130 W 76V CC LED Power Supply Demo Board using ICL5101 in PFC & LLC Topology

Application Note

About this document

Scope and purpose

This document presents the details about the ICL5101 evaluation board and ICL5101 product feature set. It illustrates all necessary steps to get the board and related environment up and running, and provides all information to become familiar with this comprehensive solution.

The ICL5101 is a mixed signal PFC + resonant controller for non-dimmable and dimmable LED light applications using LLC topology for highest efficiency levels exceeding 90 %, including a PFC stage for lowest THD < 5 % and high power factor correction figures > 95 % @ > 50 % load in a wide line input voltage range. The ICL5101 LLC CC evaluation board is designed to evaluate the performance and flexibility of the ICL5101. It supports an output power of 130 W, easily configurable by using only resistor settings without any user interface tool.

Intended audience

This document is intended for anyone who needs to use the ICL5101 evaluation board, either for their own application tests or to use it as a reference for a new ICL5101-based development.

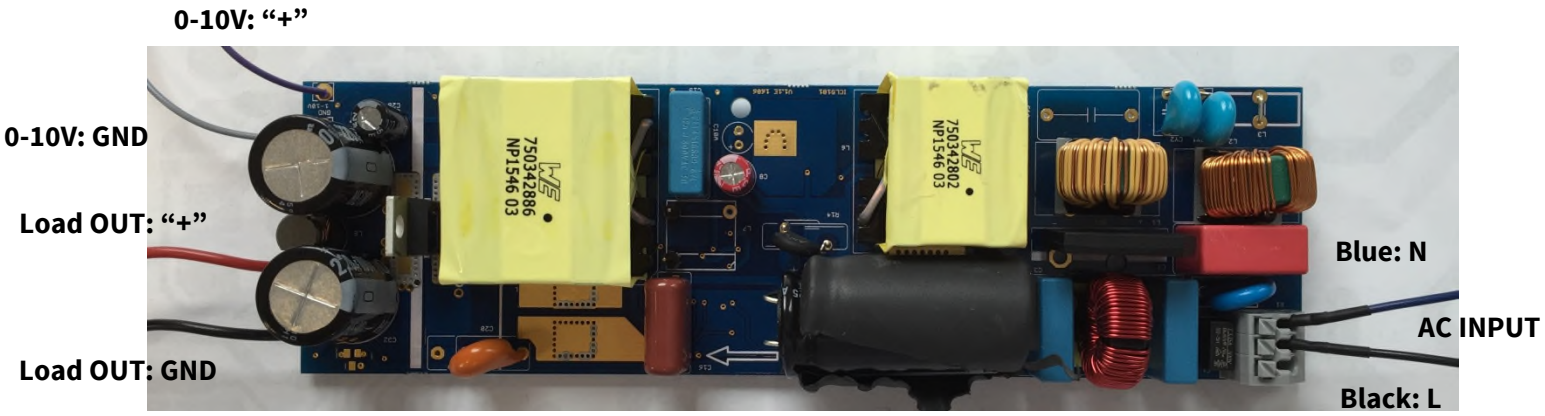
Table of Contents

1 Order Code / Board Connection / Operation Setup

1.1 Order Code

EVALLED5101E2 CC / SA001620102 / SP001619808

1.2 Connection Diagram



1.3 Line Input Voltage

Connect an AC Source at the AC INPUT stage as shown on the right hand side of the board from 90V_{AC} up to 305V_{AC}.

1.4 Load Output

Two ways to connect a load to the board – a LED or electronic load in order to test the performance of the LED driver power supply.

→ Connect a LED in a voltage range of 38VDC up to 76VDC with a nominal current up to 1.7A at the output stage from Load OUT: **GND** and Load OUT: **"+"**

→ Connect an electronic load to Load OUT: **GND** and Load OUT: **"+"**. Setup the electronic load to Constant Voltage (CV) with the values of max Voltage CV1 = 76V / min Voltage CV = 38V.

1.5 0 – 10V Dimming Interface

Connect a DC source at 0-10V: GND and 0-10V: "+". 10V is equal to the max. load current I_{OUTmax} / minimum output current I_{OUTmin} is reached, when the dimming voltage drops to 0V

2 Introduction

This application note describes the characteristics and features of a 130 W SMPS LED demonstration board with constant Current output in a voltage range from 76 V down to 38V Vout. High efficiency, high PF, low THD and very stable output current during the output voltage rage, makes it very suitable to be used as a primary power supply for low power systems, such as LED lighting. Its compact design and low BOM cost is due to Infineon IC ICL5101 (CrCM PFC and resonant block are integrated together), which is used as main controller here. With this highly integrated smart IC, the circuit design is dramatically simplified, which results space and BOM cost saving. Furthermore, numerous monitor and protection features ensure highest reliability.

Key specification measurements and waveforms are also shown in this application note.

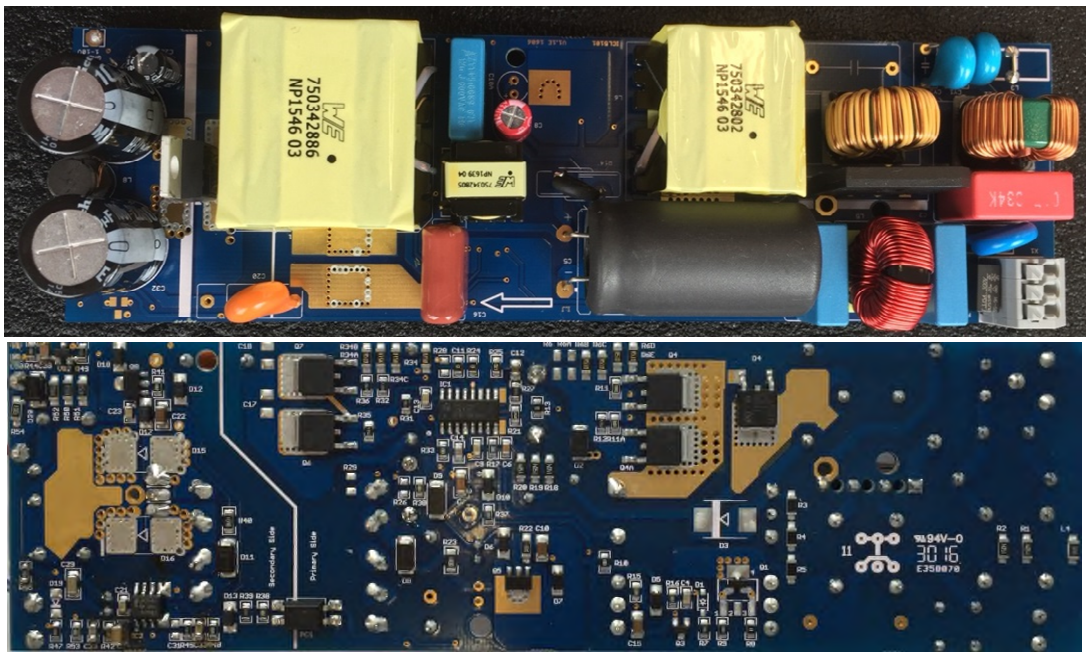


Figure 1 LLC CC Demonstration Board of 130 W / 76 V to 38V LED Driver

3 Technical Specification

This demo board consists of a CrCM PFC and a half-bridge LLC, whith constant current output stable from 38V up to 76 V_{DC} voltage.

The PFC stage of this demo board is controlled by the PFC block of the ICL5101, which has an integrated digital PFC control loop and improved compensation for low THD of AC input current. It operates in critical conduction mode (CrCM) in a load range from 10 % to 100 % to achieve a very good power factor and very low THD. When the load is smaller than 10 %, in order to limit the PFC switching frequency, the IC controls the PFC to operate in discontinuous conduction mode (DCM).

The half-bridge LLC stage has a fixed duty cycle of D=0.5 and an adjustable self-adapting dead time from 0.5 µs to 1 µs. The operation frequency starts from typical 135 kHz at start-up and decreases to a range of between 45 kHz (full load) and 75 kHz (output open loop). The current variation is tested to be smaller than 2 % from full load maximum dimming. In addition, many other protection functions are also implemented, such as Output Short Circuit Protection of the main output (OSCP), LLC primary winding short circuit protection (WSCP), Capacitive Mode Protection of the main output (CMP), LLC Over Current Protection (LOCP), over temperature protection (OTP) at certain hot spot on board and more. These protection functions are realized by the built-in protection functions of the IC ICL5101.

