LV5012MD-A19-220VEVM03

[For A19/E27 LED Bulb Application]

The single stage flyback converter for phase cut dimming

with High Power Factor

Application Note

Ver1.03

LV5012MD-A19-220VEVM03

Application Note

1. Introduction

The LV5012MD-A19-220VEVM03 is a 14W, 220VAC isolated dimmable LED driver for A19 and E27 applications. The LV5012MD-A19-220VEVM03 is a primary-side power regulated PFC controller used for commercial and residential phase-cut dimmer compatible LED lamp drivers.

2. Features

- Primary Side Flyback Control With Integrated PFC
- Compatible With Leading and Trailing Edge Dimmer
- Constant Current & Improved THD
- Short Protection - [latch off]
- Over Voltage Protection -[auto recovery]
- 2 Stage Thermal Protection -[auto recovery]

3. Performance Specifications

3.1. Application constitution

Isolation Flyback with Phase Cut Dimming

3.2. Electrical characteristics (Operating Temperature = 25°C)

Table1. LV5012MD-A19-220VEVM03 Electrical Performance Specifications

Description	Min	Typ	Max	Units	Comment
Input AC voltage	198	220	264	VAC	
Output voltage		20		V	2parallel of 6LEDs series
Output current		550		mA	
Efficiency		82		%	VAC=220V, 50Hz
Power Factor		0.95			VAC=220V, 50Hz

4. Schematic

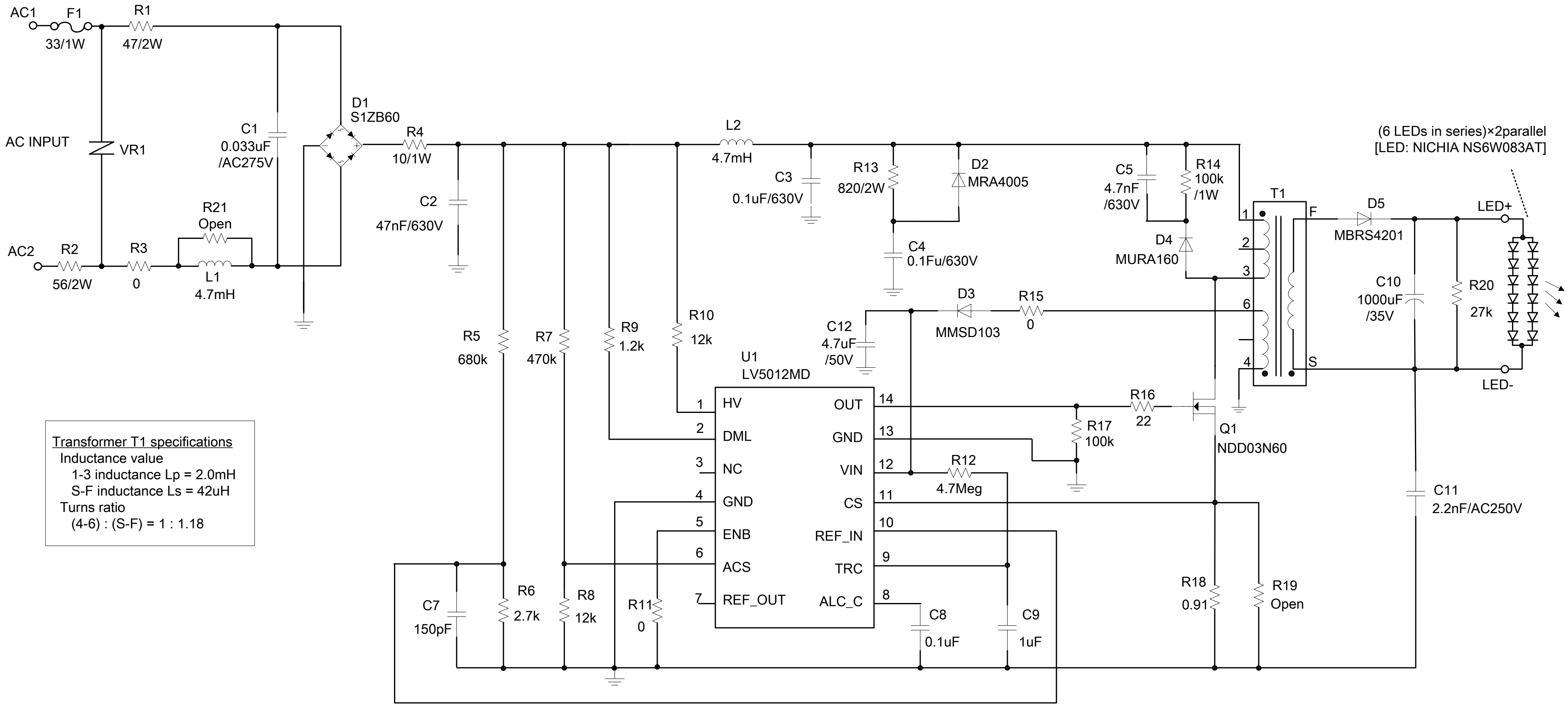


Figure1. LV5012MD-A19-220VEVM03 Schematic

5. Evaluation Board

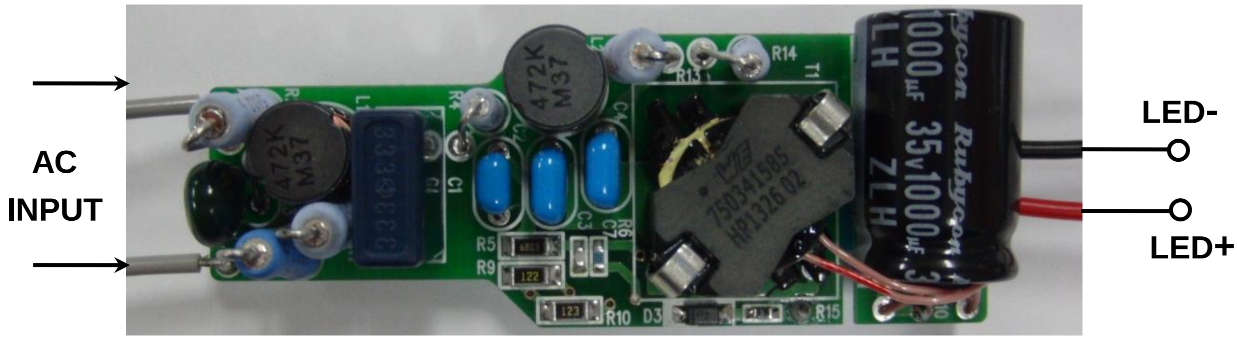


Figure2. LV5012MD-A19-220VEVM03 Transformer Side

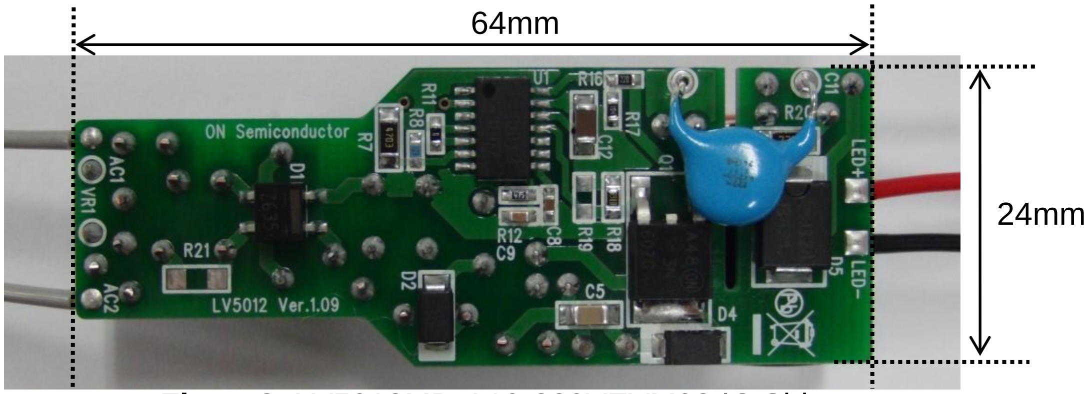


Figure3. LV5012MD-A19-220VEVM03 IC Side

6. Test Setup

6.1 Test Equipment

Voltage Source: 220VAC AC source, NF EPO2000S

Power Meter: HIOKI 3332

Volt Meter: ADVANTEST R6441D DIGITAL MULTIMETER

AMP Meter: Agilent DIGITAL MULTIMETER 34401A

Output Load: 2 Parallel of 6 LEDs series (LED: NICHIA NS6W083AT)

