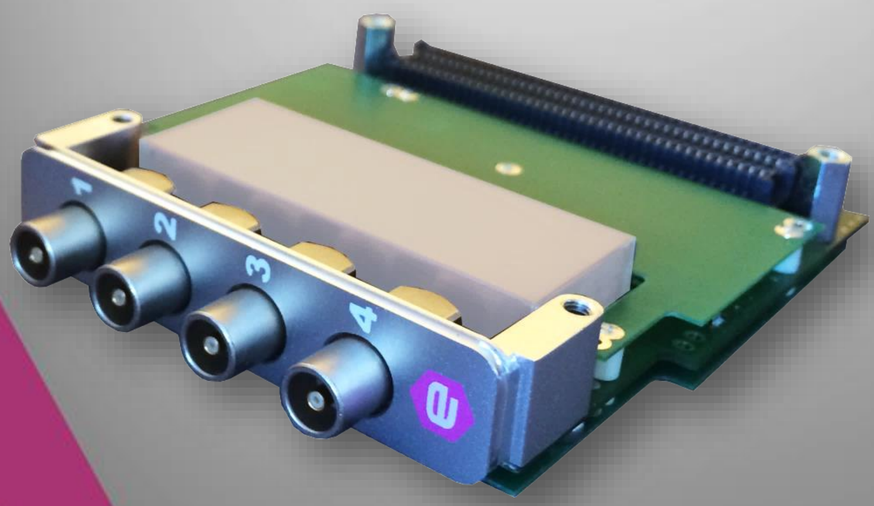
FMC-Pico-1M4

4-channel 20 bit 1 MSPS FMC Floating Ammeter

CAENels Gear For Science

User's Manual



Rev. 1.1 – January 2015

FMC – FPGA MEZZANINE CARD

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Document Revisions

Document Revision	Date	Comment
1.0	November 20th 2014	First Release
1.1	January 20th 2015	Ordering options updated

Safety information - Warnings

CAEN ELS will repair or replace any product within the guarantee period if the Guarantor declares that the product is defective due to workmanship or materials and has not been caused by mishandling, negligence on behalf of the User, accident or any abnormal conditions or operations.

Please read carefully the manual before operating any part of the instrument

WARNING

Do NOT open the boxes

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Read over the instruction manual carefully before using the instrument.
The following precautions should be strictly observed before using the device:

WARNING	• Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in this manual. • Do not use the device if it is damaged. Before you use the device, inspect the instrument for possible cracks or breaks before each use. • Do not operate the device around explosives gas, vapor or dust. • Always use the device with the cables provided. • Turn off the device before establishing any connection. • Do not operate the device with the cover removed or loosened. • Do not install substitute parts or perform any unauthorized modification to the product. • Return the product to the manufacturer for service and repair to ensure that safety features are maintained
CAUTION	• This instrument is designed for indoor use and in area with low condensation.

The following table shows the general environmental requirements for a correct operation of the instrument:

Environmental Conditions	Requirements
Operating Temperature	0°C to 50°C
Operating Humidity	30% to 85% RH (non-condensing)
Storage Temperature	-10°C to 60°C
Storage Humidity	5% to 90% RH (non-condensing)

1. Introduction

This chapter describes the general characteristics and main features of FMC-Pico-1M4 mezzanine cards.

1.1 FMC-Pico-1M4 Overview

The CAEN ELS FMC-Pico-1M4 is a standard FPGA Mezzanine Card (FMC) Low Pin Count (LPC) daughter board that allows high resolution monitoring of bipolar currents up to 1 mA with maximum sampling rate of 1 MHz. It is mechanically and electrically compliant to the FMC standard (ANSI/VITA 57.1).

The front-end is composed of a specially designed transimpedance input stage for current sensing combined with analog signal conditioning and filtering stages making use of state-of-the-art electronics. The 20-bit resolution is obtained from independent, simultaneous sampling and low-delay SAR (Successive Approximation Register) Analog to Digital Converters (ADCs).

Each channel has two full-scale measuring ranges, up to ±1 mA and ±1 µA respectively and the current source can be floating up to ±300 V respect to the FMC ground. The floating capability of the inputs is perfectly suitable for applications where the detector or current source needs to be biased.

The analog front end is designed in order to achieve low noise, low temperature dependence and very small unbalance between channels. The analog characteristics can be further improved by requesting a factory calibration of the channels. Calibration data are stored in the on-board EEPROM memory that can be read via an I2C bus on the FMC connector.

