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To: Dr. Dieckman
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Re: Type K1 & K2 Pressure Transducer Calibration

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Voltage outputs of Ashcroft type K1 and K2 pressure transducers were collected through various system pressures verified by a Helicoid dial gauge. The K1 transducer had a 2.4% slope error and an offset error of 0.022 ± 0.056 mA [95%]. The K2 transducer had a 2.7% slope error and an offset error of 0.029 ± 3.224 mV [95%]. Experimental results fall within the stated error of 2.73% (1.0% ± 0.040%/°F) at room temperature for each transducer [1, 2]. The expected and experimental calibration lines are shown below in Figure 1. Note that error bars denoting total uncertainty are too small to be visible for transducer K1 indicating a high degree of precision.

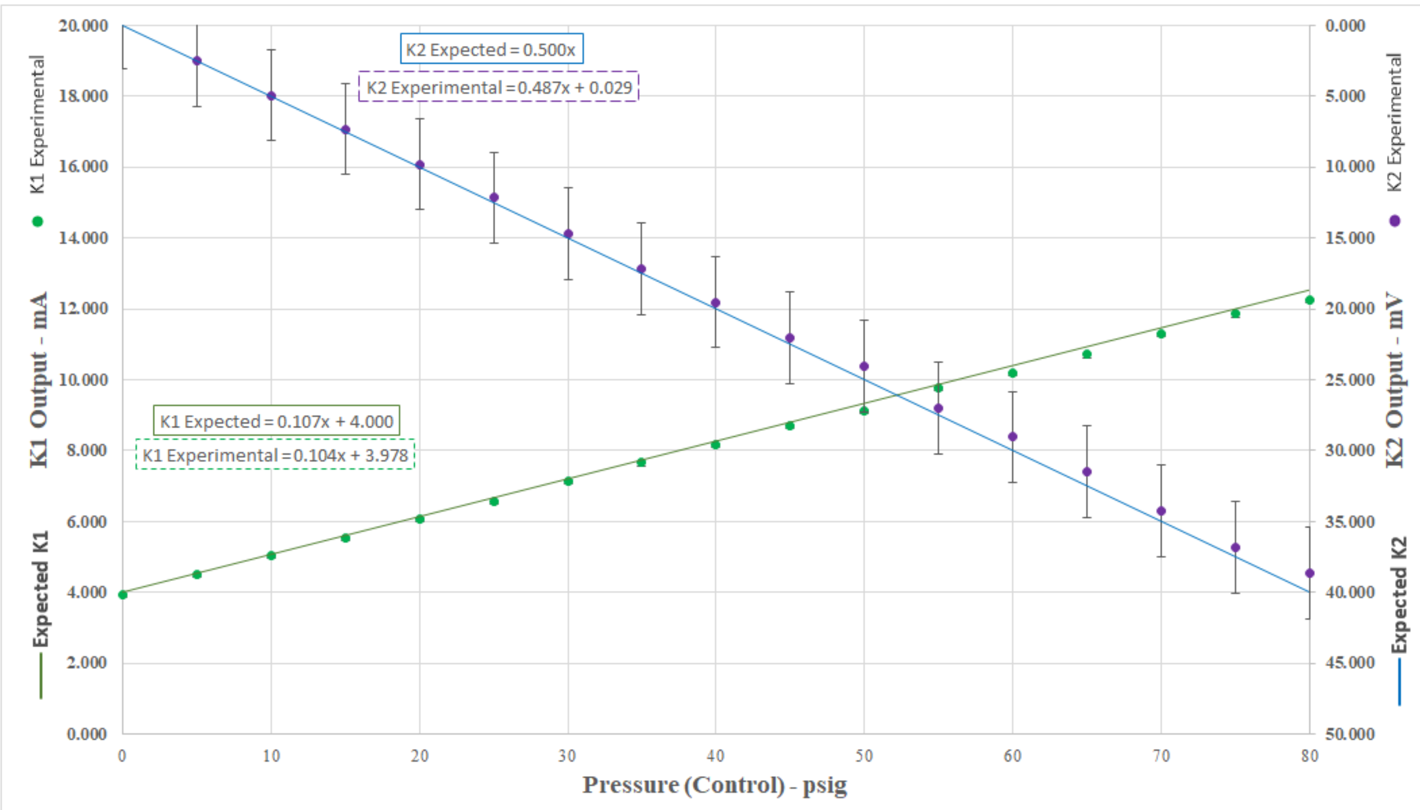


Figure 1. The K1 and K2 transducers had percent slope errors of 2.4% and 2.7% & offset errors of 0.022 ± 0.056 mA [95%] and 0.029 ± 3.224 mV [95%] respectively.

