ON Semiconductor

Is Now

To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and onsemi and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

TND6215/D

60 W USB-PD and Quick Charge 3.0 Buck-Boost Reference Design Documentation Package

ON Semiconductor®

www.onsemi.com

TECHNICAL NOTE

Overview

This reference design describes the operation and performance of the NCP81239. The design demonstrates the NCP81239 controller capabilities, as well as a fully qualified design for today's fast charging standards. This is a universal charger that is compliant to Qualcomm®, Samsung™, and USB™ fast-charging protocols.

The design depicts the typical non-inverting buck boost regulator which is optimal when the output voltage can be greater than or less than the input voltage. It is intended for the power supply designer to adopt the circuit directly into a typical system design, making only minimal component changes based on system requirements.

The design is meant to be a complete solution, but it also provides access to key features of the NCP81239. These include controlled slew rate voltage transitions, I^2C interface, wide input range, over-voltage and over-current protection, and adaptive non-overlap drivers.

Key Features

- Compliant with USB Power Delivery 3.0 Specification
- Compliant with Qualcomm Quick Charge QC2.0 Specification
- Compliant with Qualcomm Quick Charge QC3.0 Specification
- Non-Inverting Buck Boost which Allows for Any Output Voltage 0.2 V to 25.5 V with 100 mV Resolution
- Type-C Receptacle for Easy Charging of All New Phones, Tablets, and Notebook Computers
- ON Semiconductor NCP81239 Synchronous Buck Boost Controller with Four MOSFETs
- Cypress® CCG2 CYPD2134 Port Control and Policy Manager
- Small Form Factor-Fits in Automotive Cigarette Lighter

Specifications

Table 1. SPECIFICATIONS TABLE

Device	NCP81239
Application	Car Adapter
Input Voltage	5 V to 24 V DC
Output Power	Up to 60 W
Topology	Non-inverting Buck Boost
Isolation	Non-isolated
Output Voltage	3.6 V − 20 V (USB-PD, QC2.0, QC3.0)
Nominal Current	3 A

