

LED Dimming



ENERGY STAR Products Partner Meeting

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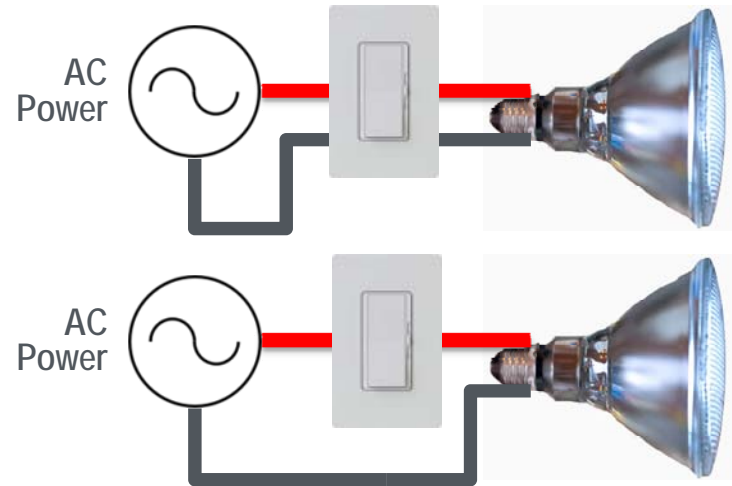
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- The behavior of an LED source on a circuit controlled by a phase-cut dimmer is a function of:
 1. the characteristics of the LED source (driver)
 2. the number and type of light sources on the circuit
 3. the characteristics of the dimmer
- Many types of behavior variation
- Many sources of behavior variation
- Behavior variation spans compatibility, performance, interoperability
- Behavior variation is significant in magnitude
- Behavior is only predictable via circuit level testing
- **Currently no standard definitions or test procedures for evaluating dimming behavior**

- LEDs are inherently dimmable
 - PWM vs. CCR
- LEDs are non-linear devices, which (typically) need a “driver”
- Most control technologies were designed for incandescent (resistive) loads
- Wide variation in LED source and dimmer circuit designs
 - Dimming curves, for both
 - Dimmer circuit loading
- Compatibility
 - Dead travel
 - Popcorn
 - Flashing, Ghosting
 - Pop-on, Drop-out
 - Audible noise
 - Inoperability
 - Premature failure
- Performance
 - Dimming range
 - Dimming curve
 - Efficacy
 - Flicker
- Predictability

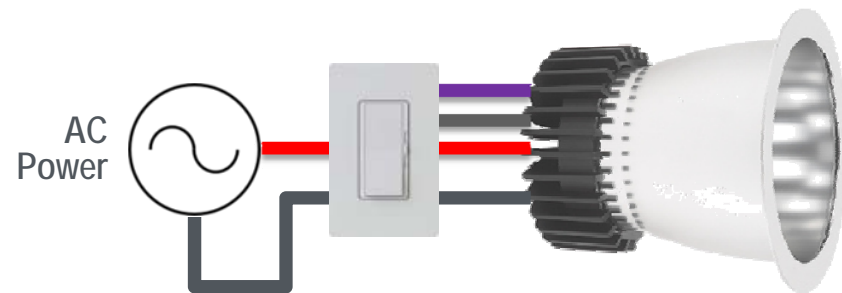
Coincident AC power and control signal

- Forward or reverse phase-cut AC sine wave
- 2-Wire (hot, dimmed hot) or 3-Wire (hot, dimmed hot, neutral)
- Dimming performance highly dependent on dimmer compatibility with LED driver

