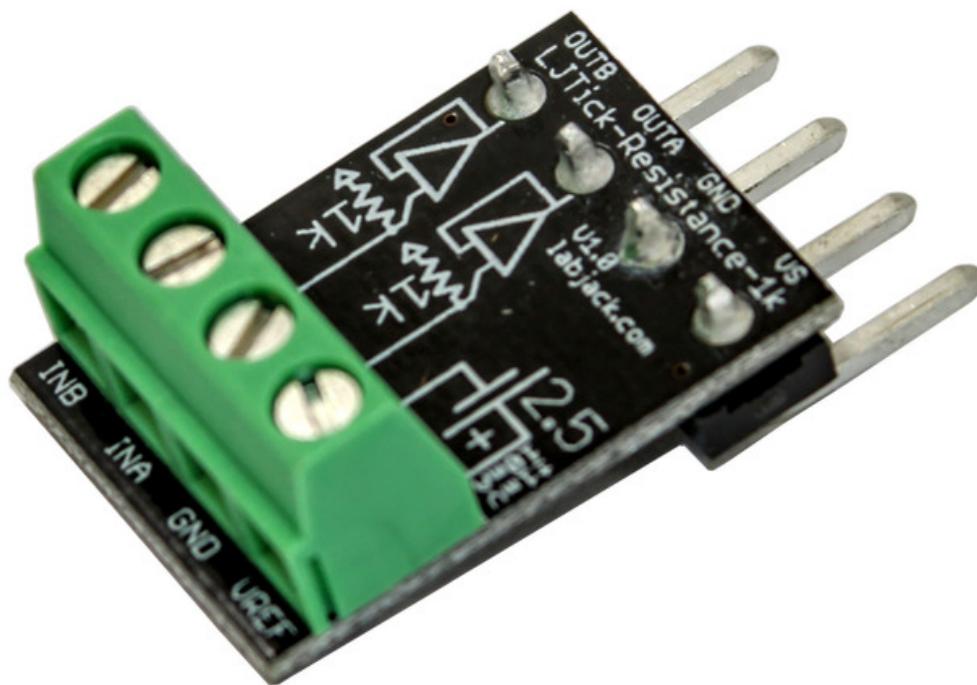


LJTick-Resistance Datasheet

LJTick-Resistance

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The LJTick-Resistance (LJTR) makes it easy for LabJack devices to measure resistive sensors. This tick gives users a regulated 2.5V signal that can be used as a excitation voltage and a known resistance value (1k, 10k, 100k, or 1M) to ground that forms a voltage divider with the unknown resistor. Measuring the voltage output of the voltage divider allows the calculation of the unknown resistance value.

The LJTR connects to an analog input block on a U3, U6, UE9, or T-series LabJack DAQ device. Thus it uses 2 analog inputs and measures 2 resistances.

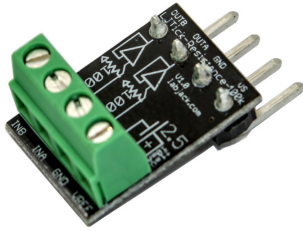


Figure 1: LJTick-Resistance



Figure 2: LJTick-Resistance with U3-LV

Common Applications

The LJTR is designed to measure the value of an unknown resistance. Some common examples are:

- Resistors
- Thermistors
- RTDs (PT100, PT1000, etc.)

Screw Terminal Descriptions

Vref: A 2.5 volt reference voltage output. Internally this reference is used for level shifting, but very little current is used, leaving substantial current available to the user if a very accurate 2.5 volt reference is needed.

GND: Same as LabJack ground (GND).

VINA/VINB: These are the LJTick-Resistance input terminals.

LJTick-Resistance Hardware Block Diagram

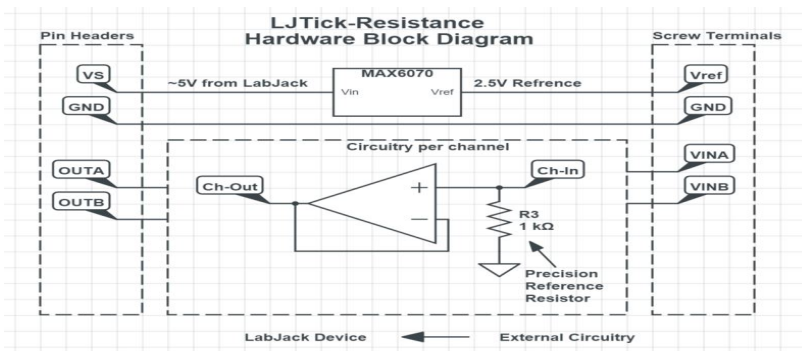


Figure 3: LJTick-Resistance Hardware Block Diagram

Note: The part labeled as the "Precision Resistor" is the 1k, 10k, 100k, or 1M precision resistor that varies between the LJTick-Resistance variants.

