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## High Efficiency, <30 mW No-load PFC



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### DESIGN NOTE

Table 1. DEVICE DETAILS

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1615C	Adapter	85 to 265 Vac	Up to 120 W	PFC	Non-isolated
Characteristic		Output Specification			
Output Voltage		400 Vdc Nominal			
Nominal Current		300 mA			
No Load Standby		< 30 mW			
Min Current		Zero			

#### Description

The NCP1615C is a high voltage PFC controller designed to drive PFC boost stages based on an innovative Current Controlled Frequency Foldback (CCFF) method. In this mode, the circuit classically operates in critical conduction mode (CrM) when the inductor current exceeds a programmable value. When the current is below this preset level, the NCP1615C linearly decays the frequency down to a minimum of about 26 kHz when the input current is zero. CCFF maximizes the efficiency at both nominal and light load. In particular, the standby losses are reduced to a minimum. An innovative circuitry allows near-unity power factor even when the switching frequency is reduced.

The integrated high voltage startup circuit eliminates the need for external startup components and consumes negligible power during normal operation. Housed in a SOIC-16 package, the NCP1615C also incorporates the features necessary for robust and compact PFC stages, with few external components.



#### Key Features

- High Voltage Startup Circuit
- Critical Conduction Mode (CrM)
- Novel CCCF Based Control Scheme Maximizes Efficiency Across Line and Load
- Skip Mode Near the Line Zero Crossing
- Fast Line/Load Transient Compensation (Dynamic Response Enhancer)
- Valley Turn On
- Input Voltage Range Detection
- PFCOK Signal
- Input to Force Controller into Standby Mode
- Input Filter Capacitor (X2) Discharge Circuitry Enables Very Low Standby Power Applications
- Line Removal Detection to Reset the Downstream Converter
- Power Savings Mode Enables < 30 mW No-Load Power

#### Safety Features

- Restart Pin Allows Adjustment of Bulk Voltage Hysteresis in Standby Mode
- Adjustable Bulk Undervoltage Detection (BUV)
- Soft Overvoltage Protection
- Integrated Brownout Detection
- Overcurrent Protection
- Open Pin Protection for FB and BUV Pins
- Internal Thermal Shutdown
- Latch Input
- Low Power Mode Operation if the Bypass Diode is Shorted

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- Open Ground Pin Fault Monitoring
- Line Overvoltage Detection

## Instructions


- Always Use an Isolated AC Supply when Testing
- When Operating with Ext. Vcc Bias (J3), it is Important to Connect the AC Line Voltage First, then Connect

External Vcc. Failure to Do This will Activate the Line Removal Detection Feature, and the Board will Not Start until Vcc is Discharged to ~4.5 V

- To Enter Power Savings Mode (PSM), Remove the Jumper Labeled “PSM” (J4)
- To Enter Standby Mode, Apply 5 V to the Test Point Labeled “STDBY”

## TRANSFORMER DESIGN

CUSTOMER TERMINAL Sn96%, Ag4%	RoHS Yes	LEAD(Pb)-FREE Yes	
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PART MUST INSERT FULLY TO SURFACE A IN RECOMMENDED GRID  
 $\phi .028(6)$   
 [.70]

TERM. NO.'s FOR REF. ONLY

ALTERNATE MARKING DETAIL

LOT CODE & DATE CODE

RECOMMENDED P.C. PATTERN, COMPONENT SIDE

**ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:**

D.C. RESISTANCE (@20°C): 5-7 (5+6, 7+8), 0.27 Ohms  $\pm 10\%$ .  
 1-12, 0.90 Ohms  $\pm 10\%$ .

DIELECTRIC RATING: 800VAC, 1 minute tested by applying 1000VAC for 1 second between pins 5-1(tie 5+6).

INDUCTANCE: 300.0 $\mu$ H  $\pm 10\%$ , 10kHz, 100mVAC, 0mADC, 5-7(5+6,7+8), Ls.

