UM1554
User manual

Single-phase energy meter with Rogowski coil sensors based on the STPM01 and STM8L MCU

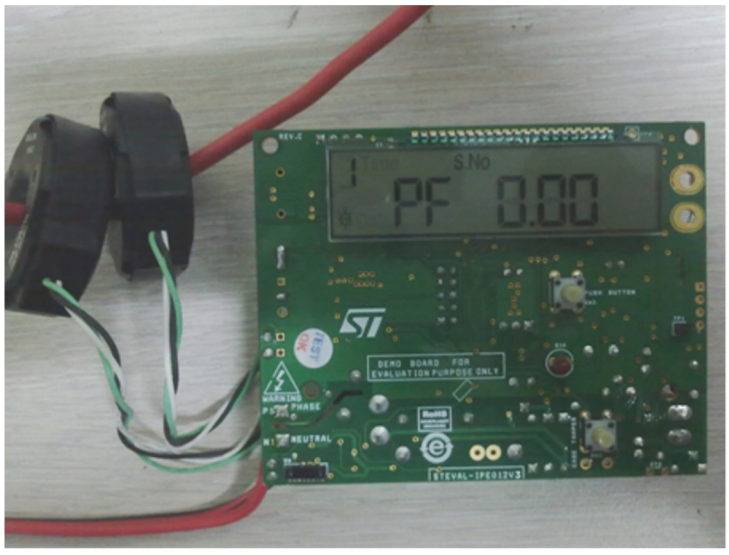
Introduction

This document describes the functioning of a single-phase energy meter with Rogowski coil sensors based on the STPM01 and STM8L MCU. The demonstration board solution is a fully functional single-phase solution with parameter display, tamper management, maximum demand (MD) calculation, EEPROM data logging and low-power management.

Meter specifications:

- Accuracy: class 1 with dynamic range 200:1
- Nominal voltage: 240 V
- Nominal current: 10 A (I_{TYP})
- Maximum current: 80 A (I_{MAX})
- Operating range: 0.6 Vb to 1.2 Vb
- Meter constant: 1600 impulses/kWh
- Power frequency range: 45 Hz to 65 Hz
- Sensor: primary side Rogowski coil and secondary side Rogowski coil

Figure 1. Single-phase energy meter with Rogowski coil sensors based on the STPM01 and STM8L MCU



AM12452v1

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1 Features

The single-phase energy meter has the following features:

- Low cost single-phase energy meter solution
- Supports IEC 61036:1996 + A1: 2000, static meter for active energy classes 1 for Ib=10 A
- Less than 4 VA power consumption for voltage circuit at reference voltage
- Less than 1 VA power consumption for current circuit at reference basic current
- Multiple tamper detection: earth, neutral missing, reverse, case tamper, magnetic tamper detection
- Case tamper detection in power-down also
- Detects, signals and continues to measure accurately under tamper condition
- Rechargeable battery is available onboard for showing LCD parameters in case of power-down mode
- Active energy pulse output 1600 impulses/kWh
- Software based auto-calibration without the need of reference meter, only reference source is required
- Microcontroller in-built RTC for date and time display
- Microcontroller STM8L152C6T6 is responsible for all the data management, display and power management
- STPM metering IC with 1st order sigma-delta ADC for energy measurements.
- Single point and fast calibration of STPM for class 1 meter
- External EEPROM used to store calibration parameters, tampering information, cumulative energy, MD and power factor (PF) data
- Active power, current, voltage, power factor and line frequency measurements
- Numeric display precision (except cumulative energy): 5+2 digits
- Numeric display precision for cumulative energy: 5+1 digits
- Energy EEPROM log precision: 0.01 kWh.

2 Overview

2.1 Safety rules

This board can be connected to mains voltage (240 V). In the case of improper use, wrong installation or malfunction, there is a danger of serious personal injury and damage to property. All operations such as transport, installation and commissioning, as well as maintenance, should be carried out only by skilled technical personnel (regional accident prevention rules must be observed).

Warning: Due to the risk of death when using this prototype on mains voltage (240 V), only skilled technical personnel who are familiar with the installation, mounting, commissioning and operation of power electronic systems and have the qualifications needed to perform these functions, may use this prototype.

2.2 Recommended reading

This documentation describes how to use the multi-tariff meter reference board.

Additional information can be found in the following documents:

- STPM01 datasheet
- STM8L152C6T6 datasheet
- Component datasheets
- IEC 62056-21 IrDA protocol mode C.

2.3 Getting technical support

For technical assistance, documentation, information and updates for products and services, please refer to your local ST distributor/office.

3 Getting started

3.1 Package

The demonstration kit package includes the following items:

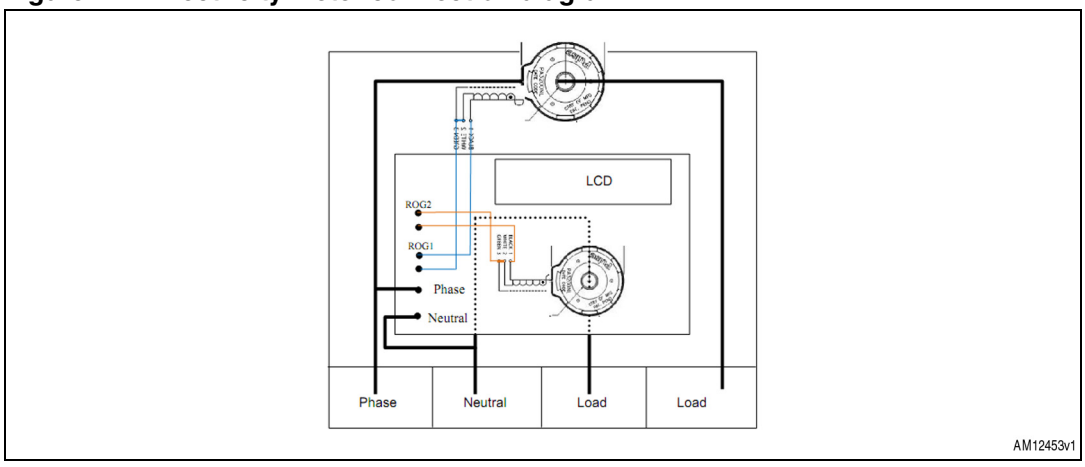
- Hardware content
  - STEVAL-IPE012V3 demonstration board
- Software
  - SerialIO GUI for IrDA communication testing
- Documentation
  - User manual
  - Presentation
  - Schematic
  - BOM list.

3.2 Hardware installation

Connect the STEVAL-IPE012V3 demonstration board with the mains supply before load. Please refer to *Figure 2* for connection with mains power and load.

Auto-scrolling LCD display indicates successful power-up of the board.

Figure 2. Electricity meter connection diagram



3.3 Software installation

The evaluation kit supports the SerialIO GUI for RS232 testing to check 62056-21 IrDA protocol mode C implementation.

3.3.1 System requirements for demonstration GUI

For demonstration board communication with the GUI, a recent version of Windows®, Windows XP must be installed on the PC.

SerialIO GUI does not require any driver installation.

