Author **Najmi Kamal**
Part number **LM3445MM**
Project Title **9W Retrofit Triac dimming**
Project Number **NSCE0144**

Title		**Off line Triac dimmer with 6 LEDs**
Description	Input	230V_{AC}
	Output	6 LEDs @ 350 mA
	Power	9W
	Freq.	45 kHz
Date		[2009-10-15]
Revision		[2.0]

Contents

1 Introduction

This technical report describes the retrofit power supply.
The main purpose of the power supply is to convert the rectified AC Input to DC regulated current for 6 LEDs. The power supply provides protection for the LEDs, limits the transient input voltage and protect against inrush current at plug in. The overall power supply conformity (e.g. mains harmonics (EN), mains interference, international safety standards etc.) are not approved for all the applicable European Norms (EN).

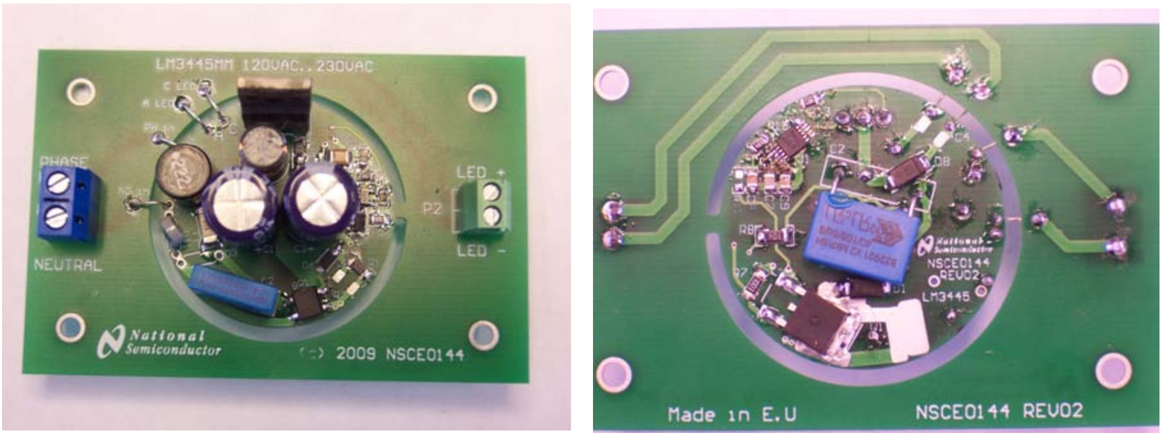
The principle of this power supply is a step down. It is regulated by the 350 mA average current with a fixed Toff time.
At the heart of the power supply is the controller LM3445 current mode control from National Semiconductor. The LM3445 switching frequency is set at a nominal 45 kHz.
With the LM3445 National Semiconductor provides a device that avoids visible flickering caused by a TRIAC forward or reverse phase dimmer. The LM3445 overcomes this challenge by translating the TRIAC-chopped waveform to a DIM signal and decoding it to a DC signal. In fact, the LED current is linearly regulated according to the dimming signal.

The LM3445 integrates many features to simplify the compatibility with Triac dimmer:

- Triac dim decoder circuit for LED dimming
- Adjustable switching frequency
- Low quiescent current
- Triac dim decoder circuit for LED dimming
- Adaptive programmable off-time allows for constant ripple current
- Thermal shutdown
- No 100Hz flicker
- Patent pending drive architecture

The report includes schematic, design description, bill of materials listing as well as a full set of performance measurements taken from a prototype unit.

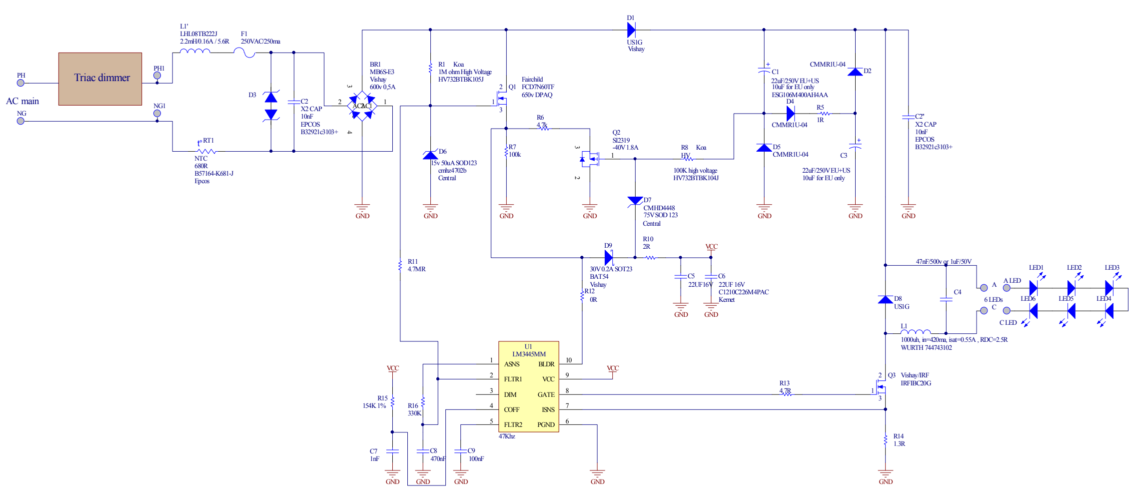
Figure 1:



This LED retrofit power supply is used with a standard Triac dimmer
The LM3445 contains all the necessary circuitry to build a line powered (mains powered) constant current LED driver whose output current can be controlled with a conventional triac dimmer.

The main source can be either 120V_{AC} (60Hz), 240V_{AC} (50Hz) or both, it is only matter of Electrolytic capacitor at the input stage.

Figure 2 shows a diagram of the Triac dimmer, LED Driver and the 7 W retrofit LEDs.



2 Specifications

Specification	Model	**NSCE0144**
	Max input power (W) DC Output current Nb of LEDs LEDs	**9W** **350mA** **6** **………..**
Input	Voltage (AC) PF Efficiency (%)	**$180V_{AC}$ …..265 V_{AC}** **0.92** **77.7%**
Output	Voltage (VF) Current (A) Ripple (mA_{pp}) Start up time (ms) Hold up time (input failure) Remote sensing Remote on/off	**19V +/-20%** **0.350A** **400mA** **10ms (V_{AC}=230V_{AC}, I_{out}=100%)** **28ms @ 100% load** **Forward Triac dimmer** **Yes, ON/OFF switch**
Isolation	Input/output	**No**
Standards	Safety Agency approvals IEC 61000-3-2 CLASS C EN55022 conduction EN55022 radiation	**No** **Yes** **No, over the limit** **No, not measured**
Other	cooling method Temperature range	**Non** **-25°C to +65°C**

Maximum component height is 25mm. The overall size area is 35mm diameter.

3 Basic Theory

3.1 Converter Theory

One of the main points is the angle detect and Dim decoder to translate the trigger point into a dc current. National Semiconductor has introduced the LM3445 LED driver that integrates most of these functions needed to translate a TRIAC dimmer angle into an average current running through a number of LEDs. On the schematic **figure 5**, on the top left side we see the entry point for the AC signal, this AC signal is first rectified using a diode bridge. Then is translated to a lower voltage level by a bleeder circuit and is fed to the BLDR pin of the LM3445.

The external bleeder circuit translates the rectified signal to a lower voltage level signal via R1, R2, Q1, D6 and is fed to the BLDR pin of the LM3445.The main function of R7 is to ensure that a minimal amount of current is drawn even at light loads, to make sure the TRIAC in the dimmer remains conductive.
When the valley fill circuit composed by C1, C3, D2, D4, D5 and R5 is drawing current from the line (bulk capacitors charging in series) there is plenty of input line current holding the TRIAC on state. When the valley fill circuit stops charging the capacitors, the output power (LED current) is being delivered by the bulk capacitors, and the line current through the TRIAC became very small. A simple Circuit composed by R6, Q2, D7 and R8 is used to add holding current when valley fill diodes D2, D5 are conducting.
This simple circuit will reduce the power consumption of the holding circuit (Q1) and increase the overall efficiency.

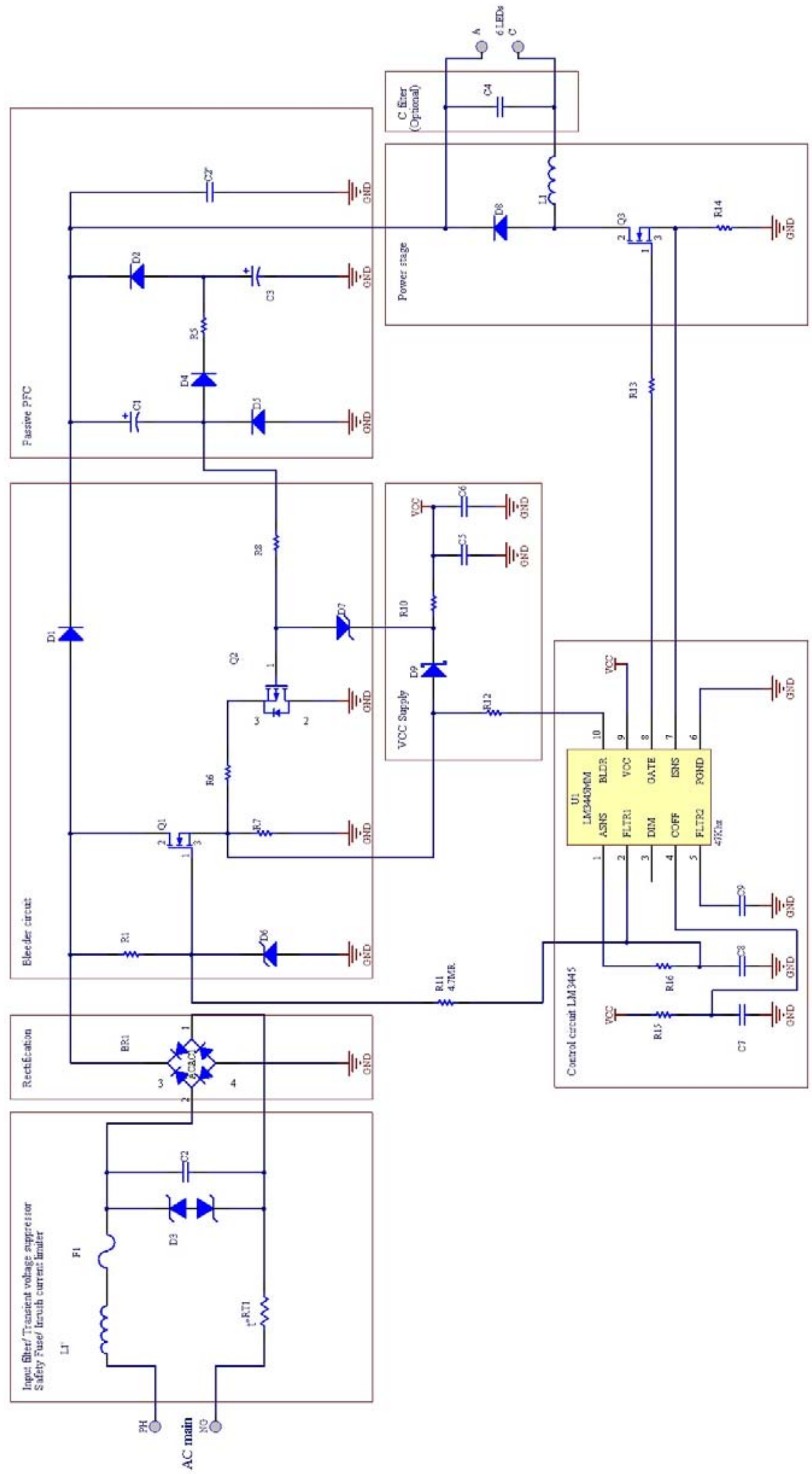
The valley-fill circuit is used to avoid high peak current during charge of the input bulk capacitor. This high input current seen in the 230V line generates high harmonics distortion and therefore is an obstacle to meet the European standard EN-61000-3-2 class C and has a poor power factor. To avoid this, a valley-fill circuit is used.
To be in line with the UL safety standard norm, we implemented a varistor protection on the primary side to absorb any high peak voltages. At plug in, the input voltage charges the input capacitors C1 and C3 with a low peak current due to the inrush current limiter RT1.

