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Function Description

Sine/Cosine

APCIe-1711 and CPCIs-1711
Multifunction counter board, optically isolated

DIN EN ISO 9001:2015 certified

Edition: 02.10-04/2022

Product information

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Personal injury

Damage to the board, the PC and peripherals

Pollution of the environment.

- Protect yourself, others and the environment!
- Read the safety precautions (yellow leaflet) carefully!

  If this leaflet is not enclosed with the documentation, please contact us and ask for it.
- Observe the instructions of this manual!

  Make sure that you do not forget or skip any step!
  We are not liable for damages resulting from the wrong use of the board.
- Pay attention to the following symbols:

NOTICE!
Designates hints and other useful information.

NOTICE!
Designates a possibly dangerous situation.
If the instructions are ignored, the board, the PC and/or peripherals may be **destroyed**.

WARNING!
Designates a possibly dangerous situation.
If the instructions are ignored, the board, the PC and/or peripherals may be **destroyed** and persons may be **endangered**.

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Chapter overview

In this manual, you will find the following information:

Chapter	Content
1	Function description including block diagram and pin assignment
2	Standard software: Information on the API software functions
3	List of technical data and limit values
4	Appendix with index
5	Contact and support address

This document solely describes the function “Sin/Cos”.

For general information on the **APCIe-1711** or **CPCIs-1711**, please read the Technical Description of these boards (see PDF link). It contains, for example, the chapter “Inserting and installing the board” that supports you in commissioning.

1 Function description

The function “Sine/Cosine” is used to acquire Sin/Cos signals shifted by 90° (1 V_{PP} or 11 μA_{PP}).

The board **APCIe-1711** or **CPCIs-1711** has two plug-in positions for extension modules (EM0 and EM1). To use the Sin/Cos function, at least one extension module EM-SINCOS-1VPP or EM-SINCOS-11µAPP has to be plugged on the board.

Up to two Sin/Cos encoders can be connected for each extension module, i.e., a maximum of four Sin/Cos encoders can be run on the board. These require an external supply voltage of 5 V.

The two channels of the EM-SINCOS-1VPP or EM-SINCOS-11µAPP are controlled together by the “Sin/Cos” function. Thus, for one extension module, the function has to be loaded only in one function module. To operate the extension module on the plug-in position EM0, the “Sin/Cos” function has to be loaded into FM0 or FM1. Via the function module FM2 or FM3, the extension module can be used on the plug-in position EM1.

A signal period of the Sin/Cos signal is divided into a defined number of steps according to the selected resolution. The maximum input frequency of the counter input also depends on the resolution.

Features:

- Up to 2 extension modules per board (EM-SINCOS-1VPP or EM-SINCOS-11µAPP)[1]
- Up to 2 Sin/Cos encoders per function module (a maximum of 4 per board)
- Optical isolation of the inputs and outputs through opto-couplers to prevent ground loops
- 1 digital input per extension module for the latch logic or interrupt logic
- 2 acquisition modes: Full Range Mode and Fast Mode
- Additional functions in Full Range Mode: compare logic, index logic and digital trigger
- 3 digital inputs (24 V) and 1 freely controllable digital output (24 V) for each function module

1.1 Board versions with “Sin/Cos” function

NOTICE!
The “Sin/Cos” function can be used with every version of the **APCIe-1711** or **CPCIs-1711**.

The I/O specifications of the different board versions are available in the Technical Description of the **APCIe-1711** and **CPCIs-1711** (see PDF link).

[1] Please specify when ordering!

