STEVAL-LLL012V1 smart LED lighting with BLE mesh network connectivity for indoor lighting

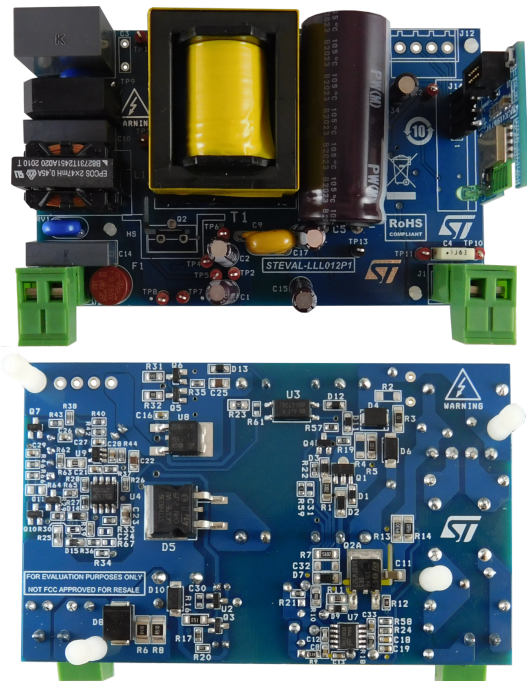
Introduction

The STEVAL-LLL012V1 evaluation kit is a 35 W constant current smart off-line LED driver working in a BLE mesh network which remotely controls the lighting nodes through the BlueNRG-M2SP wireless module.

The connectivity module manages wireless communication and LED brightness control. The driver regulates LED current through dimming to reduce power consumption and controls ON/OFF states.

The power supply can drive 0.7 A LEDs in the range of 24-48 V as well as universal input range (90 V-265 V_{AC}) with very high power factor and very low input current distortion. The power supply standby consumption is less than 300 mW.

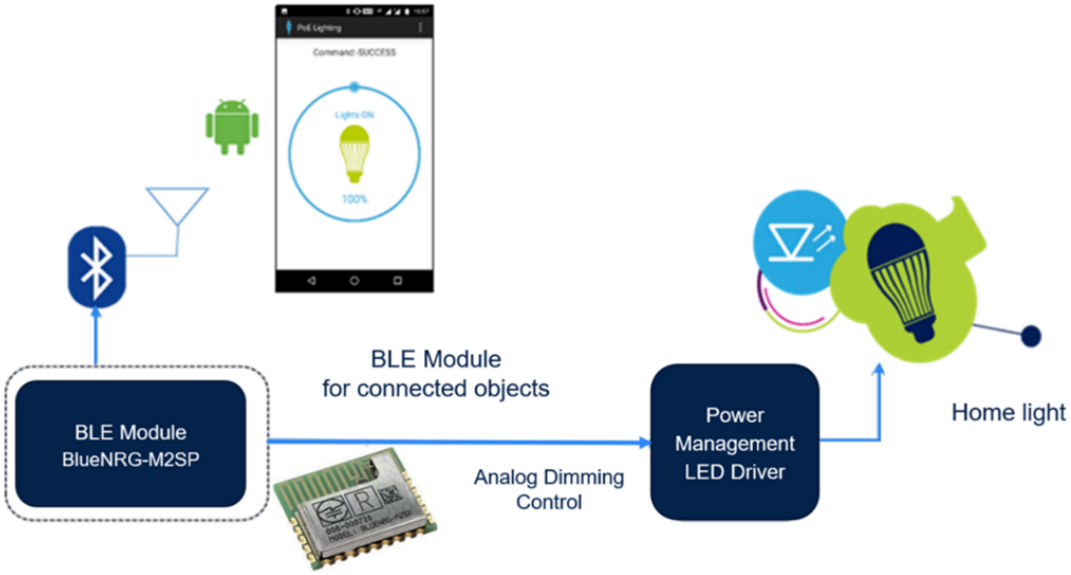
Figure 1. STEVAL-LLL012V1 evaluation kit (top and bottom)



1 Architecture

The smart lighting design architecture for the proposed solution is shown in the figure below.

Figure 2. Smart home lighting system architecture for STEVAL-LLL012V1



The ST BLE Mesh mobile app sends ON/OFF and dimming control signals to the BlueNRG-M2SP wireless connectivity module via Bluetooth to communicate with the STEVAL-LLL012V1 LED driver, which acts a lighting node in a BLE mesh network.

2 LED driver performance

Figure 3 shows the LED driver overall efficiency measurements at the entire input voltage variation and different output LED voltage settings. The efficiency is more than 86% .

Figure 4 shows the LED current regulation (CR) which is less than ±3% for the entire line and load variation.

Figure 3. Overall efficiency vs. input voltage at different LED voltages

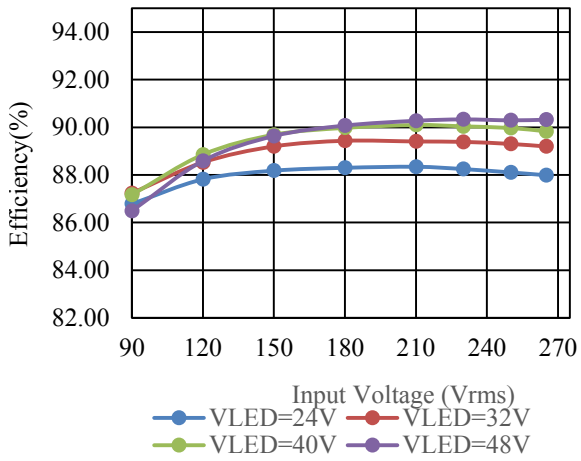


Figure 4. LED current regulation vs. input voltage at different LED voltages

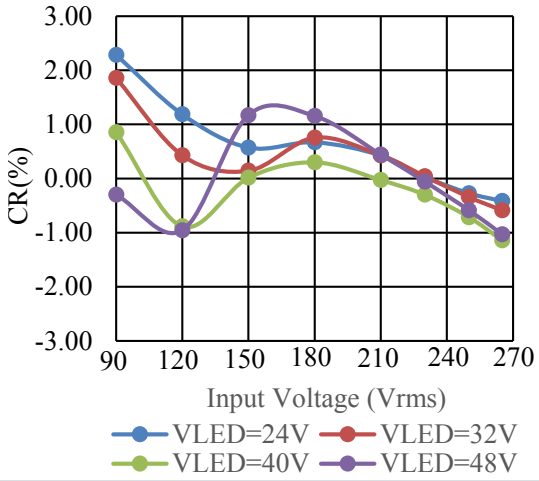


Figure 5. Total harmonic distortion vs. input voltage at different LED voltages shows the graph for input current total harmonic distortion (THD) for the entire input voltage variation and different output LED voltage settings. THD is less than 22% .

Figure 6 shows the displacement power factor (PF) that is more than 0.85 for the entire line and load variation.