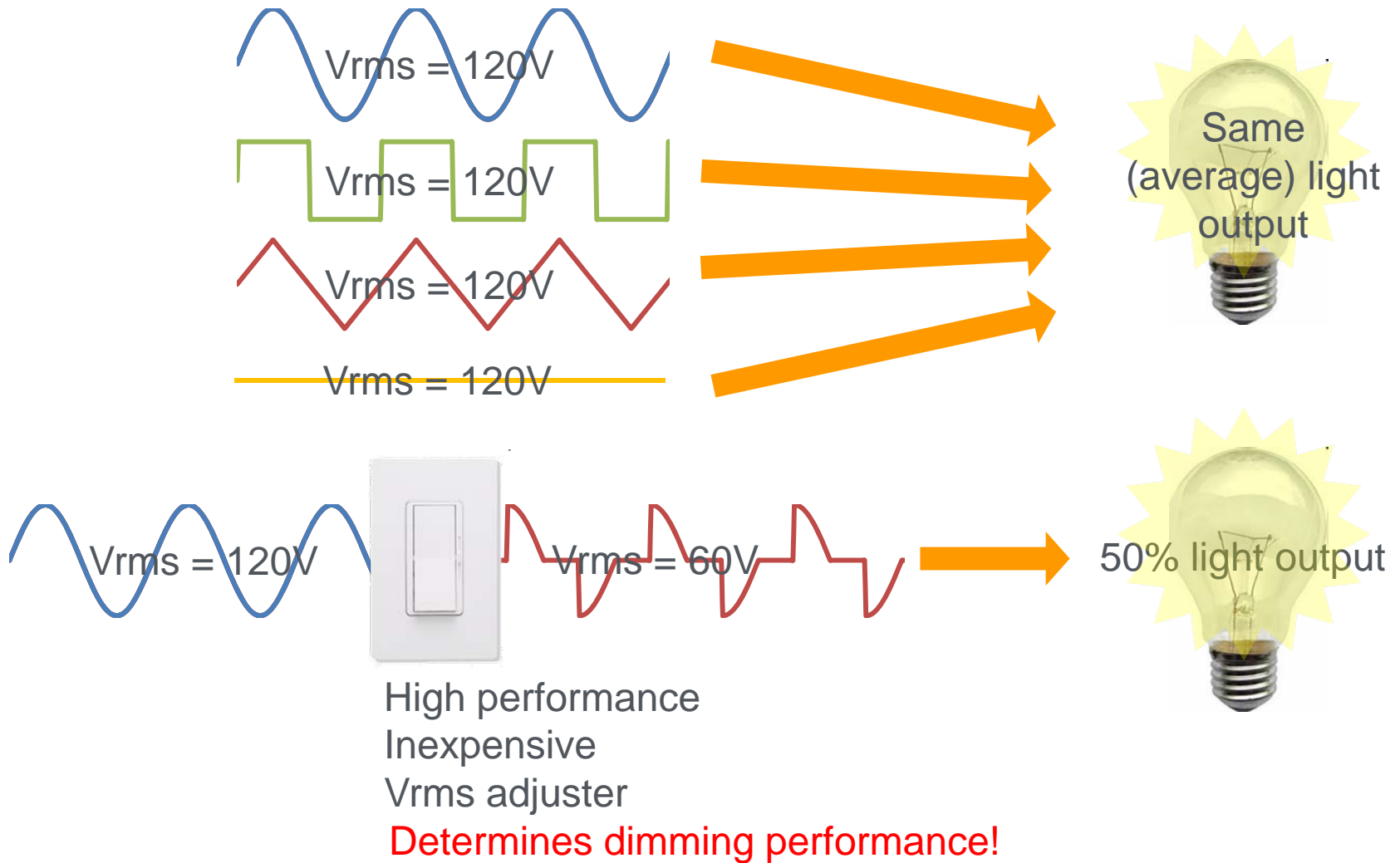


Separate AC power and control signal

