Microprocessor controlled hydraulic load unit
by Mohammad Taghi Karami

A thesis submitted in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE in AGRICULTURAL ENGINEERING
Montana State University

Abstract:
The purpose of this research project was to develop a microprocessor control unit for a hydraulic load system and to determine the accuracy of control. This was a laboratory oriented fluid power system that would use a microprocessor to simulate the loads involved in a cable conveyor system for conveying logs out of the woods. The laboratory system would duplicate the simulated loads on the hydraulic, system.

The designed system included a variable displacement hydraulic pump and motor. A tractor engine was used to power the hydraulic pump and a water brake dynamometer was used to load the hydraulic motor. The torque on the dynamometer was monitored by a strain gauge pressure transducer in parrallel with the dynamometer torque arm pressure gauge. This transducer transmitted data to a strip chart recorder which recorded the loads as a function of time. In addition a voltage output from the recorder proportional to the torque was input to the microprocessor through an A/D converter. The digital data from the A/D input was used by the control software to determine the control response needed. A computer controlled stepping motor was used to move the variable displacement arm on the hydraulic pump as required to obtain the desired load.

Test results were recorded as a series of curves on a strip chart recorder. These curves represented the actual response of the load system to the computer control system.

The objectives of this research project were accomplished as follows: a) A microprocessor control unit for a hydrostatic transmission load system was developed that could duplicate desired loads; and b) A control program was developed that could accurately duplicate a predetermined series of forces that changed as a function of real time.

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APPROVAL

of a thesis submitted by

Mohammad Taghi Karami

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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STATEMENT OF PERMISSION TO COPY

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ABSTRACT

The purpose of this research project was to develop a microprocessor control unit for a hydraulic load system and to determine the accuracy of control. This was a laboratory oriented fluid power system that would use a microprocessor to simulate the loads involved in a cable conveyor system for conveying logs out of the woods. The laboratory system would duplicate the simulated loads on the hydraulic system.

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Chapter 1

INTRODUCTION

Computer controls for real time systems are becoming more and more common. The ability to monitor variables, collect data, and control the real time systems in an accurate and fast manner, are some of the reasons the application of microprocessors and computers in research and industry have become popular.

Expansion of computer technology to agriculture has introduced an exciting area where electronic controls, computers, and microprocessors are assisting with various forms of farm tasks. Microprocessor systems are versatile and in most cases very economical tools. They are being adapted to a variety of agricultural applications which require rapid and precise control or data acquisition. These electronic devices are useful in agricultural research as well as in commercial applications. When used for research, a microprocessor system can provide the following advantages: (a) fast collection of data during complex tests; (b) precise timing and triggering of simultaneous or sequential events; (c) automatic control of numerous devices or operations; (d) versatility of operation through software control; and (e) ease of interfacing to a variety of computer terminals and digital recording systems.

Microprocessors also provide the ability to change the control strategy with a software application which may be quite desirable in any system in order to maximize the efficiency in data collection or control. Conventional electromechanical or solid state controls can be designed to handle many different control problems but anything more than a minor change in the control strategy will probably require hardware changes in wiring, components, and circuit boards. A microprocessor or microcomputer-based control system, on the other hand, would allow many complex control strategies to be implemented simply by changes in software (program). Once the inputs (from sensors, switches, and transducers) and outputs (to lights, solid state relays, valves, and stepping motors) are connected to the microcomputer, the control strategy is dependent only on the software modification.

More and more farmers are investing in personal computers for record keeping, planning market strategies, and other management related farm tasks as software becomes available. "AGNET" is an interstate computer network available to farmers through the Montana Cooperative Extension Service. It consists of 78 different computer programs that can help farmers plan or manage their particular operation. Furthermore, microprocessors are being used to monitor and control equipment operations on various on-farm systems. Some of these on-farm systems include dairy equipment, feeding equipment, and some agricultural machinery.

Agricultural operations have been highly mechanized but they still require interfacing with the operator for proper control. Engineering design has improved many of these machines and microprocessors and monitors have helped the operator make the proper decision for their operation. Some of these design improvements have come through the application of microprocessor and microcomputer technology. In addition to the existing microprocessor applications in agriculture, there are a considerable number of research projects that involve the application of microprocessors and microcomputers. Recent publications from the American Society of Agricultural Engineers (ASAE) show frequent applications for microprocessors and computer controls. Some of the typical research examples being conducted by agricultural engineers include areas such as: Agricultural Environment Controls, Food Processing (4, 15, and 25), Tractor Engine Performance and Endurance Testing (5, 14, and 17), Irrigation Scheduling and Control (10 and 22), Control and Monitoring of Solar Collectors (7), etc.

The rate at which microprocessors are being applied to agricultural problems is increasing rapidly due to the low cost of computer chips and the accuracy of data acquisition and control which can be obtained with microprocessors and digital computers. Clearly, computers will continue to take over decision making processes and the control of agricultural equipment due to their speed and accuracy. Computer scientists and computer engineers have stated that robotics and artificial intelligence (AI) will not only take over most of the manual or mechanical work of systems, but they will also take over the decision making parts of systems where humans are still the main active part. The truth in their prediction is becoming apparent in many different projects in agricultural engineering.

Statement of The Problem

The purpose of this research project was to develop a microcomputer control unit for a hydraulic load system (real system), and to determine the accuracy of control. This was a laboratory oriented fluid power system that would use a microcomputer to simulate the loads involved in a Cable Conveyor System for conveying logs out of the woods. The laboratory system would duplicate the simulated loads on the hydraulic system. Results from this study could then be used to determine the efficiency, speed of operations, and significance of computer control on a Cable Conveyor System.

Background

The Cable Conveyor System is being developed to overcome many of the current problems in logging systems. In recent decades, timber harvesting in the Rocky Mountain area has gradually progressed from the better growing sites on gentle terrain at lower elevations to steeper, more rugged terrain at higher elevations . Early logging (during the 1950's and 60's) in steep terrain employed much of the same equipment that was used in gentle terrain, principally crawler tractors. In addition cable yarders were added in some locations. All of these methods depend on a relatively dense network of roads.

A consequence of a dense network of relatively inexpensive roads in steep terrain, coupled with relatively large clearcuts, was soil erosion and widespread public antagonism. Visual impacts coupled with erosion and stream sedimentation in various locations resulted in many constraints on these harvesting methods. Road densities were reduced and road construction standards increased, requiring that cable yarding distances be increased. More partial cuts were implemented to avoid the objections to clearcutting. The consequence was costlier roads and harvesting, to the point that balloon and helicopter logging became competitive in some circumstances.

The USDA, Intermountain Forest and Range Experiment Station and Montana State University entered into a cooperative research agreement to explore ways by which timber in many mountainous areas could be harvested without having to build an extensive road network. It was proposed to design and built a microprocessor controlled zig-zag cable conveyor system which would transport logs from high elevations down to locations where they can be loaded on trucks. The proposed design includes many different components that each have to be developed. One of the main components in the system is a set of sheaves used with transducers to monitor and control the forces (loads) on the cable system by microprocessors. This thesis project was designed to develop a laboratory oriented system which would use a microcomputer to simulate the forces involved in the cable conveyor system and try to simulate the loads that would be applied to the real system.

Cable Pull Simulation Design Criteria

A system was needed to simulate the pull on a cable that would be introduced by a log being conveyed between two support towers. The system requirements for this simulation are:

A hydraulic power supply with a variable displacement pump and a motor. This hydraulic system required an external source of power and a load absorption unit. A tractor engine was used to power the hydraulic pump and a water brake dynamometer was used to load the hydraulic motor. The torque on the dynamometer was monitored by a pressure transducer in parallel with the dynamometer torque arm pressure gauge. This transducer transmitted data to a strip chart recorder which recorded the loads as a function of time. In addition a voltage output from the recorder was proportional to the torque. This voltage was input to a microprocessor through an A/D converter. Torque loads on the dynamometer are proportional to the amount of water in the dynamometer case and the square of the dynamometer RPM. Therefore, changing the dynamometer speed would result in a change in the torque on the dynamometer. Speed control for the hydraulic motor was obtained by moving the control arm on the variable displacement hydraulic pump. A computer controlled stepping motor was used to move the variable displacement arm on the hydraulic pump. The computer also monitored the torque from the dynamometer and controlled the stepping motor to obtain the desired torque.

