WORCESTER POLYTECHNIC INSTITUTE

MECHANICAL ENGINEERING DEPARTMENT

Engineering Experimentation
ME-3901, D'2012

Laboratory #5

26 April 2012

General information

Office hours

Instructors: **Cosme Furlong**

Office: HL-151

Everyday:

9:00 to 9:50 am

Christopher Scarpino

Office: HL-153

During laboratory sessions

Teaching Assistants: During laboratory sessions

General information

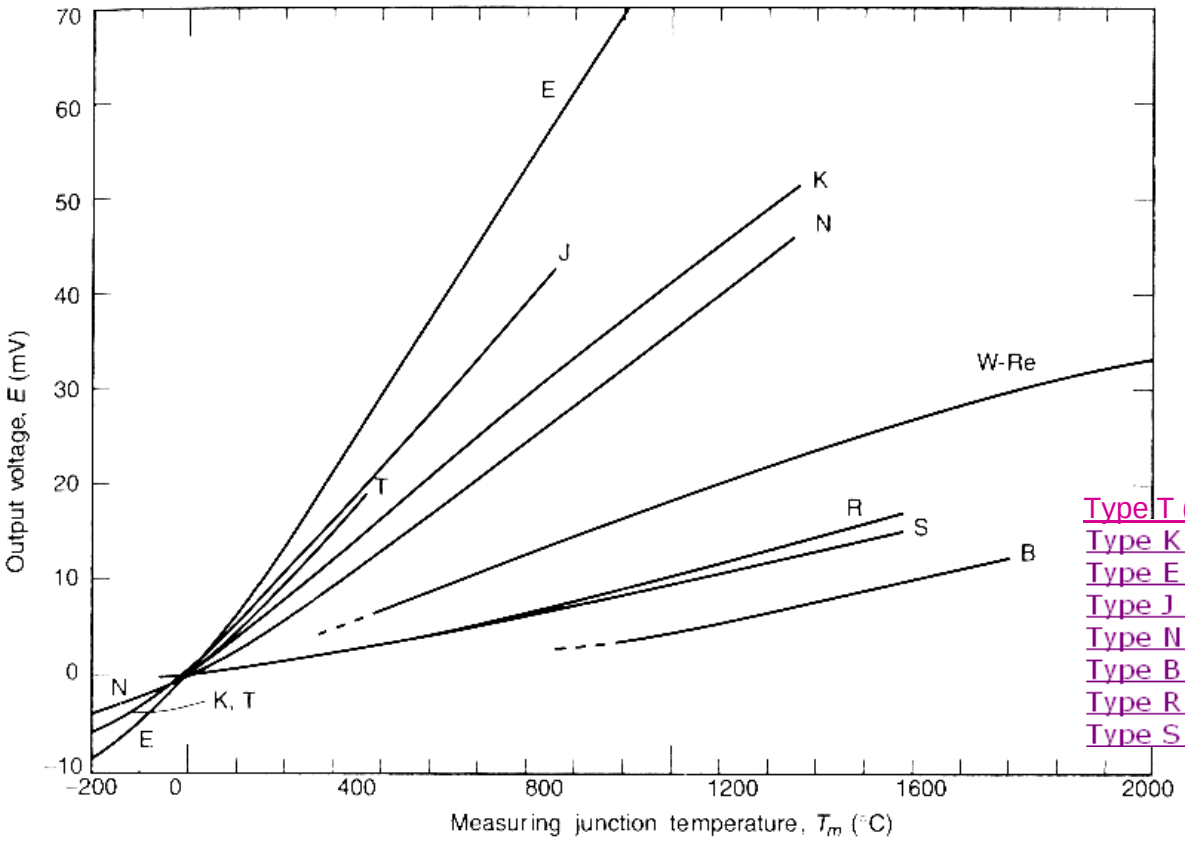
"Laboratory 5: Thermocouple Calibration"

Objectives:

- Perform calibration of a thermocouple
- Record temperature-time data
- Evaluate response time of a thermocouple (time-constant)

Thermoelectricity (thermocouples)

Thermocouple voltage versus temperature for reference junctions at 0 °C



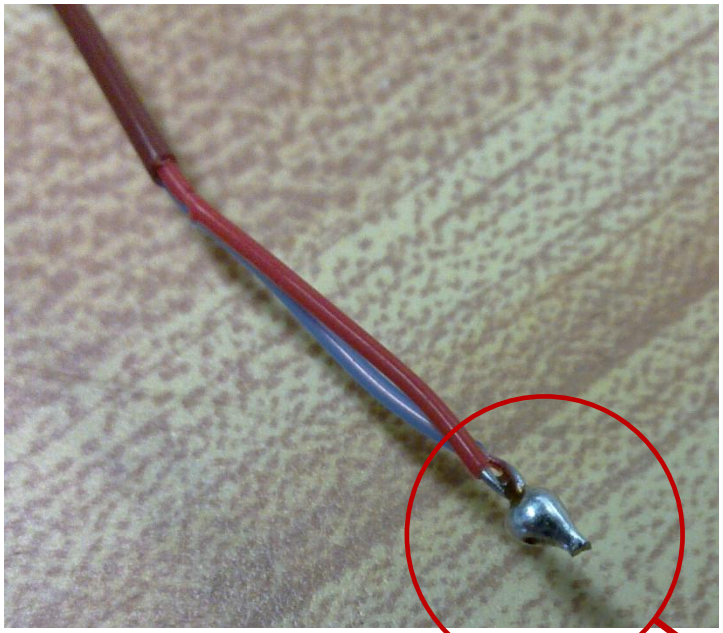
Type T (Copper / Constantan)
Type K (Chromel / Alumel)
Type E (Chromel / Constantan)
Type J (Iron / Constantan)
Type N (Nicrosil / Nisil)
Type B (Platinum / Rhodium)
Type R (Platinum / Rhodium)
Type S (Platinum / Rhodium)

We'll be using a type T thermocouple, which should not be used above 350° C since copper will oxidize rapidly above this limit.

