



UNIVERSITÀ DEGLI STUDI DI PAVIA

Dept. of Electrical, Computer and  
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Data acquisition from a temperature sensor

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# Thermistors

- A thermistor is a temperature transducer, typically featuring relatively fast response times, very good sensitivity, low cost but not so good linearity
- Depending on whether the thermistor resistance decreases or increases with the temperature, we can talk about
  - **NTC** (negative temperature coefficient) thermistors, whose resistance decreases as the temperature increases
  - **PTC** (positive temperature coefficient) thermistors, whose resistance increases as the temperature increases

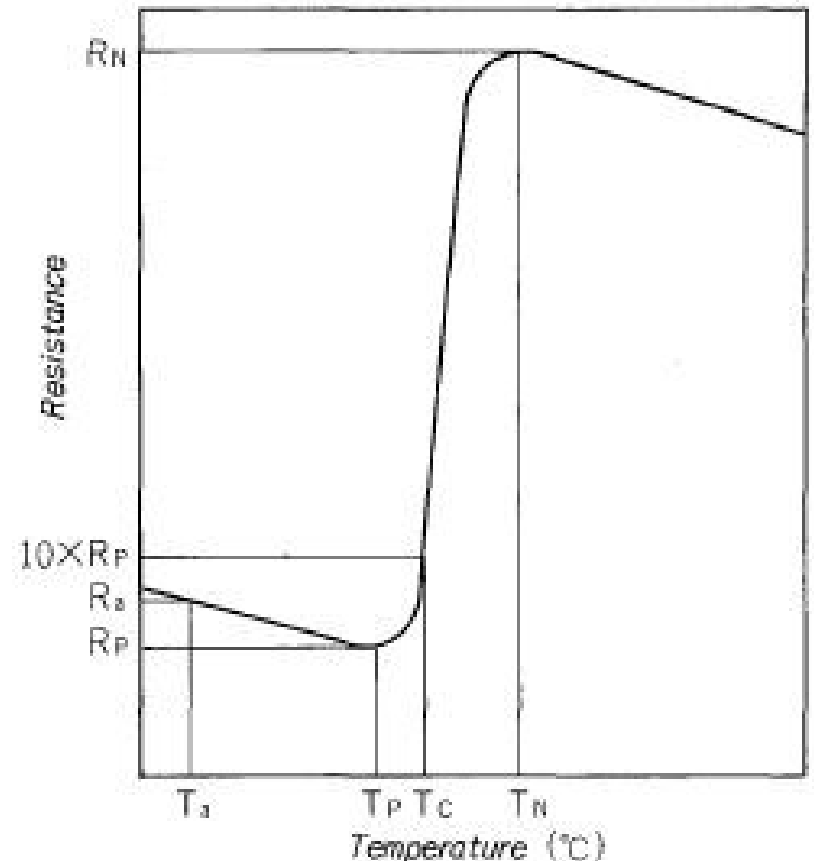


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# PTC thermistors

- Resistors whose resistance increases with the temperature - their operating principle is based on the particular properties of the material they are made of, sharply changing resistance with  $T$  (typically ceramic semiconductors, e.g.  $\text{BaTiO}_3$ )
- They generally have larger temperature coefficient than NTC thermistors - on the other hand, their  $R$ - $T$  characteristic is strongly non-linear and is provided by the manufacturer for predefined temperature intervals
- In PTC thermistors, the temperature coefficient increases very rapidly as soon as the so called Curie temperature is exceeded