Oscilloscope: LeCroy WaveRunner 6050A

Operating Temperature: 25℃

6.2 Recommended Test Setup

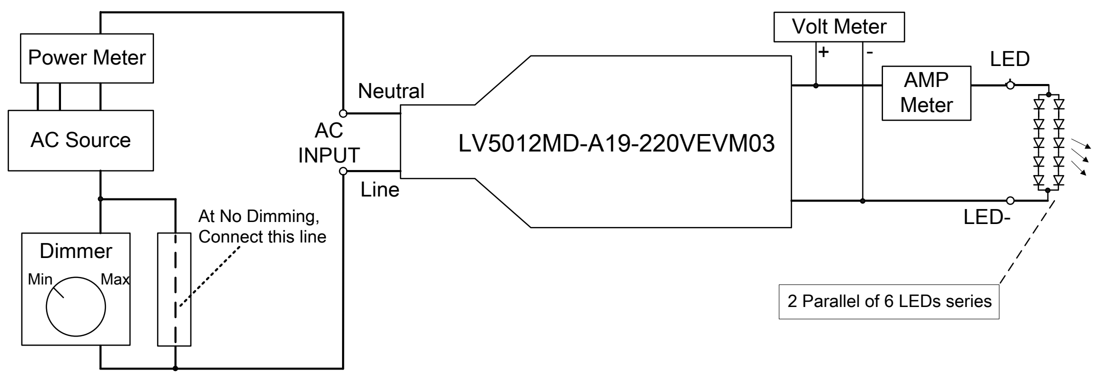


Figure4. LV5012MD-A19-220VEVM03 Recommended Test Set Up

6.3 List of Test Points

Table2. Test Points Functions

TEST POINTS NAME	DESCRIPTION
Neutral	220VAC neutral connection
Line	220VAC line voltage
LED+	LED anode connection
LED-	LED cathode connection

7.Test Procedure

7.1 Line/Load Regulation and Efficiency Measurement Procedure

1. Connect LV5012MD-A19-220VEVM like upper Figure4. An external LED load must be used to start up the EVM.
2. Prior to turning on the AC source, set the voltage to 220VAC.
3. Turn on the AC Source.
4. Record the output voltage readings from Volt Meter and the output current reading from AMP Meter. And Record the input power reading from Power Meter.
5. Change VAC from 198VAC to 264VAC and perform “4”.
6. Refer to Section 7.2 for shutdown procedure.

7.2 Equipment Shutdown

1. Turn off equipment.
2. Make sure capacitors are discharged.

7.3 Phase Angle Decode vs LED Current (at dimming)

1. Connect LV5012MD-A19-220VEVM like upper Figure4. An external LED load must be used to start up the EVM.
2. Prior to turning on the AC source, set the voltage to 220VAC.
3. Monitor the Dimmer output AC voltage between the neutral and the line by using the oscilloscope differential probe.
4. Turn on the AC Source.
5. Maximize the dimmer ratio.
6. Record the output voltage readings from Volt Meter and the output current reading from AMP Meter. And Record the input power reading from Power Meter. And Record the phase angle of Dimmer output reading from the oscilloscope differential probe.
7. Gradually lower the Dimming ratio and perform "6". Repeat it until the Dimming ratio is minimized.
8. Refer to Section 7.2 for shutdown procedure.

8. Performance Data

8.1 Efficiency

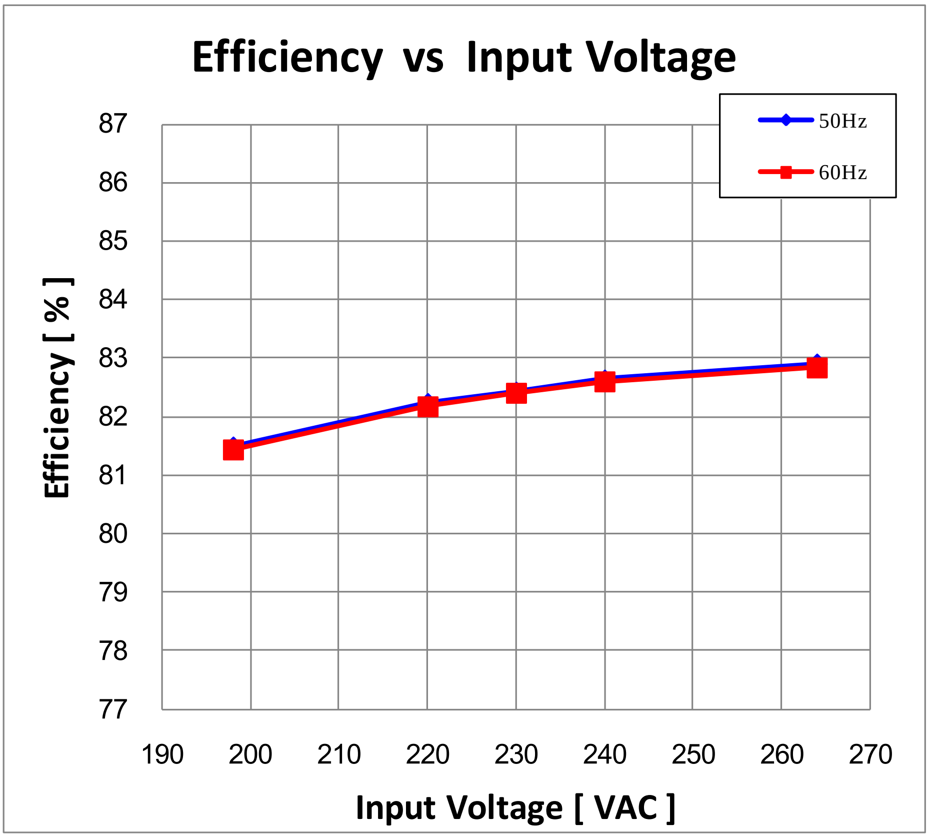


Figure5. Efficiency vs Input voltage

8.2 Power factor

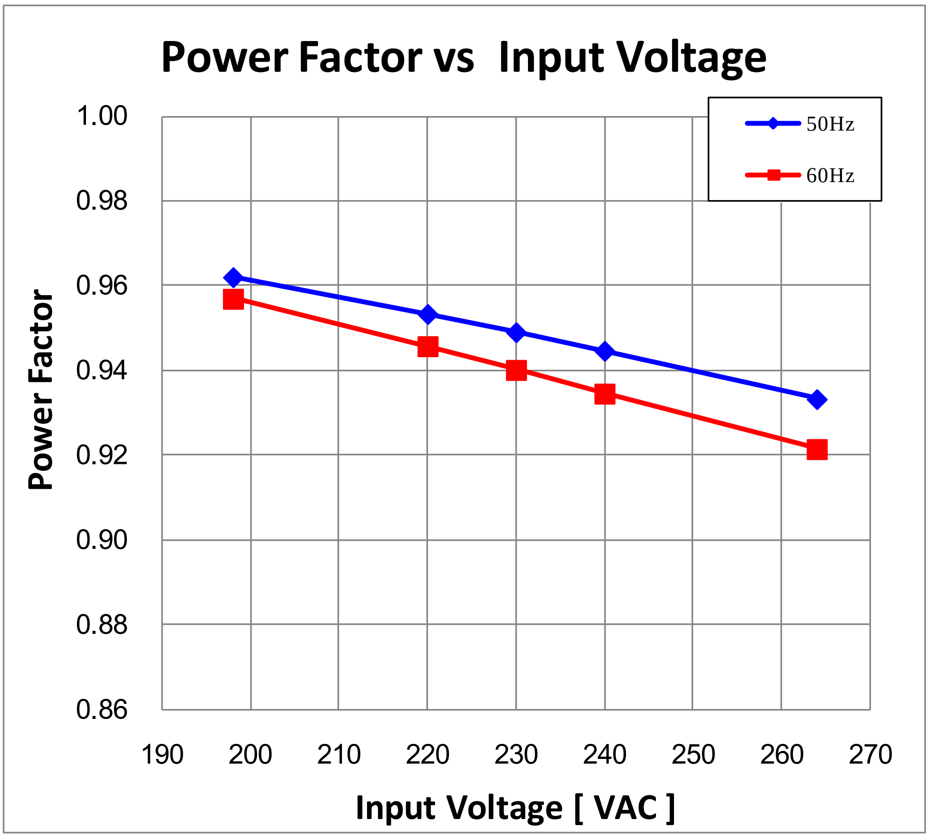
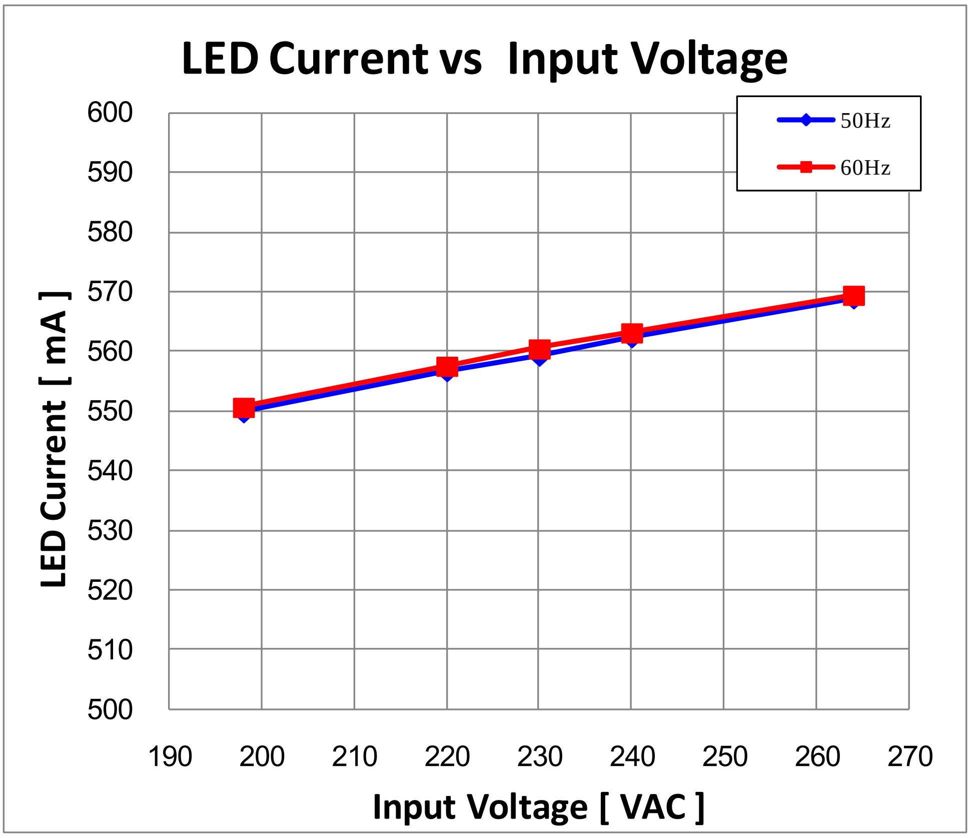