Board

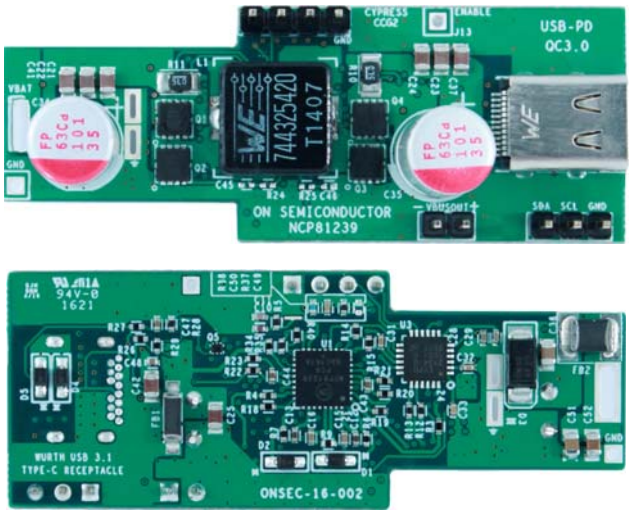

Figure 1. Reference Design Board Image

© Semiconductor Components Industries, LLC, 2016

Schematics

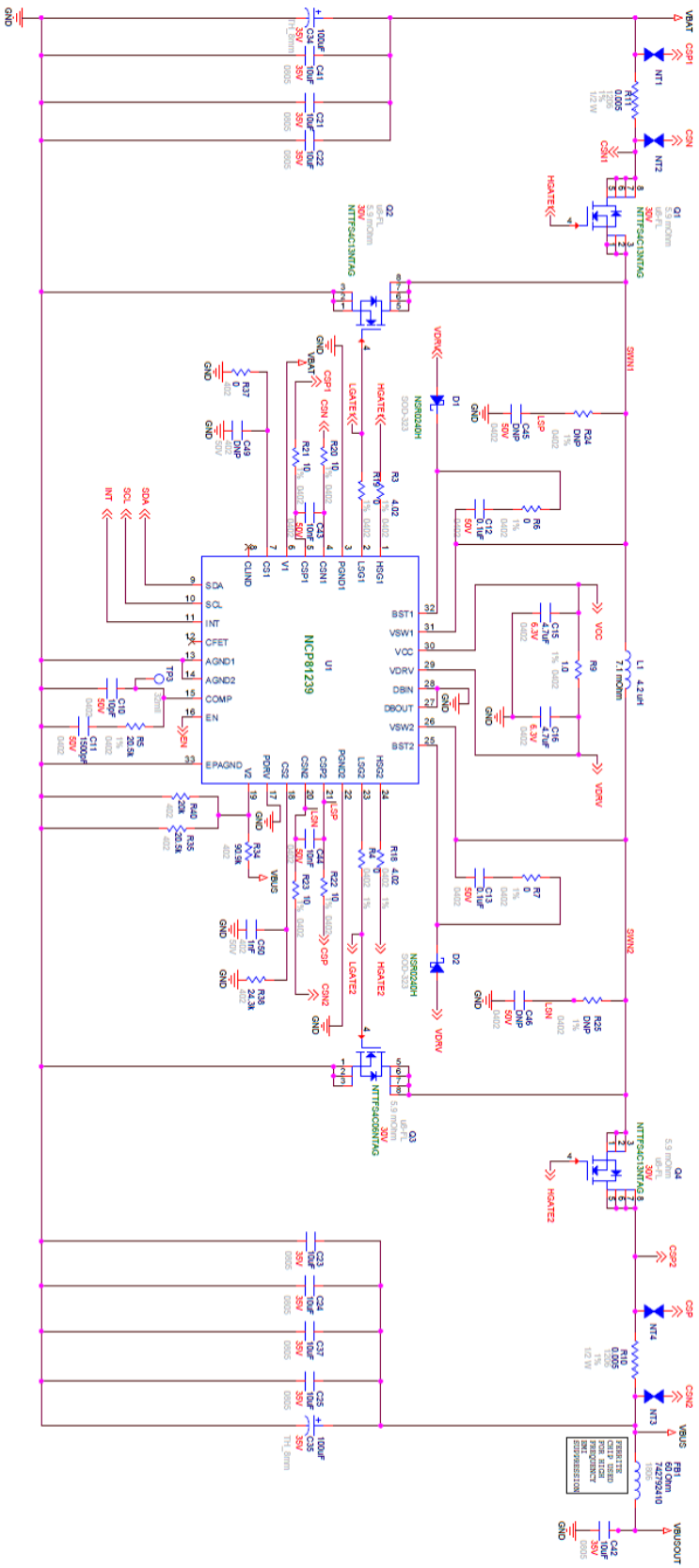

Figure 2. NCP81239 Buck-Boost Schematic

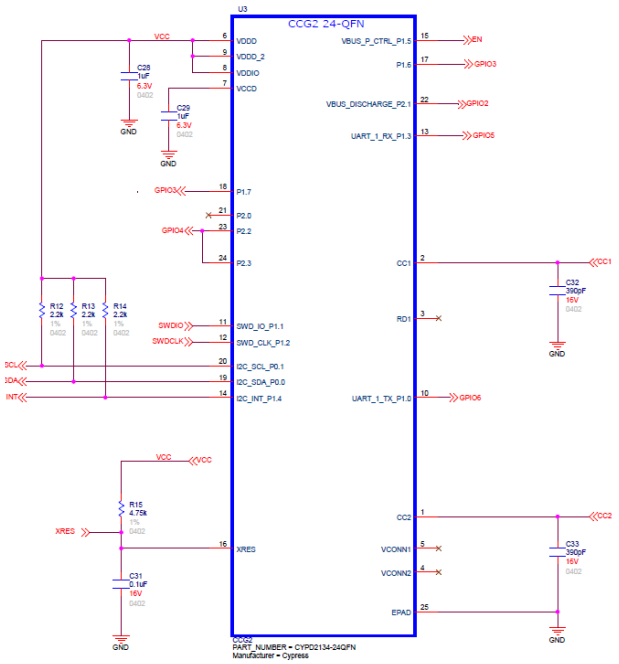

Figure 3. CCG2 QFN24 Package

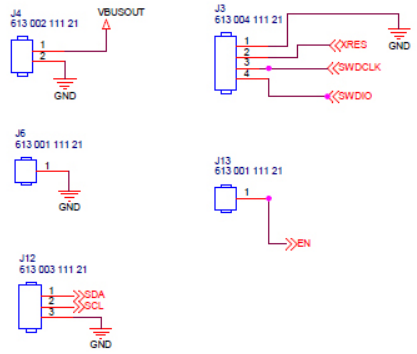

Figure 4. Connection Test Points

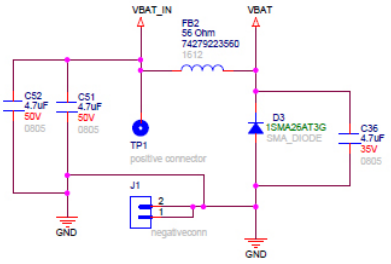

Figure 5. Input Protection Circuit

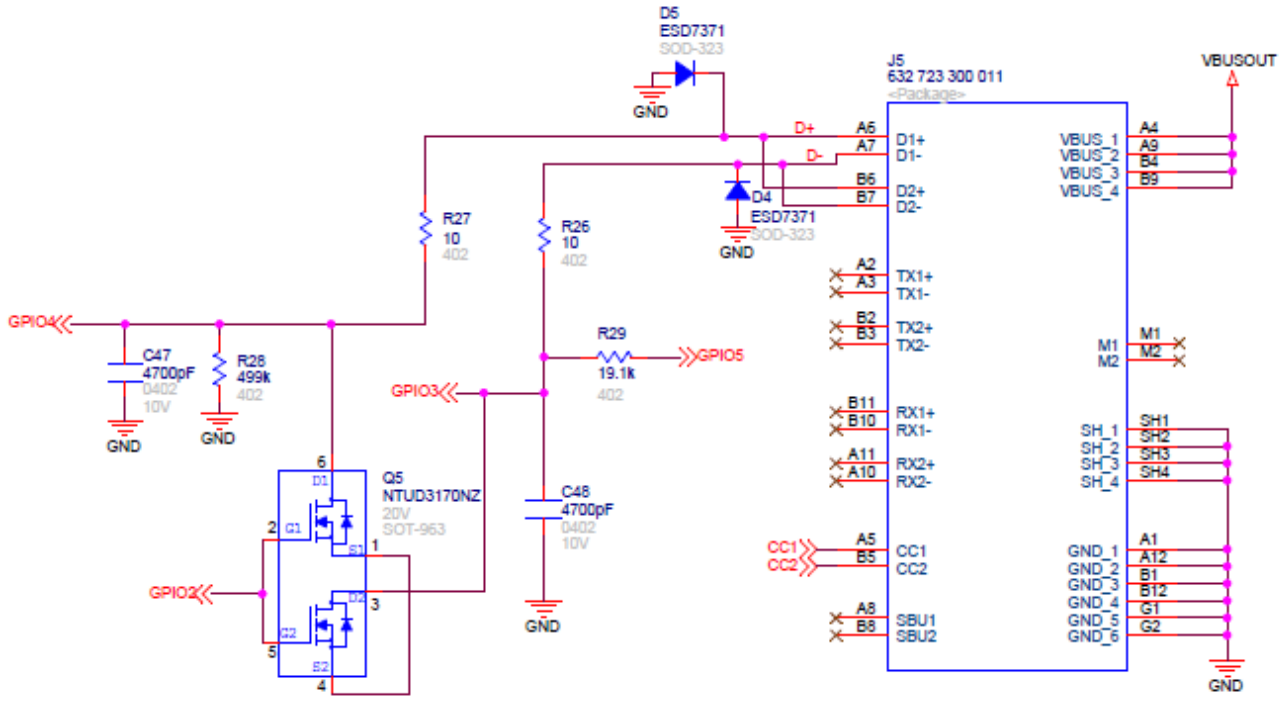

Figure 6. Type-C Receptacle and QC3.0/BC1.2 Implementation

Board Layout

