UM10433

SSL2103 dimmable isolated LED driver demo board

Rev. 1 — 9 December 2010 **User manual**

Document information

Info	Content
Keywords	SSL2103, LED driver, mains dimmable, constant current, driver, mains supply, AC/DC conversion, user manual.
Abstract	This is a user manual for the SSL2103 mains dimmable 22 W LED.

Revision history

Rev	Date	Description
v.1	20101209	First issue

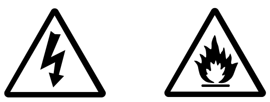
1. Introduction

The SSL2103 LED driver board is an isolated flyback converter featuring the SSL2103 controller. It is designed for applications with multiple high power LEDs that require high efficiency, galvanic isolation and a safe output voltage. It is mains dimmable for both forward phase (triac) dimmers, and reverse phase (transistor) dimmers. The design is aimed to demonstrate high performance and efficiency. It operates at 70 kHz and produces a regulated output current of up to 800 mA to drive from 6 LEDs to 18 LEDs using a 120 V (AC) or 220 V (AC) input. It can achieve an efficiency of up to 85 % with the help of an external MOSFET transistor. Isolation voltage is 2500 V.

2. Safety warning

WARNING

Lethal voltage and fire ignition hazard



The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

The board is to be connected to a mains supply so touching the reference board during operation must be avoided at all times. An isolated housing is obligatory when used in uncontrolled, non laboratory environments. Even though the secondary circuit with LED connections has galvanic isolation, this isolation is not according to any regulated norm. Galvanic isolation of the mains phase using a variable transformer is always recommended. These devices can be recognized by the symbols shown in Figure 1.

a. Isolated

b. Not Isolated

Fig 1. Variac isolation symbols

3. Connecting the board

Remark: All components referred to in the text can be located on Figure 7 "Board schematic diagram (part 1)" or Figure 8 "Board schematic diagram (part 2)" and connectors can be found on Figure 2 "Board connection diagram".

The board is optimized for either a 230 V (50 Hz) or a 120 V (60 Hz) mains supply. In addition to optimizing the mains voltage, the board is designed to work with multiple high-power LEDs with a total working voltage of between 20 V and 63 V. The output current can be limited using trimmer R68. It is possible to request the delivery of a dedicated LED load that is to be connected to K3. Connector K2 can be used to attach other LED loads. The output voltage is limited to 65 V. It is recommended to connect the LED load to the driver board, before powering up the driver, to avoid potential damage to LEDs due to inrush current as a result of the hot-plugging.

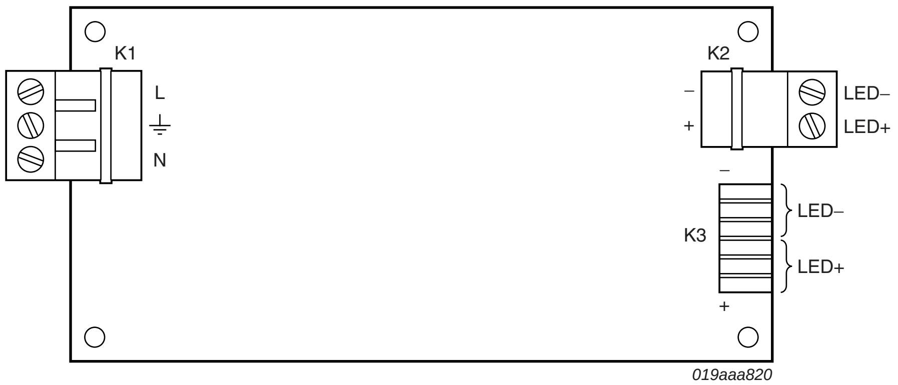


Fig 2. Board connection diagram

If a galvanically isolated transformer is used, it should be placed between the AC source and the dimmer/demo board. Connect a user defined LED (string) to connector K2 as shown in Figure 2. Note that the anode of the LED (string) is connected to the bottom side of this connector.

Remark: When the board is placed in a metal enclosure, the middle pin of connector K1 should be connected to the metal casing for grounding.

4. Specifications

Table 1 provides the specifications for the SSL2103 22 W LED driver

Table 1. Specifications

Parameter	Value	Comment
AC line input voltage	85 V (AC) to 276 V (AC)	board has been optimized for 230 V (AC) or 120 V (AC) ± 10 % variation
Output voltage (LED voltage)	20 V (DC) to 63 V (DC)	minimum load = 6 LEDs
		maximum load = 18 LEDs
Output voltage protection	65 V (DC)	
Output power (LED power)	22 W nominal	
Efficiency	> 80 %	at T_{amb} = 25 °C, nominal input voltage, nominal output current, maximum load (18 LEDs), See Figure 13 and Figure 14
Power Factor	> 0.9	nominal input voltage, nominal output current, maximum load (18 LEDs), See Figure 17 and Figure 18
Output current (LED current)	350 mA nominal	adjustable with trimmer to 800 mA at minimum load (6 LEDs)
Load current accuracy/output voltage dependency	< 5 %	nominal output current, See Figure 11 and Figure 12
Load current accuracy/input voltage dependency	< 5 %	nominal output current, See Figure 15 and Figure 16
Output current ripple	60 mA	nominal output current, maximum load (18 LEDs), See Figure 19
Switching frequency	50 kHz to 90 kHz	-
Dimming range	100 % to 0 %	for triac dimmer
Board dimensions	117 mm × 50 mm × 30 mm	L × W × H
Operating temperature	0 °C to 85 °C	-
Isolation voltage	2.5 kV	between primary and secondary circuit

5. Board photographs

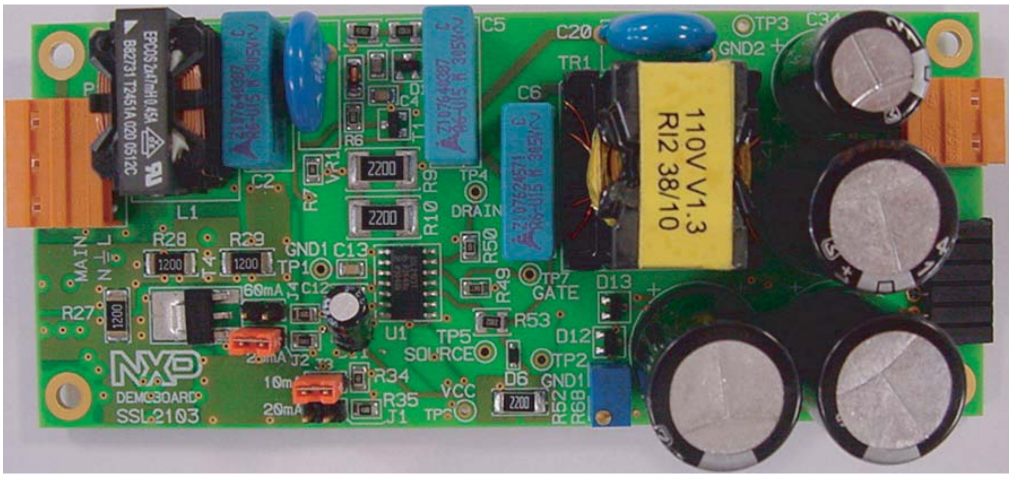


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Fig 3. Demo board (top)

