APPLICATION NOTE

Atmel AT03030: QMatrix Touchpad – 2D Position Tracking

Atmel QTouch

Features

- Two-dimensional position tracking using touch sensors
- Single tap detection
- Supports single finger operation
- Sensor design guidelines
- X-Y position reported in serial terminal
- 400dpi resolution
- Status LEDs

Introduction

This reference design demonstrates techniques to use QMatrix touch sensors for 2D position tracking application. ATxmega16D4 device is used in this touchpad design. X-Y position determined is displayed in PC HyperTerminal through USART interface. This design is suitable only for single-touch operation.

The firmware solution provided consists of QMatrix library, Touchpad library, USART driver and status LED control code. Firmware is written in C and supports GCC (Atmel® Studio) tool-chain.

This reference design can be used for low cost and low resolution touchpad applications, up to a maximum resolution of 400dpi. Applications that require higher resolution (more than 400dpi) and additional features like multi-touch can use the Atmel maXTouch® solution.

For this reference design, the hardware design files (schematic, BOM and PCB Gerber) and software source code can be downloaded from Atmel website. The provided hardware documentation can be used with no limitations to manufacture the reference hardware solution for the design.

Table of Contents

1. Abbreviations and Definitions

Following is a list of terms which will be used throughout this document.

- **Acquisition**: A single capacitive measurement process.
- **QMatrix (Mutual Capacitance)**: A type of capacitive touch sensing technology that measures the mutual capacitance between two electrodes. Each channel has a drive electrode (X Electrode) and a receive electrode (Y Electrode).
- **X Line**: The Sense Line connected to the X Electrode used in QMatrix Technology.
- **Y Line**: The Sense Line connected to the Y Electrode used in QMatrix Technology.
- **SMP**: Sampling pin used in QMatrix Sensor Design.
- **AIN0**: Analog ground Reference pin used in QMatrix Design.
- **Sensor**: A channel or group of channels used to form a touch sensor. The three types of sensors are Buttons, Sliders and Wheels.
- **Button (zero-dimensional sensor)**: It is a zero dimensional sensor used to implement On/Off digital sensors, and is composed of a single channel. It is also known as a Key.
- **Coplanar (Single Layer) design**: Both X and Y electrodes fabricated on the same layer of the PCB in QMatrix sensor design.
- **Flooded-X (Two-Layer) design**: Both X and Y electrodes are distributed in two layers of the PCB in QMatrix sensor design.
- **Atmel QTouch® Library**: The set of libraries for the touch sensing technologies offered by Atmel (QTouch, QTouchADC and QMatrix).
- **Channel**: A channel is a logical group of pins used to perform the touch acquisition measurement. It can be composed of a single pin (QTouchADC), a pair of pins (QTouch) or a matrix of pins (QMatrix).
- **Sense Electrode**: Electrodes are typically areas of copper on a printed circuit board. An electrode or a pair of electrodes used to detect a finger touch.
- **Delta**: Difference between Reference and Signal value of sensors.
- **Detection threshold**: It defines how much the touch sensor's signal value must drop below its reference level to qualify as a potential touch detect.
- **2D**: Indicates Two – Dimensional.

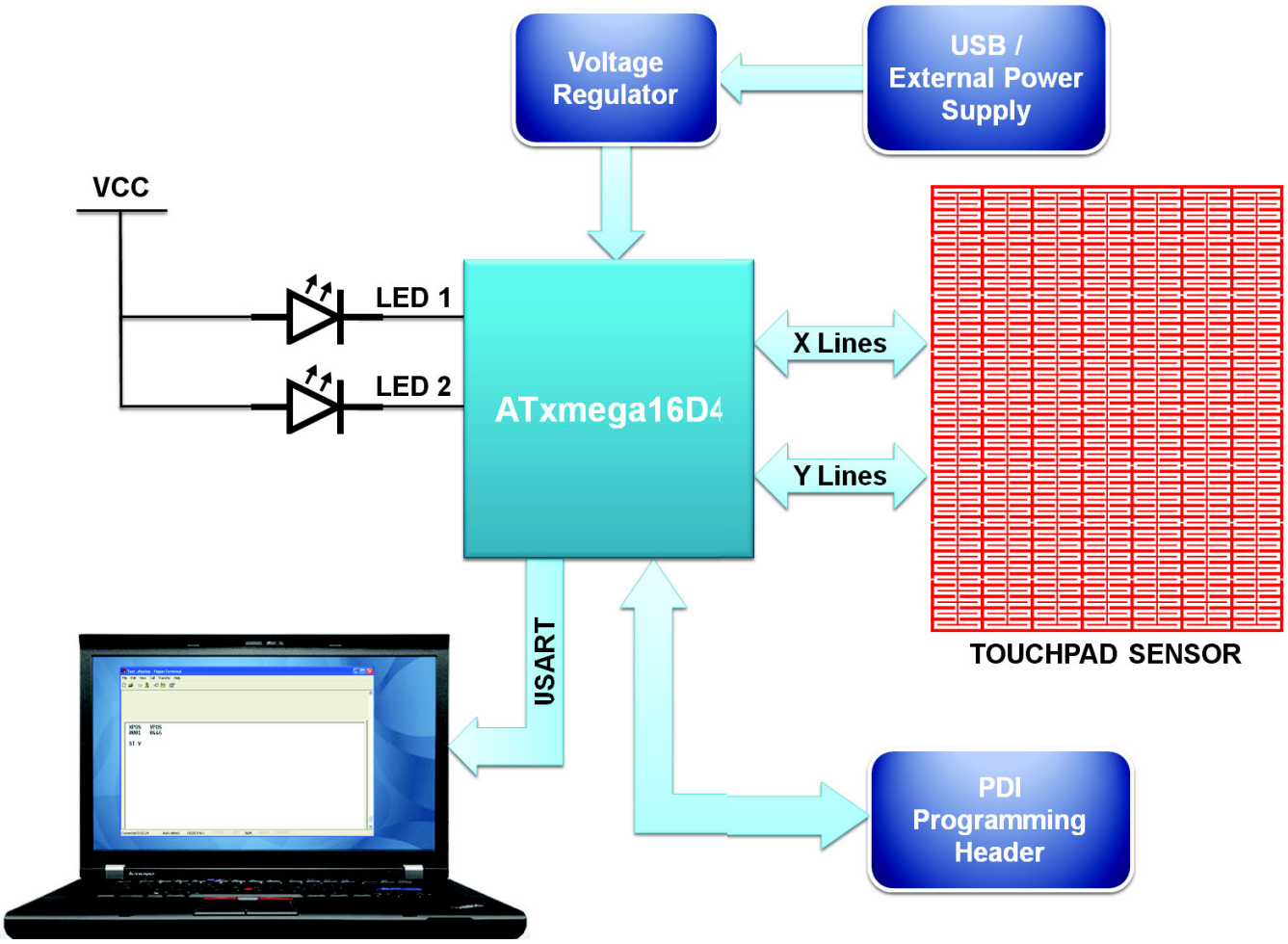
For more details refer to BSW Touch Sensor Design Guide and Atmel QTouch Library User Guide.

2. Hardware Design

2.1 System Block Diagram

The generic block diagram of this reference design is provided in Figure 2-1.

