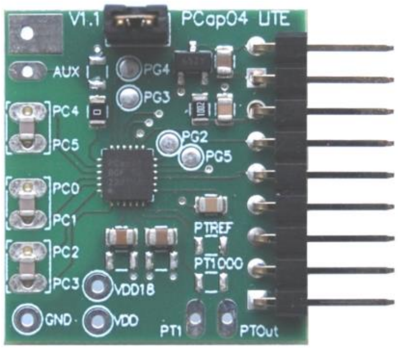

PCap04-EVA-KIT V2.0

Development Kit User Guide

PCAP04-EVA-KIT 2.0

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Content Guide

1 Introduction

The PCap04-EVA-KIT V2.0 evaluation system provides a complete system for generally evaluating the PCap04 IC. It is supplied with a main board, a plug-in board, a Windows based evaluation software, assembler software and the PicoProg Lite communication interface.

The kit includes the following elements:

PCap04 LITE V1.0 BGRP | PicoProg Lite V1.0 | USB to USB-C data cable

Figure 1: Elements of the development kit

Please download the software for the kit from https://downloads.sciosense.com/PCAP04 and look for the latest revision.

1.1 Ordering Codes

Table 1: Pin description

Ordering code	Part Number	Description
PCap04-EVA-KIT V2.0	220300004	PCap04 LITE board & PicoProg Lite & USB-C cable
PCap04 LITE V1.0 BGRP	220300005	PCap04 evaluation board

2 Quick Start Guide

In this section, we described how to set up quickly the PCap04-EVA-KIT V2.0 and establish basic operation and make measurements.

2.1 Installing the Software

It is crucial to install the software before connecting the evaluation kit to your computer. A default driver loading of your OS may interfere with correct installation.

- Download the latest zipped software installation package to the desired directory. https://downloads.sciosense.com/PCAP04
- Unzip the package to the desired directory.
- Open “setup.exe” from the unzipped directory.
- Follow the instructions on the screen.

2.2 Installing the Hardware

- Connect the PicoProg Lite PCB to the computer by means of the USB cable. The green LED should be on.
- Connect the PCap04 LITE to the PicoProg Lite. Two connectors are available, one for SPI communication and one for I2C communication. They are marked accordingly.

2.3 Quick Start for Initial Measurements

In the START menu search for PCap04 or look under program folder ScioSense for the PCap04 software and start it. The software pops up with the following window:

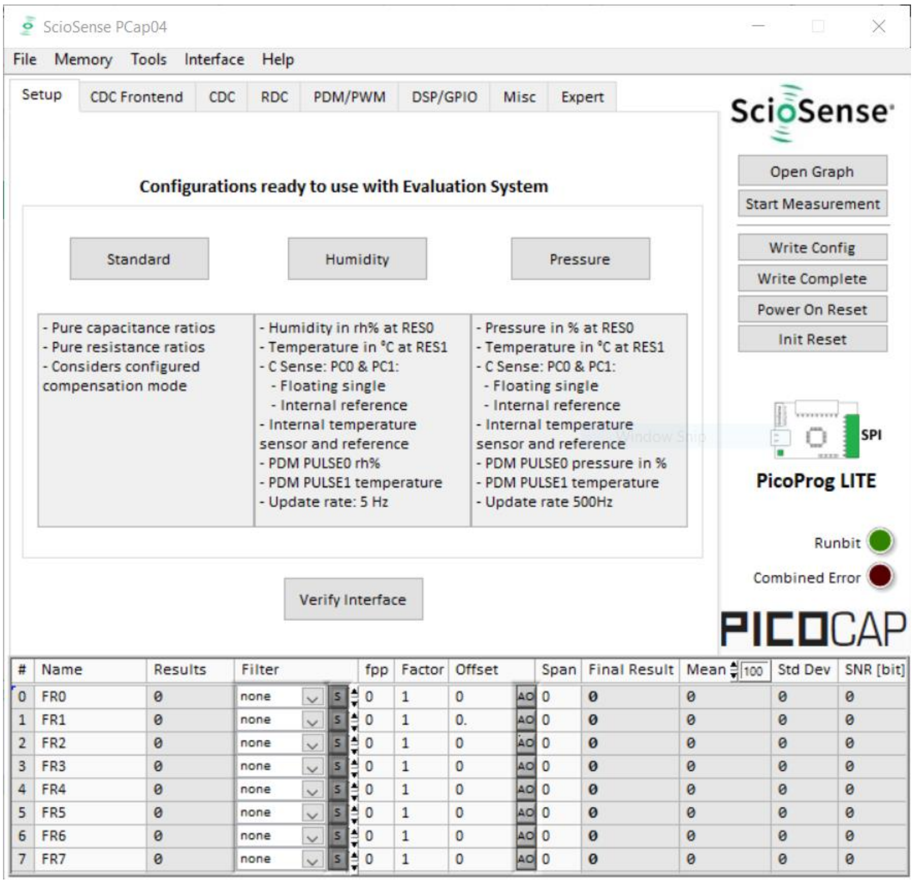


Figure 2: Start page

On the right site a little icon indicates whether a device is connected and whether SPI or I2C is used.

Click the “Verify Interface” button to confirm communication with PicoProg Lite and PCap04 is working:

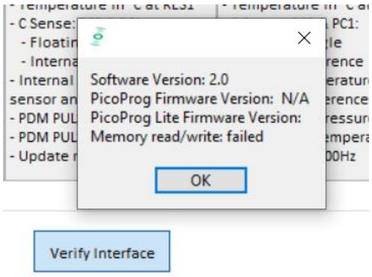


Figure 3: Verify

The PCap04 plug-in board is pre-assembled with ceramic capacitors to emulate capacitive sensors. These capacitors, each 10 pF in value, are connected to the 6 ports PC0 to PC5.

To begin measurements using these preinstalled components, it is necessary to make the following adjustments on the “CDC Frontend” tab:

1) “Capacitive Measurement Scheme” section should be set to “Floating | Single”.
2) All the capacitance ports should be turned on using the Cap. Port Select buttons
3) The Stray Compensation setting should be set to “Both”.

The resulting settings under the CDC tab should look like this:

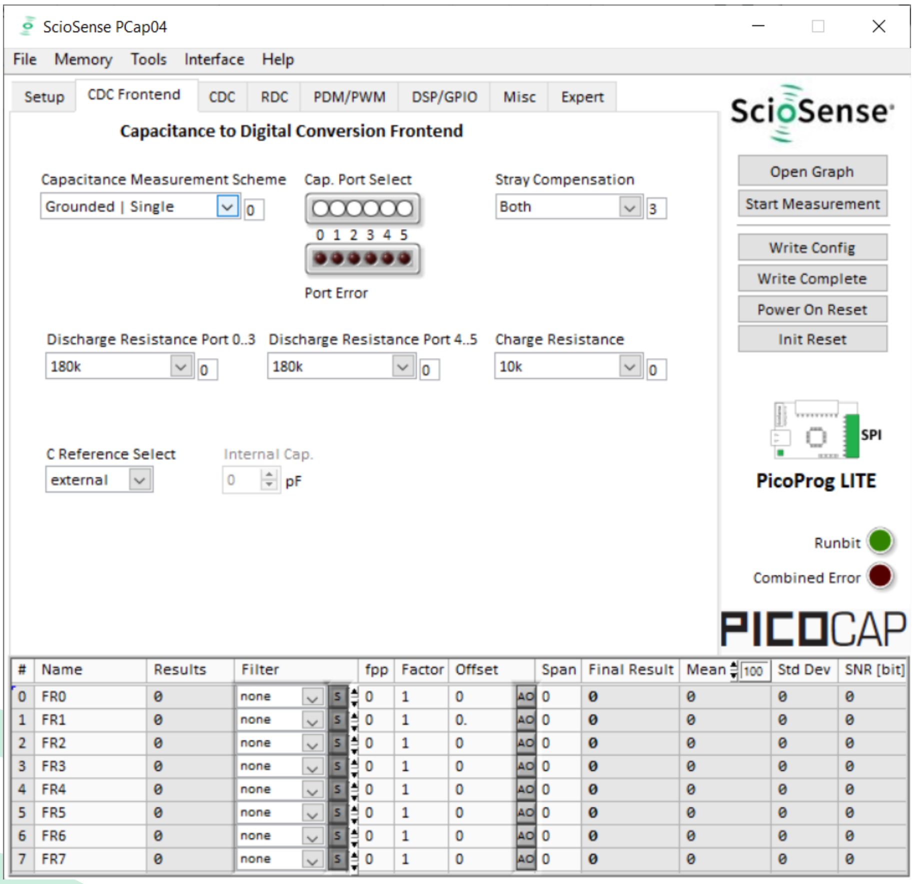


Figure 4: CDC Frontend page at the start

To begin measurements, on the right side of the window, click the following buttons in the order listed:

1) “Power On Reset”
2) “Write Complete”
3) “Start Measurement”

Measurements should now be running and your screen should resemble the following:

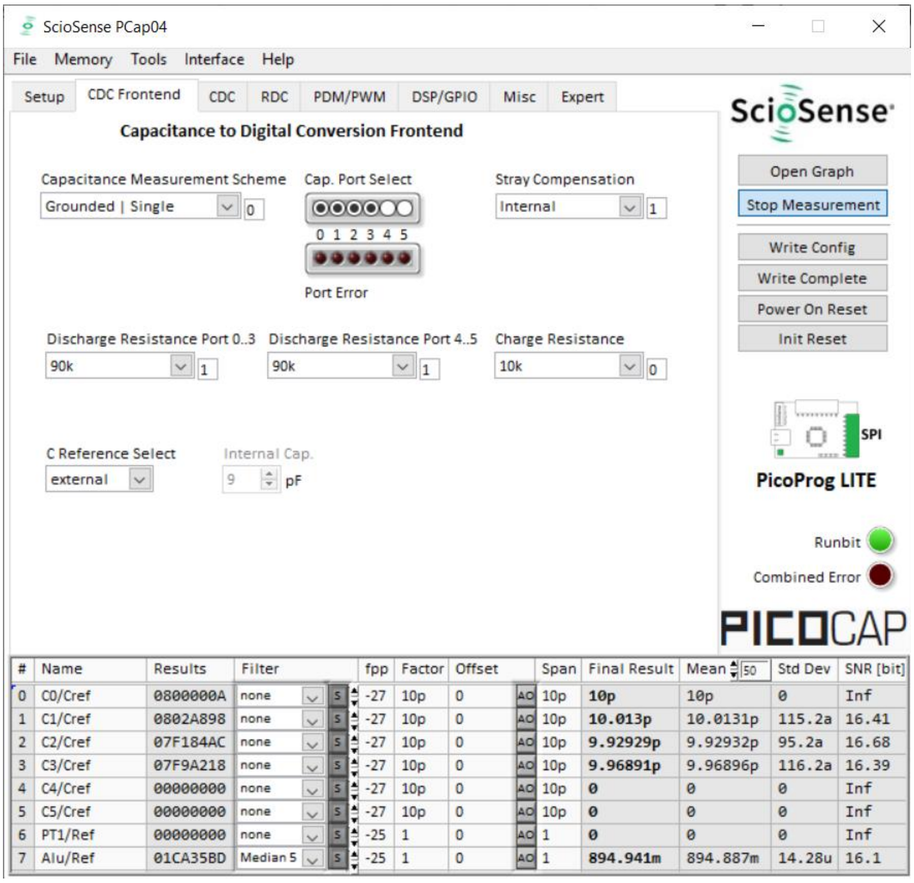


Figure 5: CDC Frontend page with running measurement

The C1 and C2 values should be continually updating but remain within a reasonably small standard deviation as shown.

At this point the above steps have been successfully completed and the operation of the EVA kit can be done. The following sections provide a detailed description of the hardware and software for advanced operation.

3 Hardware Description

3.1 PCap04 Lite Board

3.1.1 Capacitance Measurement

For the purpose of evaluating the capacitance measurement using PCap04, the board is pre-assembled with ceramic capacitors to emulate capacitive sensors. These capacitors, each 10 pF in value, are connected to the 6 ports PC0 to PC5. They are connected as single sensors in floating mode, i.e. each capacitor is connected between 2 ports, and hence there are 3 x 10 pF on-board capacitors. Please refer to section 3 of the PCap04 data sheet for more information on how to connect capacitors to the chip. In case using external reference, the capacitor connected between ports PC0 and PC1 is taken as the reference capacitor.

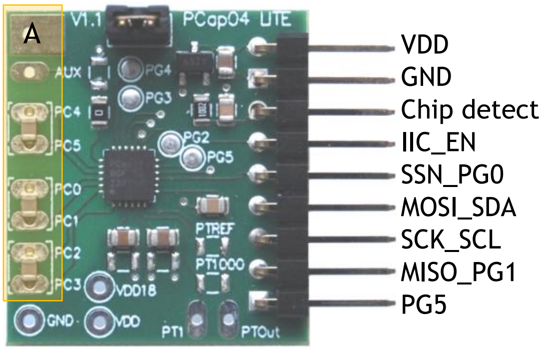


Figure 6: Details of the plug-in board (A=three C0G ceramic capacitors)

In the process of evaluation, when you are comfortable with interpreting the measurement results from the chip, these fixed capacitors can be replaced with the actual capacitive sensors of your application.

