# C-DIAS Analog Input Module CAI 086

**For eight, ±10V voltage inputs**

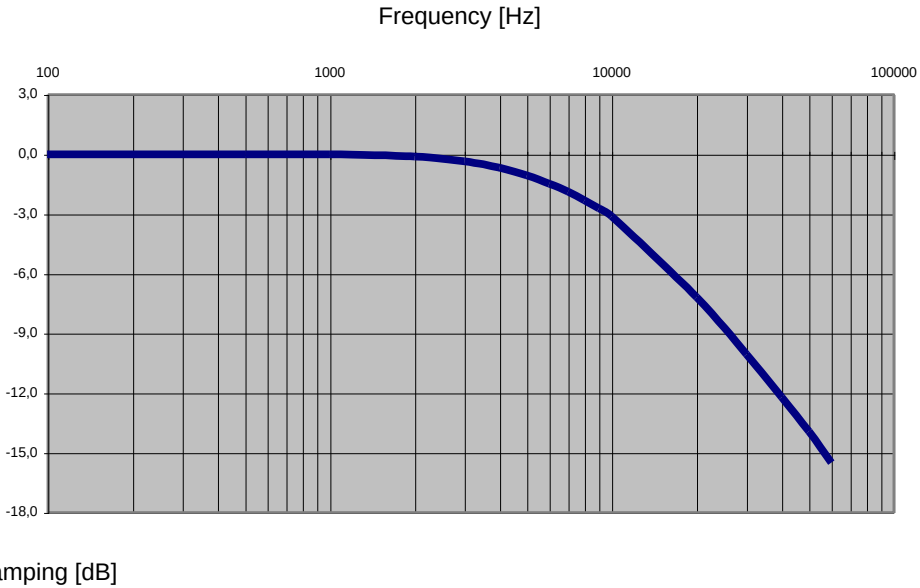

This analog input module is used for the input of voltage values in the range of ±100mV / ±1.0V and10V. An integrated measurement range switch makes high-resolution voltage measurements possible. Every analog input has a separate changeable reference output for +10 or +24V with or without the 33kΩ series resistor.
The analog inputs are galvanically separated from the C-DIAS bus.

## Technical Data

### Analog channel specifications

| | | | |
|---|---|---|---|
| Number of channels | 8 | | |
| Range | ±10V | ±1.0V | ±100mV |
| Amplification | x1 | x10 | x100 |
| Measurement values [Digit] | ±30000<br>An open input gives the value 65535 (open circuit) | | |
| Measurement values [Volt] | 333.3µV / Bit | 33.3µV / Bit | 3.3µV / Bit |
| Open circuit recognition | 10MΩ between AI- and -12.5V<br>10MΩ between AI+ and +12.5V | | |
| Resolution | 16 Bit | | |
| Conversion time per channel | ≤25µs | | |
| Input filter (common mode)<br>Input filter (difference) | 100kHz (-3 dB)<br>10kHz (-3 dB)<br>Low pass 1. adjustment (-6dB / Octave) | | |
| Common mode range | ±2.0V | ±10V | ±11V |
| Input resistance | >1MΩ | | |
| Analog channel measurement accuracy (read from the measurement range) | ±0.030%<br>(20 – +40°C)<br>±0.045%<br>(0 – +60°C) | ±0.045%<br>(20 – +40°C)<br>±0.060%<br>(0 – +60°C) | ±0.095%<br>(20 – +40°C)<br>±0.15%<br>(0 – +60°C) |
| Status display up to Version 2.0 | Red: PLL is not synchronous<br>Yellow: access to the ADC | | |
| Status display from version 2.0 | Red: Card not configurated<br>Yellow: access to the ADC | | |
| Converter | Serial SAR | | |

