

PCap04-EVA-KIT V2.0

Development Kit User Guide

PCAP04-EVA-KIT 2.0

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Content Guide

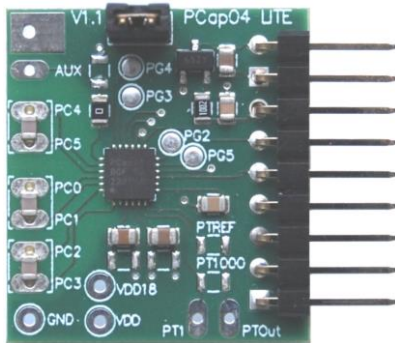
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1 Introduction

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 SciSense for the PCap04 software and start it. The software pops up with the following window:

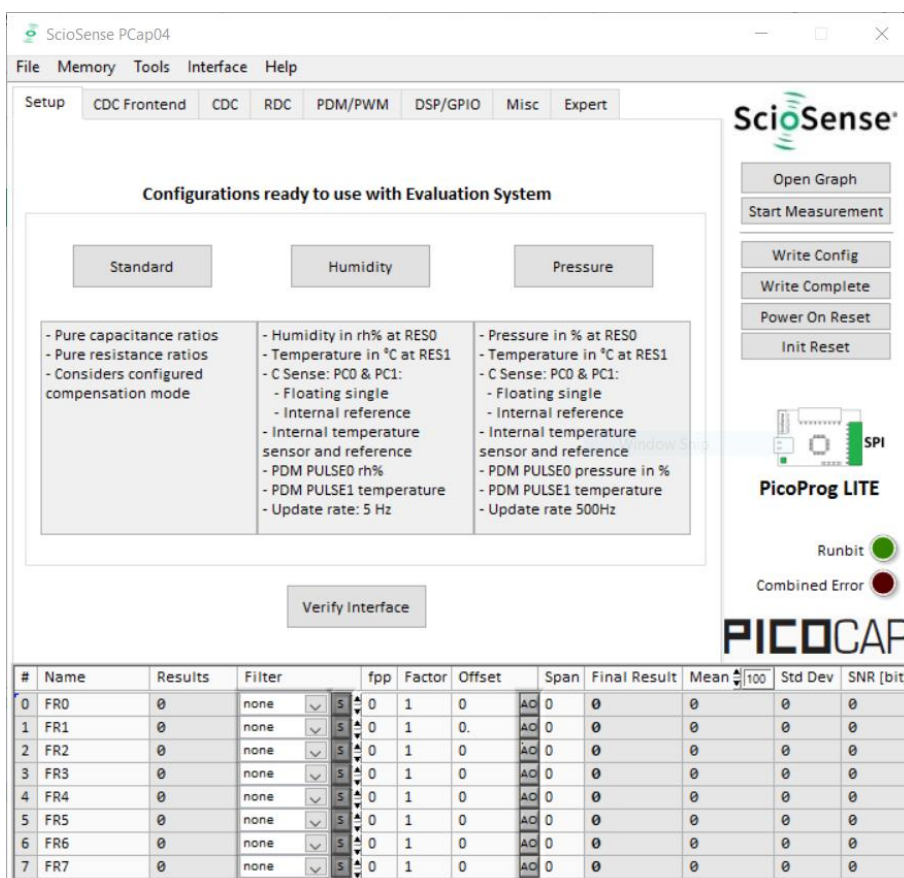


Figure 2: Start page

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:

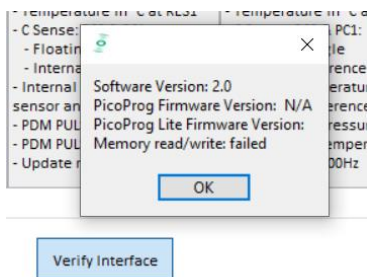


Figure 3: Verify

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:

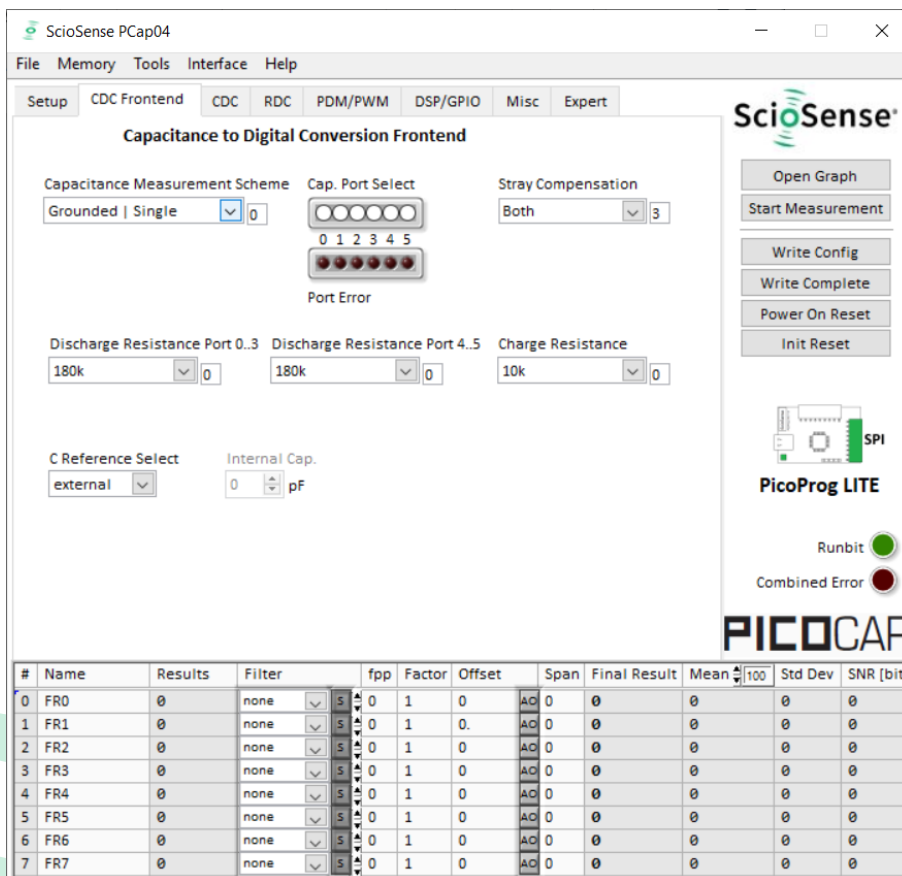


Figure 4: CDC Frontend page at the start

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:

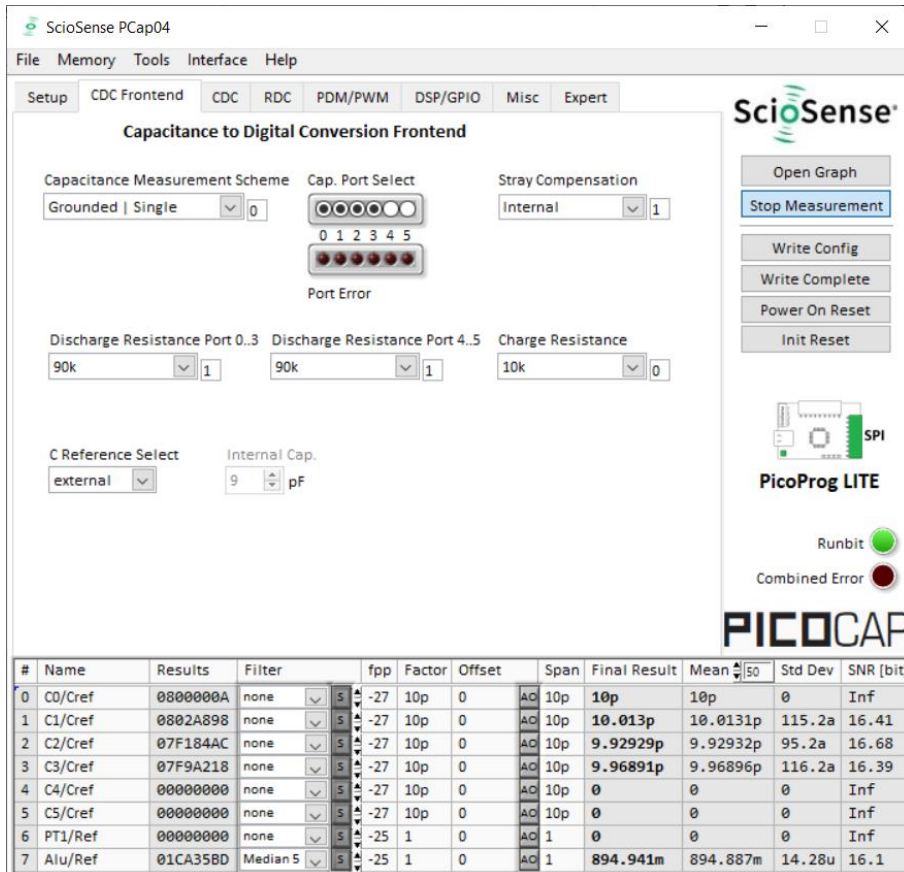


Figure 5: CDC Frontend page with running measurement

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.

