AN2103

Compact 40W LED driver – Using the RED2501 LED control IC

Overview

RediSem's 40W PPFC LED driver design is based on the RED2501 LED driver IC. It uses a unique single stage resonant converter with a passive charge-pump PFC circuit to give flicker-free DC output with good power factor and harmonic input. The design uses a single control IC, Bipolar transistors and passive PFC components to generate low output ripple with an excellent power factor, therefore achieving high performance for a low cost. The Resonant converter topology has inherently low EMI, making EMI compliance without a Y-capacitor possible resulting in low CM surge transmission to the LED. The 40W design uses a 2-charge-pump PPFC design to give good power factor correction and low harmonics over a wide input & output range. Some benefits of the 40W LED driver are:

- Low output current ripple < 5% - Zero LED flicker
- High efficiency >91%
- Low EMI (without a Y-capacitor) due to resonant converter
- Low cost 700V Bipolar transistor half-bridge
- Low cost Passive PFC circuit
- 320VAC for 1 hour operation due to half-bridge topology
- Single IC solution, equivalent to a 2 stage converter
- Low cost Primary-Side Regulation (PSR)
- Protection including SELV, short-circuit, open circuit, over-temperature

Figure 1: RediSem's 40W LED driver

Product Specifications

The 40W design uses 2 charge pump boost stages. For more details about RediSem's patented PPFC topologies and the charge pump, please review the design guide AN2101. This results in an excellent THD and PF whilst providing a low ripple to the LED load. Please review RediSem's other application designs to compare how a 1 or 3 charge pump design performs. The design uses a double sided PCB to make driver more compact. This is not necessary in cost sensitive applications.

Input	198 - 264VAC, 50Hz
Input voltage survival	0 - 320VAC 1 hour
Input Power	<45W
Output Current	Constant Current 900mA +/- 5%
Output Voltage	21-45V
Output Power	40.5W
Efficiency	> 91% at full load
Output Current Ripple (pk-pk)	< 10% pk-pk
THD	6% @ full load, 230VAC typical
Power Factor	0.97 @ full load, 230VAC typical
Size	93x39mm, 20mm component height
SELV	Peak output voltage < 55V
Protection	Short circuit, Open Circuit, OTP
Surge	1kV Differential, 2kV Common mode
Converter	Single-Stage CC LLC converter with dual PPFC boost stage
Controller IC	RED2501AD SO8 LLC PSR IC
Component Count	59 electronic components

Schematic

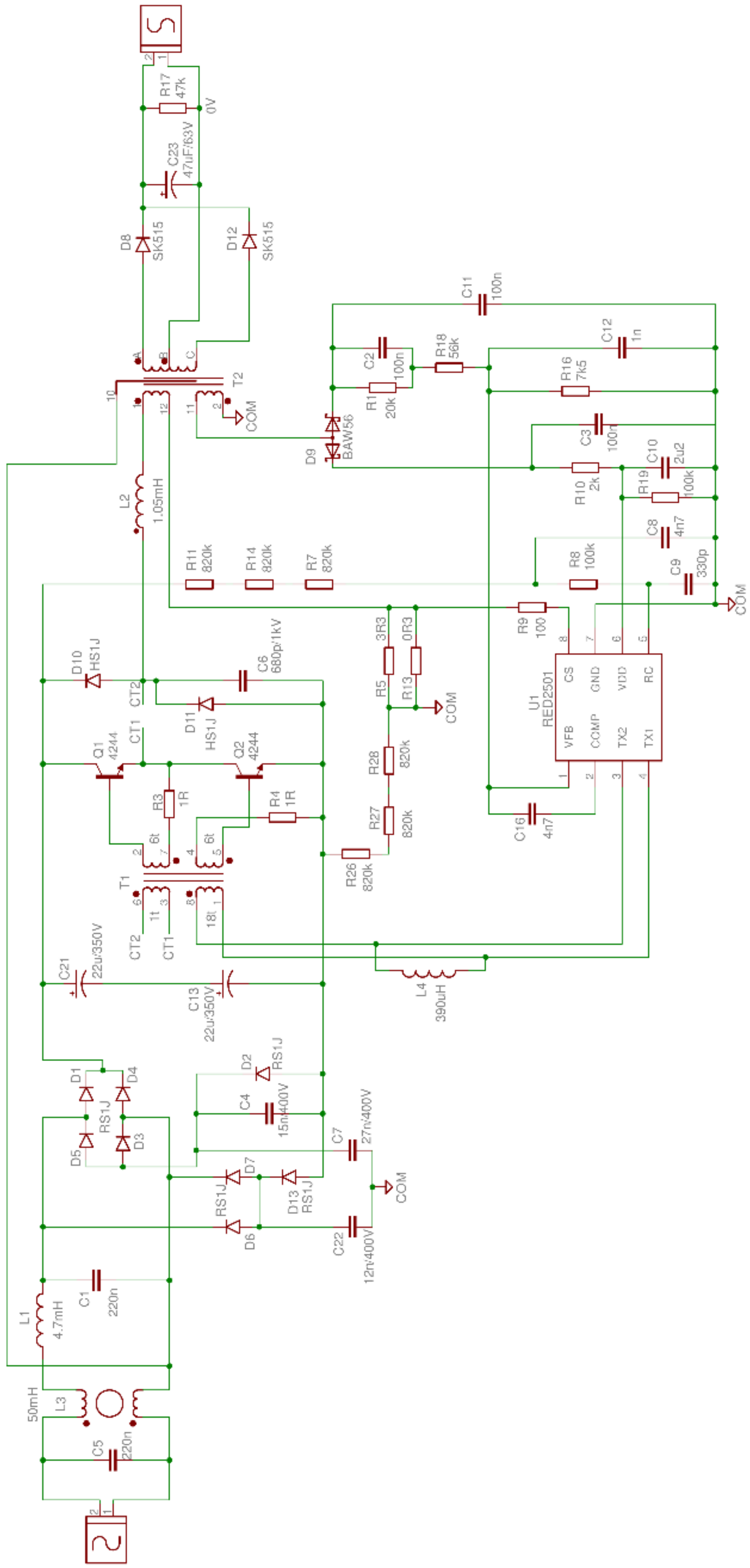


Figure 2: 40W LED Driver Schematic

Test Results

Tests have been carried out with an open unit on the bench at 25C ambient temperature. Efficiencies usually improve slightly if the unit is allowed to heat up. Pk-pk output ripple is measured with switching frequency ripple and 100Hz ripple. LF ripple is measured without the switching frequency ripple.

