

Getting started with the STDES-EMETER1PV1 single phase smart meter

Introduction

The **STDES-EMETER1PV1** single-phase smart meter is based on **STM32L433VCT6** MCU featuring ARM Cortex-M4 core and **STPM33** IC for electricity metering with an accuracy of 0.1%.

It measures electric energy consumption over defined time intervals and sends collected data back to the utility for monitoring and billing, also tracking all the tampers, with the correct date and time.

The smart meter meets the most up-to-date smart metering requirements, such as multi-tariff billing, reactive energy measurement and power quality monitoring to enhance generation, distribution, customer service and billing.

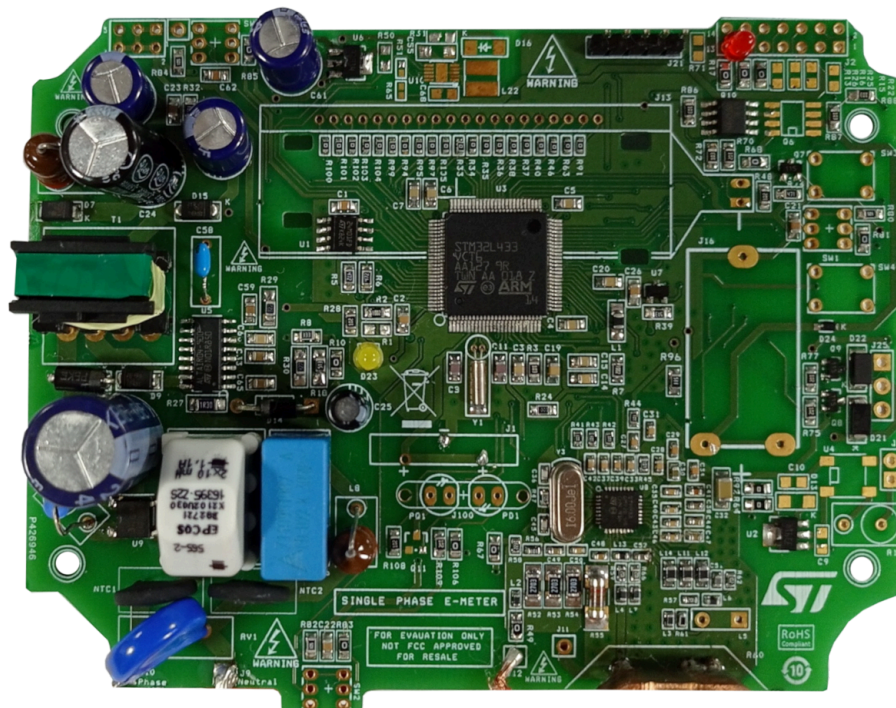
The **STDES-EMETER1PV1** comes with an expansion connector to provide GPRS/SubGHz connectivity and a relay control which allows remotely connecting/disconnecting the load.

The embedded **STPM33** IC belongs to an ASSP family of mixed signals designed for high accuracy measurement of power and energy in power line systems using a Rogowski coil, current transformer or shunt current sensors.

The device provides instantaneous voltage and current waveforms and calculates voltage and current RMS values, active, reactive and apparent powers and energies for each channel in compliance with accuracy standards (EN 50470-x, IEC 62053-2x, ANSI12.2x for AC watt meters).

The **STDES-EMETER1PV1** single-phase smart meter is a fully assembled board developed for performance evaluation only, not available for sale.

Figure 1. STDES-EMETER1PV1 single-phase smart meter



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

1 Acronyms and abbreviations

Table 1. List of acronyms

Acronym	Definition
ASSP	Application-specific standard product
LED	Light emitting diode
MCU	Microcontroller unit
SPI	Serial peripheral interface
RF	Radio frequency communication
USB	Universal serial bus

2 Getting started

2.1 Overview

The [STDES-EMETER1PV1](#) features:

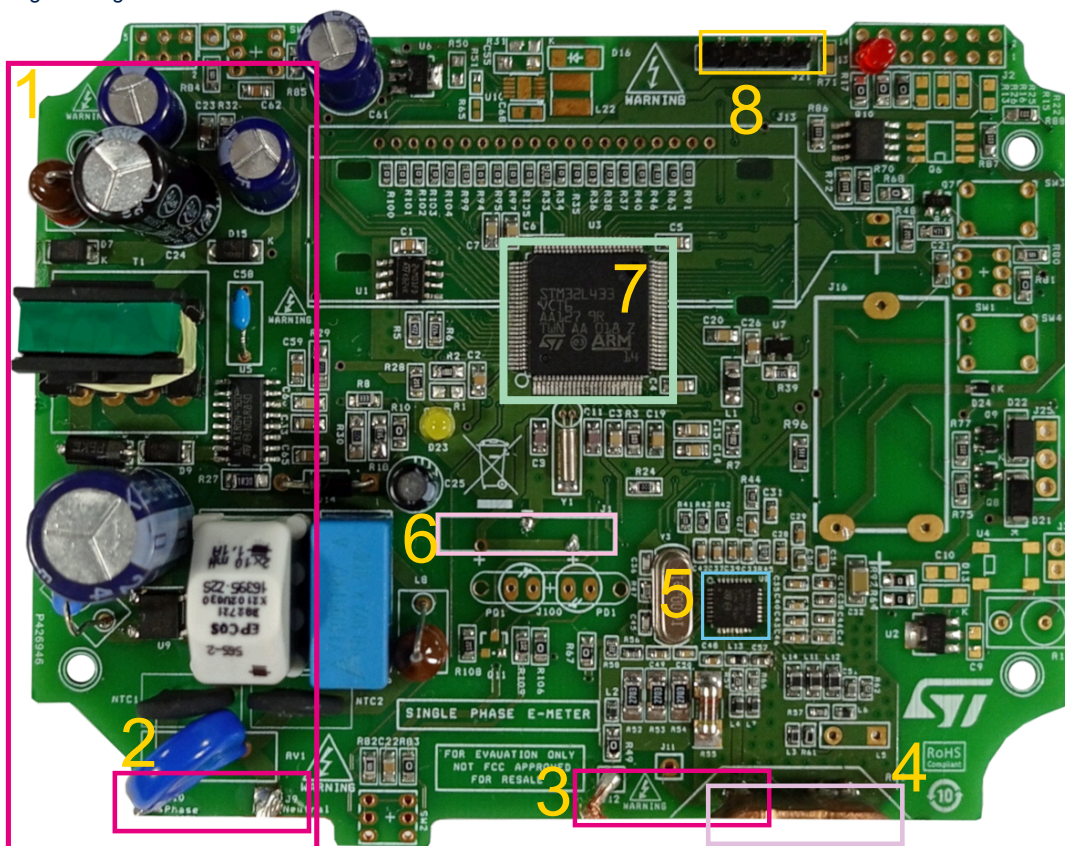
- Based on [STM32L433VCT6](#) (100 pins, LQFP) and [STPM33](#)
- [STPM33](#) interfaced using SPI with MCU
- Current transformer (CT) and shunt sensing supported for current measurements
- Shunt connected on the primary channel and CT on the secondary
- Active energy difference of two channels signaling tamper condition
- Magnetic tamper detection using Hall effect sensor by MCU interrupt line
- EEPROM interfaced using I²C with MCU to store accumulated energy
- Switch interface for case tamper and terminal cover tamper
- Low power mode supported
- Neutral missing tamper detection implemented using special duty cycling algorithm
- Connectors for GPRS or Sub 1-GHz connectivity
- Measuring RMS/instantaneous voltage, current, kW and power factor (PF)
- Glass LCD (1/8 duty cycle and 20 segments) driven by the MCU LCD controller

2.2 Hardware requirements

The [STDES-EMETER1PV1](#) input power must be supplied by 220 V_{AC}. A load of few watts must be connected at load end to test the application.

Figure 2. STDES-EMETER1PV1 smart meter main sections

1. Power supply section
2. 220 V_{AC} input power
3. Load
4. Shunt
5. STPM33 IC
6. RTC battery slot
7. STM32L433VCT6 MCU
8. Programming connector



2.3 System requirements

To run the STDES-EMETER1PV1 single-phase smart meter, you need:

- an STDES-EMETER1PV1
- an ST-LINK/V2 in-circuit debugger/programmer
- a PC/laptop running Windows 7 or 10
- IAR v8.3 development tool chain or STM32 ST LINK utility
- STSYS-NS073.bin software for application programming

