UM0874
User manual

Graphical display panel demonstration board based on the STM32F103VE

Introduction

The STM32-based graphical display panel is a device that displays images one by one as in a slideshow. The core of this demonstration board is the STM32 microcontroller which is able to read the memory card of the photographs and display them on the screen. The memory used to store the JPEG images is a micro-SD card. The MEMS is used for picture orientation. The growing popularity and use of digital cameras and cell phones with high-pixel cameras allow users to view digital photos in storage media without printing. Digital photo frames are the perfect example of enjoying these digital images. The functionality of displaying images with the STM32 shows the capability of this microcontroller in multimedia applications. The STM32 has additional features like displaying room temperature, date and time. An S-Touch™ based keypad for user interface is also on the board. Other features include USB mass storage, ZigBee®, and a rechargeable battery system. This board can be used either as a standalone solution or combined with an application (i.e. POS, card readers, security panels, USB speakers, high-end remote controllers).

Figure 1. STM32-based graphical display panel

This document explains the implementation of a digital photo frame using the STM32, an ARM Cortex-M3 based microcontroller, and explains the different parts of the application. The demonstration board is the STEVAL-CCM001V2.

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1 Features

The key features of the board are:

- STM32 high-density (64 KB RAM, 512 KB flash) microcontroller
- 320 x 240 pixel resolution parallel-interfaced TFT display using the FSMC peripheral for faster display
- Bluetooth® module footprint
- S-Touch™ based keypad for user interface
- ZigBee® for picture transfer
- STM32-based RTC available to display the date/time and calendar
- MEMS used to rotate the image as per the TFT alignment
- Micro-SD card interfaced through SDIO
- USB mini-B connector
- Uses the mass storage for connectivity to PC. User will be able to copy data directly using USB, hence the card reader functionality
- User-programmable time interval for pictures
- Temperature sensor senses temp. and is displayed on the TFT
- Onboard power supply for DPF
- Rechargeable battery circuit available
- Onboard JTAG connector for firmware upgrades and changes
- Additional ESD-protection device for USB and SD card

2 Definitions of acronyms

Table 1. Definitions of acronyms

Acronym	Definition	Comment
DPF	Digital photo frame	
JPEG	Joint photographic experts group	Compressed format of a digital image
BMP	Bitmap	Decompressed format of a digital image
MCU	Microcontroller unit	
IDCT	Inverse discrete cosine transform	
MMC/SD	Multimedia card / secured drive	
MPEG	Moving picture experts group	
FAT	File allocation table	
TFT	Thin film transistor	
LCD	Liquid crystal display	
SPI	Serial peripheral interface	
I^2C	Inter integrated circuit	
MEMS	Micro-electro-mechanical system	Motion sensor, accelerometer
USB	Universal serial bus	
LCD	Liquid crystal display	
JTAG	Joint test action group	
BMP	Bitmap picture	
RGB	Red green blue	Raw data of a color image
ESD	Electrostatic discharge	

3 Getting started

3.1 Package

The STM32-based graphical display panel demonstration board includes the following items:

- Hardware content
  - Demonstration board
- Documentation
  - User manual (this document)
  - Schematics, Gerber files, BOM
- Firmware
  - Already programmed, the STM32 device is soldered on the demonstration board
  - Object files are also available for the firmware

3.2 Setting up the board

The STM32-based graphical display panel demonstration board can be set up as follows:

1. Copy some JPEG images to the micro-SD card
2. Connect the micro-SD card to the demonstration board
3. Check that the board is powered by a 5 V adaptor with a mini-USB connector or via a mini-USB cable or through the batteries. Turn-on the power using the slide switch
4. The board can be put in mass storage mode by connecting a USB mini-B cable. For this, first connect a mini-B cable. Then switch on the SW1 to start charging the battery.

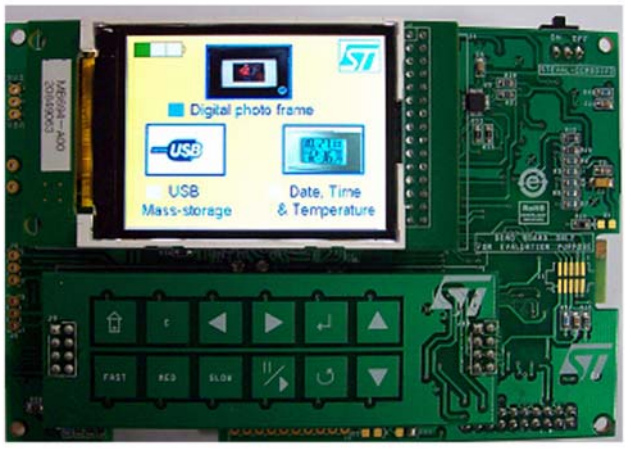
Figure 2. USB mass storage screen on the TFT display

5. To run the demonstration in DPF mode, first switch off the system, then remove the mini-B cable. Switch on the system again by sliding the SW1 SPDT switch. The home page will pop up on the TFT display. Please make sure that the Li-Ion battery is connected at BT2 terminals with the correct polarity. If the user does not have the batteries, a 3.3 V voltage power supply can be connected.
6. Three icons appear on the home page ("Digital Photo Frame", "USB Mass-storage" and "Date, Time & Temperature").

Figure 3. Home page on the TFT display

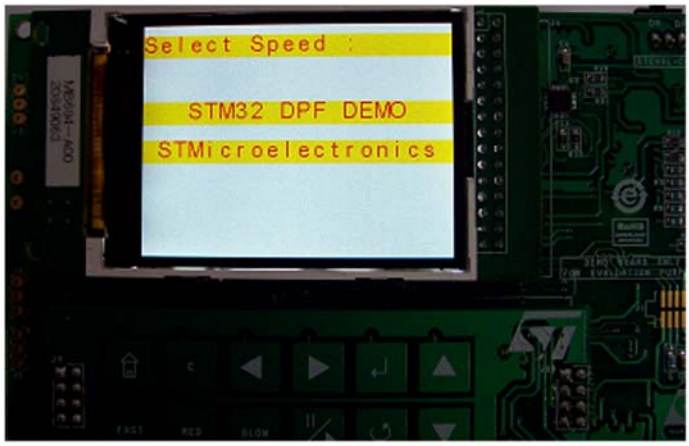
7. Any of the above-mentioned icons can be highlighted by pressing the left or right key on the S-Touch™ daughterboard

Figure 4. Home page with DPF icon selected on the TFT display



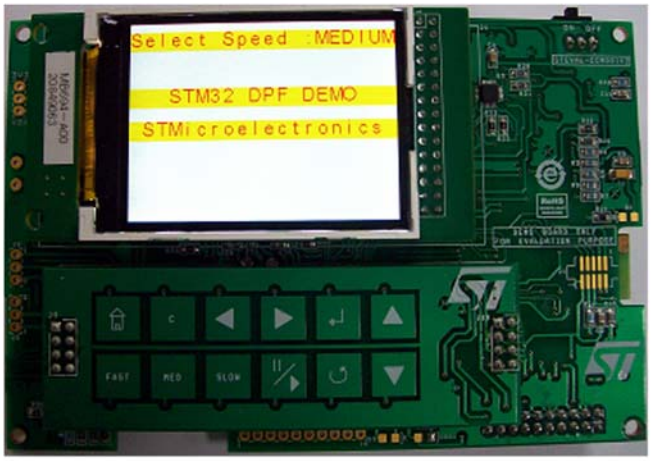
8. Once an icon is highlighted, it can be selected by pressing the “Enter” key once
9. If "Digital Photo Frame" is selected, the following screen will appear. Select the speed by pressing one of the three keys "FAST", "MED" or "SLOW".

