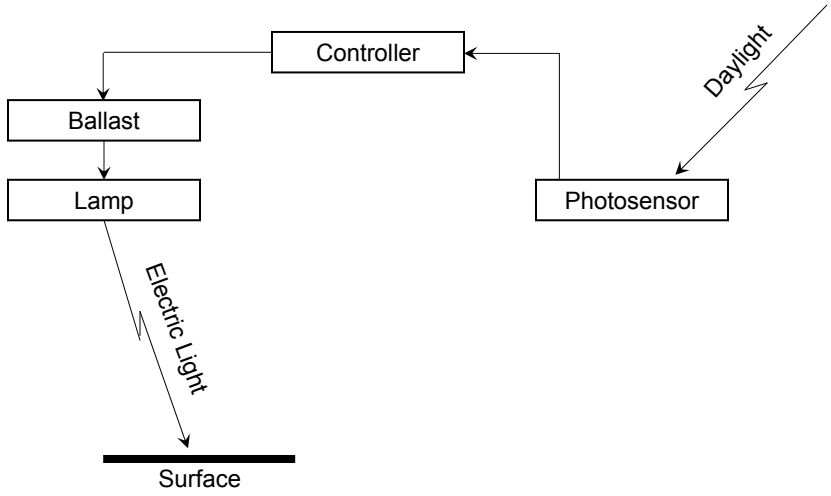
Open Loop Control System



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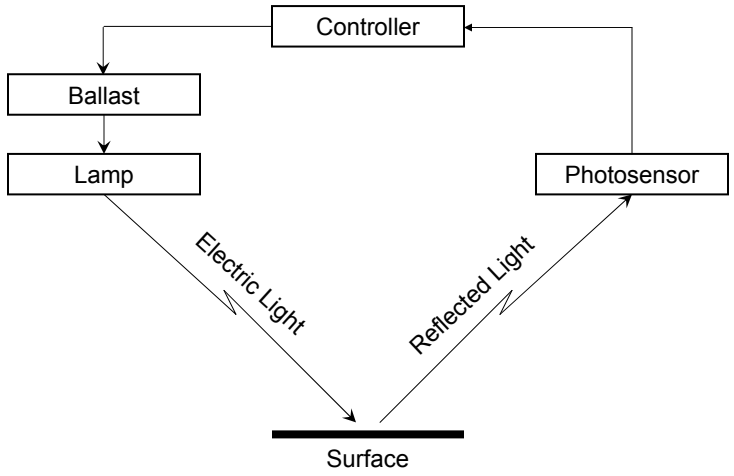
Closed Loop Control System



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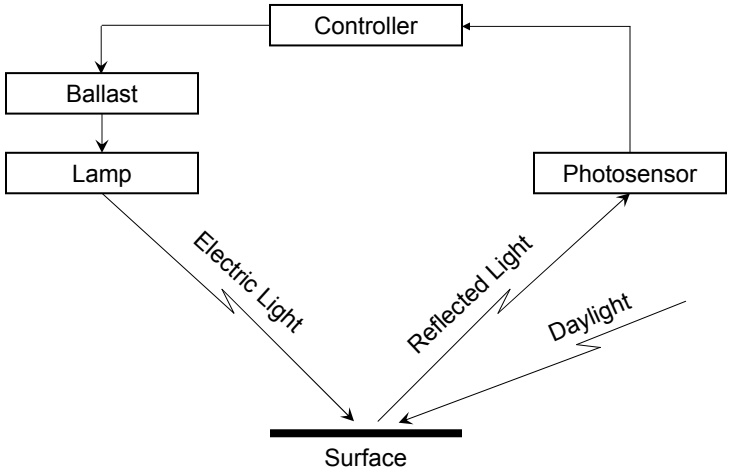
Closed Loop Control System



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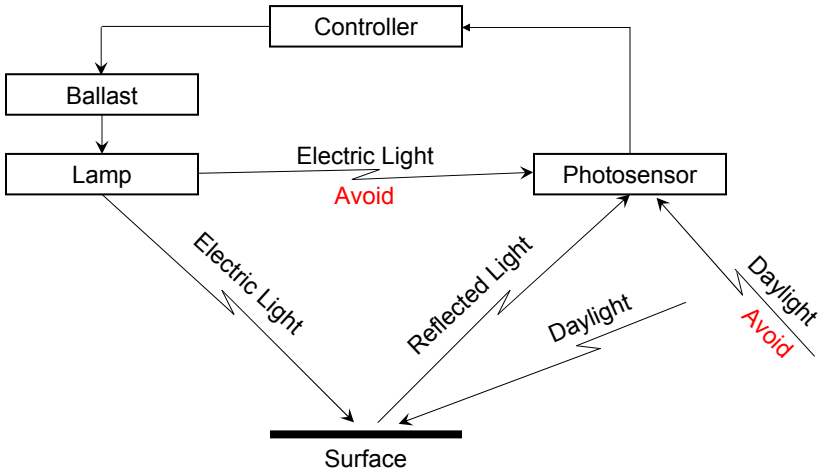
Closed Loop Control System



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Lighting Control Strategies

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Lighting Control Strategies

- Local Controls (room)
- Building Level Controls

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Lighting Control Strategies

Local Controls

- Multi-Level Switching
- Occupancy/Vacancy Sensing
- Daylight Harvesting
- Architectural Dimming
- Personal Tuning

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Multi-Level Switching

Local Control

- OFF, mid level (30-70%), Full ON
  - Could be 0-50-100 or 0-33-66-100
- Commonly referred to as “a/b switching”
- Dimming is acceptable compliance

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Occupancy/Vacancy Sensing

Local Control

- Auto ON vs Manual ON
  - per Title 24, Auto ON is prohibited in residential applications
- Auto OFF and Manual OFF
- Time delay after detecting vacancy
- Sensitivity to large and small motion

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Daylight Harvesting

Local Control

- Window (side light)
- Skylight (top light)

- The selection and placement of the sensor is critical for successful operation.
- SPOT (Sensor Placement + Optimization Tool)
- www.archenergy.com/SPOT/

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Architectural Dimming

Local Control

- Functional
- Aesthetic / Artistic

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Personal Tuning

Local Control

- Adjust for the task at hand
- Adjust for comfort

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Lighting Control Strategies

Building Level Controls

- Time Schedule
- Facility Tuning
- Load Shed
- Demand Responsive
- Adaptation Compensation
- Emergency Condition

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Time Schedule

Building Level Control

- Daily, Weekday, Weekend, Holiday
- Daylight savings, Leap year
- Astronomic

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Facility Tuning

Building Level Control

- Set for reduced power
- Lumen maintenance

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Load Shed

Building Level Control

- Demand peak reduction
  - Initiated by owner
  - Peak shave for demand reduction

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Demand Responsive

Building Level Control

- Agreement with utility company
- Reduced energy rate but with potential penalty
- Manually initiated based on message from utility
- Automatically initiated by utility

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Adaptation Compensation

Building Level Control

- Don't need as much light at night, therefore reduce the lighting power
- Based on the fact that you can read the newspaper in moonlight

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Emergency Condition

Building Level Control

- National Fire Protection Association - NFPA-101 Life Safety Code
- California Building Code (CBC)
- National Electrical Code - NEC®
- Underwriters Laboratory - UL924 - Shunt relay
- Underwriters Laboratory - UL1008 - Transfer switch

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NFPA-101 Life Safety Code

7.8 Illumination of Means of Egress

7.8.1.2 When Needed

The LSC says that the means of egress shall be illuminated during periods of occupancy

7.9 Emergency Lighting

7.9.2.7 Lighting Can be Controlled

Lights on continuously, or else will come on automatically.

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NEC® Art.700

NEC 700.20 – Switch Requirements

- Switches in emergency lighting circuits shall be arranged so that only authorized persons control the lights.
- Exceptions:
  - Multiple parallel switches OK as long as one of them is controlled by authorized people

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Applications for UL924

- Control emergency lighting that otherwise would burn 24/7.
- Bypass a dimmer or a switch.

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Stairwell Energy Savings

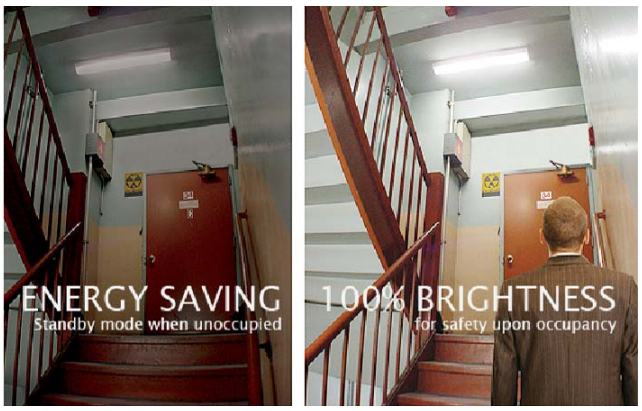

Photo courtesy of www.occu-smart.com

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Design Process

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Design Process

- Owner Project Requirements - OPR
- Basis of Design - BOD

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Energy Codes

- International Energy Conservation Code – IECC
- American Society of Heating Refrigeration & Air Conditioning Engineers / Illuminating Engineering Society – ASHRAE/IES 90.1
- California Energy Code, aka Title 24
  - Watts per Square Foot W/SF (not scope of this seminar)
  - Components are appliances, therefore covered in Title 20

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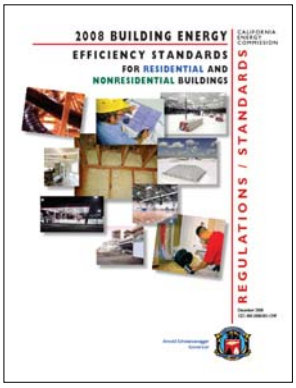
Title 24 but also Title 20

- Automatic Off
  - Vacancy sensing
  - Photo switch (for outdoor)
  - Time schedule or Curfew
- Reduction or Dimming
  - a/b switching – manual
  - a/b switching - automatic
  - dimming – manual
  - dimming – automatic
- Acceptance Testing
  (By licensed person)
  - Architect
  - Engineer
  - Contractor



http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.pdf

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Power Adjustment Factors

TABLE 146-C LIGHTING POWER ADJUSTMENT FACTORS

TYPE OF CONTROL		TYPE OF SPACE	FACTOR
Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D		Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room.	0.20
Multi-level occupant sensor (see Note 2) that reduces lighting power at least 50% when no persons are present. May be a switching or dimming (see Note 3) system.		Hallways of hotels/motels , multi-family, dormitory, and senior housing	0.25
		Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)	0.15
		Library Stacks (maximum 2 aisles per sensor)	0.15
Dimming system	Manual	Hotels/motels, restaurants, auditoriums, theaters	0.10
	Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters	0.20
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal. (See Note 1)		All building types	0.05
Manual dimming of dimmable electronic ballasts. (see Note 3)		All building types	0.10
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal when used in combination with manual dimming of dimmable electronic ballasts (see Note 1 and 3).		All building types	0.15

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Power Adjustment Factors

Combined controls	Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D combined with automatic multi-level daylighting controls		Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, corridor, conference or waiting room. The PAF may be added to the daylighting control credit			0.10
	Manual dimming of dimmable electronic ballasts (see Note 3) when used in combination with a multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D.		Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room			0.25
Automatic multi-level daylighting controls (See Note 1)	Total primary sidelit daylight areas less than 2,500 ft² in an enclosed space and all secondary sidelit areas. (see Note 4)		Effective Aperture			
		General Lighting Power Density (W/ft²)	>10% and ≤20%	>20% and ≤35%	>35% and ≤65%	> 65%
		All	0.12	0.20	0.25	0.30
	Total skylit daylight areas in an enclosed space less than 2,500 square feet, and where glazing material or diffuser has ASTM D1003 haze measurement greater than 90%		Effective Aperture			
		General Lighting Power Density (W/ft²)	0.6% ≤ EA < 1%	1% ≤ EA < 1.4%	1.4% ≤ EA < 1.8%	1.8% ≤ EA
		LPD < 0.7	0.24	0.30	0.32	0.34
		0.7 ≤ LPD< 1.0	0.18	0.26	0.30	0.32
		1.0 ≤ LPD < 1.4	0.12	0.22	0.26	0.28
		1.4 ≤ LPD	0.08	0.20	0.24	0.28

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EnergyPro - Lighting Controls

- No Lighting Controls
- Occ Sensor - Multi-Level
- Occ Sensor - Hallway
- Occ Sensor - Storage
- Occ Sensor - Library
- Dimming - Manual
- Dimming - Multiscene
- Dimming - Electronic Ballast
- Dimming w/ Occ Sensor
- Demand Responsive
- Demand Responsive w/ Dimming
- Window Daylighting
- Window Daylighting w/ Occ Sensor
- Skylight Daylighting
- Skylight Daylighting w/ Occ Sensor

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LEED®2009

- USGBC – US Green Building Council
- New Construction
  - SS Credit 8 **Light Pollution Reduction**
  - EA Prerequisite 1 **Fundamental Commissioning** of Building Energy Systems
  - EA Prerequisite 2 **Minimum Energy Performance**
  - EA Credit 1 **Optimize Energy Performance**
  - EA Credit 3 **Enhanced Commissioning**
  - EA Credit 5 **Measurement and Verification**
  - IE Credit 6.1 **Controllability of Systems—Lighting**
  - IE Credit 8.1 **Daylight and Views—Daylight**

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Sustainable Sites: SS-8
Light Pollution Reduction

- 1 Point
- Reduce lighting levels
- Operate shades and blinds
- Turn off lighting that is not needed at various times of night

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Energy & Atmosphere: EA Prereq 1
Fundamental Commissioning

- Prerequisite (Required)
- The owner prepares the OPR
- The design team develops the BOD
- The Commissioning Authority (CxA) verifies Lighting and Daylighting Controls

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Energy & Atmosphere: EA Prereq 2
Minimum Energy Performance