If you want to connect your capacitive sensors in grounded mode, then GND points are provided at the two corners of the board, where the sensor ground connections ought to be soldered.

The typical value of the capacitive sensors that can be connected to the evaluation kit lies in the range of 30 pF to 3.5 nF. The reference capacitor should be in the same order of magnitude as the sensor. Depending on the value of the sensor, the value of the internal resistor for performing the measurement has to be selected. For the pre-assembled 10 pF capacitors, an internal discharge resistor of 90 kΩ works well. See section 3 of the PCap04 data sheet on how to select the value of the internal discharge resistor.

3.1.2 Temperature Measurement

Temperature measurement or other resistive tasks may also be of interest for the user of this kit. The evaluation kit offers this possibility through the RDC (resistive-to-digital converter) ports. An on-chip thermistor coupled with an on-chip temperature-stable reference resistor made of polysilicon is sufficient for observing the temperature measurement capability of the PCap04 chip.

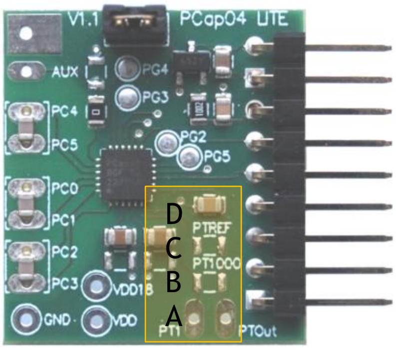


Figure 7: Temperature sensor connection pads

A	Port PT1 for second external temperature sensor (not supported by the standard firmware)
B	Port PT0 for external temperature sensor
C	Port PT2 for external reference resistor
D	10 nF COG

However, there is a possibility to connect the reference resistor and the thermistor externally to the chip, too. In case of external resistors, the temperature-stable reference resistor ought to be connected at port PT2REF on the plug-in board. The board allows you to connect the external thermistor, e.g. a PT1000 sensor at port PT0 (or PT1, not supported yet by the standard firmware). In any case, for the temperature measurement, an external capacitor 10 nF C0G has to be connected to the chip; it is already pre-assembled on board.

1 Software Description

1.1 Initialization

Configuration files, Firmware, Settings and Calibration Data are subsumed in a project (.prj) file. When opening a project file then automatically the configuration and firmware data will be transferred to the chip and the chip is initialized.

Step 1: The first to do after starting the evaluation software is to read the device version from Chip by pressing the button or to select the supported PICOCAP device on the setup page. In the initial phase start with our standard firmware that calculates the capacitance ratios and resistance ratios. It automatically recognizes the operation mode and takes care of the set number of capacitors and the kind of connection. But it does no further processing.

Step 2: If you want to change from the default SPI to I2C interface, please select under Interface --> Bus --> I2C. The LED on the PicoProg Lite interface should now turn red. When the LED does not glow at all, then it indicates that the interface is faulty.

Step 3: By pressing the 'Standard'-button, the standard project file will be open.

You also may load your own project file.

Step 4: Open Graph window and press 'Start Measurement'.

1.2 Graphical User Interface

Next, the main front panel comes up. Overall, the graphical user interface offers various windows for on-line configuration, for parameter and calibration data setting, and of course for the graphical and numerical display of the measurement data. The various windows will be explained in this chapter.

1.2.1 Front Panel

This is the main window. On the right side, the front panel shows six general buttons:

Open Graph	Open a window for graphic representation of measurement data
Start Measurement	Start or stop a running measurement
Write Config.	Transfer once more, the present settings in the evaluation software to the chip (in case of doubt)
Write Complete	Transfer the complete firmware, calibration data and configuration to the chip
Power On Reset	After Power up reset, 'Write Config.' may be necessary.
Init Reset	With an init reset, the chip is re-initialized with respect to its frontend and processor.

1.2.1.1 Setup Page

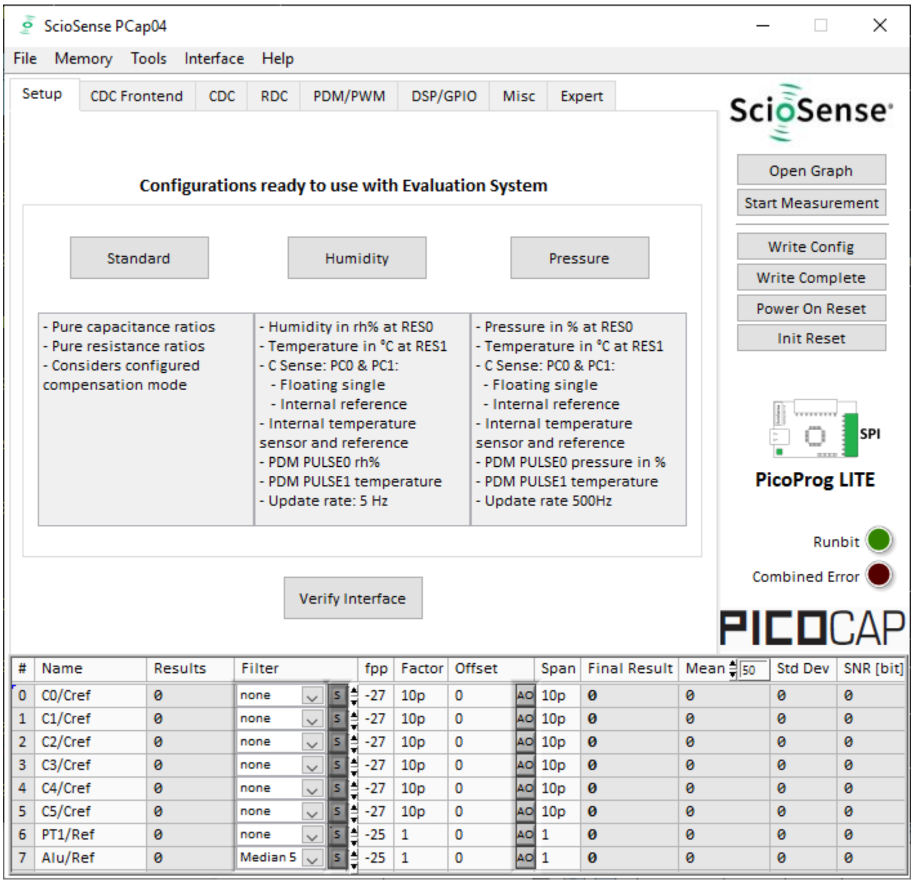


Figure 8 Setup page

Options on 'Setup' page:

Standard	Opens the <*Selected Device*>_standard.prj project file with configuration and standard firmware.
Humidity	Opens the <*Selected Device*>_humidity.prj project file with configuration and linearization firmware.
Pressure	Opens the <*Selected Device*>_pressure.prj project file with configuration and linearization firmware.
Verify Interface	When everything is in order, then pressing this button will indicate the release version number of the software and of the PicoProg Lite / PICOPROG V3.0 Firmware. It also confirms with 'Memory read/write: OK' if a supported PICOCAP device is present.

The lower part of the window is used for real-time numerical display of the measurement results. In principle it shows the content of the read registers. The content itself depends on the firmware. Figure 8 shows the content as it is given with the standard firmware. The first six rows show the capacitance ratios, the last two rows show the temperature result (resistance ratio or linearized temperature).

The tab has 12 columns of information, defining labels, data format, resolution specification (white background) and results (grey background). The information in the white fields increase convenience of reading and is stored in the project files (*.prj). All number may get a character to indicate the well-known prefixes for denoting the factor in thousands (‘p’, ‘f’, ‘a’, ‘k’...).

Name	Label for the register content, depends on the firmware.
Results	Raw hex data display of the result register content. The column before shows the width. The button column after shows whether the result is signed or unsigned.
Filter	Selection of various software filters like Sinc (rolling average) and Median (non-linear filter).
fpp	This column shows the size of the fractional part of the fixed point number and the necessary shift. Depends on the firmware.
Factor	The factor is a scaling factor that allows to scale the result according to the reference capacitor. Factor = ‘1’ gives back the initial capacitance ratio in column ‘Final Result’.
Offset	Offset to be added or subtracted in the evaluation software.
Auto Offset	By pressing [AO], the software re-calculates the ‘Offset’, setting back the ‘Final Result’ to 0
Span	Number that defines the maximum span of the sensor. Is relevant only for the calculation of the resolution in column SNR [bit].
Final Result	Display of the final result, scaled by ‘Factor’ and the ‘Offset’ added.
Mean	Display of the mean value. The sample size can be selected.
Std.Dev	Standard deviation of the ‘Final Result’.
SNR [bit]	Signal-to-Noise ratio in bit, calculated as ‘Span’/ ‘Std.Dev.’

1.2.1.2 CDC Frontend Page

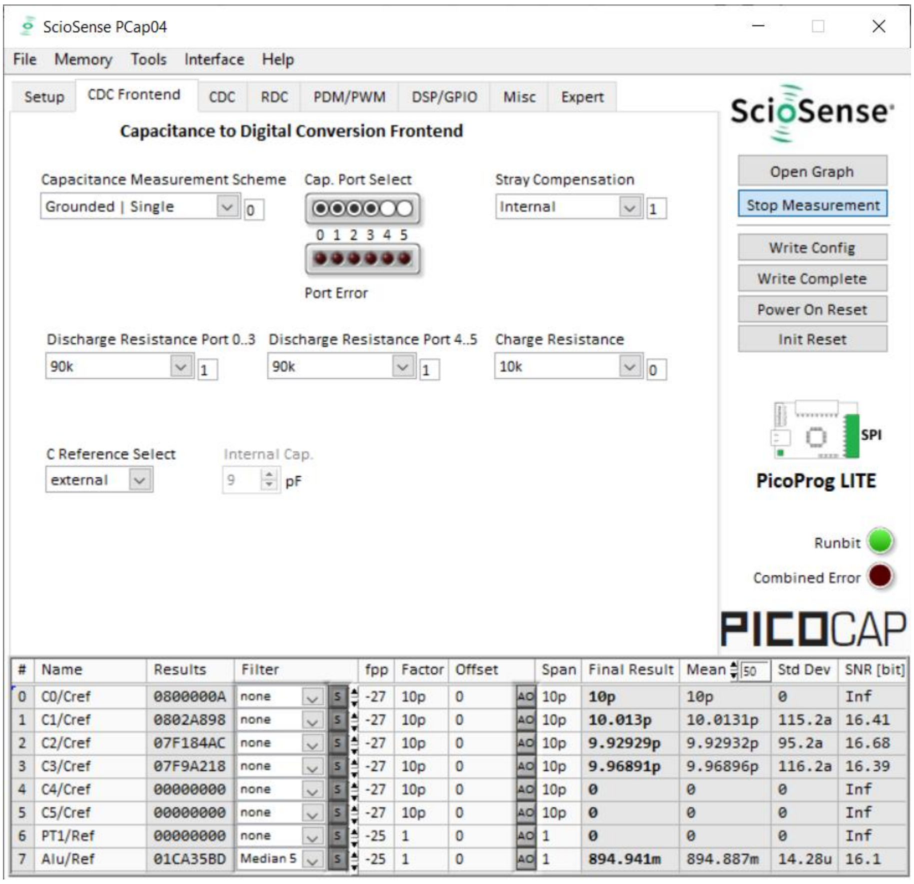


Figure 9 CDC Frontend page

Options on 'CDC Frontend' page:

Capacitance Measurement Scheme	**Grounded | Single** – Single capacitive sensor connected between a port and ground. **Grounded | Differential** – Differential capacitive sensor connected between 2 ports with the middle tap of the sensor connected to ground. **Floating | Single** – Single capacitive sensor connected between 2 ports. **Floating | Differential** – Differential capacitive sensor connected between 2 ports with the middle tap of the sensor connected to another 2 ports.
Cap. Port Select	Select which capacitive ports have to be measured (Ports 0-5), i.e. at which ports the sensors have been connected in hardware.
Stray Compensation	**None** – No compensation **Internal** – One additional measurement performed through only the chip-internal stray capacitance with respect to ground. **External** – One additional measurement per port pair, performed through a parallel connection of the capacitance at the two ports with respect to ground. **Both** – Both internal and external compensation together.
Discharge Resistance Port 0..3	Selects the value of the internal resistance (180k, 90k, 30k, 10k) for measurements on port PC0 to PC3 through which the discharge cycles during measurement are to be performed. This value has to be selected in accordance with the capacitance value of the sensor.
Discharge Resistance Port 4..5	Selects the value of the internal resistance (180k, 90k, 30k, 10k) for measurements on port PC4 to PC5 through which the discharge cycles during measurement are to be performed. This value has to be selected in accordance with the capacitance value of the sensor.
Charge Resistance	Choice of one out of 4 on-chip charging resistors (180k, 10k) for the CDC. Permitting to limit the charging current and avoiding transients.
C Reference Select	Switching between external and internal reference capacitance.
Internal Cap	Selection of internal reference capacitance value. (0..31pF)

