How to use the STDES-BLUEPLUG2 reference design for home automation smart plugs

Introduction

The STDES-BLUEPLUG2 is a reference design for home-automation and Internet of Things (IoT) applications.

The on-board BLUENRG-M2SP is compliant with Bluetooth Low Energy (BLE) specification 5.2 to allow secure communication of metering data from specific electrical loads to a smart phone with BLE support.

It supports multiple roles simultaneously and can act at the same time as Bluetooth smart master and slave device.

The device current consumption on AC mains is 3 to 7 mA.

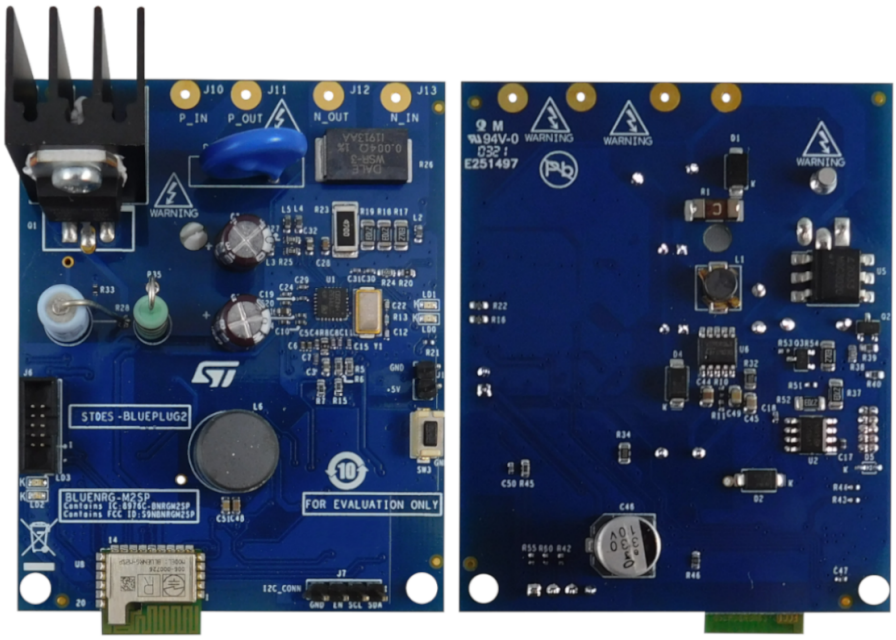
The device acts as BLE peripheral device which can be connected to any smart device using the Android ST BLE PLUG app (available for free download on Google Play) to control and monitor the load and its energy parameters.

The app features load ON/OFF turning, scheduling, dimming and metering parameters.

The STDES-BLUEPLUG2 embeds an STPM32 metering chip for high accuracy measurement of power and energy in power line systems using shunt current sensors, a three-terminal TRIAC which controls the current through AC switching for various electrical system applications, and a non-isolated buck converter supply based on the VIPER06XS. This type of supply is ideal for the applications (like ST BLE PLUG) where a large amount of current is not needed and a small form factor is required.

The STDES-BLUEPLUG2 is a fully assembled board developed for performance evaluation only, not available for sale.

Figure 1. STDES-BLUEPLUG2 reference design - top and bottom views



Fully assembled board developed for performance evaluation only, **not available for sale**

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

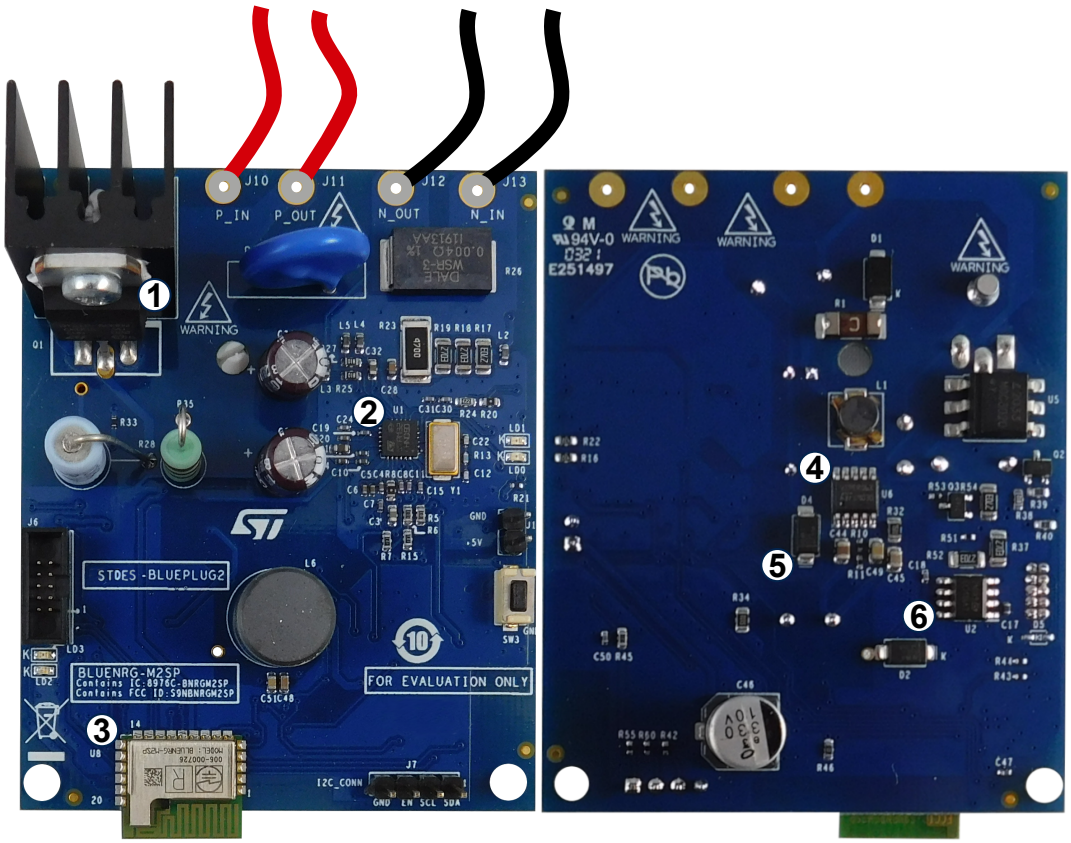
- Smart Energy Meter design with wireless connectivity
- BLE (Bluetooth Low Energy) v5.2 connectivity to:
  - control (turning ON/OFF)
  - display metering parameters
- NFC interface: to configure the design and store the logs
- Dimming of light for TRIAC dimmable load rated below 12 A
- Rated voltage: 240/120 V_{AC} (typ.)
- Rated current: 12 A (typ.)
- Power consumption of plug: 0.7 W (max.)
- Instantaneous and averaged power
- RMS and instantaneous voltage and current
- BLUENRG-M2SP module radio certifications:
  - FCC certification: S9NBNRGM2SP
  - IC certification: 8976C-BNRGM2SP

