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PCap04

Standard Board

PCAP04-EVA-KIT

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1 Introduction

The PCAP04-EVA-KIT evaluation system provides a complete system for generally evaluating the PCapØ4 IC. It is supplied with a main board, a plug-in board, a Windows based evaluation software, assembler software and the PICOPROG V3.0 programming device. The PCapØ4 evaluation board is connected to the PC's USB interface through the PICOPROG V3.0 programming device. The previous generation PICOPROG V2.0 programming device may also be used with the PCAP04-EVA-KIT.

Figure 1: Kit Content



Pos.	Item	Comment
1	PCapØ1-MB	Motherboard
2	PCapØ4-EVA-BOARD	Plug-in board based on PCapØ4 in QFN24 package
3	PICOPROG V3.0	Programmer and interface box
4	USB cable	Connects PICOPROG V3.0 to PC
5	High density DSUB15 cable	Connecting Evaluation board to programmer (optionally)
6	Wall power supply unit	9 V

The evaluation kit offers user-friendly operation of the PCapØ4 single-chip solution for capacitance measurement. This kit can be used to evaluate the capacitance measurement, temperature measurement and the pulse generation capabilities of the PCapØ4 chip. The kit also includes a CD-

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ROM containing software and data sheets. However, it is strongly recommended to use the latest data sheets and GUI software or get them on request.

2 Quick Start Guide

In this section, we described how to set up quickly the PCAP04-EVA-KIT and establish basic operation and make measurements.

2.1 Install 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.
- Unzip the package to the desired directory.
- Open "setup.exe" from the unzipped directory.
- Follow the instructions on the screen.

2.2 Install the Hardware:

- Install the software before proceeding with this step!
- Connect your computer with the PICOPROG V3.0 using USB cable.
- Connect PICOPROG V3.0 and the evaluation kit motherboard using the DB15 interfaces
- Mount the plug-in board on the corresponding socket on the motherboard.
- Set the power supply unit to 7.5 V output.
- Connect the motherboard to power via the power supply unit.
 The green LED on the EVA kit motherboard should be on.





2.3 Quick Start for Initial Measurements

From the "Start" menu, go to "All Programs" and then to the "acam" directory. Double click the "PCap04 Frontpanel" icon to begin execution of the evaluation kit software. The following screen should appear:

Figure 3: Setup page

Se	etup CDC	Frontend CC	DC RDC PDN	I/PWM	DSP/C	SPIO I	Nisc	Exp	pert		m	
	-	- Alexandria	Sele	ct Devi	ce	-				M		
			PCa	p04v1	-	Rea Versio	S. 16	evice om Chi	q		Open Gra	ph
		Configurat	ions ready to u	se witl	n Evalua	ation Sy	stei	m		Sta	rt Measur	ement
	(_		1		Write Con	fig
	St	andard	Hu	midity	-			Pres	sure	W	/rite Comp	lete
	-								1	- Po	ower On R	eset
		citance ratios tance ratios	- Humidity i - Temperatu			1000			at RESO in ®C at RES1		Init Rese	-1
	-		 Internal te sensor and PDM PULSE PDM PULSE Update rate 	referen 0 rh% 1 temp	ce	sens - PDI - PDI	ior a VI PU VI PU	nd refe	erature erence ressure in % emperature 00Hz		Rur	nbit 🔵
	Name	Results	Verify	Interfa fpp		Offset		Span	Final Result	PI	mbined E	
ŧ	FRO	0	none 💽 S	1 0	1	0	AO	0	0	0	0	0
	1.0.0.7.0	0	none 🖉 s		1	0.	AO	S	0	0	0	0
)	FR1	0	none 🖉 S	0	1	0	AO	0	0	0	0	0
)	FR1 FR2				1	0	AO	0	0	0	0	0
		0	none 🖌 S				1000	0	0	0	0	-
2	FR2	0	none 💌 S	T	1	0	AO	0	0	0	0	0
) 1 2 3	FR2 FR3	-		0	1	0	40		0	0	0	0
# 0 1 2 3 4 5 5	FR2 FR3 FR4	0	none 룾 S	• 0 • 0	1.2		-				15	

Click the "Verify Interface" Button to confirm communication with PICOPROG V3.0 is working:

Figure 4: Verify Message



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 5: CDC Frontend page at the start

