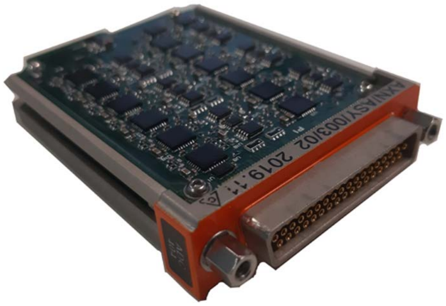
AXN/ADC/404

Full/½ bridge ADC (voltage excitation, programmable analog gain, balance and classic shunt, 6.25 kHz b/w) 12ch at 25 ksps

CURTISSWRIGHTDS.COM



Key Features

- 12 full or 1/2 bridge, potentiometer or differential ended input channels
- Programmable input range
- Programmable voltage excitation per channel
- Short on any channel does not affect others
- 16-bit simultaneous sampling with three configurable output streams on each channel
- Completion resistors and classic shunt

Applications

- Bridge sensors and strain gage measurement
- Differential voltage measurement

Overview

The AXN/ADC/404 provides independent excitation for up to 12 channels and is intended for full or 1/2 bridge sensors, or for differential input measurements.

At the heart of the AXN/ADC/404 is a hard-wired state-machine that oversamples all channels and digitally filters any noise above the user-programmable cutoff frequency.

This is achieved using cascaded, 15-tap FIR filters with output rate decimation, followed by a final FIR or IIR filter. If IIR filtering mode is selected, the last digital filter in the filtering chain is an 8th or 16th order (selectable) Butterworth filter. If FIR mode is selected, the last digital filter in the filtering chain is a 49-tap Kaiser window, Beta 6 filter.

There are three independently configurable output streams per channel, allowing different sample rate, cutoff, and filter type to be selected for each output stream.

All signals are sampled simultaneously. Thus, when several channels are sampled at different sampling rates, at the start of an acquisition cycle, all channels are aligned.

The AXN/ADC/404 supports programmable primary gain, voltage excitation (with compliance up to 32 mA), digital filter type as well as completion resistors and high accuracy.

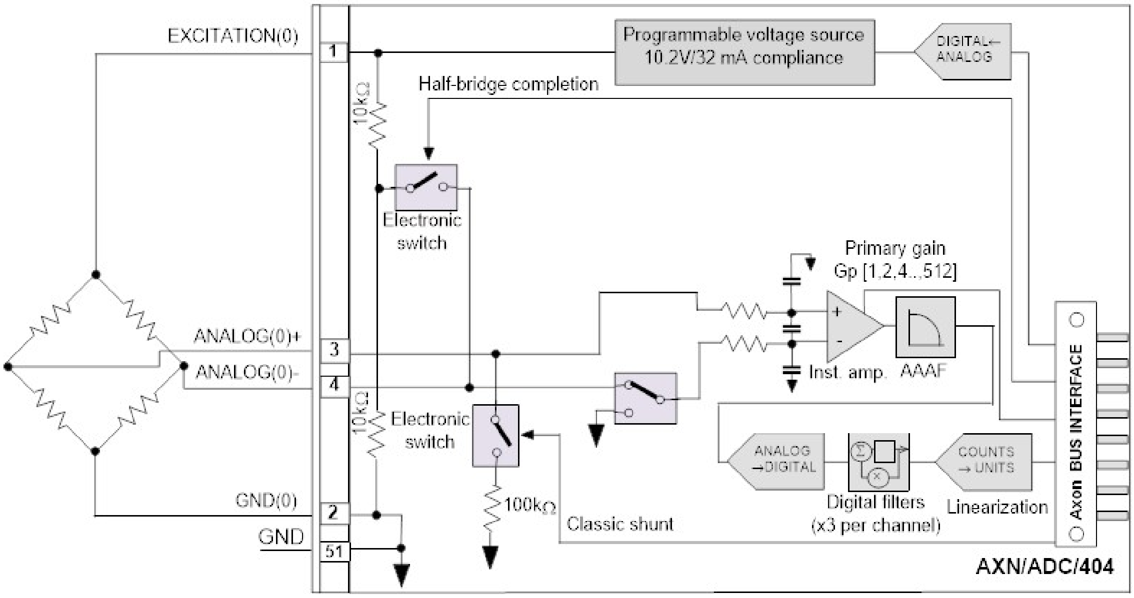


Figure 1: First of 12 channels on the AXN/ADC/404

Specifications

All values provided in the following specification tables are valid within the operating temperature range specified under “Environmental ratings” in the “General specifications” table. Module specifications are met for up to 97% of Full Scale Range (FSR).

TABLE 1 General specifications

PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Slots	–	–	1	–	Can be placed in any user-slot in any combination.
Mass					
	–	65	–	g	
	–	2.29	–	oz	Design metric is grams.
Height above chassis					For recommended clearance requirements see the *CON/KAD/002/CP* data sheet.
bare connector	–	–	11	mm	
bare connector	–	–	0.43	in.	Design metric is millimeters.
Power consumption					
+15V	–	155	171	mA	Excludes current used for Excitation(x) outputs. Excitation(x) outputs are supplied directly from +15V supply rail, therefore, additional supply rail current is the same as output current.
total power	–	2.33	2.57	W	Particular combinations of Axon chassis and modules may have power limitations. For details, contact Curtiss-Wright support (acra-support@curtisswright.com).
Environmental ratings					See *Environmental Qualification Handbook for Axon Products*.
operating temperature	-40	–	85	°C	Chassis base/side plate temperature.
storage temperature	-55	–	125	°C	

TABLE 2 Flexible analog inputs

PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Inputs	–	–	12	–	With two independently configurable output streams per channel.
Sampling rate					While the sampling rate can be set individually, each must have a power of two times any other (¼, ½ ...2, 4).
Analog[11:0]	0.25	–	25,000	sps	From ANALOG(x)± pins.
Primary sampling frequency	50	–	100	ksps	The primary sampling frequency (f_p) is set up to be the power of two of each output sample frequency. It is greater than the minimum specified value and lower or equal to the maximum specified value.
Input voltage					Differential ended voltage across the ANALOG(x)± input.
operating range	-10/Gp	–	10/Gp	V	
operating range (Gp = 1)	-10	–	10	V	Primary gain = 1.
operating range (Gp = 512)	-19.53	–	19.53	mV	Primary gain = 512.
overvoltage protection	-40	–	40	V	Voltages outside of this range can damage input.
ANALOG(x)± single ended voltage range	-10	–	10	V	Specifications defined in this data sheet for ANALOG(x)± inputs are valid only when this condition is met.