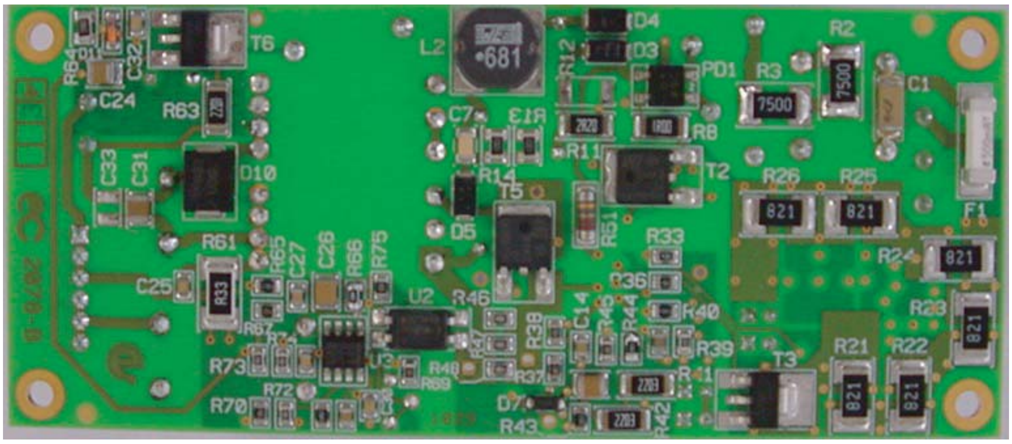

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Fig 4. Demo board (bottom)

6. Dimmers

Numerous dimmers have been tested by NXP Semiconductors. The dimming performance of the board may vary as different dimmers have different specifications. Table 2 and Table 3 show the range of dimmers that have been tested and found to be compatible with the board.

Table 2. Triac dimmer selection

Manufacturer	Type	Voltage V (AC)	Power range (W)	Load
BERKER	2819	230	60 to 400	incandescent
BERKER	2873	230	20 to 500	halogen/incandescent
Bush-Jaeger	2250U	230	60 to 600	halogen/incandescent
Bush-Jaeger	2200U	230	60 to 400	incandescent
LICHTREGLER	T10	230	60 to 300	incandescent
Gira	0300	230	60 to 400	incandescent
Gira	1184	230	60 to 400	incandescent
Lutron	S-600PH-WH	120	600	halogen/incandescent
Lutron	MIR-600	120	600	halogen/incandescent
Levitron	6602-IW	120	600	incandescent

Table 3. Transistor dimmer selection

Manufacturer	Type	Voltage V (AC)	Power range (W)	Load
JUNG	243 EX	230	20 to 360	halogen/incandescent
JUNG	225 TDE	230	20 to 525	halogen/incandescent
BERKER	2874	230	20 to 525	halogen/incandescent
BERKER	286710	230	20 to 360	halogen/incandescent
Bush-Jaeger	6513U	230	40 to 420	halogen/incandescent
Gira	0307	230	20 to 525	halogen/incandescent
PEHA	433 HAB	230	20 to 315	halogen/incandescent

7. Functional description

Remark: All components referred to in the text can be located in Figure 7 "Board schematic diagram (part 1)" or Figure 8 "Board schematic diagram (part 2)".

The IC SSL2103 is the latest extension to the SSL2101/SSL2102 platform and gives designers the flexibility of any power level by controlling external switches. In this application, it controls the flyback converter part and ensures proper dimmer operation. One of these switches controls the flyback input power and stores energy in the transformer TR1. The switch is opened when the duty factor has exceeded the level set by the PWMLIMIT pin, with a maximum of 75 %, or when the voltage on the SOURCE pin exceeds 0.5 V. The energy stored in the transformer is then discharged to D10 and the output capacitors, and finally absorbed by the load.

When dimmers are used, the circuit detects the rectified voltage change and reduces the duty cycle and oscillator frequency to reduce the output current.

The circuit has a bleeding circuit that drives two external current sinks called bleeders. These are the weak bleeder (pin WB_DRV) and the strong bleeder (pin SB_DRV).

When the voltage on both of these pins is below a certain value (typically 52 V) the strong bleeder switch (T4) closes, providing a current path that loads the dimmer during zero voltage crossing. This results in the dimmer timer being reset.

When the voltage on either of these pins is above 52 V, and the voltage on the ISENSE pin is above –100 mV, the weak bleeder switch (T3) closes. This provides a current path that loads the dimmer while the converter draws insufficient current to stabilize the dimmer latching.

The strong bleeder will always switch but the weak bleeder will not activate until the output power drops below 8 W. This happens when the LEDs are dimmed or when the maximum LED power is tuned to below 8 W. It allows the system to operate with the majority of field installed dimmers. See Figure 5 and Figure 6 that show bleeder drive outputs compared with time, for dimmed and undimmed operations.