Features

- Input voltage range: 90–305 V_{AC}
- Input voltage frequency: 47–63 Hz
- Regulated main output current: 1.7 A in a output voltage range from 38V_{DC} up to 76V_{DC}
- Efficiency at nominal load: ≥ 92.0 % at 230 V_{AC}
- Input current THD: < 10 % @ > 50% Load at 230 V_{AC}
- Harmonics: According to EN61000-3-2 Class-D
- EMI: According to EN55015
- Safety : According to EN61347-2-13
- Board dimensions: 178 mm (L) x 52 mm (W) x 32 mm (H)

4 Schematic

Figure 2 shows the schematic of the ICL5101 demonstration board.

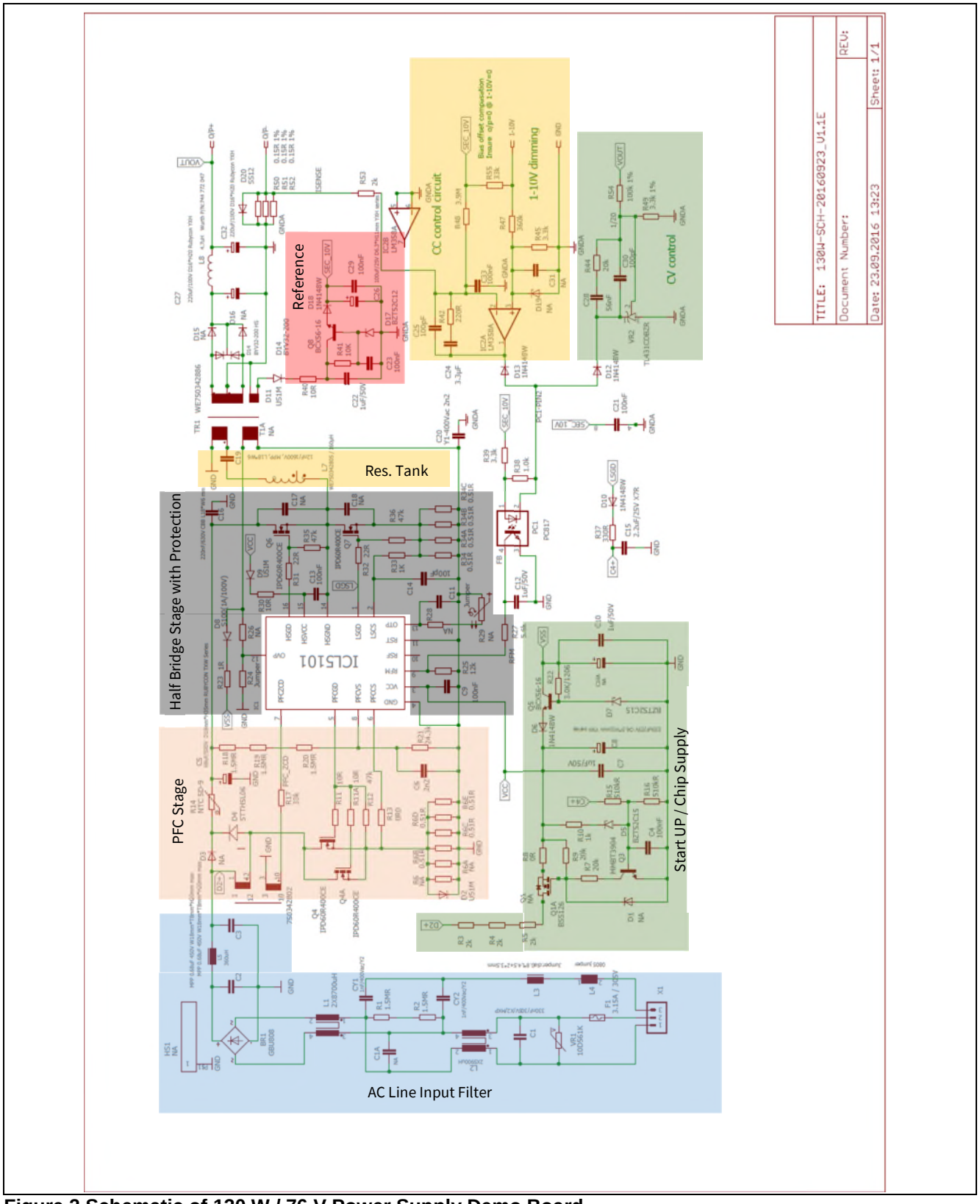


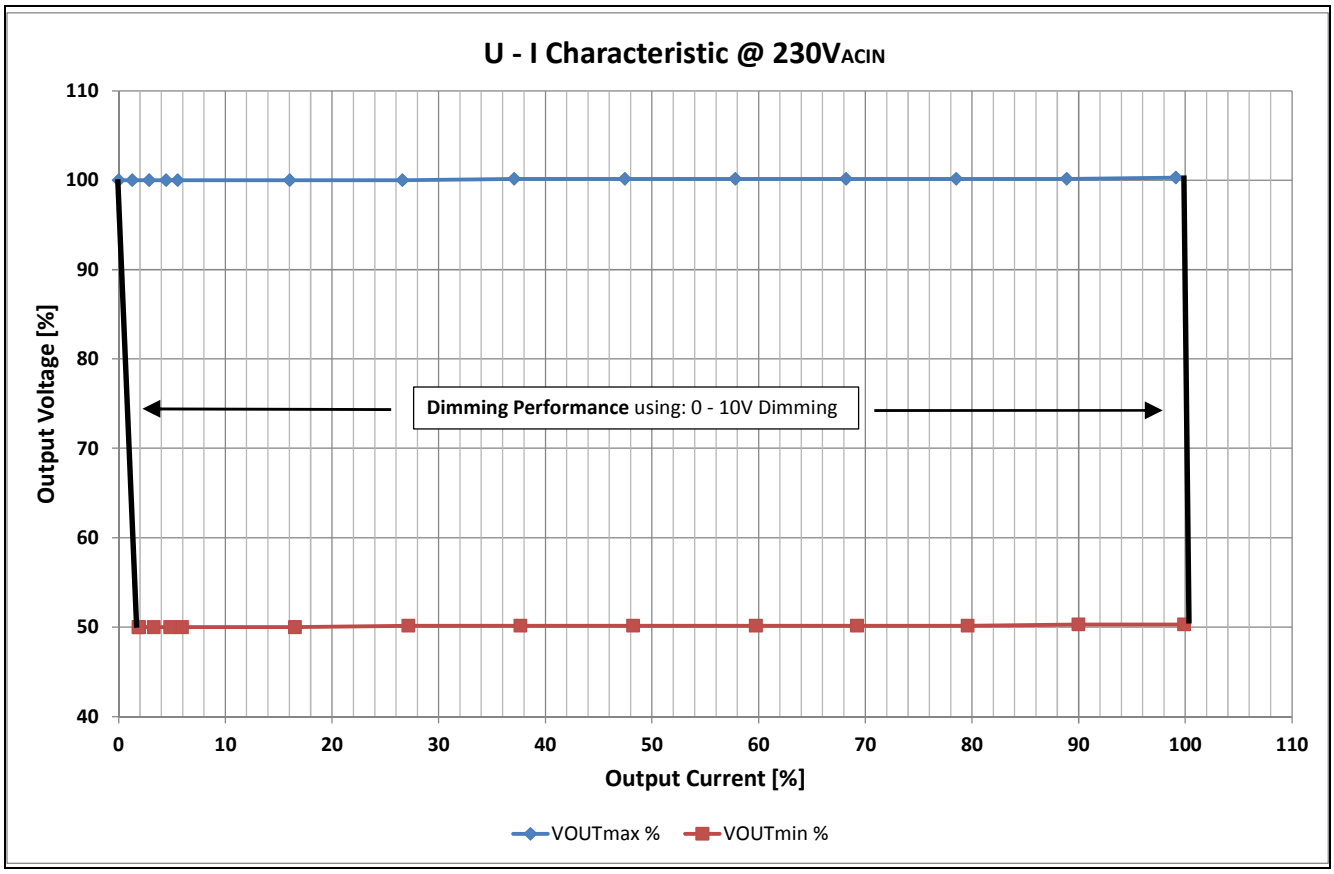
Figure 2 Schematic of 130 W / 76 V Power Supply Demo Board