Outputs of Ashcroft type K1 and K2 transducers were collected in a pressurized system through an ELVIS II board while a Helicoid gauge dictated the reference pressure of the system. Electronic measurement limitations required a mA to mV output conversion for transducer K1 through the 617 ± 12Ω (±2%) resistor shown in the 'Experimental Setup Attachment', while the K2 transducer provided a direct voltage reading. Supply voltages of the two transducers were determined through their data sheets [1 2]. The voltage collection ranges, and the resistor were selected under the 0 to 100 psig equipment limitation as shown in the 'Range Selection Attachment'. Readings were collected in sets of seven from 0 to 80 psig in increments of 5 psig on the Helicoid Gauge. The outputs of the transducers were plotted individually as a function

[1] Ashcroft – Model K1 Pressure Transmitter
[2] Ashcroft – Model K2 Pressure Transducer

of the control pressure to determine the error against expected calibration lines. The expected calibration lines were calculated through the pressure and output range of each transducer as shown in the 'Expected Values Attachment'.

The uncertainty of the two transducers were calculated through a combination of mathematically obtained bias and precision uncertainty. The bias uncertainty for each transducer was set as half of the largest difference between pairs of the minimum and maximum mV values at 0 psig. The precision uncertainty was calculated at a 95% confidence interval for each group of seven readings. Relevant formulas are shown in the 'Uncertainty Attachment'.

The experimental calibration line of transducer K1 followed a slope of 0.104 ± 0.001 mA/psig [95%] with 2.4% error and an offset error of 0.022 ± 0.056 mA [95%]. The line of transducer K2 followed a slope of 0.487 ± 0.079 mV/psig [95%] and an offset error of 0.029 ± 3.224 mV [95%] with a 2.7% slope error. Note that offset errors can be overlooked as they will be eliminated by calibrating for the experimental line during use. Experimental results are within the 2.73% error range from the transducers' respective datasheets, confirming their viability for use in the proposed inflation system. Transducer K1 was selected for the inflation system as it had a much lower offset uncertainty which will provide more repeatable results. The inflation system is shown as programmed in LabVIEW in Figures 2 and 3.

