X20(c)AI1744

1 Selecting the description

This data sheet describes 2 module revisions. The module revision is laser-marked on the side of the module. Select the desired module revision from the following table to view its description.

Module	Revision	Page
X20AI1744	≥H0	2
X20cAI1744	All	
X20AI1744	<H0	31

2 X20(c)AI1744 with Rev. ≥H0

2.1 General information

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.

- 1 full-bridge strain gauge input
- Data output rate configurable from 0.1 Hz to 7.5 kHz
- Special operating modes (synchronous mode and multiple sampling)
- Configurable filter level

2.2 Coated modules

Coated modules are X20 modules with a protective coating for the electronics component. This coating protects X20c modules from condensation and corrosive gases.
The modules' electronics are fully compatible with the corresponding X20 modules.

> **For simplification purposes, only images and module IDs of uncoated modules are used in this data sheet.**

The coating has been certified according to the following standards:

- Condensation: BMW GS 95011-4, 2x 1 cycle
- Corrosive gas: EN 60068-2-60, Method 4, exposure 21 days

2.3 Order data

Model number	Short description	Figure
	Analog inputs	
X20AI1744	X20 analog input module, 1 full-bridge strain gauge input, 24-bit converter resolution, 5 kHz input filter	
X20cAI1744	X20 analog input module, coated, 1 full-bridge strain gauge input, 24-bit converter resolution, 5 kHz input filter	
	Required accessories	
	Bus modules	
X20BM11	X20 bus module, 24 VDC keyed, internal I/O supply continuous	
X20BM15	X20 bus module, with node number switch, 24 VDC keyed, internal I/O supply continuous	
X20cBM11	X20 bus module, coated, 24 VDC keyed, internal I/O supply continuous	
	Terminal blocks	
X20TB12	X20 terminal block, 12-pin, 24 VDC keyed	

Table 1: X20AI1744, X20cAI1744 - Order data

2.4 Technical data

Model number	X20AI1744	X20cAI1744
Short description		
I/O module	1 full-bridge strain gauge input	
General information		
B&R ID code	0x1CDE	0xE754
Status indicators	Channel status, operating status, module status	
Diagnostics		
Module run/error	Yes, using status LED and software	
Open circuit	Yes, using status LED and software	
Input	Yes, using status LED and software	
Power consumption		
Bus	0.01 W	
Internal I/O	0.5 W	
Additional power dissipation caused by the actuators (resistive) [W]	Max. +0.36 [1]	
Electrical isolation		
Bus - Analog input	Yes	
Bus - Bridge supply voltage	Yes	
Channel - I/O power supply	No	
Certification		
CE	Yes	
KC	Yes	-
UL	cULus E115267 Industrial control equipment	
HazLoc	cCSAus 244665 Process control equipment for hazardous locations Class I, Division 2, Groups ABCD, T5	
ATEX	Zone 2, II 3G Ex nA nC IIA T5 Gc IP20, Ta = 0 - Max. 60°C FTZÚ 09 ATEX 0083X	
GOST-R	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	85 to 5000 Ω	
Influence of cable length	The shielded twisted pair cable should be as short as possible and run separately to the sensor (isolated from load circuit) without intermediate terminals	
Input protection	RC protection	
Common-mode range	0 to 3 VDC Permissible input voltage range (with regard to the potential strain gauge GND) on inputs "Input +" and "Input -"	
Isolation voltage between input and bus	500 V_{eff}	
Conversion procedure	Sigma-delta	
Output of the digital value		
Broken bridge supply line	Value approaches 0	
Broken sensor line	Value approaches ±end value ("open circuit" status bit is set in the *Module status* register)	
Valid value range	0xFF800001 to 0x007FFFFF (-8,388,607 to 8,388,607)	
Strain gauge supply		
Voltage	5.5 VDC / max. 65 mA	
Short circuit protection, overload protection	Yes	
Voltage drop for short circuit protection	Max. 0.2 VDC at 65 mA	

Table 2: X20AI1744, X20cAI1744 - Technical data

Model number	X20AI1744	X20cAI1744
Quantization [3]		
LSB value (16-bit)		
2 mV/V	336 nV	
4 mV/V	671 nV	
8 mV/V	1.343 µV	
16 mV/V	2.686 µV	
32 mV/V	5.371 µV	
64 mV/V	10.74 µV	
128 mV/V	21.48 µV	
256 mV/V	42.97 µV	
LSB value (24-bit)		
2 mV/V	1.31 nV	
4 mV/V	2.62 nV	
8 mV/V	5.25 nV	
16 mV/V	10.49 nV	
32 mV/V	20.98 nV	
64 mV/V	41.96 nV	
128 mV/V	83.92 nV	
256 mV/V	167.85 nV	
Max. gain drift	12 ppm/°C [4]	
Max. offset drift	2 ppm/°C [5]	
Nonlinearity	<10 ppm [5]	
Operating conditions		
Mounting orientation		
Horizontal	Yes	
Vertical	Yes	
Installation at elevations above sea level		
0 to 2000 m	No limitations	
>2000 m	Reduction of ambient temperature by 0.5°C per 100 m	
EN 60529 protection	IP20	
Environmental conditions		
Temperature		
Operation		
Horizontal installation	-25 to 60°C	
Vertical installation	-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	Up to 100%, condensing
Storage	5 to 95%, non-condensing	
Transport	5 to 95%, non-condensing	
Mechanical characteristics		
Note	Order 1x terminal block X20TB12 separately Order 1x bus module X20BM11 separately	Order 1x terminal block X20TB12 separately Order 1x bus module X20cBM11 separately
Spacing	12.5+0.2 mm	

Table 2: X20AI1744, X20cAI1744 - 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)   Quantization depends on the strain gauge factor.
4)   Based on the current measured value.
5)   Based on the entire measurement range.

2.5 LED status indicators

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

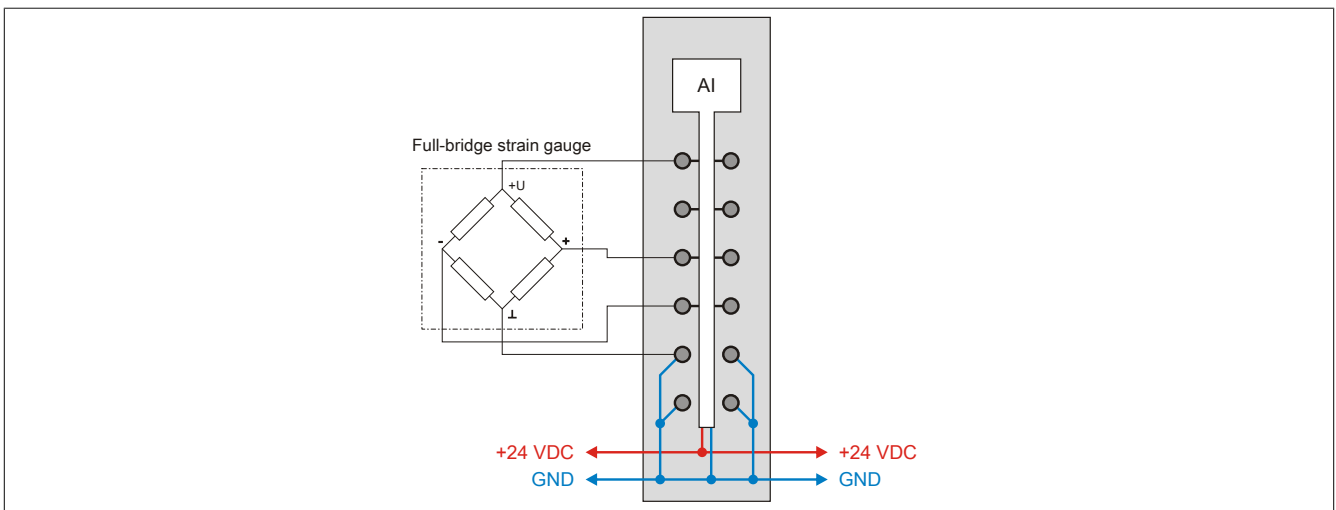| Figure	LED	Color	Status	Description
	r	Green	Off	No power to module
			Single flash	RESET mode
			Double flash	BOOT mode (during firmware update)[1]
			Blinking	PREOPERATIONAL mode
			On	RUN mode
	e	Red	Off	No power to module or everything OK
			On	Error or reset status

	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.

2.6 Pinout

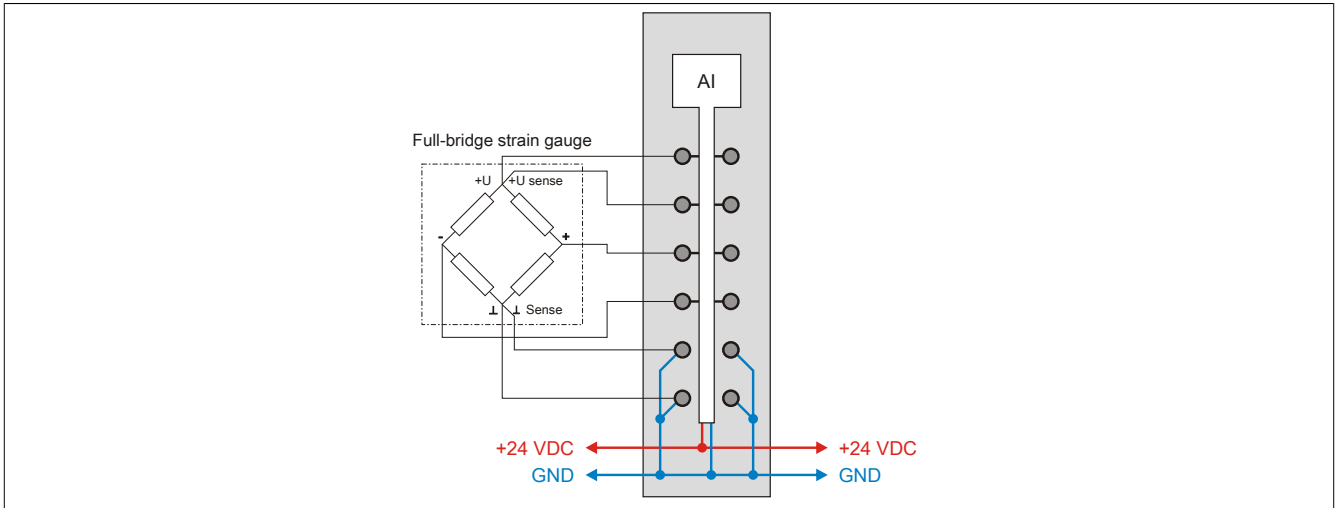|		
SG VCC		SG VCC
SG VCC		SG VCC
Input +		Input +
Input -		Input -
SG GND		SG GND
SG GND		SG GND
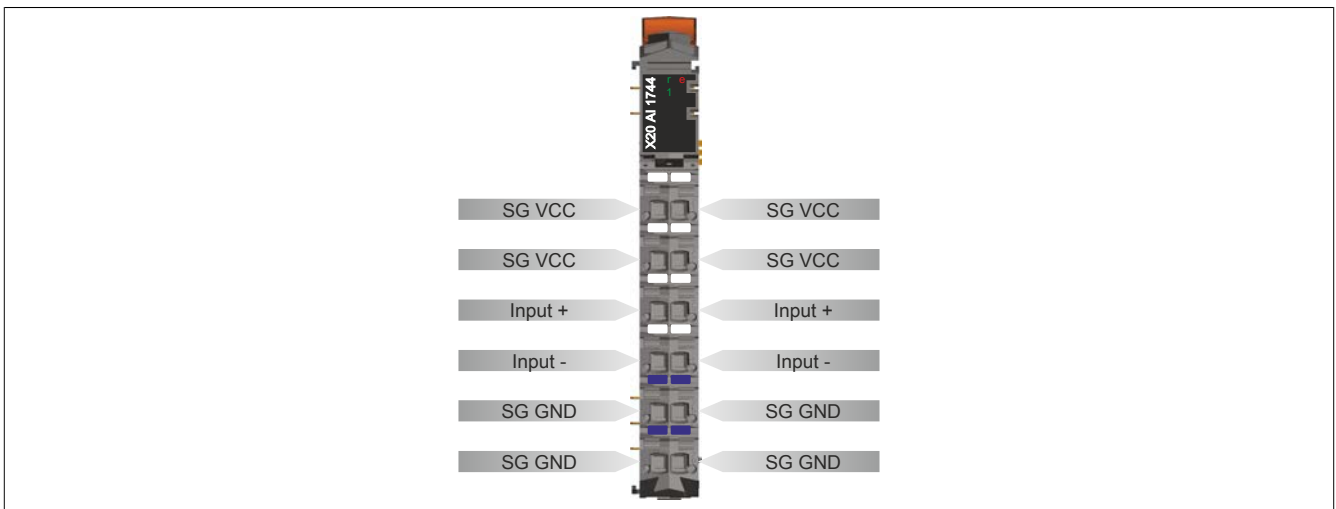
2.7 Connection examples