Top Layer

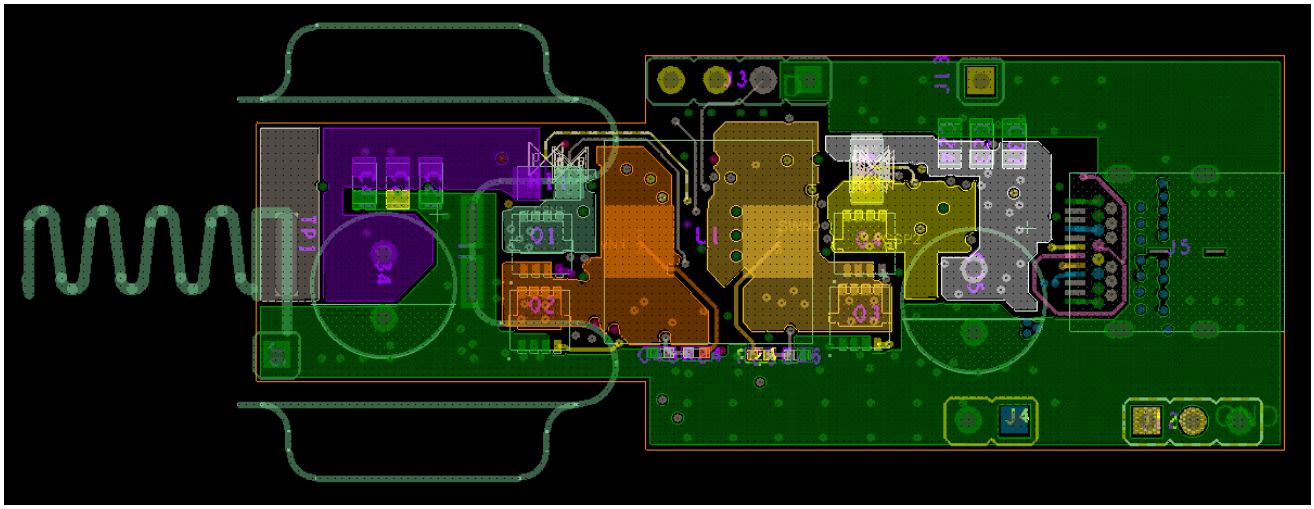

Figure 7. Top Layer

Bottom Layer

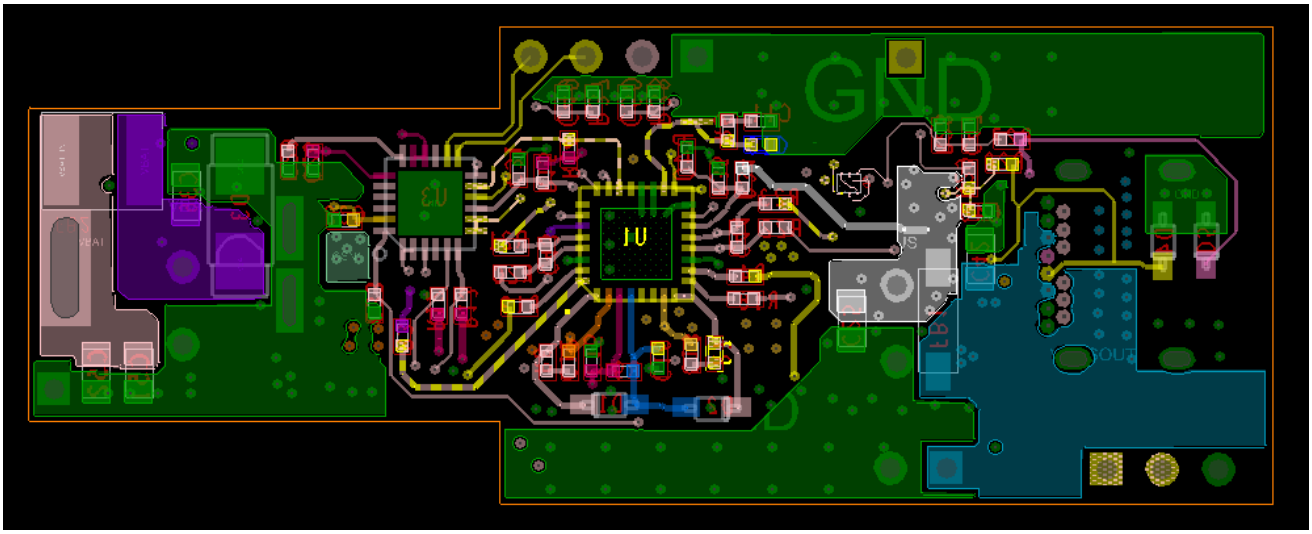

Figure 8. Bottom Layer

Performance Summary

V-I Curve

Below is a graph of output voltage vs. load current for each of the USB-PD profiles 5 V, 7 V, 8 V, 9 V, 12 V, 15 V, and 20 V. This shows that the output voltage is held constant until the load reaches approximately 125% of the rated current of 3 A. At the heavy load, the design will enter a hiccup mode, where it tries to restart every 1.2 seconds. When it does power-up, it returns to 5 V.

