WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

Engineering Experimentation
ME-3901, D'2012

Laboratory #3: Part 1

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

Please refer to handout:

"Laboratory 3: Strain and Pressure Measurement"

Objectives

The objectives of this laboratory are to:

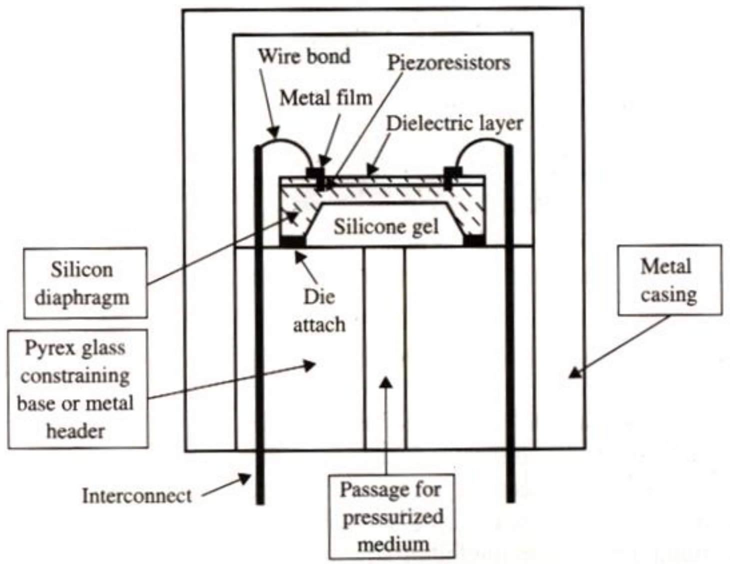
- Perform characterization of internal pressure in a thin-walled tank by measurements of mechanical strains;
- Perform uncertainty analysis of characterized internal pressures with respect to parameters involved;
- Identify, in order of importance, percentage contribution of all uncertainties to the overall uncertainty in pressure characterizations;

Background

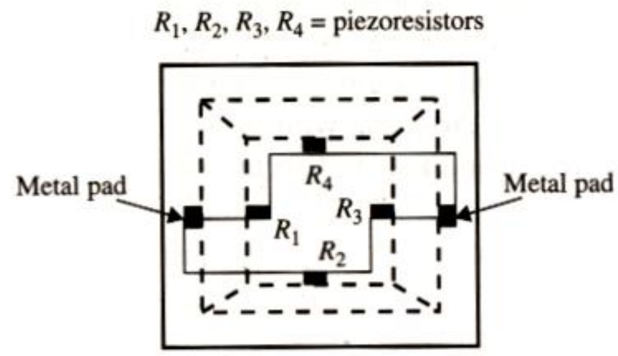
Review Hoop (tangential) and Longitudinal stresses
in
Thin-walled cylinders

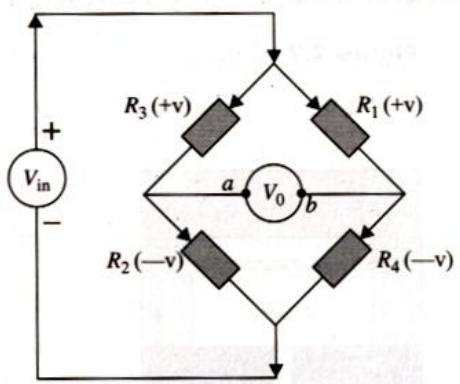
Pressure transducer: Silicon diaphragm with *Bridges*

Cross section of an electronic package



Top view of silicon die





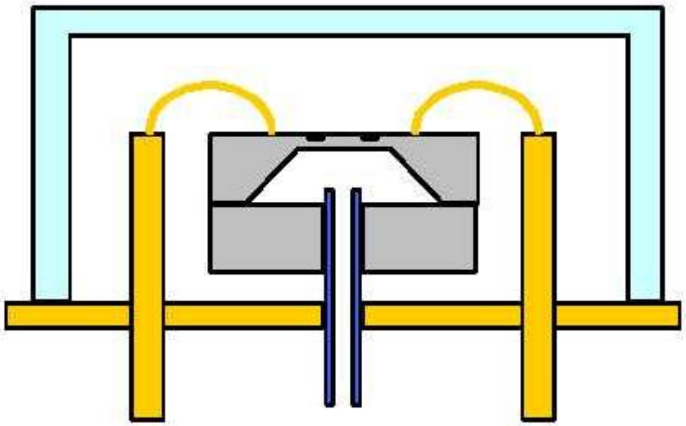
Circuit

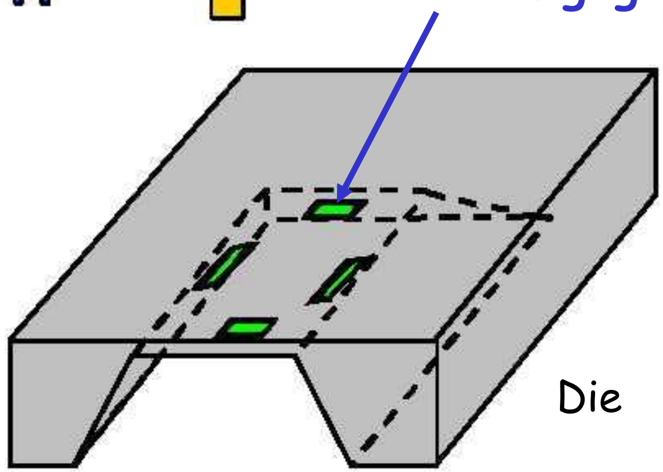
Wheatstone bridge:

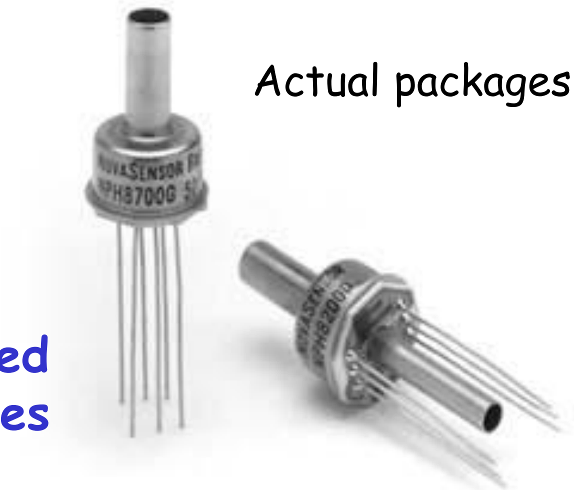
$$V_o = V_{in}\left(\frac{R_1}{R_1 + R_4} - \frac{R_2}{R_2 + R_3}\right)$$

Pressure transducer: Silicon diaphragm. Resistive sensor

Schematic

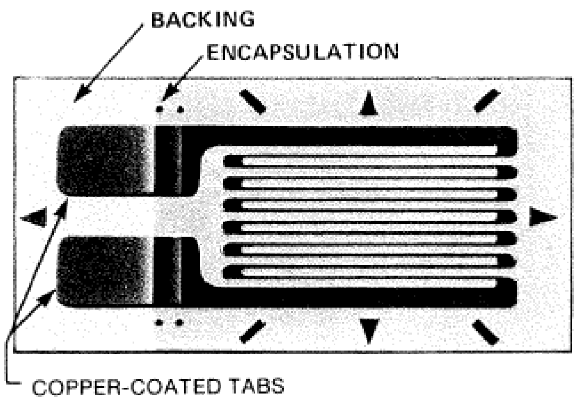


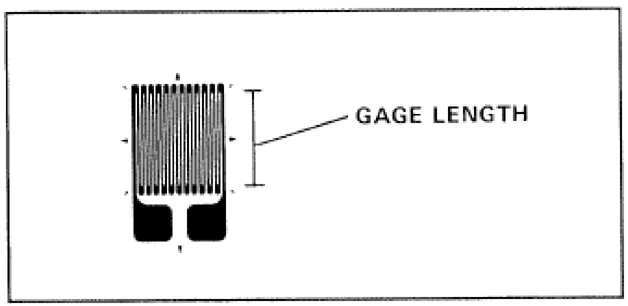


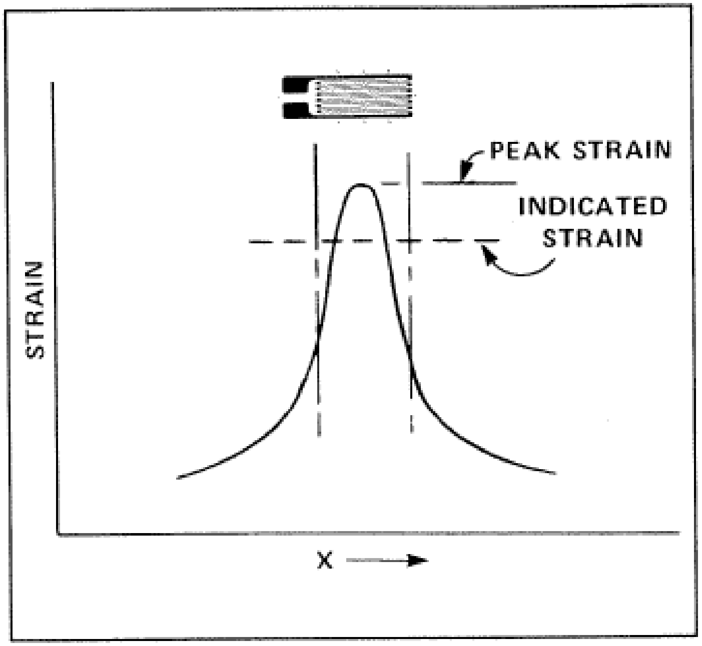


http://www.novasensor.com

Hardware. Strain gages (typical: 0.001" thick)







$$\text{Gage factor} = F = \frac{dR/R}{\varepsilon_x}$$

$$\text{Resistance} = R = \rho \frac{L}{A}$$

resistivity

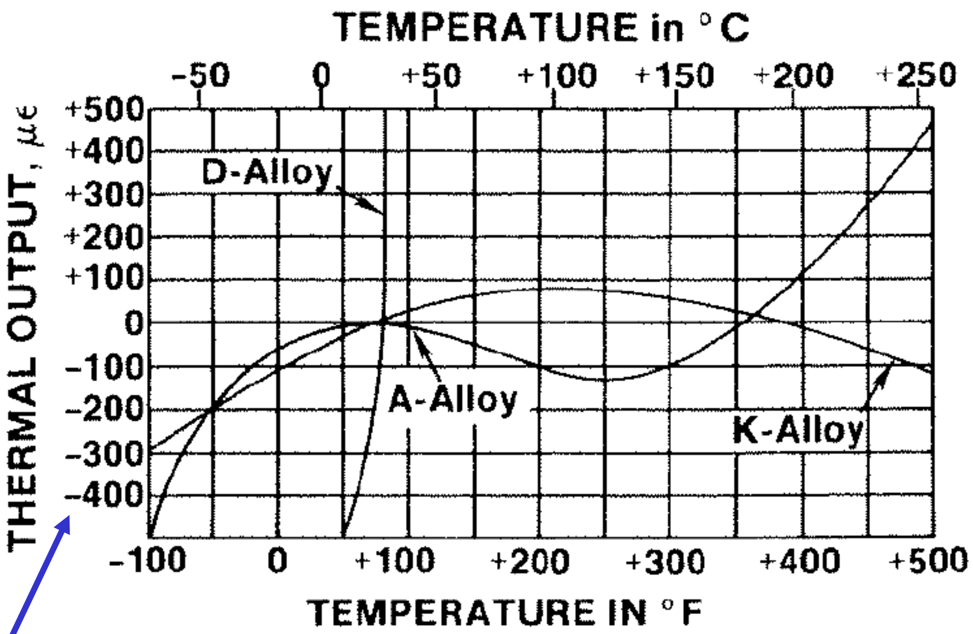
$$\varepsilon_x = \frac{1}{F}\frac{\Delta R}{R}$$

To be measured (use a bridge circuit)

Hardware. Strain gage: temperature effects

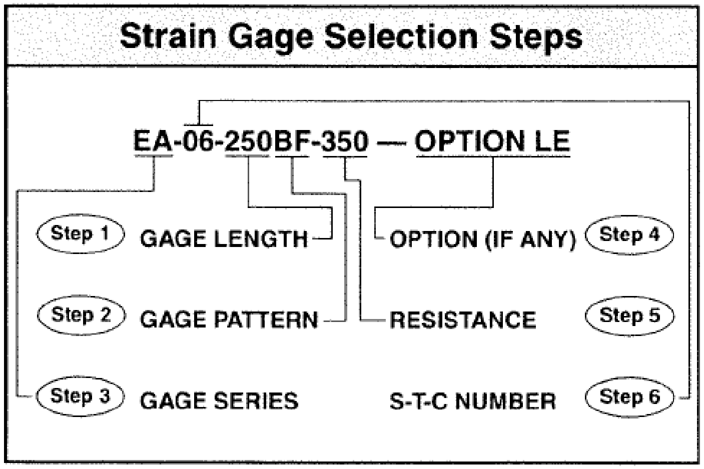
Recall Lab #1: resistance as a function of temperature. **Open for discussions**

Note units



Note signs

Hardware. Strain gage selection



CONSIDERATIONS FOR PARAMETER SELECTION

Selection Step: **1**
Parameter: **Gage Length**

- ☐ strain gradients
- ☐ area of maximum strain
- ☐ accuracy required
- ☐ static strain stability
- ☐ maximum elongation
- ☐ cyclic endurance
- ☐ heat dissipation
- ☐ space for installation
- ☐ ease of installation

Selection Step: **2**
Parameter: **Gage Pattern**

- ☐ strain gradients (in-plane and normal to surface)
- ☐ biaxiality of stress
- ☐ heat dissipation
- ☐ space for installation
- ☐ ease of installation
- ☐ gage resistance availability

Selection Step: **3**
Parameter: **Gage Series**

- ☐ type of strain measurement application (static, dynamic, post-yield, etc.)
- ☐ operating temperature
- ☐ test duration
- ☐ cyclic endurance
- ☐ accuracy required
- ☐ ease of installation

Selection Step: **4**
Parameter: **Options**

- ☐ type of measurement (static, dynamic, post-yield, etc.)
- ☐ installation environment — laboratory or field
- ☐ stability requirements
- ☐ soldering sensitivity of substrate (plastic, bone, etc.)
- ☐ space available for installation
- ☐ installation time constraints

Selection Step: **5**
Parameter: **Gage Resistance**

- ☐ heat dissipation
- ☐ leadwire desensitization
- ☐ signal-to-noise ratio

Selection Step: **6**
Parameter: **S-T-C Number**

- ☐ test specimen material
- ☐ operating temperature range
- ☐ accuracy required

Hardware. Strain gage selection

E A - 0 6 - 2 5 0 B G - 1 2 0 Option E

- **E** — Carrier Matrix (Backing)
- **A** — Foil Alloy
- **06** — Self-Temperature-Compensation
- **250** — Active Gage Length in Mils [0.001 in *(0.0254 mm)*]
- **BG** — Grid and Tab Geometry
- **120** — Resistance in Ohms
- **Option E** — Optional Feature

Carrier Matrix (Backing):

- **E:** Open-faced cast polyimide backing.
- **W:** Fully encapsulated; glass-fiber-reinforced epoxy-phenolic resin. High-endurance leadwires.
- **CE:** Thin, flexible gages with a cast polyimide backing and encapsulation featuring large, rugged, copper-coated solder tabs. This construction provides optimum capability for direct leadwire attachment.

