

Design of Fluid Control Valve Opening Control System

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Abstract

Technical problems such as the limited control times and time of existing fluid control valves and the inability to accurately control the control opening limit the long-term economic development of deep shale gas. This design is mainly based on PID control algorithm to control the opening of fluid control valve. It has the advantages of unlimited control times, high control precision and strong reliability.

Keywords

Fluid Control Valve; FPGA; PID Control.

1. Introduction

Oil and natural gas is an important resource for industrial production and an important factor supporting national development[2]. How to further improve the recovery rate of mature and new oil fields and increase crude oil production, and improve the overall management level of oil reservoirs in their life cycle, brings new and great challenges to oil workers.

Fluid control valve is the core tool for controlling reservoir fluid. Therefore, it is urgent to study the adaptive monitoring system of intelligent completion fluid control valve. The valve opening information of fluid control valve is transmitted to FPGA by displacement sensor. The FPGA compares the deviation of the opening control instruction stored in register with the opening signal collected in real time. The PID control algorithm is used to accurately control the valve opening of the fluid control valve in real time [3].

2. Fluid Control Valve Opening Control Principle

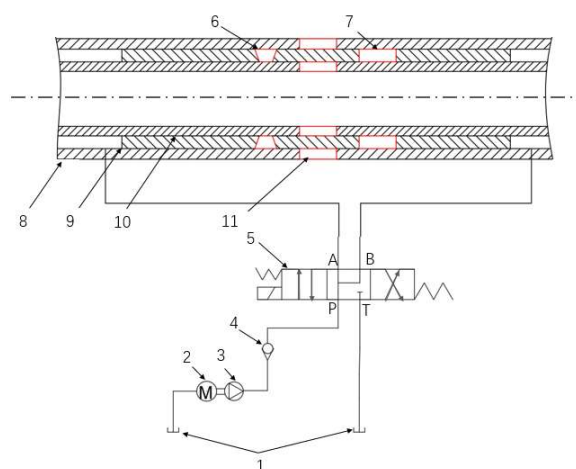


Figure 1. control schematic diagram

The fluid control valve designed in this paper is to control the movement of the inner sliding sleeve through the hydraulic system, so as to realize the change of the opening of the throttle hole and the pressure hole. The hydraulic power source of the hydraulic system uses a hydraulic

pump, which can open and close the fluid control valve several times[4,5]. The hydraulic circuit of the hydraulic system adopts three-position four-way solenoid valve and check valve, which has the advantages of easy operation, small size, low power and reliable operation[6,7]. Thus realize the fluid control valve control system opening change control.

3. System Overall Scheme Design

As shown in the following figure, the overall scheme design of the fluid control valve control system is as follows:

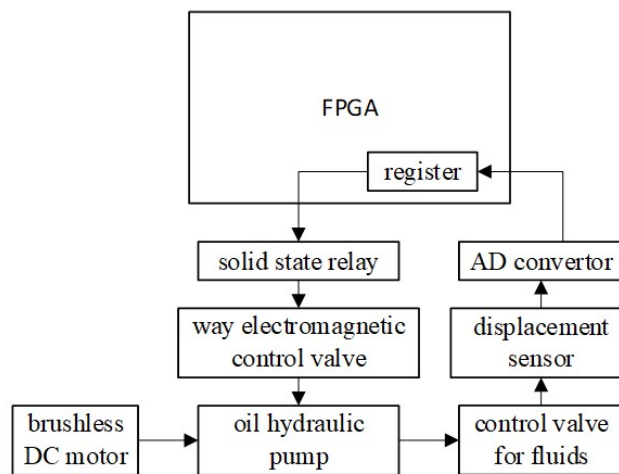


Figure 2. Flowchart of the overall scheme

3.1. Control Scheme

PID control is a kind of control algorithm developed on the basis of classical control theory. PID control system is mainly composed of two parts: PID controller and controlled object.

