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Design Note – DN05078/D

Universal AC Input, 5V3A Output, 15 Watt Charger

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP1361BABAY	Mobile, tablet Charger, adapter	90 to 264 Vac	15W	Quasi Resonant Flyback	Yes

Item	Output Specification	Test Condition
Rated Input Voltage	100Vac~240Vac	
Input Voltage Range	90Vac~264Vac	
Input Frequency Range	47Hz~63Hz	
Inrush Current	<30A	264Vac and 3A load
Average Efficiency	>84%	Measured at board end via USB connector
Full Load Efficiency	>86%	Measured at board end via USB connector
Standby Power	<30mW	115Vac&230Vac
Output Voltage	5V~5.5V, 5V at 3A	90Vac~264Vac and 0~3A
Output Current	3A	90Vac~264Vac
Rated Output Power	>15W	90Vac~264Vac
Ripple and Noise	<80mV	90Vac~264Vac, 1uF+0.1uF CAP@E-load
Rise Time	<60ms	At No/Full load,115Vac&230Vac
Startup Time	<1.5s	90Vac~264Vac and 0~3A
Over Shoot	<6.4V	At 1m USB cable end
Transient Response	4.3V~5.5V	0A-3A, 0.25A/us,10ms cycle

Circuit Description

This design note describes a 15 watt, universal AC input, isolated Quasi-Resonant flyback converter for smart phone, tablet charger and smart socket power supply etc.

The featured power supply is a primary side constant current and secondary constant voltage regulation utilizing ON semiconductor's new NCP1361 current mode controller which is in TSOP6 package. This Design Note provides the complete circuit schematic details, layout, test data and BOM for 5.1 volts, 3 amps power supply.

1. Input circuit

Rectifier, filter and EMC circuit formed by D1, C2, C3, L1, L2 and L3, NTC is 10ohm negative temperature coefficient resistor to provide inrush protection, F1 provides short-circuit protection when large AC input current occurs.

2. NCP1361 control circuit

NCP1361 is a Hybrid controller without a high voltage startup current source, so it need external startup resistor, startup resistor R16 and R24 can be connected between high voltage rail directly and Pin1. R8, and R9 consists of voltage simple network to set output voltage, C6 is a delayed capacitor to delay switching on to valley.

R4 and R5 is a current sensing resistor to decide how much current can be set, R3 and CS pin parasitic capacitor consists of a filter to filter current spike. R10, R20, R21, R22, C7, C8, C9, U2 and U4 consist of simple, feedback and a type II compensation network to provide voltage feedback control loop compensation.

R6, D6 and C4 consist of Vcc supply circuit, R6 can adjust Vcc voltage and also prevent D6 from a inrush current. An RCD-R clamp consisting of R1, R2, C3, and D5 limits drain voltage spikes caused by leakage inductance, resistor R1 has a relatively large value to prevent any excessive ringing on the drain voltage waveform and R3 can limit the reverse recovery current through D5.

3. Output synchronous rectification and filter
Synchronous rectification consist of Q1, U3 and external components, a Schottky barrier-type diode is parallel with MOSFET to reduce power loss during dead time, and filtered by C13, C14 and C5. In this application, C13 and C14 have sufficiently low ESR characteristics to allow meeting the output voltage ripple requirement without adding an LC post filter.

C12 and R12 is snubber network of Q1 to eliminate excessive ringing on secondary voltage waveform. R13 is a dummy load to prevent output voltage rising at no load.

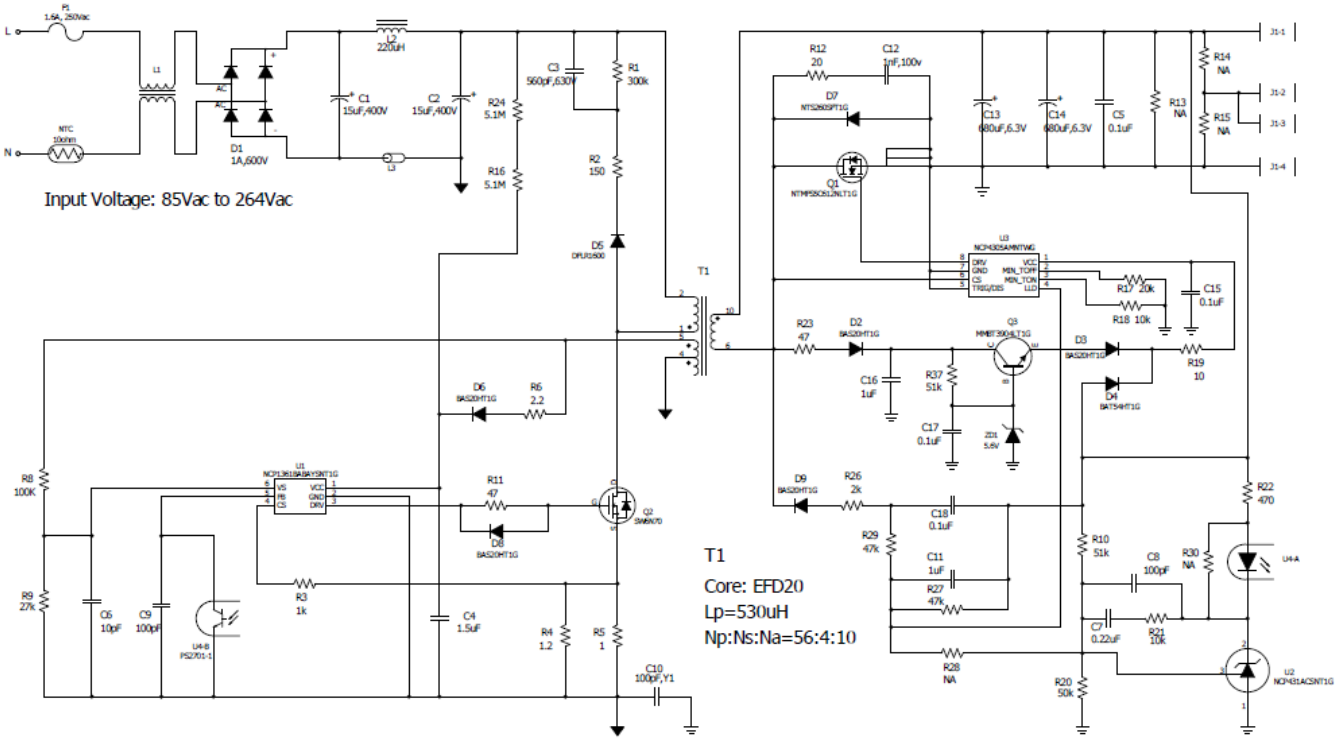
Lowest working voltage of U3 is 4.2V, in order to meet 3V lowest voltage output during CC mode an external Vcc supply circuit is needed, this circuit is consisted of R23, R37, C16, C17, D2, ZD1 and Q3. D3 and D4 provide a Vcc supply in parallel and Vcc supply is provided by D4 at no load to reduce the standby power at no load.