1.2.1.3 CDC Page

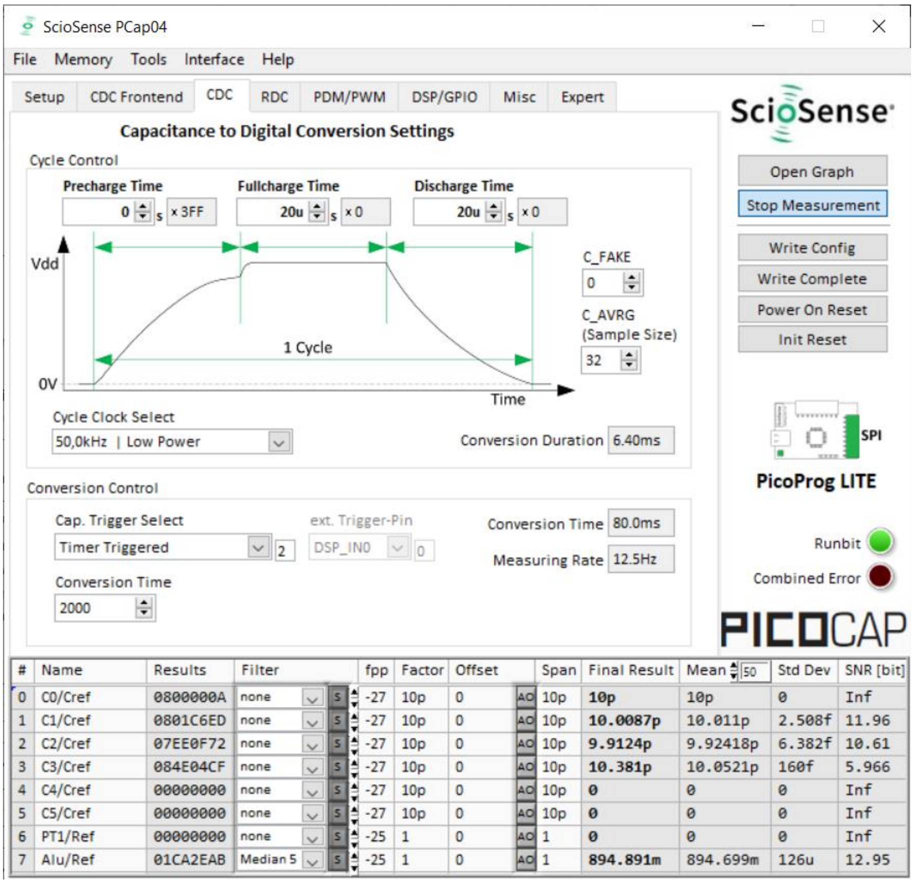


Figure 10 CDC page

Options on 'CDC' page:

Cycle Control	
Precharge Time	Time to charge via resistor for current limitation, can be set in multiples of the cycle clock
Fullcharge Time	Time for final charge without current limitation, can be set in multiples of the cycle clock
Discharge Time	Time to discharge the capacitor, can be set in multiples of the cycle clock
C_FAKE	Number of fake measurements per measurement cycle. Performing fake measurements may help in reducing noise.
C_AVRG	Enables averaging the measurement results over multiple measurement cycles. Setting to 1 → No averaging, Setting to any number N, will result in averaging over N measurement cycles for generating one measurement result. (0..8191)
Cycle Clock Select	50,0kHz | Low Power – Single capacitive sensor connected between a port and ground. 500kHz | High Speed/4 – Differential capacitive sensor connected between 2 ports with the middle tap of the sensor connected to ground. 2,00MHz | High Speed – Single capacitive sensor connected between 2 ports.

Conversion Duration	Displays the entire conversion duration per cycles for averaging and fake measurements.
C_TRIG_SEL	Selects the source that triggers the start of a capacitance measurement **Continuous** – Continuous measurement, self-triggering. Recommended when no temperature measurement is made in parallel. **Read Triggered** – Triggered by read out **Timer Triggered** – Depending on the setting the ‘Conversion Time’. Generally recommended setting → less prone to error conditions. **Timer Triggered (Stretched)** – Depending on the setting the CONV_TIME. The parameter is used as sequence period. **Pin triggered** – Triggered by external Pin, selectable from option ext.Trigger-Pin **Opcode Triggered | Off** – Started by SPI Command 0x8C **Continuous (exp.)** – (not recommended)
Ext. Trigger-Pin	Used to select the pin to be used as the source of trigger for the capacitance measurement. NOTE: In the delivered EVA board, the pins DSP_IN0 and DSP_IN1 are part of the SPI communication interface, hence only DSP_IN2 and DSP_IN3 selections are relevant.
Conversion Control	
CONV_TIME	Sets the conversion time in multiples of twice the period of the low-frequency clock
Conversion Time	Displays the entire conversion time per measurement.
Measuring rate	Displays the frequency at which capacitive measurement data is transferred from the DSP to the interface (SPI or I2C).

1.2.1.4 RDC Page

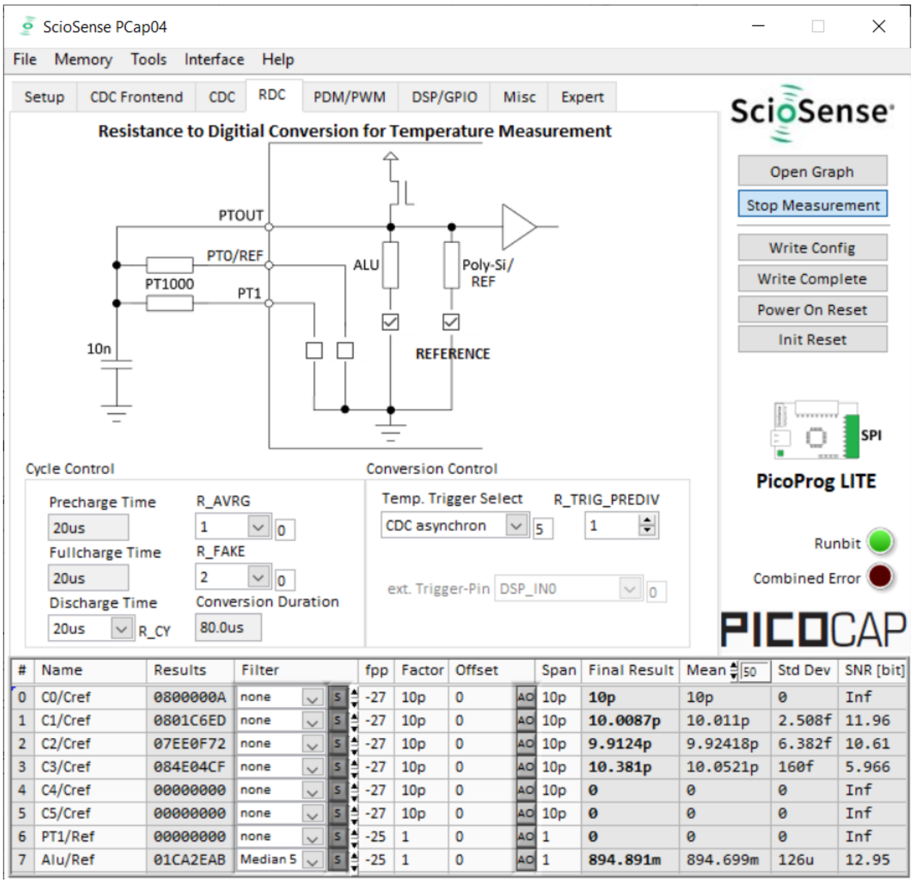


Figure 11 RDC page

Options on ‘RDC’ page:

Temp.Sensor0	To select a thermistor connected to port PT0/REF for temperature measurement. This could be e.g. an external PT1000.
Temp.Sensor1	To select a thermistor connected to port PT1 for temperature measurement.
Temp.Sensor2	To select either the internal aluminium (ALU) thermistor for temperature measurement.
Reference	To select either the internal Poly-Si thermistor or an external reference resistor at port PT0/REF for temperature measurement.

Cycle Control	
Precharge Time	Displays the precharge time. It depends on R_OLF_DIV.
Fullcharge Time	Displays the fullcharge time It depends on R_OLF_DIV.
Discharge Time	Set the discharge time. It depends on R_OLF_DIV.
R_AVRG	Set averaging for temperature measurement.

R_FAKE	Set number of fake measurements per temperature measurement cycle.
Conversion Duration	Displays the entire conversion duration per cycles for averaging and fake measurements.
Conversion Control	
Temp. Trigger Select	Selects the source that triggers the start of a temperature measurement: **Off**: Default setting when no temperature measurement is wanted. In this case, a temperature measurement can still be started by SPI Command 0x8E. **OLF_CLK**: Triggered by Low-frequency oscillator. **Pin-Triggered**: Triggered by external Pin, selectable from option ext.Trigger-Pin **CDC asynchronous**: Depending on the setting in the 'T_TRIG_PREDIV' counter on the RDC page. The DSP is triggered by the RDC end of conversion. If RDC rate is less than CDC rate the DSP is triggered directly from the CDC for inactive RDC conversions. **CDC synchronous**: Depending on the setting in the 'T_TRIG_PREDIV' counter on the RDC page. The DSP is triggered by the RDC end of conversion. Assuming that RDC rate is less than the CDC rate, the inactive RDC conversions are replaced by a delay.
R_TRIG_PREDIV	For CDC and OLF options the RDC measure rate can be reduced by setting a divider.
Conversion Time	Displays the entire conversion time per measurement.
Measuring Rate	Displays the frequency at which capacitive measurement data is transferred from the DSP to the interface (SPI or I2C).
Ext. Trigger-Pin	Used to select the pin to be used as the source of trigger for the capacitance measurement. NOTE: In the evaluation board, the pins DSP_IN0 and DSP_IN1 are part of the SPI communication interface, hence only DSP_IN2 and DSP_IN3 selections can be used.

3.1.2.1 PDM / PWM Page

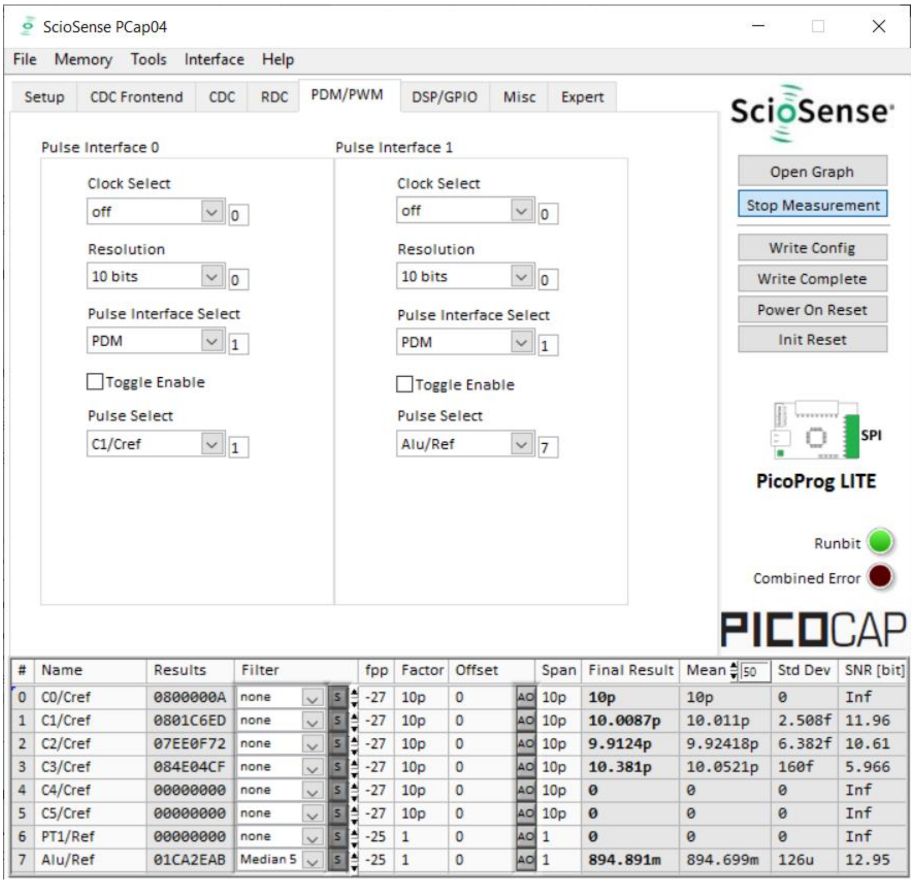


Figure 12 PDM/PWM page

Options on 'PDM / PWM' page:

Clock Select	Selects the clock frequency to be used for the PWM/PDM generation.
Resolution	Resolution of the output in bits. This resolution also determines the pulsed output range.
Pulse Interface Select	Select the pulse interface – Pulse Width Modulated Output (PWM) or Pulse Density Modulated (PDM) Output. Of the two, the PDM is the recommended interface. With PWM option, 100 kHz clock and 10-bit resolution the resulting PWM output frequency = (100 kHz / 1024) ~ 100 Hz.
Toggle Enable	activates toggle flip flop at Pulse Interface Output, especially for PDM to create 1:1 duty factor
Pulse Select	Select the measurement result which has to be given out as pulsed output – any of the capacitance or temperature measurement results.