# Main uses of thermistors

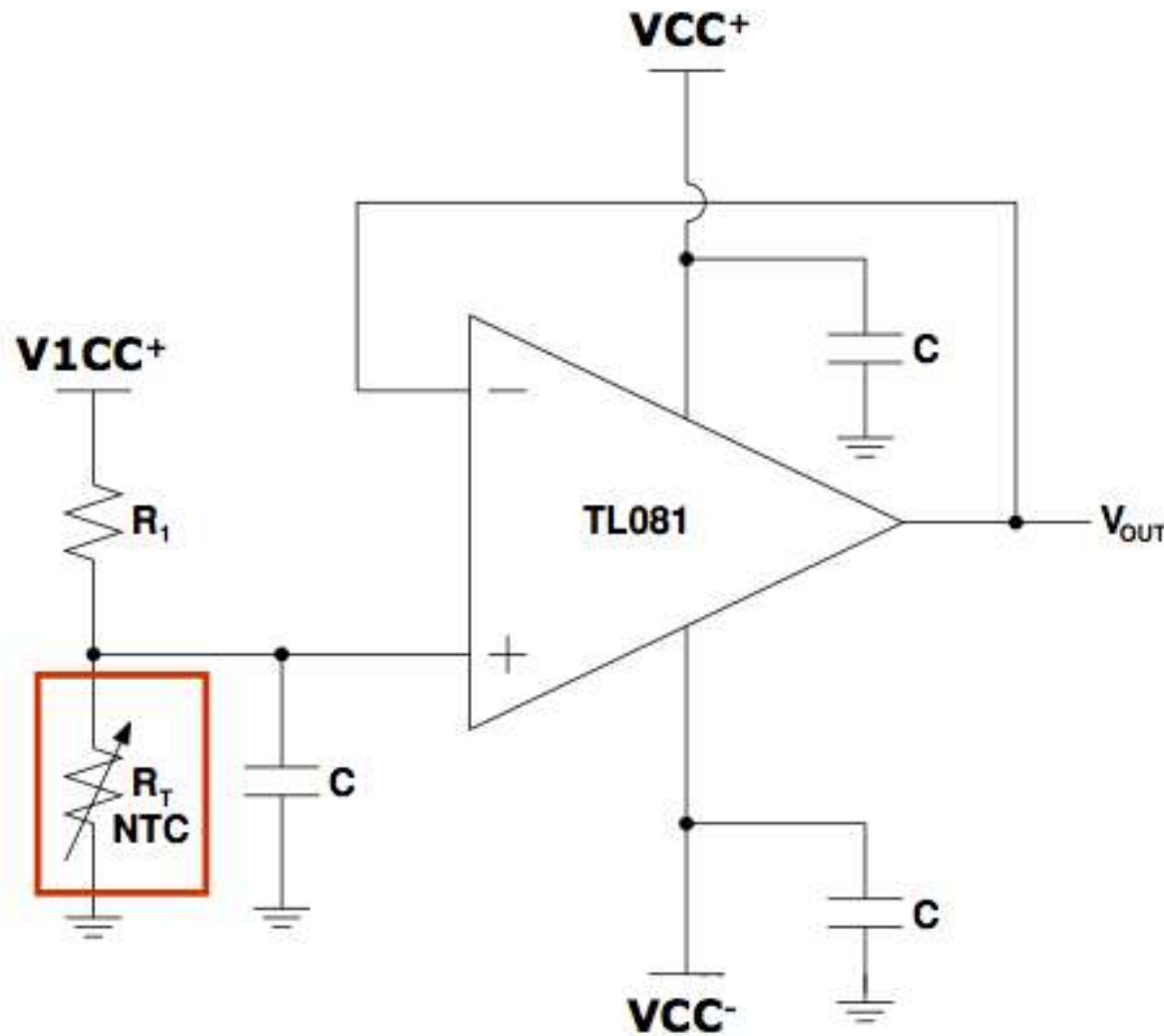
Thermistor	Function	Purpose
NTC	Temperature measurement	<ul style="list-style-type: none"><li>• Heating systems</li><li>• Household electrical appliances</li><li>• Industrial control</li></ul>
	Thermal compensation	<ul style="list-style-type: none"><li>• Industrial electronics</li><li>• Consumer electronics</li><li>• Data processing</li></ul>
PTC	Thermal protection	<ul style="list-style-type: none"><li>• Power supply circuits</li><li>• Industrial electronics</li><li>• Consumer electronics</li><li>• Data processing</li></ul>
	Overload protection	<ul style="list-style-type: none"><li>• Power supply circuits</li><li>• Telecommunication</li><li>• Automotive</li><li>• Industrial electronics</li><li>• Consumer electronics</li><li>• Data processing</li></ul>



# Purpose of the experiment

- Implement a system for data acquisition from a temperature sensor, in particular from an NTC thermistor. The system should include
  - a conditioning circuit for the signal coming from the sensor
  - a virtual instrument implemented in the LabView programming environment serving as an interface between the acquisition system and the user
- The virtual instrument should take care of acquiring the temperature and representing the time evolution of the measured voltage and the instantaneous value of the temperature

# Conditioning circuit



- $R_1 = 1.1 \text{ k}\Omega$
- $C = 100 \text{ nF}$
- $VCC^+ = +15 \text{ V}$
- $VCC^- = -15 \text{ V}$
- $V1CC^+ = 5 \text{ V}$
- $R_T$ : KE 164