U3 also provides automatic light-load and disable mode which can clamp MOSFET drive signal level down to zero and then disable the controller at light load, this light load detection consist of R26, R27, R29, C11, C18 and D9, the difference of Vcc-V_{LLD} will drop when light load is applied, for details, pls see page 35 on NCP4305 datasheet.

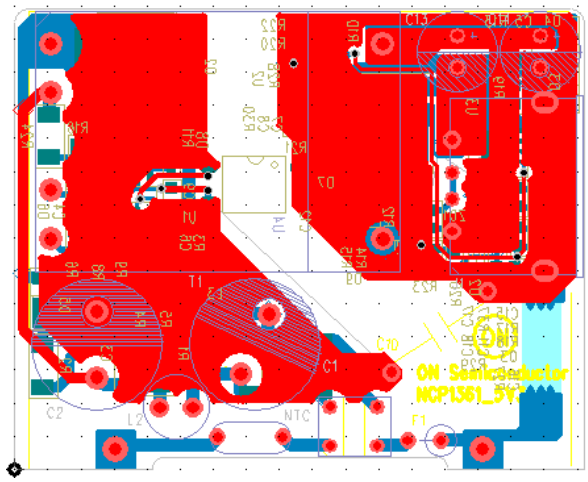
Key Features

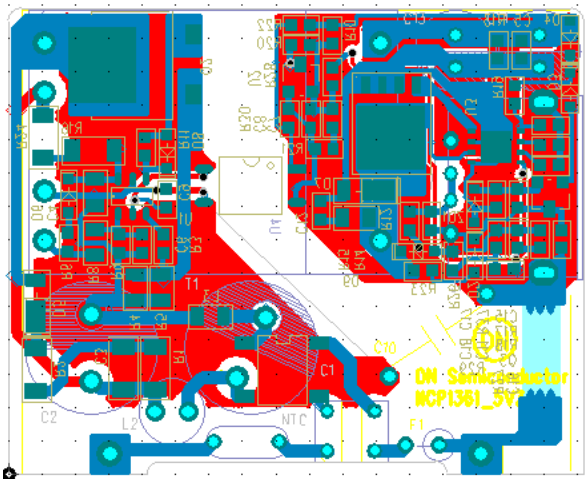
- Primary Side CC Regulation and Secondary CV Regulation
- Quasi-Resonant current mode control with Valley Switching
- Valley lockout avoids audible noise at valley jumping operation
- External 10M startup resistor
- Built in 4ms soft start
- 80kHz maximum clamp frequency operation
- Adjustable voltage control loop compensation
- Wide Operation VCC range (up to 30 V)
- Cycle by cycle current limit
- Support external 2200Uf startup
- Built in Vcc OVP (typical 26v)
- Built in output UVP in CC mode (3V+/-6.7%)
- Output OCP, SCP, OVP and controller OTP function
- CS pin open and short protection
- Vs pin open and short protection
- Meet COC V5 Tier 2
- 100pF Y capacitor
- “Travel Adapter” (TA) form factor
- Size: 43.5mm x 35mm x 15mm

