X20AI1744-10

Data sheet
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Translation of the original documentation

Publishing information

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1 General information

1.1 Other applicable documents

For additional and supplementary information, see the following documents.

Other applicable documents

Document name	Title
MAX20	X20 System user's manual

1.2 Order data

Order number	Short description	Figure
	Analog input modules	
X20AI1744-10	X20 analog input module, 1 full-bridge strain input 10 V, 24-bit converter resolution, 5 kHz input filter	
	Required accessories	
	Bus modules	
X20BM11	X20 bus module, 24 VDC keyed, internal I/O power supply connected through	
X20BM15	X20 bus module, with node number switch, 24 VDC keyed, internal I/O power supply connected through	
	Terminal blocks	
X20TB12	X20 terminal block, 12-pin, 24 VDC keyed	

Table 1: X20AI1744-10 - Order data

1.3 Module description

This module works with both 4-wire and 6-wire strain gauge load cells. The concept applied by the module requires compensation in the measurement system. This compensation eliminates the absolute uncertainty in the measurement circuit, such as component tolerances, effective bridge voltage or zero point offset. The measurement precision refers to the absolute (compensated) value, which will only change as a result of changes in the operating temperature.

Functions:

- Software filters

Software filters

The module is equipped with 2 switchable and configurable software filters:

- The IIR low-pass filter is used to generally smooth and increase the resolution of the analog value.
- The FIR filter can also selectively filter out individual interference frequencies.

2 Technical description

2.1 Technical data

Order number	X20AI1744-10
Short description	
I/O module	1 full-bridge strain gauge input
General information	
B&R ID code	0xF1A7
Status indicators	Channel status, operating state, module status
Diagnostics	
Module run/error	Yes, using LED status indicator and software
Open circuit	Yes, using LED status indicator and software
Input	Yes, using LED status indicator and software
Power consumption	
Bus	0.01 W
Internal I/O	0.65 W
Additional power dissipation caused by actuators (resistive) [W]	Max. +0.68 [1)]
Certifications	
CE	Yes
UKCA	Yes
ATEX	Zone 2, II 3G Ex nA nC IIA T5 Gc IP20, Ta (see X20 user's manual) FTZÚ 09 ATEX 0083X
UL	cULus E115267 Industrial control equipment
EAC	Yes
Full-bridge strain gauge	
Strain gauge factor	2 to 256 mV/V, configurable using software
Connection	4- or 6-wire connections [2)]
Input type	Differential, used to evaluate a full-bridge strain gauge
Digital converter resolution	24-bit
Conversion time	Depends on the configured data output rate
Data output rate	0.1 - 7500 samples per second, configurable using software (f_{DATA})
Input filter	
Cutoff frequency	5 kHz
Order	3
Slope	60 dB
ADC filter characteristics	Sigma-delta, see section "Filter characteristics of the sigma-delta A/D converter"
Operating range / Measurement sensor	162 to 5000 Ω
Influence of cable length [3)]	See section "Calculation example".
Input protection	RC protection
Common-mode range	0 to 3 VDC Permissible input voltage range (with regard to the electric potential strain gauge GND) on inputs "Input +" and "Input -"
Insulation voltage between input and bus	500 V_{eff}
Conversion procedure	Sigma-delta
Output of digital value	
Broken bridge supply line	Value approaching 0
Broken sensor line	Value approaching ±end value (status bit "Line monitoring" is set in register "Module status")
Valid range of values	0xFF800001 to 0x007FFFFF (-8,388,607 to 8,388,607)
Strain gauge supply	
Voltage	10.5 VDC / Max. 65 mA [4)]
Short-circuit and overload-proof	Yes
Voltage drop for short-circuit protection	Max. 0.2 VDC at 65 mA and 25°C

Table 2: X20AI1744-10 - Technical data

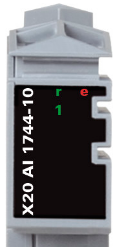
Order number	X20AI1744-10
Quantization [5]	
LSB value (16-bit)	
2 mV/V	641 nV
4 mV/V	1.28 µV
8 mV/V	2.56 µV
16 mV/V	5.13 µV
32 mV/V	10.25 µV
64 mV/V	20.51 µV
128 mV/V	41.02 µV
256 mV/V	82.03 µV
LSB value (24-bit)	
2 mV/V	2.50 nV
4 mV/V	5.01 nV
8 mV/V	10.01 nV
16 mV/V	20.03 nV
32 mV/V	40.05 nV
64 mV/V	80.11 nV
128 mV/V	160.22 nV
256 mV/V	320.43 nV
Temperature coefficient	
Rev. ≥E0	10 ppm/°C
Rev. <E0	30 ppm/°C
Electrical properties	
Electrical isolation	Bus isolated from analog input and strain gauge supply voltage Channel not isolated from I/O power supply
Operating conditions	
Mounting orientation	
Horizontal	Yes
Vertical	Yes
Installation elevation above sea level	
0 to 2000 m	No limitation
>2000 m	Reduction of ambient temperature by 0.5°C per 100 m
Degree of protection per EN 60529	IP20
Ambient conditions	
Temperature	
Operation	
Horizontal mounting orientation	-25 to 60°C
Vertical mounting orientation	-25 to 50°C
Derating	See section "Hardware configuration"
Storage	-40 to 85°C
Transport	-40 to 85°C
Relative humidity	
Operation	5 to 95%, non-condensing
Storage	5 to 95%, non-condensing
Transport	5 to 95%, non-condensing
Mechanical properties	
Note	Order 1x terminal block X20TB12 separately. Order 1x bus module X20BM11 separately.
Pitch	$12.5^{+0.2}$ mm

Table 2: X20AI1744-10 - Technical data

1) Depends on the full-bridge strain gauge being used.
2) With 6-wire connections, line compensation does not function (see section "Connection examples").
3) Sensor cable with twisted and shielded conductors, cable length as short as possible, cable routing separate from load circuits, without intermediate terminal to the sensor.
4) The maximum current of 90 mA is permitted up to an operating temperature of 45°C.
5) Quantization depends on the strain gauge factor.

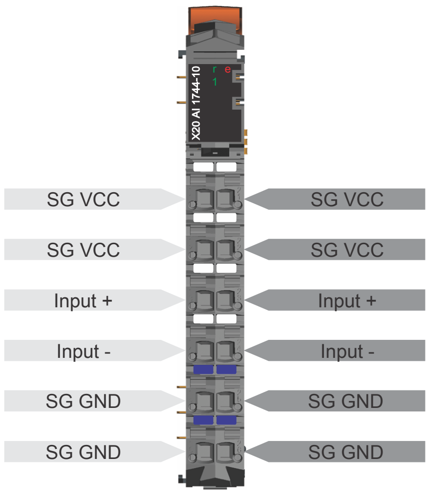
2.2 LED status indicators

For a description of the various operating modes, see section "Additional information - Diagnostic LEDs" in the X20 system user's manual.

Figure	LED	Color	Status	Description
	r	Green	Off	No power to module
			Single flash	Mode RESET
			Double flash	Mode BOOT (during firmware update)[1]
			Blinking	Mode PREOPERATIONAL
			On	Mode RUN
	e	Red	Off	No power to module or everything OK
			On	Error or reset state
	1	Green	Off	Possible causes: • Open circuit • Sensor is disconnected • Converter is busy
			On	Analog/digital converter running, value OK

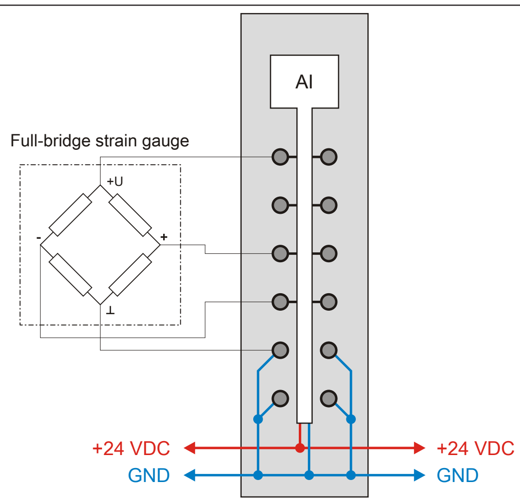
1) Depending on the configuration, a firmware update can take up to several minutes.

2.3 Pinout



2.4 Connection examples

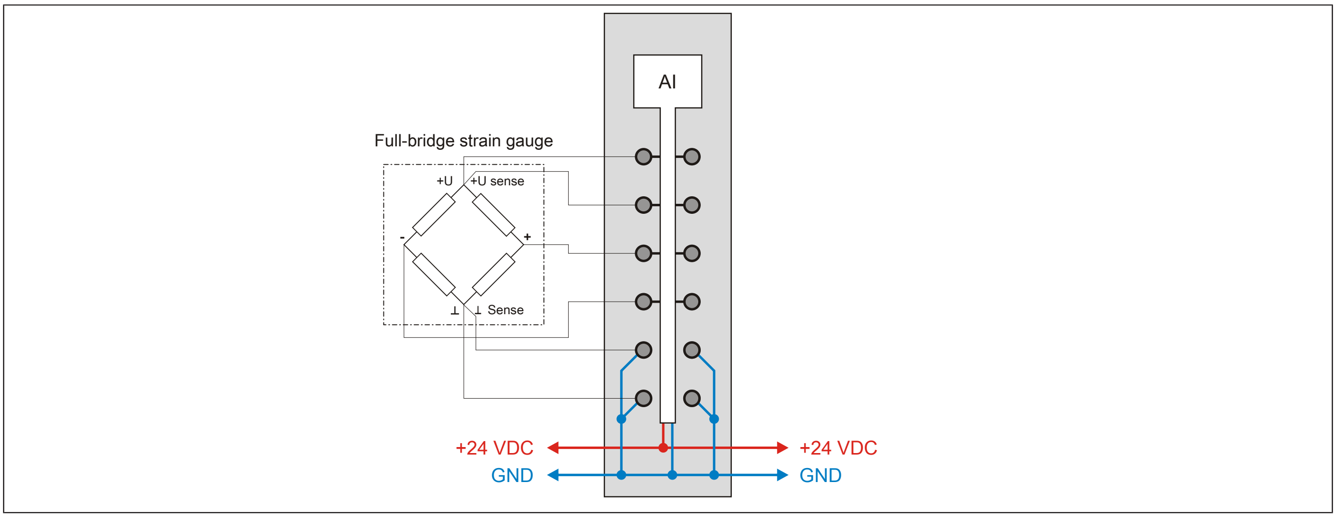
Full-bridge strain gauge with 4-wire connections