2.2 Typical applications

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

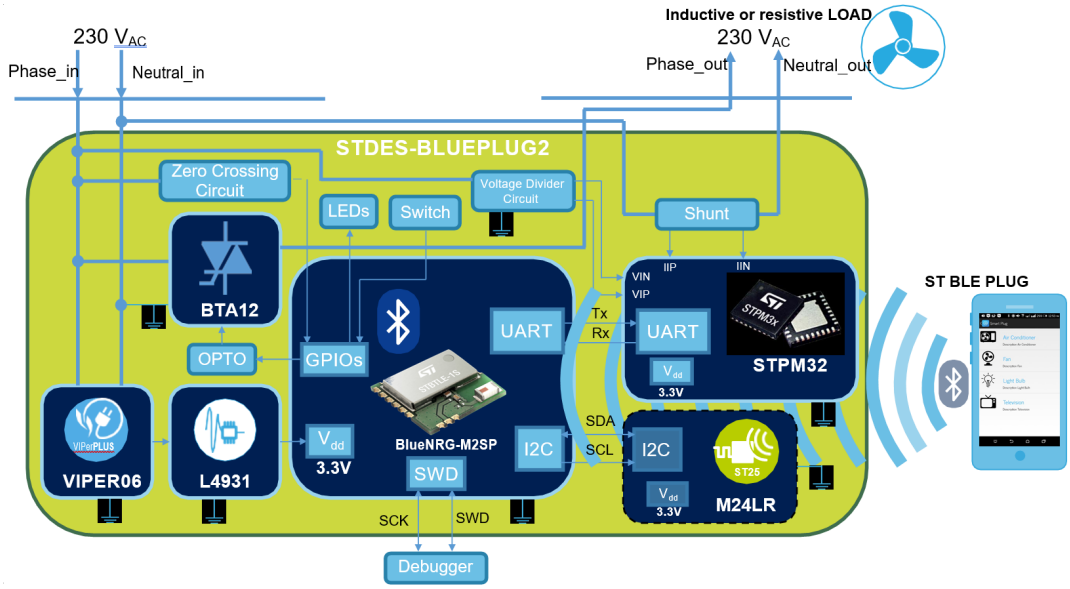
2.3 Board architecture

Figure 2. **STDES-BLUELUG2 featured components**



1. BTA12-800BWRG (12 A TRIAC)
2. STPM32TR (IC for metering applications)
3. BLUENRG-M2SP (Bluetooth Low Energy v5.2 module)
4. VIPER06XS (30 KHz offline converter)
5. STTH110RL (High voltage ultra-fast rectifier)
6. L4931 (very low drop voltage regulator)

Figure 3. **STDES-BLUEPLUG2 block diagram**



The mains supply and loads are monitored by the STPM32TR standard metering IC, while the BLUENRG-M2SP Bluetooth Low Energy module handles data and command interfacing for the ST BLE 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 VIPER06XS buck converter output.

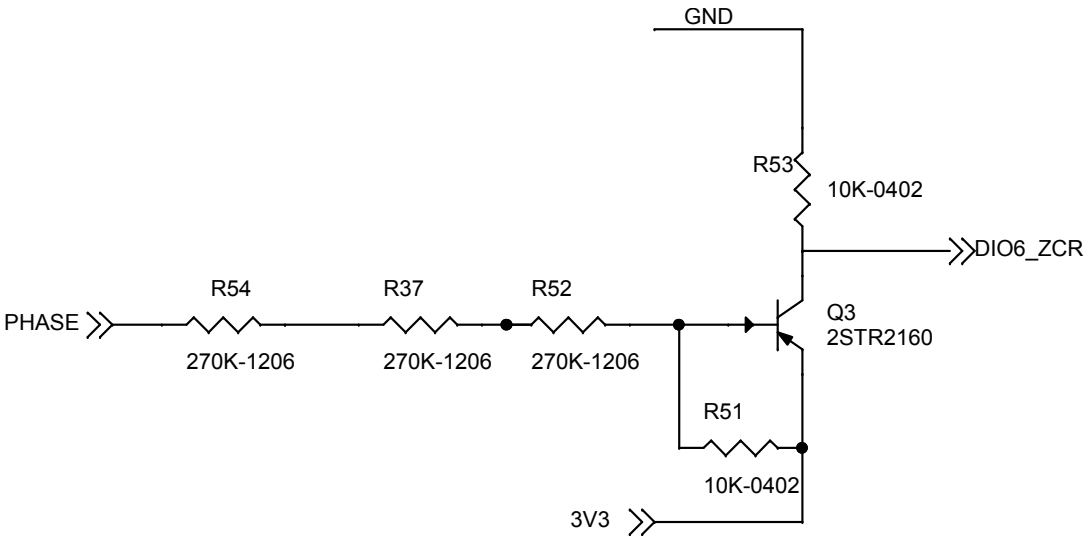
The board includes a manual switch to turn the load on and off, and LEDs to signal connectivity status.

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**

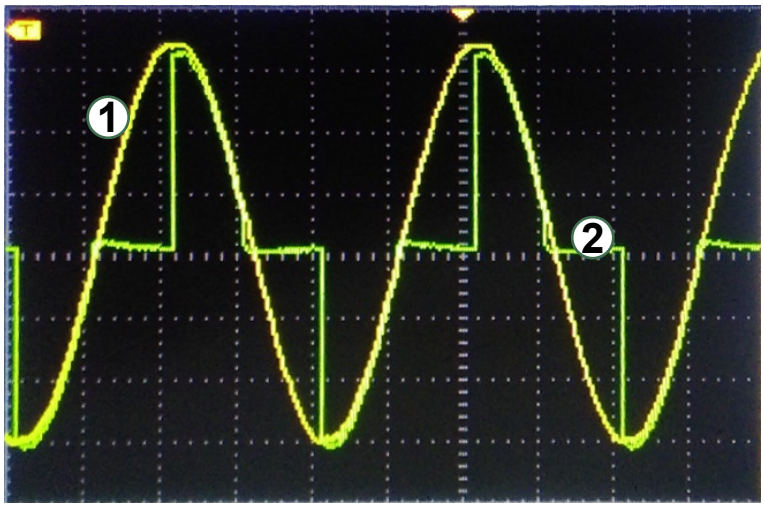


The purpose of the circuit in our design is to start the TRIAC conducting very near the moment when the load voltage crosses zero volts (at the beginning or the middle of each AC cycle represented by a sine wave), so that the output voltage can be modified by changing the firing angle of TRIAC, which 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