1.2 Block diagrams

Fig. 1-1: Block diagram: "Sin/Cos" function

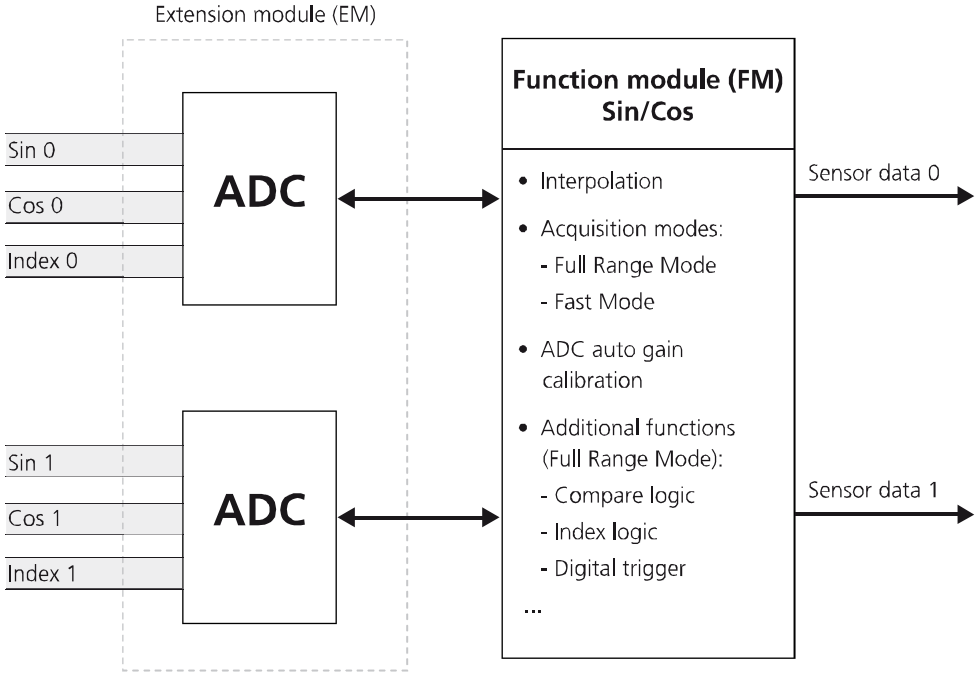
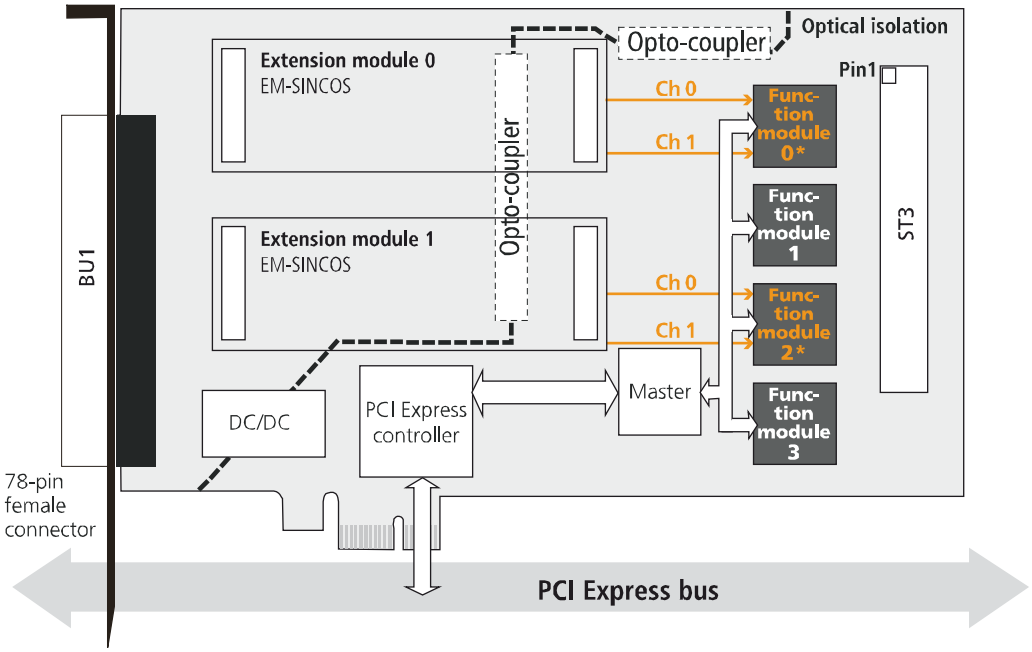
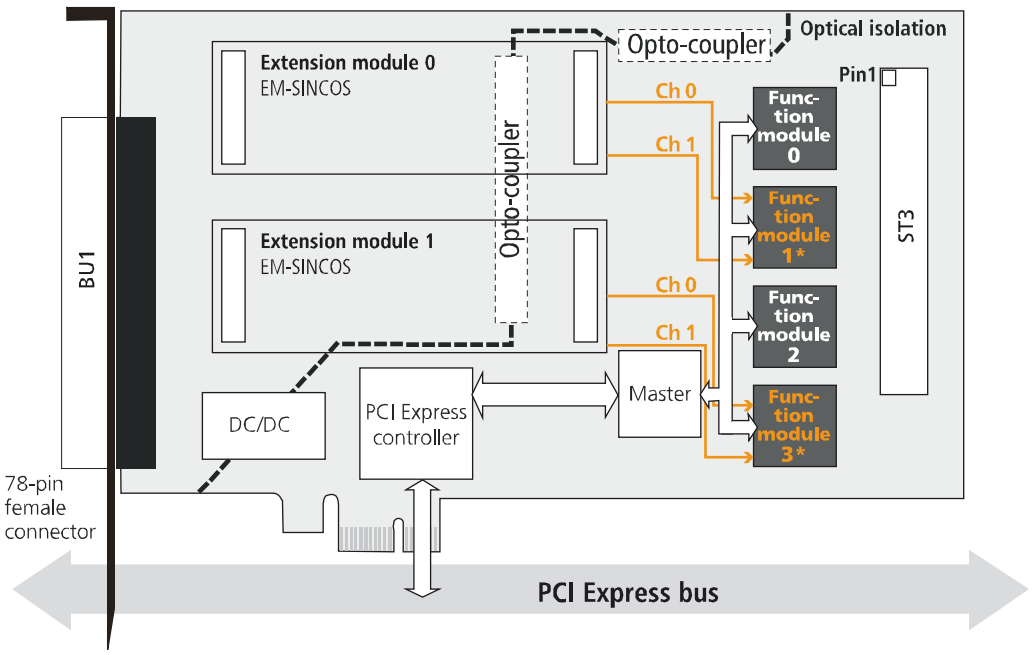


