UNIVERSITÀ DEGLI STUDI DI PAVIA

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dell'Università di Pavia

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Data acquisition from a temperature sensor (NTC/Pt1000)

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Thermistors

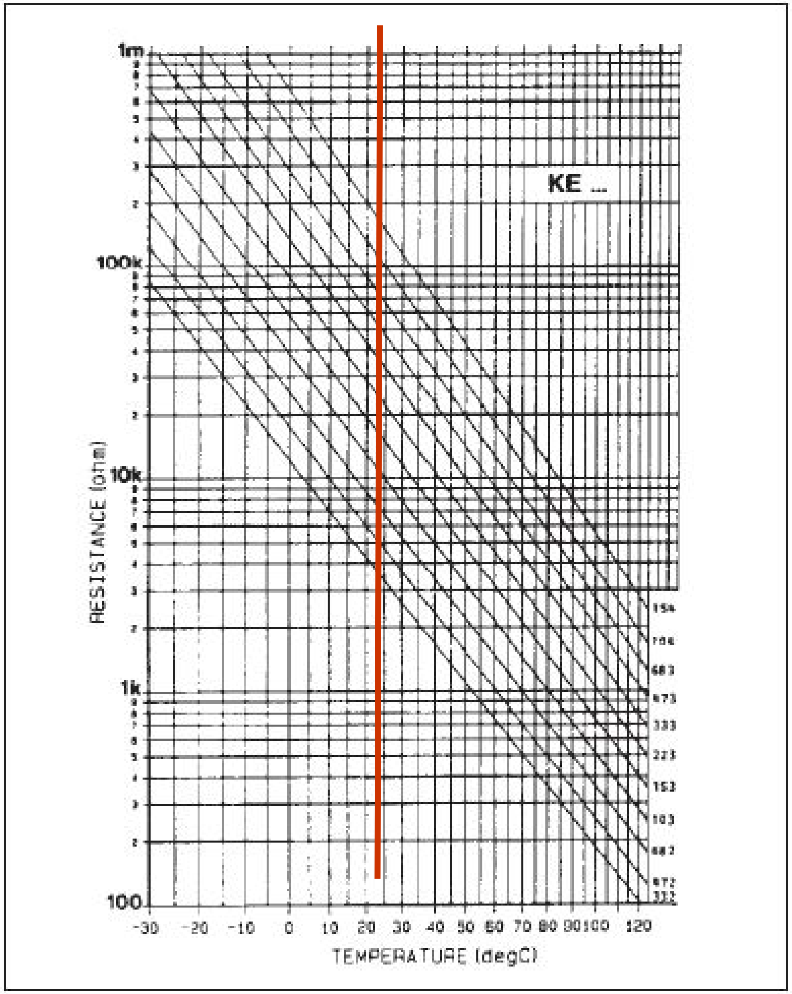
- A thermistor is a temperature transducer, typically featuring relatively fast response times, very good sensitivity, low cost but not so good linearity
- Depending on whether the thermistor resistance decreases or increases with the temperature, we can talk about
  - NTC (negative temperature coefficient)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

NTC Thermistors

- They are usually built using a mixture of metal oxides with the property, similar to semiconductors, that the conductivity increases as the temperature increases

- Compared to PTC, NTC feature better linearity and a larger operating interval. Resistance to temperature characteristic is exponential

- Linearity is intended in the Log way being R-T an EXP



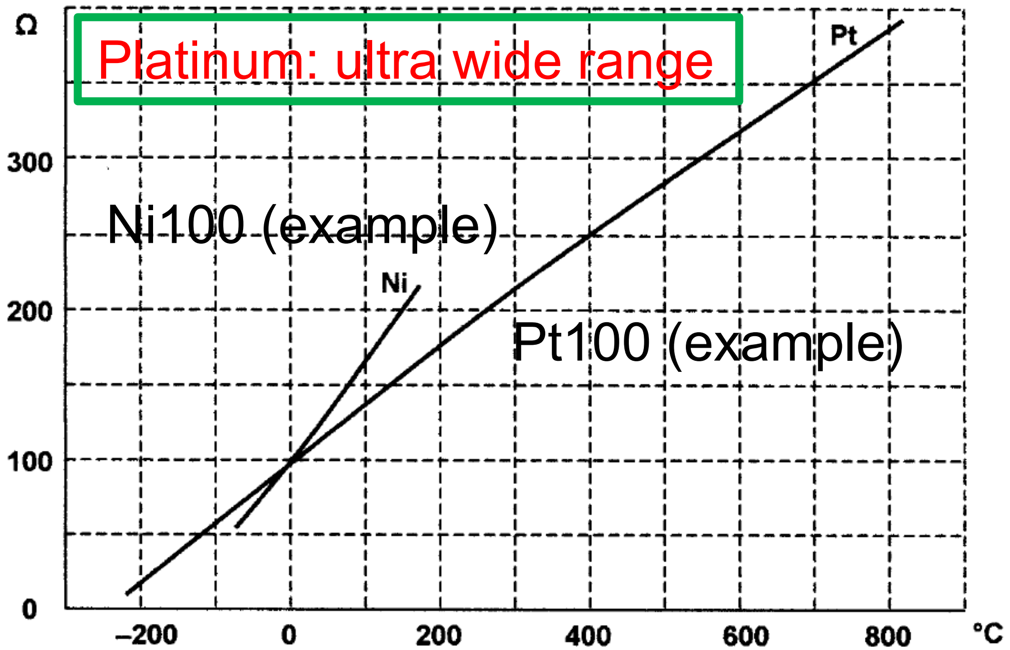
Thermo-Resistors (Ni100, Pt100, Pt1000)

