

LabJack

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14.0 Analog Inputs [T-Series Datasheet]

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Analog Inputs Overview

Basics: An [analog input](#) (commonly referred to as AIN or AI) uses an analog-to-digital converter (ADC) to convert a voltage level into a digital value. LabJack T-series devices have multiple analog inputs.

Common Uses: For information on measuring various analog signals such as typical analog sensors, measuring small voltages, measuring current (4-20mA), and measuring resistance see the [Analog Input \(App Note\)](#). There are also application specific app notes for [temperature sensors](#) and [thermocouples](#).

How to read AIN: See [3.0 Communication](#) for communication basics. Also, LabJack [Kipling's Dashboard](#) tab shows live AIN values.

Configuration: T-series AIN readings can be configured. See below for information on:

- [Summary By Device](#)
- [Available AIN Channels](#)
- [Resolution Index](#)
- [Flexible I/O - T4 Only](#)
- [Single-ended or Differential - T7 Only](#)
- [Range - T7 Only](#)
- [Settling](#)
- [Other Considerations](#)
- [Analog Input Channels Reference](#)

AIN Extended Features: T-series [AIN Extended Features](#) simplify operations such as:

- Reading thermocouples and thermistors
- Calculating RMS, RTD, average/max/min, average/threshold, and circuit element resistance

Extended Channels - T7 Only: The T7's [Extended Channels](#) range provides extra AIN channels.

AIN Summary By Device

T4

Analog Inputs: 4 high-voltage (AIN0-AIN3)
8 low-voltage (AIN4-AIN11)

Voltage Ranges: $\pm 10\text{V}$ or $0\text{-}2.5\text{V}$ ([Appendix A-3](#) and [Appendix A-3-2](#))

Resolution: 12-bit

Max Data Rate: 40 ksamples/second in stream mode ([Appendix A-1](#))

Sampling Modes: Single-ended

T7

Analog Inputs: 14 (AIN0-AIN13)

Voltage Ranges: $\pm 10\text{V}$, $\pm 1\text{V}$, $\pm 0.1\text{V}$, and $\pm 0.01\text{V}$ ([Appendix A-3](#) and [Appendix A-3-2](#))

ADC Resolution: T7 = 16-bit
T7-Pro = 16-bit and 24-bit

Effective Resolution: T7 = 16-bit to 19-bit
T7-Pro = 16-bit and 22-bit
At Gain 1x. For more details see [Appendix A-3-1](#).

Max Data Rate: 100 ksamples/second in stream mode ([Appendix A-1](#))

Sampling Modes: Configurable as single-ended or differential

Extended Channels: The number of analog inputs can be extended to 84 with [aMux80](#) (AIN48-AIN127).

Available AIN Channels

Each T-series device exposes:

- Some AINs on the screw terminals.
- Additional AINs on a connector (either a [DB15](#) or a [DB37](#)).

T4

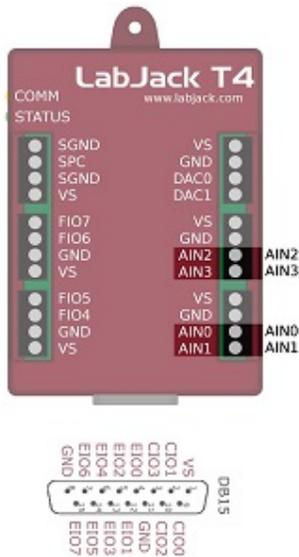


Figure 14.0-1 T4 Dedicated Analog Inputs

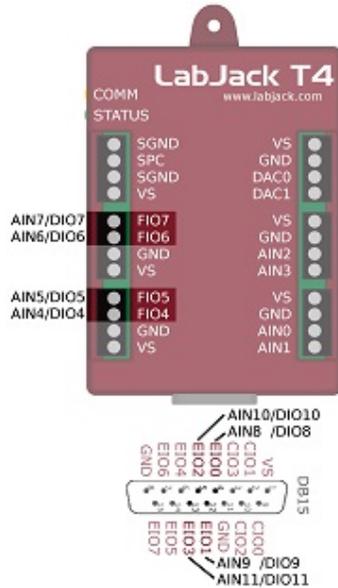


Figure 14.0-2 T4 Flexible I/O

The LabJack T4 has up to 12 built-in analog inputs, readable as AIN0-AIN11:

- AIN0-AIN3 are dedicated ± 10 volt inputs:
 - Available on screw terminals AIN0-AIN3.
 - Always ± 10 volt analog inputs.
- AIN4-AIN7 are flexible 0 to +2.5 volt inputs:
 - Available on screw terminals FIO4-FIO7.
 - Configurable to be digital inputs/outputs. See "Flexible I/O" below.
- AIN8-AIN11 are flexible 0 to +2.5 volt inputs:
 - Available on the DB15 connector.
 - Configurable to be digital inputs/outputs. See "Flexible I/O" below.

T4 AIN Channel Registers

Name		Start Address	Type	Access
AIN#(0:11)	Returns the voltage of the specified analog input.	0	FLOAT32	R

&print=true

T7



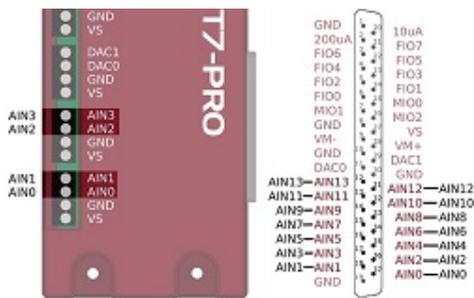


Figure 14.0-3 T7 Analog Inputs

The LabJack T7 has 14 built-in analog inputs, readable as AIN0-13:

- AIN0-AIN3 are available on the screw terminals and on the [DB37](#) connector. See "Duplicated Terminals" below.
- AIN4-AIN13 are available only on the [DB37](#) connector.

T7 AIN Channel Registers

Name		Start Address	Type	Access
AIN#(0:13)	Returns the voltage of the specified analog input.	0	FLOAT32	R

&print=true

In addition to the 14 built-in analog inputs, the T7 has special and extended channels.

- - AIN14 is internally connected to an internal [temperature sensor](#).
 - AIN15 is internally connected to GND. Useful for measuring noise or looking at offset error.
 - AIN16-AIN47 are optional extended channels that can be created with custom analog input muxing circuitry. See [Section 14.2 Extended Channels](#) for more information.
 - AIN48-AIN127 are extended channels that are available when using [aMux80](#).

T7 Extended AIN Channel Registers

Name		Start Address	Type	Access
AIN#(48:127)	Returns the voltage of the specified analog input.	96	FLOAT32	R

&print=true

Example:

To read a voltage connected to AIN1, read AIN1 (address 2). The result will be in the form of a floating point number, like 8.82332V.

Resolution Index

A higher resolution index results in lower noise and higher effective resolution but increases sample times.

Resolution Index Registers			
Name		Start Address	Type Access
 AIN#(0:13)_RESOLUTION_INDEX	The resolution index for command-response and AIN-EF readings. A larger resolution index generally results in lower noise and longer sample times.	41500	UINT16 R/W
 AIN_ALL_RESOLUTION_INDEX	The resolution index for command-response and AIN-EF readings. A larger resolution index generally results in lower noise and longer sample times. A write to this global parameter affects all AIN. A read will return the correct setting if all channels are set the same, but otherwise will return 0xFFFF.	43903	UINT16 R/W
 STREAM_RESOLUTION_INDEX	The resolution index for stream readings. A larger resolution index generally results in lower noise and longer sample times.	4010	UINT32 R/W

&print=true

Defaults:

Setting resolution index to 0 sets the default resolution index to:

- 5 for command-response mode on a T4
- 8 for command-response mode on a T7
- 9 for command-response mode on a T7-Pro

Example:

To read AIN1 with resolution index 4:

1. Set the AIN1 resolution index to 4 by writing 5 to AIN1_RESOLUTION_INDEX (address 41501)
2. Read AIN1

Resolution index ranges:

- T4 resolution index ranges from 0 to 5
- T7 resolution index ranges from 0 to 8
- T7-Pro resolution index ranges from 0 to 12
 - Settings 9-12 use the alternate high-resolution converter (24-bit sigma-delta)

Remarks:

AIN#(0:13)_RESOLUTION_INDEX and AIN_ALL_RESOLUTION_INDEX do not apply to stream mode, though they do apply to all command-response communications, including AIN EF.