# R-T characteristic for the thermistor

Thermistor resistance at temperature T

Temperature coefficient (about constant between 25 ° C and 100 ° C)

$$R_T(T) = R_T(T_0) \cdot e^{\beta \left( \frac{1}{T} - \frac{1}{T_0} \right)} \Rightarrow T = \frac{\beta \cdot T_0}{\beta + T_0 \cdot \ln \left[ \frac{R_T(T)}{R_T(T_0)} \right]}$$

Thermistor resistance at the reference temperature  
 $T_0 = 25^\circ \text{ C}$





## $T$ - $V_{OUT}$ relationship

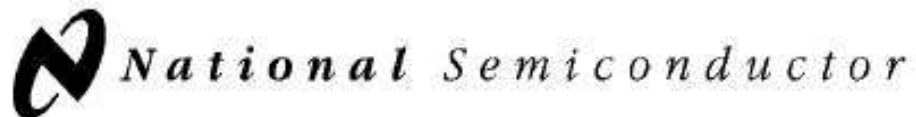
- Measured voltage as a function of the thermistor resistance

$$V_{OUT} = \frac{R_T}{R_1 + R_T} \cdot V1CC^+ = \frac{1}{1 + \frac{R_1}{R_T}} \cdot V1CC^+ \Rightarrow R_T = \frac{V_{OUT}}{V1CC^+ - V_{OUT}} \cdot R_1$$

- Relationship between temperature and measured voltage

$$T = \frac{\beta \cdot T_0}{\beta + T_0 \cdot \ln \left[ \frac{V_{OUT} \cdot R_1}{(V1CC^+ - V_{OUT}) \cdot R_{T_0}} \right]}$$

# TL081 JFET input OpAmp



December 1995

## TL081 Wide Bandwidth JFET Input Operational Amplifier

### General Description

The TL081 is a low cost high speed JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The TL081 is pin compatible with the standard LM741 and uses the same offset voltage adjustment circuitry. This feature allows designers to immediately upgrade the overall performance of existing LM741 designs.

The TL081 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift, but for applications where these requirements

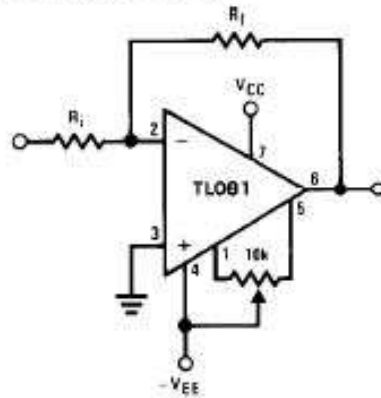
are critical, the LF356 is recommended. If maximum supply current is important, however, the TL081C is the better choice.

### Features

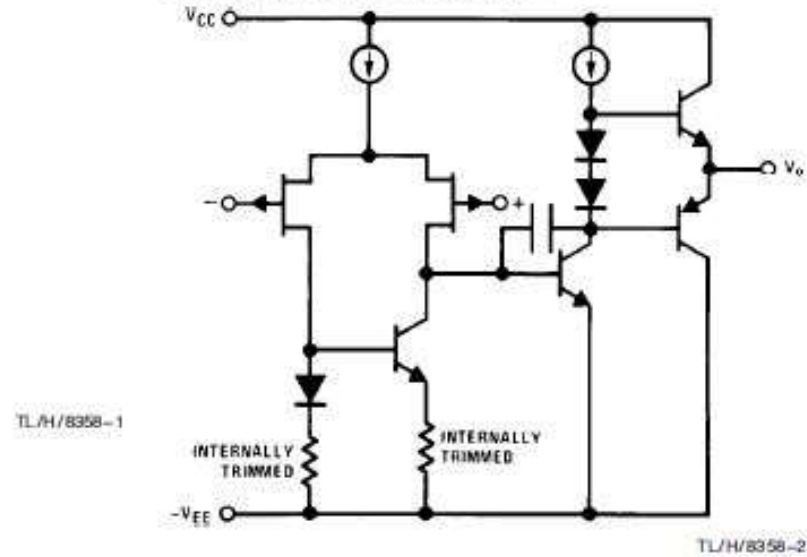
■ Internally trimmed offset voltage	15 mV
■ Low input bias current	50 pA
■ Low input noise voltage	25 nV/ $\sqrt{\text{Hz}}$
■ Low input noise current	0.01 pA/ $\sqrt{\text{Hz}}$
■ Wide gain bandwidth	4 MHz
■ High slew rate	13 V/ $\mu\text{s}$
■ Low supply current	1.8 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$ , $R_L = 10\text{k}\Omega$ , $V_O = 20\text{ Vp-p}$ , $\text{BW} = 20\text{ Hz} - 20\text{ kHz}$	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01 %	2 $\mu\text{s}$