TABLE 2	Flexible analog inputs (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
DC error					Without taking into account excitation for sensor setup where applicable (for example bridges). The DC error specifications claimed here are input channel specifications for both differential ended and single ended setup only, with symmetrical voltages. To calculate the total system error for full-bridge and half-bridge modes, the error related to excitation must also be considered.
Gp = 1, 2, 4, 8, 16, and 32; Gs = 1	–	–	0.08	%FSR	This is the operating range of the instrumentation amplifier. It is automatically selected during software setup based on the Range Maximum. Range Minimum, Linearization URL, Maximum Balance and User Compensation URL data that are specified for each channel. Asymmetric ranges with different offsets and gain scaling factors are also possible; they are done by digital scaling of signals within module logic according to a user-selected range. Gs is the secondary gain (digital gain).
Gp = 64; Gs = 1	–	–	0.1	%FSR	
Gp = 128; Gs = 1	–	–	0.13	%FSR	
Gp = 256; Gs = 1	–	–	0.18	%FSR	
Gp = 512; Gs = 1	–	–	0.25	%FSR	
Gp = 512; Gs = 2	–	–	0.4	%FSR	
Gp = 512; Gs = 4	–	–	0.64	%FSR	
Gp = 512; Gs = 8	–	–	1.0	%FSR	
AC gain error					Gp = 1, fs = 25 ksps, $f_c = f_s / 4$. (f_c : filter cutoff frequency f_s: sampling frequency)
$f_{in} \leq 500$ Hz	–	–	0.1	%	(f_{in} : input signal frequency)
500 Hz < $f_{in} \leq 2$ kHz	–	–	0.3	%	
2 kHz < $f_{in} \leq 4$ kHz	–	–	1.2	%	
Effective number of bits					Measured in Differential Ended Voltage Input Mode configuration with common mode voltage = 0.
Gp = 1	12	–	–	bits	$f_c \leq 1$ kHz and secondary gain of 1.
Gp = 512	11	–	–	bits	$f_c \leq 1$ kHz and secondary gain of 1.
Gp = 1	11.5	–	–	bits	1 kHz < $f_c \leq 6.25$ kHz and secondary gain of 1.
Gp = 512	10.5	–	–	bits	1 kHz < $f_c \leq 6.25$ kHz and secondary gain of 1.
Crosstalk					
Gp = 1...512	–	–	-80	dB	ANALOG(x)±. Typical value claimed at 1 kHz and below.
Common mode					
voltage range	-10	–	10	V	Operational voltage range. Single ended voltages on individual ANALOG(x)± pins must also fit into this range.
rejection ratio	80	–	–	dB	Applies within the above common mode voltage range; $f_{in} \leq$ 500 Hz.
rejection ratio	66	–	–	dB	Applies within the above common mode voltage range; $f_{in} >$ 500 Hz and $f_{in} \leq 2$ kHz.
rejection ratio	50	–	–	dB	Applies within the above common mode voltage range; $f_{in} >$ 2 kHz.

TABLE 2	Flexible analog inputs (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Analog filter					Analog filters are Butterworth.
Anti aliasing filter					
poles	–	–	6	–	
filter cutoff -3 dB	9.5	10	10.5	kHz	
Digital filter					For IIR8 setting of Filter Mode, digital filter is Butterworth with output sample stream decimated by 2, 4, 8, 16, 32, 64 or 128.
poles	–	–	8	–	
filter cutoff (f_c) -3 dB	0.1	–	16	f_s	The maximum value is limited to 6.25 kHz. See Filter Cutoff settings in the “Instrument settings” on page 7.
0.1 dB bandwidth	–	0.8	–	f_c	
aliasing to 0.1 dB band	–	–	-88	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than or equal to 1/4.
aliasing to f_c	–	–	-88	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than or equal to 1/4.
Filter delay	1.99	2.0	2.01	ms	Measured for $f_{in} = f_c = f_s / 4 = 1$ kHz.
Digital filter					For IIR16 setting of Filter Mode, digital filter is Butterworth with output sample stream decimated by 2, 4, 8, 16, 32, 64 or 128.
poles	–	–	16	–	
filter cutoff (f_c) -3 dB	0.1	–	16	f_s	The maximum value is limited to 6.25 kHz. See Filter Cutoff settings in the “Instrument settings” on page 7.
0.1 dB bandwidth	–	0.9	–	f_c	
aliasing to 0.1 dB band	–	–	-88	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than or equal to 1/4.
aliasing to f_c	–	–	-88	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than or equal to 1/4.
Filter delay	2.99	3.0	3.01	ms	Measured for $f_{in} = f_c = f_s / 4 = 1$ kHz.
Digital filter					For FIR setting of Filter Mode, digital filter is 49-tap Kaiser window, Beta 6 FIR filter with output sample stream decimated by 2.
poles	–	–	–	–	
filter cutoff (f_c) -6 dB	0.1	–	16	f_s	The maximum value is limited to 6.25 kHz. See Filter Cutoff settings in the “Instrument settings” on page 7.
0.1 dB bandwidth	–	0.32	–	f_c	Specified value is for $f_c = f_s / 10$ filter.
0.1 dB bandwidth	–	0.46	–	f_c	Specified value is for $f_c = f_s / 8$ filter.
0.1 dB bandwidth	–	0.59	–	f_c	Specified value is for $f_c = f_s / 6$ filter.
0.1 dB bandwidth	–	0.66	–	f_c	Specified value is for $f_c = f_s / 5$ filter.
0.1 dB bandwidth	–	0.72	–	f_c	Specified value is for $f_c = f_s / 4$ or equal or greater than $f_s / 2$ filters.
0.1 dB bandwidth	–	0.79	–	f_c	Specified value is for $f_c = f_s / 3$ filter.

TABLE 2	Flexible analog inputs (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
0.1 dB bandwidth	–	0.83	–	f_c	Specified value is for $f_c = f_s / 2.5$ filter.
aliasing to 0.1 dB band	–	–	-80	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than 1/4.
aliasing to f_c	–	–	-80	dB	Measured with $10V_{pp}$ signal for $f_c = f_s / 4 = 10$ Hz and meets specification for Filter Cutoff settings lower than 1/4.
Filter delay	3.99	4.0	4.01	ms	Measured for $f_{in} = f_c = f_s / 4 = 1$ kHz.
Input resistance					
between inputs	10	–	–	MΩ	Module powered on/off and measured between ANALOG(x)+ and ANALOG(x)-.
single ended input to GND	2	20	–	MΩ	Module powered on/off and measured at ANALOG(x)+ or ANALOG(x)-. Typical value claimed for input voltage ±5V or less. Minimum value claimed when the module is powered off and input voltage is at ±10V.
Input impedance					All measurements carried out with 1 kHz $1V_{rms}$ signal.
between inputs	–	0.46	–	MΩ	Module powered on. Measured between ANALOG(x)+ and ANALOG(x)-.
single ended input to GND	–	0.43	–	MΩ	Module powered on and measured at ANALOG(x)+ or ANALOG(x)-.
Shunt resistor					Shunt resistor can be enabled between ANALOG(x)+ and GND.
resistance	–	100	–	kΩ	Nominal resistance of shunt resistor.
error	–	0.1	–	%	Initial resistor tolerance.
Half-bridge completion					Enabled when Input Mode is set to Half-bridge.
resistance	–	10	–	kΩ	Nominal resistance of each completion resistor.
matching	–	0.01	–	%	Initial resistor ratio tolerance.
tracking TCR	–	1	–	ppm/°C	Tracking Temperature Coefficient of Resistance (TCR).

TABLE 3	Uni-polar programmable DC voltage excitation outputs				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Outputs	–	–	12	–	
Output voltage					
operating range	0	–	10.2	V	Uni-polar excitation. Minimal value setting is to be used when excitation is not loaded with external loads.

TABLE 3	Uni-polar programmable DC voltage excitation outputs (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
resolution	–	160	–	µV	
compliance	–	–	32	mA	Per channel. To GND.
short circuit current	–	65	–	mA	
short circuit duration	∞	–	–	s	To GND.
DC error					
error	–	–	0.08	%FSR	With a constant 350Ω load. Includes drift.
drift vs. room temperature	–	–	0.05	%FSR	With a constant 350Ω load. Included in error specification above.
noise	–	–	0.5	mV_{rms}	As measured on analog input; bridge unbalanced to 90% of FSR.