3 Hardware description

Figure 3. STDES-EMETER1PV1 hardware block diagram

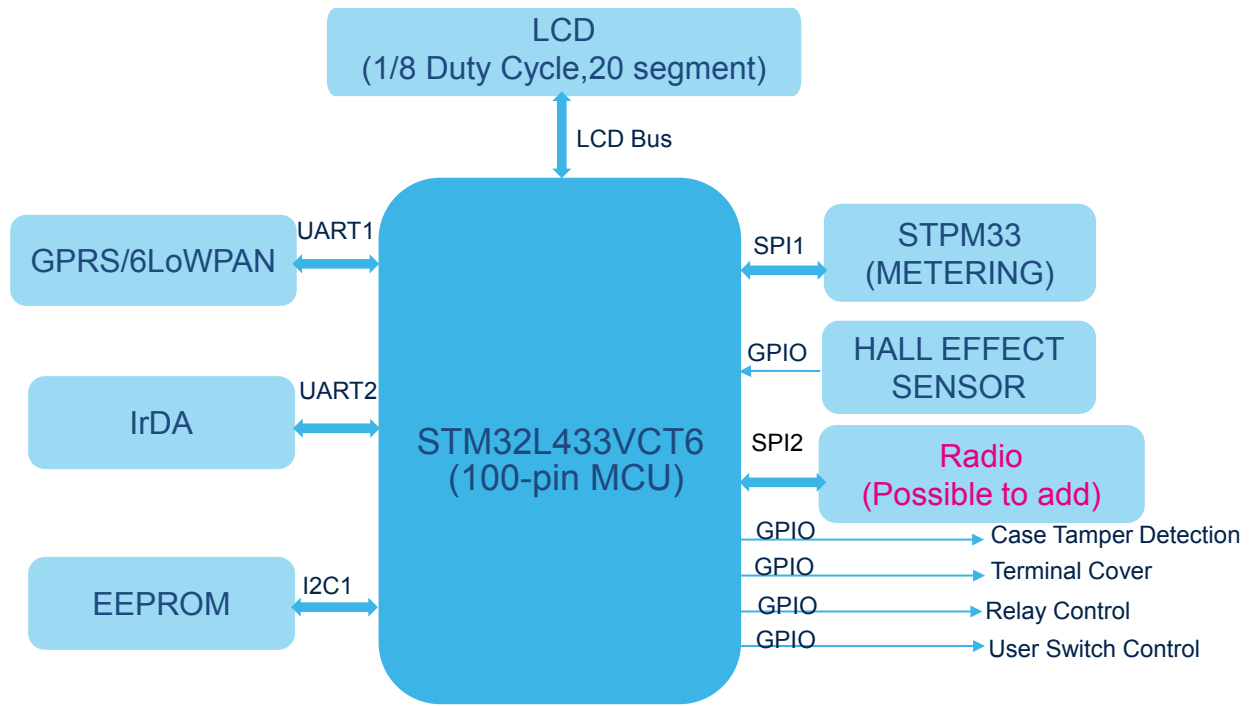


Figure 4. STDES-EMETER1PV1 top view

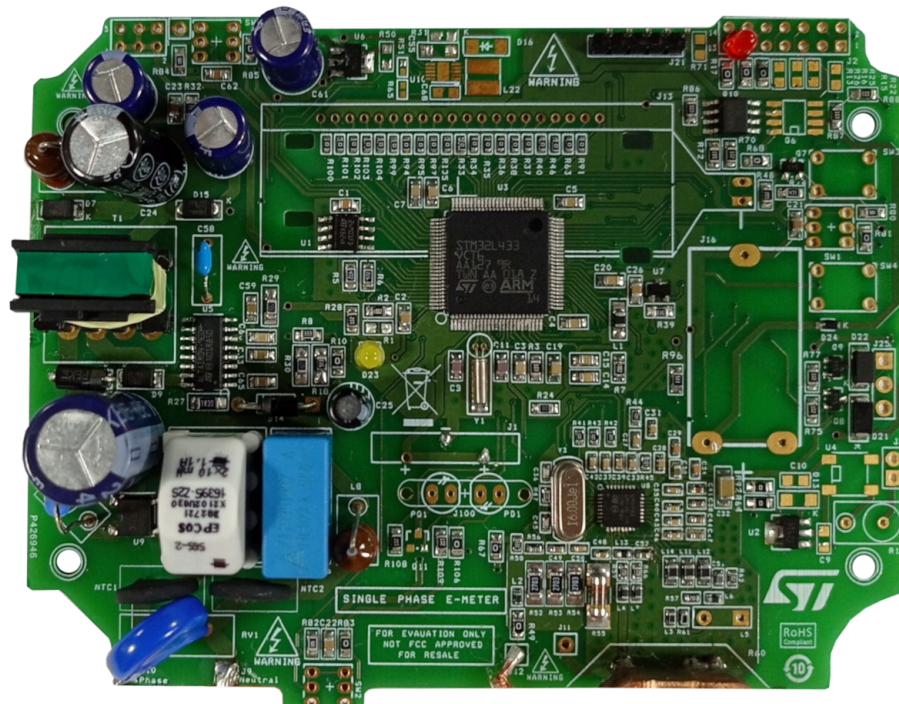
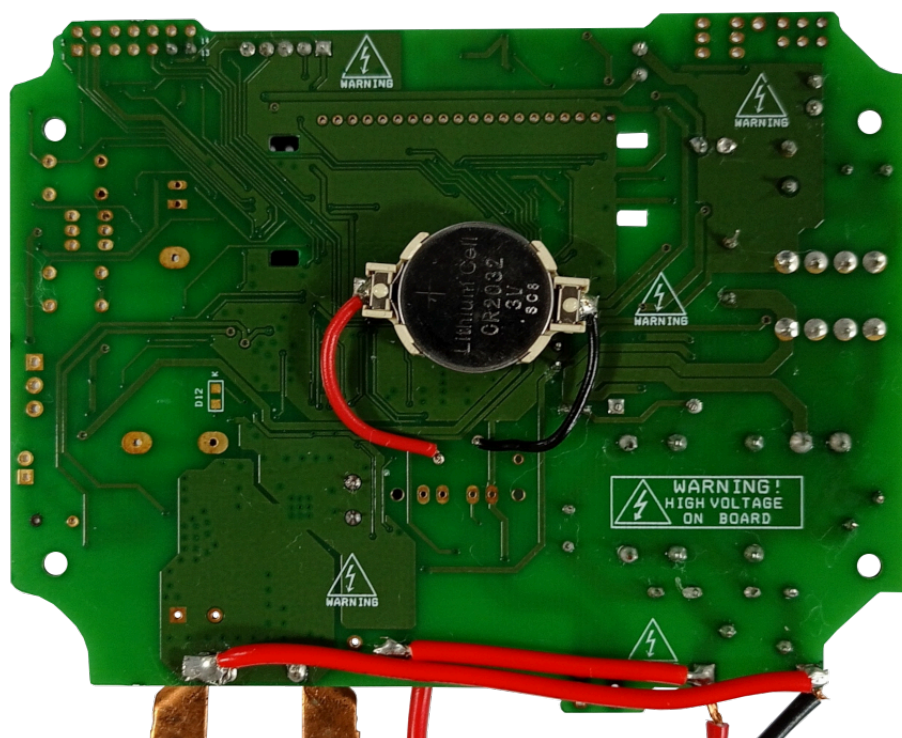


Figure 5. STDES-EMETER1PV1 bottom view



4 Component description

4.1 STPM33

The **STPM33** belongs to a mixed signal IC family designed for high accuracy measurement of power and energies in power line systems using the Rogowski coil, current transformer or shunt current sensors.

The STPM3x provides instantaneous voltage and current waveforms. It also calculates RMS values of voltage and currents, active, reactive and apparent power and energies.

The analog section consists of up to two programmable gain low-noise low-offset amplifiers and up to four second order 24-bit sigma-delta ADCs, two band gap voltage references with independent temperature compensation, a low drop voltage regulator and DC buffers.

The digital section consists of digital filtering stage, a hardwired DSP, DFE to the input and a serial communication interface (UART or SPI).

The STPM3x is fully configurable and allows a fast digital system calibration in a single point over the entire current dynamic range.

4.2 STM32L433VCT6

The **STM32L433VCT6** is an ultra-low-power microcontroller based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 80 MHz. The Arm® Cortex®-M4 core features a floating-point unit (FPU) single precision which supports all Arm® single-precision data processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The STM32L433xx devices embed high-speed memories (Flash memory up to 256 Kbyte, 64 Kbyte of SRAM), a quad SPI Flash memory interface (available on all packages) and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

The STM32L433xx devices embed several protection mechanisms for embedded Flash memory and SRAM: readout protection, write protection, proprietary code readout protection and firewall.

The devices offer a fast 12-bit ADC (5 Msps), two comparators, one operational amplifier, two DAC channels, an internal voltage reference buffer, a low-power RTC, one general-purpose 32-bit timer, one 16-bit PWM timer dedicated to motor control, four general-purpose 16-bit timers, and two 16-bit low-power timers.

In addition, up to 21 capacitive sensing channels are available. The devices also embed an integrated LCD driver 8x40 or 4x44, with internal step-up converter.

They also feature standard and advanced communication interfaces.

Some independent power supplies are supported: analog independent supply input for ADC, DAC, OPAMP and comparators, and 3.3 V dedicated supply input for USB. A VBAT input allows to back up the RTC and registers. Dedicated VDD12 power supplies can be used to bypass the internal LDO regulator when connected to an external SMPS.

4.3 ALTAIR04-900

The **ALTAIR04-900** is a high voltage all-primary-sensing switcher, operating directly from the rectified mains with minimum additional external parts. It combines a high performance low voltage PWM controller chip and a 900 V avalanche-rugged power section in the same package.

The controller is in current mode specifically designed for off-line quasi-resonant flyback converters.

The device provides a constant output voltage using the primary-sensing feedback, eliminating the need of an optocoupler, a secondary voltage reference, and a current sensor, but still maintaining an accurate regulation.

The maximum deliverable output current can be set to increase the end-product safety and reliability in case of fault events.

