Pacific Northwest National Laboratory
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PNNL-17719

Pressure Sensor Calibration using VIPA Hardware

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Prepared for the U.S. Department of Energy
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I. Introduction/Background

The pressure sensors used in the Deployable Analysis System output an analog voltage representative of the current pressure the sensor is reading. This output voltage range may be different for different sensors, but is generally between 0 and 5 volts, or 0 and 10 volts. This means that if you have a pressure sensor that has a pressure range of 0 to 100psi, and output voltage range of 0 to 10 volts, then when the sensor would output 10 volts when it senses 100psi. Similarly, if the pressure is 0 psi, the voltage output of the pressure sensor would read 0 volts.

The VIPA hardware uses a series of modules to control the system. One of the modules that the VIPA hardware uses is a 16-bit analog input module. The main purpose of this module is to read in a voltage. The inputs of these modules are connected directly to the voltage outputs of all the pressure sensors in the system. Because the sensors have different pressure and voltage output ranges, it is necessary to calibrate and scale the sensors so that the values make sense to the operator of the system.

II. VIPA and Hardware Menu Programs

VIPA is a hardware control system that provides a way to communicate digital and analog signals to and from a computer that is running VIPA communication software. In the case of DAS, a program called *vipaServer* is used to communicate to the VIPA hardware. *vipaServer* reads and writes analog and digital values to the VIPA hardware. VIPA analog signals are all in raw voltage units. A configuration file, *vipa.cfg*, exists for the *vipaServer* that maps all the channels to a physical location on the hardware. This makes it possible for a user to ask *vipaServer* for the voltage on channel 3, for example, and *vipaServer* would return the current voltage value for that channel. The program users can use to talk to *vipaServer* is called *vipaMenu*. *vipaMenu* is a small menu driven program that allows users to get and set channels on the VIPA hardware. This program is generally used for debugging and testing. *vipaMenu* may be launched from the DAS source directory with the command: ./vipaMenu .

As stated above *vipaServer* provides all analog values in raw voltages. There exists, another server program called *hardwareServer* that provides scaling of the voltage units. This server communicates to *vipaServer* and has the ability to scale voltages to more useful engineering units such as PSI or Torr. The scaling parameters are set in a configuration file called *hardware.cfg* that *hardwareServer* reads when it is first started. This file is located in a directory called “cfg” located within the main das source directory.

The scaling for voltage sensors uses gain and offset. This comes from the standard linear equation y = mx + b, where m is the slope (gain) and b is the y-intercept (or offset). In the case of a pressure sensor the equation becomes Pressure = m*voltage + b. Figure 2.0 below is a snapshot of the hardware configuration file.

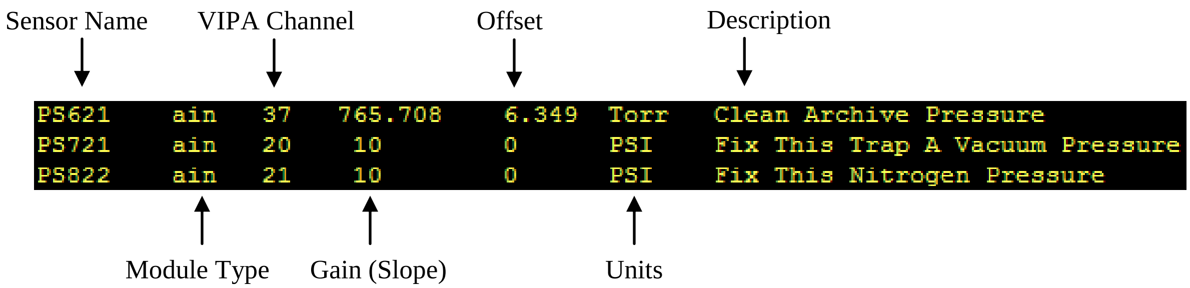

Figure 2.0 Snapshot of hardware configuration file (hardware.cfg).

The two columns that need to be modified in this file for performing calibration are the gain and offset for a particular sensor. The "units" column should also be modified to match the desired unit of measure for a given sensor.

In order to communicate with the *hardwareServer*, a *hardwareMenu* application exists. This program can be launched by running: ./hardwareMenu within the DAS source directory. When a pressure sensor value is requested using the *hardwareMenu* program, a value in engineering units is returned based on the offset and gain settings.