Note: The version of the Windows OS installed on the PC can be determined by clicking on the system icon in the control panel.

4 Hardware layout

The demonstration kit hardware is designed in a sectional approach to offer multiple functions to users.

Figure 3. Hardware layout: top view

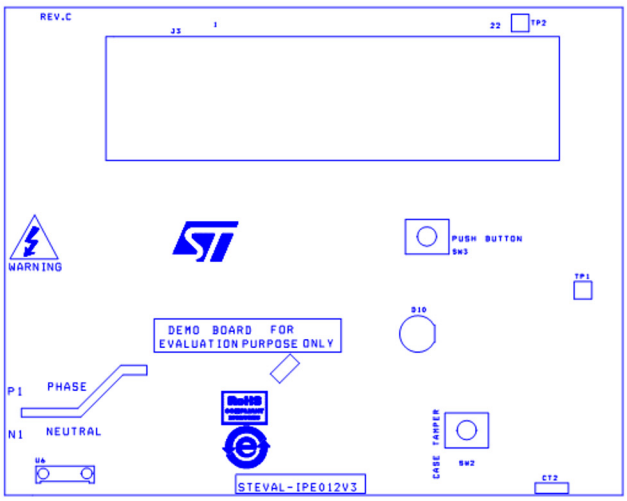
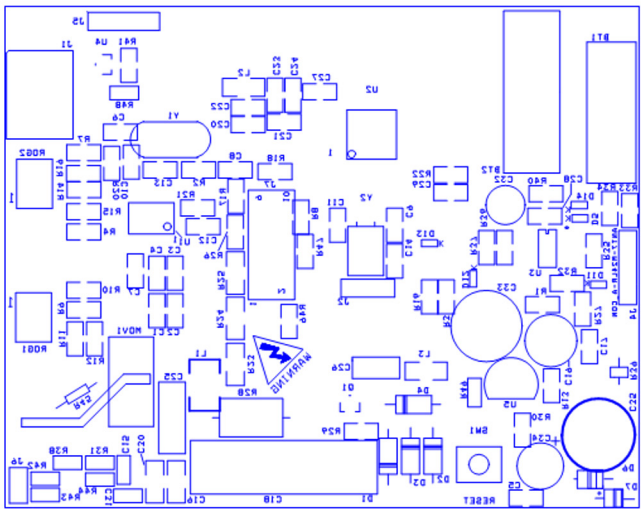


Figure 4. Hardware layout: bottom view



5 Hardware details

5.1 Metering IC U1

Programmable single-phase energy metering IC STPM01FTR (package: TSSOP20) is interfaced to the microcontroller using a three-wire SPI interface. Active energy, apparent energy, instantaneous voltage, and instantaneous current values are obtained from the STPM metering IC. For calibration of the STPM, auto-calibration is implemented.

5.1.1 Clocking Y1

A 4.194 MHz crystal is used as clock generator input for the metering IC.

For more details about auto-calibration, please refer to *Section 6.1: Auto-calibration mode*.

5.2 Microcontroller U2

The STM8l152C6T6 microcontroller (package: LQFP48, 32 K Flash, 2 KB RAM, 48-pin) is responsible for all the data management and power management tasks. The MCU consumes very low power and has an in-built RTC for date and time management.

5.2.1 LED D10

LED D10 is the pulse-out LED for cumulative energy. This is used for testing energy meter energy calculation accuracy.

5.2.2 Switch SW1 and SW2

Switch SW1 is the reset switch for the microcontroller.

Switch SW2 is the case tamper switch. This is used to detect case tampering of the energy meter solution.

For more details, refer to *Section 6.4: LCD display modes*.

5.2.3 Jumper J2

Table 1. 3-pin jumper header

Jumper	Close: 1-2	Close: 2-3	Default
J2	Microcontroller pin PA1 is connected to reset switch SW1	Microcontroller pin PA1 is connected to LED D10	Close: 2-3

A 32.768 kHz crystal is used as clock input for LSE (low speed external) for the microcontroller RTC block. The microcontroller core is clocked by HSI (high speed internal) clock.

5.3 Power supply section

Capacitive power supply is used to build 3.6 V for the metering IC and microcontroller section.

5.3.1 Programmable voltage reference U5

U5 TL431AI (package TO-92) is used to regulate 3.6 V supply.

5.3.2 Current sensor Rogowski coil 1 and 2

Rogowski coils 1 and 2 (ROG1 and ROG2) PA3202NL (actual secondary output: 416 µV/A, series resistance: 54 Ω) is the sensor for both primary and secondary current channels.

5.4 Neutral missing power supply section

The neutral missing power supply section is operational in case of neutral missing tamper. In case of neutral missing tamper condition, neutral is disconnected from the energy meter. Hence, there is no voltage input and therefore no output would be generated by the main capacitive power supply. However, in the case of load being present, there would be a valid input signal on the current channel so energy would be consumed. Since the voltage on the neutral channel is zero, so is the power (P = V x I). In order to take account of energy consumed in this case, the neutral missing power supply section provides voltage supply to the STPM metering IC. A zero crossing signal of 50 Hz is provided to the VIP pin of STPM, so STPM now calculates the energy consumption at nominal voltage level of 230 V.

5.4.1 Current sensor CT2

CT2 is used to develop the power supply for the board using a diode full wave rectifier circuit in neutral missing condition.

5.5 EEPROM U3 section

EEPROM M24C32-RMN6TP (package: SO8, 32 Kbit) is interfaced to the microcontroller using an I2C bus. Cumulative energy, MD, average PF and tamper information for seven consecutive months are logged in EEPROM. For more details about EEPROM data logging, refer to *Section 6.2: EEPROM data log*.

5.6 LCD section

LCD J3 is the connector for external 18* 4 LCD glass.

LCD glass OPT6089A (operating voltage 3 V, duty 1/4, bias 1/3) offers various energy meter specific symbols.

LCD glass is driven by microcontroller internal LCD driver.

5.7 Battery management section

Two batteries are used in the circuit.

5.7.1 Coin cell BT1

BT1 CR2032 (3 V, 225 mAh) is the microcontroller power source in halt mode to keep RTC running.

5.7.2 Rechargeable battery BT2

BT2 VL2330 (3 V, 50 mAh) for pushbutton and IrDA operation when mains power is off.

- Rechargeable battery acts as power source for the microcontroller section when the pushbutton is pressed during mains power-off
- Rechargeable battery is charged based on trickle charging mode during mains power on.

5.7.3 Small signal Schottky diode D11, D12, D13, D14, D5

Diodes (D11, D12, D13, D14, D5) BAT30KFILM (SOD - 523) based circuit is used to select power source for the microcontroller.

5.7.4 Switch SW3

Switch SW3 is the pushbutton switch. SW3 is used to control LCD display modes.

When mains power is on, on pressing the pushbutton, the LCD display is executed as per the pushbutton run mode.

When mains power is off, on pressing the pushbutton, the LCD display is executed as per the pushbutton low-power mode.

5.8 IrDA section

5.8.1 IrDA transceiver U6

IrDA transceiver TFDU6300 is used for IRDA communication.