3.1.2.2 DSP/GPIO Page

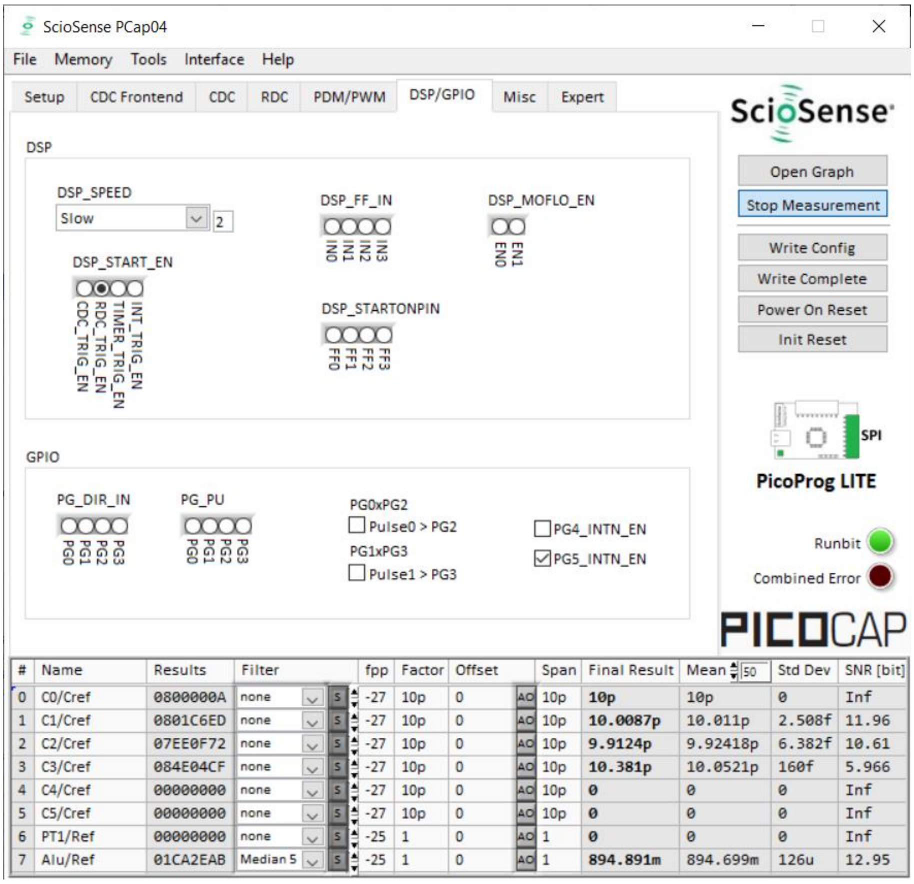


Figure 13 DSP/GPIO page

Options on 'DSP/GPIO' page:

DSP	
DSP_SPEED	Select the DSP Speed. Choose between Fastest, Fast, Slow and Slowest.
DSP_FF_IN	Pin mask for latching flip-flop activation (PG0 to PG3)
DSP_MOFLO_EN	Activates anti-bouncing filter in PG0 and PG1 lines
DSP_STARTONPIN	Not supported by standard firmware The DSP can be started externally by a signal on a pin; these buttons select the pin that has to be sensed for detecting the start signal.
DSP_START_EN	Mask for activating various trigger sources for starting the DSP
GPIO	
PG_DIR_IN	To configure the ports PG0-PG3 as input (otherwise output)
PG_UP	To enable the internal pull up on the ports PG0-PG3
PG0_X_PG2	Possible only when the selected interface for communication is IIC. Interchange PortG0 with PortG2. This is useful when the Pulsed output is needed on Port PG0 instead of PG2.
PG1_X_PG3	Possible only when the selected interface for communication is IIC. Interchange PortG1 with PortG3. This is useful when the Pulsed output is needed on Port PG1 instead of PG3.
PG4_INTN_EN	Map the Interrupt output from chip, INTN to Port PG4. This setting is useful for 24 pin QFN package, because the dedicated INTN pin is absent in this version.
PG5_INTN_EN	Map the Interrupt output from chip, INTN to Port PG5. This setting is useful for 24 pin QFN package, because the dedicated INTN pin is absent in this version.

3.1.2.3 Misc. Page

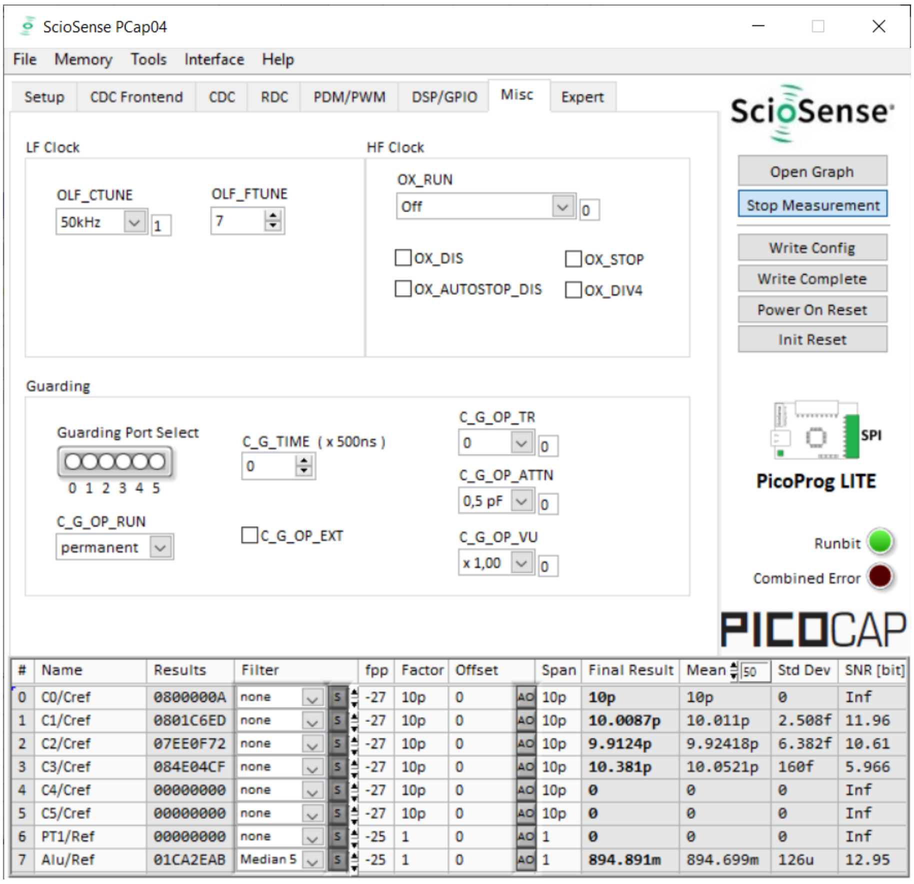


Figure 14 Miscellaneous page

Options on 'Miscellaneous' page:

LF Clock	
OLF_CTUNE	Coarse-tune the low frequency clock. (10kHz, 50kHz, 100kHz, 200kHz)
OLF_FTUNE	Fine-tune the low frequency clock. (0..15)
HF Clock	
OX_RUN	Controls the permanency or the latency of the OX generator. Latency means an oscillator settling time before a measurement starts.
OX_DIS	Disable the OX clock.
OX_AUTOSTOP_DIS	Disables the automatic stop function of the OX generator between the individual measure sequences.
OX_STOP	Stop the OX-generator
OX_DIV4	OX clock frequency := raw freq./4

Guarding	
Guarding Port Select	Individual Guard enable to each Port PC0..PC5
C_G_OP_RUN	permanent – Guarding OP is permanent activated (additional power consumption) pulsed – Guarding OP set to sleep mode between CDC conversions
C_G_TIME	Controls the pre-charge phase
C_G_OP_EXT	Switch between internal guarding OP and an optional external OP
C_G_OP_TR	Trim power consumption of guarding OP.
C_G_OP_ATTN	Capacitive attenuation of Guarding OP.
C_G_OP_VU	OP Gain (from Sense Port to Guard).

3.1.2.4 Expert Page

Please modify the settings on the Expert page only in consultation with ScioSense Support team.

3.1.3 Front Panel Menus

3.1.3.1 File Menu

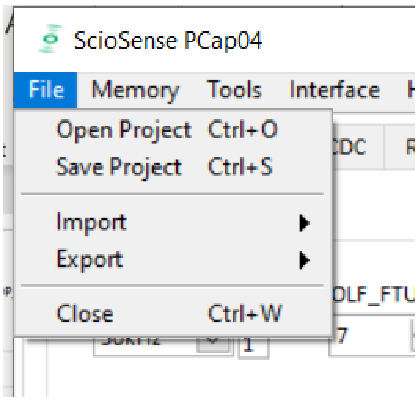


Figure 15 File Menu

Open Project	Open project file *.prj that subsumed the firmware and configuration filenames and the settings and Calibration data
Save Project	Here you can save your own project file.
Import	Import configuration (*.cfg), calibration data (*.dat) or firmware. Note: Any import will modify the active project file! Save the project file under a new name.
Export	Here you can export Config (*.cfg), Calibration (*.dat), Memory (*.dat) or Firmware (*.hex), separately

Close	Close the evaluation software

3.1.3.2 Memory Menu

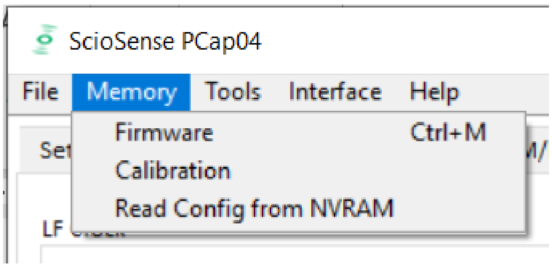


Figure 16 Memory Menu

Firmware	Opens the window to download the firmware. (section 4.2.3.1)
Calibration	Opens the Calibration window (section 4.2.3.2)
Read Config from NVRAM	Reads back the configuration information from the NVRAM and overwrites those of the GUI.

3.1.3.3 Tools Menu

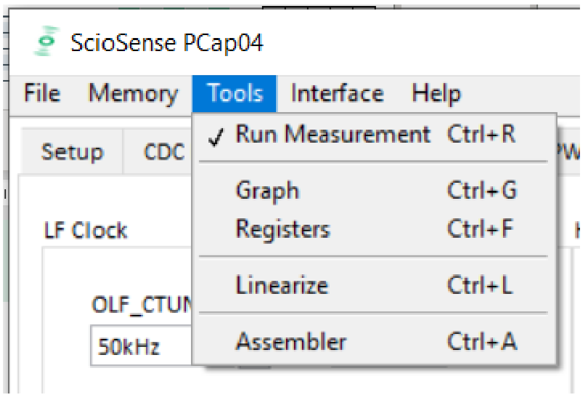


Figure 17 Tools Menu

Run Measurement	Start the measurement
Graph	Opens the window for graphical display of the various measurement results (section 4.2.3.4)
Registers	Opens the Register window (section 4.2.3.5)
Linearize	Opens the Linearize window
Assembler	Opens the assembler

3.1.3.4 Interface Menu

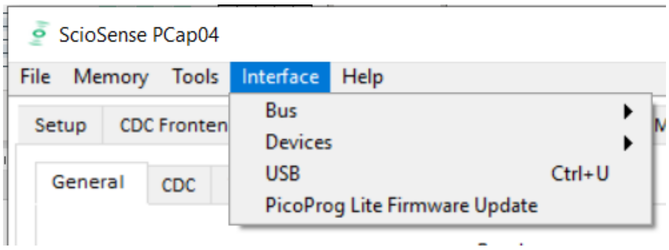


Figure 18 Interface Menu

Bus	Select between SPI and I2C interface
USB	Opens the USB Communications window with PicoProg V3.0 Settings and the possibility to send opcodes

3.1.3.5 Help Menu

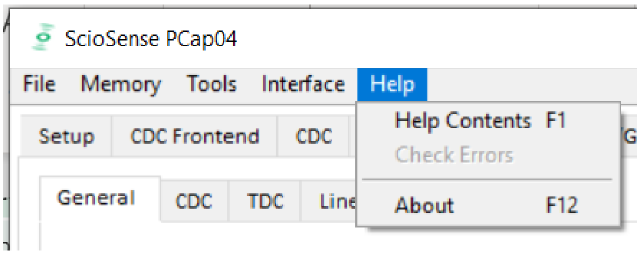


Figure 19 Help Menu

Help Contents	Opens the help window
Check Errors	Opens the error message window if there is an inconsistency after plausibility check.
About	Version

After each change in settings, the evaluation software automatically performs a plausibility check in the background. If a setting is not allowed or doesn’t fit with the setting of the other parameters, the faulty setting is highlighted in red color.

