How to use the STEVAL-BLUEPLUG1 evaluation board for home automation smart plugs

Introduction

The STEVAL-BLUEPLUG1 evaluation board for home-automation and IoT (internet of things) applications is designed to help you develop your own home or building automation subsystems for energy management, in a small form factor solution for easy integration into home and building electrical systems.

The board is compliant with Bluetooth Low Energy (BLE) specification 4.2 to allow secure communication of metering data from specific electrical loads to a smart phone with BLE support.

You can use an Android application for your smart phone to display energy measurement parameters and send dimming and scheduling commands to the Smart Plug board.

This board embeds an STPM32 metering chip for high accuracy measurement of power and energy in power line systems using shunt current sensors, and a non-isolated buck converter supply based on the VIPER06Xs. A three-terminal TRIAC controls the current through AC switching.

You can also interface the board with NFC enabled EEPROM via a dedicated connector.

Figure 1. STEVAL-BLUEPLUG1 evaluation board - top and bottom
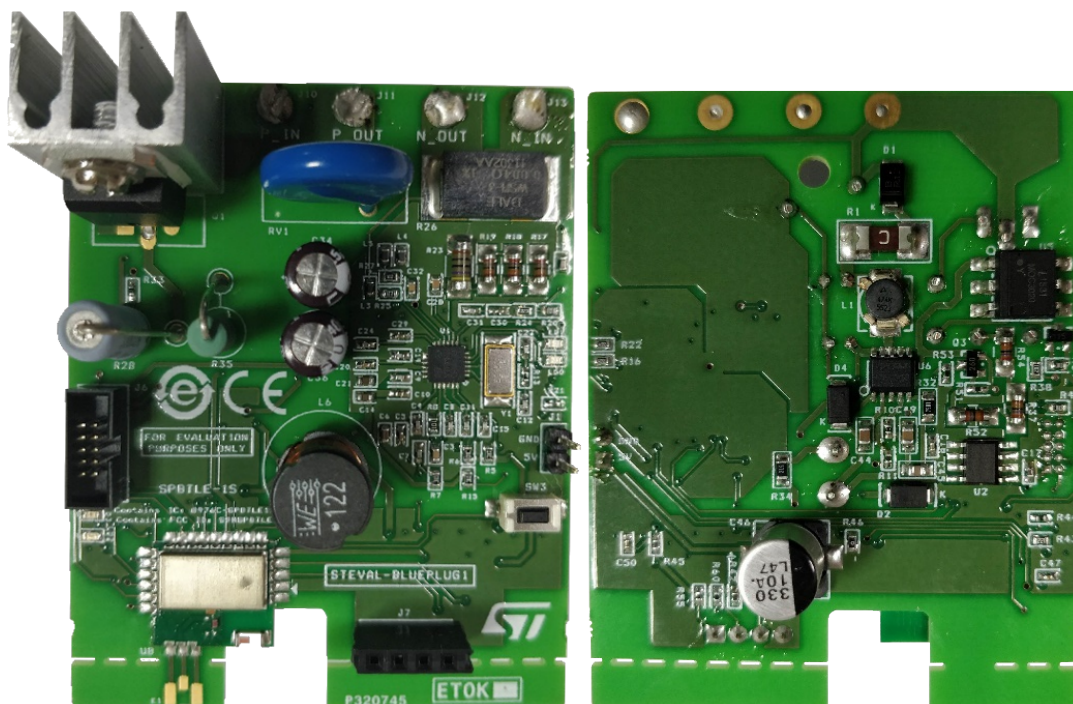
1   Safety information

FCC notices

Note: *ST reference designs and evaluation boards are intended to help and facilitate development of products. Using a direct copy of any of them does not waive the requirement for testing and certification of products mandated by governing agencies and authorities.*

This device compiles with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference
2. This device must accept any interference received, including interference that may cause undesired operation.

Electrical safety

Danger:

Due to the high voltage present on the non-isolated components, special care must be taken to avoid the risk of electric shocks and burns.

There are no protections against accidental human contact with high voltage components.

Never touch live board components when the board is connected or immediately after the board is disconnected, as the capacitors may still be charged.

Do not connect probes to any high voltage components if the board is not isolated from the mains supply, as this may cause damage to equipment.

1. The board must be used only by qualified persons.
2. De-energize the board and all its interface outputs and electrical loads before performing any electrical or diagnostic operations.
3. Only program and debug the board with the isolated JTAG in-circuit debugger/programmer to avoid damaging the tools.
4. Use a mains insulation transformer when you perform any tests with spectrum analyzers or oscilloscopes.

Note: *STMicroelectronics assumes no responsibility for accidents or injury caused by improper use of this development tool.*

Personal safety

1. Wear personal protective equipment such as latex gloves or safety glasses with side shields, or protect the EVM in an adequate lucent plastic box with interlocks from accidental touch.

