AN11095

Capacitive touch sensing using the LPC176x/5x

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Document information

Info	Content
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Abstract	This application note describes the principle of using the LPC176x/5x series of microcontrollers from NXP Semiconductors for capacitive touch sensing

Revision history

Rev	Date	Description
1	20110801	Initial version.

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1. Introduction

This application note describes a simple capacitive touch sensing method using the ADC input of the LPC176x/5x microcontroller.

The capacitive touch sensors used in this application note are areas of copper on the PCB of a PCF8883 evaluation board (see Fig 1). One of four available sensors is tied to an RC network and connected to an ADC input channel of the micro (see Fig 2).

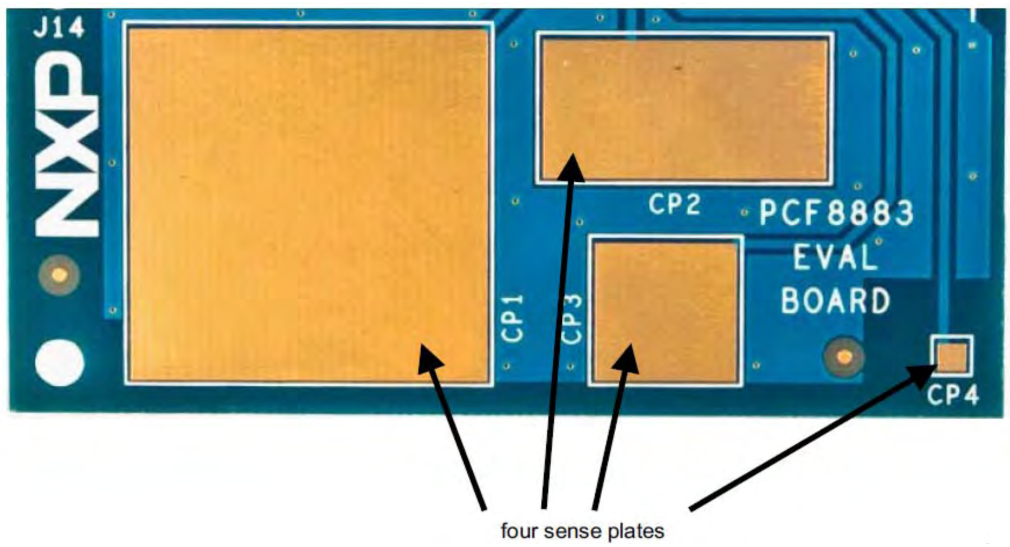


Fig 1. Sensors on the PCF evaluation board

2. Application principle

Sensing of the capacitive touch pin can be done on each of the ADC input pins, and every pin can be configured as well for a general purpose output function.

The sampling process (see Fig 2) is performed as follows:

1. Each I/O pin is configured as an output and driven high. This is used to charge the external RC network and the capacitive plate selected on the TCF evaluation board.

   When a measurement needs to be taken, the pin function is switched to the ADC input mode. Additionally, the pin drive strength is set to ‘float’, thus removing the internal pull resistor

   This causes the external capacitances to discharge via the external load resistance provided on the board, with a discharge curve which will depend on the capacitance and resistance values assembled on the board, and the parasitic capacitances related to the board itself.

   For example, the PCF evaluation board has a 5 kΩ / 50 kΩ resistor partition and a 10 pF capacitance assembled by default.

   When one of the capacitive plates gets touched, the total capacitance will include the body capacitance and increase in value, thereby increasing the time constant associated with the RC network discharge process.

In this way it is possible to compare the voltage reading being performed with a threshold value, in order to detect the button being pressed by the user in the two cases.

2. Sample the discharge curve. This is done by starting the ADC and reading out the converted value. The sample and hold function is performed in one ADC clock, and after 65 ADC clocks the ADC measurement is available in the relative data channel register AD0DRn. The end of conversion is signaled by the DONE bit being set in the ADC status register ADSTAT.
3. Finally, the I/O pin is configured back again as a ‘high’ output (back to first step) and the pull up resistor is switched on again.