Electrical Characteristics				
Input voltage	**198V**	**230V**		**264V**
Load Condition	**45V**	**25V**	**45V**	**25V**
Input Power	43.6W	26.1W	44.1W	26.2W
Output Power	39.8W	22.7W	40.4W	22.7W
Output Voltage	45V	25V	45V	25V
Output current	884mA	908mA	898mA	909mA
Output Ripple pk-pk LF		2.9%	2.3%	
Output Ripple pk-pk		6.3%	5.4%	
Efficiency		86.9%	91.7%	

Output Regulation							
Output voltage	**Io**	**Input power**	**Efficiency**	**Power Factor**	**THD**	**LF Ripple**	
45V	898mA	44.07W	91.70%	0.978	6.3%	48mA	5.3%
43V	898mA	42.28W	91.33%	0.977	5.3%	46mA	5.1%
41V	899mA	40.54W	90.92%	0.975	5.0%	45mA	5.0%
39V	900mA	38.76W	90.56%	0.973	5.7%	42mA	4.7%
37V	901mA	36.96W	90.20%	0.971	6.8%	40mA	4.4%
35V	902mA	35.17W	89.76%	0.967	8.2%	36mA	4.0%
33V	904mA	33.37W	89.40%	0.964	9.7%	34mA	3.8%
31V	905mA	31.55W	88.92%	0.960	11.2%	32mA	3.5%
29V	906mA	29.75W	88.32%	0.955	12.7%	30mA	3.3%
27V	907mA	27.94W	87.65%	0.949	14.2%	29mA	3.2%
25V	908mA	26.12W	86.91%	0.943	15.6%	29mA	3.1%
23V	909mA	24.30W	86.04%	0.936	17.0%	28mA	3.1%
21V	910mA	22.48W	85.01%	0.927	18.3%	25mA	2.7%

Line Regulation			
Input voltage	**Io**	**Input power**	**Efficiency**
165Vac	680mA	33.62W	91.02%
170Vac	736mA	36.35W	91.11%
180Vac	811mA	39.96W	91.33%
190Vac	861mA	42.39W	91.40%
198Vac	884mA	43.49W	91.47%
210Vac	895mA	43.99W	91.55%
220Vac	897mA	44.05W	91.63%
230Vac	898mA	44.07W	91.70%
240Vac	899mA	44.12W	91.69%
250Vac	900mA	44.18W	91.67%
260Vac	901mA	44.23W	91.67%
264Vac	901mA	44.24W	91.65%
270Vac	902mA	44.28W	91.67%
280Vac	902mA	44.29W	91.65%
290Vac	903mA	44.35W	91.62%
300Vac	903mA	44.37W	91.58%
310Vac	904mA	44.43W	91.56%
320Vac	904mA	44.44W	91.54%

Harmonics		
	25V	45V
THD	15.60%	6.00%
3rd Harmonic	15.50%	5.00%
5th	0.70%	1.80%
7th	0.40%	1.30%
9th	1.80%	1.60%
11th	0.80%	1.50%
13th	0.10%	1.00%

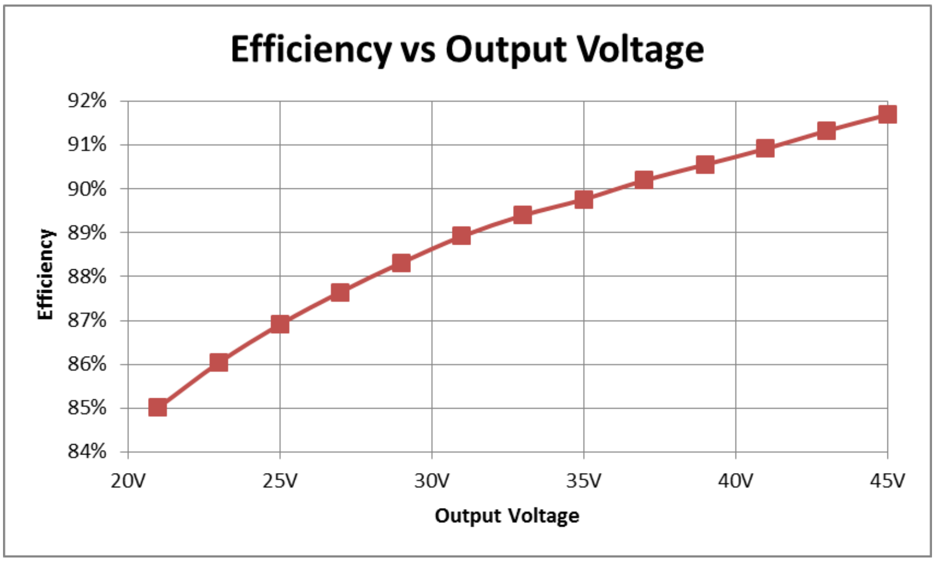


Figure 3: Efficiency @ 230VAC over output voltage range

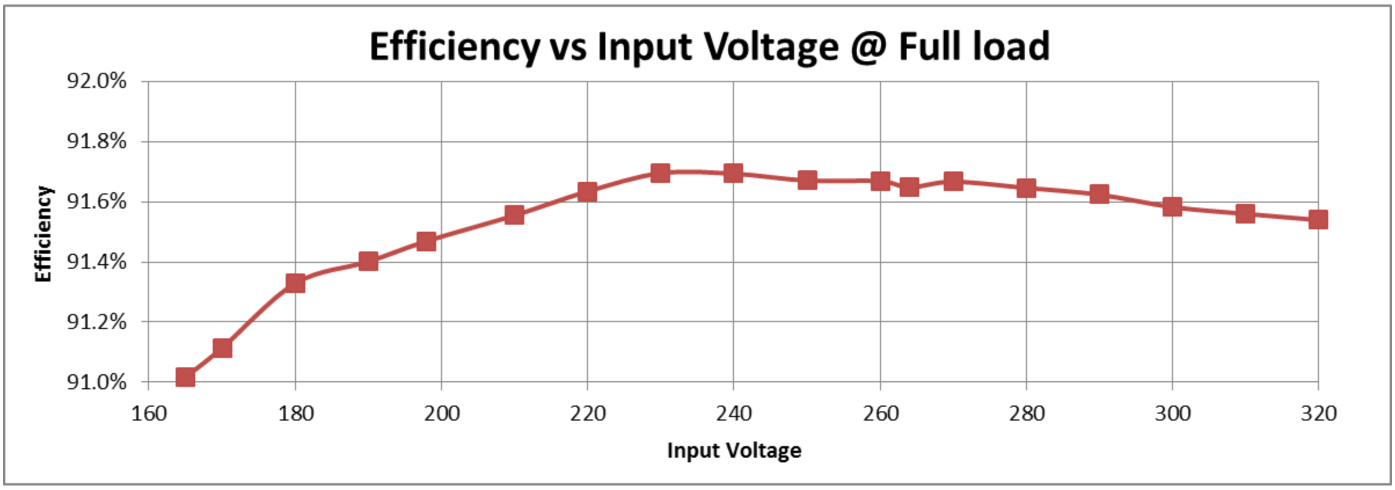


Figure 4: Efficiency over a wide mains input range (full load 45V out)