LJTick-Resistance Schematic

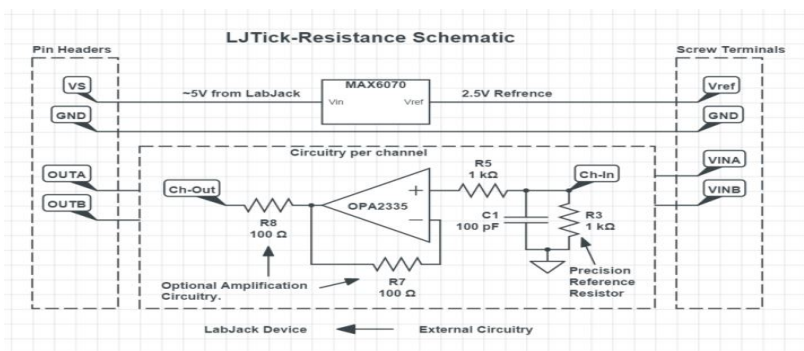


Figure 4: LJTick-Resistance Schematic

Note: The part labeled as the "Precision Resistor" is the 1k, 10k, 100k, or 1M precision resistor that varies between the LJTick-Resistance variants.

Equations

Typical wiring is to connect Vref to one side of the unknown resistance, and the other side of the unknown resistance to VIN. This forms a voltage divider with the precision resistor to ground which we will call Rfixed.

The Vref on the LJTR is exceptionally accurate. By specification it is more accurate than an analog input using the +/-10V range on even the U6-Pro and T7-Pro, so AIN feedback is generally not used but rather it is best to simply assume a constant of 2.500 V.

$$V_{out} = V_{ref} \cdot R_{fixed} / (R_{unknown} + R_{fixed})$$

$$R_{unknown} = (V_{ref} - V_{out}) \cdot R_{fixed} / V_{out}$$

$$R_{unknown} = (2.5 - V_{out}) \cdot 10000 / V_{out} \quad // \text{ LJTR-10k using the 2.5V reference}$$

Example 1, PT100 RTD: For a PT100 you expect that it will be 100.0 ohms at 0 °C and the resistance will change about 0.385 ohms/°C (most common coefficient). Say room temperature is 22 °C and putting your fingers on the sensor warms it up to 25 °C. At 22 °C you expect 108.47 ohms and at 25 °C you expect 109.63 ohms. The voltages you expect are:

$$22\text{ °C} \Rightarrow 2.255361\text{ V}$$

$$25\text{ °C} \Rightarrow 2.253003\text{ V}$$

Example 2, PT1000 RTD: For a PT1000 you expect that it will be 1000.0 ohms at 0 °C and the resistance will change about 3.85 ohms/°C (most common coefficient). Say room temperature is 22 °C and putting your fingers on the sensor warms it up to 25 °C. At 22 °C you expect 1084.7 ohms and at 25 °C you expect 1096.3 ohms. The voltages you expect are:

$$22\text{ °C} \Rightarrow 1.199213\text{ V}$$

$$25\text{ °C} \Rightarrow 1.192577\text{ V}$$

See more information see [forum topic #4257](#), which includes discussion of error due to lead-wire resistance and discussion of 3-wire and 4-wire resistance measurements.

Example 3, 10k Thermistor: The LJTR relationship between voltage and resistance is given above. To convert resistance to temperature we will use the [Steinhart-Hart](#) equation:

$$\text{TempK} = 1 / (A + B \cdot \ln(R/R_{25}) + C \cdot \ln(R/R_{25})^2 + D \cdot \ln(R/R_{25})^3)$$

"R" is the actual thermistor resistance and "R25" is the nominal thermistor resistance at 25 degrees C. The coefficients A, B, C, and D are needed, so for

the [NTCLE100E3103 thermistor](#) (for example) the datasheet tells us $A=0.003354016$, $B=0.000256985$, $C=0.000002620$, and $D=0.00000006383$.

For more information about using these equations in LJLogUD or LJLogM, see the [LJLog/Stream Scaling Equations page](#).

Note that on the T7 there you can use the [AIN-EF](#) system to do resistance, thermistor, and RTD math, but still the above is useful for understanding and troubleshooting.

Low-Pass Filter

All variations of the LJTR have $C1=100\text{pF}$ installed. This combines with Runknown to create a low-pass filter with a -3dB frequency as follows:

$$f = 1/(2\pi C1(Ru+R1+R2))$$

Table 1. Cutoff frequency for $C1=100\text{pF}$ with various source resistances.

