SENSOR TRAINING FOR ENGINEERING STUDENTS

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Abstract
In September 2004 this industry-university team with help from others in their organizations started developing laboratory experiments that could be used to introduce students to sensor technology. The authors believe knowledge of sensor mechanisms, calibrating, testing, materials, sources-of-error, related-statistics and applications would be useful to students as new employees in many organizations. This paper describes progress in building the first student laboratory experiment based on pressure sensors used in process control. Emerson Process Management has developed several types of pressure sensors and produces hundreds of thousands of sensors each year. The company donated two types for this project, 1) a diaphragm-capacitance device and 2) a piezo-resistive device. A test fixture was constructed which supplies air pressure to the sensor from a dead weight tester (provided by Emerson). Changes in capacitance of the diaphragm sensor are measured and readings from an Emerson pressure meter are taken as the pressure is varied (example results are described here). The test fixture with the diaphragm-capacitance sensor is now available for use in student labs. Detailed experiment directions will be created and the equipment will be used in student labs this year. In the future Emerson sensors will continue to be investigated and sensors from other example industries will be sought for use in student laboratory experiments.

Need for Sensor Training
Sensors are a critical part of almost every system. Process control, medical devices, mechanical positioning, motion sensing; etc., the applications are endless. While not the most expensive part of a system or product they are often the most critical element. And, the materials used to make sensors are almost endless.

Many fabrication and application issues are similar for different types of sensors even though the details of construction and sensing may differ. Making identical sensors having identical performance is the goal, but one that is always just out-of-reach. While the fabrication processes and construction details may differ, the statistical techniques and experimental methods used to isolate contributors to variation can be applied to all sensors. The business of making repeatable and accurate sensors is very difficult and there are many jobs available for creative, capable hardworking engineers.

The use of sensors in products opens the door to endless engineering opportunities and challenges. In testing new products which employ new or upgraded sensors a common challenge is to isolate the cause of low yield. A common question is “Is it the tester or the product that is failing?” Just try getting one thousand testers to produce identical measurements on thousands of product parts that are constantly being refined while the testing is on-going. Then, see how many sleepless nights you have.

New engineering graduates with training in sensor technology and sensor applications would have unique skills to offer employers in industry and other sectors where sensors play a critical role. A foundation in sensor fabrication, performance and application issues would enable new employees to more quickly become useful in sensor-related assignments. A broad sensor technology perspective would help new employees think beyond the current issues and bring related knowledge to bear on the problems.

In electrical engineering and electronics engineering technology programs typically some sensors are mentioned in order to illustrate applications. For example a common application involves the microprocessor being used to calibrate a temperature sensor. While the basic idea of non-linearity is mentioned, the related construction issues are usually not covered. Also not covered are the details of sorting out the causes of varying performance and the methods of calibrating thousands of parts at minimum cost.

In industry a few engineers are employed developing new circuits and new components. At the same time at least tenfold other engineers are employed resolving extremely difficult issues so that industries can year-after-year make thousands of products having every-increasing-capability at a profit. Sensor-related employment opportunities are endless.

Approach to sensor training

Our industry-university team with help from others in their organizations started in September 2004 developing laboratory experiments which could be used to introduce students to sensor technology. The industry participants brought to the team the real world experience of making pressure sensors for large process control applications such as oil refineries. The university team included a senior student, Dan Hanson, and we plan to have students participating in sensor projects. One goal is to work with sensor elements being used in final products and compare the performance of the sensor element with the final product. Then methods of calibration and compensation can be studied. Also, fabrication issues can be studied and discussed with engineers who developed the sensors.

Emerson Process Management is a global supplier of products, services, and solutions that measure, analyze, control, automate, and improve process-related operations. Emerson Process Management has customers in the chemical, oil and gas, pulp and paper, pharmaceutical, food and beverage, power, water and wastewater, and other process-related industries. Emerson Process Management generously provided sensors, pressure meters, a dead weight tester and technical guidance for this project.

