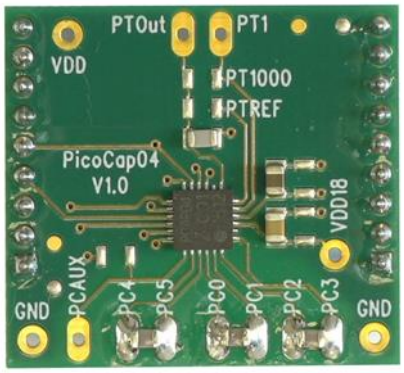


# PCAP04/02/01

## Interpreting and Scaling Raw Results

**PCAP04/02/01 Application Note**

Revision: 1

Release Date: 2021-12-07

Document Status: Production

# Content Guide

# 1 Introduction

PCAP04, PCAP02 and PCAP01 are capacitance-to-digital converters (CDC) and resistance-to-digital converters (RDC) with an integrated digital signal processor (DSP) for on-chip data post-processing.

In this application note, the STANDARD Firmware is used. The firmware translates the TDC Start and TDC Stop values into CDC and RDC values, means ratios. These ratios are calculated by means of the discharge times, depending on the configuration. From 9 possible results, 8 results are given out in the result register RES0...7.

The focus of this application note is the ratio. For the conversion into Farad and the proper setting of the scaling factor and offset please refer to the user guide (e.g., SC-001587-UG).

# 2 Choice the Reference

In these examples we use as default the 'Standard' configuration (with internal stray compensation). For illustration, we use capacitances of 10 pF and 100 pF to get ratios of external reference and sensor of a ratio of 10, 1 and 0.1.

Application:

- PC0 = Reference = 100 pF or 10 pF
- PC1 = Sensor 1 = 10 pF
- PC2 = Sensor 2 = 100 pF
- Span for each sensor = 10 pF
- Parasitic capacitance of each port about 7 pF

In the case of linear sensors, any deviation can be corrected by column 'Factor' and 'Offset':

- Column 'Factor' = reference plus parasitic capacitance
- Column 'Offset' = negative offset of parasitic capacitance

For non-linear sensors, further measures are required to compensate for any deviations.

Simplified formulas for columns 'Factor', 'Offset' and 'Span' are:

- $Column\,'Factor' = \left(1 + \frac{Parasitic}{Reference}\right)$
- $Column\,'Offset' = -(\frac{Parasitic}{Reference})$
- $Column\,'Span' = (\frac{Span}{Reference})$

Signal-to-Noise ratio (SNR) in bit is calculated as a binary logarithm of span over noise.

- $Column\,'SNR[bit]' = \frac{ln\left(\frac{'Span'}{'Noise'}\right)}{\ln(2)}$

## 2.1 Example 1, Reference = 100 pF

'Factor' = 100 pF + 7 pF, 'Offset' = -7 pF and 'Span' = 10 pF

| # | Name | Results | Filter | | fpp | Factor | Offset | | Span | Final Result | Mean 50 | Std Dev | SNR [bit] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C0/Cref | 08000004 | none | S | -27 | 107p | -7p | AO | 10p | **100p** | 100p | 0 | Inf |
| 1 | C1/Cref | 014C78DE | none | S | -27 | 107p | -7p | AO | 10p | **10,3704p** | 10,3701p | 430,7a | 14,5 |
| 2 | C2/Cref | 0809B977 | none | S | -27 | 107p | -7p | AO | 10p | **100,508p** | 100,509p | 1,183f | 13,04 |

*Figure 1: Example 1, unit [pF]*

Expected ratio, if $'Factor' = (1 + \frac{7}{100})$ , $'Offset' = -(\frac{7}{100})$ and $'Span' = (\frac{10}{100})$

- C1/Cref = 0.1
- C2/Cref = 1.0

| # | Name | Results | Filter | | fpp | Factor | Offset | | Span | Final Result | Mean 50 | Std Dev | SNR [bit] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C0/Cref | 08000004 | none | S | -27 | 1,07 | -0,07 | AO | 0,1 | **1** | 1 | 224,3a | 48,66 |
| 1 | C1/Cref | 014C772D | none | S | -27 | 1,07 | -0,07 | AO | 0,1 | **103,7m** | 103,7m | 3,708u | 14,72 |
| 2 | C2/Cref | 0809C114 | none | S | -27 | 1,07 | -0,07 | AO | 0,1 | **1,0051** | 1,00508 | 8,545u | 13,51 |

