ON Semiconductor

Design Note – DN06045/D

Triple, Low Voltage Output, Off-Line Power Supply

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1014, NCP3120	Appliances & Consumer Electronics	90 to 265 Vac	10 Watts Peak	DCM Flyback	Yes – 3 kV

Other Specification

	Output 1	Output 2	Output 3	Output 4
Output Voltage	5.0 Volts	3.3 Volts	1.8 Volts	N/A
Ripple	50 mV	50 mV	50 mV	N/A
Nominal Current	User dependent	User dependent	User dependent	N/A
Max Current	1.5 A	2 A	2 A	N/A
Min Current	Zero	Zero	Zero	N/A

PFC (Yes/No)	No
Minimum Efficiency	70% (load combination dependent)
Inrush Limiting / Fuse	Yes
Operating Temp. Range	0 to +50°C
Cooling Method / Supply Orientation	Convection
Signal Level Control	Yes, outputs on/off, output sequencing

Circuit Description

This Design Note presents an off-line, triple, low voltage output power supply intended for appliance and/or consumer electronic products that require a maximum power of 10 watts or less such as set-top boxes, modems, and similar. The efficiency is characterized below for a nominal output of 6 watts for several different load configurations. The design is intended to meet the latest Energy Star efficiency requirements for the typical steady state loads represented in the tests. The selected output voltages can easily be tailored to suit most applications but are considered representative of typical low voltage requirements for most microprocessors and their associated interface circuitry.

The power supply is configured around a discontinuous mode (DCM) flyback converter utilizing the NCP1014 monolithic switching controller/Mosfet (U1). Synchronous rectification is used on the primary 5 volt output and the NCP3120 dual, monolithic buck converter (U3) is used for the 3.3 and 1.8 volt outputs with the input power derived from the 5 volt rail. It should be noted that DCM flyback transformer operation is necessary over the entire load range to allow proper operation of the 5 V synchronous rectifier circuit associated with Q3.

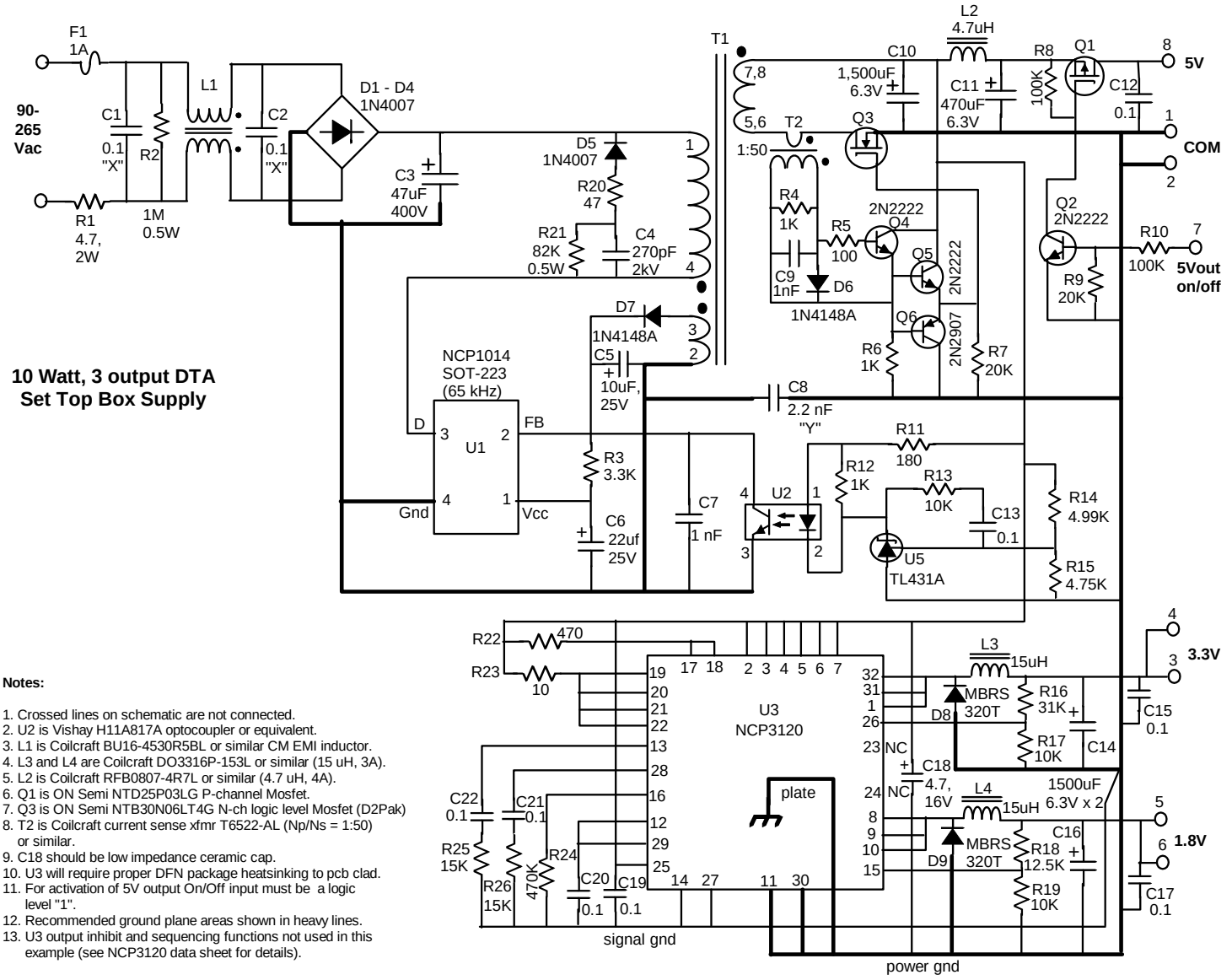
Output regulation is accomplished for the 5 V output using the conventional TL431 and optocoupler feedback scheme. Current limiting for the 5 V output is accomplished via peak primary current detection in U1 while current limiting and regulation functions for the 3.3 V and 1.8 V outputs are handled by the internal circuitry of U3.