File	1.4	- 55	Teste I		Lista										
		1	Tools I	1				Transvers		to get and the					
Se	tup	CDC Fro	ontend	CDC	RDC	PDM/I	PWM	DSP/G	SPIO	Misc	Exp	pert		m	
		Ca	apacitan	ice to D	igital C	onver	sion F	ronten	nd						
	Capaci	tance l	Measure	ment Sc	heme	Cap. Po	irt Sele	ect	3	Stray (Compe	nsation		Open Gra	ph
1	Groun	ded S	Single		0	000	000	രി	1	Interr	nal	• 1	Sta	rt Measur	ement
3						Contraction of the	2 3 4		.08			- Constant of Cons	Locost -	MENU MERINA	saaansaa)
						-								Write Con	fig
													(V	/rite Comp	lete
						Port Err	or						P	ower On R	ecet
	Disch	arge Re	esistance	Port	3 Discl	arge R	esista	nce Port	4 5	Charg	e Resi	tance			
	90k	ange ne			90k	ioise in		1	1	10k	e nesi.			Init Rese	et
	C Refe exteri	erence : nal [Select	Inte 9	ernal Ca										
	-													Rur ombined E	
	-			0,			fpp	Factor	Offset		Span	Final Result	PI	mbined E	rror
	exteri	nal [9 ts F	pF		-27	Factor 10p	Offset 0	AO	10p	Final Result	PI	ombined E	
	extern	nal [Result	9 ts F	pF	x 5	-27 -27		111100-006-007	· · · · · · · · · · · · · · · · · · ·	10p	1	PI Mean \$ 50	ombined E	
CHARLES STORES	Name C0/Cref C1/Cref C2/Cref	nal [Result	9 ts F n	pF ilter one		-27 -27 -27	10p	0	AO	10p 10p	0	PI Mean∯50 0	ombined E	rror CA SNR [J 0
	Name C0/Cref C1/Cref C2/Cref C3/Cref	nal [Resul 0 0	9 ts F n n n	iliter one one		-27 -27 -27 -27	10p 10p 10p 10p	0 0	40 40 40	10p 10p 10p 10p	0	PI Mean ∯50 0 0 0	ombined E CO(Std Dev 0	TROF
	Name C0/Cref C1/Cref C3/Cref C3/Cref	nal [Result 0 0 0 0 0 0	9 ts F n n n n	ilter one one		-27 -27 -27 -27 -27	10p 10p 10p 10p 10p	0 0 0 0 0	40 40 40 40	10p 10p 10p 10p 10p	0 0 0 0	Mean ‡ 50 0 0 0 0 0	ombined E CO Std Dev 0 0 0 0 0	rror CA SNR [t 0 0 0 0
	Name C0/Cref C1/Cref C2/Cref C3/Cref	nal [Result 0 0 0 0	9 ts F n n n n n	ilter one one one one		-27 -27 -27 -27 -27 -27 -27	10p 10p 10p 10p	0 0 0 0	40 40 40	10p 10p 10p 10p 10p	0 0 0	PI Mean ∯50 0 0 0	ombined E C D(Std Dev 0 0 0 0 0	SNR [I 0 0 0 0
	Name C0/Cref C1/Cref C3/Cref C3/Cref	nal [Result 0 0 0 0 0 0	9 ts F n n n n n n n n	iliter one one one one one		-27 -27 -27 -27 -27	10p 10p 10p 10p 10p	0 0 0 0 0	40 40 40 40	10p 10p 10p 10p 10p 10p	0 0 0 0	Mean ‡ 50 0 0 0 0 0	ombined E CO Std Dev 0 0 0 0 0	rror CA SNR [I 0 0 0 0

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 6: CDC Frontend page in use

