User's Guide

Using the UCC28782EVM-030 65-W USB-C PD High-Density Active-Clamp Flyback Converter

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1 Using the UCC28782EVM-030 65-W USB-C PD High-Density Active-Clamp Flyback Converter

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Trademarks

All other trademarks are the property of their respective owners.

2 General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

WARNING

Always follow TI's setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

> **WARNING**
>
> Failure to follow warnings and instructions may result in personal injury, property damage or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is *intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments.* If you are not suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety
   a. Keep work area clean and orderly.
   b. Qualified observer(s) must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and nonconductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety
   As a precautionary measure, it is always a good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   a. De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   b. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment connection, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   c. After EVM readiness is complete, energize the EVM as intended.

> **WARNING**
>
> While the EVM is energized, never touch the EVM or its electrical circuits, as they could be at high voltages capable of causing electrical shock hazard.

3. Personal Safety
   a. Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks to protect from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

3 Description

The UCC28782EVM-030 is a 65-W USB-C PD evaluation module (EVM) for evaluating an off-line active-clamp flyback adapter for notebook charging and other applications. The EVM meets CoC Tier 2 and DoE Level 6 efficiency requirements. It is intended for evaluation purposes and is not intended to be an end product. The UCC28782EVM-030 converts input voltage of 90-V_{RMS} to 264-V_{RMS} down to USB-C PD selectable output voltage 20-V_{DC}, with a max 3.25-A, and to 5-V_{DC}, 9-V_{DC}, and 15-V_{DC}, with a max 3.00-A output current rating and a 160-ms limit for over-power capability. The main devices used in this design are active clamp flyback controller UCC28782 and GaN MOSFETs. Please read this user's guide thoroughly before applying power to this board.

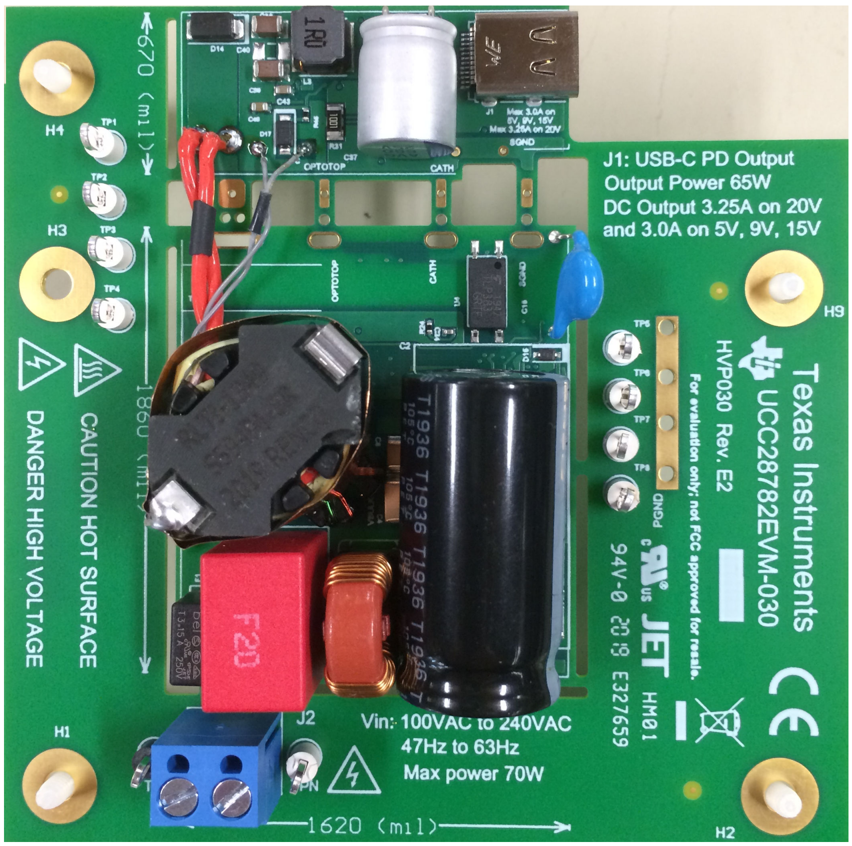

Figure 3-1. UCC28782EVM-030 top View

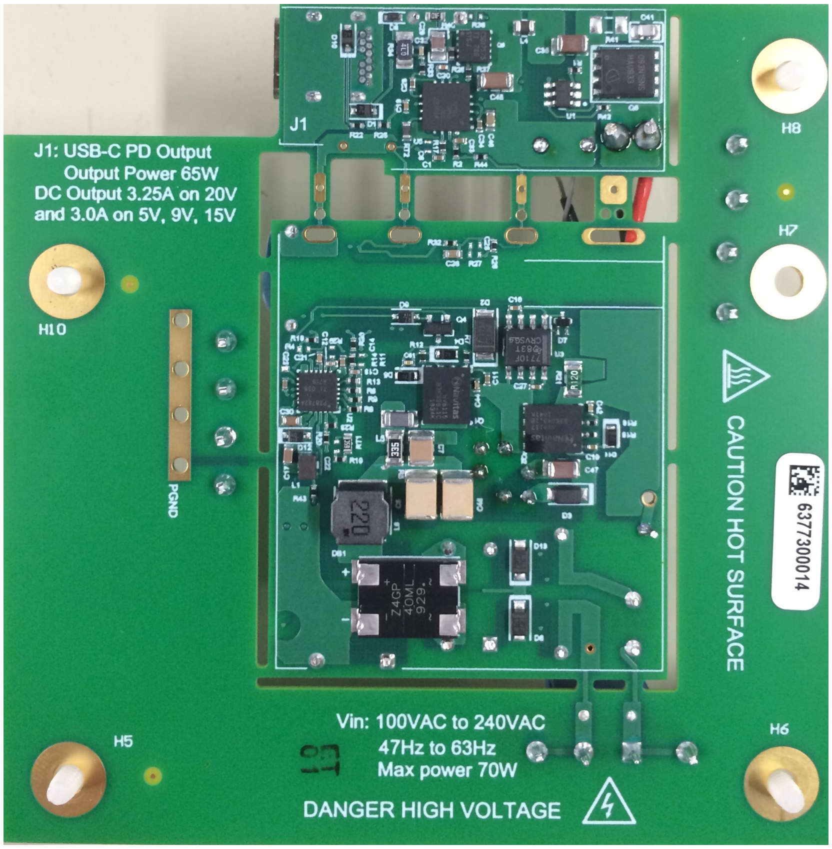

Figure 3-2. UCC28782EVM-030 bottom View

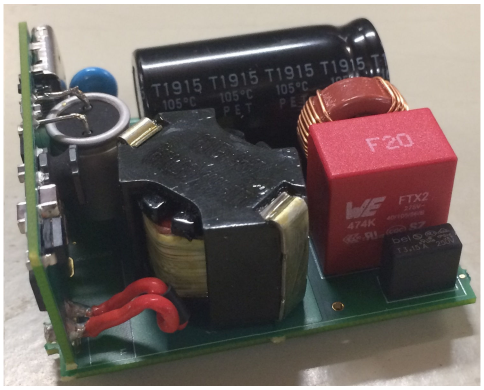

Figure 3-3. High-Density Configuration

4 Electrical Performance Specifications

Table 4-1. UCC28782EVM-030 Electrical Performance Specifications [(2)]

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
INPUT CHARACTERISTICS						
V_{IN}	Input line voltage (RMS)		90	115 / 230	264	V
f_{LINE}	Input line frequency		47	50 / 60	63	Hz
P_{STBY}	Input power at no-load	V_{IN} = 115/230 V_{RMS}, I_{OUT} = 0 A		45 / 55		mW
$P_{0.25W}$	Input power at 0.25W load	V_{IN} = 115/230 V_{RMS}, P_{OUT} = 250 mW		359 / 399		mW
OUTPUT CHARACTERISTICS						
V_{OUT}	Output voltage (USB-C PD) V_{IN} = 90 to 264 V_{RMS}	I_{OUT} = 0 to 3.25 A		19.950		V
		I_{OUT} = 0 to 3.00 A		15.060		
				9.050		
				5.050		
I_{OUT}	Full load rated output current V_{IN} = 90 to 264 V_{RMS}	V_{OUT} = 20.0 V		3.250		A
		V_{OUT} = 5.0, 9.0, or 15.0 V		3.000		
V_{OUT_pp}	Output ripple voltage V_{IN} = 115 V / 230 V_{RMS}	V_{OUT} = 20.0 V, I_{OUT} = 0 to 3.25 A		150		mVpp
		V_{OUT} = 15.0 V, I_{OUT} = 0 to 3.00 A		150		
		V_{OUT} = 9.0 V, I_{OUT} = 0 to 3.00 A		150		
		V_{OUT} = 5.0 V, I_{OUT} = 0 to 3.00 A		150		
V_{OUT_Δ}	Output voltage deviation due to load step Up / Down (I_{OUT} step change between 0 and 100% load at 100 Hz rate)	V_{OUT} = 20.0 V		-604 / 340		mVpp
		V_{OUT} = 15.0 V		-584 / 360		
		V_{OUT} = 9.0 V		-404 / 304		
		V_{OUT} = 5.0 V		-404 / 304		
P_{OUT_opp}	Over-power protection threshold	V_{IN} = 90 to 264 V_{RMS}		70		W
SYSTEMS CHARACTERISTICS						
η	Full-load efficiency (V_{IN}= 115/230V_{RMS})	V_{OUT} = 20 V, I_{OUT} = 3.25A		94.2 / 94.2		%
		V_{OUT} = 15 V, I_{OUT} = 3.00A		94.2 / 93.7		
		V_{OUT} = 9 V, I_{OUT} = 3.00A		93.5 / 93.0		
		V_{OUT} = 5 V, I_{OUT} = 3.00A		91.9 / 90.8		
η	4-point average efficiency[(1)] V_{IN}= 115/230 V_{RMS}	V_{OUT} = 20 V (CoC Tier 2, 89.0%)		93.4 / 92.4		%
		V_{OUT} = 15 V (CoC Tier 2, 88.9%)		93.1 / 91.7		
		V_{OUT} = 9 V (CoC Tier 2, 87.3%)		90.9 / 88.6		
		V_{OUT} = 5 V (CoC Tier 2, 81.8%)		88.0 / 84.1		
η	Efficiency at 10% Load V_{IN}= 115/230 V_{RMS}	V_{OUT} = 20 V (CoC Tier 2, 79.0%)		89.0 / 83.8		%
		V_{OUT} = 15 V (CoC Tier 2, 78.9%)		87.9 / 82.6		
		V_{OUT} = 9 V (CoC Tier 2, 77.3%)		85.8 / 79.8		
		V_{OUT} = 5 V (CoC Tier 2, 72.5%)		82.0 / 76.8		
T_{AMB}	Ambient operating temperature range	V_{IN} = 90 to 264 V_{RMS}, I_{OUT} = 0 to 3.00A (5V/9V/15V), or 3.25A (20V)		25		°C

(1) Average efficiency of four load points, I_{OUT} = 100%, 75%, 50% and 25% of rated full-load current for each respective output voltage.
(2) The performance listed in this table is achieved using secondary resonance and based on the test results from a single board.

