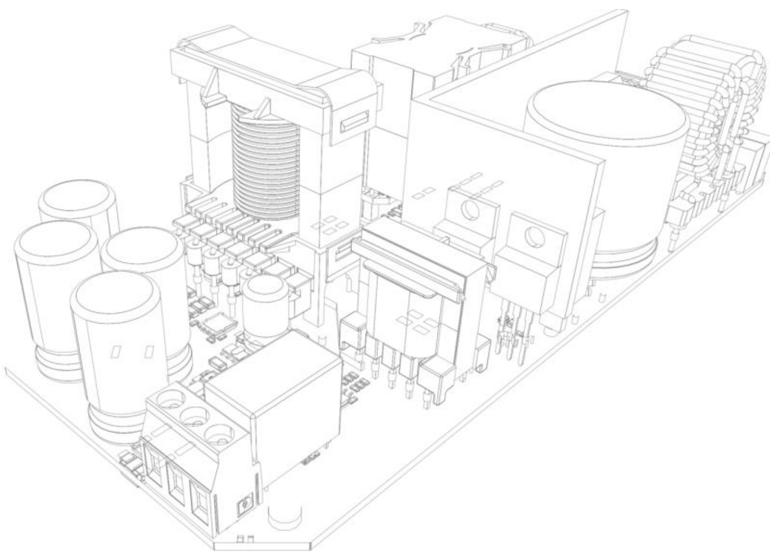


e-Bike Charger Reference Design

230W PFC + LLC Battery Charger with Soft Connection

Table of Contents

1 Overview

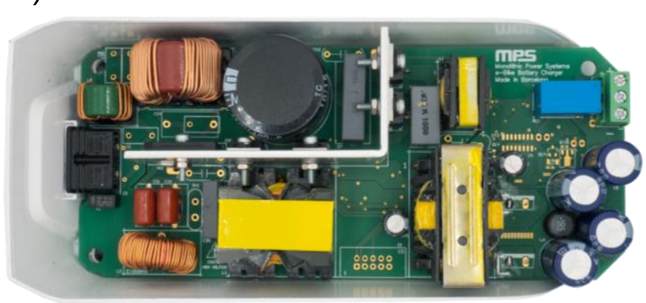
1.1 Description

The MPSB005 is an evaluation board for Lithium-ion chargers typically used in the e-Mobility applications. It also can be used as general Power Supply Unit with minimum changes. The solution is based on a PFC+LLC combo solution from a single integrated circuit with digital control (PFC). This solution offers an excellent relation performance-cost-space by avoiding the use of low frequency filters. Synchronous Rectification (SR) is included instead of diodes to increase the efficiency, besides, a constant current constant voltage control (CC-CV) that operates to guaranty a proper charge of the battery. Combining HR1203, MP6924, MP26085 and the MPS LLC-Design web tool all system requirements can be accomplished. Also, high power density and excellent performance with low cost BOM are shown.

Lithium-Ion batteries usually bring a Battery Management System (BMS) to maintain the battery in its safe operating area. This charger can interact with this type of system through a 5V output presence signal. MPSB005 also implements a Soft Connection Control (SCC), with minimum components, to avoid high current spikes in the output connection. This spikes typically triggers the BMS over current protection. SCC is achieved by balancing the converter voltage with the battery one before closing the relay. If extra control is needed the user can solder J4 connector and attach an MCU. Then direct interaction with current and voltage sensing signals as well as the relay control are possible.
Finally, Electro Magnetic Compliance (EMC) conductive tests are done to fulfill the industry standards.

1.2 Features

- Wide Operating Input Range (from 90V to 265V)
- 230W Rated Power and Constant Voltage Output
- High Efficiency Up to 93%
- Meets EuP Lot 6 and COC Version 5 Tier 2 Specifications
- Meets Class C Standard of IEC61000-3-2
- Meets EN55032 Class B Standard
- High Power Factor (PF)
- Overload Protection (Auto-Restart Mode)



- Short-Circuit Protection (SCP) (Auto Restart Mode)
- Over-Voltage Protection (OVP)
- Anti-Capacitive Mode Protection
- Soft Connection Control (SCC)
- Form Factor 172 x 74 x 50 mm
-

1.3 Applications

- e-Bike battery charger
- General AC/DC Power Supply

High Voltage

Warning: Although this board is designed to satisfy safety requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

2 System Definition

2.1 Block Diagram

The system blocks of the evaluation board are shown in the following figure. Also, the interaction of the MPS ICs with each part.

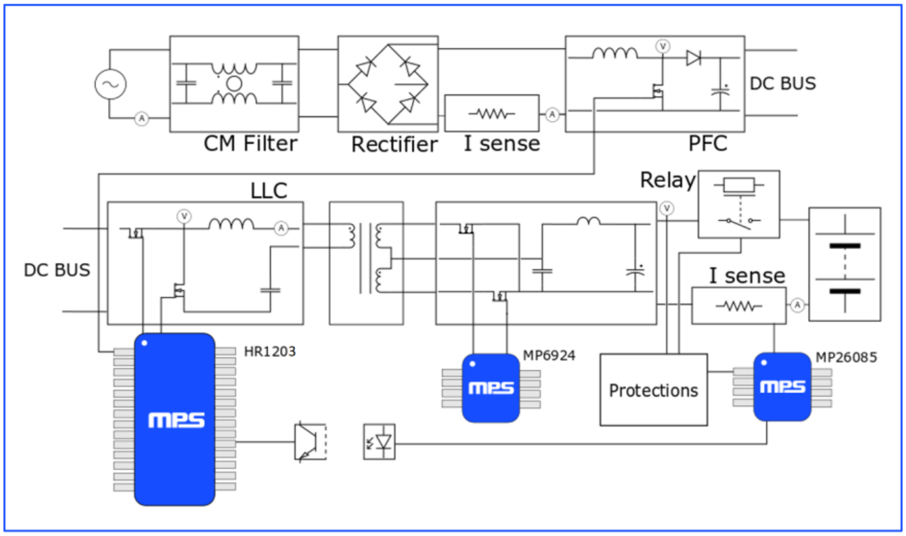


Figure 1: Block diagram

2.2 Related Solutions

The reference design is based on the following MPS solutions:

MPS Integrated Circuit	Description
HR1203	High-Performance Digital PFC + LLC Combo Controller
MP6924	Fast Turn-off, CCM/DCM Compatible Dual LLC Synchronous Rectifier with low Sleep Mode Current
MP26085	CC/CV Controller

Table 1: System Integrated Circuits

2.3 System Specifications

The electric specifications of the reference design board are listed in the following table:

PARAMETER	SPECIFICATION
Input Voltage Range	90 V to 265 V AC
Output Voltage Range	32 V to 42 V ±1.5% DC
Output current	5.5 A ±1.5%
Nominal Conditions	**Input:** 230Vac **Output:** 36Vdc 5.5A
Board form factor	172 x 74 x 50 mm
Expected efficiency	> 90 %
Standby power consumption	Meets EuP Lot 4 and COC Version 5 Tier 2 (<500 mW @ 265 V)
Conducted emissions	EN55032 Class B Standard
Output voltage ripple	±50 mV at Full load
Output current ripple	±60 mA at Full load

Table 2: System Specifications

3 Design

3.1 HR1203: PFC – LLC combo controller

The HR1203 is a high-performance controller that integrates an advanced digital PFC controller and a half-bridge LLC resonant controller. The PFC of the HR1203 employs a patented average current control scheme, which can operate both in continuous conduction mode (CCM) and discontinuous conduction mode (DCM) according to the instantaneous condition of the input voltage and output load. The IC exhibits excellent efficiency and high-power factor (PF) at light load. The half-bridge LLC resonant converter achieves high efficiency with zero-voltage switching (ZVS).

The HR1203 implements an adaptive dead-time adjustment (ADTA) function to guarantee ZVS in different load conditions. Also, can prevent the LLC converter from operating in capacitive mode, making it more robust and easier to design. Additionally, integrates a high-voltage (HV) current source internally for start-up. When the AC input is removed, the HV current source also functions as an X-cap discharger.

3.2 MP6924: Synchronous Rectifier controller

The MP6924 is a dual, fast turn-off, intelligent rectifier for synchronous rectification in LLC resonant converters. The IC drives two N-channel MOSFETs, regulates their forward voltage drop to about 45mV, and turns the MOSFETs off before the switching current goes negative.

The MP6924 has a light-load function to latch off the gate driver under light-load conditions, limiting the current to 175μA. Also, fast turn-off enables both continuous conduction mode (CCM) and discontinuous conduction mode (DCM).

3.3 MP26085: CC-CV controller

The MP26085 is a voltage and current control IC with an integrated voltage reference which is suitable for battery charger design.

