FAN6248ADPGEVB

Implementing High Power Adapter Evaluation Board User's Manual

High Power Adapter with the NCP1616, NCP13992 and FAN6248

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EVAL BOARD USER'S MANUAL

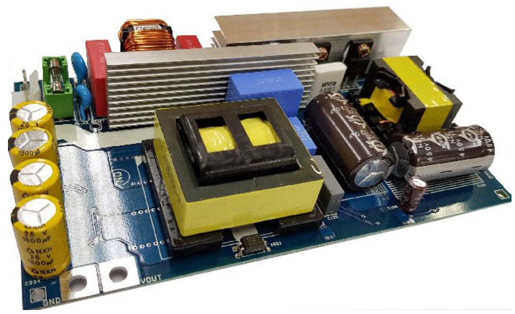

Figure 1. Evaluation Board

Description

This evaluation board user's manual provides elementary information about a high efficiency, low light load power consumption reference design that is targeting power adapter or similar type of equipments that accepts 19.5 V.

The design utiltizes NCP1616 for PFC front stage to assure unity power factor, NCP13992 for current mode LLC power stage, and FAN6248 for secondary side synchronous rectification to maximize efficiency.

The NCP1616 is a high voltage PFC controller with CrM operation. Additionally, it has an innovative Current Controlled Frequency Foldback (CCFF) method to maximizes the efficiency at both nominal and light load condition.

The NCP13992 is a current mode controller for half bridge resonant converter featuring 600 V gate drivers, high−frequency operation from 20 kHz up to 750 kHz, automatic dead−time with maximum dead−time clamp, and skip mode operation for improved light load efficiency.

The secondary side controller FAN6248 is an advanced synchronous rectifier controller that is optimized for LLC resonant converter topology with minimum external components. It has two driver stages for driving the SR MOSFETs which are rectifying the output current of the secondary transformer. These two gate driver stages have dedicated sense inputs and operate independently each other.

Key Features

- High Voltage Start−Up Circuit with Integrated Brownout Detection
- Wide Input Voltage Range
- High Efficiency
- Fast Line / Load Transient Compensation
- Light Load Operation Mode for Improved Efficiency
- Overvoltage Protection
- Auto Recovery Overload Protection
- Auto Recovery Output Short Circuit Protection
- Open Feedback Loop Protection
- Highly Integrated Self−Contained Control of Synchronous Rectification with a Minimum External Components
- Anti Shoot−Through Control for Reliable SR Operation
- Light Load Dection for Preventing Inversion Current of SR

Table 1. GENERAL INFORMATIONS

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage	V_{AC}	90	–	264	V_{AC}
Input Voltage Brown Ouput		–	70	–	V_{AC}
Output Voltage	No Load Condition	–	19.3	–	V_{DC}
	Full Load Condition	–	19.3	–	V_{DC}
Maximum Output Current		–	12.4	–	A
Output Power		–	240	–	W
Operating Frequency of LLC	Full Load Condition	100	105	110	kHz
System Efficiency	$110V_{AC}$ @ Full Load	–	93.2	–	%
	$220V_{AC}$ @ Full Load	–	95.1	–	%
Power Factor	90 VAC ~ 264 VAC @ Over 50% Load		0.95	0.99	η
Board Dimension		–	170x100x30	–	mm

Circuit Description

For the PFC front stage, utilizes the NCP1616 to optimize the efficiency and Power Factor throughout the load range. NCP1616 has an intergrated high voltage start up circuit accessible by the HV pin. The rectified input voltage supplies to HV pin at start up. After then Supply to VCC directly from the auxilirary winding of LLC transformer. In operation mode, the NCP1616 achieves power factor correction using the Current Controlled Frequency Foldback (CCFF) topology. In CCFF the circuit operates in the classical Critical Conduction Mode (CrM) when the inductor current exceeds a programmable value. Once the current falls below this preset level, the frequency is linearly reduced, reaching about 26 kHz when the current is zero. Also NCP1616 enter to skip mode at the Input current near the line zero crossing where the current is very low. Both CCFF and Skip mode optimize PFC stage efficiency. To protect the application system under abnormal condition, the NCP1616 has OVP, OCP, Brown Out and FB pin open protection.

In the primary side, the NCP13992 LLC controller provides a high efficiency and high power density by zero voltage switching (ZVS) of half−bridge MOSFETs. The power stage operates in above resonance area at around the resonant frequency caused by a resonant capacitor Cr and a resonance inductor Lr. Therefore, it can provide higher efficiency with less frequency variation for light load condition.

For fast start up and extremely low standby power, NCP13992 has Dynamic Self Supply (DSS). After start up operation, Auxiliry winding maintains the voltage bias for the controller during normal operation mode. At the light load condition, the NCP13992 operates in skip mode and light load mode operation that improve light load efficiency, reduce no−load power consumption. To protect the application system under abnormal condition, the NCP13992 has OLP, OVP, OSP and FB pin open protection.

The Secondary output rectification is utilized with SR controller FAN6248. It controls the SR MOSFET based on the instantaneous drain to source voltage sensed across Drain and Source pins. Before SR gate is turned on, SR body diode conducts as the conventional diode rectifier. Once the body diode starts conducting, the drain−to−source voltage drops below the turn−on threshold voltage V_{TH_ON} which triggers the turn−on of the SR gate. When the drain−to−source voltage reaches the turn−off threshold voltage V_{TH_OFF} as SR MOSFET current decreases to near zero, FAN6248 turns off the gate. To optimize SR turn off time, the FAN6248 has Adaptive Dead Time Control function. For stable operation under light load condition, FAN6248 increase SR turn on delay using Light Load Detection (LLD).