For stream mode, use `STREAM_RESOLUTION_INDEX` to configure AIN resolution. See [configuring AIN for stream](#) for more information.

For typical noise levels and sample times at different combinations of resolution index and gain, see [Appendix A-3-1 Noise and Resolution](#).

For general discussion on the meaning of resolution, see the [Noise and Resolution App Note](#).

Flexible I/O - T4 Only

Flexible I/O are I/O ports that may be configured as analog inputs, or as digital inputs or outputs.

Flexible I/O Configuration			
Name		Start Address	Type Access
 <code>DIO_INHIBIT</code>	A single binary-encoded value where each bit determines whether <code>_STATE</code> , <code>_DIRECTION</code> or <code>_ANALOG_ENABLE</code> writes affect that bit of digital I/O. 0=Default=Affected, 1=Ignored.	2900	UINT32 R/W
 <code>DIO_ANALOG_ENABLE</code>	Read or write the analog configuration of all digital I/O in a single binary-encoded value. 1=Analog mode and 0=Digital mode. When switching from analog to digital, the lines will be set to input. Writes are filtered by the value in <code>DIO_INHIBIT</code> .	2880	UINT32 R/W

&print=true

AIN4-AIN11 are flexible I/O. To configure these channels as analog inputs:

- Set the correct bit of `DIO_INHIBIT` to 0
- Set the correct bit of `DIO_ANALOG_ENABLE` to 1

The bit to set of `DIO_INHIBIT` and of `DIO_ANALOG_ENABLE` is the same as the channel number. For example, to configure AIN4 (screw terminal FIO4) as an analog input:

- Set bit 4 of `DIO_INHIBIT` to 0
- Set bit 4 of `DIO_ANALOG_ENABLE` to 1

AIN0-AIN3 are dedicated analog inputs and cannot be configured as digital I/O.

Note that simply doing an analog read on AIN4-AIN11 automatically configures that line (FIO4-EIO3) as analog, so few people use the 2 registers mentioned above. See "Flexible I/O Auto-Configuration" in [Section 13.1 Flexible I/O](#).

Single-ended or Differential - T7 Only

Single-ended AIN readings are read with ground (GND) as a reference point. Differential readings use a second AIN as a reference point. For more, see the [Differential Readings App Note](#).

Negative Channel Registers			
Name		Start Address	Type Access
 AIN#(0:13)_NEGATIVE_CH	Specifies the negative channel to be used for each positive channel. 199=Default=> Single-Ended.	41000	UINT16 R/W
 AIN_ALL_NEGATIVE_CH	A write to this global parameter affects all AIN. Writing 1 will set all AINs to differential. Writing 199 will set all AINs to single-ended. A read will return 1 if all AINs are set to differential and 199 if all AINs are set to single-ended. If AIN configurations are not consistent 0xFFFF will be returned.	43902	UINT16 R/W

&print=true

The AIN#(0:13)_NEGATIVE_CH and AIN_ALL_NEGATIVE_CH parameters configure whether the AIN performs differential vs. single-ended readings (not to be confused with bipolar and unipolar—the T7 is always bipolar).

Example:

To take a differential reading on AIN2, set AIN3 as its negative channel (AIN2-AIN3):

1. Write 3 to AIN2_NEGATIVE_CH (address 41002)
2. Read AIN2

To read AIN2 single-ended again (AIN2-GND):

1. Write 199 to AIN2_NEGATIVE_CH (address 41002)
2. Read AIN2

User software or the Register Matrix in Kipling can be used to configure any analog input as differential, or the Analog Inputs tab in Kipling can be used to quickly set AIN0/2/4/6/8/10/12 to differential.

Testing:

Use 2 jumper wires to securely connect each analog inputs to VS or GND. Using the default +/-10V range the readings should be as follows:

AINpos(VS) and AINneg(GND) => 5 volts
 AINpos(GND) and AINneg(VS) => -5 volts
 AINpos(VS) and AINneg(VS) => 0 volts

Built-in AIN:

For AIN0 through AIN13, differential channels are adjacent even/odd pairs such that the

positive channel is even and the negative channel is greater than the positive channel by 1. Odd channels, such as AIN3_NEGATIVE_CH (address 41003), should not be written to because only an even channel can have an associated negative channel.

Temperature and Ground:

AIN14 is the internal temperature sensor and AIN15 is GND. Neither can be read differentially.

Extended AIN:

For AIN16 and greater, the rules for pairing differential channels is different. See 14.2 Extended Channels or the Mux80 datasheet for more.

Range / Gain - T7 Only

T7 Internal Amplifier: The analog inputs are connected to a high-impedance instrumentation amplifier, as shown in [Figure 4.2-2](#). This in-amp does the following:

- Buffers the signal for the internal ADCs
- Allows for single-ended or differential conversions
- Provides gains of x1, x10, x100, and x1000 (corresponding to ranges of $\pm 10\text{V}$, $\pm 1\text{V}$, $\pm 0.1\text{V}$, and $\pm 0.01\text{V}$, respectively).

Range Registers			
Name		Start Address	Type Access
 AIN#(0:13)_RANGE	The range/span of each analog input. Write the highest expected input voltage.	40000	FLOAT32 R/W
 AIN_ALL_RANGE	A write to this global parameter affects all AIN. A read will return the correct setting if all channels are set the same, but otherwise will return -9999.	43900	FLOAT32 R/W

&print=true

Example:

If the voltage source connected to AIN1 has a known range of 0 to 0.7V, the appropriate range for AIN1 is the $\pm 1\text{V}$ range. To read AIN1 with the $\pm 1\text{V}$ range:

1. Write 1.0 to AIN1_RANGE (address 40002)
2. Read AIN1

The range registers (AIN#(0:13)_RANGE and AIN_ALL_RANGE) control the gain of the T7's internal instrumentation amplifier. The in-amp supports gains of x1, x10, x100, and x1000.

- A range of 10 sets gain=x1 so that the analog input range is ± 10 volts. This is the default range.
- A range of 1 sets gain=x10 so that the analog input range is ± 1 volts.
- A range of 0.1 sets gain=x100 so that the analog input range is ± 0.1 volts.
- A range of 0.01 sets gain=x1000 so that the analog input range is ± 0.01 volts.

Values written to RANGE are rounded up (except for values greater than 10.0, which are rounded down). For example, writing 0.5 to AIN_ALL_RANGE will set the analog input range to ± 1 volts.

The T7 knows what the internal gain is set to and adjusts the return values to give the voltage at the input terminals, so if you connect a 0.8 volt signal to the input terminals, it will be amplified to 8.0 volts before being digitized, but the reading you get back will be 0.8 volts.

Settling

The settling registers set the time from a step change in the input signal to when the signal is sampled by the ADC, as measured in microseconds. A step change in this case is caused when the internal multiplexers change from one channel to another. In general, more settling time is required as gain and resolution are increased.

The value 0 sets automatic settling, which is recommended for most applications. This "auto" settling ensures that the device meets specifications at any gain and resolution for source impedance up to at least 1000 ohms.

Settling Registers			
Name		Start Address	Type Access
 AIN#(0:13)_SETTLING_US	Settling time for command-response and AIN-EF readings.	42000	FLOAT32 R/W
 AIN_ALL_SETTLING_US	Settling time for command-response and AIN-EF readings. A write to this global parameter affects all AIN. A read will return the correct setting if all channels are set the same, but otherwise will return -9999. Max is 50,000 us.	43904	FLOAT32 R/W
 STREAM_SETTLING_US	Time in microseconds to allow signals to settle after switching the mux. Does not apply to the 1st channel in the scan list, as that settling is controlled by scan rate (the time from the last channel until the start of the next scan). Default=0. When set to less than 1, automatic settling will be used. The automatic settling behavior varies by device.	4008	FLOAT32 R/W

&print=true

Example:

To read AIN3 with a manual settling time of 500 μ s:

1. Write 500 to AIN3_SETTLING_US (address 42006)
2. Read AIN3

Remarks:

AIN#(0:13)_SETTLING_US and AIN_ALL_SETTLING_US do not apply to stream mode, though they do apply to all command-response communications, including AIN EF.

For stream mode, use STREAM_SETTLING_US to configure AIN settling. See configuring AIN for stream for more information.

The timings in Appendix A are measured with "auto" settling.

