

## **Integrating Measurement Instruments in Pneumatic Lab Activities**

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### Introduction

Measurement plays a vital role in assessing and controlling the performance of a lab activity and/or an experiment. In almost all lab activities and real world engineering applications one needs to monitor the system performance by means of measurement, i.e., speed of a conveyor belt, the pressure at the input of an actuator, to name a few. Students must be familiar with measurement methods and techniques and how to set up a measurement device to correctly measure the variable(s) of interest.

One of the courses in Mechanical Engineering Technology, offered by the University, is fluid power, which is a sophomore-level course. It covers both the theoretical and applied concepts of hydraulic and pneumatics with about 60% lecture time and 40% lab time. Table 1 shows more details about the topics and lab activities of the course.

Table 1. The topics and lab activities of fluid power course as are being currently covered.

Lecture		Lab
Hydraulics	Principles and Laws	No lab
	Pumps	Labs 1 - 4
	Cylinders	
	Valves	Labs 6, 7, 9, and 10
	Motors	Labs 5 and 8
	Circuit design and analysis	No lab
Pneumatics	Principles and Laws	No lab
	Cylinders and Valves	Labs 1 - 3
	Circuit design and analysis	No lab

For the hydraulic lab activities, there are four Vickers trainers (Figure 1) that are used which have gauges for pressure measurement. Students measure the pressure wherever needed according to the lab instruction. There are a total number of 10 hydraulic lab activities which are covered during the first half of the semester during which the relevant hydraulic lectures are being delivered. The lab activities are mainly based on the technical manual supplied by the hydraulic trainer manufacturer (Vickers which is now part of Eaton [1]). Students will build various circuits and use several components such as cylinders hydraulic motors, sequence valve, pressure reducing valve, etc. All of hydraulic lab activities include measurement and in addition, students are to draw a schematic of the circuit they have worked on. This helps them relate the components to hydraulic symbols. The trainers also include ANSI symbols shown by each component which matches the ones used in lab activities schematics.

However, for the current 3 pneumatic lab activities, students can only observe how the circuit behaves, e.g., whether cylinders connected in series extend and/or retract depending on the

circuit. In addition, as indicated in Table 1, there is no activity concerning hydraulic and pneumatic circuit design and analysis. Some software packages include measurement tools, though virtual and theoretical, so that the designer can observe how much pressure is available at the inlet of a motor, etc. However, such exercises are not being covered in the course.



Figure 1. The Vickers hydraulic trainer

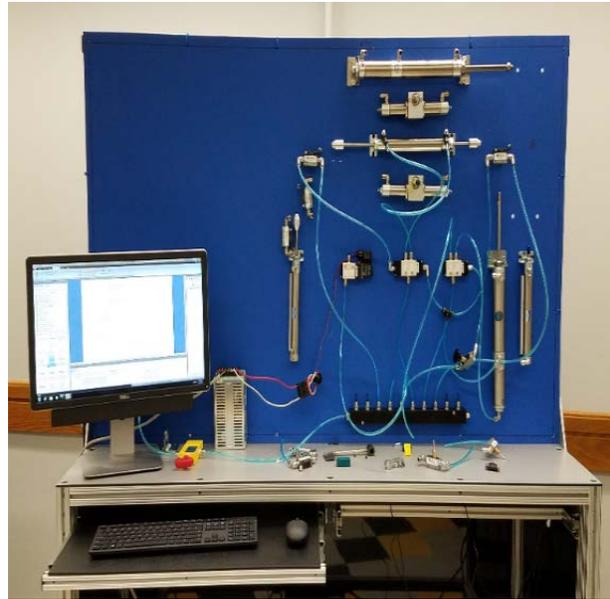


Figure 2. The pneumatic trainer

### *The goal and scope*

This article reports the development of introducing the concept of measurement in pneumatic lab activities using a software package, called Automation Studio. This is the first phase of a two-phase project which will eventually include measurement within the circuit by replacing regular cylinders with position feedback ones that send cylinders feedback to a software program. The scope of the paper is on the first phase of the project, however. Furthermore, due to the current trend in industry, in terms of more emphasis on mechatronics, both phases of the project will be on enhancing the lab activities of pneumatic circuits.