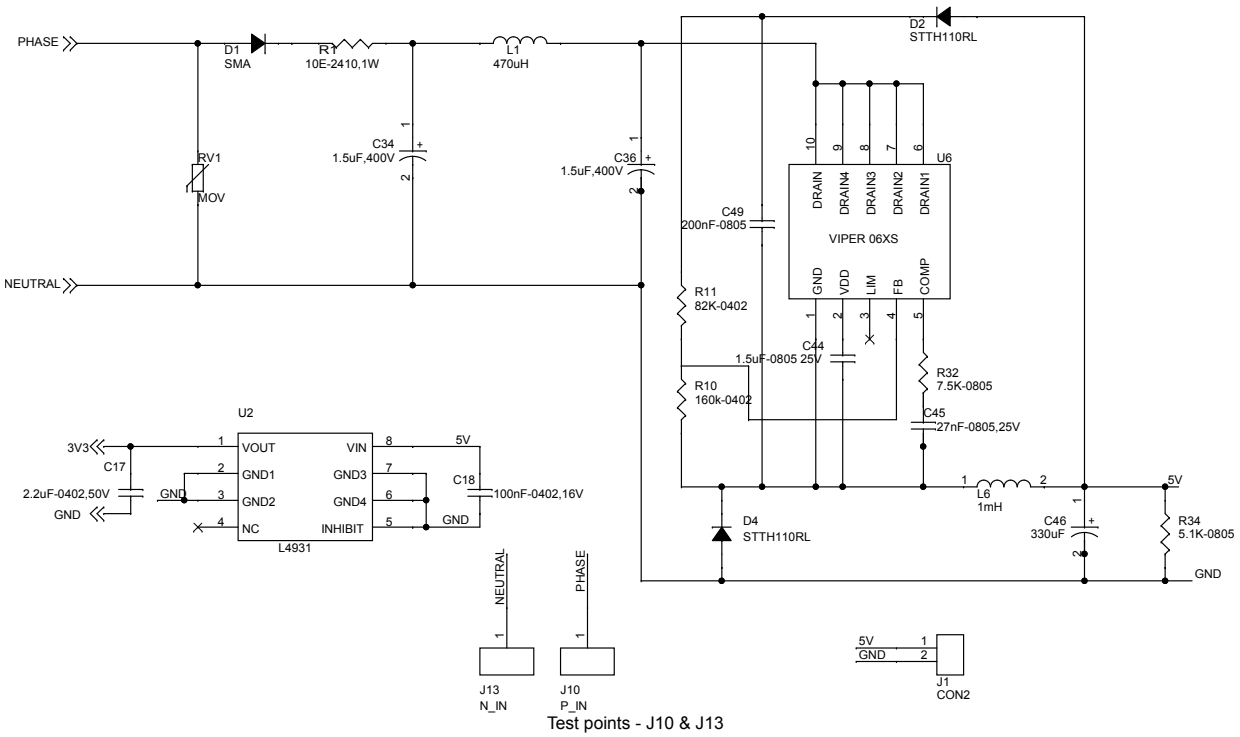
Note:
1. *AC voltage*
2. *TRIAC Output at 50% duty cycle*

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 ST BLE PLUG application, where large currents are not required, but a small form factor is necessary.

Figure 7. Non-isolated buck converter



Test points - J10 & J13

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.

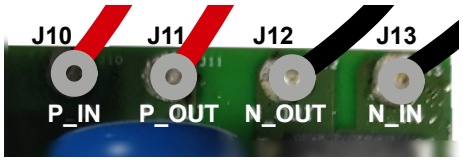
Input mains connectors:

– P_IN (J10)
– N_IN (J13)

Load connectors:

– P_OUT (J11)
– N_OUT (J12)

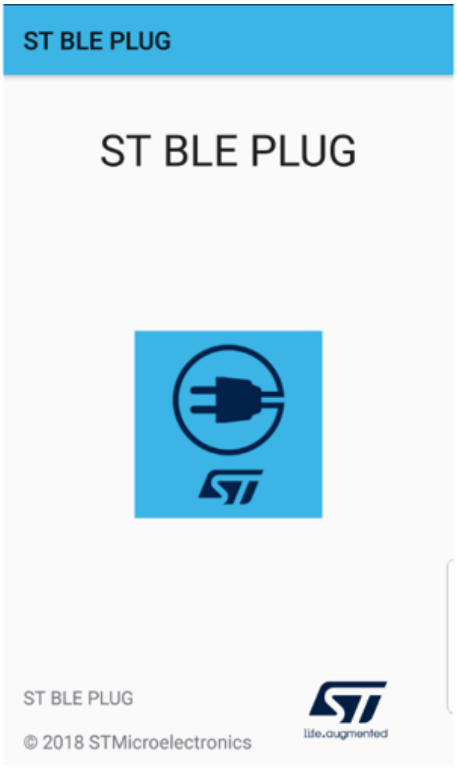
Figure 8. Phase (P) and neutral (N) input (IN) and output (OUT) connectors



Step 2. After powering up the board, RED LED (LD3) will indicate that the board is turned ON.

Step 3. Install the ST BLE PLUG 2.0 from Google Play store.

Figure 9. ST BLE PLUG launch screen



Step 4. Search for the device on your smart phone by selecting the [**Scan BLE Devices**] icon.

Step 5. Connect the devices to the App by selecting the STDES-BLUEPLUG2 device.

Figure 10. Connect the devices

Once connected with the board, the BLUE LED (LD2) will blink at the frequency of 2 Hz.

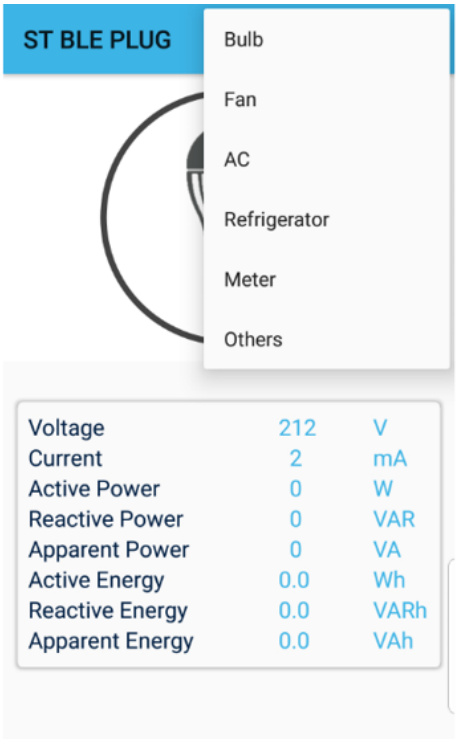
3.1 Control a load with the device

Follow the instructions below to control a load with the STDES-BLUEPLUG2 reference design and the ST BLE PLUG app.

