500-W, Wide-Mains, NCP1655A-driven Evaluation Board User's Manual

EVBUM2865/D

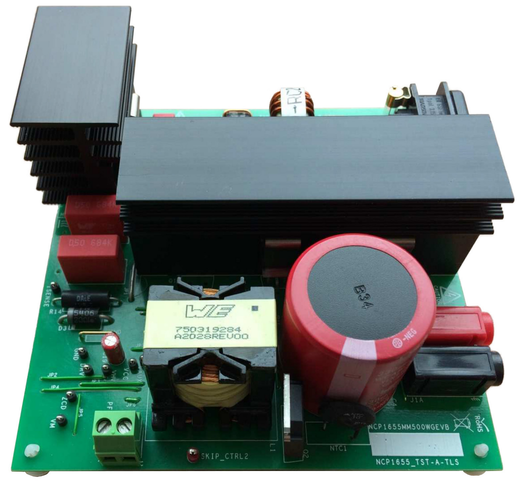


Figure 1. The Wide−mains, 500−W PFC Stage

INTRODUCTION

The NCP1655A is an innovative multimode power factor controller [1]. The circuit naturally transitions from one operation mode (CCM, CrM or DCM) to another depending on the switching period duration so that the efficiency is optimized over the line/load range. In very light−load conditions, the circuit enters the soft−SKIP mode for minimized losses. Housed in a SO−9 package, the circuit further incorporates the features necessary for building robust and compact PFC stages, with few external components.

The evaluation board is a 500−W wide−mains PFC stage.

EVB ELECTRICAL SPECIFICATIONS

Description	Value	Unit
Input Voltage Range	90−265	V rms
Line Frequency Range	45 to 66	Hz
Maximum Output Power	500	W
Nominal Output Voltage	388	V
Minimum Output Load Current	0	mA
Maximum Output Load Current	1300	mA
Load Conditions For Efficiency Measurements (10%, 20%,..)	10−100	%
Minimum Efficiency Over Above Load Range, 115 V rms	95	%
Minimum PF Over The Line Range At Full Load	95	%
Hold−Up Time (the output voltage remaining above 300 V)	> 10	ms
Peak−To−Peak Low Frequency Output Ripple	< 8	%
Voltage Source for NCP1655A Supply (*)	11.5 to 18.0	V

*As shown by Figure 3, the 18−V maximum value is due to the Zener diode (D_{Z4}) which is implemented in the board to protect it from the excessive voltages which could be applied to the V_{CC} socket. However, the NCP1655A V_{CC} pin can receive a voltage as high as 35 V.

The board contains high−voltage and hot, live parts. It must not be handled except by experienced professionals.

Be very cautious when manipulating or testing it. It embeds no circuitry to discharge the X2 capacitors of the EMI filter. Also note that the EVB delivers a voltage in the range of 400 V (V_{out} = 388 V nominally), leading to the risk of a severe electric chock, if improperly handled. Get sure that the output capacitor is properly discharged before manipulating the board.

It is the responsibility of the board users, to take all the precautions to avoid electric hazards and any other pains.

