STEVAL-ISB008V1, USB Li-Ion battery charger and
gas gauge, based on the STw4102

Introduction

This user manual describes an easy, compact, and economical solution to charging Li-Ion batteries using a USB port and a DC adaptor. In addition, battery capacity monitoring can be done through the efficient built-in gas gauge system of the STw4102 device. The board has the following devices:

■ STw4102 battery charging device

■ USBLC6-2 ESD protection device

■ STM32F103C6 microcontroller
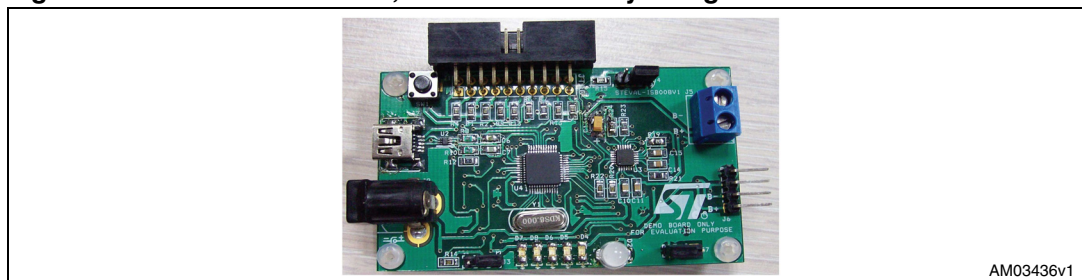
■ LD2985BXX30 voltage regulator

Key features:

■ The STw4102 is used for charging a battery through a USB or the external DC adaptor

■ The STw4102 supports gas gauge applications

■ An onboard STM32 microcontroller is used for enumeration and controlling the STw4102 to comply with USB specifications

■ Charging and discharging status is indicated by dual-color LEDs

■ Gas gauge: battery capacity status shown in five levels using LEDs in steps of 20 % each

■ This can be used as a standalone Li-Ion battery charger in various applications

The Li-Ion battery charger device can be used in the following applications:

■ Standalone chargers: already implemented in the STEVAL-ISB008V1. An explanation is given in this document

■ USB-powered chargers: already implemented in the STEVAL-ISB008V1. An explanation is given in this document

■ PDAs

■ Handheld devices

■ Cellular phones (GSM, CDMA, WCDMA)

■ Cordless phones

■ Digital cameras, USB appliances, blue tooth devices, etc.

Figure 1.   STEVAL-ISB008V1, USB Li-Ion battery charger

AM03436v1

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1 Getting started

1.1 Package

The STEVAL-ISB008V1 demonstration board package includes the following items:

● Hardware content:
  – Demonstration board STEVAL-ISB008V1
● Documentation:
  – User manual
  – Schematics, Gerber files, BOM
● Microcontroller firmware:
  – Pre-programmed STM32F103C6T6A device soldered onto the demonstration board
  – Object files are also available for the firmware

1.2 Setting up the board

● The USB Li-Ion battery charger can be set up as follows:
  – Connect the Li-Ion battery pack to the board with appropriate polarity
  – Connect either the adapter or USB cable to the board. If both voltage sources are connected, then the adapter considers as source for battery charging
  – Check the status of D2 LED. D2 is green during charging of the battery and is red during discharging
  – Five LEDs show the available capacity of the battery.

Figure 2. STEVAL-ISB008V1, USB Li-Ion battery charger parts
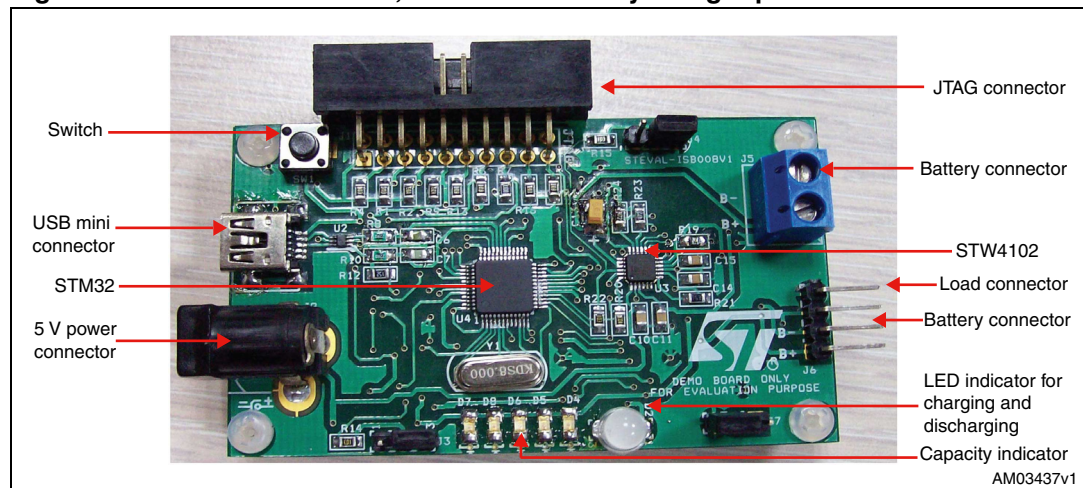
1.3 Hardware layout

The hardware layout of the PCB is shown in *Figure 3* which shows all the components mounted on the board.

Figure 3. Hardware layout details

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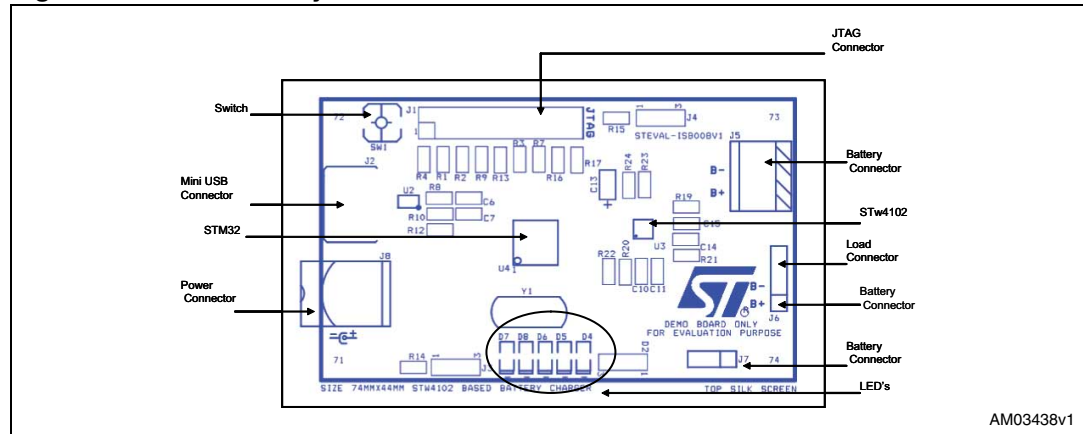
1.4 System architecture description

● The application works as a Li-Ion battery charger

● The system can be used both in USB mode and also adapter mode

● The system consists of a battery charger section for a Li-Ion battery and a microcontroller section for controlling actions

● LEDs available on the board indicate the status of the charging conditions

● Gas gauge/battery capacity status through Leds in steps of 20 % each

● A JTAG connector is available to program the microcontroller.