The *vipaServer* and *hardwareServer* refer to signals differently. The *vipaServer* refers to inputs and outputs as channel numbers. The *hardwareServer* uses sensor names. This information exists in the hardware configuration file (*hardware.cfg*). Figure 2.0 above, shows a Sensor Name and a corresponding VIPA Channel. In this case, if we wanted to find the voltage for sensor "PS621", we would launch *vipaMenu* and ask for analog input channel 37. To read this same sensor in engineering units with *hardwareMenu*, when prompted for the analog sensor name "ps621" would be entered.

The gain and offset are only applied when the *hardwareServer* is first launched, so if the configuration file is updated with a gain and offset number, it will need to be terminated and restarted. The server can be terminated through the *hardwareMenu* program.

Figure 2.1 below depicts the process of acquiring a reading form a pressure sensor. This starts from the pressure sensor, where the voltage is generated and illustrates the propagation of that voltage until it is read in software.

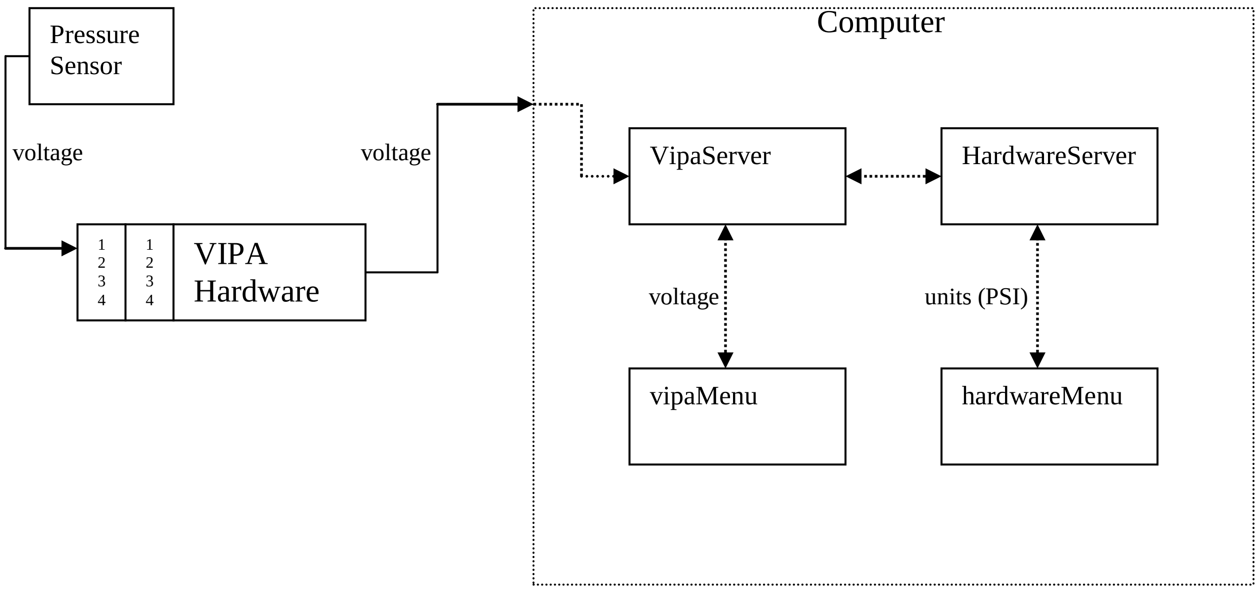

Figure 2.1 Propagation of sensor reading through the system.

This is a subset of the servers that are actually running on the system, but these are the ones necessary for calibrating the system.

In general, the *vipaMenu* program will be used to read out the raw voltages from the sensor and the *hardwareMenu* program will be used verify the results. Since the guided user interface (GUI) also communicates with the hardware server, it may also be used to verify the results. As previously stated, use the hardware configuration file to figure out what channel number the *vipaServer* is using to communicate to a particular sensor.