Constantan is an alloy of copper and nickel with a typical composition Cu57Ni43 plus the addition of small percentages of Mn and Fe.

Use the provided thermocouple wire to solder a thermocouple

Make sure the wires are securely connected to the alligator clips of the NI USB-6229

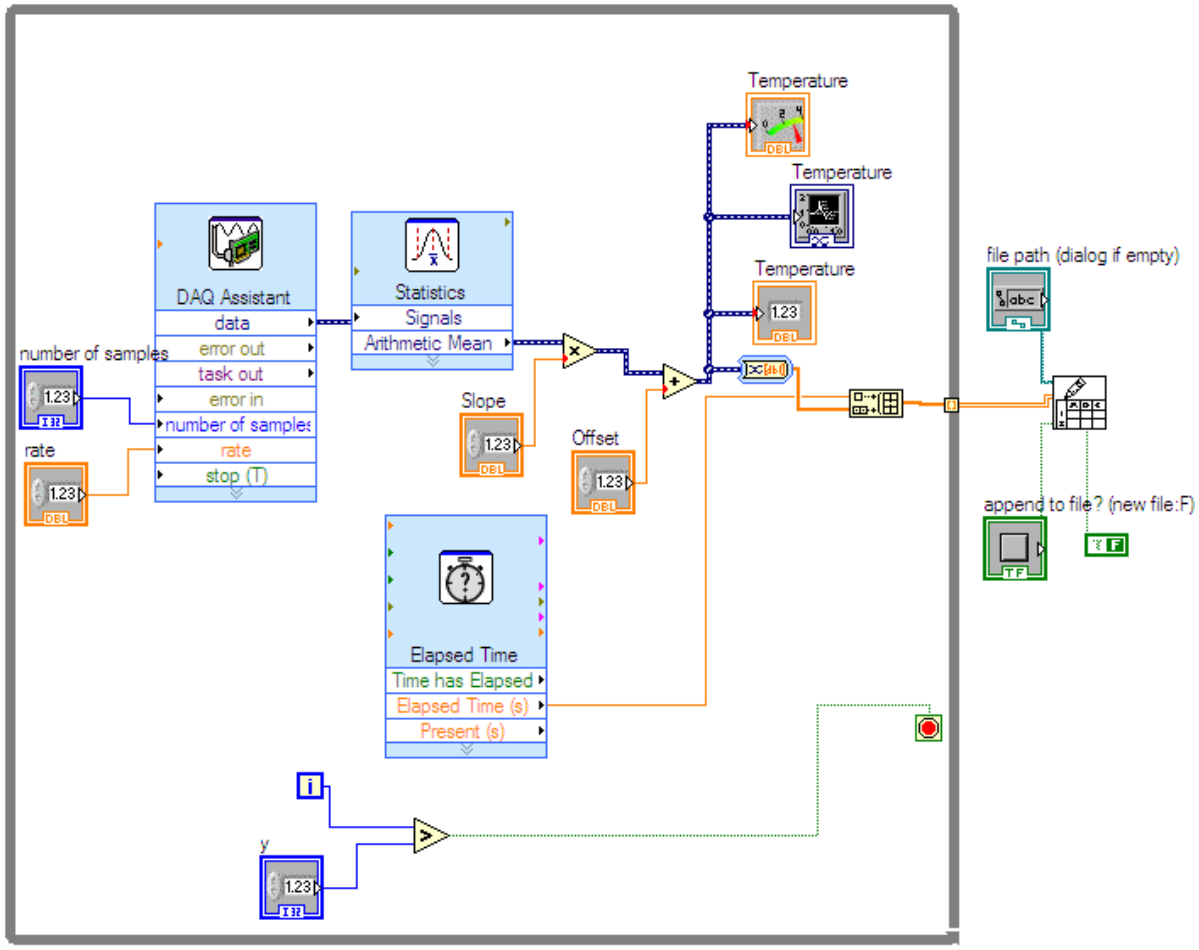


$$\left.\begin{array}{c} \dfrac{dE}{dt} \\ m,\ c_v,\ T(t) \end{array}\right\} \quad \tau = \frac{m\,c_v}{h\,A_s}$$