Quasi-resonant operation is guaranteed by a transformer demagnetization sensing input which turns on the power section. The same input also serves the output voltage monitoring, to perform CV regulation, and to achieve mains-independent maximum deliverable output current (line voltage feed-forward).

The maximum switching frequency is 166 kHz: at light-to-medium load, a special function automatically lowers the operating frequency maintaining the valley switching operation. When the load is very light, the device enters a controlled burst mode operation that, along with the built-in high voltage startup circuit and the low operating current, minimizes the standby power.

5 How to run the single-phase smart meter

Step 1. To program the STDES-EMETER1PV1 single-phase smart meter, connect it to the ST-LINK/V2, as shown in the table and figures below.

Table 2. STDES-EMETER1PV1 and ST-LINK/V2 pin connection

Signal	ST-LINK/V2 connector	STDES-EMETER1PV1 J21 connector
VCC	1	1
SWCLK	9	2
GND	10	3
SWDIO	7	4
NRST	15	5

Figure 6. STDES-EMETER1PV1 and ST-LINK/V2 pins

(Dotted yellow lines identify pin 1 and pink dotted lines identify pin 5)

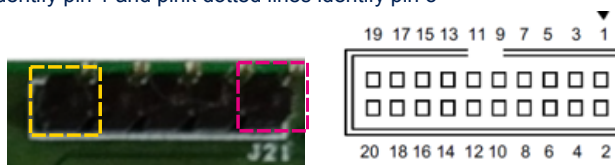
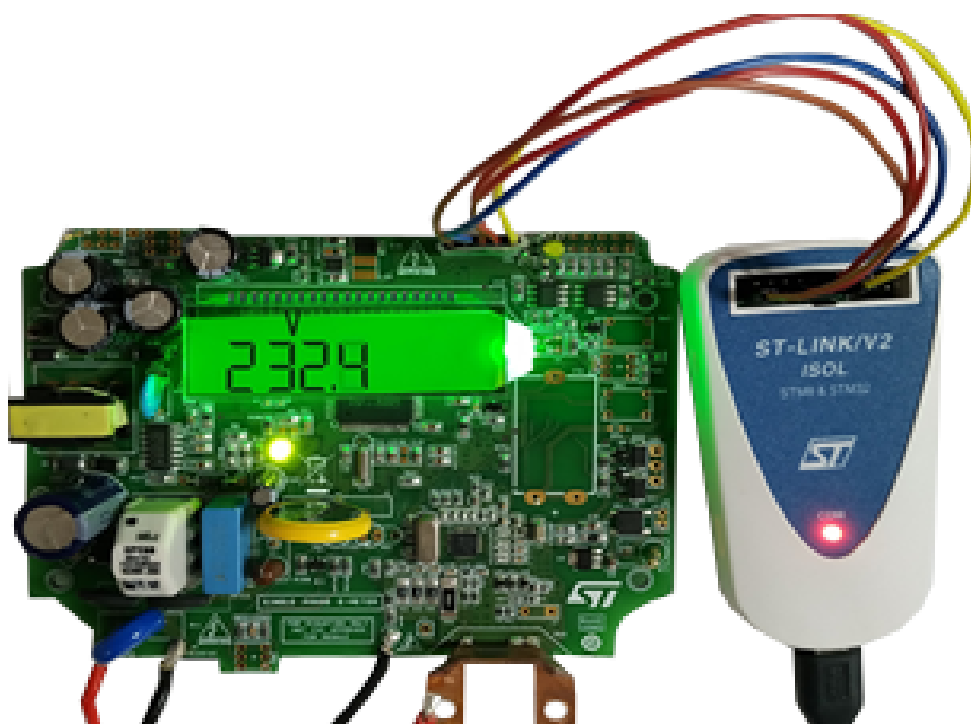


Figure 7. STDES-EMETER1PV1 and ST-LINK/V2 connection

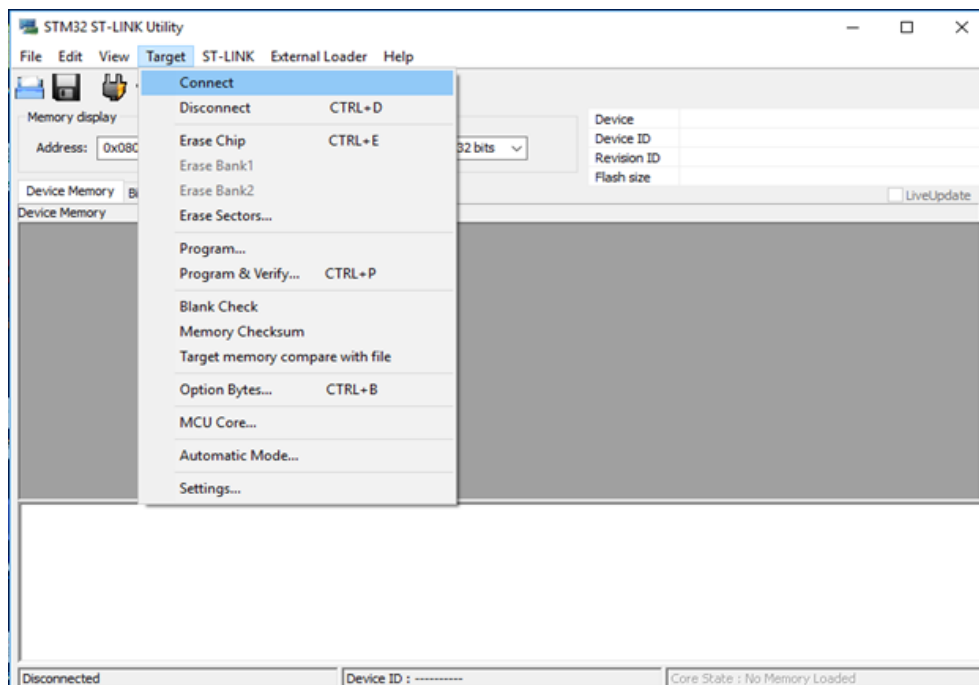


Step 2. Power the STDES-EMETER1PV1 with 220 V_{AC}.
The power supply on the board converts the 220 V into 3.3 V to power the MCU.

Step 3. Install STM32 ST LINK utility on your PC/laptop to program the MCU.

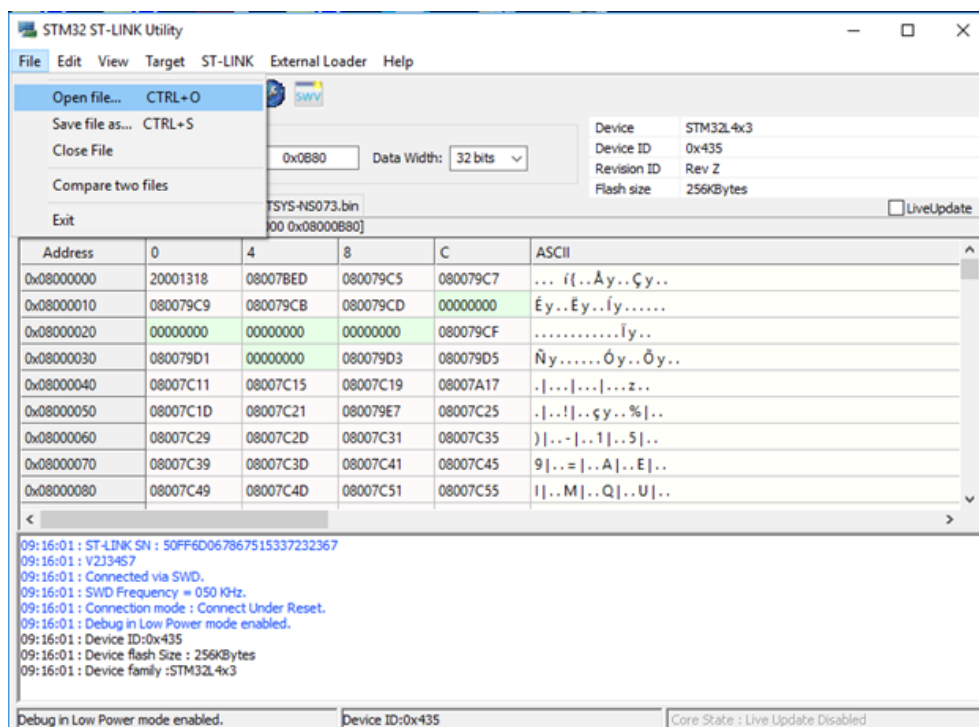
Step 4. Connect to the target.

