# NCP1014STBUCGEVB

# Non-isolated Positive Output Buck AC/DC Converter Evaluation Board User's Manual

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## EVAL BOARD USER'S MANUAL

**Figure 1. Evaluation Board Photo**

This manual describes the way, how to easily design the simple, non isolated AC/DC converter for powering low voltage control part of mains applications with triac, or SCR power switch. Some examples are: dishwashers, microwave ovens, coffee machines, night illumination and so on. In comparison with resistive, or capacitive dropper is this solution more comfortable and features some advantages such as:

- Wide Input Voltage Range 85 VAC – 265 VAC
- Smaller Size, Lower Weight, Lower Total Cost
- Good Line and Load Regulation, No Need of Additional Linear Regulators
- Efficient Design with Up to 80% Efficiency
- Overload, Short−Circuit and Thermal Protected
- Simple for Low Cost Mass Production
- Universal Design for Wide Range of Output Currents and Voltages

The monolithic power switcher, used in this application, greatly simplifies the total design and reduces time to production. The new line of the Power Switchers, NCP1010 through NCP1014, is ideal for this purpose. This IC in the SOT−223 package reduces size and is suitable for mass production. The design consists of input filter, rectifier with filtering capacitor, power stage with switcher and inductor, output ultrafast rectifier, output filtering capacitor, feedback loop with zener diode and optocoupler and indicating LED. The only component necessary for proper powering of the IC is the $V_{CC}$ capacitor. The IC is directly powered from the HV Drain circuit via internal voltage regulator. To eliminate the noise at the feedback input, some small ceramic capacitor with value of around 1.0 nF is necessary to be connected as close to the FB pin, as possible.

**SCHEMATIC DIAGRAM**

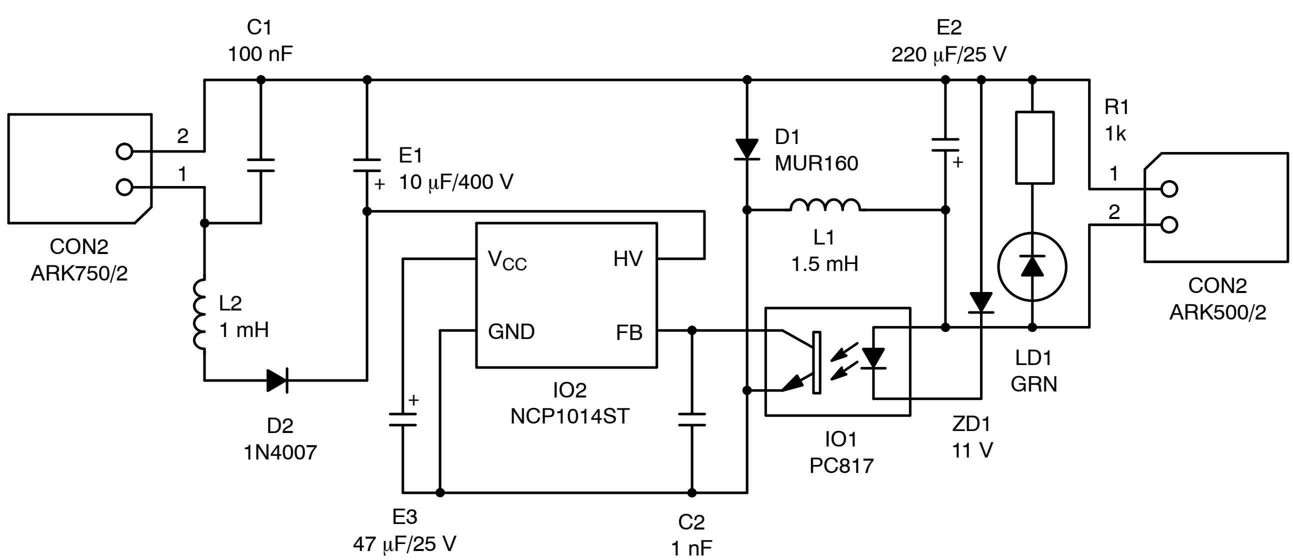


**Figure 2. Complete Schematic Diagram of the 12 V/0.2 A Converter**



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## SELECTION OF CRITICAL COMPONENTS

### Inductor selection

For the selected output power need to be selected certain minimum value of the inductance. This value is dependent on the mode of operation. Reduced value results in Discontinuous Conduction Mode of operation (DCM). Practically was found, that the borderline between Continuous Conduction Mode of operation (CCM) and DCM is commonly set slightly below maximum output power. The result is low cost of the inductor, freewheeling diode ($t_{rr}$ > 35 ns), higher efficiency and lower cost. The negative result is in lower output power and higher cost of the NCP101x Power Switcher.