EVALUATION BOARD SCHEMATIC

FAN6248ADPGEVB

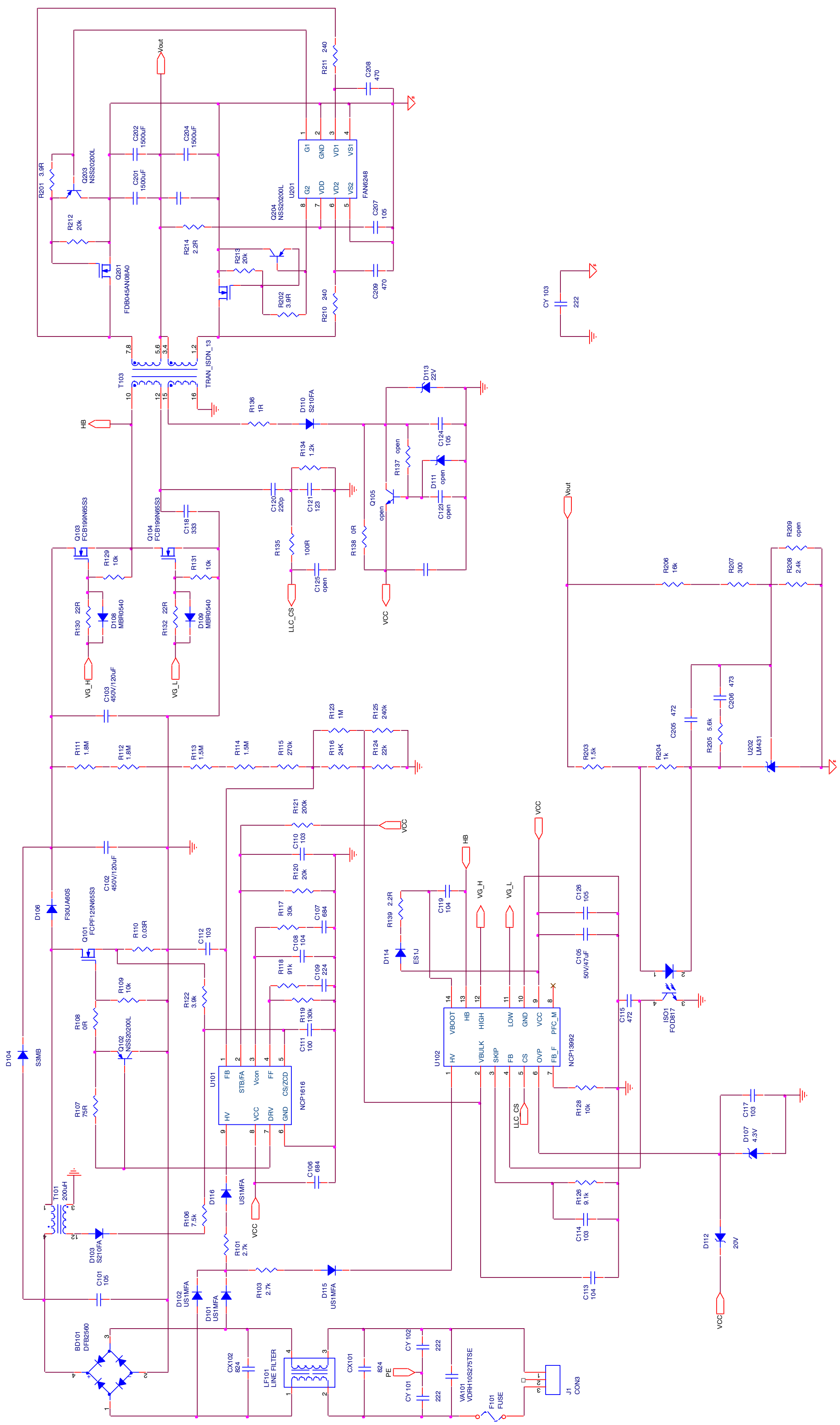

Figure 2. Evaluation Board Schematic

PCB LAYOUT

Board Dimension : 170 mm x 100 mm
PCB material : FR4
Copper Thickness : 2 oz

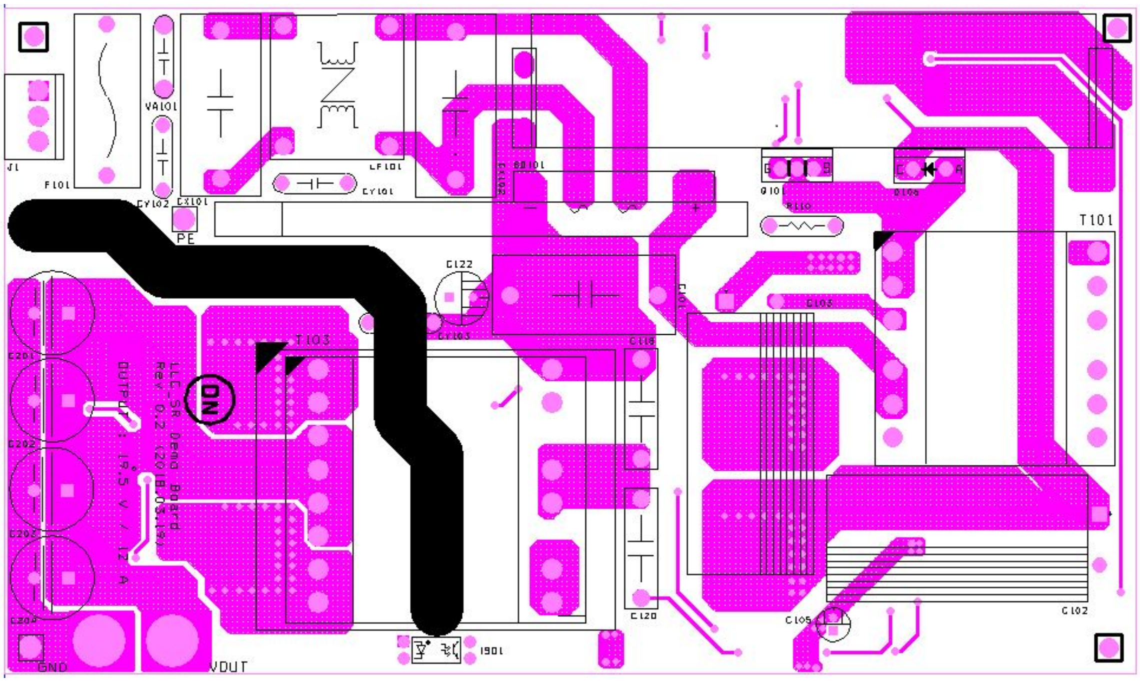

Figure 3. TOP Side View

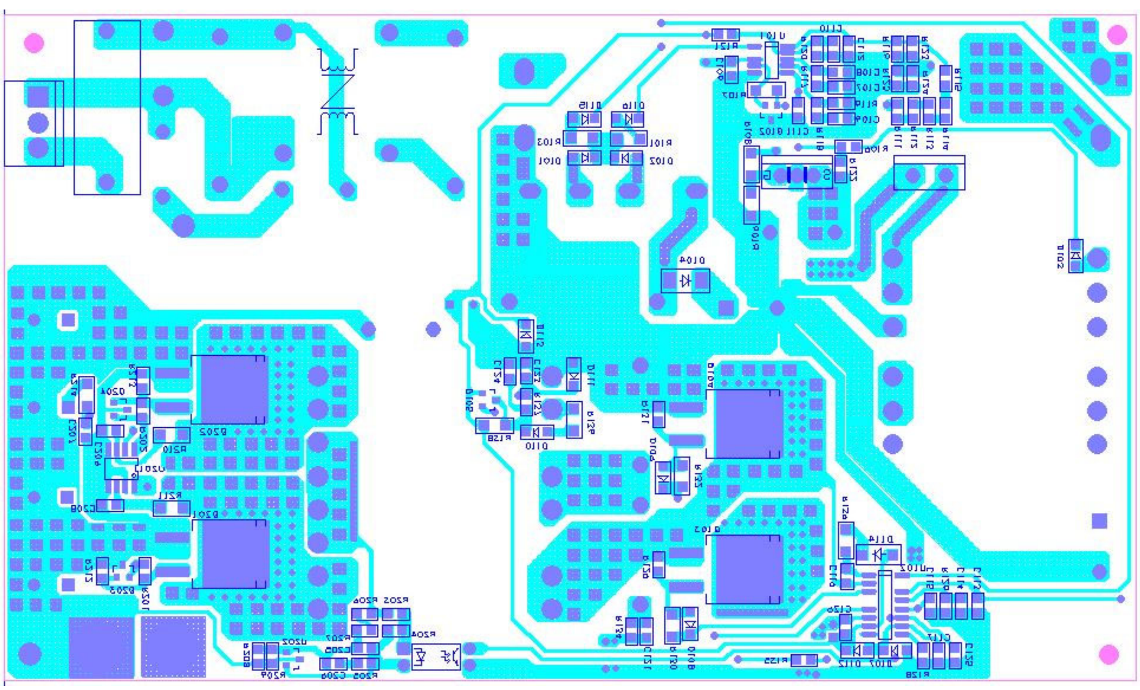

Figure 4. BOTTOM Side View

BOARD PICTURES

Board Dimension : 170 mm x 100 mm
PCB material : FR4
Copper Thickness : 2 oz

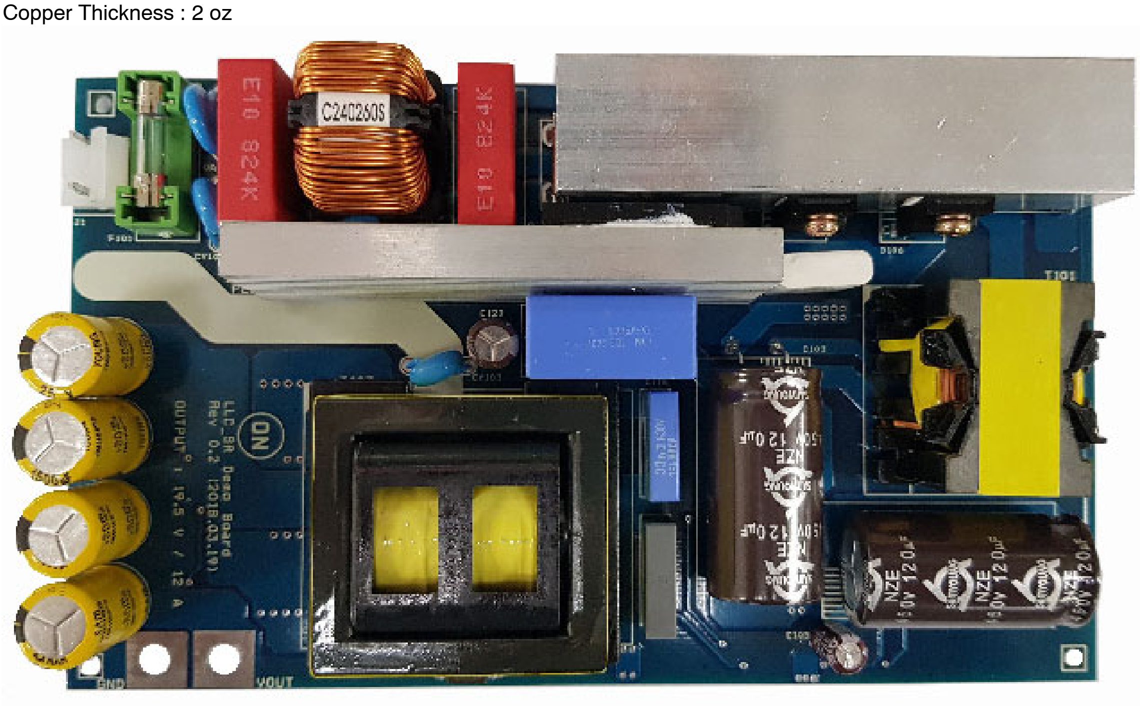

Figure 5. TOP Side View

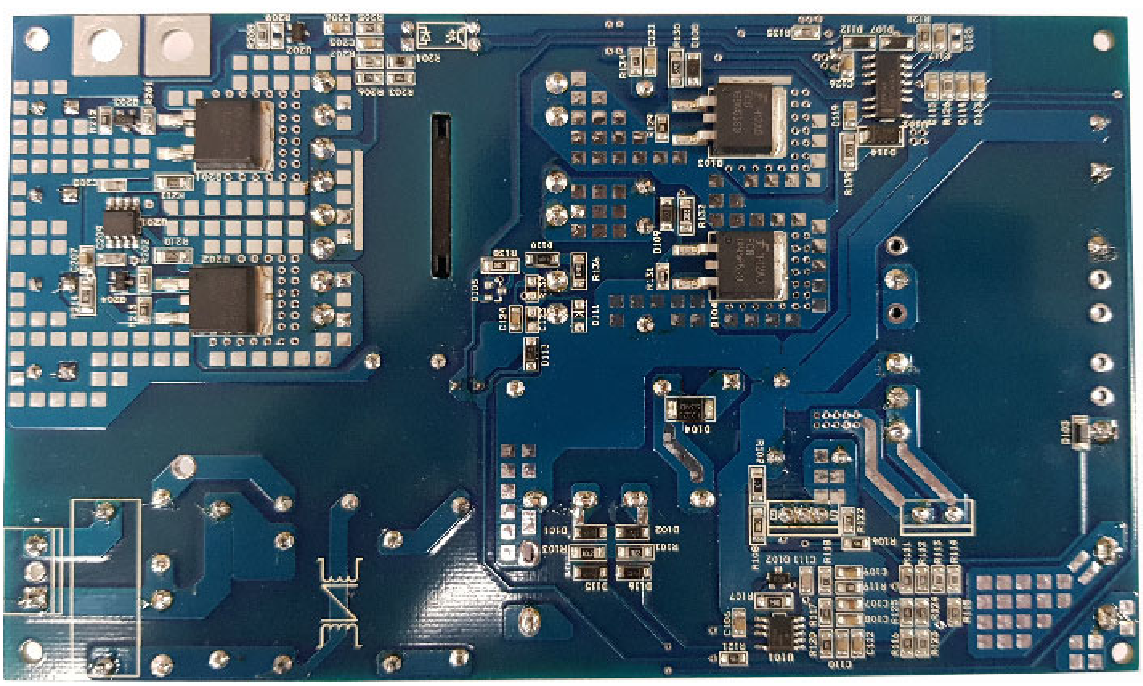

Figure 6. BOTTOM Side View

Transformer Specifications

There are two kinds of transformer used in this EVB. One is PFC circuit and otherthings is LLC circuit.

PQ3220

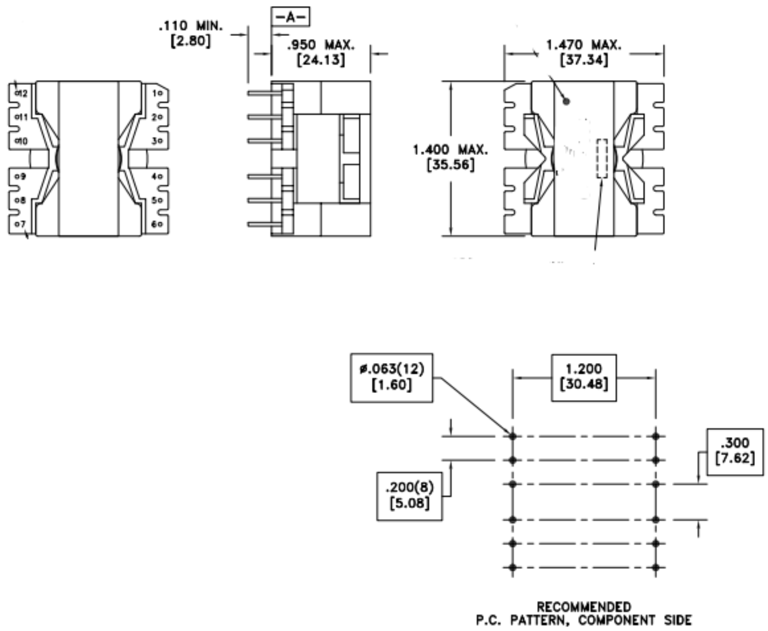

Figure 7. Transformer Dimension and Shapes (PFC)

Table 2. TRANSFORMER SPECIFICATION (PFC)

	Pin (Start → Finish)	Wire	Turns	Winding Method	Barrier Tape		
					TOP	BOT	Ts
N_p	2 → 5	0.1 φ x 60 USTC	34	Solenoid Winding	–	–	–
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							
N_s	12 → 3	0.2 φ	4.5		3 mm	3 mm	–
Insulation: Polyester Tape t = 0.025 mm, 2 Layers							

	Pin	Spec.	Remark
Inductance	2 [illegible] 5	200 μH	100 kHz, 1 V

SRX40ER

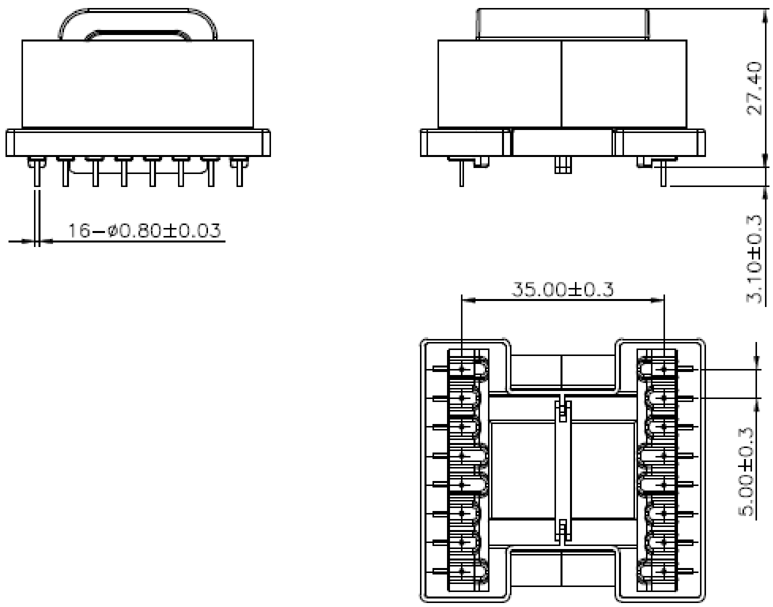

