# DN05057/D

# High Efficiency, <30 mW No-load PFC

ON Semiconductor®

www.onsemi.com

**DESIGN NOTE**

**Table 1. DEVICE DETAILS**

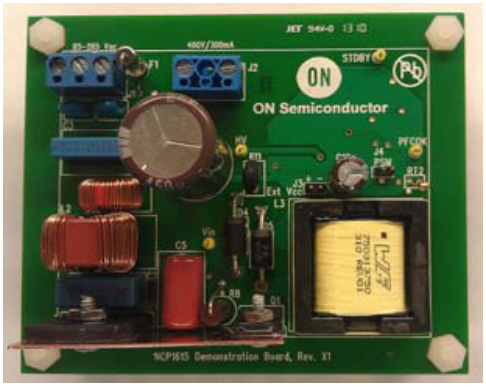
| Device | Application | Input Voltage | Output Power | Topology | I/O Isolation |
|---|---|---|---|---|---|
| NCP1615C | Adapter | 85 to 265 Vac | Up to 120 W | PFC | Non-isolated |

| 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

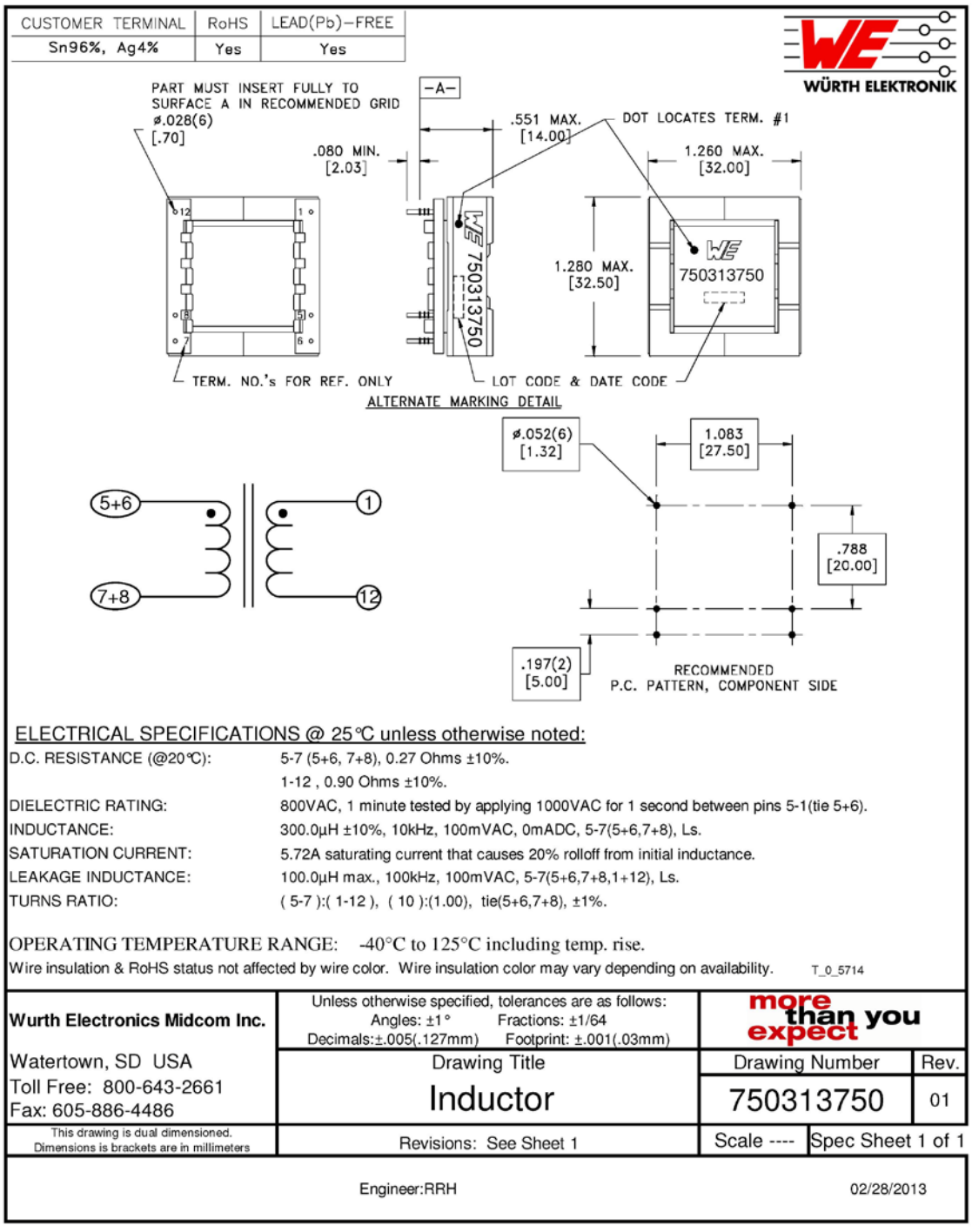
- Restart Pin Allows Adjustment of Bulk Voltage Hysteresis in Standby Mode
- Adjustable Bulk Undervoltage Detection (BUV)
- Soft Overvoltage Protection
- Integrated Brownout Detection
- Overcurrent Protection
- Open Pin Protection for FB and BUV Pins
- Internal Thermal Shutdown
- Latch Input
- Low Power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

