APPLICATION NOTE

Atmel AT01486: Low Cost Capacitive Touch TV Control Keypad

Atmel QTouch

Features

- Atmel® QTouchADC design based on Atmel ATtiny20
  - Optimal hardware design
  - Customized firmware
- Six capacitive touch keys
- Analog voltage output on touch detection
- Buzzer indication on touch detection
- Power management
- TPI programming for ATtiny20
- 5V operation

Description

TV Control Touch Keyboard is designed to be drop-in replacement for an existing electromechanical (resistive ladder) type TV controller. This keyboard outputs respective analog voltage (DC output) on touch detection. The output voltage level is dependent upon the supply voltage to the MCU.

Figure 1. TV Control Touch Keyboard

It is based on Atmel QTouchADC technology. Although it is designed for TV control application, it can be used for any other application which requires up to six keys.

Table of Contents

1. Introduction

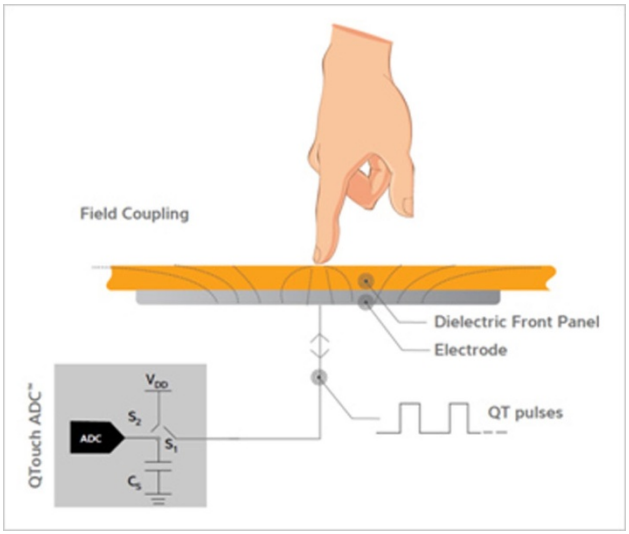
1.1 QTouchADC

QTouchADC is the newest Atmel sensing algorithm that is implemented by oversampling a standard SAR ADC. The QTouch® devices charge a sense electrode of unknown capacitance to a known potential. The electrode is typically a copper area on a PCB (could be any conductive material, including ITO).

QTouchADC only requires 1-series resistor and 1-pin per channel. No other external components are required. Compared with standard QTouch technology, QTouchADC offers faster acquisition times with shorter burst lengths, resulting in lower power consumption.

The QTouchADC method works by sharing charge between the ADC's internal sample-and-hold capacitor and the sense electrode capacitance. In the initial state, an amount of charge is built-up on an untouched sensor to set the sensor's reference level. As the finger makes contact with the sensor, it couples with the electric field of the sensor. When a sensor is touched the effective capacitance of the sensor electrode increases. This affects the amount of charge shared between the electrodes. Further charge transfers (conversions) from that sensor result in an increased signal level compared to the untouched state. If the difference between the reference level and the signal level is greater than the user-determined threshold (your delta), a touch is detected.

Figure 1-1. QTouchADC Sensing



Detailed technical description of the QTouchADC technology can be found in the application note Atmel AVR3001: QTouchADC Measurement and Tuning.