5 Schematic Diagram

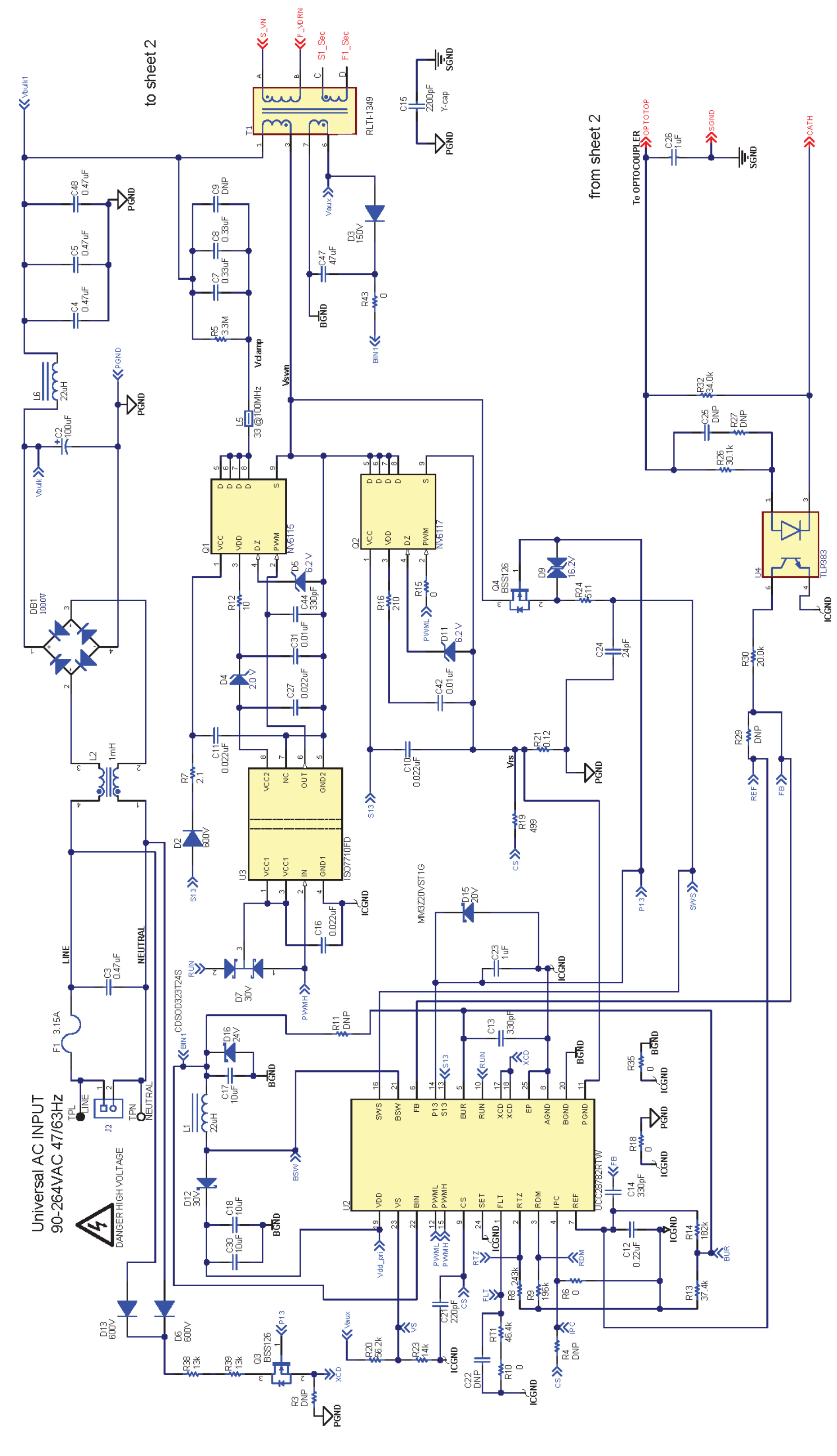

Figure 5-1. UCC28782EVM-030 Schematic Diagram (1 of 2)

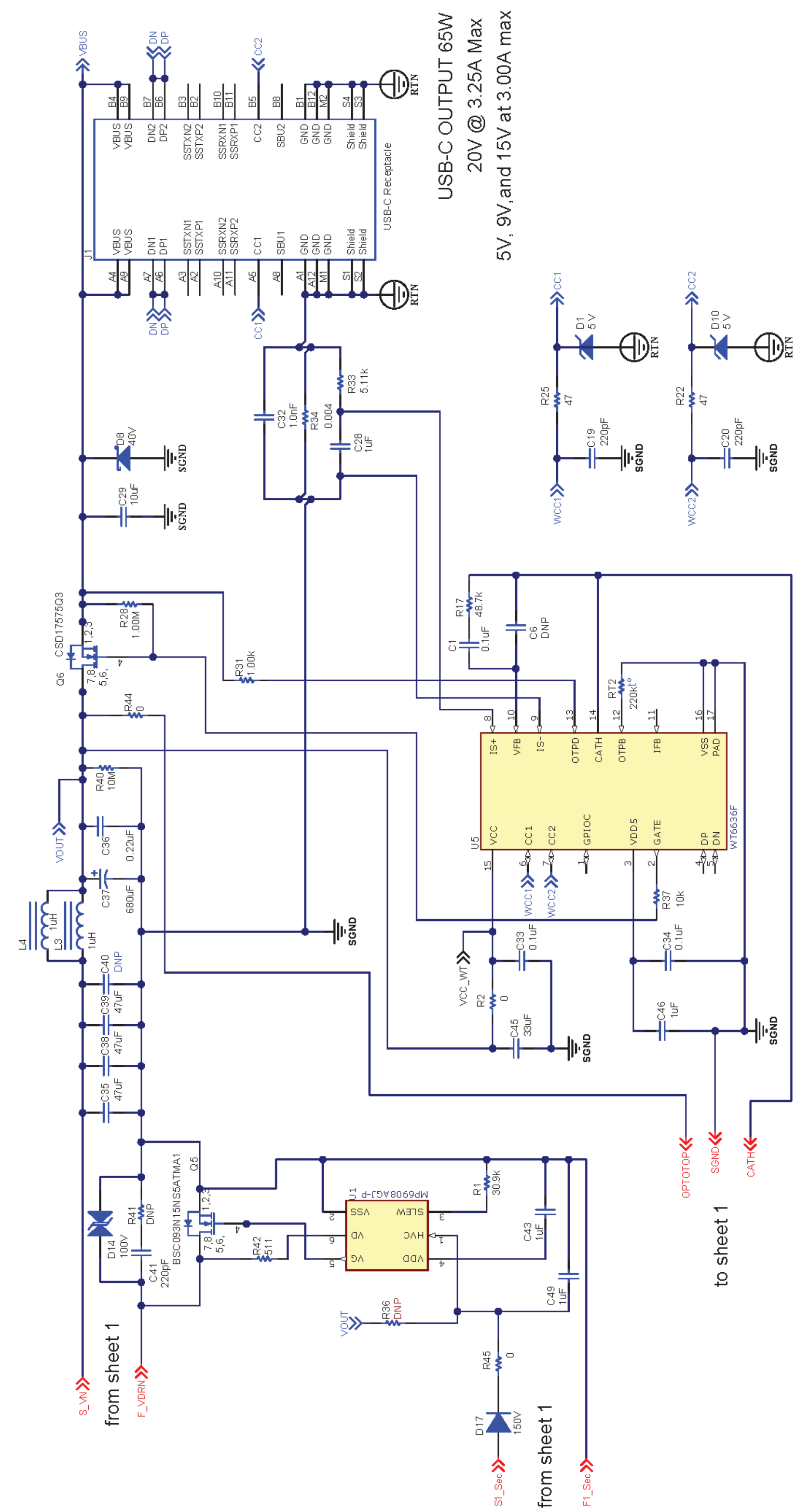

Figure 5-2. UCC28782EVM-030 Schematic Diagram (2 of 2)

6 Description

6.1 Typical Application

- USB-C PD Power Adapters
- USB-C PPS Power Adapters
- AC-to-DC or DC-to-DC auxiliary power supplies
- High-density AC-to-DC converters / Adapters for notebook computers, tablet computers, TV, and set-top box

6.2 Using the EVM on a Load with USB-C PD Communication

UCC28782EVM-030 comes populated with USB-C PD controller (WT6636F) and requires external connection through an on-board USB-C connector to a USB-C PD load so to adjust the board output to obtain 5-V, 9-V, 15-V or 20-V. A USB-C PD communicating load is required in order to make the board evaluation. An example of such a load is PM110, USB Power Delivery Tester, and PassMark Software. Without such a communication load, the board output USB-C connector (J1) does not provide output voltage. Besides, to get full load current 3.00-A from 5-V, 9-V and 15-V, a USB-C cable without E-mark may be used, but to get 3.25-A at 20-V output, an E-mark USB-C cable has to be used. In case the EVM is desired to test on a load without USB-C PD communication, the next section describes how to modify the board to make test.

•

6.3 Using the EVM on a Load without USB-C PD Communication

Normally, a USB-C PD communicated load is required in order to make evaluation. Without such a USB-C PD communication-based load, the board does not provide output voltage on USB-C (J1) connector. In such a case, the board output voltage can be obtained from C37 but only 5-V and up to 3.00-A can be obtained.

7 Test Setup

7.1 Test Setup Requirements

Safety: This evaluation module is not encapsulated and there are accessible voltages that are greater than 50 V_{DC}.

Isolation Input Transformer: A suitably rated 1:1 isolation transformer shall be used on the input(s) to this EVM and be constructed in a manner in which the primary winding(s) are separated from the secondary winding(s) by reinforced insulation, double insulation, or a screen connected to the protective conductor terminal.

WARNING

- If you are not trained in the proper safety of handling and testing power electronics please do not test this evaluation module.
- While the EVM is energized, never touch the EVM or its electrical circuits, as they could be at high voltages capable of causing electrical shock hazard.
- Caution Hot surface. Contact may cause burns. Do not touch!
- Read this user's guide thoroughly before making test.

Voltage Source: Isolated AC source or variable AC transformer capable of 264 V_{RMS} and capable of handling 100 W power level. **Warning: Do not apply DC voltage to this board when making test, or damage may happen**. If DC voltage source has to be used, the XCD pins need to be grounded by adding R3 = 0 Ω and removing Q3.

Voltmeter: Digital voltage meter

Power Analyzer: Capable of measuring 1 mW to 100 W of input power and capable of handling 264-V_{RMS} input voltage. Some power analyzers may require a precision shunt resistor for measuring input current to measure input power of 5 W or less. Please read the power analyzer's user manual for proper measurement setups for full power and for stand-by power.

Oscilloscope:
- 4-Channel, 500 MHz bandwidth.
- Probes capable of handling 600 V.

Output Load: Resistive or electronic load capable of handling 100 W at 20 V.

Recommended Wire Gauge: Insulated 22 AWG to 18 AWG.

WARNING

Caution: Do not leave EVM powered when unattended.

!! Do not apply DC voltage source to this board or damage may happen !! (See above setup of Voltage Source)

7.2 Test Setup Diagram

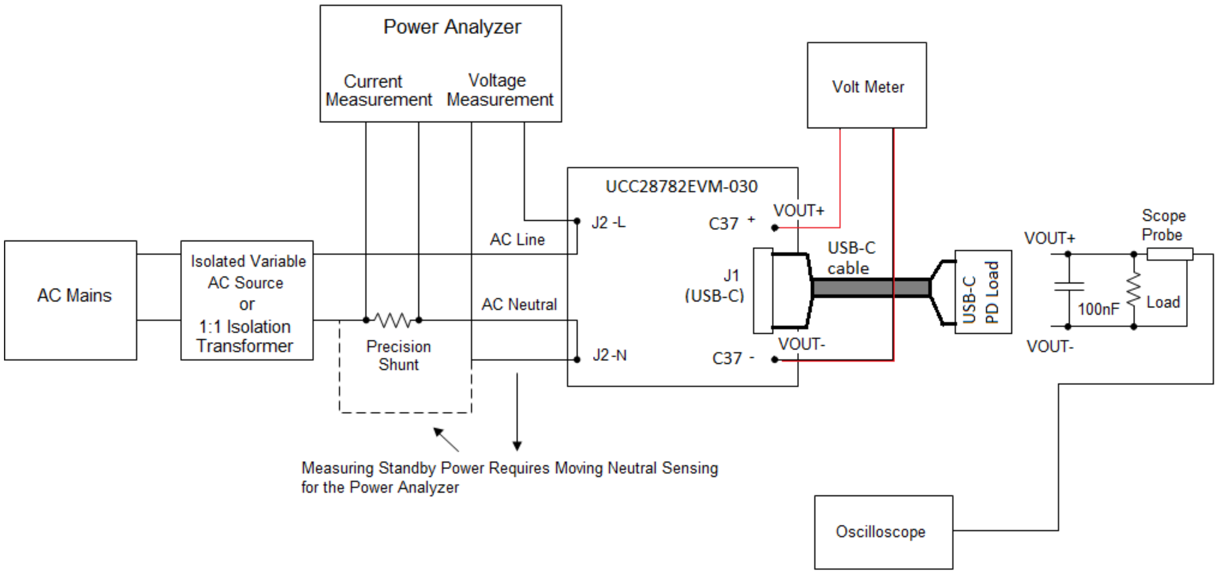

Figure 7-1. UCC28782EVM-030 Test Setup Diagram

7.3 Test Points

Table 7-1. Input / Output Terminals and Test Point Functions

Terminals and TEST POINTS		NAME	DESCRIPTION
J1	Location J1 Terminal	J1	USB-C
J2-L	Location J2 Terminal	L	AC voltage input - Line
J2-N		N	AC voltage input - Neutral
TPL	Input test points	TPL	AC input monitor - Line
TPN	Input test points	TPL	AC input monitor -Neutral
TP1 to TP4	Floating test points	TP1, TP2, TP3, TP4	Floating, need to solder connections, leave them floating if not used
TP5 to TP8	Floating test points	TP5, TP6, TP7, TP8	Floating, need to solder connections, leave them floating if not used