Circuit Schematic



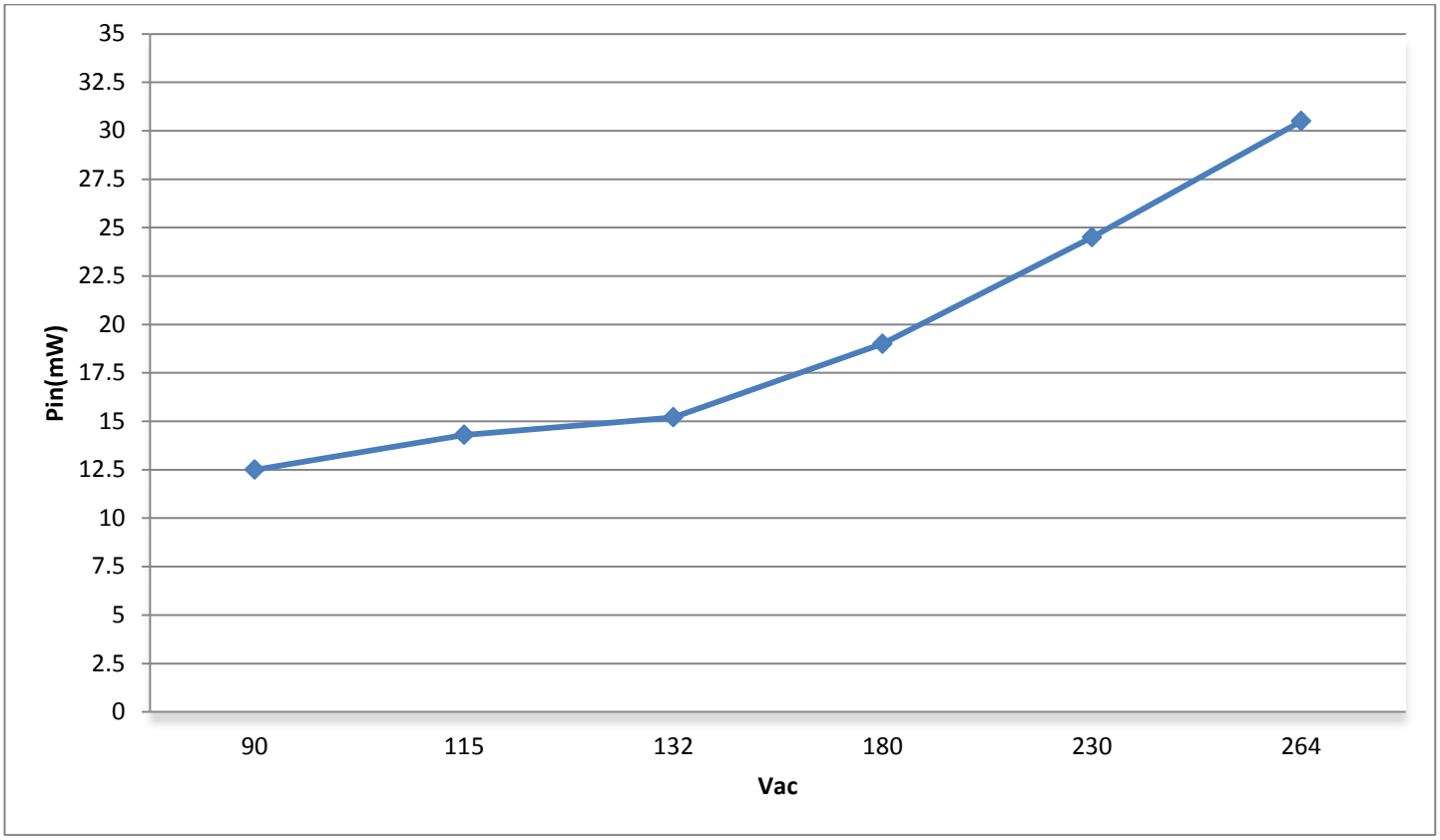
PCB layout



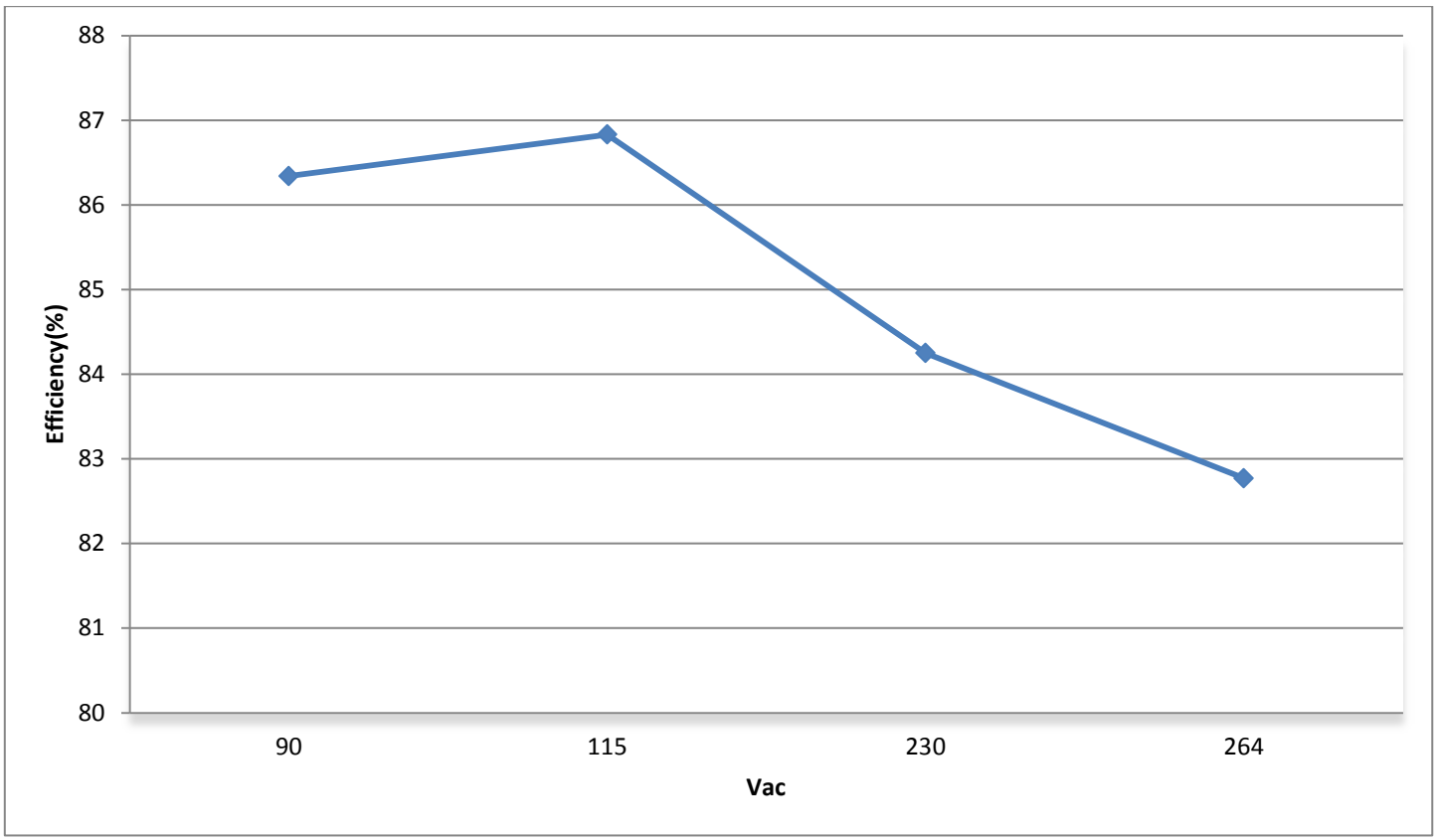


Demoboard Photo