Full-bridge strain gauge with 6-wire connections

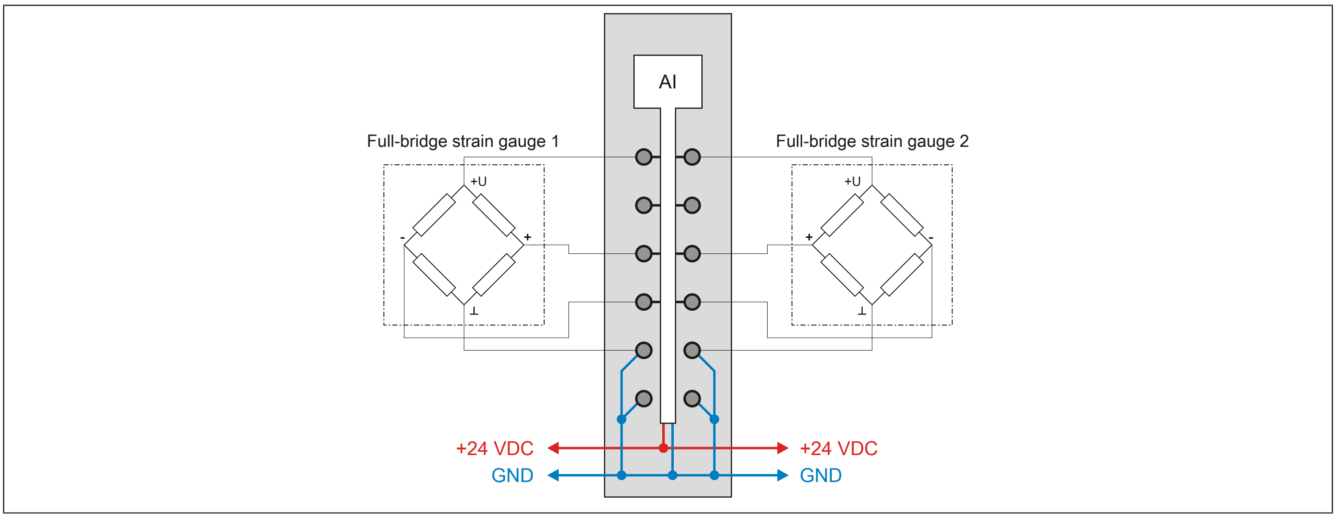
Full-bridge strain gauges can be connected to this module with 6-wire connections. Line compensation is not supported by the module, however. The sense lines are short circuited by the internally connected strain gauge VCC and GND connections (see "Input circuit diagram" on page 8). The measurement precision is therefore affected by changes in operating temperature. Longer cable lengths and smaller cable cross sections also increase the potential for errors in the measurement system.

In order to reduce cable resistance, the sense lines should be connected in parallel with the strain gauge supply lines. Optimal signal quality can be obtained by using a shielded twisted pair cable. The connections for the strain gauge supply lines, the sensor lines and the bridge differential voltage lines should each use one twisted pair cable.



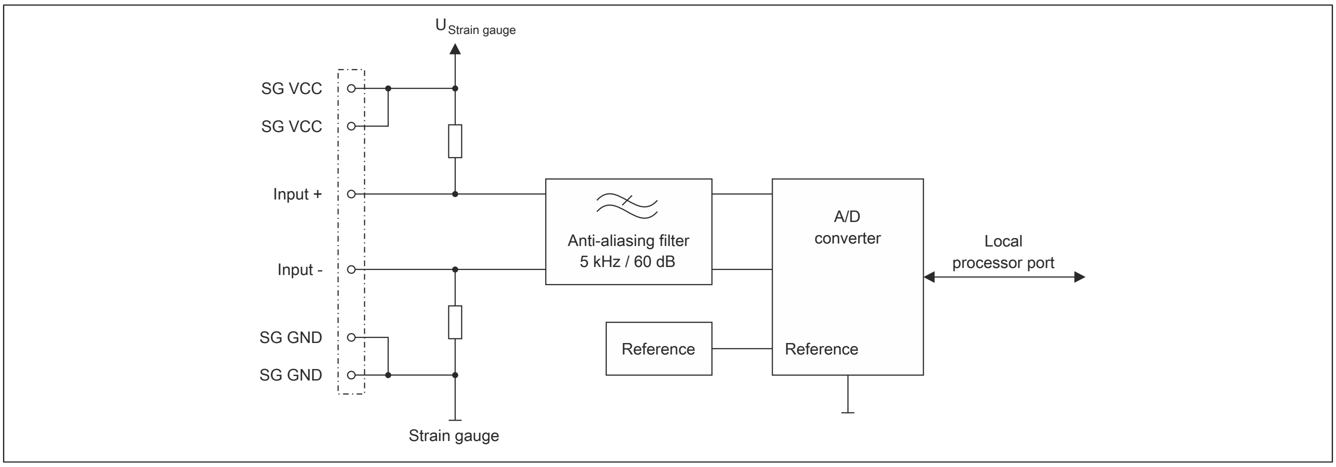
Parallel connection of 2 full-bridge strain gauges (4-wire connections)

If connecting the full-bridge strain gauges in parallel, the manufacturer's guidelines must be observed.



When connecting 3 or more full-bridge strain gauges in parallel, 2 lines must be connected together in an X20 terminal block.

2.5 Input circuit diagram

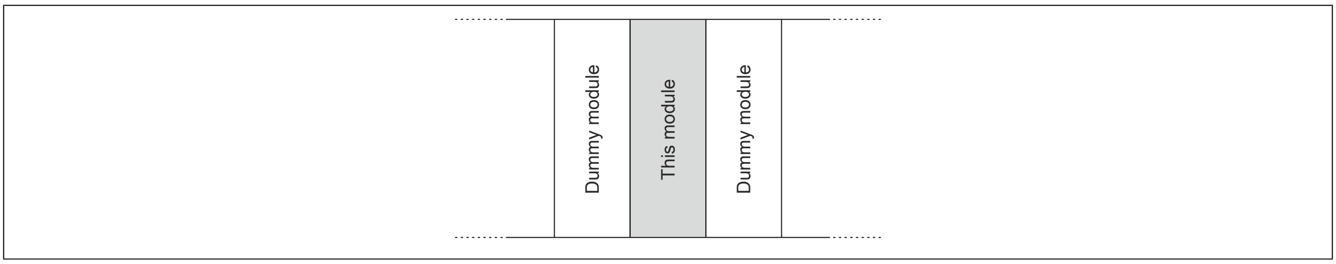


2.6 Hardware configuration

2.6.1 Hardware configuration for horizontal installation starting at 55°C ambient temperature

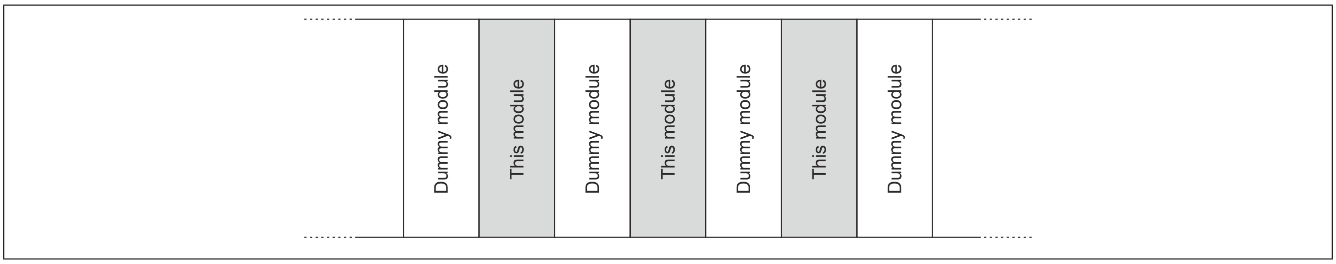
Operating a strain gauge module

Starting at an ambient temperature of 55°C, a dummy module must be connected to the left and right of the strain gauge module in a horizontal mounting orientation.



Operating multiple strain gauge modules side by side

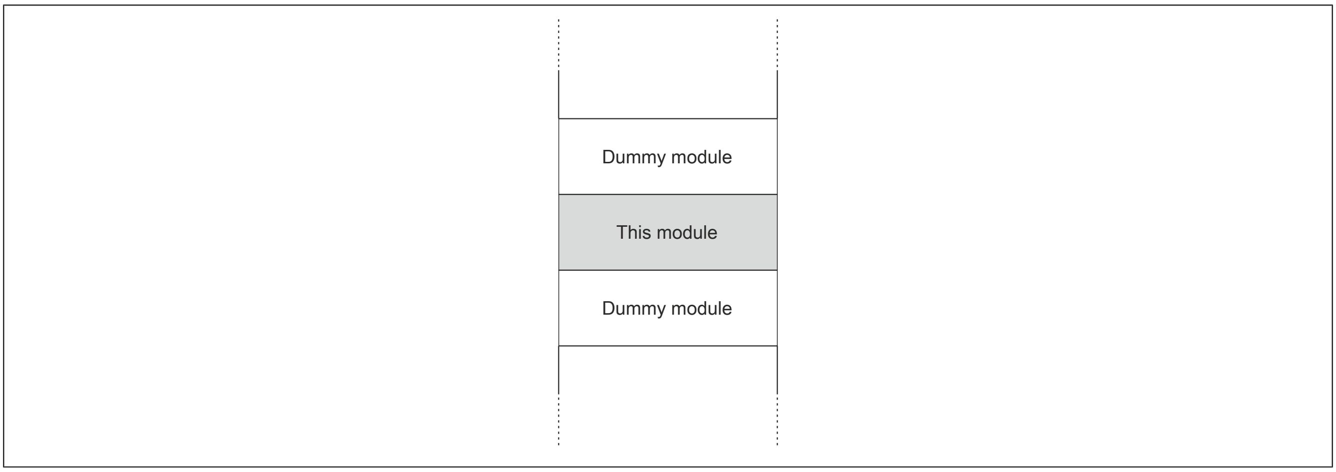
If 2 or more horizontal strain gauge modules are being operated in a cluster, the following arrangement of modules must be observed.