Figure6. Power factor vs Input voltage

8.3 Line regulation

LED Current (Output current)



Fgure7. LED current vs Input voltage

Output Voltage

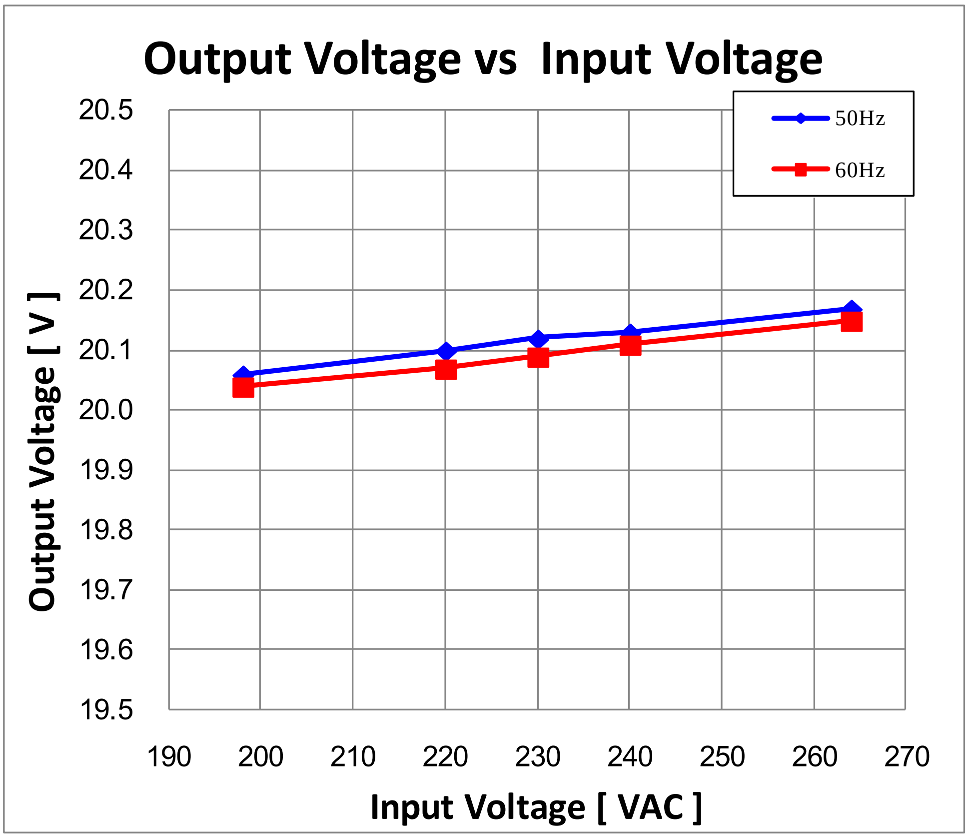
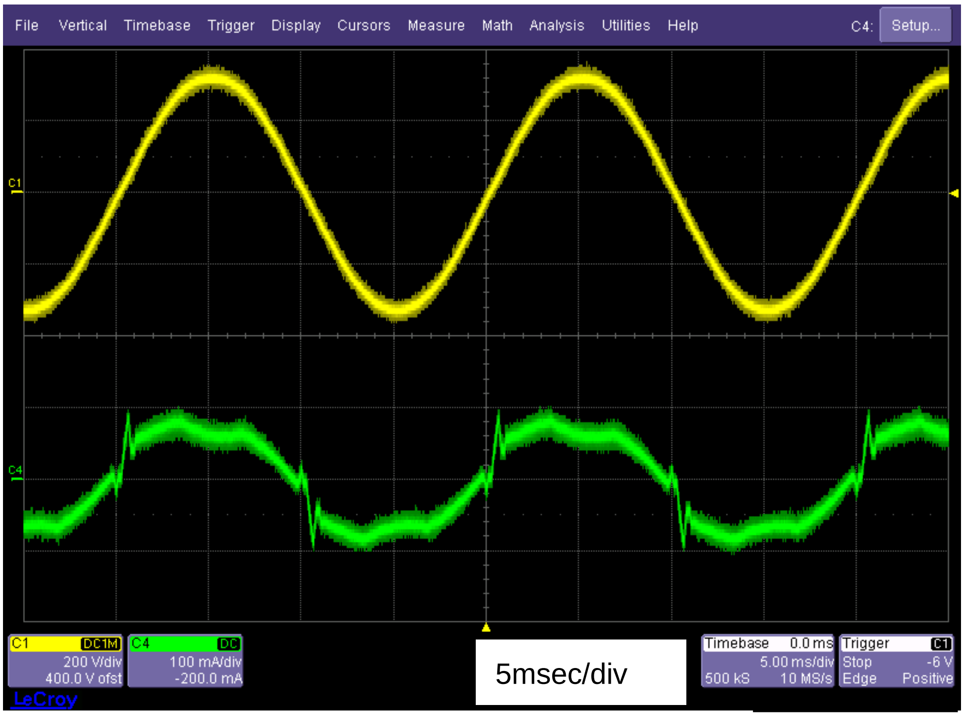


Figure8. Output voltage vs Input voltage

8.4 Input voltage/current operation waveform (No dimming)

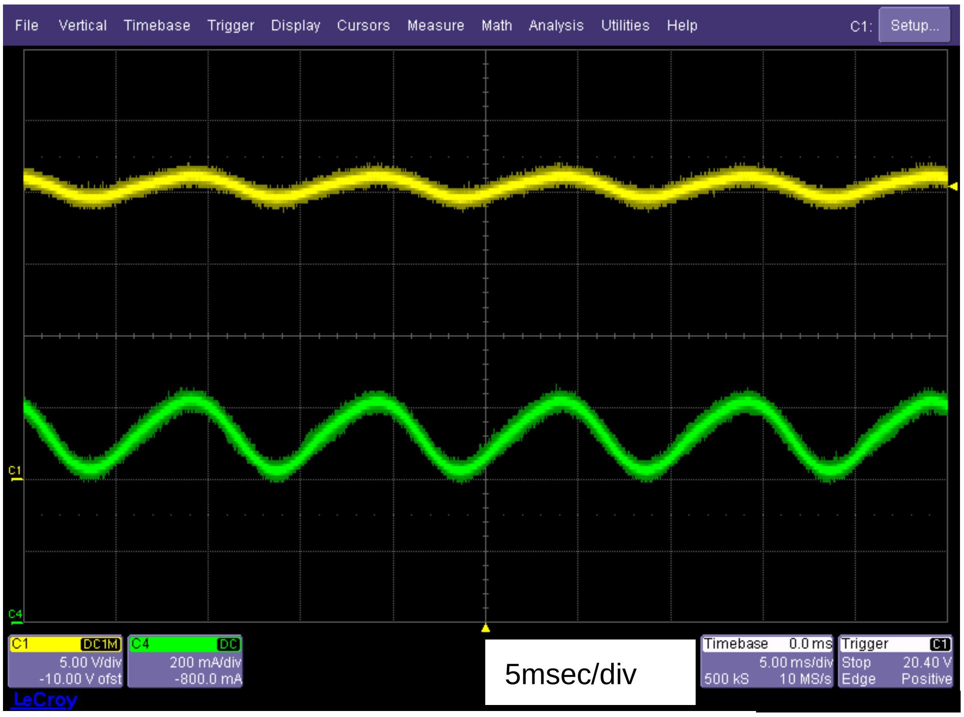


CH1
Input voltage (VAC)
[200V/div]

CH4
Input current
[100mA/div]

Figure9. Input waveform

8.5 Output voltage/current operation waveform (No dimming)



CH1
Output voltage
[5V/div]

CH4
Output current
(LED current)
[200mA/div]

Figure10. Output waveform

8.6 Switching operation waveform

CH1
Q1 Drain voltage
[200V/div]

CH4
Q1 current
[500mA/div]

Figure11. Switching operation waveform

8.7 LED Current vs Phase angle

[Measurement condition: VAC=230V, 50Hz, Dimmer= MERTEN 572599]

