

Maha Fluid Power Research Center

Intensive Course on HYDRAULIC CONTROL SYSTEMS

Dates and location:

February 22 – 26, 2027 at Purdue University, West Lafayette, IN
For online participants, lab sessions will occur on March 1 and March 2.

Participation modality:

In person at Purdue University (recommended) or Online.

The event is recommended for onsite, in-person participation, which is limited to 24 participants.

Onsite participants will maximize the learning outcomes from the hands-on labs, by directly accessing the hydraulic trainers.

Interactive lab sessions with the hydraulic trainers operated by the instructors will be offered to the online participants.

Target audience:

Industry professionals with STEM degree, already equipped with basic knowledge and experience in hydraulic components. The Maha intensive class on Fundamentals in Industrial and Mobile Hydraulics is recommended.

Course Description

This course covers the fundamental principles of hydraulic control actuation. Focus will be given to mobile applications, although the class will also describe some concepts of hydraulic servo. **The class assumes the participants being already familiar with the basics of fluid power components such as pumps, motors, cylinder, hydraulic control valves, and accumulators.**

The course details the design and functioning of complete hydraulic control systems. The basic control concepts are described first, for the case of circuits controlling a single actuator; the case of multiple actuators is covered afterwards, as an extension of the single actuator control concepts. Emphasis is given to the challenge of meeting functional requirements of a given application, while minimizing component costs and energy consumption. Starting from the basic circuits, the lectures and labs will cover current state of art systems for mobile and industrial applications, covering constant pressure systems, open center systems, load sensing systems, hydrostatic transmissions.

The course includes class lectures (mornings) but also hands-on labs experiences (afternoons). Labs will be performed using Purdue's Hydraulic Trainers specifically designed to support fluid power education. During the lab experiences, the participants will learn how to perform basic tests on components and systems, and how to analyze the functioning of system and their energy consumption.

One-hour tests (worked problem / quizzes) will be provided to all participants at the end of each day to assess the learning of class material.

Class and lab schedule

The class schedule differs for in-person participants and online participants, according to the tables below. The online participants will participate to the lab sessions remotely on Mar 23 and Mar 2.

schedule for in-person, onsite participants (US ET time zone)

	Mon, Feb 22	Tue, Feb 23	Wed, Feb 24	Thu, Feb 25	Fri, Feb 26
8:30am-10:00am	theory	Theory	theory	Theory	case study
10:00am-10:15am	break	Break	break	Break	Break
10:15am-12:30pm	theory&probs	theory&probs	theory&probs	theory&probs	case study
12:30pm-1:30pm	lunch	Lunch	lunch	Lunch	
1:30pm-3:30pm	lab 1	lab 2	lab 3	lab 4	
3:30pm-4:00pm	break	Break	break	break	
4:00pm-5:00pm	test 1	test 2	test 3	test 4	

schedule for online participants (US ET time zone)

	Mon, Feb 22	Tue, Feb 23	Wed, Feb 24	Thu, Feb 25	Fri, Feb 26
8:30am-10:00am	theory	theory	theory	theory	case study
10:00am-10:15am	break	Break	break	break	Break
10:15am-12:30pm	theory&probs	theory&probs	theory&probs	theory&probs	case study
12:30pm-1:30pm	lunch	lunch	lunch	Lunch	
1:30pm-2:30pm	test 1	test 2	test 3	test 4	

schedule for online participants (cont.)

	Mon, Mar 1	Tue, Mar 2
8:00am-10:00am	lab 1	lab 3
10:00am-10:30am	break	Break
10:30am-12:30pm	lab 2	lab 4

Morning lectures - structure

The morning sessions are classroom style lectures. The instructor will present the contents using material previously provided to the participants (pdfs and paper copies). Additional explanations will be provided using classroom blackboard or similar tools. The class participants are not required to purchase additional material; however, proper references for further readings and detailed explanations will be provided for who interested in further independent study.

Online participants will attend the classroom lectures using web-applications such as Zoom or similar, and they will have the opportunity to ask for questions and/or respond to online quizzes.

Labs - structure

In person participants will participate to afternoon labs which are hands-on experiences related to the contents presented during the morning lectures. The labs are performed at the Parker Hannifin Fluid Power and Motion Control Lab of Purdue University (Agricultural and Biological Engineering Department). Participants will be divided in groups of max 4 people and will use the Hydraulic Trainer (Fig. 1 below) to perform each experience.

Each lab experience has a handout that will be provided to each participant. The handout presents the goals of each test and describes the basic procedure to follow to perform the tests. The handout also includes specific questions related to the tests that stimulate the participant's learning.

Online participants will participate to the lab sessions where the instructor will use a head-mounted camera to perform the experience and interact with the online participants during the execution of the experience. The data collected during the experience will be used by the online participants to respond to the questions reported in the lab handout.

Figure 1 – *Hydraulic Trainers at the Purdue's Parker Hannifin Fluid Power and Motion Control lab*



Tests - structure

A test inclusive of quizzes and worked problems is provided every day to assess the comprehension of the material covered during the day.

Course completion certificate requires submitting all tests and performing with a score greater than 60/100. There is a total of four tests covering the material of Day 1 through Day 4. There is no test for the Day 5 (study cases).