- 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




ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:

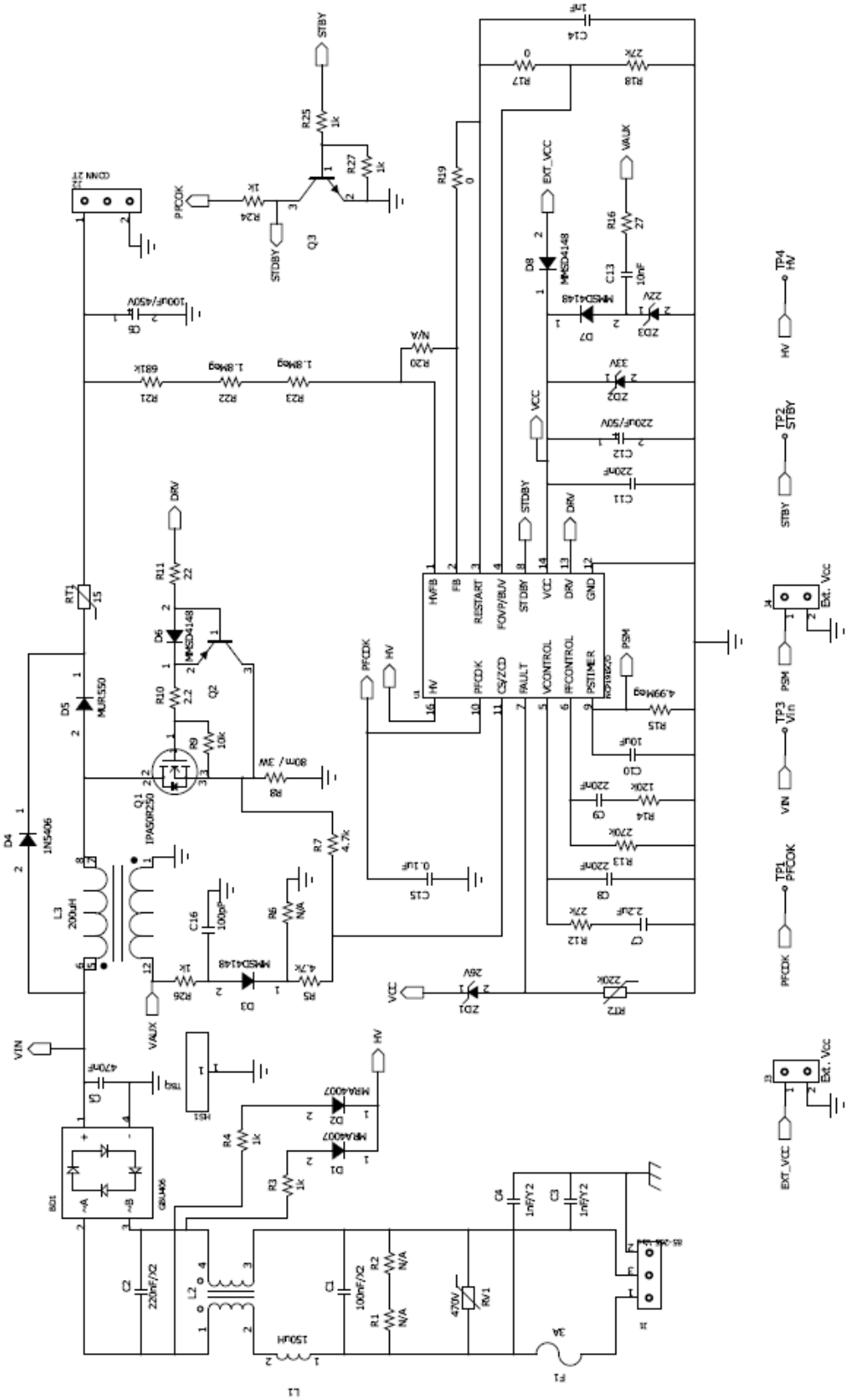
| | |
|---|---|
| D.C. RESISTANCE (@20°C): | 5-7 (5+6, 7+8), 0.27 Ohms ±10%. |
| | 1-12 , 0.90 Ohms ±10%. |
| DIELECTRIC RATING: | 800VAC, 1 minute tested by applying 1000VAC for 1 second between pins 5-1(tie 5+6). |
| INDUCTANCE: | 300.0µH ±10%, 10kHz, 100mVAC, 0mADC, 5-7(5+6,7+8), Ls. |
| SATURATION CURRENT: | 5.72A saturating current that causes 20% rolloff from initial inductance. |
| LEAKAGE INDUCTANCE: | 100.0µH 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), ±1%. |