An on/off function for the 5 V output is provided by Q2 and can be provided for the other outputs via control pins on U3 even though it is not implemented in this design example. Startup and shutdown output sequencing are also available with the NCP3120.

Key Features

- Conducted EMI filter for ac input.
- Transformer aux bias supply for low standby power.
- On/off control and start/stop sequencing available on all outputs.
- Energy Star compliant for most typical load configurations.
- Very inexpensive yet efficient dual buck regulator for 1.8 and 3.3 V outputs.
- Synchronous rectifier for main 5 V output.

Schematic



Notes:

1. Crossed lines on schematic are not connected.
2. U2 is Vishay H11A817A optocoupler or equivalent.
3. L1 is Coilcraft BU16-4530R5BL or similar CM EMI inductor.
4. L3 and L4 are Coilcraft DO3316P-153L or similar (15 uH, 3A).
5. L2 is Coilcraft RFB0807-4R7L or similar (4.7 uH, 4A).
6. Q1 is ON Semi NTD25P03LG P-channel Mosfet.
7. Q3 is ON Semi NTB30N06LT4G N-ch logic level Mosfet (D2Pak)
8. T2 is Coilcraft current sense xfmr T6522-AL (Np/Ns = 1:50) or similar.
9. C18 should be low impedance ceramic cap.
10. U3 will require proper DFN package heatsinking to pcb clad.
11. For activation of 5V output On/Off input must be a logic level "1".
12. Recommended ground plane areas shown in heavy lines.
13. U3 output inhibit and sequencing functions not used in this example (see NCP3120 data sheet for details).

Additional collateral from ON Semiconductor

- Data sheet NCP1014: Self-Supply Monolithic Switcher for Low Standby-Power Offline SMPS
- Data sheet NCP3120: Dual 2.0 A Switching Regulator (200-750 kHz)
- Design Note DN06003: NCP1014, 8 W, 3-Output Off-Line Switcher
- Design Note DN06005: NCP1014, 10 W, 3-Output Off-line Power Supply
- Design Note DN06020: NCP1014, 10W, Dual Output Power Supply
- Design Note DN06034: NCP1014, Universal Input, +/- 12 V Output, 8 Watt Power Supply
- Reference Design TND332: 8 W DTA Power Supply GreenPoint™ Reference Design
- Reference Design TND329: 5 W CCCV AC-DC Adapter GreenPoint™ Reference Design

Test Results

Efficiency versus Output Loading Configuration (Total load = 6 Watts approximately):

Configuration	5V out	3.3 Vout	1.8 Vout	Eff. @ 120 Vac	Eff. @230 Vac
1	0.25 A	0.35 A	2 A	65%	64%
2	0.5 A	0.5 A	1 A	76%	75%
3	0.3 A	1 A	0.75 A	72%	71%
4	1 A	0.15 A	0.3 A	78%	77%

