A Development of Embedded System for Speed Control of Hydraulic Motor

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Abstract

In the present study, a high-performance electro-hydraulic motor controller is designed and developed by using embedded technology. These electro-hydraulic motor is controlled using designed algorithms in ARM7embedded board with graphical programming. An optical encoder is used to detect hydraulic motor speed by reading via timer in ARM7. Hydraulic proportional valve is employed to control the flow of hydraulic motor by manipulating PWM signal. The control approaches have been tested for the function ability of the actuator, which is speed control. The results have shown that the system works successfully and gives good performance for practical applications.

Keywords: *embedded, electro-hydraulic motor control*

1 Introduction

Hydraulic actuators are used to transfer energy by converting fluid energy to mechanical energy. It plays an important role in a modern industry where controlled speed or position with high accuracy is the most significant demand. The ratio of weight, volume, and inertia to available power is significantly lower than in electro-mechanical drives and the dynamic performance are superior. Many researches on hydraulic motor control have been proposed new control algorithm to improve the overall performance of the system [1-3]. However, the requirement to implement advanced control strategies has led to an increased interest in the employ of embedded technology in this field. One design approach, which merits special consideration in this research, is the use of graphical programming with Labview to create the Graphic User Interface, and to generate and test embedded code for the target processor ARM7. The figure 1 illustrated the structure in controlling electro-hydraulic motor system and the graphic interface of the ARM7 system for such systems. The test rig of embedded controller consists of hydraulic embedded controller, a proportional valve, a valve amplifier, and a rotary hydraulic motor which coupling with load.

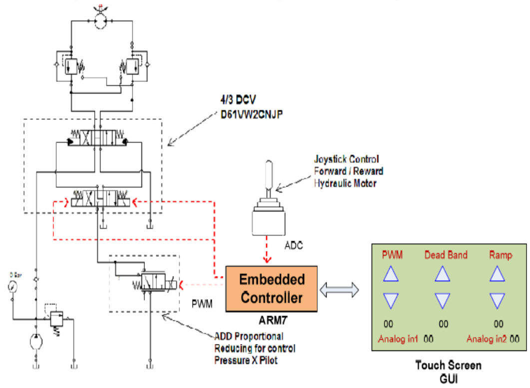

Figure 1: Structure electro-hydraulic motor system and the graphic interface

For performance evaluation, the measuring motion profile of rotary motor employ an optical encoder and DAQ card. ARM7 embedded controller is the control system's heart. It can read the input speed from touch screen, display percentage Pulse Width Modulation (PWM) in double coils of hydraulic valve and also can interface user with a setting parameter to compensate a non-linear characteristic of hydraulic system (ramp and dead band). Speed and direction of the hydraulic motor are controlled by ARM7 processor inputting timing pulse signals to its drive valve amplifier. Hydraulic motor rotational speed is directly proportional to the width of pulse signal, which means the higher width of the pulse signal, the faster motor rotate speed. As show in figure 2, the bidirectional valve amplifier (L298), will require PWM and logic signal input in order to control the speed motor and direction. This circuit can drives two coil of proportional valve with currents up to 2 Amp.

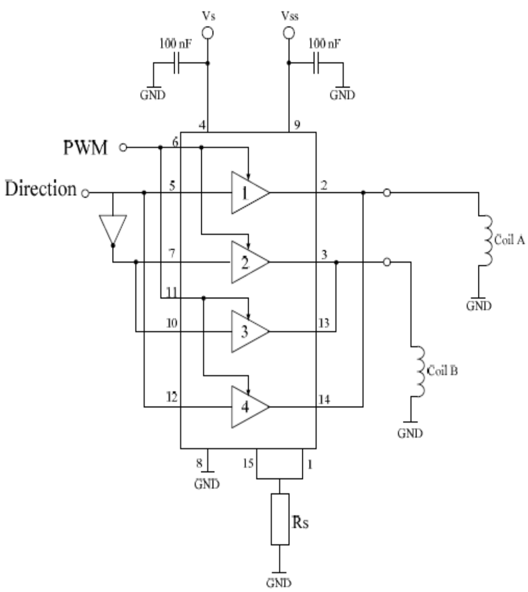

Figure 2: The valve amplifier with L298

2 Math Modeling of Hydraulic Motor Control

In this section, we describe mathematical modeling of hydraulic motor control system. In figure 3, the system consists of a model behavior of proportional valve, electronic drives, and hydraulic actuators. A common form of a transfer function of hydraulic motor control system approximation of the relationship between the load differential pressure and the input current to the proportional valve has been derived to be:

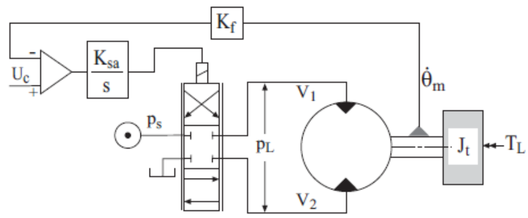

Figure 3: speed control hydraulic motor

$$\frac{P_L(s)}{Ic(s)} = \frac{K_v}{(\frac{S}{\omega})^2 + \frac{2Ds}{\omega} + 1} \tag{1}$$

In which P_L is load difference pressure, I_C is input current K_v is valve gain, ω is valve natural frequency, and D is valve damping ration.