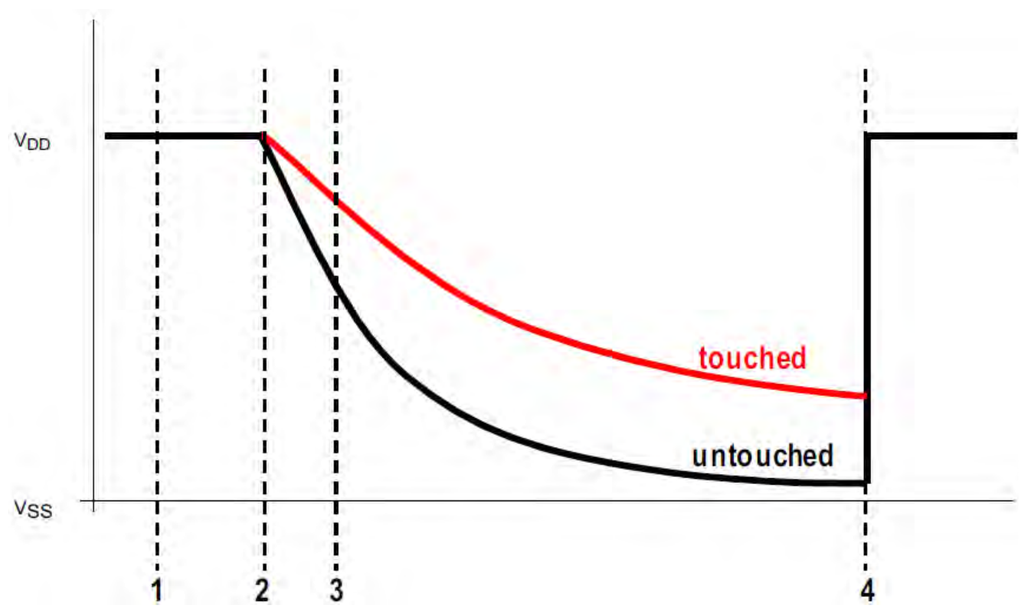


Fig 2. Waveform on ADC sensing pin

3. Hardware configuration

The hardware required for the test is an LPCXpresso 1768 stick and a PCF8883 evaluation kit (for the sensors). The following pins are used on the LPCXpresso stick:

Table 1. Hardware connection list

Signal	Port	Connector
Uart_TxD3	P0.0	J6, pin 9
AD0.0, GPIO_0.23	P0.23	J6, pin 15
AD0.1, GPIO_0.24	P0.24	J6, pin 16
AD0.2, GPIO_0.25	P0.25	J6, pin 17
AD0.3, GPIO_0.26	P0.26	J6, pin 18
AD0.4, GPIO_1.30	P1.30	J6, pin 19
AD0.5, GPIO_1.31	P1.31	J6, pin 20
AD0.6, GPIO_0.2	P0.2	J6, pin 21
AD0.7, GPIO_0.3	P0.3	J6, pin 22
GND		J6, pin 54

Connect any AD0.n port to the signal pad of connector RU1 and the GND pin to the ground pad of connector CU1 (refer to the PCF8883 evaluation board schematics and Fig 4). Diagram in Fig 3 shows ADC channel 2 and channel 3 being connected.