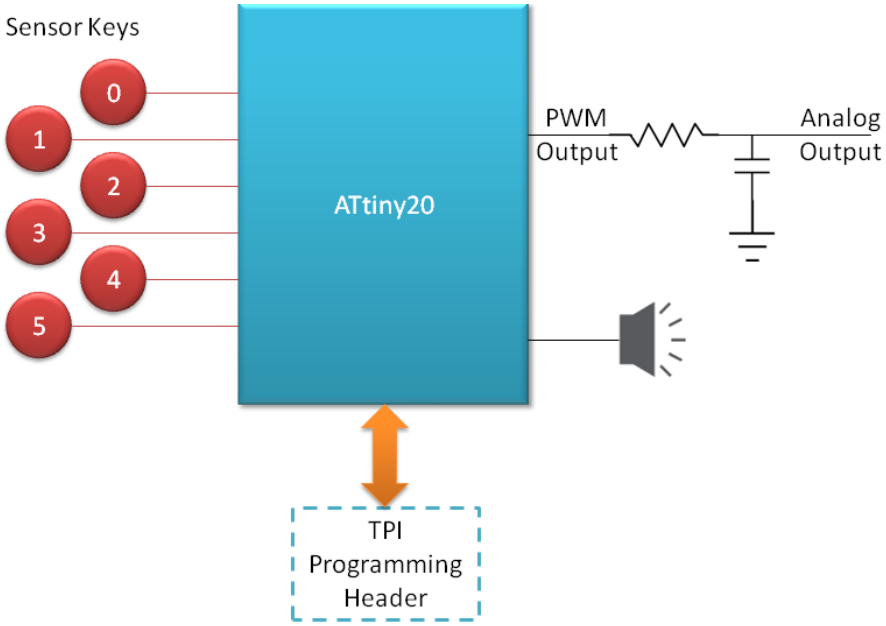
2. Hardware Design

2.1 Block Diagram

The keypad consists of the following basic components:

1) Atmel ATtiny20 Microcontroller.
2) Six self capacitance sensor electrodes.
3) PWM based analog output using low pass RC filter.
4) Buzzer for audio indication.
5) 6-pin TPI Programming Header.

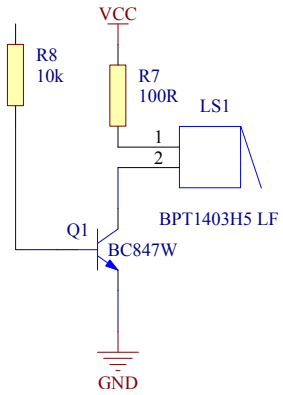
Figure 2-1. Block Diagram of TV Control Touch Keyboard



2.2 Buzzer Driver

The buzzer is driven using a transistor. The switching signal to the transistor is provided from the ATtiny20 device using hardware PWM. The buzzer is driven with 50% duty cycle at 4kHz for 80ms on touch detection.

Figure 2-2. Buzzer Drive Circuit

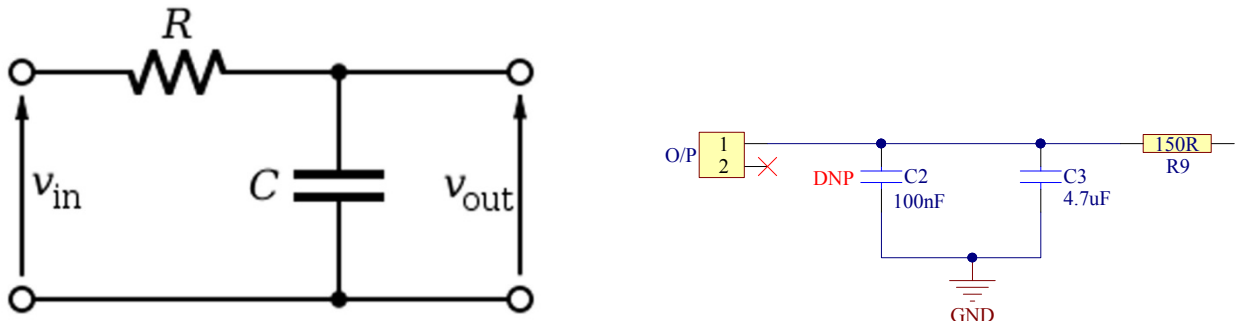


2.3 Low Pass RC Filter

Ideally an external DAC should be used to obtain analog signals from digital signal but they are relatively expensive. Another option is to use an R-2R ladder, but it is also difficult to construct and requires a lot of GPIOs.

A simple low cost technique is to use a RC filter to convert PWM signals to DC voltage. The Atmel ATtiny20 microcontroller generates output in PWM mode with varying duty cycle. A passive low pass filter is used to convert the digital PWM to analog voltage.

