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DN05082/D

15 W HVDCP Quick Charge™ 3.0 Compatible CV/CC Charger

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DESIGN NOTE

Table 1. DEVICE DETAILS

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP4371AAC, NCP1361EABAY, NCP4305D	Quick Charge 3.0, Cell Phone, Laptop Charger	90 to 265 Vac	15 W Nominal	Flyback	Isolated (3 kV)

Parameter	Output Specification
Output Voltage	Nominal: 5.0 Vdc, Min: 3.6 Vdc, Max: 12 Vdc
Output Ripple	TBD @ Full Load
Max Output Current	2.0 A @ 5 Vdc, 1.25 A @ 12 Vdc
Min Output Current	0 A
Efficiency	See Efficiency Charts
Input Protection	Fuse
Operating Temp. Range	0°C to +50°C
Cooling Method	Passive Cooling
No-load Power Consumption	< 75 mW @ 90–265 Vac

Introduction

This design note describes a 15 W, universal AC mains, isolated Quasi-Resonant flyback converter compatible with Qualcomm's High Voltage Dedicated Charging Port Quick Charge 3.0 Class A specification. The converter provides adjustable output voltage in a range from 3.6 Vdc to 12 Vdc. It maintains maximum output power 15 W at full range of the voltage output and at same time it limits the maximum output current to 2.0 A. The design is targeted for smart phone and tablet charger applications.

The charger design utilizes ON Semiconductor's new NCP4371 Qualcomm Quick Charge 3.0 Controller, NCP1361E Quasi-Resonant Controller and NCP4305 Synchronous Rectification controller.

Circuit Description

1. Input Circuitry:
   The input circuitry is formed by a fuse F1, simple EMI filter consisting of capacitor CX1, common and differential mode choke inductors L1 and L4, and the bridge rectifier B1.
2. NCP1361EABAY Control Circuitry:
   The NCP1361EABAY is a 6-pin Quasi-Resonant Controller in TSOP6 package. It features output over and under voltage protection sensing via V_S/ZCD pin, which eliminates a need for an additional circuitry to provide output voltage fault protection. The resistor divider R18, R16 is used to set the output voltage UVP/OVP levels.
   The presented design has the levels set as follows: V_{UVP} = 3.2 V and V_{OVP} = 15.0 V.
   Resistors R14 and R15 are the primary current sense resistors. To filter the turn-on spikes, a small RC filter consisting of R12 and C11 is added into the signal path between CS pin and current sense resistors.
   Regulation information from secondary side controller is transferred via optocoupler to primary side and connected to NCP1361EABAY FB pin. The primary controller is supplied via auxiliary winding. Due to wide output voltage regulation range the V_{CC} supply circuitry requires a voltage regulator consisting of Zener diode D11, R24 and a small signal transistor BSS64L. Thus the controller is protected from seeing high auxiliary

voltage. R1 and R2 are high impedance start-up resistors.
R3, R4, R5 and C19 forms a RCD clamp to limit Q1 MOSFET drain voltage spikes.

3. NCP4371 Qualcomm QC3.0 Controller:
The NCP4371AAC is an 8-pin CV/CC (constant voltage/constant current) controller in SOIC8 package. It resides on the isolated secondary side of the converter. It allows receiving and decoding control commands from Qualcomm QC3.0 compatible Portable Device. Output USB-bus voltage can be adjusted in a range from 3.6 V to 12.0 V. The NCP4371AAC controller provides a control feedback to the primary side via an optocoupler driven by the DRIVE pin.
R28, C20 and C21 form a compensation network for the constant voltage regulation loop. R27 is an output current sensing resistor. A voltage drop across the R27 is sensed at ISNS input pin and used for output current regulation. R17, C12 and C13 form a compensation network for the output current regulation.
The NCP4371 features internal discharge circuitry via VCC pin. In case the internal discharge strength is not sufficient an external discharge resistor R13 connected to the DISCHARGE pin can be used. The output capacitors are required to be discharged either a request for a lower V_{OUT} is received or a USB cable unplug event is detected. By selection of the output current sensing resistor value (R27) and current limit device option of the NCP4371 the user can scale a maximum output power and maximum current independently. In case of the presented design we selected power profile A and current limit C. Together with the R27 = 11 mΩ we will get a following power profile:

Table 2. POWER PROFILE

V_{BUS}	$I_{OUT(max)}$	$P_{OUT(max)}$
12.0 V	1.25 A	15.0 W
9.0 V	1.67 A	15.0 W
5.0 V	2.00 A	10.0 W
3.6 V	2.00 A	7.2 W

Maximum output power is scaled to 15.0 W, while the maximum output current is limited to 2.0 A as restricted by USB Type-A connector.