Figure 2-1. System Block Diagram



Touchpad design comprises of 56 touch sensors organized using 8 X lines and 7 Y lines. Table 2-1 provides pin configuration used in touchpad sensor design. QMatrix touch sensors require X + 2Y + 2 general-purpose I/O pins for realization, as shown in Figure 2-2.

Figure 2-2. Typical QMatrix Circuit

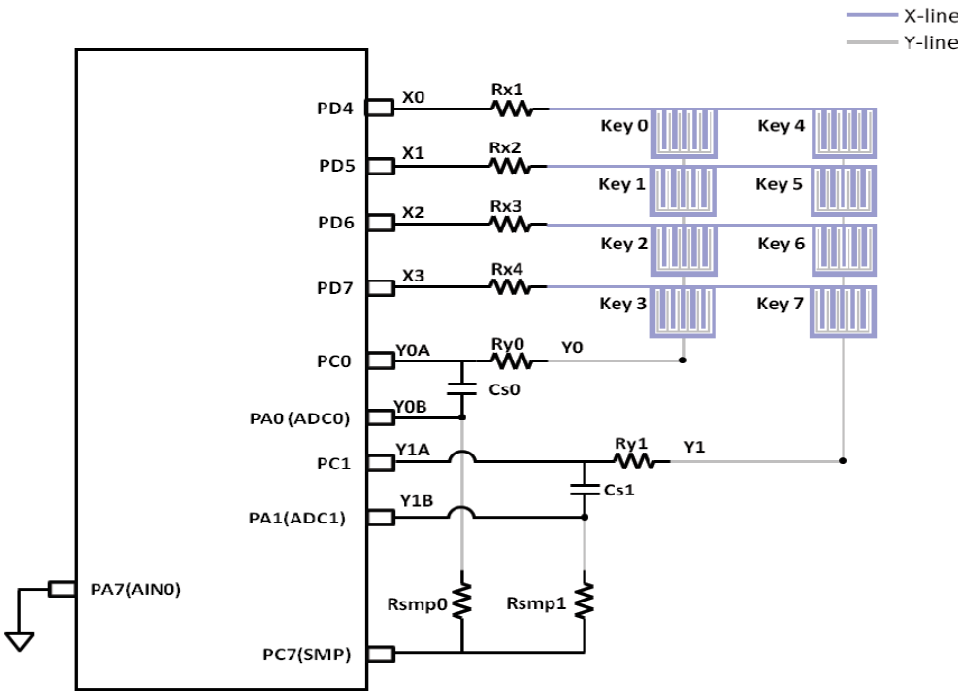


Table 2-1. Pin Configuration for Touchpad

ATxmega16D4 GPIO Pin	Pin Description	Comments
PD4	X0	Configurable I/O Pin
PD5	X1	Configurable I/O Pin
PD6	X2	Configurable I/O Pin
PD7	X3	Configurable I/O Pin
PE0	X4	Configurable I/O Pin
PE1	X5	Configurable I/O Pin
PE2	X6	Configurable I/O Pin
PE3	X7	Configurable I/O Pin
PC0	Y0A	Configurable I/O Pin
PC1	Y1A	Configurable I/O Pin
PC2	Y2A	Configurable I/O Pin
PC3	Y3A	Configurable I/O Pin
PC4	Y4A	Configurable I/O Pin
PC5	Y5A	Configurable I/O Pin
PC6	Y6A	Configurable I/O Pin
PA0	Y0B	ADC Port Pin

PA1	Y1B	ADC Port Pin
PA2	Y2B	ADC Port Pin
PA3	Y3B	ADC Port Pin
PA4	Y4B	ADC Port Pin
PA5	Y5B	ADC Port Pin
PA6	Y6B	ADC Port Pin
PC7	SMP	Sampling Pin
PA7	AIN0	Analog Ground Reference Pin

2.2 Sensor Design

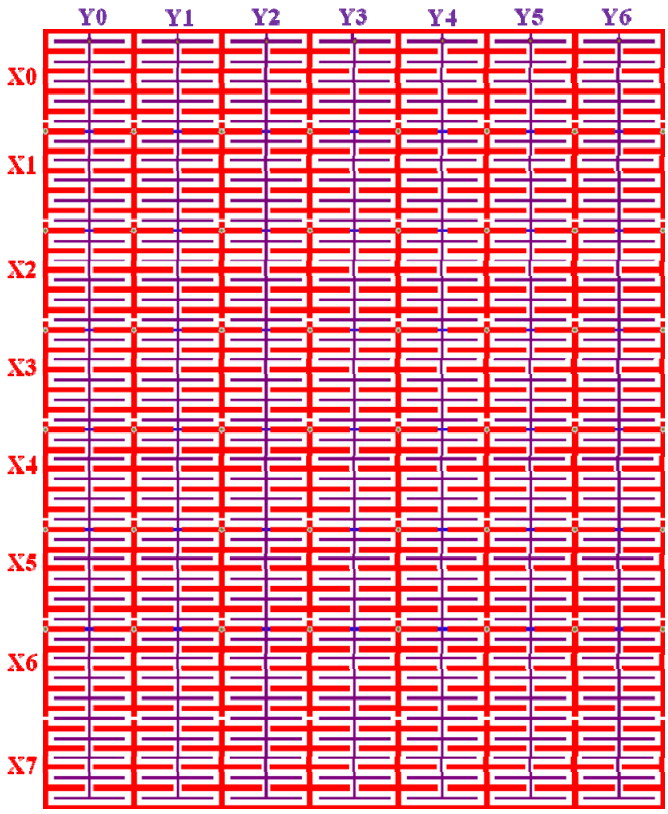
Sensor design is very important for designing touchpad using zero-dimensional touch sensors (buttons), which is used to determine 2D position. Accuracy and resolution of touch position is greatly dependent on Touch Sensor design.

The touchpad design consists of set of sensors arranged in rows and columns to form a matrix. The reference design uses a sensor pattern of eight rows (X lines) and seven columns (Y lines) similar to 56 touch keys. Mutual capacitance (QMatrix) method is used in this design. Sensor Design uses Coplanar (Single Layer) method and 1mm thick front panel is used.

Coplanar design provides flexibility for controlling the sensitivity, by adjusting XY gap in sensor electrode. This allows usage of thicker front panel. This method can be easily implemented on a flex PCB.

Refer Figure 2-3 for sensor pattern used in this reference design.

Figure 2-3. Coplanar (Single Layer) Sensor Design



2.2.1 Design Guidelines

Sensor Design guidelines specific to touchpad design is listed below:

- Fundamental guideline is to place the sensors in close proximity as shown in Figure 2-4. To locate sensors closely follow the below recommendation.
  - Sensors that share same X line, the X regions can be merged.
    As shown in Figure 2-4, each row has seven sensors sharing same X line but uses different Y line and so there is no gap between the sensors horizontally.
  - Sensors using different X lines need to have minimal separation, which should be maintained between 0.1mm to 0.5mm gap.
    As shown in Figure 2-4, each column has eight sensors sharing same Y line but uses different X line. So minimal gap is maintained between the sensors vertically.