2.6.2 Hardware configuration for vertical installation starting at 45°C ambient temperature

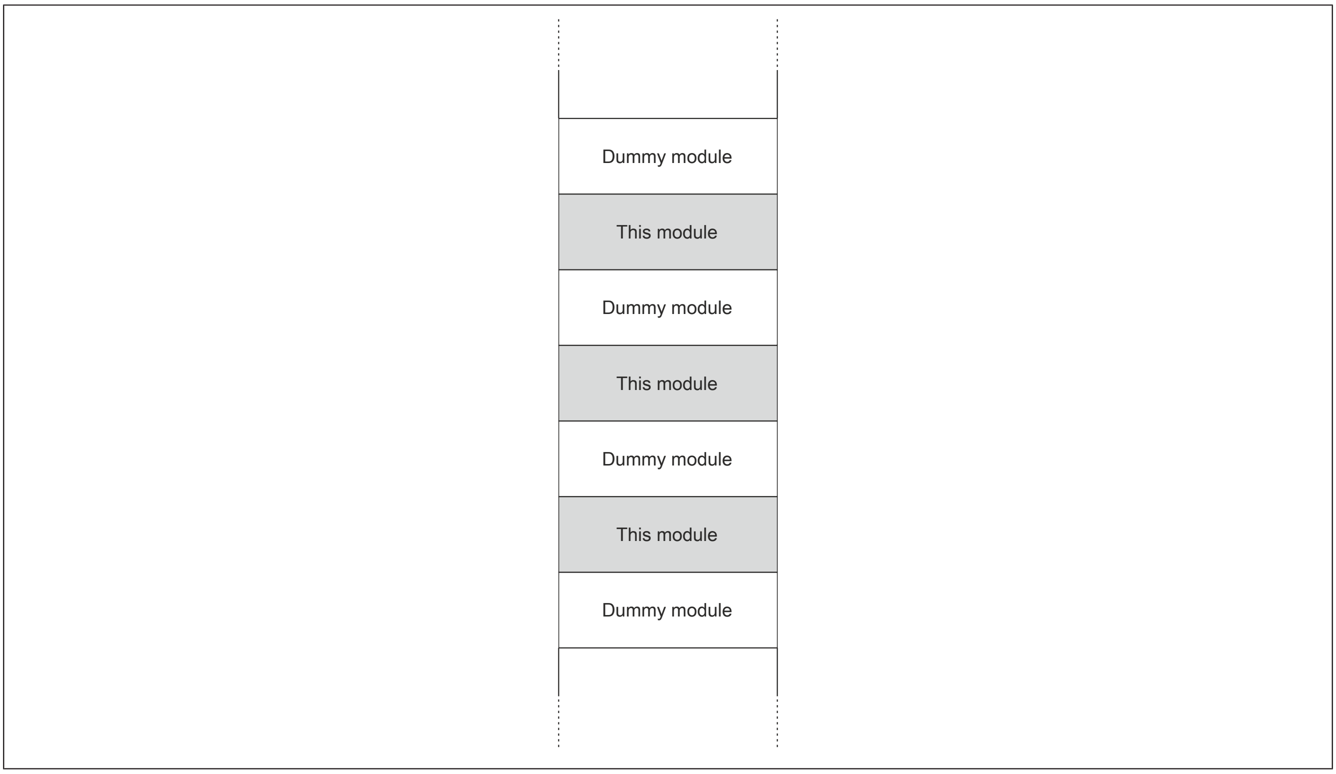
Operating a strain gauge module

Starting at an ambient temperature of 45°C, a dummy module must be connected to the left and right of the strain gauge module in a vertical mounting orientation.



Operating multiple strain gauge modules side by side

If 2 or more vertical strain gauge modules are being operated in a cluster, the following arrangement of modules must be observed.



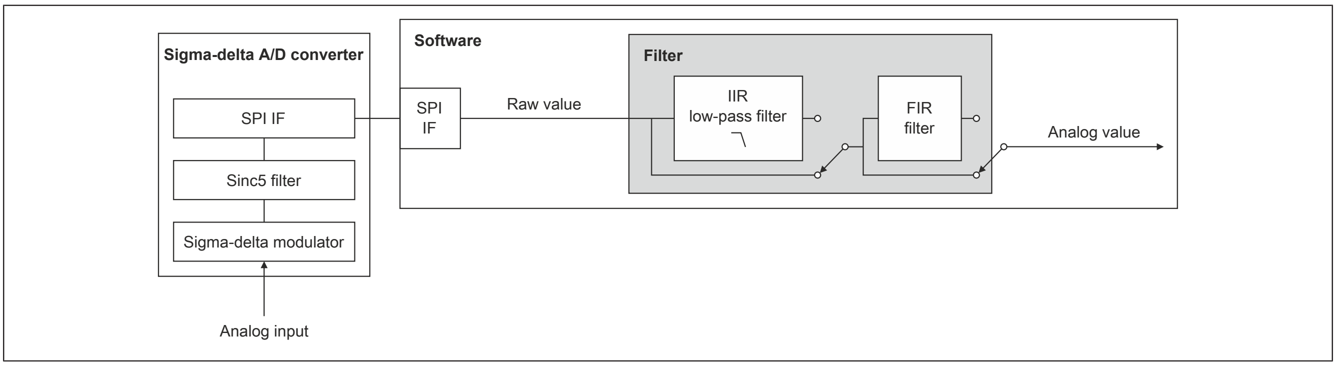
3 Function description

3.1 Software filters

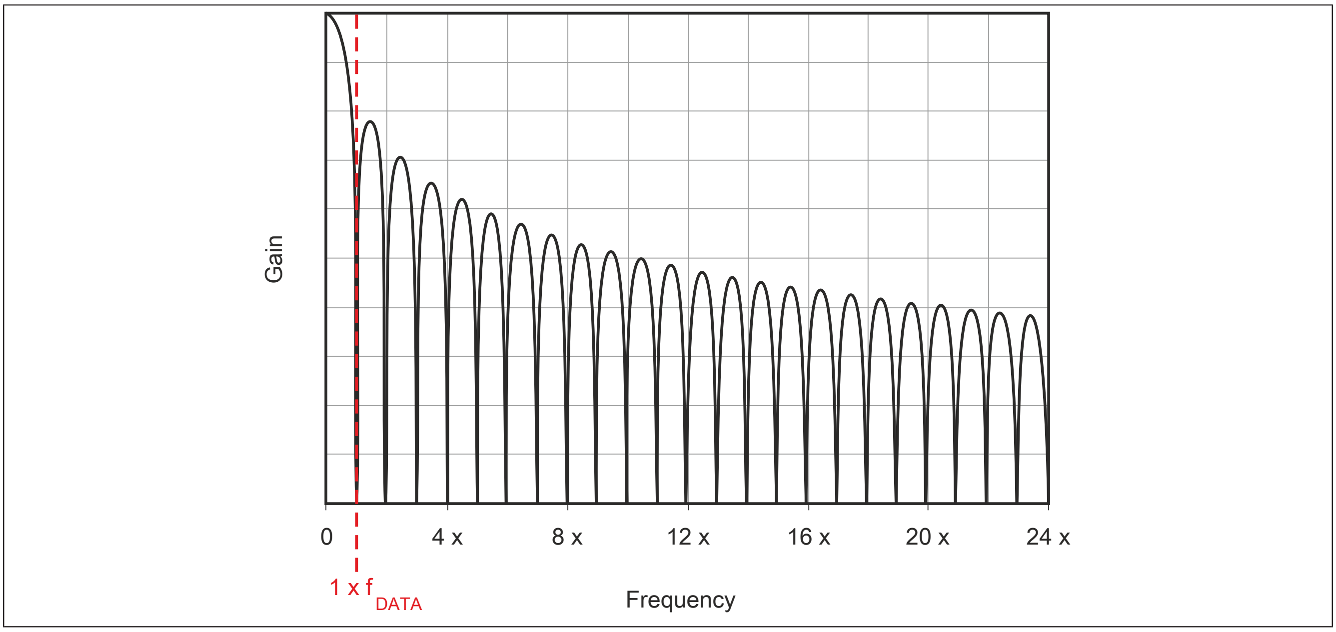
2 filters are available for the analog input. They can be individually enabled and configured at runtime. By default, both filters are disabled when the device is switched on. The filters are controlled and configured using "Function model 2 - Extended filter".

In order to allow the filter behavior to be adapted to the measuring situation or machine cycle (high dynamics and low precision or low dynamics and high precision), the filter characteristics of both the IIR low-pass filter as well as the FIR filter can be changed synchronously at any time.

Filter diagram



3.1.1 Filter characteristics of the sigma-delta A/D converter



3.1.2 IIR low-pass filter

The IIR low-pass filter is used to generally smooth and increase the resolution of the analog value. The filter works according to the following formula:

$$y = y_{Old} + \frac{x - y_{Old}}{2^{Filter\ level}}$$

- x ... Current filter input value
- y_{Old} ... Old filter output value
- y ... New filter output value

Parameter "Filter level" in the formula above is configured using register ConfigCommonOutput. "Filter level" = 0 if the IIR low-pass filter is disabled.

