Electricity metering IC expansion board based on STPM33 for STM32 NUCLEO

Introduction

The X-NUCLEO-PM33A1 is an expansion board based on the STPM33, which measures the RMS and instantaneous value of voltage, current, power, energy, and frequency.

The board communicates the information back to any PC terminal utility.

X-NUCLEO-PM33A1 can measure metering parameters for both AC and DC sources.

Measured metering parameters are sent over any PC terminal utility via VCOM.

Calibration routine is included in the firmware.

LEDs are connected to the STPM33 for pulse generation.

EEPROM is present on the board to store any metering parameter.

The X-NUCLEO-PM33A1 is compatible with STM32 Nucleo boards. The firmware is STM32CubeMX compatible providing easy portability across different STM32 MCU.

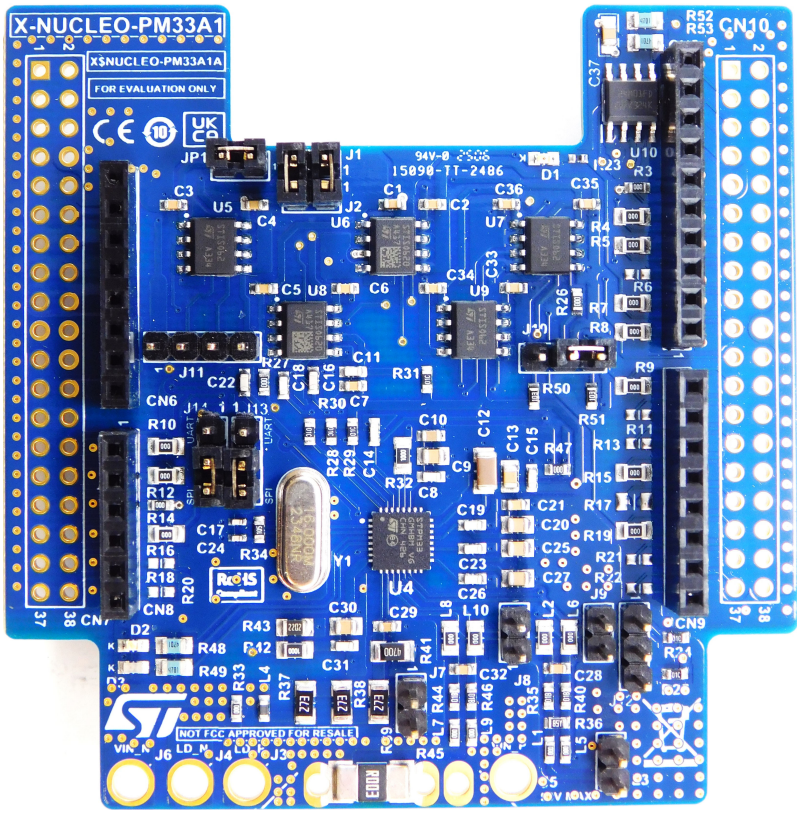
This supports both SPI and UART interface. Onboard digital isolators are present on UART and SPI connections to enable users to evaluate the STPM33 device by isolating it from the MCU.

The STPM33 is a dedicated IC for electricity metering with 0.1% accuracy.

The STPM3x is an ASSP family of mixed signals designed for high accuracy measurement of power and energy in power line systems using the Rogowski coil, current transformer, or shunt current sensors.

The STPM3x devices provide instantaneous voltage and current waveforms and calculate: voltage and current RMS values, active, reactive, and apparent powers and energies for each channel with accuracy standards (EN 50470-x, IEC 62053-2x, ANSI12.2x for AC watt meters).

Figure 1. X-NUCLEO-PM33A1



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1 Getting started

1.1 Block diagram and application scenario

Figure 2. **Block diagram**

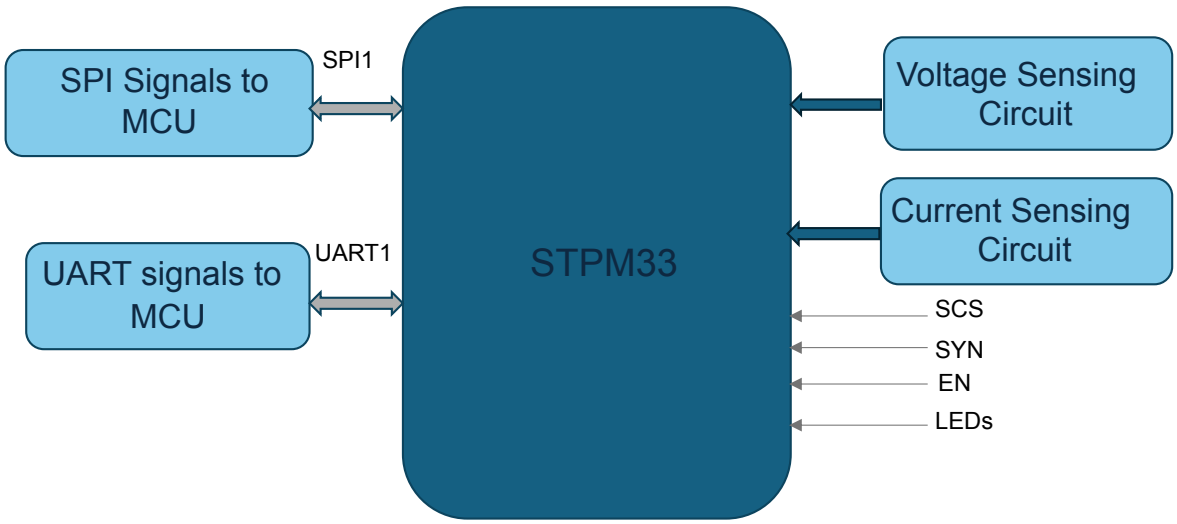
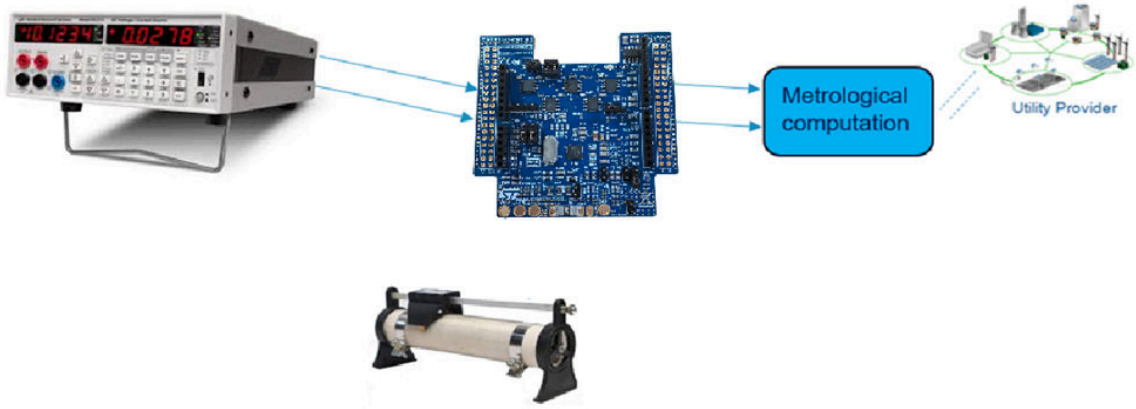


Figure 3. **Application scenario**



2 Components

2.1 STPM33

The STPM3x is an ASSP 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 and calculates the RMS values of voltage and currents, active, reactive, and apparent power and energies.

