Design Example Report

Title	***45 W 24 V Output Isolated Flyback Power Supply Using InnoSwitch™ 3-CP INN3268-H221***
Specification	90 VAC – 265 VAC Input; 24 V, 1.88 A Output
Application	Smart Speaker, Tubular Motor
Author	Applications Engineering Department
Document Number	DER-815
Date	April 10, 2019
Revision	1.0

Summary and Features

- 45 W constant power output at 24 V to 15 V
- >91% average efficiency at nominal AC input
- <75 mW no-load input power
- Low component count, 37 pcs
- Integrated protection and reliability features
  - Output short-circuit
  - Line and output OVP
  - Line surge or line overvoltage
  - Over temperature shutdown
- Meets IEC 2.5 kV ring wave, 2 kV differential surge
- Meets EN55015 conducted EMI

PATENT INFORMATION
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Important Note: Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

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1 Introduction

This engineering report describes a 45 W isolated flyback power supply that can deliver Constant Voltage (CV), Constant Current (CC) and Constant Power (CP) output. The power supply is designed to provide a 24 V constant voltage output from 0 A to 1.88 A load current. Constant current is programmed at 3 A by the IS pin resistor providing 45 W constant power output from 24 V to 15 V. The DER board is designed to operate at input voltage range from 90 VAC to 265 VAC.

The Innoswitch3-CP device is a quasi-resonant flyback controller that combines the primary and secondary controllers along with the power MOSFET in a single low profile surface mount off-line flyback switcher IC. The secondary-side controller incorporates secondary-side synchronous rectifier drive. The device also includes an innovative inductive coupling feedback link (FluxLink™), which safely bridges the isolation barrier and eliminates the need for an optocoupler.

DER-815 offers an accurate CV/CP/CC regulation throughout the input range. The key design goals were high efficiency and compact size design.

The document contains the power supply specification, schematic, bill of materials, transformer documentation, printed circuit layout, design spreadsheet, and performance data.

Figure 1 – Populated Circuit Board.

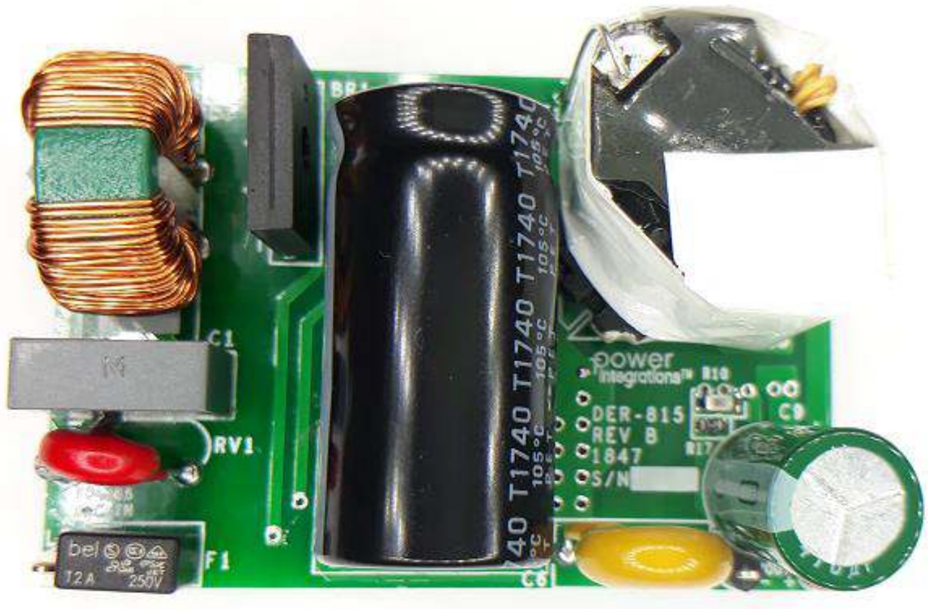

Figure 2 – Populated Circuit Board, Top View.

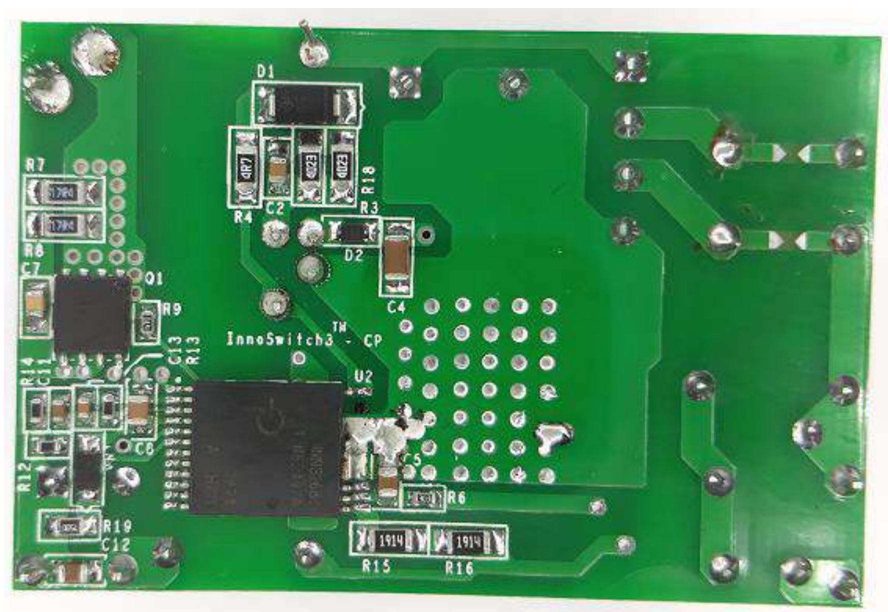

Figure 3 – Populated Circuit Board, Bottom View.

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2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	$\mathbf{V_{IN}}$	90		265	VAC	2 Wire – no P.E.
Frequency	$\mathbf{f_{LINE}}$	50	50/60	63	Hz	
No-load Input Power				75	mW	115 VAC and 230 VAC.
Output CV						
Output Voltage	$\mathbf{V_{OUT}}$		24		V	
Output Ripple Voltage	$\mathbf{V_{RIPPLE}}$		250		mV_{P-P}	
Output Power	$\mathbf{P_{OUT}}$		45		W	
Output Current	$\mathbf{I_{OUT}}$		1.875		A	CV Region.
Output Current	$\mathbf{I_{OUT}}$		3.0		A	CC Region.
Efficiency (Full Load) @ 24 V	η_{FL}	91			%	115 VAC to 230 VAC. DoE Level 6. CoC Level 5 Tier 2 .
Efficiency (10% Load) @ 24 V	$\eta_{10\%}$	82			%	
Energy Efficiency @ 24 V Average 25%, 50%, 75%, and 100%	η_{AVE}	90			%	
Environmental						
Conducted EMI		CISPR22B / EN55022B				Output Floating.
ESD Immunity	±V	15 kV				No Damage.
Combination Wave Surge	Surge	2 kV				No Damage.
Ring Wave Surge	Surge	2.5 kV				No Damage.
Safety		IEC950 / UL1950 Class II				Designed to Meet.

3 Schematic

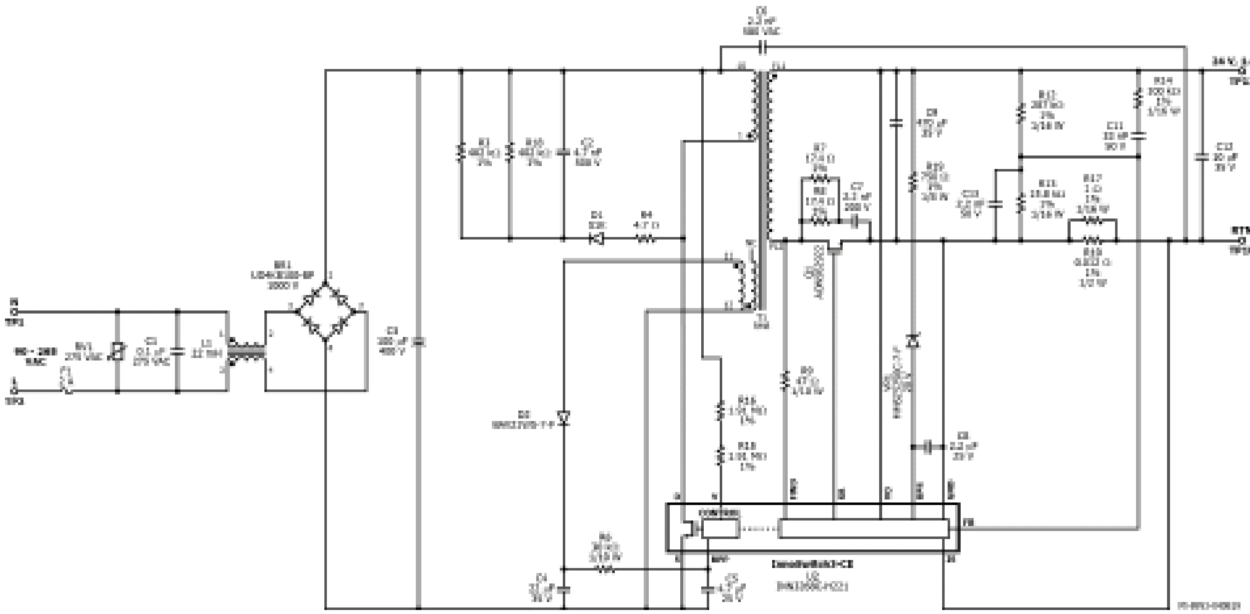

Figure 4 – Schematic.

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4 Circuit Description

The InnoSwitch3-CP incorporates primary and secondary controllers and a high voltage power MOSFET in one single package. It incorporates constant power function that extends the output current capacity while maintaining the output power rating. InnoSwitch3-CP also offers a multiple protection features including line over and under-voltage protection, output over-voltage and over-current limiting, and over-temperature shutdown.

4.1 *Input EMI Filter and Rectifier*

The input fuse F1 provides safety protection from component failures. Varistor RV1 acts as a voltage clamp that limits the voltage spike across the DC input bus during line transient voltage surge events. A 275 V rated part was selected, being slightly above the maximum specified operating input voltage (265 V). The AC input voltage is full wave rectified by the bridge rectifier (BR1) and then filtered by the bulk capacitor (C3) providing a stable DC input voltage supply to the flyback power supply. C1 and L1 provides common mode and differential mode noise input filtering. Y capacitor (C6) is placed directly between the primary input bulk capacitor positive terminal and the output return terminal to divert common mode noise back to the primary where the EMI input filter is located.

4.2 *InnoSwitch3-CP Primary-Side Control*

The power transformer is designed for flyback topology power conversion. The start winding terminal of the transformer primary is connected to the DRAIN pin of the 650 V rated integrated power MOSFET inside the InnoSwitch3-CP while the other side terminal of the primary winding is connected to the positive terminal of the bulk capacitor (C3). A low cost RCD clamp (R4, D1, C2, R3, and R18) limits the primary drain to source leakage voltage spike caused by the transformer leakage inductance. The RCD clamp values should be optimized to achieve better efficiency and standby power.

The InnoSwitch3-CP V pin is used for line UV/OV sensing and protection. Two 1.91 MΩ resistors (R15 and R16) are tied between the high-voltage DC bulk capacitor (C3) and V pin to enable this functionality. The current through R15 and R16 provide detection of input undervoltage and overvoltage. The I_{UV+} and I_{UV-} values determine the brown-in and brown-out threshold while the I_{OV-} determines the input overvoltage threshold. At power-up, after the primary bypass capacitor is charged and the ILIM state is latched, and prior to switching, the state of the V pin is checked to confirm that it is above the brown-in and below the overvoltage shutdown thresholds. In normal operation, if the V pin current falls below the brown-out threshold and remains below brown-in for longer than t_{UV}, the controller enters auto-restart. Switching will only resume once the V pin current is above the brown-in threshold. In the event that the V pin current is above the overvoltage threshold, the controller will also enter auto-restart. Again, switching will only resume once the V pin current has returned to within its normal operating range. The input line UV/OV function makes use of an internal high-voltage MOSFET on the V pin to reduce power consumption. If the cycle off-time t_{OFF} is greater than 50 ms, the internal high-voltage MOSFET will disconnect the external 3.82 MΩ resistor from the internal IC to eliminate current drawn through the resistor. The line sensing function will activate again at the beginning of the next switching cycle. The V pin function can be disabled by shorting the V pin to SOURCE pin.

The PRIMARY BYPASS (BPP) pin is connected to internal regulator that charges the BPP pin capacitor (C5) to VBPP pin by drawing current from the DRAIN (D) pin whenever the power MOSFET is off. When the power MOSFET is on, the device operates from the energy stored in the BPP pin capacitor (C5). During normal operation the primary-side of the InnoSwitch3-CP is powered by the bias supply. The bias winding of the transformer is configured as flyback with respect to the primary winding. During MOSFET turn off period, the bias winding flyback voltage V_{OUT} x (Nb/Ns) is rectified by D2 and filtered C5. The supply current to the BPP pin capacitor (C5) is delivered through resistor R6. Resistance value of R6 should be optimized to achieve the lowest No Load input power consumption. The BPP pin capacitor (C5) value also allows the user to program the current limit (ILIM) settings through the selection of capacitance value (0.47 μF and 4.7 μF for setting standard and increased ILIM settings respectively). In this design, 4.7 μF (increased ILIM) was selected for a more optimized constant current operation at low output voltage.

4.3 *InnoSwitch3-CP Secondary-Side Control*

The secondary-side block of the InnoSwitch3-CP IC is powered by a 4.4 V (VBPS) internal regulator which is supplied by either VOUT or FORWARD (FWD) pin. The (BPS) pin is connected to an external decoupling capacitor (C8) and fed internally from the regulator block. The FWD pin connects to the negative edge detection block through forward resistor (R9). A 47 Ω resistor is recommended to ensure sufficient IC supply current and works for wide range of output voltages. The voltage sensed by FWD pin is used for both handshaking and timing to turn on the SR FET (Q1) connected to the SYNCHRONOUS RECTIFIER DRIVE (SR) pin. The FWD pin voltage is used to determine when to turn off the SR FET in discontinuous conduction mode operation. This is when the voltage across the $R_{DS(ON)}$ of the SR FET (Q1) drops below zero volts. In continuous conduction mode (CCM) the SR FET is turned off when the feedback pulse is sent to the primary to demand the next switching cycle, providing excellent synchronous operation, free of any overlap for the FET turn-off.

The external resistor divider network, R12 and R13, is connected between the OUTPUT VOLTAGE and SECONDARY GROUND pins to sense the output voltage. The midpoint of the divider network is connected to the FEEDBACK (FB) pin to regulate the output voltage. The internal voltage comparator reference voltage is VFB (1.265 V). The external current sense resistors (R10 and R17) connected between ISENSE pin and SECONDARY GROUND pin are used to regulate the output current in constant current regulation mode operation. Sense resistor value is can be calculated by using $R_{IS} = I_{SV(TH)}/I_{OUT(CC)}$.

Secondary snubber (C7, R8 and R17) limits the SR FET (Q1) drain to source voltage stress.

Resistor R14 and C11 is a phase boost network with optimized value to lower the ripple voltage. Capacitor C13 provides high frequency noise filtering to prevent output voltage misdetection. Capacitor C12 helps eliminate pulse grouping during CP and CC operation by injecting ripple from the positive terminal of the output capacitor to the Is pin.

Output capacitor C9 provides output voltage filtering. A low ESR electrolytic capacitor is used for lower ripple voltage.

An external output OVP circuit (R19 and VR1) is added at the secondary-side due to internal OVP function is disabled in this application. In the event of output overvoltage, Zener diode VR1 injects current to the BPS pin forcing the device in latch mode operation.

5 PCB Layout

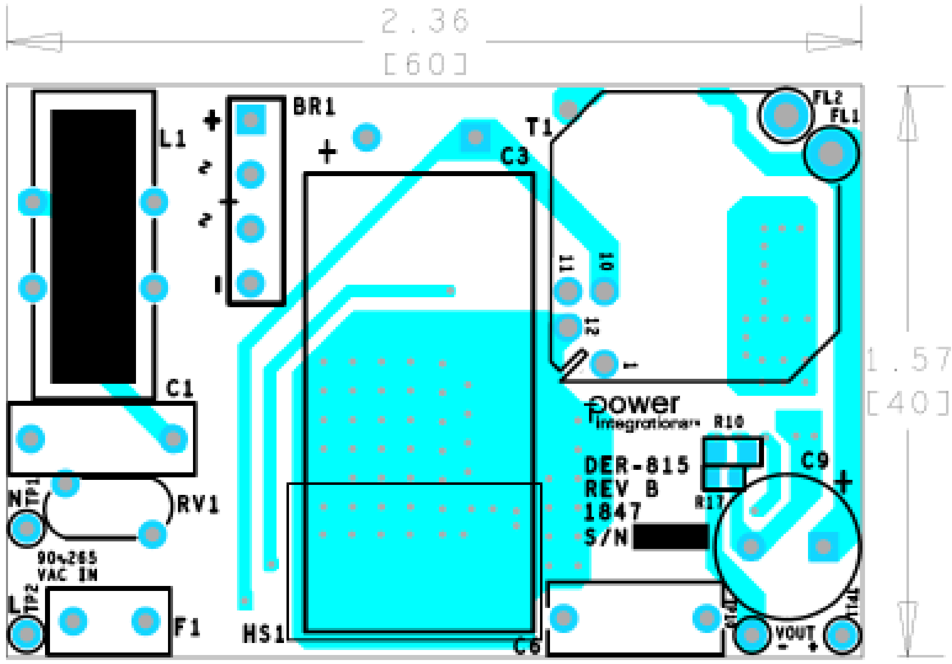

Figure 5 – Top Side.

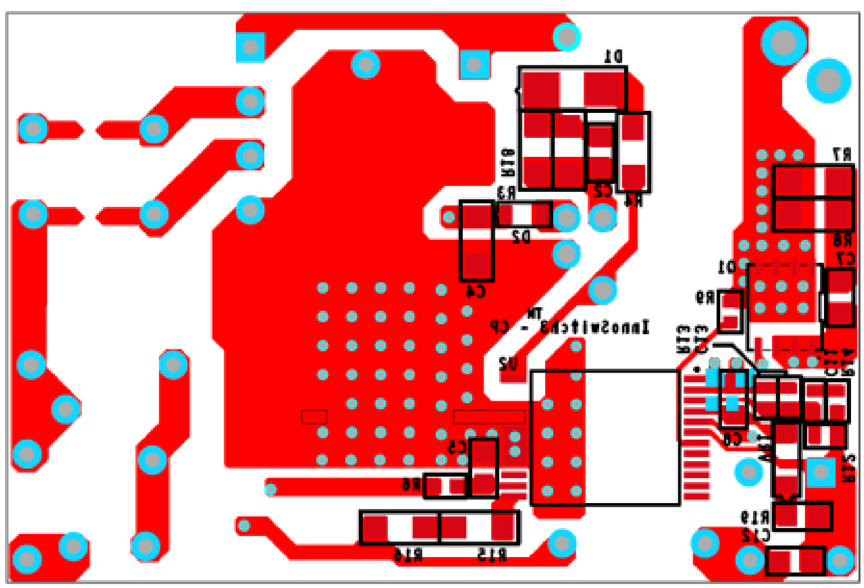

Figure 6 – Bottom Side.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge Rectifier, 1000 V, 4 A, 4-ESIP, D3K	UD4KB100-BPP	Micro Commercial
2	1	C1	0.1 UF, 20% , 275VAC, 560 VDC, X2, -40°C ~ 110°C	R46KF310000P1M	KEMET
3	1	C2	CER,4700 pF, ±10%, 500 V, X7R, Low ESL, 0805	C0805C472KCRAC7800	Kemet
4	1	C3	Electrolytic, 100 µF, 400 V, Aluminum, Radial	400BXW100MEFR16X30	Rubycon
5	1	C4	22 uF, 35 V, Ceramic, X5R, 1206	C3216X5R1V226M160AC	TDK
6	1	C5	4.7 uF, ±10%, 25 V, Ceramic, X7R, -55°C ~ 125°C, 0805	TMK212AB7475KG-T	Taiyo Yuden
7	1	C6	2.2 nF, 500 Vac, Ceramic, Y1	VY1222M47Y5UG63V0	Vishay
8	1	C7	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
9	1	C8	2.2 uF, 25 V, Ceramic, X7R, 0805	C2012X7R1E225M	TDK
10	1	C9	470 uF, 35 V, Electrolytic, Very Low ESR, 23 mOhm, (10 x 20)	EKZE350ELL471MJ20S	Nippon Chemi-Con
11	1	C11	0.033 uF, ±5%, 50 V, Ceramic, X7R, 0603 (1608 Metric)	06035C333JAT2A	AVX Corp
12	1	C12	10 uF, 35 V, Ceramic, X5R, 0805	C2012X5R1V106K085AC	TDK
13	1	C13	2.2 nF 50 V, Ceramic, X7R, 0603	C0603C222K5RACTU	Yageo
14	1	D1	DIODE, GEN PURP, 800 V, 1 A,Standard Recovery >500ns	S1K	ON Semi
15	1	D2	250 V, 0.2 A, Fast Switching, 50 ns, SOD-323	BAV21WS-7-F	Diodes, Inc.
16	1	F1	2 A, 250 V, Slow, Long Time Lag,RST	RST 2	Belfuse
17	1	L1	22 mH +/- 40% @10KHz 0.4 V, 35 mH (typ) @ 100KHz	04291-T247	Sumida
18	1	Q1	MOSFET, N-CH, 120 V, 85A (at VGS=10 V), Trench Power	AONS62922	Alpha & Omega
19	2	R3 R18	RES, 402 k, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF4023V	Panasonic
20	1	R4	RES, 4.7 R, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ4R7V	Panasonic
21	1	R6	RES, 30 k, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ303V	Panasonic
22	2	R7 R8	RES, 17.4 R, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF17R4V	Panasonic
23	1	R9	RES, 47 R, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ470 V	Panasonic
24	1	R10	RES, 0.012 R, ±1%, 0.5 W, 0805	KRL1220E-M-R012-F-T5	Susumu
25	1	R12	RES, 287 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF2873V	Panasonic
26	1	R13	RES, 15.8 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1582V	Panasonic
27	1	R14	RES, 100 k, 1%, 1/16 W, Thick Film, 0603	ERJ-3EKF1003V	Panasonic
28	2	R15 R16	RES, 1.91 M, 1%, 1/4 W, Thick Film, 1206	RMCF1206FT1M91	Stackpole
29	1	R17	RES, 1 R, 1%, 1/16 W, Thick Film, 0603	ERJ-3RQF1R0 V	Panasonic
30	1	R19	RES, 750 R, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF7500 V	Panasonic
31	1	RV1	275 Vac, 23 J, 7 mm, RADIAL	V275LA4P	Littlefuse
32	1	T1	Bobbin, RM8, Vertical, 12 pins	BRM08-1112CP-W-P5.0	MH&W
33	1	U2	InnoSwitch3-CP	INN3268C-H221	Power Integrations
34	1	VR1	DIODE, ZENER, 20 V, ±2%, 500 mW, SOD123	MMSZ5250C-E3-08	Vishay

Miscellaneous Parts

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	2	TP1 TP10	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
2	1	TP2	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
3	1	TP11	Test Point, RED, Miniature THRU-HOLE MOUNT	5000	Keystone
4	1	HS1	HEATSINK, DER-815 PRIMARY		Custom

Optional Part

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	HS1	HEAT SINK, DER815 PRIMARY	61-00247-00	Custom

7 Power Transformer Specification

7.1 *Electrical Diagram*

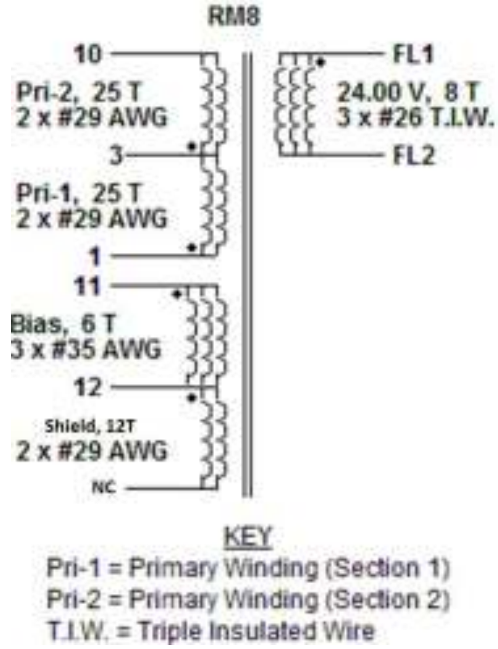

Figure 7 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1-10 V_{PK-PK}, 100 kHz switching frequency, between pin 1 and pin 10, with all other windings open.	560 μH
Tolerance	Tolerance of Primary Inductance.	±5%
Leakage Inductance	Short all bias windings and secondary windings measured at 1 V_{PK-PK}, 100 kHz switching frequency, across pin 1 and pin 3	<7 μH

7.3 *Material List*

Item	Description
[1]	Core: RM8 PC95 or Equivalent.
[2]	Bobbin, RM8, Vertical, 12 pins, Part No.: 25-01084-00.
[3]	Magnet Wire: #29 AWG.
[4]	Magnet Wire: #35 AWG.
[5]	TIW Wire: #26 AWG.
[6]	Polyester Tape 10 mm.
[7]	Polyester Tape 36 mm.
[8]	RM8 Clip.

