

STEVAL-IHP002V2: PLM smartplugV2 hardware

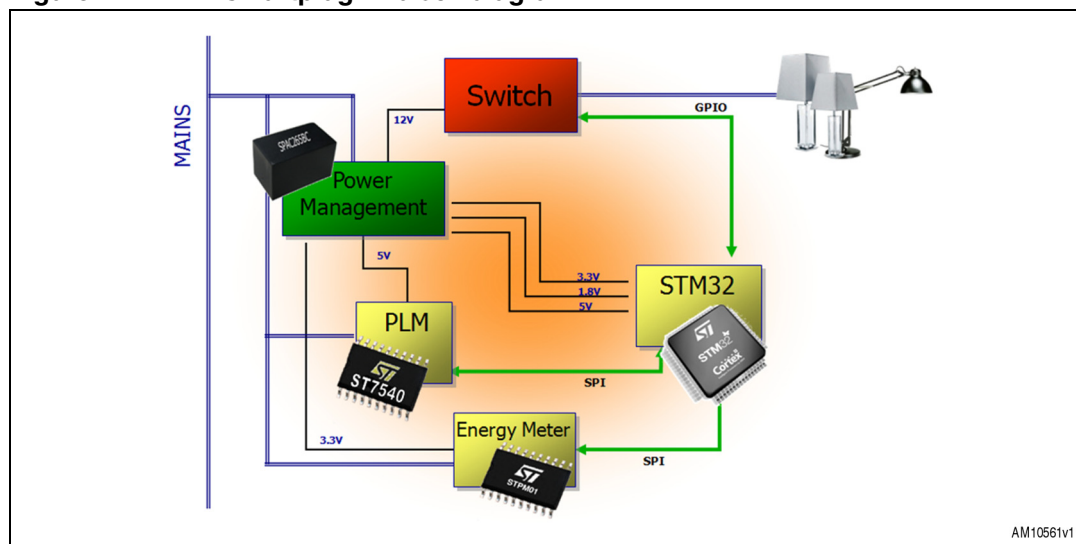
Introduction

This demonstration board is a smartplug based on the STM32F10x microcontroller, ST7540 PLM, and STPM01 energy metering ICs. The board is a node of a PLM network which allows the final user to monitor and manage the plugged load energy consumption.

The board has been developed to provide a guideline on how to build a home/building automation subsystem for energy management. It is designed to fit the dimensions of a standard box for wall installation and easy integration into home/building electrical plants. The current, power, energy and other information related to the electrical load connected to the smartplug board are sent to a PLM data concentrator through the home/building PLM network. The board includes the following functions which are illustrated in the block diagram of *Figure 1*:

- Energy measurement
- Power line communication up to 4.8 kbps
- RS232 connectivity by extension connector
- Load driver with relay

Figure 1. PLM smartplugV2 block diagram



AM10561v1

Contents

1	Overview	5
1.1	Recommended reading	5
1.2	Safety precautions	5
1.3	Getting technical support	5
1.4	Package list	6
2	PLM smartplug demonstration board components	7
2.1	Microcontroller	7
2.2	Debug	7
2.3	Reset	7
2.4	Power supplies	7
2.5	Power line communication	7
2.6	Energy measurement	8
2.7	Load drivers	9
2.8	USART communication	9
2.9	Status LEDs	10
2.10	Jumpers	10
2.10.1	Jumper placement	10
2.10.2	Jumper positions	11
2.10.3	Jumper description and default value	11
2.11	Pushbutton description	11
2.12	Connector description	12
2.12.1	STM32 JTAG connector	12
2.13	Energy meter IC calibration connector	13
3	Board configuration	14
3.1	SPTM01 calibration configuration	14
4	Bill of material and schematics	15
5	Revision history	32

List of tables

Table 1.	STM32 resources – ST7540 function mapping	8
Table 2.	STM32 resources – STPM01 function mapping	9
Table 3.	STM32 resources – RS232 function mapping	10
Table 4.	LED description	10
Table 5.	Jumper description	11
Table 6.	Pushbutton description	11
Table 7.	Connector description	12
Table 8.	JTAG connector pin description	13
Table 9.	Energy meter calibration connector pin description	13
Table 10.	Bill of material	15
Table 11.	Document revision history	32

List of figures

Figure 1.	PLM smartplugV2 block diagram	1
Figure 2.	PLM smartplugV2 board	6
Figure 3.	Wiring diagram for monitored and controlled AC load	8
Figure 4.	Wiring diagram for a controlled generic load and a monitored AC load	9
Figure 5.	Jumper placement	10
Figure 6.	Jumper positions	11
Figure 7.	Connector position	12
Figure 8.	STM32 10-pin JTAG connector	12
Figure 9.	Energy meter calibration connector	13
Figure 10.	Top page	25
Figure 11.	Power supply section	26
Figure 12.	USART expansion connector section	27
Figure 13.	Power line modem section	28
Figure 14.	MCU section	29
Figure 15.	STPM01	30
Figure 16.	Output drivers	31

1 Overview

1.1 Recommended reading

This document describes how to configure and use the PLM smartplug demonstration board. Additional information can be found in the following documents:

- ST device datasheets referenced in this document
- Third party device datasheets
- AN3287 application note
- UM1459 user manual.

1.2 Safety precautions

The board must be used only by expert technicians. Due to the high voltage (220 Vac) special care should be taken with regard to human safety.

There is no protection against accidental human contact with high voltages.

After disconnection of the board from the mains, none of the live parts should be touched immediately because of the energized capacitors.

It is mandatory to use a mains insulation transformer to perform any tests on the board in which test instruments such as spectrum analyzers or oscilloscopes are used.

Do not connect any oscilloscope probes to high voltage sections in order to avoid damaging instruments and demonstration tools.

Warning: STMicroelectronics assumes no responsibility for any consequences which may result from the improper use of this tool.

1.3 Getting technical support

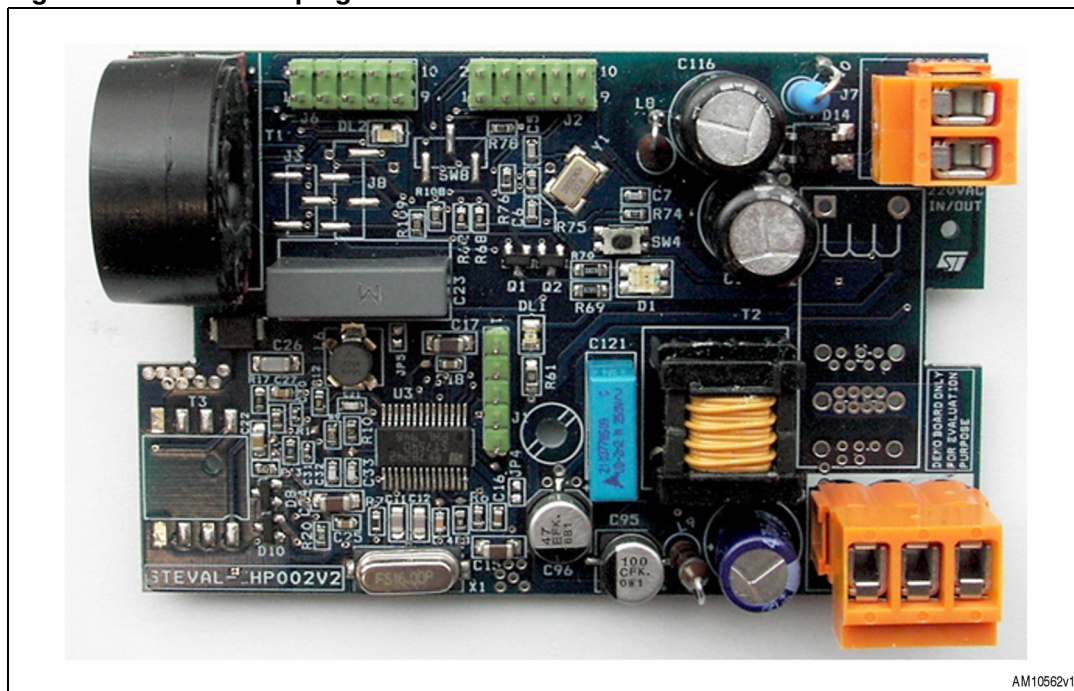
Technical assistance is provided free to all customers. For technical assistance, documentation, upgrades and information about products and services, please refer to your local ST distributor/office.