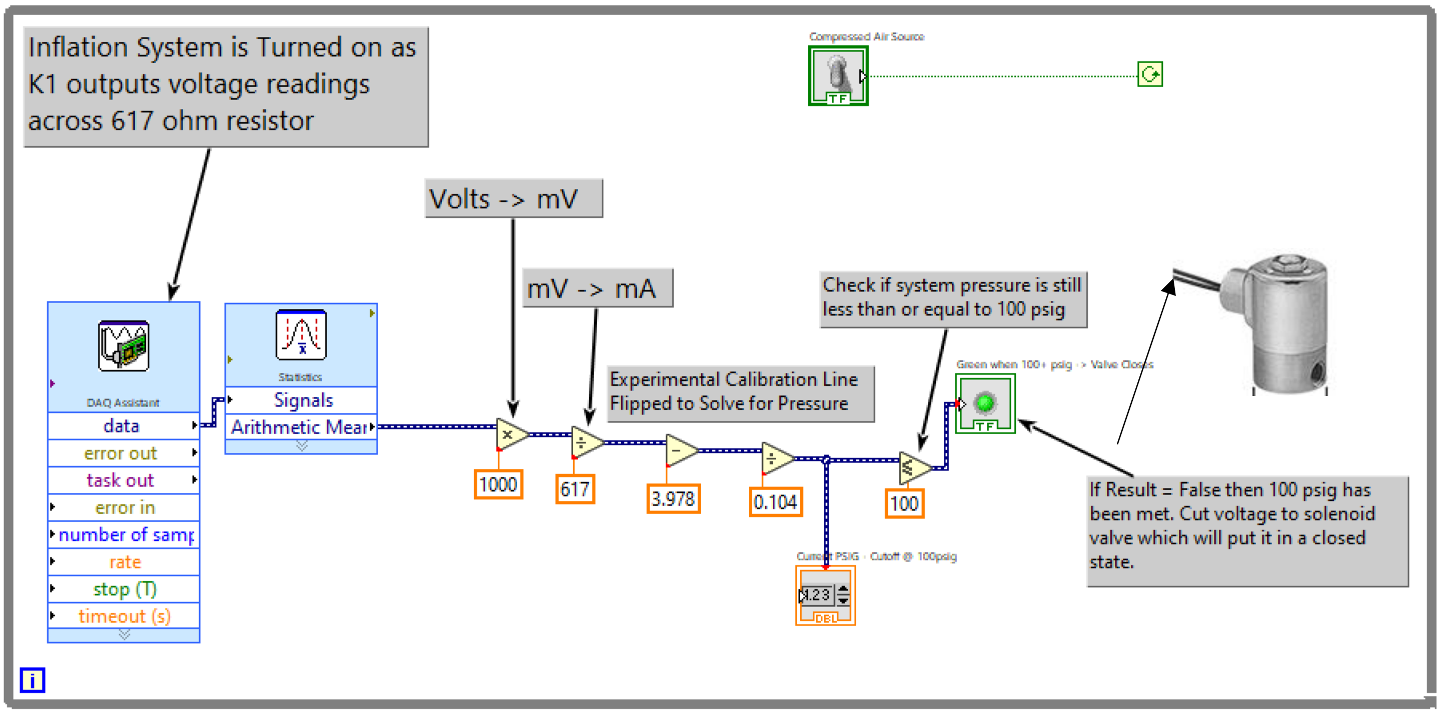


Figure 2. Proposed functional logic displayed in LabVIEW. Using transducer K1 and a high-pressure solenoid valve for the tire inflation system. Design assumes continued use of 617Ω resistor and validity of the experimental calibration line.

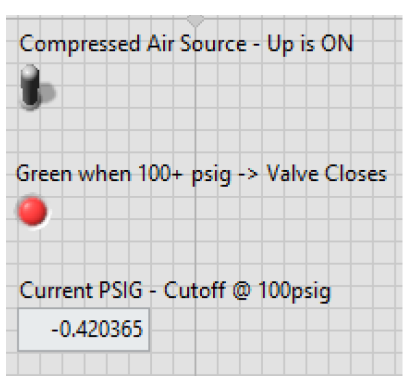


Figure 3. The control panel shows the compressor toggle switch and a live pressure indicator.

The pressure control system relies on a high-pressure solenoid valve which will be provided a continuous voltage supply during inflation. The voltage will be terminated as the LED indicator turns green, leaving the valve in a closed state. The shown system was tested through manual data entry and should operate expectedly so long as the pressure transducer is functioning. Note that drastic temperature changes will have a measurable effect on transducer outputs and therefore the automated system. However, this is deemed negligible given the required accuracy for tire inflation.

Attachments: Expected Values, Resistor Selection, Experimental Setup, Uncertainty, Calculations, Alternate Graph.

EXPECTED VALUES

This attachment shows the expected calibration lines for each transducer found from the given pressure and output spans. The experimental limit is also calculated for the purpose of finding appropriate data collection ranges and a resistor that would keep the output within voltage limitations of the ELVIS board. Table 1 and Table 2 show the minimum and maximum outputs for each transducer.

K1 - Current at Experimental Limit		
	Pressure psig	Current mA
Sensor Min	0	4
Experimental Limit	100	14.7
Sensor Max	150	20
Calibration Line (mA vs psig)	$y = 0.107x + 4.00$	

