Application Note

"How to use the PE5004 in projected capacitive touch applications."

1 Introduction

The PE5004 is a sensing circuit for capacitive sensor arrays. Capacitive sensor elements are easy and cost effective to build, either on printed circuit boards or on glass substrates coated with thin metals such as indium tin oxide (ITO). The chip integrates all circuitry needed for interfacing matrices of up to 10 x 10 sensors, making it ideal for projected capacitive touch sensing applications and reducing the overall bill of materials.

This document shows the ease of using the PE5004 in a touch sensing application with an ITO-coated glass. Possible applications are all kinds of touch- and pen-screens as well as touch pads.

For information on the working principle and complete description of the PE5004 and a guide how to design capacitive sensors please refer to the PE5004 data sheet.

Table of Content

2 Revision History

Version	Date	Changes	Page
Initial Version V1.0	03/2012		

3 System Setup

3.1 Hardware Setup

The Setup described in this document consists of:

- Controller Interface board (available from PE GmbH)

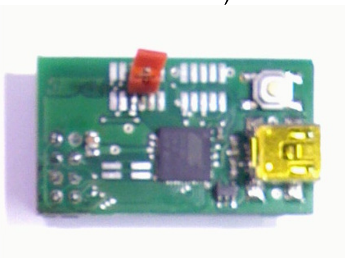

Figure 1: controller interface board, refer to AppNote 16 for details.

- PE5004 on adapter board (layout available)

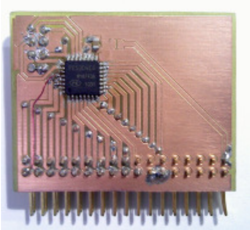

Figure 2: PE5004 on adapter board

The adapter board only consists of 4 parts: the PE5004, a block-capacitor and pin headers for interfacing between ITO- and controller-board.

- ITO cap. sensor array (by AMT Corp. or any other supplier)

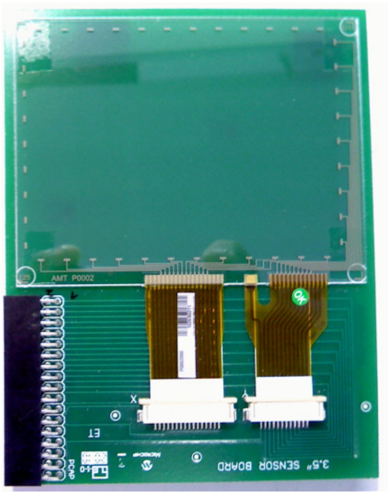

Figure 3: ITO cap. sensor array

The ITO board originates from the DM160211 Development-Kit from Microchip®.
It consists of a glass substrate with a 3.5” diagonal. The substrate is coated with a 12 x 9 ITO sensor array. The board contains no further hardware, just traces from the ITO to the pin header.