The STPM3x is a mixed signal IC family consisting of an analog and a digital section.

The analog section consists of up to two programmable gain low-noise low-offset amplifiers and up to four 2nd order 24-bit sigma-delta ADCs, two bandgap voltage references with independent temperature compensation, a low drop voltage regulator, and DC buffers.

The digital section consists of a 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.

2.2 STISO621

The STISO621 is a dual-channel digital isolator based on the ST thick oxide galvanic isolation technology. The device provides two independent channels in the same direction with Schmitt trigger input, providing robustness to noise and high-speed input/output switching time features.

- High data rate up to 100 Mbps
- Wide temperature range operation: - 40 ºC to 125 ºC
- High common-mode transient: >50 kV/µs
- From 3 to 5.5 V supply levels
- 3.3 and 5 V level translation
- Low power consumption
- Pulse width distortions < 3 ns
- 6 kV galvanic isolation

2.3 STISO620

The STISO620 is a dual-channel digital isolator based on the ST thick oxide galvanic isolation technology. The device provides two independent channels in the same direction with Schmitt trigger input, providing robustness to noise and high-speed input/output switching time features.

- Dual-channel digital isolator with 2 – 0 channel directionality
- High data rate up to 100 Mbps
- Wide temperature range operation: - 40 ºC to 125 ºC
- High common-mode transient immunity
- From 3 to 5.5 V supply levels
- Available in 8-pin SOIC narrow-body
- Low power consumption
- Pulse width distortions < 3 ns
- Galvanic isolation

3 Single phase smart meter software package description

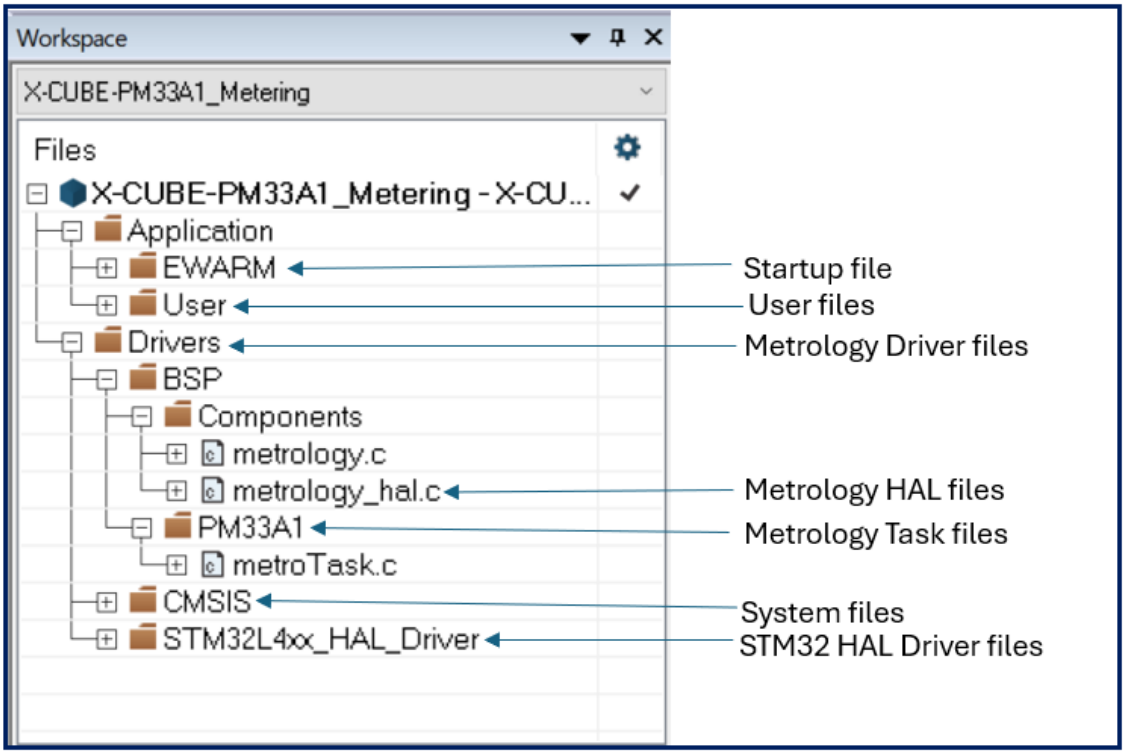
3.1 Overview

The software package includes:

- X-CUBE-PM33A1 getting started
- STPM33 library
- STM32L4 driver/STM32G0 driver
- Application files
- Html resources