- They have intrinsic PTC linear response on Linear Scale

$$R_1 = R_0 \cdot (1 + \alpha \cdot (T_1 - T_0))$$

$T_0 = 0°C$

Pure Platinum: $\alpha = 3.85\ mK^{-1}$

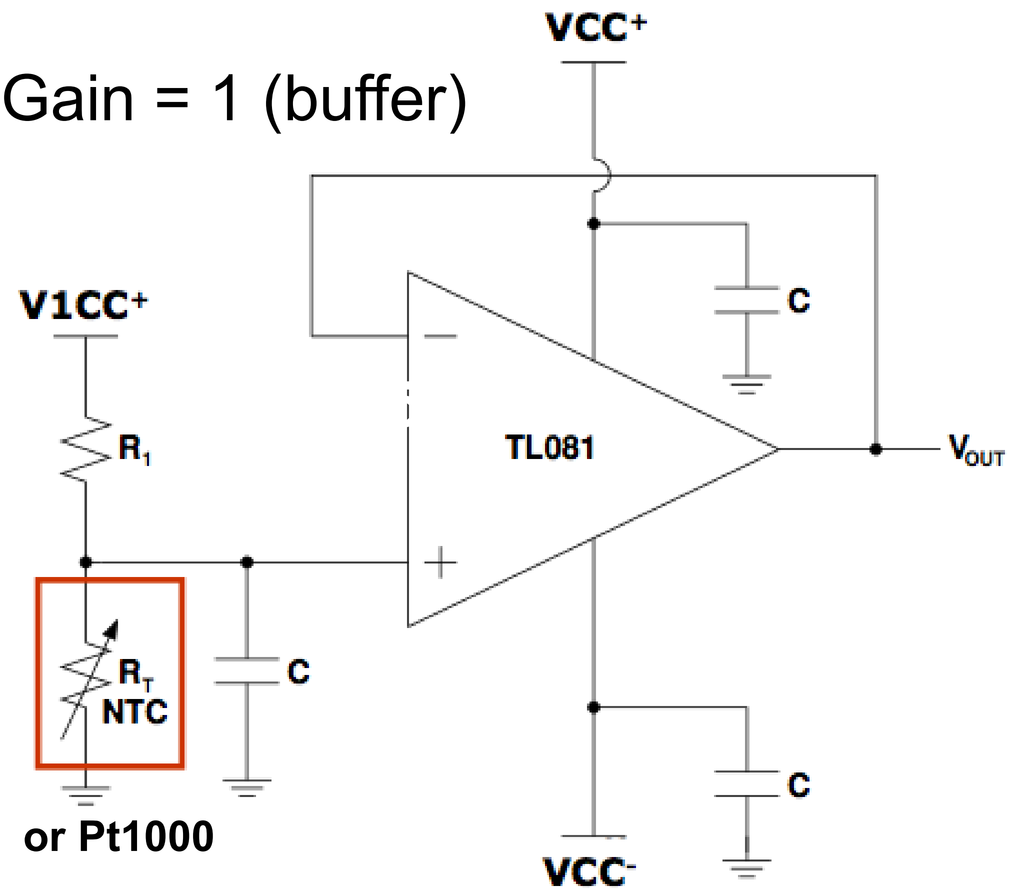


Purpose of The Experiments

- Play with a system for data acquisition from a temperature sensor, in particular from an NTC thermistor and a Pt1000. You'll play with:
    - a common conditioning circuit for the signal coming from each sensor
    - a common virtual instrument implemented in the LabVIEW 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

Simplified Conditioning Circuit Example (common)

Gain = 1 (buffer)



R1=1.1 kΩ

C=100 nF

VCC+=+15 V

VCC-=-15 V

V1CC+=5 V

RT: sensor

R-T Characteristic for the Thermistor

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

Thermistor resistance at temperature T

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

Thermistor resistance at the reference temperature T0=25° C

In KELVIN !