5.8.2 Jumper J6

Using jumper J6, IRDA transmit and receive pins allow the testing of the IRDA section using the SerialIO GUI. For more details, refer to *Section 6.6.2: SerialIO GUI*.

Table 2. Pin jumper headers

Jumper	Pin1	Pin2
J6	PC3_IRDA_Tx IRDA transmit pin	PC2_IRDA_Rx IRDA receive pin

5.9 Magnetic sensor U4

The magnetic sensor AH180 (SC59-3L) is used to detect magnetic interference in the energy meter solution. Magnetic sensor outputs low when magnetic interference occurs.

5.10 Connector section

The connector section comprises test points for different signals.

Table 3. 4-pin jumper headers

Jumper	Pin1	Pin2	Pin3	Pin4
J1	VDD	PA0_SWIM SWIM interface data pin	GND	PA1_NRST_PULSE_LED LED pulse output/reset signal
J5	PA0_SWIM SWIM interface data pin	PE6 GPIO	GND	PE7_STPM_ZCR metering IC ZCR signal
J4	GND	VDD	PC1_EEPROM_SCL	PC0_EEPROM_SDA

Table 4. J7 STPM connector, 10-pin jumper header

Pin number	Details
1	VOTP
2	SBS
3	GND
4	PB7_STPM_SDA
5	PB6_STPM_SCS
6	PB5_STPM_SCL
7	PD6_STPM_LED
8	PA3_STPM_SYN
Pin number	Details
1	VOTP

6 Single-phase energy meter features

6.1 Auto-calibration mode

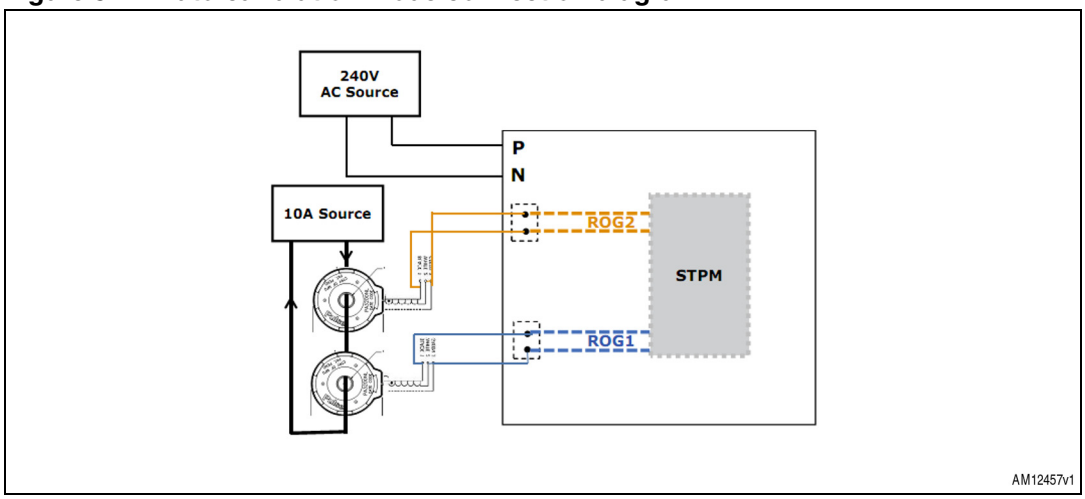
The STEVAL-IPE012V3 demonstration board supports auto-calibration using an ideal reference source for 10 A and 240 V. Calibration is performed to minimize measurement errors and to increase the accuracy of the meter.

Using auto-calibration mode, calibration parameters (CHV, CHS, and CHP) are calculated and programmed in registers of metering IC. The procedure for meter calibration is explained below by firstly giving an overview of the hardware setup, and then by describing how to connect a calibration board.

6.1.1 Steps for auto-calibration

- Connect 240 V voltage source to phase and neutral of board
- Connect 10 A source to board
- Pushbutton SW3 for more than 4 sec
- Board enters auto-calibration mode; “CALIB ON” is displayed on board
- As calibration is complete, board returns to auto-scroll display mode.

Figure 5. Auto-calibration mode connection diagram



For more details of calibration parameters, refer to the metering IC datasheet on www.st.com.

6.2 EEPROM data log

Total EEPROM data log size: 920 bytes.

Multiple parameters are stored in EEPROM, as below:

- The following metering parameters are logged in EEPROM memory for the current month and last six months
  - Cumulative energy (CE) until last month
  - Maximum demand (MD)

  - Cumulative energy (CE) consumed in current month
  - Average PF and averaging count
  - Tamper entries; four types of tamper data storage is done: earth, reverse, neutral, and case tamper. For each type of tamper, the number of tamper entries per month is four.
- Two duplicate entries of cumulative energy are stored with CRC-8 value for error detection
- 10 bytes stored for calibration data at start of EEPROM including 3 bytes of CHV, CHP, and CHS
- Last power-down date and time log
- Overflow count for cumulative energy
  - Number of times cumulative energy overflows from 99999.9 (maximum display precision).

For further details, refer to *Appendix A: EEPROM log data structure*.

6.3 Power management

The STEVAL-IPE012V3 demonstration board is designed with board power consumption 4 VA.

The board supports two modes of operation:

1. Meter run mode
2. Meter low-power mode

6.3.1 Meter run mode

When mains power is on, the board operates in run mode. The board components are powered using a capacitive supply with main power line as the source. In this mode, the rechargeable battery is in charging mode based on the trickle charging technique.

6.3.2 Meter low-power mode

When mains power goes down, the onboard microcontroller enters halt mode and metering IC is off. In this mode, the microcontroller RTC is running and low, other peripherals are off. In halt mode, the microcontroller is powered using BT1.

Therefore, pushbutton SW3 is pressed in low-power mode; BT2 supply connects to the supply input of the microcontroller and IrDA section, and so, in button pressed condition, BT2 is the main supply source. Now the meter low-power LCD display and IrDA communication are operational until pushbutton SW3 is operational.

6.4 LCD display modes

The STEVAL-IPE012V3 demonstration board offers the user different parameters. The metering parameter display is configured in a specific manner based upon the power mode of the meter:

- Meter run mode LCD display
- Meter low-power LCD display.

6.4.1 Meter run mode display

During the main power-on condition, all the critical parameters, with details of last month's logs for metering parameters, are available on the display.

Parameter display is classified for mains on condition:

- Auto-scroll mode
- Pushbutton display mode.

Auto-scroll mode

In auto-scroll mode, the following parameters are displayed on the LCD one by one:

- Cumulative active energy (kWh)
- Max. demand (kW) of last month
- Average PF of last consumption month.

Note: Auto-scroll mode interval (8sec) is configurable in "autoscroll_display.h" in the firmware.

Pushbutton mode

- In pushbutton mode, the following parameters are displayed on the LCD on pressing pushbutton SW3. Each button push displays the next pushbutton parameter.
- If pushbutton is in pressed condition for 4sec, board enters auto-calibration mode.

For more details on auto-calibration, refer to *Section 6.1: Auto-calibration mode*.