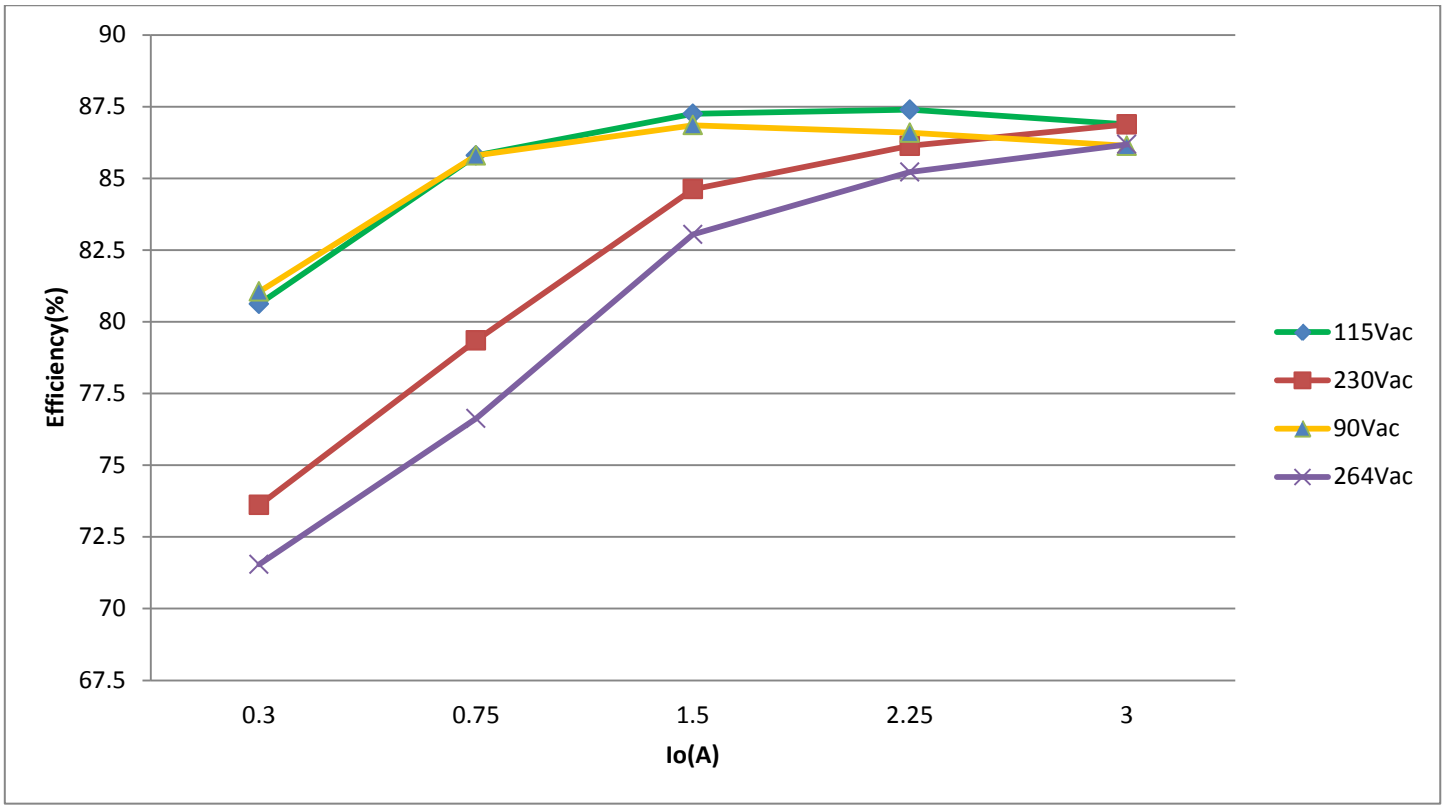
Standby Power at No Load



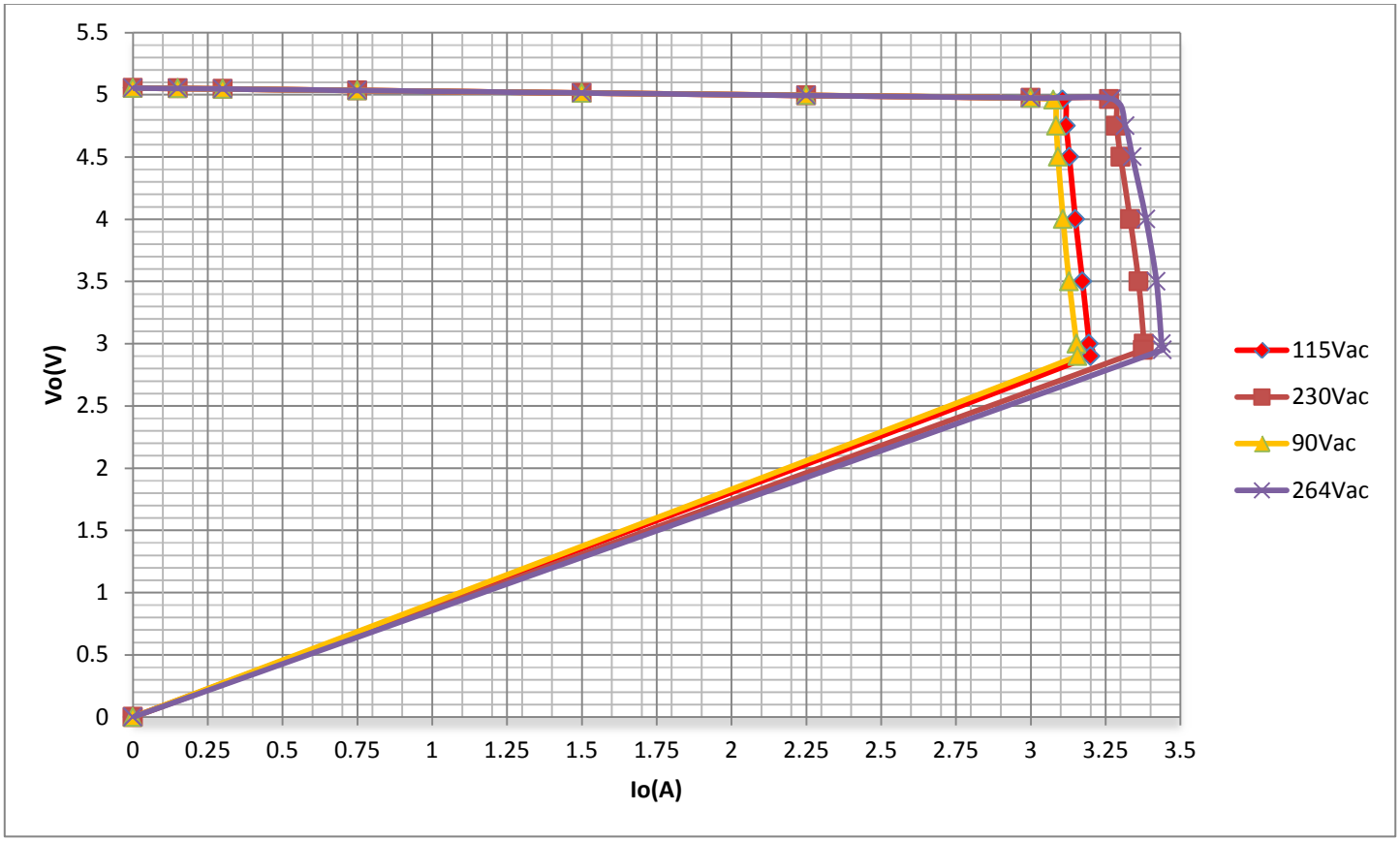
Average Efficiency Between 25%, 50%, 75% and 100% Load