## Input filter characteristics




## Analog channel accuracy (typical)

| | | | | | | |
|---|---|---|---|---|---|---|
| Range | ±10 V | | ±1.0 V | | ±100 mV | |
| Noise (ADC) | ±3 Digit | | ±4 Digit | | ±5 Digit | |
| Cross talk | ±5 Digit | | ±7 Digit | | ±9 Digit | |
| Linearity error | ±2 Digit | | ±2 Digit | | ±15 Digit | |
| Calibration error | ±2 Digit | | ±3 Digit | | ±5 Digit | |
| Temperature influence | 20 – 40°C ±3 Digit | 0 – 60°C ±8 Digit | 20 – 40°C ±4 Digit | 0 – 60°C ±10 Digit | 20 – 40°C ±10 Digit | 0 – 60°C ±32 Digit |
| Paging | ±1 Digit | ±5 Digit | ±5 Digit | ±9 Digit | ±11 Digit | ±14 Digit |
| Total error [Digit] | ±16 Digit | ±25 Digit | ±25 Digit | ±35 Digit | ±55 Digit | ±80 Digit |
| Total error [Volt] | ±5.3mV | ±8.0mV | ±0.8mV | ±1.2mV | ±0.18mV | ±0.27mV |

## Reference output specifications

| Application | +10V | +24V | +10V with 33kΩ series resistor |
|---|---|---|---|
| Accuracy (without calibration) | 9.952V ±1.55% | 23.885V ±2.75% | 33kΩ ±1.0% |
| Accuracy (with calibration) | ±0.030%<br>(20 – +40°C) | ±0.075%<br>(20 – +40°C) | ±0.10%<br>(0 – +60°C) |
| Nominal load | 1mA | 15mA | 50mW |
| Maximum load (pro channel)<br>Maximum load (total) | 10mA<br>80mA | 50mA<br>125mA | 100mW<br>800mW |

## Reference channel accuracy

| Reference voltage | +10V | | +24V | |
|---|---|---|---|---|
| Load variation (0mA / nominal load) | ±0.020% | | ±0.025% | |
| Temperature influence | 20 – +40°C<br>±0.005% | 0 – +60°C<br>±0.010% | 20 – +40°C<br>±0.025% | 0 – +60°C<br>±0.085% |
| Paging | ±0.005% | ±0.020% | ±0.025% | ±0.040% |
| Total error | ±0.030% | ±0.050% | ±0.075% | ±0.150% |

## Guidelines for using the reference outputs

The reference outputs can be used to power external sensors.
The following points should be observed:

- The maximum current consumption of all sensors cannot exceed 125mA.
- The total capacity of all sensors should not exceed 47µF.
- The spike current at power-up should not exceed 200mA.

Spike current (through capacity in the sensors) lead to failure of the analog parts, an invalid analog input value (the PGA no longer functions correctly) and the activity LED will not light. A few remedies are listed here:

- Power the sensor externally.
- Turn on the sensors in a staggered time interval.
- Repeat initialization of registers 16#00 – 16#03 with a stable reference.

When using sensors, the following turn-on sequence is generally recommended:

- The sensors should be turned on one after the other in 100ms intervals (+10 V → +24 V).
- 100ms after the last sensor is activated, reset the amplifying and reference outputs (Addresses 16#00 – 16#03).

Follow these guidelines to ensure fault-free operation of the CAI086 analog module.

## Electrical Requirements

| | | |
|---|---|---|
| Supply from C-DIAS Bus | +5V und +24V | |
| Current consumption of C-DIAS Bus (+5V-supply) | Typically180mA | Maximum 200mA |
| Current consumption of C-DIAS bus (+24V-supply) | Typically 200mA | Maximum 400mA |
| Galvanic separation (Input ←→ C-DIAS-Bus) | 500V (Maximum Isolation voltage) | |

**IMPORTANT:**
This module exceeds the standard current consumption for C-DIAS modules!
(+5V: 150mA and +24V: 150mA)

In case this C-DIAS module is mounted on an 8x module carrier (CMB 08x), the total current of the modules used must be determined and tested.
The specification for the current consumption is found in the module specific technical document under “Electrical Requirements”
The total current of the +5V supply cannot exceed 1.2A (150mA/slot).
This also applies to the total current of the +24V supply, which cannot exceed 1.2A (150mA/slot).