1.4 Package list

The PLM smartplug demonstration board package includes the following items:

- The PLM smartplug demonstration board ([Figure 2](#))
- A CD-ROM with software and documentation

Figure 2. PLM smartplugV2 board



2 PLM smartplug demonstration board components

2.1 Microcontroller

The system is managed by the STM32F103CB microcontroller. It is based on the 32-bit ARM Cortex™-M3 core with 72 MHz maximum frequency, 128 KB flash and 20 KB SRAM embedded memories. For further details please refer to the STM32F103x4 STM32F103x6 and the STM32F103x8 STM32F103xB datasheets. The microcontroller is driven by an external 8 MHz crystal for the high speed main clock. Some jumpers are connected to the microcontroller GPIOs in order to allow firmware configuration.

2.2 Debug

Software debug is via a standard 20-pin JTAG connection. The JTAG connector is not insulated, so for debugging use the JTAG opto-insulation board (order code: AIJTAG/OPTO-1/A), a battery supplied notebook, or supply the board through an insulated AC source.

2.3 Reset

The reset sources are:

- Power-on reset
- Pushbutton reset
- JTAG reset from an in-circuit emulator

2.4 Power supplies

The board is powered directly by the mains. It includes an insulated extended range power supply and both 50 Hz and 60 Hz frequencies.

The power supply is based on the Altair05T-800 controller for AC-DC converter. It provides 12 Vdc; the 3.3 Vdc is generated an LD1117AXX33 linear regulator starting from the 12 Vdc.

2.5 Power line communication

The board allows digital data communication through power line modulation using the ST7540 power line modem. For more details about the modem please refer to the ST7540 datasheet. The ST7540 supports B-FSK modulation up to 4800 bps; it is compliant with CENELEC band A, B, and C, supports preamble and unique word reception synchronization, and has a 500 mArms output current with 12 Vpp single-ended thanks to its integrated amplifier. The modem is coupled with the mains by a coupling transformer. The ST7540 is managed by an SPI and two control lines: the REG_DATA line, which is used to select the access to the configuration register or to the data, and the RxTx line which is used to select the reception or transmission mode. Moreover, the ST7540 provides information about the preamble/unique-word detection (CD/PD) and the carrier sensing (BU) by two digital outputs. [Table 1](#) shows the MCU resources mapping used for ST7540 management.

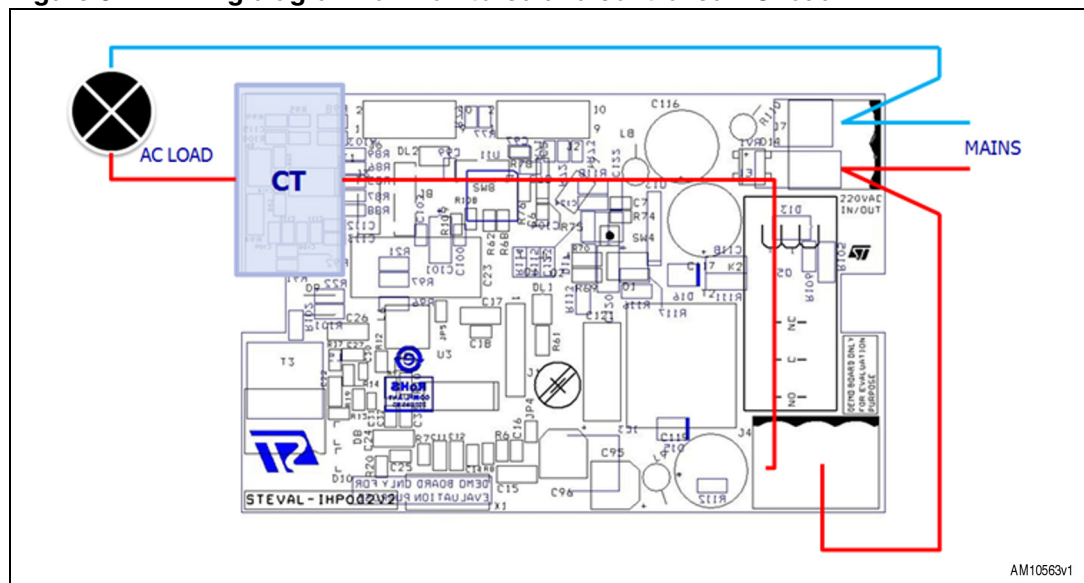
Table 1. STM32 resources – ST7540 function mapping

STM32 resource	ST7540 function
PA1	REG_DATA
PA2	CD/PD
PA3	BU
PA4	RxTx
SPI1-SCK (PA5)	SCK
SPI1-MISO (PA6)	TXD
SPI1-MOSI (PA7)	RXD

2.6 Energy measurement

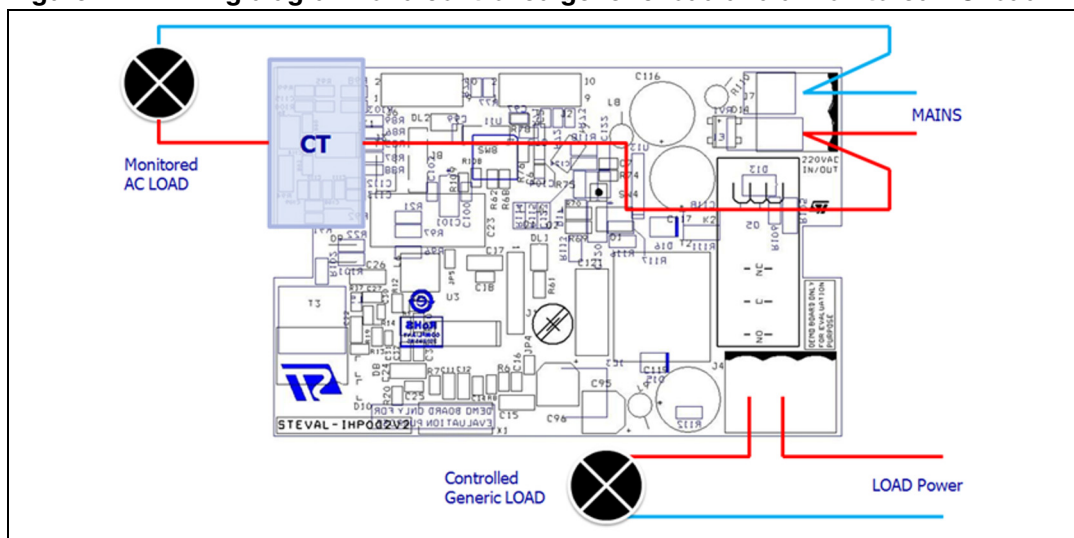
The energy meter section is based on the STPM01 programmable single-phase energy meter IC. The STPM01 supports 50-60 Hz -IEC62052-11, IEC62053-2X specifications with less than 0.1 % error. For further details please refer to the STPM01 datasheet. The current sensing is done by the current transformer; the STPM01 also measures the mains voltage. The image in [Figure 3](#) shows the wiring diagram in case the user wants to drive and monitor the same AC load. In this case, in fact, it is necessary to power the common contact of the output relay by the phase.

Figure 3. Wiring diagram for monitored and controlled AC load



It is also possible to control a generic load (AC or DC) different from the monitored AC one with the wiring diagram shown in [Figure 4](#).