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

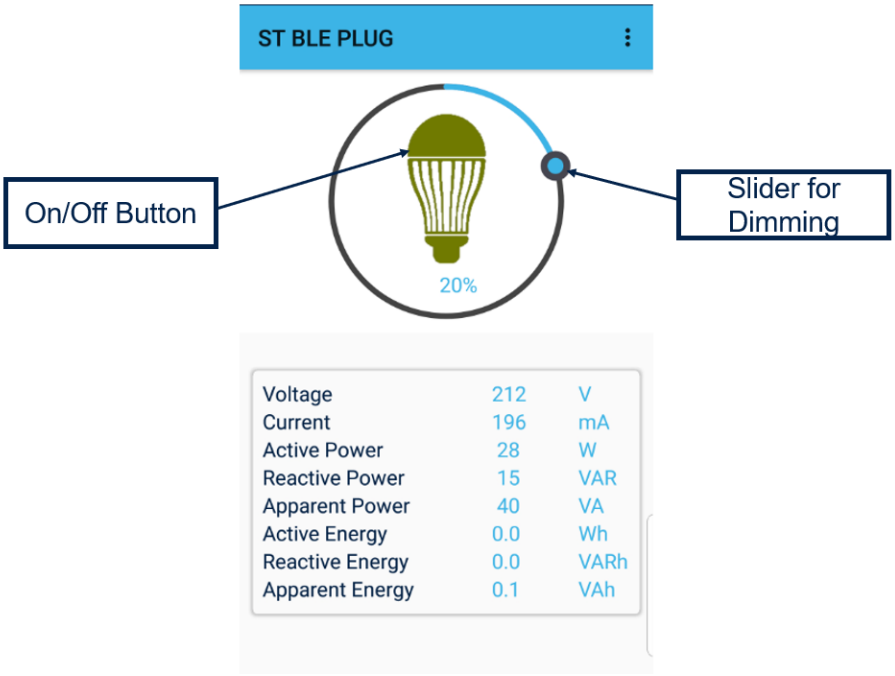
Step 2. Select the load type ([**Bulb**] for this example).

Figure 11. ST BLE PLUG - load type panel



Step 3. Control the light bulb and view the parameters in the load control panel.

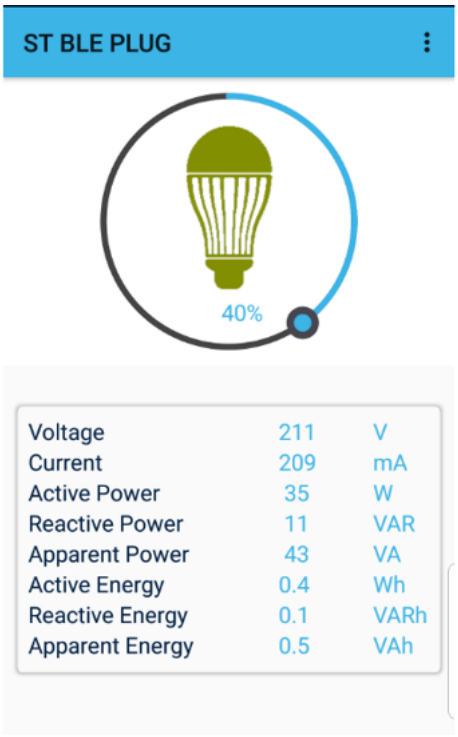
Figure 12. ST BLE PLUG - controlling the bulb



– Select the bulb image to turn it on or off
– Use the slider to control dimming

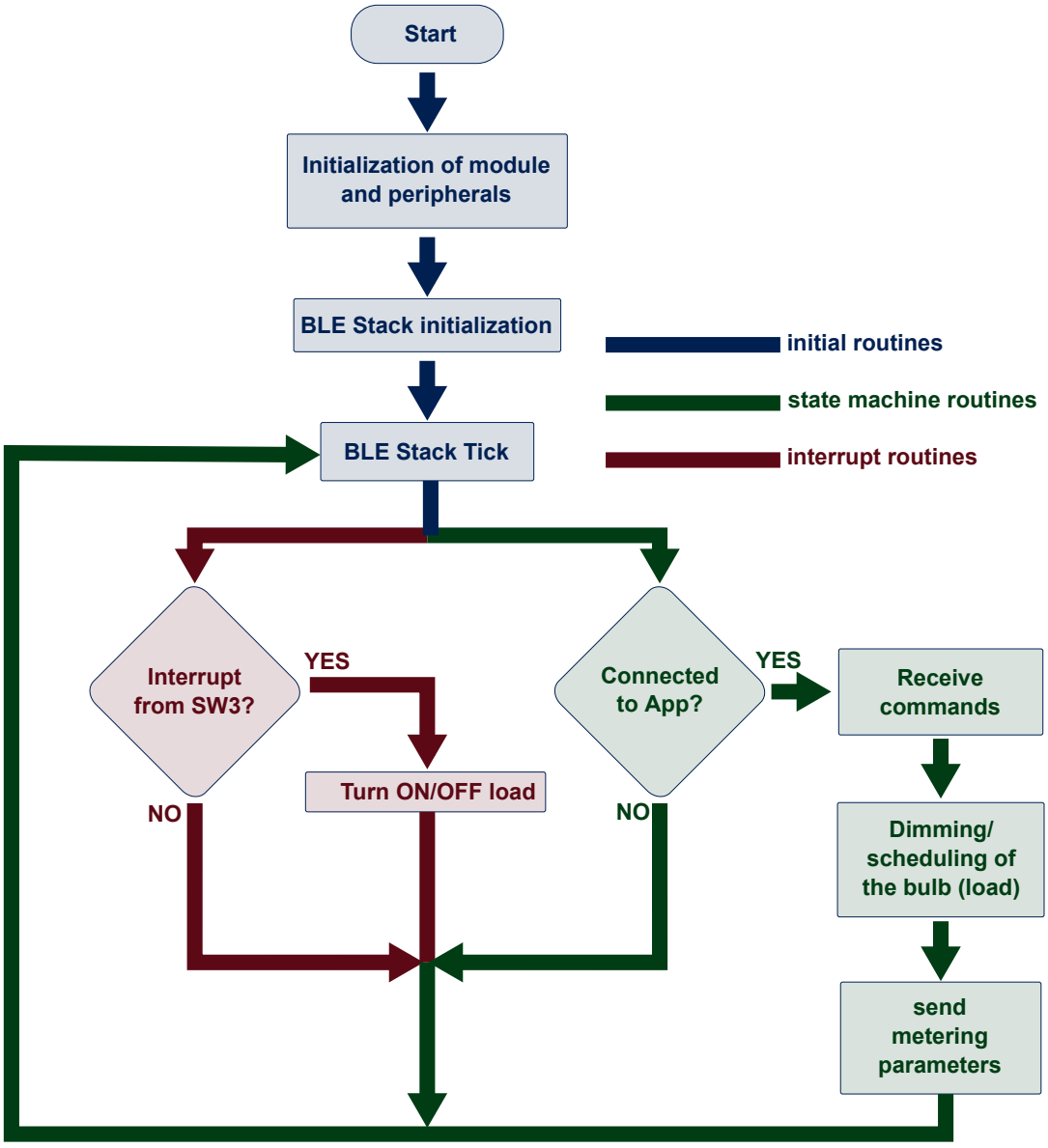
Note: LED lights are not particularly suitable to evaluate the dimming function.