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7.4 *Transformer Build Diagram*

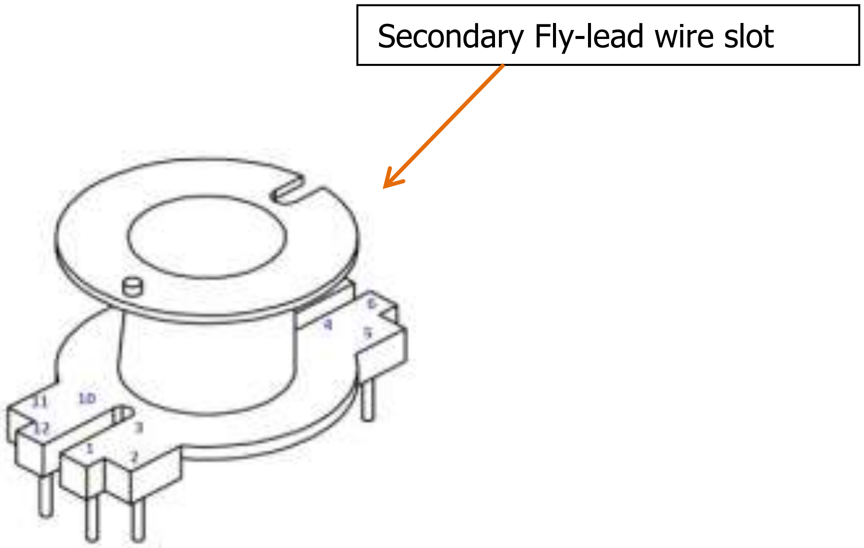

Figure 8 – Transformer Bobbin.

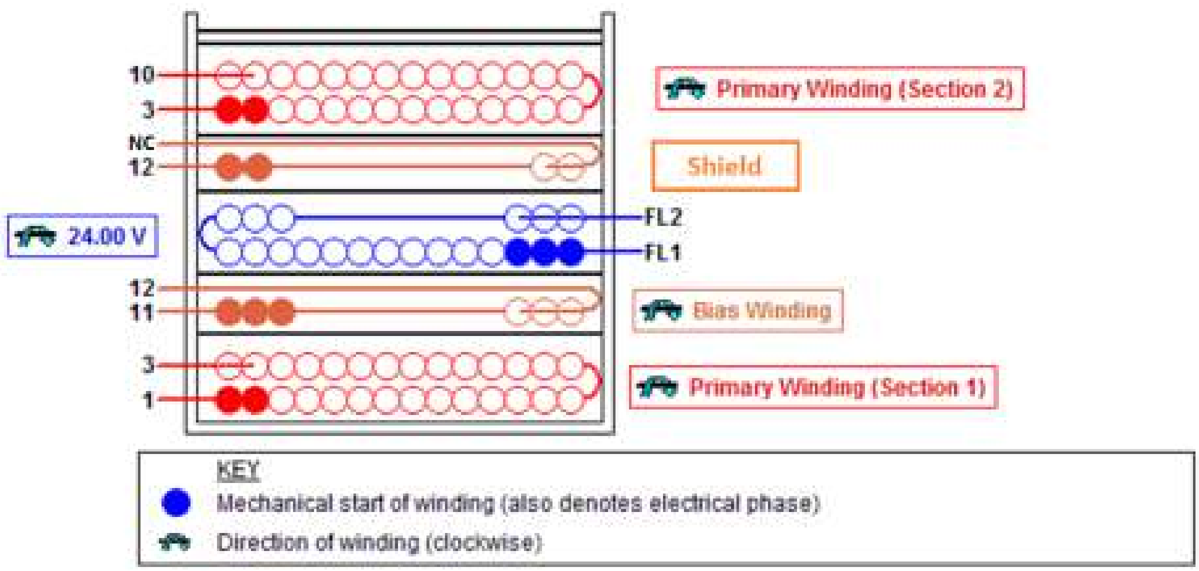

Figure 9 – Transformer Bobbin.

7.5 *Inductor Construction*

Winding Directions	Bobbin is oriented on winder jig such that terminal pin 1 and pin 12 are in the left side facing upward. The winding direction is clockwise.
Winding 1	Use magnetic wire, Item [3]. Start at pin 1 and wind 25 turns (Bifilar) evenly in 2 layers. Finish the winding on pin 3.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation
Winding 2	Use magnetic wire, Item [4]. Start at pin 11 and wind 6 turns evenly in 1 layer. Finish the winding at pin 12.
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation
Winding 3	Position the bobbin so that pin 6 and 7 are facing upward with the secondary wire slot in the right side. Use TIW wire Item [5]. Start at fly lead wire FL1 and wind 8 turns (Trifilar) evenly in 2 layers. Finish the winding with fly lead wire FL2
Insulation	Apply 1 layer of polyester tape, Item [6] for insulation
Winding 4	Use magnetic wire, Item [3]. Start at pin 12 and wind 12 turns (Bifilar) evenly for 1 layer. Finish the winding at the right side of the bobbin and cut the wire with no connection.
Winding 5	Position the bobbin with pin 1 and pin 12 facing upward. Use magnetic wire, Item [3]. Start at pin 3 and wind 25 turns (Bifilar) evenly in 2 layers. Finish the winding on pin 10.
Insulation	Apply 2 layer of polyester tape, Item [6] for insulation
Core Grinding	Grind the center leg of the ferrite core to meet the nominal inductance specification of 515 μH.
Core Assembly	Use 2 pcs RM8 Clip item (7) to fix the top and bottom core. Cut the clip terminals.
Cut Terminal Pins	Cut terminal pins 4-9, pin 2 and pin 3.
Cut Bobbin Extension	Cut the bobbin extension where the terminal pin 5, 6, 7 and 8 is located.
Varnishing	Dip the transformer in a varnish.
Safety Insulation Tape	After varnishing the transformer. Apply 2 layers safety insulation tape item (7) as shown in the figures.
+Bulk Terminal Lead	Connect/Solder a 20 mm long terminal lead as shown in the figure. Bend the lead terminal by 90º.

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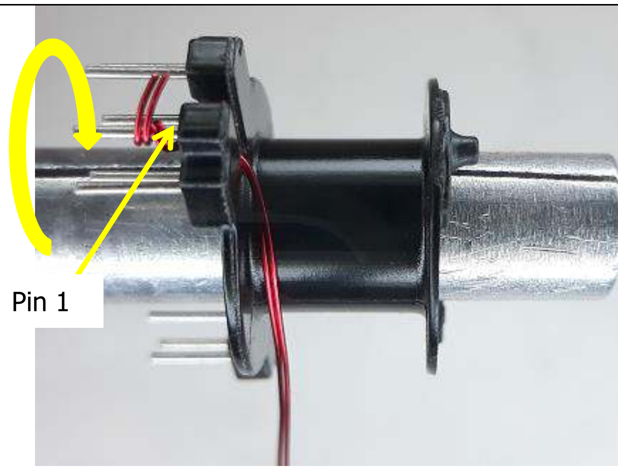
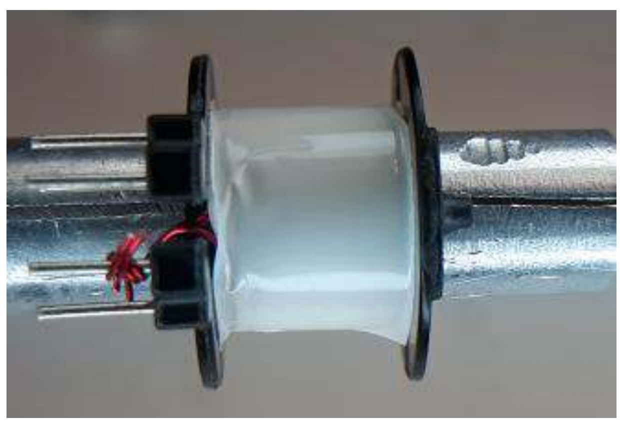
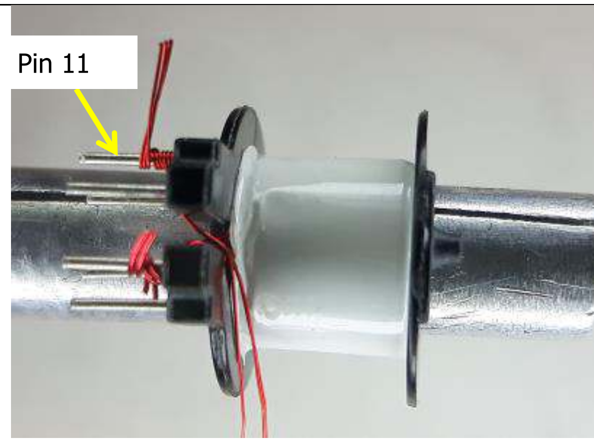
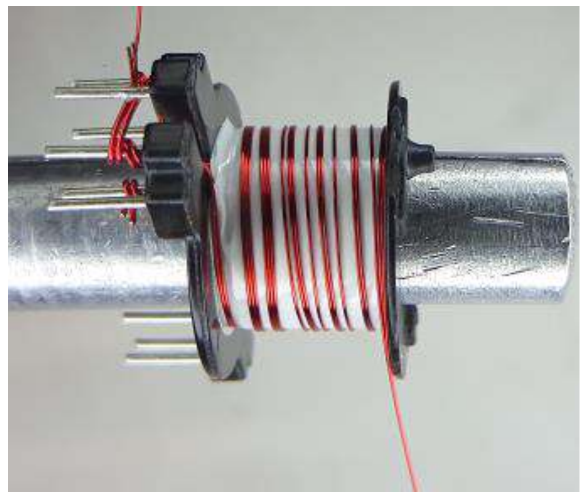
7.6 *Winding Illustrations*

Winding Directions Bobbin is oriented on winder jig such that terminal pin 1 and pin 12 are in the left side facing upward. The winding direction is clockwise.	
Winding 1- Primary 1 Use magnetic wire, Item [3]. Start at pin 1 and wind 25 turns (Bifilar) evenly in 2 layers. Finish the winding on pin 3.	
Insulation Apply 1 layer of polyester tape, Item [6] for insulation	

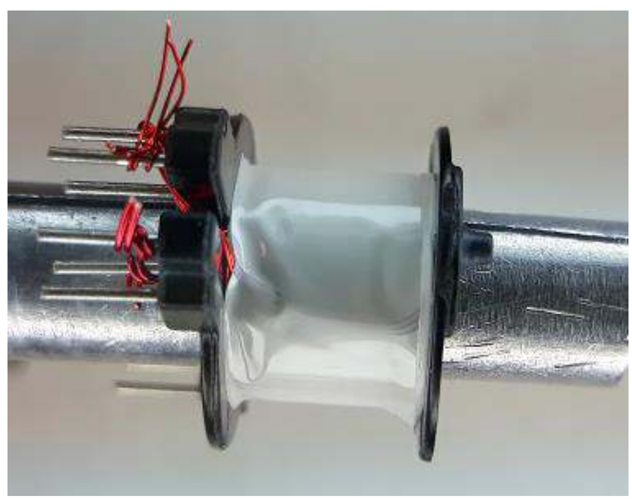
Winding 2- Bias
Use magnetic wire, Item [4]. Start at pin 11 and wind 6 turns evenly in 1 layer. Finish the winding at pin 12.



Windings must be evenly distributed.



Insulation
Apply 1 layer of polyester tape, Item [6] for insulation



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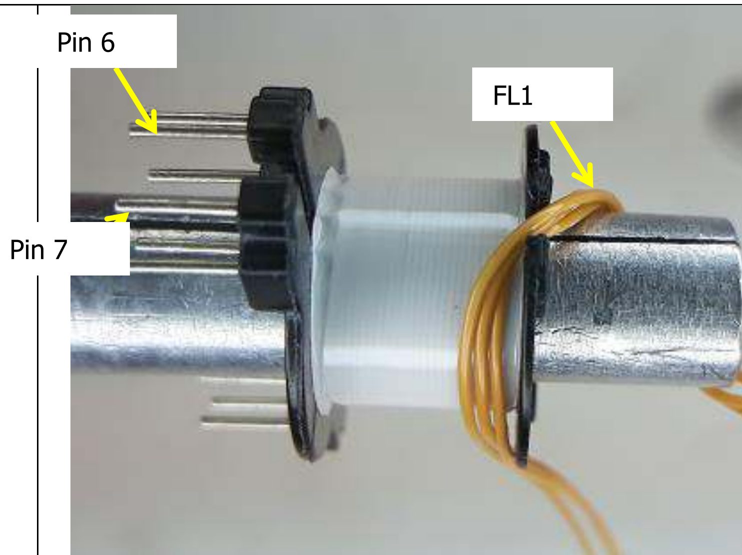
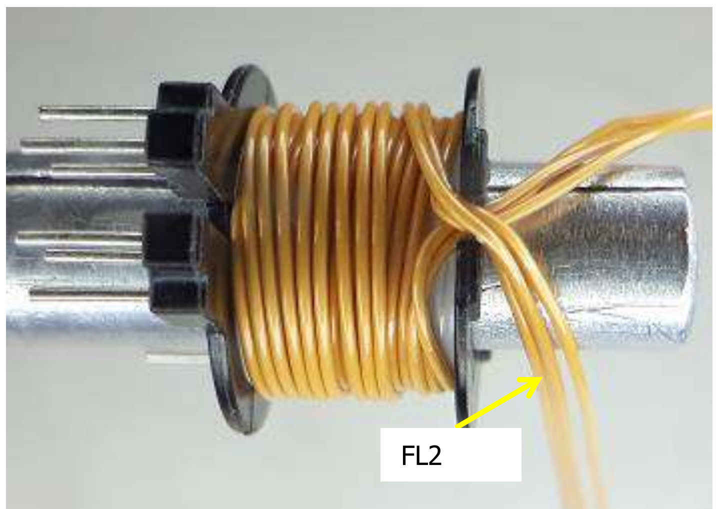
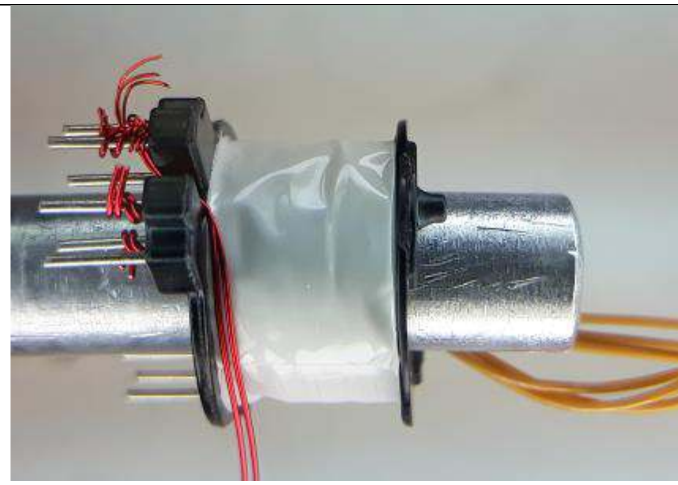
Winding 3- Secondary Winding
Position the bobbin so that pin 6 and 7 are facing upward with the secondary wire slot in the right side. Use TIW wire Item [5]. Start at Fly Lead wire FL1 and wind 8 turns (Trifilar) evenly in 2 layers. Finish the winding with Fly Lead wire Fl2



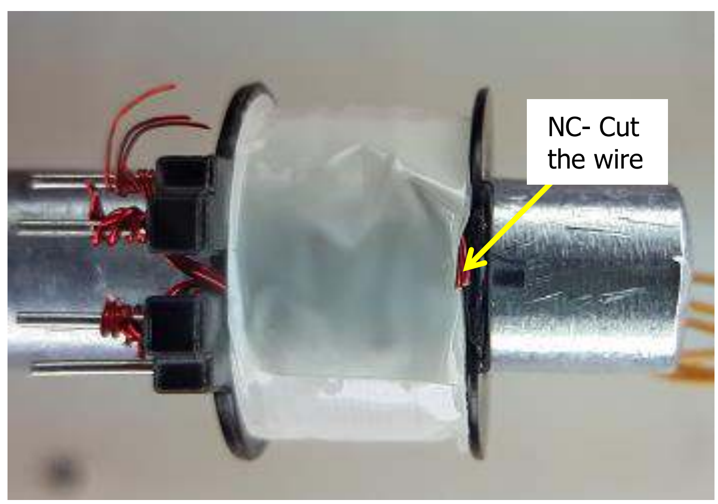


Insulation
Apply 1 layer of polyester tape, Item [6] for insulation

Winding 4- Shield Winding
Use magnetic wire, Item [3]. Start at pin 12 and wind 12 turns (Bifilar) evenly for 1 layer. Finish the winding at the right side of the bobbin and cut the wire with no connection.



Insulation
Apply 1 layer of polyester tape, Item [6] for insulation



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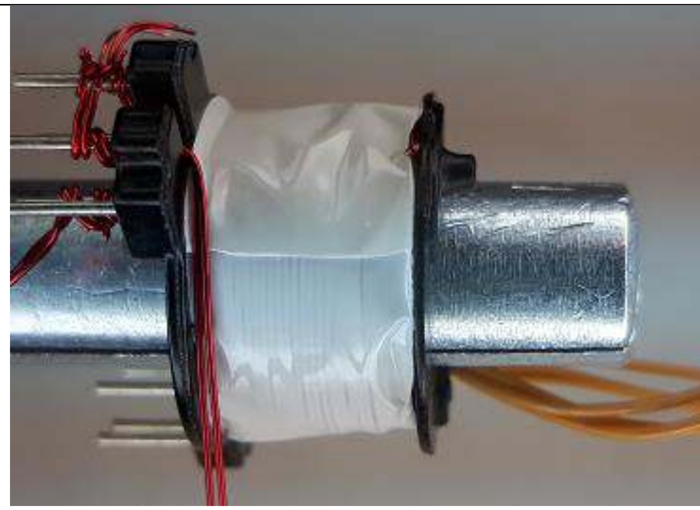
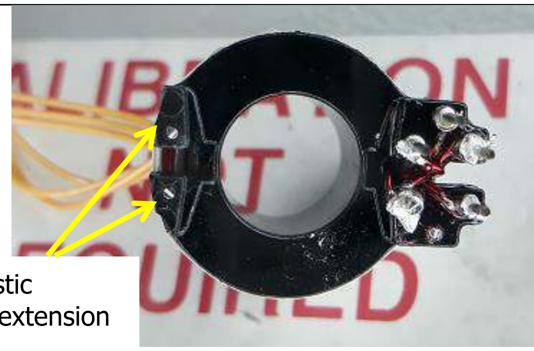
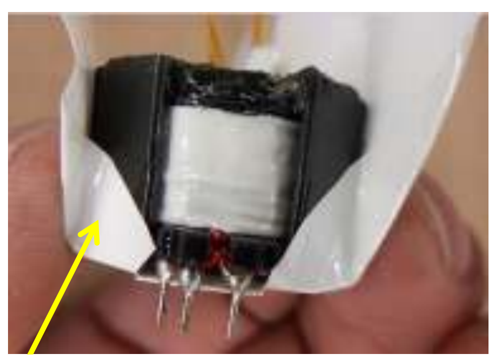
Winding 5- Primary 2
Position the bobbin with pin 1 and pin 12 facing upward. Use magnetic wire, Item [3]. Start at pin 3 and wind 25 turns (Bifilar) evenly in 2 layers. Finish the winding on pin 10.



Insulation
Apply 2 layers of polyester tape, Item [6] for insulation

Cut Terminal Pins Cut terminal pins 4-9, pin 2 and pin3. **Cut Bobbin Extension** Cut the bobbin extension where the terminal pin 5, 6, 7 and 8 is located	 Cut plastic bobbin extension
Safety Insulation Tape After varnishing the transformer. Apply 2 layers safety insulation tape item (7) as shown in the figures. Cut the tape 5.5 mm X 8 mm to make a slot for the primary terminal leads. Fold excess tape as shown in the figure. This is to make sure core edges are covered	   Fold and fix the tape in the core

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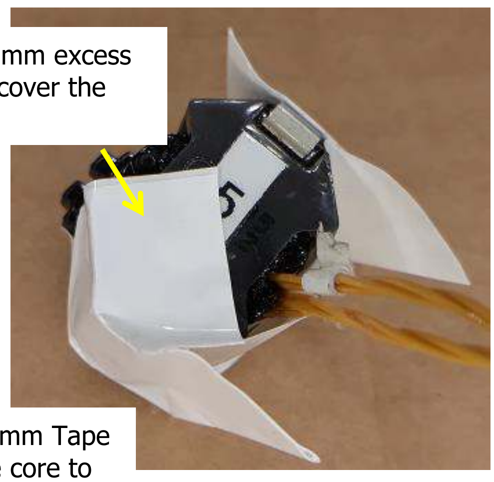
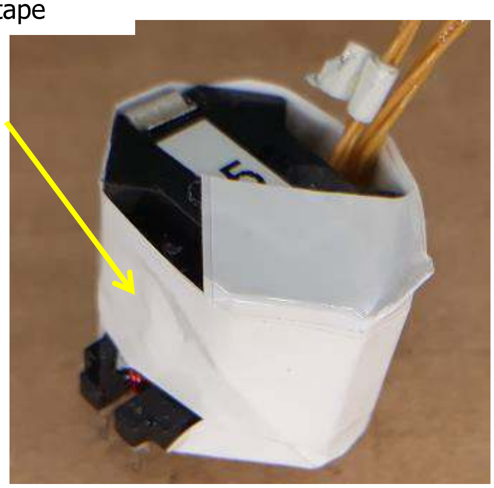
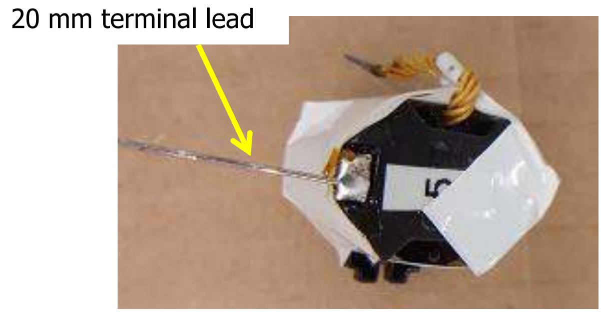
Fold the 2 layer tape as shown in the figure.