Figure 2-3. RC Filter Circuit

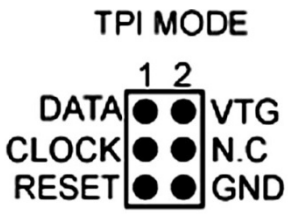


Low-pass filter circuit consists of a resistor in series with a load, and a capacitor in parallel with the load. The capacitor exhibits reactance and block low-frequency signals. At higher frequencies the reactance drops, and the capacitor effectively functions as a short circuit.

2.4 TPI Programming

The ATtiny20 supports TPI Programming. TPI is a very tiny programming interface for the newer TINY line of AVR®s with limited pins. Since the small sized tinyAVR®s lacks on-chip debugging circuit, the TPI protocol uses a new programming interface of three pins, in a half-duplex protocol.

Figure 2-4. TPI Header



A six pin TPI header is provided for the same. TPI programming can be done using AVRISP mkII and Atmel STK®600.

When the device's RSTDSB pin is set only High Voltage Programming can be used to program the chip. Since the RESET line needs to be raised to +12V for programming, this is currently only supported by the newer STK600 programming board.

3. Analog Output

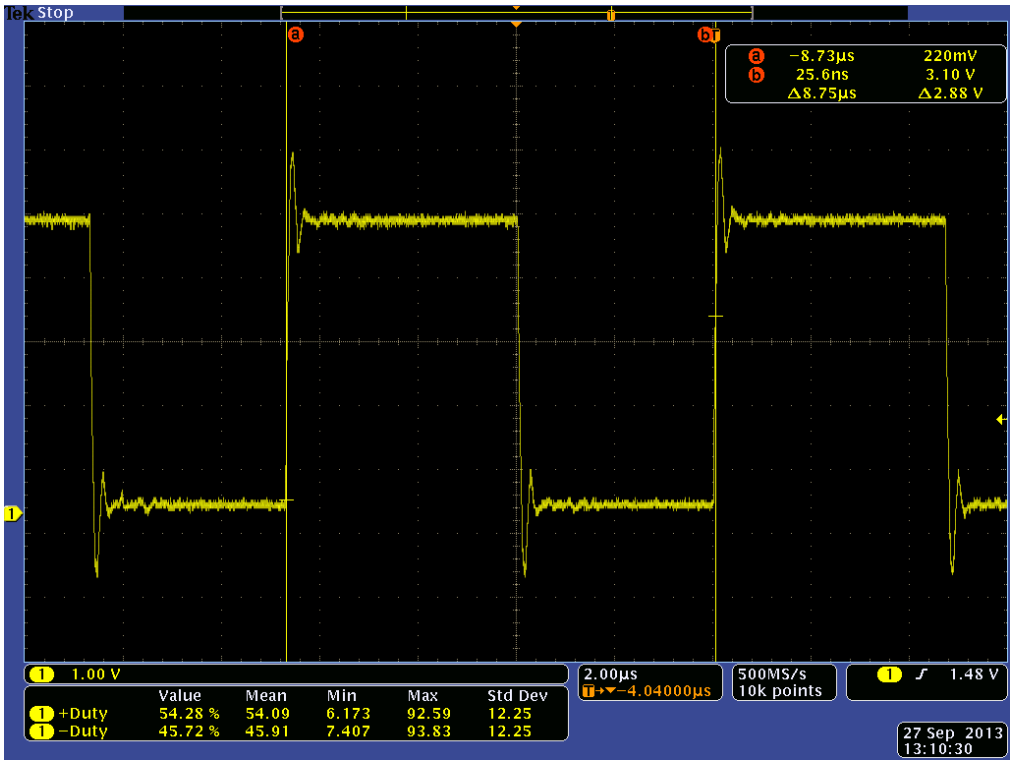
The board communicates the touch status to the host controller through ANO pin. The output is RC filtered PWM signal. There is a specific output voltage for each key.

PWM output will be generated during key press. In the idle state, when none of the touch keys are touched, the PWM output will be held high.

3.1 PWM Signal Generation

The PWM signal is generated using 16-bit Timer/Counter1 module of the Atmel ATtiny20. The Timer is configured to 16-bit Fast PWM mode. The System clock frequency in this case is 4MHz and clock prescaler has been disabled. The timer period is set to 34 counts for the PWM frequency of 117kHz.

