

# Design and Impliment of Powertrain Control System for the All Terrian Vehicle

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**Abstract**— This paper, presents design and implement of a control system for control the angular position of dc motor that control the close and open of a hydraulic pump and hydraulic motor that make the All Terrain Mobile Robot moves forward and backward by controlling the DC Motor rotating direction, all the hardware where the normal power train system replaced by a hydraulic power train system installed in the institute of Real Time System in Siegen University for the project of DORIS Robot ,modelling and simulation has been done for design the DC Motor PID controller and the implementation of the controller has been done by using ATMEGA16 microcontroller and AVR studio software , C program written and upload to the brain of the control system .

**Keywords**— DC Motor , PID controller, position control, hydraulic pump, robot

## I. INTRODUCTION

In this paper, a PID controller design for a DC motor angular position control that open and close a hydraulic pump on an all-terrain vehicle (ATV) is presented.

DC motor angular position systems are usually controlled by proportional integral- derivative (PID) control algorithms with PID coefficients tuned for optimizing operation. The objective of a PID controller in a position control system is to maintain a position set point at a given value and be able to accept new set-point values dynamically. Modern position control environments require controllers that are able to cope with parameter variations and system uncertainties.

To implement a PID controller the proportional gain  $K_P$ , the integral gain  $K_I$  and the derivative gain  $K_D$  must be determined carefully. controlling the DC motor without using the PID controller will give some oscillation in the signal and because the system is nonlinear, controlling by function is the best way to control the nonlinear systems and PID controller is the best choice to achieve this task. Tow DC motors will control the Tow hydraulic pump valves which rotating in limited angle not 360 degree but between certain value. This system mounted on an all-terrain vehicle (ATV) to drive 8 which will describe in detail in the next section. for the system of a hydraulic pump and its valve return spring

special torque should be apply from the motor to overcome the valve resistance and has be done by controlling the motor speed. The more motor speed the less torque the less motor speed the more torque .controlling speed has done by using PWM (pulse width modulation) all of this written in c code using AVR studio and load it to the ATMEAG16 microcontroller.

The hardware and some of the hardware installed in the workshop of electrical engineering department in Siegen University .his control system is the first control system that should implement on this project to convert it to unmanned ground Robot other control system should design and implement like steering control system and cruise control system which is also a part of this project.

## II. SYSTEM DESCRIPTION

1. DORIS robot (dual media Outdoor Robot Intelligent System) as shown in figure 1, is a research project of the Institute for Real-Time Learning Systems in Siegen university. It is an autonomous acting vehicle for outdoor use under the most difficult conditions. It consists of many subsystems like gas control system ,break control system , steering control system , security system and power train control system which will be the research task ,the hydraulic power train system which drive the wheel forward and backward.



Fig. 1. DORIS robot

task is to rotate each DC Motor independently to reach the desired position according to the driver desired signal

2. Two hydraulic pumps one for left and one for right side controlled by two 12V DC motor as shown in figure 2. by rotating the pump valve clockwise allow to drive the wheel forward and rotating the pump valve counter clockwise allow to drive the wheel backward as shown in figure. Two potentiometers connected to the two motors as shown in figure 3 to detect the angular position and send the signal to the atmega16 microcontroller to process it and correct the error .

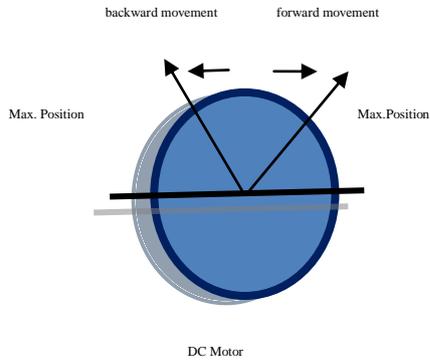


Figure 2. simulated targeted positions



Figure 4 Gas and brake Pedal

4. ATMEGA16 microcontroller is the brain of the system where all the control operations , error correction and sensors information's processes in the microcontroller by using AVR Studio software and c program as shown in figure 5.