Cut the excess tape on the left side but keep on a 13 x 13 mm excess tape to cover top core as shown in the figure





+Bulk Terminal Lead Connect/Solder a 20 mm long terminal lead as shown in the figure. Bend the lead terminal by 90º.	

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8 Transformer (T1) Spreadsheet

1	ACDC_InnoSwitch3-CP_Flyback_081518; Rev.1.3; Copyright Power Integrations 2018	INPUT	INFO	OUTPUT	UNITS	InnoSwitch3-CP Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	VAC_MIN	90		90	V	Minimum AC line voltage
4	VAC_MAX			265	V	Maximum AC input voltage
5	VAC_RANGE			UNIVERSAL		AC line voltage range
6	FLINE			60	Hz	AC line voltage frequency
7	CAP_INPUT	100.0		100.0	uF	Input capacitance
9	**SETPOINT 1**					
10	VOUT1	24.00		24.00	V	Output voltage 1, should be the highest output voltage required
11	IOUT1	1.880		1.880	A	Output current 1
12	POUT1			45.12	W	Output power 1
13	EFFICIENCY1	0.90		0.90		Converter efficiency for output 1
14	Z_FACTOR1	0.50		0.50		Z-factor for output 1
16	**SETPOINT 2**					
17	VOUT2	15.00		15.00	V	Output voltage 2
18	IOUT2	3.000		3.000	A	Output current 2
19	POUT2			45.00	W	Output power 2
20	EFFICIENCY2	0.90		0.90		Converter efficiency for output 2
21	Z_FACTOR2	0.50		0.50		Z-factor for output 2
72	PERCENT_CDC	0%		0%		Percentage (of output voltage) cable drop compensation desired at full load
73	CDC_SCALING_SETPOINT	3		3		Select the setpoint number for the voltage used for cable drop compensation (typically the 5V output)
77	**PRIMARY CONTROLLER SELECTION**					
78	ENCLOSURE	ADAPTER		ADAPTER		Power supply enclosure
79	ILIMIT_MODE	INCREASED		INCREASED		Device current limit mode
80	VDRAIN_BREAKDOWN	650		650	V	Device breakdown voltage
81	DEVICE_GENERIC	AUTO		INN32X8		Device selection
82	DEVICE_CODE			INN3268C		Device code
83	PDEVICE_MAX			50	W	Device maximum power capability
84	RDSON_25DEG			0.99	Ω	Primary MOSFET on-time resistance at 25°C
85	RDSON_100DEG			1.54	Ω	Primary MOSFET on-time resistance at 100°C
86	ILIMIT_MIN			1.683	A	Primary MOSFET minimum current limit
87	ILIMIT_TYP			1.850	A	Primary MOSFET typical current limit
88	ILIMIT_MAX			2.017	A	Primary MOSFET maximum current limit
89	VDRAIN_ON_MOSFET			0.75	V	Primary MOSFET on-time voltage drop
90	VDRAIN_OFF_MOSFET		Warning	593.31	V	The peak drain voltage on the MOSFET is higher than 90% of the device BVDSS: Decrease the device VOR
94	**WORST CASE ELECTRICAL PARAMETERS**					
95	FSWITCHING_MAX	72000		72000	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
96	VOR	150.0		150.0	V	Voltage reflected to the primary winding (corresponding to setpoint 1) when the primary MOSFET turns off
97	VMIN			98.54	V	Valley of the rectified minimum input AC voltage at full load
98	KP			0.765		Measure of continuous/discontinuous mode of operation
99	MODE_OPERATION			CCM		Mode of operation

100	DUTYCYCLE			0.605		Primary MOSFET duty cycle
101	TIME_ON			10.86	us	Primary MOSFET on-time
102	TIME_OFF			5.71	us	Primary MOSFET off-time
103	LPRIMARY_MIN			528.3	uH	Minimum primary magnetizing inductance
104	LPRIMARY_TYP			556.1	uH	Typical primary magnetizing inductance
105	LPRIMARY_TOL			5.0	%	Primary magnetizing inductance tolerance
106	LPRIMARY_MAX			583.9	uH	Maximum primary magnetizing inductance
108	**PRIMARY CURRENT**					
109	IAVG_PRIMARY			0.487	A	Primary MOSFET average current
110	IPEAK_PRIMARY			1.847	A	Primary MOSFET peak current
111	IPEDESTAL_PRIMARY			0.377	A	Primary MOSFET current pedestal
112	IRIPPLE_PRIMARY			1.846	A	Primary MOSFET ripple current
113	IRMS_PRIMARY			0.775	A	Primary MOSFET RMS current
115	**SECONDARY CURRENT**					
116	IPEAK_SECONDARY			11.541	A	Secondary MOSFET peak current
117	IPEDESTAL_SECONDARY			2.359	A	Secondary MOSFET pedestal current
118	IRMS_SECONDARY			4.942	A	Secondary MOSFET RMS current
119	IRIPPLE_CAP_OUT			3.928	A	Output capacitor ripple current
123	**TRANSFORMER CONSTRUCTION PARAMETERS**					
124	**CORE SELECTION**					
125	CORE	RM8	Info	RM8		The transformer windings may not fit: pick a bigger core or bobbin and refer to the Transformer Parameters tab for fit calculations
126	CORE NAME			PC95RM08Z		Core code
127	AE			64.0	mm^2	Core cross sectional area
128	LE			38.0	mm	Core magnetic path length
129	AL			5290	nH	Ungapped core effective inductance per turns squared
130	VE			2430	mm^3	Core volume
131	BOBBIN NAME			B-RM08-V		Bobbin name
132	AW			30.0	mm^2	Bobbin window area
133	BW			8.80	mm	Bobbin width
134	MARGIN			0.0	mm	Bobbin safety margin
136	**PRIMARY WINDING**					
137	NPRIMARY			50		Primary winding number of turns
138	BPPEAK			3767	Gauss	Peak flux density
139	BMAX			3322	Gauss	Maximum flux density
140	BAC			1660	Gauss	AC flux density (0.5 x Peak to Peak)
141	ALG			222	nH	Typical gapped core effective inductance per turns squared
142	LG			0.346	mm	Core gap length
143	LAYERS_PRIMARY			3		Primary winding number of layers
144	AWG_PRIMARY			25		Primary wire gauge
145	OD_PRIMARY_INSULATED			0.518	mm	Primary wire insulated outer diameter
146	OD_PRIMARY_BARE			0.455	mm	Primary wire bare outer diameter
147	CMA_PRIMARY			413.5	Cmils/A	Primary winding wire CMA
149	**SECONDARY WINDING**					
150	NSECONDARY	8		8		Secondary winding number of turns
151	AWG_SECONDARY			20		Secondary wire gauge
152	OD_SECONDARY_INSULATED			1.118	mm	Secondary wire insulated outer diameter
153	OD_SECONDARY_BARE			0.812	mm	Secondary wire bare outer diameter
154	CMA_SECONDARY			206.7	Cmils/A	Secondary winding wire CMA
156	**BIAS WINDING**					
157	NBIAS			6		Bias winding number of turns

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161	**PRIMARY COMPONENTS SELECTION**					
162	LINE UNDERVOLTAGE					
163	BROWN-IN REQURED			72.00	V	Required line brown-in threshold
164	RLS			3.56	MΩ	Connect two 1.78 MOhm resistors to the V-pin for the required UV/OV threshold
165	BROWN-IN ACTUAL			71.40	V	Actual brown-in threshold using standard resistors
166	BROWN-OUT ACTUAL			64.58	V	Actual brown-out threshold using standard resistors
168	**LINE OVERVOLTAGE**					
169	OVERVOLTAGE_LINE		Warning	297.50	V	The device voltage stress will be higher than 90% of the breakdown voltage when overvoltage is trigerred
170						
171	BIAS WINDING					
172	VBIAS			9.00	V	Rectified bias voltage at the lowest output setpoint
173	VF_BIAS			0.70	V	Bias winding diode forward drop
174	VREVERSE_BIASDIODE			53.80	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
175	CBIAS			22	uF	Bias winding rectification capacitor
176	CBPPP			4.70	uF	BPPP pin capacitor
180	**SECONDARY COMPONENTS SELECTION**					
181	**RECTIFIER**					
182	VDRAIN_OFF_SRFET			83.73	V	Secondary rectifier reverse voltage (not accounting parasitic voltage ring)
183	SRFET	AO4294	Info	AO4294		The voltage stress (including the parasitic ring) on the secondary MOSFET selected may exceed the device BVDSS: pick a MOSFET with a higher BVDSS
184	VBREAKDOWN_SRFET			100	V	Secondary rectifier breakdown voltage
185	RDSON_SRFET			15.5	mΩ	SRFET on time drain resistance at 25degC for VGS=4.4V
186						
187	FEEDBACK COMPONENTS					
188	RFB_UPPER			100.00	kΩ	Upper feedback resistor (connected to the output terminal)
189	RFB_LOWER			#NUM!	kΩ	Lower feedback resistor required to obtain the output for cable drop compensation
190	CFB_LOWER			330	pF	Lower feedback resistor decoupling capacitor
194	**SETPOINTS ANALYSIS**					
195	**TOLERANCE CORNER**					
196	USER_VAC	90		90	V	Input AC RMS voltage corner to be evaluated
197	USER_ILIMIT	TYP		1.850	A	Current limit corner to be evaluated
198	USER_LPRIMARY	TYP		556.1	uH	Primary inductance corner to be evaluated
199						
200	SETPOINT SELECTION					
201	SETPOINT	2		2		Select the setpoint which needs to be evaluated
202	FSWITCHING			58643.0	Hz	Maximum switching frequency at full load and the valley of the minimum input AC voltage
203	VOR			94.0	V	Voltage reflected to the primary winding when the primary MOSFET turns off
204	VMIN			98.62	V	Valley of the minimum input AC voltage
205	KP			0.852		Measure of continuous/discontinuous mode of operation
206	MODE_OPERATION			CCM		Mode of operation
207	DUTYCYCLE			0.490		Primary MOSFET duty cycle
208	TIME_ON			9.20	us	Primary MOSFET on-time
209	TIME_OFF			8.70	us	Primary MOSFET off-time
211	**PRIMARY CURRENT**					
212	IAVG_PRIMARY			0.485	A	Primary MOSFET average current

213	IPEAK_PRIMARY			1.726	A	Primary MOSFET peak current
214	IPEDESTAL_PRIMARY			0.256	A	Primary MOSFET current pedestal
215	IRIPPLE_PRIMARY			1.470	A	Primary MOSFET ripple current
216	IRMS_PRIMARY			0.754	A	Primary MOSFET RMS current
218	**SECONDARY CURRENT**					
219	IPEAK_SECONDARY			10.786	A	Secondary MOSFET peak current
220	IPEDESTAL_SECONDARY			1.598	A	Secondary MOSFET pedestal current
221	IRMS_SECONDARY			4.811	A	Secondary MOSFET RMS current
222	IRIPPLE_CAP_OUT			3.761	A	Output capacitor ripple current
224	**MAGNETIC FLUX DENSITY**					
225	BPPEAK			3291	Gauss	Peak flux density
226	BMAX			2999	Gauss	Maximum flux density
227	BAC			1277	Gauss	AC flux density (0.5 x Peak to Peak)

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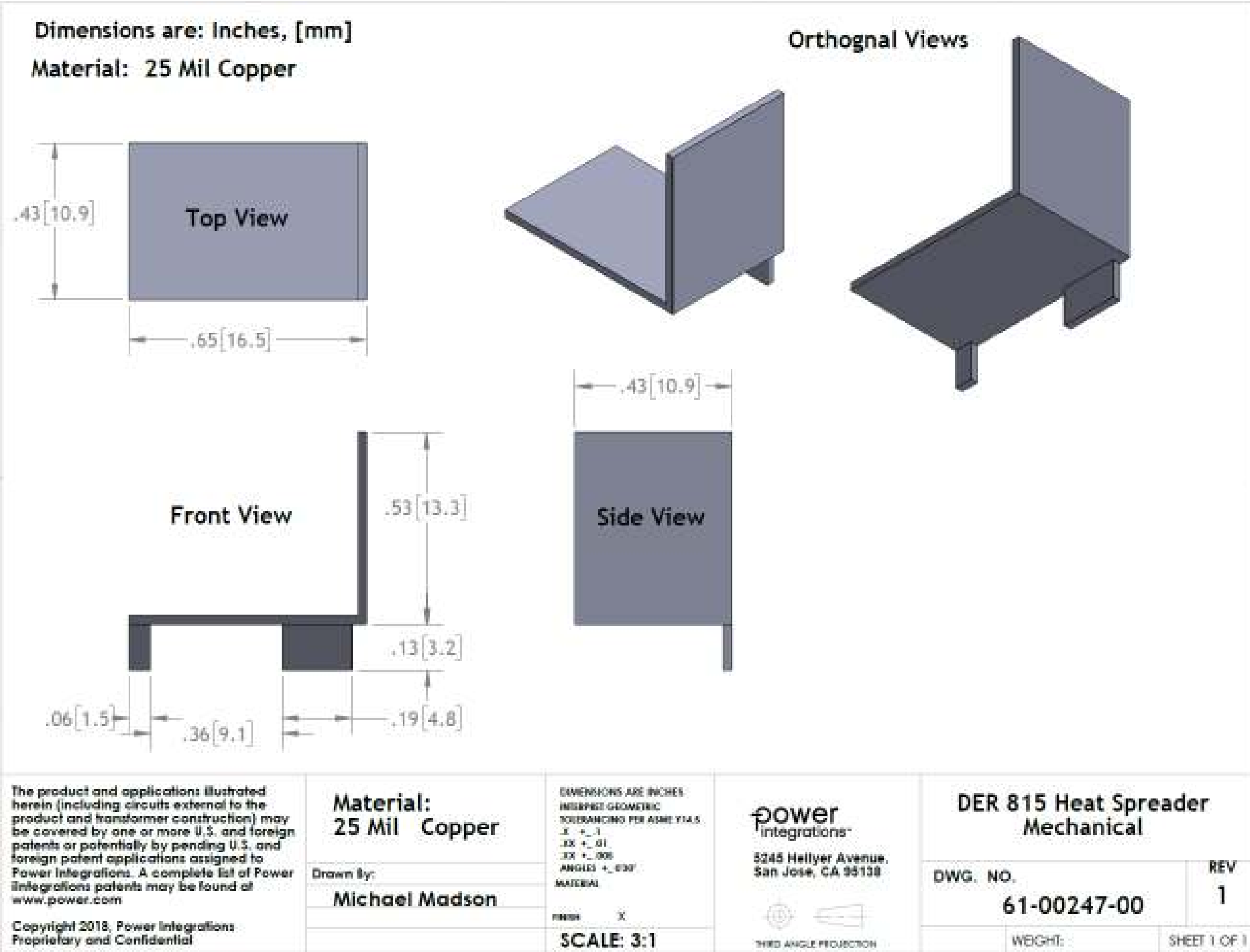
9 Heat Sink Specification (Optional)



10 Performance Data

All measurements were performed at room temperature.

10.1 *CV-CC-CP Output Characteristic Curve*

DUT: Open Frame unit
Load: E-Load CC Mode load during CV Operation, CR Mode Loading during CP and CC Mode Operation
Ambient Temperature: 25 ºC

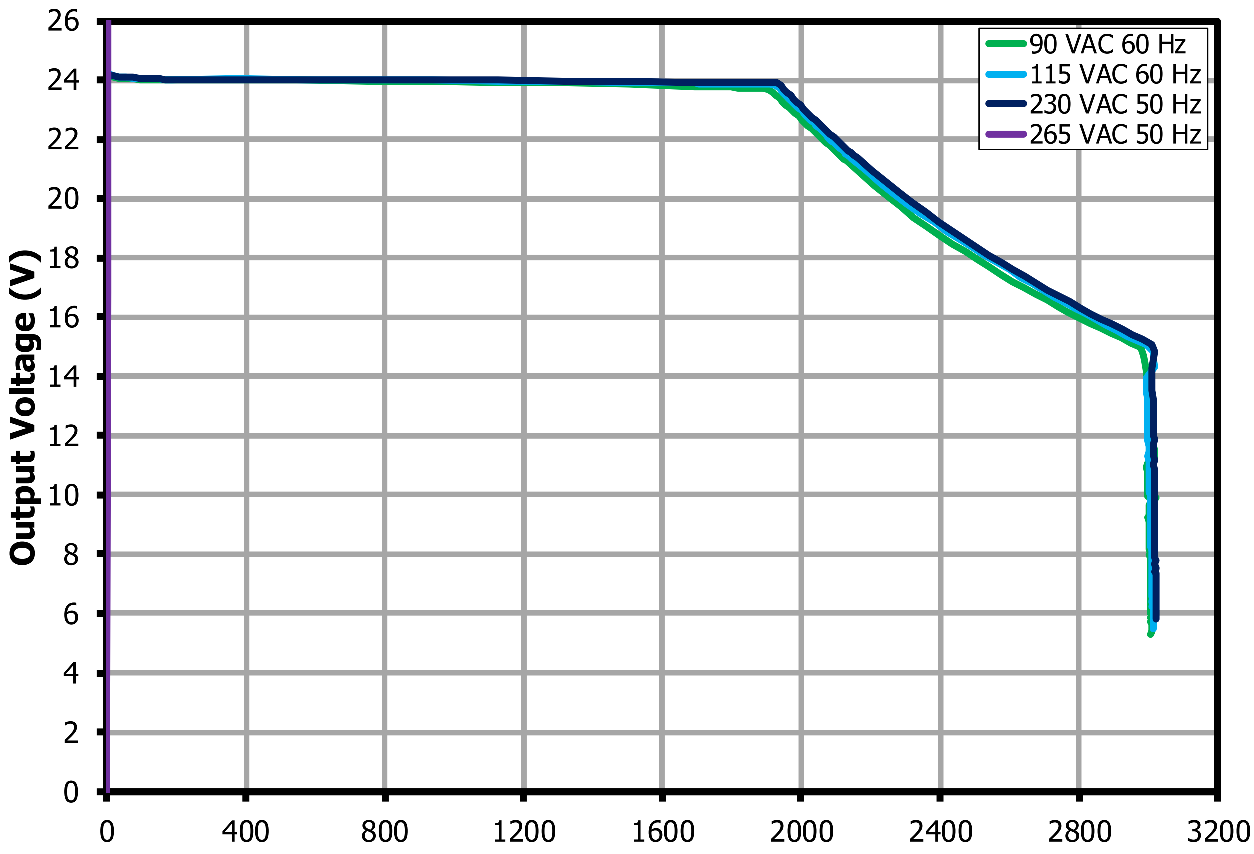


Figure 10 – CV-CC-CP Curve.

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10.2 *Efficiency at 24 V Full Load*

DUT: Open Frame unit
Load: 1880 mA CC mode load
Ambient Temperature: 25 ºC
Soak time: 60 s Soak time, 30 s per input line

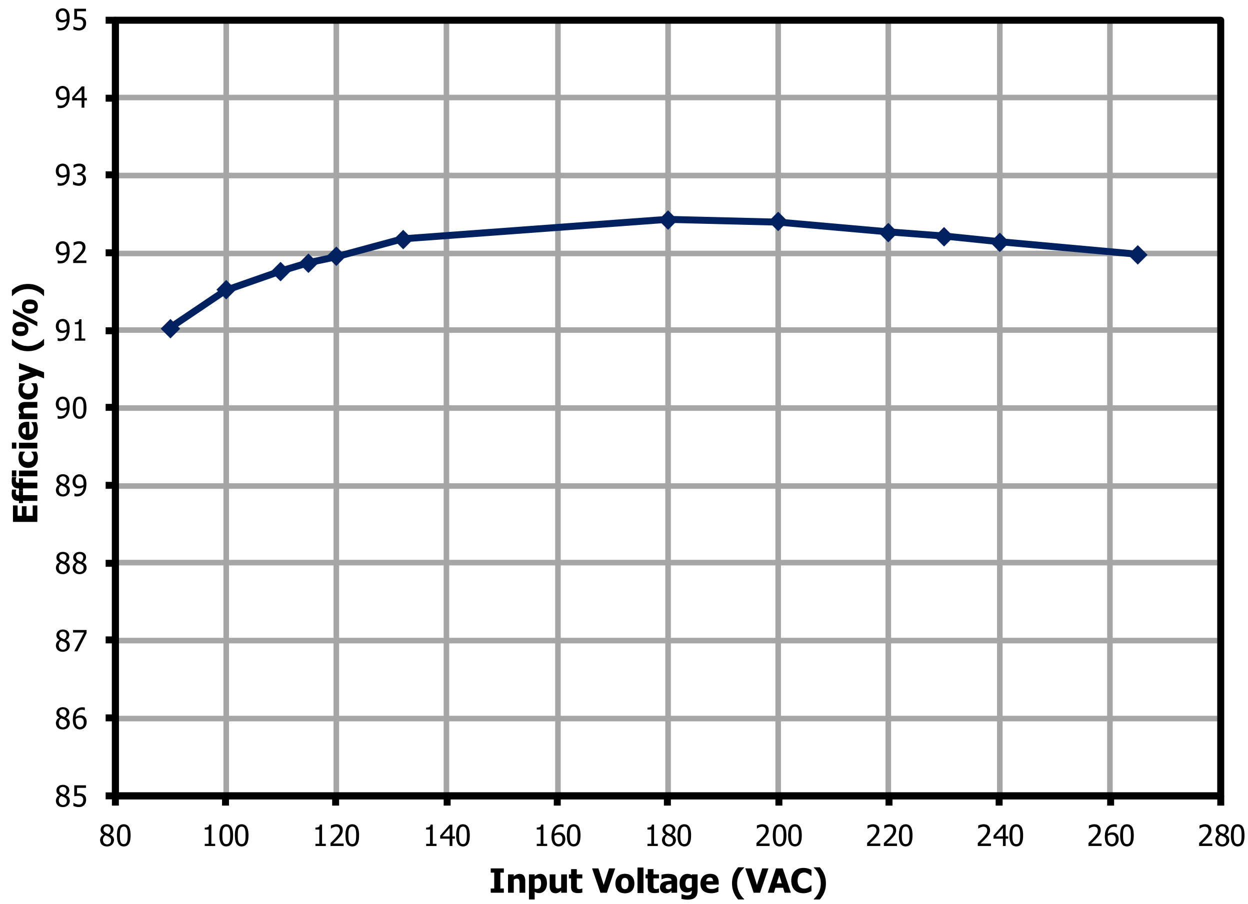

Figure 11 – Efficiency vs. Line.