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

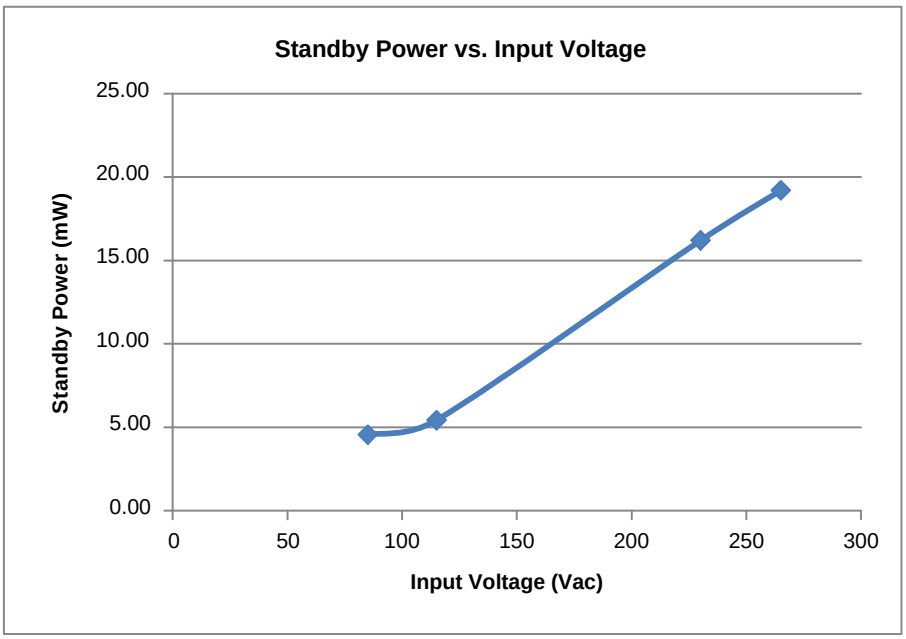
Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability. T_0_5714