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 7). 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.
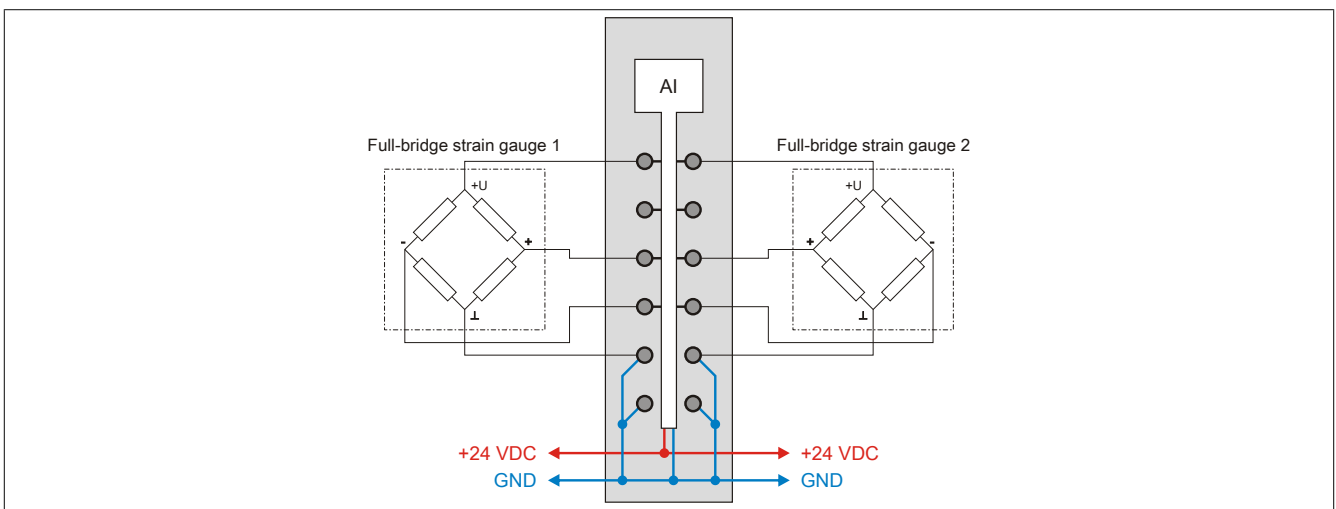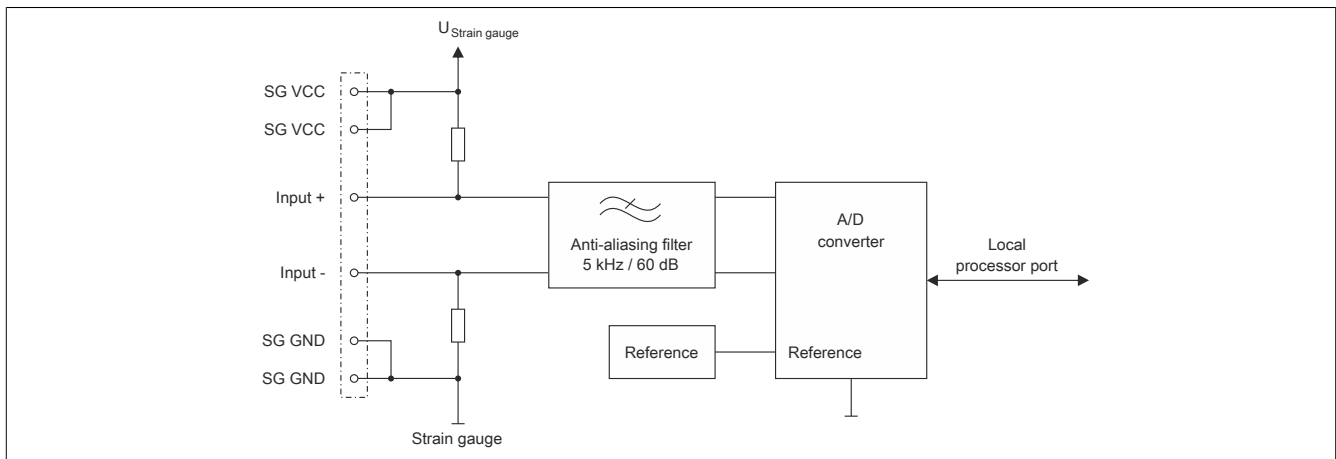

Figure 1: Connection example - Parallel connection of 2 full-bridge strain gauges

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

2.8 Input circuit diagram

2.9 Effective resolution of the A/D converter

The A/D converter on 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:

Based on 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 16.9 bits:
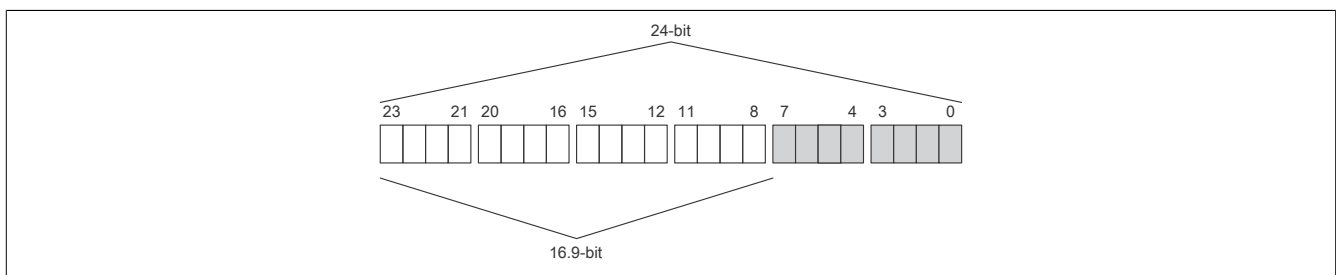
The low-order bits (grayed out) contain only noise instead of valid values and must therefore not be evaluated.

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

2.10 Calculation example / Quantization

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

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

- Rated load: 1000 kg
- Strain gauge factor: 4 mV/V

The value for the positive full-scale deflection at a specified rated load of 1000 kg is derived from the bridge factor of the strain gauge load cell (multiplication with the bridge supply voltage from the module):

4 mV/V × 5.5 V = 22 mV

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	22.0 mV	1000 kg
0x0000 0001	1	2.62 nV	0.119 g
0x0000 20C3	8387	22.0 µV	1 kg
0x0001 0000	65536	171.9 µV	7.81 kg

The values for each LSB can be found in the technical data of the module under "Quantization" (1 LSB in reference to 16-bit and 1 LSB in reference to 24-bit).

## 2.11 Filter characteristics of the sigma-delta A/D converter
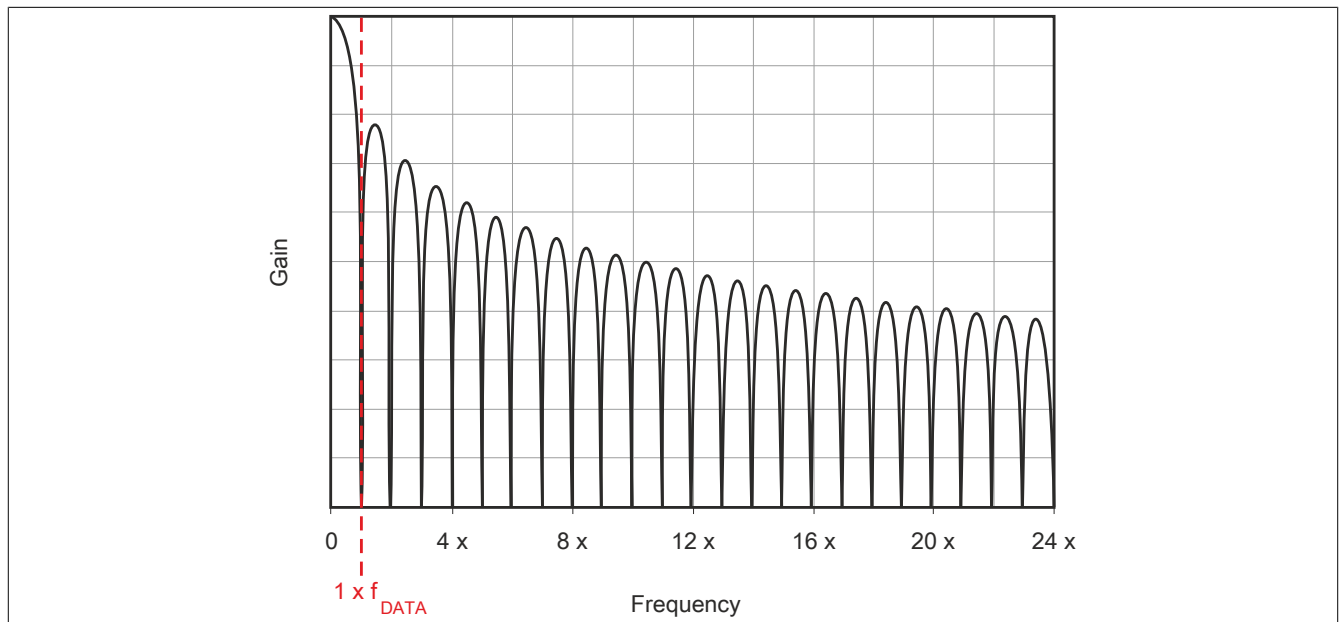
2.12 Software filters

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
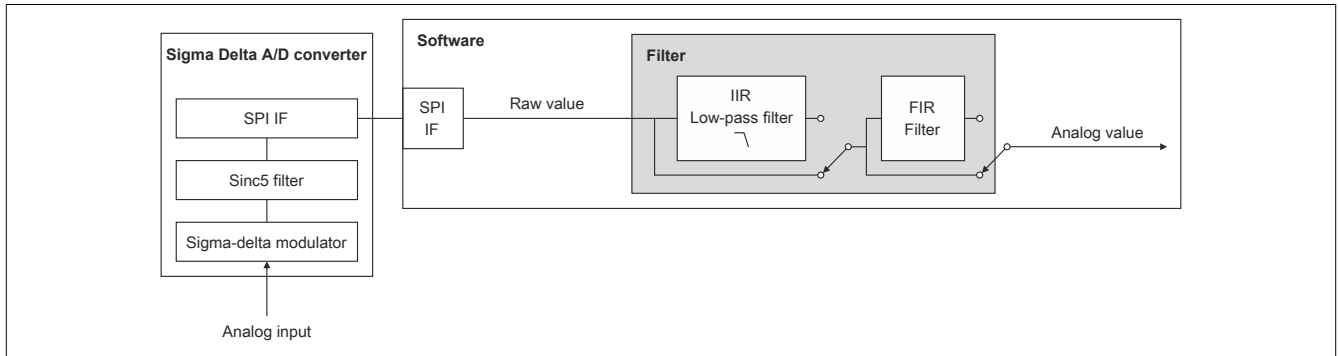
2.12.1 IIR low-pass filter

2.12.1.1 General information

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 "ConfigCommonOutput01" on page 27. "Filter level" = 0 if the IIR low-pass filter is disabled.

