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 $180°$ 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:

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

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-linearity Identification:** The potentiometer used to measure the motor's position had a non-linear response in a certain region, affecting position control accuracy.
  <u>*Solution:*</u> Created a function that was called in the setup function, that rotated the motor slowly while checking for a large change in readings (indicative of the non-linear region).

- **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.
  <u>*Solution:*</u> 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 $25°$ and $35°$.
- 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 $180°$ was found to be 506.
- The output of the motor position vs time is shown in the below graph.

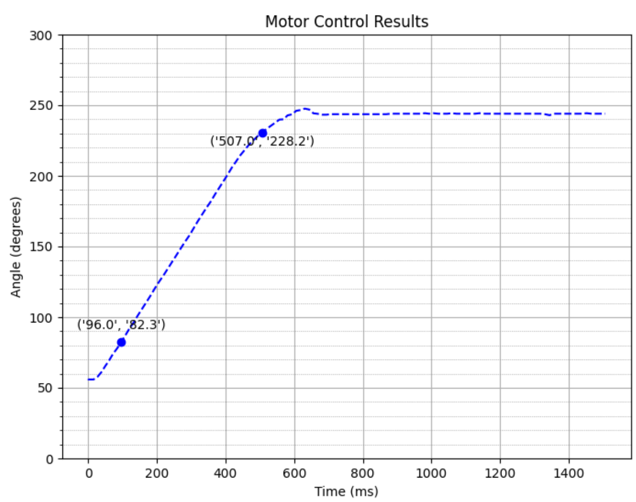
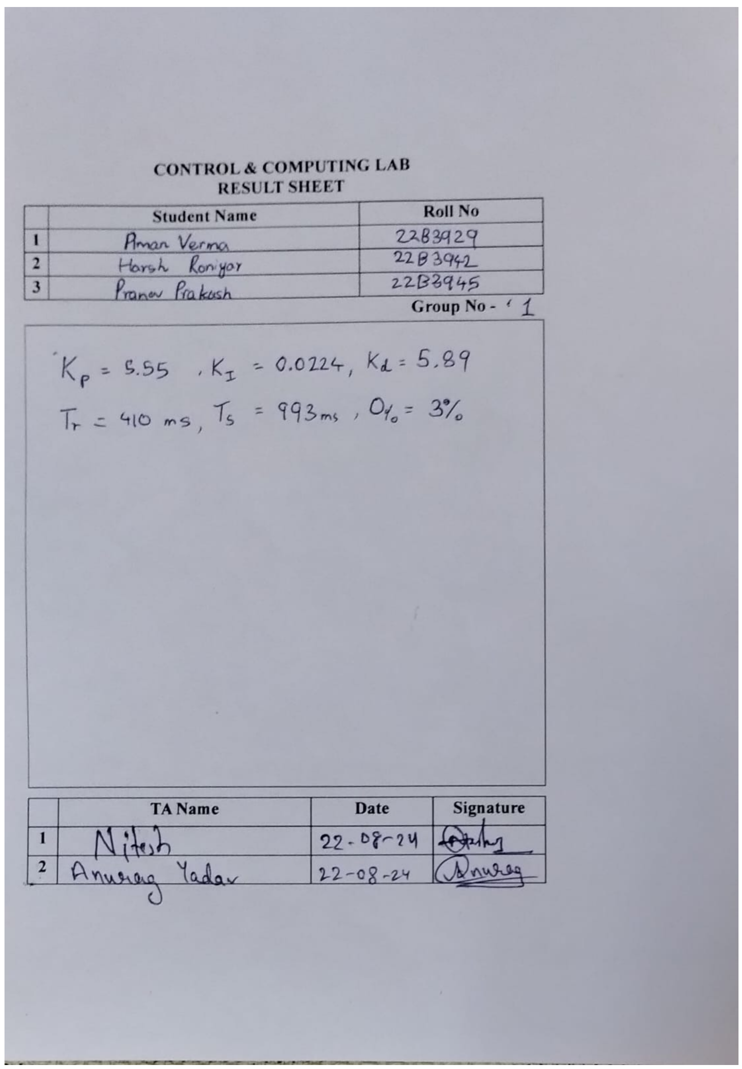


Figure 1: Motor Position vs Time

5 Observations and Inference

- The PID controller was able to rotate the motor by 180° 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° 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 Raniyar	22B3942
3	Pranav Prakash	22B3945

Group No - 1

$K_p = 5.55$, $K_I = 0.0224$, $K_d = 5.89$

$T_r = 410$ ms, $T_s = 993$ ms, $O\% = 3\%$

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