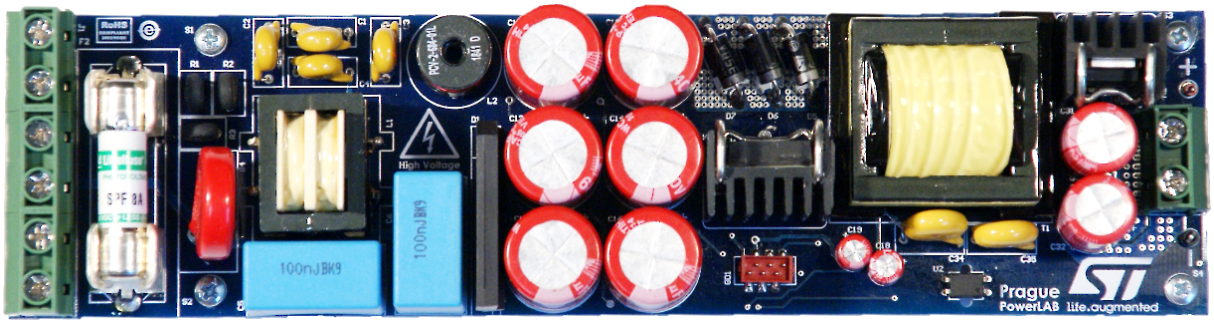
Ultra-wide range 100 W flyback converter with STEVAL-ISA211V1

Introduction

This 24 V/100 W output converter with reinforced isolation represents an ideal auxiliary power supply for many industrial applications. It features a very wide input range from the standard European 230 V_{AC} up to 690 V_{AC} or 1 kV_{DC}, and can continue operation for a limited time with input voltages as low as 150 V_{DC}.

The default fixed-frequency operation can be changed to quasi-resonant mode through a simple resistor setting.

Figure 1. STEVAL-ISA211V1 photo top view



1 Overview

Table 1. **STEVAL-ISA211V1 board parameters**

Symbol	Parameter	Test Conditions	min	typ.	max	Unit
V_{IN}	Input voltage AC	100W load	230	-	690	V
	Input voltage DC	100W load	250	-	1000	
	Input voltage AC	50W load	180	-	690	
	Input voltage DC	50W load	150	-	1000	
V_{OUT}t	Output voltage	-	-	24	-	V
P_{OUT}	Output power	Vin 230VAC – 1kVDC	100	-	-	W
η	Efficiency	Vin 230VAC, 100W load	-	86.0	-	%
		Vin 400VAC, 100W load	-	88.0	-	
		Vin 1kVDC, 100W load	-	85.9	-	
		Vin 150VDC, 50W load	-	86.2	-	