Figure 5. Start of DPF demonstration on the TFT display



10. After selecting one of the speeds, the image slideshow starts

Figure 6. Start of DPF demonstration with medium speed on the TFT display

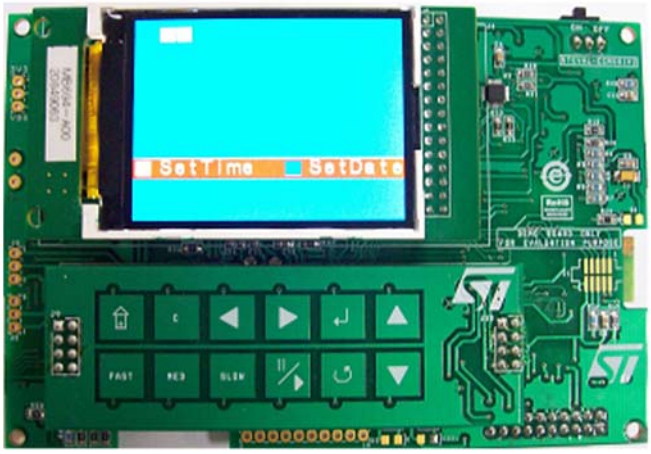


11. During the slideshow, the speed can be changed.

Figure 7. Change of speed during DPF demonstration on the TFT display

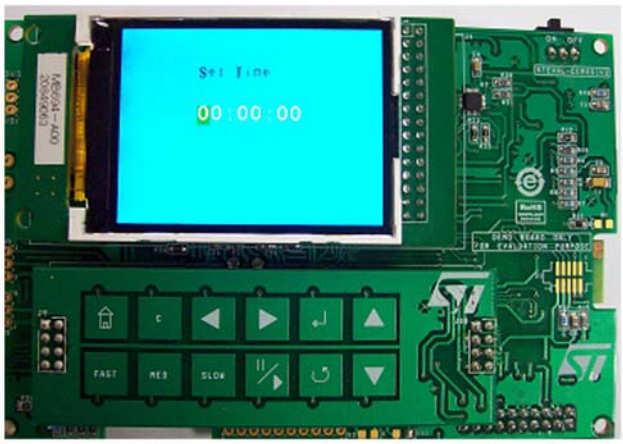
12. The slideshow can be paused by pressing the “Play n Pause” key. To resume, press the same key
13. During the slideshow, the user can rotate the board to see the MEMS functionality. The image will appear according to the frame alignment
14. To set the time and date, press the "C" calendar key. The following window will pop up. Select one of the options "Set Time" or "Set Date"

Figure 8. Set date and time screen on the TFT display



15. If "Set Time" is selected, the following window will pop up. The right and left keys help the user to move the cursor. Time digits can be entered using the up and down keys
16. Once the time values are entered, press the "Enter" key to store the values
17. Similarly, the date can be set through the "Set Date" menu

Figure 9. Set time screen on the TFT display



If the user is going to use a brand new micro-SD card and an unprogrammed board, follow these steps before inserting it into the demonstration board:

1. Format the micro-SD card through Windows Explorer using a card reader or the demonstration board in mass storage mode
2. Copy any JPEG images to the micro-SD card
3. Insert the card into the micro-SD slot on the board
4. Program the demonstration board using the suitable tool for example, using J-Link and IAR work bench, or JFlash
5. Remove the JTAG flex cable from the demonstration board
6. Follow the steps mentioned above for setting up the demonstration

Figure 10. HomePageMenu. jpg

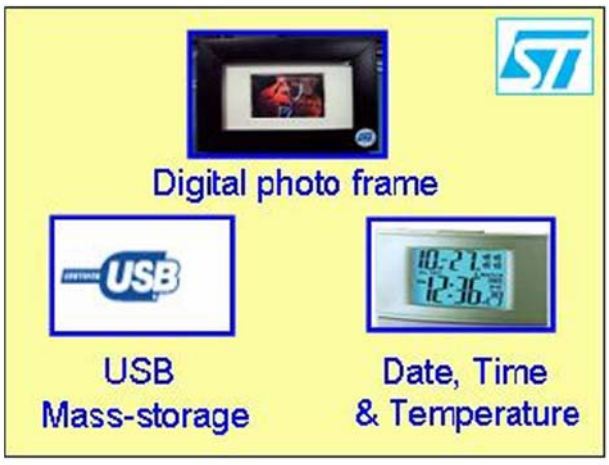
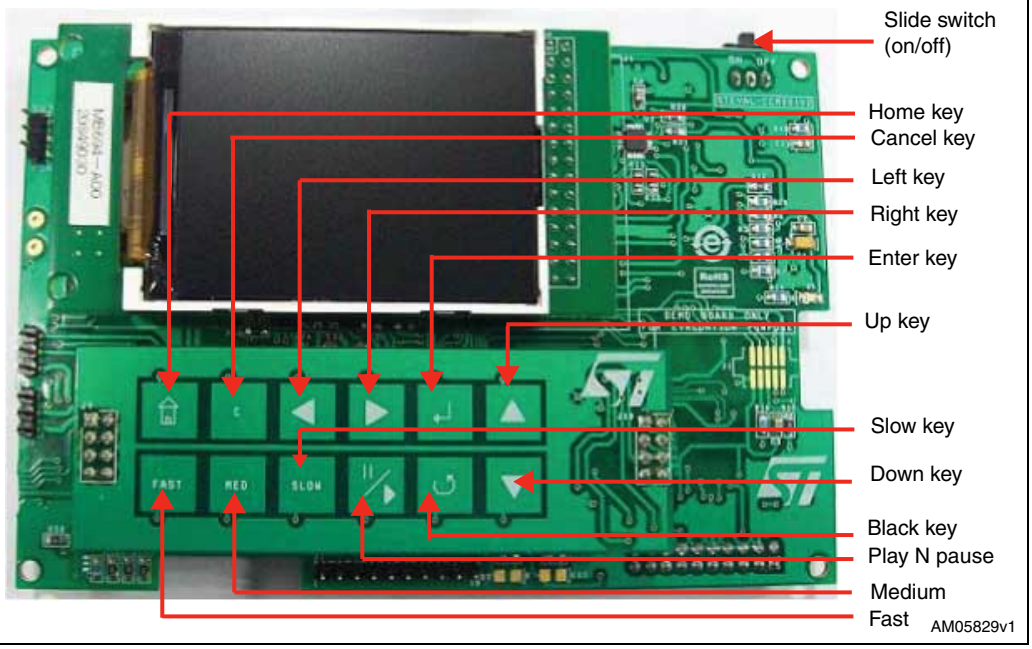


Figure 11. STM32-based graphical panel display with touch keys' notation



3.3 Hardware layout

The STM32-based graphical panel display board is built using STMicroelectronics' ARM® Cortex-M3 core-based STM32F103VE in a 100-pin LQFP100 package. The ST components used in this board are listed below. *Figure 14* and *15* show the component layout to help the user to locate different components / sections on the board.

Table 2. ST component list

ST component	Part no.
Microcontroller	STM32F103VET6
ESD protection for SD	EMIF06-MSD02N16
ESD protection for USB	USBLC6-2P6
Voltage regulator	LD1117D33TR
Battery interface	L6920D
Battery charger	STW4102IQT
Power MOSFET	STT5PF20V
Power Schottky rectifier	STPS3L60U
MEMS	LIS331DLH
Temp. sensor	STLM75
S-Touch™	STMPE1208SQTR

