

Transformer Application

MR16 / AR111 LED Driver Solutions

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2. General requirements of MR16 LED lamps
3. Operation principles of typical MR16 electronic transformers
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MR16 Lighting System

MR16 lamp



- Standard format for **halogen Multifaceted Reflector** light bulbs

- Usually operate at 12VAC (i.e. ~17 volt peak)



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

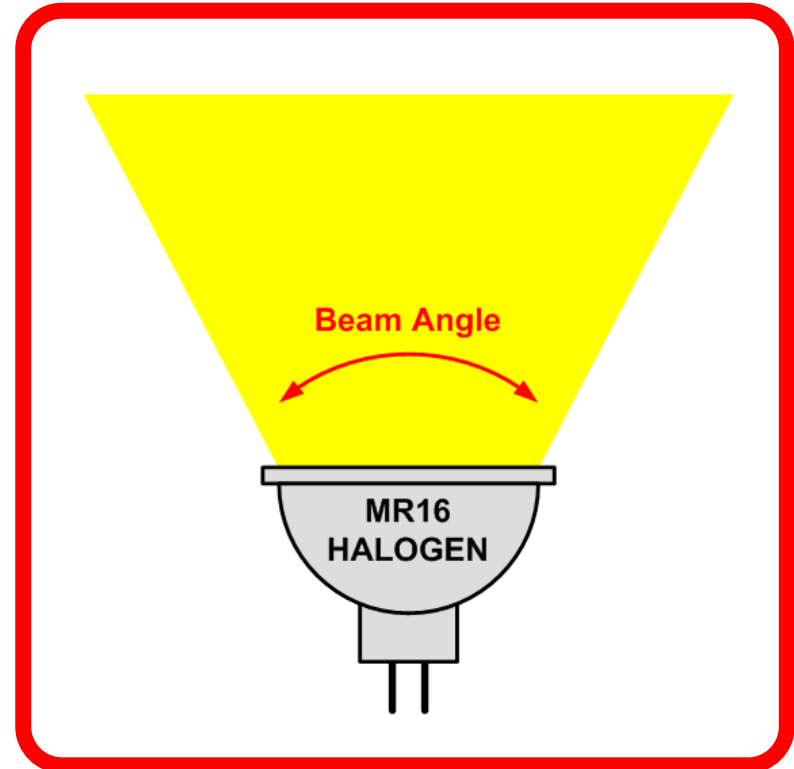


MR16 Lighting System

ANSI designation for MR16 halogen lamps

- **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

20W minimum



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

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

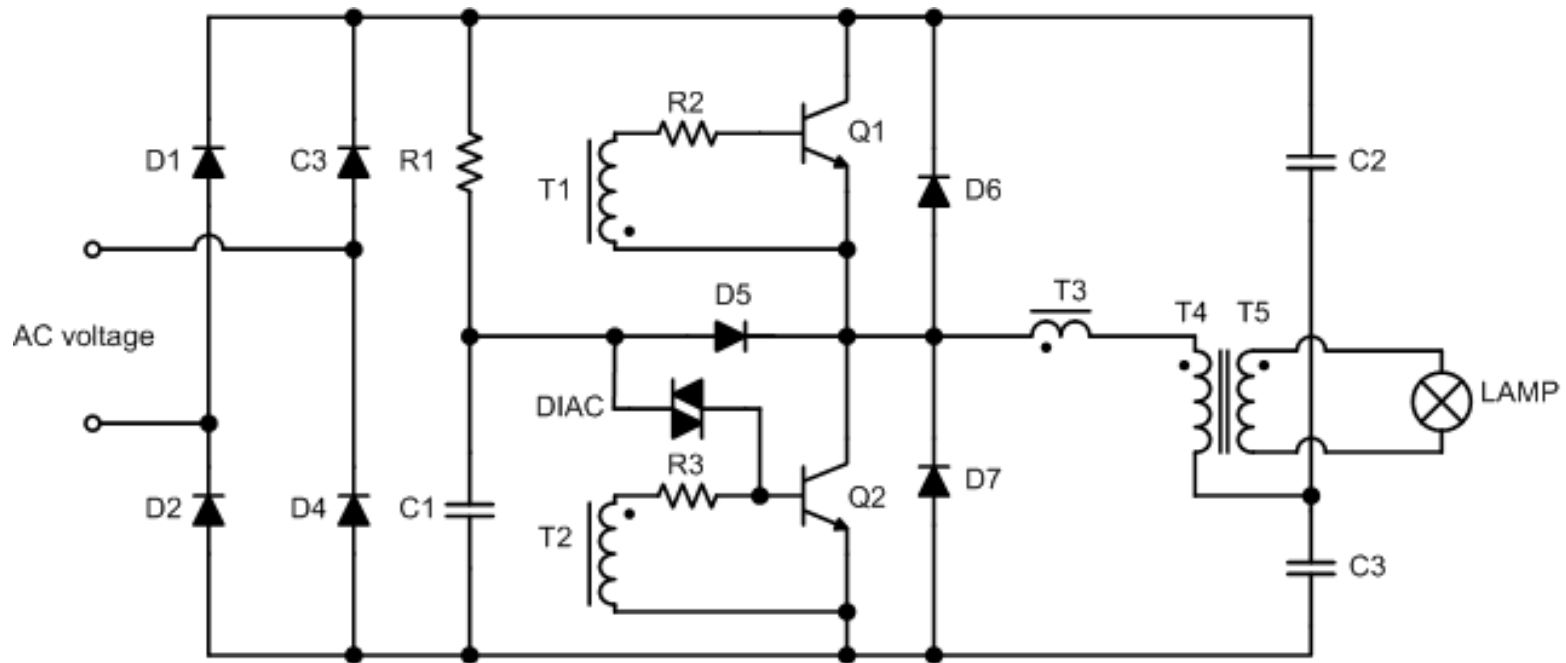
General Requirements of MR16 LED Lamps

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%)