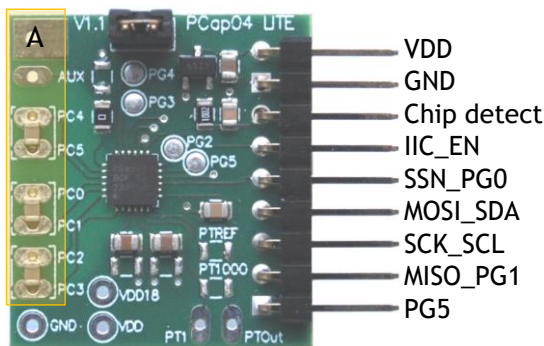


Figure 6: Details of the plug-in board (A=three COG ceramic capacitors)

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.

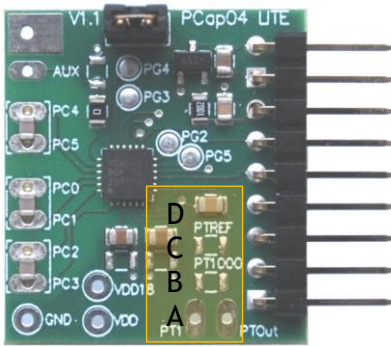


Figure 7: Temperature sensor connection pads

- 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 COG 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

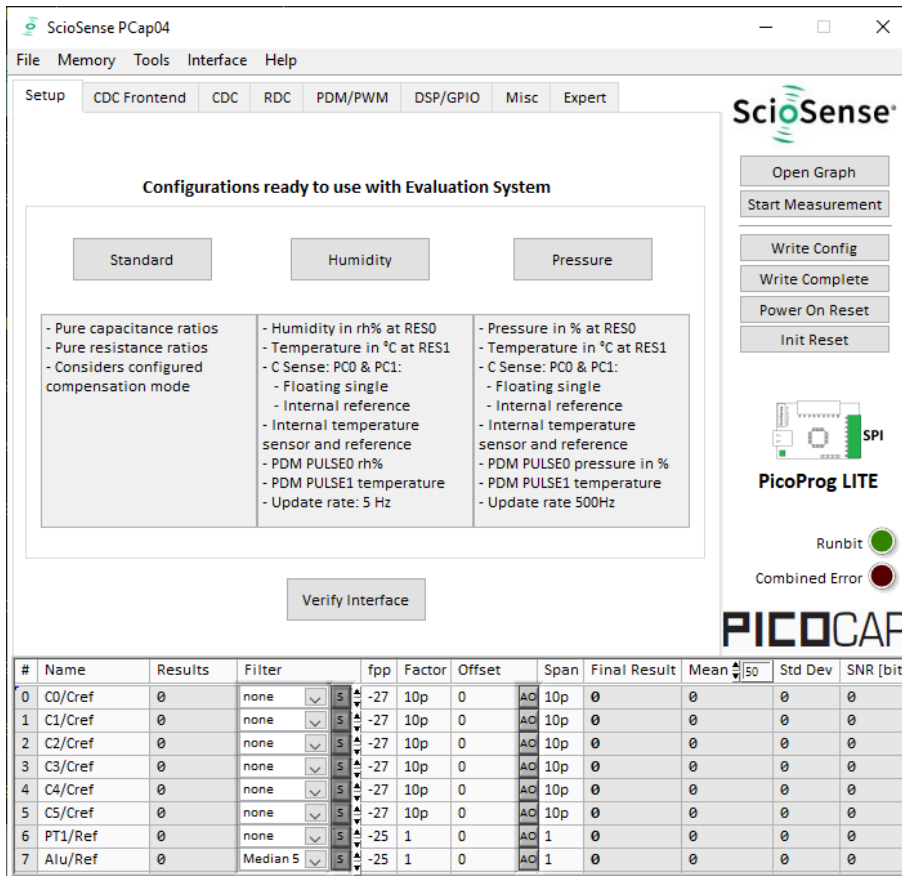


Figure 8 Setup page

Options on 'Setup' page:

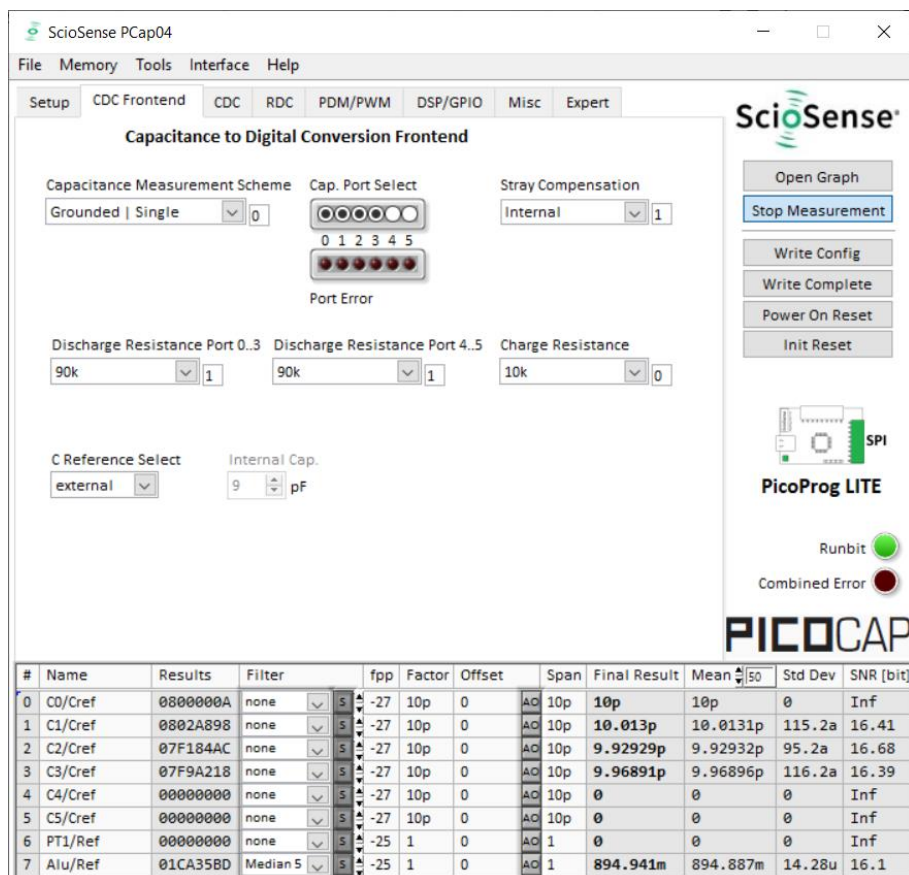
| | |
|------------------|--|
| Standard | Opens the <Selected Device>_standard.prj project file with configuration and standard firmware. |
| Humidity | Opens the <Selected Device>_humidity.prj project file with configuration and linearization firmware. |
| Pressure | Opens the <Selected Device>_pressure.prj 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



Capacitance to Digital Conversion Frontend

Capacitance Measurement Scheme: Grounded | Single 0

Cap. Port Select: 0 1 2 3 4 5

Stray Compensation: Internal 1

Discharge Resistance Port 0..3: 90k 1

Discharge Resistance Port 4..5: 90k 1

Charge Resistance: 10k 0

C Reference Select: external

Internal Cap.: 9 pF

Runbit (Green)

Combined Error (Red)

| # | Name | Results | Filter | fpp | Factor | Offset | Span | Final Result | Mean | Std Dev | SNR [bit] |
|---|---------|----------|----------|-----|--------|--------|------|--------------|----------|---------|-----------|
| 0 | C0/Cref | 0800000A | none | S | -27 | 10p | 0 | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 0802A898 | none | S | -27 | 10p | 0 | 10.013p | 10.0131p | 115.2a | 16.41 |
| 2 | C2/Cref | 07F184AC | none | S | -27 | 10p | 0 | 9.92929p | 9.92932p | 95.2a | 16.68 |
| 3 | C3/Cref | 07F9A218 | none | S | -27 | 10p | 0 | 9.96891p | 9.96896p | 116.2a | 16.39 |
| 4 | C4/Cref | 00000000 | none | S | -27 | 10p | 0 | 0 | 0 | 0 | Inf |
| 5 | C5/Cref | 00000000 | none | S | -27 | 10p | 0 | 0 | 0 | 0 | Inf |
| 6 | PT1/Ref | 00000000 | none | S | -25 | 1 | 0 | 0 | 0 | 0 | Inf |
| 7 | Alu/Ref | 01CA35BD | Median 5 | S | -25 | 1 | 0 | 894.941m | 894.887m | 14.28u | 16.1 |

Figure 9 CDC Frontend page

Options on 'CDC Frontend' page:

| | |
|--------------------------------|--|
| Capacitance Measurement Scheme | <p>Grounded Single – Single capacitive sensor connected between a port and ground.</p> <p>Grounded Differential – Differential capacitive sensor connected between 2 ports with the middle tap of the sensor connected to ground.</p> <p>Floating Single – Single capacitive sensor connected between 2 ports.</p> <p>Floating Differential – Differential capacitive sensor connected between 2 ports with the middle tap of the sensor connected to another 2 ports.</p> |
| 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 | <p>None – No compensation</p> <p>Internal – One additional measurement performed through only the chip-internal stray capacitance with respect to ground.</p> <p>External – One additional measurement per port pair, performed through a parallel connection of the capacitance at the two ports with respect to ground.</p> <p>Both – Both internal and external compensation together.</p> |
| 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