Figure 13. ST BLE PLUG - load control panel



4 State machine

Figure 14. State machine

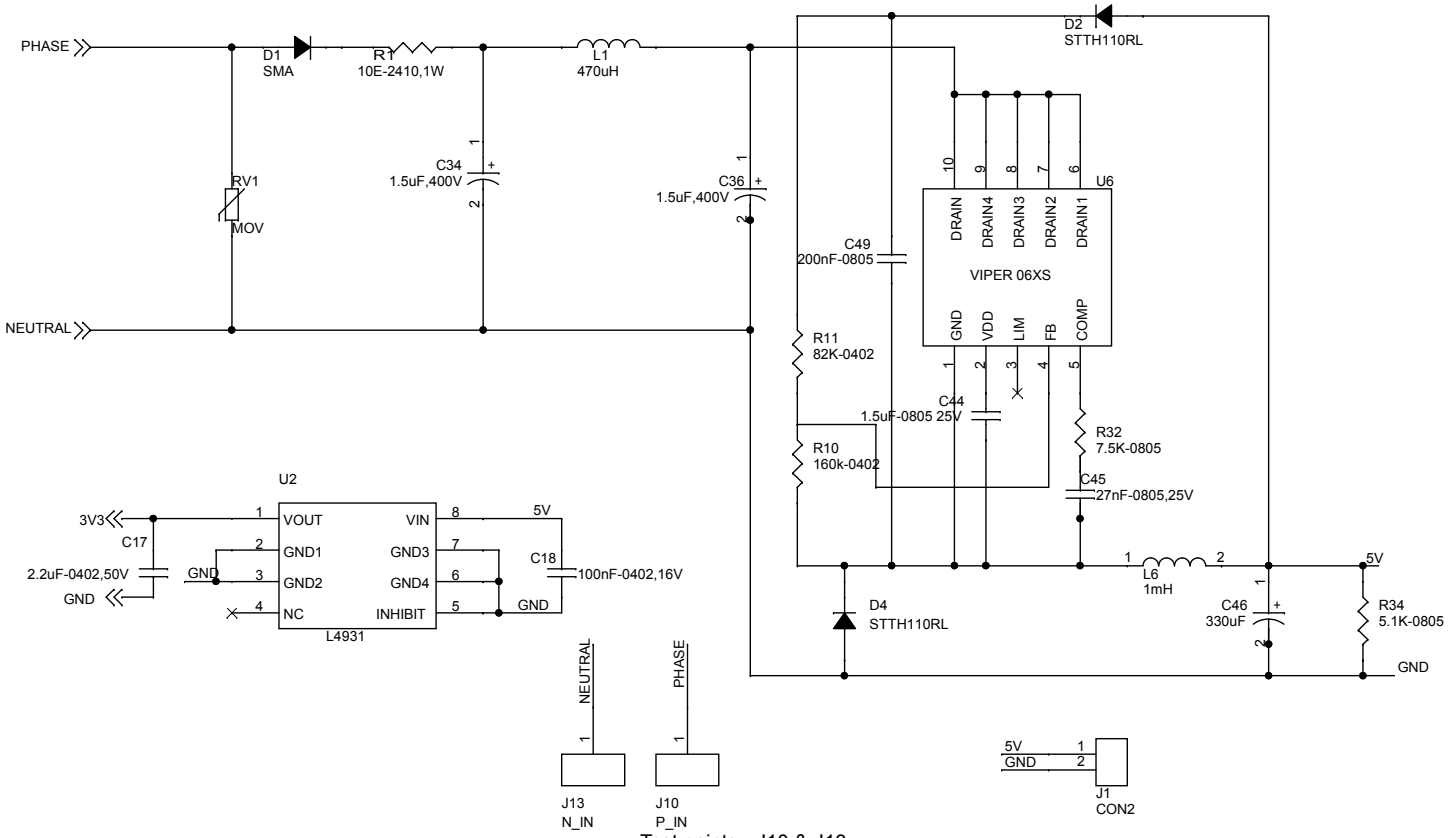


The following events occur in the state machine figured above:

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 15. **STDES-BLUEPLUG2 schematic diagram (1 of 4)**



Test points - J10 & J13

Figure 16. STDES-BLUEPLUG2 schematic diagram (2 of 4)