Runknown [ohms]	-3dB Freq [Hz]
100	15,923,566.9
1,000	1,592,356.7
10,000	159,235.7
100,000	15,923.6
1,000,000	1,592.4
10,000,000	159.2
100,000,000	15.9

The reason for the filter is that this type of resistance measurement application often leads to an input wire with very high source impedance which is therefore very susceptible to noise. For example, say wire A connects Vref to a 1M resistor, and wire B connects the other side of the resistor to VIN. Wire A is driven strongly by the low-source impedance Vref, and is not particularly susceptible to noise. Wire B, however, has 1M of source impedance and thus is weakly driving VIN, and is quite susceptible to noise. Capacitor C1 can help eliminate much of this noise.

Choosing the 1k, 10k, 100k, or 1M Version

A rule of thumb is to choose the version that most closely matches your typical resistance value, but to really get into details here is a [spreadsheet that lists output voltage versus resistance](#) for the different versions. Save a copy of this to your Google Drive or local machine if you want to edit.

For example, say you have a 10k thermistor and want to measure a 0.1°C change around the area of 20°C . From L73 we expect a resistance of 12260 ohms at 20.0°C , and from F73 we know that we will get a change of about -490 ohms/degree round 20°C , so at 20.1°C we expect 12309 ohms. We put those resistances in B46 & B47, and then look at the resulting Vout changes for the different LJTR variations in row 52. We can see that the -10k variation gives the largest change at 2.467 mV and thus is a likely choice.

One other consideration, though, is that if we choose the -1k variation the voltages being measured are less than 1 volt so we can use the ± 1 volt analog input range on the U6/T7 and get better resolution than on the ± 10 volt range. Similar logic can be used to keep readings below the limit of a low voltage analog input on the U3 (2.44V) and T4 (2.5V).

Resolution

To evaluate resolution we need to look at 3 steps:

1. The thermistor or RTD has a varying resistance related to temperature.
2. The LJTR converts varying resistance to varying voltage.
3. The LabJack digitizes the varying voltage.

Thermistor Example:

1. Let's say we plan to use a Vishay NTCLE100E3103 10k thermistor to measure from +20 to +150 °C. Use a chart provided by the manufacturer (or use coefficients with an online calculator) to find the resistance at the ends of the range of interest:

<http://www.vishay.com/docs/29049/ntcle100.pdf>

°C	Ohms
15	15698
20	12488
145	205.5
150	182.6

We get the smallest change at the higher temperatures (only ~23 ohms), as expected with all NTC thermistors, so this is where we focus our further evaluation. We will look at 145 °C and 150 °C where the resistance changes from 205.5 to 182.6 ohms.

2. Use the LJTR equations from above, or a copy of [our LJTR spreadsheet](#), to get the voltages. That results in 2.4497 volts at 205.5 ohms, and 2.4552 volts at 182.6 ohms. Thus a change of 0.0055 volts per 5 degrees, or 0.0011 volts/°C.

3. The noise level of our 12-bit class devices is generally just 1 or 2 counts, so to get the voltage resolution just look at span divided by counts. The input range of low voltage analog inputs (FIO/EIO) on the T4 is 0-2.5 volts, so voltage resolution is $2.5 / 2^{12} = 0.0006$ volts/count (U3 is about the same), which we combine with our 0.0011 volts/°C number from above to get:

$$(0.0011 \text{ volts/°C}) / (0.0006 \text{ volts/count}) = 1.8 \text{ counts/°C or } 0.55 \text{ °C/count}$$

So the resolution is about half a degree C when using this 10k thermistor with a U3/T4 to measure around 150 °C. For improvement move to a higher resolution device such as the U6 or T7 families, and for these high resolution devices use the applicable appendix in their data sheet to determine voltage resolution for different configurations. For example, from [Table A.3.1.1 of the T-Series Datasheet](#), we see that the T7-Pro has an effective resolution of 0.0000057 V at Range=10 and ResolutionIndex=12 which equates to 0.005 °C.

RTD Example:

1. Let's say we plan to use a PT100 that will be 100.0 ohms at 0 °C and has the standard response of 0.385 ohms/°C. We are interested in room temperature so we look at 22 and 25 °C.

°C	Ohms
22	108.47
25	109.63

$$22 \text{ °C} \Rightarrow 2.255361 \text{ V}$$

$$25 \text{ °C} \Rightarrow 2.253003 \text{ V}$$

2. Use the LJTR equations from above, or a copy of [our LJTR spreadsheet](#), to get the voltages. That results in 2.255361 volts at 108.47 ohms, and 2.253003 volts at 109.63 ohms. Thus a change of 0.002358 volts per 3 degrees, or 0.000786 volts/°C.