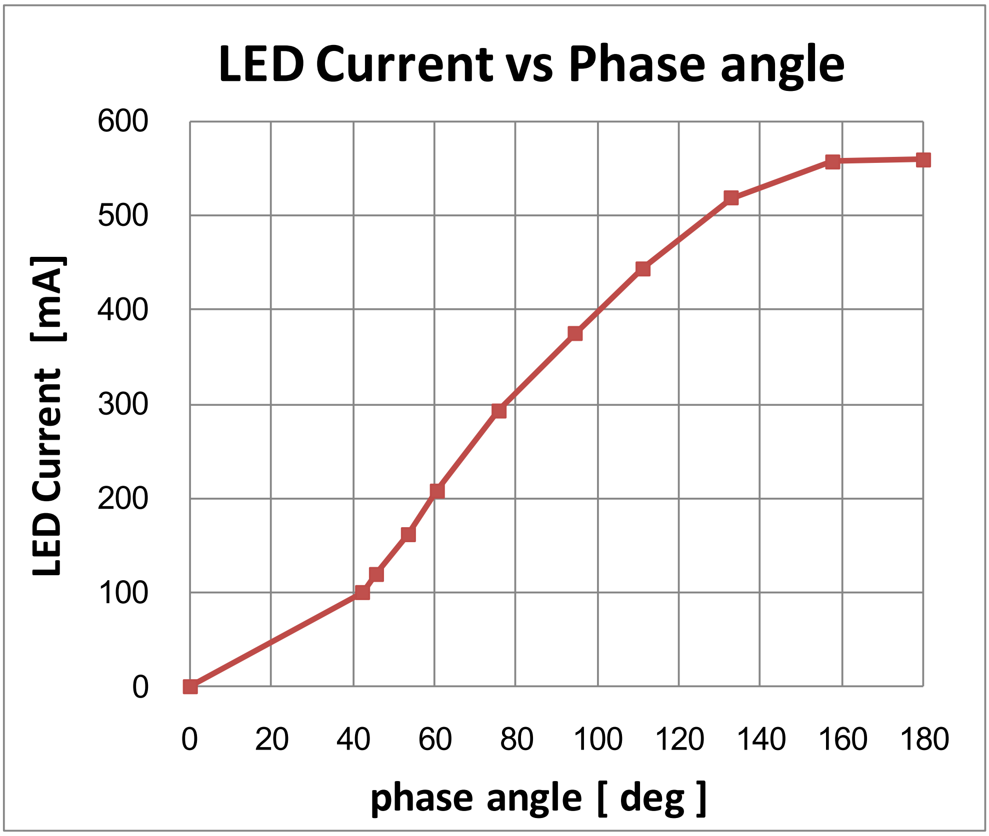


Figure12. LED current vs Phase angle

8.8 Dimming operation waveform

[Measurement condition: VAC=230V, 50Hz, Dimmer= MERTEN 572599]

Phase angle = 120 degree

Figure13. Dimming operation waveform at phase angle=120degree

Phase angle = 60 degree

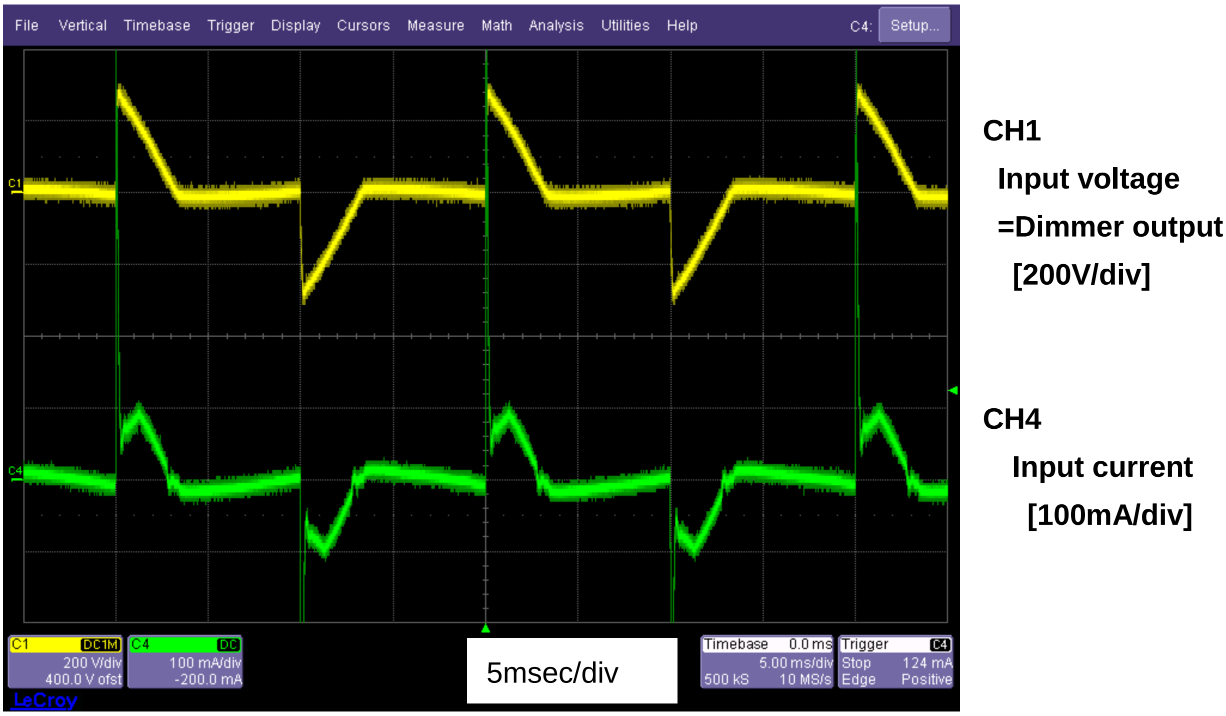


Figure14. Dimming operation waveform at phase angle=60degree

8.9 EMI data

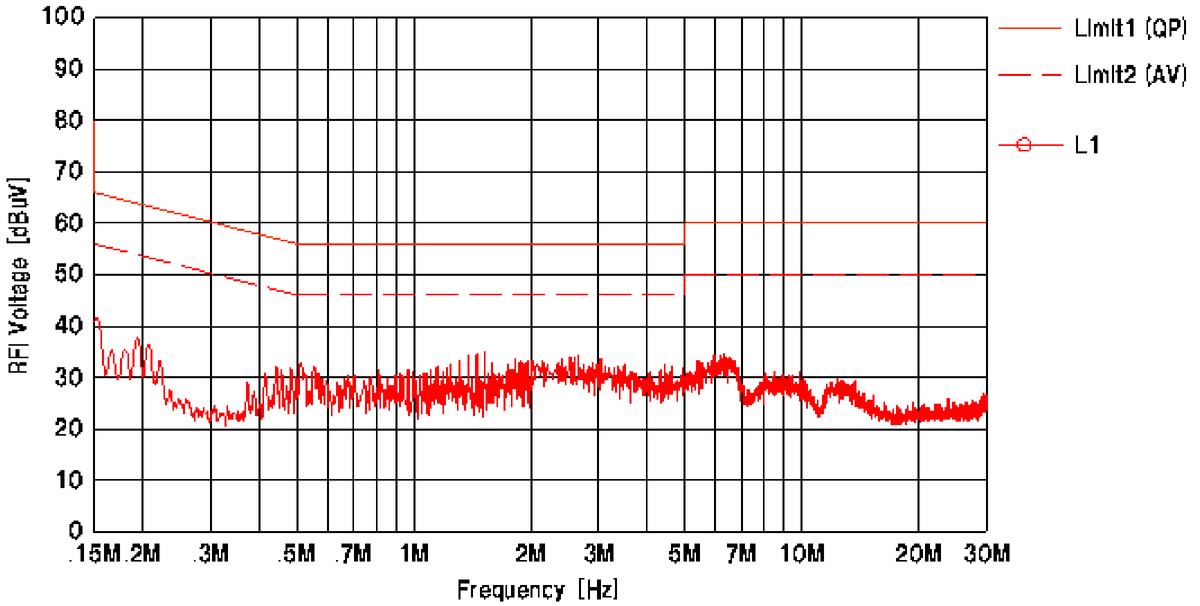
Conducted Emission

QP Measurement

[Measurement condition: VAC=230V, 50Hz]

Limit1 : CISPR Pub.15 Mains (QP)
Limit2 : CISPR Pub.15 Mains (AV)