Foil Alloy:

- **A:** Constantan alloy in self-temperature-compensated form.
- **P:** Annealed constantan.
- **D:** Isoelastic alloy.
- **K:** Nickel-chromium alloy (similar to Karma).

Self-Temperature-Compensation:

The S-T-C number is the approximate thermal expansion coefficient in ppm/°F of the structural material on which the gage is to be used. The following standard compensations are available:

A and K alloy: 06, 13.
P alloy: 08

The D alloy is not available in self-temperature-compensated form. 'DY' is used instead.

Optional Feature:

- **W:** Integral printed circuit terminal, polyimide encapsulation.
- **E:** Polyimide encapsulation, leaving a portion of solder tab exposed.
- **SE:** Solder dots plus polyimide encapsulation.
- **L:** Preattached, soft, formable copper leads.
- **LE:** Leads plus polyimide encapsulation.

GAGE SERIES	DESCRIPTION AND PRIMARY APPLICATION	TEMPERATURE RANGE	STRAIN RANGE	FATIGUE LIFE: Strain Level in $\mu\epsilon$	FATIGUE LIFE: Number of Cycles
EA	General-purpose static and dynamic stress analysis. Wide range of options available.	Normal: –100° to +350°F *(–75° to +175°C)* Special or Short Term: –320° to +400°F *(–195° to +205°C)*	±3% for gage lengths under 1/8 in *(3.2 mm)* ±5% for 1/8 in & over	±1800 ±1500 ±1200	10^5 10^6 10^8
CEA	Universal general-purpose strain gages. Constantan grid completely encapsulated in polyimide, with large, rugged, copper-coated tabs. Primarily used for general-purpose static and dynamic stress analysis.	Normal: –100° to +350°F *(–75° to +175°C)* Stacked rosettes limited to +150°F *(+65°C)*	±3% for gage lengths under 1/8 in *(3.2 mm)* ±5% for 1/8 in & over	±1500 ±1500	10^5 10^{6*}
ED	Excellent for dynamic measurements. High gage factor and extended fatigue life.	Dynamic: –320° to +400°F *(–195° to +205°C)*	±2% Nonlinear at strain levels over ±0.5%	±2500 ±2200	10^6 10^7
WA	Stress analysis and transducer applications. Wide temperature range and extreme environmental capability. High-endurance leadwires.	Normal: –100° to +400°F *(–75° to +205°C)* Special or Short Term: –320° to +500°F *(–195° to +260°C)*	±2%	±2000 ±1800 ±1500	10^5 10^6 10^7
WK	Widest temperature range and most extreme environmental capability. High-endurance leadwires.	Normal: –452° to +550°F *(–269° to +290°C)* Special or Short Term: –452° to +750°F *(–269° to +400°C)*	±1.5%	±2200 ±2000	10^6 10^7
EP	High-elongation measurements (post yield). Only available in 08 S-T-C value.	–100° to +400°F *(–75° to +205°C)*	±10% for gage lengths under 1/8 in *(3.2 mm)* ±20% for 1/8 in & over	±1000 EP gages show zero shift under high-cyclic strains.	10^4
WD	For wide-range dynamic strain measurements in severe environments. High-endurance leadwires.	Dynamic: –320° to +500°F *(–195° to +260°C)*	±1.5% Nonlinear at strain levels over ±0.5%	±3000 ±2500 ±2200	10^5 10^7 10^8

Strain gage bridge: basic Wheatstone bridges

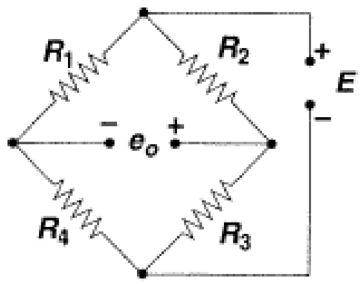


Fig. 1 — Basic Wheatstone Bridge Circuit.

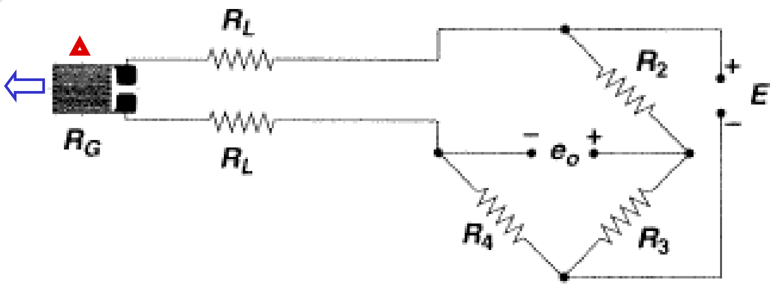


Fig. 2 — Two-wire quarter-bridge circuit.

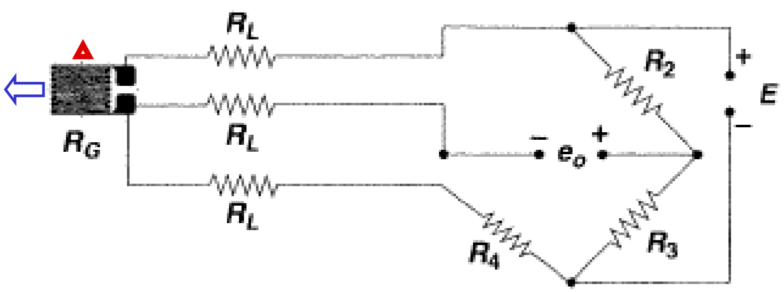
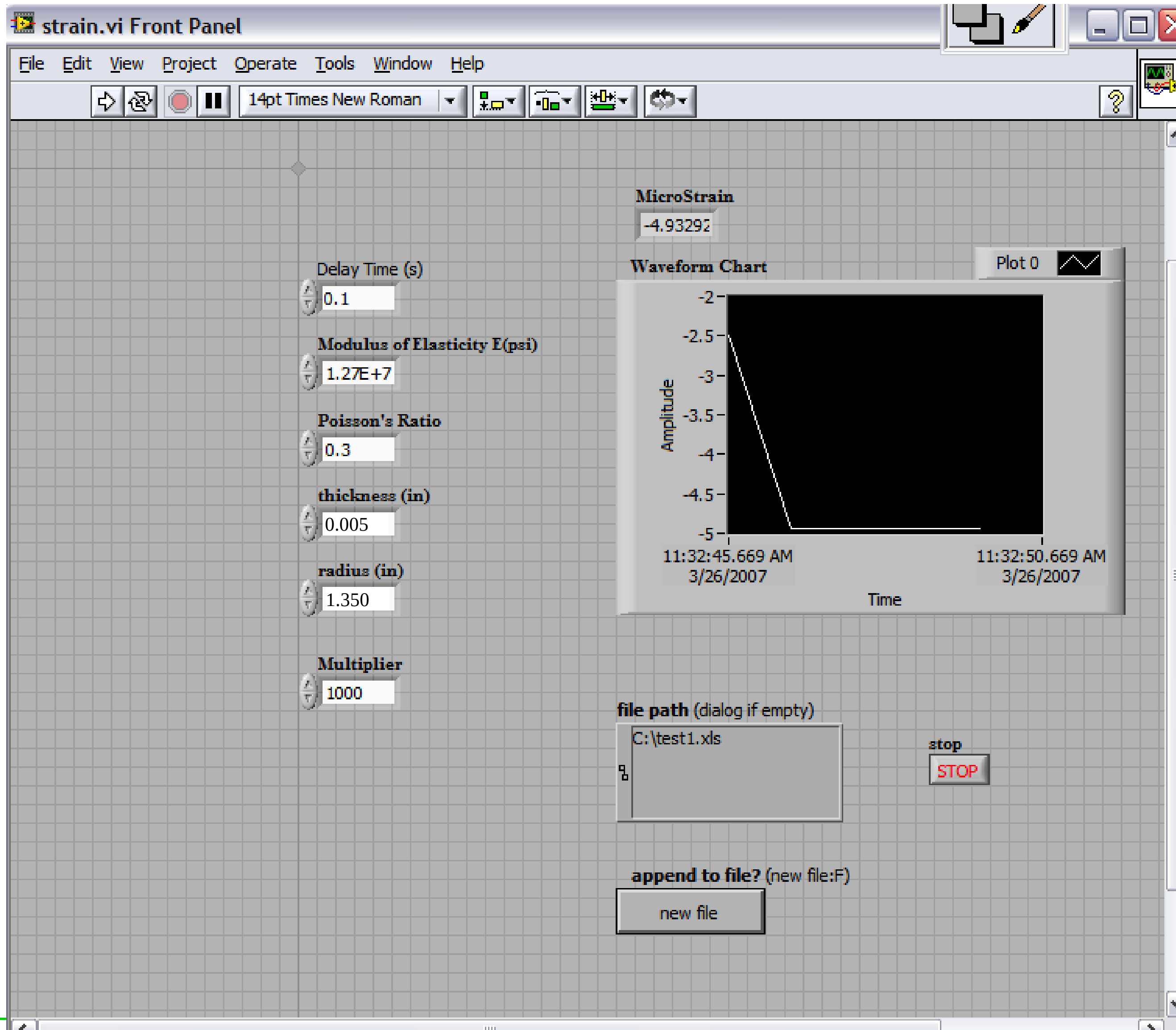


Fig. 3 — Three-wire quarter-bridge circuit.

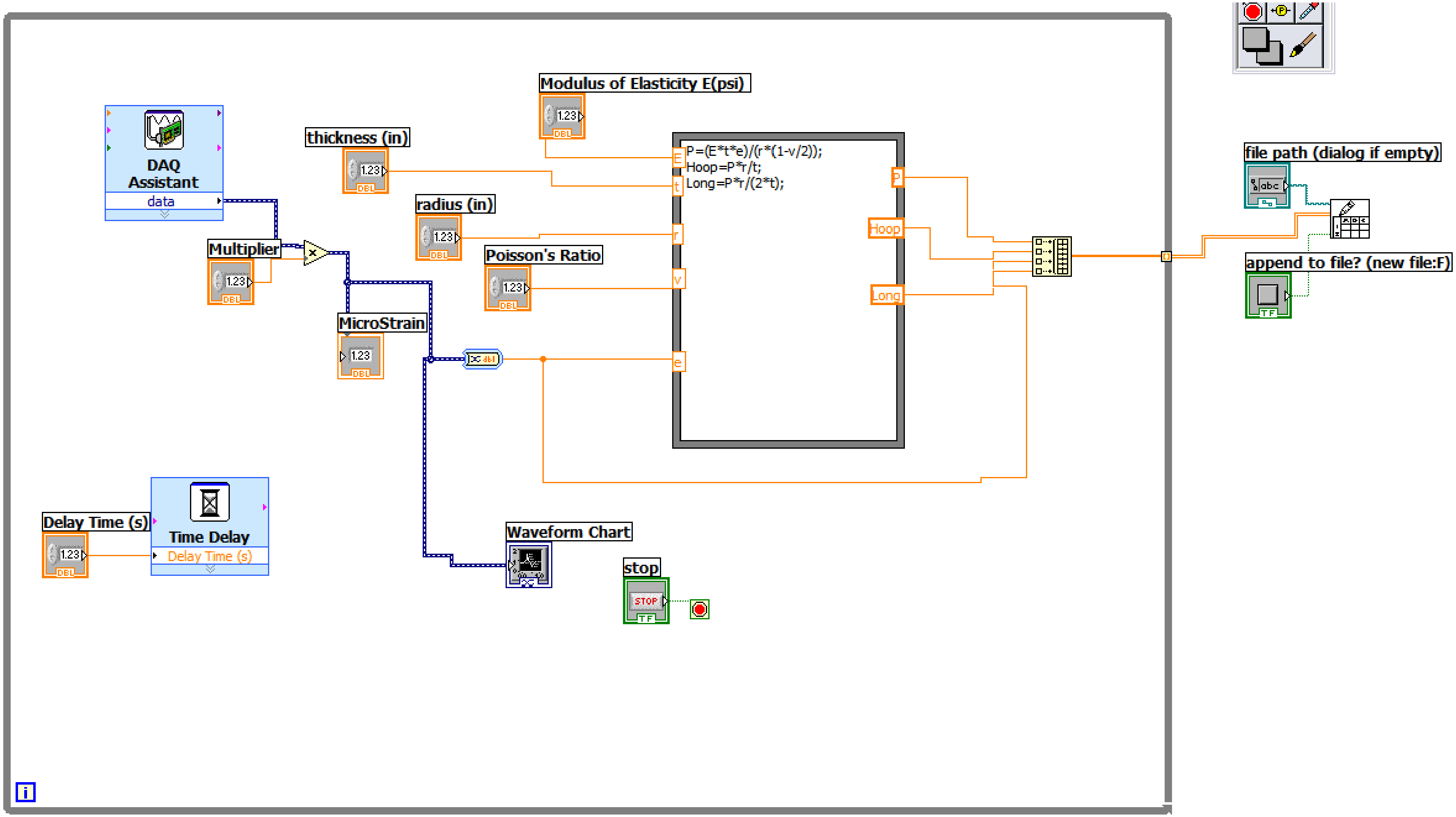
This is one possible VI: strain -> internal pressure