A metallic shield has a dual function of shielding the analog front end from external noise sources and also galvanically isolates the internal electronics that could be floating up to ±300 V.

A trigger signal can be fed to the FMC connector in order to start the conversion of data samples: this feature allows synchronizing the board acquisition to an external event - e.g. machining revolution frequency in storage rings.

Data readout can be performed via separate SPI links - i.e. one for each channel, sharing the same clock signal - or can be daisy-chained thus requiring less signals to be handled.

1.2 Device Description

Both sides and the front view of the FMC-Pico-1M4 can be seen on the following **Figure 1**, **Figure 2** and **Figure 3**.

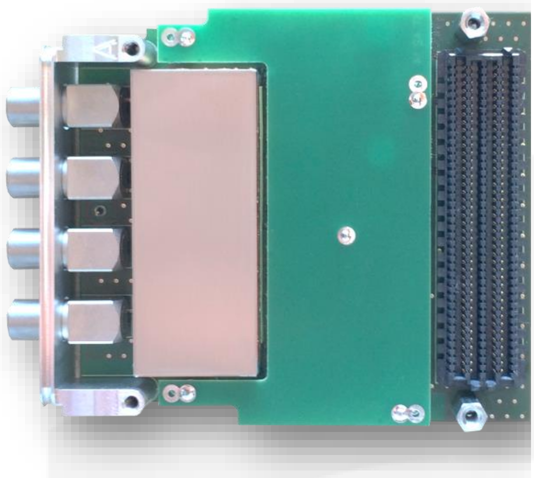

Figure 1: FMC-Pico-1M4 *side 1*

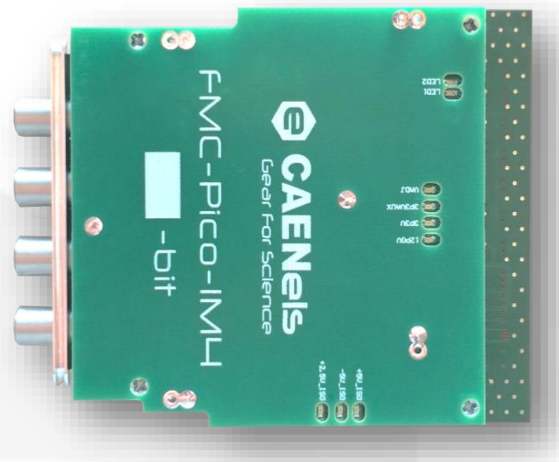

Figure 2: FMC-Pico-1M4 *side 2*

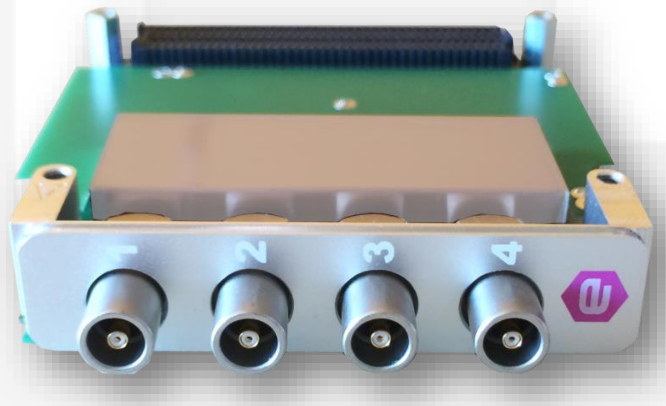

Figure 3: FMC-Pico-1M4 front view

The FMC-Pico-1M4 device is composed of several building blocks:

- the analog front-end;
- the ADC and isolation section;
- the range selection block;
- the power supply part.

The block diagram of the whole device can be seen on the **Figure 4**.