- Prerequisite (Required)
- Title 24-2005, Part 6
- Regulated (non-process) energy includes lighting (for the interior, parking garage, surface parking, façade, or building grounds)
- Predicted energy use must be not less than 10% below the applicable standard (T24)

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Energy & Atmosphere: EA Credit 1
Optimize Energy Performance

- 1 to 16 points
  - This is the greatest point gatherer
- NB = New Bldg, EB = Existing Bldg

Remember:
This is based on
Title 24-2005

NB	EB	Pts
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	4
20%	16%	5

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Energy & Atmosphere: EA Credit 3
Enhanced Commissioning

- 2 Points
- Begin the commissioning process early (design review at 10% and at 60%)
- Review submittals and site observations
- Prepare Functional Performance Tests
- Verify training of Owner
- Reconfirms performance after occupancy

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Energy & Atmosphere: EA Credit 5
Measurement and Verification

- 3 Points
- Provide for the ongoing accountability of building energy consumption over time
- International Performance Measurement & Verification Protocol (IPMVP) Volume III
- Install metering equipment to measure energy use

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Indoor Environmental: IE Credit 6.1
Controllability of Lighting

- 1 Point
- Provide individual lighting controls
  - For not less than 90% of the building occupants
  - Adjustments to suit individual task needs and preferences
- Provide lighting system controls in multi-occupant spaces
  - Adjustments that meet group needs and preferences
- Controls may be: on/off, multi-level, dimming, task/ambient

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Indoor Environmental: IE Credit 8.1
Daylight

- 1 Point
- Design the building to maximize interior daylighting
  - Automatic photocell-based controls reduce energy use
  - The real point grabber is in the EA Credit 1 Optimize Energy Performance

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BREAK

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Lighting Control Components

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Lighting Control Components

- Wallbox Switches
- Pushbuttons
- Contact Closures - Input
- Contact Closures - Output
- Occupancy/Vacancy Sensors

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Lighting Control Components

- Photosensor for Outdoor
- Photosensor for Indoor
- Time Schedule
- Architectural Dimming
- Emergency Condition
- User Interface / Dashboard

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Switches

- Single pole switch (SPST)
- 3-way switch (SPDT)
- 4-way switch (DPDT)

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Pushbuttons

– single button
– multi button keypad
– touch screen display
– keypad locations
– drawing symbol

– single press, double press, press and hold
– action – select preset, raise, lower, toggle, dim up/down, on, off
– button labels

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Contact Closures - Input

– from security system
– from door or partition system
– from another automated system such as Energy Management System (EMS), or Building Automation System (BAS)
– from utility Demand event

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Contact Closures - Output

– to Audio/Video (A/V) system
– to Window shades/blinds
– to EMS/BMS/BAS

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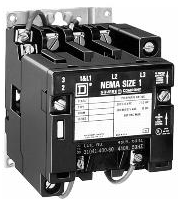
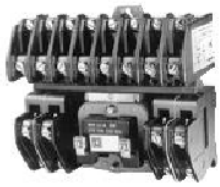
Relays & Contactors

- Relays
- Contactors





Photos courtesy of GE and Square D

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Multi-Pole Lighting Contactor

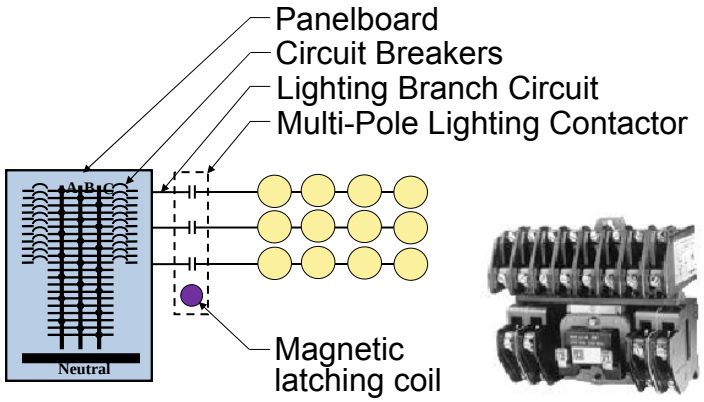

Photo courtesy of Square D

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Power Contactor

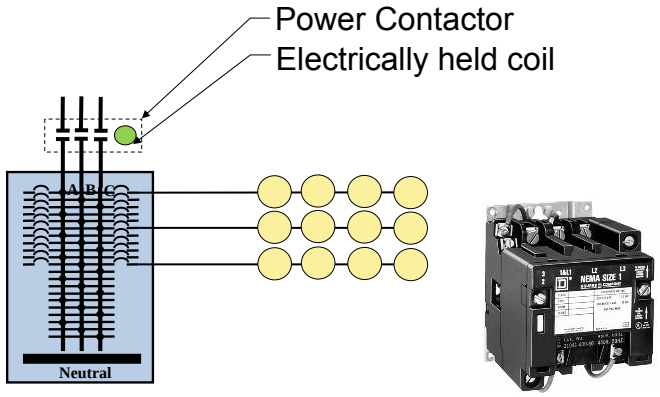

Photo courtesy of Square D

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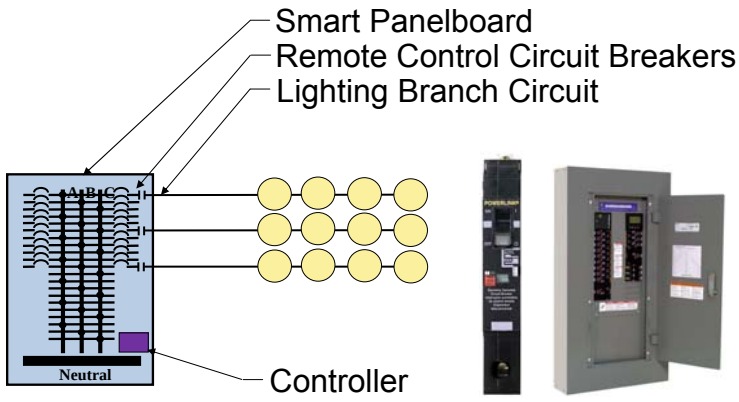
Remote Control Circuit Breaker



Photos courtesy of Square D

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Occupancy/Vacancy Sensors

- Occupancy Sensor Technologies
  - Infrared
  - Ultrasonic
  - Audiophonic
  - Dual technology
- Sensor Location
- Delay setting
- Sensitivity setting
- Mounting:
  - Ceiling, Wall/Corner, Wallbox, Task, Luminaire

Photo courtesy of The Watt Stopper

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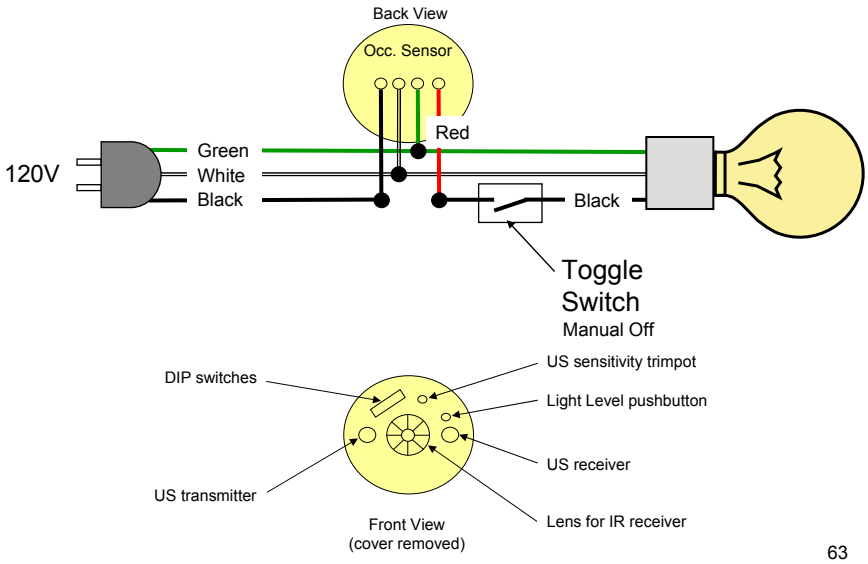
Line Voltage Occ Sensor W.D.



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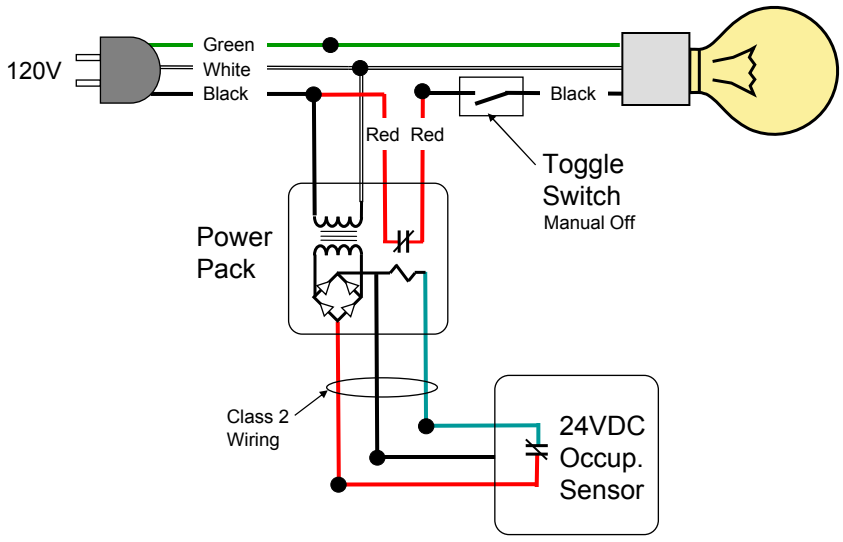
Low Voltage Occ Sensor W.D.



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Photosensor for Outdoor

– On/Off adjustable setting
– Time delay
– Deadband

Photos courtesy of The Watt Stopper

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Photosensor for Indoor

– Sensor response characteristics
– Sensor location & orientation
– Open loop, closed loop

Photos courtesy of The Watt Stopper

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Timer Switch

- Manual ON, Manual OFF, Automatic OFF
- Time duration adjustable
- Warning prior to shutoff: audible, visual
- Low-cost alternative to an occupancy sensor
- Leaves lights on for a pre-set period of time
- Install in place of a wall switch
- Used in storage rooms, copy rooms, etc.

Photo courtesy of The Watt Stopper

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Timer Switch Wiring Diagram

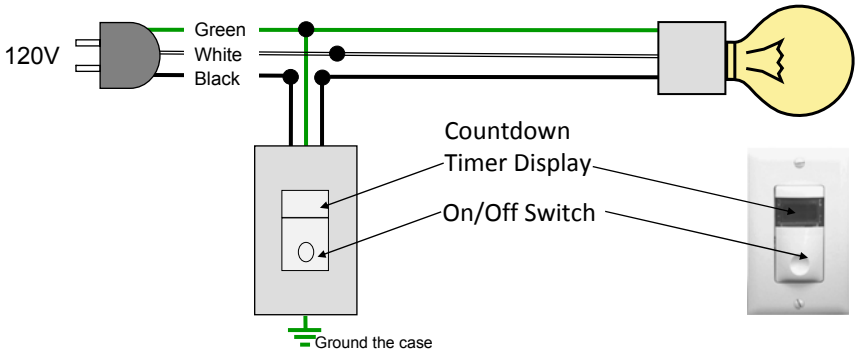

Photo courtesy of The Watt Stopper

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Time Schedule - Time Switch

- Time-of-day
- Day-of week
- Holiday
- Backup power
- Output signal
  - Single pole or multi-pole
  - Power rated contacts (maintained: NO, NC) (power rated means 20A, 120V or 277V)
  - Signal duty contacts (maintained or momentary) (signal duty is low voltage, low amperage)

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Astronomic Time Switch

- Same as Time Switch +
- dawn, dusk, offsets
- Latitude, Longitude, Time Zone, ZIP code

Photo courtesy of Tork

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Architectural Dimming

- Wallbox dimmers
  - Single gang
  - Line voltage: 2-wire, or 3-wire
  - 0-10VDC
  - Digital Addressable Lighting Interface (DALI)
  - Multi-scene, multi-channel
- Dimming Panels

Photo courtesy of LUTRON

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Emergency Condition

- Code required egress lighting
  - NFPA 101
  - NEC 700.4
- Night lights
- Transfer switch: double pole, double throw (DPDT)
  - When switching the Hot, must also switch the Neutral

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UL924 Relay

– UL924 relay (Normally Closed)
  - Normally Closed (NC): contact is closed when the relay coil is de-energized
  - Shunt with On/Off manual switch
  - Shunt with 3-way pair
  - Shunt with (bypasses) dimmer
  - Wiring diagrams

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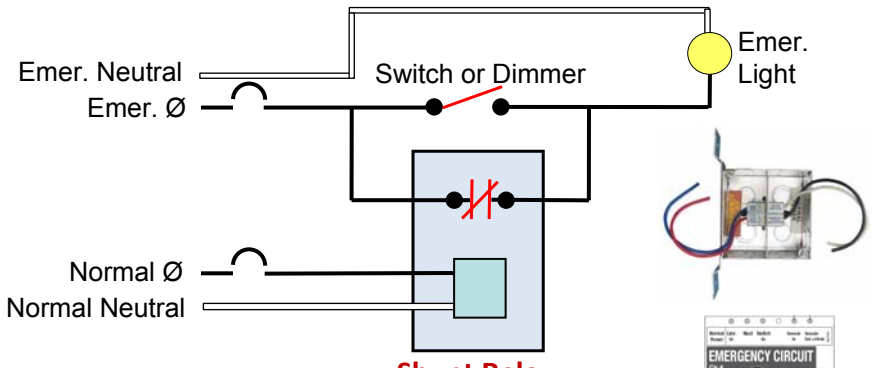
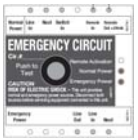
UL 924 Shunt Device





When Normal Power fails, a shunt bypasses any other control devices to force the Emergency Lights ON.