10.3 *Efficiency at 15 V with CV Mode Load*

DUT: Open Frame unit
Load: 15 V CV mode load
Ambient Temperature: 25 ºC
Soak time: 60 s Soak time, 30 s per input line

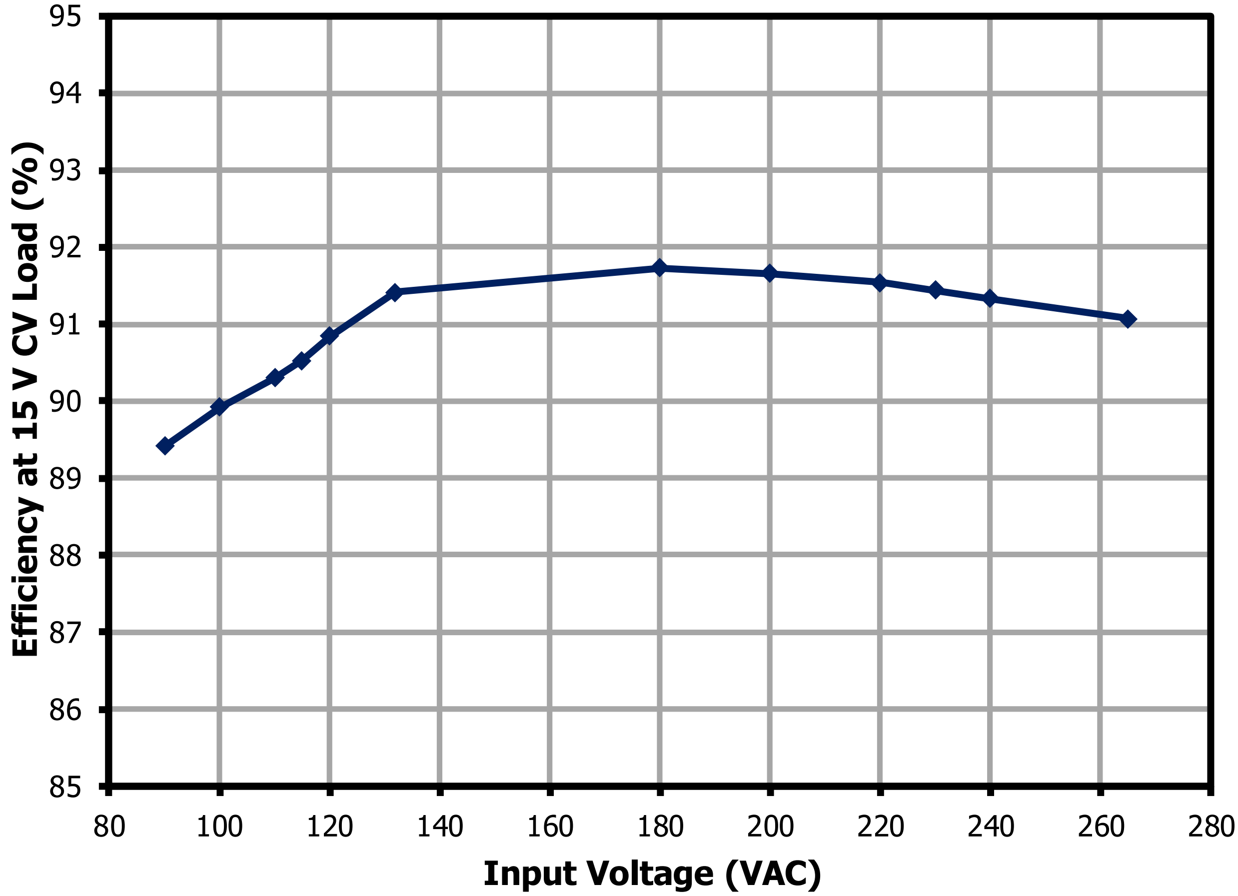

Figure 12 – Efficiency at 15 V vs. Line.

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10.4 *Efficiency vs. Load at V_{OUT} = 24 V*

DUT: Open Frame unit
Load: 188 mA – 1880 mA CC mode load
Ambient Temperature: 25 ºC
Soak time: 60 s Soak time, 30 seconds soak time per load step

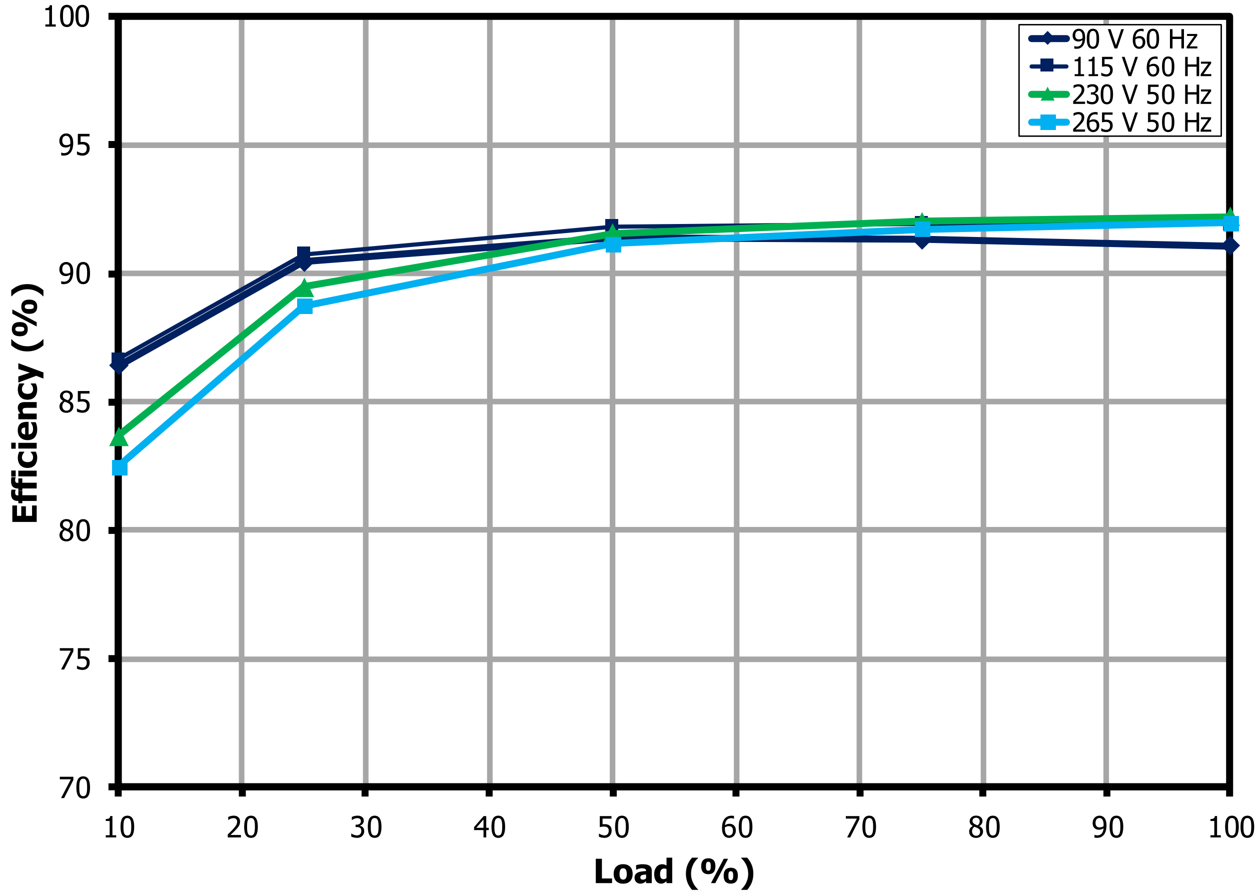

Figure 13 – Efficiency vs. Load.

10.5 *Energy Efficiency*

Set-up: Open Frame unit
Load: 188 mA – 1880 mA CC mode load
Ambient Temperature: 25 ºC

Nameplate Output Voltage: 24 V
Nameplate Output Current: 1880 mA
Ambient Temperature: 25 ºC

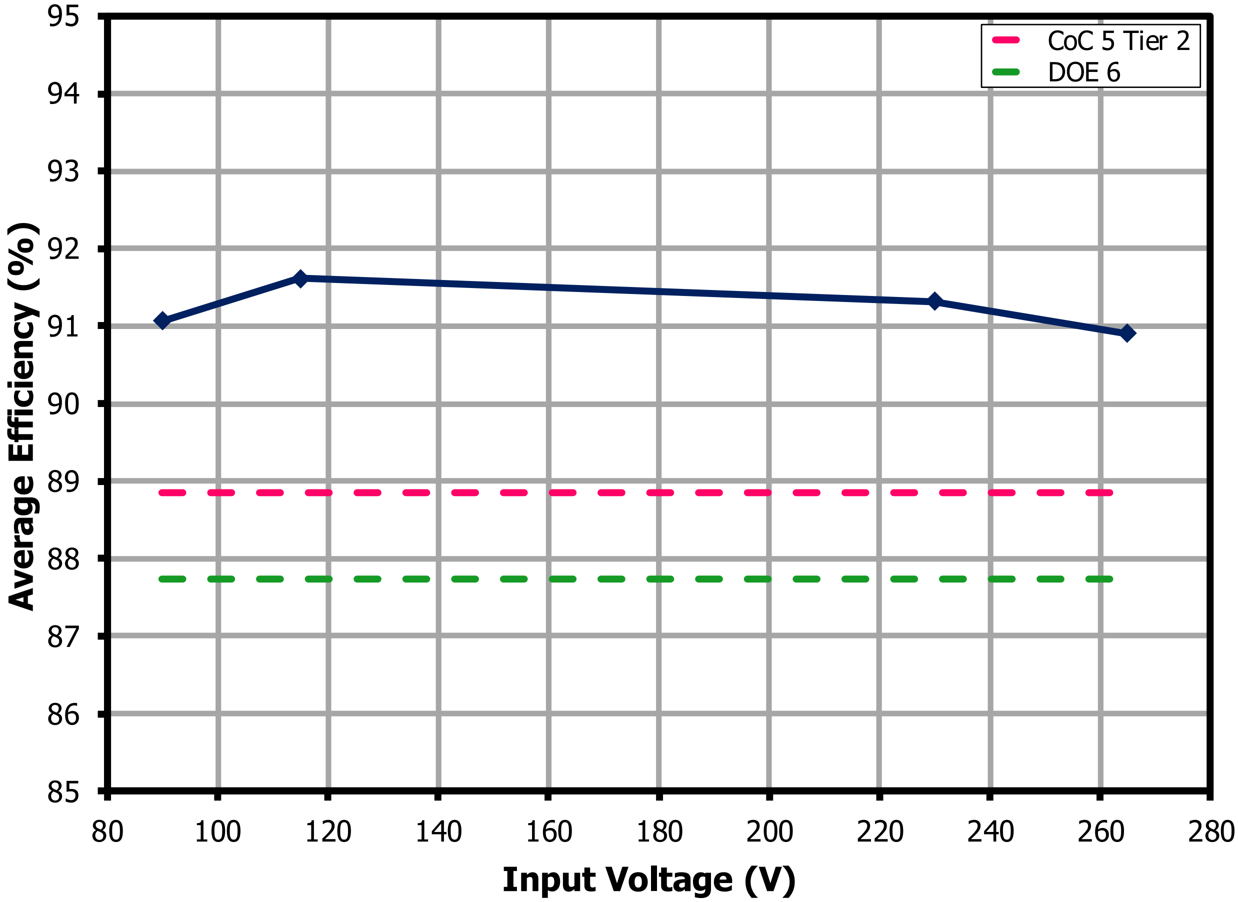

Figure 14 – Average Efficiency vs. Line.

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10.6 *Efficiency at 10% Load*

DUT: Open Frame unit
Load: 188 mA (10%)
Ambient Temperature: 25 ºC

Nameplate Output Voltage: 24 V
Nameplate Output Current: 1880 mA
Ambient Temperature: 25 ºC

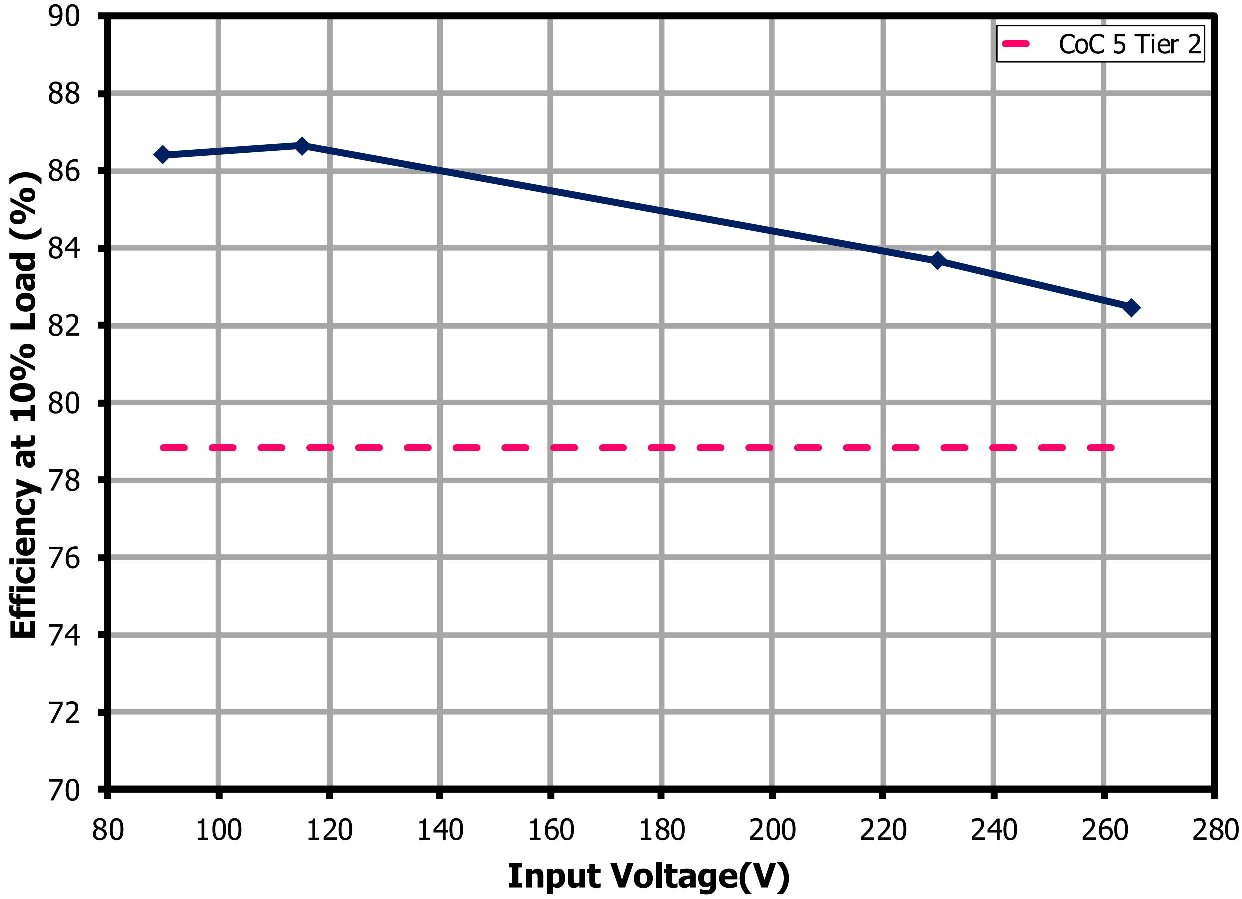

Figure 15 – Average Efficiency vs. Line.

10.7 ***No-Load Input Power***

DUT: Open Frame unit
Load: 0 A
Ambient Temperature: 25 ºC

Nameplate Output Voltage: 24 V
Nameplate Output Current: 1880 mA
Ambient Temperature: 25 ºC

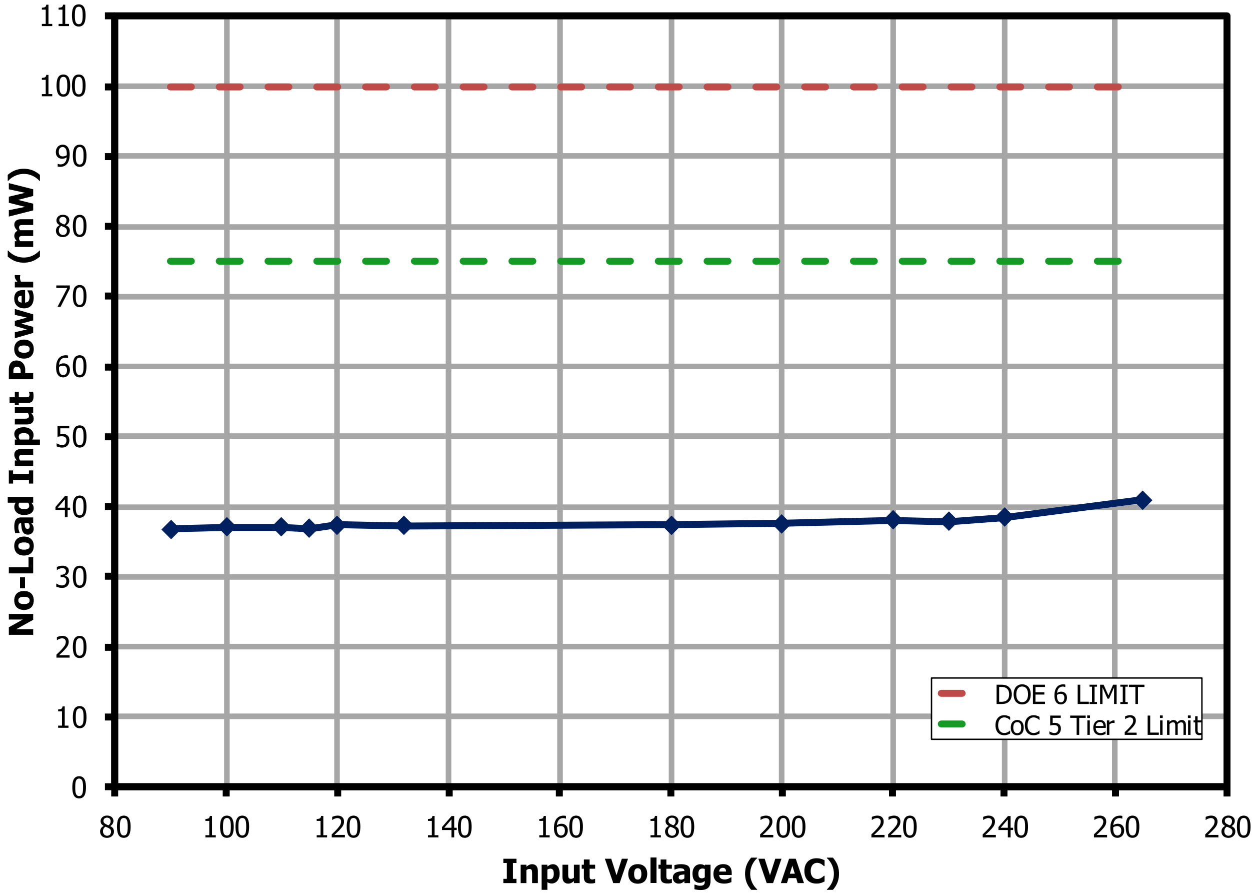

Figure 16 – No-Load Output Voltage vs. Line.

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10.8 ***No-Load Output Voltage Regulation***

Set-up: Open Frame unit
Load: 0 A
Ambient Temperature: 25 ºC

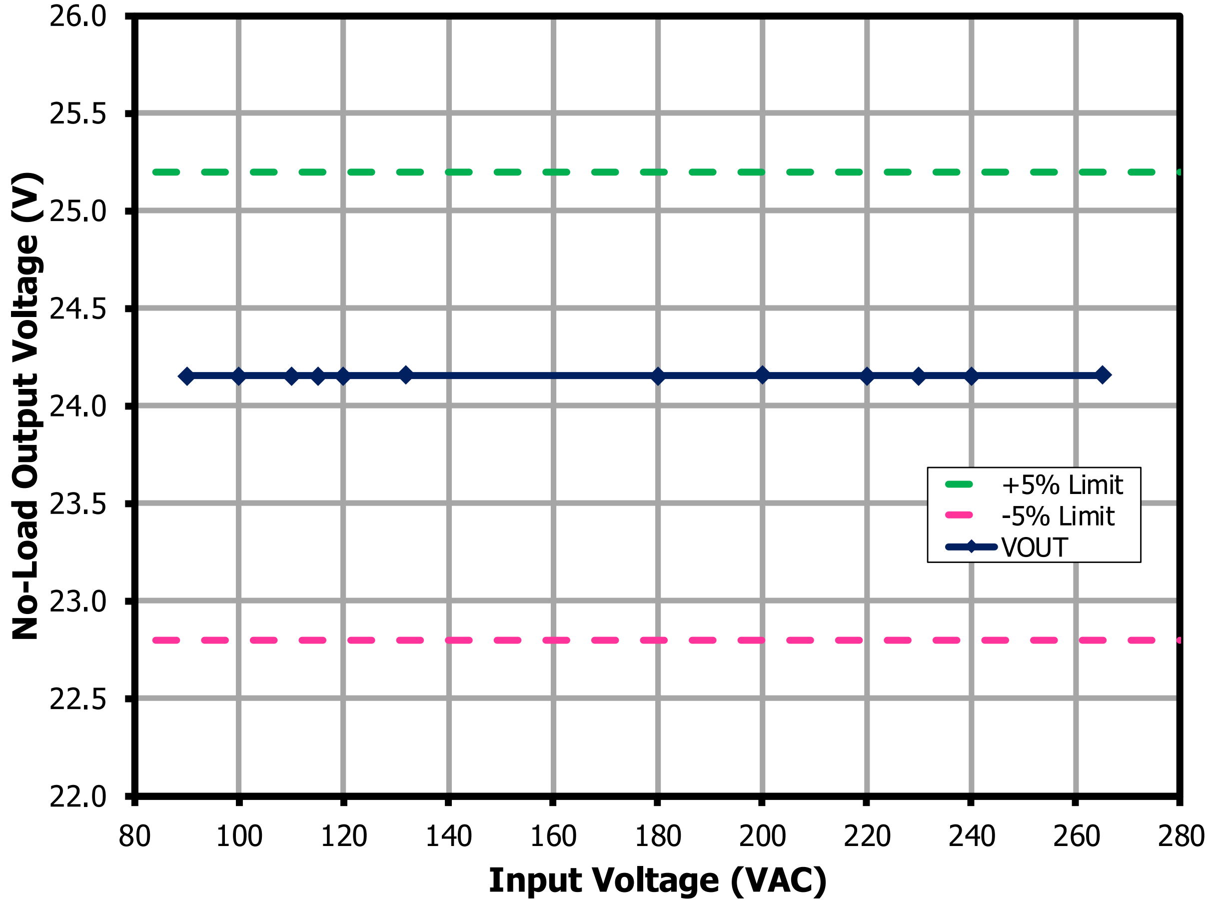

Figure 17 – No-Load Output Voltage vs. Line.

