

# EE324: Control Systems Lab

## Experiment 1: DC Motor Position Control

### Group 1 - Thursday

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## 1 Objective

To design and implement a PID position controller using Arduino Mega for a DC motor.

The specific objectives were:

- To rotate the dc motor by an angle of  $180^\circ$  from any given point.
- To ensure that the task is constrained by the design specifications of rise time  $t_r = 0.5s$ , settling time  $t_s = 1s$  and 10% overshoot.

## 2 Control Algorithm

The control algorithm used in this experiment is a PID controller. The PID controller is given by the following equation:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \quad (1)$$

where  $u(t)$  is the control input,  $e(t)$  is the error signal,  $K_p$ ,  $K_i$  and  $K_d$  are the proportional, integral and derivative gains respectively.

Some important code snippets below shows the implementation of the PID position controller in Arduino.

```
/*
  Experiment 1 : DC Motor Control

  Group 1:
  22B3929 - Aman Verma
  22B3942 - Harsh S Roniyar
  22B3945 - Pranav Prakash
*/

#define RANGE_DIFF 3
#define ERROR_RANGE_HIGH 6
#define ERROR_RANGE_LOW -6

int ctrl_a = 5;
int ctrl_b = 6;
int potpin = A0;

:

float p = 5.55;
float i = 0.0224;
float d = 5.89;

:

void control_motor(char d, int speed) {
  if (d == 's') {
    analogWrite(ctrl_a, 0);
    analogWrite(ctrl_b, 0);
  } else if (d == 'f') {
    analogWrite(ctrl_a, 0);
    analogWrite(ctrl_b, speed);
  } else {
    analogWrite(ctrl_a, speed);
    analogWrite(ctrl_b, 0);
  }
}

void setup() {
  Serial.begin(9600);
  pinMode(potpin, INPUT);
  pinMode(ctrl_a, OUTPUT);
  pinMode(ctrl_b, OUTPUT);
}
```

```

    read_pot_val();
    init_val = new_val;
    find_non_linear();

    fin_val = int(180 + init_val);

    if(fin_val > 350){
        fin_val = int(init_val - 180);
    }

    update_dir(fin_val - init_val);
}

void loop() {
    read_pot_val();

    error = float(fin_val-new_val);
    integrate = integrate + error;
    tot_err = p*error + i*integrate + d*(error-preverror);
    preverror=error;

    if(start == 0){
        start = millis();
    }

    if(tot_err<0){
        control_motor('b', (min(abs(tot_err),255)));
    } else {
        control_motor('f', (min(abs(tot_err),255)));
    }

    Serial.print(millis() - start);
    Serial.print(",");
    Serial.println(new_val);
}

```

### 3 Challenges Faced and Solutions

- **Tuning of the PID Gains:** Finding the appropriate values for the PID gains ( $K_p$ ,  $K_i$ ,  $K_d$ ) to meet the design specifications was challenging. Solution: Started with a proportional-only controller, then introduced integral and derivative gains gradually, fine-tuning based on the observed response.

- **Non-linearities in the Potentiometer:** The potentiometer used to measure the motor's position had a non-linear response in a certain region, affecting position control accuracy. *Solution:* Identified non-linear regions by analyzing the potentiometer output across its range.
- **Overshoot and Stability Issues:** Achieving a balance between a fast response (low rise time) and minimal overshoot was difficult. Over-tuning for speed lead to excessive overshoot or instability. *Solution:* Gradually tuned the derivative gain ( $K_d$ ) to dampen oscillations and reduce overshoot while maintaining a quick response. Monitored the system's step response closely during tuning to prevent instability.

## 4 Results

- The non-linear region was found to be between  $25^\circ$  and  $35^\circ$ .
- The final values of the PID gains were  $K_p = 5.55$ ,  $K_i = 0.0224$  and  $K_d = 5.89$ .
- The rise time was found to be 0.41s, settling time was found to be 0.993s and the overshoot was found to be 3%.
- The analog reading of potentiometer corresponding to a swing of  $180^\circ$  was found to be 506.
- The output of the motor position vs time is shown in the below graph.

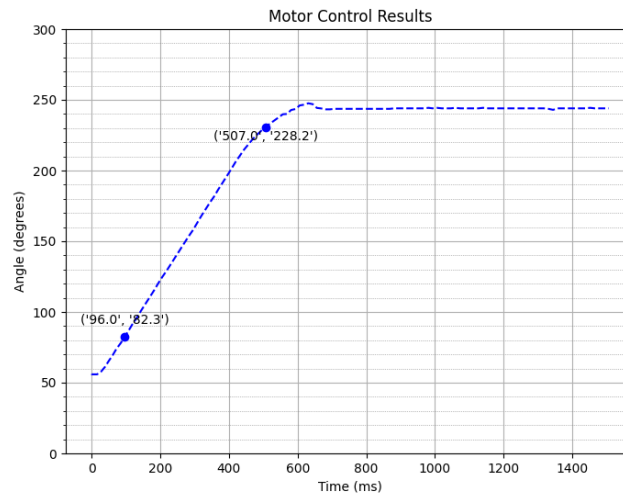


Figure 1: Motor Position vs Time

## 5 Observations and Inference

- The PID controller was able to rotate the motor by  $180^\circ$  from any given point.
- The rise time, settling time and overshoot were found to be within the design specifications.
- The potentiometer reading corresponding to a swing of  $180^\circ$  was not exactly 512 as expected. This was due to the non-linear region of the potentiometer.


## 6 TA Result Sheet

**CONTROL & COMPUTING LAB  
RESULT SHEET**

	Student Name	Roll No
1	Aman Verma	22B3929
2	Harsh Ranjor	22B3942
3	Pranav Prakash	22B3945

Group No - ' 1

$$K_P = 5.55, K_I = 0.0224, K_d = 5.89$$
$$T_r = 410 \text{ ms}, T_s = 993 \text{ ms}, O\% = 3\%$$

	TA Name	Date	Signature
1	Nitesh	22-08-24	
2	Anurag Yadav	22-08-24	