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

## CIRCUIT SCHEMATIC

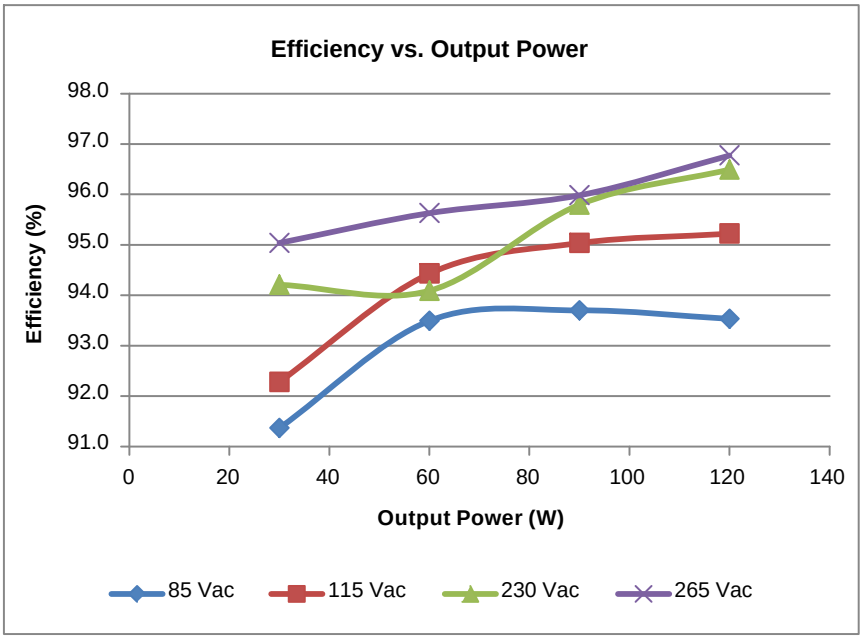


## EFFICIENCY PLOTS




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

**Figure 1. Standby Power**

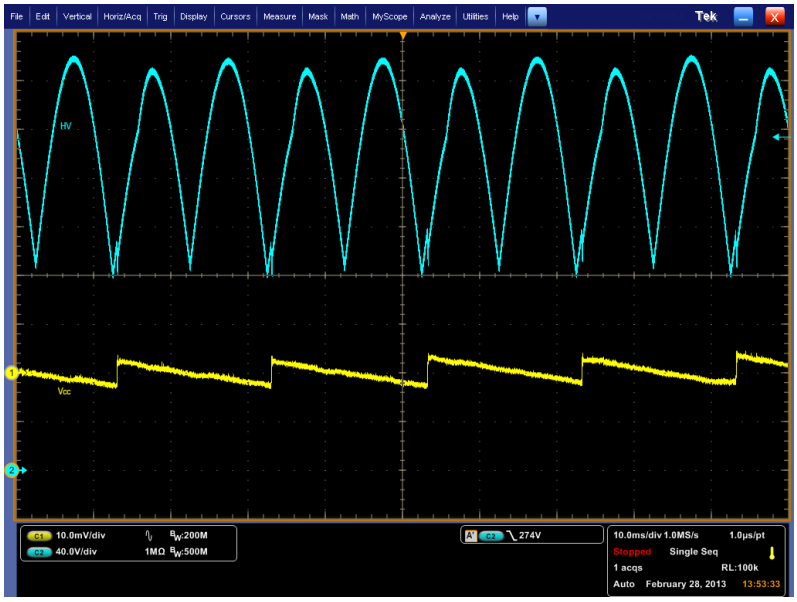



| VAC | Pin (W) | Io (mA) | Vout (V) | Po (W) | Eff (%) |
|---|---|---|---|---|---|
| 85 | 31.0 | 71.2 | 397.8 | 28.3 | 91.4 |
| 85 | 62.4 | 146.5 | 397.9 | 58.3 | 93.5 |
| 85 | 94.0 | 221.3 | 398.0 | 88.1 | 93.7 |
| 85 | 126.2 | 296.5 | 398.1 | 118.0 | 93.5 |
| 115 | 30.9 | 71.7 | 398.2 | 28.6 | 92.3 |
| 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**

