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AND8190/D

Non-isolated Negative Output Buck AC/DC Converter

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APPLICATION NOTE

This application note describes how to easily design a simple, non−isolated AC/DC converter for powering the low voltage control portion of line−powered applications that use a triac or SCR power switch. Examples of such applications include dishwashers, microwave ovens, coffee machines, illumination, etc. Compared to passive solutions using resistors or capacitors to reduce the voltage, this design has significant advantages such as:

- Wide input voltage range 85 – 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 protection
- Convenient for mass production due to SMD devices
- 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. ON Semiconductor's NCP1010 – 1014 family, a new line of Power Switchers, is ideal for this purpose. The NCP101x is offered in a SOT−223 package for reduced size, and is suitable for mass production.

The design consists of the input filter, rectifier with filtering capacitor, the power stage with switcher and inductor, output ultrafast rectifier, output filtering capacitor, the feedback loop with Zener diode and optocoupler, and an indicator LED. The only component necessary for proper powering of the IC is the V_{CC} capacitor, since the IC is directly powered from the HV Drain circuit via an internal voltage regulator. To eliminate noise at the feedback input, a small ceramic capacitor of around 1 nF should be connected as close to the FB pin as possible.

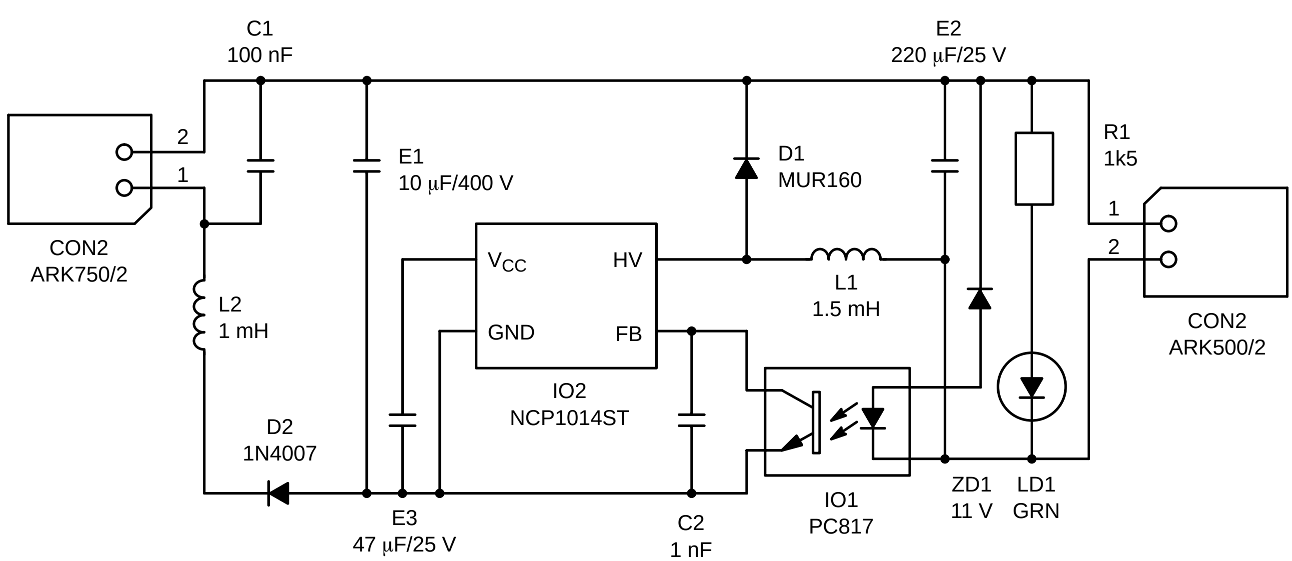

Figure 1. Complete Schematic Diagram of the 12 V/0.2 A Converter

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SELECTION OF CRITICAL COMPONENTS

Inductor Selection

The desired output power determines the minimum value of the inductance. This value is dependent on the mode of operation. A reduced inductor value results in Discontinuous Conduction Mode of operation (DCM). In practice, the switch−over point between Continuous Conduction Mode of operation (CCM) and DCM is commonly set to be slightly below maximum output power. This achieves a reasonable compromise between inductor size and ripple current, efficiency, and overall lower cost. The only significant negative aspect of this particular operating mode is a higher peak−to−average current ratio in the inverter circuit.

