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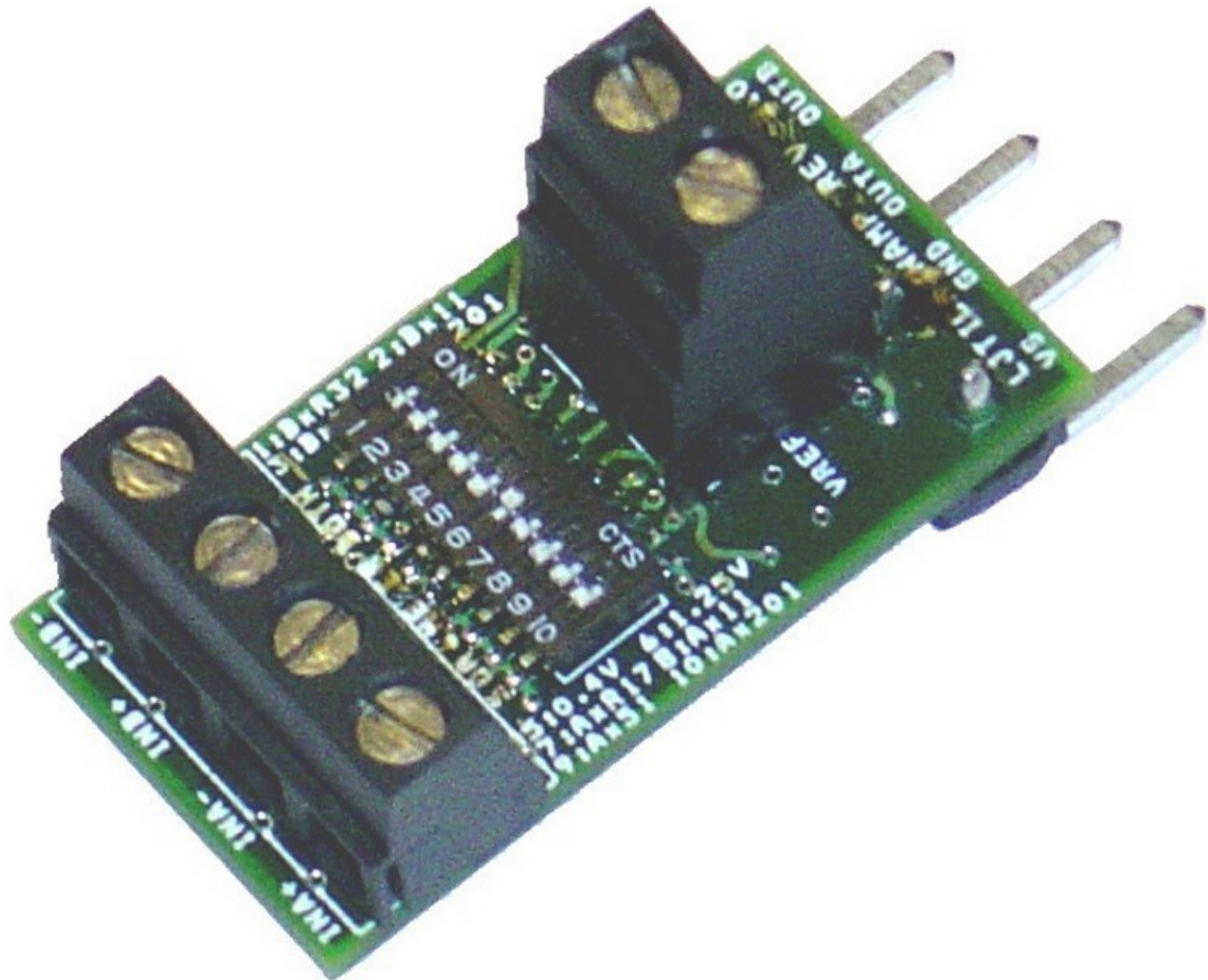# LJTick-InAmp Datasheet

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LJ Tick-InAmp Datasheet Overview

The LJTick-InAmp (LJTIA) is a signal-conditioning module that provides two instrumentation amplifiers ideal for low-level signals such as bridge circuits (strain gauges) and thermocouples. The LJTIA has 5 gain settings per channel and two selectable output voltage offsets (Voffset). The 4-pin design plugs into the standard AIN/AIN/GND/VS screw-terminal block found on LabJacks such as the U3 and UE9.

The pictures below show the LJTIA plugged into the U3 on the left and plugged into the UE9 on the right.

Figure 1: LJTick-InAmp (LJTIA)

Figure 2: LJTIA With U3

Figure 3: LJTIA With UE9

The block of 4 screw-terminals at the left edge of the LJTIA (Figure 1 above) provides a positive and negative input for each differential channel. Towards the LabJack side of the LJTIA is a pair of screw-terminals that provide a ground connection (GND) and a +2.50 volt reference (VREF). The reference is capable of sourcing enough current (see Specifications) to function as the excitation voltage for most common bridge circuits.

