UM0673
User manual

STEVAL-ISF001V2, 3 kW FOT PFC board based on the L6563S

Introduction

The power board STEVAL-ISF001V2 is a 3 kW PFC designed for industrial and domestic applications. The board must be used for demonstration purposes in order to evaluate the potential of the FOT (fixed-off-time control, patented by ST) to implement a high-power PFC with performance comparable to a standard continuous-mode PFC, but using a simpler controller chip originally designed for TM (transition-mode) PFC operating conditions. This demonstration board works directly from the AC mains supply in the single range voltage (185 Vrms - 265 Vrms) and provides a 400 V stable and regulated DC bus output capable of a maximum of 7.5 A.

The low voltage necessary to supply the driver is generated by an auxiliary winding on the main inductor, so an external power supply is not needed to start the operation of the board.

The design is:

- quick to set up and install
- re-usable (the Gerber files are available for free)
- ready for downsizing if required.

Note: Please read Section 2 of this manual before attempting any operation.

Figure 1. Line, inductor, switch and diode current in FF-CCM PFC

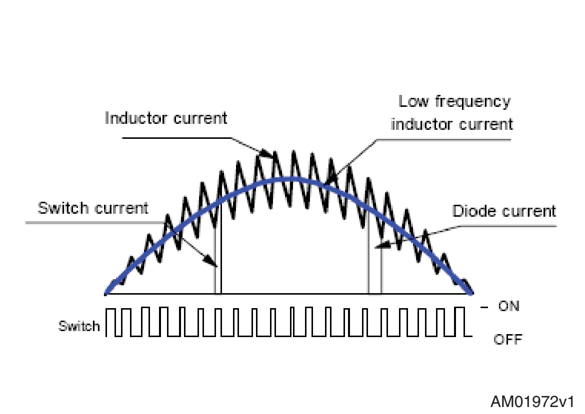
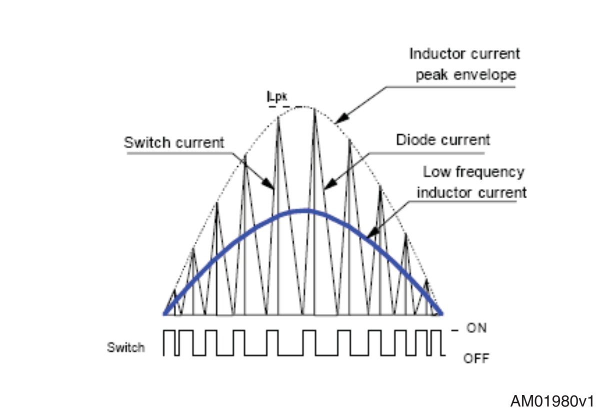


Figure 2. Line, inductor, switch and diode current in TM PFC



Contents

1 Board description

The STEVAL-ISF001V2 can be used for several kinds of applications:

- Inverter for motor control
- Air conditioning system
- Welding machine DC power supply section.

This demonstration board offers customization options as well, making it an excellent choice as an original platform for a more complete and dedicated system. Special care has been taken during the layout process to provide a very low level of interference. Considering the power delivered and the level of current present on the board, we advise no major modification of the layout for customization of the system in order to avoid noise that could cause the board to malfunction.

The board includes:

- An input stage composed of a 25 A power rectifier bridge
- An input filter stage necessary to comply with the EMC emission levels
- A control stage composed of the L6563S
- A power stage composed of a power MOSFET and power ultra-fast diodes
- A power inductor designed and manufactured specifically for this application
- An output filter stage composed of an electrolytic capacitor sized to have the ripple required by the specification.

Figure 3. STEVAL-ISF001V2 demonstration board

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2 Safety and operating instructions

2.1 General

During assembly and operation the 3 kW FOT PFC board poses several inherent hazards including bare wires and hot surfaces. If the board or its components are improperly used or installed incorrectly, there is danger of serious personal injury and damage to property.

All operations involving transportation, installation and use, as well as maintenance is to be carried out by skilled technical personnel (national accident prevention rules must be observed). For the purposes of these basic safety instructions, "skilled technical personnel" are suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.

Warning: Many sources of serious hazard are present on this board. The board works directly from the mains, is not galvanically isolated, and provides on the output high-voltage DC levels that can be the cause of serious electrical shock, serious burns or death. Hot surfaces that can cause burns are present on the board.

This board must be used only in a power laboratory only by engineers and technicians who are experienced in power electronics technology and under protection.

STMicroelectronics is not responsible for damages to property nor personal injury.