ile	ams PC	- ini	Tools	Interfac	e Help	-										
	Capac	CDC F	Frontend Capacita e Measure Single	CDC nce to	RDC Digital	Conv Cap.	Port	t Sele	ect	nd	Visc tray (nterr	Compe	nsation	Sto	Open Gra	ph ement
	Disch 90k	narge l	Resistanc	e Port 0	3 Disc 90k	Port	Erro	sista		1000	narg Ok	e Resis	stance		Write Con Vrite Comp ower On R Init Rese	eset
	C Ref		e Select	Int 9	ternal Ca	- CONT										
	-	rnal		9		- CONT		fpp	Factor	Offset		Span	Final Result	PI	Rur ombined E CO(rror 🖲
±	exter	rnal	Resu	9 Its	lq		s			Offset 0	AO	0000000		PI Mean \$ 50	ombined E	
1	exter	rnal e	Resu 0800	9 Its 005E	Filter			fpp -27 -27	Factor 10p 10p	ternareeraka.		10p	10p	PI Mean ∯50 10p	ombined E	SNR [b
12	exter Name C0/Cre	rnal ef	Resu 0800 385D	9 Its 005E FFCC	Filter none		5	-27	10p	0	40	10p	10p 74,209p	PI Mean ∯ 50 10p 74,204p	ombined E C C C Std Dev 0 7,172f	SNR (b 10,45
	exter Name C0/Cre C1/Cre	en al	Resu 0800 385D 1242	9 Its 005E FFCC 4D70	Filter none none			-27 -27	10p 10p 10p	0 0	40 40	10p 10p	10p 74,209p 22,8237p	Mean \$50 10p 74,204p 22,8228p	ombined E Std Dev 0 7,172f 3,324f	SNR (b Inf 10,45
	exter Name C0/Cre C1/Cre C2/Cre	ef ef ef	Resu 0800 385D 1242 127A	9 Its 005E FFCC 4D70 D60A	Filter none none			-27 -27 -27	10p 10p	0 0 0	40 40 40	10p 10p 10p	10p 74,209p	PI Mean ∯ 50 10p 74,204p	ombined E C C C Std Dev 0 7,172f	SNR [t Inf 10,45
	exter Name C0/Cre C1/Cre C2/Cre C3/Cre	e ef ef ef ef ef	Resu 0800 3850 1242 127A 0000	9 Its 005E FFCC 060A 0000	Filter none none none			-27 -27 -27 -27	10p 10p 10p 10p	0 0 0 0	40 40 40 40 40	10p 10p 10p 10p 10p	10p 74,209p 22,8237p 23,0998p	Mean \$50 10p 74,204p 22,8228p 23,0987p	ombined E Std Dev 0 7,172f 3,324f 3,384f	SNR [t SNR [t Inf 10,45 11,55
E C	Name C0/Cre C1/Cre C2/Cre C3/Cre C4/Cre	ef ef ef ef ef	Resu 0800 3850 1242 127A 0000 0000	9 1ts 005E FFCC 4D70 0000 0000	Filter none none none none none			-27 -27 -27 -27 -27 -27	10p 10p 10p 10p 10p	0 0 0 0 0	40 40 40 40 40	10p 10p 10p 10p	10p 74,209p 22,8237p 23,0998p 0	Mean ∯50 10p 74,204p 22,8228p 23,0987p 0	ombined E Std Dev 0 7,172f 3,324f 3,384f 0	rror CAI SNR [t 10,45 11,55 11,53 Inf

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

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

3 Hardware Description

3.1 Connecting Capacitors and Resistors

This evaluation kit can be used for evaluating capacitance measurement by connecting capacitive sensors. Further, it can be used for evaluating temperature measurement by connecting external temperature sensitive resistors or for generating quasi analog voltage (pulse width/density modulated) that is dependent on the sensor connected to the system.

Depending on the purpose of evaluation, a modification has to be made to the same plug-in board. Following is a picture of the Mother board with the plug-in board.

Figure 7: The evaluation kit's motherboard and plug-in board

The following sections describe the modifications for each application in detail.

3.2 Hardware Architecture

3.2.1 PCAP04 BOARD

For the purpose of evaluating the capacitance measurement using PCapØ4, the 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. 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 PCapØ4 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 8: 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 ends 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 k Ω works well. See section 3 of the PCapØ4 data sheet on how to select the value of the internal discharge resistor.

3.2.2 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 onchip thermistor coupled with an on-chip temperature-stable reference resistor made of polysilicon is sufficient for observing the temperature measurement capability of the PCapØ4 chip.



Figure 9 Temperature sensor connection pads

Pos.	Item	Comment
A	Port PT1 for second external temperature sensor	not supported by the standard firmware
В	Port PT0 for external temperature sensor	
С	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.

3.2.3 Pulse Code Generation

Any of the capacitance or temperature measurement results from the PCapØ4 chip can be given out as a pulse width modulated or pulse density modulated signal. This output can be filtered to generate an analog output signal that can be used for further controlling.

These pulse width or pulse density codes can be generated at Ports PG0, PG1, PG2 or PG3 (in block A). Since ports PG0 and PG1 are used for the SPI Interface in the board, the hardware allows to get a valid pulse width/density modulated signal on PG2 or PG3. However, when I2C communication mode is used the pulsed signals can be optionally obtained on the ports PG0 and PG1.