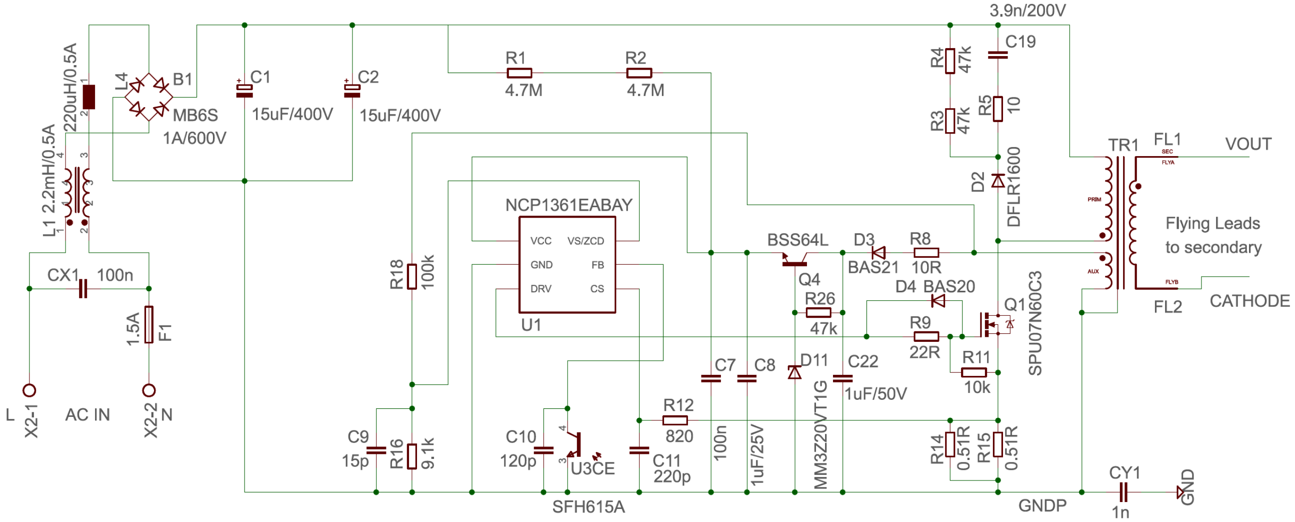
4. NCP4305D Synchronous Rectification Controller:
The flyback transformer secondary voltage is rectified by a NCP4305D synchronous rectifier in order to achieve higher efficiency. The NCP4305D senses a voltage drop across output MOSFET transistor Q2 and turns it on and off accordingly. Resistors R20 and R21 allows to adjust minimum MOSFET driver on and off times. The Light-Load Detect (LLD) circuitry allows putting the NCP4305D controller into a stand-by mode in case of light or no-load operating condition.
The NCP4305D is supplied via a Schottky diode D6 under normal operating conditions. If the output voltage falls below 4.5 V the NCP4305D is supplied by the transformer forward voltage via the circuitry consisting of D8, R6, C15, R25, D7, D9 and Q3. This situation will occur when the converter is running in Constant Current mode or when the requested output voltage from the Portable Device is below 5.0 V.

Key Features

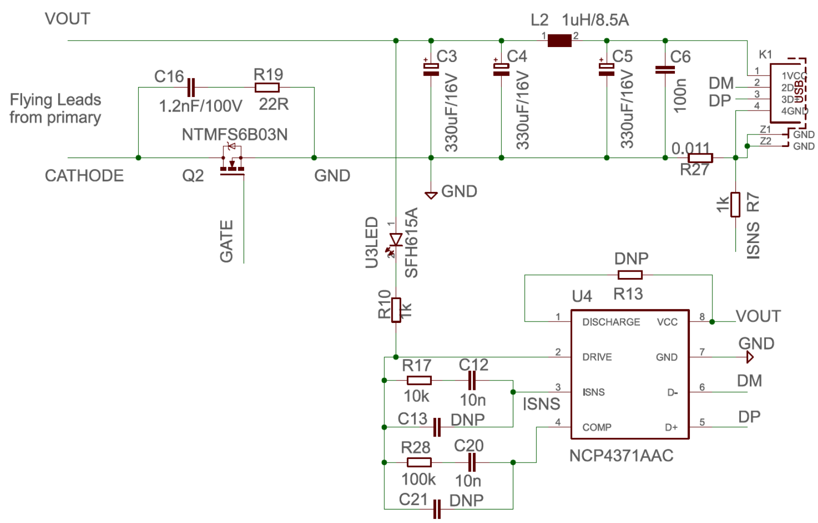
- Universal AC Input Range (90–265 Vac).
- Input Filter for Conducted EMI Attenuation
- Very Low Standby and No-load Power Consumption
- Quasi-Resonant Current Mode Control with Valley Switching
- Valley Lockout Avoids Audible Noise at Valley Jumping Operation
- Secondary Synchronous Rectification Control for High Efficiency
- Qualcomm Protocol Controller Supports QC2.0 and QC3.0
- Output 5 V/2.00 A, 9 V/1.67 A and 12 V/1.25 A
- Highly Configurable Power and Current Limit Profiles
- Standby Power < 75 mW @ 5 V Output
- Support Output Capacitor Discharge Function while Portable Device is Unplugged or during Transition from Higher to Lower Output Voltage
- Smooth Output Voltage Transition