2.1.1 Power board 3 kW FOT PFC intended use

The power board 3 kW FOT PFC is designed for demonstration purposes only and shall not be used for electrical installation or machinery. The technical data as well as information concerning the supply conditions shall be taken from the documentation and strictly observed.

2.2 Power board 3 kW FOT PFC installation

The installation and cooling of the 3 kW FOT PFC shall be in accordance with the specifications and the targeted application (see *Section 2.2.2*).

- Excessive strain on the board shall be avoided. In particular, no components are to be bent or isolating distances altered during the course of transportation or handling.
- No contact shall be made with electronic components and contacts.
- The boards contain electrostatically-sensitive components that are prone to damage through improper use. Electrical components must not be mechanically damaged or destroyed (to avoid potential health risks).

2.2.1 Electronic connection

National accident prevention rules must be followed when working on the main power supply, with the power supply, or powering the board in general.

The electrical installation shall be completed in accordance with the appropriate requirements (e.g., cross-sectional areas of conductors, fusing, PE connections. For further information, see *Section 2.2.2*).

2.2.2 3 kW FOT PFC demonstration board setup

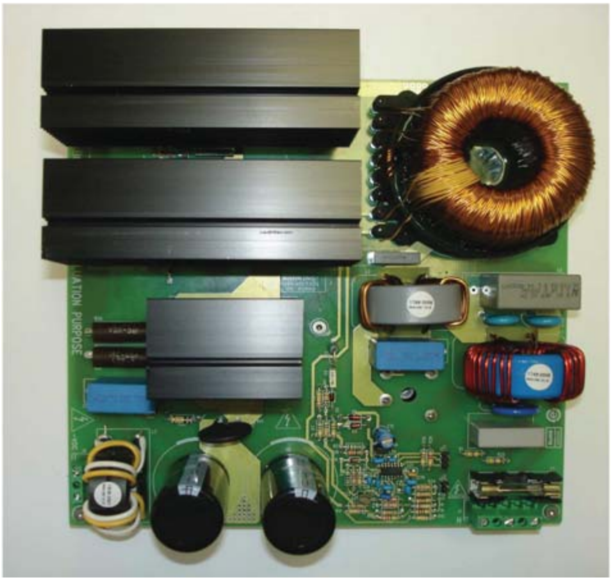
It is preferable to use an AC supply isolated and protected against overload and short-circuit during the evaluation test of the power board 3 kW FOT PFC (in compliance with technical equipment and accident prevention rules).

A proper load, able to dissipate or in any case absorb and reuse the power delivered by the system, has to be used. In the case of a resistive and dissipative dummy load, the user must pay attention to the temperature that the load could reach and provide the necessary equipment to avoid hot surfaces and fire hazards during the tests (fan, water-cooled load, etc).

Caution: Do not touch the boards and its components after disconnection from the voltage supply, as several parts and power terminals which contain possibly energized capacitors need to be allowed to discharge.

2.3 Hardware layout

Figure 4. Power board 3 kW FOT PFC STEVAL-ISF001V2 (top view)



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The mains input connector is present on the right side of the board. Connect a sinusoidal supply voltage with amplitude in the range of 185 Vrms to 265 Vrms. The power source has to be able to supply the power required by the system, according to the output load the user intends to connect on the output port.

The output connector is present on the left side (close to the output electrolytic capacitors). Please note that the output voltage is regulated by the system for the target value of 400 V (consider a tolerance of 5%, due to the net value of the passive components on the board), which gives a value for a resistive load between 530 Ω (minimum power delivered) to 53 Ω (maximum power delivered).

Warning: The STEVAL-ISF001V2 has no insulation shield or any other type of protection.

Caution: The demonstration board must be handled very carefully, as high-potential (energy) parts are open and can be touched. The user MUST avoid connecting or removing cables during operation of the board or touching any part of the system when it is connected to the main power supply.

Note: After turning the power supply off, if the load is disconnected, the DC-link capacitor may still hold voltage.

Note: It is preferable to test the kit in ambient temperature not higher than 45 degrees Celsius.

2.4 Environmental considerations

The STEVAL-ISF001V2 must only be used in a power laboratory. The high voltage involved in the system presents a serious shock hazard. If the board is to be used to measure or capture waveforms or any other interaction between the board and laboratory equipment, an AC-isolated power supply has to be used.

Note: Any measurement equipment must be isolated from the main power supply before powering up the PFC. To use an oscilloscope with the kit, it is safer to isolate the AC supply AND the oscilloscope or use isolated differential probes. This prevents a shock from occurring as a result of touching any SINGLE point in the circuit but does NOT prevent shocks when touching TWO or MORE points in the circuit.