Fig. 1-2: Block diagram: Configuration example 1



* FM0 and FM2 with "Sin/Cos" function

Fig. 1-3: Block diagram: Configuration example 2



* FM1 and FM3 with "Sin/Cos" function

1.3 Used signals

Table 1-1: Used signals

Signal name	Pin name	Signal type	Function
EMy_Sin0+	EMy [0]	1 V_{ss} / 11 μA_{ss} differential	Trace A+ (sine) of the Sin/Cos encoder 0
EMy_Sin0-	EMy [4]		Trace A- (sine) of the Sin/Cos encoder 0
EMy_Cos0+	EMy [1]	1 V_{ss} / 11 μA_{ss} differential	Trace B+ (cosine) of the Sin/Cos encoder 0
EMy_Cos0-	EMy [5]		Trace B- (cosine) of the Sin/Cos encoder 0
EMy_Index0+	EMy [2]	differential	Trace C+ (index) of the Sin/Cos encoder 0
EMy_Index0-	EMy [6]		Trace C- (index) of the Sin/Cos encoder 0
EMy_Sin1+	EMy [7]	1 V_{ss} / 11 μA_{ss} differential	Trace A+ (sine) of the Sin/Cos encoder 1
EMy_Sin1-	EMy [10]		Trace A- (sine) of the Sin/Cos encoder 1
EMy_Cos1+	EMy [8]	1 V_{ss} / 11 μA_{ss} differential	Trace B+ (cosine) of the Sin/Cos encoder 1
EMy_Cos1-	EMy [11]		Trace B- (cosine) of the Sin/Cos encoder 1
EMy_Index1+	EMy [9]	differential	Trace C+ (index) of the Sin/Cos encoder 1
EMy_Index1-	EMy [12]		Trace C- (index) of the Sin/Cos encoder 1

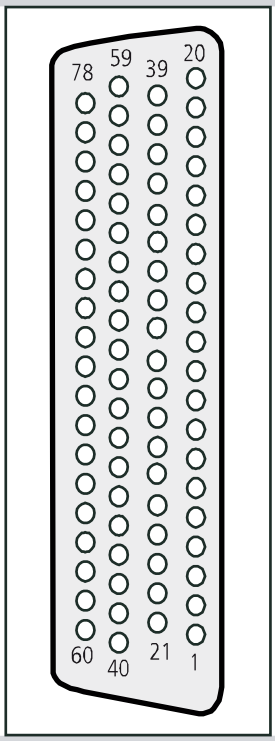
Signal name	Pin name	Signal type	Function
EMy_DIG_IN	EMy [3]	24 V / optional 5 V	Digital trigger input (can be used for the latch logic or interrupt logic)
DIG_IN_0_x	Ex	24 V / optional 5 V	Digital inputs for free use
DIG_IN_1_x	Fx	24 V / optional 5 V	
DIG_IN_2_x	Gx	24 V / optional 5 V	
DIG_OUT_Hx	Hx	24 V	Digital output for free use

y = Number of the extension module (0 or 1)
x = Number of the function module (0-3)

1.4 Pin assignment: Extension modules

Fig. 1-4: Pin assignment: 78-pin D-Sub female connector (2 EM-SINCOS modules)