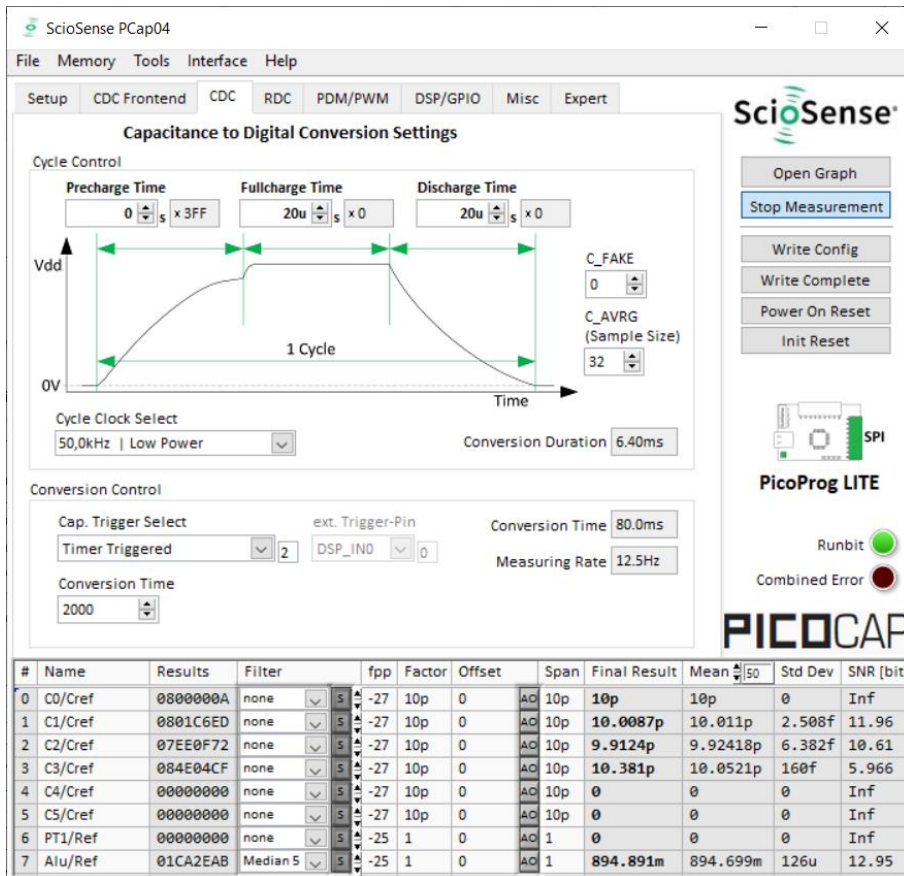


Figure 10 CDC page

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 | <p>Selects the source that triggers the start of a capacitance measurement</p> <p>Continuous – Continuous measurement, self-triggering. Recommended when no temperature measurement is made in parallel.</p> <p>Read Triggered – Triggered by read out</p> <p>Timer Triggered – Depending on the setting the 'Conversion Time'. Generally recommended setting → less prone to error conditions.</p> <p>Timer Triggered (Stretched) – Depending on the setting the CONV_TIME. The parameter is used as sequence period.</p> <p>Pin triggered – Triggered by external Pin, selectable from option ext.Trigger-Pin</p> <p>Opcode Triggered Off – Started by SPI Command 0x8C</p> <p>Continuous (exp.) – (not recommended)</p> |
| Ext. Trigger-Pin | <p>Used to select the pin to be used as the source of trigger for the capacitance measurement.</p> <p>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.</p> |
| 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

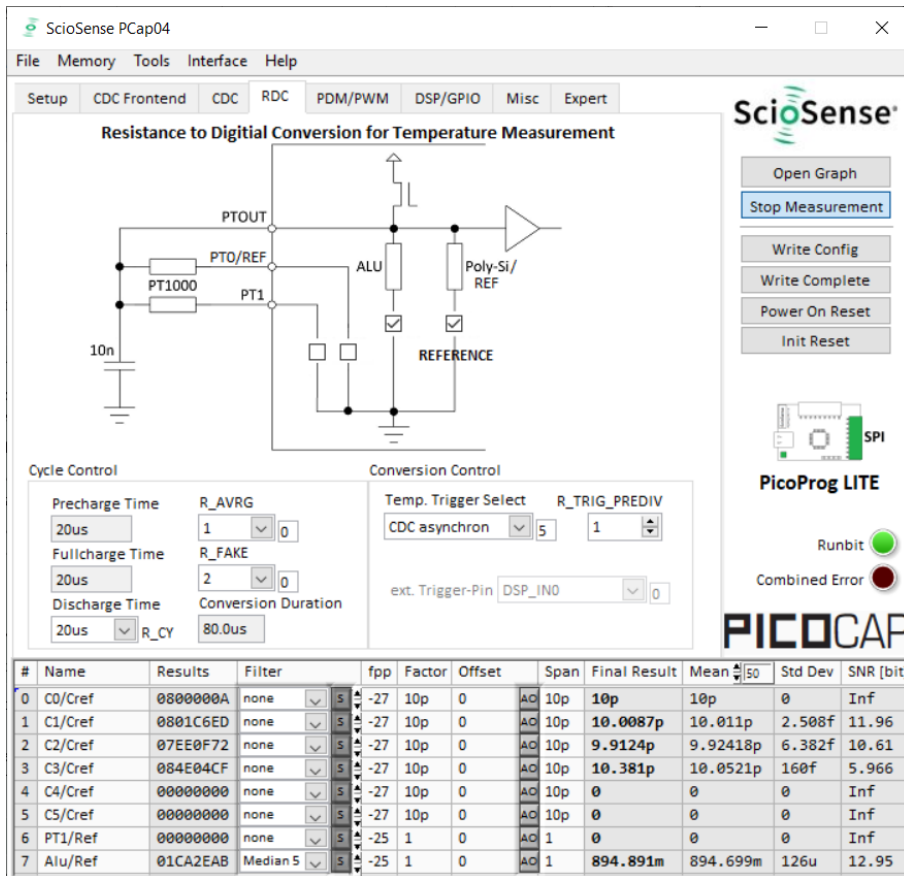


Figure 11 RDC page

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 | <p>Selects the source that triggers the start of a temperature measurement:</p> <p>Off: Default setting when no temperature measurement is wanted. In this case, a temperature measurement can still be started by SPI Command 0x8E.</p> <p>OLF_CLK: Triggered by Low-frequency oscillator.</p> <p>Pin-Triggered: Triggered by external Pin, selectable from option ext.Trigger-Pin</p> <p>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.</p> <p>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.</p> |
| 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 | <p>Used to select the pin to be used as the source of trigger for the capacitance measurement.</p> <p>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.</p> |