3.1.4 Special Windows

3.1.4.1 Firmware Window

In the ‘Firmware’ Window the write data can be edited.

If the NVRAM is read (‘Read’ button), the content is automatically compared with the ‘Write Data’ window content. If contents are equal this will be indicated by a green illuminated LED.

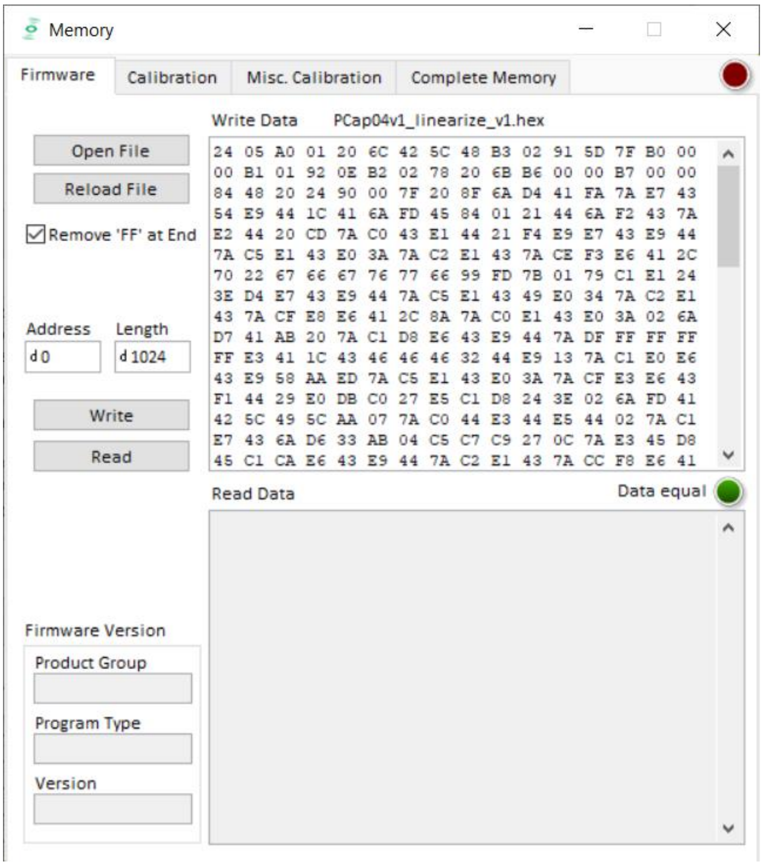


Figure 20 Firmware Window

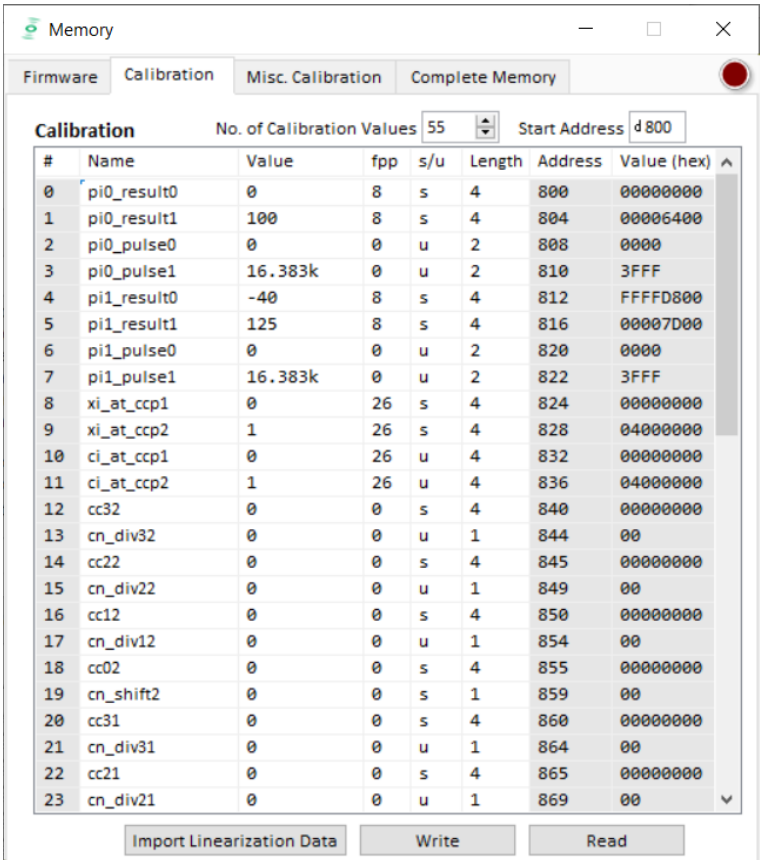
Open File	Select and open a firmware file (.hex) or import firmware from a project file. The content is shown in the ‘Write Data’ window.
Reload File	Reload the last opened firmware file (.hex). The content is shown in the ‘Write Date’ window again.
Read	Pressing this button, the content of the NVRAM is read and shown in the ‘Read Data’ window. In ‘Address’ and ‘Length’ you can specify how many bytes you want read, starting at which address.
Write	Writes the firmware into the chip’s NVRAM. The status of the write process is indicated by the green bar. The successful end is indicated by a pop-up window. For verification we recommend to read back the NVRAM afterwards and compare it with the source.

Firmware Version	In the firmware, a specific address is reserved to save 3 byte information about the application and the version of the software. The coding is specified in the header file of the supported PICOCAP device, for example: *pcap_standard.h*. The header file is found in the library directory of the assembler.

3.1.4.2 Calibration Window

The NVRAM provides the possibility to store data like linearization coefficients, division steps, alert levels etc.. This way, one and the same firmware can be used for various types of sensors.

The Calibration data are part of the project file. After opening a project, the Calibration data need to be written manually. Therefore please open the “Memory / Calibration” menu and then press “Write” or use the ‘Write Complete’ button.



#	Name	Value	fpp	s/u	Length	Address	Value (hex)
0	pi0_result0	0	8	s	4	800	00000000
1	pi0_result1	100	8	s	4	804	00006400
2	pi0_pulse0	0	0	u	2	808	0000
3	pi0_pulse1	16.383k	0	u	2	810	3FFF
4	pi1_result0	-40	8	s	4	812	FFFFD800
5	pi1_result1	125	8	s	4	816	00007D00
6	pi1_pulse0	0	0	u	2	820	0000
7	pi1_pulse1	16.383k	0	u	2	822	3FFF
8	xi_at_ccp1	0	26	s	4	824	00000000
9	xi_at_ccp2	1	26	s	4	828	04000000
10	ci_at_ccp1	0	26	u	4	832	00000000
11	ci_at_ccp2	1	26	u	4	836	04000000
12	cc32	0	0	s	4	840	00000000
13	cn_div32	0	0	u	1	844	00
14	cc22	0	0	s	4	845	00000000
15	cn_div22	0	0	u	1	849	00
16	cc12	0	0	s	4	850	00000000
17	cn_div12	0	0	u	1	854	00
18	cc02	0	0	s	4	855	00000000
19	cn_shift2	0	0	s	1	859	00
20	cc31	0	0	s	4	860	00000000
21	cn_div31	0	0	u	1	864	00
22	cc21	0	0	s	4	865	00000000
23	cn_div21	0	0	u	1	869	00

Figure 21 Calibration Window

Import Linearization Data	Imports Linearization Data from “Linearize / Pulse” window
Write	Writes the data into the chip’s NVRAM.
Read	Pressing this button, the Linearization Data are read from the NVRAM and shown in the tab.

3.1.4.3 Misc. Calibration Window

This window shows miscellaneous calibration bits at address d'956-d'959 (4 byte). The meaning of the content strongly depends on the firmware.

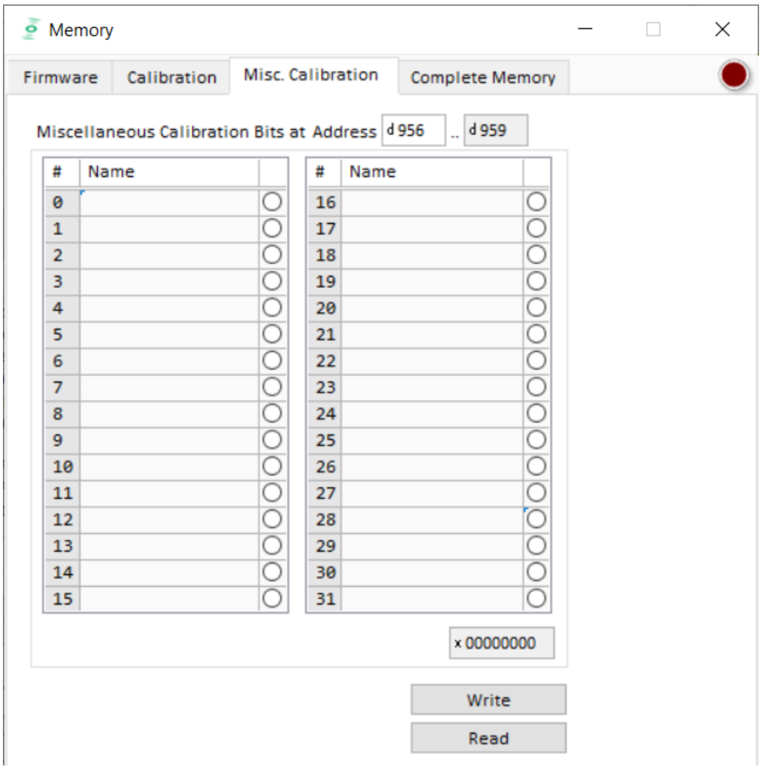


Figure 22 Misc. Calibration Window

Write	Writes the data into the chip's NVRAM.
Read	Pressing this button, the bits are read from the NVRAM and shown in the tab.

3.1.4.4 Complete Memory

Figure 23 Complete Memory Window

Write	Writes the complete NVRAM.
Store	The complete data transfer from Memory (volatile) to FLASH (non-volatile) is performed by a STORE
Erase	During this ERASE procedure, first the complete NVRAM will erased (set to zero) and afterwards the MEM_LOCK bits will be cleared.
Read	Pressing this button, the complete NVRAM are read and shown in the tab.
Recall	This means that the complete Memory is copied from the FLASH (non-volatile) to the Memory (volatile). After a power-on reset, a recall is processed.

3.1.4.5 Graph Window

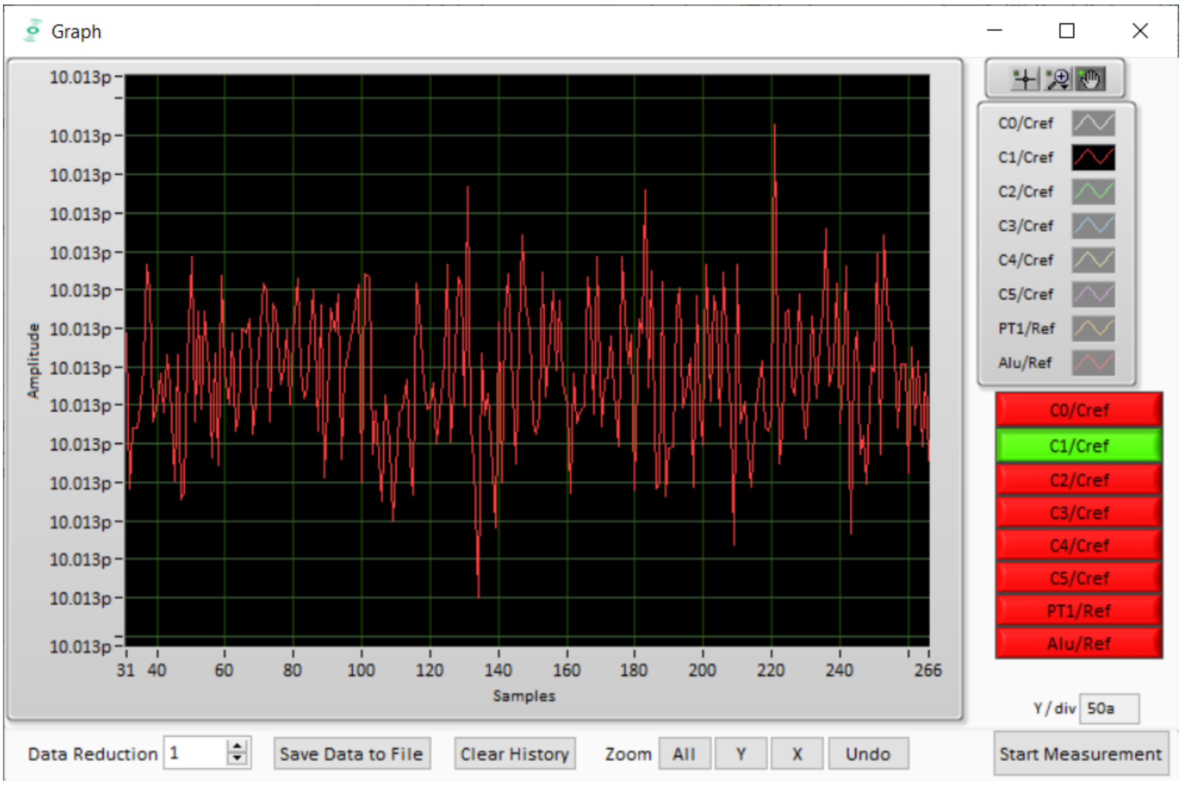


Figure 24 Graph Window

The data to be displayed are selected in the field at the bottom right. The labels in the buttons are the same as in the diagnostics window. To display data press the corresponding button so that it gets green. Top right of the 'Graph' Windows are various options for automatic zoom in/out, center or scale in other ways. Below the graph are various automatic zoom functions for the x-axis and the y-axis.