Pin		Pin			Pin		Pin
78	EM0_ Index1-	59	EM0_Index1+		39	EM0_Index0+	20
77	EM0_Cos1-	58	EM0_Cos1+		38	EM0_Cos0+	19
76	EM0_Sin1-	57	EM0_Sin1+		37	EM0_Sin0+	18
75	EM1_Index1-	56	EM0_Index0-		36	EM1_DIG_IN	17
74	EM1_Cos1-	55	EM1_Index1+		35	EM1_Index0+	16
73	EM1_Sin1-	54	EM1_Cos1+		34	EM1_Cos0+	15
72	+24 V / U_{Ref}*	53	EM1_Sin1+		33	EM1_Sin0+	14
71	FM3: DIG_OUT_H3	52	U_{Ref}*		32	FM3: DIG_IN_0_3	13
70		51	FM3: DIG_IN_2_3		31		12
69		50			30		11
68	FM2: DIG_OUT_H2	49			29	FM2: DIG_IN_0_2	10
67		48	FM2: DIG_IN_2_2		28		9
66		47			27		8
65	FM1: DIG_OUT_H1	46			26	FM1: DIG_IN_0_1	7
64		45	FM1: DIG_IN_2_1		25		6
63		44			24		5
62	FM0: DIG_OUT_H0	43			23	FM0: DIG_IN_0_0	4
61		42	FM0: DIG_IN_2_0		22		3
60		41			21		2
		40				GND	1

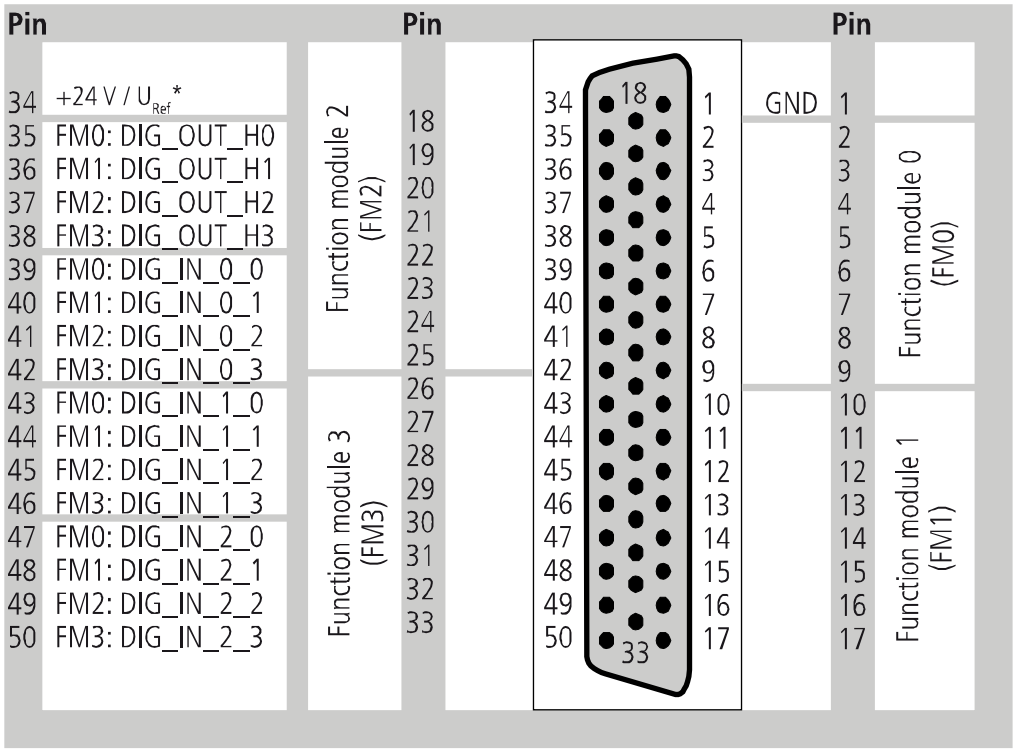


EM0_Cos0-			
EM0_Sin0-			
EM0_DIG_IN			
EM1_Index0-			
EM1_Cos0-			
EM1_Sin0-			
GND			
FM3: DIG_IN_1_3			
FM2: DIG_IN_1_2			
FM1: DIG_IN_1_1			
FM0: DIG_IN_1_0			

FM = Function module
EM = Extension module
* Pins 52 and 72: see Technical Description of the board

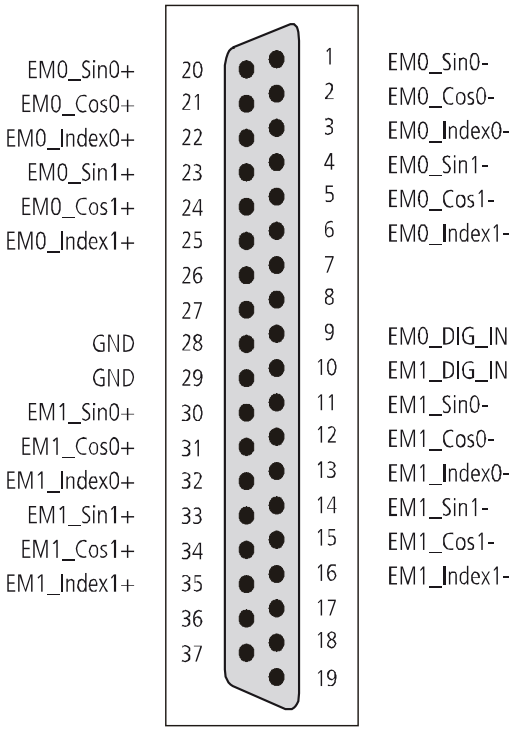
The following pin assignments apply only if the cable **ST1711-50-37** is connected to the 78-pin D-Sub female connector of the board. For further information on this, please refer to the Technical Description of the **APCIe-1711** and **CPCIs-1711** (see PDF link).