2.12.1.2 Filter characteristics of the 1st-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
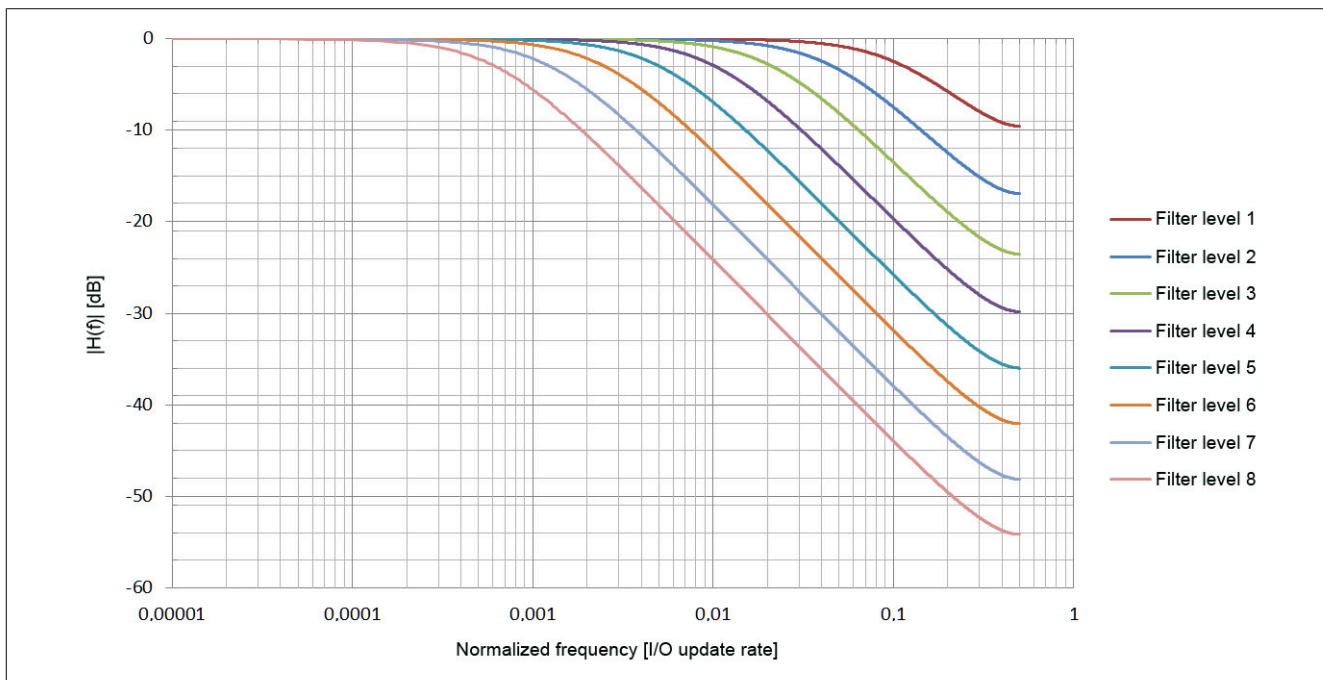
Phase shift of the IIR low-pass filter
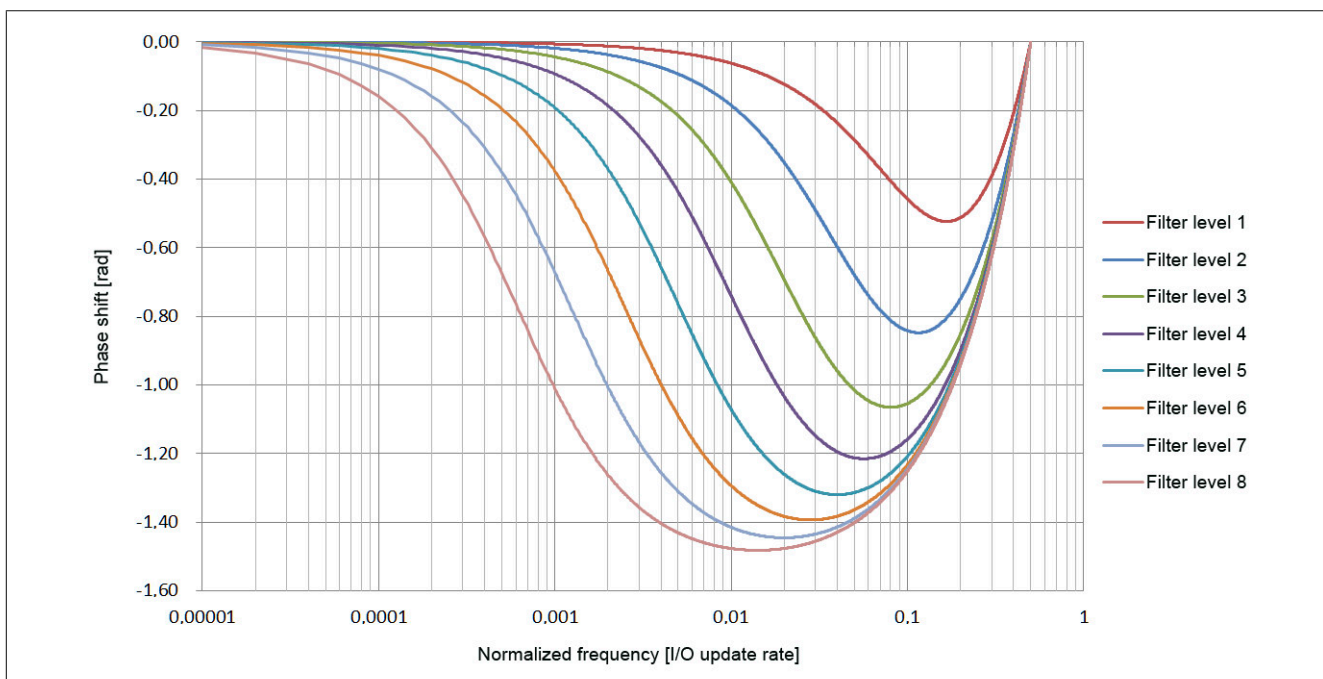
Step response of the IIR low-pass filter

Group delay of the IIR low-pass filter

2.12.2 FIR filter
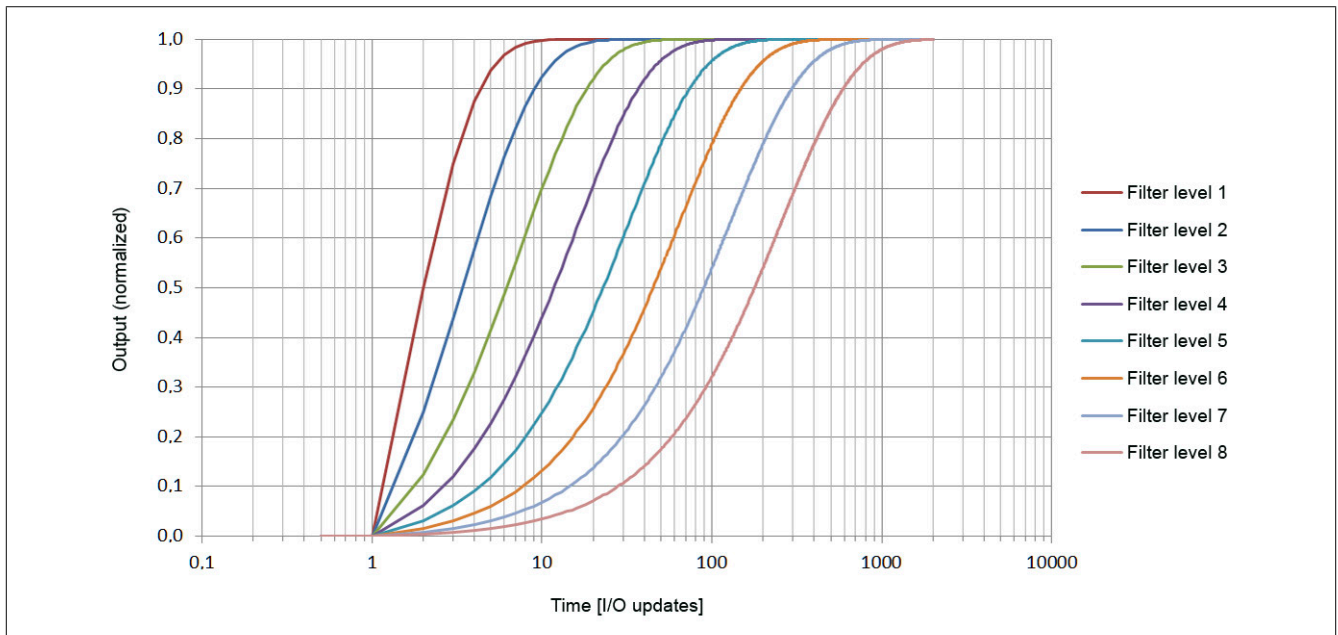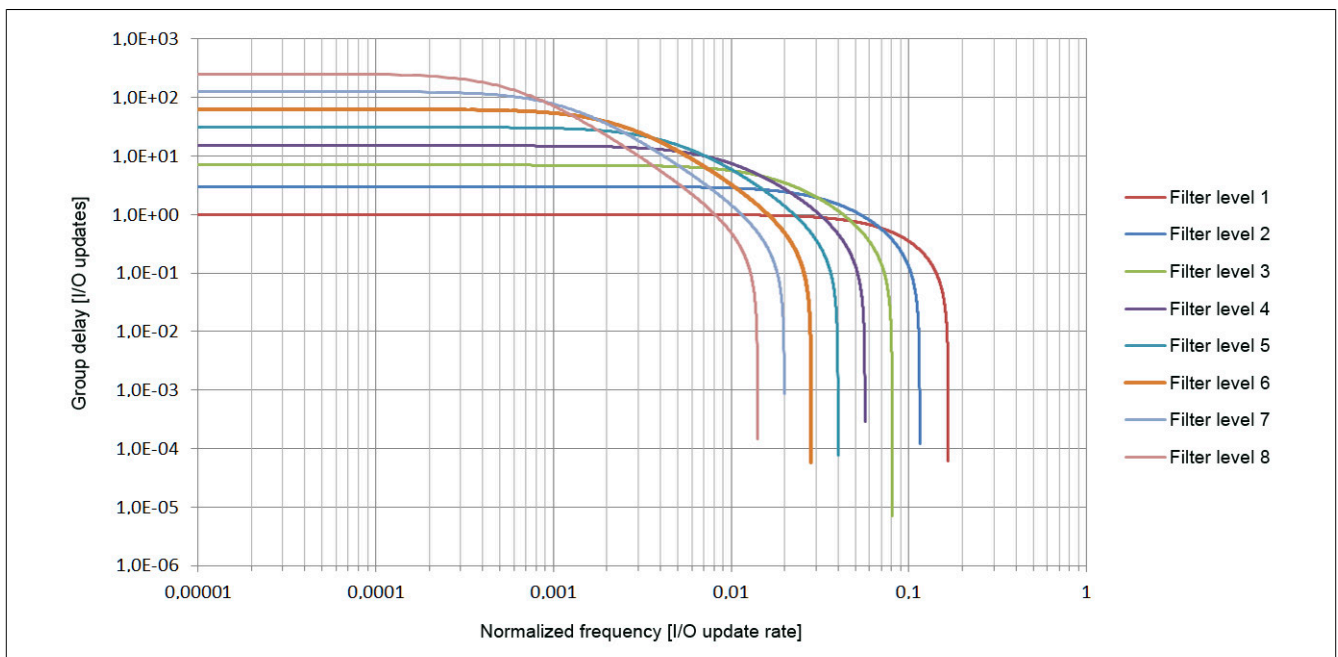
Like the IIR low-pass filter, the FIR filter can also be used to smooth out the signal and increase its resolution. In addition, configuring the filter length accordingly makes it possible to target and efficiently filter out individual interference frequencies. The source of these interference frequencies 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 "Selectable data rate" mode) or 1/filter frequency (FIR filter in "High-resolution data rate" mode) until the filter is engaged. During tuning, bit 5 is set in register "StatusInput01" on page 29.

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

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 "Selectable data rate" mode.

Set value [1] [2]	Data rate (f_{Data}) [Hz] [3] [4]	f_{Notch} [Hz]	I/O update rate [Hz]		I/O update time [ms]	
			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 20
2) Function model 2: Bits 0 to 3 of register "ConfigDatarateOutput01" on page 28
3) Function model 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})

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

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

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

1) Setpoint of register "ConfigHighResolutionOutput01" on page 28
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 set value and varies between 42 and 56 µs. The following formula can be used to precisely calculate the I/O update time:

$$\text{I/O update time} = 1e6 * (1e\text{-}5 - 10 / (\text{Set value} * [10 / (5e\text{-}6 * \text{Set value})]))$$

Key: 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 set value:
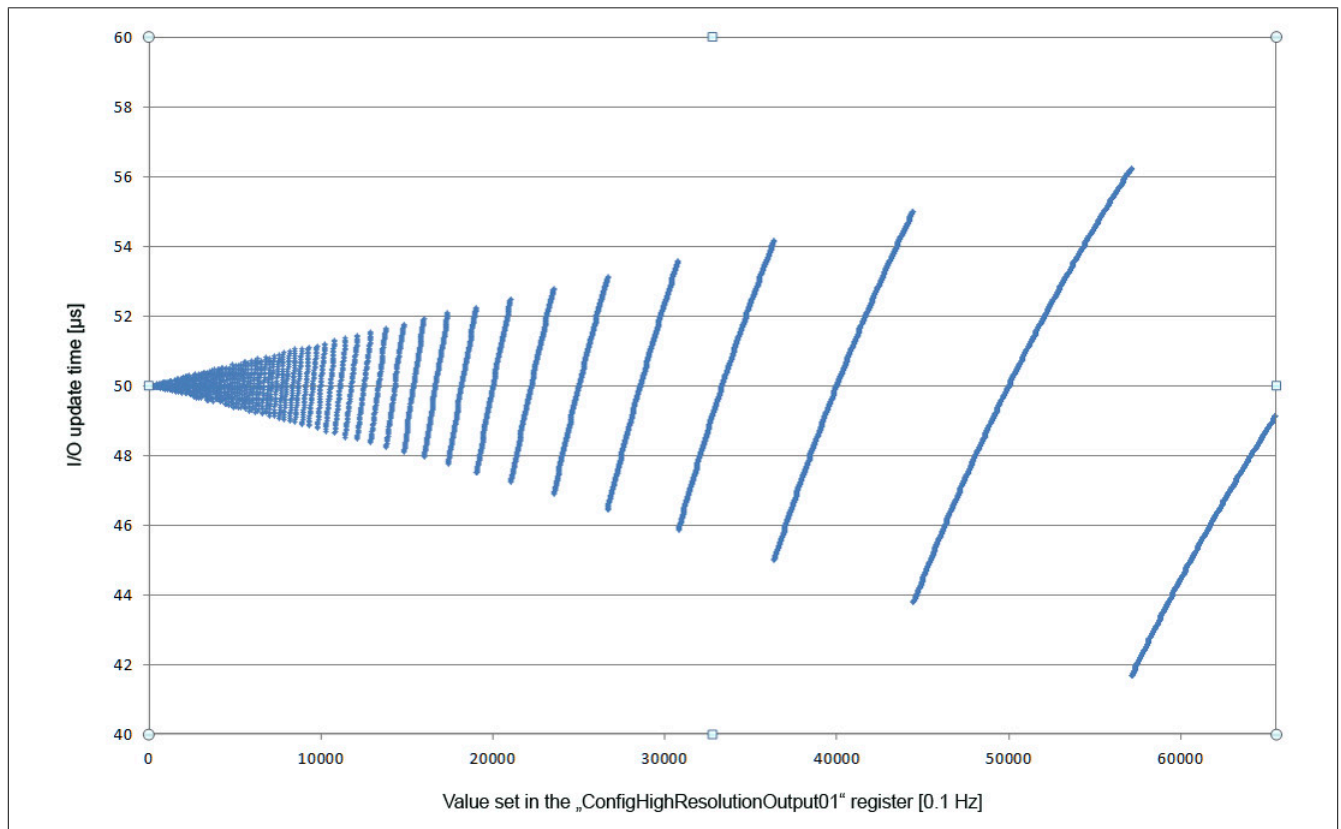
2.12.2.3 Examples for the gain of the FIR filter