**IMPORTANT:**
La consommation de courant de ce module dépasse les valeurs typiques pour les modules C-DIAS!
(+5 V: 150 mA et +24 V: 150mA)

Si ce module C-DIAS est monté sur un fond de panier de taille 8 (CMB 08x), le courant total des modules utilisés doit être déterminé et vérifié.
Les données de la consommation de courant sont mentionnées dans la documentation technique du module respectif dans le paragraphe "Spécifications électriques"
Le courant total de l'alimentation +5 V ne peut pas dépasser 1,2A (150mA/module).
Cela vaut également pour le courant total de l'alimentation +24 V, lequel ne peut également pas dépasser 1,2A (150mA/module).

## Miscellaneous

| | |
|---|---|
| Article number | 12-009-086 |
| Hardware version | 1.x – 4.x |
| Standard | UL (E247993) |

## Operating Conditions

| | | |
|---|---|---|
| Storage temperature | -30 – +90°C | |
| Operating temperature | +20 – +40°C<br>for the above mentioned precision | 0 – +60°C maximal |
| Humidity | 0 – 95%, Uncondensed | |
| EMV-stability | According to EN 61000-6-2 (Industrial area) | |
| Shock resistance | EN 60068-2-27 | 150m/s² |
| Protection type | EN 60529 | IP 20 |

**CAUTION:**

To ensure the high precision of the analog input module over a long period, it is necessary to compensate the deterioration of the components yearly. This can be done through a factory adjustment or a recalibration.

When the deterioration of the analog input module has no great influence to the application, a yearly calibration is not necessary. However, the specified precision is then not guaranteed from SIGMATEK anymore.

A 10-minute minimum warm-up phase must be allowed!

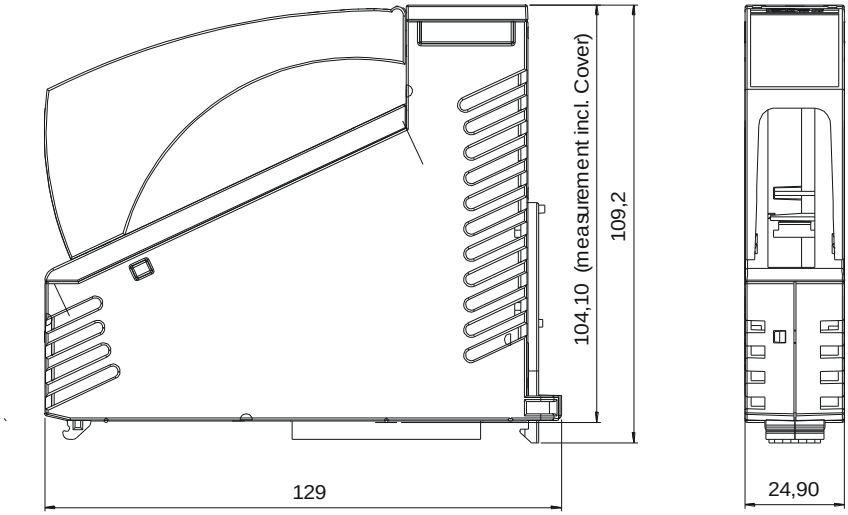
**ATTENTION:**

Pour garantir la précision élevée du module d'entrée analogique sur une longue période, il est nécessaire de compenser annuellement la détérioration des composants. Cela peut être réalisé au moyen d'un ajustement à l'usine ou de l'étalonnage.