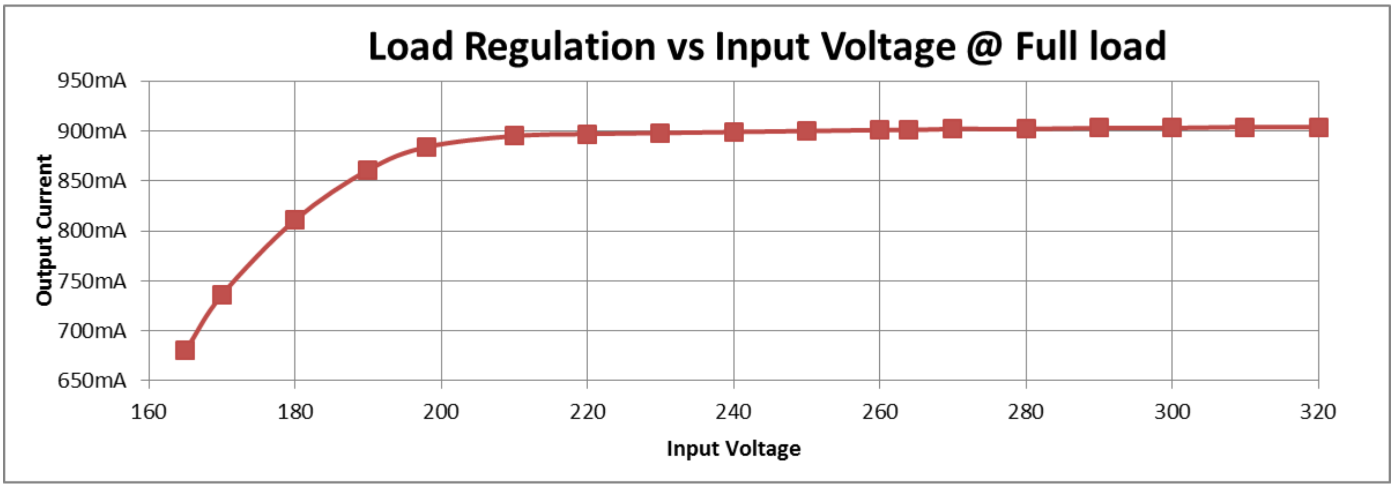


Figure 5: Output regulation over a wide mains input range (full load 45V out)