# TL081 JFET input OpAmp

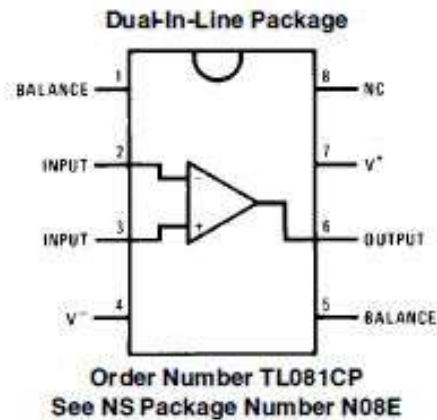
Typical Connection



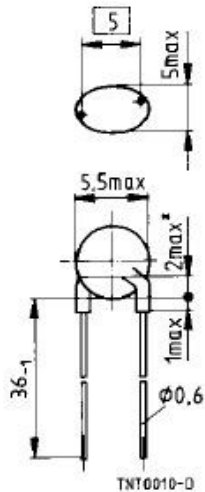
Simplified Schematic



Connection Diagram



# KE-164 NTC thermistor



## Applications

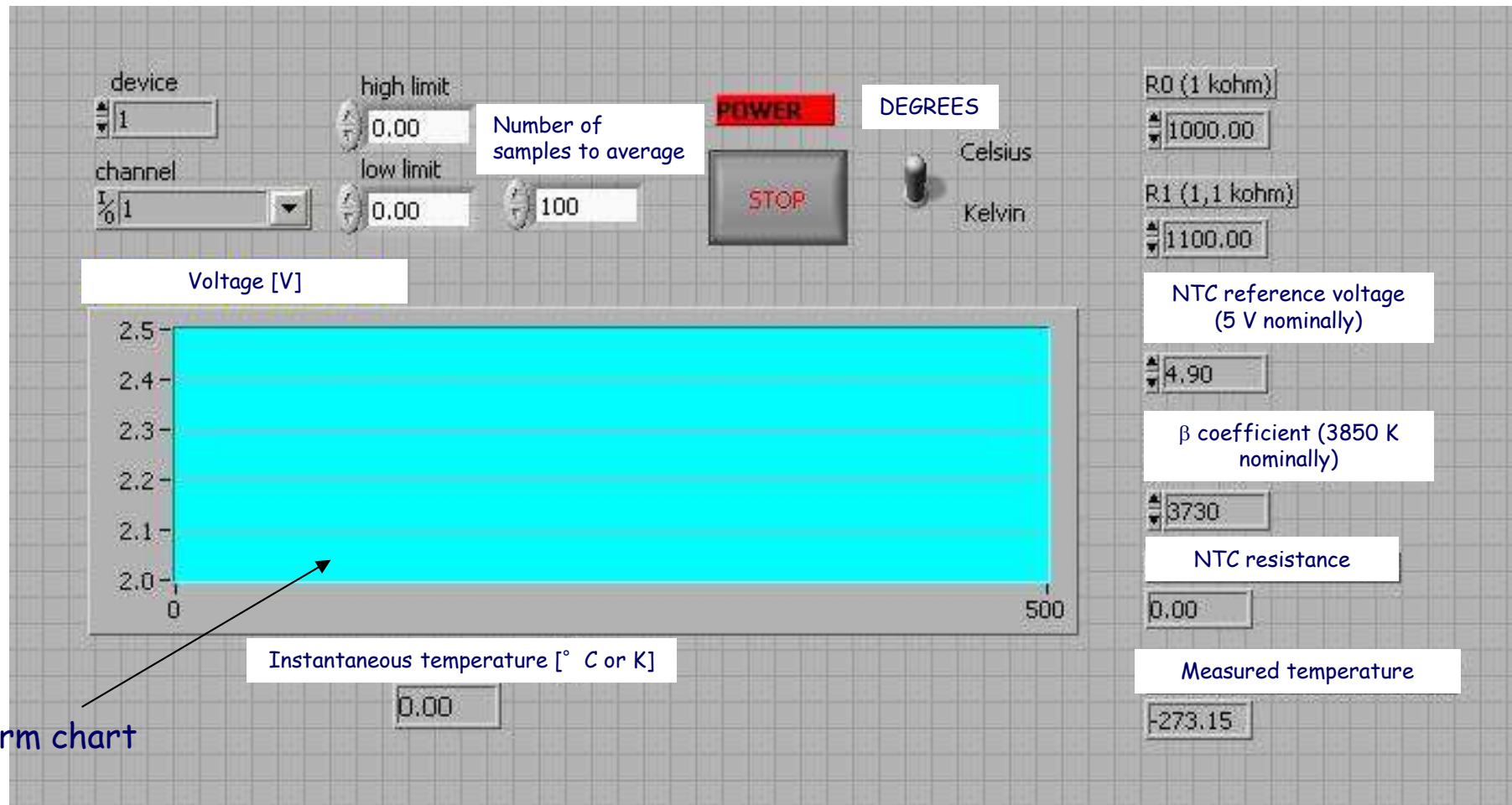
- Temperature compensation
- Temperature measurement
- Temperature control