TABLE 4	Top-block built-in temperature sensor				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Inputs (Top-block Temperature)	–	–	1	–	From sensor provided within top-block.
Input temperature					
full scale range	-55	–	125	°C	
DC error	–	0.5	1.0	°C	Sensor manufacturer specification.

TABLE 5	On board PCB temperature sensor				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Inputs (ModuleTemperature)	–	–	1	–	From sensor provided on module PCB.
Input temperature					
full scale range	-55	–	125	°C	
DC error	–	0.5	1.0	°C	Sensor manufacturer specification.

Setting up the AXN/ADC/404

All module setup can be defined in XML using XidML® schemas (see http://www.xidml.org).

Instrument settings

SETUP DATA	CHOICE	DEFAULT	NOTES
Manufacturer	-	-	-
Name	ACRA CONTROL	ACRA CONTROL	Name of manufacturer.
PartReference	AXN/ADC/404/B	AXN/ADC/404/B	The instrument part reference.
SerialNumber	AAB1234	AAB1234	Unique name for each module.
Channels	-	-	-
Analog(11:0) *Analog Input*	-	-	-
Settings	-	-	-
Input Mode	Differential ended voltage Single ended voltage Full-bridge Half-bridge	Differential ended voltage	Specifies operation mode of input.
Filter Mode(0)	FIR IIR8 IIR16	FIR	Specifies the filter mode for a specific channel of the 1st parameter. FIR is Kaiser window Beta = 6, 49-tap FIR filter; IIR8 is 8th order Butterworth IIR filter; and IIR16 is 16th order Butterworth IIR filter.
Filter Mode(1)	FIR IIR8 IIR16	FIR	Specifies the filter mode for a specific channel of the 2nd parameter. FIR is Kaiser window Beta = 6, 49-tap FIR filter; IIR8 is 8th order Butterworth IIR filter; and IIR16 is 16th order Butterworth IIR filter.
Filter Mode(2)	FIR IIR8 IIR16	FIR	Specifies the filter mode for a specific channel of the 3rd parameter. FIR is Kaiser window Beta = 6, 49-tap FIR filter; IIR8 is 8th order Butterworth IIR filter; and IIR16 is 16th order Butterworth IIR filter.
Filter Cutoff(0)	1/4 1/2 1 2 4 8 16 1/10 1/8 1/6 1/5 1/3 1/2.5	1/4	Required cutoff point for the filter is the chosen value referenced to the user sampling frequency. Setting for 1st channel parameter.

SETUP DATA	CHOICE	DEFAULT	NOTES
Filter Cutoff(1)	1/4 1/2 1 2 4 8 16 1/10 1/8 1/6 1/5 1/3 1/2.5	1/4	Required cutoff point for the filter is the chosen value referenced to the user sampling frequency. Setting for 2nd channel parameter.
Filter Cutoff(2)	1/4 1/2 1 2 4 8 16 1/10 1/8 1/6 1/5 1/3 1/2.5	1/4	Required cutoff point for the filter is the chosen value referenced to the user sampling frequency. Setting for 3rd channel parameter.
Excitation Amplitude	0 to 10.2	0	Required excitation (in V) for the top of the bridge. Excitation is unipolar.
Linearization URL	UTF-8 String		Specifies the URL to the linearization lookup file.
User Compensation URL	UTF-8 String		Specifies the URL to the user compensation file.
User Compensation Channel	No compensation Channel independent Top-block temperature sensor Module temperature sensor	No compensation	This setting defines which channel is used as the compensation channel for the linear user calibration.
Balance Type	Auto-balance	Auto-balance	Specifies the balance type to be carried out on the channel.
Balance Options	None Lock previous Allowed	None	Specifies balancing options.
Maximum Balance	0 to 10	0	Specifies reserve for balance, which is added on top of user defined range to check and avoid railing on instrumentation amplifier.
Balance Target	-10 to 10	0	Specifies a value that the channel should be balanced to.
Classic Shunt	Disabled Enabled	Disabled	Specifies if switch connecting classic shunt resistor is to be enabled between ANALOG(x)+ and GND nets.

Parameter definitions

NAME/DESCRIPTION	BASE UNIT	DATA FORMAT	BITS	REGISTER DEFINITION
Global Parameters				
Top-blockTemperature Top-block temperature signal data.	Celsius	OffsetBinary	16	R[15:0]
ModuleTemperature Module temperature signal data.	Celsius	OffsetBinary	16	R[15:0]
BalanceStatus Balance status register. Two bit values represent the balance status of each channel: 00 – Not allowed to use balance value; auto-balance disabled. 01 – Allowed to use balance; but no valid correction value in EPROM, so not using any value. 10 – Allowed to use balance; there is a valid value in EPROM, using it even though the value is outside the Maximum Balance range. 11 – Allowed to use balance; there is a valid value in EPROM, using it as the value is within the Maximum Balance range. Note: Channel 0 information on LSB position.	BitVector	BitVector	32	R[31:0] R[31:24] Reserved R[23:22] BalanceStatus for Analog(11) R[21:20] BalanceStatus for Analog(10) R[19:18] BalanceStatus for Analog(9) R[17:16] BalanceStatus for Analog(8) R[15:14] BalanceStatus for Analog(7) R[13:12] BalanceStatus for Analog(6) R[11:10] BalanceStatus for Analog(5) R[9:8] BalanceStatus for Analog(4) R[7:6] BalanceStatus for Analog(3) R[5:4] BalanceStatus for Analog(2) R[3:2] BalanceStatus for Analog(1) R[1:0] BalanceStatus for Analog(0)
ReadCounter Incrementing counter for debug usage.	Count	OffsetBinary	16	R[15:0]
Report Reports the status of the module	BitVector	BitVector	16	R[15:0] R(15) ModuleTemperature sensor not responding R(14) Top-blockTemperature sensor not responding R[13:2] Reserved R(1) ADC for Analog[11:8] not responding R(0) ADC for Analog[7:0] not responding
Analog(11:0) Parameters				
Analog(2:0) Analog signal data.	Volt	OffsetBinary	16	R[15:0]

Configurable parameters

Analog(11:0)(2:0)

SETUP DATA	CHOICE	DEFAULT	NOTES
Range Maximum	-10 to 10	10	Range maximum for Analog channel.
Range Minimum	-10 to 10	-10	Range minimum for Analog channel.

NOTE: It is recommended that names do not contain any of the following five characters "/><\.

Getting the most from the AXN/ADC/404

Wiring configurations

Figures 2 to 6 show possible wiring configurations for the AXN/ADC/404.