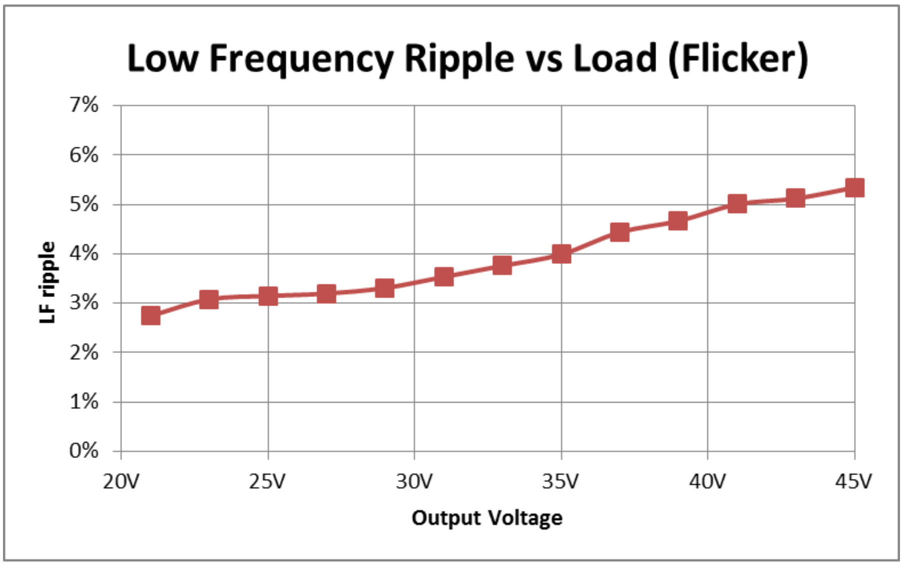


Figure 6: Low Frequency ripple (Flicker) @ 230V over output voltage

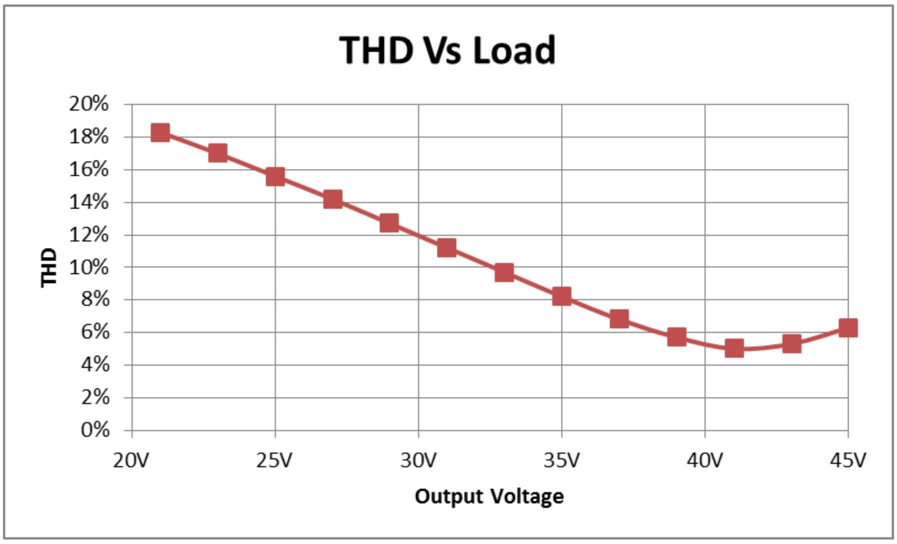


Figure 7: THD @ 230V over output voltage

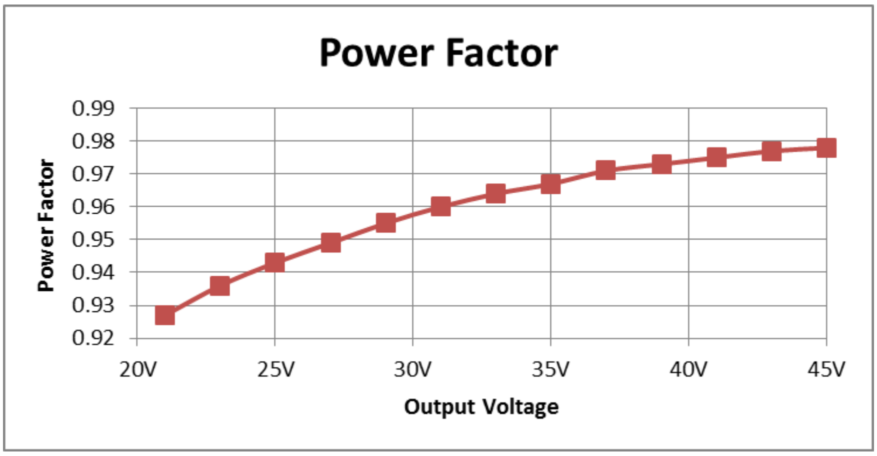


Figure 8: Power Factor @ 230V over output voltage

Thermal characteristics

Component temperatures have been measured with the PCB housed in a plastic box in a fan circulated oven.

Temperature	198V		264V	
	43V	23V	43V	23V
Ambient	55.5C	55.3C	55.5C	55.4C
Top transistor Q1	92.0C	92.2C	94.0C	99.9C
Bottom transistor Q2	96.5C	89.8C	91.6C	97.5C
Transformer T2	92.4C	83.2C	90.2C	84.1C
Main inductor L2	95.7C	95.9C	97.5C	100.7C
Bulk Cap C13	82.5C	78.1C	81.8C	80.4C
Common mode L3	79.3C	70.4C	75.2C	69.4C
Diff mode L1	88.2C	75.5C	81.9C	73.9C
Schottky diode D8	90.5C	85.4C	89.7C	85.9C
Schottky diode D12	80.5C	78.1C	79.9C	78.6C

