Design Example Report

Title	***10 W Single Output Power Supply Using InnoSwitch™3-TN INN3073M***
Specification	85 VAC – 265 VAC Input; 5 V, 2 A Output
Application	Single Output Open Frame Appliances Power Supply
Author	Applications Engineering Department
Document Number	DER-709
Date	November 1, 2021
Revision	1.0

Summary and Features

- 10 W output from 85 VAC to 265 VAC
- Built in synchronous rectification for >85% efficiency at nominal AC input
- All the benefits of secondary-side control with the simplicity of primary-side regulation
    - Insensitive to transformer variation
    - Extremely fast transient response independent of load timing
- <15 mW no-load input power at nominal AC inputs
- <1% output voltage ripple
- Primary sensed output overvoltage protection (OVP) eliminates optocoupler for fault protection
- Accurate thermal protection with hysteretic shutdown

Power Integrations
5245 Hellyer Avenue, San Jose, CA 95138 USA.
Tel: +1 408 414 9200 Fax: +1 408 414 9201
www.power.com

Table of Contents

1 Introduction 4
2 Power Supply Specification 5
3 Schematic 6
4 Circuit Description 7
4.1 Input Circuit Description 7
4.2 Primary-Side Circuit 7
4.3 Secondary-Side Circuit 7
5 PCB Layout 9
6 Bill of Materials 10
7 Transformer (T1) Specification 11
7.1 Electrical Diagram 11
7.2 Electrical Specifications 11
7.3 Material List 11
7.6 Winding Illustrations 13
7.7 Transformer Design Spreadsheet 17
8 Performance Data 20
8.1 Average Efficiency at PCB END 20
8.1.1 115 VAC Input 20
8.1.2 230 VAC Input 20
8.2 Full Load Efficiency vs. Line 21
8.3 Efficiency vs. Load 22
8.4 No-Load Input Power 25
8.5 Line and Load Regulation 26
8.5.1 Line Regulation (Full load) 26
8.5.2 Load Regulation 27
8.6 Output Voltage Ripple 30
9 Thermal Performance 33
9.1 IR Camera Reading at 25 ºC Ambient Temperature 33
9.1.1 Input: 85 VAC; Output: 5 V / 2 A 33
9.1.2 Input: 265 VAC; Output: 5 V / 2 A 34
9.2 Thermocouple Reading at 40 ºC Ambient Temperature 35
10 Waveforms 36
10.1 Load Transient Response 36
10.2 InnoSwitch3-TN Drain to Source Voltage Waveforms 37
10.2.1 Steady-State Waveforms 37
10.2.2 Start-Up Waveforms 37
10.2.3 Waveforms with Output Shorted 38
10.3 SRFET Drain to Source Voltage Waveforms 39
10.3.1 Steady-State Waveforms 39
10.3.2 Start-Up Waveforms 39
10.3.3 Waveforms with Output Shorted 40
10.4 Over Voltage Protection 41
10.4.1 Full Load Condition (2 A) 41

10.4.2 No-Load Condition (0 A) 41
11 Conductive EMI 42
11.1 115 VAC Input 42
11.2 230 VAC Input 44
12 Surge Test 46
12.1 Differential Surge Test 46
Note: AR means auto-restart 46
12.2 RingWave Test 46
12.3 EFT / Burst Test 47
13 Revision History 48

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.

1 Introduction

This document is an engineering report describing a 5 V / 2 A output embedded power supply utilizing INN3073M from the InnoSwitch3-TN family of ICs.

This design shows the high power density and efficiency that is possible due to the high level of integration while still providing exceptional performance.

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

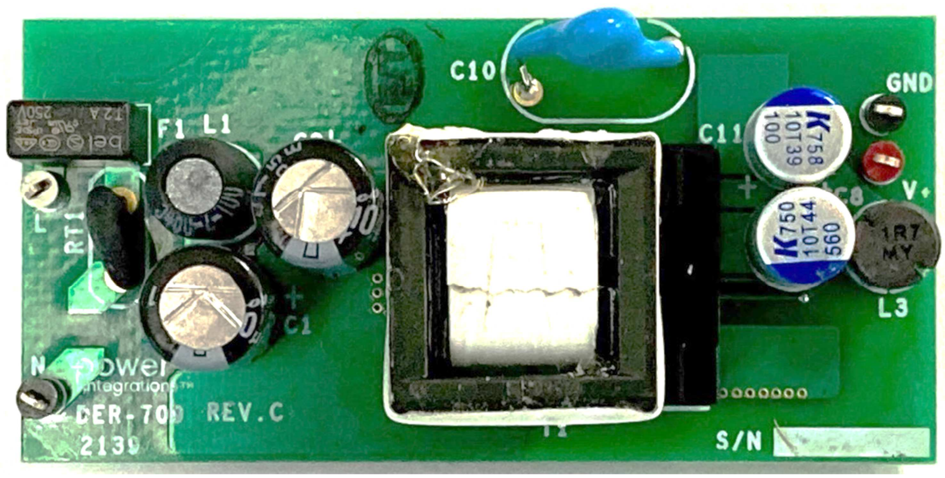


Figure 1 – Populated Circuit Board Photograph, Top.

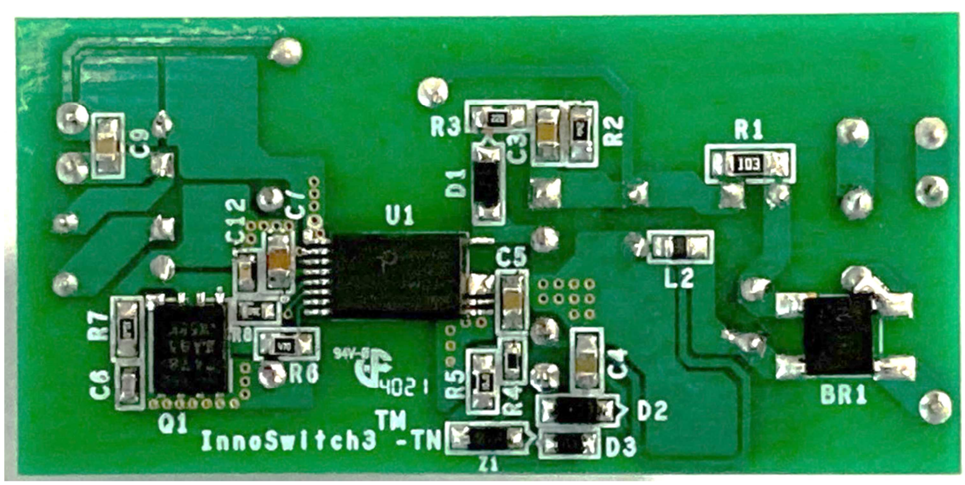


Figure 2 – Populated Circuit Board Photograph, Bottom.

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	V_{IN}	85	115/230	265	VAC	2 Wire Input.
Frequency	f_{LINE}	47	50/60	63	Hz	
No Load Input Power				15	mW	
Output						
Output Voltage	V_{OUT}	4.75	5	5.25	V	±5 %
Output Ripple Voltage	V_{RIPPLE}			50	mV	200 MHz Bandwidth.
Output Current	I_{OUT}	0	2		A	
Average Efficiency						Measured at 115 / 230 VAC, 25 ºC 25%, 50%, 75%, and 100% Load
	η(AVE) [at board end]	79			%	COC5 T1 Limit.
		78.7			%	DOE6 Limit.
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B Load Floating				
Safety		Designed to meet IEC950, UL1950 Class II				
Differential Surge		1			kV	1.2/50 µs surge, IEC 1000-4-5, Series Impedance: Differential Mode: 2 Ω.
Ring Wave		2			kV	100 kHz Ring Wave, 12 Ω Common Mode.
EFT		6			kV	15 ms @ 5 kHz. 0.75 mS @ 100 kHz.
Ambient Temperature	T_{AMB}	0		40	ºC	Free Convection, Sea Level.

3 Schematic

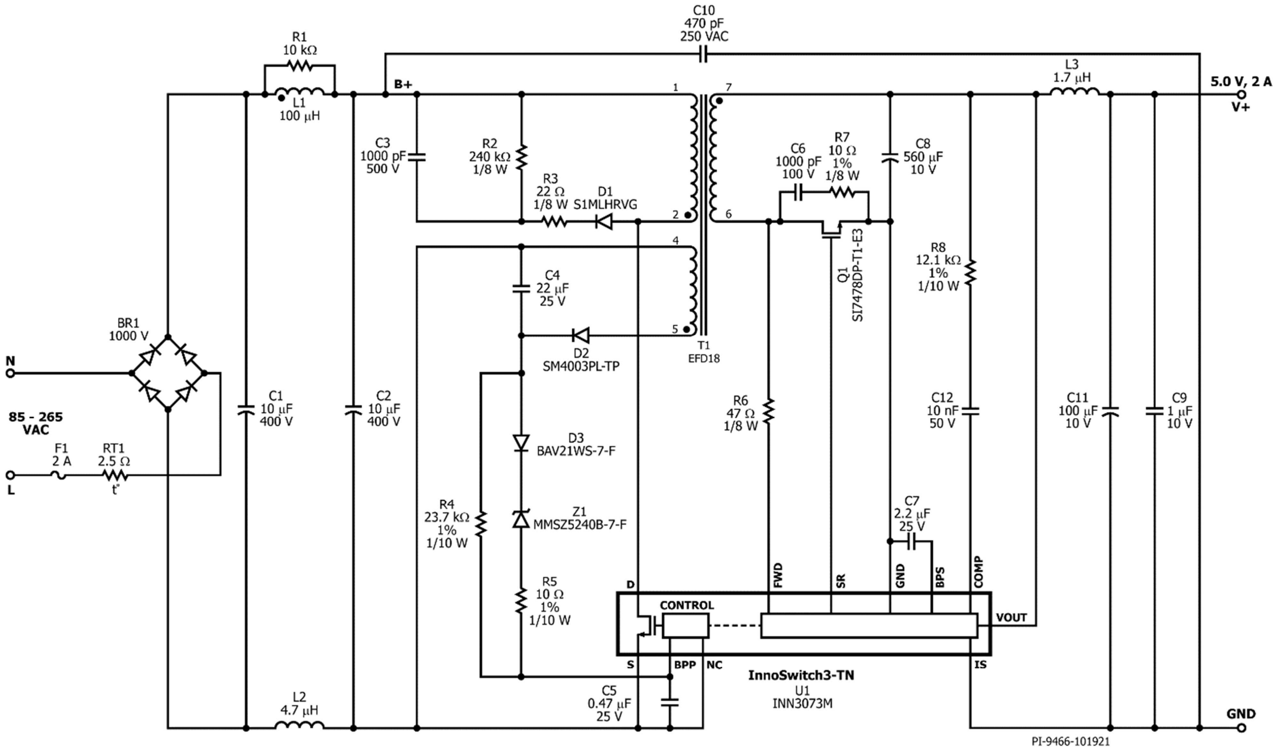


Figure 3 – Schematic.

4 Circuit Description

The InnoSwitch3-TN IC combines primary, secondary and feedback circuits in a single surface mounted off-line flyback switcher IC. The IC incorporates the primary MOSFET, the primary-side controller, the secondary-side controller for synchronous rectification and the Fluxlink™ technology that eliminates the need for an optocoupler needed on a secondary sensed feedback system.

4.1 *Input Circuit Description*

Fuse F1 isolates the circuit and provides protection from component failure while thermistor RT1 limits inrush current and for surge protection.

Bridge rectifier BR1 rectifies the AC line voltage and provides a full wave rectified DC across input capacitors C1 and C2. Differential inductors L1 and L2 placed in between input capacitors provides differential noise filtering.

4.2 *Primary-Side Circuit*

One end of the transformer T1 primary is connected to the rectified DC bus; the other is connected to the drain terminal of integrated 725 V power MOSFET inside the INN3073M (U1).

A low cost RCD clamp formed by diode D1, resistors R3 and R2, and capacitor C13 limits the peak Drain voltage of U1 at the instant turn-off of the MOSFET. The clamp helps dissipate the energy stored in the leakage inductance of transformer T1.

The IC is self-starting, using an internal high-voltage current source to charge the BPP pin capacitor, C5, when AC is first applied. During normal operation the primary-side block is powered from an auxiliary winding on the transformer. The output of this is configured as a flyback winding which is rectified and filtered using diode D2 and capacitor C4, and fed in the BPP pin via a current limiting resistor R4. The primary-side overvoltage protection is obtained using Zener diode Z1 in series with blocking diode D3 and resistor R5. In the event of overvoltage at output, the increased voltage at the output of the bias winding will cause the Zener diode Z1 to conduct and triggers the OVP latch in the primary-side controller of the InnoSwitch3-TN IC.

4.3 *Secondary-Side Circuit*

The secondary-side of the IC provides output voltage, output current sensing and gate drive for MOSFET providing synchronous rectification. Secondary winding of the transformer is rectified by MOSFET Q1 and filtered by capacitors C8, C11 and inductor L3 which forms π-filter configuration to achieve very low output voltage ripple. RC snubber C6 and R7 connected to MOSFET Q1 helps reduce high frequency ringing during switching transients.

The gate of Q1 is turned on by the secondary-side controller inside U1, based on the winding voltage sensed via resistor R7 and fed into the FWD pin of the IC.

In continuous conduction mode operation, the power MOSFET is turned off just prior to the secondary-side controller commanding a new switching cycle from the primary. In discontinuous mode the MOSFET is turned off when the voltage drop across the MOSFET falls below ground. Secondary-side control of the primary-side MOSFET ensures that it is never on at the same time with the synchronous rectification MOSFET on time. The MOSFET drive signal is the output on the SR pin.

The secondary-side of the IC is self-powered from either the secondary winding forward voltage or the output voltage. The output voltage powers the device then fed into VOUT pin and charges the decoupling capacitor C7 via an internal regulator.

Output current is sensed by monitoring the voltage drop between the IS and GND pins. Once the constant current threshold is exceeded, the device will enter into Auto-Restart feature until load current is reduced below the constant current threshold.

The IC regulates output voltage to 5 V through VOUT pin and internal feedback divider network. Feedforward components C12 and R8 helps achieved better sensing on COMP pin, which results in lower output voltage ripple.

5 PCB Layout

PCB Material FR4 copper 2oz with thickness of 0.062"

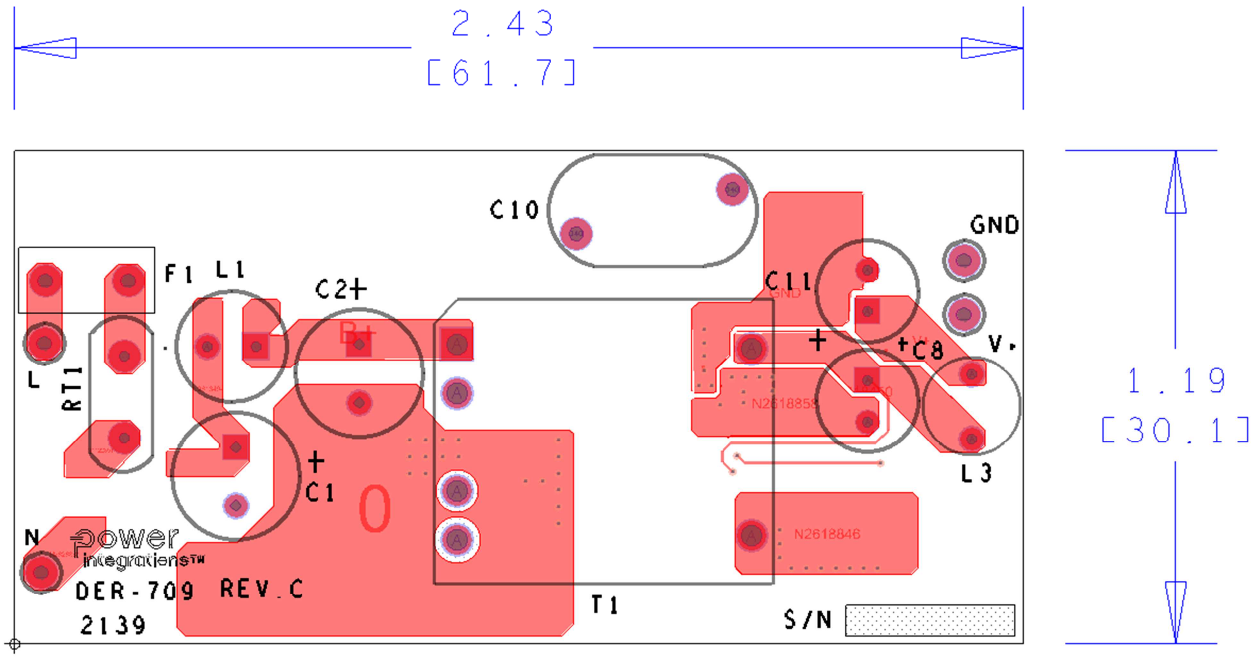


Figure 4 – Printed Circuit Layout, Top.