Fig. 1-5: Pin assignment: 50-pin D-Sub female connector (ST1711-50-37 cable)



* Pin 34: see Technical Description of the board

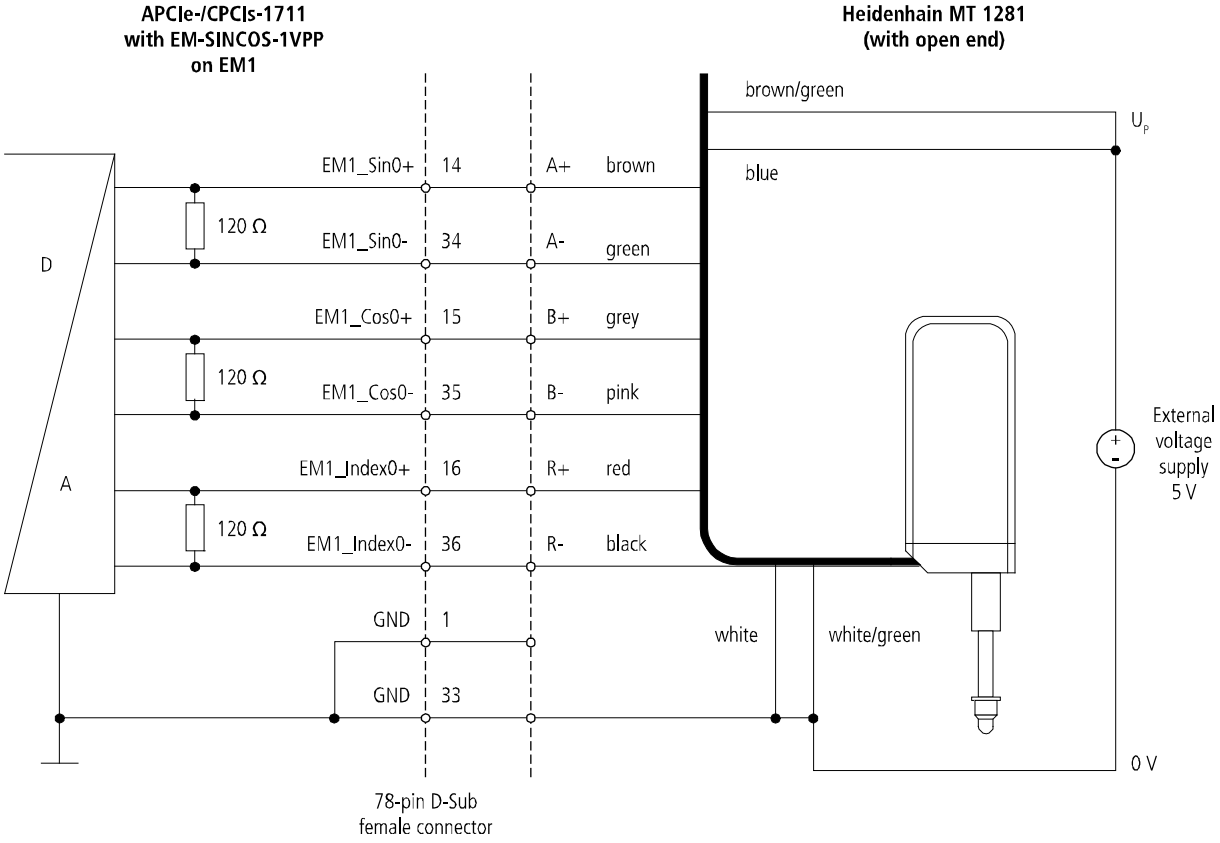
Fig. 1-6: Pin assignment: 37-pin D-Sub male connector (ST1711-50-37 cable)