8 Performance Data and Typical Characteristic Curves

8.1 Efficiency Result of 4-Point Average on 20-Vout

Table 8-1. Efficiency Test Data on 20-Vout

V_{IN} (VRMS)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(%)	EFFICIENCY	EFFICIENCY 4pt-AVERAGE	Average Switching Frequency @ Full Load
90	69.693	20.010	3.250	100%	93.31%		150 kHz
90	52.107	20.010	2.440	75%	93.70%		
90	35.067	20.000	1.630	50%	92.96%		
90	17.583	20.000	0.810	25%	92.13%		
90	7.269	20.000	0.325	10%	89.42%		
115	68.871	19.953	3.250	100%	94.16%	93.4%	160 kHz
115	51.772	19.952	2.440	75%	94.03%		
115	34.912	19.945	1.630	50%	93.12%		
115	17.535	19.945	0.810	25%	92.13%		
115	7.284	19.943	0.325	10%	88.99%		
230	69.940	19.944	3.250	100%	94.02%	92.4%	220 kHz
230	52.065	19.946	2.440	75%	93.48%		
230	35.343	19.947	1.630	50%	91.99%		
230	17.950	19.943	0.810	25%	89.99%		
230	7.733	19.942	0.325	10%	83.81%		
264	69.440	20.010	3.250	100%	93.65%		230 kHz
264	52.558	20.010	2.440	75%	92.90%		
264	35.744	20.000	1.630	50%	91.20%		
264	18.252	20.000	0.810	25%	88.76%		
264	7.979	20.000	0.325	10%	81.47%		
CoC Tier 2, 4pt-average						89.0%	
CoC Tier 2, 10%-load						79.0%	

8.2 Efficiency Result of 4-Point Average at 15-Vout

Table 8-2. Efficiency Test Data on 15-Vout

V_{IN} (VRMS)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(%)	EFFICIENCY	EFFICIENCY 4pt-AVERAGE	Average Switching Frequency @ Full Load
90	48.061	15.019	3.000	100%	93.75%		155 kHz
90	36.039	15.015	2.250	75%	93.74%		
90	24.315	15.014	1.500	50%	92.62%		
90	12.296	15.013	0.750	25%	91.57%		
90	5.071	15.009	0.300	10%	88.79%		
115	47.673	14.968	3.000	100%	94.19%	93.1%	176 kHz
115	35.851	14.968	2.250	75%	93.94%		
115	24.230	14.969	1.500	50%	92.67%		
115	12.274	14.967	0.750	25%	91.46%		
115	5.107	14.967	0.300	10%	87.91%		
230	47.953	14.976	3.000	100%	93.69%	91.7%	192 kHz
230	36.174	14.972	2.250	75%	93.12%		
230	24.534	14.971	1.500	50%	91.553%		
230	12.708	14.969	0.750	25%	88.34%		
230	5.439	14.969	0.300	10%	82.56%		
264	48.242	15.020	3.000	100%	93.40%		190 kHz
264	36.535	15.018	2.250	75%	92.49%		
264	24.734	15.016	1.500	50%	91.06%		
264	13.123	15.013	0.750	25%	85.80%		
264	5.553	15.010	0.300	10%	81.10%		
CoC Tier 2, 4pt-average						88.9%	
CoC Tier 2, 10%-load						78.9%	

8.3 Efficiency Result of 4-Point Average at 9-Vout

Table 8-3. Efficiency Test Data on 9-Vout

V_{IN} (VRMS)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(%)	EFFICIENCY	EFFICIENCY 4pt-AVERAGE	Average Switching Frequency @ Full Load
90	28.912	8.987	3.000	100%	93.25%		133 kHz
90	21.927	8.985	2.250	75%	92.20%		
90	15.573	8.983	1.500	50%	86.52%		
90	7.49	8.982	0.750	25%	90.43%		
90	3.089	8.981	0.300	10%	87.23%		
115	28.836	8.987	3.000	100%	93.50%	90.9%	140 kHz
115	21.937	8.986	2.250	75%	92.17%		
115	15.152	8.984	1.500	50%	88.94%		
115	7.562	8.982	0.750	25%	89.08%		
115	3.141	8.981	0.300	10%	85.78%		
230	29.001	8.987	3.000	100%	92.97%	88.62%	132 kHz
230	22.432	8.985	2.250	75%	90.12%		
230	15.323	8.985	1.500	50%	87.96%		
230	8.074	8.984	0.750	25%	83.45%		
230	3.378	8.982	0.300	10%	79.76%		
264	29.108	8.987	3.000	100%	92.62%		129 kHz
264	22.677	8.984	2.250	75%	89.14%		
264	15.458	8.986	1.500	50%	87.19%		
264	8.271	8.982	0.750	25%	81.44%		
264	3.391	8.981	0.300	10%	79.45%		
CoC Tier 2, 4pt-average						87.3%	
CoC Tier 2, 10%-load						77.3%	

8.4 Efficiency Result of 4-Point Average at 5-Vout

Table 8-4. Efficiency Test Data on 5-Vout

V_{IN} (VRMS)	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (A)	P_{OUT}(%)	EFFICIENCY	EFFICIENCY 4pt-AVERAGE	Average Switching Frequency @ Full Load
90	16.201	4.959	3.000	100%	91.84%		95 kHz
90	12.643	4.952	2.250	75%	88.13%		
90	8.512	4.951	1.500	50%	87.25%		
90	4.312	4.949	0.750	25%	86.09%		
90	1.732	4.948	0.300	10%	85.69%		
115	16.174	4.953	3.000	100%	91.87%	88.0%	96 kHz
115	12.614	4.951	2.250	75%	88.31%		
115	8.571	4.949	1.500	50%	88.61%		
115	4.349	4.948	0.750	25%	85.34%		
115	1.810	4.948	0.300	10%	82.02%		
230	16.357	4.951	3.000	100%	90.81%	84.1%	82 kHz
230	13.045	4.950	2.250	75%	85.38%		
230	9.117	4.949	1.500	50%	81.42%		
230	4.702	4.947	0.750	25%	78.91%		
230	1.928	4.947	0.300	10%	76.96%		
264	16.328	4.953	3.000	100%	91.00%		79 kHz
264	13.148	4.952	2.250	75%	84.74%		
264	9.315	4.950	1.500	50%	79.71%		
264	4.811	4.948	0.750	25%	77.14%		
264	2.003	4.948	0.300	10%	74.11%		
CoC Tier 2, 4pt-average						81.8%	
CoC Tier 2, 10%-load						72.5%	

8.5 Efficiency Typical Results

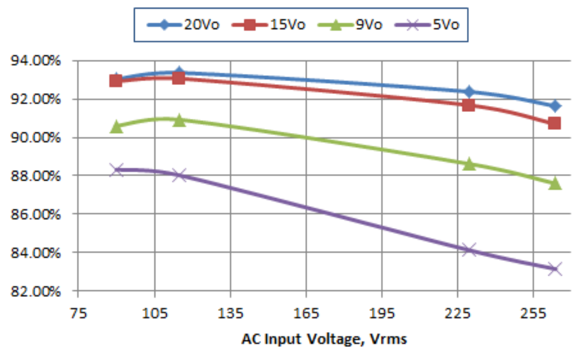

Figure 8-1. 4pt-Average Efficiency vs. Input Voltage

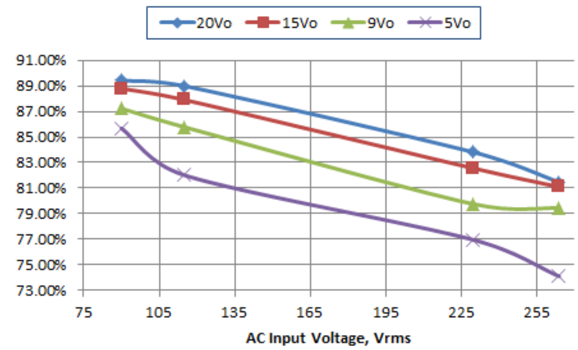

Figure 8-2. Efficiency of 10%-Load vs. Input Voltage

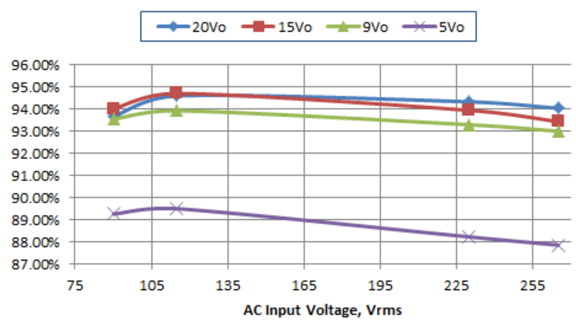

Figure 8-3. Full-load Efficiency vs. Input Voltage

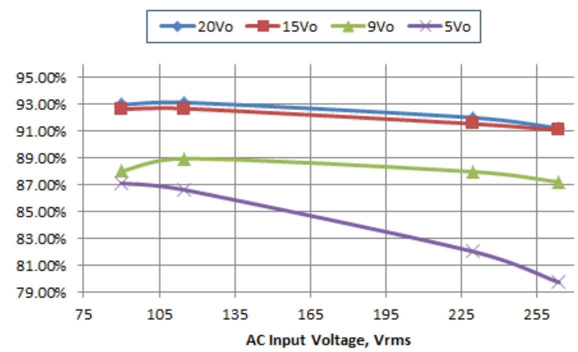

Figure 8-4. Efficiency of 50%-load vs. Input Voltage

8.6 Output Characteristics

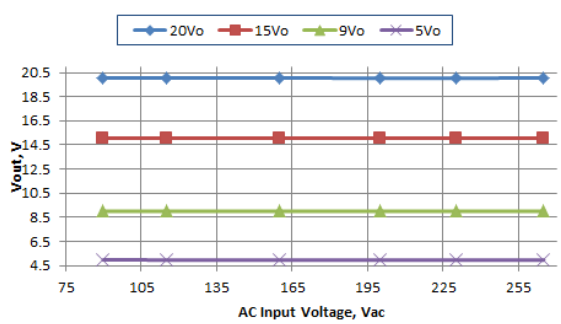

Figure 8-5. V_{OUT} at Full-Load vs. Input Voltge

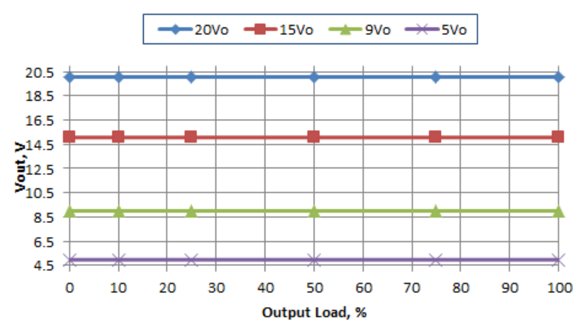

Figure 8-6. V_{OUT} vs. Output Current

8.7 Switching Frequency

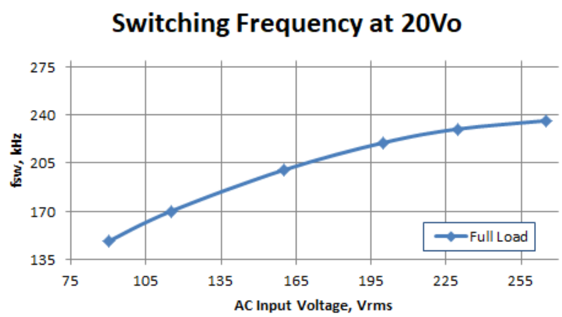

Figure 8-7. Average Switching Frequency vs. Input at 20-Vo Full Load

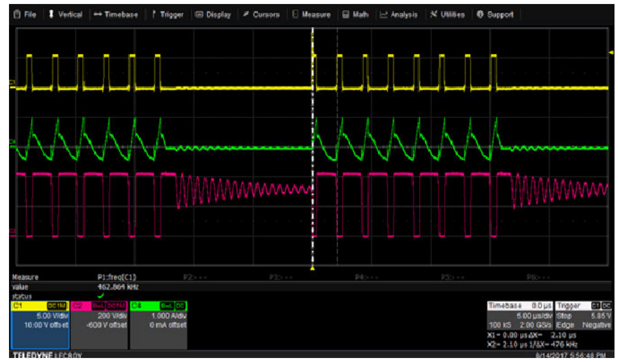

Figure 8-8. Maximum switching frequency about 240 kHz (Yellow = PWML, Green = Transformer Primary Winding Current, Red = Switch Node Voltage

8.8 Key Switching Waveforms and Operation Mode Load Current

This section shows typical operation modes in Table 8-5 along with typical load currents in this design and with Vin = 115Vac and Vo = 20V as an example.