Circuit Diagram

Primary Side



Output Regulation



Synchronous Rectification

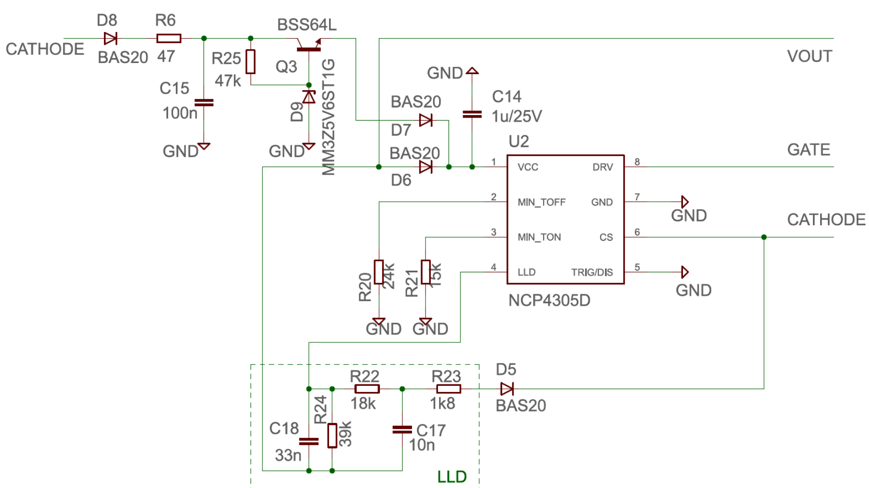


Figure 1. Circuit Diagram

PCB Layout

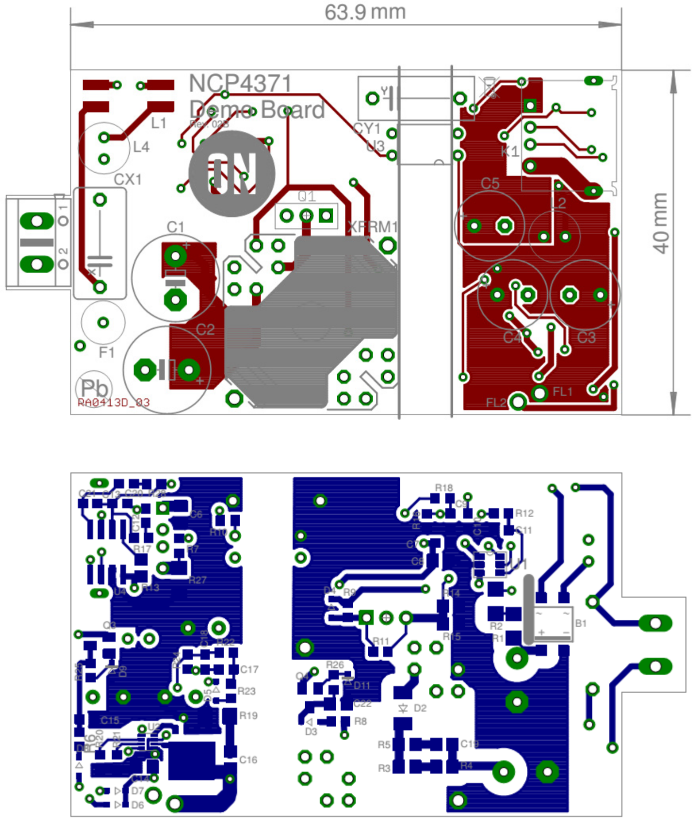


Figure 2. PCB Layout

Demoboard Photo

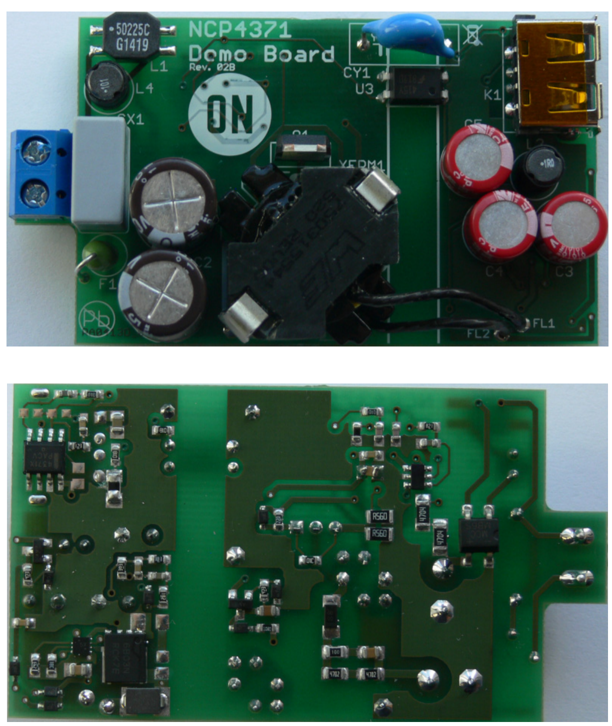


Figure 3. Demoboard Photo

Standby Power at No Load at 5 V Output

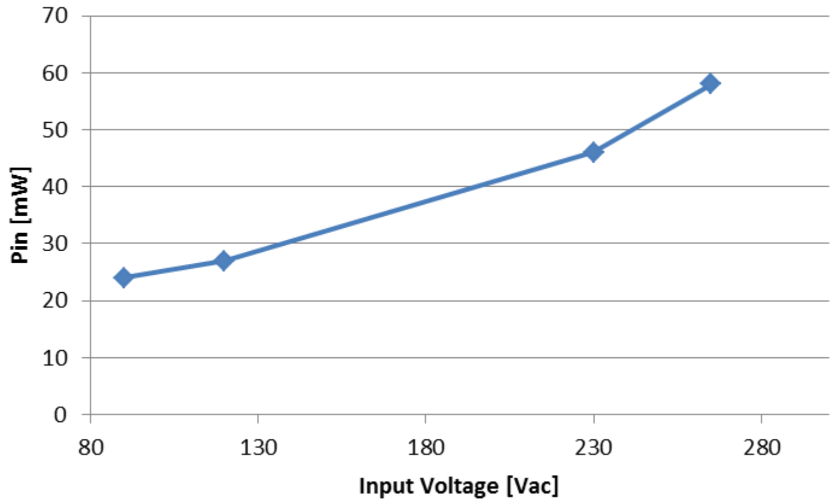


Figure 4. Standby Power at No Load an 5 V Output

4-Point Average Efficiency at 5 V Output

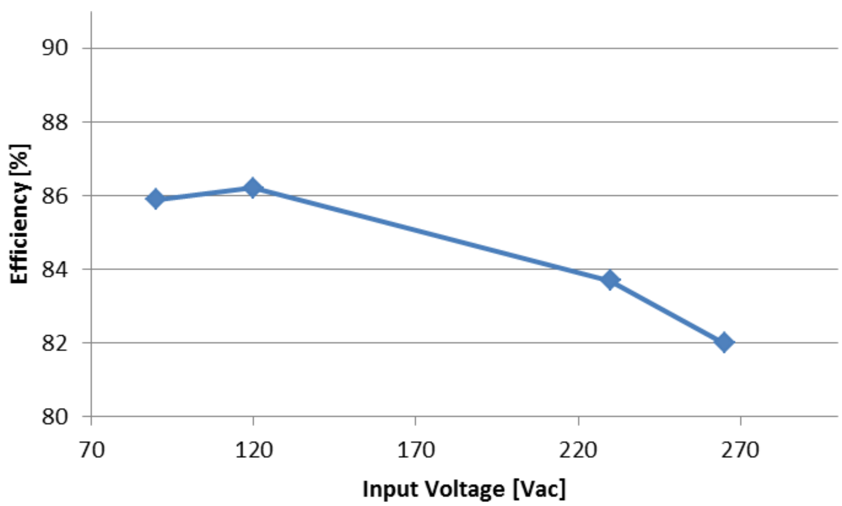


Figure 5. 4-Point Average Efficiency at 5 V Output

Efficiency vs. Load Curves at 5 V Output

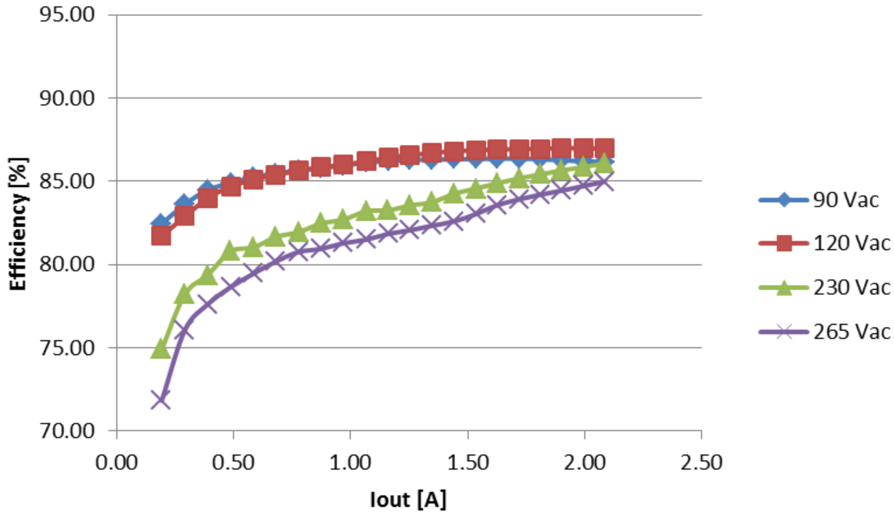


Figure 6. Efficiency vs. Load Curves at 5 V Output

Output V/A Characteristics at 5 V Output

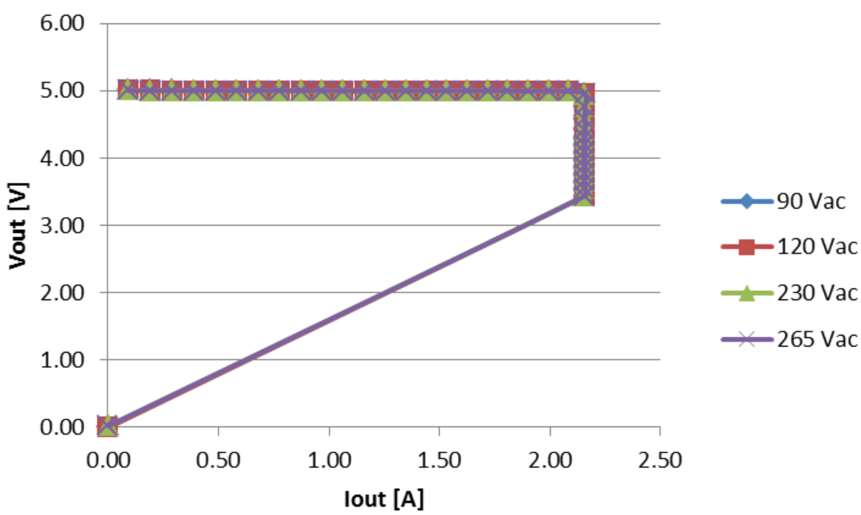


Figure 7. Output V/A Characteristics at 5 V Output

4-Point Average Efficiency at 9 V Output

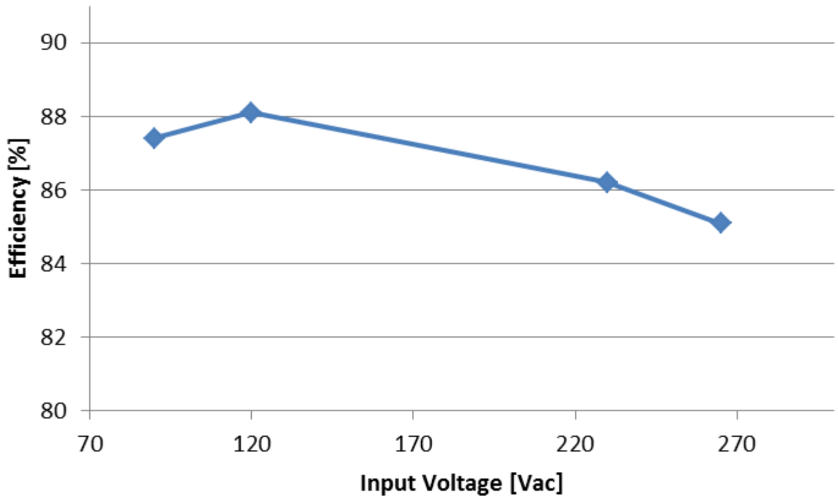


Figure 8. 4-Point Average Efficiency at 9 V Output

Efficiency vs. Load Curves at 9 V Output

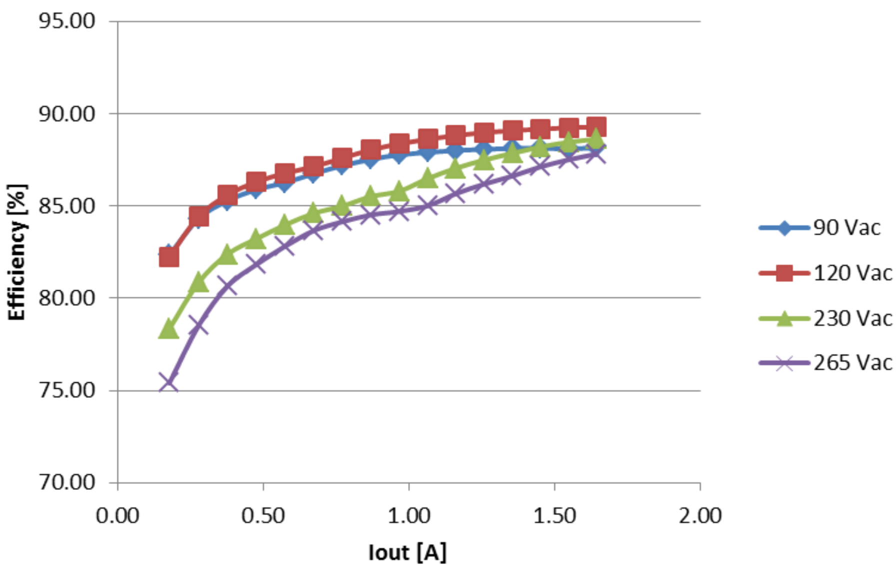