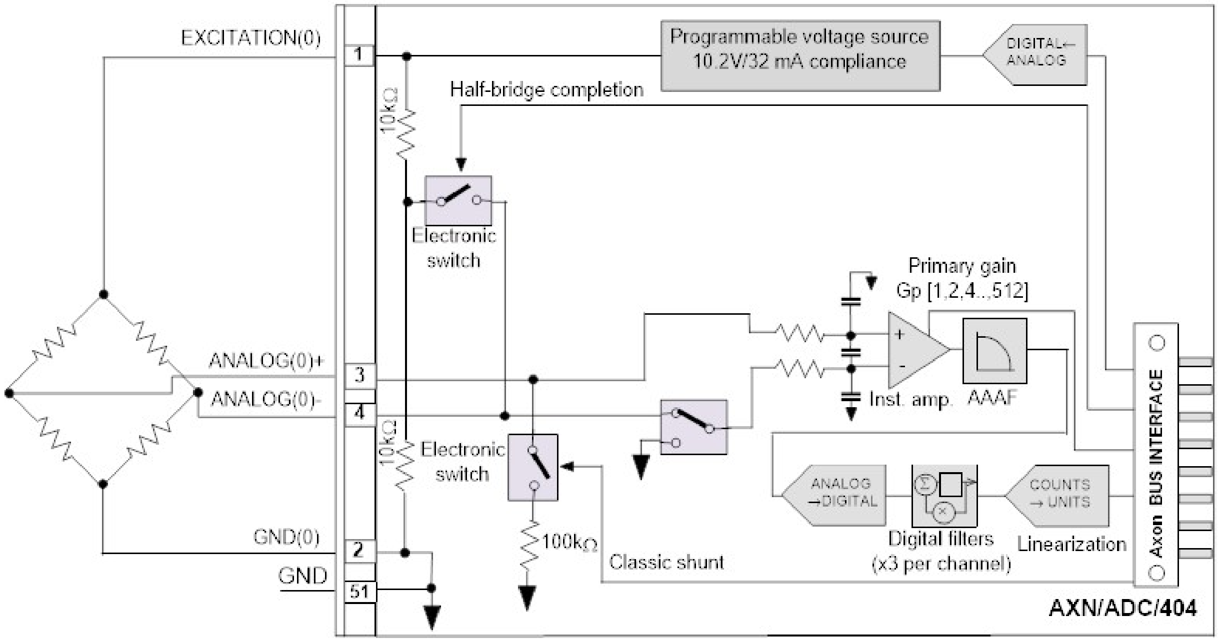


Figure 2: First channel in full-bridge configuration

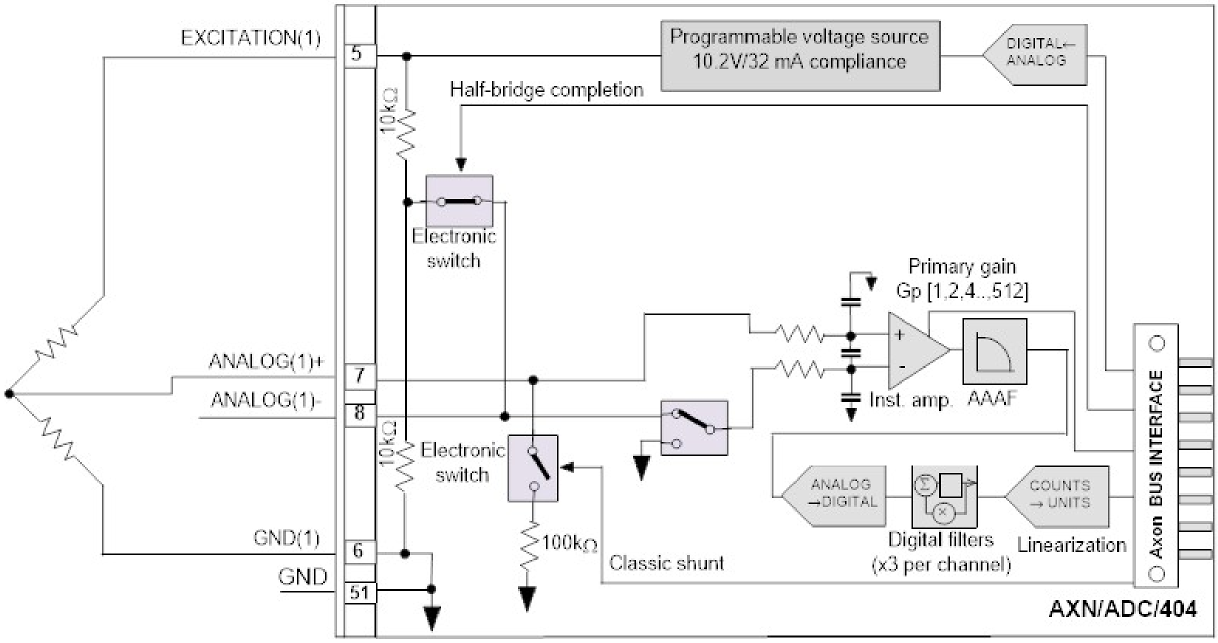


Figure 3: Second channel in half-bridge configuration, with matched pair of internal completion resistors enabled

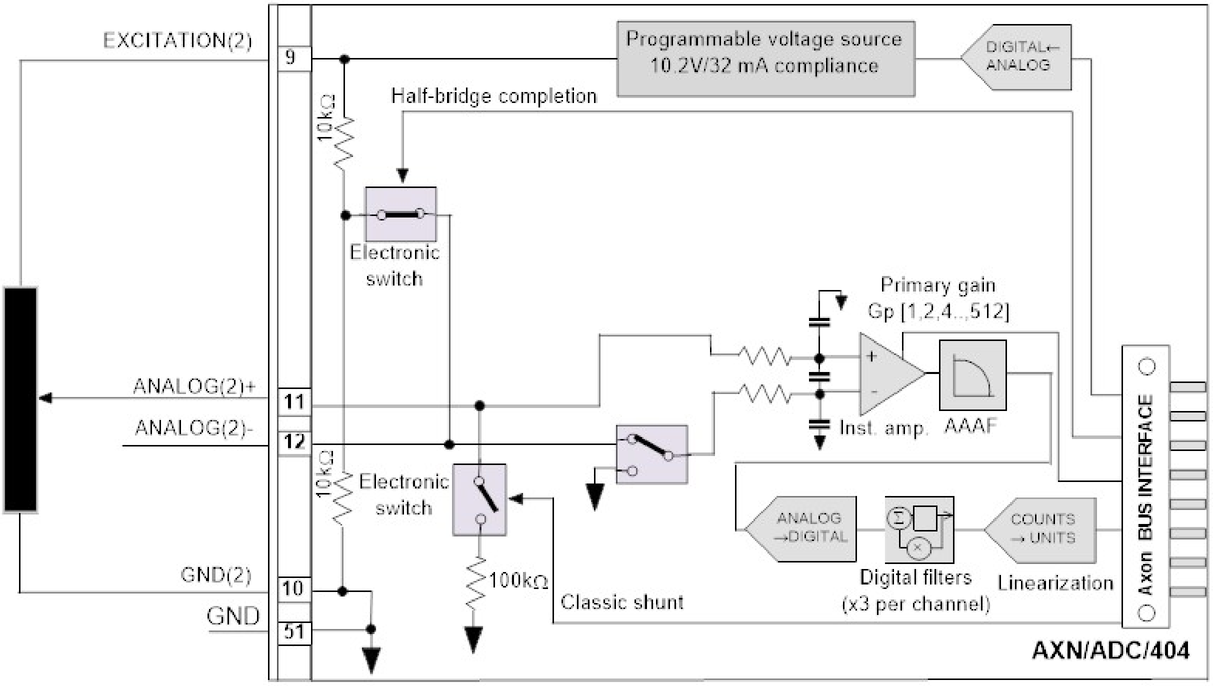


Figure 4: Third channel in potentiometer configuration, with matched pair of internal completion resistors enabled