See the Analog Input Settling Time (App Note) for more details.

Other Considerations

Streaming AIN: See [3.2 Stream Mode](#) for streaming analog inputs. Some stream configurations override the normal AIN configurations:

- Use `STREAM_SETTLING_US` instead of `AIN_SETTLING_US`.
- Use `STREAM_RESOLUTION_INDEX` instead of `AIN_RESOLUTION_INDEX`.

Floating Inputs: The analog inputs are not artificially pulled to 0.0 volts, as that would reduce the input impedance, so readings obtained from floating channels will generally not be 0.0 volts. The readings from floating channels depend on adjacent channels and sample rate and have little meaning. See the [floating input application note](#).

Connections: For information regarding typical analog input connections, please see the [Analog Input App Note](#).

Address Step Size:

Addresses of the `FLOAT32` type increment in steps of 2 because `FLOAT32` uses two sets of 16-bits. `FLOAT32` registers include `AIN#`, `AIN#_RANGE`, and `AIN#_SETTLING_US`.

Addresses of the `UINT16` type increment in steps of 1 because `UNIT16` uses only one set of 16-bits. `UINT16` registers include `AIN#_NEGATIVE_CH` and `AIN#_RESOLUTION_INDEX`.

T7 Only: Duplicated Terminals (AIN0-AIN3):

AIN0-AIN3 appear on the built-in screw-terminals and also on the DB37 connector. Users should only connect to one or the other, not both at the same time.

To prevent damage due to accidental short circuit, both connection paths have their own series resistor. All AIN lines have a 2.2k series resistor, and in the case of AIN0-AIN3 the duplicated connections each have their own series resistor, so if you measure the resistance between the duplicate terminals you will see about 4.4k.

Calibration:

For [command-response](#) communication, analog input [calibration](#) is automatically applied by firmware and the `AIN#` registers return calibrated voltages.

For [stream](#) communication, the `AIN#` registers return raw binary values and calibration is automatically performed by [LJM](#). For applications not using [LJM](#), see the [low-level Modbus streaming example](#).

Analog Input Channels Reference

Table 14.0-1 Analog Input Channel Overview

Built-in Analog Inputs	Extended Channels
<div style="display: flex; justify-content: space-between; width: 100%;"> AIN0 AIN1 AIN2 AIN3 </div>	

AIN	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	AIN (48-127)
T4	AIN (0-3) High-Voltage $\pm 10V$				AIN (4-11) Low-Voltage 0-2.5V							N/A			N/A		
T7	AIN (0-13) High-Voltage $\pm 10V$ Options: SE/Diff, Gains (1000x, 100x, 10x, 1)												Special Channels		AIN (48-127) <u>Mux80</u>		

14.1 AIN Extended Features [T-Series Datasheet]

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AIN Extended Features Overview

Analog Extended Features (AIN-EF) simplify some common analog input applications. Each AIN-EF feature:

- collects one or more input samples
- performs math on the collected samples

AIN-EF is only supported in command-response mode and not in stream mode.

Kipling Walkthrough: Kipling's [Register Matrix](#) can be used to perform AIN-EF features. For example:

- [Configuring & Reading a Thermocouple](#)

Available AIN Extended Features

For any given AIN channel, one AIN-EF feature may be selected. AIN-EF indices:

Index	AIN-EF Name	Supported Devices
0:	None (disabled)	All T-series
1:	Offset and Slope	All T-series
3:	Max, Min, Avg	All T-series
4:	Resistance	All T-series
5:	Average and Threshold	All T-series
10:	RMS Flex	All T-series
11:	RMS Auto	All T-series
20:	Thermocouple type E	T7 only
21:	Thermocouple type J	T7 only
22:	Thermocouple type K	T7 only
23:	Thermocouple type R	T7 only
24:	Thermocouple type T	T7 only

25:	<u>Thermocouple</u> type S	T7 only
30:	<u>Thermocouple</u> type C	T7 only
40:	<u>RTD</u> PT100	All T-series
41:	<u>RTD</u> PT500	All T-series
42:	<u>RTD</u> PT1000	All T-series
50:	<u>Thermistor</u> using Steinhart-Hart equation	All T-series
51:	<u>Thermistor</u> using Beta equation	All T-series

AIN-EF Usage

To use any AIN-EF:

1. Set the EF_INDEX to select an extended feature
2. Configure the extended feature using the EF_CONFIG registers
3. Configure normal AIN configurations through the normal AIN registers
4. Read from READ_A to perform the extended feature operation
5. Read additional results from B, C, and D

For a quick example of setting up an AIN-EF in thermocouple mode, see [Configuring & Reading a Thermocouple](#).

1. Set the AIN#_EF_INDEX to select an extended feature

Name	Start Address	Type	Access
 AIN#(0:13)_EF_INDEX Specify the desired extended feature for this analog input with the index value. List of index values: 0=None(disabled); 1=Offset and Slope; 3=Max/Min/Avg; 4=Resistance; 5=Average and Threshold; 10=RMS Flex; 11=FlexRMS; 20=Thermocouple type E; 21=Thermocouple type J; 22=Thermocouple type K; 23=Thermocouple type R; 24=Thermocouple type T; 25=Thermocouple type S; 30=Thermocouple type C; 40=RTD model PT100; 41=RTD model PT500; 42=RTD model PT1000.	9000	UINT32	R/W
 AIN_ALL_EF_INDEX Write 0 to deactivate AIN_EF on all AINs. No other values may be written to this register. Reads will return the AIN_EF index if all 128 AINs are set to the same value. If values are not the same returns 0xFFFF (65535).	43906	UINT32	R/W

&print=true

Write to AIN#(0:14)_EF_INDEX or AIN_ALL_EF_INDEX to select the AIN extended feature.

2. Configure the extended feature using the AIN#_EF_CONFIG registers

Name		Start Address	Type	Access
 AIN#(0:13)_EF_CONFIG_A	Function dependent on selected feature index.	9300	UINT32	R/W
 AIN#(0:13)_EF_CONFIG_B	Function dependent on selected feature index.	9600	UINT32	R/W
 AIN#(0:13)_EF_CONFIG_C	Function dependent on selected feature index.	9900	UINT32	R/W
 AIN#(0:13)_EF_CONFIG_D	Function dependent on selected feature index.	10200	FLOAT32	R/W
 AIN#(0:13)_EF_CONFIG_E	Function dependent on selected feature index.	10500	FLOAT32	R/W
 AIN#(0:13)_EF_CONFIG_F	Function dependent on selected feature index.	10800	FLOAT32	R/W
 AIN#(0:13)_EF_CONFIG_G	Function dependent on selected feature index.	11100	FLOAT32	R/W

&print=true

Each AIN-EF index requires different configuration parameters, so the meaning of the AIN#_EF_CONFIG registers depend on which AIN#_EF_INDEX is set.

3. Configure normal AIN configurations through the normal AIN registers

Analog input range, resolution, settling, and negative channel settings are configured through the normal [AIN registers](#).

4. Read from AIN#_EF_READ_A to perform the extended feature operation

Name		Start Address	Type	Access
 AIN#(0:13)_EF_READ_A	Function dependent on selected feature index.	7000	FLOAT32	R

&print=true

Only reading AIN#_EF_READ_A will trigger the selected AIN-EF operation. The AIN#_EF_READ_A result is returned. Additional results are saved for later retrieval.

If the AIN-EF index uses stream-burst, reading AIN#_EF_READ_A will block for the length of time it takes to collect the necessary samples.

5. Read additional results B, C, and D

Name		Start Address	Type	Access
 AIN#(0:13)_EF_READ_B feature index.	Function dependent on selected	7300	FLOAT32	R/W
 AIN#(0:13)_EF_READ_C feature index.	Function dependent on selected	7600	FLOAT32	R/W
 AIN#(0:13)_EF_READ_D feature index.	Function dependent on selected	7900	FLOAT32	R

&print=true

Reading from result registers other than AIN#_EF_READ_A will read the saved values and will not initiate a new reading.

14.1.0.1 Excitation Circuits [T-Series Datasheet]

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Overview

AIN-EF indices that need to measure resistance (Resistance, RTD, Thermistor) can use different types of excitation circuits. The excitation circuit converts the varying resistance to a voltage signal that can be measured by the LabJack.

Individual AIN-EF indices may only support a subset of the circuits listed here.

