Dimmable single string LED Driver for 35W indoor lighting applications using HVLED001B

Introduction

The EVAL-SSR01B-35W is intended to drive one LED string with a maximum output current of 700 mA for a maximum power of 35 W. The LED current can be finely adjusted using a PWM signal (for example, provided by a microcontroller) on the SELV portion of the board.

The universal input capability makes this board suitable in worldwide design.

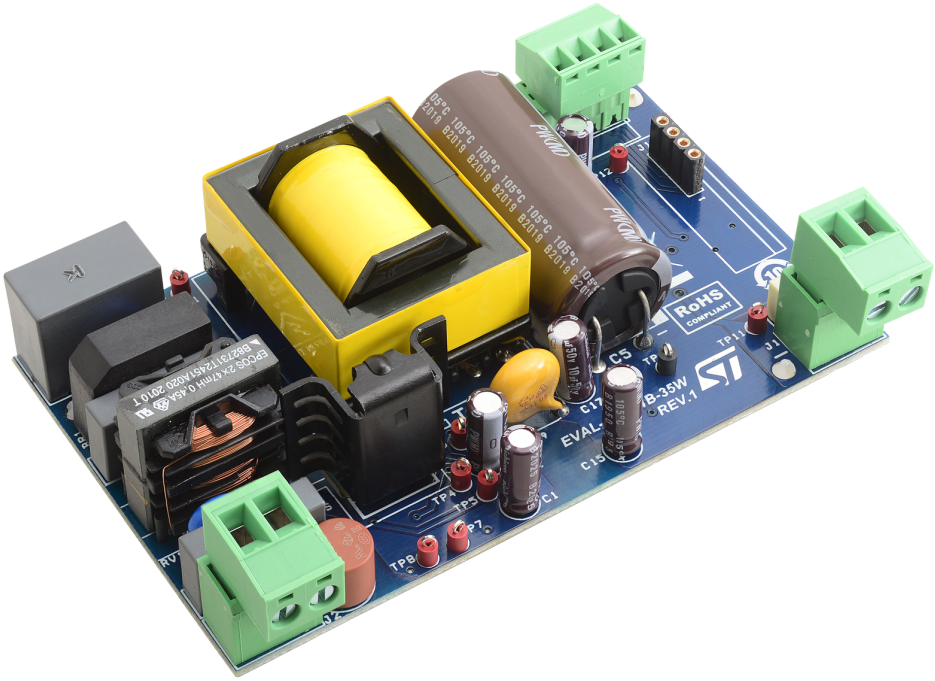
On the secondary side, the board includes a connector to plug a daughterboard that allows managing the LED light with digital control (for example, using a Bluetooth module).

A very high power factor and efficiency are obtained even at light loads. Input voltages are managed by the HVLED001B protections, improving the reliability of the application.

The output capacitor is automatically discharged at turn-off to prevent any harm from contact with the output connector.

Output open circuit and overload protections include auto restart for safe operation in lighting environments.

Figure 1. EVAL-SSR01B-35W evaluation kit (60 x 100 mm)



1 Main characteristics

- Input voltage: VIN: 90 ÷ 265 V_{RMS}, f: 45 ÷ 66 Hz
- Output current: 700 mA (V_{LED} = 24 V_{DC} ÷ 48 V_{DC}), P_{MAX} = 35 W
- Output voltage: 24 V_{DC} ÷ 48 V_{DC}
- Dimming: 100% to 10%
- Dimming interfaces: PWM input
- High power factor, low THD
- PFC / THD:
  - >0.98 / <10% @ 230 VAC, >0.99 / <6% @ 115 VAC @ full load
  - >0.88 / <18% @ 230 VAC, >0.95 / <10% @ 115 VAC @ half load
- Efficiency @ 230 V_{AC}, full load: > 89%
- Average (4 points) efficiency: >88% at 115 VAC and 230 VAC
- No load: better than 250 mW
- Fast VOUT discharge
- Short-circuit protection with auto-restart
- Open load voltage limiting (54.3 V)
- RoHS compliant

Table 1. Description of connector signals

Con	Pin	Signal name	Dir	Description and use
J1	1	LED cathode	Output	Connect to the cathode of the LED string
	2	LED anode	Output	Connect to the anode of the LED string
J2	1	AC mains	Input	First connection to AC mains – Warning, high voltage
	2	AC mains	Input	First connection to AC mains – Warning, high voltage
J12	1	3.3V	Output	Regulated 3.3V with 50mA capability - suitable to supply external board.
	2	PWM input	Input	A PWM signal applied to this terminal sets an output current proportional to signal's duty cycle. The recommended PWM signal amplitude is 3.3V. The recommended PWM signal frequency is 500Hz.
	3	ON/OFF	Input	Set this pin to 3.3V to turn off the LED string. Set to 0V or left open during normal operation
	4	GND	Ground	Secondary side signal reference voltage
J14	1	3.3V	Output	Regulated 3.3V with 50mA capability - suitable to supply external board.
	2	PWM input	Input	A PWM signal applied to this terminal sets an output current proportional to signal's duty cycle. The recommended PWM signal amplitude is 3.3V. The recommended PWM signal frequency is 500Hz.
	3	ON/OFF	Input	Set this pin to 3.3V to turn off the LED string. Set to 0V or left open during normal operation
	4	GND	Ground	Secondary side signal reference voltage

Table 2. Main components

Main components	
HVLED001B	Quasi-resonant flyback controller
STF10LN80K5	N-channel 800V, 0.55Ohm typ., 8A MDmesh K5 Power MOSFET in a TO-220FP package
STTH803G	Ultrafast diode 300V, 8A in a D2PAK package
STTH108A	Ultrafast diode 800V, 1A in an SMA package
STPS1H100A	Power Shottky rectifier diode 100V, 1A in an SMA package
TSM1012	Low consumption voltage and current controller for battery chargers and adaptors in an SO-8 package
TSX561ILT	Micropower, wide bandwidth (900kHz), 16V CMOS operational amplifiers in an SOT23-5 package
LF33ABDT	Very low drop voltage regulator with inhibit function
TL431ACL3T	Adjustable voltage reference in an SOT23-3 package

