Transformer Application

MR16 / AR111 LED Driver Solutions

Table of content

MR16 Lighting System

MR16 lamp

- Standard format for halogen **M**ultifaceted **R**eflector light bulbs
- Usually operate at 12VAC (i.e. ~17 volt peak)

- Requires a magnetic or electronic transformer to power from 110 / 220VAC

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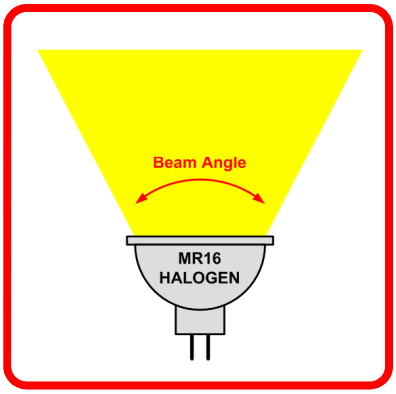
MR16 Lighting System

ANSI designation for MR16 halogen lamps

20W minimum

- **ESX** 20 watt, 10 degree beam
- **BAB** 20 watt, 35 degree beam
- **EXT** 50 watt, 15 degree beam
- **EXZ** 50 watt, 25 degree beam
- **EXN** 50 watt, 40 degree beam
- **FNV** 50 watt, 60 degree beam
- **FPA** 65 watt, 15 degree beam
- **FPC** 65 watt, 25 degree beam
- **FPB** 65 watt, 40 degree beam
- **EYF** 75 watt, 15 degree beam
- **EYJ** 75 watt, 25 degree beam
- **EYC** 75 watt, 40 degree beam



Power supplies for MR16 halogen lamps are designed to deliver 20W output minimum

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Common power sources for MR16

Magnetic Transformer vs Electronic Transformer

	Magnetic transformer	Electronic Transformer
Reliability	High	Relatively low
Line Harmonics	Very low	Relatively high
Compatibility to TRIAC dimmers	Good	Fairly good
Efficiency	~ 80% - 85%	~ 90% - 95%
Physical Size	50/50/50 mm typ. (D/W/H) for 30VA output	60/30/30 mm typ. (D/W/H) for 60VA output
Weight	Heavy (Iron E-I core)	Light weight
Cost	Relatively high	Low

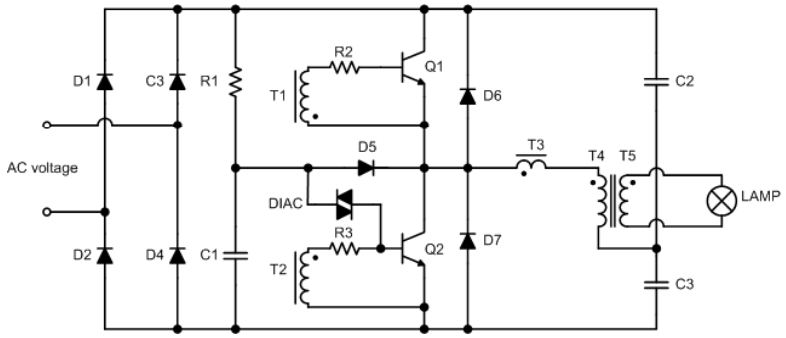
General Requirements of MR16 LED Lamps

Customers like to have a MR16 solution fulfilled the requirements:

1. No visible flicker of light
2. Compatible with different electronic transformers as many as possible (with average LED current regulation)
3. LED current never drop to zero
4. Compatible with magnetic transformers (with average LED current regulation)
5. Compatible with DC power supply (with average LED current regulation)
6. Reasonably low input surge current
7. Passes both input line conductive and radiated EMI testes (EN55015F)
8. Fulfills certain efficiency requirement (thermal consideration and varies case to case, usually 60%)