2 System overview

2.1 General description of product architecture

Figure 4. System architecture details

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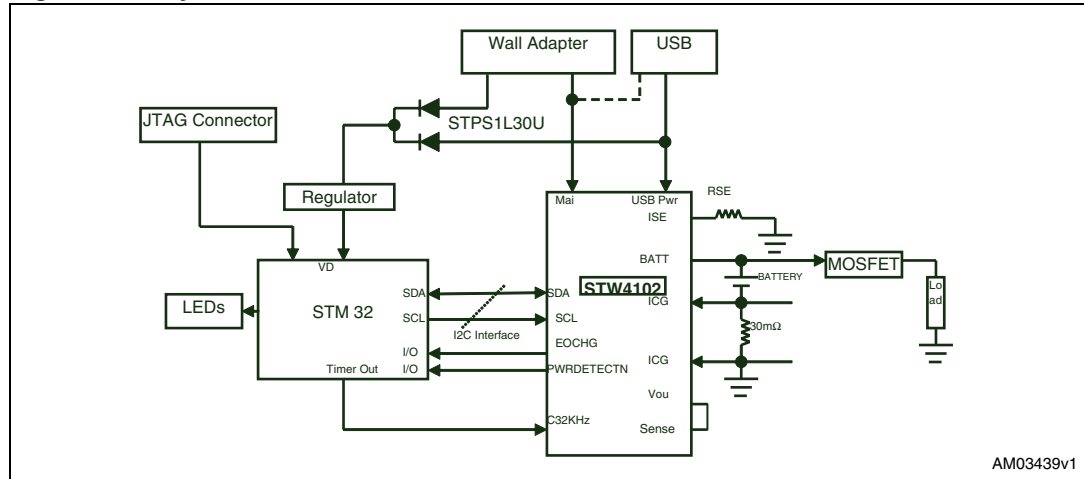
As described in the block diagram, the STw4102 battery charger, in addition to the STM32 microcontroller, acts as a completely standalone battery charger featuring gas gauge implementation, which shows the remaining capacity of the battery in an efficient manner with the help of five LEDs assigned to different capacity levels. The different capacity levels are mentioned in the user interface section. Similarly, two status LEDs show charging, discharging, and some faulty conditions.

The firmware programmed on the demonstration board considers the battery capacity as 1200 mAh by default. This "maximum capacity" value is used to find out the percentage of the available battery capacity which is shown using the 5 LEDs.

The maximum capacity value can be changed by the user using the S1 switch and J7 jumper. This needs to be done when the user connects a battery to the demonstration board which is different to the 1200 mAH rating. This is further explained in *Section 3.2*.

The STw4102 supports a 24-bit accumulator. The LSB value corresponds to a charge of 54.5 nAh. Under these conditions the 24-bit accumulator has a capacity of 914 mA. Please refer to the STw4102 datasheet; *Dual source USB Li-Ion charger with gas gauge*, at http://www.st.com for details. In addition to this the microcontroller (the host controller for the STW4102) can implement a software counter to measure the available capacity for higher capacity batteries.

The demonstration board firmware allows the user to change the maximum capacity up to 2100 mAh in steps of 300 mAh.

The STM32 is used to control and monitor the STw4102 battery charger device. All the communication between the STw4102 and STM32 is done using the I^2C interface.

This board has a USB connector and a connector for the DC adapter. These can be used for charging the battery connected to the STw4102 device. The board can supply a typical battery charging current of 400 mA in the case of a USB port, whereas in the case of a DC adapter the range is extended to 800 mA.

3 Working of board

3.1 Operational description

Operation of the battery charger and gas gauge function mainly depends on the STw4102 battery charger device. The STM32 microcontroller is used for charging, and gas gauge processes. In addition, the microcontroller controls the discharging of the battery when a load is connected to the load terminals provided on the board.

Special care must be taken in the case of a USB to respect the USB specification. The STM32 firmware smartly handles different states of charging during enumeration, suspend mode, and also in resume mode.

Table 1. Description of firmware actions in USB charging mode

USB state (refer to USB specifications)	USB power budgeting specification	Microcontroller actions	STw4102 device actions
Attached, powered, default, address states	USB device can draw no more than 100 mA from V_{BUS}	USB section enabled Endpoint0 transactions. Sets the 'USB_ICHG' bits of REG_CHG0 to 00b to draw no more then 100 mA current	The STw4102 supports a maximum of 60 mA current in this mode
Configured	USB device can draw up to 500 mA for high-power bus-powered functions or up to 100 mA for low-power devices (This rating is put in the configuration descriptor field "bMaxPower")	USB state machine changed to "configured" and sets the 'USB_ICHG' bits of REG_CHG0 to 10b to draw no more then 500 mA from V_{BUS}	The STw4102 supports a maximum of 500 mA current in this mode
Suspended	USB device can draw <2.5 mA current from V_{BUS}	Microcontroller executes USB suspend interrupt and enters power saving mode, reducing power consumption, all LEDs are OFF, microcontroller sets the 'USB_ICHG' bits of REG_CHG0 to 11b for charging current to zero ampere. And disable the battery monitoring. Put the gas gauge in standby mode by setting the STDBY pin as high	The STw4102 device charging current set to zero Ampere

Table 2. Different states of device shown through LED D2 status

| Charge condition	Description	D2 (Green)	D2 (Red)
Charge in progress	When the device is in trickle charge or fast-charge status	Toggling	Off
Charge done	End of charge pin goes low or charge is 100 %	On	Off

Table 2.   Different states of device shown through LED D2 status (continued)

Charge condition	Description	D2 (Green)	D2 (Red)
Discharging	When load is connected to board and charging is disabled	Off	Toggling
Battery low	When battery voltage is less than critical battery voltage or Rcap < 15 %	Off	On
Battery absent	When the battery pack is removed	Off	On

3.2   Initial settings for new battery

To give flexibility to the user to connect any Li-Ion battery to the demonstration board, firmware provides an option to the user to program the battery capacity in the demonstration board using a jumper switch and LEDs. If the user wants to program the maximum battery capacity, use the following steps:

Figure 5.   Initial setting for new battery before power-on
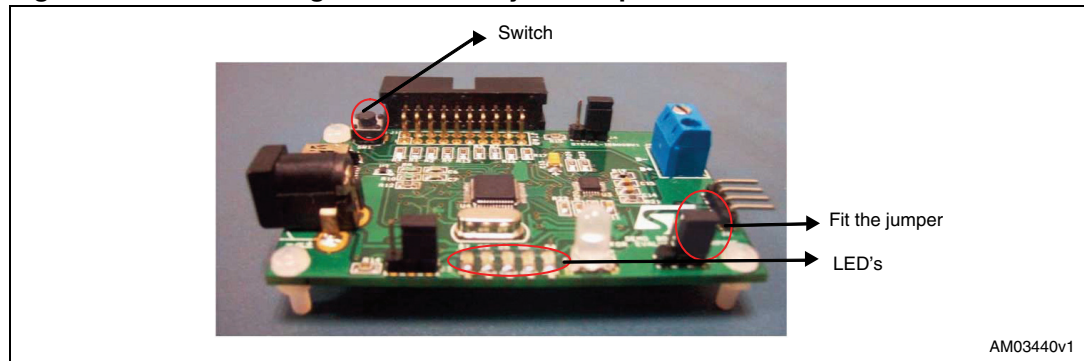
- Set the J7 jumper between pin 1 and 2 before power-on, as shown in *Figure 5*

- Connect either the adapter or the USB cable to power-on the board

- Using the SW1, set the capacity of the battery. Pressing the switch once increases the battery capacity in multiples of 300 mAh up to a maximum of 2100 mAH. The five levels of LEDs are used to indicate the capacity of the battery

- When the user first presses SW1 the D4 LED lights up, indicating 300 mAh. Press again to set 600 mAh. The LED lights up according to BCD format. The user must press the switch repeatedly to increase the capacity. The maximum allowed is 2100 mAH

- If the user exceeds the limit, the D2 LED is red, indicating the maximum capacity the user can enter as 2100 mAh. If the user wants to enter less capacity, the board should be restarted and the correct capacity of the battery entered

- Once the capacity is entered by pressing the switch, again set the jumper between pin 2 and 3, as shown in *Figure 5*, without powering off the demonstration board

- When a battery capacity is programmed to the board the value is stored in the internal flash of the microcontroller by EEPROM emulation

Now the 5 LEDs show the available capacity of the battery according to the programmed capacity of the battery. Once the battery capacity is programmed, it is not necessary to reconfigure again

Table 3. **J7 jumper setting**

Jumper	Description
1-2	Set for normal operation once the capacity is entered
2-3	Enter the battery capacity
Open	Not allowed

Figure 6. **Setting of jumpers after power-on**

Fit the jumper

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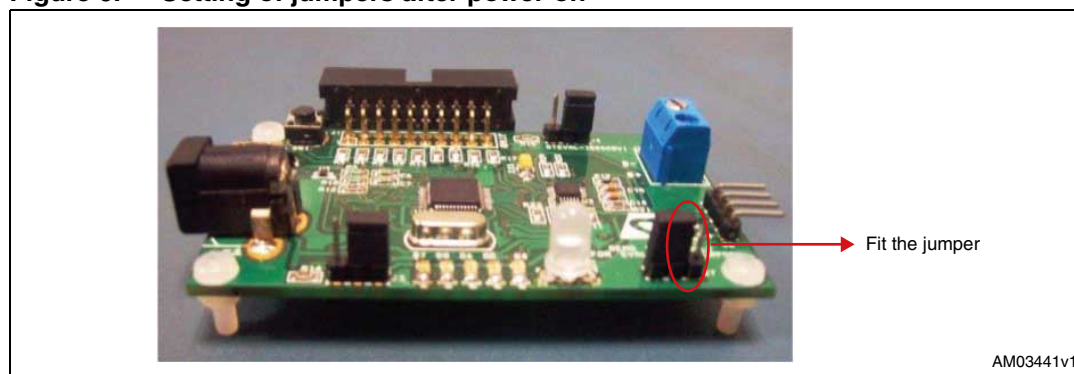
## 3.3 Battery charging and discharging in the case of the STw4102

The board supports the onboard J4 jumper to select the charging and discharging mode of battery. By default the board supports charging mode.

Table 4. **J4 jumper setting**

Jumper	Description
1-2	Set the jumper for discharging mode
2-3	Set the jumper for charging mode
Open	Charging mode, by default

Figure 7. Battery charging using the STw4102
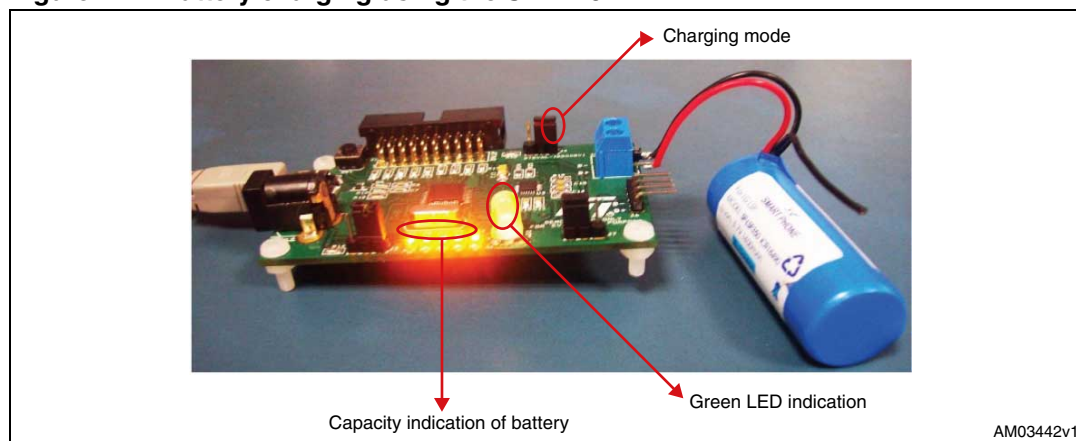
The board is programmed to support a charging voltage of 4.2 V. When the battery voltage approaches the programmable charge voltage (4.20 V), the charger enters into a constant voltage charging mode and the charging current decreases. When the current level reaches the end-of-charge level the battery is almost fully charged, and the charger enters maintenance mode.

The gas gauge system monitors the battery charging and discharging. The demonstration board has 5 LEDs which are used to show the present status of the battery charge with respect to the mAH rating of the battery which was programmed by the user. as shown in *Table 5*.

To discharge the battery connect the jumper between pin 1 and 2 of J4. Connect the load to the J6 connector, as shown in *Figure 7*.