time-constant of the thermocouple

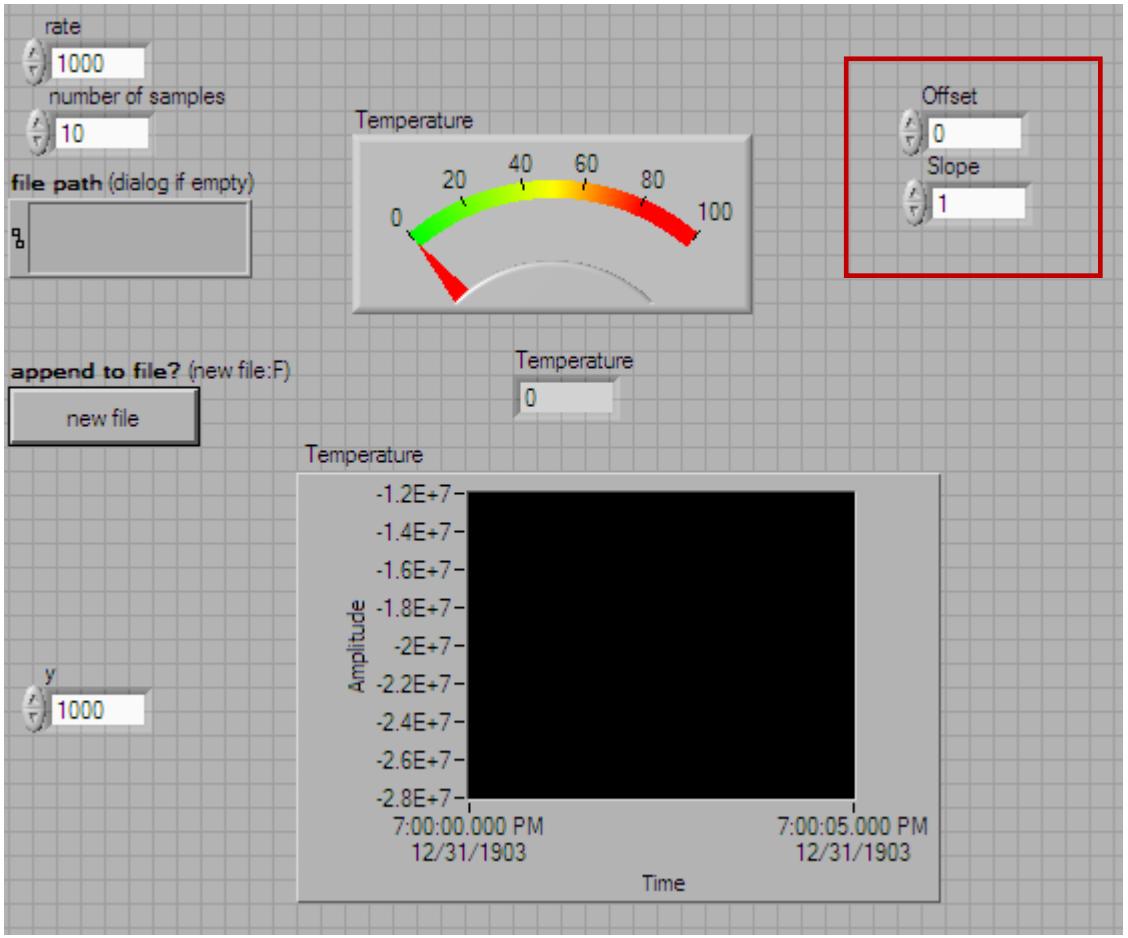
Download and modify the provided VI to read temperature

(Suggested Block diagram)



Download and modify the provided VI to read temperature

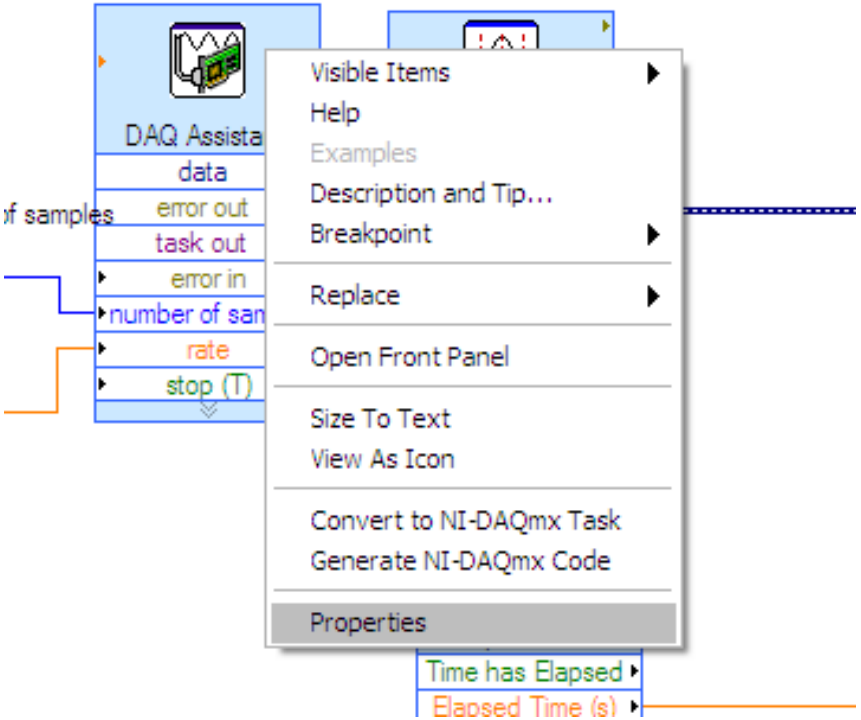
(Suggested **Block diagram**)



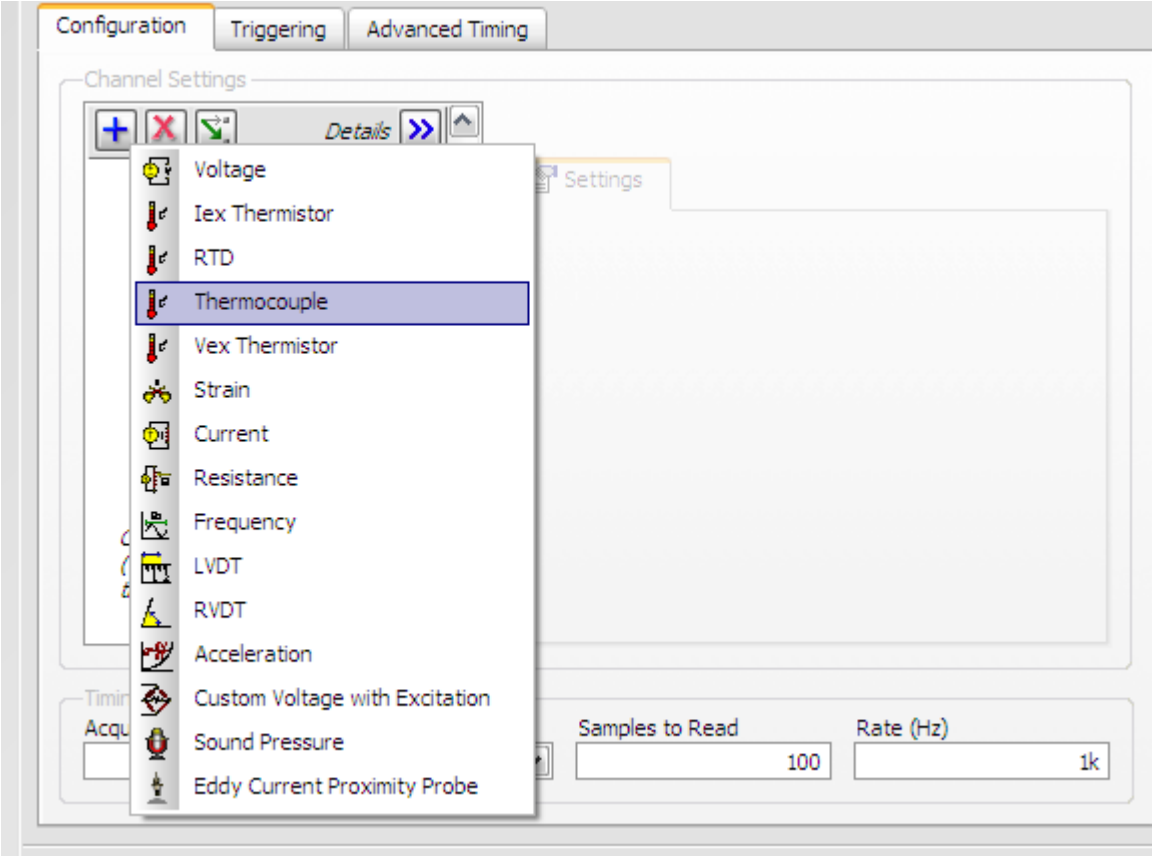
Use equation of a line.