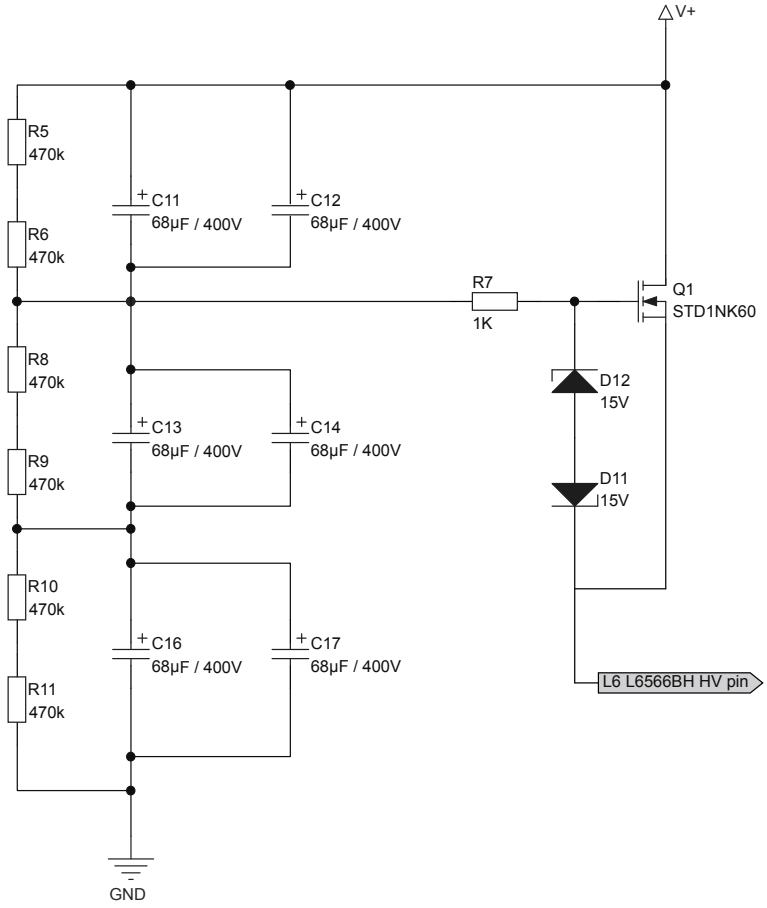
2 Design description

The converter is based on the L6566BH multi-mode controller in standard single-switch Flyback topology with isolated output, implementing discontinuous-conduction mode operation for every input voltage.

2.1 Input stage

The board comes equipped with an industrial 1 kV 10.3x38 mm fuse, but a footprint for a standard 5x20 mm fuse is available for testing on lower voltages. The input voltage is rectified and stabilized by six 68 µF / 400 V capacitors arranged in a series of three paralleled pairs, which are balanced with two 1206 SMD resistors.

Figure 2. HV startup circuit



The above circuit provides safe HV startup. Transistor Q1 acts as a simple voltage follower of the voltage divided by the input capacitors, approx. ⅔ of V+. During off-state, the HV pin voltage is only biased by leakage currents. Both Q1 and HV pin are protected by Zener diodes D11 and D12.

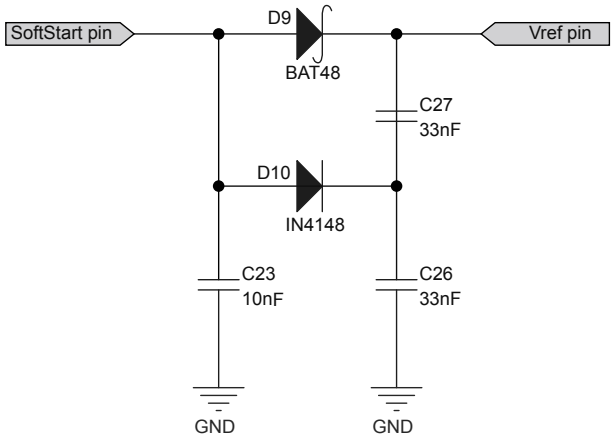
2.2 Soft start

The capacitor connected to the SS pin of the L6566BH controller is used for both soft-start and overload protection. During the soft-start phase, the capacitor is charged by current i_{SS} = 20 µA (typ.) from zero voltage until V_{SS} reaches 2 V. During this period, the setpoint for the primary winding current rises from zero to maximum, and the COMP pin used for feedback is ignored. After soft-start, the voltage remains at 2 V until an overload appears, in which case the capacitor is again charged with a current exactly one quarter of the soft-start current. If the overload lasts long enough for V_{SS} to reach 5 V, the device stops switching, thus allowing some tolerance for short overload events.

The time to charge the output capacitors to the nominal output voltage depends on the load and input voltage. As the COMP pin is ignored during soft-start, an inappropriate SS capacitor may provoke output overvoltage. To prevent this, the soft-start time must be set for a maximum input voltage and no load, thus triggering an overload state for any other condition.

It is not possible in this application to ensure a safe soft-start and no stops due to overload for every condition with one capacitor, so the board implements a modified soft-start circuit shown below.

Figure 3. Soft start circuit



In this circuit, the soft-start capacitor C23 ensures a smooth soft-start for every input voltage and output load, while the Vref voltage divider (capacitors C26 and C27) with D10 delays overload protection. D9 clamps the SS pin to Vref to trigger an auto-restart in case of an overload.

Note: For a latch function, D9 diode can be soldered out.

2.3 QR mode, switching frequency, ZCD and OVP

To change from the default Fixed-frequency (FF) mode to Quasi-resonant (QR) mode, R26 = 0Ω must be mounted. Both ZCD resistors R23 and R28 must also be mounted for QR operation. These resistors also provide overvoltage protection (OVP) in both QR and FF modes. If OVP is not required, it is necessary to clamp ZCD pin to GND with resistor R23 (e.g., 330 kΩ) to ensure stability.