2 Overview

2.1 Features

- Smart Energy Meter design with wireless connectivity
- BLE (Bluetooth Low Energy) v4.2 connectivity for control and metering panel: Smart-phone connectivity for energy consumption dashboard, control of appliances
- Dimming: Some loads can be controlled. For example, AC Induction fan speed, Heaters, Incandescent lamps
- Scheduling: Set the time of day for ON or OFF of the load
- NFC interface: To configure the design, store the logs (connector for adapter board)
- Rated voltage: 240 VAC (typ.)
- Rated current: 12 A (typ.)
- Power consumption of plug: 1.6 W (max.)
- Instantaneous and averaged power
- RMS and instantaneous voltage and current
- Radio certifications:
    - FCC certified: S9NSPBTLE1S
    - IC certified: 8976C-SPBTLE1S
- CE certified
- RoHS and China RoHS compliant

2.2 Typical applications

- Control and monitoring of energy parameters using BLE.
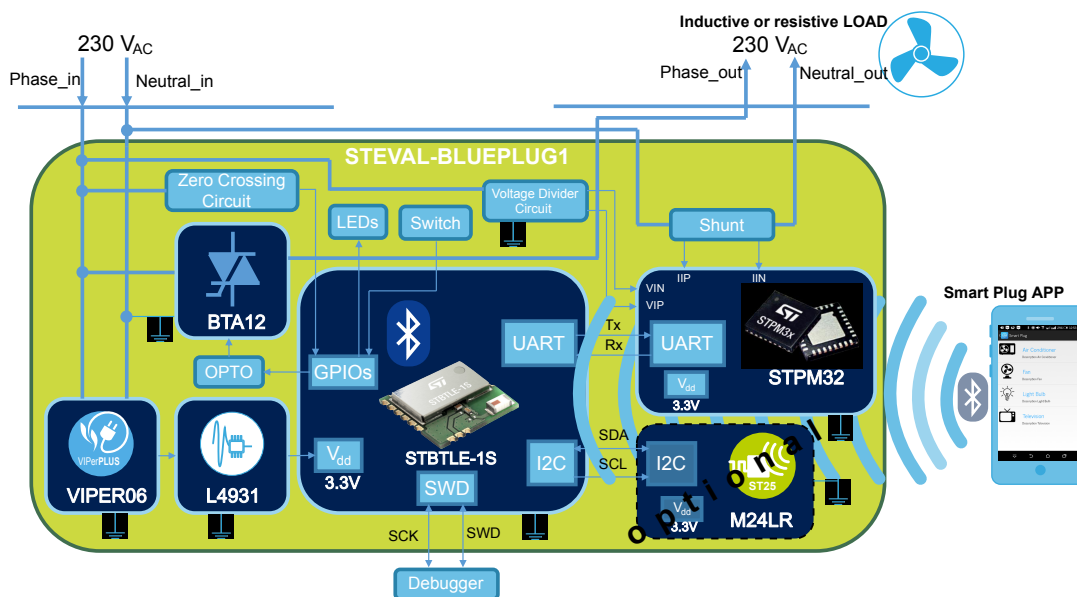- Smart metering
- Home automation
- Smart lighting

2.3 Board architecture

Figure 2. STEVAL-BLUEPLUG1 featured components
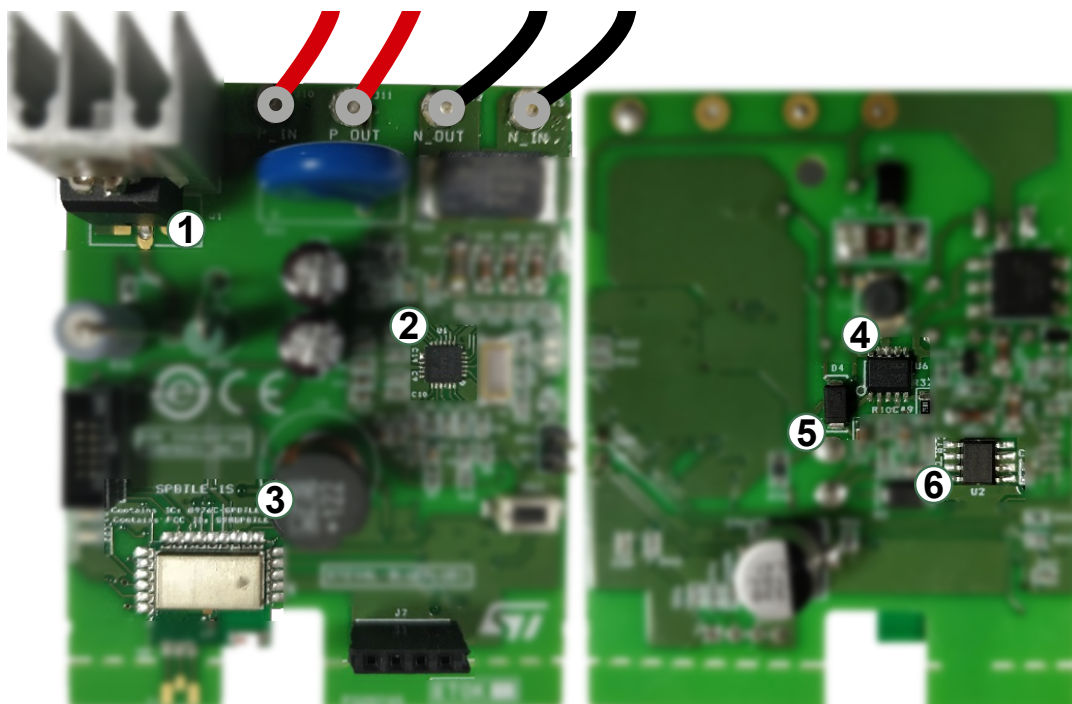
1. BTA12-800BWRG (12 A TRIAC)
2. STPM32 (IC for metering applications)
3. SPBTLE-1S (Bluetooth Low Energy v4.2 module)
4. VIPER06 (30 KHz offline converter)
5. STTH110RL (High voltage ultrafast rectifier)
6. L4931 (very low drop voltage regulator)

Figure 3. STEVAL-BLUEPLUG1 block diagram

The mains supply and loads are monitored by the STPM32 standard metering IC, while the SPBTLE-1S Bluetooth Low Energy module handles data and command interfacing for the Smart Plug Android app developed for the board, and can store data via the EEPROM connector.