Figure 8. Transformer Dimension and Shapes (LLC)

Table 3. TRANSFORMER SPECIFICATION (LLC)

	Pin (Start → Finish)	Wire	Turns	Winding Method	Barrier Tape		
					TOP	BOT	Ts
N_p	12 → 10	0.1 φ x 50 USTC	31	Solenoid Winding	–	–	–
Insulation: Polyester Tape, t = 0.025 mm, 2 Layers							
N_s	5 → 1 7 → 3	0.10 φ x 120 USTC	3	Bifilar	–	–	–
Insulation: Polyester Tape, t = 0.025 mm, 1 Layers							
N_s	6 → 2 8 → 4	0.10 φ x 150 USTC	3	Bifilar	–	–	–
Insulation: Polyester Tape, t = 0.025 mm, 2 Layers							
N_{aux}	15 → 16	0.2 φ	2	Solenoid Winding	–	–	–
Insulation: Polyester Tape, t = 0.025 mm, 2 Layers							

	Pin	Spec.	Remark
Inductance Lm	12 ⍰ 10, Other Pin Open	650 µH	100 kHz, 1 V
Inductance Llkg	12 ⍰ 10 1, 2, 3, 4, 5, 6, 7, 8 Pin Short	80 µH	100 kHz, 1 V

Start Up PFC Stage

Figure 9 show that the NCP1616 start up waveforms by high voltage start up circuit. The output voltage reflects rectifiered voltage around 115 V by bridge diodes until the V_{CC} voltage reaches start up threshold 17 V. Once V_{CC} is charged to the start up threshold voltage, the HV start up regulator is disabled and the controller is enabled. After LLC start up operation, V_{CC} bias comes from the auxiliary winding of LLC transformer. After then PFC stage start up and the PFC output voltage regulated target voltage.

