



Documentation

EVA5010 User Guide

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1 Revision History

Version	Date	Changes	Page
Initial Version 1.0	09/2010		
Version 1.1	09/2010	Bill of material	16
Version 1.2	09/2010	7.4 USB read issues added	16

2 Overview

The EVA5010 is designed to evaluate the PE5010 of Productivity Engineering GmbH. The PE5010 is an integrated circuit for signal conditioning for capacitive sensors. The circuit provides two channels for single-ended and/or differential measurements.

PE5010 converts input capacitance to a digital value using a 12Bit sigma-delta converter.

Key features:

- PCB with IC, controller and sensor interface
- controller used to control PE5010 registers and support USB communication between PC software and PE5010
- Sensor interface for different kinds of sensors or to connect trim able capacitors to demonstrate the functionality of IC
- recording of sensor events in a defined time interval, either in normal mode or in interrupt mode
- detailed representation of data in MS Excel format for a graphical view in Windows OS

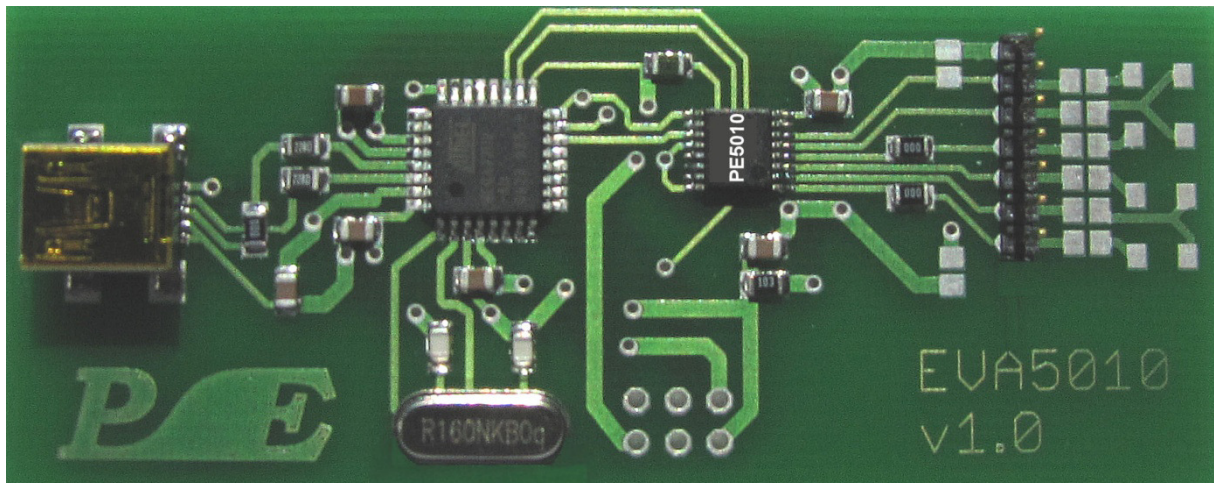


Figure 1 – EVA5010 board

3 Control software „EVA5010“

3.1 Installation

After downloading the software it needs to be installed by executing the file “**Install_EVA5010_v10.exe**”.

The EVA5010 comes with a graphical user interface for WindowsXP™ platforms. It is recommended to start with this software interface to learn about the basic functionality of the chip on the board.

All necessary files will be copied into the target directory and a group will be created in the “Start” Menu. To communicate via USB to the Atmel controller an Atmel specific DLL will be used.

The installation also consists of the source code for the GUI and firmware for the Atmel controller. This way it is possible to design specific applications.

Note: The Firmware for the Evaluation Board is divided into two categories. The first one was developed by PE. This part of firmware controls the PE5010 and does SPI communication. The second part of the firmware is provided by Atmel Corporation. It consists of a DLL files and the associated source codes. So it is possible to communicate between a PC and Atmel controller via USB.

3.2 Tab “Setup”

After starting the software, the tab “Setup” will be loaded. While no EVA5010 is connected all fields and buttons are disabled. The software automatically detects a connected device and enables default input fields.