Figure 4. Wiring diagram for a controlled generic load and a monitored AC load



The STPM01 is controlled by the MCU with an SPI communication bus and digital control line. [Table 2](#) shows the MCU resources mapping for energy meter IC management:

Table 2. STM32 resources – STPM01 function mapping

STM32 resource	Energy meter function
PA11	SYN
SPI2-MOSI/MISO (PB15/PB14)	SDA
SPI2-SCK (PB13)	SCL
PB12	SCS

2.7 Load drivers

The board can supply any kind of load (DC or AC) up to 16 A since the contacts of the relay are just available on connector J3. If the user wants to control and monitor a load at the same time, it is necessary to refer to the wiring diagram shown in [Figure 3](#). In this case it is possible to connect only AC loads. [Figure 3](#) and [4](#) show the connection of the load to the normally opened contact; it is also possible to use the normally closed contact connecting the load to the third contact of the connector J3.

2.8 USART communication

The board includes a USART communication interface which is used as the configuration port connecting an external RS232 adaptor; it also allows the power supply of the MCU in order to avoid the board connection to the mains during configuration. This interface is not insulated so must be used carefully, by a battery powered laptop, if the board is connected to the mains without connecting the adaptor to the power supply. [Table 3](#) shows the MCU resources mapping.

Table 3. STM32 resources – RS232 function mapping

STM32 resource	Serial communication function
USART1-TX (PA9)	RS232-TX
USART1-RX (PA10)	RS232-RX

2.9 Status LEDs

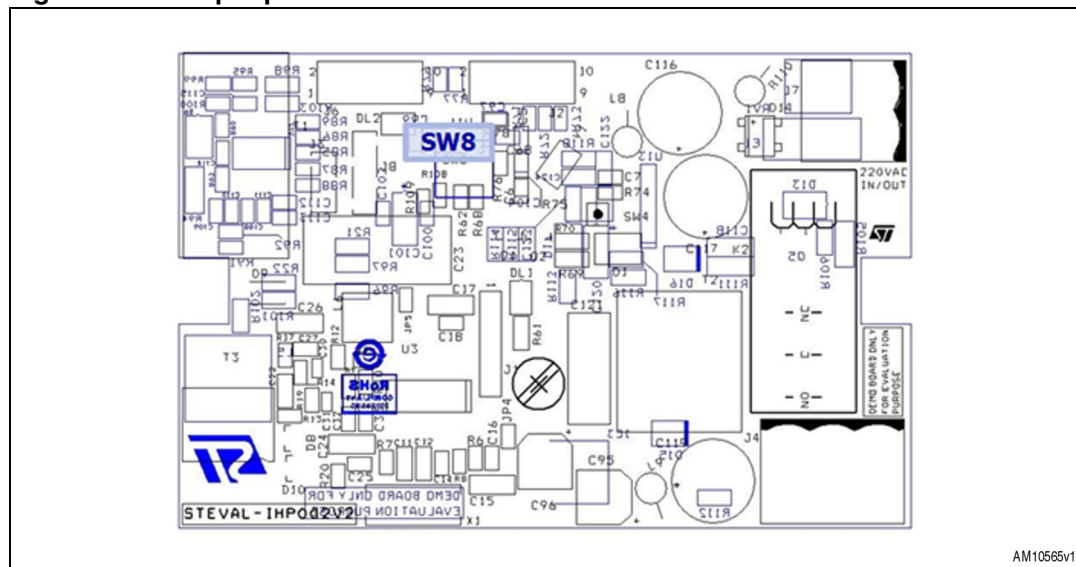
Table 4. LED description

LED	Description
DL1	5 V power supply
D1	General purpose bi-color
DL2	Energy measurement

2.10 Jumpers

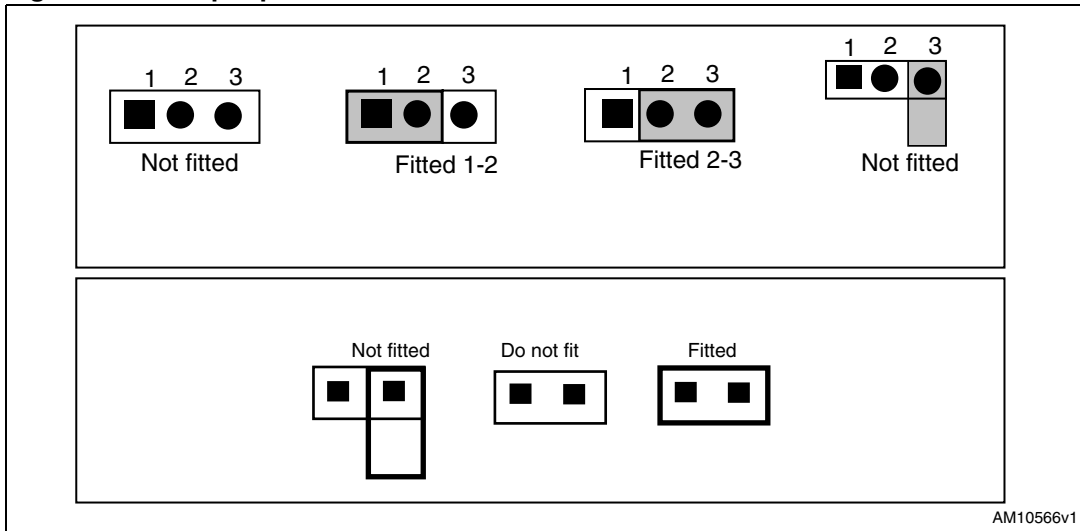
2.10.1 Jumper placement

Figure 5. Jumper placement



2.10.2 Jumper positions

Figure 6. Jumper positions



2.10.3 Jumper description and default value

Table 5. Jumper description

Jumper	Description	Default
SW8	Running mode: – Fitted (1-2): calibration mode – Fitted (2-3): normal mode	Fitted (2-3)

2.11 Pushbutton description

Table 6. Pushbutton description

Switch	Description
SW4	STM32 reset button

2.12 Connector description

Figure 7. Connector position

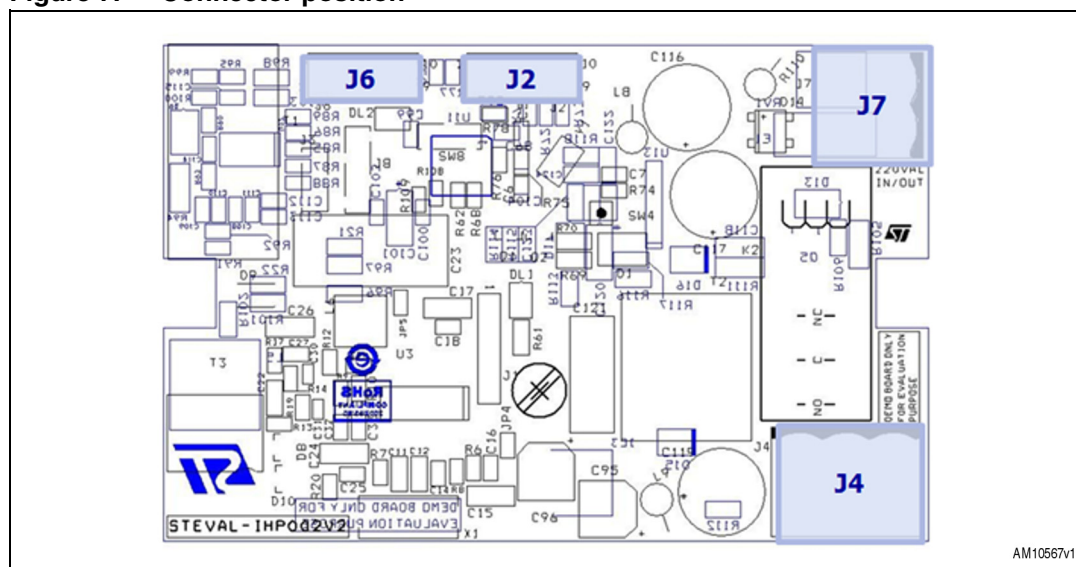


Table 7. Connector description

Connector	Description
J2	STM32 JTAG connector
J4	Output relay contacts
J6	STPM01 calibration connector
J7	AC input