(CH1 : HV, CH2 : V_{CC}, CH3 : V_{DRV}, CH4 : PFC output)

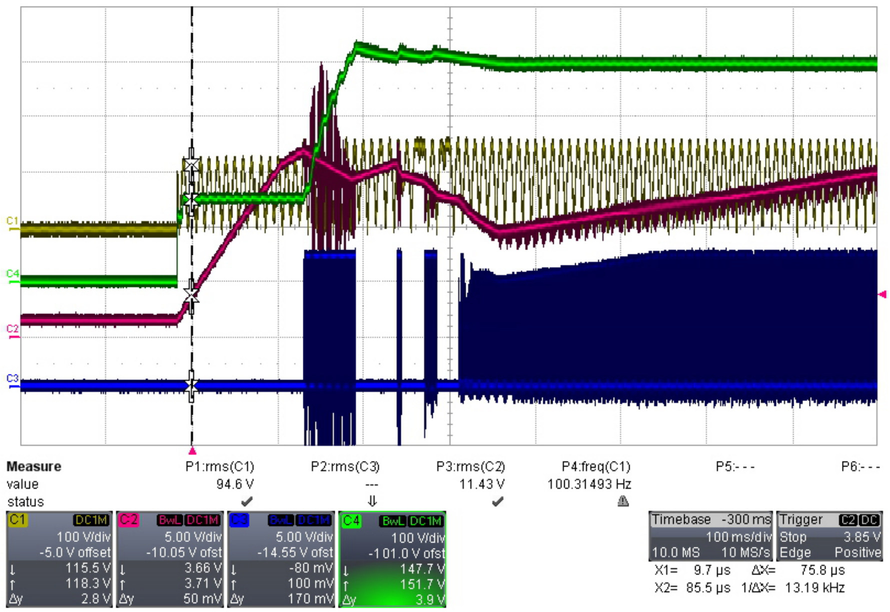

Figure 9. PFC Stage Start Up Waveforms

Start Up LLC Stage

The NCP13992 supply voltage is charged by the HV start up circuit and controller disables the HV start up current source after the V_{CC} pin voltage level reaches threshold voltage. After start up operation, the auxiliary winding maintains the voltage bias for the controller during normal operating modes. Figure 10 shows that the NCP13992 start up waveforms. After reaches V_{CC} on threshold voltage, NCP13992 start up after PFC stage steady state operation. NCP13992 detect PFC operation by Vbulk / PFC−FB pin.

(CH1 : HV, CH2 : VCC, CH3 : MLOWER, CH4 : PFC Output)

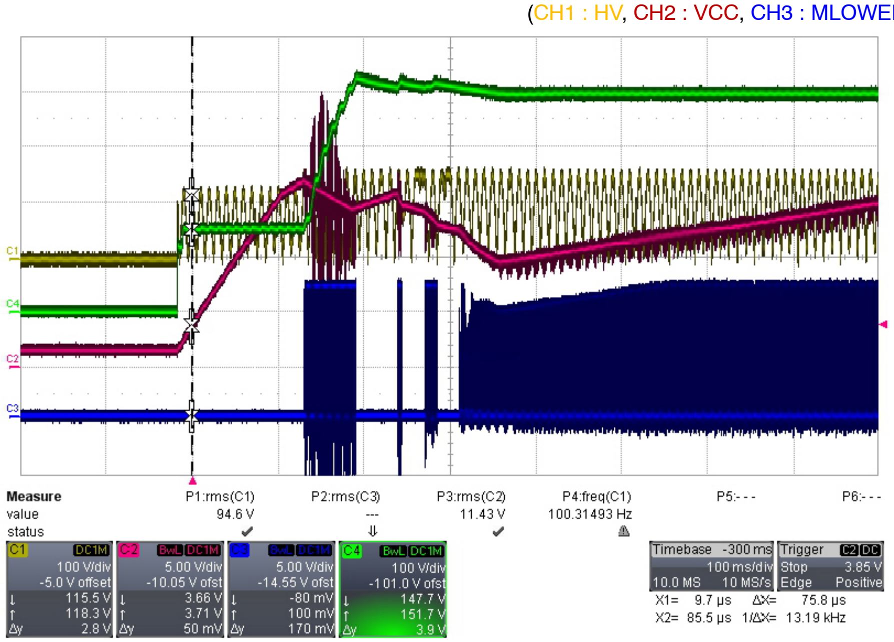

Figure 10. LLC Stage Start Up Waveforms

Start Up SR Stage

When V_{DD} is higher than $V_{DD\_GATE\_ON}$ of FAN6248, SR gate signals are generated. If the sensed drain voltage cannot meet turn−on condition, SR operation may be delayed after $V_{DD\_GATE\_ON}$.

(CH1 : V_{DD}, CH2 : GATE1, CH3 : GATE2, CH4 : Output Voltage)

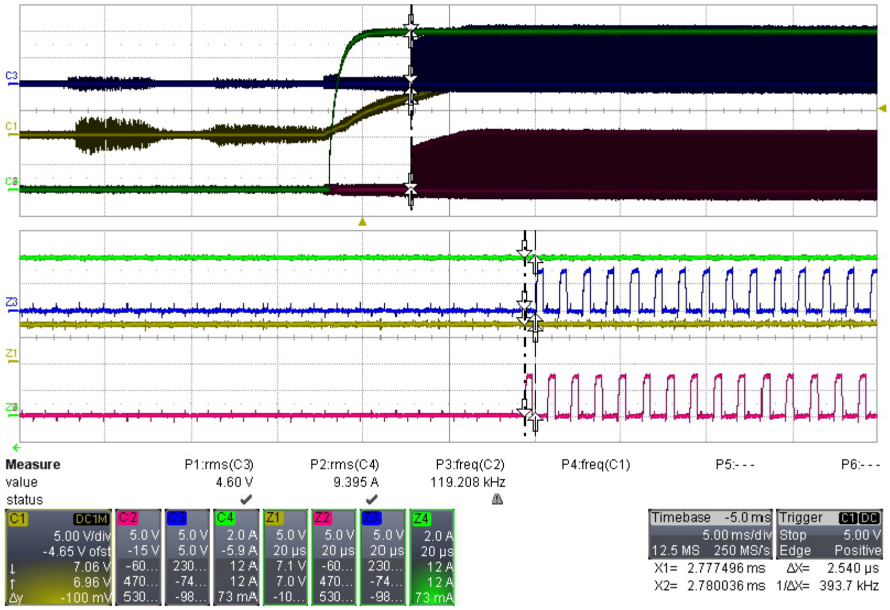

Figure 11. SR Stage Start Up Waveforms

Current Controlled Frequency Foldback

The NCP1616 PFC controller achieves power factor correction using the novel Current Controlled Frequency Foldback (CCFF) topology. In this mode, the circuit operates in classical Critical Conduction Mode (CrM) with ZCD when the inductor current exceeds a programmable value. When the current falls below this preset level, the NCP1616 linearly reduces the operating frequency down to a minimum of about 26 kHz when input current reaches zero.

(CH2 : V_{DS}, CH3 : DRV, CH4 : Input Current)