Figure 3-1. PWM Signal for ON/OFF Key



3.2 PWM Resolution

The PWM resolution is dependent on many factors such as

- System clock frequency
- Waveform generation mode used
- Clock prescaler
- TOP value

Higher clock frequency will allow for larger number of clock ticks within the given time period required for a specified frequency in this case 117kHz. The waveform generation mode defines whether 8, 9, 10, or 16-bit PWM resolution can be achieved, the clock prescaler can divide the timer clock by a predetermined scale, and the TOP value determines the end of each counting cycle. The resolution of the PWM output can be calculated as follows:

$$\text{Resolution} = (1/34) * V_{CC}$$

3.3 D.C Voltage Output

Table 3-1. Analog Output Values

KEY	ANALOG OUTPUT (VCC = 5V)	DUTY CYCLE
IDLE STATE	5.0V	-
ON/OFF	2.7V	54.38%
MENU	3.4V	68.58%
PROG +	1.7V	34.25%
PROG -	3.9V	77.16%
VOL +	2.4V	48.56%
VOL -	4.4V	85.72%
TV/AV*	1.3V	25.69%

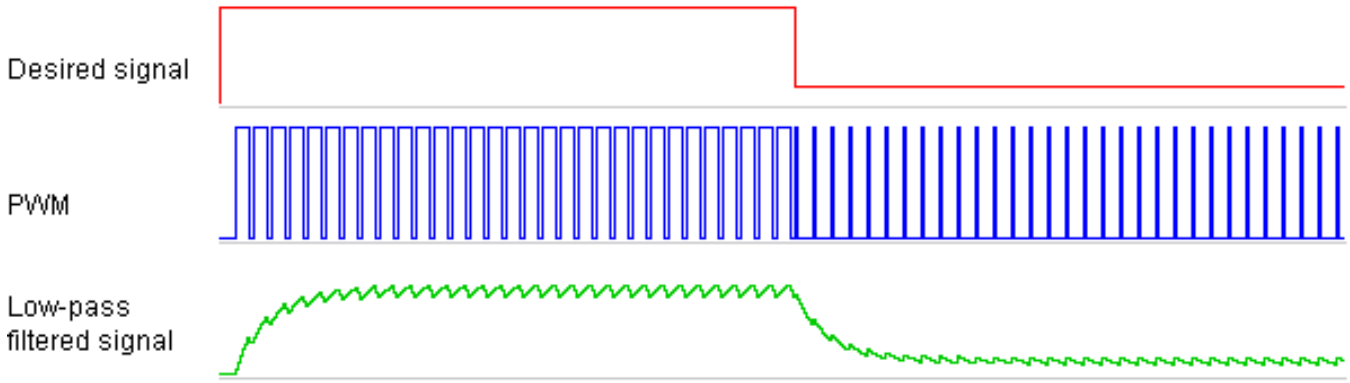
* PROG + and PROG – need to be touched together to activate the TV/AV function.

3.4 Noise Margin for PWM Output

Conversion from digital to analog would carry some ripple voltage in the output. The Low pass filter has to be designed to maintain the tolerable noise margin in the system.

The settings in the hardware and firmware have been done to have a noise margin below 0.02V. The theoretical ripple voltage of the system is 0.015154V.

Figure 3-2. Representative View of Analog Voltage Signal after Filtering



The resistor (R) has been chosen to have a low value of 150Ω so as to minimize the drop in voltage after the filtering effect. Since the PWM frequency is in kHz range, the cut-off frequency is selected in Hz so as to provide significant attenuation to the high frequency signal.

$$f = \frac{1}{2\pi RC}$$

The C value was calculated using the above formula after selecting 225Hz as the cut-off frequency.