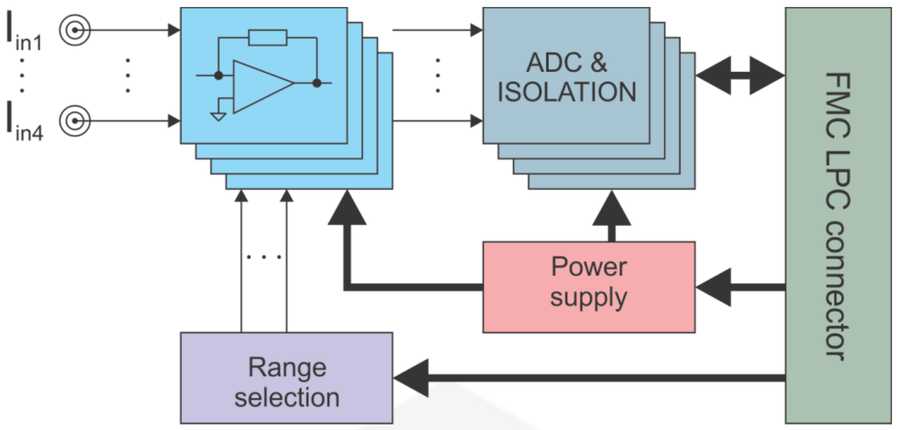

Figure 4: FMC-Pico-1M4 block diagram

The analog front end is built from several functional blocks (**Figure 5**). The current signal is fed to the device through the LEMO triaxial connector. The next stage is current-to-voltage conversion where the current signal is transformed to a voltage one, filtering and translation from sigle-ended to differential signalling is also performed. The analog-to-digital conversion of the signal is obtained from this last stage. Before the digital data stream reaches the FMC connector it is galvanically isolated from the analog front end. The digital voltage levels are also adapted to the FMC carrier ones. Each analog front end has two measurement ranges which can be independently selected from channel to channel.

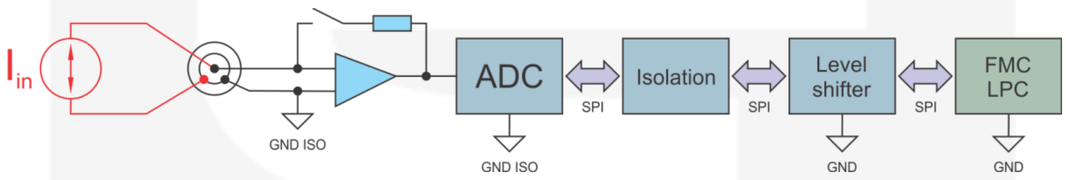

Figure 5: detailed block diagram of a single channel

The power supply part is responsible for the generation of the appropriate isolated power supply rails (+5 V, -5 V and 2.5 V), which are required for the high-quality analog-to-digital signal conversion.

There are several light emitting diodes (LEDs) on the FMC-Pico-1M4 board. The four green ones are signaling the precence of the power supply voltages that are supplied from the carrier board (12P0V, 3P3V, 3P3VAUX and VADJ).

The group of three red LEDs shows the status of power supply voltages that are generated on-board by the power supply module. The user can freely use two additional yellow LEDs upon its discretion (board status signalling, range selection, etc.).

2. Installation and Operation

The FMC-Pico-1M4 board must be installed on the air cooled FMC carrier board which is compliant to the FMC standard. The FMC carrier must support at least the low-pin count connector (LPC - 160 pins) but the FMC-Pico-1M4 can be also mounted on the high-pin count (HPC - 400 pins) connector. Only the LPC pins are connected on the mezzanine module. The FMC carrier must support VADJ voltage range between 1.2 V and 3.3V. During the installation and handling the ESD precautions must be respected to prevent electrostatic discharges.

2.1 Ground Connections

For safety and performance reasons the triaxial connectors are used for the measurement current inlet. The measured current path is through the center wire and the inner shield of the triaxial cable (see **Figure 6**). By convention the current that flows from the source into the FMC board through the center wire is measured as positive, on the contrary the current that is sinked by the current source and flows from the FMC board through the center wire is measured as negative. The return current path is always established through the inner cable shield.

Figure 6: Measured current path

There can be large potential difference between the inner and the outer triaxial cable shield because of the front end isolation. Therefore the outer shield of the triaxial cable must be grounded (see **Figure 7**). The voltage between both shields must be limited as breakdown may occur so the maximum value of the isolation voltage is given in the electrical specifications section.

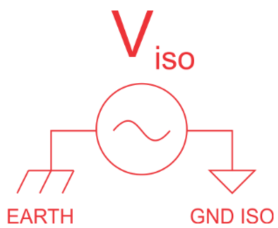

Figure 7: Definition of isolation voltage

Grounding can be done in two different ways. The first option is to make the ground connection at the current source side (see **Figure 8**), but we can also make the ground connection on the FMC board side through the FMC bezel which is connected to the grounded chassis (see **Figure 9**). In the latter case we must make an electrical connection on the FMC-Pico-1M4 board, because the outer shield of the triaxial connector is not hardwired to the bezel. If we want to make this connection we must solder two jumpers on the FMC-Pico-1M4 board, which are in fact two 0-Ω chip resistors of 0805 form factor (see **Figure 10**). The grounding technique depends on the user requirements and it is upon exclusive user discretion.

