KAD/TDC/102

Thermocouple ADC (reference compensation, 250Hz b/w) - 15ch at 1ksps

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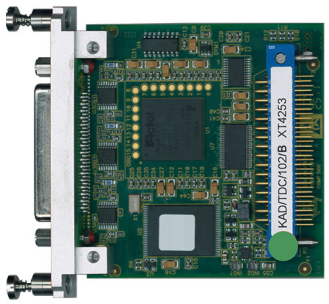

Key Features

- 15 grounded or isolated thermocouple input channels and compensation block (may use third party block) measurement
- Supports multiple thermocouple types with digital reference junction compensation and programmable thermocouple type per module
- Accuracy (0.5°C typical for K-type and XK_L-type in -50 to 150°C range, 1°C typical outside this range)
- Short on any channel does not affect others
- 16-bit simultaneous sampling on each channel

Applications

- Thermocouple temperature measurements

Overview

The KAD/TDC/102 is used to condition and digitize up to fifteen thermocouple channels and three channels of module junction temperature.

Together, the KAD/TDC/102 and the CON/KAD/010 connector use the preconfigured module junction temperature channels 0 and 2, to perform linearization and cold junction compensation for each thermocouple channel.

At the heart of the KAD/TDC/102 is a hard-wired state-machine that oversamples all channels at a rate up to 50ksps and digitally filters any noise above the user-programmable cutoff frequency.

This is achieved using cascaded, half-band, Finite-Impulse-Response (FIR) filters followed by an 8^{th} order Butterworth Infinite-Impulse-Response (IIR) filter with a default cutoff point set at one quarter of the sampling frequency ($f_c = f_s / 4$).

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

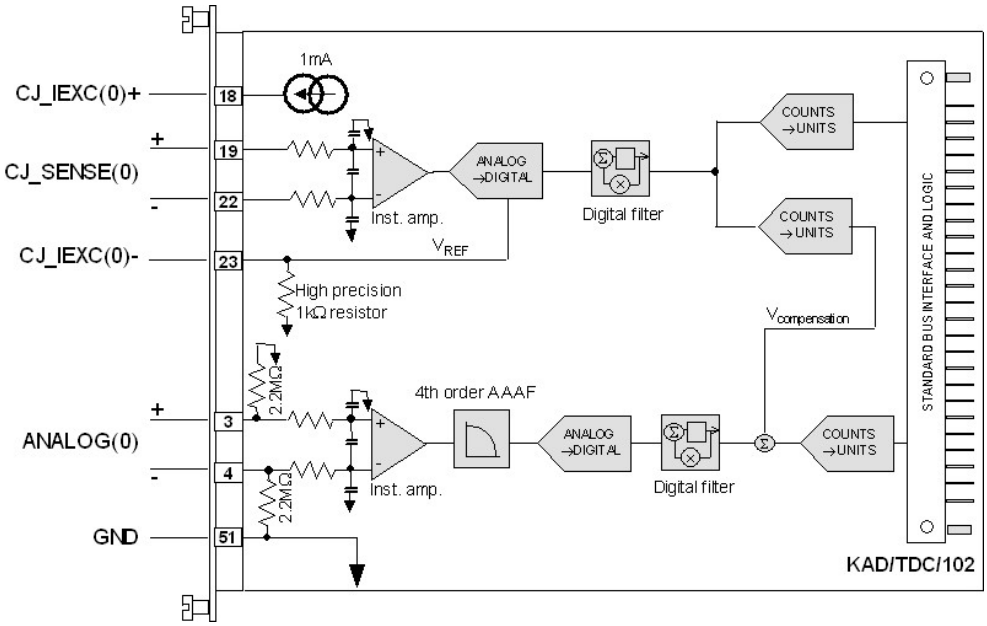

Figure 1: First of three reference junction channels plus first of 15 thermocouple channels