This IC compares the DC voltage and the current level at the output of the power supply to achieve the voltage reference and current limitation, respectively. It provides a feedback through an opto-coupler to the PWM controller IC at the primary side, HR1203 in this case.

3.4 LLC converter stage

To design the LLC converter, we used the LLC design tool from MPS available in the web side.

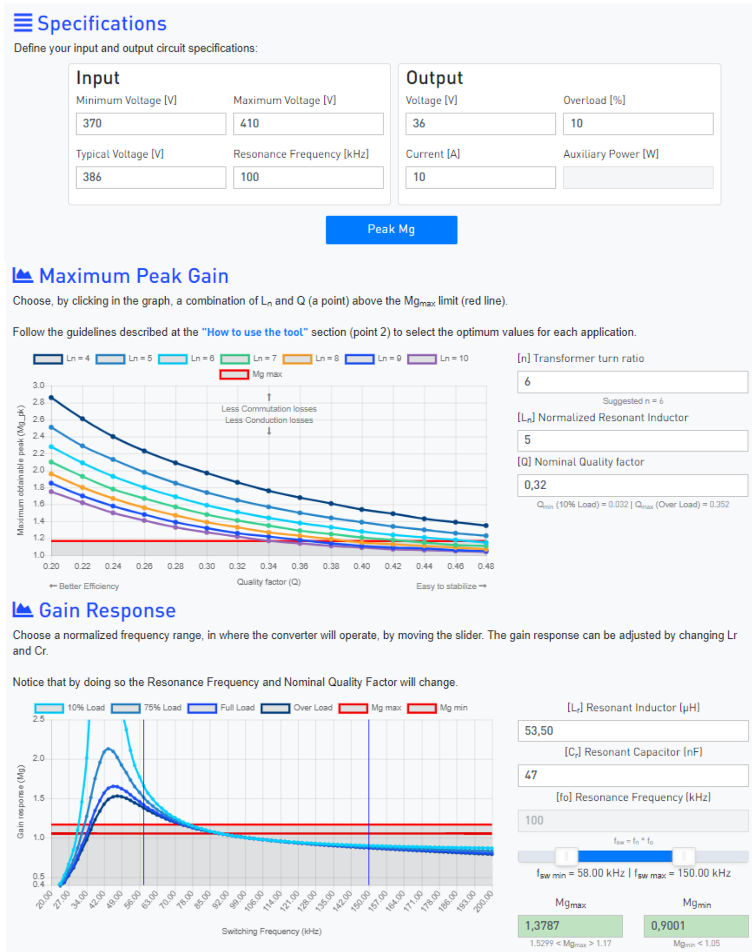


Figure 2: LLC design tool


Show Final Results

Final Results

Tank Design		Transformer Design		Frequency Range		RMS Current Values	
L_r	C_r	L_m	n	fs_{min}	fs_{max}	Primary	Secondary
71.30 µH	33 nF	285.20 µH	5	76780.36 Hz	207514.47 Hz	2.45 A	7.89 A

Figure 3: LLC design tool final results

3.5 Schematic

PFC.schDoc: Power Factor Correction stage (AC/DC).

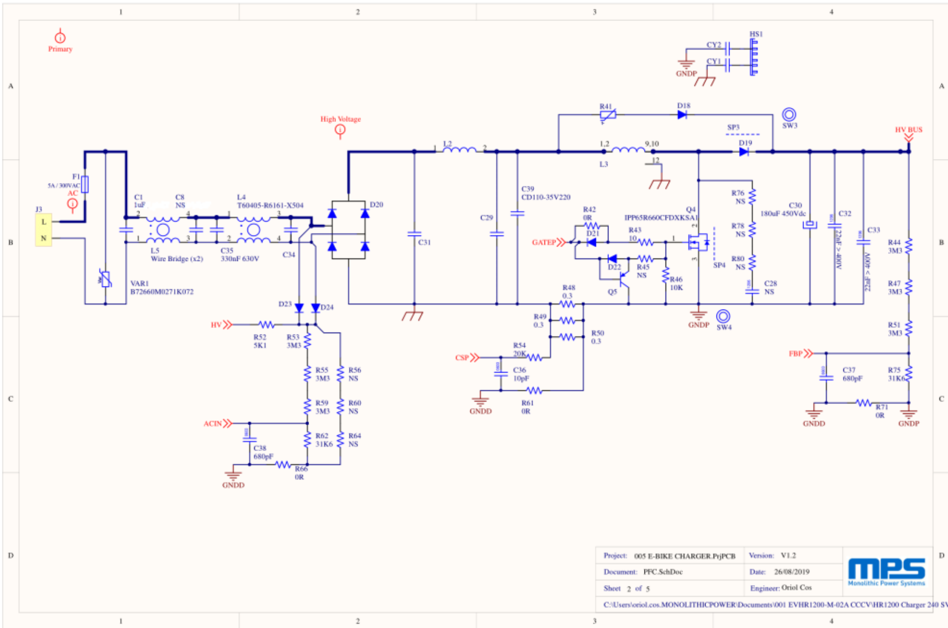


Figure 4: PFC Stage

LLC.schDoc: Resonant converter stage (DC/DC), bias secondary supply and CCCV.

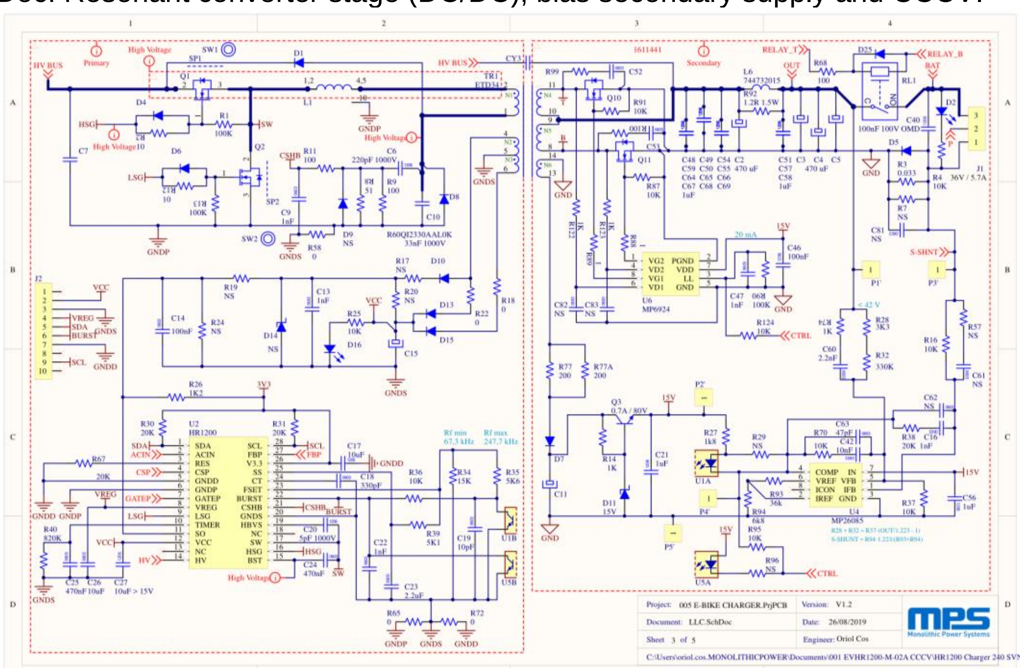


Figure 5: LLC Stage, CCCV and SR

CTRL.schDoc: Relay control block.