In between the blocks of screw-terminals is a 10-position DIP switch used to specify gain and offset.

Table 1. DIP Switch Descriptions

Switch #	Name	Description	
1	BxR32	Custom gain determined by R32	Applies to channel B only. All off equals a gain of 1.
2	Bx11	Gain of 11	
3	Bx52	Gain of 51	
4	Bx201	Gain of 201	
5	0.4V	Output offset of +0.4 volts.	Voffset applies to both channels. Switch # 5 or 6 should always be on, but not both.
6	1.25V	Output offset of +1.25 volts.	
7	AxR17	Custom gain determined by R17	Applies to channel A only. All off equals a gain of 1.
8	Ax11	Gain of 11	
9	Ax51	Gain of 51	
10	Ax201	Gain of 201	

Each channel has a switch (numbers 1 & 7) that has been left without factory-installed gain resistors: R17 for channel A and R32 for channel B. Resistors can be installed by the end-user to provide custom gains according to G=1+(100k/R). For example, a resistance of 100 ohms would provide the maximum allowable gain of 1001. Also, multiple switches can be closed at the same time to get a few other gains (x61, x211, x251, and x261), as the gain settings resistors (10k, 2k, and 500) wind up in parallel. The packages for resistors R17 & R32 are 0805, while all other resistors and capacitors are 0603. The tolerance of the factory installed resistors is 0.1% & 25 ppm/degC, so consider the RG20P series from digikey.com (100ohm = RG20P100BCT).

Extending from the back of the LJTick-InAmp are four pins. The first two pins provide +5 volt power and ground from the LabJack. The other two pins are the instrumentation amplifier outputs and connect to analog inputs on the LabJack. The four pins plug directly into the 5.0 mm spaced screw-terminals on the LabJack U3, UE9, or other future devices as shown in Figure 4.
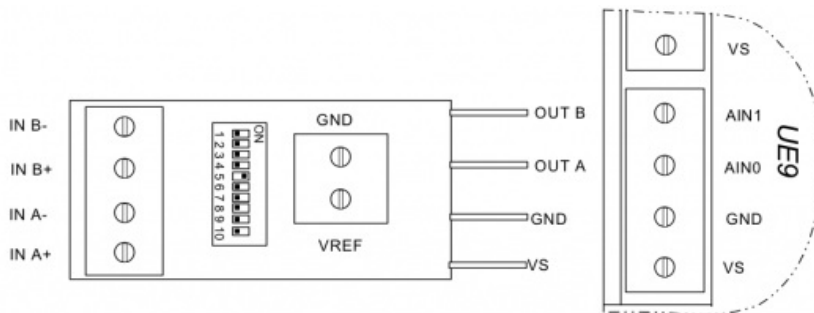

Figure 4: LJTick-InAmp lined up to UE9

Each channel on the LJTIA has an AD623 instrumentation amplifier (in-amp) from Analog Devices. The allowable signal range (Vin) is determined by a combination of Gain, Voffset, Vcm, and Vout. See the Signal Range Tables in Appendix A.

Voffset: This is an offset voltage added to the in-amp output. If DIP switch #5 is on, the offset is +0.4 volts, and if DIP switch #6 is on, the offset is +1.25 volts. The same offset applies to both channels of the LJTick-InAmp. One offset must always be selected (0 volts is not an option), but both offsets should never be enabled at the same time. The +0.4 volt offset is generally used with signals that are mostly unipolar, while the +1.25 volt offset is generally used with bipolar signals.

Vcm: This is the common mode voltage of the differential inputs. For an in-amp, that is defined as the average of the common mode voltage of each input. For

instance, if the negative input is grounded, and single-ended signal is connected to the positive input, Vcm is equal to Vin/2. Another common situation is when using a wheatstone bridge where VREF=2.5 is providing the excitation. In this case, each input is at about 1.25 volts compared to ground, and thus Vcm is about 1.25 volts.

Vin: This is the voltage difference between IN+ and IN-. In the following Signal Range Tables, the "Low" column is the minimum Vin where Vout is 10 mV or higher, the "High 2.5V" column is the maximum Vin where Vout is 2.5 volts or less, and the "High 4.5V" column is the maximum Vin where Vout is 4.5 volts or less.

Vout: This is the single-ended (referred to ground) voltage output from the in-amp. Because of the power supply to the in-amp, the full output swing is about 0.01 volts to 4.5 volts. The "Low" and "High" columns in the Signal Range Tables give the output at the respective Vin.