Figure 2. Circuit diagram

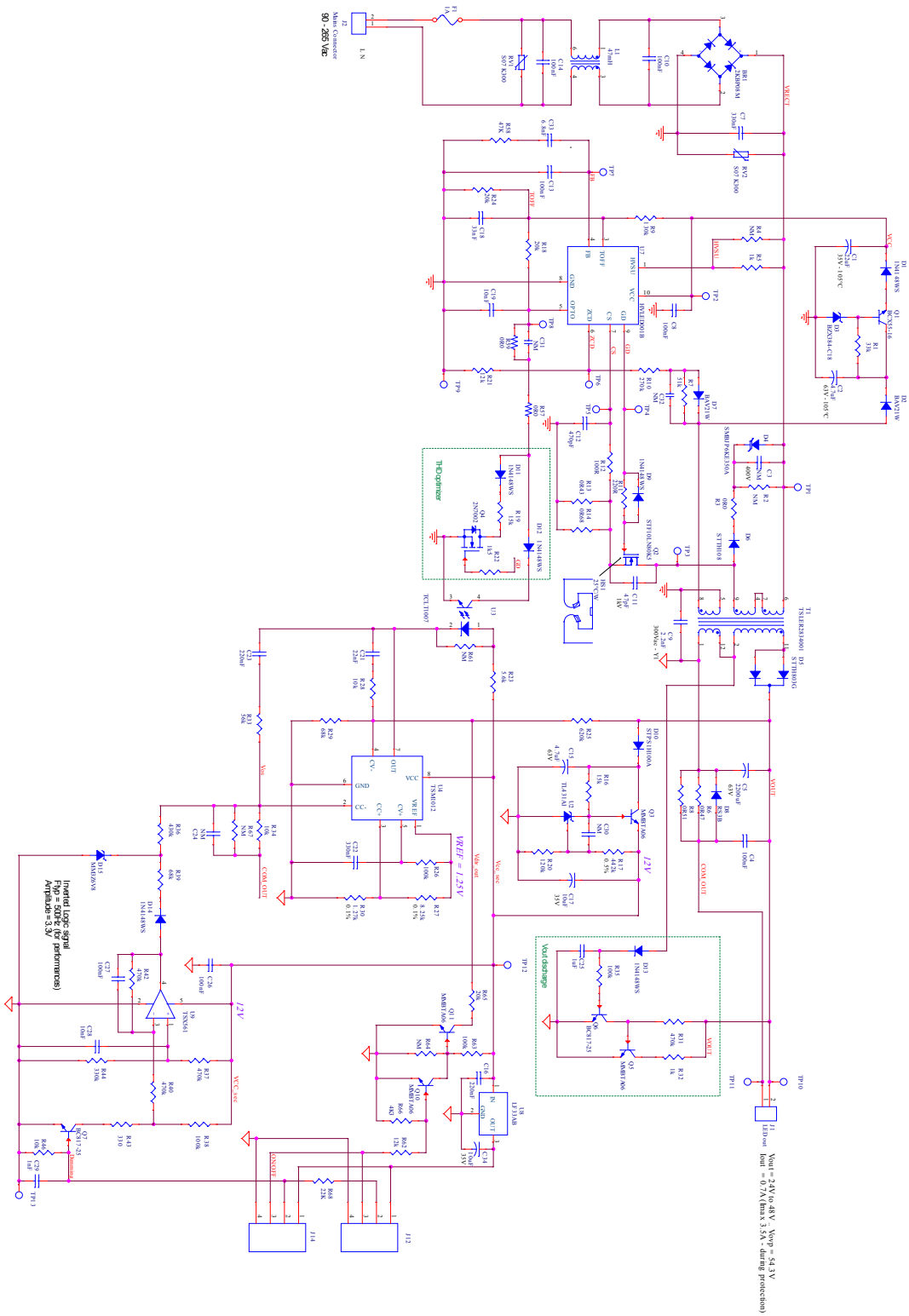


Table 3. Part list

Q.ty	Ref.	Value – Part number	Rating	Tol.	Package
1	BR1	2KBP08M	800V - 2A		Through-hole
1	C1	22uF	35V - 105°C	20%	Through-hole
2	C2, C15	4.7uF	63V - 105°C	20%	Through-hole
1	C3	Not mounted			Through-hole
1	C4	100nF	63V	5%	Through-hole
1	C5	2200uF	63V - 105°C	20%	Through-hole
1	C7	330nF	$305V_{AC}$	10%	Through-hole
4	C8, C13, C26, C27	100nF	50V	10%	0603
1	C9	2n2, Y1	$300V_{AC}$	20%	Through-hole
2	C10, C14	100nF, X2	$300V_{AC}$	10%	Through-hole
1	C11	47pF	1k V	5%	1206
1	C12	470pF	50V	10%	0603
1	C16	220nF	50V	10%	0603
2	C17, C34	10uF	35V - 105°C	20%	Through-hole
1	C18	33nF	50V	10%	0603
1	C21	22nF	50V	10%	0603
2	C22	330nF	25V	10%	0805
1	C23	220nF	50V	10%	0805
3	C24, C30, C31	Not mounted			0603
1	C25	1uF	25V	10%	0805
2	C28-C19	10nF	50V	10%	0603
1	C29	1nF	50V	10%	0603
1	C32	Not mounted			1206
1	C33	6.8nF	50V	10%	0603
6	D1, D9, D11, D12, D13, D14	1N4148WS	$100V_{RRM}$ - $0.2AI_F$		SOD3223
2	D2-D7	BAV21W	$200V_{RRM}$ - $0.4AI_F$		SOD123
1	D3	BZX384-C18	18V - 300mW		SOD323
1	D4	SMBJP6KE350A			SMB
1	D5	STTH803G	$300V_{RRM}$ - $8AI_F$		D2PAK
1	D6	STTH108A	$800V_{RRM}$ - $1AI_F$		SMA
1	D8	RS3B	$100V_{RRM}$ - $3AI_F$		SMC
1	D10	STPS1H100A	$100V_{RRM}$ - $1AI_F$		SMA
1	D15	MM3Z6V8	6.8V - 300mW		SOD323
1	HS1	HEATSINK			Through-hole
2	J1, J2	HEADER	$300V_{AC}$ - 20A		Through-hole
1	J12	HEADER	10A		Through-hole
1	J14	STRIP	150V - 3A		Through-hole
1	L1	TDK - B82731T2451A	2x47mH - 0.45A		Through-hole

Q.ty	Ref.	Value – Part number	Rating	Tol.	Package
1	F1	FUSE	$250V_{AC}$ - 1A		Through-hole
2	RV1, RV2	TDK - B72207S0301K101	$300V_{AC}$		Through-hole
1	R1	33K		5%	1206
2	R2, R4	Not mounted		1%	1206
1	R3	Chip resistor 0R		1%	1206
1	R5	1K		5%	1206
1	R6	0R47		1%	1210
1	R7	51K		1%	1206
1	R8	0R51		1%	1210
1	R9	130K		5%	0805
1	R10	270K		1%	0805
1	R11	220R		5%	0805
1	R12	100R		5%	0805
1	R13	0R43		1%	1206
1	R14	0R68		1%	1206
1	R16	15K		5%	1206
1	R17	442K		0.5%	0603
1	R18	20K		5%	0603
1	R19	15K		5%	0603
1	R20	120K		0.5%	0603
2	R21, R62	12K		1%	0603
1	R22	1K5		5%	0603
1	R23	5K6		5%	0805
2	R24, R65	20K		0.5%	0603
1	R25	620K		0.5%	0805
3	R26, R35, R38	100K		5%	0603
1	R27	8K25		0.1%	0603
3	R28, R46, R34	10K		5%	0603
1	R29, R39	68K		0.5%	0603
1	R30	1K27		0.1%	0603
1	R31	470K		5%	0805
1	R32	1K		5%	0805
1	R33	56K		5%	0603
1	R36	430K		0.5%	0603
3	R40, R37, R42	470K		5%	0603
1	R43	330R		5%	0603
1	R44	330K		5%	0603
2	R57, R59	0R			0603
1	R58	47K		5%	0603
1	R61	Not mounted			0603
1	R64	Not mounted			0805