Y-Zoom will be chanced with the keys [+], [-] and X-Zoom with the keys [*], [/]. With the cursor control keys [←], [→], [↑], [↓] is it possible to move the graph.

The data displayed can be stored into a text file. For long-term investigations it is possible to reduce the data displayed and stored. The field 'Data Reduction' allows to define the level of data reduction.

3.1.4.6 Registers Window

These windows display the configuration data in hexadecimal format as they are currently used. Also the result registers' content is shown in hexadecimal format, but updated only when the button is pressed. Finally, the various status bits are shown.

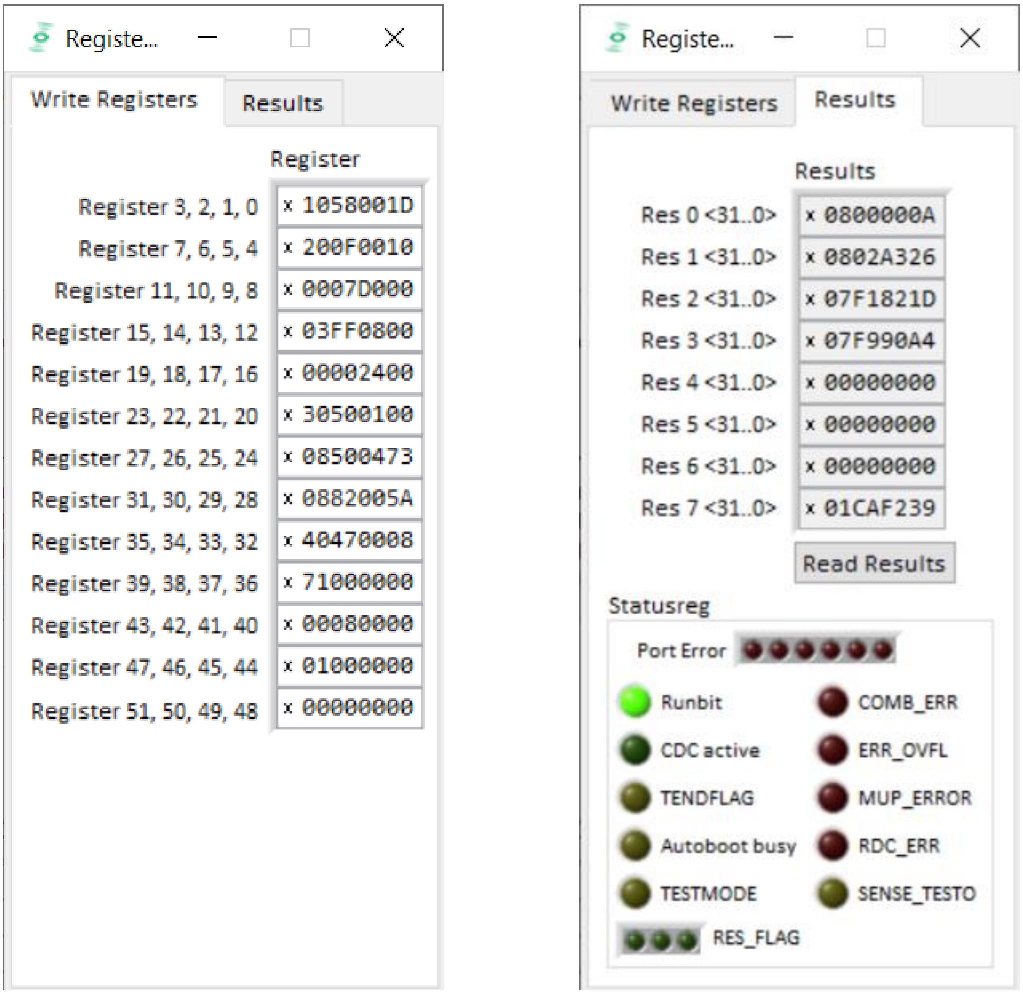


Figure 25 Write Registers and Results

3.1.5 Linearize

3.1.5.1 Sensor Characterization

The first step is the characterization of the sensor. Therefore, it is necessary to collect data at several measurement points and at several temperatures.

As mentioned earlier, the data collection should be made of minimum 12 measurements, taken at least at 3 different temperatures. The temperatures should cover the operating temperature range of interest of the final device. The number of calibration points is set at the top left. This is the first thing to be done. Then calibration can begin. Line by line the user can enter the reference values for Z and □ at the various calibration points. Having the cursor in this line it is sufficient to press the acquire button to get the actual ci_ratio result. But of course the value can be entered manually, too.

The graph on the bottom left shows the Z, ϑ distribution of the calibration points. Ideally it should have dots on three different lines covering the operating range of the sensor.

The table on the left shows the calculated calibration coefficients and the graph below shows the deviation due to the mathematical approximation.

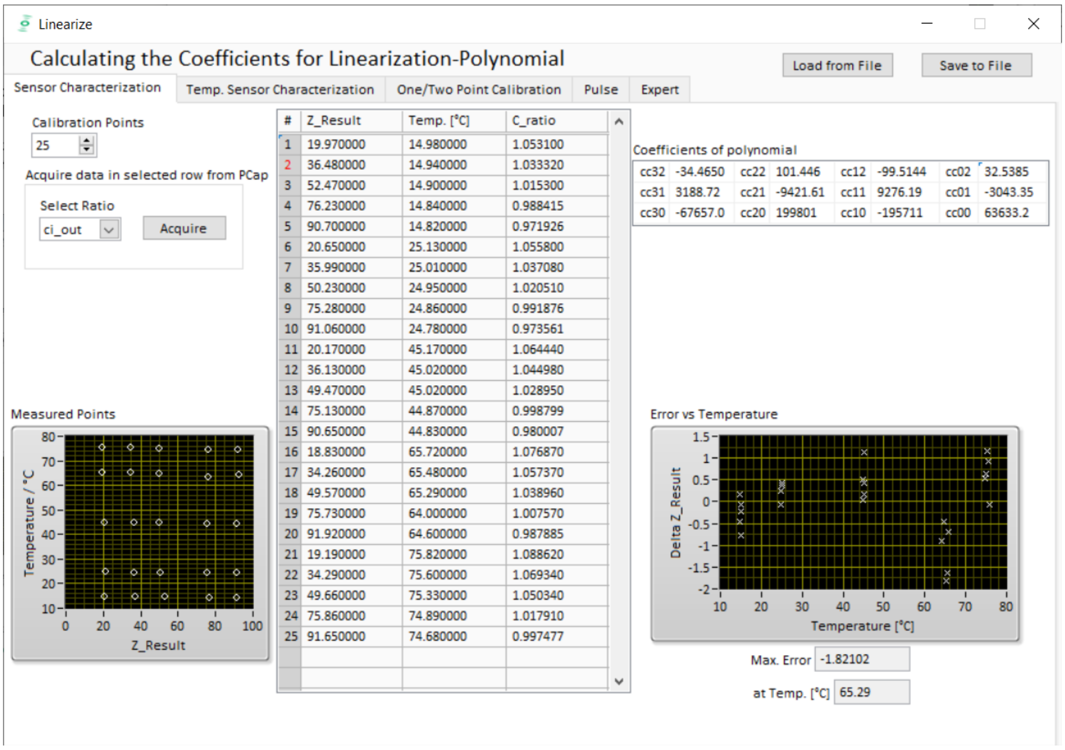


Figure 26 Sensor Characterization

3.1.5.2 Temperature Sensor Characterization

Together with the calibration of the capacitance sensor it is mandatory to calibrate the temperature, too. Whether the internal aluminum sensor is used or an external platinum sensor or any other sensor: they need to be calibrated to get the correct temperature information which is then used as input for the polynomial correction of the capacitance measurement.

The tab „Temperature Sensor Characterization" (Figure 27) offers a tool very similar to the capacitive sensor characterization. The resistance ratio has to be collected at several temperature points. For best approximation 4 calibration points are needed. In case of 2 or 3 calibration points a 2nd respectively a 3rd order polynomial is calculated.

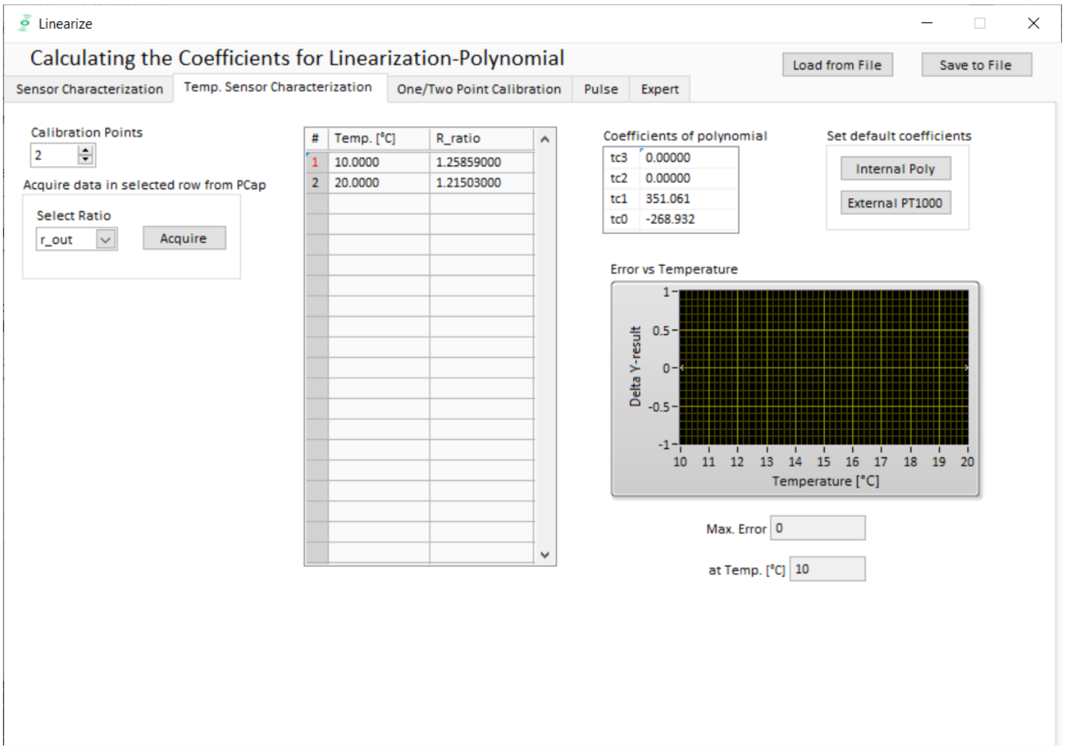


Figure 27 Temp. Sensor Characterization

On the right side of the tab "Temperature Sensor Characterization" there are two buttons to select default characteristic data for the internal aluminum sensor and a platinum sensor. The aluminum is assumed to be linear in a range of 10 °C to 70°C so only two coefficients are used.

In case the default values are used it is necessary to have at least a two point calibration of the temperature (see next section).

3.1.5.3 One/Two Point Calibration

Once a batch is characterized with respect to the capacitive sensor and the resistive temperature sensor it might be sufficient to perform two-point or even one-point calibration for the rest of the sensors in the batch.

The tab “One/Two Point Calibration” offers a simple GUI to do that. On this page the user enters the reference values for Z and ϑ. CCP1 stands for capacitance calibration point 1 etc.. When the calibration conditions are reached pressing the acquire buttons will read the actual ratios while the theoretical ones are calculated on basis of the linearization coefficients. Together with programmable limits for minimum and maximum this gives an additional set of 12 parameters to be written into the EEPROM.