In a series of laboratory projects students will take data, analyze results and study sensor technology topics. These will include general characteristics, materials, methods of interfacing, methods of compensating for non-linearity, methods of testing, methods of selecting, sensor limitations, sources of errors, applications and requirements. The laboratories will include study material which is readily available on the web. A web site is being built which will include references to experts, other web sites, sensor technology centers, descriptions of local projects and interactive training tools.

Emerson Pressure Sensor

The pressure sensor in our first experiment consists of two matching steel cylinders welded together with a diaphragm sandwiched between (Figure 1). The diaphragm moves between the two plates in response to the difference in pressure between two air inlets (Figure 2). The capacitance between the diaphragm and each plate ($C = \epsilon A/d$) changes as the diaphragm is moved by the pressure difference. The Emerson pressure meter product consists of the sensor, electronics, and LCD readout housed in a heavy-duty steel chamber (Figure 3).

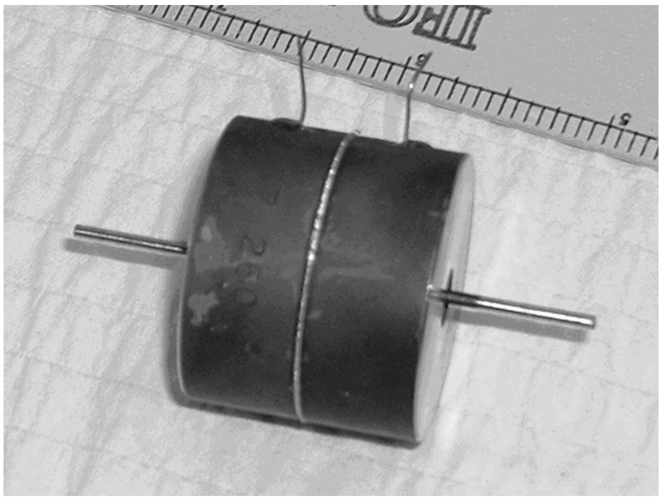

Figure 1. Emerson Pressure Sensor

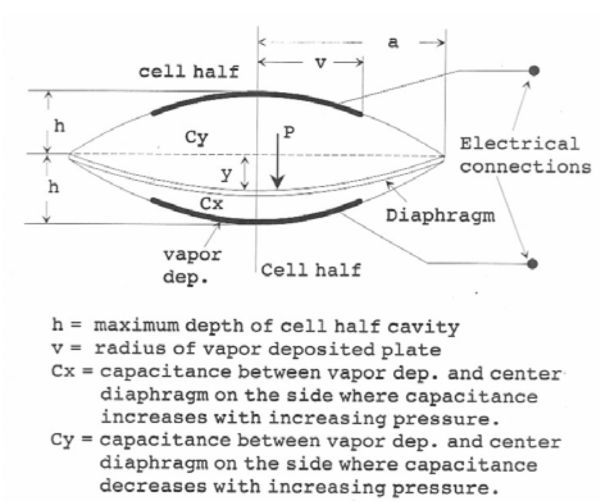

Figure 2. Sensor Capacitances

Figure 3. Emerson Pressure Meter

Pressure Sensor Test Fixture

A test fixture (Figures 4 & 5) was constructed for the purpose of gaining experience with the equipment and to test designs for student lab equipments. The test fixture consists of a pressure sensor, pressure meter, capacitance meter, air-pressure source, valves and pipes. Valves 3 and 4 provide a means of venting each side of the sensor to the atmosphere.