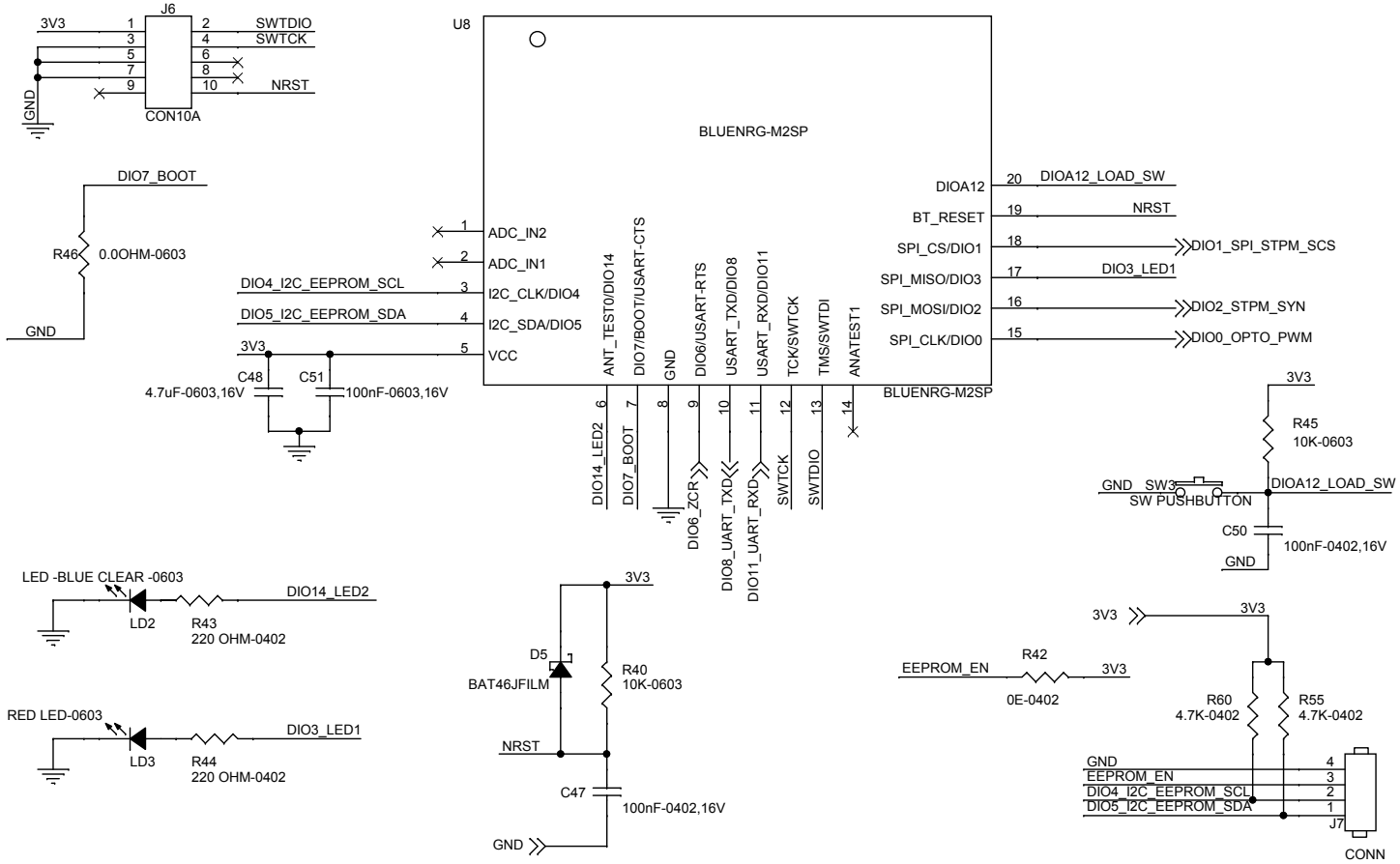


Figure 17. STDES-BLUEPLUG2 schematic diagram (3 of 4)

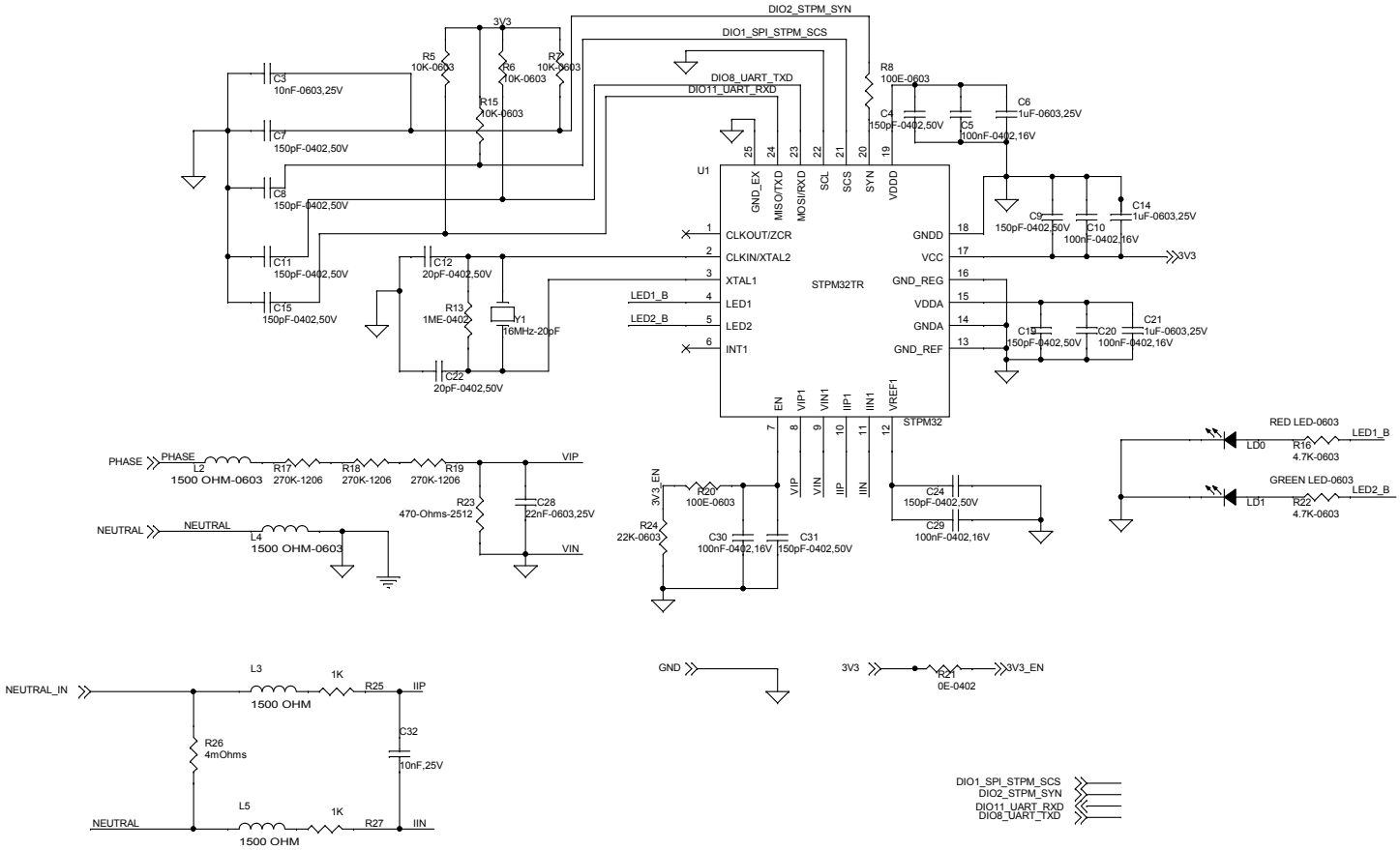
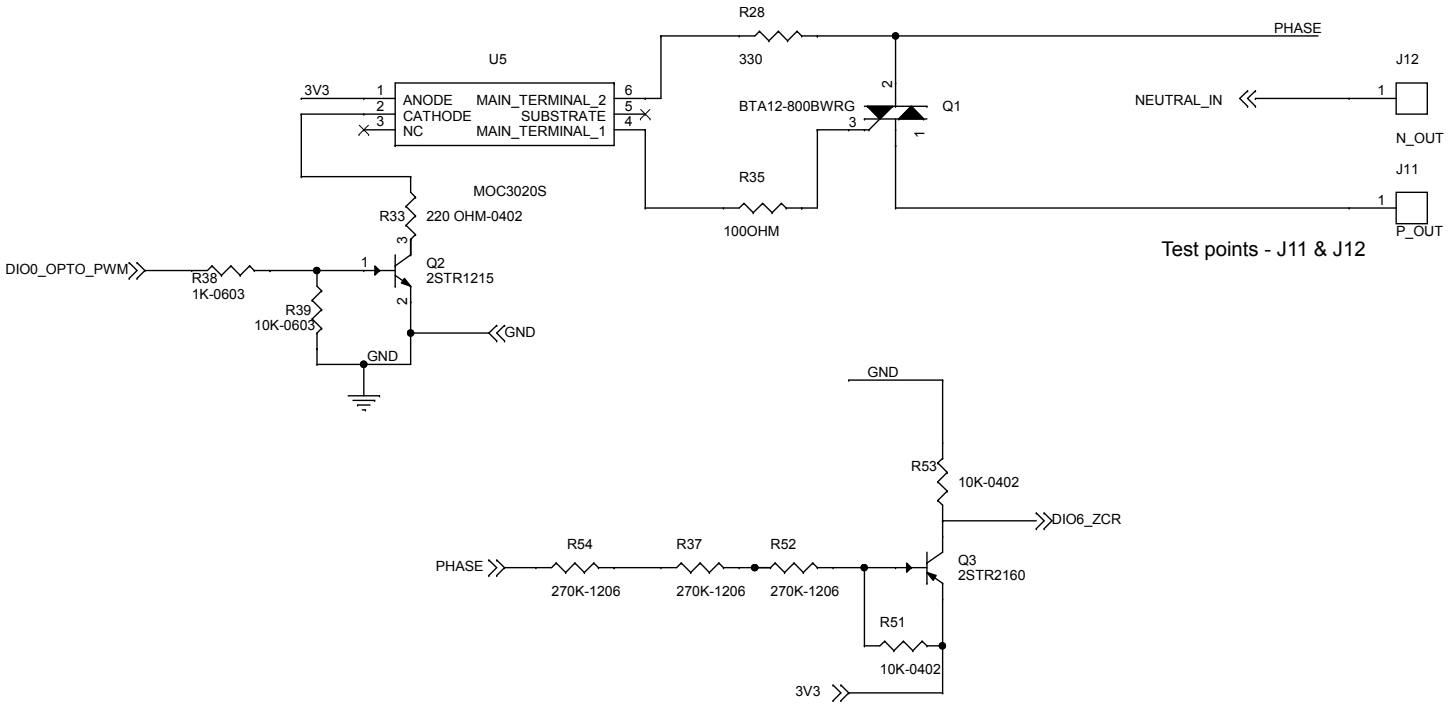