Phase1



Phase2

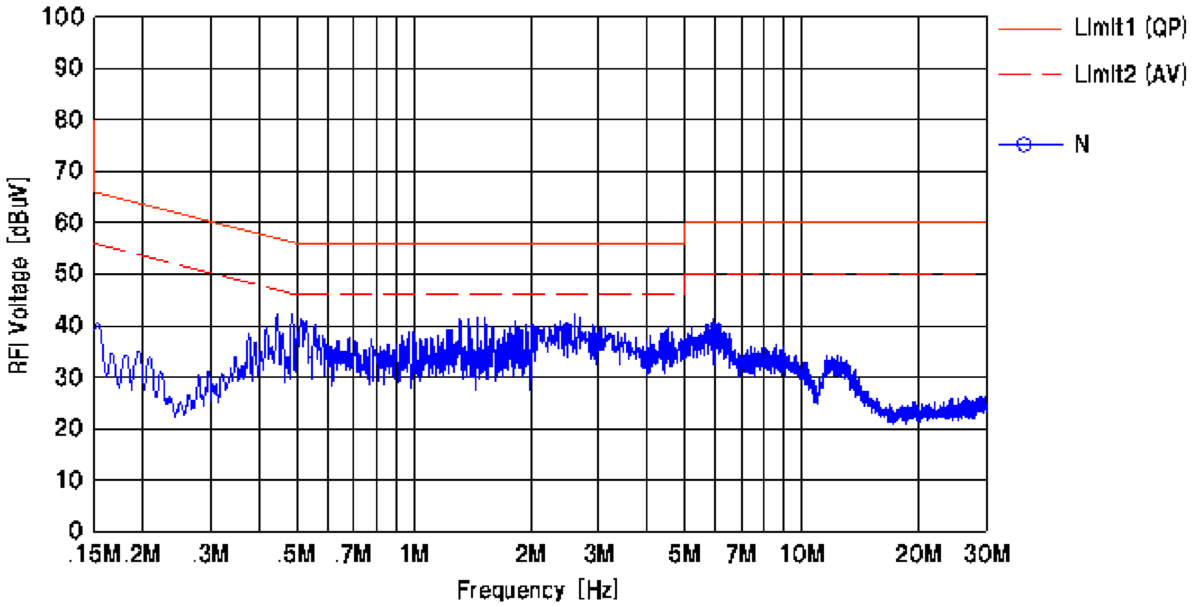


Figure15. Conducted Emission, QP Measurement

9. Board Layout

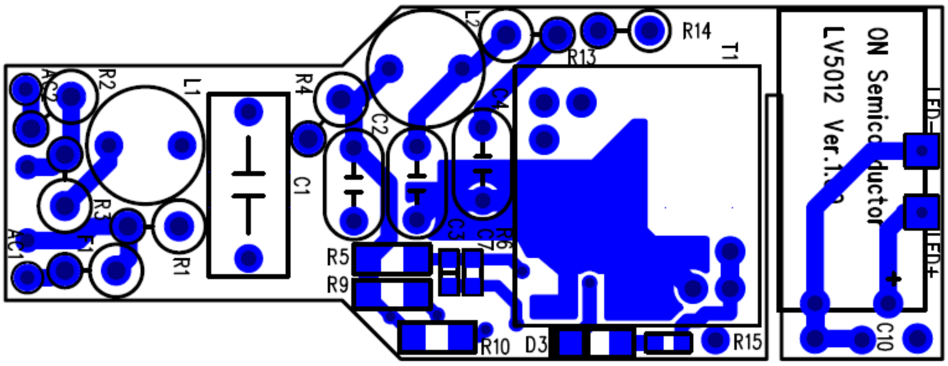


Figure16. Transformer Side Layout

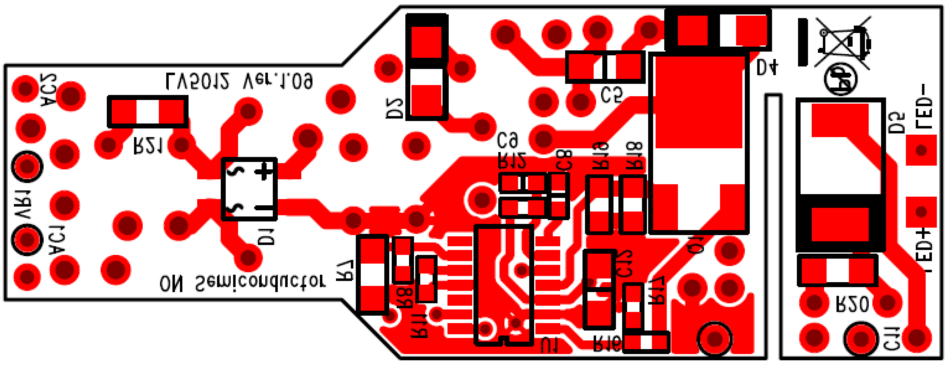


Figure17. IC Side Layout

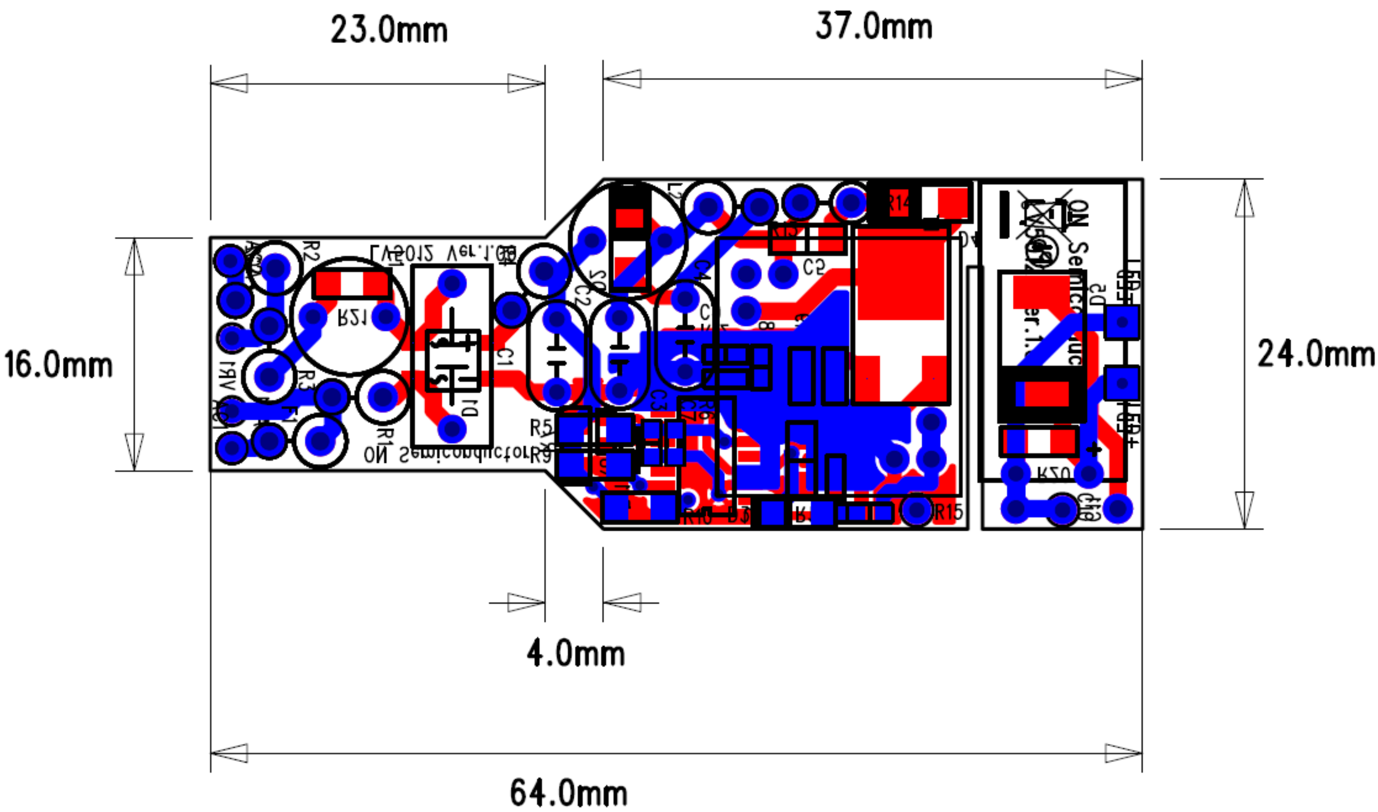


Figure18. Board Size

10.Bill of materials

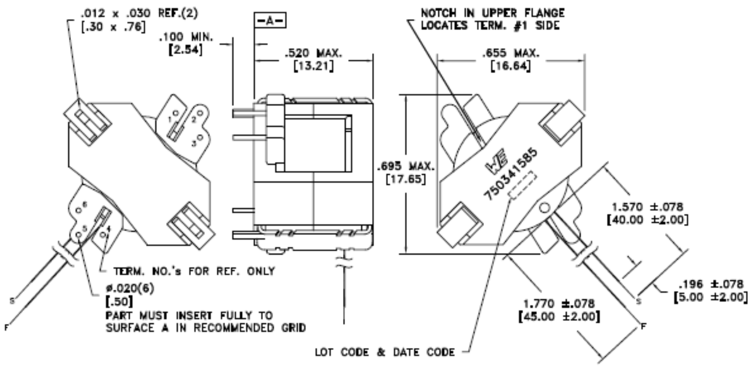
No	Designator	Description	Value	Footprint	Manufacturer	Manufacturer Part Number
1	C1	Metallized Polyester Film Capacitor	0.033uF/275VAC	Radial	OKAYA	LE333
2	C2	Capacitor,Ceramic,X7R	47nF/630V	Radial	MURATA	RDER72J473K3K1C11B
3	C3	Capacitor,Ceramic,X7R	0.1uF/630V	Radial	MURATA	RDER72J104K8K1C11B
4	C4	Capacitor,Ceramic,X7R	0.1uF/630V	Radial	MURATA	RDER72J104K8K1C11B
5	C5	Capacitor,Ceramic,X7R	4.7nF/630V	1206	MURATA	GRM31BR72J472KW01L
6	C7	Capacitor,Ceramic,CH	150pF/50V	0603	MURATA	GRM1882CH1H151JA01
7	C8	Capacitor,Ceramic,X7R	0.1uF/50V	0603	MURATA	GRM188R71H104KA93D
8	C9	Capacitor,Ceramic,X7R	1uF/25V	0603	MURATA	GRM188R71E105KA12D
9	C10	Aluminum Electrolytic Capacitor	1000uF/35V	Radial	Rubycon	35ZLH1000
10	C11	Capacitor,Ceramic,E	2.2nF/250VAC	Radial	MURATA	DE1E3KX222MA4BL01
11	C12	Capacitor,Ceramic,X7R	4.7uF/50V	1206	MURATA	GRM31CR71H475KA12L
12	D1	Diode,Bridge	0.8A,600V	1Z(SMD)	SHINDENGEN	S1ZB60
13	D2	Diode,STD Recovery	1A,600V	SMA	ON Semiconductor	MRA4005T3G
14	D3	Diode	0.2A,250V	SOD-123	ON Semiconductor	MMSD103T1G
15	D4	Diode,Ultrafast	1A,600V	SMA	ON Semiconductor	MURA160T3G
16	D5	Diode,Schottky	4A,200V	SMC	ON Semiconductor	MBRS4201T3G
17	F1	Metal Film Fuse Resistor	33,1W	Axial	Panasonic	ERQ1ABJ330
18	L1	Power Inductor	4.7mH	Radial	Sumida	RCH895NP-472K
19	L2	Power Inductor	4.7mH	Radial	Sumida	RCH895NP-472K
20	Q1	N-Channel Power MOSFET	600V,2.6A	DPAK	ON Semiconductor	NDD03N60Z
21	R1	Metal Film Resistor	47,2W	Axial	Panasonic	ERG2SJ470
22	R2	Metal Film Resistor	56,2W	Axial	Panasonic	ERG2SJ560
23	R3	Jumper	0	-	-	-
24	R4	Metal Film Resistor	10,1W	Axial	Panasonic	ERG1SJ100
25	R5	Chip Resistor	680k	1206	Rohm	KTR18EZPJ684
26	R6	Chip Resistor	2.7k,1%	0603	KOA	RK73H1JTTD272
27	R7	Chip Resistor	470k	1206	Rohm	KTR18EZPJ474
28	R8	Chip Resistor	12k,1%	0603	KOA	RK73H1JTTD123
29	R9	Anti-surge Chip Resistor	1.2k	1206	Rohm	ESR18EZPJ122
30	R10	Anti-surge Chip Resistor	12k	1206	Rohm	ESR18EZPJ123
31	R11	Jumper	0	0603	KOA	RK73Z1JTTD000