Figure 12. Demonstration board: top side

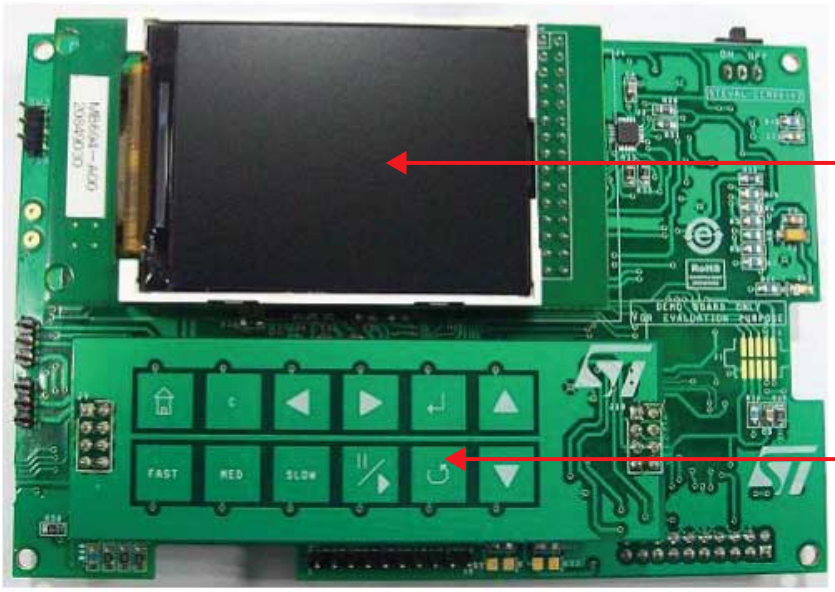


Figure 13. Demonstration board: bottom side

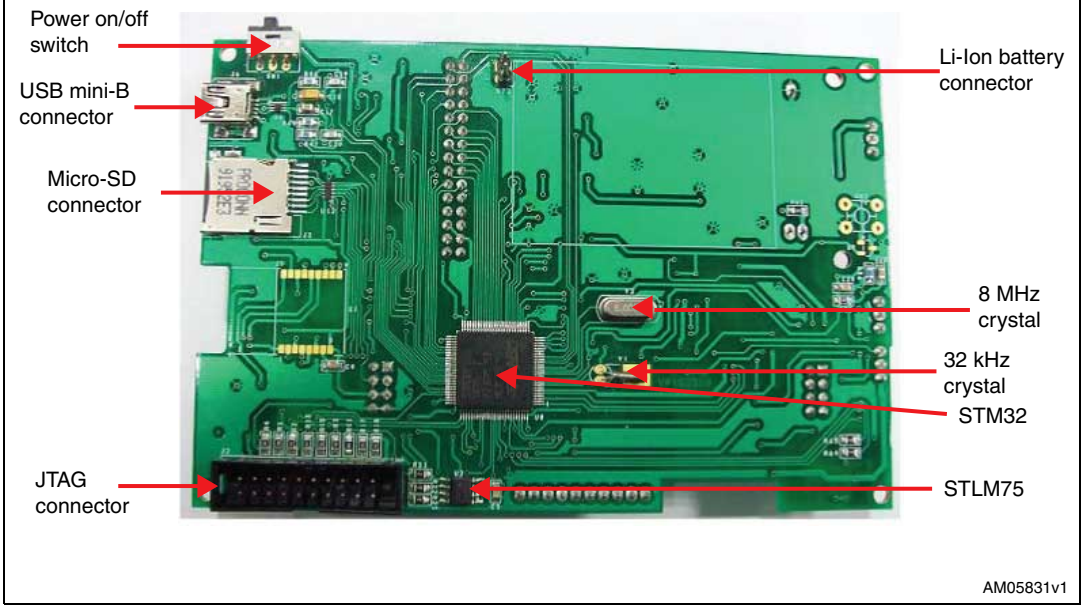


Figure 14. Hardware layout: top side

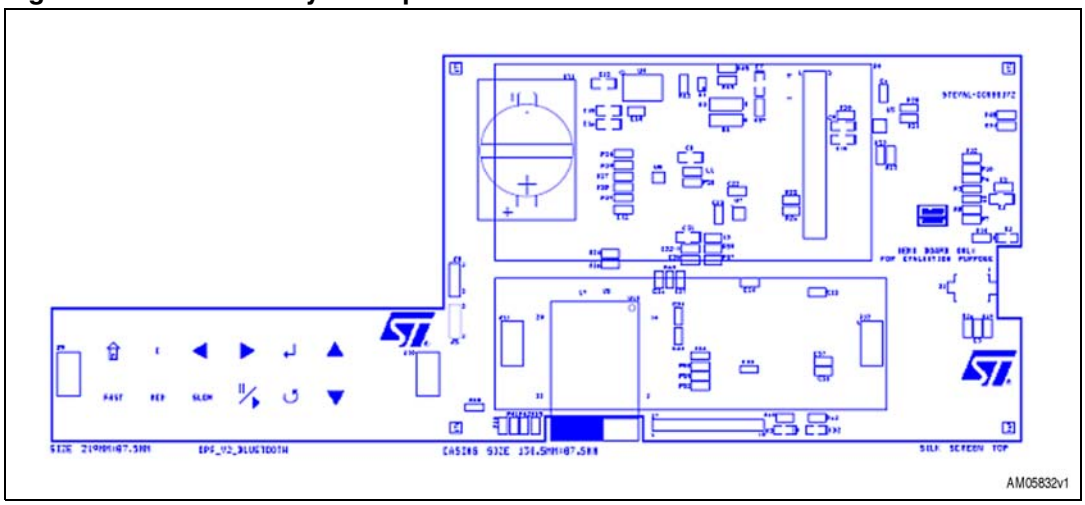
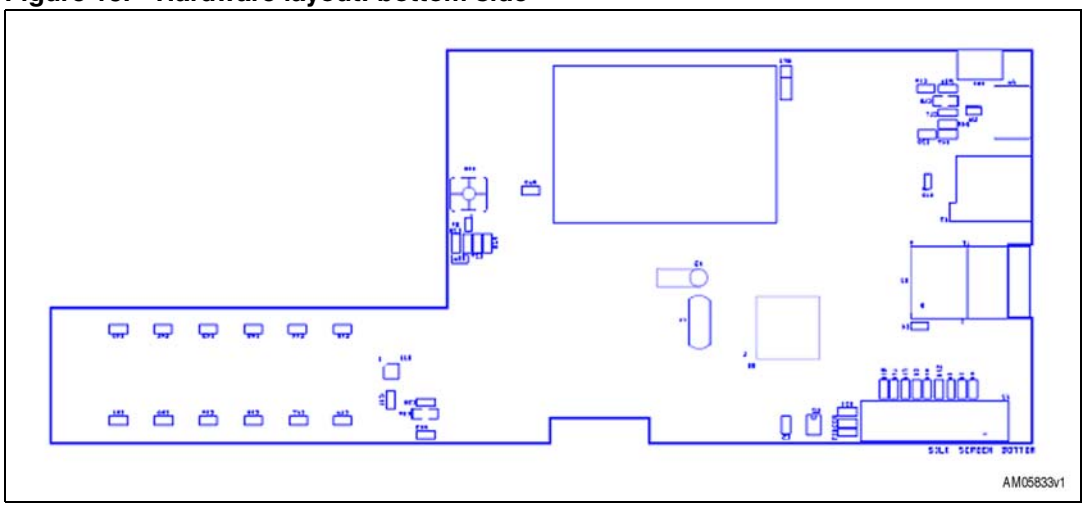


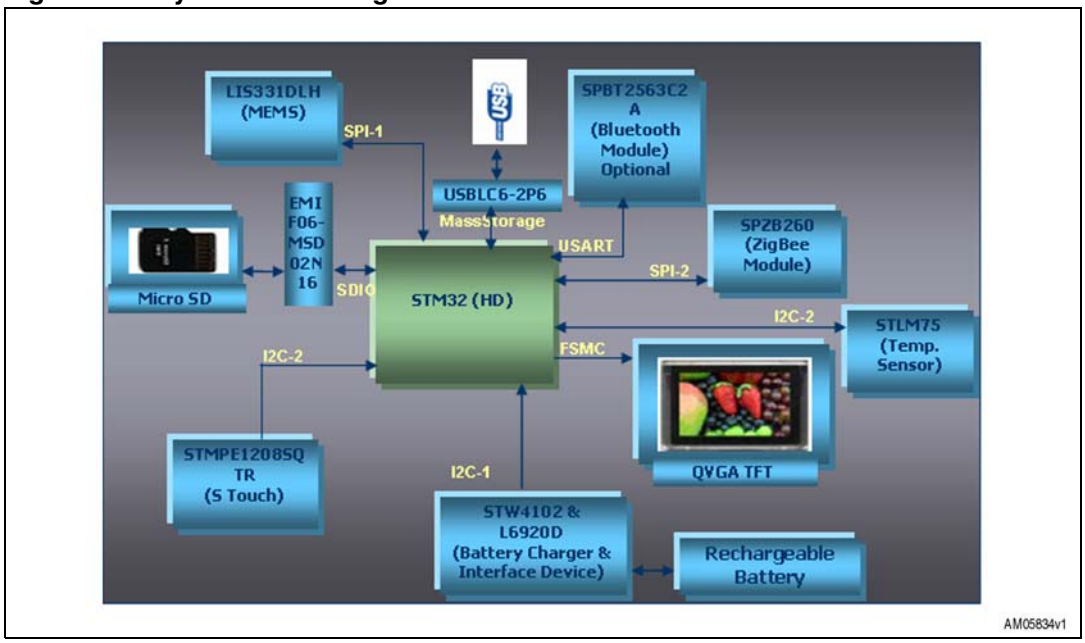
Figure 15. Hardware layout: bottom side



4 System overview

4.1 Hardware design description

Figure 16. System block diagram



The hardware block diagram is given in *Figure 16*. As shown, the STM32 microcontroller is the main controller of the system.