The 12 A TRIAC acts as a switch for the load and phase controller for dimming.

The supplies for the ICs are regulated from the VIPER06 buck converter output.

The board includes a manual switch to turn the load on and off, and LEDs to signal connectivity status.

2.4 Zero crossing detector circuit

A zero crossing circuit is an electrical circuit that begins operation with the AC load voltage at close to 0 V in the AC cycle. Zero crossing detection is used for the dimming reference point to fire the TRIAC accordingly.

The circuit has three resistors connected to phase of the AC line to lower the resultant voltage and a resistor on the base of a PNP transistor which acts as a pull up resistor: when the voltage at the base drops below the base operating voltage, the transistor switches to output LOW.

Figure 4. Zero crossing detector circuit
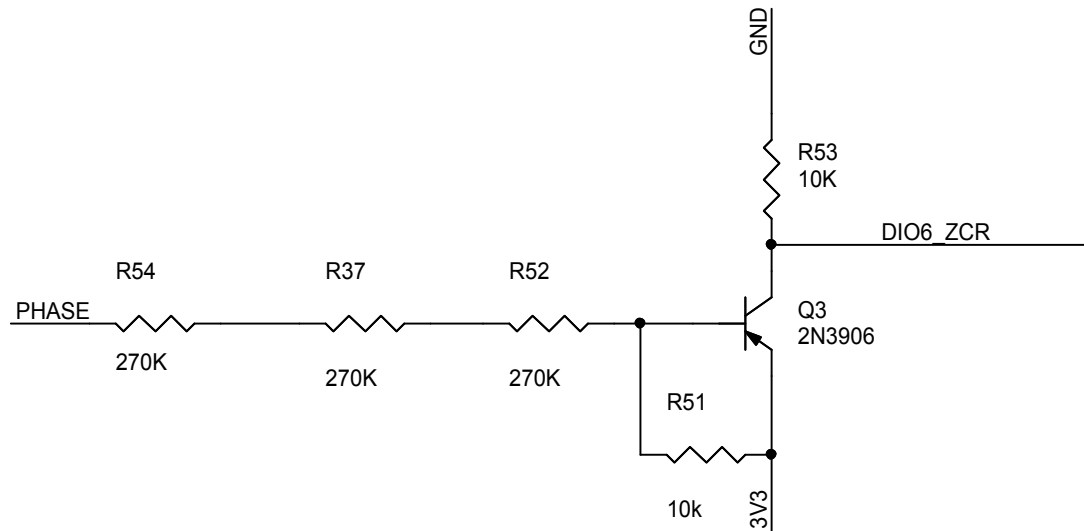
The purpose of the circuit in our design is to start the TRIAC conducting very near the moment when the load voltage crosses zero volts (at the beginning or the middle of each AC cycle represented by a sine wave), so that the output voltage can be modified by changing the firing angle of TRIAC, which in turn will change the required output waveform.
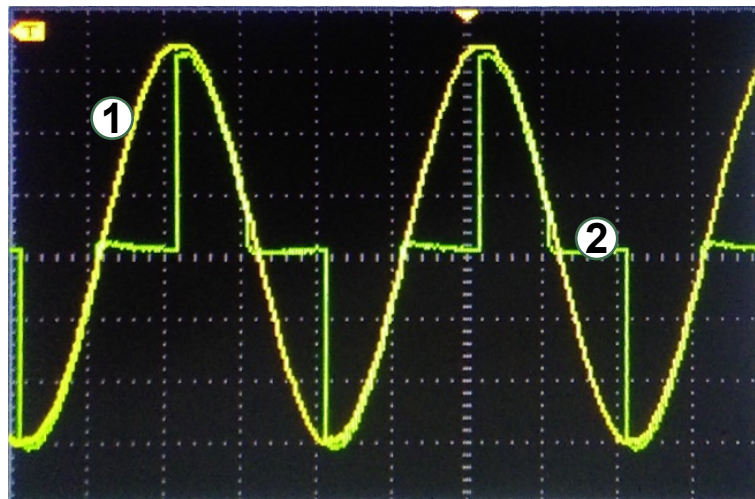
Figure 5. Zero crossing detection with oscilloscope
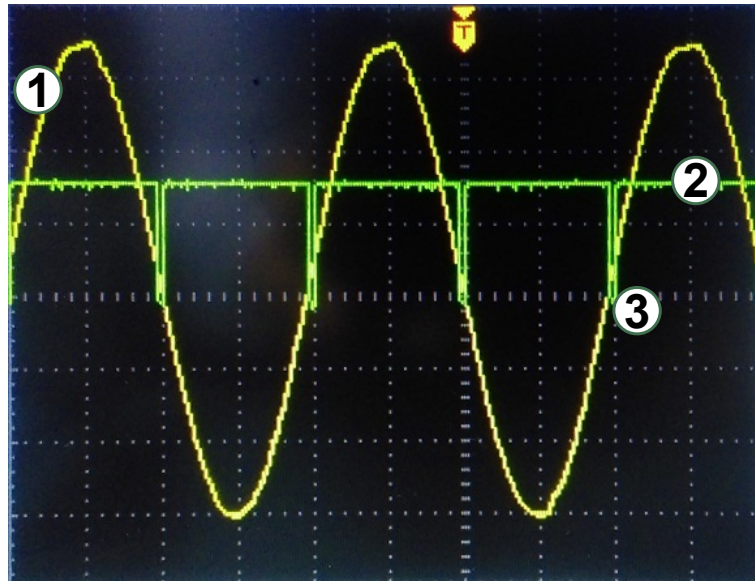
Note: 1.   AC voltage
        2.   Output of the transistor
        3.   Output of the transistor goes low as ac voltage approaches zero