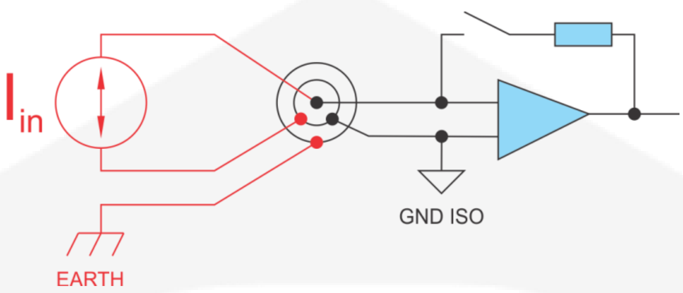

Figure 8: Grounding at the current source side

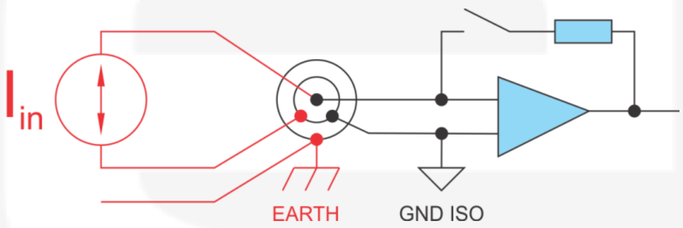

Figure 9: Grounding at the FMC board side

Figure 10: Jumpers for connecting the bezel to the input connectors

2.2 Signals Definitions and Pinout

Interface signals are grouped into five categories:

- *ADC Interface*: signals which are interfacing ADCs on the FMC-Pico-1M4 board;
- *Range Selection*: signals which are used for the selection of the measurement ranges;
- *General Purpose LEDs*: driving signals for the two general purpose LEDs;
- *Onboard EEPROM*: interface signals for onboard EEPROM memory;
- *Power Supply Interface*.

The definition of signal direction is as follows:

- **C2M**: carrier board sources the signal (output), mezzanine board is the signal sink (input);
- **M2C**: mezzanine board sources the signal (output), carrier board is the signal sink (input).

The LPC connector assignment of signals, its pin name and the direction, sorted by category, are presented in the following **Table 1**, **Table 2**, **Table 3**, **Table 4**, **Table 5**.

ADC Interface

Signal name	*LPC Pin Assignment*	*Pin Name*	*Direction*
CNV	H10	LA04_P	C2M
SCK	H11	LA04_N	C2M
SCK_RTRN	G12	LA08_P	M2C
SDO1	H17	LA11_N	M2C
SDO2	H16	LA11_P	M2C
SDO3	H14	LA07_N	M2C
SDO4	H13	LA07_P	M2C
BUSY_CMN	G13	LA08_N	M2C

Table 1: ADC interface signals

Range Selection

Signal name	*LPC Pin Assignment*	*Pin Name*	*Direction*
R1	G10	LA03_N	C2M
R2	G09	LA03_P	C2M
R3	H08	LA02_N	C2M
R4	H07	LA02_P	C2M

Table 2: Range selection signals

General Purpose LEDs

Signal name	*LPC Pin Assignment*	*Pin Name*	*Direction*
LED1	D11	LA05_P	C2M
LED2	D12	LA05_N	C2M

Table 3: General purpose LED signals

On-board EEPROM Interface

Signal name	*LPC Pin Assignment*	*Pin Name*	*Direction*
System Management I2C serial clock	C30	SCL	C2M
System Management I2C serial data	C31	SDA	bidirectional
I2C channel select	C34	GA0	C2M
I2C channel select	D35	GA1	C2M

Table 4: On-board EEPROM interface signals

Power Supply Interface

Signal name	*LPC Pin Assignment*	*Pin Name*	*Direction*
VADJ	G39, H40	VADJ	C2M
3P3VAUX	D32	3P3VAUX	C2M
3P3V	C39, D36, D38, D40	3P3V	C2M
12P0V	C35, C37	12P0V	C2M