Figure 5. Total harmonic distortion vs. input voltage at different LED voltages

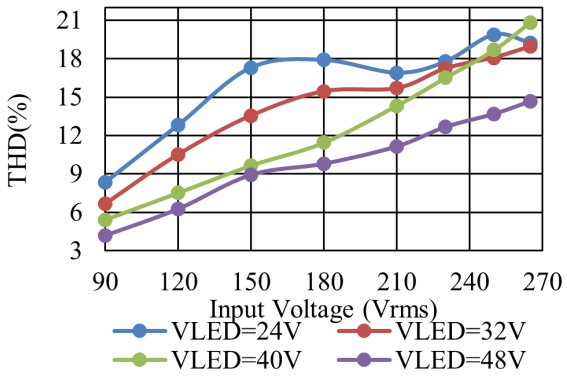
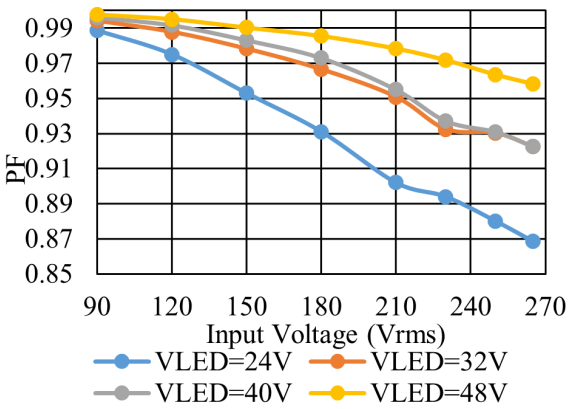


Figure 6. Power factor vs. input voltage at different LED voltages



3 Start-up and shutdown waveforms

The figures below show the start-up waveforms at line frequency and switching states at different input voltages (90, 230 and 265 V_{AC}) and full LED load (48 V/0.7 A).

Figure 7. Start-up plot at 90 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current

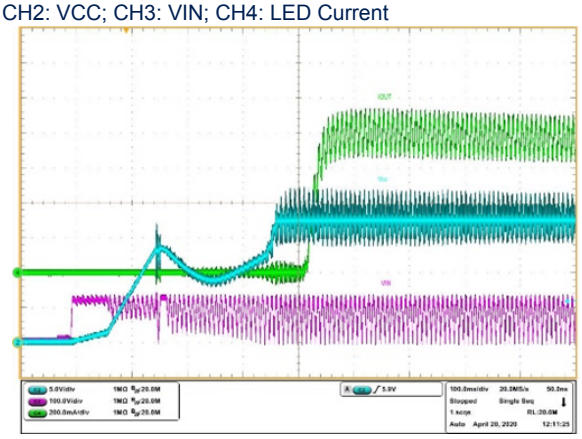


Figure 8. Start-up plot at 230 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current

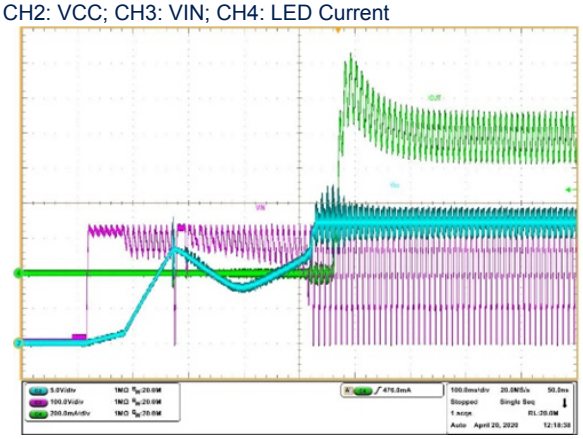


Figure 9. Start-up plot at 265 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current

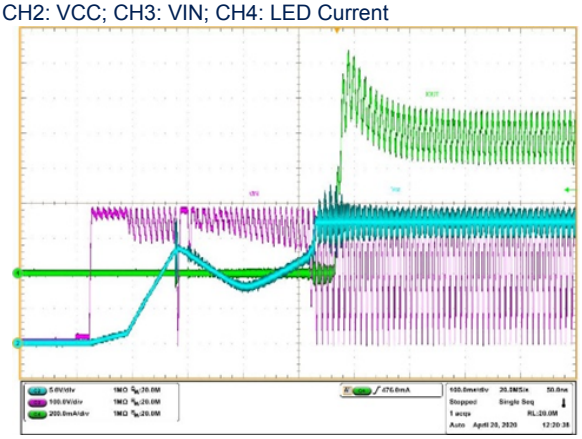


Figure 10. Shutdown plot at 90 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current

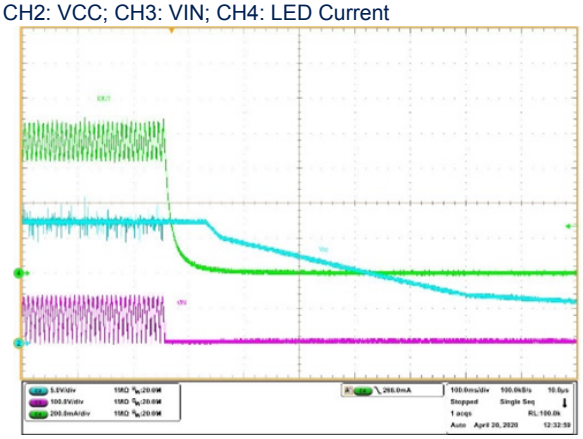


Figure 11. Shutdown plot at 230 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current

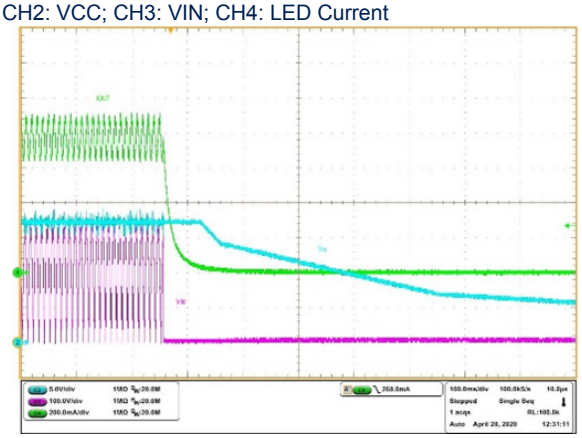
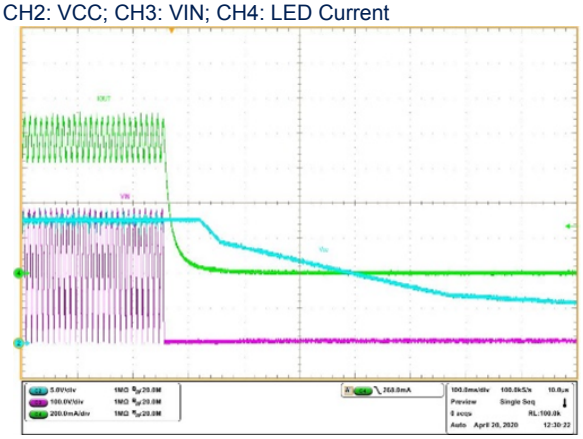


Figure 12. Shutdown plot at 265 V_{AC} input

CH2: VCC; CH3: VIN; CH4: LED Current



4 Steady state switching mode waveforms

The figures below show steady state switching waveforms at line frequency and switching states at different input voltages (90, 115, 230 and 265 V_{AC}) and full LED load (48 V/0.7 A).