Figure 6. AC at 50% phase

Note: 1.   AC voltage
        2.   TRIAC Output at 50% duty cycle

2.5   Power supply

For power supply, a non-isolated Buck converter using the VIPER06Xs offline converter is used, with PWM operation at 30 kHz and frequency jittering for lower EMI. Standby power is very low, at < 30 mW.

This type of supply is ideal for the Smart Plug application, where large currents are not required, but a small form factor is necessary.

Figure 7. Non-isolated buck converter
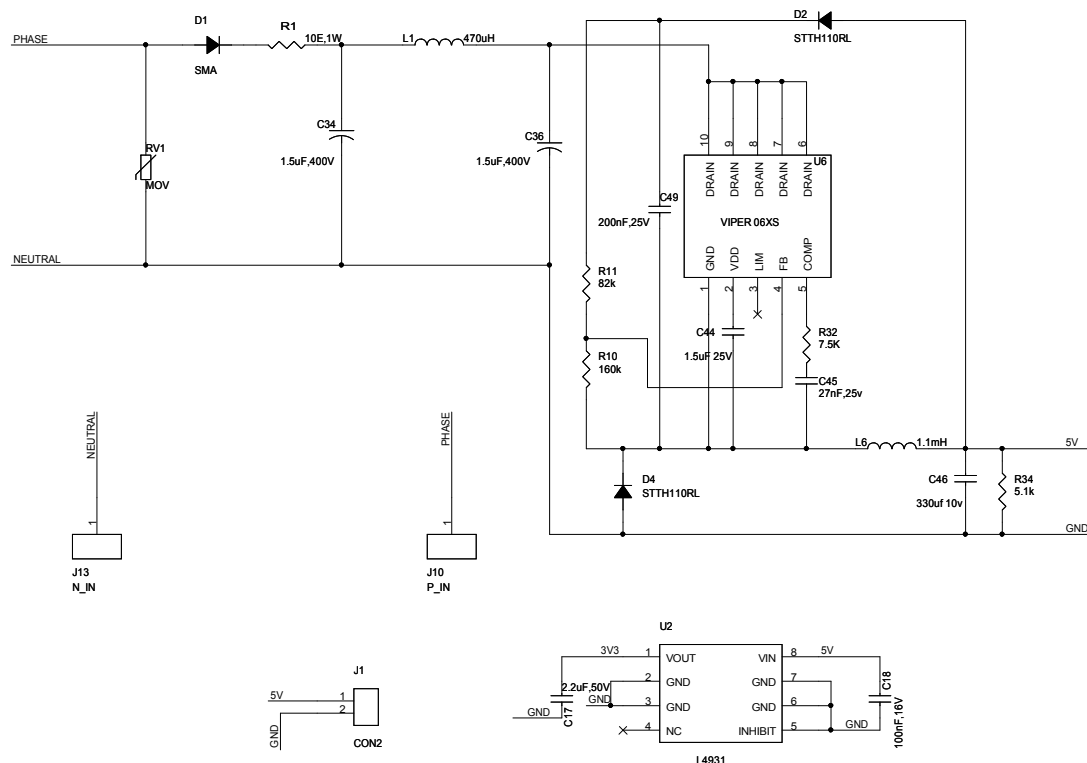
DO NOT MOUNT J10, J13

REGULATOR

The output of supply is set to 4.3 V, which is further regulated by the L4931 LDO to 3.3 V and 500 mA, to power all the analog and digital sections.

3   Set up the board and connect with the Android app

Warning:

*Before performing this task, please review all the safety procedures and precautions associated
with high voltage electrical circuits, and prepare the necessary protection equipment.*

Use the procedure below to set up the board.