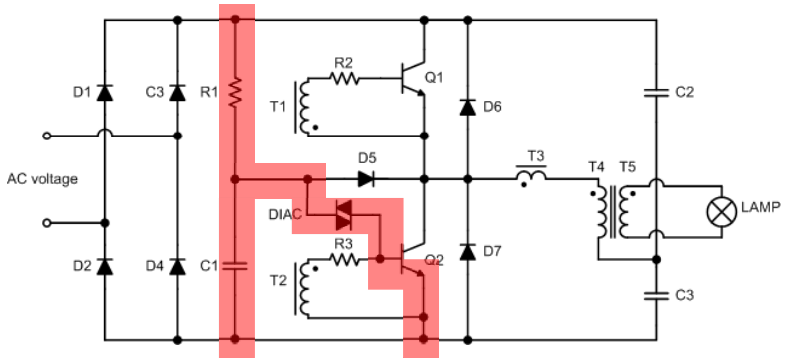
Electronic Transformer + Halogen Lamp

Driving MR16 halogen lamps with an electronic transformer



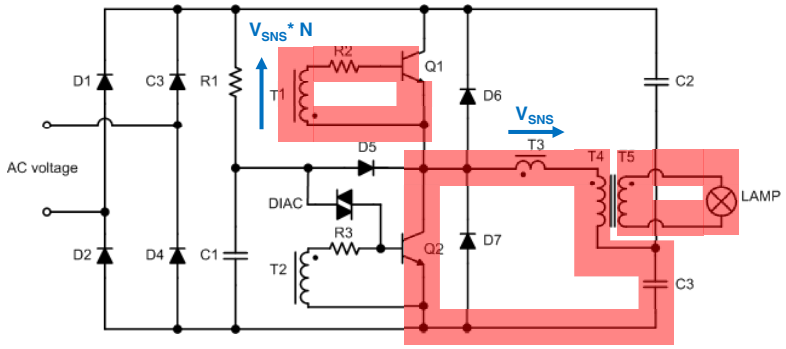
Electronic Transformer + Halogen Lamp (1)

Driving MR16 halogen lamps with an electronic transformer



Electronic Transformer + Halogen Lamp (2)

Driving MR16 halogen lamps with an electronic transformer



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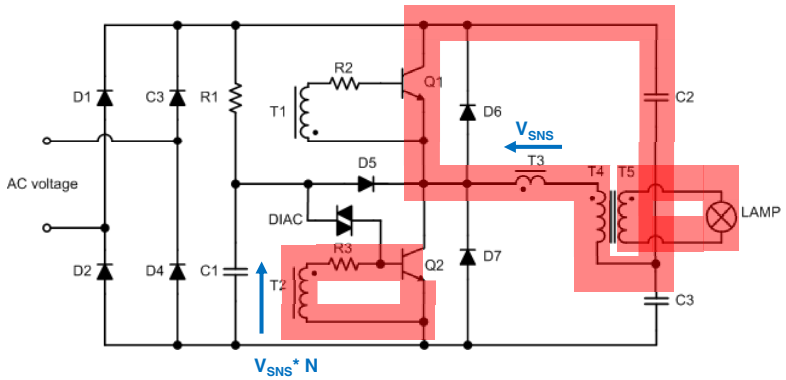
Electronic Transformer + Halogen Lamp (3)

Driving MR16 halogen lamps with an electronic transformer



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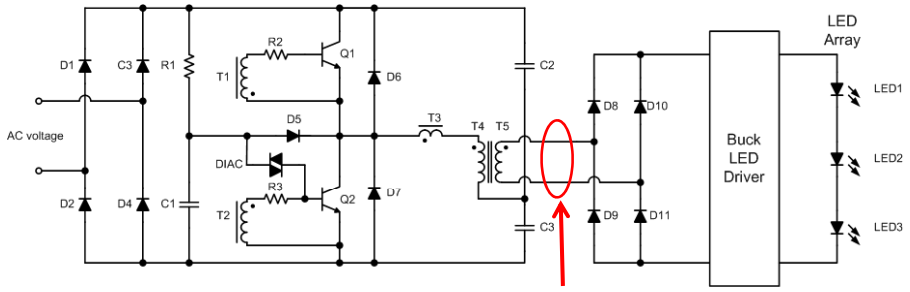
Electronic Transformer + LED

Driving LED lamps with an electronic transformer



For the same luminous output, a LED MR16 lamp takes much lower input current / power than a halogen MR16 lamp

The lowered input current can be inadequate to maintain contionuous operation of the electronic transformer