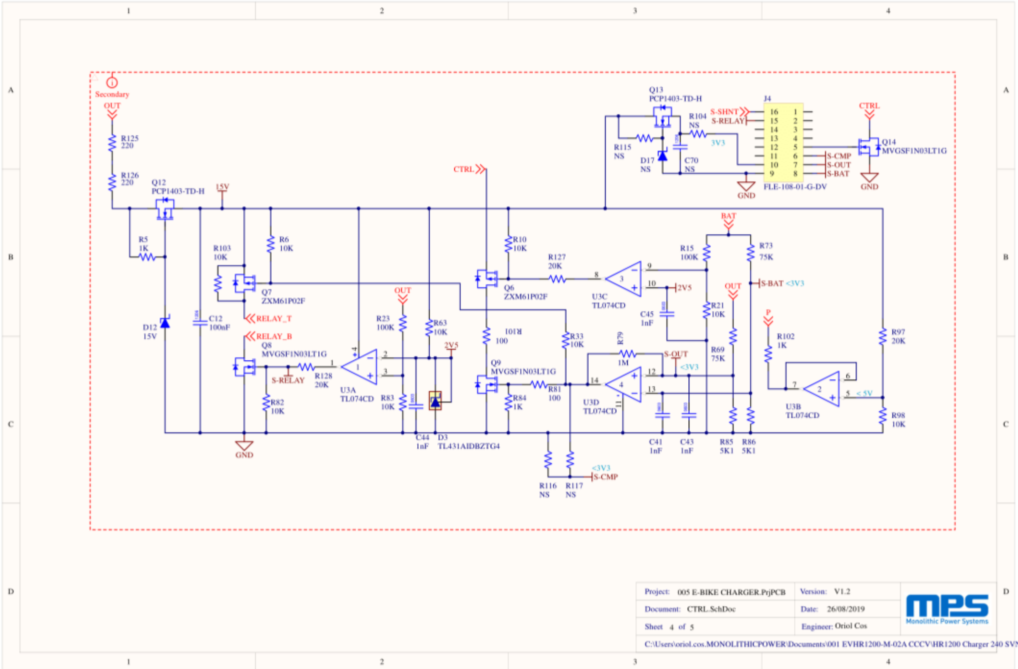


Figure 6: Relay control

3.6 BOM

Designator	Qty	Value	Part Number	Manufacturer	Package
C1	1	1uF	ECQ-E2W105KH	Panasonic	DIP
C34, C35		33nF 630V	MKS4J023302E00KSSD	WIMA	DIP
C2, C3, C4, C5	4	470 uF	ESK477M063AL4EA	KEMET	
C6	1	220pF 1000V	GRM31A7U3A221JW31D	Murata	1206
C7	1	330nF 630Vdc	R60334-630-N	NISSEI-ARCOTRONICS	
C9, C13, C16, C22, C41, C43, C44, C45, C47	9	1nF	0603 1nF		0603
C10	1	33nF 1000V	R60QI2330AAL0K	Kemet	DIP
C11, C15, C39	3	220uF 35Vdc, 0.1 uF	CD110-35V220	JIANGHAI, Kemet	r3.5mm, DIP
C12, C46	2	100nF	1206 100nF		1206
C14	1	100nF	0603 100nF		0603
C17	1	10uF	1206 10uF		1206
C18	1	330pF	0603 330pF		0603
C19, C36	2	10pF	0603 10pF		0603
C20	1	5pF 1000V	MC1206N4R7C102CT	MULTICOMP	1206
C21, C56	2	1uF	1206 1uF		1206
C23	1	2.2uF	0805 2.2uF		0805
C24	1	470nF	0603 470nF		0603
C25	1	470nF	0805 470nF		0805
C26	1	10uF	0805 10uF		0805
C27	1	10uF > 15V	1206 10uF 25V		1206
C28, C61, C62, C70, C81, C82, C83, CY2	9	NS			
D14, D17, D21, D22, J2, Q5, Q13, Q14	8	NS			
R7, R17, R19, R20, R24, R29, R45, R56	8	NS			
R57, R60, R64, R76, R78, R80, R96, R104	8	NS			
R115, R116, R117, U5	8	NS			
C29, C31	2	TF684K2Y10BL270D9R	TF684K2Y10BL270D9R	CARLI	DIP
C30	1	180uF 450Vdc	ELG187M450AS3AA	KEMET	DIP
C32, C33	2	22nF > 400V	C1206V223KCRACTU	KEMET	1206
C37, C38	2	680pF	0603 680pF		0603

C40	1	100nF 100V OMD	VJ1206Y104KBBAT4X	Vishay	1206
C42	1	10nF	0603 10nF		0603
C48, C49, C50, C51, C54, C55, C57, C58	9	1uF	GRM32DC72A475KE01L	Murata	1206
C59, C64, C65, C66, C67, C68, C69	7	1uF	GRM32DC72A475KE01L	Murata	1207
C52, C53, C63	3	47pF	0603 47pF		0603
C60	1	2.2nF	0603 2.2nF		0603
CY1, CY3	2	2n2 CY	DE1E3RA222MN4AN01F	Murata	
D1, D8, D18	3	2454084, RS1J	RS1J	ON SEMICONDUCTOR	DO-214AC
D2, D16	2	Green	SML-D12P8WT86C	ROHM	0603
D3	1	1494941	TL431AIDBZTG4	TEXAS INSTRUMENTS	SOT-23-3
D4, D6, D9, D10, D25	5	2453269RL	1N4148WS	ON SEMICONDUCTOR	SOD-323F
D5, D7, D13, D15	4	1843674	B160	DIODES	DO-214AC
D11, D12	2	15V	BZX84C18LT1G	ON SEMICONDUCTOR	SOT-23-3
D19	1	QH08TZ600	QH08TZ600	POWER INTEGRATIONS	TO-220AC
D20	1	GBU8J	GBU8J	On Semiconductor	GBU8L
D23, D24	2	WSGC10DH	WSGC10DH	ZOWIE	
F1	1	5A / 300VAC	SS-5H-5A-APH	EATON BUSSMANN SERIES	
HS1	1	HS1	HS1	MonolithicPowerSystems	
J1	1	400A 16A	MKDSN2,5/3-5.08	PHOENIX CONTACT	
J3	1	250V 2.5A	RAPC322X	Schurter	Screw
J4	1	200-FLE10801GDV	FLE-108-01-G-DV	Samtec	SMD
L1	1		005-L1	PROELEC	EF20
L2	1	330u 3.1A	7447065	Würth Elektronik	25x10
L3	1	005-L3	005-L3	PROELEC	DIP
L4	1		T60405-R6161-X504	VAC	
L5	1	Wire Bridge (x2)	Wire Bridge (x2)		

L6	1	1uH 7A	744732015	WURTH ELEKTRONIK	
Q1, Q2	2	0.54 ohm	IPP65R380E6	Infineon	TO-220AC
Q3	1	0.7A / 80V	2SCR514PFRAT100	ROHM Semiconductor	
Q4	1	650V 16A	IPP65R660CFDXKSA1	Infineon	TO-220AC
Q6, Q7	2	9525297	ZXM61P02F	DIODES INC.	SOT-23-3
Q8, Q9	2	2630354	MVGSF1N03LT1G	ON SEMICONDUCTOR	SOT-23-3
Q10, Q11	2	100V 55A 19mR	NVMFS6B14NLT1G	ON SEMICONDUCTOR	SO-8FL
Q12	1	60V 4.5A 117mR	PCP1403-TD-H	ON SEMICONDUCTOR	SOT-89-3
R1, R13, R15, R23, R90	5	100K	0603 100K		0603
R2, R12	2	10R	0805 10R		0805
R3	1	0.033	2512		2512
R4, R6, R10, R16, R21, R25, R33, R36, R37	9	10K	0603 10K		0603
R46, R63, R70, R82, R83, R87, R91, R95	8	10K	604 10K		0604
R98, R99, R100, R103, R124	6	10K	605 10K		0605
R5, R14, R74, R84, R102, R122, R123	7	1K	0603 1K		0603
R8	1	51	1206 51R		1206
R9, R68	2	100	1206 100R		1206
R11, R81, R101	3	100	0603 100R		0603
R18, R22	2	0	1206 0R		1206
R26	1	1K2	0603 1K2		0603
R27	1	1k8	0603 1K8		0603
R28	1	3K3	0603 3K3		0603
R30, R31, R38, R54, R67, R97, R127, R128	8	20K	0603 20K		0603
R32	1	330K	0603 330K		0603
R34	1	15K	0603 15K		0603
R35	1	5K6	0603 5K6		0603
R39, R85, R86	3	5K1	0603 5K1		0603
R40	1	820K	0603 820K		0603
R41	1	2	SL22 2R018	AMETHERM	Disc 22mm
R42, R58, R61, R65, R66, R71, R72	7	0R, 0	603		0603
R43	1	10	0603 10R		0603
R44, R47, R51, R53, R55, R59	6	3M3	1206 3M3		1206
R48, R49, R50	3	0.3	MCWW25XR300FTL	MULTICOMP	2512

R52	1	5K1	1206 5K1		1206
R62, R75	2	31K6	0603 31K6		0603
R69, R73	2	75K	0603 75K		0603
R77, R77A	2	200	1206 200R		1206
R79	1	1M	0603 1M		0603
R88, R89	2	1	0603 1R		0603
R92	1	1.2R 1.5W	35221R2JT	TE	2512
R93	1	36k	0603 36K		0603
R94	1	6k8	0603 6K8		0603
R125, R126	2	220	1206 220R		1206
RL1	1	18916 75	OJE-SS-124HMF,F000	OEG - TE CONNECTIVITY	DIP
SP1, SP2, SP3, SP4	4	3.5W/ m.K 4kV	2015-54	BERGQUIST	TO-220
SW1, SW2, SW3, SW4	4	534-3103, M2	3103	Keystone	M2
TR1	1		005-TR1	PREELEC	ETD34_V
U1	1	23225 14	FOD817A3SD	ON SEMICONDUCTO R	DIP SMD
U2	1		HR1200GY	MonolithicPowerS ystems	SOIC-28/TSSO P-28
U3	1	11030 10	TL074CD	TEXAS INSTRUMENTS	SOIC-14
U4	1		MP26085DJ	MonolithicPowerS ystems	SOIC-8
U6	1		MP6924GS	MonolithicPowerS ystems	SOIC-8
VAR1	1	99585 84	B72660M0271K072	EPCOS	4032