Figure 10 General purpose interface ports PG0 to PG3 in block A

3.2.4 Motherboard

The motherboard connects to the PICOPROG V3.0 programmer. It serves the various power options. It can be powered via wall plug supply (B), the voltage being set from 1.8 V to 4.5 V by jumpers (C). Further, it supports a battery power option (D). The power options are switchable via jumper (E). Power present is indicated by a green LED.

There is a jumper 'Current' on the mother board (F). The current consumption of the PCapØ4 chip during operation can be directly measured from these jumper terminals.

All interface signals and general purpose I/O signals can be monitored by means of a separate jumper in block A.

4 Software Description

4.1 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 V3.0 programmer 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'.

4.2 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.

4.2.1 Front Panel

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.

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

4.2.1.1 Setup Page

Se	etup CDC	Frontend CD0	RDC	PD	M/P\	MM	DSP/C	SPIO	Misc	Exp	pert		Im	
				-	ect C		ce		100	evice			Open Gra	
		Configuration	ons read	-	ap04	0.576	Evalua			om Chi	p	Sta	art Measur	
		comparad	c c	,	use			inter of					Write Con	fig
	St	andard		H	lumi	dity				Pres	sure		Vrite Comp	lete
	D	citance ratios	- Hum	1.474	14.01		DECO			- 1- 11	at RESO	F	ower On R	eset
		tance ratios configured lon mode	- C Sei - Fic - Int - Inte senso - PDM - PDM - Upd	nse: l atin erna mai t ranc PULS PULS ate ra	PCO 8 g sin l refe cemp d refe SEO rh SEO rh SE1 te ste: 5	ereno ereno ereno ereno ereno 5 Hz	ce ure ce erature	- C S - Fl - Ir - Int sen: - PD - PD	ense loati itern erna sor a M PU M PU	: PCO 8 ng sing al refe I temp nd refe LSEO p	gle rence erature erence ressure in % emperature		Init Rese Rur ombined E	nbit 🥥
	Name	Results	Filter	Verif	donnese	erfac		Offset		Span	Final Result	PI Mean \$ 50		
	Concernance	0800005E	none		5	-27	10p	0	40	10p	10p	10p	0	Inf
	CO/Cref		none		5	-27	10p	0	AO	10p	74,2086p	74,2064p	6,71f	10,54
)	CO/Cref C1/Cref	3B5DEA4B		-	5	-27	10p	0	AO	10p	22,82p	22,8232p	3,616f	11,43
1		12418816	none					121	AO	10p	22 0062-	22 0002-	3,582f	
	C1/Cref	C = C 14 = C 5 = C 15 C = C 1	none none	Contract of the	▼	-27	10p	0	AU	TOD	23,0963p	23,0993p	5,5021	11,45
	C1/Cref C2/Cref	12418816	1.4940.05	-	5	-27 -27	10p 10p	0	1000	10p	23,0963p 0	25,0993p 0	0	11,45 Inf
# 1 2 3 4	C1/Cref C2/Cref C3/Cref	12418816 127A20FD	none	•				-	AO					
) 1 2 3	C1/Cref C2/Cref C3/Cref C4/Cref	12418816 127A20FD 00000000	none none	•		-27	10p	0	AO	10p 10p	0	0	0	Inf

Figure 11 Setup page

Options on 'Setup' page:

Select Device	Select the PICOCAP device which you use. <pcap04v0> means silicon version "Z" <pcap04v1> means release silicon version "v1"</pcap04v1></pcap04v0>
Read Device Version from Chip	Reads the device version from chip
Standard	Opens the <i><selected device="">_</selected></i> standard.prj project file with configuration and standard firmware.
Humidity	Opens the <i><selected device="">_</selected></i> humidity.prj project file with configuration and linearization firmware.
Pressure	Opens the <i><selected device="">_</selected></i> pressure.prj project file with configuration and linearization firmware.

When everything is in order, then pressing this button will indicate the release version number of the software and of the 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 principal it shows the content of the read registers. The content itself depends on the firmware. Figure 1-16 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.'

