ON Semiconductor

Design Note – DN05053/D

NCP1129, 12 Watt, Off-line Buck Regulator

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1129 MBRS3200	Smart Meters Electric Meters, White Goods	85 to 265 Vac	12W at 12Vout	Off-Line 65 kHz Buck	Non-isolated

	Output Specification
Output Voltage	12 to 28 Vdc depending on selected Z1 zener value
Output Ripple	Less than 1%
Typical Current	250 mA to 1 amp
Max Current	1 amp maximum (12 Vout)
Min Current	zero

PFC (Yes/No)	No, Pout < 25 watts
Efficiency	Dependent on Freewheel diode selection
Inrush Limiting / Fuse	Fused input
Operating Temp. Range	0 to +50°C (dependent on U1 heatsinking)
Cooling Method / Supply Orientation	Convection
Signal Level Control	None

Circuit Description

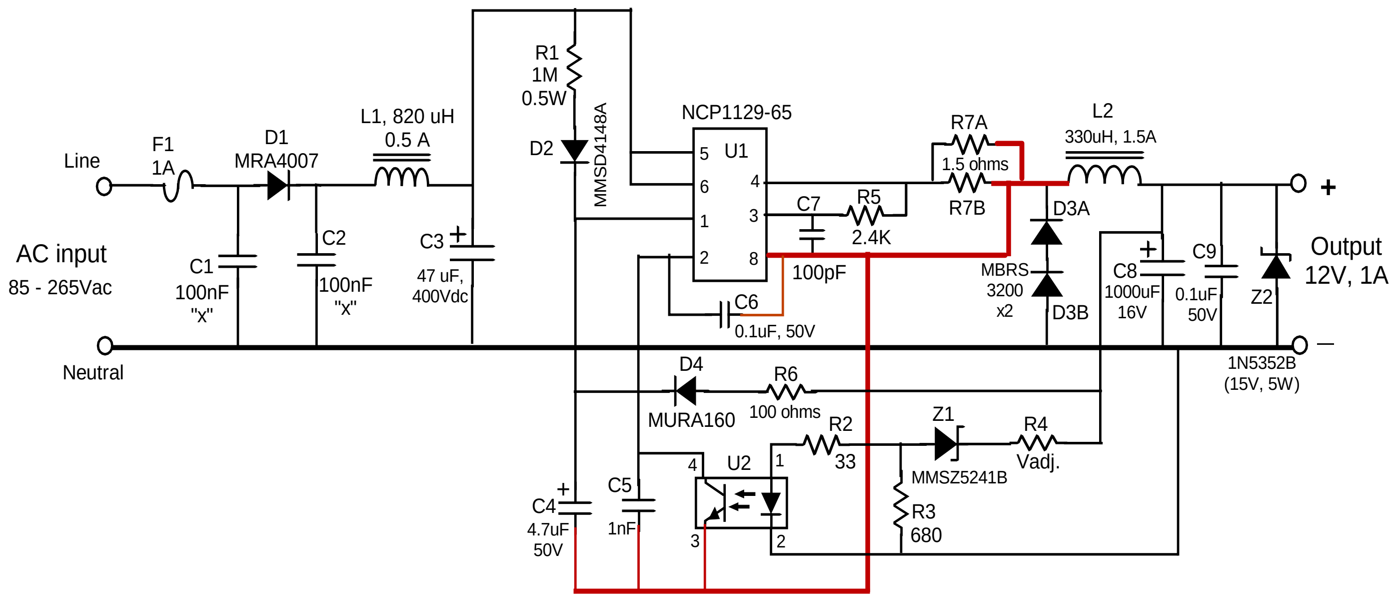
This design note describes a simple, low power (15 W or less), constant voltage buck power supply intended for powering electronics for white goods, electrical meters, and industrial equipment where isolation from the AC mains is not required. The efficiency limitations of the off-line buck converter are also discussed with emphasis on switching losses caused by the freewheel diode recovery characteristics. The output voltage can be set from 12 to approximately 28 volts (or higher) by using the appropriate zener diode for Z1 and selection of trim resistor R4. The new ON Semiconductor NCP1129 co-packaged controller/Mosfet in a DIP 8 package is utilized as the buck switching element. Output regulation is accomplished by utilizing a simple zener/optocoupler sensing scheme. The optocoupler is necessary because the control logic is at a switching node common to the freewheel diode (D3) cathode. This was done along with half-wave input line rectification to allow a common connection from the input line neutral to the negative output terminal.