Table 5: Power supply interface signals

2.3 Signal Descriptions

- **CNV**: Convert Input. A rising edge on this input initiates a new conversion;
- **SCK**: Serial Data Clock Input. The conversion result or daisy-chain data from another ADC is shifted out on the rising edges of this clock MSB first;

- **SCK_RTRN**: Serial Data Clock Return. The return clock signal, which is used for ADC data synchronization on the FMC carrier board;

- **SDO1-4**: Serial Data Output. The conversion result or daisy-chain data is output on this pin on each rising edge of SCK MSB first. The output data is in 2's complement format;

- **SDI1-4** (internal signal): In chain mode the pin is treated as a serial data input pin where data from previous ADC in the daisy chain is input;

- **BUSY_CMN**: Common BUSY Indicator. Goes high at the start of a new conversion and returns low when all the conversions have finished. BUSY signals from all four ADCs are OR-ed to make one common BUSY_CMN signal;

- **R1-R4**: Range selection signal; when high, RNG0 is selected on the current channel, otherwise RNG1 is active;

- **LED1-LED2**: User LEDs control signal; when high, the LED is lit;

- **SCL**, **SDA**, **GA0** and **GA1** signals are connected to the on-board EEPROM chip 24AA64. The user is encouraged to consult the original manufacturer's datasheet for detailed signal description;

3. Controlling the FMC

3.1 Digital Interface

The ADC conversion is controlled by CNV signal. A rising edge on CNV will start a conversion. Once a conversion has been initiated, it cannot be restarted until the conversion is complete. For optimum performance, CNV should be driven by a clean low jitter signal. Converter status is indicated by the BUSY output which remains high while the conversion is in progress. To ensure that no errors occur in the digitized results, any additional transitions on CNV should occur within 40 ns from the start of the conversion or after the conversion has been completed. Once the conversion has completed, the ADC begins acquiring the input signal.

The ADC has an internal clock that is trimmed to achieve a maximum conversion time of 675 ns. With a minimum acquisition time of 312 ns, throughput performance of 1Msps is guaranteed.

The ADC has a serial digital interface. The serial output data is clocked out on the SDO pin when an external clock is applied to the SCK pin. Clocking out the data after the conversion will yield the best performance. With a shift clock frequency of at least 64MHz, a 1MSps throughput is still achieved. The serial output data changes state on the rising edge of SCK and can be captured on the falling edge or next rising edge of SCK. D19 remains valid until the first rising edge of SCK. On-board ADCs can be controlled in two modes:

- *Normal mode* (see **Figure 11**) enables simultaneous reading of the ADC output data in parallel from all the four ADCs.

- In *chain-mode* (see **Figure 12**), the ADCs are daisy-chained, so the output from the ADC1 is passed to the ADC2 and so on. The last ADC, the ADC4, outputs concatenated data from all four ADCs through its SDO4 pin. In this way it is possible to use just one serial data output (SDO4) instead of four.