APPLICATION SCHEMATIC

Power Section

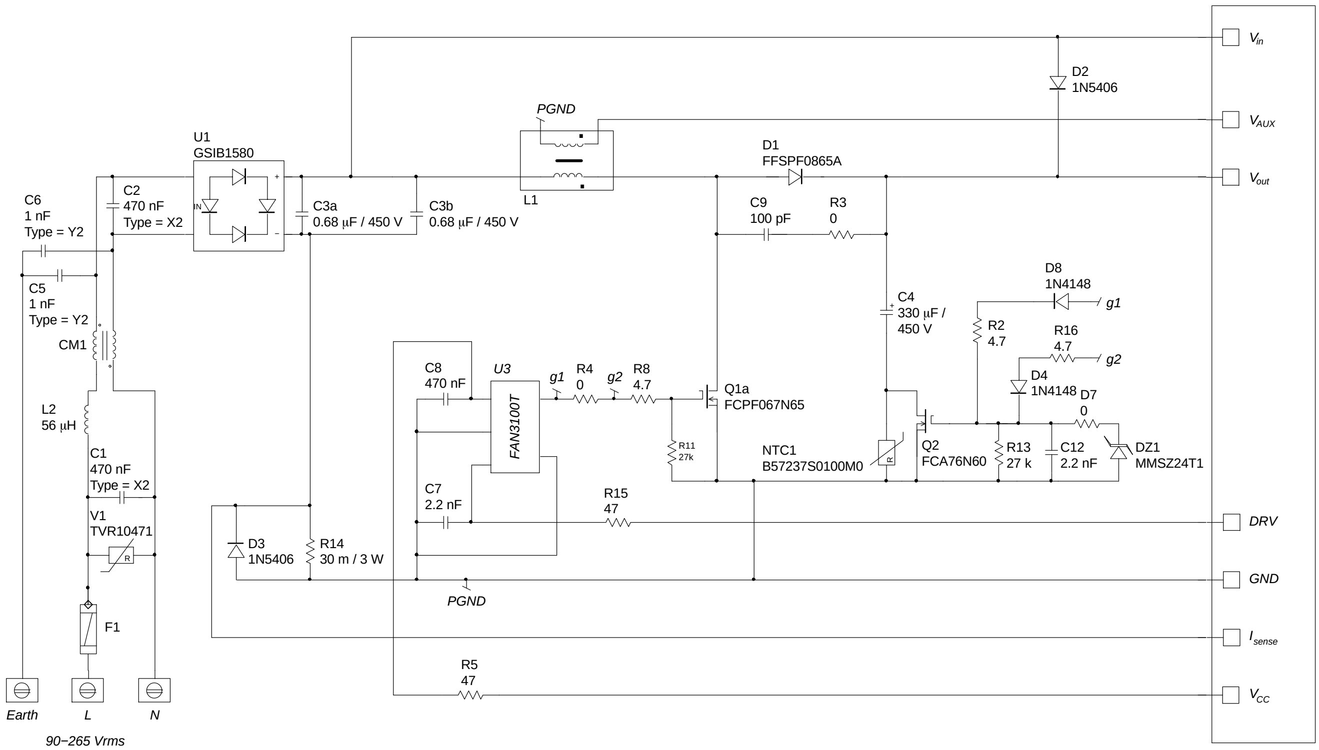


Figure 2. Power Section of the Application Schematic

Figure 2 shows the power section of the application schematic. A SOT23−5 driver (FAN3100T from **onsemi** [2]) is used to drive one single FCPF067N65 MOSFETS (Q_{1a}) [3]. Note however that as shown in the annex, the board supports the implementation of two MOSFETs in parallel (*Q1a* and *Q1b*), which can provide a further improved efficiency. Silicon Carbide Schottky diode (SiC) FFSPF0865A from **onsemi** is used as the boost diode [4]. An NTC is placed in series with the bulk capacitor C_4 to limit inrush currents when the PFC stage is plugged in. MOSFET Q_2 (FCA76N60 − 600−V, 36−mΩ, TO−3P MOSFET from **onsemi** [5]) is implemented to bypass the NTC when the bulk capacitor is charged. Practically, the drive voltage and the output of charge pump (R_1, C_{11}, D_{Z1}, D_7) are applied to the Q_2 gate so that Q_2 is on and the NTC bypassed as soon as the PFC stage is in operation.