Specifications

Parameter	Conditions	Min	Typical	Max	Units
General					
Supply Voltage		3.6	5	5.5	volts
Supply Current	No Loads		1.5		mA
Operating Temperature		-40		85	°C
Signal Specs					
Gain Accuracy (1)			0.35	1.2	%
Offset Accuracy (1)	G = 1		0.5	1.2	%
	G = 11		0.5	1.2	%
	G = 51		2.5	4.0	%
	G = 201		10	15.0	%
Input Bias Current (2)			17		nA
Input Impedance			2		GΩ
Each Input vs. GND (3)	Normal Operation			-0.3 to +5.3	volts
Each Input vs. GND (3)	No Damage			-10 to +15	volts
Typical Output Range	Load ≥ 10 kΩ	0.01		VS - 0.5	
-3 dB Bandwidth	x1		18		kHz
	x11		18		kHz
	x51		18		kHz
	x201		10		kHz
Vref					
Output Voltage		2.495	2.50	2.505	volts
Initial Accuracy			0.2		%
Current Output (4)	For rated V accuracy	0		25	mA

(1) The max accuracy specs are the tested device limits and are expected to be met whether device is warmed up or not. Typical specs are what is normally seen with a warmed up device at room temperature. Gain and offset are very stable at a stable temperature, so a user-calibration can achieve accuracy much better than the specs listed here.
(2) The current in/out of the input terminals is nanoamps from -0.3 to +5.3 volts. Beyond that range it increases up to 10mA at -10 or +15 volts.
(3) This is the limit of the voltage on any input terminal versus ground. See Appendix A for actual limits in different situations.
(4) Higher currents will not cause damage, but the reference voltage will start to sag. The reference output can handle a continuous short-circuit to ground and has a short-circuit current of about 45 mA typically.

Dimensions
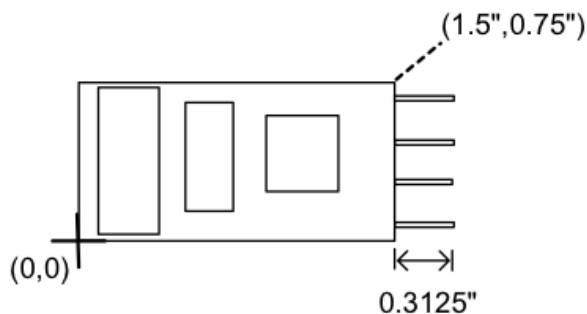
Declaration of Conformity

Manufacturers Name: LabJack Corporation

Manufacturers Address: 3232 S Vance St STE 200, Lakewood, CO 80227 USA

Declares that the product

Product Name: LJTick-InAmp

Model Number: LJTIA

conforms to the following Product Specifications:

EMC Directive: 89/336/EEC

EN 55011 Class A

EN 61326-1: General Requirements

Appendix A - Signal Range Tables

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The following tables cover most common situations with the LJTIA, but for other cases there is an online tool available at analog.com:

http://www.analog.com/designtools/en/diamond/#difL=-0.015&difR=0.3&difSl=0.3&gain=11&l=2.5&pr=AD623&r=2.5&sl=2.5&tab=1&ty=1&vn=0&vp=5&vr=0.4

"+Vs" = VS (typically 5.0 volts), "-Vs" = 0, "Vref" = Voffset (0.4 or 1.25 volts), "Vcm" = Vcm and "Vdiff" = Vin. Our definitions of Vin, Vcm, and Voffset, can be found on the main page of the LJTIA datasheet.

The output amplifiers on the LJTIA have a range of about 0.01 volts to 4.5 volts (VS-0.5 actually).

The "Low" column on the left in the tables below is the minimum Vin. Usually this is the Vin that results in the minimum Vout of 0.01 volts, but sometimes there are other limiting factors, so the "Low" column on the right shows the Vout corresponding to each Vin.

The "High 2.5V" and "High 4.5V" columns on the left are listing the upper limit of Vin that results in a Vout of 2.5 or 4.5 volts, although sometimes there other limiting factors and those Vout values cannot be achieved. The columns on the right list the actual Vout that results from the Vin values on the left.

Example: Assume Voffset of the LJTIA is set to 0.4V and gain of the LJTIA is set to x11. Assume the Vin signals come from a bridge with 5 volt excitation, so Vcm is 2.5 volts. According to the latest tool from analog.com, the signal voltage can go from about -0.018V to +0.309V. Beyond those limits generates an error. Note that the table below shows similar values of -0.035 to +0.327, which are not exactly the same likely because they come from an older version of the calculator.

Table A1.1. Voffset = 0.4V

Vcm	Vin (Differential) (Volts)			Vout (Single Ended) (Volts)		
Gain	Low	High 2.5 V	High 4.5V	Low	High 2.5V	High 4.5V
0V						
1	-0.3	0.3	N/A	0.01	0.7	N/A
11	-0.0354	0.116	N/A	0.0106	1.58	N/A
51	-0.00764	0.0231	N/A	0.0104	1.58	N/A
201	-0.00194	0.00587	N/A	0.0101	1.58	N/A
1.25V						
1	-0.39	2.1	3.68	0.01	2.5	4.08
11	-0.0354	0.191	0.334	0.0106	2.5	4.07
51	-0.00764	0.0412	0.0712	0.0104	2.5	4.08
201	-0.00194	0.0104	0.0183	0.0101	2.5	4.07