T-VOUT Relationship (Thermistor)

- 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

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

TL081 JFET Input OpAmp

National Semiconductor

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.

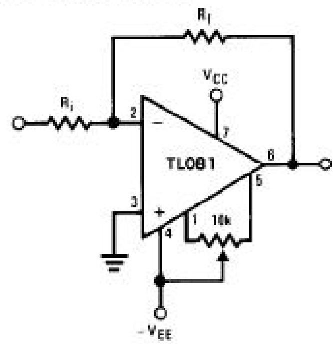
The TL081 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices has low noise and offset voltage 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	$25\ nV/\sqrt{Hz}$
■ Low input noise current	$0.01\ pA/\sqrt{Hz}$
■ Wide gain bandwidth	4 MHz
■ High slew rate	$13\ V/\mu s$
■ Low supply current	1.8 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20$ Vp-p, BW = 20 Hz−20 kHz	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01%	$2\ \mu s$

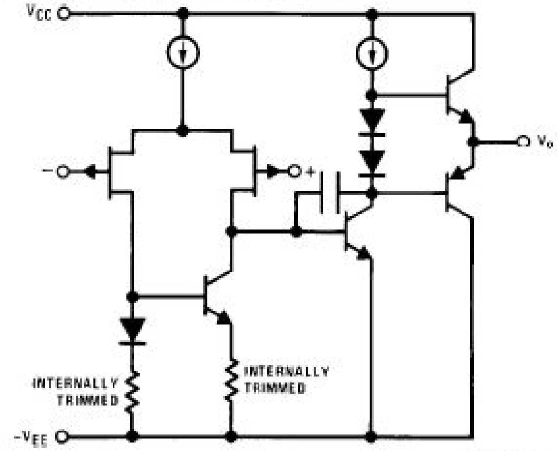
TL081 JFET Input OpAmp

Typical Connection



TL/H/8358–1

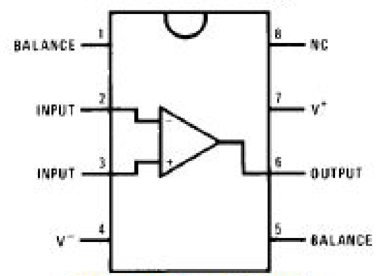
Simplified Schematic



TL/H/8358–2

Connection Diagram

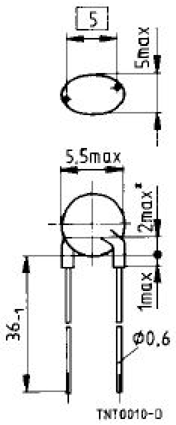
Dual-In-Line Package



TL/H/8358–4

Order Number TL081CP
See NS Package Number N08E

TDK B57045K NTC Thermistor



Electrical specification and ordering codes

R_{25} Ω	No. of R/T characteristic	$B_{25/100}$ K	Ordering code
1 k	1011	3730 ±3%	B57045K0102K000
2.2 k	1013	3900 ±3%	B57045K0222K000
4.7 k	4001	3950 ±3%	B57045K0472K000
6.8 k	2903	4200 ±3%	B57045K0682K000
10 k	2904	4300 ±3%	B57045K0103K000
33 k	1012	4300 ±3%	B57045K0333K000
47 k	4003	4450 ±3%	B57045K0473K000
68 k	2005	4600 ±3%	B57045K0683K000
100 k	2005	4600 ±3%	B57045K0104K000
150 k	2005	4600 ±3%	B57045K0154K000

Applications

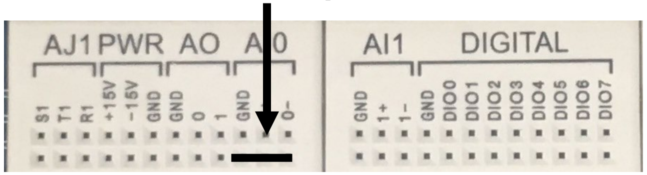
- Temperature compensation
- Temperature measurement
- Temperature control

