DAFTAR REFERENSI

[1] "International vocabulary of metrology-Basic and general concepts and associated terms (VIM) 3rd edition 2008 version with minor corrections," 2012.

[2] T. P. Tunggal, L. A. Kirana, A. Z. Arfianto, E. T. Helmy, and F. Waseel, "Design of contact and non-contact tachometer using microcontroller," *Journal of Robotics and Control (JRC)*, vol. 1, no. 3, pp. 65–69, May 2020, doi: 10.18196/jrc.1315.

[3] D. N. Kaputra, K. Kosjoko, and A. F. S. P. Nusantara, "Pengaruh Variasi Kemiringan Sudut Sudu Pengarah Angin 20°, 40°, dan 60° terhadap Tingkat Efisiensi Turbin Angin Sumbu Vertikal," *J-Proteksion: Jurnal Kajian Ilmiah dan Teknologi Teknik Mesin*, vol. 7, no. 1, pp. 28–34, Aug. 2022, doi: 10.32528/jp.v7i1.7860.

[4] I. Siregar and S. Lubis, "Analisa Pengaruh Sudut Sudu Impeller Pada Unjuk Kerja Blower Sentrifugal," vol. 1, no. 1, pp. 11–18, 2020.

[5] "Criteria For Laboratories Accredited to Calibrate Tachometers, Centrifuges and Measure Rotational Speed," 2017.

[6] S. A. Ananda and E. Tanaka Soewangsa, "Studi Karakteristik Motor DC Penguat Luar Terhadap Posisi Sikat," *Jurnal Teknik Elektro*, vol. 3, no. 1, pp. 51–56, 2003, [Online]. Available: http://puslit.petra.ac.id/journals/electrical/51

[7] T. N. Trong, "The control structure for dc motor based on the flatness control," *International Journal of Power Electronics and Drive Systems*, vol. 8, no. 4, pp. 1814–1821, Dec. 2017, doi: 10.11591/ijpeds.v8i4.pp1814-1821.

[8] I. W. R. Saputra, "Mesin DC," Apr. 29, 2013. https://blogs.itb.ac.id/el2244k0112211011iwayanrakanandasaputra/2013/04/29/mesin-dc/ (accessed Feb. 23, 2023).

[9] S. Muttaqin, "Analisa Karakteristik Generator dan Motor DC."

[10] Rodwell International Corporation, *Basic Motor Theory*. 1999.

[11] "Arduino Uno." https://upload.wikimedia.org/wikipedia/commons/6/6e/A000066_featured_4.jpg (accessed Feb. 23, 2023).

[12] Nurhalija, D. Irma Ardianti, Khairina, A. Aidiel Fitra, and M. Yakob, "Pemanfaatan LM393 IR Sensor Module Sebagai Pengukur Kecepatan Rotasi Berbasis Mikrokontroler," *Jurnal Hadron*, vol. 1, no. Jurnal Hadron, 2019.

[13] Nurhalija, D. Irma Ardianti, Khairina, A. Aidiel Fitra, and M. Yakob, "PEMANFAATAN LM393 IR SENSOR MODULE SEBAGAI PENGUKUR KECEPATAN ROTASI BERBASIS MIKROKONTROLER," 2019.

[14] A. Asmara Putra, E. Susanto, and N. Prihatiningrum, "Sistem Perekam Kecepatan Sepeda Motor Saat Kecelakaan Menggunakan MicroSD," *e-Proceeding of Engineering*, vol. 8, no. Telkom University, pp. 11479–11484, 2021.

[15] A. Akbar Firdaus, Khuria, K. Wijaya Kusuma, N. Salvaningtyas, and M. Azmita, "Pemantauan Kecepatan Turbin Angin Sumbu Vertikal Secara Real-time Berdasarkan Internet of Things," *Journal of ALINIER*, vol. 3, no. Teknik Elektro ITN Malang, 2022, [Online]. Available: www.elektro.itn.ac.id

[16] R. Muhardian and Krismadinata, "Kendali Kecepatan Motor DC Dengan Kontroller PID dan Antarmuka Visual Basic," *JTEV (Jurnal Teknik Elektro dan Vokasional)*, vol. 06, no. Universitas Negeri Padang, 2020, [Online]. Available: http://ejournal.unp.ac.id/index.php/jtev/index

[17] M. R. Putera and R. Hidayat, "Kendali Kecepatan Motor DC Menggunakan Pengendali PID Dengan Ecoder Sebagai Feedback," *STRING*, vol. 7, no. Pusat Kajian dan Inovasi Teknologi (SAKAINTEK), 2022.