The torque on the hydraulic rotary motor is given by;

$$T_L = J_L \alpha + B\omega \tag{2}$$

In which, T_L is motor torque, J_L is load inertia, and B is viscous damping

$$\frac{\omega(S)}{P_L(S)} = \frac{\frac{V}{B}}{(\frac{J_L}{B}s + 1)} \tag{3}$$

The following equation is valid for the amplifier which should provide DC current into the proportional valve

$$\frac{I_e(s)}{U_c(s)} = \frac{K_{sa}}{\tau_a + 1}, K_{sa} = \frac{1}{R}, \tau_a = \frac{L}{R} \tag{4}$$

In which, I_e, U_c, R and L is proportional valve amplifier output current, voltage, resistance, and inductance respectively. From equation 1-4, the transfer function of hydraulic motor drive can be express is:

$$\frac{\omega(s)}{U_c(s)} = \frac{K_{sa}}{\tau_a s + 1} \frac{K_v}{(\frac{s}{\omega})^2 + \frac{2Ds}{\omega} + 1} \frac{\frac{V}{B}}{(\frac{J_L}{B} s + 1)} \quad (5)$$

And the block diagram of equation 5 is show in figure 4.

3 Structure of Embedded Controller

The increasing use of electronic control units in hydraulic applications has caused an increasing need for consideration of the embedded control system and its implementation in which many future directions are surveyed in [4-6]. The structure programming of proportional valve controller in this research is shown in figure 4: The embedded processor, LPC2378 is Philips's processor chip, which bases on the ARM7 core. LPC2378 includes a PWM modulator, digital IO, and a 16-channel 10- bit A/D converter. A/D in ARM processor samples control signal from a Joystick to regulate speed by using it outputs a PWM signal to control proportional valve after compensated non-linear characteristic and one bit of digital output is used to control the direction of hydraulic motor via valve amplifier, L298. The setting compensated parameters of proportional valve controller such as control ramp, dead band, and frequency could be set by the touch- screen man-machine interface, so as to the controller can be applied in different types of proportional valves and motor.