5 Key Measurements

5.1 U – I Characteristic, Dimming Performance, PF and THD

5.1.1 U – I Characteristic

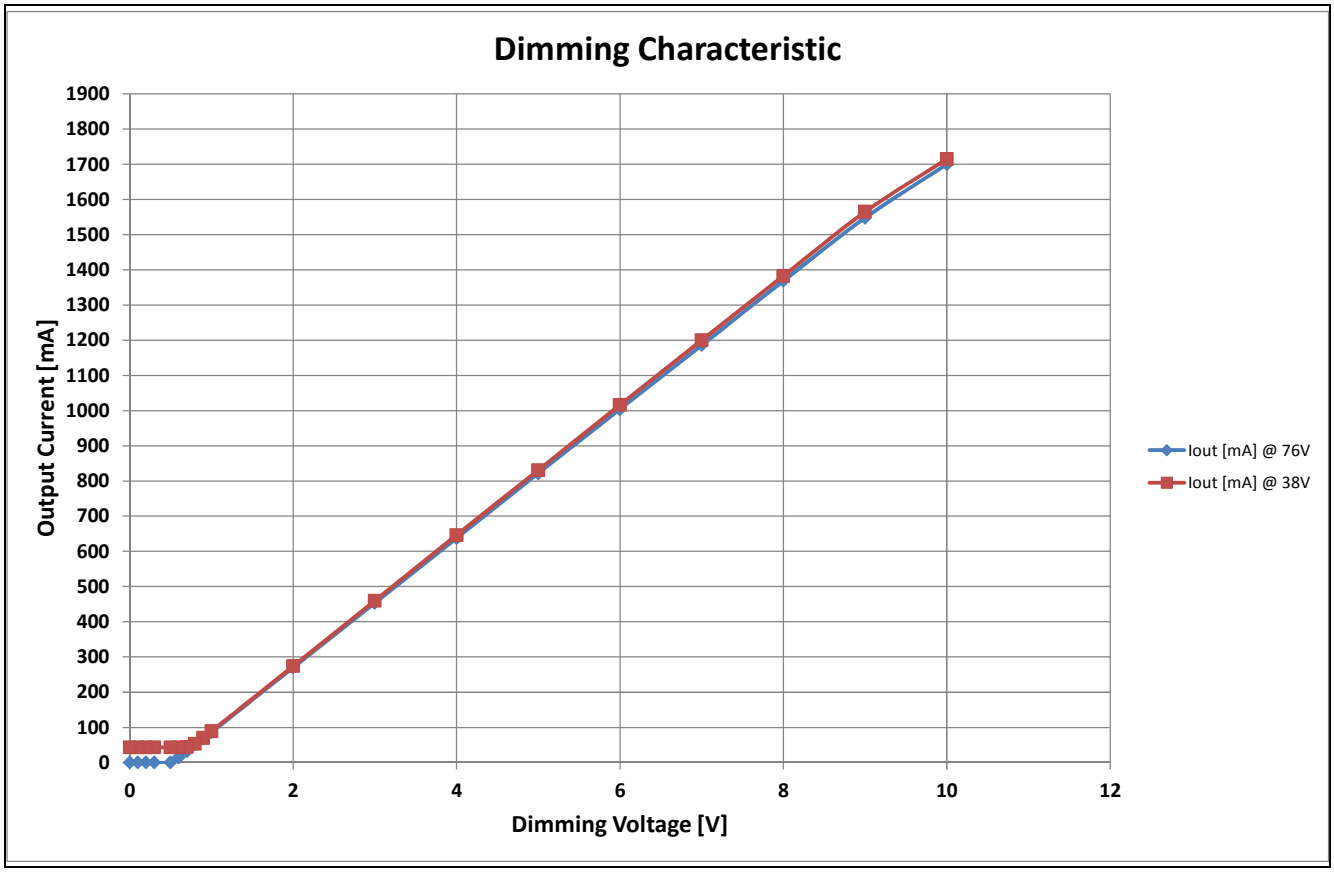
The output Current of the demo board is tested under nominal load I_{OUTnom} = 1.7A at 230 V_{AC} in a voltage range between 38V_{DCmin} up to 76V_{DCmax}.



Constant Current Operation at different Output Voltage Values in %

5.1.2 Dimming Performance

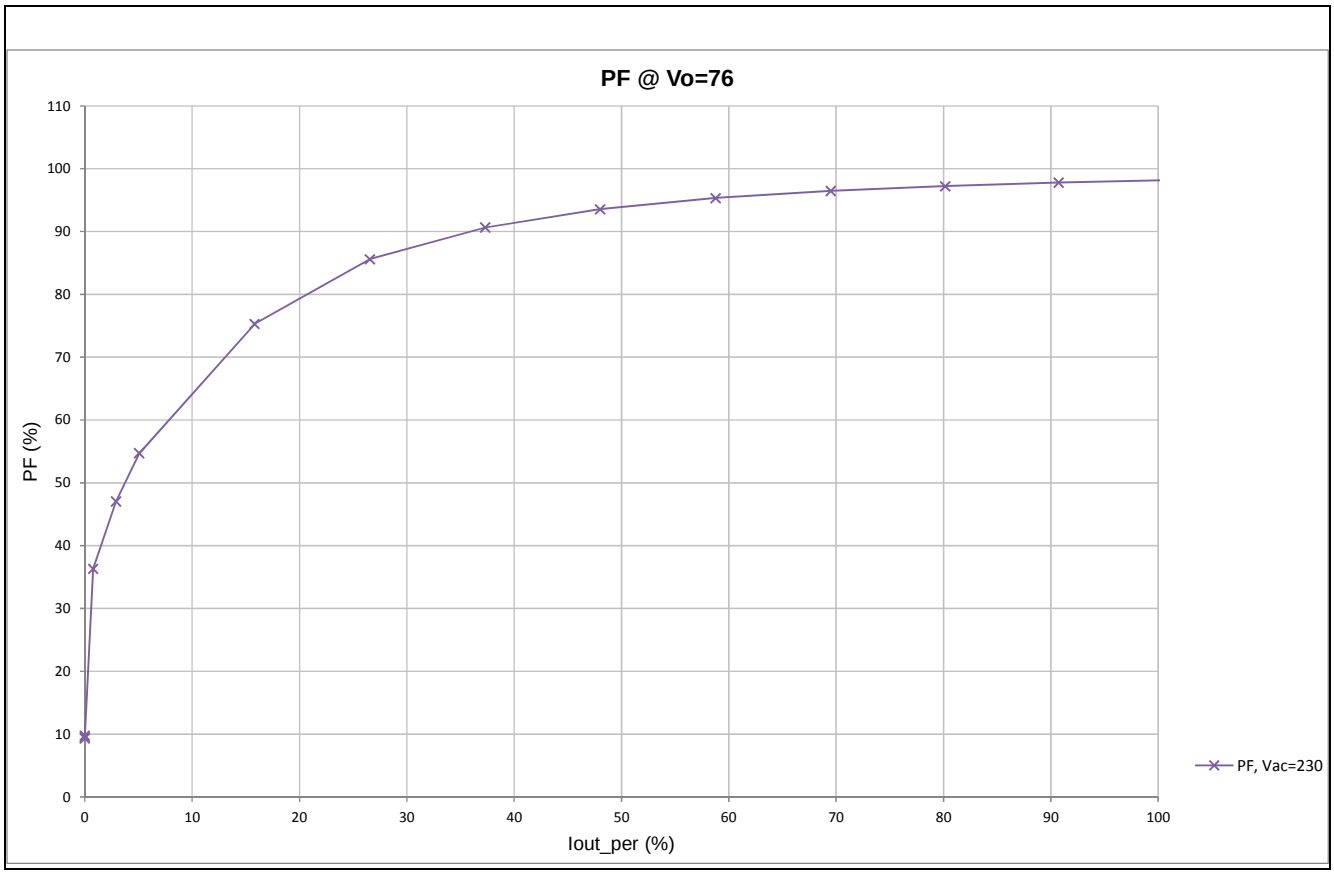
The chart below shows the output current versus the 0 – 10V dimming voltage tested at 230 VAC input voltage.