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 *ACD/BAC/002/B* data sheet.
bare connector	–	–	11	mm	
bare connector	–	–	0.43	in.	Design metric is millimeters.
Access rate	–	–	2	Msps	Maximum combined access rate for read and write.
Power consumption					
+5V	100	–	140	mA	
±7V	–	–	–	mA	
±12V	30	–	45	mA	
total power	1.22	–	1.78	W	Particular combinations of chassis and Acra KAM-500 modules may have power or current limitations. For details, see *TEC/NOT/016 - Power dissipation, TEC/NOT/049 - Power estimation*, and the relevant chassis data sheet.
Environmental ratings					See *Environmental Qualification Handbook*.
operating temperature	-40	–	85	°C	Chassis base/side plate temperature.
storage temperature	-55	–	105	°C	

TABLE 2	Cold junction				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Inputs	–	–	3	–	From PT100 sensors provided within the CON/KAD/010 connector. Resistive PT100 sensors are supplied from 1mA current source (typical value). The resistance measurement is ratiometric, compared with the embedded, high precision 1kΩ resistor.
Sampling rate					While the sampling rate can be set individually, each must have a power of two times any other (¼, ½ ...2, 4).
JunctionTemperature[2:0]	0.5	–	1,000	sps	
Input temperature					

TABLE 2	Cold junction (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
full scale range	-50	–	120	°C	
Input voltage					
operating range	0	–	250	mV	The measurement is a ratiometric resistance measurement performed with 1mA (typical) excitation current, Therefore, 0 to 250mV range is stated as the input voltage range.
overvoltage protection	-10	–	10	V	Voltages outside of this range can damage input.
DC error	–	0.04	0.2	%FSR	Temperature averaged over 200 samples. This includes any CON/KAD/010 error.
Effective number of bits	–	13.5	–	bits	$0 < f_{in} < 4Hz$ (f_{in} : input signal frequency)
Crosstalk	–	-98	-80	dB	$0 < f_{in} < 4Hz$
Analog filter					Analog filter is Butterworth.
poles	–	–	1	–	
filter cutoff -3dB	31.5	35	38.5	kHz	
Digital filter					Digital filter is embedded in the A/D converter. See “Signal filtering on reference junction channels” on page 8.
filter cutoff -3dB	–	4	–	Hz	
0.1dB bandwidth	–	0.1	–	f_c	(f_c : filter cutoff frequency)

TABLE 3	Thermocouple inputs				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
Inputs	–	–	15	–	
Sampling rate					While the sampling rate can be set individually, each must have a power of two times any other (¼, ½ ...2, 4).
Temperature[14:0]	0.5	–	1,000	sps	
Input temperature					The input temperature range is limited by the input voltage range of ±100mV and depends on the specific thermocouple type and the required cold junction temperature range. Refers to thermocouple type and maximum programmable range only (see “Accuracy” on page 7).
full scale range K-type thermocouple	-270	–	1,372	°C	For accuracy figures within a -200°C and 1100°C range, refer to the DC error parameter rows in this table.
full scale range B-type thermocouple	0	–	1,820	°C	
full scale range J-type thermocouple	-210	–	1,200	°C	
full scale range E-type thermocouple	-270	–	1,000	°C	
full scale range N-type thermocouple	-270	–	1,300	°C	
full scale range R-type thermocouple	-50	–	1,767	°C	
full scale range S-type thermocouple	-50	–	1,767	°C	
full scale range T-type thermocouple	-270	–	400	°C	