Gain	Low	High 2.5 V	High 4.5V	Low	High 2.5V	High 4.5V
2.5V						
1	-0.39	2.1	3.6	0.01	2.5	4
11	-0.0354	0.191	0.327	0.0106	2.5	4
51	-0.00764	0.0412	0.0803	0.0104	2.5	4.5
201	-0.00194	0.0104	0.0179	0.0101	2.5	4
Vin/2						
1	-0.15	2.05	4.1	0.25	2.5	4.5
11	-0.0354	0.118	N/A	0.0106	1.7	N/A
51	-0.00764	0.024	N/A	0.0104	1.59	N/A
201	-0.00194	0.0059	N/A	0.0101	1.59	N/A

Table A1.2. Voffset = 1.25V

Vcm	Vin (Differential) (Volts)			Vout (Single Ended) (Volts)		
Gain	Low	High 2.5 V	High 4.5V	Low	High 2.5V	High 4.5V
0V						
1	-0.3	0.3	N/A	0.95	1.55	N/A
11	-0.107	0.107	N/A	0.073	2.43	N/A
51	-0.0231	0.0231	N/A	0.0719	2.43	N/A
201	-0.005879	0.00587	N/A	0.0701	2.43	N/A
1.25V						
1	-1.24	1.25	3.25	0.01	2.5	4.5
11	-0.112	0.114	0.295	0.018	2.5	4.5
51	-0.0243	0.0245	0.0637	0.0107	2.5	4.5
201	-0.00616	0.00622	0.0162	0.0114	2.5	4.5
2.5V						
1	-1.24	2.1	3.25	0.01	2.5	4.5
11	-0.112	0.191	0.295	0.018	2.5	4.5
51	-0.0243	0.0412	0.0637	0.0105	2.5	4.5
201	-0.00616	0.00622	0.0161	0.0114	2.5	4.5
Vin/2						
1	-0.15	1.25	4.1	1.1	2.5	4.5
11	-0.0983	0.113	0.118	0.169	2.5	2.55
51	-0.0226	0.0236	N/A	0.0974	2.45	N/A
201	-0.00584	0.0059	N/A	0.0762	2.44	N/A

Appendix B - Resolution Tables

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The following tables use typical noise measurements with the LabJack U3 and UE9 to determine the noise-free and effective resolutions that can be expected with the LJTick-InAmp (LJTIA). The LJTIA was connected to an analog input on the LabJack and had IN+ shorted to IN- shorted to GND.

The counts of peak-to-peak noise were determined by collecting 128 points from the analog input and subtracting the minimum binary value from the maximum binary value. For the U3 these are based on 12-bit values, while for the UE9 these are based on 24-bit values.

The noise-free resolution is based on the peak-to-peak noise counts, and corresponds to the resolution where no variation would be seen.

The RMS noise counts is the standard deviation of the 128 collected binary values, and the effective resolution values are based on this RMS value. The effective resolution can be thought of as a specification met by most points, while the noise-free specifications are met by all points.

The "@LJ Inputs" values are in terms of the LabJack U3/UE9 analog input, which is the LJTIA output. Those values are divided by the LJTIA gain to determine the "@LJTIA Inputs" values, which are the resolutions that apply to the signal input to the LJTIA. For instance, a single-ended channel on the LabJack U3 with an LJTIA gain of 201 has a noise-free resolution of about 9 µV and an effective resolution of about 1.8 µV.

LabJack U3:

Table B.1. LJTIA Gain = 1-201 with a U3.

LJTIA Gain = 1

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
SE	2	11	0.001191	0.00119141	0.5	13	0.000298	0.00029785
Diff	2	11	0.002383	0.00238281	0.5	13	0.000596	0.0005958
0-3.6	2	11	0.002383	0.00238281	0.5	13	0.000596	0.0005957

LJTIA Gain = 11

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
SE	2	11	0.001191	0.00010831	0.5	13	0.000298	0.00002708
Diff	2	11	0.002383	0.00021662	0.5	13	0.000596	0.00005415
0-3.6	2	11	0.002383	0.00021662	0.5	13	0.000596	0.00005415

LJTIA Gain = 51

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
SE	2	11	0.001191	0.00002336	0.5	13	0.000298	0.00000584
Diff	2	11	0.002383	0.00004672	0.5	13	0.000596	0.00001168
0-3.6	2	11	0.002383	0.00004672	0.5	13	0.000596	0.00001168

LJTIA Gain = 201

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
SE	2	11	0.001806	0.00000898	0.5	12.7	0.000367	0.00000182
Diff	2	11	0.003612	0.00001797	0.5	12.7	0.000733	0.00000365
0-3.6	2	11	0.003612	0.00001797	0.5	12.7	0.000733	0.00000365

LabJack UE9 & UE9-Pro (LJTIA Gain = 1 & 11):

All "counts" data in the following UE9 tables are from 24-bit values. To equate to counts at a particular resolution (Res) use the formula counts/(2^(24-Res)). For instance, with the UE9 set to 12-bit resolution and the 0-5 volt range, there are 8192 counts of noise when looking at 24-bit values. To equate this to 12-bit data, we take 8192/(2^12), which equals 2 counts of noise when looking at 12-bit values.