- Touchpad sensor pattern is formed using sensors arranged in rows and columns organized as a matrix.
  Touchpad library implementation puts restrictions on the number of rows / columns in the design.
  - Minimum number of rows / columns that can be used is limited to two.
  - Maximum number of rows / columns that can be used is limited to eight.

- Segment size of the sensor for a given X and Y line should be in the range 5mm to 8mm.
  - Segment size of sensor used beyond 8mm will not have proper linearity and have low resolution.

- Touchpad designs that use small segment size say 5mm x 5mm, Flooded-X (Two-Layer) design is preferred. Since it is difficult to realize Coplanar (Single layer) touchpad designs for small segment size.
  Refer Figure 2-5 for spacing recommendations for Flooded-X (Two-Layer) design.

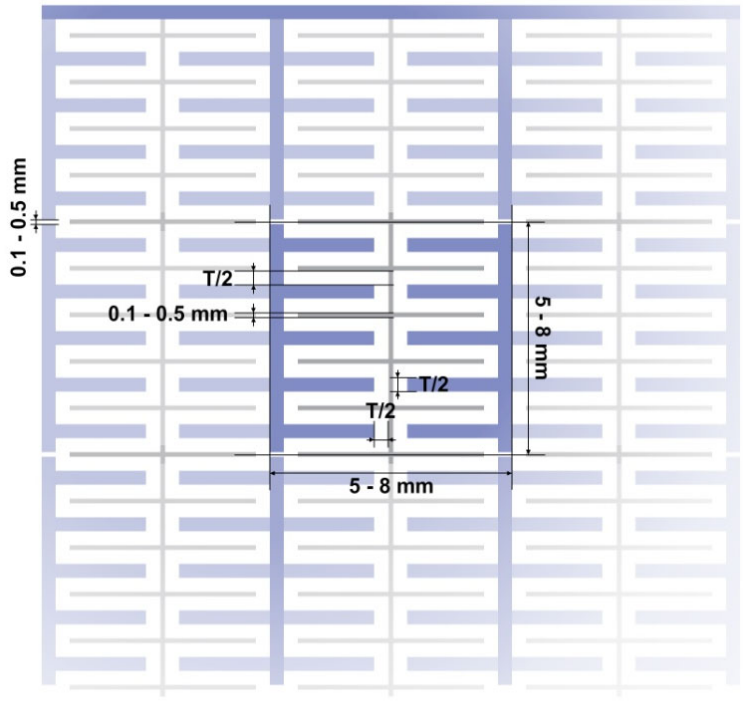
- Shape of the touchpad sensor pattern should be rectangular or square. Other fancy shapes are not recommended, as they may not provide expected results.

- No additional touch sensor should be designed using same Atmel MCU used to design touchpad.
  - This is restricted by touchpad library implementation.

- Resolution is mainly dependent on sensor size and number of sensors used to form sensor pattern.
  - Better resolution can obtained using many sensors of small segment size.
  - Designs using few sensors which are bigger in size, the resolution achieved will be low.

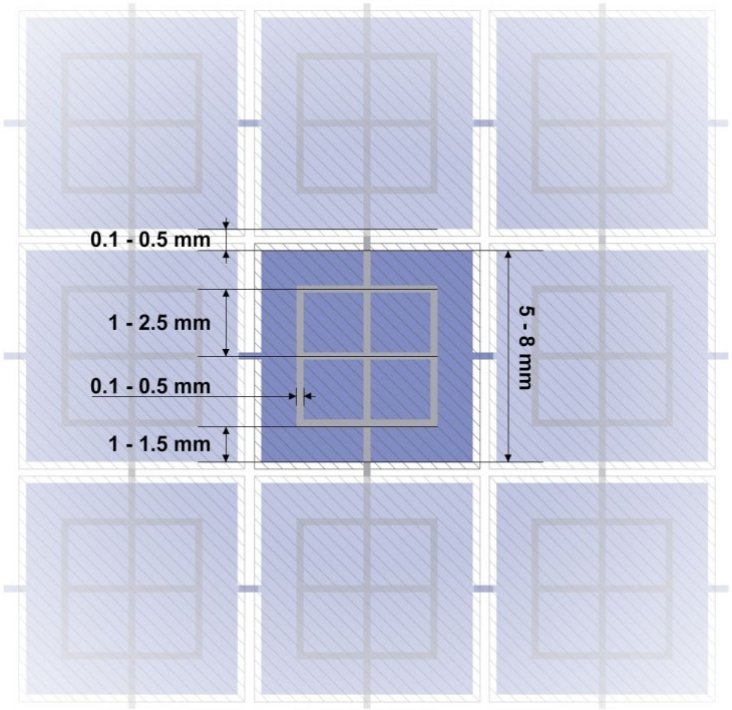
For general Sensor Design Guidelines refer to “BSW Touch Sensor Design Guide”.

Figure 2-4. Recommended Spacing for Coplanar (Single Layer) Design



- ‘T’ refers to Front panel thickness used in design.

Figure 2-5. Recommended Spacing for Flooded-X (Two Layer) Design



2.2.1.1 Sensor Arrangement

Sensors in touchpad should be connected sequential as shown in Figure 2-6.

In this reference design, 56 sensors are arranged in the below order for 8 X lines and 7 Y lines.

Figure 2-6. Sensor Arrangement

	X0	X1	X2	X3	X4	X5	X6	X7
Y0	S0	S1	S2	S3	S4	S5	S6	S7
Y1	S8	S9	S10	S11	S12	S13	S14	S15
Y2	S16	S17	S18	S19	S20	S21	S22	S23
Y3	S24	S25	S26	S27	S28	S29	S30	S31
Y4	S32	S33	S34	S35	S36	S37	S38	S39
Y5	S40	S41	S42	S43	S44	S45	S46	S47
Y6	S48	S49	S50	S51	S52	S53	S54	S55

2.3 LED Indication

Two LEDs are used to indicate the single tap and touchpad state. These LEDs are driven by BC847B transistor. The state of the transistor is controlled by connected ATxmega16D4 GPIO pin.

LED1 is configured for single tap indication. This is set to operate in toggle mode. The LED1 turns ON when single tap event is detected first time and turns OFF in the subsequent single tap detection.

LED2 is configured to indicate touchpad active status. This LED will be in ON as long as there is a touch.

Table 2-2 details pin configuration used for LEDs.

Table 2-2. Pin Configuration for LEDs

GPIO Pin	Pin Description
PD0	LED1
PD1	LED2

2.4 Communication Interface

Serial communication using USART interface is used to display the touchpad X-Y position on HyperTerminal of host PC. Figure 2-7 shows the communication header available on the PCB. Table 2-3 details pin configuration of USARTD0 used in touchpad.