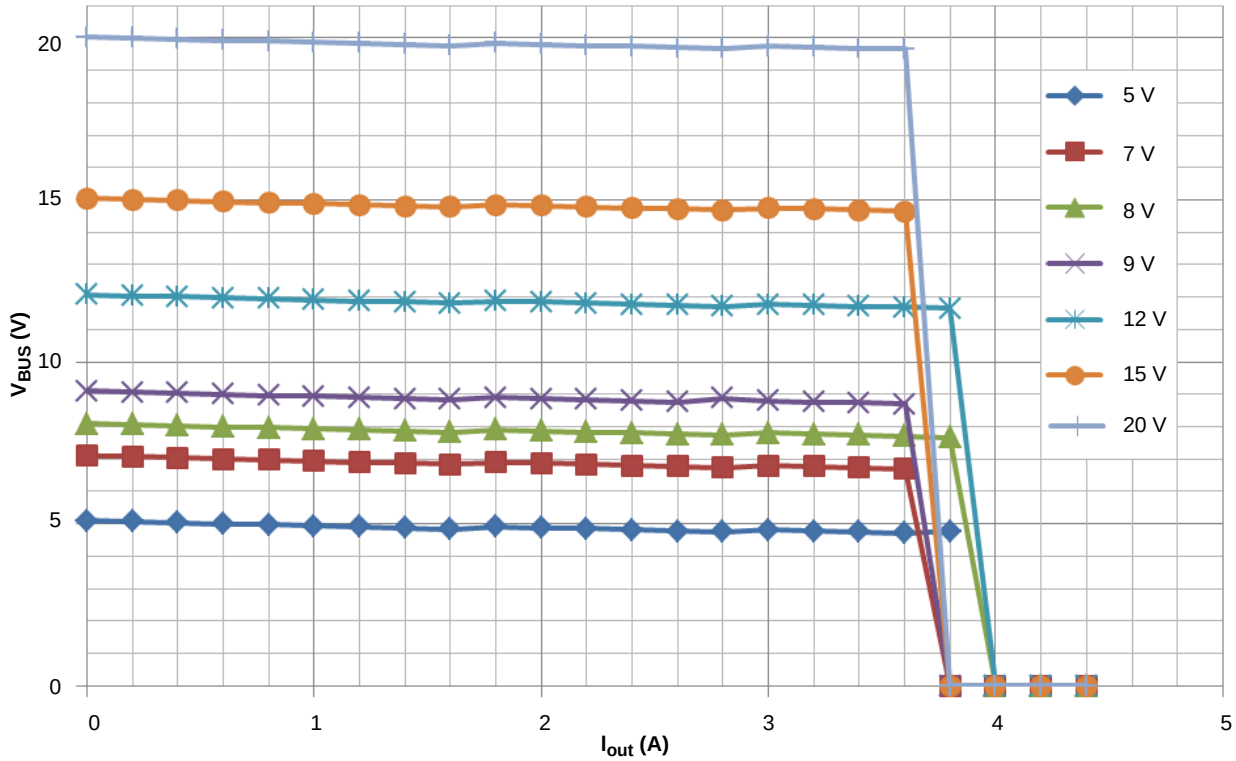

Figure 9. V-I Curve for USB-PB Profiles

Efficiency vs Load Current at 12 Vin

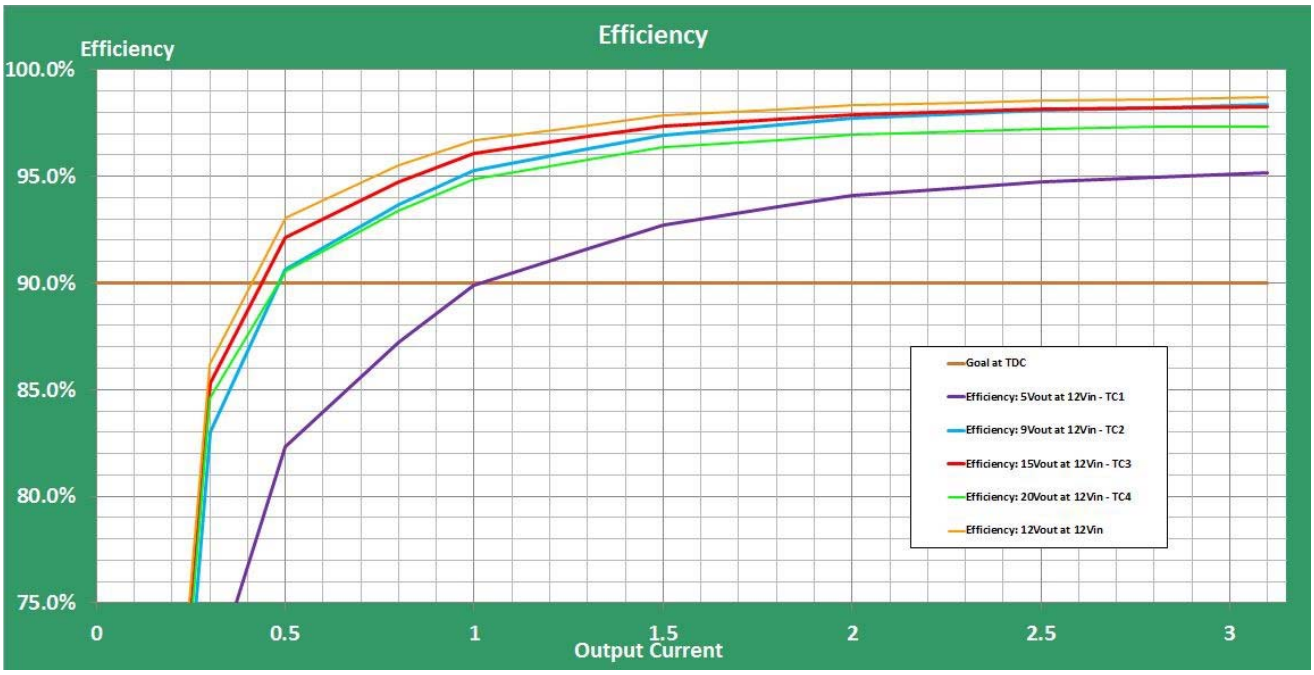

Figure 10. Efficiency vs Load Current at 12 Vin Graph

Table 2. EFFICIENCY VS LOAD CURRENT RESULTS TABLE

Results Summary					
	5 V Out at 12 V In − TC1	**9 V Out at 12 V In − TC 2**	**15 V Out at 12 V In − TC 3**	**20 V Out at 12 V In − TC 4**	**12 V Out at 12 V In**
Efficiency at TDC − POWERTRAIN	94.9%	98.2%	98.2%	97.2%	98.6%
Peak Efficiency − POWERTRAIN	95.2%	98.3%	98.2%	97.3%	98.7%
VR Power Loss at TDC	0.8 W	0.5 W	0.8 W	1.5 W	0.5 W

Thermal Measurements

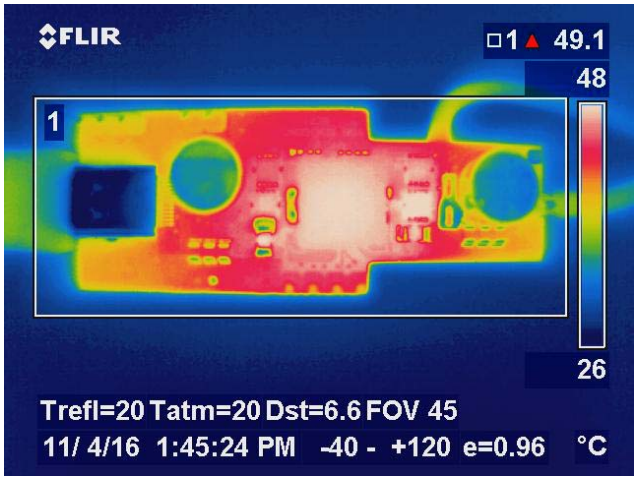

Figure 11. Thermal Measurements at 12 Vin, 5 Vout, 3 A (15 W)