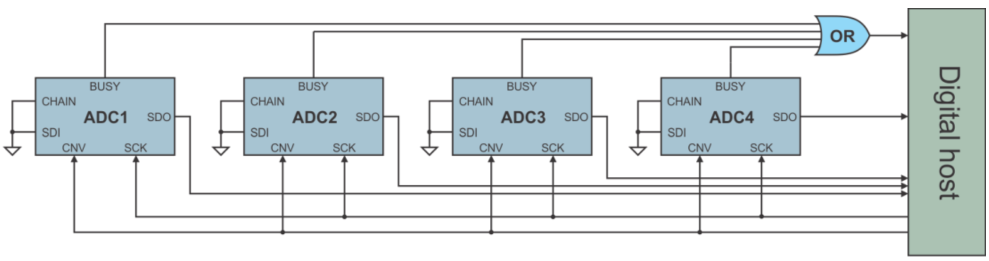

Figure 11: *Normal mode* block diagram

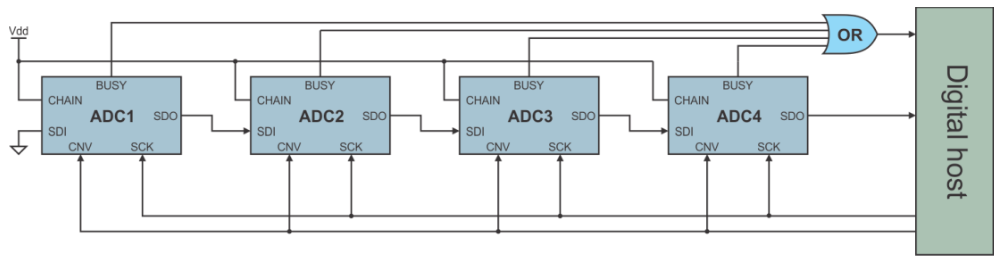

Figure 12: *Chain-mode* block diagram

3.2 ADC Mode Selection

Default factory mode selection for FMC-Pico-1M4 is *normal mode*. If the user wants to control the FMC-Pico-1M4 in *chain mode* he has to change solder jumpers on the PCB (see **Figure 13**). Solder jumpers are 0402-sized SMD chip resistors with resistance value of 0 Ω and the four **"N"** resistors must be mounted if using the *normal mode* while the four marked with a **"C"** when using the *chain mode*.

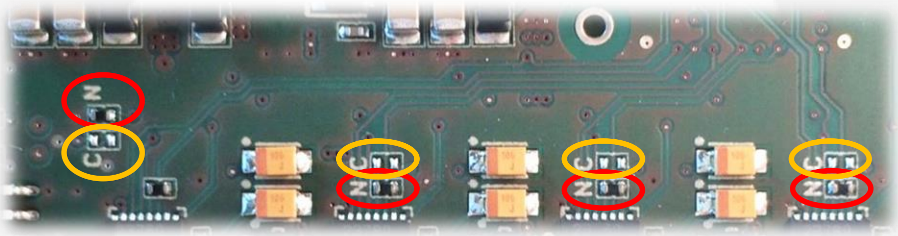

Figure 13: Mode selection jumpers

3.3 Timing Diagrams

In *Normal mode* the SDO signal is always driven. MSB (D19) of the new conversion data is available at the falling edge of BUSY. This is the simplest way to operate the four ADCs. Normal Mode timing diagram is shown on the **Figure 14Figure 14**.

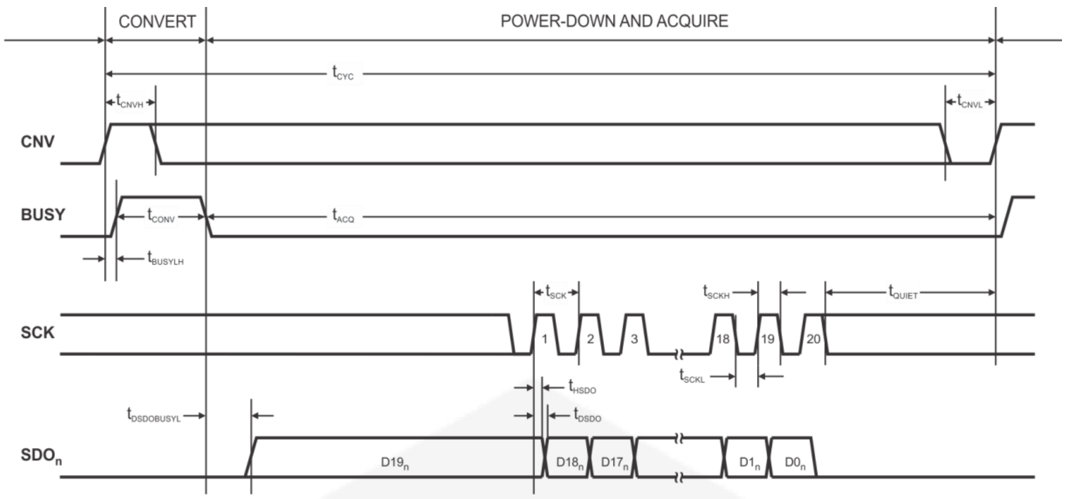

Figure 14: *Normal-mode* timing diagram

In *chain-mode*, SDO is always enabled and SDI serves as the serial data input pin (SDI) where daisy-chain data output from another ADC can be input. This is useful for applications where hardware constraints may limit the number of lines needed to interface to a large number of converters. The MSB of converter n will appear at SDO of converter n+1 after 20 SCK cycles. The MSB of converter n is clocked in at the SDI pin of converter n+1 on the rising edge of the first SCK. *Chain-mode* timing diagram can be seen on the

Figure 15.