For calibration: set slope to 1 and offset to zero

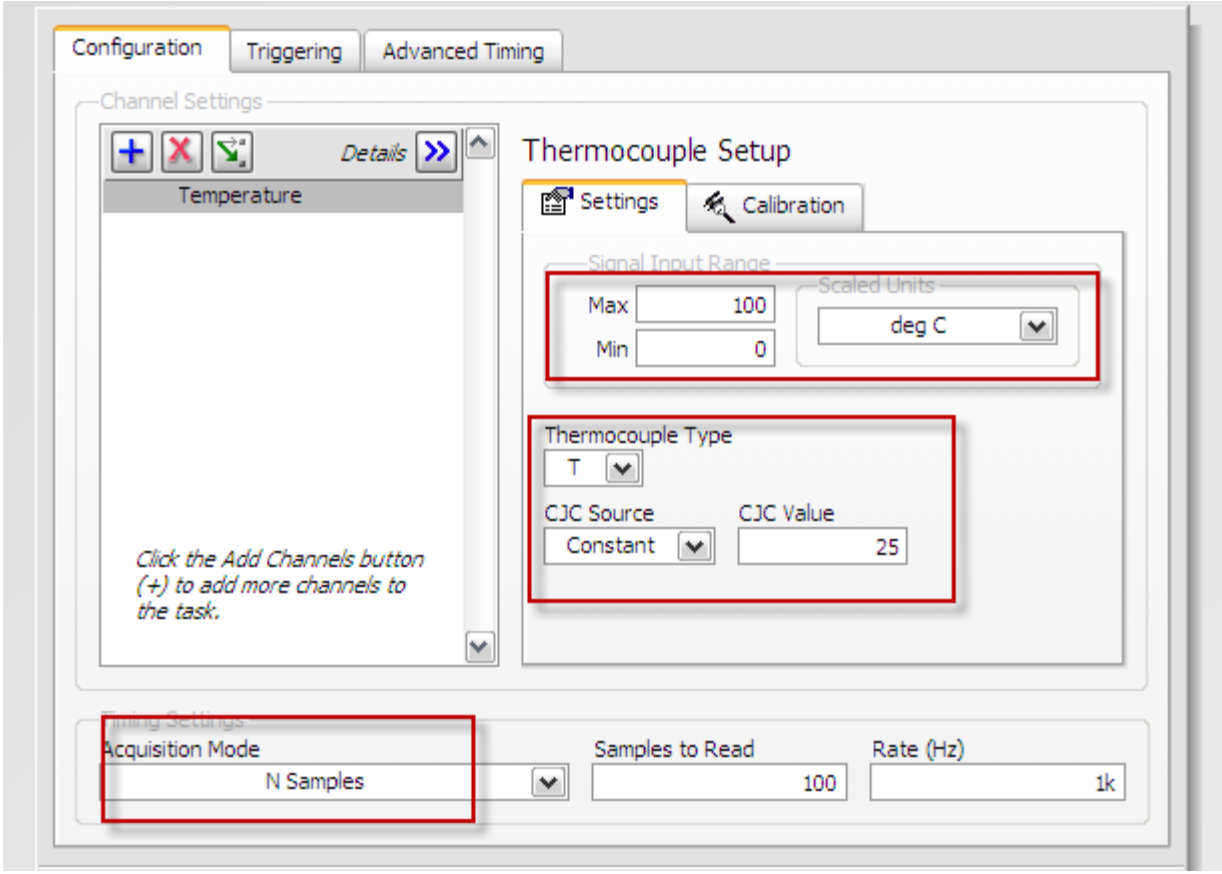
Configure your Thermocouple Channel through DAQ Assistant