TABLE 3	Thermocouple inputs (continued)				
PARAMETER	MIN.	TYP.	MAX.	UNITS	CONDITION/DETAILS
full scale range T99-type thermocouple	-59	–	229	°C	
full scale range XK_L-type thermocouple	-200	–	800	°C	For accuracy figures within a -200°C and 800°C range, refer to the DC error parameter rows in this table.
full scale range C-type thermocouple	0	–	2,315	°C	
overvoltage protection	-40	–	40	V	Voltages outside of this range can damage input.
Input voltage					
operating range	-100	–	100	mV	
overvoltage protection	-40	–	40	V	Voltages outside of this range can damage input.
DC error	–	0.5	1.5	°C	Temperature averaged over 200 samples for a grounded or isolated K-type and XK_L-type thermocouple measured for FSR of -50°C to 150°C. This error includes the cold junction measurement error, and is met for an ambient temperature change rate of up to 1°C per minute using an ACD/CJB/003.
DC error	–	1.0	2.5	°C	Temperature averaged over 200 samples for a grounded or isolated K-type and XK_L-type thermocouple measured outside -50°C to 150°C and within a -200°C to 1100°C temperature range. This error includes the cold junction measurement error, and is met for an ambient temperature change rate of up to 1°C per minute using an ACD/CJB/003.
Effective number of bits	–	13.5	–	bits	$0 < f_{in} < 250Hz$ (f_{in} : input signal frequency)
Crosstalk	–	-90	-78	dB	$0 < f_{in} < 250Hz$
Common mode					
voltage range	-10	–	10	V	Operational voltage range (see “Common mode voltage effects” on page 7).
rejection ratio	90	110	–	dB	Applies within the above common mode voltage range, $0 \leq f_{in} < 250Hz$.
Analog filter					Analog filter is Butterworth.
poles	–	–	4	–	
filter cutoff -3dB	2.95	3	3.15	kHz	
Digital filter					Digital filter is Butterworth.
poles	–	–	8	–	
filter cutoff -3dB	0.25	–	16	f_s	The maximum value is limited to 250Hz (f_s: sampling frequency).
0.1dB bandwidth	–	0.8	–	f_c	
aliasing to 0.1dB band	–	–	-72	dB	
aliasing to f_c	–	–	-74	dB	
Filter delay	–	20	–	ms	Where $f_{in} = f_c = 100Hz$ (f_{in} : input signal frequency). See “Understanding filter delays” on page 7.
Input resistance					
between inputs	700	800	–	kΩ	Module powered off. Within ±100mV input range.
between inputs	10	–	–	MΩ	Module powered on. Within ±100mV input range.
each input to GND	2.1	2.2	–	MΩ	Module powered off. Within ±100mV input range.
each input to GND	10	–	–	MΩ	Module powered on. Within ±100mV input range.

Setting up the KAD/TDC/102

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	KAD/TDC/102/B	KAD/TDC/102/B	The instrument part reference.
SerialNumber	AB1234	AB1234	Unique name for each module.
Channels	-	-	-
Temperature(14:0) Analog Input.	-	-	Temperature input channels.
Settings	-	-	-
Thermocouple Type	UTF-8 String	.\LookupFiles\Thermocouple\TYPE K.LU	Specifies a URL where a specific thermocouple type lookup file can be found.
Filter Cutoff	0.25 0.5 1 2 4 8 16	0.25	Required cutoff point for the filter is the chosen value multiplied by the user sampling frequency. 0.25 is recommended as any higher may lead to aliasing. 1 is the sampling rate.
JunctionTemperature(2:0) Junction Temperature Input.	-	-	Reference junction temperature channels.
Settings	-	-	-

Parameter definitions

NAME/DESCRIPTION	BASE UNIT	DATA FORMAT	BITS	REGISTER DEFINITION
Temperature(14:0) Parameters				
Temperature Temperature signal data.	Celsius	OffsetBinary	16	R[15:0]
JunctionTemperature(2:0) Parameters				
JunctionTemperature Reference junction temperature signal data.	Celsius	OffsetBinary	16	R[15:0]

Configurable parameters

Temperature(14:0)

SETUP DATA	CHOICE	DEFAULT	NOTES
Range Maximum	-270 to 1820	1372	Range maximum for thermocouple channels.
Range Minimum	-270 to 1820	-270	Range minimum for thermocouple channels.