Figure 8. STM32 ST LINK utility - target connection



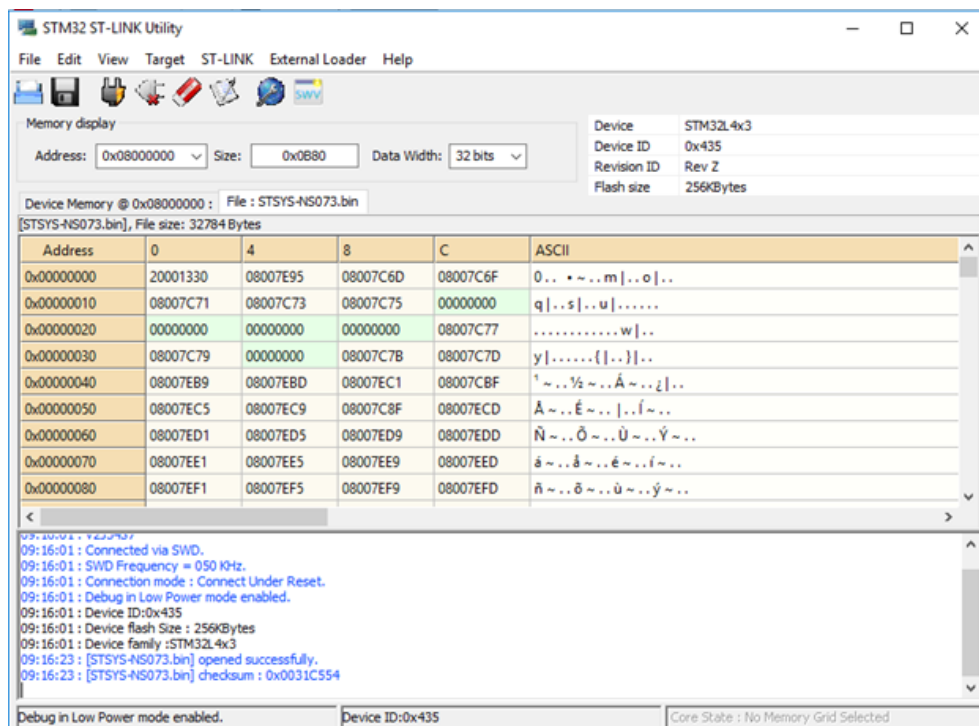
Step 5. Open the binary file.

Figure 9. STM32 ST LINK utility - file opening



Step 6. Enable debug in low power mode.

Figure 10. STM32 ST LINK utility - file selected



Once the **STDES-EMETER1PV1** is programmed with the binary file, the LCD displays various values, one by one, as shown below.

Figure 11. STDES-EMETER1PV1 - LCD display while running

1. Voltage
2. Current
3. Active power
4. Frequency
5. Date
6. Time
7. Accumulative energy



6 Firmware description

6.1 Overview

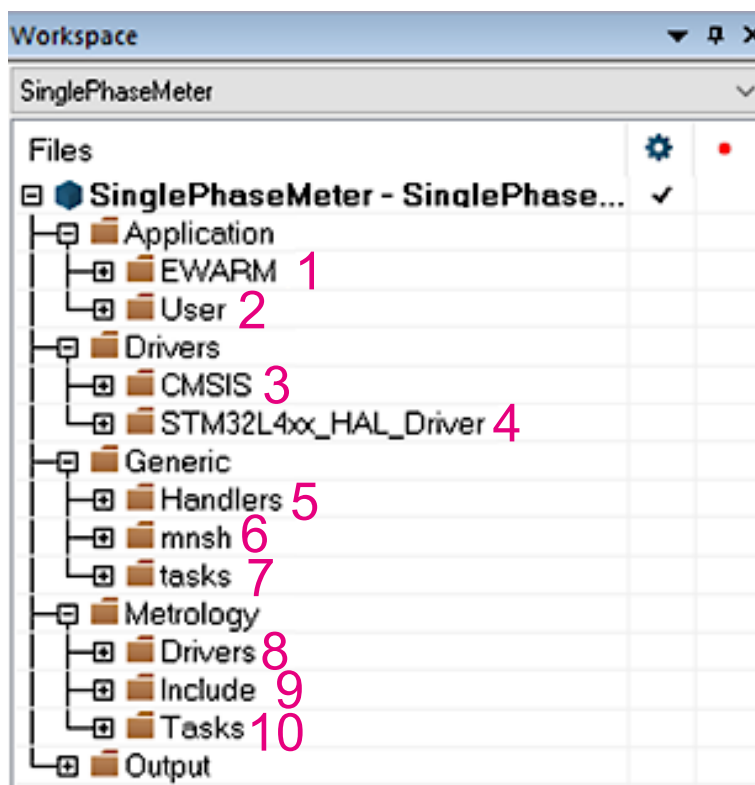
The STSW-EMETER1-FW software package for the STDES-EMETER1PV1 includes:

- the STDES-EMETER1PV1 user manual
- STPM33 Library
- STM32L4_Driver
- Application files

6.2 Folder structure

Figure 12. STSW-EMETER1-FW folder structure

1. Startup file
2. User files
3. System files
4. STM32 HAL driver files
5. EEPROM/NVRAM handler files
6. Minishell file
7. Minishell task files
8. Metrology driver files
9. Include files to select ST devices
10. Metrology task files

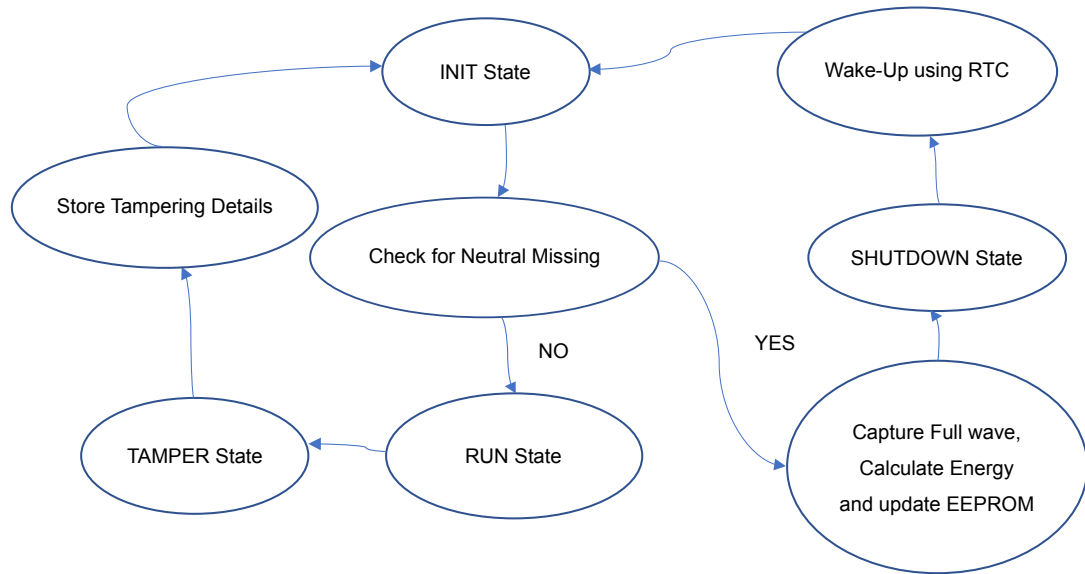


6.3 APIs

Detailed technical information about the APIs available to the user can be found in a compiled HTML file located inside the "Documentation" folder of the software package where all the functions and parameters are fully described.

6.4 State machine

Figure 13. STSW-EMETER1-FW state machine



- **INIT State:**
 - initializes MCU and peripherals
- **Check for Neutral Missing:**
 - checks neutral missing occurs
 - if yes, it initializes MCU at lower frequency
 - if proper voltage is built at V_{DD} , it reads and stores in the EEPROM
- **RUN State:**
 - refreshes metering data reading by reading [STPM33](#)
 - updates LCD
 - updates EEPROM
- **Tamper State:**
 - if any tamper is detected, stores the details in the EEPROM with the related time
- **Capture State in case of Neutral missing:**
 - captures one full wave and calculates energy
 - stores the value in the EEPROM
- **SHUTDOWN State:**
 - in case of Neutral Missing, shuts [STPM33](#) and MCU down for some time (2 seconds in this case)
 - periodically wakes up using RTC
- **Wake up using RTC State:**
 - periodically wakes up using RTC

Figure 14. STDES-EMETER1PV1 circuit schematic (1 of 8)