III. Calibration

The method used to calibrate these sensors is to apply a gain and offset. This is possible because the output of the pressure sensors is linear. The idea is to apply the general linear equation: y = mx + b, where m is the slope (or gain) and b is the offset. In the case of a pressure sensor, the equation looks as follows:

Pressure = *m**vipaVoltage + *offset*

where vipaVoltage is the voltage read in from the output of the pressure sensor. The terms that need to be calculated and entered into the hardware configuration file are *m* and *offset*. This method of calibration requires the user to have a calibrated pressure guage that can be used for measuring pressure at the different ranges. The method for calibrating the sensor is as follows:

1. Measure low pressure information

a. put the sensor under vacuum
b. record calibrated low pressure reading from calibrated pressure guage (this value will be the *calibratedLowPressureReading*)
c. using vipaMenu, record the low pressure voltage from the sensor (this value will be the *lowPressureVolage*)

2. Measure high pressure information

a. put sensor at atmospheric pressure
b. record calibrated high pressure reading from calibrated pressure guage (this value will be the *calibratedHighPressureReading*)
c. using vipaMenu, record the high pressure voltage from the sensor (this will be the *highPressureVoltage*)

3. Calculation

a. Using the information obtained from steps 1 & 2, calculate gain and offset for the sensor.

Recall that the equation for calculating pressure is:

Pressure = *m**vipaVoltage + *offset*

To find m, the slope, use the following equation:

$$m = \frac{calibratedHigh\mathrm{Pr}essure\mathrm{Re}ading - calibratedLow\mathrm{Pr}essure\mathrm{Re}ading}{high\mathrm{Pr}essureVoltage - low\mathrm{Pr}essureVoltage}$$

After the slope is determined, the offset may be calculated with either of the equations below:

$$offset = calibratedLow\mathrm{Pr}essure\mathrm{Re}ading - (m * low\mathrm{Pr}essureVoltage)$$

or

$$offset = calibratedHigh\mathrm{Pr}essure\mathrm{Re}ading - (m * high\mathrm{Pr}essureVoltage)$$

The plot below illustrates the basic idea of the calibration for a sensor. Notice that in this case a 5.4 voltage reading from the sensor corresponds to a 64 psi pressure reading.

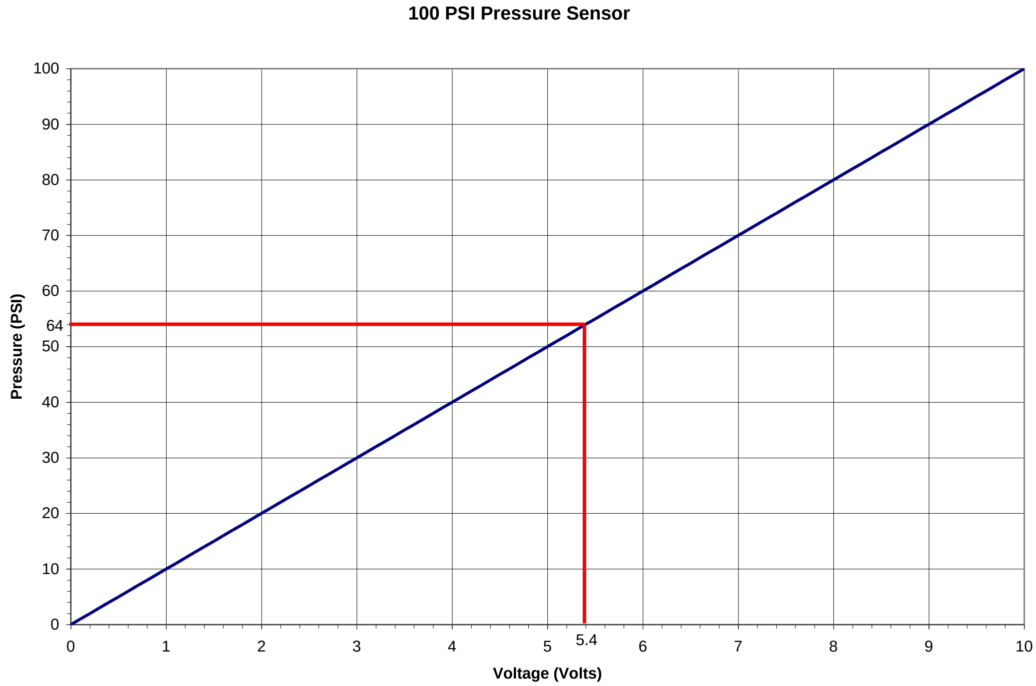

Figure 3.0 Calibration plot for 100 psi sensor with 0 to 10 volt output