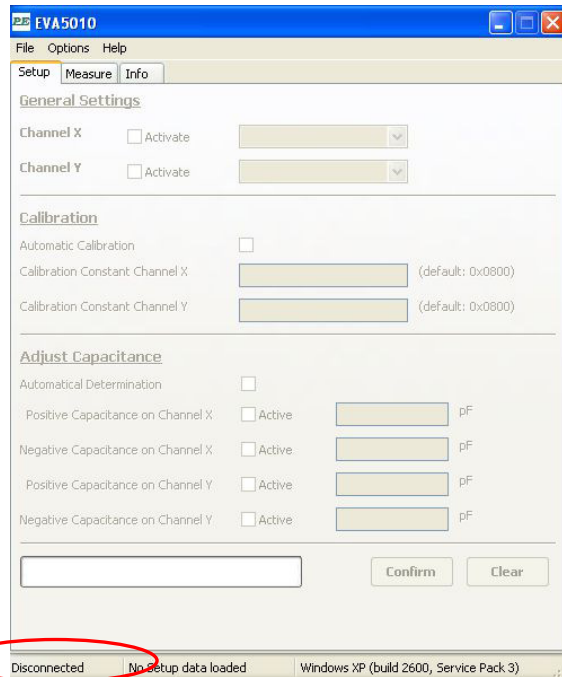


Figure 2 - No Device detected

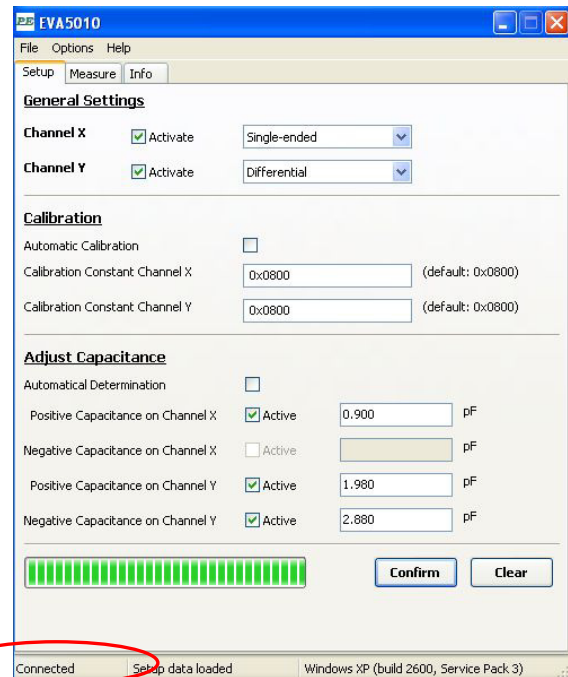


Figure 3 - Device detected

After a device was found, all obligate properties can be set by the user.

Channel X is activated at all times.

The setup data will be transferred to PE5010 by using the button “Confirm”.

Note: Before performing a measurement all setup data have to be confirmed by clicking “Confirm”.

Calibration data can be set in hex format with leading “0x” or integer decimal format without prefix.

The Adjust capacitance is set in decimal format with maximum 3 numbers after the decimal point.

By confirming setup data, the limits for all parameters will be checked and violations will be shown by an error message.

The adjust capacitance can only be set in steps of internal CAPDAC of the PE5010. The current value is stored in firmware.

By confirming setup data, the correct value for the adjust capacitance will be determined.

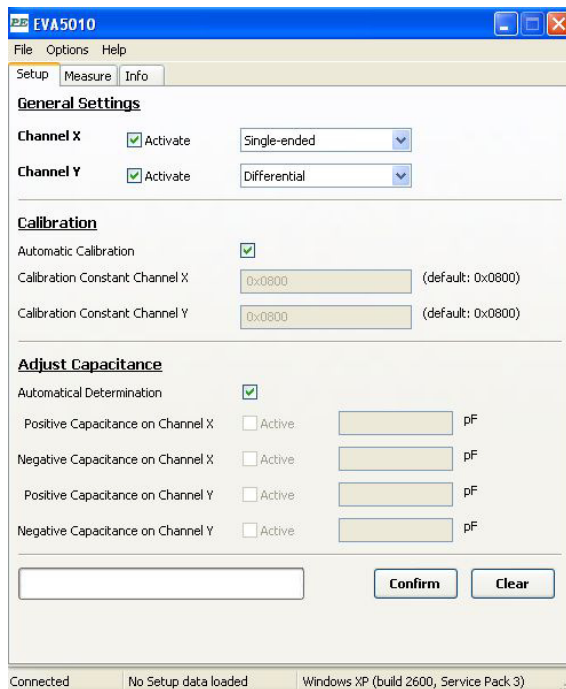


Figure 4 - ???