3.2 Folder structure

Figure 4. Folder structure

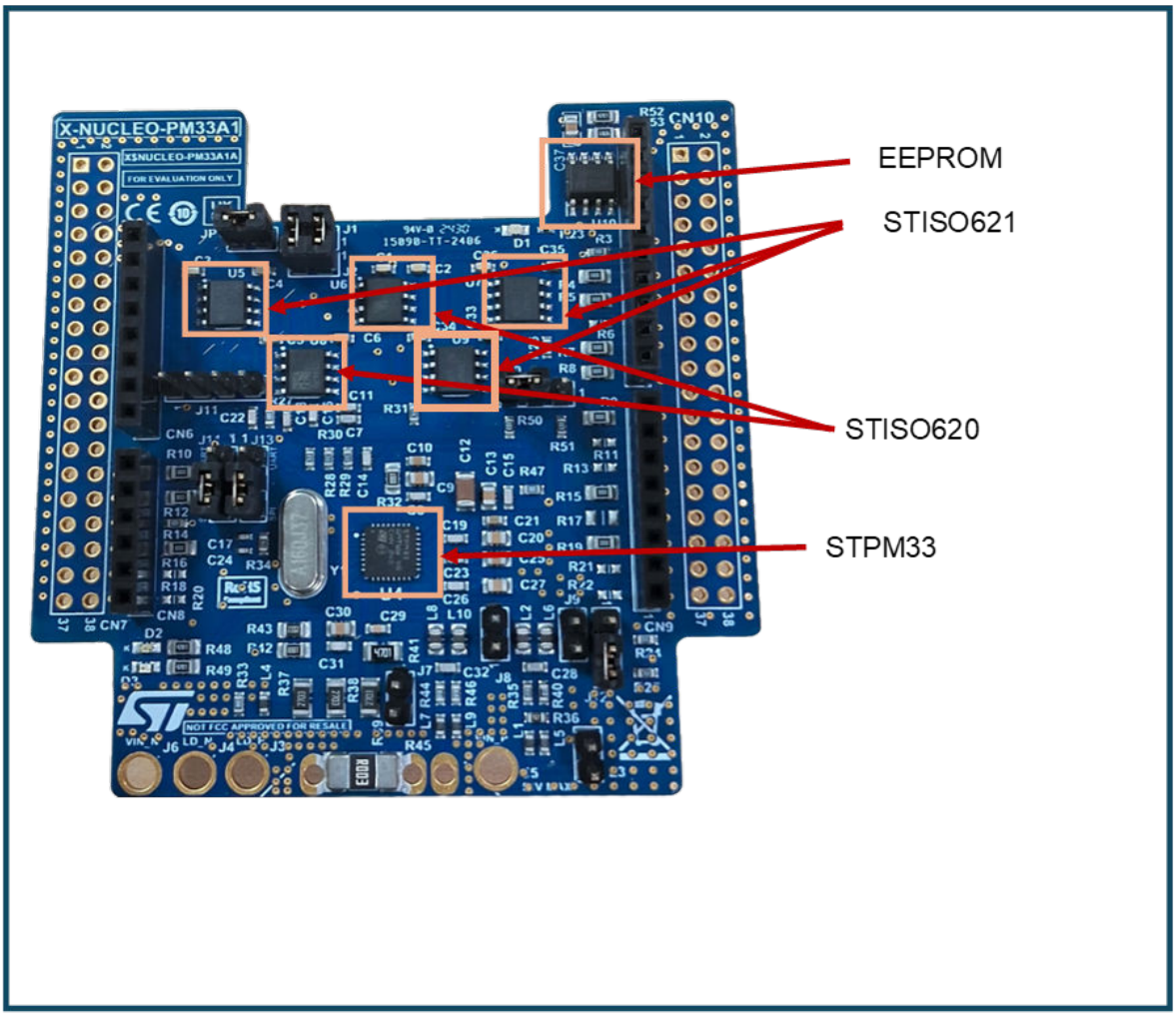


4 Getting started with X-CUBE -PM33A1

Some hardware connections need to be done to start working with the board.
The STPM33 on X-NUCLEO-PM33A1 can be interfaced using an SPI or UART interface.

4.1 Hardware components on the board

Figure 5. PCB design



4.2 Connections

Connections

Step 1. Connect the one end of shunt resistor "R45" and jumper "J6" to the +ve and -ve terminal of the voltage to be measured respectively.

Step 2. Connect jumper "J6" and another end of shunt resistor "R45" to the +ve and -ve terminal of the load to be measured respectively.

Figure 6. **Visualized connections for voltage and load**

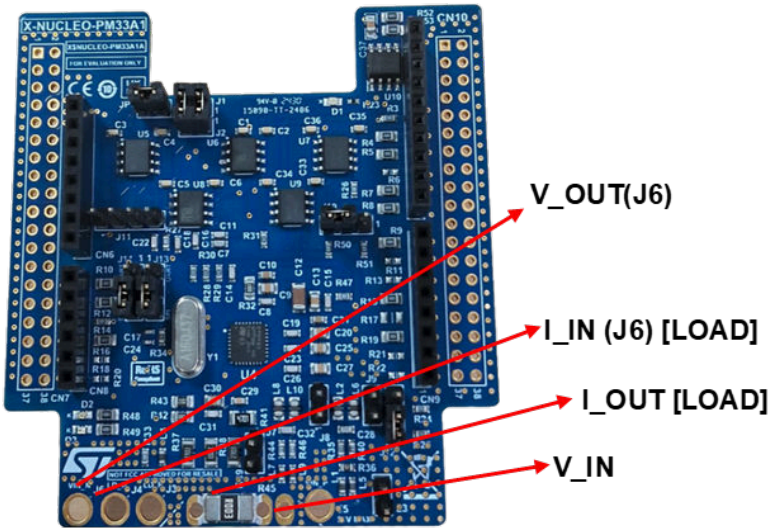


Table 1. **Connections for voltage and load**

Jumper	Description
One end of shunt resistor R45	+ve terminal of the voltage to be measured
J6	-ve terminal of the voltage to be measured
Another end of shunt resistor R45	-ve terminal of the LOAD
J6	+ve terminal of the LOAD

4.3 SPI and UART selection

To select SPI protocols, connect the jumper as below:

Step 1. On J10 connector, jumpers must be fitted on pin number 1 and 2

Step 2. On J13 connector, jumpers must be fitted on pin number 2 and 3

Step 3. On J14 connector, jumpers must be fitted on pin number 2 and 3

■

For selection between UART protocols connect the jumper as below:

Step 1. On J10 connector, jumpers must be fitted on pin number 2 and 3

Step 2. On J13 connector, jumpers must be fitted on pin number 1 and 2

Step 3. On J14 connector, jumpers must be fitted on pin number 1 and 2

Figure 7. **Jumper for SPI and UART configuration**

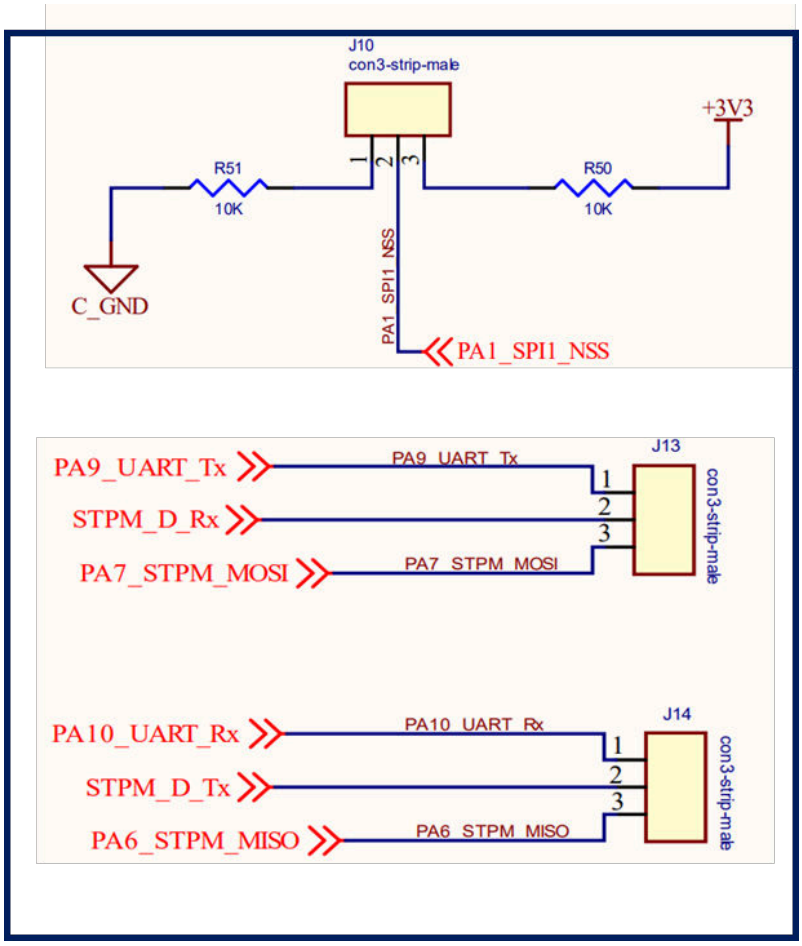


Figure 8. **SPI configuration**

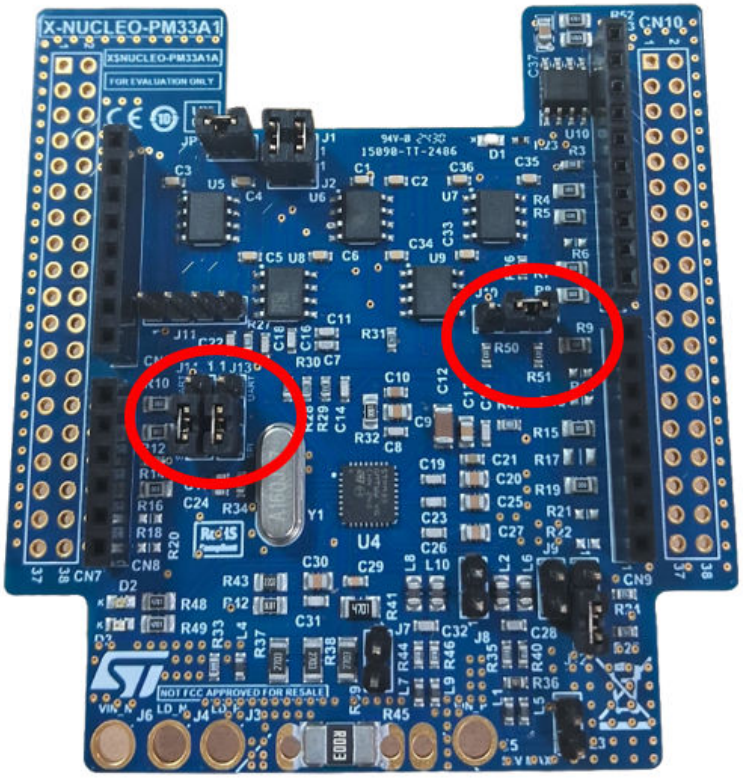
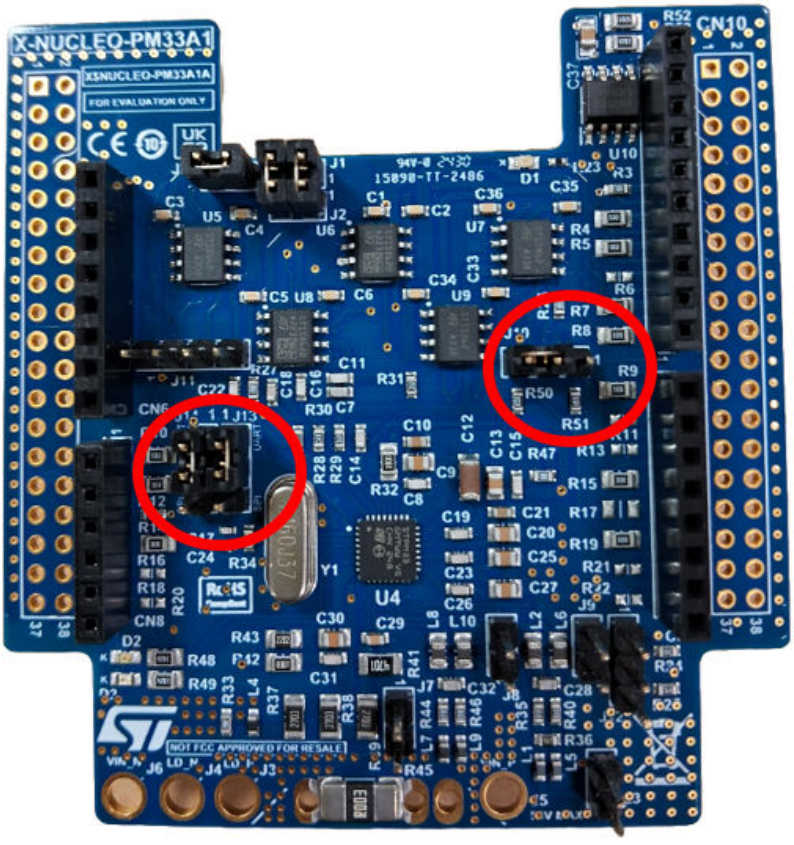
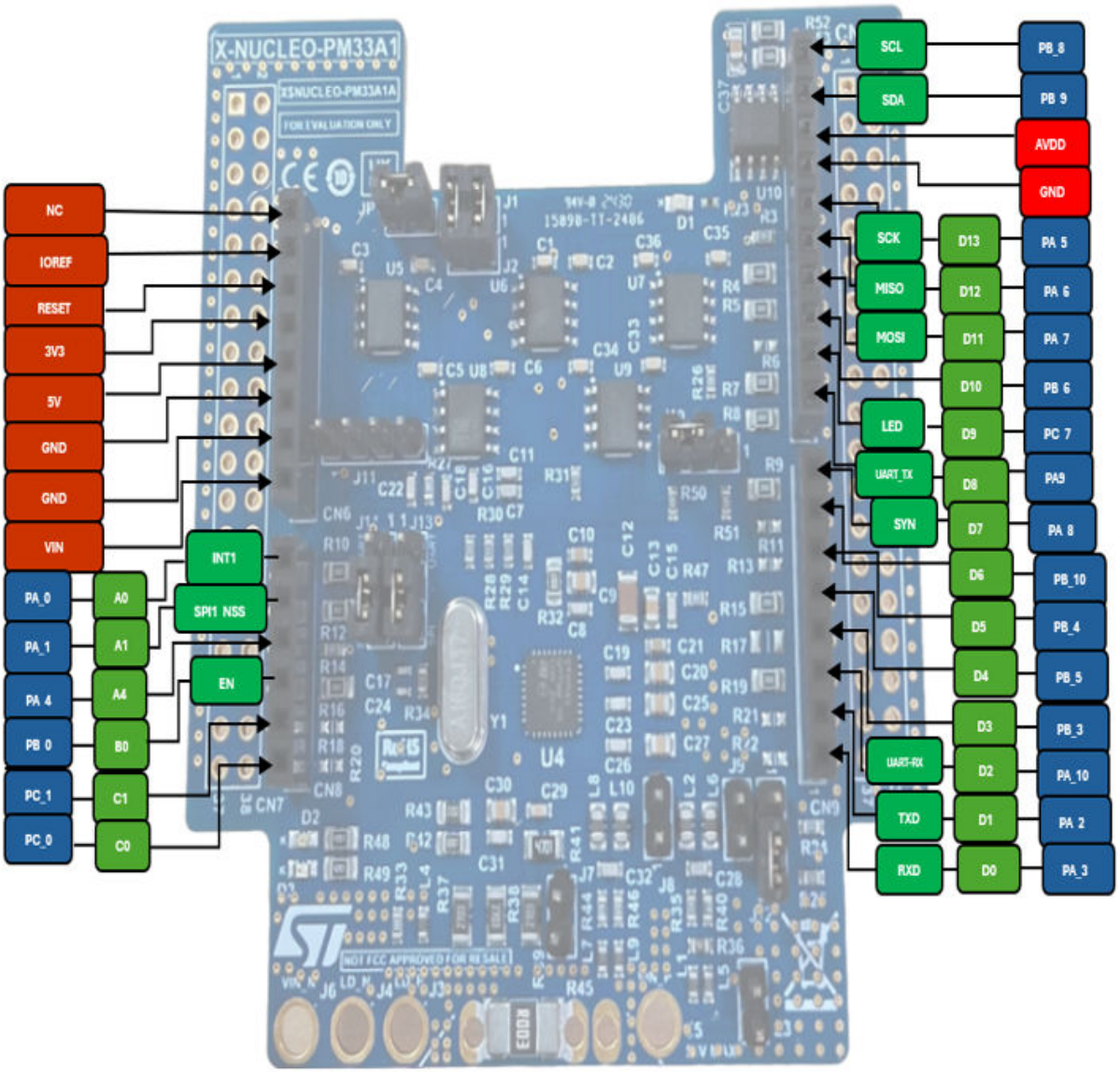