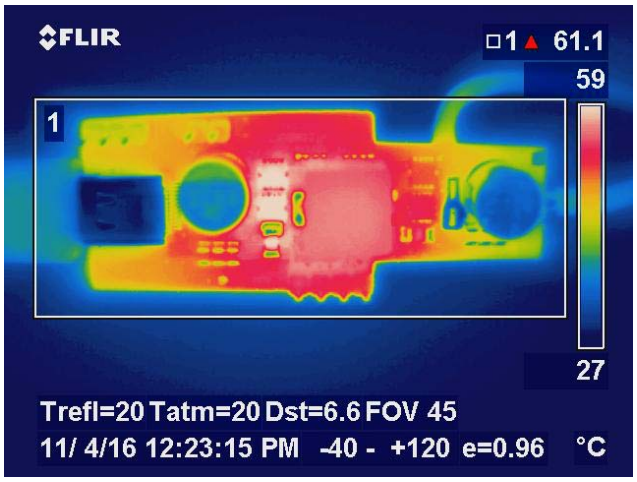

Figure 12. Thermal Measurements at 12 Vin, 15 Vout, 3 A (45 W)

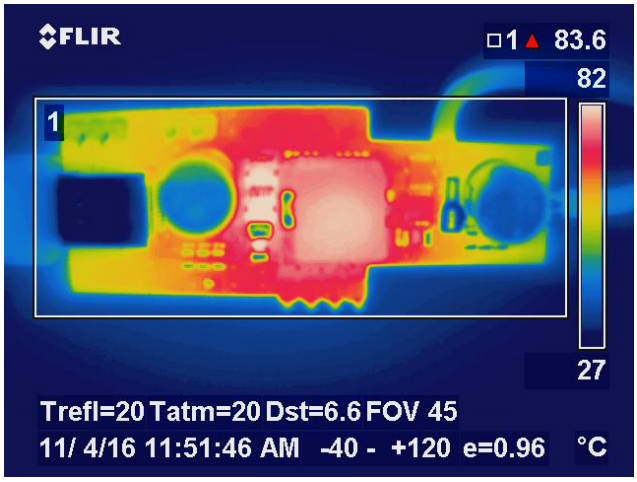

Figure 13. Thermal Measurements at 12 Vin, 20 Vout, 3 A (60 W)

Startup and Shutdown Timings

Startup and shutdown timings are shown below. These are initiated by driving the Enable pin high and low, respectively. By default the NCP81239 starts up at 5 V. Enable and Disable are controlled by CYPD2134 in the application. The waveforms are shown here for reference only. When Enable goes low, the NCP81239 controls the output voltage so that it decays linearly to 0 V. It is required that a USB-PD adapter discharge VBUS to 800 mV or less in 650 ms following a detach event.

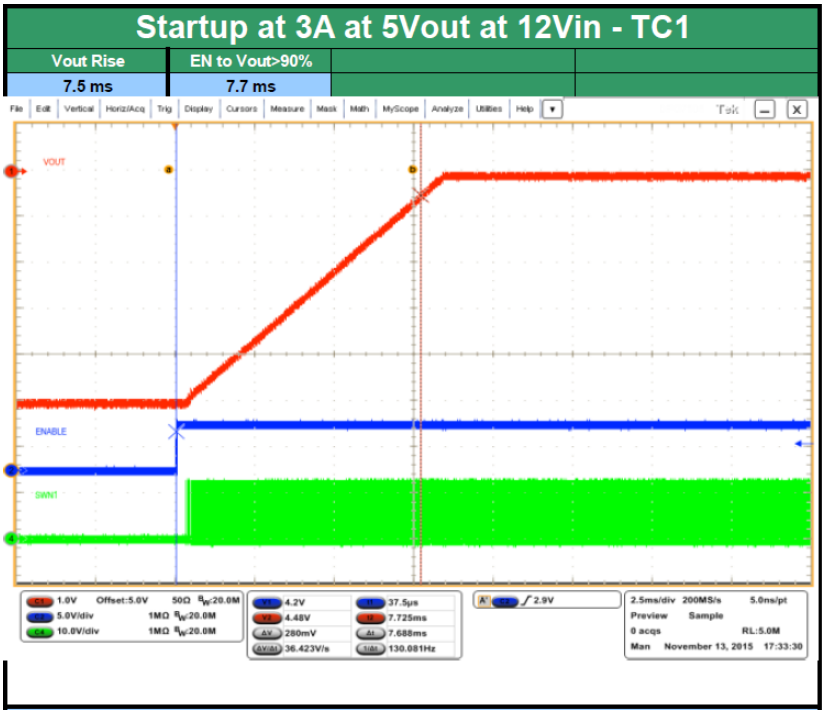

Figure 14. Startup at 3 A, 5 Vout, 12 V In Waveform

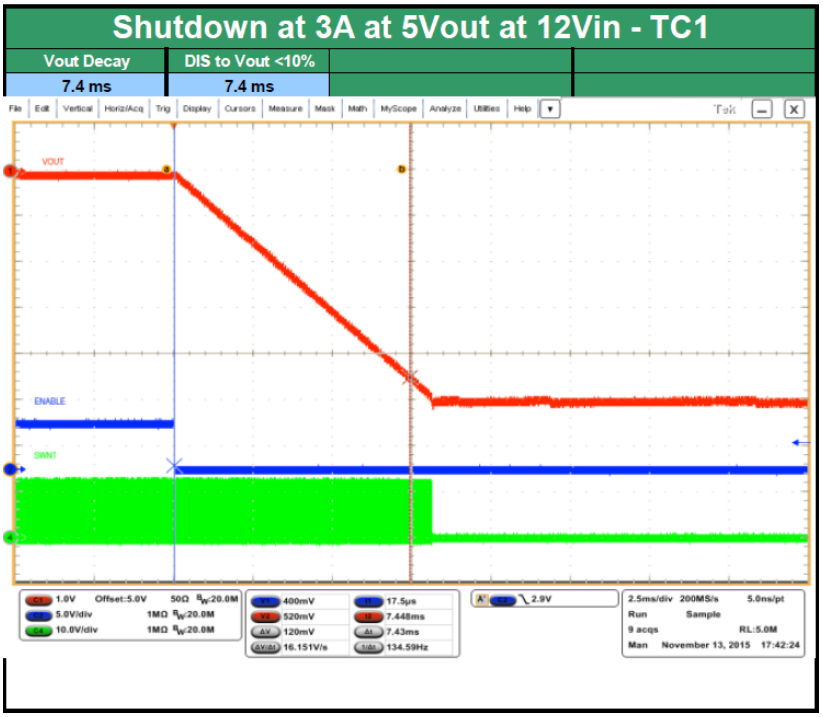

Figure 15. Shutdown at 3 A, 5 Vout, 12 V In Waveform

USB-PD Voltage Profile Transitions

After the reference design is powered and is plugged into a device, it will provide 5 V. From here, the device can request a higher voltage profile. Below is an example of a transition from 5 V to 20 V. The output (VBUS) rises linearly with a slew rate which can be programmed over the I^2C interface. In the image below, it can also be noted that the controller has a very smooth transition between buck and boost mode.