Figure 18. STDES-BLUEPLUG2 schematic diagram (4 of 4)



6 Bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	U1	STPM32TR, QFN-24L	ASSP for metering applications with up to four independent 24-bit 2nd order sigma-delta ADCs, 4 MHz OSF and 2 embedded PGLNAs	ST	STPM32TR
2	1	U2	L4931CD33-TR , SO8	Very low drop regulator with inhibit	ST	L4931CD33-TR
3	1	U5	MOC3020S, 6-SMD, Gull Wing	Optoisolator	Lite-On Inc.	MOC3020S
4	1	U6	VIPER06XS, SSOP10	Energy saving high voltage converter for direct feedback	ST	VIPER06XS
5	1	U8	BLUENRG-M2SP, QFN , 7 dbm	Very low power application processor module for Bluetooth low energy v5.2	ST	BLUENRG-M2SP
6	1	Q1	BTA12-800BWRG, THROUGH HOLE TO220AB	Standard and Snubberless Triacs	ST	BTA12-800BWRG
7	1	Q2	2STR1215, SOT-23, 40 V, 0.8 A W	Low voltage fast switching NPN bipolar transistor	ST	2STR1215
8	1	Q3	2STR2160, SOT-23	Low voltage fast switching PNP bipolar transistor	ST	2STR2160
9	1	D1	SMA	General purpose diode	Bourns Inc.	CD214A-R12000
10	2	D2, D4	STTH110A, SMA	Ultra-fast diode	ST	STTH110A
11	2	C3,C32	10nF-0603, SMD 0603, 25V and above V, ±1 %,	Multilayer ceramic capacitors	Kemet	C0603C103F3GACTU
12	9	C4, C7, C8, C9, C11, C15, C19, C24, C31	150 pF-0402, SMD, 50 V, ±5 %	Multilayer ceramic capacitors	Taiyo Yuden	UMK105CG151JV-F
13	8	C5, C10, C18, C20, C29, C30, C47, C50	100 nF, SMD 0402, 16 V, ±10 %,	Multilayer ceramic capacitors	Yageo	CC0402KRX7R7BB104