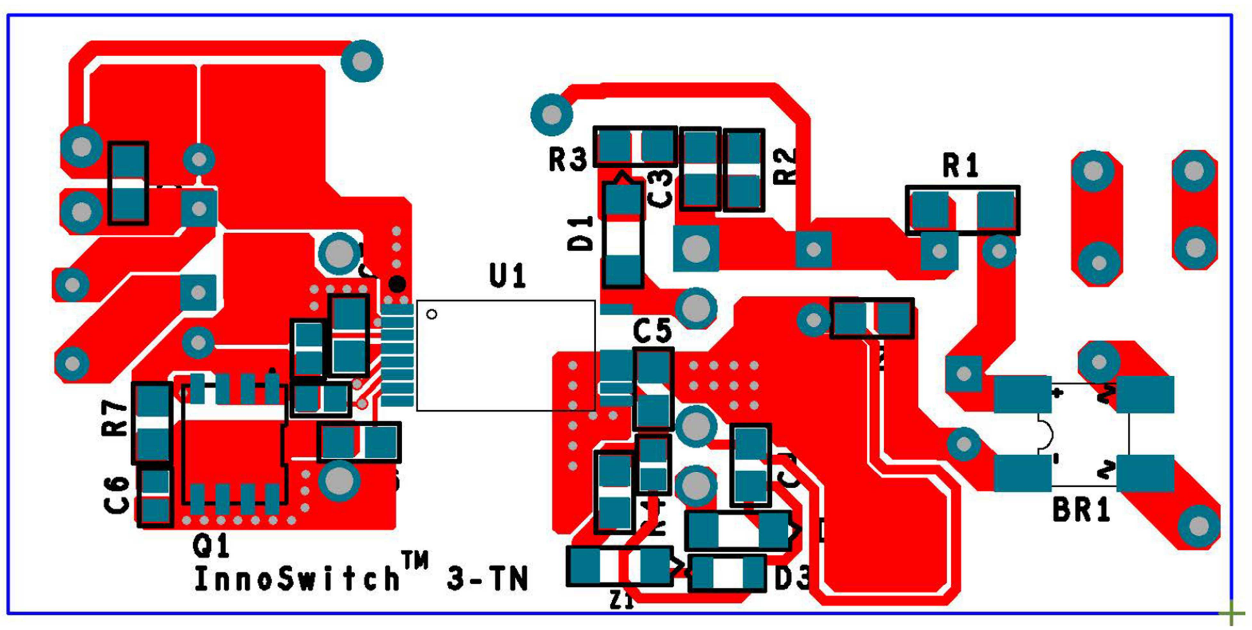


Figure 5 – Printed Circuit Layout, Bottom.

6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	Bridge rectifier, 1 PH, 1 kV, 1.5 A, 4-SMD,4SOPA	UABF1510-13	Diodes, Inc.
			Bridge rectifier, 1 PH, 1 kV, 1.5 A, 4-SMD	FTB10F-15FTR	SMC Diode
2	2	C1 C2	10 μF, ±20%, 400 V, Electrolytic, -40°C ~ 105°C,2000 Hrs @ 105 °C, (8 x 16), LS 3.5mm	400AX10MEFC8X16	Rubycon
3	1	C3	1000 pF, 10%, 500 V, Ceramic, X7R, 0805	C0805C102KCRACTU	Kemet
4	1	C4	22 μF, ±20%, 25 V, Ceramic X5R, 0805	GMC21X5R226M25NT	CAL-CHIP
5	1	C5	0.47 μF, ±10%,25 V, Ceramic, X7R, 0805	CGA4J2X7R1E474K125AA	TDK
6	1	C6	1000 pF, 100 V, Ceramic, NP0, 0603	C1608C0G2A102J	TDK
7	1	C7	2.2 μF, ±10%, 25V, Ceramic X7R, 0805	CL21B225KAFNFNE	Samsung
8	1	C8	560 μF, 10 V, Aluminum - Polymer, Radial, Can 12 mΩ 2000 Hrs @ 105 °C, (6.3 x 12)	A750EQ567M1AAAE012	KEMET
9	1	C9	CER, 1 μF, 10V, X7R, 0805	CL21B105KPFNNNE	Samsung
10	1	C10	470 pF, ±10%, 250 VAC, Ceramic, Radial, Disc,X1, Y1	DE1B3RA471KN4AN01F	Murata
11	1	C11	100 μF, ±20%, 10 V, Aluminum Polymer, 2000 Hrs @ 105 °C, (6.3 x 9)	A758EK107M1AAAE016	KEMET
12	1	C12	10 nF 50 V, Ceramic, X7R, 0603	C0603C103K5RACTU	Kemet
13	1	D1	Diode, Standard, 1000 V, 1 A, SMT, Sub SMA	S1MLHRVG	TAIWAN SEMI
14	1	D2	200V, 1 A, Standard Recovery, SOD-123FL	SM4003PL-TP	Micro Commercial
15	1	D3	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	2	GND N	Test Point, BLK, Miniature THRU-HOLE MOUNT	5001	Keystone
18	1	L	Test Point, WHT, Miniature THRU-HOLE MOUNT	5002	Keystone
19	1	L1	100 μH, 0.490 A, 20%	RL-5480-2-100	Renco
20	1	L2	4.7 μH, 600 mA SMD INDUCTOR, MULTILAYER	MLZ2012N4R7LT000	TDK
21	1	L3	1.7 μH, Unshielded, Wirewound, Inductor, 3.52A, 22.8 mΩ Max, Radial, 6.0 mm diam, 6.5 mm H, 4.0 mm LS	RCH664NP-1R7M	Sumida
22	1	Q1	60 V, 15 A, N-Channel, PowerPAK SO-8	SI7478DP-T1-E3	Vishay
23	1	R1	RES, 10 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ103V	Panasonic
24	1	R2	RES, 240 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ244V	Panasonic
25	1	R3	RES, 22 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ220V	Panasonic
26	1	R4	RES, 23.7 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF2372V	Panasonic
27	2	R5 R7	RES, 10 Ω, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF10R0V	Panasonic
28	1	R6	RES, 47 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ470V	Panasonic
29	1	R8	RES, 12.1 kΩ, 1%, 1/10 W, Thick Film, 0603	ERJ-3EKF1212V	Panasonic
30	1	RT1	NTC Thermistor, 2.5 Ω, 3 A	SL08 2R503	Ametherm
31	1	T1	Bobbin, EFD18, Horizontal, 7 pins (5primary, 2secondary)		
32	1	U1	InnoSwitch3-TN, MinSOP-16	INN3073M	Power Integrations
33	1	V+	Test Point, RED,Miniature THRU-HOLE MOUNT	5000	Keystone
34	1	Z1	Diode Zener 10 V 500 mW SOD123	MMSZ5240B-7-F	Diodes, Inc.

7 Transformer (T1) Specification

7.1 *Electrical Diagram*

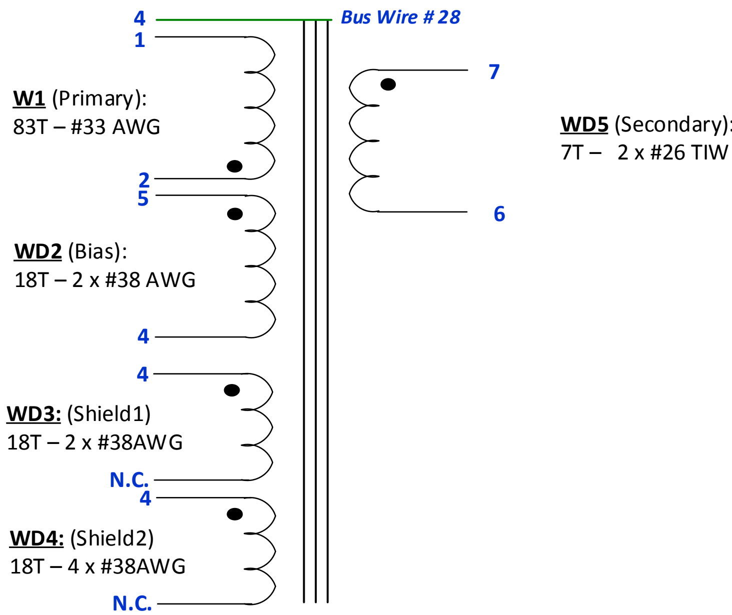


Figure 6 – Transformer Electrical Diagram.

7.2 *Electrical Specifications*

Parameter	Condition	Spec.
Nominal Primary Inductance	Measured at 1 V_{PK-PK}, 100 kHz switching frequency, between pin 2 and 3, with all other windings open.	1.03 mH ±5%
Resonant Frequency	Between pin 2 and 3, other windings open.	705 kHz (Min.)
Primary Leakage Inductance	Between pin 2 and 3, with pins:FL1-FL2 shorted.	35 µH (Max.)

7.3 *Material List*

Item	Description
[1]	Core: EFD1816-HT-P95.
[2]	Bobbin: EFD1816-Horz-7pins (5/2); PI#: 25-01019-00.
[3]	Magnet Wire: #33 AWG, Double Coated.
[4]	Magnet Wire: #38 AWG, Double Coated.
[5]	Magnet Wire: #26 AWG, Triple Insulated Wire.
[7]	Bus Wire: #28 AWG, Alpha Wire, Tinned Copper.
[8]	Tape: 3M 13450-F, Polyester Film, 1 mil Thickness, 9.5mm Width.
[9]	Tape: 3M 13450-F, Polyester Film, 1 mil Thickness, 4.9 mm Width.
[10]	Varnish: Dolph BC-359.

7.4 *Transformer Build Diagram*

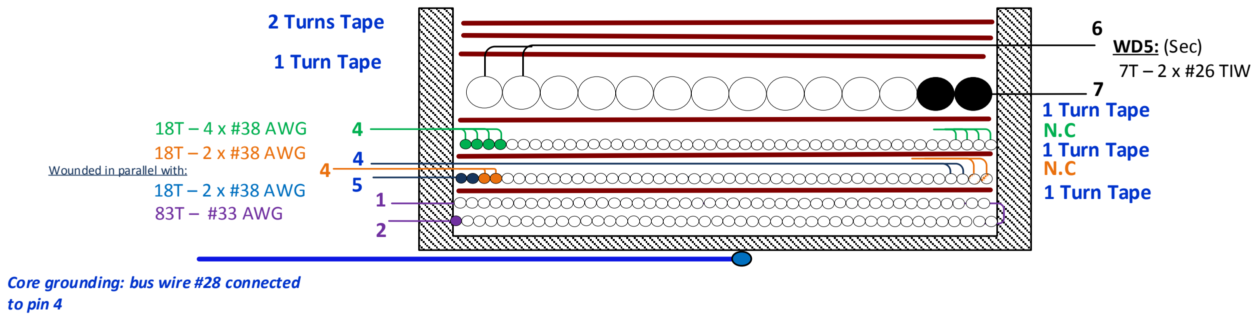


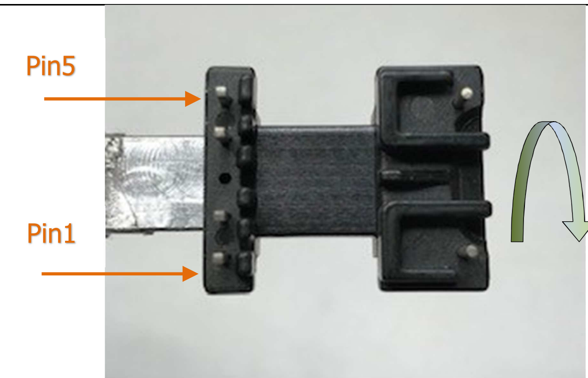
Figure 7 – Transformer Electrical Diagram.

7.5 *Winding Instructions*

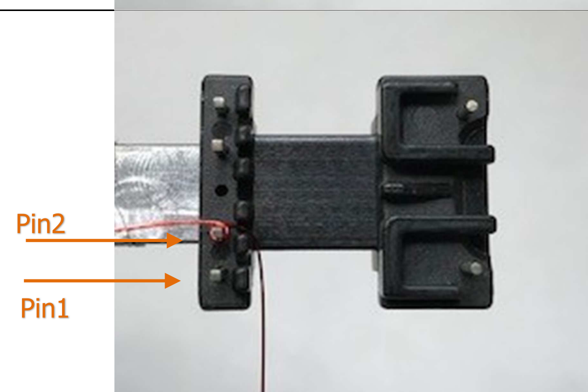
Bobbin Preparation	Position the bobbin Item [2] on the mandrel such that the primary-side of the bobbin is on the left side. Winding direction is clock-wise direction.
Winding 1 – Primary	Use a AWG #33, Item [3]. Start at pin 2 and wind 83 turns in 2 layers. Finish at pin 1.
Insulation	Apply 1 layer of polyester tape, Item [8] for insulation
Winding 2 and 3 – Bias and shield 1	Use magnetic wire AWG #38 Item [4] for winding 2 and 3. Prepare bifilar wire for winding 2 and bifilar wire for winding 3. For Winding 2, start at pin 5 while pin 4 for Winding 3. Wind winding 2 and winding 3 evenly together for 18 turns from left to right. For winding 2, Finish the winding back to the left on pin 4. For winding 3, cut the finish terminal as shown in the figure.
Insulation	Apply 1 layer of polyester tape, Item [8] for insulation
Winding 4 – Shield 2	Use magnetic wire, Item [4] – AWG #38. Prepare 4 wires (quadfilar). Start at pin 4 and wind 18 turns evenly from left to right for 1 layer. Finish the winding at the right side of the bobbin and cut the wire as shown in the figure.
Insulation	Apply 1 layer of polyester tape, Item [8] for insulation
Winding 5 – Secondary	Use magnetic wire, Item [5] – TIW #26. Prepare 2 wires (bifilar). Start at pin 7 and wind 7 turns evenly from right to left for 1 layer and finish at pin 6.
Insulation	Apply 3 layers of polyester tape, Item [8] for insulation
Core Fixing and Varnishing	Prepare AWG #28 TIN wire, Item [7]. Terminate the wire on pin 4 and wrap around the core as shown in the figure. Secure the core and TIN wire with 2 layers of tape Item [9]. Varnish transformer using Item [10]

7.6 ***Winding Illustrations***

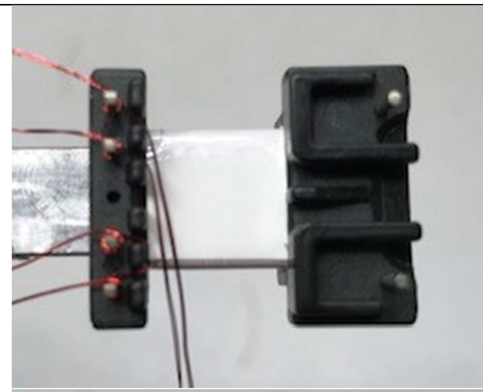
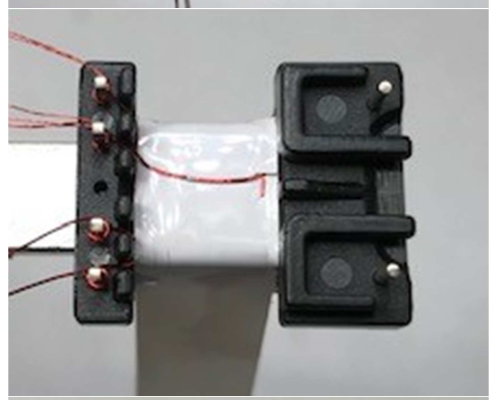
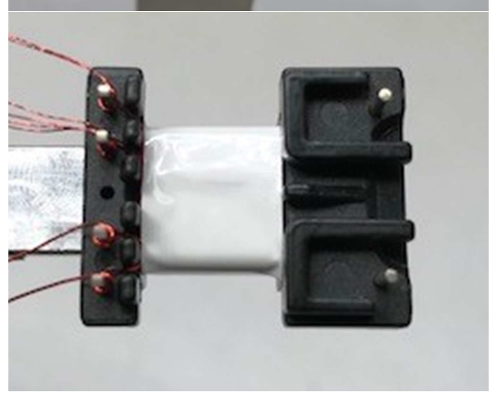
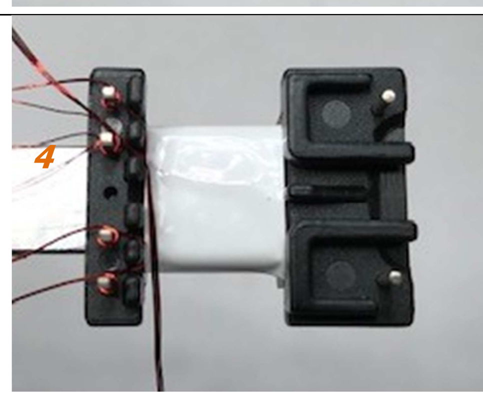
Bobbin Preparation
Position the bobbin Item [2] on the mandrel such that the primary-side of the bobbin is on the left side.
Winding direction is clock-wise direction.