Q.ty	Ref.	Value – Part number	Rating	Tol.	Package
1	R63	100K		5%	0805
1	R66	4K3		5%	0603
1	R67	Not mounted			0603
1	R68	22K		5%	0603
1	Q1	BCX55-16TF			SOT89
1	Q2	STF10LN80K5			TO220FP
4	Q3, Q5, Q10, Q11	MMBTA06			SOT23
1	Q4	2N7002			SOT23
2	Q6, Q7	BC817-25			SOT23
1	U2	TL431ACL3T			SOT23
1	U3	TCLT1007			SOP4L
1	U4	TSM1012I			SO8
1	U7	HVLED001B			SSOP10
1	U8	LF33ABDT			DPAK
1	U9	TSX561ILT			SOT23-5
1	T1	Italcoil - TSLER2834001			Through-hole

Figure 3. EVAL-SSR01B-35W board connections

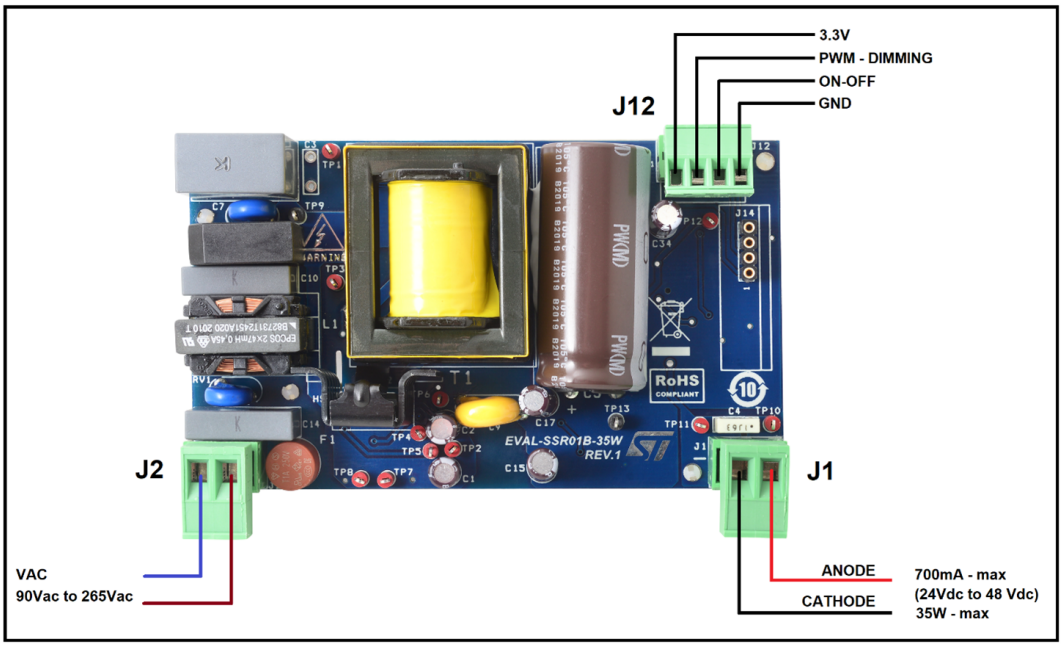


Figure 4. **EVAL-SSR01B-35W top side**

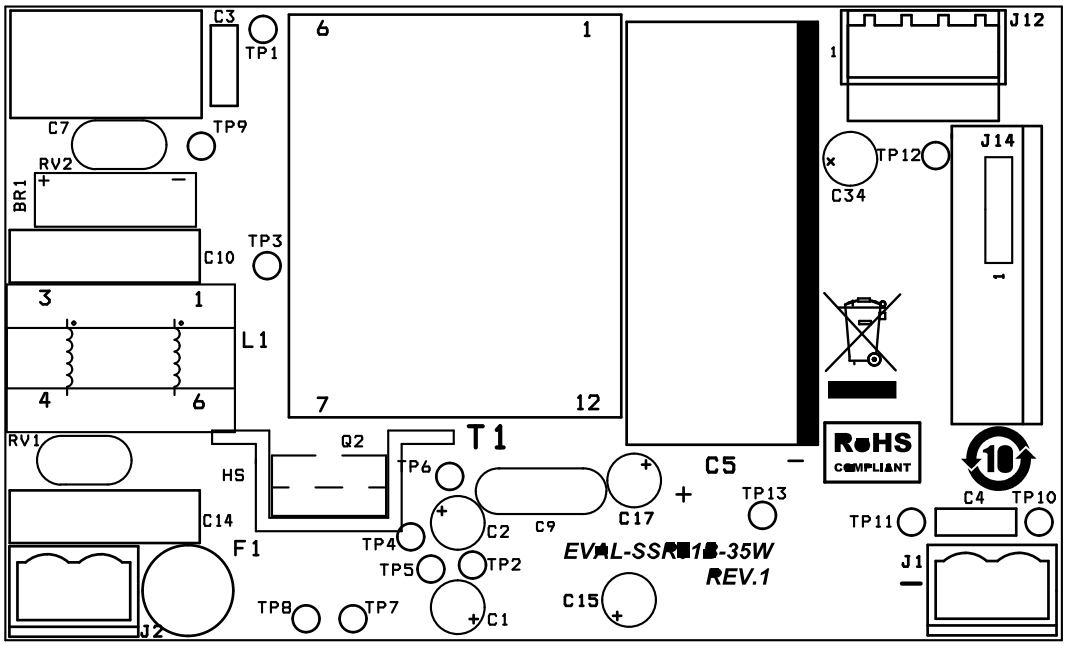
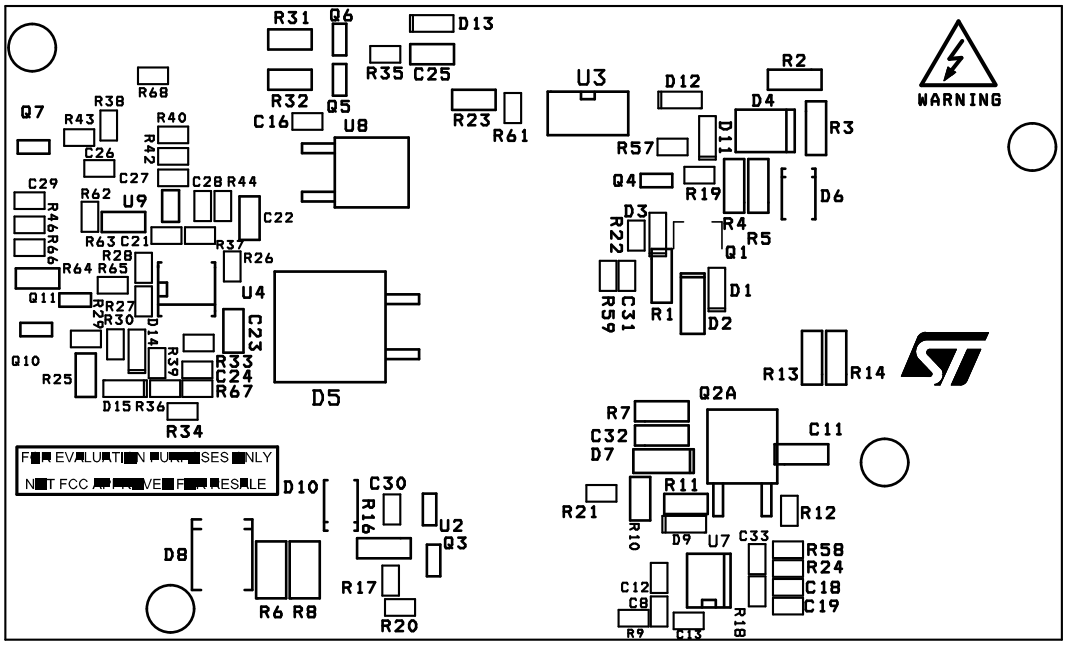