Waveforms

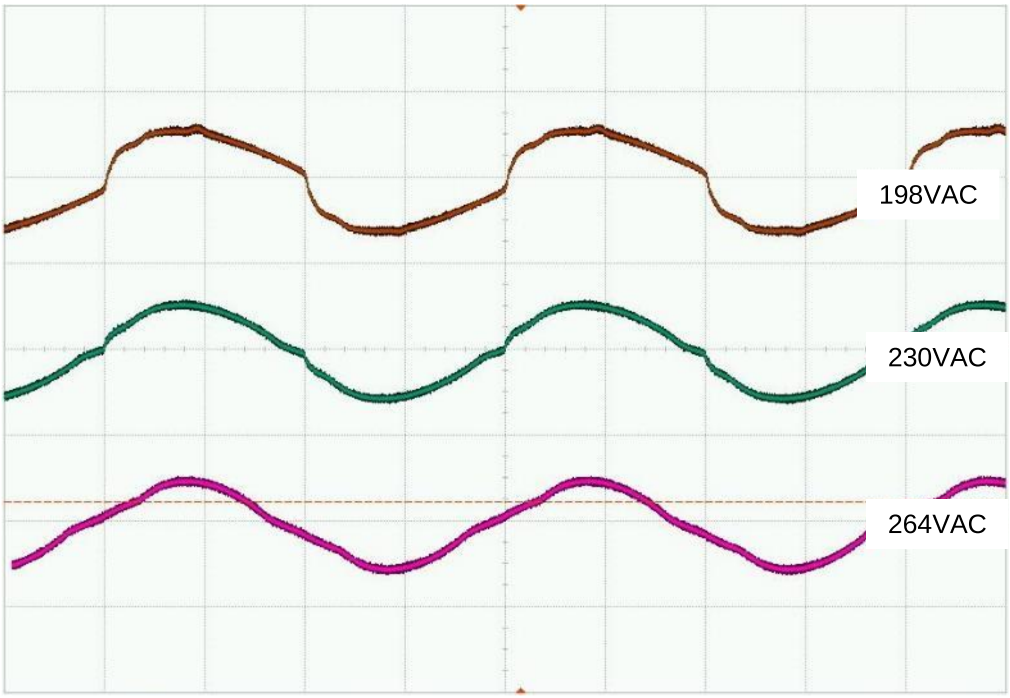


Figure 9: 50Hz Input current 40W @ 198, 230, 264VAC

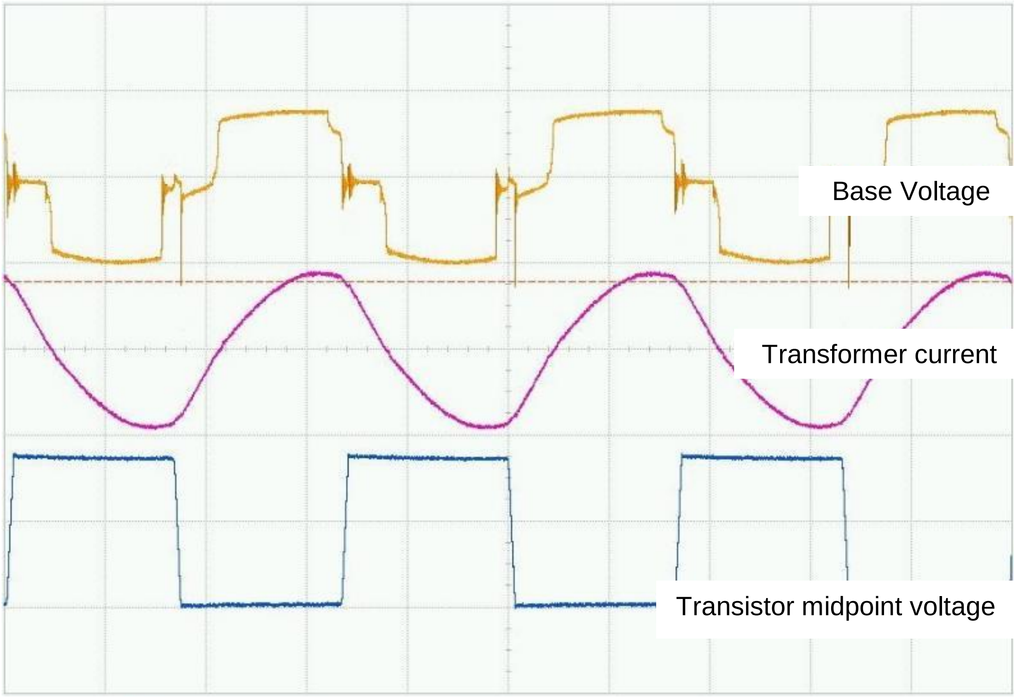


Figure 10: LLC switching current, midpoint, Vbe

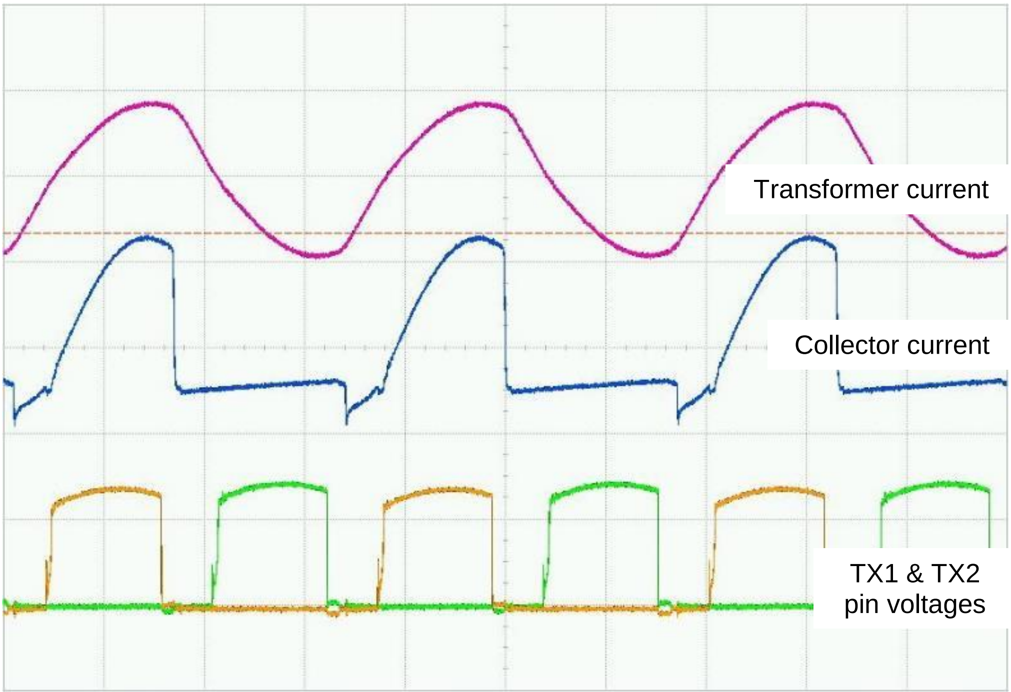


Figure 11: Base drive waveforms, TX1, TX2, transistor current, total current

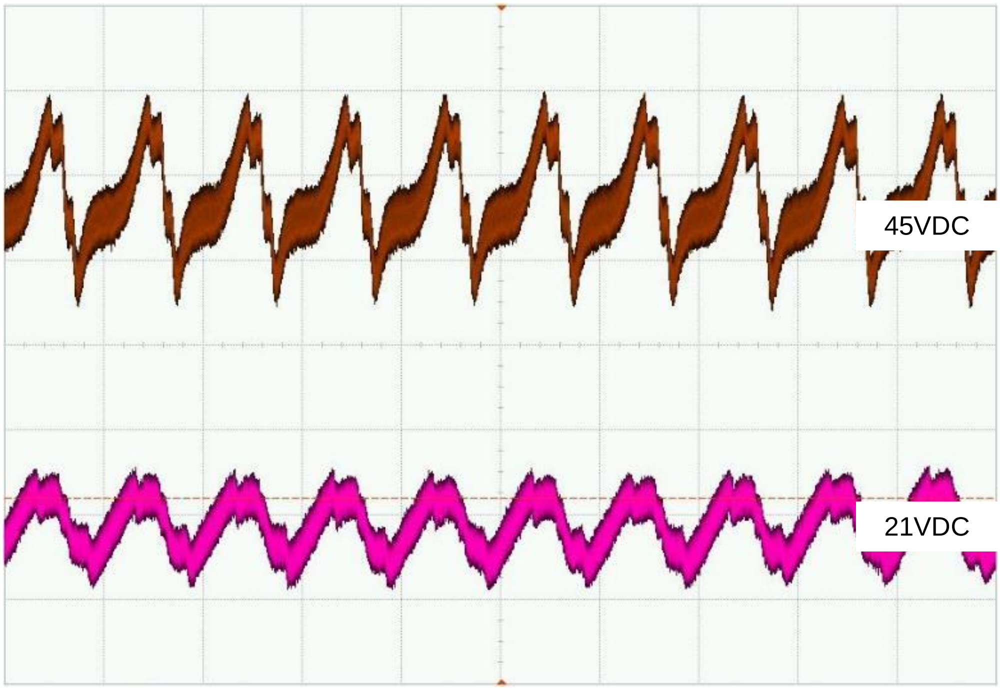


Figure 12: 100Hz Output current ripple, full load & half load 230VAC (20mA/div)

