ON Semiconductor

Design Note – DN06052/D

5 V, 400 mA Current Boosted Buck Converter

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1014	Off-line, 2 W, 5 V power source	90 to 270 Vac	2 W	Buck	None

Other Specification

	Output
Output Voltage	5.2 Vdc
Ripple	100 mV p/p
Nominal Current	400 mA
Max Current	450 mA
Min Current	Zero

PFC (Yes/No)	No
Minimum Efficiency	65%
Inrush Limiting / Fuse	Yes
Operating Temp. Range	0 to +70°C
Cooling Method / Supply Orientation	convection
Signal Level Control	None

Others	EMI filter for conducted emissions compliance

Circuit Description

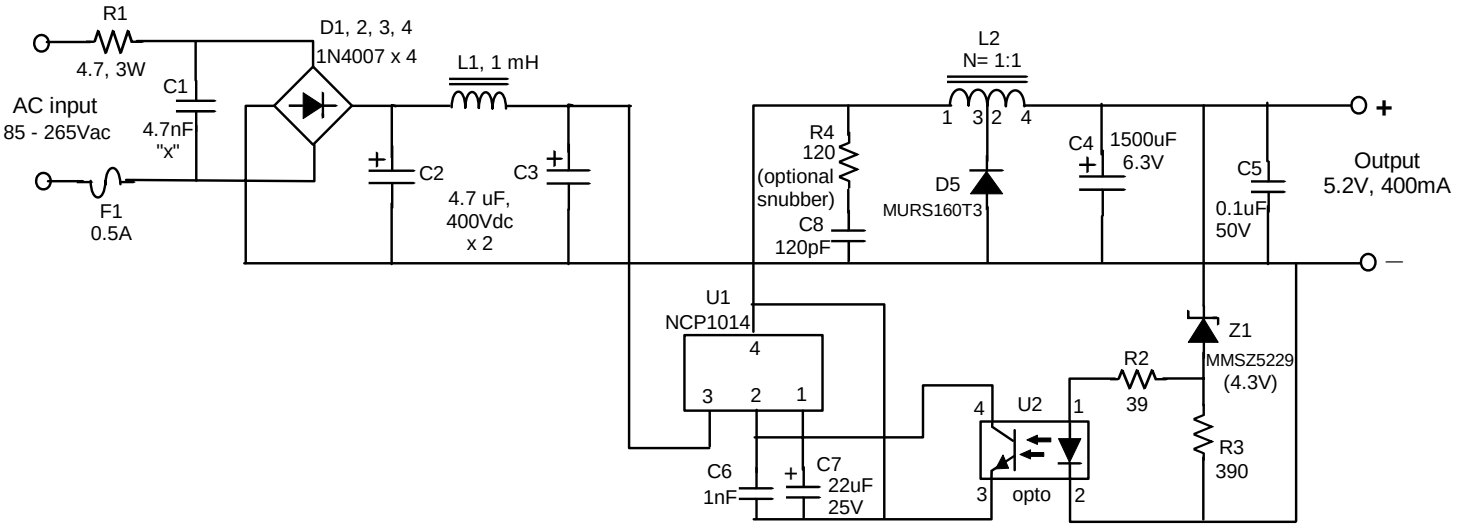
For low power applications where line isolation is not required, the buck converter provides a very simple yet effective approach to providing a regulated output voltage. An issue does arise, however, when the ratio of the input to output voltage gets very high as would be the case with 5 V out. For 120 Vac in, the dc bulk will be about 165 V. This results in a 33:1 voltage conversion ratio. Since the duty cycle of the buck is defined by D=Vout/Vin, this results in D=0.03 or 3%. At a switching frequency of 100 kHz, this translates to a nominal on-time for the power switch of 300 ns which is approaching the inherent signal propagation delay of the NCP1014 monolithic controller. Another problem with this very small on-time is the fact that a large output choke inductance is required to keep the converter operating in continuous conduction mode with minimal magnetizing current. The magnetizing current severely intrudes on the overall peak current capability of the NCP1014. A technique to overcome the extreme conversion ratio is to use a tapped inductor and connect the freewheeling diode (D5) toward the output end of the buck inductor. This technique not only increases the switch on-time but effectively creates an output current boosting effect which is beneficial in that it lowers the peak current in the switch. The more the tap moves toward the output end of the choke, the greater the current boosting effect and the better the overall conversion efficiency will be due to the expanded duty cycle. The increased current is gained via duty cycle expansion rather than increased peak switch current. The full technical details and limitations of this tapped buck inductor circuit technique are presented in ON Semiconductor's application note AND8318 and another example for LED applications is presented in the application note AND8328. It is also recommended that the NCP1014 monolithic switcher data sheet be reviewed.

The 5 volt example presented in this design note can be constructed with off-the-shelf components. By utilizing a custom made inductor for L2 with a winding ratio of 3:1, the output current can be boosted to almost one ampere.

Key Features

- Regulated 5 Vout, 2 watt off-line power supply
- Current boosted output using tapped buck inductor
- Input EMI filter for agency emissions compliance
- Inherent over-current and over-temperature protection with NCP1014
- Measured efficiency of 65% at 115 Vac and 63% at 230 Vac. Exceeds Energy Star 2.0 efficiency criteria for External Power Supplies.

Schematic



Notes:

1. L1 is Coilcraft RFB0807-102L or equivalent (1 mH, 250 mA) for EMI reduction.
2. L2 is Coilcraft MSD1278-274KL (270 uH)
3. U2 is Vishay H11A817A or similar opto.
4. U1 is 100 kHz version of NCP1014 in SOT-223 package.
5. R1 should be wire wound due to increased joule rating w.r.t. inrush current.
6. Crossed lines on schematic are not connected.
7. C4 should be a low-Z electrolytic cap.
8. Vout = Vz1 + 0.9V (approx)
9. R4 / C8 snubber not required for 120 Vac input only.

5 V, 400 mA Off-line Buck with Tapped Choke

Caution: The output of this converter is not isolated from the AC mains so a lethal shock hazard is present if the output load is not isolated from physical contact.

Bibliography and References

- Application note AND8318: Offline Buck Converter with Tapped Inductor Improves Performance
- Application note AND8328: 700 mA LED Power Supply Using Monolithic Controller and Off-Line Current Boosted (Tapped Inductor) Buck Converter
- Data sheet NCP1014: Self-Supply Monolithic Switcher for Low Standby-Power Offline SMPS

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