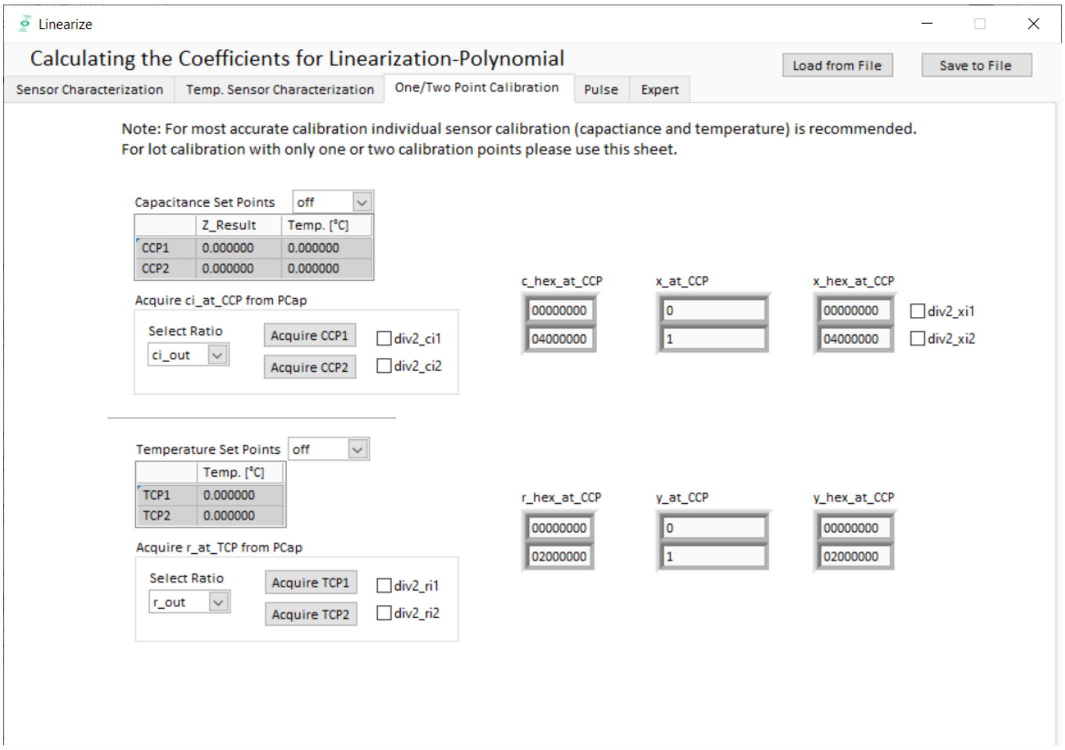


Figure 28 One/Two Point Calibration

3.1.5.4 Pulse

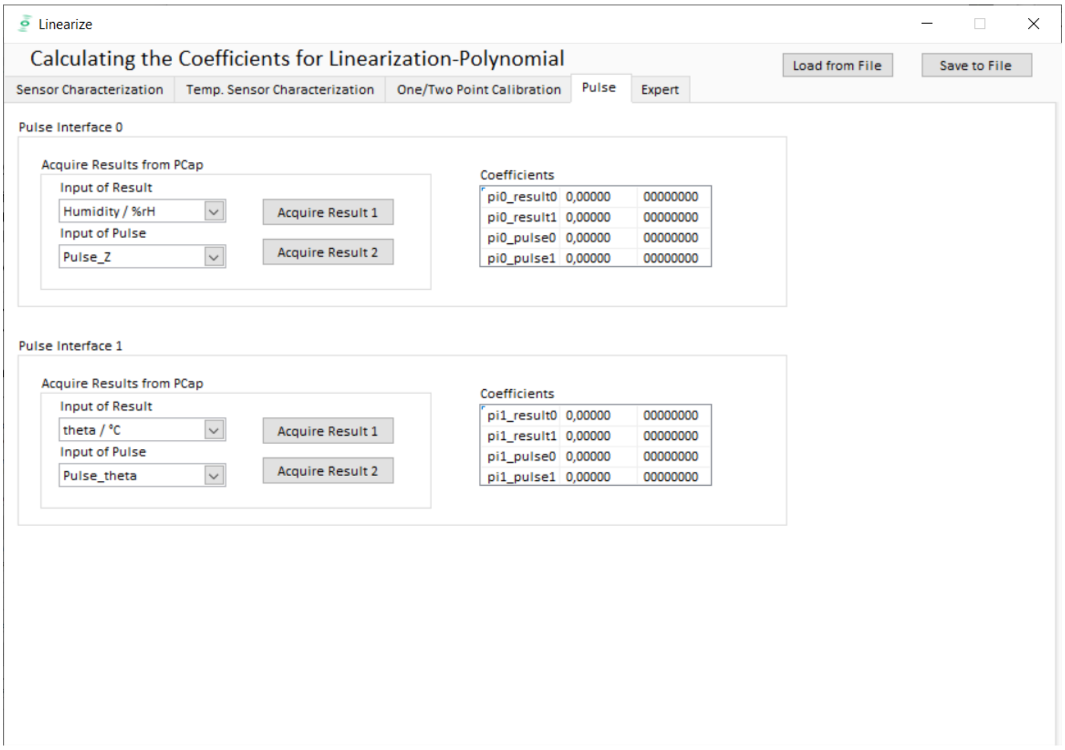


Figure 29 Pulse

3.1.5.5 Expert

As indicated by the name this tab is for experts only. There you set the fixed point position of the result Z. It further displays the numbers of division steps respectively shift operation to achieve the maximum resolution over all calculations.

Those are stored in the NVRAM, too. But they are calculated by the DLL and for information purpose only.

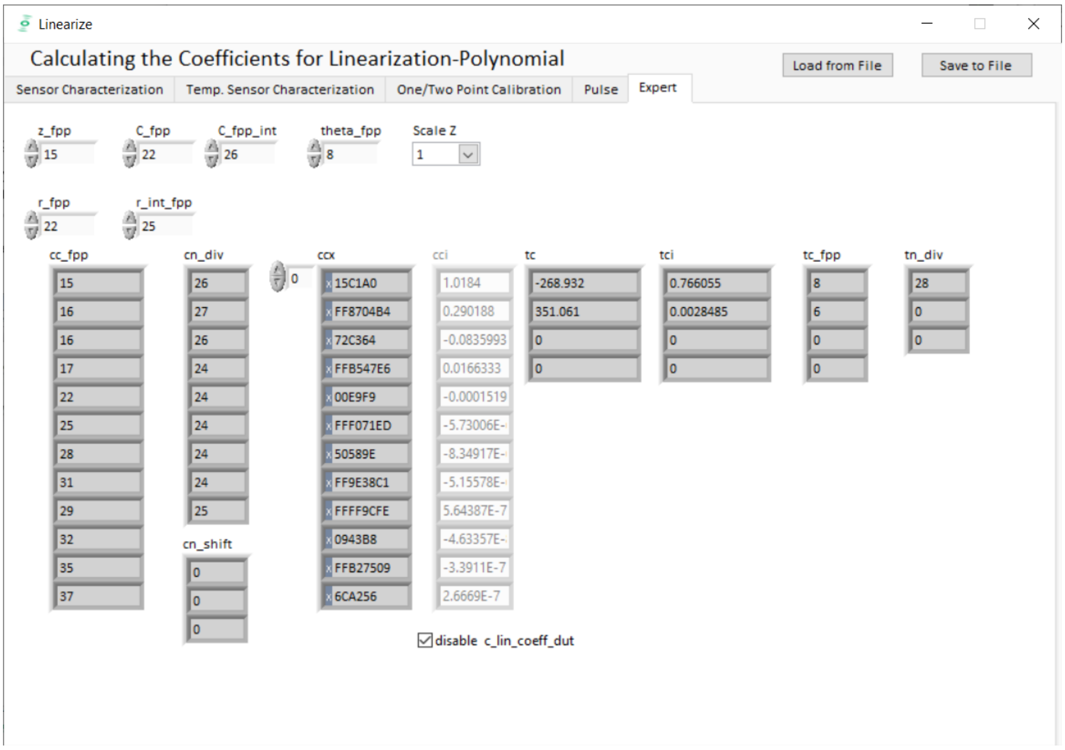


Figure 30 Expert

3.1.5.6 Assembler

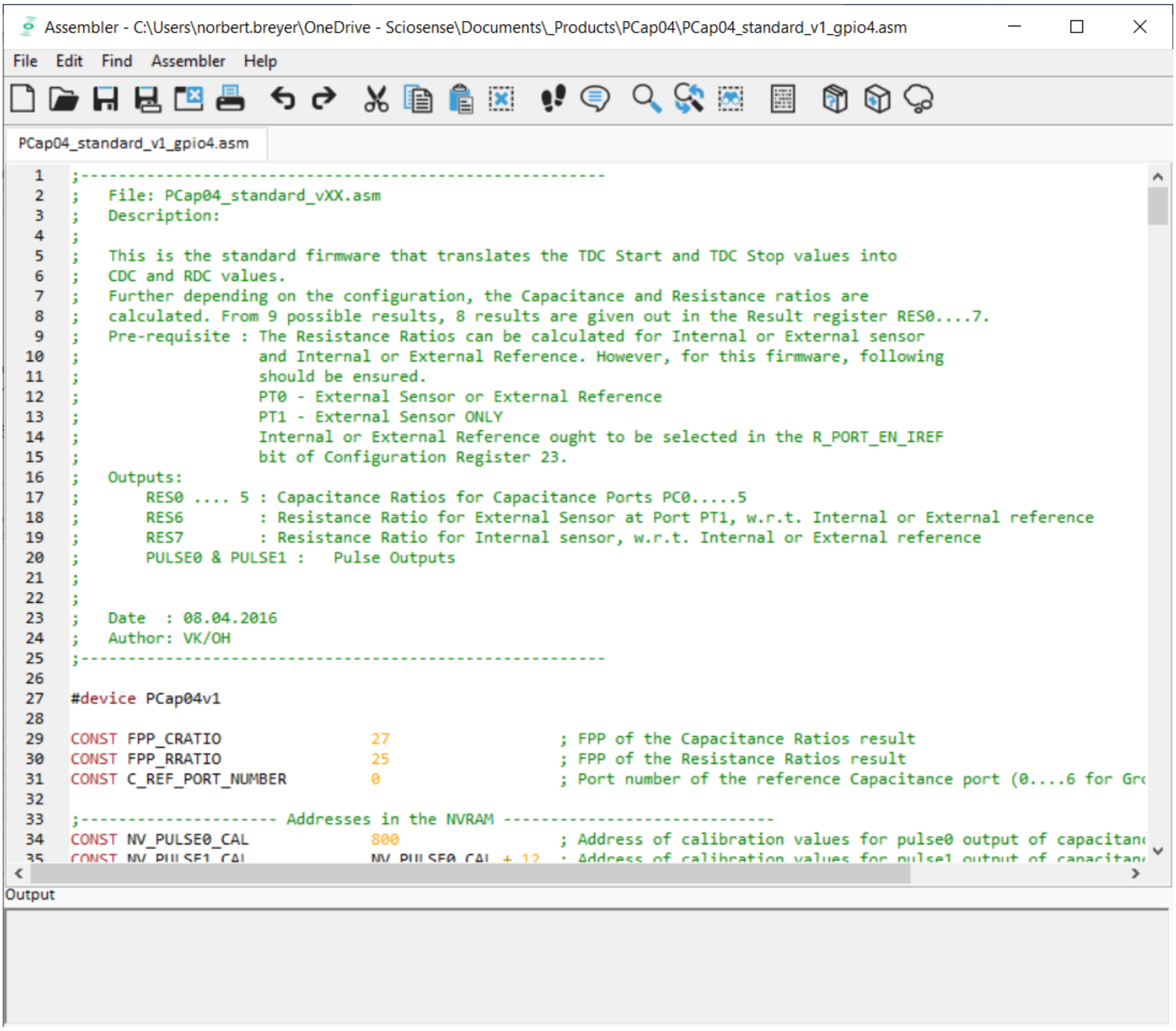


Figure 31 Assembler

This is a comfortable editor with syntax highlighting, search and replace, copy and paste functions.

Under menu item “Assembler” the user finds the compile and download options.

Whether the call of these functions was successful or not is indicated by the messages at the bottom of the assembler window.

Debugging is not supported in this software revision.

3.2 Scaling Results

PCap04 in general calculates capacitance ratios. The measured ratios include of course all effects from parasitic capacitances. Nonetheless, in many cases users might be interested in an intuitive understanding the displayed values without making a full calibration run.

The following shows by example how to set Factor and Offset to give a suitable display.

Starting point: 10 pF between PC0 and PC1, 12.2 pF between PC2 and PC3, 8 pF between PC4 and PC5.

In grounded configuration, the chip measures 10pF reference against 10 pF at PC1, 12.2 pF at PC2 and PC3 and 8 pF at PC4 and PC5. In floating configuration 10pF reference is measured against 12.2 pF and 8 pF.

a) Grounded single, no compensation

The capacitance seen includes the port parasitic capacitance as well as the internal “parasitic” capacitance (5 pF to 6 pF), which is dominated by the comparator delay (about 10 pF).

The base capacitance is then not 10 pF but 25 pF. Thereof 15 pF are Offset which can be subtracted.