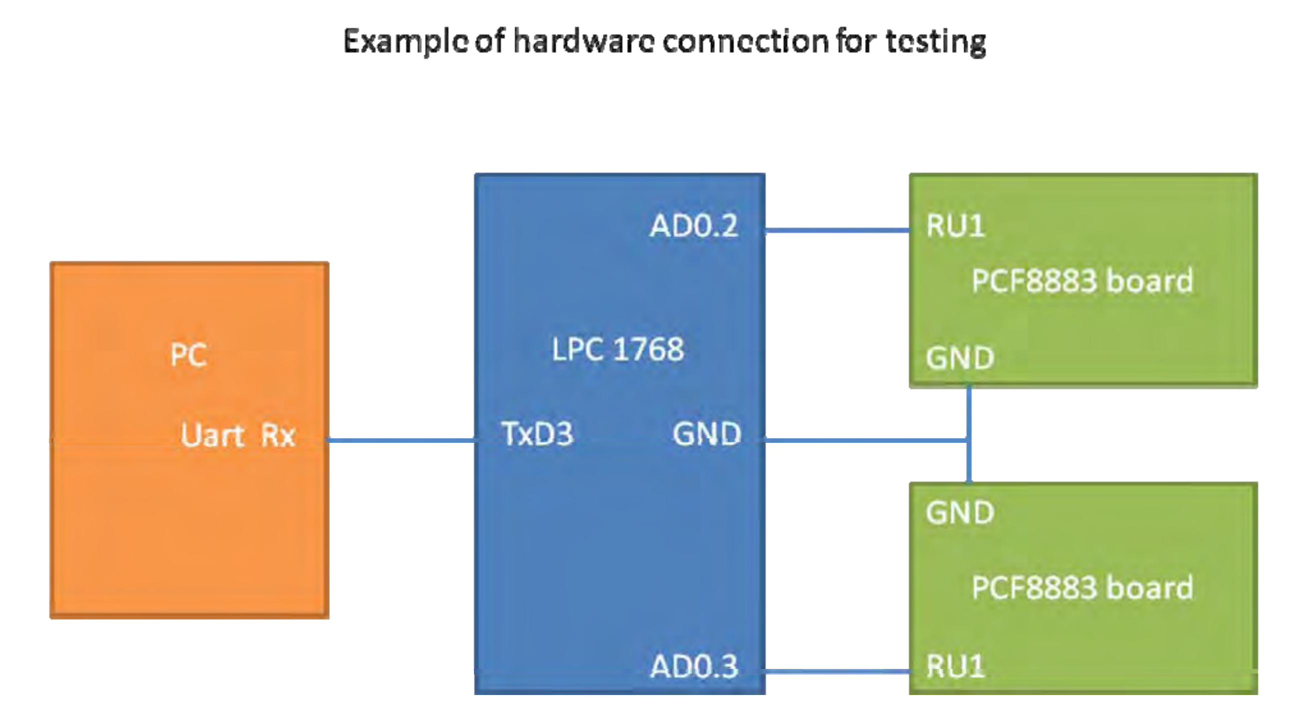
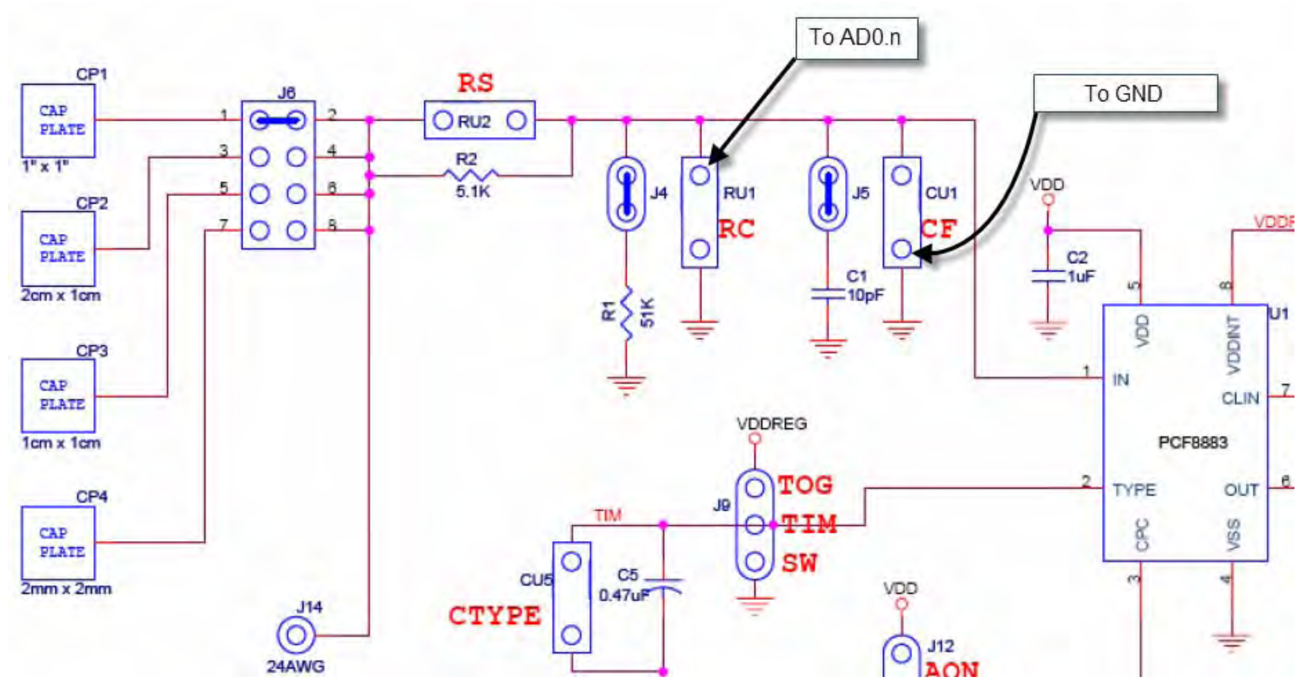


Fig 3. Hardware connection diagram

Note: For simultaneous testing of multiple channels, multiple PCF evaluation boards are required since only one type of sensor can be selected at one time on the PCF boards.



Note: CF pad connection for GND side was chosen for convenience, RC pad pin could be used as well

Fig 4. Schematic details for hardware connection

The default sensor plate selected on the PCF evaluation board is CP1.

The other sensors can be chosen by using Jumper J5, although this would require a small hardware modification (cutting a board trace as documented in the PCF evaluation board user manual).

4. Demo code description

The LPC176x/5x example code follows the same principle as described in AN11023 for the Cortex-M0 platform, although there are a few differences and enhancements introduced.