Figure 5. **EVAL-SSR01B-35W bottom side**



2 Circuit description

The EVAL-SSR01B-35W implements a single-stage high power factor flyback converter controlled by the HVLED001B with secondary side regulation (SSR) and constant current output.

The control loop consists of two paths designed around TSM1012 (U4) that integrates one voltage reference and two operational amplifiers with ORed outputs.

The voltage loop is controlled via the first operational amplifier, the resistor divider R25, R29, and the optocoupler which is directly connected to the output.

The current loop is controlled via the second operational amplifier, the sense resistor R6//R8 and the optocoupler.

The EVAL-SSR01B-35W can be controlled by providing the proper digital signals via connector J12 (see Table 1 for details).

A square wave PWM-DIMMING signal applied to pin J12-2 makes the transistor Q7 switch and consequently vary the voltage on the inverting input of TSX561 (U9), whose output voltage is thus proportional to the PWM duty cycle.

This voltage adds an offset on TSM1012 pin 2 resulting in decreased output current on the string LEDs.

MOSFET Q4 modifies the OPTO feedback signal in order to improve THD. Since it is driven by the GD signal of the main MOSFET Q2, it is turned on and off following the flyback duty cycle. Since duty cycle becomes bigger starting from mains peak voltage to zero crossing, the OPTO pin is reduced more and more as zero crossing approaches. This operation changes the current sense shaping allowing better THD in flyback converters.

A discharge circuitry is included to switch Q6 off and Q5 on when switching activity interruption is detected through the secondary auxiliary winding, consequently discharging converter VOUT through R32.