An isolated AC power supply can be constructed using an isolation transformer and a variable transformer.

Note: Isolating the application rather than the oscilloscope is highly recommended in any case.

3 PFC board connection

The PFC board is manufactured ready to use. Using jumper J3, the supply of the driver L6563S can be connected directly to the supply generated by the auxiliary winding present on the boost inductor or to an isolated low-voltage external supply. This option can be used to debug or to test an inductor not equipped with an auxiliary winding. Set jumper J3 to position 2-3 to use the standard auxiliary power supply already present on the board. If an external supply is used, set J3 to position 1-2 and connect a 15 V DC supply capable of at least 100 mA to J4 (+15 on J4 pin1, ground on J4 pin2). Connect the board to the AC power supply.

Use a suitable cable, in terms of insulation and cross-section, to be able to conduct the current from the supply according to the load connected to the output port.

Connect the output port to the load.

Note: Even if the system is able to start up and maintain the output voltage regulated to the target value, also under open-load condition, the technical specification in terms of PF and THD cannot be guaranteed.

The systems accept a minimum power load to work properly.

Supply the PFC board with a sinusoidal supply voltage with amplitude in the range of 185 Vrms to 265 Vrms. The power source has to be able to supply the power required by the system, according to the output load the user intends to connect to the output port.

Caution: Do not supply the system with a voltage value higher than 265 Vrms, as risk of serious damage to the board and to property is present in this case. Do not supply the system with a voltage below the minimum allowed, 185 Vrms, as the systems cannot start or operate properly in this condition.

Note: Low voltage supply and maximum output load present the worst operating conditions for the system and sufficient cooling is mandatory.

3.1 STEVAL-ISF001V2 description

The demonstration board STEVAL-ISF001V2 developed by STMicroelectronics provides a compact, and ready-to-use solution for the implementation of a simple PFC system able to supply load with power close to the maximum delivered in most typical domestic installations. For such a range of power the use of a continuous-mode PFC operation becomes mandatory to drain from the mains a current with an rms value which does not exceed the maximum allowed from the metering system and to have a reasonable size of the devices involved in the system’s operations.

The use of a standard continuous-mode driver chip necessitates using a more expensive and complex driver with all the required passive components.

STMicroelectronics has patented a solution that allows using a simple driver, designed for a transition-mode operation, in a fixed-off-time, variable frequency, PWM modulation. This kind of modulation gives a current on the boost inductor of the PFC that is comparable with the current of a typical continuous-mode modulation.

Modulating T_{ON} and fixing T_{OFF} of the PWM signal applied to the main switch, it is possible to maintain continuous current on the inductor around a sinusoidal envelope. As a consequence of maintaining constant T_{OFF} and varying T_{ON}, the overall PWM period is modulated which gives a variable frequency control.

Using a variable frequency control has advantages in terms of noise input filter size. In fact, the noise energy is spread over a frequency range with lower energy content for each frequency.

For further technical information and correct sizing and calculation of the device on the board, please consult STMicroelectronics' AN1792 "Design of fixed-off-time-controlled PFC pre-regulators with the L6562".

The features of the STEVALISF001V1 include:

- PFC FOT power systems based on the L6563S
- Power stage based on MDmesh™ V Power MOSFET
- 185 Vrms < Vin rms <265 Vrms
- Vout 400 V regulated (±5%)
- Iout max 7.5 A
- Driver with inductor saturation detection
- Optimized EMC input filter.

3.2 STEVAL-ISF001V2 circuit description

Figure 5 shows the entire electronic schematic.

Starting from the input section, a common-mode EMC filter is fitted in order to be compliant with the EMC regulations concerning industrial and domestic applications. (EN55014 and EN55022).

The alternative voltage from the mains is then rectified by the input low-frequency bridge that provides a rectified sinusoidal waveform (with a frequency that is doubled with respect to the input main waveform) to the next boost stage. The capacitor C7 has been calculated to have a residual ripple, around the sinusoidal envelope at maximum load and minimum input voltage, of 6% of the Vin peak value.

The main boost inductor, designed and produced by MAGNETICA (Italy), is a ferrite inductor core designed to minimize the hysteresis losses.

The technical sheet with a complete order code is given in *Figure 6*.

The inductor has a secondary-side winding that provides the low-voltage auxiliary supply to the driver L6563S.