2.12.1 STM32 JTAG connector

Figure 8. STM32 10-pin JTAG connector

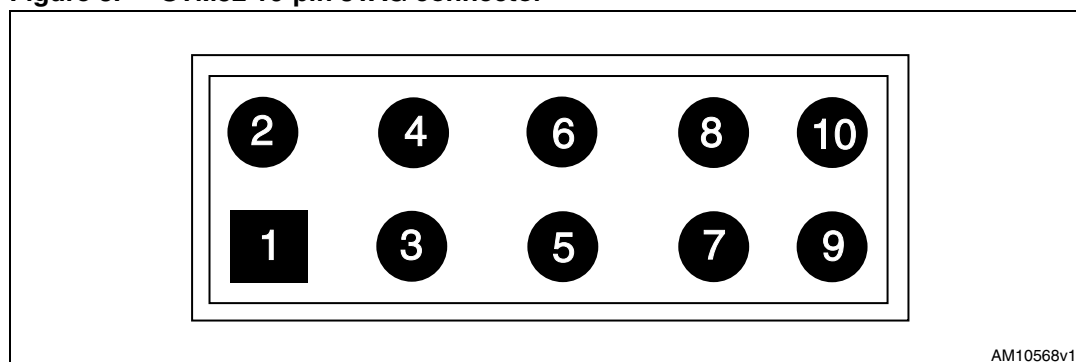


Table 8. JTAG connector pin description

Pin	Description
1	VCC
2	TMS
3	GND
4	TCK
5	GND
6	TDO
7	N.C.
8	TDI
9	GND
10	Reset

2.13 Energy meter IC calibration connector

Figure 9. Energy meter calibration connector

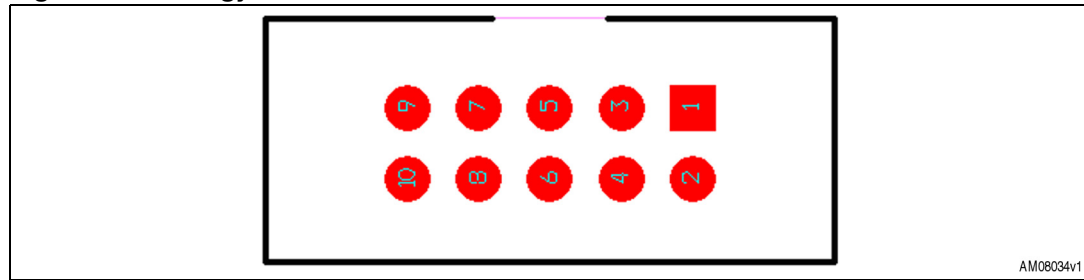


Table 9. Energy meter calibration connector pin description

Pin	Description
1	VCC
2	TMS
3	GND
4	TCK
5	GND
6	TDO
7	N.C.
8	SYN_CAL
9	SBG
10	Not connected

3 Board configuration

3.1 SPTM01 calibration configuration

To calibrate the STPM01, the SW8 must be set according to [Table 5](#). When this switch is set in calibration mode, the STPM01 can be driven by an external programmer using the J6 connector.

4 Bill of material and schematics

Table 10. Bill of material

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
C5,C6	22 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0603				
C122	470 nF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C7	22 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0603				
C11,C12	33 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C14,C27, C103C114, C115	10 nF	±10%	50 V		Ceramic capacitor X7R	SMD 0603	muRata	GRM188R71H10 3KA01D	RS code: 204-0779	
C15,C17, C24	10 µF	±10%	16 V		Ceramic capacitor X7R	SMD 1206	KEMET	C1206C106K4PA C7800	RS code: 648-0755	
C16,C18, C25,,C109, C110,C111 ,C112,C113,C97,C98, C99,C100, C104	100 nF	±10%	50 V		Ceramic capacitor X7R	SMD 0603	muRata	GRM188R71H10 4KA93D	RS code: 624-2480	
C21,C33	100 pF	±5%	50 V		Ceramic capacitor COG	SMD 0603	muRata	GRM1885C1H10 1JA01D	RS code: 653-0327	
C22	10 µF	±10%	10 V		Ceramic capacitor X5R	SMD 0805	muRata	GRM21BR61A10 6KE19L	RS code: 106-846	

**Table 10. Bill of material (continued)**

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrellec/other code	More info
C23	68 nF	±20%	300 V		X2 Capacitor	Through hole	Any		Distrelec code: 821885	
C26	6.8 nF	±5%	50 V		Ceramic capacitor COG	SMD 1206	muRata	GRM3195C1H68 2JA01D	RS code: 624-2597	
C30	15 pF	±5%	50 V		Ceramic capacitor COG	SMD 0402	muRata	GRM1555C1H15 0JZ01D	RS code: 624-2935	
C31	22 pF	±5%	50 V		Ceramic capacitor COG	SMD 0402	muRata	GRM1555C1H22 0JZ01D	RS code: 624-2187	
C32	270 pF	±5%	50 V		Ceramic capacitor COG	SMD 0603	KEMET	C0603C271J5GA C7867	RS code: 147-207	
C95	100 µF	+/-20%	16 V		Electrolytic capacitor	SMD	Any		RS code: 565-695	
C96	47 µF	+/-20%	25 V		Electrolytic capacitor	SMD	Any		RS code: 565-712	
C101	10 µF	10%	10 V		Tantalium capacitor	SMD	Any		RS code: 464-7619	
C123	10 nF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C124	1 nF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C108	1 nF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0603				
C116,C117	4.7 µF	+/-20%	400 V		Electrolytic capacitor	Through hole	Any		RS code: 365-4745	
C118	470 pF	+/-10%	400 V		Ceramic capacitor X7R	SMD 1206	Any		RS code: 192-718	

Table 10. Bill of material (continued)

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
C119	470 μ F	+/-20%	16 V		Electrolytic capacitor low ESR	Through hole	Any		Distrelec code:801839	
C120	2.2 μ F	+/-10%	35 V		Tantalum capacitor	SMD	Any		RS code: 699-3324	
C121	2.2 nF	+/-20%	250 V		Y2 ceramic capacitor	Through hole	Any		RS code: 216-1595	
DL1	Red				Chip LED	SMD 0805	Any		Distrelec code: 250154	
DL2	Blue				Chip LED	SMD 0805	Any		Distrelec code: 250159	
D1	Bi-color LED red/green				LED bi-red, green	SMD	Any		RS code: 419-053	
D6,D13, D17	LL4148				Switching diode_	SOD-80	Any		Distrelec code: 601496	
D8,D10	BAT54S				Small signal Schottky diodes	SOT-23	STMicroelectronics	BAT54SFILM		
D9	SM6T15CA				Transil	SMB	STMicroelectronics	SM6T15CA		
D14	MB6S-RC				Diode bridge	SOIC4	Taiwan Semiconductor		RS code: 652-7501	
D15	STPS1H100A				High voltage power Schottky rectifier	SMA	STMicroelectronics	STPS1H100A		
D16	STTH1L06A				Turbo 2 ultrafast high voltage rectifier	SMA	STMicroelectronics	STTH1L06A		

**Table 10. Bill of material (continued)**

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
F1	1 A				Fuse with clip 1 A	SMD	Schurter	3404.2416.22	RS code: 703-2742	
IC3	LD1117ADT3 3TR				Low drop fixed and adjustable positive voltage regulators	DPAK	STMicroelectronics	LD1117ADT33T R		
JP4,JP5	Close				Do not fit	Do not fit	Do not fit	Do not fit	Do not fit	
J1	Peak meter connector				5-way single row stripline connector (male connector) 2,54 mm pitch	Vertical through hole	Any		RS code:495- 8470	
J2	JTAG				2x10-way double row stripline connector (male connector) 2,54 mm pitch	Vertical through hole	Any		RS code: 1732764	
J3	USART				3-way single row stripline connector (male connector) 2,54 mm pitch	SMD	Tyco Electronics	1241150-3	RS code: 528-6237	
J4	CON3				3-way vertical closed header, 5.08 mm pitch	Through hole	PHOENIX CONTACT	SL 5.08/3/180B	RS code: 294-8443	
J6	CAL CON				2x10-way double row stripline connector (male connector) 2,54mm pitch	Vertical through hole	Any		RS code: 1732764	