Table 2-3. Pin Configuration for USART

GPIO Pin	Pin Description
PD3	USART_TX
PD2	USART_RX

Figure 2-7. Communication Header

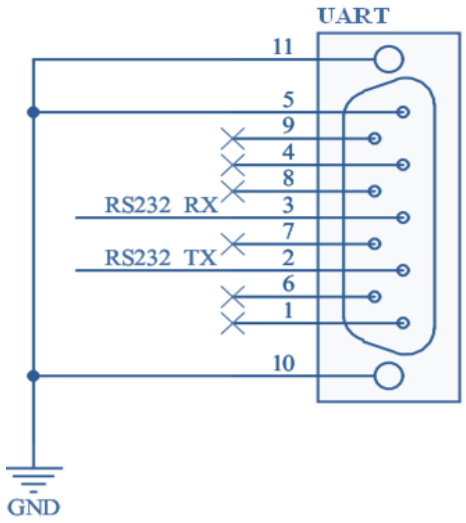


Figure 2-8. Communication Signals – USART

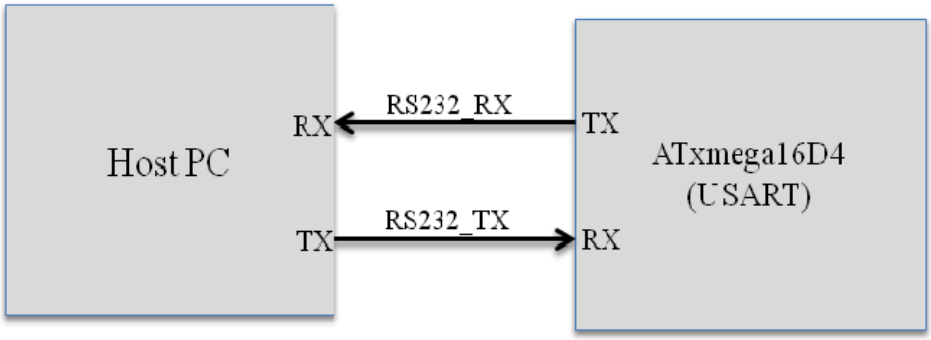
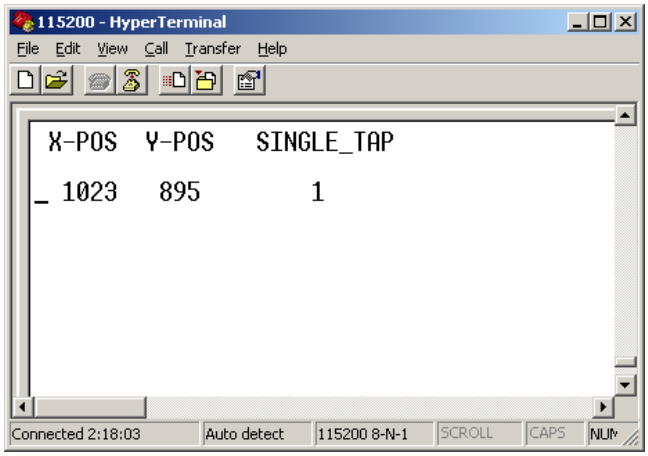


Figure 2-9 shows PC HyperTerminal screenshot, with X-Y Position display and Single tap indication.

Figure 2-9. X-Y Position Display



2.5 Power Supply Considerations

The reference design can be powered by using any of the following power supply sources.

2.5.1 USB Supply

The reference board can be powered with the Mini-B USB header available on the board. This supply acts as a source of power to the on-board voltage regulator and power indication LED.

2.5.2 External Supply

The reference board can be powered using +5V external supply. Power can be provided using J7 header available on board. This also acts as source of power to the on-board voltage regulator and power indication LED.

2.5.3 On-board Regulator

A linear drop-out regulator, which is mounted on the board acts as a regulated power supply source for the Atmel ATxmega16D4 device. This on-board regulator can be bypassed using zero Ohm resistor provision available. In such case, external supply provided should be +3.3V.

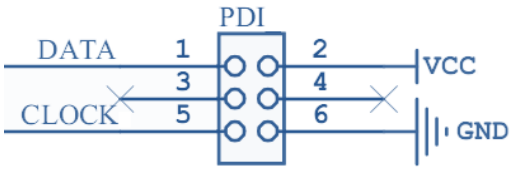
Using external supply, which is not regulated by the on-board regulator, should adhere to the power supply considerations mentioned in the application note Atmel AT02259: QTouch® Schematic and Layout Checklist.

2.6 Programming and Debugging

2.6.1 PDI Interface

The ATxmega16D4 device can be programmed using PDI interface. The on-board PDI header can be used for programming the device. This can also be used for On-Chip Debugging (OCD). Figure 2-10 shows the programming header available on the PCB.

Figure 2-10. Programming Header



2.6.2 Touch Data

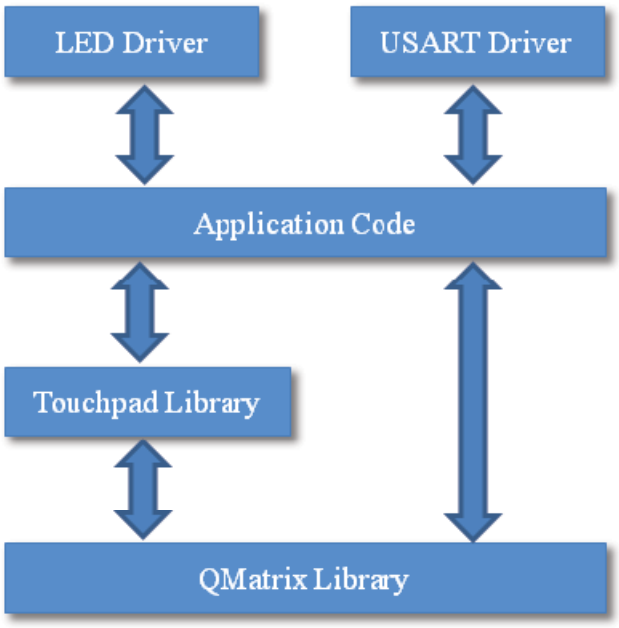
Touch data is transmitted using QDebug protocol through Bit Bang SPI interface. QT600 USB Interface Bridge is used to transmit touch data to QTouch Analyzer. The real time touch data can be used for debugging and analysis. Table 2-4 shows pins configured for QDebug in Touch Data Header available.

Table 2-4. Pin Configuration for Touch Data Debug

ATxmega16D4 GPIO Pin	Pin Description
PB0	DBG_MISO
PB1	DBG_SS
PB2	DBG_MOSI
PB3	DBG_SCK

3. Firmware

Figure 3-1. Firmware Block Diagram



3.1 Touchpad Library

Touchpad library (*libtouchpad.a*) is a software library which calculates X-Y position of the touchpad sensor for the given resolution. This library is built for the Atmel ATxmega16D4 device and linked into application code to calculate the X-Y position.

This library is available as part of firmware that can be downloaded along with this document.

The below sections provides details of touchpad library APIs and its usage.

3.1.1 touchpad.h – Header File

The *touchpad.h* header file which needs to be included in user's application and it has the type definitions and function prototypes of the API's needs to be used for touchpad X-Y calculation.

3.1.2 Public Functions

This section provides details of touchpad library public functions and its usage.

3.1.2.1 qt_init_touchpad

Table 3-1. qt_init_touchpad

Function	Description	
`uint8_t qt_init_touchpad(uint8_t num_x, uint8_t num_y, xy_resolution_t resolution, uint8_t position_hysteresis)`	Initializes touchpad library with the input parameters provided	
	Input	num_x: Number of X lines of the touchpad sensor num_y: Number of Y lines of the touchpad sensor resolution: Number of positions to be reported per sensor area position_hysteresis: Hysteresis of reported X-Y position value
	Output	None
	Return	Returns TRUE if successful or FALSE otherwise

Resolution

Resolution is the number of positions to be reported for each sensor area. It can have values from four to seven bits (16 to 128 positions).