Figure 9. Efficiency vs. Load Curves at 9 V Output

Output V/A Characteristics at 9 V Output

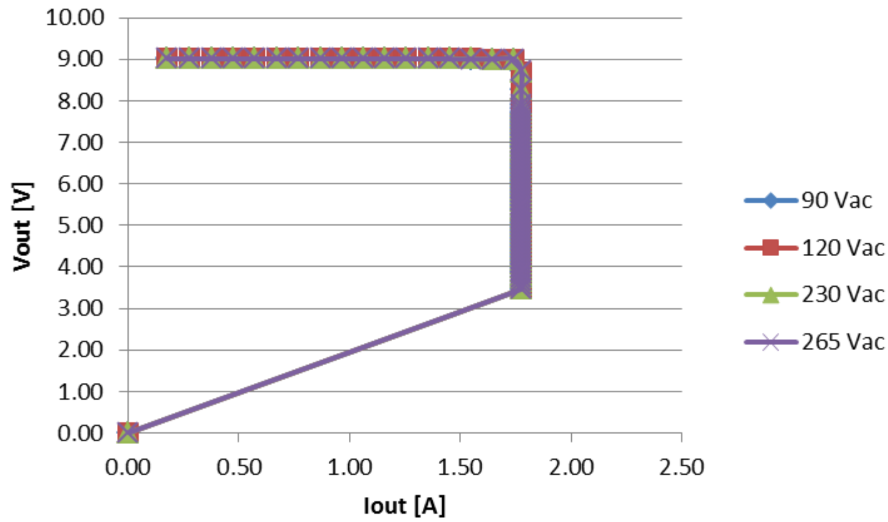


Figure 10. Output V/A Characteristics at 9 V Output

4-Point Average Efficiency at 12 V Output

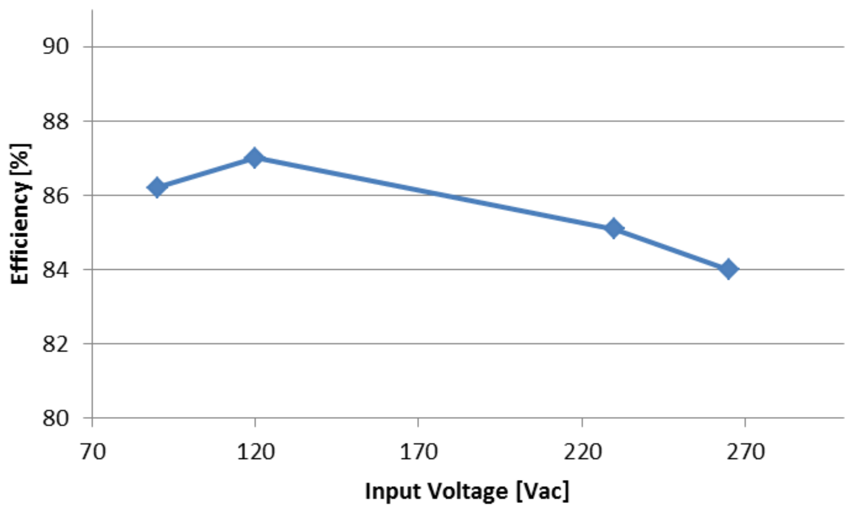


Figure 11. 4-Point Average Efficiency at 12 V Output

Efficiency vs. Load Curves at 12 V Output

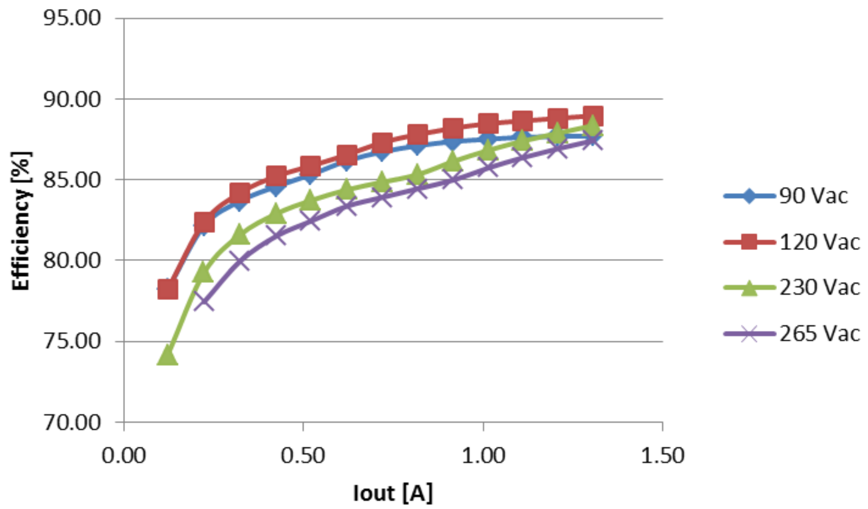


Figure 12. Efficiency vs. Load Curves at 12 V Output

Output V/A Characteristics at 12 V Output

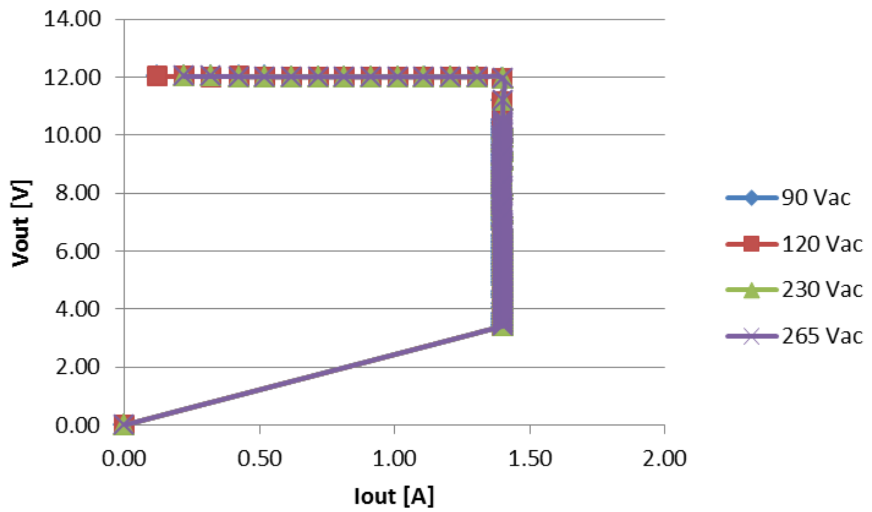


Figure 13. Output V/A Characteristics at 12 V Output

OUTPUT VOLTAGE CHANGE

Figure 14. Transition from 5.0 V to 9.0 V

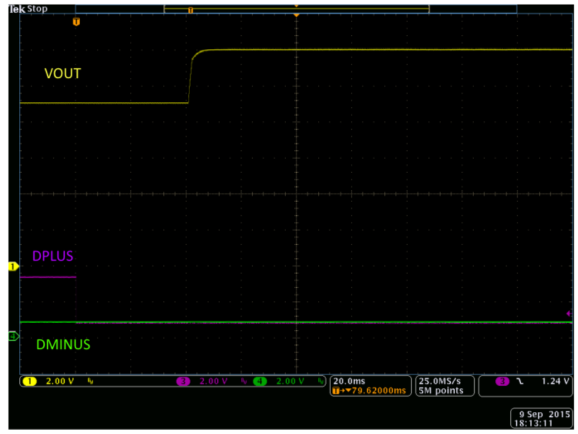


Figure 15. Transition from 9.0 V to 12.0 V

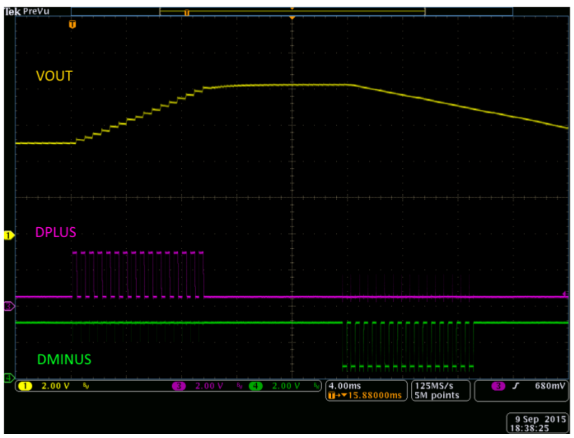


Figure 16. Continuous Mode Ramp Up and Down

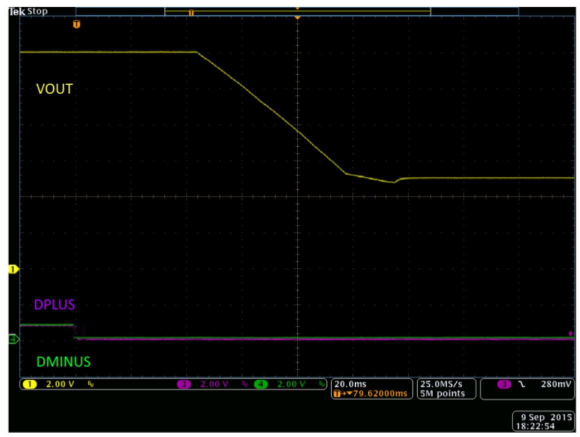


Figure 17. USB Cable Unplug Discharge

TRANSIENT RESPONSE

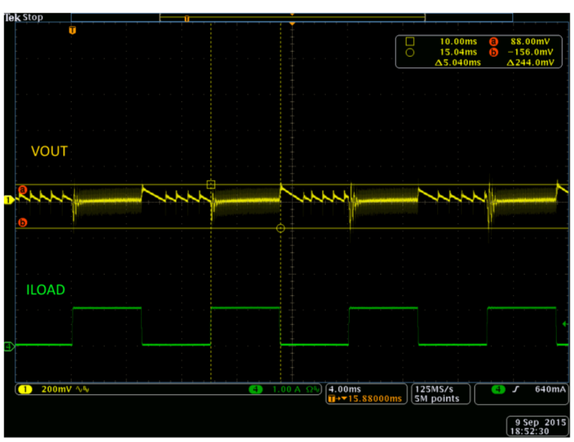


Figure 18. Load Change 0 to 1 A at 5 V

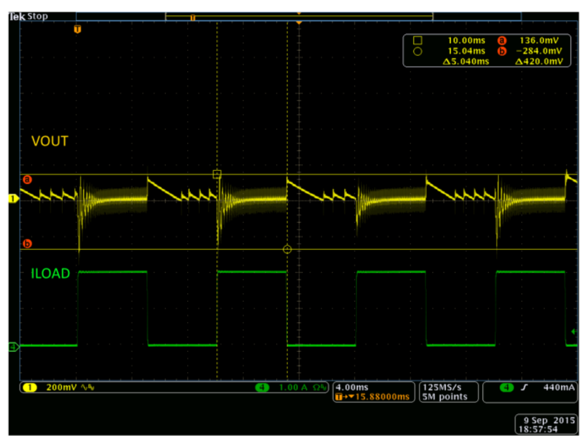


Figure 19. Load Change 0 to 2 A at 5 V