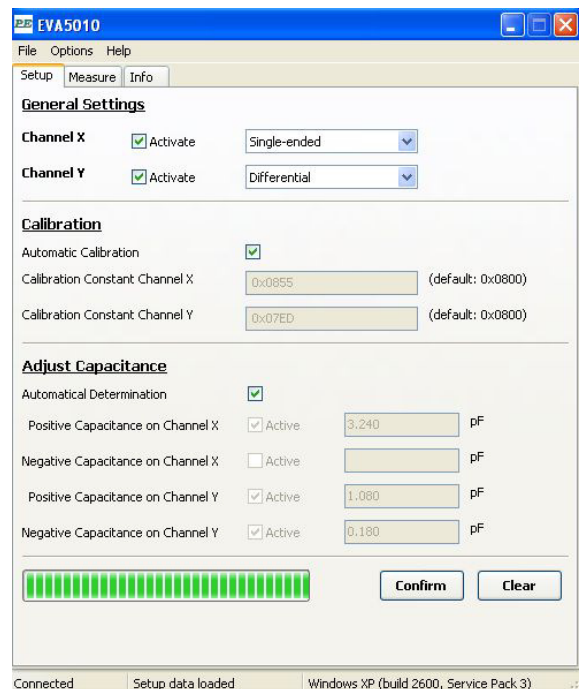


Figure 5 - ???

Auto calibration and determination before (Figure 4) and after (Figure 5) confirmation

The calibration constant and adjust capacitance can also be determined automatically. The corresponding check boxes have to be checked.

After confirming these options, the determined values will be shown.

Overview Tab “Setup”

General Settings:

Choose used Channels and differential or single-ended operating mode. The channels can have different operating modes.

Calibration:

If “Automatic Calibration” is activated the calibration constant will be determined. In this case the values cannot be changed any more. If it is not activated the calibration constant has to be set manually (default: 0x0800) for each channel.

The software decides in accordance to general settings if one or two channels are being used.

Adjust Capacitance

If “Automatic Determination” is activated the adjust capacitance will be determined in accordance to general settings. After confirmation determined values will be shown.

3.3 Tab “Measure”

In tab “Measure” conditions for measurements have to be set.
 Measurement can be started after all settings have been completed.
 The results are shown in the text box. Result and setup data can be saved to a file.

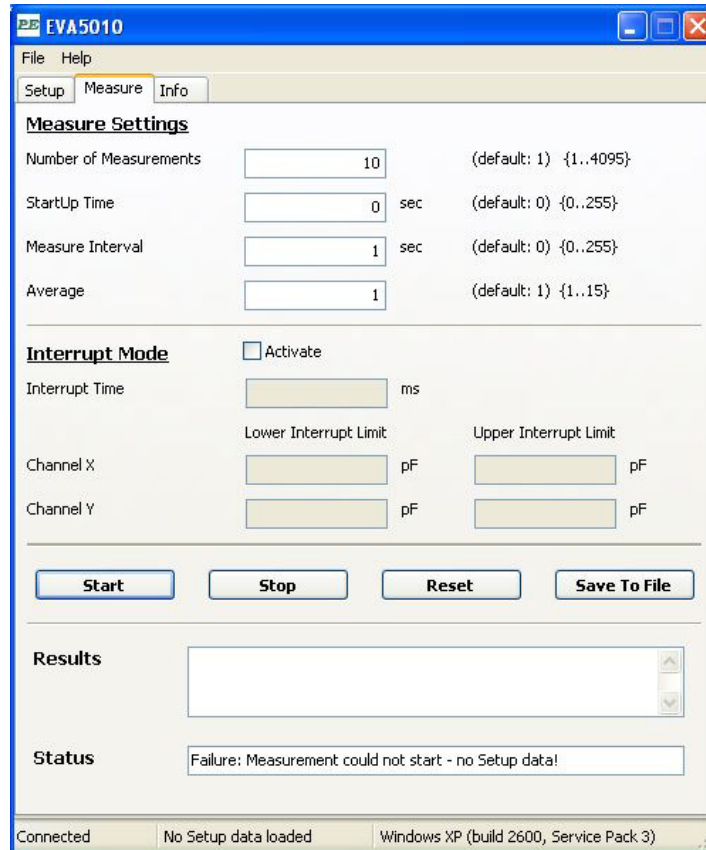


Figure 6 - If Setup is not performed, measurement could not be started

The PE5010 supports two kinds of measurements. Default mode is the “normal mode”. In this mode, measurements will be performed with a predefined number and an interval. Averaging and/or start up time can be set. The PE5010 stops automatically when the specified number of measurements has been reached. It is possible to stop measurements at any time by pushing “Stop”. A stop in start up time or measurement interval is executed after the relevant time has expired.