Control Section

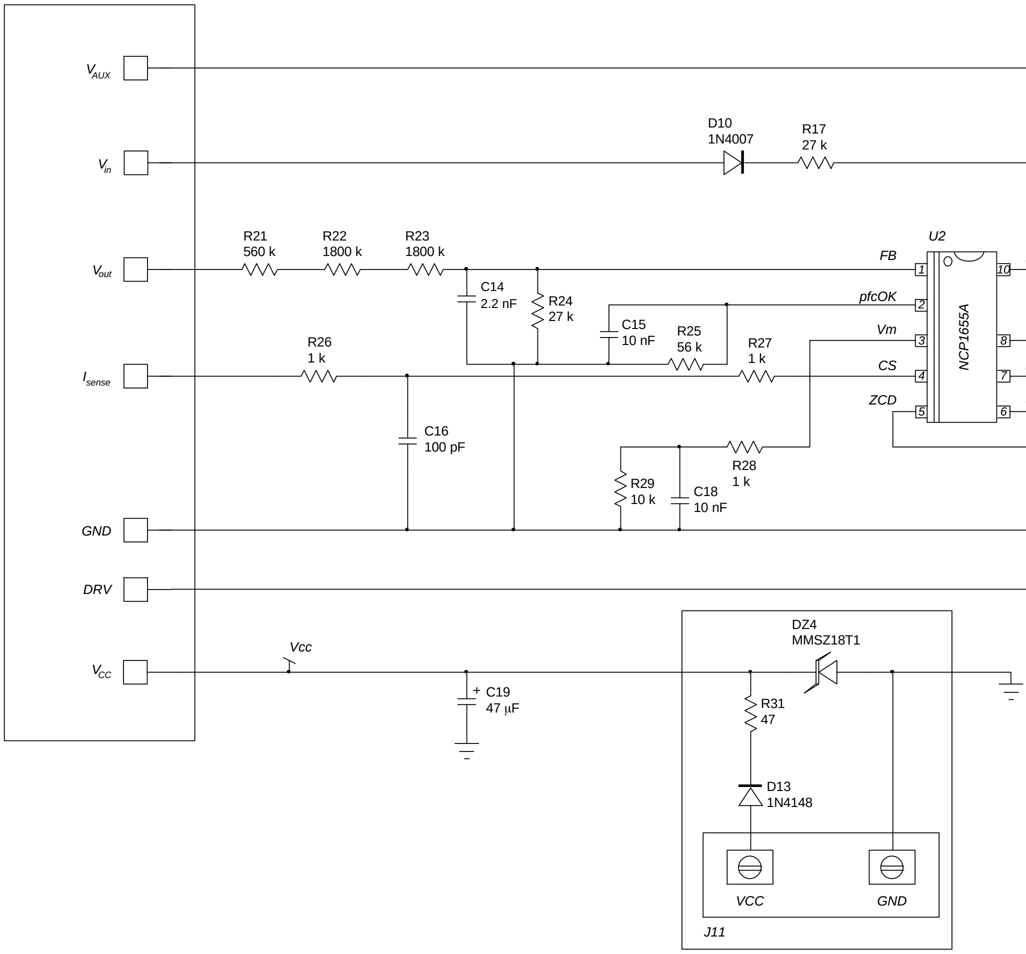


Figure 3. Control Section of the Application Schematic

An external power source is to be applied to the board (using socket J_{11}) to power the NCP1655A. Apply 12 V or more to ensure that the circuit has enough voltage to startup. Note however that due to the protecting Zener diode (D_{Z4}) implemented in the board, the power source voltage should not exceed 18 V.

IMPORTANT REMARK:

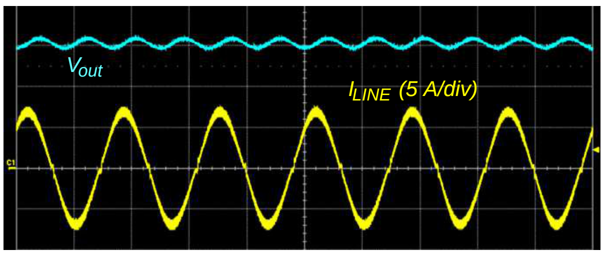
Proposed circuitry is only intended to illustrate the NCP1655 operation. It should not be re−used in practical applications as is unless appropriate verifications are made to check that it can meet reliability and safety requirements and comply with relevant norms.

In particular, no circuitry to discharge the X2 capacitors of the EMI filter is implemented in the evaluation board. Also, the inrush management circuitry may not be re−used if risks exist that the NTC is not properly shorted when the PFC stage starts switching. If the NTC is not shorted, the V_{OUT} voltage will be the sum of the bulk capacitor voltage plus the voltage produced by the inductor current across the NTC (V_{C4} + (R_{NTC} x I_L)) and in this case, too high a (R_{NTC} x I_L) voltage can be destructive for the application. It must be also noted that the inrush management circuitry increases the current loop when the boost stage fuels the bulk capacitor, making the layout less optimal for very high−speed switching operation, particularly with high t_{RR} boost diodes.

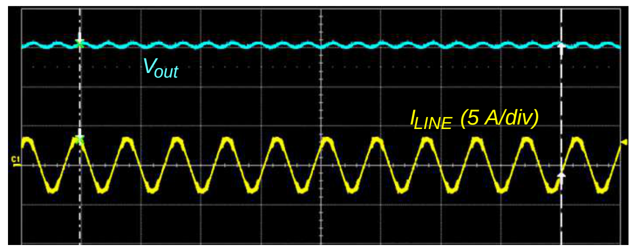
TYPICAL WAVEFORMS

Figure 4 shows the line current at 115 V rms and at below different load levels:

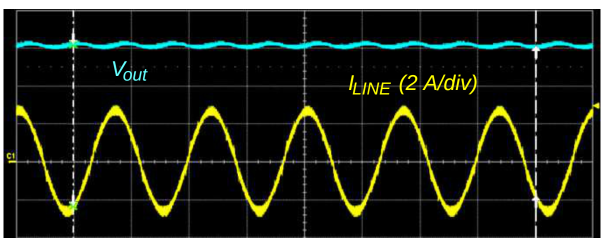
- At full load, the NCP1655 operates in CCM.
- At 50% of the load, the system operates in critical conduction mode
- At 40% of the load, the circuit operates in critical conduction mode with a 125−kHz clamp (frequency−clamped critical conduction mode − FCCrM) leading to valley 2 operation near the line zero crossing as illustrated by Figure 5.
- At 20% load, the NCP1655 frequency foldback makes the PFC stage operate at nearly 30 kHz. Note that the circuit continues turning on at the valley and that the number of valleys depends on the line instantaneous voltage. For instance, the number of skipped valleys is high at the top of the sinusoid where the resonant period is short while turn on in the second valley is obtained at the line zero crossing where the resonant period is long. See Figure 6. However, the NCP1655 always turns on at the valley as long as valleys are detectable.



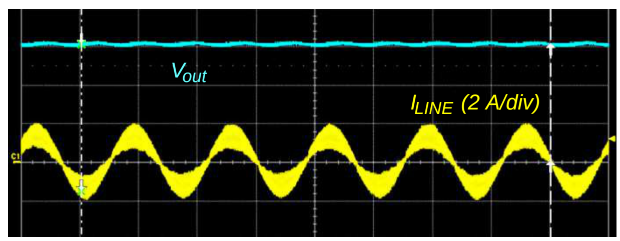
a) 115 V rms, Full Load (1.30 A)



b) 115 V rms, 50% Load (1.30 A)

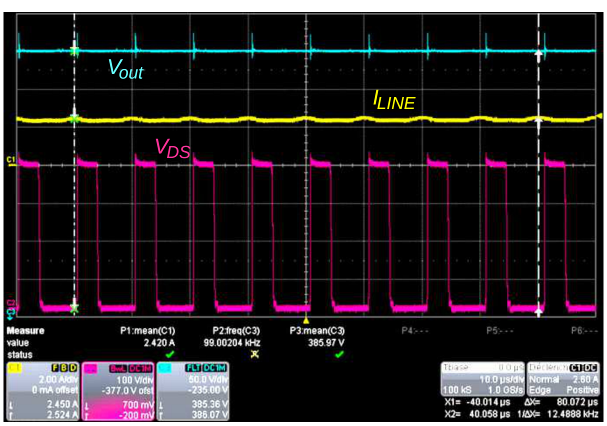


c) 115 V rms, 40% Load (1.30 A)

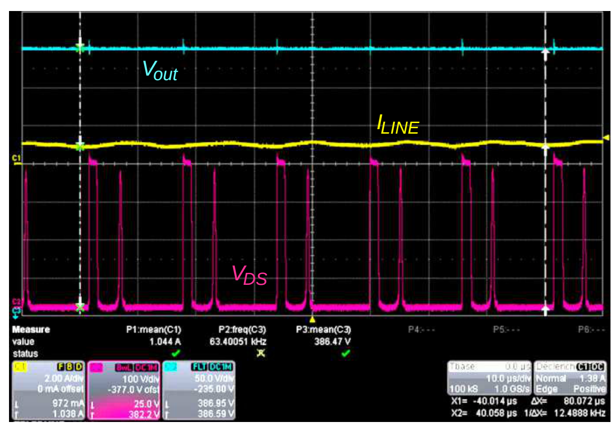


d) 115 V rms, 20% Load (1.30 A)