Features

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

DAQmx Create Channel.vi and DAQmx Read.vi

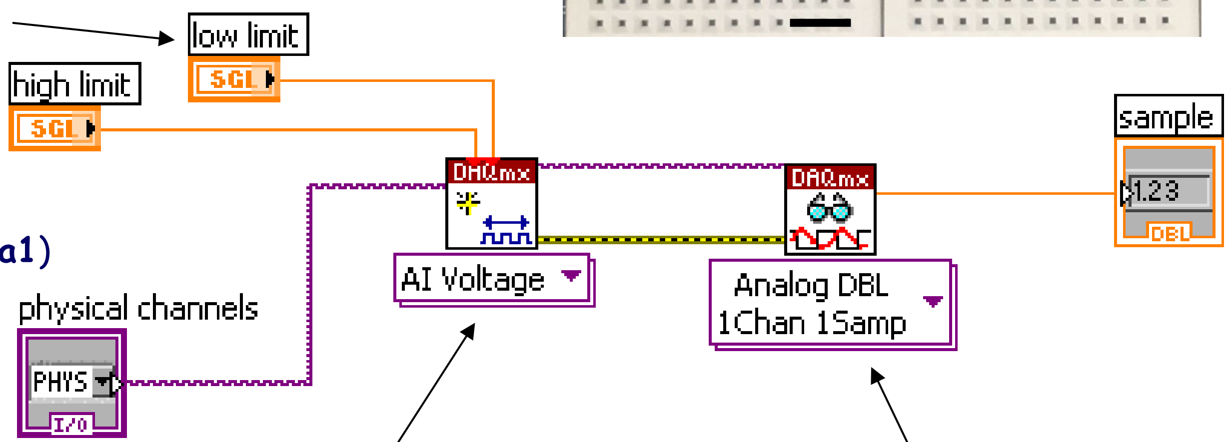
- DAQmx Create Channel.vi provides the acquisition board with information about the type and range of the signals to be acquired and about the input channel
- DAQmx Read.vi samples the signal from the specified channel and yields the measured value



expected limits for the signal to be acquired

input channel (e.g. **Dev2/a1**)

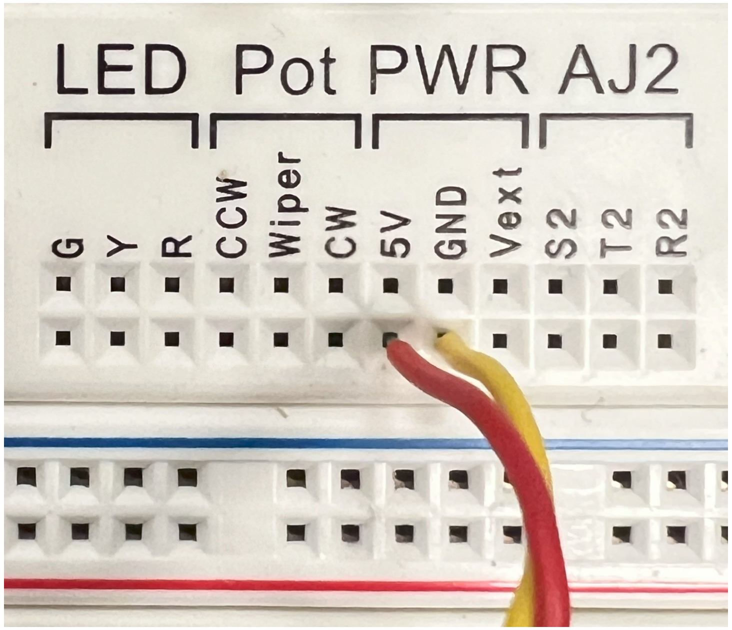
(MYDAQ, AI0)