3.4.2 Transient Analysis Model

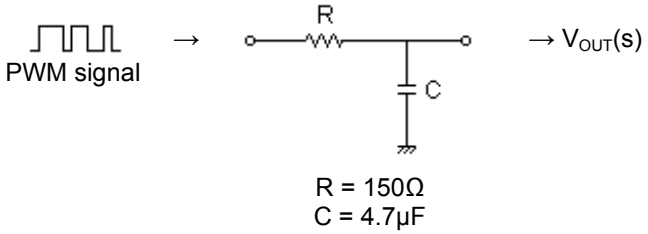


Table 3-2. Transient Analysis of the RC Low Pass Filter

TRANSIENT ANALYSIS PARAMETER	VALUE
Transfer function	$G(s) = \frac{1418.43971631}{s + 1418.43971631}$
Cut-frequency	$f_c = 225.75169Hz$
Peak-to-peak ripple voltage Duty cycle = 50%	$\Delta V_{pk-pk} = 0.015154V$
Settling time (0% to 90%)	$t_r = 0.0016233\ sec$

4. Pin Configuration

4.1 QTouchADC Sensing

The touch sensing is done using the internal ADC module of the microcontroller. Thus pins which are connected to the ADC module are connected to the sensor electrodes.

Table 4-1. Pin Configuration of Sense Pins

FUNCTIONALITY	MCU PIN #	MCU PIN NAME
KEY0	12	PORTA1
KEY1	11	PORTA2
KEY2	10	PORTA3
KEY3	9	PORTA4
KEY4	8	PORTA5
KEY5	7	PORTA6

4.2 Analog Output

The analog output is generated by using the PWM module of the microcontroller.

Table 4-2. Pins Configuration for Analog Voltage Output

FUNCTIONALITY	MCU PIN #	MCU PIN NAME
ANALOG OUTPUT	5	PORTB2 (OC0A)

4.3 Buzzer

The buzzer is driven using PWM module of the microcontroller.