The cycle by cycle current limitation controls the maximum power in case of short circuit or an excessive load. If the voltage across R14 rises above 1.27V, the PWM uses this information to terminate the Mosfet conduction. A delay circuit will prevent the start of another cycle for 180 µs.
In case of open LEDs, the voltage across the capacitor C4 will become higher and clamp to the input voltage, this capacitor has been selected to support 500V.

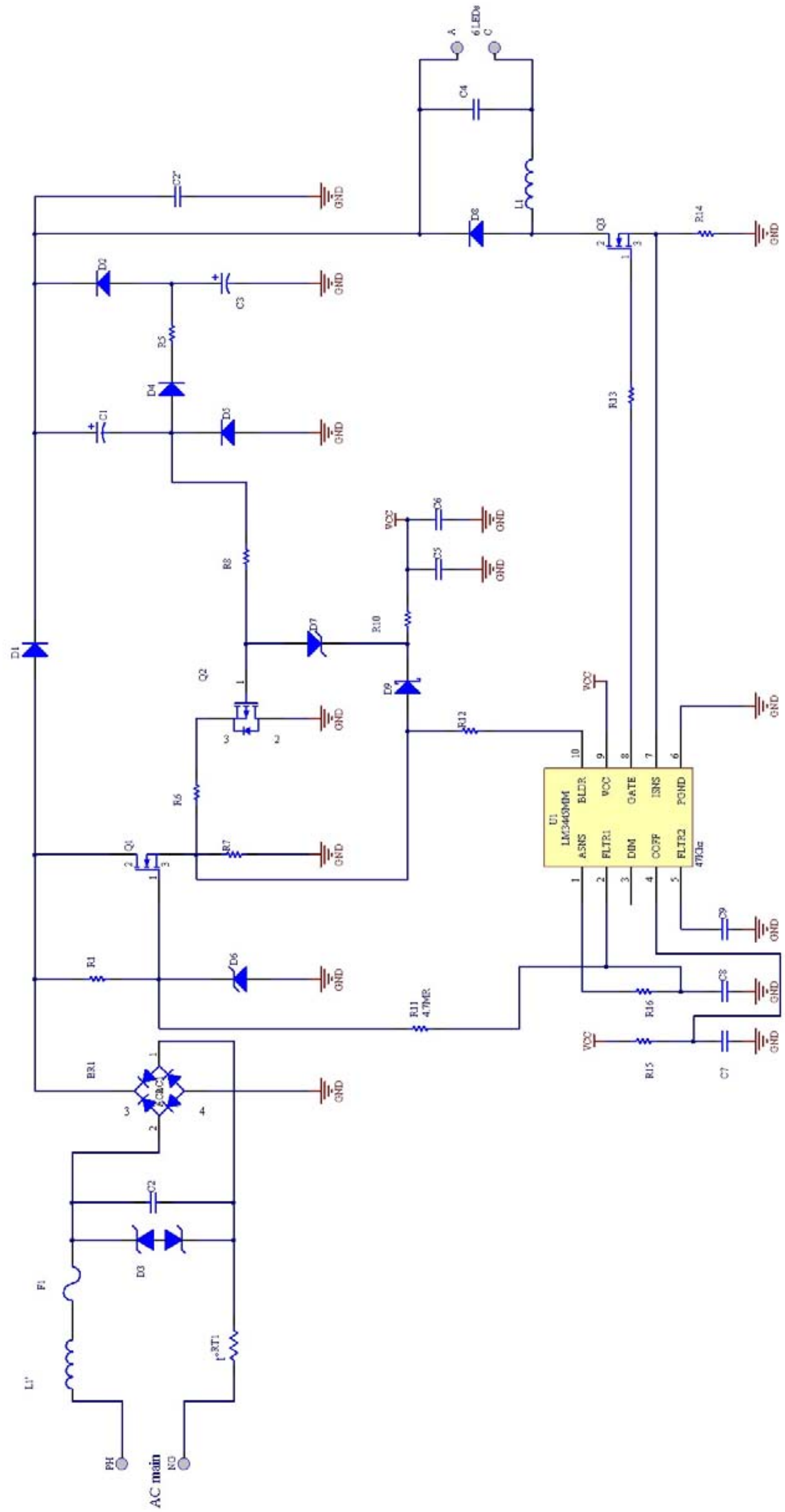
The mains filter is located at the input, consisting of L1' and C2 used to fulfill the EN55022 norm. This filter is necessary to minimize interference transmission from the power supply to the mains and vice versa. The switching frequency has been adjusted close to 50 kHz to keep an easy input filter.

This converter will operate in continuous conduction mode at full power and discontinuous mode at low power during dimming. To eliminate most of the ripple current seen in the inductor, it is possible to have a 1 μF capacitor in parallel to C4. This LED driver uses a constant off-time control to regulate current through a string of LEDs. The resistor R15 and capacitor C7 create a constant current ramp which is fed into the C_{off} pin and thus generates the T_{off} time. While Mosfet Q3 is conducting, the LED current increases through the inductance until reaching the reference FLTR2 fixed by the TRIAC dimmer. With this reference peak current reached the Mosfet turns OFF and diode D8 conducts during the period T_{off}. That means by varying FLTR2 pin (reference) by the TRIAC dimming, the current through the LED is varying. Hence we achieve dimming.

4 Block diagram



5 Schematic


LM3445MM
ASNS
FLTR1
DIM
COFF
FLTR2
BLDR
VCC
GATE
ISNS
PGND
GND
AC main

6 Bill of Materials

Bill of Materials Report

Document P/N: 980None

For procurement use only	
Dept Charge #	
Assembly Site	
Build Date:	

Date opened: 10/16/2009
Time opened: 10:27:51 AM

Project Name:	NSCE0144
Project File:	Free Documents
Base ID:	
PCB Revision:	2 nd
Assembly Variant:	None
Schematic Rev:	Rev03
Build Quantity:	1
Generated:	10/12/2009 1:58:16 PM

Item	Designator	Value	Part Number	Manufacturer	Supplier		2nd sources	Manufacturer	Quantity	Required
									40	40
1	BR1	600v 0,5A	MB6S-E3	Vishay					1	1
2	C1	22uF / 250V / EKA / 85deg	12D5238	Vishay / Roedersteim EKA	Burklin		ESK226M250AH4AA	Arcotronic	1	1
3	C2	10nF 350VAC X2	B32921c3103+	Epcos					1	1
4	C2"	10nF 350VAC X2	B32921c3103+	Epcos					1	1
5	C3	22uF / 250V / EKA / 85deg	12D5238	Vishay / Roedersteim EKA	Burklin		ESK226M250AH4AA	Arcotronic	1	1
6	C4	47nF/500v or 1uF/50V or NC	C1210C105K5RAC	Kemet					1	1
7	C5	22UF 16V 1210	C1210C226M4PAC	Kemet					1	1
8	C6	22UF 16V 1210	C1210C226M4PAC	Kemet					1	1
9	C7	1nF / 100V	C0805C102J1RAC	Kemet					1	1
10	C8	470nF 25V	C0805C474K3RAC	Kemet					1	1
11	C9	100nF / 50V	C0805C104K5RAC	Kemet					1	1
12	D1	400V / 1A /SMA	US1G	Vishay					1	1
13	D2	400V / 1A /SOT123 ULTRAFAST	CMMR1U-04	Central					1	1
14	D3	V390ZA05	846-8204	Harris Semiconductor	RS-ONLINE				1	1
15	D4	400V / 1A /SOT123 ULTRAFAST	CMMR1U-04	Central					1	1
16	D5	400V / 1A /SOT123 ULTRAFAST	CMMR1U-04	Central					1	1
17	D6	15v 50uA SOD123	cmhz4702b	Central					1	1
18	D7	75V SOD 123	CMHD4448	Central					1	1
19	D8	400V / 1A / SMA	US1G	Vishay					1	1
20	D9	30V 0,2A SOT 23 shottky	BAT54	Fairchild					1	1
21	F1	SMD SSQF 250mA FUSE	547118-11	ESKA	Conrad				1	1
22	L1	WURTH 744743102	744743102	Wurth					1	1
23	L1'	4.7mH/0.1A / 14R	LHL08TB472J	tayo yuden	RM-GMBH				1	1
24	Q1	650v DPAQ	FCD7N60TF	Fairchild					1	1
25	Q2	-40V 1.8A	SI2319	Vishay-Siliconix					1	1
26	Q3	600v 3A D2PAQ	IRFIBC20G	Vishay					1	1
27	R1	1M ohm High Voltage 1206	HV732BTBK105J	Koa					1	1
28	R5	1R / 5% / 1206	YAGEO						1	1
29	R6	3.3k / 5% / 0805	YAGEO						1	1
30	R7	100k / 5% / 1206	YAGEO						1	1
31	R8	100K high voltage 1206	HV732BTBK104J	Koa					1	1
32	R10	2R / 5% / 0805	YAGEO						1	1
33	R11	NC							1	1
34	R12	0R / 5% / 0805	YAGEO						1	1
35	R13	1R / 5% / 0805	YAGEO						1	1
36	R14	1.3R / 1% / 1206	VISHAY						1	1
37	R15	154K / 1% / 0805	VISHAY						1	1
38	R16	330K / 5% / 0805	YAGEO						1	1
39	RT1	680R 5%	B57164-K681-J	Epcos					1	1
40	U1		LM3445MM	NATIONAL SEMICONDUCTOR					1	1

Manually enter information below for items not included in schematics. i.e. shunts, sockets, screws, cables, etc.