Parameters for recovering of internal pressure

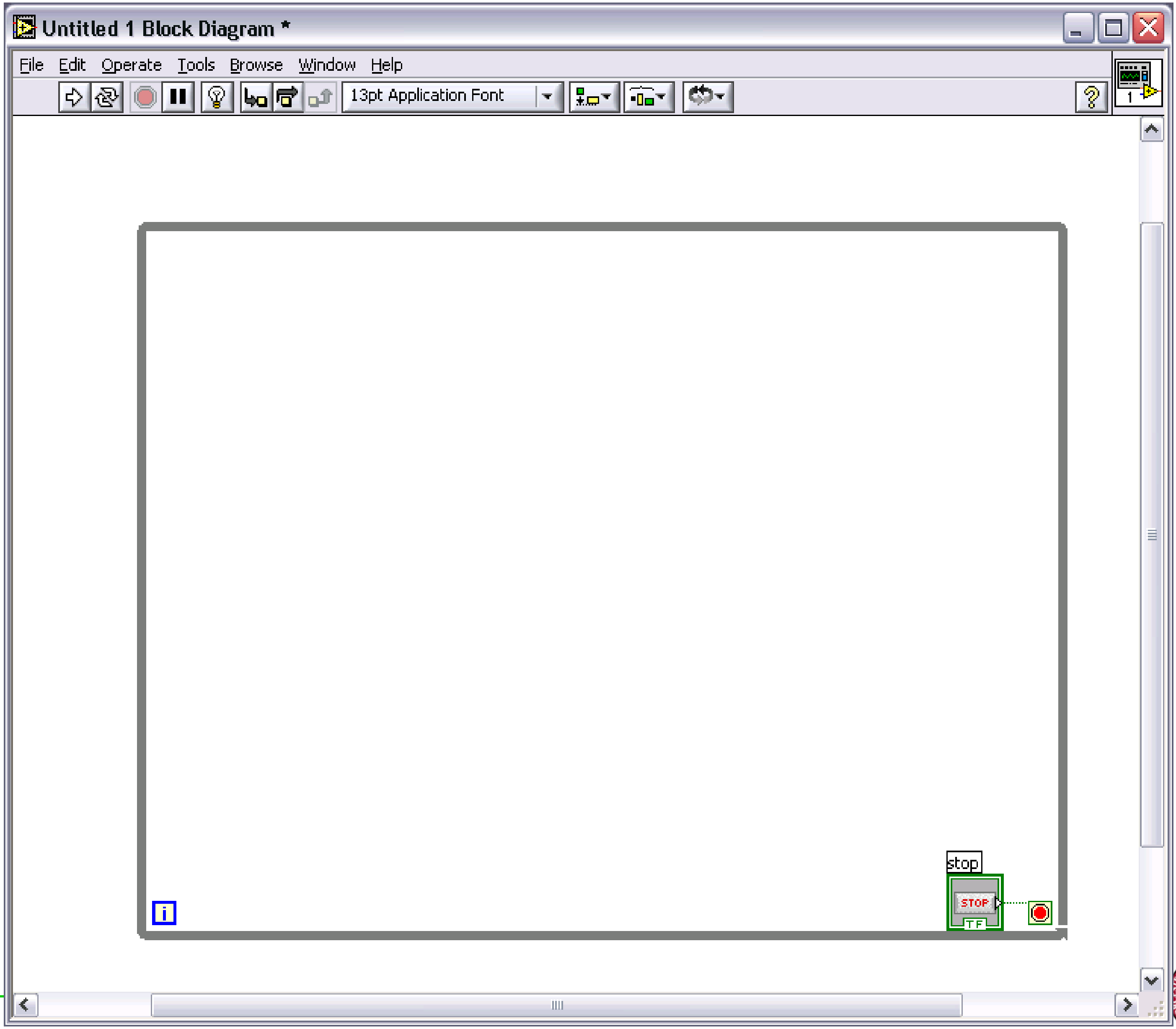


Strain measure ments

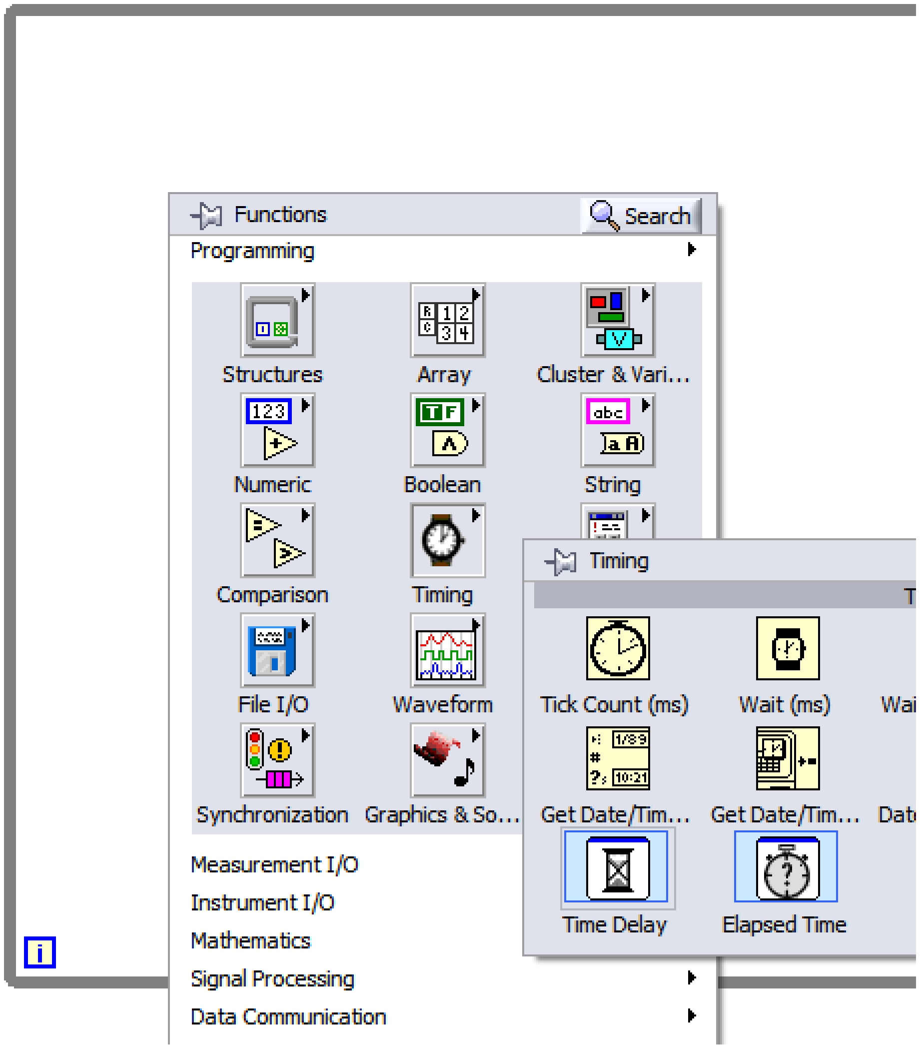
Write array to file, '2D data' and 'Enable indexing'



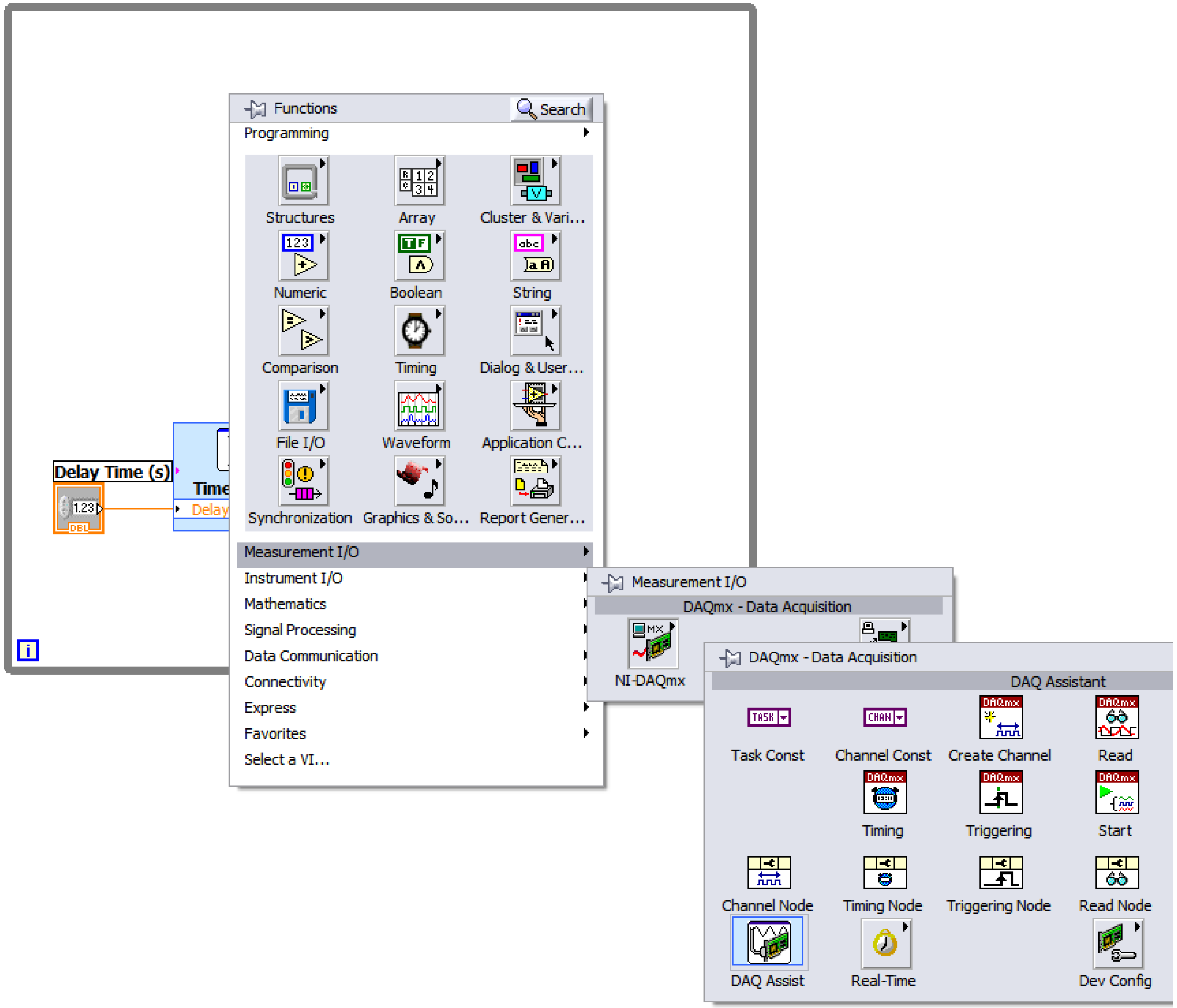
Create a 'while loop' with a stop button