## Features

- Wide resistance range
- Cost-effective
- Lacquer-coated thermistor disk
- Tinned copper leads
- Marked with resistance and tolerance
- Available on tape (PU: 1500 pcs)

Type	$R_{25}$ Ω	No. of R/T characteristic	$B_{25/100}$ K	Ordering code
K 164/1 k/+	1 k	1011	3730	B57164-K102-+
K 164/1,5 k/+	1,5 k	1013	3900	B57164-K152-+
K 164/2,2 k/+	2,2 k	1013	3900	B57164-K222-+
K 164/3,3 k/+	3,3 k	4001	3950	B57164-K332-+
K 164/4,7 k/+	4,7 k	4001	3950	B57164-K472-+
K 164/6,8 k/+	6,8 k	2903	4200	B57164-K682-+
K 164/10 k/+	10 k	2904	4300	B57164-K103-+
K 164/15 k/+	15 k	1014	4250	B57164-K153-+
K 164/22 k/+	22 k	1012	4300	B57164-K223-+
K 164/33 k/+	33 k	1012	4300	B57164-K333-+
K 164/47 k/+	47 k	4003	4450	B57164-K473-+
K 164/68 k/+	68 k	2005	4600	B57164-K683-+
K 164/100 k/+	100 k	2005	4600	B57164-K104-+
K 164/150 k/+	150 k	2005	4600	B57164-K154-+
K 164/220 k/+	220 k	2007	4830	B57164-K224-+
K 164/330 k/+	330 k	2006	5000	B57164-K334-+
K 164/470 k/+	470 k	2006	5000	B57164-K474-+

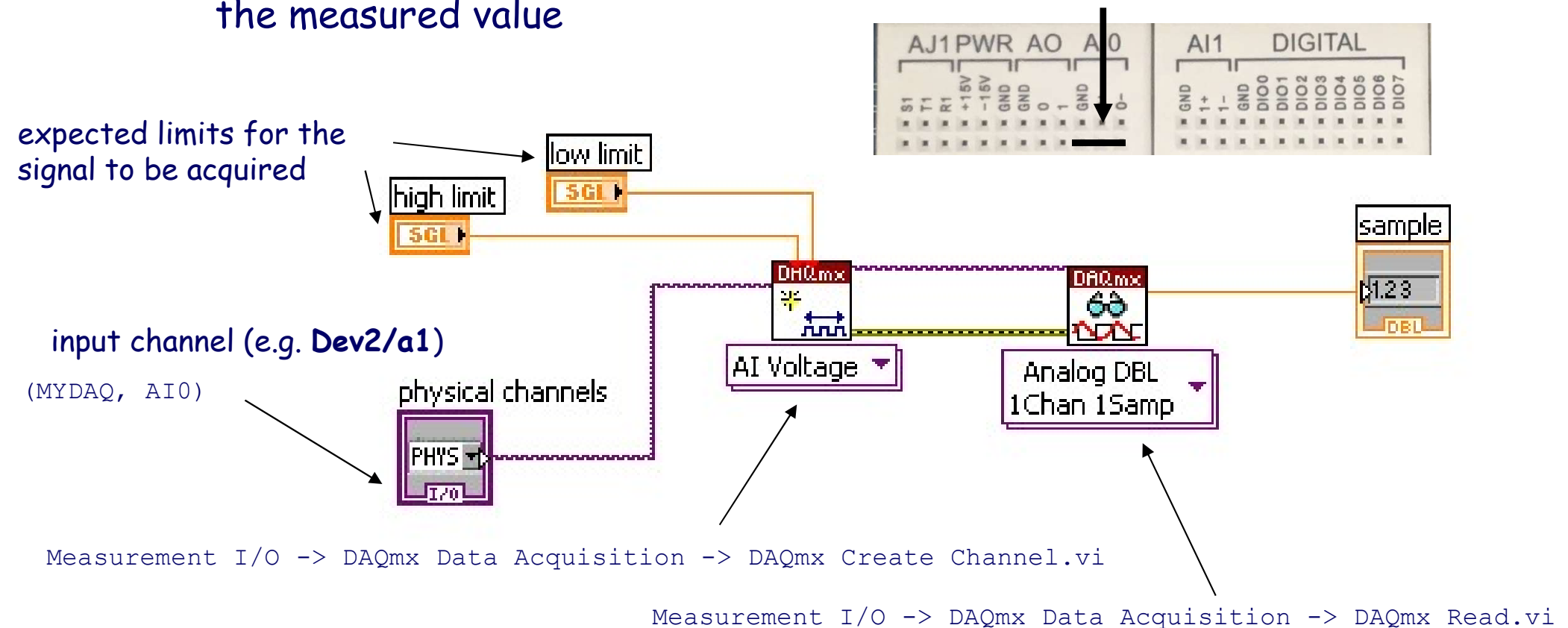
# Front panel (example)