Table B.2. LJTIA Gain = 1, Resolution 0-18 with a UE9

Resolution=0-12, LJTIA Gain=1								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	12288	10.4	0.0037	0.00370048	2350	12.8	0.000701	0.00070111
0-2.5	20480	9.7	0.003006	0.00300572	4100	12	0.00061	0.00061035
Resolution = 17,LJTIA Gain = 1								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs

volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	408	15.3	0.000124	0.00012394	78	17.7	0.000023	0.00002348
0-2.5	620	14.7	0.000094	0.00009393	120	17.1	0.00018	0.0000178

Resolution = 18+ (UE9-PRO, LJTIA Gain = 1)								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	96	17.4	0.000029	0.00002891	20	19.7	0.000006	0.00000587

Table B.3. LJTIA Gain = 11, Resolution 0-18 with a UE9

Resolution = 0-12, LJTIA Gain = 11								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	12288	10.4	0.0037	0.00033641	2350	12.8	0.000701	0.00006374
0-2.5	20480	9.7	0.003006	0.00027325	4100	12	0.00061	0.00005549

Resolution = 17, LJTIA Gain = 11								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	408	15.3	0.000124	0.00001127	78	17.7	0.000023	0.00000213
0-2.5	620	14.7	0.000094	0.00000854	120	17.1	0.00018	0.00000162

Resolution = 18+ (UE9-PRO, LJTIA Gain = 11)								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	110	17.2	0.000033	0.00000302	20	19.7	0.000006	0.00000053

LabJack UE9 & UE9-Pro (LJTIA Gain = 51 & 201):

All "counts" data in the following UE9 tables are from 24-bit values. To equate to counts at a particular resolution (Res) use the formula counts/(2^(24-Res)). For instance, with the UE9 set to 12-bit resolution and the 0-5 volt range, there are 8192 counts of noise when looking at 24-bit values. To equate this to 12-bit data, we take 8192/(2^12), which equals 2 counts of noise when looking at 12-bit values.

Table B.4. LJTIA Gain = 51, Resolution 0-18 with a UE9

Resolution = 0-12, LJTIA Gain = 51								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	12288	10.4	0.0037	0.00007256	2350	12.8	0.000701	0.00001375
0-2.5	20480	9.7	0.003006	0.0005894	4100	12	0.00061	0.00001197

Resolution = 17, LJTIA Gain = 51								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	472	15.1	0.000142	0.00000279	87	17.6	0.000025	0.00000049

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-2.5	776	14.4	0.000116	0.00000227	147	16.8	0.000022	0.00000043
Resolution = 18+ (UE9-PRO), LJTIA Gain = 51								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	172	16.6	0.00005	0.00000099	29	19.2	0.000008	0.00000016

Table B.5. LJTIA Gain = 201, Resolution 0-18 with a UE9

Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
Resolution = 0-12, LJTIA Gain = 201								
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	16384	10	0.004883	0.00002429	3500	12.2	0.001063	0.00000529
0-2.5	32768	9	0.004883	0.00002429	6480	11.3	0.00061	0.00000493
Resolution = 17, LJTIA Gain = 201								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	1232	13.7	0.000376	0.00000187	185	16.5	0.000054	0.00000027
0-2.5	2104	13	0.000305	0.00000152	376	15.4	0.000058	0.00000029
Resolution = 18+ (UE9-PRO), LJTIA Gain = 201								
Range	Peak-to-peak Noise	Noise-Free Resolution	Noise-Free Res. @LJ Inputs	Noise-Free Res. @LJTIA Inputs	RMS Noise	Effective Resolution	Effective Res. @LJ Inputs	Effective Res. @LJTIA Inputs
volts	counts	bits	volts	volts	counts	bits	volts	volts
0-5	484	15.1	0.000142	0.00000071	106	17.3	0.000031	0.00000015

Appendix C - Thermocouples

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Appendix C - Thermocouples

Thermocouples are not particularly accurate or easy to use, but they are a very common way to measure temperature. Some applications with extreme temperatures or specific mechanical requirements might require thermocouples, but whenever possible consider instead using a silicon type temperature sensor such as the EI-1022 (-40 to +100 degrees C) or the very accurate and waterproof EI-1034 (-17 to +150 degrees C). Both of those probes are available from LabJack, and provide a high-level linear voltage output that connects directly to analog inputs.