Example 1

Filter setting = 10:

- f_{Notch} = 1000 Hz
- f_c = 439.3 Hz
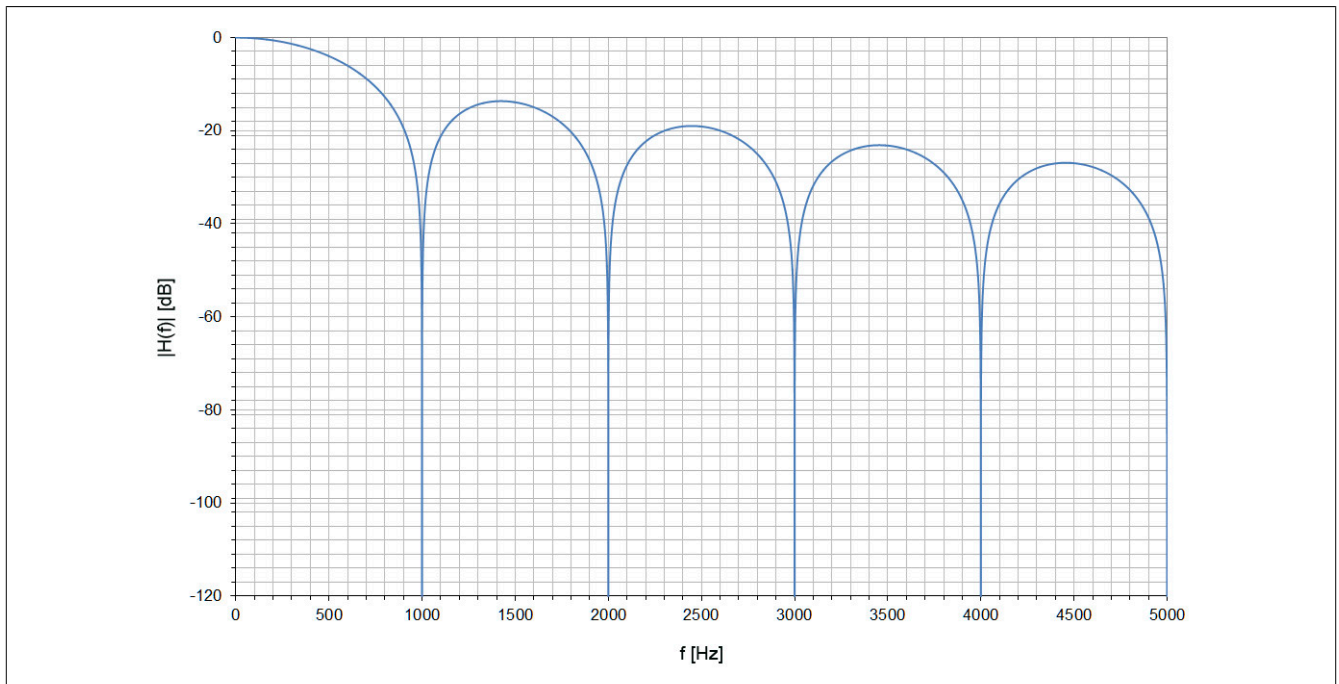
Example 2

Filter setting = 6:

- f_{Notch} = 50 Hz
- f_c = 21.8 Hz
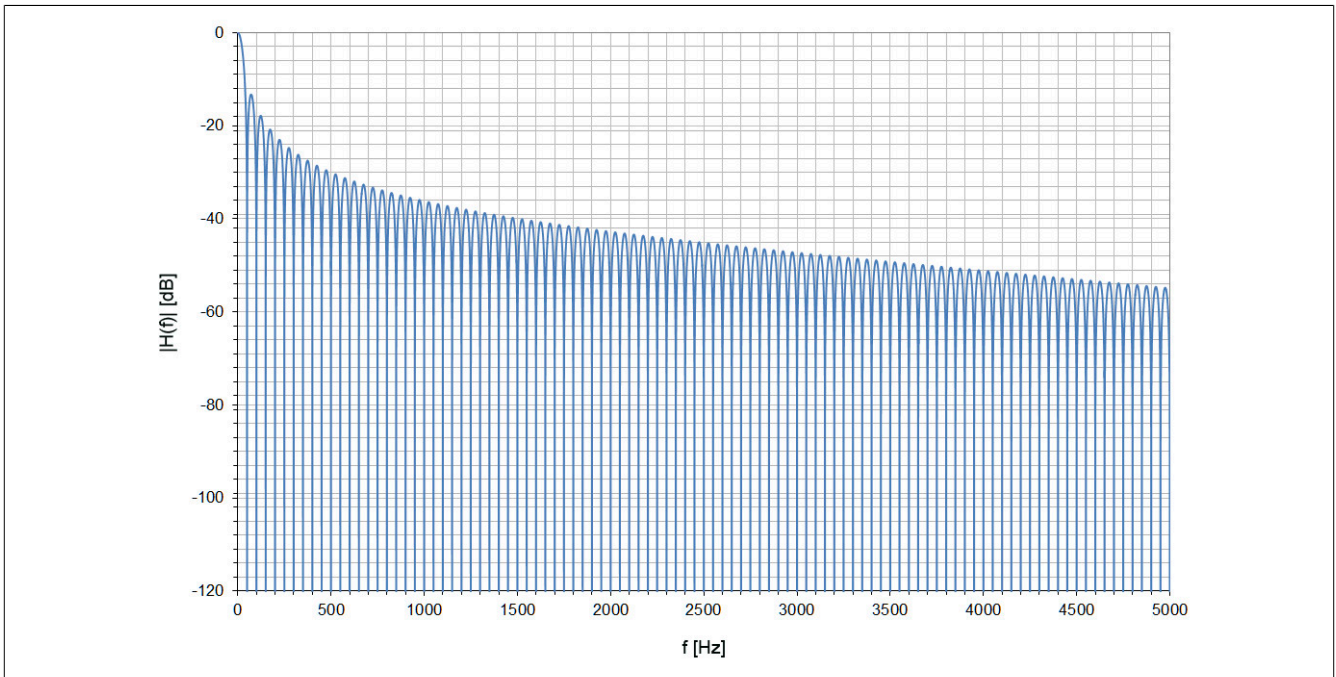
Detailed excerpt from the filter curve shown above:
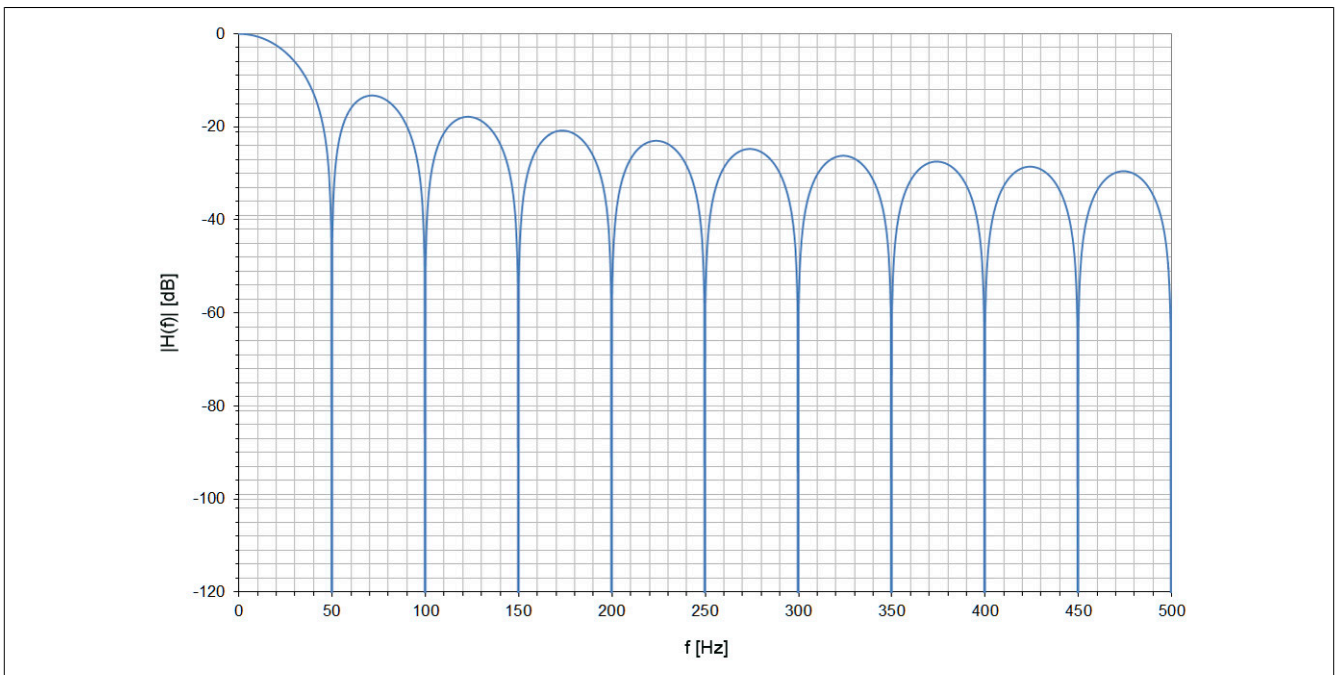
2.13 Hardware configuration

2.13.1 Hardware configuration for horizontal installation at 55°C ambient temperature

Operating a strain gauge module

At an ambient temperature of 55°C or higher, a dummy module must be connected to the left of the strain gauge module if installed horizontally.
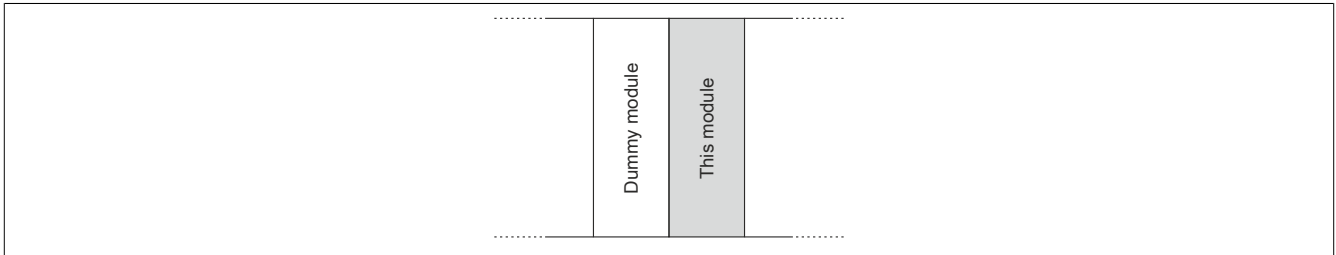
Operating multiple strain gauge modules side by side

If 2 or more horizontal strain gauge modules are being operated in a cluster, the following arrangement of modules must be observed.
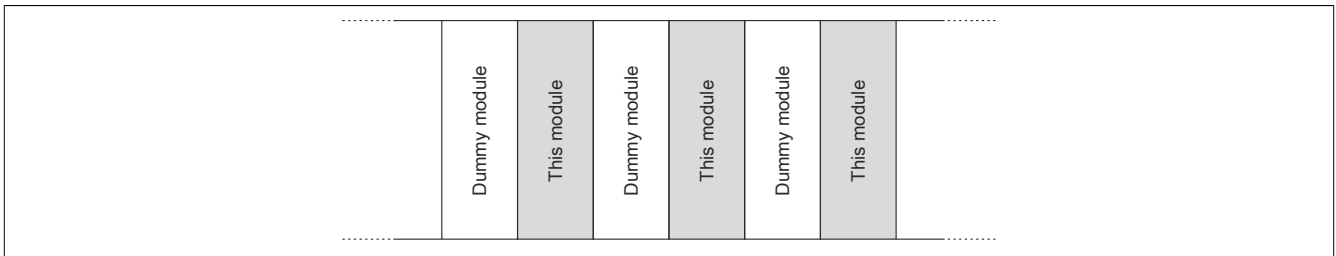
2.13.2 Hardware configuration for vertical installation at 45°C ambient temperature

Operating a strain gauge module

At an ambient temperature of 45°C or higher, a dummy module must be connected to the left of the strain gauge module if installed vertically.

This module
Dummy module

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.