Table 5. Battery capacity shown through level-LEDs D4 to D8

LEDs	Charging		Discharging	
	Status	Rcap %	Status	Rcap %
D7	ON	100 %	OFF	<80 %
D8	ON	>80 %	OFF	<60 %
D6	ON	>60 %	OFF	<40 %
D5	ON	>40 %	OFF	<20 %
D4	ON	>20 %	OFF	<10 %

In the case of charging when the Rcap % exceeds any level (as defined in *Table 5*), the corresponding LEDs turn on and the other LEDs (above that level) keep on toggling. For discharging when capacity drops to a certain level the corresponding LED turns off and the other LEDs (below that level) keeps on toggling.

Figure 8. Discharging the battery
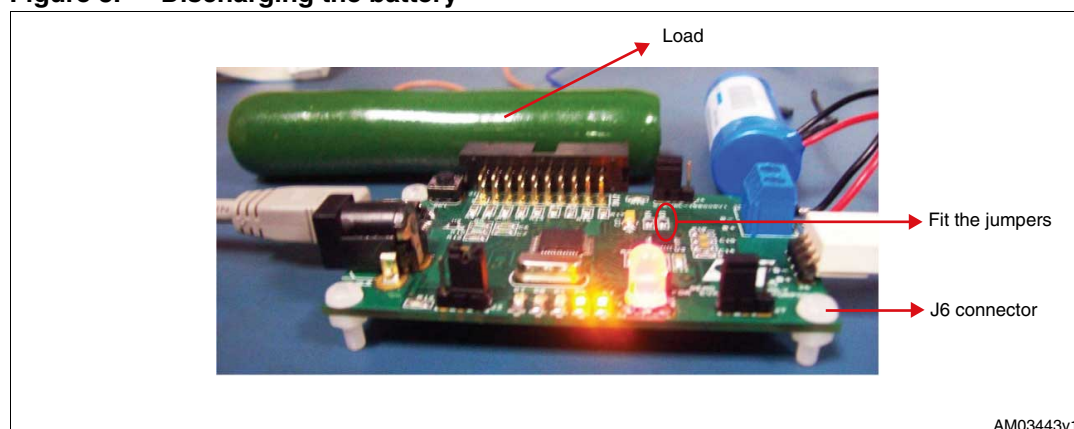
Connect the load to the load terminals of the board, referring to *Table 6*. There is a MOSFET which acts as a switch between load and battery. When the J4 jumper fits on pin 1 and 2 of J4 the MOSFET is turned on by the microcontroller by reading the state of the jumper. The battery starts to supply power to the load. When the battery voltage falls below the programmed critical voltage, the discharging is stopped by the microcontroller. In the demonstration board critical battery voltage is programmed to 3.1 V. When the battery voltage falls below this voltage LED D2 turns on in red.
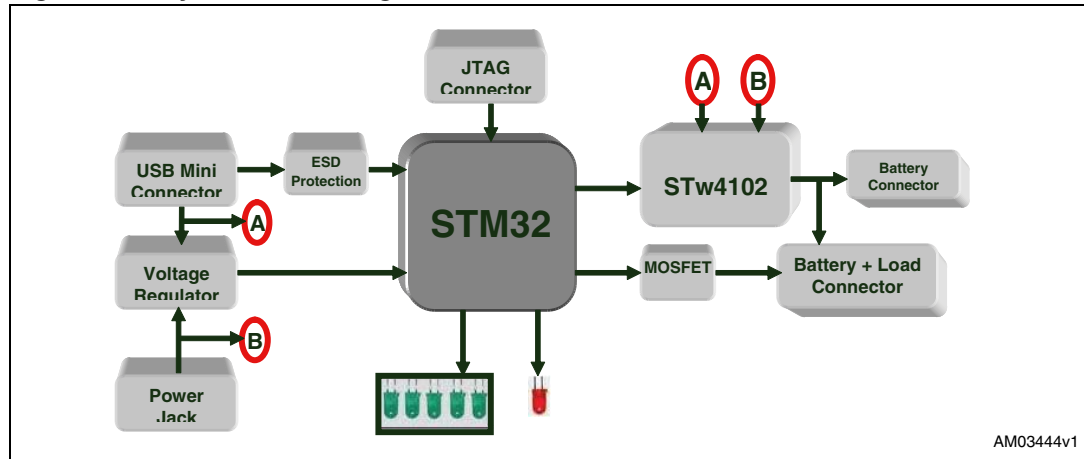
Table 6. J6 pin description

Pin number	Jumper	Description
1	B+	Battery positive terminal
2	B-	Battery negative terminal
3	Load+	Load positive terminal
4	Gnd	Ground

4 Hardware design description

The hardware block diagram is shown in *Figure 9*.

Figure 9.   System block diagram

4.1   Microcontroller (STM32)

The STM32 microcontroller is a 32-bit MCU based on the popular ARM 32-bit Cortex™-M3 CPU, running at 72 MHz with a performance of 90 DMIPS with 1.25 DMIPS/MHz. The microcontroller has single-cycle multiplication and hardware division. The device supports low-power modes like sleep, stop, and also standby. The microcontroller has up to 9 communication interfaces which include two I^2Cs (400 kHz), three USARTs (4.5 Mbps), two SPIs (18 MHz), CAN 2.0B Active interface, and USB 2.0 (12 Mbps) full-speed interface. For more details refer to the STM32 datasheet; *32-bit ARM Cortex MCU,* and reference manual at http://www.st.com.

For this application a minimum of one I^2C to interface with the STw4102 is needed, USB to support the USB-based charger and some general purpose IOs for user interface. The part numbers used to develop this application are shown in *Table 7*.

Table 7.   Microcontroller details

Feature	Description
Sales type	STM32F103C6T6A
Package	LQFP-48 (7 x 7) mm
Flash - Kbytes	32
SRAM - Kbytes	10
Operating voltage	2.0 to 3.6 V

4.2 Battery charger (STw4102)

The STw4102 is a standalone constant-current, constant-voltage (CCCV) linear charger dedicated to Li-Ion batteries. The device has a dual-charging capability which uses the main input adaptor (wall or car adapter) or a USB cable. The STw4102 contains an accurate gas gauge based on a 13-bit AD converter and battery voltage monitor with a 7- to 12-bit AD converter. For more details refer to the STw4102 datasheet; *Dual USB/wall adapter Li-ion battery charger with gas gauge*, at http://www.st.com.

Table 8. STw4102 details

Feature	Description
Order code	STW4102IQT
Package	QFN24
Operating voltage VUSB	4.25 to 5.5 V
Operating voltage VMAIN	4.25 to 16 V

4.3 ESD protection device

USBLC6-2P6 is a monolithic application specific device, dedicated to ESD protection of high speed interfaces, such as USB 2.0, Ethernet links and video lines. For more details please refer to the USBLC6-2P6 datasheet; *Very low capacitance ESD protection*, at http://www.st.com.