The demo software is able to handle multiple channels, and can be configured to use all of the available ADC channels on the LPC17xx device.

In the file *config.h* the user can specify a mapping between a logic keypad number and the associated ADC channel number. Additionally, the user can specify if a specific keypad (numbered from 1 to 8) is used or not. This is used at compile time to reduce the size of the code in case the keypad is not used.

There is a table of callback functions, which are defined in files *callbacks.h, callbacks.c* and are related to the functions which are called by the application whenever a key press is detected.

A calibration loop is run at startup which performs a number of successive readings on each channel, calculates a reference mean value, and stores this for later use in order to calculate the detection thresholds.

After the calibration loop is finished, the CPU goes to sleep by issuing a “wait for interrupt” instruction, waiting for the post-processing to be performed.

The sampling of the channels is done periodically, being triggered by the Systick timer every 10 msec. This periodic event could be generated via any other timer, though. Systick was chosen since only this periodic timing functionality is really required.

When the Systick interrupt is triggered, the configured ADC channels (the channels which are defined as being used, thus linked to a “logical” keypad number) get sampled one after the other by triggering the ADC channel conversion in software.

The ADC clock was chosen as close as possible to its top supported speed of 13 MHz, for reducing the latency when performing the conversion.

When the Systick interrupt routine has finished looping over all active ADC channels, at the end of the Systick handler, a GPIO pin is used to toggle the led on the LPCXpresso stick, to provide a “heartbeat” signal. The interrupt handler is then exited.

At this time, the CPU is woken up from sleep and starts processing the readings by calling the function `processKeystrokes()`.

The default rule being chosen for the detection of a sensor being touched requires the current ADC reading to be above 8 % of the average. A total of M consecutive detections (default of 8) being performed in a row define a key press event.

This is used to implement debounce functionality, and can be changed as desired and appropriate.

When it is detected that a key has been pressed, the associated callback function is run.

The default example callbacks are all outputting a debug string on the UART3 interface, which includes a progressive counter, the keypad number pressed, the last ADC reading and the average (threshold) value for that channel. The UART configuration is very simple, set at 115200 bps, 8 bit, 1 stop bit. Neither parity check nor control flow are used.

The software example is written in C language and compiled using Keil’s uVision (MDK-ARM, V4.20). For LPC176x/5x microcontroller configuration the standard CMSIS startup modules (startup_LPC176x/5x.s and system_LPC176x/5x.c) from Keil were used.

The system clock used is the IRC, and the CPU is configured to run at 100 MHz via the internal PLL. The demo software was tested on the LPCXpresso stick assembled with a LPC1768 device.

4.1 Implementation details

The actual demo code determines the compare thresholds at the beginning of the application, but does not update the threshold values during the application’s lifetime.

For a more sophisticated behavior, it might be desirable to adapt the thresholds at runtime, to take into account possible changes in the environment which can have an influence on the sensor’s behavior (temperature, aging, dirt etc), if the system is staying powered for long periods without being restarted. Also, some filtering might be introduced to reduce other effects like interference and noise on the readings.

The user might also choose, e.g., another timer to trigger slower periodic updates of the threshold, or to perform a full periodic calibration (instead of just a start-up calibration), or to change the thresholds dynamically during the processing of the readings.

However, all of this is highly application and system dependent, so the demo application does not cover such scenarios.

Additionally, more advanced strategies might be used to determine the most effective thresholds and algorithms to determine a key press event. This would depend as well from the board layout and the RC characteristic of each load connected to the ADC pins. The demo code is just using a simple static threshold level for the detection process.

The processing done within the Systick interrupt routine is kept to a minimum, and the processing of the ADC readings is delegated to the application layer. This is in order to keep the IRQ latency to the minimum possible, improving the system response.

In case other system or peripheral interrupts might be active, and preempt the Systick interrupt, the user will have to ensure that the sampling steps 2 and 3 are not being disrupted. This means the higher priority interrupts will need to be masked, to preserve the timing relationship between the switching of the IO pin to ADC mode, and the ADC trigger point on the discharge curve.

5. References

For further details please refer to the following publications:

- Datasheets / User Manuals / Application Notes / Example code:

  http://nxp.com/microcontrollers/
- AN10832: “PCF8883 - capacitive proximity switch with auto-calibration”:

  http://www.nxp.com/documents/application_note/AN10832.pdf
- UM10370: “User Manual for the PCF8883 Evaluation Kit OM11055”:

  http://www.nxp.com/documents/user_manual/UM10370.pdf
- AN11023: “Capacitive touch sensing using the LPC11xx”:

  http://www.nxp.com/documents/application_note/AN11023.pdf

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