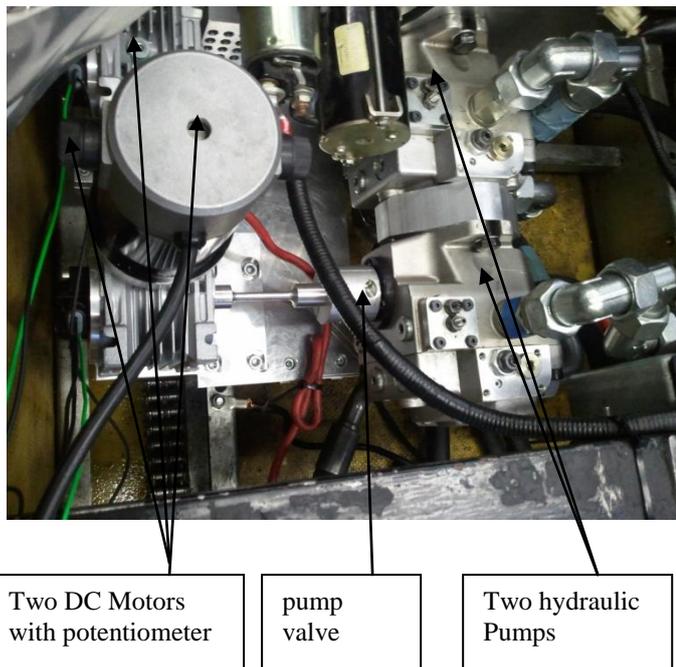


Fig. 3. DC Motors and the Hydraulic pumps

3.Tow Pedal one for driving the Vehicle forward and the other to drive the vehicle backward as it shown in figure 4. the

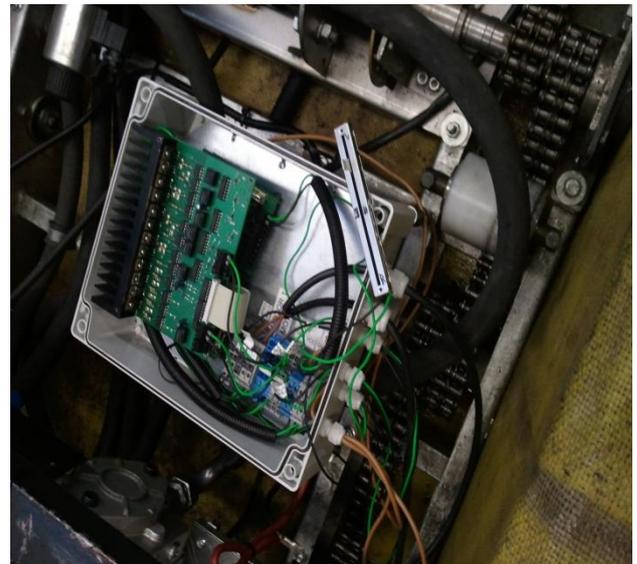


Fig. 5. microcontroller board

figure 6a and b shows the hydraulic circuit of the Power train system and the complex system ,the hydraulic pump complex that drives the hydraulic motors is the targeted part to be control.