SATURATION CURRENT: 5.72A saturating current that causes 20% rolloff from initial inductance.

LEAKAGE INDUCTANCE: 100.0 $\mu$ H max., 100kHz, 100mVAC, 5-7(5+6,7+8,1+12), Ls.

TURNS RATIO: ( 5-7 ):( 1-12 ), ( 10 ):(1.00), tie(5+6,7+8),  $\pm 1\%$ .

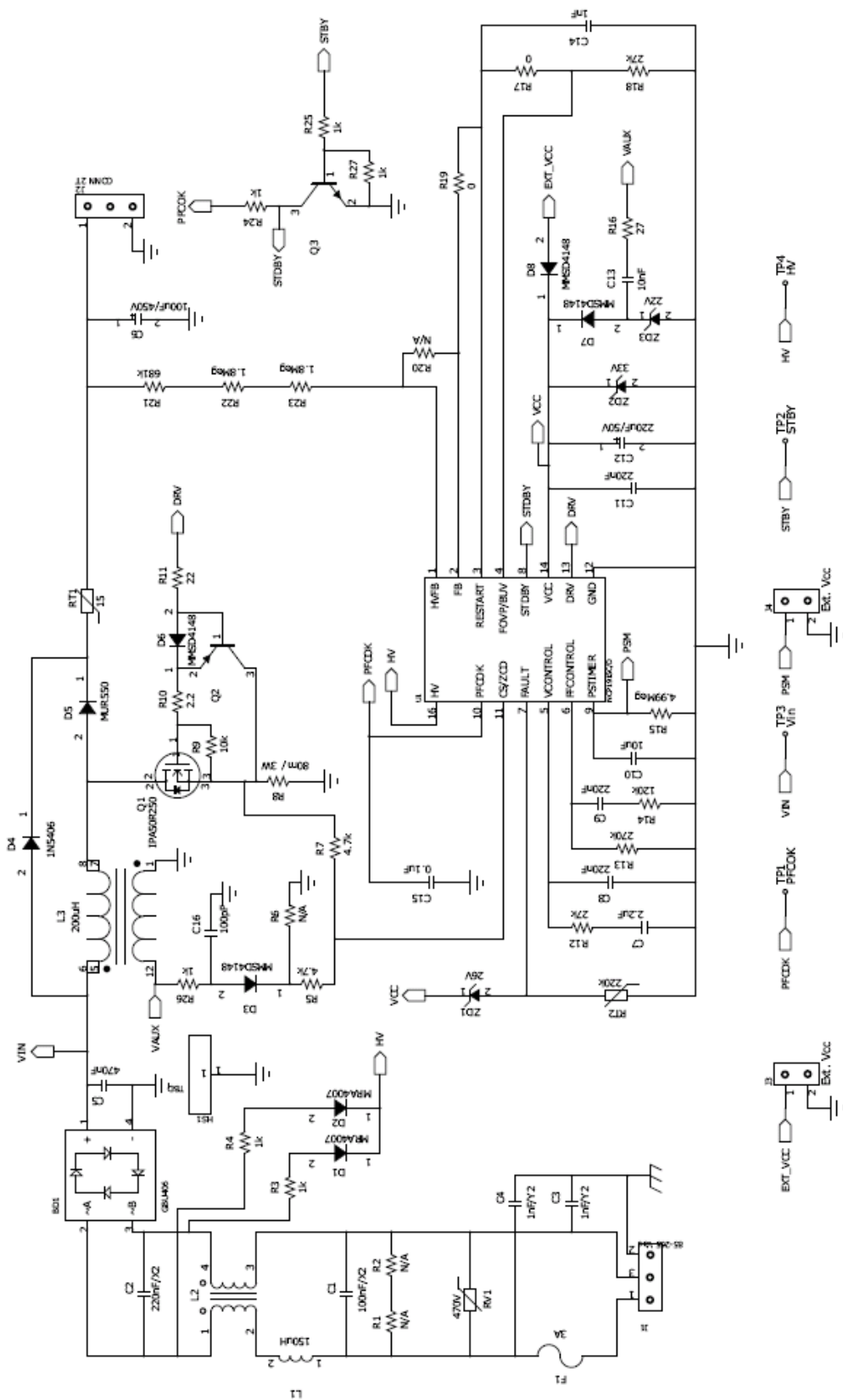
OPERATING TEMPERATURE RANGE: -40°C to 125°C including temp. rise.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability. T\_0\_5714