Output Current I_{OUT} versus 0 – 10 V Dimming Voltage

5.1.3 PF vs. P_{OUT}

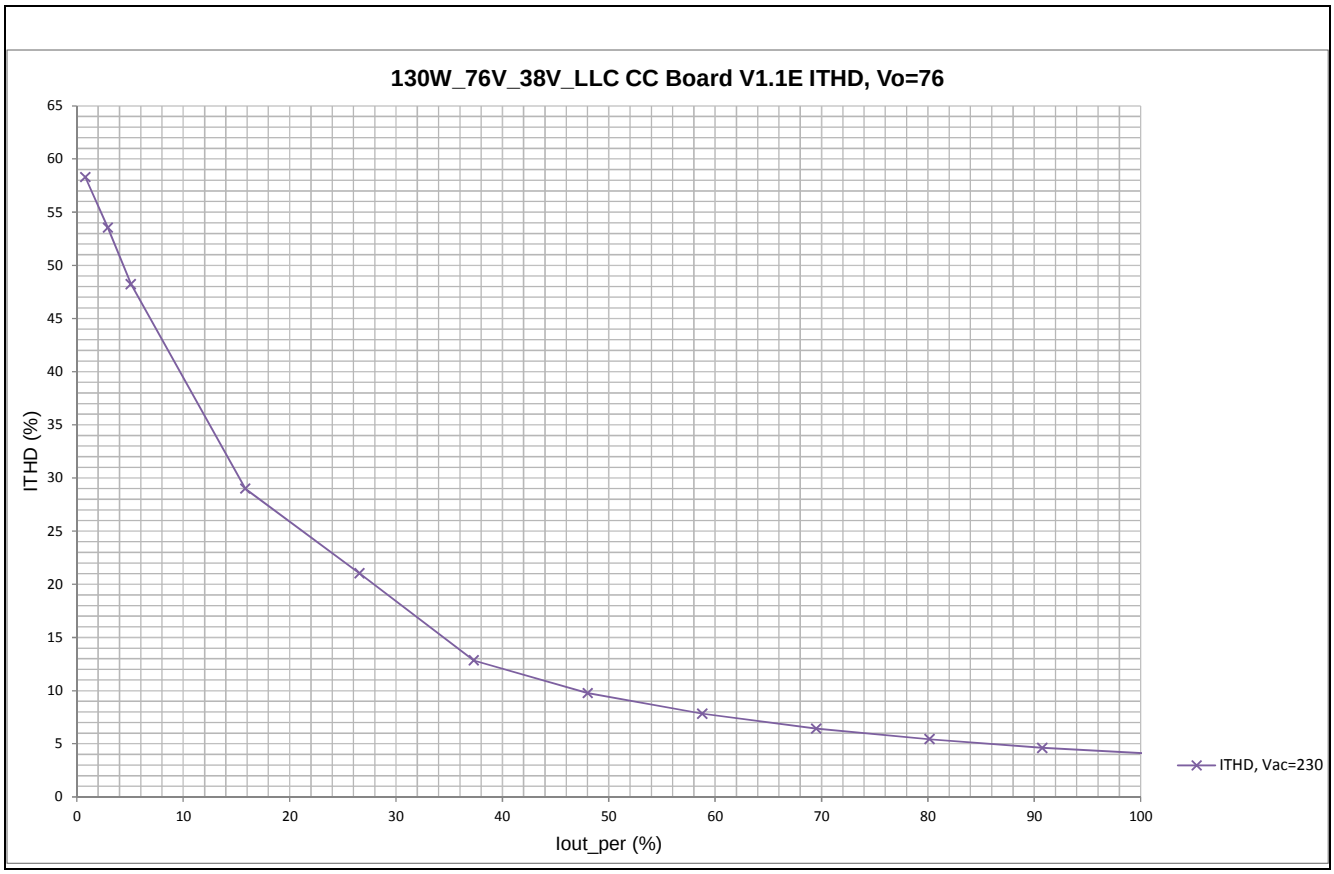
Due to the smart internal digital PFC controller of the ICL5101, a PF of greater than 90 % @ 50% load is achieved at V_{IN} = 230 VAC.



Power Factor versus Load in %

5.1.4 THD vs. P_{OUT}

Due to the smart THD adjustment at the ZCD pin of the ICL5101, a THD below than 10 % @ 50% load is achieved at V_{IN} = 230 VAC.



THD versus Load in %

5.2 Surge Protection

Description SURGE Protection

In case of a surge event, the voltage at the BUS capacitors C5 & C8 rises up, the driver stages of the ICL5101 are shut off when V_{LSCS} > 0.8V and V_{BUS} > 109% for longer than 500ns. After the surge the controller restarts automatically when V_{BUS} drops below 109% of the rated voltage. This feature allows driving 500V MOSFETs at the half bridge stage when adequate EMI and DC LINK networking is present.

SURGE Detection

If the bus voltage exceeds:

V_{BUS} > 109%

and the voltage at the low side current sense pin 2 exceeds:

V_{LSCS} > 0.8V

for longer than

t = 500ns

SURGE Protection

All Gate Drives OFF

Auto Restart:

V_{BUS} < 109%

Measurement

Surge Event of 1.7kV WITHOUT Varistor VR1

Figure 3: SURGE **1.7kV** / FULL Load / Detail
L → N / Phase: 90°
Ch 1 dark blue: V_{LSCS} LS Current Sense to IC GND
Ch 2 blue: V_{BUS} to Power GND
Ch 3 magenta: V_{LSDS} LS Drain to Power GND
Ch 4 green: V_{PFCDS} PFC Drain to Power GND

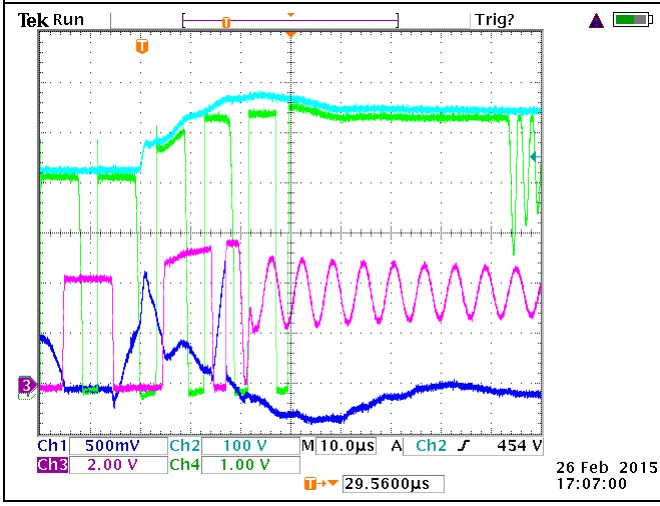
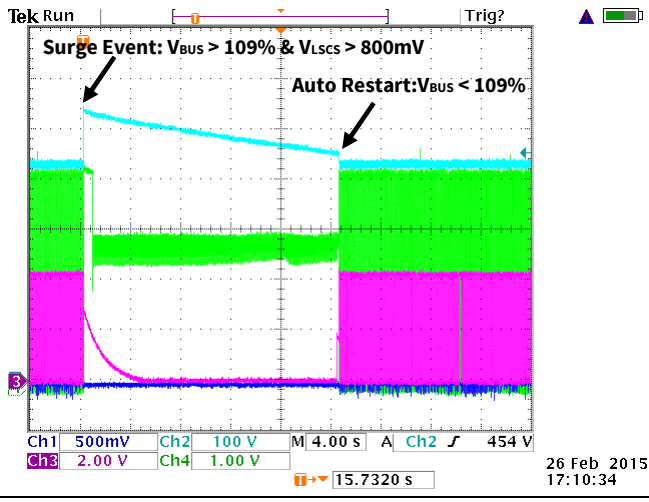