Conducted EMI results

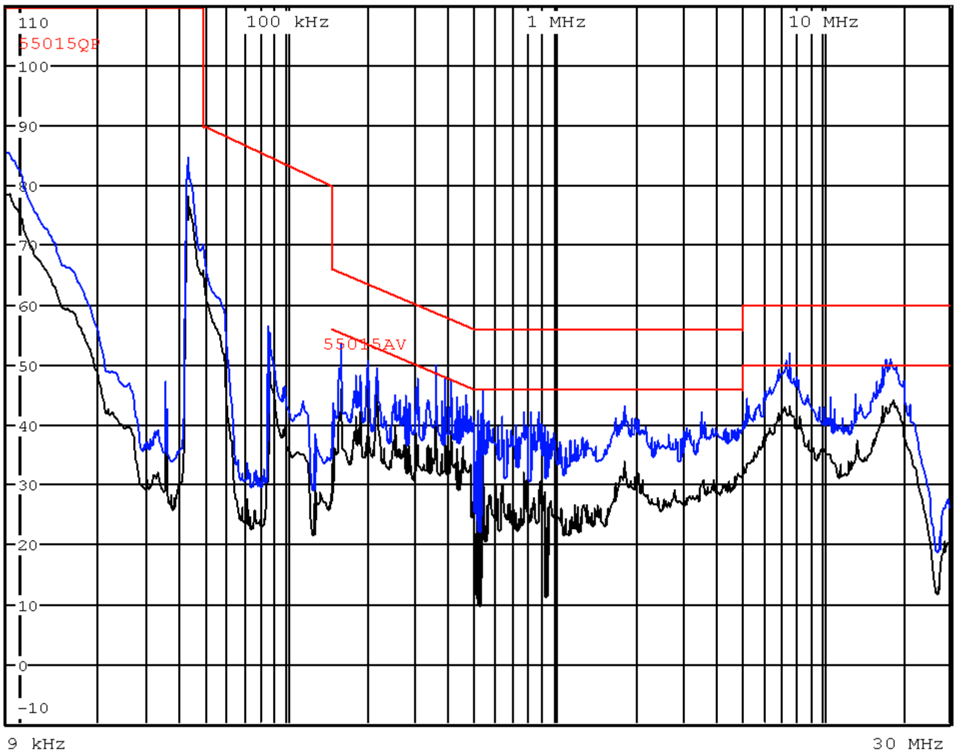


Figure 13: 40W driver conducted emissions

Please note that the clips on the transformer are connected to the “quiet” point. Failure to ground the core will result in an increase of approximately 7dB in EMI over the frequency range of 150kHz to 5MHz.

40W Driver BOM

Code	Description	Qty	Supplier	Part no.
C1, 5	220nF X2 MKP 20% 275VAC	2	Tenta	MEX224K275A203
C2,3,11	100nF 0603 X7R 10% 25VDC	3		
C4	15nF MKP 5% 400VDC	1	Faratronic	C312G153J3SC000
C6	680pF 1206 X7R 10% 500VDC	1		
C7	27nF MKP 5% 400VDC	1	Faratronic	C312G273J40C000
C8,16	4.7nF 0603 X7R 10% 50VDC	2		
C9	330pF 0603 COG 5% 50VDC	1		
C10	2.2uF 0603 X7R 10% 16VDC	1		
C12	1nF 0603 X7R 10% 16VDC	1		
C13, 21	22uF ELEC 20% 350VDC	2	Aishi	EGW2VM220W20OT
C22	12nF MKP 5% 400VDC	1	Faratronic	C312G123J3SC000
C23	47uF ELEC 20% 63VDC	1	Aishi	ERM1JM470F12OT
D1,2,3,4,5,6,7,13	RS1J SMA Fast Diode 600VDC 1A	8	TSC	RS1J R3
D8, D12	SK515C SMC Schottky 150VDC 5A	2	TSC	SK515C
D9	BAW56 SOT23 Dual Diode	1		
D10,D11	HS1J SMA Ultrafast Diode 600VDC 1A	2	TSC	HS1J
L1	4.7mH Drum Core 10x16	1	Boody	BDF-9375-664-0
L2	1.05mH RM8 Resonant Inductor	1	Boody	BDF-9374-664-0
L3	50mH UU9.8 CM	1	Boody	BDF-9376-664-0
L4	390uH 0410 0.25W Axial	1		
R1	20k 0603 0.06W 1%	1		
R3,4	1R 0603 0.06W 1%	2		
R5	3.3R 1206 0.25W 1%	1		
R7,11,14,26,27,28	820k 0805 0.125W 1%	6		
R8,19	100k 0603 0.06W 1%	2		
R9	100R 0603 0.06W 1%	1		
R10	2k 0603 0.06W 1%	1		
R13	0.3R 1206 0.25W 1%	1		
R16	7.5k 0603 0.06W 1%	1		
R17	47k 1206 0.25W 1%	1		
R18	56k 0603 0.06W 1%	1		
P1, P2	Terminal 2 Pin	2		
Q1,Q2	BJT 700V 3A TO126 NPN	2	Jilin	3DD4244DM Ts=2-2.5us
T1	Base Drive 18:6:6:1 turns	1	ACME	A062T9*5*4CRX
T2	RM8 power transformer	1	Boody	BDF-93XX-664-0
U1	RED2501 LLC LED controller IC	1		
	Total Component Count	59		

Supplier List

Jilin – Jilin Sino Microelectronics (Huawei) - 吉林华微 www.hwdz.com.cn
ACME Electronics -越峰电子 www.acme-ferrite.com.tw
Boody - 惠州宝电 http://www.boody.com.cn
Fara - Xiamen Faratronic - 厦门法拉 http://www.faratronic.com
Aishi - Aihua Global - 湖南艾华 www.aihuaglobal.com
TSC - Taiwan Semiconductor - 台半 www.taiwansemi.com

Wound Components

Base Drive transformer (T1)

The base drive transformer is a key part of the converter. It is important to start with the suggested core material, size and turns ratio before changing parameters. Read the application note AN2101 for more details. L4 has been added in parallel with the base drive winding to “trim” the base drive inductance for optimal switching performance.

申請單號： G1505589 4/6

ACME Electronics orporation
越峰電子材料股份有限公司

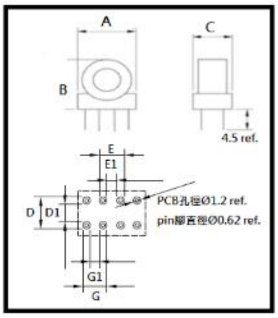
規格書名稱/Specifications：A062T9*5*4C(RX)	客戶料號/Customer P/N：

一、形狀、尺寸、材質/Shape, dimensions & material：

(1)形狀、尺寸：如下圖所示(單位：mm)/Shape & dimensions：

(2)材質Material：

圖例/Drawing：



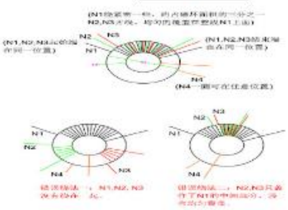
尺寸規格/Dimensions(mm)：

繞線后尺寸:

A：	10.5±0.5
B：	13±0.5
C：	7±0.5
D：	5.2 max
D1：	2.8 min
E：	4 max
E1：	1.6 min
G：	3.8 max
G1：	1.4 min

繞線前尺寸:

A：	10Max
E：	4.2Min
C：	4.9Max



二、電磁特性規格(Electrical Characteristics)：

高導磁率材質(High Ui Materials)

材質 (Material)	初導磁率ui (Initial Permeability)
A062	6000±25%

測試條件(Test Conditions)

測試項目 Test items	測試條件 Test Conditions	測試溫度Test Temperature	規格Spec	測試儀器 Test Equipment	測試線包 Test Winding	測試點位	備注Remark
W1(mH)	1KHz/0.25V	25℃ ±3℃	1.1±25%	E4980A/卡尺	0.2mm/ 18Ts	1--8	
W2a(uH)	1KHz/0.25V		110±25%		0.2mm/ 6Ts	2--7	
W2b(uH)	1KHz/0.25V		110±25%		0.2mm/ 6Ts	4--5	
W3(uH)	1KHz/0.25V		2.82±25%		0.25mm/ 1Ts	3--6	
W4(uH)	1KHz/0.25V		50Max			短路4--5 測試1--8	

塗層顏色Coating Color（選擇項目為“■”：Selected items is ■）：

□非塗裝Uncoating ■綠色Green □黑色Black □淺綠色Light Green □灰色Gray □透明Transparent □藍色Blue

注意事項: Remarks

1.該產品為繞線后尺寸規格

2.在1腳位面，磁环用白色油漆做标记.