JunctionTemperature(2:0)

SETUP DATA	CHOICE	DEFAULT	NOTES
Range Maximum	-55 to 125	125	Range maximum for reference junction channels.
Range Minimum	-55 to 125	-55	Range minimum for reference junction channels.

NOTE: It is recommended that names are less than 20 characters, have no white space or contain any of the following five characters "/><\.

Getting the most from the KAD/TDC/102

Bias current return path

The KAD/TDC/102 does not require external bias returns, and provides the return for bias currents internally via a 2.2MΩ resistor from each input to ground.

Accuracy

The accuracy of the KAD/TDC/102 is specified for K-type thermocouples over the range specified in the DC error parameter rows in Table 3 on page 3. It is also met for J, XK_L, and E-type thermocouples that have a similar sensitivity. For thermocouples with a lower sensitivity (R, S, and T-type), the accuracy figure can be estimated by scaling the accuracy claimed for a K-type thermocouple by the ratio of its sensitivity (K-type thermocouple), to the sensitivity of the considered thermocouple.

Common mode voltage effects

The KAD/TDC/102 has a high Common-Mode Rejection Ratio (CMRR). However, in some configurations CMRR performance can be degraded by external circuitry. An example of this is when a thermocouple or external calibrator connected to a KAD/TDC/102 input is not isolated and additionally pulled elsewhere than the module's GND. This doesn't happen with isolated or grounded thermocouples but could happen if using certain calibrator configurations during testing.

For example, a thermocouple simulator is connected to a PC via a USB port (so they have a common GND) and the chassis GND is connected to the PC GND (the PCM link is from a KAD/BCU/101/C so there is no isolation between the internal grounds of each device). The thermocouple simulator generates approximately 1.6V common mode voltage on its output terminals (via roughly 25kΩ internal resistance). This causes approximately 0.7µA of current to flow to each of the module inputs.

There is approximately 15Ω difference in resistance between the K-type thermocouple leads (which interconnect the KAD/TDC/102 and the simulator) which is responsible for the presence of 11µV DC differential error voltage at inputs of the module. This is equivalent to approximately 0.28°C error in measurement with a K-type thermocouple within most of the thermocouple temperature range.

Isolating the calibrator from the module, or grounding one of its terminals, removes the unwanted effect which could be otherwise experienced with some types of simulators and some test circuits.

Mating connector

Because the compensation sensors are in the CON/KAD/010 mating connector (that ships with the module as part of the ACD/CJB/003), we recommend that only this mating connector is used (see "Ordering information" on page 10).

The CON/KAD/010 connector has three built-in PT100, high accuracy (1/3 of class B, DIN/IEC 60751 specification) sensors. The following table indicates which PT100 sensor is associated with which KAD/TDC/102 channel.

TABLE 4	CON/KAD/010 built-in PT100 sensor for each KAD/TDC/102 channel
KAD/TDC/102 channel (Temperature(x))	CON/KAD/010 built-in PT100 sensor (JunctionTemperature(x))
0	0
1	0
2	0
3	2
4	2
5	2
6	0
7	0
8	0
9	2
10	2
11	2
12	0
13	2
14	0

NOTE: The CON/KAD/010 built-in PT100 JunctionTemperature(1) is not assigned. Testing showed that JunctionTemperature(1) does not provide improved accuracy.

The CON/KAD/010 connector provides a compact accurate solution for the cold junction block and with the ACD/BAC/002/B, part of the ACD/CJB/003, guarantees the specified accuracy for an ambient temperature change rate of up to 1°C per minute.

For complete mechanical and electrical specifications, refer to the ACD/CJB/003, ACD/BAC/002/B, and CON/KAD/010 data sheets.

Understanding filter delays

The Acra KAM-500 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 will always be 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 cutoff point is one quarter the sampling frequency, as this results in the maximum filtering of aliasing frequencies.