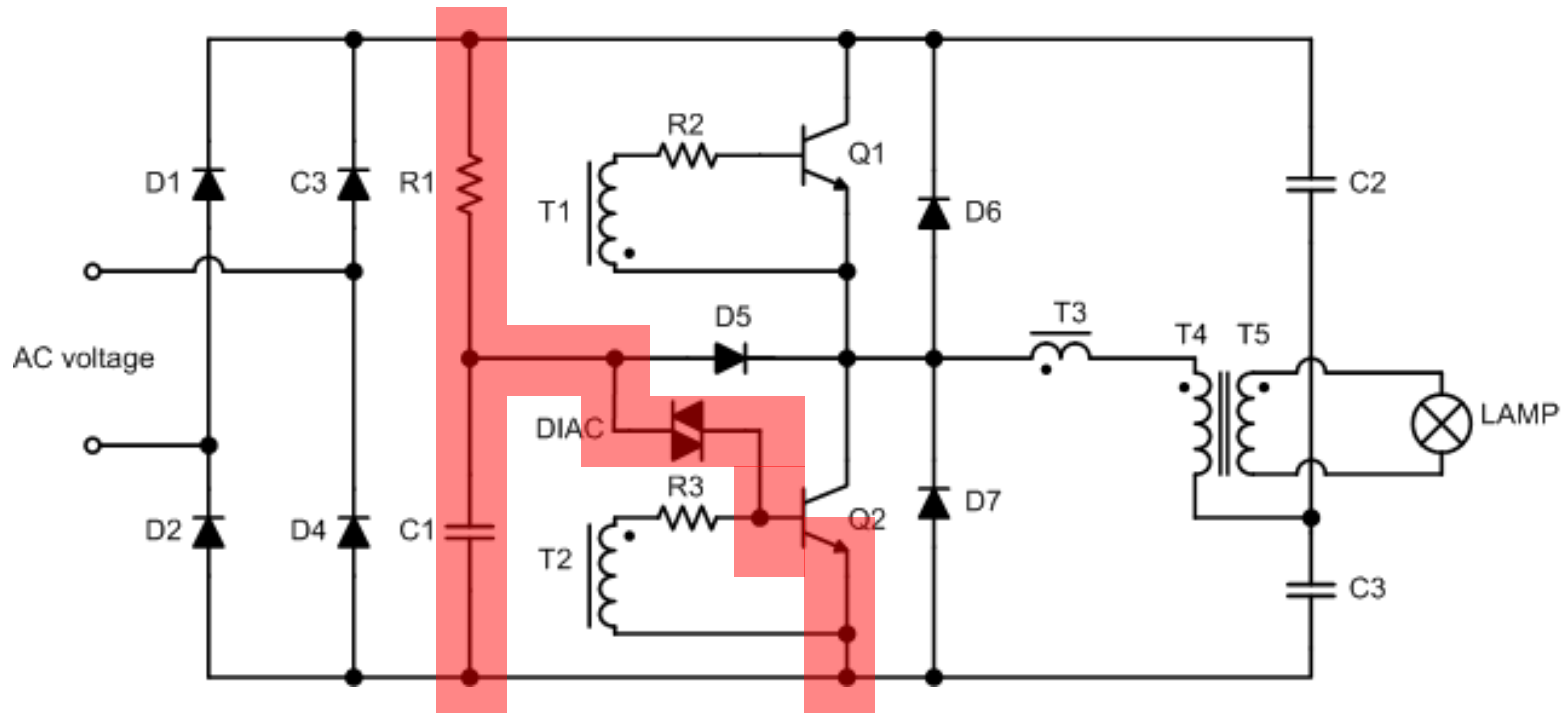
Electronic Transformer + Halogen Lamp

Driving MR16 halogen lamps with an electronic transformer



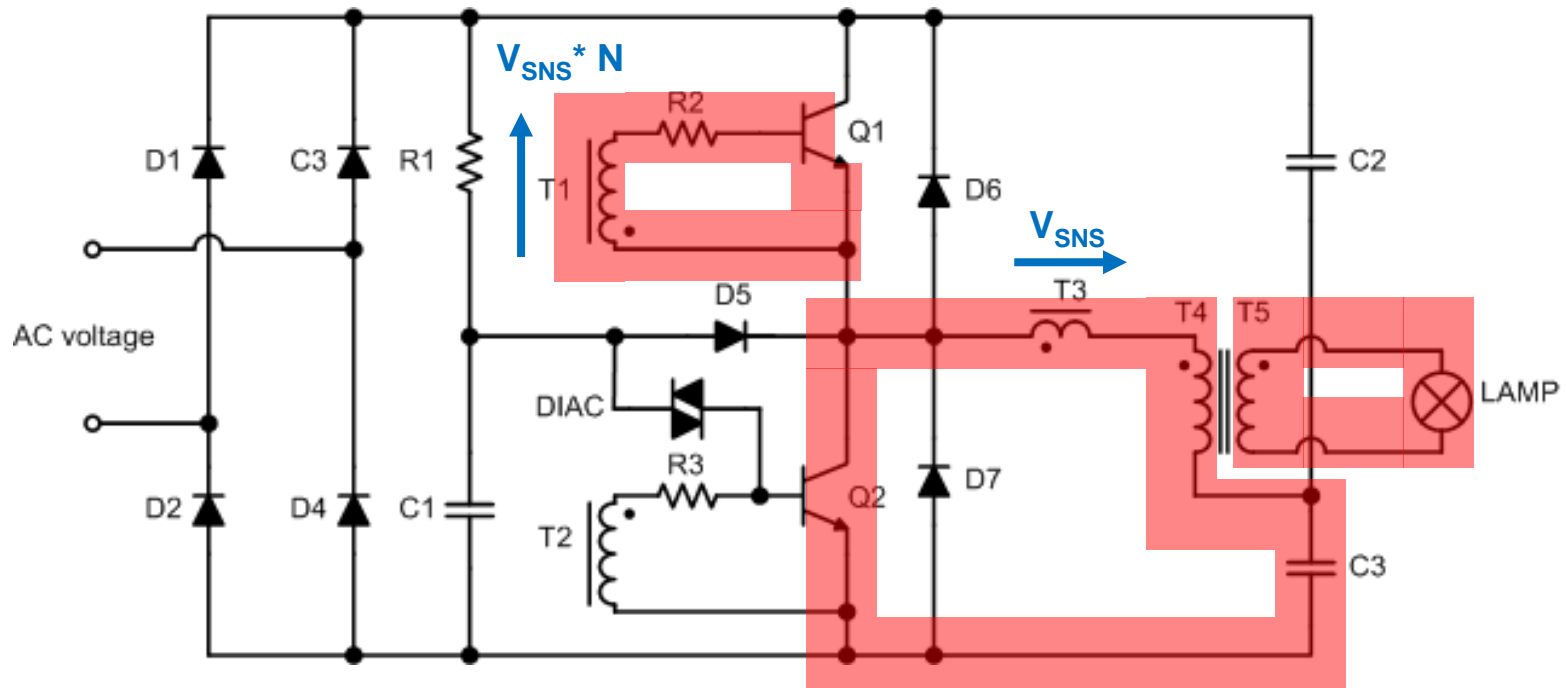
Electronic Transformer + Halogen Lamp (1)

Driving MR16 halogen lamps with an electronic transformer



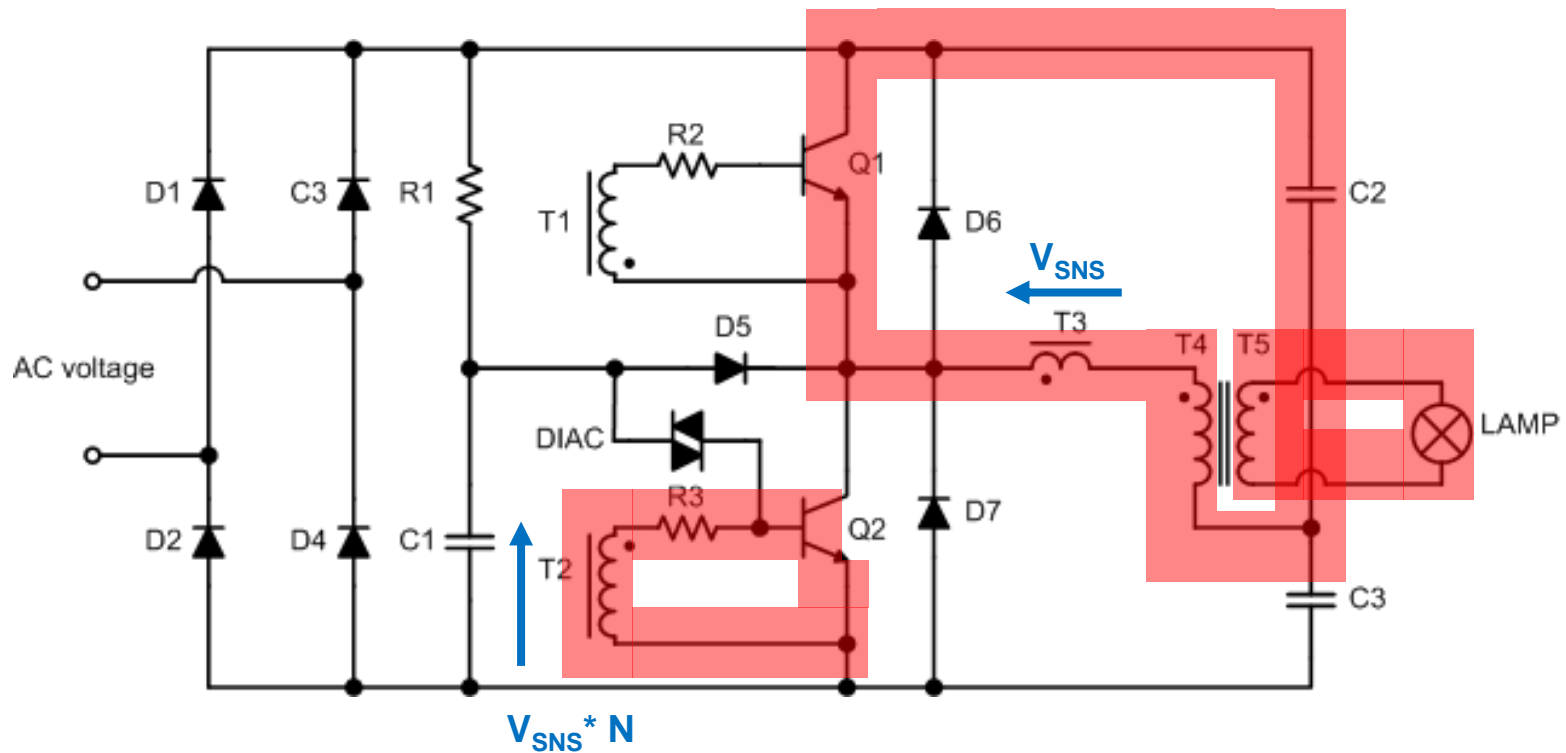
Electronic Transformer + Halogen Lamp (2)

Driving MR16 halogen lamps with an electronic transformer



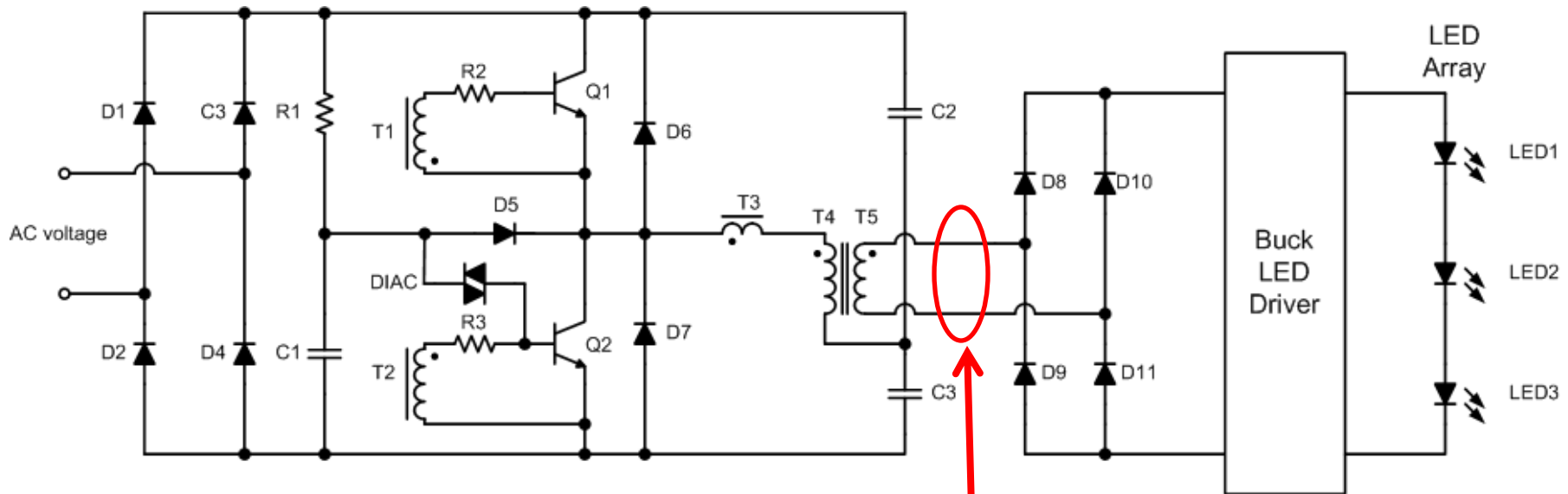
Electronic Transformer + Halogen Lamp (3)

Driving MR16 halogen lamps with an electronic transformer



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 continuous operation of the electronic transformer

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	<ol style="list-style-type: none"> Continuous output current 	<ol style="list-style-type: none"> Continuous input current (good compatibility to elec. Transformer.) Good power factor 	<ol style="list-style-type: none"> Adaptive to different configuration of LED string
Disadvantages	<ol style="list-style-type: none"> Pulsating input current Requires high input capacitor (difficult to MR16 applications) 	<ol style="list-style-type: none"> Requires electrolytic output capacitor to provide continuous LED current Only suitable for long LED string 	<ol style="list-style-type: none"> Pulsating input and output currents Relatively high peak switch current Requires electrolytic output capacitor to provide continuous LED current

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.

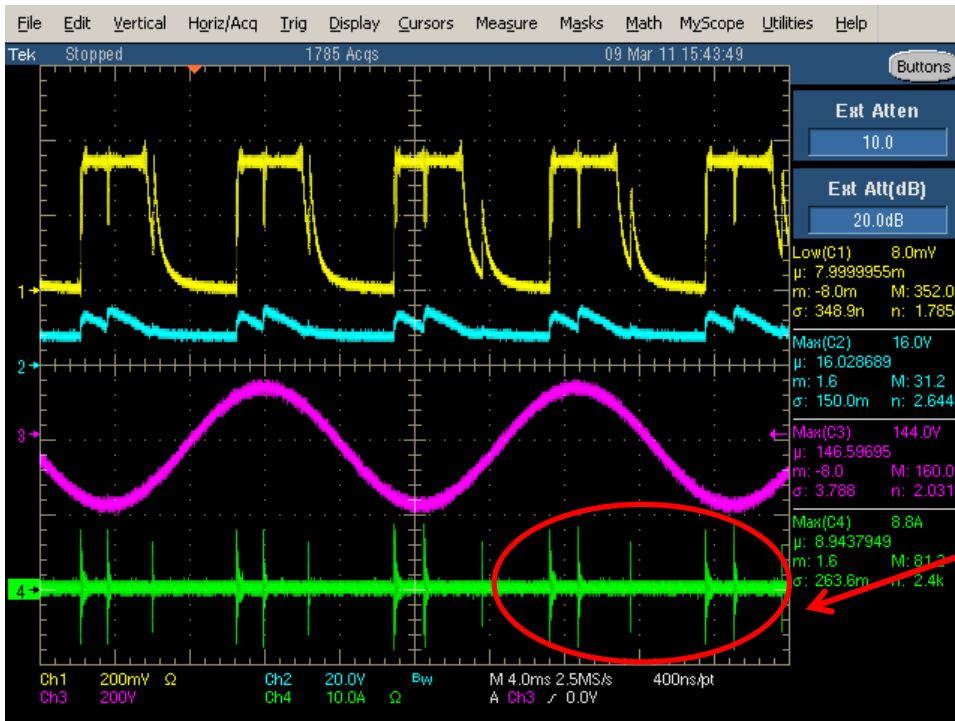
Resistive characteristics:

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

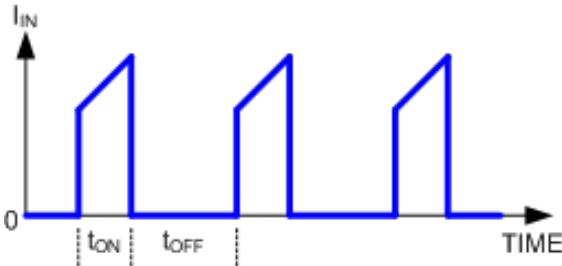
Up to 18A peak to peak surge input current

Getting Electronic Transformers Work

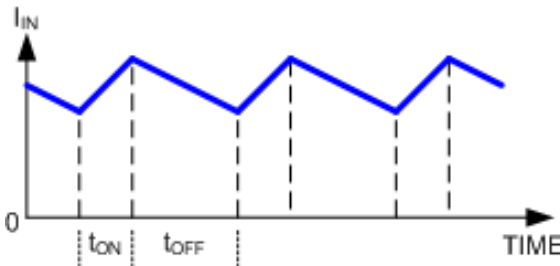
Because electronic transformers cannot accept capacitive load, the **input capacitance** of a LED driver for MR16 must be **very low. (e.g. <1uF)**

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

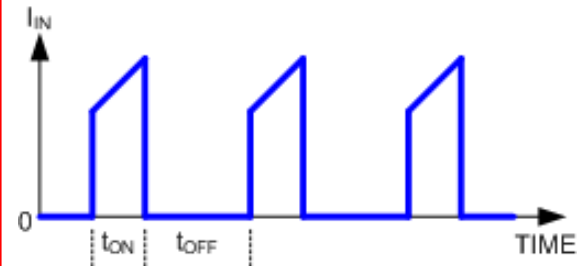
Buck



Boost



Buck-boost



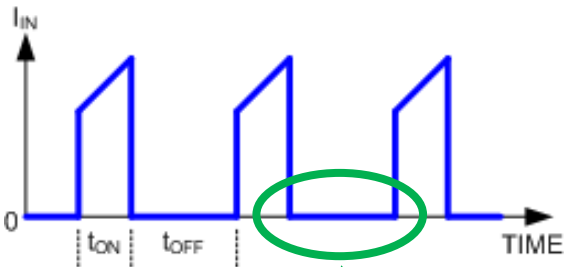
$$I_{IN} = I_L$$

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)**

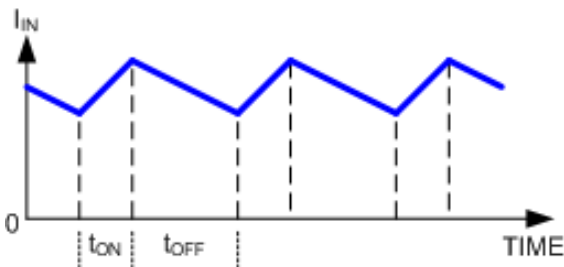
With low input capacitance, the input current (CCM) of LED driver circuits are:

Buck



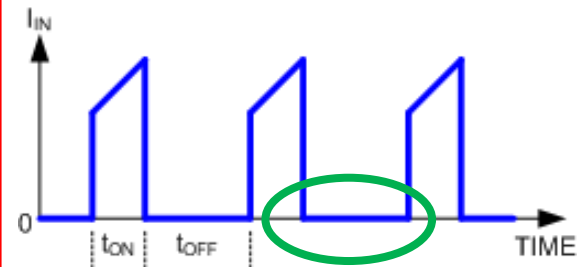
Electronic transformer may stop working

Boost



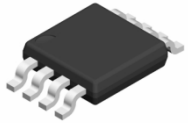
Continuous input current
 $I_{IN} = I_L$

Buck-boost

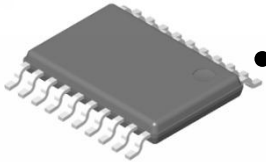


Electronic transformer may stop working

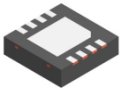
MR16 / AR111 LED Driver Solutions



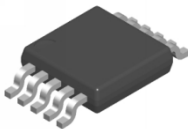
- **LM3401** - Hysteretic PFET Controller for High Power LED Drive



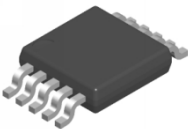
- **LM3409** - PFET Buck Controller for High Power LED Driver



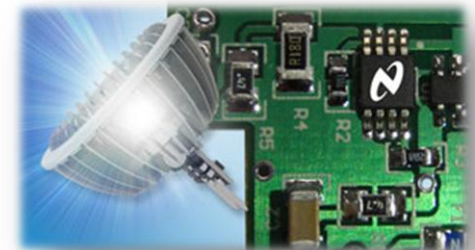
- **LM3414** - 1A 60W Constant Current Buck LED Driver



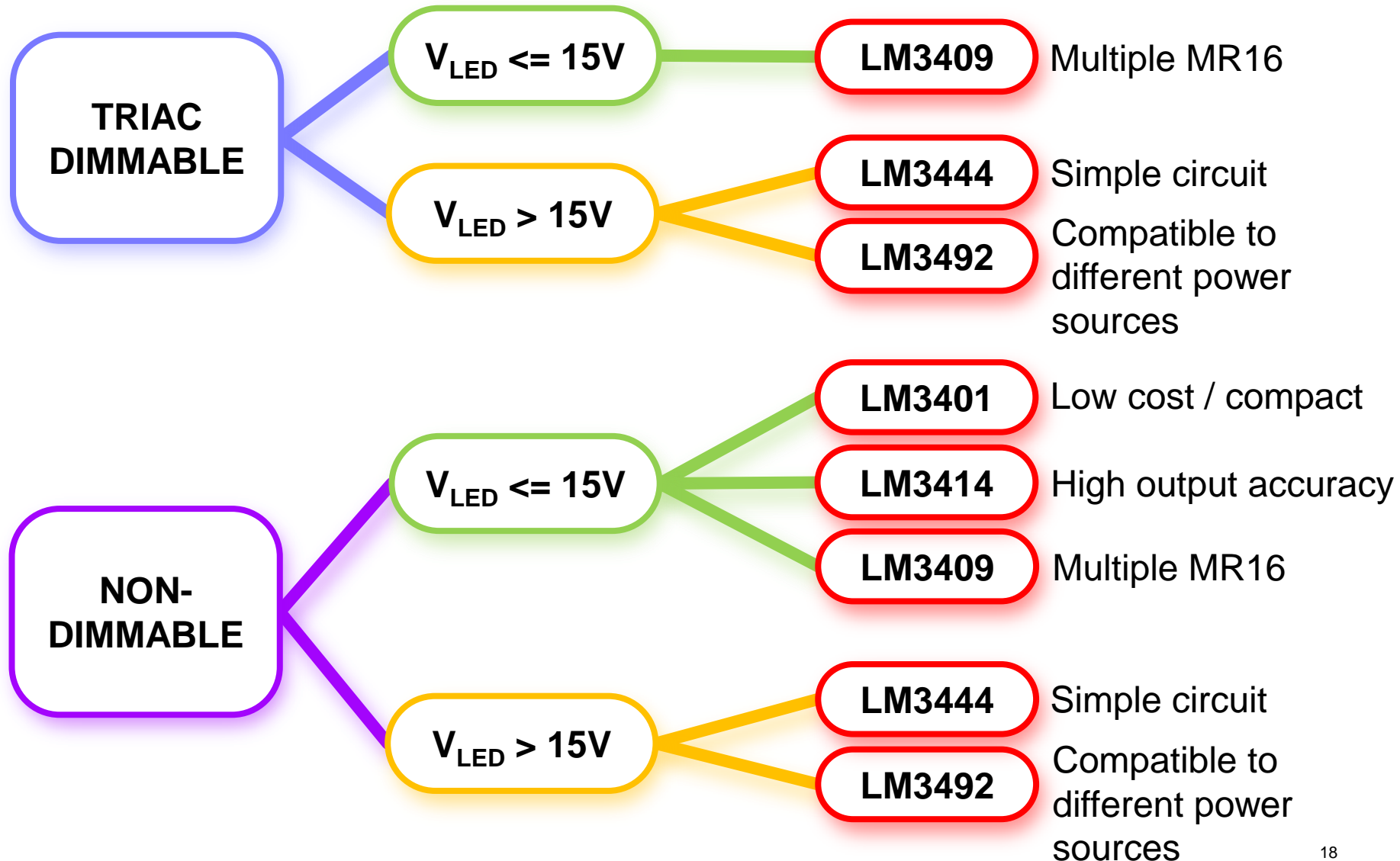
- **LM3492** - Two-Channel LED Driver with Boost Converter and Fast Current Regulator