10.9 *Output Voltage Regulation at Full Load*

DUT: Open Frame unit
Load: 1880 mA CC Load
Ambient Temperature: 25 ºC
Soak time: 60 s Soak time, 30 s per input line

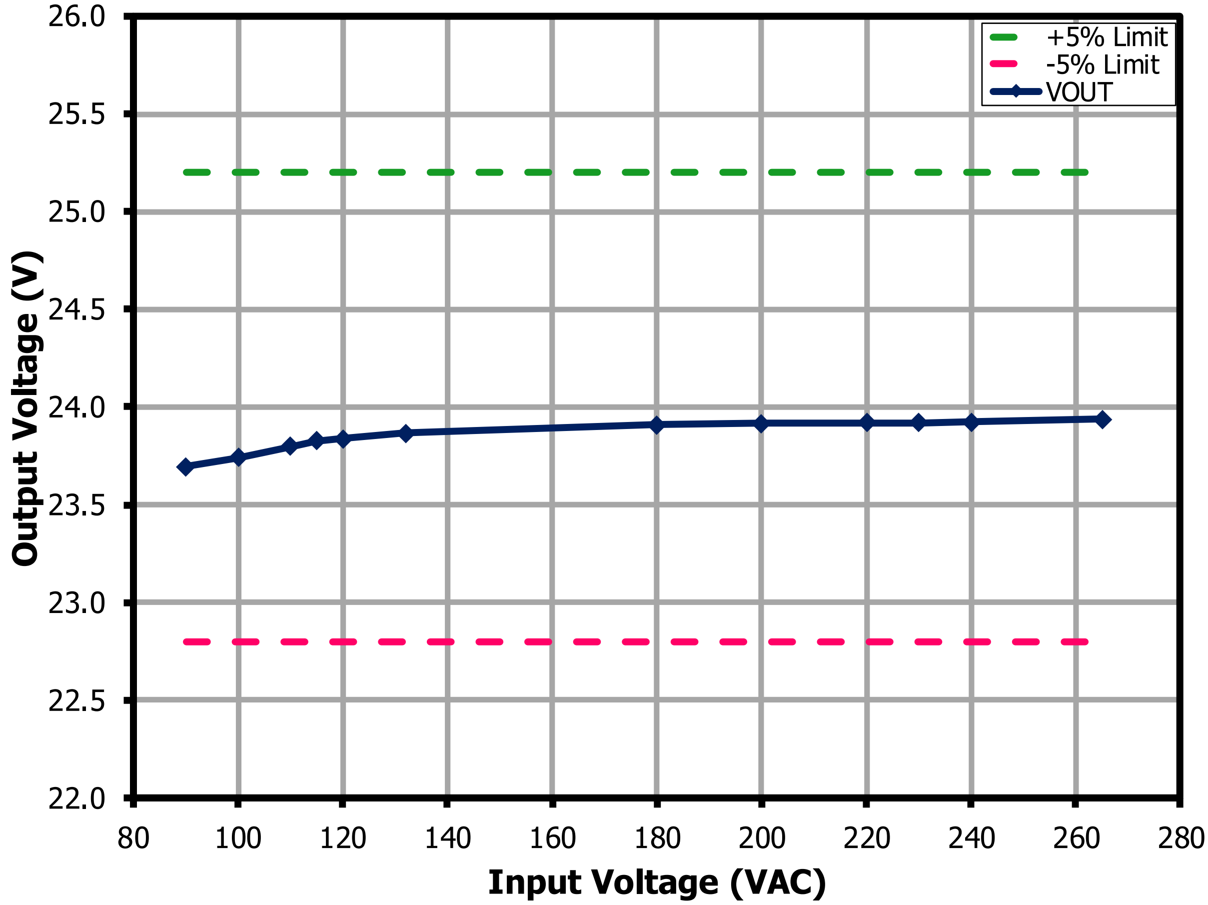

Figure 18 – Output Voltage Regulation vs. Line.

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10.10 ***Output Load Voltage Regulation***

Set-up: Open Frame unit
Load: 188 mA to 1880 mA with CC Mode Loading
Ambient Temperature: 25 ºC
Soak time: 30 s per input line, 30 s per load step

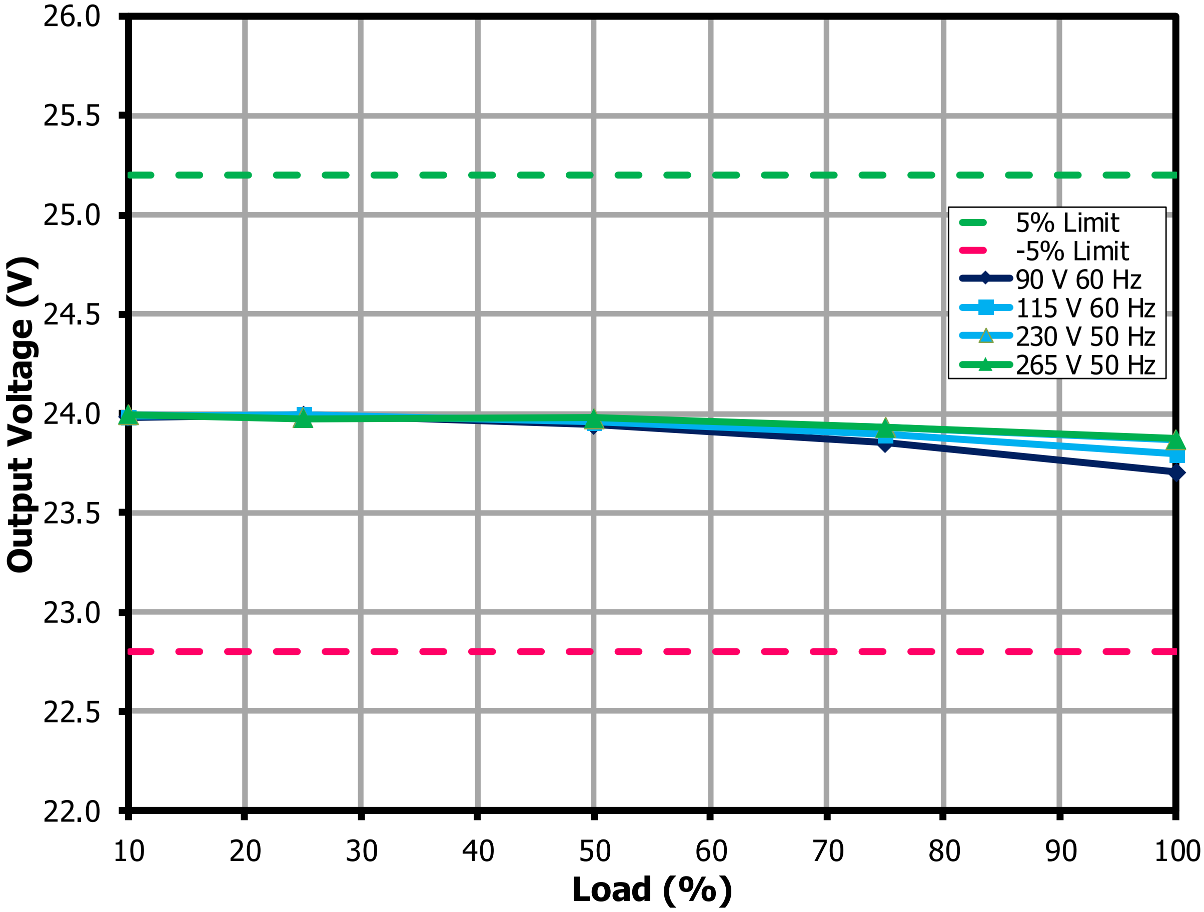

Figure 19 – Output Voltage Regulation vs. Line.

10.11 *Output Current Regulation at 15 V with CV Mode Load*

Set-up: Open Frame unit
Load: 15 V CV Mode Load
Ambient Temperature: 25 ºC
Soak time: 30 s per input line

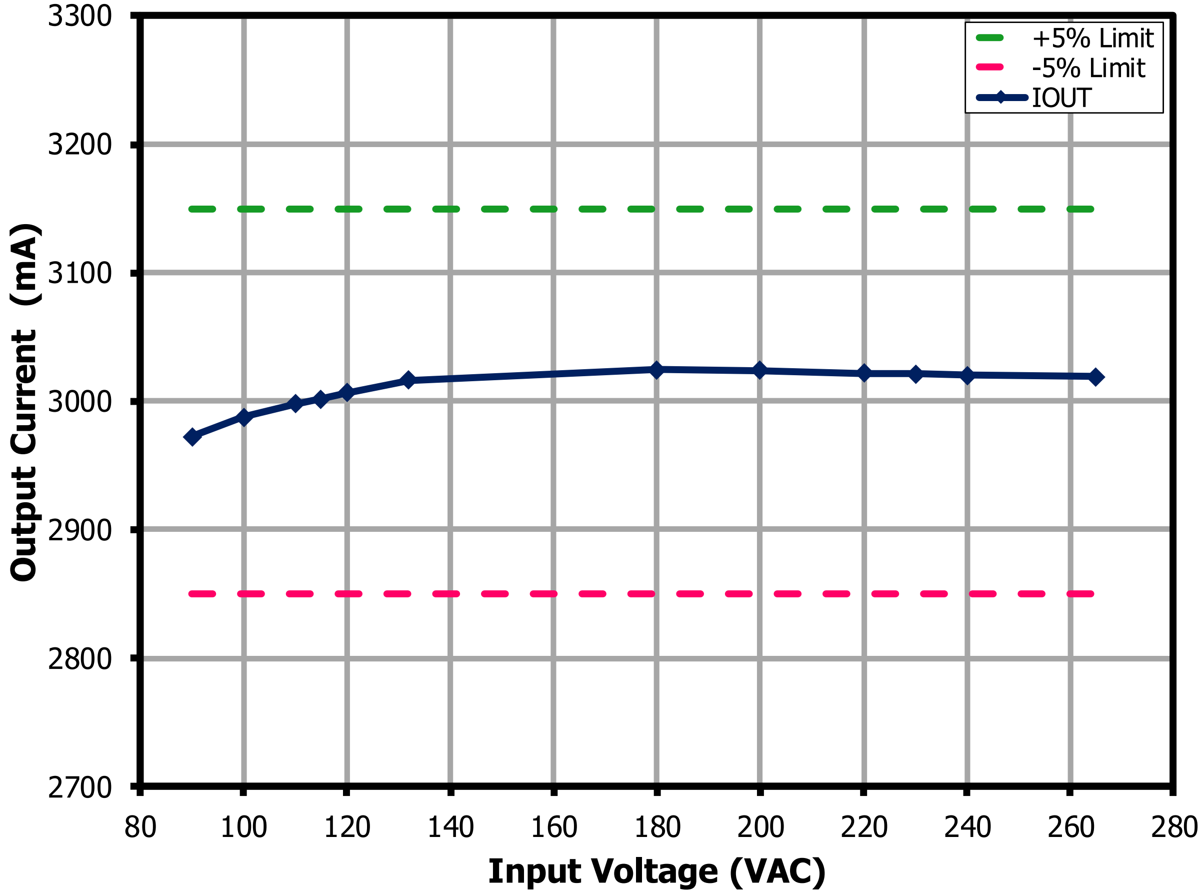

Figure 20 – Output Current Regulation at 15 V vs. Line.

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11 Test Data

11.1 *24 V Full Load with 1.88 A CC Mode Load*

Input		Input Measurement			Output Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	90.04	997.3	48.85	23.69	1876.7	44.47	91.0
100	60	100.02	931.6	48.68	23.74	1876.7	44.55	91.5
110	60	110.08	880.1	48.67	23.80	1876.7	44.66	91.8
115	60	115.07	857.9	48.66	23.83	1876.3	44.71	91.9
120	60	120.06	837	48.64	23.84	1876.3	44.73	92.0
132	60	132.09	794	48.6	23.87	1877.1	44.8	92.2
180	50	180.12	643.7	48.54	23.91	1876.7	44.87	92.4
200	50	200.16	613.8	48.57	23.92	1876.7	44.88	92.4
220	50	220.18	590.3	48.65	23.92	1876.7	44.89	92.3
230	50	230.25	580.3	48.68	23.92	1876.7	44.89	92.2
240	50	240.22	569.9	48.73	23.92	1876.7	44.9	92.1
265	50	265.25	532.3	48.84	23.94	1876.7	44.92	92.0

11.2 *15 V Full Load CV Mode Loading*

Input		Input Measurement			Output Measurement			Efficiency (%)
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90	60	90.04	1015.5	49.89	15.0	2972.5	44.61	89.4
100	60	100.02	951.4	49.86	15.0	2987.4	44.83	89.9
110	60	110.08	898.5	49.82	15.0	2997.9	44.99	90.3
115	60	115.07	875	49.76	15.0	3001.6	45.05	90.5
120	60	120.05	852.5	49.65	15.0	3006.5	45.1	90.8
132	60	132.09	807.3	49.52	15.0	3016.6	45.27	91.4
180	50	180.12	654.4	49.48	15.0	3024.5	45.39	91.7
200	50	200.15	623.6	49.49	15.0	3023.7	45.36	91.7
220	50	220.18	599.7	49.54	15.0	3021.8	45.35	91.5
230	50	230.24	589.8	49.58	15.0	3021.1	45.34	91.4
240	50	240.2	579.4	49.62	15.0	3020	45.32	91.3
265	50	265.23	541.5	49.73	15.0	3018.8	45.29	91.1

11.3 *Load Regulation at 24 V with CC Mode Load*

	Load Setting		Input Measurement		Load Measurement				Efficiency (%)
	% Load	Load (A)	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{OUT} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
90 V 60 Hz	100	1880	90.05	999.5	48.84	23.70	1876.7	44.48	91.1
	75	1410	90.07	793.3	36.73	23.85	1406.6	33.55	91.3
	50	940	90.08	575.9	24.56	23.94	937.6	22.45	91.4
	25	470	90.1	343.1	12.4	23.99	467.5	11.22	90.5
	10	188	90.11	162.0	5.137	23.98	185.1	4.44	86.4
	Load Setting		**Input Measurement**		**Load Measurement**				**Efficiency (%)**
	% Load	**Load (A)**	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{OUT} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
115 V 60 Hz	100	1880	115.08	859	48.57	23.80	1876.3	44.65	91.9
	75	1410	115.09	687.1	36.56	23.89	1407.0	33.62	92.0
	50	940	115.1	508.4	24.45	23.96	937.2	22.45	91.8
	25	470	115.11	294.9	12.37	24.00	467.9	11.23	90.8
	10	188	115.12	134.4	5.145	23.99	185.9	4.46	86.6
	Load Setting		**Input Measurement**		**Load Measurement**				**Efficiency (%)**
	% Load	**Load (A)**	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{OUT} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
230 V 50 Hz	100	1880	230.26	580.7	48.56	23.87	1876.7	44.79	92.2
	75	1410	230.27	463.6	36.59	23.93	1407.3	33.68	92.0
	50	940	230.28	326.1	24.54	23.97	937.2	22.47	91.6
	25	470	230.28	177.9	12.53	23.98	467.5	11.21	89.5
	10	188	230.28	80.4	5.318	23.99	185.5	4.45	83.7
	Load Setting		**Input Measurement**		**Load Measurement**				**Efficiency (%)**
	% Load	**Load (A)**	V_{IN} (V_{RMS})	I_{IN} (A_{RMS})	P_{OUT} (W)	V_{OUT} (V_{DC})	I_{OUT} (mA_{DC})	P_{OUT} (W)	
265 V 50 Hz	100	1880	265.27	532.3	48.71	23.87	1876.7	44.80	92.0
	75	1410	265.27	414.4	36.7	23.93	1407.0	33.67	91.7
	50	940	265.28	290.8	24.66	23.98	937.6	22.48	91.2
	25	470	265.28	159.5	12.63	23.97	467.5	11.21	88.7
	10	188	265.28	73.4	5.397	23.99	185.5	4.45	82.5

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11.4 *No-Load Input Power and No-Load Voltage*

Input		Input Measurement			No-Load
VAC (V_{RMS})	Freq (Hz)	V_{IN} (V_{RMS})	I_{IN} (mA_{RMS})	P_{IN} (mW)	V_{OUT} (V_{DC})
90	60	90.1	11.19	36.84	24.16
100	60	100.07	11.24	37.08	24.15
110	60	110.13	11.31	37.08	24.16
115	60	115.12	11.35	36.9	24.15
120	60	120.1	11.40	37.38	24.15
132	60	132.14	11.49	37.26	24.16
180	50	180.16	11.29	37.44	24.16
200	50	200.2	11.36	37.62	24.16
220	50	220.23	11.49	38.1	24.15
230	50	230.28	11.66	37.92	24.16
240	50	240.26	11.92	38.52	24.16
265	50	265.29	12.61	40.98	24.16

12 Thermal Performance

12.1 Thermal Scan at 25 ºC Ambient

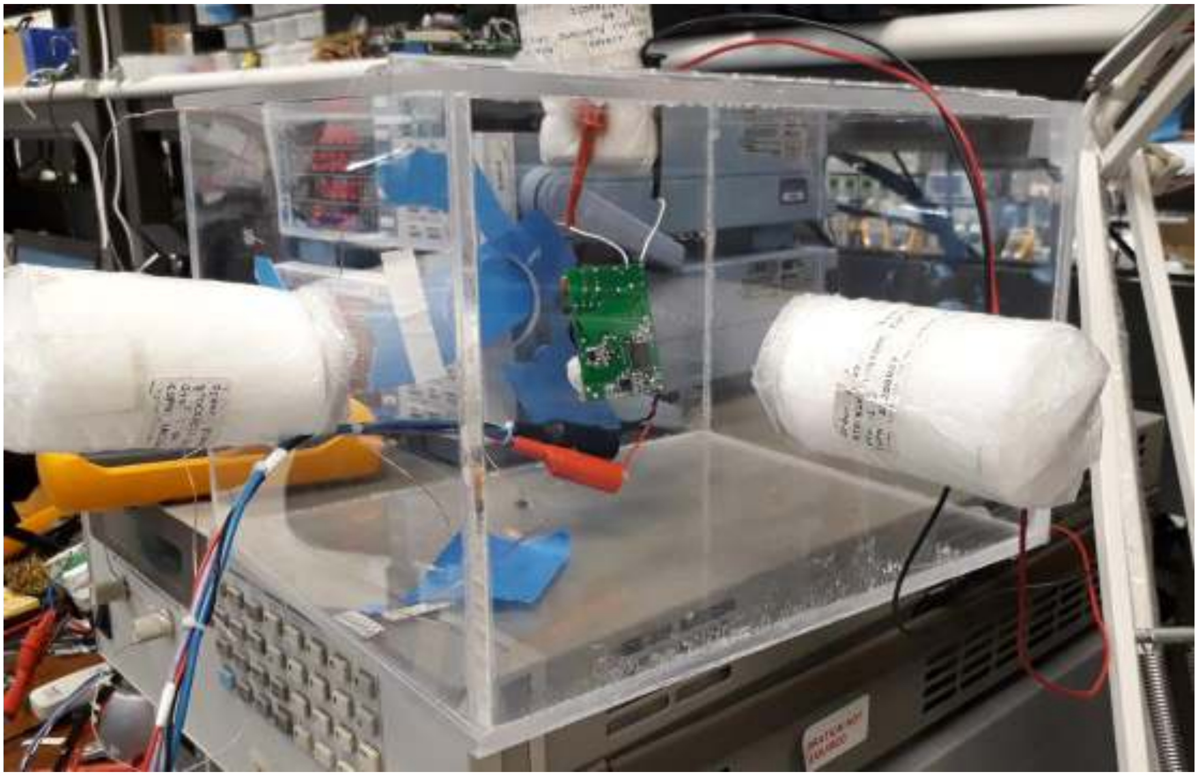

Figure 21 – Test Set-up Picture.

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12.1.1 Thermal Scan at 24 V Full Load (1.88 A CC Mode Load) - No Heat Sink

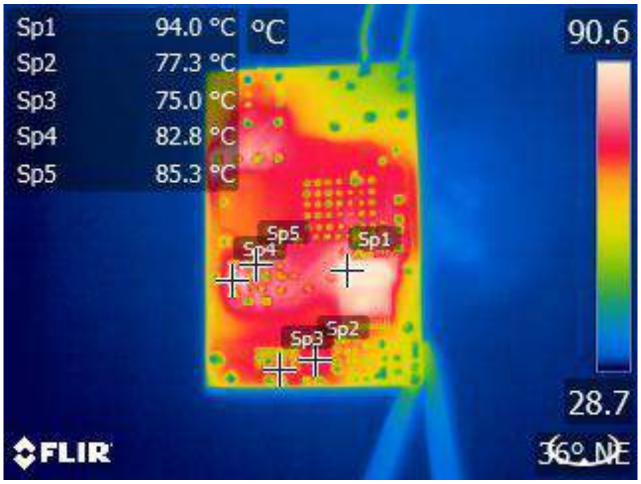

Figure 22 – 90 VAC 60 Hz, 24 V Full Load, Bottom.

U1 - InnoSwitch3-CP	94.0 C
Q1 – SR FET	77.3 C
R7/R8 - Secondary Snubber Resistor	75.0 C
D1 - Primary Snubber Diode	82.8 C
R3/R18 - Primary Snubber Resistor	85.3 C

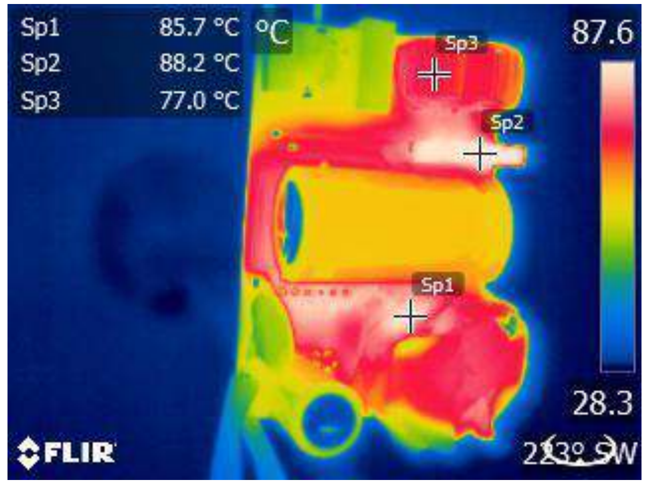

Figure 23 – 90 VAC 60 Hz, Full Load, Top.

T1 - Transformer	85.7 C
BR1 - Bridge Diode	88.2 C
L1 - Input CMC	77.0 C
Ambient Temperature	28.5 C

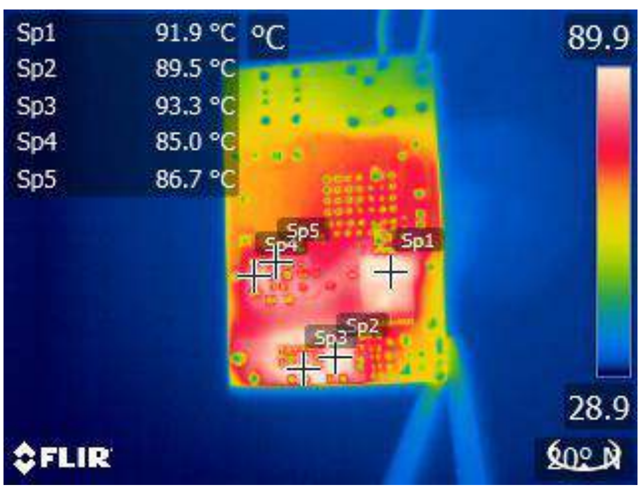

Figure 24 – 265 VAC 50 Hz, Full Load, Bottom.

U1 - InnoSwitch3-CP	91.9 C
Q1 - SR FET	89.5 C
R7/R8 - Secondary Snubber Resistor	93.3 C
D1 - Primary Snubber Diode	85.0 C
R3/R18 - Primary Snubber Resistor	86.7 C

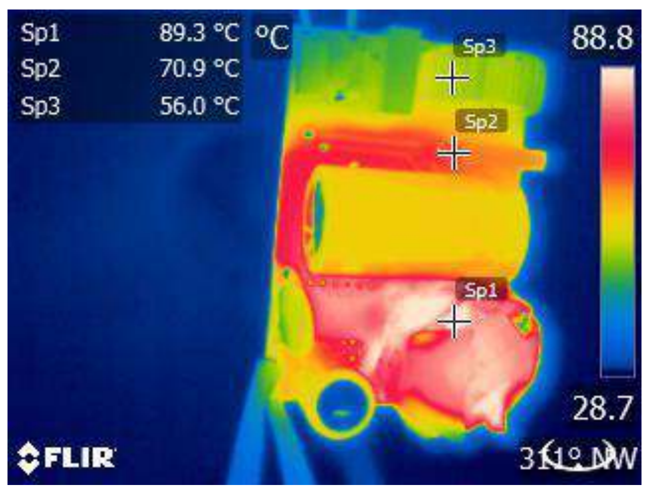

Figure 25 – 265 VAC 50 Hz, Full Load, Top.