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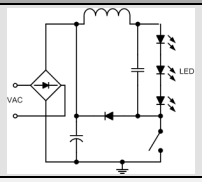
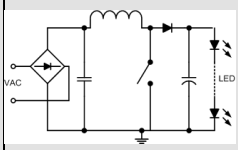
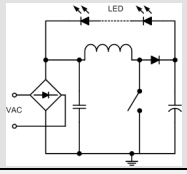
Pros and Cons of common circuit topologies

	Floating Buck	Boost	Floating Buck-boost
General structure			
Function	Step-down ($V_{LED} < V_{IN(max)}$)	Step-down ($V_{LED} > V_{IN(max)}$)	Step-up/down ($V_{LED} < V_{IN(max)}$) ($V_{LED} > V_{IN(max)}$)
LED voltage	12V max.	15V min.	Virtually not limited
System efficiency	~ 65%	~ 70%	~ 60%
Advantages	1. Continuous output current	1. Continuous input current (good compatibility to elec. Transformer.) 2. Good power factor	1. Adaptive to different configuration of LED string
Disadvantages	1. Pulsating input current 2. Requires high input capacitor (difficult to MR16 applications)	1. Requires electrolytic output capacitor to provide continuous LED current 2. Only suitable for long LED string	1. Pulsating input and output currents 2. Relatively high peak switch current 3. Requires electrolytic output capacitor to provide continuous LED current

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Getting Electronic Transformers Work

The best MR16 LED lamp should behave like halogen lamps which has high luminous efficiency and resistive input characteristic. Capacitive load can cause unstable operation of electronic transformers.

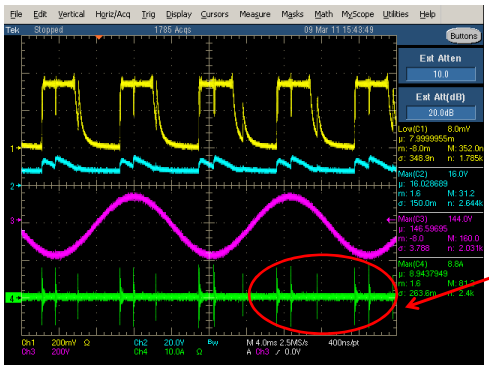
Resistive characteristics:

- **Input voltage and current are always in-phase**
- **Non-pulsating input current**
- **Low THD (Total Harmonic Distortion)**
- **Very low input capacitance**

Getting Electronic Transformers Work

Large capacitor at input of the LED driver introduces high spike current to the bridge rectifier and electronic transformer, which can eventually damage the driver circuit and electronic transformer

Buck LED driver + 100uF input E.cap



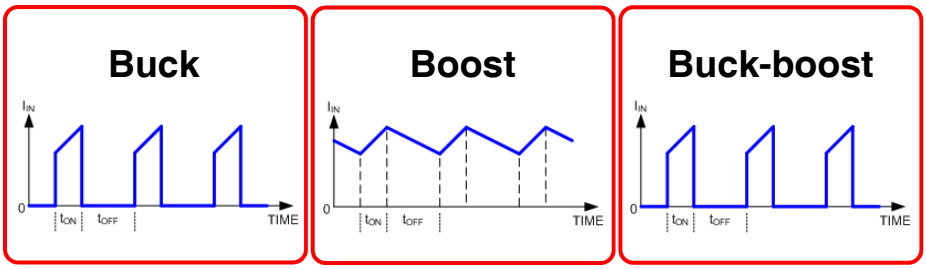
Top Trace: Iout (200mA/DIV)
Second Trace: V_{Cin} (20V/DIV)
Third Trace: V_{Line}(200V/DIV)
Bottom Trace: I_{IN} (10A/DIV)

Up to 18A peak to peak surge input current

Getting Electronic Transformers Work

Because electronic transformers cannot accept capacitive load, the input capacitance of a LED driver for MR16 must be very low. (e.g. <1uF)

With low input capacitance, the input current (CCM) of LED driver circuits are:



$I_{IN} = I_L$

Getting Electronic Transformers Work

Because electronic transformers cannot accept capacitive load, the input capacitance of a LED driver for MR16 must be very low. (e.g. <1uF)