Figure 9. **UART configuration**



4.4 Pin descriptions

Figure 10. **Pin diagram**



4.5 GPIO connections

Table 2. **GPIO connections**

No.	STM32 pins from Arduino® connector	Signals of STPM going to STM32
1	PA6 (SPI MISO)	SPI MISO/UART TxD*
2	PA9 (UART TxD)	
3	PA7 (SPI MOSI)	SPI MOSI/UART RxD*
4	PA10 (UART RxD)	
5	PA5	SPI CLK
6	PA8	SYN
7	PA1	SPI1 NSS

No.	STM32 pins from Arduino® connector	Signals of STPM going to STM32
8	PB0	EN
9	PA0	INT1

5 Calibration

Step 1. Mount the X-NUCLEO-PM33A1 on STM32 NUCLEO

Step 2. Program the NUCLEO board with the firmware given

Step 3. Connect the voltage and load terminal as given in the table

Step 4. Connect any terminal utility at baud rate 115200

Figure 11. Output on terminal

```
<LF>
** Metering Data : Measurement Counter 0  ***<LF>
<LF>
RMS Voltage : 9.82V<LF>
RMS Current : 2.18A<LF>
Power Active : 9.80W<LF>
Active Energy : 0.00 WH<LF>
**********<LF>
```

5.1 Amplitude calibration of the STPM33

5.2 Steps for the calibration

Step 1. Update the R1, R2, Ks, AI in the "pm33a1_conf.c" file as per actual hardware.

Figure 12. Application parameters

```
/* APPLICATION PARAMETERS  */
float r1 = 810000;/*  #ohm  */
float r2 = 4700 ;/*    #Ohm  */
float ks = 3;/*  #mv/A , CT sensitivity  */
float ai = 2 ;/* #current gain  */
```

Step 2. Update the macro value in "pm33a1_conf.h" file for the expected value of voltage and current (The value at which calibration is performed).

Figure 13. Macro value

```
#define EXPECTED_VOLTAGE ((float)10)  /*In Volt*/
#define EXPECTED_CURRENT ((float)1)    /*In Ampere*/
```

Step 3. Program the board with the given firmware.

Step 4. Reset the STPM33, by pressing the "RESET" button on the NUCLEO board, so that all the registers are in default state.

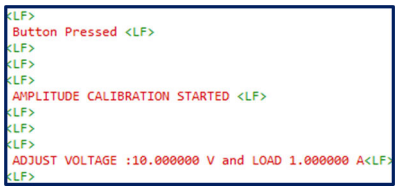
Step 5. Apply the voltage and load to the board. The board reads the voltage and current values without any calibration done to it.

Figure 14. Metering data

```
<LF>
** Metering Data : Measurement Counter 4  ***<LF>
<LF>
RMS Voltage : 9.80V<LF>
RMS Current : 1.11A<LF>
Power Active : 9.60W<LF>
Active Energy : 0.00 WH<LF>
**********<LF>
```

Step 6. On the hardware part, press the "User button" on the NUCLEO board. Once we press the button, in the output terminal we get a message as follows:

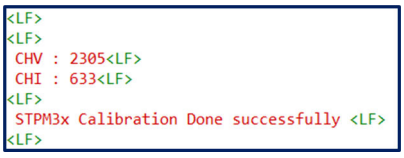
Figure 15. User button



We need to adjust the source voltage and load value as in the above image in actual power supply and load.

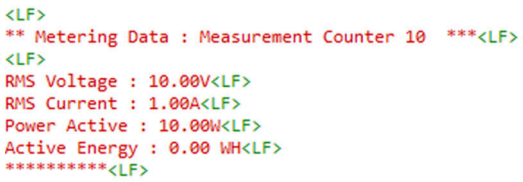
Step 7. Press the user button once again to perform the amplitude calibration. After pressing the button, the firmware calculates the CHV and CHI values and writes to the calibration registers.

Figure 16. Amplitude calibration



Step 8. After the calibration is done successfully, we get the calibrated voltage and current values as per the power supply.

Figure 17. Calibration completed



Note: EEPROM support is not included in this firmware version. It is to be offered in future.