4.1.1 Microcontroller (STM32)

The STM32 is a 32-bit MCU based on the popular ARM 32-bit Cortex™-M3 CPU running at 72 MHz with performance of 90 DMIPS with 1.25 DMIPS/MHz. The memories embedded in it contain up to 20 Kbytes of SRAM and 128 Kbytes of flash memory. The microcontroller has single-cycle multiplication and hardware division. It has 80 fast general-purpose IOs to enhance the overall performance. The IOs are 5 V tolerant.

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, please refer to the STM32F103VE datasheet.

For the digital photo frame application, the firmware is using the two SPIs, two I^2Cs, SDIO, FSMC and USB interfaces. One of the SPIs is interfaced with MEMS and the other one with the ZigBee® module. The SD card is interfaced with SDIO and the TFT with FSMC. The STLM75 and STMPE1208SQTR use I^2C-2 and the STW4102 uses I^2C-1 to communicate with the controller.

The microcontroller works on a single voltage from 2 V to 3.6 V, unlike several microcontrollers requiring dual voltage. In this application the voltage bus is managed with 3.3 V.

4.1.2 Mini-USB type B connector

A mini-USB type B connector is available on the board for connecting the USB cable with the mini-B connector or a USB adaptor with mini-B connector. An ESD-protection device (USBLC6) is also mounted for protecting the USB bus.

Although the microcontroller has built-in protection of ESD up to 2 KV (human body model), It can be noted that the USBLC6 device provides additional protection of USB signals compliant to IEC61000-4-2 level 4: 15 kV (air discharge), 8 kV (contact discharge).

The USBLC6 device is recommended for additional protection.

4.1.3 LCD connector

A 30-pin LCD connector is available to connect the TFT module MB694. The LCD module is mounted on the board. It is interfaced through the embedded FSMC controller. It is a color TFT module with 2.4" diagonal length.

4.1.4 JTAG connector

A 20-pin JTAG connector is available on the board to program the microcontroller through JTAG and debug the firmware.

4.1.5 Micro-SD connector

The micro-SD connector is provided for the micro-SD card. It is interfaced with SDIO.

4.1.6 MEMS

MEMS (LIS331DLH) is available on the board and is used for the auto-rotation of the images (portrait or landscape) according to the frame alignment.

4.1.7 Temperature sensor

The temperature sensor, STLM75 mounted on the board, senses the room temperature and the measured temperature is displayed on the TFT.

4.1.8 S-Touch™ based keypad

The S-Touch™ keypad, based on the STMPE1208SQTR, is a user interface available on this demonstration board which helps to navigate through the menu. This keypad is a daughterboard having 12 keys. In *Figure 11* the touch keys are shown.

4.1.9 Bluetooth® module

The footprint for the Bluetooth® module SPBT2563C2A is available on the board. It's an optional feature which is not included in the present firmware package.

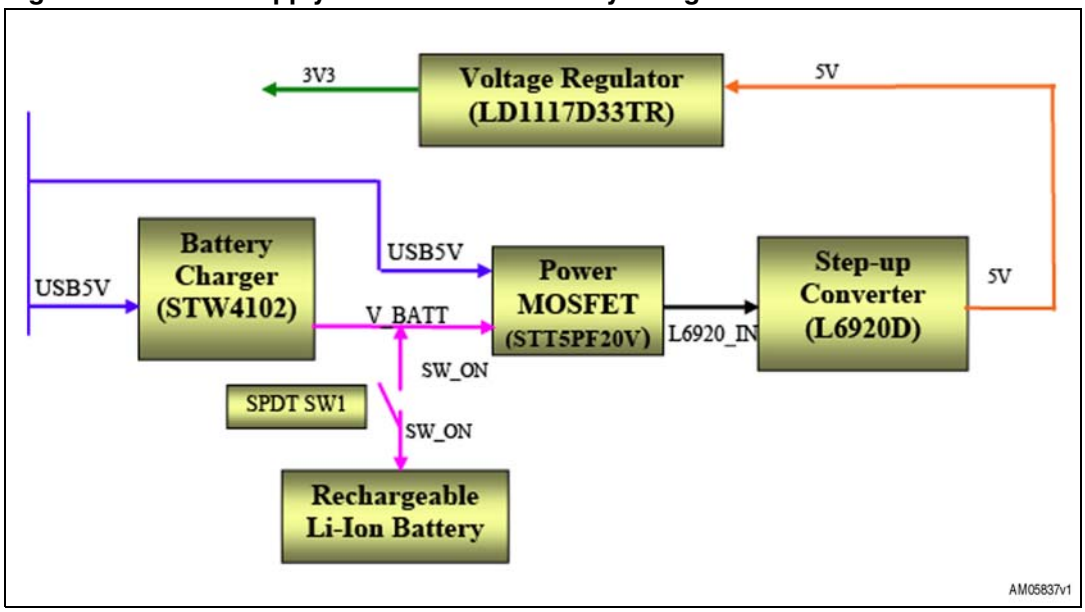
4.1.10 ZigBee® module

The ZigBee® module, SPZB260 footprint, is available on the board. This can be used by user to build their own applications by mounting the ZigBee® module.

4.1.11 Power supply unit

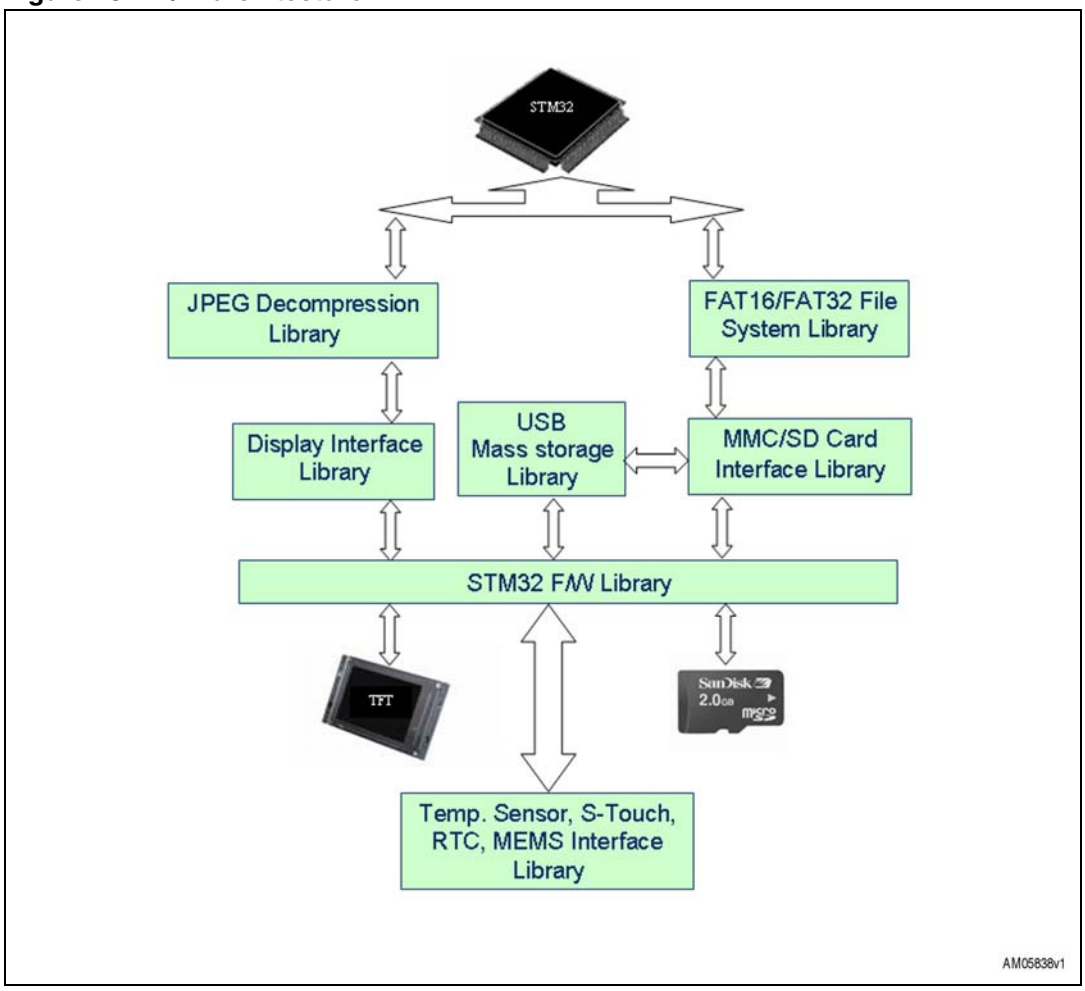
The onboard power supply unit contains components like the battery charger system (STW4102), step-up converter (L6920), voltage regulator (LD1117D33TR) and ESD-protection on the USB bus (USBLC6), Power MOSFET (STT5PF20V). See *Figure 17*.