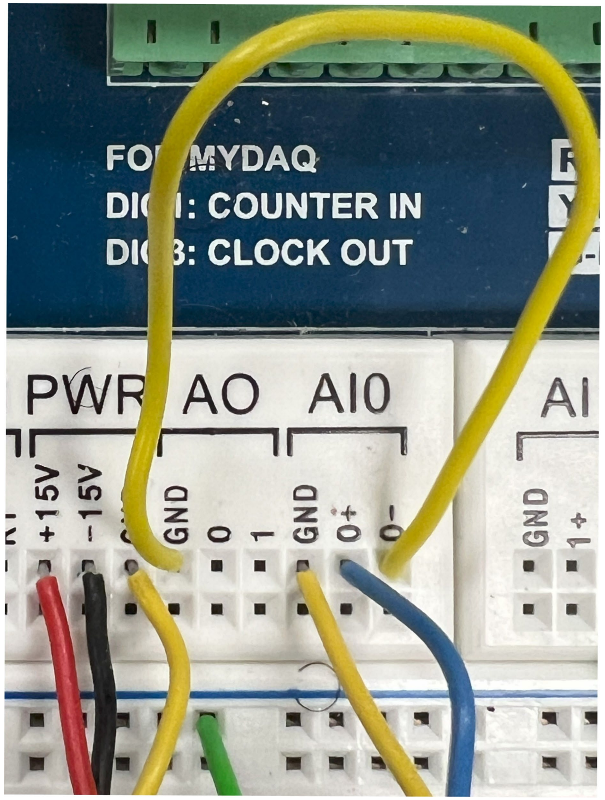


Measurement I/O -> DAQmx Data Acquisition -> DAQmx Create Channel.vi

Measurement I/O -> DAQmx Data Acquisition -> DAQmx Read.vi

Common Setup



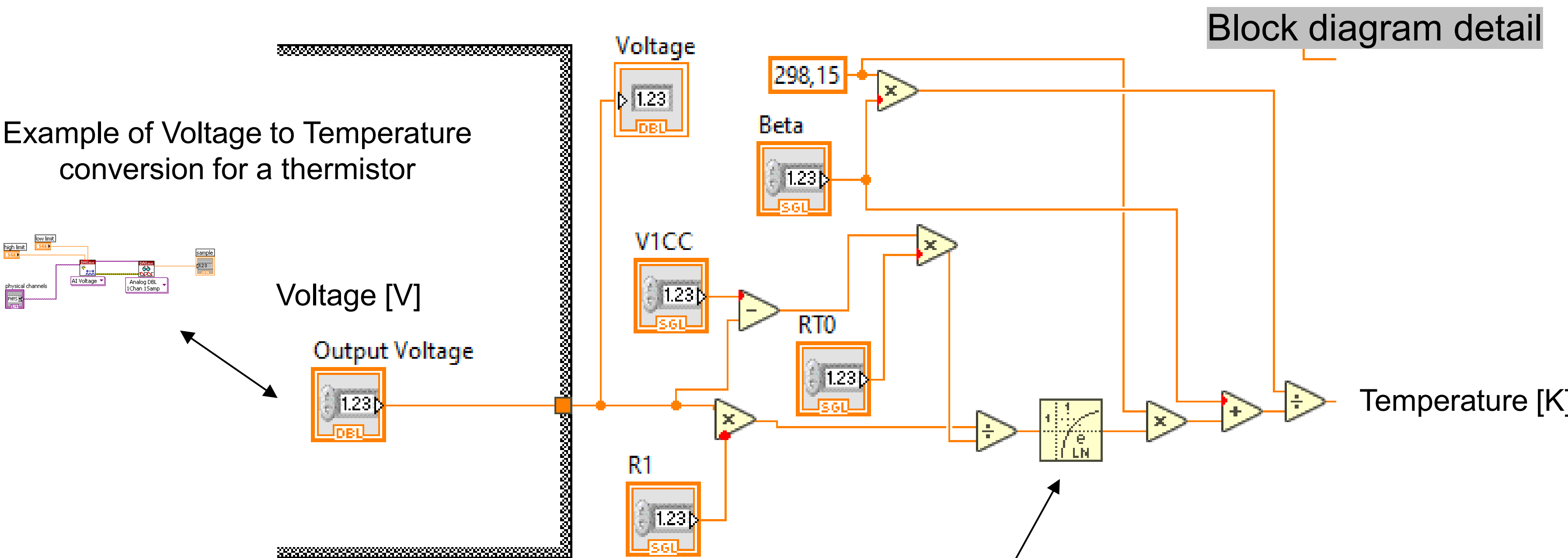


Temperature Calculation (Thermistor-Select True)

Launch: Thermistor_and_Pt1000_2025.vi

- 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

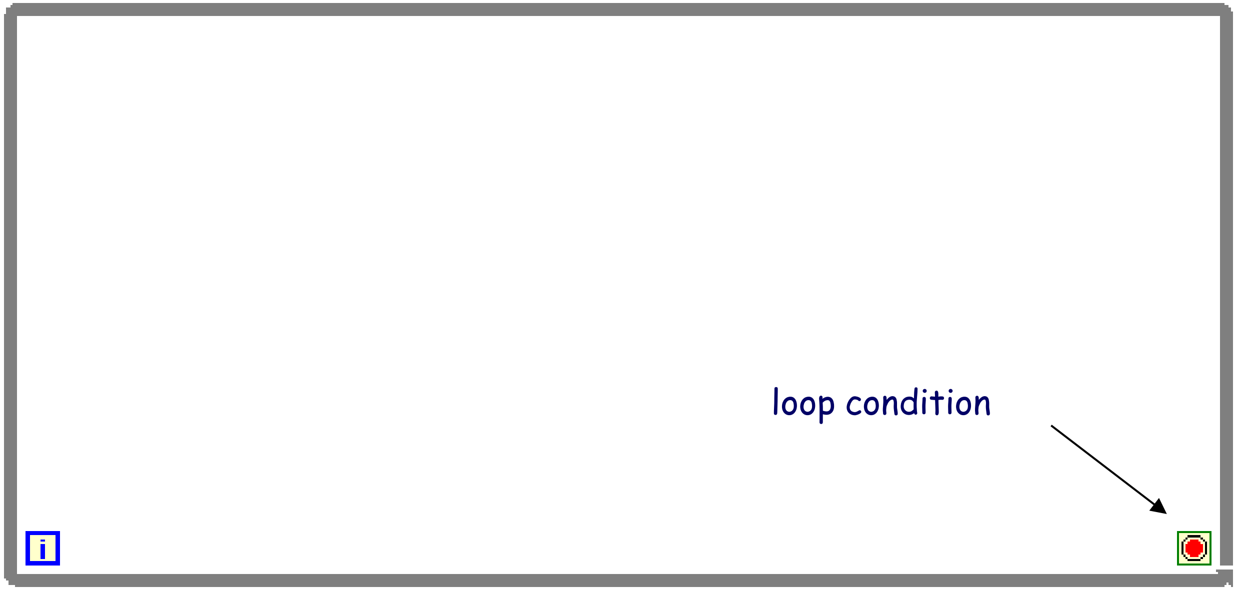
Example of Voltage to Temperature conversion for a thermistor