The main problem associated with off-line buck converters is the efficiency associated with the combination of low duty cycle (Vout less than 50V) and the power Mosfet and freewheel diode turn-on switching loss. ON Semiconductor application note AND8318 discusses one solution for both of these issues by using a tapped buck inductor. This solution, however, typically requires a non-standard inductor which may not be an “off-the-shelf” component.

At initial Mosfet turn-on, the freewheel diode recovery characteristics causes a significant leading edge spike of current to flow through both devices that can easily exceed 3 to 5 times the normal peak load current of the devices. This is particularly acute at high input line (230 Vac) if a fast recovery type of diode is used where the reverse recovery characteristics are slower with increased diode PRV voltage rating. Conventional high voltage Schottky diodes (typically several in series) and silicon carbide (SiC) diodes will greatly reduce the turn-on switching loss but there will still be a leading edge current spike associated with the devices’ junction capacitance. The table and waveforms shown below compare the representative efficiencies and switching characteristics when using the three diode types. The SiC diode definitely exhibited the best performance, but the present day cost of this part may be prohibitive for the intended application, and a pair of (or 3) series standard Schottky rectifiers are probably the best compromise. Tests have shown that the use of a typical ultra-fast recovery rectifier for D3 may prohibit continuous output currents much greater than about 500 mA due to excessive heating of the Mosfet and/or the freewheel diode itself. Obviously good pc board layout with liberal copper clad for heatsinking will certainly help the thermal issues.

Protection features in the NCP1129 include peak overcurrent limiting which can be set by proper selection of current sense resistor R7, and the Vcc pin will latch the chip off if the Vcc exceeds 27 volts, allowing for overvoltage detection. Over-temperature protection at 150C (internal) is also included.

Schematic



Notes:

1. Vout set by Z1 (Vout = Vz + 1V approx).
2. L1 is Wurth 7447728215; L2 is Wurth 7447709331.
3. Thick lines indicate recommended ground plane area.
4. U1 should use clad heatsinking around pins 5 and 6.
5. D3A/B should have large pad areas for heatsinking.
6. Z2 is optional output OVP zener.
7. Crossed schematic lines are not connected.
8. U2 is NEC PS2561L-1 optocoupler or similar (CTR > 0.5)
9. R4 will adjust Vout upwards only.
10. Red ground plane area should be minimized to lower capacitance (switched node).
11. Clad pour recommended around U1 pins 5 and 6 for heatsinking.

Off-Line Buck Converter Using NCP1129
With Optocoupler Voltage Sensing (Rev 1A)

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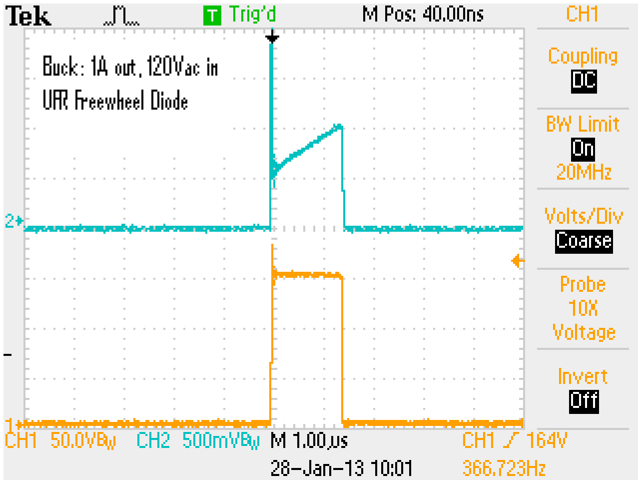
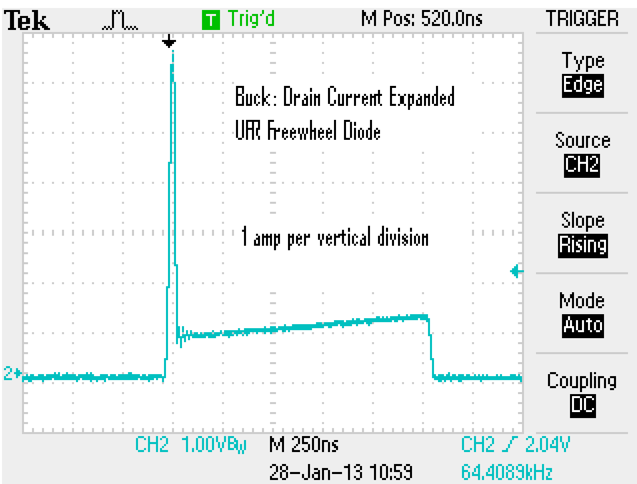
Mosfet Source Voltage (yellow) and Current (blue)