The test results show the converter is stable and working in quasi-resonant mode for universal input voltage with constant LED current. All the power component measurements are well within the optimum range.

Figure 13. Switching plot at 265 V_{AC} input (channels 1, 2, 3 and 4)

CH1: MOSFET Drain; CH2: VCC; CH3: Gate drive; CH4: LED Current

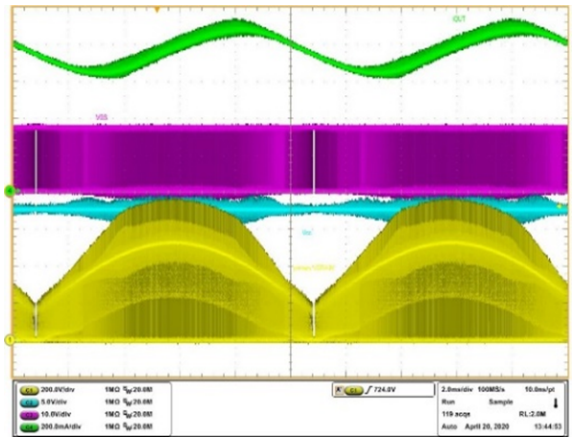


Figure 14. Switching plot at 230 V_{AC} input (channels 1, 3 and 4)

CH1: MOSFET Drain; CH3: Gate drive; CH4: Peak Current Sense

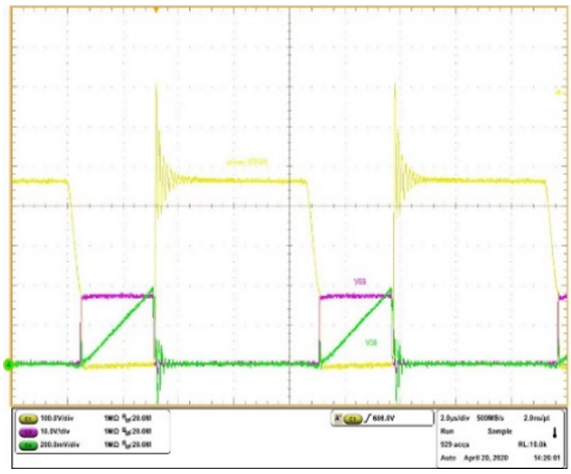


Figure 15. Switching plot at 230 V_{AC} input (channels 1, 2 and 3)

CH1: MOSFET Drain; CH2: VCC; CH3: Gate drive

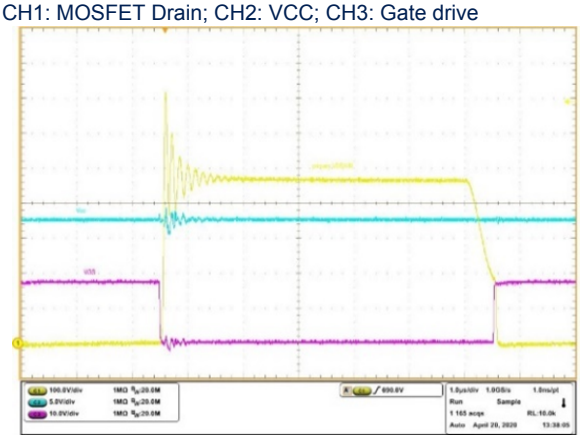


Figure 16. Switching plot at 265 V_{AC} input (channels 1, 2 and 3)

CH1: MOSFET Drain; CH2: VCC; CH3: Gate drive

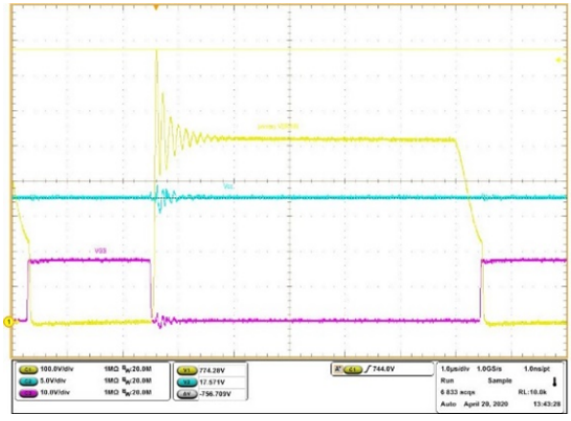


Figure 17. Switching plot at 90 V_{AC} input (channels 1, 2 and 3)

CH1: MOSFET Drain; CH2: VCC; CH3: Gate drive

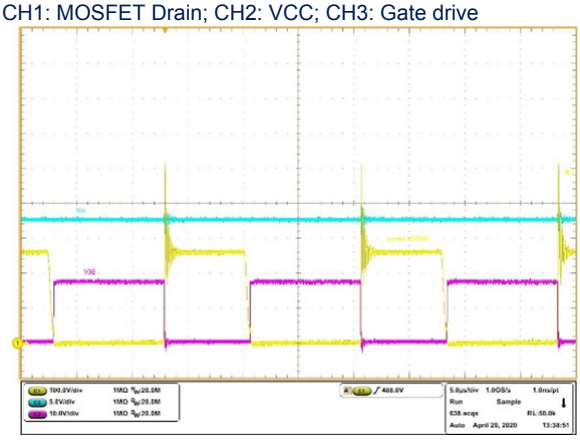
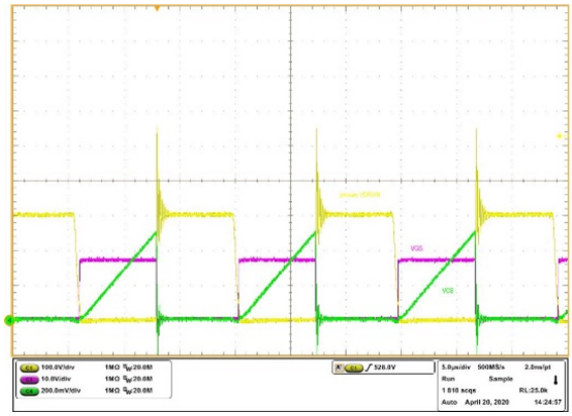


Figure 18. Switching plot at 115 V_{AC} input (channels 1, 2 and 3)

CH1: MOSFET Drain; CH3: Gate drive; CH4: Peak Current Sense



5 Protection and smart lighting features

The LED driver is protected against open and short-circuit condition. The figures below show the LED open condition waveforms at full load and the LED short and short removal conditions.