- AAM: Adaptive Amplitude Modulation
- ABM: Adaptive Burst Mode
- LPM: Low Power Mode
- SBP1: First Standby Power Mode
- SBP2: Second Standby Power Mode

Table 8-5. Operation Mode and Load Current at 20-V Output and 115Vac Input

Mode	AAM	ABM	LPM	SBP1	SBP2	Survival
Burst Frequency, f_{BUR}	Not Applicable	> 25kHz (2 to 9 pulses)	about 25kHz (2 pulses)	8.5kHz to 25kHz (2 pulses)	< 8.5kHz (2 pulses)	about 8 pulses
Typical Load Current	1.8 A to 3.25 A	0.5 A to 1.8 A	0.2 A to 0.5 A	0.1 A to 0.2 A	< 0.1 A	Not Applicable

Figure 8-9. Typcial Waveform in AAM Operation Yellow = PWML, Red = PWMH, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

Figure 8-10. Typical Waveform in ABM Operation Yellow = PWML, Red = PWMH, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

Figure 8-11. Typical Waveform in ABM Operation Yellow = PWML, Red = Vgs of SR MOSFET, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

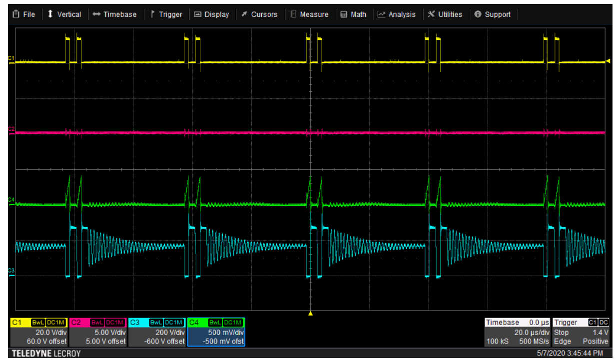

Figure 8-12. Typical Waveform in LPM Operation Yellow = PWML, Red = PWMH, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

Figure 8-13. Typical Waveform in SBP1 Operation Yellow = PWML, Red = PWMH, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

Figure 8-14. Typical Waveform in SBP2 Operation Yellow = PWML, Red = PWMH, Green = Transformer Primary Winding Current (0.2 V/A), Blue = Switch Node Voltage

8.9 Start Up

Yellow = PWML, Red = Switch Node Voltage, Blue = Output Voltage, Green = Transformer Primary Winding Current.

Figure 8-15. 115 V_{AC} and Full Load Startup

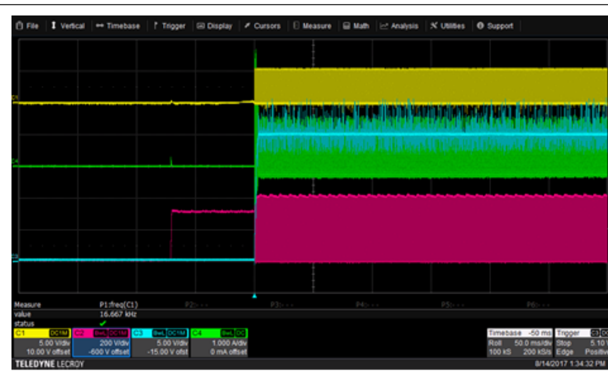

Figure 8-16. 230 V_{AC} and Full Load Startup

8.10 Output Voltage Adjustment by USB-C PD

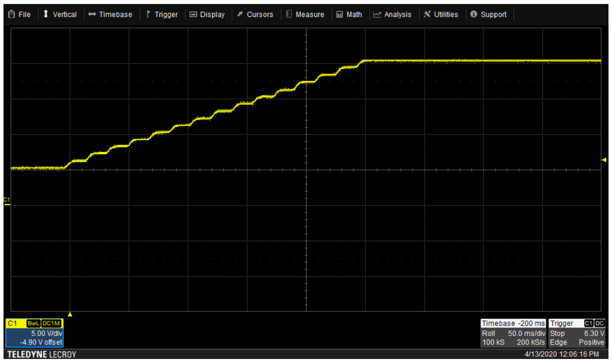

Figure 8-17. USB-C PD Output Change from 5 V to 20 V

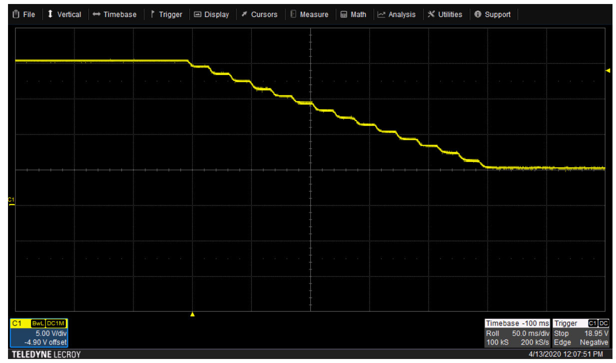

Figure 8-18. USB-C PD Output Change from 20 V to 5 V

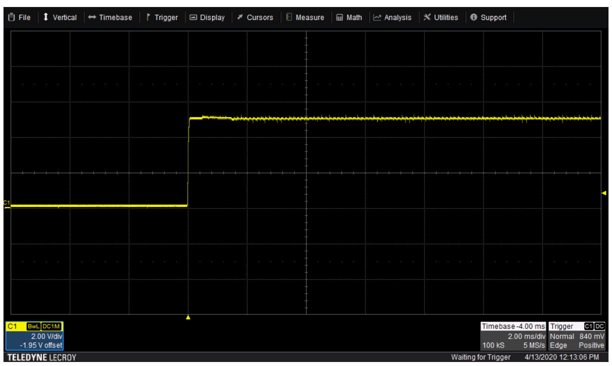

Figure 8-19. 5-V Output Power On

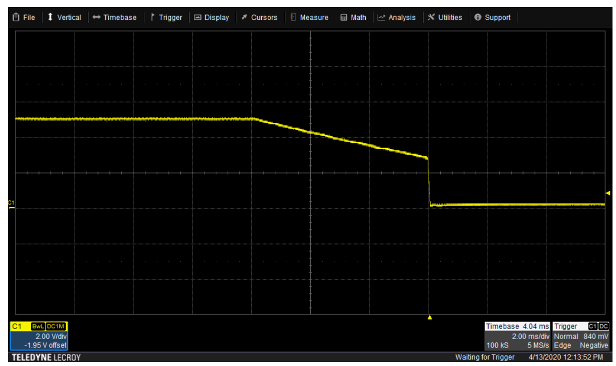

Figure 8-20. 5-V Output Power Off

8.11 Line Transient Response

Yellow = VOUT, Red = Line voltage.

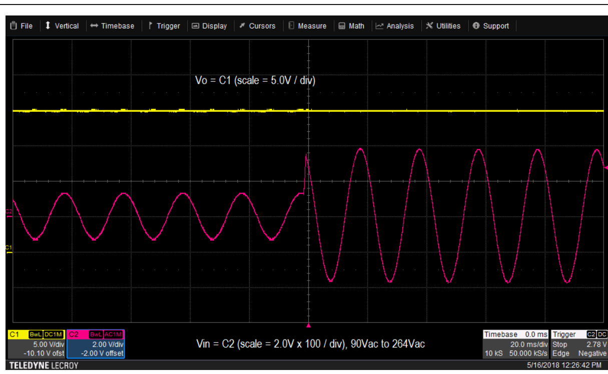

Figure 8-21. Output Voltage Response to Line Transient with Full Load.

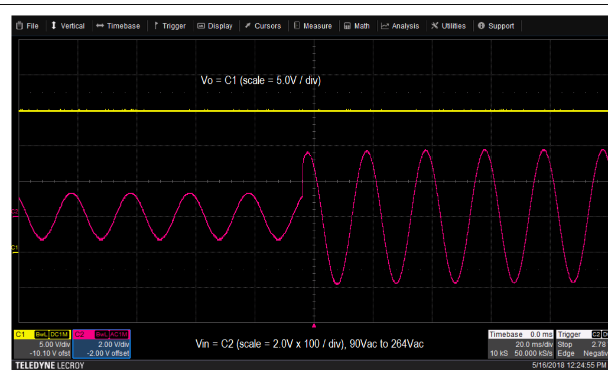

Figure 8-22. Output Voltage Response to Line Transient with No Load.

8.12 Output Ripple Voltage

Blue = Output Voltage Ripple, Oscilloscope Channel Bandwidth = 20 MHz, Voltage span between two dashed lines is 150 mV. The ripples are with the 50% load condition unless specified in the associated figures.