Figure 17. Power supply unit with Li-Ion battery charger



4.2 Firmware architecture description

Figure 18. F/W architecture



4.2.1 Firmware library for STM32

The firmware library for the STM32 can directly be used for different peripherals of the STM32.

For this application, the firmware library for the STM32 is used for driving the different peripherals.

The firmware uses two SPIs, two I^2Cs, SDIO and FSMC for this application. One of the SPIs (SPI1) is interfaced with MEMS and the other one (SPI2) with the ZigBee® module. I^2C1 is with battery charger and I^2C2 with temperature sensor and S-Touch™. SDIO is the interface used for the micro-SD card. The TFT is connected to the controller through the FSMC interface. Refer to *Figure 16 on page 14* for a pictorial view of the different interfaces used in this application. The Systick timer is used to produce the required delay for the LCD-TFT library or slideshow.

The user can download the latest STM32 firmware library from http://www.st.com.

4.2.2 Display interface (TFT AM-240320L8TNQW00H) driver library

The TFT used is QVGA (320 x 240) resolution. It is diagonally 2.4" in size. The TFT has an amorphous, transmissive, normally white display format with 12 o'clock alignment. It adopts one backlight with 4 high brightness white LEDs.

It has real 262K color display and supports 5-6-5 and 6-6-6 RGB mode. We use the 5-6-5 RGB mode which means it takes 5, 6, 5 most significant bits for red, green and blue respectively to form one pixel of data. The TFT controller is ILI9320. The TFT internal RAM capacity is 172,800 bytes to display direct data. This TFT is to be used under conditions with a temperature range of 0 to 35 deg C and humidity under 60%.

This TFT is interfaced through FSMC, a parallel interface. The TFT driver firmware library writes the graphics file from the MMC/SD card to the TFT RAM in order to display it on the TFT screen.

The TFT driver firmware library also contains functions for displaying text lines, clearing TFT screen with a given color, setting the display window on the TFT, and setting the text color. These functions are used in this application.

This library is available with the 'STM3210E-EVAL demonstration firmware' available on www.st.com.

4.2.3 SD/MMC library

The SD/MMC cards are very common in mass storage media and are frequently used in many digital cameras and cell phones. SD cards are found in different forms. According to the dimensions, they are called SD, mini-SD, or micro-SD cards.

In this application we use micro-SD (SD/Micro-SD) cards for storing JPEG images.

The SD card can store images depending on their memory capacity. For instance, a 64 MB card can store up to 200 JPEG images of 2 megapixel (1600 x 1200) resolution.

The library for the SD/MMC has functionalities for read and write operations. Read/write commands are issued to the card for these operations. For this application, the firmware library for the SD/MMC card reads data in the card through the SDIO. The SDIO is a dedicated IP for the SD card.

This library is available in the demonstration firmware 'STM32F10xxx USB developer kit' mass storage example.

4.2.4 File system library

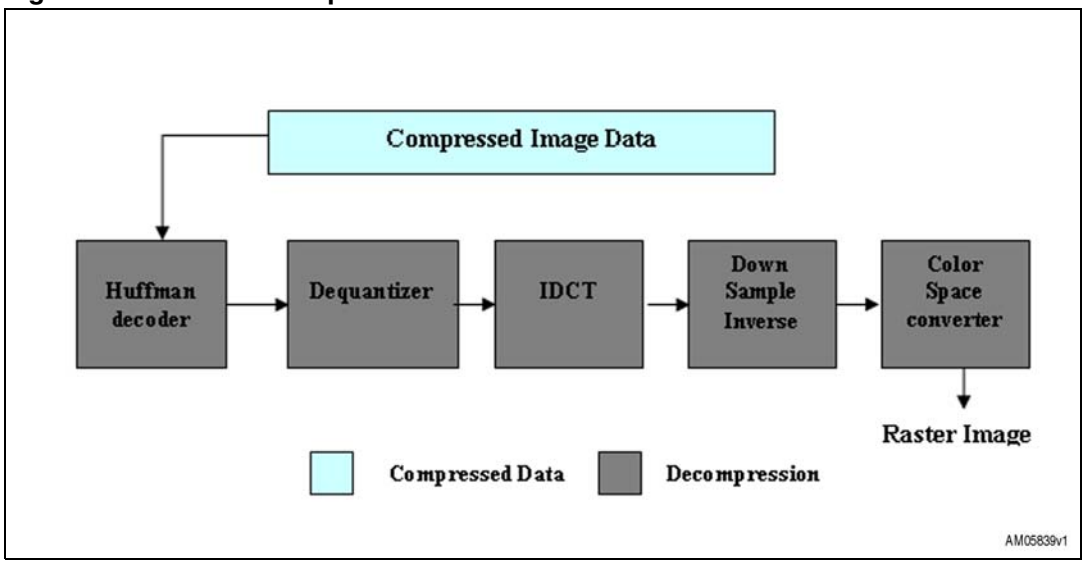
In order to implement the DPF, the firmware uses the file system library (FAT16/32) on the STM32. When copying the images from the computer to the micro-SD card, the operating system copies the files and stores them according to the FA16/FAT32 file system format. The file system running on the demonstration board reads the files from the memory card one by one and decompresses the JPEG images for display on the TFT.

There is freeware in the file system on the web and some are licensed versions available from companies.

4.2.5 JPEG decompression library

Most of the images taken by a digital camera are in JPEG format which is a compressed format of image data. To display this image on the TFT, it must be decompressed into RGB data. The decompressed format is called BMP format. BMP files are of different types depending upon the RGB format. Generally, the BMP images we see in our PCs are 24-bit BMP. In this case, one pixel contains 24 bits with 8 bits associated each with R, G and B, but the TFT used in this application supports 5-6-5 RGB format. The JPEG decompression library decompresses the JPEG, resizes the image to fit the TFT resolution and then converts them into 5-6-5 RGB format.

Figure 19. JPEG decompression



The JPEG decompression library first extracts the RGB data from the JPEG luminance and chrominance components namely Y, Cr and Cb using Huffman decoding and IDCT (Inverse Discrete Cosine Transform). Each pixel has now 3 bytes of data, 1 byte each for R, G and B. To convert this 24-bit (8-8-8) RGB format to 16-bit (5-6-5) RGB it is required to extract 5, 6 and 5 most significant bits of R, G and B respectively.

The TFT we are using is of QVGA (320 x 240) resolution. Hence after extracting RGB, the library downsamples the higher resolution image into 320 x 240 resolution to fit the TFT screen.

The JPEG decompression library using Huffman decoding and IDCT (Inverse Discrete Cosine Transform) decompresses a JPEG image of any resolution and converts it into a BMP image of 5-6-5 RGB format with 320 x 240 resolution.

4.2.6 Other libraries

The firmware also includes source code for the MEMS, temperature sensor, S-Touch™, RTC, and menu navigation. Refer to the f/w architecture block diagram in *Figure 18 on page 17*.

4.3 Hardware schematic

The following figures represent the schematic diagrams for the board.