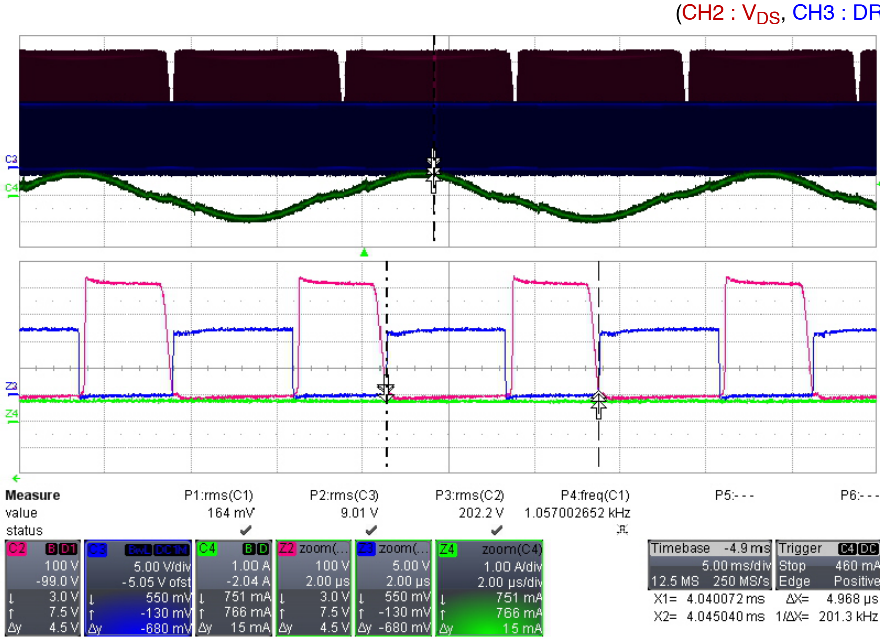

Figure 12. Critical Conduction Mode Operation

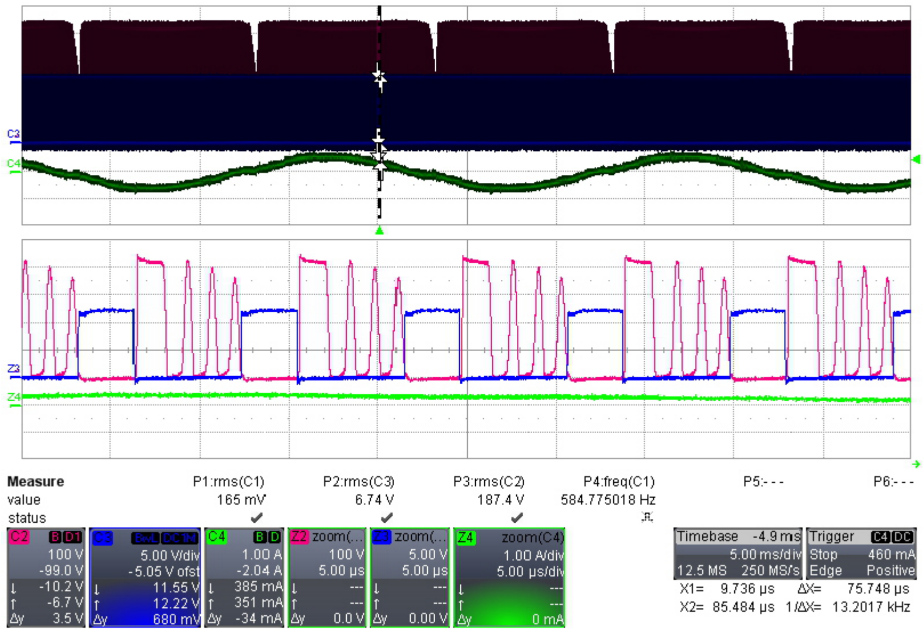

Figure 13. Current Controlled Frequency Foldback Operation

Light Load Mode Operation

The NCP13992 implements proprietary light load and quiet skip mode operating techniques that improve light load efficiency, reduce no−load power consumption and significantly reduce acoustic noise.

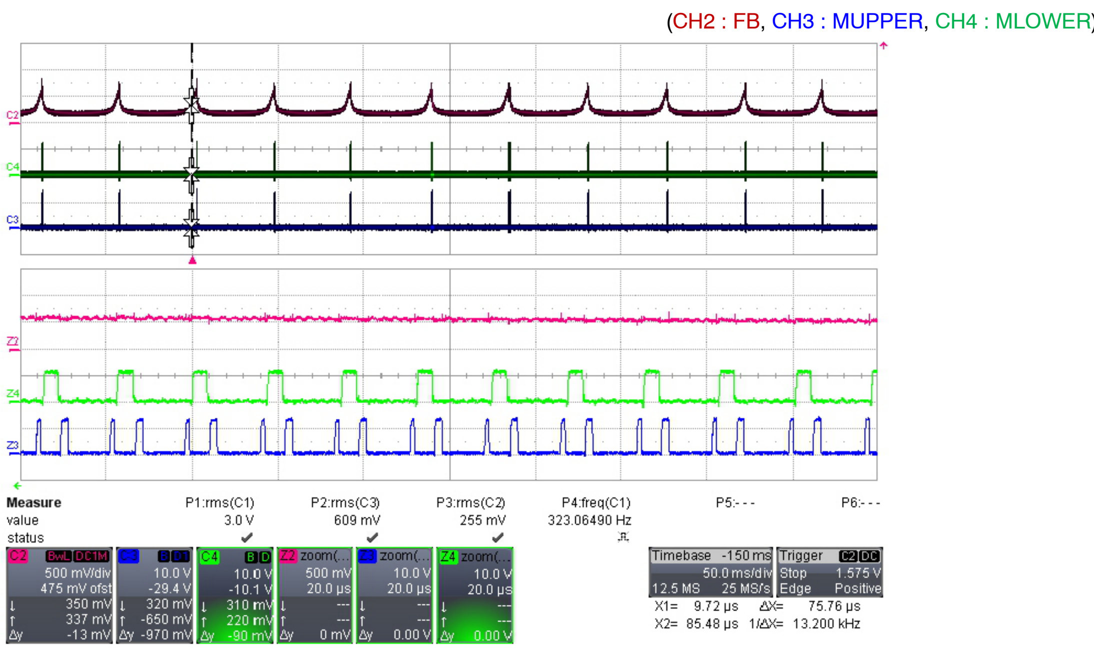

Figure 14. Light Load and Skip Mode Operation Waveforms

LLC Operation

Below waveform is normal operation mode of LLC in heavy load condition. The LLC operated in above resonance area.

(CH1 : MUPPER, CH2 : MLOWER, CH4 : Primary Current)

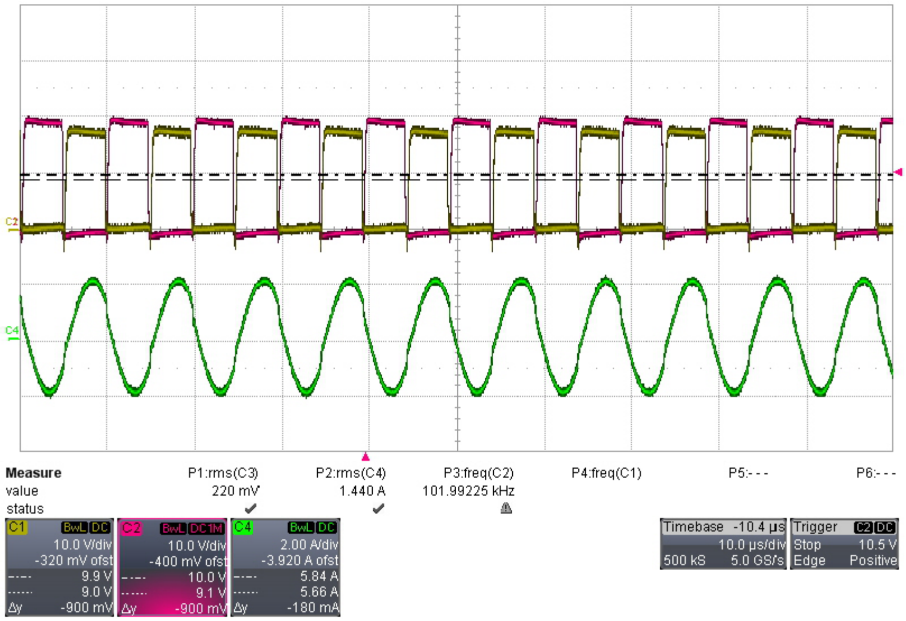

Figure 15. LLC Operation Waveforms

Synchronous Rectification Control and Normal Operation

FAN6248 controls the SR MOSFET based on the instantaneous drain−to−source voltage sensed across DRAIN and SOURCE pins. Before SR gate is turned on, SR body diode conducts as the conventional diode rectifier. Once the body diode starts conducting, the drain−to−source voltage drops below the turn−on threshold voltage V_{TH_ON} which triggers the turn−on of the SR gate. Then the drain−to−source voltage is determined by the product of turn−on resistance R_{ds_on} of SR MOSFET and instantaneous SR current. When the drain−to−source voltage reaches the turn−off threshold voltage V_{TH_OFF} as SR MOSFET current decreases to near zero, FAN6248 turns off the gate. If a SR dead time is larger or smaller than the dead time regulation target t_{DEAD}, FAN6248 adaptively changes internal offset voltage to compensate the dead time. In addition, to prevent cross conduction SR operation, FAN6248 has 200 ns of turn−on blaking time just after alternating SR gate is turned off.