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

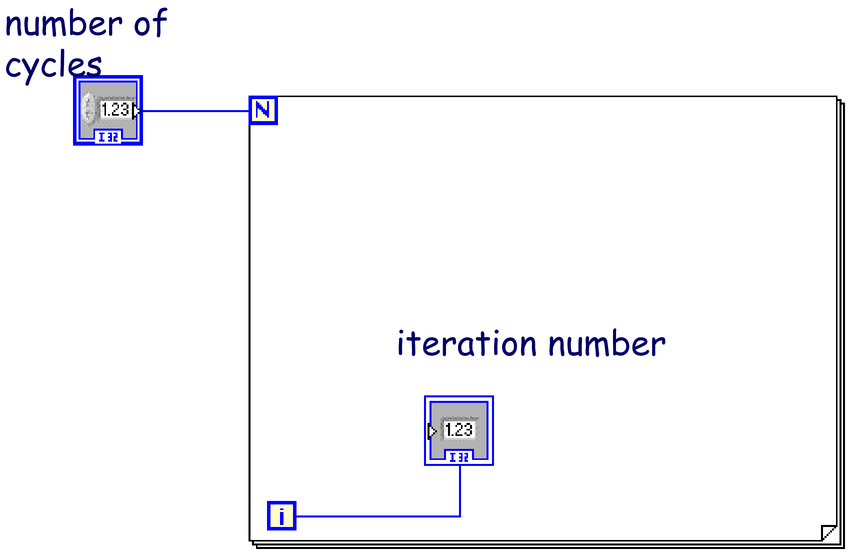
While Loop

- 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



For Cycle (for averaging)

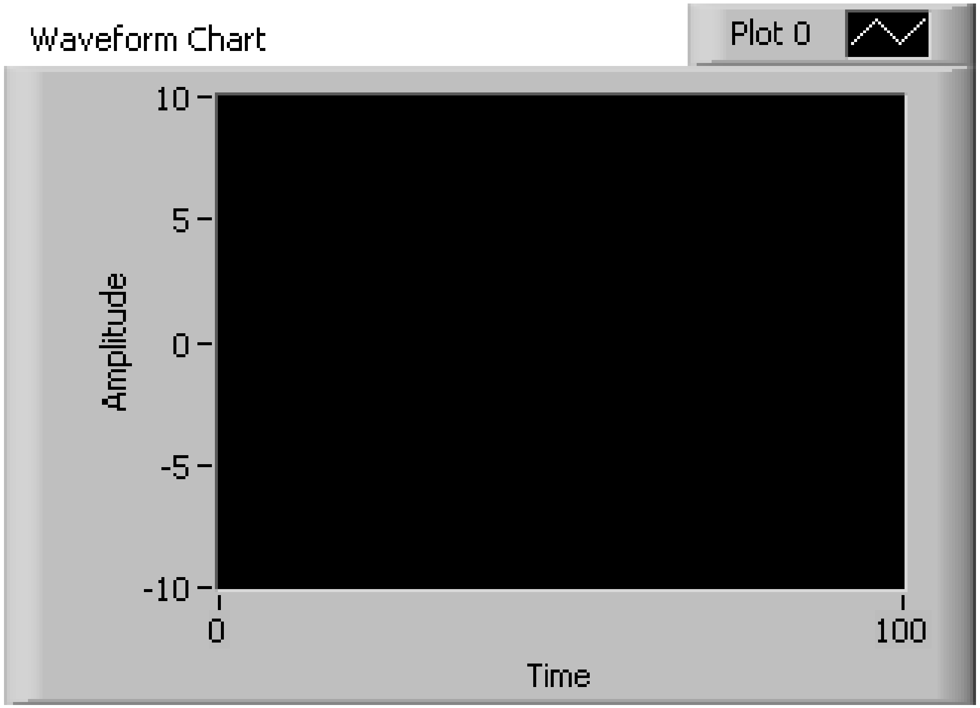
- Needed to reduce the disturbances by means of averaging and improve the measurement accuracy