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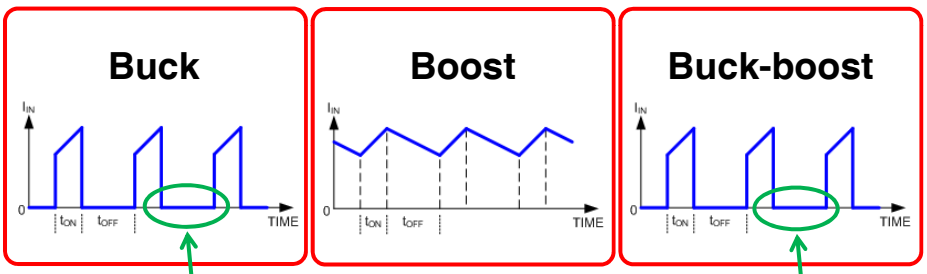

Electronic transformer may stop working

Continuous input current $I_{IN} = I_L$

Electronic transformer may stop working

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MR16 / AR111 LED Driver Solutions

- **LM3401 - Hysteretic PFET Controller for High Power LED Drive**

- **LM3409 - PFET Buck Controller for High Power LED Driver**

- **LM3414 - 1A 60W Constant Current Buck LED Driver**

- **LM3492 - Two-Channel LED Driver with Boost Converter and Fast Current Regulator**

- **LM3444 - AC-DC Offline LED Driver**

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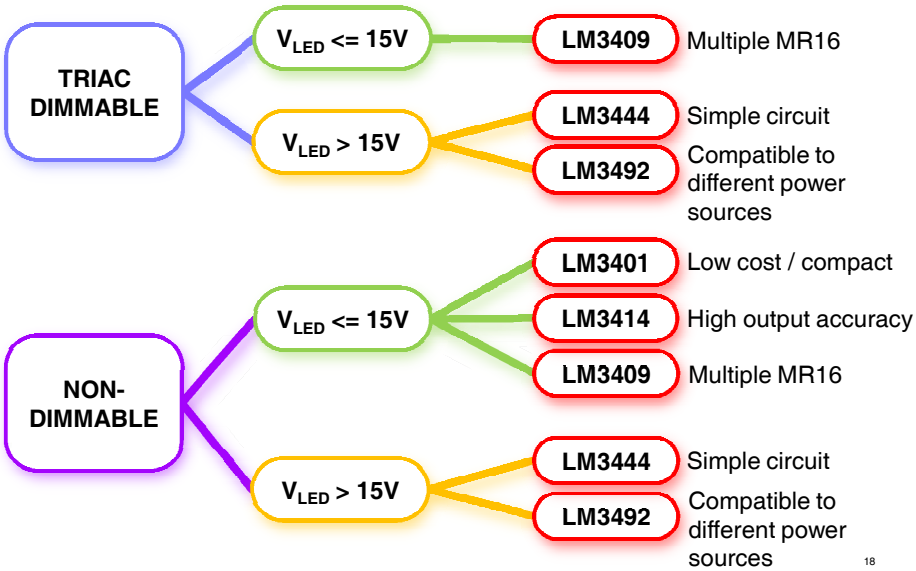
Product Selection Chart



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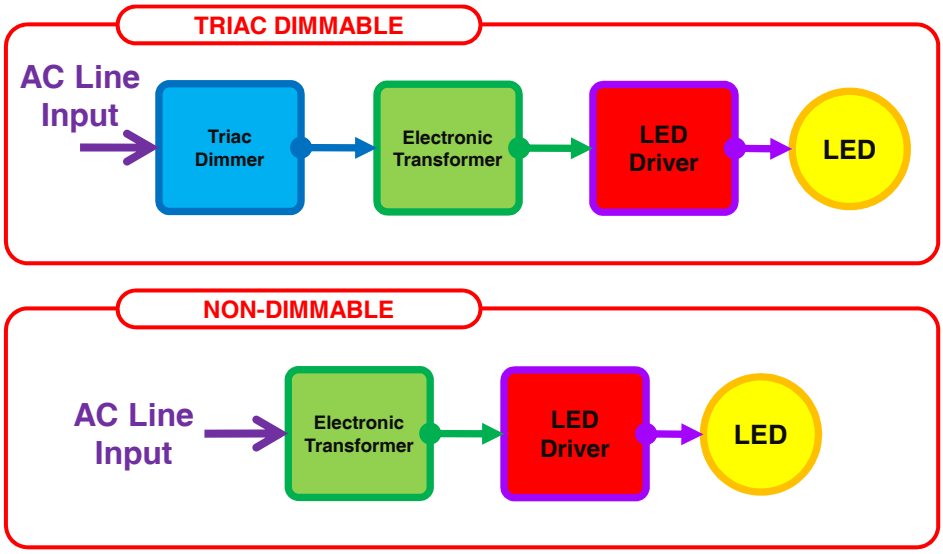
Triac Dimmable vs Non-dimmable