For AIN-EF indices that require excitation circuits, the circuit indices below are written to AIN#_EF_CONFIG_B.

The most commonly used circuit is #4, as it is designed for the LJTick-Resistor.

These circuits all use a voltage source or current source for excitation. Note that any noise in the excitation source will result in proportionate noise in the sensor signal. Sources designed for excitation (e.g. voltage reference) are recommended rather than power supplies (e.g. VS).

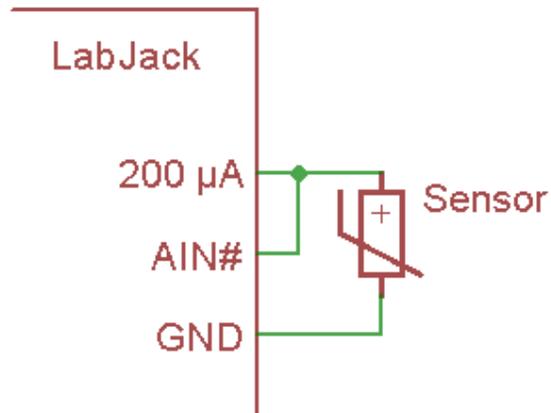
Current Source Excitation Circuits

The first 3 excitation circuits are specific to current source excitation. A current source varies voltage so it can provide the specified fixed current.

Circuit 0 – 200 μ A Current Source - T7 Only:

This excitation circuit uses the 200 μ A current source available on the T7 to excite a sensor. It calculates resistance based on the measured voltage and the stored factory calibration value for 200UA. This circuit is useful for smaller resistances such as RTDs.

The following figure shows a basic single sensor connection, but if the AIN is configured and connected as differential, multiple sensors can be put in series as shown in figures from the 200UA/10UA documentation.



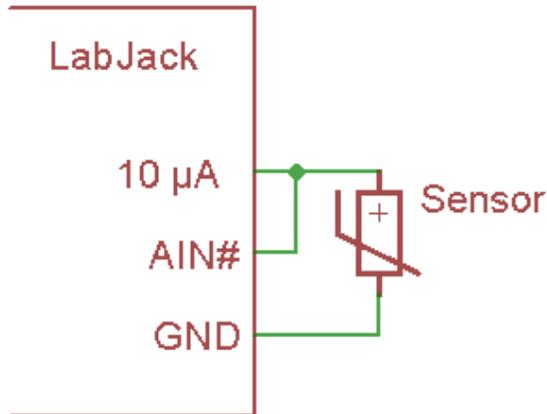
Configuration registers:

- AIN#_EF_CONFIG_C - Ignored
- AIN#_EF_CONFIG_D - Ignored
- AIN#_EF_CONFIG_E - Ignored

Circuit 1 – 10 μ A Current Source - T7 Only:

This excitation circuit uses the 10 μ A current source available on the T7 to excite a sensor. It calculates resistance based on the measured voltage and the stored factory calibration value for 10UA. This circuit is useful for larger resistances such as thermistors.

The following figure shows a basic single sensor connection, but if the AIN is configured and connected as differential, multiple sensors can be put in series as shown in figures from the 200UA/10UA documentation.



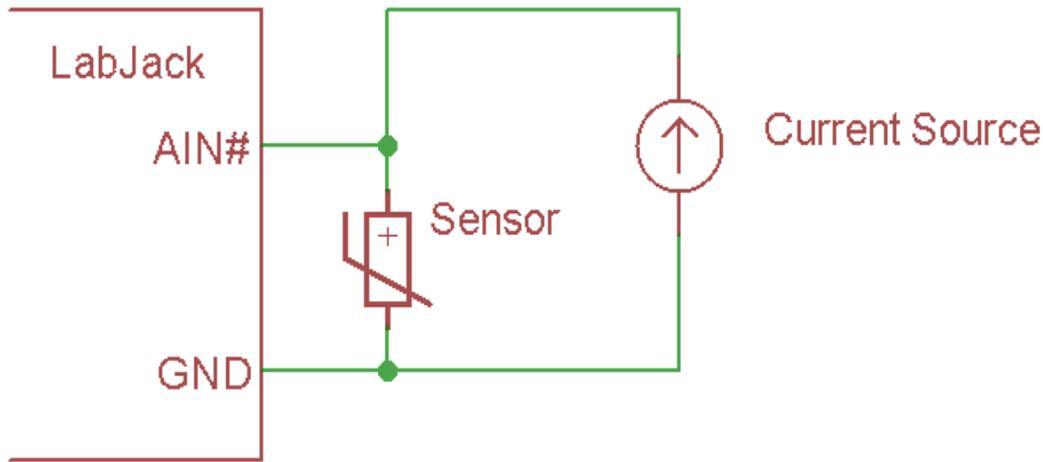
Configuration registers:

- AIN#_EF_CONFIG_C - Ignored
- AIN#_EF_CONFIG_D - Ignored
- AIN#_EF_CONFIG_E - Ignored

Circuit 2 – Custom Current Source:

This excitation circuit uses a current source external to the LabJack. The current provided by the source is specified during configuration of the AIN#_EF.

The following figure shows a basic single sensor connection, but if the AIN is configured and connected as differential, multiple sensors can be put in series.



Configuration registers:

- AIN#_EF_CONFIG_C - Ignored
- AIN#_EF_CONFIG_D - Excitation Amps
- AIN#_EF_CONFIG_E - Ignored

Resistive Divider Excitation Circuits

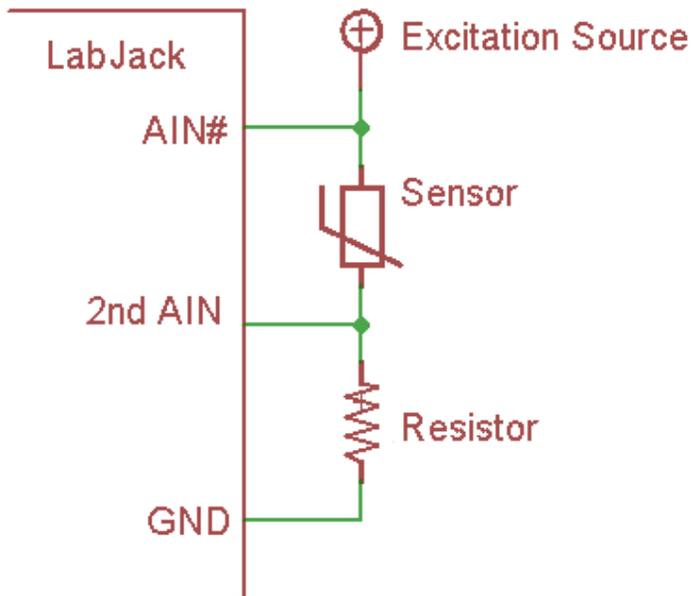
Divider circuits rely on an excitation source and a fixed resistor in series with the sensor.

Circuit 3 – Divider with Measured Excitation - Differential:

This circuit has an excitation source in series with a sensor which is then in series with a fixed resistor to ground. The device takes the single-ended reading of 2ndAIN to get $V_{resistor}$, and takes the differential reading of AIN# to get V_{sensor} . $V_{resistor}$ is divided by the specified fixed resistance to get current, and then V_{sensor} is divided by that current to get the resistance of the sensor.

The drawing shows the most common way of connecting. AIN# is a positive differential channel (e.g. AIN2) and 2ndAIN is the negative associated with that channel (e.g. AIN3). Alternatively, any differential pair of analog inputs can be connected across the sensor, and 2ndAIN can be any single-ended analog input. This allows multiple sensors to be connected in series with a single excitation source.

AIN# must be pre-configured by the user as differential or an error will be thrown. Thus this circuit is supported on the T7 but not the T4.