Photos courtesy of LC&D and The Watt Stopper

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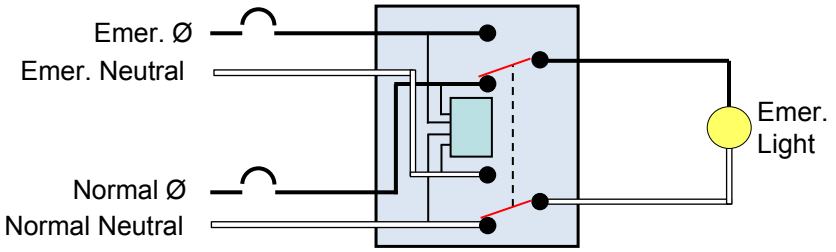
UL1008 Auto Transfer Switch



Automatic Transfer Switch

Automatic Transfer Switch:

- EM light connected to EM Source only in EM condition, otherwise connected to Normal Source
- Senses when Normal Source fails and transfers to the Emergency Source.
  - When switching the Hot between sources, must also switch the Neutral.
- Double pole, double throw (DPDT)

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User Interface / Dashboard

- Information reported
  - Real-time power
  - Energy history (trends)
- Controls / System Commands

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Dimming Technologies

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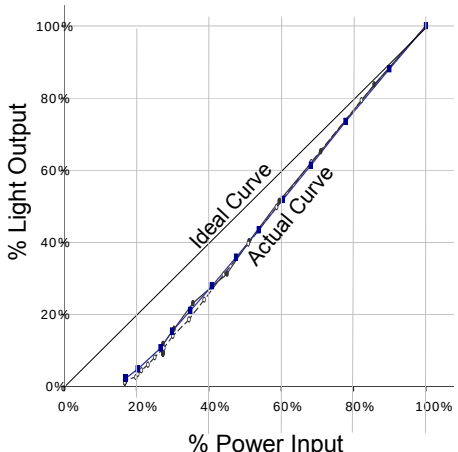
Dimming Saves Energy



(Three brands of DALI dimming ballasts)

Courtesy of LBNL

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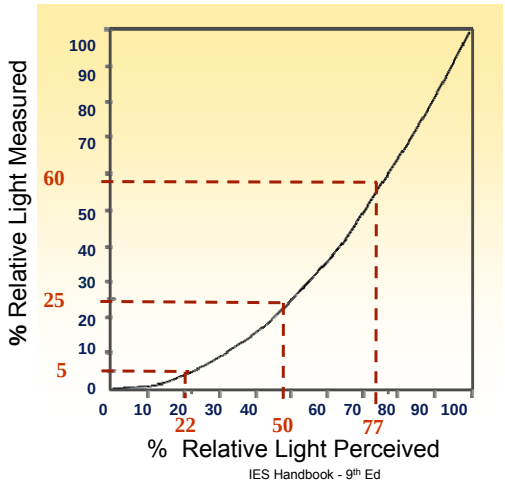
Perceived vs Measured Light



IES Handbook - 9th Ed

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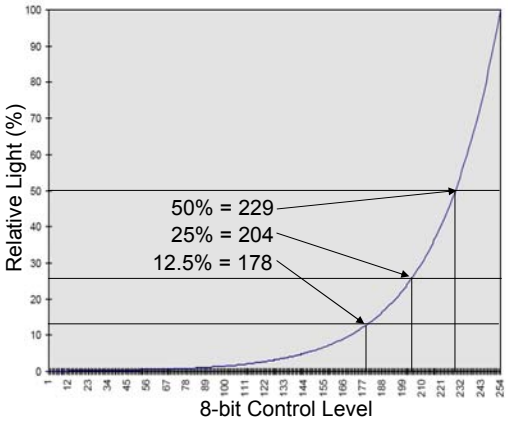
DALI Logarithmic Dimming



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Dimming Technologies

- Step Dimming (0-50-100), (0-33-66-100)
- 2-Wire Line Voltage Dimming
  - Forward Phase Control
  - Reverse Phase Control
- 3-Wire Line Voltage Fluorescent Dimming
  - Power
  - Class 1
- (4-Wire) Low Voltage 0–10VDC
- (4-Wire) Low Voltage DALI
- Pulse Width Modulation (PWM)

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Dual Signal Dimming Ballasts

- 2-Wire & 0-10VDC
- 3-Wire & DALI
- 0-10VDC & DALI

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Dimming Requirement !

The controller **must** be compatible with the ballast / transformer / driver.

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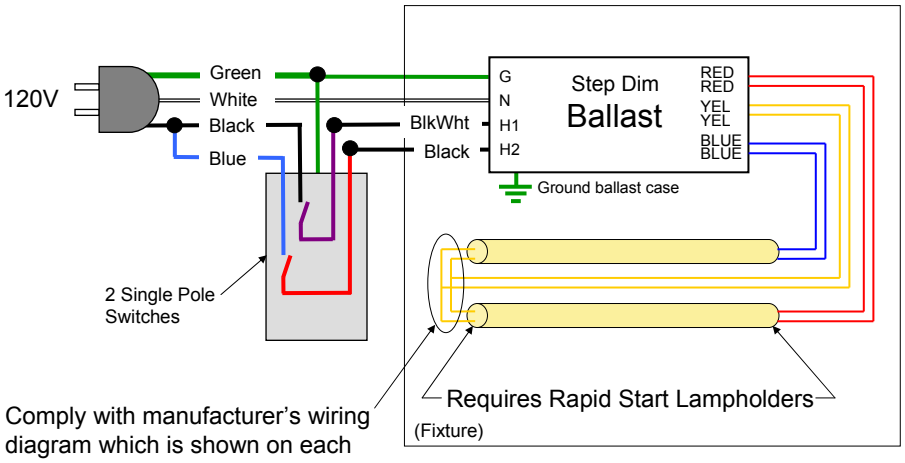
Step Dim Ballast



Comply with manufacturer's wiring diagram which is shown on each ballast label.

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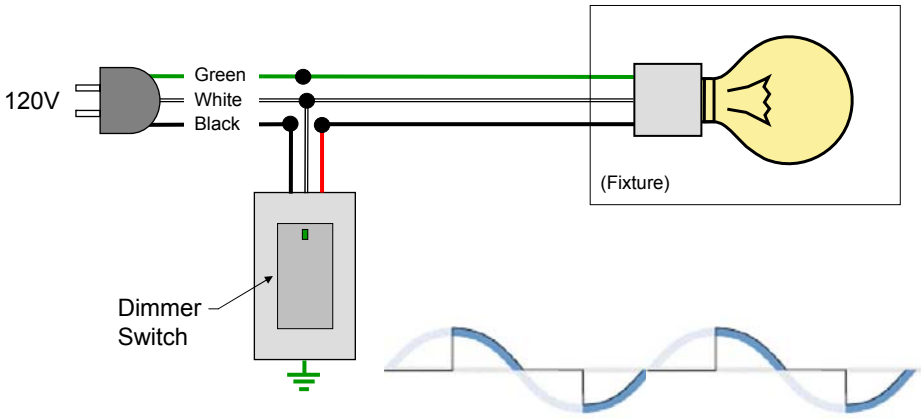
2-Wire Phase Control Dimmer



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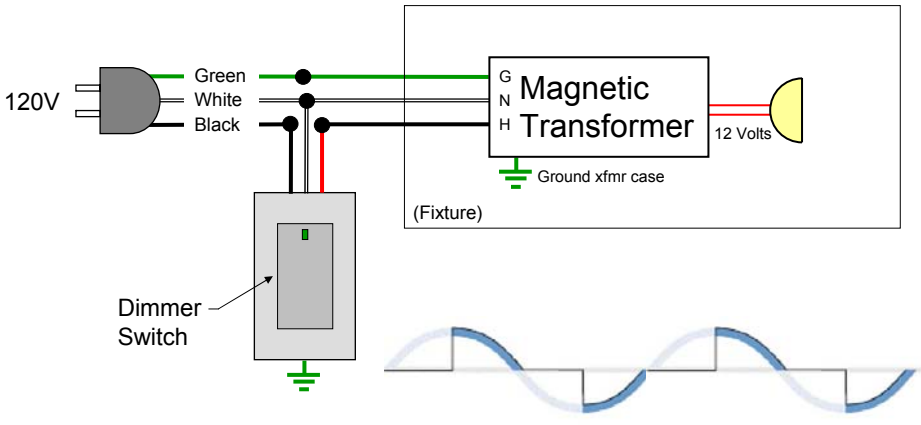
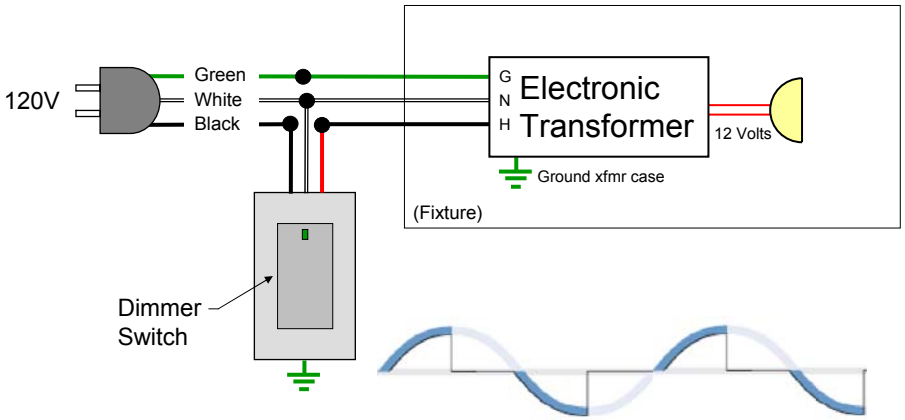
Forward Phase Control Dimmer