3.1.2.1 PDM / PWM Page

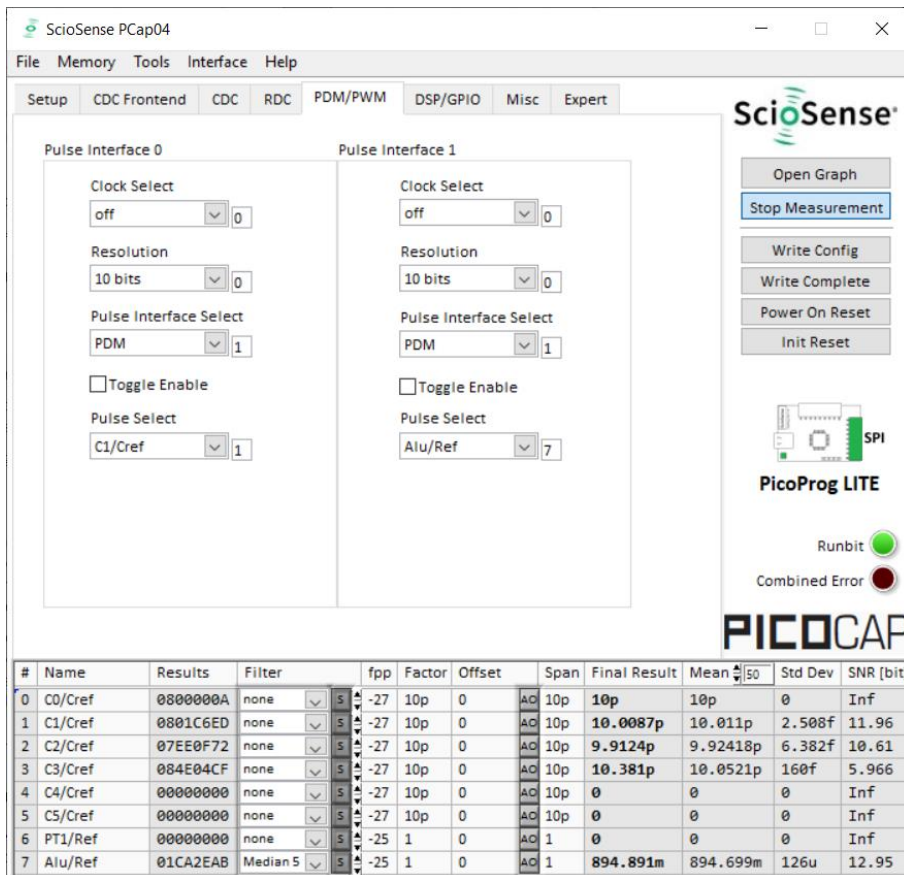


Figure 12 PDM/PWM page

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

The screenshot shows the SciSense PCap04 software interface with the DSP/GPIO tab selected. The interface includes a menu bar (File, Memory, Tools, Interface, Help) and a sub-menu bar (Setup, CDC Frontend, CDC, RDC, PDM/PWM, DSP/GPIO, Misc, Expert). The DSP section contains settings for DSP_SPEED (Slow), DSP_FF_IN (pins IN0, IN1, IN2, IN3), DSP_MOFLO_EN (pin EN0), DSP_START_EN (pins INT_TRIG_EN, RDC_TRIG_EN, CDC_TRIG_EN), and DSP_STARTONPIN (pins FFO, FF1, FF2, FF3). The GPIO section contains settings for PG_DIR_IN (pins PG0, PG1, PG2, PG3), PG_PU (pins PG0, PG1, PG2, PG3), PG0xPG2 (Pulse0 > PG2), PG1xPG3 (Pulse1 > PG3), PG4_INTN_EN, and PG5_INTN_EN. On the right, there are buttons for Open Graph, Stop Measurement, Write Config, Write Complete, Power On Reset, and Init Reset. Below these are icons for SPI, PicoProg LITE, and PICO CAP. At the bottom, a table displays measurement results for various channels.

| # | Name | Results | Filter | fpp | Factor | Offset | Span | Final Result | Mean | Std Dev | SNR [bit] |
|---|---------|----------|----------|-----|--------|--------|------|--------------|----------|---------|-----------|
| 0 | C0/Cref | 0800000A | none | S | -27 | 10p | 0 | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 0801C6ED | none | S | -27 | 10p | 0 | 10.0087p | 10.011p | 2.508f | 11.96 |
| 2 | C2/Cref | 07EE0F72 | none | S | -27 | 10p | 0 | 9.9124p | 9.92418p | 6.382f | 10.61 |
| 3 | C3/Cref | 084E04CF | none | S | -27 | 10p | 0 | 10.381p | 10.0521p | 160f | 5.966 |
| 4 | C4/Cref | 00000000 | none | S | -27 | 10p | 0 | 0 | 0 | 0 | Inf |
| 5 | C5/Cref | 00000000 | none | S | -27 | 10p | 0 | 0 | 0 | 0 | Inf |
| 6 | PT1/Ref | 00000000 | none | S | -25 | 1 | 0 | 0 | 0 | 0 | Inf |
| 7 | Alu/Ref | 01CA2EAB | Median 5 | S | -25 | 1 | 0 | 894.891m | 894.699m | 126u | 12.95 |

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

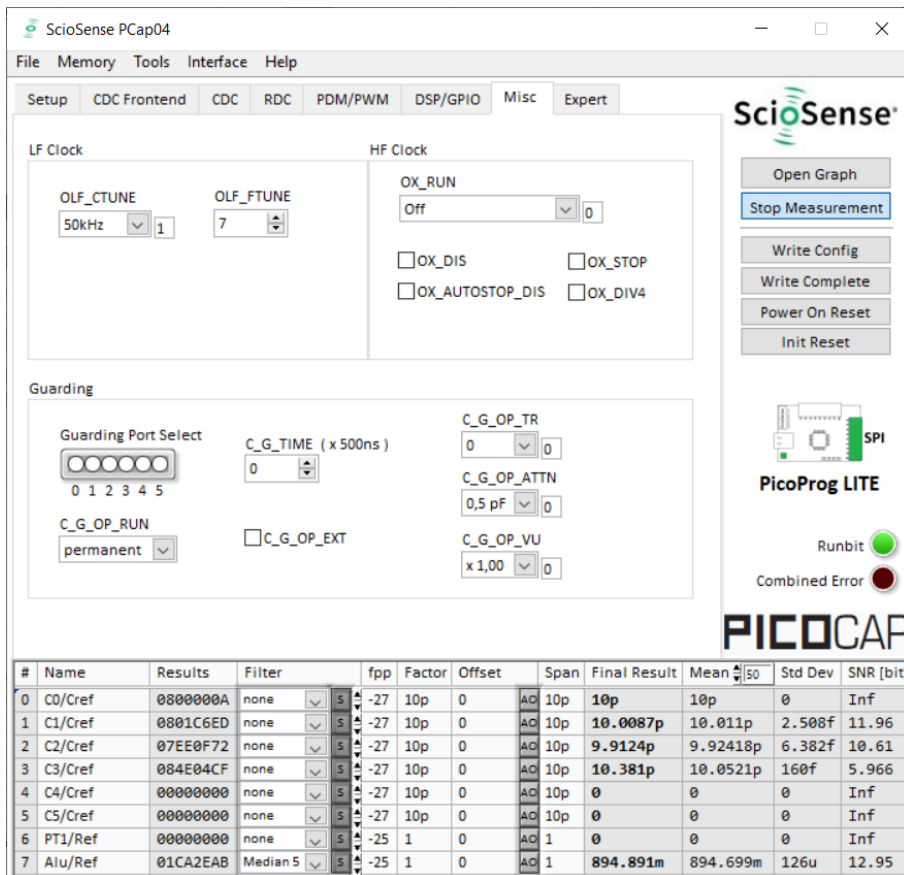


Figure 14 Miscellaneous page

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

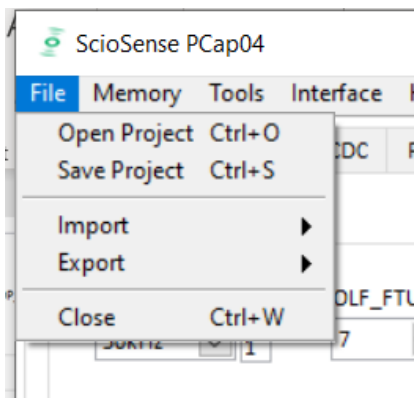


Figure 15 File Menu

| | |
|--------------|--|
| 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

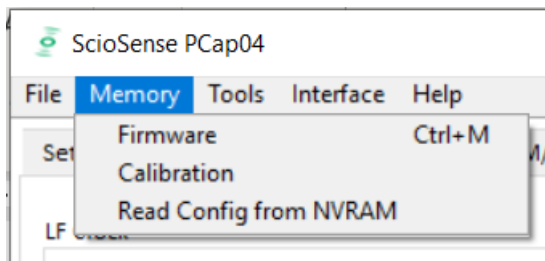


Figure 16 Memory Menu

| | |
|------------------------|--|
| 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

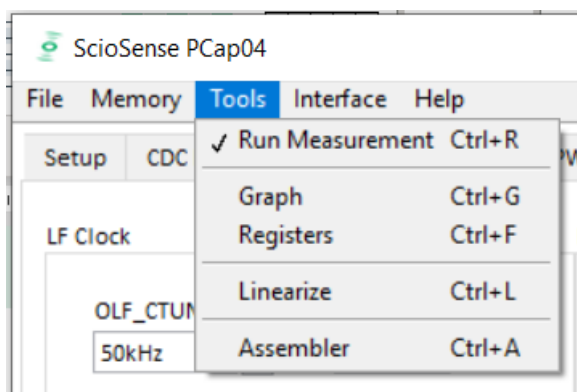


Figure 17 Tools Menu

| | |
|-----------------|---|
| 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

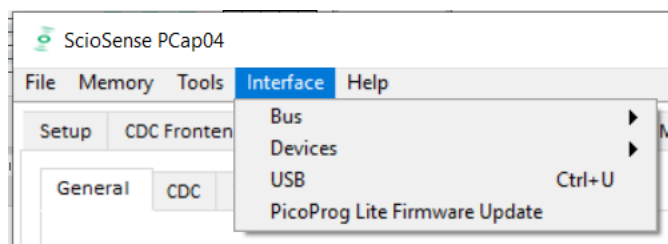


Figure 18 Interface Menu

| | |
|-----|---|
| 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

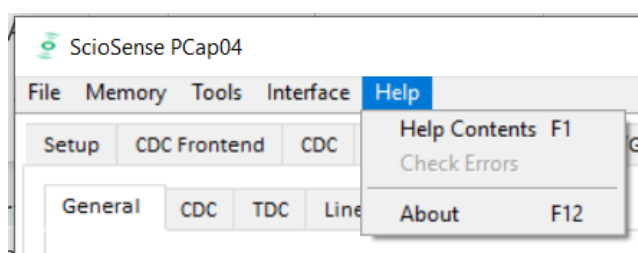


Figure 19 Help Menu

| | |
|---------------|---|
| 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.