In pushbutton mode, the following parameters are displayed on the LCD:

- All LCD segments on
- Date and time
- Max. demand since last reset
- Cumulative energy for last six months
- Max. demand for last six months
- Instantaneous PF
- Instantaneous voltage
- Instantaneous current
- Instantaneous load in Watts.

When the pushbutton SW3 is released, the LCD display returns to auto-scroll mode after a pushbutton mode interval (10 sec).

Note: Pushbutton mode interval (8sec) is configurable in "pushbutton_display.h" in the firmware.

6.4.2 Meter low-power mode display

In low-power mode, the display is off until pushbutton SW3 is pressed. When pushbutton SW3 is pressed in low-power mode, the display is on in auto-scroll display mode. The display is active until pushbutton SW3 is in a pressed condition.

6.5 Tamper detection

The STEVAL-IPE012V3 demonstration board supports multiple tamper detection and their logging in EEPROM.

6.5.1 Tamper types

The five types of tamper detection are:

1. Earth tamper
2. Reverse tamper
3. Neutral missing tamper
4. Case tamper
5. Magnetic interference

6.5.2 LCD symbol for tamper condition

- Earth tamper: 
- Reverse tamper: 
- Neutral missing tamper: 
- Case tamper: 
- Magnetic interference:  .

Three tampers (earth, reverse and neutral missing) are detected using a software algorithm based on meter readings from the metering IC.

In the case of neutral missing tamper detection, the board starts recording energy when the load current is 2 A or higher.

Case tamper is detected using switch SW2 and magnetic interference is detected using magnetic sensor U4. Symbol 'BP' is shared for displaying case tamper as well as magnetic interference. It means that if any of the tampers are detected, symbol 'BP' is displayed on the LCD.

For tamper definitions, refer to *Appendix B: Tamper definitions*.

Note: In the present solution, magnetic tamper is not logged in EEPROM. Logging can be easily done by modifying the EEPROM log structure.

6.6 62056-21 IrDA protocol mode C

The STEVAL-IPE012V3 demonstration board supports 62056-21 IrDA protocol mode C. IrDA is used as the communication channel for reading meter data. In such systems, a handheld unit (HHU) or a unit with equivalent functions is connected to a tariff device (energy meter). The protocol offers five alternative protocol modes, A, B, C, D and E. This user manual covers mode C use. In mode C, data exchange is bi-directional and is always initiated by the HHU with the transmission of a request message. In this mode, the HHU acts as a master and the tariff device acts as a slave. These protocol modes permit meter reading, manufacturer specific operation, and programming mode. It is designed to be highly suitable for electricity metering environments, particularly with regards to electrical isolation and data security.

6.6.1 IrDA modes

- Data read out mode

  In data read out mode, the tariff device responds with all the data logged in EEPROM as per EEPROM data structure (refer to *Appendix A: EEPROM log data structure*). Each data block consists of a sequence of data lines separated by carriage return (CR) and line feed (LF).

- Manufacturer specific mode

  In manufacturer specific mode, RTC date and time setting is done.

- Programming mode

  In programming mode, as per the protocol, data read and write can be done at different locations of EEPROM.

6.6.2 SerialIO GUI

The SerialIO GUI can be used as the test GUI for 62056-21 IrDA protocol mode C implementation. Here, the protocol is tested using serial communication. For this testing, a daughterboard with an RS232 converter is required to map PC serial data signals to 3.4 V data signals of the board.

Steps for serial communication based protocol testing:

1. Demount R41 and R42 from board.
2. Comment “#defines IRDA_MODE_ENABLE” in “emter_irda.h”.
3. Connect the RS232 daughterboard as shown in *Figure 6*.
4. Write data into the SerialIO GUI data box and send.

Figure 6. SerialIO GUI hardware setup

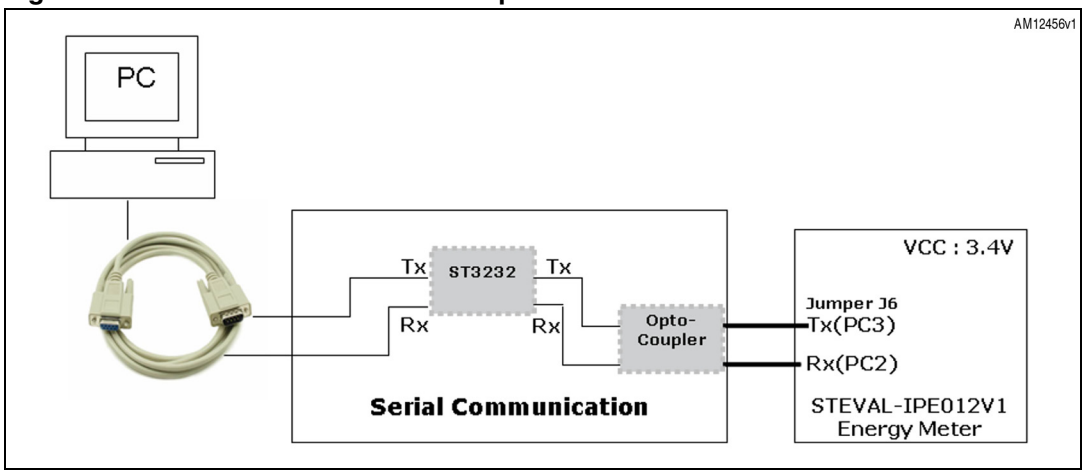
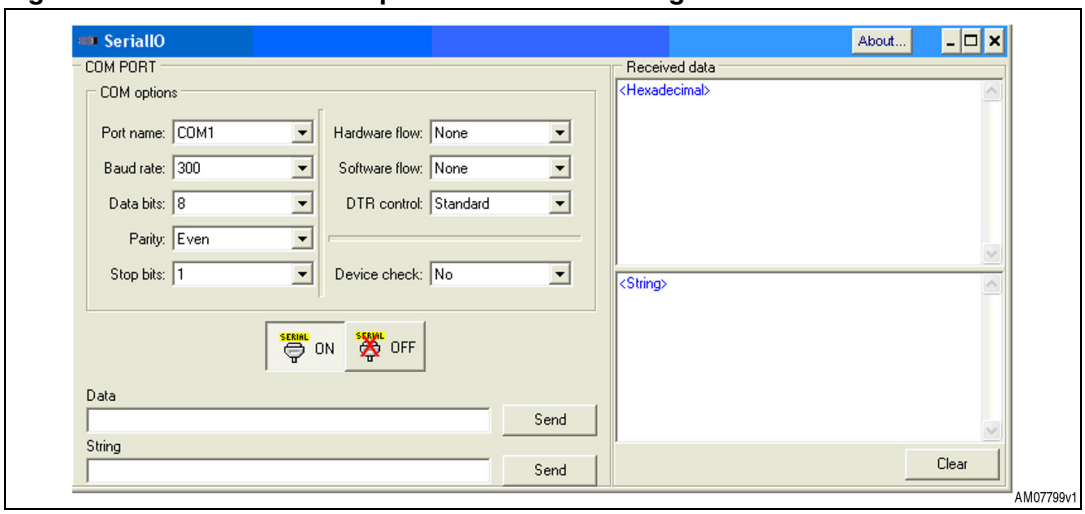


Figure 7. SerialIO GUI with protocol mode C settings



Note: For more details about IRDA mode C, refer to the IEC 62056-21 IRDA protocol mode C document.