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



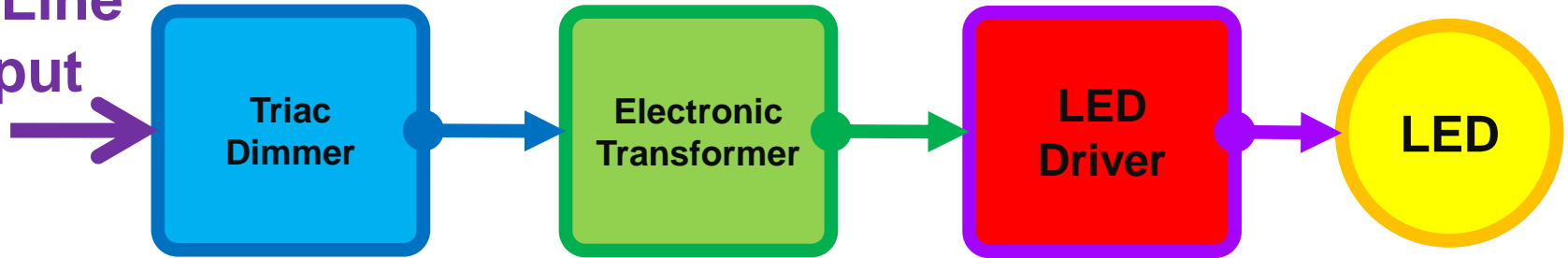
Product Selection Chart



Triac Dimmable vs Non-dimmable

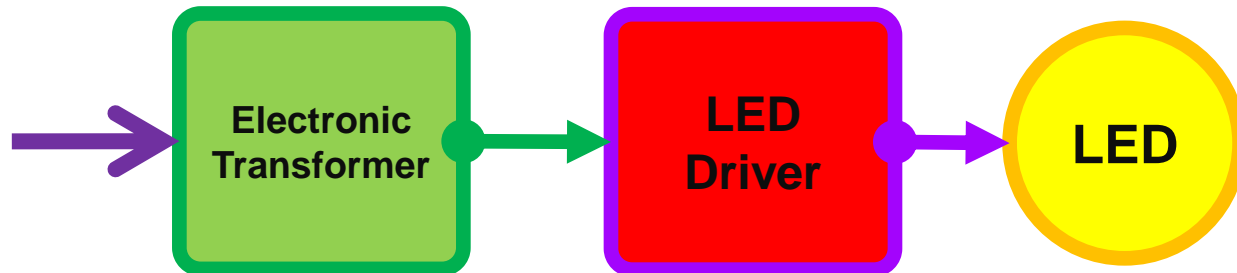
TRIAC DIMMABLE

AC Line
Input

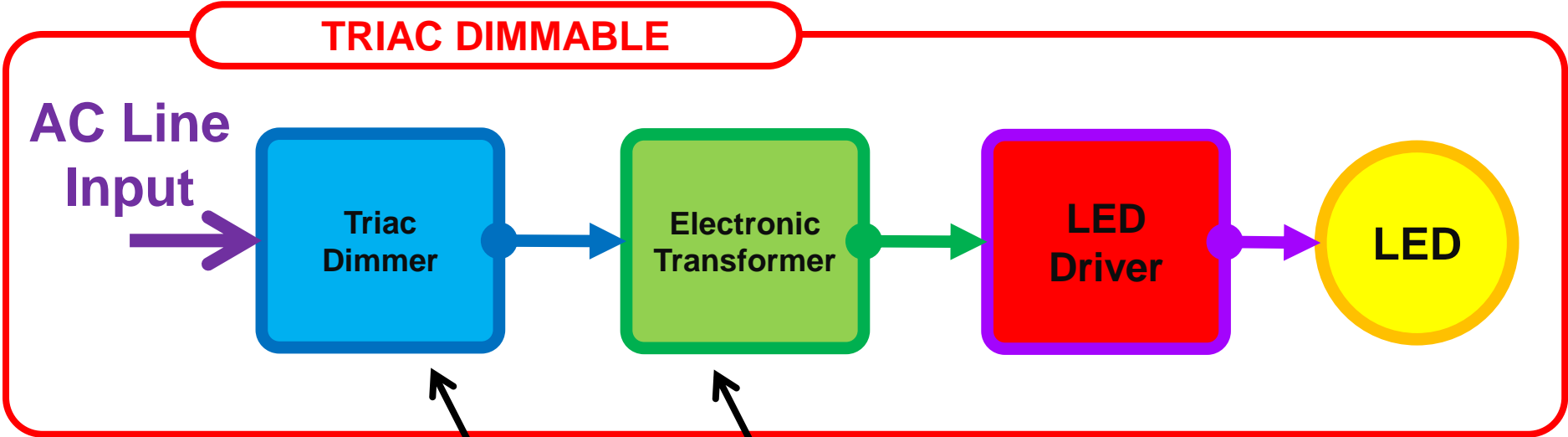


NON-DIMMABLE

AC Line
Input

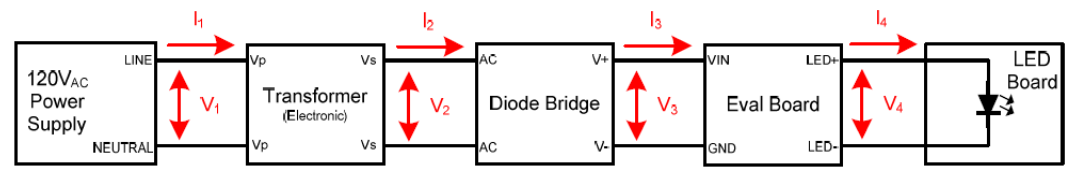
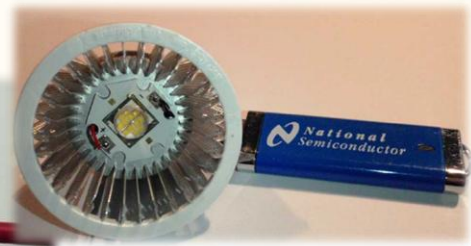
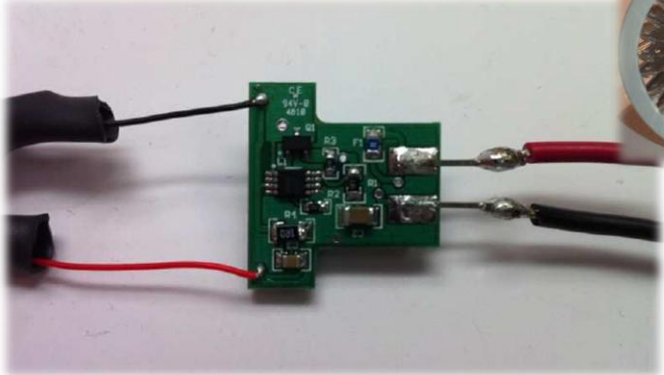
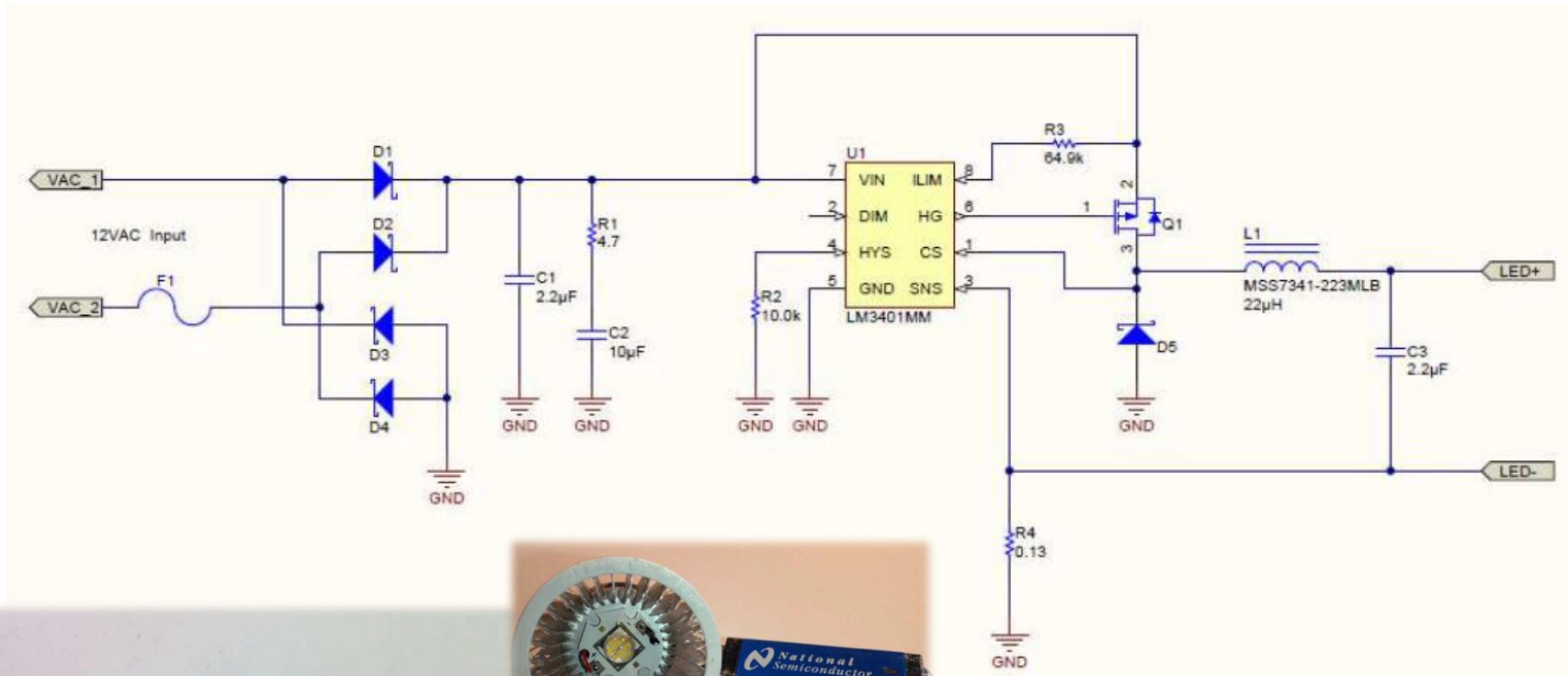


Triac Dimmable MR16 solution



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

LM3401 (non-dimmable)



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	-

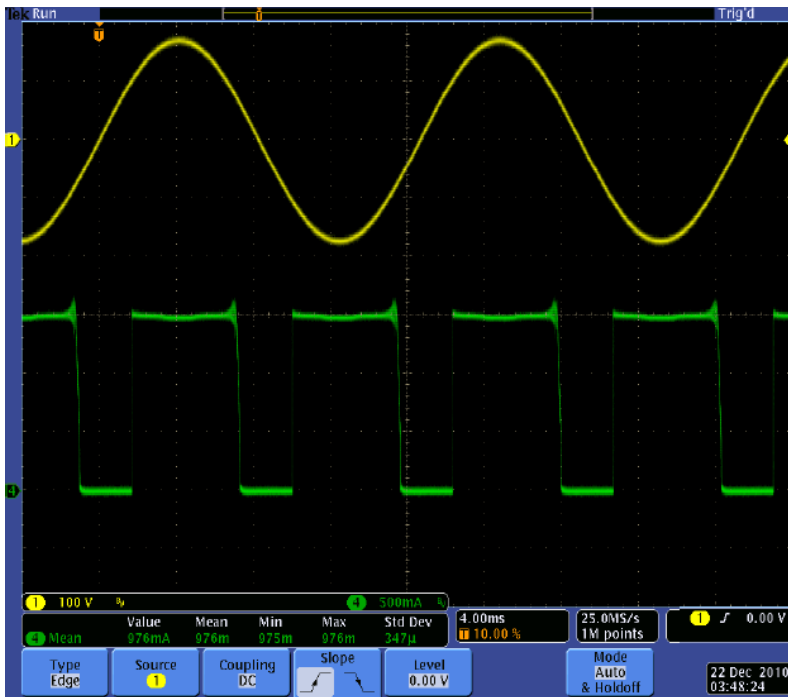
Specs	LM3401 STD CKT 3 LEDs @ 0.7A	Units
V_{IN}	119.94	VAC
I_{IN}	0.069	A
P_{IN}	6.93	W
$V_{OUT}^{(1)}$	8.19	VDC (1)
$I_{LED}^{(1)}$	0.614	A (1)
$P_{OUT}^{(2)}$	5.66	W (2)
Efficiency	81.7%	-
Power Factor	0.849	-

**Performance with electronic
transformer (LET-60)**

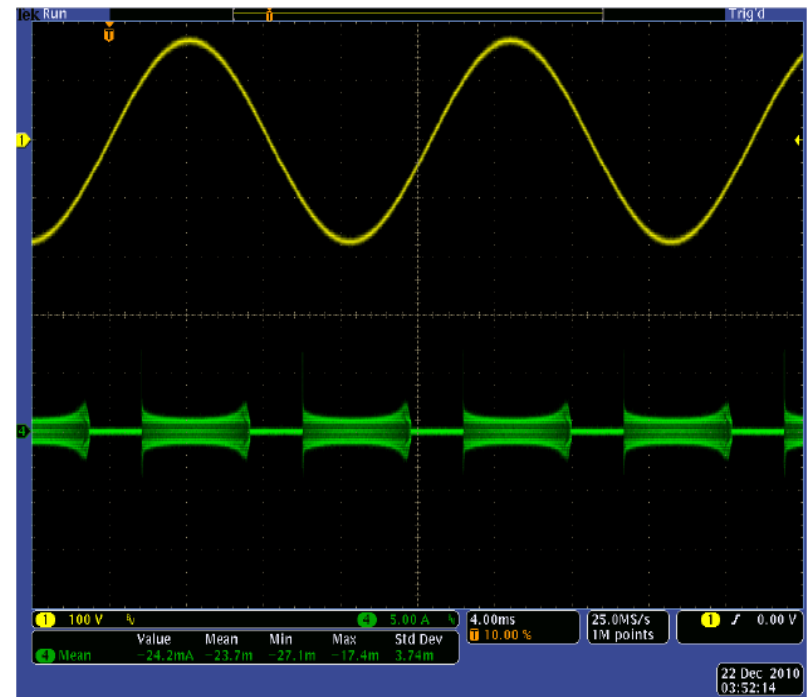
Specs	LM3401 STD CKT 3 LEDs @ 0.7A	Units
V_{IN}	119.44	VAC
I_{IN}	0.072	A
P_{IN}	7.24	W
$V_{OUT}^{(1)}$	8.44	VDC (1)
$I_{LED}^{(1)}$	0.651	A (1)
$P_{OUT}^{(2)}$	6.02	W (2)
Efficiency	83.1%	-
Power Factor	0.853	-