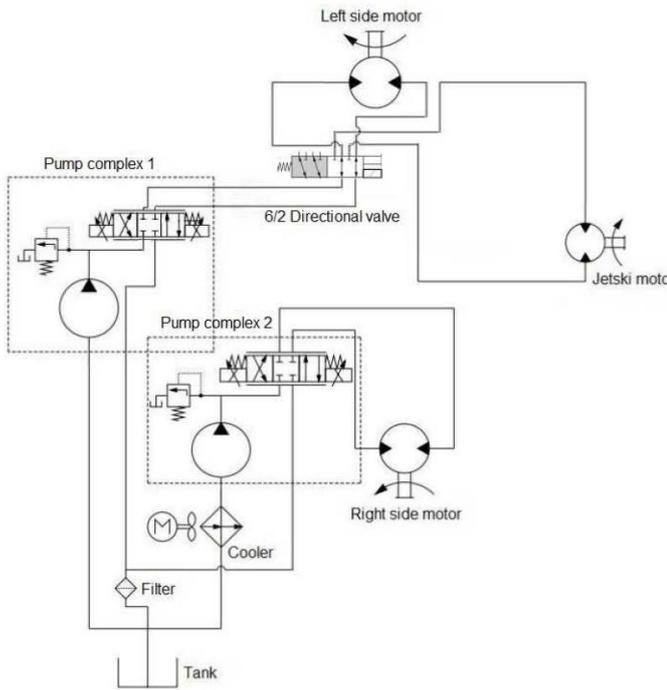


Fig.6a Hydraulic Circuit

A mathematical model for one Motor should conclude and the other on is the same mathematical model .As reference we consider a DC motor as shown in figure 5. A simple mathematical relationship between the shaft angular position and voltage input to the DC motor may be derived from physical laws. In the point of control system, DC servo motor can be considered as SISO plant Therefore, complications related to multi-input system

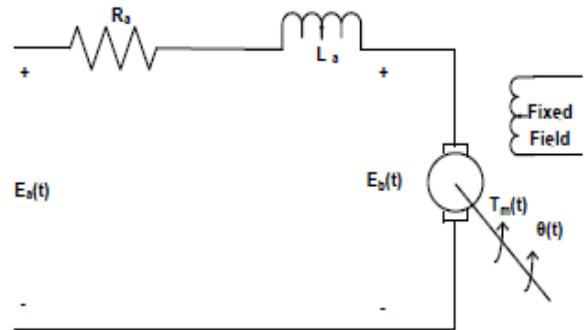


Fig. 7. Schematic Diagram of a DC Motor

Left side motor  
Right side motor  
Pump complex 1&2



Cooler  
Jetski motor  
6/2 Directional valve  
Tank with Filter

Fig.6b Hydraulic Circuit complex

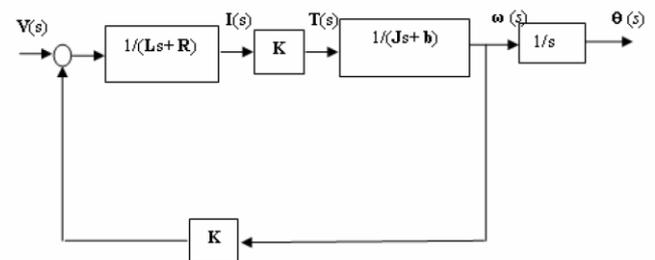


Fig. 8. Block Diagram representation of a DC motor

are discarded. DC servo motors have the field coil in parallel with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position. The dynamic behaviour of the DC motor is given by the following equations [1], and can be represented by the block diagram as shown in figure 5.

$$E_a(s) = R_a I_a(s) + L_a s I_a(s) + E_b(s)$$

$$T_m(s) = K_t I_a(s)$$

$$E_b(s) = K_b s \theta(s)$$

$$T_m(s) = (J_m s^2 + D_m s) \theta(s)$$

### III. SYSTEM MATHMATICAL MODEL

where,

Ra=Armature resistance in ohm

La=Armature inductance in Henry

ia=Armature current in ampere

ea=Armature voltage in volts

eb=Back EMF in volts

Kb=Back EMF constant in volt/(rad/sec)

Kt=Torque constant in N-m/Ampere

Tm=Torque developed by the motor in N-m

$\theta(t)$ =Angular displacement of shaft in radians

J=Moment of inertia of the motor and load in  $K:gm^2/rad$

Dm=Frictional constant of motor and load in Nm/(rad/sec).