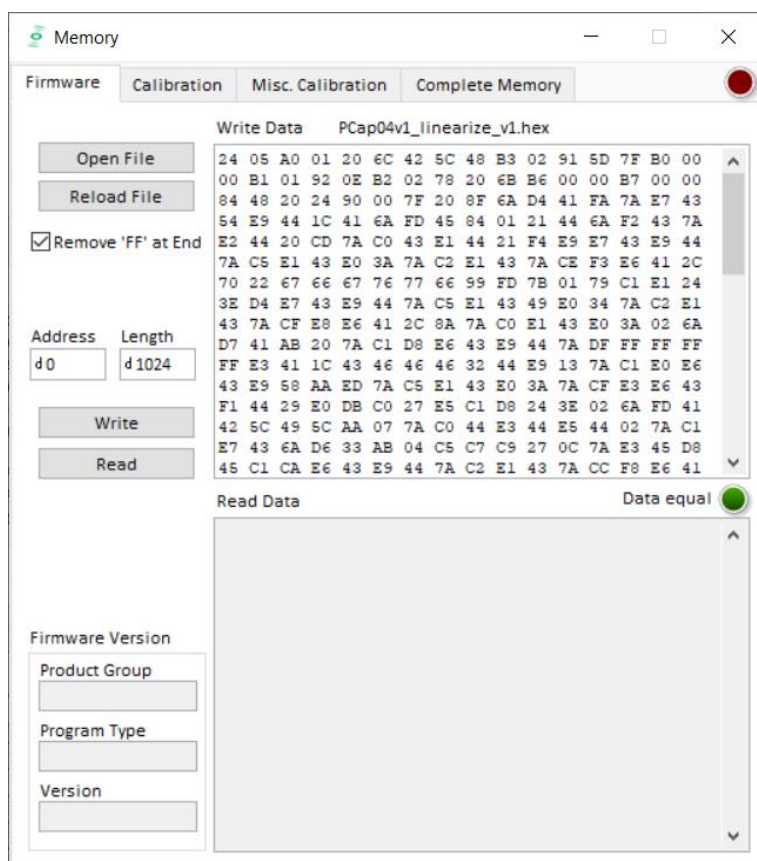


Figure 20 Firmware Window

| | |
|-------------|---|
| 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: <i>pcap_standard.h</i> . 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.

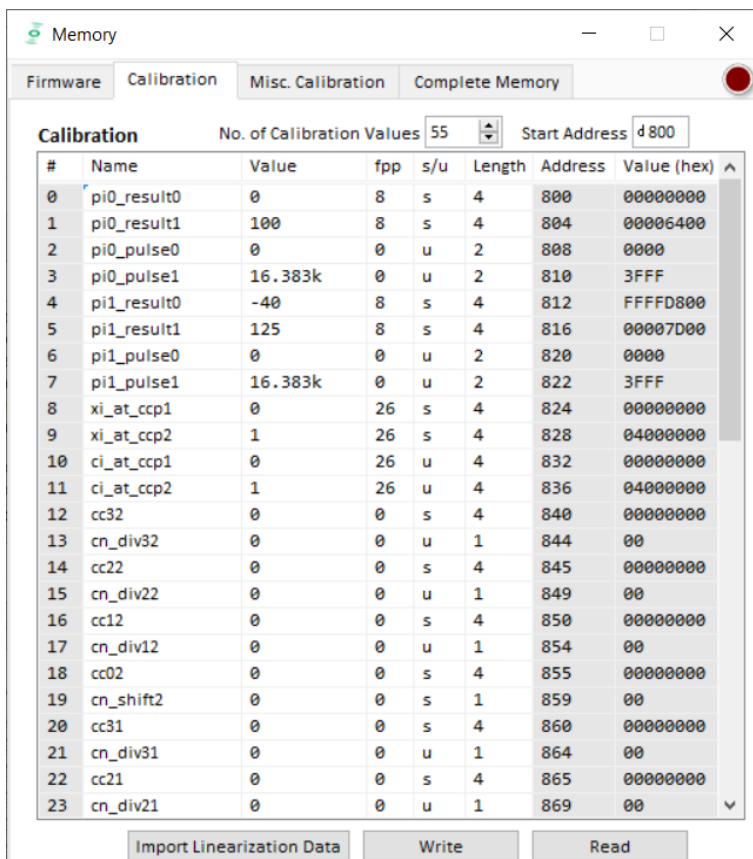


Figure 21 Calibration Window

| | |
|---------------------------|--|
| 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.

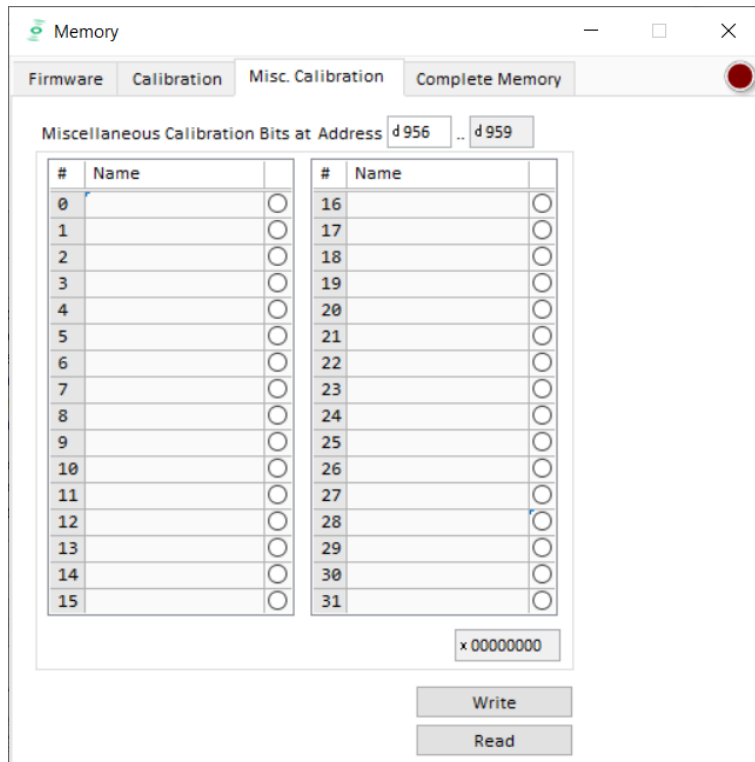


Figure 22 Misc. Calibration Window

| | |
|-------|--|
| 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

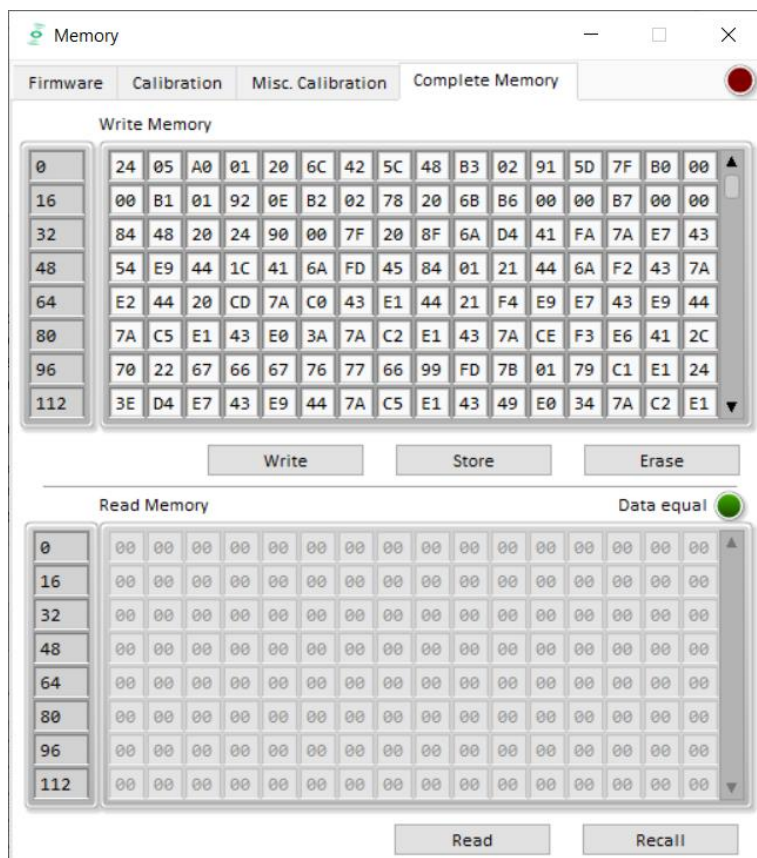


Figure 23 Complete Memory Window

| | |
|--------|--|
| 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 be 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