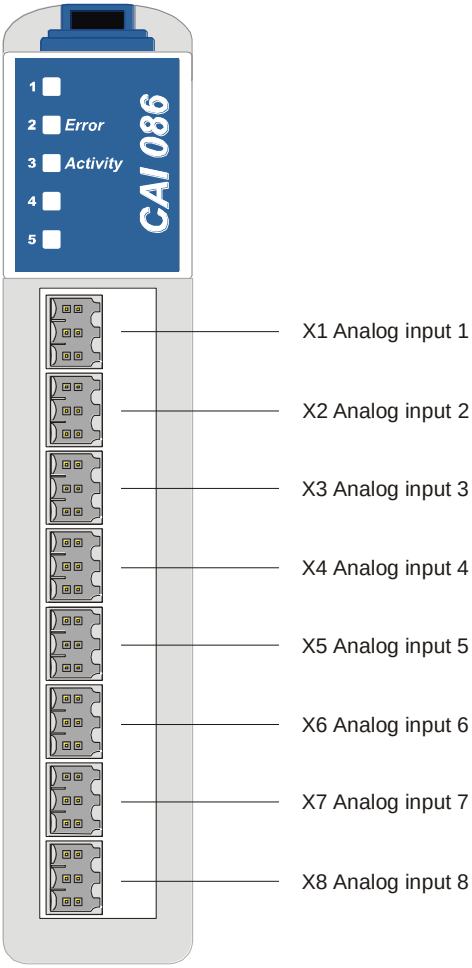
Si la détérioration du module d'entrée analogique n'a pas une grande influence sur l'application, l'étalonnage annuel peut ne pas être pris en considération. Toutefois dans ce cas la spécification concernant la précision n'est plus garantie par Sigmatek.

En outre, une période d’échauffement de 10 minutes est nécessaire!

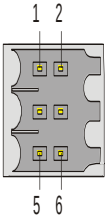
# Mechanical Dimensions



# Terminal Assignment



**X1 – X8: Connector Input 1 - 8**




| Pin | Function |
|---|---|
| 1 | Input - |
| 2 | Input + |
| 3 | Input - |
| 4 | Input + |
| 5 | Analog GND |
| 6 | Reference output |

**Applicable Connector plugs**

**X1-X8:** 6-pol. Weidmüller plug B2L/B2CF 3,5/6 gold plated

X1, X2, X3, ..., X8 have the same assignment!

The complete C-Dias connector set CKI 111 with spring terminal is available at SIGMATEK under the article number 12-600-111.

# Status Display


## Up to Hardware version 2.0

| LED No. | LED Color | Meaning |
|---|---|---|
| 2 | Red | PLL not synchronous to C-DIAS Bus |
| 3 | Yellow | Reading Analog values |

## Ab Hardwareversion 2.0

| LED No. | LED Color | Meaning |
|---|---|---|
| 2 | Red | Card not configurated |
| 3 | Yellow | Reading Analog values |

# Wiring Instructions

The signals received by the analog module are very small in comparison to the digital signals. To ensure fault-free operation, careful wiring method must be maintained.

- The 0 V connection for the supply voltage must be connected to the 0 V collection point over the shortest route possible.
- The connection lines to the analog inputs must be as short as possible and avoid parallel connection to digital signal lines.
- The signal lines should be 2 and/or 3 pin or 4 pin shielded wire. Or be at least twisted

### General Information

More Information on the possible connection types such as:
- Voltage measurement
- Current measurement
- Distance measurement
- Temperature measurement with thermal resistors
- Temperature measurement with Thermal elements
- Bridges

Are found in the document “C-DIAS input circuit”.

# Addressing

The analog module is not automatically read into the process image by the operating system.

**Caution: The CAI 086 is designed to operate in synchronous Real-Time. The Data integrity as described below is only then guaranteed.**

**Attention: Le CAI 086 est conçu pour fonctionner en synchrone en temps réel. L'intégrité des données comme décrit ci-dessous est garantie uniquement dans ce mode.**

### Up to Hardware version 2.0

| Address | Access | | Function |
|---|---|---|---|
| 16#00 | WRITE | WORD | Amplifier [1)]<br>Bit 0,1: 00 = x1 (channel 1 ±10V)<br>01 = x10 (channel 1 ±1.0V)<br>10 = x100 (channel 1 ±100mV)<br>11 = x1000 (not supported)<br>Bit 2,3: channel 2<br>...<br>Bit 15,16: channel 8 |
| 16#02 | WRITE | WORD | Reference output [1)]<br>Bit 0,1: 00 = +10V + 33kΩ (channel 1)<br>01 = +10V (channel 1)<br>10 = +24V + 33kΩ (channel 1)<br>11 = +24V (channel 1)<br>Bit 2,3: channel 2<br>...<br>Bit 15,16: channel 8 |
| 16#04 | WRITE | WORD | Multiplexer: channel select [1)]<br>Bit 0 - 2: channel (Bit 3 = 1)<br>000 channel 1 001 channel 2<br>010 channel 3 011 Channel 4<br>100 channel 5 101 channel 6<br>110 channel 7 111 Channel 8<br>Bit 3: 0 = Automatic conversion of all 8 channels<br>1 = only selected channel is converted<br>(1-channel measurement) |