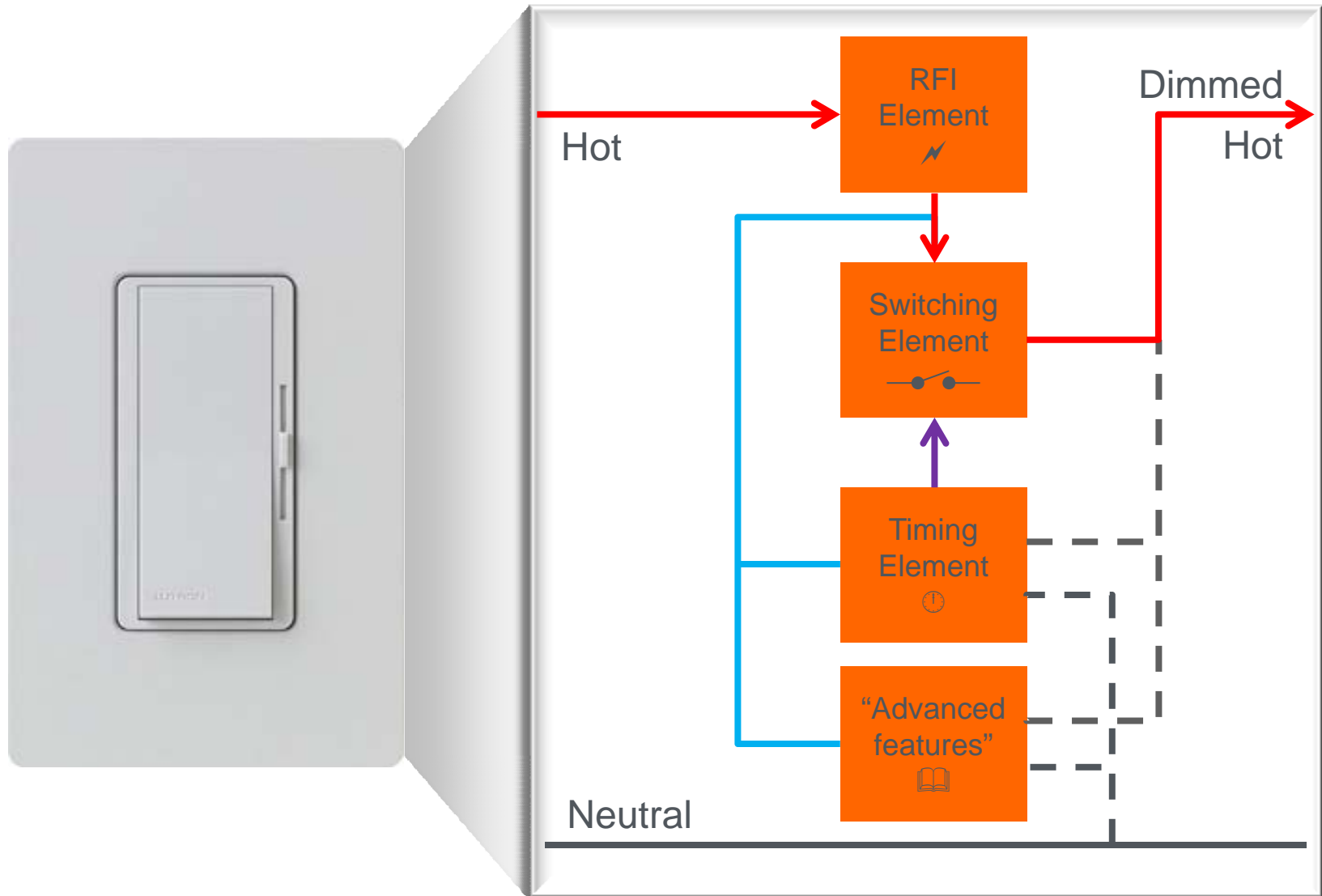
- Fluorescent 3-Wire
- 0-10V
- DALI
- DMX512