Step 1.   On the evaluation board, connect the input mains and output load connectors.
Input mains connectors:
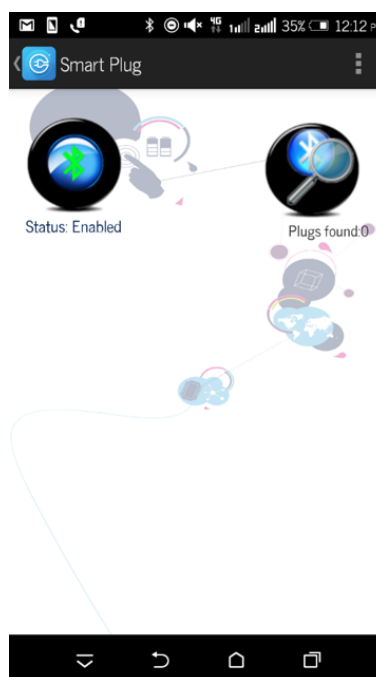–   P_IN (J10)
–   N_IN (J13)

Load connectors:
–   P_OUT (J11)
–   N_OUT (J12)

Figure 8. Phase (P) and neutral (N) input (IN) and output (OUT) connectors
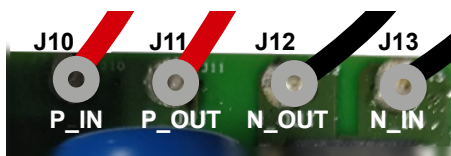
Step 2.   After powering up the board, RED LED (LD3) will indicate that the board is turned ON.

Step 3.   Install the `SmartPlug.apk` Android app from the release package and launch it.

Figure 9. Smart Plug launch screen

Step 4.   Search for the device on your smart phone by selecting the [**Plugs found**] icon.

Step 5.   Connect the device to the App by selecting the Smart_Plug_NRG1 device.
Once connected with the board, the BLUE LED (LD2) will blink at the frequency of 2 Hz.

3.1 Control a load with the device

Follow the instructions below to control a load with the STEVAL-BLUEPLUG1 board and the Smart Plug app.

Step 1. Connect the board to a mains supply and a load, such as a light bulb.

**Step 2.** Select the load type; i.e., [**Light Bulb**] for this example.

Figure 10. Smart Plug - load type panel
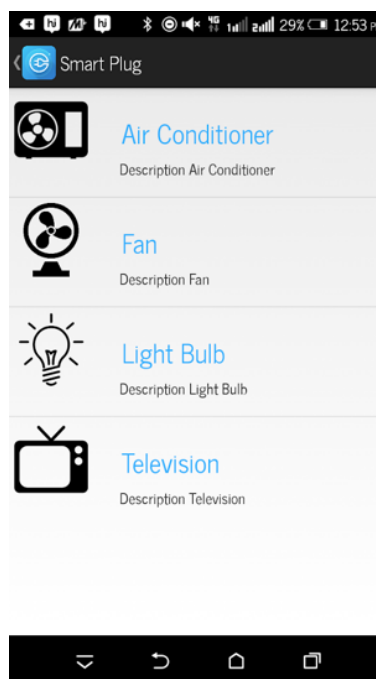
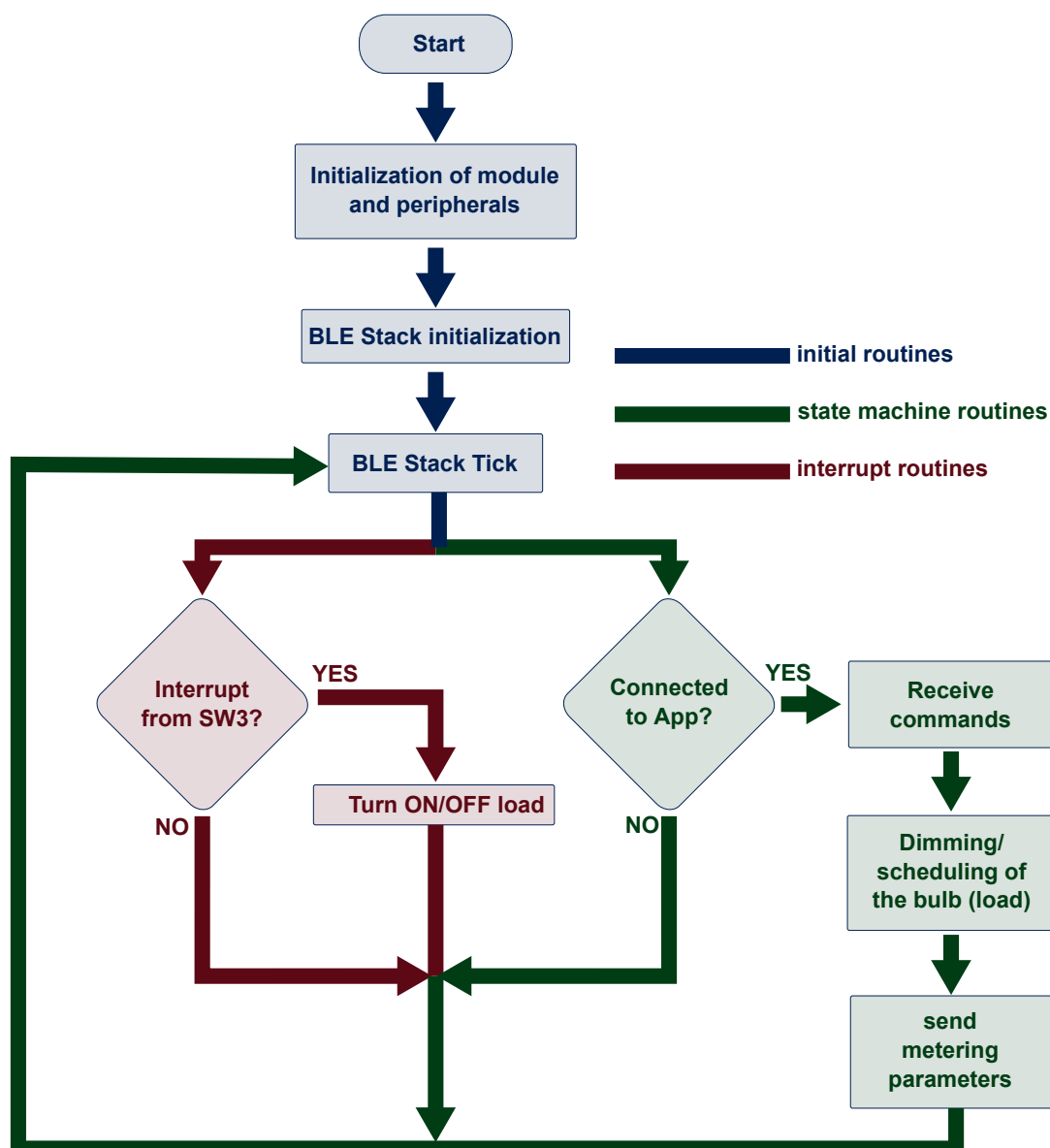**Step 3.** Control the light bulb and view the parameters in the load control panel.
– select the bulb image to turn it on or off
– use the slider to control dimming