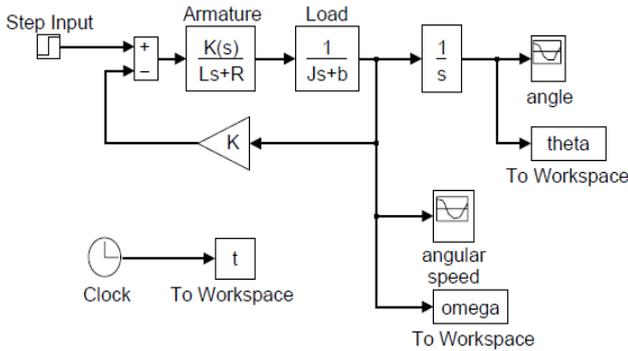


Fig. 9. Simulink Block Diagram

After simplification and taking the ratio of  $\frac{\theta(s)}{E_a(s)}$  the transfer function will be as below after some simplifications [7],

$$G(s) = \frac{k}{((Js+b)(Ls+R)+K^2)*s} \quad (1)$$

with  $j=0.01$ ,  $b=0.1$ ,  $l=0.5$ ,  $R=1$ ,  $k=0.01$  [6] the transfer function will be

$$G(s) = \frac{0.01}{(0.005s^2+0.06s+0.1)} * \frac{1}{s} \quad [2]$$

#### IV. PID CONTROLLER

Proportional-integral-derivative (PID) controllers [2] are widely used in industrial control systems because of the reduced number of parameters to be tuned. They provide control signals that are proportional to the error between the reference signal and the actual output (proportional action), to the integral of the error (integral action), and to the derivative of the error (derivative action), namely

$$U(t) = K_p \left[ e(t) + \frac{1}{T_i} \int_0^t e(\tau) d\tau + T_d \frac{d}{dt} e(t) \right] \quad (2)$$

Where  $u(t)$  and  $e(t)$  denote the control and the error signals respectively, and  $K_p$ ,  $T_i$  and  $T_d$  are the parameters to be tuned. The corresponding transfer function is given as

$$U(s) = K_p \left[ 1 + \frac{1}{T_i(s)} + T_d(s) \right] \quad (3)$$

These functions have been enough to the most control processes. Because the structure of PID controller is simple, it is the most extensive control method to be used in industry so far. The PID controller is mainly to adjust an appropriate proportional gain ( $K_p$ ), integral gain ( $K_i$ ), and differential gain ( $K_d$ ) to achieve the optimal control performance. The PID controller system block diagram of this paper is shown in figure 10 and the simulink block diagram for the system shown in figure 8 [5] and the block diagram result shows in figure 9. Transfer function can also be expressed as [1]

$$K(s) = \frac{U(s)}{E(s)} = K_p + \frac{K_i}{s} + K_d s \quad (4)$$

The main features of PID controllers are the capacity to eliminate steady-state error of the response to a step reference signal (because of integral action) and the ability to anticipate output changes (when derivative action is employed). Tuning the PID controller achieved experimental on the plant. A lot of experiment has been done till getting the best result for  $K_p$ ,  $K_d$  and  $K_i$ .

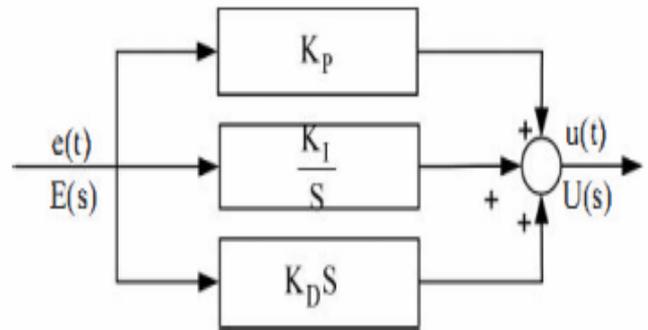


Fig. 10. PID Controller Block Diagram.

and to overcome the effect of the valve torque and according to the relationship between the torque and the motor speed we give a small rotating speed (RPM) by adjusting the OCR (output compare register) in the atmega16 microcontroller to be equal to the desired value.

The power train control system for both vehicle side where in this controller the targeted value is the angular position as shown in figure 11.