## POWER SAVINGS MODE

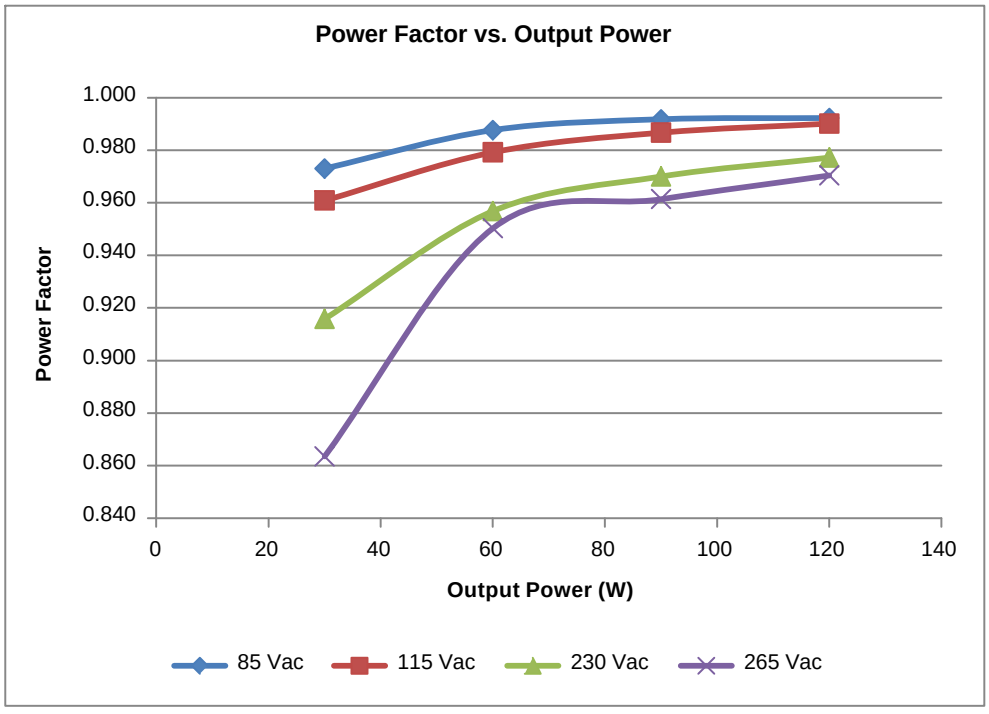



- $V_{CC}$ is regulated at $V_{CC(PS\_on)}$, typically 11 V, by turning on the HV start-up circuit at the valley of every half-cycle.
- The start-up circuit turns on at the valley of every half-cycle provided that $V_{CC}$ is below $V_{CC(PS\_on)}$.
- The start-up circuit is disabled once $V_{CC}$ exceeds $V_{CC(PS\_on)}$. 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**