If QR operation is selected, the switching frequency increases with lower load. When it reaches its limit (set with R25), the converter starts implementing valley skipping mode for lower loads and burst mode for no load or very light loads. As switching losses are proportional to switching frequency and input voltage, for a full input voltage range it is advisable to choose the limit near the 51.3 kHz FF operation switching frequency; i.e., R25 = 39 kΩ. If input voltage range for QR operation only involves lower voltages (e.g., only 230 V_{AC}), R25 may be reduced to 16 kΩ; i.e., approx. 125 kHz frequency limit.

2.4 Other features

The PCB is designed to accommodate modifications and additional features, including footprints for Voltage Feed-Forward and AC_OK components. While the values depend on the required purpose, they should be similar to or the same as the ratios indicated in schematic to ensure necessary clearance.

3 Realized application

The following figures show the layout of the two-layer, 35µm Cu thickness, 226mm x 57.5mm application board.

Figure 4. **STEVAL-ISA211V1 photo top view**

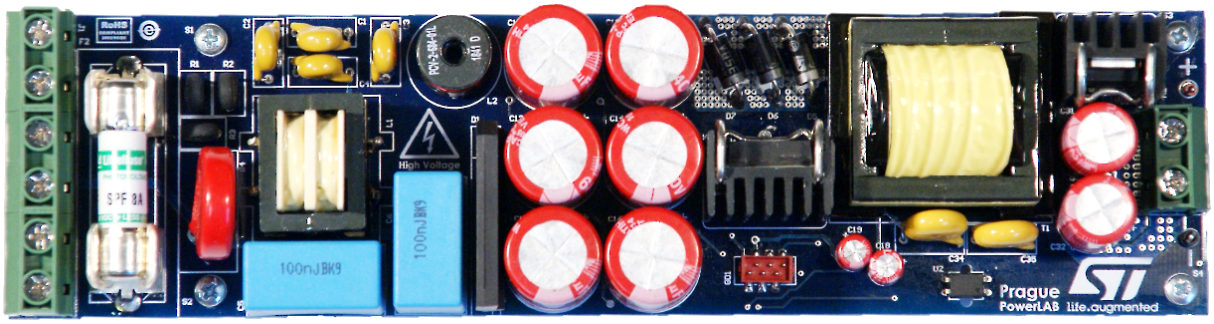


Figure 5. **STEVAL-ISA211V1 silk top layer**

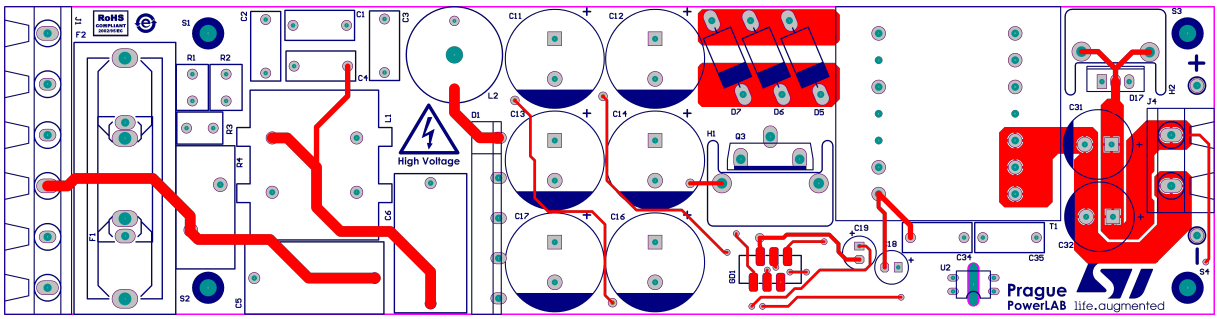
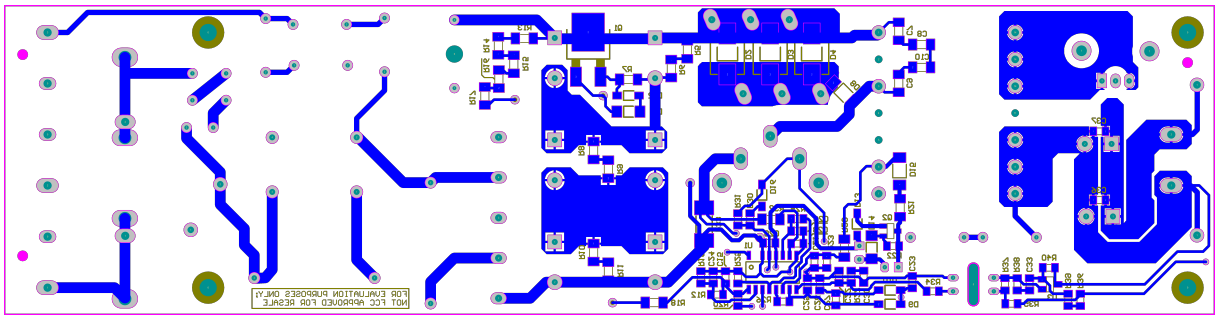
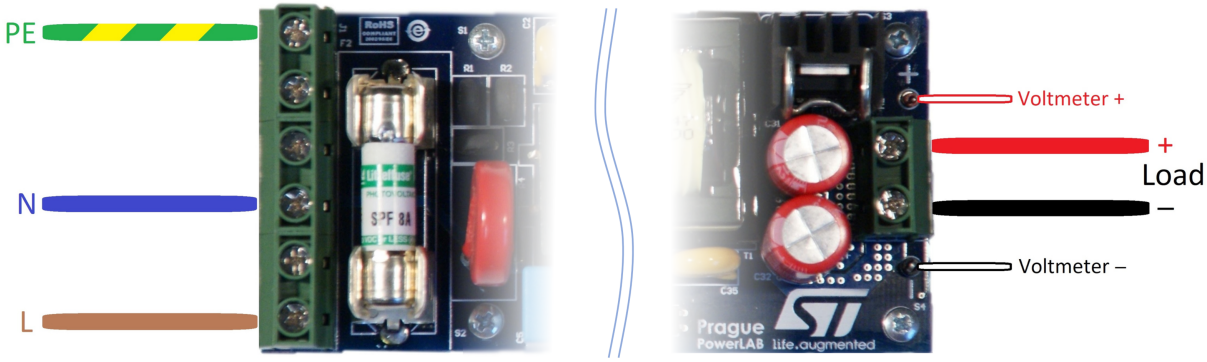


Figure 6. **STEVAL-ISA211V1 silk top layer**



The Mains are connected to input terminal J1, and the output terminal is J4. For voltage sensing or for another light load, two test points marked + and – near J4 are also connected to output.