Figure 4. Line Current at 115 V rms

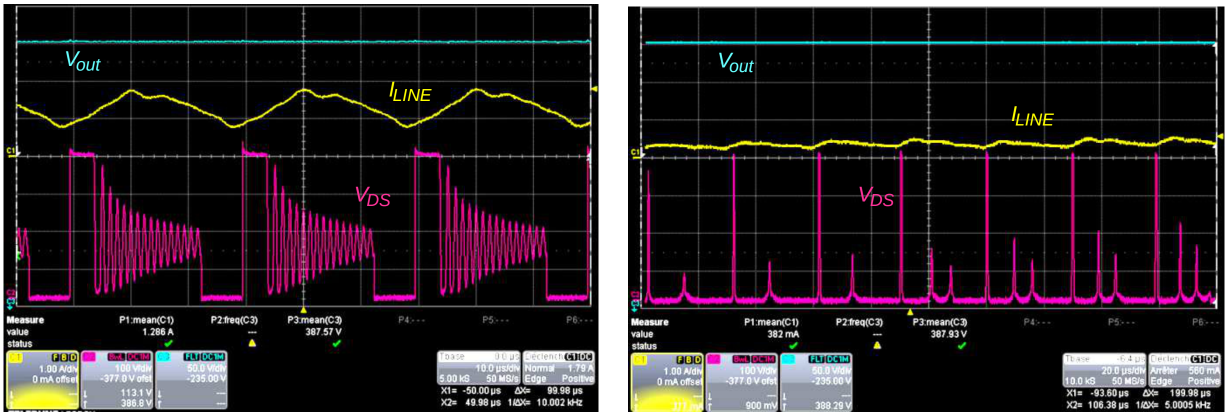


a) Top of the Sinusoid



b) Near the Line Zero Crossing

Figure 5. Operation at 115 V rms, 40% Load



a) Top of the Sinusoid b) Near the Line Zero Crossing

Figure 6. Low Frequency Operation at 115 V rms, 20% Load

CCM OPERATION

The transition point is measured by increasing /decreasing the load by 1−mA steps.

Table 1.

Line rms Voltage	Load Current for Exiting CCM	Load Current for Entering CCM
90 V	524 mA	610 mA
115 V	779 mA	893 mA
150 V	1034 mA	1205 mA
180 V	1133 mA	1460 mA
230 V	888 mA	1021 mA
265 V	798 mA	922 mA

BOARD PERFORMANCE

Efficiency

The efficiency is measured on an automated bench at 90 V rms, 115 V rms, 230 V rms and 265 V rms. For each of these four line levels, measurements start with a full−load 30−mn warm−up, after which the load is decreased from 1.30 A down to 0.13 A by 0.13−A steps. The measure is made after 5 mn at the operating point under test.

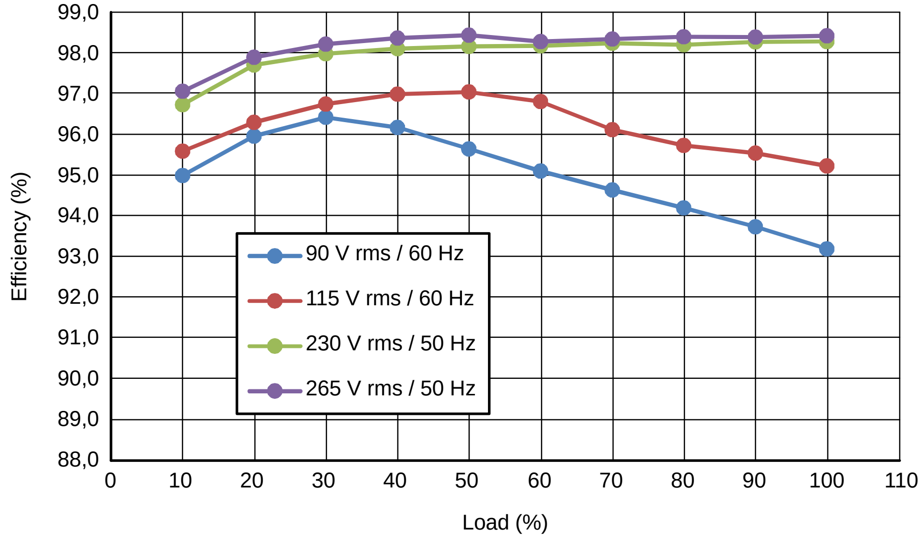
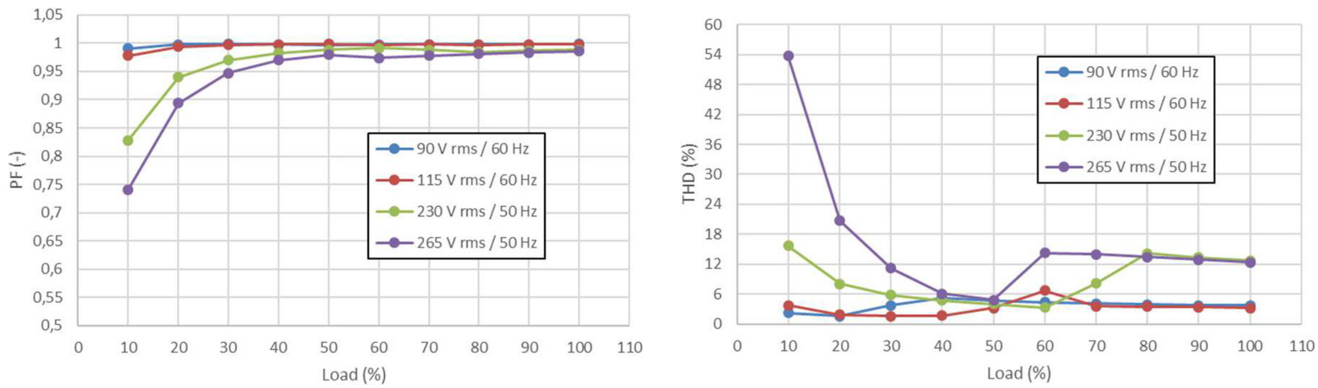