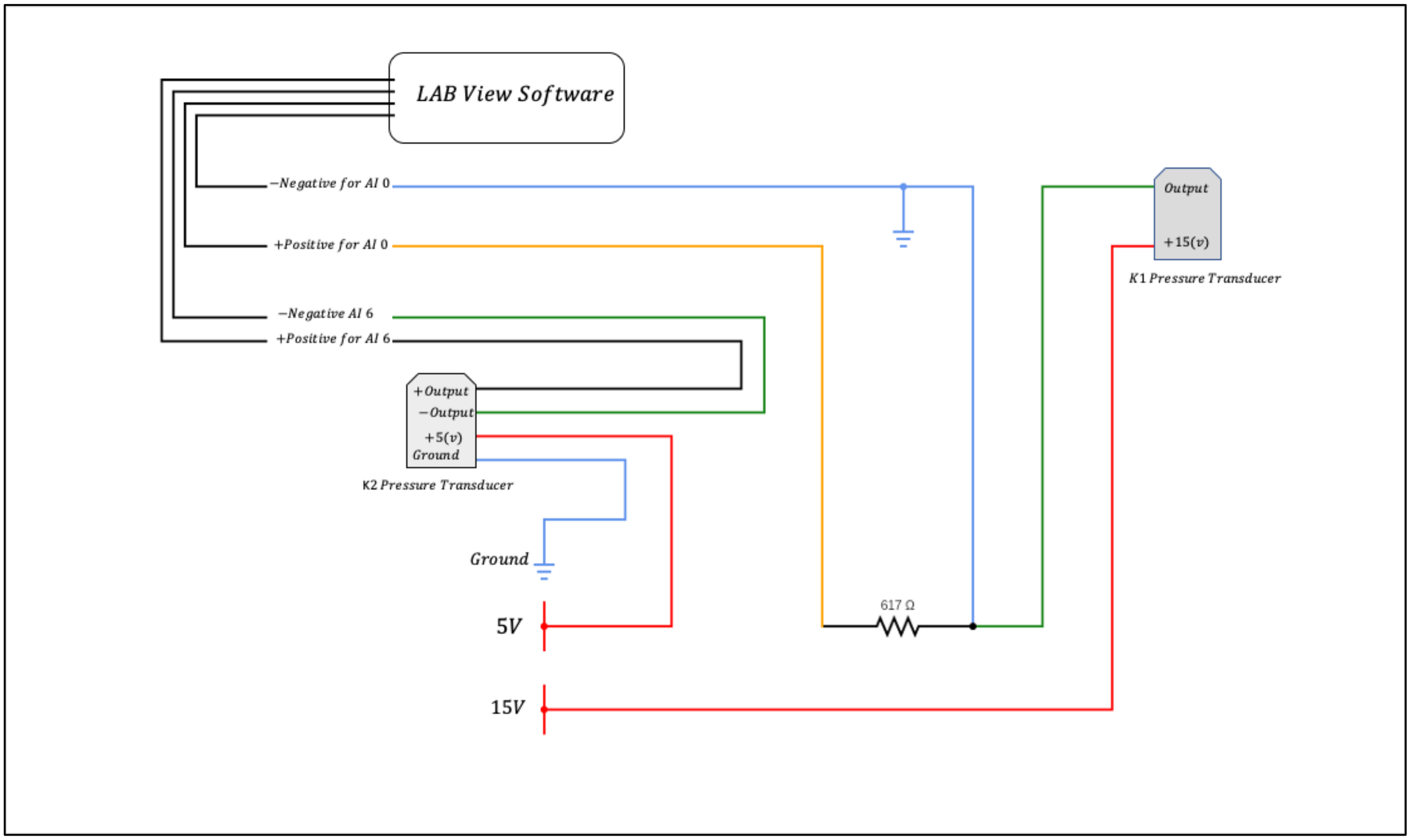
K2 - Voltage At Experimental Limit		
	Pressure psig	Voltage mV
Sensor Min	0	0
Experimental Limit	100	50.0
Sensor Max	100	50
Calibration Line (mV vs psig)	$y = 0.500x$	

RESISTOR SELECTION

The table below makes use of the expected calibration line for K1 found in the ‘Expected Values Attachment’ to calculate the output range when using a 617Ω resistor. The output range is held within the 10-volt limitation of the ELVIS board.

Resistor Optimization				
	Resistance ohms	Current mA	Voltage Volts	Voltage Span Volts
Min	617	0.004	2.47	6.58
Max	617	0.01467	9.05	

EXPERIMENTAL SETUP



UNCERTAINTY

Standard Deviation - (Sample)

$$\boldsymbol{\sigma = \sqrt{\frac{\sum(x_i - \overline{x})^2}{N - 1}}}$$

where

x_i is each voltage measurement in individual groups of seven points from the two transducers

$\overline{x}$ is the mean of each group of seven measurements

N is the number of data points in each data set

Standard Error of the Mean

$$\boldsymbol{\sigma_M = \frac{\sigma}{\sqrt{N}}}$$

where

σ is the standard deviation

N is the number of data points

Uncertainty - Precision

$$\boldsymbol{U_{xP} = \frac{Z * \sigma_M}{\sqrt{N}}}$$

where

Z is the z-score used for the desired confidence interval (1.96 for 95% CI)

σ_M is the standard error of the data set

N is the number of data points in each data set

Uncertainty - Combined

$$\boldsymbol{U_x = \sqrt{u_{xB}^2 + u_{xP}^2}}$$

where

U_{xB} is the bias uncertainty of the individual sensors

U_{xP} is the precision uncertainty of the individual sensors

CALCULATIONS

K1 Current Output at Each Pressure (mA)

$$\boldsymbol{C = \left(\frac{V_A}{R}\right) * 1000}$$

where

C is held as the current output of K1 in mA at each tested pressure

V_A is the voltage average of each individual set of seven points

R is the resistance value of the resistor in ohms

K2 Voltage Output at Each Pressure (mV)

$$\boldsymbol{V_{K2} = (V_A * 1000)}$$

where

V_{K2} is held as the voltage output of K2 in mV at each tested pressure

V_A is the voltage average of each individual set of seven points

ALTERNATE GRAPH