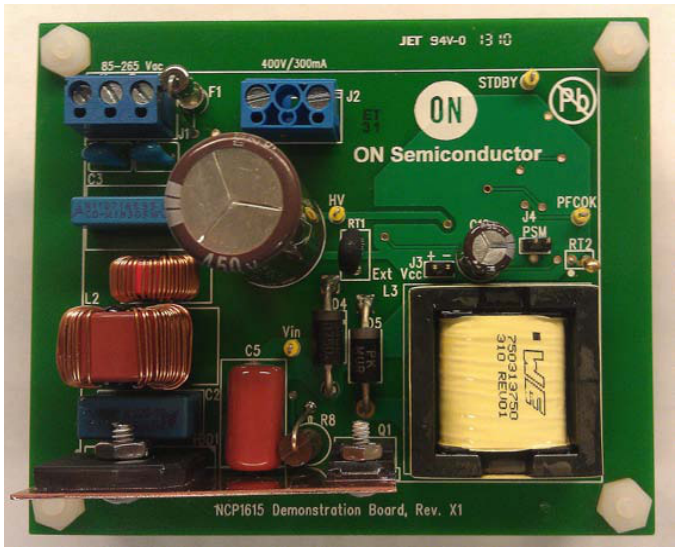
## POWER FACTOR

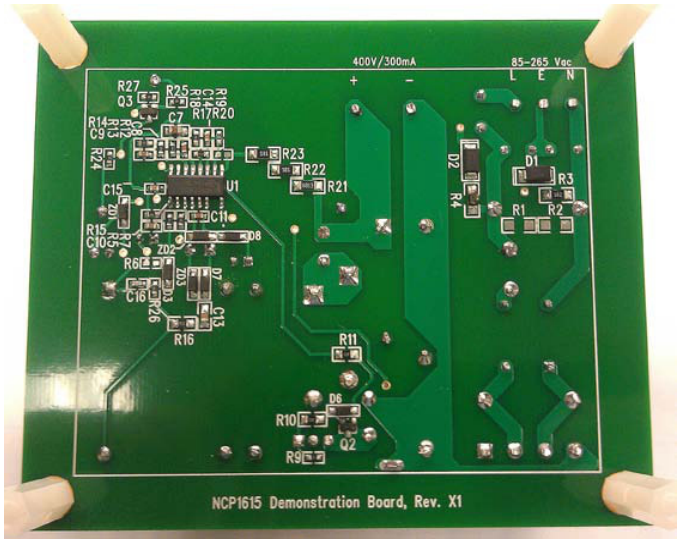


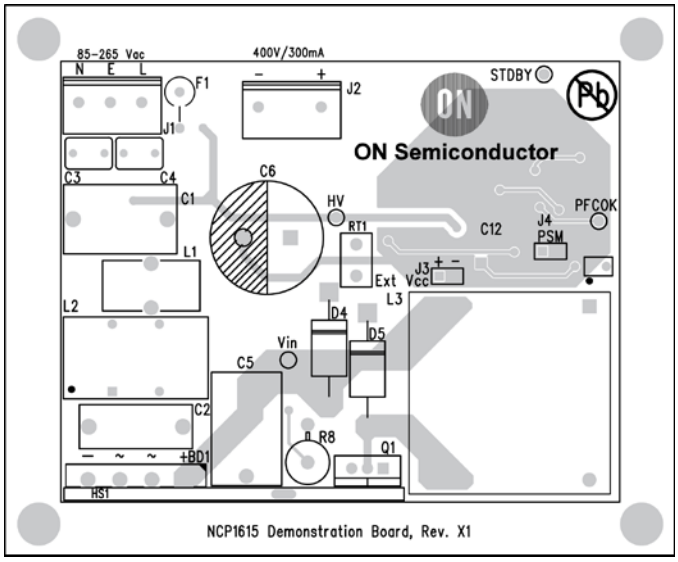

| VAC | Pin (W) | Po (W) | PF |
|---|---|---|---|
| 85 | 31.0 | 28.3 | 0.973 |
| 85 | 62.4 | 58.3 | 0.988 |
| 85 | 94.0 | 88.1 | 0.992 |
| 85 | 126.2 | 118.0 | 0.992 |
| 115 | 30.9 | 28.6 | 0.961 |
| 115 | 61.6 | 58.2 | 0.979 |
| 115 | 92.6 | 88.0 | 0.987 |
| 115 | 124.0 | 118.1 | 0.990 |
| 230 | 30.2 | 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**

## DEMO BOARD


85−265 Vac
400V/300mA
STDBY
ON Semiconductor
PFCOK
HV
Vin
Ext Vcc
NCP1615 Demonstration Board, Rev. X1