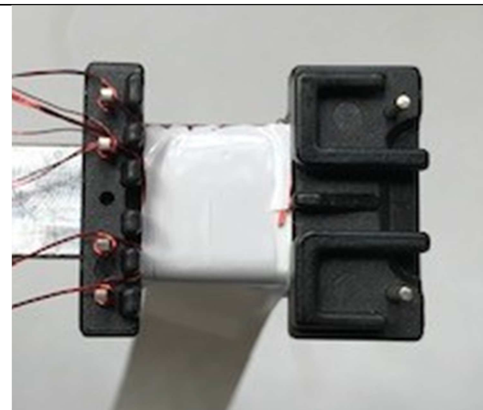
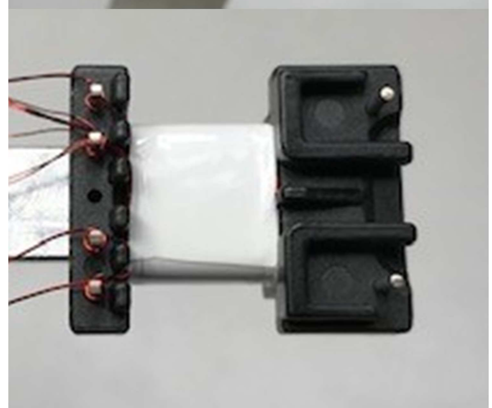
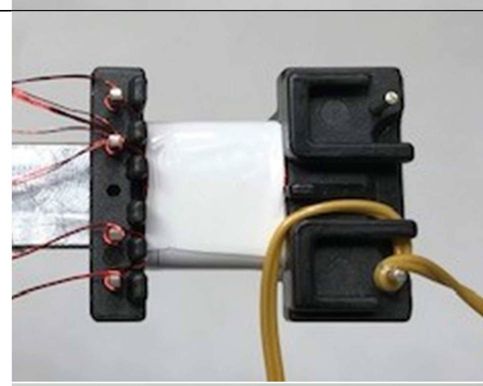
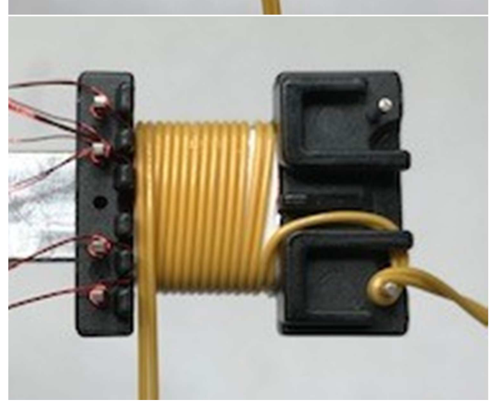


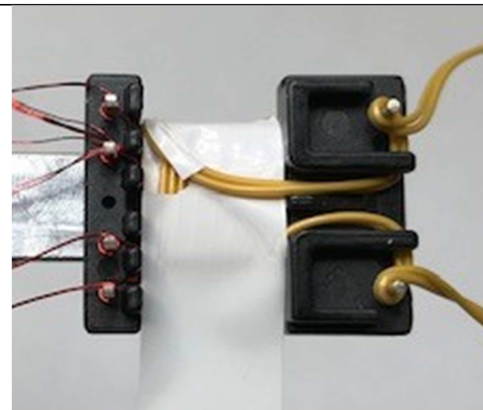
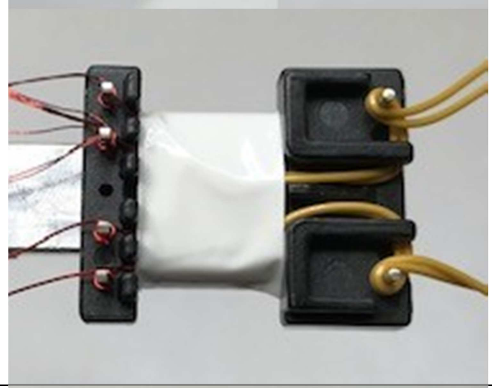
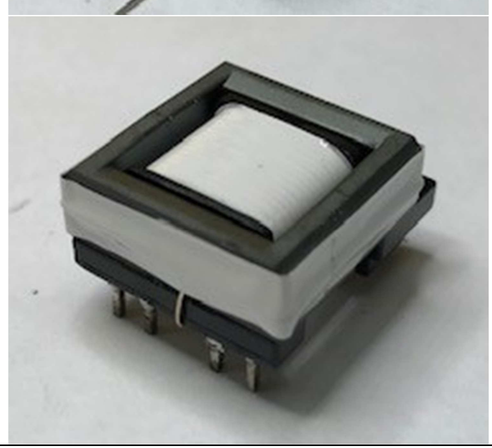
Winding 1 - Primary
Use a #33 AWG, Item [3]. Start at pin 2 and wind 83 turns in 2 layers. Finish at pin 1.



Apply 1 layer of polyester tape, Item [8] for insulation

Winding 2 and 3 – Bias and shield 1 Use magnetic wire AWG #38 Item [4] for winding 2 and 3. Prepare bifilar wire for winding 2 and bifilar wire for winding 3. For Winding 2, start at pin 5 while pin 4 for Winding 3.	
Wind winding 2 and winding 3 evenly together for 18 turns from left to right. For winding 2, Finish the winding back to the left on Pin 4. For winding 3, cut the finish terminal as shown in the figure.	
Apply 1 layer of polyester tape, Item [8] for insulation	
Winding 4- Shield 2 Use magnetic wire, Item [4] – AWG #38. Prepare 4 wires (quadfilar). Start at pin 4 and wind 18 turns evenly from left to right for 1 layer.	

Finish the winding at the right side of the bobbin and cut the wire as shown in the **figure.** Apply 1 layer of polyester tape, Item [8] for insulation	 
Winding 5 - Secondary Use magnetic wire, Item [5] – TIW #26. Prepare 2 wires (bifilar). Start at p in 7 and wind 7 turns evenly from right to left for 1 layer and finish at pin 6.	 

Apply 3 layers of polyester tape, Item [8] for insulation	 
Core Fixing and Varnishing Prepare AWG #28 TIN wire, Item [7]. Terminate the wire on pin 4 and wrap around the core as shown in the figure. Secure the core and TIN wire with 2 layers of tape Item [9]. Varnish transformer using Item [10]	 

8 Transformer Design Spreadsheet

1	ACDC_InnoSwitch3-TN_Flyback_101221; Rev.0.2; Copyright Power Integrations 2021	INPUT	INFO	OUTPUT	UNITS	InnoSwitch3 TN Flyback Design Spreadsheet
2	**APPLICATION VARIABLES**					
3	VIN_MIN	85		85	V	Minimum AC input voltage
4	VIN_MAX	265		265	V	Maximum AC input voltage
5	VIN_RANGE			UNIVERSAL		Range of AC input voltage
6	LINEFREQ			60	Hz	AC Input voltage frequency
7	CAP_INPUT	20.0		20.0	uF	Input capacitor
8	VOUT			5.00	V	Output voltage at the board
9	CDC	0		0	mV	Cable drop compensation desired at full load
10	IOUT	2.000		2.000	A	Output current
11	POUT			10.00	W	Output power
12	EFFICIENCY	0.83		0.83		AC-DC efficiency estimate at full load given that the converter is switching at the valley of the rectified minimum input AC voltage
13	FACTOR_Z			0.50		Z-factor estimate
14	ENCLOSURE			OPEN FRAME		Power supply enclosure
18	**PRIMARY CONTROLLER SELECTION**					
19	DEVICE_GENERIC	INN3073		INN3073		Generic device code
20	DEVICE_CODE			INN3073M		Actual device code
21	POUT_MAX			12.0	W	Power capability of the device based on thermal performance
22	ICC_MIN			2.00	A	Minimum constant current regulation threshold of the device
23	ICC_TYP			2.20	A	Typical constant current regulation threshold of the device
24	ICC_MAX			2.40	A	Maximum constant current regulation threshold of the device
25	RDSON_100DEG			7.88	Ω	Primary switch on time drain resistance at 100 degC
26	ILIMIT_MIN			0.600	A	Minimum current limit of the primary switch
27	ILIMIT_TYP			0.650	A	Typical current limit of the primary switch
28	ILIMIT_MAX			0.700	A	Maximum current limit of the primary switch
29	VDRAIN_BREAKDOWN			725	V	Device breakdown voltage
30	VDRAIN_ON_PRSW			1.05	V	Primary switch on time drain voltage
31	VDRAIN_OFF_PRSW			503.4	V	Peak drain voltage on the primary switch during turn-off
35	**WORST CASE ELECTRICAL PARAMETERS**					
36	FSWITCHING_MAX	69000		69000	Hz	Maximum switching frequency at full load and valley of the rectified minimum AC input voltage
37	VOR	60.0		60.0	V	Secondary voltage reflected to the primary when the primary switch turns off
38	VMIN			83.62	V	Valley of the minimum input AC voltage at full load
39	KP			0.88		Measure of continuous/discontinuous mode of operation
40	MODE_OPERATION			CCM		Mode of operation
41	DUTYCYCLE			0.421		Primary switch duty cycle
42	TIME_ON			8.32	us	Primary switch on-time
43	TIME_OFF			8.39	us	Primary switch off-time
44	LPRIMARY_MIN			979.2	uH	Minimum primary inductance
45	LPRIMARY_TYP			1030.7	uH	Typical primary inductance
46	LPRIMARY_TOL			5.0	%	Primary inductance tolerance
47	LPRIMARY_MAX			1082.3	uH	Maximum primary inductance
49	**PRIMARY CURRENT**					

50	IPEAK_PRIMARY			0.644	A	Primary switch peak current
51	IPEDESTAL_PRIMARY			0.067	A	Primary switch current pedestal
52	IAVG_PRIMARY			0.134	A	Primary switch average current
53	IRIPPLE_PRIMARY			0.644	A	Primary switch ripple current
54	IRMS_PRIMARY			0.239	A	Primary switch RMS current
56	**SECONDARY CURRENT**					
57	IPEAK_SECONDARY			7.635	A	Secondary winding peak current
58	IPEDESTAL_SECONDARY			0.789	A	Secondary winding current pedestal
59	IRMS_SECONDARY			3.330	A	Secondary winding RMS current
63	**TRANSFORMER CONSTRUCTION PARAMETERS**					
64	**CORE SELECTION**					
65	CORE	CUSTOM		CUSTOM		Core selection. Refer to the 'Transformer Construction' tab to see the detailed report
66	CORE CODE	EFD1816		EFD1816		Core code
67	AE	27.37		27.37	mm^2	Core cross sectional area
68	LE	39.35		39.35	mm	Core magnetic path length
69	AL	2000		2000	nH/turns^2	Ungapped core effective inductance
70	VE	1077.3		1077.3	mm^3	Core volume
71	BOBBIN	EFD1816		EFD1816		Bobbin
72	AW	22.80		22.80	mm^2	Window area of the bobbin
73	BW	9.50		9.50	mm	Bobbin width
74	MARGIN			0.0	mm	Safety margin width (Half the primary to secondary creepage distance)
76	**PRIMARY WINDING**					
77	NPRIMARY			83		Primary turns
78	BPEAK			3413	Gauss	Peak flux density
79	BMAX			3024	Gauss	Maximum flux density
80	BAC			1512	Gauss	AC flux density (0.5 x Peak to Peak)
81	ALG			150	nH/turns^2	Typical gapped core effective inductance
82	LG			0.213	mm	Core gap length
84	**SECONDARY WINDING**					
85	NSECONDARY			7		Secondary turns
87	**BIAS WINDING**					
88	NBIAS			18		Bias turns
92	**PRIMARY COMPONENTS SELECTION**					
93	BIAS DIODE					
94	VBIAS			12.0	V	Rectified bias voltage
95	VF_BIAS			0.70	V	Bias winding diode forward drop
96	VREVERSE_BIASDIODE			92.97	V	Bias diode reverse voltage (not accounting parasitic voltage ring)
97	CBIAS			22	uF	Bias winding rectification capacitor
98	CBPP			4.70	uF	BPP pin capacitor
102	**SECONDARY COMPONENTS SELECTION**					
103	RFWD			47	Ω	Forward pin resistor
104	CBPS			2.2	uF	BPS pin capacitor
108	**MULTIPLE OUTPUT PARAMETERS**					
109	OUTPUT 1					
111	VOUT1			5.00	V	Output 1 voltage
112	IOUT1			2.00	A	Output 1 current
113	POUT1			10.00	W	Output 1 power
114	IRMS_SECONDARY1			3.330	A	Root mean squared value of the secondary current for output 1
115	IRIPPLE_CAP_OUTPUT1			2.662	A	Current ripple on the secondary waveform for output 1
116	NSECONDARY1			7		Number of turns for output 1
117	VREVERSE_RECTIFIER1			36.49	V	SRFET reverse voltage (not accounting parasitic voltage ring) for output 1
118	SRFET1	Si7478DP		Si7478DP		Secondary rectifier (Logic MOSFET) for output 1
119	VF_SRFET1			0.018	V	SRFET on-time drain voltage for output 1
120	VBREAKDOWN_SRFET1			60	V	SRFET breakdown voltage for output 1

148	PO_TOTAL			10.00	W	Total power of all outputs
149	NEGATIVE OUTPUT			N/A		If negative output exists, enter the output number; e.g. If VO2 is negative output, select 2

9 Performance Data

9.1 *Average Efficiency at PCB END*

	DOE 6 Limit (%)	COC5_T2 Limit (%)
Average Efficiency	78.7	79.0
10% Load	---	69.73

9.1.1 115 VAC Input

	Input		Input Measurement			Output Measurement			Efficiency (%)	Average Efficiency (%)
% Load	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)		
100	115	60	115.2	186.0	11.5	4.91	1997.6	9.8	85.7	**86.7**
50	115	60	115.2	145.6	8.6	4.96	1498.1	7.4	86.8	
75	115	60	115.2	107.4	5.7	5.00	997.4	5.0	86.8	
25	115	60	115.2	58.7	2.9	5.02	498.4	2.5	87.3	
10	115	60	115.2	24.3	1.2	5.00	198.7	1.0	85.9	---