Figure 20. Schematic: microcontroller section

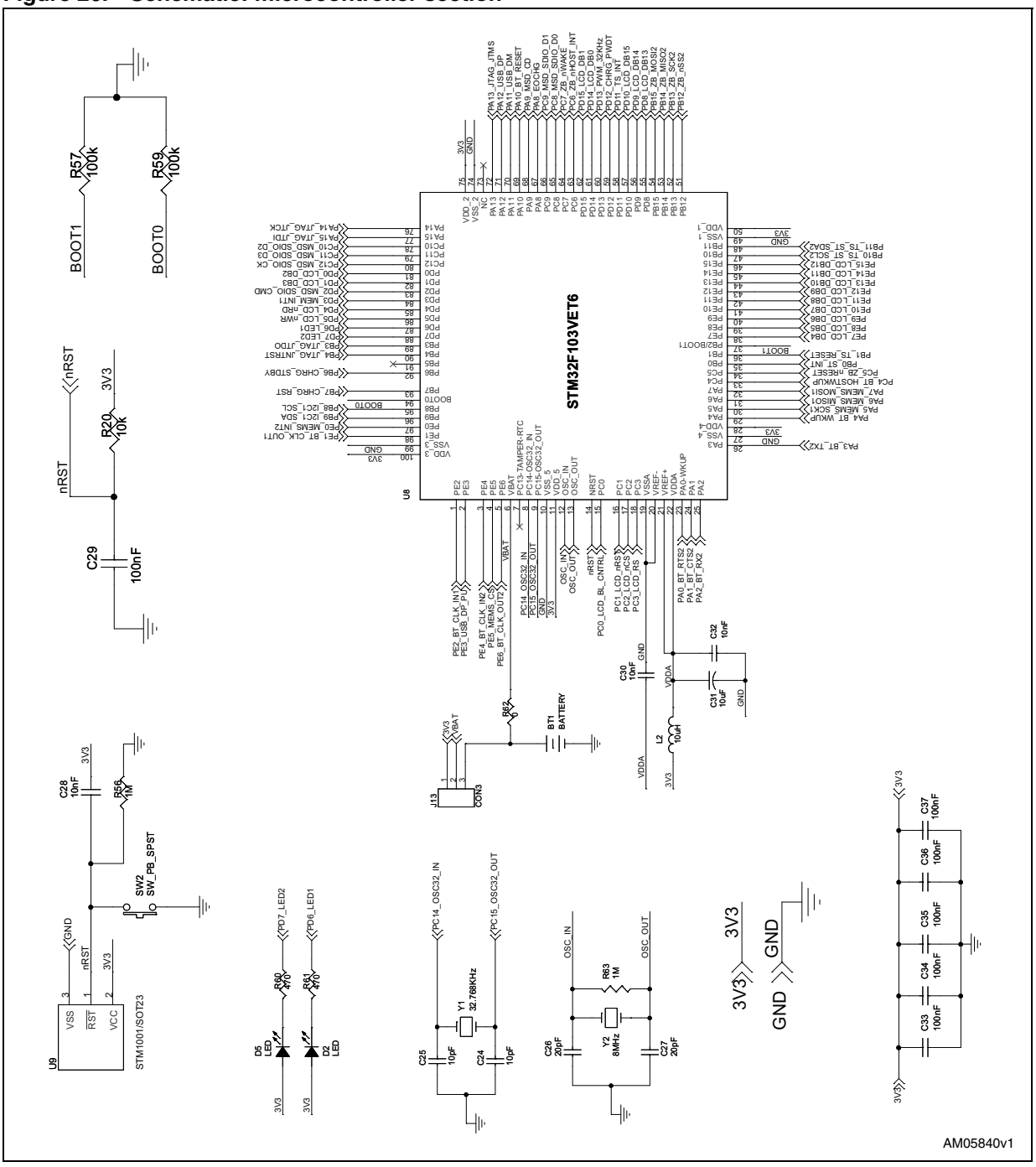


Figure 21. Schematic: connectors (TFT, micro-SD, JTAG, touch board)

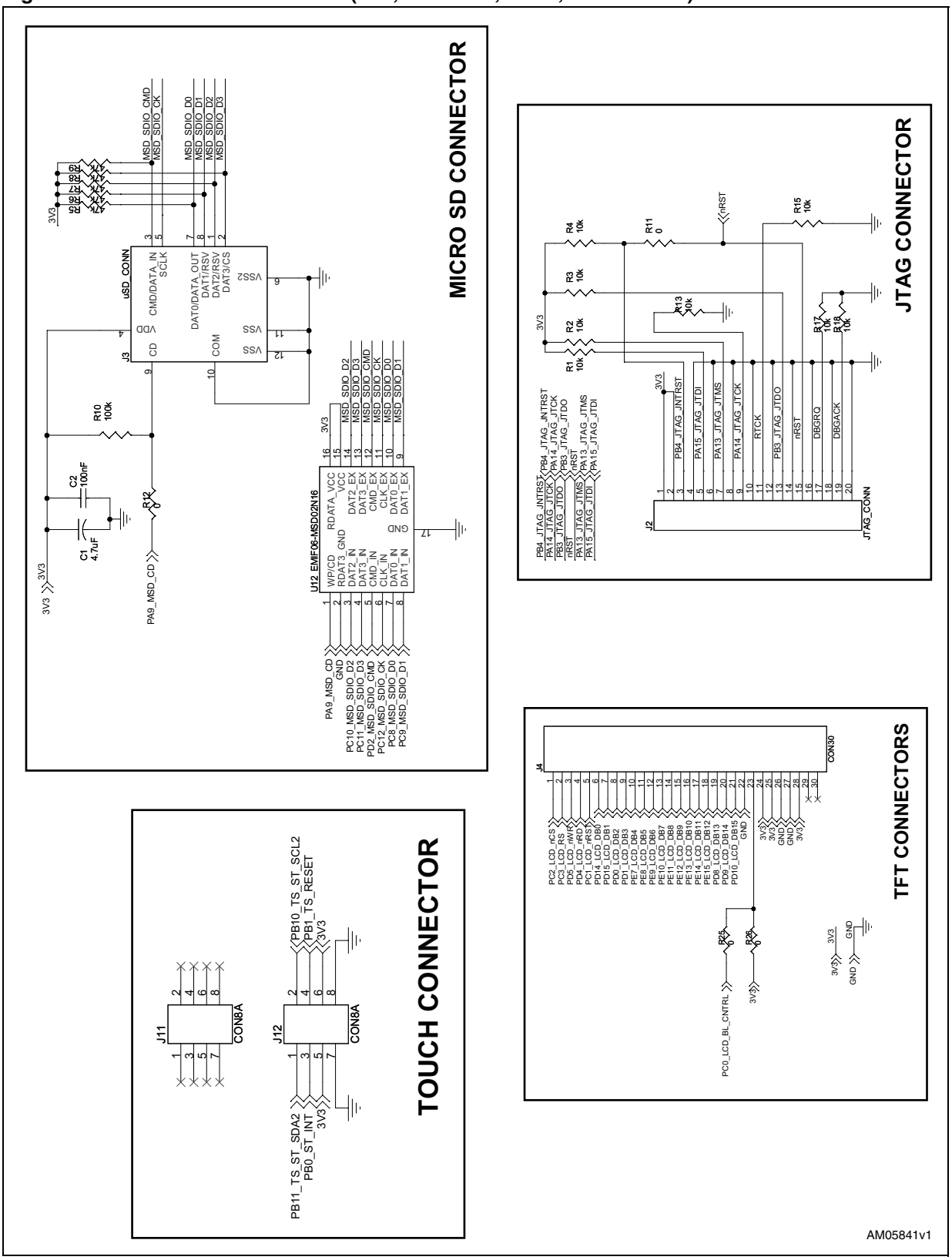


Figure 22. Schematic: connectors (temp. sensor, ZigBee®, Bluetooth®)