The Acra KAM-500 filters signals using over-sampling signal processing techniques. The following figure shows a delay for an 8th order filter where f_c = 1kHz. All filters cause a delay inversely proportional to the filter cutoff frequency (f_c), so to calculate the delay for other f_c values, multiply the delay by (1kHz / f_c). The frequency axis then needs to be rescaled to the new f_c by dividing the frequency values by (1kHz / f_c). For example, an 8th order Butterworth filter with an f_c of 1kHz delays a 1kHz signal by 1ms; a filter with an f_c of 10Hz delays a 10Hz signal by 0.1s. The delay for IIR filters (for example Butterworth) varies with the input frequency.

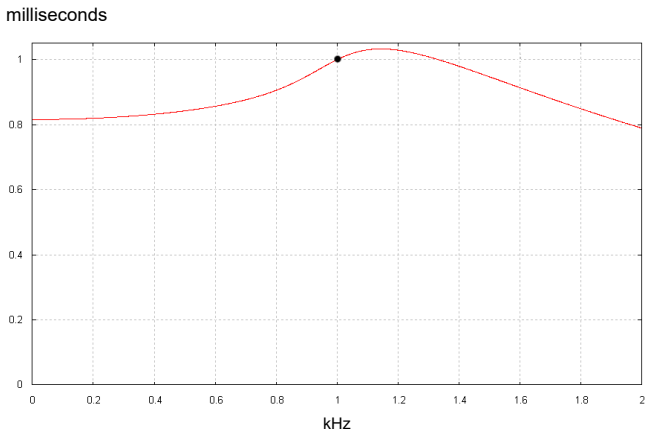

Figure 2: Filter delay for 8th order Butterworth filter where f_c = 1kHz

The filter delay for the KAD/TDC/102 is:

$$T_D \approx T_A + \frac{1}{f_C} + T_{Butterworth8}(f)$$

T_D is the filter delay

T_A (analog filter delay) ≈ 0

Signal filtering on reference junction channels

As well as an RF filter on the cold junction channels, the KAD/TDC/102 provides a digital filter, which is built into the analog-to-digital converter. This means—unlike other Curtiss-Wright analog modules—the filter characteristics of the KAD/TDC/102 reference junction channels are fixed. The cutoff frequency (-3dB) point is approximately at 4Hz and is not dependent on the sampling rate that is used.

The built-in digital filter has 50Hz and 60Hz attenuation (>65dB), and similar attenuation for frequencies above 90Hz. The following figure shows the magnitude characteristic of the filter.

(Image used with permission of Analog Devices, Inc.)