400V/300mA
85−265 Vac
NCP1615 Demonstration Board, Rev. X1


85−265 Vac
400V/300mA
STDBY
ON Semiconductor
PFCOK
HV
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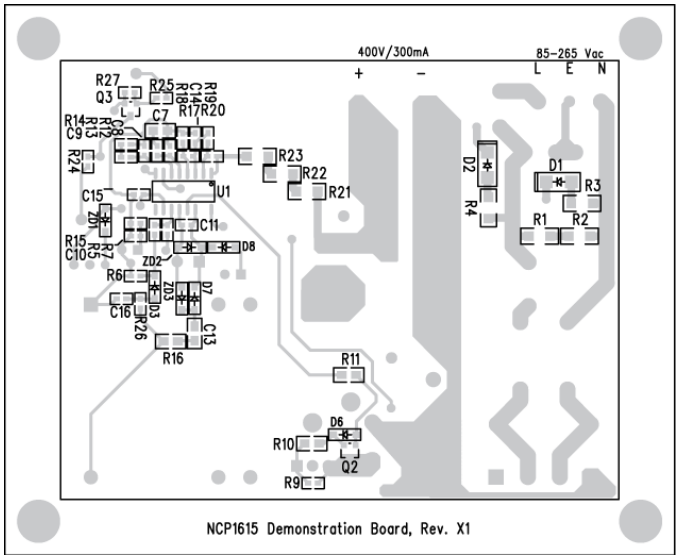
NCP1615 Demonstration Board, Rev. X1


400V/300mA
85−265 Vac
NCP1615 Demonstration Board, Rev. X1

## BILL OF MATERIALS

### Table 2. BILL OF MATERIALS

| Qty | Ref | | Component Type | Value | Rating | Pkg/Dimensions | P/N | Supplier |
|---|---|---|---|---|---|---|---|---|
| 1 | L1 | − | DM Choke | 150 μH | | 7447021_WURTH | 7447021 | WURTH |
| 1 | L2 | − | CM Choke | 8.5 mH | | IND_744823210 | 744823210 | WURTH |
| 1 | L3 | − | PFC Transformer | 300 μH | | 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 μF | 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 μF | 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 μF | 450 V | 18 x 40 mm | EKXG451ELL101MM40S | UCC |
| 1 | C12 | − | Electrolytic | 220 μF | 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 kΩ | | R0603W | CRCW060310K0FKEA | Vishay/Dale |
| 1 | R14 | SMT | Resistor | 120 kΩ | | R0603W | CRCW0603120KFKEA | Vishay/Dale |
| 4 | R24, R25, R26, R27 | SMT | Resistor | 1 kΩ | | R0603W | CRCW06031K00FKEA | Vishay/Dale |
| 1 | R13 | SMT | Resistor | 270 kΩ | | R0603W | CRCW0603270KFKEA | Vishay/Dale |
| 2 | R12, R18 | SMT | Resistor | 27 kΩ | | R0603W | CRCW060327K0FKEA | Vishay/Dale |
| 2 | R5, R7 | SMT | Resistor | 4.7 kΩ | | R0603W | CRCW06034K70FKEA | Vishay/Dale |
| 1 | R15 | SMT | Resistor | 4.99 MΩ | | R0603W | CRCW06034M99FKEA | Vishay/Dale |
| 1 | R11 | SMT | Resistor | 22 Ω | | R0805W | CRCW080522R0JNEA | Vishay/Dale |
| 1 | R16 | SMT | Resistor | 27 Ω | | R0805W | CRCW080527R0JNEA | Vishay/Dale |
| 1 | R10 | SMT | Resistor | 2.2 Ω | | R0805W | CRCW08052R20JNEA | Vishay/Dale |
| 2 | R3, R4 | SMT | Resistor | 1 kΩ | | R1206W | CRCW12061K00JNEA | Vishay/Dale |
| 2 | R22, R23 | SMT | Resistor | 1.8 MΩ | | R1206W | CRCW12061M80JNEA | Vishay/Dale |
| 1 | R21 | SMT | Resistor | 681 kΩ | | R1206W | CRCW1206681KFKEA | Vishay/Dale |
| 1 | R8 | − | Resistor | 100 mΩ | | 3 W | LOB3R100FLFLT | TT Electronics |
| 1 | RT1 | − | NTC | 10 Ω | | 5 mm | B57153S0100M000 | EPCOS |
| 1 | RT2 | − | NTC | 220 kΩ | | 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 |

**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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