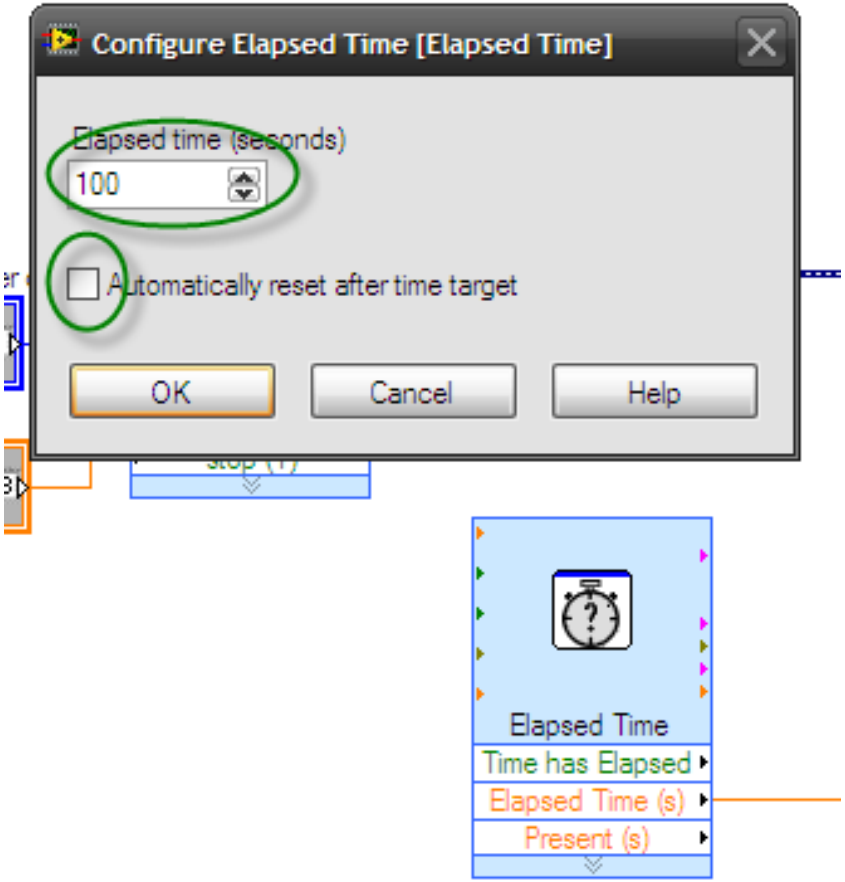
Configure your Thermocouple Channel through DAQ Assistant



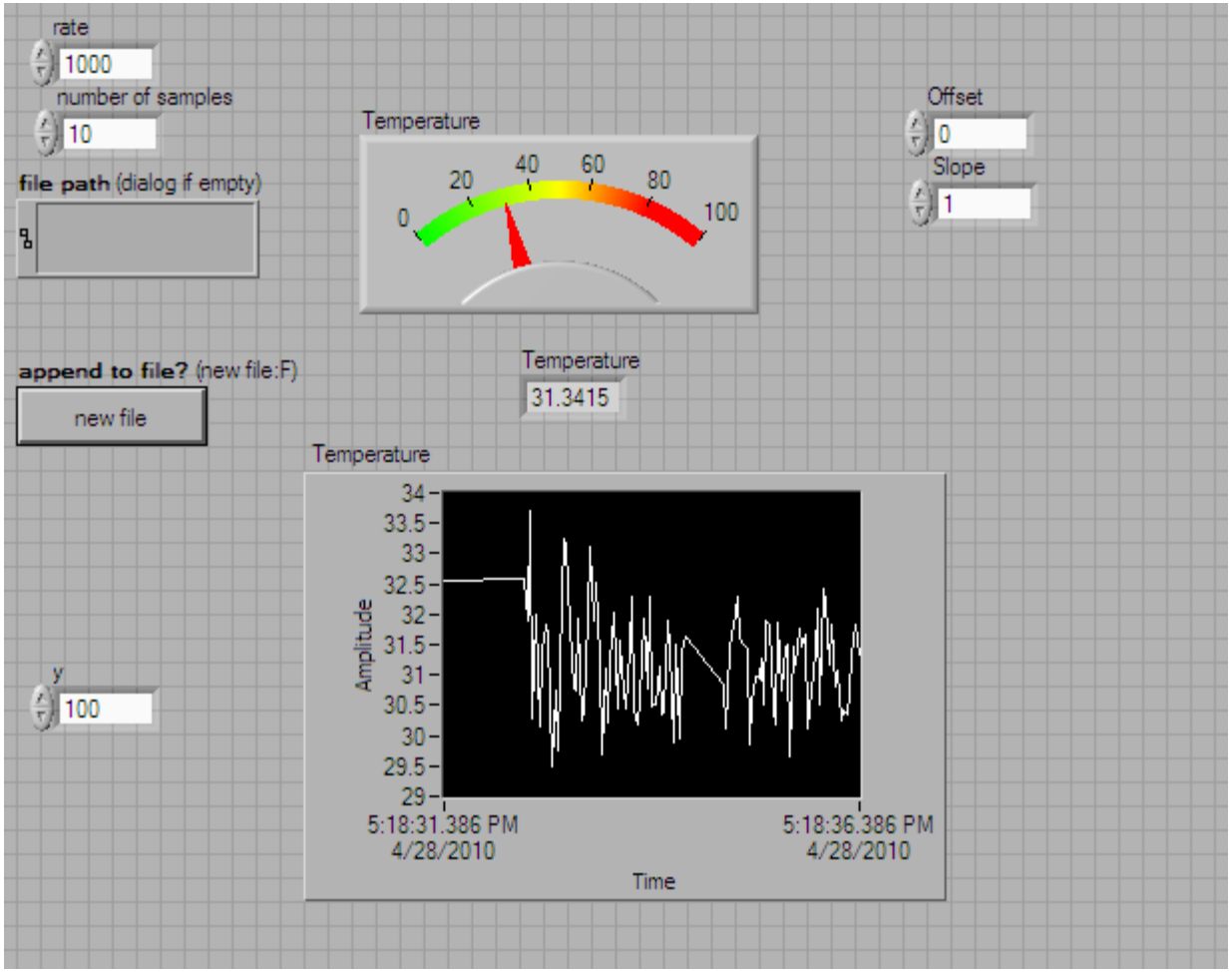
Make sure you have connected a **type-T** thermocouple to the NI USB-6229(channel 0 in this example)