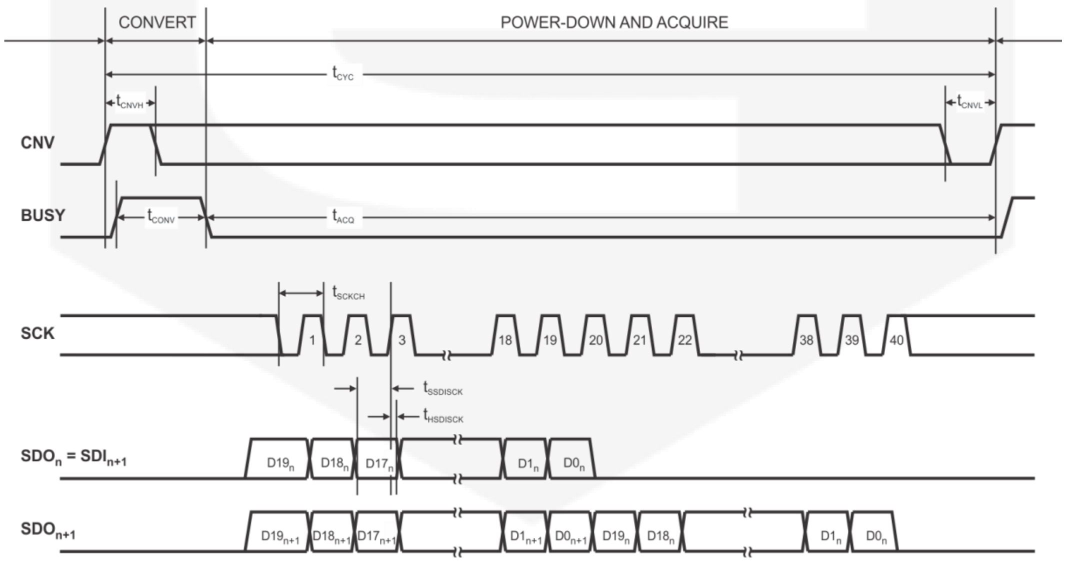

Figure 15: *Chain-mode* timing diagram

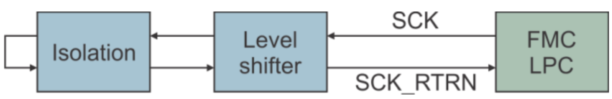

Figure 16: Clock loopback block diagram

3.4 Timing Characteristics

Symbol	*Parameter*	*Min*	*Max*
f_{SMPL}	Maximum Sampling Frequency		1
t_{CONV}	Conversion Time	615	675
t_{ACQ}	Acquisition Time	312	
t_{CYC}	Time Between Conversions	1	
t_{CNVH}	CNV High Time	20	
t_{BUSYLH}	CNV↑ to BUSY Delay		13
t_{CNVL}	Minimum Low Time for CNV	20	
t_{QUIET}	SCK Quiet Time from CNV↑	20	
t_{SCK}	SCK Period	10	
t_{SCKH}	SCK High Time	4	
t_{SCKL}	SCK Low Time	4	
$t_{SSDISCK}$	SDI Setup Time From SCK↑	4	
$t_{HSDISCK}$	SDI Hold Time From SCK↑	1	
t_{SCKCH}	SCK Period in Chain Mode	13.5	
t_{DSDO}	SDO Data Valid Delay from SCK↑		8
t_{HSDO}	SDO Data Remains Valid Delay from SCK↑	1	
$t_{DSDOBUSYL}$	SDO Data Valid Delay from BUSY↓		5

Table 6: Timing characteristics

3.5 Integration on DAMC-FMC25

The FMC-Pico-M4 can be installed on the DAMC-FMC25 MTCA.4 carrier board produced by CAEN ELS (see **Figure 17**). Up to two FMC cards can be installed on a single carrier, allowing to configure an 8-channel current-measuring board. Please note that the input channels of one FMC board can be at a different potential respect to the input channels of the other FMC board installed. Since the input channels of one FMC board can float up to ±300 V respect to ground, the maximum potential difference between the input channels of one FMC board and the other can be of 600 V.

Figure 17: two FMC-Pico-1M4 installed on a DAMC-FMC25

4. Ordering Options

The ordering code of the **FMC-Pico-1M4** is the following:

F	M	C	-	P	I	C	O	-	1	M	4	-	2	0

NOTE: *fields/characters shaded in grey color are fixed.*

4.1 Optional Codes

Input mating connectors can be purchased separately by the ordering code (it includes 4 mating connectors as a kit).