6.7 Pulse-out LED

LED D10 is used as the pulse-out for cumulative energy. It works on a meter constant of 3200 impulses/kWh.

The LED output can be used to test the accuracy of the meter.

Appendix A EEPROM log data structure

All the parameters below are stored in EEPROM:

- Calibration data (10 bytes)
  - (3 bytes of CHV, CHP, CHS then 7 times 0x00)
- Total cumulative energy
  - (At two locations - to keep duplicate entries)
- Total cumulative till last month
  - (Month-wise for last six months and current month)
- Maximum demand
  - (Month-wise for last six months and current month)
- Cumulative energy
  - (Month-wise for last six months and current month)
- Average PF and averaging count
  - (Month-wise for last six months and current month)
- Tamper information - earth, reverse, neutral missing, case tamper
  - (Month-wise for last six months and current month and four entries per month with count for tamper and date and time details)
- Count of cumulative energy overflow
- Count of cumulative energy overflow
- Date and time of last power-down
- Total size required: 920 bytes.

Data storage structure in EEPROM as follows:

- Calibration data (CHV, CHP, CHS)
- CE main entry with CRC
  - N Month : CE till last month: MD : CE current month : average PF : tamper
  - N-1 Month : CE till last month: MD : CE current month : average PF : tamper
  - N-2 Month : CE till last month: MD : CE current month : average PF : tamper
  - N-3 Month : CE till last month: MD : CE current month : average PF : tamper
  - N-4 Month : CE till last month: MD : CE current month : average PF : tamper
  - N-5 Month : CE till last month: MD : CE current month : average PF : tamper
  - N-6 Month : CE till last month: MD : CE current month : average PF : tamper
- CE duplicate copy with CRC
- Count for cumulative energy overflow
- Power-down date and time.

Where N is the current month

- All parameters are logged for a total of 7 months including the current month and the last 6 months
- In current month log, data is updated at day end and on power-down
- Total cumulative energy log is updated half-hourly
- Month serial order is updated at 24:00 hrs on last date of each calendar month.

6.8 Size overview

Table 5. EEPROM parameter size overview

Parameter	Size (in bytes)
Calibration data	10 (3 bytes (CHV, CHP, CHS) + 7 dummy bytes for future use)
Total cumulative energy duplicate entry 1	7 (4 bytes + 2 bytes + 1 byte (CRC))
Cumulative energy until last month	42 (7*6): without CRC
Maximum demand log	63 (7*(3+3+3))
Monthly cumulative energy log	42 (7*6)
Average PF log	42 (7*4 + 7*2)
Earth tamper log	175 (7*((4*(3+3)) +1))
Reverse log	175 (7*((4*(3+3)) +1))
Neutral missing log	175 (7*((4*(3+3)) +1))
Case tamper log	175 (7*((4*(3+3)) +1))
Total cumulative energy duplicate entry 2	7(4 bytes + 2 bytes + 1 byte (CRC))
Count for CE overflow	1 byte
Power-down entry	6 bytes

Note: EEPROM data structuring is done in a modular way in order to support future updates.

Reconfigure parameters in header file “emeter_datamgmt.h”, to modify the log structure entry count.

6.9 Entry structure

- Calibration data log

  CHV, CHP, and CHS are calibration parameters for the current and voltage channel for the metering IC.

Table 6. Calibration data

Calibration data	Start address	Size
(CHV, CHP, CHS, 7 times 0x00)	0x00	10

For more details on calibration parameters, refer to metering IC datasheet on www.st.com.

- Total cumulative energy log

  Two duplicate entries are stored. One at the start of EEPROM and another at the end of EEPROM.

  This is done to make sure that, if EEPROM is corrupted at one point, another entry with the correct CRC is considered as a valid value.

  7 bytes (4 bytes: kWh, 2 bytes: impulse count and 1 byte: CRC): total cumulative energy entry.
- Cumulative energy until last month

  Cumulative energy until last month states energy consumed up to the last calendar month reset.

  6 bytes (4 bytes: kWh and 2 bytes: impulse count): cumulative energy entry up to last month.
- Monthly maximum demand

  3 bytes (1 byte: integer value and 2 bytes: impulse count): MD value, 3 bytes (date) 3 bytes (time).
- Current monthly cumulative energy

  Current monthly cumulative energy states energy consumed in that particular current month until the last calendar month reset.

  6 bytes (4 bytes: kWh and 2 bytes: impulse count), current cumulative energy entry.
- Monthly average PF

  PF average value is the sum of PF readings and PF averaging count is the number of PF readings. 4 bytes (PF average value) 2 bytes (PF averaging value).
- Monthly tamper log

  For the monthly tamper log, the following four types of tamper data are logged:
  - Earth tamper
  - Reverse tamper
  - Neutral missing tamper
  - Case tamper

  For each type of tamper, there are 4 entries per month. So, for each type of tamper, the storage per month is:
  - Tamper count: 1 byte
  - Four entries of date: 3 bytes x 4 : 12 bytes
  - Four entries of time: 3 bytes x 4 : 12 bytes.

Note: For each tamper entry log, the tamper count: number of tampers in month D: date and T: time is of 3 bytes.

Appendix B Tamper definitions

- Earth tamper: using earth in place of neutral (load current is passed partially or fully through earth)
- Reverse connection: reversal of phase and neutral at mains
- Neutral missing tamper: when neutral is disconnected, the board is not powered. During this condition (single-wire conditions), power supply is generated by a CT for powering up the board.
- Case tamper: if an attempt is made to open the meter body, the meter logs the date/time of the meter opening tamper
- Magnetic tamper: if a magnet is near to the board, it pulls magnetic sensor output IO low.

Appendix C BOM list and schematics

Table 7. BOM

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
ST devices	U1	STPM metering engine	TSSOP20	ST	STPM01FTR		STPM01FTR
	U2	STM8L microcontroller	LQFP48	ST	STM8L152C6T6		STM8L152C6T6
	U3	EEPROM 32 Kb	SO8	ST	M24C32-RMN6TP		M24C32-RMN6TP
	U5	Voltage reference	TO92	ST	TL431AIZ		TL431AIZ
	D5,D11,D12,D13,D14	Small signal diode	SOD-523	ST	BAT30KFILM		BAT30KFILM
	D6,D7	Diode Schottky 40 V 1 A	DO-41	ST	1N5819		1N5819
Crystal and oscillator	Y1	4194.304 kHz oscillator	2-pin (3.5 mm)	ECS Inc	ECS-42-12-4X	Digi-Key	X1046-ND
	Y2	32.768 kHz oscillator	2-pin (cylindrical)	Abracon Corporation	AB26T-32.768 kHz	Digi-Key	535-9032-ND
Connectors and jumpers	J1	Swim connector (SMT, 4-pin, 1.27 mm pitch)	SMD	ERNI	ERNI	ERNI	284697
	J2	3-pin connector	3-pin (2.54 mm)	Any			
	J4,J5	4-pin connector	4-pin (2.54 mm)	Any			
	J6	2-pin connector	2-pin (2.54 mm)	Any			
	J7	10 way, 2x5-pin	2x5 (2.54 mm)	Any			
LEDs	D10	LED	Leaded (3 mm)	HLMP-K150	Digi-Key	516-1311-ND	