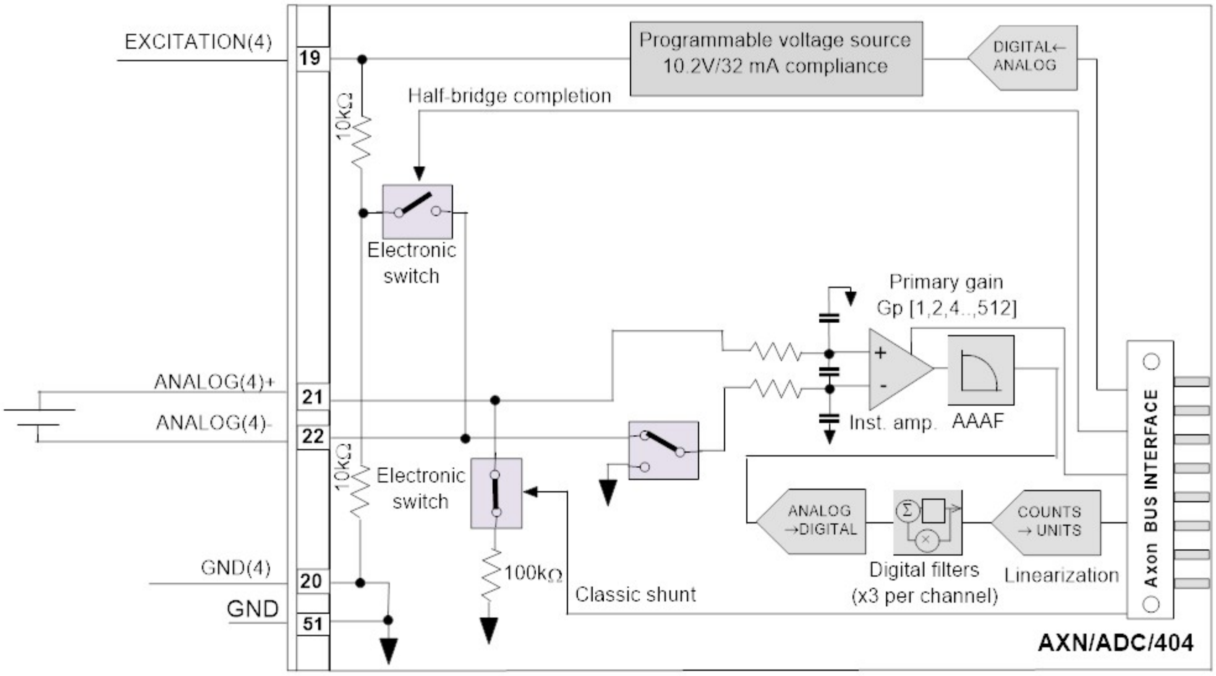


Figure 5: Fourth channel in differential ended configuration, with internal shunt resistor enabled (bias current return path)

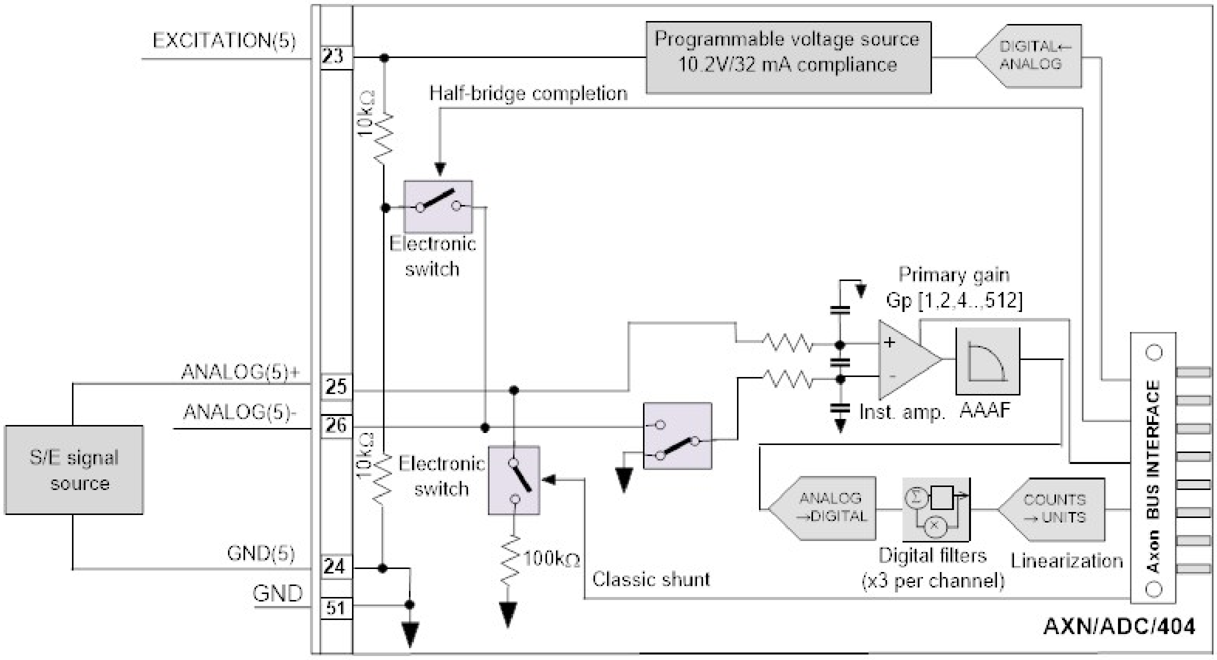


Figure 6: Fifth channel in single ended configuration

Bias current return path

As shown in Figure 5 on page 11, the analog inputs can be used as differential inputs (that is, not from a bridge). In this case, if the signal source is isolated with respect to the Axon (for example a battery or isolated thermocouple), a common-mode resistance between one of the inputs and ground (GND) must be used to provide a return for bias currents, and reduce common-mode noise pick-up. Bias currents are in the order of nAs. To correctly set up the return path for bias currents, either internal shunt resistors must be enabled to internally pull-down to GND or an external path to GND must be used, for example short (0Ω) to GND. Figure 5 on page 11 shows the internal shunt resistor that provides a return path for the bias current.

NOTE: To enable the internal shunt resistor, set the Classic Shunt setting to Enabled.

Excitation setup

Setting Excitation Mode to Voltage can contribute error to the overall measurement. Therefore, it is recommended to use as close as possible to full-scale excitation, to minimize the percentage error.

For optimal accuracy, ensure each channel uses its corresponding excitation. If the excitation is not used, it should be set to the minimum value.

Excitation drift on potentiometer and half-bridge configurations

We recommend a full-bridge input configuration for the AXN/ADC/404 (see Figure 2 on page 10). With this configuration, the differential input amplifier removes common mode voltage or common mode pickup noise on the input lines. A similar configuration can be achieved with a potentiometer by using completion resistors, however, only the common mode voltage, which is added to both inputs as a result of excitation drift, is compensated for.

NOTE: For the AXN/ADC/404, internal completion resistors can be enabled by setting Input Mode to Half-bridge (see Figure 3 on page 10).

Error and drift for potentiometer and half-bridge configurations

For potentiometer and half-bridge configurations, internal completion resistors are enabled when Input Mode is set to Half-bridge. These matched resistors have a defined matching error, as well as tracking TCR, which may result in an additional error of measurement. The initial matching error can be compensated for by balancing the bridge. This is done by setting the balance to a value which nulls the reading for the ambient temperature at which balancing was carried out. However, the tracking TCR error introduced is the result of the drift of the matching ratio as the temperature changes, and so cannot be compensated for.