At the startup the current and voltage on the main inductor is still zero, so any voltage can be generated by the secondary auxiliary winding. In this condition, and only during the startup, the two resistors R7 and R13, 150 kΩ each, with the Zener diode D4 (fitted for limitation purposes) charge the capacitor C12 and supply the driver that starts the PWM operation. As soon the PWM signal starts to switch, a voltage is present across the auxiliary winding, so the low supply voltage across the capacitor C12 is maintained.

The two boost diodes paralleled conduct the peak inductor current at the end of the T_{ON} period. At the maximum power and minimum input voltage the peak current can reach 29 A.

Diode D2 and NTC resistor NV1 are used to limit the inrush current, due to the electrolytic capacitor on the output, during the startup or small decrease of the mains.

The chosen switching devices are two power MOSFETs, MDmesh™ V family, STW88N65M5. These two power MOSFETs placed in parallel assure a low $R_{DS(on)}$, limiting the conduction power losses.

Good efficiency and good thermal behavior of the system can be reached.

To properly drive the power MOSFET and to minimize switching losses, during the on and off transient, a small push-pull driver was interposed between the driver and the two gates. A reading of the current conducted by the two power MOSFETs, equal to the current on the main inductor during the T_{ON} period, is necessary for the driver to set the right current level on the inductor according to the input instantaneous voltage and the output power delivered to the load. This current is sensed by a sensing resistor paralleling two 0,07 Ω non-inductive sensing resistors. The output DC bus voltage is sensed by the driver through the resistive net composed of R12, R16, R17, and R24.

As described in the L6563S datasheet, a PFC pre-regulator output voltage monitoring/disable function exists. This pin senses the output voltage of the PFC pre-regulator through a resistor divider and is used for protection purposes. If the voltage at the pin exceeds 2.5 V, the IC is shut down, its consumption goes almost to the startup level and this condition is latched. The PWM_LATCH pin is asserted high. Normal operation can be resumed only by cycling Vcc. This function is used for protection in case the feedback loop fails.

The RC net, on pin ZCD, is used to fix the desired T_{OFF} time according to the sizing calculation of the application (for complete design rules, please refer to "Design of fixed-off-time-controlled PFC pre-regulators with the L6562").

The small signal bit Q3 is used to implement a T_{OFF} modulation according to the input voltage. At the moment of low voltage on the input waveform (near the zero-crossing of the input sinusoidal supply) and in order to minimize the distortion on the input current due to the low input voltage, the T_{OFF} period needs to be reduced. Acting in this way, the ratio between T_{ON} and T_{OFF} is increased and the distortion on the input current can be reduced.