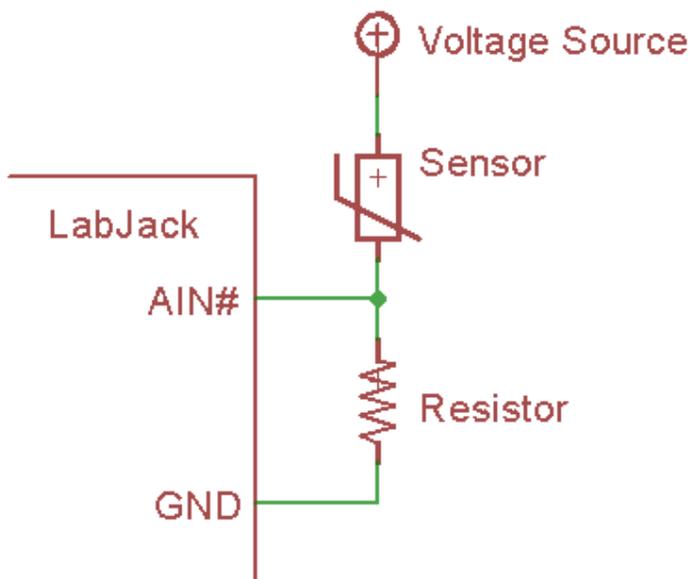
Configuration registers:

- AIN#_EF_CONFIG_C - 2nd AIN: Channel Number to Measure Vresistor
- AIN#_EF_CONFIG_D - Ignored
- AIN#_EF_CONFIG_E - Fixed Resistor Ohms

Circuit 4 – Voltage Source with Specified Value:

This excitation circuit uses a voltage source and a shunt resistor. Values for the output of the voltage source and the resistor must be provided during AIN#_EF configuration. When using this circuit, the LabJack will measure the voltage between the sensor and the resistor, then calculate the resistance of the sensor.

This is the most common circuit used with the LJTick-Resistance.



Configuration registers:

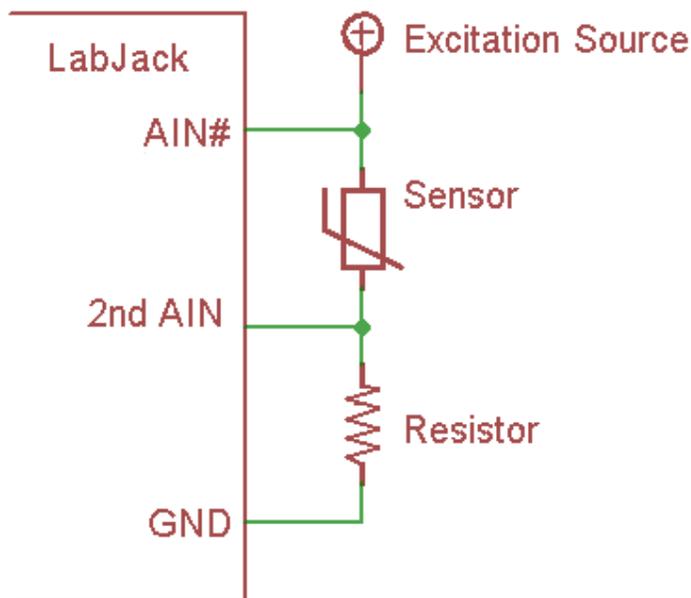
- AIN#_EF_CONFIG_C - Ignored
- AIN#_EF_CONFIG_D - Excitation Volts
- AIN#_EF_CONFIG_E - Fixed Resistor Ohms

Circuit 5 – Divider with Measured Excitation - Single-Ended:

This circuit has an excitation source in series with a sensor which is then in series with a fixed resistor to ground. The device takes the single-ended reading of 2ndAIN to get $V_{resistor}$, and takes the single-ended reading of AIN# minus the reading from 2ndAIN to get V_{sensor} . $V_{resistor}$ is divided by the specified resistance to get current, and then V_{sensor} is divided by current to get the resistance of the sensor.

Must be connected exactly as shown in the drawing. AIN# and 2ndAIN can be any channels.

This excitation circuit looks the same as circuit #3, but the voltage across the sensor is determined by the difference of 2 single-ended readings rather than a single differential reading. That means this circuit is supported on all devices and is limited to a single sensor in series with the excitation source.



Configuration registers:

- AIN#_EF_CONFIG_C - 2nd AIN: Channel Number to Measure $V_{resistor}$
- AIN#_EF_CONFIG_D - Ignored
- AIN#_EF_CONFIG_E - Fixed Resistor Ohms

14.1.1 Thermocouple (T7 Only) [T-Series Datasheet]

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Overview - T7 Only

This feature is only supported on the T7.

AIN#_EF_INDEX values:

- 20:** Thermocouple type E
- 21:** Thermocouple type J
- 22:** Thermocouple type K
- 23:** Thermocouple type R
- 24:** Thermocouple type T
- 25:** Thermocouple type S
- 30:** Thermocouple type C

This Thermocouple Extended Feature automatically performs calculations for the thermocouple types listed above.

Thermocouple AIN-EF indices read two analog inputs—one AIN connected to a thermocouple and a second AIN connected to a Cold-Junction Compensation (CJC) sensor.

For more information, see the [Thermocouples Application Note](#) and the [Thermocouples with the T7 App Note](#).

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Options: Select temperature units for AIN#_EF_READ_A and AIN#_EF_READ_C:

- 0 = K
- 1 = °C
- 2 = °F

AIN#_EF_CONFIG_B - CJC Modbus address: The Modbus address of the second AIN channel that will be read to acquire the CJC reading

The default is the on-board temperature sensor (TEMPERATURE_DEVICE_K, at address 60052).

AIN#_EF_CONFIG_D - CJC Slope: A slope to be applied to the CJC reading

This value is always in units of K/volt, regardless of AIN#_EF_CONFIG_A, so for the internal sensor it will nominally be 1.00 and for an LM34 it will be 55.56.

Default is 1.0.

AIN#_EF_CONFIG_E - CJC Offset: An offset to be applied to the CJC reading

This value is always in units of K, regardless of AIN#_EF_CONFIG_A, so for the internal sensor it will nominally be 0.0 and for an LM34 it will be 255.37.

Default is 0.0.

Remarks

The normal [analog input settings](#) are used for negative channel, resolution index, settling, and range.

Differential thermocouple readings have the advantage of mitigating bad ground loops and ground offset problems. See the [Thermocouples App Note](#) for more information.

The ± 0.1 volt range is automatically used if the range of the applicable channel (AIN#_RANGE) is set to the default ± 10 volts. Otherwise, the specified range will be used.

CJC calculations are always done in kelvin, regardless of whether AIN#_EF_CONFIG_A is used to change the output units. AIN#_EF_CONFIG_D and AIN#_EF_CONFIG_E should be used as needed to convert the CJC sensor reading to kelvin.

Results

Results are read from the following registers.

AIN#_EF_READ_A: Final calculated temperature of the remote end of the thermocouple

AIN#_EF_READ_B: Measured thermocouple voltage.

AIN#_EF_READ_C: CJC temperature.

AIN#_EF_READ_D: Thermocouple voltage calculated for CJC temperature.

Only reading AIN#_EF_READ_A triggers a new measurement.

Example

Assume a type K thermocouple is connected to AIN3/GND. To configure:

```
AIN3_EF_INDEX = 22    // feature index for type K thermocouple
AIN3_EF_CONFIG_B = 60052 // Set the CJC source (the address for device
                        // temperature sensor). 60052 is TEMPERATURE_DEVICE_K
AIN3_EF_CONFIG_D = 1.0 // slope for CJC reading
AIN3_EF_CONFIG_E = 0.0 // offset for CJC reading
```

Read AIN3_EF_READ_A to get the calculated temperature. If the remote end is at room temperature, it will read as approximately 298 kelvin.

For a more detailed walkthrough, see [Configuring & Reading a Thermocouple](#).

14.1.2 Offset and Slope [T-Series Datasheet]

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Overview

AIN#_EF_INDEX: 1

This Offset and Slope Extended Feature automatically adds a slope and an offset to analog readings.

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_D - Slope: Custom slope to be applied to the analog voltage reading. Default is 1.00.

AIN#_EF_CONFIG_E - Offset: Custom offset to be applied to the analog voltage reading. Default is 0.00.

Remarks

The normal [analog input settings](#) are used for negative channel, resolution index, settling, and range.

Results

For results, read AIN#_EF_READ_A.

AIN#_EF_READ_A - Returns the calculated voltage:

```
measured volts * slope + offset
```

Only reading AIN#_EF_READ_A triggers a new measurement.

Example

To configure Offset and Slope AIN-EF for AIN3:

```
AIN3_EF_INDEX = 1      // feature index for Offset and Slope
AIN3_EF_CONFIG_D = 2.0 // slope
AIN3_EF_CONFIG_E = -0.5 // offset
```

Now each read of AIN3_EF_READ_A will return $(AIN3 \text{ volts} * 2.0) - 0.5$.