6 Schematic diagrams

Figure 18. **X-NUCLEO-PM33A1 circuit schematic (1 of 3)**

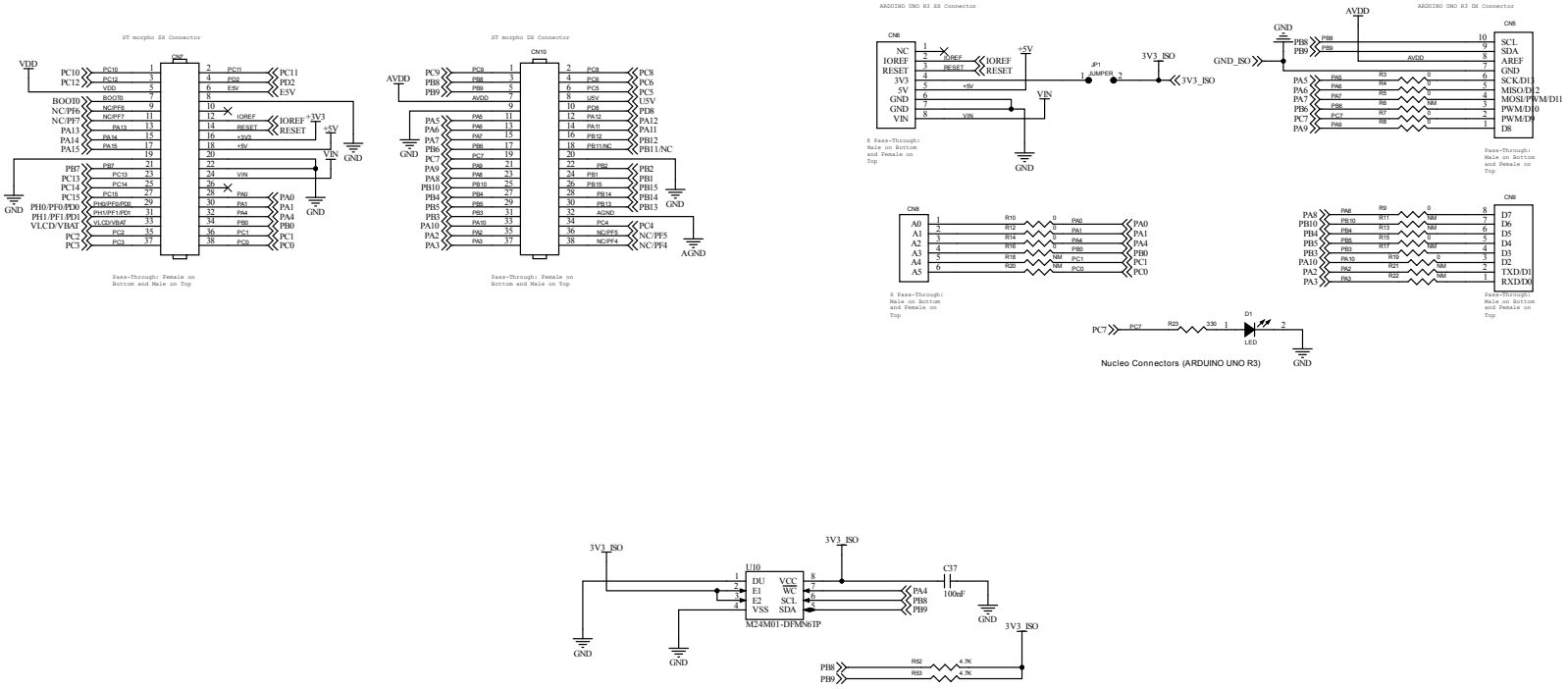


Figure 19. X-NUCLEO-PM33A1 circuit schematic (2 of 3)