Figure 19. LED open condition at 230 V_{AC}

CH1: MOSFET Drain; CHM1:Vout LED; CH4: LED Current

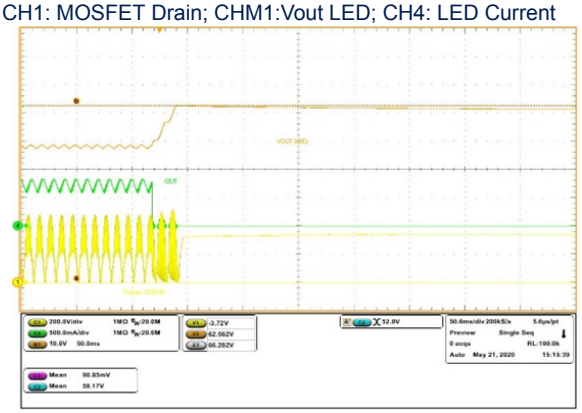


Figure 20. LED open condition at 265 V_{AC}

CH1: MOSFET Drain; CHM1:Vout LED; CH4: LED Current

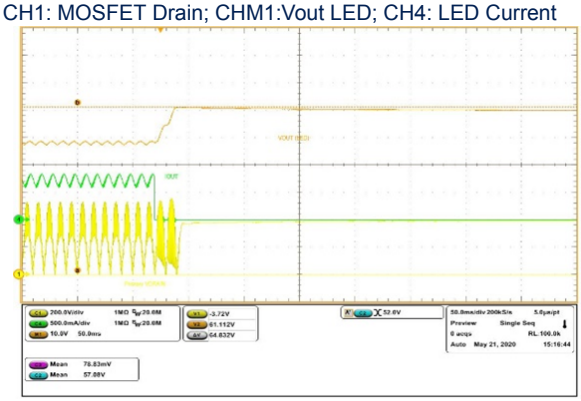


Figure 21. LED short condition at 230 V_{AC}

CH1: MOSFET Drain; CHM1:Vout LED; CH4: LED Current

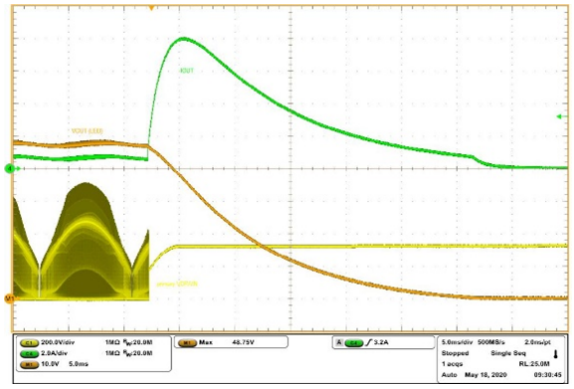


Figure 22. LED remove short condition at 230 V_{AC}

CH1: MOSFET Drain; CHM1:Vout LED; CH4: LED Current

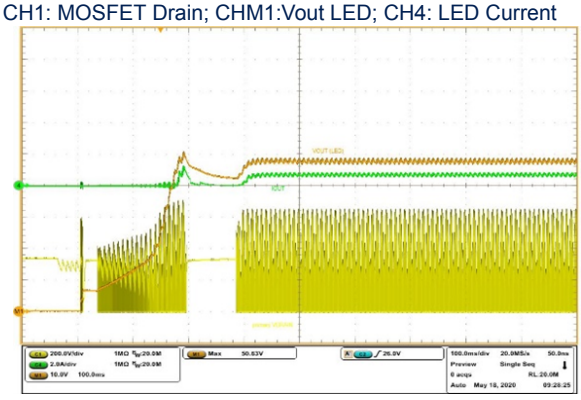


Figure 23, Figure 24 and Figure 25 show the power supply smart features: the dimming and the ON/OFF signal sent by the user to the BlueNRG-M2SP and the control signal generated.

Figure 26 shows the board standby power consumption which is 0.21 W at nominal input voltage.

Figure 23. LED ON/OFF condition and dimming at full load

CH2: ON/OFF Signal; CH3: Dimming signal; CH4: LED Current

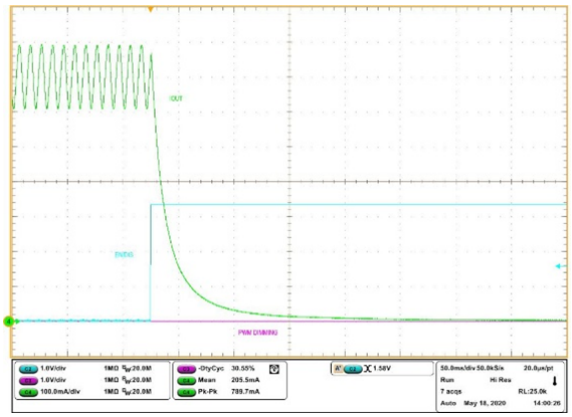


Figure 24. LED 50% dimming at full load

CH2: ON/OFF Signal; CH3: Dimming signal; CH4: LED Current

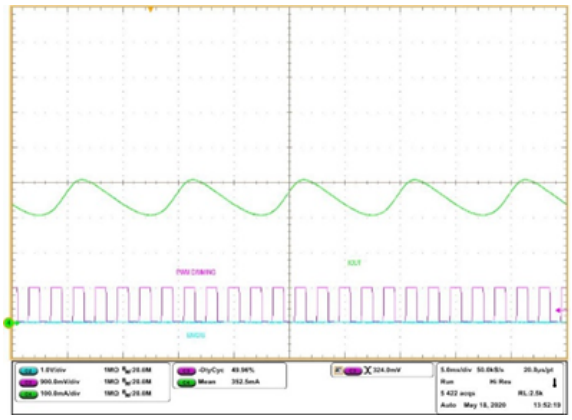


Figure 25. LED ON/OFF condition and 75% dimming at full load

CH2: ON/OFF Signal; CH3: Dimming signal; CH4: LED Current

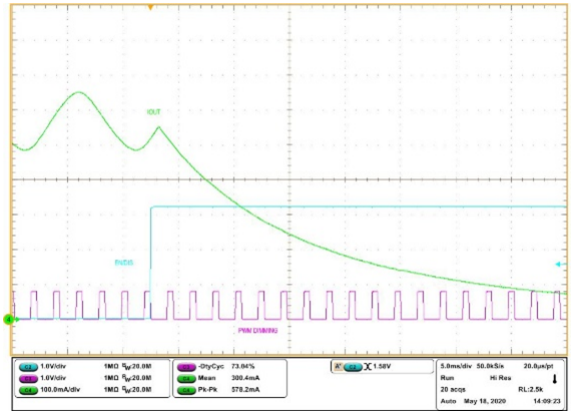


Figure 26. Standby power consumption: 0.21 W at nominal input voltage

The following figures show the analog dimming test result using PWM signal coming from the BlueNRG-M2SP wireless module.