This module
Dummy module
This module
Dummy module
This module
Dummy module
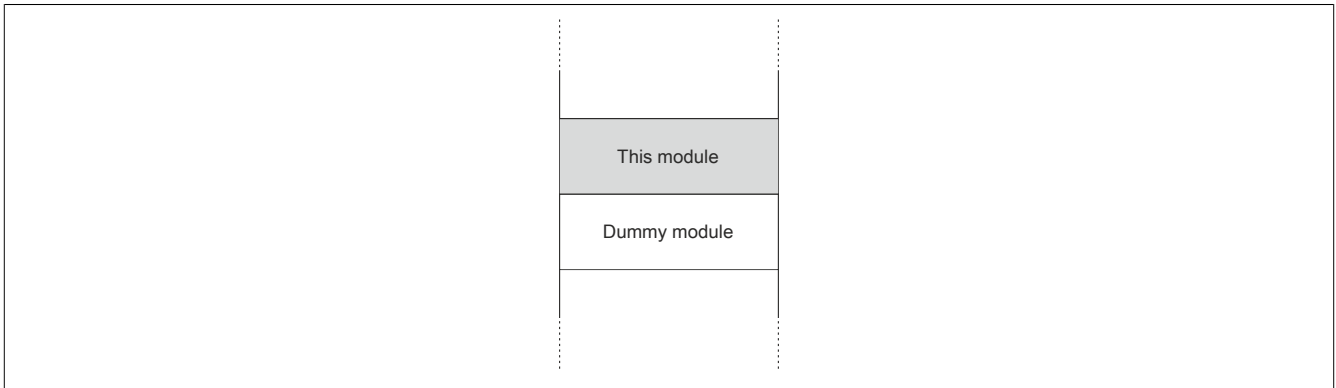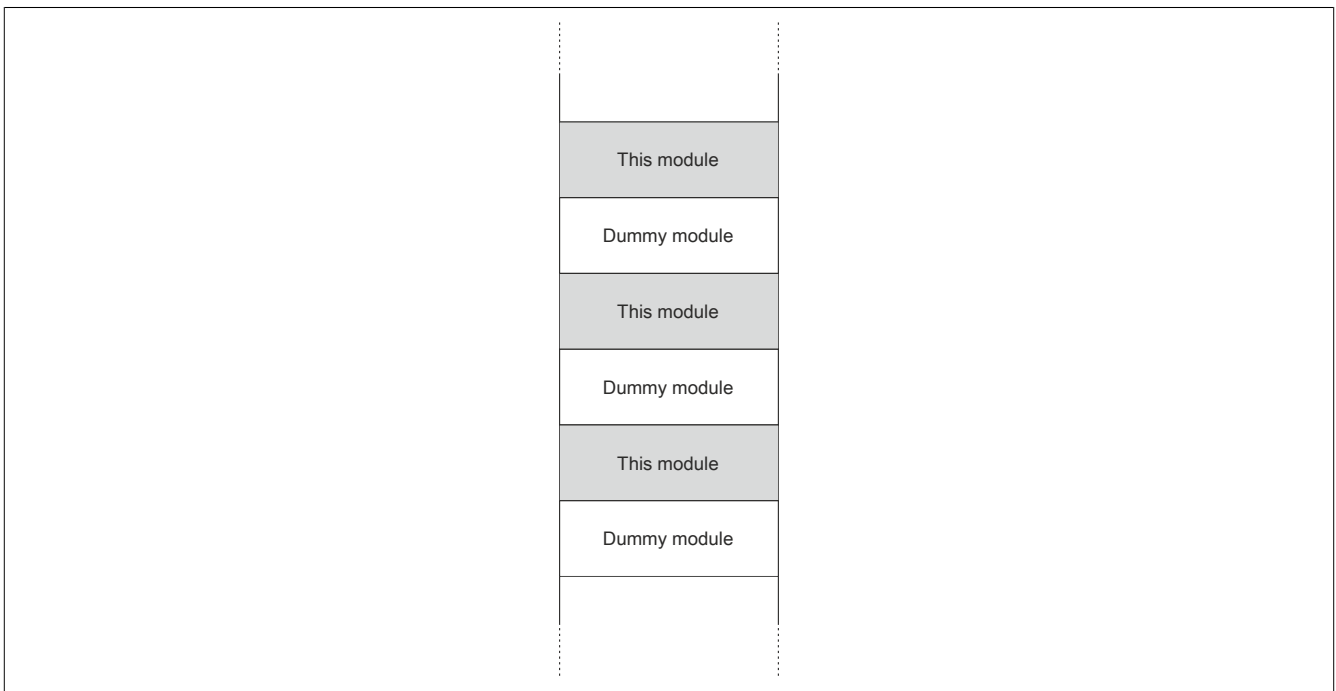
2.14 Register description

2.14.1 General data points

In addition to the registers listed in the register description, the module also has other more general data points. These registers are not specific to the module but contain general information such as serial number and hardware version.

These general data points are listed in section "Additional information - General data points" of the X20 system user's manual.

2.14.2 Function model 0 - Standard

| Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration						
16	ConfigOutput01	USINT			●	
18	ConfigCycletime01	UINT				●
32	AdcClkFreqShift01	USINT				●
Analog signal - Communication						
2	StatusInput01	USINT	●			
4	AnalogInput01	DINT	●			

2.14.3 Function model 1 - Multiple sampling

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.

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 X2X Link, it is possible to disable unneeded registers (see "Number of measured values" on page 25).

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 through 10th measured value (AnalogInput07 to AnalogInput10) should be disabled by setting Number of measured values to "6 measured values" in the I/O configuration.

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

2.14.4 Function model 2 - Extended filter

This function model allows the IIR low-pass filter and the FIR filter to be enabled.

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
Analog signal - Configuration						
272	ConfigCommonOutput01	USINT			●	
288	ConfigFilterOutput01	UINT				●
273	ConfigDatarateOutput01	USINT			●	
274	ConfigHighResolutionOutput01	UINT			●	
Analog signal - Communication						
2	StatusInput01	USINT	●			
4	AnalogInput01	DINT	●			
256	AdcConvTimeStampInput01	DINT	●			

2.14.5 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 X2X Link even if synchronous mode is activated in register "ConfigOutput01" on page 20. 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	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.

2.14.5.1 CAN I/O bus controller

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

2.14.6 Register for the "0 - Standard" and "254 - Bus controller" function models

2.14.6.1 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
USINT	See 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	Synchronous mode
		1111	Reserved
4 - 6	Standard measurement range (bit 6 = 0)	000	16 mV/V
		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)

2.14.6.1.1 Synchronous mode

The analog/digital converter (A/D converter) can optionally be operated and read synchronously to X2X Link. Synchronous mode is enabled by selecting the respective operating mode in register . A time between 200 and 2000 µs must also be set in register . 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	$50 \text{ µs} + \dfrac{\text{X2X cycle time}}{128}$
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.

2.14.6.2 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 X2X Link (based on the A/D converter cycle time set in this register). It is of course necessary for the X2X Link cycle time and the A/D converter cycle time to have a certain ratio. 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	Value
UINT	50 to 2000

2.14.6.3 A/D converter clock frequency shift

Name:
AdcClkFreqShift01

In rare cases, strain gauge modules connected to neighboring slots can influence one another. This can result in temporary, minimal deviations in measured values. This can only occur if the sigma-delta A/D converters on the neighboring strain gauge modules are operated at exactly the same clock frequency.

In most cases, these clock frequencies vary slightly due to part variances. When they are the same however, this register on the strain gauge module provides a safe way for an application to prevent this type of mutual influence.

Data type	Value
SINT	-128 to 127

This register can be used to vary the clock frequency in increments of 200 ppm. Setting values from -50 to 50 cover a range of -10000 ppm to 10000 ppm. This corresponds with -1% to 1%.

Values beyond this range will cause activation of a default mode. The frequency shift is derived from the last 2 digits of the serial number by the module firmware. This saves time that would otherwise be needed for programming, provided that the last two digits of the serial numbers on the neighboring modules are not the same

Register value	Frequency shift in ppm	Example of a sampling rate[1]
127	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number
...	...	...
51	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the 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	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number
...	...	...
-128	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number

[1] Nominal sampling rate of 500 samples per second

Important:

As shown in the table above, shifting the A/D converter clock frequency will equally shift the A/D converter sampling rate. Shifting the A/D converter clock frequency too much can cause problems with disturbance suppression particularly when a very specific sampling rate has been defined to suppress existing disturbances (e.g. 50 Hz to suppress the 50 Hz hum). See also "Filter characteristics of the sigma-delta A/D converter" on page 8.
It's situations like this where the option to manually shift the frequency in the I/O configuration or ASIOACC library should be utilized rather than relying on the default frequency shift that is based on the serial number.

A frequency shift like the one shown below would be sufficient to prevent modules from influencing one another and would not cause any noticeable difference to the filter characteristics.

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

Information:

- **This register has no effect in synchronous mode because the firmware regulates the A/D converter clock frequency in such a way that the A/D converter cycle is synchronous with the X2X cycle.**
- **When writing to this register using the ASIOACC library, only the lowest value byte of the written value is accepted. For example, the value 256 (=0x100) is identical to the value 0 (=0x00).**

2.14.6.4 Module status

Name:
StatusInput01

The current state of the module is indicated in this register.

Data type	Values
USINT	See bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter value	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	-	

2.14.6.5 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 8,388,606	Valid range
	8,388,607	Positive full-scale deflection / Overflow / Open circuit

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 7).

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

	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	21.3	±1,290,000	20.8	±912,000	19.7	±425,000	18.7	±212,000
5	20.7	±851,000	20.3	±645,000	19.3	±322,000	18.3	±161,000
10	20.4	±691,000	19.9	±490,000	18.9	±244,000	17.9	±122,000
15	20.1	±562,000	19.3	±320,000	18.7	±212,000	17.7	±106,000
25	19.7	±425,000	19.2	±301,000	18.5	±185,000	17.5	±92,000
30	19.6	±397,000	19.0	±262,000	18.1	±140,000	17.1	±72,000
50	19.4	±346,000	18.8	±230,000	17.9	±122,000	16.9	±61,000
60	19.3	±320,000	18.8	±230,000	17.8	±114,000	16.8	±57,000
100	19.1	±280,000	18.5	±185,000	17.4	±86,000	16.4	±43,000
500	18.0	±130,000	17.3	±80,000	16.3	±40,000	15.3	±20,000
1000	17.2	±75,000	16.5	±46,000	15.6	±25,000	14.6	±12,000
2000	16.6	±49,600	16.1	±35,000	15.3	±20,000	14.3	±10,000
3750	16.2	±37,600	15.7	±26,600	14.7	±13,000	13.7	±6,600
7500	15.8	±28,500	15.3	±20,200	14.4	±10,800	13.4	±5,400

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	23	±4,194,000	22.6	±3,179,000	22.1	±2,248,000	21.7	±1,703,000
5	22.3	±2,582,000	22.4	±2,767,000	21.9	±1,957,000	21.3	±1,291,000
10	22.3	±2,582,000	22	±2,097,000	21.6	±1,589,000	21	±1,049,000
15	22	±2,097,000	21.7	±1,703,000	21.3	±1,291,000	20.7	±852,000
25	21.7	±1,703,000	21.4	±1,384,000	21.1	±1,124,000	20.5	±741,000
30	21.8	±1,826,000	21.3	±1,291,000	20.8	±913,000	20.4	±692,000
50	21.3	±1,291,000	21.1	±1,124,000	20.4	±692,000	19.9	±489,000
60	21.3	±1,291,000	20.9	±978,000	20.5	±741,000	19.8	±456,000
100	20.9	±978,000	20.7	±852,000	20.2	±602,000	19.6	±397,000
500	20.1	±562,000	19.6	±397,000	19.1	±281,000	18.6	±199,000
1000	19	±262,000	18.6	±199,000	18.1	±140,000	17.5	±93,000
2000	18.5	±185,000	18.1	±140,000	17.8	±114,000	17	±66,000
3750	18.1	±140,000	17.8	±114,000	17.3	±81,000	16.6	±50,000
7500	17.7	±106,000	17.3	±81,000	16.9	±61,000	16.2	±38,000

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

2.14.7 Register for "Function model 1 - Multiple sampling"

2.14.7.1 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 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)

2.14.7.2 A/D converter cycle time

Name:
ConfigCycletime01_MultiSample

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

In order for multiple sampling to work, the X2X cycle time must be divisible by the A/D converter cycle time (i.e. result in a whole number).

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

2.14.7.3 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. This is why it is possible to configure the number of measured values to be transferred (see).

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

2.14.7.4 Module status

Name:
StatusInput01

The current state of the module is indicated in this register.

Data type	Values
USINT	See 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	-	

2.14.7.5 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 7).

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

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
15.4	22,000	14.6	12,000	13.8	7,000	12.8	4,000

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
17.1	70,000	16.7	53,000	16.4	43,000	15.9	31,000

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

2.14.8 Register for "Function model 2 - Extended filter"

2.14.8.1 A/D converter configuration 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 bit structure.

Bit structure:

Bit	Description	Value	Information
			Filter level
0 - 3	IIR low-pass filter	0000	0: IIR low-pass filter switched off
		0001	1
		0010	2
		0011	3
		0100	4
		0101	5
		0110	6
		0111	7
		1000	8
		1001 - 1111	The analog input value indicates an invalid range.
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)

2.14.8.2 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	"Selectable data rate" mode: A selectable data rate is used for the FIR filter (default). Configuration takes place in register "ConfigDatarateOutput01" on page 28.
	1	"High-resolution data rate" mode: A high-resolution data rate is used for the FIR filter. Configuration takes place in register "ConfigHighResolutionOutput01" on page 28.