EM = Extension module

1.5 Connection example

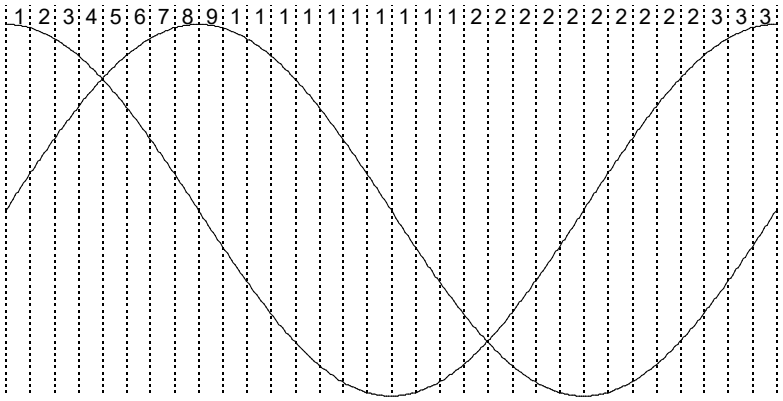
Fig. 1-7: Basic input circuit (EM-SINCOS-1VPP)



1.6 Acquisition principle

A Sin/Cos encoder transfers two sinusoidal signals that have a common signal period, with each signal being transferred on a differential trace. The two traces are shifted by 90° so that one trace is referred to as sine and the other one as cosine.
This signal period is indicated in the data sheet of the encoder and is needed for the initialisation of the counter.

Fig. 1-8: Division of a signal period (resolution: 32)



If, for example, a connected Sin/Cos encoder has a signal period of 2 µm, this means that with a distance of 0.4 mm an exact total of 200 sine periods and cosine periods is passed through. With the aid of the resolution, this hardware-specific distance is divided one more time into 25 to 8192 steps. Accordingly, with an encoder that has a signal period of 10 µm and a selected resolution of 100, the increment is 0.1 µm.

1.7 Function parameters

To provide for a correct acquisition of data from the Sin/Cos encoder, the following parameters have to be indicated accordingly with the initialisation:

- Channel number
- Resolution
- Mode.

The return value is the maximum input frequency which the Sin/Cos input may be operated with. The higher the resolution is selected, the lower is the maximum frequency of the sine signals at the input, which can be processed.

The individual parameters are explained in the following chapters.

1.7.1 Channel number

The extension modules EM0 and EM1 both have two channels (0 and 1) to acquire Sin/Cos signals. More information on this can be found in Chapters 1.3 and 1.4.

1.7.2 Resolution

The resolution determines the actual increment, i.e. the smallest change in distance that can be measured. The increment is the quotient of the signal period and the selected resolution.
The signal period is specified in the data sheet of the connected encoder. If your encoder is, for instance, a displacement transducer, the signal period is indicated in micrometres. This parameter is required to calculate in the application the standardised value from the raw value (see Chapter 1.7.3).

$$\text{Increment} = \frac{\text{Signal period}}{\text{Resolution}}$$

NOTICE!
If the resolution is increased, the maximum input frequency, which can be processed, decreases.

In the following table, all available resolutions are listed. Some of these resolutions are only available in “Fast Mode”. For more information on the modes, see Chapter 1.7.4.

Table 1-2: Available resolutions

Resolution	Maximum input frequency (Hz)	Availability (Mode)
16	250,000	Full Range Mode, Fast Mode
25	26,000	Fast Mode
32	162,500	Full Range Mode, Fast Mode
40	16,300	Full Range Mode, Fast Mode
50	26,000	Fast Mode
64	81,300	Full Range Mode, Fast Mode
80	16,300	Full Range Mode, Fast Mode
100	26,000	Full Range Mode, Fast Mode
125	20,800	Fast Mode
128	40,600	Full Range Mode, Fast Mode
160	16,300	Full Range Mode, Fast Mode
200	26,000	Full Range Mode, Fast Mode
250	20,800	Fast Mode
256	20,300	Full Range Mode, Fast Mode
320	16,300	Full Range Mode, Fast Mode

Resolution	Maximum input frequency (Hz)	Availability (Mode)
400	13,000	Full Range Mode, Fast Mode
500	10,400	Full Range Mode, Fast Mode
512	10,200	Full Range Mode, Fast Mode
800	6,500	Full Range Mode, Fast Mode
1000	5,200	Full Range Mode, Fast Mode
1024	5,100	Full Range Mode, Fast Mode
1600	3,300	Full Range Mode, Fast Mode
2000	2,600	Full Range Mode, Fast Mode
2048	2,540	Full Range Mode, Fast Mode
4096	1,270	Full Range Mode, Fast Mode
8192	635	Full Range Mode, Fast Mode

1.7.3 Output format

The encoder data is output as raw values, i.e. as 32-bit signed values. You get the actual value by multiplying the raw value by the increment.

$$\text{Actual value} = \text{Raw value} \cdot \text{increment}$$

With a signal period of 10 µm and a resolution of 100 (increment: 0.1 µm), the calculation result would therefore be the following distance data:

Table 1-3: Example of distance calculation from raw value (Full Range Mode)

Raw value	Decimal value	Distance (with increment of 0.1 µm)
0x80000000	-2,147,483,648	-214.75 m
⋮	⋮	⋮
0xFFFFFFFE	-2	-0.2 µm
0xFFFFFFFF	-1	-0.1 µm
0x00000000	0	0 µm
0x00000001	1	0.1 µm
0x00000002	2	0.2 µm

Raw value	Decimal value	Distance (with increment of 0.1 µm)
0x00000003	3	0.3 µm
⋮	⋮	⋮
0x7FFFFFFF	2,147,483,647	214.75 m

1.7.4 Acquisition modes

The board **APCIe-1711** or **CPCIs-1711** supports two different modes for the acquisition of Sin/Cos encoder data:

a) Full Range Mode

In Full Range Mode, there is always the complete 32-bit range of values available. This mode is appropriate for measurements in case of which the indicated maximum input frequency with the selected resolution is not exceeded.
In the event that this frequency is exceeded anyhow, maybe also during two read accesses, all of the following measurement results are incorrect in relation to the previously defined zero point. During the first reading of the encoder data, i.e. while or after the cut-off frequency is exceeded, the exceeding is output as return value 1 in the parameter “Frequency error”.
After an error has occurred, the reference point has to be redefined so that reliable data will be output again. For this purpose, the counter at the desired encoder position has to be deleted.

b) Fast Mode

The Fast Mode has to be applied if between two read accesses to the Sin/Cos encoder data, encoder movements faster than the selected resolution allows, should also be possible.
During two read commands, the input frequency can be up to 250 kHz in this mode. But if the frequency is exceeded during the read access, a frequency error is displayed, too. In this case, this measurement value is incorrect. If the frequency limit is adhered to in the case of a further write access, the measurement value in Fast Mode will be correct again in relation to the reference point originally defined.
The Fast Mode is specially suited if, for example, a measuring point is to be approached fast, and at the same time, a measurement (while the encoder is not moving) with a highly precise increment is required. Compare logic, index logic and digital trigger are not available in this mode. According to the selected resolution, the measurement range is reduced (see the following table).

Table 1-4: Limited measurement range (Fast Mode)

Resolution	Measurement range (bits)
16	28
25	28.64
32	29
40	29.32

Resolution	Measurement range (bits)
50	29.64
64	30
80	30.32
100	30.64
125	30.97
128	31
160	31.32
200	31.64
250	31.97
≥ 256	32

1.7.5 Input frequency

To receive correct values when the Sin/Cos encoder data is acquired, it is necessary that the maximum input frequency, which depends on the resolution, is complied with. This frequency directly relates to the sine signal.
With the aid of the signal period, the maximum movement speed for encoders (v_{max}) can be calculated from the product of the signal period and the maximum input frequency (f_{max}).
If you divide the input frequency (f_{max}) by the number of periods per revolution, you obtain the maximum speed for shaft encoders (n_{max}).

$$v_{max} = \text{Signal period} \cdot f_{max}$$

$$n_{max} = \frac{f_{max}}{\text{Periods per revolution}}$$

Table 1-5: Conversion from maximum frequency

Frequency (Hz)	Max. velocity (with signal period of 2 µm)	Max. speed (with 2048 periods per revolution)
635	0.08 m/min	18.6 rev/min
1,270	0.15 m/min	37.21 rev/min
2,540	0.3 m/min	74.41 rev/min
2,600	0.31 m/min	76,17 rev/min
3,300	0.4 m/min	96.68 rev/min

Frequency (Hz)	Max. velocity (with signal period of 2 µm)	Max. speed (with 2048 periods per revolution)
5,100	0.61 m/min	149.41 rev/min
5,200	0.62 m/min	152.34 rev/min
6,500	0.78 m/min	190.43 rev/min
10,200	1.22 m/min	298.83 rev/min
10,400	1.25 m/min	304.69 rev/min
13,000	1.56 m/min	380.86 rev/min
16,300	1.96 m/min	477.54 rev/min
20,300	2.44 m/min	594.73 rev/min
20,800	2.5 m/min	609.38 rev/min
26,000	3.12 m/min	761.72 rev/min
40,600	4.87 m/min	1189.45 rev/min
81,300	9.76 m/min	2381.84 rev/min
162,500	19.5 m/min	4760.74 rev/min

1.7.6 Error logging

When the Sin/Cos encoder data is acquired, two different types of error can basically occur.