There are three main issues when making measurements with a thermocouple:

1. **Cold Junction Effects:** The voltage generated at the LJTIA by the thermocouple is related to the difference in temperature of the end of the thermocouple and the LJTIA. In order to know the temperature at the end of the thermocouple, the temperature of the LJTIA must also be known. Most LabJacks have an internal temperature sensor, but even then for improved performance an external sensor (e.g. EI-1034 or LM34CAZ) might be needed. Once the cold junction temperature is known, it is easily handled in software.
2. **Non-Linear Output:** The output of a thermocouple is non-linear. NIST (nist.gov) provides tables and equations to convert a thermocouple voltage to a temperature. The LabJack UD driver provides a convenient function that uses the NIST equation to handle the conversion, and DAQFactory has built-in conversion functions of its own.
3. **Small Output Voltage:** The small output voltage of a thermocouple makes it difficult to get good temperature resolution. The LJTIA is used to amplify the thermocouple voltage before it is sent to an analog input.

The following diagram shows the typical connection of a thermocouple to the LJTIA:
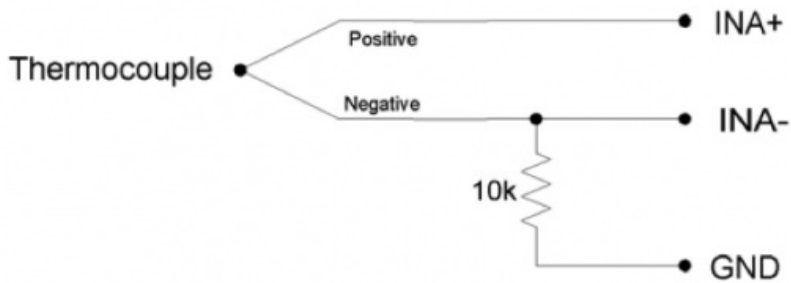
The thermocouple is connected to IN+ (positive lead) and IN- (negative lead), and IN- is also connected to GND through a 10 kΩ resistor (meaning that Vcm=Vin/2).

Care must be taken when placing the negative thermocouple lead and resistor lead into the same screw-terminal, to make sure that both are solidly contacted. Sometimes the thermocouple wire is thicker than the resistor wire, making it easy for the resistor to lose contact. In such a case the LJTIA output will likely be stuck near 0 volts, Voffset, or 5 volts.

In most situations, a short can simply be used for the GND connection instead of a 10 kΩ resistor, but note that if a short is used the negative lead of the thermocouple is grounded at the LJTIA. This is not recommended when using multiple probes and when the probes could be contacting grounded metal somewhere in the system. The 10 kΩ resistor maintains some isolation between the negative thermocouple lead and ground, and yet provides a path for the LJTIA bias currents.

It is possible to install the 10 kΩ resistors (Digikey #P10KGCT) on the LJTIA PCB. For channel A, install the resistor on R8. For channel B, install the resistor on R23. Obviously this reduces the input impedance of the negative input of the LJTIA to 10 kΩ, which might not be desirable for some signals besides thermocouples.

The output offset of the LJTIA can be set to 0.4 volts or 1.25 volts. For the best accuracy, the actual system offset should be measured. If the end of the thermocouple is at the same temperature as the cold junction, the thermocouple voltage should be zero, so place the end of the thermocouple near the LJTIA and note the voltage measured by the analog input (should be near 0.4 volts or 1.25 volts). This is the actual system offset, and should be subtracted from further analog input readings before dividing by the gain to get the thermocouple voltage.

The UD driver for Windows has a convenient function that takes in thermocouple type, thermocouple voltage, and cold junction temperature, and returns the thermocouple temperature. The following pseudocode demonstrates a measurement:

```
//Read the amplified and offset thermocouple voltage from an analog input.
eGet (lngHandle, LJ_ioGET_AIN, tcChannel, &valueAIN, 0);

//Get the internal temperature reading (channel 133 on the UE9 or channel 30 on the U3).
eGet (lngHandle, LJ_ioGET_AIN, internalTempChannel, &cjTempK, 0);

//To get the thermocouple voltage we subtract the offset from the AIN voltage
//and divide by the LJTIA gain.
tcVolts = (valueAIN - offsetVoltage)/51;

//Convert TC voltage to temperature.
TCVoltsToTemp (LJ_ttK, tcVolts, cjTempK, &TCTempK);
```

Go to labjack.com for thermocouple examples in C, VB, LabVIEW, and more. For DAQFactory examples go to daqexpress.com.

The following table shows the minimum and maximum allowable temperatures (from NIST) for some common thermocouple types. The table also shows the thermocouple voltages generated at those limits. Note that these extremes might not be allowed continuously, and thermocouple manufacturers will often provide a reduced range that is recommended for continuous use.

Table C1. Minimum and maximum temperature and voltage ranges

| Type | Min | | Max | |
	Temp (°C)	Voltage (mV)	Temp (°C)	Voltage (mV)

B	0	0	1820	13.82
E	-270	-9.835	1000	76.373
J	-210	-8.095	1200	69.553
K	-270	-6.458	1372	54.886
N	-27-	-4.345	1300	47.513
R	-50	-0.226	1768	21.101
S	-50	-0.236	1768	18.693
T	-270	-6.258	400	20.872

The following tables show the measurement range for different thermocouple types with different gain and offset settings for the LJTick-InAmp. Also shown is the resulting temperature resolution.