4 BOM and schematics

Table 1. Bill of material

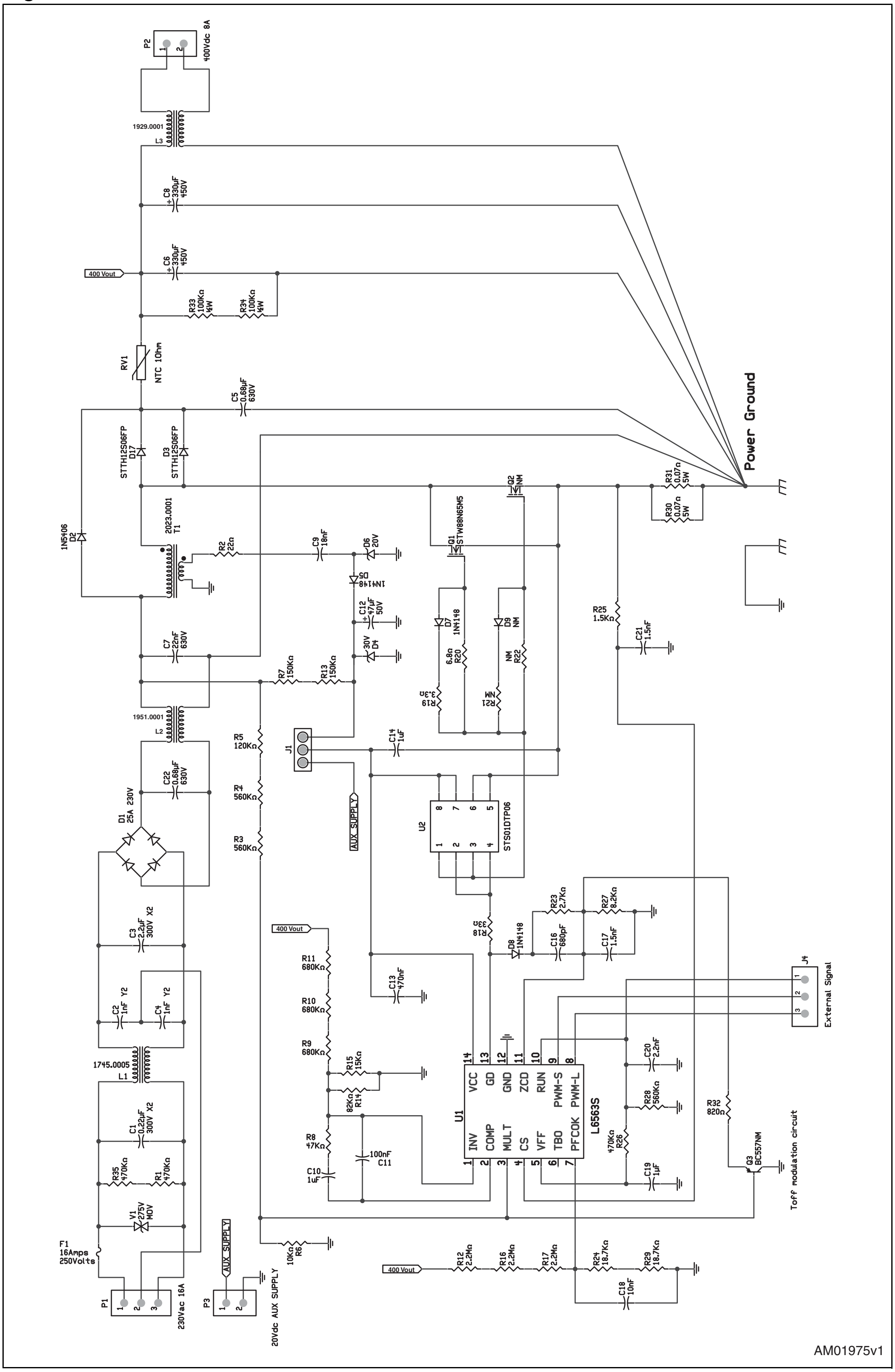
Item	Qty	Reference	Part
1	1	C1	0.22 μF 300Vac X2
2	2	C2,C4	10 nF Y2
3	1	C3	2.2 μF 300Vac X2
4	1	C7	220 nF 630 V
5	2	C6,C8	330 μF 450 V
6	1	C9	18 nF
7	1	C10	1μF
8	1	C11	100 nF
9	1	C13	470 nF 50 V
10	1	C12	47 μF 50 V
11	1	C16	680 pF
12	1	C17	1.5 nF
13	1	C18	10 nF
14	1	C19	1 nF
15	1	C20	2.2 nF
16	1	C21	1.5 nF
17	1	D1	25 A 220 AC diode bridge
18	1	D2	1N5406
19	2	D3,D17	STTH12S06FP
20	1	D4	30 V Zener
21	4	D5,D7,D8,D9	1N4148
22	1	D6	20 V Zener
23	1	F1	Fuse 16 A
24	1	P1	220AC 16 A three-way connector
25	1	P2	OUT/400 V 8 A two-way connector
26	1	P3	20vDC Aux supply stripline
27	1	J1	Jumper stripline
28	1	U2	STS01DTP06 (SMD)
29	1	U1	L6563S (SMD)
30	1	P4	External signal stripline
31	1	L1	MAGNETICA 1745.0005 2 mH 18 A
32	1	Q1,Q2[(1)]	STW88N65M5 (heatsink PADA 8355)

Table 1. Bill of material (continued)

Item	Qty	Reference	Part
33	1	Q3	BC557
34	1	RV1	NTC 1 Ω 26 mm (ex. SIEMENS S464)
35	1	R1	470 kΩ 1/2 W
36	1	R2	22 Ω 1 W
37	2	R3,R4	560 kΩ
38	1	R5	120 kΩ
39	1	R6	10 kΩ
40	2	R7,R13	150 kΩ
41	1	R8	47 kΩ
42	3	R9,R10,R11	680 kΩ
43	3	R12,R16,R17	2.2 MΩ
44	1	R14	82 kΩ
45	1	R15	15 kΩ
46	1	R18	33 Ω
47	2	R19,R21	3.3 Ω
48	2	R20,R22	6.8 Ω
49	1	R23	2.7 kΩ
50	2	R24,R29	18.7 kΩ
51	1	R25	1.5 kΩ
		R26	470 kΩ
52	1	R27	8.2 kΩ
53	1	R28	560 kΩ
54	2	R30,R31	0.07 Ω 5 W Lob5 non-inductive
55	1	R32	820 Ω
56	2	R33,R34(2)	100 kΩ 1/2 W
57	1	T1	MAGNETICA 1922.0001
58	1	L2	MAGNETICA 1389.0008 1.2 mH 18 A
59	1	L3	MAGNETICA 1929.0001 31μH 8 A
60	1	V1	Metal oxide varistor 22 mm 275 V
61	1	C22	680 nF 630 V
62	1	C5	0.68 μF 630 V
63	1	C14	1 μF (SMD)
64	1	R35	470 kΩ 1/2 W