Figure 7. Efficiency versus Load

The efficiency remains above 93% from 10% to 100% of the load at the 4 tested line levels (90 V rms, 115 V rms, 230 V rms and 265 V rms).

Power Factor and THD

Power factor and THD are measured over the load range. Practically, the load current is swept starting from 1300 mA to 130 mA with 130−mA steps.



a) Power Factor (PF)

b) Total Harmonic Distortion (THD)

Figure 8. PF and THD versus Load

BILL OF MATERIAL

Table 2. BILL OF MATERIAL

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufac-turer	Manufacturer Part Number	Substitution Allowed	Lead Free
POWER SECTION									
J10	1	AC Connector	GSF1.1xxx.xx			SCHURTER	GSF1.1201.31	NO	YES
	1	Fuse	8 A / 250 V			SCHURTER	34562611	NO	YES
J1b	1	VBULK connector				Multicomp	24.243.1	NO	YES
J1a	1	GND connector				Multicomp	24.243.2	NO	YES
HS1	1	Diodes Bridge (U1) Heatsink	4.5°C/W			Fischer Elektronik	SK481−50	NO	YES
HS2	1	Q1a, Q1b and D1 Heatsink	2.8°C/W			Fischer Elektronik	SK481−100	NO	YES
	3	HS1 and HS2 Heatsink clip				Fischer Elektronik	THFU1	NO	YES
C1, C2	2	X2 capacitor	470 nF	277 V	through−hole	Wurth Elektronik	890334025039CS	NO	YES
C3a, C3b	2	Filtering capacitor	680 nF	450 V	through−hole	Wurth Elektronik	890283425008CS	NO	YES
C4	1	Electrolytic capacitor	330 µF	450 V	through−hole	Wurth Elektronik	8.61141E+11	NO	YES
C5, C6	2	Y2 capacitors (note)	1 nF	275 V	through−hole	EPCOS	B32021A3102	NO	YES
C9	1	High−voltage capacitor	100 pF	500 V	through−hole	Vishay	D101K20Y5PL6.J5.	NO	YES
C7, C12	2	Capacitor	2,2 nF	25 V, 10%	SMD, 1206	various	various	YES	YES
C8	1	Capacitor	470 nF	25 V, 10%	SMD, 1206	various	various	YES	YES
CM1	1	Common−Mode Filter	2 mH	6 mW	through−hole	Wurth Elektronik	7448031002	NO	YES
D1	1	Boost diode	FFSPF0865A	8 A, 650V	TO220F	**onsemi**	FFSPF0865A	NO	YES
D2, D3	2	Bypass diode	1N5406	3 A, 600 V	Axial	**onsemi**	1N5406G	NO	YES
D4, D8	2	Switching diode	D1N4148	100 V	SOD123	Vishay	1N4148W−V	NO	YES
DZ1	1	24−V zener diode	MMSZ24T1	24 V, 0.5 W	SOD−123	**onsemi**	MMSZ24T1G	NO	YES
L1	1	Boost Inductor	175 µH, 14 A		PQ3230	Wurth Elektronik	750 317557	NO	YES
L2	1	DM Choke	56 µH	17 mW	through−hole	BOURNS	2310−V−RC	NO	YES
Q1a	1	Power MOSFET	FCFP067N65	650V	TO220F	**onsemi**	FCPF067N65S3L1	NO	YES
Q2	1	Power MOSFET	FCA76N60	600 V, 76 A	TO−3PN	**onsemi**	FCA76N60N	NO	YES
NTC1	1	Inrush Current Limiter	10 W @ 25°C		through−hole	EPCOS	B57237S0100M0	NO	YES
R2, R8, R16	3	SMD resistor, 1206, 1/4W	4,7 W	10%, 1/4 W	SMD, 1206	various	various	YES	YES
R3	1	Through hole resistor	0 W	1 W	through−hole	Vishay	AC01		
R5, R15	2	SMD resistor, 1206, 1/4W	47 W	10%, 1/4 W	SMD, 1206	various	various	YES	YES
R3	1	Through hole resistor	0 W	1 W	through−hole	Vishay	AC01		
R4, D7	2	SMD resistor, 1206, 1/4W	0 W	10%, 1/4 W	SMD, 1205	various	various	YES	YES
R11, R13	2	SMD resistor, 1206, 1/4W	27 kW	10%, 1/4 W	SMD, 1206	various	various	YES	YES
R14	1	Current sense resistor	30 mW	1%, 3W	through−hole	Vishay	LVR03R0300FE12	NO	YES
U1	1	Diodes Bridge	GSIB1580	15 A, 800 V	through−hole	VISHAY	GSIB1580	NO	YES
U3	1	High−speed, low−side driver	FAN3100T	2 A	SOT23−5	**onsemi**	FAN3100TSX	NO	YES
V1	1	TVS Varistor		275 V rms		Wurth Elektronik	820513011	NO	YES