### *Current pneumatic lab*

The pneumatic lab, which is still in development phase, includes 6 trainers. One of the trainers is partially ready on which students can perform three labs. The pneumatic equipment were all provided by Bimba Manufacturing [2] who collaborates with the college to build the trainers. Each trainer has two sides: one for basic lab activities and the other side for advanced activities. The basic lab activities which cater to students and in particular, fluid power course. The advanced activities cater to Bimba's customers training and also will be used for research and development. The focus of this paper is on the former.

## Lab development

As shown in Table 1, there are 10 hydraulic and 3 pneumatic lab activities. Students perform the lab activities in groups, typically three or four students in each group. All the lab activities include the following steps for students to perform:

- 1- Setting up the lab.
- 2- Building the circuit to perform the task(s) required (i.e., to extend two cylinders in parallel and to retract in the same order).
- 3- Testing and reporting to the instructor.
- 4- Drawing the circuit using the components depicted in the lab exercise, upon instructor's approval of the circuit.
- 5- Answering questions and/or filling tables in the lab exercise.

## The new lab activities

The authors developed the two new lab activities based on the above steps to be consistent with other lab activities as explained below.

### Lab 1: Introduction to Famic Automation Studio

Famic Automation Studio™ is a software package for designing and simulating hydraulic and pneumatic circuits [3]. The pneumatic trainers are equipped with PCs on which the package is installed (Figure 2). Students will be able to use the software to design and simulate a pneumatic circuit using the software and then build it on the trainer. Figure 3 shows a screenshot of Automation Studio.

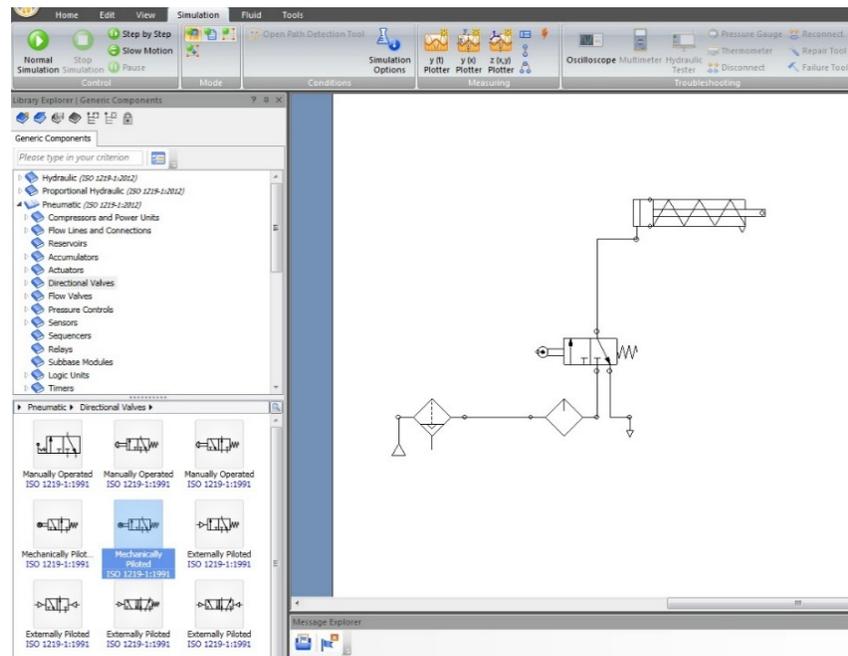


Figure 3. The pneumatic circuit used for the first lab activity using Automation Studio.

The lab activity has two sections. In the first section, the instructor introduces the software and gives the circuit shown in Figure 3. The circuit consists of a two-position, three-way, mechanically-piloted valve, and a single-acting cylinder. The basic information to build the circuit, such as pressure, bore size, etc. are provided so students will be able to build the circuit and simulate it. Next, the instructor discusses dynamic measurement tools which are essentially “gauges” that one can insert at components’ ports to measure, for instance, the pressure (Figure 4). These are theoretical calculations which students have learned during the lecture portion of the course. The software also, provides details of the formulas for review, as shown in Figure 5, so students can refer to them to calculi theoretical quantities.