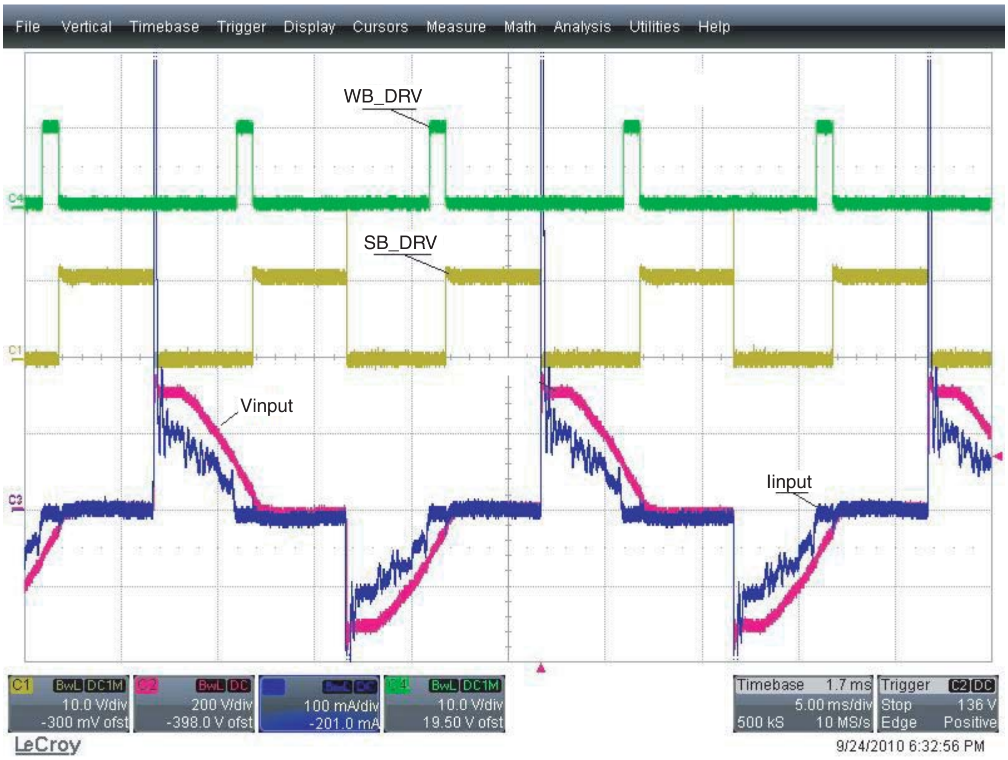


Fig 5. Dimmed bleeder operation

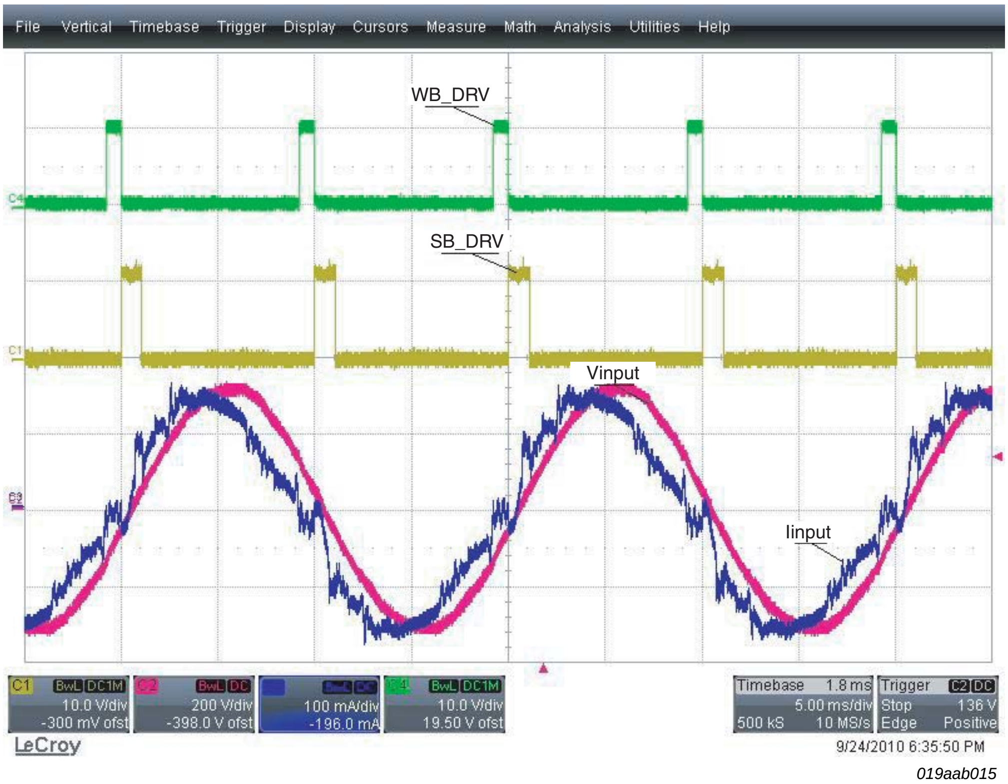


Fig 6. Undimmed bleeder operation

7.1 Bleeder settings

The demo board allows the users to disable the bleeders or choose between two configurations of load. This ensures good operation of the dimmer with the converter or a reduction of power losses in the bleeders.

- Weak bleeder - jumper (J1-J3) selects a current of 10 mA or 20 mA
- Strong bleeder - jumper (J2-J4) selects a current of 25 mA or 60 mA

7.2 Power factor

This board is optimized to work with a power factor above 0.9. In order to achieve this, the converter operates at constant t_{on} mode. The output power of the converter is buffered by capacitors C21, C22, C23 and C34. Due to this configuration, the circuit has a resistive input current behavior during undimmed operation (see Figure 6). During dimmed operation however, not only the dimmer latch and hold current must be maintained, but a damper must be added to dampen the inrush current and to dissipate the electrical power stored in the LC filter within the dimmer. An active damping solution has been chosen for the demo board to improve efficiency (see Section 7.5).

7.3 Dimming detection

The dimming reference voltage is derived from a non-buffered rectified mains voltage. The dimming range is detected by sensing the average rectified voltage by a resistive divider. The converter duty factor and frequency is set by the voltage on the

BRIGHTNESS and PWMLIMIT pins (see Figure 7 and Figure 8). The peak current through the inductor is reduced by balancing the voltage levels at these two inputs, before the frequency of the converter falls. This eliminates audible noise from the transformer.

7.4 Output voltage and output current

Voltage and current regulation is achieved by utilizing two operational amplifiers. Both amplifier outputs are in an or-configuration, to drive the optocoupler U2. This is done via diodes D12 and D13 and the amplifier with the lowest output is dominant.

U3B is used for voltage control. The power supply output is sensed through resistive divider R73 and R74 and presented to the inverting input of the operational amplifier. The resistors are selected to provide 2.5 V to pin 5 when the output is at the desired maximum voltage (approximately 62 V in this case). Frequency compensation is provided by R/C network R71 and C28.

Current is controlled by sensing the output current through R61 and presenting the sense signal to U3A where it is compared to a trimmed down value from VC1. The output overcurrent threshold level is set by adjusting R68 so that the resultant voltage level presented to pin 3 of U3, with no output load, equals the voltage drop that appears across R61 at the maximum desired current. In this design, the nominal current is set at 350 mA which requires 105 mV of bias at pin 3 under no output load. Frequency compensation (bandwidth) of the current amplifier is set by R66 and C26.

7.5 Active damping - inrush current

A damper is required to limit inrush current. Inrush current occurs when the input capacitors encounter fast voltage changes as in the following situations.

- when the board is hot-plugged into an AC input source.
- when the board is fed from a leading edge phase cut dimmer.

There are many ways to perform damping. A single resistor is the cheapest solution but could lead to thermal issues and low efficiency. The damper resistor plays a major factor in the power losses of the system. At low power ratings (< 10 W), a serial resistor is suitable due to acceptable losses. At higher power, an active circuit becomes the preferred solution to achieve high efficiency.

The solution applied here utilizes an active damper using a MOSFET transistor (T2). T2 is used to bypass damping resistors R9 and R10 following inrush current. The MOSFET transistor will be ON as long as the current in the circuit is small enough to keep the bipolar transistor T1 from pulling down the gate of MOSFET T2.

8. Board optimization

The following modifications must be carried out in order to meet different customer application requirements.

8.1 Changing the output voltage and LED current

Compared to other topologies, a flyback converter has the major advantage that it is suitable for driving a broader range of output voltages. Essentially, changing the turns ratio while maintaining the value of the primary inductance, will shift the output working voltage accordingly. The efficiency of the driver is linked to the output voltage. A lower output voltage increases the transformation ratio and causes higher secondary losses. In practice, a mains dimmable flyback converter has an efficiency of between 80 % for high output voltages (such as 60 V) down to 50 % for low output voltages (such as 3 V). Synchronous rectification might become advisable to reduce losses at low voltages. The NXP TEA1791 can be used for this purpose. For exact calculations of transformer properties and peak current, refer to application note *AN10754* and the calculation tool that is provided with it.

8.2 Changing the output ripple current

The LED voltage, the LED dynamic resistance and the output capacitor determine the output current ripple. The value of C_{out} (21-22-23-34) has been chosen to optimize capacitor size with light output. A ripple of ± 25 % results in an expected deterioration of light output < 1 %.

