10.4 AI261

10.4.1 Technical Data

Module ID	**AI261**
General Information	
Model Number	7AI261.7
Short Description	2003 analog input module, 1 input for evaluation of full-bridge strain gauge, 24 bit, screw-in module
C-UL-US Listed	Yes
B&R ID Code	$20
Slot	AF101 adapter module, CP interface
Static Characteristics	
Module Type	B&R 2003 screw-in module
Input Type	Differential
Number of Inputs	1
Affects 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
Shielding	
Module Side	Using stress relief clamp on the module
Sensor Side	Using HF foil capacitor 10 nF/630 V to grounded sensor housing (use short connection lines)
Maximum Continuous Overload (without damage)	+30 V for all connections except GND
Output of the Digital Value during Overload	
Broken Supply Line	Value goes to 0
Broken Sensor Line	Value goes to ±limit
Software Evaluation	Evaluation using configuration word 12 (module status)
Digital Converter Resolution	24 Bit
Effective Converter Resolution	See Table "Effective Resolution of the Measurement Range in Bits"

Module ID	AI261
Quantization Measurement Range ±1...2 mV/V Measurement Range ±3...4 mV/V Measurement Range ±5..0.8 mV/V Measurement Range ±9...15 mV/V	LSB value (16 Bit) 275 nV 550 nV 1.1 µV 2.2 µV
Data Format Delivered to the Application Program	Set using software
Measurement Value Preparation Calibration Linearization Conversion	 Using software, also during operation y = k * x + d To physical units (32 bit representation)
Measurement Range	±1 to ±16 mV/V, Set using software
Input Current	<140 nA
Operating Range / Measurement Sensor	75 to 5000 Ω
Bridge Voltage Short Circuit and Overload Protection Connection	4.5 VDC ±3 % / max. 60 mA Yes 4-line connection Connection of a 6-line strain gauge cell (see section "6-Line Strain Gauge Cell")
Conversion Method	Sigma Delta
Conversion Time	1 ms
Analog Input Measurement Error Maximum Error at 25 °C Temperature Coefficient Maximum Error over Complete Temperature Range	 ±55 ppm ±11 µV ±3 ppm/°C ±1.1 µV/°C ±0.016 % ±50 µV
Sensor Type	Isolated
Common Mode Rejection	>120 dB at 50 / 60 Hz Scan Frequency ≥ 75 Hz
Common Mode Voltage	1.2 to 3.8 V
Protection	RC protection
Internal Power Consumption	Max. 0.6 W
Dynamic Characteristics	
Application Scan Time	4 - 100 ms
Data Output Rate on the Module	7 - 500 Hz, can be set using software
Scan Repeat Time	1 / data output rate
Response Time 1 LSB Data Output Rate > 100 Hz Data Output Rate ≤ 100 Hz	 Approx. 250 ms Approx. 500 ms
Input Filter Characteristics Order Transition / Cut-off Frequency	 1st 6 Hz also see diagram "Transient Behavior as Load Changes"
Software Filter 3 dB Cut-off Frequency 64 dB Frequency (1st notch)	 0.0395 x data output rate 0.14 x data output rate
Operating Characteristics	
Isolation Voltage under Normal Operating Conditions between Channel and Bus	No electrical isolation
Missing Codes	Yes, if output range > converter resolution
Non-linearity	±0.0015 % of final value
Mechanical Properties	
Dimensions	B&R 2003 screw-in module

10.4.2 General Information

A full-bridge strain gauge can be used for the following tasks:

- Force measurement
- Elasticity measurement
- Weight measurement
- Pressure measurement
- Stress measurement
- Torque measurement

10.4.3 Effective Resolution of the Measurement Range in Bits

The following table contains an overview of the effective resolution of the measurement range in bits. The corresponding conversion range is given next to it.
The data output rate for the hardware lies between 50 Hz and 500 Hz. Output rates of <50 Hz can also be set in software.
This output rate is achieved because the convertor read out at 8x the set output rate. For the calculation, eight values are added together and then divided by eight.
To determine the effective resolution, look in the table for 8 times the set data output rate.