Item	Designator	value	Part Number	PackageReference	Supplier				Quantity	Required
41	P11			header					0	0
42	P2			header					0	0
43									0	0
44									0	0
45									0	0
46									0	0

7 Start up phase

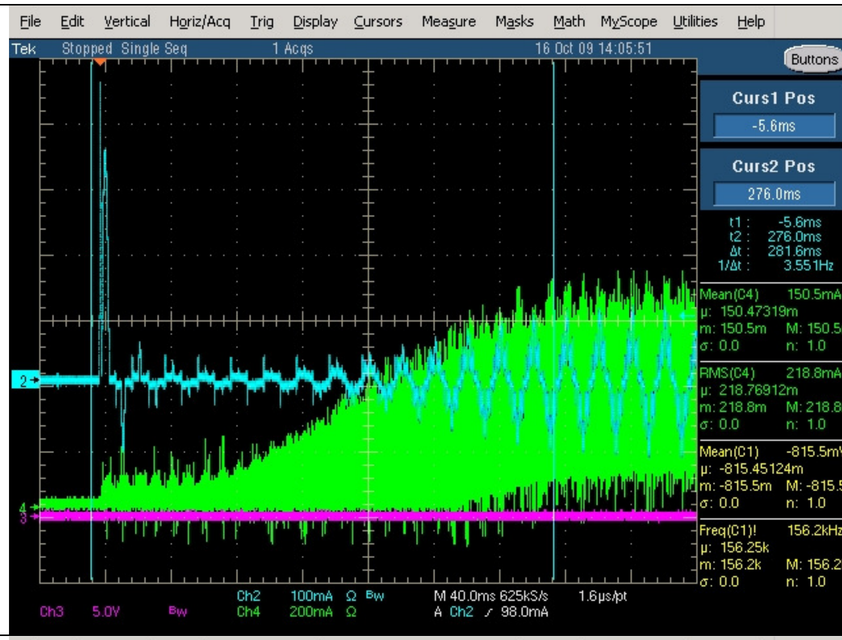
7.1 Plug in into the network line

At plug in, the input voltage charges the input capacitor with a low peak current due to the DCR of the input filter and the NTC.
As soon as the voltage on the pin 9 reaches the voltage threshold of the VCC, the device turns into active mode and start switching.

CH3: input Current
CH4: LED Current

Condition :
Measurement done at hot plug in
V_{in}: 180V_{AC}
V_{out}:6 LEDs@0.35A

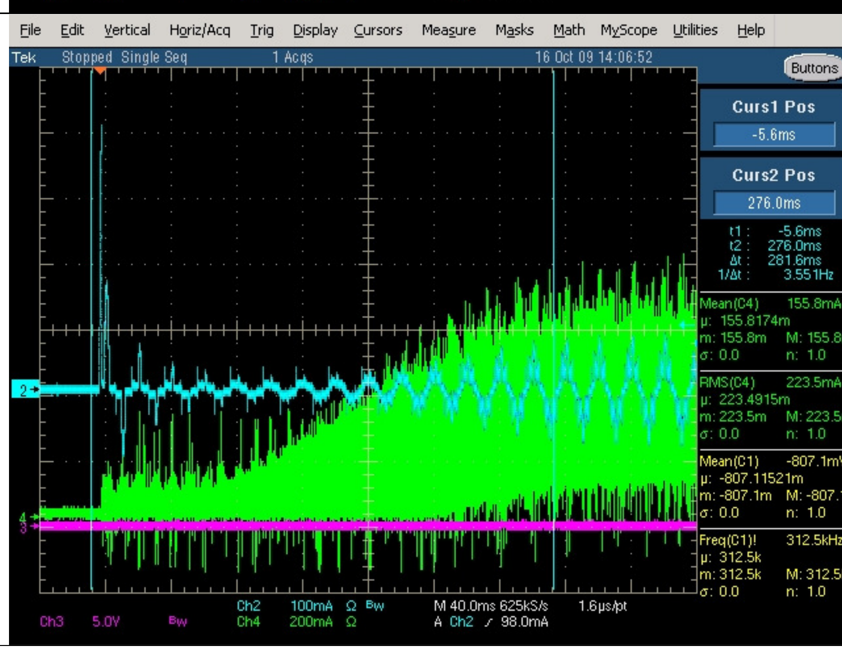
Max peak current: 0.45A



CH3: input Current
CH4: LED Current

Condition:
Measurement done at hot plug in
V_{in}: 265V_{AC}
V_{out}:6 LEDs@0.35A

Max peak current: 0.4 A



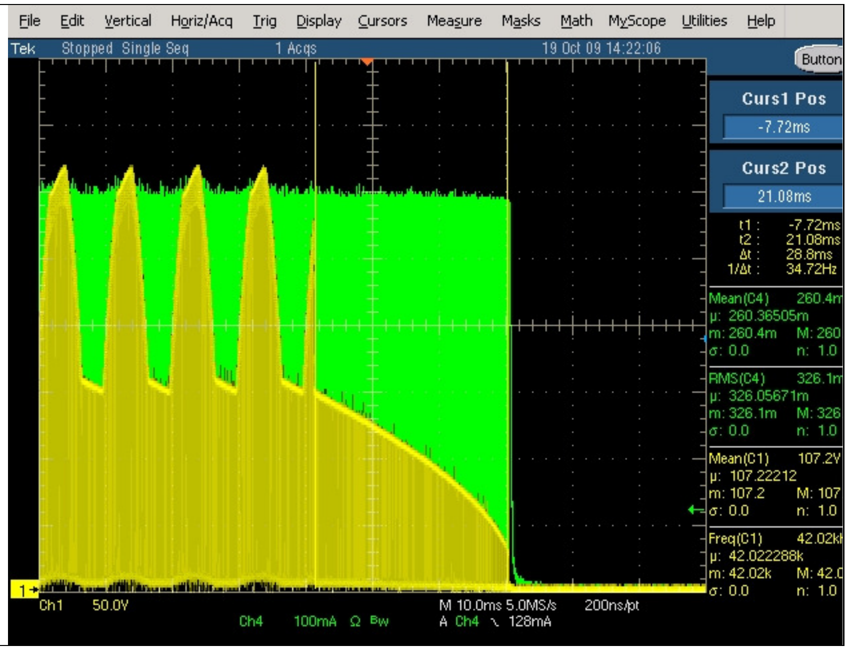
7.2 Holding time

The LED current must wait at least this minimum time before switching off the AC/DC converters. This is to ensure that any peak current is seen in the main during main disturbances.
The following plot shows the timing between the plug out and LED current off with V_{in} 230VAC.

CH1: Drain voltage
CH2: LED current

Condition :
Measurement done at plug out
V_{in}: 230V_{AC}
V_{out}:6LEDs@0.35A

Holding time:
28 ms

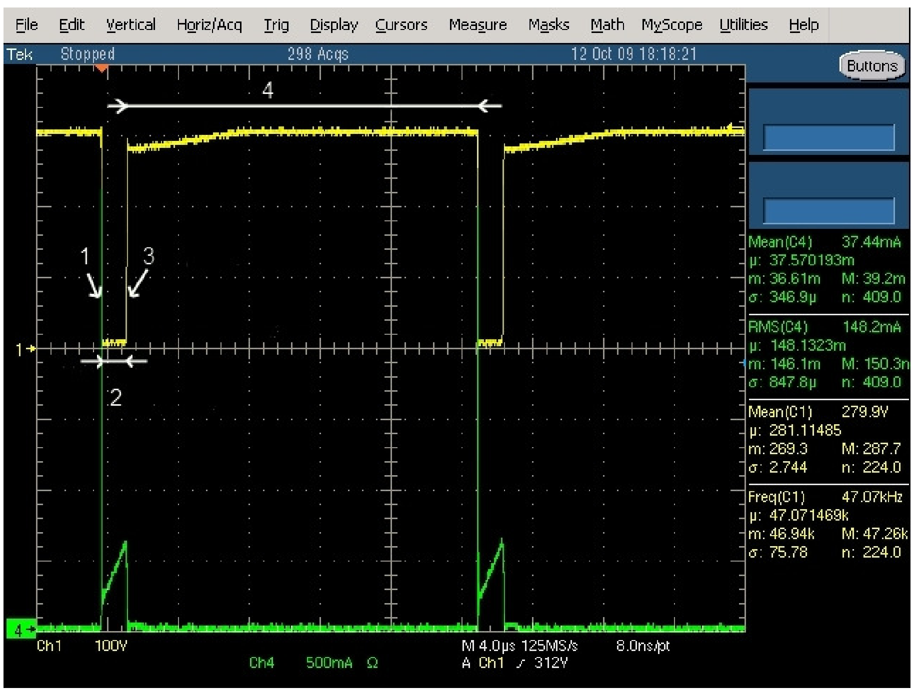


8 Measurement

8.1 One complete cycle:

This plot shows in detail the drain source voltage and drain current of Q3 for one complete cycle in on mode.
The cycle can be divided into different phases as shown on the plot:

1. Switch on phase
2. Conducting phase
3. Switch off phase
4. Off phase, Energy released into the load

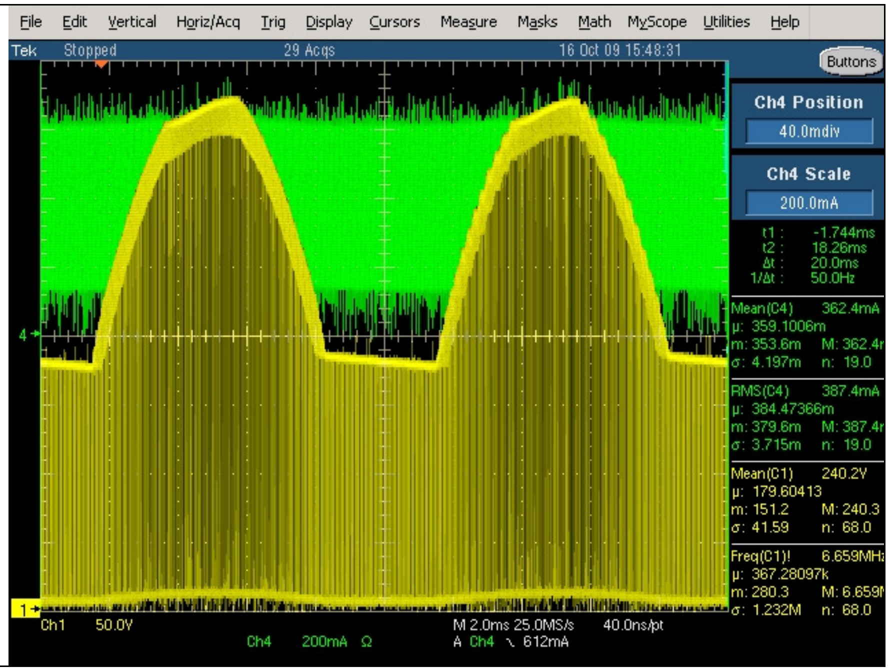


CH1: V_D Q3
CH4: I_D Q3

8.2 One complete 50 Hz cycle: $V_{IN\ max}$ with max power

CH1: V_D Q3
CH4: Inductor current

Condition:
V_{in}: 265V_{DC}
V_{out}: 6 LEDs@0.35A

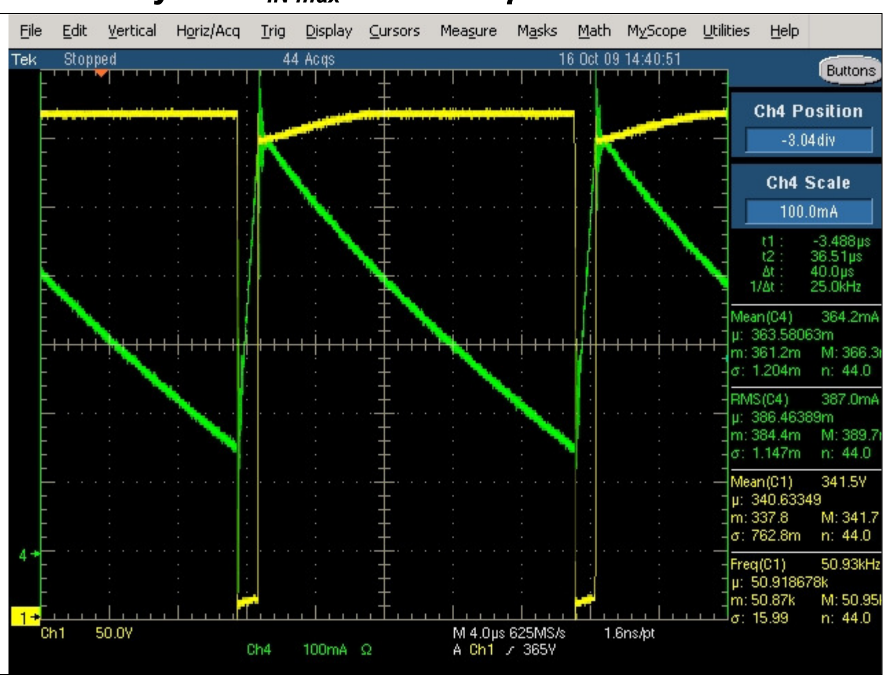


8.3 One complete PWM cycle: $V_{IN\ max}$ with max power

CH1: V_D Q3
CH4: Inductor current

Condition:
V_{in}: 265V_{AC}
V_{out}: 6 LEDs@0.35A

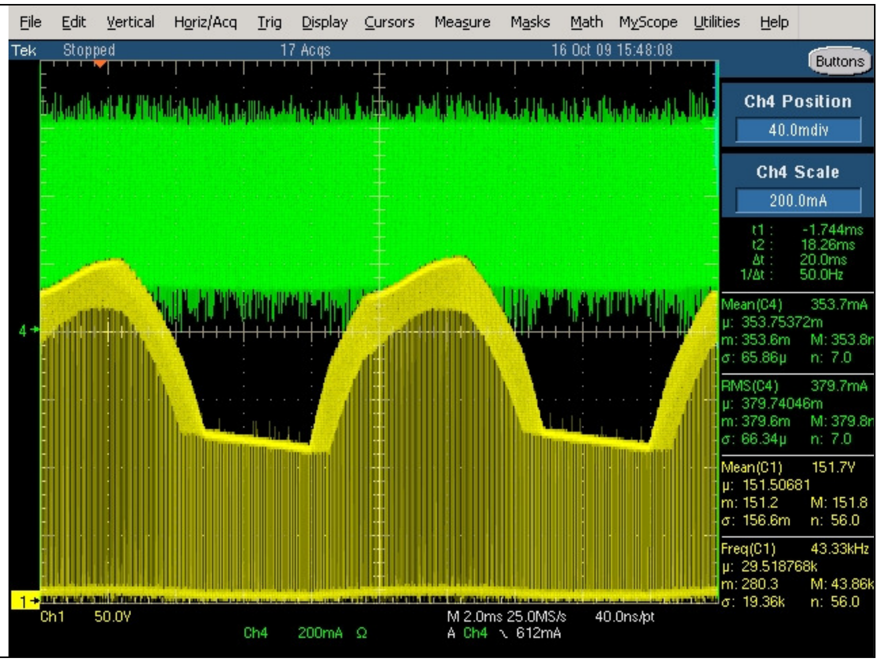
Zoom of the max drain voltage
VD max: 380Vdc



8.4 One complete 50 Hz cycle: $V_{IN\ min}$ with max power

CH1: V_D Q3
CH4: Inductor current

Condition:
V_{in}: 180V_{AC}
V_{out}: 6 LEDs@0.35A



8.5 One complete PWM cycle: $V_{IN\ min}$ with max power

CH1: V_D Q3
CH4: Inductor current

Condition:
V_{in}: 180V_{AC}
V_{out}: 6 LEDs@0.35A

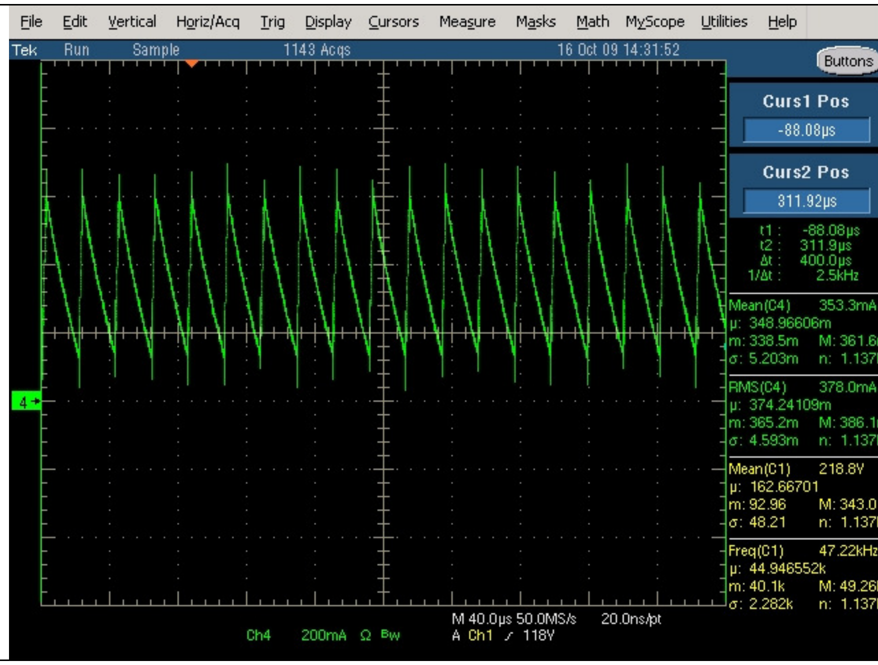
Zoom of the min drain voltage
VD min: 130Vdc

8.6 Output regulation: Ripple current at 180$V_{in\ AC}$

CH4: LED current

Condition:
V_{in}: 180V_{AC}
V_{out}: 6 LEDs@0.353A

No output capacitor



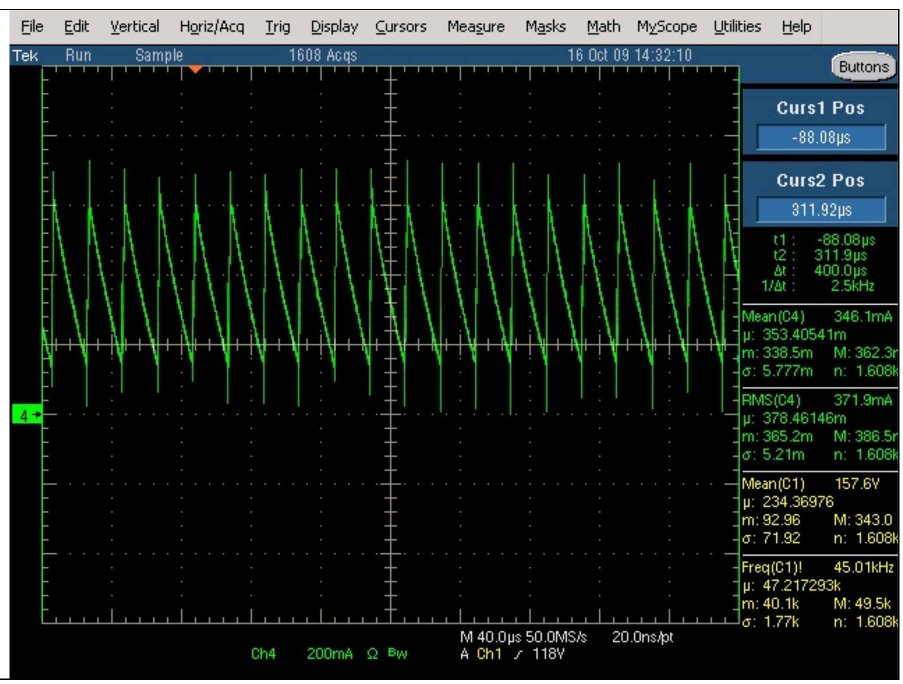
8.7 Output regulation: Ripple current at 265$V_{in\ AC}$