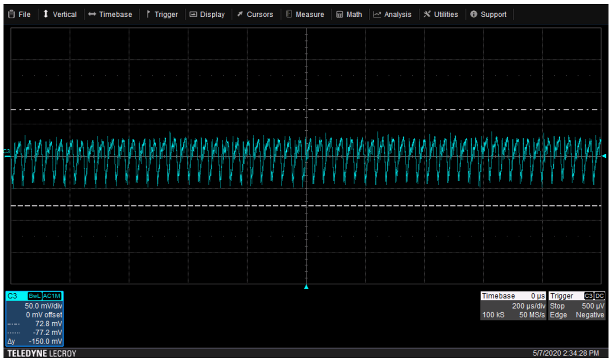

Figure 8-23. Typical Ripple Voltage of V_{OUT} = 20 V

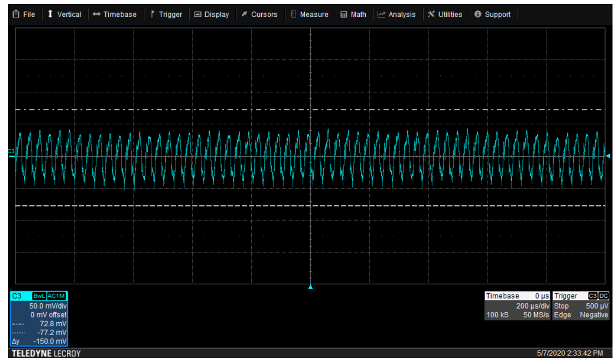

Figure 8-24. Typical Ripple Voltage of V_{OUT} = 15 V

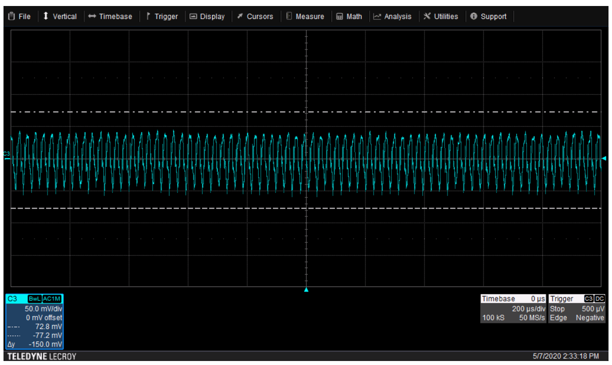

Figure 8-25. Typical Ripple Voltage of V_{OUT} = 9 V

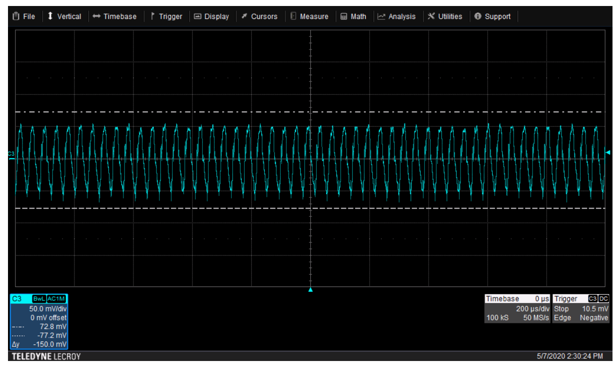

Figure 8-26. Typical Ripple Voltage of V_{OUT} = 5 V

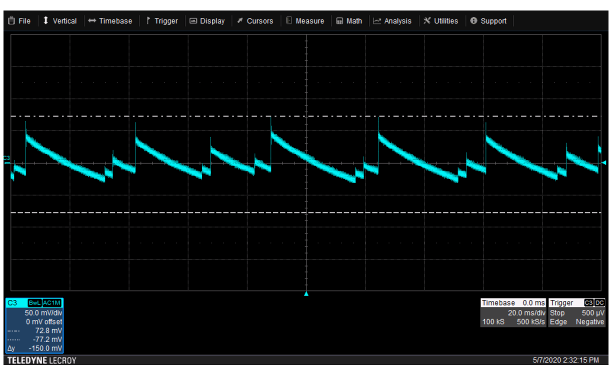

Figure 8-27. Typical Ripple Voltage of V_{OUT} = 5 V at No Load

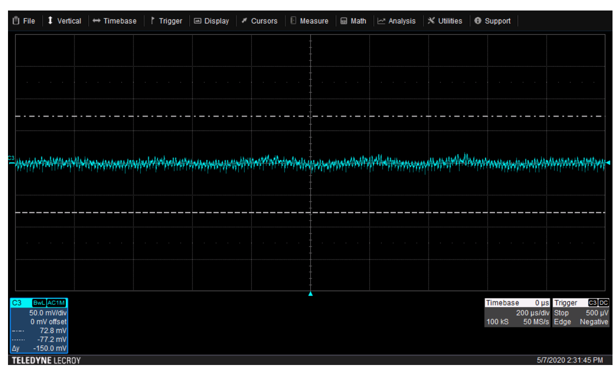

Figure 8-28. Typical Ripple Voltage of V_{OUT} = 5 V at Full Load

8.13 Boost Function for VDD Bias

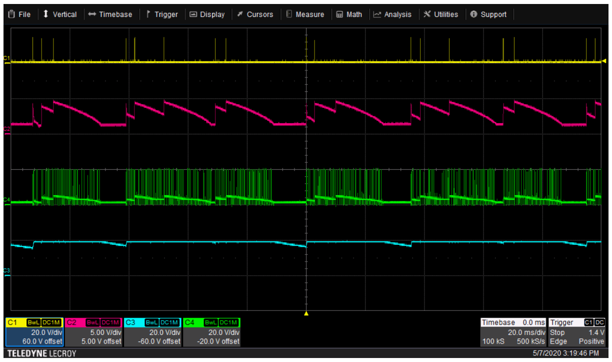

Figure 8-29. Boost Operation at 5 V_{OUT} and No Load (Yellow = PWML, Red = BIN, Green = BSW, Blue = VDD)

Figure 8-30. Boost Operation at 5 V_{OUT} and Full Load (Yellow = PWML, Red = BIN, Green = BSW, Blue = VDD)

8.14 X-Capacitor Discharge

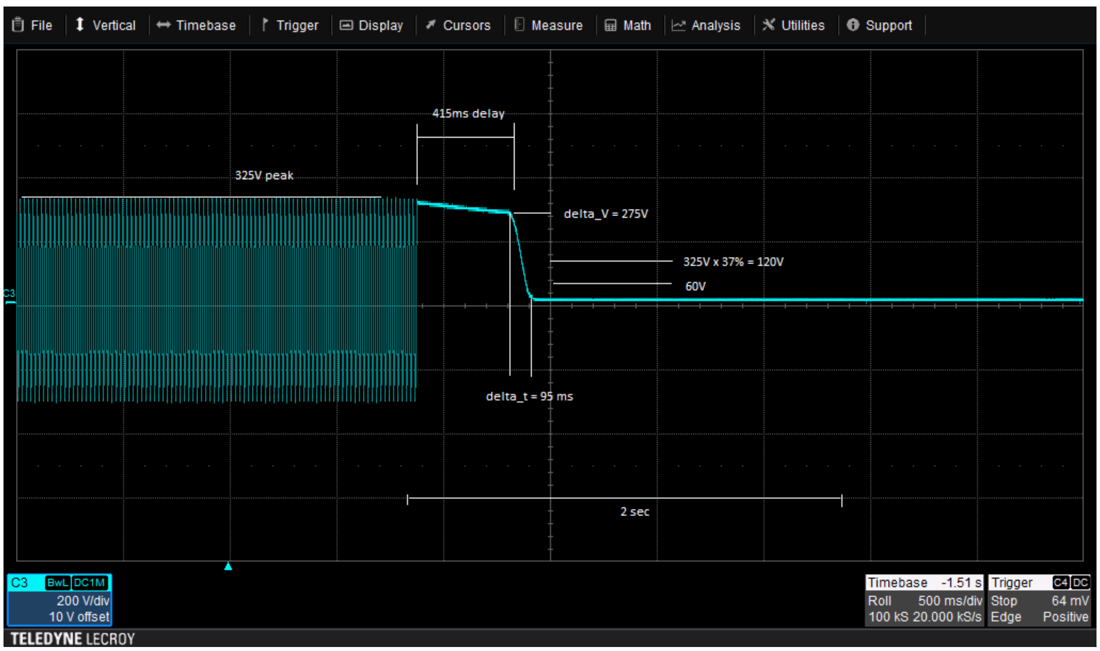

Figure 8-31. Typical X-Capacitor Discharge

8.15 USB-C PD Over Current Limit

Figure 8-32 shows the converter USB-C PD Over Current Limit with respect to input voltage. Figure 8-33 shows the converter auto-retry to resume operation after over current.

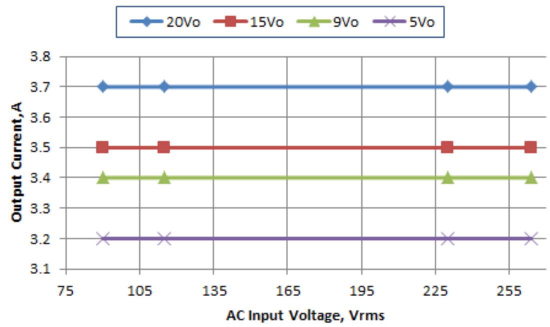

Figure 8-32. USB-PD Current Limit vs. Input Voltage

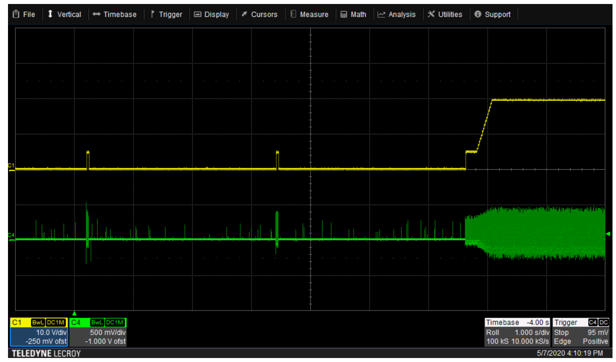

Figure 8-33. USB-C PD Over Current Limit Retry and Resume (Yellow = V_{OUT}, Green = Transformer Primary Current, 0.2 V/A)

8.16 Load Transient Response

Figure 8-34 to Figure 8-37 show output voltage V_{OUT} deviation when load current step change is between 0 and 100%, at 100-Hz rate.

Blue = V_{OUT}, Green = Load Current.

Figure 8-34. Load Transient Response at V_{OUT} = 20 V Overshoot / Undershoot = 357 mV / -619 mV

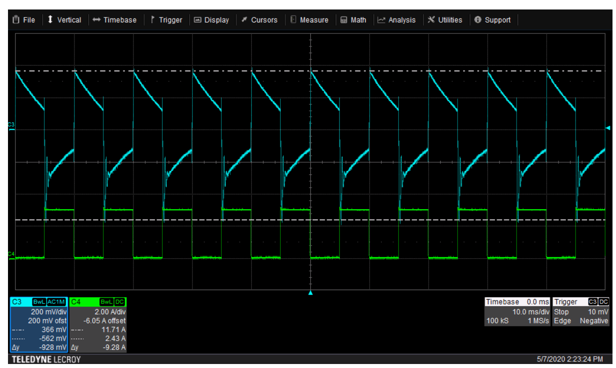

Figure 8-35. Transient Response at V_{OUT} = 15 V Overshoot / Undershoot = 366 mV / -562 mV

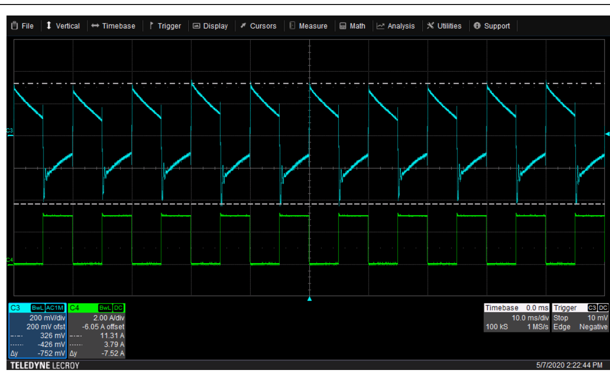

Figure 8-36. Transient Response at V_{OUT} = 9 V Overshoot / Undershoot = 326 mV / -426 mV

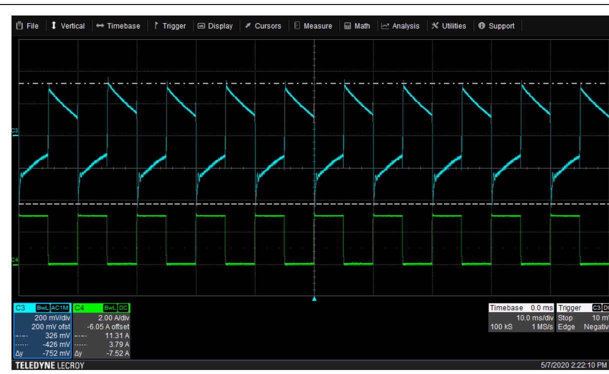

Figure 8-37. Transient Response at V_{OUT} = 5 V Overshoot / Undershoot = 326 mV / -426 mV

8.17 EN55022 Class B Conducted EMI Test Result

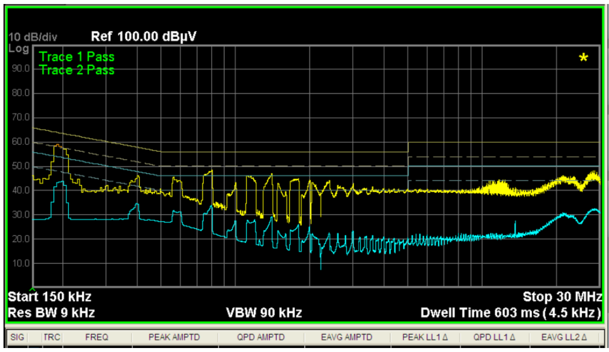

Figure 8-38. VIN = 115 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground, Ref Fig 54 and 55)