For example, from the LJTIA Signal Range Tables the max input voltage (for an output of 2.5 volts or less) is about 5.9 mV with a gain of 201, an offset of 0.4 volts, and a common mode voltage of Vin/2. From the NIST K-type thermocouple table the temperature corresponding to 5.9 mV is about 144 degrees C. The basic resolution of a K-type thermocouple is roughly 37 uV/degC, so since this example has a gain of 201 the resulting resolution is about 7.5 mV/degC. From the Resolution Tables in Appendix B, the U3 has a noise-free single-ended resolution of about 1.2 mV, so the noise-free temperature resolution would be about 0.16 degrees C. The UE9 has a noise-free resolution of about 94 uV (0-2.5 volts, 17-bit), so the noise-free temperature resolution would be about 0.013 degrees C. The UE9-Pro has a noise-free resolution of about 29 uV (0-5 volts, 18-bit), so the noise-free temperature resolution would be about 0.004 degrees C. These calculations assume no noise from the thermocouple signal itself.

Table C2. Temperature measurement ranges and resolution for LJTIA Gain 1-201, Voffset 0.4-1.25

	LJTIA Gain = 1, Voffset = 0.4					LJTIA Gain = 11, Voffset = 0.4		
Type	Min (°C)	Max (°C)	Resolution (µV/°C)		Type	Min (°C)	Max (°C)	Resolution (~µV/°C)
B	0	1820	8		B	0	1820	84
E	-270	1000	68		E	-270	1000	747
J	-210	1200	55		J	-210	1200	606
K	-270	1372	37		K	-270	1372	411
N	-270	1300	33		N	-270	1200	363
R	-50	1768	12		R	-50	1768	129
S	-50	1768	10		S	-50	1768	115
T	-270	400	40		T	-270	400	445
	LJTIA Gain = 51, Voffset = 0.4					LJTIA Gain = 201, Voffset = 0.4		
Type	Min (°C)	Max (°C)	Resolution (µV/°C)		Type	Min (°C)	Max (°C)	Resolution (µV/°C)
B	0	1820	387		B	0	1112	1526
E	-160	337	3462		E	-34	93	13644
J	-189	438	2809		J	-39	111	11069
K	-270	578	1905		K	-51	144	7509
N	-270	686	1685		N	-78	199	6639
R	-50	1768	598		R	-50	627	2358
S	-50	1768	531		S	-50	664	2093
T	-270	400	2065		T	-53	133	8139
	LJTIA Gain = 201, Voffset = 1.25							
Type	Min (°C)	Max (°C)	Resolution (µV/°C)					
B	0	1112	1526					
E	-113	93	13644					
J	-131	111	11069					
K	-196	144	7509					
N	-270	199	6639					
R	-50	627	2358					
S	-50	664	2093					

C.1 - LJTIA Thermocouple Troubleshooting

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Following is a basic procedure for troubleshooting and testing thermocouples connected to an LJTick-InAmp. We will look at the voltages using the test panel in LJControlPanel. This takes software complications out of the loop. Make sure all other LabJack related software is closed.

Start by removing all signals from the LJTIA, and jumper all 4 inputs (INA+/INA-/INB+/INB-) to GND. Turn off all switches on the LJTIA, except #5, to give you a gain of x1 and offset of 0.4 volts. You should see that both channels measured by the LabJack measure about 0.4 volts.

Now turn on switches 3 and 9 (in addition to 5), to give a gain of x51 and offset of 0.4 volts. The voltages measured by the LabJack will likely change a little, but should both still be near 0.4 volts.

Now remove the jumpers, connect the +/- of a thermocouple to INA+/INA-, and also connect a 10k resistor from INA- to GND. Pull on both leads going into INA- to make sure both are clamped securely.

A thermocouple gives you a voltage related to the difference in temperature between the 2 ends. So if the remote end is at the same temperature as the LJTIA end, the voltage difference created by the thermocouple should be about 0. That means you should get a reading about the same as when you had jumpers to ground.

Now try changing the temperature of the remote end of the thermocouple. Here are charts where you can look to see what voltage you expect:

http://www.temperatures.com/tctables.html

For example, say you have a Type K thermocouple:

http://www.pyromation.com/downloads/data/emfk_c.pdf

The voltage at the 25 deg C end is 1.000 mV and the voltage at the 35 deg C end is 1.407 mV, so the difference is 407 uV. That is the voltage difference that should be created across the INA+/INA- terminals. You can confirm it with a DMM if you have one good enough. The LJTIA multiplies this by x51 and adds about 0.4, so your voltage measured on the test panel should be about 0.4208 volts. That is, about 0.0208 volts higher than the reading with no temperature difference.

You can confirm that 0.421 volts by measuring FIO0 versus GND with a DMM and see if it is the same as the test panel reading. If not, the reason is usually that the signal is varying. The DMM will give an average reading over 0.5 or 1.0 seconds, whereas the U3 gives a reading sampled over perhaps 500 microseconds.