The total resolution for X-axis = no. of X lines * no. of positions for one sensor.

The total resolution for Y-axis = no. of Y lines * no. of positions for one sensor.

Touchpad resolution (dpi) = no. of sensors available in 1 inch area * no. of positions for one sensor.

Where, no. of sensors available in 1 inch area = 1 inch area in mm / 1 sensor area in mm.

In this reference design, one sensor area is 8mm x 8mm and firmware uses seven bit position resolution. Using above calculation, touchpad resolution for this design is 406 dpi.

Table 3-2, shows position and resolution possible with 8X x 7Y sensor configuration with one sensor area 8mm x 8mm for different resolution inputs.

Table 3-2. Touchpad Position Resolution

Resolution [bits]	Positions Per Sensor	X-axis Positions	Y-axis Positions	Touchpad Resolution [dpi]
7	128	1024	896	406
6	64	512	448	203
5	32	256	224	102
4	16	128	112	51

Resolution Range: 4 to 7bits.

Position Hysteresis

It is the number of positions the user has to move back, before the new X-Y touch position is reported when the direction of scrolling is changed. This is used to avoid jittering in the reported X-Y position.

Hysteresis can range from 0 (1 position) to 7 (8 positions). Hysteresis setting can be used when the reported position jitters due to noise effects.

Position Hysteresis Range: 0 to 7.

3.1.2.2 qt_get_xy

Table 3-3. `qt_init_touchpad`

Function	Description	
`touch_position_t qt_get_xy(void)`	Calculates X-Y position and returns it	
	Input	None
	Output	None
	Return	Updates the X and Y values computed in structure '`touch_position_t`'

3.2 QMatrix Library

QMatrix library is a software library which performs touch acquisition and post-processing. This reference design uses ATxmega16D4 8X x 7Y sensor configuration library which supports up to 56 channels.

Refer QTouch Library User Guide for QMatrix Library API usage.

3.3 USART Module

USART Module consists of USART driver code and functions to convert integer to ASCII to display X-Y Position in HyperTerminal of host PC using RS232 interface. This module is sending data using polling method. ATxmega16D4 USARTD0 peripheral is used and it is configured as below.

Baud rate : 115200

Start bits : 1

Data bits : 8

Parity : Disabled

Stop bits : 1

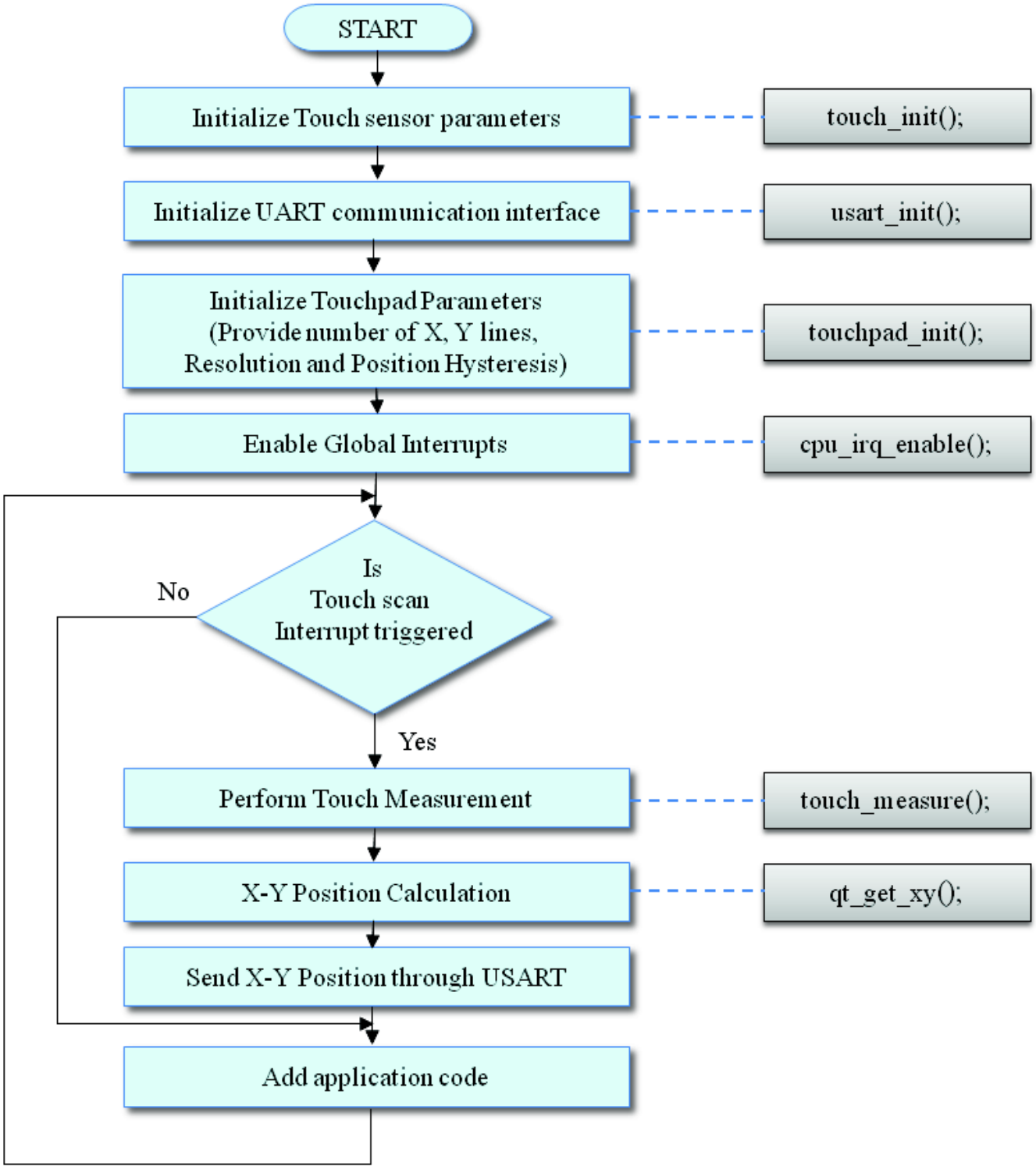
3.4 LED Interface

This module controls LED indication for the single tap and touchpad state.

3.5 Application Code

The application code implementation flow is provided in the Figure 3-2.

Figure 3-2. Application Flow Diagram



Measurement period depends on touch acquisition duration and USART transmission time. In this firmware solution, measurement period is set to 30ms.

Note: Things to be taken care while tuning the Touchpad sensor: QTouch Analyzer can be used for tuning purpose.

- The delta for each sensor in the touchpad should be peaking at the same amplitude. This gives improved linearity of reported X-Y position and also uniform sensitivity across the touchpad. Burst Length can be adjusted to compensate for imbalance.
- Make sure the delta for each sensor in the touchpad peak at around 25 counts and above. If touch delta is not enough to calculate position, the reported X-Y position can be jittery.
- Set the Detection Threshold for each sensor in the touchpad to report a touch when the finger lightly contacts the touchpad surface.