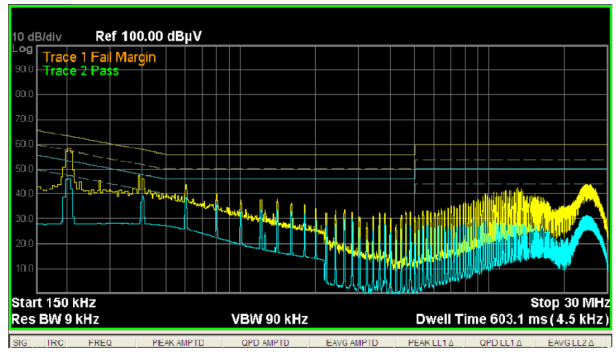

Figure 8-39. VIN = 230 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground, Ref Fig 54 and 55)

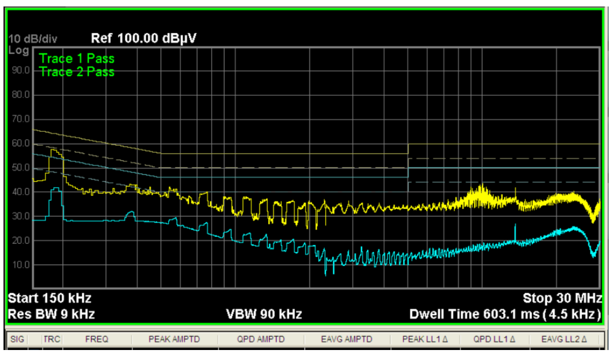

Figure 8-40. VIN = 115 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground, Shielding between Transformer and EMI Filter, Ref Fig 54 and 55)

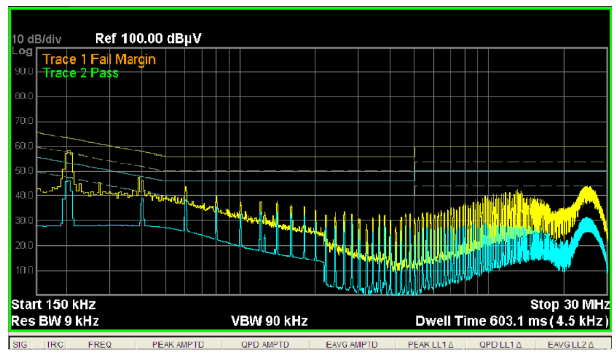

Figure 8-41. VIN = 230 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground, Shielding between Transformer and EMI Filter, Ref Fig 54 and 55)

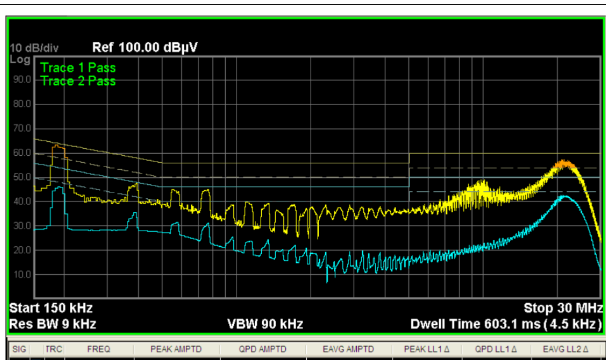

Figure 8-42. VIN = 115 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Grounded to LISN Ground, Shielding between Transformer and EMI Filter, Ref Fig 54 and 55)

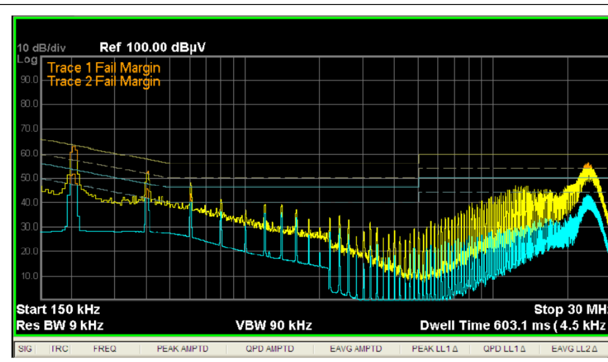

Figure 8-43. VIN = 230 V_{RMS}, VOUT = 20 V, Load = 3.25 A (Output Grounded to LISN Ground, Shielding between Transformer and EMI Filter, Ref Fig 54 and 55)

Note

Please note this was evaluated on an EMI station for pre-qualification purpose only. It is recommended that all final designs be verified by an agency-qualified EMI test house.

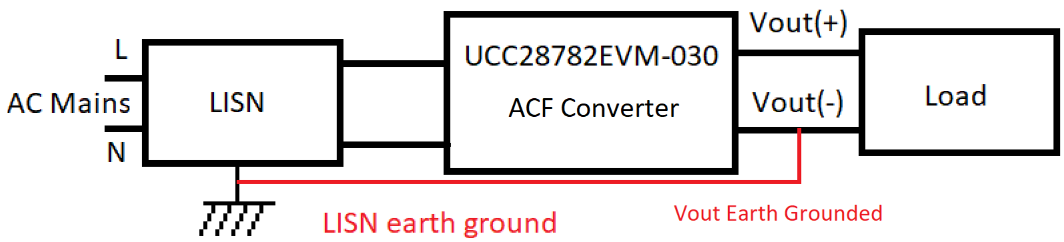

Figure 8-44. LISN Earth Ground and Vout Earth Grounded

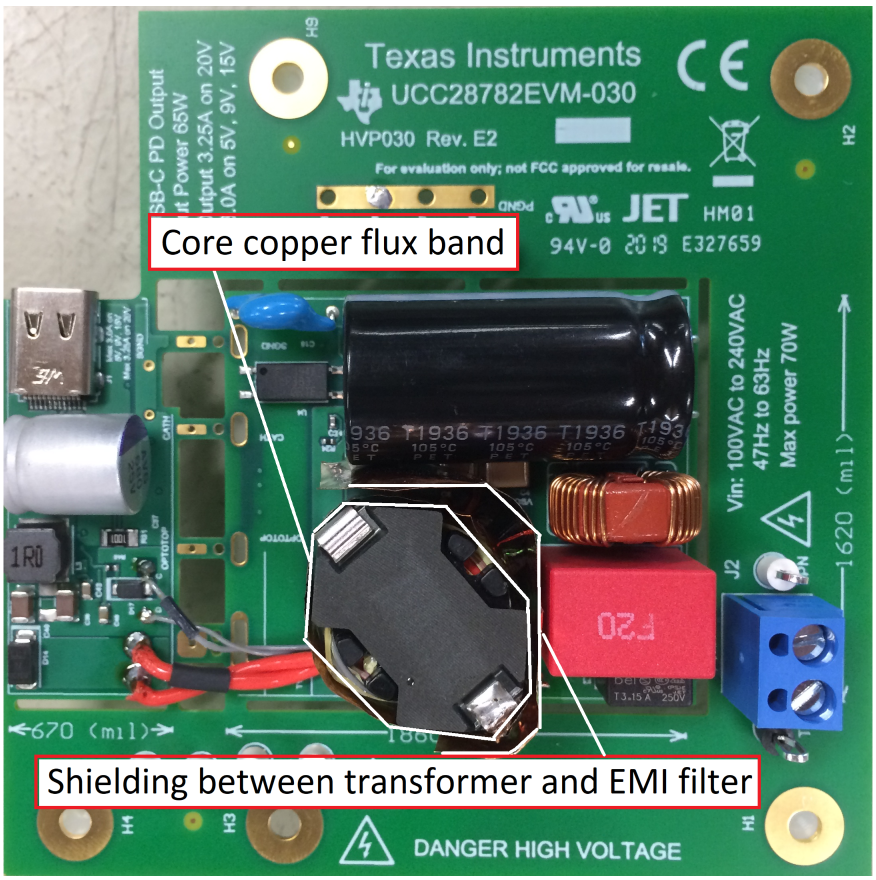

Figure 8-45. Transformer Flux-Band and Shielding between Transformer and EMI Filter

8.18 Thermal Images at Full Load (20V and 3.25 A)

Figure 8-46. V_{IN} = 90 V_{AC}, Top Side (Transformer: 75.6 °C)

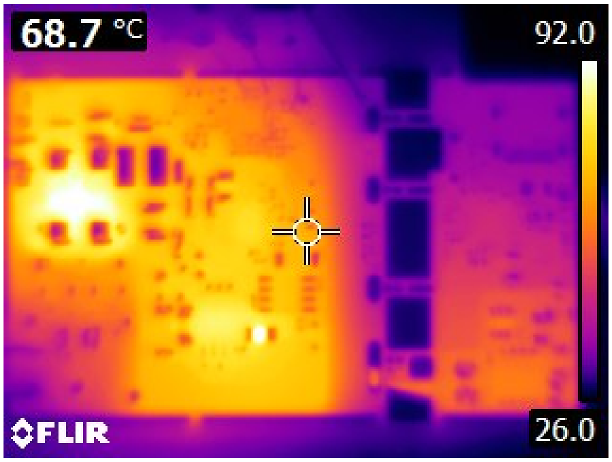

Figure 8-47. V_{IN} = 90 V_{AC}, Bottom Side (DB1: 92.0 °C)

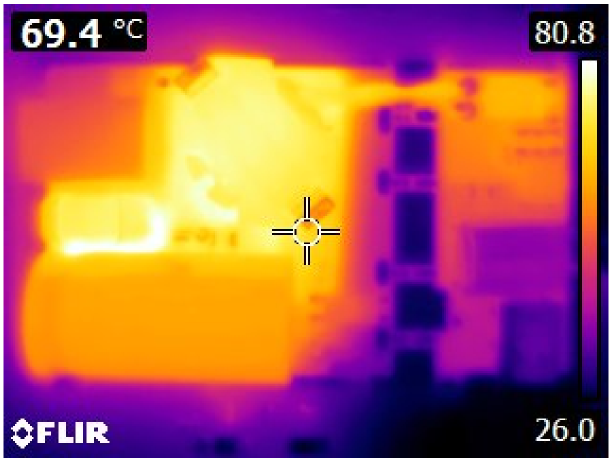

Figure 8-48. V_{IN} = 115 V_{AC}, Top Side (Transformer: 80.8 °C)

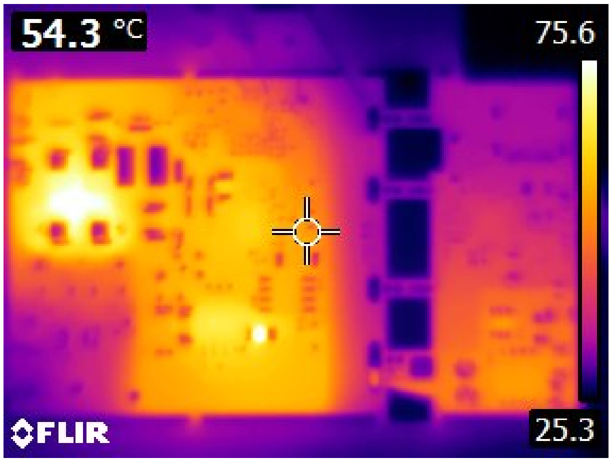

Figure 8-49. V_{IN} = 115 V_{AC}, Bottom Side (DB1: 75.6 °C)

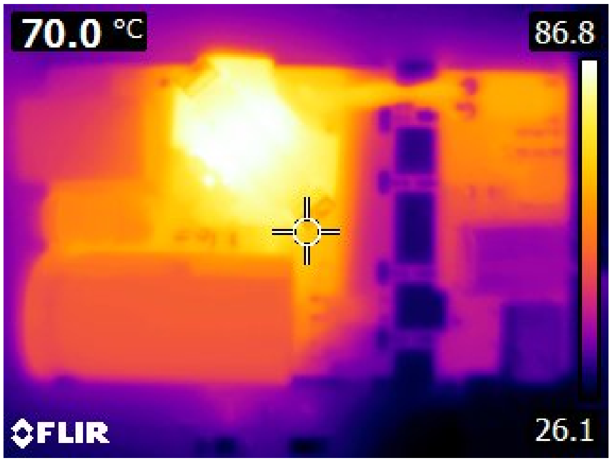

Figure 8-50. V_{IN} = 230 V_{AC}, Top Side (Transformer: 86.8 °C)