Efficiency Vs Load Curves

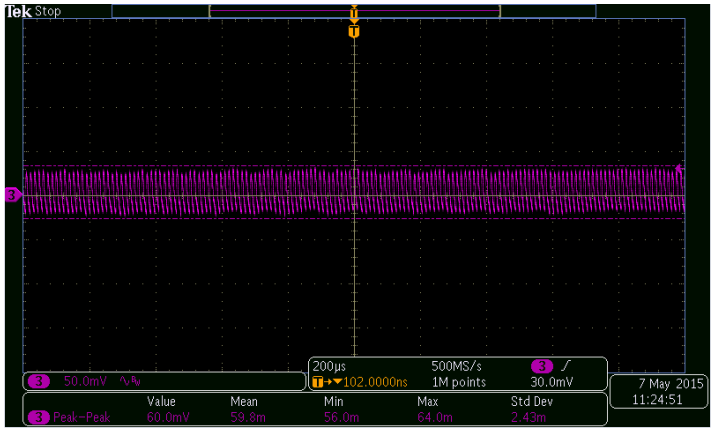


I-V Curves

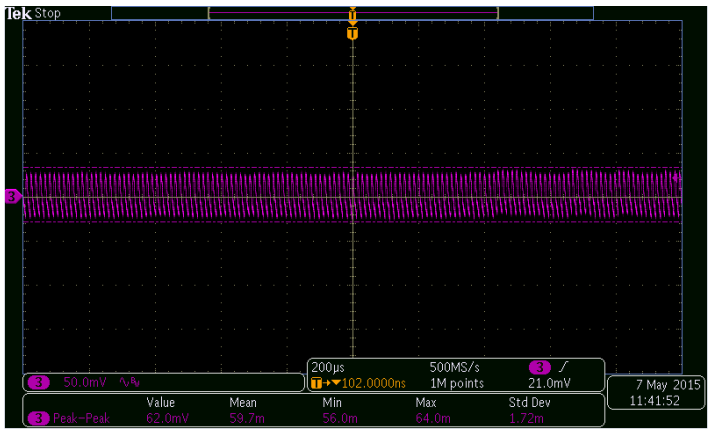


Output Ripple Voltage

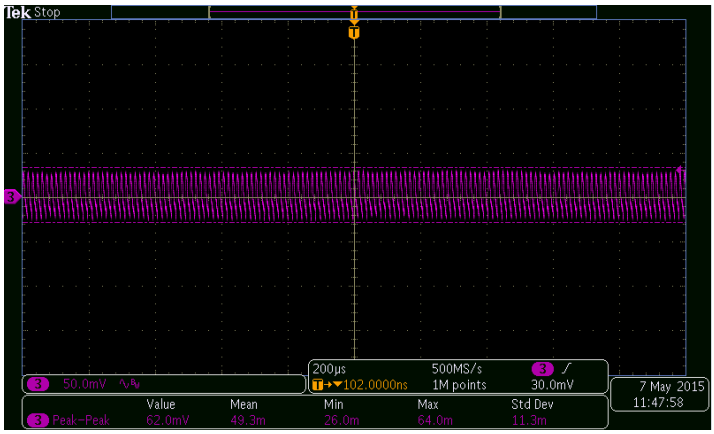
(Test condition: tested at E-load with 1m cable, 1uF E-CAP and 0.1uF ceramic in parallel)