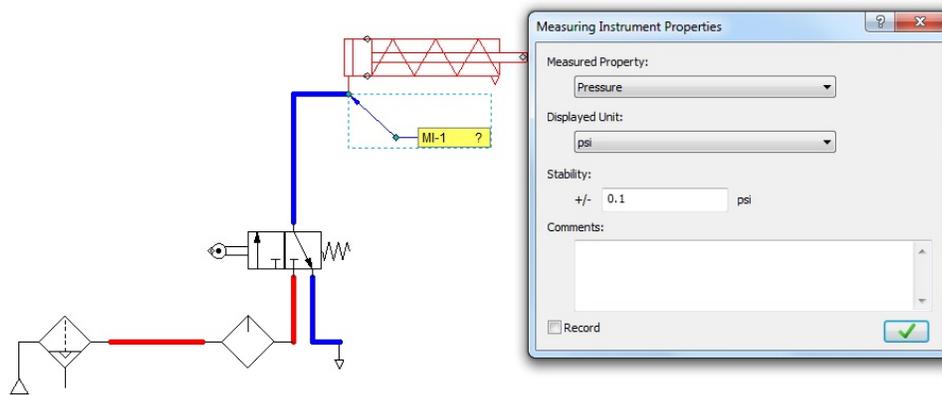


Figure 4. Inserting a dynamic measurement tool in a model.

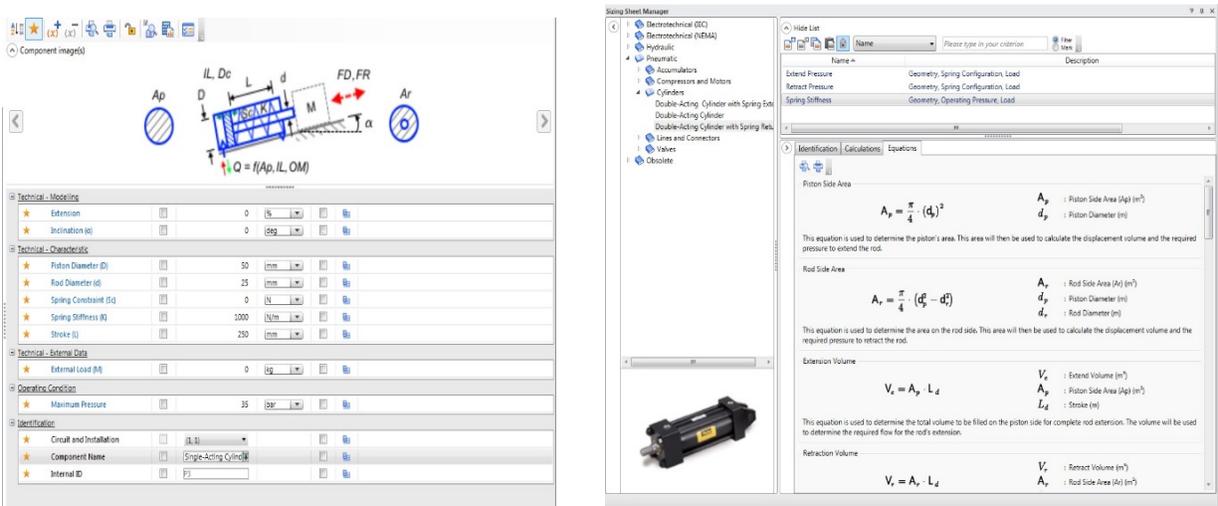


Figure 5. Component properties window (left) and sizing sheet manager (right)

In the second section of the lab, students build and simulate the circuit shown in Figure 6 which has been discussed in the course textbook [4] (one of the advantages of the textbook is that it includes simulations of some of the circuits using Automation Studio. Students will be able to compare and contrast the results of hand calculation with the ones generated by the software). Then, students will modify the circuit to include another cylinder in parallel to the existing one

and simulate it. The software provides some theoretical calculations such as the cylinder's cycle time and speed. Finally, students will build the actual circuit on the board to verify their simulation.