| | | | |
|---|---|---|---|
| 16#04 | READ | WORD | Multiplexer: actual value (1- channel measurement)<br>Bit 4 - 6: actual value (Bit 3 = 1)<br>000 channel 1 001 channel 2<br>010 channel 3 011 channel 4<br>100 channel 5 101 channel 6<br>110 channel 7 111 channel 8<br><br>After the conversion time is passed, the channel counter (Bit 4 - 6) increments and the actual value are stored. Channel 1 (address 16#08) follows channel 8 (address 16#16). Channel 1 – 8 make up a ring buffer with the last 6 converted analog values. The most current value represents Bit 4 - 6. |
| 16#06 | WRITE | WORD | Conversion time per channel in 5µs increments [2)]<br>2 = 10µs / channel (80µs for 8 channels)<br>5 = 25µs / channel (Default)<br>199 = 995µs / channel (Maximum ≤1ms) |
| 16#08 | READ | WORD | Channel 1 Analog value |
| 16#0A | READ | WORD | Channel 2 Analog value |
| 16#0C | READ | WORD | Channel 3 Analog value |
| 16#0E | READ | WORD | Channel 4 Analog value |
| 16#10 | READ | WORD | Channel 5 Analog value |
| 16#12 | READ | WORD | Channel 6 Analog value |
| 16#14 | READ | WORD | Channel 7 Analog value |
| 16#16 | READ | WORD | Channel 8 Analog value |
| 16#18 | READ | BYTE | PLL Status register<br>Bit 0: 1 = PLL synchronous (to C-DIAS-Sync)<br>Bit 1: 1 = PLL online (C-DIAS-Sync recognized) |
| 16#19 | READ<br>WRITE | BYTE | PLL Period (in ms)<br>Default : 1 |
| 16#1A | READ<br>WRITE | BYTE | JTAG Master<br>(TDI / TDO, TMS) |
| 16#1B | READ | BYTE | FPGA Version |

[1)] After conversion of the amplification, reference output or channel select; the following values for a cycle (=conversion time x 8) is invalid!

[2)] After the change over of the conversion time, the following values for the conversion time [old] + conversion time [new] x 8 is invalid.

For the hardware calibration, the calibration values for offset, multiplier and divisor are set at the manufacturer. These values stored in a serial EEPROM found in the module.

## Up to Hardware version 2.0

| Address | Access | | Function |
|---|---|---|---|
| 16#00 | WRITE | DOUBLE WORD | Amplifier[1)]<br>Bit 0,1: 00 = x1 (Channel 1 ±10V)<br>01 = x10 (Channel 1 ±1,0V)<br>10 = x100 (Channel 1 ±100mV)<br>11 = x1000 (not supported)<br>...<br>Bit 14,15: Channel 8<br>Reference output [1)]<br>Bit 16,17: 00 = +10V + 33kΩ (Channel 1)<br>01 = +10V (Channel 1)<br>10 = +24V + 33kΩ (Channel 1)<br>11 = +24V (Channel 1)<br>...<br>Bit 30,31: Channel 8 |
| 16#04 | READ WRITE | WORD | Multiplexer: Channel selection[1)]<br>Bit 0,1: Conversion mode<br>00 1 Channel<br>01 2 Channels<br>10 4 Channels<br>11 8 Channels<br>Bit 2 - 7: reserved<br>Bit 8 - 15: binary channel selection for conversion mode<br>Bit 8: Channel 1<br>Bit 9: Channel 2<br>...<br>(Channels selected when Bit = '1') |
| 16#06 | READ WRITE | WORD | Conversion time per channel in 5µs steps[1) 3)]<br>Bit 0 - 7:<br>2 = 10µs / Channel (80µs for 8 channels)<br>5 = 25µs / Channel (Default)<br>199 = 995µs / Channel (Maximum ≤1ms)<br>Bit 8 - 15: reserved |