The size for the buffer capacitor can be estimated from the following equation:

$$C_{out} = \frac{I_{LED}}{\Delta I} \times \frac{1}{6 \times f_{net} \times R_{dynamic}} \quad (1)$$

Example:

For a ripple current of ± 5 % with a mains frequency of 50 Hz and a dynamic resistance of 0.6 Ω, C6 is 20 ÷ (300 × 0.6) = 111 µF. For a ripple current of 25 % and a dynamic resistance of 6 Ω, 4 ÷ (300 × 6) = 2200 µF. Using a series of LEDs, the dynamic resistance of each LED can be added to the total dynamic resistance.

8.3 Improving the power factor

The power factor can be increased by reducing the primary capacitance to an absolute minimum to filter the converter. The current then follows the input voltage. This modification has the following consequences:

- it is necessary to greatly increase the output capacitance to minimize the output current ripple
- because the voltage ripple on the primary capacitors is larger, the peak current through the inductor must increase to have the same output power. This results in higher switching losses that can cause thermal issues. A transformer that can handle the higher current is also required
- dimmer support is improved because the current follows the input voltage. However, for some dimmer duty factors additional current bleeding is still necessary

8.4 Adapting to high power reverse phase (transistor) dimmers.

Reverse phase (transistor) dimmers differ in two ways that can be beneficial but can also cause problems with dimming detection:

- The negative phase-cut (trailing edge) causes no inrush current when the dimmer triggers. Triac dimmers have a sudden voltage difference over the input leading to a steep charge of the input capacitors. The resulting peak current leads to higher damper dissipation. Because this steep charge is missing, the input capacitors have less stress, and the input circuit is less prone to audible noise.
- Transistor dimmers contain active circuitry that requires a load charge during the time that the dimmer is active. The dimensioning of the circuit generating the internal supply voltage inside the dimmer is made critical in order to avoid excessive internal dimmer losses. This results in the remaining voltage drop over the lamp being low enough to reach the load charge. For dimmers such as the Busch-Jaeger 6519U, the minimum lamp load is specified at 40 W which is equivalent to a 1.3 kΩ resistor load at 230 V (AC). Such a load results in highly inefficient operation at low output power levels, since most energy is wasted driving the dimmer instead of producing light.

To minimize losses, the weak bleeder on the demo board is set to a maximum current of either 10 mA or 20 mA by using a jumper. The weak bleeder normally only switches on during dimmed operation. The voltage drop with some transistor dimmers is, however, not sufficient to cause full dimming range control (minimum 10 % instead of < 1 %). This is because in this application, the average rectified voltage is used to determine the dimming position. To compensate for the reduced voltage difference, voltage detection can be made more sensitive by replacing R41 with a zener diode, such as the BZV85-C200 for 230 V (AC) or the BZV85-C68 for 120 V (AC). Because of increased sensitivity, the dimming curve is also steeper when using triac dimmers.

8.5 Multiple driver support

It is possible to attach multiple converters to a single dimmer. When using triac dimmers the inrush current rises, though not proportionally, to the number of converters.

Transistor dimmers are more suitable for use with multiple converters because the dimming range increases with added bleeder action and there is no inrush current.

9. Board schematic

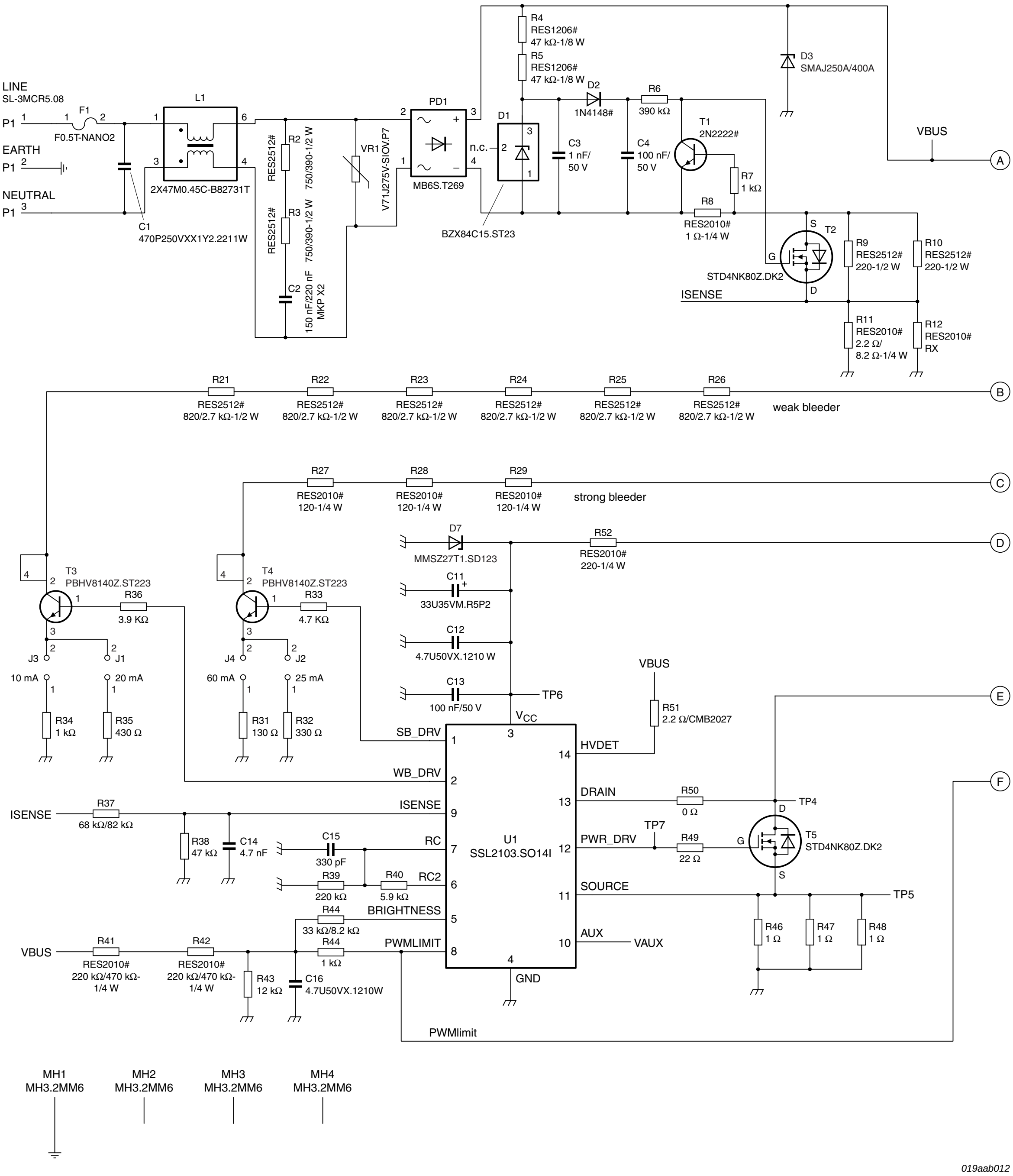


Fig 7. Board schematic diagram (part 1)