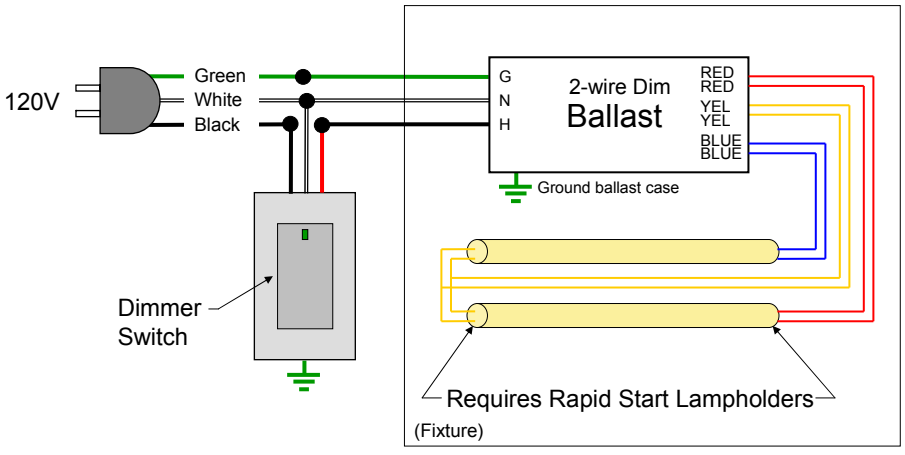
86

Reverse Phase Control Dimmer



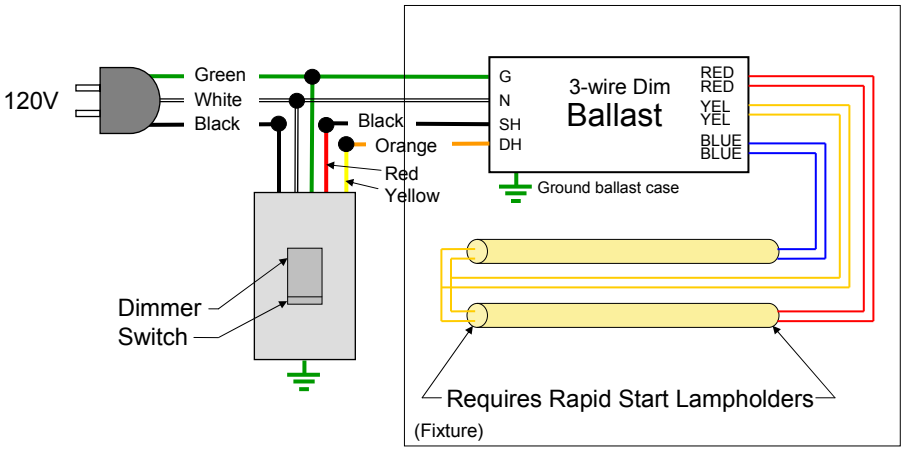
87

2-Wire Phase Control Dimmer



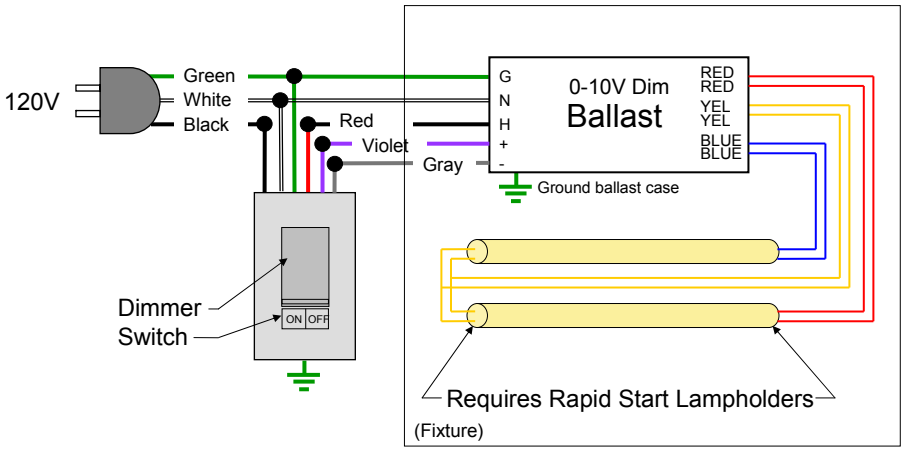
88

3-Wire Phase Control Dimmer



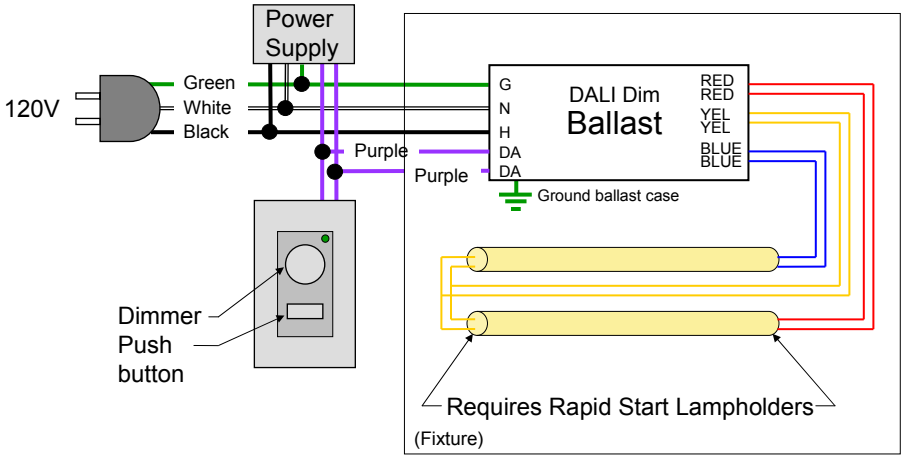
89

0-10VDC Dimming



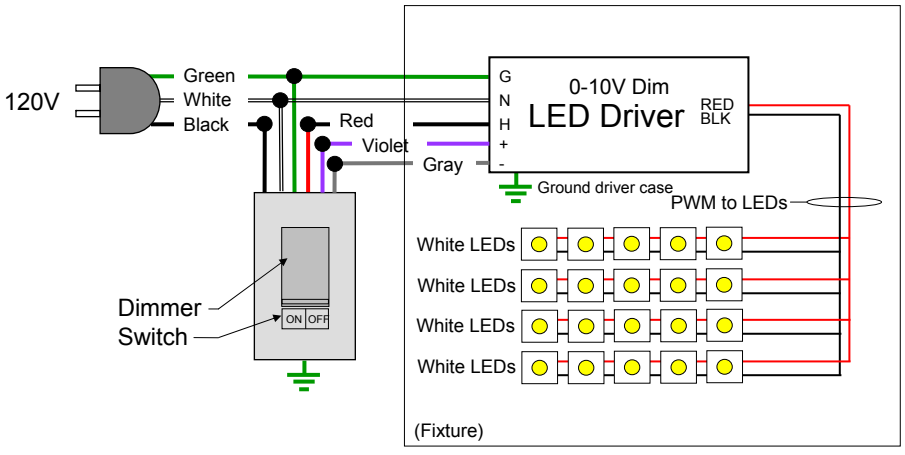
90

DALI Dimming



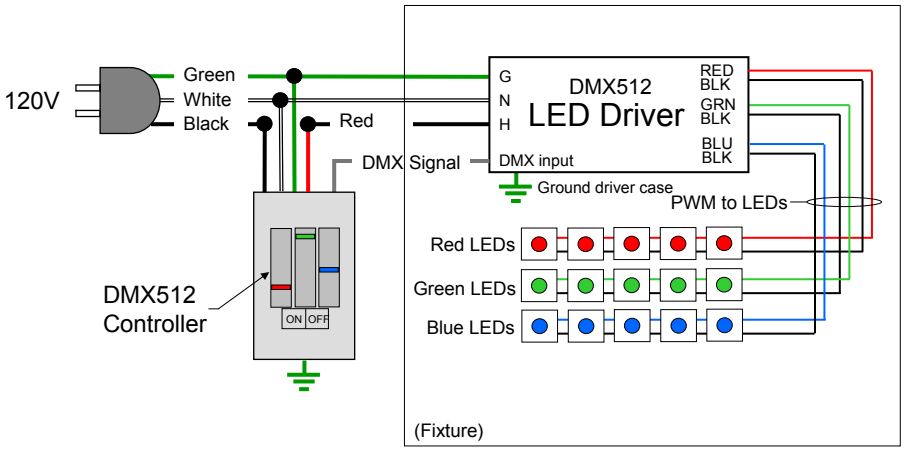
91

PWM Dimming of White LEDs Using 0-10VDC Control



92

Color Mixing of RGB LEDs Using DMX512 Control



93

Dimming Requirement !

The controller **must** be compatible with the ballast / transformer / driver.

94

LUNCH

(30 Minutes)

95

Sidebar Special

- Wiring between Ballasts and Lamps
- Lampholders

96

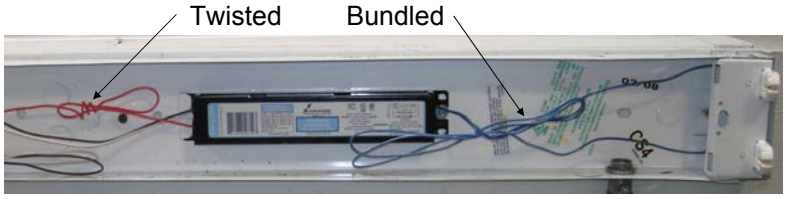
One Manufacturer has said:

- “Most of our 2L T8 dimming ballasts use parallel wired ‘yellow’ filaments.
  But we do have some 2L T8 dimming ballasts that use series wired ‘yellow’ filaments.”
- “Most of our 2L T5 dimming ballasts use series wired ‘yellow’ filaments.
  But we do have some 2L T5 dimming ballasts that use parallel wired ‘yellow’ filaments.”
- “So the bottom line is to check cutsheets and ballast labels.”

97

Ballast/Lamp Wiring

- Twisted/Bundled is OK for Instant Start,
- Not acceptable for Program Start or Dimming.



98

Fluorescent Lampholders

- Tall vs Short
- Remember that the lamp must be within 1/2” of a grounded metal surface

99

Fluorescent Lampholders

- Surface contact vs Knife-edge contact

100

Fluorescent Lampholders

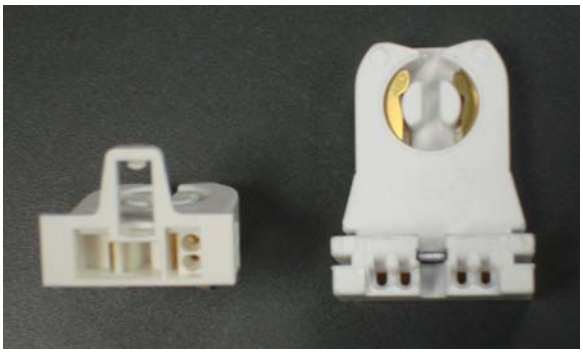
- Labeled as “Shunted” or with a “S”

Look closely and you can see the word “SHUNTED”

101

Fluorescent Lampholders

- Single Terminal dual port vs Two Terminal dual port



102

LUNCH

(30 Minutes)

103

Control Narratives

104

Sample Narratives

- Sequence of Operation:

  Wallbox Occupancy Sensors in storage rooms, janitor closets, etc: Set the time delay to 5 minutes. Enabled the Audible and Visible Alert functions

105

Strategies for Room Types

- From the Department Of Energy (DOE):
  - *Commercial Lighting Solutions*
  - www.lightingsolutions.energy.gov

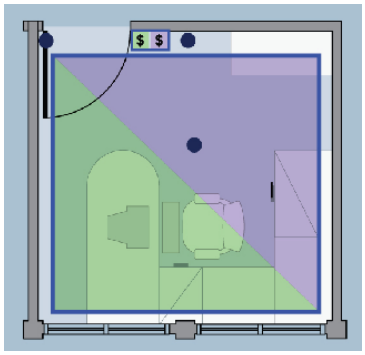
106

Commercial Lighting Solutions

- Box Retail: Dropped Ceiling
- Box Retail: Open Ceiling
- Grocery Store
- Pharmacy
- Specialty Market
- Office

107

Commercial Lighting Solutions



Control	Zone	Description
$ $		Dual general lighting zones (light level switching ballast) controlled by switches integral to a wallbox vacancy sensor (or stand-alone switches if vacancy sensor alternately mounted).
$ $		General lighting zone controlled by integral dual-switch wallbox vacancy sensor
●		The vacancy sensor may be located at the wall switch, corner mounted over the door or ceiling mounted

108

Sample Narrative from DOE

- Robust option combining the energy saving of occupancy-based automatic shutoff with flexible multilevel switching.
  - A vacancy sensor will turn the lights off when the space is unoccupied.
  - The occupant will turn the lights on to one or two increments between off and full light output using two manual switches installed at the wallbox using either stand alone switches or switches integral to a wall switch vacancy sensor. (cont.)

109

Sample Narrative from DOE

- The vacancy sensor will feature a time delay setting that is short enough to achieve intended energy savings (and meet code requirements) but long enough to avoid significant reductions in lamp life due to very frequent switching.
- A vacancy sensor time delay of at least 15 minutes is recommended. If programmable time delays are enabled by the control system, the time delay can be shortened to about 5 minutes after normal operating hours.

110

Strategies for Room Types

- From the New Building Institute:
  - *Advanced Lighting Guidelines*
  - www.algonline.org

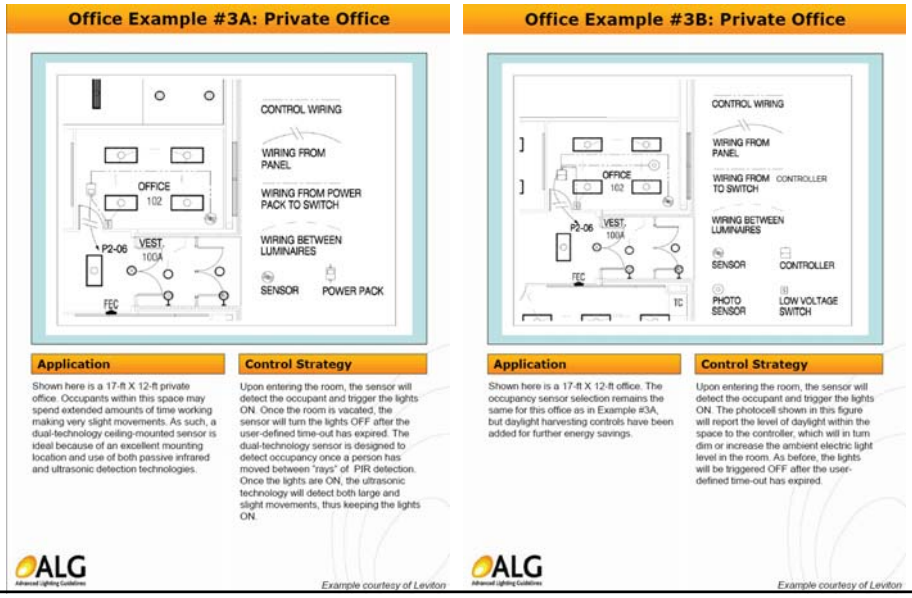
111

Advanced Lighting Guidelines

- Large Private Office
- Medium Private Office
- Small Private Office (2)
- Open Office
- Conference Room (3)
- Classroom (4)
- Warehouses (2)
- Big Box Retail

112

Advanced Lighting Guidelines



Sample Narrative from ALG

- Control Strategy Office Example #3A
  - Upon entering the room, the sensor will detect the occupant and trigger the lights ON. Once the room is vacated, the sensor will turn the lights OFF after the time-out has expired. The dual-technology sensor is adjusted to turn ON using PIR detection, and once the lights are ON, the ultrasonic technology will keep the lights ON.

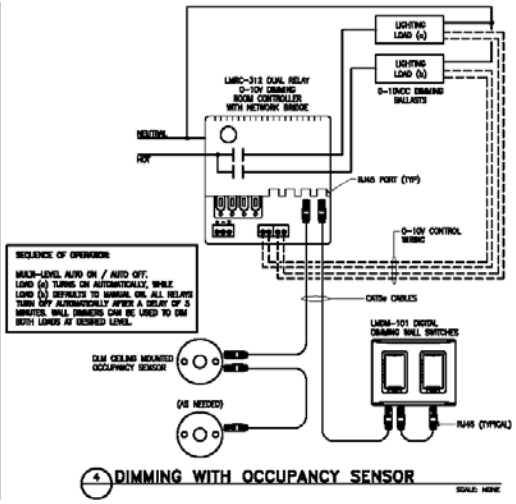
114

Sample Narrative from ALG

- Control Strategy Office Example #3B
  - Upon entering the room, the sensor will detect the occupant and trigger the lights ON. The photocell will report the level of daylight within the space to the controller, which will in turn adjust the ambient electric light level in the room. As in #3A, the lights will be triggered OFF after the user-defined time-out has expired.

115

Recent Project Narrative 1

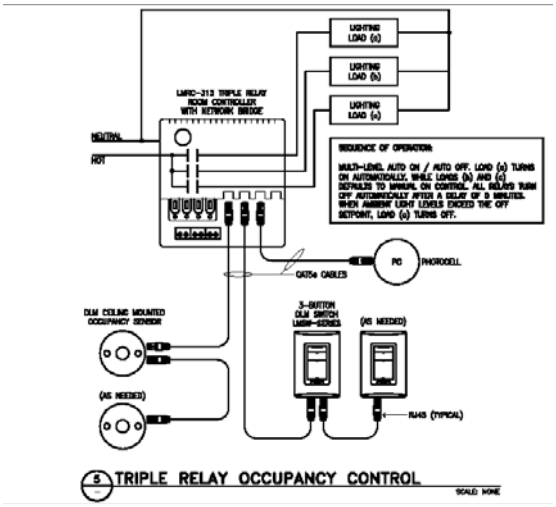


Sequence of Operation

Multi-level Auto ON / Auto OFF, Load (a) turns on automatically, while Load (b) defaults to manual ON, all relays turn OFF automatically after a delay of 5 minutes, wall dimmers can be used to dim both loads at desired level.