(CH1 : V_{DS1}, CH2 : V_{GATE1}, CH3 : V_{DS2}, CH4 : V_{GATE2})

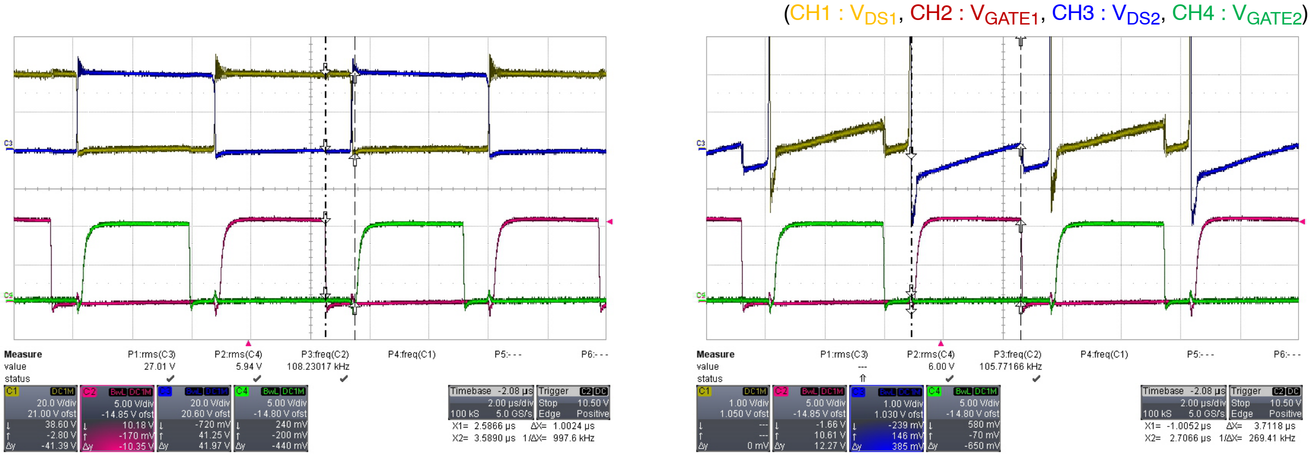

Figure 16. SR Gate and Drain Voltage Waveforms at Full Load Condition

(CH1 : V_{DS1}, CH2 : V_{GATE1}, CH3 : V_{DS2}, CH4 : V_{GATE2})

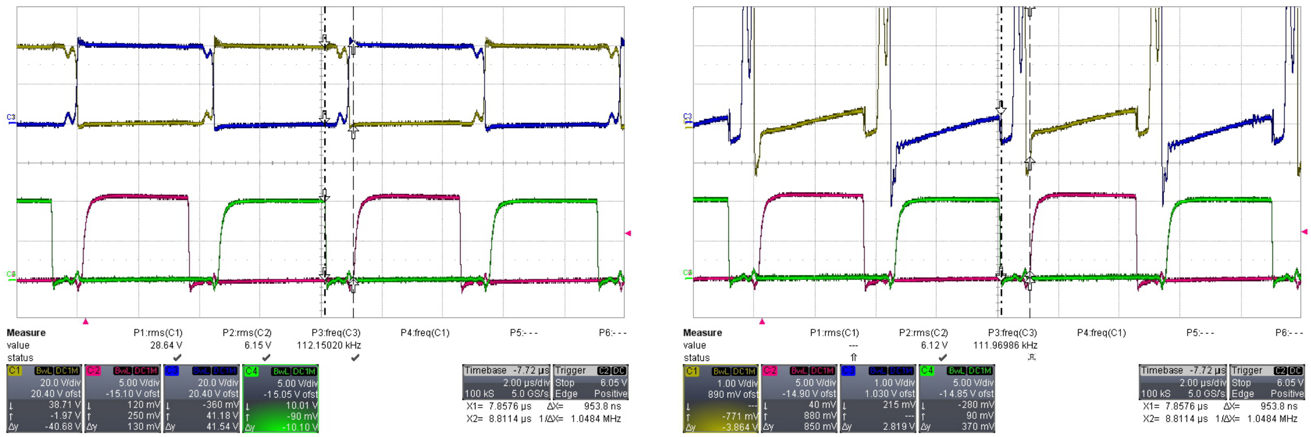

Figure 17. SR Gate and Drain Voltage Waveforms at Light Load Condition

Output Current Transient Response

There are no output voltage drop and overshoot during load current transition.

(CH1 : V_{OUT}, CH2 : V_{GATE1}, CH3 : V_{GATE2}, CH4 : Output Current)

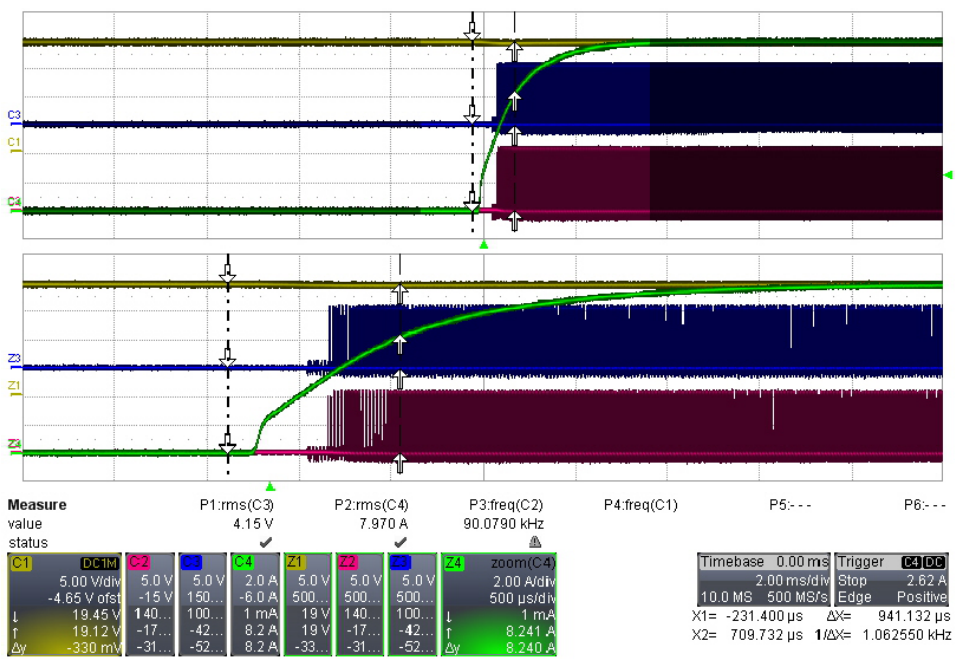

Figure 18. Output Load Transient Response at 0 to 12 A

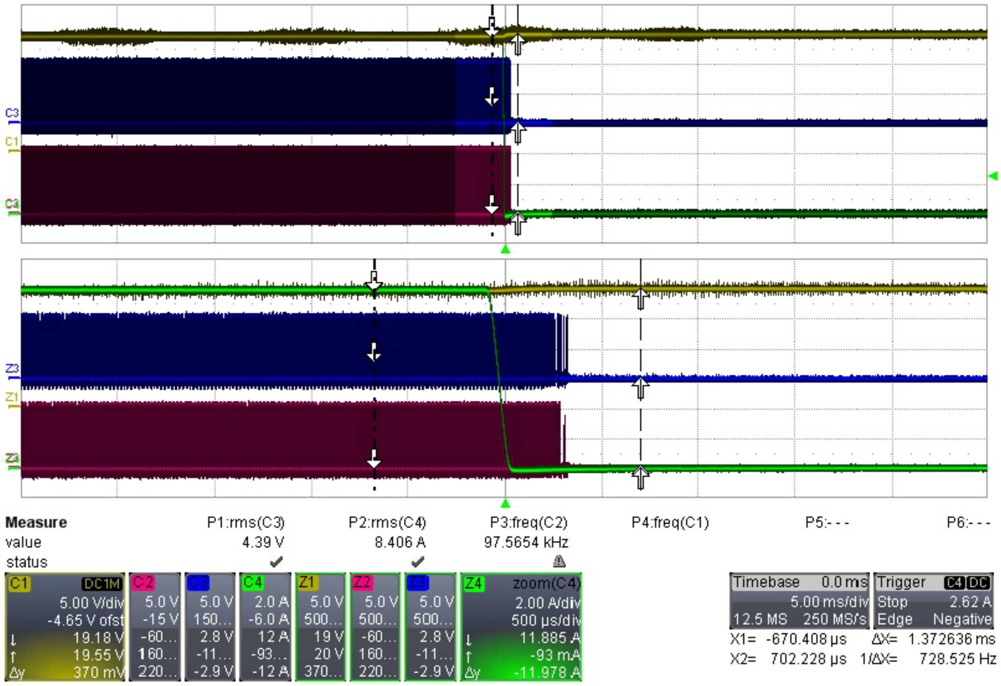

Figure 19. Output Load Transient Response at 12 to 0 A

System Efficiency & PF

Figure 20 presents the system efficiency of the EVB with various input voltage. The EVB demonstrated that the 240 W power application can approach 95% peak system efficiency at high line. Also the PF is over 0.96 at wide input range.