[18] D. Hendrawati, "Respon Sistem dari Parameter Kontroler PID Pada Kontrol Posisi Motor DC," *Prosiding SNST ke-3*, pp. 41–46, 2012.

[19] M. Irhas, Iftitah, and S. Asyiqah, "Penggunaan Kontrol PID Dengan Berbagai Metode Untuk Analisis Pengaturan Kecepatan MOTOR DC,"

Jurnal Fisika dan Terapannya, vol. 7, no. 1, pp. 78–86, 2020, [Online]. Available: http://journal.uin-alauddin.ac.id/index.php/jft

[20] P. Siagian, "Simulasi Matlab Untuk Perancangan PID Controller," *Jurnal PROCESSOR*, vol. 6, no. 1, pp. 51–60, 2011.

[21] D. Somwanshi, M. Bundele, G. Kumar, and G. Parashar, "Comparison of fuzzy-PID and PID controller for speed control of DC motor using LabVIEW," in *Procedia Computer Science*, 2019, vol. 152, pp. 252–260. doi: 10.1016/j.procs.2019.05.019.

[22] C. T. Chao, N. Sutarna, J. S. Chiou, and C. J. Wang, "An optimal fuzzy PID controller design based on conventional PID control and nonlinear factors," *Applied Sciences (Switzerland)*, vol. 9, no. 6, 2019, doi: 10.3390/app9061224.

[23] B. Dhiya' Ushofa, L. Anifah, G. Buditjahjanto, and Endryansyah, "Sistem Kendali Kecepatan Putaran Motor DC pada Conveyor dengan Metode Kontrol PID," *Jurnal Teknik Elektro*, vol. 11, no. Universitas Negeri Surabaya, pp. 332–342, 2022.

[24] Kasmira, A. Waris, and M. T. Sapsal, "Rancang Bangun Sistem Kendali Kecepatan Putar Motor DC menggunakan PID Controller pada Mesin Pengaduk," *Jurnal AgriTechno*, vol. 11, no. Universitas Hasanuddin Makassar, 2018.

[25] A. Ma'arif, R. Istiarno, and Sunardi, "Kontrol Proporsional Integral Derivatif (PID) pada Kecepatan Sudut Motor DC dengan Pemodelan Identifikasi Sistem dan Tuning," *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, vol. 9, no. 2, pp. 374–388, Apr. 2021, doi: 10.26760/elkomika.v9i2.374.

[26] E. Ramdani, "Parameter Identifikasi Transfer Fungsi Menggunakan MATLAB," *SETRUM*, vol. 4, no. 1, 2015.

[27] H. Om Bansal, "Tuning of PID Controllers using Simulink," *International Journal of Mathematical Modeling, Simulation and Applications*, vol. 2, no. 3, pp. 337–344, 2009, [Online]. Available: https://www.researchgate.net/publication/268802558