4.2.1.2 CDC Frontend Page

Fil	le Memory	Tools In	terface	e Help										
s	etup CDC Fr	rontend	CDC	RDC	PDM/	/PWM	DSP/G	SPIO	Misc	Exp	ert	0	m	
	c	apacitanc	e to D	Digital C	onve	rsion F	ronten	nd						
													Open Gra	nh
	Capacitance		-		Cap. P	ort Sele	ect	S	tray (Compe	nsation		openara	part
	Grounded	Single	•	0	00	000		1	nterr	nal	• 1	Sto	p Measure	ement
					-	234								
					99	000							Write Con	fig
					Port Er	ror	_					N	/rite Comp	lete
												P	ower On R	eset
	Discharge R	esistance	Port 0	.3 Disch	narge R	lesista	nce Port	45 C	harge	e Resis	stance		Init Rese	t
	90k		1	90k		-	• 1	3	.0k					J
	C Reference external	Select	Inte 9	ernal Ca pF										
													Rur ombined Er	2
*			a.			fpp	Factor	Offset		Span	Final Result	PI	mbined Er	2
-	external		g s F	pF		- 10 Million	Factor 10p	Offset 0	AO	Span 10p	Final Result 10p	PI	ombined Er	
)	external Name	Results	9 s F 05E n	pF		-27		A CONTRACTOR OF	40	20000000	()	PI Mean \$ 50	Std Dev	SNR (b
)	external Name CO/Cref	Results	9 s F 05E n FCC n	Filter	5 S	-27	10p	0		10p	10p	PI Mean ∯50 10p	ombined Er	SNR (b 10,45
2	external Name C0/Cref C1/Cref	Results 080000 3B5DFf	9 8 F 85E n FCC n D70 n	Filter	10 IN IN	-27 -27	10p 10p	0 0	AC	10p 10p	10p 74,209p	PI Mean∯50 10p 74,204p	ombined Er CO Std Dev 0 7,172f	SNR (b Inf 10,45 11,55
23	external Name C0/Cref C1/Cref C2/Cref	Result: 080000 3B5DFf 124241	9 9 95E n FCC n 070 n 60A n	Filter tone tone		-27 -27 -27	10p 10p 10p	0 0 0	40 40 40	10p 10p 10p 10p 10p	10p 74,209p 22,8237p	Mean ∯50 10p 74,204p 22,8228p	ombined Er Std Dev 0 7,172f 3,324f	SNR (b Inf 10,45 11,55
2 2 3 4	external Name C0/Cref C1/Cref C2/Cref C3/Cref	 Results 080000 385DFr 124240 127AD0 	9 85E n FCC n 070 n 60A n 800 n	Filter none none none		-27 -27 -27 -27 -27 -27 -27 -27	10p 10p 10p 10p	0 0 0 0	40 40 40 40	10p 10p 10p 10p	10p 74,209p 22,8237p 23,0998p	Mean 550 10p 74,204p 22,8228p 23,0987p	0 Std Dev 0 7,172f 3,324f 3,384f	Tror CAF SNR (b) Inf 10,45 11,55 11,53
# 0 1 2 3 4 5 6	external Name C0/Cref C1/Cref C2/Cref C3/Cref C4/Cref	 Results 080000 385DFr 124240 127AD0 000000 	9 85E n FCC n 50A n 800 n 800 n	Filter tone tone tone		-27 -27 -27 -27 -27 -27 -27 -27	10p 10p 10p 10p 10p	0 0 0 0 0	40 40 40 40	10p 10p 10p 10p 10p	10p 74,209p 22,8237p 23,0998p 0	Mean ∯50 10p 74,204p 22,8228p 23,0987p 0	0 5td Dev 0 7,172f 3,324f 3,384f 0	rror SNR [bi Inf 10,45 11,55 11,53 Inf

Figure 12 CDC Frontend page



Options on 'CDC Frontend page:

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.
Select which capacitive ports have to be measured (Ports 0-5), i.e. at which ports the sensors have been connected in hardware.
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.
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.
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.
Choice of one out of 4 on-chip charging resistors (180k, 10k) for the CDC. Permitting to limit the charging current and avoiding transients.
Switching between external and internal reference capacitance.
Selection of internal reference capacitance value. (031pF)