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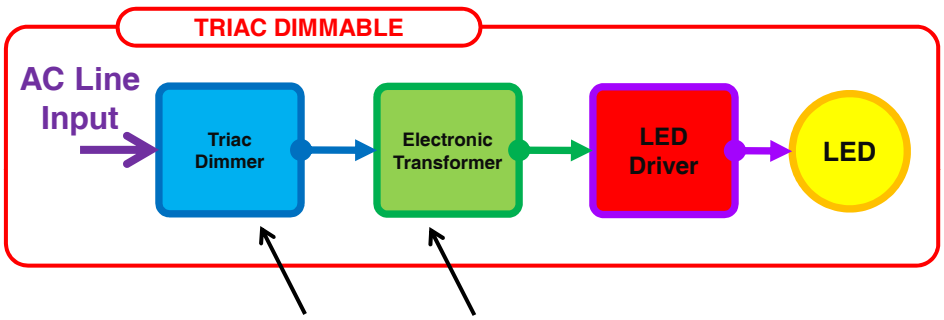
Triac Dimmable MR16 solution



The LED driver circuit must be able to make both the triac dimmer and electronic transformer to conduct

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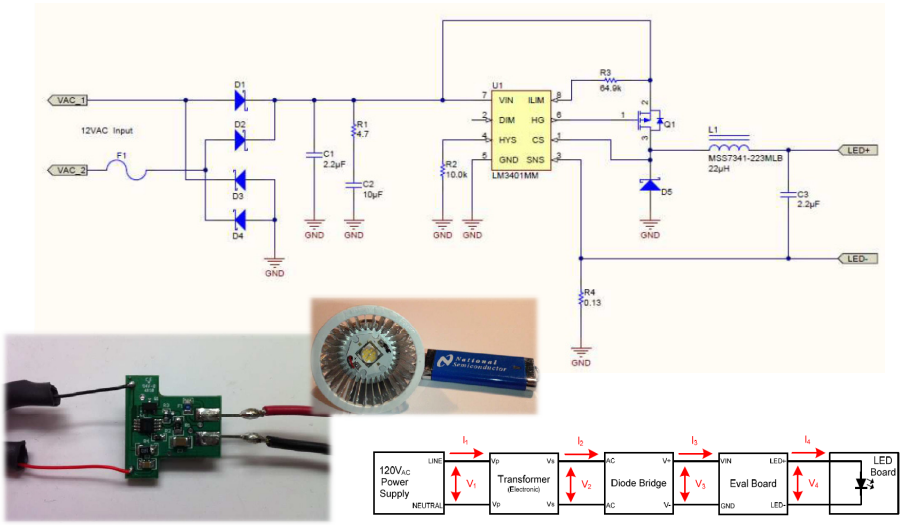
LM3401 (non-dimmable)



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LM3401 (non-dimmable)

Performance without transformer

Specs	LM3401 STD CKT 3 LEDs @ 0.7A	Units
V_{IN}	12.05	VAC
I_{IN}	0.659	A
P_{IN}	7.33	W
V_{OUT} (1)	8.43	VDC
I_{LED} (1)	0.700	A
P_{OUT} (2)	6.47	W
Efficiency	88.3%	-
Power Factor	0.924	-

Performance with electronic transformer (LET-60)

Specs	LM3401 STD CKT 3 LEDs @ 0.7A	Units
V_{IN}	119.94	VAC
I_{IN}	0.069	A
P_{IN}	6.93	W
V_{OUT} (1)	8.19	VDC (1)
I_{LED} (1)	0.614	A (1)
P_{OUT} (2)	5.66	W (2)
Efficiency	81.7%	-
Power Factor	0.849	-