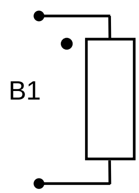
Table 3: Bill of Materials

INDUCTIVE COMPONENT	CODE	005-L1
	DESIGNER	O. Cos

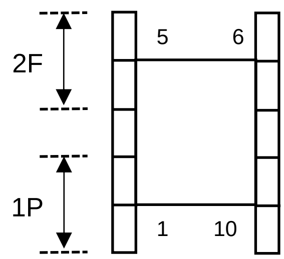
MATERIALS LIST		
Quantity	Units	Description
1	-	EF20 (vertical) coil former
2	-	½ core N87 / 3C94
	-	Gap
	-	Litz 200x0.05

WINDINGS			Turns	WIRE			PINOUT		TUBE		INSULATORS		ELECTRIC	
#	Start	End		Ø	Class	Color	Start	End	Start	End	Layers	Mater.	Ω	µH
B1	1P	2F	40	Litz 200x0.05		-	1, 2	4, 5	No	No	2	Poly. Adhe.	-	71.3

ELECTRIC SCHEME

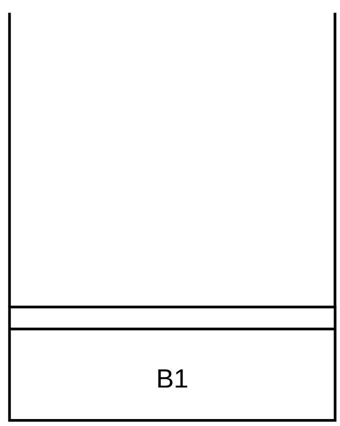


BOTTOM VIEW



ASSEMBLY DETAILS

WINDOW VIEW



MANUFACTURING NOTES

- Adjust the inductance value with the gap.

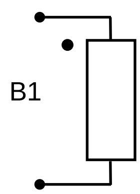
VERIFICATION	
Inductance	B1 = 71.3 µH (±15%)

INDUCTIVE COMPONENT	CODE	005-L3
	DESIGNER	O. Cos

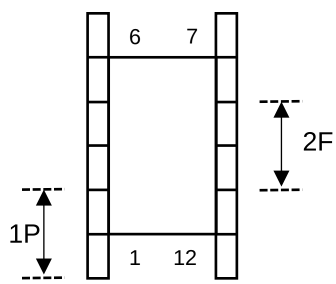
MATERIALS LIST		
Quantity	Units	Description
1	-	PQ 32-30 coil former Norwe
2	-	½ core PQ 32-30, 3C90
	-	Gap
	-	Litz 100x0.1

WINDINGS			Turns	WIRE			PINOUT		TUBE		INSULATORS		ELECTRIC	
#	Start	End		Ø	Class	Color	Start	End	Start	End	Layers	Mater.	Ω	µH
B1	1P	2F	30	Litz 100x0.1		-	1, 2	9, 10	No	No	2	Poly. Adhe.	-	260

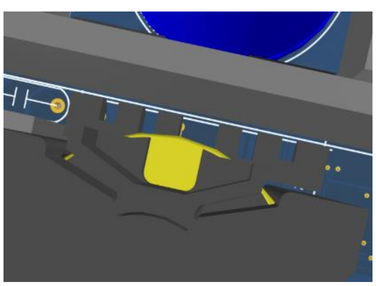
ELECTRIC SCHEME



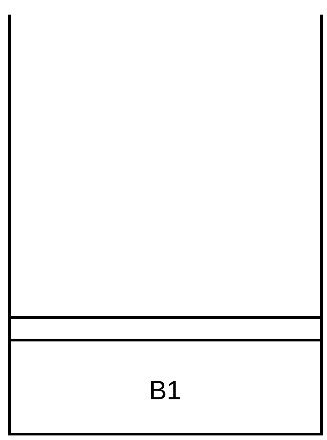
BOTTOM VIEW



ASSEMBLY DETAILS



WINDOW VIEW



MANUFACTURING NOTES

- Adjust the inductance value with the gap.

- Keep the 2F solder inside the plastic perimeter. To avoid short circuits with the heat sink. *Assembly details.*

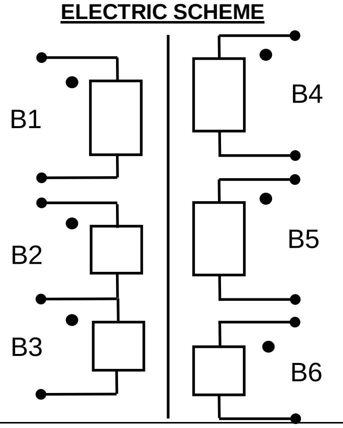
VERIFICATION	
Inductance	B1 = 260 µH (±15%)

	INDUCTIVE COMPONENT	CODE	005-TR1
		DESIGNER	O. Cos

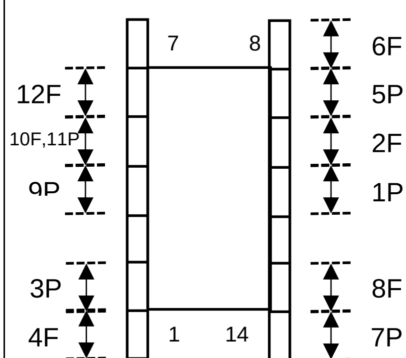
MATERIALS LIST		
Quantity	Units	Description
1	-	ETD34 coil former (vertical) Norwe
2	-	½ core ETD34, N87 / 3C94
	-	Litz 200 x 0.05
	-	Litz 100 x 0.1
	-	0.4
	-	Gap

WINDINGS			Turns	WIRE			PINOUT		TUBE		INSULATORS		ELECTRIC	
#	Start	End		Ø	Class	Color	Start	End	Start	End	Layers	Mater.	Ω	uH
B4	1P	2F	5	Litz 100x0.1		-	11	10	Yes	Yes	3	Poly. 50µ	-	-
B1	3P	4F	26	Litz 200x0.05		-	2	1	Yes	Yes	3	Poly. 50µ	-	311.8
B5	5P	6F	5	Litz 100x0.1		-	9	8	Yes	Yes	1	Poly. 50µ	-	-
B6	7P	8F	4	0.4	-	-	14	13	Yes	Yes	3	Poly. 50µ	-	-
B2	9P	10F	4	0.4	-	-	4	5	Yes	Yes	-	-	-	-
B3	11P	12F	4	0.4	-	-	5	6	Yes	Yes	2	Poly. Adhe.	-	-

ELECTRIC SCHEME

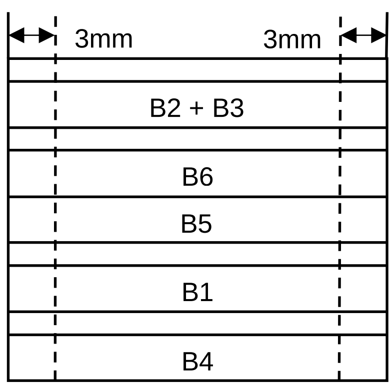


BOTTOM VIEW



ASSEMBLY DETAILS

WINDOW VIEW



MANUFACTURING NOTES

-Use 3mm adhesive tape to keep the clearance distance.

-Wind B2 and B3 at the same time.

-Keep the solders as small as possible.

-Don't use more insulator than specified.

-Adjust the B1 inductance value with a gap.

VERIFICATION			
Inductance	B1 = 311 uH (±15%)		
Turns ratio	$n = N_2/N_1$		
Dielectric strength	Connect pins	Voltage	Connect pins
	1, 2, 4, 5, 6	3000 V_{AC}	8, 9, 10, 11, 13, 14

3.7 Layout recommendations

As the HR1203 is a combo solution the best place to be is in between the two stages (PFC-LLC) to reduce the length of the gate signals and the sensing ones. C18 connected to pin CT(U2.24), in charge of setting the switching frequency of the LLC bridge, and R67 connected to pin RES (U2.3), to produce the system clock, need to be as close as possible to the device.
Also, the reader needs to take special care with the sensing signals, avoid big loops and rout them away from switching nodes.