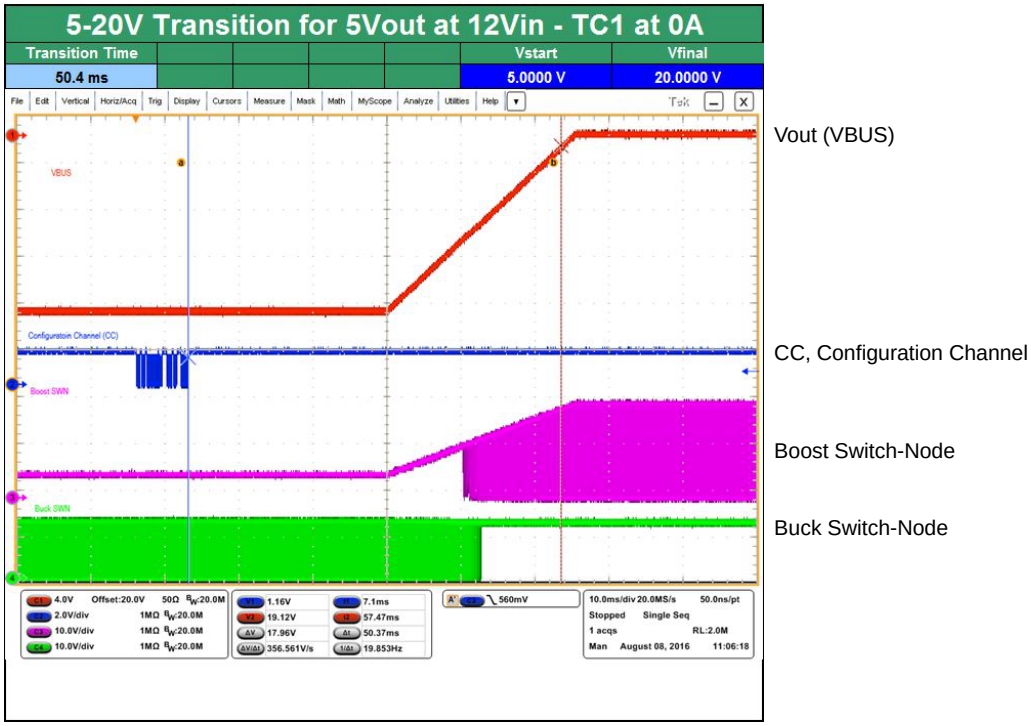

Figure 16. Transition Waveform from 5 V − 20 V

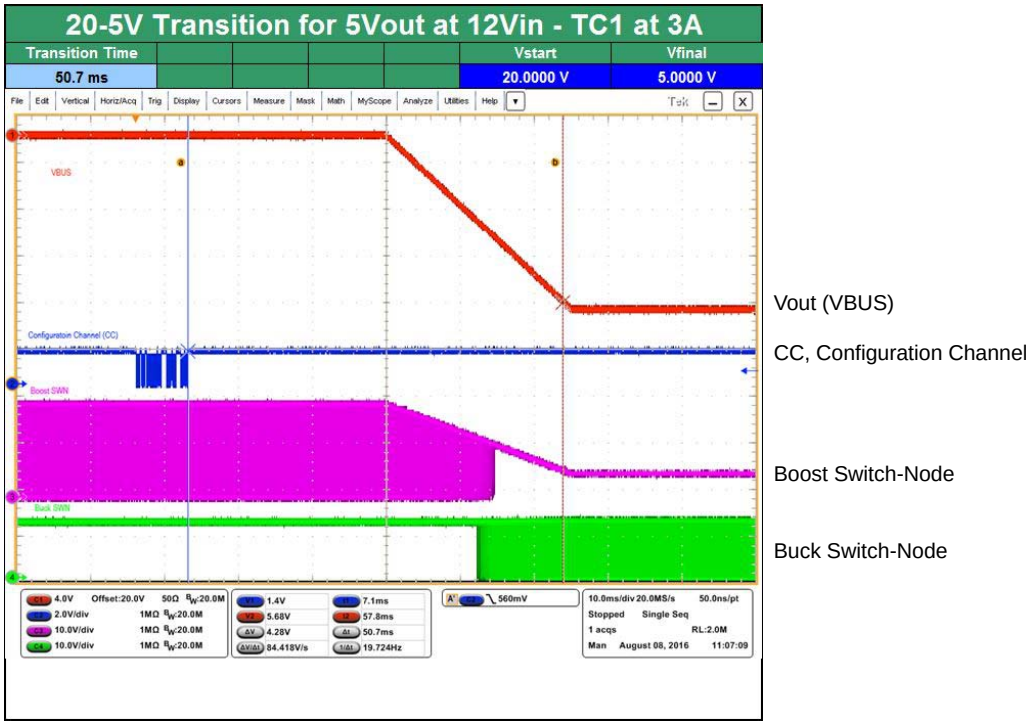

Figure 17. Transition Waveform from 20 V − 5 V

Qualcomm Quick Charge Modes

If a device with a Qualcomm processor is plugged into the reference design, the adapter will enter QC2.0 or QC3.0 mode. In QC3.0 mode the adapter will translate pulses on DPLUS into an increment on VBUS of 200 mV. It will translate pulses on DMINUS into a decrement on VBUS of 200 mV. In QC2.0 mode, the output voltage follows the table below.