14.1.3 RTD [T-Series Datasheet]

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Overview

AIN#_EF_INDEX values:

40: PT100

41: PT500

42: PT1000

This RTD Extended Feature automatically performs calculations for a Resistance Temperature Detector (RTD). RTD types are listed above.

When AIN#_EF_READ_A is read, the T-series device reads an analog input and calculates the resistance

of the RTD. Temperature is then calculated using the rational polynomial technique.

An RTD (aka PT100, PT1000) is a type of temperature sensor. See the [Temperature Sensors App Note](#).

An RTD provides a varying resistance, but the LabJack measures voltage, so some sort of circuit must be used to convert the varying resistance to a varying voltage. This AIN-EF supports various excitation circuits. The best option is usually the [LJTick-Resistance](#), which would be [excitation circuit #4](#).

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Options: Selects temperature units:

- 0 = K
- 1 = °C
- 2 = °F

AIN#_EF_CONFIG_B - Excitation Circuit Index: The index of the voltage divider excitation circuit to be used.

See [14.1.0.1 Excitation Circuits](#) for circuit indices.

AIN#_EF_CONFIG_C - 2nd AIN: Channel Number to Measure Vresistor For excitation circuits 3 and 5 this is the extra AIN used to measure the voltage across the fixed resistor. Ignored for other excitation circuits.

AIN#_EF_CONFIG_D - Excitation Volts or Amps For excitation circuit 2 this is the fixed amps of the current source. For excitation circuit 4 this is the fixed volts of the voltage source. Ignored for other excitation circuits.

AIN#_EF_CONFIG_E - Fixed Resistor Ohms: For excitation circuits 3, 4 and 5, this is the ohms of the fixed resistor.

Remarks

The normal [analog input settings](#) are used for negative channel, resolution index, settling, and range.

T7 only: If [voltage will stay below 1.0V](#), use the 1.0V range for improved resolution and accuracy.

Results

For results, read the following registers.

AIN#_EF_READ_A: Calculated temperature.

AIN#_EF_READ_B: Resistance of the RTD.

AIN#_EF_READ_C: Voltage across the RTD.

AIN#_EF_READ_D: Current through the RTD.

Only reading AIN#_EF_READ_A triggers a new measurement, so you must always read A before reading B, C or D.

Example

The LJTick-Resistance-1k is the best and easiest way to measure an RTD, but if you don't have an LJTR the 200UA source on the T7 is a quick way to get readings.

200UA current source, circuit #0:

Connect 200UA to AIN0 and connect a PT100 RTD from AIN0 to GND:

```
AIN0_EF_INDEX = 40    // Set AIN_EF0 to RTD100.
AIN0_EF_CONFIG_A = 0  // Set result units to kelvin.
AIN0_EF_CONFIG_B = 0  // Set excitation circuit to 0.
```

Now each read of AIN0_EF_READ_A will measure the voltage on AIN0, use that to calculate resistance based on the factory stored value for 200UA, and use that to calculate temperature.

LJTick-Resistance-1k, circuit #4:

Connect a PT100 RTD from Vref to VINA on an LJTick-Resistance-1k that is plugged into the AIN0/AIN1 block.

```
AIN0_EF_INDEX = 40    // Set AIN_EF0 to RTD100.
AIN0_EF_CONFIG_A = 0  // Set result units to kelvin.
AIN0_EF_CONFIG_B = 4  // Set excitation circuit to 4.
AIN0_EF_CONFIG_D = 2.50 // Vref on the LJTR is 2.50 volts.
AIN0_EF_CONFIG_E = 1000 // We are using the 1k version of the LJTR.
```

Now each read of AIN0_EF_READ_A will measure the voltage on AIN0, do the voltage divider math to determine the resistance of the RTD, and use that to calculate temperature.

14.1.4 RMS [T-Series Datasheet]

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Overview

AIN#_EF_INDEX values:

10: RMS Flex

11: RMS Auto

This RMS Extended Feature calculates the true root mean square voltage of a signal connected to an analog input. It also calculates peak-to-peak voltage, DC offset (average voltage), and period (1/frequency) of the analog waveform.

RMS Flex: RMS Flex uses registers to specify the number of samples to collect and the frequency at which to collect those samples. The LabJack will then use the entire data set to calculate RMS.

RMS Auto: RMS Auto will collect samples for more than one period and attempt to find a period within the data set. The LabJack will then compute RMS for only the detected period's period.

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Number of Samples: The number of samples to be acquired.

- Default: 200
- Max: 16384

AIN#_EF_CONFIG_B - Hysteresis (RMS Auto only): The smallest step (analog voltage in binary) that will trigger period detection when using RMS Auto. Larger values will better reject noise. Smaller values can increase the accuracy of the period calculation.

- Default: 100 (16-bit counts)
- This value is meaningless for RMS Flex

AIN#_EF_CONFIG_D - Scan Rate: The frequency at which samples will be collected.

- Default: 6000

Sample Time

The maximum possible sample time is 180 ms.

Sample time is the number of samples divided by the sample frequency. For example, the period is 16.7 ms when using a scan rate of 6000 Hz and 100 samples:

$$100 \text{ samples} / 6000 \text{ samples per second} = 16.7 \text{ ms}$$

RMS Flex Considerations

RMS Flex requires the sample time to be an even multiple of the period to be measured.

RMS Auto Considerations

RMS Auto requires the sample time to be set so that 1.5 to 4 periods will be observed.

The hysteresis value also needs to be set to control the sensitivity of period detection.

Accuracy

Stream-burst is used to acquire the specified number of samples at hardware timed intervals. The true RMS is then calculated using the following piece-wise math:

$$(\sum(\text{each sample}^2) / \text{number of samples})^{0.5}$$

The accuracy of this calculation depends on the number of samples per cycle. Smooth waveforms will not require many samples per cycle, but waveforms with lots of harmonic content will require more samples per cycle.

Stream Configuration

This extended feature internally uses Stream-Burst to acquire the data set, so stream AIN configurations apply.

Results

For results, read the following registers.

AIN#_EF_READ_A: RMS Voltage

AIN#_EF_READ_B: Peak-to-Peak Voltage

AIN#_EF_READ_C: DC Offset Voltage (Average)

AIN#_EF_READ_D: Period (Seconds)

Only reading AIN#_EF_READ_A triggers a new measurement. Because multiple measurements are taken, a read of AIN#_EF_READ_A blocks for the length of the sample time.

14.1.5 Thermistor [T-Series Datasheet]

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Overview

AIN#_EF_INDEX values:

50: calculate temperature using the Steinhart-Hart equation

51: calculate temperature using the beta equation

This Thermistor Extended Feature automatically performs the necessary calculations for thermistors using the Steinhart-Hart equation or the beta equation.

Steinhart-Hart vs. beta: The beta function works well over a limited range of about 50 °C. Typical error is $\sim\pm 0.5$ °C. The Steinhart-Hart is usually more accurate (± 0.01 °C) across a larger range. Note that this is just the accuracy of the math converting resistance to temperature, and there are likely other sources of error in your measurement that are similar or greater (e.g. accuracy of the thermistor itself and accuracy of the resistance to voltage conversion circuit).

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Thermistor Options: Selects temperature units:

- 0 = K
- 1 = °C
- 2 = °F

AIN#_EF_CONFIG_B - Excitation Circuit Index: The index of the voltage divider excitation circuit to be used.

See [14.1.0.1 Excitation Circuits](#) for circuit indices.

AIN#_EF_CONFIG_C - 2nd AIN: Channel Number to Measure Vresistor For excitation circuits 3 and 5 this is the extra AIN used to measure the voltage across the fixed resistor. Ignored for other excitation circuits.

AIN#_EF_CONFIG_D - Excitation Volts or Amps For excitation circuit 2 this is the fixed amps of the current source. For excitation circuit 4 this is the fixed volts of the voltage source. Ignored for other excitation circuits.

AIN#_EF_CONFIG_E - Fixed Resistor Ohms: For excitation circuits 3, 4 and 5, this is the ohms of the fixed resistor.

AIN#_EF_CONFIG_F - R25 Ohms: The nominal resistance in ohms of the thermistor at 25 °C.