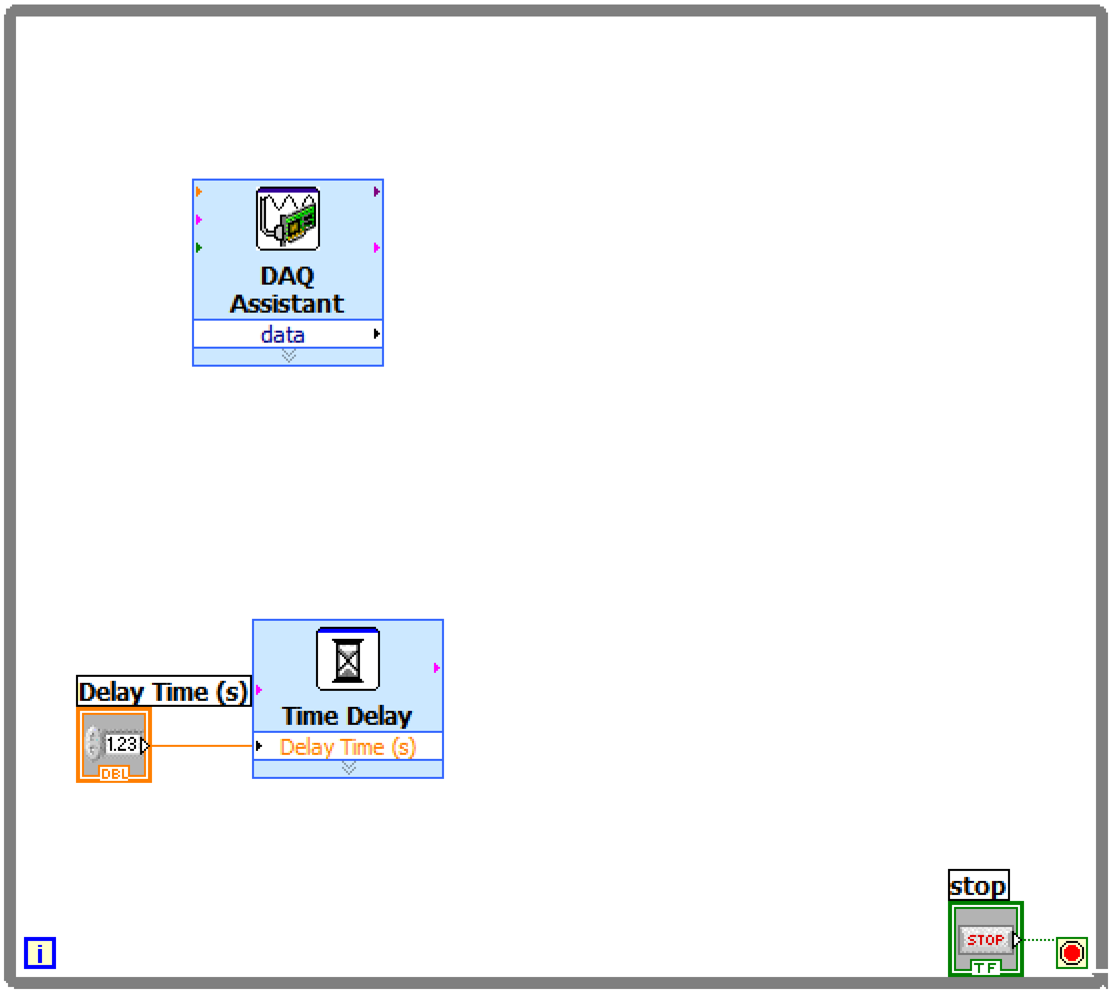
Add a 'time delay'; and create control



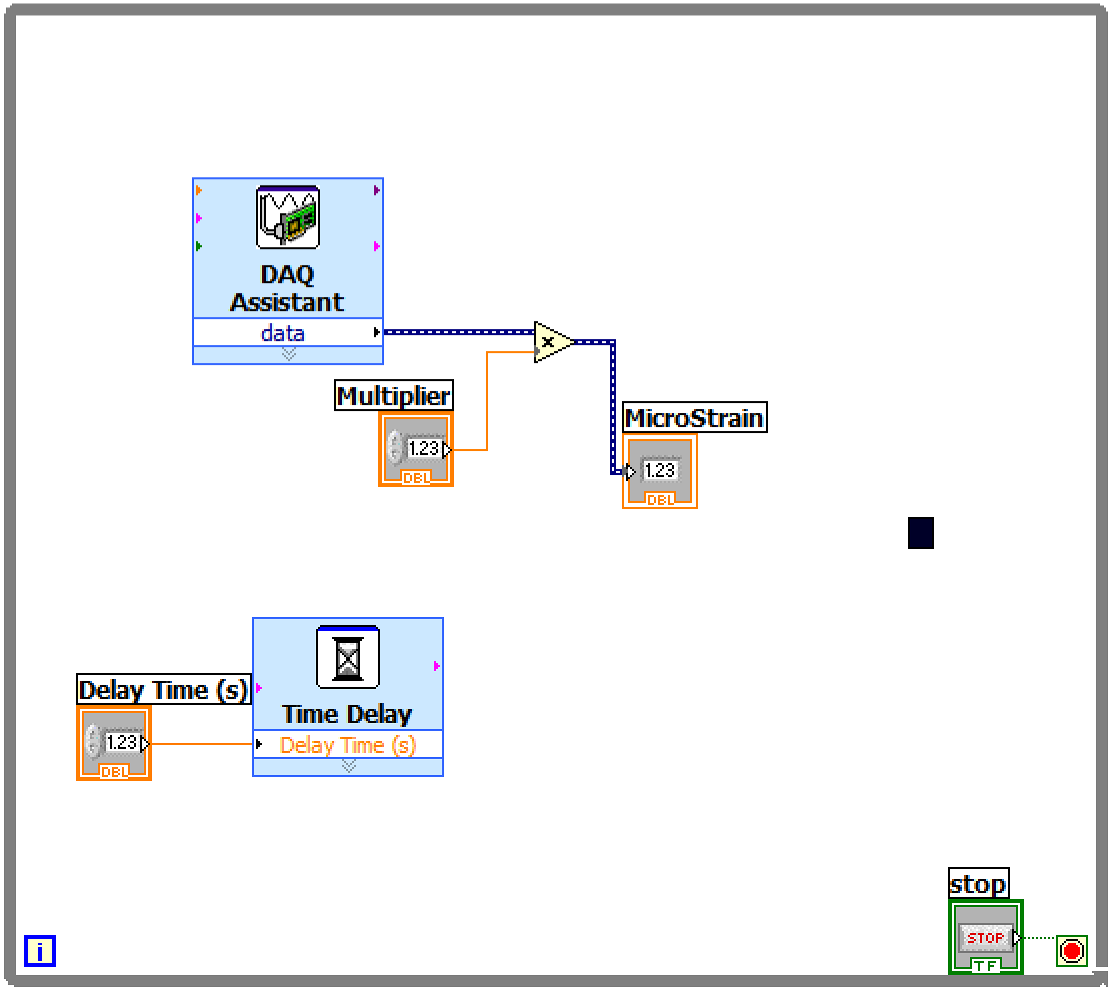
Create a Voltage input channel using DAQ Assistant, +10 V max, -10 V min, 1 sample on demand



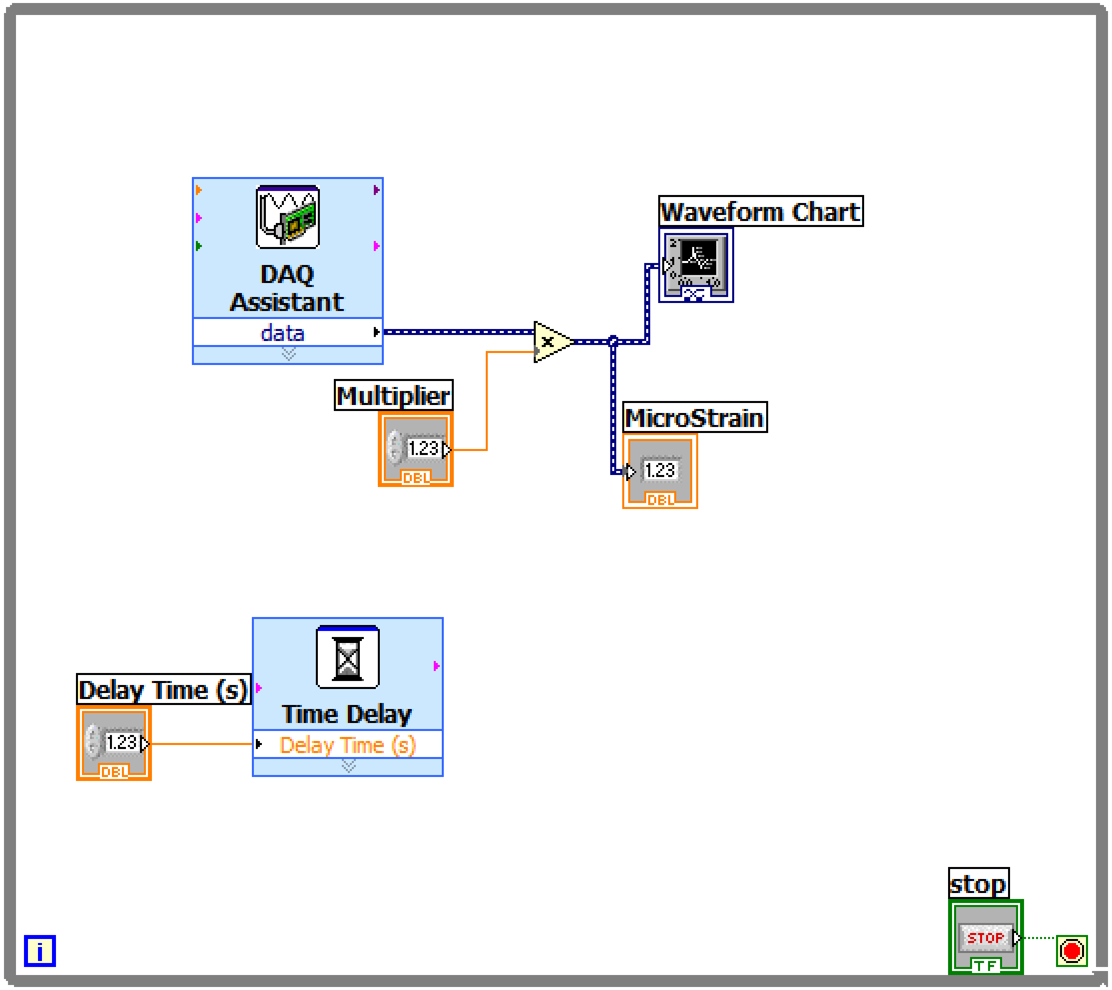
The VI looks like this now



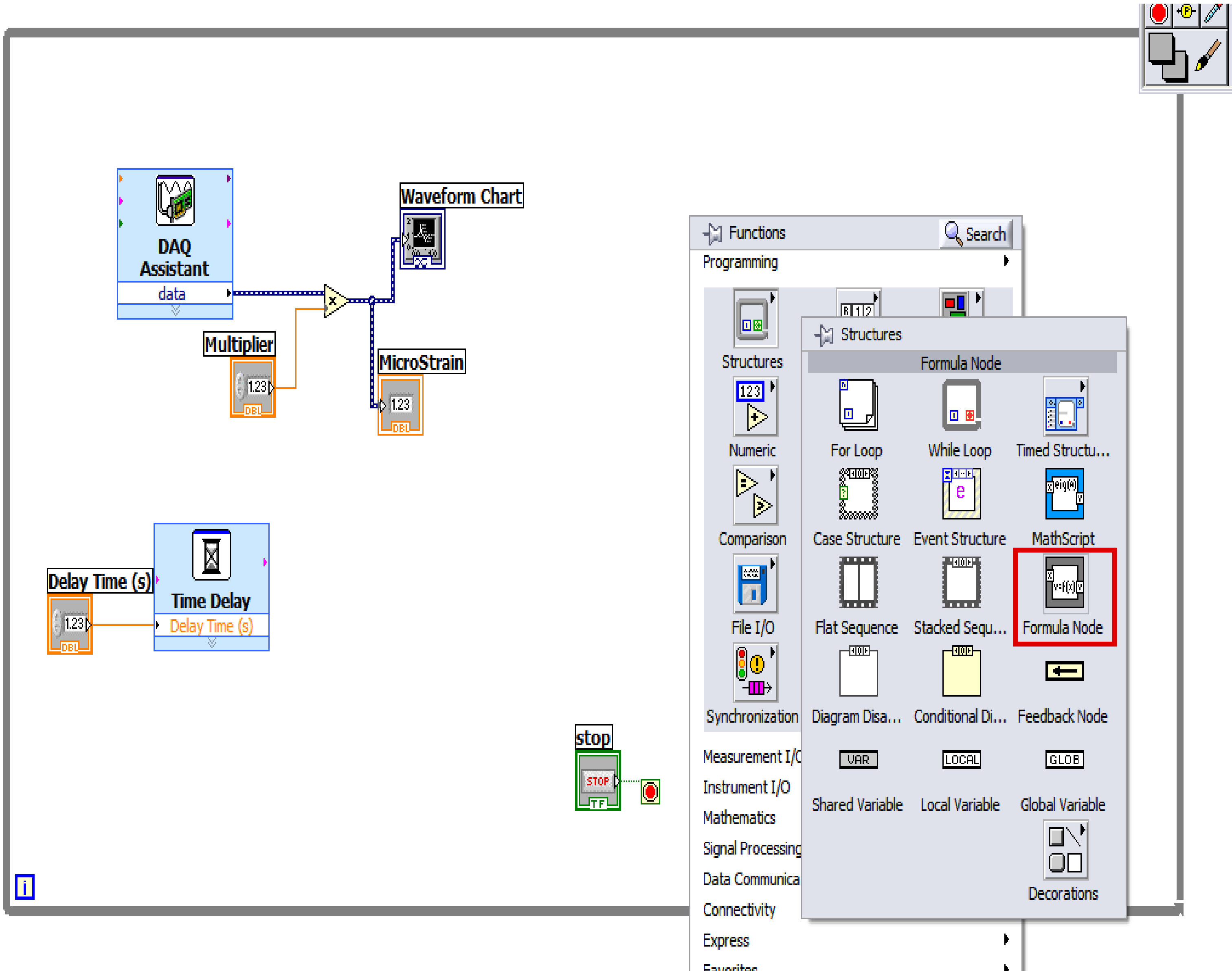
Add a numeric operator and create indicator for the result