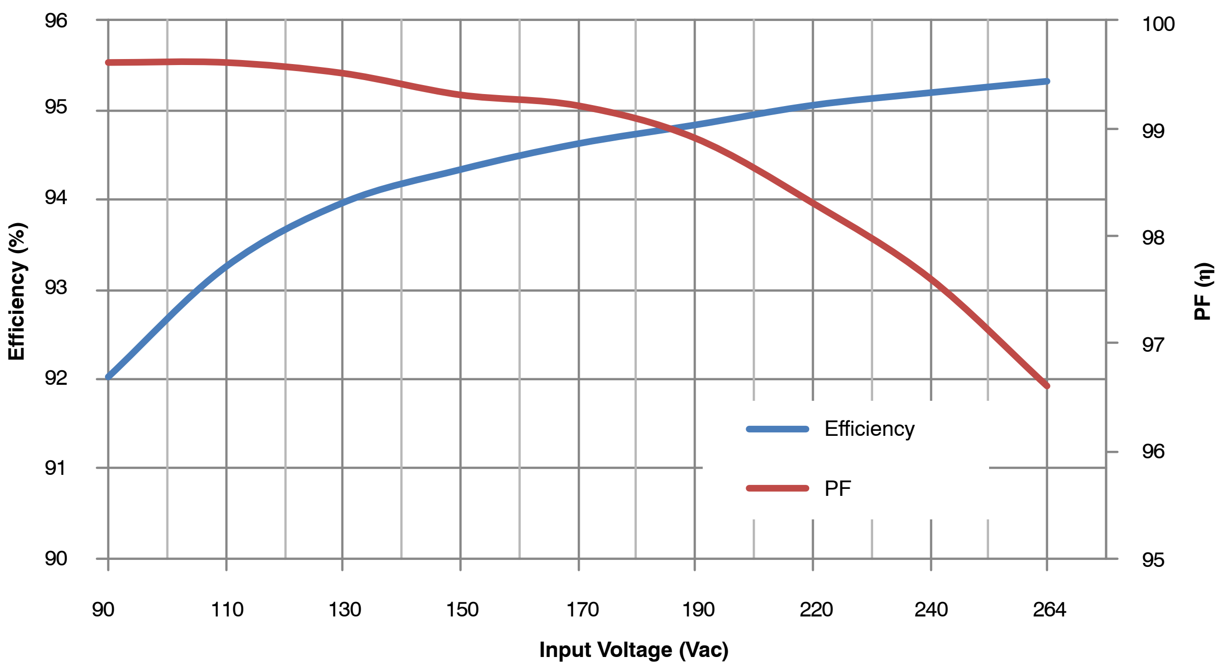

Figure 20. System Efficiency by the Input Voltage.

Table 4. MEASURING RESULTS OF EFFICIENCY & PF

Vac	90	110	130	150	170	190	220	240	264
Efficiency	92.02%	93.25%	93.97%	94.34%	94.63%	94.84%	95.06%	95.20%	95.33%
PF	0.9961	0.9960	0.9952	0.9930	0.9920	0.9891	0.9829	0.9760	0.9661

Figure 21 and Figure 22 show system efficiency & PF by the output load condition, respectively.

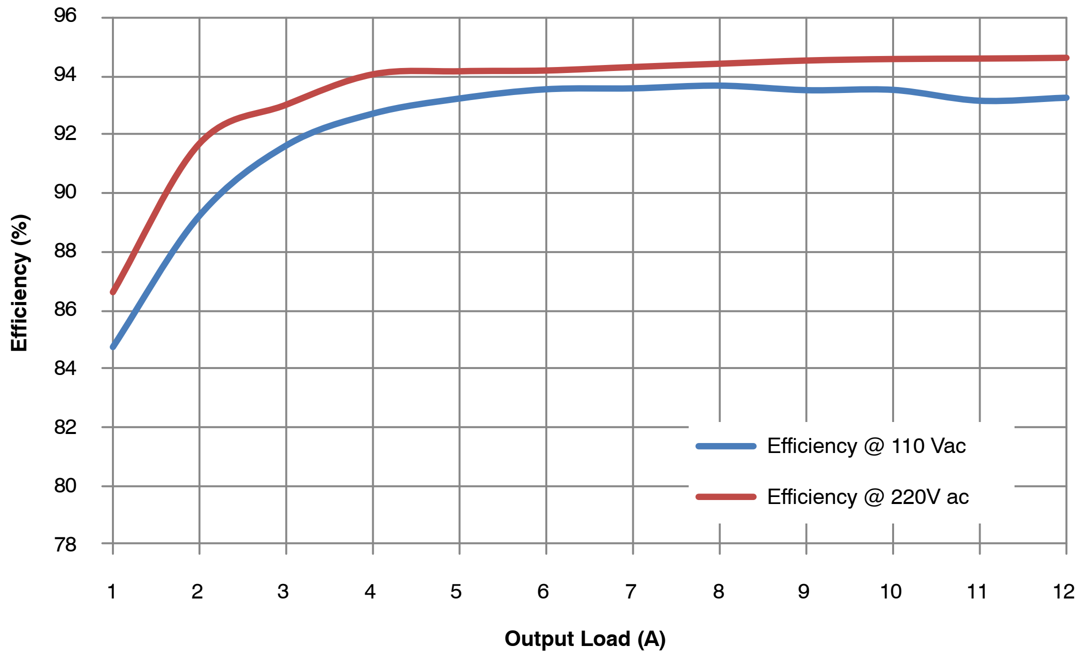

Figure 21. Comparison Efficiency by Low and High Line

Table 5. MEASURING RESULTS OF EFFICIENCY BY LOAD CONDITION

Output Current	1 A	2 A	3 A	4 A	5 A	6 A
Efficiency @ 110 Vac	84.75%	89.23%	91.62%	92.71%	93.22%	93.54%
Efficiency @ 220 Vac	86.61%	91.69%	93.02%	94.07%	94.17%	94.19%
Output Current	**7 A**	**8 A**	**9 A**	**10 A**	**11 A**	**12 A**
Efficiency @ 110 Vac	93.57%	93.67%	93.51%	93.52%	93.15%	93.25%
Efficiency @ 220 Vac	94.31%	94.43%	94.54%	94.59%	94.60%	94.63%

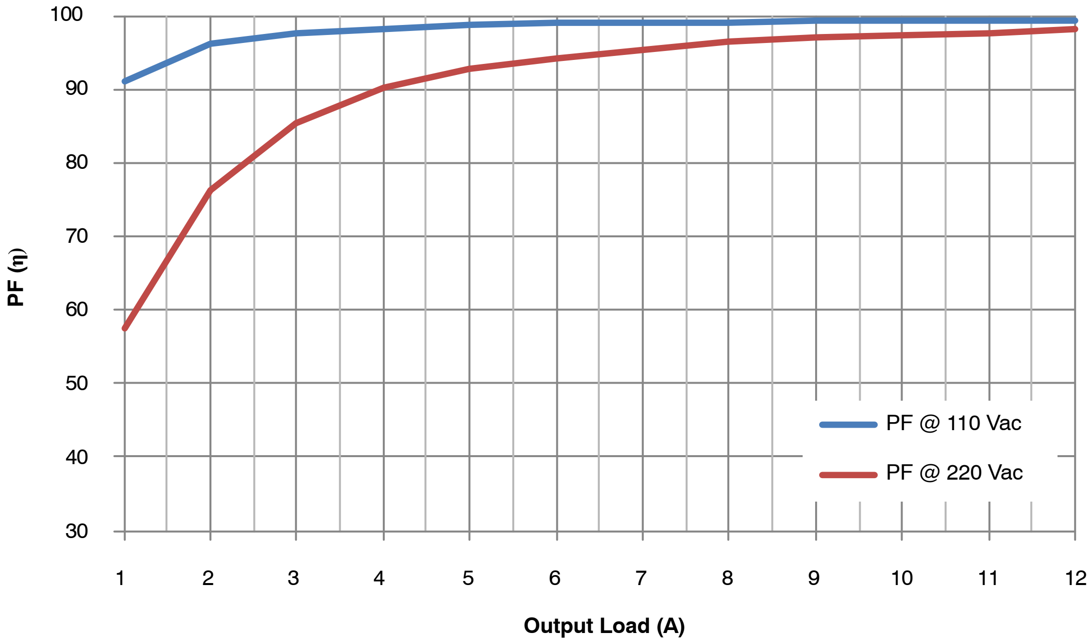

Figure 22. Comparison PF by Low and High Line

Table 6. MEASURING RESULTS OF EFFICIENCY BY LOAD CONDITION

Output Current	**1 A**	**2 A**	**3 A**	**4 A**	**5 A**	**6 A**
PF @ 110 Vac	0.9120	0.9620	0.9780	0.9830	0.9880	0.9910
PF @ 220 Vac	0.5760	0.7640	0.8560	0.9040	0.9280	0.9427
Output Current	**7 A**	**8 A**	**9 A**	**10 A**	**11 A**	**12 A**
PF @ 110 Vac	0.9920	0.9930	0.9940	0.9950	0.9960	0.9960
PF @ 220 Vac	0.9556	0.9660	0.9720	0.9760	0.9790	0.9830