Table 10. Bill of material (continued)

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
J7	CON2				2-way vertical closed header, 5.08 mm pitch	Through hole	PHOENIX CONTACT	SL 5.08/2/180B4.5	RS code: 294-7428	
J8	RFID reader				4-way single row stripline connector (male connector) 2,54 mm pitch	SMD	Tyco Electronics	1241150-4	RS code: 528-6243	
L5	22 μ H	$\pm 10\%$	2.1 A		Smd inductor	SMD	EPCOS	B82464A4223K	RS code: 496-0445	
L6	220 μ H	$\pm 10\%$	240 mA		Smd inductor	SMD	EPCOS	B82462A4224K	RS code: 495-8048	
L8	470 μ H	+/-5%	170 mA		Inductor	Through hole	Any		RS code: 191-0677	
L9	10 μ H	+/-10%	500 mA		Inductor	Through hole	Any		RS code: 191-0481	
Q1,Q2	BC857B				PNP transistor	SOT23	Any		RS code: 445-2051	
Q5	2STR1215				Low voltage fast-switching NPN power transistor	SOT-23	STMicroelectronics	2STR1215		
R6	1.1 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R7	47 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R8	15 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R9,R88, R71,R72, R73,R108, R109	4.7 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R10	13 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				

**Table 10. Bill of material (continued)**

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
R12,R62, R68,R90, R93	1 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R13	2.7 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R14	1.8 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R17	470 Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R19,R85, R86,R87	2.4 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R20	56 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R21,R22, R96,R97, R101,R102	261 k Ω	+/-1%		1/8 W	Mini melf Resistor	SMD 0805	Any		Digi-Key code: RT0805FRE 07261KL- ND	
R61,R106	1 k Ω	+/-5%		1/8 W	Resistor	SMD 0805				
R74,R76, R77,R78, R79	10 k Ω	+/-5%		0.1 W	Resistor	SMD 0603				
R112,R118	10 k Ω	+/-5%		1/8 W	Resistor	SMD 0805				
R69,R70	82 Ω	+/-5%		1/8 W	Resistor	SMD 0805				
R75	1 M Ω	+/-5%		0.1 W	Resistor	SMD 0603				
R89	560 Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R91,R92	6.8 Ω	+/-1%		0.1 W	Resistor	SMD 0603			Farnell code: 1500646	
R94	2 M Ω	+/-1%		1/4 W	Resistor	SMD 1206				
R95	0	+/-1%		0.1 W	Resistor	SMD 0603				



Table 10. Bill of material (continued)

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
R98,R103	475 Ω	+/-1%		1/8 W	Mini melf resistor	SMD 0805	Any		Digi-Key code: RT0805FRE 07475RL	
R99	43 k Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R100	100 Ω	+/-1%		0.1 W	Resistor	SMD 0603				
R105	1 k Ω (do not fit)	+/-1%		1/4 W	Resistor	SMD 1206				
R110	22 Ω	+/-5%		1 W	Fuse resistor	Through hole	Any		RS code: 214-0920	
R111	120 k Ω	+/-5%		1/4 W	Resistor	SMD 1206				
R113	10 Ω	+/-5%		1/8 W	Resistor	SMD 0805				
R114	27 k Ω	+/-1%		1/8 W	Resistor	SMD 0805				
R115	4.7 k Ω	+/-1%		1/8 W	Resistor	SMD 0805				
R116	2.2 Ω	+/-1%		1/8 W	Resistor	SMD 0805				
R117	22 Ω	+/-1%		1/8 W	Resistor	SMD 0805				
RV1	VAR275V		275 V		SMD varistor	SMD	EPCOS	B72650M271K72	Distrelec code: 730096	
SW4	Rst				Surface mount tactile switch	SMD	C & K	Y78B22110FP	RS code 505-9186	
SW8	Calibration settings				3-way single row stripline connector (male connector) 2,54 mm pitch	SMD	Tyco Electronics	1241150-3	RS code: 528-6237	Single stripline 3 poli

**Table 10. Bill of material (continued)**

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
TP8,TP9,TP10,TP11,TP12,TP13,TP14,TP15,TP16,TP17,TP18,TP19,TP20,TP21,TP22,TP23,TP25,TP26,TP27	Test point				Test point	Test point	Test point	Test point	Test point	
T1	Current transformer				Current transformer	Through hole	VAC	T60404-E 4622-X503		
T2	Custom transformer				Custom transformer	Through hole	MAGNETICA	1921.0013 rev.2		
T3	Line transformer				Line transformer	SMD	VAC	T60403-K5024-X044		
U3	ST7540				FSK power line transceiver	HTSSOP28	STMicroelectronics	ST7540TR		
U11	STM32F103C BT6				Medium-density performance line ARM-based 32-bit MCU	LQFP48	STMicroelectronics	STM32F103CBT6		
U12	STPM01				Programmable single phase energy metering IC with tamper detection	TSSOP20	STMicroelectronics	STPM01FTR		



Table 10. Bill of material (continued)

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrelc/other code	More info
U13	ALTAIR05T-800						STMicroelectronics			
X1	16 MHz				16 MHz crystal	SMD	Any		RS code: 547-6531	
Y1	8 MHz				8 MHz crystal	SMD	ABRACON	ABM3B-8.000 MHz-B2	RS code: 703-1997	
k2	16 A 12 Vdc coil (do not fit)		12 V/ 16 A		Low profile SPDT power relay	Through hole	OMRON	G2RL-1-E 12DC	RS code: 365-0535	
C5,C6	22 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0603				
C122	470 nF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C7	22 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0603				
C11,C12	33 pF	+/-10%	50 V		Ceramic capacitor X7R	SMD 0805				
C14,C27, C103C114, C115	10 nF	±10%	50 V		Ceramic capacitor X7R	SMD 0603	muRata	GRM188R71H10 3KA01D	RS code: 204-0779	
C15,C17, C24	10 uF	±10%	16 V		Ceramic capacitor X7R	SMD 1206	KEMET	C1206C106K4PA C7800	RS code: 648-0755	
C16,C18, C25,C109, C110,C111 ,C112, C113,C97, C98,C99, C100, C104	100 nF	±10%	50 V		Ceramic capacitor X7R	SMD 0603	muRata	GRM188R71H10 4KA93D	RS code: 624-2480	

**Table 10. Bill of material (continued)**

Reference	Part / value	Tolerance %	Voltage current	Watt	Technology information	Package-foot-print	Manufacturer	Manufacturer code	RS/Distrellec/other code	More info
C21,C33	100 pF	±5%	50 V		Ceramic capacitor COG	SMD 0603	muRata	GRM1885C1H101JA01D	RS code: 653-0327	
C22	10 µF	±10%	10 V		Ceramic capacitor X5R	SMD 0805	muRata	GRM21BR61A106KE19L	RS code: 106-846	
C23	68 nF	±20%	300 V		X2 capacitor	Through hole	Any		Distrelec code: 821885	
C26	6.8 nF	±5%	50 V		Ceramic capacitor COG	SMD 1206	muRata	GRM3195C1H682JA01D	RS code: 624-2597	
C30	15 pF	±5%	50 V		Ceramic capacitor COG	SMD 0402	muRata	GRM1555C1H150JZ01D	RS code: 624-2935	
C31	22 pF	±5%	50 V		Ceramic capacitor COG	SMD 0402	muRata	GRM1555C1H220JZ01D	RS code: 624-2187	
C32	270 pF	±5%	50 V		Ceramic capacitor COG	SMD 0603	KEMET	C0603C271J5GAC7867	RS code: 147-207	
C95	100 µF	+/-20%	16 V		Electrolytic capacitor	SMD	Any		RS code: 565-695	
J7a	CON3				2-way cable mount screw terminal, 5.08 mm	Through hole	Phoenix Contact	BL 5.08/2	RS code: 403-875	Not mounted on PCB