Phase-cut dimming was designed for incandescent sources



Anatomy of a phase-cut dimmer







Some sources of LED phase-cut dimming behavior variation



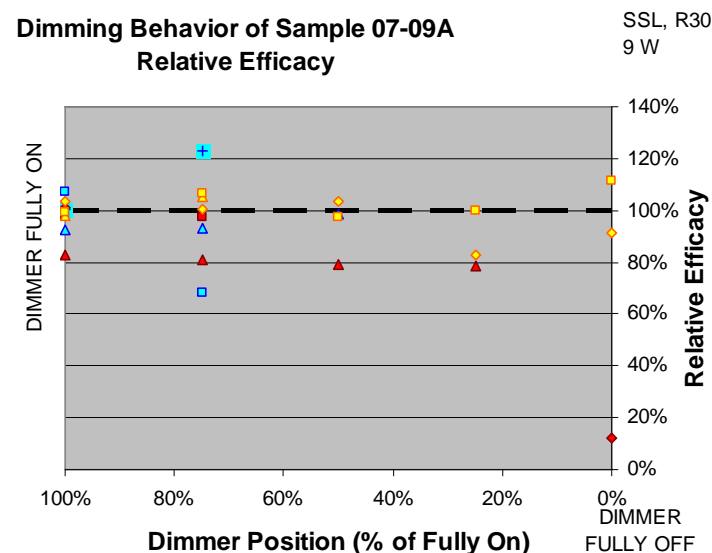
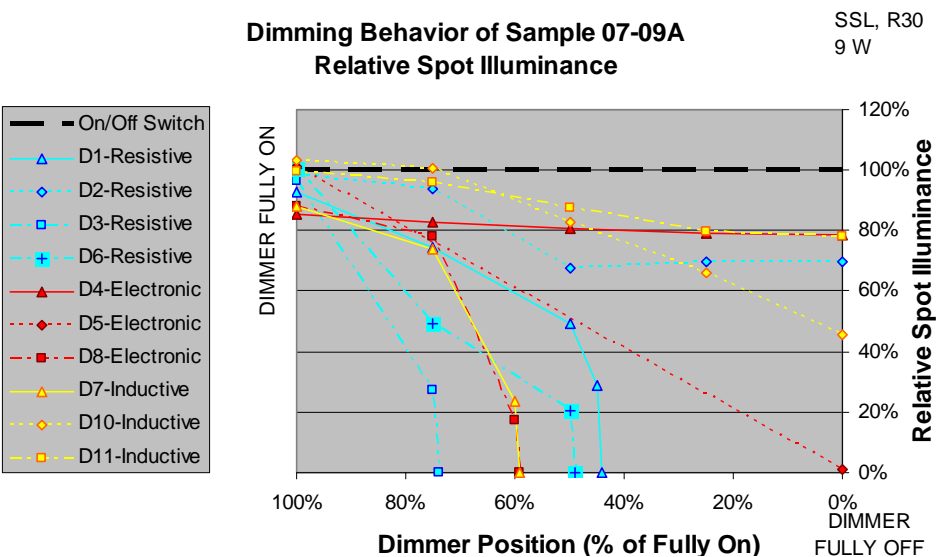
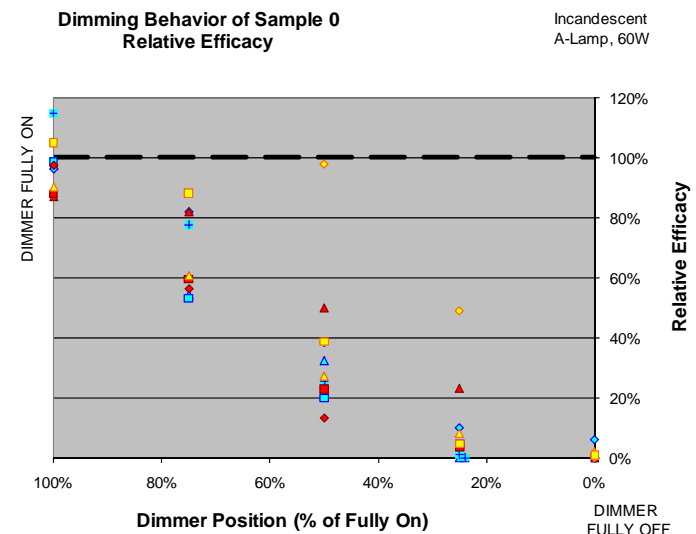
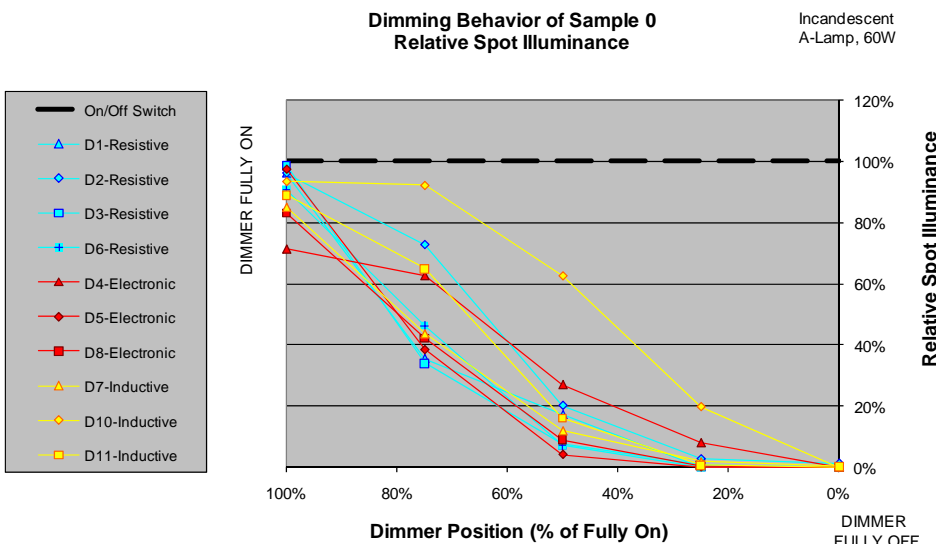
- 1) Higher I_{RMS} increases component stress
- 2) Low PWM duty cycle and/or frequency creates objectionable flicker
- 3) TRIAC current too low, and/or timing circuit unstable
- 4) Reduced V_{RMS} and/or conduction angle difficult to measure
- 5) No suitable path through LED source for dimmer standby current