CH4: LED current

Condition:
V_{in}: 265V_{AC}
V_{out}: 6 LEDs@0.346A

Peak to peak Ripple current :410mA

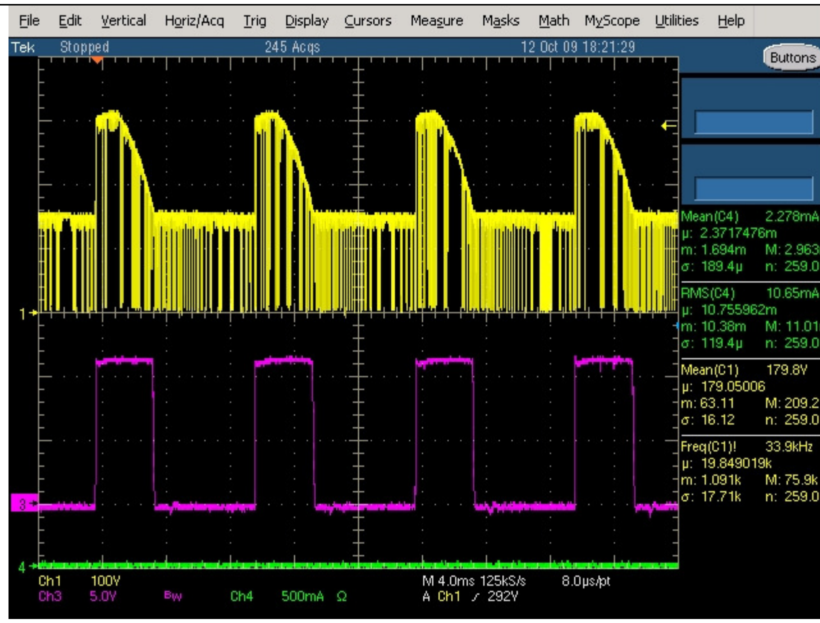
No output capacitor



8.8 Dimming

A simple Circuit composed by R6, Q2, D7 and R8 is used to add holding current when valley fill diodes D2, D5 are conducting.
This simple circuit will reduce the power consumption of the holding circuit (Q1) and increase the overall efficiency. The Ch3 shows Q2 p mosfet ON when the output cap are in parallel discharging to the LEDs via the diode D2 and D5.
Only forward phase Triac dimmer can be used. To make it working with a reverse phase Triac, a simple circuit must implemented.

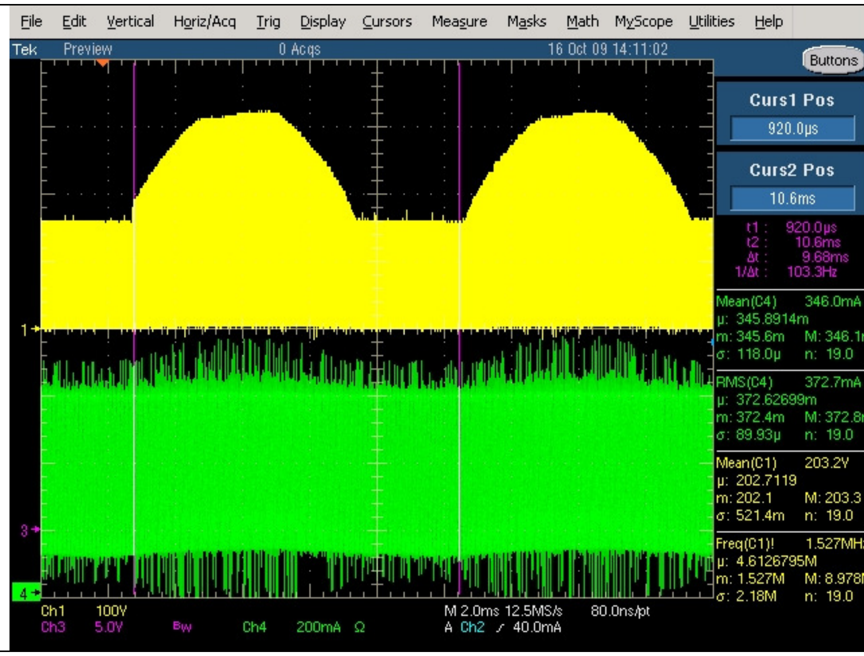
CH1: Q3 drain
CH3: Q2 drain



The following plots show dimming at different phase.

CH1: V_D Q3
CH4: LED current

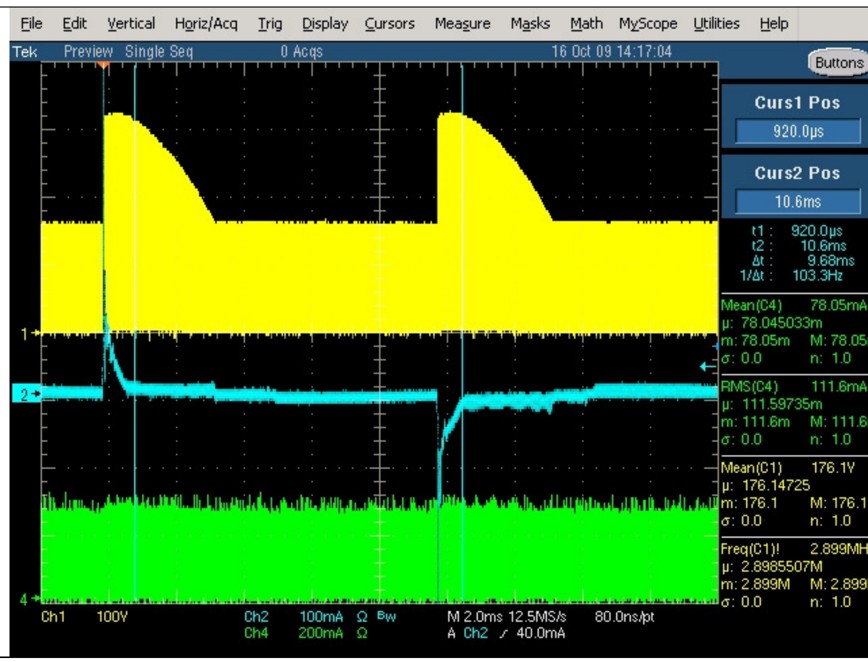
No dimming 0%
Output current.
:346mA



CH1: V_D Q3
CH4: LED current
CH2: Input current

Triac Chopped waveform around 50%
Test done with a Triac dimmer.

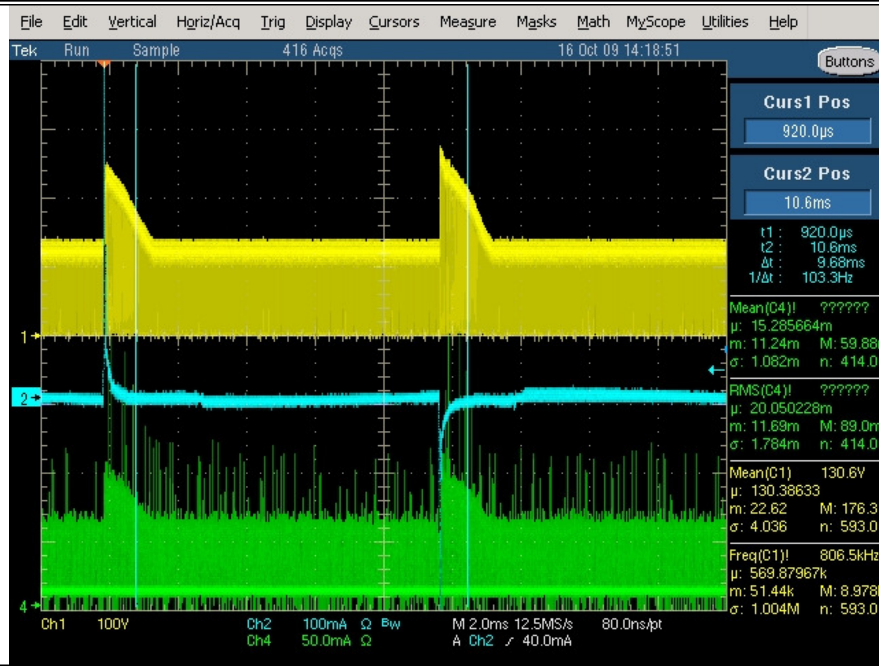
Output current.
:78mA



CH1: V_D Q3
CH4: LED current
CH2: Input current

Triac Chopped waveform around 70%
Test done with a Triac dimmer.

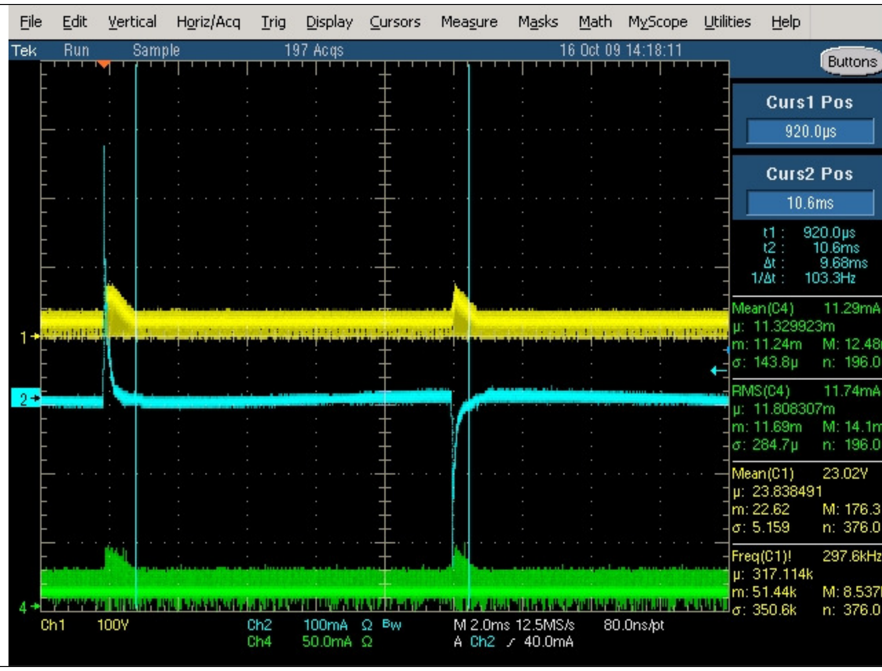
Output current. :50mA



CH1: V_D Q3
CH4: LED current
CH2: Input current

Dimming close to maximum 90%
Test done with a Triac dimmer.