3.5.1 Single Tap Detection

Firmware solution provides demonstration of single tap detection feature. This single tap detection is indicated using LED and also indicated in PC HyperTerminal. The LED toggles for every single tap detection.

Note: Below listed features also can be implemented in user application code.

- Double-tap detection
- Horizontal Scroll detection
- Vertical Scroll detection

4. Schematic Design

Figure 4-1. Schematic – Part 1

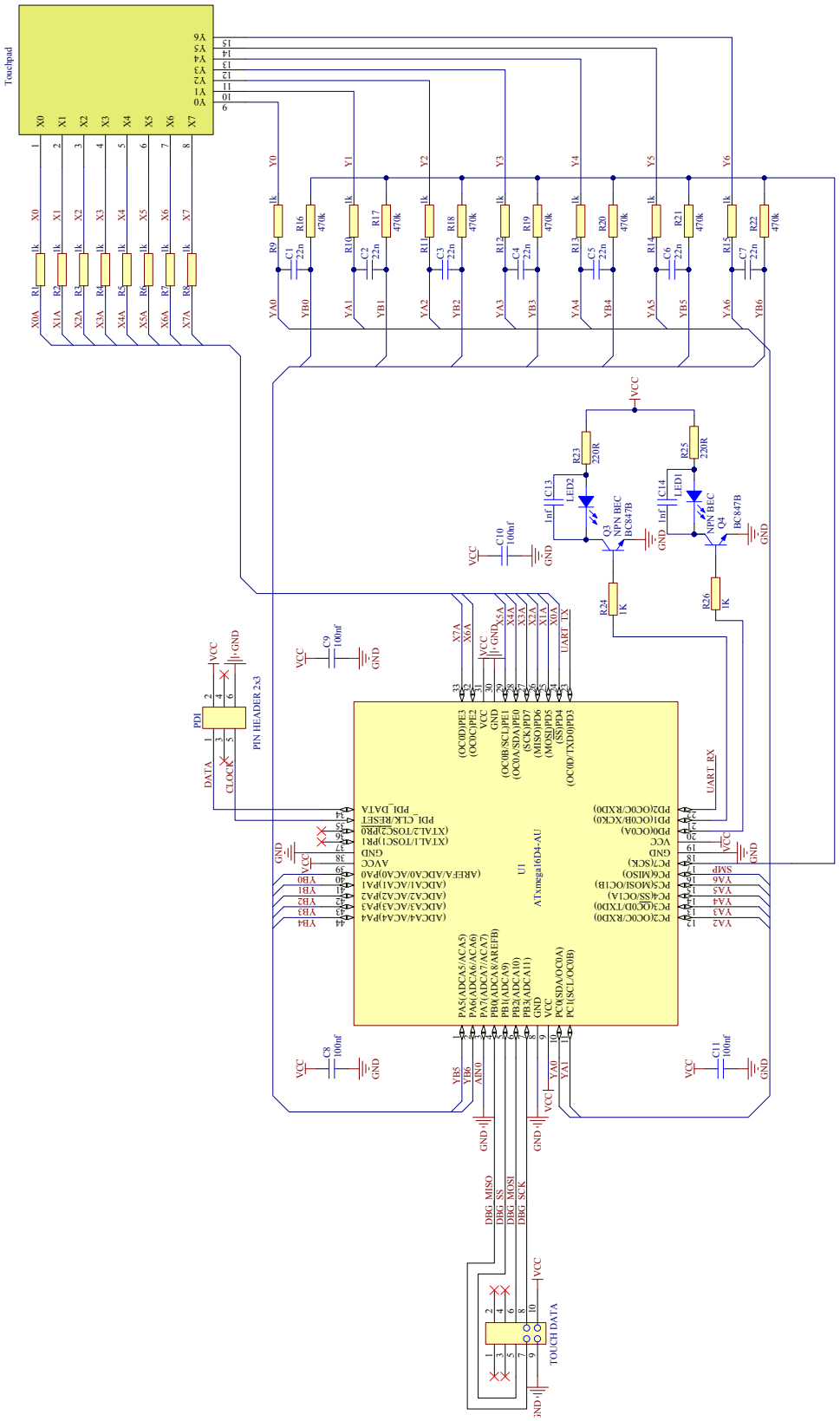
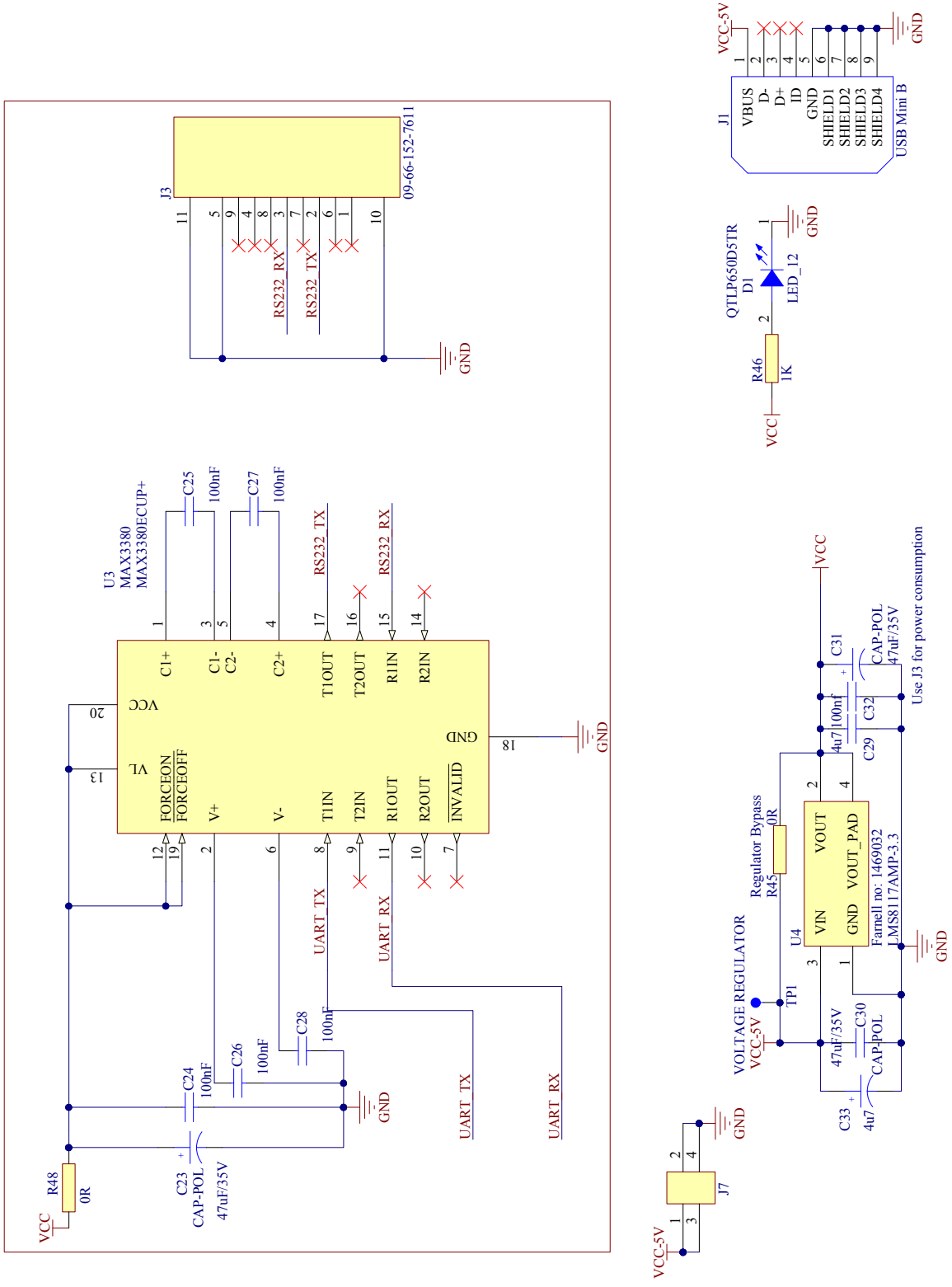