Dimmer loading rules have changed

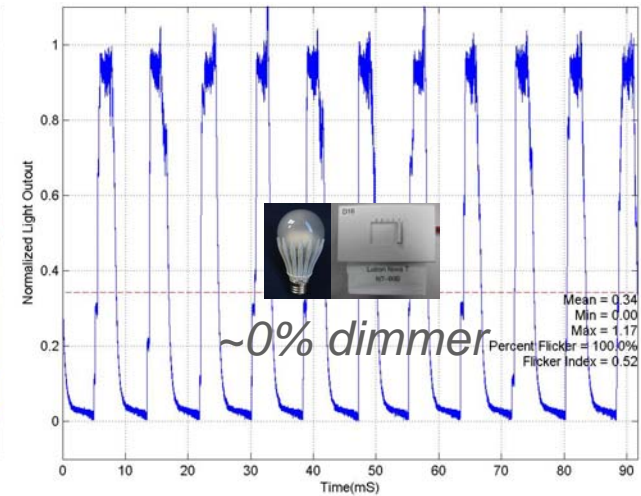
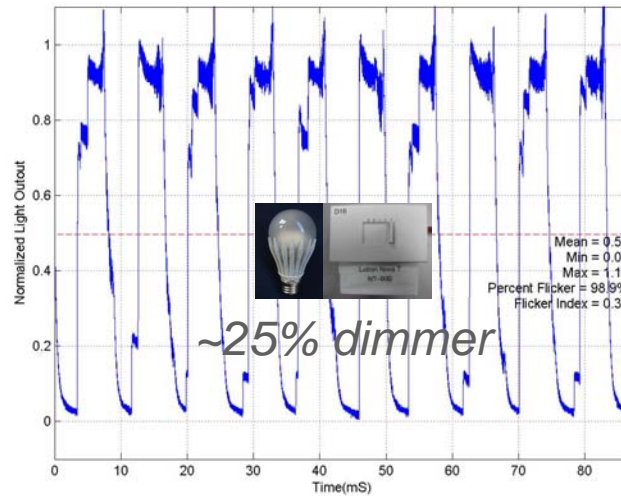
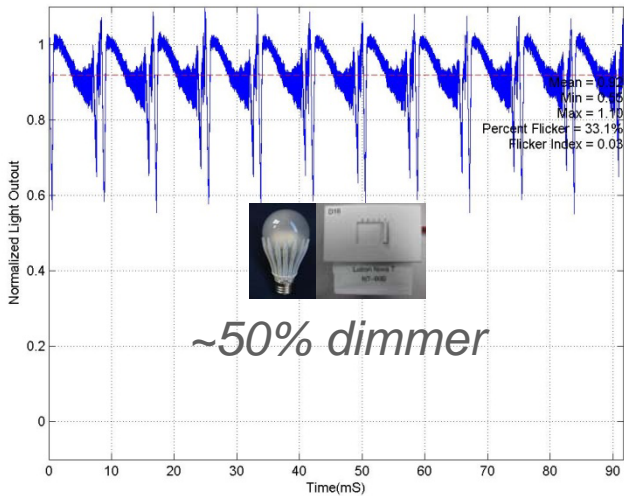
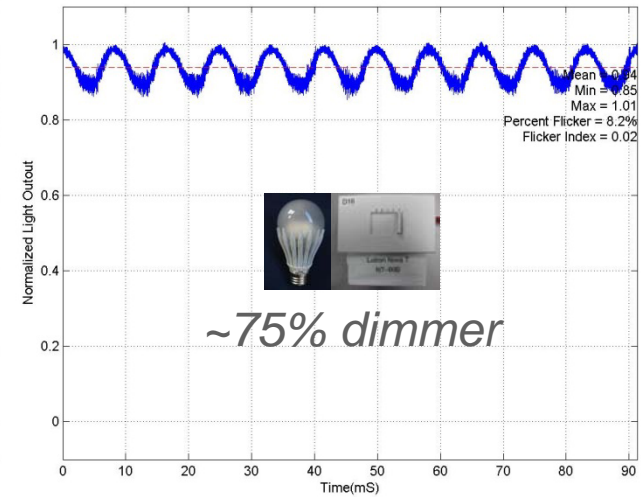
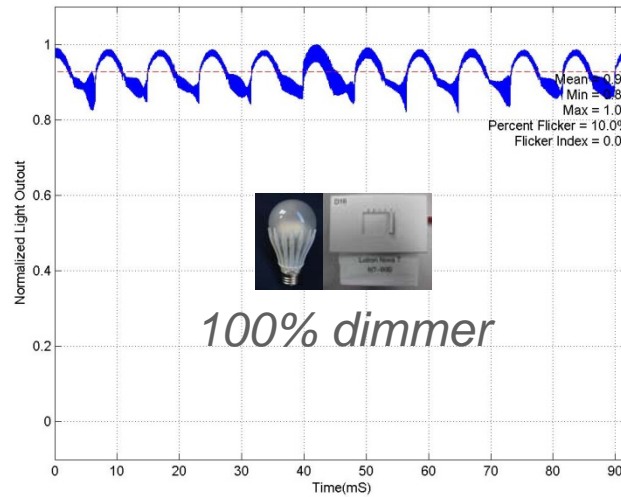
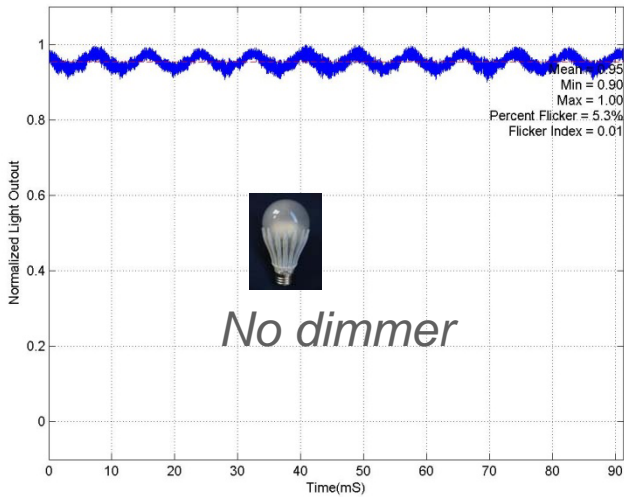
- Minimum load varies by dimmer
- Maximum load varies by dimmer **and LED source**

Dimmer	Source	Possible loading
600W incandescent	60W incandescent 	1-10
600W incandescent	12W LED 	1-10? 3-10
600W ELV	50W halogen 	1-12
600W ELV	10W LED 	1-10? 2-30