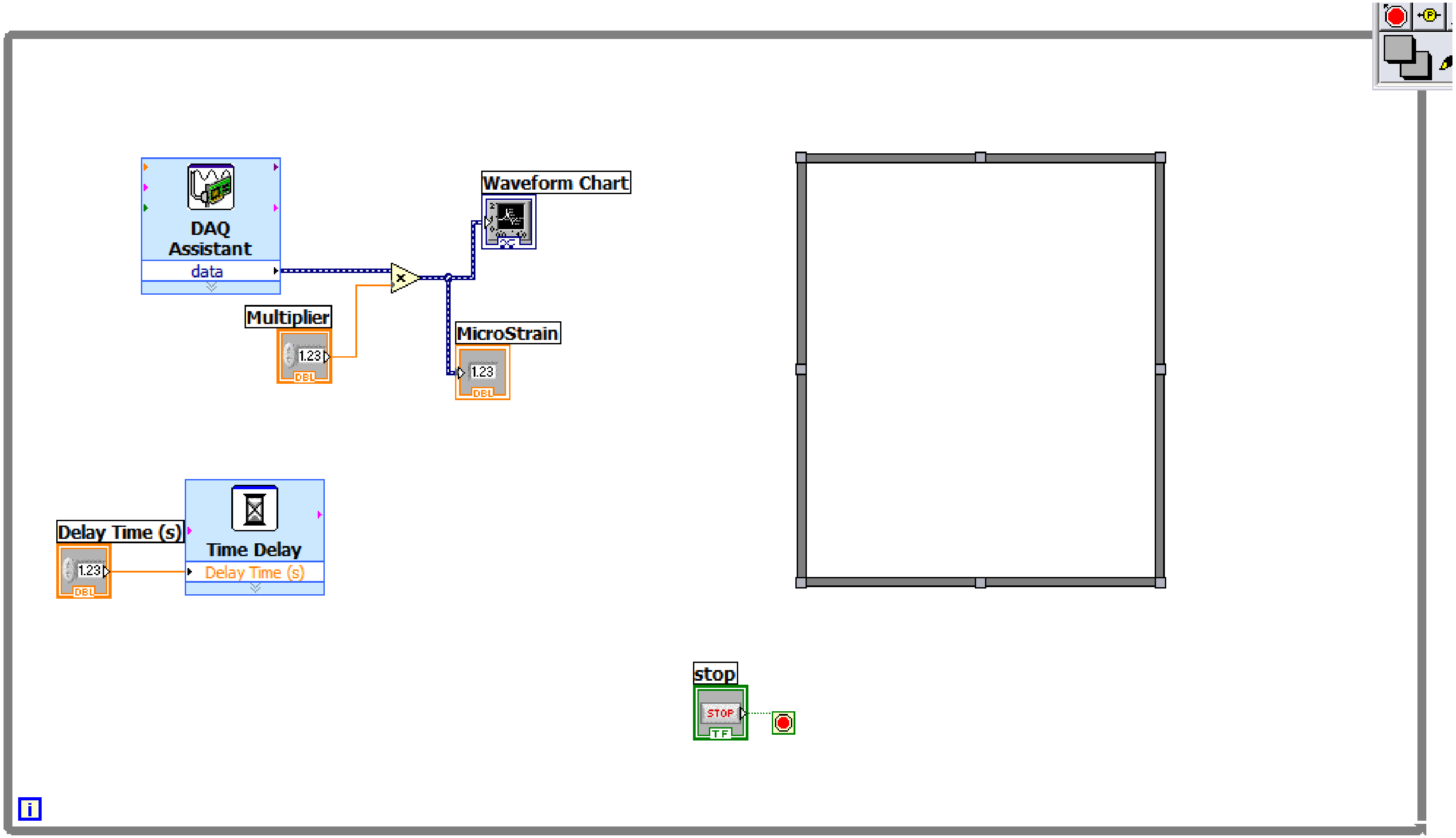


Add a display chart on the front panel and wire it up

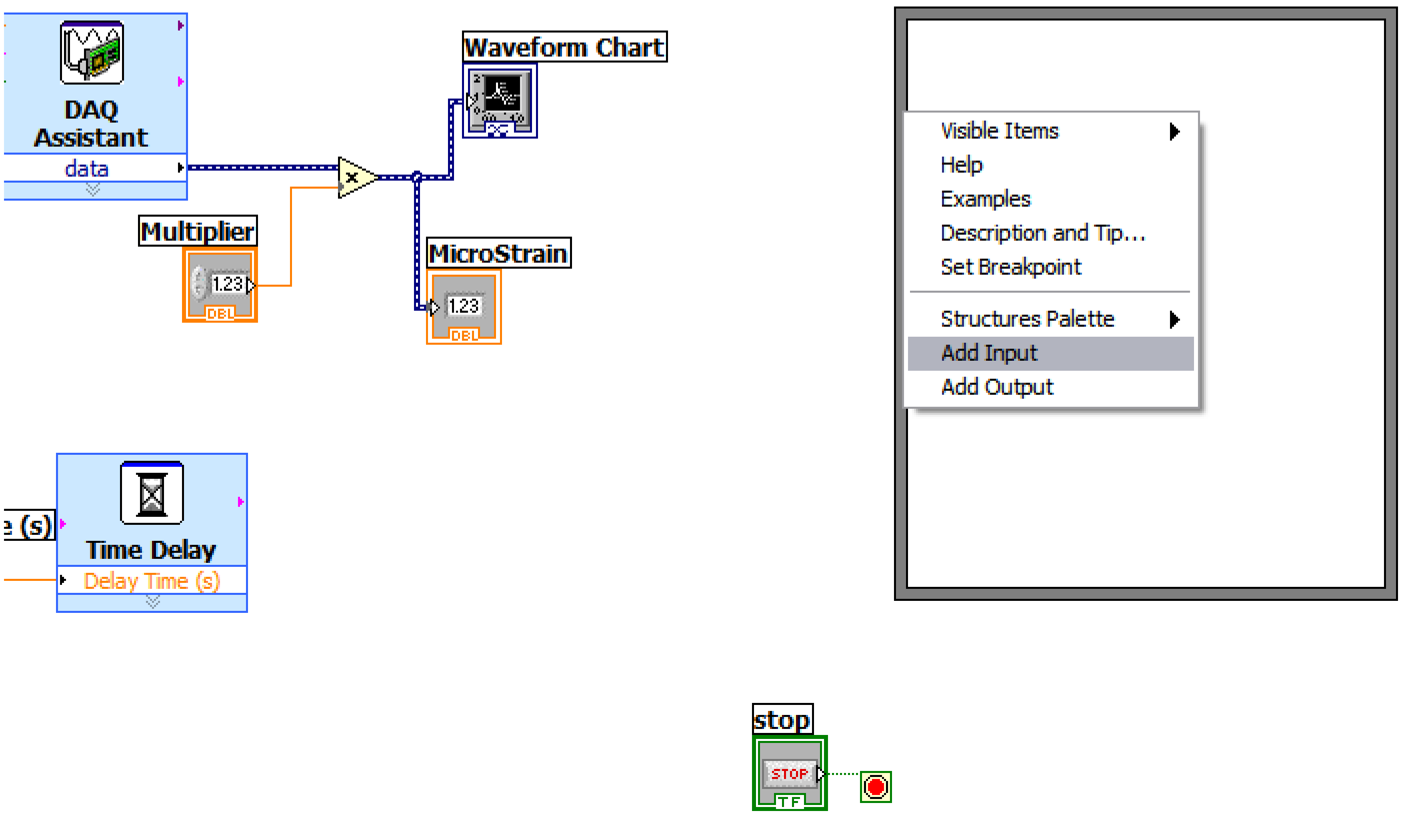


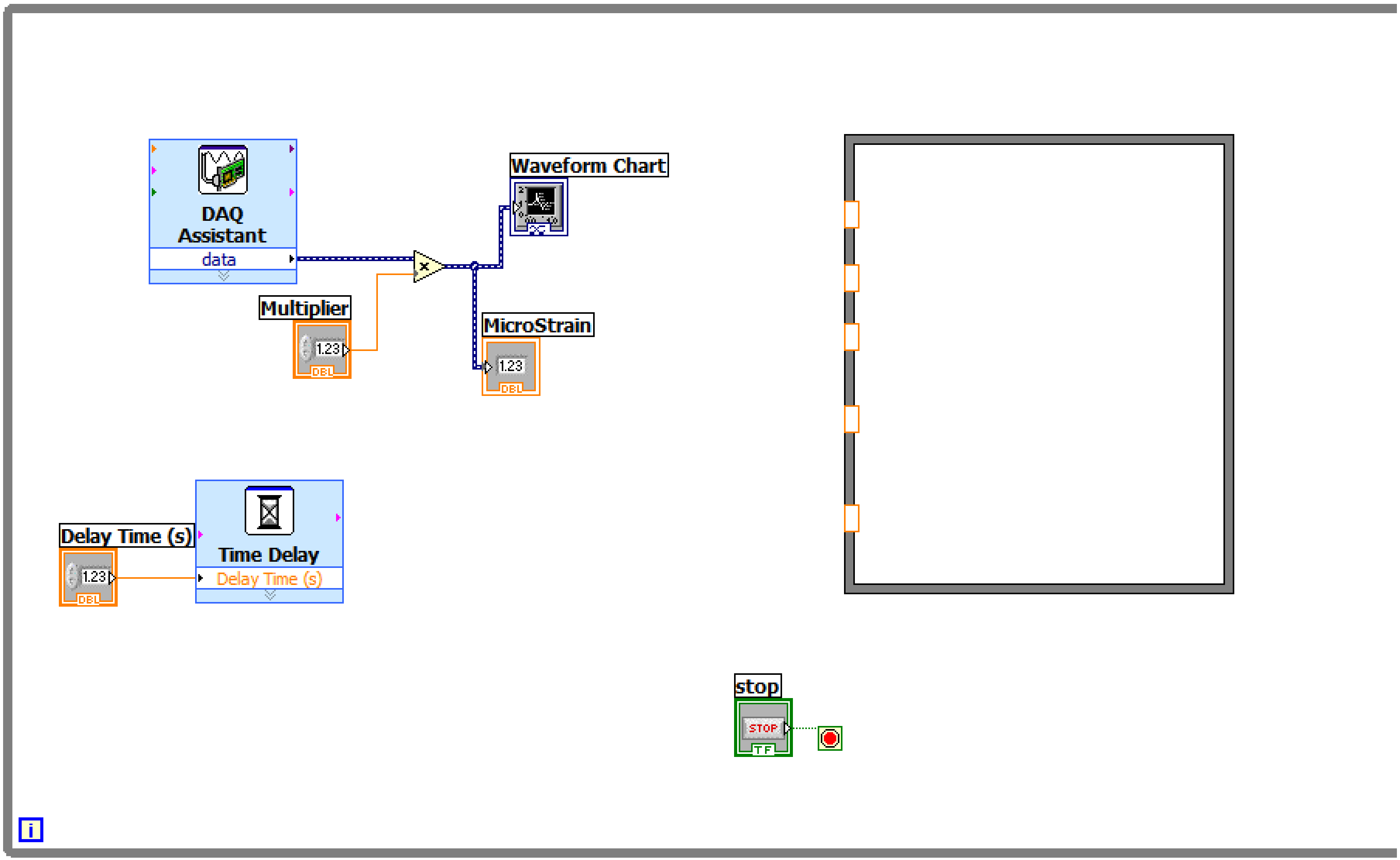
Create a formula node




DAQ Assistant
data
Waveform Chart
Multiplier
MicroStrain
Delay Time (s)
Time Delay
Delay Time (s)
stop
STOP

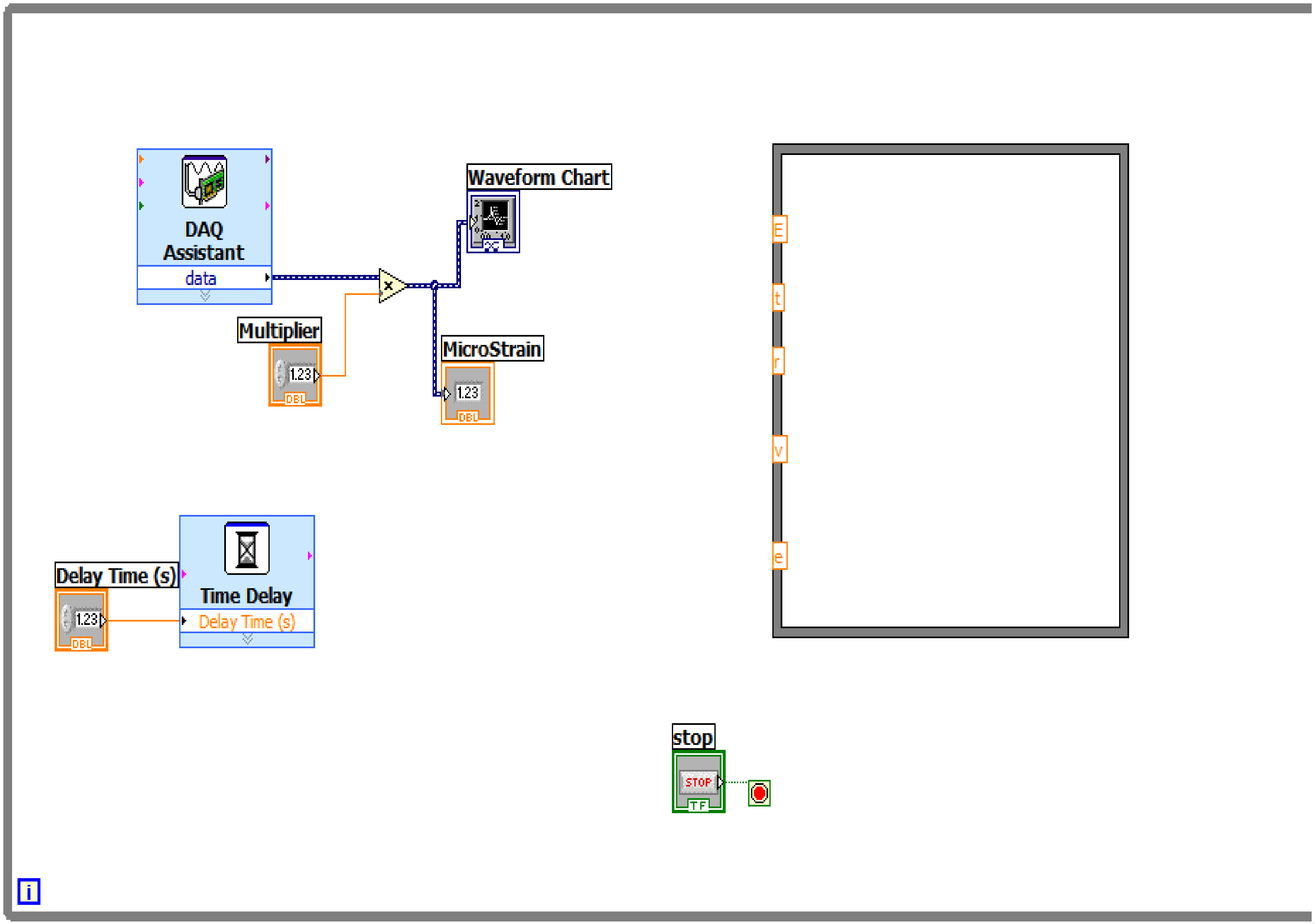
Add inputs by right-clicking on the left border of the formula node