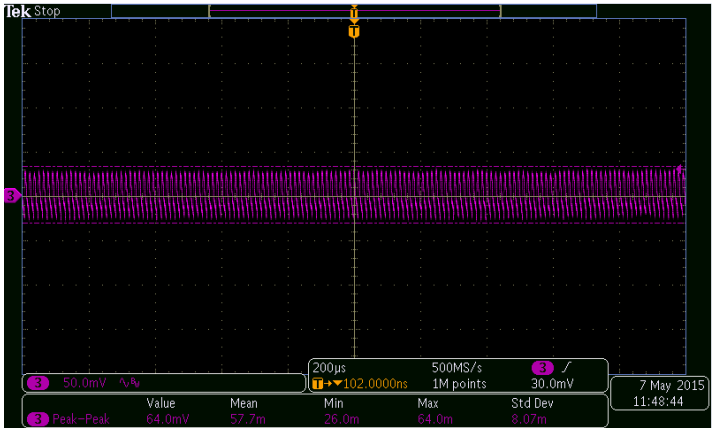
90Vac and 3A load



115Vac and 3A load

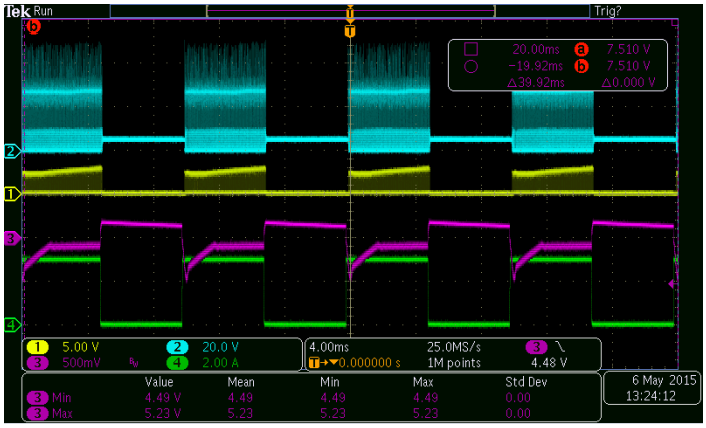


230Vac and 3A load

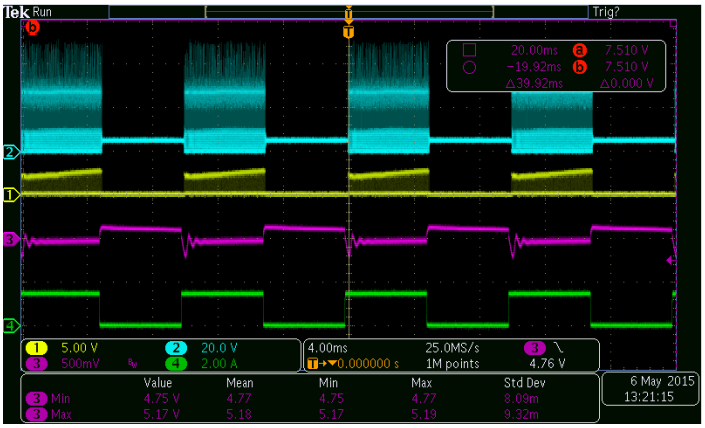


264Vac and 3A load

Transient Response

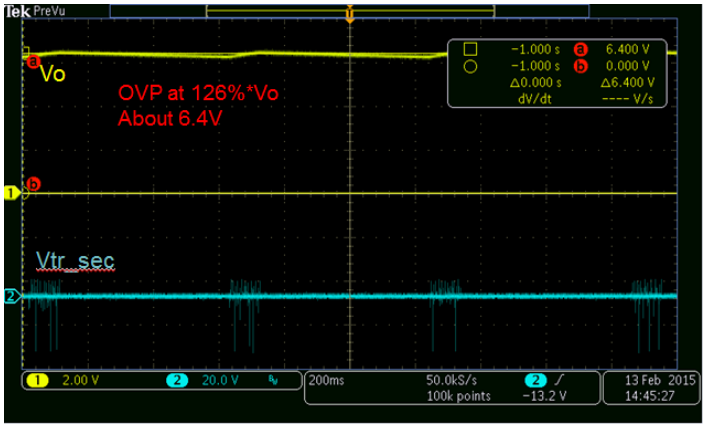


Test Condition: 0A-3A, 250mA/us
10ms cycle, 230Vac



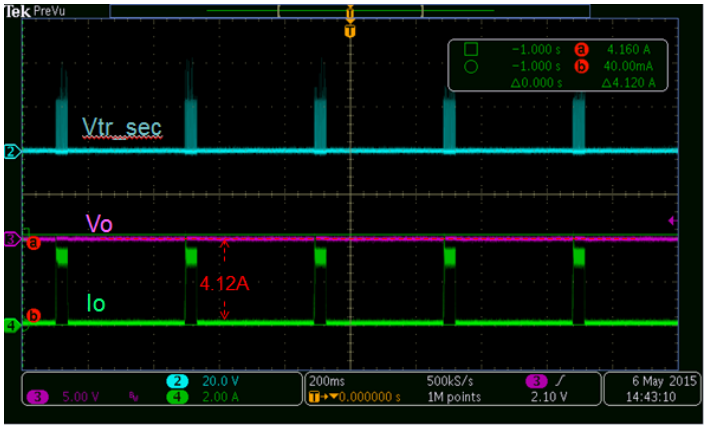
Test Condition: 0A-1.5A, 250mA/us
10ms cycle, 230Vac