Bill of Material

Table 3. BILL OF MATERIAL

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed
B1	1	Surface Mount Glass Passivated Bridge Rectifiers	MB6S	−	SOIC−4	Vishay	MB2S−E3/45	Yes
C1, C2	2	Polarized Capacitor, High Voltage	15 μF/400 V	20%	E5−10−AX	Nichicon	UVC2G150MPD	Yes
C10	1	Ceramic Capacitor	120 pF	10%	C0603	Kemet	C0603C120K5RACTU	Yes
C11	1	Ceramic Capacitor	220 pF	10%	C0603	Kemet	C0603C220K5RACTU	Yes
C12, C17, C20	3	Ceramic Capacitor	10 nF	10%	C0603	Kemet	C0603C103K5RACTU	Yes
C13, C21	2	Ceramic Capacitor	DNP	10%	DNP	DNP	DNP	Yes
C8, C14	2	Ceramic Capacitor	1 μF/25 V	10%	C0805	Kemet	C0805C105K5RACTU	Yes
C16	1	Ceramic Capacitor, 100 V	1.2 nF/100 V	10%	C0805	Kemet	C0805C122K2RACTU	Yes
C18	1	Ceramic Capacitor	33 nF	10%	C0603	Kemet	C0603C330K5RACTU	Yes
C19	1	Ceramic Capacitor, 200 V	3.9 nF/200 V	10%	C0805	Kemet	C0805C392K2RACTU	Yes
C22	1	Ceramic Capacitor	1 μF/50 V	10%	C0805	Murata Electronics	GRM21BR71H105KA12L	Yes
C3, C4, C5	3	Aluminum Polymer Capacitor	330 μF/16 V	20%	E3,5−8	Würth Elektronik	870025374005	Yes
C6	1	Ceramic Capacitor	100 nF	10%	C0805	Kemet	C0805C104K5RACTU	Yes