The second mode is the interrupt mode. The relevant box has to be checked. Measurements are carried out continuously in the interrupt interval. If a violation of interrupt limits occurs, the corresponding measured values are written into the “Results” box. The PE5010 does not stop automatically in interrupt mode. This mode has to be terminated by the user (Exception: Disconnection of PC).

Information about Start, Stop and limit violations will be shown in the “status” box.

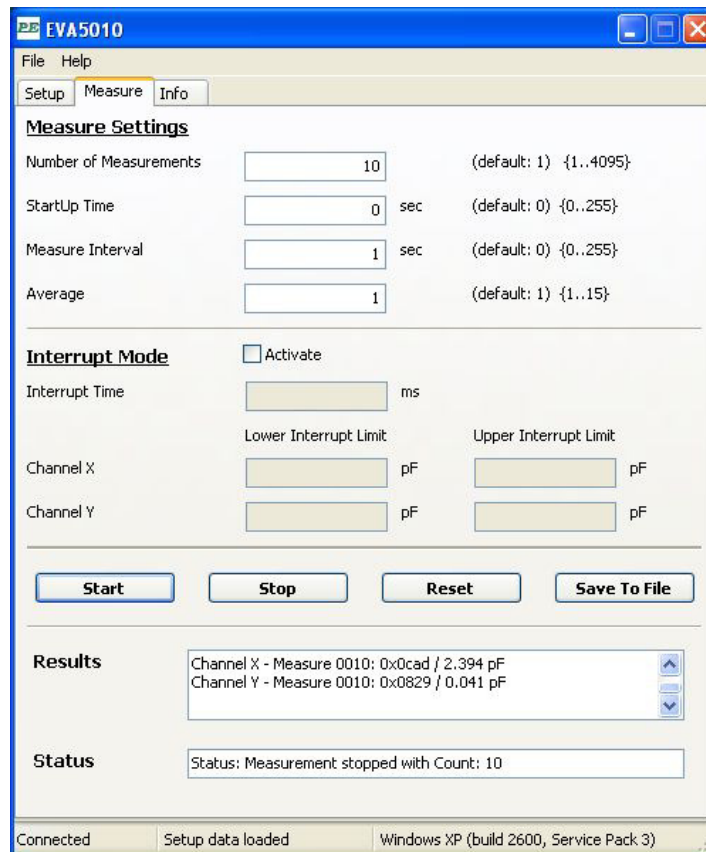


Figure 7 - Measurement successfully finished

Number of Measurements	number of measurements which are performed with actual setup data (Minimum=1, Maximum=4095) (Disabled in interrupt mode)
StartUp Time	time before starting first measurement in seconds (Minimum=0, Maximum=255) (Disabled in interrupt mode)
Measure Interval	time interval between two measurements in seconds (Minimum=0, Maximum=255) (Disabled in interrupt mode)
Average	numbers of measurements for arithmetic mean value calculation
Interrupt Time	time interval (polling) in ms (Minimum=600, Maximum=1000) (Only in interrupt mode)
Channel X/Y	lower and upper limits for interrupt mode in pF (Minimum=-2pF, Maximum=+2pF) (Only in interrupt mode)
Button "Start"	Start Measurement with setup data and specified measure settings
Button "Stop"	Stop Measurement
Button "Reset"	Clear all settings
Button "Save To File"	Save setup data, measure settings and measure results to file
Result Box	Textbox with measure results
Status Box	Status information

After performing a measurement it is possible to save all data by clicking “Save To File”.

A csv-file will be generated, so it is possible to evaluate measurement data e.g. in MS Excel or “Araneae” text editor.

In this file all important configurations will be stored. At first setup data and determined values are shown. After this measurement settings are written. Finally the measurement results in hex and decimal notation are written.