Output current. :10mA



8.9 Protection

For safety reasons and to fulfill short circuit requirements, it has been ensured that no component should overheat and burn in case of short circuit.

8.9.1 Short circuit protection

The cycle by cycle current limitation controls the maximum power in case of short circuit or an excessive load. The voltage across resistor R14 is proportional to the drain current and is sensed by the input ISNS pin 7 of the LM3445. If the voltage across R14 rises above 1.27V, the PWM uses this information to terminate the Mosfet conduction. It will also inhibit the Start Pulse Generator and the COFF comparator by holding the COFF pin low. A delay circuit will prevent the start of another cycle for 180 µs. The typical threshold of the I_{SEN} signal in working condition is 750mV.

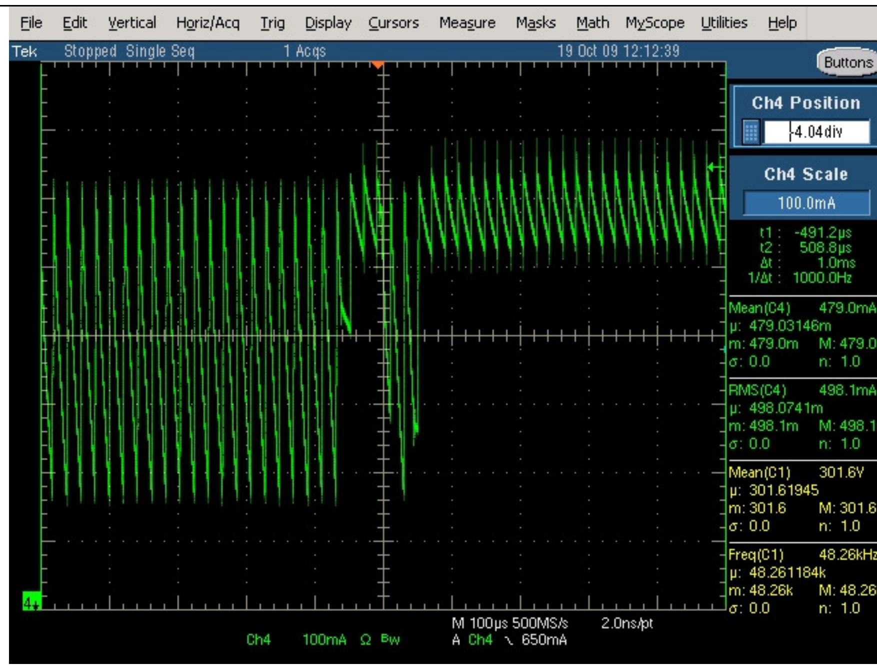
The following plots show a typical protection after short circuit on the LEDs.

CH4: LED current

Condition:
SHORT CIRCUIT
No triac dimmer
Vin :230VAC

Keeping the short circuit we observed a high temperature in the coil L1and Mosfet Q3.

T_{L1}=115 deg
T_{Q3}=90 deg

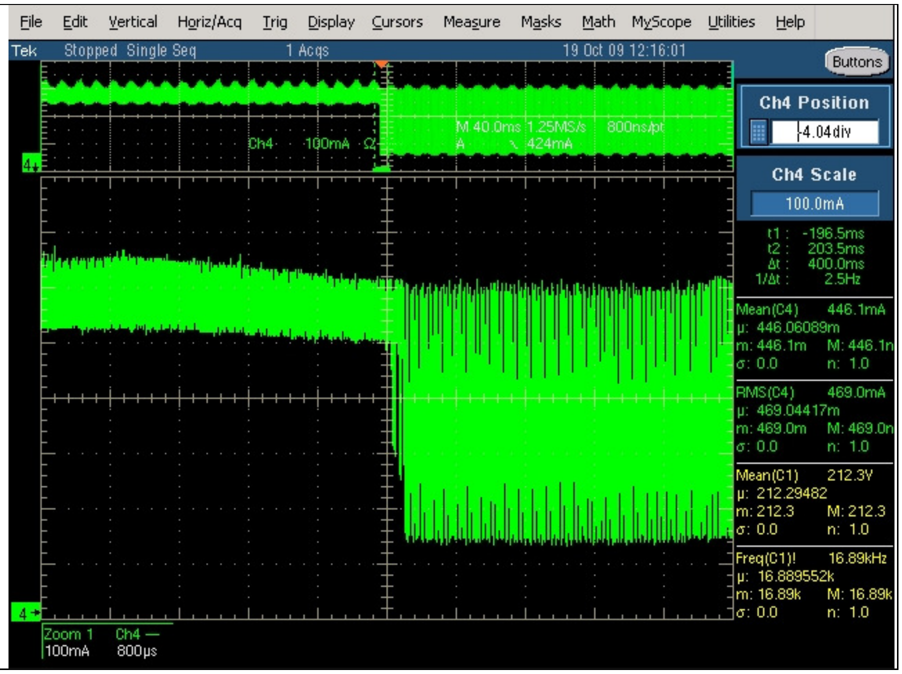


As soon as the short circuit is removed from the output, the power supply will go back to the regulated current 350mA.

CH4: LED current

Condition:
SHORT CIRCUIT REMOVED
No triac dimmer
Vin :230VAC

LED current ON

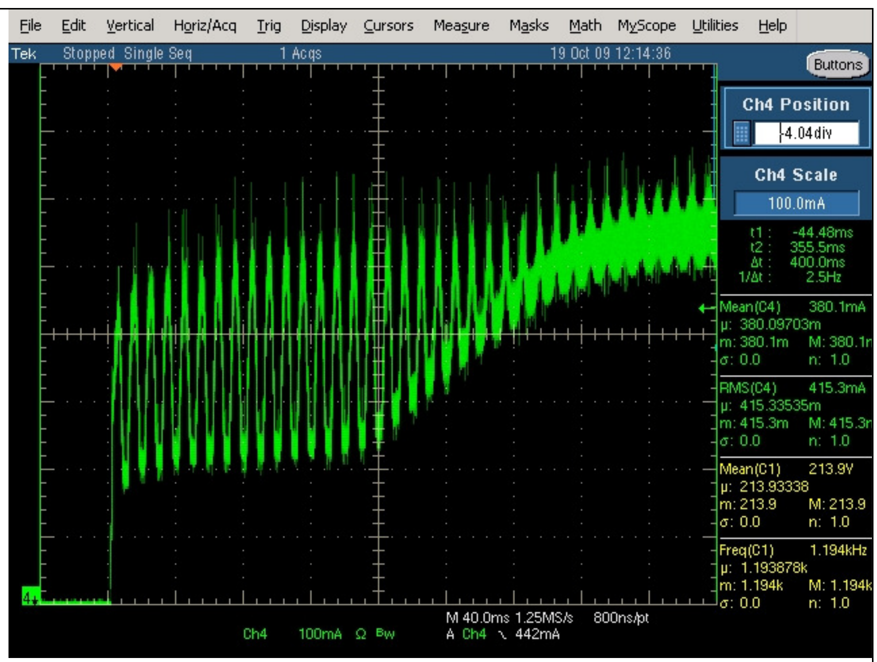


The following plot shows a start up phase during short circuit.
This is to ensure that switching ON and OFF the retrofit, it doesn't break.

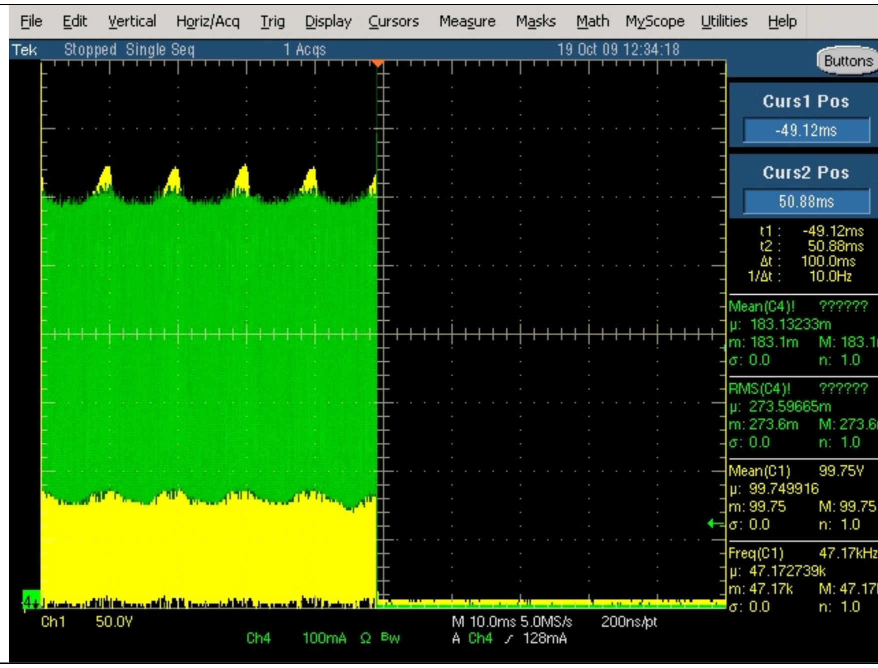
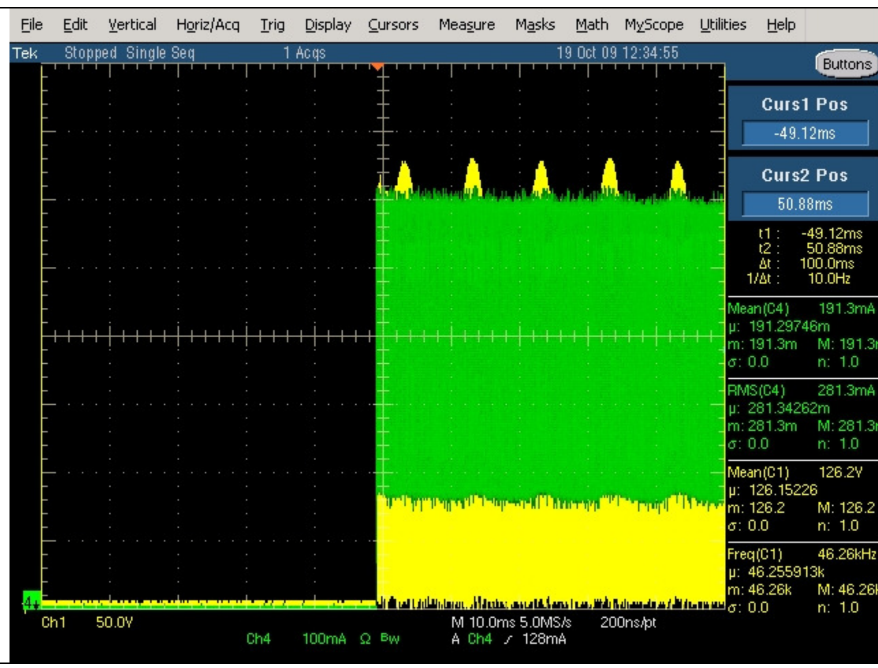
CH4: LED current

Condition:
Start up phase during short circuit.