4.2.1.3 CDC Page

	Memory 1	ools Interfa	ice Help										
Setu	CDC Fro	ntend CDC	RDC	PDM/	PWM	DSP/0	SPIO N	lisc	Exp	pert		m	
	Ca	pacitance to	Digital (Conver	sion	Setting	s				M		
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[Precharge Ti	me	Fullcharge	Time		Disch	arge Time	e				Open Gra	ph
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			-			-						Write Con	fig
Vdd	ł									C_FAKE	14	Vrite Comp	
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			15/15	8.8		1				(Sample Size)		Init Rese	
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0								\searrow		1			
	o	54552					Tir	ne					
1.1.1	Cycle Clock S	10000000									2		
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10	50,0kHz Lo	w Power					Conver	sion	Durat	ion 6,40ms	e.,		
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Con # N: 0 CC	version Contr Cap. Trigger Timer Trigger Conversion T 2000	rol Select ered Time Results	Filter	DSP_I	fpp -27 -27	* 0 Factor	Cor Me Offset	easu	sion Ti uring R Span 10p	ime 80,0ms ate 12,5Hz Final Result	PI Mean \$ 50	ombined E	
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# N: 0 CC 1 C: 2 C:	version Contr Cap. Trigger Timer Trigger Conversion T 2000 ame J/Cref	rol Select ered Time Results 0800005E 3B5DEA4B	Filter none none	DSP_I	fpp -27 -27 -27	 Factor 10p 10p 	Cor Me Offset 0 0	easu Ao	sion Ti uring R Span 10p 10p 10p	ime 80,0ms ate 12,5Hz Final Result 10p 74,2086p	Mean \$ 50 10p 74,2064p	Std Dev 6,71f 3,616f	SNR (bi Inf 10,54
# N: 0 CC 1 C1 2 C2 3 C3	version Contr Cap. Trigger Timer Trigge Conversion T 2000 ame D/Cref L/Cref 2/Cref	Results 0800005E 3B5DEA4B 12418816	Filter none none	DSP_1	fpp -27 -27 -27 -27 -27 -27	 Factor 10p 10p 	Cor Me Offset 0 0 0	AC AC	sion Ti uring R Span 10p 10p 10p	me 80,0ms ate 12,5Hz Final Result 10p 74,2086p 22,82p	Mean \$50 10p 74,2064p 22,8232p	Std Dev 6,71f 3,616f	rror CAF SNR (bi Inf 10,54 11,43
Con # Ni 0 CC 1 C1 2 C2 3 C5 4 C4	version Contr Cap. Trigger Timer Trigge Conversion T 2000 ame 0/Cref L/Cref 2/Cref 8/Cref	Results 0800005E 3B5DEA4B 12418816 127A20FD	▼ 2 Filter none none none	DSP_1	N0 fpp -27 -27 -27 -27 -27 -27 -27 -27	 Factor 10p 10p 10p 	Cor Me Offset 0 0 0 0 0	AC AC	Span 10p 10p 10p 10p	me 80,0ms ate 12,5Hz Final Result 10p 74,2086p 22,82p 23,0963p	Mean ∯50 10p 74,2064p 22,8232p 23,0993p	0 5td Dev 6,71f 3,616f 3,582f	rror CAF SNR (bi Inf 10,54 11,43 11,45
Con # N: 0 CC 1 C1 2 C2 3 C3 4 C4 5 C5	version Contr Cap. Trigger Timer Trigge Conversion T 2000 ame D/Cref L/Cref 2/Cref 3/Cref 4/Cref	Results 0800005E 385DEA4B 12418816 127A20FD 00000000	▼ 2 Filter none none none none	DSP_1	fpp -27 -27 -27 -27 -27 -27 -27 -27 -27	 Factor 10p 10p 10p 10p 	Cor Me Offset 0 0 0 0 0 0 0 0	AC AC AC	sion Ti uring R Span 10p 10p 10p 10p	me 80,0ms ate 12,5Hz Final Result 10p 74,2086p 22,82p 23,0963p 0	Mean ∯50 10p 74,2064p 22,8232p 23,0993p 0	0 5td Dev 6,71f 3,616f 3,582f 0	rror CAF SNR (bi Inf 10,54 11,43 11,45 Inf

Figure 13 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 $1 \rightarrow No$ averaging, Setting to any number N, will result in averaging over N measurement cycles for generating one measurement result. (08191)
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).

4.2.1.4 RDC Page



Figure 14 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 aluminum (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.								