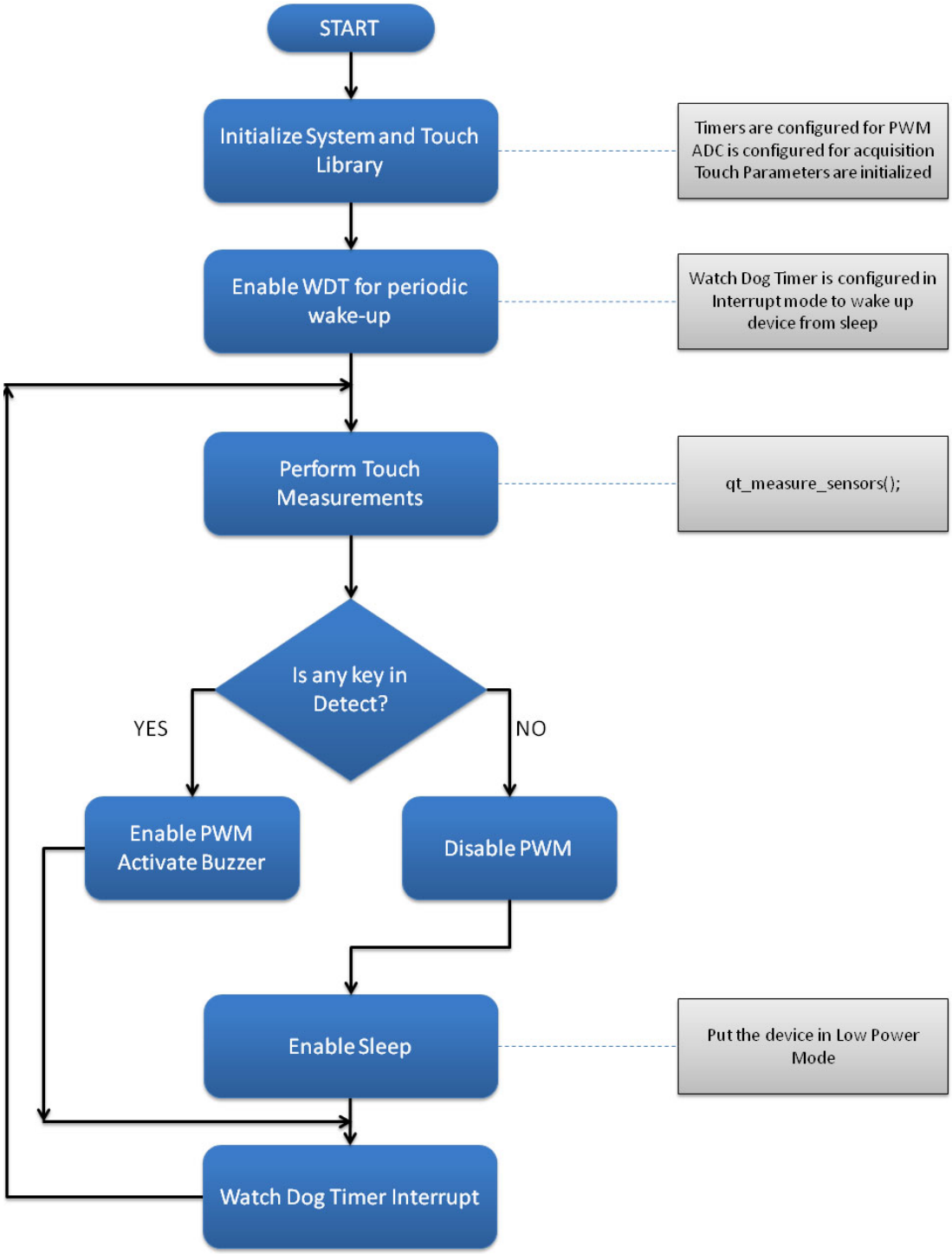
Table 4-3. Pin Configuration for Buzzer

FUNCTIONALITY	MCU PIN #	MCU PIN NAME
BUZZER	6	PORTA7 (OC0B)

5. Firmware

The firmware of the TV Control Touch Keyboard has two basic parts. The touch library which performs the capacitive touch measurements and the User Application Code which takes care of PWM generation and buzzer output based on the sensor states. Refer to Section 6.4 of Atmel QTouch Library 5.0 User Guide for details of firmware flow and configuration.

5.1 Application Code Flow



5.2 Sensitivity Tuning in Firmware

In QTouchADC method does not use any external components. All sensitivity tuning parameters are to be adjusted in the firmware using the following parameters. Refer to the Section 2 of Atmel AVR3001: QTouchADC Measurement and Tuning for better understanding of the optimal settings for good sensitivity.

5.2.1 Over-sampling

Increasing the over-sampling increases the sensitivity of the sensors. This parameter is to be modified in the Linker Options in the IAR™ IDE.

```
/* Default value: 1.
Values: 1u, 4u and 16u */
#define DEF_QT_BURST_LENGTH           (0x01u)
```

5.2.2 Detect Threshold (NTHR)

Increasing the detect threshold decreases the sensitivity. This parameter can be modified in the *touch_config_tiny20.h* file.

```
/* Sensor detection threshold value.
   Range: 1u to 255u. */
#define DEF_QT_SENSOR_0_THRESHOLD       (6u)
#define DEF_QT_SENSOR_1_THRESHOLD       (6u)
#define DEF_QT_SENSOR_2_THRESHOLD       (6u)
#define DEF_QT_SENSOR_3_THRESHOLD       (6u)
#define DEF_QT_SENSOR_4_THRESHOLD       (6u)
#define DEF_QT_SENSOR_5_THRESHOLD       (6u)
```

5.2.3 Charge Share Delay (CSD)

Increasing the charge share delay time allows for increased time for charge transfer between sensor electrode and sampling capacitor. For good sensitivity it is necessary to ensure that full charge transfer takes place. This parameter can be modified in the *touch_config_tiny20.h* file.

```
/* Range: 1, 2, 4, 8 or 10 internal System Clock cycles.
CAUTION: Do NOT append 'u' or () in this case. */
#define DEF_QT_DELAY_CYCLES             1
```