| | | | |
|---|---|---|---|
| 16#08 | READ | WORD | Channel 1 Analog value |
| 16#0A | READ | WORD | Channel 2 Analog value |
| 16#0C | READ | WORD | Channel 3 Analog value |
| 16#0E | READ | WORD | Channel 4 Analog value |
| 16#10 | READ | WORD | Channel 5 Analog value |
| 16#12 | READ | WORD | Channel 6 Analog value |
| 16#14 | READ | WORD | Channel 7 Analog value |
| 16#16 | READ | WORD | Channel 8 Analog value |
| 16#18 | READ | BYTE | PLL Configuration register<br>Bit 0: PLL locked<br>Bit 1: PLL online |
| 16#18 | WRITE | BYTE | PLL Configuration register[2) 3)]<br>Bit 0 - 7: Register selection 0: Offset counter Bit 0 - 7<br>Register selection 1: Offset counter Bit 8 - 9<br>(Bit 0 - 9 value range: 0 - 950, resolution: 1µs)<br>Register selection 2: period counter Bit 0 - 7<br>Register selection 3: period counter Bit 8 - 9<br>(Bit 0 - 9 value range: 0 - 1000, resolution: 1 µs) |
| 16#19 | READ<br>WRITE | BYTE | PLL Configuration register 1[2) 3)]<br>Bit 0 - 3: PLL period (1 - 15 ms)<br>Bit 4 - 6: Register selection for the counter configuration |
| 16#1A | READ<br>WRITE | BYTE | JTAG Master<br>(TDI / TDO, TMS) |
| 16#1B | READ | BYTE | FPGA version |

[1)] After a write access and/or change of conversion time, amplification, reference output or channel selection, the following measurement values for a cycle are reset to zero. After an additional cycle the data is then valid.
[2)] With a cycle time greater than 1ms, the period counter must be set to a value of 1000.
[3)] Caution must be taken to ensure that the cycle time and conversion time so that the measurement of all channels is complete within the cycle time.

For the Hardware calibration the values for Offset, Multiplier and Divisor are set at the factory. These values are stored in a serial EEPROM located in the module.

# Data in the EEPROM

**Module data** (organized byte wise)

| Address | Data | Description |
|---|---|---|
| $00 | $xx | Checksum ($00 - $07) |
| $01 | 123 | Identification |
| $02 | 5 | Module group 5 = CAI |
| $03 | 8 | Variant 8 = CAI086 |
| $04 | 8 | Number of channels (8x AI) |
| $05 | $1x | Hardware version $10 = HW-V1.0, $11 = HW-V1.1, … |
| $06 - $07 | 0 | Free |
| $08 | $xx | Checksum ($08 - $0F) |
| $09 | 123 | Identification |
| $10 | | Serial number |
| $0A | 1 | FPGA Family 1 = Xilinx |
| $0B | 1 | FPGA Update 1 = Platformflash |
| $0C | $1A | FPGA Update address LO |
| $0D | $00 | FPGA Update address HI |
| $0E - $0F | 0 | Free |

**AI-Calibration data** (Word wise organized)

| Address | Data | Description |
|---|---|---|
| $40 | $xxxx | Checksum |
| $42 | 12345 | Identification |
| $44 | 73 | Length of the following Data block in WORD ($44 - $D7) |
| $46 | $0008 | Number of channels (8x AI) |
| | | |
| $48 | I.e.. -32776 | Offset for 0V channel -1 (±10V) |
| $4A | I.e.: 65300 | Gain-Divisor channel -1 (±10V) from a fixed multiplier of 60000 |
| $4C - $4F | - | Calibration value channel -2 (±10V) |
| $50 - $53 | - | Calibration value channel -3 (±10V) |
| $54 - $57 | - | Calibration value channel -4 (±10V) |
| $58 - $5B | - | Calibration value channel -5 (±10V) |
| $5C - $5F | - | Calibration value channel -6 (±10V) |
| $60 - $63 | - | Calibration value channel -7 (±10V) |