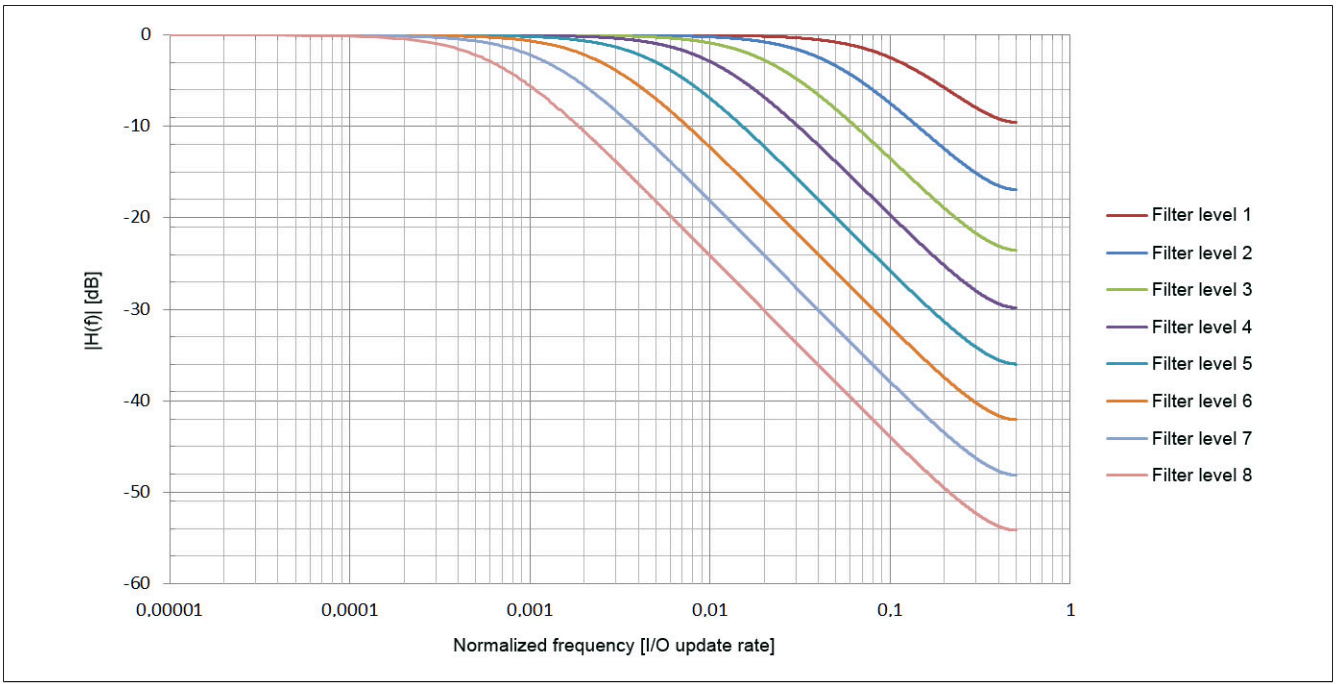
3.1.2.1 Filter characteristics of the first-order IIR low-pass filter

Limit frequency f_c

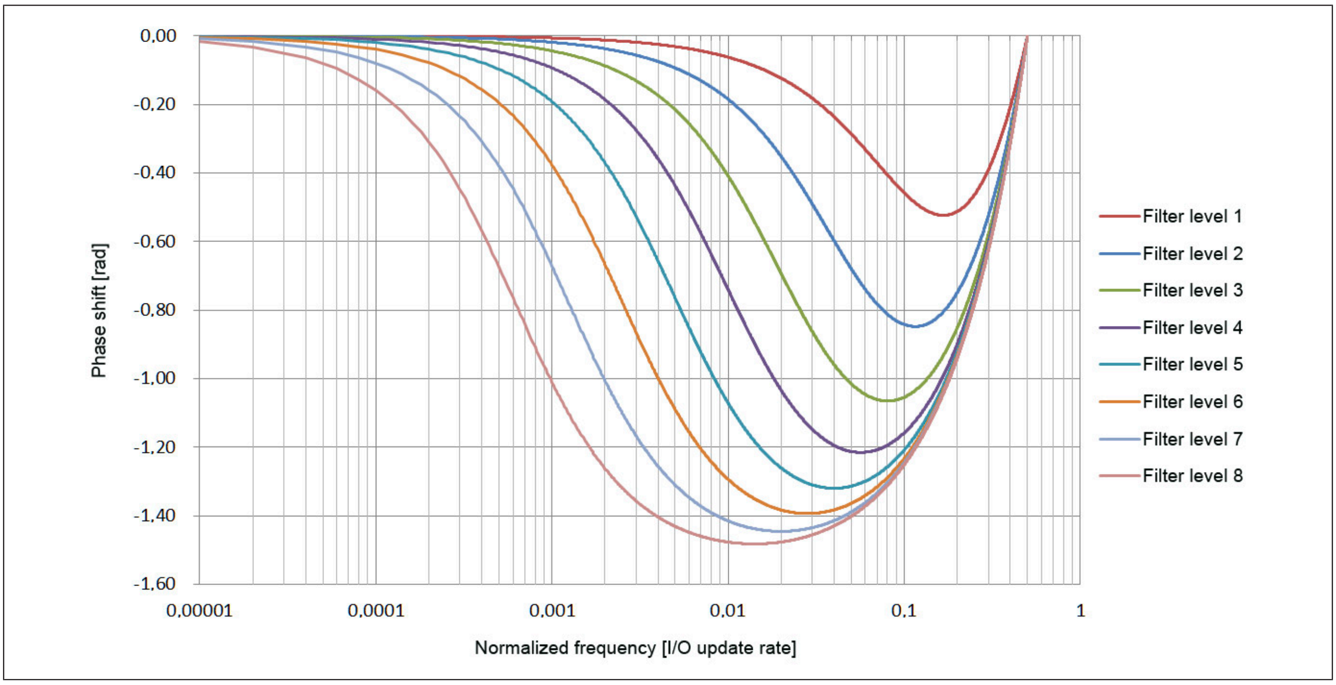
The following table provides an overview of the -3 dB limit frequency f_c depending on the configured filter level.

Filter level	Normalized f_c [I/O update rate]	f_c [Hz] I/O update rate = 15000/s	f_c [Hz] I/O update rate = 20000/s
1	0.11476	1721.4	2295.2
2	0.046	690	920
3	0.02124	318.6	424.8
4	0.01026	153.9	205.2
5	0.00504	75.6	100.8
6	0.0025	37.5	50
7	0.00124	18.6	24.8
8	0.00062	9.3	12.4

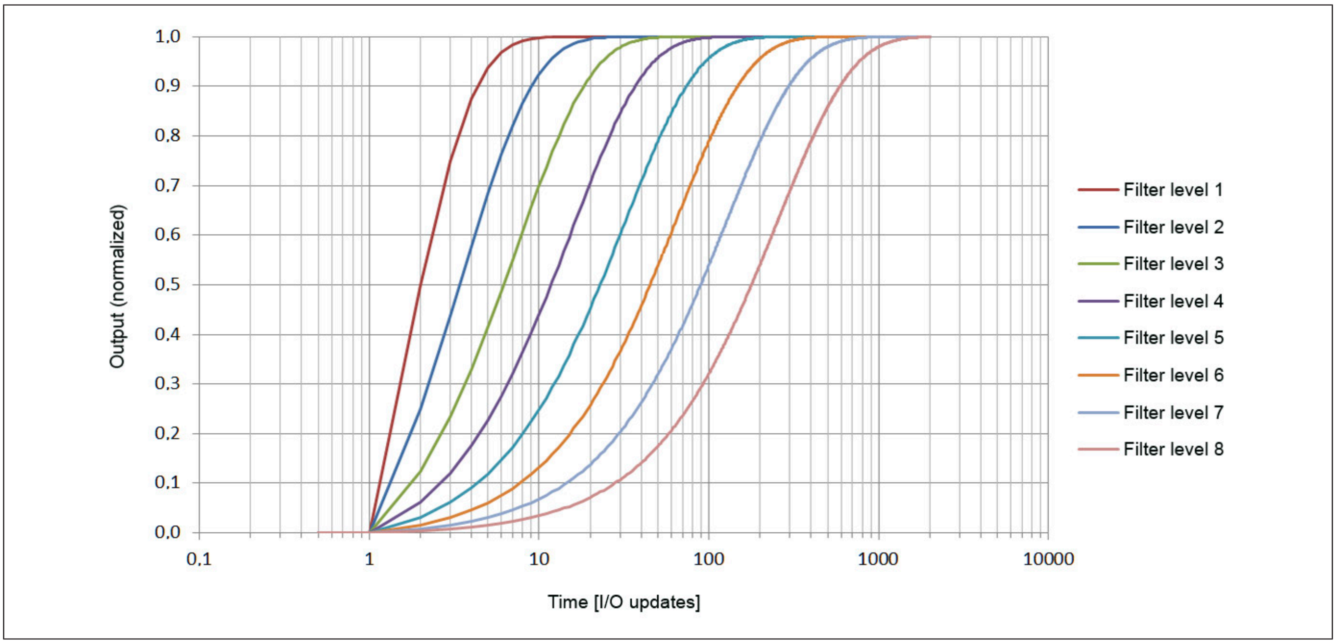
Gain of the IIR low-pass filter



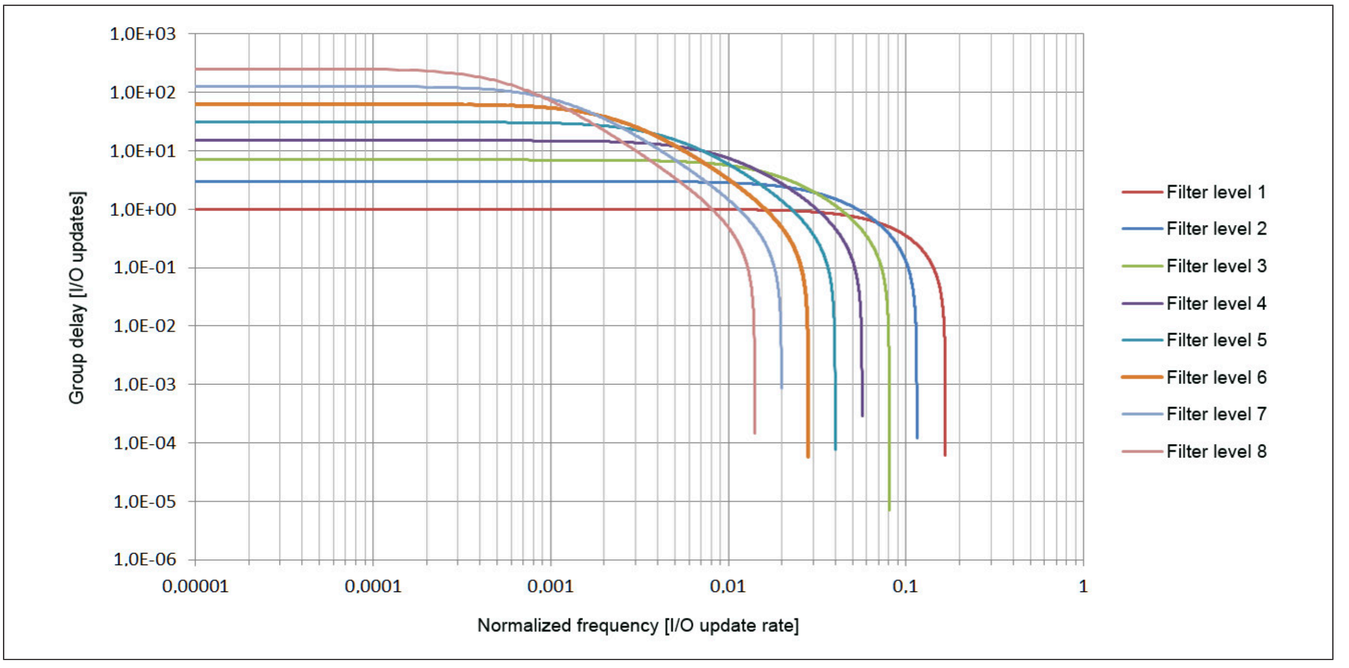
Phase shift of the IIR low-pass filter



Step response of the IIR low-pass filter



Group delay of the IIR low-pass filter



3.1.3 FIR filter

Like the IIR low-pass filter, the FIR filter can also be used to smooth out the signal and increase its resolution. In addition, configuring the filter length accordingly makes it possible to target and efficiently filter out individual interference frequencies. The source of these interference frequencies may be mechanical or electromagnetic. Multiples of these are also filtered out (as long as they are a whole-number factor of the data output rate).