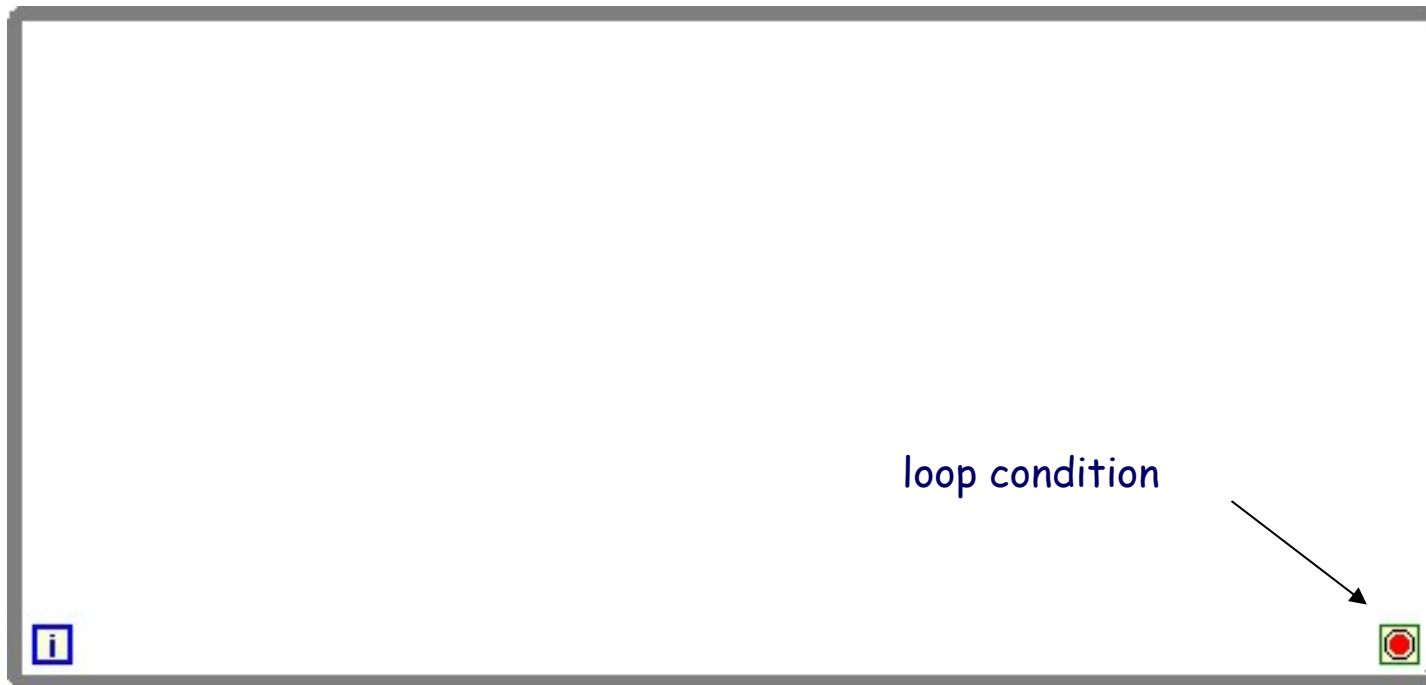
# DAQmx Create Channel.vi and DAQmx Read.vi