Name:
ConfigDatarateOutput01

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

Data type	Values
USINT	See 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)

Name:
ConfigHighResolutionOutput01

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

Data type	Values	Information
UINT	0	Disables the FIR filter
	1 to 65,535	0.1 to 6553.5 Hz

2.14.8.3 Module status

Name:
StatusInput01

The current state of the module is indicated in this register. 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 bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter values	0	A/D converter value is valid
		1	A/D converter value is invalid
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	-	

2.14.8.4 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	Function
DINT	-2,147,483,648 to 2,147,483,647	Timestamp [µs] of the last analog conversion

2.14.9 Minimum cycle time

The minimum cycle time defines how far the bus cycle can be reduced without communication errors occurring. Note that very fast cycles decrease the idle time available for handling monitoring, diagnostics and acyclic commands.

Minimum cycle time
250 µs

2.14.10 Minimum I/O update time

The minimum I/O update time defines how far the bus cycle can be reduced while still allowing an I/O update to take place 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 "Selectable data rate" mode" on page 12.

Depending on the setting in register "ConfigCycletime01_MultiSample" on page 25, the I/O update time in "function model 1 - Multiple sampling" is 50 or 100 µs.

3 X20AI1744 - With Rev. <H0

3.1 General information

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.

- 1 full-bridge strain gauge input
- Data output rate configurable from 2.5 Hz to 7.5 kHz
- Special operating modes (synchronous mode and multiple sampling)

3.2 Order data

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

Table 7: X20AI1744 - Order data

3.3 Technical data

Model number	X20AI1744
Short description	
I/O module	1 full-bridge strain gauge input
General information	
B&R ID code	0x1CDE
Status indicators	Channel status, operating status, module status
Diagnostics	
Module run/error	Yes, using status LED and software
Open circuit	Yes, using status LED and software
Input	Yes, using status LED and software
Power consumption	
Bus	0.01 W
Internal I/O	1.25 W
Additional power dissipation caused by the actuators (resistive) [W]	Max. +0.36 [1]
Electrical isolation	
Bus - Analog input	Yes
Bus - Bridge supply voltage	Yes
Channel - I/O power supply	No
Certification	
CE	Yes
KC	Yes
UL	cULus E115267 Industrial control equipment
HazLoc	cCSAus 244665 Process control equipment for hazardous locations Class I, Division 2, Groups ABCD, T5
ATEX	Zone 2, II 3G Ex nA nC IIA T5 Gc IP20, Ta = 0 - Max. 60°C FTZÚ 09 ATEX 0083X
GOST-R	Yes

Table 8: X20AI1744 - Technical data

Model number	X20AI1744
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	2.5 - 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	85 to 5000 Ω
Influence of cable length	The shielded twisted pair cable should be as short as possible and run separately to the sensor (isolated from load circuit) without intermediate terminals
Input protection	RC protection
Common-mode range	0 to 3 VDC Permissible input voltage range (with regard to the potential strain gauge GND) on inputs "Input +" and "Input -"
Isolation voltage between input and bus	500 V_{eff}
Conversion procedure	Sigma-delta
Output of the digital value	
Broken bridge supply line	Value approaches 0
Broken sensor line	Value approaches ±end value ("open circuit" status bit is set in the *Module status* register)
Valid value range	0xFF800001 to 0x007FFFFF (-8,388,607 to 8,388,607)
Strain gauge supply	
Voltage	5.5 VDC / max. 65 mA [3]
Short circuit protection, overload protection	Yes
Voltage drop for short circuit protection	Max. 0.2 VDC at 65 mA
Quantization [4]	
LSB value (16-bit)	
2 mV/V	336 nV
4 mV/V	671 nV
8 mV/V	1.343 µV
16 mV/V	2.686 µV
32 mV/V	5.371 µV
64 mV/V	10.74 µV
128 mV/V	21.48 µV
256 mV/V	42.97 µV
LSB value (24-bit)	
2 mV/V	1.31 nV
4 mV/V	2.62 nV
8 mV/V	5.25 nV
16 mV/V	10.49 nV
32 mV/V	20.98 nV
64 mV/V	41.96 nV
128 mV/V	83.92 nV
256 mV/V	167.85 nV
Temperature coefficient	
Rev. ≥E0	10 ppm/°C
Rev. <E0	30 ppm/°C
Operating conditions	
Mounting orientation	
Horizontal	Yes
Vertical	Yes
Installation at elevations above sea level	
0 to 2000 m	No limitations
>2000 m	Reduction of ambient temperature by 0.5°C per 100 m
EN 60529 protection	IP20
Environmental conditions	
Temperature	
Operation	
Horizontal installation	0 to 55°C
Vertical installation	0 to 50°C
Derating	See section "Hardware configuration"
Storage	-25 to 70°C
Transport	-25 to 70°C

Table 8: X20AI1744 - Technical data

Model number	X20AI1744
Relative humidity	
Operation	5 to 95%, non-condensing
Storage	5 to 95%, non-condensing
Transport	5 to 95%, non-condensing
Mechanical characteristics	
Note	Order 1x terminal block X20TB12 separately Order 1x bus module X20BM11 separately
Spacing	12.5$^{+0.2}$ mm

Table 8: X20AI1744 - 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) The maximum current of 90 mA is permitted up to an operating temperature of 45°C.
4) Quantization depends on the strain gauge factor.

3.4 LED status indicators

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

| Figure	LED	Color	Status	Description
	r	Green	Off	No power to module
			Single flash	RESET mode
			Double flash	BOOT mode (during firmware update)[1]
			Blinking	PREOPERATIONAL mode
			On	RUN mode
	e	Red	Off	No power to module or everything OK
			On	Error or reset status
	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.

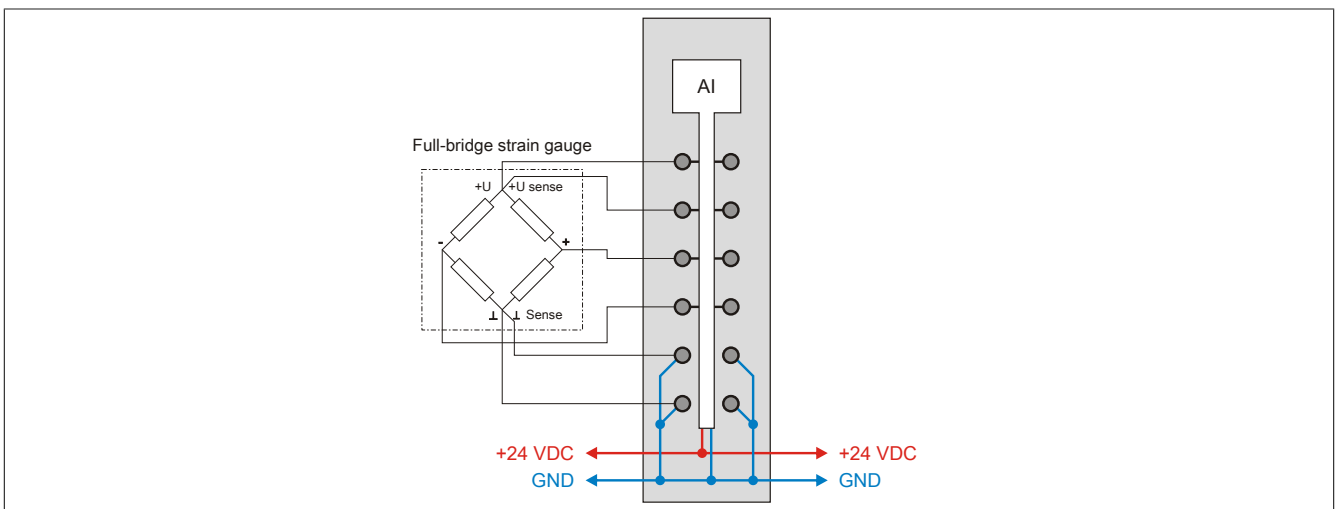## 3.5 Pinout
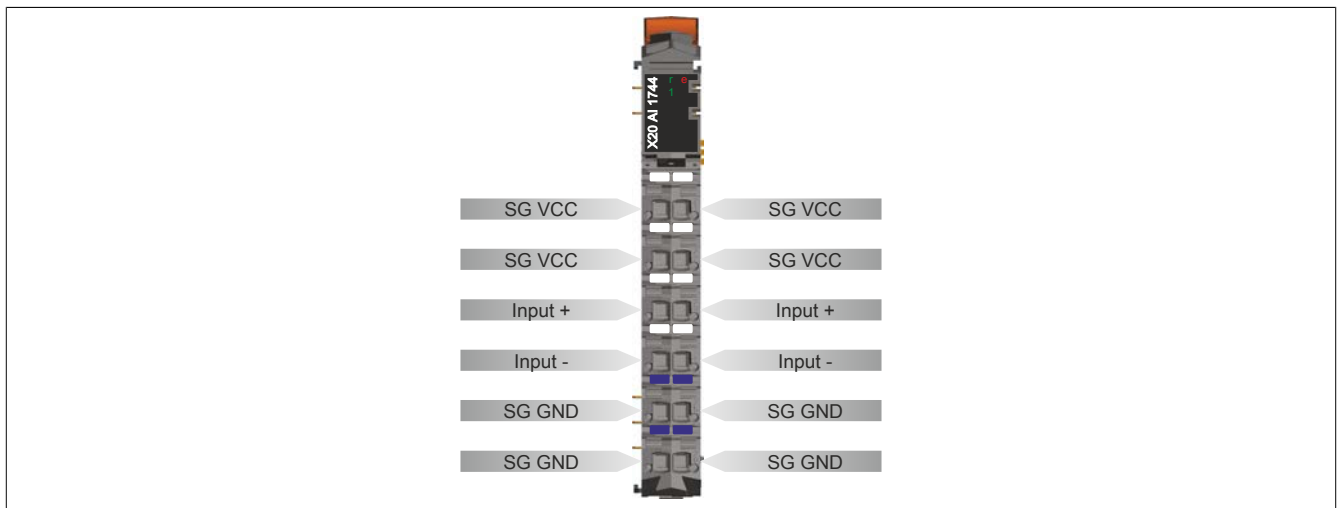
3.6 Connection examples
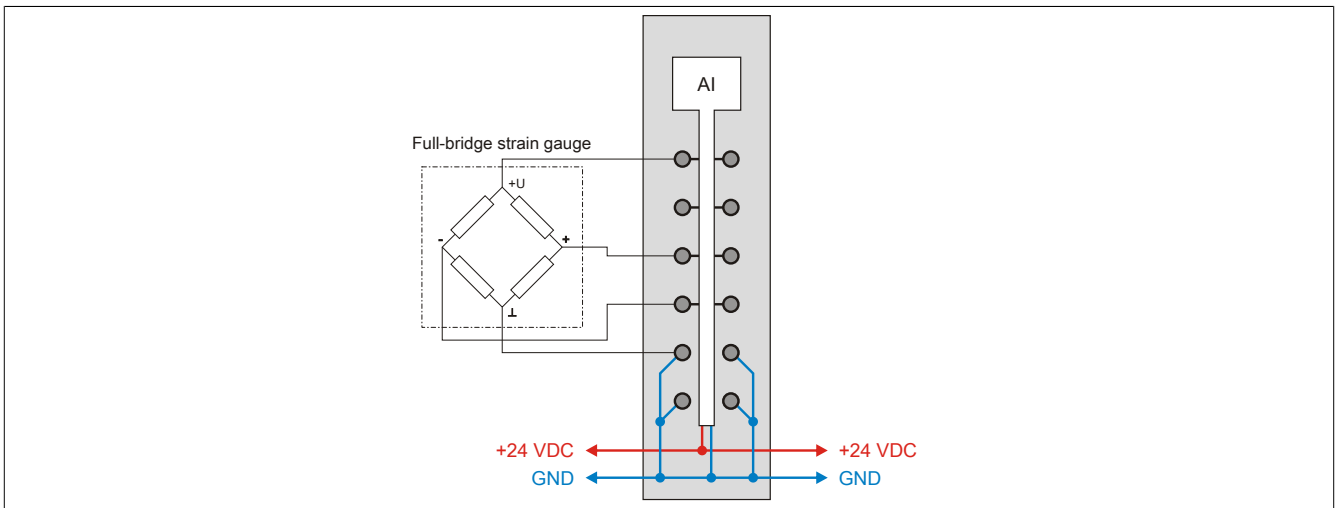
Full-bridge strain gauge with 4-wire connections