Figure 4: SURGE **1.7kV** / FULL Load / Auto Restart
L → N / Phase: 90°
Ch 1 dark blue: V_{LSCS} LS Current Sense to IC GND
Ch 2 blue: V_{BUS} to Power GND
Ch 3 magenta: V_{LSDS} LS Drain to Power GND
Ch 4 green: V_{PFCDS} PFC Drain to Power GND



6 Power Magnetic Specification

6.1 Common Mode Choke Spec L1

SPECIFICATION
FOR APPROVAL

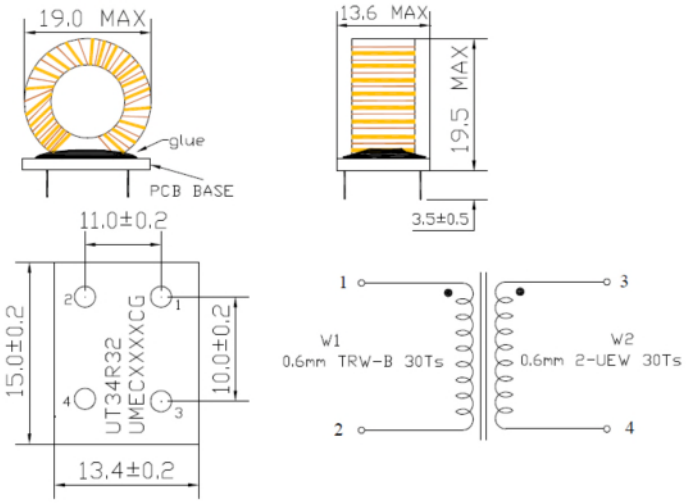
Universal Microelectronics Co., Ltd.
3,27Th Rd., Taichung Industrial Park,
Taichung, Taiwan, R.O.C.
(TEL: 886-4-23590096 FAX: 886-4-2359-0129)
http://www.umec-web.com E-mail: business@umec.com.tw

UM MODEL NO. TG-UT34R32	CHOKE		ISSUE NO.AP-15033	
CUSTOMER: INFINEON	CUSTOMER'S P/N: CM-8700uH-R12K	DATE: 19/OCT/2015	UM REV: A	SHEET: 1 OF 4

ELECTRICAL SPECIFICATION AT 25℃ :

1. TURNS RATIO & PHASE: 30:30Ts, AT 15.75KHz, 1V, PIN(1-2):(3-4).
**2. INDUCTANCE : 8700uH±30%, AT 40KHz,1V, PIN(1-2), PIN(3-4).
3. LEAK INDUCTANCE : 10uH MAX, AT 40KHz,1V, PIN(1-3), PIN(2-4)SHORT.
4. D.C.Resistance: 60mΩ MAX., PIN(1-2), PIN(3-4).
5. HI-POT: (1) 2000Vrms/50Hz/0.5mA/60sec, PIN 1 TO PIN 3.
(2) 2400Vrms/50Hz/0.5mA/2sec, PIN 1 TO PIN 3.

** NOTE: The sign "**" is out of specification and we ask for the value that must be changed.



Common Mode Choke L1

6.2 Common Mode Choke Spec L2

SPECIFICATION FOR APPROVAL

Universal Microelectronics Co., Ltd.
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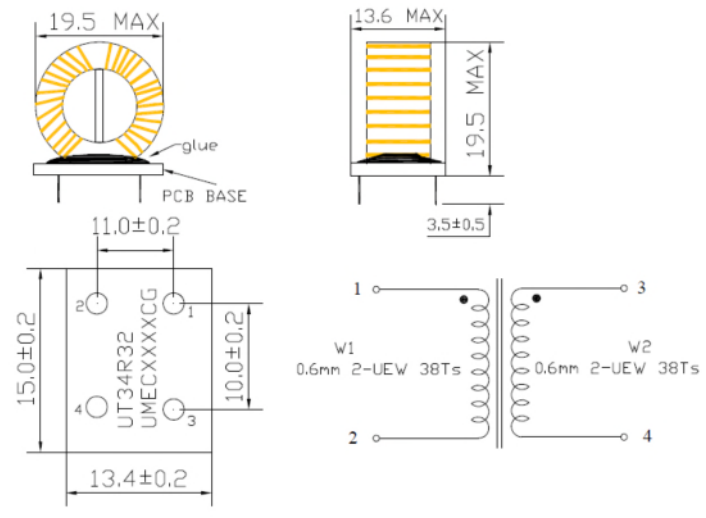
UM MODEL NO. TG-UT34R33	CHOKE		ISSUE NO.AP-15034	
CUSTOMER: INFINEON	CUSTOMER'S P/N: CM-5900uH-R5K	DATE: 19/OCT/2015	UM REV: A	SHEET: 1 OF 4

ELECTRICAL SPECIFICATION AT 25℃ :

1. TURNS RATIO & PHASE: 38:38Ts, AT 15.75KHz, 1V, PIN(1-2):(3-4).
**2. INDUCTANCE : 5900uH±30%, AT 40KHz,1V, PIN(1-2), PIN(3-4).
3. LEAK INDUCTANCE : 100uH MAX, AT 40KHz,1V, PIN(1-3), PIN(2-4)SHORT.
**4. D.C.Resistance: 90mΩ MAX., PIN(1-2), PIN(3-4).
5. HI-POT: (1) 2000Vrms/50Hz/0.5mA/60sec, PIN 1 TO PIN 3.
(2) 2400Vrms/50Hz/0.5mA/2sec, PIN 1 TO PIN 3.

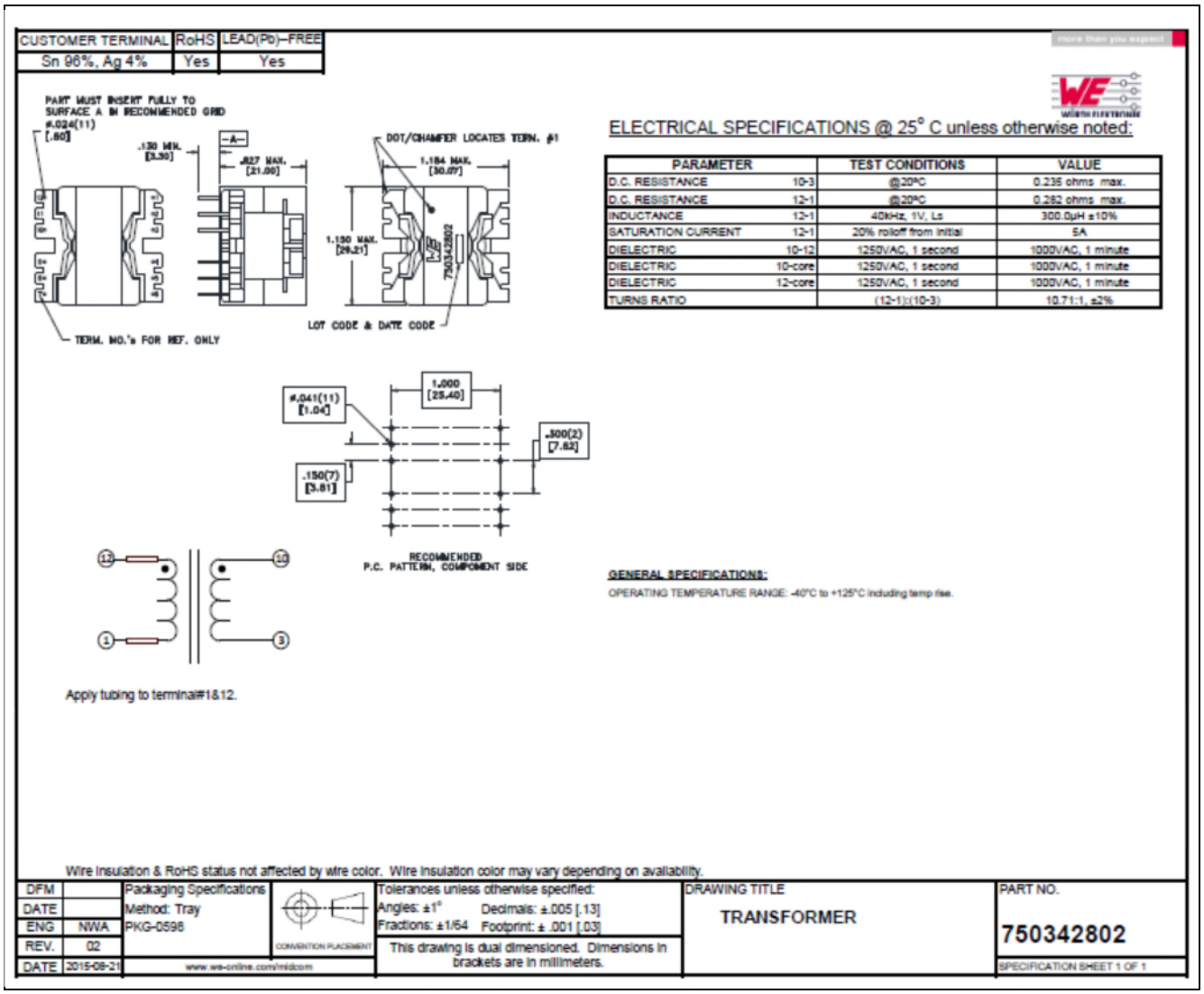
** NOTE: The sign "**" is out of specification and we ask for the value that must be changed.