The current ripple in the inductor during the $T_{on}$ time may be expressed by Equation 1.

$$\Delta I_{ripple(Ton)} = T_{on} \cdot \left( \frac{(V_{min} - V_{ds} - V_O)}{L_{min}} \right) \quad \text{(eq. 1)}$$

Where:
$T_{on}$ = ON Time, Internal Power Switch in ON,
$V_{min}$ = Minimum Rectified Input Voltage,
$V_{ds}$ = Drain−to−Source Voltage Drop,
$V_o$ = Output Voltage,
$L_{min}$ = Minimum Inductor Value.

The current ripple in the inductor during the $T_{off}$ time may be expressed by Equation 2.

$$\Delta I_{ripple(Toff)} = T_{off} \cdot \left( \frac{V_O}{L_{min}} \right) \quad \text{(eq. 2)}$$

$T_{off}$ = OFF Time, Internal Power Switch in OFF.

The current through the inductor at the beginning of the $T_{on}$ time is shown by Equation 3.

$$I_{init} = I_{set} - \Delta I_{ripple} \quad \text{(eq. 3)}$$

$I_{set}$ = Peak Switching Current Set by the FB Loop.

The average current through the inductor over one switching cycle can be expressed by Equation 4.

$$I_C = f_{op\_min} \cdot \left( \left( \frac{\Delta I_{ripple}}{2 + I_{init}} \right) \cdot T_{on} + \left( \frac{\Delta I_{ripple}}{2 + I_{init}} \right) \cdot T_{off} \right) \quad \text{(eq. 4)}$$

$I_c$ = Inductor Operating Current,
$f_{op\_min}$ = Minimum Operating Frequency

The theoretical minimum inductor value corresponds to Equation 5.

$$L_{min} = \frac{(2 \cdot V_O \cdot I_O \cdot (V_{min} - V_{ds} - V_O))}{(\Delta I_{ripple}^2 \cdot f_{op\_min} \cdot (V_{min} - V_{ds}))} \quad \text{(eq. 5)}$$

$I_O$ = Output DC Current.

The theoretical maximum output power will be shown in Equation 6.

$$P_{out\_max} = L_{min} \cdot (I_{set}^2 - I_{init}^2) \cdot f_{op\_min} \cdot \frac{\left( \frac{(V_{min} - V_{ds})}{(V_{min} - V_{ds} - V_O)} \right)}{2} \quad \text{(eq. 6)}$$

The current ripple in the inductor during the normal operation will be shown in Equation 7.

$$\Delta I_{ripple} = \frac{((V_{min} - V_{ds} - V_O) \cdot V_O)}{((V_{min} - V_{ds}) \cdot f_{op\_min} \cdot L_{min})} \quad \text{(eq. 7)}$$

The output current will be shown in Equation 8.

$$I_O = f_{op\_min} \cdot \frac{((I_{set} + I_{init}) \cdot T_{on} + (I_{set} + I_{init}) \cdot T_{off})}{2} \quad \text{(eq. 8)}$$

**Table 1. TABLE OF PRESELECTED INDUCTORS** ($V_{min}$ = 120 V, $V_{ds}$ = 9 V, $V_O$ = 12 V, $I_{set}$ = 0.405 A, $f_{op\_min}$ = 59 kHz)

| Inductance (µH) | Coilcraft Part Number (see appendix for address) | $\Delta I_{ripple}$ (A) | Output Current (A) |
|---|---|---|---|
| 470 | RFB0810−471 | 0.39 | 0.25 |
| 680 | RFB0810−681 | 0.27 | 0.32 |
| 820 | RFB0810−821 | 0.22 | 0.34 |
| 1000 | RFB0810−102 | 0.18 | 0.36 |
| 1500 | RFB0810−152 | 0.12 | 0.40 |

NOTE: The output current is the theoretical value and need to be multiplied by the efficiency (~0.7).

**Freewheeling diode selection**

The freewheeling diode needs to be selected accordingly to the mode of operation. For the CCM operation needs to be used the ultra fast diode with $t_{rr}$ < 35 ns. For the DCM operation the standard ultra fast diode with $t_{rr}$ < 75 ns is enough.