OVP



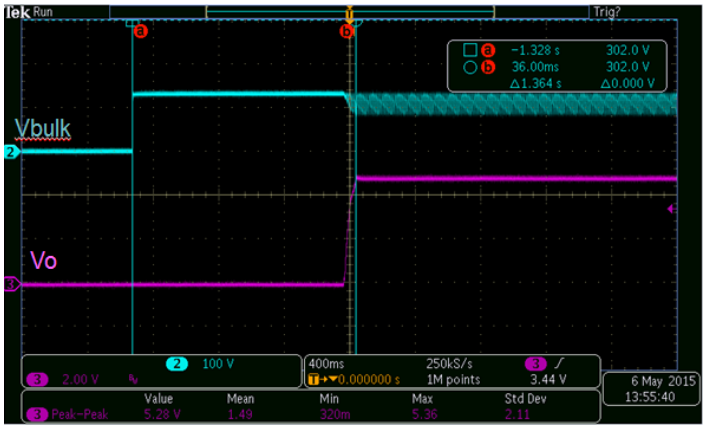
Test condition: 264Vac, no dummy load

SCP



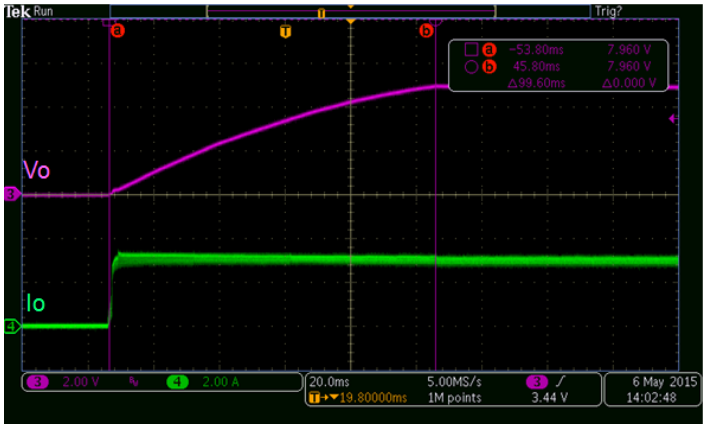
Test condition: SC at board end

Startup Time



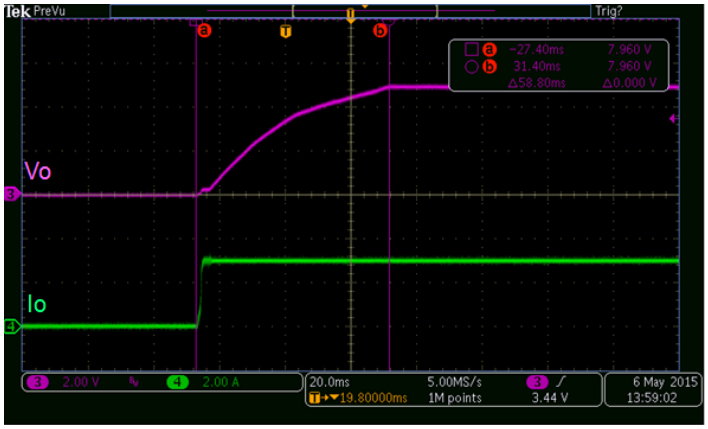
90Vac and 3A CC load

Startup with Ext. 2200Uf capacitor

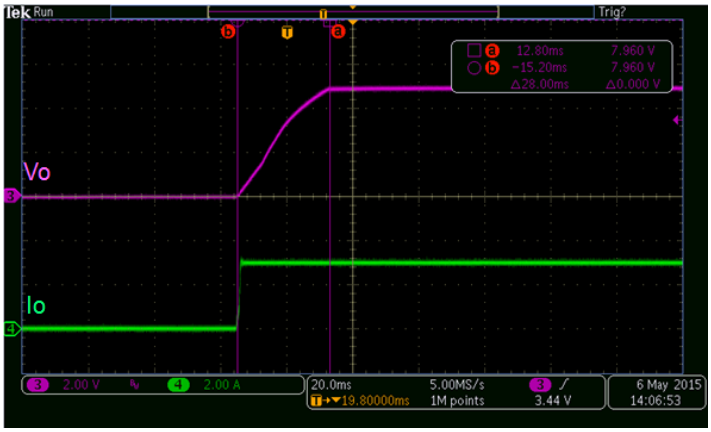


90Vac, 3A CC load with Von=0V

Output Voltage Rise Time

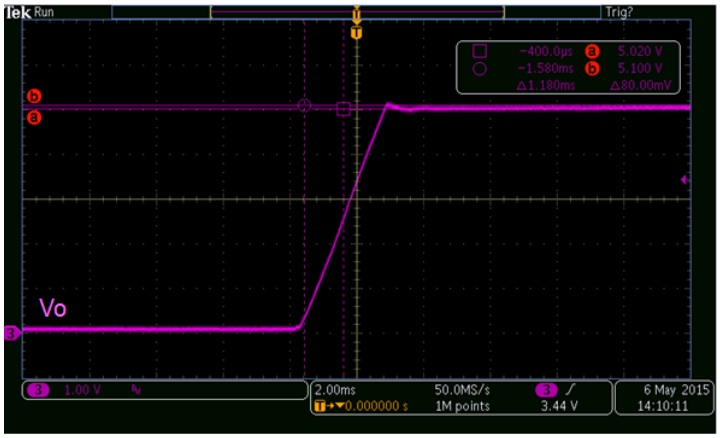


115Vac and 3A CC load

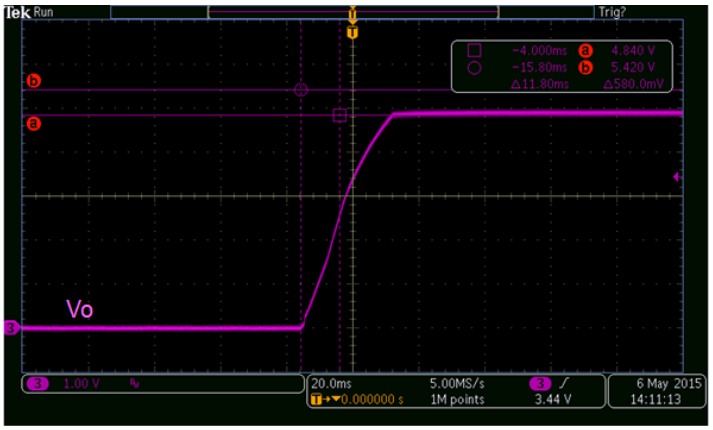


230Vac and 3A CC load

Output Voltage Overshoot

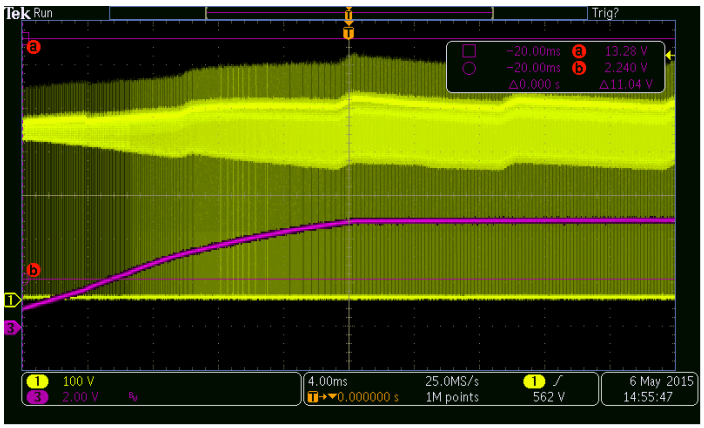


230Vac and no load

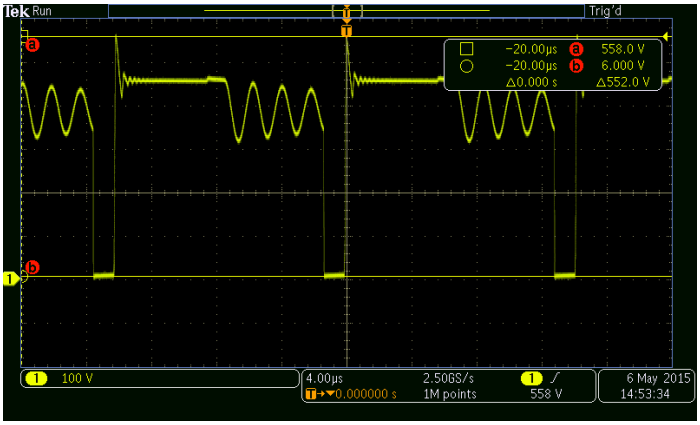


230Vac and 3A CC load

MOSFET Drain Voltage

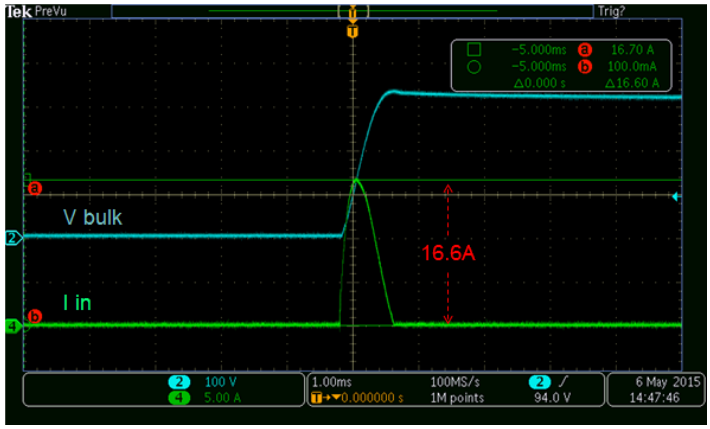


Startup at 264Vac and 3A CC load



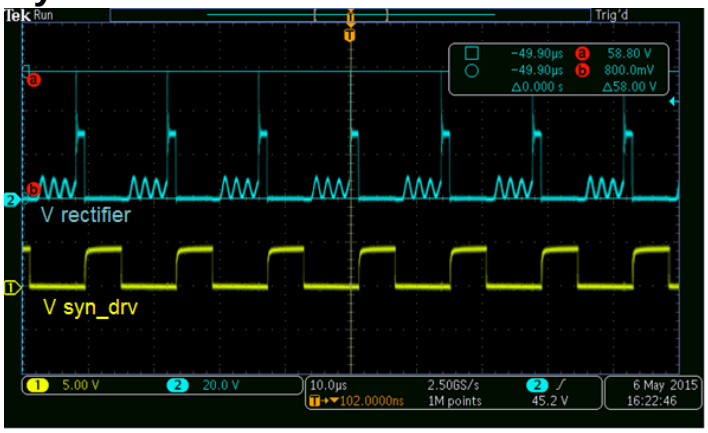
Work at 264Vac and 3A CC load

Inrush Current



264Vac and 3A CC load

Secondary Diode Reverse Voltage And Syn. drive



264Vac and 3A CC load

DN05078/D
BOM

Item	Qty	Referen	Type	Part Name	MFR	Value	Package	Description
1	2	C5 C15	Ceramic Capacitor	Std	std	0.1uF	603	Capacitor, Ceramic, 50V, 10%
2	1	C17	Ceramic Capacitor	Std	std	0.1uF	603	Capacitor, Ceramic, 50V, 10%
3	1	C18	Ceramic Capacitor	Std	std	0.1uF	603	Capacitor, Ceramic, 50V, 10%
4	1	C7	Ceramic Capacitor	Std	std	0.22uF	603	Capacitor, Ceramic, 50V, 10%
5	1	C4	Ceramic Capacitor	C2012X7R1H155K	TDK	1.5uF	805	Capacitor, Ceramic, 50V, 10%
6	2	C8-9	Ceramic Capacitor	Std	std	100pF	603	Capacitor, Ceramic, 50V, 10%
7	1	C10	Ceramic Capcitor	CS65-B2GA101KYN	TDK	100pF,Y1	Lead type	Safety standard approved,10%
8	1	C6	Ceramic Capacitor	Std	std	10pF	603	Capacitor, Ceramic, 50V, 10%
9	1	C12	Ceramic Capacitor	C1608C0G2A102J	TDK	1nF,100v	603	Capacitor, Ceramic, SMD, 5%
10	1	C11	Ceramic Capacitor	C1608X6S1H105K	TDK	1uF	603	Capacitor, Ceramic, 50V, 10%
11	1	C16	Ceramic Capacitor	C1608X6S1H105K	TDK	1uF	603	Capacitor, Ceramic, 50V, 10%
12	1	C3	Ceramic Capcitor	C3216C0G2J561	TDK	560pF,630V	1206	Capacitor, Ceramic, Chip, 5%
13	1	D1	Bridge rectifier	LMB6S	FSC	1A,600V	Micro-DIP	Bridge Rectifier, 600V, 1A
14	4	D2,D3,D6,I	Switching diode	BAS20HT1G	ON	0.2A,200V	SOD323	Switching diode, SMD
15	1	D4	Schotty diode	BAT54HT1G	ON	0.2A,30V	SOD323	Schotty diode, SMD
16	1	D5	Standard rectifier	DFLR1600	Diodes	1A,600V	SOD123FL	Standard Rectifier, 1A, 600V
17	1	D7	Schotty rectifier	NTS260SFT1G	ON	2A,60V	SOD123-2	Schotty Rectifier, 2A, 60V
18	1	D8	Switching diode	BAS20HT1G	ON	0.2A,200V	SOD323	Switching diode, SMD
19	1	L3	Ferrite bead	UPZ2012E102-1R5	Shunlord/TDK		805	600ohm @100MHz
20	1	L1	Common filter	150-1327	Wurth-Midcon	500uH	TH type	T type,6.3x3x3,dual-wire in parallel
21	1	F1	Micro Fuse	20T-016H	Hollyfuse	1.6A, 250Vac	Axial lead	Micro Fuse, 1.6A/250V