32	R12	Chip Resistor	4.7Meg	0603	Panasonic	ERJ3GEYJ475V
33	R13	Metal Film Resistor	820,2W	Axial	Panasonic	ERG2SJ821
34	R14	Metal Film Resistor	100k,1W	Axial	Panasonic	ERG1SJ104
35	R15	Jumper	0	0603	KOA	RK73Z1JTTD000
36	R16	Chip Resistor	22	0603	KOA	RK73B1JTTD220
37	R17	Chip Resistor	100k	0603	KOA	RK73B1JTTD104
38	R18	Low Ohmic Chip Resistor	0.91,1%	0805	Rohm	MCR10EZHFLR910
39	R19	Open	-	-	-	-
40	R20	Anti-surge Chip Resistor	27k	1206	Rohm	ESR18EZPJ273
41	R21	Open	-	-	-	-
42	T1	Transformer		RM6	WE-Midcom	750341585 Rev.6A
43	U1	LED Driver		MFP14S	ON Semiconductor	LV5012MD
44	VR1	Varistor	470V	Radial	Nippon Chemi-con	TND05V-471KB00AAA0

11.Transformer specification

CUSTOMER TERMINAL	RoHS	LEAD(Pb)–FREE
Sn96%, Ag4%	Yes	Yes

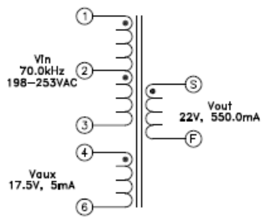
more than you expect

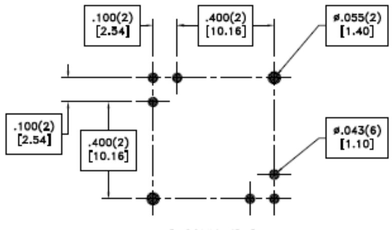
Midcom WÜRTH ELEKTRONIK



ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	1–2	@20°C	1.214 ohms ±10%
D.C. RESISTANCE	2–3	@20°C	1.663 ohms ±10%
D.C. RESISTANCE	4–6	@20°C	0.446 ohms ±10%
D.C. RESISTANCE	S–F	@20°C	0.075 ohms ±10%
INDUCTANCE	1–3	70kHz, 100mVAC, Ls	2.0mH ±10%
INDUCTANCE	S–F	70kHz, 100mVAC, Ls	42.0uH ±20%
LEAKAGE INDUCTANCE	1–3	tie(4+6+S+F), 70kHz, 100mVAC, Ls	20.0uH max.
DIELECTRIC	S–1	tie(3+4), 3750VAC, 1 second	–
TURNS RATIO		(1–3):(4–6)	8.18:1, ±2%
TURNS RATIO		(1–3):(S–F)	6.923:1, ±2%





RECOMMENDED
P.C. PATTERN, COMPONENT SIDE

GENERAL SPECIFICATIONS:
OPERATING TEMPERATURE RANGE: –40°C to +125°C including temp rise.

Wire insulation & RoHS status not affected by wire color.
Wire insulation color may vary depending on availability.

REV.	DATE	Packaging Specifications		Tolerances unless otherwise specified	DRAWING TITLE	PART NO.
		Method: Tray PKG–0936 www.we–online.com/midcom	CONVENTION PLACEMENT	Angles: ±1° Fractions: ±1/64 Decimals: ±.005 [.13] Footprint: ±.001 [.03]	TRANSFORMER	750341585
6A	7/13	SEE REVISION SHEET FOR REVISION LEVEL		This drawing is dual dimensioned. Dimensions in brackets are in millimeters.	eiSos p/n: 750341585 compliant RoHS	SPECIFICATION SHEET 1 OF 1

12.Detailed Descriptions for Application Circuit Setting

The LV5012MD-A19-220VEVM03 is the isolated flyback converter with phase cut dimming. The explanation of each parts of the application circuit is described in figure19. How to set this application circuit is described below.