Table 3. QUALCOMM HIGH VOLTAGE DEDICATED CHARGING PORT (HVDCP) TABLE

Portable Device		Adapter
DPLUS	**DMINUS**	**Output Voltage**
0.6 V	0.6 V	12 V
3.3 V	0.6 V	9 V
0.6 V	3.3 V	QC3.0
3.3 V	3.3 V	20 V
0.6 V	GND	5 V

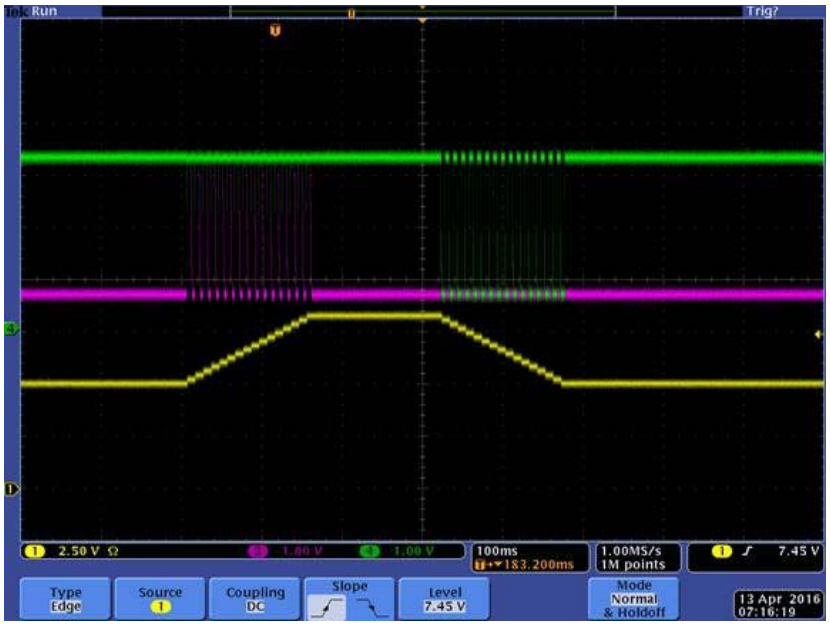

Figure 18. QC3.0 Voltage Increment and Decrement Waveform

Cable Compensation

The USB-PD specification requires that VBUS must be regulated to ±5% of the target profile, except at 5 V where it must be between 4.75 V and 5.5 V. The USB-PD specification also allows for up to 500 mV of drop across a USB-C to USB-C cable. In order to keep VBUS within these limits, cable compensation was implemented on this design. When the current is greater than 1.6 A and less than 2.8 A, the output voltage is increased by 100 mV. When the output current is greater than 2.8 A, the output voltage is increased by another 100 mV. Below is a plot of the output voltage vs. load current on both sides of a 1 meter USB-C to USB-C cable.

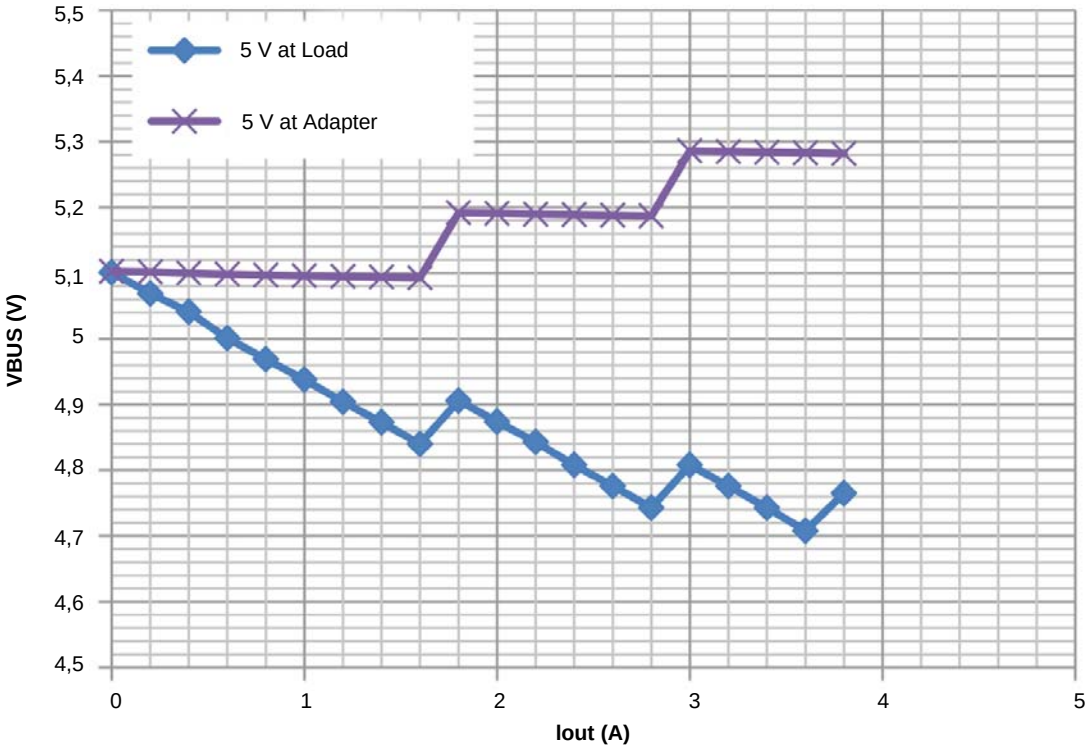

Figure 19. VBUS at Adapter and VBUS at the Load Graph

Bill of Materials (BOM)

Table 4. BILL OF MATERIALS (Note 1)