<b>Würth Electronics Midcom Inc.</b>  Watertown, SD USA Toll Free: 800-643-2661 Fax: 605-886-4486	Unless otherwise specified, tolerances are as follows: Angles: $\pm 1^\circ$ Fractions: $\pm 1/64$ Decimals: $\pm .005(.127\text{mm})$ Footprint: $\pm .001(.03\text{mm})$	<b>more than you expect</b>	
	Drawing Title <b>Inductor</b>	Drawing Number <b>750313750</b>	Rev. <b>01</b>
This drawing is dual dimensioned. Dimensions in brackets are in millimeters	Revisions: See Sheet 1	Scale ----	Spec Sheet 1 of 1
Engineer:RRH		02/28/2013	

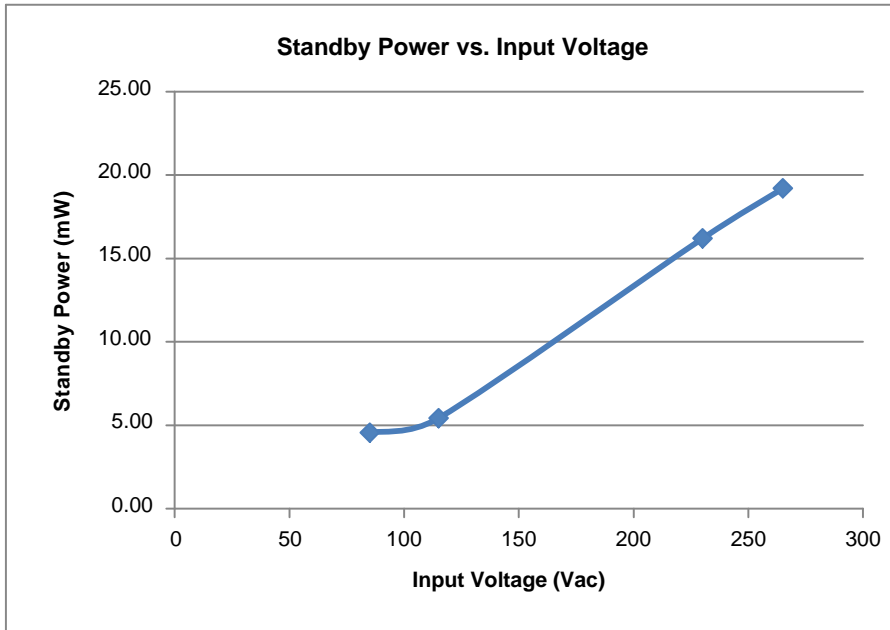
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## CIRCUIT SCHEMATIC