*Figure 2: Example 1, Unit [Ratio]*

## 2.2 Example 2, Reference = 10 pF

'Factor' = 10 pF + 7 pF, 'Offset' = -7 pF and 'Span' = 10 pF

| # | Name | Results | Filter | | fpp | Factor | Offset | | Span | Final Result | Mean 50 | Std Dev | SNR [bit] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C0/Cref | 08000019 | none | S | -27 | 17p | -7p | AO | 10p | **10p** | 10p | 0 | Inf |
| 1 | C1/Cref | 082F3348 | none | S | -27 | 17p | -7p | AO | 10p | **10,3918p** | 10,3919p | 271,1a | 15,17 |
| 2 | C2/Cref | 32AC3C83 | none | S | -27 | 17p | -7p | AO | 10p | **100,68p** | 100,673p | 2,675f | 11,87 |

*Figure 3: Example 2, Unit [pF]*

Expected ratio if using $'Factor' = (1 + \frac{7}{10})$ , $'Offset' = -(\frac{7}{10})$ and $'Span' = (\frac{10}{10})$

- C1/Cref = 1.0
- C2/Cref = 10.0

| # | Name | Results | Filter | | fpp | Factor | Offset | | Span | Final Result | Mean 50 | Std Dev | SNR [bit] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C0/Cref | 08000019 | none | S | -27 | 1,7 | -0,7 | AO | 1 | **1** | 1 | 0 | Inf |
| 1 | C1/Cref | 082F2B15 | none | S | -27 | 1,7 | -0,7 | AO | 1 | **1,03915** | 1,03919 | 27,27u | 15,16 |
| 2 | C2/Cref | 32ABD1FC | none | S | -27 | 1,7 | -0,7 | AO | 1 | **10,0676** | 10,0673 | 257u | 11,93 |

*Figure 4: Example 2, Unit [Ratio]*

## 2.3 Data Range

In order to avoid the limitation of the result register, one should keep an eye on the ratio. PCAP04 has specified 5 integer bits, but due to the STANDARD FW only 4 integer bits are available. The maximum possible ratio is therefore 15.999 (with integer = 4 bits and fractional = 27 bits).

$$Max.Ratio = 2^{(integer)} - \frac{1}{2^{(fractional)}}$$

Different ratios are shown in Figure 5. External reference (PC0 = 10 pF) and sensor (PC1 = 10 pF, PC2 = 100 pF and PC3 = 330pF) are used. The result register RES3 (C3/Cref) is at the limit, showing '0x7FFFFFFF', ratio = 16. Parasitic will not be considered to show the pure ratio.

| # | Name | Results | Filter | | fpp | Factor | Offset | | Span | Final Result | Mean 50 | Std Dev | SNR [bit] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | C0/Cref | 0800001A | none | S | -27 | 10p | 0 | AO | 10p | **10p** | 10p | 0 | Inf |
| 1 | C1/Cref | 082F6B91 | none | S | -27 | 1 | 0 | AO | 1 | **1,02315** | 1,02316 | 16,69u | 15,87 |
| 2 | C2/Cref | 3255F53F | none | S | -27 | 1 | 0 | AO | 1 | **6,29197** | 6,29203 | 160,8u | 12,6 |
| 3 | C3/Cref | 7FFFFFFF | none | S | -27 | 1 | 0 | AO | 1 | **16** | 16 | 13,21u | 16,21 |

*Figure 5: Example, Showing Ratios*

Therefore, it is recommended to use a reference capacity in the same range as the sensor capacity.

# 3 Summary / Result

The measurement result depends a lot on the configuration, especially the settings for the compensation. With the right setting for the scaling factor and offset it is possible to get the expected ratio displayed in the results.

# 4 Copyrights & Disclaimer



Devices sold by Sciosense B.V. are covered by the warranty and patent indemnification provisions appearing in its General Terms of Trade. Sciosense B.V. makes no warranty, express, statutory, implied, or by description regarding the information set forth herein. Sciosense B.V. reserves the right to change specifications and prices at any time and without notice. Therefore, prior to designing this product into a system, it is necessary to check with Sciosense B.V. for current information. This product is intended for use in commercial applications. Applications requiring extended temperature range, unusual environmental requirements, or high reliability applications, such as military, medical life-support or life-sustaining equipment are specifically not recommended without additional processing by Sciosense B.V. for each application. This product is provided by Sciosense B.V. “AS IS” and any express or implied warranties, including, but not limited to the implied warranties of merchantability and fitness for a particular purpose are disclaimed.

Sciosense B.V. shall not be liable to recipient or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data herein. No obligation or liability to recipient or any third party shall arise or flow out of Sciosense B.V. rendering of technical or other services.

# 5 Revision information

*Table 1: Revision history*

| Revision | Date | Comment | Page |
|---|---|---|---|
| 1 | 2021-12-07 | First edition | All |

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

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

**Address:** Sciosense B.V.
High Tech Campus 10
5656 AE Eindhoven
The Netherlands

**Contact:** www.sciosense.com
info@sciosense.com