DIMENSION :



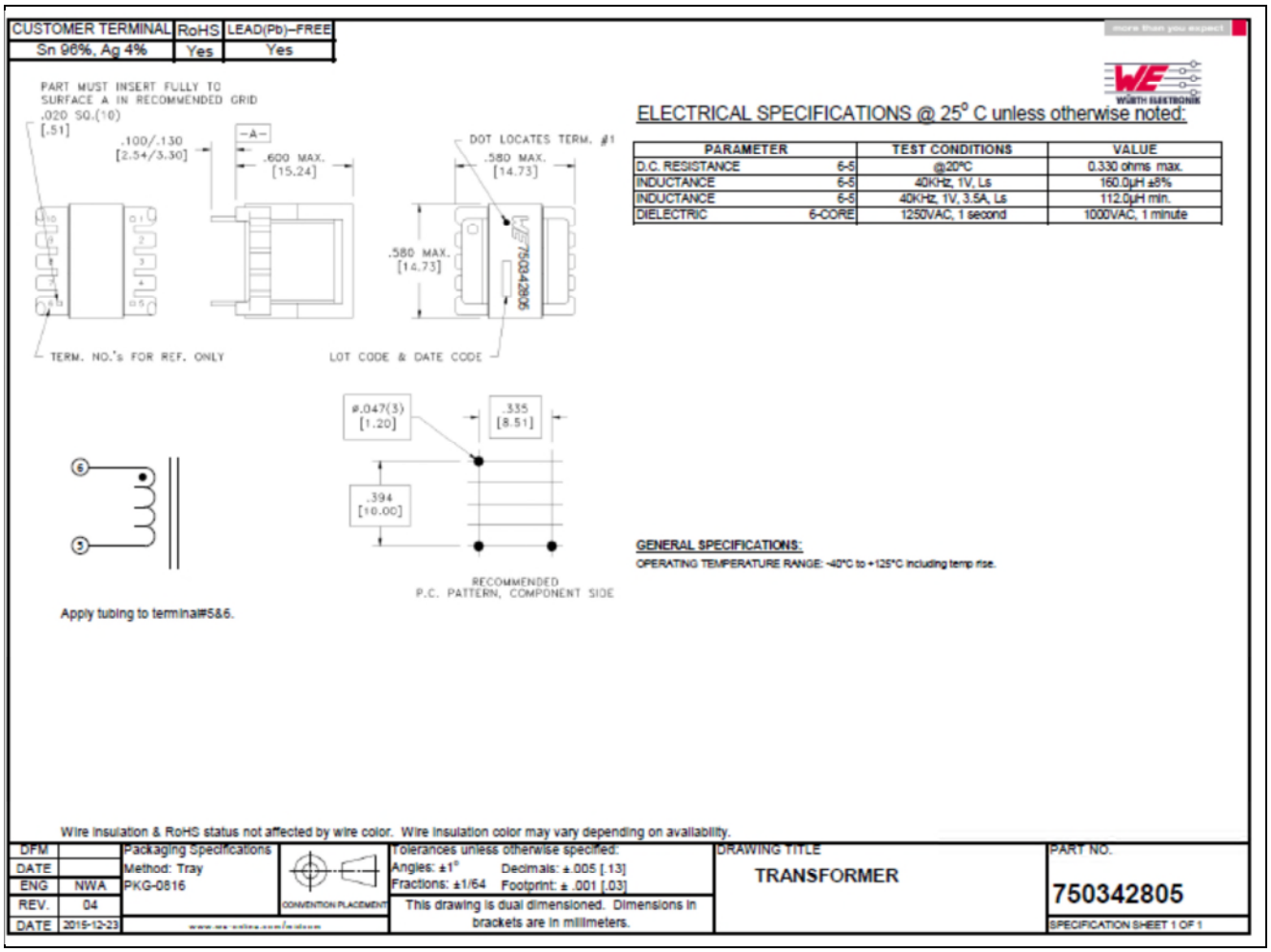
Common Mode Choke L2

6.3 PFC Choke Spec L6



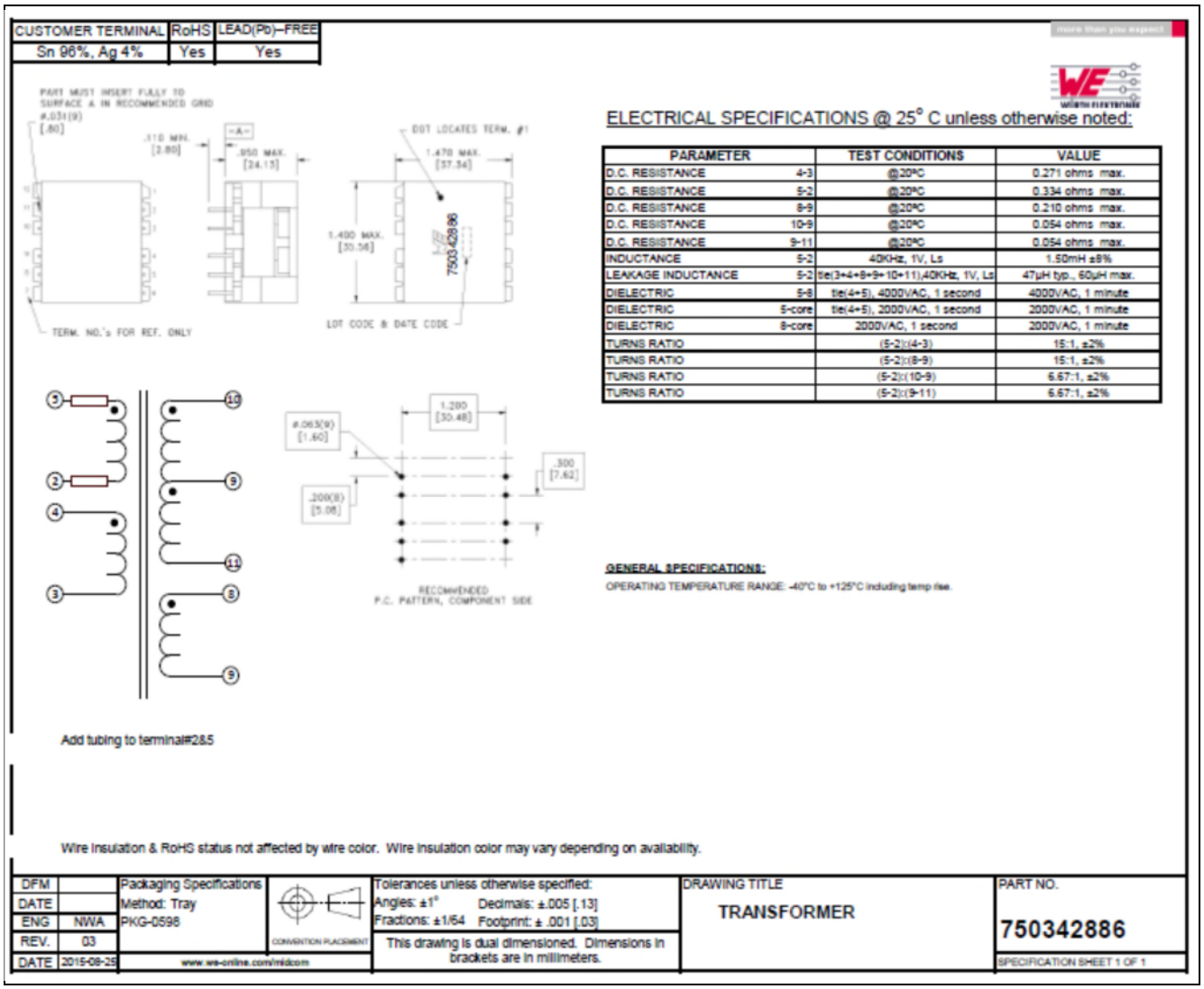
PFC Choke

6.4 LLC Resonant Choke Spec L7