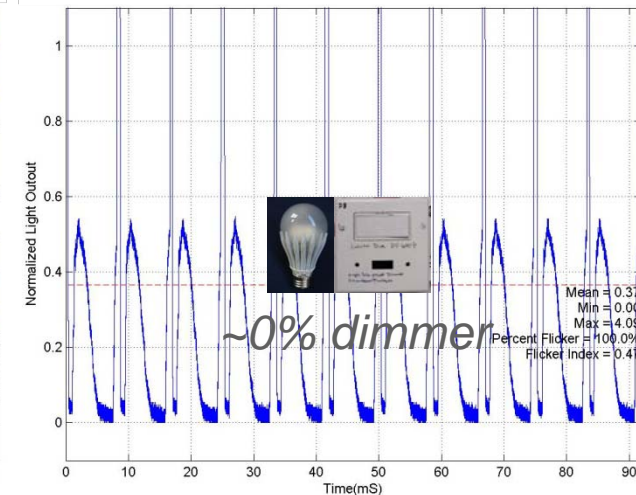
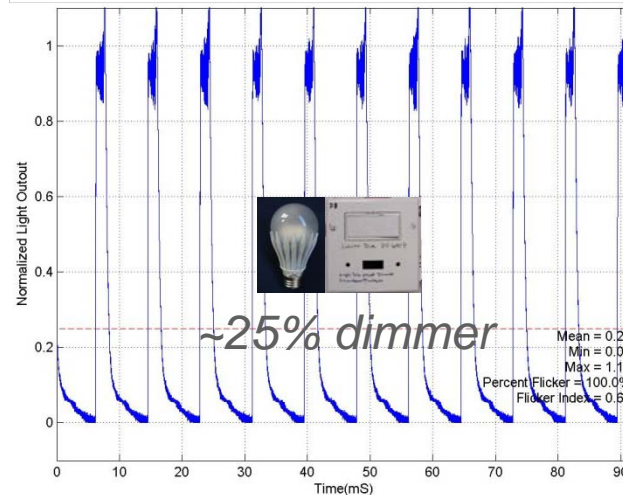
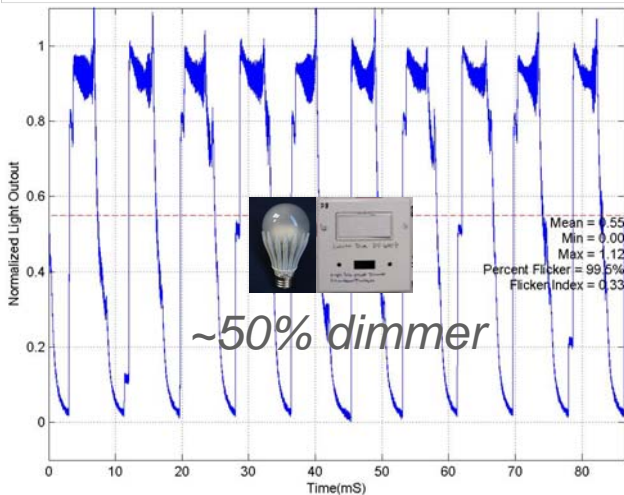
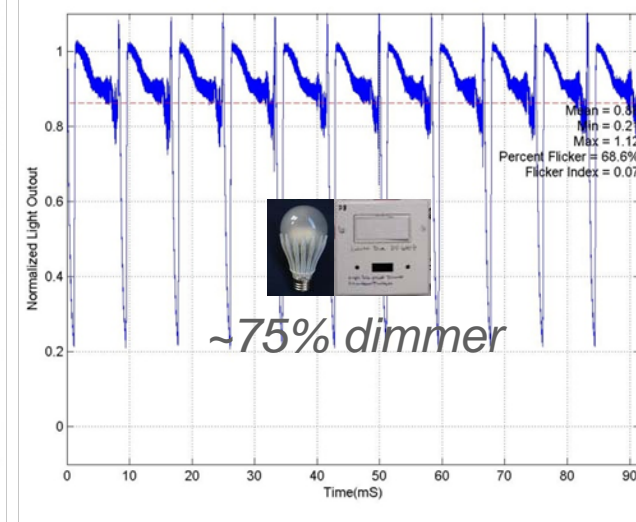
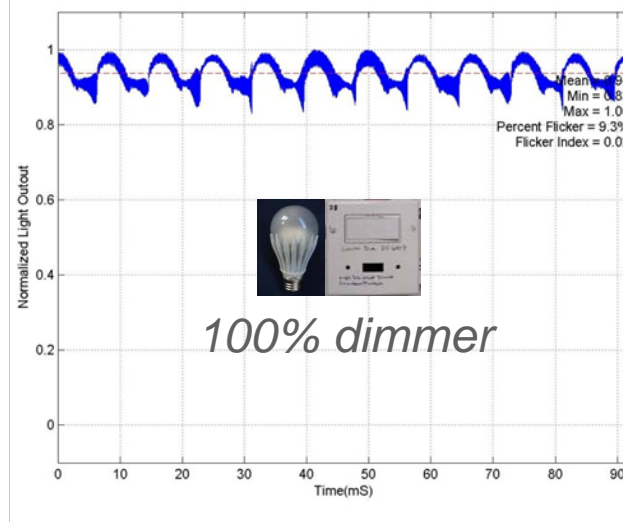
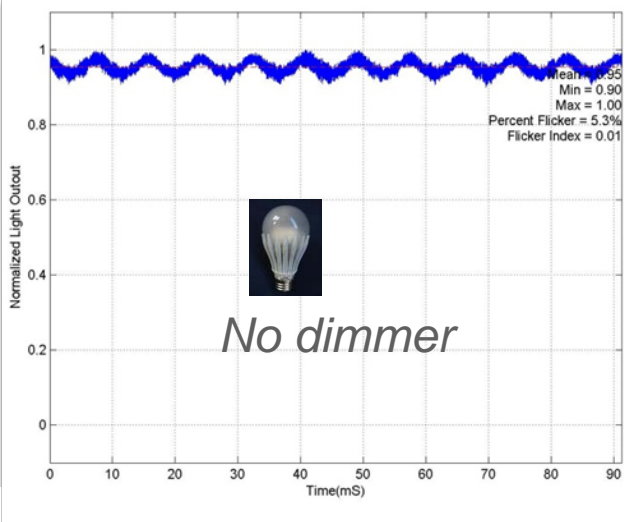
Some examples of LED phase-cut dimming performance variation