9.1.2 230 VAC Input

	Input		Input Measurement			Output Measurement			Efficiency (%)	Average Efficiency (%)
% Load	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)		
100	230	50	230.2	118.9	11.5	4.94	1997.6	9.9	85.5	**85.4**
50	230	50	230.2	95.2	8.7	4.99	1498.1	7.5	85.7	
75	230	50	230.3	68.9	5.8	5.01	997.4	5.0	85.9	
25	230	50	230.3	39.3	3.0	5.02	498.4	2.5	84.6	
10	230	50	230.3	18.9	1.2	5.00	198.7	1.0	80.4	---

9.2 ***Full Load Efficiency vs. Line***

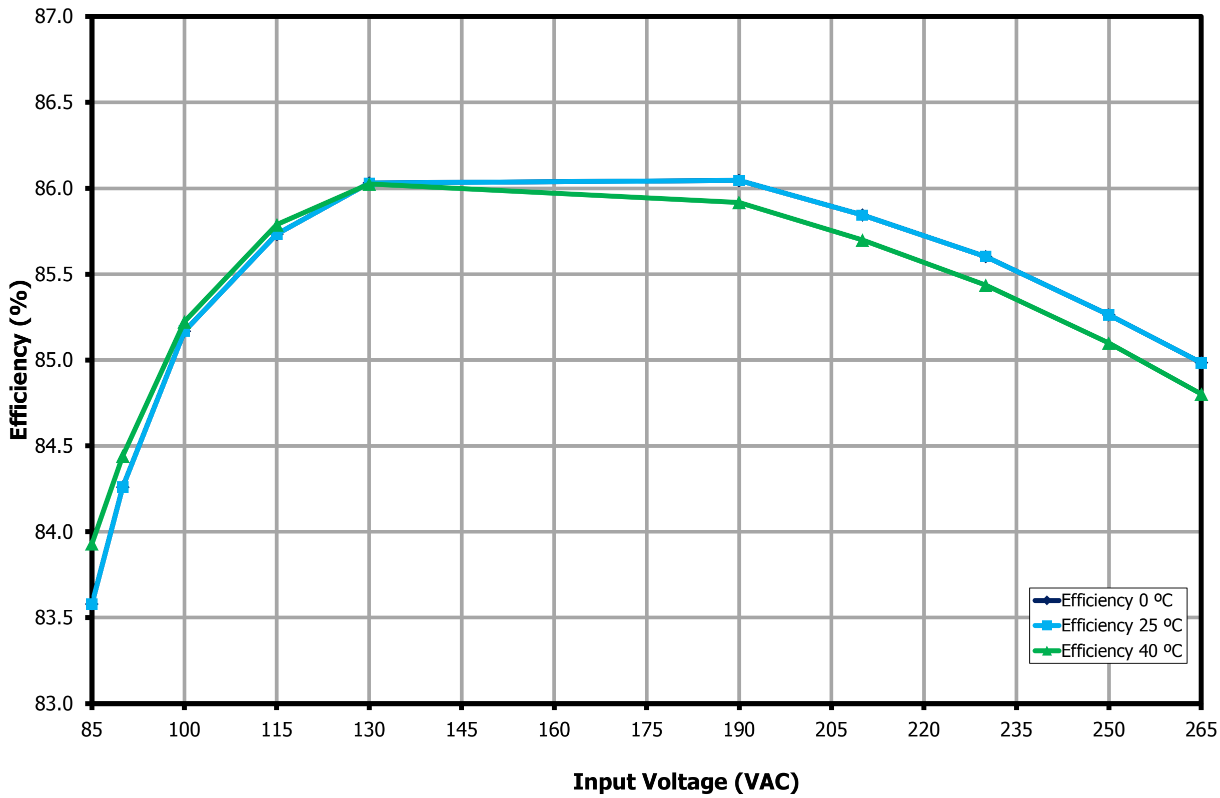


Figure 8 – Full load Efficiency vs. Input Line Voltage.

9.3 *Efficiency vs. Load*

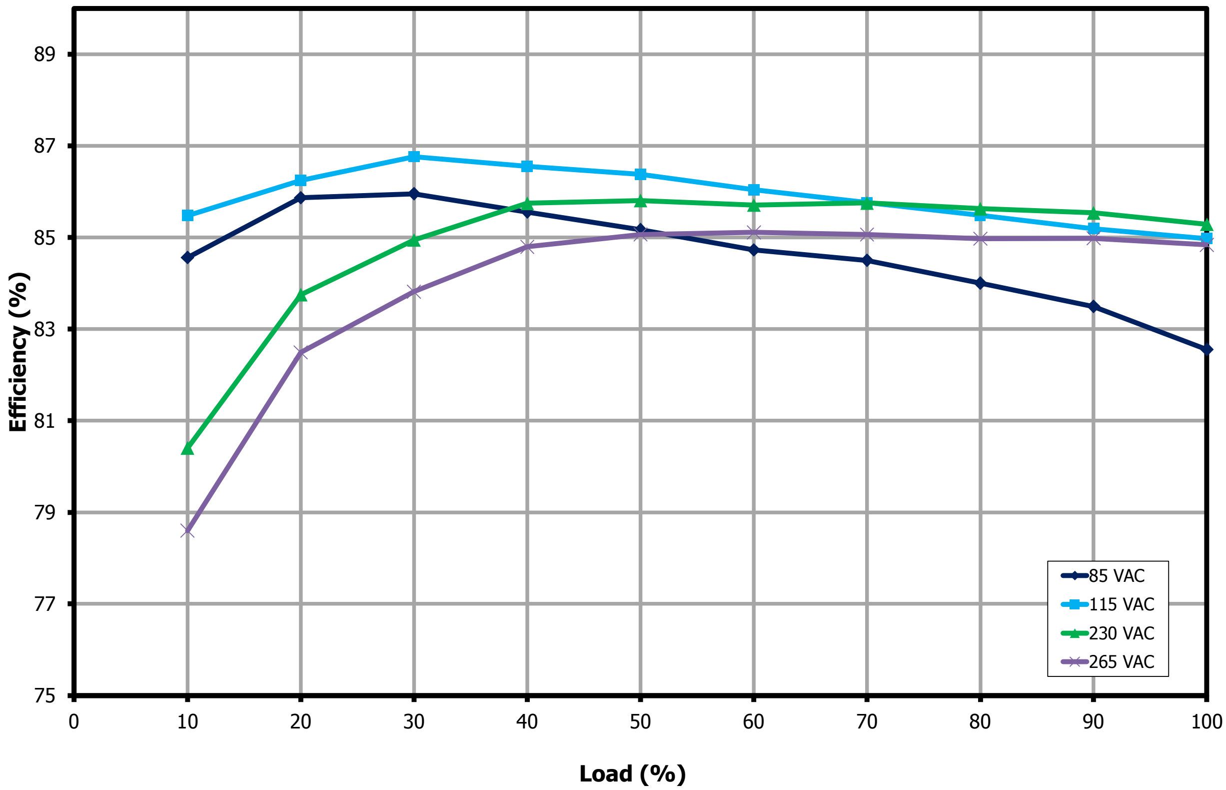


Figure 9 – Efficiency vs. Load, 0 ºC Ambient Temperature.

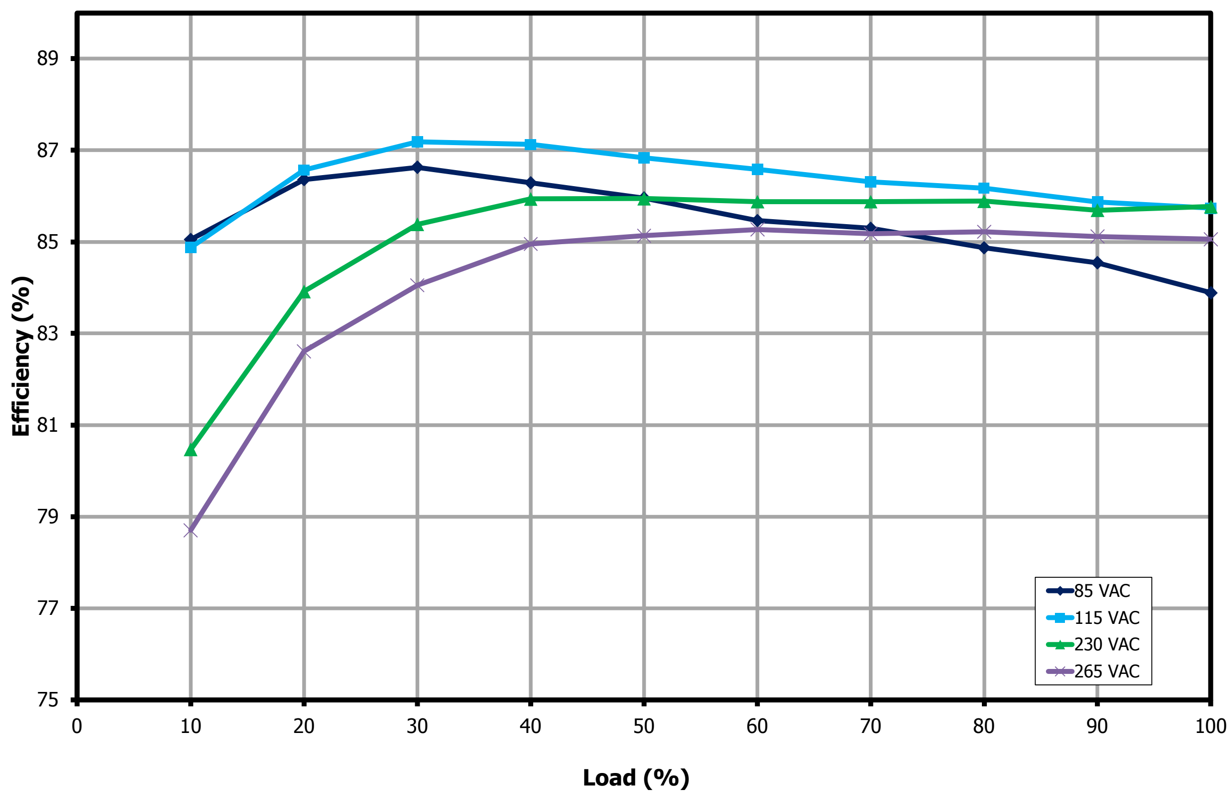


Figure 10 – Efficiency vs. Load, 25 ºC Ambient Temperature.

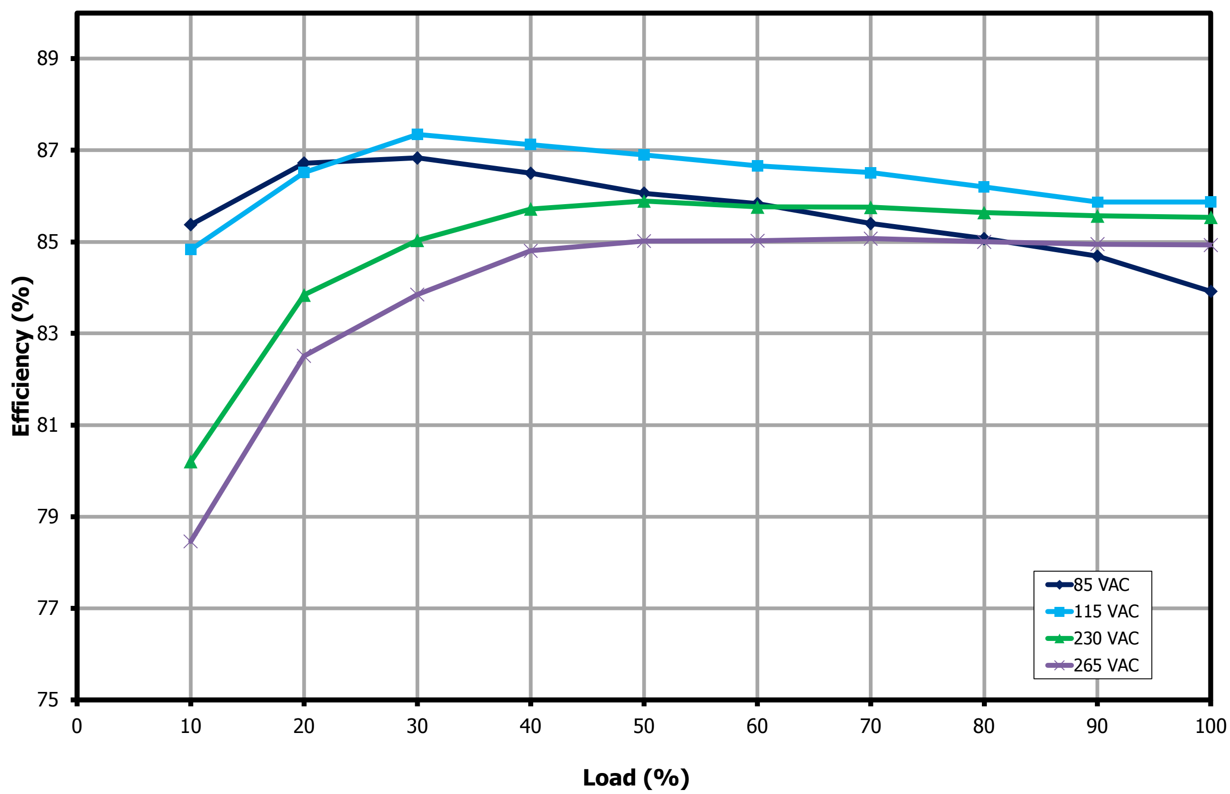


Figure 11 – Efficiency vs. Load, 40 ºC Ambient Temperature.