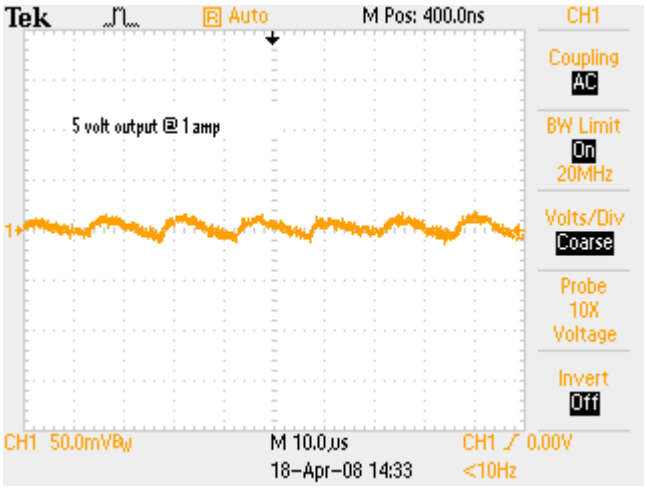
ENERGY STAR minimum efficiency requirement for 6 W output = 70.4% (satisfied by Configuration 2, 3, 4)

Standby (no load) power consumption: @ 120 Vac input: 90 mW
@ 230 Vac input: 240 mW

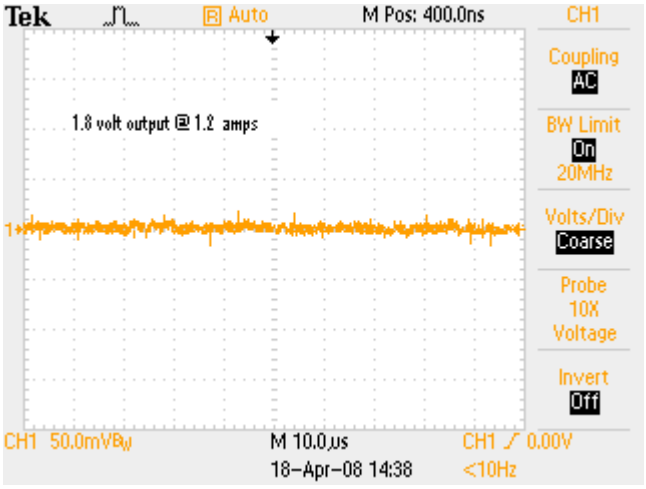
Line and load regulation: Better than 1% on all outputs.

Output Ripple Profiles: 5Vout @ 1 A and 1.8 Vout @ 1.2 A.

5 Vout @ 1 A



1.8 Vout @ 1.2 A



DN06045/D

MAGNETICS DESIGN DATA SHEET

Project / Customer: ON Semiconductor - STB power supply - 10 watts max.

Part Description: 10 watt flyback xfmr, 65 kHz/5Vout

Schematic ID: T1

Core Type: EF16 (E16/8/5); 3C90 material (Ferroxcube) or similar

Core Gap: Gap for 1.5 mH inductance

Inductance: 1.5 mH +/-10%

Bobbin Type: 8 pin horizontal mount for EF16

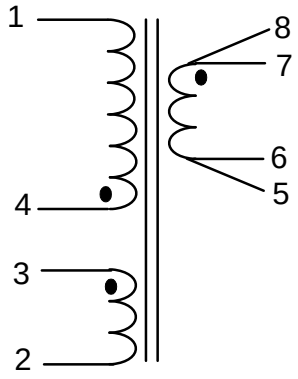
Windings (in order):

Winding # / type	Turns / Material / Gauge / Insulation Data
Vcc/Boost (3 - 2)	12 turns of #34HN spiral wound over 1 layer. Insulate with 1 layer of tape (1000V insulation to next winding)
Primary (4 - 1)	90 turns of #34HN over 2 layers (45 turns/layer); Insulate for 3 kV to the next winding with tape.
5V Secondary (7,8 - 5,6)	6 turns of 2 strands of #26HN wound bifilar over one layer with 2 mm end margins and cuffed ends. Self leads to pins as shown below. Insulate with final layer of tape.