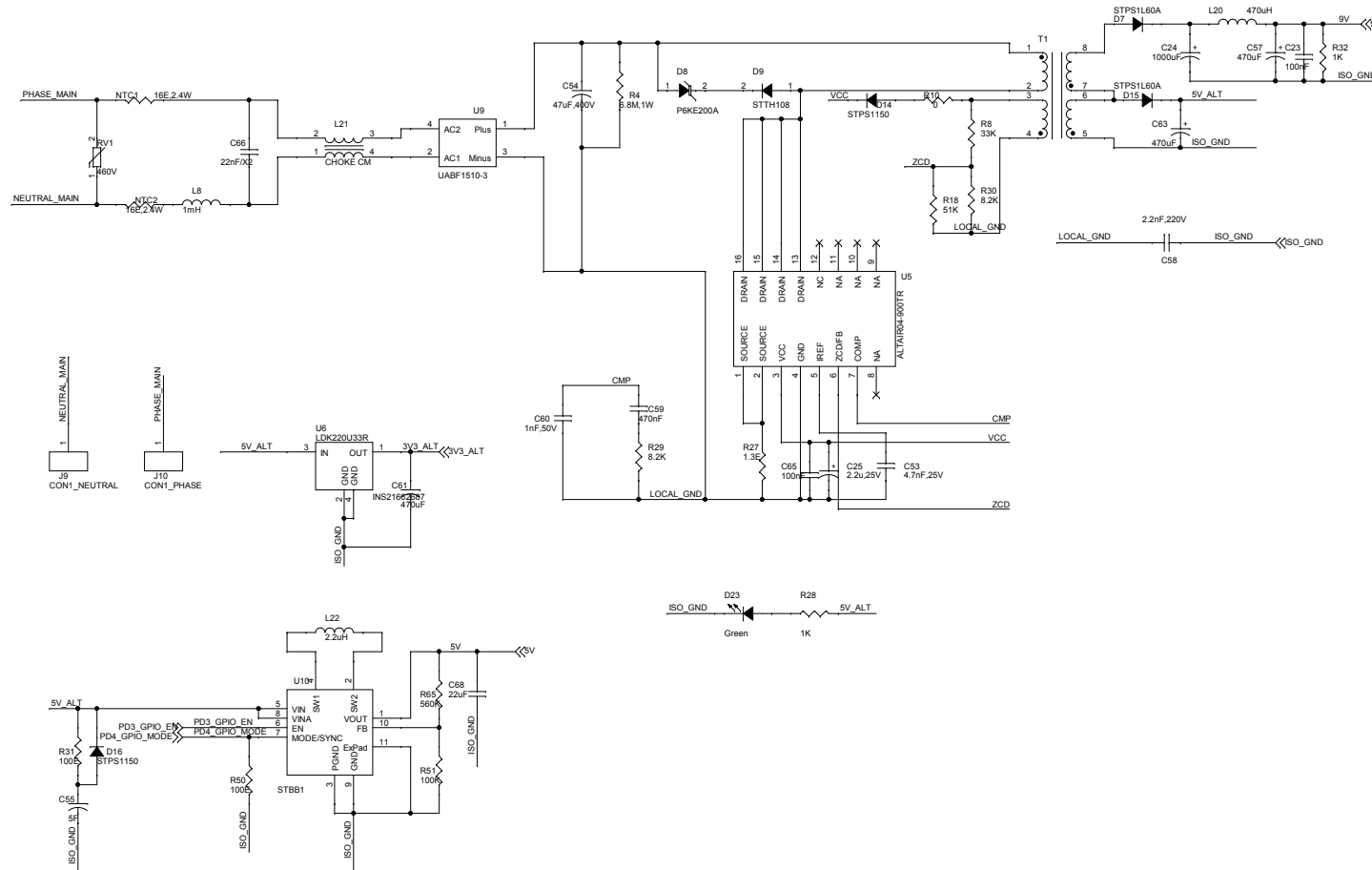


Figure 15. STDES-EMETER1PV1 circuit schematic (2 of 8)

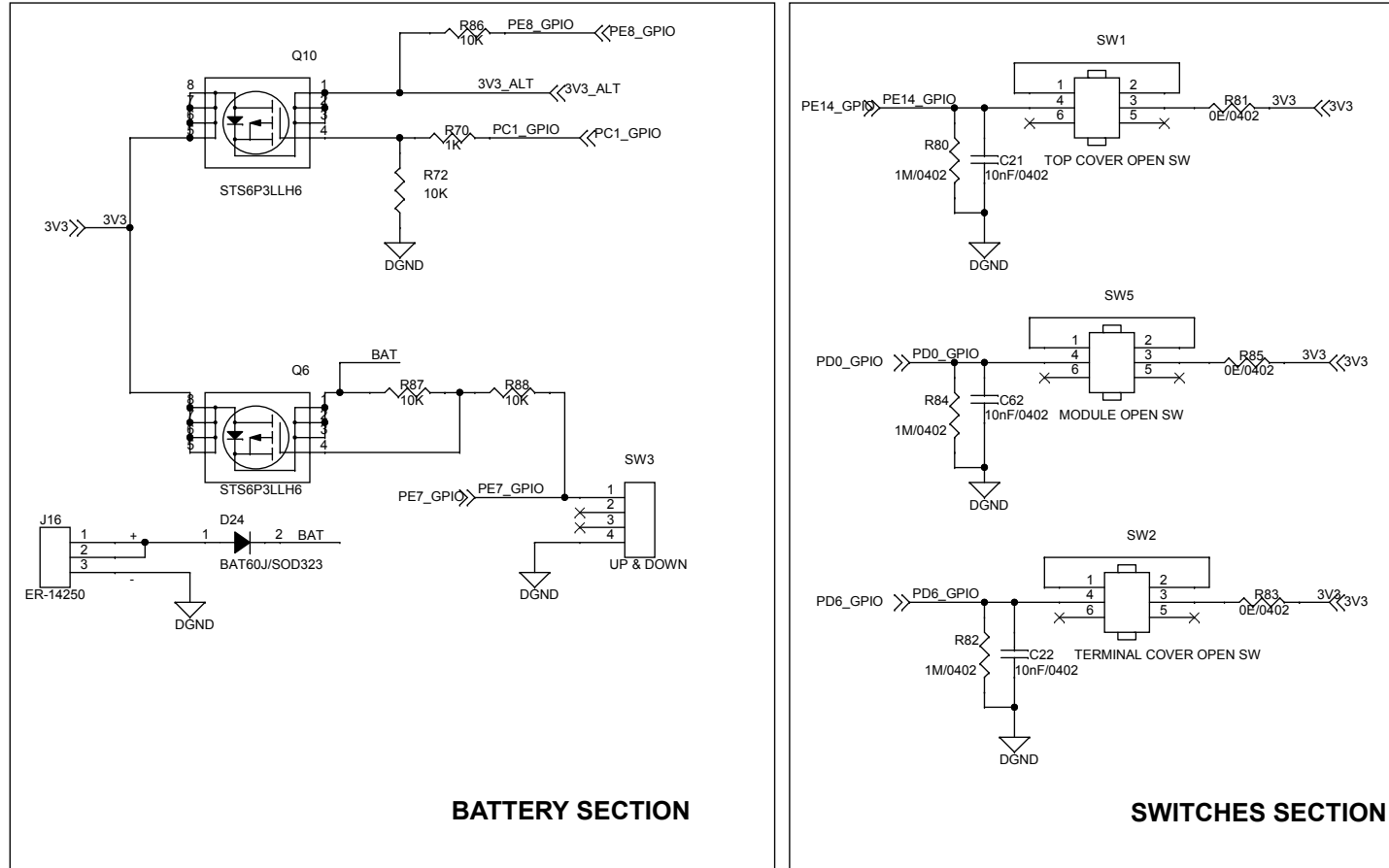
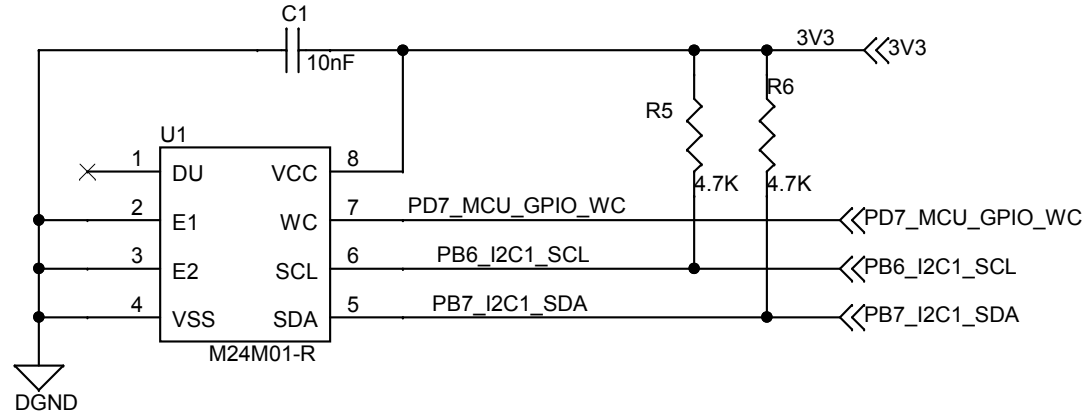
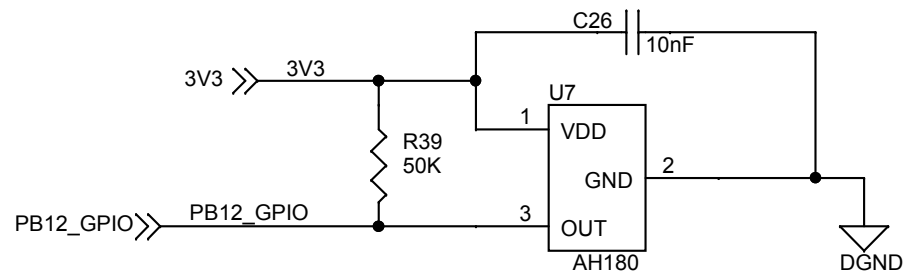


Figure 16. STDES-EMETER1PV1 circuit schematic (3 of 8)