Please note that the test will be kept confidential, the individual or overall test scores will not be shared to participants or employers.

Specific Learning Outcomes

After completion of the course, the participant will be capable of (course learning objectives):

- CL 1. Describe the operation, represent with proper symbology, the control and the energy consumption features of the hydraulic architectures available for controlling single and multiple actuators: primary controlled system, metering systems such as open center systems, constant pressure systems, load sensing systems, hydrostatic transmissions.
- CL 2. Discuss the features of the hydraulic control technologies commonly available for servosystems, mobile machinery and industrial applications, particularly in terms of cost, functionality and energy consumption.

- CL 3. Formulate, and present the most energy efficient solution for the hydraulic control system of a given fluid power application, given its functional requirements.
- CL 4. Apply proper experimental methods for basic troubleshooting of hydraulic control systems.
- CL 5. Test and properly report steady state performance of hydraulic control systems, including representing the power losses vs the useful power.
- CL 6. Experimentally measure and interpret the basic features of metering control systems, such as servosystems, including load sensing systems and open center systems

Tentative Schedule

The table below provides the schedule for the minicourse, which will occur from Mon – Thu (whole day) and Fri morning.

Day	Title	Topic	Textbook pages (*)
1. Monday morning (theory)	Single Actuator Control basics	Orifices	81-96
		Interpretation of orifices in fluid power systems: metering, compensator, orifices in pilot lines.	
		Control of single actuator – basic concepts and architectures	261-277
		Flow Supply vs Pressure Supply Primary vs. Secondary regulation Load conditions: resistive and overrunning loads	
		Control of a single actuator: metering configurations	293-329
		Metering control concepts: meter in, meter out	
		Control with combined metering,	
		Operating envelope of a valve-cylinder system	
1. Monday afternoon (lab)	Lab 1	Introduction to the hydraulic trainer Experience 1 – Pump and orifice characterization Experience 2 – Hydraulic regeneration Experience 3 – Meter-in, Meter-out, Bleed off configurations	

2. Tuesday morning (theory)	Single Actuator Control advanced	Methods for controlling overrunning loads: meter-out and counterbalance valves Open Center systems Basic Open Center – Valve design Advanced Open center systems: Negative and Positive flow control Load Sensing systems for a single actuator Basics of LS control LS systems with fixed displacement pump LS Systems with variable displacement pump Load sensing valve: design and architecture LS pump: controls architecture LS with independent metering valves Electronic LS	333-354 357-377 379-411
2. Tuesday afternoon (lab)	Lab 2	Experience 4 - Counterbalance valve Experience 5 – Open center circuit single function Experience 6 – Load sensing system – single function	
3. Wednesday morning (theory)	Multiple Actuators	Constant pressure systems Constant pressure system with variable displacement pump Constant pressure system with unloader (CPU) Constant pressure system based on a fixed displacement pump and accumulator Control of multiple actuators: series and parallel actuators Flow dividers and combiners Constant pressure systems for multiple actuators Open center systems for multiple actuators Load Sensing systems for multiple actuators LS systems without pressure compensation (LS) LS pressure compensated systems (LSPC) LSPC with pre-compensated valve technology LSPC with post-compensated valve technology Flow saturation and flow sharing in Load Sensing systems Flow saturation with pre-compensated LSPC	413-423 427-445 449-454 457-472 475-509

		Flow saturation with post-compensated LSPC Pre vs Post compensation comparison Independent metering with load sensing	
3. Wednesday afternoon (lab)	Lab 3	Experience 7 – Estimation of cylinder frictional force Experience 8 – Closed loop controls Experience 9 – Dual pressure circuit Experience 10 – Multi-user constant pressure circuit	
4. Thursday morning (theory)	Hydrostatic Transmissions and Actuators	Classifications and theoretical layouts Open circuit hydrostatic transmissions Closed circuit hydrostatic transmissions Applications for propulsions Power split transmissions (<i>if time allows</i>) Hydrostatic Actuators and Electro-Hydrostatic Actuators	543-559 560-572 572-581 593-624 631-642
4. Thursday afternoon (lab)	Lab 4	Experience 11 – Load sensing system with multiple functions – effect of compensators Experience 12 – Open center system with multiple functions	
5. Friday morning (practice)	Case studies	Case Study: Skid Steer loaders circuit Case Study: Wheel loaders Case Study: Excavator circuits	

(*) textbook pages refer to the book *Hydraulic Fluid Power: Fundamentals, Applications, and Circuit Design* by Andrea Vacca and Germano Franzoni. Purchase of the book is not required. All the class material (slides) will be shared to the class participants (printed copies, pdf).

Cost

Free registration for:

- 1 participant from Maha Fluid Power Research Center - Basic Members
- 2 participants from new Maha Fluid Power Research Center Basic Members (joining the center after Aug 2026)
- 3 participants from Maha Fluid Power Research Center Executive Members

\$ 1,500 / additional participants from members (*)

\$3,500 / participant for non-members (*)

(*) registration priority goes to members benefitting from free registration as detailed above

Registration includes all course material (books not included), lunches, and coffee breaks. No dinner/hotel accommodation provided.