Figure 27. **LED current linearity at different LED voltage and dimming value**

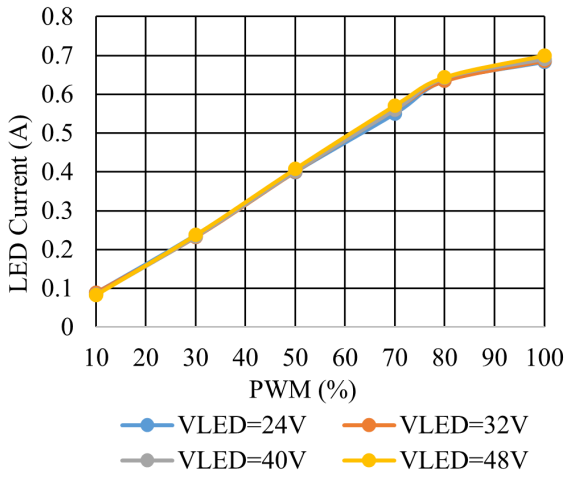
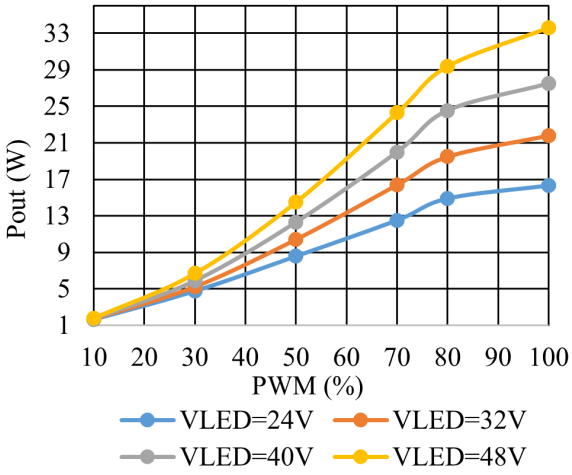


Figure 28. **Output power at different LED voltage and dimming value**



6 EMI measurements

The STEVAL-LLL012V1 board has been tested according to the EMI limits applicable for lighting loads. The measured limits at different input voltages are well within the normative limits as shown in the figures below.

Figure 29. EMI measurement at full load input voltage (100 V_{AC})

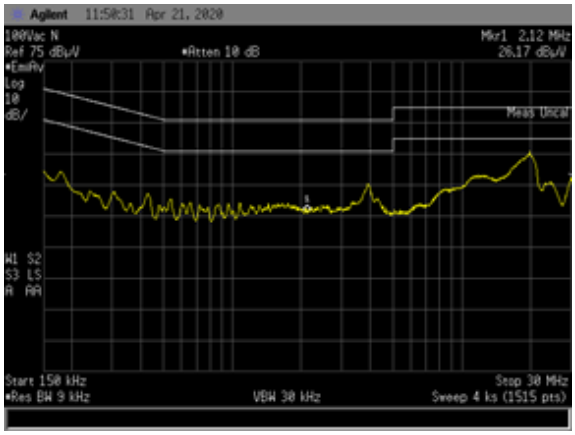
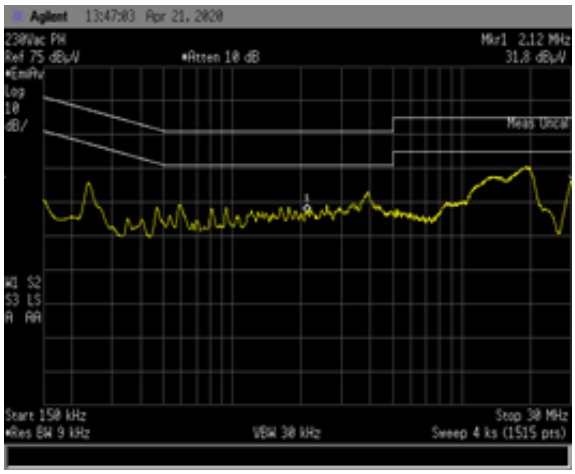


Figure 30. EMI measurement at full load input voltage (230 V_{AC})