Figure 10. Top page

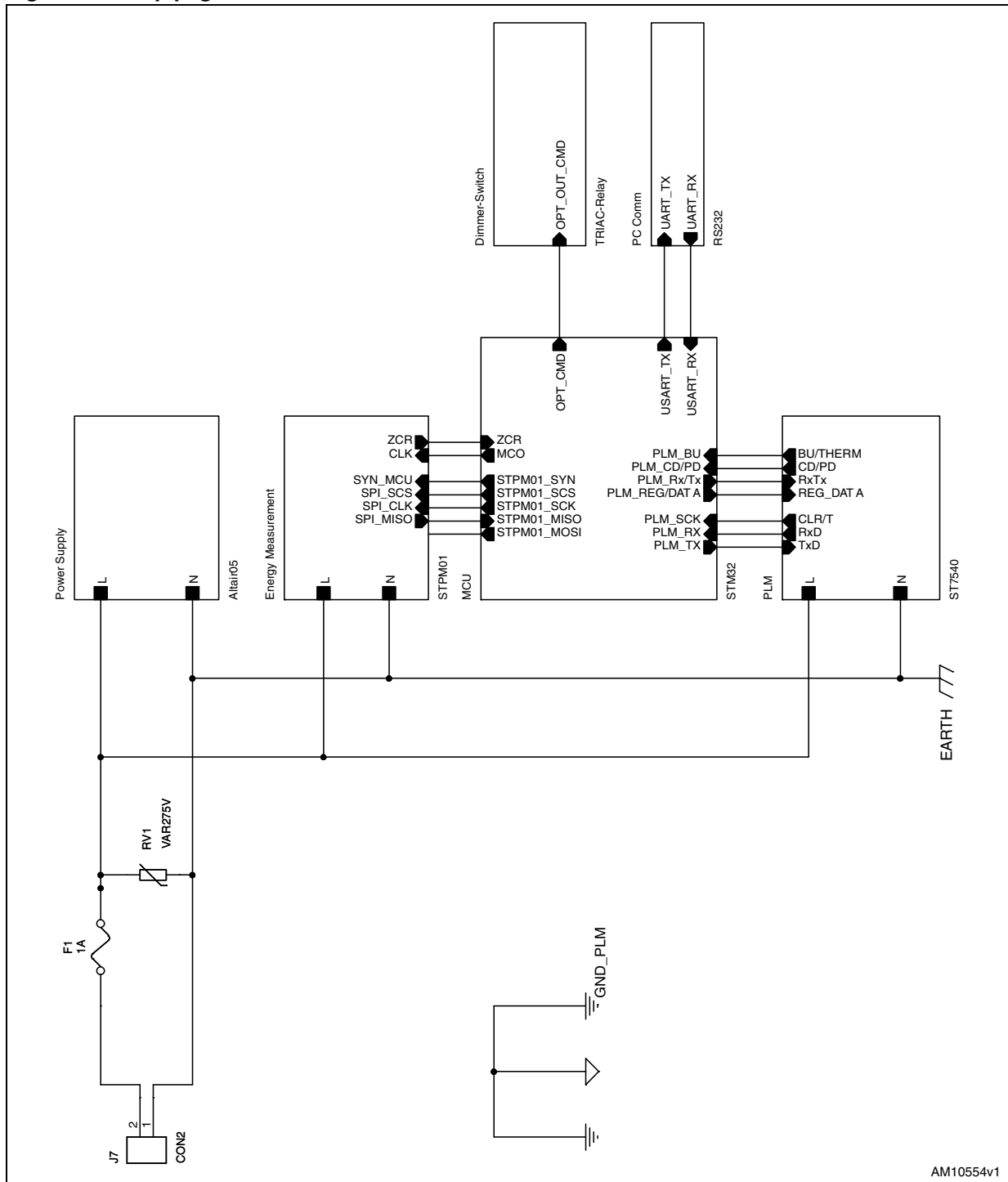
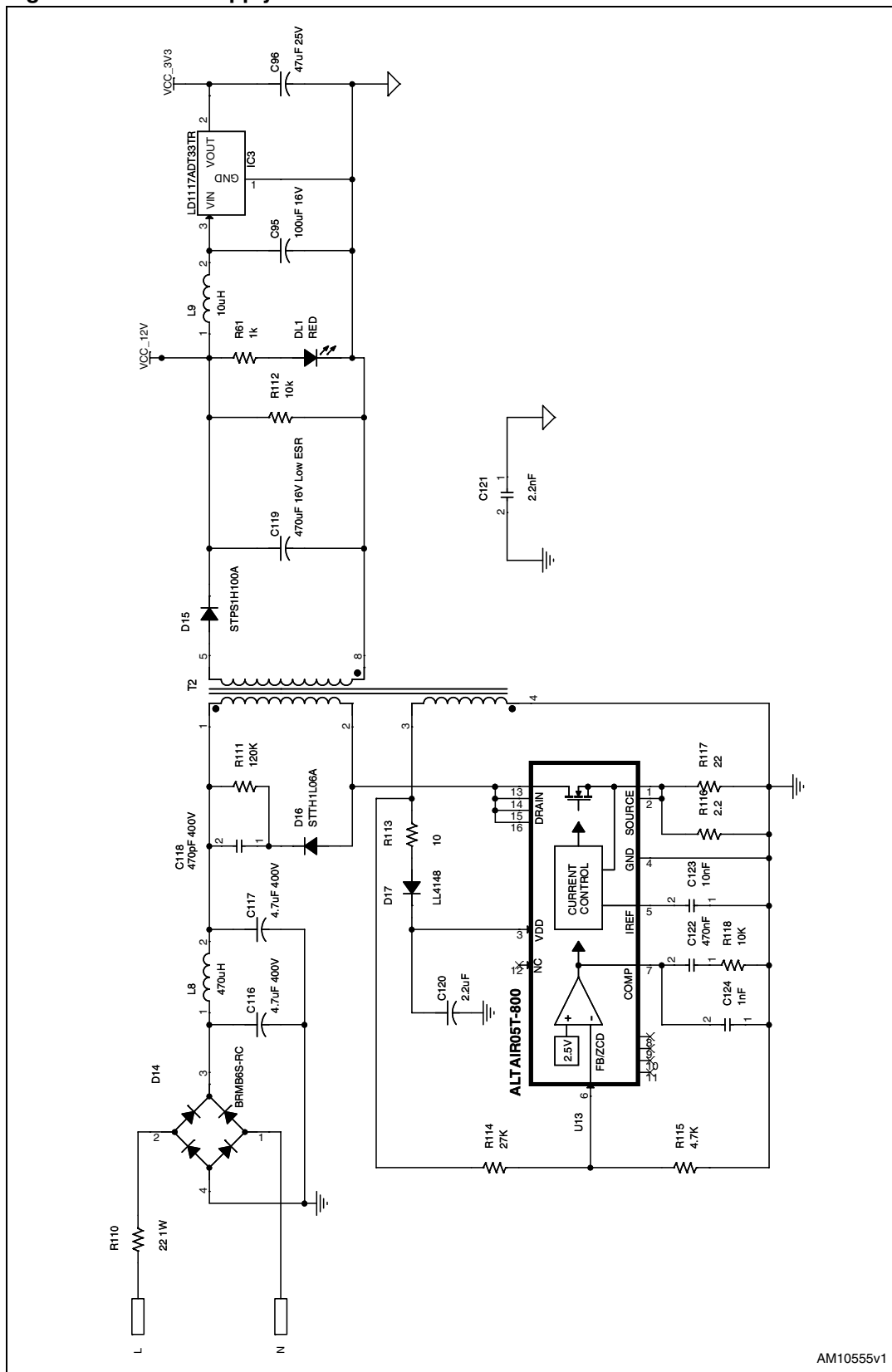