Table 7. BILL OF MATERIALS

Reference	Vendor	Part Number	Type	Value	PC / Board
BD101	ON Semiconductor	DFB2560	TS−6P−4L	600 V / 25 A	1
CX101, CX102	PILKO	PCMP 327 / 820 nF (Pitch: 22.5 mm)	MKP RADIAL	275 Vac / 820 nF	2
CY101, CY102, CY103	TDK	CD45B2GA222K	Y−Cap	400 V / 2.2 nF	2
C101	PILKOR	PCMP 327 / 1 μF (Pitch: 22.5 mm)	MKP RADIAL	275 Vac / 1 μF	1
C102, C103	SAMYOUNG	KMF−series: 18 x 40	KMF	450 V / 120 μF	2
C124, C126, C207	TDK	C2012X7R1E105K085AB	MLCC_2012	25 V / 1 μF	3
C105	SAMYOUNG	KMF−series: 5 x 11	KMF	50 V / 47 μF	1
C106, C107	TDK	C2012X7R1H684K125AE	MLCC_2012	50 V / 680 nF	2
C108, C113, C119	TDK	C2012X8R1E104K125AA	MLCC_2012	25 V / 100 nF	3
C109	TDK	C2012X7R1H224K125AE	MLCC_2012	50 V / 220 nF	1
C110, C112, C114, C117	TDK	C2012C0G1H103J060AA	MLCC_2012	50 V / 10 nF	4
C111	TDK	CGJ4C2C0G2A100J060AA	MLCC_2012	50 V / 10 pF	2
C115, C205	TDK	C2012CH1H472J085AA	MLCC_2012	50 V / 4.7 nF	2
C118	PILKOR	PCMP 384 / 33 nF	33 nF	−	1
C120	PILKOR	PCMP 384 / 220 pF 630 V (Pitch : 15 mm)	MMKP RADIAL	630 V / 220 pF	1
C121	TDK	C2012C0G1H123J060AA	MLCC_2012	25 V / 12 nF	1
C122	SAMYOUNG	KMF−series: 8 x 11	KMF	50 V / 100 μF	1
C125	TDK	C2012 C0G1E101J060AA	MLCC_2012	25 V / 100 pF	1
C201, C202, C203, C204	SAMYOUNG	NXH−series: 12.5 x 20	NXH	25 V / 1500 μF	4
C206	TDK	C2012C0G1H473J060AA	MLCC_2012	25 V / 47 nF	1
C208, C209	TDK	CGJ4C2C0G2A470J060AA	MLCC_2012	50 V / 47 pF	2
D101, D102, D115, D116	ON Semiconductor	US1MFA	SOD−123FA	1000 V / 1 A	4
D103, D110	ON Semiconductor	S210FA	SOD−123FA	100 V / 2 A	2
D104	ON Semiconductor	S3MB	SMB	1000 V / 3 A	1
D106	ON Semiconductor	FFPF30UA60S	TO−220F−2L	600 V / 30 A	1
D107	ON Semiconductor	MMSZ4V3T1G	SOD−123	4.3 V / 0.5 W	1
D108, D109	ON Semiconductor	MBR0540	SOD−123	40 V / 0.5 A	2
D112	ON Semiconductor	MMSZ20T1G	SOD−123	20 V / 0.5 W	1
D113	ON Semiconductor	MMSZ22T1G	SOD−123	22 V / 0.5 W	1
D114	ON Semiconductor	ES1J	SMA	600 V / 1 A	1
F101 (Holder)	STELVIO	PTF78	5 x 20	Fuse Holder	1
F101 (Fuse)	Little Fuse	021 7004.MXP Fast−acting	5 x 20	250 Va / 4A	1
ISO1	ON Semiconductor	FOD817B	4−pin DIP	Optocoupler	1
J1	MOLEX	5273−03A	3−pin	Connector	1
LF101	EMC parts	CV240260SK	133T−F	300 Va / 4 A	1
Q101	ON Semiconductor	FCPF125N65S3	TO−220F	650 V / 24 A	1
Q102, Q203, Q204	ON Semiconductor	NSS20200L	SOT−23	−20 A / 4 A	3
Q103, Q104	ON Semiconductor	FCB199N65S3	D2 PAK	650 V / 14 A	2
Q201, Q202	ON Semiconductor	FDB045AN08A0	D2 PAK	75 V / 235 A	2
R101, R103	Yageo	RC1206JR−07272RL	CHIP_R_3216	2.7 kΩ	2
R106	Yageo	RC0805JR−07752RL	CHIP_R_2012	7.5 kΩ	1
R107	Yageo	RC1206JR−07750RL	CHIP_R_3216	75 Ω	1
R108, R138	Yageo	RC1206JR−07000RL	CHIP_R_3216	0 Ω	2

Table 7. BILL OF MATERIALS (continued)

Reference	Vendor	Part Number	Type	Value	PC / Board
R109	Yageo	RC1206JR−07103RL	CHIP_R_3216	10 kΩ	1
R110	PILKO	MPR5W 0.03ΩJ	Metal plate R	0.03 Ω	1
R111, R112	Yageo	RC0805JR−07185RL	CHIP_R_2012	1.8 MΩ	2
R113, R114	Yageo	RC0805JR−07155RL	CHIP_R_2012	1.5 MΩ	2
R115	Yageo	RC0805JR−07274RL	CHIP_R_2012	270 kΩ	1
R116	Yageo	RC0805JR−07243RL	CHIP_R_2012	24 kΩ	1
R117	Yageo	RC0805JR−07303RL	CHIP_R_2012	30 kΩ	1
R118	Yageo	RC0805JR−07913RL	CHIP_R_2012	91 kΩ	1
R119	Yageo	RC0805JR−07134RL	CHIP_R_2012	130 kΩ	1
R120, R212, R213	Yageo	RC0805JR−07203RL	CHIP_R_2012	20 kΩ	3
R121	Yageo	RC0805JR−07204RL	CHIP_R_2012	200 kΩ	1
R122	Yageo	RC0805JR−07392RL	CHIP_R_2012	3.9 kΩ	1
R123	Yageo	RC0805JR−07105RL	CHIP_R_2012	1 MΩ	1
R124	Yageo	RC0805JR−07223RL	CHIP_R_2012	22 kΩ	1
R125	Yageo	RC0805JR−07244RL	CHIP_R_2012	240 kΩ	1
R126	Yageo	RC0805JR−07912RL	CHIP_R_2012	9.1 kΩ	1
R128	Yageo	RC0805JR−07104RL	CHIP_R_2012	100 kΩ	1
R129, R131	Yageo	RC0805JR−07103RL	CHIP_R_2012	10 kΩ	2
R130, R132	Yageo	RC1206JR−07220RL	CHIP_R_3216	22 Ω	2
R134	Yageo	RC0805JR−07122RL	CHIP_R_2012	1.2 kΩ	1
R135	Yageo	RC0805JR−07101RL	CHIP_R_2012	100 Ω	1
R136	Yageo	RC1206JR−071R0L	CHIP_R_3216	1 Ω	1
R139, R214	Yageo	RC1206JR−072R2L	CHIP_R_3216	2.2 Ω	2
R201, R202	Yageo	RC0805JR−073R9L	CHIP_R_2012	3.9 Ω	2
R203	Yageo	RC0805JR−07152L	CHIP_R_2012	1.5 kΩ	1
R204	Yageo	RC0805JR−07102L	CHIP_R_2012	1 kΩ	1
R205	Yageo	RC0805JR−07562L	CHIP_R_2012	5.6 kΩ	1
R206	Yageo	RC0805JR−07163L	CHIP_R_2012	16 kΩ	1
R207	Yageo	RC0805JR−07301L	CHIP_R_2012	300 Ω	1
R208	Yageo	RC0805JR−07242RL	CHIP_R_2012	2.4 kΩ	2
R210, R211	Yageo	RC1206JR−07241L	CHIP_R_3216	240 Ω	2
T101	TDK	PQ3220	−	200 μH	1
T103	FEELUX	SRX40ER	−	650 μH	1
U101	ON Semiconductor	NCP1616A1DR2G	SOIC−9	PFC	1
U102	ON Semiconductor	NCP13992AXDR2G	SOIC−16	LLC	1
U201	ON Semiconductor	FAN6248HC	SOIC−8	SR	1
U202	ON Semiconductor	LM431SBCM3X	SOT−23	Shunt	1
VA101	HIEL	HVR431D10	VARISTOR	−	1

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