Table 9. USBLC6 details

Feature	Description
Order code	USBLC6-2P6
Package	SOT23-6L

4.4 Voltage regulator

The LD2985A/Bxx is a 150 mA fixed-output voltage regulator. The ultra-low drop voltage and the low quiescent current make them particularly suitable for low noise, low-power applications, and in battery powered systems. For more details please refer to the LD2985A/Bxx datasheet; *Very low drop and low noise voltage regulator low ESR capacitor compatible with inhibit function*, at http://www.st.com.

The STw4102 device needs 3 V input for one of the input pins for proper operation. As the STM32 device supports a voltage range from 2.6 to 5 V, 3 V was chosen for the design.

Table 10. Voltage regulator

Feature	Description
Sales type	LD2985BM30R
Package	SOT23-5L

4.5 Power MOSFET

The MOSFET is used to connect the load to battery. During the discharging process the microcontroller turns on the MOSFET so as to consume power from the battery. For more details please refer to the STT3PF30L datasheet; *P-Channel 30V 0.14 Ω - 3A SOT23-6L STripFET™ II Power MOSFET,* at http://www.st.com.

Table 11.   MOSFET

Feature	Description
Sales type	STT5PF20V
Package	SOT23-6L

5 Firmware architecture description

Figure 10. Firmware flow chart
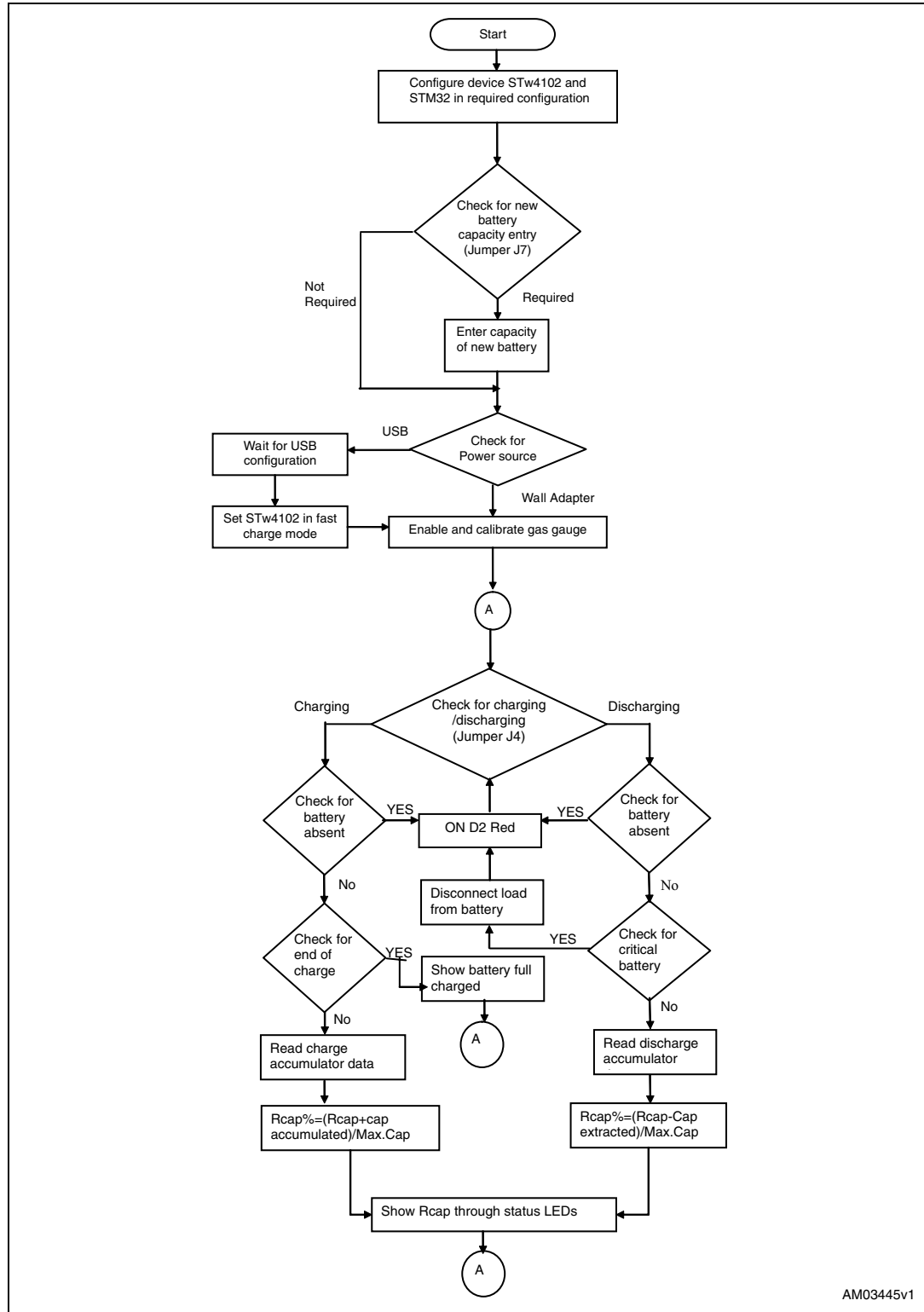
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6 Connectors and jumpers

6.1 JTAG connector

Figure 11. JTAG connector

Debug-JTAG port
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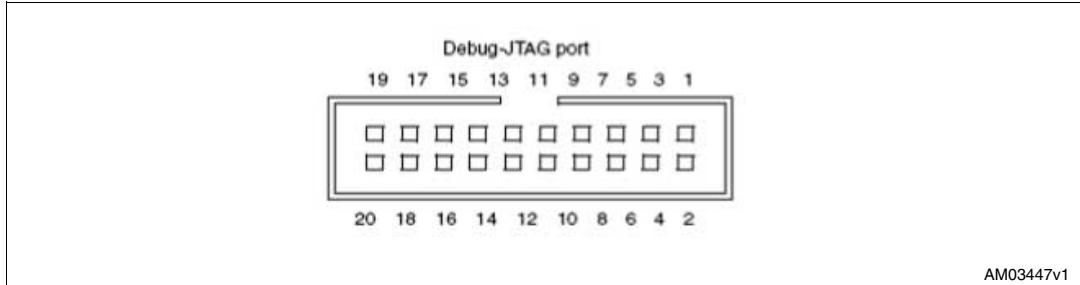
Table 12. JTAG pin description

Pin number	Description	Pin number	Description
1	3.3 V power	2	3.3 V power
3	TRST	4	GND
5	TDI	6	GND
7	TMS	8	GND
9	TCK	10	GND
11	RTCK	12	GND
13	TDO	14	GND
15	nSRST	16	GND
17	DBGRQ	18	GND
19	DBGACK	20	GND

The JTAG connector is available onboard for re-programming the microcontroller and debugging.