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 35). 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.
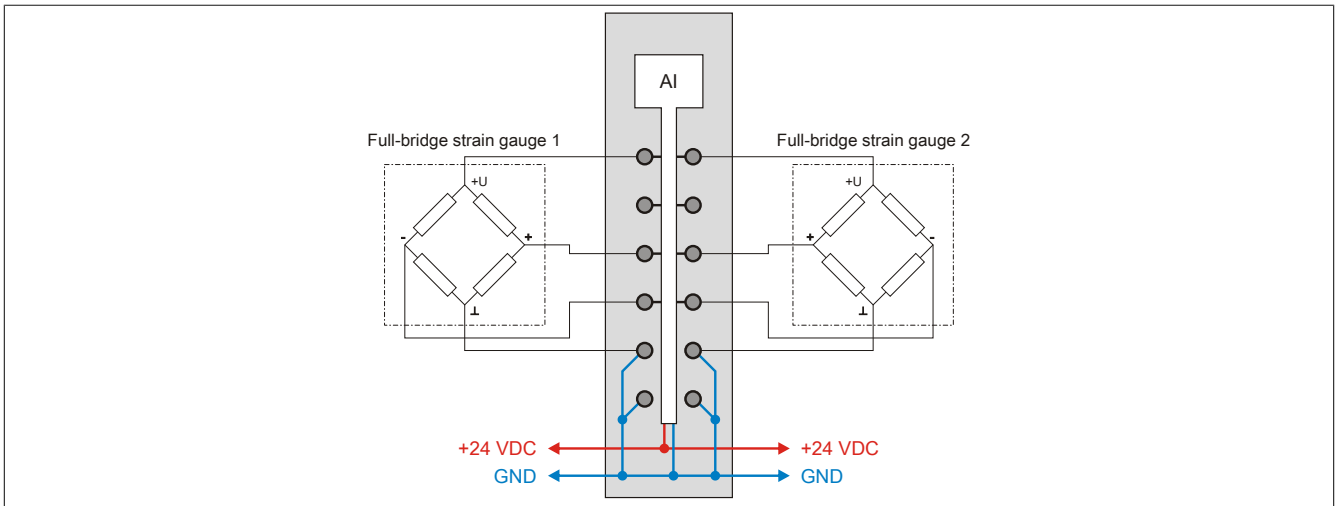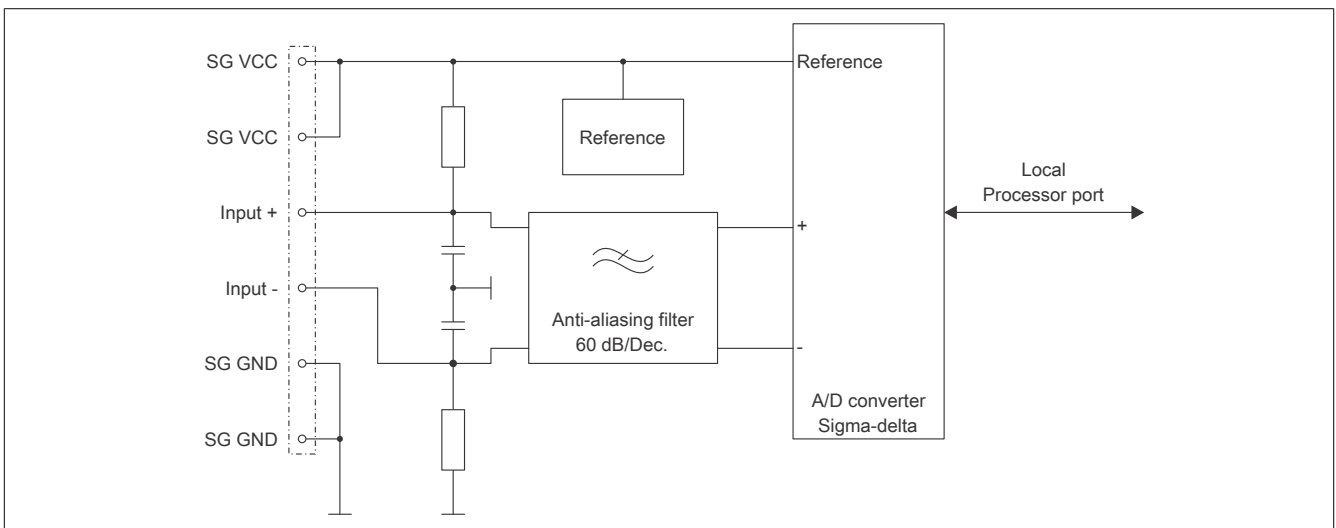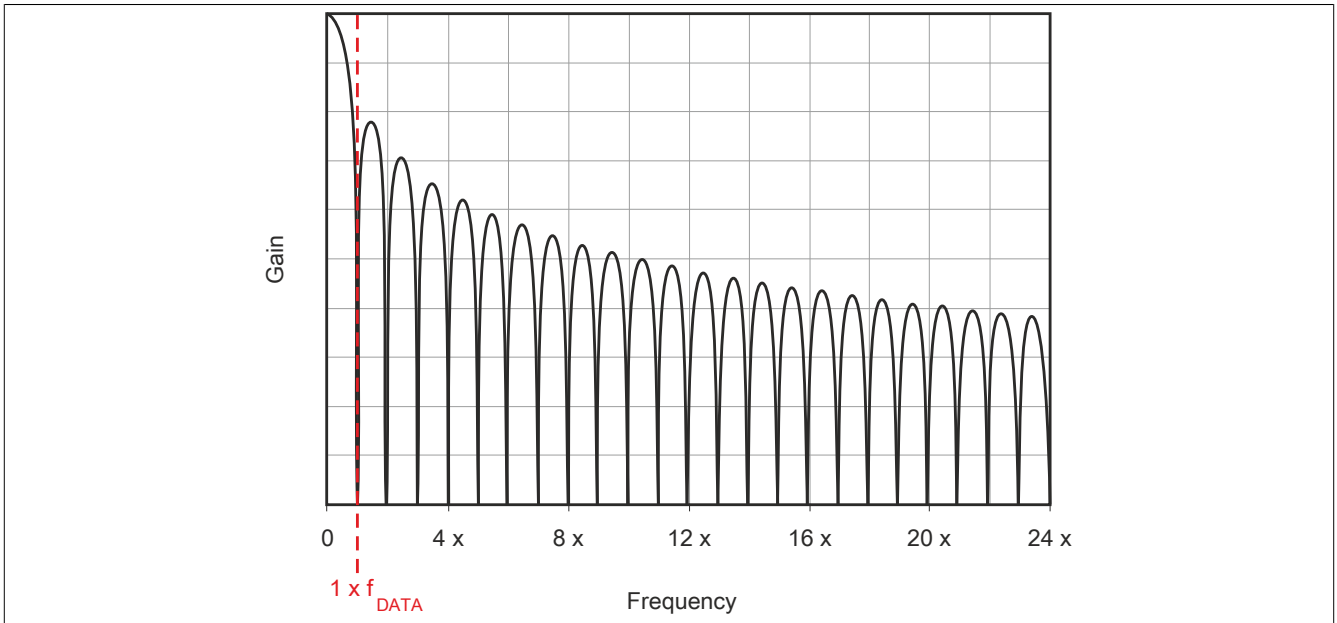

Figure 2: Connection example - Parallel connection of 2 full-bridge strain gauges

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

3.7 Input circuit diagram

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

3.9 Effective resolution of the A/D converter

The A/D converter on 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:

Based on 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 16.6 bits:
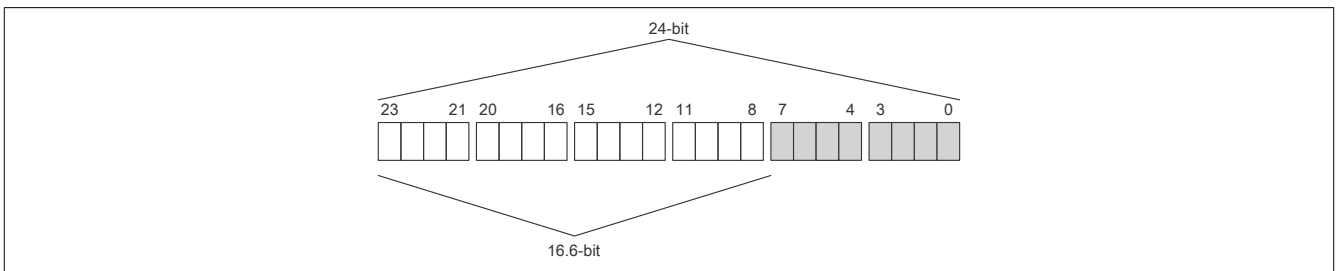
The low-order bits (grayed out) contain only noise instead of valid values and must therefore not be evaluated.

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

3.10 Calculation example / Quantization

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

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

- Rated load: 1000 kg
- Strain gauge factor: 4 mV/V

The value for the positive full-scale deflection at a specified rated load of 1000 kg is derived from the bridge factor of the strain gauge load cell (multiplication with the bridge supply voltage from the module):

4 mV/V × 5.5 V = 22 mV

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	22.0 mV	1000 kg
0x0000 0001	1	2.62 nV	0.119 g
0x0000 20C3	8387	22.0 µV	1 kg
0x0001 0000	65536	171.9 µV	7.81 kg

The values for each LSB can be found in the technical data of the module under "Quantization" (1 LSB in reference to 16-bit and 1 LSB in reference to 24-bit).

3.11 Hardware configuration

3.11.1 Hardware configuration for horizontal installation at 50°C ambient temperature

Operating a strain gauge module

At an ambient temperature of 50°C or higher, a dummy module must be connected to the left of the strain gauge module if installed horizontally.
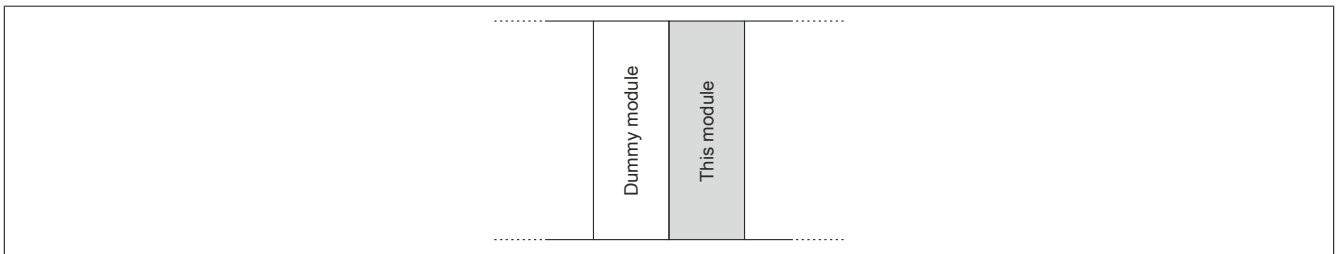
Operating multiple strain gauge modules side by side

If 2 or more horizontal strain gauge modules are being operated in a cluster, the following arrangement of modules must be observed.
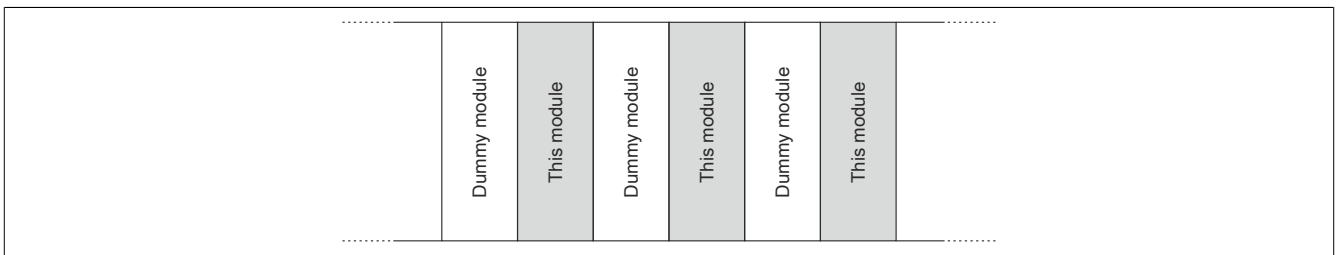
3.11.2 Hardware configuration for vertical installation at 40°C ambient temperature

Operating a strain gauge module

At an ambient temperature of 40°C or higher, a dummy module must be connected to the left of the strain gauge module if installed vertically.

This module
Dummy module

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.