For example, when the voltage across the bridge is 10V, then 1 ppm/°C causes 10 µV/°C of drift on the channel being read. For a 60°C ambient temperature change, tracking TCR is responsible for 600 µV of drift.

Compensation for lead resistance

In bridge applications, if the lead resistance can be measured or estimated, add the voltage drop across the leads to the excitation voltage. For example, for 0.5Ω leads in a 350Ω full-bridge, where 5V is desired across the bridge, the excitation should be set to 5V + (0.5 × 2 × 5 / 350) = 5.014.

Digital filters overview

The AXN/ADC/404 samples all channels simultaneously at a high rate, which is defined in the f_p range in Table 2 on page 2. Sample values are scaled by various blocks (such as internal calibration, user compensation, junction compensation, balance, and user range) and then passed into the digital filter and decimation blocks. These scaled samples pass through a cascade of digital anti-aliasing filters and decimations, which are there to lowering the sample rate to the last user-selected filter, while maintaining aliasing at a negligible level. Then, depending on the Filter Mode and Filter Cutoff settings chosen, the sample passes through the final user-selected filter and decimator.

The AXN/ADC/404 offers three types of final filters:

- FIR
- IIR8
- IIR16

Using the Filter Mode setting, each can be individually selected per channel and/or stream.

The FIR filter is a 49-tap Kaiser window Beta 6 filter. The advantage of this filter is constant filter delay versus input signal frequency, which facilitates time correlation of various signals in post-processing and visualization, and guarantees lack of phase distortions for non-sinusoidal input signals. The disadvantage is it has less flat passband, which gets narrower versus f_c for lower f_c settings.

IIR8 and IIR16 filters are Butterworth type filters of 8th and 16th order respectively. These filters offer more flat passband than FIR (especially IIR16), which is constant versus f_c regardless of Filter Cutoff selection. For most Filter Cutoff settings, IIR type filters (especially IIR8) offer a lower filter delay than FIR filters. The disadvantage is that the delay of Butterworth filters is not constant; it varies over input frequency range, making analysis of time correlation of various signals more difficult. Also it causes phase distortions of non-sinusoidal signals.

Each type of filter has seven base cutoff frequencies (Filter Cutoff settings: 1/10, 1/8, 1/6, 1/5, 1/4, 1/3 and 1/2.5), where a different set of filter coefficients is used for digital signal processing (DSP) maths in the final filtering block. These filters operate at twice the specific parameter output sample rate, therefore, the filter sample stream is decimated by a factor of 2 to produce the parameter sample stream. It is possible to output at the maximum sampling rate for these filters.

As for the remaining cutoff frequencies (Filter Cutoff settings: 1/2, 1, 2, 4, 8, 16), the filter uses coefficients as per 1/4 Filter Cutoff setting, but operates at a higher sample rate and uses decimation to produce the final output sample stream. As a result, the target filter cutoff value is effectively achieved. The downside of this approach is that it limits the maximum sampling frequency. Also, the module should not be configured whereby the parameter sample rate and filter cutoff setting would result in the maximum specified f_c for the card being exceeded.

Understanding filter delays (IIR8 and IIR16 filter modes)

The Axon uniquely samples all signals at the start of an acquisition cycle and at equal intervals of time thereafter. Signals sampled at the same sample rate are always sampled at the same time, independently of how they are stored or transmitted. (This has significant advantages for issues such as time correlation.) However, before signals are sampled they are filtered to remove noise components that might alias. The recommended Filter Cutoff setting is 1/4 or lower for IIR8 Filter Mode setting, or 1/2.5 or lower for IIR16 Filter Mode setting, as this results in the maximum filtering of aliasing frequencies. The Axon filters signals using over-sampling signal processing techniques. The following two figures show a delay for an 8th order filter (IIR8 setting) and a 16th order filter (IIR16 setting) normalized to f_c. Charts are plotted up to the Nyquist frequency of the output sample stream where the Filter Cutoff setting is 1/4. Where a higher Filter Cutoff setting is used, a delay chart should be considered only up to the Nyquist frequency of the output sample stream (f_s / 2), as frequencies above the Nyquist frequency are already aliased signals and cannot be easily analyzed.

All filters cause a delay inversely proportional to the filter cutoff frequency (f_c), so to calculate the delay for other f_c values, divide the delay by f_c (expressed in Hz). The frequency axis then needs to be rescaled to the new f_c by multiplying the normalized frequency values by f_c. For example, an 8th order Butterworth filter with an f_c of 1 kHz delays a 1 kHz signal by 1 ms; a filter with an f_c of 10 Hz delays a 10 Hz signal by 0.1 s. The delay for IIR filters (for example Butterworth) varies with the input frequency.

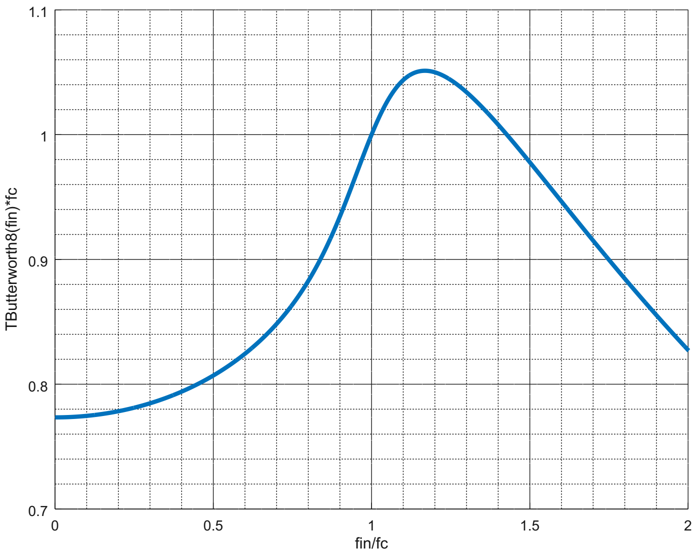


Figure 7: Filter delay for IIR8 Filter Mode setting normalized to f_c

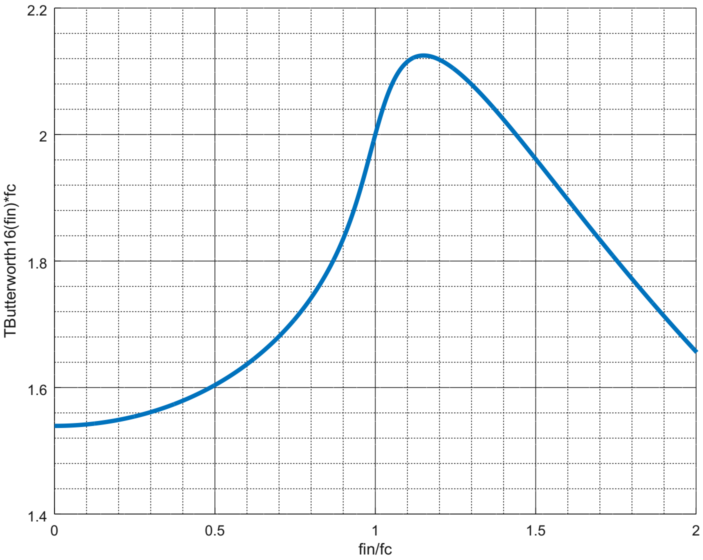


Figure 8: Filter delay for IIR16 Filter Mode setting normalized to f_c

The filter delay for the AXN/ADC/404 is:

$$T_D \approx T_A + \frac{1}{f_C} + T_{Butterworth}\left(f_{in}\right)$$

T_D is the filter delay

T_A (analog filter delay) ≈ 0

Understanding filter delays (FIR filter mode, Filter Cutoff settings of 1/4, 1/2, 1, 2, 4, 8 and 16)

The Axon uniquely samples all signals at the start of an acquisition cycle and at equal intervals of time thereafter. Signals sampled at the same sample rate are always sampled at the same time independently of how they are stored or transmitted. (This has significant advantages for issues such as time correlation.) However, before signals are sampled they are filtered to remove noise components that might alias. The recommended Filter Cutoff setting is 1/4 or lower for FIR Filter Mode setting, as this results in the maximum filtering of aliasing frequencies. The Axon filters signals using over-sampling signal processing techniques. All filters cause a delay inversely proportional to the filter cutoff frequency (f_C).