6.2 USB connector

The standard USB mini-B type (5-pin) connector is used. An additional 4 connections (pins 6-9 in the schematics) are connected to the body of the connector. Confirm that these pins (shell/shield) are connected to the ground through an RC circuit. The maximum current drawn by the board from the USB host/hub is less than 500 mA in any condition, to respect the USB specifications.

Figure 12. Mini-B USB connector

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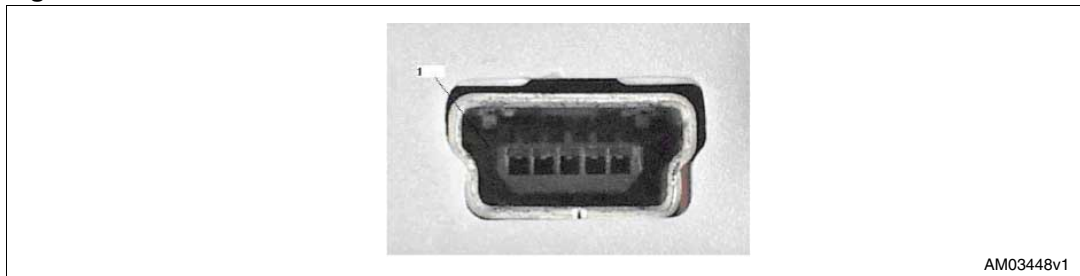
Table 13. USB connector pin description

Pin number	Description	Pin number	Description
1	VBUS(Power): +5 V supply from USB bus	6	SHIELD
2	DM: USB D- signal	7	SHIELD
3	DP: USB D+ signal	8	SHIELD
4	--	9	SHIELD
5	GND: ground signal		

6.3 Power supply connector

The adaptor connector is available for connecting an external voltage source. An adaptor of 5 V DC can be used.

Figure 13. Power supply connector

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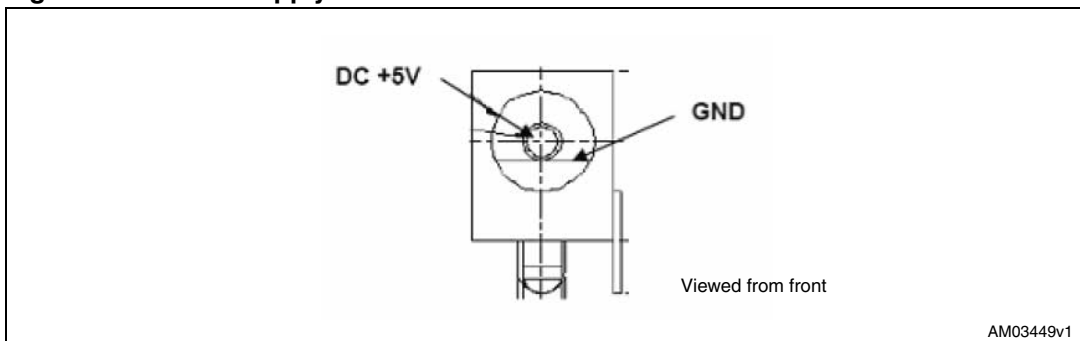
7 Hardware schematic

Figure 14, *15* and *16* shows the schematic diagrams for the board.

Figure 14. Microcontroller section schematic
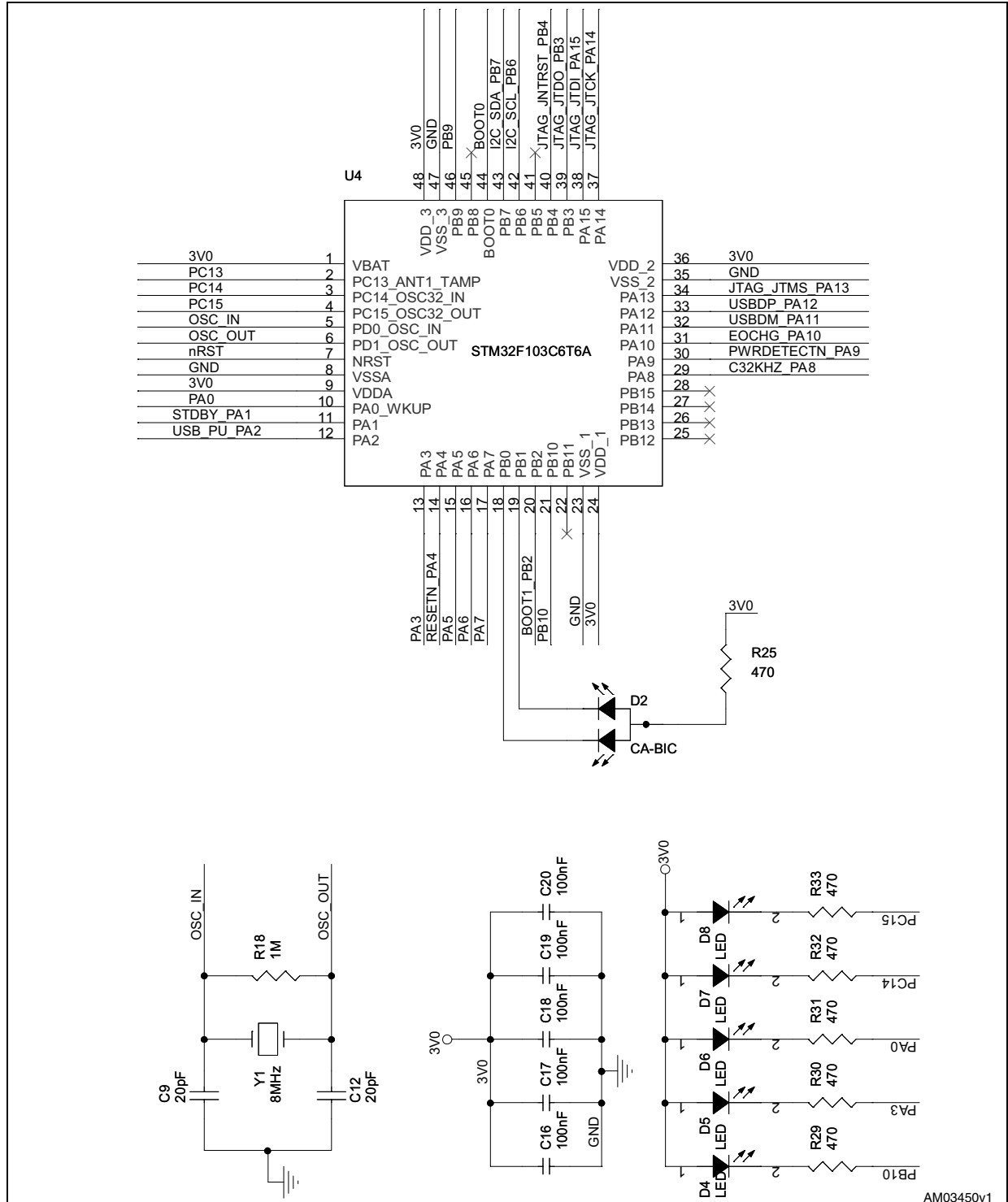
Figure 15.   STw4102 battery charger, MOSFET_STT5PF20V, wall adaptor and anti tamper circuit schematics