LED lamp + Dimmer A



LED lamp + Dimmer B





LED Product Report Card

Manufacturer: Cree
Applicable Model Numbers: LR24 – 325KA35

Manufacturer's Description

Type of Fixture: Recessed Downlight
Operating Voltage: 120 / 277 Vac
Input Power: 48W
Current: 0.4 – 1.7 A
Frequency: 50 / 60 Hz
Control Types: 0-10 VDC Control Protocol
Dimming Range: 5% - 100%
Output Power: N/A
Lumens: 3200 lumens

Lutron Test Results

Date Tested: Feb 25, 2009
Model Number Tested: LR24 – 325KA35
Smooth and Continuous: Yes
Test Notes:

Lutron Recommended Compatible Products

Product	Part Number	Fixtures per Dimmer	Measured Light Output Range ⁽¹⁾	Comments
Nova	NFTV	1 – 40 ⁽⁴⁾	5% - 100%	Requires PP-120H or PP-277H
Nova T*	NTFTV	1 – 40 ⁽⁴⁾	5% - 100%	Requires PP-120H or PP-277H
Diva	0-10V Control			Available soon
Interfaces	GRX-TVI ⁽²⁾	1 – 40 ⁽⁴⁾	5% - 100%	Range depends on dimmer selected
	GRX-TVM2 ⁽³⁾	1 - 40	5% - 100%	Range depends on dimmer selected

⁽¹⁾ Values are based on light output using the specified dimming control, and may not be an indication of the fixture's full capability

⁽²⁾ Controlled with 3-Wire Fluorescent dimmers, Homeworks, RadioRA, or Commercial Systems

⁽³⁾ Controlled with Homeworks or Commercial Systems

⁽⁴⁾ 60 fixtures for 277V applications.

Comments: The ability to set the low-end trim is available on select 3-Wire Fluorescent dimmers, Homeworks, and Commercial Systems products. Refer to product documentation or www.lutron.com for details.

Dimmer LED Bulb Compatibility

Company	Part Number	Compatible
Juno	TL201LED TRAC 12 LED Module 12W	IP106, ATE06, 6633-P, TGI06
	120V LED Strip	None
LLF/CREE	LED LR6 2700K 12W 100mA	IP106
Lightolier	C410LEDDL30KCCLP & C420LEDDL30KCCLP	VPE04, VPE06, IPE04, 6615, ATE06
WAC Lighting	LD-700MA-18-DIM-NIS Dimmable Constant Current LED Driver	VPE04, VPE06, VPI06, IP106, ATE06, VRE06
	IC20LED & IC22LED	VPE04, VPE06
Cooper Lighting	LED Lamp assembly (LED 71684)	VPE04, VPE06, ATE06, IPE04
Light Emitting Designs, LLC	LED CFLA-120-10-195-SW LED PAR38-120-5-80-DL LED-PAR30-120-7-7-DL LED-A15-120-3-36DL-CL GU10 3X1W AC 85-260V Cree, LED-MR20-12-6-3-SW-60 LED-MR16-12-3-3-SW LED-MR16-12-3-48-DL	None
LEDTRONICS	PAR38-180-XPW-120AMD - 120VAC	IPE04, IP106*, 6615
	R30-123-SIW-120AMD - 120VAC	IPE04, IP106*
	PAR20-66-XCW-120AMD - 120VAC	IPE04, IP106
	PAR30-15W-XXW-120AMD - 120VAC	6615
	PAR38-7X3W-XIW-120AMD - 120VAC	None
	LEDPAR38WW	VPE06*, VPE04*, VRE06*, ATE06*, VRM10*
Environmental Lights	12VDC LED Strip	VRM10, 6613
Philips LED driver/light engine combination	0-10V LED Driver	IP710
Lightech	LED-36-700-120-D-BF	VPE04, ATE06, VRE06