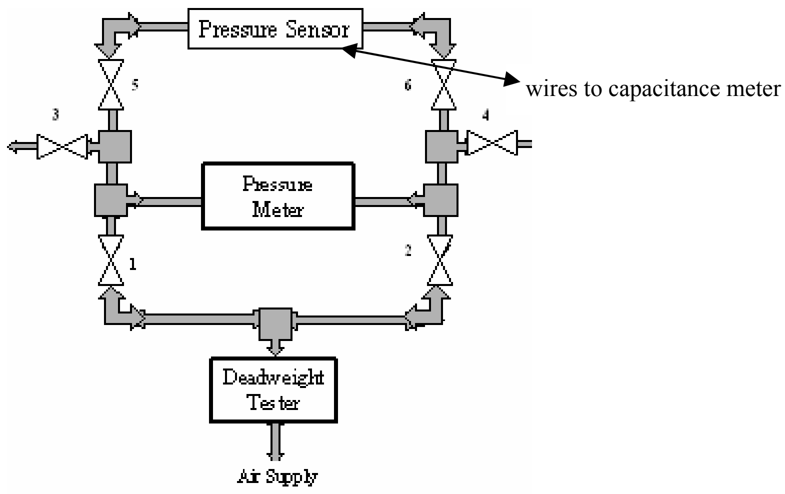

Figure 4. Test Fixture Diagram

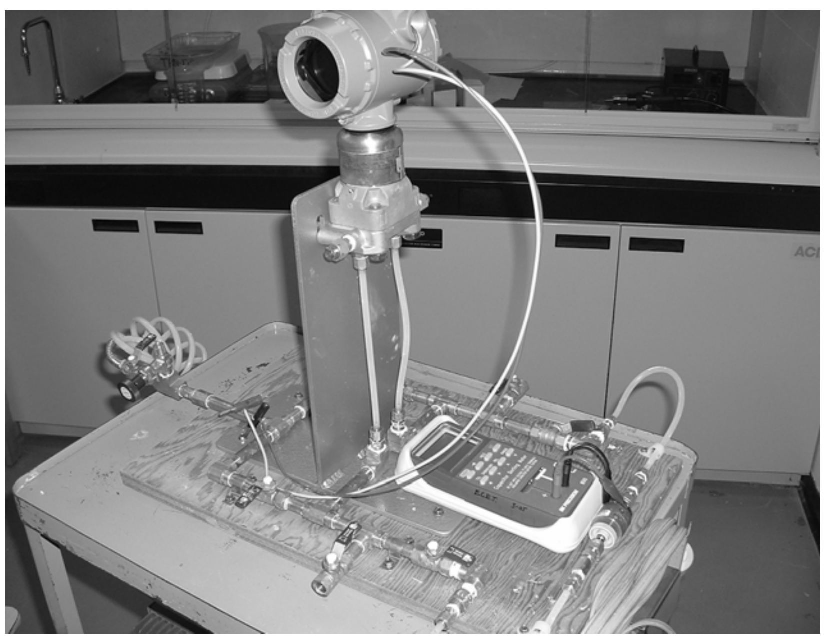

Figure 5. Test Fixture

The dead weight tester (Figure 6) is an air-pressure regulator which reduces a high-level input-air-pressure to a value determined by weights placed on a floating cylinder.

Figure 6. Dead Weight Tester

Testing

An example of the measurements that can be taken with the fixture is described in this section. The pressure as measured by the Emerson meter was recorded (Figure 7) as increasing amounts of weight (in inches of water) were placed on the floating spindle of the dead weight tester. As expected the relationship was linear over most of the range of inlet pressure. An offset of 3.8 inches of water was observed which is thought to be caused by the weight of the spindle.