	Steinhart-Hart	Beta
AIN#_EF_CONFIG_G	A coefficient	β
AIN#_EF_CONFIG_H	B coefficient	°C at which β was calculated
AIN#_EF_CONFIG_I	C coefficient	No meaning
AIN#_EF_CONFIG_J	D coefficient	No meaning

The G, H, I, and J config registers have different meaning for Steinhart-Hart and beta. Steinhart-Hart coefficients are normally provided in the thermistor's datasheet or obtained from the manufacturer.

There are 2 forms of the Steinhart-Hart equation:

$$1/T = A + B \cdot \ln(R/R25) + C \cdot \ln(R/R25)^2 + D \cdot \ln(R/R25)^3$$

$$1/T = A + B \cdot \ln(R) + C \cdot \ln(R)^2 + D \cdot \ln(R)^3$$

We use the former with "R/R25". If you have coefficients that were generated based on the "R" equation, just set R25 = 1 (AIN#_EF_CONFIG_F = 1).

Further, sometimes the ^2 term is dropped and the equation is written "A + B*ln(R) + C*ln(R)^3". If you have coefficients that were generated based on this form set C = 0 (AIN#_EF_CONFIG_I = 0) and pass the given C value for D (AIN#_EF_CONFIG_J).

The [online calculator from daycounter.com](#) uses the "R/R25" form, and thus is useful for testing. LabJack provides a [Thermistor Calculator spreadsheet](#) that is also useful for testing and troubleshooting (make a copy if you want an editable version). The [online calculator from thinksrs.com](#) can be used to test "R" based coefficients or the beta equation, and can also be used to generate "R" based Steinhart-Hart coefficients from 3 resistance-temperature pairs.

Remarks

The normal [analog input registers](#) are used to control negative channel, resolution index, settling, and

range.

T7 only: If voltage will stay below 1.0V, use the 1.0V range for improved resolution and accuracy.

Results

For results, read the following registers.

AIN#_EF_READ_A: Calculated thermistor temperature

AIN#_EF_READ_B: Thermistor resistance

AIN#_EF_READ_C: Thermistor voltage

Only reading AIN#_EF_READ_A triggers a new measurement, so you must always read A before reading B or C.

Example

This example configures a LabJack to read from a Vishay NTCLE100E3103 10k Thermistor using a LabJack LJTick-Resistance to complete the excitation circuit. The LJTick-Resistance is connected to the AIN0/1 terminal block. The thermistor is connected between the Vref and INA terminals on the LJTick-Resistance.

```
AIN0_EF_INDEX = 50      -- Steinhart-Hart
AIN0_EF_CONFIG_A = 1   -- Output degrees Celsius.
AIN0_EF_CONFIG_B = 4   -- Excitation circuit #4.
AIN0_EF_CONFIG_C = 0   -- Second AIN, not used for excitation circuit #4.
AIN0_EF_CONFIG_D = 2.5 -- 2.5 V provided by the LJTick-Resistance
AIN0_EF_CONFIG_E = 10000 -- 10 kΩ shunt resistor provided by the LJTick-Resistance-10k.
AIN0_EF_CONFIG_F = 10000 -- R25 The nominal resistance of the thermistor at 25 °C.
AIN0_EF_CONFIG_G = 0.003354016 -- Constants from the thermistor's datasheet.
AIN0_EF_CONFIG_H = 0.000256985
AIN0_EF_CONFIG_I = 0.000002620
AIN0_EF_CONFIG_J = 0.00000006383
```

Results:

```
AIN0_EF_READ_A = 23.19 -- Temperature of the thermistor. (°C)
AIN0_EF_READ_B = 10829.4 -- Calculated resistance. (Ω)
AIN0_EF_READ_C = 1.299774 -- Voltage across the thermistor. (V)
```

14.1.6 Resistance [T-Series Datasheet]

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Overview

AIN#_EF_INDEX: **4**

This Resistance Extended Feature will calculate the resistance of a given circuit element.

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_B - Excitation Circuit Index: The index of the voltage divider excitation circuit to be used.

See [14.1.0.1 Excitation Circuits](#) for circuit indices.

AIN#_EF_CONFIG_C - 2nd AIN: Channel Number to Measure Vresistor For excitation circuits 3 and 5 this is the extra AIN used to measure the voltage across the fixed resistor. Ignored for other excitation circuits.

AIN#_EF_CONFIG_D - Excitation Volts or Amps For excitation circuit 2 this is the fixed amps of the current source. For excitation circuit 4 this is the fixed volts of the voltage source. Ignored for other excitation circuits.

AIN#_EF_CONFIG_E - Fixed Resistor Ohms: For excitation circuits 3, 4 and 5, this is the ohms of the fixed resistor.

Remarks

The normal [analog input settings](#) are used for negative channel, resolution index, settling, and range.

T7 only: If [voltage will stay below 1.0V](#), use the 1.0V range for improved resolution and accuracy.

Results

For results, read the following registers.

AIN#_EF_READ_A: Resistance of sensor

AIN#_EF_READ_B: Voltage of sensor

AIN#_EF_READ_C: Current through sensor

Only reading AIN#_EF_READ_A triggers a new measurement, so you must always read A before reading B or C.

Example

200UA current source, circuit #0:

An unknown resistor to be measured (a 10 kΩ resistor is used in this test) is connected in series with the 200UA current source available on the T7.

```
AIN0_EF_INDEX = 4
AIN0_EF_CONFIG_B = 0 -- Excitation circuit 0 (200 μA current source)
```

Typical reading results:

- AIN0_EF_READ_A returns 10089.7 Ω
- AIN0_EF_READ_B returns 2.012 V

- AIN0_EF_READ_C returns 199 μ A

LJTick-Resistance-1k, circuit #4:

Connect a resistor to measure from Vref to VINA on an LJTick-Resistance-1k that is plugged into the AIN0/AIN1 block.

```
AIN0_EF_INDEX = 4    // Set AIN_EF0 to RTD100.
AIN0_EF_CONFIG_B = 4 // Set excitation circuit to 4.
AIN0_EF_CONFIG_D = 2.50 // Vref on the LJTR is 2.50 volts.
AIN0_EF_CONFIG_E = 1000 // We are using the 1k version of the LJTR.
```

Now each read of AIN0_EF_READ_A will measure the voltage on AIN0 and do the voltage divider math to determine the resistance of the resistor.

14.1.7 Average Min Max [T-Series Datasheet]

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Overview

AIN#_EF_INDEX: 3

This Average Mix Max Extended Feature will sample an analog input a specified number of times at a specified rate, then calculate the average, min, and max voltage.

If you are using this feature to reduce noise by oversampling-and-averaging, consider maximizing resolution first, since that is the best and fastest way to reduce noise.

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Number of Samples: The number of samples to be acquired.

- Default: 200
- Max: 16384

AIN#_EF_CONFIG_D - Scan Rate: The frequency at which samples will be collected.

- Default: 6000

Sample Time

The maximum possible sample time is 180 ms.

Sample time is the number of samples divided by the sample frequency. For example, the period is

16.7 ms when using a scan rate of 6000 Hz and 100 samples:

```
100 samples / 6000 samples per second = 16.7 ms
```

If the signal has a known periodic component, then setting the sample time to an even multiple of the period will generally improve results.

Stream Configuration

This extended feature internally uses Stream-Burst to acquire the data set, so stream AIN configurations apply.

Results

For results, read the following registers.

AIN#_EF_READ_A: Average volts

AIN#_EF_READ_B: Max volts

AIN#_EF_READ_C: Min volts

Only reading AIN#_EF_READ_A triggers a new measurement. Because multiple measurements are taken, a read of AIN#_EF_READ_A blocks for the length of the sample time.

Example

To measure a 10 Hz sine wave with amplitude 0.1 V and DC offset of 1.2 V, set the number of samples to 100 and the scan rate to 1000. The total acquisition time is 100 ms, which is an even multiple of the signal's period.

```
AIN0_EF_INDEX = 3
AIN0_EF_CONFIG_A = 100 -- Number of samples
AIN0_EF_CONFIG_D = 1000 -- Scan rate
```

Results, with noise levels less than 600 μ V:

```
AIN0_EF_READ_A = 1.201 V -- Average volts
AIN0_EF_READ_B = 1.301 V -- Max volts
AIN0_EF_READ_C = 1.101 V -- Min volts
```

We can change the sample time to emphasize the benefit of matching to the period. If we change AIN0_EF_CONFIG_A to 70 (an odd multiple of the signal's period), then the results are still centered on 1.2, 1.3, and 1.1 V—but noise levels are ± 5 mV.