Example

Set output rate: 25 Hz for a measurement range of 2 mV/V

Effective resolution: 8x set data output rate:
25 Hz x 8 = 200 Hz ⇒ 15 bit or ±18000

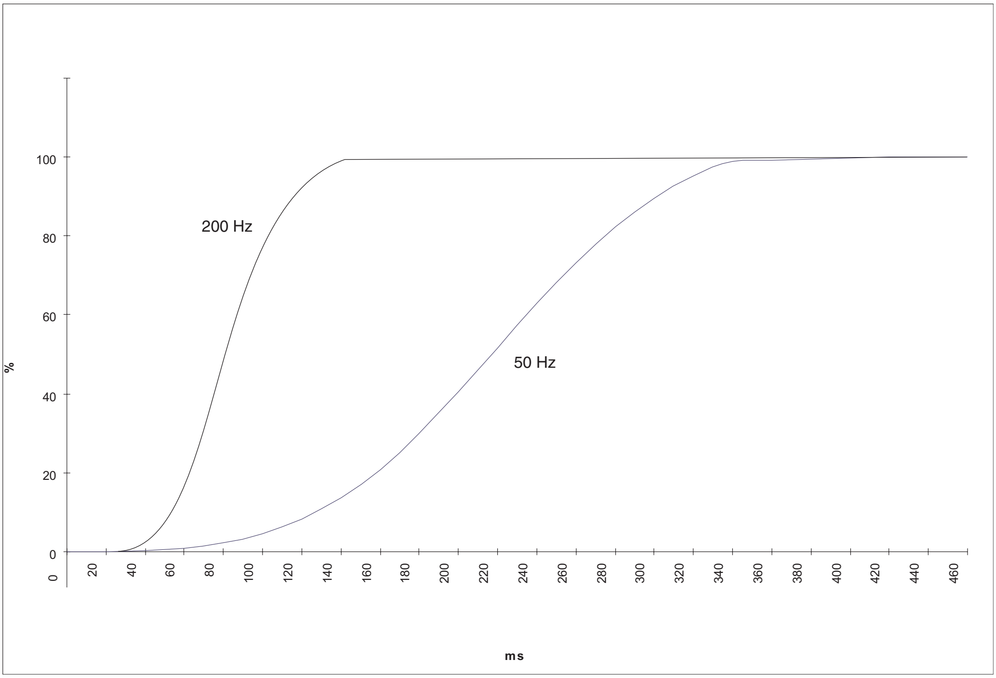
Data Output Rate		Measurement Range							
HW	SW	±2 mV/V		±4 mV/V		±8 mV/V		±16 mV/V	
50 Hz	7 Hz	16 Bit	±35000	16.5 Bit	±50000	17 Bit	±69000	17.5 Bit	±99000
100 Hz	12 Hz	15.5 Bit	±25000	16 Bit	±33000	16.5 Bit	±51000	17 Bit	±69000
150 Hz	18 Hz	15.5 Bit	±20000	16 Bit	±29000	16.5 Bit	±42000	17 Bit	±56000
200 Hz	25 Hz	15 Bit	±18000	15 Bit	±27000	16 Bit	±36000	16.5 Bit	±49000
400 Hz	49 Hz	14.5 Bit	±11000	15 Bit	±18000	15.5 Bit	±24000	16 Bit	±36000

10.4.4 Transient Behavior as Load Changes

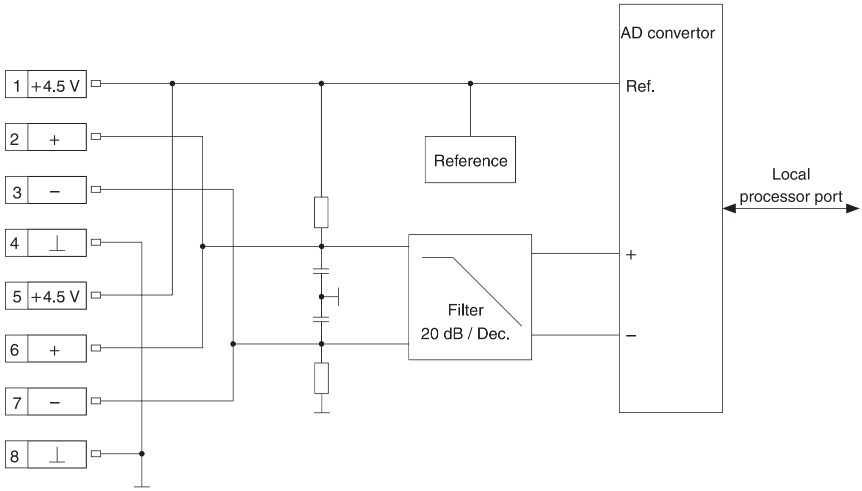
The following diagram shows the transient behavior as the load changes in relation to the data output rate:

Curve 1 ..... Data output rate = 50 Hz

Curve 2 ..... Data output rate = 200 Hz



10.4.5 Input Circuit Diagram

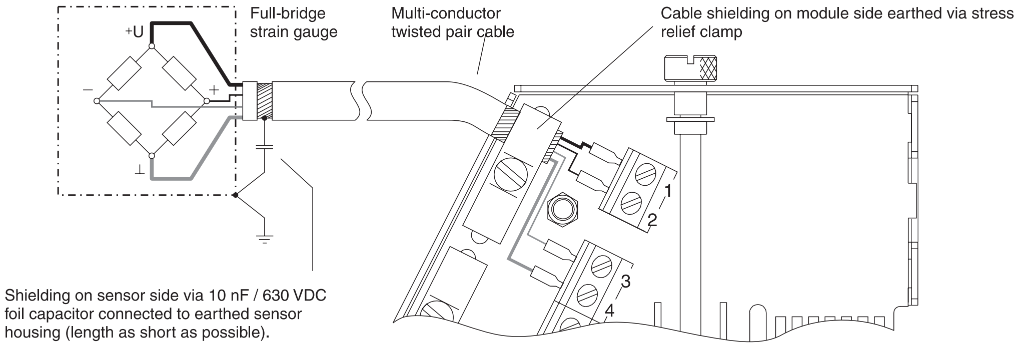


10.4.6 Connection

Terminal Assignments

Connection	Designation	Description
1	+4.5 V	+4.5 V strain gauge supply
2	+	Differential input
3	-	
4	⊥	GND
5	+4.5 V	+4.5 V strain gauge supply
6	+	Differential input
7	-	
8	⊥	GND

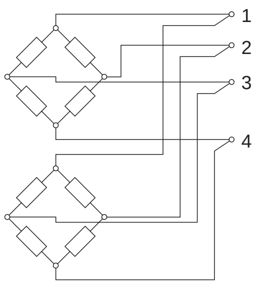
Full-Bridge Strain Gauge Wiring



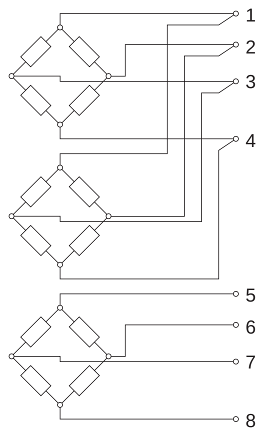
Parallel Connection

For parallel connection of full-bridge strain gauges, please refer to the manufacturer's guidelines.

Parallel connection of two full-bridge strain gauges



Parallel connection of three full-bridge strain gauges



10.4.7 6-Line Strain Gauge Cells

General Information

Precision can be improved by using strain gauge cells with feedback of the bridge voltage. The additional sensor lines compensate for the thermal resistance of the feed lines.

4-Line Concept of the AI261

AI261 modules work with 4-line strain gauge cells. The AI261 concept requires compensation in the measurement system. This compensation eliminates all absolute uncertainty in the measurement circuit, such as component tolerances, effective bridge voltage, or zero offset.
The measurement precision refers to the absolute (compensated) value which will only change as a result of changes in operating temperature.

6-Line Strain Gauge Cells on the AI261

If a 6-line strain gauge cell is connected to the AI261, the line compensation no longer functions. The measurement precision is therefore susceptible to changes in operating temperature. Long cable runs and small cable cross-sections used between the evaluation device (AI261) and the strain gauge cell increase the probability of errors in the measurement system.
The following example shows the discrepancy between the measured value and the actual value when the operating temperature range lies between 25 °C and 55 °C.