Result:
The switching power supply reaches his peak current and regulate.



8.9.2 Open loop protection

CH1: V_D Q3 **CH4:** LED current Condition: Open loop Result: Power supply OFF	
CH1: V_D Q3 **CH4:** LED current Condition: Open loop removed Result: Power supply ON	

8.10 Efficiency

The following picture shows the efficiency for different input configuration.

PF	0.92			
Ithd	39.20%			
Vin (V)		180VAC	230VAC	265VAC
Iin (A)		0.0537	0.0429	0.0384
Pin (W)		8.94	9.16	9.39
Vout (V)		19.86	19.86	19.87
Iout (A)		0.35	0.355	0.357
Eff (%)		0.778	0.770	0.755

The test has been done with the following configuration.
R5 = 0R
R13= 1R
R6 = 3K3

8.11 EN630003-2 CLASS C

The measurement has been done with the Chroma model 61603 and Zimmer LMG95.
The harmonics are within the Class C limits of EN61000-3-2, the PF is 0.92 and the I THD is 40%.

As the input power is lower than 25W, the harmonic currents shall not exceed the power-related limits Class D, table 3, column 2:
3^{th} harm 3.4mA/W, 5^{th} harm 1.9mA/W…
Or
3^{th} harm. < 86% of fundamental
5^{th} harm. < 61% " "

Harmonics (n)	Result (mA)	Class C limit (mA)
AH0	0.64	
AH1	39.85	
AH2	0.018	
AH3	7.46	31.17
AH4	0.021	
AH5	4.83	
AH6	0.023	
AH7	10.69	9.17
AH8	0.037	
AH9	6.19	4.58

8.12 Conductive EMI

In switched mode power supplies, there is a high dV/dt across the FET when it switches off. This is caused by abruptly cutting off the current through the inductance. This high dV/dt is undesirable for a number of reasons:

- High switching losses in the FET.
- Cause EMI Emission.
- High output ripple.

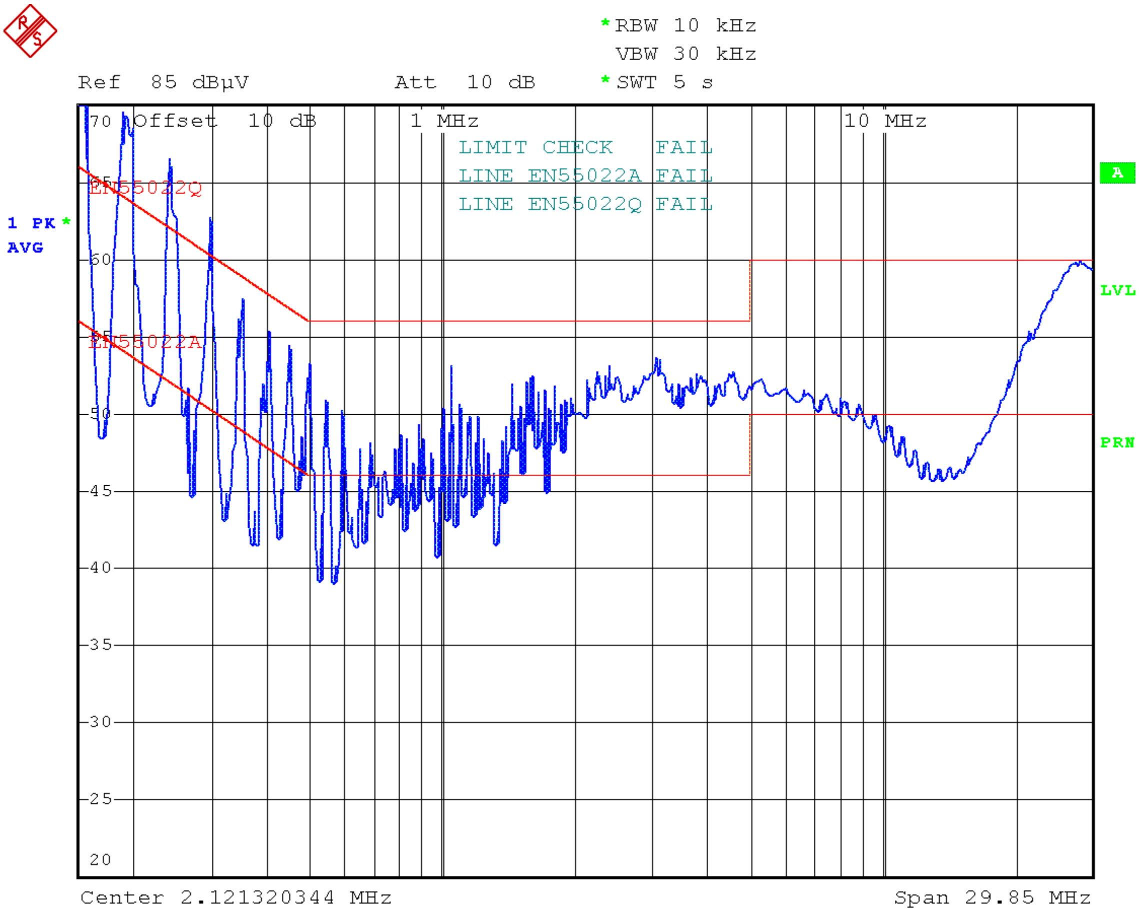
This high dV/dt can be reduced by a clamp network.

The next plots show the conducted EMI result for Neutral and Phase following the EN55022.

As the layout is not yet finalized, some peak frequencies are over the limit at very low frequency.

Phase L1:

Neutral : N1



Date: 16.OCT.2009 17:19:15

8.13 Thermal behavior

The tests have been done with AC input voltage from 180 VAC to 260VAC with an output current of 350mA over a temperature range from -25°C to +65°C.

Due to the fact of the small factor, a small core of the inductance has been used and therefore saturate at ambient temperature higher than 65°C.
For higher ambient temperature, a higher core density is necessary.

The temperature measurement has been taken on key components as L1, Q3, D8, C3 and C2'.
Start up test has been as well done at this ambient temperature.

Vin 180VAC

Ambient Temperature		-25°C	25°C	45°C	65°C
Components					
Inductor	L1	38°C	82°C	97°C	117°C
Mosfet	Q3	8°C	57°C	74°C	82°C
Switching diode	D8	25°C	71°C	88°C	107°C
Passif PFC	C3	0°C	49°C	66°C	71°C
X2 cap	C2'	0°C	46°C	64°C	82°C

Vin 230VAC

Ambient Temperature		-25°C	25°C	45°C	65°C
Components					
Inductor	L1	41°C	85°C	100°C	120°C
Mosfet	Q3	12°C	60°C	79°C	84°C
Switching diode	D8	27°C	73°C	90°C	111°C
Passif PFC	C3	1°C	49°C	66°C	71°C
X2 cap	C2'	0°C	49°C	66°C	83°C

Vin 260VAC

Ambient Temperature		-25°C	25°C	45°C	65°C
Components					
Inductor	L1		86°C	103°C	122°C
Mosfet	Q3		63°C	83°C	87°C
Switching diode	D8		74°C	95°C	114°C
Passif PFC	C3		49°C	68°C	74°C
X2 cap	C2'		49°C	67°C	85°C

9 Inductor specification

Spezifikation für Freigabe / specification for release

Kunde / customer : ____________________

Artikelnummer / part number : **744743102** LF

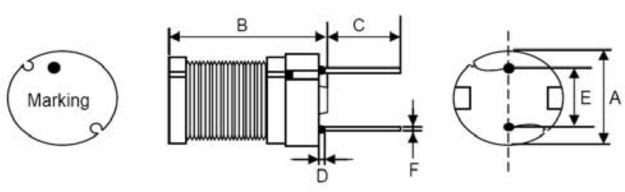
Pb LEAD FREE WÜRTH ELEKTRONIK · RoHS compliant · WÜRTH ELEKTRONIK

Bezeichnung : **Tonneninduktivität WE-TI**

description : **Filter Choke WE-TI**

DATUM / DATE : 2004-11-30

A Mechanische Abmessungen / dimensions:



	7,8 X 12	
A	8,0 max.	mm
B	12,5 max.	mm
C	5,0 ± 1,0	mm
D	1,5 max.	mm
E	5,0 ± 0,5	mm
F	ø 0,70 ref	mm

● = Start of winding   Marking = Inductance code

B Elektrische Eigenschaften / electrical properties:

Eigenschaften / properties	Testbedingungen / test conditions		Wert / value	Einheit / unit	tol.
Leerlauf-Induktivität / inductance	1 kHz / 0,25V	L_O	1000,0	µH	±10%
Nenn-Induktivität / nominal inductance	1 kHz/0,25V/IN	L_N		µH	typ.
DC-Widerstand / DC-resistance	@20°C	$R_{DC\ max.}$	2,50	Ω	max.
Nennstrom / nominal current	ΔT=40 K	I_N	0,42	A	max.
Sättigungsstrom/ saturating current	|ΔL/Lo|-10%	I_{sat}	0,55	A	typ.

D Prüfgeräte / test equipment:

HP 4274 A & HP E3633 A für/for L_0

HP 34401 A für/for I_N und/and R_{DC}

E Testbedingungen / test conditions:

Luftfeuchtigkeit / humidity:	33%
Umgebungstemperatur / temperature:	+20°C

F Werkstoffe & Zulassungen / material & approvals

Basismaterial / base material:	Ferrit/ferrite
Draht / wire:	2-UEW 155°C

G Eigenschaften / general specifications:

Lagertemperatur / storage temperature: -25°C - + 85°C

Betriebstemp. / operating temperature: -25°C - +85°C

It is recommended that the temperature of the part does not exceed 125°C under worst case operating conditions.