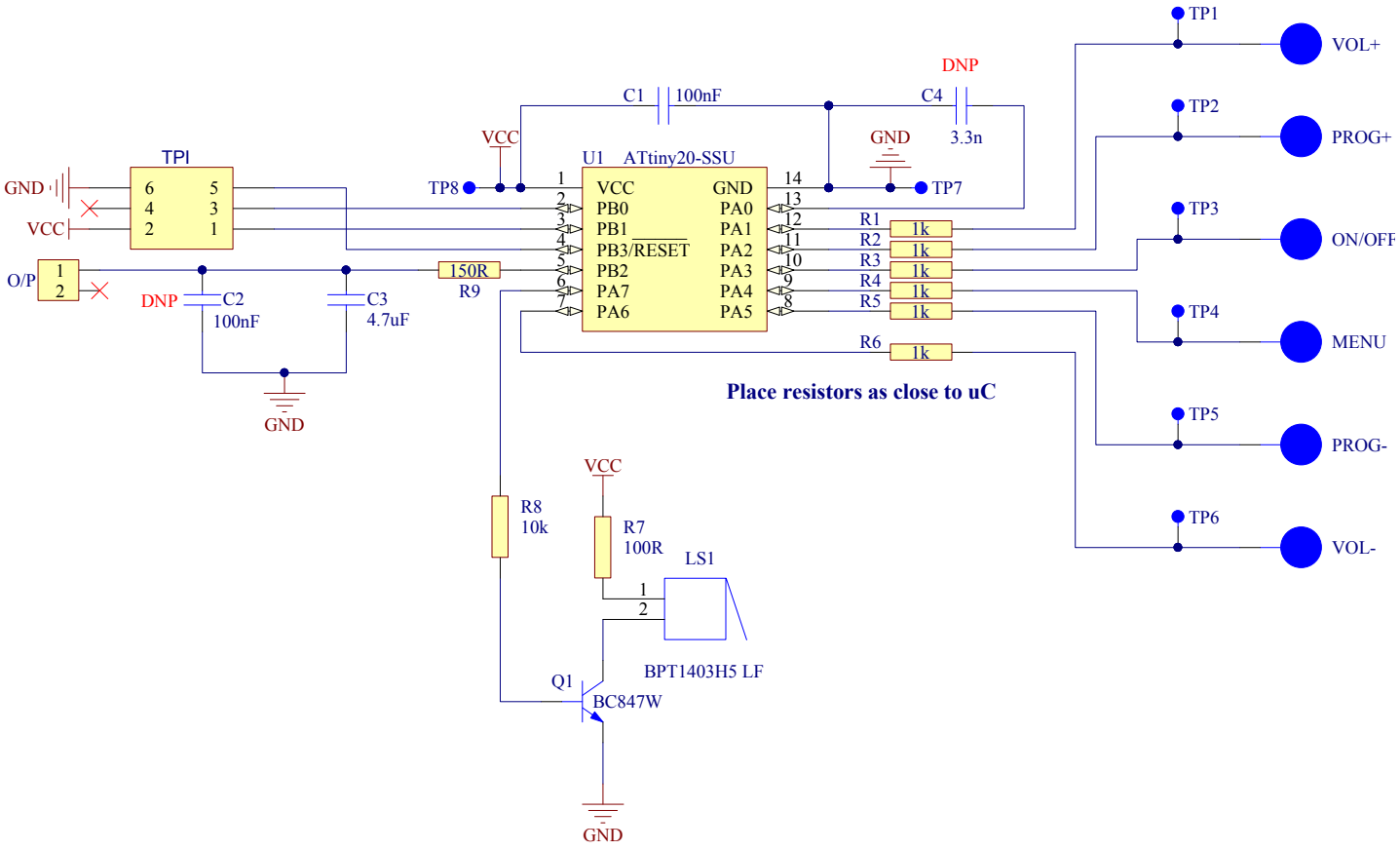
5.3 Files in Firmware

The source code contains the following files:

FILENAME	DESCRIPTION
libtiny20-6qt-k-0rs.r90	Touch Library file for QTouchADC on Atmel ATtiny20
touch_api_tiny20.h	Touch Library API file
touch_config_tiny20.h	Configuration file for setting of tuning parameters
main.c	User application code

6. Schematic Design

Figure 6-1. Schematic of the Atmel ATtiny20 Based TV Control Touch Keyboard



7. PCB Layout

The design for the TV Control Touch Keyboard follows a dual layer construction. The sensors are on the top layer which is to be covered by a dielectric front panel. The bottom layer has the components and the necessary routing and ground loading. FR4 PCB substrate material is recommended for optimal performance.