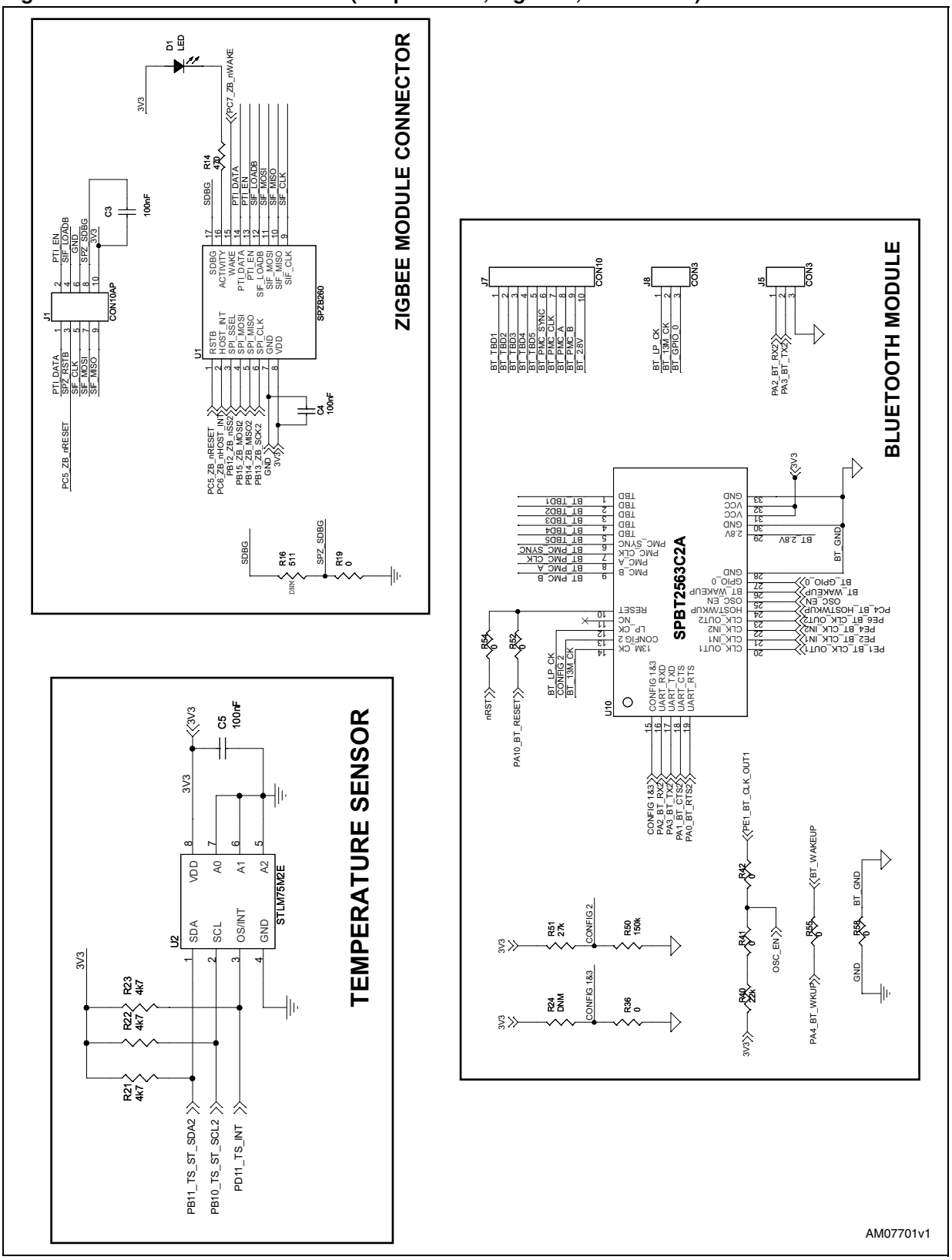


Figure 23. Schematic: power, MEMS and USB

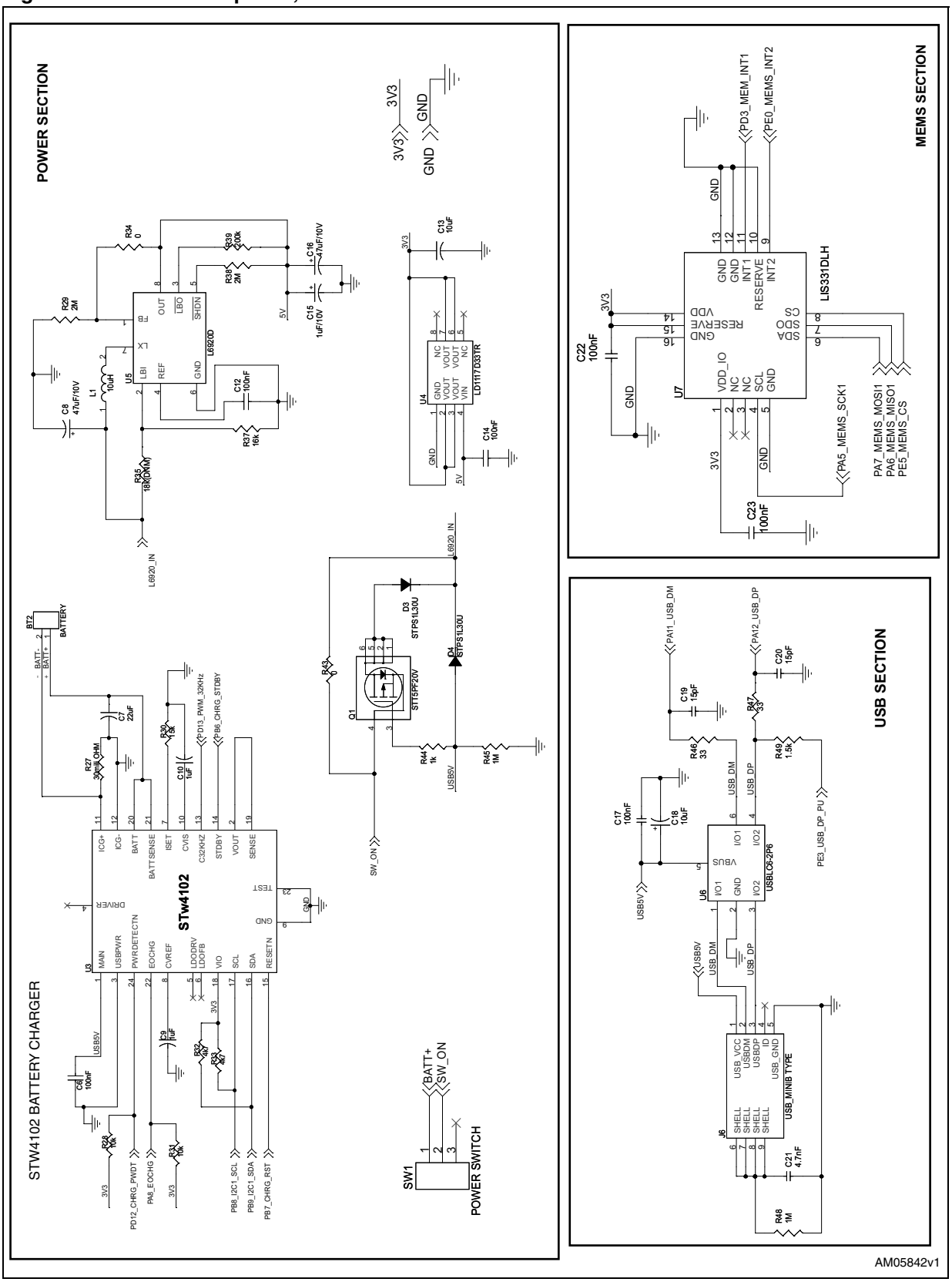
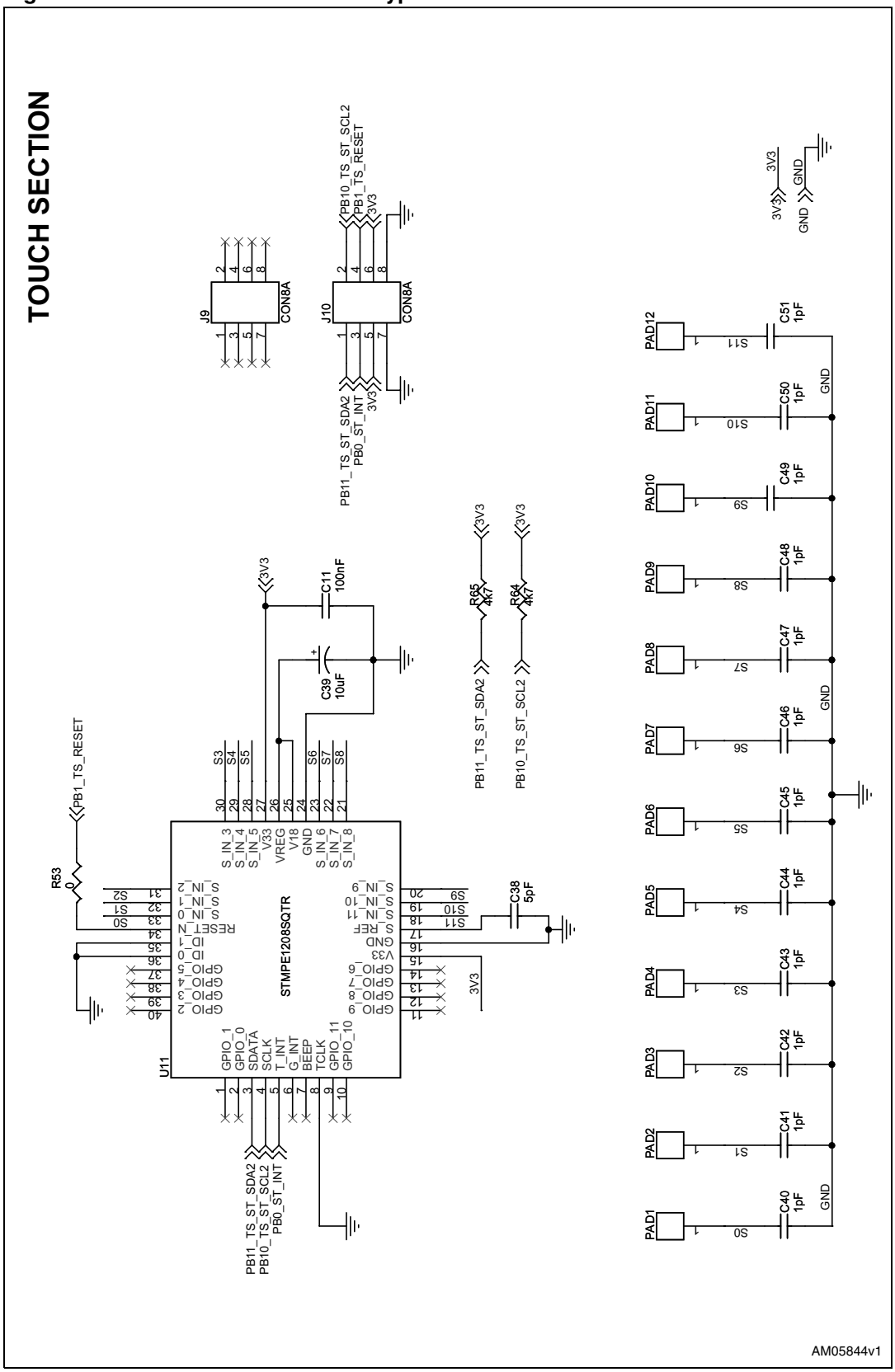