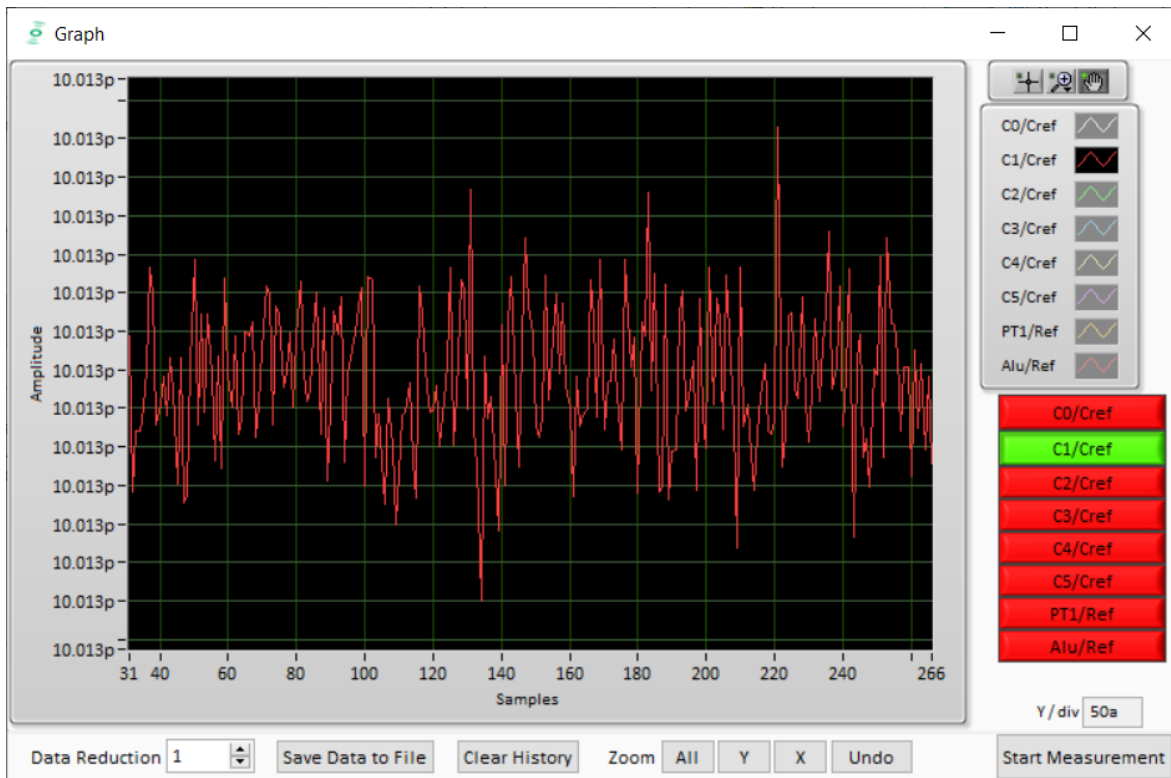


Figure 24 Graph Window

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 changed 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.

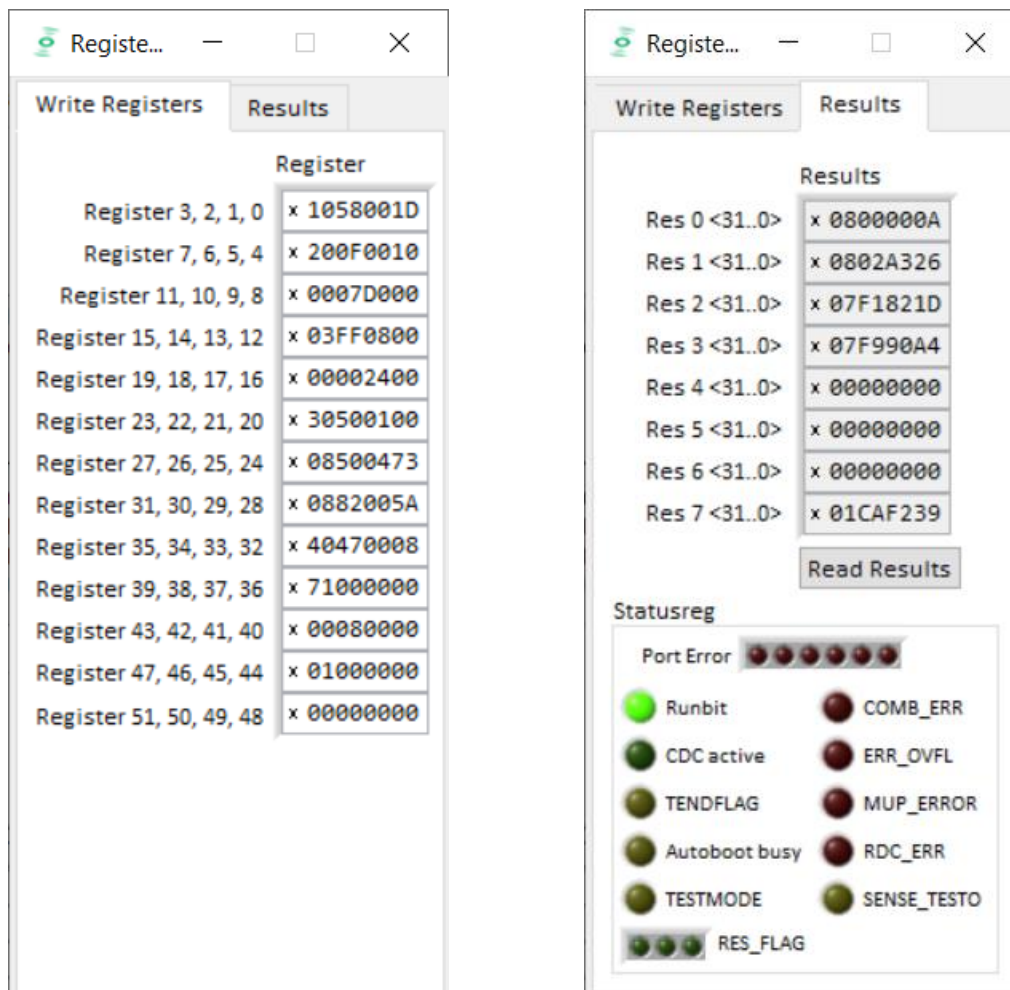


Figure 25 Write Registers and Results

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 \varnothing 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, \varnothing 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.

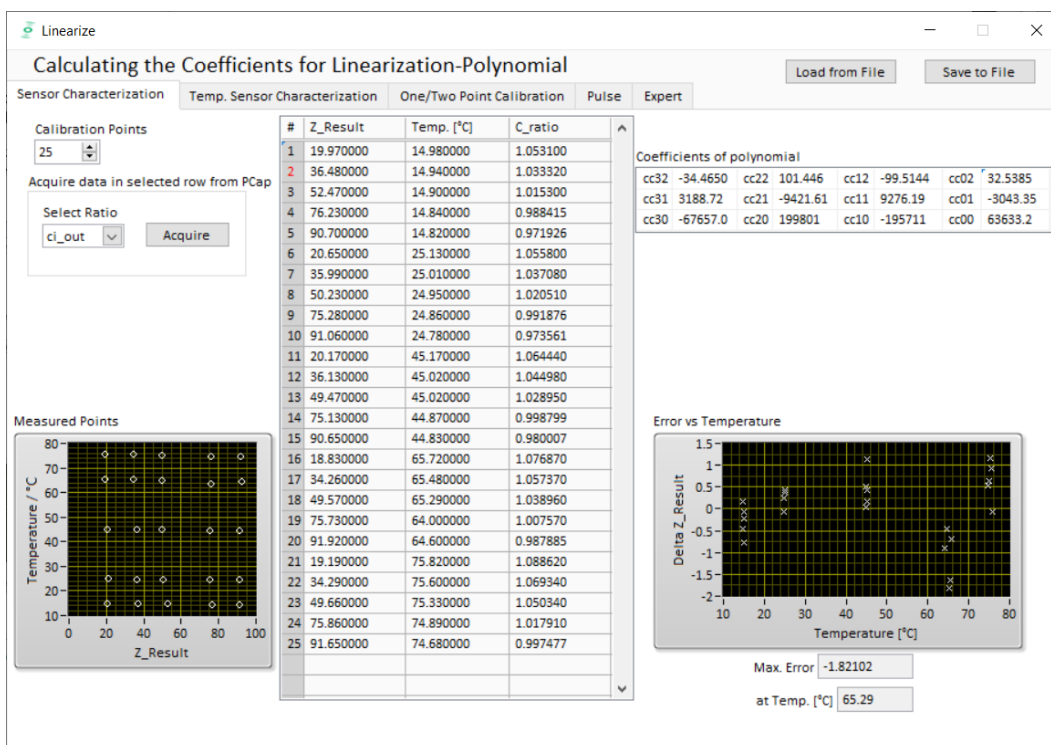


Figure 26 Sensor Characterization

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.

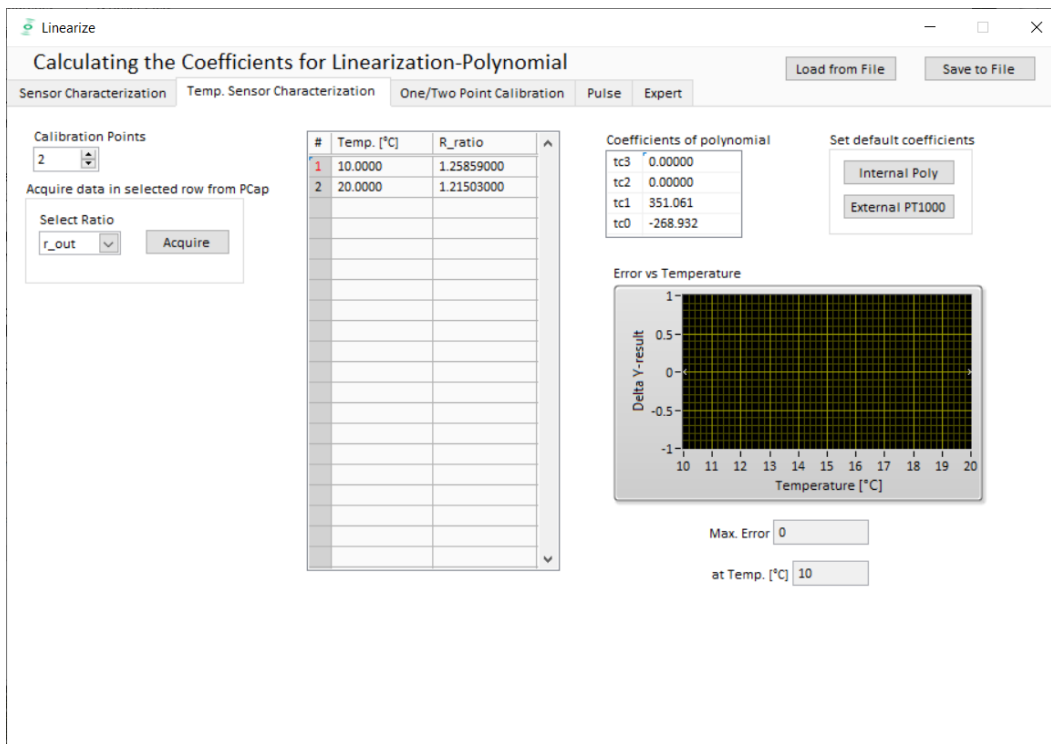


Figure 27 Temp. Sensor Characterization

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.