STW4102 BATTERY CHARGER

MOSFET_STT5PF20V

Anti tamper circuit

Wall adaptor

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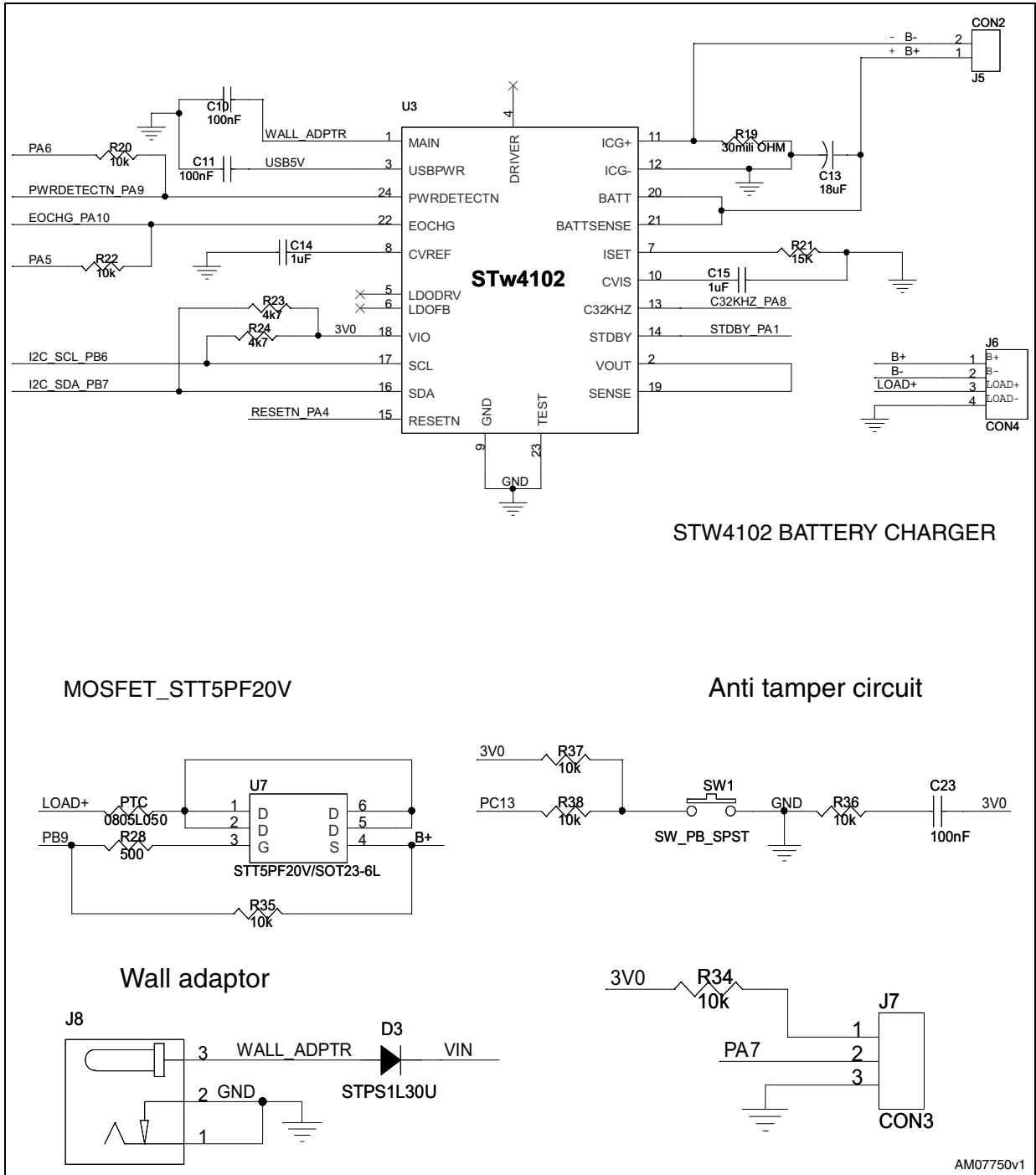
Figure 16. Boot jumpers, JTAG connector, power supply and USB schematics
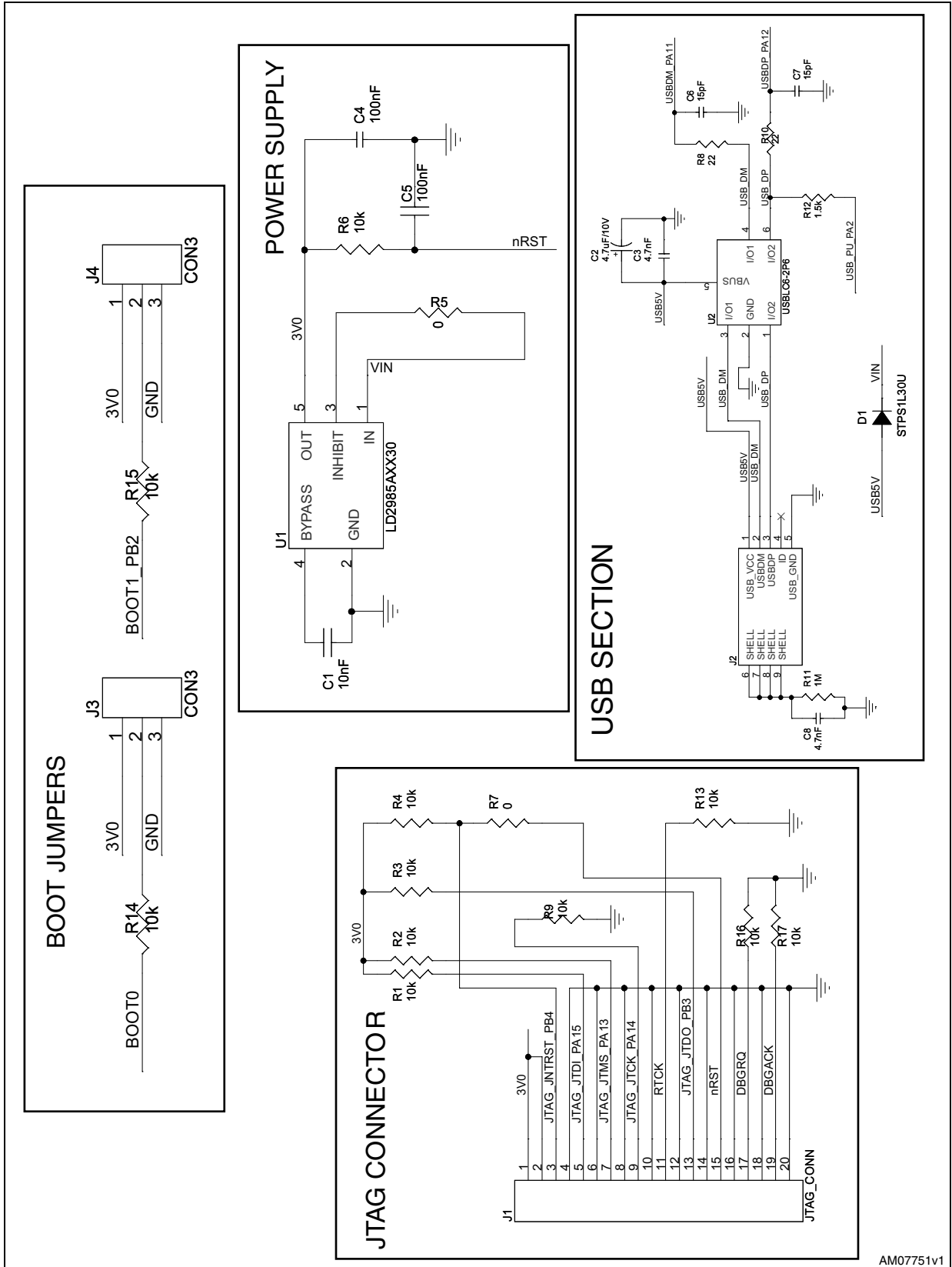
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7.1 Bill of materials