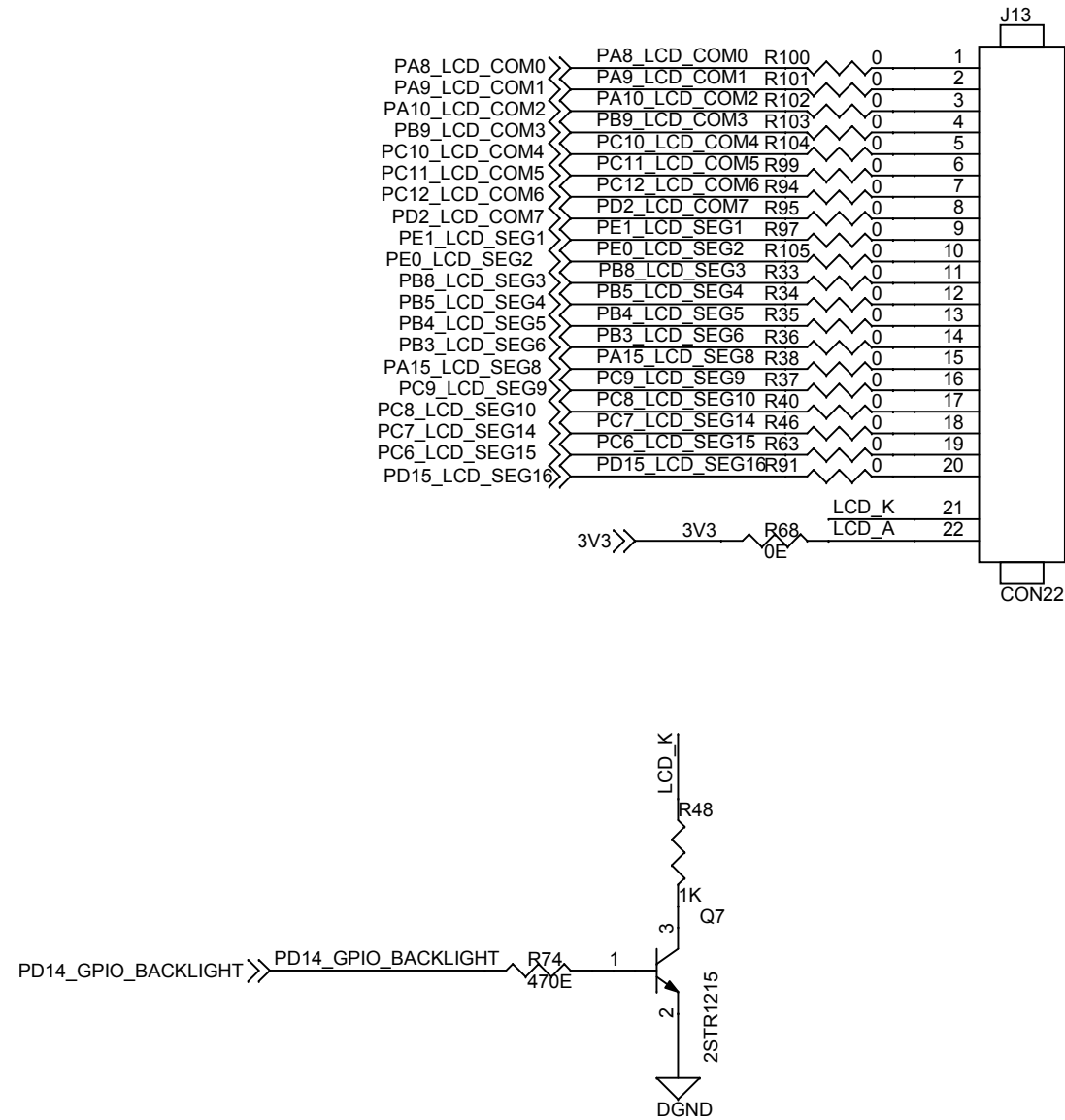


EEPROM SECTION



HALL SENSOR SECTION

Figure 17. STDES-EMETER1PV1 circuit schematic (4 of 8)



Schematic diagrams

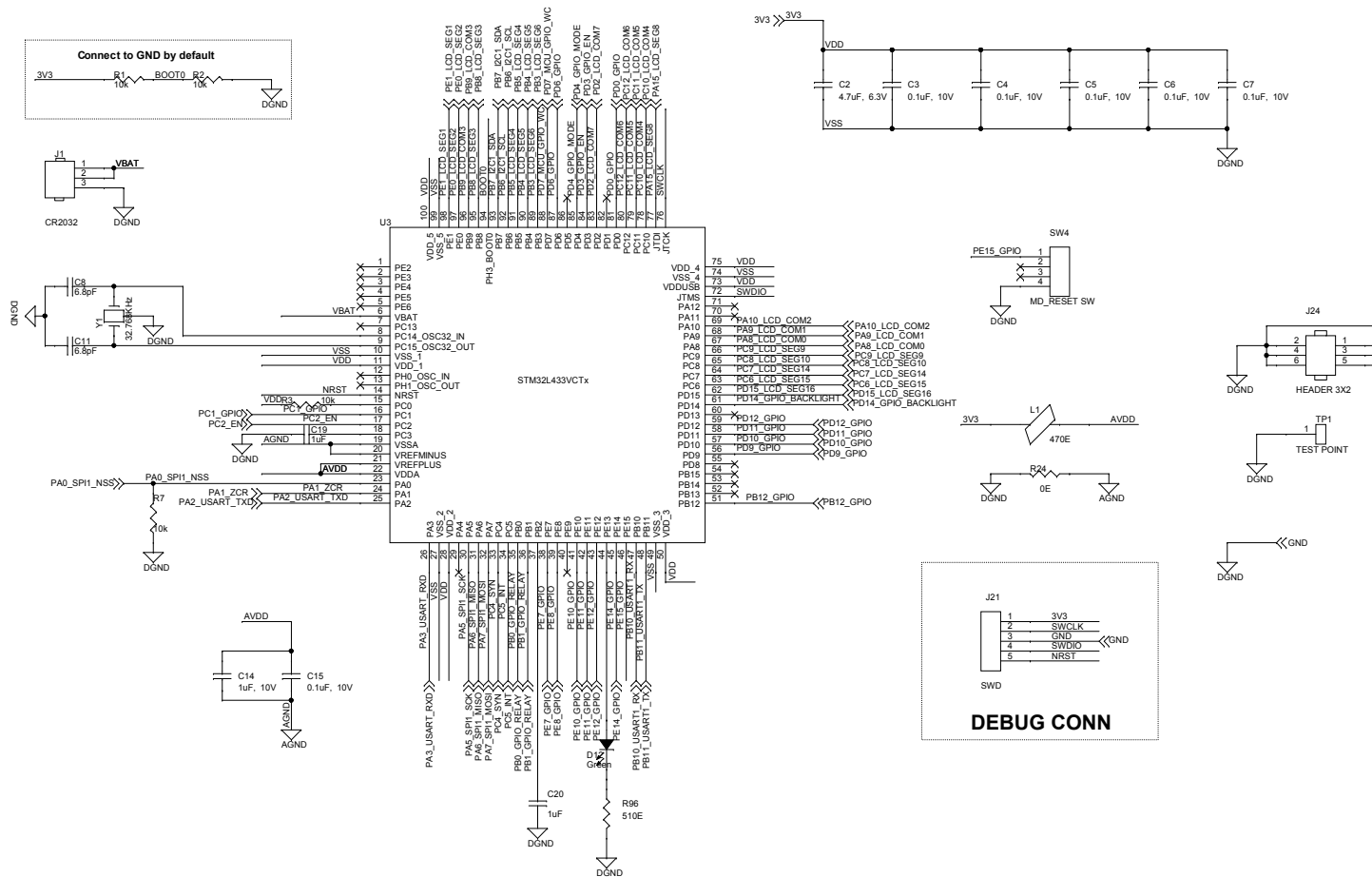
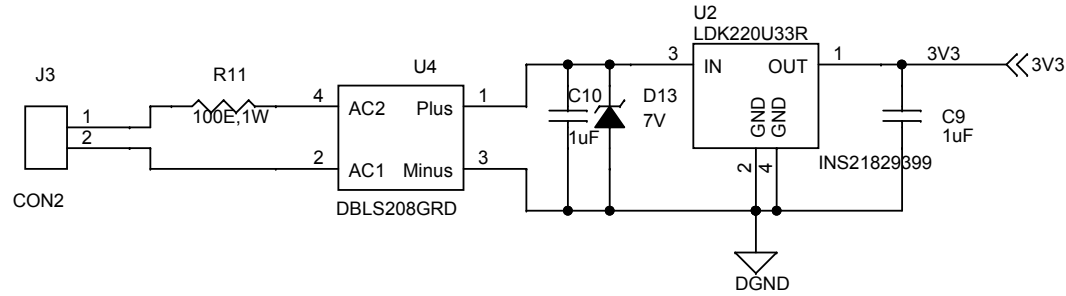
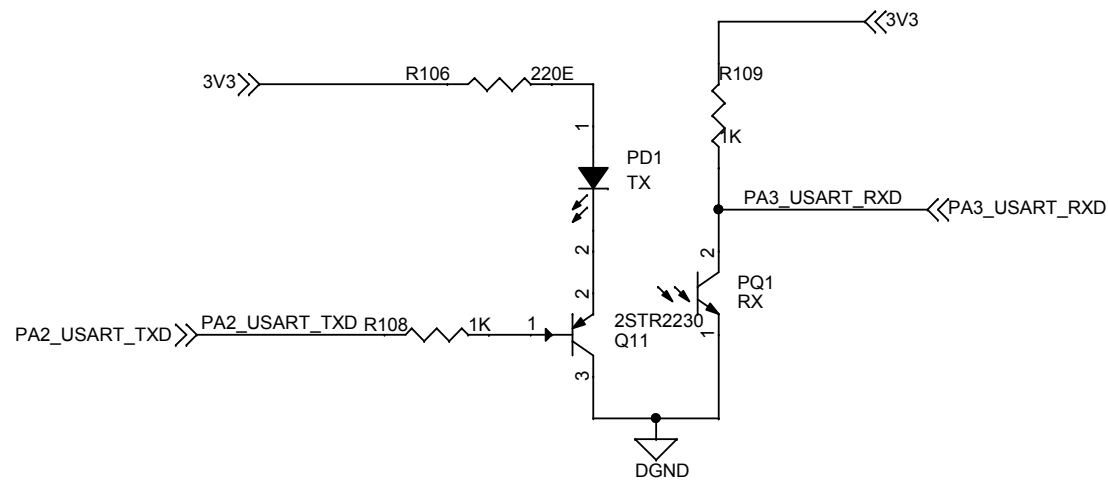