1. Only 1 mounted
2. R33 and R34 have to be mounted far from the surface

Figure 5. Schematic of the STEVAL-ISF001V2 board



5 Experimental measurements

Table below shows the performance of the PFC board during lab testing.

Table 2. Lab preliminary electrical measurements

		185 Vac	230 Vac	265 Vac
Low-power range	Vout	406	406	406
	Iout	0.75	0.75	0.75
	Pout	306	306	307
	Pin	319	317	318
	Efficiency (%)	96%	96.5%	96.2%
	PF	0.971	0.964	0.95
Medium-power range	Vout	4.6	406	406
	Iout	1.49	1.49	1.49
	Pout	606	607	606
	Pin	628	626	623
	Efficiency (%)	96.5	97%	97.3%
	PF	0.989	0.985	0.975
High-power range	Vout	406	406	406
	Iout	3.7	3.7	3.7
	Pout	1506	1506	1507
	Pin	1558	1550	1546
	Efficiency (%)	96.7%	97.2	97.5
	PF	0.995	0.995	0.985
Full load	Vout	406	406	406
	Iout	6.3	6.3	6.3
	Pout	2559	2558	2562
	Pin	2640	2650	2640
	Efficiency (%)	96.9%	96.5%	97%
	PF	0.988	0.997	0.998

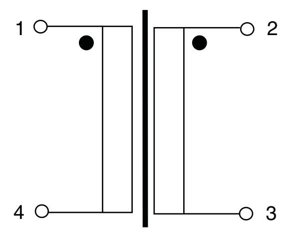
Figure 6. Common-mode inductor L1 (MAGNETICA 1745.0005) technical sheet

STP 03	Product Technical Specification	*Code*: **1745.0005**
Product: Common Mode Inductor 2x2mH 18A		
Customer: **STMicroelectronics**		*Customer Code:*

TYPICAL APPLICATION

DISTURB SUPPRESSION ON AC/DC POWER LINE OF 270V MAX.

SCHEMATIC

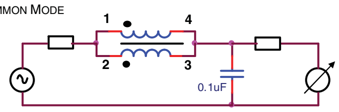


TECHNICAL DATA

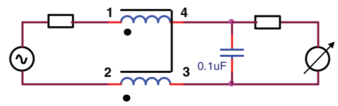
INDUCTANCE (1-4=2-3) *(MEASURE 1KHZ, TA 20°C)*	2mH min
RESISTANCE (1-4=2-3) *(MEASURE D.C, TA 20°C)*	10mΩ max
LEAKAGE INDUCTANCE *(MEASURE 1-4 AND 2-3 IN S.C, F 10KHZ, TA 20°C)*	1% NOM
OPERATING VOLTAGE *(F 50-60HZ, IR 18A MAX, TA 20°C)*	270VAC MAX
OPERATING CURRENT *(MEASURE 1-4 AND 2-3 , TA 20°C)*	18A MAX
OPERATING FREQUENCY *(CURRENT 18A MAX, TA 20°C)*	50 – 60Hz
INSULATION (1-4 ⇔ 2-3) *(F 50HZ, TEST DURATION 2", TA 20°C)*	1500V MAX
OPERATING TEMPERATURE RANGE *(IR 18A MAX)*	-10°C ÷+45°C
MAXIMUM DIMENSIONS	29x26 H46mm
WEIGHT	100g CIRCA

SETUP OF MEASURE

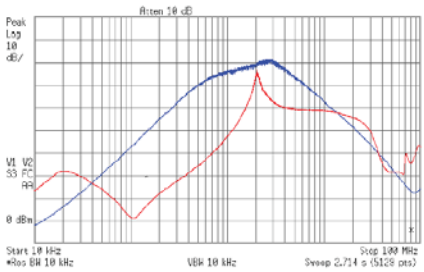
COMMON MODE



DIFFERENTIAL MODE



ATTENUATION COMMON MODE DIFFERENTIAL MODE



MAGNETICA

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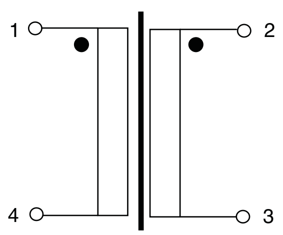
Figure 7. Common-mode inductor L2 (MAGNETICA 1951.0001) technical sheet

STP 03	Product Technical Specification	*Code*: **1951.0001**
Product: **Common Mode Inductor 2x220uH/18A**		
Customer: **ST Microelectronics**		*Customer Code:*

TYPICAL APPLICATION

EMC SUPPRESSION ON AC/DC POWER LINE OF 270V MAX.