116

Recent Project Narrative 2



Sequence of Operation

Multi-level Auto ON / Auto OFF, Load (a) turns on automatically, while Loads (b) and (c) defaults to manual ON, all relays turn OFF automatically after a delay of 5 minutes, when ambient light levels exceed the off setpoint Load (a) turns OFF.

117

Hardware, Protocols, & Systems

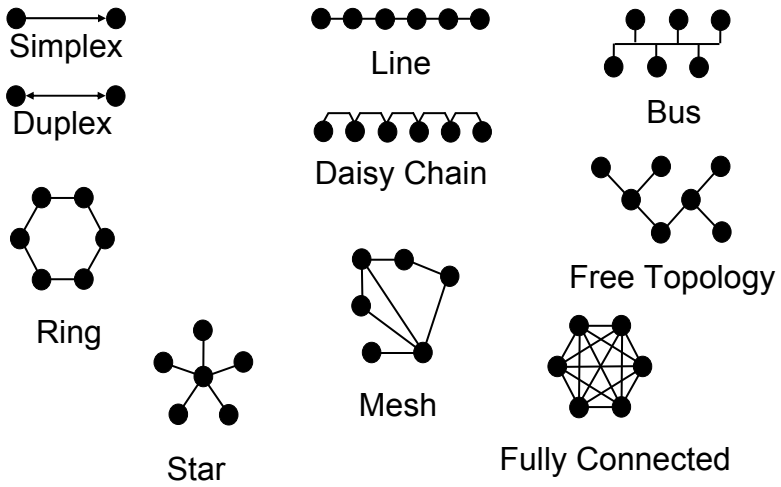
118

Hardware

- Topology
- Medium
- Connectors

119

Topology



120

Medium

- 2 wire to contact closure
- RS232
- RS485
- Ethernet
- USB
- IR
- Wireless RF

121

Connectors

- Screw terminals
- Pigtails
- Twist wire nuts
- Pushin
- Lever
- Insulation piercing
- RJ11
- RJ45
- 5 pin DIN
- DB9
- DB25

122

Protocols

- ACN
- ASCII
- BACnet
- DALI
- DMX512
- EnOcean
- Konnex
- LonWorks
- MIDI
- Modbus
- RDM
- SMPTE
- TCP/IP
- ZigBee
- Z-Wave
- (IES TM-23)

123

Gateway

- Device that translates one protocol into another protocol
- May be unidirectional or bidirectional
- Takes time to translate

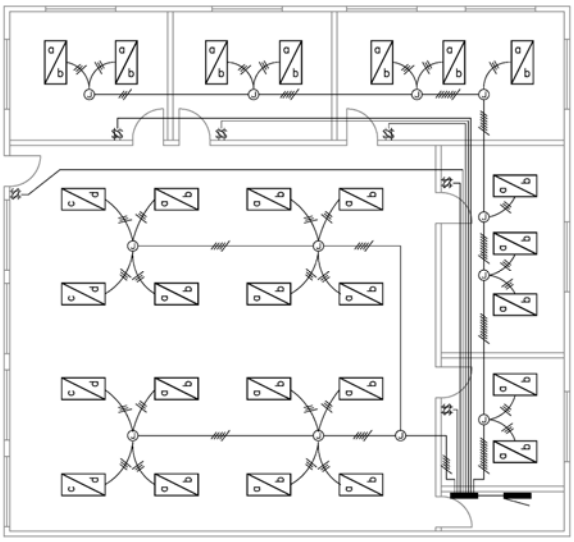
124

Systems

- Wired
  - Centralized
  - Distributed
- Wireless
  - Mesh Network
  - Micro Power

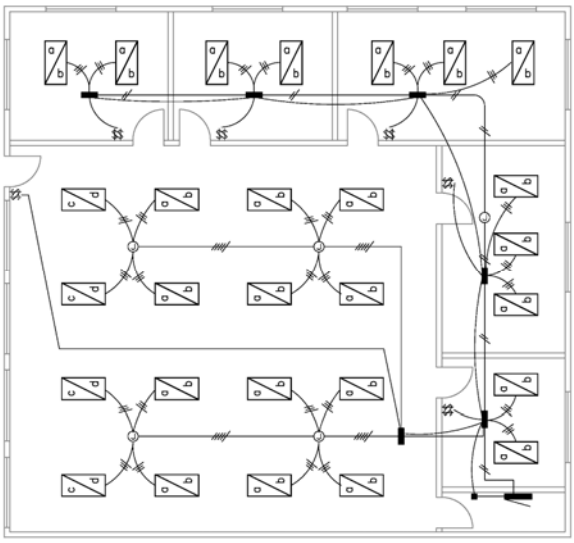
125

Wired - Centralized



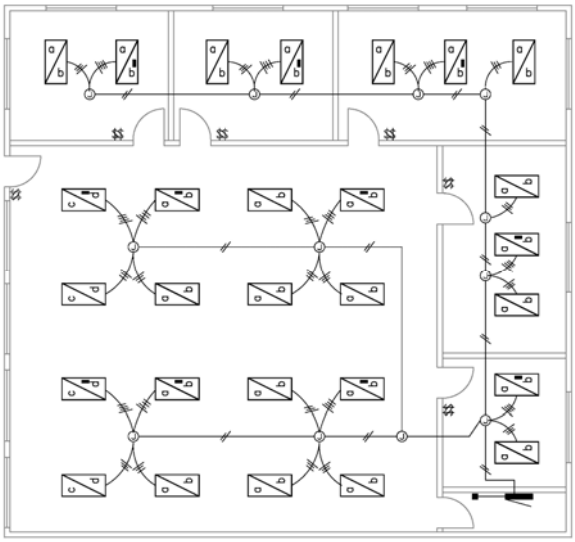
126

Wired - Distributed



127

Wireless



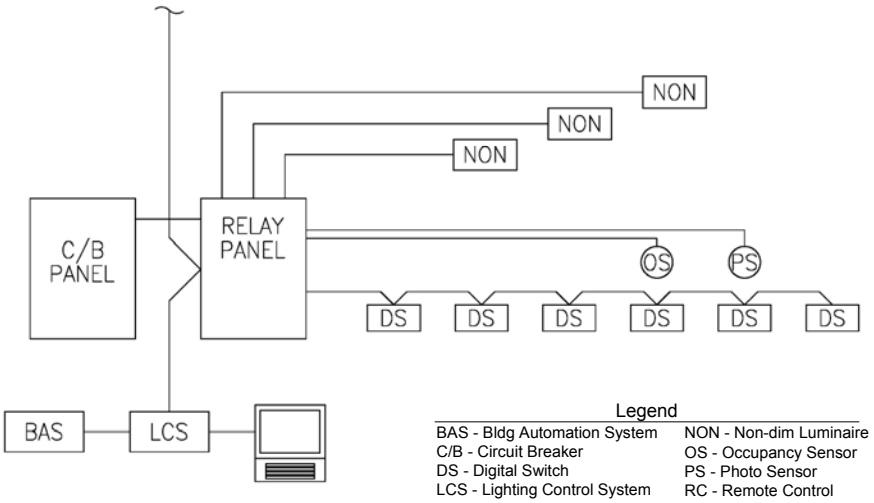
128

Relay Systems

- Central Panels in electrical rooms
  - Lighting branch circuit control
  - Long homeruns
  - Local low voltage & override switches
  - Local latching line voltage switches
- Distributed Boxes in ceiling above respective rooms
- Inputs (Sw, OS, PS):
  - Homerun to central panel
  - Discrete wiring or digital

129

Relay Systems

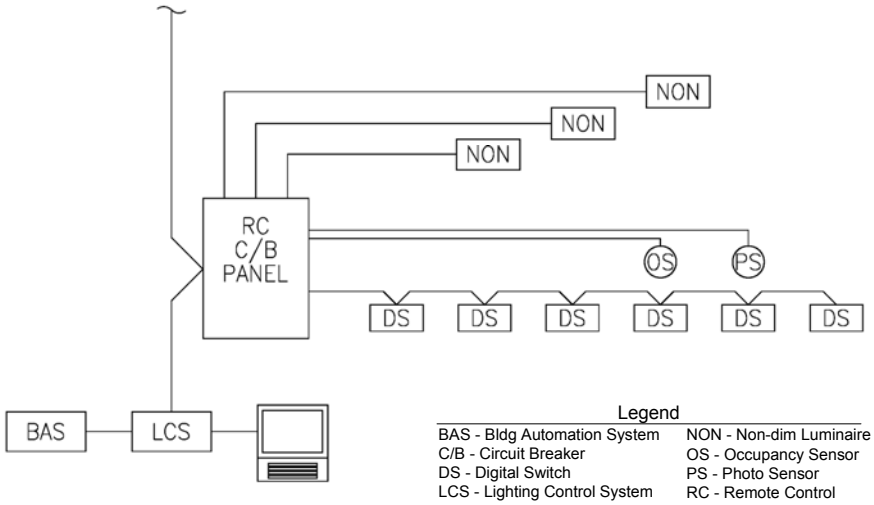


Remote Control Circuit Breaker

- Circuit breaker has integral motor operated contactor
- Motor operated contactor attached to load terminal of standard circuit breaker

131

Remote Control Circuit Breaker

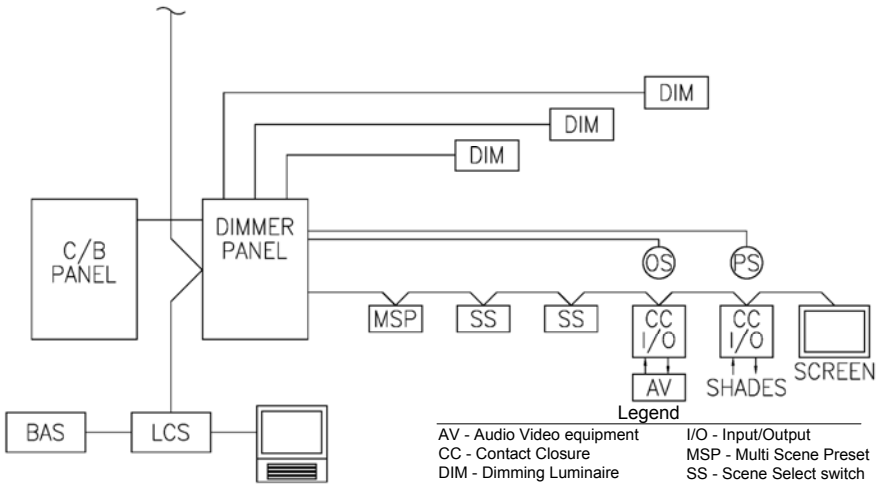


Dimming Systems

- Central Panels in electrical rooms
  - Lighting branch circuit control
  - Long homeruns
  - Local scene selection stations
  - Multi-Scene Multi-Channel stations
- Distributed Boxes in ceiling above respective rooms
- Inputs (Sw, OS, PS):
  - Homerun to central panel
  - Discrete wiring or digital

133

Dimming Systems



Local Digital Networks (DALI)

- Digital Addressable Lighting Interface (DALI) Protocol
- Components
- Wiring
- Systems integration
- Integration with BAS
  - Access to lighting system information
  - Access to setpoints, control templates
- Wireless

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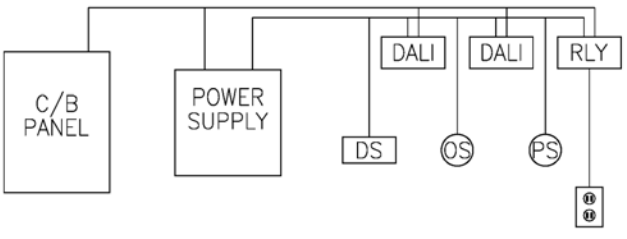
Local Digital Networks (DALI)

Single Room Application

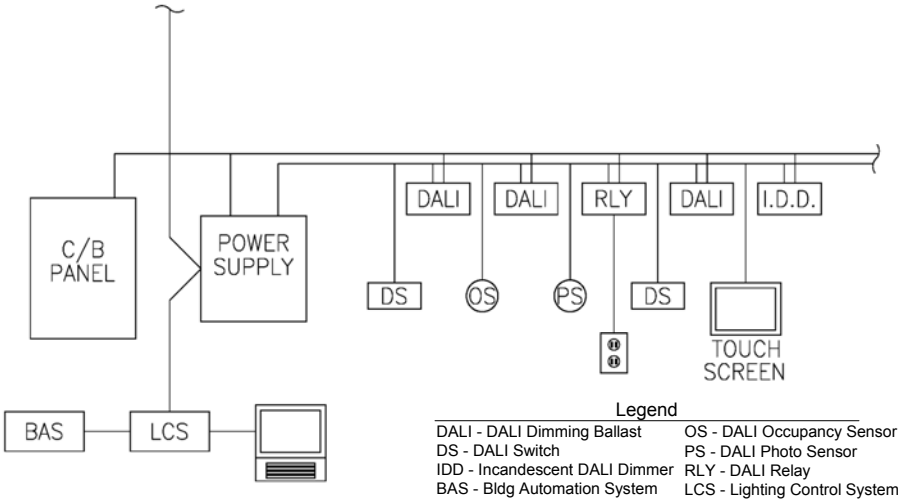


Legend

DALI - DALI Dimming Ballast
DS - DALI Switch
OS - DALI Occupancy Sensor
PS - DALI Photo Sensor
RLY - DALI Relay

Local Digital Networks (DALI)

System Application



Legend

DALI - DALI Dimming Ballast	OS - DALI Occupancy Sensor
DS - DALI Switch	PS - DALI Photo Sensor
IDD - Incandescent DALI Dimmer	RLY - DALI Relay
BAS - Bldg Automation System	LCS - Lighting Control System

Digital Component System

- Modular per room
- Module per luminaire
- Plug-and-Play components
  - Occupancy sensor
  - Photo sensor
  - Scene control
  - Handheld control
  - Remote commissioning
- Integration with BAS
  - Access to energy information
  - Access to setpoints, control templates