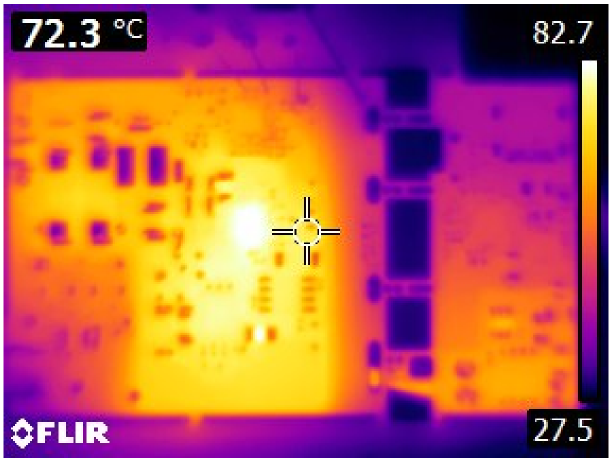

Figure 8-51. V_{IN} = 230 V_{AC}, Bottom Side (Q1: 82.7 °C)

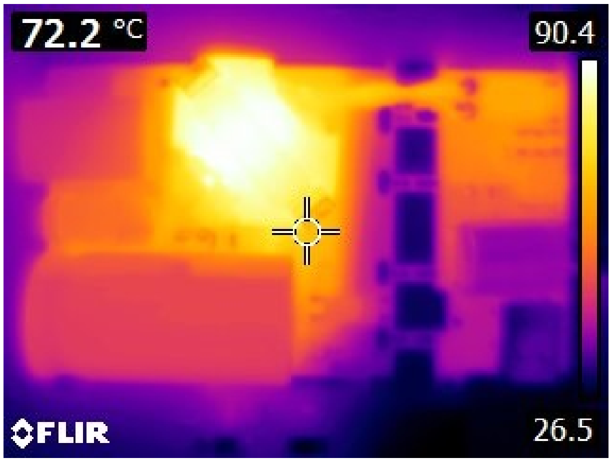

Figure 8-52. V_{IN} = 265 V_{AC}, Top Side (Transformer: 90.4 °C)

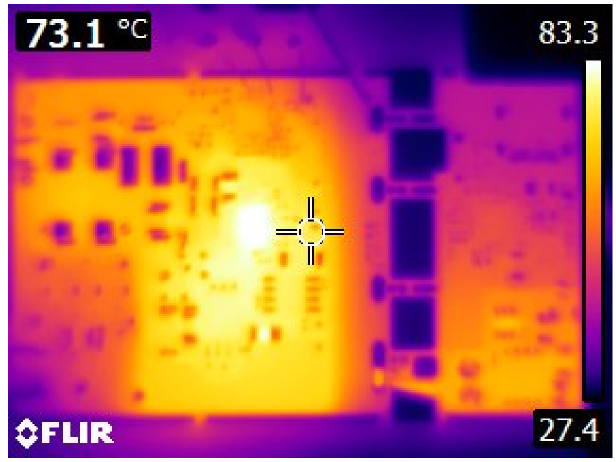

Figure 8-53. V_{IN} = 265 V_{AC}, Bottom Side (Q1: 83.3 °C)

9 Transformer Details

Renco Electronics transformer part number RLTI-1349 is used on this design and wound on an RM8 core set.

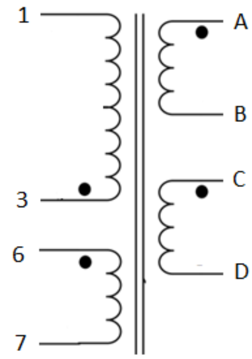

Figure 9-1. Transformer Schematic Diagram

Table 9-1. Transformer Specifications at 25°C

PARAMETER	VALUE	PINS/LEADS	TEST CONDITIONS
Inductance (µH)	110, ± 5%	1 – 3	Open all other pins, 100kHz, 0.1V
Leakage Inductance (µH)	2.5 Max.	1 – 3	Short A - B, 100kHz, 0.1V
D.C. resistance (Ω)	0.1, ±15%	1 – 3	
D.C. resistance (Ω)	0.006 Max.	A – B	
D.C. resistance (Ω)	0.02, ±15%	6 – 7	
D.C. resistance (Ω)	0.12, ±15%	C – D	
Dielectric (VAC, 60Hz)	3000	1, 6 – A	1 mA, 60 Hz, 1 s
Turns-ratios	1 : 0.2 : 0.2 : 0.32	(1-3):(A-B):(6-7):(C-D)	1.0V @ 10kHz to 1 - 3

10 EVM Assembly and Layout

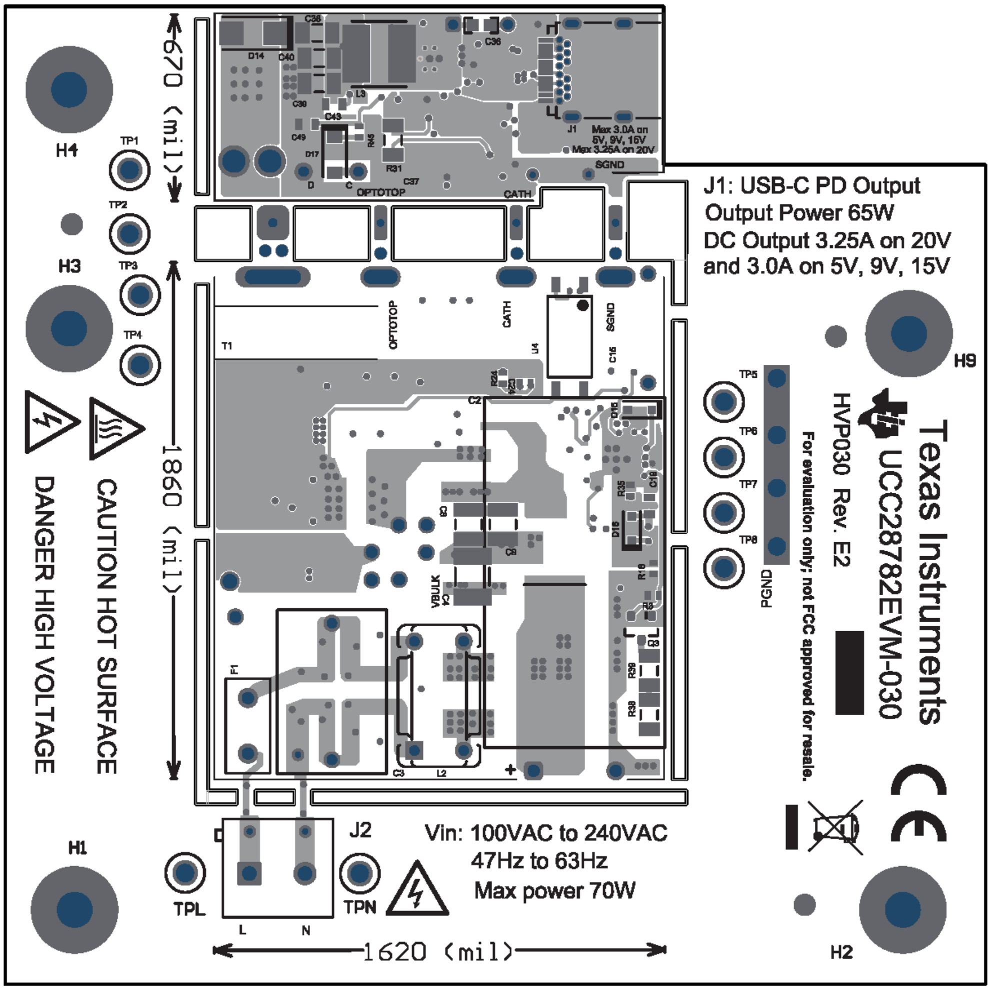

Figure 10-1. EVM Assembly (Top View)

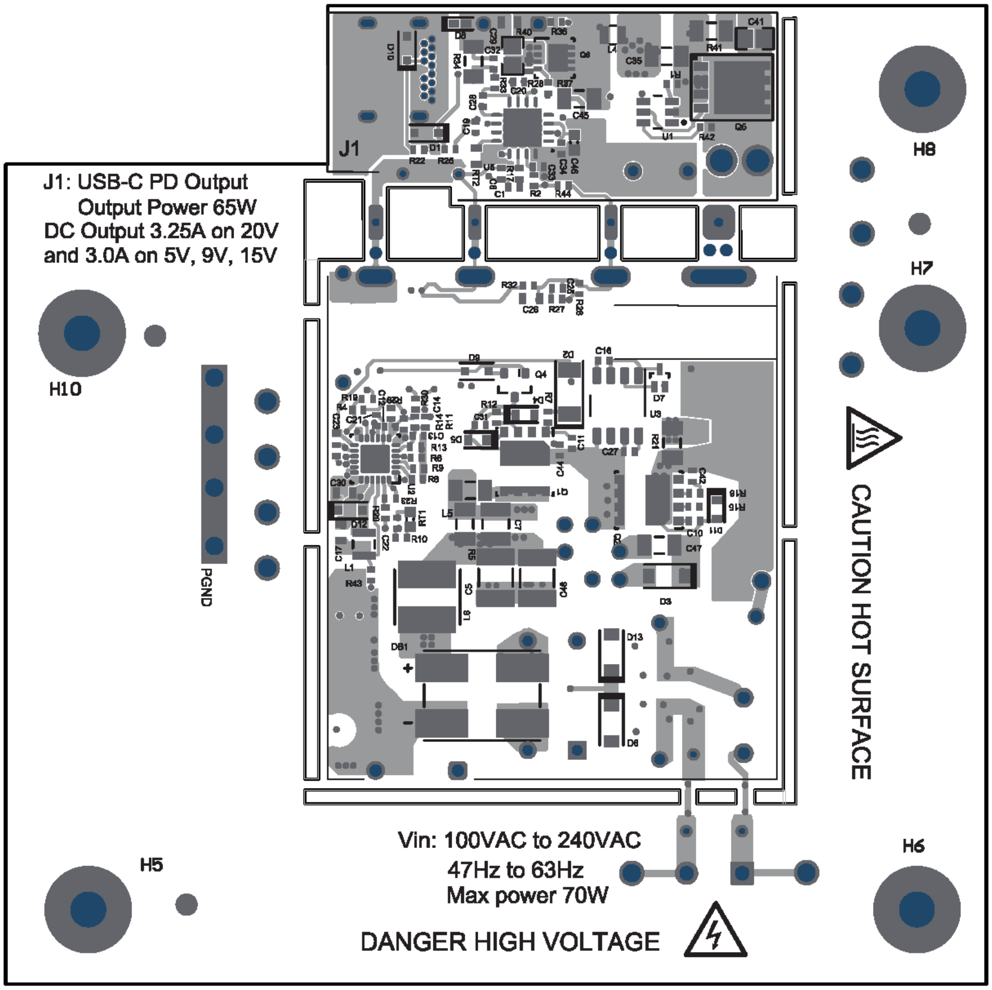

Figure 10-2. EVM Assembly (Bottom View)

11 List of Materials

UCC28782EVM-030 list of materials for the schematic diagrams shown in Figure 5-1 and in Figure 5-2.