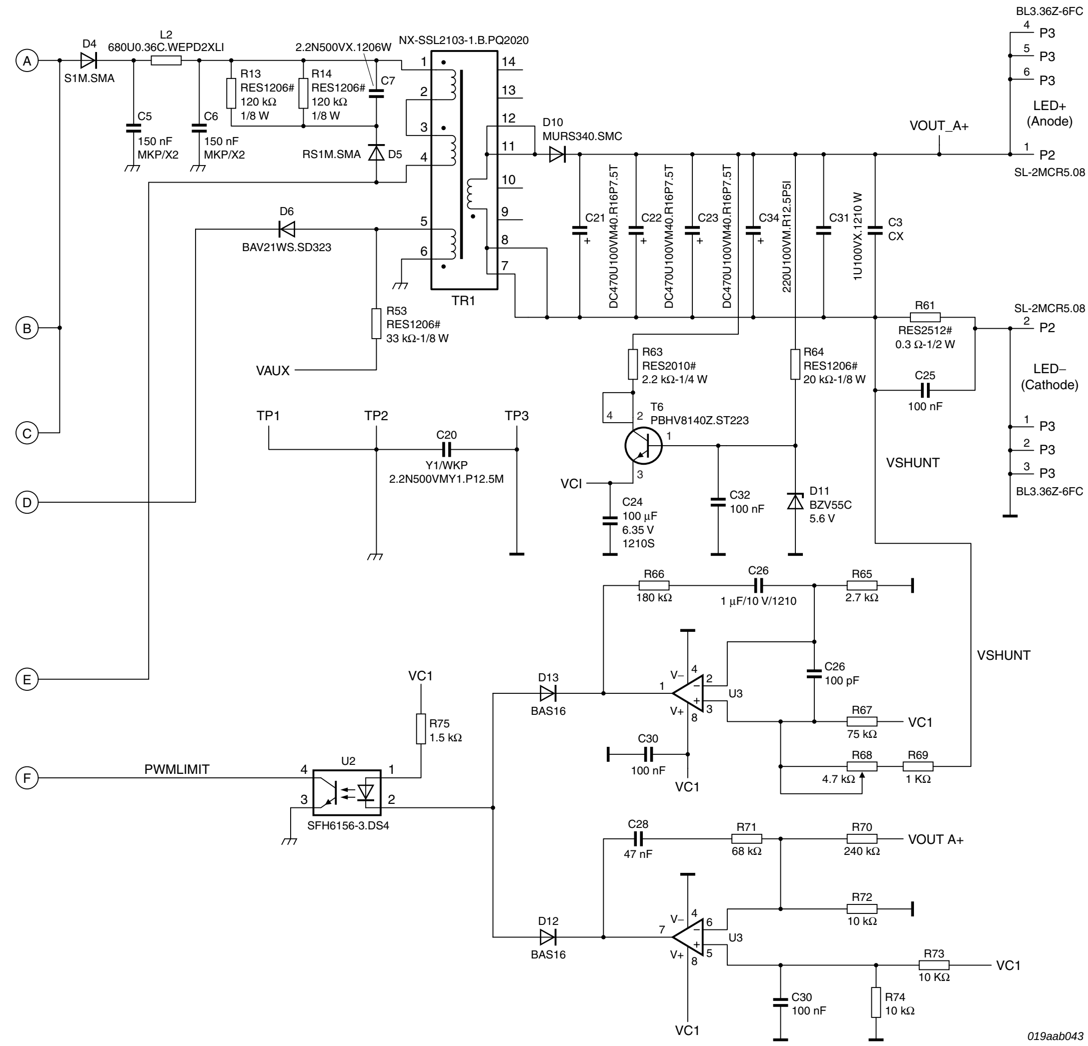


Fig 8. Board schematic diagram (part 2)

10. Bill Of Materials (BOM)

Table 4. Bill of materials 230 V (AC) and 120 V (AC)

Part numbers accompanied with an asterisk (*) are for 120 V (AC). Power is measured in Watts unless otherwise stated.

Part number	Reference	Part	Value	Power (W)	Tolerance (%)	Voltage (V)	Package	Type	Manufacturer	SMD
1	P1	connector 3 pin	male	-	-	-	-	SL 5.08/3/90	Weidmuller	-
2	P1’	connector 3 pin	female	-	-	-	-	BL 5.08/3	Weidmuller	-
3	P3	connector 6 pin	female	-	-	-	-	BL3.36Z	Fischer	-
4	P2	connector 2 pin	male	-	-	-	-	SL 5.08/2/90	Weidmuller	-
5	P2’	connector 2 pin	female	-	-	-	-	BL 5.08/2	Weidmuller	-
6	F1	fuse	0.5 AT	1	-	-	Free	0461.500ER	LITTELFUSE	Y
7	VR1	varistor	-	71 Joules	10	275	Free	B72214S0271K101	EPCOS	-
8	R2	resistor	390 Ω	1	5	200	2512	-	-	Y
8*	R2	resistor	750 Ω	1	5	200	2512	-	-	Y
9	R3	resistor	390 Ω	1	5	200	2512	-	-	Y
9*	R3	resistor	750 Ω	1	5	200	2512	-	-	Y
10	R4	resistor	47 kΩ	0.5	5	200	1206	-	-	Y
11	R5	resistor	47 kΩ	0.5	5	200	1206	-	-	Y
12	R6	resistor	390 kΩ	0.25	5	-	0805	-	-	Y
13	R7	resistor	1 kΩ	0.25	5	-	0805	-	-	Y
14	R8	resistor	1 Ω	0.5	5	200	2010	-	-	Y
15	R9	resistor	220 Ω	1	5	500	2512	-	-	Y
16	R10	resistor	220 Ω	1	5	500	2512	-	-	Y
17	R11	resistor	8.2 Ω	0.5	5	200	2010	-	-	Y
17*	R11	resistor	2.2 Ω	0.5	5	200	2010	-	-	Y
18	n.c.	-	-	-	-	-	-	-	-	-
19	R13	resistor	120 kΩ	0.5	5	200	1206	-	-	Y
20	R14	resistor	120 kΩ	0.5	5	200	1206	-	-	Y
27	R21	resistor	2.7 kΩ	1	5	-	2512	-	-	Y
27*	R21	resistor	820 Ω	1	5	-	2512	-	-	Y
28	R22	Resistor	2.7 kΩ	1	5	-	2512	-	-	Y
28*	R22	resistor	820 Ω	1	5	-	2512	-	-	Y
29	R23	resistor	2.7 kΩ	1	5	-	2512	-	-	Y
29*	R23	resistor	820 Ω	1	5	-	2512	-	-	Y

Table 4. Bill of materials 230 V (AC) and 120 V (AC) *…continued*

Part numbers accompanied with an asterisk (*) are for 120 V (AC). Power is measured in Watts unless otherwise stated.