C7, C15	2	Ceramic Capacitor	100 nF	10%	C0603	Kemet	C0603C104K5RACTU	Yes
C9	1	Ceramic Capacitor	15 pF	10%	C0603	Kemet	C0603C150K5RACTU	Yes
CX1	1	100 nF, 310 VAC, Polyester Film, X2	100 nF	20%	XC10B6	Vishay	F339MX241031KDA2B0	Yes
CY1	1	1 nF, 500 Vac, Ceramic, Y1	1 nF	20%	YC10B5	TDK Corporation	CD70ZU2GA102MYNKA	Yes
D11	1	Diode, Zener 20 V	MM3Z20VT1G	−	SOD323−R	ON Semiconductor	MM3Z20VT1G	Yes
D2	1	Standard Recovery Rectifier 1.0 A, 600 V	DFLR1600	−	SOD−123_ MINI−SMA	Diodes	DFLR1600−7	Yes
D3	1	High Voltage Switching Diode, 250 V	BAS21	−	SOD323−R	ON Semiconductor	BAS21HT1G	Yes
D4, D5, D6, D7, D8	5	High Voltage Switching Diode, 200 V	BAS20	−	SOD323−R	ON Semiconductor	BAS20HT1G	Yes
D9	1	Diode, Zener 5.6 V	MM3Z5V6ST1G	−	SOD323−R	ON Semiconductor	MM3Z5V6ST1G	Yes
F1	1	Fuse, 1.5 A, Axial	1.5 A	−	PICOFUSE_ VERTICAL	Littelfuse Inc.	0263 01.5	Yes
K1	1	HORIZONTAL USB 2.0 A TYPE THT SLIM TYPE	USB 2.0, Type A	−	614104150121	Würth Elektronik	614104150121	Yes
L1	1	Common Mode Power Line Choke	2.2 mH/0.5 A	20%	MURATA5000	Murata Electronics	50225C	Yes