Table 7. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Capacitors	C1,C3,C4,C20,C23,C27	1 µF	SMD0805		Any		
	C2,C29	1 nF	SMD0805		Any		
	C5,C14,C15,C17,C21,C22,C24,C28,C31	100 nF	SMD0805		Any		
	C6,C8	15 pF	SMD0805		Any		
	C7,C10	10 nF	SMD0805		Any		
	C9,C11	12 pF	SMD0805		Any		
	C12	4.7 µF	SMD1206		Any		
	C16,C30	4.7 µF	Tantulum SMD EIA 3216-18/size A	Any			
	C13	22 nF	SMD0805		Any		
	C25	1 nF/500 V	Leaded	Vishay/BC Components	D102K25Y5PL63L6R	Digi-Key	1457PH-ND
	C26	100 µF/50 V	Leaded	Panasonic - ECG	ECE-A1HN101U	Digi-Key	P1284-ND
	C32	6.8 µF/16 V	Leaded	Panasonic - ECG	ECE-A1CKG6R8	Digi-Key	P909-ND
	C33	470 µF/35 V	Leaded	Nichicon	UVR1V471MPD	Digi-Key	493-1084-ND
	C34	47 µF/50 V	Leaded	Panasonic - ECG	ECA-1HM470	Digi-Key	P5181-ND
	C35	1000 µF/16 V	Leaded	Panasonic - ECG	ECA-1CM102	Digi-Key	P5142-ND
Resistors	R1,R13,R32,R36,R37	10 kΩ	SMD0805		Any		

Table 7. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Resistors	R3,R8,R11,R17,R18,R20,R21,R27,R33,R34,R35,R42,R43,R44,R46,R47,R49	0	SMD0805		Any		
	R4,R10,R14,R19	1 kΩ	SMD0805		Any		
	R7	42.2 kΩ	SMD0805		Any		
	R9,R15	2 MΩ	SMD0805		Any		
	R12	100 Ω	SMD0805		Any		
	R16	2.2 kΩ	SMD0805		Any		
	R22,R41	100 kΩ	SMD0805		Any		
	R23,R24,R25	261 kΩ	SMD1206		Any		
	R26	475 Ω	SMD0805		Any		
	R28	82, 2 W	Leaded	Yageo	RSF200JB-82R	Digi-Key	82W-2-ND
	R29	15 kΩ	SMD0805		Any		
	R30	22 kΩ	SMD0805		Any		
	R31	47 Ω	SMD0805		Any		
	R38	5.1 Ω	SMD0805		Any		
	R39	10 E, 2 W	Leaded	Vishay/BC Components	PR02000201500JR500	Digi-Key	PPC150W-2CT-ND
	R40	8 kΩ	SMD0805		Any		
	R45	27 E, 5 W	Leaded	Vishay/BC Components	AC05000002709JAC00	Digi-Key	PPC5W27.0CT-ND
	R48	12 kΩ	SMD0805		Any		
Inductors	L1	220 µH	SMD	Panasonic - ECG	ELJ-FB221JF	Digi-Key	PCD1469CT-ND

Table 7. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Inductors	L2, L3	1 µH	SMD	Panasonic - ECG	ELJ-FC1R0JF	Digi-Key	PCD1228CT-ND
Diodes	D1,D2,D3,D4,	Diode GPP 1 A 1000 V DO41	Leaded	Fairchild Semiconductor	1N4007	Digi-Key	1N4007FSCT-ND
Misc. components	U6	Infrared transceiver module (SIR, 115.2 kbit/s)	SMD-8-pin	Vishay Electronics	TFDU4300	Digi-Key	751-1073-1-ND
	U4	Micropower Omnipolar Hall-Effect sensor switch	SC-59-3L	Diodes Inc.	AH180_SC59-3L	Digi-Key	AH180-WGDICT-ND
	SW1	Reset switch for micro	Leaded	TYCO ELECTRONICS	1555986	Farnell	FSM10JH
	SW2	Case tamper switch	Leaded	TYCO ELECTRONICS	1555986	Farnell	FSM10JH
	SW3	LCD_PUSH switch	Leaded	TYCO ELECTRONICS	1555986	Farnell	FSM10JH
	J3	LCD glass 18x4	22-pin connector	OPT6089A	PIE Electronics	PIE Electronics	
	MOV1	SUR absorber 10 mm 750 V 2500 A ZNR	Leaded	Panasonic - ECG	ERZ-V10D751	Digi-Key	P7260-ND
	ROG1, ROG2	Rogowski coil, current sensor	Leaded	Pulse Electronics	PA3202NL	ELECTRIC CENTER	PA3202NL
	BT1	Battery lithium coin 3 V W/TABS	Leaded	Panasonic - BSG	CR-2032/F4N	Digi-Key	P245-ND

Table 7. BOM (continued)

Category	Reference designator	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Misc. components	BT2	BATT LITH COIN 3 V 23 mm 50 mA VERT	Leaded	Panasonic - BSG	VL-2330/VCN	Digi-Key	P086-ND
	Q1	Transistor NPN 45 V 0.1 A SOT23	SOT23	Fairchild Semiconductor	BC847BMTF	Digi-Key	BC847BMTFCT-ND