3.繞線前成品規格為A062T9*5*4C ，A/B級，滿足需求即可委外繞線(AL內控2820+/-20%)

4.繞線規範檢測(如右圖)各繞組不能剪斷分開。

5.產品電感和耐壓測試，抽樣按AQL-0.065標準執行。

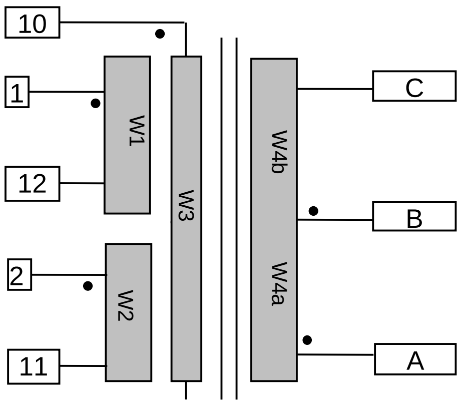
繞線後成品耐壓測試

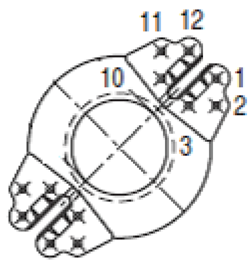
測試點位	規格Spec
1--2	800VAC/0.5A/60s
1--3	800VAC/0.5A/60s
1--4	800VAC/0.5A/60s
2--3	800VAC/0.5A/60s
2--4	800VAC/0.5A/60s
3--4	800VAC/0.5A/60s

AR01-60107-A

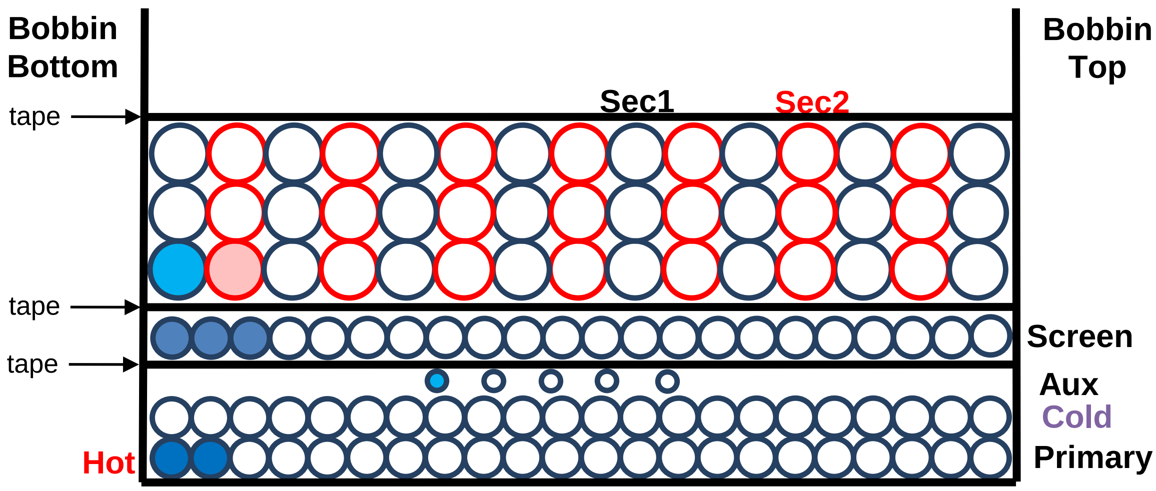
Transformer (T2)
Core: RM8
Material: Acme P47, TDK PC44 or equivalent, gapped

The recommended transformer structure is shown below. It is important to follow the winding structure and direction as it particularly affects EMI. The two secondaries should be wound bifilar as this gives best EMI performance and lowest overshoot on the output diodes. The transformer also has clips to hold the transformer together. This helps EMI significantly, so please test EMI with these clips fitted..





Winding	Turns	Start Pin	End Pin	Wire	Layers	Type	Purpose	Direction
W1	30	1	12	0.25mmx2s	2	ECW	Primary	Clockwise 順時
W2	5	2	11	0.14mm	1	ECW	Aux	Clockwise 順時
Tape	1							
W3	10	10	-	0.23mmx3s	1	ECW	Prim Screen	Anti-clockwise 逆時
Tape	1							
W4a	19	A	B	0.35mm	3	TEXE	Secondary	Clockwise 順時
W4b	19	B	C	0.35mm	3	TEXE	Secondary	Clockwise 順時
Tape	2							



Drum Inductor winding (L1)

Core dimensions: 10mm diameter x 16mm high x 4mm centre core diameter
Wire: 0.23mm ECW
Winding: 350 turns
Inductance: 4.7mH +/- 10%

Resonant Inductor winding (L2)

Core: RM8
Material: Acme P47, TDK PC44 or equivalent, gapped
Wire: 30 x 0.07mm ECW
Winding: 110 turns, start at Pin1 & end Pin7
Inductance: 1.05mH +/- 3%

Note that Pin1 is connected to the "hot" noisy end of the winding. This keeps the noisy end of the winding on the inside of the bobbin and the quieter end on the outside to act as a screen. If the converter is being affected by noise, the core can be connected to a quiet point.