Appendix D - Bridge Circuits

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Appendix D - Bridge Circuits Overview

A bridge circuit generally outputs a small differential voltage. The LJTick-InAmp provides the amplification needed to acquire such a signal, converts the differential signal to single-ended, and provides a 2.5 volt reference voltage (VREF) that can be used for excitation.

A common example would be a Wheatstone bridge made of 350 ohm strain gauges. If VREF/GND is used to provide the excitation voltage for the bridge, it will draw about 2.5/350 = 7 mA, and the common mode voltage (Vcm) of the differential signal will be about 1.25 volts. The outputs would be connected to IN+ and IN-. If Voffset is set to 1.25 volts and the gain is set to 201, the allowable input range for the LJTIA is –0.00616 to +0.00622 volts (with 0-2.5 volt output).

D.1 - Bridge Troubleshooting

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Following is a basic procedure for troubleshooting and testing a bridge connected to an LJTick-InAmp. We will look at the voltages using the test panel in LJControlPanel. This takes software complications out of the loop. Make sure all other LabJack related software is closed.

Start by removing all signals from the LJTIA, and jumper all 4 inputs (INA+/INA-/INB+/INB-) to GND. Turn off all switches on the LJTIA, except #5, to give you a gain of x1 and offset of 0.4 volts. You should see that both channels measured by the LabJack measure about 0.4 volts.

Now turn on switches 3 and 9 (in addition to 5), to give a gain of x51 and offset of 0.4 volts. The voltages measured by the LabJack will likely change a little, but should both still be near 0.4 volts.

Now remove the jumpers. Connect Vexc+/Vexc- on the bridge to VREF/GND on the LJTIA. Connect Vout+/Vout- on the bridge to INA+/INA- on the LJTIA. If the bridge is reasonably balanced and is in the zero condition, the bridge output should be near 0.0 mV and the LJTIA output should still be near 0.4 volts. If not, use a DMM to confirm that the raw bridge output voltage is near 0.0 mV.

A bridge has an output specification such as 2.0 mV/V which we will use for this example. Since we are using VREF for excitation, and it is about 2.5 volts, then we will get about 5mV of differential output (Vsig+ versus Vsig-) at full scale (rated load/strain/pressure/etc.).

Change the bridge so it is at some known condition. For example, if rated load is 100 pounds, and we are at 50 pounds, then the bridge should give about 2.5 mV of output, and thus the LJTIA will give about (0.0025*51)+0.4 = 0.528 volts of output. Use a DMM to confirm those voltages at the input (INA+ versus INA-) and output (OUTA versus GND) of the LJTIA, and also confirm that the test panel reports about 0.528 volts.

In general, the troubleshooting technique is to:

- use a DMM to measure the LJTIA input voltage (INA+ versus INA-)
- use a DMM and the test panel to measure the LJTIA output voltage (OUTA versus GND)
- confirm the LJTIA output is (input*gain)+offset
- confirm that the DMM reading of the LJTIA output and the test panel reading both agree

Appendix E - Testing & Troubleshooting the LJTIA

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Testing Basic Operation

Following is a procedure for testing basic operation of the LJTick-InAmp.

For T-series devices, use the Register Matrix tab to read the analog input voltages from the LabJack and to also control the analog output.

For the U3/U6/UE9, use the test panel in LJControlPanel to read the analog input voltages from the LabJack and to also control the analog output.

Start by removing all signals from the LJTIA, and jumper all 4 inputs (INA+/INA-/INB+/INB-) to GND. Turn off all switches on the LJTIA, except #5, to give you a gain of x1 and offset of 0.4 volts. You should see that both channels measured by the LabJack measure about 0.4 volts.

Leave INA- & INB- jumpered to GND, but change INA+ & INB+ so they are both jumpered to DAC0. Set DAC0 to 1.5 volts, and the output should read about 1.5*1 + 0.4 = 1.9 volts.

Turn on switches 2 and 8 (in addition to 5), to give a gain of x11 and offset of 0.4 volts. Set DAC0 to 0.1 volts, and the output should read about 0.1*11 + 0.4 = 1.5 volts.

You can do similar to test the gains of x51 and x201, but the analog output on your LabJack might not go low enough. The limit for Vin at G=x51 is 0.024 volts, and the limit for Vin at G=x201 is 0.0059 volts. Set DAC0 & DAC1 to 0.0, use a DMM to measure the actual voltage output by both, and if either is low enough use that for testing.

Troubleshooting

Signals Not Referred to GND

You can't just connect 2 floating voltages to IN+ and IN- of an instrumentation amp. See the Differential Readings app note.

Common-Mode Voltage Out of Range

This is a common issue when trying to measure individual cell voltages in a battery pack with multiple cells in series. See the Differential Readings app note.

Source Impedance Too High

The LJTick-InAmp has high input impedance and low input bias currents, but some signal sources are particularly sensitive (e.g. some sources called "electrodes"). Such sources need an amp with very high input impedance, but usually more importantly ultra low input bias currents.