7 Schematic diagrams

Figure 31. **Power board circuit schematic**

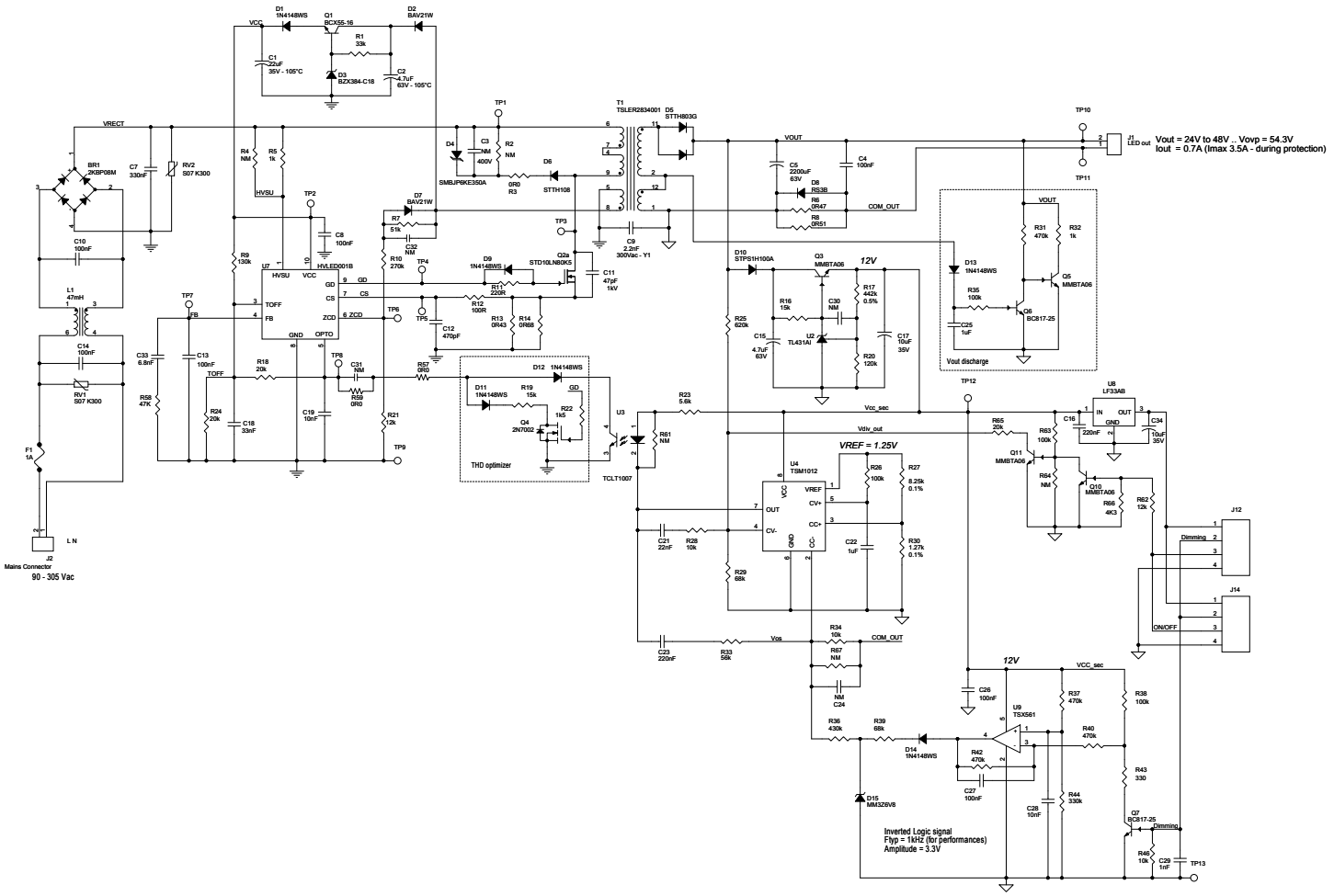
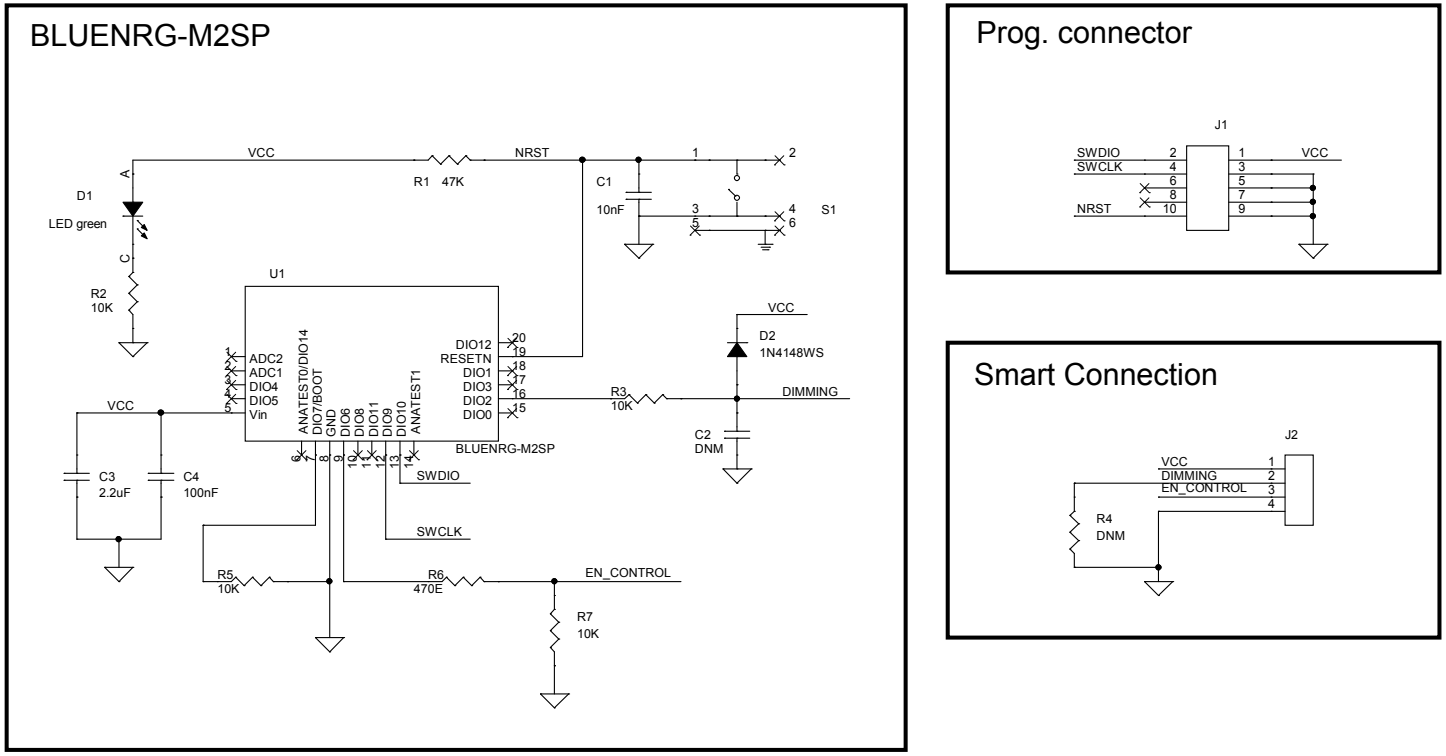


Figure 32. Connectivity board circuit schematic



8 Bill of materials

Table 1. Power board bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	C1	22 µF, Ø 5 x h11 x p2, 35 V, radial, can 2000 hrs @ 105°C	Aluminum electrolytic capacitors	Nichicon	UPW1V220MDD
2	2	C2 C15	4.7 µF, Ø 5 x h11 x p2, 63 V, radial, can 2000 hrs @ 105°C	Aluminum electrolytic capacitors	Nichicon	UPW1J4R7MDD
3	0	C3	7.3x2.5xp5	Capacitor	Any	Any
4	1	C4	100 nF , 7.3x2.5xp5 , 63 V,	Capacitor	Kemet	R82DC3100DQ50J
5	1	C5	2200 µF, Ø 18 x h40 x p7.5, 63 V, radial, can 8000 hrs @ 105°C	Aluminum electrolytic capacitor	Nichicon	UPW1J222MHD
6	1	C7	330 nF 18x10xp15 630 V	Film capacitor	Kemet	R463I333050M1K
7	4	C8 C13 C26 C27	100 nF, 0603, 50 V, X7R	Ceramic capacitors	Kemet	C0603C104M5RACTU
8	1	C9	2.2 nF, Ø 12 x 10.16, 300 V_{AC}	Capacitor	Vishay	AY1222M47Y5UC63L0
9	2	C10 C14	100 nF, 18x5xp15, 630 V	Film capacitors	Kemet	R463I310050M1K
10	1	C11	47 pF, 1206, 1000 V ±5%	Ceramic capacitor	Murata	GRM31A7U3A470JW31D
11	1	C12	470 pF, 0603, 50 V ±10%, X7R	Ceramic capacitor	Kemet	C0603C471K5RACTU
12	2	C17 C34	10 µF, Ø 5 x h11 x p2, 50 V, radial, can 2000 hrs @ 105°C	Aluminum electrolytic capacitor	Nichicon	UPW1V100MDD
13	1	C18	33 nF, 0603, 50 V, ±10%, X7R	Ceramic capacitor	Kemet	C0603C333K5RACTU
14	1	C21	22 nF, 0603, 50 V, ±10%, X7R	Ceramic capacitor	Kemet	C0603C223K5RACTU
15	2	C22 C25	1 µF, 0805, 25 V, ±10%, X7R	Ceramic capacitors	Kemet	C0805C105K3RACTU
16	1	C16	220 nF, 0603, 50 V, ±10%, X7R	Ceramic capacitor	Murata	GCM188R71H224KA64J
17	1	C23	220 nF, 0805, 50 V, ±10%, X7R	Ceramic capacitor	Samsung	CL21B224KBFNNNE
18	0	C24 C30 C31	0603	Ceramic capacitors (not mounted)		
19	2	C28 C19	10 nF, 0603, 50 V, X7R, ±20%	10nF 50V Ceramic Capacitor 0603	Kemet	C0603C103M5RACTU