Figure 19. STDES-EMETER1PV1 circuit schematic (6 of 8)



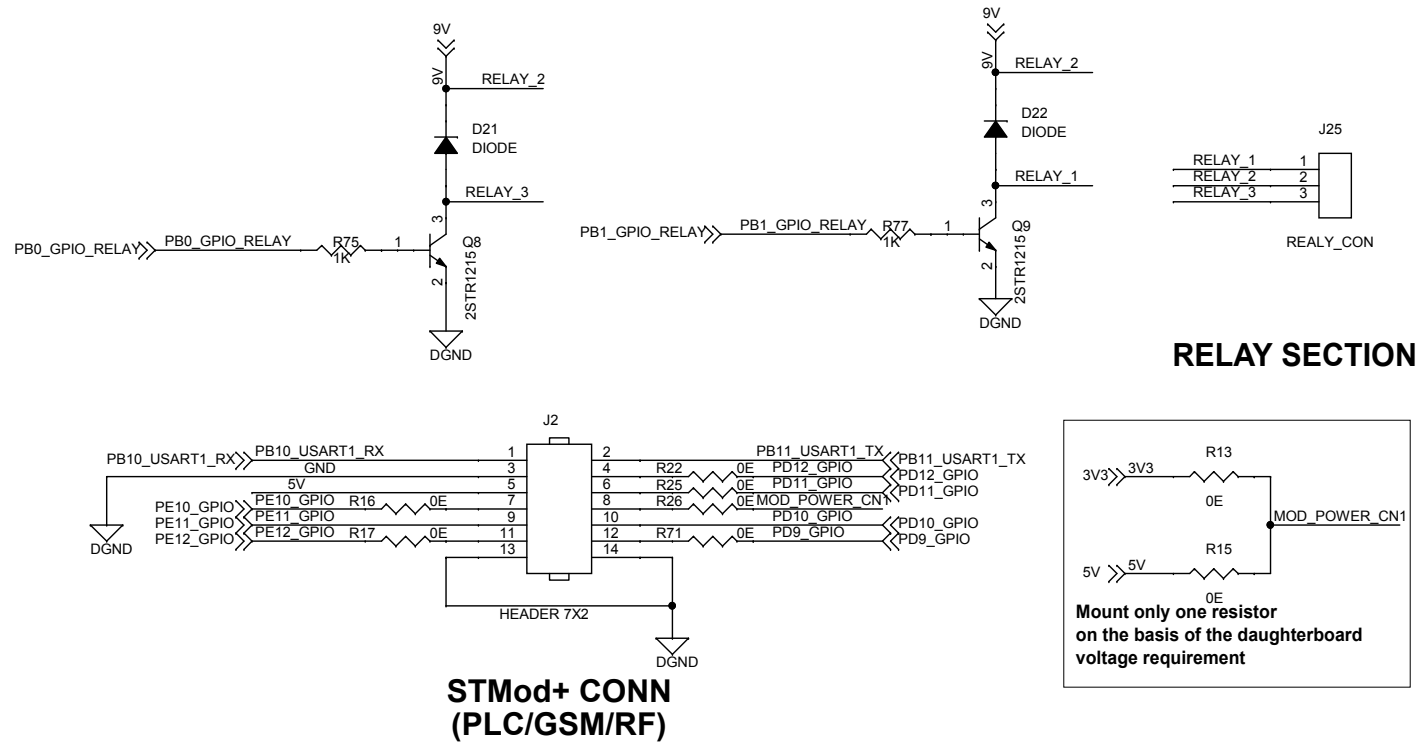
NEUTRAL MISSING SECTION



IR SECTION



Figure 20. STDES-EMETER1PV1 circuit schematic (7 of 8)

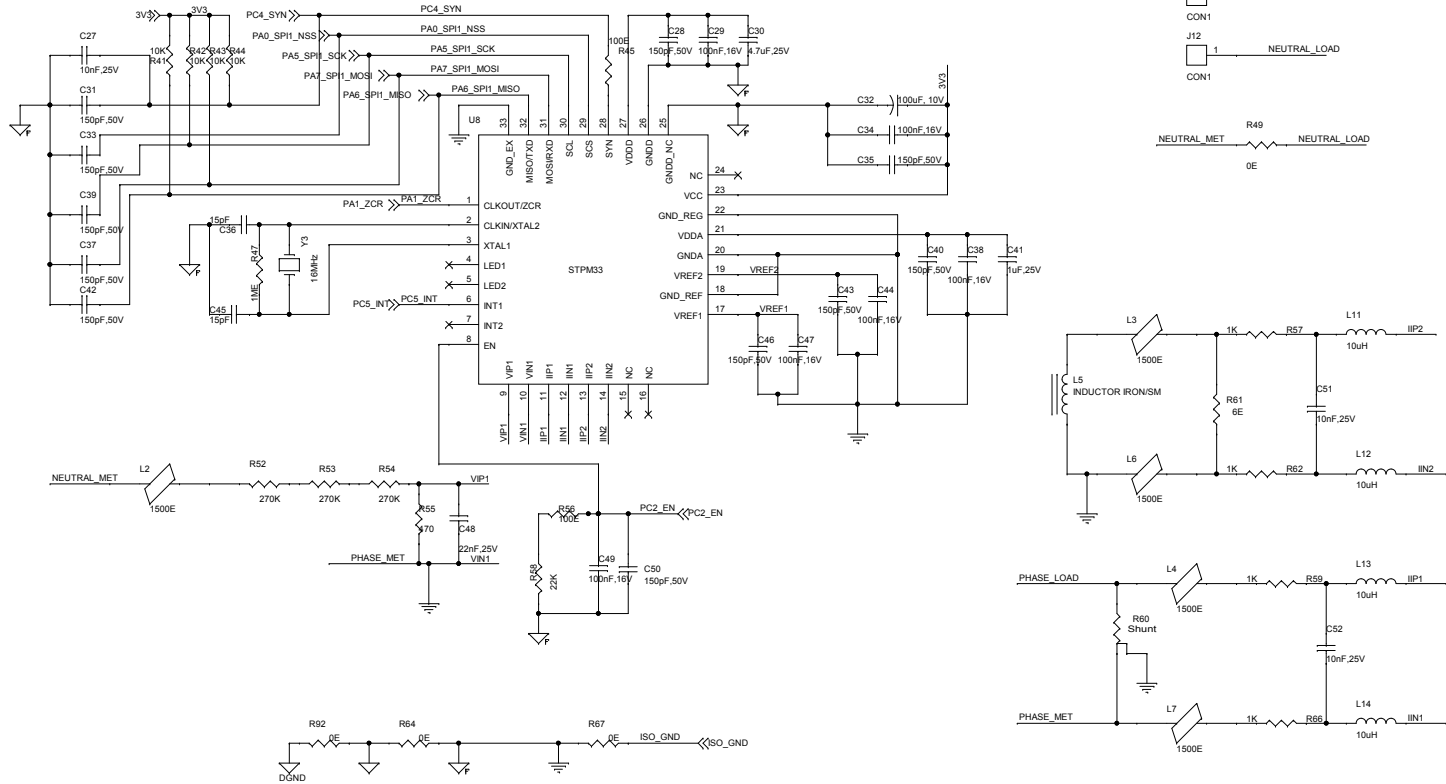


RELAY SECTION

STMod+ SECTION



Figure 21. STDES-EMETER1PV1 circuit schematic (8 of 8)



8 Bill of materials

Table 3. STDES-EMETER1PV1 bill of materials

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
1	1	U1	M24M01-R, SO-8	1-Mbit serial I ² C bus EEPROM	ST	M24M01-R
2	2	U2, U6	LDK220U33R, SOT-89	200 mA low quiescent current and low noise LDO	ST	LDK220U33R
3	1	U	STM32L433VCT6, LQFP100	Ultra-low-power with FPU ARM Cortex-M4 MCU 80 MHz with 256 Kbytes Flash, LCD, USB	ST	STM32L433VCT6
4	2	Q6, Q10	STS6P3LLH6, SMA	P-channel 30 V, 0.024 Ohm typ., 6 A, STripFET VI DeepGATE Power MOSFET in SO-8 package	ST	STS6P3LLH6
5	3	Q7, Q8, Q9	2STR1215, SOT-23	Low voltage fast-switching NPN power transistor	ST	2STR1215
6	1	Q11	2STR2230, SOT-23	Low voltage fast-switching PNP power transistor	ST	2STR2230
7	1	U5	ALTAIR04-900, SO16N	Off-line all-primary-sensing switching regulator	ST	ALTAIR04-900
8	1	U8	STPM33, QFN32L 5x5x1	ASSP for metering applications with up to four independent 24-bit 2 nd order sigma-delta ADCs, 4 MHz OSF and 2 embedded PGLNA	ST	STPM33