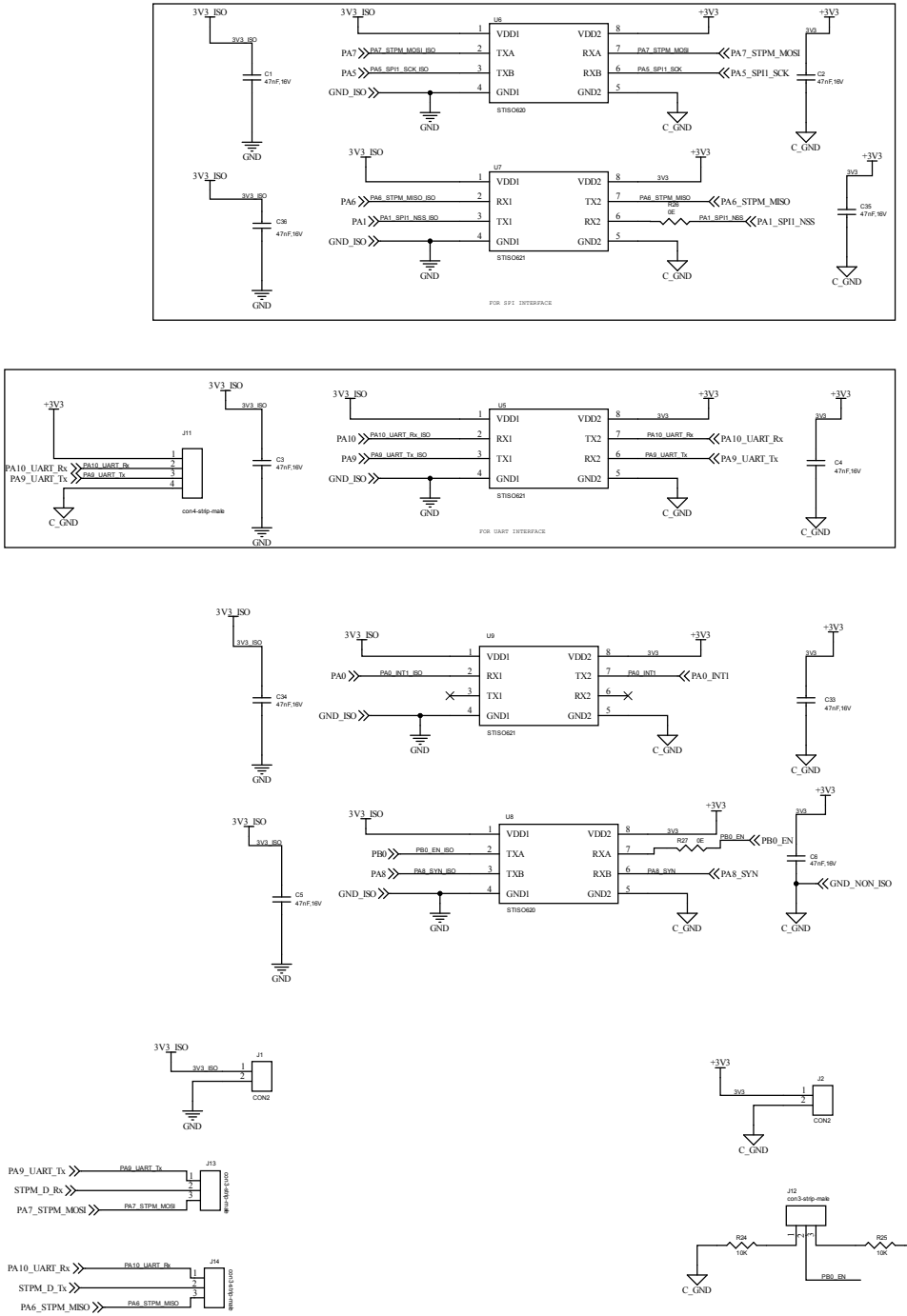
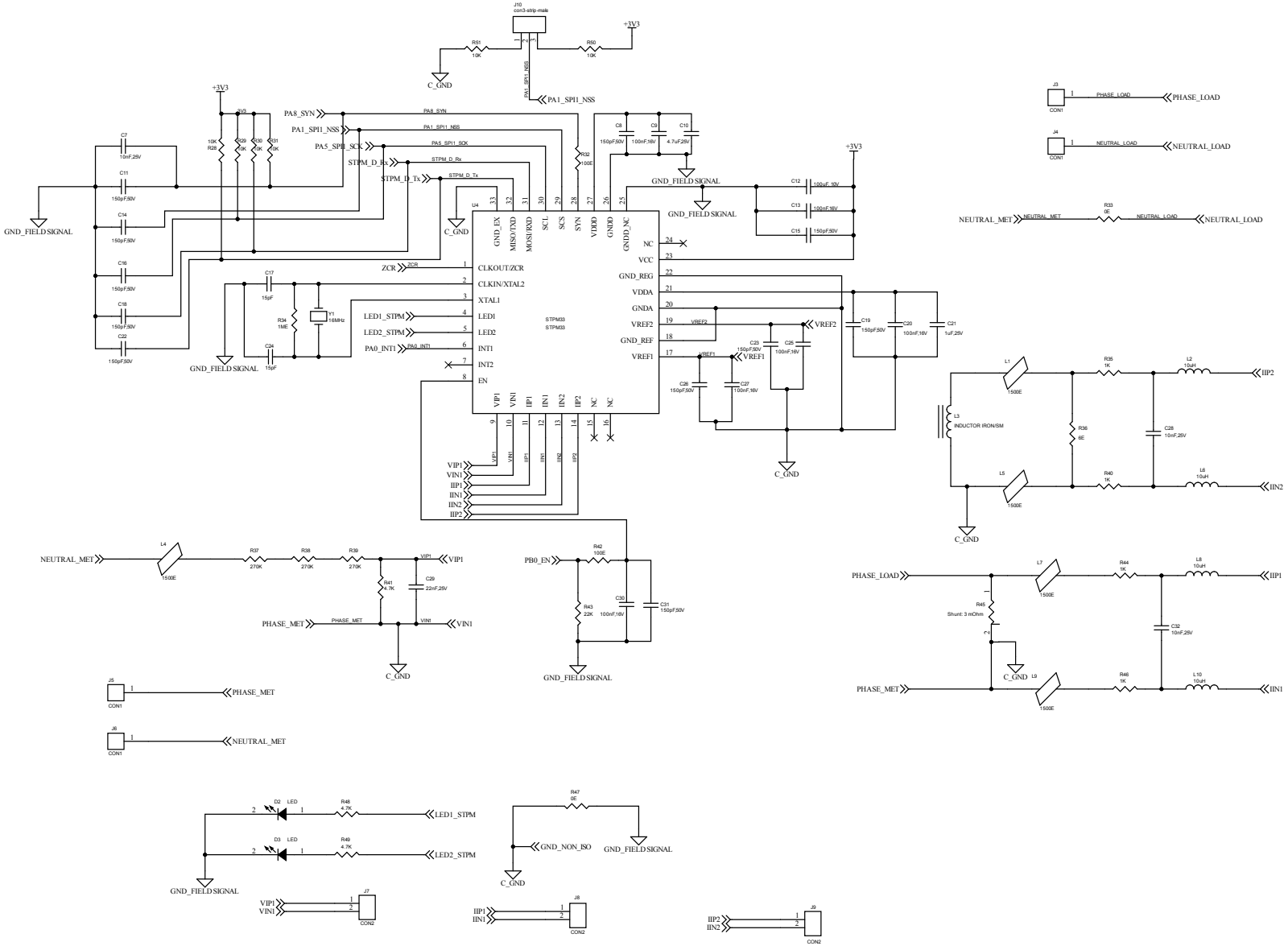


Figure 20. X-NUCLEO-PM33A1 circuit schematic (3 of 3)



7 Bill of materials

Table 3. **X-NUCLEO-PM33A1 bill of materials**

Item	Quantity	Reference	Part / value	Description	Manufacturer	Part number
1	1	U4	STPM33TR, QFN32L 5x5x1	ASSP for metering applications with up to four independent 24-bit 2nd order sigma-delta ADCs, 4 MHz OSF and 2 embedded PGLNA	STMicroelectronics	STPM33TR
2	2	U6,U8	STISO620, SO8N	Dual-channel digital isolator	STMicroelectronics	STISO620
3	3	U5,U7,U9	STISO621, SO8N	Dual-channel digital isolator	STMicroelectronics	STISO621
4	1	U10	M24M01-DFMN6TP, 8-SOIC	IC EEPROM 1MBIT I2C 1MHZ 8SOIC	STMicroelectronics	M24M01-DFMN6TP
5	2	CN7,CN10	Header 19x2 2.54 mm pitch	Header 19x2 2.54 mm pitch (not mounted)	Würth Elektronik	61303821121
6	1	CN5	CON10 550 VAC 2.54 mm pitch	10 Pass-through Male on bottom and Female on top	4UCON	SSQ-110-03-F-S
7	1	CN8	CON6 550 VAC 2.54 mm pitch	6 Pass-through: Female on bottom and Male on top	4UCON	SSQ-106-03-F-S
8	2	CN6,CN9	CON8 550 VAC 2.54 mm pitch	8 Pass-through Male on bottom and Female on top	4UCON	SSQ-108-03-F-S
9	11	C8,C11,C14, C15,C16,C18 ,C19,C22,C2 3,C26,C31	150pF,50V	150 pF ±5% 50V Ceramic Capacitor C0G, NP0 0603 (1608 Metric)	Würth Elektronik	885012006058
10	7	C9,C13,C20, C25,C27,C30 ,C37	100nF,16V	0.1 µF ±10% 16V Ceramic Capacitor X7R 0805 (2012 Metric)	Würth Elektronik	885012207045
11	1	C10	4.7uF,25V	4.7 µF ±10% 25V Ceramic Capacitor X6S 0603 (1608 Metric)	Murata Electronics	GRM188C81E475KE11D
12	3	C7,C28,C32	10nF,25V	10000 pF ±10% 25V Ceramic Capacitor X5R 0603 (1608 Metric)	Würth Elektronik	885012206065
13	1	C12	100uF,10V	100 µF ±20% 10V Ceramic Capacitor JB 1206 (3216 Metric)	TDK Corporation	C3216JB1A107M160AC
14	2	C17,C24	15pF	15 pF ±5% 10V Ceramic Capacitor C0G, NP0 0402 (1005 Metric)	Würth Elektronik	885012005008
15	1	C21	1uF,25V	1 µF ±10% 25V Ceramic Capacitor X5R 0603 (1608 Metric)	Würth Elektronik	885012206076
16	1	C29	22nF,25V	0.022 µF ±10% 25V Ceramic Capacitor X7R 0603 (1608 Metric)	Würth Elektronik	885012206067