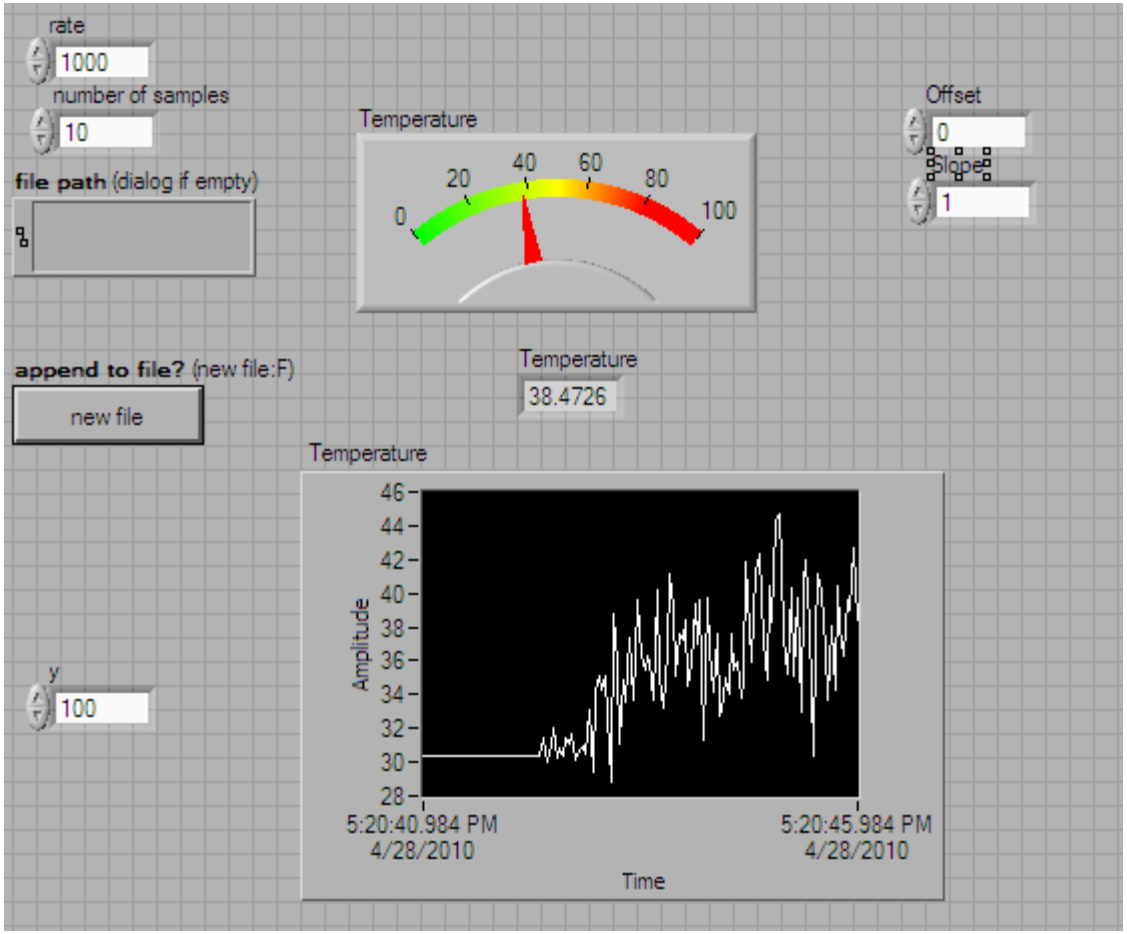
Make sure you configure the timer so that it records the time properly without resetting



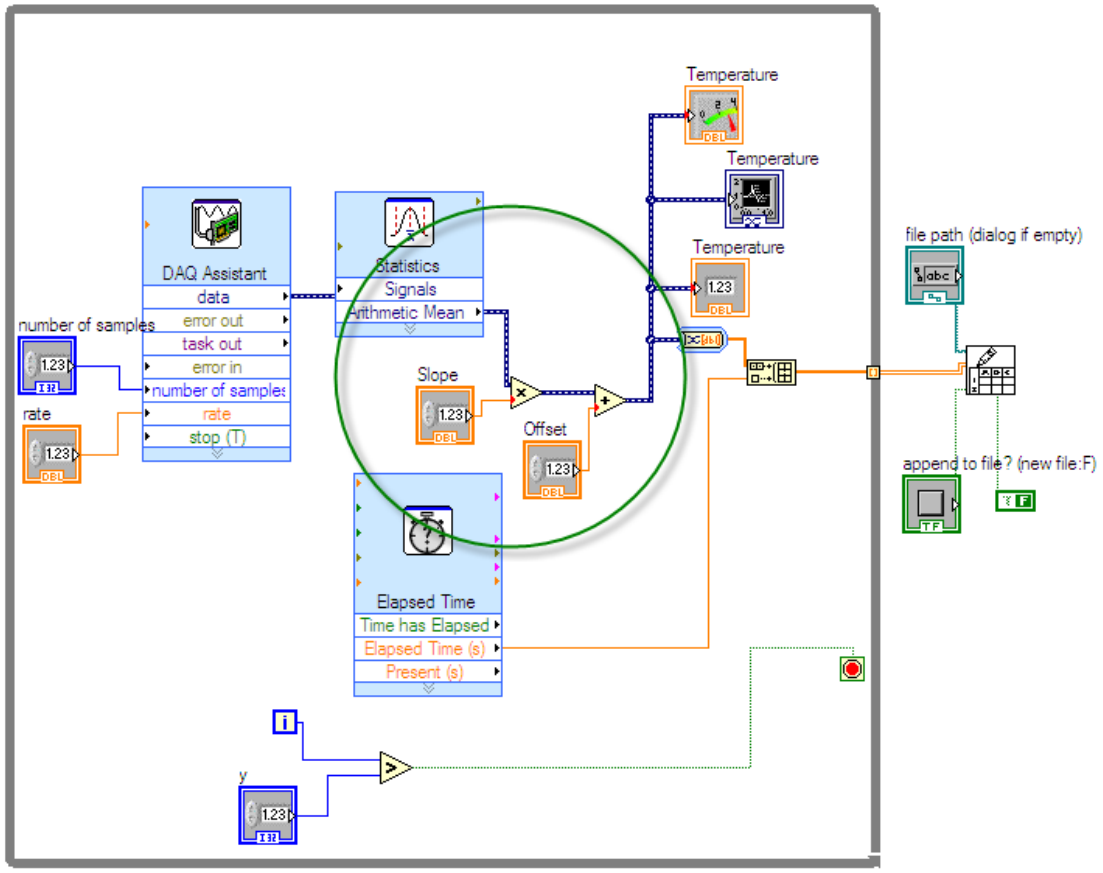
Proceed to calibrate thermocouple with respect to a thermometer: "hot" and "cold" baths