3 Measurement results

Figure 6. **EVAL-SSR01B-35W efficiency at 48 V_{OUT}**

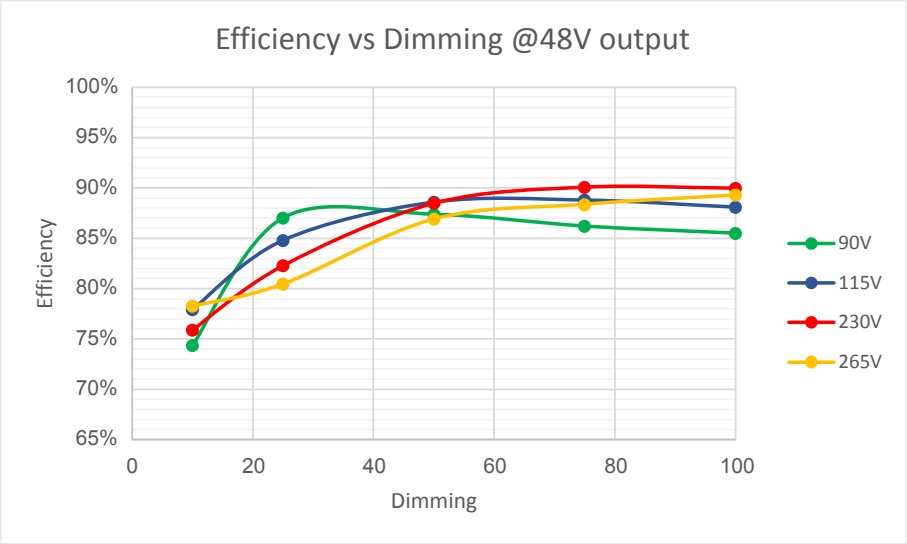


Figure 7. **EVAL-SSR01B-35W Total Harmonic Distortion at 48 V_{OUT}**

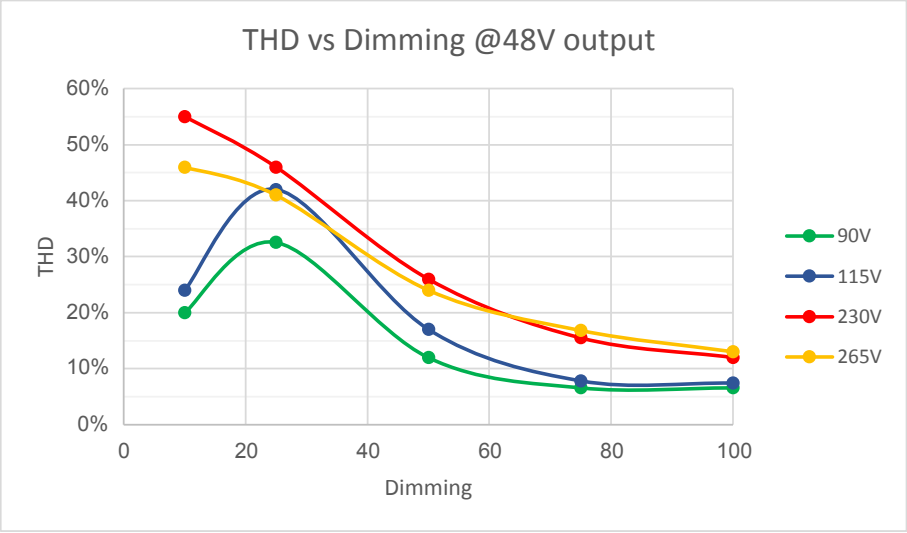


Figure 8. **EVAL-SSR01B-35W Power Factor at 48 V_{OUT}**

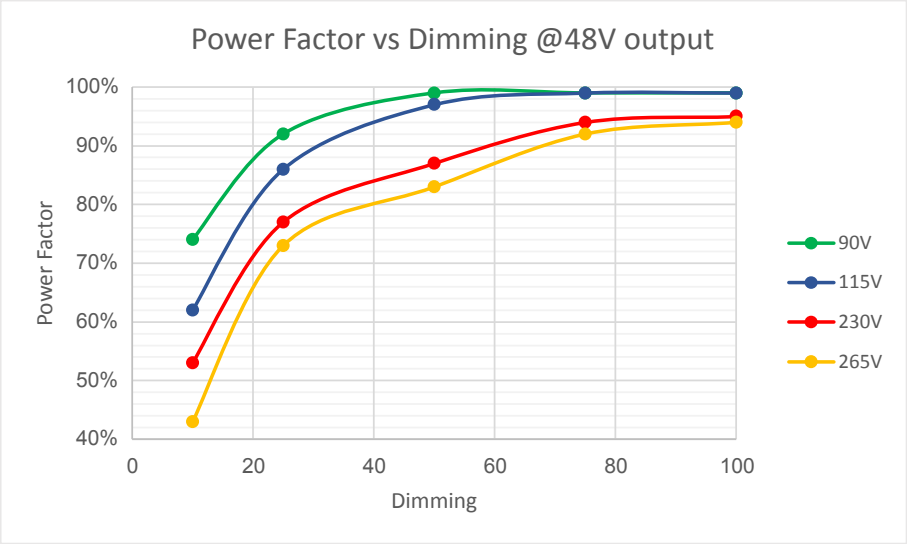


Table 4. **Efficiency table (Vout = 48 V)**

PWM DIMMING @ f = 500 Hz	@ V_{IN} = 115 VAC	@ V_{IN} = 230 VAC
100%	88.1%	90.0%
75%	88.8%	90.1%
50%	88.6 %	88.5%
25%	84.8%	82.3%
4 points avg	87.6%	87.7%
10%	77.9%	75.9%