#	Name	Results	Filter	fpp	Factor	Offset	Span	Final Result	Mean 50	Std Dev	SNR [bit]
0	C0/Cref	08000013	none	-27	25p	-15p	10p	**10p**	10p	0	Inf
1	C1/Cref	0808B6B7	none	-27	25p	-15p	10p	**10,1064p**	10,1063p	234,5a	15,38
2	C2/Cref	08BF5F56	none	-27	25p	-15p	10p	**12,3361p**	12,336p	225,2a	15,44
3	C3/Cref	08BA5E49	none	-27	25p	-15p	10p	**12,275p**	12,2748p	316,8a	14,95
4	C4/Cref	075FA4B4	none	-27	25p	-15p	10p	**8,04252p**	8,04221p	291,4a	15,07
5	C5/Cref	07688199	none	-27	25p	-15p	10p	**8,15071p**	8,15064p	257,6a	15,24

Figure 32 Grounded single, no compensation

b) Floating single, no compensation

The influence of parasitic capacitances is the same and therefore the setting for Factor and Offset are the same.

#	Name	Results	Filter	fpp	Factor	Offset	Span	Final Result	Mean 50	Std Dev	SNR [bit]
0	C0/Cref	08000009	none	-27	25p	-15p	10p	**10p**	10p	0	Inf
1	C1/Cref	08B81EAB	none	-27	25p	-15p	10p	**12,2476p**	12,2474p	273,1a	15,16
2	C2/Cref	076008D8	none	-27	25p	-15p	10p	**8,0473p**	8,04729p	167,9a	15,86

Figure 33 Floating single, no compensation

c) Ground single, internal compensation

Now the chip sees only the port parasitic capacitance, not the internal one. This is in the order of 5 pF to 6 pF. Accordingly, the total base capacitance is 15 pF (Factor) with an offset of 5 pF.

#	Name	Results	Filter	fpp	Factor	Offset	Span	Final Result	Mean	Std Dev	SNR [bit]
0	C0/Cref	08000021	none	-27	15p	-5p	10p	**10p**	10p	0	Inf
1	C1/Cref	080E6BCE	none	-27	15p	-5p	10p	**10,1056p**	10,1059p	219,2a	15,48
2	C2/Cref	0946D492	none	-27	15p	-5p	10p	**12,3938p**	12,3935p	283a	15,11
3	C3/Cref	093E1B82	none	-27	15p	-5p	10p	**12,3299p**	12,3295p	353,1a	14,79
4	C4/Cref	06ECA6E1	none	-27	15p	-5p	10p	**7,98329p**	7,98315p	274,7a	15,15
5	C5/Cref	06FBDDE2	none	-27	15p	-5p	10p	**8,09473p**	8,09469p	214,2a	15,51

Figure 34 Ground single, internal compensation

d) Floating single, internal compensation

Again, the chip sees only the port parasitic capacitance. But due to the different port pattern the correction factors are slightly higher.

#	Name	Results	Filter	fpp	Factor	Offset	Span	Final Result	Mean	Std Dev	SNR [bit]
0	C0/Cref	0800000C	none	-27	20p	-10p	10p	**10p**	10p	1,632E-	52,44
1	C1/Cref	08E7E36C	none	-27	20p	-10p	10p	**12,2645p**	12,2646p	301,6a	15,02
2	C2/Cref	0735B673	none	-27	20p	-10p	10p	**8,02454p**	8,02458p	252,1a	15,28

Figure 35 Floating single, internal compensation

Using floating in combination with an internal reference there is a deviation as we have internally only a single grounded capacitor. This is measured twice and the factor needs to be doubled.

e) Floating, both compensation

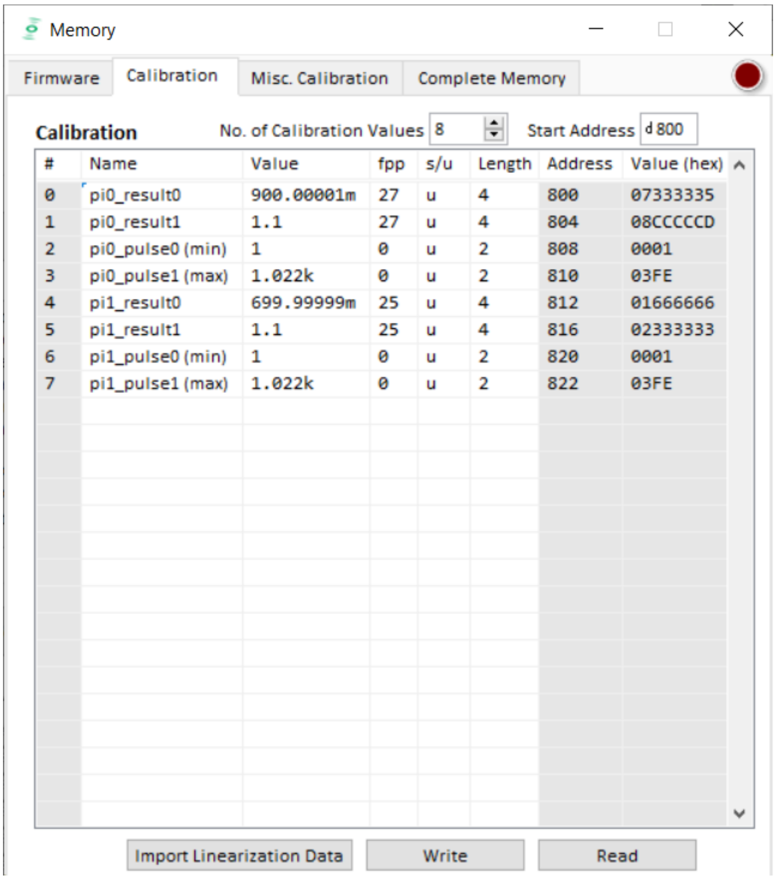
Now all parasitic capacitances are compensated. The initial base capacitance without offset can be used.

#	Name	Results	Filter	fpp	Factor	Offset	Span	Final Result	Mean	Std Dev	SNR [bit]
0	C0/Cref	0800001A	none	-27	10p	0	10p	**10p**	10p	0	Inf
1	C1/Cref	09E81FB7	none	-27	10p	0	10p	**12,3834p**	12,1831p	1,414p	2,822
2	C2/Cref	066773EF	none	-27	10p	0	10p	**8,00514p**	6,40549p	3,703p	1,433

Figure 36 Floating, both compensation

3.3 Scaling PDM Output

Here we describe how to scale the PDM output when working with the standard firmware. Open the Memory window and select tab calibration:



#	Name	Value	fpp	s/u	Length	Address	Value (hex)
0	pi0_result0	900.00001m	27	u	4	800	07333335
1	pi0_result1	1.1	27	u	4	804	08CCCCCD
2	pi0_pulse0 (min)	1	0	u	2	808	0001
3	pi0_pulse1 (max)	1.022k	0	u	2	810	03FE
4	pi1_result0	699.99999m	25	u	4	812	01666666
5	pi1_result1	1.1	25	u	4	816	02333333
6	pi1_pulse0 (min)	1	0	u	2	820	0001
7	pi1_pulse1 (max)	1.022k	0	u	2	822	03FE

Figure 37 Scaling PDM Output

Set fpp to 27 and s/u to S for signed. Enter the capacitance ratios at minimum and maximum sensor signal. Set pix_pulse1 (max) to the value according to the set resolution of the PDM. This is 1023 at 10 bit and 65535 at 16 bit.

Press “Write” to write the data into the chip.

4 Schematics, Layers & BOM

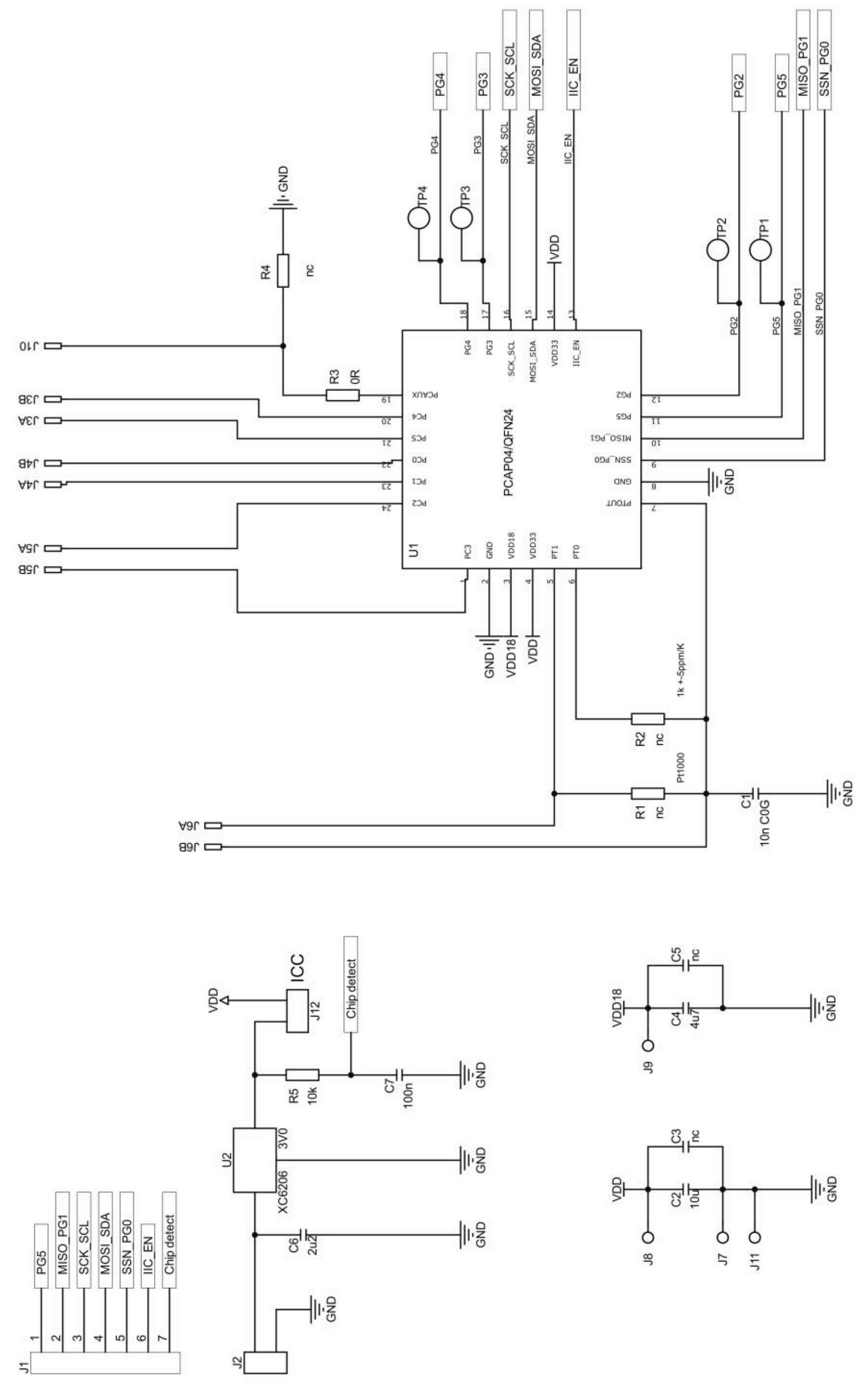


Figure 38: PCap04 LITE BGRP schematics

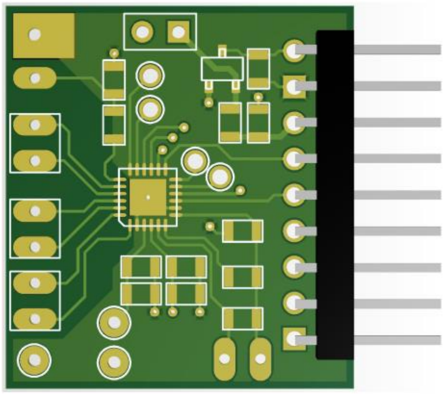


Figure 39: PCap04 LITE layout 2:1t

Table 2: Bill of materials for PCap04 LITE

Quantity	Designator	Value	Comment	Footprint
3	J3, J4, J5	10p	CHIP-CAPACITOR 0805	
1	C1	10n/C0G	CHIP-CAPACITOR 0805	
1	C7	100n	CHIP-CAPACITOR 0805	
1	C6	2u2	CHIP-CAPACITOR 0805	
1	C4	4u7	CHIP-CAPACITOR 0805	
1	C2	10u	CHIP-CAPACITOR 0805	
1	R3	0R	CHIP-RESISTOR 0805	
1	R5	10k	CHIP-RESISTOR 0805	
1	U1		PCap04 QFN24	
1	U2	3,0V	LDO XC6206 3,0V	

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7 Revision information

Table 3: Revision history

Revision	Date	Comment	Page
1.0.2	2017	Latest version with old PICOPROG	All
2	May 2023	Release of second version for the kit which comes with PicoProg Lite	All
3	July 2023	Schematics J1 corrected, layout and board pictures updated	1, 2, 7, 8, 40

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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