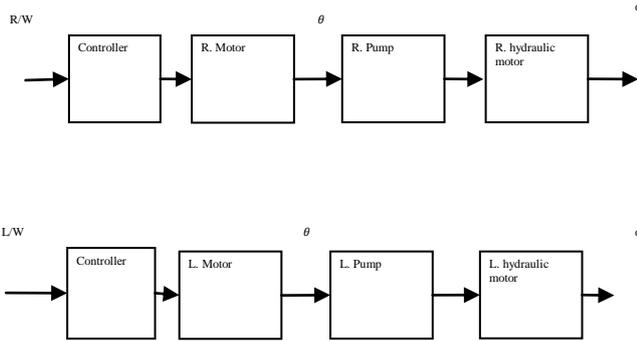


Figure 11. block diagram of Power train control system

The function PID\_CONTROLLER used to control the angular position by taking the sensor value from the Motor and compare it with the value from the pedal and then the error processes and cancelled.

```

PID_CONTROLLER (){
    ERROR =ADC_BREAK - ADC_MOTOR_2;
    INTEGRAL = INTEGRAL + (ERROR * DT);
    DERIVATIVE = (ERROR - PREERROR) / DT;
    OUTPUT = (KP * ERROR) + (KI * INTEGRAL) + (KD * DERIVATIVE);
    PREERROR = ERROR;
    IF (OUTPUT>1023){
        OUTPUT=1023;
    }
    ELSE IF(OUTPUT<-1023){
        OUTPUT=-1023;
    }
    IF(OUTPUT<0){
        PWM_RATE =100;
        //_MOTOR_1_START = 1;
        _MOTOR_2_START = 1;
        //_MOTOR_1_DIRECTION = TURNING_LEFT;
        _MOTOR_2_DIRECTION = TURNING_LEFT;
    }
    ELSE IF(OUTPUT>0){
        PWM_RATE =100;
        //_MOTOR_1_START = 1;
        _MOTOR_2_START = 1;
        //_MOTOR_1_DIRECTION = TURNING_RIGHT;
    }
}

```

```

_MOTOR_2_DIRECTION = TURNING_RIGHT;
}
ELSE {
_MOTOR_1_START = 0;
_MOTOR_2_START = 0;
STOP_MOTOR(MOTOR_1);
STOP_MOTOR(MOTOR_2);
}
}
}

```

## V. EXPERIMENTAL RESULTS

The experimental results of the proposed position controlled system as shown in figure 12 for driving the vehicle forward and backward and comparing the satisfied results obtained for one DC Motor because the second one have the same characteristics and same position as we mentioned in the system description one for left side and one for right side and they should be rotating synchronous with the same speed and same position so all the results for one motor . It can observe that the response to the input signal is fast with small error and damped oscillation figure 12. the overshoot of the propose position controlled system is smaller than the overshoot by using a system without PID controller figure 13.

Using of  $k_p = 0.06$ ,  $k_d = 0.02$  and  $k_i = 0.02$  will not give a good result with a big error in the beginning figure 16 and by connecting the DC Motor to the pump valve the resistance from the pump valve return spring give an error in the beginning for some millisecond and then be constant figure 17. with several input signal for the DC Motor connected to the hydraulic pump shows also the effect of the valve return spring and the changing from an angle to the other angle takes around 215ms and the step from on sample to the next step is 21.5 microsecond according to the sample rate from signal 1 to signal 2 as shown in figure 15. and the best PID parameters choice that achieved experimentally seen in figure 18 and simulated as in figure 19 with the same parameters .