Table 5. **Standby consumption**

	@ V_{IN} = 115 V_{AC}	@ V_{IN} = 230 V_{AC}
Pin [W]	0.115	0.235

Figure 9. **115 V_{IN_AC} at 48 V-0.7 A - power on**

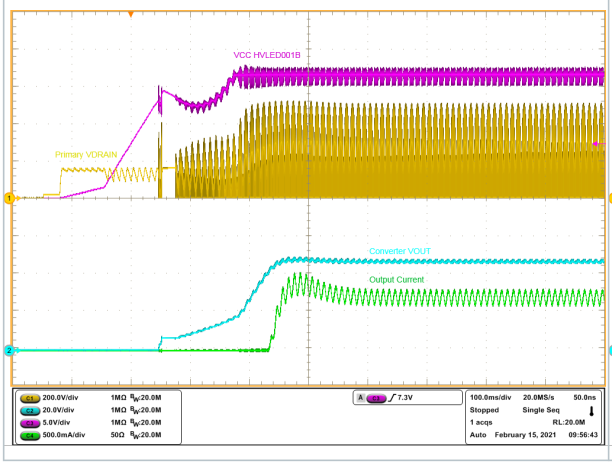


Figure 10. **230 V_{IN_AC} at 48 V-0.7 A - power on**

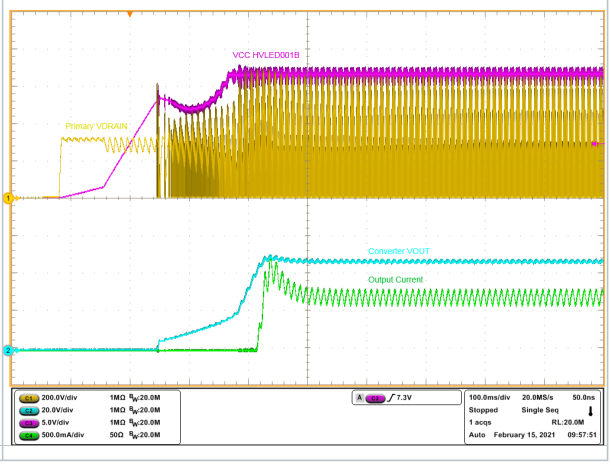


Figure 11. 115 V_{IN_AC} at 48 V-0.7 A - enable

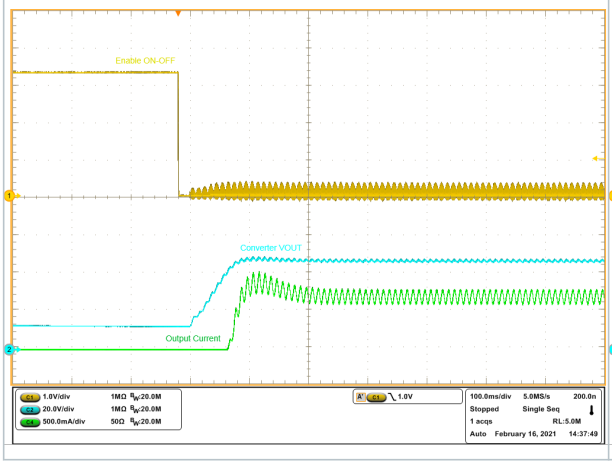


Figure 12. 230 V_{IN_AC} at 48 V-0.7 A - enable

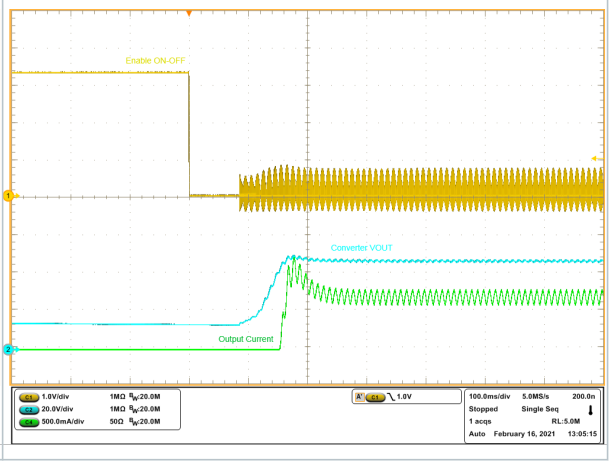


Figure 13. 115 V_{IN_AC} at 48 V-0.7 A - disable

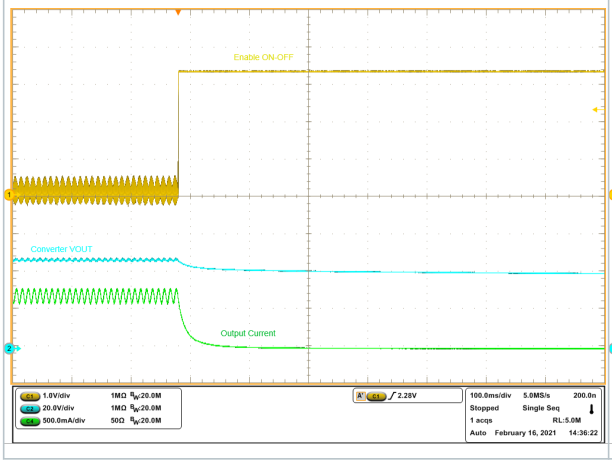


Figure 14. 230 V_{IN_AC} at 48 V-0.7 A - disable

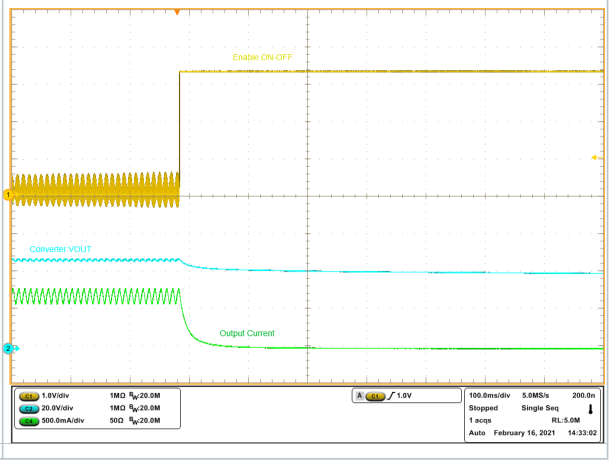


Figure 15. 115 V_{IN_AC} dimming 100%-10%-100%

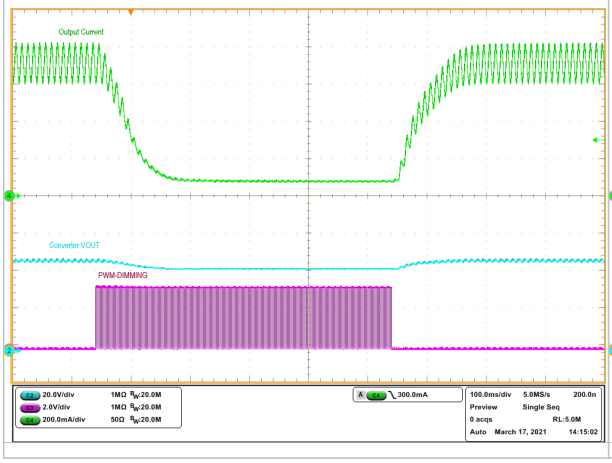


Figure 16. 230 V_{IN_AC} dimming 100%-10%-100%

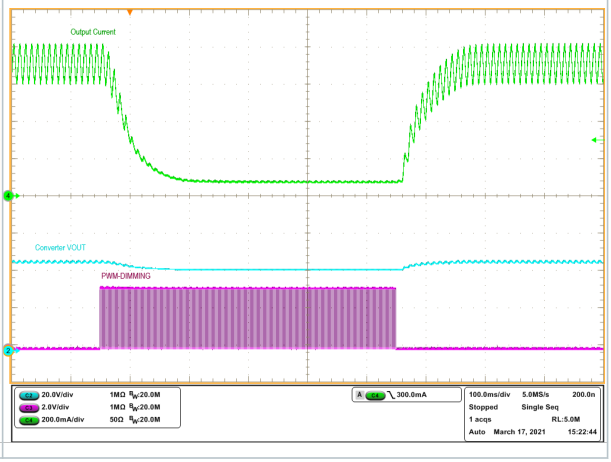


Figure 17. 115 V_{IN_AC} dimming 100%-10% - zoom