SCHEMATIC

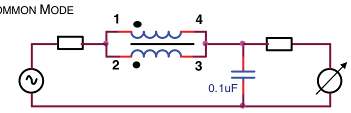


TECHNICAL DATA

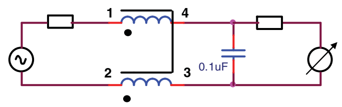
INDUCTANCE (1-4=2-3) *(MEASURE 1KHZ, TA 20°C)*	200uH MIN
RESISTANCE (1-4=2-3) *(MEASURE D.C, TA 20°C)*	8.9mΩ MAX
LEAKAGE INDUCTANCE *(MEASURE 1-4; 2-3 IN S.C, F 10KHZ, TA 20°C)*	1.2% NOM
OPERATING VOLTAGE *(F 50-60HZ, IR 18A MAX, TA 20°C)*	270VAC MAX
OPERATING CURRENT *(MEASURE 1-4 AND 2-3 ,TA 20°C)*	18A MAX
OPERATING FREQUENCY *(CURRENT 18A MAX, TA 20°C)*	50 – 60HZ
INSULATION (1-4 ⇔ 2-3) *(F 50HZ, DURATION TEST 2", TA 20°C)*	1500V MAX
OPERATING AMBIENT TEMPERATURE *(IR 18A MAX)*	-10°C ÷+45°C
MAXIMUM DIMENSIONS	30x34 H32MM
WEIGHT	36g APPROX

SETUP OF MEASURE

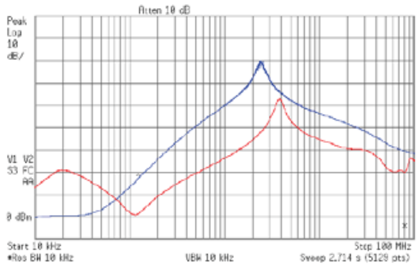
COMMON MODE



DIFFERENTIAL MODE



INSERTION LOSS COMMON MODE DIFFERENTIAL MODE



MAGNETICA

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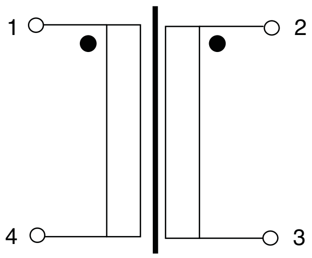
Figure 8. Common-mode inductor L3 (MAGNETICA 1929.0001) technical sheet

STP 03	Product Technical Specification	*Code*: **1929.0001**
Product: Common Mode Inductor 2x30uH/8A		
Customer: **STMicroelectronics**		*Customer Code:*

TYPICAL APPLICATION

DISTURB SUPPRESSION ON AC/DC POWER LINE OF 400V MAX.

SCHEMATIC

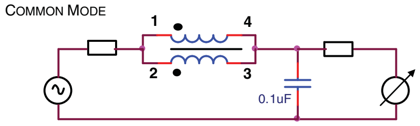


TECHNICAL DATA

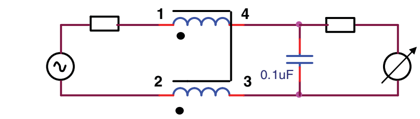
INDUCTANCE (1-4=2-3) *(MEASURE 1KHZ, TA 20°C)*	30uH min
RESISTANCE (1-4=2-3) *(MEASURE D.C, TA 20°C)*	7.36mΩ max
LEAKAGE INDUCTANCE *(MEASURE 1-4 AND 2-3 IN S.C, F 10KHZ, TA 20°C)*	1% NOM
OPERATING VOLTAGE *(F 50-60HZ, IR 8A MAX, TA 20°C)*	400DC MAX
OPERATING CURRENT *(MEASURE 1-4 AND 2-3 ,TA 20°C)*	8A MAX
OPERATING FREQUENCY *(CURRENT 8A MAX, TA 20°C)*	50 – 60Hz
INSULATION (1-4 ⇔ 2-3) *(F 50HZ, TEST DURATION 2", TA 20°C)*	1500V MAX
OPERATING TEMPERATURE RANGE *(IR 8A MAX)*	-10°C ÷+45°C
MAXIMUM DIMENSIONS	40x21 H40MM
WEIGHT	36g APPROX