Other topics to take in consideration as a general AC/DC design are the following:

- Isolation from N and L lines to ground (typically 3 mm).
- Isolation from Primary to Secondary (typically 6 mm).
- Do not place copper planes under CM and DM filters.
- If more than one CM filter is used place it 90º to avoid cross talk and increase the effectivity.
- Reduce high dV/dt (PFC and LLC switch) nodes area and dI/dt loops (output rectification).
- Place decoupling capacitors near the ICs >100nF and connect power ground and signal ground in a single point near the bulk capacitor.
- Adequate the wide of the traces to its usage. AC and High Voltage narrow DC and Low voltage wide. (typically, 1 A/mm).

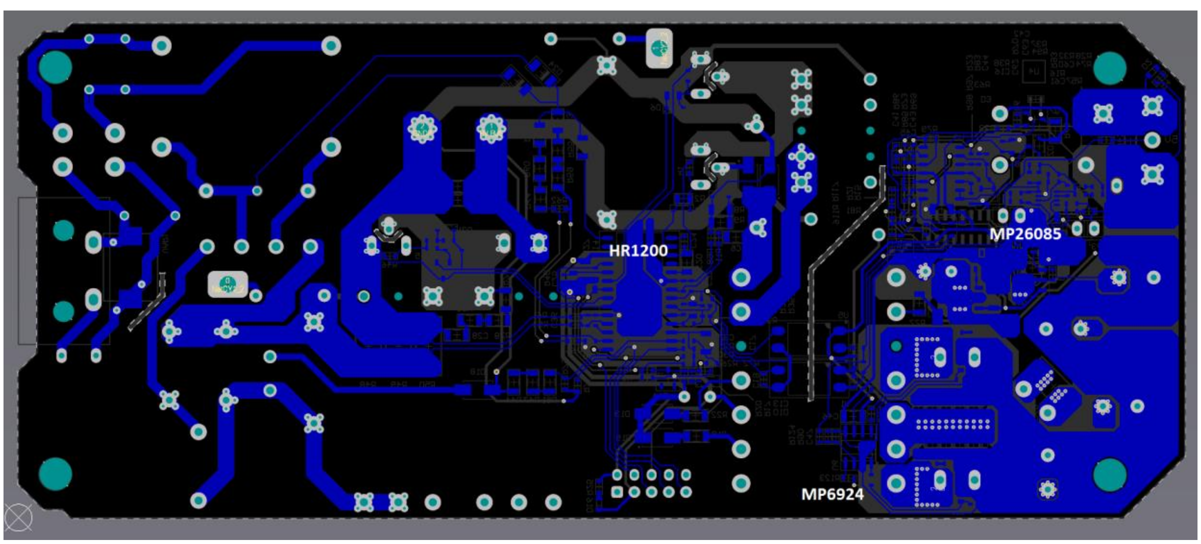


Figure 4: PCB bottom layer.

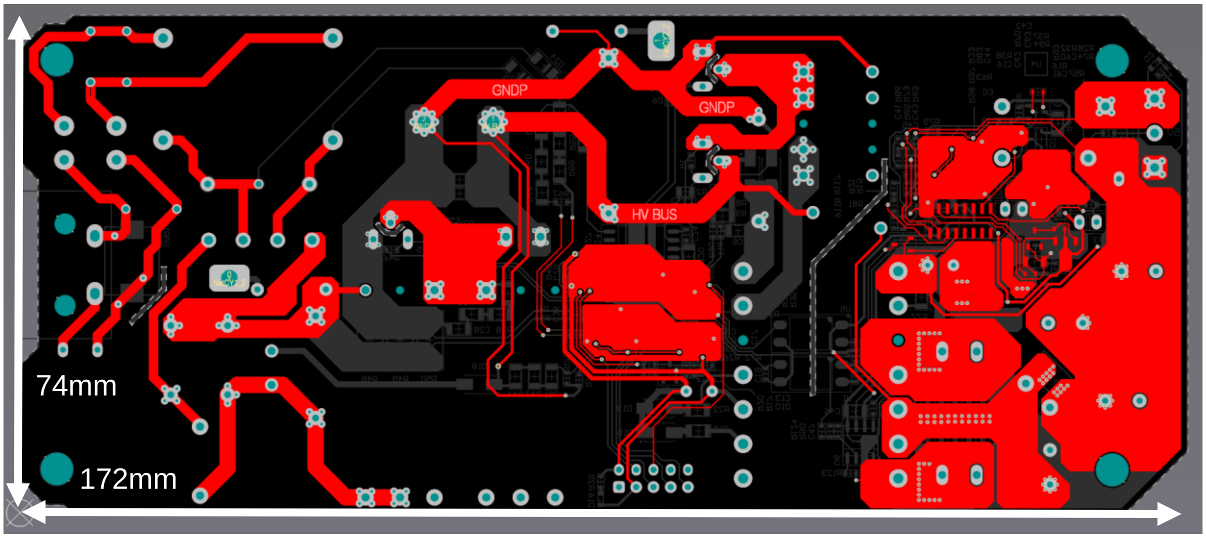


Figure 7: PCB top layer.

4 Test Results

4.1 Test overview

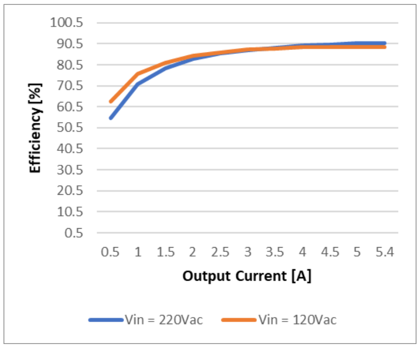


Figure 8: Efficiency vs. Load

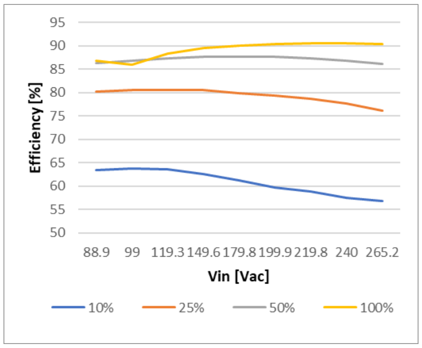


Figure 9: Efficiency vs. Vin

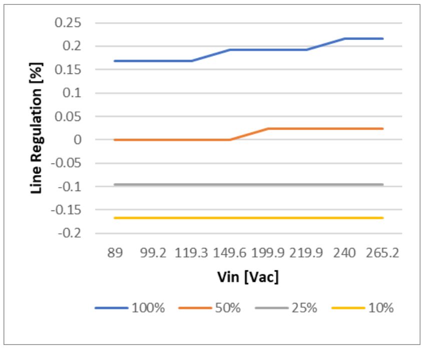


Figure 10: Line regulation

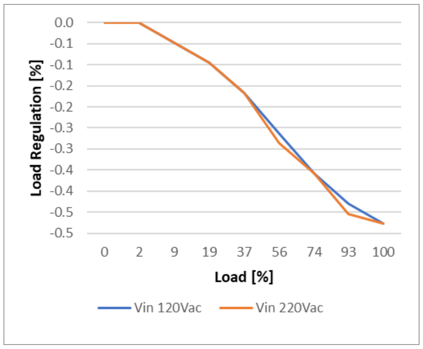


Figure 11: Load Regulation

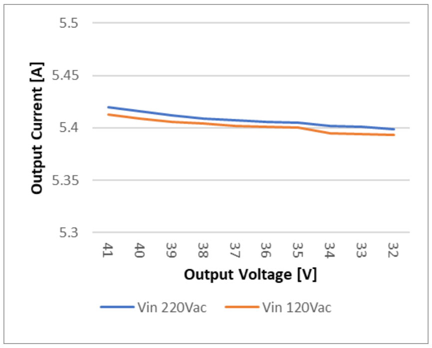


Figure 12: Output current

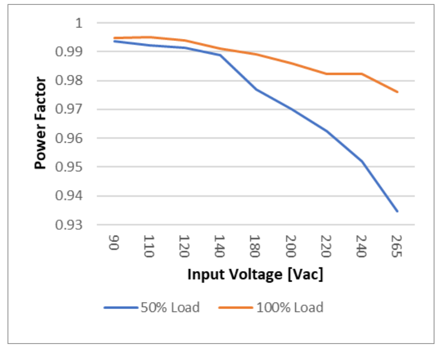


Figure 11: Power Factor

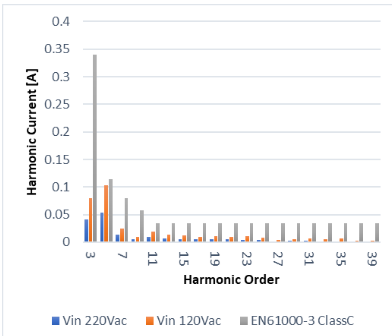


Figure 12: Current harmonic distribution

4.2 Waveforms

In the following section some waveforms are shown to prove the correct operation of the evaluation board. If not specified the operation conditions are the nominal ones (Table 1).