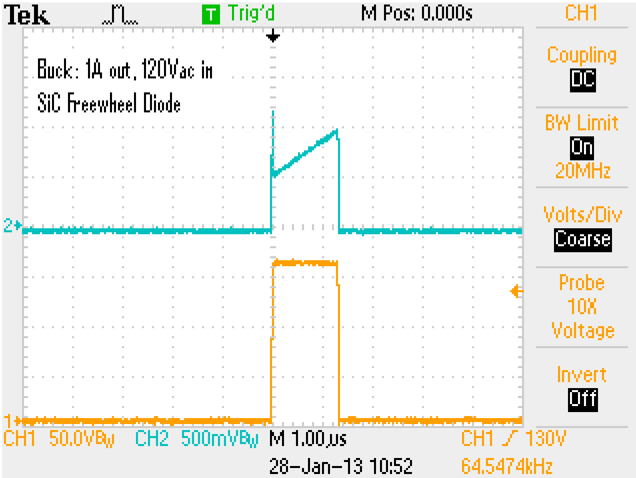
12V, 1A output, 120 Vac input with ultra-fast recovery freewheel diode.



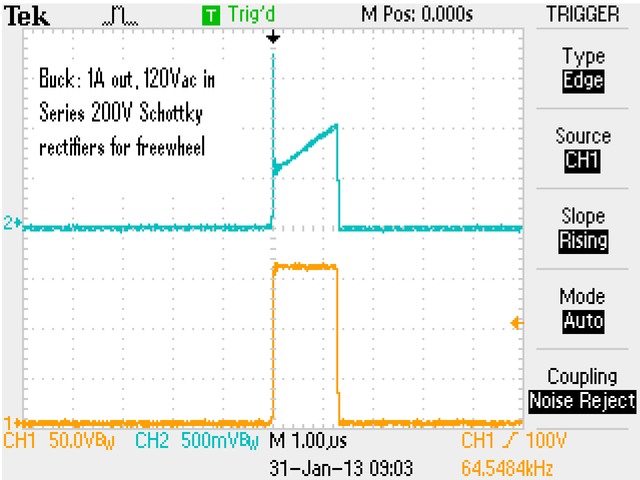
Expanded drain current waveform showing current spike magnitude.



Waveforms with 1.5A, 600V SiC freewheel diode.



Waveforms with pair of 3A, 200V MBRS3200 Schottky freewheel diodes in series.



Freewheel Diode Efficiency Comparisons

Freewheel Device	Efficiency (12V/1A output; 120Vac input)
3A/600V Ultra-fast	76% (unable to run at 230Vac without eventual thermal shutdown)
1.5A/600V SiC diode	83% (operation at full load at 230Vac without thermal issues)
3A/200V Schottky x 2 (MBRS3200 in series)	81.5% (operation at full load at 230Vac with acceptable thermals)

Summary

The NCP1129 co-packaged controller/Mosfet in a DIP 8 package can be used to design a simple, yet effective off-line buck converter for applications that don't require input to output isolation. Care must be taken, however, in the selection of the freewheel diode due to its reverse recovery characteristics and the overall impact on conversion efficiency. Utilizing the buck controller at the high-side switching node in conjunction with optocoupler feedback provides the most effective, low noise technique for sensing and regulating the output voltage.

References:

ON Semiconductor Application Notes: AND8318, AND8328
ON Semiconductor Design Notes: DN05014, DN06011, DN06052
ON Semiconductor NCP1129/1126 Data Sheet