Figure 8. Microcontroller schematic

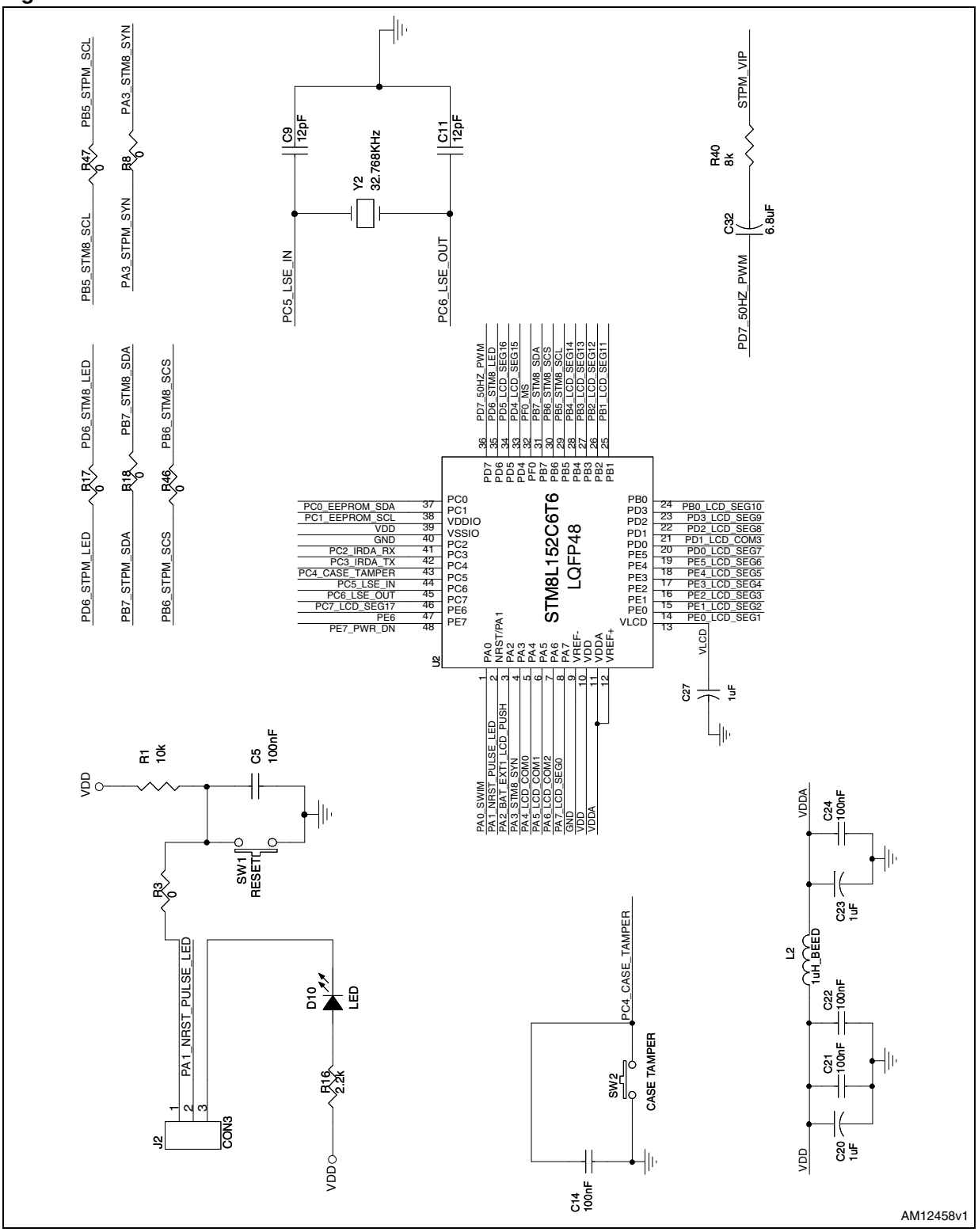


Figure 9. Battery, connector, magnetic sensor and IrDA module schematics

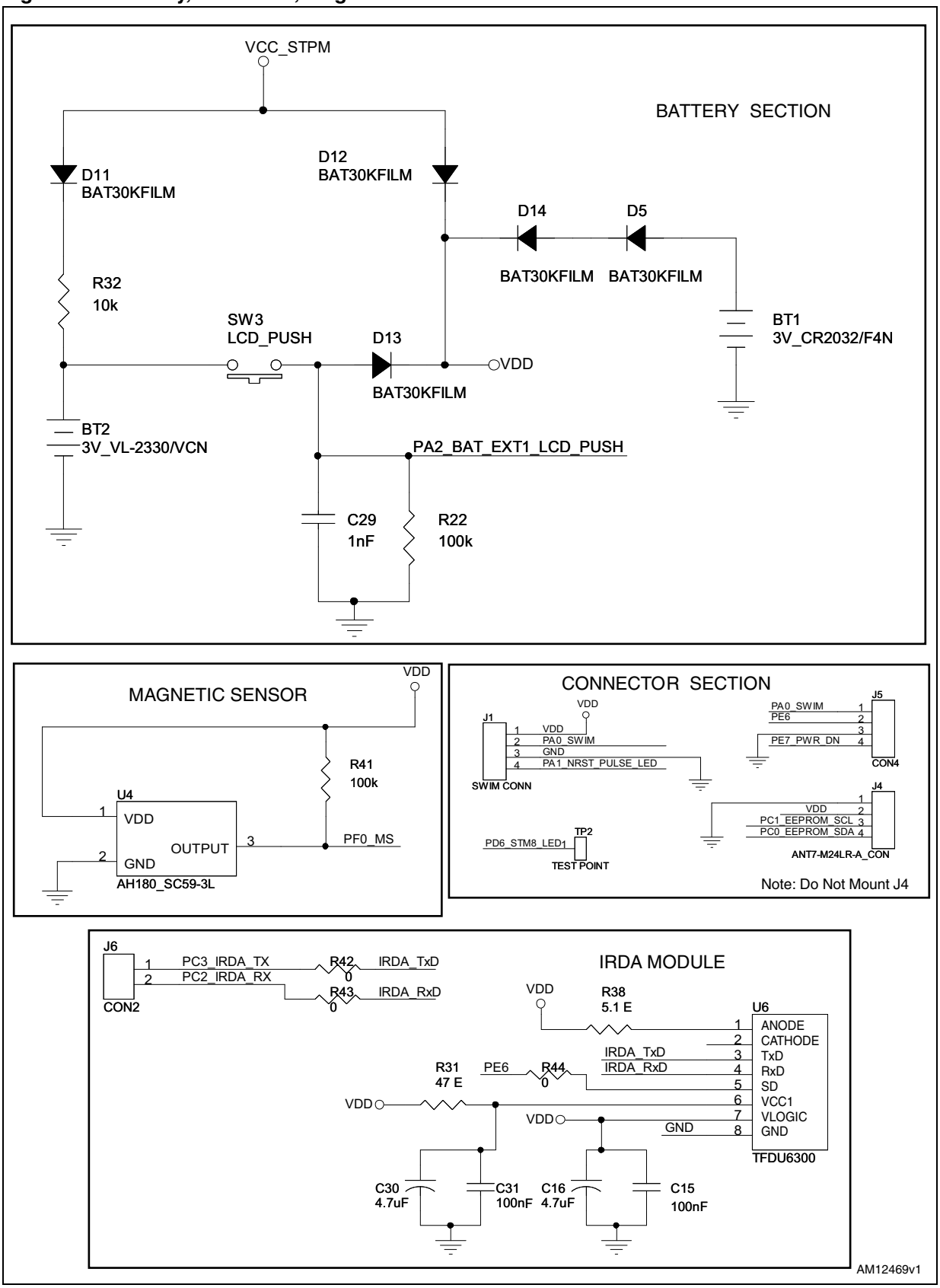
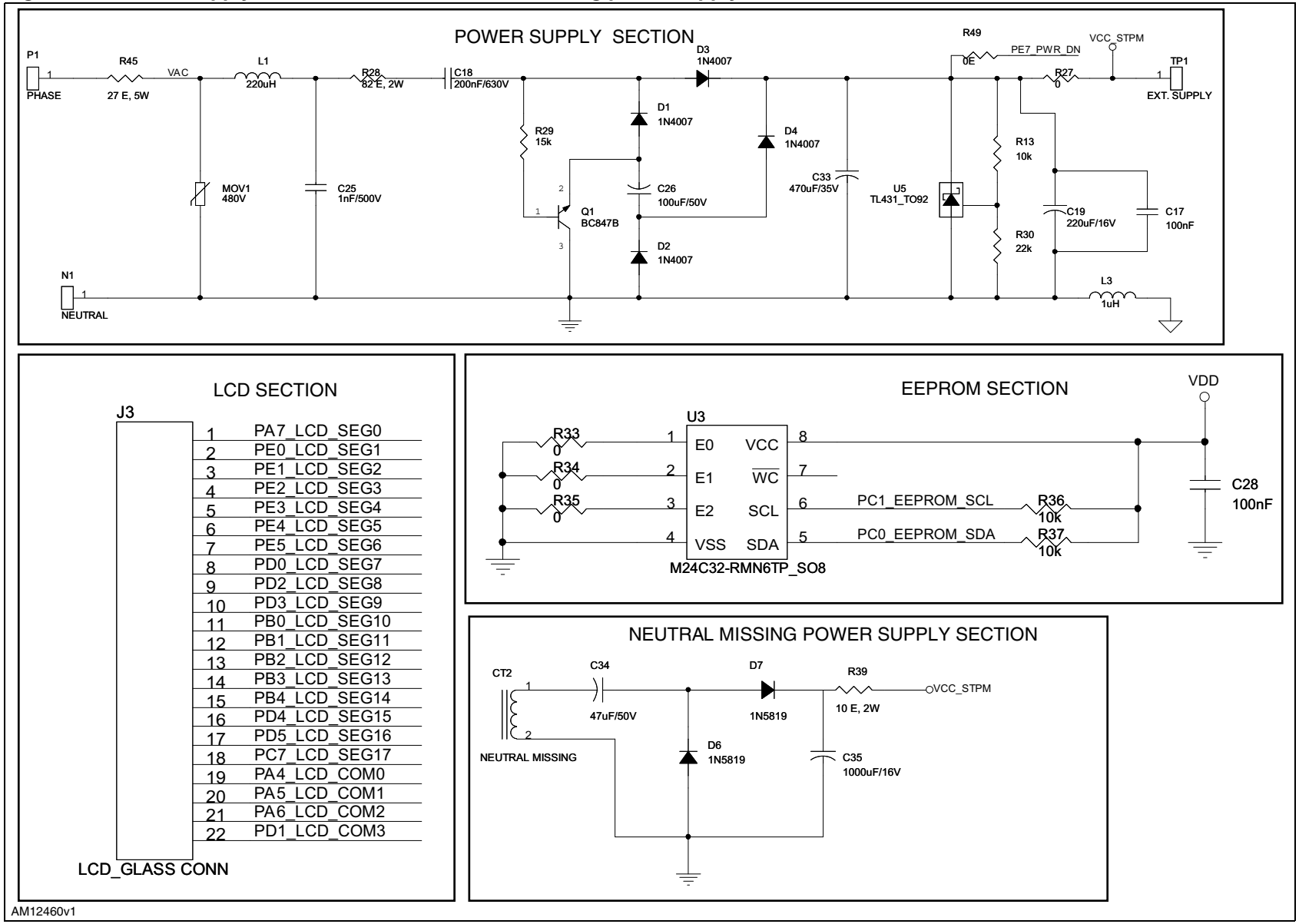
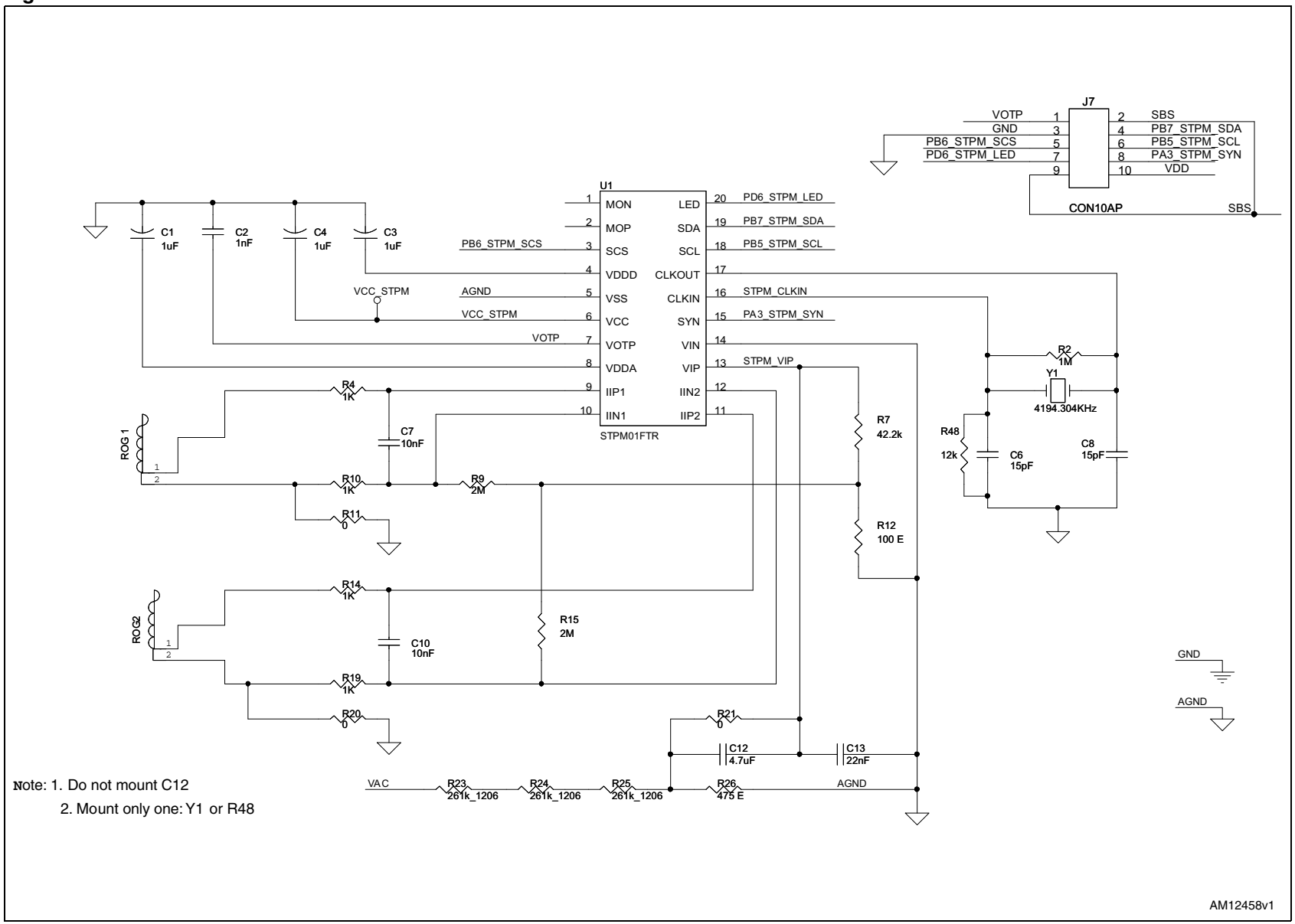


Figure 10. Power supply, EEPROM, LCD and neutral missing power supply schematics



AM12460v1

Figure 11. STPM schematic



Note: 1. Do not mount C12

2. Mount only one: Y1 or R48

Revision history

Table 8. Document revision history

Date	Revision	Changes
30-Aug-2012	1	Initial release.

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