4.2.1.5 PDM / PWM Page

ams	PCap04												X
File I	Memory To	ols Interfac	ce Help										
Setup	CDC Front	tend CDC	RDC	PDM/P	WM	DSP/G	SPIO I	Misc	Exp	pert	0	m	
Pul	se Interface (٥		Pul	se In	terface 1	L						
	Clock Sele	ect				Clock Se	elect					Open Graj	oh
	OHF / 1	5	, iii			OHF / 1			5		Sta	irt Measure	ement
	Resolutio	un .	27			Resolut	ion					Write Con	fig
	14 bits	• 2				10 bits	S.	•	0		[W	Vrite Comp	
	Pulse Inte	erface Select	t			Pulse Ir	nterface	Sele	ect		P	ower On Re	eset
	PDM	• 1				PDM			1			Init Rese	et
	Toggle	Enable				Togg	le Enabi	e					
	Pulse Sel	ect				Pulse S	elect						
	C1/Cref	• 1				Alu/Re	f	•	7				
											ء PI	Run ombined Er	
# Na	me	Results	Filter		fpp	Factor	Offset		Span	Final Result	Mean \$ 50	Std Dev	SNR [bit
	2019 E	0800005E	none	₽ 5 ‡		10p	0	AO		10p	10p	0	Inf
10.0	State Stat		none	▼ 5 •		10p	0	40	1222	74,2086p	74,2064p	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	10,54
2 C2/	Cref	12418816	none	▼ 5 €		10p	0	AO	1222.000	22,82p	22,8232p	COLORADO AND A	11,43
20 2.54	Cont. No.			5	-27	10p	0	AO	10p	23,0963p	23,0993p	3,582f	
3 C3/			none					-		1			11,45
3 C3/ 4 C4/	Cref	00000000	none	. 5	-27	10p	0	AO		0	0	0	11,45 Inf
3 C3/ 4 C4/ 5 C5/	Cref	00000000 00000000	none none	•	-27 -27	10p	0	AO	10p	0	0	0	11,45 Inf Inf
3 C3/ 4 C4/ 5 C5/ 6 PT1	/Cref /Cref L/Ref	00000000 00000000 00000000	none		-27 -27	0.00030	18	-	10p 1			0	11,45 Inf Inf Inf

Figure 15 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.

4.2.1.6 DSP/GPIO Page

	ams PCap04												×
Fil	e Memory T	ools Interfa	ce Help										
	etup CDC From	ntend CDC	RDC	PDM	1/PWM	DSP/G	iPIO I	Misc	Exp	bert.	Q	m	
	DSP_SPEED Slow DSP_START ORDC_TRIG_EN CDC_TRIG_EN CDC_TRIG_EN			DSI	P_FF_IN	ONPIN	6	P_M	OFLO_E	EN		Open Gra rt Measure Write Con /rite Comp ower On R Init Rese	ement fig lete eset
G	2 2 2 2 2 2										-		
	PG_DIR_IN	PG_PU	© PG3		PG1xP0	se0 > PG		1		_INTN_EN _INTN_EN		Rur ombined E	rror 🦲
#	Name	Results	Filter		fpp	Factor	Offset		Span	Final Result	Mean 🛔 50	Std Dev	SNR [bit]
ro.	C0/Cref	0800005E	none	• S		10p	0	40	10p	10p	10p	0	Inf
1	C1/Cref	3B5DEA4B	none	• 5		10p	0	40		74,2086p	74,2064p	6,71f	10,54
2	C2/Cref	12418816	none	. 5		10p	0	AO	10p	22,82p	22,8232p	3,616f	11,43
3	C3/Cref	127A20FD	none	• 5		10p	0	40	10p	23,0963p	23,0993p	3,582f	11,45
4	C4/Cref	00000000	none	. 5		10p	0	AO	10p	0	0	0	Inf
5	C5/Cref	00000000	none	• 5	-27	10p	0	AO	10p	0	0	0	Inf
6	PT1/Ref	00000000	none	• 5		1	0	AO	1	0	0	0	Inf
7	Alu/Ref	01DD2CBE	Median 5	• 5	-25	1	0	AO	1	931,982m	931,937m	30,36u	15,01

Figure 16 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.