Figure 11. Power supply section



AM10555v1

Figure 12. USART expansion connector section

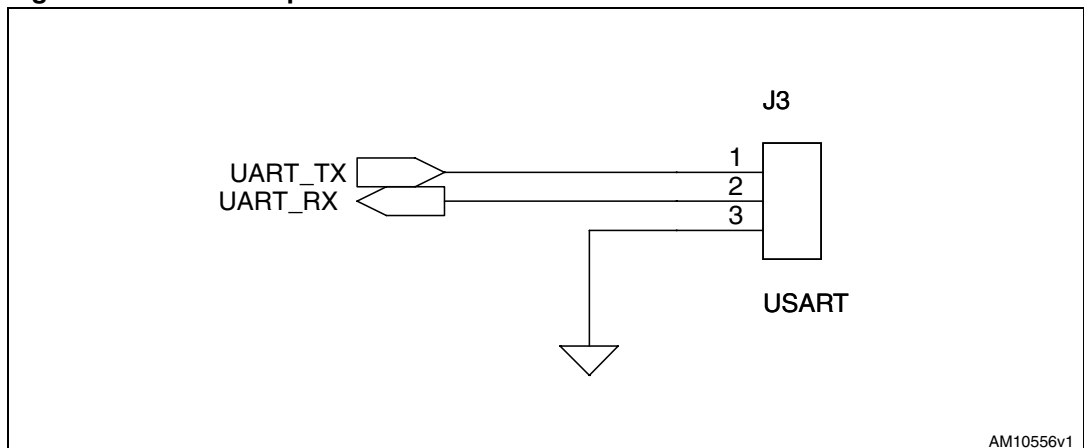
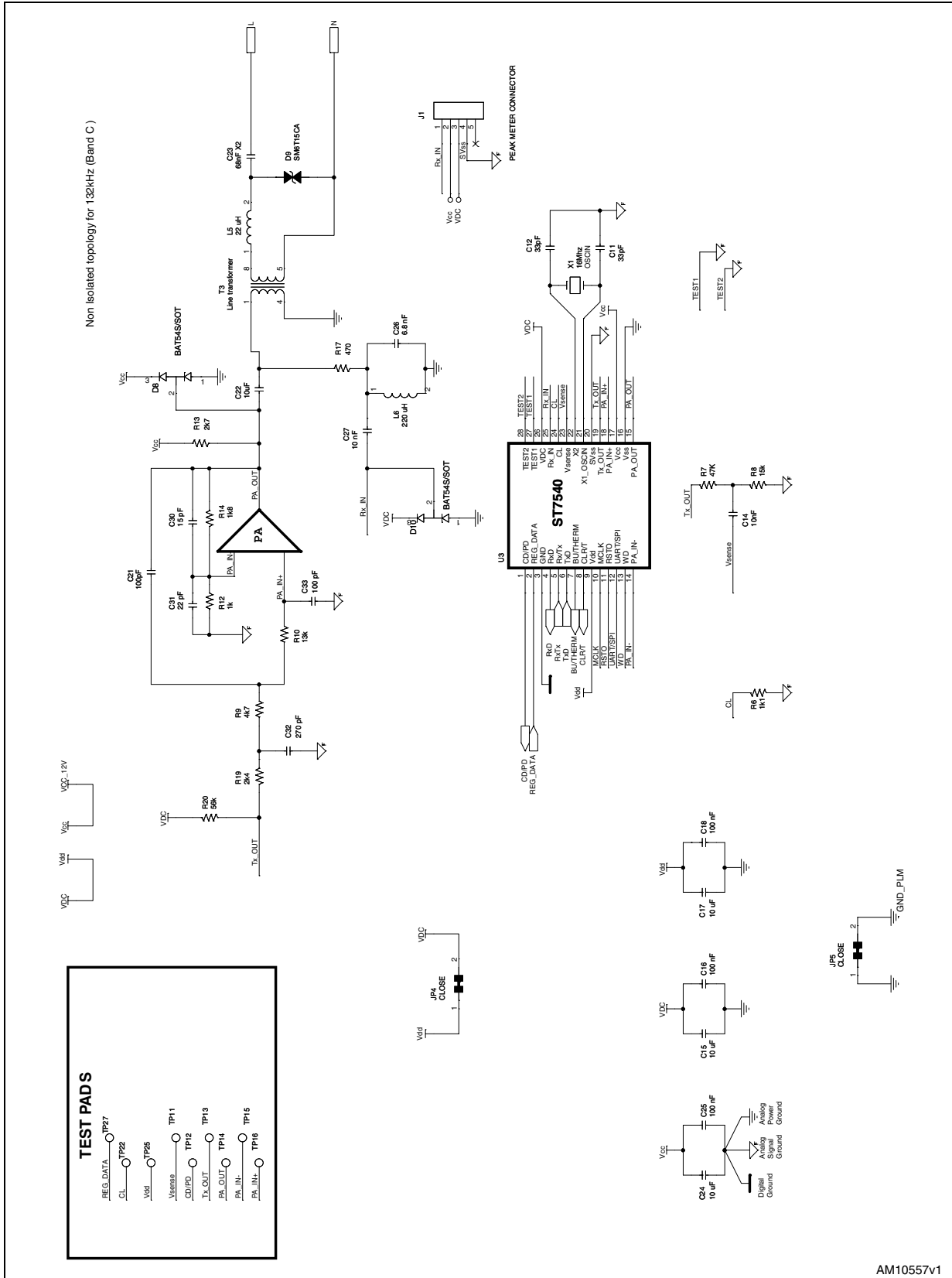