T1 - Transformer	89.3 C
BR1 - Bridge Diode	70.9 C
L1 - Input CMC	56.0 C
Ambient Temperature	28.5 C

12.1.2 Thermal Scan at 24 V Full Load (1.88 A CC Mode Load) - With Heat Sink

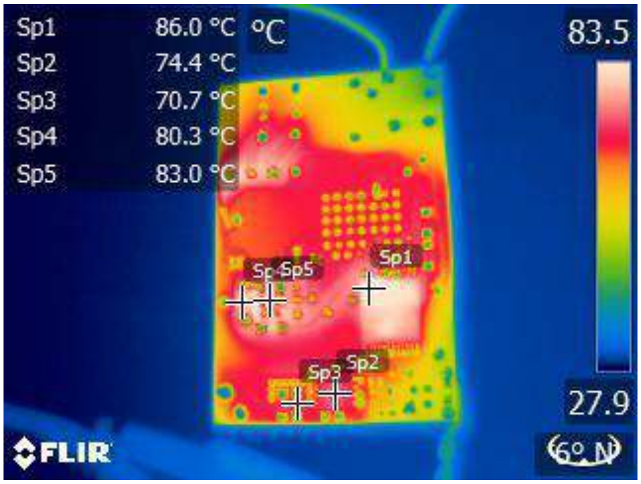

Figure 26 – 90 VAC 60 Hz, 24 V Full Load, Bottom

U1 - InnoSwitch3-CP	86.0 C
Q1 - SR FET	73.6 C
R7/R8 - Secondary Snubber	70.7 C
D1 - Primary Snubber Diode	79.9 C
R3/R18 - Primary Snubber Resistor	81.7 C

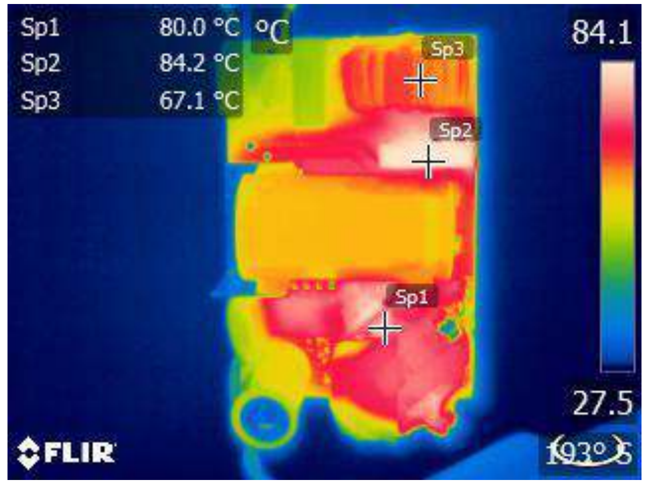

Figure 27 – 90 VAC 60 Hz, Full Load, TOP

T1 - Transformer	80.0 C
BR1 - Bridge Diode	84.2 C
L1 - Input CMC	67.1 C
Ambient Temperature	28.0 C

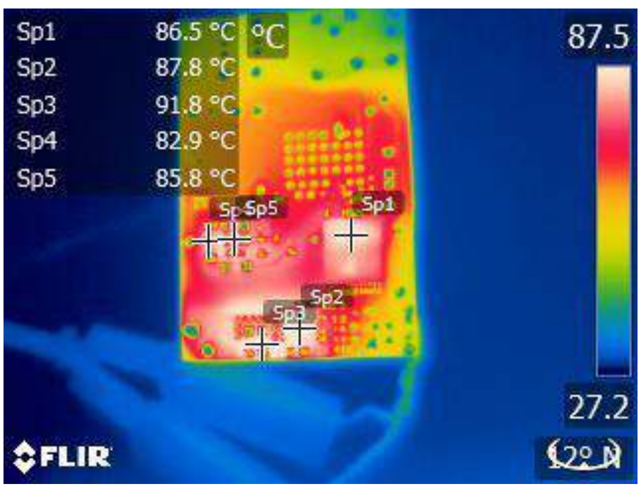

Figure 28 – 265 VAC 50 Hz, Full Load, Bottom

U1 - InnoSwitch3-CP	86.5 C
Q1 - SR FET	87.8 C
R7/R8 - Secondary Snubber	91.8 C
D1 - Primary Snubber Diode	82.9 C
R3/R18 - Primary Snubber Resistor	95.8 C

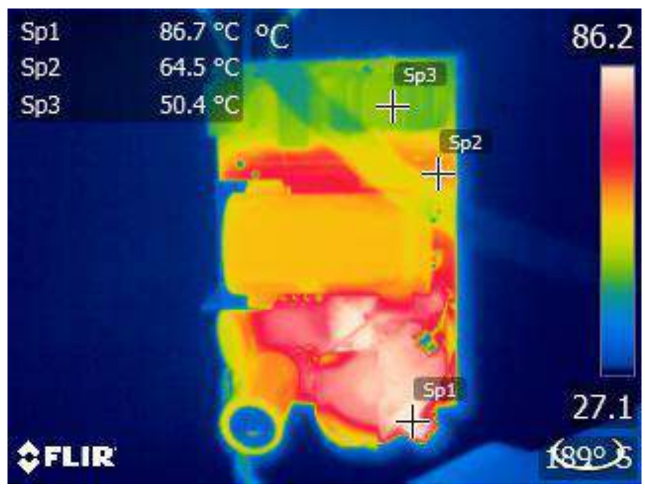

Figure 29 – 265VAC 50 Hz, Full Load, Top

T1 - Transformer	86.7 C
BR1 - Bridge Diode	64.5 C
L1 - Input CMC	50.4 C
Ambient Temperature	28.0 C

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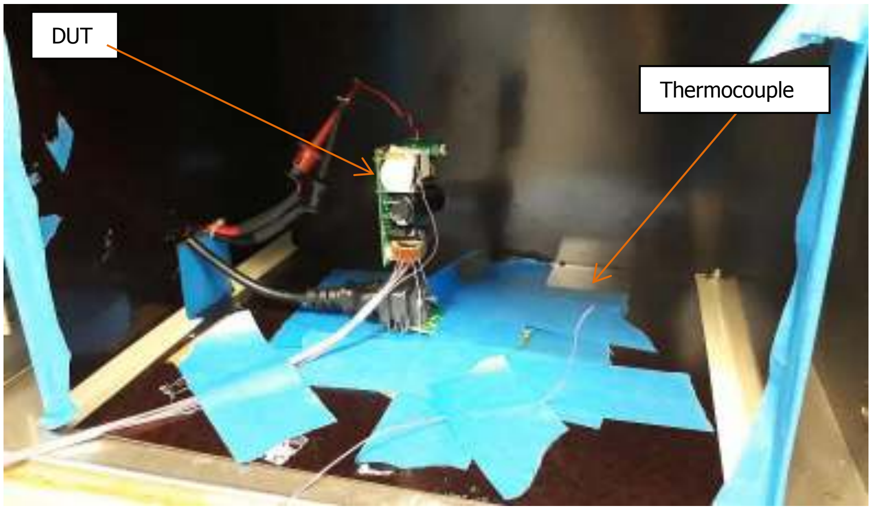
12.2 ***Thermal Performance at 55 ºC Chamber Ambient Temperature***



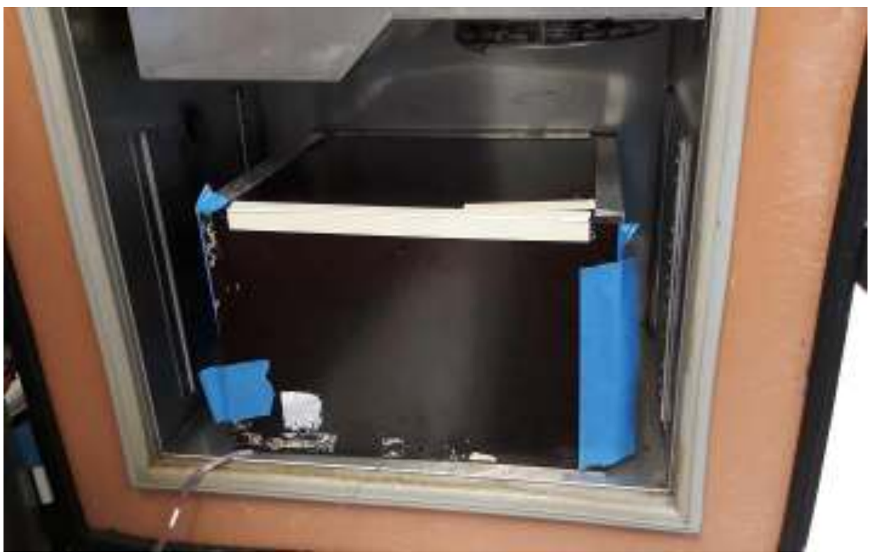


Figure 30 – Test Set-up Picture Thermal at 55 ºC Ambient.

12.2.1 Thermal Performance Data without Heat Sink at 55 ºC Chamber Ambient Temperature

12.2.1.1 Thermal Performance Data Summary at 24 V Full Load

E-Load is set at 1.88 A CC mode load
Soak time: 1.5 hr.

Components	Case Temperature (º)		Pass/Fail
	90 V 1.88 A CC Mode Load	265 V 1.88 A CC Mode Load	
D1 - Primary Snubber Diode	99.6	93.0	Pass
T1 - Power Transformer	101.2	102.5	Pass
Q1 - SR FET	106.4	108.1	Pass
U1 - Innoswitch3-CP	110.6	100.0	Pass
L1 - Input CMC	95.2	73.2	Pass
C9 - Output Capacitor	88.6	86.4	Pass
Ambient Temperature	57.8	57.5	Pass

12.2.1.2 Thermal Performance Data during 1 kHz 3 A Transient Loading

E-Load is set at 0 A – 3 A CC mode dynamic loading
Soak time: 1.5 hr.

Components	Case Temperature (º)		Pass/Fail
	90 V 0 A – 3 A Transient Load	265 V 0 A – 3 A Transient Load	
D1 - Primary Snubber Diode	92.4	92.9	Pass
T1 - Power Transformer	98.2	106.2	Pass
Q1 - SR FET	105.4	119.5	Pass
U1 - Innoswitch3-CP	100.5	107.8	Pass
L1 - Input CMC	84.9	71.8	Pass
C9 - Output Capacitor	89.2	95.4	Pass
Ambient Temperature	57.8	57.6	Pass

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12.2.2 Transient Loading Set-up

E-Load Set at CC Mode Dynamic Loading
I_{OMIN} = 0 A
I_{OMAX} = 3 A
Slew Rate: 800 ms / μA
Frequency: 1 kHz
Duty Cycle: 80%
Ambient Temperature: 55 ºC

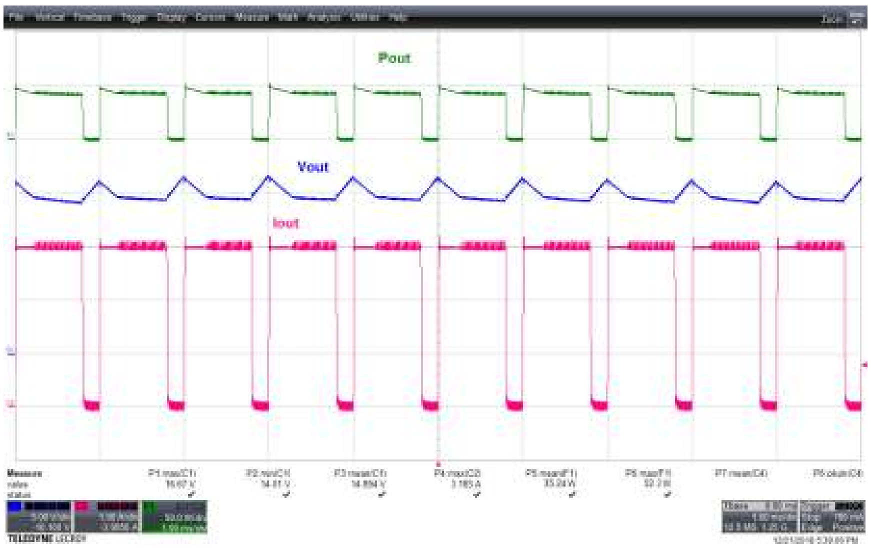

Figure 31 – Output Transient Load Waveform at 90 V / 60 Hz.

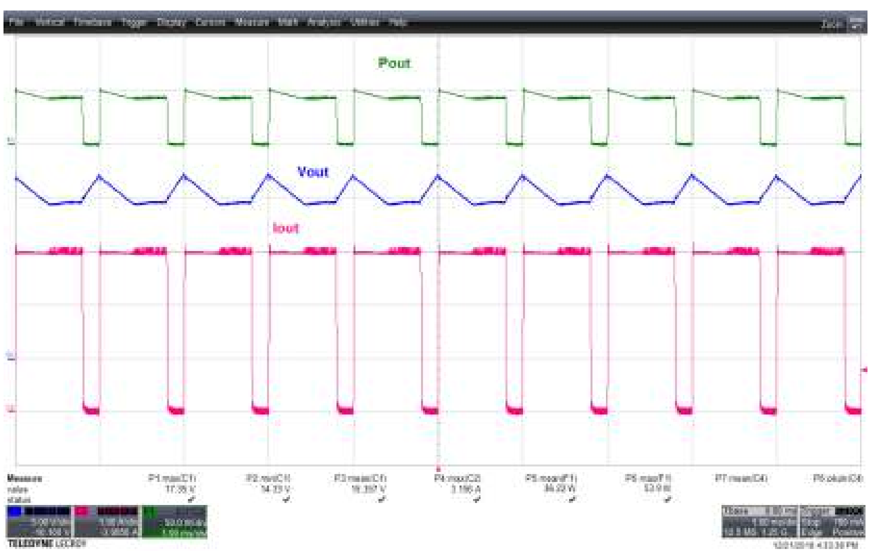

Figure 32 – Output Transient Load Waveform at 265 V / 50 Hz.

12.2.3 OTP Test - No Heat Sink

E-Load is set at 1.88 CC mode load
Temperature ramp rate: 0.4 ºC / min

Test Condition	Thermal Data at U1 OTP Latch up							Pass/Fail
	D1	T1	Q1	U1	L1	C5	AMB	
90 V 1.88 A CC Mode Load	112.7	113.8	120.6	126.6	107.6	102.0	70.9	Pass

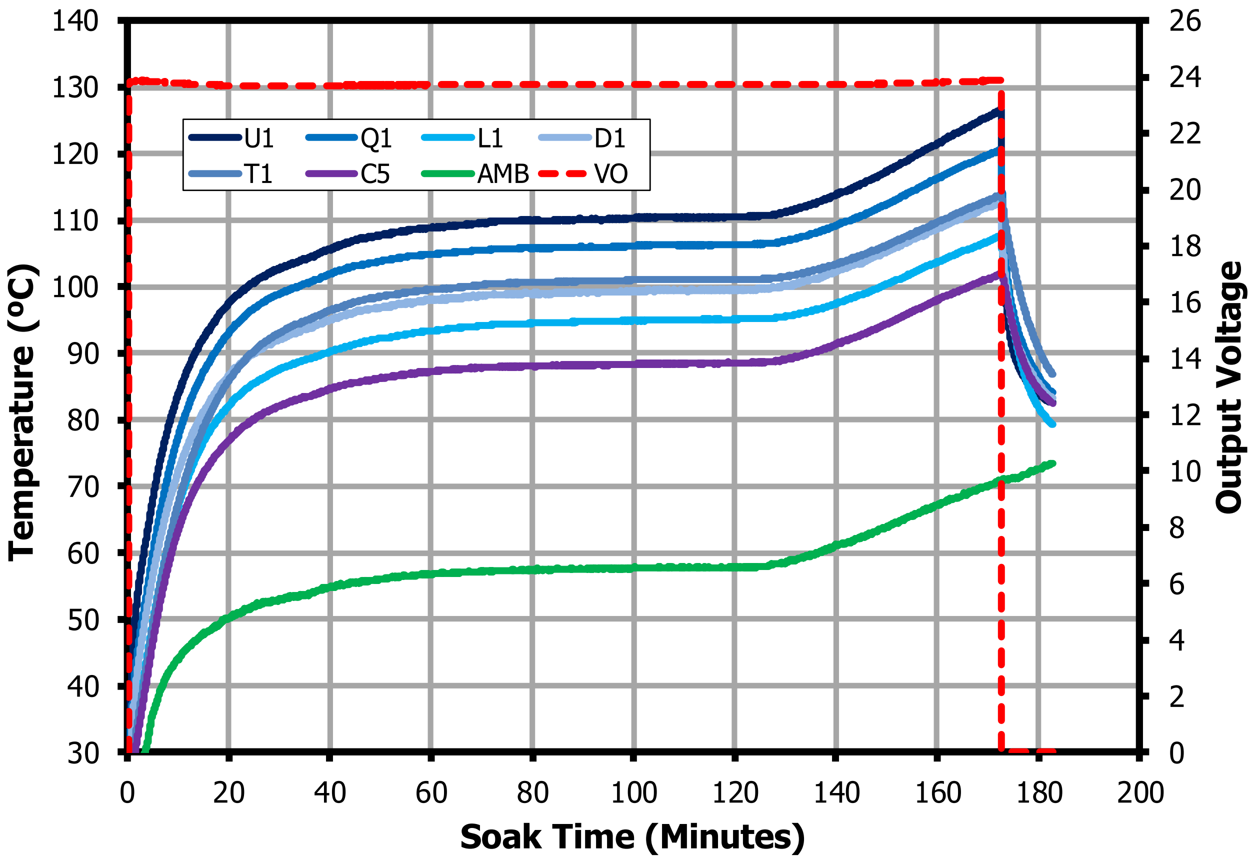

Figure 33 – OTP Thermal Profile.

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12.2.4 Thermal Performance with Heat Sink at 55 ºC Chamber Ambient Temperature

12.2.5 Thermal Performance Data Summary at 24 V Full Load

E-Load is set at 1.88 A CC mode load
Soak time: 1.5 hr.

Components	Case Temperature (ºC)		Pass/Fail
	90 V 1.88 A CC Mode Load	265 V 1.88 A CC Mode Load	
D1 - Primary Snubber Diode	93.4	91.7	Pass
C9 - Output Capacitor	78.4	81.2	Pass
T1 - Power Transformer	98.5	103.6	Pass
U1 - Innoswitch3-CP	98.3	95.9	Pass
Q1 - SR FET	96.3	104.2	Pass
L1 - Input CMC	86.3	68.9	Pass
BR1 - Bridge Rectifier	94.0	77.3	Pass
C1 - Input Bulk Capacitor	78.0	72.9	Pass
Ambient Temperature	58.1	58.2	Pass

12.2.6 Thermal Performance Data Summary at 15 V Full Load

E-Load is set at 15 CV mode load
Soak time: 1.5 hr.

Components	Case Temperature (ºC)		Pass/Fail
	90 V 15 V 3 A CV Mode Load	265 V 15 V CV Mode Load	
D1 - Primary Snubber Diode	96.0	90.7	Pass
C9 - Output Capacitor	89.8	85.8	Pass
T1 - Power Transformer	105.6	106.9	Pass
U1 - Innoswitch3-CP	108.6	98.1	Pass
Q1 - SR FET	109.3	109.6	Pass
L1 - Input CMC	86.1	68.9	Pass
BR1 - Bridge Rectifier	95.1	78.2	Pass
C1 - Input Bulk Capacitor	80.0	73.7	Pass
Ambient Temperature	59.0	58.2	Pass

13 Waveforms

Waveforms were taken room temperature (25 ºC)

13.1 *Start-up Profile at 24 V Full Load*

E-Load is set at 1.88 A CC mode loading

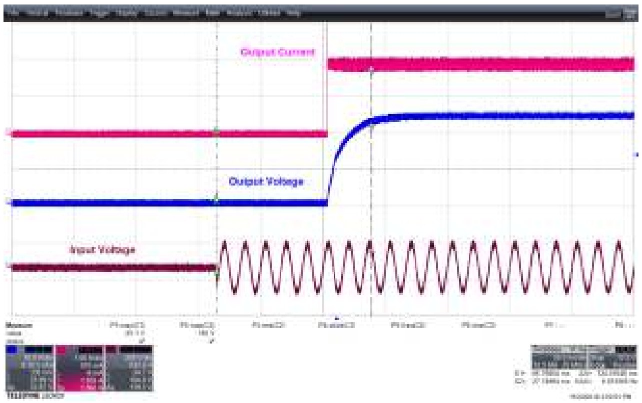

Figure 34 – 90 VAC 60 Hz, 24 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 125 ms.

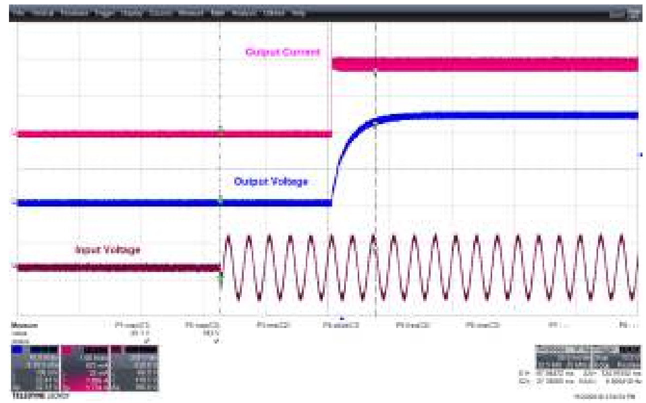

Figure 35 – 115 VAC 60 Hz, 24 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 125 ms.

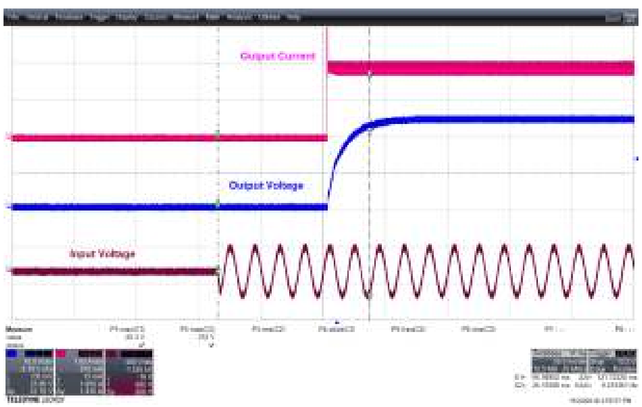

Figure 36 – 230 VAC 50 Hz, 24 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 122 ms.

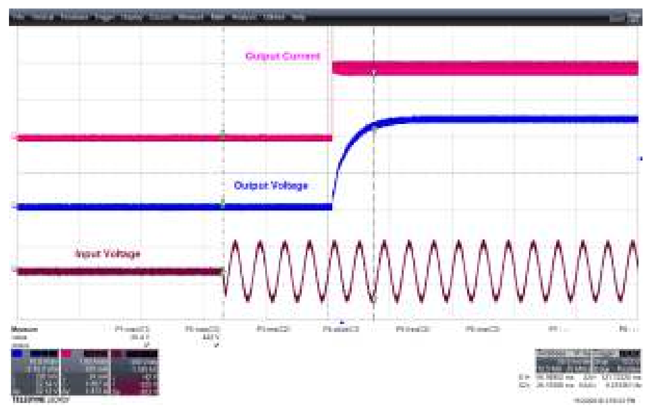

Figure 37 – 265 VAC 50 Hz, 24 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 122 ms.

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13.2 *Start-up Profile at 15 V Full Load*

E-Load is set at 15 V CV mode loading

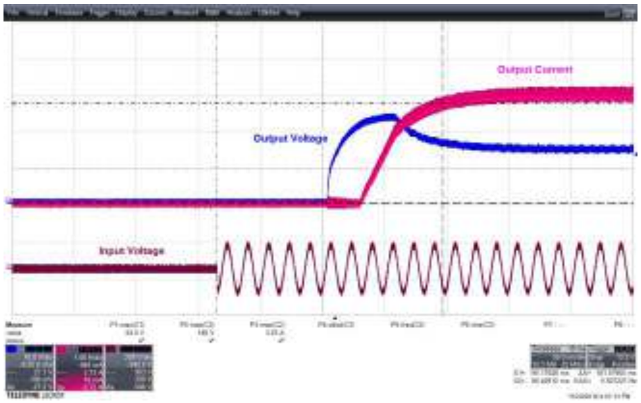

Figure 38 – 90 VAC 60 Hz, 15 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 181 ms.