	A	B	C	D	E	F
1	EVA5010 v1.0					
2	Date:	20.08.2010				
3	Time:	14:42				
4						
5		CHANNEL X	CHANNEL Y			
6	Setup Settings:					
7	Status:	active	active			
8	Automatic Calibration:	enable	enable			
9	Sensor mode:	Single-ended	Differential			
10	Calibration Constant:	0x083e	0x07b5			
11	Automatic Adjust Capacitance:	enable	enable			
12	Positive Adjust Capacitance:	0.360 pF	not active			
13	Negative Adjust Capacitance:	disable	not active			
14						
15						
16	Normal Mode	enable				
17	Number of Measurements	10				
18	StartUp Time[s]	0				
19	Measure Interval[s]	1				
20	Average	1				
21						
22	Interrupt Mode	disable				
23						
24						
25	MEASUREMENT RESULTS	ChannelX [hex]	ChannelX [pF]	ChannelY [hex]	ChannelY [pF]	
26	Measure 0001:	0x0cac	2.392	0x082b	0.043	
27	Measure 0002:	0x0cad	2.394	0x082b	0.043	
28	Measure 0003:	0x0cb0	2.400	0x082d	0.045	
29	Measure 0004:	0x0cac	2.392	0x082f	0.047	
30	Measure 0005:	0x0cae	2.396	0x082c	0.044	
31	Measure 0006:	0x0cae	2.396	0x081d	0.029	
32	Measure 0007:	0x0cb0	2.400	0x0829	0.041	
33	Measure 0008:	0x0cad	2.394	0x082c	0.044	
34	Measure 0009:	0x0cad	2.394	0x082c	0.044	
35	Measure 0010:	0x0cad	2.394	0x0829	0.041	
36						

Figure 8 - Example – generated csv-file

3.4 Tab "Info"

At the beginning of this Tab there is information about Product and Vendor ID from the USB controller (on the EVA5010 Board it is Atmega32U2).

The next section shows the USB status. At first the status "connected" or "disconnected".

After this there are information about the HID report file, subdivided into IN, OUT and Feature report.

This information could be useful if problems in communications occur.

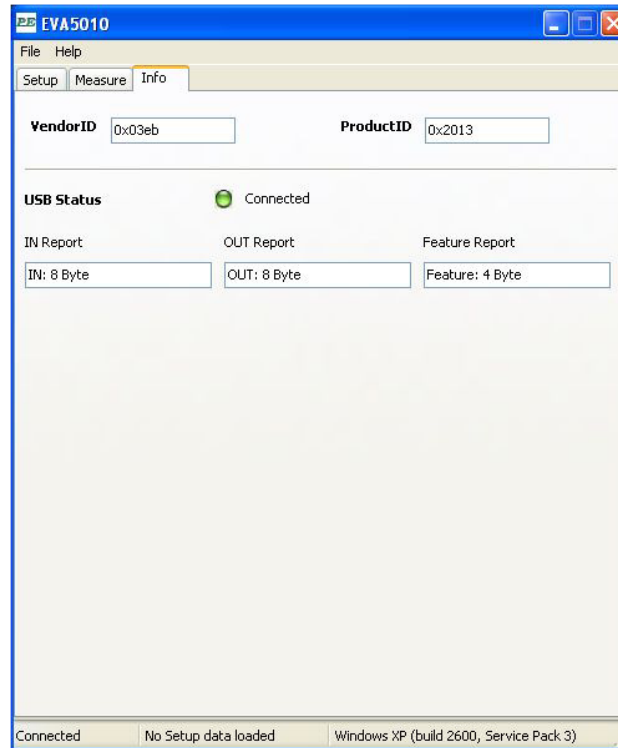


Figure 9 - "Info" Tab if device is connected

4 Introduction of EVA5010 Hardware

The Evaluation Board for PE5010 consists of two ICs and some standard components. The ICs are the PE5010 and ATmega32U2. ATmega32U2 implements a USB controller and an SPI. All commands from the PC will be sent via USB and converted in SPI commands. ATmega32U2 is supplied by USB with 5V. An internal regulator provides a 3,3V supply voltage for the PE5010. A sensor interface to demonstrate the functionality of the PE5010 is also implemented on the board.

Features of the PE5010:

- 12Bit sigma delta converter
- Two channels
- Single-ended or differential measurements for each channel
- Implemented calibration routine for both channels
- Internal offset capacitance
- SPI slave
- Low conversation time

4.1 PE5010 General Description

The PE5010 is a 2-channel 12-bit sigma-delta capacitive-to-digital converter (CDC) with an SPI. The capacitance to be measured is connected directly to the inputs of the PE5010.

PE5010 can detect capacitance changes from single-ended capacitors in a range of $\pm 4\text{pF}$ with a resolution of 2fF . Changes in differential sensors can be detected in a range of $\pm 2\text{pF}$ with a resolution of 1fF .