**Performance with electronic
transformer (HATCH)**

LM3401 (non-dimmable)

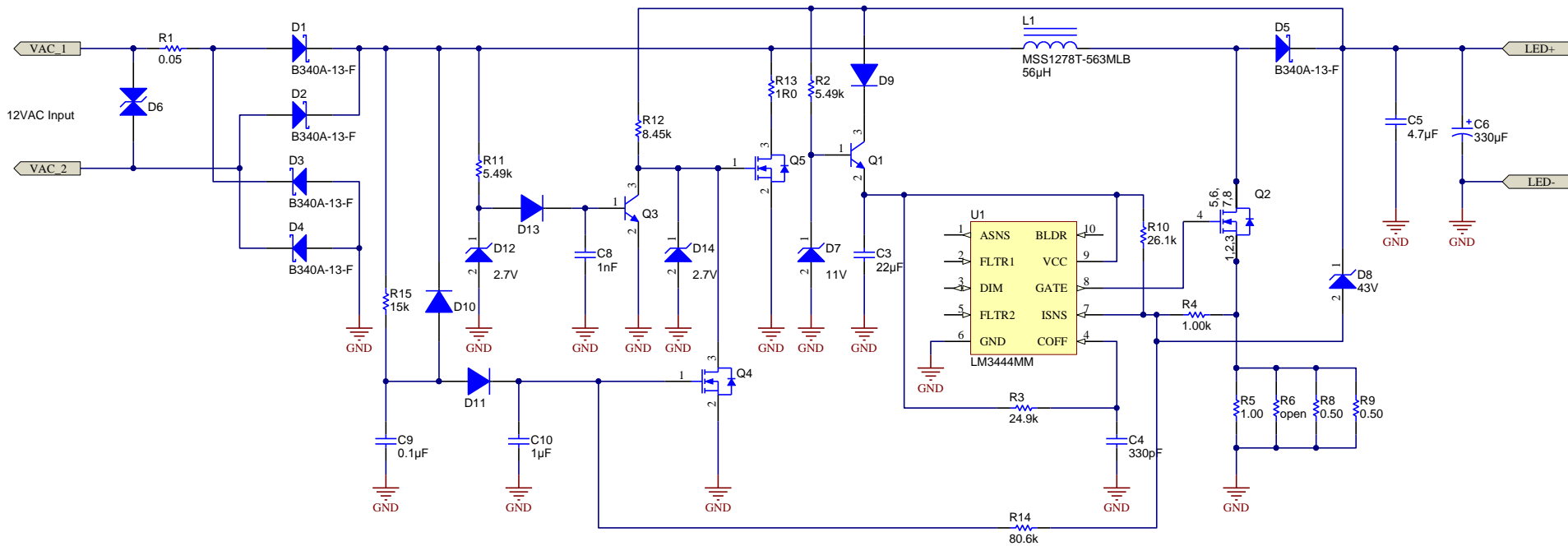


Input voltage, LED current

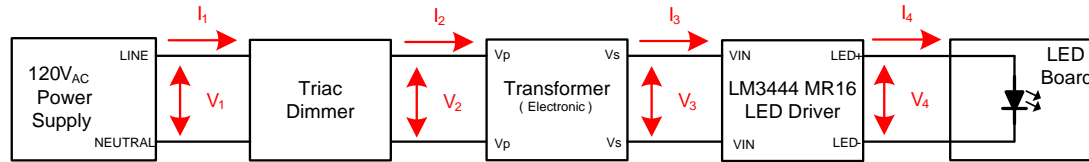


Input voltage, Input current

LM3444 (dimmable)



Bench Circuit



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)

Compatibility Score Card

AR-111 LED Lamp score card, on 220VAC

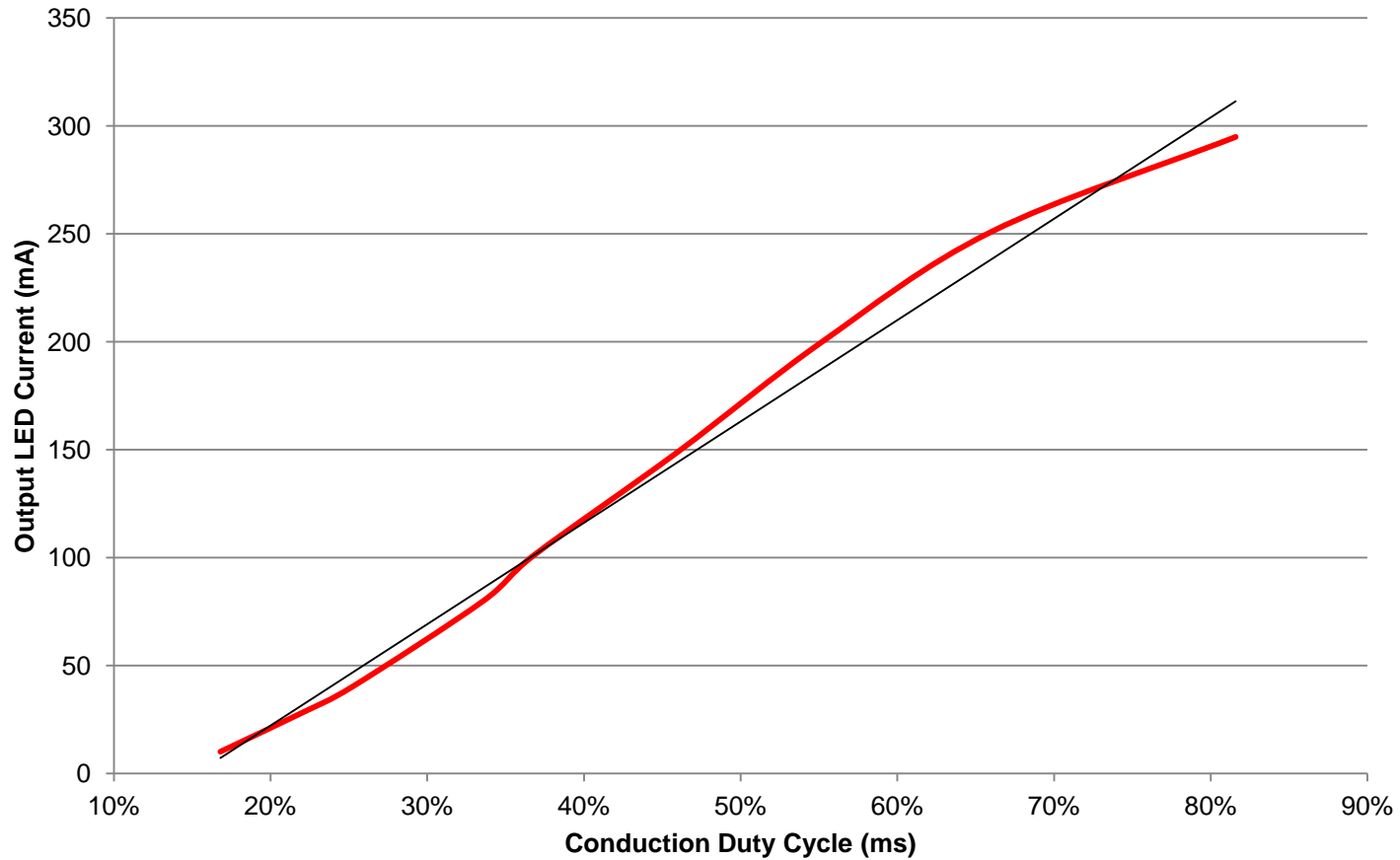
LAMP UNDER TEST: LM3444AR111 (BOM120208)

Measured full input power: 15W

Performance on conduction duty cycle

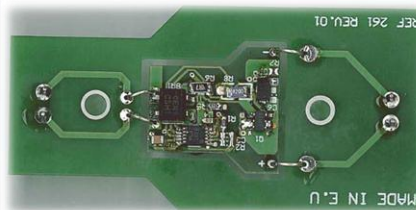
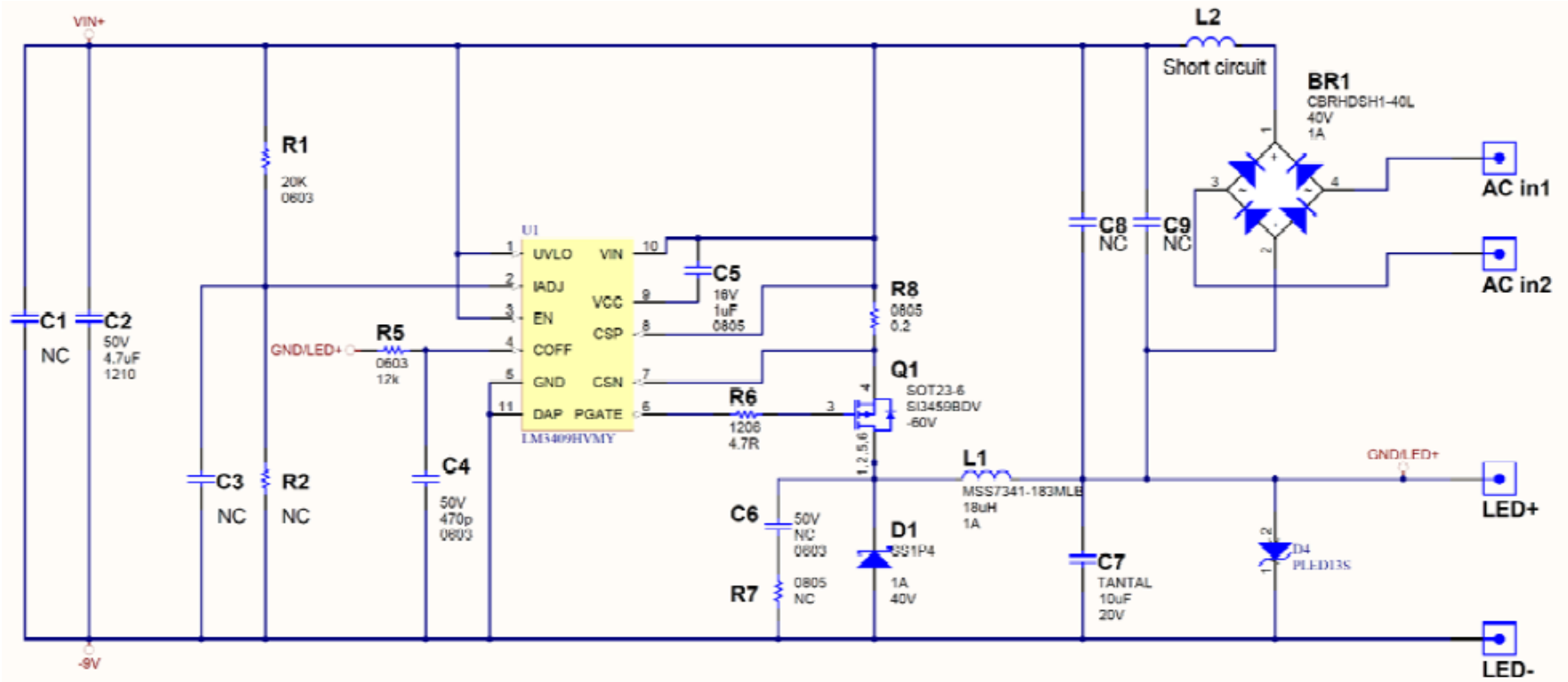
Dimmer	E-Transformer	Performance on conduction duty cycle														Remark		
		10%	20%	30%	40%	50%	60%	70%	80%	90%	80%	70%	60%	50%	40%		30%	20%
JUNON BTB04-600SL	Philips ETK50, 50W					L	L	L	L	L	L	L	L	L	L			
	Philips ET-E60, 20~60W					L	L	L	L	L	L	L	L	L	L	F		
	Rio RT50M, 20~50W				L	L	L	L	L	L	L	L	L	L	L	L	L	L
	Kengo DET-60T, 10~60W					L	L	L	L	L	L	L	L	L	L	L	L	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
	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	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	L	L
	Kengo DET-60T, 10~60W					L	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	L	F
	OSRAM ET-PARROT 105, 35~105W			F	L	L	L	L	L	L	L	L	L	L	L	L	F	
	OSRAM ET-P60				L	L	L	F	L	L	F	L	L	F	L	L	L	L
	OSRAM HTM 105, 35~105W			L	L	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	L	F	F	
	Wipo ET 105, 35~105W		L	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	L
	Kengo DET-60T, 10~60W					L	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	L
	OSRAM ET-PARROT 105, 35~105W				L	L	L	L	L	F	L	F	L	L	L	L	L	L
	OSRAM ET-P60				L	L	L	F	F	F	F	F	F	F	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	<p>MEANS "NOT LIGHT UP"</p> <p>MEANS "LIGHT UP WITHOUT FLICKER"</p> <p>MEANS "FLICKERING"</p>																