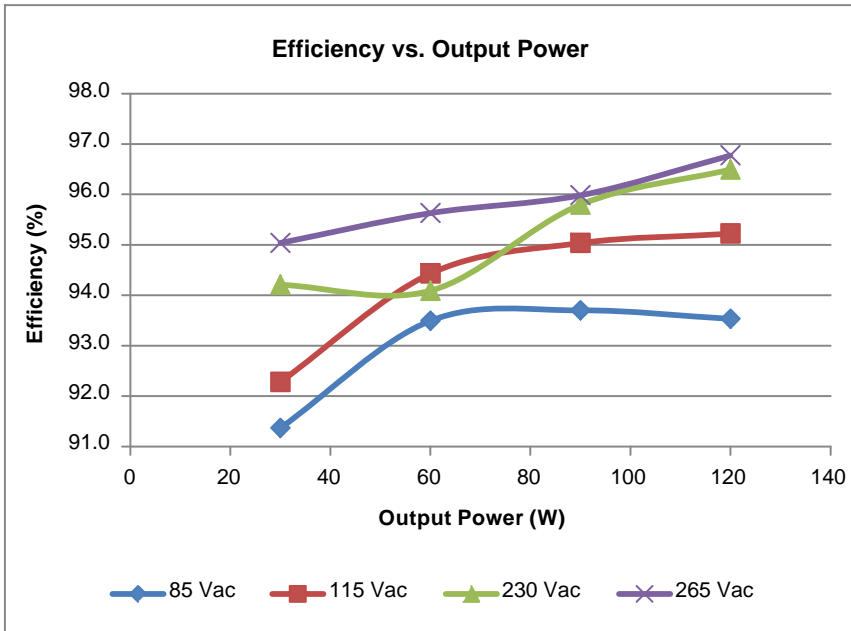
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## EFFICIENCY PLOTS



VAC	Pin (mW)
85	4.55
115	5.42
230	16.2
265	19.2

Figure 1. Standby Power



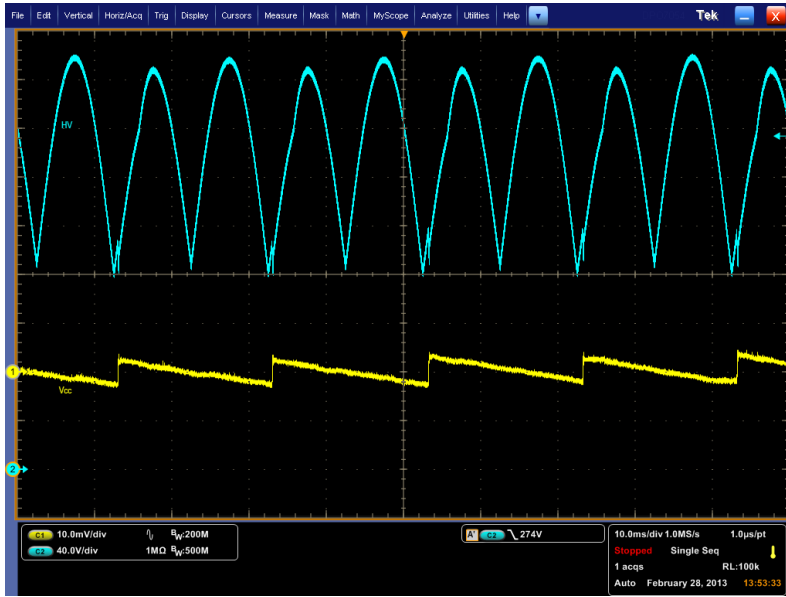
VAC	Pin (W)	Io (mA)	Vout (V)	Po (W)	Eff (%)
85	31.0	71.2	397.8	28.3	91.4
85	62.4	146.5	397.9	58.3	93.5
85	94.0	221.3	398.0	88.1	93.7
85	126.2	296.5	398.1	118.0	93.5
115	30.9	71.7	398.2	28.6	92.3
115	61.6	146.1	398.3	58.2	94.4
115	92.6	220.9	398.3	88.0	95.0
115	124.0	296.5	398.3	118.1	95.2
230	30.2	71.4	398.2	28.4	94.2
230	62.0	146.4	398.2	58.3	94.1
230	92.3	221.9	398.3	88.4	95.8
230	122.4	296.5	398.3	118.1	96.5
265	30.1	71.8	398.3	28.6	95.0
265	61.3	147.1	398.2	58.6	95.6
265	92.1	221.9	398.3	88.4	96.0
265	122.3	297.2	398.3	118.4	96.8