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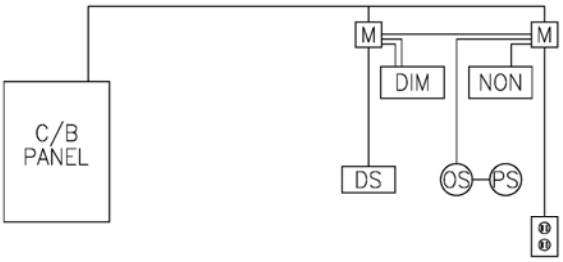
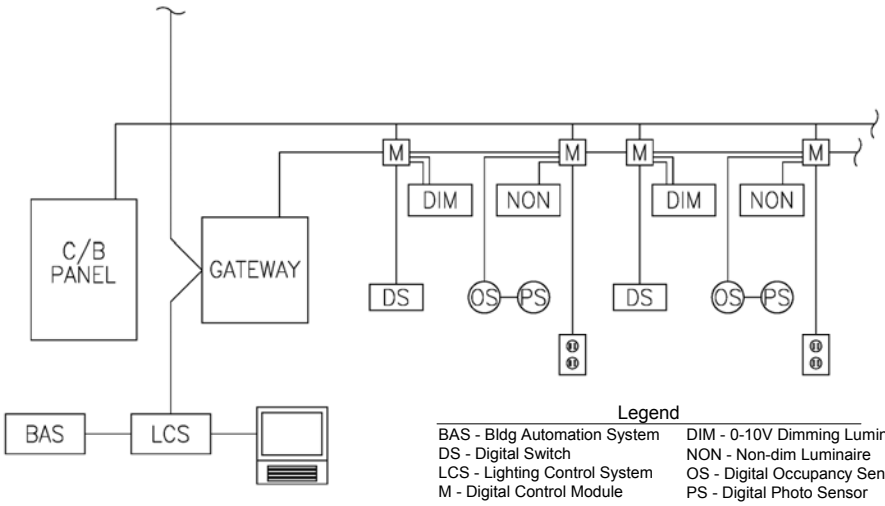
Digital Component System
Single Room Application



Legend

BAS - Bldg Automation System	DIM - 0-10V Dimming Luminaire
DS - Digital Switch	NON - Non-dim Luminaire
LCS - Lighting Control System	OS - Digital Occupancy Sensor
M - Digital Control Module	PS - Digital Photo Sensor

Digital Component System
System Application



Legend

BAS - Bldg Automation System	DIM - 0-10V Dimming Luminaire
DS - Digital Switch	NON - Non-dim Luminaire
LCS - Lighting Control System	OS - Digital Occupancy Sensor
M - Digital Control Module	PS - Digital Photo Sensor

Theatrical (DMX512)

- Distributed dimmers at fixtures
- Devices at/on fixtures
- Control consoles

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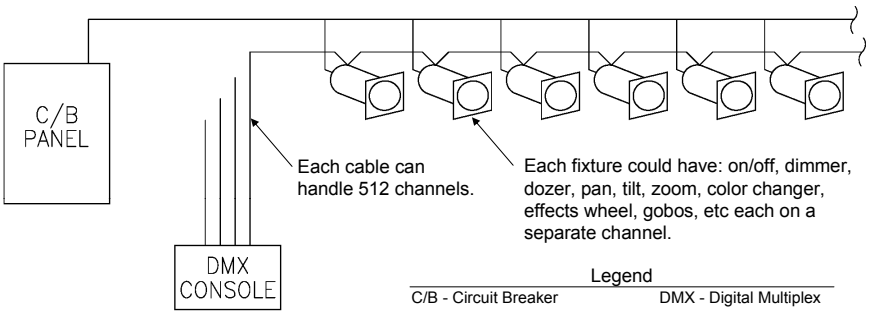
Theatrical (DMX512)



Multi-Media Systems

- Slide shows
- Museum tours
- Multiple protocols

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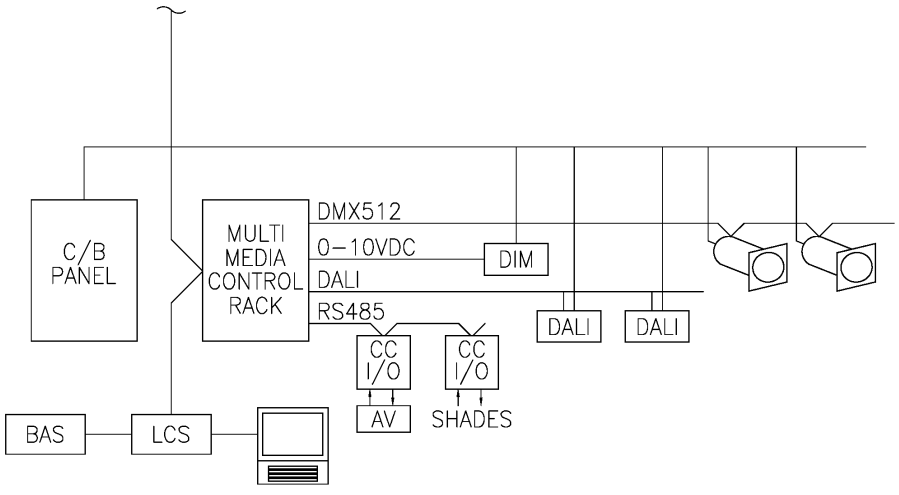
Multi-Media Systems



LoVo Powerline Carrier for LED

- LED luminaires
  - each on separate cable:
    - ≤20 watts,
    - CAT5 up to 150 ft, 18AWG up to 100 meters
    - 350 mA at 60VDC
  - each addressable
- Sensors for motion, daylight, task light, LED temp, volts, amps
- Hub power supply and controller, 64 channels
- Centralized driver delivers DC power and a network link to each luminaire
- A single pair of wires will carry both the constant-current DC power needed to power a LED and a proprietary power-line communication signal

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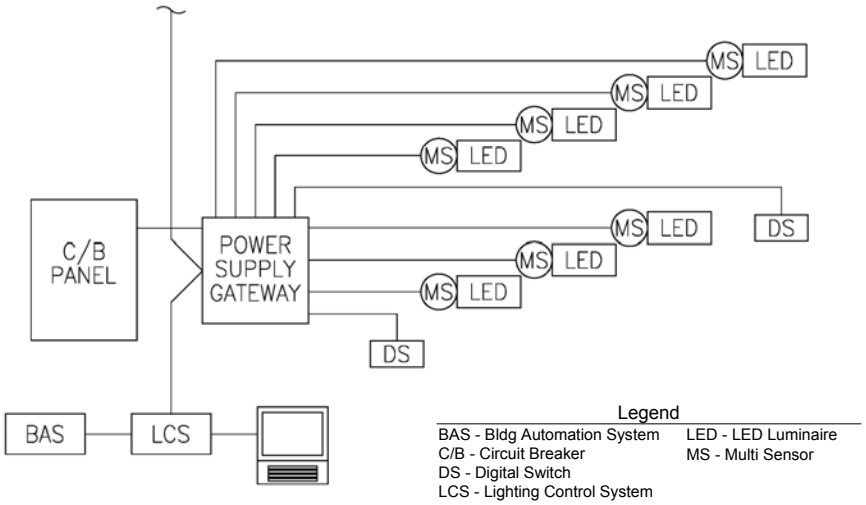
LoVo Powerline Carrier for LED



Wireless Mesh Network

- ZigBee carrier
- Discrete MAC address
- Mesh Network
- 2.4 GHz

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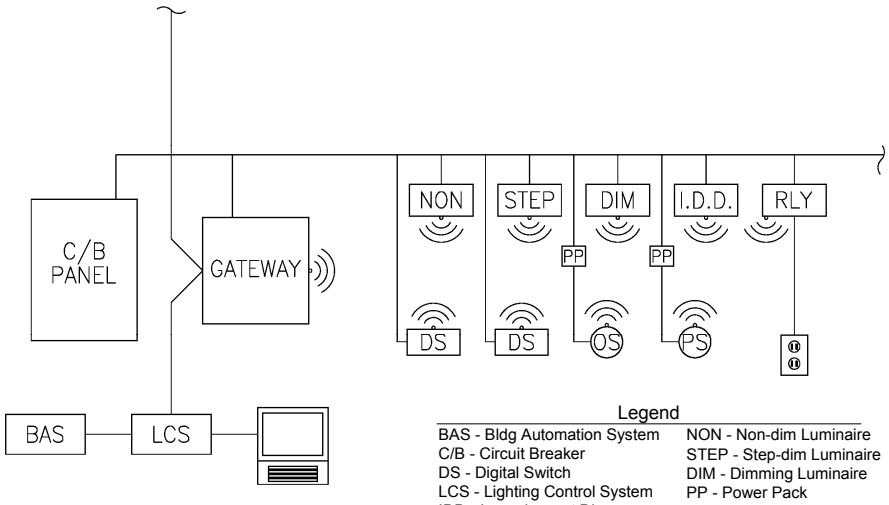
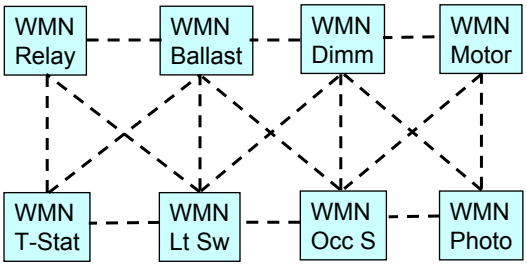
Wireless Mesh Network



Wireless Mesh Network



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Wireless Micro Power

- EnOcean protocol
- 868 and 315 MHz
- Flea power (microwatts)
- Energy harvesting
  - Photovoltaic (light to electricity)
  - Peltier (heat to electricity)
  - Piezo (mechanical to electricity)
  - Inductive (magnetic to electricity)

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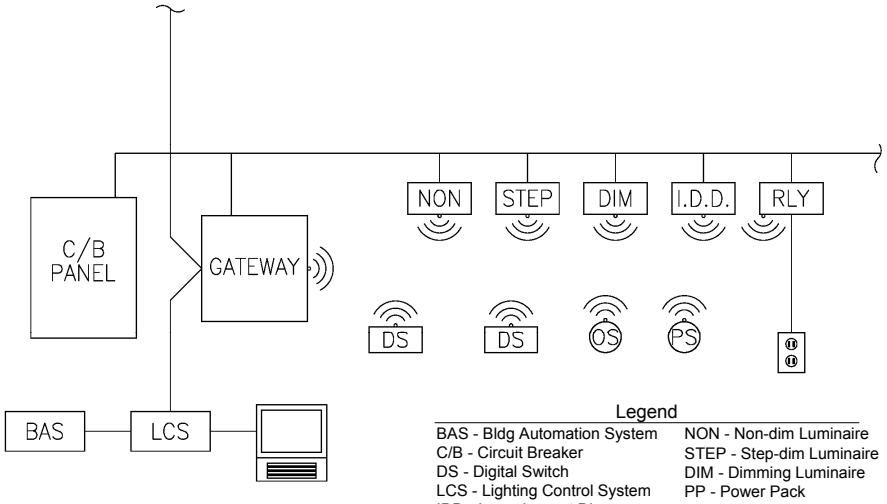
Wireless Micro Power



Legend

BAS - Bldg Automation System	NON - Non-dim Luminaire
C/B - Circuit Breaker	STEP - Step-dim Luminaire
DS - Digital Switch	DIM - Dimming Luminaire
LCS - Lighting Control System	PP - Power Pack
IDD - Incandescent Dimmer	RLY - Relay

BREAK

152

Research

153

A Life Cycle Cost Evaluation of Multiple Lighting Control Strategies

Prepared For: **Daintree Networks**

Prepared By: **Clanton & Associates, Inc.**

Dane Sanders, PE, LEED™ AP

Darcie Chinnis, EI, LEED™ AP

With Contributions by:

Group 14 Engineering

&

Energy Products Associates, LLC

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Systems Evaluated

- 1 – Localized Control (Title 24 compliant)
- 2 – Relay Panel for Switching
- 3 – Panel for Switching & Daylight Dimming
- 4 – Addressable All Dimming
- 5 – Wireless Daylight Dimming
- 6 – Wireless All Dimming

Courtesy of Clanton & Assoc and Daintree Networks

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Quantitative Findings

- Space planning effects access to daylight, therefore lighting energy.
- Advanced lighting controls can achieve nearly 50% less energy than code-compliant lighting controls.
- Wireless lighting controls have lower capital costs than the other lighting control systems studied in office retrofit applications.
- Using dimmable ballasts everywhere can be cost effective.
- Addressable, networked lighting control systems (wired and wireless) significantly reduce labor costs.
- Reduced labor and energy costs of advanced, networked lighting control systems can out-weigh increased equipment and commissioning costs.
- Addressable, networked lighting control systems (wired & wireless) offer more features for the same or less life cycle cost as the other lighting control systems evaluated

Courtesy of Clanton & Assoc and Daintree Networks

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Qualitative Findings

- Employee satisfaction is likely to increase with their ability to control their lighting to provide the optimal luminous environment.
- Addressable, networked lighting systems allow for easy system reconfiguration, allowing the system to be adapted for future uses with minimal time and cost.
- Addressable, networked lighting systems are adaptable to changing room conditions, allowing sensor locations to be adjusted based on interior configurations.
- Real-time energy monitoring is possible through addressable, networked lighting systems (wired & wireless), allowing the operator of a building to understand the interaction of the users with the lighting system, provide education about the capabilities of the lighting system and personal energy use, and encourage education and awareness of lighting energy use.