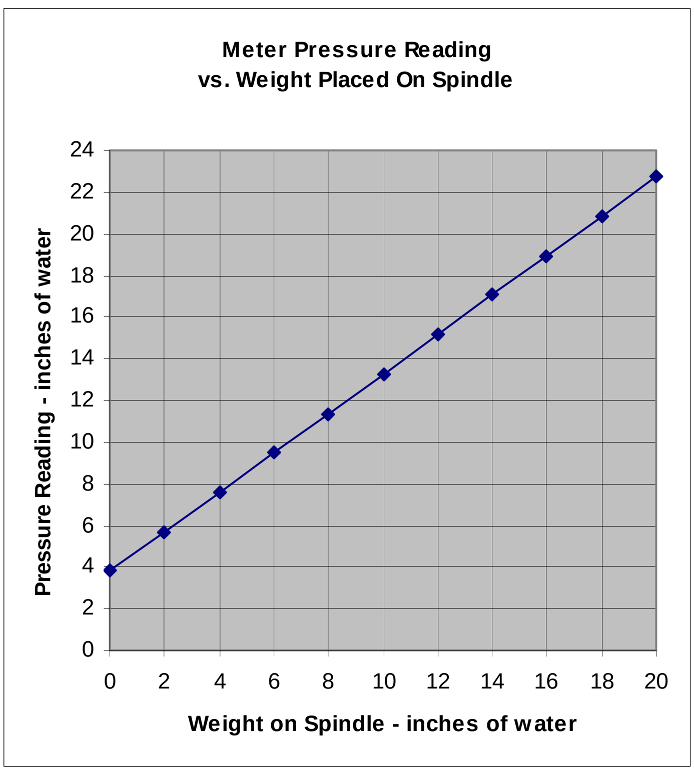

Figure 7. Meter Reading vs. Dead Weight Tester

Capacitances between the diaphragm and the each plate were measured as air-pressure supplied to one air-inlet of the sensor was varied from 3.8 to 22.8 inches of water. At the same time the air inlet on the other side of the sensor was left open to room air pressure. The inlet pressure was increased in steps of 2 inches of water. When no external pressure was applied to the sensor the initial capacitance of each side of the sensor was about 26pF as estimated from the data plot…This initial capacitance consists of the sensor capacitance plus capacitance between wires leading to the sensor. The starting weight of 3.8 inches of water is close to the unloaded weight of the spindle which was thought to be 4 inches of water.

The plots of capacitance readings taken on each side of the sensor differ due to the nonlinear relationship between pressure and the position of the diaphragm. As the inlet pressure was increased to one side of the sensor the diaphragm moved away from one of the plates. The total change in capacitance over the range of inlet pressure varied from 25.6pF to 23.3pF. At the same time the diaphragm moved closer to the other plate and the sensor capacitance increased from 27pF to 32.2pF.

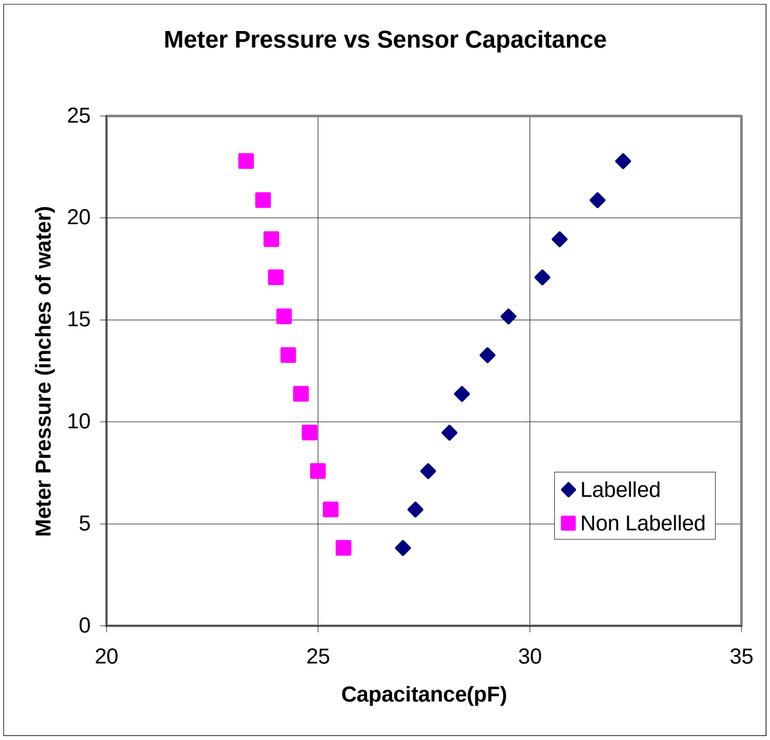

Figure 8. Example Capacitance Measurements

Future Work

Our next step is to create detailed descriptions of one or more experiments for students to work in the coming year. The term started recently and thus far one sensor laboratory class was held (Figure 9). The theory of operation was presented and the students recorded capacitance values and pressure meter readings. The students asked several questions and seemed very interested in learning about the sensor. Student reactions will be used to guide updating the experiment draft.

Figure 9. First Sensor Laboratory Class

We plan to continue working with the Emerson pressure sensors and create additional experiments. Also we are considering other types of sensors for future laboratory experiments.