Average efficiency = 94.57%

Figure 2. Efficiency

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## POWER SAVINGS MODE

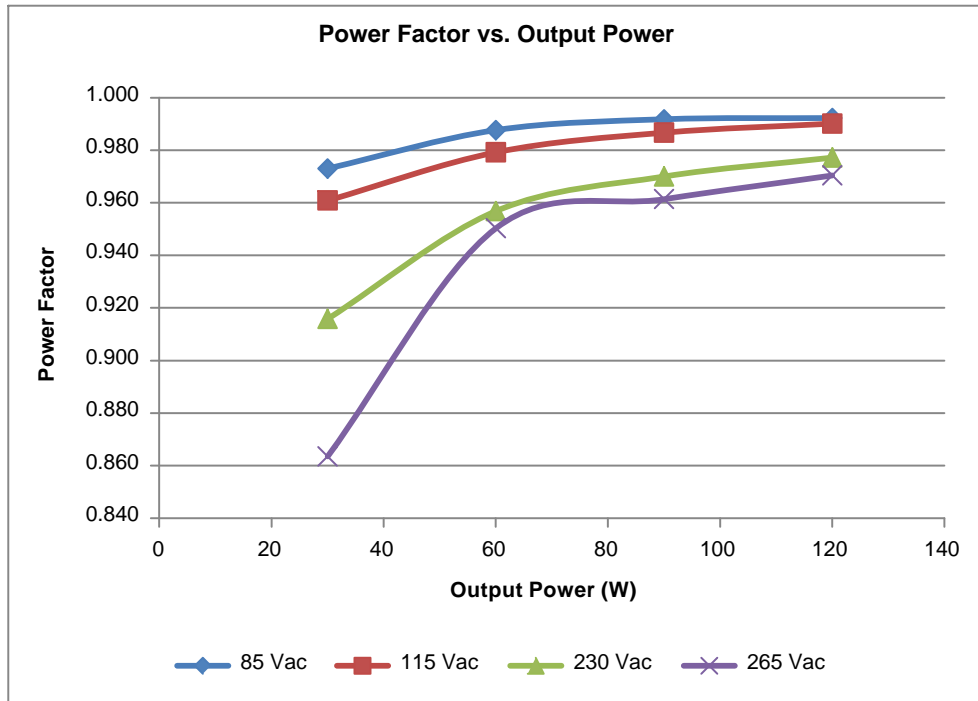


- $V_{CC}$  is regulated at  $V_{CC(PS\_on)}$ , typically 11 V, by turning on the HV start-up circuit at the valley of every half-cycle.
- The start-up circuit turns on at the valley of every half-cycle provided that  $V_{CC}$  is below  $V_{CC(PS\_on)}$ .
- The start-up circuit is disabled once  $V_{CC}$  exceeds  $V_{CC(PS\_on)}$ . There is no hysteresis in the comparator ensuring that  $V_{CC}$  will be below the  $V_{CC(PS\_on)}$  regulation level during the next half-cycle.
- Measured data with 2-wire connection:
  - 5.42 mW at 115 Vac
  - 16.2 mW at 230 Vac

$V_{CC}$  in Regulation  
 Ch. 1 (Yellow):  $V_{CC}$  (AC Coupled)  
 Ch. 2 (Blue): HV