Freigabe erteilt / general release:

Kunde / customer

Datum / date   Unterschrift / signature

Würth Elektronik

Geprüft / checked   Kontrolliert / approved

ME	Version 3	04-11-30
ME	Version 2	04-11-05
ME	Version 1	04-08-10
Name	Änderung / modification	Datum / date

Würth Elektronik eiSos GmbH & Co.KG

D-74638 Waldenburg · Max-Eyth-Strasse 1 - 3 · Germany · Telefon (+49) (0) 7942 - 945 - 0 · Telefax (+49) (0) 7942 - 945 - 400

http://www.we-online.com

Spezifikation für Freigabe / specification for release

Kunde / customer : ______________________

Artikelnummer / part number : **744743102** LF

LEAD FREE · WÜRTH ELEKTRONIK · RoHS compliant

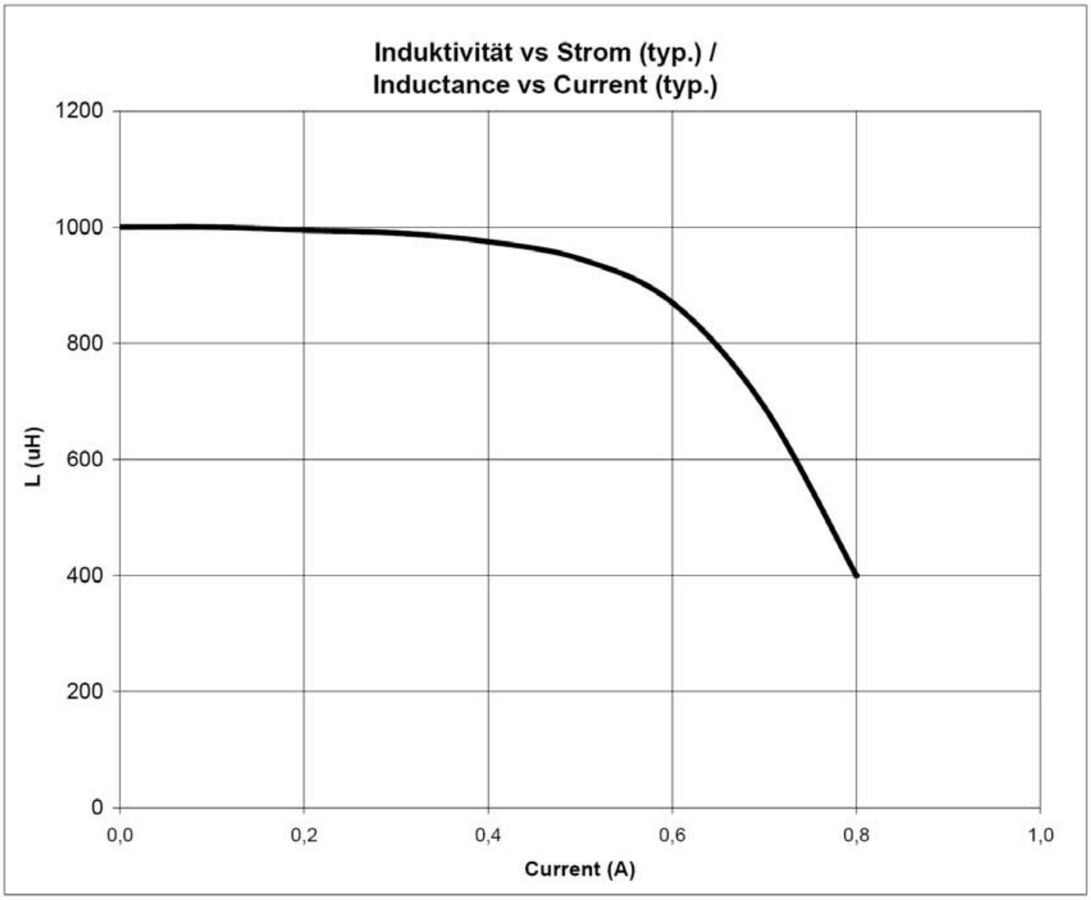
WÜRTH ELEKTRONIK

Bezeichnung : **Tonneninduktivität WE-TI**

description : **Filter Choke WE-TI**

DATUM / DATE : 2004-11-30

H Induktivitätskurve / Inductance curve :



Freigabe erteilt / general release:

Kunde / customer		
.... Datum / date	.... Unterschrift / signature	

Würth Elektronik	
.... Geprüft / checked	.... Kontrolliert / approved

Name	Änderung / modification	Datum / date
ME	Version 3	04-11-30
ME	Version 2	04-11-05
ME	Version 1	04-08-10

This electronic component is designed and developed with the intention for use in general electronics equipments. Before incorporating the components into any equipments in the field such as aerospace, aviation, nuclear control, submarine, transportation, (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. where higher safety and reliability are especially required or if there is possibility of direct damage or injury to human body. In addition, even electronic component in general electronic equipments, when used in electrical circuits that require high safety, reliability functions or performance, the sufficient reliability evaluation-check for the safety must be performed before use. It is essential to give consideration when to install a protective circuit at the design stage.

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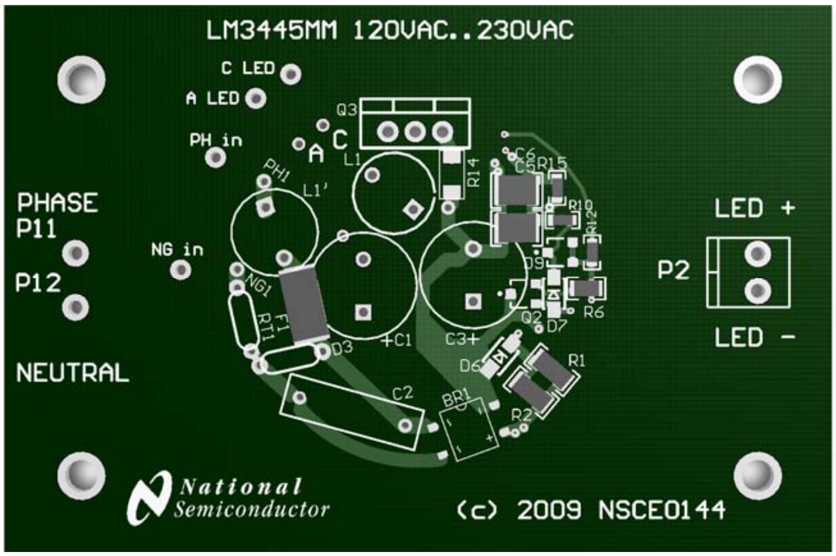
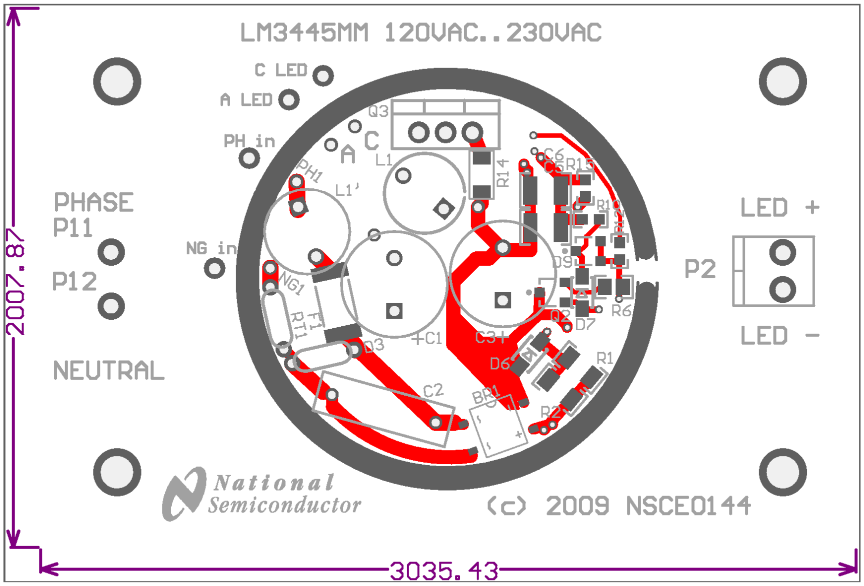
10 Layout Design

TOP 3D SOLDER AND COMPONENTS

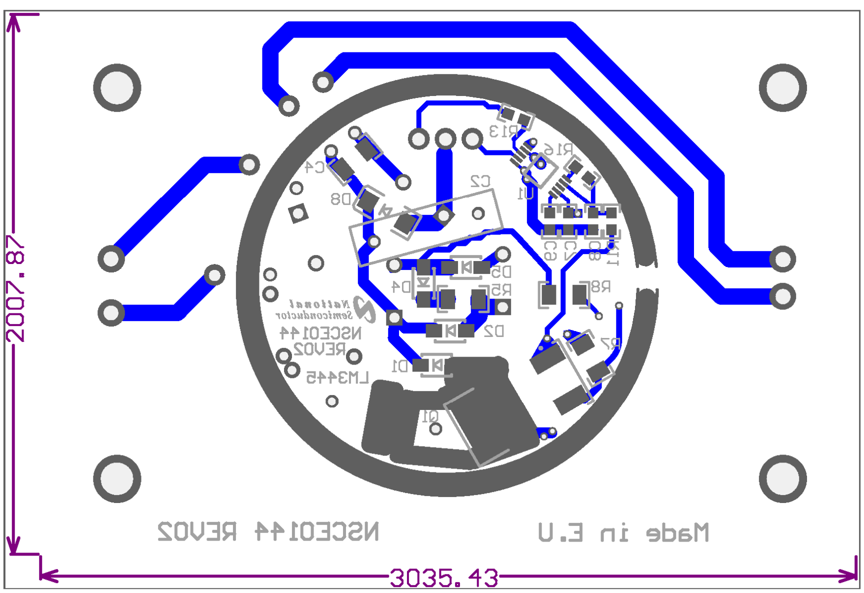


BOTTOM 3D SOLDER AND COMPONENTS

TOP SOLDER AND COMPONENTS



BOTTOM SOLDER AND COMPONENTS



11 Summary Table

12 Revision History

Status	Date	Description of change (s)
Rev. 2.0	2009-10-01	Efficiency improved

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