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
9	1	U10	STBB1-AXX, DFN10 3x3	High efficiency single inductor dual mode buck-boost DC-DC converter with 2.3 A switches peak current	ST	STBB1-AXX
10	2	D7, D15	STPS1L60A, SMA	1 A 60 V Power Schottky Rectifier	ST	STPS1L60A
11	1	D8	P6KE200A, SMA	600 W TVS in DO-15	ST	P6KE200A
12	1	D9	STTH108, SMA	800 V, 1 A ultra-fast diode	ST	STTH108
13	2	D14,D16	STPS1150, DO-41	150 V power Schottky rectifier	ST	STPS1150
14	2	C1, C26	10 nF, SMD0805, 10 V	Capacitors	Any	Any
15	1	C2	4.7 μ F, SMD0805, 10 V	Capacitor	Any	Any
16	6	C3, C4, C5, C6, C7, C15	0.1 μ F, SMD0805, 6.3 V	Capacitors	Any	Any
17	2	C8, C11	6.8 pF, SMD0805, 10 V	Capacitors	Any	Any
18	4	C9, C10, C19, C20	1 μ F, SMD0805, 10 V	Capacitors	Any	Any
19	1	C14	1 μ F, SMD0805, 10 V	Capacitor	Any	Any
20	3	C21, C22, C62	10 nF/0402, SMD0805, 10 V	Capacitors	Any	Any
21	2	C23, C65	100 nF, SMD0805, 10 V	Capacitors	Any	Any
22	1	C24	1000 μ F, $\varnothing$ 10x20 - pitch 5, 10 V	Capacitor	Any	Any
23	1	C25	2.2 μ F, $\varnothing$ 6,3x10 - pitch 2,5, 10 V	Capacitor	Any	Any
24	3	C27, C51, C52	10 nF, SMD0603, 25 V	Capacitors	Any	Any
25	11	C28, C31, C33, C35, C37, C39, C40, C42, C43, C46, C50	150 pF, SMD0402, 25 V	Capacitors	Any	Any
26	6	C29, C34, C38, C44, C47, C49	100 nF, SMD0402, 50 V	Capacitors	Any	Any
27	1	C30	4.7 μ F, SMD0603, 16 V	Capacitor	Any	Any

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
28	1	C32	100 μ F, SMD1206, 25 V	Capacitor	Any	Any
29	2	C36, C45	15 pF, SMD0402, 10 V	Capacitors	Any	Any
30	1	C41	1 μ F, SMD0603, 10 V	Capacitor	Any	Any
31	1	C48	22 nF, SMD0603, 25 V	Capacitor	Any	Any
32	1	C53	4.7nF, SMD0805, 25 V,	Capacitor	Any	Any
33	1	C54	47 μ F, THT $\varnothing$ 12.5x25 - pitch 5, 25 V	Capacitor	Any	Any
34	1	C55	5 F, THT $\varnothing$ 10x20 - pitch 5, 400 V	Capacitor	Any	Any
35	3	C57, C61, C63	470 μ F, THT, lead spacing 7.5 mm, 5 V	Capacitors	Any	Any
36	1	C58	2.2 nF, SMD0805, 220 V	Capacitor	Any	Any
37	1	C59	470 nF, SMD0805, 50 V	Capacitor	Any	Any
38	1	C60	1 nF, THT $\varnothing$ 8x11.5 - pitch 3.5, 50 V	Capacitor	Any	Any
39	1	C66	22 nF/X2, THT, lead spacing 15 mm (18 mm x 7 mm x 12.5 mm), 50 V	Capacitor	Any	Any
40	1	C68	22 μ F, THT, 10 V	Capacitor	Any	Any
41	2	D12, D23	SMD0805	Green LEDs	Any	Any
42	1	D13	7 V, THT	Diode	Any	Any
43	2	D21, D22	THT	Diodes	Any	Any
44	1	D24	SOD323, THT, Pitch 2.54 mm	10 V general purpose signal Schottky diode	ST	BAT60
45	1	J1	CR2032	Jumper	Any	Any
46	1	J2	7X2, THT 2.54 mm pitch	Header	Any	Any
47	1	J3	CON2, THT 2.54 mm pitch	Connector	Any	Any
48	1	J9	CON1_NEUTRAL, single pin THT	Connector	Any	Any
49	1	J10	CON1_PHASE, Single Pin THT,	Connector	Any	Any
50	2	J11, J12	CON1, single pin THT	Connectors	Any	Any
51	1	J13	CON22, 20 pin THT	LCD connector	Any	Any

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
52	1	J16	ER-14250, THT	Battery connector	Any	Any
53	1	J21	SWD, THT 2.54 mm pitch	Connector	Any	Any
54	1	J24	3X2, THT	Header	Any	Any
55	1	J25	REALY_CON, THT 2.54 mm pitch	Connector	Any	Any
56	2	L1, R74	470E, SMD1206	Inductors	Any	Any
57	5	L2, L3, L4, L6, L7	1500E, SMD0603	Inductors	Any	Any
58	1	L5	2 pin, 2.54 mm	Inductor	Any	Any
59	1	L8	1mH, 1000 μ H $\pm$ 10% SMD 1005	Fixed inductor	Any	Any
60	4	L11, L12, L13, L14	10 μ H, SMD0805	Fixed inductors	Any	Any
61	1	L20	470 μ H, SMD 6.3 x 6.3 x 3.0 mm	Inductor	Any	Any
62	1	L21	CM, THT	Inductor	Any	Any
63	1	L22	2.2 μ H, SMD	Inductor	EPCOS	B82721-K2701
64	2	NTC1,NTC2	16E, 2.4 W, 16 Ohms 2.9 amps 1207 k	Inrush current limiters	TDK	B57236S0160M000V9
65	1	PD1	TX, THT	TX THT	Any	Any
66	1	PQ1	RX, THT	RX THT	Any	Any
67	1	RV1	460 V, THT, diameter 14 mm	THT	Any	Any
68	12	R1, R2, R3, R7, R41, R42, R43, R44, R72, R86, R87, R88	10 K, SMD0805	Resistors	Any	Any
69	1	R4	6.8 M, 1 W, SMD1206	Resistor	Any	Any
70	2	R5, R6	4.7 K, SMD0805	Resistors	Any	Any
71	1	R8	33 K, SMD0805	Resistor	Any	Any
72	21	R10, R33, R34, R35, R36, R37, R38, R40, R46, R63, R91, R94, R95, R97, R99, R100, R101, R102, R103, R104, R105	0, SMD0402	Resistors	Any	Any
73	1	R11	100 E, 1 W, THT	Resistor	Any	Any

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
74	14	R13, R15, R16, R17, R22, R24, R25, R26, R49, R64, R67, R68, R71, R92	0 E, SMD0805	Resistors	Any	Any
75	1	R18	51 K, SMD1206	Resistor	Any	Any
76	1	R27	1.3E, SMD1206	Resistor	Any	Any
77	12	R28, R32, R48, R57, R59, R62, R66, R70, R75, R77, R108, R109	1 K, SMD0805	Resistors	Any	Any
78	2	R29, R30	8.2 K, SMD0805	Resistors	Any	Any
79	4	R31, R45, R50, R56	100E, SMD0805	Resistors	Any	Any
80	1	R39	50 K, SMD0805	Resistor	Any	Any
81	1	R47	1ME, SMD0603	Resistor	Any	Any
82	1	R51	100K, SMD0805	Resistor	Any	Any
83	3	R52, R53, R54	270 K, SMD0204	Resistors	Any	Any
84	1	R55	470, SMD0207	Resistor	Any	Any
85	1	R58	22 K, SMD0805	Resistor	Any	Any
86	1	R60	THT	Resistor	Isabellenhuet Heusler GmbH & Co. KG	BKW-M-R0003-5.0
87	1	R61	6E, SMD0603	Resistor	Any	Any
88	1	R65	560K, SMD0805	Resistor	Any	Any
89	3	R80, R82, R84	1M/0402, SMD0805	Resistors	Any	Any
90	3	R81, R83, R85	0E/0402, SMD0805	Resistors	Any	Any
91	1	R96	510E, SMD0805,	Resistor	Any	Any
92	1	R106	220E, SMD0805	Resistor	Any	Any
93	1	SW1	THT	Top cover open switch	Any	Any
94	1	SW2	THT	Terminal cover open switch	Any	Any
95	1	SW3	THT	Up and down switch	Any	Any
96	1	SW4	MD_RESET SW, THT	Reset switch	Any	Any
97	1	SW5	THT	Open module switch	Any	Any
98	1	TP1	THT	Test point	Any	Any
99	1	T1	EE 16 N87, vertical	Bobbin coil	Any	Any
100	1	Y1	32.768 KHz, THT	THT	Any	Any

Item	Q.ty	Ref.	Value	Description	Manufacturer	Part Number
101	1	Y3	16 MHz, THT, pitch 5 mm	THT	Any	Any
102	2	U4, U9	DBLS208GRD	Bridge rectifier	Taiwan Semiconductor	DBLS208GRD
103	1	U7	AH180	Board mount Hall effect magnetic sensor	Diodes Incorporated	AH180

Revision history

Table 4. Document revision history

Date	Revision	Changes
23-Aug-2021	1	Initial release.

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