Figure 3. Power Savings Mode

## POWER FACTOR

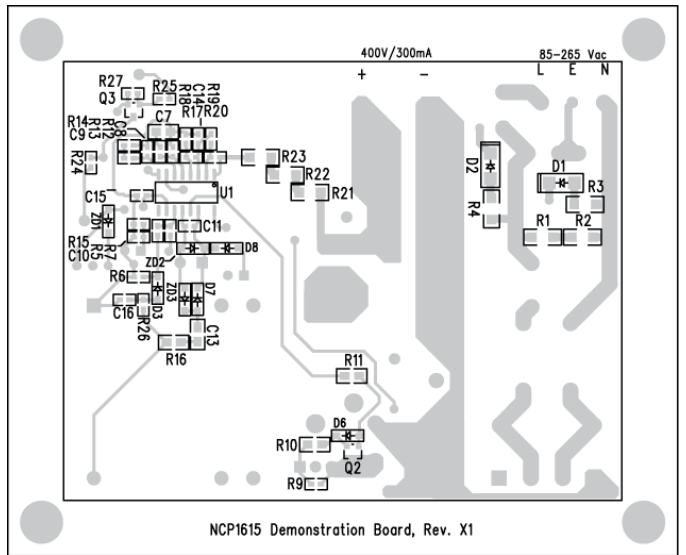
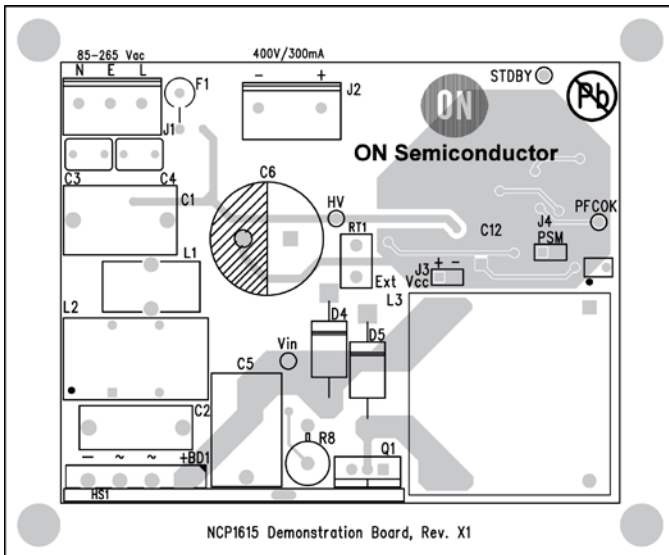
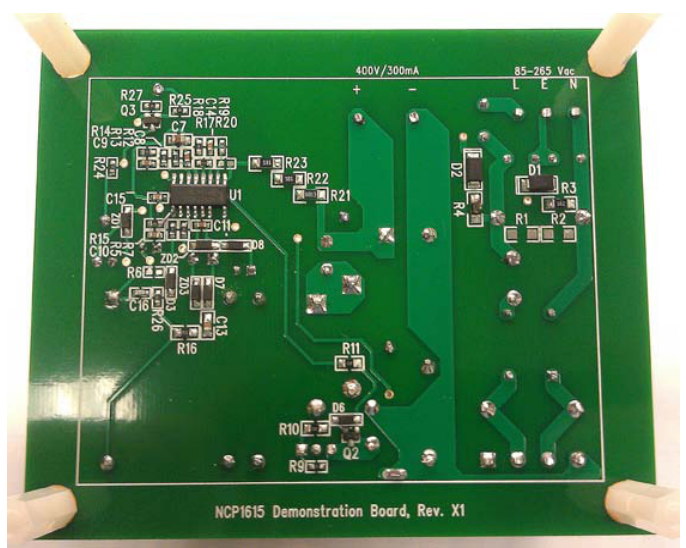
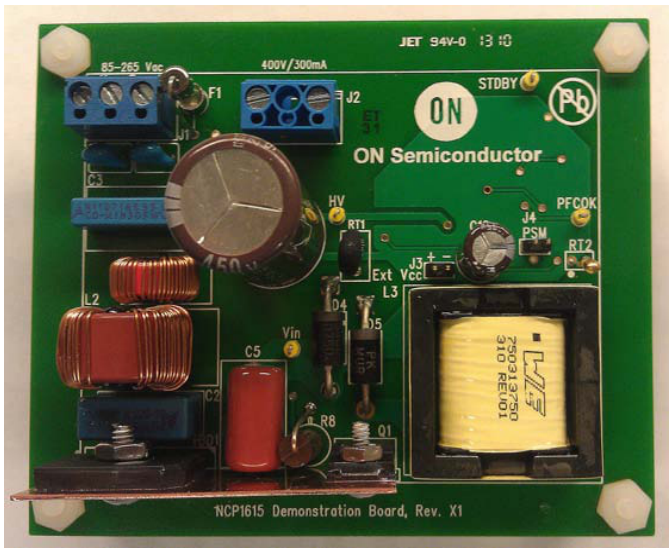