Output Current Linearity



LM3409

(dimnable, designed for multiple MR16 systems)



LM3409

(dimmable, designed for multiple MR16 systems)

Specifications

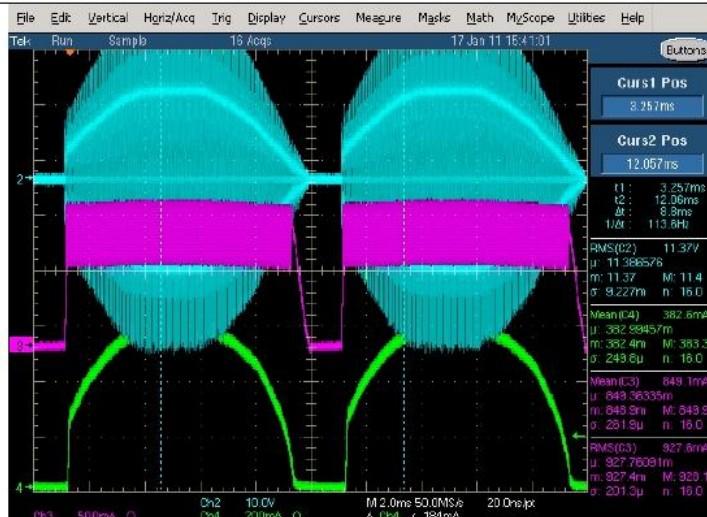
Specification	Model	REF 261
	Max input power (W)	4.87W
	DC Output current	350mA
	# of LEDs	3
	LEDs	Osram
Input	Voltage (AC)	0V _{AC} 14 V _{AC}
	PF	0.94
	Efficiency (%)	67%
Output	Voltage (depending on LED V _F)	8.8V +/-20%
	Current (A)	0.350A
	Ripple (mA _{pp})	500mA with 350mA LED current
	Frequency ripple	100hz
	Start up time (ms)	
	Hold up time (input failure)	
	Remote sensing	
	Remote on/off	Yes, ON/OFF switch
Isolation	Input/output	No
Dimming	With TRIAC Dimmer*	Yes*
Standards	Safety Agency approvals	No
	IEC 61000-3-2 CLASS C	No
	EN55015 conduction	No
	EN55015 radiation	No
Other	Cooling method	passive
	Life time	(NO ELCO)
	Temperature range	-20°C to +.....°C

LM3409

(dimmable, designed for multiple MR16 systems)

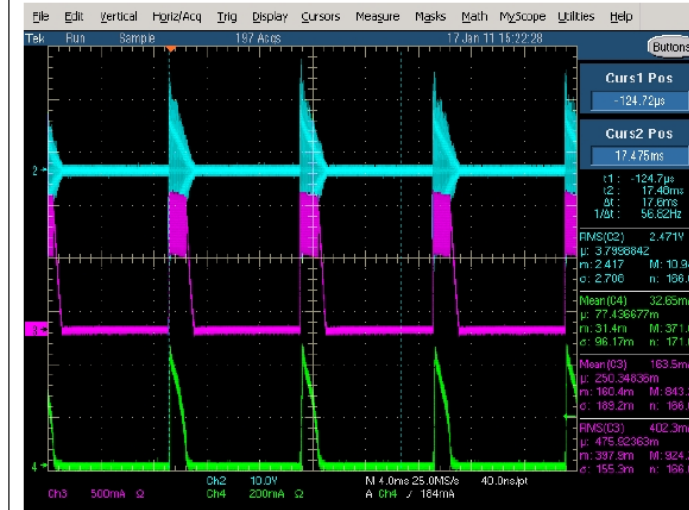
CH2: AC input
(12Vrms)
CH3: Inductor
current
CH4: LED
current 0.38A

Condition:
Vin Main:
230VAC
Vin : 11.37Vrms
Full dimming



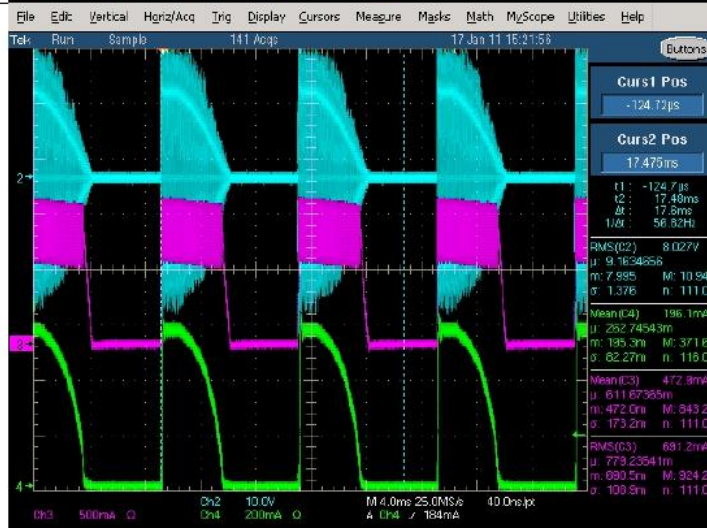
CH2: AC input
(2.47Vrms)
CH3: Inductor
current
CH4: LED
current 0.032A

Condition:
Vin Main:
230VAC
Vin : 2.47Vrms
Low dimming



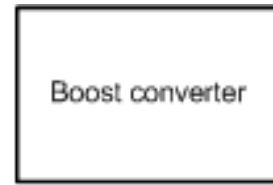
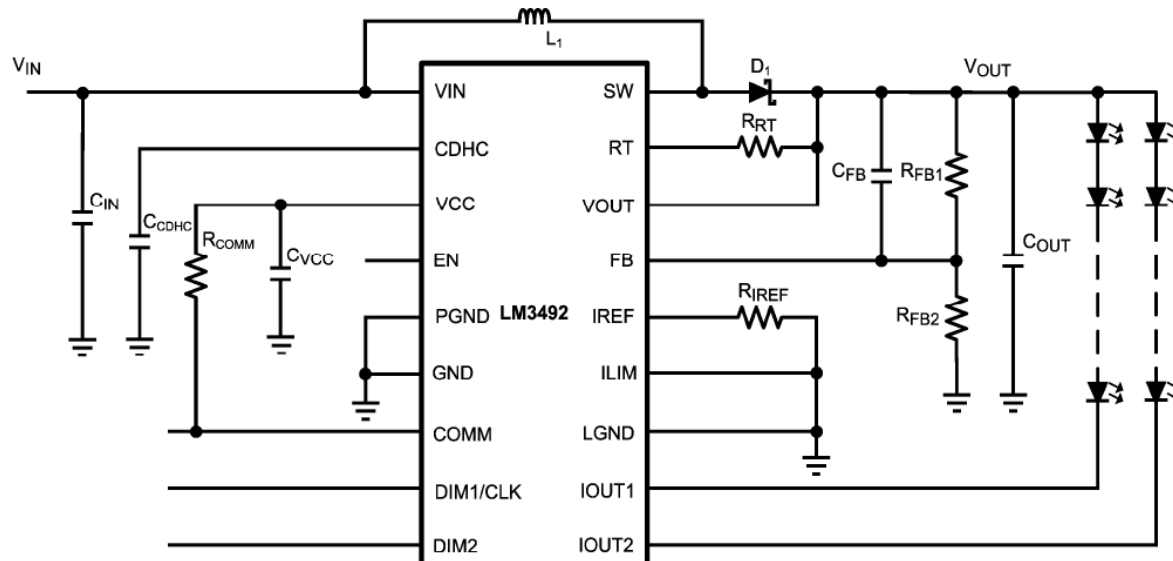
CH2: AC input
(8Vrms)
CH3: Inductor
current
CH4: LED
current 0.19A

Condition:
Vin Main:
230VAC
Vin : 8Vrms
50% dimming

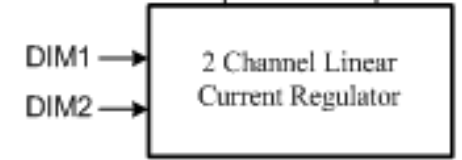
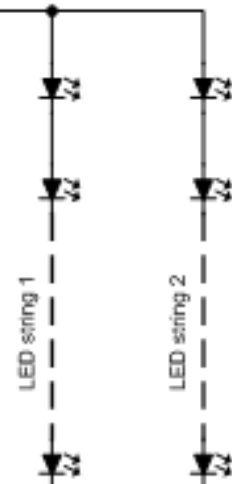


LM3492 (Boost + 2 ch. linear LED driver)

- Integrated boost power switch
- Integrated 2 ch. linear current regulator
- Automatic voltage headroom control
- Wide input voltage range 4.5V-6V