Courtesy of Clanton & Assoc and Daintree Networks

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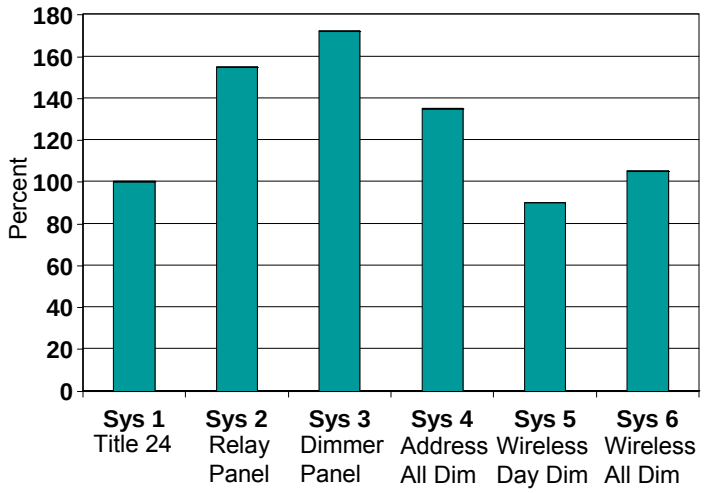
Relative Capital Cost



Courtesy of Clanton & Assoc and Daintree Networks

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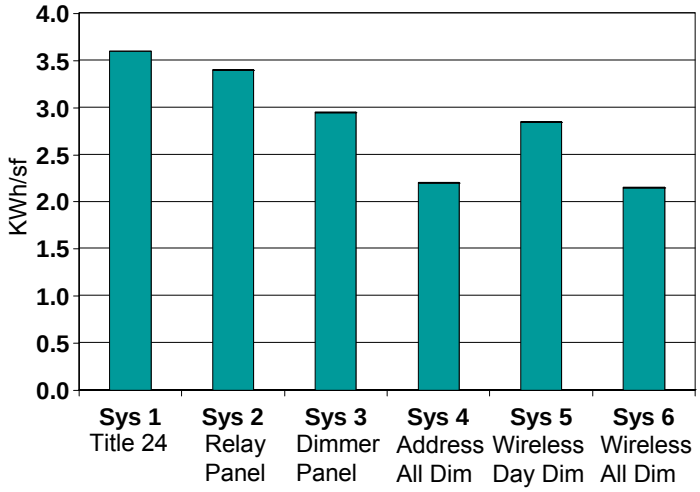
Annual Energy Use



Courtesy of Clanton & Assoc and Daintree Networks

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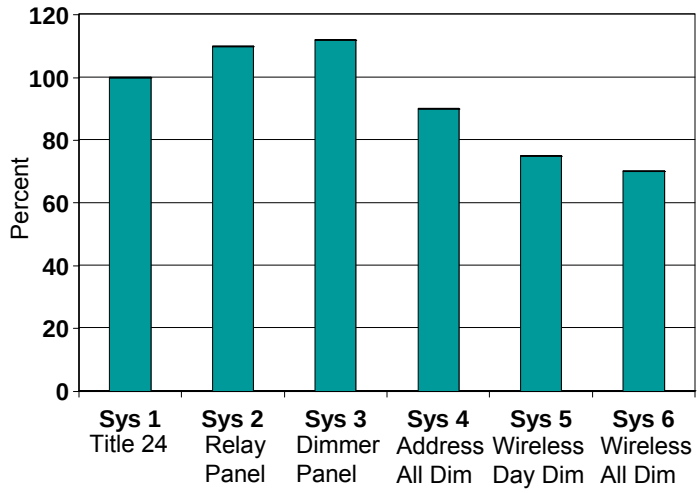
Relative Life Cycle Cost



Courtesy of Clanton & Assoc and Daintree Networks

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Incentives

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SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

New Dimming Ballasts Offering

Announced
May 3, 2011

FOR OVER 100 YEARS...LIFE. POWERED BY EDISON.

Dimming Ballasts Strategies

- **Mandatory**
  - All dimming ballasts are tuned by 20%
- **Optional**
  - Tuning + Occupancy Sensors (OS)
  - Tuning + Daylight Harvesting (DH)
  - Tuning + OS + DH

Note: The strategies listed above will have Demand Response capabilities

- Optional
  Auto Demand Response (ADR) combined with the above.

Dimming Ballasts Offering

Energy Efficiency (EE) Customized Solutions • **EE incentive: $0.05/kWh and $100/kW**	
LT-32843	Dimming Ballasts - 20% Tuning
LT-57958	Dimming Ballasts - 20% Tuning + Occupancy Sensor
LT-36502	Dimming Ballasts - 20% Tuning + Daylight Harvesting
LT-78223	Dimming Ballasts - 20% Tuning + Occupancy Sensor + Daylight Harvesting with Side Lighting Photo Controls
Energy Efficiency (EE) and Demand Response (DR) * • **EE incentives: $0.05/kWh and $100/kW** • **Auto-DR incentives: up to $300/kW**	
LT-48272	Dimming Ballasts - 20% Tuning + Auto Demand Response
LT-60897	Dimming Ballasts - 20% Tuning + Occupancy Sensor + Auto Demand Response
LT-49584	Dimming Ballasts - Daylight Harvesting + Auto Demand Response
LT-89432	Dimming Ballasts - 20% Tuning + Occupancy Sensor + Daylight Harvesting with Side Lighting Photo Controls + Auto Demand Response

*** Those projects with both EE and DR Solution Codes are eligible to receive a bonus**

Offering, cont'd

- Energy Efficiency (EE) incentives through Customized Solutions approach **at $0.05/kWh and $100/kW**
- Demand Response (DR) incentives through Technical Assistance & Technology Incentive (TA&TI) Program up to **$300/kW** (of measured load reduction)
  - Requires compatibility with Auto-DR
- Bonus incentives for integrated EE+DR installations
  - Details to come via The Contractor Connection E-Newsletter

Terms and Conditions

- Applications must be submitted through the Online Application Tool and utilize the Dimmable Ballast Calculation Tool
- Ballasts must be NEMA approved
- Ballasts must have continuous dimming; stepped dimming ballasts are not eligible
- Tuning level (20%) must be factory set or set on-site and must be locked in
- For projects applying for EE+DR incentives, customers must be enrolled in qualifying Auto-DR Program

How to Convey the Control System Design

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Specifications

- AIA, CSI, MasterSpec
- Intent (Narrative, Sequence of Operation)
- Submittals
- Warranties
- Responsibilities
- Deliverables
  - As-Built drawings
  - Manuals
  - Training
  - Spare parts
  - Special tools
- Components
- Systems
- Integration with other systems (AV, BMS, Etc)
- Commissioning process
  - Paperwork
  - Installation Verification
  - Start Up (by manufacturer)
  - Scene (dimmer) setting by Lighting Designer
  - Acceptance Testing per Title 24
  - Cx oversight by Third party

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Specifications: CSI Format

SECTION 260000 - TITLE OF SPEC SECTION

PART 1 - GENERAL

1.1 Related Documents
1.2 Summary
1.3 Submittals
1.4 Quality Assurance
1.5 Coordination

PART 2 - PRODUCTS

PART 3 - EXECUTION

3.1 Installation
3.2 Field Quality Control
3.3 Commissioning
3.4 Training

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Specifications: Electrical

- 260500 COMMON WORK RESULTS FOR ELECTRICAL
- 260519 ELECTRICAL POWER CONDUCTORS AND CABLES
- 260523 CONTROL ELECTRICAL POWER CABLES UTP
- 260533 RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS
- 260553 IDENTIFICATION FOR ELECTRICAL SYSTEMS

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Specifications: Electrical

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- 260523 CONTROL ELECTRICAL POWER CABLES UTP
- 260533 RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS
- 260553 IDENTIFICATION FOR ELECTRICAL SYSTEMS
- **260923 LIGHTING CONTROL DEVICES**
- **260933 CENTRAL DIMMING CONTROLS**
- **260936 MODULAR DIMMING CONTROLS**
- **260943 NETWORK LIGHTING CONTROLS**
- **262726 WIRING DEVICES**
- **263323 CENTRAL BATTERY EQUIPMENT**
- **265100 INTERIOR LIGHTING**
- **265561 THEATRICAL LIGHTING**
- **265600 EXTERIOR LIGHTING**

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Commissioning

- Who does the initial commissioning?
  - Contractor, employee, consultant, manufacturer?
- Post-sales support - maintenance
  - Who handles re-commissioning when changes are required due to changes in the function of the space?
  - Who maintains the system?
  - How much does it cost?
- Commissioning & maintenance must be written into the specifications!

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Narratives

- In specifications
- On drawings (preferred)

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Drawings

- Lighting Floor Plans
- Diagrams
- Schedules

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Lighting Floor Plans

- Room Names and No.
- Luminaire locations, ID
- Identify egress lighting
- Lighting branch circuits
  - Normal
  - Emergency
  - Panel name and circuit number

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Lighting Floor Plans

- Control components
  - Wallbox devices
  - Ceiling devices
  - Control stations
  - Cabinets

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Lighting Floor Plans

- Zones of control
  - a/b switching
  - multi-zone dimming
- Daylighting zones
  - Sidelight primary
  - Sidelight secondary
  - Skylight

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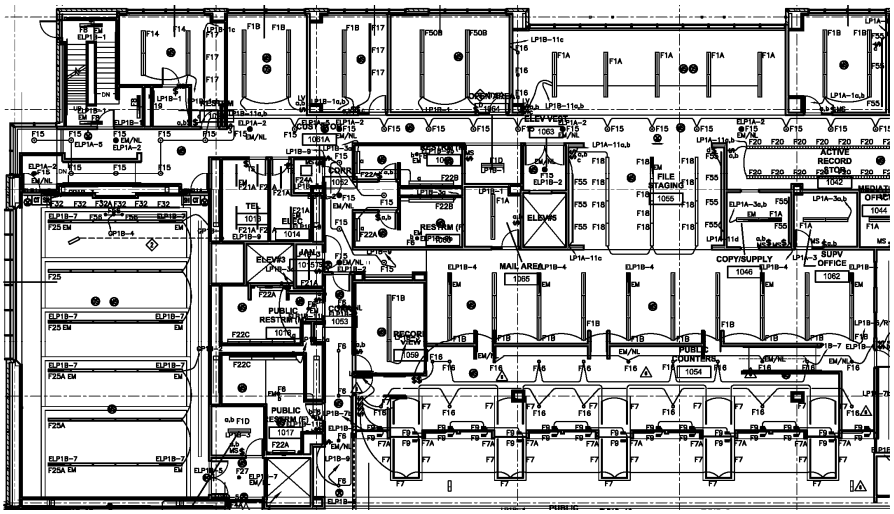
Lighting Floor Plans



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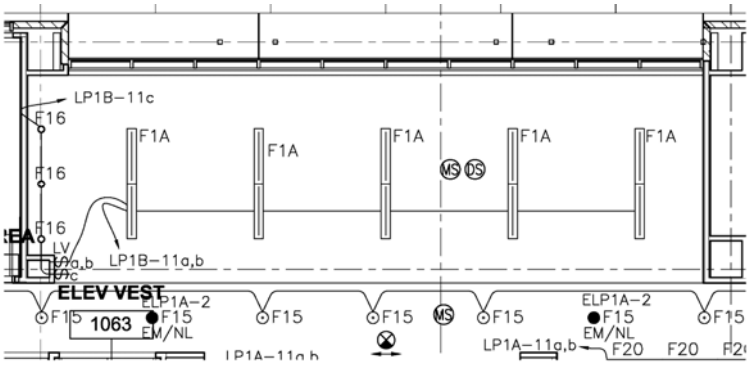
Lighting Floor Plans



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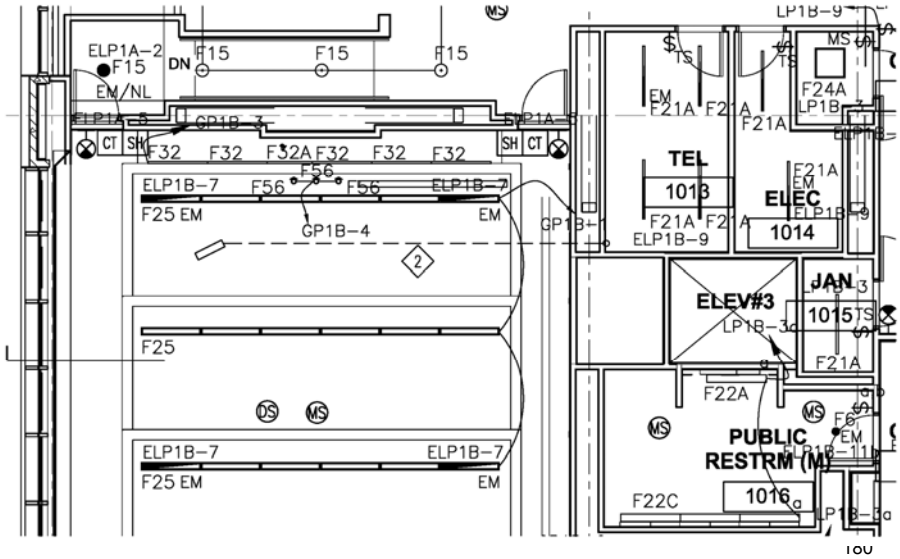
Lighting Floor Plans



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Narratives

Lighting Sequence of Operation

I. Local Dimming & Occupancy Sensors / Local Switch & Occupancy Sensors
   1. Installed in areas other than described in other sections.
   2. Occupants shall manually turn on lights using the local switch upon entering the room. Occupant sensors will sense occupancy and will keep the lights on. In the event that the room is vacant for 30 minutes, occupant sensor shall automatically turn off lights.

II. Ecosystem Dimming (using Bus Supply and BMJ modules)
   1. Installed at Stair #1, Stair #4, Public Queuing 1010, Main Lobby 1001, and Corridor 2001.
   2. The Lutron Ecosystem in conjunction with the WattStopper relay panel shall be used to dim and control the lighting in these areas via daylight sensors. Emergency fixtures in these areas shall be on 24/7 and are to be connected to the emergency source for egress lighting. Emergency fixtures shall dim to preset levels after hours via the time clock and shall reset to 100% full brightness in the event of power failure.
   3. Photosensors will be installed in the daylight harvesting area (i.e. with 15 feet of the exterior glazing). Photosensors shall be programmed to automatically dim the lighting fixtures located within the daylit area during the day. The photosensors are used and located to control each different lighting zone or group of fixtures. By default, the sensors shall be set to maintain an average light level of 15 to 20 footcandles at the Public Lobbies and Stairs.
   4. The system is programmable and is provided with astronomic timeclock.
   5. Once the system is programmed, users have the capability to dim the lights lower than what the photosensor commands or manually turn off the lights. However, users will not be able to raise the light intensity of the daylit harvest area nor override what the photosensor commands the system. Controls are located in areas not accessible to the public.