Performance with electronic transformer (HATCH)

Specs	LM3401 STD CKT 3 LEDs @ 0.7A	Units
V_{IN}	119.44	VAC
I_{IN}	0.072	A
P_{IN}	7.24	W
V_{OUT} (1)	8.44	VDC (1)
I_{LED} (1)	0.651	A (1)
P_{OUT} (2)	6.02	W (2)
Efficiency	83.1%	-
Power Factor	0.853	-

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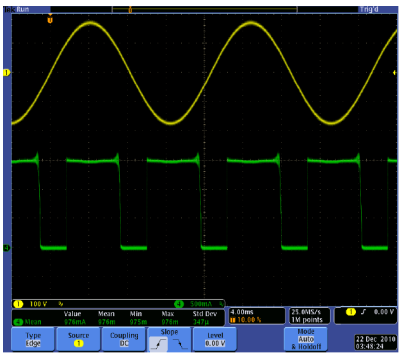
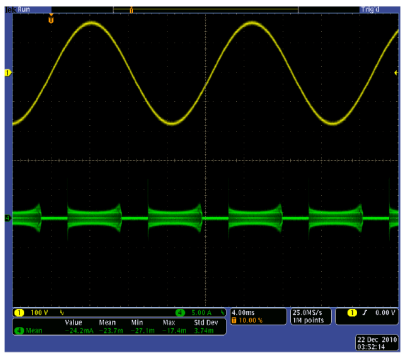
LM3401 (non-dimmable)

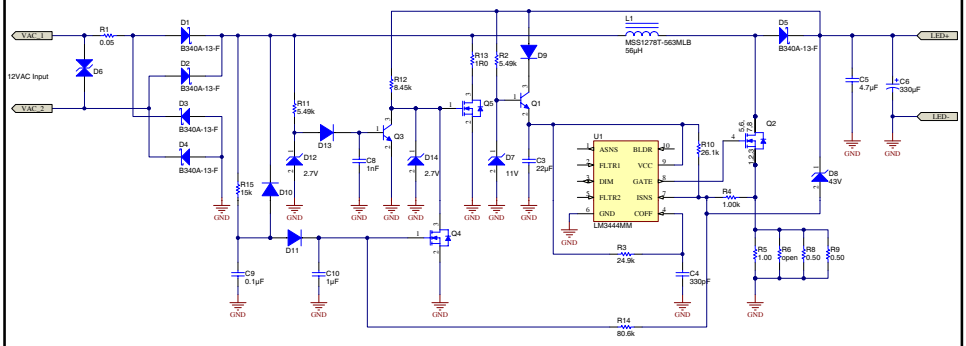


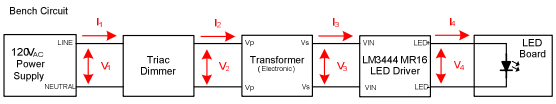
Input voltage, LED current



Input voltage, Input current

LM3444 (dimmable)





Measurement Results

Input Voltage	Input Current (mA)	Input Voltage (V)	LED Current (mA)	LED Voltage (V)	Efficiency (%)
12V DC	1095	12	282	38.0	81.6
12V AC	12.1		247	37.6	76.7
Osram ET-A60 (220V AC)	15.5		293	38.2	72.2

Remarks:
1. 12V DC Power is supplied by Agilent E3634A
2. 50Hz AC Power is supplied by Kikusui PCR 500LA
3. Efficiency is measured by Agilent 34401A
   (Measured Power Supply as input, LEDs as output. All system included bridge & LM3492)

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Compatibility Score Card

AR-111 LED Lamp score card, on 220VAC

LAMP UNDER TEST: LM3444AR111 (BOM120208)