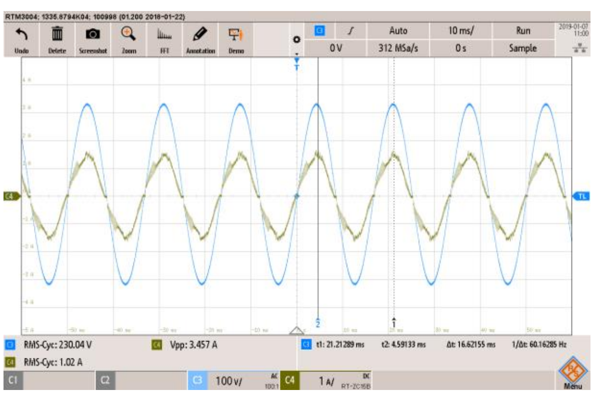


Figure 13: Input characteristics

Vin 220Vac, Vout 42V, Iout 5.5A

Waveforms:	C3: Input AC voltage (100V/div) C4: Input AC current (1A/div)

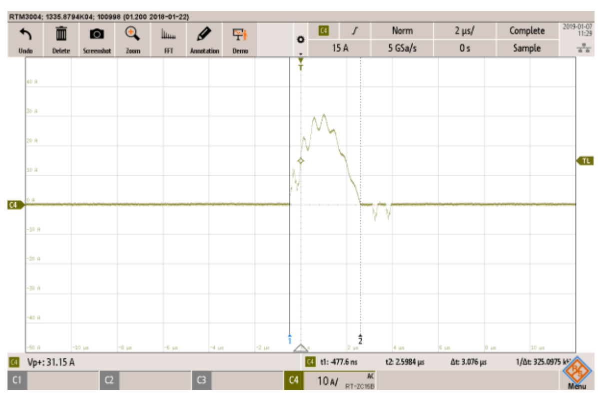


Figure 14: System inrush current

Vin 220Vac, No load

Waveforms:	C3: Input AC current (10A/div)

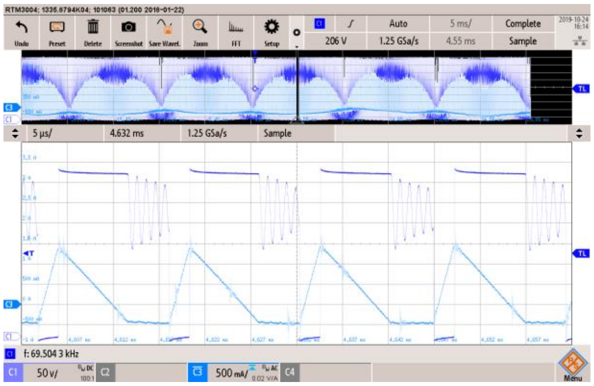


Figure 15: PFC High Line – Half Load

Vin 220Vac, Vout 42V, Iout 2.75A (50% Load)

Waveforms: C1: Switch node voltage PFC (50V/div)
C3: PFC Ind. current (500mA/div)

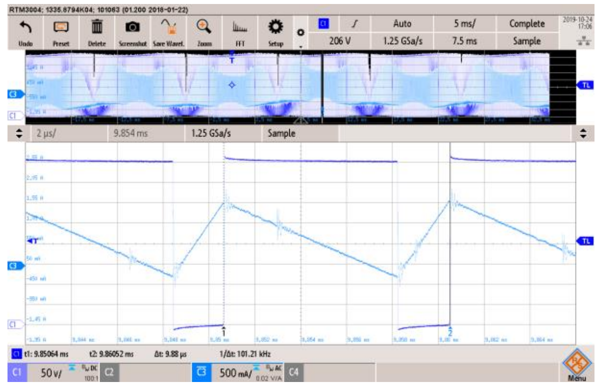


Figure 16: PFC High Line – Full Load

Vin 220Vac, Vout 42V, Iout 5.5A (100% Load)

Waveforms: C1: Switch node voltage PFC (50V/div)
C3: PFC Ind. current (500mA/div)

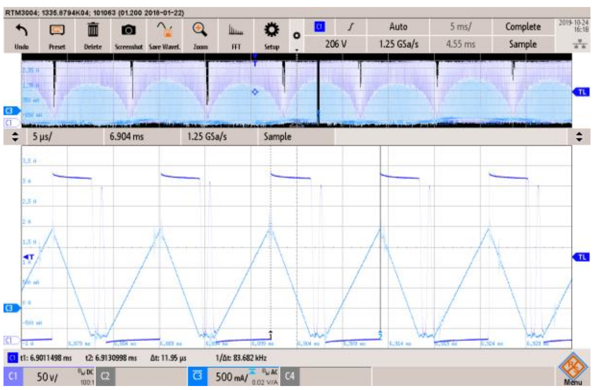


Figure 17: PFC Low Line – Half Load

Vin 110Vac, Vout 42V, Iout 2.75A (50% Load)

Waveforms: C1: Switch node voltage PFC (50V/div)
C3: PFC Ind. current (500mA/div)

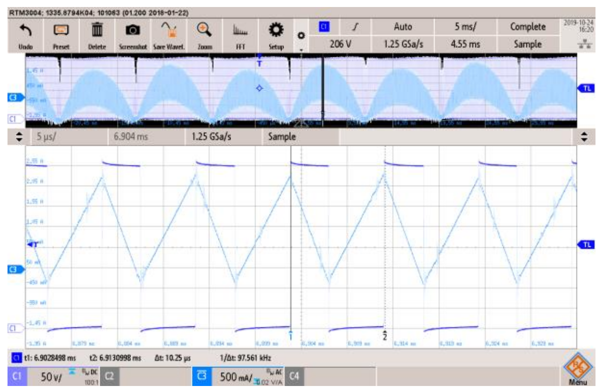


Figure 18: PFC Low Line – Full Load

Vin 110Vac, Vout 42V, Iout 5.5A (100% Load)

Waveforms: C1: Switch node voltage PFC (50V/div)
C3: PFC Ind. current (500mA/div)

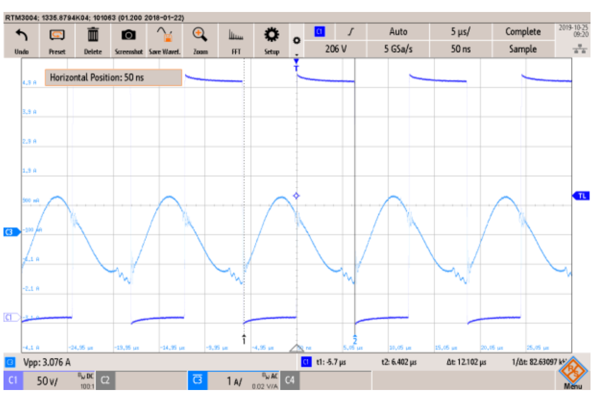


Figure 19: LLC Constant Current – Half Load

Vin 220Vac, Vout 42V, Iout 2.75A (50% Load)

Waveforms: C1: Switch node voltage LLC (50V/div)
C3: Resonant Ind. current (500mA/div)

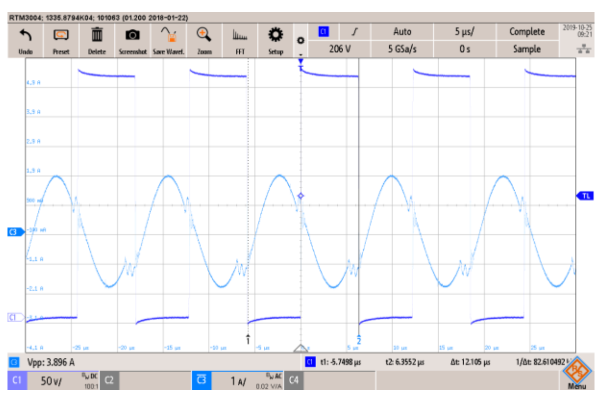


Figure 20: LLC Constant Current – Full Load

Vin 220Vac, Vout 42V, Iout 5.5A (100% Load)

Waveforms: C1: Switch node voltage LLC (50V/div)
C3: Resonant Ind. current (500mA/div)