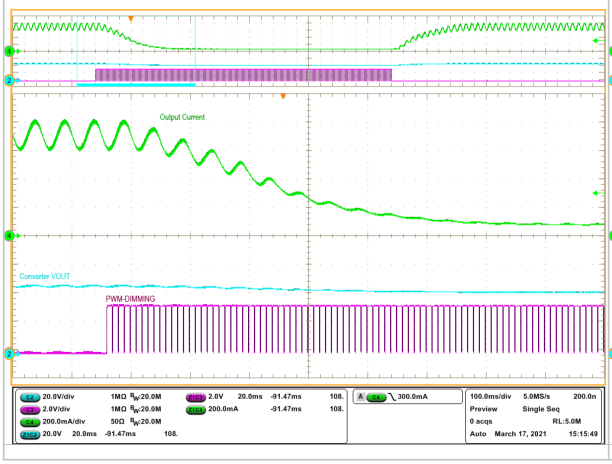


Figure 18. 115 V_{IN_AC} dimming 10%-100% - zoom

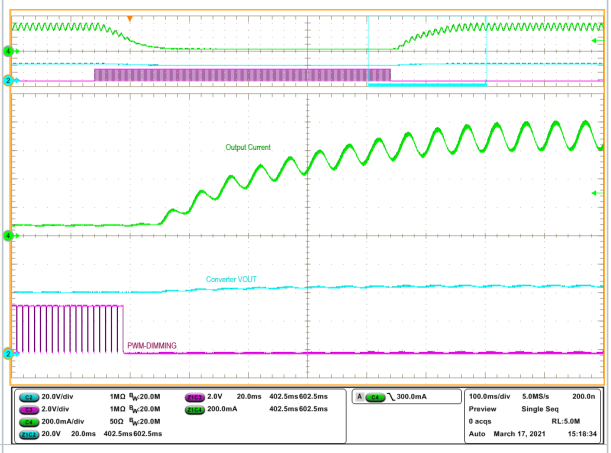


Figure 19. 115 V_{IN_AC} dimming 75%-25%-75%

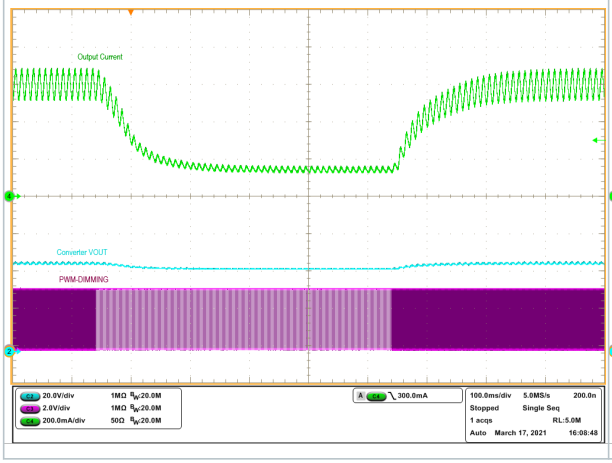


Figure 20. 230 V_{IN_AC} dimming 75%-25%-75%

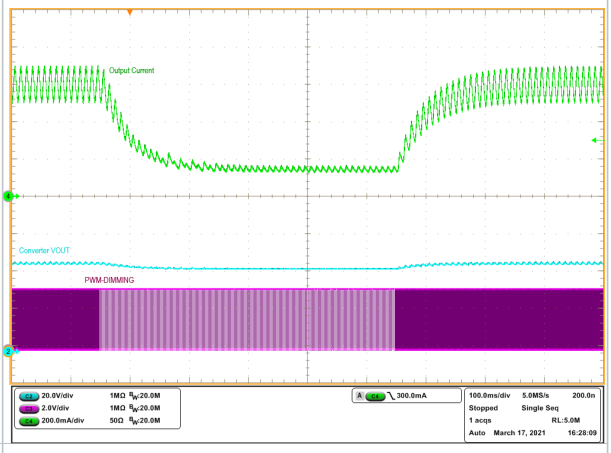


Figure 21. 115 V_{IN_AC} dimming 75%-25% - zoom

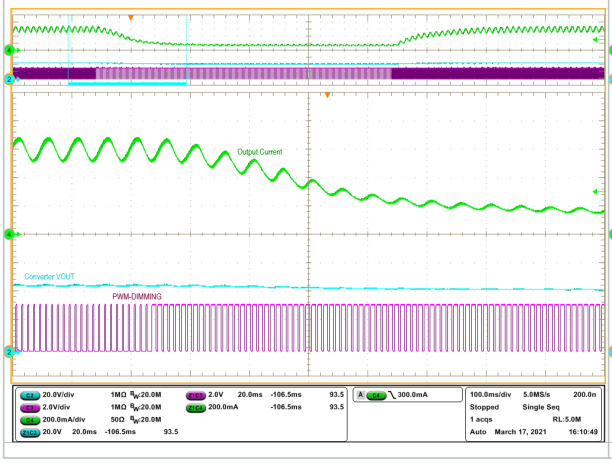


Figure 22. 115 V_{IN_AC} dimming 25%-75% - zoom

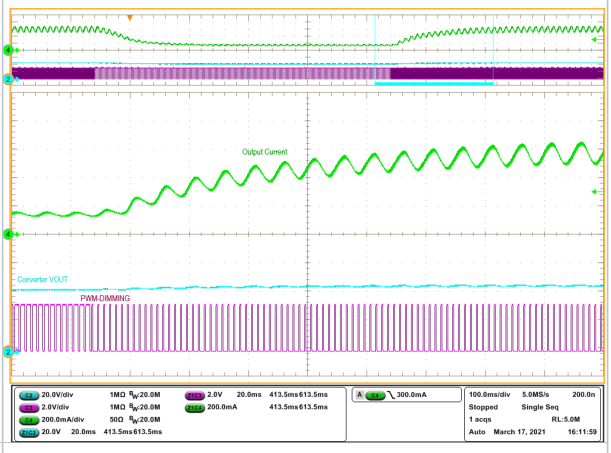


Figure 23. 115 V_{IN_AC} at 48 V-0.7 A - power down

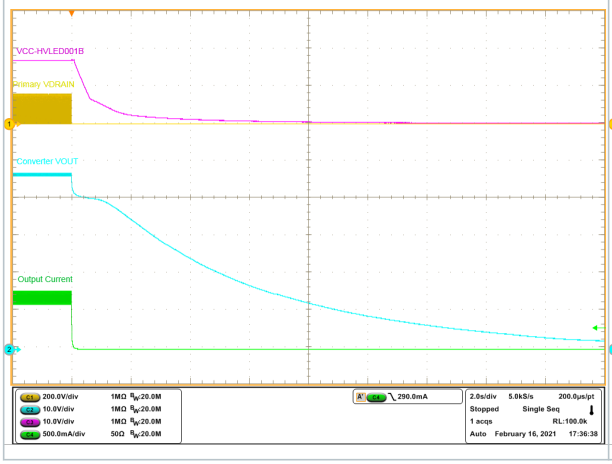
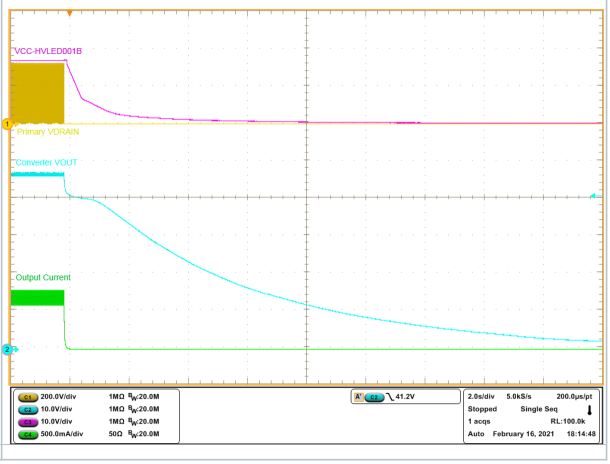


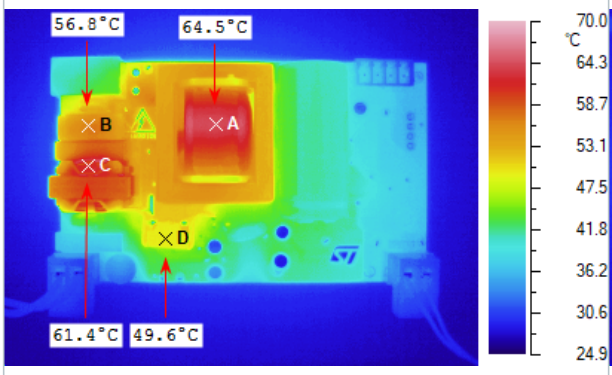
Figure 24. 230 V_{IN_AC} at 48 V-0.7 A - power down



4 Thermal maps

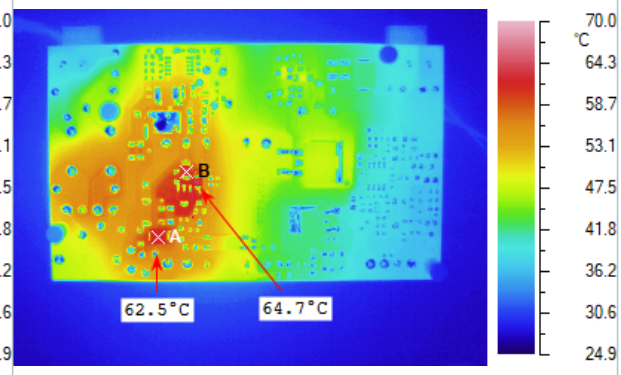
The following figures show the thermal maps on the top and bottom sides of the board at full load conditions, with the main components indicated.