<u>Entry</u>

Designation	Value
Accepted (classic) working range	25 °C to 55 °C (ΔT = 30 °C)
Bridge resistance (input resistance)	300 Ω
Copper connection cable, temperature coefficient	0.39 %/K

<u>Formulas for calculation of the table entries</u>

Designation	Formula
Line resistance	$R = 2 * l / (\gamma * A)$ R = 2 * cable length [m] / (56 * cross-section [mm^2])
Resistance change	$\Delta R = R * 0.39 \% * \Delta T$ $\Delta R = R * 0.0039 * 30$
Temperature effects in ppm	(ΔR / Bridge resistance) * 10^6 $(\Delta R / 300) * 10^6$
Temperature effects in %	(ΔR / Bridge resistance) * 100 $(\Delta R / 300) * 100$

Calculated examples for different cable lengths and cross-sections

Designation	Unit	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7
Cable length	[m]	10	6	6	6	6	6	4
Cross section	[mm^2]	0.25	0.14	0.25	0.22	0.34	0.5	0.5
Resistance (forward and return line)	[Ω]	1.43	1.54	0.86	0.98	0.64	0.43	0.29
Resistance change at ΔT = 30 °C	[mΩ]	168	181	101	115	75	51	34
Temperature effects	[ppm]	560	604	337	384	250	170	114
Temperature effects	[%]	0.056	0.060	0.034	0.038	0.025	0.017	0.011
Deviation for measurement range 0 to 1000 kg	[g]	560	604	337	384	250	170	114

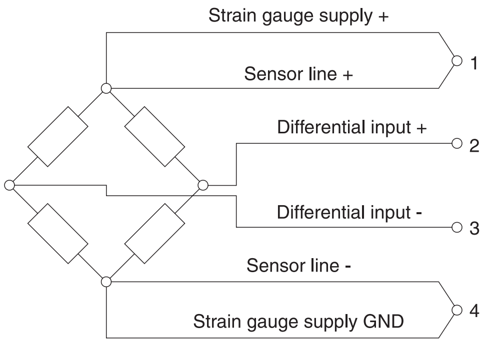
Wiring

In order to reduce cable resistance, the sense lines for 6-line connection should be connected in parallel with the supply lines.
Optimal signal quality can be obtained by using shielded, twisted pair (data) cable. The connections for the two strain gauge supply voltage lines (input), the two sensor lines, and the two bridge differential voltage lines (output) should each use one twisted pair cable run respectively .

Pair 1: Strain gauge supply +
Strain gauge supply GND

Pair 2: Sensor line +
Sensor line -

Pair 3: Differential input +
Differential input -



10.4.8 Variable Declaration

The variable declaration is valid for the following controllers:

- 2003 PCC CPU
- Remote I/O Bus Controller
- CAN Bus Controller

The variable declaration is made in PG2000. The variable declaration is described in Chapter 4, "Module Addressing".

Automation Studio™ Support: See Automation Studio™ Help starting with V 1.40

Accessing screw-in modules is also explained in the sections "AF101" and "CPU".

Data access takes place using data and configuration words. The following table provides an overview of which data and configuration words are used for this module.

Data Access	VD Data Type	VD Module Type	VD Chan.	R	W	Description
Data word 0	LONG	Transp. In	0	●		Standardized value or calibrated raw value
Configuration word 4	LONG	Transp. In	8	●		Calibrated raw value during standardizing/taring
	LONG	Transp. Out	8		●	Reference value/tare value as calibrated raw value
Configuration word 6	LONG	Transp. Out	12		●	Standardized reference value/tare value
Configuration word 8	WORD	Transp. Out	16		●	Command number for standardizing and taring
Configuration word 9	WORD	Transp. Out	18		●	Sensor damping
Configuration word 10	WORD	Transp. Out	20		●	Data output rate of the converter
Configuration word 12	WORD	Transp. In	24	●		Module status
Configuration word 14	WORD	Transp. In	28	●		Module type
	WORD	Transp. Out	28		●	Module configuration

10.4.9 Access using CAN Identifiers

Access via CAN Identifiers is used if the slave is being controlled by a device from another manufacturer. Access via CAN Identifiers is described in an example in Chapter 4, "Module Addressing".
The transfer modes are explained in Chapter 5, "CAN Bus Controller Functions".

Data cannot be packed on the AI261. Therefore one CAN object is transferred per screw-in module. If an adapter module AF101 is equipped with a four AI261 modules, the CAN object has the following structure:

Slot	CAN ID [1]	Word 1		Word 2		Word 3	Word 4
1	542	Data LL	Data ML	Data MH	Data HH	Not used (2 byte data)	
2	543	Data LL	Data ML	Data MH	Data HH	Not used (2 byte data)	
3	544	Data LL	Data ML	Data MH	Data HH	Not used (2 byte data)	
4	545	Data LL	Data ML	Data MH	Data HH	Not used (2 byte data)	

[1] CAN ID = 542 + (nd - 1) x 16 + (ma - 1) x 4 + (sl - 1)

nd ..... Node number of the CAN slave = 1

ma .... Module address of the AF101 = 1

sl .... Slot number of the screw-in module on the AF101 (1 - 4)

B&R 2000 users have to exchange the data so that the high data is first (Motorola format)!