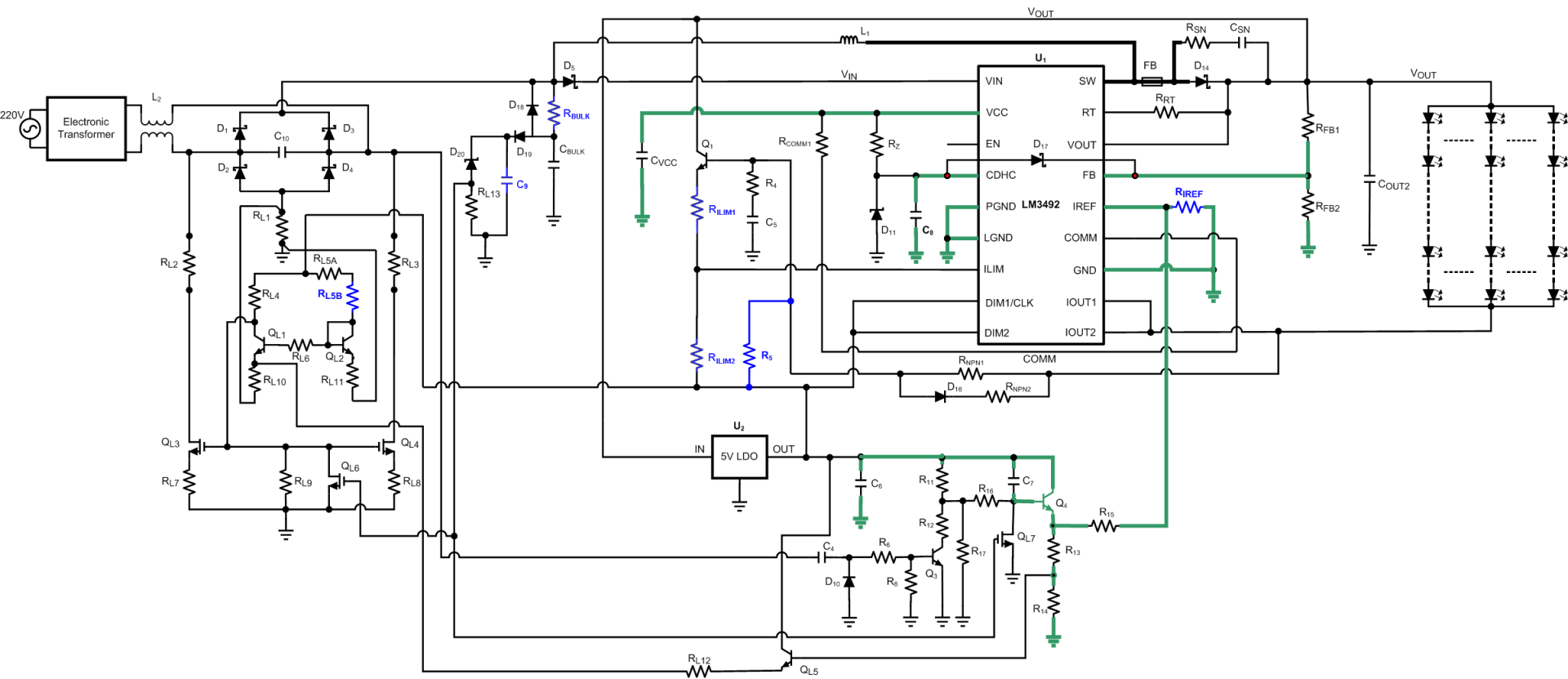


Boost converter provide the output voltage to power LED strings



Individual dimmable current regulator control LED current and brightness

LM3492 (dimmable)



Green color route (quiet ground “GND” related) should be kept short.

“FB” net needs to be quiet, keep it away from the “SW” net.

Mind the kelvin sense connection of “RL1”.

LM3492 (dimmable)

Performance with 12VAC

Specs	LM3492 BOOST 6 LEDs	Units
V_{IN}	12	VAC
P_{IN}	6.9	W
V_{OUT}	18.54	VDC
I_{LED}	0.295	A
P_{OUT}	5.47	W
Efficiency	79.2	%

Specs	LM3492 BOOST 6 LEDs	Units
V_{IN}	220	VAC
P_{IN}	7.28	W
V_{OUT}	18.42	VDC
I_{LED}	0.278	A
P_{OUT}	5.12	W
Efficiency	70.3	%

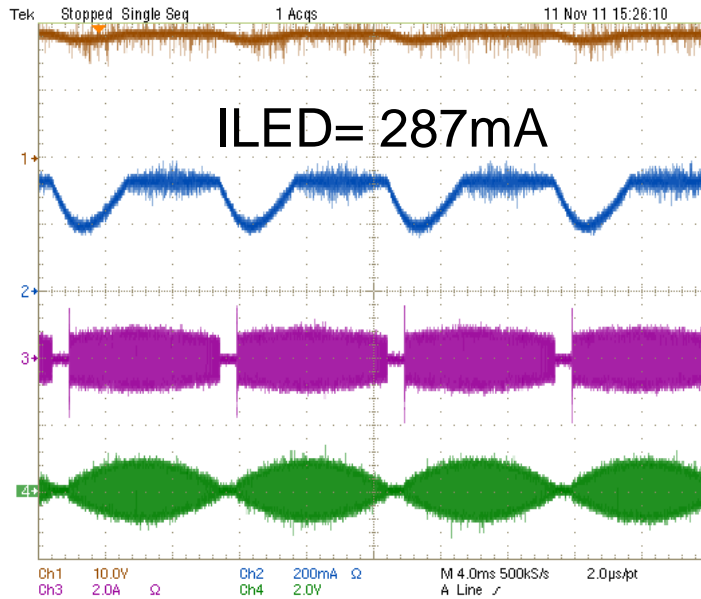
Performance with electronic transformer (Philips ETK50)

Performance with electronic transformer (RIO RT50M)

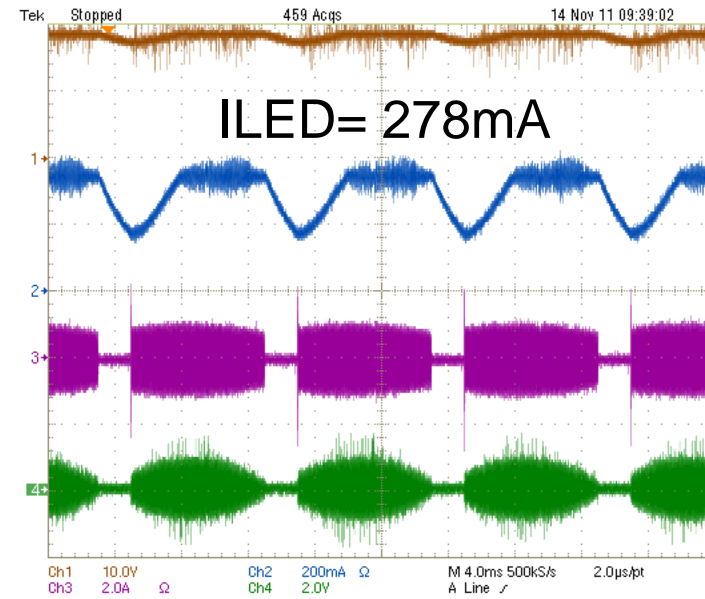
Specs	LM3492 BOOST 6 LEDs	Units
V_{IN}	220	VAC
P_{IN}	7.27	W
V_{OUT}	18.45	VDC
I_{LED}	0.287	A
P_{OUT}	5.3	W
Efficiency	72.8	%

LM3492 (dimmable)

Electronic Transformer Waveform (RIO RT50M)



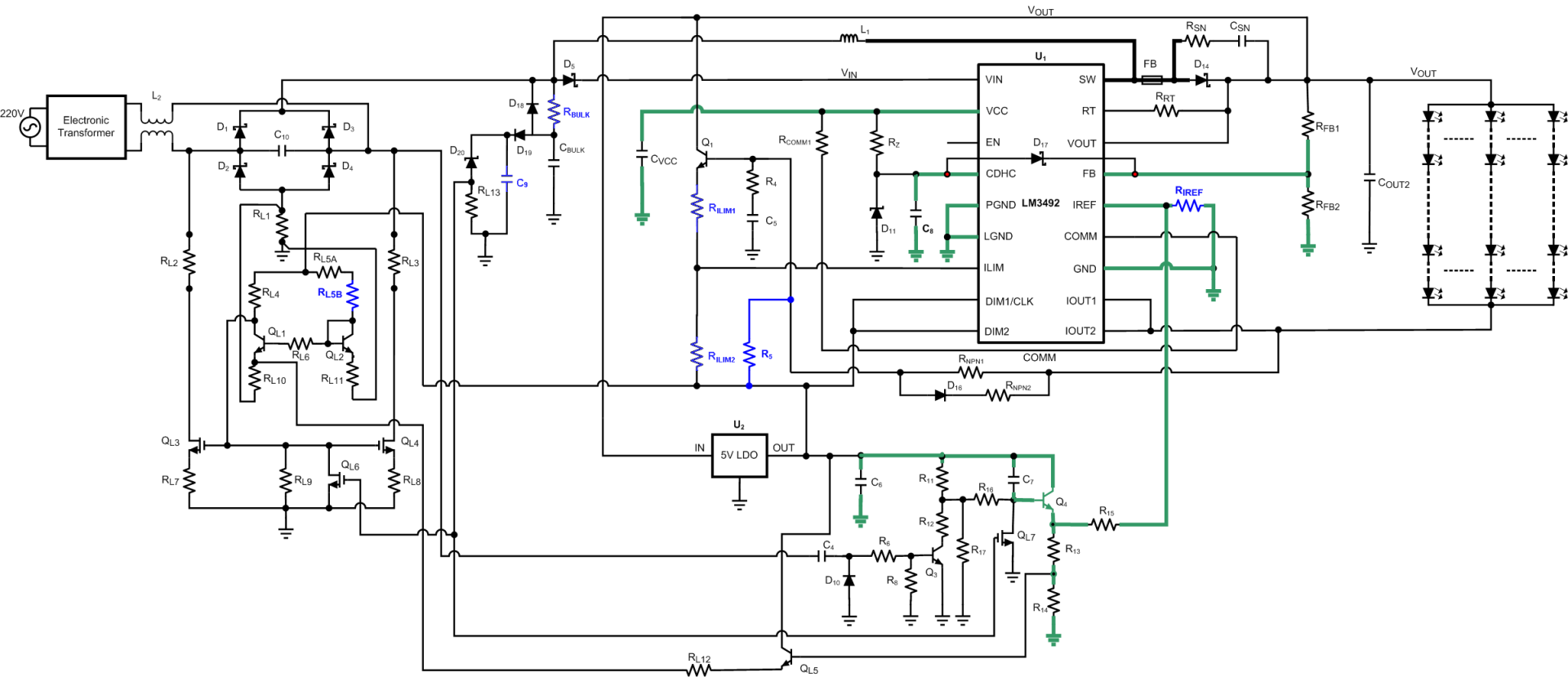
Electronic Transformer Waveform (Philips ETK50)



1. 220V 50Hz AC Power is supplied by Kikusui PCR 500LA
2. Rio RT50M E-Transformer