Item	Quantity	Reference	Part / value	Description	Manufacturer	Part number
17	10	C1,C2,C3,C4,C5,C6,C33,C34,C35,C36	47nF,16V	0.047 µF ±10% 16V Ceramic Capacitor X7R 0603 (1608 Metric)	Würth Elektronik	885012206044
18	1	D1	LED 20 mA SMD-0603	Three LED (Red 520nm LED Indication - Discrete 3.2V 0603 (1608 Metric))	Würth Elektronik	150060RS75000
19	1	D2	LED 20 mA SMD-0603	Three LED (Green 520nm LED Indication - Discrete 3.2V 0603 (1608 Metric))	Würth Elektronik	150060GS75000
20	1	D3	LED 20 mA SMD-0603	Three LED (Orange 520nm LED Indication - Discrete 3.2V 0603 (1608 Metric))	Vishay Semiconductors	TLMO1100-GS15
21	1	JP1	VH/T M2OE/W.325/10/MOD	JUMPER (2 (1 x 2) Position Shunt Connector Black Closed Top 0.100" (2.54mm) Tin)	Würth Elektronik	60900213421
22	4	J3,J4,J5,J6	2.54 mm through hole	Connector (CON1) (not mounted)	Harwin	M22-2510146
23	5	J1,J2,J7,J8,J9	2 Pin x 2.54 mm	Connector (CON2)	Würth Elektronik	61300211121
24	1	J10	3pinx2.54mm	Connector (CON3)	Würth Elektronik	61300311121
25	1	J11	4pinx2.54mm	Connector (CON4)	Würth Elektronik	61300411121
26	3	J12,J13,J14	3pinx2.54mm	Connector (CON3)	Amphenol FCI	94611-203HLF
27	1	L4	1500E	FERRITE BEAD 1.5 KOHM 0603 1LN	TDK Corporation	MMZ1608Y152BTA00
28	4	L1,L5,L7,L9	0 Ohm	0 Ohms Jumper Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200 Thick Film (0 Ohm Resistor to be mounted)	Stackpole Electronics Inc	RMCF0603ZT0R00
29	4	L2,L6,L8,L10	0 Ohm	0 Ohms Jumper Chip Resistor 0805 (2012 Metric) Moisture Resistant Thick Film (0 Ohm Resistor to be mounted)	Yageo	RC0805JR-070RL
30	1	L3	INDUCTOR IRON/SM	CONN HEADER VERT 2POS 2.54MM	Würth Elektronik	61300211121
31	6	R24,R25,R28,R29,R30,R31	10K	10 kOhms ±1% 0.125W, 1/8W Chip Resistor 0603 (1608 Metric) Anti-Sulfur Thin Film	Würth Elektronik	560112116005
32	2	R32,R42	100E	RES 100 OHM 1% 1/8W 0805	Würth Elektronik	560112120020
33	3	R26,R27,R47	0E	0 Ohms Jumper 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Moisture Resistant Thick Film	Würth Elektronik	560112116001

Item	Quantity	Reference	Part / value	Description	Manufacturer	Part number
34	1	R34	1ME	1 mOhms ±5% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Thick Film	Würth Elektronik	560112116076
35	4	R35,R40,R44 ,R46	1K	1 kOhms ±1% 0.125W, 1/8W Chip Resistor 0603 (1608 Metric) Anti-Sulfur Thin Film	Würth Elektronik	560112116014
36	1	R36	7.5E	7.5 Ohms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Moisture Resistant Thick Film	Yageo	RC0603FR-077R5L
37	3	R37,R38,R39	27K	27 kOhms ±5% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film	Yageo	RC1206JR-0727KL
38	1	R41	470 Ohm	470 Ohms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film	TE Connectivity Passive Product	CRGCQ1206F470R
39	1	R43	22K	22 kOhms ±1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film	TE Connectivity Passive Product	CRGCQ0805F22K
40	1	R45	Shunt	Current Sense Resistors - SMD MSMA, 2512 SIZE, 3 Watt, 3 mOhm, 50 TCR NiCu Metal AEC-Q	Eaton	MSMA2512R0030FGN
41	4	R48,R49,R52 ,R53	4.7K	4.7 kOhms ±1% 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Thick Film	Walsin Technology Corporation	WR08X4701FTL
42	8	R6, R11, R13, R17, R18, R20, R21, R22	0	0 Ohms Jumper 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Automotive AEC-Q200, Moisture Resistant Thick Film (not mounted)	Würth Elektronik	560112116001
43	12	R3, R4, R5, R7, R8, R9, R10, R12, R14, R15, R16, R19	0	0 Ohms Jumper 0.125W, 1/8W Chip Resistor 0805 (2012 Metric) Automotive AEC-Q200 Thick Film	Würth Elektronik	560112120002
44	1	R23	330	330 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Anti-Sulfur, Automotive AEC-Q200 Thick Film	Würth Elektronik	560112110231
45	1	Y1	16MHZ	16 MHz ±20ppm Crystal 18pF 40 Ohms HC-49/US	Würth Elektronik	830058383B

Item	Quantity	Reference	Part / value	Description	Manufacturer	Part number
46	1	R33	0	Thick Film Resistors - SMD 0 Ohms 0805 31.6A 0 Ohms Hi Curr Jumper AEC-Q200	Stackpole Electronics Inc	HCJ0805ZT0R00
47	2	R50,R51	10K	Thick Film Resistors - SMD 10K Ohms 0805 0.125W 5% Std Power AEC-Q200	Würth Elektronik	560112120004
48	6		Shunt Connector	JUMPER W/TEST PNT 1X2PINS 2.54MM. Jumper to be connected as follows: 1. JP1 Pin: 1-2 2.J1 Pin 1- J2 Pin 1 3.J1 Pin 2 -J2 Pin 2 4.J13 Pin 2-3 5.J14 Pin: 2-3 6.J10 Pin: 1-2	Würth Elektronik	60900213421

8 Board versions

Table 4. **X-NUCLEO-PM33A1 versions**

Finished good	Schematic diagrams	Bill of materials
X$NUCLEO-PM33A1A[1]	X$NUCLEO-PM33A1A schematic diagrams	X$NUCLEO-PM33A1A bill of materials

1. *This code identifies the X-NUCLEO-PM33A1 evaluation board first version.*

9 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine

whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Notice for Innovation, Science and Economic Development Canada (ISED)

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2015/863/EU (RoHS).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032).

Revision history

Table 5. **Document revision history**

Date	Revision	Changes
13-May-2025	1	Initial release.

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