VAC	Pin (W)	Po (W)	PF
85	31.0	28.3	0.973
85	62.4	58.3	0.988
85	94.0	88.1	0.992
85	126.2	118.0	0.992
115	30.9	28.6	0.961
115	61.6	58.2	0.979
115	92.6	88.0	0.987
115	124.0	118.1	0.990
230	30.2	28.4	0.916
230	62.0	58.3	0.957
230	92.3	88.4	0.970
230	122.4	118.1	0.977
265	30.1	28.6	0.864
265	61.3	58.6	0.950
265	92.1	88.4	0.961
265	122.3	118.4	0.970

Figure 4. Power Factor

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## DEMO BOARD



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## BILL OF MATERIALS

**Table 2. BILL OF MATERIALS**

Qty	Ref		Component Type	Value	Rating	Pkg/Dimensions	P/N	Supplier
1	L1	-	DM Choke	150 $\mu$ H		7447021_WURTH	7447021	WURTH
1	L2	-	CM Choke	8.5 mH		IND_744823210	744823210	WURTH
1	L3	-	PFC Transformer	300 $\mu$ H		EFD-30	750313750	WURTH
1	C1	-	X2	100 nF	305 Vac	5 x 10.5 x 18 mm	B32922C3104M	
1	C2	-	X2	220 nF	305 Vac	7 x 12.5 x 18 mm	B32922C3224M	
1	C10	SMT	Ceramic	10 $\mu$ F	6.3 V	C0603W	C1608X5R0J106K080AB	TDK
1	C16	SMT	Ceramic	100 pF	50 V	C0603W	C1608X7R1H101K	TDK
1	C15	SMT	Ceramic	100 nF	50 V	C0603W	C1608X7R1H104K080AA	TDK
3	C8, C9, C11	SMT	Ceramic	220 nF	50 V	C0603W	C1608X7R1H224K080AB	TDK
1	C7	SMT	Ceramic	2.2 $\mu$ F	16 V	C0805W	C2012X7R1C225K125AB	TDK
1	C13	SMT	Ceramic	10 nF	50 V	C0805W	C2012X7R1H103K	TDK
1	C14	SMT	Ceramic	1 nF	50 V	C0603W	CGA3E2X7R1H102K080AA	TDK
2	C3, C4	-	Y2	1 nF	250 Vac	5 mm	DE2E3KY102MA2BM01	Murata
1	C5	-	MKP	470 nF	400 V	15 mm	ECW-F4474JL	Panasonic
1	C6	-	Electrolytic	100 $\mu$ F	450 V	18 x 40 mm	EKXG451ELL101MM40S	UCC
1	C12	-	Electrolytic	220 $\mu$ F	35 V	8 x 15 mm	EKY-350ELL221MH15D	UCC
1	F1	-	Fuse	3 A	250 V/3 A	2AG	0224003.HXP	LITTELFUSE
1	RV1	-	MOV	2.5 kA	470 V	10 mm	S10K300	EPCOS
2	R1, R2	SMT	Resistor	Open		R1206W		
2	R6, R20	SMT	Resistor	Open		R0603W		
2	R17, R19	SMT	Resistor	0		R0603W	CRCW06030000Z0EA	Vishay/Dale
1	R9	SMT	Resistor	10 k $\Omega$		R0603W	CRCW060310K0FKEA	Vishay/Dale
1	R14	SMT	Resistor	120 k $\Omega$		R0603W	CRCW0603120KFKEA	Vishay/Dale
4	R24, R25, R26, R27	SMT	Resistor	1 k $\Omega$		R0603W	CRCW06031K00FKEA	Vishay/Dale
1	R13	SMT	Resistor	270 k $\Omega$		R0603W	CRCW0603270KFKEA	Vishay/Dale
2	R12, R18	SMT	Resistor	27 k $\Omega$		R0603W	CRCW060327K0FKEA	Vishay/Dale
2	R5, R7	SMT	Resistor	4.7 k $\Omega$		R0603W	CRCW06034K70FKEA	Vishay/Dale
1	R15	SMT	Resistor	4.99 M $\Omega$		R0603W	CRCW06034M99FKEA	Vishay/Dale
1	R11	SMT	Resistor	22 $\Omega$		R0805W	CRCW080522R0JNEA	Vishay/Dale
1	R16	SMT	Resistor	27 $\Omega$		R0805W	CRCW080527R0JNEA	Vishay/Dale
1	R10	SMT	Resistor	2.2 $\Omega$		R0805W	CRCW08052R20JNEA	Vishay/Dale
2	R3, R4	SMT	Resistor	1 k $\Omega$		R1206W	CRCW12061K00JNEA	Vishay/Dale
2	R22, R23	SMT	Resistor	1.8 M $\Omega$		R1206W	CRCW12061M80JNEA	Vishay/Dale
1	R21	SMT	Resistor	681 k $\Omega$		R1206W	CRCW1206681KFKEA	Vishay/Dale
1	R8	-	Resistor	100 m $\Omega$		3 W	LOB3R100FLFLT	TT Electronics
1	RT1	-	NTC	10 $\Omega$		5 mm	B57153S0100M000	EPCOS
1	RT2	-	NTC	220 k $\Omega$		2.5 mm	NTCLE100E3224JB0	Vishay/Dale
1	Q3	SMT	NPN	MMBT3904L	40 V/200 mA	SOT-23	MMBT3904LT1G	ON Semiconductor
1	Q2	SMT	PNP	MMBT589	30 V/1 A	SOT-23	MMBT589LT1G	ON Semiconductor