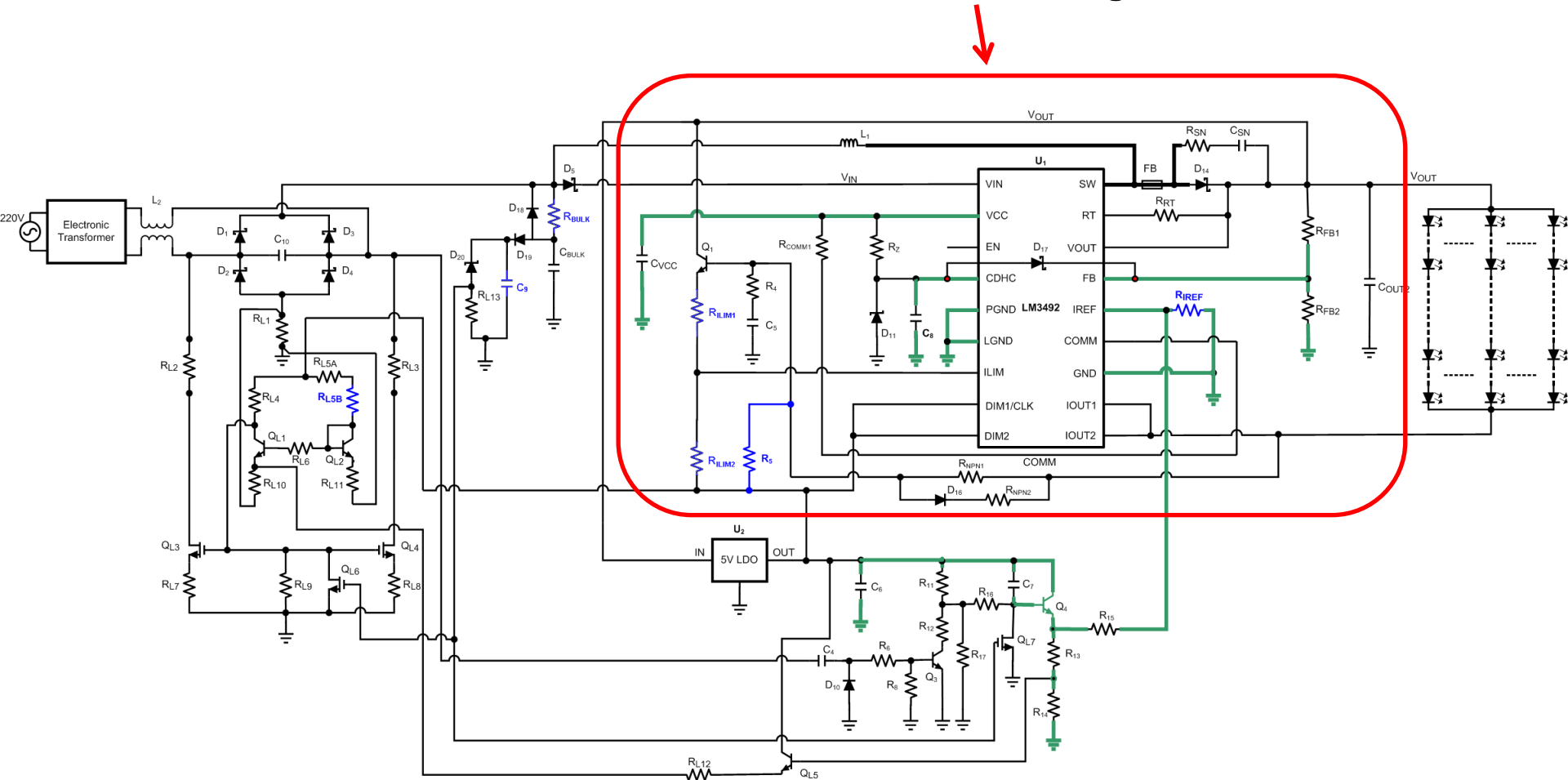
CH1: LED Voltage
CH2: LED Current
CH3: Output Current from Transformer
CH4: Output Voltage from Transformer
(100mV * 200 = 20V/div)

Operation principles of the LM3492 MR16 solution

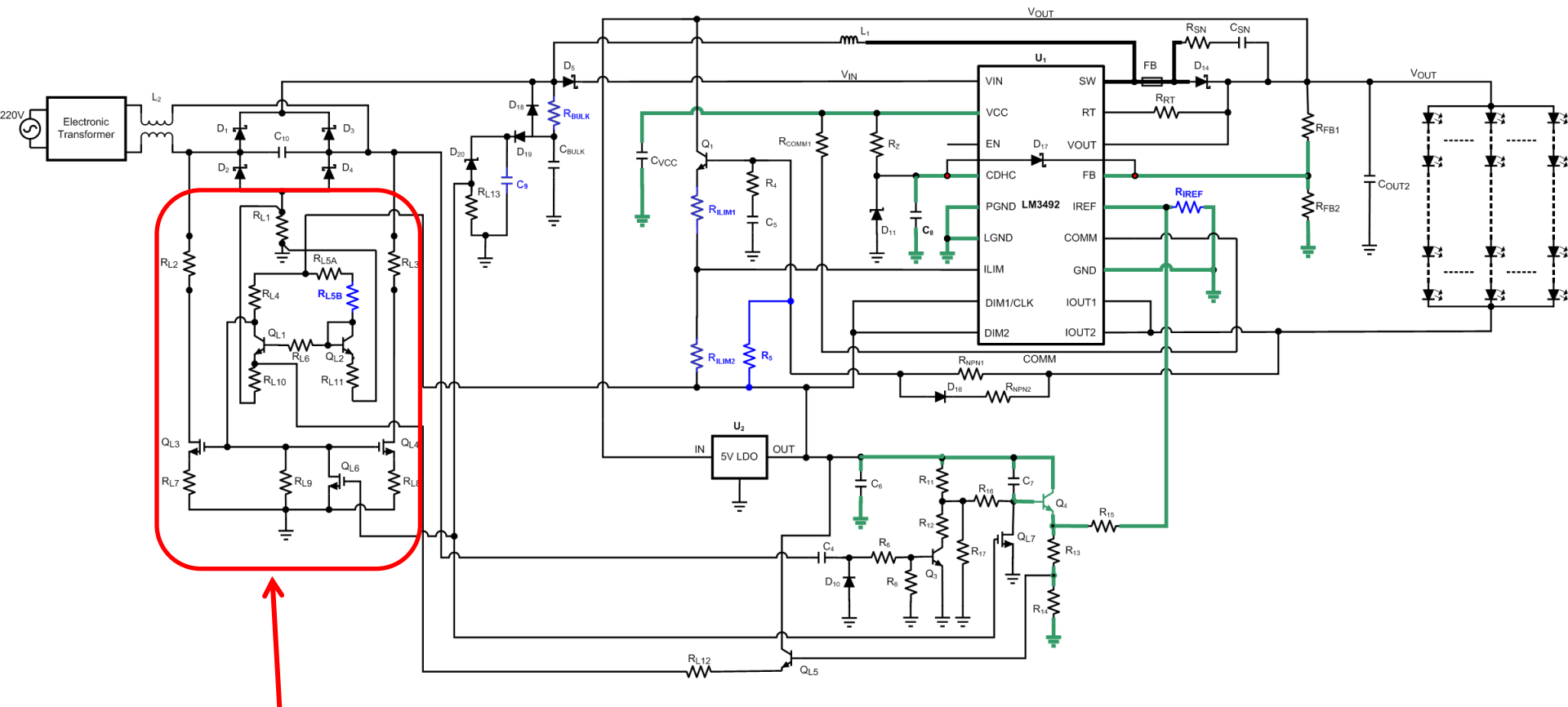


Operation principles of the LM3492 MR16 solution

Boost LED driver stage

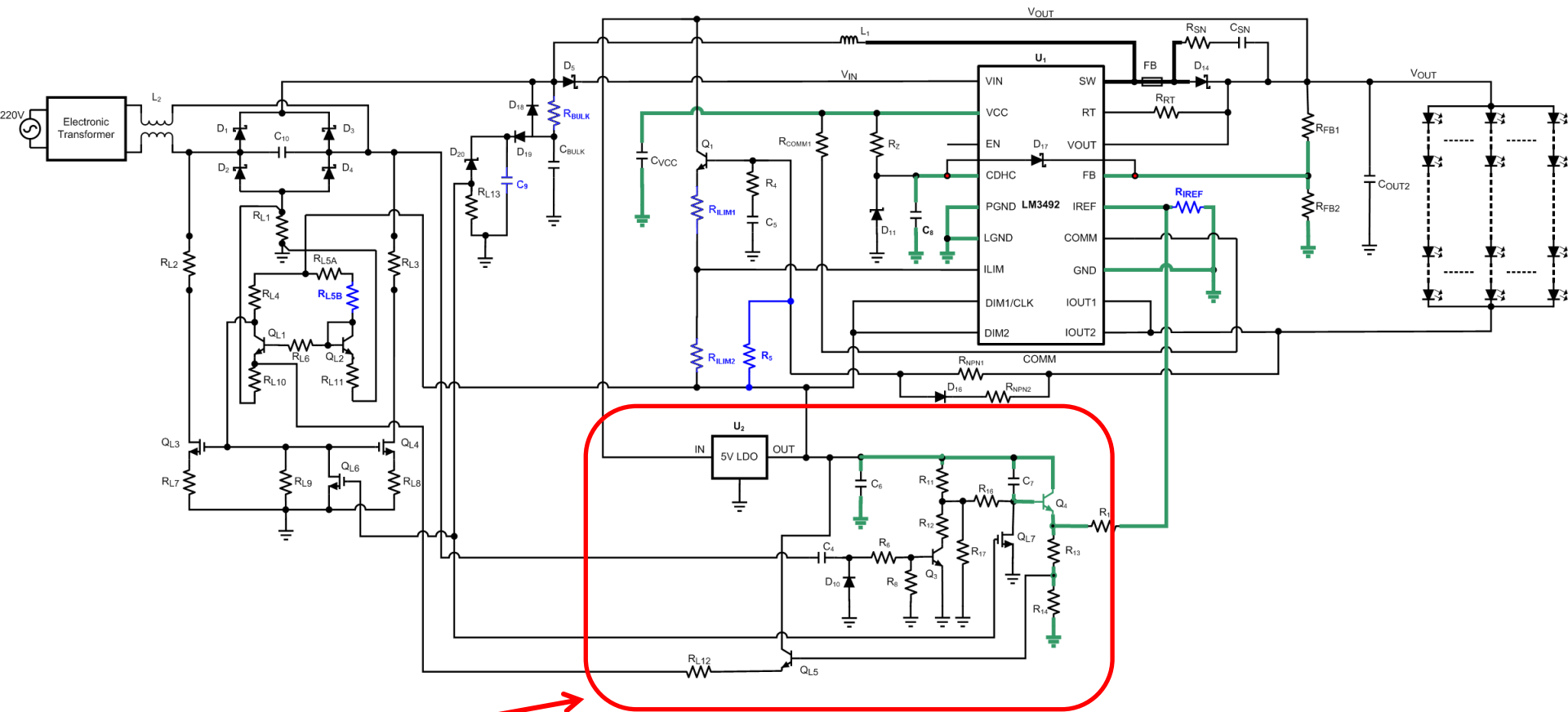


Operation principles of the LM3492 MR16 solution



Current sensor for constant input current regulation and AC dummy load circuit

Operation principles of the LM3492 MR16 solution



Electronic transformer detection and IOUT reference adjustment circuit

• Q&A?