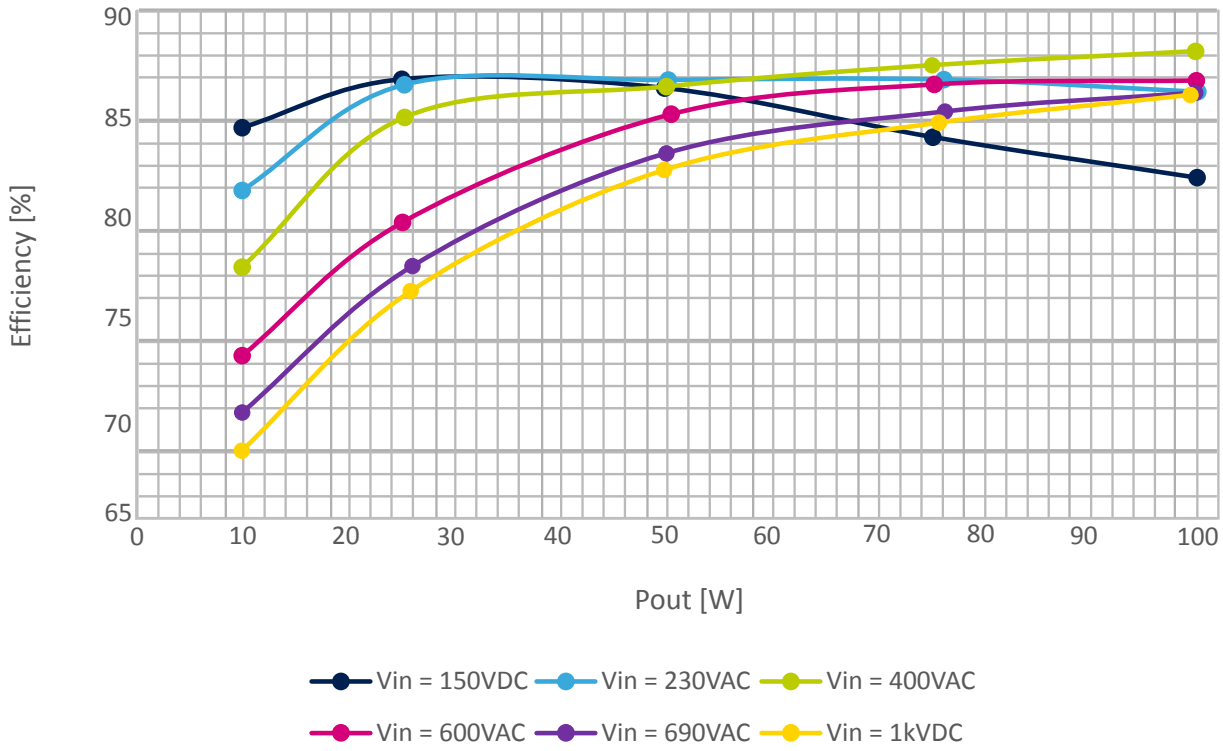
Figure 7. Mains and load connection



3.1 Measurement result