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
14	3	C14, C21, C6	1 µF-0603, 25 V, SMD, ±10 %	Ceramic capacitors	Taiyo Yuden	TMK107BJ105KA-T
15	2	C34, C36	1.5 µF,400V, through hole radial Can, 400 V, ±20 %	Aluminum capacitors	Nichicon	ULD2G1R5MED1TD
16	1	C49	200 nF-0805, SMD, X7R, 25 V, ±10 %	Ceramic capacitor	Samsung Electro-Mechanics America, Inc.	CL21B224KAFNNNG
17	2	C12,C22	20 pF-0402, SMD, 50 V, ±5 %	Ceramic capacitor	Murata Electronics North America	GRM1555C1H200JA01D
18	1	C17	2.2 µF-0402, SMD, X5R, 50 V, ±10 %	Ceramic capacitor	TDK Corporation	C1005X5R1V225K050BC
19	1	C44	1.5 µF-0805, SMD, X7R, 25 V, ±10 %	Ceramic capacitor	TDK Corporation	C2012X7R1E155M125AC
20	1	C45	27 nF-0805, SMD, X7R, 25 V, ±10 %	Multilayer ceramic capacitor	Kemet	C0805C273K3HACTU
21	1	C28	22 nF-0603, SMD, 25 V, ±5 %	Ceramic Capacitor	Kemet	C0603C223J3RACTU
22	1	C46	330 µF, 10 V, SMD RADIAL CAN, ±20 %	Aluminum electrolytic capacitor	Nichicon	UUR1A331MNL1GS
23	1	C48	4.7 µF-0603, SMD, 16 V, ±10 %	Multilayer ceramic capacitor	Murata Electronics	GRM188R61E475KE11D
24	1	C51	100 nF-0603, SMD, 16 V, ±10 %	Multilayer ceramic capacitor	AVX	581-0603YD104KAT2A
25	1	R1	10E-2410, 1 W, SMD 2410, 250 VAC, 125 VDC, 0.5 A	Surface mount fuses	LittelFuse	650-2410SFV050FM1252
26	7	R5, R6, R7, R15, R39, R40, R45	10 K, SMD 0603, 0.1 W, ±1 %,	Thick film chip resistors	Vishay Dale	RCG060310K0FKEA
27	2	R8,R20	100E-0603, SMD, 1/4 W, ±5 %	Thick film chip resistors	Rohm Semiconductor	ESR03EZPJ101
28	1	R10	160 k, SMD 0402, 1/16 W, ±1 %	Thick film chip resistor	Yageo	RC0402FR-07160KL
29	1	R11	82 k-0402, SMD, 1/16 W, ±5 %	Thick film resistor	Yageo	RC0402JR-0782KL
30	1	R13	1ME-0402, SMD, 1/10 W, ±1 %	Chip resistor	KOA Speer	RK73H1ETTP1004F
31	2	R16 ,R22	4.7 K-0603, SMD, 1/4 W, ±5 %	Resistors	Rohm Semiconductor	ESR03EZPJ472
32	6	R17,R18,R19,R37,R52,R54	270K-1206, SMD 1206, 1/4 W, ±1 %,	Thin film chip resistor	Vishay Dale	TNPW1206270KBEEA
33	2	R21,R42	0E, SMD 0402, 1/10 W, ±5 %	Metal film resistor	Yageo	RC0402JR-070RL
34	1	R23	470 Ohms, SMD 2512, 1 W, ±1 %	Chip resistor - surface mount	Stackpole Electronics Inc.	RMCF2512FT470R

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
35	1	R24	22K-0603, SMD 0603, 1/10 W, ±5 %,	Thick film resistor	Panasonic Electronic Components	ERJ-3GEYJ223V
36	3	R25, R27, R38	1 K, SMD 0603, 1/10 W, ±1 %	Resistors	Yageo	RC0603FR-071KL
37	1	R26	4 mOhms, 4527 J-Lead, ±1 %	Current dense resistor	Vishay Dale	WSR34L000FEA
38	1	R28	330 Ohms , THROUGH HOLE, 3 W, ±5 %	Metal oxide film resistor	Panasonic Electronic Components	ERG-3SJ331
39	1	R32	7.5 K, SMD 0805, 1/4 W, ±1 %	Chip resistor	Stackpole Electronics Inc.	RNCP0805FTD7K50
40	3	R33, R43, R44	220 OHM-0402, SMD 0402, 1/10 W, ±5 %,	Metal thick film resistors	Panasonic Electronic Components	ERJ-2GEJ221X
41	1	R34	5.1 k, SMD 0805, 1/5 W, ±0.1 %	Thin film chip resistor	Stackpole Electronics Inc.	RTAN0805BKE5K10
42	1	R35	100OHM, THROUGH HOLE, 3 W, ±5 %,	Wire-wound resistor	Yageo	PNP300JR-73-100R
43	1	R46	0.0OHM, SMD 0603, 1/10 W, ±5 %	Thick film resistor	Yageo	RC0603JR-070RL
44	2	R51, R53	10 K, SMD 0402, 1/16 W, ±1 %	Metal thick film resistors	Yageo	RC0402JR-0710KL
45	2	R55, R60	4.7 K, SMD 0402, 1/5 W, ±5 %	Metal thick film resistors	Rohm Semiconductor	ESR03EZPJ472
46	1	RV1	MOV, Through hole, 430 V 4.5 KA DISC 14 MM	Varistor	EPCOS (TDK)	B72214S0271K101
47	1	L1	470 uH, SMD, ± 10 %	Power inductor	EPCOS (TDK)	B82462A4474K000
48	4	L2,L3,L4,L5	1500 OHM-0603, SMD	Ferrite bead	TDK Corporation	MMZ1608Y152BTA00
49	1	L6	1 mH, Through Hole, 600 mA, ±20 %	Fixed inductor	Wurth	7447471102
50	1	LD0,LD3	SMD 0603, 2 V, 20 m A	Red LED	Lite-On Inc.	LTST-C191KRKT
51	1	LD1	SMD 0603, 2 V, 20 mA	Green LED	Lite-On Inc.	LTST-C191KGKT
52	1	LD2	SMD 0603, 3.3 V, 20 mA	Blue LED	Vishay Semiconductor Opto Division	VLMB1310-GS08
53	1	Y1	16 MHz -20 pf, SMD, 30 PPM	Crystal with load capacitor	ECS Inc.	ECS-160-20-23A-EN-TR
54	1	J1	2-pin connector, Through Hole Pitch 2.54 mm	Headers and wire housings	Harwin Inc.	M20-9990246
55	1	J6	Through Hole Pitch 1.27mm	Programming SWD connector	CNC Tech	3220-10-0100-00

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
56	1	J7	4-pin Through Hole Pitch 2.54 mm	Connector for NFC-EEPROM daughter board	AmpheNol FCI	68002-404HLF
57	1	J10	P_IN, Through Hole	Test point	Any	Any
58	1	J11	P_OUT, Through Hole	Test point	Any	Any
59	1	J12	N_OUT, Through Hole	Test point	Any	Any
60	1	J13	N_IN, Through Hole	Test point	Any	Any
61	1	SW3	SW Push Button , SMD, 12 V, 0.05 A	Tactile switch	Panasonic Electronic Components	EVQ-5PN04K
62	1	Heat Sink(Q1)	V7700W (25*16*16 mm)	Aluminum heat sink	Assmann WSW Components	V7700W

Revision history

Table 1. **Document revision history**

Date	Revision	Changes
11-May-2021	1	Initial release.
13-May-2021	2	Updated Section 3 Set up the board and connect with the Android app.

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