L2	1	Radial Leaded Wire Wound Inductor WE−TI	1 μH/8.5 A	20%	WE−TI_5075	Würth Elektronik	7447462010	Yes
L4	1	Radial Leaded Wire Wound Inductor WE−TI	220 μH/0.5 A	10%	WE−TI_5075	Würth Elektronik	7447462221	Yes
Q1	1	600 V CoolMOS Power Transistor	SPU07N60C3	−	INF−PG−TO−251−3−21_A_ 1PRIMARY	Infineon	SPU07N60C3	Yes
Q2	1	Power MOSFET 100 V 132 A 4.8 mΩ Single N-channel SO−8FL	NTMFS6B03N	−	SO−8FL	ON Semiconductor	NTMFS6B03NT1G	No
Q3, Q4	2	NPN Bipolar Small Signal Transistor	BSS64L	−	SOT23	ON Semiconductor	BSS64LT1G	Yes
R1, R2	2	Resistor SMD	4.7 MΩ	1%	R1206	Rohm	MCR18ERTF4704	Yes
R11, R17	2	Resistor SMD	10 kΩ	1%	R0603	Rohm	MCR03ERTF1002	Yes
R12	1	Resistor SMD	820 Ω	1%	R0603	Rohm	MCR03ERTF8200	Yes
R13	1	Resistor SMD	DNP	DNP	R0805	DNP	DNP	Yes
R14, R15	2	Current Sense Resistor SMD	0.51 Ω	1%	R0805	Panasonic	ERJ−6RQFR51V	Yes
R16	1	Resistor SMD	9.1 kΩ	1%	R0603	Rohm	MCR03ERTF9102	Yes
R18, R28	2	Resistor SMD	100 kΩ	1%	R0603	Rohm	MCR03ERTF1003	Yes
R19	1	Resistor SMD	22 Ω	1%	R1206	Rohm	MCR25ERTF22R	Yes
R20	1	Resistor SMD	24 kΩ	1%	R0603	Rohm	MCR03ERTF2402	Yes
R21	1	Resistor SMD	15 kΩ	1%	R0603	Rohm	MCR03ERTF1502	Yes