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Diagrams

- Riser diagram
  - Cabinets – Location, Type, ID
  - Wire – Type, ID
- Sub-system diagrams
  - Individual components – Location, Type, ID
  - Wire – Type, ID
- Component wiring diagrams
  - Occupancy sensors
  - Photo sensors
  - Relays

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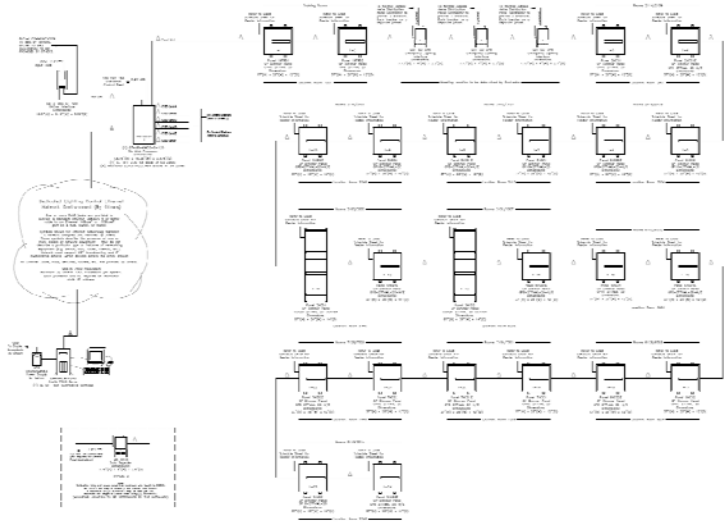
Riser Diagram



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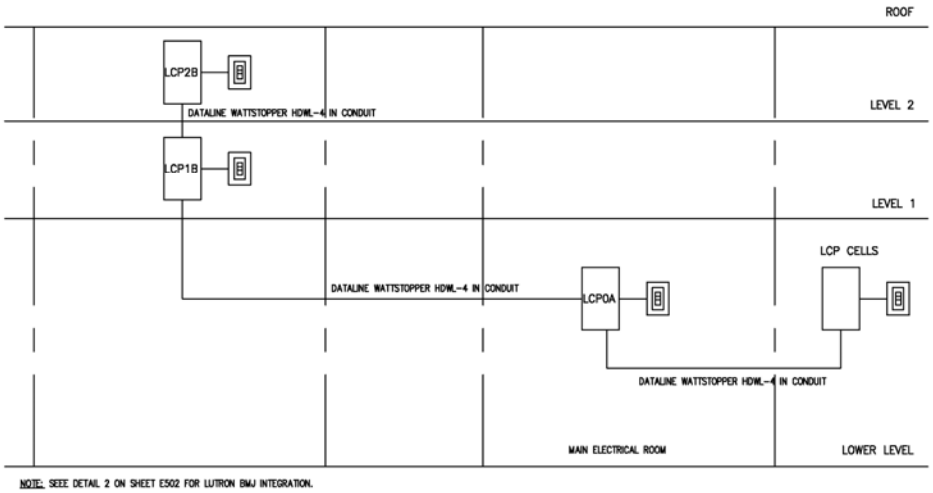
Riser Diagram



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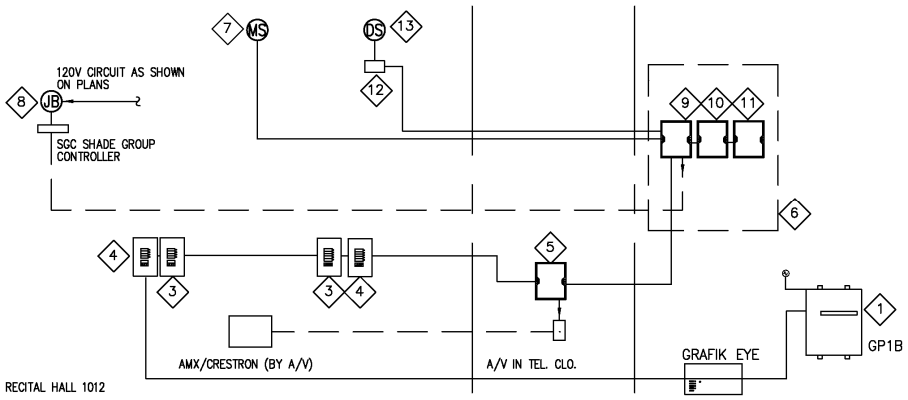
Sub-System Diagram



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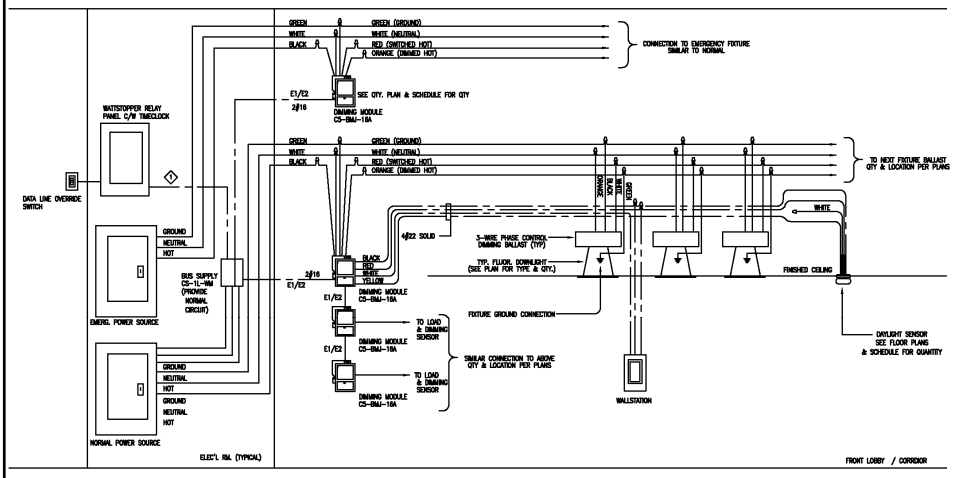
Daylight Harvesting Wiring



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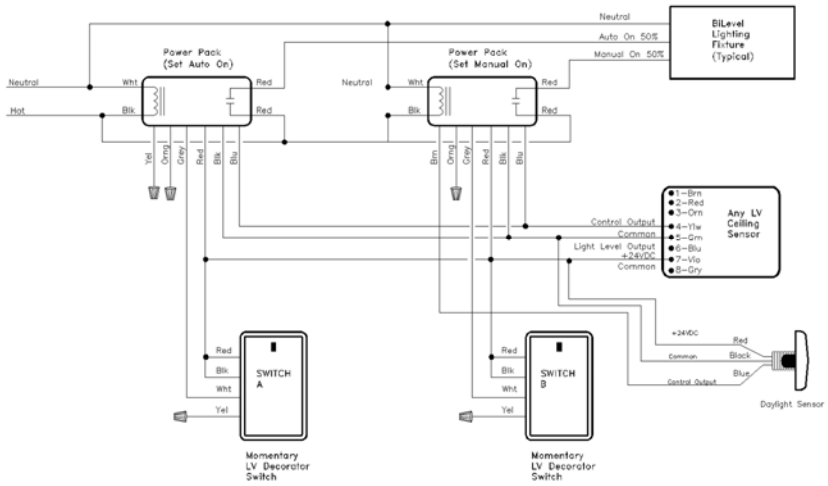
Component Wiring Diagrams



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Schedules

- Relay panel schedules
- Dimmer panel schedules
- Override switch schedules
- Daylight zone schedules
- Shade control schedules
- Component schedules
- Time schedules

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Schedule: Dimmer Panel

DIMMING PANEL "GP2A" (277V) CP12 277/4ML 20 (14 KAIC)

CIRCUITING DIMMING PANEL	CIRCUIT #	Zone	Room	Lighting	Type	QTY	Load Type	Watts	Total	CKT LOAD
DIMMING PANEL "GP2A"	1	1	RECITAL HALL 1012	24' RECESSED @ DESK	F25	3	FL HI-LUME	384	1152	1152
	2	2	RECITAL HALL 1012	24' RECESSED @ SEATING	F25A	2	FL HI-LUME	192	384	384
	3	3	RECITAL HALL 1012	4' LINEAR COVE @ REAR WALL	F32	5	FL HI-LUME	32	160	185
				3' LINEAR COVE @ REAR WALL	F32A	1	FL HI-LUME	25	25	
	4	4	RECITAL HALL 1012	RECESSED (LOGO)	F56	3	MLV	50	150	150
	5	1	RECITAL HALL 1014	24' RECESSED @ DESK	F25	3	FL HI-LUME	384	1152	1152
	6	2	RECITAL HALL 1014	24' RECESSED @ SEATING	F25A	2	FL HI-LUME	192	384	384
	7	3	RECITAL HALL 1014	4' LINEAR COVE @ REAR WALL	F32	5	FL HI-LUME	32	160	185
				3' LINEAR COVE @ REAR WALL	F32A	1	FL HI-LUME	25	25	
	8	4	RECITAL HALL 1014	RECESSED (LOGO)	F56	3	MAG. LV	50	150	150
	9	-	SPARE							
	10	-	SPARE							
	11	-	SPARE							
	12	-	SPARE							
								TOTAL PANEL CONNECTED LOAD (WATTS)		3742
								TOTAL PANEL CONNECTED LOAD (AMPS @480V, 3 PHASE, 4W + G)		4.5

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Schedule: Wallbox Dimmers

WALL BOX DIMMING SCHEDULE (LUTRON DIVA WALL BOX DIMMER)

Zone	Room	Lighting	Type	QTY	Load Type	Watts	Total	CKT LOAD
1	CONFERENCE RM 1027	12' DIRECT/INDIRECT PENDANT	F50B	2	FL HI-LUME	192	384	384
1	PUBLIC WORKSHP 1038	12' DIRECT/INDIRECT PENDANT	F50B	2	FL HI-LUME	192	384	384
1	CONFERENCE RM 2092	12' DIRECT/INDIRECT PENDANT	F50B	2	FL HI-LUME	128	256	256
1	JURY DELIBERATION ROOMS 2120	8' DIRECT/INDIRECT PENDANT	F50A	2	FL HI-LUME	128	256	256
1		4' DIRECT/INDIRECT PENDANT	F23	1	FL HI-LUME	64	64	64
1	JURY DELIBERATION ROOMS 2122	8' DIRECT/INDIRECT PENDANT	F50A	2	FL HI-LUME	128	256	256
1		4' DIRECT/INDIRECT PENDANT	F23	1	FL HI-LUME	64	64	64

WALL BOX DIMMING SCHEDULE (LUTRON NOVA-T SERIES)

1	CONTROL STATION 0073	2X4 FLUORESCENT	F24	2	FL HI-LUME	64	128	128
2	CONTROL STATION 0073	TRACK LIGHTS (120V)	F37	10'	HALOGEN TRACK	1800	1800	1800

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Schedule: Shade Control

SUMARY OF SHADE CONTROL IN COURTROOMS				
	ONE ZONE			
COURTROOM	BLACKOUT (EXTERIOR)	BLACKOUT (LIGHTWELL)	SHEER SHADE	LUTRON CAT #
LOWER LEVEL				
0010	N	N	N	DELETE TWO
LEVEL ONE				
1012	Y	N	Y	SG-3WDN-WH-E01
1032	Y	N	Y	SG-3WDN-WH-E01
1002	N	N	Y	SG-3WDN-WH-E01 SG-3WN-WH-E01
LEVEL TWO				
2012	Y	Y	Y	SG-3WDN-WH-E01
2072	N	Y	N	SG-3WN-WH-E01
2052	N	Y	N	SG-3WN-WH-E01
2032	Y	Y	Y	SG-3WDN-WH-E01

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Schedule: Relay Panel

RELAY OUTPUTS				TIME SCHEDULE		OVERRIDE CONTROL
Elect Panel	Ckt	Relay	Description	M-F Times	S-S Times	Type, Name, Source
LP-1A	1	01	Office 101	7:00 - 19:00	OFF	LVS-1
LP-1A	1	02	Office 101	7:00 - 19:00	OFF	LVS-1
LP-1A	2	03	Office 102	7:00 - 19:00	OFF	LVS-2
LP-1A	2	04	Office 102	7:00 - 19:00	OFF	LVS-2
LP-1A	3	05	Corridor	6:30 - 21:00	OFF	
LP-1A	4	06	Warehouse	6:00 - 21:30	6:00 - 21:30	LVS-3
LP-1A	5	07	Warehouse	6:00 - 21:30	6:00 - 21:30	LVS-3
		08				

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Conclusion

- From Concept
- To Construction

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References

- Clanton & Associates: “A Life Cycle Cost Evalution of Multiple Lighting Control Strategies”
- IES Seminar: Lighting Controls for Nonresidential Buildings
- LCA: Education Express: http://www.aboutlightingcontrols.org/Education_Express/welcome.php
- NBI
- NEMA
- DOE

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Credits

- Acuity Brands
- Adura Technologies
- Clanton & Associates, Inc.
- Benjamin
- DALI
- Douglas
- Daintree Networks
- Eaton/CH
- EnOcean
- Enovity
- EMerge Alliance
- ETC
- Functional Devices
- General Electric
- HOK
- ILC
- Illumra
- LC&D
- Leviton
- Lumenergi
- Lutron
- Redwood Systems
- Southern California Edison
- Siemens
- Square D
- Sylvania
- Tyco Electronics
- Watt Stopper

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THE END

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