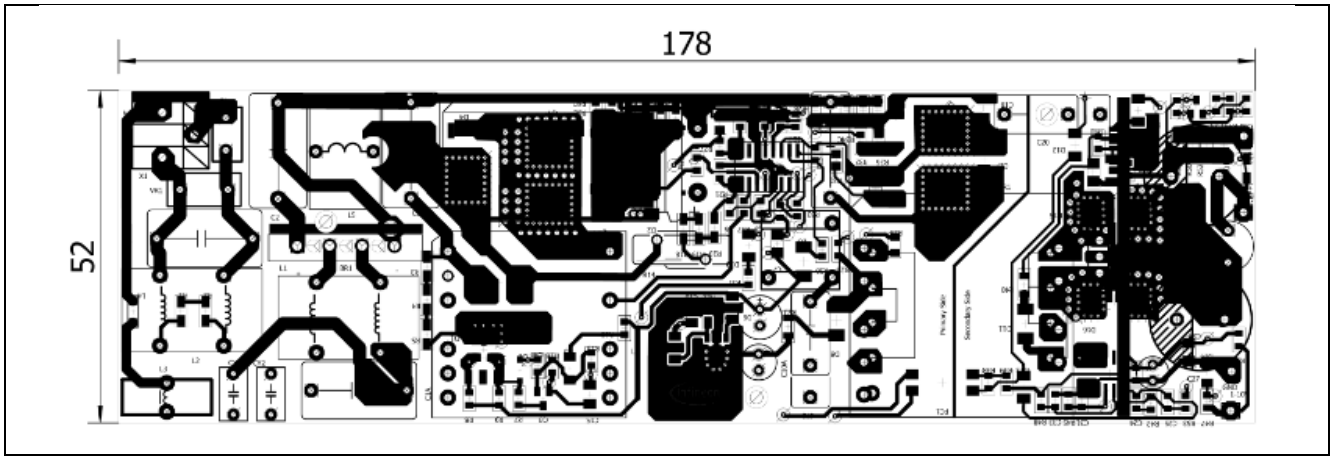
LLC Resonant Choke

6.5 LLC Transformer Spec TR1

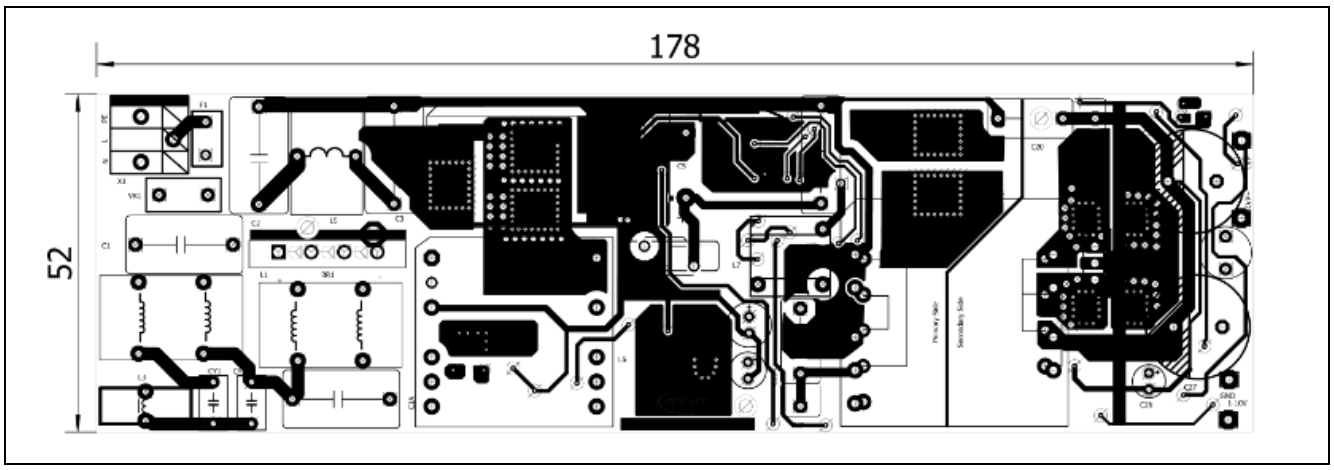


LLC Transformer

7 Board Layout



Layout (Bottom View)



Assembly Print (Top View)