| | | |
|---|---|---|
| $64 - $67 | - | Calibration value channel -8 (±10V) |
| $68 - $6B | - | Calibration value channel -1 (±1.0V) |
| $6C - $6F | - | Calibration value channel -2 (±1.0V) |
| $70 - $73 | - | Calibration value channel -3 (±1.0V) |
| $74 - $77 | - | Calibration value channel -4 (±1.0V) |
| $78 - $7B | - | Calibration value channel -5 (±1.0V) |
| $7C - $7F | - | Calibration value channel -6 (±1.0V) |
| $80 - $83 | - | Calibration value channel -7 (±1.0V) |
| $84 - $87 | - | Calibration value channel -8 (±1.0V) |
| | | |
| $88 - $8B | - | Calibration value channel -1 (±100mV) |
| $8C - $8F | - | Calibration value channel -2 (±100mV) |
| $90 - $93 | - | Calibration value channel -3 (±100mV) |
| $94 - $97 | - | Calibration value channel -4 (±100mV) |
| $98 - $9B | - | Calibration value channel -5 (±100mV) |
| $9C - $9F | - | Calibration value channel -6 (±100mV) |
| $A0 - $A3 | - | Calibration value channel -7 (±100mV) |
| $A4 - $A7 | - | Calibration value channel -8 (±100mV) |
| | | |
| $A8 | I.e.: 59700 | Calibration value Reference -1 (+10V) from 10.0V = 60000 |
| $AA | - | Calibration value Reference -2 (+10V) |
| $AC | - | Calibration value Reference -3 (+10V) |
| $AE | - | Calibration value Reference -4 (+10V) |
| $B0 | - | Calibration value Reference -5 (+10V) |
| $B2 | - | Calibration value Reference -6 (+10V) |
| $B4 | - | Calibration value Reference -7 (+10V) |
| $B6 | - | Calibration value Reference -8 (+10V) |
| | | |
| $B8 | I.e.: 47600 | Calibration value Reference -1 (+24V) from 30.0V = 60000 |
| $BA | - | Calibration value Reference -2 (+24V) |
| $BC | - | Calibration value Reference -3 (+24V) |
| $BE | - | Calibration value Reference -4 (+24V) |
| $C0 | - | Calibration value Reference -5 (+24V) |
| $C2 | - | Calibration value Reference -6 (+24V) |
| $C4 | - | Calibration value Reference -7 (+24V) |
| $C6 | - | Calibration value Reference -8 (+24V) |

| | | |
|---|---|---|
| $C8 | I.e.: 32980 | Calibration value series resistance-1 (33kΩ) in Ohm |
| $CA | - | Calibration value series resistance -2 (33kΩ) |
| $CC | - | Calibration value series resistance -3 (33kΩ) |
| $CE | - | Calibration value series resistance -4 (33kΩ) |
| $D0 | - | Calibration value series resistance -5 (33kΩ) |
| $D2 | - | Calibration value series resistance -6 (33kΩ) |
| $D4 | - | Calibration value series resistance -7 (33kΩ) |
| $D6 | - | Calibration value series resistance -8 (33kΩ) |

**Calculation of the analog input values**

| | | |
|---|---|---|
| I.e.: | Offset | -32776 |
| | Gain Multiplier | 60000 |
| | Gain Divisor | 65300 |

**Conversion formula for the analog inputs**

$$Digitalvalue = \frac{(ADC\_rawvalue + Offset) \cdot Gain}{Divisor}$$

**Example:**

I.e.: value for 0 V: $\frac{(32776 + (-32776)) \cdot 60000}{65300} = 0$

Value for -10 V: $\frac{(126 + (-32776)) \cdot 60000}{65300} = -30000$

Value for +10 V: $\frac{(65426 + (-32776)) \cdot 60000}{65300} = 30000$