Table 11-1. UCC28782EVM-030 List of Materials

Quantity	Designator	Description	PartNumber	Manufacturer
1	C1	Capacitor, ceramic, 0.1 µF, 25 V, 10%, X7R, 0402	GRM155R71E104KE14D	MuRata
1	C2	Capacitor, AL, 100 µF, 400 V, 20%, TH	400BXW100MEFR16X30	Rubycon
	C2 second source	Capacitor, AL, 100 µF, 400 V, 20%, TH	860 021 380 020	Wurth Electronik
1	C3	Capacitor, Film, 0.47 µF, 275 V, 10%, TH	890324024005	Wurth Electronik
3	C4, C5, C48	Capacitor, ceramic, 0.47 µF, 500 V, 20%, X7R, 1812	1812Y5000474KXTWS2	Knowles Syfer
2	C7, C8	Capacitor, ceramic, 0.33 µF, 250 V, 10%, X7R, 1210	C1210C334KARACAUTO	Kemet
4	C10, C11, C16, C27	Capacitor, ceramic, 0.022 uF, 50 V, 10%, X7R, 0402	GRM155R71H223KA12D	MuRata
1	C12	Capacitor, ceramic, 0.22 µF, 16 V, 10%, X7R, 0402	GRM155R71C224KA12D	MuRata
3	C13, C14, C44	Capacitor, ceramic, 330 pF, 50 V, 10%, X7R, 0402	GRM155R71H331KA01D	MuRata
1	C15	Capacitor, ceramic, 2200 pF, 250 V, 20%, E, Dia 9mm	DE1E3RA222MN4AN01F	MuRata
3	C17, C18, C30	Capacitor, ceramic, 10 µF, 35 V, 10%, X5R, 0603	GRM188R6YA106MA73D	MuRata
2	C19, C20	Capacitor, ceramic, 220 pF, 50 V, 10%, X7R, 0402	C3216X5R1E476M160AC	TDK
2	C21	Capacitor, ceramic, 220 pF, 50 V, 5%, NP0, 0402	GRM155R71H221KA01D	MuRata
1	C23	Capacitor, ceramic, 1 µF, 25 V, 10%, X5R, 0402	GRM1555C1H221JA01D	MuRata
1	C24	Capacitor, ceramic, 24 pF, 50 V, 5%, NP0, 0402	GRM155R61E105KA12D	MuRata
1	C26, C43	Capacitor, ceramic, 1 µF, 25 V, 10%, X7R, 0603	GRM1555C1H240JA01D	MuRata
2	C28	Capacitor, ceramic, 1 µF, 6.3 V, 20%, X7R, 0402	C1608X7R1E105K080AB	TDK
1	C29	Capacitor, ceramic, 10 µF, 35 V, 10%, X5R, 0805	GRM155R70J105MA12D	MuRata
2	C31, C42	Capacitor, ceramic, 0.01 uF, 50 V, 5%, X7R, 0402	C0402C103J5RACTU	Kemet
1	C32	Capacitor, ceramic, 1000 pF, 50 V, 10%, X7R, 0402	885012205061	Wurth Elektronik
2	C33, C34	Capacitor, ceramic, 0.1 µF, 25 V, 10%, X7R, 0402	GRM155R71E104KE14D	MuRata
4	C35, C38, C39, C47	Capacitor, ceramic, 47 µF, 25 V, 20%, X5R, 1206	GRM188R61E106KA73D	MuRata
1	C36	Capacitor, ceramic, 0.22 µF, 50 V, 10%, X7R, 0603	CGA3E3X7R1H224K080A B	TDK
1	C37	Capacitor, aluminum polymer, 680 µF, 25 V, 20%, TH	687AVG025MGBJ	Illinois Capacitor
1	C41	Capacitor, ceramic, 220 pF, 250 V, 5%, NP0, 0805	GRM21A5C2E221JW01D	MuRata
1	C45	Capacitor, ceramic, 33 µF, 25 V, 20%, X5R, 1206	C3216X5R1E336M160AC	TDK
1	C46	Capacitor, ceramic, 1 µF, 25 V, 10%, X7R, 0603	GCM188R71E105KA64D	MuRata
0	C40	Not used, 1206		
0	C9	Not used, 1210		
0	C6, C22, C25	Not used, 0402		
2	D1, D10	Diode, TVS, 5 V, bidirectional, SOD-323	PESD5V0L1BA,115	NXP Semiconductor
1	D2	Diode, Ultrafast, 600 V, 1 A, AEC-Q101, SMAF	ES1JAF	ON Semiconductor
2	D3, D17	Diode, Schottky, 150 V, 1 A, SOD-123	SS115LW RVG	Taiwan Semiconductor
1	D4	Diode, Zener, 2 V, 150 mW, SOD-523F	CZRU52C2	Comchip Technology
2	D5, D11	Diode, Zener, 6.2 V, 150 mW, SOD-523F	CZRU52C6V2	Comchip Technology
2	D6, D13	Diode, Switching, 600 V, 1 A, SOD-123	ES1JFL	ON Semiconductor
1	D7	Diode, Schottky, 30 V, 0.2 A, SOT-523	BAT54CT-7-F	Diodes Inc.
1	D8	Diode, Schottky, 40 V, 0.2 A, SOD-523	RB521SM-40T2R	Rohm
1	D9	Diode, TVS, Bi, 16.2 V, SOD-323	DF2B18FU,H3F	Toshiba

Table 11-1. UCC28782EVM-030 List of Materials (continued)

Quantity	Designator	Description	PartNumber	Manufacturer
1	D12	Diode, Schottky, 30 V, 0.8 A, SOD-323	CUS08F30,H3F	Toshiba
1	D14	Diode, TVS, Bi, 100 V, SMA	SMAJ100CA	Littelfuse
1	D15	Diode, Zener, 20 V, 300mW, SOD-323	MM3Z20VST1G	ON Semiconductor
1	D16	Diode, TVS, 24 V, Clamping 9 A, SOD-323	CDSOD323-T24SC	Bourns Inc
1	DB1	Diode, P-N-bridge, 1000 V, 4 A, Z4-D	Z4DGP410L-HF	Comchip Technology
1	F1	Fuse, 3.15 A, 250 VAC/VDC, TH	RST 3.15-BULK	Bel-Fuse
1	L1	Inductor, Wirewound, 22 uH, 0.49 A, 0.56 Ω, SMD	BRC2518T220K	Taiyo Yuden
1	L2	Coupled inductor, 1 mH, 2 A, 0.045 ohm, TH	744821201	Wurth Elektronik
1	L3	Inductor, Shielded, Ferrite, 1 µH, 8 A, 0.012 Ω, SMD	SRN6045TA-1R0Y	Bourns Inc
1	L4	Inductor, Wirewound, Ceramic, 1 µH, 0.09 Ω, SMD	LBR2012T1R0M	Taiyo Yuden
1	L5	Ferrite Bead, 33 ohm@100 MHz, 9 mΩ at 6 A, 1206	BLM31PG330SN1L	Fair-Rite Products
1	L6	Inductor, Shielded, Ferrite, 22 µH, 1.8 A, 0.089 Ω, SMD	74404064220	Wurth Elektronik
1	Q1	650V AllGaN Power IC with iDrive, PQFN-8	NV6115	Navitas Semi
1	Q2	650V AllGaN Power IC with iDrive, PQFN-8	NV6117	Navitas Semi
2	Q3, Q4	MOSFET, N-Channel, 600 V, 0.021 A, AEC-Q101, SOT-23	BSS126H6327XTSA2	Infineon Technologies
1	Q5	MOSFET, N-Channel, 150 V, 87 A, PG-TDSON-8	BSC093N15NS5ATMA1	Infineon Technologies
1	Q6	MOSFET, N-Channel, 30 V, 60 A, DQG0008A (VSON-CLIP-8)	CSD17575Q3	Texas Instruments
1	R1	Resistor, 30.9 kΩ, 1%, 0.063 W, 0402	CRCW040230K9FKED	Vishay-Dale
8	R2, R6, R10, R15,R18, R35, R36, R43, R44, R45	Resistor, 0 Ω, 5%, 0.063 W, 0402	CRCW04020000Z0ED	Vishay-Dale
1	R5	Resistor, 3.3 M, 5%, 0.25 W, 1206	CRCW12063M30JNEA	Vishay-Dale
1	R7	Resistor, 2.1 Ω, 1%, 0.063 W, 0402	CRCW04022R10FKED	Vishay-Dale
1	R8	Resistor, 243 kΩ, 1%, 0.063 W, 0402	CRCW0402243KFKED	Vishay-Dale
1	R9	Resistor, 196 kΩ, 1%, 0.063 W, 0402	CRCW0402196KFKED	Vishay-Dale
1	R12	Resistor, 10 Ω, 1%, 0.063 W, 0402	RC0402FR-0710RL	Yageo
1	R13	Resistor, 37.4 kΩ, 1%, 0.063 W, 0402	CRCW040237K4FKED	Vishay-Dale
1	R14	Resistor, 182 kΩ, 1%, 0.063 W, 0402	RC0402FR-07182KL	Yageo America
1	R16	Resistor, 210 Ω, 1%, 0.063 W, 0402	CRCW0402210RFKED	Vishay-Dale
1	R17	Resistor, 4.7 kΩ, 1%, 0.063 W, 0402	CRCW04024K70FKEDC	Vishay-Dale
1	R19	Resistor, 499 Ω, 1%, 0.063 W, 0402	CRCW0402499RFKED	Vishay-Dale
1	R20	Resistor, 56.2 kΩ, 1%, 0.063 W, 0402	CRCW040256K2FKED	Vishay-Dale
1	R21	Resistor, 0.12 Ω, 1%, 0.5 W, 1206	RL1632R-R120-F	Susumu
2	R22, R25	Resistor, 47 Ω, 5%, 0.063 W, 0402	CRCW040247R0JNED	Vishay-Dale
1	R23	Resistor, 14 kΩ, 1%, 0.063 W, 0402	CRCW040214K0FKED	Vishay-Dale
2	R24, R42	Resistor, 511 Ω, 1%, 0.063 W, 0402	CRCW0402511RFKED	Vishay-Dale
1	R26	Resistor, 30.1 kΩ, 1%, 0.063 W, 0402	CRCW040230K1FKED	Vishay-Dale
1	R28	Resistor, 1.00 MΩ, 1%, 0.063 W, 0402	RMCF0402FT1M00	Stackpole Electronics Inc
1	R30	Resistor, 20.0 kΩ, 1%, 0.063 W, 0402	CRCW040220K0FKED	Vishay-Dale
1	R31	Resistor, 1.00 kΩ, 1%, 0.25 W, 1206	RC1206FR-071KL	Yageo America
1	R32	Resistor, 34.0 kΩ, 1%, 0.063 W, 0402	CRCW040234K0FKED	Vishay-Dale
1	R33	Resistor, 5.11 kΩ, 1%, 0.063 W, 0402	CRCW04025K11FKED	Vishay-Dale
1	R34	Resistor, 0.004 Ω, 1%, 0.25 W, 1206	WSL12064L000FEA	Vishay-Dale

Table 11-1. UCC28782EVM-030 List of Materials (continued)

Quantity	Designator	Description	PartNumber	Manufacturer
1	R37	Resistor, 10 kΩ, 5%, 0.063 W, 0402	CRCW040210K0JNED	Vishay-Dale
2	R38, R39	Resistor, 13 kΩ, 5%, 0.25 W, 1206	ERA-8AEB133V	Vishay-Dale
1	R40	Resistor, 10 MΩ, 5%, 0.1 W, 0603	CRCW060310M0JNEA	Vishay-Dale
0	R3, R4, R11, R27, R29, R36	Not use, 0402		
0	R41	Not use, 1206		
1	RT1	Thermistor NTC, 47 kΩ, 5%, 0603	NCP18WB473J03RB	MuRata
1	RT2	Thermistor NTC, 220 kΩ, 5%, 0603	NCP18WM224J03RB	MuRata
1	T1	Transformer, 110 µH, TH	RLTI-1349	Renco Electronics
1	U1	Fast turn-off intelligent SR controller	MP6908AGJ-P	Monolithic Power Systems
1	U2	UCC28782BRTW, RTW0024B (WQFN-24)	UCC28782BRTWR	Texas Instruments
1	U3	High Speed, Digital Isolator, SOIC-8	ISO7710FD	Texas Instruments
1	U4	Opto-isolator Transistor Output 5000 Vrms 1 Channel 6-SO	TLP383(GR-TPL,E	Toshiba
1	U5	USB PD/QC4/QC4+ Controller	WT6636F	Weltrend

12 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (June 2020) to Revision B (August 2020) **Page**

- Updated all figure numbers and section numbers................................ 5
- Removed Section of EMI Frequency Dithering................................ 5
- Added a note how to use a DC input voltage to the board................................ 11
- Changed test results of efficiency................................ 13
- Changed the output voltage ripple waveforms................................ 20
- Updated EMI test results with 230Vac................................ 24

Changes from Revision * (May 2020) to Revision A (June 2020) **Page**

- Added a note how to use a DC input voltage to the board................................ 5
- Changed test results of efficiency................................ 7
- Changed the output voltage ripple waveforms................................ 13
- Added Figure 38 and 39................................ 13
- Changed Figure 48 and Figure 49................................ 13
- Added Figure 50 to Figure 55................................ 13