9.4 ***No-Load Input Power***

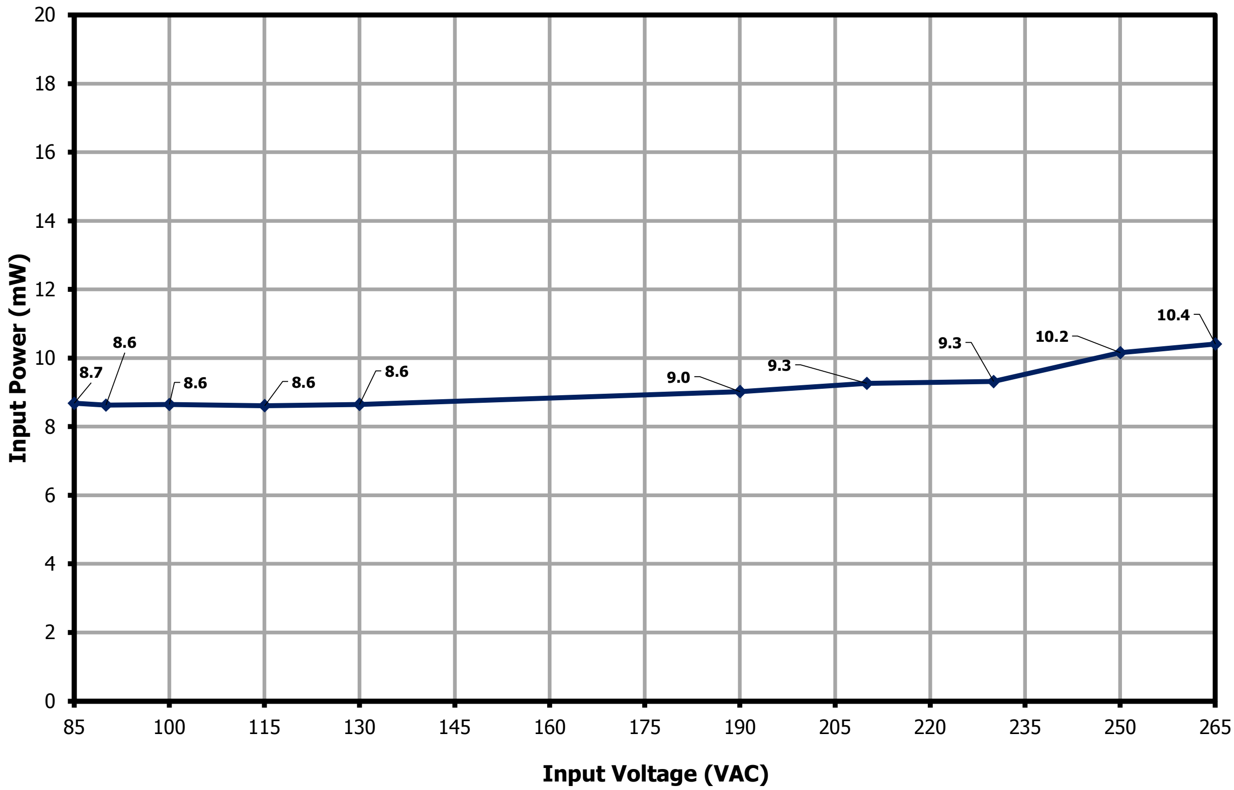


Figure 12 – No-Load Input Power vs. Input Line Voltage, 25 ºC Ambient Temperature**.**

9.5 ***Line and Load Regulation***

9.5.1 Line Regulation (Full load)

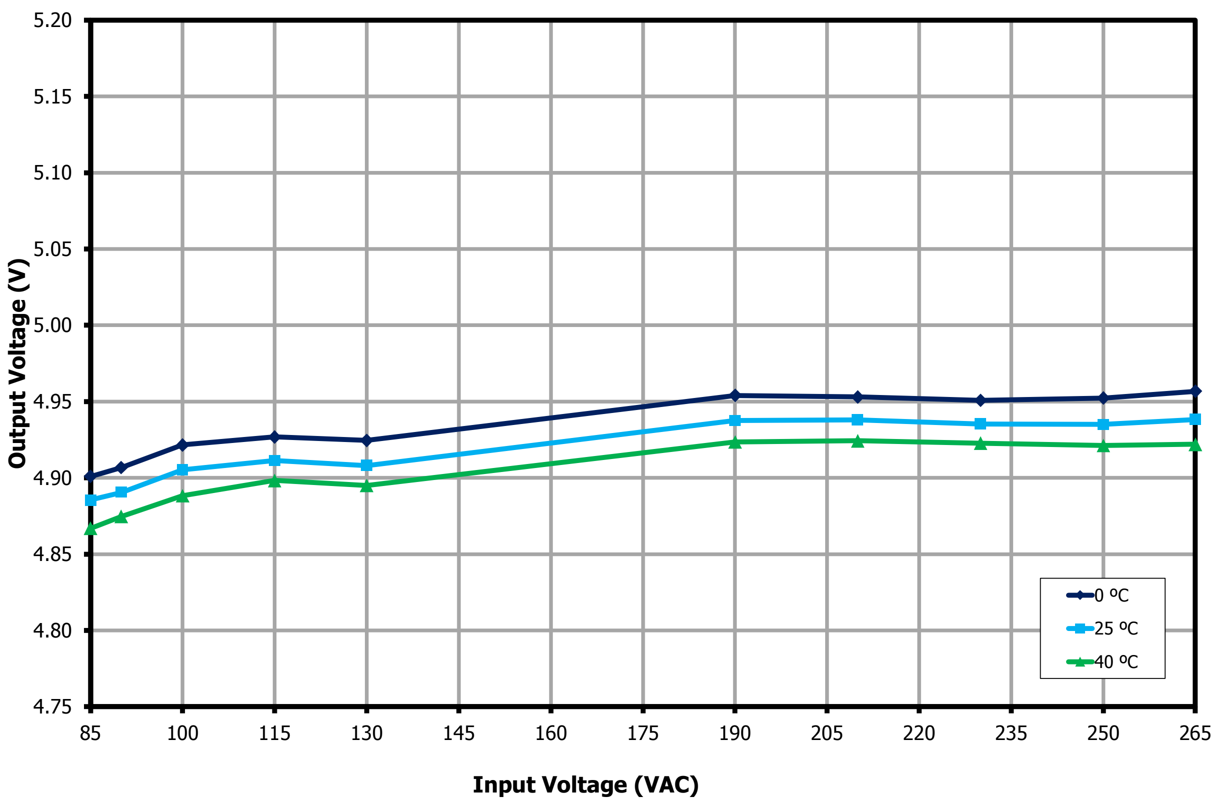


Figure 13 – Output Voltage vs. Input Line Voltage.

9.5.2 Load Regulation

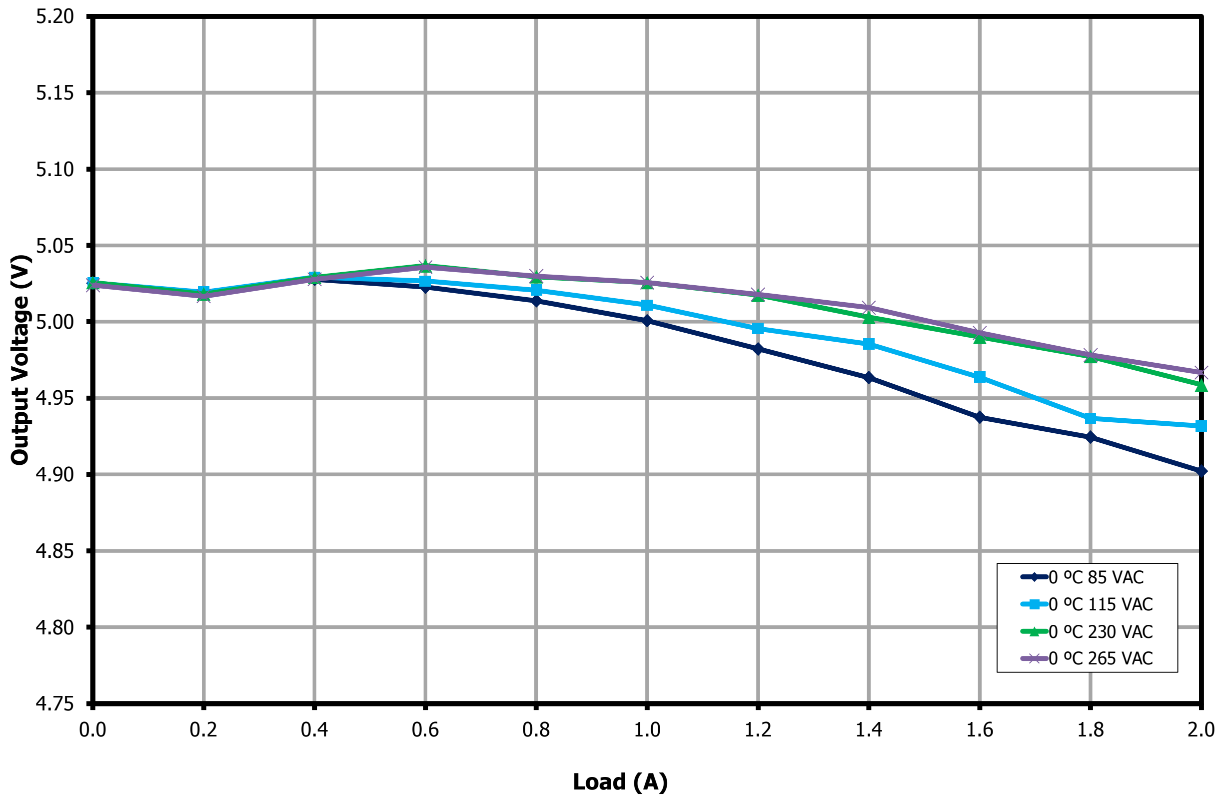


Figure 14 – Output Voltage vs. Load, 0 ºC Ambient Temperature.

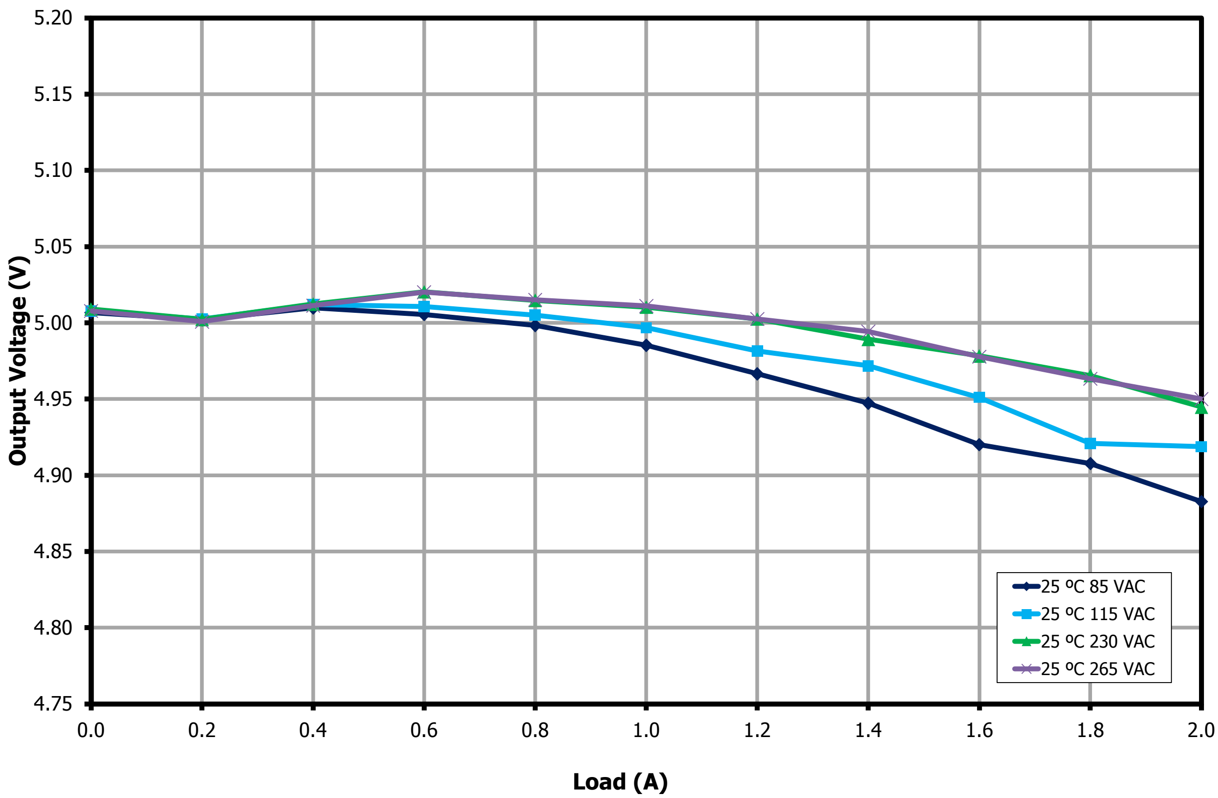


Figure 15 – Output Voltage vs. Load, 25 ºC Ambient Temperature.

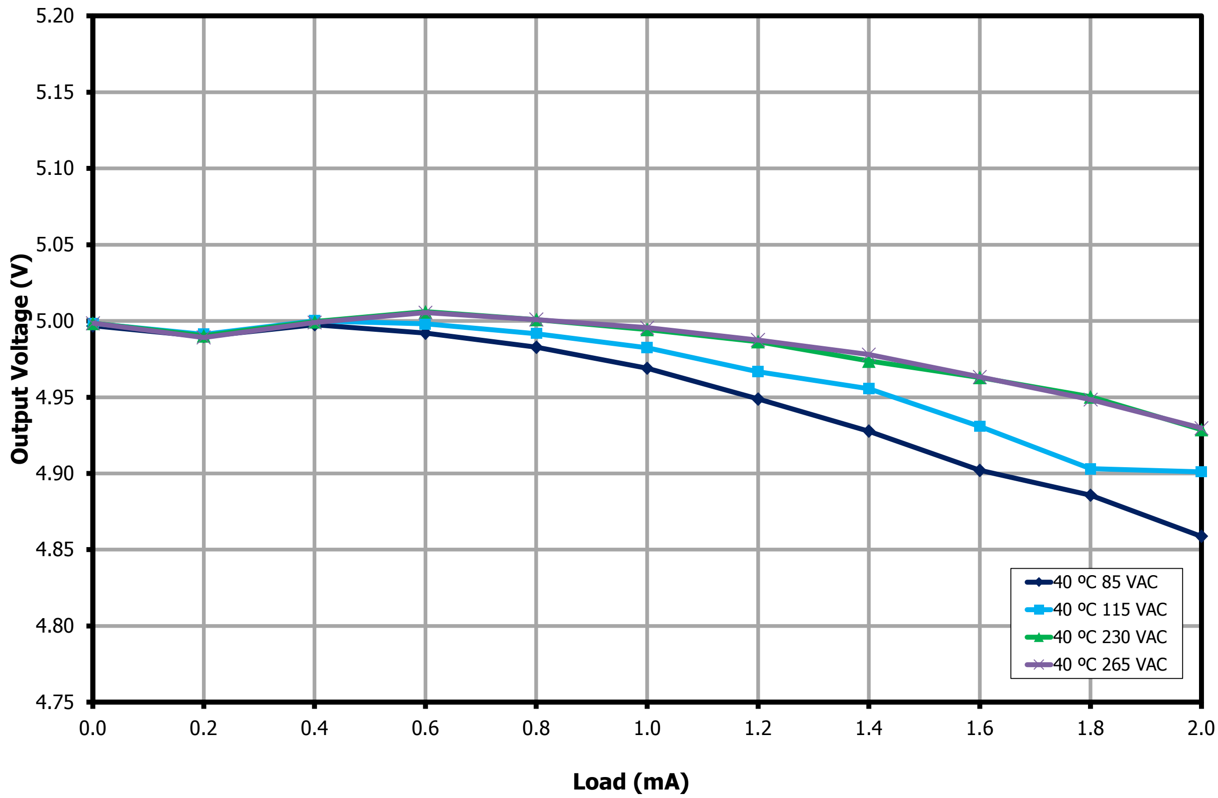


Figure 16 – Output Voltage vs. Load, 40 ºC Ambient Temperature.