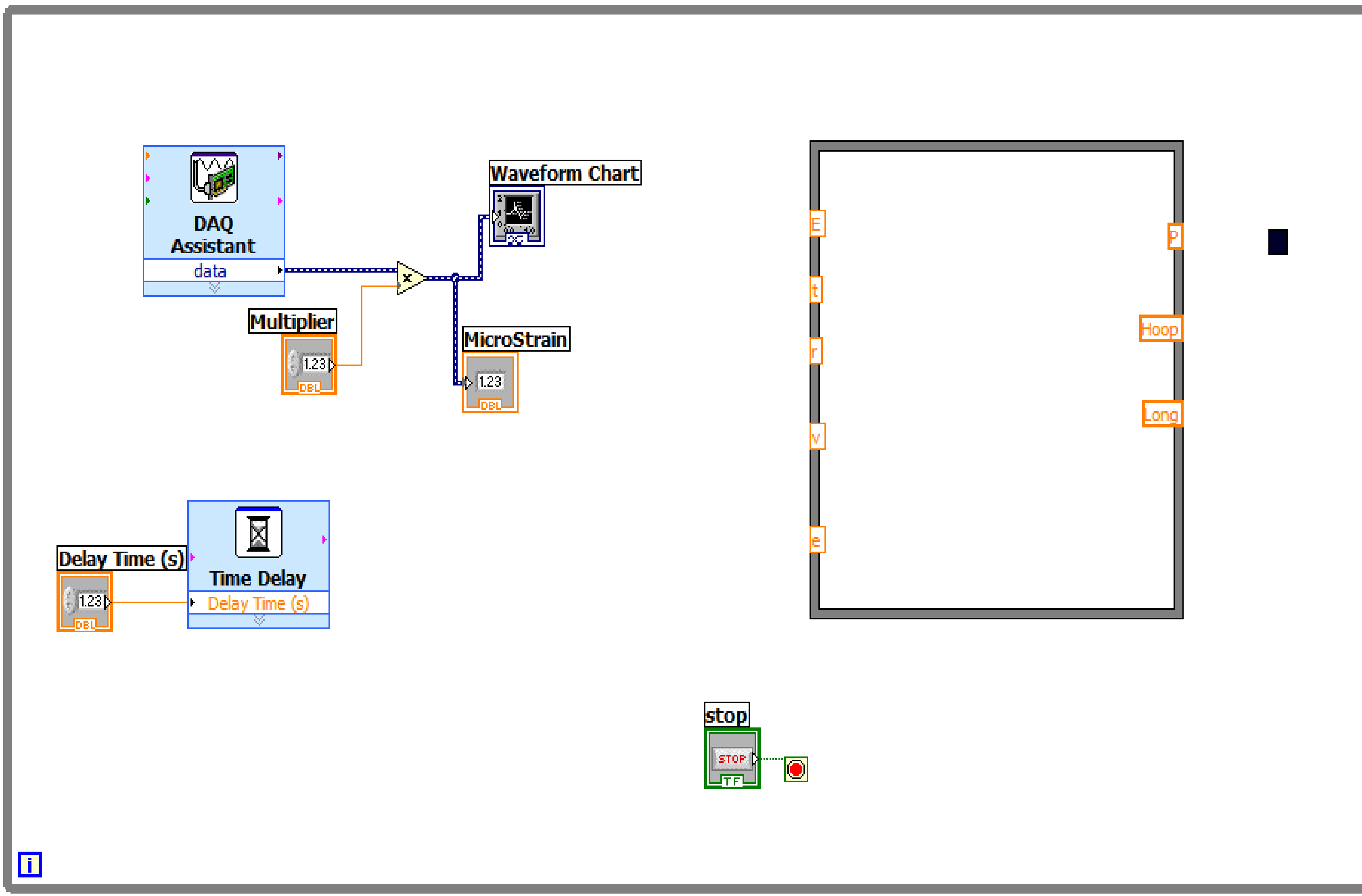


DAQ Assistant
data
Waveform Chart
Multiplier
MicroStrain
Delay Time (s)
Time Delay
Delay Time (s)
stop
STOP

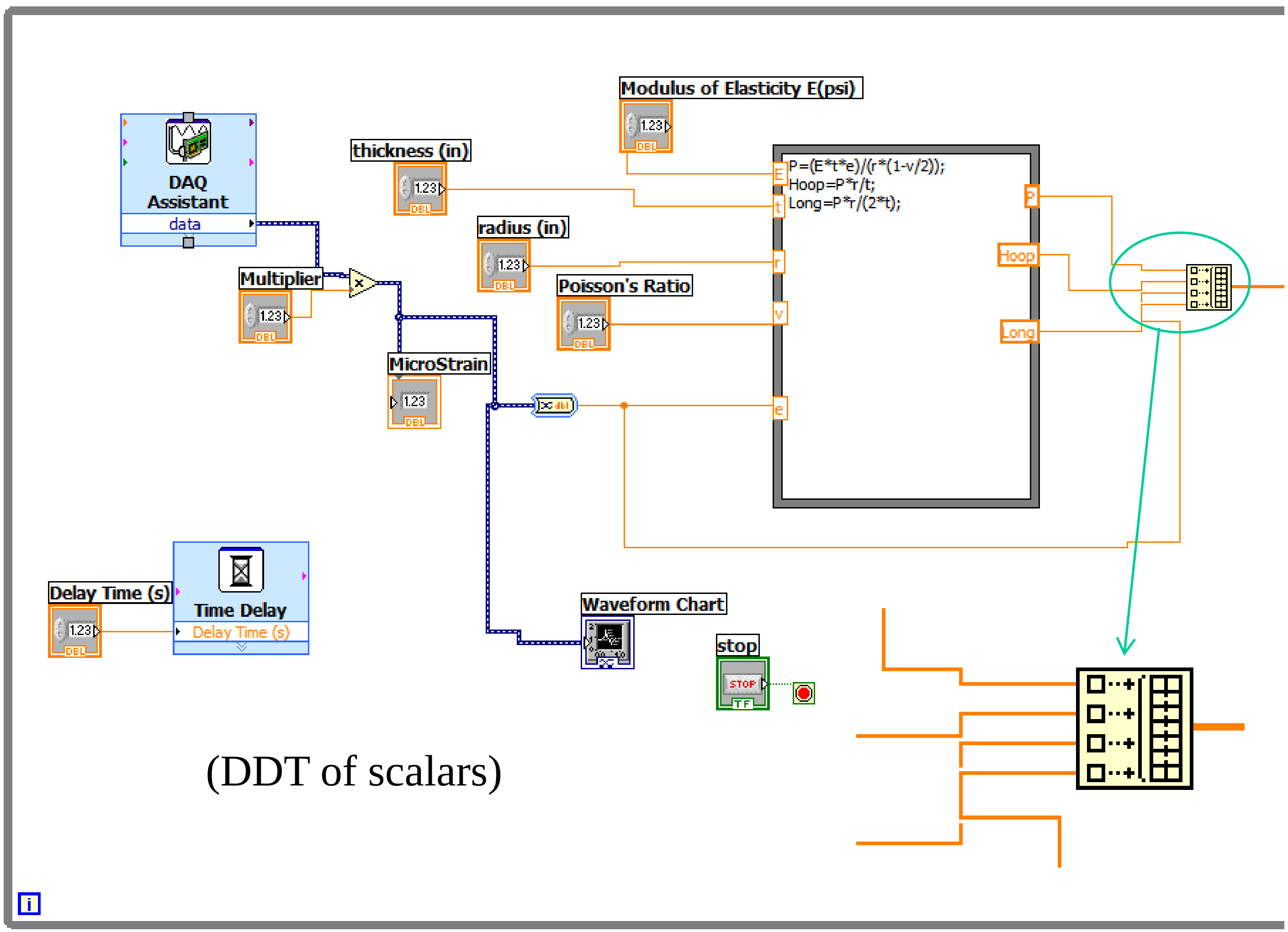
Name the inputs



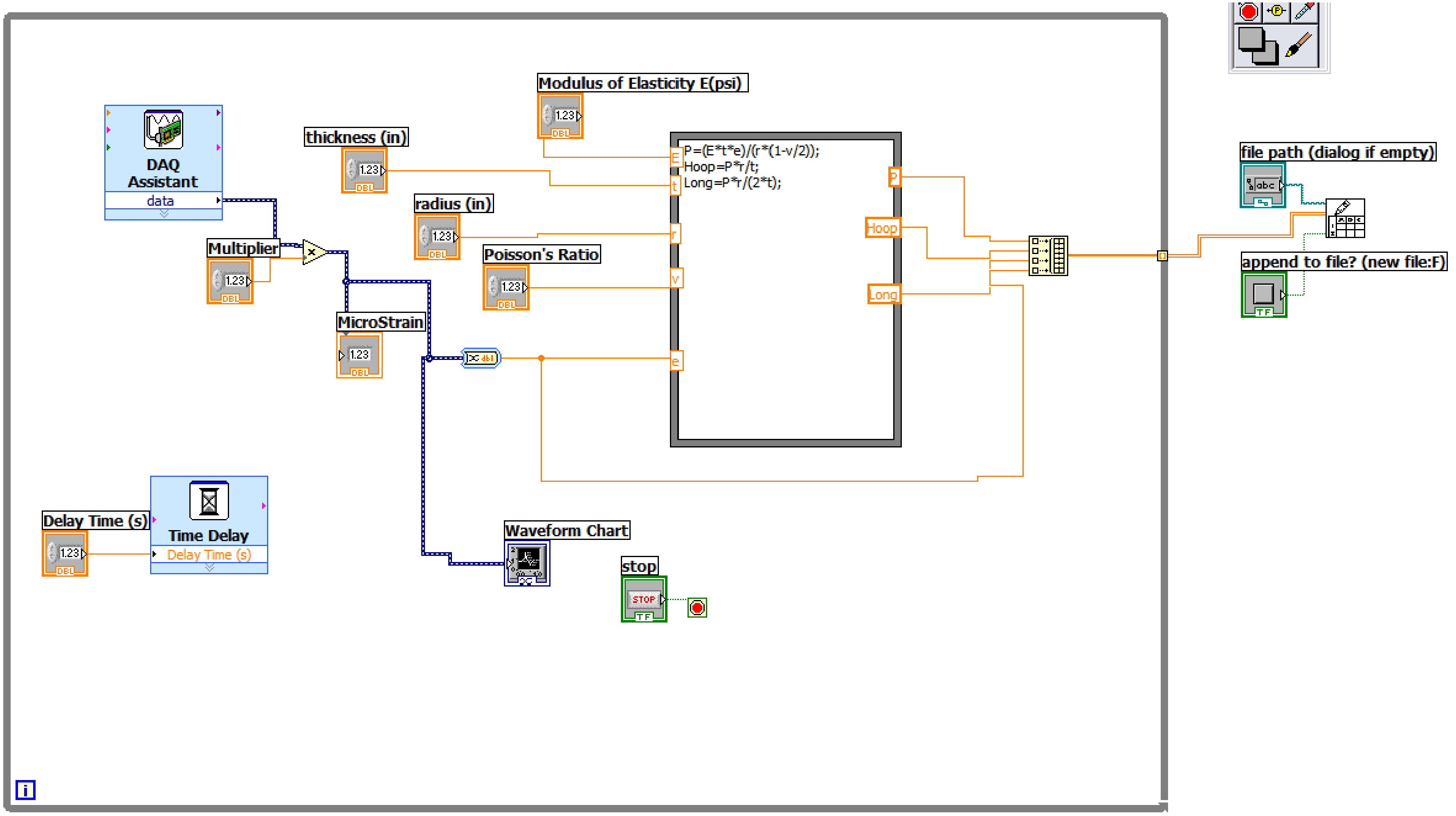
Add outputs by right-clicking on the right border of the formula node and name them as shown