Figure 7-1. PCB Layout - Top Layer

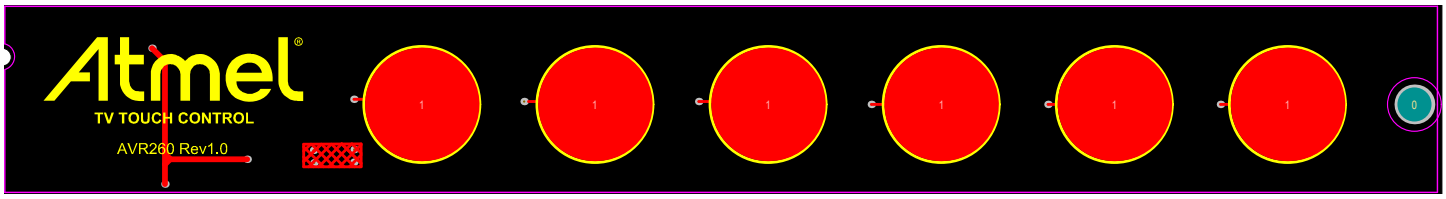


Figure 7-2. PCB Render – Top Layer

Figure 7-3. Bottom Layer

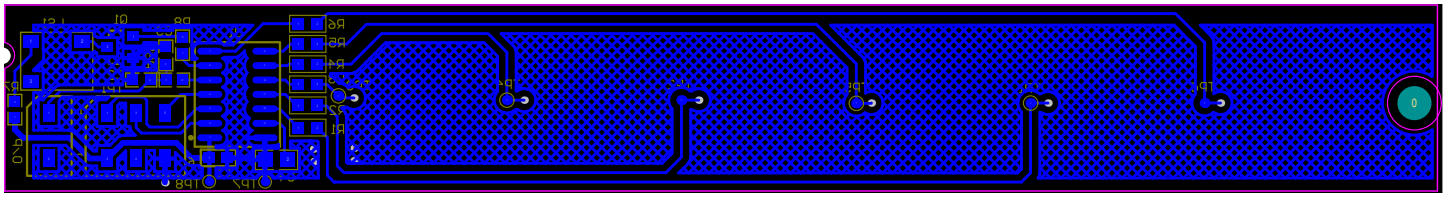
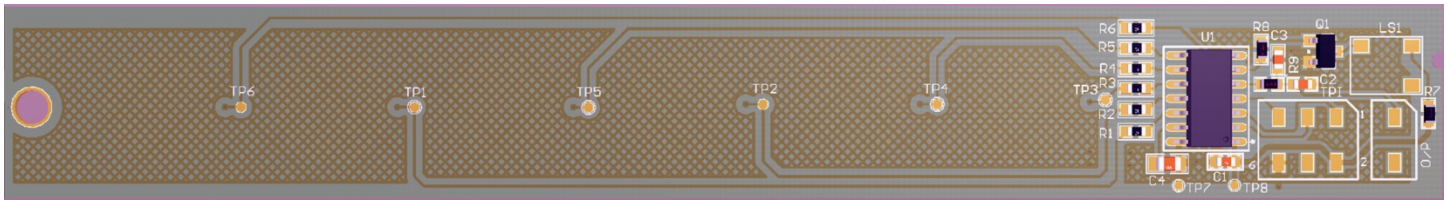


Figure 7-4. PCB Render – Bottom Layer



8. Component List

DESIGNATOR	COMPONENT TYPE	COMPONENT VALUE	FUNCTIONALITY
U1	MCU 14pin-SOIC	ATtiny20	
R1, R2, R3, R4, R5, R6	SMD resistor (0603)	1k	Series resistor for Touch
R7	SMD resistor (0603)	100E	Buzzer drive resistor
R8	SMD resistor (0603)	10k	Transistor bias resistor
R9	SMD resistor (0603)	150E	Low Pass Filter (R)
C2	SMD capacitor (0603)	4.7µF	Low Pass Filter (C)
Q1	Transistor	BC847W	Buzzer Drive
LS1	Piezo Buzzer		Buzzer

9. Recommended Reading

- AVR3001: QTouchADC Measurement and Tuning
- Atmel QTouch Library 5.0 User Guide
- QTAN0079: Buttons, Sliders and Wheels Touch Sensor Design Guide

10. Revision History

Doc. Rev.	Date	Comments
42208A	10/2013	Initial document release

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