Figure 25. 115 V_{IN_AC} at 48 V – top view



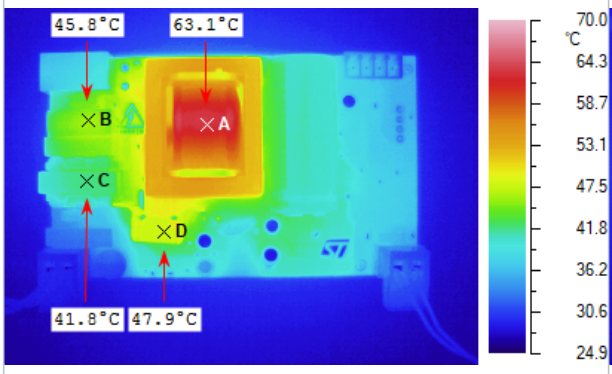
A - Ref Des: T1
B - Ref Des: BR1
C - Ref Des: L1
D - Ref Des: Q2

Figure 26. 115 V_{IN_AC} at 48 V – bottom view



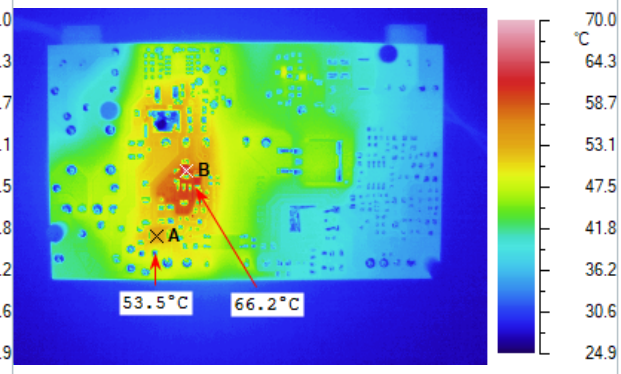
A - Ref Des: D4
B - Ref Des: D2, (D1, D3, R1, and Q1)

Figure 27. 230 V_{IN_AC} at 48 V – top view



A - Ref Des: T1
B - Ref Des: BR1
C - Ref Des: L1
D - Ref Des: Q2

Figure 28. 230 V_{IN_AC} at 48 V – bottom view



A - Ref Des: D4
B - Ref Des: D2, (D1, D3, R1, and Q1)

5 EMI results

The following figures show the EMI plots at full load conditions.

Figure 29. 115 V_{IN} at 48 V-0.7 A - Neutral

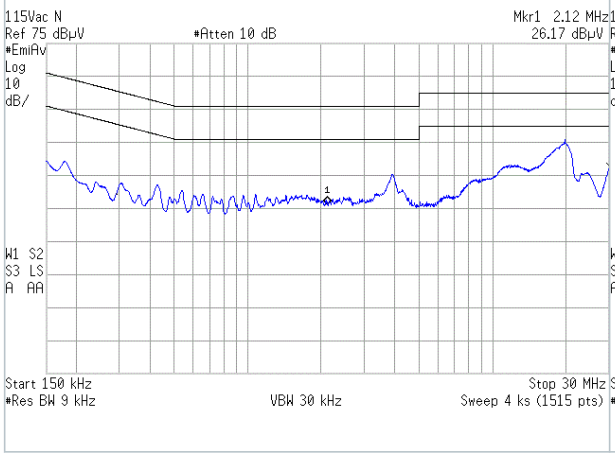


Figure 30. 115 V_{IN} at 48 V-0.7 A - Phase

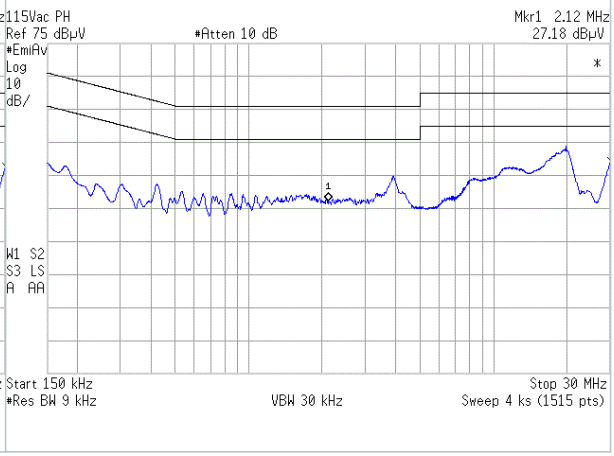


Figure 31. 230 V_{IN} at 48 V-0.7 A - Neutral

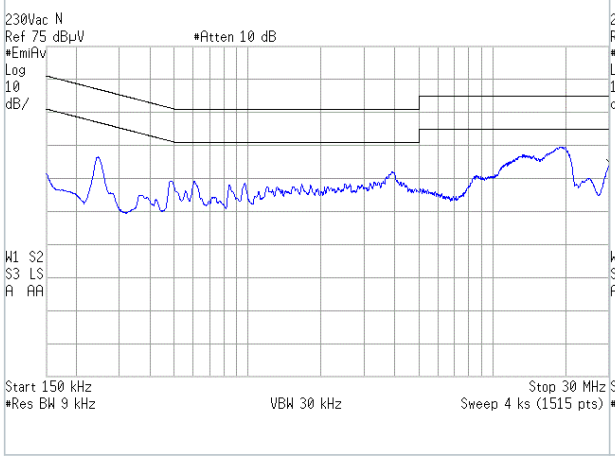
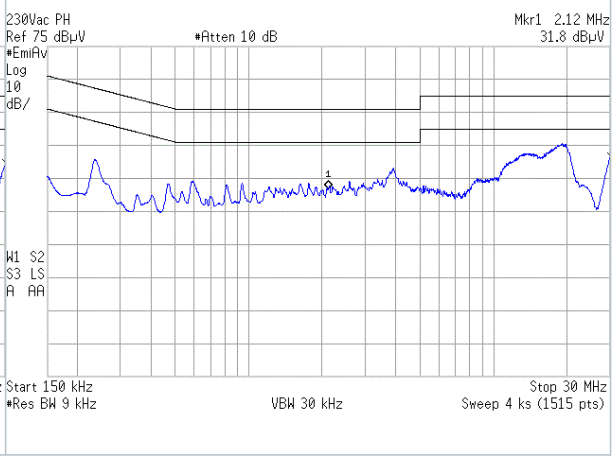


Figure 32. 230 V_{IN} at 48 V-0.7 A - Phase



6 References

1. HVLED001B Datasheet (see www.st.com).
2. AN4932, HVLED001A – enhanced QR high power factor flyback controller for LED drivers (see www.st.com).
3. AN5316, 35 W wide input range flyback converter using HVLED001B quasi-resonant flyback controller and STF10LN80K5 (see www.st.com).
4. AN1059, Design equations of high-power-factor flyback converters based on the L6561 (see www.st.com).

Revision history

Table 6. **Document revision history**

Date	Version	Changes
05-May-2021	1	Initial release.

Contents

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