3.2 Assembly

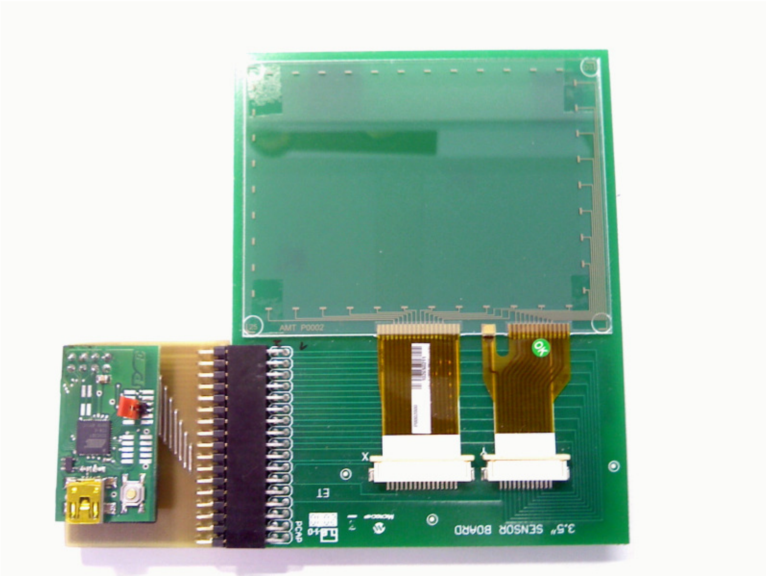

Figure 4: Board assembly

4 Sensing Basics

When connecting the USB-cable to the CIB on startup, the Microcontroller Unit (MCU) initiates the PE5004 and performs calibration. It continuously reads the measured capacity afterwards. A plot of the measured values vs. time is shown in Figure 5.
When the sensor field is not touched, a so called “baseline” can be observed. This baseline corresponds to the untouched sensor capacity. During a touch event, the capacity will change, and so does the result from the PE5004. Typically, the raw data during a touch are lower than the baseline, but this strongly depends on the environmental conditions (sensor shape, coating, grounded or floating operation etc).

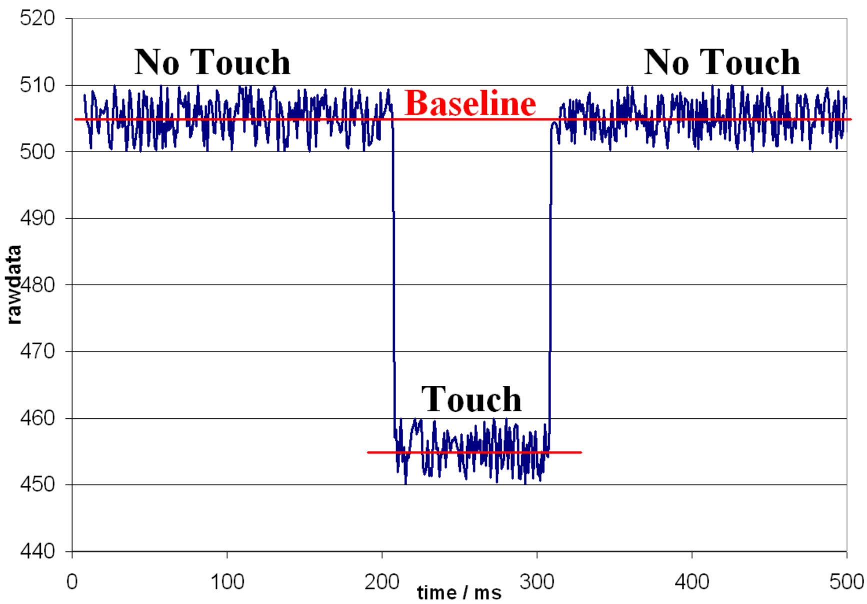

Figure 5: Raw data with baseline

5 Touch recognition

A touch can be detected as major change from the baseline. Therefore the baseline is continuously subtracted from the measured data, resulting in near-zero values in the untouched state. The baseline is measured during calibration at startup of the interface board. A good visual display for the measured data is the grid view (see Figure 6). It shows the matrix data in an isometric view. In the example given below, the substrate is touched at the left center, resulting in lower values at this position (negative peak). This touch can easily be detected by introducing a threshold level. The pad is touched if measured data is lower than the threshold value. Bouncing during proximity can be avoided by using a hysteresis.

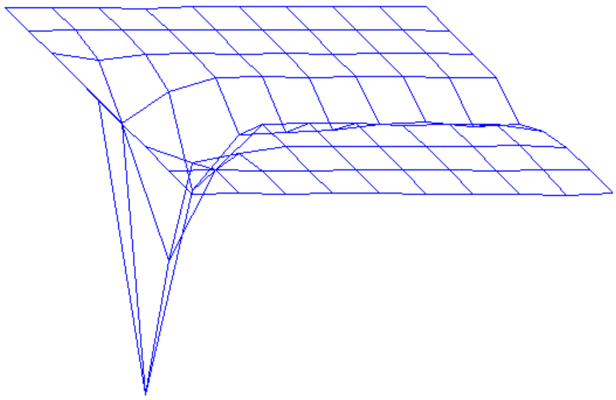

Figure 6: Raw data in grid-view

6 Touch position

6.1 Single touch

The rough position of a touch can be determined by finding the minimum value in the matrix.
Calculating the 2 dimensional center of mass (com) in the matrix interpolates between the sensors, increasing overall accuracy.
Center of mass is generally calculated using the formula below.