The basic capacitance, especially for single-ended mode, can be balanced in defined limits with internal adjustable capacitances.

The PE5010 can automatically calibrate sensors. It is also possible to calibrate manually.

There are several commands for settings and measurements.

All results have to be evaluated simultaneously, because there is no possibility for internal storage.

5 How to design an application

5.1 PCB specification

The PCB (printed circuit board) consists of the ATmega32U2 with Mini USB jack and the PE5010 with a connector for external sensor. Additionally it is possible to assemble trimable capacitors to emulate sensors. The board is powered by the USB interface.

5.2 Series capacitance and sensor parameters

Single-ended sensors with a basis capacitance higher than the offset capacitance of the PE5010 can be used with restricted conditions. In this case a series capacitance is applied. This changes the properties of the sensor. The changes are reflected in the following calculation.

Estimating series capacitance:

$$C_S \sim \frac{11pF \times C_{Sensor,max}}{C_{Sensor,max} - 11pF}$$

$C_{Sensor,max}$ is the maximum achievable capacitance of the sensor and C_S is the approximate series capacitance.

In the next step the capacitive input range with series capacitance is determined.

$$C_{in,min} = \frac{C_S \times C_{Sensor,min}}{C_S + C_{Sensor,min}} \qquad C_{in,max} = \frac{C_S \times C_{Sensor,max}}{C_S + C_{Sensor,max}}$$

$C_{in,min}$ and $C_{in,max}$ are the minimum and maximum values at the input of the PE5010. Both values have to be in the range of $0 \leq C_{in} \leq C_0$. Otherwise C_S has to be decremented. C_0 is described in the data sheet.

The maximum capacitance change of a sensor is calculated to: $\Delta C_{in} = C_{in,max} - C_{in,min}$

Example:

A humidity sensor with $C_{Sensor,min} = 80pF$ (0% rel. humidity) and $C_{Sensor,max} = 110pF$ (100% rel. humidity).

At the beginning the series capacity is roughly determined.

$$C_S \sim \frac{11pF \times C_{Sensor,max}}{C_{Sensor,max} - 11pF} = \frac{11pF \times 110pF}{110pF - 11pF} \sim 12,2pF$$

C_S shall be set to 12pF.

Within series capacitance C_S the input range for the PE5010 is determined.

$$C_{in,min} = \frac{C_S \times C_{Sensor,min}}{C_S + C_{Sensor,min}} = \frac{12pF \times 80pF}{12pF + 80pF} \sim 10,43pF$$

$$C_{in,max} = \frac{C_S \times C_{Sensor,max}}{C_S + C_{Sensor,max}} = \frac{12pF \times 110pF}{12pF + 110pF} \sim 10,82pF$$

Minimum and maximum values are within limits of the PE5010 input range.

$$\Delta C_{in} = C_{in,max} - C_{in,min} = 0,39pF \qquad \frac{\Delta C_{in}}{100} = \frac{3,9fF}{1\% \text{ rel.humidity}}$$

From the dynamic range of the sensor the sensitivity of 3,9fF for 1% relative humidity can be derived.

6 Description

The Evaluation Kit was designed to help understand and evaluate the features of the PE5010 capacitive-to-digital converter. Used external devices are standard components and do not represent a completely fine-tuned OEM application. The BOM (bill of material) for a final application may look different.

6.1 Evaluation Board Specifications

Table 1 – Board specification

Parameter	Symbol	Min	Typ	Max	Unit	Notice
Operating temperature	T_{amb}	-40	27	80	°C	
Supply Voltage ATmega32U2	V_{DD1}	4,5		5,5	V	@ $f_{CLK}=16\text{MHz}$ supplied via USB
Supply Voltage PE5010	V_{DD2}	3,0	3,3	3,6	V	Supplied by internal regulator ATmega32U2
Frequency	f_{CLK}		16		MHz	ATmega32U2