**Table 2. TABLE OF PRESELECTED FREEWHEELING DIODES**

| Part number | $V_{RRM}$ (V) | $I_{F(AV)}$ (A) | $t_{rr}$ (ns) | Package |
|---|---|---|---|---|
| MUR160 | 600 | 1.0 | 75 | Axial Lead |
| MURA160T3 | 600 | 1.0 | 75 | SMD SMA |
| MURS160T3 | 600 | 1.0 | 75 | SMD SMB |
| MURS260T3 | 600 | 2.0 | 75 | SMD SMB |

**Electrical Specification of the example at Figure 2:**
Input: 85 VAC – 265 VAC
Output: + 12 V / 200 mA

NOTE: The polarity is proportional to common line.

## COMPONENT LAYOUT

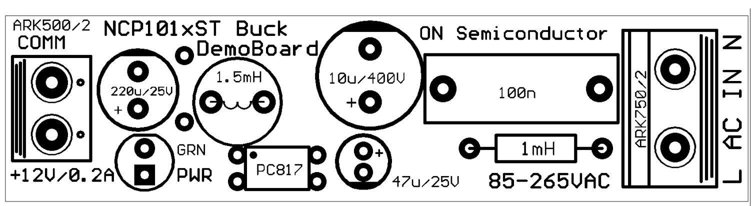


**Figure 3. Component Layout – Top Side**

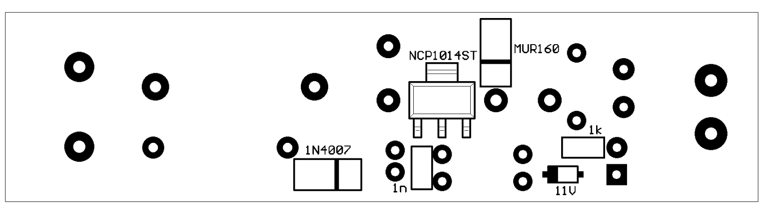


**Figure 4. Component Layout – Bottom Side**

## PCB LAYOUT

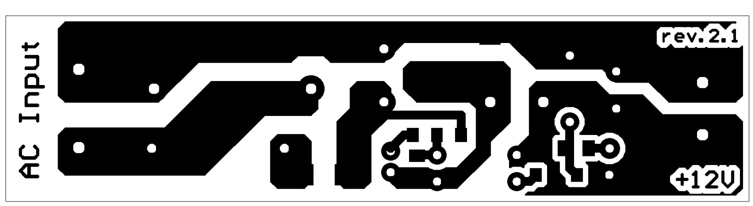


**Figure 5. PCB Layout**

## EMI TEST RESULTS

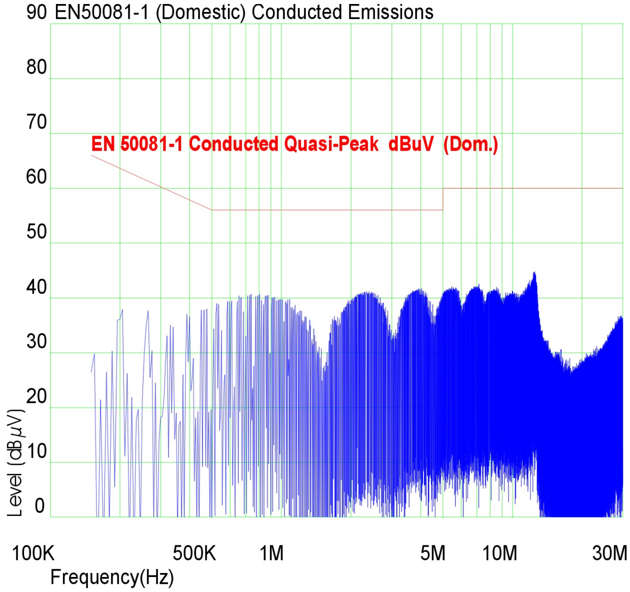


**Figure 6. Conducted EMI**

**Test Conditions:**
Input: 230 VAC
Output: 11.7 VDC
Load: Resistive 68 R

## TEST PROCEDURE

**Necessary Equipment:**

- 1 Current limited 90 – 265 Vrms AC source (current limited to avoid board destruction in case of a defective part) or a 380 VDC source (e.g. AGILENT 681x)
- 1 AC Volt-Meter able to measure up to 300 V AC (e.g. KEITHLEY 2000)
- 1 AC Amp-Meter able to measure up to 1 A AC (e.g. KEITHLEY 2000)
- 1 DC Volt-Meter able to measure up to 20 V DC (e.g. KEITHLEY 2000)
- 1 DC Amp-Meter able to measure up to 500 mA DC (e.g. KEITHLEY 2000)
- 1 DC Electronic Load (e.g. AGILENT 6060B)