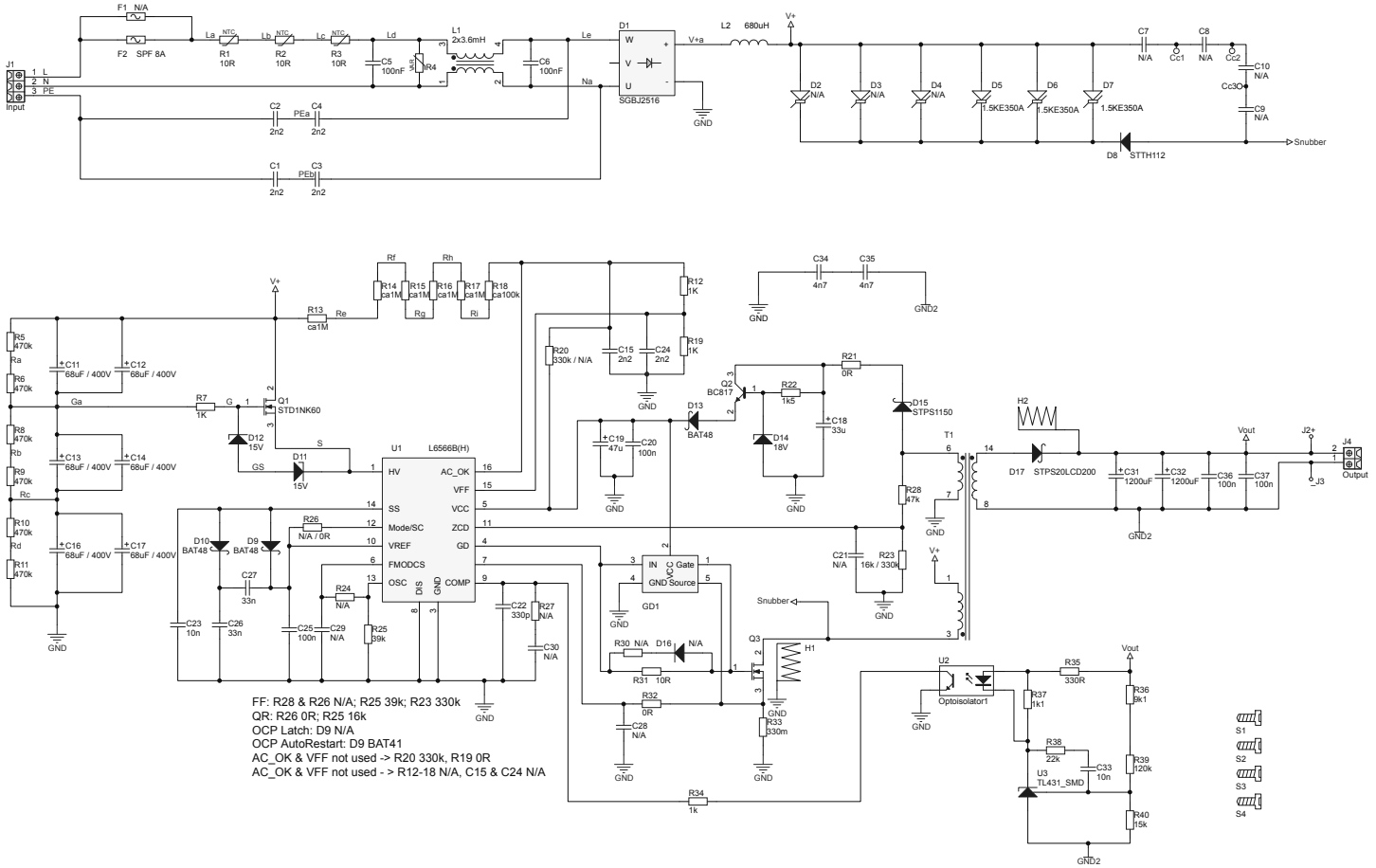
The following figure shows the efficiency measurement results for various input voltages.