Table 3. BILL OF MATERIAL (continued)

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed
R22	1	Resistor SMD	18 kΩ	1%	R0603	Rohm	MCR03ERTF1802	Yes
R23	1	Resistor SMD	1.8 kΩ	1%	R0603	Rohm	MCR03ERTF1801	Yes
R24	1	Resistor SMD	39 kΩ	1%	R0603	Rohm	MCR03ERTF3902	Yes
R25, R26	2	Resistor SMD	47 kΩ	1%	R0603	Rohm	MCR03ERTF4702	Yes
R27	1	Current Sense Resistor SMD	0.011 Ω	1%	R1206	Rohm	ERJ−8CWFR011V	Yes
R3, R4	2	Resistor SMD	47 kΩ	1%	R0805	Rohm	MCR10ERTF4702	Yes
R5	1	Resistor SMD	10 Ω	1%	R0805	Rohm	MCR10ERTF10R0	Yes
R6	1	Resistor SMD	47 Ω	1%	R0603	Rohm	MCR03ERTF47R0	Yes
R7, R10	2	Resistor SMD	1 kΩ	1%	R0603	Rohm	MCR03ERTF1001	Yes
R8	1	Resistor SMD	10 Ω	1%	R0603	Rohm	MCR03ERTF10R0	Yes
R9	1	Resistor SMD	22 Ω	1%	R0603	Rohm	MCR03ERTF22R0	Yes
U1	1	QR Flyback Controller	NCP1361EABAY	−	TSOP6	ON Semiconductor	NCP1361EABAYSNT1G	No
U2	1	Secondary-Side Synchronous Rectification Driver	NCP4305D	−	WDFN8_2x2	ON Semiconductor	NCP4305DMTTWG	No
U3	1	Optocoupler	SFH615A−4	−	DIP4	Vishay	SFH615A−4	Yes
U4	1	Qualcomm Quick Charge 3.0 HVDCP Controller	NCP4371AAC	−	SO08	ON Semiconductor	NCP4371AACDR2G	No
XFRM1	1	Flyback Transformer, RM8, 12-pin	CUST_TRF_ RM8FL_NCP4371_ PART1VER2	−	RM8−12	Würth Elektronik	750315544	No

NOTE: All parts are Pb-Free.

References

[1] ON Semiconductor data sheet for NCP4371/D Qualcomm Quick Charge™ 3.0 HVDCP Controller.

[2] [2] ON Semiconductor data sheet for NCP1361/D Low Power Offline Constant Current PWM Current-Mode Controller.

[3] ON Semiconductor data sheet for NCP4305/D Secondary Side Synchronous Rectification Driver.

[4] Würth Electronic http://www.we−online.com/.

PUBLICATION ORDERING INFORMATION

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