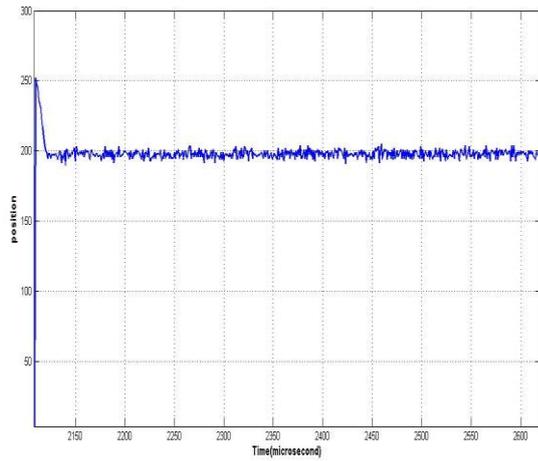


Fig. 12. the response to the input signal

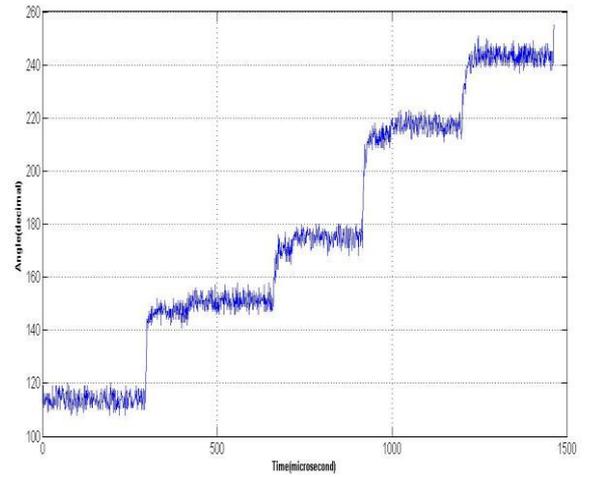


Fig. 15. with several input signal

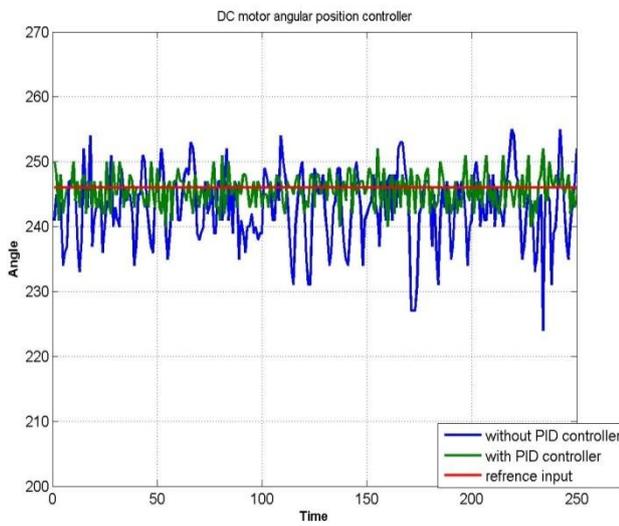


Fig. 13. the system with and without PID

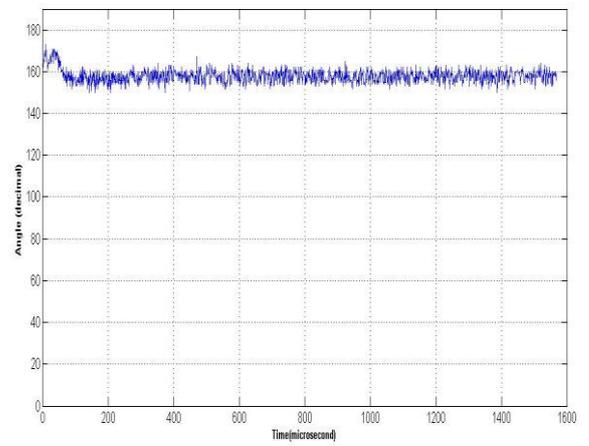


Fig. 16.  $k_p=0.06, k_d=0.02, k_i=0.02$

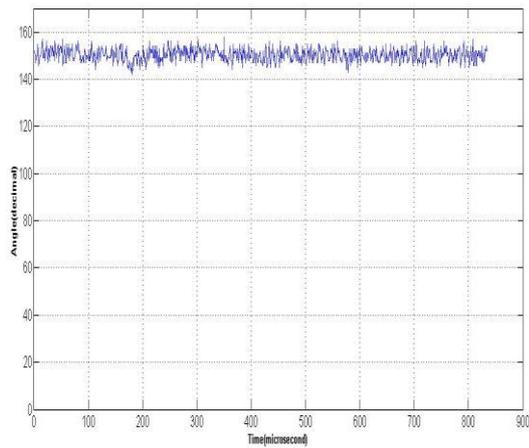


Fig. 14.  $k_p=0.05, k_d=0.01, k_i=0.01$

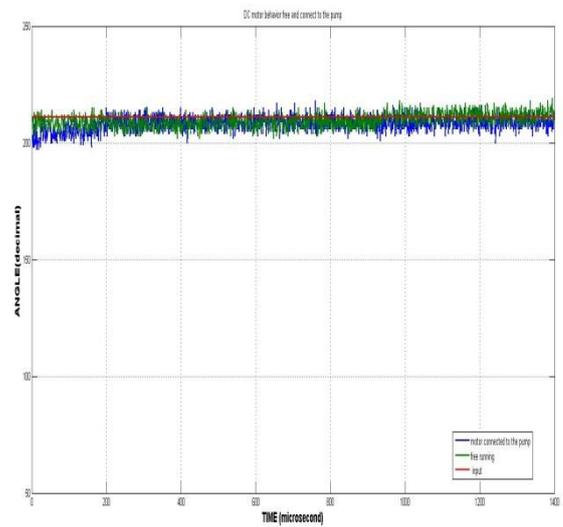


Fig. 17. DC Motor free and connected to the hydraulic pump

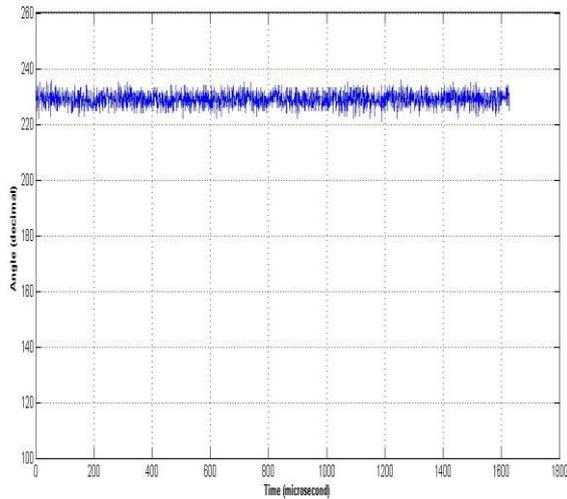


Fig. 18.  $k_p=0.05, k_d=0.01, k_i=0$

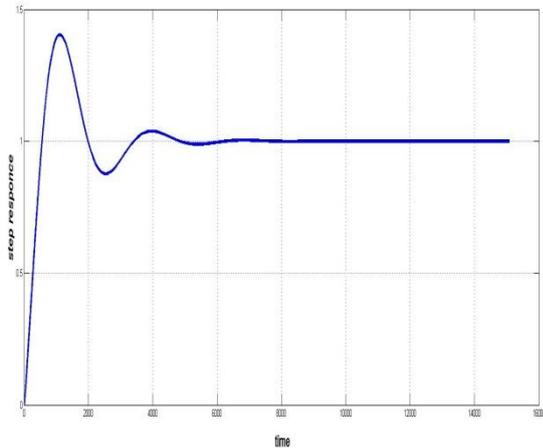


Fig. 19. simulated dc motor with PID controller

## VI. CONCLUSION

In this research, a PID control system for DC Motor angular position was proposed for driving the hydraulic pump and hydraulic Power train system on the all terrain Mobile Robot this controller has an advantage in both noise reduction and oscillation reduction and the control system runs well, and has a good system response.

Parameters	Value
$K_p$	0.05
$K_i$	0.01
$K_d$	0.00
Overshoot	20%
Steady state error	2%
Response time	21.5 microsecond

Table 1 PID controller specifications

## VII. DC MOTOR PARAMETERS

parameters	Motor 1	Motor2	unit
Rotor inertia	52	52	gcm <sup>2</sup>
Terminal resistance	1.8	1.8	Ohm
Inductance	2.4	2.4	mH
Mech. time constant	15	15	ms
Electr. time constant	1.3	1.3	ms
Speed regulation constant	300	300	rpm/Ncm
Torque constant	2.45	2.45	Ncm/A
Thermal resistance	16	16	K/W
Thermal time constant	10	10	min
Axial play	< 0.01	< 0.01	mm

Table 2 DC Motor parameters

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