22	1	Q3	NPN Transistor	MMBT3904LT1G	ON		SOT23	General NPN Transistor, SMD
23	1	U2	Voltage reference	NCP431ACSNT1G	ON		SOT23	Programmable precision reference
24	1	U1	PSR Controller	NCP1361BABAYSN	ON		TSOP-6	PSR Controller, TSOP-6
25	1	U3	Syn. rectified controller	NCP4305AMNTWG	ON		DFN8	Syn. Rectified Controller
26	1	Q2	NMOSFET	SW6N70	SAMWIN	6A, 700V	DPAK	NMOS, 6A, 700V, DPAK
27	1	NTC	NTC	SPNL05D100MBI	Shunlord	10ohm	lead type	NTC, 10ohm, diameter:5mm
28	1	U4	Optical coupler	PS2701-1	NEC		SOP	optical coupler, standard SOP package
29	1	L2	Axial leaded fixed inductor	7447462221	Wurth	220uH	Lead type	Axial leaded fixed inductor
30	1	T1	Transformer	750342872	WE-midcon		TH type	EFD20-10Pin
31	1	R19	Resistor	Std	Std	10	603	Resistor, Chip, 1/8W, 1%
32	1	R8	Resistor	Std	Std	100K	805	Resistor, Chip, 1/5W, 1%
33	1	R18	Resistor	Std	Std	10k	603	Resistor, Chip, 1/8W, 1%
34	1	R21	Resistor	Std	Std	10k	603	Resistor, Chip, 1/8W, 1%,

BOM(Con't)

Item	Qty	Referen	Type	Part Name	MFR	Value	Package	Description
35	1	R3	Resistor	Std	Std	1k	603	Resistor, Chip, 1/8W, 1%
36	1	R6	Resistor	Std	Std	2.2	603	Resistor, Chip, 1/8W, 1%
37	1	R17	Resistor	Std	Std	20k	603	Resistor, Chip, 1/8W, 1%
38	1	R9	Resistor	Std	Std	27k	603	Resistor, Chip, 1/8W, 1%
39	1	R26	Resistor	Std	Std	2k	603	Resistor, Chip, 1/8W, 1%
40	2	R11,R23	Resistor	Std	Std	47	603	Resistor, Chip, 1/8W, 1%
41	1	R22	Resistor	Std	Std	470	603	Resistor, Chip, 1/8W, 1%
42	2	R27,R29	Resistor	Std	Std	47k	603	Resistor, Chip, 1/8W, 1%
43	1	R20	Resistor	Std	Std	50k	603	Resistor, Chip, 1/8W, 1%
44	1	R10	Resistor	Std	Std	51k	603	Resistor, Chip, 1/8W, 1%
45	1	R37	Resistor	Std	Std	51k	603	Resistor, Chip, 1/8W, 1%
46	2	R28,R30	Resistor	Std	Std	NA	603	Resistor, Chip, 1/8W, 1%
47	2	R4	Resistor	Std	Std	1.2	805	Resistor, Chip, 1/5W, 1%
48	2	R5	Resistor	Std	Std	1	805	Resistor, Chip, 1/5W, 1%
49	1	R2	Resistor	Std	Std	150	1206	Resistor, Chip, 1/4W, 1%
50	1	R12	Resistor	Std	Std	20	805	Resistor, Chip, 1/5W, 1%
51	1	R1	Resistor	Std	Std	300k	1206	Resistor, Chip, 1/4W, 1%
52	2	R16,R24	Resistor	Std	Std	5.1M	1206	Resistor, Chip, 1/4W, 1%
53	1	R13	Resistor	Std	Std	NA	805	Resistor, Chip, 1/5W, 1%
54	2	R14,R15	Resistor	Std	Std	NA	603	Resistor, Chip, 1/8W, 1%
55	2	C1,C2	Electrolytic capacito	ERK2GM150G12OT	AiSHi	15uF,400V	10mm(die.)x12	size,10mmx12.5mm
56	2	C13,C14	Electrolytic solid ca	PX681M6R3E090P	CapXon	680uF,6.3V	6.3mm(die.)x9	size, 6.3mmx9mm
57	1	Q1	MOSFET	NTMFS5C612NLT1G	ON		SO8FL	MOSFET, NChan, 60V
58	1	J1	USB connector	USB A Type	Std		TH type	USB connector, Type A
59	1	ZD1	Zener	MM3Z5V6T1G	ON	5.6V	SOD323	GENERIC ZENER-DIODE

References

ON Semiconductor datasheet for NCP1361/6 CC/CV primary side PWM current mode controller.
ON Semiconductor design note DN05073, DN05074.

Design note created by David Dou; e-mail: david.dou@onsemi.com