Part number	Reference	Part	Value	Power (W)	Tolerance (%)	Voltage (V)	Package	Type	Manufacturer	SMD
30	R24	resistor	2.7 kΩ	1	5	-	2512	-	-	Y
30*	R24	resistor	820 Ω	1	5	-	2512	-	-	Y
31	R25	resistor	2.7 kΩ	1	5	-	2512	-	-	Y
31*	R25	resistor	820 Ω	1	5	-	2512	-	-	Y
32	R26	resistor	2.7 kΩ	1	5	-	2512	-	-	Y
32*	R26	resistor	820 Ω	1	5	-	2512	-	-	Y
33	R27	resistor	120 Ω	0.5	5	-	2010	-	-	Y
34	R28	resistor	120 Ω	0.5	5	-	2010	-	-	Y
35	R29	resistor	120 Ω	0.5	5	-	2010	-	-	Y
36	R31	resistor	130 Ω	-	1	-	0805	-	-	Y
37	R32	resistor	330 Ω	-	1	-	0805	-	-	Y
38	R33	resistor	4.7 kΩ	-	5	-	0805	-	-	Y
39	R34	resistor	1 kΩ	-	1	-	0805	-	-	Y
40	R35	resistor	430 Ω	-	1	-	0805	-	-	Y
41	R36	resistor	3.9 kΩ	-	5	-	0805	-	-	Y
42	R37	resistor	82 kΩ	-	1	-	0805	-	-	Y
42*	R37	resistor	68 kΩ	-	1	-	0805	-	-	Y
43	R38	resistor	47 kΩ	-	1	-	0805	-	-	Y
44	R39	resistor	220 kΩ	-	1	-	0805	-	-	Y
45	R40	resistor	5.9 kΩ	-	1	-	0805	-	-	Y
46	R41	resistor	470 kΩ	0.5	5	-	2010	-	-	Y
46*	R41	resistor	220 kΩ	0.5	5	-	2010	-	-	Y
47	R42	resistor	470 kΩ	0.5	5	-	2010	-	-	Y
47*	R42	resistor	220 kΩ	0.5	5	-	2010	-	-	Y
48	R43	resistor	12 kΩ	-	1	-	0805	-	-	Y
49	R44	resistor	8.2 kΩ	-	1	-	0805	-	-	Y
50	R45	resistor	1 Ω	-	1	-	0805	-	-	Y
51	R46	resistor	1 Ω	-	1	-	0805	-	-	Y
52	R47	resistor	1 Ω	-	1	-	0805	-	-	Y

Table 4. Bill of materials 230 V (AC) and 120 V (AC) *…continued*

Part numbers accompanied with an asterisk (*) are for 120 V (AC). Power is measured in Watts unless otherwise stated.

Part number	Reference	Part	Value	Power (W)	Tolerance (%)	Voltage (V)	Package	Type	Manufacturer	SMD
53	R48	resistor	1 Ω	-	1	-	0805	-	-	Y
54	R49	resistor	22 Ω	-	5	-	0805	-	-	Y
55	R50	resistor	0 unit	-	5	-	0805	-	-	Y
56	R51	resistor	2.2 Ω	-	5	-	melf	CMB02070	VISHAY	Y
57	R52	resistor	220 Ω	-	5	-	2010	-	-	Y
58	R53	resistor	33 kΩ	-	5	-	0805	-	-	Y
59	R61	resistor	0.3 Ω	-	1	-	2512	-	-	Y
60	R63	resistor	2.2 KΩ	-	1	-	0805	-	-	Y
61	R64	resistor	20 KΩ	-	1	-	0805	-	-	Y
62	R65	resistor	2.7 KΩ	-	1	-	0805	-	-	Y
63	R66	resistor	180 KΩ	-	1	-	0805	-	-	Y
64	R67	resistor	75 KΩ	-	1	-	0805	-	-	Y
65	R68	trimmer	5 kΩ	-	10	-	-	10 turns	VISHAY	-
66	R69	resistor	1 kΩ	-	1	-	0805	-	-	Y
67	R70	resistor	240 KΩ	-	1	-	0805	-	-	Y
68	R71	resistor	68 kΩ	-	1	-	0805	-	-	Y
69	R72	resistor	10 kΩ	-	1	-	0805	-	-	Y
70	R73	resistor	10 kΩ	-	1	-	0805	-	-	Y
71	R74	resistor	10 kΩ	-	1	-	0805	-	-	Y
72	R75	resistor	1.5 kΩ	-	1	-	0805	-	-	Y
73	C1	capacitor	470 pF	-	15	250	2211	GA352QR7GF471KW01L	Murata	Y
74	C2	capacitor	220 nF	-	20	275	Poly	BFC233922224	VISHAY	-
74*	C2	capacitor	150 nF	-	20	305	Poly	B32923C3154M	Epcos	-
75	C3	capacitor	1 nF	-	10	50	0805	-	-	Y
76	C4	capacitor	100 nF	-	10	50	0805	-	-	Y
77	C5	capacitor	150 nF	-	20	305	Poly	B32923C3154M	Epcos	-
78	C6	capacitor	150 nF	-	20	305	Poly	B32923C3154M	Epcos	-
79	C7	capacitor	2.2 nF	-	10	200	1206	-	-	Y
80	C11	capacitor	33 µF	-	20	35	radial	-	-	-

Table 4. Bill of materials 230 V (AC) and 120 V (AC) *…continued*

Part numbers accompanied with an asterisk (*) are for 120 V (AC). Power is measured in Watts unless otherwise stated.

Part number	Reference	Part	Value	Power (W)	Tolerance (%)	Voltage (V)	Package	Type	Manufacturer	SMD
81	C12	capacitor	4.7 μF	-	10	50	1210	-	-	Y
82	C13	capacitor	100 nF	-	10	50	0805	-	-	Y
83	C14	capacitor	4.7 nF	-	10	50	0805	-	-	Y
84	C15	capacitor	330 pF	-	10	50	0805	-	-	Y
85	C16	capacitor	4.7 μF	-	10	50	1210	-	-	Y
86	C20	capacitor	2.2 nF	-	20	760	ceramic	WKP222MCPEJ0KR	VISHAY	-
87	C21	capacitor	470 μF	-	20	100	radial	ECA2AHG471	Panasonic	-
88	C22	capacitor	470 μF	-	20	100	radial	ECA2AHG471	Panasonic	-
89	C23	capacitor	470 μF	-	20	100	radial	ECA2AHG471	Panasonic	-
90	C24	capacitor	100 μF	-	10	6.3	1210	-	-	Y
91	C25	capacitor	100 nF	-	10	50	0805	-	-	Y
92	C26	capacitor	1 μF	-	10	10	1210	-	-	Y
93	C27	capacitor	100 pF	-	10	50	0805	-	-	Y
94	C28	capacitor	47 nF	-	10	50	0805	-	-	Y
95	C29	capacitor	100 nF	-	10	50	0805	-	-	Y
96	C30	capacitor	100 nF	-	10	50	0805	-	-	Y
97	C31	capacitor	1 μF	-	10	100	1210	-	-	Y
98	C32	capacitor	100 nF	-	10	50	0805	-	-	Y
99	C34	capacitor	220 μF	-	20	100	radial	ECA2AHG221	Panasonic	-
100	L1	inductor	47 mH	-	-	-	-	B82731T2451A020	EPCOS	-
101	L2	inductor	680 μH	-	-	-	-	744776268	Wurth	Y
102	TR1	transformer	-	-	-	220	PQ2020	N87/3F3	-	-
102*	TR1	transformer	-	-	-	110	PQ2020	N87/3F3	-	-
103	PD1	rectifier bridge	0.5 A	-	-	-	TO269AA	MB6S	VISHAY	Y
104	D1	diode	15 V	0.25	5	15	SOT23	BZX8-C15	NXP	Y
105	D2	diode	signal	0.5	-	75	Melf	LS4148	Reactron	Y
106	D3	diode	400 V	400	5	400	DO-214AC	SMAJ400A	LITTLEFUSE	Y
106*	D3	diode	250 V	400	5	250	DO-214AC	SMAJ250A	LITTLEFUSE	Y
107	D4	diode	1 A	-	-	1000	SMA	RS1M	Fairchild	Y

Table 4. Bill of materials 230 V (AC) and 120 V (AC) *…continued*

Part numbers accompanied with an asterisk (*) are for 120 V (AC). Power is measured in Watts unless otherwise stated.