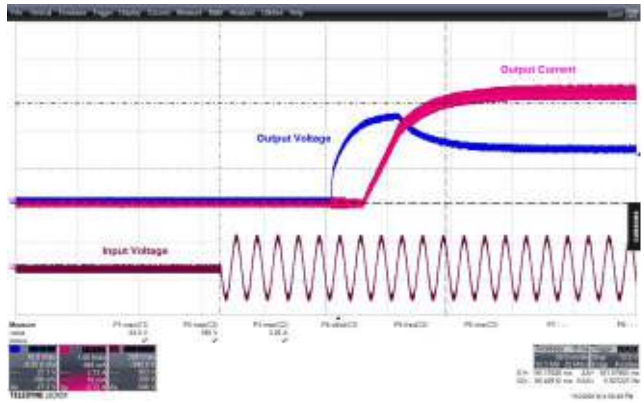

Figure 39 – 115 VAC 60 Hz, 15 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 181 ms.

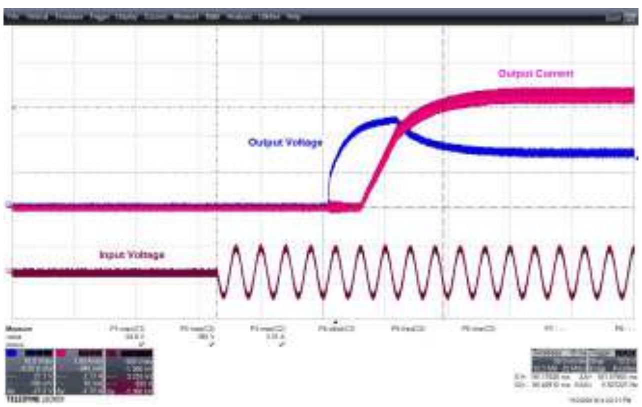

Figure 40 – 230 VAC 50 Hz, 15 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 182 ms.

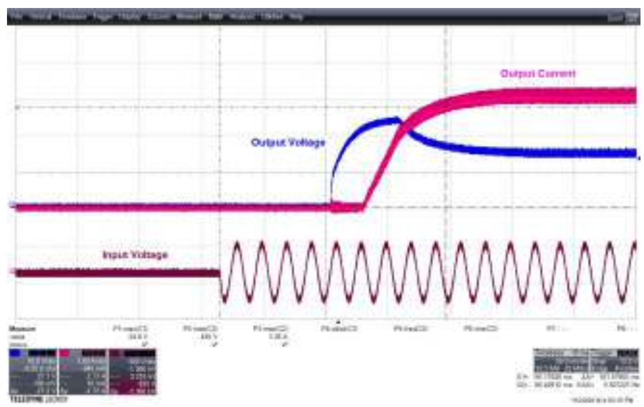

Figure 41 – 265 VAC 50 Hz, 15 V Full Load Start-up.
Upper: I_{OUT}, 1 A / div.
Lower: V_{OUT}, 10 V / div., 50 ms / div.
Turn-On Delay = 182 ms.

13.3 *Transient Load Response*

Duty cyle: 50%, Frequency = 25 Hz, Slew Rate = 200 mA / µs, I_{OUT} = 0 A - 1.88 A

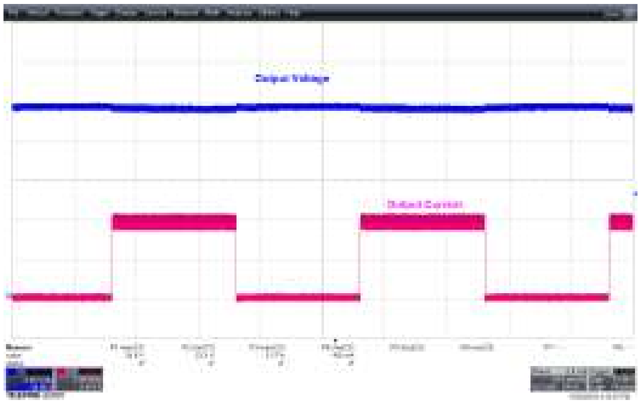

Figure 42 – 90 VAC 60 Hz, 0 A - 1.88 A Transient Load.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A / div., 10 ms / div.

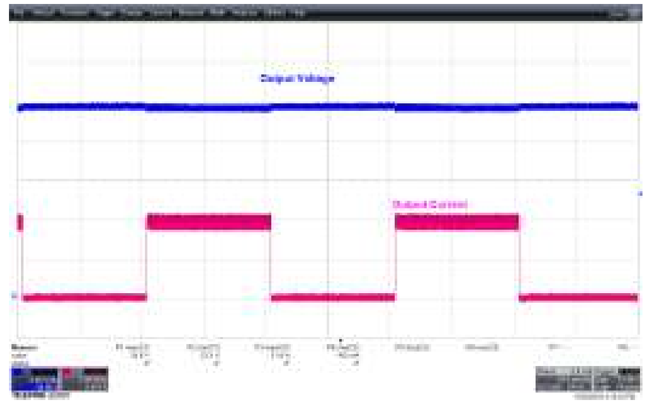

Figure 43 – 115 VAC 60 Hz, 0 A - 1.88 A Transient Load.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A / div., 10 ms / div.

Figure 44 – 230 VAC 50 Hz, 0 A - 1.88 A Transient Load.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A / div., 10 ms / div.

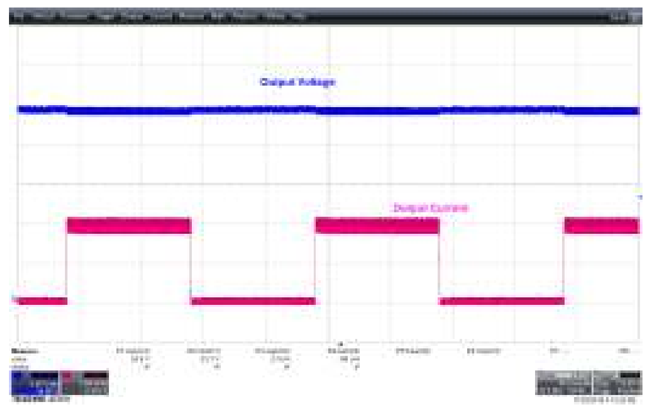

Figure 45 – 265 VAC 50 Hz, 0 A - 1.88 A Transient Load.
Upper: V_{OUT}, 5 V / div.
Lower: I_{OUT}, 1 A / div., 10 ms / div.

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13.4 *Output Ripple Voltage at V_{OUT} = 24 V Full Load*

E-Load set at 1.88 A CC mode load

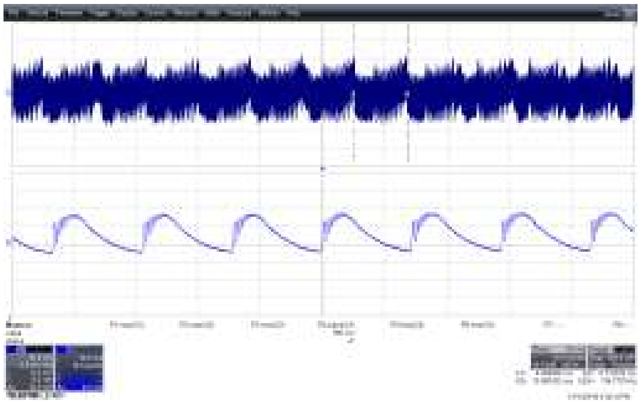

Figure 46 – 90 VAC 60 Hz, 24 V Full Load Normal.
Lower: V_{RIPPLE}, 50 mV / div., 10 ms / div.
V_{RIPPLE} = 198 mV.

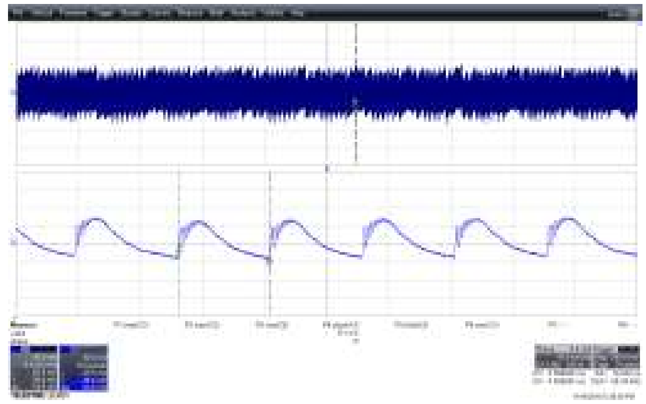

Figure 47 – 115 VAC 60 Hz, 24 V Full Load Normal.
Lower: V_{RIPPLE}, 50 mV / div., 10 ms / div.
V_{RIPPLE} = 171 mV.

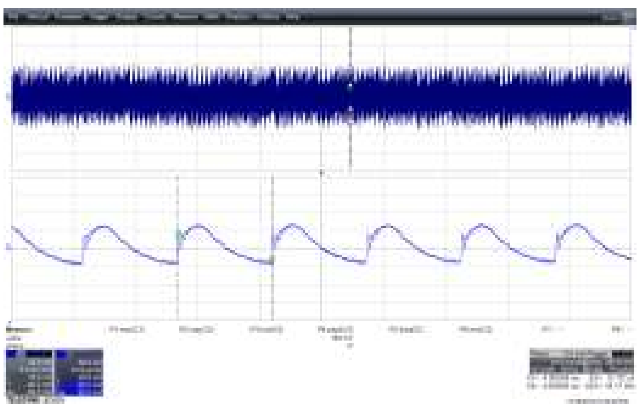

Figure 48 – 230 VAC 50 Hz, 24 V Full Load Normal.
Lower: V_{RIPPLE}, 50 mV / div., 10 ms / div.
V_{RIPPLE} = 184 mV.

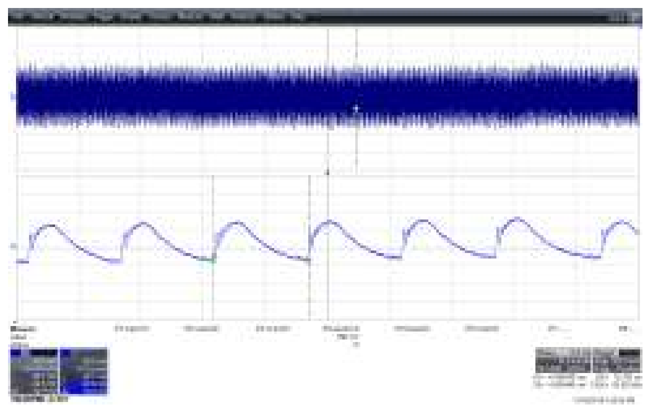

Figure 49 – 265 VAC 50 Hz, 24 V Full Load Normal.
Lower: V_{RIPPLE}, 50 mV / div., 10 ms / div.
V_{RIPPLE} = 188 mV.

13.5 *Overvoltage Test at No-Load Condition*

Unit is operating normally no-load. OVP test was performed by connecting a parallel resistor (39 kΩ) on lower feedback voltage divider (R13). Unit is at no-load condition.

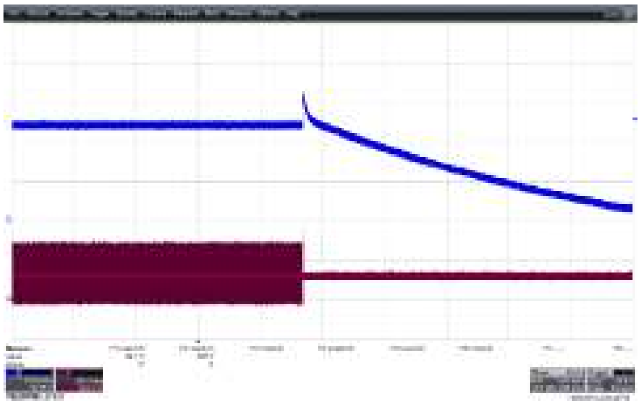

Figure 50 – 90 VAC 60 Hz, No-Load, OVP.
Upper: V_{OUT}, 10 V / div., 5 s / div.
Lower: Primary V_{DS}, 200 V / div.
V_{OVP} = 32.7 V.

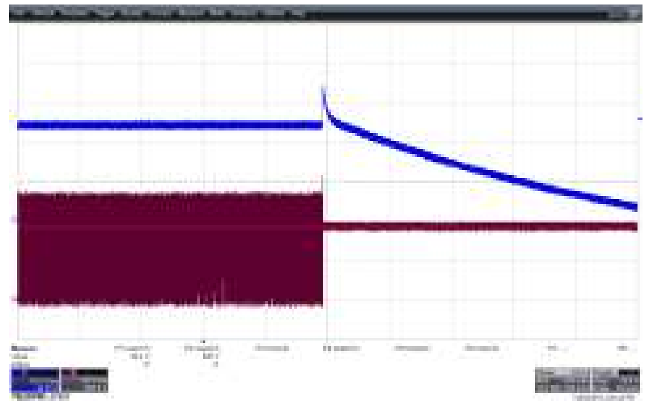

Figure 51 – 265 VAC 50 Hz, No-Load, OVP.
Upper: V_{OUT}, 10 V / div., 5 s / div.
Lower: Primary V_{DS}, 200 V / div.
V_{OVP} = 34.4 V.

13.6 *Overvoltage Test at 1 A Load*

Unit is operating normally with 1 A load. OVP test was performed by connecting a parallel resistor (39 kΩ) on lower feedback voltage divider (R13). Unit is at no-load condition.

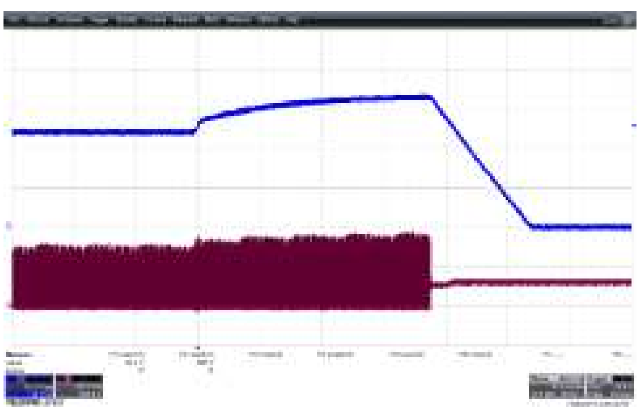

Figure 52 – 90 VAC 60 Hz, I_{OUT} = 1 A, OVP.
Upper: V_{OUT}, 10 V / div., 5 s / div.
Lower: Primary V_{DS}, 200 V / div.
V_{OVP} = 34.1 V.

Figure 53 – 265 VAC 50 Hz, I_{OUT} = 1 A, OVP.
Upper: V_{OUT}, 10 V / div., 5 s / div.
Lower: Primary V_{DS}, 200 V / div.
V_{OVP} = 34.4 V.

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13.7 *Output Voltage and Current During Output Short-Circuit*

Test performed by applying a hard short circuit across the output terminal while unit is operating at full load (1.88 A CC mode load).

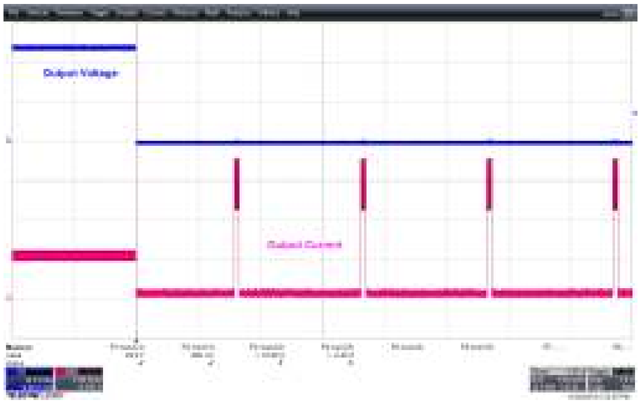

Figure 54 – 90 VAC 60 Hz, Full Load Short.
Upper: V_{OUT}, 10 V / div., 1 s / div.
Lower: I_{OUT}, 2 A / div.

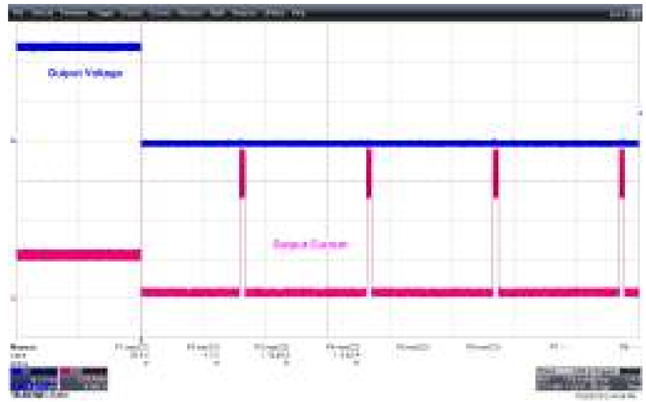

Figure 55 – 265 VAC 50 Hz, Full Load Short.
Upper: V_{OUT}, 10 V / div., 1 s / div.
Lower: I_{OUT}, 2 A / div.

13.8 *Drain Voltage and Current Waveforms at V_{OUT} = 24 V Full Load*

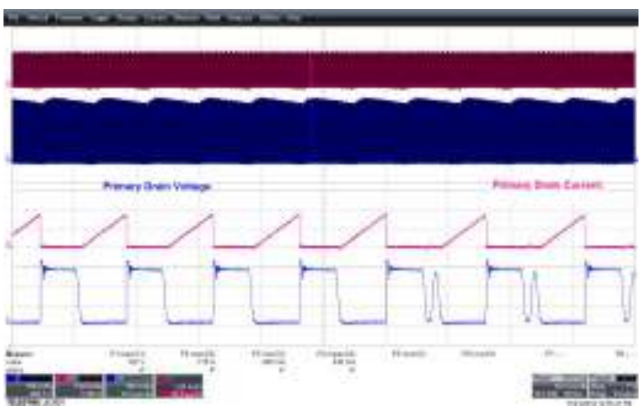

Figure 56 – 90 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.78 A, V_{DS} = 332 V.

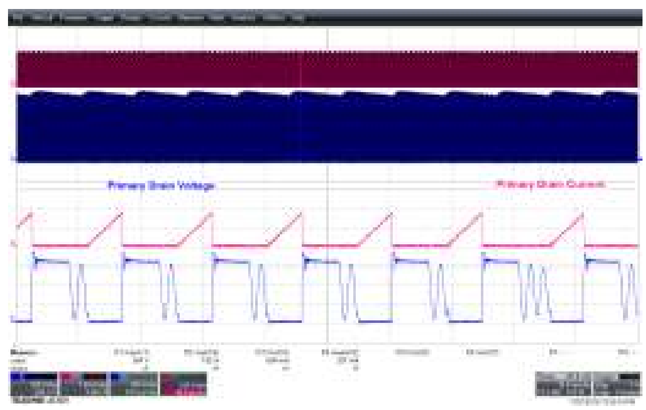

Figure 57 – 115 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.82 A, V_{DS} = 364 V.

Figure 58 – 230 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.79 A, V_{DS} = 535 V.

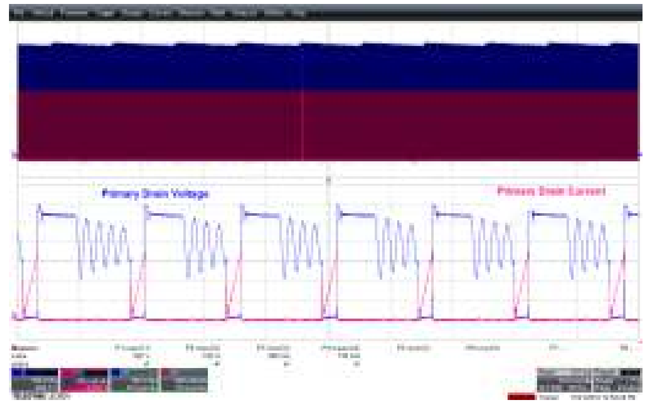

Figure 59 – 265 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.83 A, V_{DS} = 592 V.

Figure 60 – 90 VAC 60 Hz, 24 V Full Load Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V / div., 200 μs / div.
I_{DS} = 1.75 A, V_{DS} = 336 V.

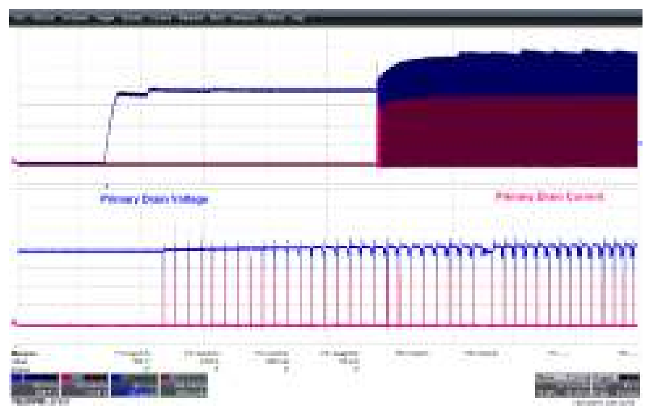

Figure 61 – 265 VAC 50 Hz, 24 V Full Load Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 200 μs / div.
I_{DS} = 2.63 A, V_{DS} = 592 V.

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13.9 *Drain Voltage and Current Waveforms at V_{OUT} = 15 V Full Load*

E-load set at 15 V CV mode load

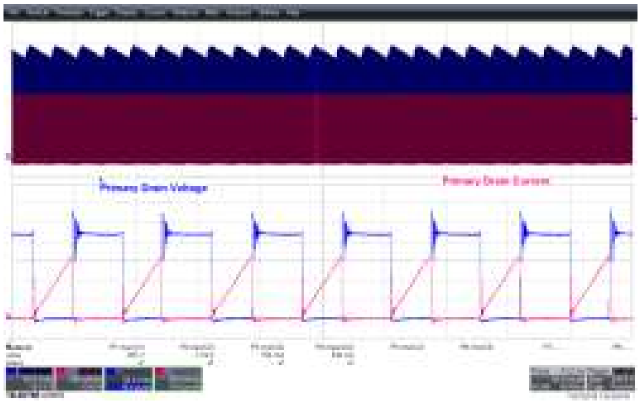

Figure 62 – 90 VAC 60 Hz, 15 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.
I_{DS} = 1.74 A, V_{DS} = 297 V.

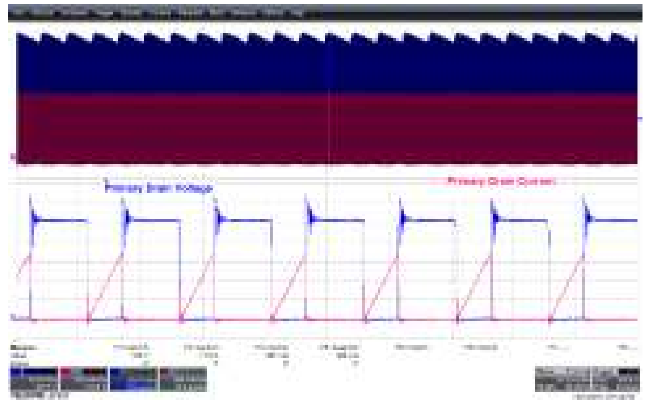

Figure 63 – 115 VAC 60 Hz, 15 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V / div., 10 μs / div.
I_{DS} = 1.75 A, V_{DS} = 330 V.