Example:
Data output rate = 15000 samples/s, averaging over 15 values → "Notch" at 1 kHz (2 kHz, etc.)

When reconfiguring the filter, it takes 1/data rate (FIR filter in mode "Selectable data rate") or 1/filter frequency (FIR filter in mode "High-resolution data rate") until the filter is tuned. During tuning, bit 5 is set in register "StatusInput01" on page 32.

3.1.3.1 Characteristics of the FIR filter in mode "Selectable data rate"

The following table applies to "Function model 0 - Standard" and "Function model 254 - Bus controller" as well as for "Function model 2 - Extended filter" in mode "Selectable data rate".

			I/O update rate [Hz]		I/O update time [ms]	
Setpoint 1) 2)	Data rate (f_{Data}) [Hz] 3) 4)	f_{Notch} [Hz]	Function model 0 and 254	Function model 2 ("Selectable data rate" mode)	Function model 0 and 254	Function model 2 ("Selectable data rate" mode)
0000	2.5	2.5	2.5	15000	400	0.0667
0001	5	5	5	15000	200	0.0667
0010	10	10	10	15000	100	0.0667
0011	15	15	15	15000	66.6667	0.0667
0100	25	25	25	15000	40	0.0667
0101	30	30	30	15000	33.3333	0.0667
0110	50	50	50	15000	20	0.0667
0111	60	60	60	15000	16.6667	0.0667
1000	100	100	100	15000	10	0.0667
1001	500	500	500	15000	2	0.0667
1010	1000	1000	1000	15000	1	0.0667
1011	2000	2000	2000	20000	0.5	0.05
1100	3750	3750	3750	15000	0.2667	0.0667
1101	7500	7500	7500	15000	0.1333	0.0667
1110	Reserved					
1111	Reserved					

1) Function model 0 and 254: Bits 0 to 3 of register "ConfigOutput01" on page 27
2) Function model 2: Bits 0 to 3 of register "ConfigDatarateOutput01" on page 32
3) Function models 0 and 254: Data rate = 1/Filter length [s] (f_{Notch}) = I/O update rate
4) Function model 2: Data rate = 1/Filter length [s] (f_{Notch})

3.1.3.2 Characteristics of the FIR filter in mode "High-resolution data rate"

The following table applies to "Function model 2 - Extended filter".

Setpoint [0.1 Hz] [1]	Data rate (f_{Data}) [Hz]	f_{Notch} [Hz]	I/O update time [µs]
1 to 65535	Setpoint / 10	= Data rate	≈50 µs [2]

1) Setpoint from register "ConfigHighResolutionOutput01" on page 32
2) The value varies between 42 and 56 µs (see also the next section "I/O update time")

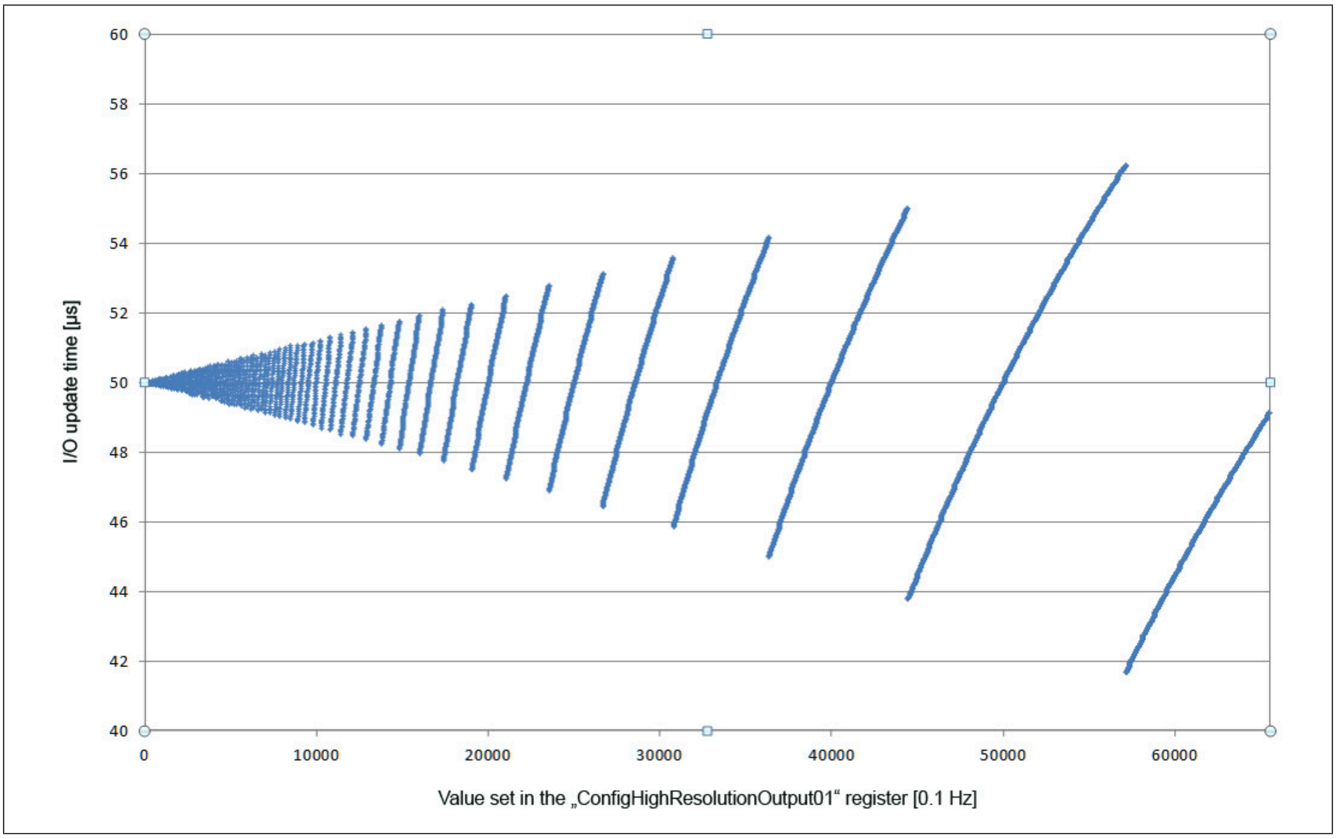
I/O update time

The value of the I/O update time depends on the setpoint and varies between 42 and 56 µs. The following formula can be used to precisely calculate the I/O update time:

I/O update time = 1e6 · (1e-4 - 10 / (Setpoint · [10 / (5e-5 · Setpoint)]))

Legend: The square brackets in the formula above mean that the calculated value must be rounded to a whole number.

The following image shows the I/O update time depending on the setpoint:

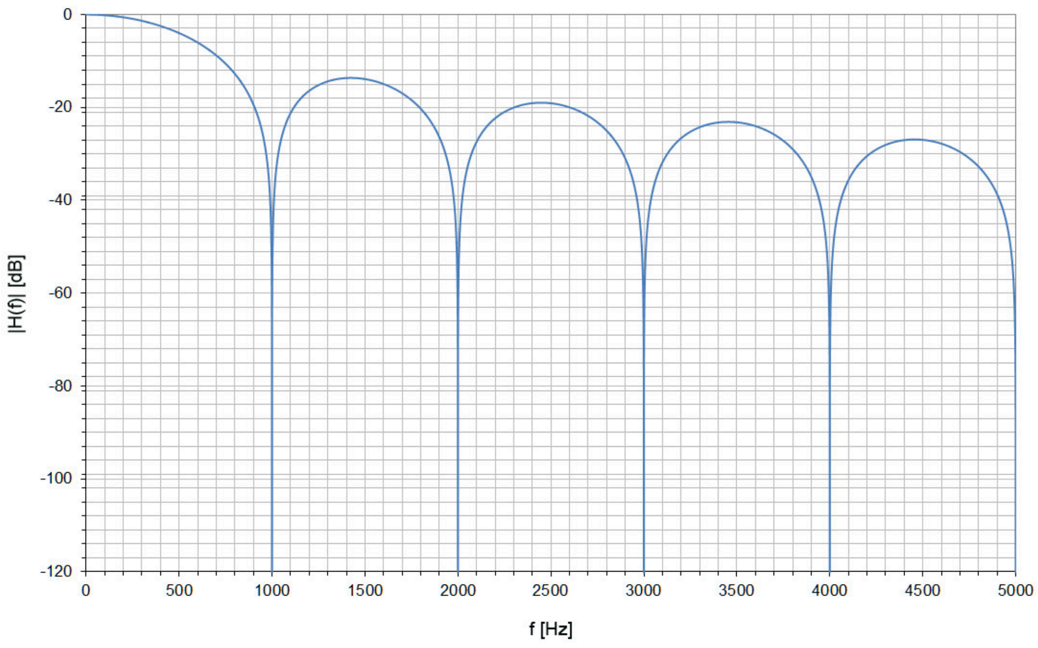


3.1.3.3 Examples for the gain of the FIR filter

Example 1

Filter setting = 10:

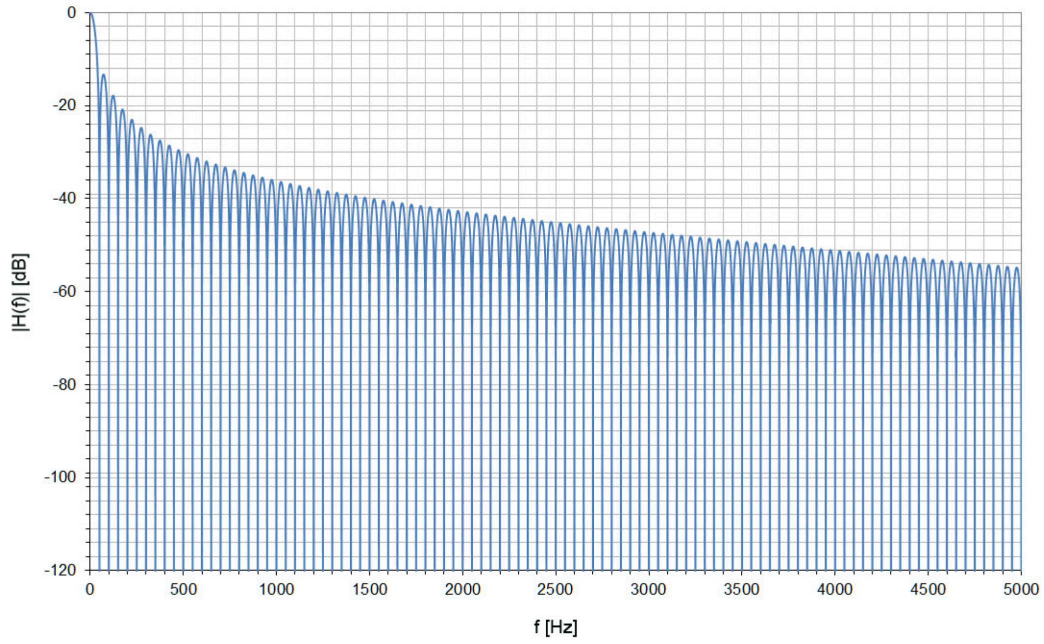
- f_{Notch} = 1000 Hz
- f_c = 439.3 Hz



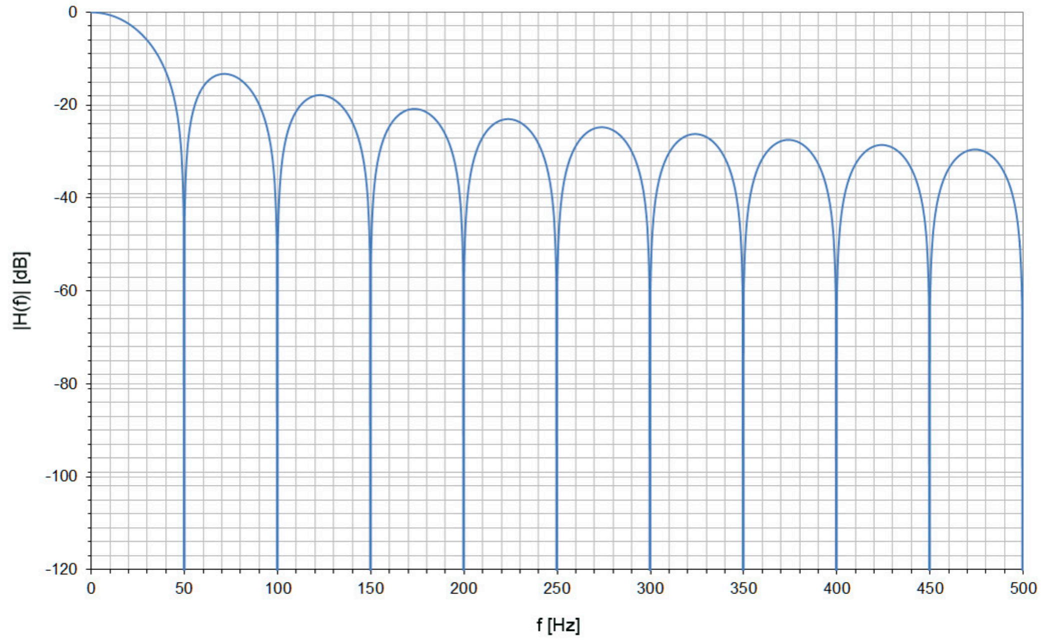
Example 2

Filter setting = 6:

- f_{Notch} = 50 Hz
- f_c = 21.8 Hz



Detailed excerpt from the filter curve shown above:



4 Commissioning

4.1 Using the module on the bus controller

Function model 254 "Bus controller" is used by default only by non-configurable bus controllers. All other bus controllers can use other registers and functions depending on the fieldbus used.

For detailed information, see section "Additional information - Using I/O modules on the bus controller" in the X20 user's manual (version 3.50 or later).

4.1.1 CAN I/O bus controller

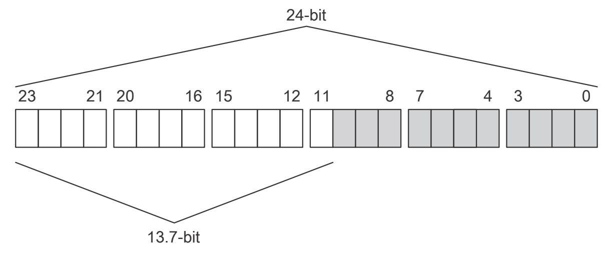
The module occupies 1 analog logical slot on CAN I/O.

4.2 Effective resolution of the A/D converter

The A/D converter for the module provides a 24-bit measured value. The actual attainable noise-free resolution is always less than 24-bit, however. This "effective resolution" depends on the data rate and measurement range.

Example:

Because of the conversion method, a data rate of 2.5 Hz and a specified measurement range of 2 mV/V result in an effective resolution of 13.7 bits:



The low-order bits (shown in gray) contain only noise instead of valid values and are therefore not permitted to be evaluated.

With "Function model 1 - Multisampling", only the highest 16 bits are made available.

Effective resolution

In principle, the effective resolution of the A/D converter is dependent on the data rate and measurement range.

Configurable data rates

Value	Data rate in Hz
0	2.5
1	5
2	10
3	15
4	25
5	30
6	50
7	60
8	100
9	500
10	1000
11	2000
12	3750
13	7500

Measurement range

The following table shows how the effective resolution (in bits) or effective range of values of the strain gauge value depend on the module configuration (data rate, measurement range):

	Measurement range							
	±16 mV/V		±8 mV/V		±4 mV/V		±2 mV/V	
Data rate f_{DATA} [Hz]	Bits	Range of values	Bits	Range of values	Bits	Range of values	Bits	Range of values
2.5	16.9	±61,100	15.4	±21,600	14.5	±11,600	13.7	±6,650
5	16.6	±49,700	15.2	±18,800	14.2	±9,410	13.6	±6,210
10	16.0	±32,800	15.2	±18,800	14.2	±9,410	13.1	±4,390
15	16.0	±32,800	15.2	±18,800	14.1	±8,780	13.1	±4,390
25	15.9	±30,600	14.7	±13,300	13.9	±7,640	12.7	±3,330
30	15.7	±26,600	14.6	±12,400	13.6	±6,210	12.7	±3,330
50	15.4	±21,600	14.5	±11,600	13.3	±5,040	12.2	±2,350
60	15.2	±18,800	14.3	±10,100	13.1	±4,390	12.2	±2,350
100	14.9	±15,300	13.8	±7,130	13.0	±4,100	12.0	±2,050
500	13.8	±7,130	12.8	±3,570	11.7	±1,660	10.7	±832
1000	13.3	±5,040	12.3	±2,520	11.3	±1,260	10.3	±630
2000	12.7	±3,330	11.9	±1,910	10.8	±891	9.7	±416
3750	12.4	±2,700	11.4	±1,350	10.4	±676	9.2	±294
7500	12.0	±2,050	11.0	±1,020	10.1	±549	8.9	±239

Table 3: Effective resolution of the strain gauge value in bits for the measurement range 2 to 16 mV/V

	Measurement range							
	±256 mV/V		±128 mV/V		±64 mV/V		±32 mV/V	
Data rate f_{DATA} [Hz]	Bits	Range of values	Bits	Range of values	Bits	Range of values	Bits	Range of values
2.5	20.8	±913,000	20.0	±524,000	18.8	±228,000	17.6	±99,300
5	20.2	±602,000	19.5	±371,000	18.3	±161,000	17.4	±86,500
10	20.1	±562,000	19.4	±346,000	18.3	±161,000	17.0	±65,500
15	19.8	±456,000	19.0	±262,000	17.9	±122,000	17.0	±65,500
25	19.7	±426,000	18.8	±228,000	17.9	±122,000	16.7	±53,200
30	19.7	±426,000	18.5	±185,000	17.5	±92,700	16.7	±53,200
50	19.2	±301,000	18.3	±161,000	17.5	±92,700	16.3	±40,300
60	19.2	±301,000	18.2	±151,000	17.2	±75,300	16.2	±37,600
100	18.9	±245,000	17.9	±122,000	16.8	±57,100	15.9	±30,600
500	17.6	±99,300	16.8	±57,100	15.8	±28,500	14.8	±14,300
1000	17.2	±75,300	16.2	±37,600	15.2	±18,800	14.3	±10,100
2000	16.5	±46,300	15.8	±28,500	14.7	±13,300	13.8	±7,130
3750	16.1	±35,100	15.4	±21,600	14.3	±10,100	13.3	±5,040
7500	15.9	±30,600	15.0	±16,400	14.0	±8,190	13.0	±4,100

Table 4: Effective resolution of the strain gauge value in bits for the measurement range 32 to 256 mV/V

4.3 Clock frequency offset

In rare cases, strain gauge modules in directly adjacent slots may have an influence on each other. This influence manifests itself in temporary, minor measured value deviations. This can only occur if the sigma-delta A/D converters of the adjacent strain gauge modules are operated at exactly the same clock frequency.

In most cases, these clock frequencies already differ sufficiently due to component scattering. Where this is not the case, the strain gauge module provides a safe method for how an application can exclude the mutual influence of measured values.

The clock frequency can be varied in steps of 200 ppm in register "AdcClkFreqShift" on page 31. Setpoints from -50 to 50 cover a range from -10000 ppm to 10000 ppm. This corresponds to -1% to 1%.

Values outside this range result in a default mode being enabled. The frequency offset is derived by the module's firmware from the last 2 digits of the serial number. This mode reduces the programming effort but requires that the serial numbers of adjacent modules differ in the last two digits.