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed
U1	1	USB POWER DELIVERY 4-SWITCH BUCK/BOOST			32QFN	ON Semiconductor	NCP81239	No
Q1,2,4	3	MOSFET N-CH 30 V 38 A U8FL	14 mΩ		u8-FL	ON Semiconductor	NTTFS4C13N	No
Q3	1	MOSFET N-CH 30 V 65 A U8FL	6.1 mΩ		u8-FL	ON Semiconductor	NTTFS4C06N	No
L1	1	4.2UH SHIELDED WIREWOUND INDUCTOR 11 A 7.1 mΩ	4.2 μH	20%	10x10x5mm	Wurth Elektronic	744 325 420	No
C23,24,25,37,42	5	CAP CER 10 μF 35 V X5R 0805	10 μF	10%	0805	muRata	GRM21BR6YA106KE43L	Yes
C35	1	CAP ALUM POLY 100 μF 20% 35 V T/H	100 μF	20%	RTH 8 mm	Nichicon	RL81V101MDN1KX	Yes
C21,22,41	3	CAP CER 10μF 35 V X5R 0805	10 μF	10%	0805	muRata	GRM21BR6YA106KE43L	Yes
C34	1	CAP ALUM POLY 100 μF 20% 35 V T/H	100 μF	20%	RTH 8 mm	Nichicon	RL81V101MDN1KX	Yes
FB1	1	FERRITE BEAD 60 Ω 1806 1 LN	60 Ω		1806	Wurth Elektronic	742 792 410	Yes
R6,7	2	RES SMD 0.0 Ω JUMPER 1/16 W 0402	0 Ω	Jumper	402	Vishay Dale	CRCW04020000Z0ED	Yes
C12,13	2	CAP CER 0.1 μF 50 V X5R 0402	0.1 μF	10%	0402	muRata	GRM155R61H104KE19D	Yes
C15,16	2	CAP CER 4.7 μF 6.3 V X5R 0402	4.7 μF	20%	0402	Wurth Elektronic	885 012 105 008	Yes
R9	1	RES SMD 1 Ω 1% 1/16 W 0402	1 Ω	1%	0402	Vishay Dale	CRCW04021R00FKED	Yes
D1,2	2	DIODE SCHOTTKY 40 V 250 MA SOD323			SOD−323	ON Semiconductor	NSR0240H	No
R3,18	2	RES SMD 4.02 Ω 1% 1/16 W 0402	4.02 Ω	1%	0402	Vishay Dale	CRCW04024R02FKED	Yes
R4,19	2	RES SMD 0.0 Ω JUMPER 1/16W 0402	0 Ω	Jumper	0402	Vishay Dale	CRCW04020000Z0ED	Yes
C10	1	CAP CER 10 PF 50 V NP0 0402	10 pF	5%	0402	Wurth Elektronic	885 012 005 055	Yes
C11	1	CAP CER 1500PF 50 V X7R 0402	1500 pF	10%	0402	Wurth Elektronic	885 012 205 062	Yes
R5	1	RES SMD 20.5 kΩ 1% 1/16 W 0402	20.5 kΩ	1%	0402	Vishay Dale	CRCW040220K5FKED	Yes
R10,11	2	RES SMD 0.005 Ω 1% 1/2 W 1206	5 mΩ	1%	1206	Vishay Dale	WSL12065L000FEA18	Yes
C43,44	2	CAP CER 10000 PF 50 V X7R 0402	10 nF	10%	0402	Wurth Elektronic	885 012 205 067	Yes
R20,21,22,23	4	RES SMD 10 Ω 1% 1/16 W 0402	10 Ω	1%	0402	Vishay Dale	CRCW040210R0FKED	Yes
FB2	1	FERRITE BEAD 56 Ω 1612 1LN	56 Ω		1612	Wurth Elektronic	742 792 235 60	Yes
C36,51,52	3	CAP CER 4.7 μF 50 V X5R 0805	4.7 μF	10%	0805	muRata	GRM21BR61H475KE51L	Yes
D3	1	TVS DIODE 26 VWM 42.1 VC SMA			SMA	ON Semiconductor	1SMA26AT3G	No
Q5	1	DUAL MOSFET 2N-CH 20 V 0.22 A SOT−963			SOT−963	ON Semiconductor	NTUD3170NZ	No
U3	1	IC MCU 32 BIT 32 KB FLASH 24 QFN			24QFN	Cypress Semiconductor	CYPD2134−24QFN	No
C28,29	2	CAP CER 1 μF 6.3 V X5R 0402	1 μF	20%	0402	Wurth Elektronic	885 012 105 006	Yes
R15	1	RES SMD 4.75 kΩ 1% 1/16 W 0402	4.75 kΩ	1%	0402	Vishay Dale	CRCW04024K75FKED	Yes
C32,33	2	CAP CER 330 PF 25 V X7R 0402	330 pF	10%	0402	Wurth Elektronic	885 012 205 041	Yes
C31	1	CAP CER 0.1 μF 16 V X7R 0402	0.1 μF	10%	0402	Wurth Elektronic	885 012 205 037	Yes
R24,25	0		DNP		0402			
C45,46	0		DNP		0402		DNP	
R12,13,14	3	RES SMD 2.2 kΩ 1% 1/16 W 0402	2.2 kΩ	1%	0402	Vishay Dale	CRCW04022K20FKED	Yes
J12	1	CONN HEADER 3 POS 2.54			−	Wurth Elektronic	613 003 111 21	Yes
J3	1	CONN HEADER 4 POS 2.54			−	Wurth Elektronic	613 004 111 21	Yes
J4	1	CONN HEADER 3 POS 2.54			−	Wurth Elektronic	613 002 111 21	Yes
J5	1	USB TYPE-C RECEPTACLE			−	Wurth Elektronic	632 723 300 011	Yes
R28	1	RES SMD 499 kΩ 1% 1/16 W 0402	499 kΩ	1%	0402	Vishay Dale	CRCW0402499KFKED	Yes
R26,27	2	RES SMD 10 Ω 1% 1/16 W 0402	10 Ω	1%	0402	Vishay Dale	CRCW040210R0FKED	Yes
R29	1	RES SMD 19.1 kΩ 1% 1/16 W 0402	19.1 kΩ	1%	0402	Vishay Dale	CRCW040219K1FKED	Yes
D4,5	2	TVS DIODE 5.3 VWM SOD−323			SOD−323	ON Semiconductor	ESD7371HT1G	No
R34	1	RES SMD 90.9 kΩ 1% 1/16 W 0402	90.9 kΩ	1%	0402	Vishay Dale	CRCW040290K9FKED	Yes
R40	1	RES SMD 20 kΩ 1% 1/16 W 0402	20 kΩ	1%	0402	Vishay Dale	CRCW040220K0FKED	Yes
R35	1	RES SMD 20.5 kΩ 1% 1/16 W 0402	20.5 kΩ	1%	0402	Vishay Dale	CRCW04220K5FKED	Yes
R37	1	RES SMD 0.0 Ω JUMPER 1/16 W 0402	0	Jumper	0402	Vishay Dale	CRCW04020000Z0ED	Yes
R38	1	RES SMD 24.3 kΩ 1% 1/16 W 0402	24.3 kΩ	1%	0402	Vishay Dale	CRCW040224K3FKED	Yes
C49	0		DNP		0402			
C50	1	CAP CER 1000 PF 50 V X7R 0402	1 nF	10%	0402	Wurth Elektronic	885 012 205 061	Yes
C47,48	2	CAP CER 4700 PF 10 V X7R 0402	4700 pF	10%	0402	Wurth Elektronic	885 012 205 010	Yes

1. All parts are Pb-Free

Cypress is a registered trademark of Cypress Semiconductor Corporation. Qualcomm is a registered trademark of Qualcomm Incorporated. Samsung is a trademark of Samsung in the United States or other countries. USB is a trademark of USB Implementers Forum, Inc. All other brand names and product names appearing in this document are trademarks of their respective holders

ON Semiconductor and ON are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative