Final Project Report

Project Title: Distributed Sensing and Control of Hydraulic Circuits

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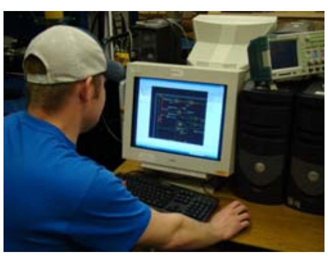
Summary: Funding provided by the National Fluid Power Association was used support the development of new laboratory activities focusing on distributed sensing and control of hydraulic circuits. The purpose of this work was to better prepare young engineers for the advanced fluid power control systems that are prevalent in today's mobile vehicle systems. Of particular interest were improved student knowledge of electro-hydraulic control, fluid power sensing, speed and position sensing and control, and the application of distributed embedded systems.

Deliverable 1: Distributed Position Control of Hydraulic Cylinders

During the 2008 spring semester, students in the ISU ABE department led the design of new experiments which included closed loop feedback control of hydraulic cylinders, pressure sensing, and distributed hydraulic control with CAN Bus embedded systems. The successfully completed labs were then integrated into an undergraduate Fluid Power course in which 30 students were exposed to these new activities. This lab introduced students to common techniques for position sensing in hydraulic cylinders and the importance of feedback control in hydraulic systems.

In additional to several new class exercises, a large group exercise was also developed to emphasize the interaction of multiple fluid power control systems. Four hydraulic trainers and one operator's station were linked together over a distributed CAN Bus network. Each team of students designed an embedded system program to receive commands from the operator's joystick over the CAN Bus network then complete a closed loop feedback control routine based on the joystick command. Each station also reported back the true cylinder position to an LCD panel at the operator's station which displayed the position of each to the user. This lab was extremely effective in demonstrating the benefits of CAN based fluid power control as well as introducing the students to CAN protocols, addressing, and hardware components. It provided the students with an excellent example of the current direction of fluid power control system design and helped build technical communication skills required to work in a team environment.



Picture 1: An Iowa State Agricultural and Biosystems Engineering student uses the PLUS+1 GUIDE software from TSD Integrated Controls to create a firmware program that will receive CAN Bus cylinder position commands, control the position of a hydraulic actuator, and transmit the actual cylinder position back to an operator's panel.

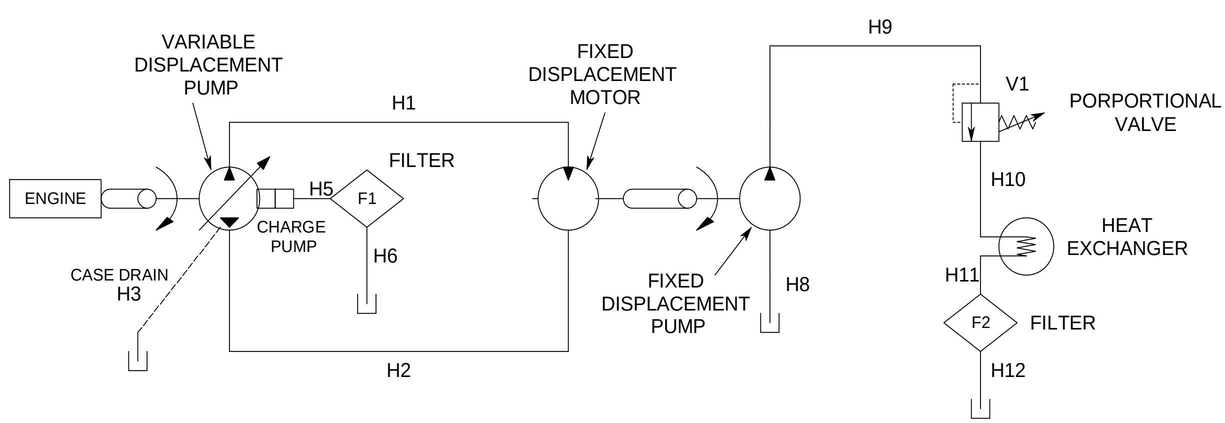
Picture 2: An Iowa State Agricultural and Biosystems Engineering student uses a PLUS+1 development board to link the electronic control module to an electro-hydraulic trainer. The PLUS+1 controller received cylinder set point commands from a CAN Bus interface, operated solenoid valves to manipulate the position of a hydraulic cylinder, and monitored the cylinder position with an in-cylinder position sensor.

Deliverable 2: Development of an Electronically Controllable Hydrostatic Trainer

Hydrostatic drive trains are used in a wide variety of agricultural and industrial products ranging from lawn mowers to bulldozers. These drive trains are fluid drive systems which provide complete control over the speed and direction of a vehicle through activation of a control lever or electrical switch. A typical hydrostatic drive train consists of a mechanical power source, usually a diesel or gasoline engine, driving a variable displacement hydraulic pump. The pump converts mechanical power into fluid power and supplies a flow of pressurized hydraulic fluid to one or more hydraulic motors. These hydraulic motors convert the fluid power back into mechanical power turning the wheels or tracks of the vehicle. Hydrostatic drive trains place precise control of vehicle speed in the operator's hands.

A hydrostatic drive train system was designed to provide a classroom training experience to engineering students and to demonstrate the distributed control of complete hydraulic systems. The trainer consisted of a 16 Hp gas engine which provided power to a variable displacement pump (Sauer Danfoss H1P053). The variable displacement pump was used to drive a fixed displacement motor (Sauer Danfoss CP222) which simulated the drive wheels of an agricultural vehicle. A torque and speed sensor was used to measure the output power from the fixed displacement motor and to determine the overall efficiency of the hydrostatic drive system. A load on the drive was provided by connecting a fixed displacement pump (Sauer Danfoss CP222) to the motor and using a proportional relief valve (Eaton Vickers KBCG-6-250) to control the power through the system. The heat and power loss generated by the relief valve was dissipated through an air cooled heat exchanger.

The variable displacement drive pump and the load controlling relief valve were electronically controlled. Simulated loading schemes were used to drive the proportional valve and an electronic feedback control circuit was implemented to change the drive pump displacement in order to maximize available horsepower. All electronic controls were implemented through Sauer Danfoss PLUS+1 controllers. Distributed communication between control points and between sensors measuring engine power, hydraulic motor power, hydraulic pressure, and oil temperature were linked via a Controller Area Network (CAN Bus) system. Students worked within teams to design the communication architecture as well as implementing the feedback control circuit and fault protection logic.



Picture 3: A diagram of the hydrostatic transmission trainer designed by students in the Iowa State Agricultural and Biosystems Engineering department. The trainer is designed to simulate a live hydrostatic drive system on a commercial agricultural or construction vehicle. Electronic sensors and controls provided by PLUS+1 controllers where used to implement a distributed CAN Bus feedback control system.