$$\vec{r}_c = \frac{\sum_i \vec{r}_i \cdot d_i}{\sum_i d_i} \tag{1}$$

i … index variable

$\vec{r}_c$ … vector to center of mass

d_i … fractional mass at position i

In a two-dimensional case with the axes named x and y, the interpolated position $\begin{pmatrix} x_c \\ y_c \end{pmatrix}$ can be calculated as follows:

$$\vec{r}_c = \begin{pmatrix} x_c \\ y_c \end{pmatrix} = \frac{\sum_i \begin{pmatrix} x_i \\ y_i \end{pmatrix} \cdot d_i}{\sum_i d_i} \tag{2}$$

d_i … raw-data at position $\begin{pmatrix} x_i \\ y_i \end{pmatrix}$.

6.2 Multi touch

Multiple touches are detected using the formula above for single touched, except that the area of the calculation is restricted to the nearby fields of a minimum.
The figures below show example data of a multi-touch situation. The threshold-value for the touch in this example is -100. Beginning with the lowest minimum at position (2;5) , the center of mass of this touch is calculated. The exact position of the second touch is calculated the same way.

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	-42	0	-67	-57	0	0	0	0	0
5	0	-118	-75	-109	-96	-41	0	0	0	0
6	0	-11	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	-42	0	-67	-57	0	0	0	0	0
5	0	0	-75	-109	-96	-41	0	0	0	0
6	0	-11	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0

Figure 7: Two touches in data field, (a) 1st touch (b) 2nd touch

6.3 Resolution

The figures below show 2 nearby touches (data has been inverted). In the first figure there is a minimum between the two maximums. On the right hand side, the touches are closer to each other, separation is not possible anymore. Thus the precondition for detecting separate touches is a spacing of at least 2 sensor fields.

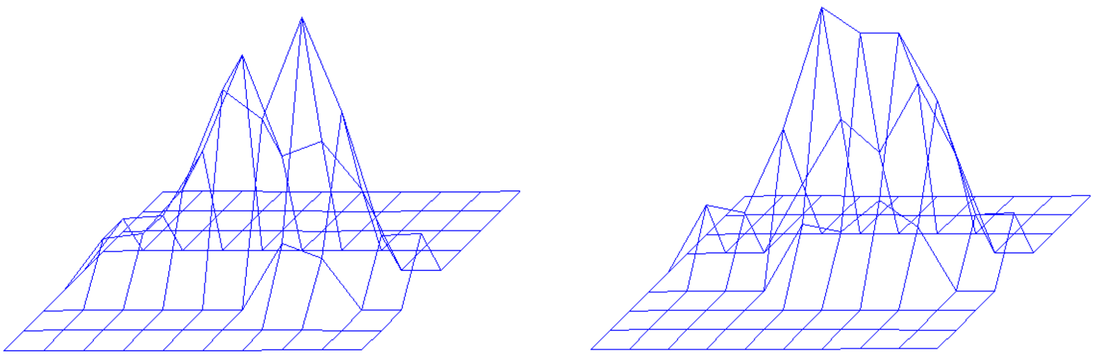

Figure 8: Two nearby touches, (a) distinctable (b) indestinctable

7 Implementation

With the touch detection from the former chapters put into software and the assembly shown in Figure 4, a pointing device can easily be implemented.
The MCU from the controller board is In-System-reprogrammed to enumerate as HID-device.
All it has to do is detecting the touch and sending relative or absolute (depending on the HID-configuration) positions via USB.