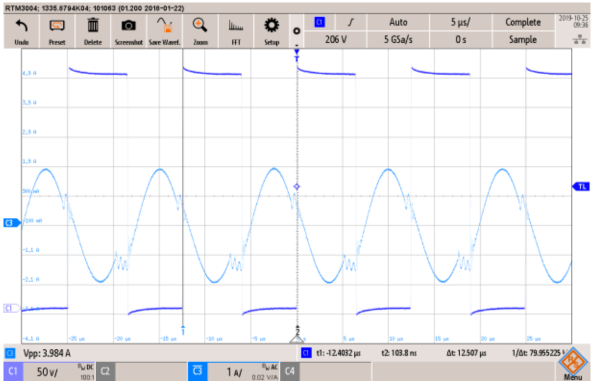


Figure 21: LLC Constant Voltage – 41V
Vin 220Vac, Vout 41V, Iout 5.5A

Waveforms: C1: Switch node voltage LLC (50V/div)
C3: Resonant Ind. current (500mA/div)

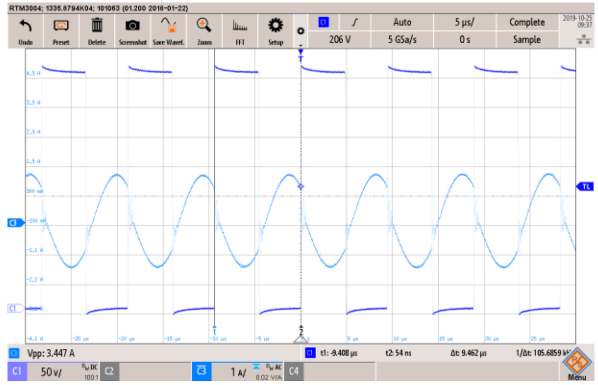


Figure 22: LLC Constant Voltage – 36V
Vin 220Vac, Vout 36V, Iout 5.5A

Waveforms: C1: Switch node voltage LLC (50V/div)
C3: Resonant Ind. current (500mA/div)

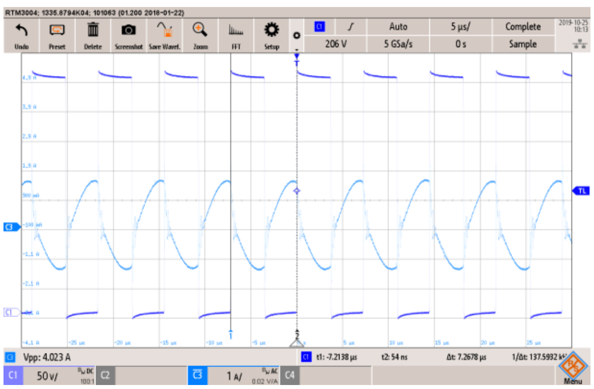


Figure 23: LLC Constant Voltage – 32V
Vin 220Vac, Vout 32V, Iout 5.5A

Waveforms: C1: Switch node voltage LLC (50V/div)
C3: Resonant Ind. current (500mA/div)

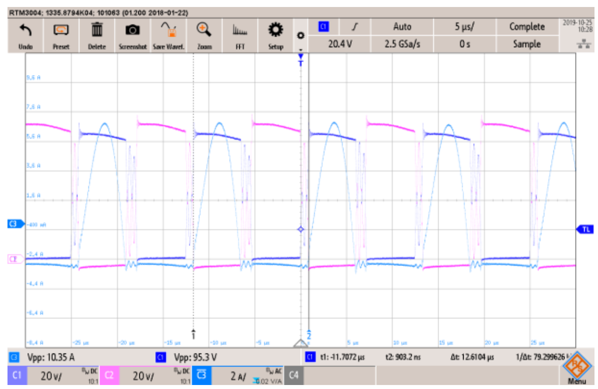


Figure 24: SR Constant Voltage – 41V
Vin 220Vac, Vout 41V, Iout 5.5A

Waveforms: C1: Q10 Drain Source voltage (20V/div)
C2: Q12 Drain Source voltage (20V/div)
C3: Q12 Drain Source current (2A/div)

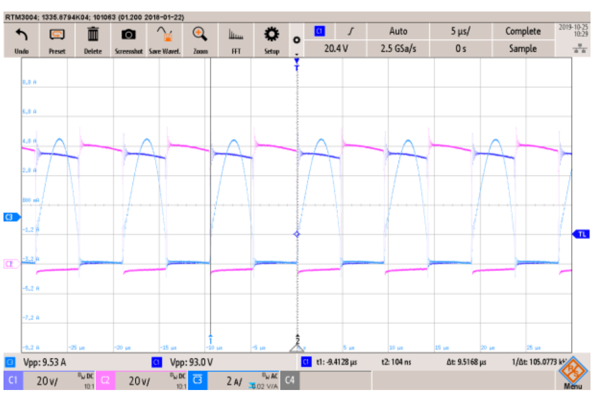


Figure 25: SR Constant Voltage – 36V
Vin 220Vac, Vout 36V, Iout 5.5A

Waveforms: C1: Q10 Drain Source voltage (20V/div)
C2: Q12 Drain Source voltage (20V/div)
C3: Q12 Drain Source current (2A/div)

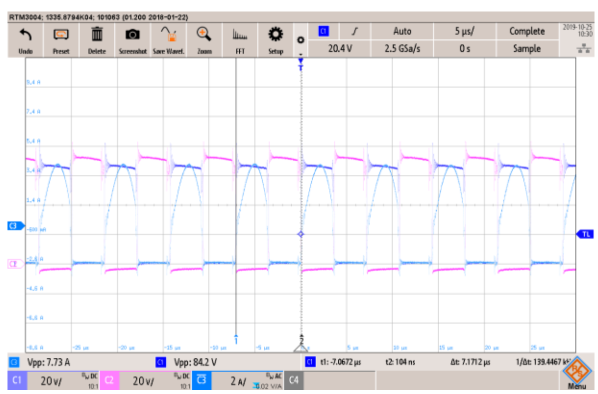


Figure 26: SR Constant Voltage – 32V
Vin 220Vac, Vout 32V, Iout 5.5A

Waveforms: C1: Q10 Drain Source voltage (20V/div)
C2: Q12 Drain Source voltage (20V/div)
C3: Q12 Drain Source current (2A/div)

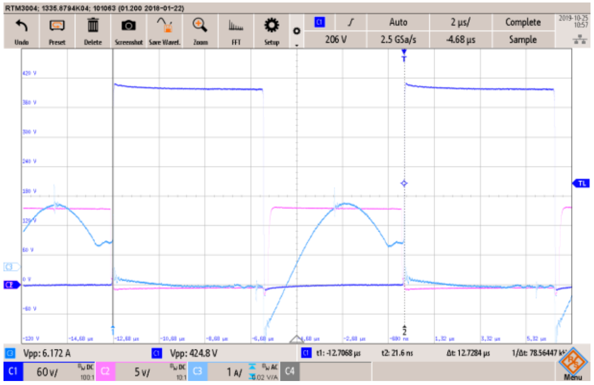


Figure 27: Q2 Soft Switching detail
Vin 220Vac, Vout 36V, Iout 5.5A

Waveforms:
C1: Q2 Drain Source voltage (60V/div)
C2: Q2 Gate Source voltage (5V/div)
C3: Q2 Drain Source current (1A/div)

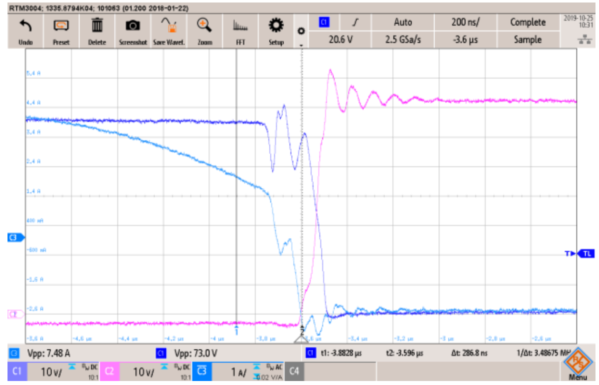


Figure 28: Q12 Soft Switching detail
Vin 220Vac, Vout 32V, Iout 5.5A

Waveforms:
C1: Q10 Drain Source voltage (20V/div)
C2: Q12 Drain Source voltage (20V/div)
C3: Q12 Drain Source current (2A/div)

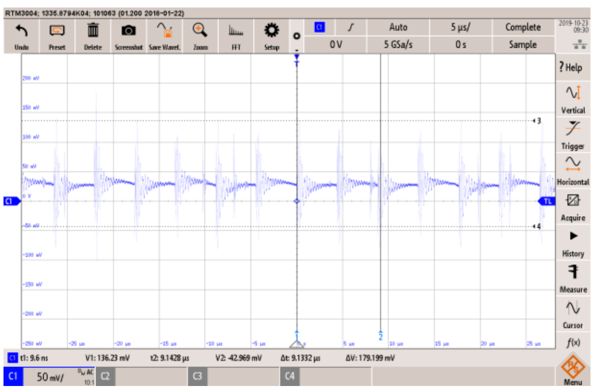


Figure 29: Output Voltage Ripple (C40)
Vin 220Vac, Vout 42V, Iout 5.5A, Fsw LLC 85kHz