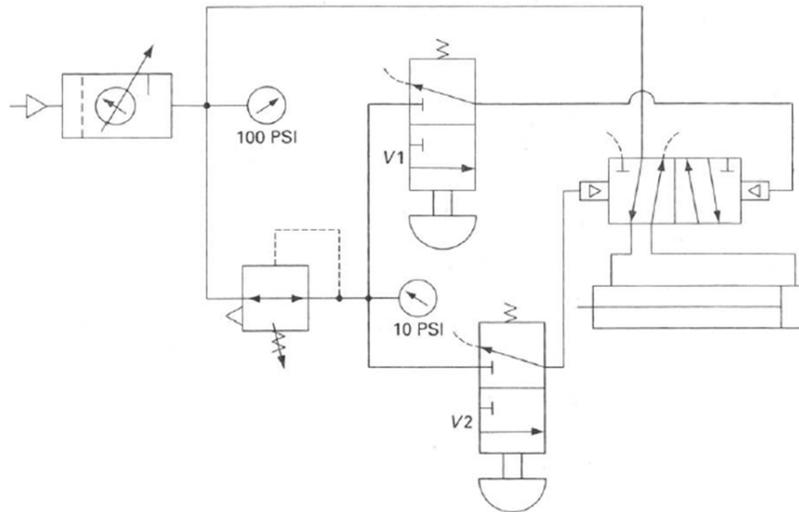


Figure 6. The circuit discussed in Chapter 14 of the textbook [4, Ch. 14, pp. 519]

*Lab 2: Extending two cylinders with different load*

This lab has two parts: the first part is an exercise for students to design and build a pneumatic circuit that utilizes two cylinders to lift a load. The schematic is shown in Figure 7.

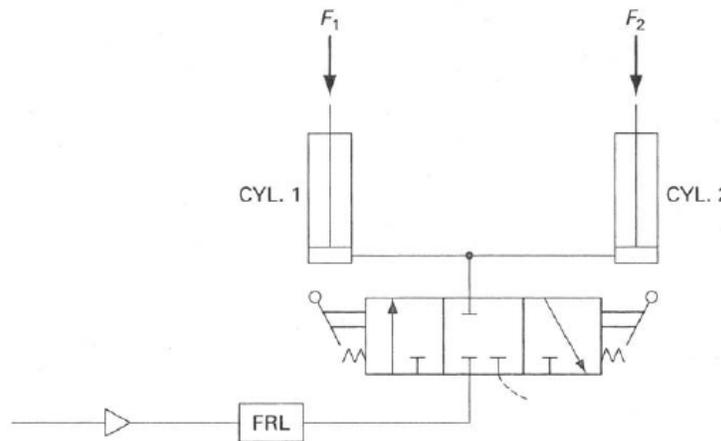


Figure 7. The circuit used in the last part of the lab activity [4, Ch. 14, pp. 537]

For this lab, based on hand calculation, students should choose two cylinders with appropriate ratings to lift an arbitrary weight of 5 pounds with the input pressure of 25 psi. Then, students will build and simulate the circuit, shown in Figure 8, to verify their calculation. Similar to the first lab, they should utilize dynamic measurement to measure appropriate quantities such as pressure at cylinders' cap ends.