Figure 8. STEVAL-ISA211V1 efficiency measurements



4 Schematic diagrams

Figure 9. **STEVAL-ISA211V1 circuit schematic**



5 Bill of materials

Table 2. **STEVAL-ISA211V1 bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	4	C1, C2, C3, C4	2n2 Y1 cap RM 10 12mm dia Y1 cap RM 10 12mm dia 760 V	Capacitors	Vishay	VY1222M37Y5VQ63V0
2	2	C5, C6	100n CAP RM22.5 26x13.5 CAP RM22.5 26x13.5 2000 VDC	Capacitors	Kemet	PHE450SD6100JR06L2
3	0	C7, C8, C9, C10	1206	Capacitors (not mounted)	Any	
4	6	C11, C12, C13, C14, C16, C17	68 µF RM7.5 18 mm 400 V	Electrolytic capacitor	Würth Elektronik	860241381006
5	0	C15, C21, C24, C28, C29, C30	0805	Capacitors (not mounted)	Any	
6	1	C18	33µ RM2.5 6.3 mm 50 V	Electrolytic capacitor	Würth Elektronik	860080673003
7	1	C19	47µ RM2.5 6.3 mm 25 V	Electrolytic capacitor	Würth Elektronik	860240473003
8	4	C20, C25, C36, C37	100 n 0805 50 V ±10%	Multilayer capacitors	Any	
9	1	C22	330 p 0805 50 V ±10%	Multilayer capacitor	Any	
10	2	C23, C33	10 n 0805 50 V ±10%	Multilayer capacitors	Any	
11	2	C26, C27	33 n 0805 50 V ±10%	Multilayer capacitors	Any	
12	2	C31, C32	1200 µF RM5 13 mm 35 V	Electrolytic capacitors	Würth Elektronik	860040578015
13	2	C34, C35	4 n7 Y1 cap RM 10 12mm dia Y1 cap RM 10 12 mm 760 V	Y1 cap RM 10 12mm dia	Vishay	VY1472M51Y5VQ63V0
14	1	D1		SGBJ bridge rectifier 3-phase	MULTICOMP PRO	SGBJ2516
15	0	D2, D3, D4	SMC	not mounted	Any	
16	3	D5, D6, D7	1.5KE350A DO-201 RM 15mm Transil	Transil	ST	1.5KE350A
17	1	D8	STTH112 SMA Diode	Diode	ST	STTH112A
18	3	D9, D10, D13	BAT48 SOD123 Schottky diode	Schottky diode	ST	BAT48ZFILM
19	3	D11, D12, D14	BZV55C18 SOD80_minimel	Zener diode	MULTICOMP PRO	BZV55C18
20	1	D15	STPS1150 SMA Schottky diode	Schottky diode	ST	STPS1150A
21	0	D16	SOD123	not mounted	Any	
22	1	D17	STPS20LCD200CT TO-220AB Schottky diode	Schottky diode	ST	STPS20LCD200CT
23	1	D17		Thermal paste	Any	
24		F1		Fuse holder	LITTELFUSE	05200101Z
25	2	F2	10x38mm	Fuse holder	SCHURTER	0751.0505
26	1	F2	SPF 8A Fuse 10x38mm 1000 V 8 A	Fuse	LITTELFUSE	0SPF008.T
27	3	FM1, FM2, FM3		Fiducial Mark v1	Any	
28		GD1		GDModule (not mounted)	Any	
29	1	H1	WA-T247-101E	Heatsink TO247	OHMITE	WA-T247-101E