Linearize

Calculating the Coefficients for Linearization-Polynomial

Sensor Characterization Temp. Sensor Characterization One/Two Point Calibration Pulse Expert

Note: For most accurate calibration individual sensor calibration (capactiance and temperature) is recommended.
For lot calibration with only one or two calibration points please use this sheet.

Capacitance Set Points off

| | Z_Result | Temp. [°C] |
|------|----------|------------|
| CCP1 | 0.000000 | 0.000000 |
| CCP2 | 0.000000 | 0.000000 |

Acquire ci_at_CCP from PCap

Select Ratio ci_out

Acquire CCP1 div2_ci1

Acquire CCP2 div2_ci2

c_hex_at_CCP 00000000 04000000

x_at_CCP 0 1

x_hex_at_CCP 00000000 04000000

div2_xi1 div2_xi2

Temperature Set Points off

| | Temp. [°C] |
|------|------------|
| TCP1 | 0.000000 |
| TCP2 | 0.000000 |

Acquire r_at_TCP from PCap

Select Ratio r_out

Acquire TCP1 div2_r1

Acquire TCP2 div2_r2

r_hex_at_CCP 00000000 02000000

y_at_CCP 0 1

y_hex_at_CCP 00000000 02000000

Figure 28 One/Two Point Calibration

3.1.5.4 Pulse

Linearize

Calculating the Coefficients for Linearization-Polynomial

Load from File

Save to File

Sensor Characterization

Temp. Sensor Characterization

One/Two Point Calibration

Pulse

Expert

Pulse Interface 0

Acquire Results from PCap

Input of Result

Humidity / %rH

Acquire Result 1

Input of Pulse

Pulse_Z

Acquire Result 2

Coefficients

| | | |
|-------------|---------|----------|
| pi0_result0 | 0,00000 | 00000000 |
| pi0_result1 | 0,00000 | 00000000 |
| pi0_pulse0 | 0,00000 | 00000000 |
| pi0_pulse1 | 0,00000 | 00000000 |

Pulse Interface 1

Acquire Results from PCap

Input of Result

theta / °C

Acquire Result 1

Input of Pulse

Pulse_theta

Acquire Result 2

Coefficients

| | | |
|-------------|---------|----------|
| pi1_result0 | 0,00000 | 00000000 |
| pi1_result1 | 0,00000 | 00000000 |
| pi1_pulse0 | 0,00000 | 00000000 |
| pi1_pulse1 | 0,00000 | 00000000 |

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.

Linearize

Calculating the Coefficients for Linearization-Polynomial

Sensor Characterization Temp. Sensor Characterization One/Two Point Calibration Pulse Expert

Load from File Save to File

z_fpp 15 C_fpp 22 C_fpp_int 26 theta_fpp 8 Scale Z 1

r_fpp 22 r_int_fpp 25

cc_fpp 15 16 17 22 25 28 31 29 32 35 37

cn_div 26 27 26 24 24 24 24 25

cn_shift 0 0 0

ccx 15C1A0 FF8704B4 72C364 FF8547E6 00E9F9 FFF071ED 50589E FF9E38C1 FFFF9CFE 0943B8 FFB27509 6CA256

cci 1.0184 0.290188 -0.0835993 0.0166333 -0.0001519 -5.73006E-7 -8.34917E-7 -5.15578E-7 5.64387E-7 -4.63357E-7 -3.3911E-7 2.6669E-7