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
20	1	C29	1 nF, 0603, 50 V, ±10%	Ceramic capacitor	Yageo	CC0603KRX7R9BB102
21	0	C32	1206	Ceramic capacitor (not mounted)		
22	1	C33	6.8 nF, 0603, 50 V , X7R, ±10%	Ceramic capacitor	Kemet	C0603C682K5RACTU
23	1	R1	33 KOhms, 1206 , 0.25 W, 1/4W, ±5%	Chip resistor	Stackpole	RMCF1206JT33K0
24	0	R2 R4	1206	Resistors (not mounted)		
25	1	R3	0 Ohms, 1206, 0.25 W	Jumper	Stackpole	RMCF1206ZT0R00
26	0	R64	0805	Resistor (not mounted)		
27	1	R5	1 KOhms, 1206 , 0.25 W, ±5%	Resistor	Yageo	RC1206JR-071KL
28	1	R6	470 mOhms, 1210, 0.5 W	Chip resistor	Panasonic	ERJ-14BQFR47U
29	1	R8	510 mOhms, 1210, 0.5 W, ±1%	Chip resistor	Yageo	RL1210FR-070R51L
30	1	R7	51 kOhms, 1206, 0.25 W, ±1%	Chip resistor	Yageo	RC1206FR-0751KL
31	1	R9	130 kOhms, 0805, 0.125 W, ±5%	Chip resistor	Yageo	RC0805JR-07130KL
32	1	R10	270 kOhms, 0805, 0.125 W, ±1%	Chip resistor	Yageo	RC0805FR-07270KL
33	1	R11	220 Ohms, 0805, 0.125 W, ±5%	Chip resistor	Vishay	CRCW0805220RJNEA
34	1	R12	100 Ohms, 0805, 0.5 W, ±5%	Chip resistor	Panasonic	ERJ-P06J101V
35	1	R13	430 mOhms, 1206 , 0.5 W, ±1%	Chip resistor	Vishay	RCWE1206R430FKEA
36	1	R14	680 mOhms, 1206, 0.5 W	Chip resistor	Yageo	RL1206FR-7W0R68L
37	1	R16	15 KOhms, 1206, 0.25 W, ±5%	Chip resistor	Stackpole	RMCF1206JT15K0
38	1	R17	442 kOhms, 0603, 0.1 W, ±0.5%	Chip resistor	Yageo	RT0603DRE07442KL
39	1	R20	120 kOhms, 0603 , 0.063 W, ±0.5%	Chip resistor	Susumu	RR0816P-124-D
40	1	R18	20 kOhms, 0603, 0.1 W, ±5%	Chip resistor	Stackpole	RMCF0603JT20K0
41	1	R19	15 kOhms, 0603, 0.1 W, ±5%	Chip resistor	Stackpole	RMCF0603JG15K0
42	1	R22	1.5 kOhms, 0603, 0.1 W, ±5%	Chip resistor	Stackpole	RMCF0603JT1K50

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
43	1	R23	5.6 kOhms, 0805, 0.1 W, ±5%	Chip resistor	Stackpole	RMCF0603JT5K60
44	2	R24 R65	20 kOhms, 0603, 0.063 W, ± 0.5%	Chip resistors	Susumu	RR0816P-203-D
45	2	R21 R62	12 kOhms, 0603, 0.1 W, ±1%	Chip resistors	Stackpole	RMCF0603FT12K0
46	1	R25	620 kOhms, 0805 0.1 W, ±0.5%	Chip resistor	Stackpole	RC0603FR-07620KL
47	3	R26 R35 R38	100 kOhms, 0603, 0.1 W, ±5%	Chip resistors	Yageo	RC0603JR-07100KL
48	1	R27	8.25 kOhms, 0603, 0.2 W, ±0.1%	Chip resistor	Panasonic	ERJ-PB3B8251V
49	1	R30	1.27 kOhms, 0603, 0.2 W, ±0.1%	Chip resistor	Panasonic	ERJ-PB3B1271V
50	3	R28 R46 R34	10 kOhms, 0603, 0.1 W, ±5%	Chip resistors	Stackpole	RMCF0603JT10K0
51	1	R29	68 kOhms, 0603, 0.1 W, ±0.5%	Chip resistor	Yageo	RT0603DRE0768KL
52	1	R31	470 kOhms, 0805, 0.125 W, ±5%	Chip resistor	Stackpole	RMCF0805JT470K
53	1	R32	1 kOhms, 0805 , 0.125 W, ±5%	Chip resistor	TE Connectivity	CRG0805J1K0
54	1	R33	56 kOhms, 0603 , 0.1 W, ±5%	Chip resistor	Panasonic	ERJ-3GEYJ563V
55	1	Q2A	MOSFET Power DPAK 800V 8A	N-channel 800 V, 0.55 Ω typ., 8 A MDmesh K5 Power MOSFET in DPAK package	ST	STD10LN80K5
56	1	R36	430 kOhms, 0603, 0.1 W, ±0.5%	Chip resistor	Yageo	RT0603DRD07430KL
57	1	R39	68 kOhms, 0603, 0.063 W, ±0.5%	Chip resistor	Susumu	RR0816P-683-D
58	3	R40 R37 R42	470 kOhms, 0603, 0.1 W, ±5%	Chip resistors	Yageo	RC0603JR-07470KL
59	1	R43	330 Ohms, 0603, 0.1 W, ±5%	Chip resistor	Bourns	CR0603-JW-331ELF
60	1	R44	330 kOhm, 0603, 0.1 W, ±5%	Chip resistor	Stackpole	RMCF0603JT330K
61	2	R57 R59	0 Ohms, 0603, 0.1 W	Chip resistors	Yageo	RC0603JR-070RL
62	1	R58	47 kOhms, 0603, 0.1 W ±5%	Chip resistor	Panasonic	ERJ-3GEYJ473V
63	0	R61	0603	Resistor (not mounted)		
64	1	R63	100 kOhms, 0805, 0.125 W, ±5%	Chip resistor	Yageo	RC0805JR-07100KL