Table 14.   BOM

Category	Ref. des.	Comp. descr.	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
ST devices	U1	Voltage regulator IC LD2985BM30R	SOT23-5L	STMicroelectronics	LD2985BM30R		
	U2	ESD protection device USBLC6-2P6	SOT23-6L	STMicroelectronics	USBLC6-2P6		
	U3	Dual USB/wall adapter Li-ion battery charger with gas gauge STw4102	QFN24	STMicroelectronics	STW4102IQT		
	U4	Microcontroller STM32 Family, ARM-based 32-bit MCU	LQFP48	STMicroelectronics	STM32F103C6T6A		
	U7	P-Channel, power MOSFET STT5PF20V	SOT23-6L	STMicroelectronics	STT5PF20V		
	D1,D3	Low-drop power Schottky rectifier STPS1L30U	SMA	STMicroelectronics	STPS1L30U		
Crystal and oscillator	Y1	Quartz crystal 8 MHz	11.35 mm x 4.35 mm, SS4	Jauch	Q 8.0-SS4-30-30/30		

Table 14. **BOM** (continued)

Category	Ref. des.	Comp. descr.	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Connectors and jumpers	J1	JTAG connector	Box Header, Straight 20way, 2x10pin, 2.54 mm x 2.54 mm pitch	MULTICOMP	MC9A12-2034	Farnell	Part# 1099258
	J2	Mini USB connector	SMD USB Mini-B type connector	KYCON	KMBX-SMT-5S-S-30TR		1
	J3,J4,J7	3-pin jumper	Jumper 3 pin, 1x3way, 2.54 mm pitch	SAMTEC	TSW-103-23-G-S		
	J5	Terminal block	2-pin terminal block, screw termination 5.08 mm pitch	PHOENIX CONTACT	Part# 1711725	Farnell	Part# 3041165
	J6	Rechargeable battery connector	Header 4 pin, 1x4way, right angle, 2.54 mm pitch	Any			
	J8	Power jack 2.5 mm	Socket, DC power, 2.5 mm	CLIFF electronic components	DC10B	Farnell	Part# 224960
LEDs	D4,D5,D6,D7, D8	SMD1206	OSRAM	LGN971	Farnell	Part# 1226371	5
	D2	Dual color LED, common anode	Through hole	Any			

Table 14.   BOM (continued)

Category	Ref. des.	Comp. descr.	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Capacitors	C6,C7	15 pF	SMD0805	Any			
	C9,C12	20 pF	SMD0805	Any			
	C3,C8	4.7 nF	SMD0805	Any			
	C1	10 nF	SMD0805	Any			
	C4,C5,C10, C11,C14, C15,C16,C17, C18,C19,C20, C23	100 nF	SMD0805	Any			
	C2	4.7 µF/10 V tantalum/electrolytic	EIA 3216-18/ size A	Any			
	C13	18 µF	EIA 3528-21/ size B	Any			

Table 14.   BOM (continued)

Category	Ref. des.	Comp. descr.	Package	Manufacturer	Manufacturer's ordering code / orderable part number or equivalent	Supplier	Supplier ordering code
Resistors	R1,R2,R3,R4, R6,R9,R13, R14,R15,R16, R17,R20,R22, R34,R36,R37, R38	10 kΩ	SMD0805	Any			
	R5,R7	0	SMD0805	Any			
	R8,R10	22 Ω	SMD0805	Any			
	R11,R18	1 kΩ	SMD0805	Any			
	R12	1.5 kΩ	SMD0805	Any			
	R19	RESISTOR, METAL STRIP, 0.03 Ω 1 % 0.12 5 W	SMD0805		WSL-0805 .03 1 % EB E3	Farnell	Part# 1107335
	R21	15 kΩ	SMD0805	Any			
	R23,R24	4.7 kΩ	SMD0805	Any			
	R25,R29,R30, R31,R32,R33	470 Ω	SMD0805	Any			
	R28	500 Ω	SMD0805	Any			
	PTC	500 mA rating	SMD0805	Any			
Misc	SW1	Pushbutton switch	(6 mm X 6 mm) pushbutton, through hole	Tyco Electronics	FSM2JH	Farnell	Part# 1555981

Note: PTC not mounted onboard, replaced by a short

The term "equivalent" has been used where the exact part number from the mentioned vendor may not have been used.

8 References

1. STw4102 datasheet
2. STM32 datasheet; *32-bit ARM Cortex MCU*

9 Revision history

Table 15. Document revision history

Date	Revision	Changes
27-Jul-2010	1	Initial release.

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