$$e(t) = r \text{ in}(t) - \text{yout}(t)$$

the control algorithm of the continuous time PID controller is:

$$u(t) = K_p[e(t) + \frac{1}{T_i} \sum_0^t e(t)dt + \frac{T_d de(t)}{dt}]$$

$a_0 = k_p + k_i + k_d$, $a_1 = k_p + 2k_d$, $a_2 = k_d$, the above formula can be transformed:

$$u(k) = u(k-1) + a_0 e(k) - a_1 e(k-1) + a_2 e(k-2)$$

3.2. FPGA Implementation of Control Algorithm

When designing input in FPGA, you can adopt modular design. According to the modular design idea, each module is instantiated in the top-level design of PID algorithm. The top-level design of PID control algorithm is shown as follows:

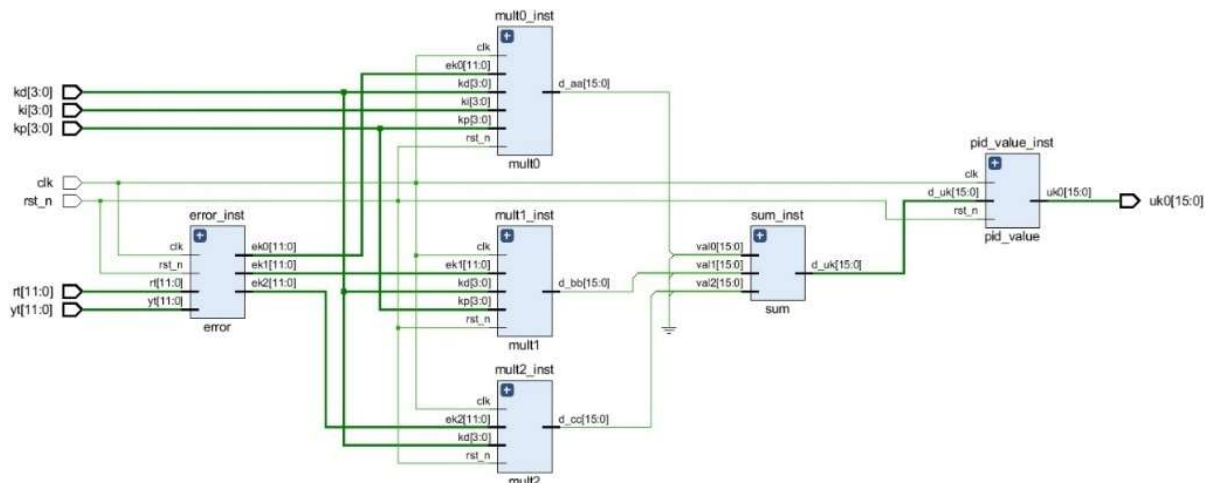


Figure 3. RTL view of PID top-level module

3.3. Data Collection System

The AD acquisition module in this paper uses TI's AD9226 chip and FPGA to realize high-speed sampling of downhole signals[8]. The AD9226 has a resolution of 12 and a maximum adoption frequency of 65MHZ. Among them, the simulation diagram of AD data acquisition part are as follows:



Figure 4. Simulation diagram of AD9226 data acquisition

3.4. PWM Driver Module

The design of PWM driver module is to change the duty cycle of the output pulse according to the input signal. When designing the program, we set N to 100, so that the duty cycle of the output pulse can be divided into 100 levels.

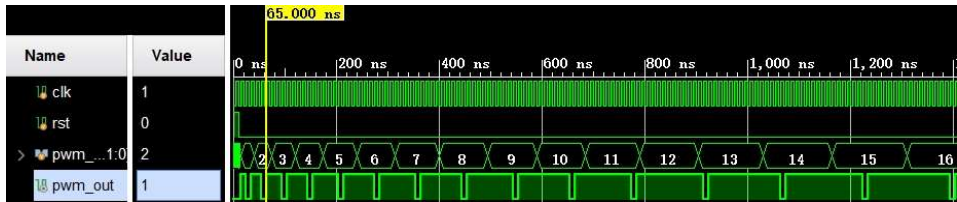


Figure 5. Simulation results of PWM driver

3.5. Ethernet Communication Module

Ethernet communication rate is high, stable and reliable, anti-interference and strong compatibility, sustainable development potential, widely used in the field of industrial control[9]. The RTL view and simulation diagram of Ethernet are as follows:

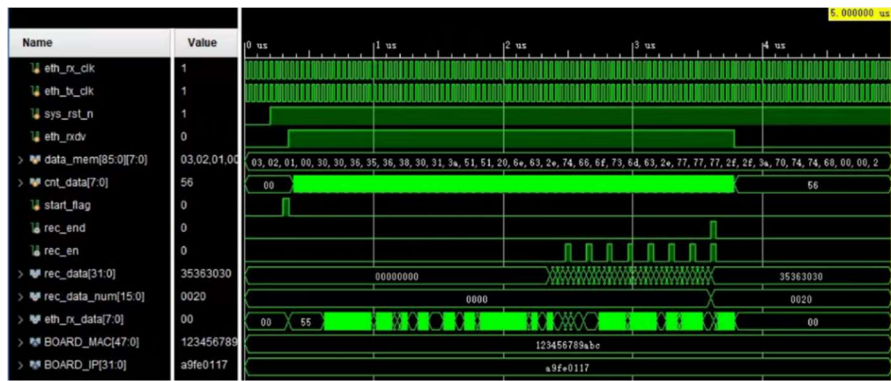


Figure 6. Ethernet simulation diagram

3.6. Fluid Control Valve Opening Adjustment Accuracy Experiment

The purpose of the experiment: To carry out the intelligent completion fluid control valve opening adjustment accuracy experiment, is to verify whether the fluid control valve displacement sensor can accurately detect the fluid control valve opening, and verify whether the set opening adjustment accuracy is reasonable.

Experimental principle: By controlling the on-off of the three-position four-way solenoid valve, and recording the reading of the displacement sensor instruction, compared with the actual displacement data, so as to determine whether the control of the fluid control valve valve opening is accurate.

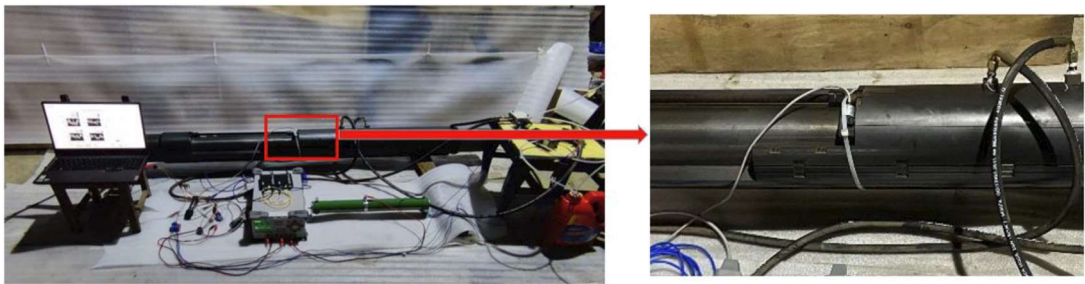


Figure 7. Schematic diagram of the position of the displacement sensor

The fluid control valve selected in this experiment has a circular orifice with a maximum orifice distance of 29.620 mm. When the valve opening is 0, the displacement sensor value is the maximum distance of the hole; When the opening is 100%, the displacement sensor value is 0. The displacement sensor is analyzed according to the actual displacement data collected by the experiment and the theoretical calculated displacement data. The theoretical data, actual values, errors and accuracy of the displacement sensor are shown in the following table:

Table 1. Error table of actual and theoretical values

opening degree	Actual value(mm)	Theoretical value(mm)	Error(mm)	Precision(%)
75%	7.601	7.659	0.058	0.2
50%	14.985	15.064	0.079	0.27
25%	22.248	22.469	0.021	0.07
10%	26.875	26.912	0.037	0.12
5%	28.372	28.453	0.081	0.27
3%	28.980	29.045	0.065	0.22
1%	29.475	29.537	0.062	0.21

4. Conclusion

It can be seen from Table 2 that the accuracy of each opening distance measured by the displacement sensor is less than 0.27%, indicating that the FPGA control system design based on PID control algorithm is feasible. And it has certain reliability of opening control precision.

Conflict of Interest

The authors have no conflicts to disclose.

Author Contributions

Zhijian Wan: Writing–original draft(equal);Data curation(equal);Methodology (equal).

Min Wan: Conceptualization (equal); Resources (equal); Project administration.

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