Calibrate by subjecting the thermocouple to two known temperatures: "hot" and "cold" baths

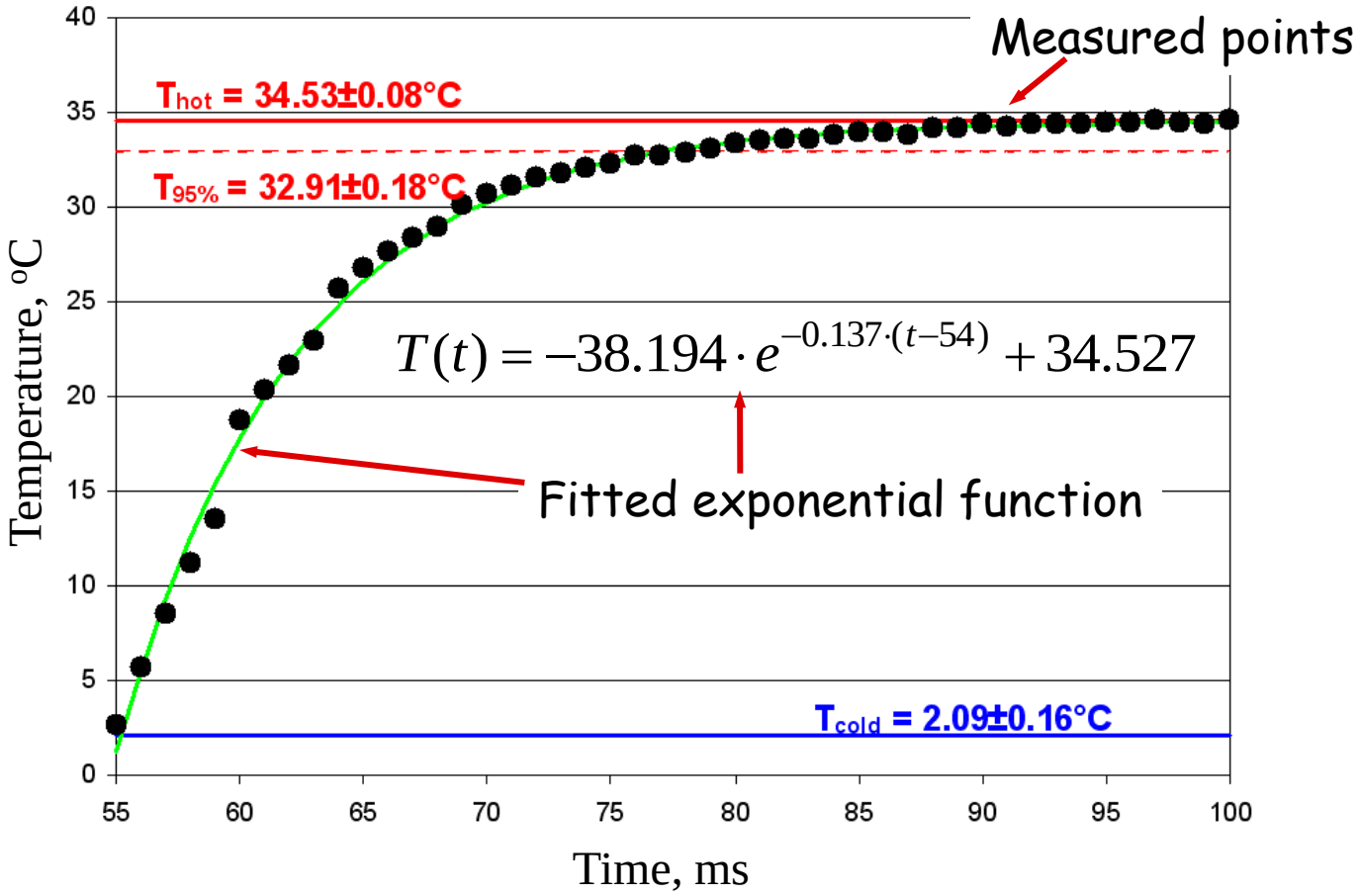


Once you have two calibration readings calculate the slope and the offset for linear approximation calibration and modify the VI to use the calibration constants



Time Constant

Definition:
One time-constant is the time for a system to reach 63.2% of the nominal differential value/state (see lecture notes)



Procedure to Calculate the Time-constant (1)

(e.g., time for a system to reach 95% the nominal value)

- Increase sampling rate to 1000 Hz (also adjust the recorded number of samples to record long enough time)
- Insert the thermocouple in the cold junction. After stabilization, mean of a few points (≈100) of the cold water bath is referred to as $T_{cold.}$
- Move the thermocouple junction from the cold to the hot junction while taking measurements. Continue measuring till the variations between nearby values is lesser than the resolution of the system.
- After stabilization, mean of a few points (≈100) of the hot water bath is referred to as $T_{hot.}$