9.6 *Output Voltage Ripple*

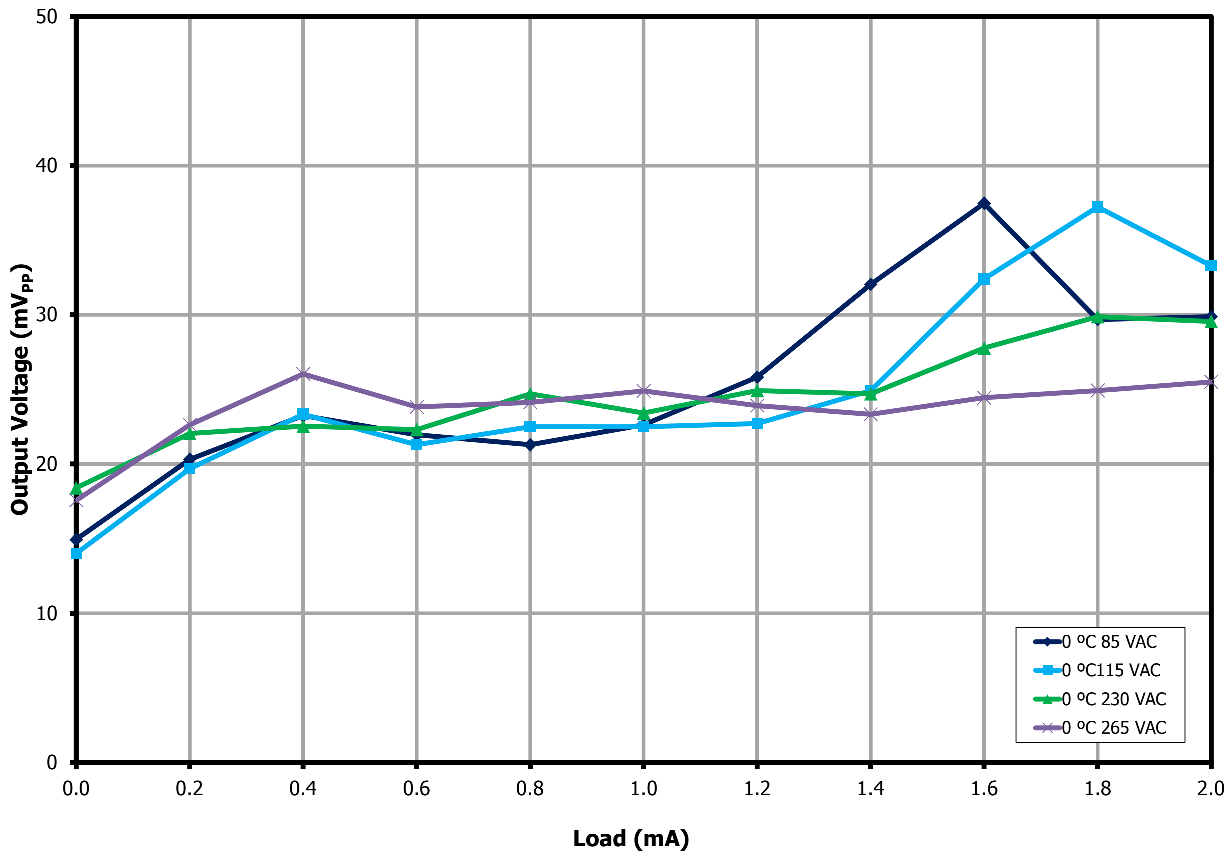


Figure 17 – Output Voltage vs. Load, 0°C Ambient Temperature.

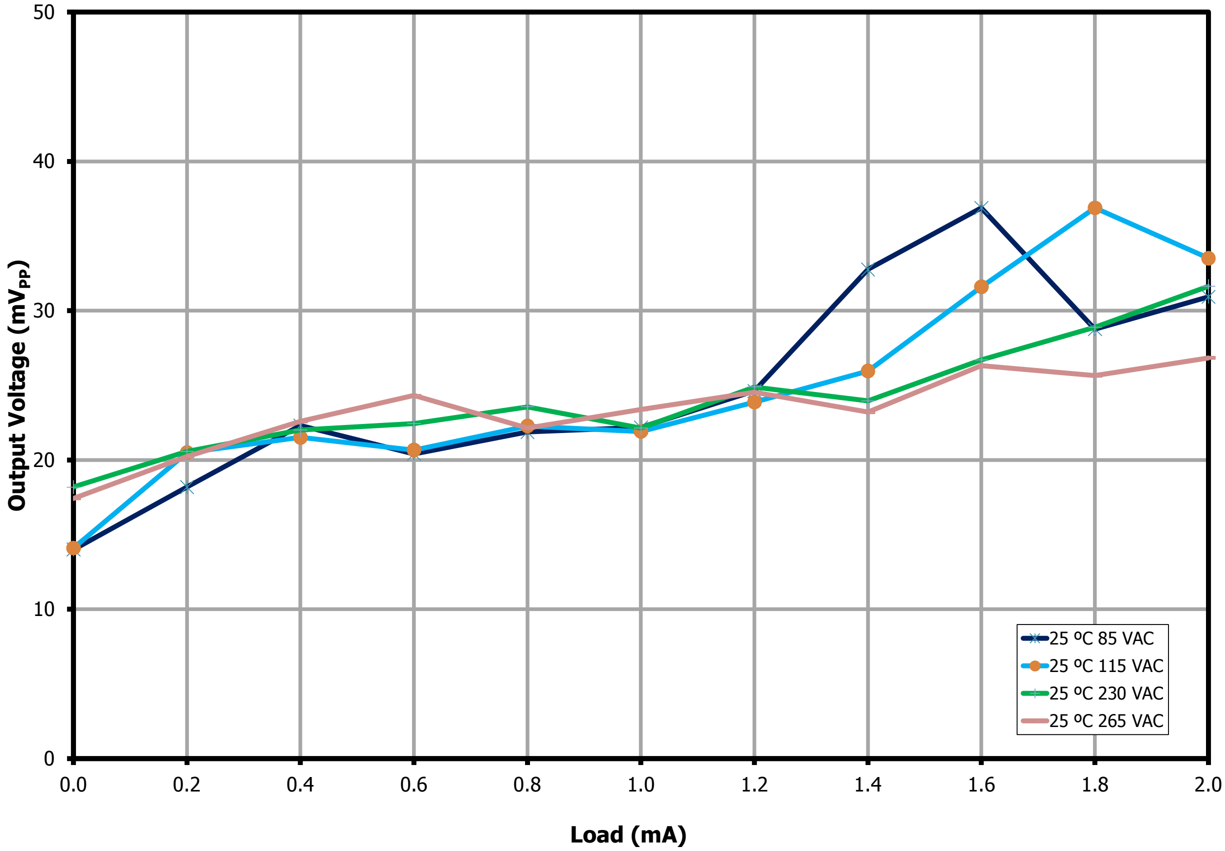


Figure 18 – Output Voltage vs. Load, 25 ºC Ambient Temperature.

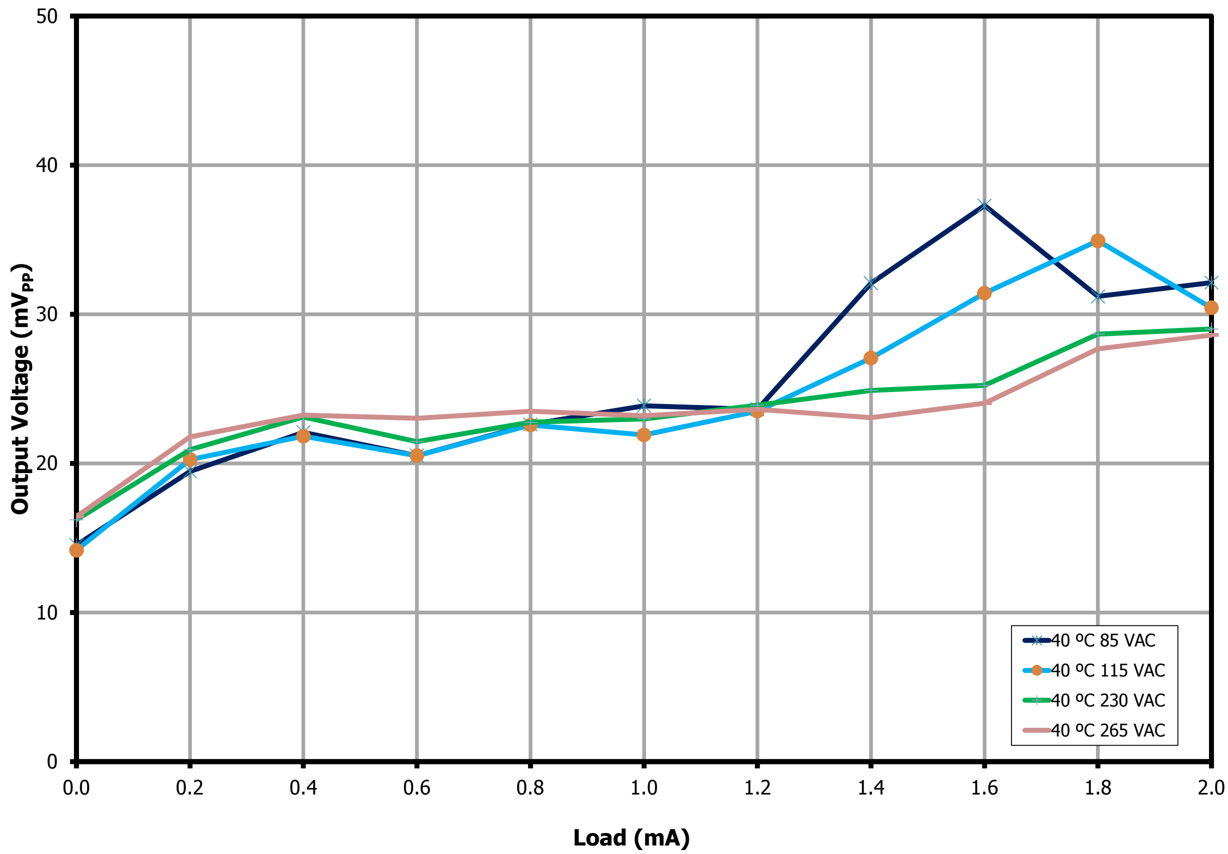


Figure 19 – Output Voltage vs. Load, 40 ºC Ambient Temperature.

10 Thermal Performance

10.1 *IR Camera Reading at 25 ºC Ambient Temperature*

10.1.1 Input: 85 VAC; Output: 5 V / 2 A

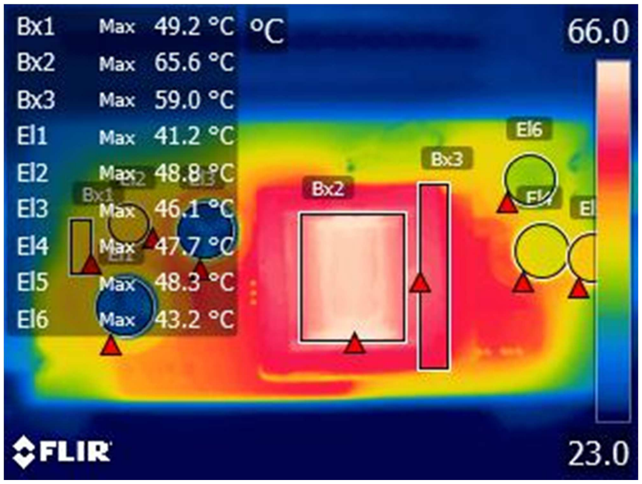


Figure 20 – Component Side.

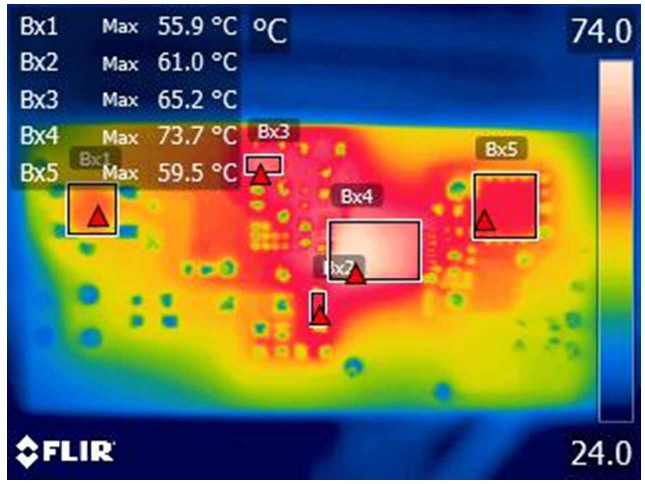


Figure 21 – Solder Side.

	Reference	ºC
Ambient		24.3
Thermistor	RT1	49.2
Transformer Wire	T1	65.6
Transformer Core	T1	59.0
Input Capacitor	C1	41.2
Input Inductor	L1	48.8
Input Capacitor	C2	46.1
Output Capacitor	C8	47.7
Output Inductor	L3	48.3
Output Capacitor	C11	43.2

	Reference	ºC
Ambient		24.9
Bridge Diode	BR1	55.9
Primary Snubber Diode	D1	61.0
Bias Diode	D2	65.2
InnoSwitch3-TN	U1	73.7
SRFET	Q1	59.5

10.1.2 Input: 265 VAC; Output: 5 V / 2 A

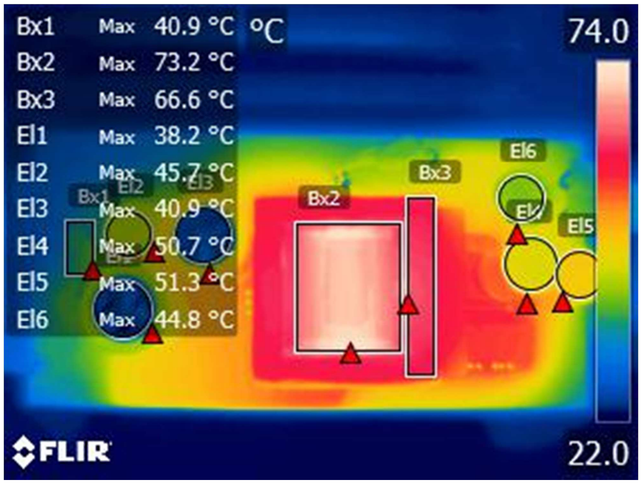


Figure 22 – Component Side.

a

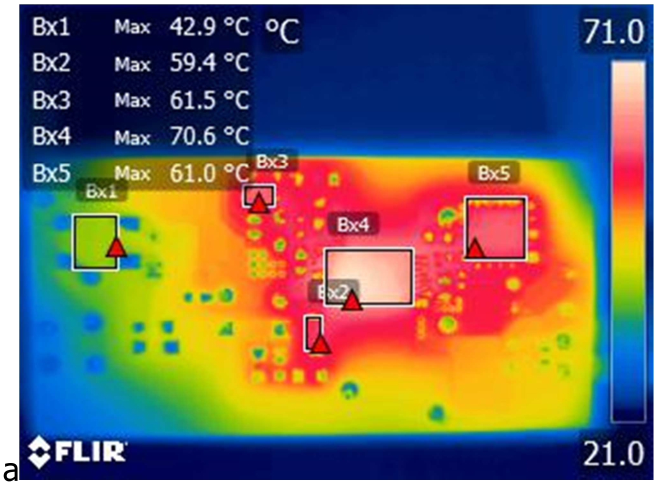


Figure 23 – Solder Side.

	Reference	ºC
Ambient		23.9
Thermistor	RT1	40.9
Transformer Wire	T1	73.2
Transformer Core	T1	66.6
Input Capacitor	C1	38.2
Input Inductor	L1	45.7
Input Capacitor	C2	40.9
Output Capacitor	C8	50.7
Output Inductor	L3	51.3
Output Capacitor	C11	44.8

	Reference	ºC
Ambient		23.9
Bridge Diode	BR1	42.9
Primary Snubber Diode	D1	59.4
Bias Diode	D2	61.5
InnoSwitch3-TN	U1	70.6
SRFET	Q1	61.0

10.2 *Thermocouple Reading at 40 ºC Ambient Temperature*

	Reference	Thermals at 85 VAC Input (ºC)	Thermals at 265 VAC Input (ºC)
Ambient		40.1	39.9
InnoSwitch3-TN	U1	76.5	79.9
SRFET	Q1	67.6	70.8
Bridge Diode	BR1	61.4	53.5
Fuse	F1	49.8	46.6
Thermistor	RT1	57.5	52.6
Input Capacitor	C1	58.8	54.8
Input Inductor	L1	58.8	56.3
Input Capacitor	C2	63.4	62.4
Transformer Wire	T1	71.5	76.8
Transformer Core	T1	68.6	73.4
Y Capacitor	C4	58.5	60.1
Output Capacitor	C8	64.2	67.1
Output Inductor	L3	62.0	63.8
Output Capacitor	C11	62.6	65.5

11 Waveforms

11.1 *Load Transient Response*

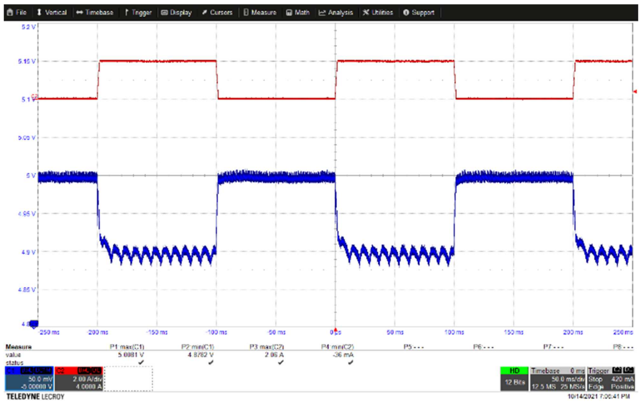


Figure 24 – Input: 85 VAC, Output Load: 0 A – 2 A @ 100 ms Duration,
1 ms / µs Slew Rate.
CH1, V_{OUT}, 50 mV / div., 50 ms / div., -5 V Offset.
CH2, I_{OUT}, 2 A / div., 50 ms / div.
V_{OUT} (Max.): 5.0081 V.
V_{OUT} (Min.): 4.8782 V.