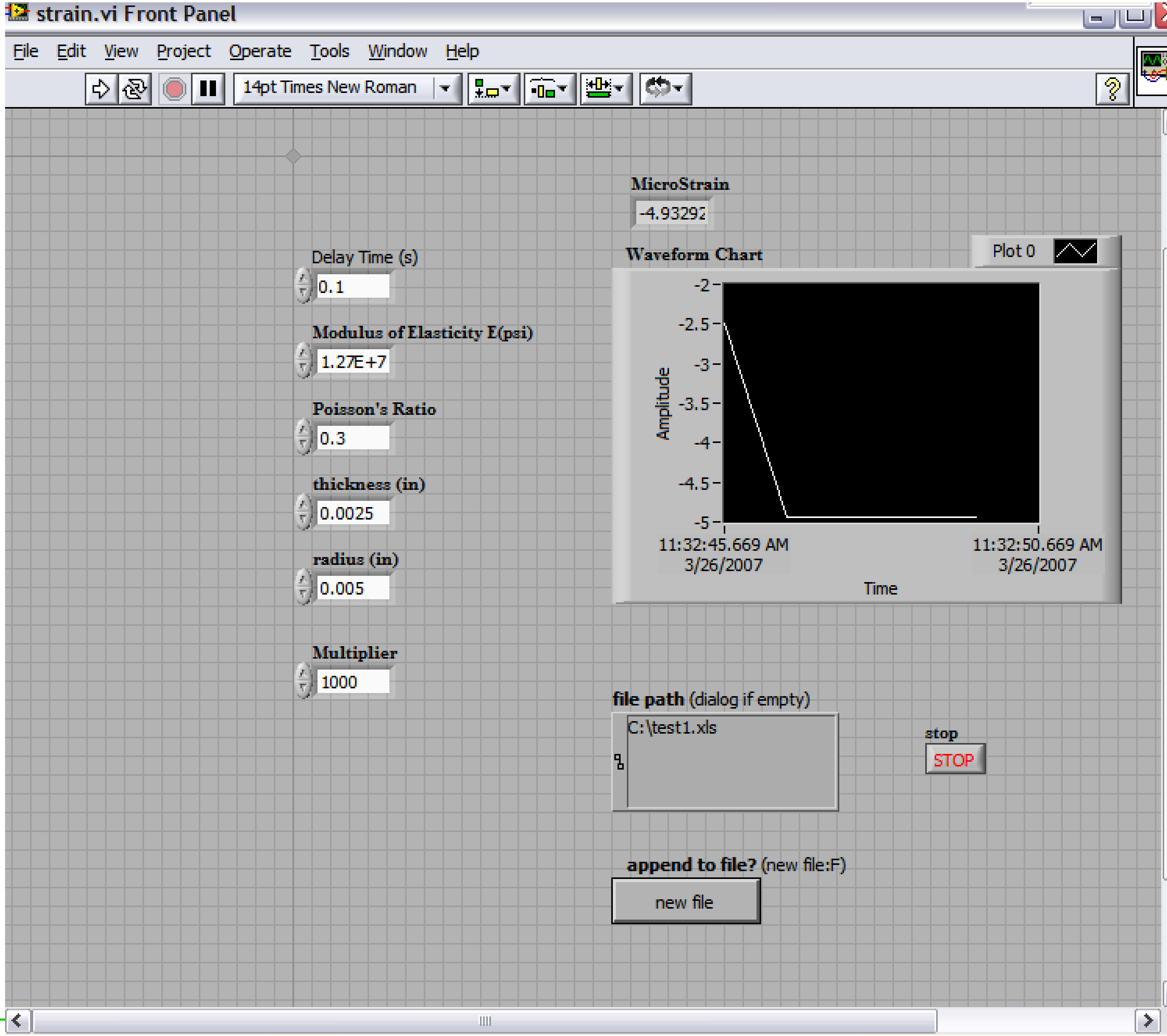


Create controls for input parameters; wire-up and write the governing equations, for dynamic data choose Single Scalar



Write array to file, '2D data' and 'Enable indexing'




strain.vi Front Panel
File Edit View Project Operate Tools Window Help
14pt Times New Roman
MicroStrain
-4.93292
Delay Time (s)
0.1
Modulus of Elasticity E(psi)
1.27E+7
Poisson's Ratio
0.3
thickness (in)
0.0025
radius (in)
0.005
Multiplier
1000
Waveform Chart
Plot 0
Amplitude
-2
-2.5
-3
-3.5
-4
-4.5
-5
11:32:45.669 AM 3/26/2007
11:32:50.669 AM 3/26/2007
Time
file path (dialog if empty)
C:\test1.xls
stop
STOP
append to file? (new file:F)
new file

Hardware. Signal conditioner/amplifier: 2310

Set 'excitation' to '10' volts; Calculate the appropriate gain factor; Adjust the gain settings (1-11) x Amplifier

More during class discussions (use gain of 191)

Hardware. Specifications: strain gages

EA-13-240LZ-120

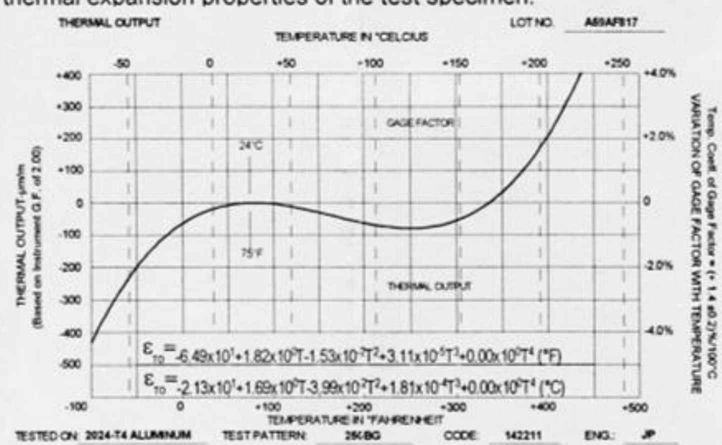
EA-13-240LZ-120	Gage Type
120.0 ±0.3%	Resistance in ohms at 24°C
2.095±0.5%	Gage Factor at 24°C
(+0.2 ±0.2)%	Transverse Sensitivity at 24°C
E	Option
A59AF817	Lot Number
144016-6834	Code

Student Gages

Vishay Micro-Measurements

P.O. Box 27777
Raleigh, North Carolina 27611
(919) 365-3800

SELF-TEMPERATURE COMPENSATION: These gages have been manufactured with self-temperature compensation (STC) characteristics to minimize thermal output (see Tech Note TN-504). Thermal output data given below are valid only for the indicated test material, since thermal output is a function of the thermal expansion properties of the test specimen.



GENERAL INFORMATION
SERIES EA STRAIN GAGES

GENERAL DESCRIPTION: Student Gages are EA Series gages. This series is a general-purpose family of constantan alloy strain gages widely used in experimental stress analysis. EA gages are constructed with a 0.001 inch *(0.03 mm)* tough, flexible polyimide film backing. All Student Gages include Option E, a polyimide encapsulation of the grid face, with exposed solder tabs. See Tech Note TN-505 for assistance in gage selection.

TEMPERATURE RANGE: Normal use temperature range for static strain measurement is -100°F to +350°F *(-75°C to +175°C)*. For special or short-term exposure, an expanded range of -320°F to +400°F *(-195°C to +205°C)* may be used.

STRAIN LIMITS: Approximately 5% for 0.240 in *(6 mm)* gage length and approximately 3% for 0.120 in *(3 mm)* and 0.060 in *(1.5 mm)* gage lengths for single cycle use. See Tech Tip TT-605 for high elongation measurements.

FATIGUE LIFE: Dependent on gage length and method of cycling; 10^8 cycles at ±1200µε, 10^6 cycles at ±1500µε. Derate 10% for nonzero mean strains of same absolute (peak-to-peak) values. See Tech Note TN-508 for additional data.

ADHESIVES: M-Bond 200 is an excellent, general purpose adhesive for those learning to bond strain gages (see Instruction Bulletin B-127). M-Bond AE-10 may be used when a wider range of bonding properties is needed (see Instruction Bulletin B-137). Refer to Instruction Bulletin B-129 for proper surface preparation, and to Catalog A-110 for other bonding agents.

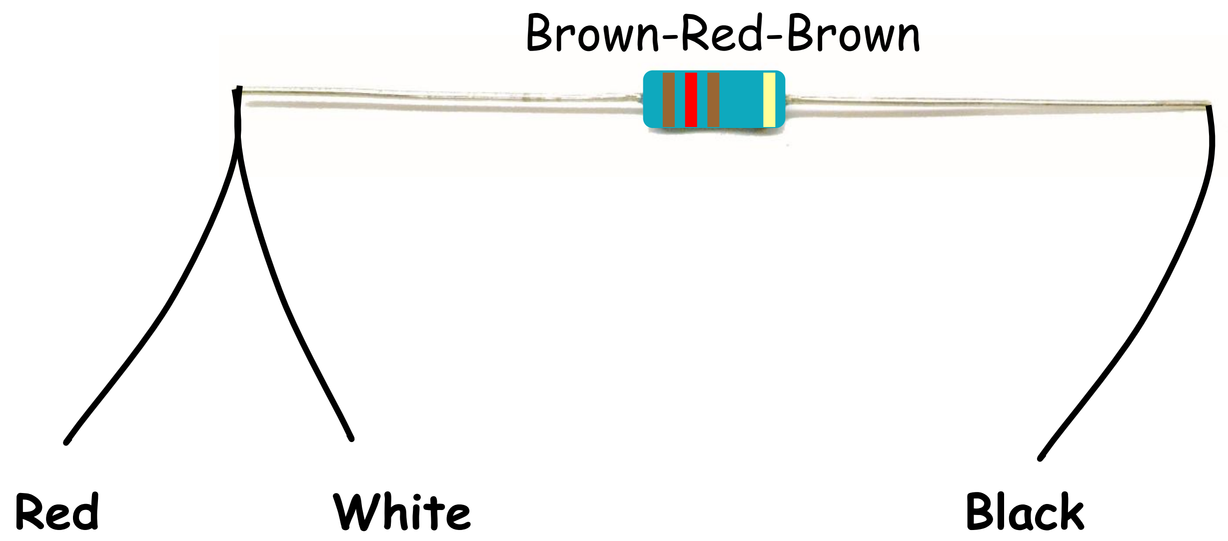
SOLDER: M-Line solder type 361 is recommended for leadwire attachment when operating temperatures do not exceed +300°F *(+150°C)*. See Catalog A-110 for higher temperature solders.

PROTECTIVE COATINGS: Because of Option E encapsulation, Student Gages require no further protection under most laboratory conditions. When further protection is required, refer to Catalog A-110 for M-Coat protective coatings information.

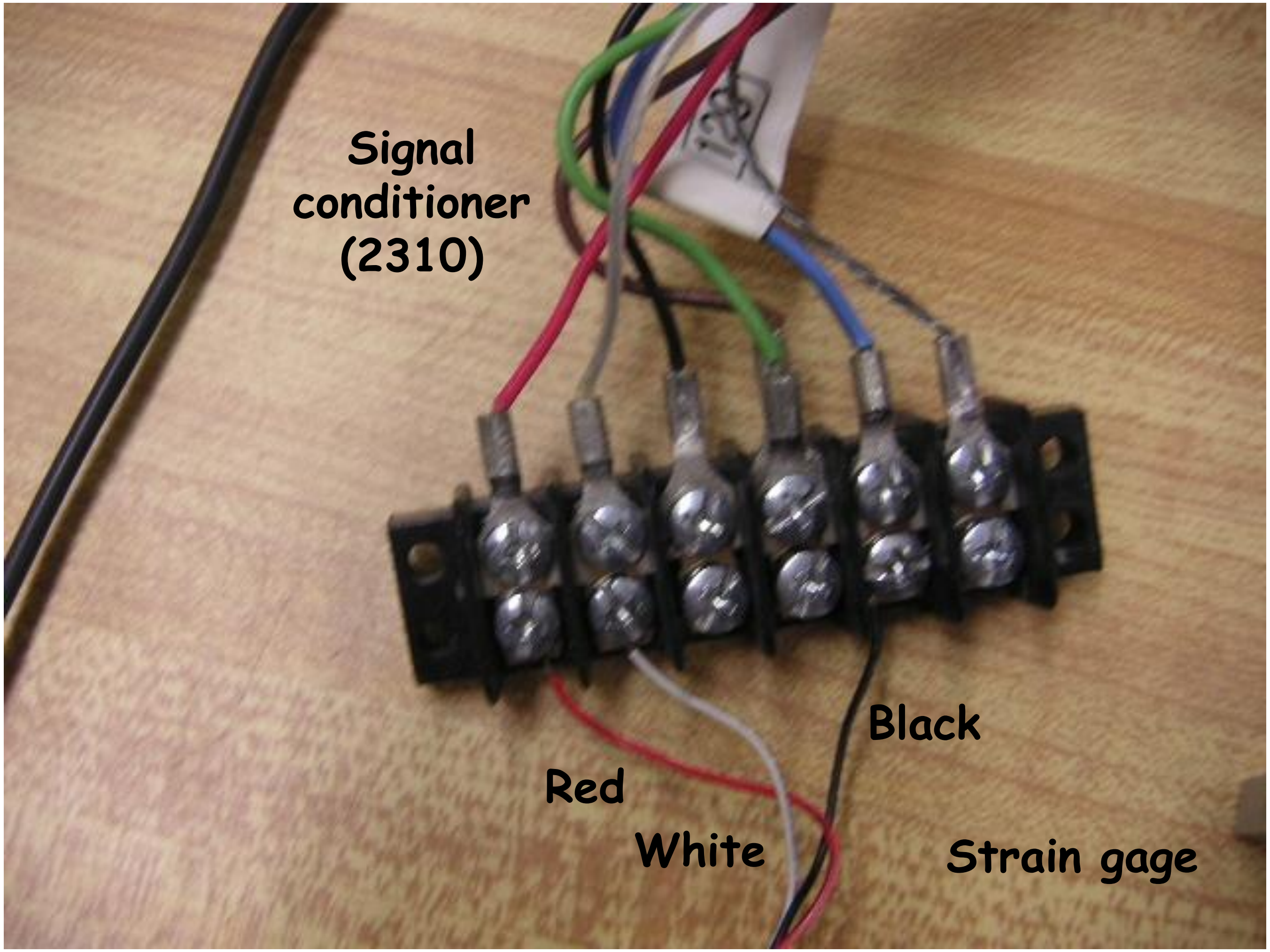
NOTE: The backing of Student Gages has been specifically treated for optimum bond formation with all appropriate gage adhesives. No further cleaning is necessary if contamination of the prepared surface is avoided during handling. Should contamination occur, clean with a cotton swab slightly moistened with a low residue solvent such as isopropyl alcohol. Allow the gage to dry for several minutes before bonding.