Figure 4-2. Schematic – Part 2



5. PCB Layout

Figure 5-1. Top Layer

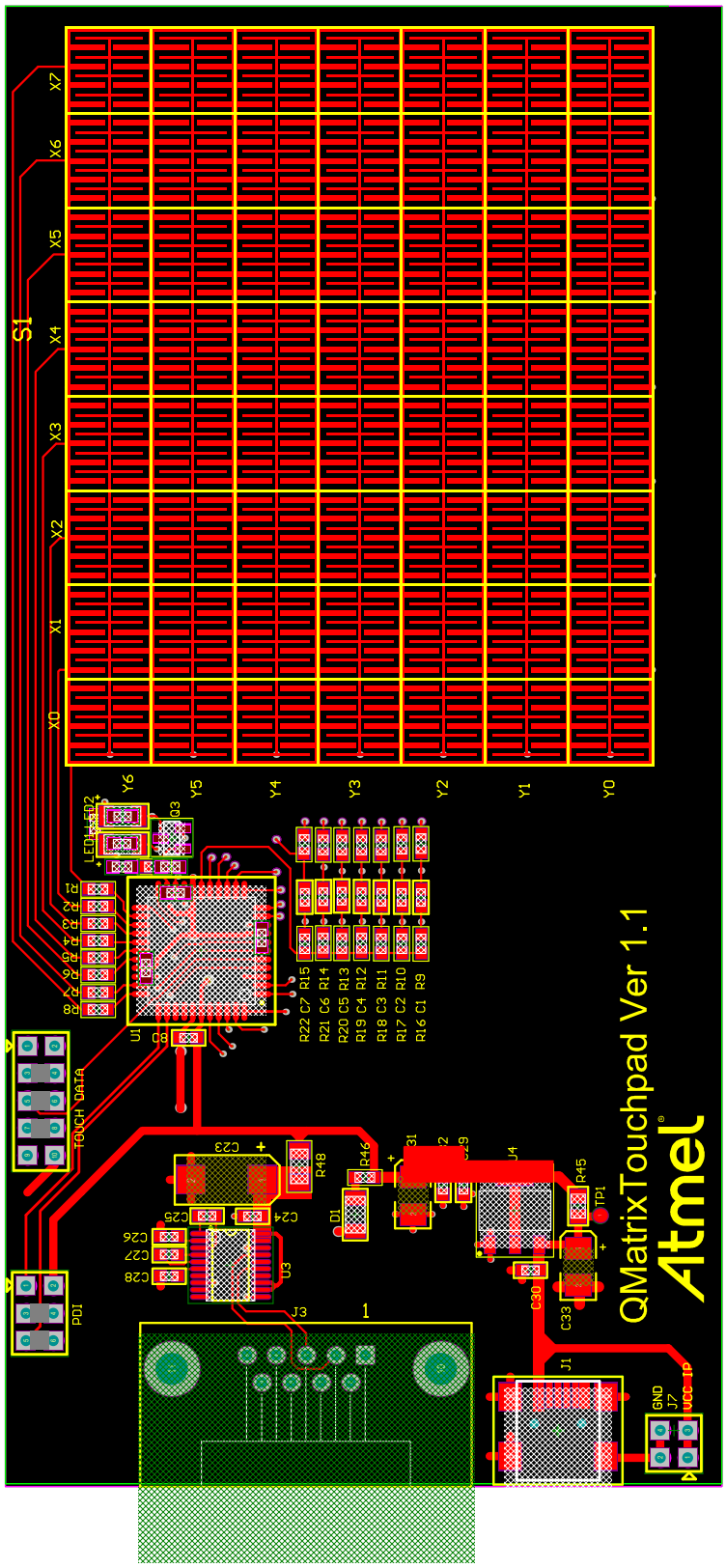
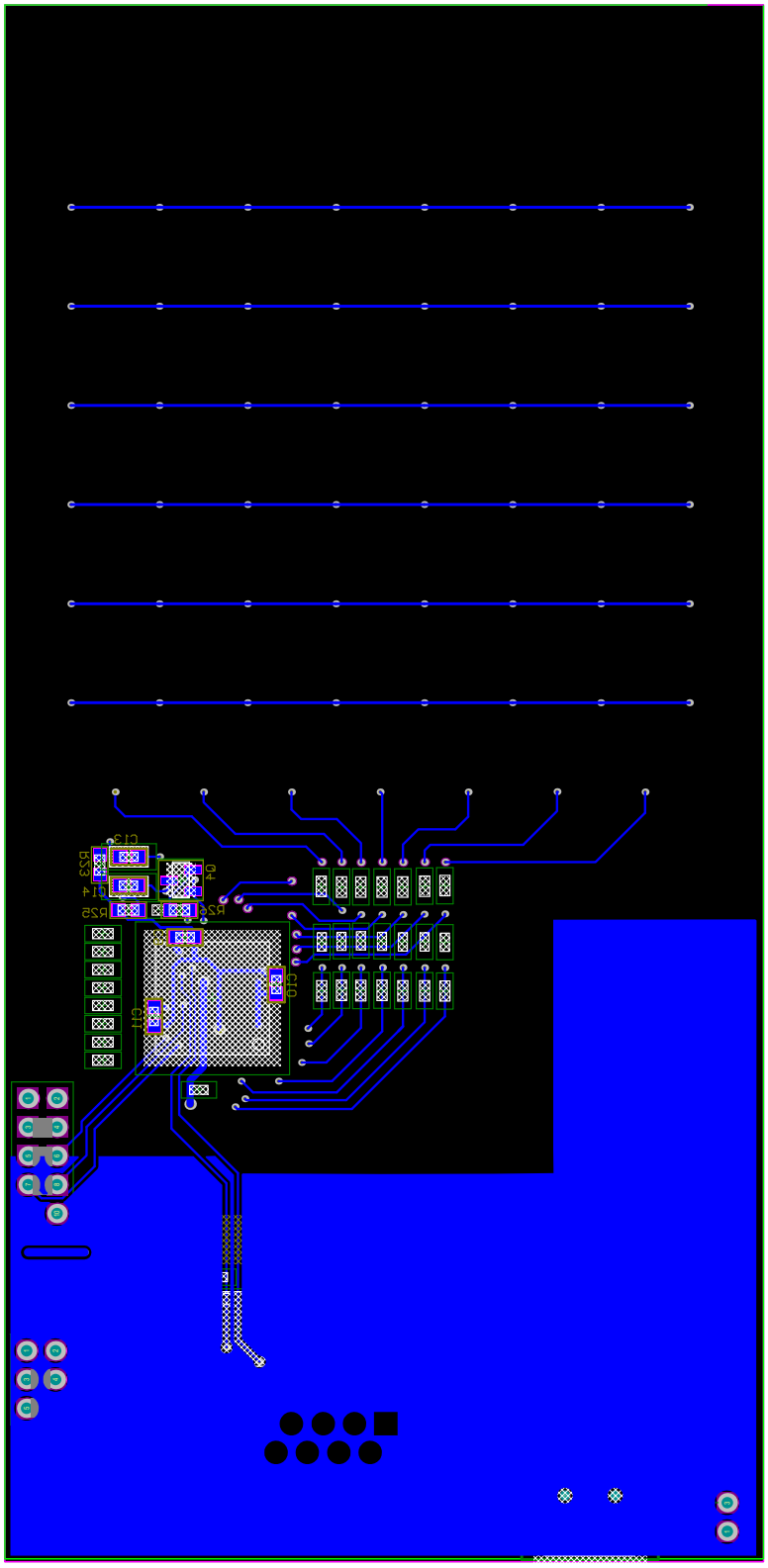