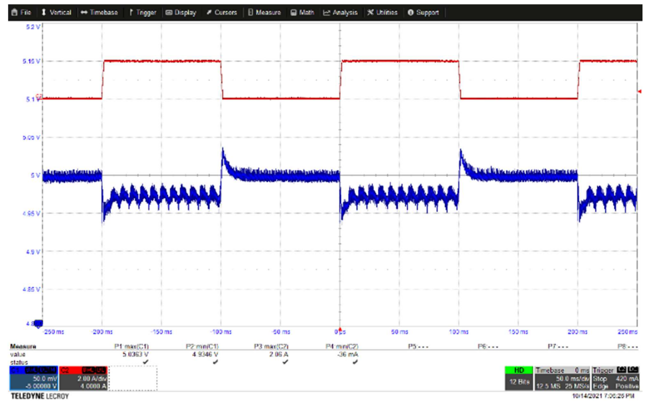


Figure 25 – Input: 115 VAC, Output Load: 0 A – 2 A @ 100 ms Duration,
1 ms / µs Slew Rate.
CH1, V_{OUT}, 50 mV / div., 50 ms / div., -5 V Offset.
CH2, I_{OUT}, 2 A / div., 50 ms / div.
V_{OUT} (Max.): 5.0363 V.
V_{OUT} (Min.): 4.9346 V.

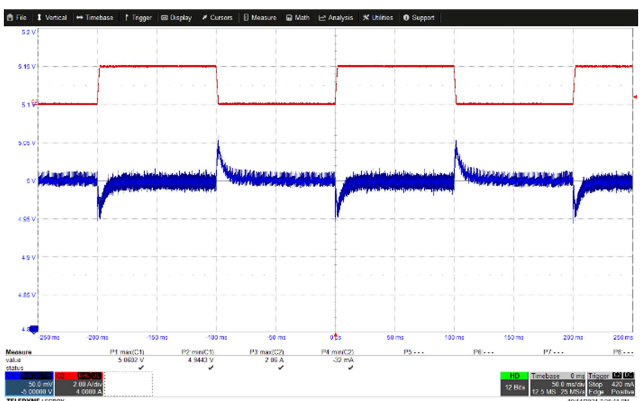


Figure 26 – Input: 230 VAC, Output Load: 0 A – 2 A @ 100 ms Duration,
1 ms / µs Slew Rate.
CH1, V_{OUT}, 50 mV / div., 50 ms / div., -5 V Offset.
CH2, I_{OUT}, 2 A / div., 50 ms / div.
V_{OUT} (Max.): 5.0602 V.
V_{OUT} (Min.): 4.9443 V.

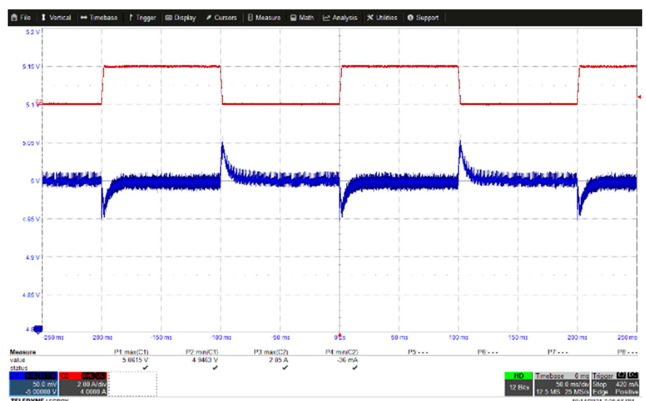


Figure 27 – Input: 265 VAC, Output Load: 0 A – 2 A @ 100 ms Duration,
1 ms / µs Slew Rate.
CH1, V_{OUT}, 50 mV / div., 50 ms / div., -5 V Offset.
CH2, I_{OUT}, 2 A / div., 50 ms / div.
V_{OUT} (Max.): 5.0615 V.
V_{OUT} (Min.): 4.9463 V.

11.2 ***InnoSwitch3-TN Drain to Source Voltage Waveforms***

11.2.1 Steady-State Waveforms

Figure 28 – Input (Min.): 85 VAC, Load: 2 A
CH1, V_{DS}, 100 V / div., 10 µs / div.
V_{DS} (Max.): 242 V.
Derating: 33.38 %.

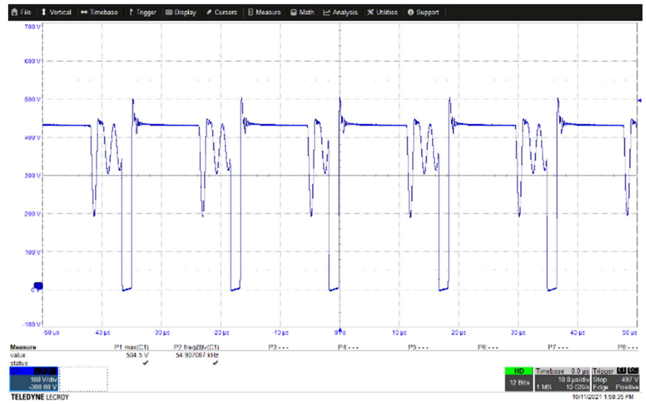


Figure 29 – Input (Max.): 265 VAC, Load: 2 A
CH1, V_{DS}, 100 V / div., 10 µs / div.
V_{DS} (Max.): 504.5 V.
Derating: 69.59 %.

11.2.2 Start-Up Waveforms

Figure 30 – Input (Min.): 85 VAC, Load: 2 A
CH1, V_{DS}, 100 V / div., 5 ms / div.
V_{DS} (Max.): 241 V.
Derating: 33.24 %.

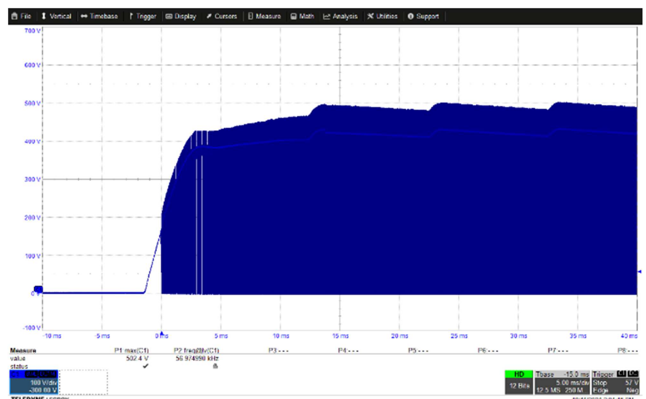


Figure 31 – Input (Max.): 265 VAC, Load: 2 A
CH1, V_{DS}, 100 V / div., 5 ms / div.
V_{DS} (Max.): 502.4 V.
Derating: 69.3 %.

11.2.3 Waveforms with Output Shorted

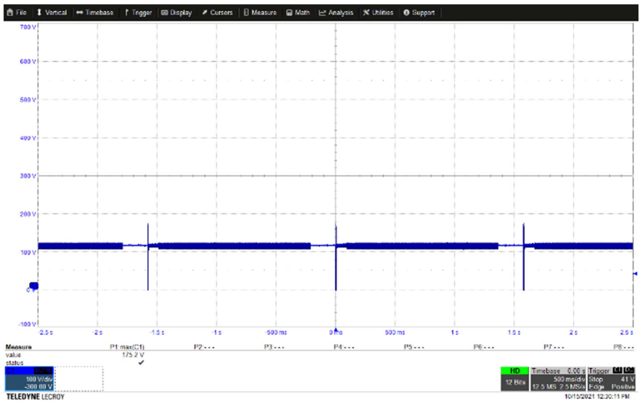


Figure 32 – Input (Min.):85 VAC, Output: Shorted.
CH1, V_{DS}, 100 V / div., 500 ms / div.
V_{DS} (Max.): 175.2 V.
Derating: 24.17 %.

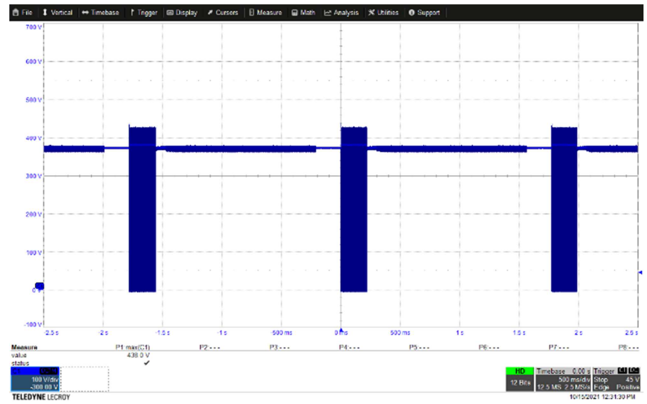


Figure 33 – Input (Max.): 265 VAC, Output: Shorted.
CH1, V_{DS}, 100 V / div., 500 ms / div.
V_{DS} (Max.): 438 V.
Derating: 60.41 %.

11.3 *SRFET Drain to Source Voltage Waveforms*

11.3.1 Steady-State Waveforms

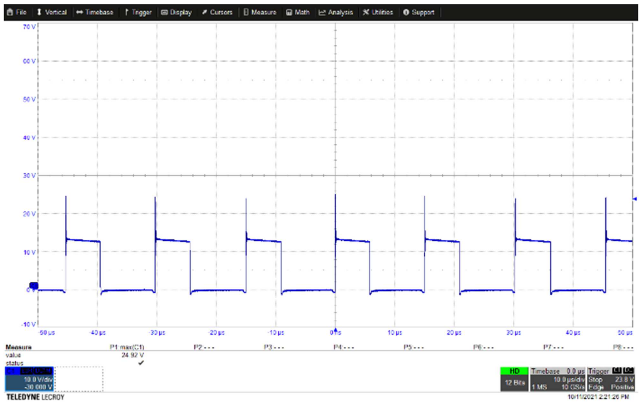


Figure 34 – Input (Min.): 85 VAC, Load: 2 A.
CH1, V_{DS}, 10 V / div., 10 µs / div.
V_{DS} (Max.): 24.92 V.
Derating: 41.53 %.

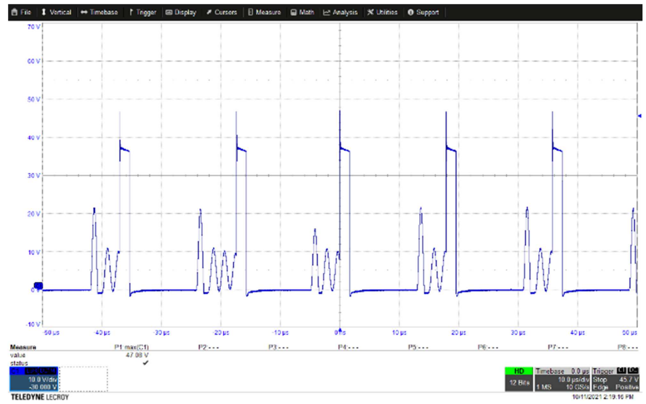


Figure 35 – Input (Max.): 265 VAC, Load: 2 A.
CH1, V_{DS}, 10 V / div., 10 µs / div.
V_{DS} (Max.): 47.08 V.
Derating: 78.45 %.

11.3.2 Start-Up Waveforms

Figure 36 – Input (Min.): 85 VAC, Load: 2 A.
CH1, V_{DS}, 10 V / div., 5 ms / div.
V_{DS} (Max.): 25.66 V.
Derating: 42.77 %.

Figure 37 – Input (Max.): 265 VAC, Load: 2 A.
CH1, V_{DS}, 10 V / div., 5 ms / div.
V_{DS} (Max.): 47.08 V.
Derating: 78.47 %.

11.3.3 Waveforms with Output Shorted

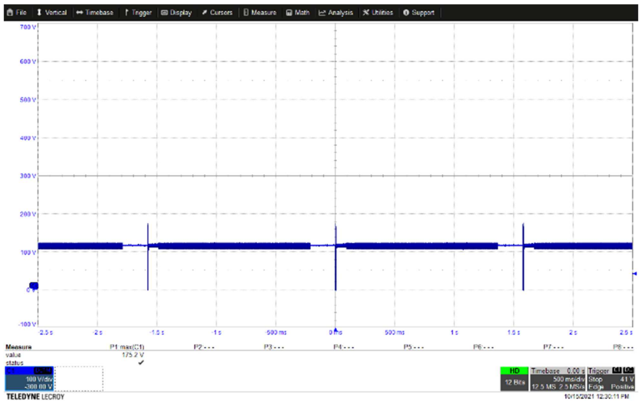


Figure 38 – Input (Min.):85 VAC, Output:Shorted.
CH1, V_{DS}, 10 V / div., 500 ms / div.
V_{DS} (Max.): 20.72 V.
Derating: 34.53 %.

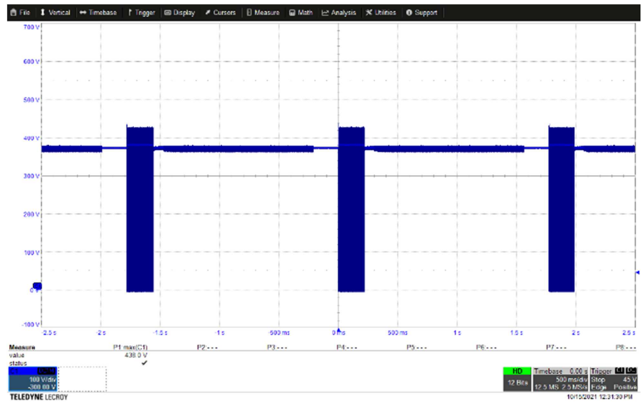


Figure 39 – Input (Max.): 265 VAC, Output:Shorted.
CH1, V_{DS}, 10 V / div., 500 ms / div.
V_{DS} (Max.): 50.96 V.
Derating: 84.93 %.

11.4 ***Over Voltage Protection***

11.4.1 Full Load Condition (2 A)

Figure 40 – Input (Min.): 85 VAC, Load: 2 A.
CH1, V_{OUT}, 1 V / div., 1 ms / div.
V_{OUT} (Max.): 5.584 V.

Figure 41 – Input (Max.): 265 VAC, Load: 2 A.
CH1, V_{OUT}, 1 V / div., 1 ms / div.
V_{OUT} (Max.): 5.622 V.

11.4.2 No-Load Condition (0 A)

Figure 42 – Input (Min.): 85 VAC, Load: 0 A.
CH1, V_{OUT}, 1 V / div., 500 ms / div.
V_{OUT} (Max.): 6.356 V.

Figure 43 – Input (Max.): 265 VAC, Load: 0 A.
CH1, V_{OUT}, 1 V / div., 500 ms / div.
V_{OUT} (Max.): 6.398 V.