Chapter 2

REVIEW OF SELECTED LITERATURE

Flexibility is a key element in increasing productivity and energy efficiency in mechanical and process systems. Today microprocessors and microcomputers have provided the built-in intelligence that engineering systems should have in order to respond to diverse and changing demands with maximum speed and efficiency. Computers are becoming the most cost-effective alternatives for achieving functional flexibility since they are inherently flexible. Microprocessors and computers could be reprogrammed to perform different tasks without making any physical changes in the system. This provides modifications and upgrading of engineering systems at minimum cost.

To understand the design of real-time control systems, one should be aware of the methods by which a computer can be interfaced to external equipment, the types of program instructions, and microelectronics that are required for this interaction.

Microprocessors in a Control System

The words "microprocessor", "microcomputer" and "computer" will be used throughout this chapter interchangeably. The word "Microprocessor" describes a single computer chip which contains the logic of a central processing unit (CPU), plus various amounts of the "depository and conduit" logic that surrounds the CPU (16). Central Processing Unit (CPU) itself includes Arithmetic and Logic Unit (ALU) and Control unit. The microprocessor unit (MPU) is the basic processing unit of the microcomputer system but not much is possible from using a microprocessor alone. Thus the MPU is connected to input/output (I/O) and memory devices as shown in Figure 1.

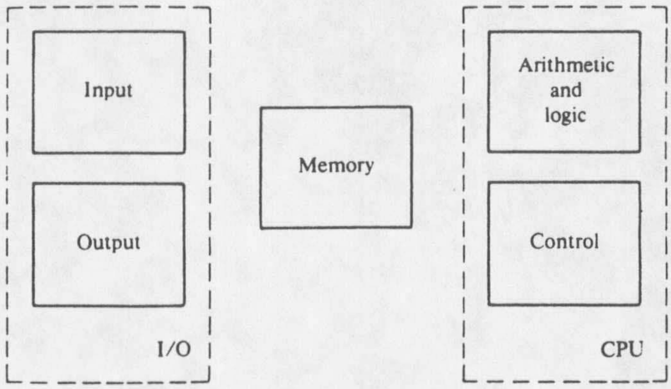

Figure 1: Basic functional units of a computer

The memory unit might consist of several devices such as read/write or random-access memory (RAM) and read-only memory (ROM). Memories store necessary programs (software) for the particular application of the microprocessor. The primary connection to external devices such as CRTs (Cathode Ray Tubes), Keyboards, or Teletypes is accomplished through an input/output (I/O) unit. This interfacing unit of the microcomputer system is implemented with one or more special chips which are provided by the microcomputer manufacturers (2). The signals going out of and coming into a microprocessor chip are seldom directly sent to interfaces and memory. Instead, additional logic is used to form a standardized communication device called "bus" to which peripherals and memory would be interfaced (3). The microprocessor system transmits information through three buses or communication lines: the data bus, address bus, and control bus.

The word "Microcomputer" describes a product that contains all of the functions found in a computer. The word microprocessor has come to describe a special type of electronic logic and its package. This electronic logic must contain the equivalent of a central processing unit (CPU) and the package should be a single chip. In contrast, the word microcomputer has come to describe special electronic logic including a variety of different packages, ranging from a single DIP to a box full of electronics.

Instructions and Programs (software)

A group of instructions that a specific microprocessor can execute is called its "instruction set". MPU instruction sets might have as few as 8 or as many as 200 or more instructions. Several of these instructions could make a program statement and a group of statements would make a program. All the tasks done by computers require program writing or software development. A program written using the instruction codes of a microprocessor is called assembly language programming. Thus the process of developing assembly level programs is based on writing statements containing labels, instruction mnemonics such as operating codes (Op-codes) or operators and operands as variables. The assembly language follows the structure of the machine language closely. In the assembly process, each statement written in symbolic form is translated into its equivalent binary form (1s and 0s), consisting of instruction code and memory location. This kind of language is referred to as a low level language. Universal programming languages, originally designed for second and third generation computers, are application oriented and include words and phrases used in English. Of these programming languages, FORTRAN and ALGOL are designed for scientific users, COBOL for business systems, and BASIC for instructional time sharing or general problem solving. The above programming languages are called high level languages. Once a program is written in a high level language, a special program called a "compiler" converts the program to binary object code, which is consequently run on the machine. Note that the compile process or "compilation" follows essentially the same line as assemblers, in assembling the source code into machine readable object code. An interpreter, unlike a compiler, translates the instructions of the source program and also executes them immediately.

Hardware Interfacing

Interfacing is defined as the mating of one component