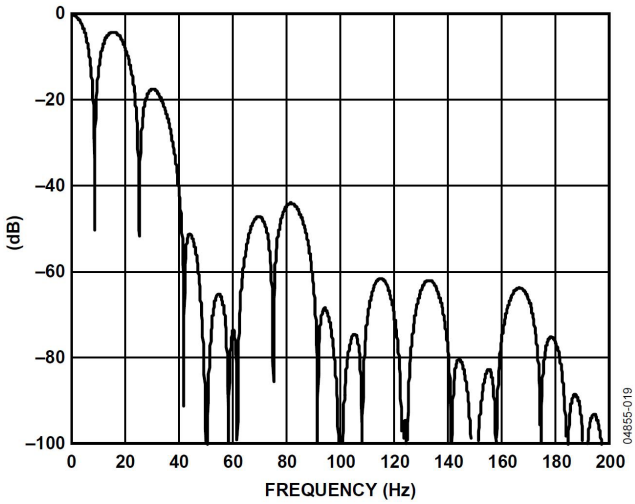

Figure 3: Magnitude characteristic of built-in A/D digital filter

Connector pinout of the KAD/TDC/102

PIN	NAME	SEE SPECIFICATIONS TABLE	COMMENT
1	ANALOG(12)+	Thermocouple inputs	
2	ANALOG(12)-	Thermocouple inputs	
3	ANALOG(0)+	Thermocouple inputs	
4	ANALOG(0)-	Thermocouple inputs	
5	ANALOG(1)+	Thermocouple inputs	
6	ANALOG(1)-	Thermocouple inputs	
7	ANALOG(2)+	Thermocouple inputs	
8	ANALOG(2)-	Thermocouple inputs	
9	ANALOG(3)+	Thermocouple inputs	
10	ANALOG(3)-	Thermocouple inputs	
11	ANALOG(4)+	Thermocouple inputs	
12	ANALOG(4)-	Thermocouple inputs	
13	ANALOG(5)+	Thermocouple inputs	
14	ANALOG(5)-	Thermocouple inputs	
15	ANALOG(13)+	Thermocouple inputs	
16	ANALOG(13)-	Thermocouple inputs	
17	DNC		Do not connect
18	CJ_IEXC(0)+	Cold junction	Excitation current to cold junction channel 0
19	CJ_SENSE(0)+	Cold junction	Sense line for cold junction channel 0
20	DNC		Do not connect
21	DNC		Do not connect
22	CJ_SENSE(0)-	Cold junction	Sense line for cold junction channel 0
23	CJ_IEXC(0)-	Cold junction	Excitation current from cold junction channel 0
24	CJ_IEXC(1)+	Cold junction	Excitation current to cold junction channel 1
25	CJ_SENSE(1)+	Cold junction	Sense line for cold junction channel 1
26	DNC		Do not connect
27	DNC		Do not connect
28	CJ_SENSE(1)-	Cold junction	Sense line for cold junction channel 1
29	CJ_IEXC(1)-	Cold junction	Excitation current from cold junction channel 1
30	CJ_IEXC(2)+	Cold junction	Excitation current to cold junction channel 2
31	CJ_SENSE(2)+	Cold junction	Sense line for cold junction channel 2
32	DNC		Do not connect
33	DNC		Do not connect
34	CJ_SENSE(2)-	Cold junction	Sense line for cold junction channel 2
35	CJ_IEXC(2)-	Cold junction	Excitation current from cold junction channel 2
36	ANALOG(14)+	Thermocouple inputs	
37	ANALOG(14)-	Thermocouple inputs	
38	ANALOG(6)+	Thermocouple inputs	
39	ANALOG(6)-	Thermocouple inputs	
40	ANALOG(7)+	Thermocouple inputs	
41	ANALOG(7)-	Thermocouple inputs	
42	ANALOG(8)+	Thermocouple inputs	
43	ANALOG(8)-	Thermocouple inputs	
44	ANALOG(9)+	Thermocouple inputs	
45	ANALOG(9)-	Thermocouple inputs	
46	ANALOG(10)+	Thermocouple inputs	
47	ANALOG(10)-	Thermocouple inputs	
48	ANALOG(11)+	Thermocouple inputs	
49	ANALOG(11)-	Thermocouple inputs	
50	GND	Internal ground	
51	GND	Internal ground	
52	CHASSIS	Chassis	

Ordering information

PART NUMBER	DESCRIPTION
KAD/TDC/102/B	Thermocouple ADC (reference compensation, 250Hz b/w) - 15ch at 1ksps

By default, an ACD/CJB/003 (which includes an ACD/BAC/002/B and a CON/KAD/010) is included with each module in the shipment.

Revision history

REVISION	DIFFERENCES	STATUS
KAD/TDC/102/B	A/D converters are reset to default configuration after every read - this fixes problem with possible corruption of A/D configuration registers	Recommended for new programs
KAD/TDC/102	First release	Not 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
KSM-500	This module is supported by the KSM-500 suite of software tools

Related documentation

DOCUMENT	DETAILS
DOC/DBK/001	Acra KAM-500 Databook
DOC/HBK/002	Environmental Qualification Handbook
DOC/MAN/018	KSM-500 Databook
DOC/MAN/030	DAS Studio 3 User Manual
TEC/NOT/010	Thermocouples
TEC/NOT/016	Power dissipation
TEC/NOT/049	Power estimation