4.2.1.7 Misc. Page

S	etup CDC	Frontend C	DC	RDC	PDM/	PWM	DSP/0	SPIO 1	Misc	Exp	pert		Im	
1	F Clock					HEC	Clock			die -	άŭ	V		
1	CIOCK					- nrs							Open Gra	oh
	OLF CTU	NE	DLF_FT	TUNE			OX_RUN	K.					openara	PHI -
	200kHz		11	-			Permar	nent		•	1	Sta	art Measur	ement
							OX D	IS		10	OX_STOP		Write Con	fig
								UTOSTO				V	Vrite Comp	lete
									P	Power On Reset				
													Init Rese	et
	0 1 2 C_G_OP_	3 4 5	4	Ę	E (×50	Ons)		7 C_G_01 2,0 pF		TN 3				
	012	3 4 5	4			0ns)		C_G_OI	P_AT	TN 3			ombined E	_
	0 1 2 C_G_OP_	3 4 5 RUN	4	Ę		fpp	Factor	C_G_0 2,0 pF C_G_0	P_AT	TN 3	Final Result	PI	ombined E	2
	0 1 2 C_G_OP_ pulsed	3 4 5 RUN	4]C_G_0		fpp	Factor 10p	C_G_OI 2,0 pF C_G_OI x 1,00	P_AT P_VU P_VU	TN 3	Final Result 10p	PI	ombined E	
# 2	0 1 2 C_G_OP_ pulsed	3 4 5 RUN RESUITS	Fi E no]C_G_0	P_EXT	fpp -27 -27		C_G_0 2,0 pF C_G_0 x 1,00	P_AT P_VU P_VU	TN 3 0 Span	1	PI Mean \$ 50	ombined E	TAP
)	0 1 2 C_G_OP_ pulsed Name C0/Cref	3 4 5 RUN	Fi E no	C_G_0	P_EXT	fpp -27 -27 -27	10p	C_G_01 2,0 pF C_G_01 x 1,00 Offset 0	P_AT P_VU P_VU A0	TN 3 0 Span 10p	10p	PI Mean \$50 10p	ombined E Std Dev 0 6,71f 3,616f	SNR (b) Inf 10,54
1	0 1 2 C_G_OP_ pulsed Name CO/Cref C1/Cref	3 4 5 RUN	Fi E no B no 6 no	C_G_0	P_EXT • 5 • 5	fpp -27 -27 -27 -27	10p 10p	C_G_01 2,0 pF C_G_01 x 1,00 Offset 0 0	P_AT P_AT P_VU V V A0 A0 A0 A0	TN 3 0 Span 10p 10p	10p 74,2086p	Mean \$50 10p 74,2064p	ombined E Std Dev 0 6,71f 3,616f	SNR (b) Inf 10,54
2	0 1 2 C_G_OP_ pulsed Name CO/Cref C1/Cref C2/Cref	3 4 5 RUN Results 0800005 3B5DEA4 1241881	Fi E no B no D no	C_G_O	P_EXT	fpp -27 -27 -27 -27 -27 -24	10p 10p 10p	C_G_01 2,0 pF C_G_01 × 1,00 Offset 0 0 0	P_AT P_VU	TN 3 0 5pan 10p 10p 10p	10p 74,2086p 22,82p	PI Mean ∯50 10p 74,2064p 22,8232p	ombined E Std Dev 0 6,71f 3,616f	SNR (b Inf 10,54
)	0 1 2 C_G_OP_ pulsed Name C0/Cref C1/Cref C2/Cref C3/Cref	3 4 5 RUN Results 0800005 3B5DEA4 1241881 127A20F	Fi E no B no D no NO no	C_G_O	P_EXT • 5 • 5	fpp -27 -27 -27 -27 -27 -24	10p 10p 10p 10p	C_G_01 2,0 pF C_G_01 × 1,00 0 0 0 0 0	P_AT P_AT P_VU V V A0 A0 A0 A0	TN 3 0 5pan 10p 10p 10p 10p	10p 74,2086p 22,82p 23,0963p	PI Mean ∯50 10p 74,2064p 22,8232p 23,0993p	ombined E Std Dev 0 6,71f 3,616f 3,582f	Tror SNR (b) Inf 10,54 11,43 11,45
) 1 2 3	0 1 2 C_G_OP_ pulsed Name C0/Cref C1/Cref C2/Cref C3/Cref C3/Cref C4/Cref	3 4 5 RUN Results 0800005 3B5DEA4 1241881 127A20F 0000000	Fi E no B no 6 no 10 no 10 no	C_G_O	P_EXT	fpp -27 -27 -27 -27 -27 -24	10p 10p 10p 10p 10p	C_G_01 2,0 pF C_G_01 × 1,00 0 0 0 0 0 0 0 0	P_AT P_VU	TN 3 0 0 10p 10p 10p 10p 10p 10p 10p	10p 74,2086p 22,82p 23,0963p 0	Mean ∯50 10p 74,2064p 22,8232p 23,0993p 0	ombined E Std Dev 0 6,71f 3,616f 3,582f 0	rror CAI SNR (b Inf 10,54 11,43 11,45 Inf

Figure 17 Misc. page

Options on 'Misc.' Page:

LF Clock

OLF_CTUNE	Coarse-tune the low frequency clock. (10kHz, 50kHz, 100kHz, 200kHz)
OLF_FTUNE	Fine-tune the low frequency clock. (015)

HF Clock

OX_RUN	Controls the permanency or the latency of the OX generator. Latency means an
	oscillator settling time before a measurement starts.