6.2 Schematic

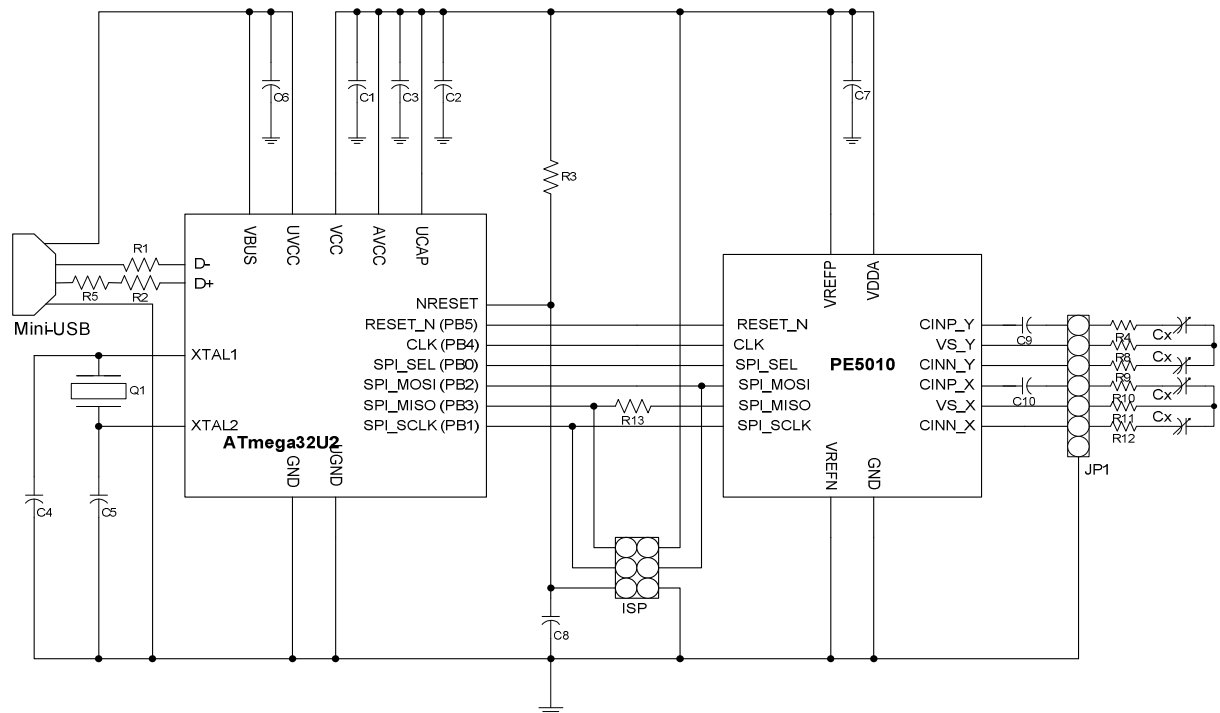


Figure 10 - Schematic of the EVA5010 Evaluation Kit

6.3 Layout

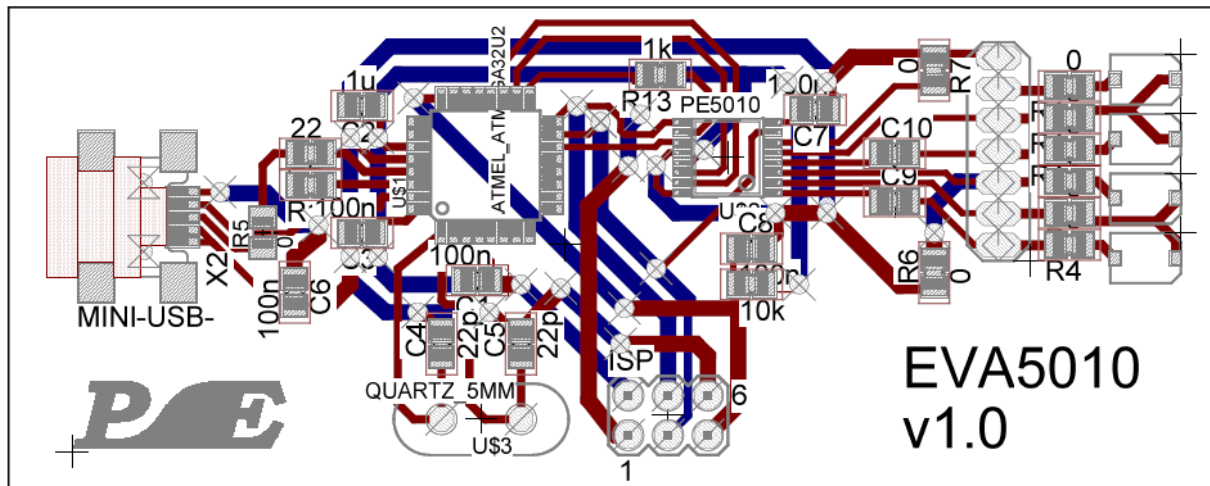


Figure 11 - Layout of the EVA5010 Evaluation Kit

6.4 Jumpers

It might be necessary to mount some variable devices for different applications on the EVA5010 board. The following table shows all variable devices and their field of application.