*Raise low end setting to prevent flickering or turn off at the lowest setting

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Lamp manufacturer guidance



Brand	Series	Model	Load	Type	Dimming level Max.>Min. (flux%) 1 lamp	Flickering 1 lamp	Flickering 3 lamp	Flickering 5 lamp	Flickering 8 lamp
Leviton	Decora	6161	500W	LE	99%-0	No	No	No	No
Leviton	Trimatron	6684	600W	LE	100%-0	No	No	at~40%	at~40%
Leviton	SureSlide	6613	600W	LE	100%-2%	No	No	No	No
Leviton	Illuminatech	IP106-IL	600W	LE	100%-9%	No	at~60%	~40%-50%	~0%-40%
Lutron	Ariadni	AY-600P	600W	LE	100%-5%	No	No	No	No
Lutron	Diva	DV-600P	600W	LE	99%-2%	No	No	No	at~70%
Lutron	Diva	DVPDC-203P	200W	LE	99%-29%	No	0~50%	no dimmability	no dimmability
Lutron	Glyder	GL-600	600W	LE	100%-2%	No	No	No	No
Lutron	NOVA	NLV-1000	1000W	LE	100%-3%	No	No	No	No
Lutron	Qoto	Q-600P	600W	LE	100%-4%	No	No	No	at~70%
Lutron	Skylark	S-600P	600W	LE	90%-3%	No	No	No	at~80%
Lutron	Toggler	TG-600P	600W	LE	100%-5%	No	No	No	at~70%
Lutron	Credenza	TT-300	300W	LE	100%-0	No	No	No	at~40%



Brand	Model	Man./Country	Type	Load	Dimmability			
					1 lamp	3 lamps	5 lamps	8 lamps
Lutron	TG-600R-WH	USA	-	600W	OK	OK	OK	OK
Leviton	OLI805	-	-	600W	OK	OK	OK	OK
Lutron	GL-600-WH	St. Kitts/USA	-	600W	OK	Flicker	Flicker	Flicker
Lutron	S-600PR-WH	USA	R	600W	OK	Flicker	Flicker	Flicker
Leviton	6613-PL	China	-	600W	OK	OK	OK	OK
Leviton	IP106	-	-	-	OK	OK	OK	Flicker
Leviton	6161	China	-	500W	OK	OK	OK	OK
Lutron	NLV-1000	USA	-	1000W	OK	OK	OK	OK
Lutron	TT-300NLH-WH	St. Kitts/USA	-	300W	OK	OK	OK	OK
Lutron	DVPDC-203P	USA	-	200W	OK	OK	OK	OK
Lutron	Q-600P	-	-	-	OK	Flicker	Flicker	Flicker
Lutron	AY-600P	USA	-	500W	OK	Flicker	Flicker	Flicker
Lutron	DV-600P	USA	-	250W	OK	OK	OK	OK

“Standard” guidance?



Dimming information reporting format

Dimmer Make	Dimmer Series - Model	Dimmer Trim Requirements	Transformer Make (low voltage lamps)	Transformer Model (low voltage lamps)	LED Lamp or Luminaire Series - Model	Dimming Range, max-min (% lumens)	Minimum Lamps or Luminaires (per circuit)	Maximum Lamps or Luminaires (per circuit)	Additional Comments
"Dimmer Make 1"	"Dimmer Series A" - "Dimmer Model #"	Low End	N/A	N/A	"PAR38 Series" - "PAR38ABC123"	99% - 0%	1	6	
					"PAR38 Series" - "PAR38XYZ456"				
					"PAR38 Series" - "PAR38EFG789"				
"Dimmer Make 2"	"Dimmer Series A" - "Dimmer Model #"	N/A	"Transformer Make 1"	"Transformer Model #"	"Brand Y MR16s" - "MR16ABC123"	100% - 5%	1	40	
"Dimmer Make 2"	"Dimmer Series B" - "Dimmer Model #"	N/A	"Transformer Make 1"	"Transformer Model #"	"Brand Y MR16s" - "MR16ABC123"	100% - 5%	1	3	
					"Brand Y MR16s" - "MR16XYZ456"		1 + 1	10 + 10	

- SSL-7A (compatibility): in development; ETA 2H 2012
- SSL-7B (performance): initiated upon completion of 7A
- Defined compatibility and performance for SSL-7 compliant phase-cut controls and lamps/luminaires
 - Current scope covers forward phase-cut controls only
 - Current scope covers light sources which connect to electrical branch circuit, and have electronic power supply
- Defines design specifications for lamps/luminaires and phase-cut controls
- Defines compliance test procedures for lamps/luminaires and phase-cut controls

- Criteria requirements
 - More than definitions
 - Compatibility and performance specifications
 - Test procedures
- Allow manufacturer self-certification of anything?
- Do “representative dimmers” exist? In other words... do some dimmers matter more than others?
- Do “smart SSL sources” exist? How well do they address dimmer variation? What is their market viability?
- Does criteria need to include matched (SSL source – dimmer) pairs?
 - UL 1472 “Solid-State Dimming Controls”

- Creating ideal specifications is not difficult; we all know what users want: incandescent performance
- Creating relaxed specifications is very difficult
 - What behavior must be predicted and promised?
 - How much user dissatisfaction is acceptable?
- Assumptions or generalizations about the impact of the dimmer on the dimming behavior of an LED source is risky
- Existing dimmed sockets are hard to address without knowledge of the installed dimmer
- Combinational testing is time consuming and expensive
- Avoiding false promises is more important than clearing invisible hurdles
- A forward-looking path (e.g. SSL-7), while not ideal, may result in the least confusion, dissatisfaction, and technology perception degradation

Questions?



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