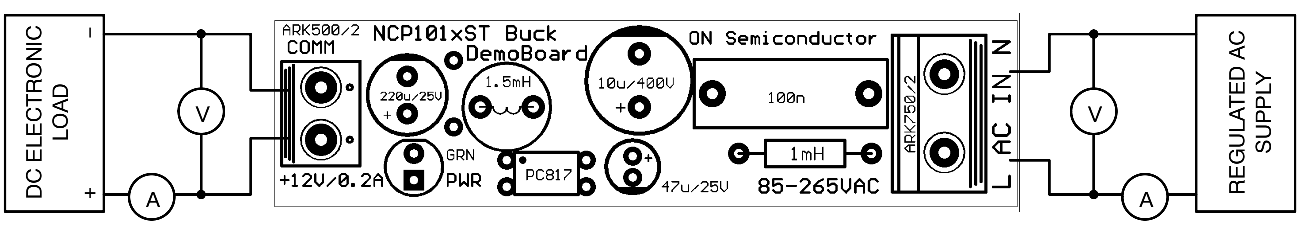


**Figure 7. Test Setup**

**Test Procedure**

- Connect the test setup as shown in Figure 7.
- Apply an input voltage, Uin = 90 – 265 Vac
- Apply Iout(load) = 0 A
- Check that Uout is 12 Vdc
- Increase Iout(load) load to: 12 V / 200 mA
- Check that Uout is 12 V
- Power down the load
- Power down Uin
- End of test

NOTE: Be careful when manipulating the boards in operation, lethal voltages up to 265 Vac are present on the primary side.

## BILL OF MATERIAL

**Table 3. NCP1014STBUCGEVB EVALUATION BOARD BILL OF MATERIALS**

| Designator | QTY | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed | RoHS Compliant |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | Capacitor X2 | 100 nF | ±10% | Through Hole | Vishay | F1772−410−2030 | Yes | Yes |
| C2 | 1 | CMS Capacitor | 1 nF | ±10% | 1206 | AVX | 12065C102KAT2A | Yes | Yes |
| CON1 | 1 | Input Terminal Block | LP7.5/2/903.2 OR | – | LP7.5/2 | WeidMuller | LP7.5/2/903.2 OR | Yes | Yes |
| CON2 | 1 | Output Terminal Block | PM5.08/2/90 | – | PM5.08/2 | WeidMuller | PM5.08/2/90 | Yes | Yes |
| D1 | 1 | Ultrafast Power Rectifier | MURA160 | – | SMA | ON Semiconductor | MURA160T3G | No | Yes |
| D2 | 1 | 1 A, 1000 V Standard Rectifier | 1N4007 | – | Axial Lead | ON Semiconductor | 1N4007RLG | No | Yes |
| E1 | 1 | Electrolytic Capacitor | 10 uF / 400 V | ±20% | Through Hole | Panasonic | ECA2GHG100 | Yes | Yes |
| E2 | 1 | Electrolytic Capacitor | 220 uF / 25 V | ±20% | Through Hole | Panasonic | ECA1EHG221 | Yes | Yes |
| E3 | 1 | Electrolytic Capacitor | 47 uF / 25 V | ±20% | Through Hole | Rubycon | 25ML47M6.3X5 | Yes | Yes |
| IO1 | 1 | Opto−Coupler | PC817 | – | DIL−4 | Sharp | PC817X1J000F | Yes | Yes |
| IO2 | 1 | Monolithic Power Switcher | NCP1014 | – | SOT−223 | ON Semiconductor | NCP1014ST65T3G | No | Yes |
| L1 | 1 | Inductor | 1.5 mH | ±10% | RFB0810 | Coil Craft | RFB0810−152 | Yes | Yes |
| L2 | 1 | Inductor | 1 mH / 1.6 A | ±10% | Through Hole | Fastron | SMCC−R10X−YY | Yes | Yes |
| LD1 | 1 | LED | Green LED 5 mm | – | Through Hole | Avago | HLMP−HM57−SV000 | Yes | Yes |
| R1 | 1 | CMS Resistor | 1 kΩ | ±1% | 1206 | Vishay | RCA12061K00FKEA | Yes | Yes |
| ZD1 | 1 | Zener Diode | 11 V | ±5% | SOD−123 | ON Semiconductor | MMSZ11T1G | No | Yes |

## ADDITIONAL INFORMATION

**TECHNICAL PUBLICATIONS**:
**Technical Library:** www.onsemi.com/design/resources/technical−documentation
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