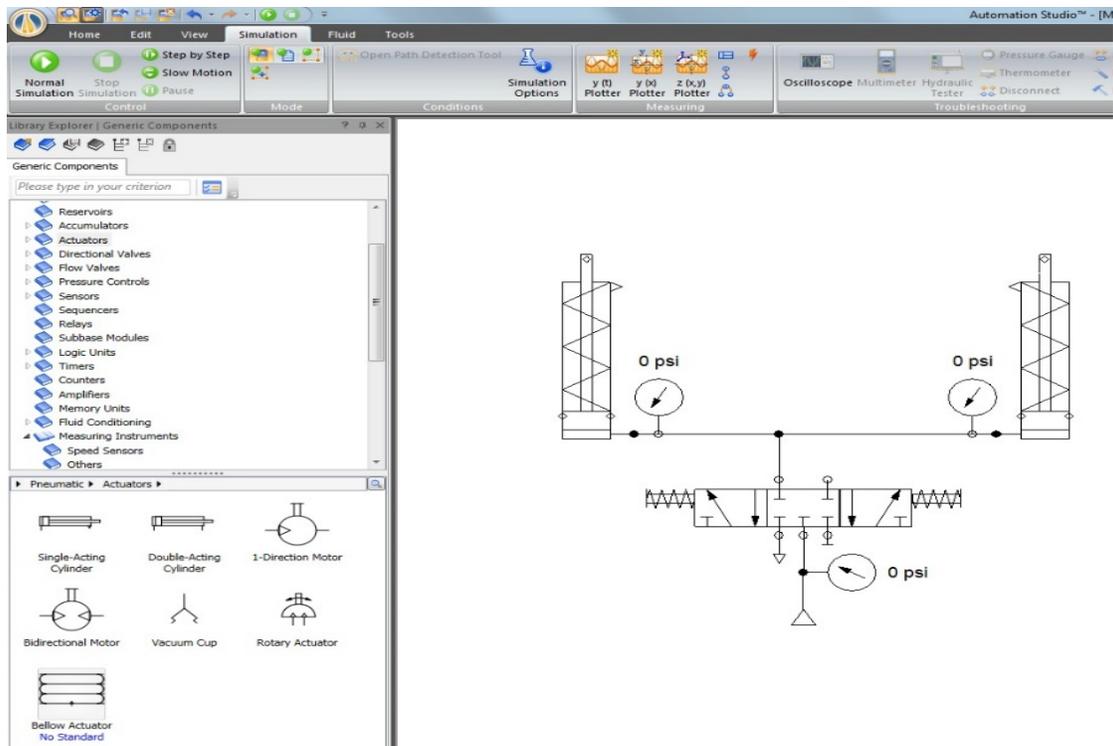


Figure 8. The model of the second lab circuit built in Automation studio

Then, students replace one cylinder with another one with a different bore size and simulate it. Figure 9 shows a snapshot of the simulation of two cylinders with different piston and rod sizes. The gages in the figure show the pressure at the cap end of the cylinders during the retraction cycle.

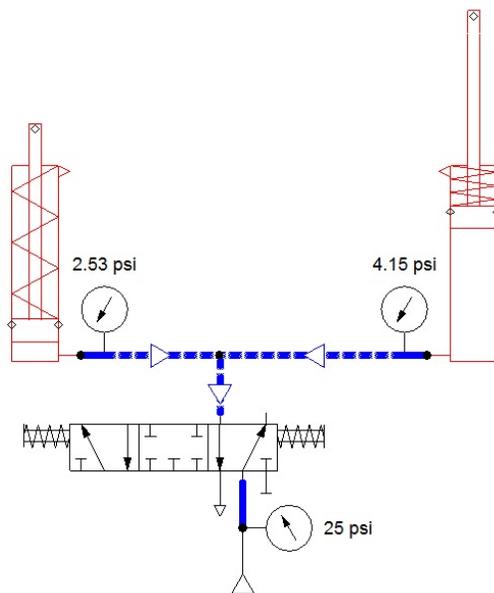


Figure 9. The simulation of the circuit shown in Figure 8. The cylinders have different specifications

In summary, students follow these steps to complete the first part of the lab:

- a- Given the known variables such as, cylinders' spec., pressure, etc., calculate the maximum weight that each cylinder can lift.
- b- Estimate the cylinders speed (students are to measure the time it takes for each cylinder to fully extend and then calculate the speed of each cylinder)
- c- Build the circuit using Automation Studio to verify the calculation.
- d- Replace one cylinder with the one of different rating and repeat Steps a to c.

In the second part, students will build the circuit on the pneumatic trainer to verify Step c. Also, they should answer the following questions:

- 1- Do you observe any difference between the hand calculation, the simulation, and the actual circuit built? Where do you observe the differences, if any, and why?
- 2- Explain what you observed in Part D. Propose a solution to modify the circuit so both cylinders extend/retract synchronously.
- 3- How would you modify the circuit for overrunning loads (e.g., loads that are more than the allowed maximum loads)

#### *Plans for assessment*

Upon completion of both phases, the authors will develop a survey to be given to the students enrolled in the course to collect their opinion on the devised lab activities. Of particular interest is whether the lab instructions are clear and consistent. Furthermore, the authors will seek students' suggestions on how to improve the lab activities, whether more activities should be added, and as such. The authors are planning to finalize the survey so that it will be ready for next fall semester.

#### *Conclusion*

As mentioned earlier, this paper presents the first phase of a two-phase project which focuses on integrating measurement into pneumatic lab activities. The authors are planning to extend this lab activity to include measurement by means of another software package provided by Bimba, the industry partner, to measure the positions of cylinders shown in Figure 7. The measurement requires using position feedback cylinders that send a signal back to the software to provide the necessary information. The authors will collaborate with the industrial partner to acquire necessary hardware and software to complete the second phase of the project.

#### *Acknowledgement*

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