Figure 24. Schematic: S-Touch™ keypad section



5 Bill of material

Table 3. BOM

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
ST devices	U1 (not mounted)	ZigBee® module	12-pin SMD	STMicroelectronics	SPZB260		
	U2	Temperature sensor	SO-8	STMicroelectronics	STLM75M2E		
	U3	Battery charger system	QFN24	STMicroelectronics	STW4102IQT		
	U4	3.3 V out voltage regulator	SO-8	STMicroelectronics	LD1117D33TR		
	U5	Step up converter	TSSOP8	STMicroelectronics	L6920D		
	U6	ESD protection for USB	SOT23-6L	STMicroelectronics	USBLC6-2P6		
	U7	3-axis MEMS	LGA16 (3x3x1)	STMicroelectronics	LIS331DLH		
	U8	Microcontroller, ARM 32-bit Cortex™-M3 CPU, 512 kΩ flash, 64 kΩ RAM	100 pin LQPF	STMicroelectronics	STM32F103VET6		
	U9	Reset superviser (not used)	SOT23	STMicroelectronics	STM1001SWX6F		
	U10 (not mounted)	Bluetooth® module	33-pin interface	STMicroelectronics	SPBT2563C2A		

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
ST devices	U11	S-Touch™	QFN40	STMicroelectronics	STMPE1208SQTR		
	U12	ESD protection for µSD card	Micro QFN 16L	STMicroelectronics	EMIF06-MSD02N16		
	Q1	Power MOSFET	SOT23-6L	STMicroelectronics	STT5PF20V		
	D3, D4	Power Schottky rectifier	SMD	STMicroelectronics	STPS1L30U		
Crystal and oscillator	Y1	32.768 kHz	2-pin through-hole	Jauch	Q 0.032768-MMTF32-12.5-30		
	Y2	8 MHz	2-pin through-hole	Jauch	Q 8.0-SS4-22-30/30		
Connectors, jumpers and switches	SW1	Power switch : slide switch : SPDT, right angle	3-pin, 2.54 mm pitch through-hole	EAO	09-10290-01	Farnell	674357
	SW2	Reset switch : Push Button :SPST	Through-hole	Any			
	J1(not mounted)	CON10AP (ZigBee® module programming connector)	SMD	Any			

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Connectors, jumpers and switches	J2	JTAG_CONN	Box Header, Straight 20-way, 2 x 10-pin, 2.54 mm x 2.54 mm pitch, through-hole	Protectron	P9603-20-15-1		
	J3	uSD_CONN	SMD	Any			
	J4	CON30 LCD	Socket, 2 x 15-pin, 2.54 mm x 2.54 mm pitch, through-hole	Any			
	J5,J8,J13	CON3	3-pin header, 2.5 mm pitch, through-hole	Any			
	J6	USB_MINIB TYPE	SMD	Any			
	J7	CON10	10-pin header, 2.5 mm pitch, through-hole	Any			
	J9,J10	CON8A	Header, 2 x 4-pin, 2.54 mm x 2.54 mm pitch, through-hole	Any			
Connectors, jumpers and switches	J11,J12	CON8A	Socket, 2 x 4-pin, 2.54 mm x 2.54 mm pitch, through-hole	Any			
	BT1	Battery CR2032 holder	Through-hole	Renata	HU2032-LF	Mouser	614-HU2032-LF
	BT2	Li-Ion 2-pin battery conn	2-pin header, 2.5 mm pitch, through-hole	Any			

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
LEDs	D1	LED for ZigBee®	SMD	Any			
	D2,D5	LED for test purpose	SMD	Any			
Capacitors	C1	4.7 µF	EIA 3528-21/ Size A	Any			
	C2,C3,C4, C5,C6,C11, C12,C14, C17,C22, C23,C29, C33,C34, C35,C36, C37	100 nF	SMD0805	Any			
	C7	22 µF	SMD0805	Any			
	C8,C16	47 µF/10 V	EIA 3528-21/ size A	Any			
	C9,C10	1 µF	EIA 3528-21/ size A	Any			

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Capacitors	C13,C18, C31,C39	10 µF	EIA 3528-21/ size A	Any			
	C15	1 µF/10 V	EIA 3528-21/ size A	Any			
	C19,C20	15 pF	SMD0805	Any			
	C21	4.7 nF	SMD0805	Any			
	C24,C25	10 pF	SMD0805	Any			
	C26,C27	20 pF	SMD0805	Any			
	C28,C30,C32	10 nF	SMD0805	Any			
	C38	6 pF	SMD0805	Any			
	C40,C41, C42,C43, C45,C46, C48,C49, C50,C51	(Not mounted)	SMD0805				
	C44,C47	1 pF	SMD0805				
Inductors	L1,L2	10 µH	SMD0805	Any			
Resistors	R1,R2,R3, R4,R13,R15 ,R17,R18, R20,R28, R31	10 kΩ	SMD0805	Any			
	R5,R6,R7, R8,R9	47 kΩ	SMD0805	Any			
	R10,R57, R59	100 kΩ	SMD0805	Any			

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Resistors	R11,R12, R19,R25, R26,R34, R36,R41, R42,R43, R52,R53, R54,R55, R58,R62	0	SMD0805	Any			
	R14,R60, R61	470 Ω	SMD0805	Any			
	R16	511 Ω	SMD0805	Any			
	R21,R22, R23,R32, R33,R64, R65	4.7 kΩ	SMD0805	Any			
	R24	DNM	SMD0805	Any			
	R27	30 mΩ	SMD0805	Any			
	R29,R38	2 MΩ	SMD0805	Any			
	R30	15 kΩ	SMD0805	Any			
	R35	18 kΩ (DNM)	SMD0805	Any			
	R37	16 kΩ	SMD0805	Any			
	R39	200 kΩ	SMD0805	Any			
	R40	22 kΩ	SMD0805	Any			
	R44	1 kΩ	SMD0805	Any			
	R45,R48, R56,R63	1 MΩ	SMD0805	Any			
	R46,R47	33 Ω	SMD0805	Any			

Table 3. BOM (continued)

Category	Ref. des.	Component description	Package	Manufacturer	Manufacturer's ordering code / orderable part number	Supplier	Supplier ordering code
Resistors	R49	1.5 kΩ	SMD0805	Any			
	R50	150 kΩ	SMD0805	Any			
	R52	200 kΩ	SMD0805	Any			
Others	TFT	TFT: 320 x 240	Module: MB694	Ampire			MB694
	Micro-SD card	micro-SD card		Any			
	BT1	Li coin battery, 3 V, CR2032		Any			
	BT2	Li-Ion rechargeable battery, 3.3 V	Any				1

6 Revision history

Table 4. Document revision history

Date	Revision	Changes
30-Jun-2010	1	Initial release.

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