Part number	Reference	Part	Value	Power (W)	Tolerance (%)	Voltage (V)	Package	Type	Manufacturer	SMD
108	D5	diode	1 A	-	-	1000	SMA	RS1M	Fairchild	Y
109	D6	diode	250 mA	-	-	200	-	BAV21WS	VISHAY	Y
110	D7	diode	27 V	0.5	-	-	SOD123	MMSZ27T1G	ON SEMI	Y
111	D10	diode	3 A	-	-	400	SMC	MURS340	VISHAY	Y
112	D11	zener diode	5.6 V	-	5	-	Melf	BZV55--C5V6	NXP	Y
113	D12	diode	signal	0.25	-	75	SOT23	BAS16	-	Y
114	D13	diode	signal	0.25	-	75	SOT23	BAS16	-	Y
115	T1	transistor	NPN	0.25	-	40	SOT23	2N2222	-	Y
116	T2	transistor	MOS	-	-	800	DPAK	STD4NK80Z	ST	Y
117	T3	transistor	NPN	-	-	400	SOT223	PBHV8140Z	NXP	Y
118	T4	transistor	NPN	-	-	400	SOT223	PBHV8140Z	NXP	Y
119	T5	transistor	MOS	-	-	800	DPAK	STD4NK80Z	ST	Y
120	T6	transistor	NPN	-	-	400	SOT223	PBHV8140Z	NXP	Y
121	U1	IC controller	-	-	-	-	SO-14	SSL2103	NXP	Y
122	U2	optocoupler	-	-	-	5300	SMD	SFH6156	VISHAY	Y
123	U3	AOP	-	-	-	-	SO-8	LMV358	NS	Y

11. Transformer specification

Figure 9 is a schematic of the transformer:

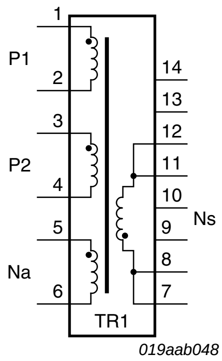


Fig 9. Transformer schematic

11.1 Winding specification

Table 5. Winding specification

No.	Section	Wire	Layers	Turns	Pin	
					Begin	End
1	P1	-	-	-	1	2
2	ISO	0.2	-	-	-	-
3	Ns	-	-	-	7, 8	11, 12
4	ISO	0.2	-	-	-	-
5	P2	-	-	-	3	4
6	ISO	0.2	-	-	-	-
7	Na	-	-	-	6	5
8	ISO	0.2	-	-	-	-

11.2 Electrical characteristics

Table 6. Inductance

The tolerance is ± 10 %, at 1 A; nominal frequency = 100 kHz; breakdown voltage P1, P2...Ns = 2.5 kV.

Section	Inductance	
	230 V (AC)	120 V (AC)
Primary	875 μH	433 μH
Secondary	219 μH	87 μH
Auxiliary	79 μH	43 μH

11.3 Core and bobbin

- Core: PQ2020, 3F3/N87
- Bobbin: CPV-PQ20/20-1S-14P-Z

11.4 Physical dimensions

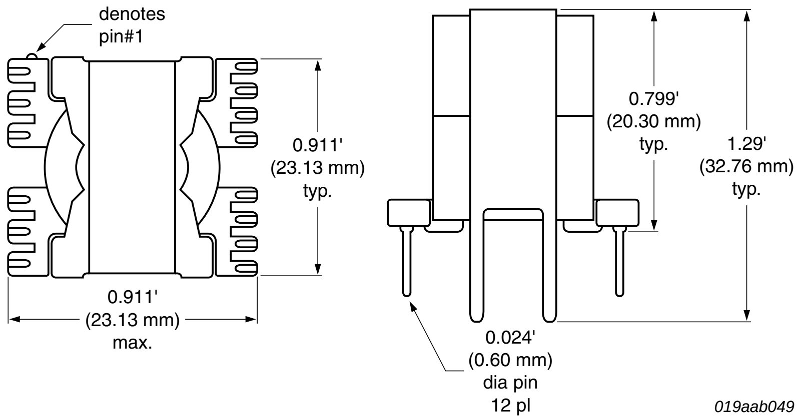
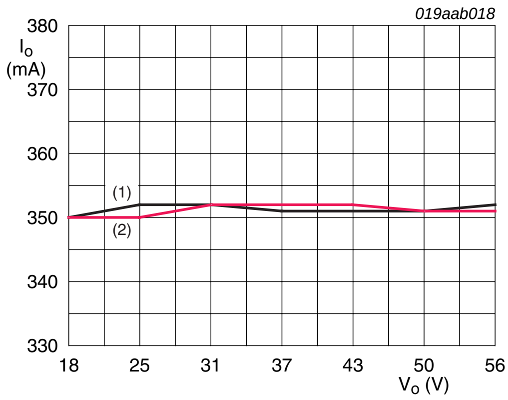


Fig 10. Transformer dimensions

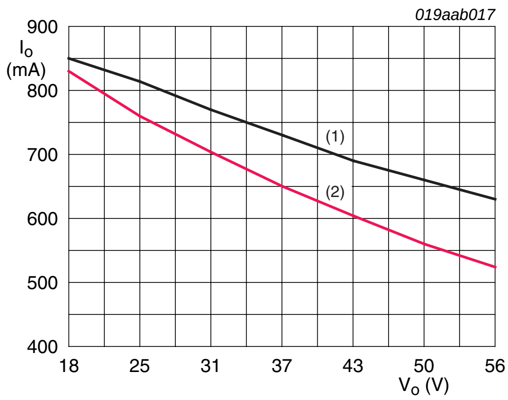
12. Appendix A - Load curves



(1) 230 V input

(2) 120 V input

Fig 11. Load current regulation

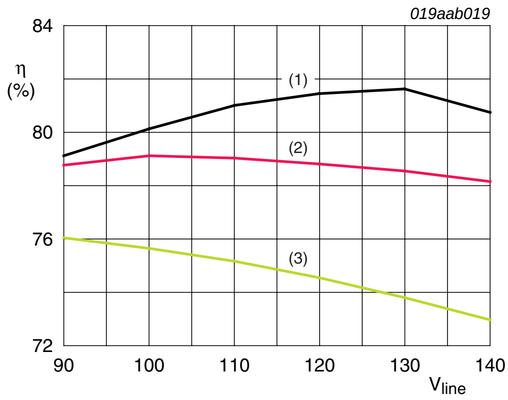


(1) 230 V input

(2) 120 V input

Fig 12. Maximum output current

13. Appendix B - Efficiency curves



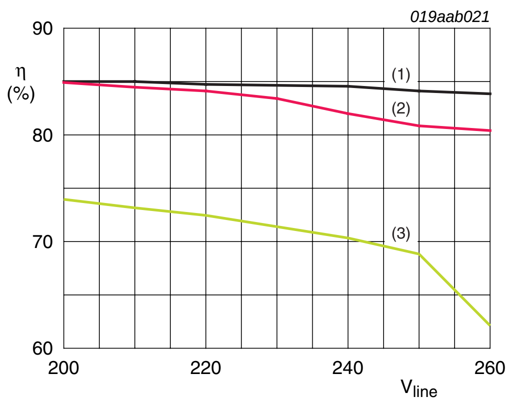
I_{out} = 350 mA

(1) 18 LEDs

(2) 12 LEDs

(3) 6 LEDs

Fig 13. Efficiency curve - 120 V (AC)