Figure 13. Power line modem section



AM10557v1

Figure 14. MCU section

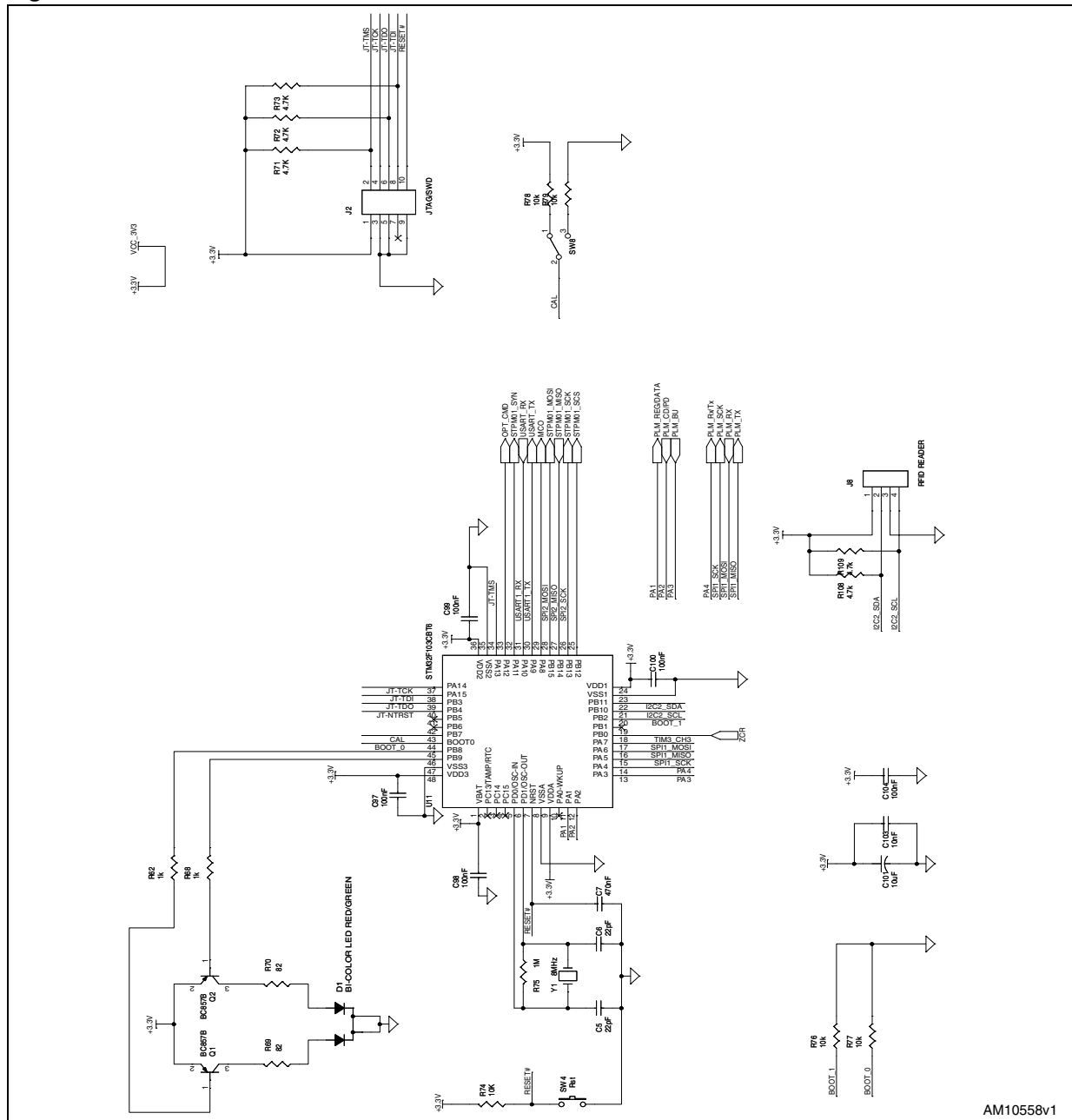
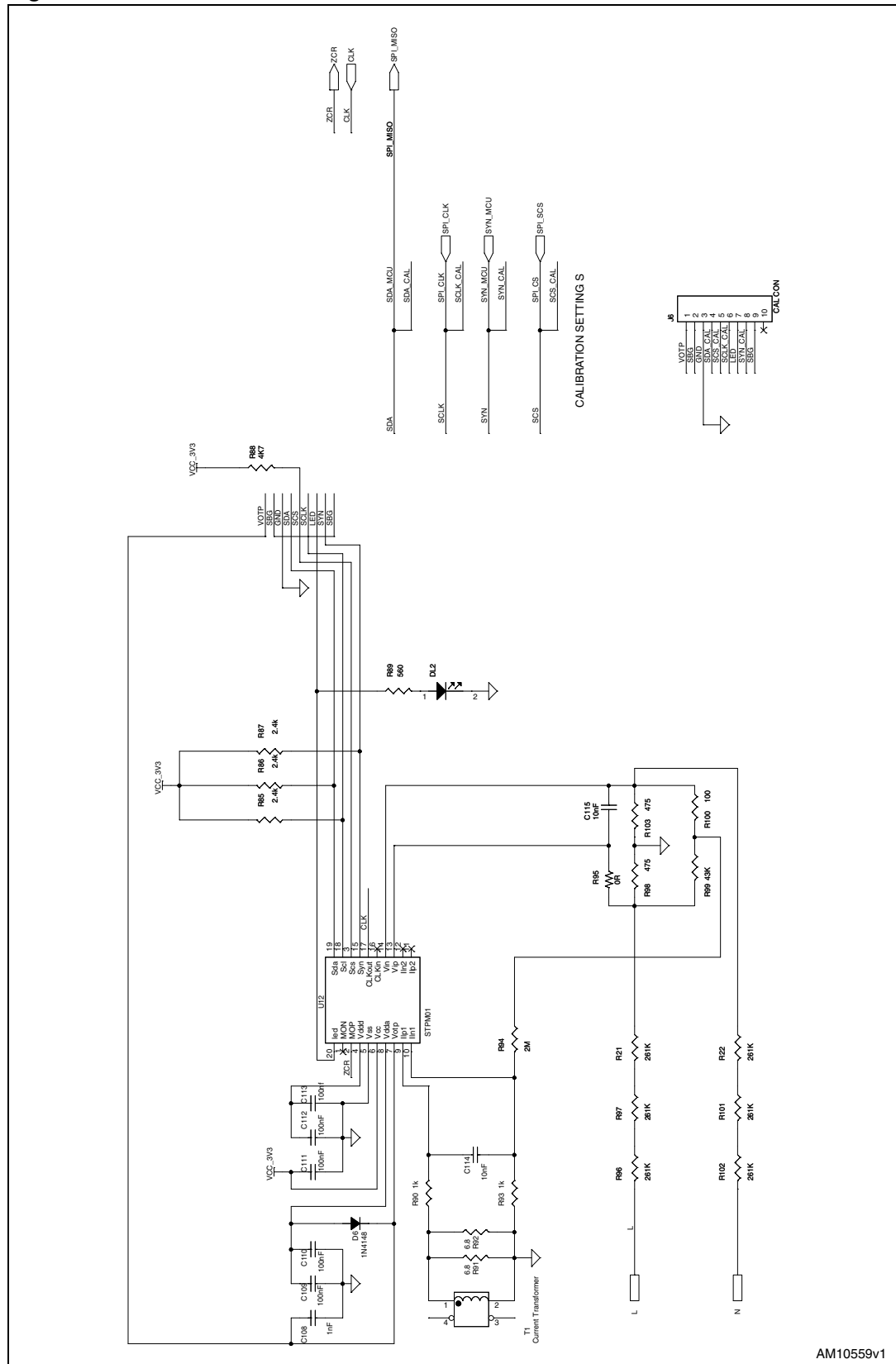
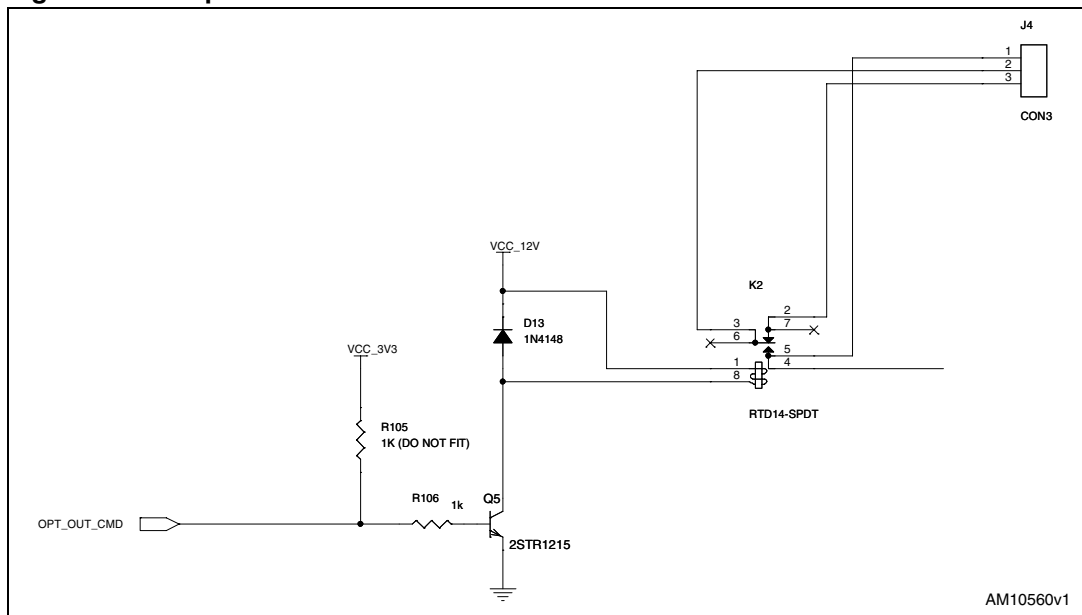


Figure 15. STPM01



AM10559v1

Figure 16. Output drivers



5 Revision history

Table 11. Document revision history

Date	Revision	Changes
09-Nov-2011	1	Initial release.

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