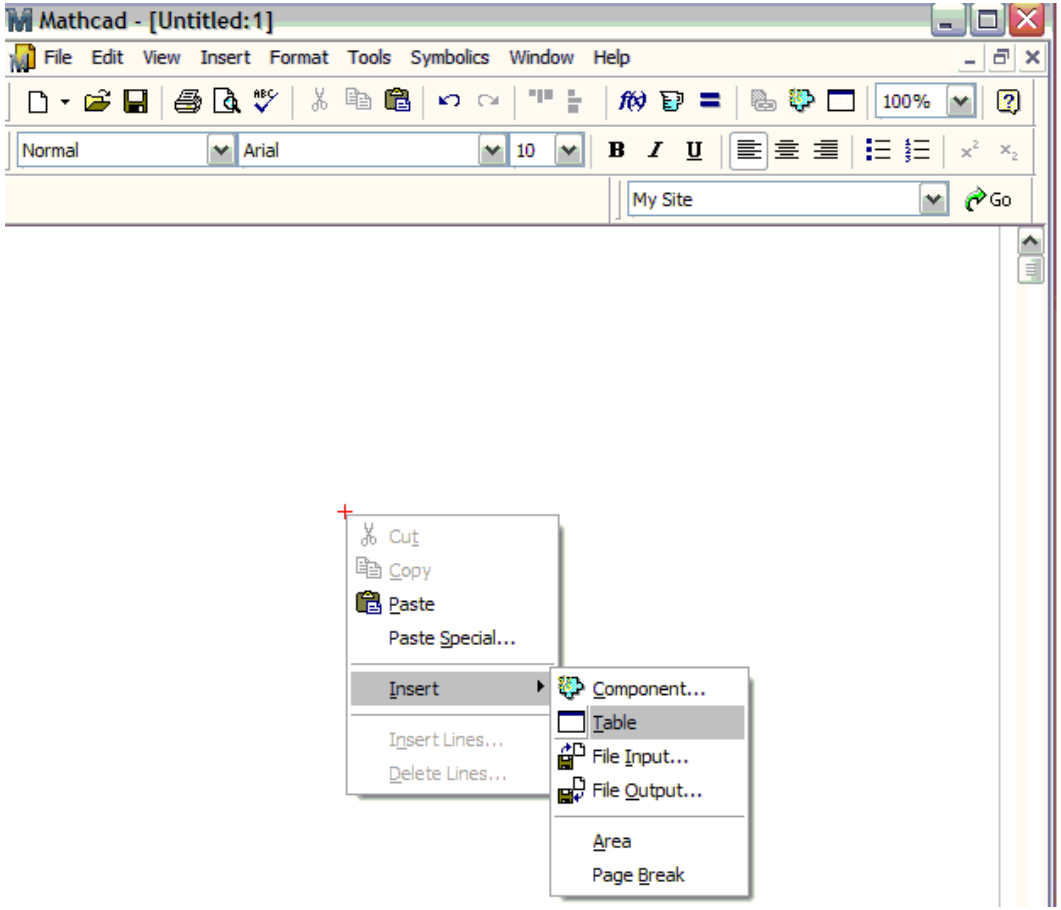
Procedure to Calculate the Time-constant (2)

(e.g., time for a system to reach 95% the nominal value)

- 95% of the transition is calculated as:
- $T_{95\%} = T_{cold} + 0.95(T_{hot} - T_{cold})$; compute also $T_{63.2\%}$ (corresponding to one time constant)
- In Mathcad:
  - import the two columns time(t) and temperature(T).
  - Use function expfit() to fit an exponential curve between t and T with guess values, e.g., A, b and C = 34.0,-3.0 and 2.0 respectively.
  - Calculate the values of temperature(T_calc) for each time instant and plot both the curves to verify.
- The Mathcad file has been included for your reference

Procedure to Calculate the Time-constant (3)

How to create a table in Mathcad



Select a cell and right-click to import data from your excel file for the variables time(t) and temperature(T)

Suggested procedure to calculate the time-constant (4)

Mathcad screenshot

This is the mathematical model fitted to the experimentally measured data

Vector containing initial "guess" values may need to be modified (in this case, 34, -3, 2.09 as shown)

Vector containing "fitted" coefficients

data :=

	0	1
0	1	1.223
1	2	5.487
2	3	9.205
3	4	12.447
4	5	15.274
5	6	17.739
6	7	19.888
7	8	21.762
8	9	23.397
9	10	...

$t := data^{\langle 0 \rangle}$

$T := data^{\langle 1 \rangle}$

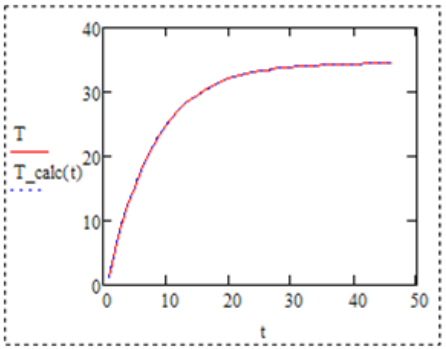
$\begin{pmatrix} A \\ b \\ C \end{pmatrix} := expfit\left(t, T, \begin{pmatrix} 34 \\ -3 \\ 2.09 \end{pmatrix}\right)$

$\begin{pmatrix} A \\ b \\ C \end{pmatrix} = \begin{pmatrix} -38.194 \\ -0.137 \\ 34.527 \end{pmatrix}$

$T\_calc(t) := A \cdot \exp(b \cdot t) + C$

$T\_calc(t) =$

	0
0	1.223
1	5.487
2	9.205
3	12.447
4	15.274
5	17.739
6	19.888
7	21.762
8	...



Procedure to Calculate the Time-constant (5)

Time response computations:

(1) Determine the time-constant, t_τ , of the thermocouple with

$$T(t_\tau + t_0) = T_{63.2\%}$$

(Use exponential response function and solve for t_τ)

(2) Also determine t_R , which corresponds to $T_{95\%}$ as

$$T\left(t_R + t_0\right) = T_{95\%}$$

Your results must include:

- Calibration function, e.g., $T_{true} = 1.0148 \cdot T_{uncalibrated} - 0.1406°C$
- Temperature data, e.g., $T_{cold} \pm \Delta T_{cold}, T_{hot} \pm \Delta T_{hot}$, etc
- Evaluated time-constant t_τ and also t_R (include measured uncertainties)

Your lab reports are due on Tuesday, April 30th