Common Mode inductor (L3)

Core: UU9.8
Material: μ_i = 10k or greater with polished cores
Wire: 0.21 ECW
Winding: 140 turns
Inductance: > 50mH

Note that greater inductance will give greater EMI margin in the region of 300kHz to 5MHz

Changing the Output Characteristics

Change the output Current

To adjust the output current the only change that is required is to change the secondary turns in the transformer. More turns gives proportionally higher output voltage and less current. The converter has a maximum output power of:

$$0.9A * 45V \;= 40.5\text{W}$$

Change the number of secondary turns to select any combination of current and voltage that results in 40.5W output power and the input characteristics will remain the same. For example, if an output current of 1.2A is required instead of 900mA, the maximum output voltage will be:

$$\frac{40.5W}{1.2A} = 34\text{V}$$

and the required number of secondary turns will be:

$$19 \text{ turns} * \frac{0.9\text{A}}{1.2A} = 14 \text{ turns}$$

So, by reducing the number of secondary turns from 19 to 14, the output current will change from 900mA to 1.2A. Leave all other components the same and PF, THD, % ripple will all remain the same. When changing output voltage and current the only components that need to change are the output components that are shown in the figure below:

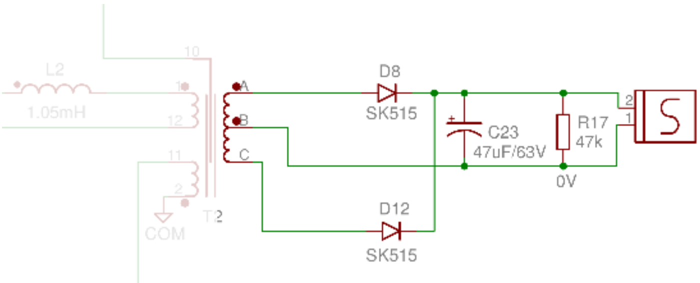


Figure 14: Secondary side components

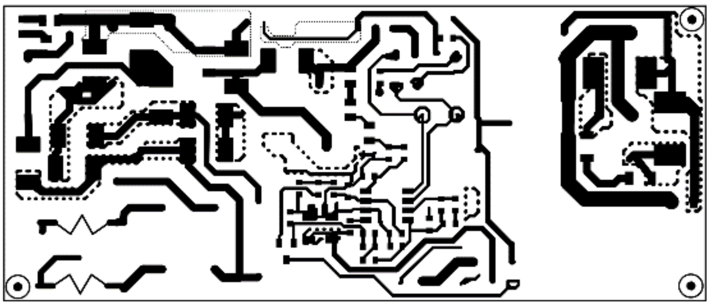
To improve performance further:

- Increase the secondary wire cross-sectional area proportional to the increase in output current
- For optimal EMI performance, change the screen proportionally to the number of output turns
- Reduce the output diode voltage to 100V and efficiency will improve.
- Reduce the output capacitor voltage rating and increase the capacitance value, both proportional to the output current increase.
- For fine-tuning the output current, change the number of primary turns slightly, or change R5

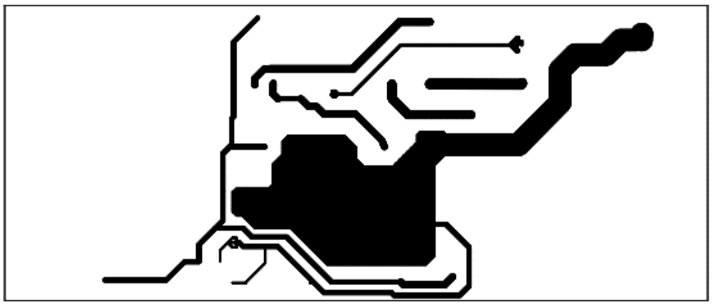
Change the LED output voltage range

Significant cost savings can be made and / or the performance can be improved if the output voltage range is reduced. A small reduction in output voltage range can result in a reduction in HT voltage and therefore HT caps C13 & C21 can become one 10uF 500V e-cap. Further reduction in output voltage range from 50% to around 25% can result in the removal of one of the boost stages, D6, D7, D13, C22. In addition, the wound components can also be optimised. Consult the design note AN2101 or other RediSem reference designs for further details.

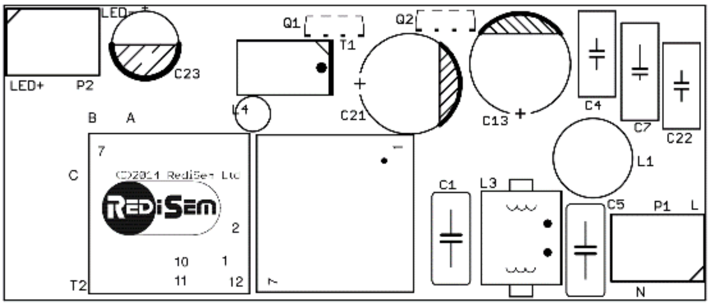
PCB Layout



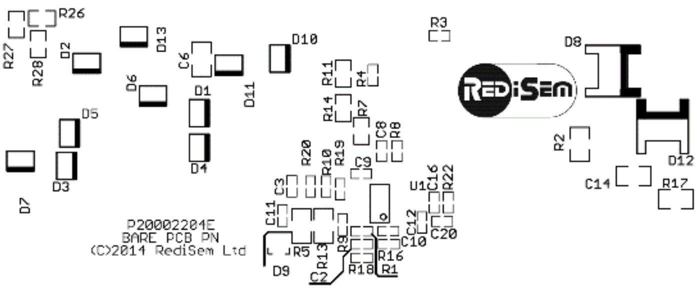
Bottom Copper



Top Copper



Top Silkscreen



Bottom Silkscreen

PCB bottom View

About RediSem

RediSem designs and supplies semiconductor ICs for energy efficient power management applications. RediSem uniquely combines extensive experience in power electronics with in-depth knowledge of IC design and manufacturing and works with the world's top suppliers and customers. RediSem's unique patented IC and converter technologies deliver maximum efficiency and performance, while reducing overall bill of materials cost through the use of bipolar transistors.

RediSem's range of LED control ICs can be used with RediSem's patented single stage LED control solution to provide very high efficiencies with low EMI – all with a single IC. When combined, these features deliver a low cost, high performance LED driver solution.

RediSem's fluorescent driver controller ICs achieve the advanced performance of MOSFET drivers by using bipolar transistors at a fraction of the BOM cost. RediSem's range of SMPS (Switched Mode Power Supply) control ICs enables low-cost LLC converters with bipolar transistors that deliver very high efficiencies already meeting DoE Level VI regulations, have low standby power and have much lower EMI compared to flyback converters.

All RediSem ICs are supported by comprehensive turn-key application designs enabling rapid time to market. For further information please use our contact details below

Contact Details

RediSem Ltd.
301-302 IC Development Centre
No 6 Science Park West Avenue
Hong Kong Science & Technology Park
Shatin, New Territories
Hong Kong

Tel. +852 2607 4141
Fax. +852 2607 4140
Email: info@redisem.com
Web: www.redisem.com

Disclaimer