Table 2 - Field of applications for variable devices

Device	Default value	Description
C9, C10	0 Ohm	Series capacitance for special purposes (see section 7.3)
R7	Not mounted	0 Ohm for single-ended mode - Channel X
R6	Not mounted	0 Ohm for single-ended mode - Channel Y
R10	Not mounted	0 Ohm if emulating sensor on Channel X
R11		Positive input
R12		Virtual ground
R4	Not mounted	0 Ohm if emulating sensor on Channel Y
R8		Positive input
R9		Virtual ground

6.5 Bill of Material (BOM)

Table 3 - Required devices

Board position	Amount	Value	Package	Notice
PE5010	1		TSSOP16	
ATmega32U2	1		TQFP32	
R1, R2	2	22Ohm	0805	
R3	1	10kOhm	0805	
R5	1	0Ohm	0805	
R13	1	1kOhm	0805	
C1, C3, C6, C7, C8	5	100nF	0805	
C2	1	1uF	0805	
C4, C5	2	22pF	0805	
C9, C10	2	0Ohm	0805	For special purpose change with capacitor (refer to section 7.3)
Quartz_5mm	1	16MHz	5mm	
MINI_USB	1			USB jack
ISP	1	2x3 way		Pitch spacing 2,54mm
JP1	1	1x7 way		Pitch spacing 2,0mm

Table 4 - Optional devices (not assembled on Evaluation Kit)

Board position	Amount	Value	Package	Notice
R6,R7	2	0 Ohm	0805	Needed for single ended sensors
R4,R8,R9, R10, R11, R12	6	0 Ohm	0805	Assembled if emulating sensors
Cx	4	2.5-10.0pF		Trim able capacitor CTZ3

7 Operation

7.1 Emulating sensors with trim-able capacitor

To evaluate the functionality of the PE5010, there is no need for a real sensor. A sensor can be stimulated by trim-able capacitors.

Therefore trim-able capacitors with corresponding bridges (R4, R8, R9; R10, R11, R12) have to be mounted. For stimulating a single-ended sensor only the positive input and virtual ground is assembled with a capacitor. The negative input is set to ground via R6 or R7.

It is mandatory, that no sensor is connected.

7.2 Using sensor interface

The Evaluation Board has a sensor interface to connect different kinds of sensors. This interface can be used individually.

For using a single-ended sensor the negative input should be set to ground (R6 and/or R7).

When using the sensor interface bridges (resistors) to trim-able capacitors must not be mounted!

7.3 Single-ended sensor with higher basic capacitance

The PE5010 operates with a basic capacitance of sensors up to 11pF. There are capacitive sensors which have a basic capacitance of 100pF and more. Those single-ended sensors can be used with the PE5010 considering restricted conditions. A series capacitor has to be used with the sensor. This will also change the characteristics of the sensor. It can be calculated according to section 5.2 if all requirements are met for the corresponding application.

7.4 Software problems in USB communication between ATmega μ C and PC

The following note is relevant for understanding the software code that has been implemented in the microcontroller on the board:

Reading results via USB can cause problems as has been discovered during development of the firmware and the Graphical User Interface software. Sometimes the result data sent from the PE5010 to the ATmega is not available via USB despite a USB read command was performed.

A workaround is, to send the same command sequence (WRITE + READ) via USB again until correct data will be returned.

Tests have shown that these errors do not occur more than 5 times in succession. Otherwise the USB device is disconnected. It is assumed that the reason for this behavior is in the ATmega .dll.

A delay time of 20ms between write and read command is necessary.

8 Notes

9 Contact

Germany

Stuttgart

Productivity Engineering
Process Integration GmbH
Behringstrasse 7
D-71083 Herrenberg
Germany
Phone.: +49 (0) 70322798 0
Fax: +49 (0) 70322798 29
Email: info@pe-gmbh.com
Web: www.pe-gmbh.com

Dresden

Productivity Engineering GmbH
Branch
Sachsenallee 9
D-01723 Kesselsdorf
Germany
Phone.: +49 (0) 35204777 00
Fax: +49 (0) 35204777 000
Email: info@pe-gmbh.com

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