Waveforms: C1: Output voltage ripple (50mV/div)

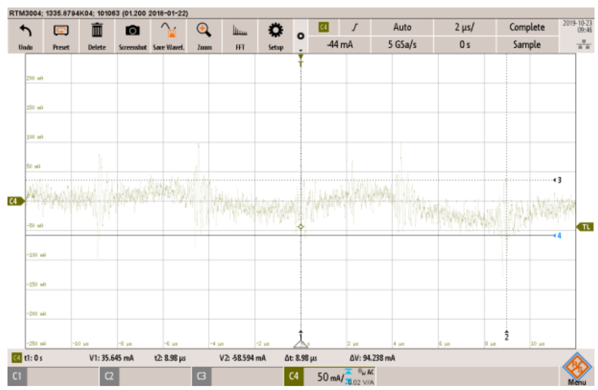


Figure 30: Output Current Ripple
Vin 220Vac, Vout 42V, Iout 5.5A, Fsw LLC 85kHz

Waveforms: C4: Output current ripple (50mV/div)

4.3 Thermal Measurements

The following figure guaranty that the systems fulfils the thermal behaviour specified.

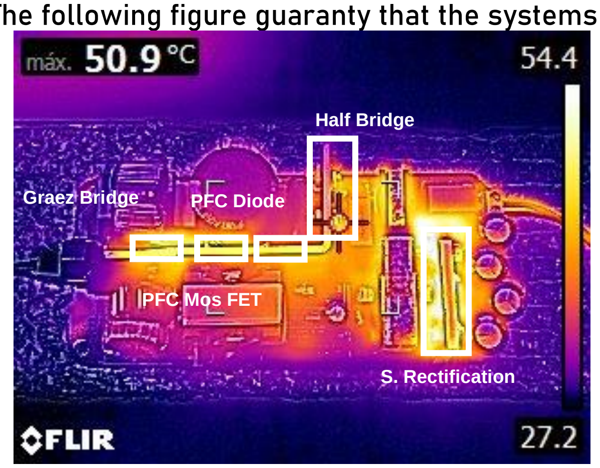


Figure 31: Thermal image (Top View)
Vin 220Vac, Vout 42V, Iout 5.5A, 25ºC

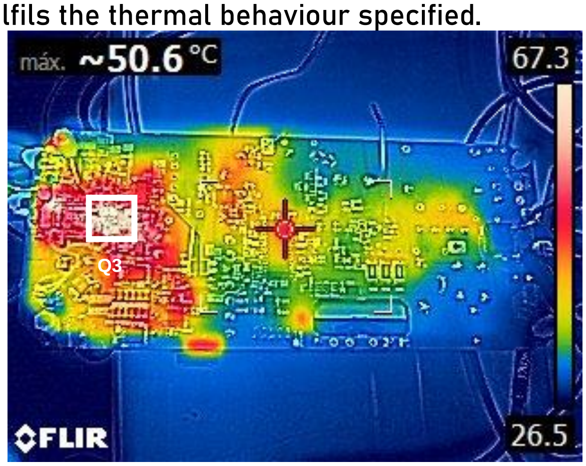


Figure 32: Thermal image (Bottom View)
Vin 220Vac, Vout 42V, Iout 5.5A, 25ºC

4.4 Conducted Emissions

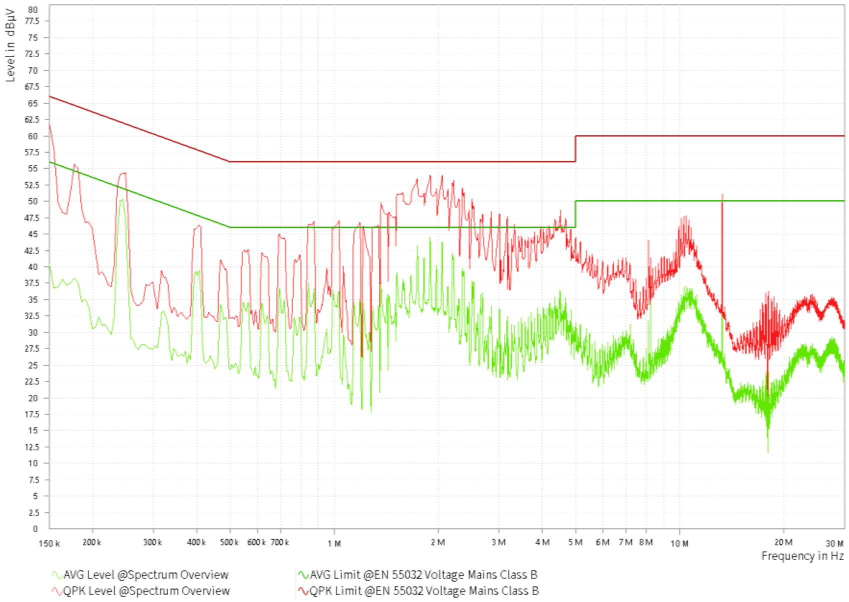


Figure 33: Conducted emission LINE according EN55032 class B.
Vin 220Vac, Vout 42V, Iout 5.5A, Fsw $_{LLC}$ 85kHz, Average (green) and QPK (red).

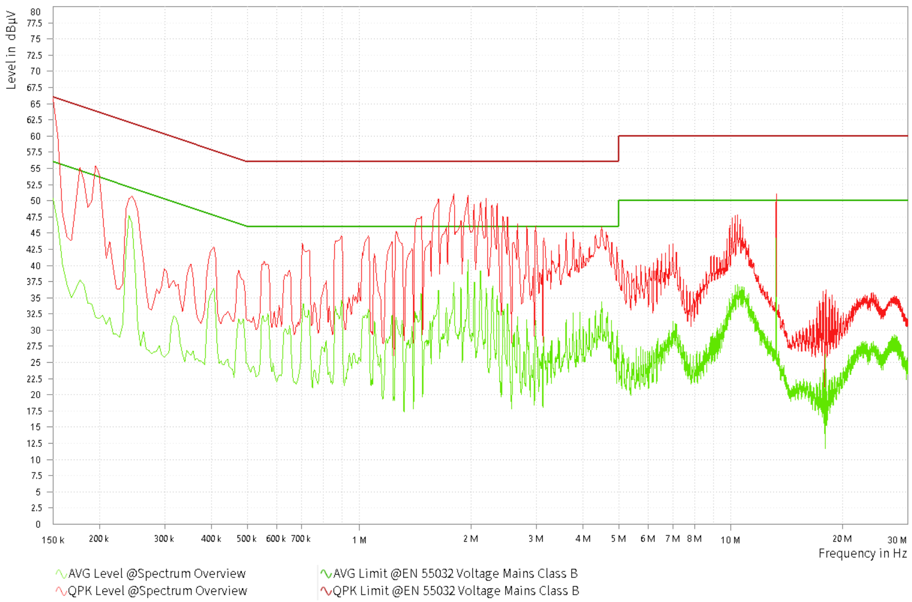


Figure 33: Conducted emission NEUTRAL according EN55032 class B.
Vin 220Vac, Vout 42V, Iout 5.5A, Fsw $_{LLC}$ 85kHz, Average (green) and QPK (red).

5 Hardware start-up

To quick start the EVB, follow the steps below:

1. Pre-set the AC power supply to 90 VAC ≤ VIN ≤ 265 VAC.
2. Turn the power supply off.
3. Connect the line and neutral terminals of the power supply output to the L (J3, L) and N (J3, N) ports.

If you are using the board as a **Charger** (skip steps 11-14):

4. Connect the charger presence signal (P, J1.2) to the BMS system.
5. Connect the positive terminal (+) of the BMS system to V_{OUT} (J1, 3).
6. Connect the negative terminal (–) of the BMS system to GND (J1,1).
7. Connect the charger to the mains or AC power supply.
8. Once you receive a 5V signal at J1.2, apply the battery voltage at the charger terminals (J1, 3 and 1).
9. The charger will automatically adequate it's voltage to the battery one, switch the relay and start charging the battery.
10. After removing the battery disconnect the charger to reset the output relay.

If you are using the board as a **Power Supply Unit** (skip steps 4-10):

11. Bypass the relay and remove R95.
12. Connect the positive terminal (+) of the load to V_{OUT} (J1, 3).
13. Connect the negative (–) of the load to GND (J1,1).
14. Connect to the mains or AC power supply on after making the connections.

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