Note: *LED lights are not particularly suitable to evaluate the dimming function.*

Figure 11. Smart Plug - load control panel
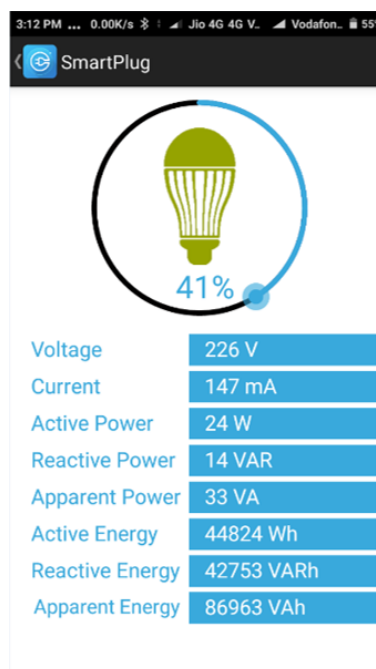
4 State machine

**Figure 12. State machine**

The following events occur in the state machine figured above:

1. The peripherals are initialized, including:
    – USART for STPM
    – the timer for firing the TRIAC
    – I2C for the NFC/RFID EEPROM
    – GPIOs and System Clock.
2. In the RUN state, the API constantly checks for data packets from the BLE device.
3. Metering interrupts are performed at 1 Hz, and the data is sent to the BLE device, according to the user settings.
4. An interrupt updates the data packet.
5. The TRIAC is fired according to the data packet.

5 Schematic diagrams

Figure 13. STEVAL-BLUEPLUG1 schematic - SPBTLE-1S

Figure 14. STEVAL-BLUEPLUG1 schematic - STPM32

Figure 15. STEVAL-BLUEPLUG1 schematic - Viper power supply
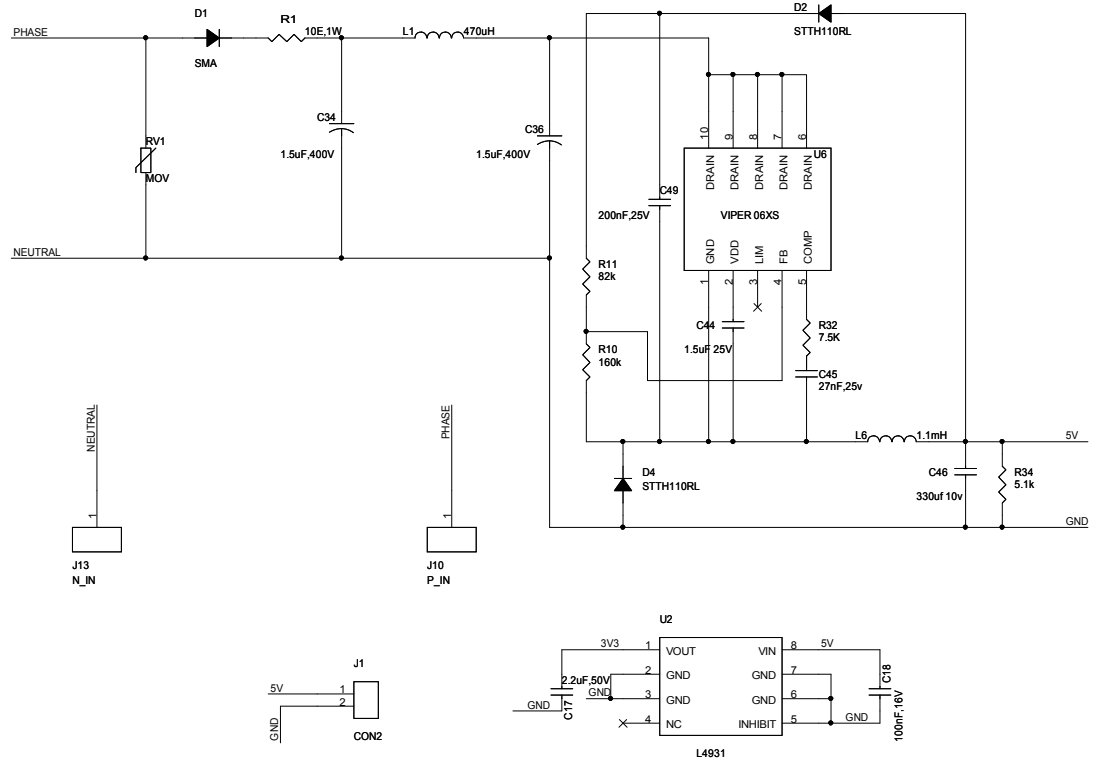
DO NOT MOUNT J10, J13