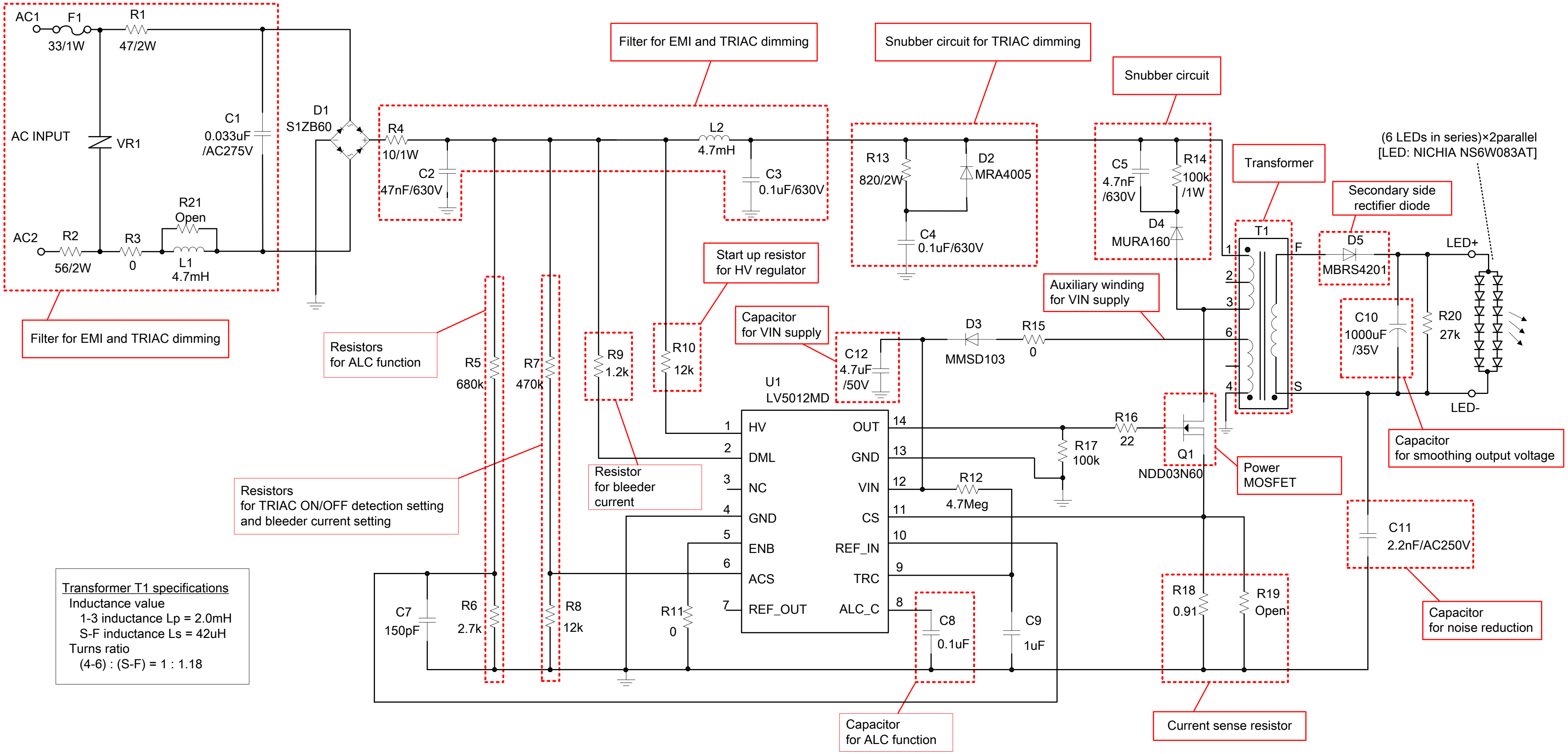


Figure19. The description of each parts of LV5012MD-A19-220VEVM03

12.1 Transformer design

At first calculate about primary inductance and secondary inductance.

The primary inductance L_p is calculated

$$L_p = \frac{(V_{AC}\,peak)^2 \times D_p^2 \times \eta \times 0.565}{2 \times P_{OUT} \times f}$$

where,

L_p : Primary side inductance

$V_{AC\,peak}$: Input peak voltage

η : Conversion efficiency of transformer

f : Switching frequency = 70k [Hz]

P_{OUT} : Output power of secondary side

$P_{OUT} = V_{OUT} \times I_{OUT}$

V_{OUT} : Output voltage (LED voltage)

I_{OUT} : Output current (LED current)

D_p : Duty of primary side current

$$D_p = \frac{T_p}{T}$$

T_p : Time of primary side current

T : Switching period = 1/70k [sec]

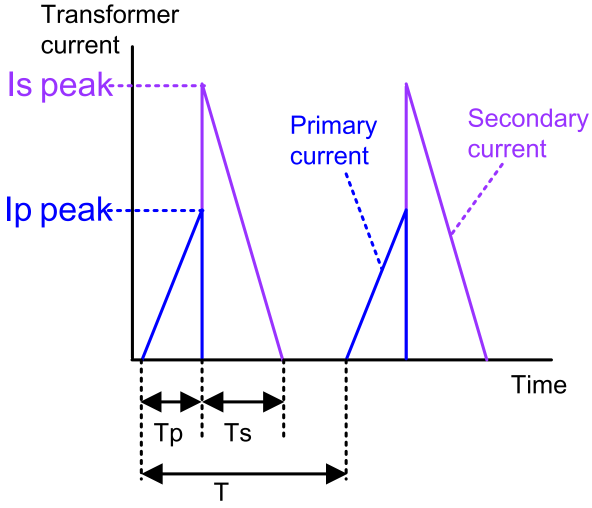


Figure20. Transformer current

The secondary inductance L_s is calculated

$$L_s = \frac{(V_{OUT} + V_f)^2 \times D_s^2}{L_p \times (I_p\,peak)^2 \times f^2}$$

where,

L_s : Secondary side inductance

V_f : Forward voltage of the rectifier diode

$I_{p\,peak}$: Peak current of Primary side inductance *"L_p"*

(*Refer to section "12.3")

D_s : Duty of secondary side current

$$D_s = \frac{T_s}{T}$$

T_s : Time of secondary side current

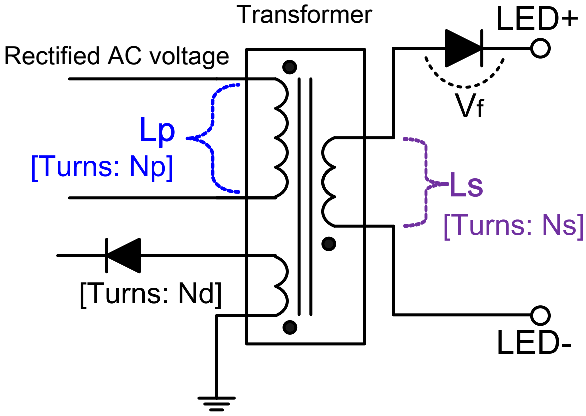


Figure21. Transformer Turns

Next calculate about Turns Raito by primary inductance and secondary inductance.

$$\frac{Np}{Ns} = \sqrt{\frac{Lp}{Ls}}$$

where,

Np : Turns of primary side

N_S : Turns of secondary side

Design the most suitable transformer with the winding turns ratio and the inductance value. Confirm that the operation with the designed transformer is a current discontinuous mode.

The auxiliary winding turns N_d is calculated

$$\frac{N_d}{N_S} = \frac{V_{IN}}{V_{OUT}}$$

where,

N_d : Turns of auxiliary winding

V_{IN} : V_{IN} pin voltage

12.2 REF_IN pin and ALC_C pin setting

- **R5, R6 setting**

Please set R5, R6 so that the voltage peak of the REF_IN pin is around 1.1V to 1.9V.

e.g. V_{AC}=220V → R5=680kΩ, R6=2.7kΩ

REF_IN peak = (220V×$\sqrt{2}$) ×2.7k / (680k+2.7k) = 1.23V

- **C8 setting**

Please connect capacitor of about 0.1uF to an ALC_C pin.

By the above setting, ALC function of LV5012MD becomes effective. Thereby the application of LV5012MD can achieve good line regulation and total harmonic distortion.

12.3 CS pin setting

• R18, R19 setting

The output power of second side is set by the current sense resistor (R18, R19) connected to CS pin. The current sense resistor is calculated,

$$\frac{R18 \times R19}{R18 + R19} = \sqrt{\frac{0.141 \times L_p \times f \times \eta}{2 \times P_{OUT}}}$$

Figure22 is the operation outline diagram.

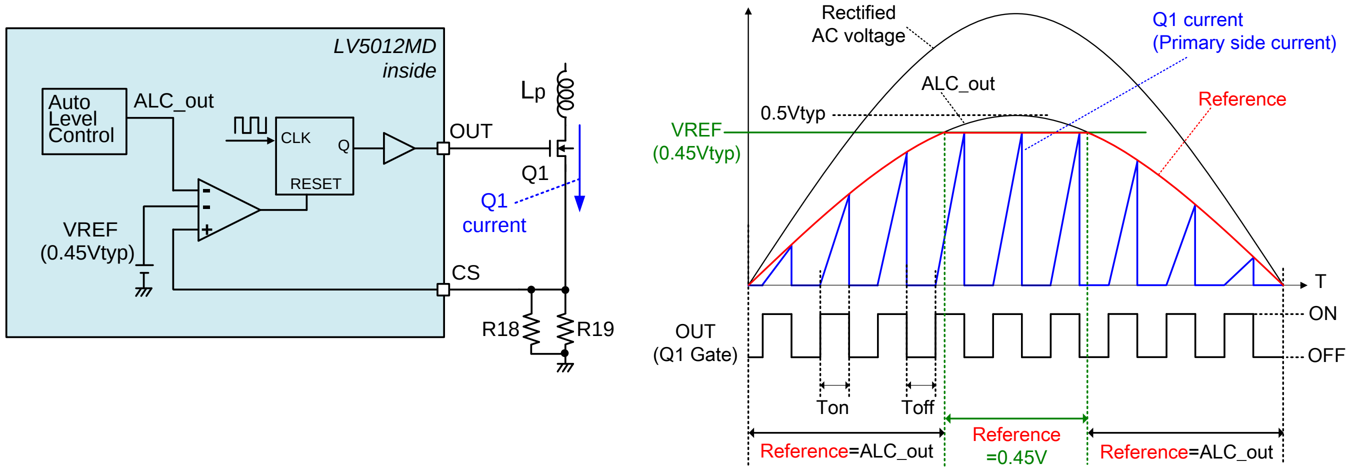


Figure22. Operation outline diagram (No dimming)

The peak current of L_p "$I_{p\,peak}$" is the following expression.

$$I_{p\,peak} = \frac{R18 + R19}{R18 \times R19} \times 0.45$$

(In the case of ALC_out > VREF(0.45V))

12.4 ACS pin and DML pin setting

LV5012MD contains the function for TRIAC dimming. This function is operated by setting ACS pin and DML pin.

Figure23 is the outline diagram of TRIAC dimming operation.

Please set the TRIAC ON/OFF threshold and the Bleeder operation threshold in tune with the characteristic of TRIAC dimmer. The TRIAC ON/OFF threshold and the Bleeder operation threshold are calculated as follow.