- DAQmx Create Channel.vi provides the acquisition board with information about the type and range of the signals to be acquired and about the input channel
- DAQmx Read.vi samples the signal from the specified channel and yield the measured value



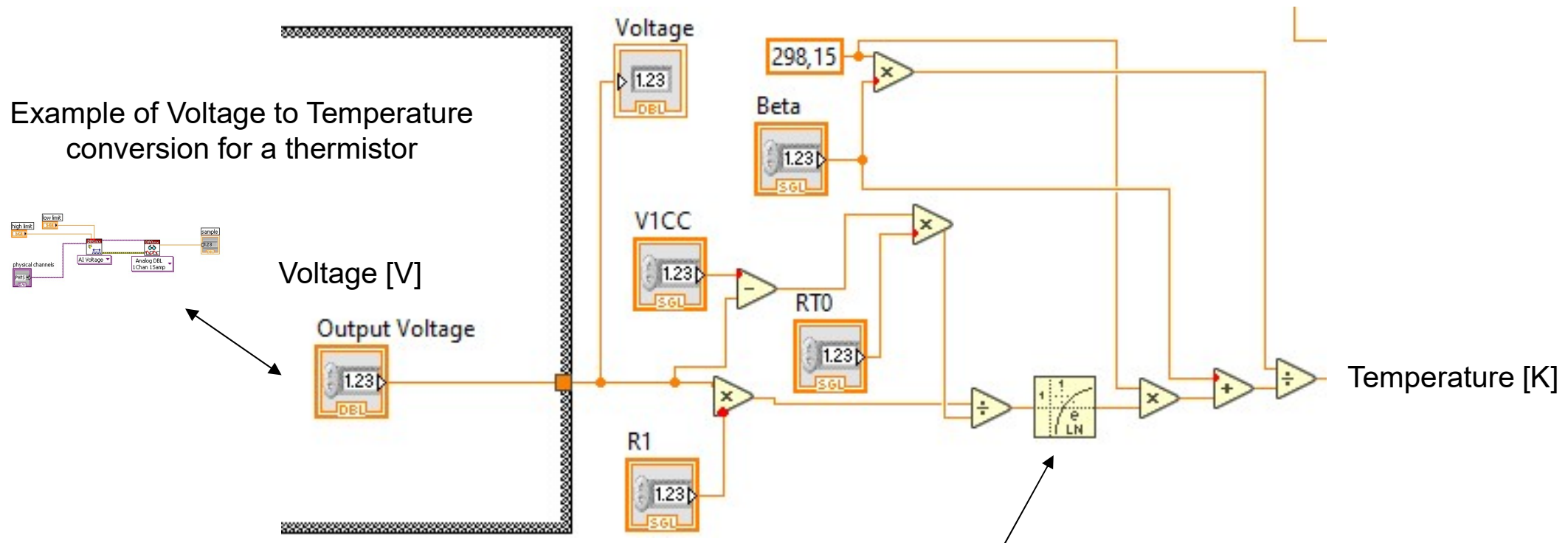
# While loop

- Needed for continuous acquisition of the signal coming from the conditioning circuit (you can find it in the Structures menu from the Functions palette ) - a "stop" button should be included in the virtual instrument to stop the acquisition



# Temperature Calculation

- Basic and advanced algebraic and mathematical blocks/functions can be used to convert the op-amp output voltage into temperature (recommended)
- Offset and Gain Errors may need to be considered and compensated