3. The noise level of our 12-bit class devices is generally just 1 or 2 counts, so to get the voltage resolution just look at span divided by counts. The input range of low voltage analog inputs (FIO/EIO) on the T4 is 0-2.5 volts, so voltage resolution is $2.5 / 2^{12} = 0.0006$ volts/count (U3 is about the same), which we combine with our 0.000786 volts/°C number from above to get:

$$(0.000786 \text{ volts/°C}) / (0.0006 \text{ volts/count}) = 1.3 \text{ counts/°C or } 0.76 \text{ °C/count}$$

So the resolution is about 3/4 a degree C when using a PT100 with a U3/T4. For improvement move to a higher resolution device such as the U6 or T7 families, and for these high resolution devices use the applicable appendix in their data sheet to

determine voltage resolution for different configurations. For example, from [Table A.3.1.1 of the T-Series Datasheet](#), we see that the T7-Pro has an effective resolution of 0.0000057 V at Range=10 and ResolutionIndex=12 which equates to 0.007 °C.

Accuracy

Now we continue the above resolution discussion to move into the realm of accuracy. As with most signals, the best accuracy is usually achieved with an in-situ calibration. This means connecting everything up and then at different temperatures note the voltage reading from a particular channel and the actual temperature from some reference or known condition. Then use that information in your software to equate further voltage readings to temperature.

Without an in-situ calibration, no calibration is applied and thus an error analysis needs to be performed on the entire system to come up with total error. Such an analysis is quite complex, but we can look at a list of error sources and see which appear important.

1. Accuracy of the thermistor or RTD itself in its conversion of temperature to resistance. The datasheet for the Vishay NTCLE100E3103 10k thermistor says the R25 tolerance is $\pm 2.0\%$ (best grade) and the Beta tolerance is $\pm 0.75\%$.
2. Accuracy of the LJTR in its conversion of resistance to voltage. One source of error is the reference voltage accuracy of $\pm 0.04\%$. The other notable source of error is the tolerance of R_{fixed} which is $\pm 0.05\%$.
3. Accuracy of the LabJack in its digitization of the voltage. For the T4 this is found in [Table A.3-1 of the T-Series Datasheet](#) and is 0.13% full-span. For the T7 this is found in [Table A.3-2 of the T-Series Datasheet](#) and is 0.01% full-span.
4. Voltage drop error due to current flowing in sensor wires. If using a 2-wire connection the resistance of the lead wires could be noticeable. With a thermistor this error only might be noticeable at high temperatures where the thermistor resistance is smaller. In our example in the Resolution section above the thermistor changes about 23 ohms from 145 °C to 150 °C, so 0.1 °C equates to about 0.5 ohms. Lead wires that are too skinny or too long could have a resistance of 0.5 ohms and thus cause 0.1 °C error. For example, 200 ft of 18 AWG wire has a resistance of about 1.28 ohms. See related discussion in [forum topic 4257](#).

In this list of errors, #1 is dominant for this thermistor and the other error sources are negligible. Some RTDs have a much better accuracy rating and thus the other errors might be important.

Specifications:

Parameter	Conditions	Min	Typical	Max	Units
General					
Vs, Supply Voltage (1)		2.8	5	5.5	Volts
Supply Current			1.2		mA
Operating Temperature		-40		85	°C
VREF					
Output Voltage		2.499	2.500	2.501	Volts
Initial Accuracy				± 0.04	%
Maximum Output Current			10		mA
Temperature Coefficient			1.5	6	ppm/°C
Op-Amp Buffer					
Typical Input Voltage Range		-0.1		VS - 1.5	Volts
Typical Output Voltage Range	Load \geq 100k Ω	0.001		VS - 0.001	Volts
Input Bias Current			± 70	± 200	pA
Offset Voltage			1	5	μ V
Rfixed					


Accuracy				± 0.05	%
Temperature Coefficient				± 10	ppm/°C

(1) The maximum input voltage to the buffer amplifier is $V_S - 1.5$, so for proper operation with signals up to 2.5 volts, V_S must be greater than 4.0 volts.

For more specifications about the reference voltage IC and Op Amp used in the LJTick-Resistance look at the following datasheets:

- Maxim [MAX6070 datasheet](#)
- Texas Instruments [OPA2335 datasheet](#)

File Attachment:

 [Maxim MAX6070 Datasheet](#)

 [Texas Instruments OPA2335 Datasheet](#)