The TRIAC ON threshold of the rectified AC is determined below.

$$V_{ac}\_triac\ on = \frac{R7 + R8}{R8} \times 1.7$$

The TRIAC OFF threshold of the rectified AC is determined below.

$$V_{ac}\_triac\ off = \frac{R7 + R8}{R8} \times 1.3$$

The Bleeder operation threshold of the rectified AC is determined below.

$$V_{ac}\_bleeder = \frac{R7 + R8}{R8} \times 0.85$$

Please set R7, R8 on the basis of these expressions according to TRIAC dimmer.

In addition, please set R9 between the rectified AC voltage and DML pin to satisfy the following expression.

$$\left(\frac{R7 + R8}{R8} \times 0.85 \right) - (R9 \times 0.02) < 50\ [V]$$

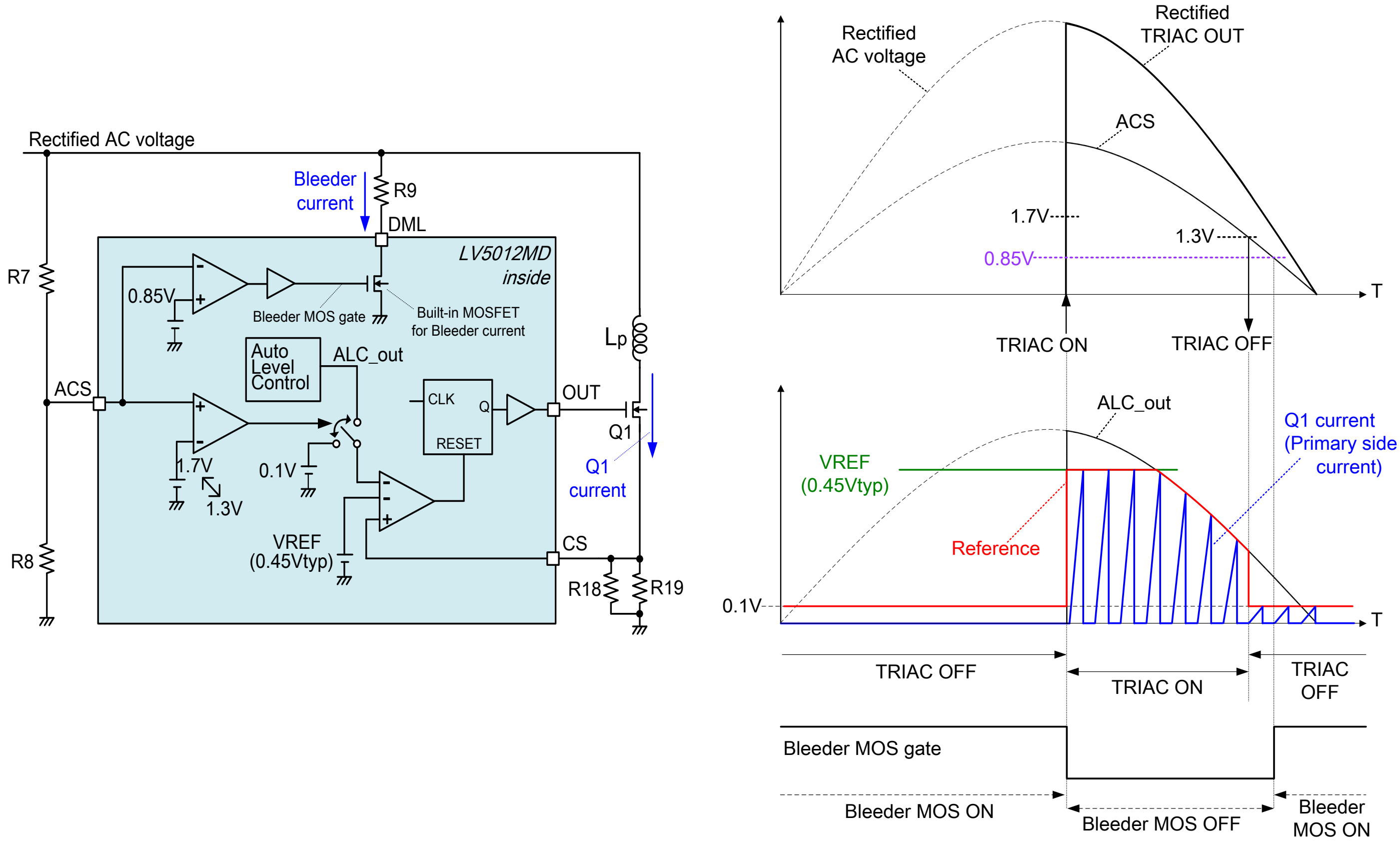


Figure23. Outline diagram of TRIAC dimming operation

12.5 HV pin setting

• R10 setting

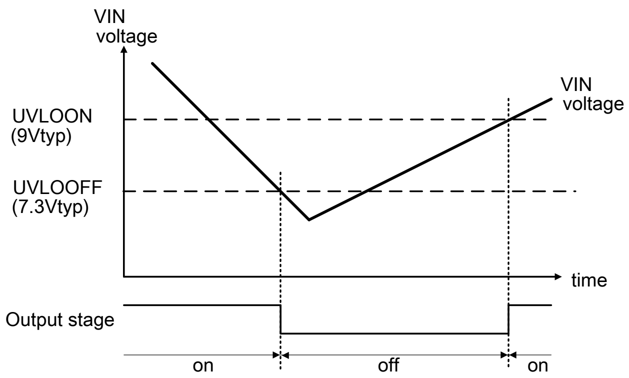
LV5012MD has a high voltage regulator built-in for self-supplying from the rectified AC voltage. It outputs 12V, and thereby the circuit in the IC starts. Please connect R10=12kΩ between HV pin and the rectified AC voltage to operate HV regulator normally.

12.6 Protection function

	tilte	outline	monitor point
1	UVLO	Under Voltage Lock Out	VIN voltage
2	OCP	Over Current Protection	CS voltage
3	OVP	Over Voltage Protection	VIN voltage
4	OTP	Over Temperature Protection	PN Junction temperature

1. UVLO(Under Voltage Lock Out)

If VIN voltage is 7.3V or lower, then UVLO operates and the IC stops. When UVLO operates, the power supply current of the IC is about 80uA or lower. If VIN voltage is 9V or higher, then the IC starts switching operation.

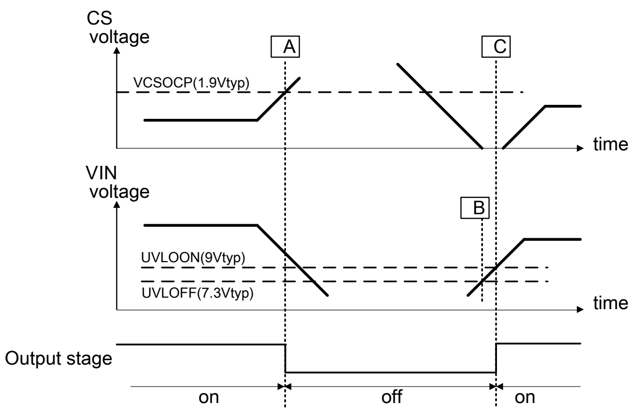


2. OCP(Over Current Protection)

CS pin is used to sense current in primary winding of transformer via external MOSFET. This provides an additional level of protection in the event of a fault. If the voltage of the CS pin exceeds VCSOCP(1.9Vtyp.)(A), the internal comparator will detect the event and turn off the MOSFET. The peak switch current is calculated

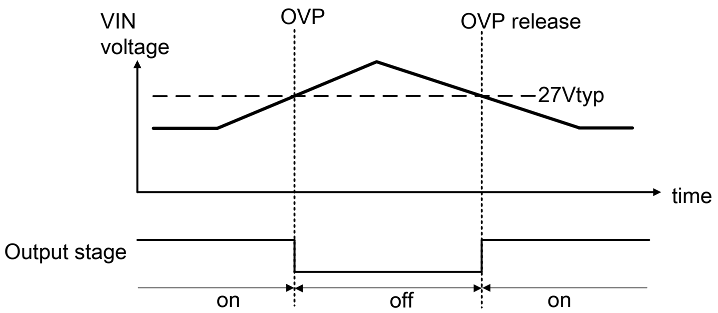
Iocp(peak)[A] = VCSOCP[V] / Rcs[Ω]

The VIN pin is pulled down to fixed level, keeping the controller latched off. The latch reset occurs when the user disconnects LED from VAC and lets the VIN falls below the VIN reset voltage,UVLOOFF(7.3Vtyp.)(B). Switching restarts when VIN rises UVLOON(9Vtyp.)(C).



3. OVP(Over Voltage Protection)

If the voltage of VIN pin is higher than the internal reference voltage VINOVP(27Vtyp), switching operation is stopped. The stopping operation is kept until the voltage of VIN is lower than VINOVP(27Vtyp). If the voltage of VIN pin is lower than VINOVP(27Vtyp), the switching operation is restated. Please see OVP waveform chart.



4. OTP(Over thermal protection)

LV5012MD has the gradually thermal protection system. If the junction temperature exceeds 140 degrees Celsius, 1st stage protection mode is started. At 1st stage protection mode, the internal reference level compared with CS pin voltage is set to 0.1V. And the LED current is restricted to low values (approximately 5%).

If the junction temperature exceeds 155 degrees Celsius, the switching operation and startup circuit are stopped. Please see OTP waveform chart.