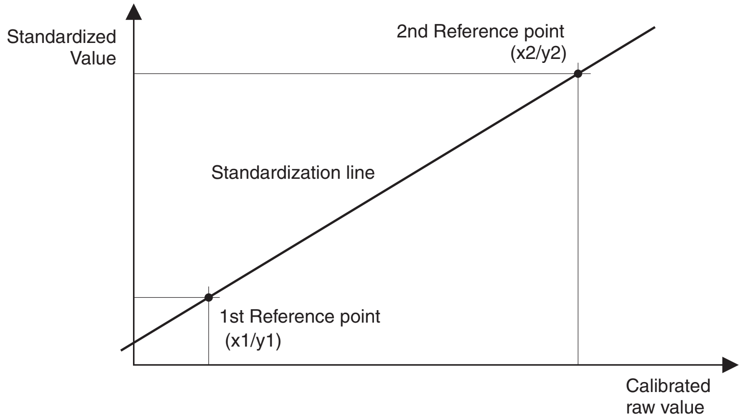
For more information on ID allocation, see Chapter 5, "CAN Bus Controller Functions".

Chapter 3 B&R 2003 Modules

10.4.10 Terms

The following terms are used to describe data and configuration words:

Term	Description
Calibrated raw value	Corresponds to the converter value aligned to sensor damping
Standardized value	Corresponds to the calibrated raw value converted to a physical unit
Standardization line	The calibrated raw value is converted to a standardized value along this line
1st / 2nd reference point	The standardizing line is calculated using these coordinates



10.4.11 Description of Data and Configuration Words

Data Words 0+1 (read)

Data words 0 and 1 contain the standardized value or the calibrated raw value from the full-bridge strain gauge with 24 bit resolution.

Value Range	
Valid value range	$007FFFFF to $FF800001
Overflow	$7FFFFFFF
Underflow	$80000001
Invalid value	$80000000

Configuration Words 4+5 (read)

During standardization or taring, configuration words 4 and 5 contain the calibrated raw value for the 1st or 2nd reference point of the standardization lines determined by the module.

Configuration Words 4+5 (write)

Configuration words 4 and 5 defines either the first or second reference point as a calibrated raw value.

Configuration Words 6+7 (write)

Configuration words 6 and 7 defines either the first or second reference point as standardized value.

Configuration Word 8 (write)

Configuration word 8 defines the command number for standardization and taring.

Bit	Description
8 - 15	0
4 - 7	Command number for standardization and taring 0............No effects 1 - 5.......See sections "Standardization" and "Taring" 6 - 15.....Reserved
0 - 3	0

15							8	7							0
0	0	0	0	0	0	0	0					0	0	0	0

Configuration Word 9 (write)

Configuration word 9 defines sensor damping. When output of calibrated raw values is set, the convertor and value output are started (configuration word 14 = $x800).

Value range: 1 mV/V to 16 mV/V

0 is not allowed
(error code 5000, supplementary code k30ma see App. B "Error Messages")

Configuration Word 10 (write)

Configuration word 10 defines the data output rate of the convertor.

Value range: 7 to 500

0 is not allowed
(error code 5000, supplementary code k30ma see App. B "Error Messages")

See also, section "Effective Resolution of the Measurement Range in Bits"

Configuration Word 12 (read)

Configuration word 12 contains the module status (current status unlatched).

Bit	Description
12 - 15	x .... Not defined, masked out
11	0 .... Converter value ready 1 .... Converter value not yet ready
10	x .... Not defined, masked out
9	0 .... Wait for the first conversion after setting the damping 1 .... The first conversion after setting the damping has taken place
8	0 .... Command to set damping has not yet arrived 1 .... Command to set damping has arrived, Bit 9 cleared
4 - 7	If this bit pattern is the same as the command number defined in configuration word 8, the command is executed.
3	x .... Not defined, masked out
2	0 .... Converter parameter settings are OK 1 .... Converter parameter settings are invalid
1	0 .... Sensor supply is OK 1 .... Sensor supply is overloaded
0	0 .... Reference voltage is OK 1 .... Reference voltage not available

15							8	7							0
x	x	x	x		x							x			

Configuration Word 14 (read)

The High Byte of configuration word 14 defines the module code.