Vacuum varnish assembly

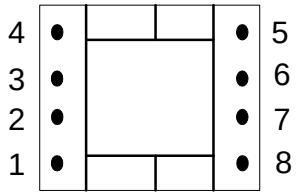
Hipot: 3 kV from boost/primary to secondary

Schematic



Lead Breakout / Pinout

(Bottom View - facing pins)



Bill of Materials

Part	Qty	ID	Description	Comments
Semiconductors				
MRA4007T3G	5	D1, 2, 3, 4, 5	1A, 800V diode	ON Semi
MMSD4148T1	2	D6, D7	100 mA signal diode	ON Semi
MBRS320T	2	D8, D9	3A, 20V Schottky diode	ON Semi
MMBT2222AWT1	3	Q2, 4, 5	500 mA, 40V NPN xstr	ON Semi
MMBT2907AWT1	1	Q6	500 mA, 40V PNP xstr	ON Semi
NCP1014ST65T3G	1	U1	Monolythic PWM controller - 65 kHz	ON Semi
NTD25P03LG	1	Q1	P-channel Mosfet, 30V	ON Semi
NTB30N06LT4G	1	Q3	N-channel Mosfet, logic level	ON Semi
NCP3120MNTXG	2	U3	Dual buck regulator	ON Semi
Optocoupler	1	U2	SFH6156A-4 (4 pin) or similar	Vishay
TL431ACD (SOIC-8)	1	U5	Programmable zener	ON Semi
Capacitors				
"X" cap, (box package)	2	C1, C2	100 nF "X2" capacitor, 270 Vac	Vishay
"Y" cap, disc package	1	C8	2.2 nF "Y2" cap, 270 Vac	Vishay
Ceramic cap, disc	1	C4	270 pF, 2 kV capacitor (snubber)	Vishay
Ceramic cap, monolythic	8	C12, 13, 15, 17,	0.1 uF, 50V ceramic cap	Vishay
		19, 20, 21, 22		
Ceramic cap, monolythic	2	C14, C16	2.2 uF, 16V low impedance ceramic	Vishay
Ceramic cap, monolythic	1	C18	4.7 uF, 16V, multilayer	Vishay
Ceramic cap, monolythic	2	C7, C9	1 nF, 50V ceramic cap	Vishay
Electrolytic cap	1	C11	470 uF, 6.3V	UCC, Rubycon
Electrolytic cap	1	C3	47 uF, 400Vdc	UCC, Rubycon
Electrolytic cap	3	C10, C14, 16	1500 uF, 6.3 V (low ESR)	UCC, Rubycon
Electrolytic cap	1	C5	10uF, 25V	UCC, Rubycon
Electrolytic cap	1	C6	22 uF, 25V	UCC, Rubycon
Resistors				
Resistor, 2W	1	R1	4.7 ohm, 2W ceramic, axial lead	Ohmite
Resistor, 1/2W	1	R2	1 Meg, 1/2W, axial lead, metal film	Ohmite
Resistor, 1/4W	1	R4	1K	5% SMD (1206)
Resistor, 1/4W	1	R21	82K	5% SMD (1210)
Resistor, 1/8W	2	R6, R12	1K	1% SMD
Resistor, 1/8W	1	R5	100 ohms	1% SMD
Resistor, 1/8W	1	R3	3.3K	1% SMD
Resistor, 1/8W	1	R7, R9	20K	1% SMD
Resistor, 1/8W	1	R11	180 ohms	1% SMD
Resistor, 1/8W	2	R8, R10	100K	1% SMD
Resistor, 1/8W	3	R13, 17, 19	10K	1% SMD
Resistor, 1/8W	1	R14	4.99K	1% SMD
Resistor, 1/8W	1	R15	4.75K	1% SMD
Resistor, 1/8W	1	R16	31K	1% SMD
Resistor, 1/8W	1	R20	47 ohms	1% SMD
Resistor,1/8W	1	R22	470 ohms	1% SMD
Resistor,1/8W	1	R23	10 ohms	1% SMD
Resistor,1/8W	1	R24	470K	1% SMD
Resistor,1/8W	2	R25, R26	15K	1% SMD
Resistor, 1/8W	1	R18	12.5K	1% SMD
Miscellaneous				
Fuse (TR5 type)	1	F1	1 to 1.5A, 250 Vac	Bussmann
Magnetics				
EMI Inductor	1	L1	BU16-4530R5BL (or similar)	Coilcraft
Choke, 4.7 uH, 4A	1	L2	RFB0807-4R7L (or similar)	Coilcraft
Choke, 15 uH, 3 A	2	L3, L4	DO3316P-153L (15 uH, 3A)	Coilcraft
Flyback Transformer (custom)	1	T1		See drawing
Current sense transformer (1:50)	1	T2	T6522-AL (or equivalent)	Coilcraft

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