WPI

For this lab: *simulate* strain gage, e.g., by use of 120 Ω ± 5% resistor (better tolerances should be used)



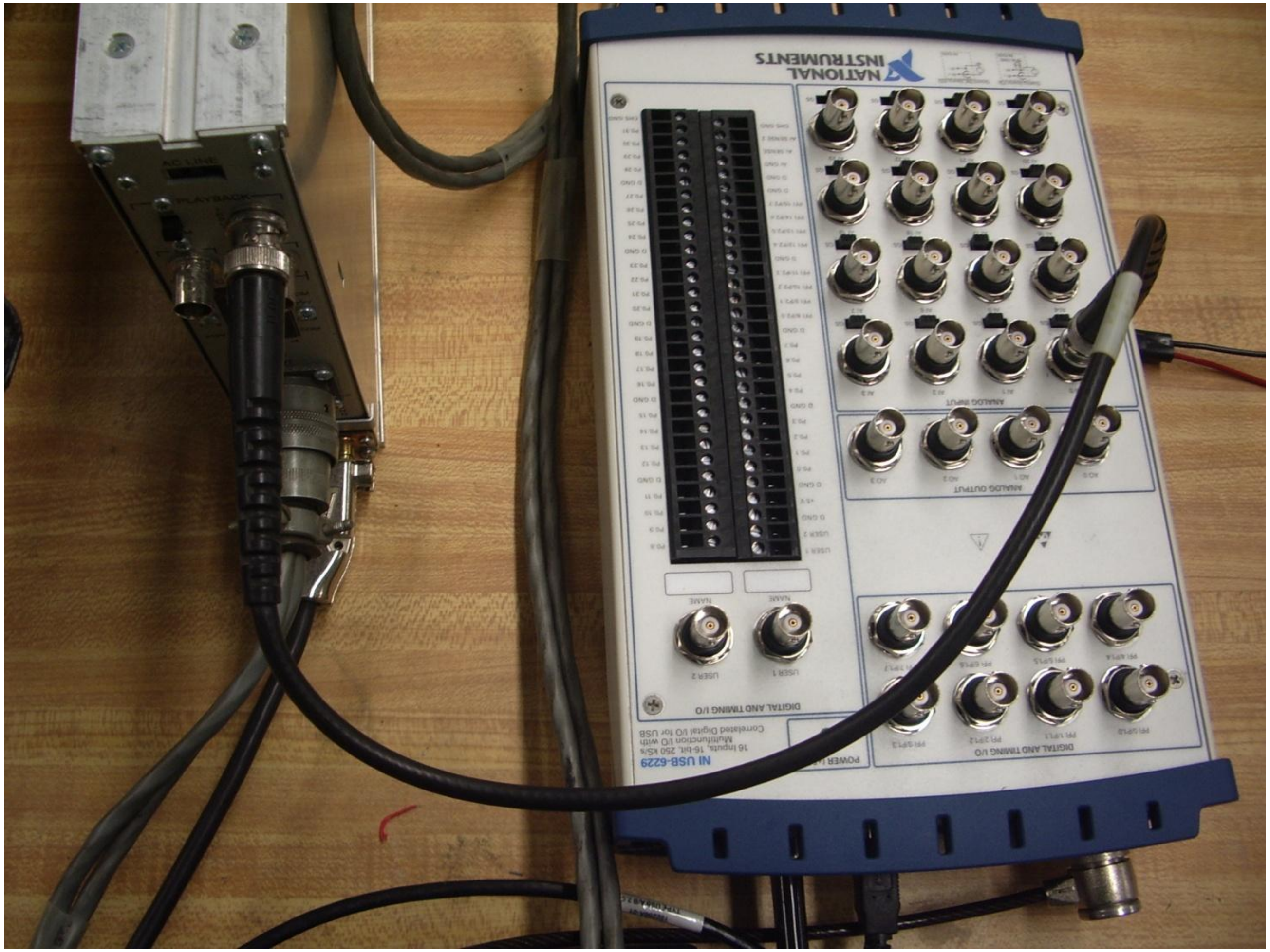
Wire strain gage (or simulated gage) wires to the terminal strip of the amplifier



Term.	Strain Gage
Red	Red
White	White
Blue	Black

The DAQ is connected with the output of the 2310

BNC cable from 2310's output (see ±10 terminal)



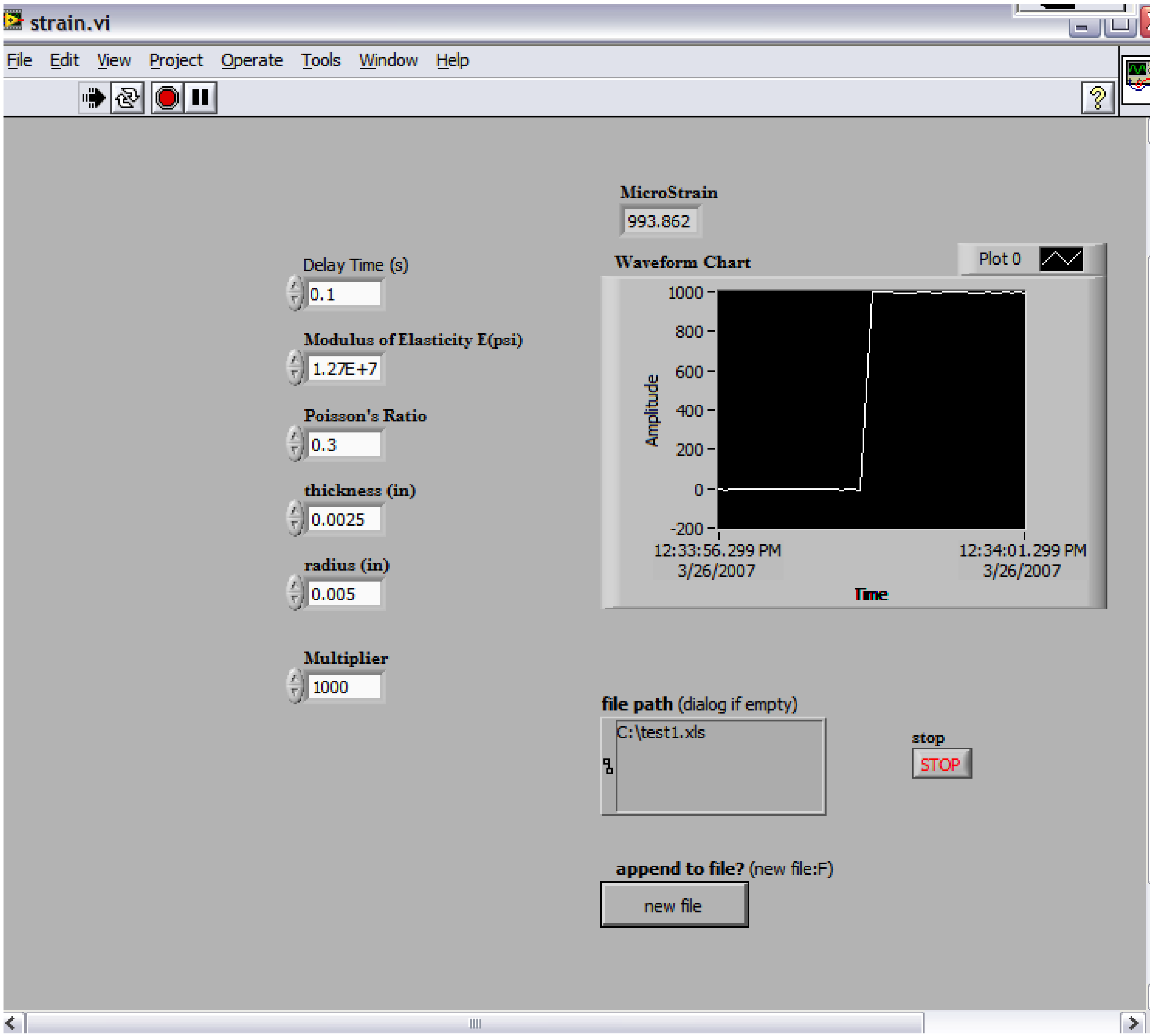
Test your VI and Hardware

(Run your VI)

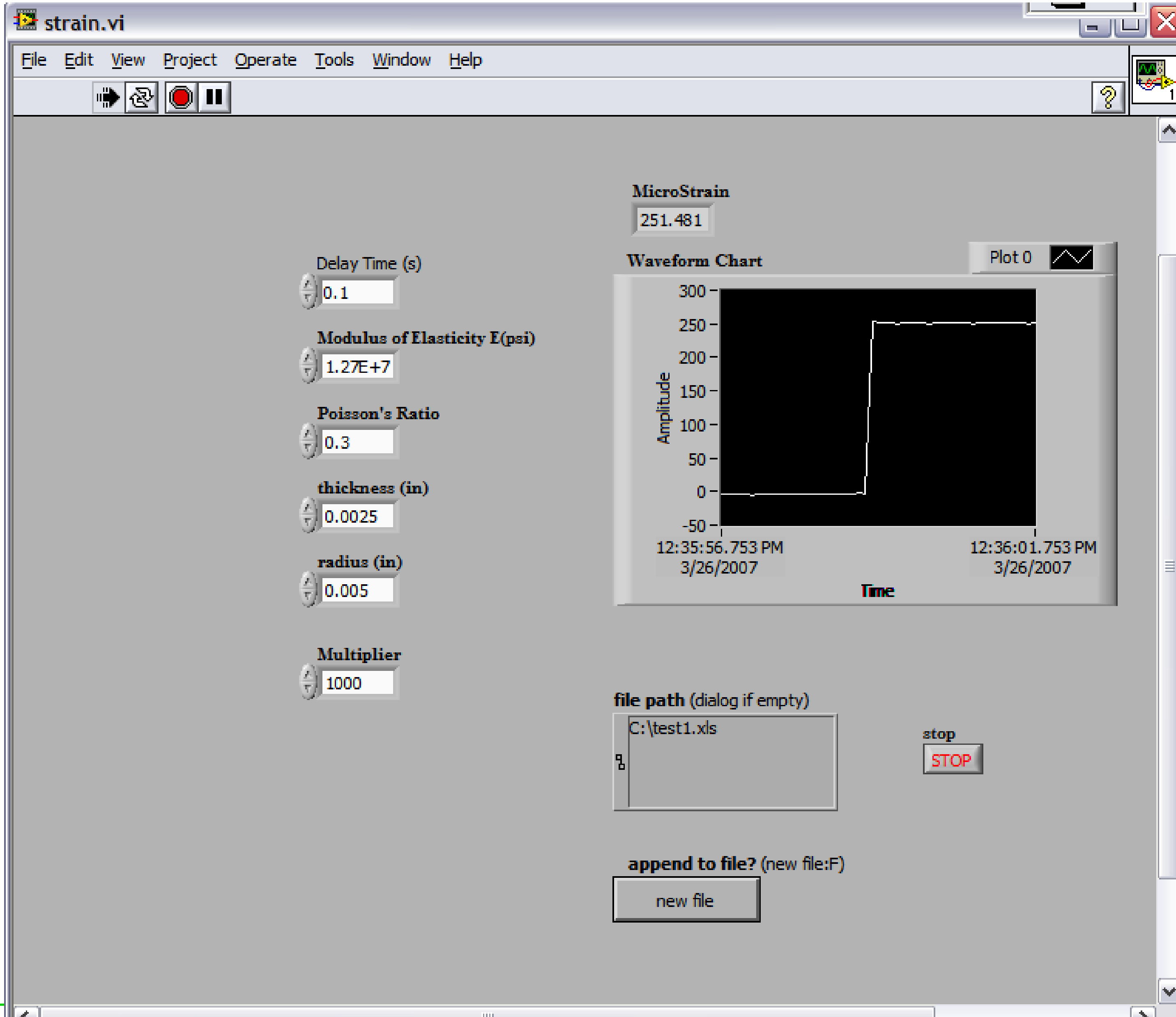
Use “Shunt” resistors of the 2310 Module

Equalize signals. Use "trim" knob of 2310 to have same +/- output LED signals

Trigger shunt resistor 'A', about 1000 MicroStrains



Trigger shunt resistor 'B'



Your VI is ready to GO