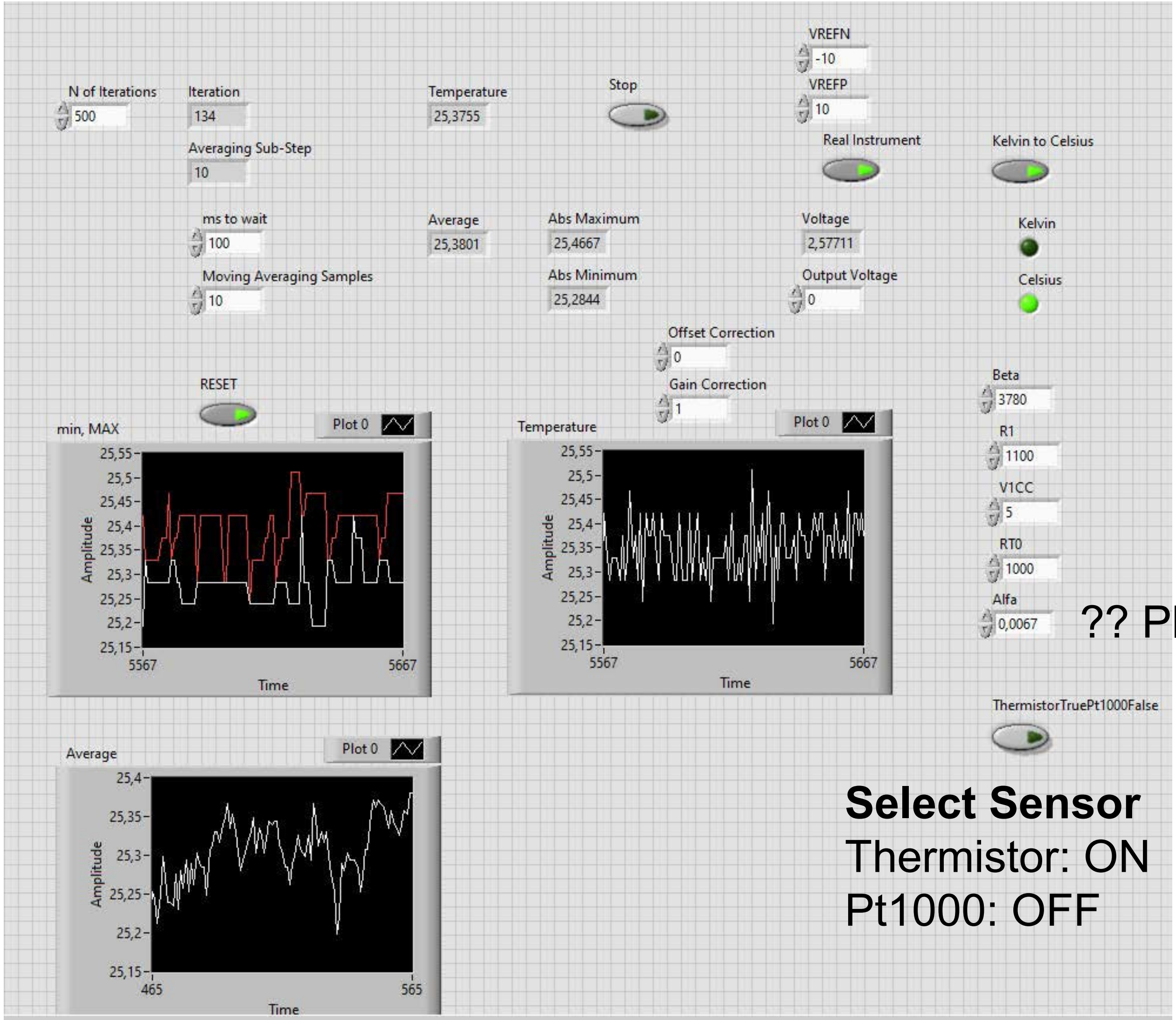
- Instead of representing (in the graph or in the numeric indicator) each individual acquired sample of the signal, we can represent the average value of every N samples: the speed at which the measurement result is represented on the graph will decrease by a factor of N