Bit	Description
8 - 15	Module code = $20
0 - 7	x .... Not defined, masked out

15							8	7							0
0	0	1	0	0	0	0	0	x	x	x	x	x	x	x	x

Configuration Word 14 (write)

The module is configured using configuration word 14.

Bit	Description
14 - 15	0
13	0 .... The standardized value or calibrated raw value from the full-bridge strain gauge will be entered in data words 0 and 1, according to the data output rate. 1 .... The standardized value or calibrated raw value from the full-bridge strain gauge will be entered in data words 0 and 1, according to the data output rate. Once the value has been read, the word will be set to invalid ($80000000). This ensures that the value is only read once per data cycle. **Attention:** When operated on the CP interface on an AF101 module with a revision ≥ 02.00, automatic mode must be switched off on the CPU or on the AF101 module!
12	0
11	0 .... Output of the converter value as a standardized value from the full-bridge strain gauge. 1 .... Output of the converter value as raw value calibrated to the sensor damping.
0 - 10	0

15							8	7							0
0	0		0		0	0	0	0	0	0	0	0	0	0	0

10.4.12 AI261 Start-up

An example program is available from B&R. This program explains how to use the AI261.
If you are interested in obtaining this program, contact your local sales representative.

The following steps should be carried out during start-up

Step	Configuration Word	Description
1	14	Configure module
2	10	Define the data output rate of the converter
3	9	Define the sensor damping. When output of calibrated raw values is set, the converter will be started and value output begins (configuration word 14 = $x800).
4		When standardized values are used, (configuration word 14 = $x000) standardizing/taring must be carried out at this point. The converter and value output are started in command number 4 or 5.

10.4.13 Standardization

Through standardization, the calibrated raw value is assigned a value corresponding to the physical unit. The conversion takes place along a standardization line.

The line equation is

$$y = k * x + d$$

y ...... standardized value
k ...... slope
x ...... calibrated raw value
d ..... y, if x = 0 (Offset)

There are two types of standardization:

- Establishing the standardization line
  (the calibrated raw values for the reference points are not known)
- Standardization when booting
  (standardization line already known)

Establishing the standardization line

This type of standardization is carried out if the calibrated raw values for the reference points are not already known. This is the case when:

- the system is first put into operation.
- the process conditions have changed.

<u>The following commands must be carried out</u>

No.	Commands to carry out
1	Set up conditions for the first reference point (weight, pressure, torque etc.).
2	Enter command number 1 ($0010) in configuration value 8. The converter determines the first reference point of the standardization line.
3	Poll configuration word 12 until the acknowledgement ($xx1x) is received after approx. 1 s.
4	Read the values from configuration words 4+5. These contain the calibrated raw value of the first reference point.
5	Save the calibrated raw value. It must be entered each time the system is booted or after each reset (see "Standardization when booting ").
6	Write the calibrated raw value to configuration words 4+5.
7	Write the standardized value corresponding to the calibrated raw value to configuration words 6+7.
8	Enter command number 2 ($0020) in configuration word 8. The values in configuration words 4+5 and 6+7 will be taken as the first reference point of the standardization line.
9	Poll configuration word 12 until the acknowledgement ($xx2x) is received after <100 ms.
10	Set up conditions for the second reference point
11	Enter command number 3 ($0030) in configuration word 8. The converter determines the second reference point for the standardization line.
12	Poll configuration word 12 until the acknowledgement ($xx3x) is received after approx. 1 s.
13	Read the values from configuration words 4+5. These contain the calibrated raw value of the second reference point.
14	Save the calibrated raw value. It must be entered each time the system is booted or after each reset (see "Standardization when booting").
15	Write the calibrated raw value to configuration words 4+5.
16	Write the standardized value corresponding to the calibrated raw value to configuration words 6+7.
17	Enter command number 4 ($0040) in configuration word 8. The values in configuration words 4+5 and 6+7 are used as the second reference point of the standardization line, the standardization parameters are calculated, the conversion procedure and value output are started.
18	Poll configuration word 12 until the acknowledgement ($xx4x) is received after <100 ms.