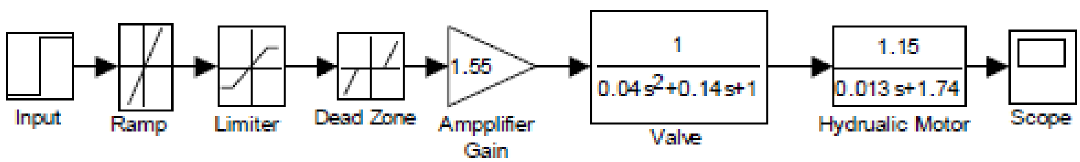

Figure 4: The block diagram of hydraulic motor control system

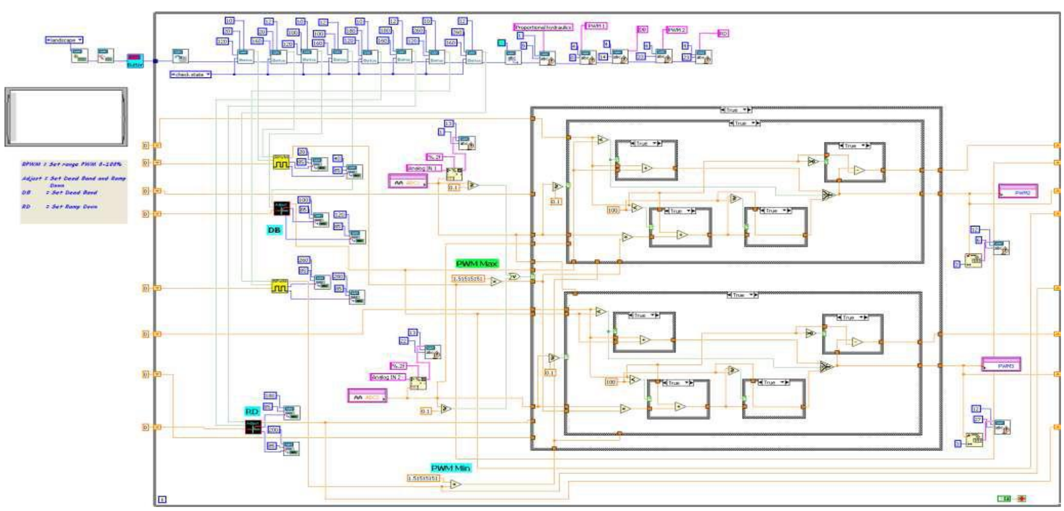

Figure 5: The embedded controller graphical programming

In this project, LabVIEW programming uses to design hydraulic embedded controller that incorporates with PWM, A/D, output logic signal control processing, and control analysis capability. Unlike other high-level programming development tools, LabVIEW Embedded Development Module can provide delivers a full-function graphical language for embedded software design from control algorithm to implementation target embedded ARM7. The implement software was built on a plug-in framework of hydraulic motor control with can describe their entire application graphically. The figure 5: illustrates the hydraulic motor control framework with graphical programming.

4 Simulations and Experimental Results

In order to test the performance and function ability of the new developed embedded for future motor hydraulic controller. The Simulation and experimental test were carried out with speed control to verify the controller performance. Speed control simulation experiment using hydraulic motor had been employed by unified control block diagram as in figure 3.

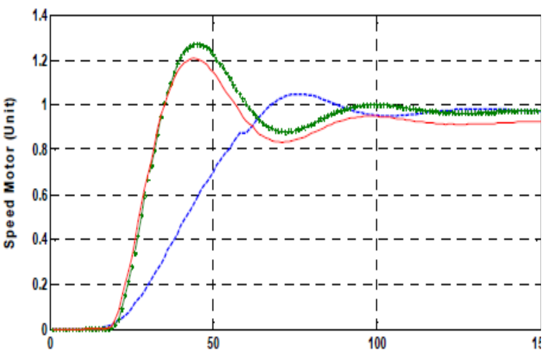

Figure 6: The simulation result

Figure 6. shows the simulation results hydraulic motor control. The plotted against the actual speed output of the electro- hydraulic motor and time. This can be observed in the case of when the system was compensated with non-linear parameter (ramp and dead band). Its dynamic output can provide the satisfied response (small jerk and steady state error).

In experimental test rig, the embedded controller structure is presented in figure.7. For the experiment result shown in Figure 8, the speed of motor hydraulic controller compensated with non-linear parameters can yield good performance.

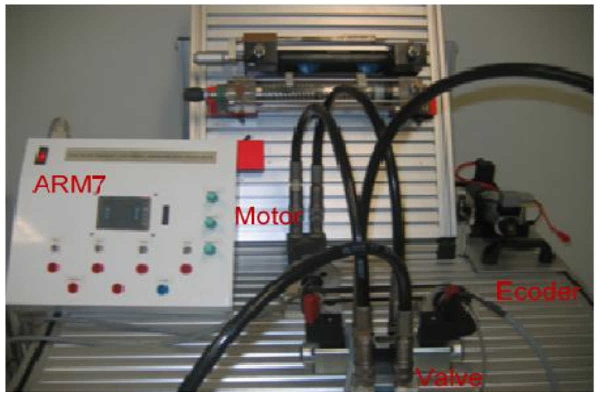

Figure 7: The experimental test rig

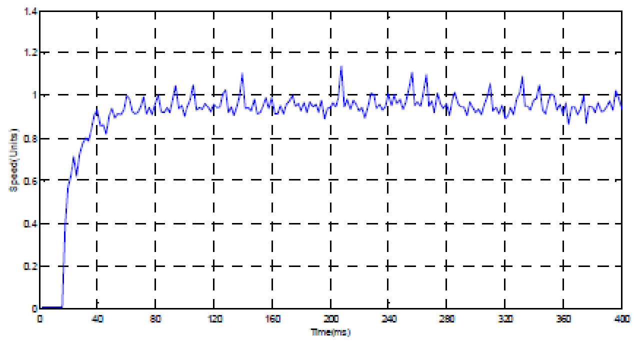

Figure 8: The Experimental result

5 Conclusions

New embedded controller of hydraulic motor was presented where ARM7 microcontroller and graphical programming with hardware drivers were developed together. The actuator realizes control of speed and direction control with compensated nonlinear function making it satisfy dynamic response. The compensated function can be setting via man-machine interface(touch screen). This actuator system is expected to play great role in many different industrial areas especially in hydraulic man-machine interaction application. Further work will focus on the control algorithm of intelligent control in embedded controller that can provide better performance than this process.

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