REGULATOR

Figure 16. STEVAL-BLUEPLUG1 schematic - Snubberless TRIAC section
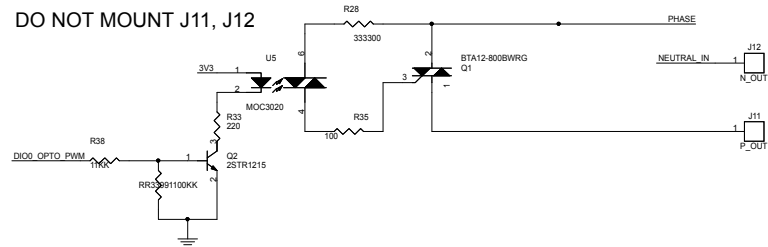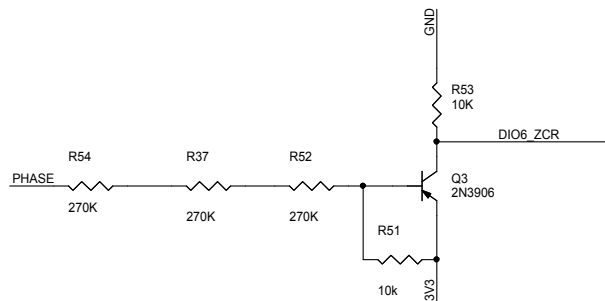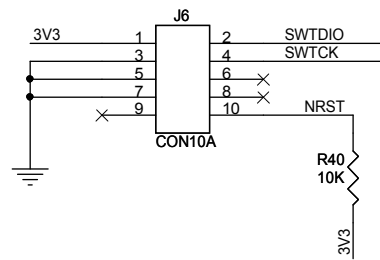

DO NOT MOUNT J11, J12

Figure 17. STEVAL-BLUEPLUG1 schematic - ZCD

Figure 18. STEVAL-BLUEPLUG1 schematic - SWD

Figure 19. STEVAL-BLUEPLUG1 schematic - M24LR dual EEPROM

6   Bill of materials

Table 1. STEVAL-BLUEPLUG1 bill of materials

Item	Qt.y	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	U1	-	ASSP for metering applications with up to four independent 24-bit 2nd order sigma-delta ADC	ST	STPM32TR
2	1	U2	-	Voltage Regulator	ST	L4931CD33-TR
3	1	U6	-	Energy saving 4W high voltage converter	ST	VIPER06XS
4	1	U8	-	Very low power module for Bluetooth Smart v4.2	ST	SPBTLE-1S
5	1	D2,D4	-	High voltage ultrafast rectifier diode	ST	STTH110RL
6	1	Q1	-	12 A standard and Snubberless™ TRIACS	ST	BTA12-800BWRG
7	1	Q2	40 V, 0.8 A	NPN bipolar transistor	ST	2STR1215
8	1	Q3	-	PNP bipolar transistor	ST	2STR2160
9	1	Y1	-	CRYSTAL 16.000 MHZ 20pF	ECS Inc.	ECS-160-20-23A-EN-TR
10	1	C3,C32	10nF 25V	CAP CER	Kemet	C0603C103F3GACTU
11	1	C4,C7,C8,C9, C11,C15,C19, C24,C31	150pF 50V ±5%	CAP CER	Taiyo Yuden	UMK105CG151JV-F
12	1	C5,C10,C18,C 20,C29,C30,C 47,C50	100nF 16V	CAP CER	Yageo	CC0402KRX7R7BB104
13	1	C14,C21	1µF 25V	CAP CER X5R 0603	Taiyo Yuden	TMK107BJ105KA-T
14	1	C34,C36	1.5µF 400V	Aluminum Capacitors Radial	Nichicon	ULD2G1R5MED1TD
15	1	C49	0.22µF 25V	CAP CER X7R 0805	Samsung Electro-Mechanics America, Inc.	CL21B224KAFNNNG
16	1	C12,C22	20pF 50V	CAP CER	Murata Electronics North America	GRM1555C1H200JA01D
17	1	C17	2.2µF 35V	CAP CER X5R 0402	TDK Corporation	C1005X5R1V225K050BC
18	1	C44	1.5µF 25V	CAP CER X7R 0805	TDK Corporation	C2012X7R1E155M125AC
19	1	C45	0.027µF 25V	CAP CER X8R 0805	Kemet	C0805C273K3HACTU
20	1	C28	22nF 25V	CAP CER	Kemet	C0603C223J3RACTU