The filter delay for this mode and these f_c settings is:

$$T_D \approx T_A + \frac{4}{f_c}$$

T_D is the filter delay

T_A (analog filter delay) ≈ 0

Understanding filter delays (FIR filter mode, Filter Cutoff settings of 1/10, 1/8, 1/6, 1/5, 1/3, 1/2.5)

For this FIR mode and its f_c settings, the filter delay formula is different than in the previous section. The delay is such that the Filter Cutoff is 1/4 for FIR mode (the FIR filters delay is not f_c dependent, but rather dependent on the rate and number of filter taps). The following formula effectively defines the delay:

$$T_D \approx T_A + \frac{16}{f_s}$$

T_D is the filter delay

T_A (analog filter delay) ≈ 0

Aliasing

Aliasing is an effect in signal sampling systems, which can cause sampled signals greater than half the sample rate to become indistinguishable from signals in the bandwidth of interest. To prevent the possibility of aliasing, sampling systems offer filtering. With Axon modules, filtering consists of a pre-sampler analog anti-aliasing filter and a post-sampler cascaded digital filter. Axon analog modules support three main types of digital filters: IIR8; IIR16; and FIR. Each can be configured to a various Filter Cutoff frequencies, allowing you to select the cutoff frequency best suited to the application.

One criteria may be aliasing attenuation. Aliasing figures presented in the Specifications tables (starting on page 2) are met or exceeded for Filter Cutoff settings lower or equal to 1/4. For higher Filter Cutoff settings (1/3 and 1/2.5, which still offer Filter Cutoff below the Nyquist frequency), the worst case figures may be lower due to the proximity of the cutoff frequency to the Nyquist frequency and the limited attenuation a specific filter type can achieve for the closest possible aliasing frequencies.

The following table below presents the theoretical worst case aliasing values for the Filter Cutoff settings for the three main filter types.

TABLE 6 Theoretical worst case aliasing values

PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
IIR8					
aliasing to 0.1 dB bandwidth	–	–	-80	dB	Filter Cutoff setting of 1/3.
aliasing to f_c	–	–	-72	dB	Filter Cutoff setting of 1/3.
aliasing to 0.1 dB bandwidth	–	–	-60	dB	Filter Cutoff setting of 1/2.5.
aliasing to f_c	–	–	-40	dB	Filter Cutoff setting of 1/2.5.
IIR16					
aliasing to 0.1 dB bandwidth	–	–	-80	dB	Filter Cutoff setting of 1/3 and 1/2.5.
aliasing to f_c	–	–	-80	dB	Filter Cutoff setting of 1/3 and 1/2.5.
FIR					
aliasing to 0.1 dB bandwidth	–	–	-76	dB	Filter Cutoff setting of 1/3 and 1/2.5.
aliasing to f_c	–	–	-74	dB	Filter Cutoff setting of 1/3 and 1/2.5.

Use of Filter Cutoff settings of 1/2 and higher is not recommended. While using a Filter Cutoff of 1/2 or higher can help to lower filter delays through the system and/or improve AC gain error within the bandwidth of interest, it may cause significant aliasing due to not meeting the Nyquist criteria.

User compensation

The module offers optional user-compensation per channel. It is linear correction, which can be applied at the digital signal processing path, just after the A/D converter and the channel's correction blocks, but before auto-balance, user range scaling, digital filtering, and output linearization. It allows samples to be corrected by first applying multiplication through user-defined gain compensation values and then adding a user-offset compensation value to produce the output value.

The User Compensation Channel setting determines if compensation is disabled (No compensation), if it is constant correction (Channel independent), or if the selected correction coefficients depends on another parameter (any other channel or one of the module temperature sensors).

Examples where this feature can be used include user calibration/correction of module channel and external sensor/cabling errors compensation. Both uses may also be dependent on one of the other parameter of the module (for example, channel correction could depend on module temperature, or external sensor correction on some other channel).

The User Compensation URL setting links to a file with compensation coefficients. This file could contain either a single set of gain and offset compensation coefficients, or could contain multiple sets with information for what value of reference compensation channel, specific set of gain and offset compensation coefficients is valid. In the latter case, the module compensation block interpolates linearly output value for any value of reference compensation channel between defined compensation channel values, allowing smooth correction change. If the correction channel value is outside of defined in User Compensation URL, then correction coefficients of closest defined compensation channel value are used.

During compilation of the user configuration, DAS Studio 3 software takes into account the user-defined range, Balance Headroom, Linearization URL, Input Mode, User Compensation Channel, and URL to select the appropriate instrumentation amplifier analog gain for a specific channel, thereby avoiding railing on analog circuits side and A/D converter.

Two example files of User Compensation are distributed with DAS Studio 3 software (see DASStudio\3.x\LookupFiles\Examples folder). These files contain a set of three values for each defined compensation point: *ReferenceSourceValue*, *Gain* and *Offset*. ReferenceSourceValue is the point at which a specified pair of Gain and Offset is defined. Gain is a gain correction. Offset is the offset value to be applied, expressed in volts.

For the Channel Independent setting of User Compensation Channel, only one set of values is expected in the compensation file, and ReferenceSourceValue could contain any value there (for example 0) as it is effectively ignored. In a situation where compensation depends on an other channel (for example Module temperature sensor), multiple groups of compensation points are expected, each defined for different ReferenceSourceValue.

DAS Studio 3 software takes the user defined sets of compensation points, interpolates between them, and extrapolates outside the minimum and maximum ReferenceSourceValue (rails corrections to the nearest), and loads such points into the non-volatile settings of module memory in the form of a compensation table. The module itself uses this table to calculate compensation gain and offset values based on the current output value from the selected User Compensation Channel. This calculation is further interpolated based on the nearest points within the non-volatile memory compensation table.

NOTE: Some corrections may cause demand of very different voltage ranges and therefore analog gain, than if compensation was not used. This may lead to compilation errors when the maximum allowed operating range defined for a specific channel (for Gp = 1) in Table 2 on page 2 is exceeded.

Auto-balancing

The module offers an auto-balancing feature, which is carried out inside internal logic as digital correction and applied on sample within the processing chain. The module stores digital balance corrections in non-volatile memory, so they can be reloaded and used after power-up. There are three Balance Option settings: None, Lock previous and Allowed, which are set per channel.

The None setting disables auto-balancing and causes any balance correction already stored in non-volatile memory to be ignored.