LAMPIRAN

Lampiran 1 Data Tegangan Keluaran Arduino Uno

PWM	Tegangan (V DC)
0	0
5	0,11
15	0,21
20	0,41
40	0,8
80	1,57
100	1,96
120	2,35
140	2,74
180	3,52
200	3,91
220	4,3
230	4,49
240	4,68
250	4,88
255	4,97

```
#include <util/atomic.h>
#include <Keypad.h>
#include <Wire.h> // for I2C LCD
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);

#define ENCA 2
#define PWM 3
#define IN1 12
#define IN2 13

const int ROW_NUM = 4; //four rows
const int COLUMN_NUM = 4; //four columns

char keys[ROW_NUM][COLUMN_NUM] = {
  {'1','2','3', 'A'},
  {'4','5','6', 'B'},
  {'7','8','9', 'C'},
  {'*','0','#', 'D'}
};

byte pin_rows[ROW_NUM] = {7, 6, 5, 4}; //connect to the row pinouts
of the keypad
byte pin_column[COLUMN_NUM] = {11, 10, 9, 8}; //connect to the
column pinouts of the keypad

Keypad keypad = Keypad( makeKeymap(keys), pin_rows, pin_column,
ROW_NUM, COLUMN_NUM );

String inputString;
long inputInt;

long prevT = 0;
int posPrev = 0;
volatile int pos_i = 0;

//float v1Filt = 0;
float v2Filt = 0;
float v1Prev = 0;
int count = 5;
int dir = 0;
int pwr = 0;
float eintegral = 0;
float ederivative = 0;
float last_error = 0;
```

```
const int d = 10;
int dataArray[d], total;
int avg;
int y = 0;

void setup() {
  Serial.begin(9600);

  lcd.begin();
  //lcd.backlight();
  pinMode(ENCA, INPUT);
  pinMode(PWM, OUTPUT);
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  //inputString.reserve(5);

  attachInterrupt(digitalPinToInterrupt(ENCA),readEncoder,RISING);
}

void loop() {
  //int pwr = 0;
  int i = 0;

  char key = keypad.getKey();
  lcd.setCursor(0, 0);
      lcd.print("SV:");
      lcd.print(inputInt);
  if (key) {
    lcd.setCursor(count, 0);
      lcd.print(key);
    //Serial.println(key);
    count++;

    if (key >= '0' && key <= '9') {     // only act on numeric keys
      inputString += key;               // append new character to
input string
    } else if (key == '#') {
      if (inputString.length() > 0) {
        inputInt = inputString.toInt(); // YOU GOT A INT NUMBER
        inputString = "";               // clear input
        lcd.clear();
        count = 5;
        // DO YOUR WORK HERE

      }
```

```
  } else if (key == '*') {
    inputString = "";                    // clear input
    lcd.clear();
    count = 5;
  } else if (key == 'B') {
    dir = 1;
    pwr = 0;
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Arah putar kanan");
    delay(3000);
    lcd.clear();
    count = 5;
  } else if (key == 'C') {
    dir = -1;
    pwr = 0;
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Arah putar kiri");
    delay(3000);
    lcd.clear();
    count = 5;
  }
}

float rpm_set = inputInt;

//read the position in atomic block
//to avoid potential misreads
int pos = 0;
ATOMIC_BLOCK(ATOMIC_RESTORESTATE){
  pos = pos_i;
}

//Compute velocity
long currT = micros();
float deltaT = ((float) (currT-prevT))/1.0e6;
float velocity1 = (pos - posPrev)/deltaT;
posPrev = pos;
prevT = currT;

//convert count/s to RPM
float v1 = velocity1/7.5*60.0;

//low-pass filter (5 Hz cutoff)
```

```
  //v1Filt = 0.969*v1Filt + 0.0155*v1 + 0.0155*v1Prev;
  //low-pass filter (25 Hz cutoff)
  v2Filt = 0.854*v2Filt + 0.0728*v1 + 0.0728*v1Prev;
  v1Prev = v1;

  float kp = 0.000549282900980062;
  float ki = 0.00329525381930268;
  float kd = -0.0000536543450559128;
  float e = rpm_set-v2Filt;

  eintegral = eintegral + e*deltaT;
  ederivative = (e - last_error)/deltaT;
  float u = kp*e + ki*eintegral +
kd*10.2374355778205/((1+10.2374355778205)*ederivative);

  pwr = u;
  if (pwr < 0) {
    pwr = 0;
  } else if (pwr > 17) {
      pwr = 17;
  }

  last_error = e;

  setMotor(dir, pwr, PWM, IN1, IN2);

  for(int index=0; index<d-1; index++) {
    dataArray[index] = dataArray[index+1];
  }
  dataArray[d-1] = v2Filt;
  total=0;
  for (int index=0; index<d; index++) {
    total+=dataArray[index];
  }
  avg = total/d;
  y = y+1;

  Serial.print(v2Filt);
  Serial.print(" ");
  Serial.print(avg);
  Serial.print(" ");
  Serial.print(pwr);
  Serial.print(" ");
  Serial.print(rpm_set);
  Serial.print(" ");
```

```
  Serial.print(y);
  Serial.println();

  lcd.setCursor(0,1);
  lcd.print("PV:");

  if (y==50) {
    lcd.print(avg);
    y = 0;
  }

  lcd.setCursor(11,1);
    lcd.print("rpm");
  lcd.setCursor(11,0);
    lcd.print("rpm");
  delay(10);

}

void setMotor(int dir, int pwmVal, int pwm, int in1, int in2){
  analogWrite(pwm, pwmVal);
  if(dir == 1){
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
  }
  else if(dir == -1){
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
  }
  else{
    digitalWrite(in1, LOW);
    digitalWrite(in1, LOW);
  }
}

void readEncoder(){
  int increment = 1;
  pos_i = pos_i+increment;
}
```