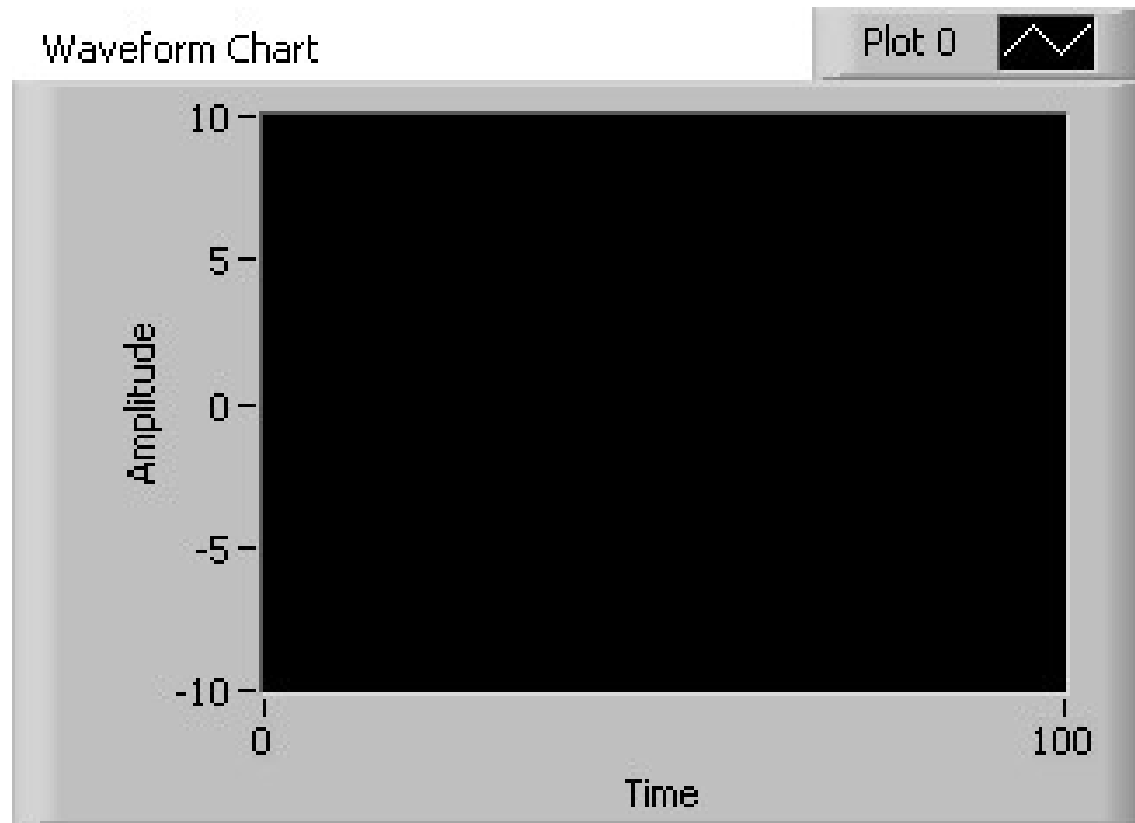


Natural log (base 2.718): Mathematics, Elementary, Exponential, LN



# Waveform chart

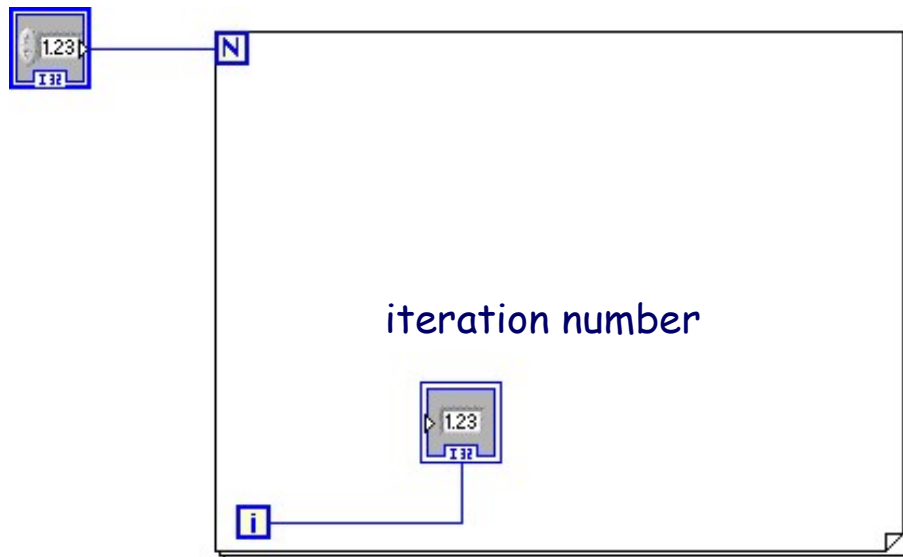
- You can use a waveform chart for a graphical representation of the acquired data ('Graph' menu of the Controls palette, from the front panel window) - the acquired sample can be directly fed to the waveform chart



# For cycle

- Use a for cycle to reduce the effects of zero average disturbances and improve the measurement accuracy

number of cycles



Instead of representing (in the graph or in the numeric indicator) each individual acquired sample of the signal, we can represent the average value of  $N$  samples - the speed at which the measurement result is represented on the graph will decrease by a factor of  $N$