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
30	1	H2	WA-T220-101E	Heatsink TO220	OHMITE	WA-T220-101E
31	1	J1	3x MC000054 6x Screw 1kV RM 9.52 - 3Pin 6x Screw 1kV RM 9.52 - 3Pin	6x Screw 1kV RM 9.52 - 3Pin	MULTICOMP PRO	MC000054
32	2	J2, J3	1.32 mm	Test point	VERO	20-313145
33	1	J4	RM 9.52 2x Screw 1kV RM 9.52	Jumper	MULTICOMP PRO	MC000054
34	1	L1	2x3.6mH Coilcraft E35xx	CMM	Coilcraft	E3502-AL
35	1	L2	680µH Ind Coilcraft PCV-2 1.3 A	Ind Coilcraft PCV-2	Coilcraft	PCV-2-684-01L
36	1	L2	8G206M3X30	Polyamide screw	DREMEC	8G206M3X30
37	1	L2	M3/BN81 M3	Polyamide nut	BOSSARD	M3/BN81
38	2	L2	1404830 M3	Polyamide pad	BOSSARD	1404830
39	1	Q1	STD1NK60T4 D pak MOSFET	MOSFET	ST	STD1NK60T4
40	1	Q2	BC817-40 SOT23	Signal BJT	Any	
41	1	Q3	SMICA-SOT93-2	Isolation pad	NINIGI	SMICA SOT93-2
42	1	Q3	STW12N170K5 TO-247	Power MOSFET	ST	STW12N170K5
43	3	R1, R2, R3	10R NTC RM5 dia 8.5 NTC RM5 dia 8.5	Resistors	EPCOS	B57153S0100M000
44	1	R4	V1000LA160BP Var RM8.5 dia 20 V1000LA Varistor	Varistor	LITTELFUSE	V1000LA160BP
45	6	R5, R6, R8, R9, R10, R11	470k 1206 Resistor 0.25 W 1%	Resistors	Any	
46	1	R7	1K 1206 Resistor 0.25 W 1%	Resistor	Any	
47		R12, R24, R27, R30	0805	Resistors (not mounted)	Any	
48		R13, R14, R15, R16, R17, R18, R28	1206	Resistors (not mounted)	Any	
49	1	R19	0 R 0805 0.125 W ±1%	Resistor	Any	
50	2	R20, R23	330 k 0805 0.125 W ±1%	Resistor	Any	
51	2	R21, R32	0R 1206 0.25 W ±1%	Resistor	Any	
52	1	R22	1k5 0805 0.125 W ±1%	Resistor	Any	
53	1	R25	39k 0805 0.125 W ±1%	Resistor	Any	
54		R26	0805	Resistor (not mounted)	Any	
55	1	R31	10 R 0805 Resistor 0.125 W ±1%	Resistor	Any	
56	1	R33	330 m 2512 1 W ±1%	Current Sense Resistor	Any	
57	1	R34	1 k 0805 0.125 W ±1%	Resistor	Any	
58	1	R35	330 R 0805 0.125 W ±1%	Resistor	Any	
59	1	R36	9k1 0805 Resistor 0.125 W ±1%	Resistor	Any	
60	1	R37	1k1 0805 Resistor 0.125 W ±1%	Resistor	Any	
61	1	R38	22k 0805 Resistor 0.125 W ±1%	Resistor	Any	
62	1	R39	120k 0805 Resistor 0.125 W ±1%	Resistor	Any	
63	1	R40	15k 0805 Resistor 0.125 W ±1%	Resistor	Any	
64	4	S1, S2, S3, S4	M3 10 mm	Spacer stud	Würth Elektronik	970100351

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
65	4	S1, S2, S3, S4		Screw M3	Bossard	1006614
66	1	T1		Custom transformer	Würth Elektronik	750318247
67	1	U1	L6566BH SOIC16 PWM controller	PWM controller	ST	L6566BH
68	1	U2	HCPL-817-00DE PDIP4 Optoisolator	Optoisolator	Broadcom / Avago	HCPL-817-00DE
69	1	U3	TL431AIL3T SOT23 LP Voltage reference	Voltage reference	ST	TL431AIL3T

Revision history

Table 3. **Document revision history**

Date	Version	Changes
11-Dec-2020	1	Initial release.

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