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**Table 2. BILL OF MATERIALS** (continued)

Qty	Ref		Component Type	Value	Rating	Pkg/Dimensions	P/N	Supplier
1	D4	-	Fast Acting	1N5406	600 V/3 A	DO201AD	1N5406G	ON Semiconductor
1	BD1	-	Bridge	GBU406	600 V/4 A	18.5 x 22 mm	GBU406	Diodes
4	D3, D6, D7, D8	SMT	General Purpose	MMSD4148	100 V/200 mA	SOD-123	MMSD4148T1G	ON Semiconductor
1	ZD3	SMT	Zener	22 V	500 mW	SOD-123	MMSZ22T1G	ON Semiconductor
1	ZD1	SMT	Zener	27 V	500 mW	SOD-123	MMSZ27T1G	ON Semiconductor
1	ZD2	SMT	Zener	33 V	500 mW	SOD-123	MMSZ33T1G	ON Semiconductor
2	D1, D2	-	Rectifier	MRA4007	1000 V/1 A	SMA	MRA4007T3G	ON Semiconductor
1	D5	-	Fast Acting	MUR550	520 V/5 A	DO201AD	MUR550APFRLG	ON Semiconductor
1	U1	-	PFC Controller	NCP1615C		SO16NB_LESS_PIN_15	NCP1615CDR2G	ON Semiconductor
1	Q1	-	HV MOSFET	IPA50R250CP	500 V/13 A	TO-220FP	IPA50R250CP	Infineon
4	TP1, TP2, TP3, TP4	-	Test Point			TESTPOINT		
2	J3, J4	-	SIP-2P			0.1" Pitch	104351-1	TE Connectivity
1	J2	-	2T Screw Block			10 mm Pitch	ED200/2DS	On Shore Technology
1	J1	-	3T Screw Block			5 mm Pitch	OSTTA030161	On Shore Technology
4	J5, J6, J7, J8	-	Standoff			MTGNP685H370V6P	4820	Keystone Electronics
1	HS1	-	Heatsink			Cut to fit		

## REFERENCES

[1] NCP1615 Datasheet ([NCP1615/D](#))

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