Standardization when booting

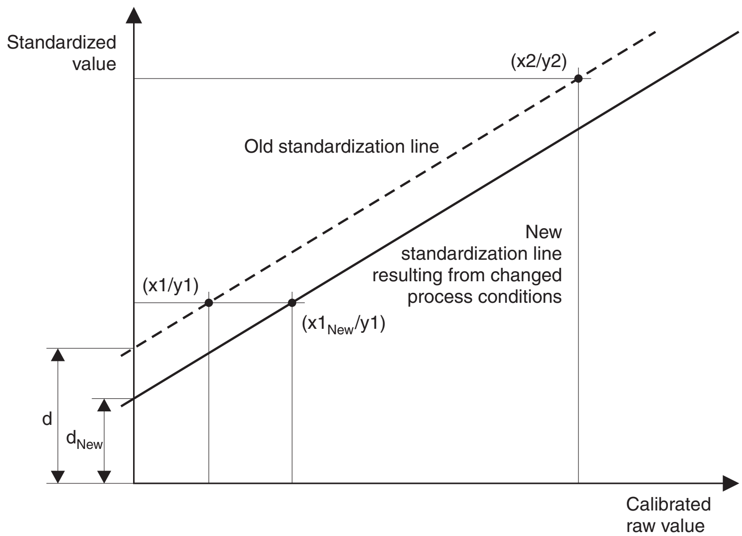
This type of standardization is carried out if the standardization line is already known (calibrated raw values for the reference points are already known). Carried out during each boot procedure or after resetting the system.

The following commands must be carried out

No.	Commands to carry out
1	Write the calibrated raw value for the first reference point on the standardization line to configuration words 4+5. The calibrated raw values for the first and second reference points are determined while establishing the standardization line.
2	Write the standardized value corresponding to the calibrated raw value in configuration words 6+7.
3	Enter command number 2 ($0020) in configuration word 8. The values in configuration words 4+5 and 6+7 are used as the first reference point of the standardization line.
4	Poll configuration word 12 until the acknowledgement ($xx2x) is received after <100 ms.
5	Write the calibrated raw value for the second reference point of the standardization line to configuration words 4+5 .
6	Write the standardized value corresponding to the calibrated raw value in configuration words 6+7.
7	Enter command number 4 ($0040) in configuration word 8. The values in configuration words 4+5 and 6+7 are used as the second reference point of the standardization line, the standardization parameters are calculated, the conversion procedure and value output is started.
8	Poll configuration value 12 until the acknowledgement ($xx4x) is received after <100 ms.

10.4.14 Taring

Tarig is necessary if the standardization line is shifted because of the process but the slope remains the same. During taring, the offset of the standardization line is recalculated (d_{new}).



Taring can take place any time during operation under the following conditions:

- A standardization must have been carried out
- The conditions for the first reference point must be fulfilled

The following commands must be carried out

No.	Commands to carry out
1	Set conditions corresponding to the first reference point (weight, pressure, torque etc.).
2	Enter command number 1 ($0010) in configuration word 8. The converter determines the first reference point of the standardization line.
3	Poll configuration word 12 until the acknowledgement ($xx1x) is received after approx. 1 s.
4	Read the value from configuration word 4+5. This contains the raw value for the first reference point.
5	Write the calibrated raw value in configuration words 4+5.
6	Write the standardized value corresponding to the calibrated raw value to configuration words 6+7.
7	Enter command number 5 ($0050) in configuration word 8. The values in configuration words 4+5 and 6+7 are used as the first reference point for the standardization line and the new offset value for the standardization line is calculated without changing the gradient (d_{new} - see graph above). Then the conversion procedure and value output are started.
8	Poll configuration word 12 until the acknowledgement ($xx5x) is received after <100 ms.

Carrying Out Taring

If the process requires that taring be carried out, it must be done each time the system boots.

<u>The following tips will help you to do this correctly</u>

- For frequently changing process conditions, follow the instructions given in the table above.
- For infrequently changing process conditions, the new raw value for the lower limit point can be saved and the procedure listed above can be started at command 5, "Write calibrated raw value in configuration words 4+5".
  Another possibility is to change the raw value for the upper limit according to the change to the lower limit and then use the new raw value for standardization when booting.