The current ripple in the inductor during the T_{on} time may be expressed by the equation

$$\Delta I_{ripple}(T_{on}) = T_{on} \cdot \left(\frac{(V_{min} - V_{ds} - V_o)}{L_{min}}\right)$$

T_{on} = ON time, internal power switch is 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 the equation

$$\Delta I_{ripple}(T_{off}) = T_{off} \cdot \left(\frac{V_o}{L_{min}}\right)$$

T_{off} = OFF time, internal power switch is off.

The current through the inductor at the beginning of the T_{on} time is

$$I_{init} = I_{set} - \Delta I_{ripple}$$

I_{set} = Peak switching current set by the FB loop.

The average current through the inductor over one switching cycle can be expressed by the equation

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

I_c = Inductor operating current

f_{op_min} = Minimum operating frequency.

The theoretical minimum inductor value is given by the expression

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

I_o = Output DC current.

The theoretical maximum output power will be

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

The current ripple in the inductor during the normal operation will be

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

The output current will be

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

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)	**ΔI_{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

The output current is the theoretical value and must be multiplied by the efficiency (~ 0.7).

Freewheeling Diode Selection

The freewheeling diode needs to be selected according to the mode of operation. For CCM operation an ultra−fast diode with reverse recovery time t_{rr} < 35 ns must be used. For the DCM operation a standard ultra−fast diode with t_{rr} < 75 ns is adequate.

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 in Figure 1:

Input: 85 – 265 VAC

Output: + 12 V / 200 mA

Note: The polarity is relative to the common line.

COMPONENT LAYOUT

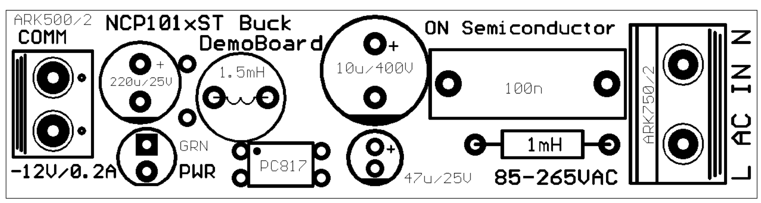

Figure 2. Component Layout – Top Side

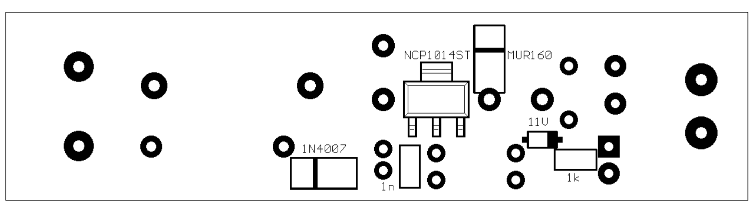

Figure 3. Component Layout – Bottom Side

PCB LAYOUT

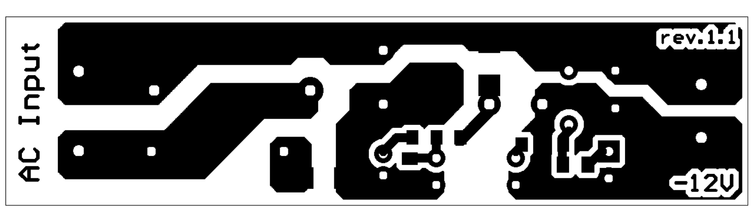

Figure 4. PCB Layout

EMI Test Results:

Test Conditions:

Input: 230 VAC

Output: 11.7 VDC

Load: Resistive 68 R

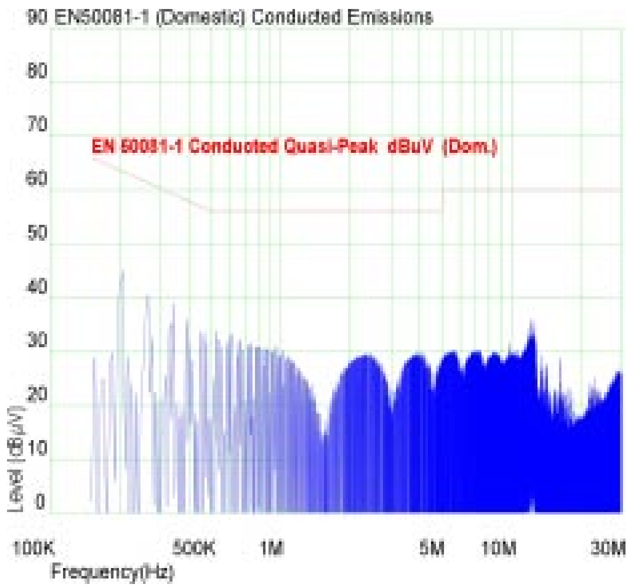

Figure 5. Conducted EMI

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