14.1.8 Average and Threshold [T-Series Datasheet]

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Overview

AIN#_EF_INDEX: 5

This Average and Threshold Extended Feature will read an input a specified number of times at a specified rate, then average the readings and set a flag if the average is above a specified threshold. Can be used with analog inputs or digital inputs.

Configuration

To configure, write to the following registers.

AIN#_EF_CONFIG_A - Number of Samples: Number of samples to be acquired.

- Default: 200
- Max: 16384

AIN#_EF_CONFIG_B - Digital Override: Selects whether this AIN-EF takes samples from the default analog line or from a specified digital line.

- When set to zero, the normal AIN# will be used.
 - This is the default.
 - For example, if AIN2_EF_CONFIG_B is 0, samples are collected from AIN2 when AIN2_EF_READ_A is read.
- When set to non-zero, sets the Modbus address of a digital IO.
 - For example, if AIN2_EF_CONFIG_B is 2001 (the address of FIO1), samples are collected from FIO1 when AIN2_EF_READ_A is read.

AIN#_EF_CONFIG_D - Scan Rate: The frequency at which samples will be collected.

- Default: 6000

AIN#_EF_CONFIG_E - Threshold: If the computed average is above this value, then the threshold flag (AIN#_EF_READ_A) will be set.

Sample time

The maximum possible sample time is 180 ms.

Sample time is the number of samples divided by the sample frequency. For example, the period is 16.7 ms when using a scan rate of 6000 Hz and 100 samples:

$$100 \text{ samples} / 6000 \text{ samples per second} = 16.7 \text{ ms}$$

If the signal has a known periodic component, then setting the sample time to an even multiple of the period will generally improve results.

Stream Configuration

This extended feature internally uses Stream-Burst to acquire the data set, so stream AIN configurations apply.

Results

For results, read the following registers.

AIN#_EF_READ_A - Threshold Flag: Returns 1.0 if the average is greater than the threshold, 0.0 if not.

AIN#_EF_READ_B - Average: The average of the collected samples.

Only reading AIN#_EF_READ_A triggers a new measurement. Because multiple measurements are taken, a read of AIN#_EF_READ_A blocks for the length of the sample time.

Example - Analog Input

A 10 Hz sine wave with magnitude 0.1 V and DC offset of 1.2 V is connected to AIN2. A threshold value less than the expected 1.2 V average will produce a positive result.

```
AIN2_EF_INDEX = 5
AIN2_EF_CONFIG_A = 100 -- 100 samples
AIN2_EF_CONFIG_B = 0 -- Use AIN2 to collect samples
AIN2_EF_CONFIG_D = 1000 -- Scan rate
AIN2_EF_CONFIG_E = 1.15 -- Threshold
```

Reading register AIN2_EF_READ_A returns 1.0, indicating that the average is greater than the threshold. If, instead, the threshold written to AIN2_EF_CONFIG_E was 1.25, then AIN2_EF_READ_A would then return 0.0 to indicate that the threshold was greater than the average.

Example - Digital Input

A 10 Hz sine wave with magnitude 1.2 V and DC offset of 1.6 V is connected to FIO0. The input signal should be interpreted as high two out of three times. In this case, the threshold of 0.65 is a ratio. If the average of the readings is 0.65 or greater, the AIN2_EF_READ_A register should be 1.0.

```
AIN2_EF_INDEX = 5
AIN2_EF_CONFIG_A = 100 -- 100 samples
AIN2_EF_CONFIG_B = 2000 -- Modbus address of FIO0
AIN2_EF_CONFIG_D = 1000 -- Scan rate
AIN2_EF_CONFIG_E = 0.65 -- Threshold
```

Reading register AIN2_EF_READ_A returns 1.0 and the calculated average is 66%.

14.2 Extended Channels (T7 Only) [T-Series Datasheet]

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Overview - T7 Only

The T7 has 14 built-in analog inputs (AIN0 through AIN13). For applications that need more, up to 112 total external analog inputs can be utilized by multiplexing the built-in analog inputs. Each built-in analog

channel may be multiplexed into 8 new channels, where the starting extended channel number is:

```
startingExtendedChannel = builtinChannel * 8 + 16
```

The extended channel range begins at AIN16.

When a built-in channel is multiplexed, the original channel number becomes unavailable.

For example, if AIN4 is multiplexed, AIN48 through AIN55 are exposed as usable AIN and AIN4 is no longer available.

Differential Channels Pairings

For differential channels in the extended range, a channel may be the positive channel if it is one of the following ranges:

- AIN16 through AIN23
- AIN32 through AIN39
- AIN48 through AIN55
- AIN64 through AIN71
- AIN80 through AIN87
- AIN96 through AIN103
- AIN112 through AIN119

The negative channel is 8 higher than the positive channel. For example, the positive channel AIN48 is paired with AIN56 as the negative channel.

The differential channel pairs for the built-in AIN0 through AIN13 are adjacent even/odd pairs such that the positive channel is even and the negative channel is greater than the positive channel by 1. Since the built-in AIN are multiplexed as described above, an extended negative channel is 8 higher than its corresponding extended positive channel. For example, a valid differential extended channel pair would be a positive channel of AIN70 and AIN78 as the negative channel, since:

- AIN70 maps to AIN6 and
- AIN78 maps to AIN7.

For more information on differential extended channels, see the [Mux80 Datasheet](#).

MIO

The [DB37 connector](#) has 3 MIO lines designed to address expansion multiplexer ICs (integrated circuits), allowing for up to 112 total external analog inputs. Whenever a read is done on analog input channel numbers 16 to 127, the T7 will automatically control the MIO lines to read the correct multiplexed AIN.

Mux80

The [Mux80](#) accessory is used to multiplex AIN4 through AIN13, expanding them from 10 inputs to 80 inputs. AIN0 through AIN3 are still available (on the screw terminals of the T7). The extended channels can be read using the following registers. For further details, see the Mux80 Datasheet.

Mux80 Extended Channels

Name		Start Address	Type	Access
 AIN#(48:127) input.	Returns the voltage of the specified analog input.	96	FLOAT32	R

&print=true

Note that when using the Mux80 board, the T7's MIO(0-2) lines are consumed for multiplexer signaling.

Other Multiplexers

If you are interested in adding multiplexers yourself, see further information in [Section 2.6.1 of the U6 Datasheet](#). The DG408 from Intersil is a recommended multiplexer, and a convenient ± 12 volt power supply is available on the DB37 so the multiplexers can pass bipolar signals (see V_{m+}/V_{m-} documentation in [Section 16.0](#)).

Differential Tables

The tables below show which channels are positive (Pos) or negative (Neg) when paired differentially.

Built-in AIN (not multiplexed):

Pos	Neg
0	1
2	3
4	5
6	7
8	9
10	11
12	13

AIN0 and AIN1 (multiplexed with an external multiplexer):

Pos	Neg
16	24
17	25
18	26
19	27
20	28
21	29

Pos	Neg
22	30

23	31
----	----

AIN2 and AIN3 (multiplexed with an external multiplexer):

Pos	Neg
32	40

33	41
----	----

34	42
----	----

35	43
----	----

36	44
----	----

37	45
----	----

38	46
----	----

39	47
----	----

AIN4 and AIN5 multiplexed with the Mux80 (or an external multiplexer):

Pos	Neg
48	56

49	57
----	----

50	58
----	----

51	59
----	----

52	60
----	----

53	61
----	----

54	62
----	----

55	63
----	----

AIN6 and AIN7 multiplexed with the Mux80 (or an external multiplexer):

Pos	Neg
64	72

65	73
----	----

66	74
----	----

67	75
----	----

68	76
----	----

69	77
----	----

Pos	Neg
71	79

AIN8 and AIN9 multiplexed with the Mux80 (or an external multiplexer):

Pos	Neg
80	88
81	89
82	90
83	91
84	92
85	93
86	94
87	95

AIN10 and AIN11 multiplexed with the Mux80 (or an external multiplexer):

Pos	Neg
96	104
97	105
98	106
99	107
100	108
101	109
102	110
103	111

AIN12 and AIN13 multiplexed with the Mux80 (or an external multiplexer):

Pos	Neg
112	120
113	121
114	122
115	123
116	124
117	125
118	126