12 Conductive EMI

12.1 *115 VAC Input*

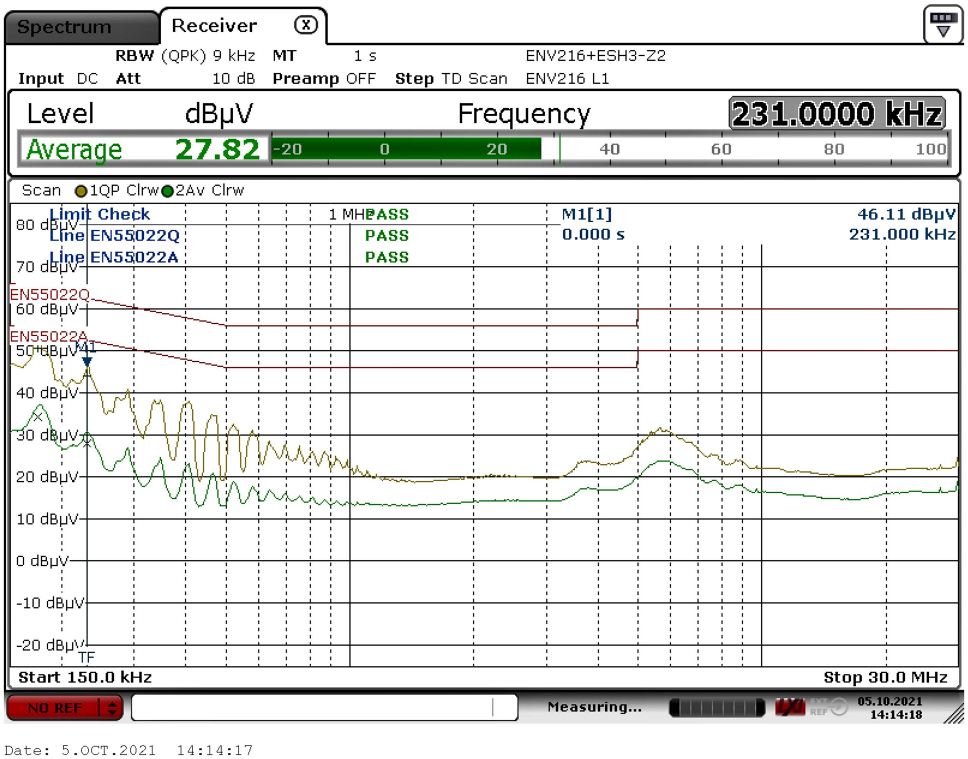
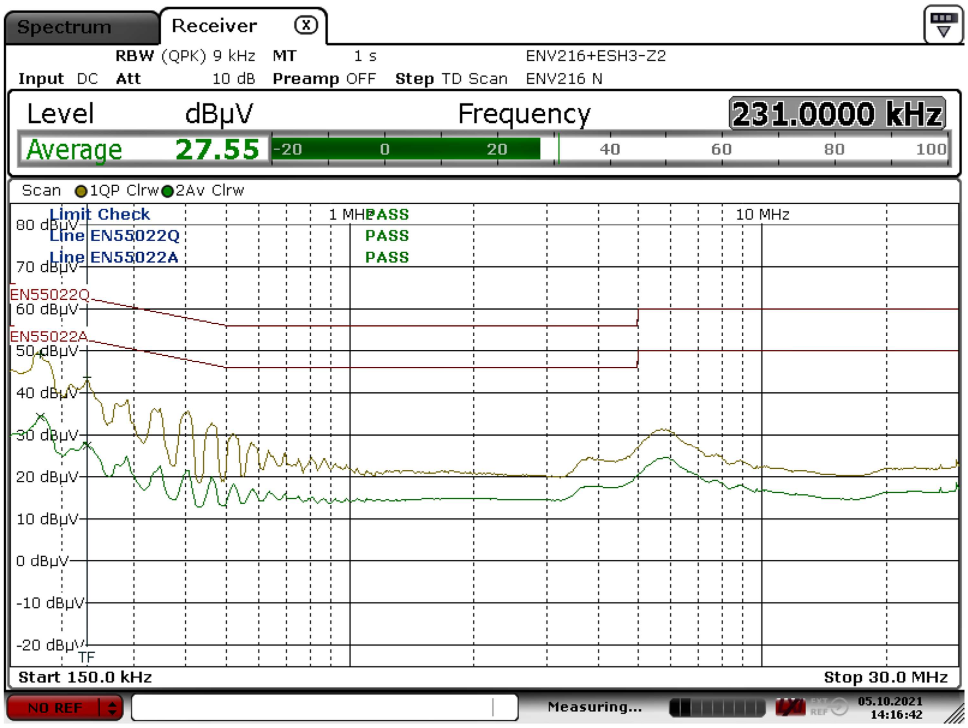


Figure 44 – Line; Ungrounded (Graph).

Trace1: EN55022Q Trace2: EN55022A

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	174.7500 kHz	50.38 L1	-14.35 dB
2 Average	174.7500 kHz	34.17 L1	-20.56 dB
1 Quasi Peak	231.0000 kHz	44.00 L1	-18.41 dB
2 Average	231.0000 kHz	28.06 L1	-24.35 dB

Figure 45 – Line; Ungrounded (Table).



Date: 5.OCT.2021 14:16:41

Figure 46 – Line; Ungrounded (Graph).

Trace1: EN55022Q Trace2: EN55022A

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	177.0000 kHz	48.97 N	-15.66 dB
2 Average	177.0000 kHz	34.34 N	-20.29 dB
1 Quasi Peak	231.0000 kHz	43.55 N	-18.86 dB
2 Average	231.0000 kHz	27.55 N	-24.86 dB

Figure 47 – Line; Ungrounded (Table).

12.2 ***230 VAC Input***

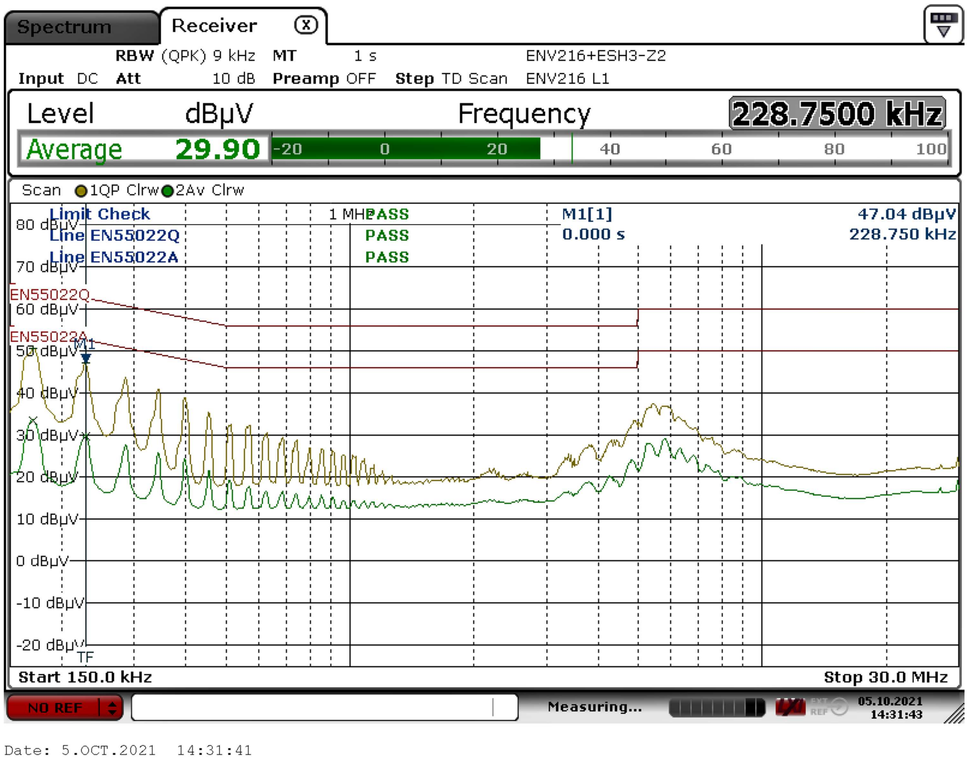
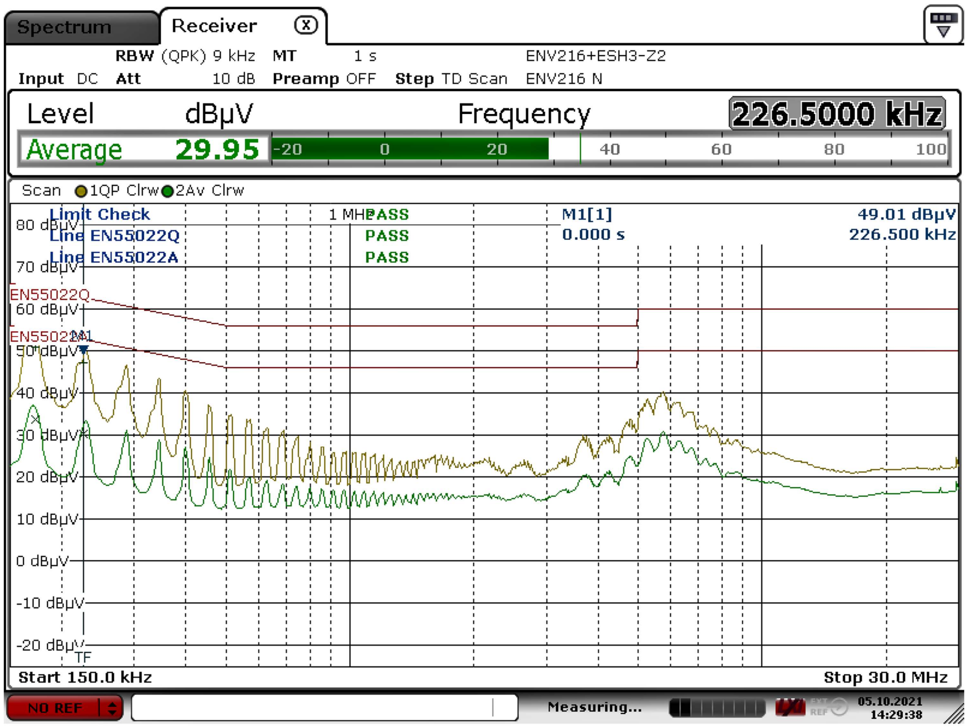


Figure 48 – Line; Ungrounded (Graph).

Trace1: EN55022Q Trace2: EN55022A

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	170.2500 kHz	50.47 L1	-14.48 dB
2 Average	170.2500 kHz	33.35 L1	-21.60 dB
1 Quasi Peak	228.7500 kHz	47.18 L1	-15.31 dB
2 Average	228.7500 kHz	29.82 L1	-22.67 dB

Figure 49 – Line; Ungrounded (Table).



Date: 5.OCT.2021 14:29:37

Figure 50 – Line; Ungrounded (Graph).

Trace1: EN55022Q Trace2: EN55022A

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Quasi Peak	172.5000 kHz	50.92 N	-13.92 dB
2 Average	172.5000 kHz	33.59 N	-21.25 dB
1 Quasi Peak	226.5000 kHz	47.09 N	-15.49 dB
2 Average	226.5000 kHz	30.27 N	-22.31 dB

Figure 51 – Line; Ungrounded (Table).

13 Surge Test

13.1 *Differential Surge Test*

Surge Voltage (kV)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number of Strikes	Test Result
1	0	L, N	2	10	PASS (No AR)
-1	0	L, N	2	10	PASS (No AR)
1	90	L, N	2	10	PASS (No AR)
-1	90	L, N	2	10	PASS (No AR)
1	180	L, N	2	10	PASS (No AR)
-1	180	L, N	2	10	PASS (No AR)
1	270	L, N	2	10	PASS (No AR)
-1	270	L, N	2	10	PASS (No AR)

Note: AR means auto-restart

13.2 *RingWave Test*

Ring Wave Voltage (kV)	Phase Angle (°)	IEC Coupling	Generator Impedance (Ω)	Number of Strikes	Test Result
+ 4	0	L, N-PE	12	10	PASS (2/10 AR)
- 4	0	L, N-PE	12	10	PASS (4/10 AR)
+ 4	90	L, N-PE	12	10	PASS (4/10 AR)
- 4	90	L, N-PE	12	10	PASS (0/10 AR)
+ 4	270	L, N-PE	12	10	PASS (3/10 AR)
- 4	270	L, N-PE	12	10	PASS (2/10 AR)
+ 5	0	L, N-PE	12	10	PASS (1/10 AR)
- 5	0	L, N-PE	12	10	PASS (4/10 AR)
+ 5	90	L, N-PE	12	10	PASS (0/10 AR)
- 5	90	L, N-PE	12	10	PASS (3/10 AR)
+ 5	270	L, N-PE	12	10	PASS (0/10 AR)
- 5	270	L, N-PE	12	10	PASS (4/10 AR)
+ 6	0	L, N-PE	12	10	PASS (7/10 AR)
- 6	0	L, N-PE	12	10	PASS (1/10 AR)
+ 6	90	L, N-PE	12	10	PASS (7/10 AR)
- 6	90	L, N-PE	12	10	PASS (5/10 AR)
+ 6	270	L, N-PE	12	10	PASS (5/10 AR)
- 6	270	L, N-PE	12	10	PASS (4/10 AR)

13.3 *EFT / Burst Test*

Ring Wave Voltage (kV)	Phase Angle (°)	T-Burst	T-Burst	T-Rep	Coupling	Result
+ 2	0	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
- 2	0	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
+ 2	0	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)
- 2	0	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)
+ 2	90	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
- 2	90	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
+ 2	90	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)
- 2	90	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)
+ 2	270	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
- 2	270	5 kHz	15 ms	120 s	L, N - PE	Pass (No AR)
+ 2	270	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)
- 2	270	100 kHz	750 µs	120 s	L, N - PE	Pass (No AR)

14 Revision History

Date	Author	Revision	Description & Changes	Reviewed
01-Nov-21	JMR	1.0	Initial Release.	Apps & Mktg

For the latest updates, visit our website: www.power.com

Power Integrations Worldwide Sales Support Locations

WORLD HEADQUARTERS
5245 Hellyer Avenue
San Jose, CA 95138, USA.
Main: +1-408-414-9200
Customer Service:
Worldwide: +1-65-635-64480
Americas: +1-408-414-9621
e-mail: usasales@power.com

CHINA (SHANGHAI)
Rm 2410, Charity Plaza, No. 88,
North Caoxi Road,
Shanghai, PRC 200030
Phone: +86-21-6354-6323
e-mail: chinasales@power.com

CHINA (SHENZHEN)
17/F, Hivac Building, No. 2, Keji
Nan 8th Road, Nanshan District,
Shenzhen, China, 518057
Phone: +86-755-8672-8689
e-mail: chinasales@power.com

GERMANY (AC-DC/LED Sales)
Einsteinring 24
85609 Dornach/Aschheim
Germany
Tel: +49-89-5527-39100
e-mail: eurosales@power.com

GERMANY (Gate Driver Sales)
HellwegForum 1
59469 Ense
Germany
Tel: +49-2938-64-39990
e-mail: igbt-driver.sales@
power.com

INDIA
#1, 14th Main Road
Vasanthanagar
Bangalore-560052
India
Phone: +91-80-4113-8020
e-mail: indiasales@power.com

ITALY
Via Milanese 20, 3rd. Fl.
20099 Sesto San Giovanni (MI) Italy
Phone: +39-024-550-8701
e-mail: eurosales@power.com

JAPAN
Yusen Shin-Yokohama 1-chome Bldg.
1-7-9, Shin-Yokohama, Kohoku-ku
Yokohama-shi,
Kanagawa 222-0033 Japan
Phone: +81-45-471-1021
e-mail: japansales@power.com

KOREA
RM 602, 6FL
Korea City Air Terminal B/D,
159-6
Samsung-Dong, Kangnam-Gu,
Seoul, 135-728 Korea
Phone: +82-2-2016-6610
e-mail: koreasales@power.com

SINGAPORE
51 Newton Road,
#19-01/05 Goldhill Plaza
Singapore, 308900
Phone: +65-6358-2160
e-mail: singaporesales@power.com

TAIWAN
5F, No. 318, Nei Hu Rd.,
Sec. 1
Nei Hu District
Taipei 11493, Taiwan R.O.C.
Phone: +886-2-2659-4570
e-mail: taiwansales@power.com

UK
Building 5, Suite 21
The Westbrook Centre
Milton Road
Cambridge
CB4 1YG
Phone: +44 (0) 7823-557484
e-mail: eurosales@power.com