Customization and calibration of the input ranges of the FMC-Pico-1M4 can be performed as a service by indicating the values of the full-scale input ranges:

5. Technical Specifications

Technical Specifications for the FMC-Pico-1M4 mezzanine cards are hereafter presented:

General Technical Specifications	
Board Type	FPGA Mezzanine Card - FMC VITA 57.1
FMC Connector Type	LPC (HPC compliant)
Number of Channels	4
On Board Input Connectors	Triaxial - LEMO 00.650 Series (EPL.00.650)

Table 7: General information for the FMC-Pico-1M4

5.1 Electrical Specifications

Electrical Specifications	
Current Polarity	Bipolar
Full-Scale Current	RNG0: ± 1 mA RNG1: ± 1 µA (configurable upon request)
Maximum Sampling Rate	1 MSPS
Equivalent Signal-to-Noise ("-20" model)	RNG0: > 100 dB RNG1: > 90 dB
Resolution	20 bit
Conversion Time - T_{CONV}	650 ns
Bandwidth (-3dB)	> 10 kHz
Temperature Coefficient - TC	10 ppm/°C
Unbalance of Input Channels	< 0.05 % without calibration
Differential TC	< 25 ppm/°C
Front End Isolation Voltage	± 300 V

Table 8: Electrical specifications for FMC-Pico-1M4

5.2 Equivalent Input Noise

Different equivalent input noise typical values for the two different measuring ranges and for different sampling rates are hereafter presented.

Noise tests are performed by shorting the signal ground on the chassis ground and by shielding the inputs.

Equivalent Input Noise		
	RNG0: ±1 mA	**RNG1: ±1 µA**
F_S = 2 ksps	1 ppm/FS **-120 dB**	2.5 ppm/FS **-112 dB**
F_S = 20 ksps	2 ppm/FS **-114 dB**	7 ppm/FS **-103 dB**
F_S = 200 ksps	5 ppm/FS **-107 dB**	10 ppm/FS **-100 dB**
F_S = 1 Msps	8 ppm/FS **-102 dB**	15 ppm/FS **-96 dB**

Table 9: Equivalent Input noise for different sampling rates

The basic sampling rate is 1 Msamples/s and the computation is made by averaging the number of samples in order to reach the other listed values – e.g. averaging of 5 samples to obtain the F_S = 200 ksps equivalent input noise value.

5.3 Digital Interface and Power Supply Requirements

The FMC-Pico-1M4 is designed to operate in the LVCMOS mode from 1.2 V to 3.3 V, depending on the voltage supply level provided by the carrier board on the VADJ pins. VREF_A_M2C pin is unconnected on the mezzanine module.

The current consumption for all four power supply voltages is indicated in the table 3. To prevent overheating of the FMC board the user must ensure appropriate airflow.

Power Supply Voltage	*Allowed Voltage Range [V]*	*Number of Pins*	*Max Current Consumption*	*Tolerance*
VADJ	**1.2 – 3.3**	2	10 mA @ 2.5 V	±5 %
3P3VAUX	**3.3**	1	5 mA	±5 %
3P3V	**3.3**	4	25 mA	±5 %
12P0V	**12**	2	150 mA	±5 %

Table 10: Current consumption for all power supply voltages

The FMC-Pico-1M4 also carries a small serial EEPROM chip (24AA64) which is accessible from the carrier board through the I2C bus. The EEPROM is powered by the 3P3VAUX power supply. The EEPROM is not write-protected so the user should take care not to overwrite the factory programmed data.

6. Mechanical Dimensions

The FMC-Pico-1M4 board complies with the FMC standard known as ANSI/VITA 57.1. The board is a single-width, air cooled FMC card with front panel I/O connectors and used region 1. The stacking height of the FMC-Pico-1M4 is 10 mm.

There are four LEMO triaxial connectors (EPL.00.650) available on the front panel. The user must use appropriate mating connectors to meet electrical specifications (e.g. LEMO FFC.00.65). The channel numbering is shown on **Figure 18**.

Figure 18: Front Panel Layout

The mechanical dimensions of the FMC board can be found in the following table.

Dimension	*Value*
FMC Form Factor	Single-width
Physical Width	69 mm
Physical Depth (including bezel)	78.5 mm

Table 11: Mechanical dimensions