Lampiran 3 Data Uji Akurasi Alat

Setting		Pembacaan									
		1	2	3	4	5	6	7	8	9	10
800	alat	781	803	843	818	772	792	811	802	777	814
	standar	795.3	812.9	811.7	823.2	773.5	800.7	818.5	782.4	783.2	801.3
1000	alat	1004	1036	973	1028	1002	961	1041	1015	983	1018
	standar	999.5	1014	965.5	1025	1008	983.8	1018	1021	991.7	1037
1500	alat	1507	1537	1477	1516	1531	1472	1521	1554	1489	1552
	standar	1503	1574	1445	1504	1583	1462	1514	1569	1493	1537
2000	alat	2001	2014	1985	2004	2011	1983	2018	1979	2014	2003
	standar	2003	2007	1992	2001	1987	2011	2014	1993	1995	2003
2500	alat	2509	2524	2485	2511	2497	2509	2536	2515	2498	2491
	standar	2317	2306	2302	2312	2309	2311	2306	2308	2302	2312

800 rpm						
Respon Sistem	Ulangan					Rata-rata
	1	2	3	4	5	
Rise Time (s)	0.2109	0.1303	0.1089	0.1203	0.1327	0.14062
Settling Time (s)	-	-	-	-	-	-
Overshoot (%)	27.5	44.625	42.125	40.75	45.875	40.175

1000 rpm						
Respon Sistem	Ulangan					Rata-rata
	1	2	3	4	5	
Rise Time (s)	0.6017	0.5132	0.1584	0.1726	0.1924	0.32766
Settling Time (s)	-	-	-	-	-	-
Overshoot (%)	17	39.3	32.7	34.4	0.29	24.738

1500 rpm						
Respon Sistem	Ulangan					Rata-rata
	1	2	3	4	5	
Rise Time (s)	0.1532	0.1417	0.1392	0.1799	0.1446	0.15172
Settling Time (s)	-	-	-	-	-	-
Overshoot (%)	19.1333	20.6667	19.1333	21.8	18.2667	19.8

2000 rpm						
Respon Sistem	Ulangan					Rata-rata
	1	2	3	4	5	
Rise Time (s)	0.2106	0.3306	0.2902	0.2389	0.3435	0.28276
Settling Time (s)	1.3821	1.2925	1.4593	1.3651	1.3521	1.37022
Overshoot (%)	10.3	14.6	14.6	16.5	14.65	14.13

2500 rpm						
Respon Sistem	Ulangan					Rata-rata
	1	2	3	4	5	
Rise Time (s)	0.5028	0.1244	0.2416	0.6321	0.586	0.41738
Settling Time (s)	1.593	1.1953	1.6347	1.3902	1.2905	1.42074
Overshoot (%)	19.2	18.4	18.12	16.84	18.76	18.264

820-2
Users Manual

Miscellaneous Specifications

Battery Type.....3 x AA Alkaline LR6
Flash Frequency
Range .....30 FPM to 300,000 FPM
0.5 Hz to 5000 Hz
Accuracy .....0.02 %
Resolution .....30 FPM to 999 FPM = 0.1
1000 FPM to 300,000 FPM = 1
0.5 Hz to 999 Hz = 0.1
1000 Hz to 5000 Hz = 1
Frequency Setting .....FPM or Hz
Flash Pulse
Duration .....Adjustable in µs or degrees
Delay.....Adjustable in ms or degrees
Light
Color .....Approx. 6500 K
Emission Output .....4800 lx @ 6000 FPM
30 cm (11.9 in) at 3°
External Trigger
Method .....Connector to externally control trigger
Frequency Range .....0.5 Hz to 5000 Hz
High Level.....3 V to 32 V
Low Level .....<1 V
Minimum Pulse Width ...50 µs Connection

TA_LAST YUDHA

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