tc -268.932 351.061 0 0

tci 0.766055 0.0028485 0 0

tc_fpp 8 6 0 0

tn_div 28 0 0 0

☒ disable c_lin_coeff_dut

Figure 30 Expert

3.1.5.6 Assembler

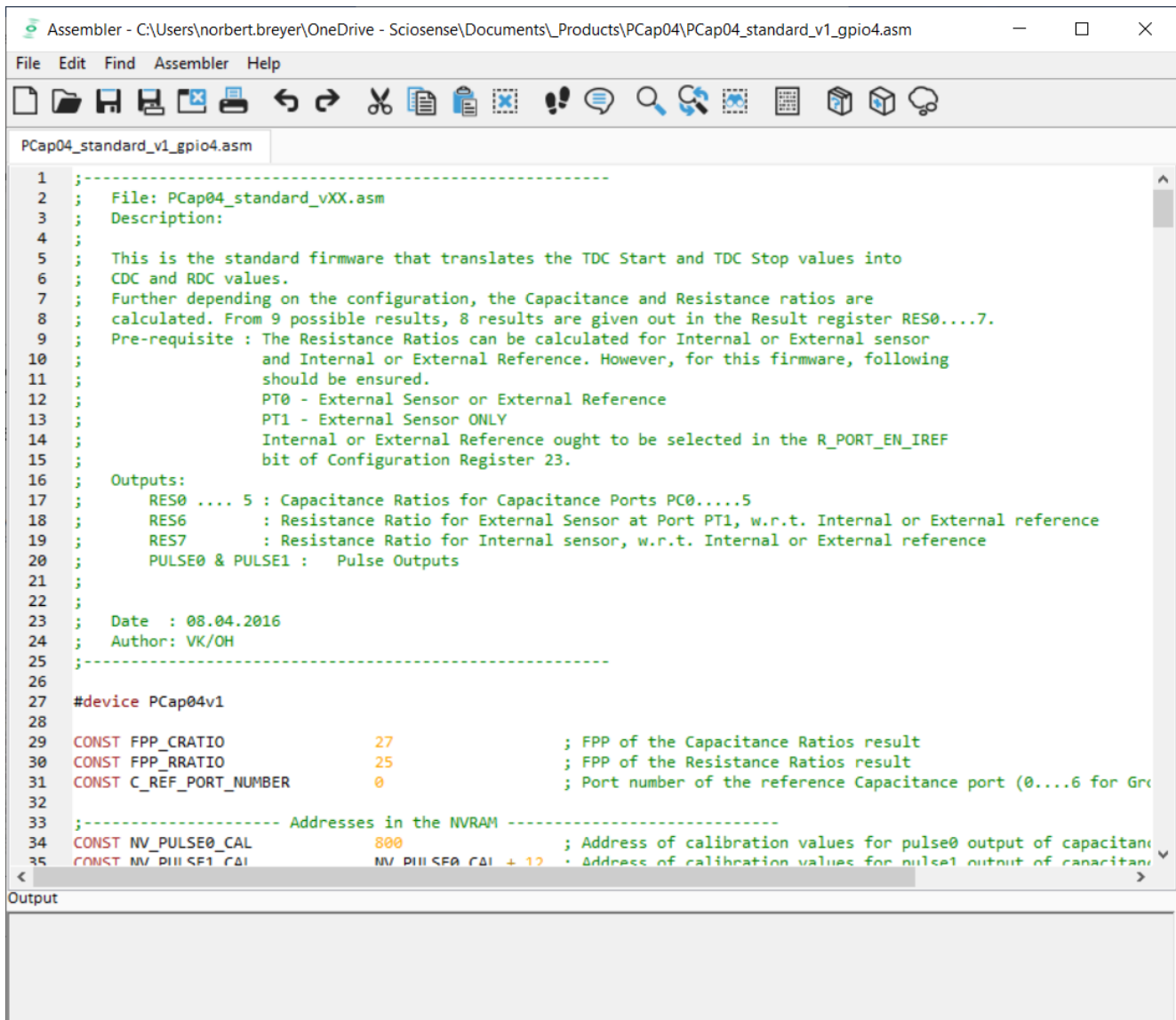


Figure 31 Assembler

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 | Std Dev | SNR [bit] |
|---|---------|----------|--------|-----|--------|--------|--------|--------------|----------|---------|-----------|
| 0 | C0/Cref | 08000013 | none | -27 | 25p | -15p | AO 10p | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 0808B6B7 | none | -27 | 25p | -15p | AO 10p | 10,1064p | 10,1063p | 234,5a | 15,38 |
| 2 | C2/Cref | 08BF5F56 | none | -27 | 25p | -15p | AO 10p | 12,3361p | 12,336p | 225,2a | 15,44 |
| 3 | C3/Cref | 08BA5E49 | none | -27 | 25p | -15p | AO 10p | 12,275p | 12,2748p | 316,8a | 14,95 |
| 4 | C4/Cref | 075FA4B4 | none | -27 | 25p | -15p | AO 10p | 8,04252p | 8,04221p | 291,4a | 15,07 |
| 5 | C5/Cref | 07688199 | none | -27 | 25p | -15p | AO 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 | Std Dev | SNR [bit] |
|---|---------|----------|--------|-----|--------|--------|--------|--------------|----------|---------|-----------|
| 0 | C0/Cref | 08000009 | none | -27 | 25p | -15p | AO 10p | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 08B81EAB | none | -27 | 25p | -15p | AO 10p | 12,2476p | 12,2474p | 273,1a | 15,16 |
| 2 | C2/Cref | 076008D8 | none | -27 | 25p | -15p | AO 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 | AO 10p | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 080E6BCE | none | -27 | 15p | -5p | AO 10p | 10,1056p | 10,1059p | 219,2a | 15,48 |
| 2 | C2/Cref | 0946D492 | none | -27 | 15p | -5p | AO 10p | 12,3938p | 12,3935p | 283a | 15,11 |
| 3 | C3/Cref | 093E1B82 | none | -27 | 15p | -5p | AO 10p | 12,3299p | 12,3295p | 353,1a | 14,79 |
| 4 | C4/Cref | 06ECA6E1 | none | -27 | 15p | -5p | AO 10p | 7,98329p | 7,98315p | 274,7a | 15,15 |
| 5 | C5/Cref | 06FBDDE2 | none | -27 | 15p | -5p | AO 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 | AO 10p | 10p | 10p | 1,632E- | 52,44 |
| 1 | C1/Cref | 08E7E36C | none | -27 | 20p | -10p | AO 10p | 12,2645p | 12,2646p | 301,6a | 15,02 |
| 2 | C2/Cref | 0735B673 | none | -27 | 20p | -10p | AO 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 | AO 10p | 10p | 10p | 0 | Inf |
| 1 | C1/Cref | 09E81FB7 | none | -27 | 10p | 0 | AO 10p | 12,3834p | 12,1831p | 1,414p | 2,822 |
| 2 | C2/Cref | 066773EF | none | -27 | 10p | 0 | AO 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:

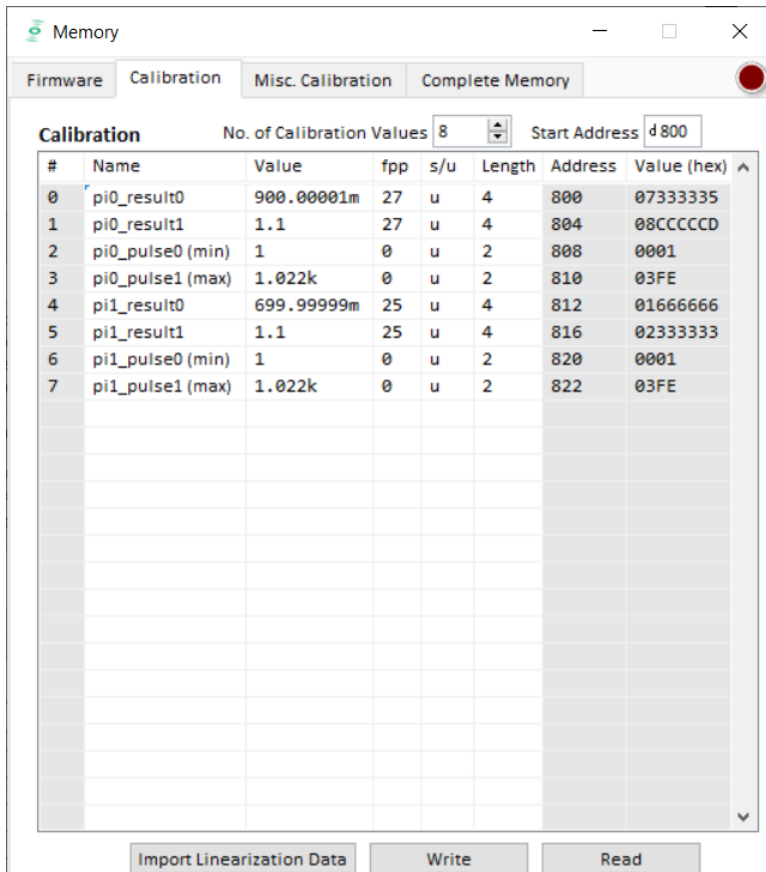
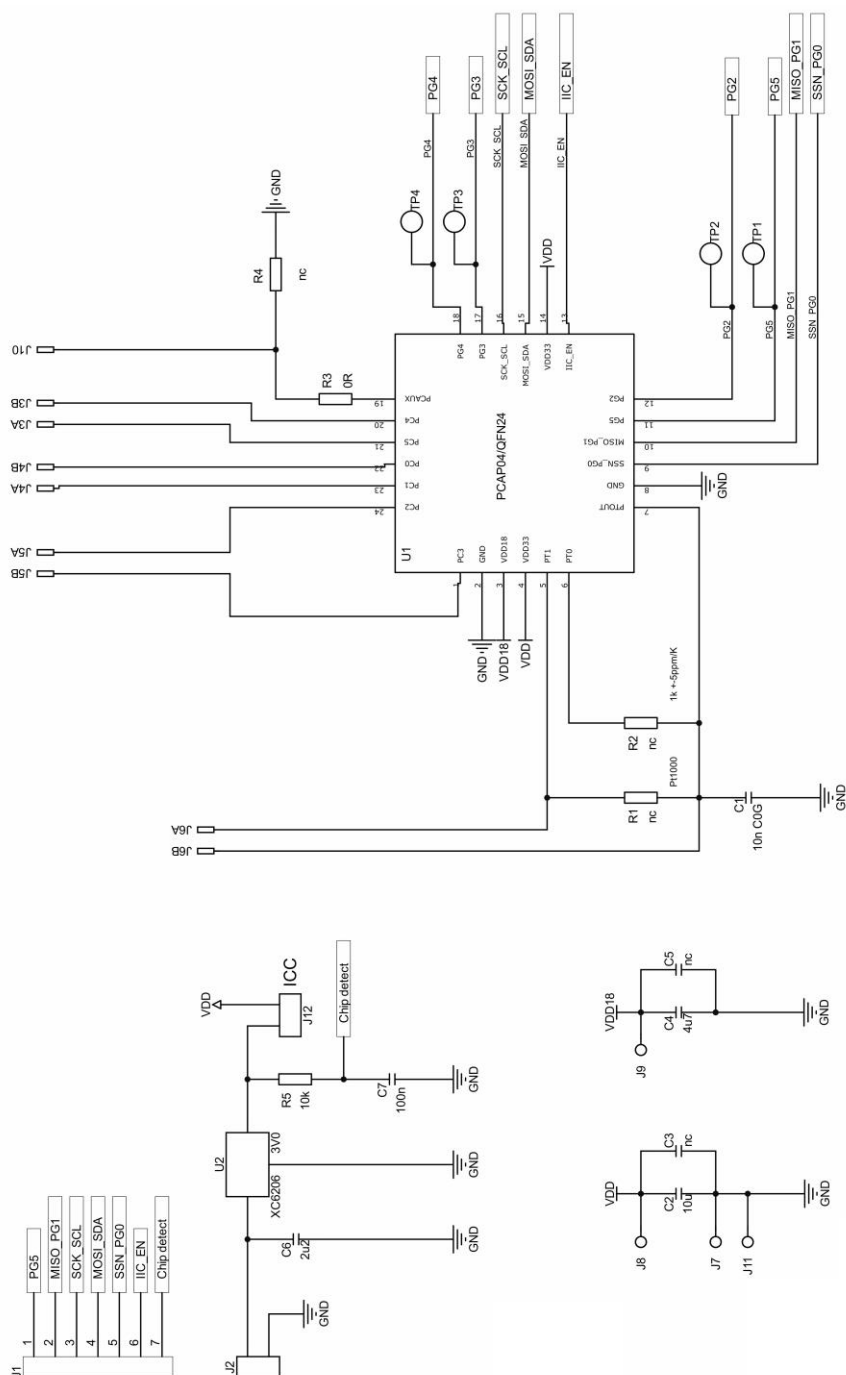


Figure 37 Scaling PDM Output

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.



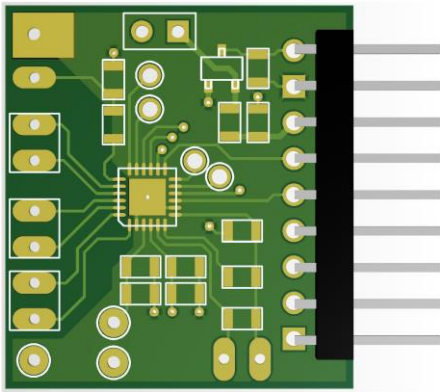


Figure 39: PCap04 LITE layout 2:1t

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 | |

5 RoHS Compliance & ScioSense Green Statement

RoHS: The term RoHS compliant means that Sciosense B.V. products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead does not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.

ScioSense Green (RoHS compliant and no Sb/Br): ScioSense Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

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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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