This module
Dummy module
This module
Dummy module
This module
Dummy module
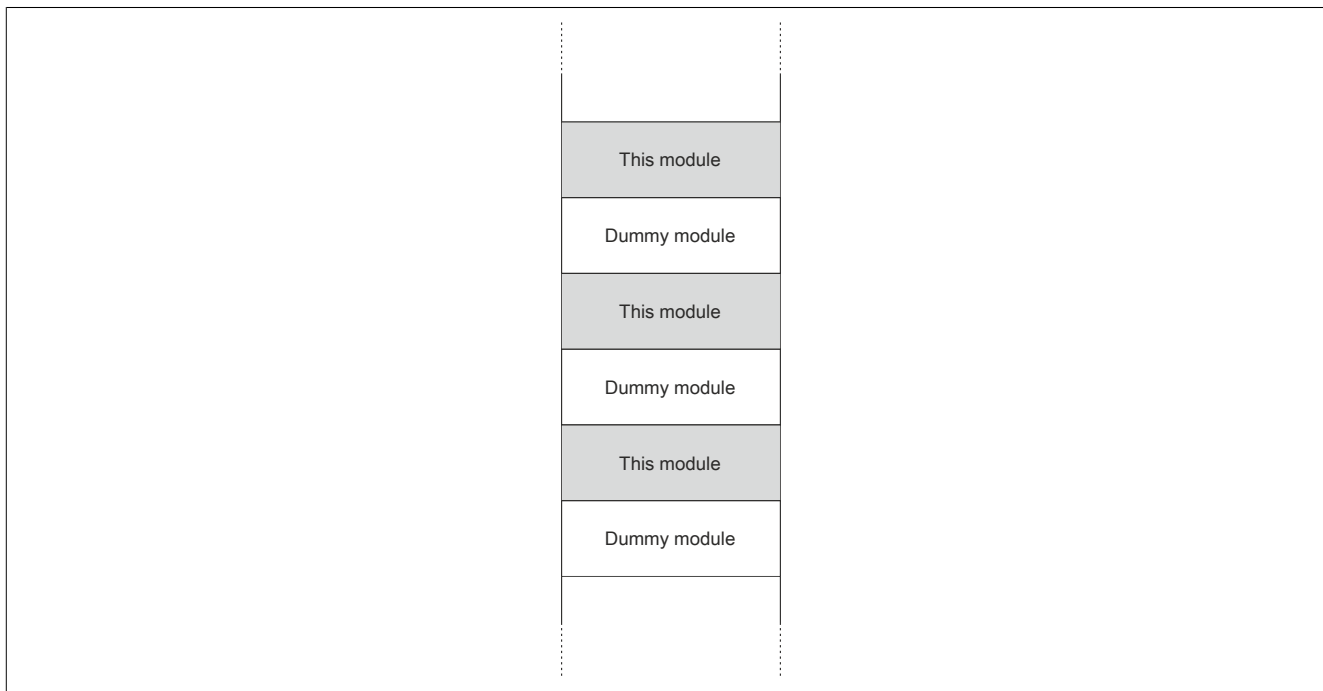
3.12 Register description

3.12.1 General data points

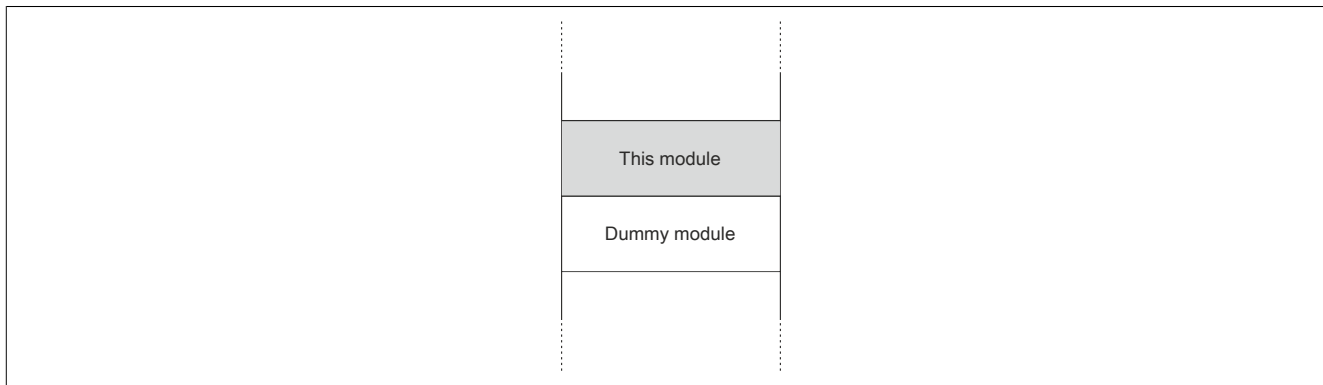In addition to the registers listed in the register description, the module also has other more general data points. These registers are not specific to the module but contain general information such as serial number and hardware version.

These general data points are listed in section "Additional information - General data points" of the X20 system user's manual.

3.12.2 Function model 0 - Standard

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
2	StatusInput01	USINT	●			
4	AnalogInput01	DINT	●			
16	ConfigOutput01	USINT			●	
18	ConfigCycletime01	UINT				●
32	AdcClkFreqShift01[1]	USINT				●

1) Firmware version 8 / Upgrade 1.3.0.0 or higher

3.12.3 Function model 1 - Multiple sampling

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.

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 X2X Link, it is possible to disable unneeded registers (see).

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 through 10th measured value (AnalogInput07 to AnalogInput10) should be disabled by setting Number of measured values to "6 measured values" in the I/O configuration.

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

3.12.4 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 X2X Link even if synchronous mode is activated in register "ConfigOutput01" on page 42. 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	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.

Register	Name	Data type	Read		Write	
			Cyclic	Acyclic	Cyclic	Acyclic
2	StatusInput01	USINT	•			
4	AnalogInput01	DINT	•			
16	ConfigOutput01	USINT			•	
18	ConfigCycletime01	UINT				•
32	AdcClkFreqShift01[1]	USINT				•

1) Firmware version 8 / Upgrade 1.3.0.0 or higher

3.12.5 Register for the "0 - Standard" and "254 - Bus controller" function models

3.12.5.1 Module status

Name:
StatusInput01

The current state of the module is indicated in this register.

Data type	Values
USINT	See bit structure.

Bit structure:

Bit	Description	Value	Information
0	A/D converter value	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	-	

3.12.5.2 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 8,388,606	Valid range
	8,388,607	Positive full-scale deflection / Overflow / Open circuit

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 36).

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

Data rate f_{DATA} [Hz]	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
2.5	21.3	±1,290,000	20.8	±912,000	19.7	±425,000	18.7	±212,000
5	20.7	±851,000	20.3	±645,000	19.3	±322,000	18.3	±161,000
10	20.4	±691,000	19.9	±490,000	18.9	±244,000	17.9	±122,000
15	20.1	±562,000	19.3	±320,000	18.7	±212,000	17.7	±106,000
25	19.7	±425,000	19.2	±301,000	18.5	±185,000	17.5	±92,000
30	19.6	±397,000	19.0	±262,000	18.1	±140,000	17.1	±72,000
50	19.4	±346,000	18.8	±230,000	17.9	±122,000	16.9	±61,000
60	19.3	±320,000	18.8	±230,000	17.8	±114,000	16.8	±57,000
100	19.1	±280,000	18.5	±185,000	17.4	±86,000	16.4	±43,000
500	18.0	±130,000	17.3	±80,000	16.3	±40,000	15.3	±20,000
1000	17.2	±75,000	16.5	±46,000	15.6	±25,000	14.6	±12,000
2000	16.6	±49,600	16.1	±35,000	15.3	±20,000	14.3	±10,000
3750	16.2	±37,600	15.7	±26,600	14.7	±13,000	13.7	±6,600
7500	15.8	±28,500	15.3	±20,200	14.4	±10,800	13.4	±5,400

Table 9: Effective resolution of the strain gauge value in bits for the measurement range 2 to 16 mV/V

Data rate f_{DATA} [Hz]	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
2.5	23	±4,194,000	22.6	±3,179,000	22.1	±2,248,000	21.7	±1,703,000
5	22.3	±2,582,000	22.4	±2,767,000	21.9	±1,957,000	21.3	±1,291,000
10	22.3	±2,582,000	22	±2,097,000	21.6	±1,589,000	21	±1,049,000
15	22	±2,097,000	21.7	±1,703,000	21.3	±1,291,000	20.7	±852,000
25	21.7	±1,703,000	21.4	±1,384,000	21.1	±1,124,000	20.5	±741,000
30	21.8	±1,826,000	21.3	±1,291,000	20.8	±913,000	20.4	±692,000
50	21.3	±1,291,000	21.1	±1,124,000	20.4	±692,000	19.9	±489,000
60	21.3	±1,291,000	20.9	±978,000	20.5	±741,000	19.8	±456,000
100	20.9	±978,000	20.7	±852,000	20.2	±602,000	19.6	±397,000
500	20.1	±562,000	19.6	±397,000	19.1	±281,000	18.6	±199,000
1000	19	±262,000	18.6	±199,000	18.1	±140,000	17.5	±93,000
2000	18.5	±185,000	18.1	±140,000	17.8	±114,000	17	±66,000
3750	18.1	±140,000	17.8	±114,000	17.3	±81,000	16.6	±50,000
7500	17.7	±106,000	17.3	±81,000	16.9	±61,000	16.2	±38,000

Table 10: Effective resolution of the strain gauge value in bits for the measurement range 32 to 256 mV/V

3.12.5.3 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
USINT	See 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	Synchronous mode[1]
		1111	Reserved
4 - 6	Standard measurement range (bit 6 = 0)	000	16 mV/V
		001	8 mV/V
		010	4 mV/V
		011	2 mV/V
	Extended measurement range (bit 6 = 1)[2]	100	256 mV/V
		101	128 mV/V
		110	64 mV/V
		111	32 mV/V
7	Reserved	0	(must be 0)

1) A/D converter is operated synchronously with X2X Link if possible - firmware version 2 or higher.
2) Firmware version 4 or higher

3.12.5.3.1 Synchronous mode

Beginning with firmware version 2, the analog/digital converter (A/D converter) of the module can be operated and read synchronously to X2X Link. Synchronous mode is enabled by selecting the respective operating mode in register "ConfigOutput01" on page 42. A time between 200 and 2000 µs must also be set in register "Config-Cycletime01" on page 43. 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
    A/D converter cycle times >1500 µs
	Max. ±1 µs
	Max. ±4 µs

X2X link dead time	$50 \ \mu s + \dfrac{X2X \ cycle \ time}{128}$

Settling time
    Firmware version ≤4
    Firmware version ≥5
	Max. 150 x A/D converter cycle 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.

3.12.5.4 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 X2X Link (based on the A/D converter cycle time set in this register). It is of course necessary for the X2X Link cycle time and the A/D converter cycle time to have a certain ratio. 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	Value
UINT	50 to 2000

3.12.5.5 A/D converter clock frequency shift

Name:

AdcClkFreqShift01

In rare cases, strain gauge modules connected to neighboring slots can influence one another. This can result in temporary, minimal deviations in measured values. This can only occur if the sigma-delta A/D converters on the neighboring strain gauge modules are operated at exactly the same clock frequency.

In most cases, these clock frequencies vary slightly due to part variances. When they are the same however, this register on the strain gauge module provides a safe way for an application to prevent this type of mutual influence.

Data type	Value
SINT	-128 to 127

This register can be used to vary the clock frequency in increments of 200 ppm. Setting values from -50 to 50 cover a range of -10000 ppm to 10000 ppm. This corresponds with -1% to 1%.

Values beyond this range will cause activation of a default mode. The frequency shift is derived from the last 2 digits of the serial number by the module firmware. This saves time that would otherwise be needed for programming, provided that the last two digits of the serial numbers on the neighboring modules are not the same

Register value	Frequency shift in ppm	Example of a sampling rate[1]
127	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number
...	...	...
51	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the 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	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number
...	...	...
-128	((SerialNo. modulo 100) - 50) * (-200) ppm	Based on the serial number

1)   Nominal sampling rate of 500 samples per second

Important:

As shown in the table above, shifting the A/D converter clock frequency will equally shift the A/D converter sampling rate. Shifting the A/D converter clock frequency too much can cause problems with disturbance suppression particularly when a very specific sampling rate has been defined to suppress existing disturbances (e.g. 50 Hz to suppress the 50 Hz hum). See also "Filter characteristics of the sigma-delta A/D converter" on page 36.
It's situations like this where the option to manually shift the frequency in the I/O configuration or ASIOACC library should be utilized rather than relying on the default frequency shift that is based on the serial number.

A frequency shift like the one shown below would be sufficient to prevent modules from influencing one another and would not cause any noticeable difference to the filter characteristics.

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

> **Information:**
>
> - **This register has no effect in synchronous mode because the firmware regulates the A/D converter clock frequency in such a way that the A/D converter cycle is synchronous with the X2X cycle.**
> - **When writing to this register using the ASIOACC library, only the lowest value byte of the written value is accepted. For example, the value 256 (=0x100) is identical to the value 0 (=0x00).**

3.12.6 Register for "Function model 1 - Multiple sampling"

3.12.6.1 Module status

Name:
StatusInput01

The current state of the module is indicated in this register.

Data type	Values
USINT	See 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	-	

3.12.6.2 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).

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

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
15.4	22,000	14.6	12,000	13.8	7,000	12.8	4,000

Table 11: 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
17.1	70,000	16.7	53,000	16.4	43,000	15.9	31,000

Table 12: Effective resolution of the strain gauge value in bits for the measurement range 32 to 256 mV/V

3.12.6.3 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 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)[1]	100	256 mV/V
		101	128 mV/V
		110	64 mV/V
		111	32 mV/V
3 - 7	Reserved	0	(must be 0)

[1] Firmware V4 and later. In the standard measurement range (2 to 16 mV/V), open-circuit detection works reliably at all adjustable data rates. In the extended measurement range (32 to 256 mV/V), open circuit detection does not work reliably (because of the variable input impedance of the amplifier in relation to the set data rate).

3.12.6.4 A/D converter cycle time

Name:
ConfigCycletime01_MultiSample

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

In order for multiple sampling to work, the X2X cycle time must be divisible by the A/D converter cycle time (i.e. result in a whole number).

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

3.12.6.5 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. This is why it is possible to configure the number of measured values to be transferred (see "Function model 1 - Multiple sampling" on page 39).

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

3.12.7 Minimum cycle time

The minimum cycle time defines how far the bus cycle can be reduced without communication errors occurring. Note that very fast cycles decrease the idle time available for handling monitoring, diagnostics and acyclic commands.

Minimum cycle time
250 µs

3.12.8 Minimum I/O update time

The minimum I/O update time defines how far the bus cycle can be reduced while still allowing an I/O update to take place in each cycle.

There is no limitation or basic dependency on the bus cycle time. In function model "0 - Standard", the I/O update time is defined using registers "ConfigOutput01" on page 42 and "ConfigCycletime01" on page 43.

Depending on the setting in register "ConfigCycletime01_MultiSample" on page 46, the I/O update time in function model "1 - Multiple sampling" is 50 or 100 µs.