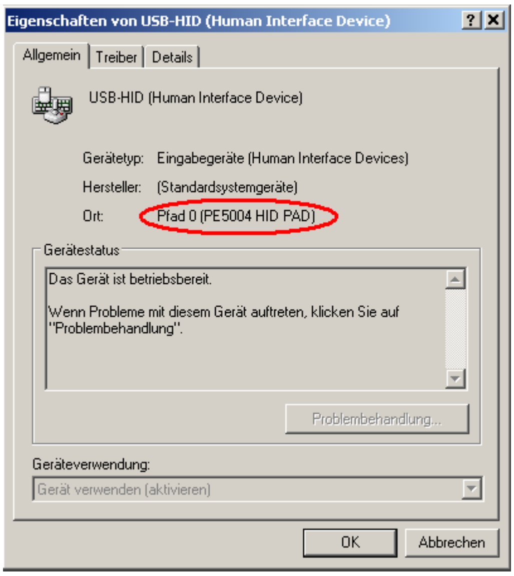

Figure 9: Using the PE5004 in a touchpad-design

The ITO-Board shows some design weaknesses (long and crossing traces). They lead to an uneven background distribution and different sensor behavior (see Figure 10, the diagonal line results from parasitics at trace crossings). Nevertheless, the PE5004 is still capable of handling these different sensors. The differences are finally eliminated during calibration.

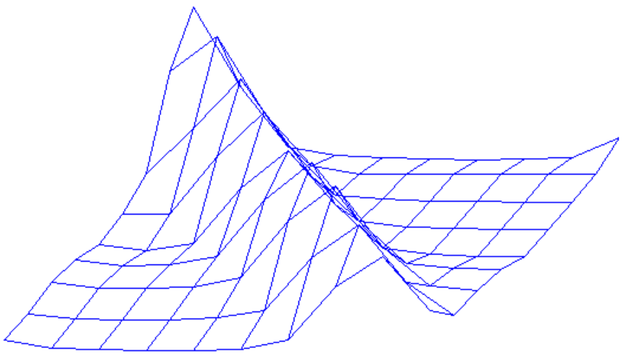

Figure 10: different sensor background

The PE5004 is fast enough to refresh the whole array with up to 100 Hz, allowing Windows® 7 to interpret multiple touches and interpret gestures when the HID-device is configured as multi-touch-screen. See http://msdn.microsoft.com/en-us/windows/hardware/gg487437.aspx for details.

8 Schematics

8.1 5004 adapter board

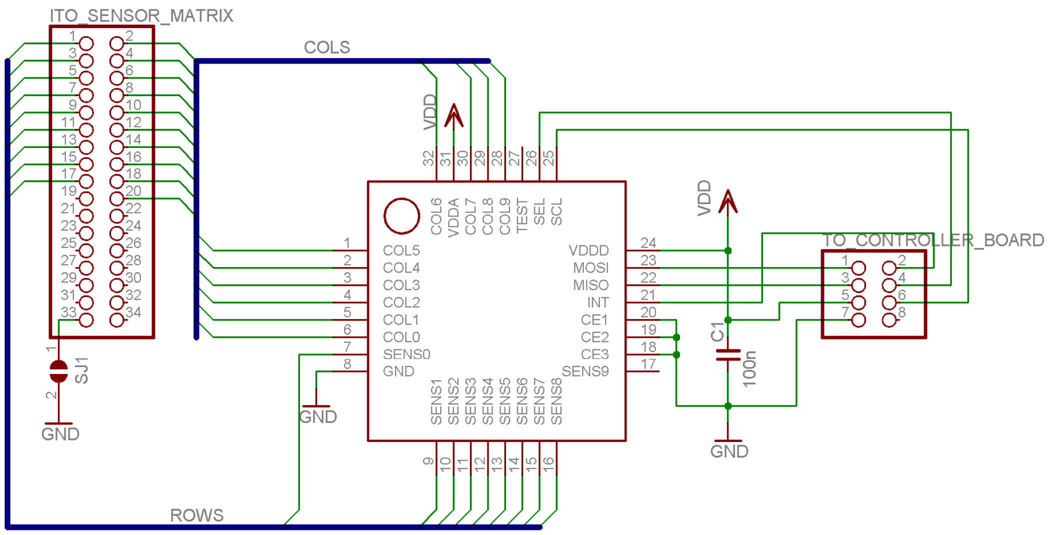

Figure 11: Schematic of PE5004 Adapter Board

8.2 Controller interface board

The schematics of the CIB are documented in AppNote 16.

9 Notes

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