Item	Qt.y	Ref.	Part/Value	Description	Manufacturer	Order code
21	1	C46	330µF 10V ±20%	CAP ALUM SMD	Nichicon	UUR1A331MNL1GS
22	1	C6	4.7uF 25V ±10%	Multilayer Ceramic Capacitors MLCC - SMD/SMT 0603 X5R	Murata Electronics	GRM188R61E475KE11D
23	1	D1	2KV 1A	DIODE GEN PURP 2KV 1A	Bourns Inc.	CD214A-R12000
24	1	LD0,LD3	-	LED RED CLEAR	Lite-On Inc.	LTST-C191KRKT
25	1	LD2	-	LED BLUE CLEAR	Vishay Semiconductor Opto Division	VLMB1310-GS08
26	1	LD1	-	LED GREEN CLEAR	Lite-On Inc.	LTST-C191KGKT
27	1	RV1	470V 6KA DISC 14MM	VARISTOR	EPCOS (TDK)	B72214P2301K101
28	1	R5,R6,R7,R15,R39,R40,R45	10K Ω 1/10W ±1%	RES	Vishay Dale	RCG060310K0FKEA
29	1	R8,R20, R35	100 Ω 3 W ±5%	RES	Yageo	PNP300JR-73-100R
30	1	R1	-	Fuse Resistor	LittelFuse	650-2410SFV050FM1252
31	1	R13	1.0M Ω 1/10W ±1%	RES	KOA Speer	RK73H1ETTP1004F
32	1	R11	82K Ω 1/16W ±5%	RES SMD 0402	Yageo	RC0402JR-0782KL
33	1	R32	7.5K Ω 1/4W	RES SMD 0805 WIDE	RΩ Semiconductor	LTR10EZPJ752
34	1	R10	160K Ω 1/16W ±1%	RES SMD 0402	Yageo	RC0402FR-07160KL
35	1	R55,R60	4.7K Ω 1/5W ±5%	RES SMD	Yageo Dale	RCS04024K70JNED
36	1	R17,R18,R19,R37,R52,R54	270K	miniMELF resistor	Vishay Beyschlag	MMA02040C2703FB300
37	1	R21, R42	0.0 Ω	RES	Yageo	RC0402JR-070RL
38	1	R23	470 Ω ±1% 1W	SMD 0207	Vishay Beyschlag	MMB02070C4700FB200
39	1	R24	22K Ω 1/10W ±5%	RES SMD 0603	Panasonic Electronic Components	ERJ-3GEYJ223V
40	1	R25,R27,R38	RES 1K Ω 1% 1/10W	RES	Yageo	RC0603FR-071KL
41	1	R26	0.004 Ω 3W ±1%	RES SMD 4527	Vishay Dale	WSR34L000FEA
42	1	R28	330 Ω ±5%	RES SMD	Panasonic Electronic Components	ERG-3SJ331
43	1	R33,R43,R44	220 Ω 1/10W ±5%	RES SMD	Panasonic Electronic Components	ERJ-2GEJ221X
44	1	R34	5K Ω 0.15W ±0.1%	RES SMD 0603	Vishay Thin Film	PNM0603E5001BST5

Item	Qt.y	Ref.	Part/Value	Description	Manufacturer	Order code
45	1	R51,R53	10K Ω 1% 1/16W	RES SMD 0402	Yageo	RC0402JR-0710KL
46	1	R16,R22	4.7K Ω 5% 1/4W	RES SMD	RΩ Semiconductor	ESR03EZPJ472
47	1	R46	0.0Ω 1/10W	RES SMD JUMPER 0603	Yageo	RC0603JR-070RL
48	1	L1	470µH 170MA 5.6 Ω	FIXED IND	EPCOS (TDK)	B82462A4474K000
49	1	L2,L3,L4,L5	1.5 KΩ	FERRITE BEAD 0603 1LN	TDK Corporation	MMZ1608Y152BTA00
50	1	L6	1.2MH	FIXED	WURTHZ	-
51	1	SW3	-	SWITCH TACTILE SPST-NO 0.05A 12V	Panasonic Electronic Components	EVQ-5PN04K
52	1	J1	-	2 PIN CONNECTOR 2.54MM	Harwin Inc.	M20-9990246
53	1	J10 , J11 , J12 , J13	-	1 PIN CONNECTOR for external Supply, 2.54mm Pitch	Not mounted	-
54	1	J6	-	10 Positions Header Connector 0.050" (1.27mm) Through Hole Gold	CNC Tech	3220-10-0100-00
55	1	J7	-	4 PIN CONNECTOR 2.54MM	Amphenol FCI	68002-404HLF
56	1	U5	-	Photocoupler TRIAC Driver Output	Lite-On Inc	MOC3020S
57	1	Heat Sink for Q1	-	Dimension is H*W*D is 20*16*12 (mm)	-	-
58	1	E1	-	Do not mount	Not mounted	-

Revision history

Table 2. Document revision history

Date	Version	Changes
02-May-2018	1	Initial release.

Contents

List of figures

List of tables

IMPORTANT NOTICE – PLEASE READ CAREFULLY