Setpoint	Frequency offset in ppm	Sampling rate example[1]
127	((Serial no. modulo 100) - 50) * (-200) ppm	Depends on serial number
...	...	...
51	((Serial no. modulo 100) - 50) * (-200) ppm	Depends on serial number
50	10000	505
49	9800	504.9
...	...	...
2	400	500.2
1	200	500.1
0	0	500
-1	-200	499.9
-2	-400	499.8
...	...	...
-50	-10000	495
-51	((Serial no. modulo 100) - 50) * (-200) ppm	Depends on serial number
...	...	...
-128	((Serial no. modulo 100) - 50) * (-200) ppm	Depends on serial number

1) Nominal sampling rate of 500 samples per second

IMPORTANT:

As can be seen from the table above, offsetting the A/D converter clock frequency also offsets the A/D converter sampling rate to the same extent. Particularly in applications where a very specific sampling rate has been selected to suppress existing interference (e.g. 50 Hz to suppress the 50 Hz mains hum), offsetting the A/D converter clock frequency too generously can impair disturbance suppression. See also "Filter characteristics of the sigma-delta A/D converter" on page 10.
In such cases, the option of frequency offsetting via the I/O configuration or library ASIOACC should be used and not the default frequency offset based on the serial number.

A frequency offset according to the following pattern is suitable for preventing mutual interference between modules while only imperceptibly influencing the filter characteristics.

Slot	1	2	3	4	5	6	...
A/D converter clock frequency offset	0	2	-1	1	-2	0	...

Information:

- **In synchronous mode, this register has no effect since the firmware regulates the A/D converter clock frequency so that the A/D converter cycle is synchronized with the X2X cycle.**
- **When writing to this register using library ASIOACC, only the least significant byte of the written value is applied by the firmware. For example, the value 256 (0x100) is identical to the value 0 (0x00).**

4.4 Bridge voltage and quantization

The following example shows the influence of the length of the measuring cable on the bridge voltage of the module and the quantization calculated with it.

4.4.1 Bridge voltage

Although the measuring bridge must be adjusted with the module, the line length has an influence on the accuracy of the measurement. The reason for this is the voltage drop on the power supply lines of the measuring bridge. As a result, the bridge supply voltage at the measuring bridge is no longer the full 10.5 V. The reduced bridge voltage also affects the quantization.

Example

Characteristics of the measuring device used:

- Full-bridge strain gauge with 4-wire connection
- Material-dependent conductivity of the line (copper: $12 \frac{m}{\Omega \cdot mm^2}$)
- Cross section of the line: 22 AWG = 0.34 mm^2
- Length of the line: 5 m
- Nominal current of the measuring bridge: 15 mA
- Bridge voltage of the module: 10.5 V

Actual bridge voltage taking the voltage drop on the measuring line into account:

$$10.5\ V - \frac{2 \cdot 5\ m}{12 \frac{m}{\Omega \cdot mm^2} \cdot 0.34\ mm^2} \cdot 0.015A = 10.463\ V$$

The quantization must be calculated using the actual calculated bridge voltage (see "Quantization" on page 22).

4.4.2 Quantization

In a weighing application, the corresponding weight located on the connected load cell should be determined from the value derived from the module.

Example

The characteristics of the strain gauge load cell are as follows:

- Rated load: 1000 kg
- Strain gauge factor: 4 mV/V
- Actual bridge voltage: 10.463 V

Maximum quantization:
Multiplying the bridge factor of the strain gauge load cell with the bridge supply voltage from the module results in the value for the positive full-scale deflection at a specified rated load of 1000 kg:

4 mV/V · 10.5 V = 42 mV

Actual quantization:
Taking the voltage drop on the measuring line into account, the actual bridge voltage is 10.463 V (for the calculation, see section "Bridge voltage" on page 21). If this voltage is multiplied by the strain gauge factor of 4 mV/V, the following actual quantization results:

4 mV/V · 10.463 V = 41.85 mV

These 41.85 mVcorrespond to 99.6% of the maximum possible measurement range.

Information:

If the quantization decreases, the maximum possible effective resolution also decreases (see "Effective resolution of the A/D converter" on page 18).

With a simple Rule of Three calculation, the corresponding value can be calculated (as seen in the table) from weight to the converter value and vice versa. This simplified theoretical approach is only valid for an ideal measurement system. Calibration of the entire measurement system is recommended because not only the module, but particularly the strain gauge bridges exhibit tolerances (offset, gain). When taring, the gradient offset is recalculated and the gain of the linear equation is determined when normalized. In addition to the calculation displayed in the table, these calculations must also be carried out in the application.

24-bit value of the module		Quantization	Corresponding weight
0x007F FFFF	8,388,607	41.85 mV	1000 kg
0x0000 0001	1	4.99 nV	0.119 g
0x0000 20C3	8387	41.84 µV	1 kg
0x0001 0000	65536	327.0 µV	7.81 kg

The values for 1 LSB are also included in the module's technical data under item "Quantization" (1 LSB each for 16 bits and 24 bits).

4.5 Recording multiple measured values per X2X cycle

In function model Function model 1 - Multisampling, the A/D converter is operated synchronously to X2X Link with a fixed specified A/D converter cycle time. The value is configurable as 50 or 100 µs.

Information:

"Function model 1 - Multisampling" can only be used on channel 1.

The module returns between 3 and 10 measured values per X2X cycle depending on the configuration. With an X2X cycle time of 400 µs and A/D converter cycle time of 50 µs, exactly 8 measurements are performed and the module can return 8 values (strain gauge value 01 to strain gauge value 08).

If a longer cycle time is used, the values returned correspond to the last measurements. If using an X2X cycle time that is not a whole number multiple of the A/D converter cycle time, then the conversion cannot be synchronized with X2X Link. In this case, the module outputs the invalid value 0x8000.

Example 1

If using an X2X cycle time of 800 µs, it is possible to perform 16 measurements per X2X cycle if the A/D converter cycle time equals 50 µs. The first 6 measured values are discarded; the last 10 measured values are provided by the module.

With a shorter X2X cycle time, the number of measured values should not exceed the number of measurements that can actually be made. All other measured values are invalid (0x8000). To minimize the load on the X2X Link network, it is possible in Automation Studio to hide the registers that are not required (AnalogInputXX) and thus disable the transfer.

Example 2

If using an X2X cycle time of 300 µs, it is possible to perform 6 measurements per X2X cycle if the A/D converter cycle time equals 50 µs. For this reason, only the first 6 registers are valid. The registers for the 7th to 10th measured value (AnalogInput07 to AnalogInput10) should be hidden (disabled) by configuring setting "Number of measured values" to "6 measured values" in the I/O configuration in Automation Studio.

Number of measured values

If the X2X cycle time is too short, then not all 10 measurements can be performed. To reduce the load on X2X Link, it makes sense to only transfer as many values as measurements that can be made. The maximum possible number of measured values to be transferred is determined by selecting the X2X cycle time and the A/D converter cycle time.

To minimize the load on the X2X Link network, it is possible in Automation Studio to hide the registers that are not required (AnalogInputXX) and thus disable the transfer.

Example: A/D converter cycle time = 50 µs

X2X cycle time	Number of measured values to be transferred
250 µs	5
300 µs	6
350 µs	7
400 µs	8
450 µs	9
≥500 µs	10

Example: A/D converter cycle time = 100 µs

X2X cycle time	Number of measured values to be transferred
300 µs	3
400 µs	4
500 µs	5
600 µs	6
700 µs	7
800 µs	8
900 µs	9
≥1 ms	10

4.6 Synchronous mode

The analog/digital converter (A/D converter) of the module can optionally be operated and read out synchronously to the X2X Link network. Synchronous mode is enabled by selecting the respective operating mode in register "ConfigOutput01" on page 27. A time between 200 and 2000 µs must also be set in register "ConfigCycletime01" on page 27. If this time is a whole number factor or multiple of the configured cycle time of X2X Link, then the A/D converter is read synchronously to X2X Link.

Information:

The A/D converter cycle time must be ≥1/4 of the X2X cycle time!

Bit 2 in Module status is set (i.e. A/D converter not running synchronously)...

- ... If the configured A/D converter cycle time cannot be synchronized with X2X Link.
- ... If the module is still in the settling phase.

Jitter, dead time and settling time:

Jitter	
A/D converter cycle times <1500 µs	Max. ±1 µs
A/D converter cycle times >1500 µs	Max. ±4 µs
X2X Link dead time	$50\ \mu s + \frac{\text{X2X cycle time}}{128}$
Settling time	150 x X2X cycle time

The settling time corresponds to the time needed until the A/D converter can be operated after enabling synchronous mode or following conversion of the A/D converter cycle time.

5 Register description

5.1 General data points

In addition to the registers described in the register description, the module has additional general data points. These are not module-specific but contain general information such as serial number and hardware variant.

General data points are described in section "Additional information - General data points" in the X20 System user's manual.

5.2 Function model 0 - Standard

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration						
16	ConfigOutput01 (A/D converter configuration)	USINT			•	
18	ConfigCycletime01	UINT				•
32	AdcClkFreqShift01	USINT				•
Analog signal - Communication						
2	StatusInput01	USINT	•			
4	AnalogInput01	DINT	•			

5.3 Function model 1 - Multisampling

In this function model, the A/D converter is operated synchronously to X2X Link with a predefined A/D converter cycle time. The value is configurable as 50 or 100 µs.

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration						
1601	ConfigGain01_MultiSample	USINT			•	
1603	ConfigCycletime01_MultiSample	USINT				•
Analog signal - Communication						
2	StatusInput01	USINT	•			
1534 + N * 4	AnalogInput0N (N = 1 to 10)	INT	•			

5.4 Function model 2 - Extended filter

The IIR low-pass filter and FIR filter can be enabled in this function model.

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration						
272	ConfigCommonOutput01 (A/D converter and IIR filter configuration)	USINT			•	
288	ConfigFilterOutput01	UINT				•
273	ConfigDatarateOutput01	USINT			•	
274	ConfigHighResolutionOutput01	UINT			•	
Analog signal - Communication						
2	StatusInput01	USINT	•			
4	AnalogInput01	DINT	•			
256	AdcConvTimeStampInput01	DINT	•			

5.5 Function model 254 - Bus controller

In function model "254 - Bus controller", the module behaves as it does in "Function model 0 - Standard" with the exception that it is not synchronized to the X2X Link network even if synchronous mode is enabled in register "ConfigOutput01" on page 27. Instead, the module behaves as if the set A/D converter cycle time is not a factor or multiple of the X2X cycle time and attempts to maintain the set A/D converter cycle time as precisely as possible.