Figure 5-2. Bottom Layer



6. Bill of Materials (BOM)

Table 6-1. BOM

Description	Designator	Qty.	Value
Ceramic capacitor, SMD 0603, X7R, 50V, ±10%	C1, C2, C3, C4, C5, C6, C7	7	22nF
Ceramic capacitor, SMD 0603, X7R, 50V, ±10%	C8, C9, C10, C11, C24, C25, C26, C27, C28, C32	10	100nF
Ceramic capacitor, SMD 0603, NPO, 100V, ±1%	C13, C14	1	1nF
SMD tantalum capacitor, 35V	C23, C31, C33	3	47µF
Ceramic capacitor, SMD 0603, X7R, 16V, ±10%	C29, C30	1	4µ7
Yellow SMD LED	D1	1	Power indication
Yellow SMD LED	LED1, LED2	2	Single tap and touchpad state indication
BJT Transistor, NPN	Q3, Q4	2	BC847B
Thick film resistor, SMD 0603, 1/10W, 1%	R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R24, R26, R46	18	1kΩ
Thick film resistor, SMD 0603, 1/10W, 1%	R16, R17, R18, R19, R20, R21, R22	7	470kΩ
Thick film resistor, SMD 0603, 1/10W, 1%	R23, R25	2	220R
Thick film resistor, SMD 0603, 1/10W, 1%	R45	1	0Ω
Thick film resistor, SMD 1206, 1/10W, 1%	R48	1	0Ω
AVR® 8-bit RISC MCU	U1	1	ATxmega16D4-AU
RS232 Level Converter, 2.35V to 5.5V	U3	1	MAX3380ECUP
3.3V 1A Low Dropout Linear Regulator SOT223_4	U4	1	LMS8117AMP-3.3
USB Mini-AB Connector, SMD	J1	1	MUSB-05-F-AB-SM-A

7. References

[1]. Atmel QTouch Library User Guide
http://www.atmel.com/Images/doc8207.pdf

[2]. BSW Touch Sensor Design Guide
http://www.atmel.com/Images/doc10752.pdf

[3]. Atmel AT02259: QTouch Schematic and Layout Checklist
http://www.atmel.com/Images/Atmel-42094-QTouch-Schematic-and-Layout-Checklist_Application-Note_AT02259.pdf

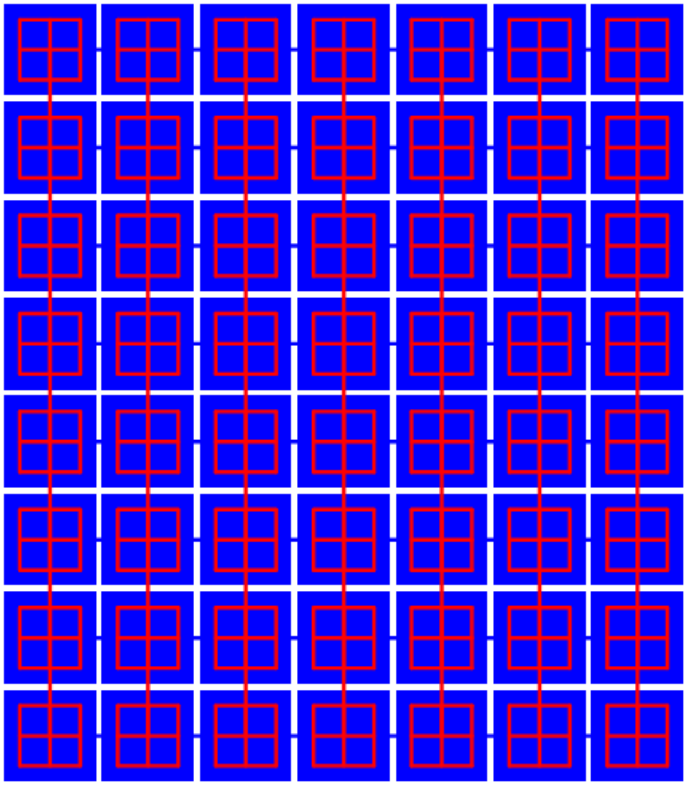
[4]. AVR XMEGA® D4 Devices Datasheet
http://www.atmel.com/Images/Atmel-8135-8-and-16-bit-AVR-microcontroller-ATxmega16D4-32D4-64D4-128D4_datasheet.pdf

[5]. Atmel AVR XMEGA D Manual
http://www.atmel.com/Images/Atmel-8210-8-and-16-bit-AVR-Microcontrollers-XMEGA-D_Manual.pdf

Appendix A. Sensor Pattern for Flooded-X (Two-Layer) Design

Refer to Figure A-1 for Flooded-X sensor pattern that could be used in touchpad design.

Figure A-1. 8X x 7Y QMatrix Flooded-X (Two-Layer) Design



Appendix B. Revision History

Doc. Rev.	Date	Comments
42202A	11/2013	Initial document release

Atmel | Enabling Unlimited Possibilities®

Atmel Corporation
1600 Technology Drive
San Jose, CA 95110
USA
Tel: (+1)(408) 441-0311
Fax: (+1)(408) 487-2600
www.atmel.com

Atmel Asia Limited
Unit 01-5 & 16, 19F
BEA Tower, Millennium City 5
418 Kwun Tong Road
Kwun Tong, Kowloon
HONG KONG
Tel: (+852) 2245-6100
Fax: (+852) 2722-1369

Atmel Munich GmbH
Business Campus
Parkring 4
D-85748 Garching b. Munich
GERMANY
Tel: (+49) 89-31970-0
Fax: (+49) 89-3194621

Atmel Japan G.K.
16F Shin-Osaki Kangyo Building
1-6-4 Osaki, Shinagawa-ku
Tokyo 141-0032
JAPAN
Tel: (+81)(3) 6417-0300
Fax: (+81)(3) 6417-0370