Table 2. BILL OF MATERIAL (continued)

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufac-turer	Manufacturer Part Number	Substitution Allowed	Lead Free
CONTROL SECTION									
R10, R17, R24	3	SMD resistor, 1206, 1/4W	27 kW	1%	SMD, 1206	various	various	YES	YES
R21	1	SMD resistor, 1206, 1/4W	560 kW	1%	SMD, 1206	various	various	YES	YES
R22, R23	2	SMD resistor, 1206, 1/4W	1800 kW	1%	SMD, 1206	various	various	YES	YES
R25	1	SMD resistor, 1206, 1/4W	56 kW	1%	SMD, 1206	Vishay	various	YES	YES
R26, R27, R28	3	SMD resistor, 1206, 1/4W	1 kW	1%	SMD, 1206	Vishay	various	YES	YES
R29	1	SMD resistor, 1206, 1/4W	10 kW	1%	SMD, 1206	Vishay	various	YES	YES
R31	1	SMD resistor, 1206, 1/4W	47 W	1%	SMD, 1206	Vishay	various	YES	YES
D10	1	Standard Recovery Diodes	1N4007	1000 V	through−hole	**onsemi**	1N4007G	NO	YES
D13	1	Switching diode	D1N4148	100 V	SOD123	Vishay	1N4148W−V	NO	YES
DZ4	1	18−V zener diode	MMSZ27T1	18 V, 0.5 W	SOD−123	**onsemi**	MMSZ18T1G	NO	YES
C14	1	Capacitor	2.2 nF	25 V, 10%	SMD, 1206	various	various	YES	YES
C15, C18	1	Capacitor	10 nF	25 V, 10%	SMD, 1206	various	various	YES	YES
C16	1	Capacitor	220 pF	25 V, 10%	SMD, 1206	various	various	YES	YES
C22	1	Capacitor	220 nF	25 V, 10%	SMD, 1206	various	various	YES	YES
C19	1	Electrolytic Capacitor	47 μF	35 V	through−hole	Wurth Elektronik	860020472006	YES	YES
U2	1	controller	NCP1655		SOIC9	**onsemi**	NCP1655ADR2G	NO	YES
J11	1	Vcc socket				Wurth Elektronik	691,253,510,002	YES	YES

REFERENCES

[1] NCP1655 data sheet: https://www.onsemi.com/download/data−sheet/pdf/ncp1655−d.pdf
[2] FAN3100T data sheet: https://www.onsemi.com/download/data−sheet/pdf/fan3100t−d.pdf
[3] FCPF067N65 data sheet: https://www.onsemi.com/pdf/datasheet/fcpf067n65s3−d.pdf
[4] FFSPF0865 data sheet: https://www.onsemi.com/pdf/datasheet/ffspf0865a−d.pdf
[5] FCA76N60 data sheet: https://www.onsemi.com/download/data−sheet/pdf/fca76n60n−d.pdf

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