Register	Offset[1]	Name	Data type	Read		Write	
				Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration							
16	0	ConfigOutput01 (A/D converter configuration)	USINT			•	
18	18	ConfigCycletime01	UINT				•
32	32	AdcClkFreqShift01	USINT				•
Analog signal - Communication							
2	4	StatusInput01	USINT	•			
4	0	AnalogInput01	DINT	•			

1) The offset specifies the position of the register within the CAN object.

5.6 Registers for function models "0 - Standard" and "254 - Bus controller"

5.6.1 A/D converter configuration

Name:
ConfigOutput01

The data rate and measurement range of the A/D converter can be configured in this register.

Data type	Values	Bus controller default setting
USINT	See the bit structure.	13

Bit structure:

Bit	Description	Value	Information
0 - 3	Data rate f_{DATA} (samples per second):	0000	2.5
		0001	5
		0010	10
		0011	15
		0100	25
		0101	30
		0110	50
		0111	60
		1000	100
		1001	500
		1010	1000
		1011	2000
		1100	3750
		1101	7500 (bus controller default setting)
		1110	Synchronous mode
		1111	Reserved
4 - 6	Standard measurement range (bit 6 = 0)	000	16 mV/V (bus controller default setting)
		001	8 mV/V
		010	4 mV/V
		011	2 mV/V
	Extended measurement range (bit 6 = 1)	100	256 mV/V
		101	128 mV/V
		110	64 mV/V
		111	32 mV/V
7	Reserved	0	(must be 0)

5.6.2 A/D converter cycle time

Name:
ConfigCycletime01

This register is only used in Synchronous mode. If synchronous mode is enabled in the A/D converter configuration, then the module attempts to operate the A/D converter as synchronously as possible to the X2X Link network (based on the A/D converter cycle time set in this register). For this it is of course necessary that the cycle time of the X2X Link network and the A/D converter cycle time are in a certain ratio to each other. The following conditions must be observed:

1) A/D converter cycle time ≥ 1/4 X2X cycle time
2) A/D converter cycle time corresponds to a whole number factor or multiple of the X2X cycle time
3) A/D converter cycle time must be in the range 50 to 2000 µs

Data type	Values	Information
UINT	50 to 2000	Bus controller default setting: 400

5.6.3 A/D converter clock frequency offset

Name:
AdcClkFreqShift01

In rare cases, strain gauge modules in directly adjacent slots may have an influence on each other.

In most cases, these clock frequencies already differ sufficiently due to component scattering. Where this is not the case, the strain gauge module uses this register to provide a safe method for how an application can exclude the mutual influence of measured values. For details, see "Clock frequency offset" on page 20.

Data type	Values	Information
SINT	-128 to 127	Bus controller default setting: 127

5.6.4 Module status

Name:
StatusInput01

This register contains the current state of the module.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter values	0	Valid A/D converter value
		1	Invalid A/D converter value (analog value = 0xFF800000). Possible causes: • Strain gauge supply error • I/O power supply error • A/D converter not (yet) configured
1	Line monitoring	0	OK
		1	Open circuit
2	Only valid in synchronous mode	0	A/D converter runs synchronous to X2X Link
		1	A/D converter does not run synchronous to X2X Link
3 - 7	Reserved	-	

5.6.5 Strain gauge value

Name:
AnalogInput01

This register contains the raw value determined by the A/D converter for the full-bridge strain gauge with 24-bit resolution.

Data type	Values	Information
DINT	-8,388,608	Negative invalid value
	-8,388,607	Negative full-scale deflection / Underflow
	-8,388,606 to 8388606	Valid range
	8,388,607	Positive full-scale deflection / Overflow / Open circuit

For additional details, see "Effective resolution of the A/D converter" on page 18.

5.7 Register for "Function model 1 - Multisampling"

5.7.1 A/D converter configuration

Name:
ConfigGain01_MultiSample

The measurement range for the A/D converter can be configured in this register.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 2	Standard measurement range (bit 2 = 0)	000	16 mV/V
		001	8 mV/V
		010	4 mV/V
		011	2 mV/V
	Extended measurement range (bit 2 = 1)	100	256 mV/V
		101	128 mV/V
		110	64 mV/V
		111	32 mV/V
3 - 7	Reserved	0	(must be 0)

5.7.2 A/D converter cycle time

Name:
ConfigCycletime01_MultiSample

The A/D converter cycle time can be configured in this register.

In order for multisampling to work, the X2X cycle time must be divisible by the A/D converter cycle time to produce a whole number.

Data type	Value	Information
USINT	0	50 µs (default)
	1	100 µs
	2 to 255	Reserved

5.7.3 Module status

Name:
StatusInput01

This register contains the current state of the module.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter values	0	Valid A/D converter value
		1	Invalid A/D converter value
1	Line monitoring	0	OK
		1	Open circuit An open circuit was found during at least one measurement in this X2X cycle. This bit is reset if all measurements are OK after correcting this error, i.e. it does not have to be acknowledged.
2	Synchronous mode	0	A/D converter runs synchronous to X2X Link
		1	A/D converter does not run synchronous to X2X Link
3 - 7	Reserved	-	

5.7.4 Strain gauge value - Multiple

Name:
AnalogInput01 to AnalogInput10

This register contains the raw value determined by the A/D converter for the full-bridge strain gauge with 16-bit resolution. The module returns between 3 and 10 measured values per X2X cycle depending on the configuration.

Effective resolution

In principle, the effective resolution of the A/D converter is dependent on the data rate and measurement range (see "Effective resolution of the A/D converter" on page 18).

The following table shows how the effective resolution (in bits) or effective range of values of the strain gauge value depend on the module configuration (data rate, measurement range):

Measurement range							
±16 mV/V		±8 mV/V		±4 mV/V		±2 mV/V	
Bits	Range of values	Bits	Range of values	Bits	Range of values	Bits	Range of values
11.7	±1,700	10.7	±840	9.8	±430	8.8	±220

Table 5: Effective resolution of the strain gauge value in bits for the measurement range 2 to 16 mV/V

Measurement range							
±256 mV/V		±128 mV/V		±64 mV/V		±32 mV/V	
Bits	Range of values	Bits	Range of values	Bits	Range of values	Bits	Range of values
15.8	±27,600	15.0	±16,400	13.7	±6,520	12.8	±3,570

Table 6: Effective resolution of the strain gauge value in bits for the measurement range 32 to 256 mV/V

5.8 Register for "Function model 2 - Extended filter"

5.8.1 A/D converter and IIR filter configuration

Name:
ConfigCommonOutput01

The IIR low-pass filter and measurement range of the A/D converter can be configured in this register.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 3	IIR low-pass filter: Definition of the filter level	0000	IIR low-pass filter switched off
		0001	Filter level 1
		0010	Filter level 2
		0011	Filter level 3
		0100	Filter level 4
		0101	Filter level 5
		0110	Filter level 6
		0111	Filter level 7
		1000	Filter level 8
		1001 - 1111	Not permitted
4 - 6	Default measurement range	000	16 mV/V
		001	8 mV/V
		010	4 mV/V
		011	2 mV/V
	Extended measurement range	100	256 mV/V
		101	128 mV/V
		110	64 mV/V
		111	32 mV/V
7	Reserved	0	(must be 0)

5.8.2 Data rate configuration

Name:
ConfigFilterOutput01

Whether a selectable data rate or a high-resolution data rate is being used for the FIR filter is configured in this register.

Data type	Values	Information
UINT	0	Mode "Selectable data rate": A selectable data rate is used for the FIR filter (default). Configuration takes place in register "ConfigDatarateOutput01" on page 32.
	1	Mode "High-resolution data rate": A high-resolution data rate is used for the FIR filter. Configuration takes place in register "ConfigHighResolutionOutput01" on page 32.

5.8.2.1 Selectable data rate

Name:
ConfigDatarateOutput01

The data rate of the FIR filter can be configured in mode "Selectable data rate" in this register.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 3	Data rate f_{DATA} (samples per second):	0000	2.5
		0001	5
		0010	10
		0011	15
		0100	25
		0101	30
		0110	50
		0111	60
		1000	100
		1001	500
		1010	1000
		1011	2000
		1100	3750
		1101	7500
		1110 - 1111	The analog input value indicates an invalid range.
4 - 7	Reserved	0	(must be 0)

5.8.2.2 High-resolution data rate

Name:
ConfigHighResolutionOutput01

The data rate of the FIR filter can be configured in 0.1 Hz steps (0.1 to 6553.5 Hz) in this register.

Data type	Values	Information
UINT	0	Disables the FIR filter
	1 to 65535	0.1 to 6553.5 Hz

5.8.3 Module status

Name:
StatusInput01

This register contains the current state of the module. If there is a fault in the module power supply or strain gauge supply, the analog input value indicates an invalid range and the buffer of the enabled filter is reset.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter values	0	Valid A/D converter value
		1	Invalid A/D converter value
1	Line monitoring	0	OK
		1	Open circuit
2	Reserved	-	
3	Module power supply	0	OK
		1	Error in module power supply
4	Strain gauge supply	0	OK
		1	Error in strain gauge supply
5	FIR filter ready	0	OK
		1	FIR filter not yet ready
6 - 7	Reserved	-	

5.8.4 A/D converter conversion timestamp

Name:
AdcConvTimeStampInput01

This register holds the timestamp of the last analog conversion. This is always the point in time in [µs] at which the conversion of the latest A/D converter raw value is completed.

Data type	Values	Explanation
DINT	-2,147,483,648 to 2147483647	Timestamp [µs] of the last analog conversion

5.9 Minimum cycle time

The minimum cycle time specifies how far the bus cycle can be reduced without communication errors occurring. It is important to note that very fast cycles reduce the idle time available for handling monitoring, diagnostics and acyclic commands.

Minimum cycle time
250 µs

5.10 Minimum I/O update time

The minimum I/O update time specifies how far the bus cycle can be reduced so that an I/O update is performed in each cycle.

For the I/O update times for function models "0 - Standard", "2 - Extended filter" and "254 - Bus controller", see section "Characteristics of the FIR filter in mode "Selectable data rate"" on page 14.

Depending on the setting in register "ConfigCycletime01_MultiSample" on page 29, the I/O update time in "Function model 1 - Multisampling" is 50 or 100 µs.