The frequency error indicates that during or, in Full Range Mode also before the last read access, the specified maximum input frequency has been exceeded. In Full Range Mode, this helps that the reference point is internally shifted so that all further measurements are incorrect, since they refer to this new point. If afterwards the maximum input frequency is complied with, no further errors will be indicated, although the measurement values are incorrect. For this reason, the return values should always be monitored and errors be dealt with accordingly.

NOTICE!
If an error has occurred in Full Range Mode, the reference point is permanently shifted which results in errors during the following measurement process.

Another type of error is the amplitude error. Both in Full Range Mode and in Fast Mode, it produces measurement values that are permanently incorrect in relation to the originally defined reference point. An amplitude error can occur if, for instance, an encoder is not or incorrectly connected or if it has a mechanical error.

1.8 Compare logic

Using the compare logic, a trigger can be released to latch the counter value.
There are two compare logic modes:

a) Simple mode

In Simple mode, a reference value can be indicated. As soon as the counter value corresponds to the reference value, a trigger is released.

b) Modulo mode

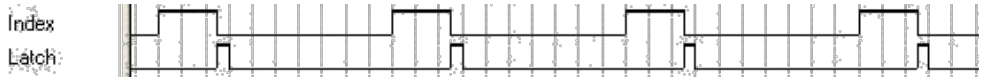
In Modulo mode, a reference value is indicated as well. When the counter value corresponds to the reference value or a multiple of it, a trigger is released.

1.9 Index logic

The index signal of a Sin/Cos encoder can be used either for latching or latching and deleting the counter value.
You can select if the rising edge, the falling edge or both edges of the index signal should count.
Depending on the mode, the counter value is latched only once or endlessly after each defined edge.

Example

Index logic with falling edge in continuous mode



1.10 Digital Trigger

The digital 24 V trigger input of the extension module EM0 or EM1 can be used to latch the Sin/Cos counter value.
You can select if the rising edge, the falling edge or both edges of the trigger signal generated externally should count. By means of the counter, you can define after which number of edges the Sin/Cos counter value is to be latched.

Examples:

- Selected edge: rising
  Counter value: 1
  The Sin/Cos counter value is latched after every rising edge of the trigger signal.
- Selected edge: rising
  Counter value: 3
  The Sin/Cos counter value is latched after every third rising edge of the trigger signal.
- Selected edge: rising and falling
  Counter value: 3
  The Sin/Cos counter value is latched after every third edge of the trigger signal.

2 Standard software

2.1 Access to the software functions

The API software functions supported by the board are listed in an HTML document. A description of how to access the respective file can be found in the document “Quick installation PC boards” (see PDF link), in the chapter “Standard software”.

2.2 Digital I/O

Software functions
i_PCIe1711_ReadInputsEFG (...)
i_PCIe1711_WriteOutputH (...)

In addition to the function-specific software functions, the EnDat 2.2 function module also supports the shared functions, i.e. function-independent software functions (“xPCIe-1711 Shared functions”). For more detailed information on this, please refer to the HTML document mentioned in Chapter 2.1.

3 Technical data and limit values

3.1 Sin/cos counter inputs

	EM-SINCOS-1VPP	**EM-SINCOS-11µAPP**
Number of inputs:	2 (with A, B and C signals each)	2 (with A, B and C signals each)
Input type:	Sin/Cos 1 V_{PP}	Sin/Cos 11 μA_{PP}
Input frequency:	250 kHz max. (may be lower depending on mode and resolution)	250 kHz max. (may be lower depending on mode and resolution)
Signal size:	0.6–1.2 V_{PP} (1 V_{PP} typ.)	7–16 μA_{PP} (11 μA_{PP} typ.)
ESD:	2 kV	2 kV

3.2 Digital inputs

Number of inputs:	4 (common GND according to DIN EN IEC 61131-2)
Nominal voltage:	24 VDC
Optical isolation:	1000 V (via opto-couplers)
Input voltage:	0-30 V
Max. input frequency:	1 MHz (at nominal voltage)
Input impedance:	> 1 MΩ
Overvoltage protection:	30 V
Logic input levels:	UH_{max}: 30 V UH_{min}: 19 V UL_{max}: 14 V UL_{min}: 0 V

3.3 Digital output

Number of outputs:	1
Output type:	High-Side (load to GND according to DIN EN IEC 61131-2)
Nominal voltage:	24 VDC
Optical isolation:	1000 V (via opto-couplers)
Max. output saturation voltage:	2 V
Supply voltage:	5-30 V
Max. current per output:	90 mA
Total current limit:	270 mA (via PTC)
Max. output frequency:	100 kHz (load-dependent)
Protection against overtemperature:	165°C
Saturation voltage:	1.8 V typ. (at 24 V, 90 mA)

4 Appendix

4.1 Index

5 Contact and support

Do you have any questions? Write or call us:

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Phone: +49 7229 1847-0
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