8 Bill of Material (BOM)

Part	Value	Device	Package	Supplier	OrderNr/Link
1-10V	Kabel, Spezifikation AWG24, 200mm, abisoliert 10mm, verzinnt, rot			manufacturer	
BR1	GBU808 or GBU8M,8A/1kV	GBU808	SIP-4Pin	Farnell	1611584
C1	330nF, 305VAC, 10%, LS15mm	Epcos: B32922C3334K*	CAP-18-9-15	Epcos	B32922C3334K
C2	MPP 0.68uF 450V	Epcos: B32672P4684K000	FCAP-18-9-15	Farnell	2469037
C3	MPP 0.68uF 450V	Epcos: B32672P4684K000	FCAP-18-9-15	Farnell	2469037
C4	100nF/ 50V	C0805	0805	Farnell	1414664
C5	68uF/500V	68uF/500V D18mm*H35mm RUBYC	E45-22	Rubycon	500TXW68MEFC18X35
C6	2n2/ 50V/ X7R	C-EUC0805	C0805	Standard	
C7	1uF/ 50V/ X7R	C1206	1206	Farnell	1301811
C8	220uF/25V D6.3*H11mm	Würth: 860010473011	E2,5-7	Farnell	2465679
C9	100nF/ 50V	C0805	0805	Farnell	1414664
C10	1uF/ 50V/ X7R	C1206	1206	Farnell	1301811
C11	0 Ohm/ 1%	R-EU_R0805	R0805	Standard	
C12	1uF/ 50V	C0805	0805	Farnell	2094043
C13	100nF/ 50V	C0805	0805	Farnell	1414664
C14	100pF/ 50V	C0805	0805	Standard	
C15	2.2uF/ 25V/ X7R	C1206	1206	Standard	
C16	220nF/630V CBB	C-EUFCAP L18*W6 mm	FCAP-18-6-15-2	Standard	
C19	12nF/1600V, MPP, L18*W6	C-EUFCAP-18-6-15/10	FCAP-18-6-15/10	EPCOS	B32672L1123J000
C20	2.2nF/ 400Vac/ Y5U/Y1	C-EUFCAP-18-6-15/10	FCAP-18-6-15/10	Vishay	440LD22 10PCM
C21	100nF/ 50V	C0805	0805	Farnell	1414664
C22	1uF/ 50V/ X7R	C1206	1206	Farnell	1301811
C23	100nF/ 50V	C0805	0805	Farnell	1414664
C24	100nF/ 50V	C0805	0805	Farnell	1414664
C25	100pF/ 50V	C0805	0805	Standard	
C26	100uF/25V D6.3*H11mm	25YXH100MEFC6.3X11	E2,5-5	DigiKey	1189-1898-ND
C27	220uF/100V D16*H20 Rubycon YXH	ECAPECAP-16-7.5	ECAP-16-7.5	Farnell	
C28	100nF/ 50V	C0805	0805	Farnell	1414664
C29	100nF/ 50V	C-EUC1206	C1206	Standard	
C30	100pF/ 50V	C0805	0805	Standard	
C32	220uF/100V D16*H20 Rubycon YXH	ECAPECAP-16-7.5	ECAP-16-7.5	Farnell	
C33	100nF/ 50V	C0805	0805	Farnell	1414664
CY1	1nF/400Vac/Y2	1nF/400Vac/Y2	C050-025X075		
CY2	1nF/400Vac/Y2	1nF/400Vac/Y2	C050-025X075		
D2	US1M	DO-214AC	DO-214AC	Standard	
D4	STTH5L06B-TR	DIODE-DPACK-THERMAL	D-PAK_TO252AA	Farnell	2344054
D5	BZT52C15	Z-DIODE	HSOD-80	Farnell	2420637
D6	1N4148W	CGRM4001-G	SOD-123_MINI-SMA	Standard	
D7	BZT52C15	Z-DIODE	HSOD-80	Farnell	2420637
D8	S100	Schottky Diode 1A/100V/SMA	DO214AC	Farnell	1611177
D9	US1M	DO-214AC	DO-214AC	Standard	
D10	1N4148W	CGRM4001-G	SOD-123_MINI-SMA	Standard	
D11	US1M	DO-214AC	DO-214AC	Standard	
D12	1N4148W	CGRM4001-G	SOD-123_MINI-SMA	Standard	
D13	1N4148W	CGRM4001-G	SOD-123_MINI-SMA	Standard	
D14	BYV32-200 200V, 20A, TO220	mit Heatsink FK 237 SA 220 V	TO220ABS-HS	Farnell	2317407
D17	BZT52C12	Z-DIODE	HSOD-80	Farnell	1431257
D18	1N4148W	CGRM4001-G	SOD-123_MINI-SMA	Standard	
D20	SS12	DIODE-DO-214AC	DO-214AC	Standard	
F1	3.15A/	FUSE8.5-4	FUSE4-8.5	Standard	
GND	Kabel, Spezifikation AWG24, 200mm, abisoliert 10mm, verzinnt, schwarz			manufacturer	
IC1	ICL5101	ICL5101	SO16	Infineon	ICL5101
IC2	LMV358M	LMV358M	SO08	TI	LMV358M
L1	2X8700uH	Common Mode Choke	B2	UMEC	TG-UT34R32
L2	2X5900uH	Common Mode Choke	B2	UMEC	TG-UT34R33
L3	Jumper:dia0.8*L4.5+2*3.5mm	Wire 11mm	R12	manufacturer	
L4	1206 jumper	WE-CBF_1206	1206	Standard	
L5	360uH	FERRITE_R16	R12	Wuerth	750315755
L6	750342802	PQ26	PQ26	Wuerth	750342802 rev03
L7	750342805	160uF/ EE13	EE13-20151221	Wuerth	750342805
L8	4.7uH Wurth P/N:744 772 047	INDUCTOR_MULTICOMP_2.2MH	INDUCTOR_MULTICOMP_2.2MH	Wuerth	744772047
O/P+	Kabel, Spezifikation AWG18, 200mm, abisoliert 10mm, verzinnt, violet			manufacturer	
O/P-	Kabel, Spezifikation AWG18, 200mm, abisoliert 10mm, verzinnt, grau			manufacturer	
PC1	FOD817A3S	SFH617A	DIL4-SMD	Farnell	2322514
Q1A	BSS126	NMOSSOT23	SOT23	Infineon	BSS126
Q3	MMBT3904	NPN_TRANSITOR_SMD	SOT23	Farnell	9846727
Q4	IPD60R400CE	MOSFET N-CH.	TO-252	Infineon	IPD60R400CE
Q4A	IPD60R400CE	MOSFET N-CH.	TO-252	Infineon	IPD60R400CE
Q5	BCX56-16	NPN, 3pin	SOT89	Infineon	BCX56-16
Q6	IPD60R400CE	MOSFET N-CH.	TO-252	Infineon	IPD60R400CE
Q7	IPD60R400CE	MOSFET N-CH.	TO-252	Infineon	IPD60R400CE
Q8	BCX56-16	NPN, 3pin	SOT89	Infineon	BCX56-16
R1	1.5M Ohm/ 1%	R-EU_R1206W	R1206	Standard	
R2	1.5M Ohm/ 1%	R-EU_R1206W	R1206	Standard	
R3	2k Ohm/ 1%	R1206	1206	Farnell	1469985
R4	2k Ohm/ 1%	R1206	1206	Farnell	1469985
R5	2k Ohm/ 1%	R1206	1206	Farnell	1469985

Table of Contents

R6B	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R6C	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R6D	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R6E	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R7	20k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R8	0 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R9	20k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R10	1k Ohm/ 1%	R0805	0805	Farnell	1469847
R11	10 Ohm/ 1%	R0805	R0805	Standard	
R11A	10 Ohm/ 1%	R0805	R0805	Standard	
R12	47k Ohm/ 1%	R0805	R0805	Standard	
R13	0 Ohm/ 1%	R0805	R0805	Standard	
R14	NTC 5D-9	VDR-SL15	VDR-SL15	Farnell	9751866
R15	510k Ohm/ 1%	R0805	R0805	Standard	
R16	510k Ohm/ 1%	R0805	R0805	Standard	
R17	33k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R18	1.5M Ohm/ 1%	R-EU_R1206W	R1206	Standard	
R19	1.5M Ohm/ 1%	R-EU_R1206W	R1206	Standard	
R20	1.5M Ohm/ 1%	R-EU_R1206W	R1206	Standard	
R21	24.3k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R22	3.0k Ohm/1206/ 1%	R1206W	R1206W	Standard	
R23	1.0 Ohm/ 1%	R-EU_R1206	R1206	Standard	
R24	0 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R25	12k Ohm/ 1%	R0805	R0805	Standard	
R27	5.6k Ohm/ 1%	R0805	R0805	Standard	
R30	10 Ohm/ 1%	R0805	R0805	Standard	
R31	22 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R32	22 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R33	1k Ohm/ 1%	R0402	0402	Farnell	1469662
R34	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R34A	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R34B	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R34C	0.51 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R35	47k Ohm/ 1%	R0805	R0805	Standard	
R36	47k Ohm/ 1%	R0805	R0805	Standard	
R37	330 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R38	1.0k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R39	3.3k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R40	10 Ohm/ 1%	R-EU_R1206	R1206	Standard	
R41	10k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R42	220 Ohm/ 1%	R-EU_R0805	R0805	Standard	
R44	20k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R45	3.3k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R47	360k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R48	3.9M Ohm/ 1%	R-EU_R0805	R0805	Standard	
R49	3.3k Ohm/ 1%	R-EU_R0805	R0805	Standard	
R50	0.15 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R51	0.15 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R52	0.15 Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R53	2k Ohm/ 1%	R0805	0805	Farnell	1469884
R54	100k Ohm/ 1%	R-EU_R1206W	R1206W	Standard	
R55	33k Ohm/ 1%	R-EU_R0805	R0805	Standard	
TR1	750342886 rev03	PQ3220 Ns: 9Ts*2; NP: 60Ts Lr:120	EER35-35	Wuerth	750342886 rev03
VR1	10D561K	VDR-VS10	VDR-S10	Wuerth	820415511B
VR2	TL431CDBZR	TL431CLP	SOT23	Farnell	2095478
X1	CON3P	WAGO3P	WAGO3P	Farnell	1891581
not assembled					
C1A	not assembled				
C10A	not assembled				
C17	not assembled				
C18	not assembled				
C31	not assembled				
D1	not assembled				
D3	not assembled				
D15	not assembled				
D16	not assembled				
D19	not assembled				
HS1	not assembled				
Q1	not assembled				
R6	not assembled				
R6A	not assembled				
R26	not assembled				
R28	not assembled				
R29	not assembled				
T1A	not assembled				
PCB Version	**V1.1E/ 31.05.2016**		**130W-SCH-20160531_V1.1E_01.csv**		
PCB	**1.55mm, FR4, 35um, 2-Layer, position and reference print top/ bottom**				

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Major changes since the last revision

Date	Version	Changed by	Change Description

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