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
65	1	R66	4.3 kOhms, 0603, 0.1 W, ±5%	Chip resistor	Yageo	RC0603JR-074K3L
66	0	R67	0603	Resistor (not mounted)		
67	6	D1 D9 D11 D12 D13 D14	SOD323	General purpose diodes	Vishay	1N4148WS-E3-08
68	1	D4	SMB 330 V 482 V	TVS diode	Micro Commercial Co.	SMBJP6KE350AL-TP
69	S	D5	D2PACK 300 V 8 A	Ultra-fast diode	ST	STTH803G-TR
70	1	D6	SMA 800 V 1 A	Ultra-fast diode	ST	STTH108A
71	1	D10	SMA 100 V 1 A	Power Schottky rectifier	ST	STPS1H100A
72	2	D7 D2	SOD123 200 V 0.25 A	General purpose diodes	Vishay	BAV21W-HE3-08
73	1	D3	SOD323 18 V 0.2 W	Zener diode	Vishay	BZX384C18-HE3-08
74	1	D15	SOD323 6.8 V 0.3 W	Zener diode	On Semiconductors	MM3Z6V8T1G
75	1	D8	SMC 100 V 3 A	Diode	Vishay	RS3B-E3/57T
76	1	BR1	4-SIP, KBP 800 V 2 A	Bridge rectifier	Vishay	VS-2KBP08
77	1	Q1	NPN 60 V 1 A/ 1.25 W SOT-89 BCX55	Transistor	Nexperia	BCX55-16TF
78	1	Q2	TO220FP 800 V 8 A	Power MOSFET (not mounted)	ST	STF10LN80K5
79	4	Q3 Q5 Q10 Q11	NPN 80 V 0.5 A SOT23 MMBTA06	Transistor	On Semiconductors	MMBTA06LT3G
80	1	Q4	SOT23 60 V 0.115 A	N-Channel power MOSFET	Infineon	2N7002H6327XTSA2
81	2	Q6 Q7	NPN SOT23 45 V 0.5 A	Transistor	Taiwan Semiconductor	BC817-25 RF
82	1	U2	Op-Amp SOT23 36 V	Adjustable micro-power shunt voltage reference	ST	TL431ACL3T
83	1	U3	4-SMD, Gull Wing 5kV	Optoisolator	Vishay	TCLT1007
84	1	U4	Op-Amp SO8	Low consumption voltage and current controller for battery chargers and adapters	ST	TSM1012IDT

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
85	1	U7	HVLED001B SSOP10	High power factor flyback controller with constant voltage primary sensing and ultra-low standby consumption	ST	HVLED001BTR
86	1	U8	LDO DPACK	Very low drop voltage regulator with inhibit	ST	LF33ABDT-TR
87	1	U9	SOT23-5	Micro-power, 16 V CMOS Op-Amp, single, GBP 900kHz	ST	TSX561ILT
88	2	RV1 RV2	470 V 1.2 KA Ø 9xp5	Varistor	TDK EPCOS	B72207S0301K101
89	1	L1	47 MH 450 MA 2LN TH 21.5x21.1x13.5	Line filter	TDK EPCOS	B82731T2451A020
90	1	F1	250 V/1 A Ø 8.5xp5 250 V 1 A	Fuse	Littelfuse	38211000000
91	1	T1	31.4x38.2x25.6	High frequecy transformer	Itacoil	TSLER2834001
92	2	J1 J2	2 pin - 5.08 mm	Connectors	Wurth Electronik	691311500102
93	0	J12	4 pin - 3.5 mm	Header (not mounted)	Any	Any
94	1	J14	TH 2.54mm	4-pole socket connector	Fischer	BL5.36Z
95	4		L 9.5xØ 4.4	Board support resting mount	Essentra Components	PST-6-01
96	11	TP1 TP2 TP3 TP4 TP5 TP6 TP7 TP8 TP10 TP11 TP12	TH Ø 1	Red test points	KEYSTONE	5000
97	2	TP9 TP13	TH Ø 1	Black test points	KEYSTONE	5001

Table 2. Connectivity board bill of materials

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
1	1	C1	10 nF, 0805 (2012 Metric), 50 V, X7R	Ceramic capacitor	Yageo	CC0805KRX7R9BB103
2	1	C2	0805 (2012 Metric), SMD	Ceramic capacitor (not mounted)	Any	Any
3	1	C3	2.2µF ±10% 50 V (2012 Metric), X7R, 0805	Ceramic capacitor	Yageo	CC0805KKX7R9BB225
4	1	C4	100 nF, 0805 (2012 Metric), ±10% 50 V, X7R 0805	Ceramic capacitor	Yageo	CC0805KRX7R9BB104

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
5	1	D1	Radial TH, 2.1 V, 569 nm	Green LED	Lite ON	LTL-4232N
6	1	D2	SC-90, SOD-323F, 75 V, 150 mA,	General purpose diode	Fairchild/ON Semiconductor	1N4148WS
7	1	J1	10 p, 12.65 mm x 5.10 mm	Connector header	CNC Tech	3220-10-0100-00
8	1	J2	con4-strip-male, TH, through-hole, right angle, 4-position 0.100" (2.54mm)	Connector header	Wurtz	61300411021
9	1	R1	47K, 0805 (2012 Metric), 0.125 W, ±1% 1/8 W 0805, SMD	Chip resistor	Yageo	RC0805FR-0747KL
10	4	R2 R3 R5 R7	10K, 0805 (2012 Metric), 0.125 W, ±1% 1/8 W 0805, SMD	Chip resistors	Yageo	RC0805FR-0710KL
11	1	R4	0805 (2012 Metric), 0.125 W, ±1% 1/8 W 0805, SMD	Chip resistor (not mounted)		
12	1	R6	470E, 0805 (2012 Metric), 0.125 W, ±1% 1/8 W 0805, SMD	Chip resistor	TE Connectivity	CRGCQ0805F470R
13	1	S1	SMT, 3.00 mm x 2.60 mm	Tactile switch	Würth Elektronik	435171014816
14	1	U1	20-SMD module, 2.4 GHz ~ 2.4835 GHz	Very low power application processor module for Bluetooth® low energy v5.2	ST	BLUENRG-M2SP

9 Conclusions

The test results shown demonstrate the good performances achieved by the STEVAL-LLL012V1.

The converter is stable and working in quasi-resonant mode for universal input voltage input with constant LED current. All the power components are well within the optimum range.

The board design is robust and reliable from an electrical point of view. The LED driver is well protected against open and short-circuit conditions.

The board is also compliant with the EMI normative limits applicable for lighting loads.

Revision history

Table 3. **Document revision history**

Date	Version	Changes
03-Mar-2021	1	Initial release.
17-May-2021	2	Updated Introduction.

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