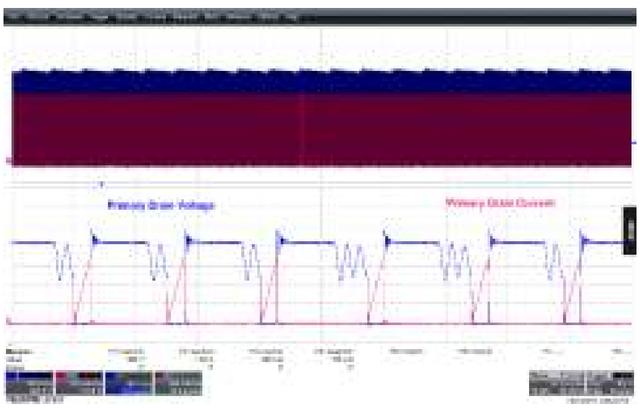

Figure 64 – 230 VAC 60 Hz, 15 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.84 A, V_{DS} = 489 V.

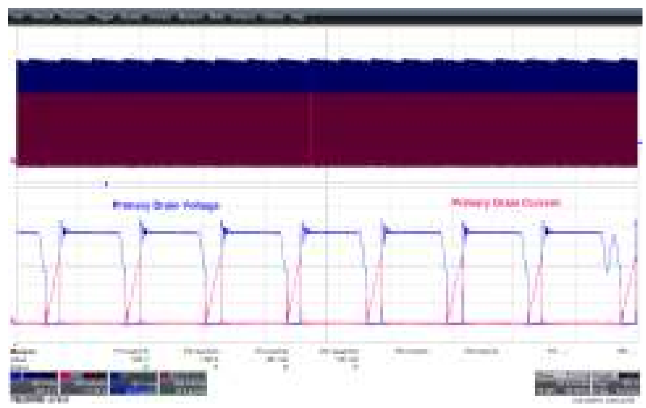

Figure 65 – 265 VAC 60 Hz, 15 V Full Load Normal.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 10 μs / div.
I_{DS} = 1.86 A, V_{DS} = 543 V.

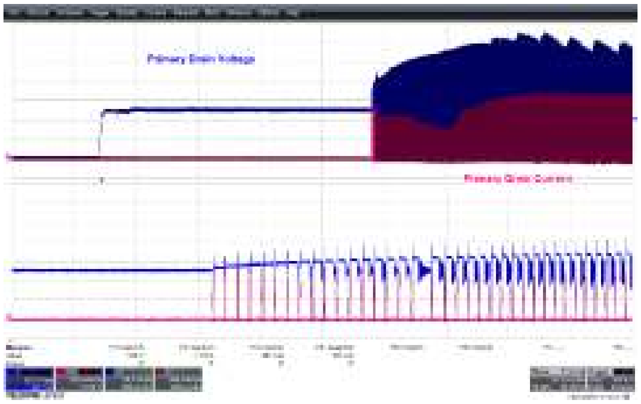

Figure 66 – 230 VAC 60 Hz, 15 V Full Load Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 50 V / div., 200 µs / div.
I_{DS} = 1.79 A, V_{DS} = 330 V.

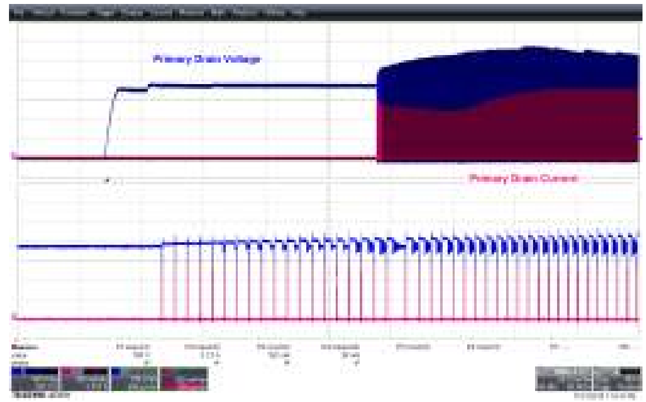

Figure 67 – 265 VAC 60 Hz, 15 V Full Load Start-up.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 200 µs / div.
I_{DS} = 2.21 A, V_{DS} = 590 V.

13.10 *Drain Voltage and Current Waveform during Output Short-Circuit*

Figure 68 – 90 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 500 mA / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
I_{DS} = 1.82 A, V_{DS} = 193 V.

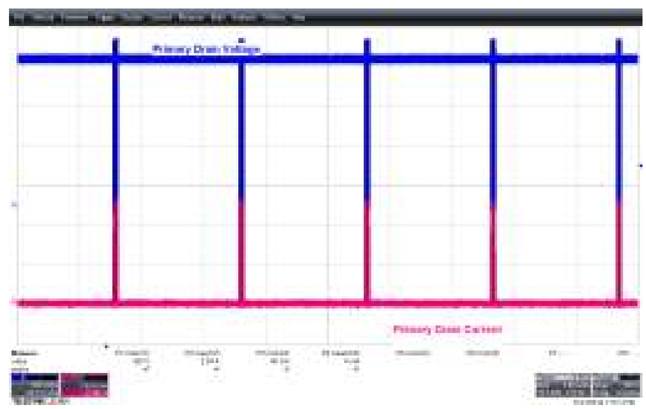

Figure 69 – 265 VAC 60 Hz, Output Shorted.
Upper: I_{DRAIN}, 1 A / div.
Lower: V_{DRAIN}, 100 V / div., 1 s / div.
I_{DS} = 2.65 A, V_{DS} = 429 V.

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13.11 *SR FET Drain Voltage and Current Waveform at V_{OUT} = 24 V*

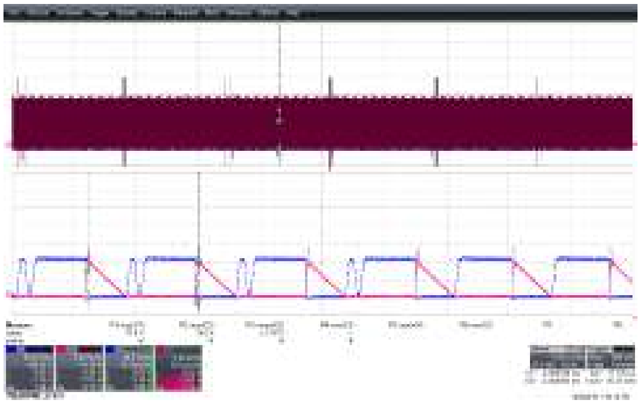

Figure 70 – 90 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 5 A / div.
Lower: V_{DRAIN}, 20 V / div., 10 µs / div.
I_{DS} = 15 A, V_{DS} = 77.8 V.

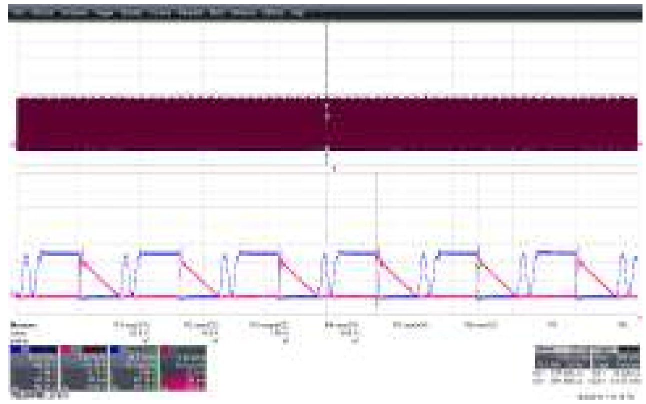

Figure 71 – 115 VAC 60 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 5A / div.
Lower: V_{DRAIN}, 2 0 V / div., 10 µs / div.
I_{DS} = 14.4 A, V_{DS} = 53.9 V.

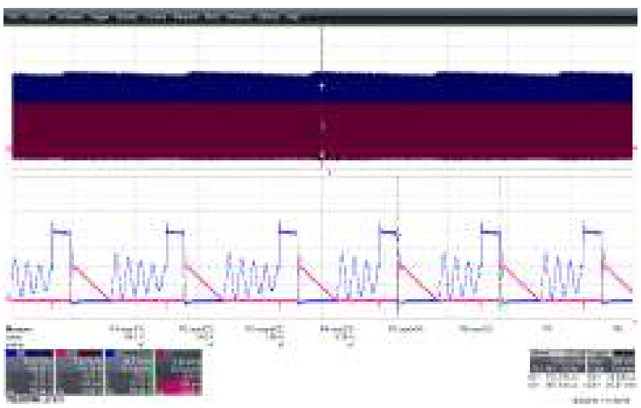

Figure 72 – 230 VAC 50 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 5 A / div.
Lower: V_{DRAIN}, 20 V / div., 10 µs / div.
I_{DS} = 14 A, V_{DS} = 89.1 V.

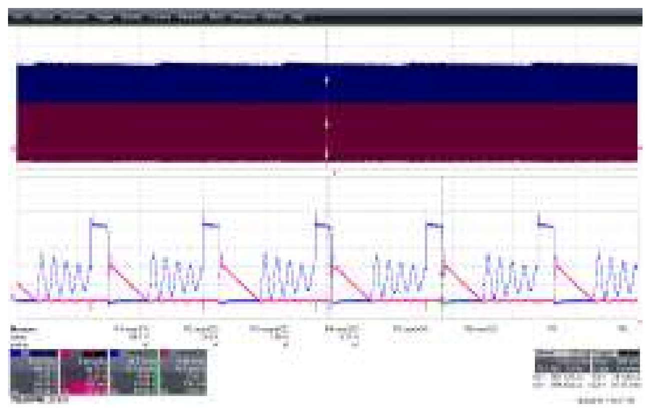

Figure 73 – 265 VAC 50 Hz, 24 V Full Load Normal.
Upper: I_{DRAIN}, 5 A / div.
Lower: V_{DRAIN}, 20 V / div., 10 µs / div.
I_{DS} = 13.9 A, V_{DS} = 99.7 V.

14 Conducted EMI

14.1 *Test Set-up*

EMI measurement is done using R-load = 12.8 Ω resistor load with floating output terminals (not grounded)

14.2 *Equipment and Load Used*

1. Rohde and Schwarz ENV216 two line V-network.
2. Rohde and Schwarz ESRP EMI test receiver.
3. Chroma measurement test fixture.
4. Full Load with input voltage set at 230 VAC 50 Hz and 115 VAC.

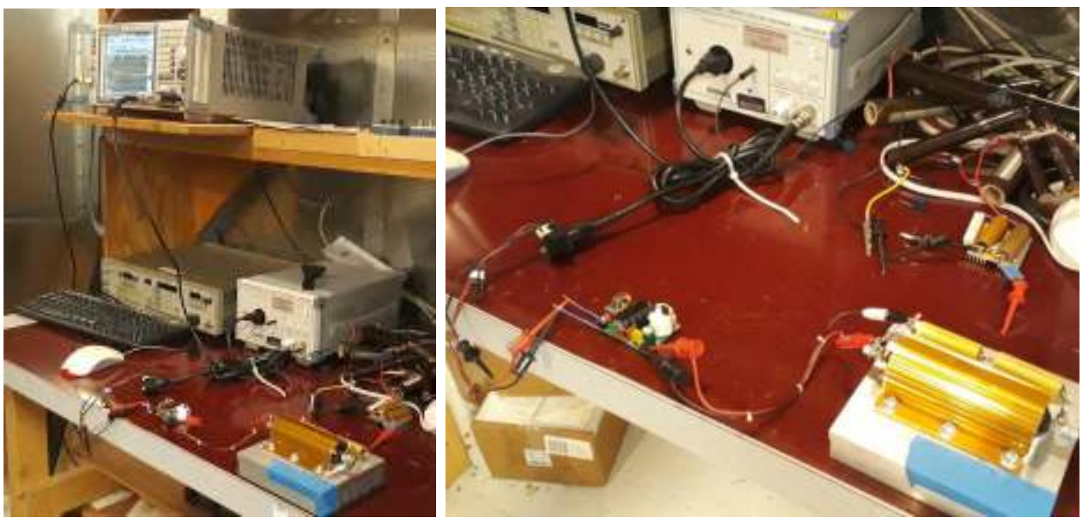

Figure 74 – Conducted EMI Test Set-up.

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14.3 *EMI Test Result*

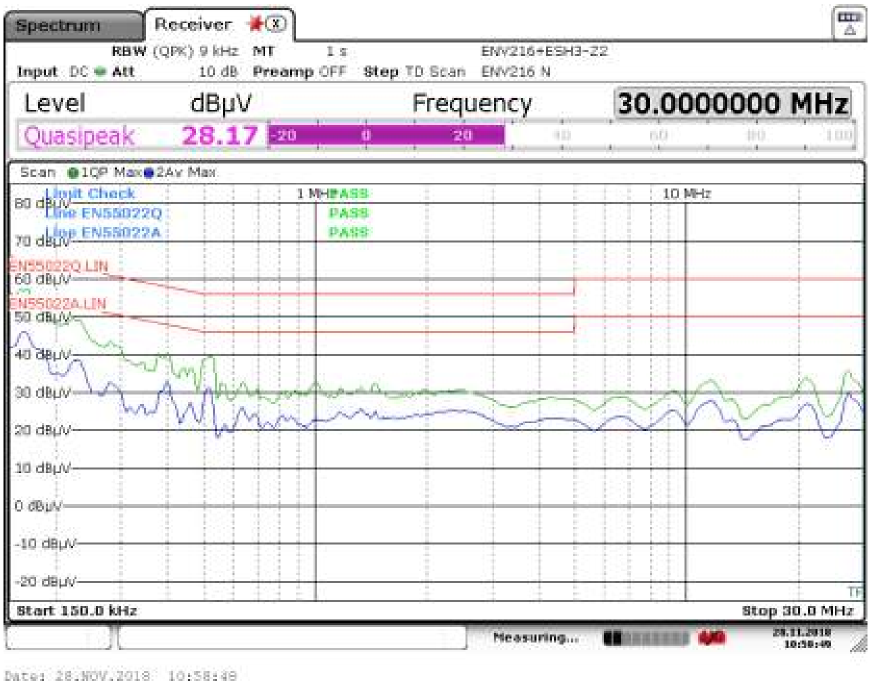

Figure 75 – Conducted EMI QP Scan at Full Load, 115 VAC 60 Hz and EN55015 B Limits.

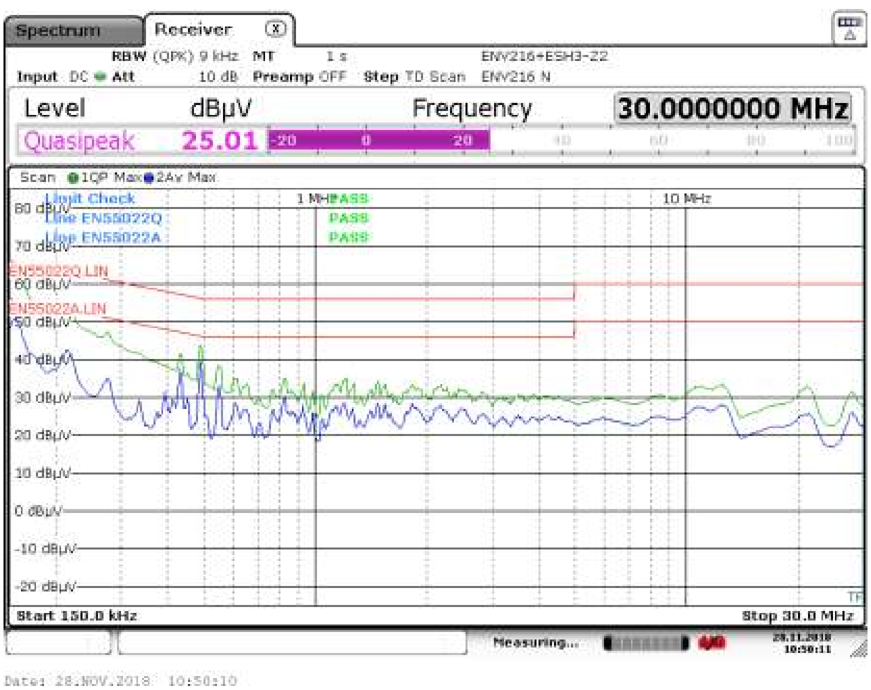

Figure 76 – Conducted EMI QP Scan at Full Load, 230 VAC 50 Hz and EN55015 B Limits.

15 Line Surge

Unit was subjected to ±2500 V 100 kHz ring wave and ±2000 V differential surge. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

15.1 *Differential Surge Test Results*

Source Impedance: 2Ω
Repetition Rate: 1/30 s
No. of surge strike per location: 10 strikes

Differential Surge	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
2000	230	L to N	0	Pass
-2000	230	L to N	0	Pass
2000	230	L to N	90	Pass
-2000	230	L to N	90	Pass
2000	230	L to N	180	Pass
-2000	230	L to N	180	Pass
2000	230	L to N	270	Pass
-2000	230	L to N	270	Pass

15.2 *Ring Wave Surge Test Results*

Source Impedance: 12Ω
Repetition Rate: 1/30 s
No. of surge strike per location: 10 strikes

Differential Surge	Input Voltage (VAC)	Injection Location	Injection Phase (°)	Test Result (Pass/Fail)
2500	230	L, N to PE	0	Pass
-2500	230	L, N to PE	0	Pass
2500	230	L, N to PE	90	Pass
-2500	230	L, N to PE	90	Pass
2500	230	L, N to PE	180	Pass
-2500	230	L, N to PE	180	Pass
2500	230	L, N to PE	270	Pass
-2500	230	L, N to PE	270	Pass

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16 ESD

Unit was subjected to ±8 kV, ±10 kV, ±12 kV and ±15 kV ESD air discharge test. An LED indicator connected across the resistor load was used to observe the output behavior during to ESD. A test failure was defined as a non-recoverable interruption of output requiring repair or recycling of input voltage.

No.	Voltage Level (kV)	Discharge Location	Remarks	Pass/Fail
1	+8	+ Output Terminal	No Damage / No AR	Pass
2	+8	- Output Terminal	No Damage / No AR	Pass
3	-8	+ Output Terminal	No Damage / No AR	Pass
4	-8	- Output Terminal	No Damage / No AR	Pass
5	+10	+ Output Terminal	No Damage / No AR	Pass
6	+10	- Output Terminal	No Damage / No AR	Pass
7	-10	+ Output Terminal	No Damage / No AR	Pass
8	-10	- Output Terminal	No Damage / No AR	Pass
9	+12	+ Output Terminal	No Damage / No AR	Pass
10	+12	- Output Terminal	No Damage / No AR	Pass
11	- 12	+ Output Terminal	No Damage / No AR	Pass
12	-12	- Output Terminal	No Damage / No AR	Pass
13	+15	+ Output Terminal	No Damage / No AR	Pass
14	+15	- Output Terminal	No Damage / No AR	Pass
15	-15	+ Output Terminal	No Damage / No AR	Pass
16	-15	- Output Terminal	No Damage / No AR	Pass

17 **Brown-Out / Brown-Out Recovery Test**

No abnormal overheating or voltage overshoot/undershoot was observed during and after 0.5 V / s.

17.1 ***Brown-Out Test at V_{OUT} = 24 V***

E-load set at 1.88 A CC mode load

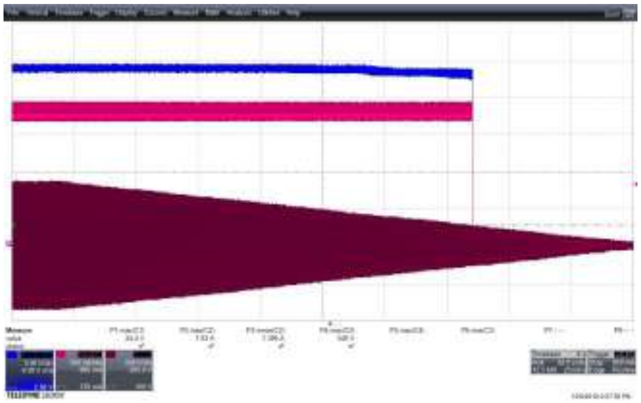

Figure 77 – Brown-Out from 230 V / 60 Hz to 0 V.
Slew Rate: 0.5 V / s.
Upper2: V_{OUT}, 5 V / div.
Upper1: I_{OUT}, 500 mA / div.
Lower: V_{IN}, 200 V / div., 50 s / div.

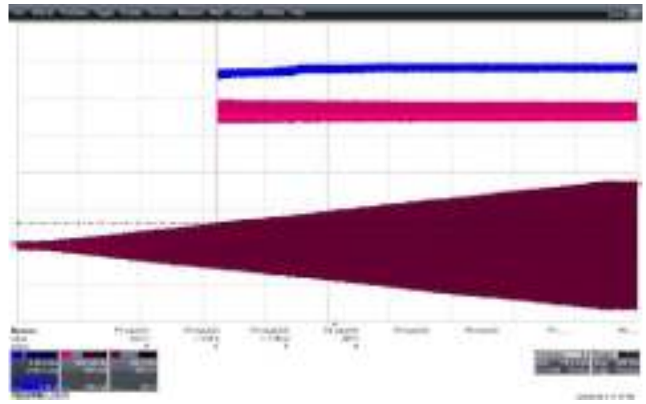

Figure 78 – Brown-Out Recovery from 0 V - 230 V.
Slew Rate: 0.5 V / s.
Upper2: V_{OUT}, 5 V / div.
Upper1: I_{OUT}, 500 mA / div.
Lower: V_{IN}, 200 V / div., 50 s / div.

17.2 ***Brown-Out Test at V_{OUT} = 15 V Full Load***

E-load set at 15 V CV mode load

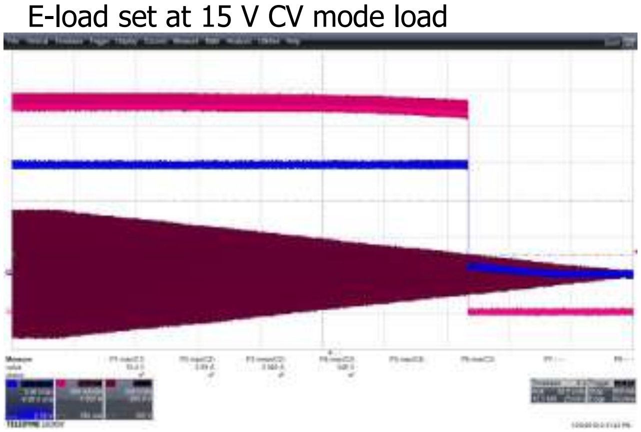

Figure 79 – Brown-Out from 230 V / 60 Hz to 0 V.
Slew Rate: 0.5 V / s.
Upper2: V_{OUT}, 5 V / div.
Upper1: I_{OUT}, 500 mA / div.
Lower: V_{IN}, 200 V / div., 50 s / div.

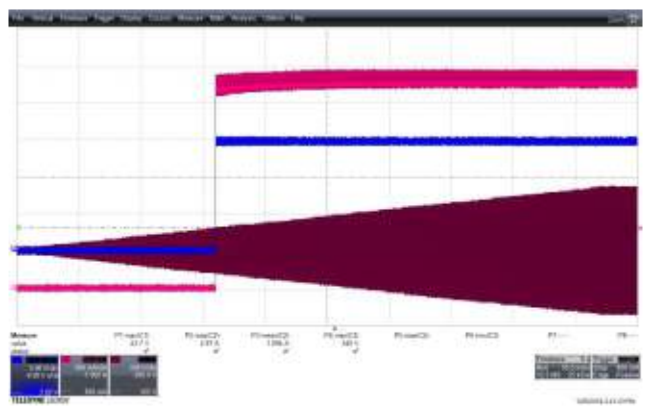

Figure 80 – Brown-Out Recovery from 0 V - 230 V.
Slew Rate: 0.5 V / s.
Upper2: V_{OUT}, 5 V / div.
Upper1: I_{OUT}, 500 mA / div.
Lower: V_{IN}, 200 V / div., 50 s / div.

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18 Revision History

Date	Author	Revision	Description and Changes	Reviewed
10-Apr-19	MGM	1.0	Initial release	Apps & Mktg

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