The Lock previous setting does not allow for auto-balancing to store new corrections, however, if there is already a valid value stored in non-volatile memory (that is, successful auto-balancing completed previously), it will be used as correction.

Choosing Allowed means that as well as using the last valid balance correction, the channel will be re-balanced if a specific request is issued from the Bridge Balancer tool of DAS Studio 3 software.

As auto-balancing is done within the module as digital correction, the input range must allow headroom to avoid railing of data after auto-balancing is done. There is a setting Maximum Balance, which defines the required headroom to be applied on top of the user-specified range for each channel. The setup software sets instrumentation amplifier gain to cover for the required headroom.

There is also a Balance Target setting, which defines the target balance value.

Once the auto-balance start command is issued by Bridge Balancer, all channels which have the Balance Option set to Allowed, monitor thousands of incoming samples and then calculate the average value. The whole procedure takes about one second. If even a single input sample was at either rail of A/D, balancing is deemed to be incorrect and non-volatile memory is not updated for this channel.

When auto-balance is successful, the new balance correction is calculated as a difference between Balance Target and the average value calculated during auto-balancing, and it is stored in non-volatile memory. At this stage, it is not checked if the calculated correction is within the Maximum Balance range. Instead, this is separately reported in the BalanceStatus register, where each channel status is represented by a 2-bit status value (channel 0 result on the 2 least significant bits of the register):

00 – Not allowed to use balance value, auto-balance disabled.

01 – Allowed to use balance, but no valid correction value in EPROM, therefore not using any value.

10 – Allowed to use balance, there is a valid value in EPROM, therefore using it even though the value is outside the Maximum Balance range.

11 – Allowed to use balance, there is a valid value in EPROM, therefore using it as the value is within the Maximum Balance range.

The Bridge Balancer tool displays the result of the last auto-balancing procedure.

NOTE: The balance correction section of non-volatile memory is not changed when the system is reprogrammed. Caution needs to be taken in case the Balance Target, defined range, linearization, or Input Mode for a specific parameter was changed between the time when the channel was balanced and a new configuration was created. In this scenario, affected channels would need to be re-balanced, otherwise they may be using invalid corrections from the previous setup.

In a scenario where correction is outside of Maximum Balance headroom, there is a risk that there may be some railing of the user range. This will depend on the remaining headroom for a specific analog gain, which is selected by the compiler tool to cover the user range expanded by Maximum Balance. It is also dependent on by how much the correction exceeded Maximum Balance.

Such a scenario may indicate a failure, damage or some other problem such as with cabling or a sensor. A thorough inspection should be carried out. If a hardware problem is ruled out but the Maximum Balance had been set too low, then we recommended you reprogram the system with a wider Maximum Balance and redo auto-balancing. This ensures none of the balanced channels reports balance correction to be outside of Maximum Balance, which guarantees the full parameter range without risk of railing.

NOTE: In this data sheet, EPROM refers to onboard non-volatile memory where balance corrections or module configurations are stored.

Unused inputs

It is recommended that unused input channels are not left floating, as this may introduce more noise into the system and so degrade card performance. It is possible to set up each channel in a specific way, so that no external wiring is required to avoid channels floating. In order to do so, set Input Mode to Half-bridge, Excitation Amplitude to 0, and then set Classic Shunt to Enabled.

Connector pinout of the AXN/ADC/404

PIN	NAME	SEE SPECIFICATIONS TABLE	COMMENT
1	EXCITATION(0)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 0
2	GND(0)-	Internal ground	
3	ANALOG(0)+	Flexible analog inputs	Analog input
4	ANALOG(0)-	Flexible analog inputs	Analog input
5	EXCITATION(1)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 1
6	GND(1)-	Internal ground	
7	ANALOG(1)+	Flexible analog inputs	Analog input
8	ANALOG(1)-	Flexible analog inputs	Analog input
9	EXCITATION(2)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 2
10	GND(2)-	Internal ground	
11	ANALOG(2)+	Flexible analog inputs	Analog input
12	ANALOG(2)-	Flexible analog inputs	Analog input
13	EXCITATION(3)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 3
14	GND(3)-	Internal ground	
15	ANALOG(3)+	Flexible analog inputs	Analog input
16	ANALOG(3)-	Flexible analog inputs	Analog input
17	GND	Internal ground	
18	GND	Internal ground	
19	EXCITATION(4)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 4
20	GND(4)-	Internal ground	
21	ANALOG(4)+	Flexible analog inputs	Analog input
22	ANALOG(4)-	Flexible analog inputs	Analog input
23	EXCITATION(5)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 5
24	GND(5)-	Internal ground	
25	ANALOG(5)+	Flexible analog inputs	Analog input
26	ANALOG(5)-	Flexible analog inputs	Analog input
27	EXCITATION(6)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 6
28	GND(6)-	Internal ground	
29	ANALOG(6)+	Flexible analog inputs	Analog input
30	ANALOG(6)-	Flexible analog inputs	Analog input
31	EXCITATION(7)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 7
32	GND(7)-	Internal ground	
33	ANALOG(7)+	Flexible analog inputs	Analog input
34	ANALOG(7)-	Flexible analog inputs	Analog input
35	EXCITATION(11)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 11
36	EXCITATION(8)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 8
37	GND(8)-	Internal ground	
38	ANALOG(8)+	Flexible analog inputs	Analog input
39	ANALOG(8)-	Flexible analog inputs	Analog input
40	EXCITATION(9)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 9
41	GND(9)-	Internal ground	
42	ANALOG(9)+	Flexible analog inputs	Analog input
43	ANALOG(9)-	Flexible analog inputs	Analog input
44	EXCITATION(10)+	Uni-polar programmable DC voltage excitation outputs	Excitation to top of bridge for channel 10
45	GND(10)-	Internal ground	
46	ANALOG(10)+	Flexible analog inputs	Analog input
47	ANALOG(10)-	Flexible analog inputs	Analog input
48	GND(11)-	Internal ground	
49	ANALOG(11)+	Flexible analog inputs	Analog input
50	ANALOG(11)-	Flexible analog inputs	Analog input
51	GND	Internal ground	
52	CHASSIS	Chassis	

Ordering information

PART NUMBER	DESCRIPTION
AXN/ADC/404/B	Full/½ bridge ADC (voltage excitation, programmable analog gain, balance and classic shunt, 6.25 kHz b/w) 12ch at 25 ksps

By default, the standard mating connector, CON/KAD/002/CP, is included with each module in the shipment. Its part number will be added to the Confirmation of Order unless an alternative option is specified (see the *Cables* data sheet).

Revision history

REVISION	DIFFERENCES	STATUS
AXN/ADC/404/B	Support for different input setup, range setup, balance settings, linearization, compensation, and input mode settings per channel.	Recommended for new programs
AXN/ADC/404	First release	Recommended for new programs

Supporting software

SOFTWARE	DETAILS
DAS Studio 3	User interface for setup and management of data acquisition, network switches, recorders and ground stations in an integrated environment

Related products

MODULE	DETAILS
GS Works 9	Real-time and post-test data visualization and analysis software

Related documentation

DOCUMENT	DETAILS
DOC/MAN/030	DAS Studio 3 User Manual
DOC/HBK/008	Environmental Qualification Handbook for Axon Products.
TEC/NOT/001	Strain gages and ideal bridges
TEC/NOT/019	Digital filtering
TEC/NOT/082	Analog modules specifications explained