Measured full input power: **15W**

Performance on conduction duty cycle

Dimmer	E-Transformer	10%	20%	30%	40%	50%	60%	70%	80%	90%	80%	70%	60%	50%	40%	30%	20%	10%	Remark
JUNON BTB04-600SL	Philips ETK50, 50W					L	L	L	L	L	L	L	L	L	L				
	Philips ET-E60, 20~60W					L	L	L	L	L	L	L	L	L	L	F			
	Rio RT50M, 20~50W				L	L	L	L	L	L	L	L	L	L	L	L	L	L	
	Kengo DET-60T, 10~60W					L	L	L	L	L	L	L	L	L	L	L	L		
	NVC ET60E, 60W				L	L	L	L	L	L	L	L	L	L	L	L	F		
	OSRAM ET-PARROT 105, 35~105W	L	L	L	L	L	L	L	F	F	F	L	L	L	L	L	L	L	
	OSRAM ET-P60			L	L	L	L	F	F	L	F	F	L	L	L	L	L	F	
	OSRAM HTM 105, 35~105W	L	L	L	L	L	L	L	F	L	F	L	L	L	L	L	L	L	
	Tridonic VIPER, 60W				L	L	L	F	L	L	L	F	L	L	L	L			
	Wipo ET 105, 35~105W	F	F	L	L	L	L	F	L	F	L	F	L	L	L	L	L	F	
CLIPSAL KB31RD400	Philips ETK50, 50W					L	L	L	L	L	L	L	L	L	L				
	Philips ET-E60, 20~60W					L	L	L	L	L	L	L	L	L	L	F	L		
	Rio RT50M, 20~50W			L	L	L	L	L	L	L	L	L	L	L	L	L	L		
	Kengo DET-60T, 10~60W					L	L	L	L	L	L	L	L	L	L	L	L		
	NVC ET60E, 60W		F	L	L	L	L	L	L	L	L	L	L	L	L	L	F		
	OSRAM ET-PARROT 105, 35~105W			F	L	L	L	L	L	L	L	L	L	L	L	F			
	OSRAM ET-P60				L	L	F	L	L	F	L	L	F	L	L	L			
	OSRAM HTM 105, 35~105W			L	L	L	L	L	L	L	L	L	L	L	L	L			
	Tridonic VIPER, 60W					L	L	L	L	L	L	L	L	L	F	F			
	Wipo ET 105, 35~105W		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L		
Hager XP515 P60 series	Philips ETK50, 50W					L	L	L	L	L	L	F	L	L	L	L			
	Philips ET-E60, 20~60W					L	L	L	L	L	L	L	L	L	L	F			
	Rio RT50M, 20~50W				L	L	L	L	L	L	L	L	L	L	L	L	L		
	Kengo DET-60T, 10~60W					L	L	L	L	L	L	L	L	L	L	L	L		
	NVC ET60E, 60W					L	L	L	L	L	L	L	L	L	L	L	L		
	OSRAM ET-PARROT 105, 35~105W			L	L	L	L	L	F	L	F	L	L	L	L	L	L	L	
	OSRAM ET-P60			L	L	L	F	F	F	F	F	F	L	L	L	L	L		
	OSRAM HTM 105, 35~105W	L	L	L	L	L	L	L	F	L	F	L	L	L	L	L	L	L	
	Tridonic VIPER, 60W				F	L	F	F	F	L	L	F	L	L	F	L			
	Wipo ET 105, 35~105W	F	F	L	L	L	L	L	L	L	L	L	L	L	L	L	F	L	
SCORE	11/30																		

MEANS "NOT LIGHT UP"
MEANS "LIGHT UP WITHOUT FLICKER"
MEANS "FLICKERING"

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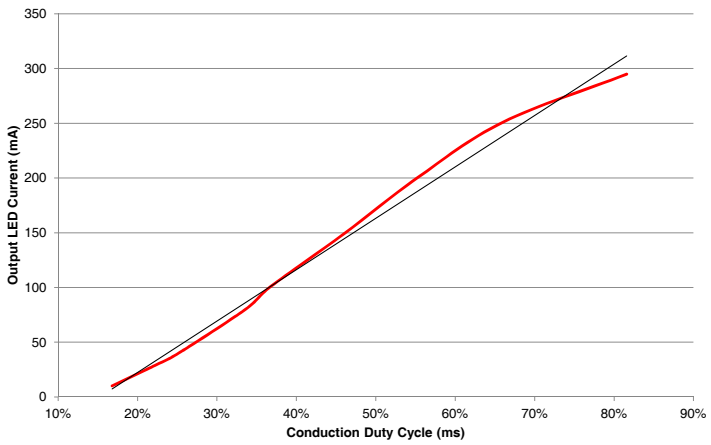
Output Current Linearity



- Q&A?