I_{out} = 350 mA

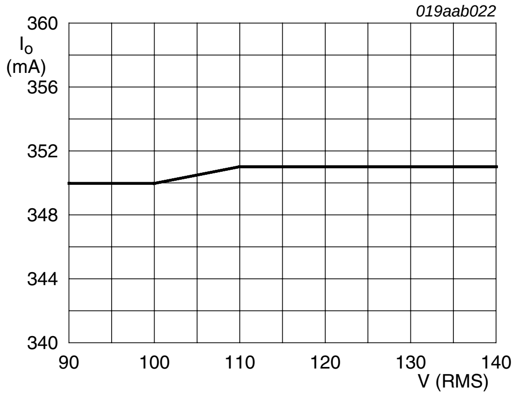
(1) 18 LEDs

(2) 12 LEDs

(3) 6 LEDs

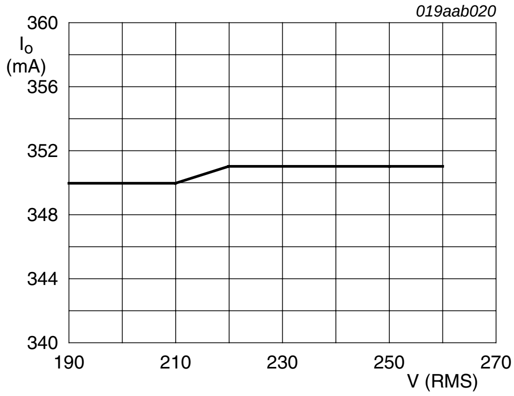
Fig 14. Efficiency curve - 230 V (AC)

14. Appendix C - Input voltage dependency



V_{out} = 56 V

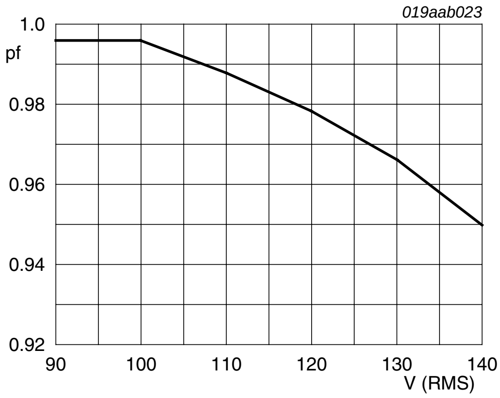
Fig 15. 120 V (AC) Input voltage to output current dependency



V_{out} = 56 V

Fig 16. 230 V (AC) Input voltage to output current dependency

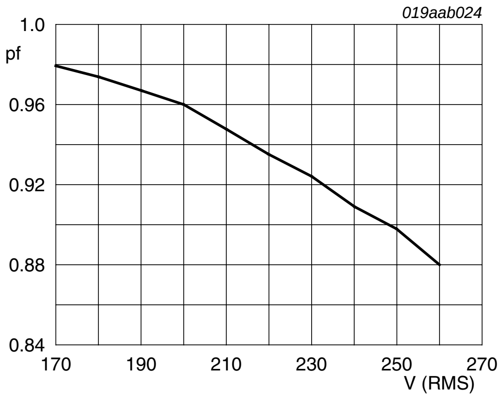
15. Appendix D - Power factor



V_{out} = 56 V

I_{out} = 350 mA

Fig 17. Power factor 120 V (AC)

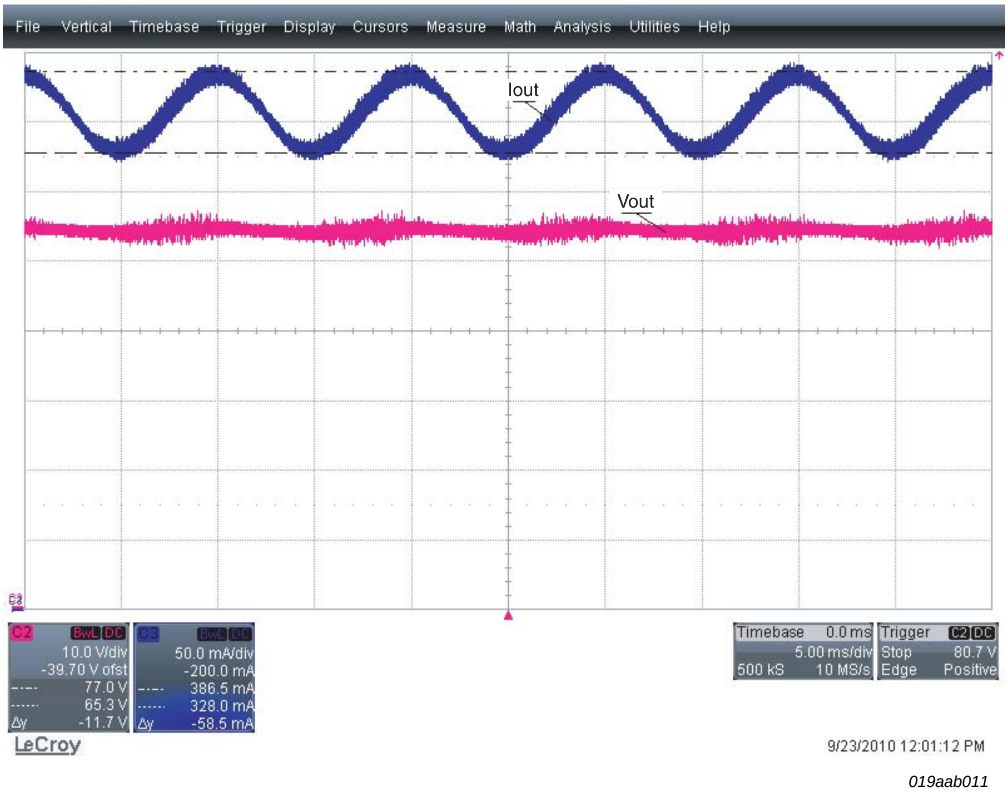


V_{out} = 56 V

I_{out} = 350 mA

Fig 18. Power factor 230 V (AC)

16. Appendix E - Output ripple current



Maximum load = 350 mA

Fig 19. Output ripple current

17. References

[1] **AN10952 —** SSL2103 dimmable mains LED driver

[2] **SSL2103 —** Data sheet

[3] **SMPS —** IC for dimmable LED lighting

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