SETUP OF MEASURE

COMMON MODE



DIFFERENTIAL MODE



ATTENUATION COMMON MODE DIFFERENTIAL MODE

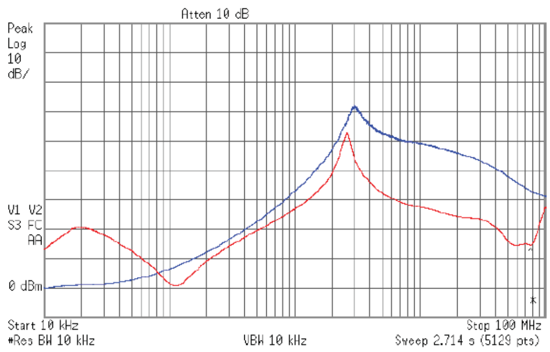


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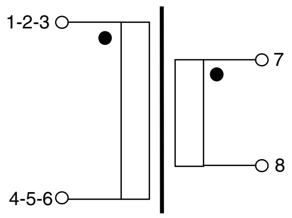
Figure 9. Boost inductor with auxiliary winding, T1 (MAGNETICA 1922.0001) technical sheet

STP 04	Product Technical Specification	*Code* : **1922.0001**
Product: **PFC Inductor 1.5mH 13A**		
Customer: **STMicroelectronics**		*Customer Code:*

TYPICAL APPLICATION

INDUCTOR FOR BUCK, BOOST AND BUCK-BOOST DC/DC CONVERTER, SUITABLE ALSO IN HALF-BRIDGE, PUSH-PULL AND FULL-BRIDGE APPLICATIONS

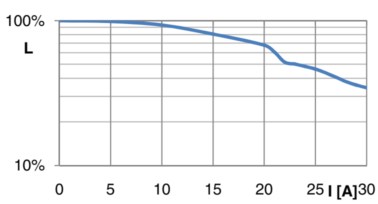
SCHEMATIC



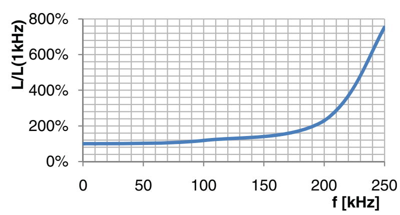
TECHNICAL DATA

INDUCTANCE *(MEASURE 1KHZ, TA 20°C)*	
PIN 1,2,3-4,5,6	1.5mH ±15%
PIN 7-8	18uH ±15%
RESISTANCE *(DC MEASURE, TA 20°C)*	
PIN 1,2,3-4,5,6	100mΩ MAX
PIN 7-8	185mΩ MAX
OPERATING CURRENT *(DC MEASURE , TA 20°C)*	13A MAX
OPERATING VOLTAGE *(F 70KHZ, IR 13A , TA 20°C)*	500V MAX
SATURATION CURRENT *(DC MEASURE, L ≥ 35%NOM, TA 20°C)*	29A MAX
RESONANCE FREQUENCY *(TA 20°C)*	250KHZ NOM
OPERATING AMBIENT TEMPERATURE *(IR 13A MAX)*	-10°C ÷+45°C
MAXIMUM DIMENSIONS	75x80 H62mm
WEIGHT	820g APPROX

INDUCTANCE VS CURRENT



INDUCTANCE VS FREQUENCY



PIN DESCRIPTION

PIN (*)	*FUNCTION*	*PIN (*)*	*FUNCTION*
1_A	PFC BOBBIN START	5_B	PFC BOBBIN END
2_A	PFC BOBBIN START	6_B	PFC BOBBIN END
3_A	PFC BOBBIN START	7	AUXILIARY BOBBIN START
4_B	PFC BOBBIN END	8	AUXILIARY BOBBIN END

(*)PIN WITH THE SAME SUBSCRIPT MUST BE CONNECTED TOGETHER ON PCB

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6 Revision history

Table 3. Document revision history

Date	Revision	Changes
24-Sep-2009	1	Initial release.
19-Dec-2012	2	– Modified BOM in *Table 1*. – Modified: *Figure 5* accordingly to *Table 1*. – Updated title on the cover page and other minor text changes.