Waveform Chart

- You'll see also 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



Real Common Panel



?? Play with α

Select Sensor
Thermistor: ON
Pt1000: OFF

R-T Characteristic for the Pt1000

Pure Platinum: $\alpha = 3.85\ mK^{-1}$

Pt1000 resistance at temperature T [° C]

Temperature coefficient (quite constant between 0 ° C and 100 ° C)

$$R(T) = R_0\,(1 + \alpha \cdot (T - T_0))$$

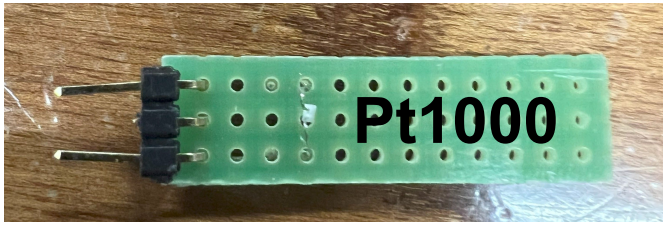
$$T = \frac{R(T) - R_0 + \cancel{\alpha R_0 T_0}}{\alpha R_0}$$

Pt1000 resistance at the reference temperature T_0=0° C

Calculation can be simplified, in Celsius Since T_0=0°C

In CELSIUS !

For Kelvin, just operate conversion adding 273.15 K



T-VOUT Relationship (Pt1000)

- Measured voltage as a function of the thermistor resistance (unchanged)

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

- Relationship between temperature and measured voltage

$$T[°C] = \frac{V_0 R_1 - R_0 V1CC + R_0 V_0}{\alpha R_0 (V1CC - V_0)}$$

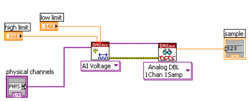
What about real α ? Set Gain to 1 and Offset to 0 and play with α

Find an α value that matches the digital thermometer in the room

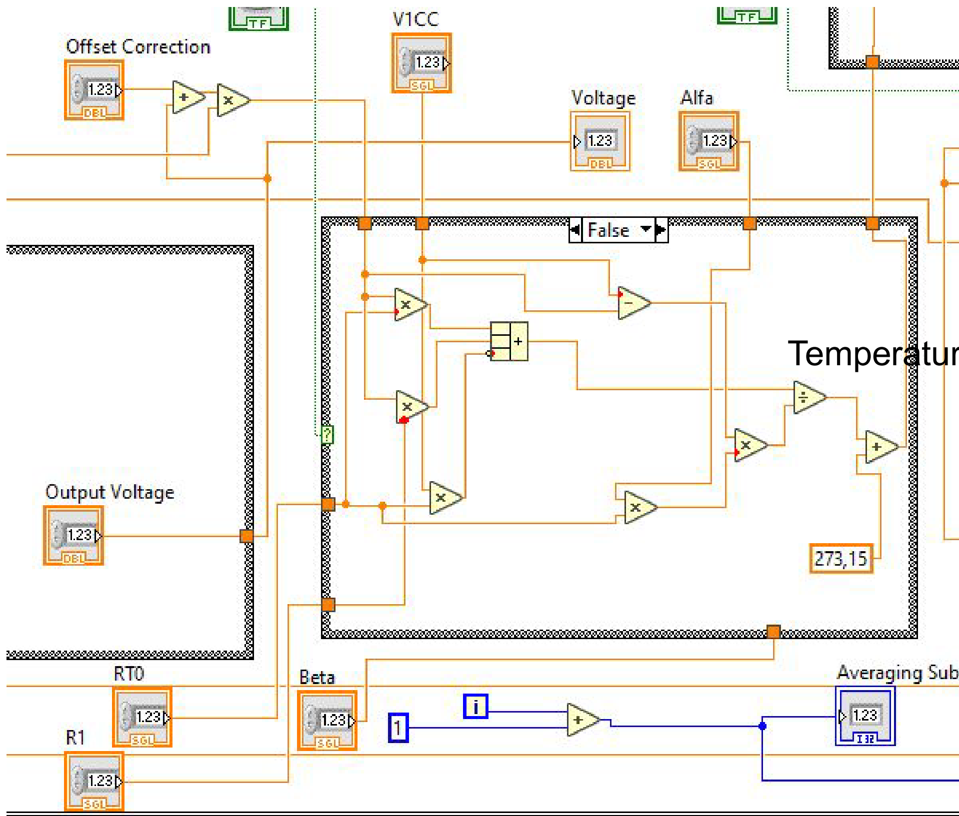
Temperature Calculation (Pt1000-Select False)

- 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

Example of Voltage to Temperature conversion for a Pt1000



Voltage [V]



Temperature [°C]

Temperature [K]