Kendali Kecepatan dan Posisi Motor DC

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Isi Pembahasan

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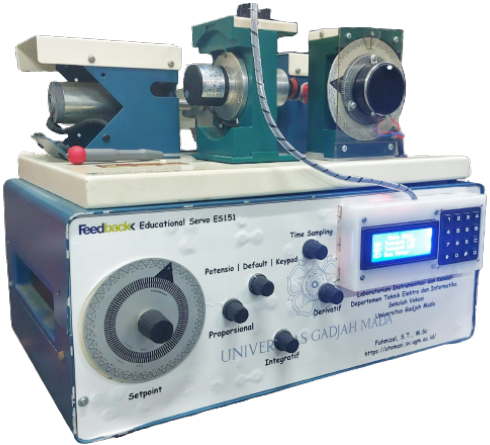
2. Pemodelan Sistem Motor DC
3. Perancangan Kendali PID Motor DC
4. Simulasi Kendali PID
5. Sistem Mekanikal dan Elektrikal
6. Desain GUI

Pengenalan Sistem

Pengenalan Sistem

Feedback Educational Servo ES151 merupakan sebuah modul motor DC servo yang digunakan untuk edukasi dalam penerapan kendali posisi dan kendali kecepatan.

Pada modul ini potensiometer digunakan untuk kendali posisi, tachogenerator digunakan untuk kendali kecepatan, dan *rotary encoder* yang dapat digunakan untuk kendali posisi maupun kecepatan.



Pemodelan Sistem Motor DC

Struktur Fisik

Parameter:

J	:	Momen inersia rotor $(Kg.m^2)$
b	:	Koefisien gaya gesek viskos $(N.m.s)$
Ke	:	Koefisien gaya elektromotif $(V/rad/sec)$
Kt	:	Koefisien torsi motor $(N.m/Amp)$
R	:	Resistansi kumparan (Ohm)
L	:	Induktansi kumparan (H)

Struktur:

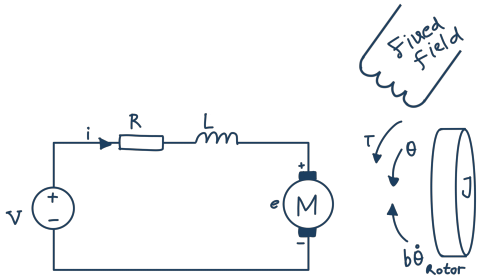
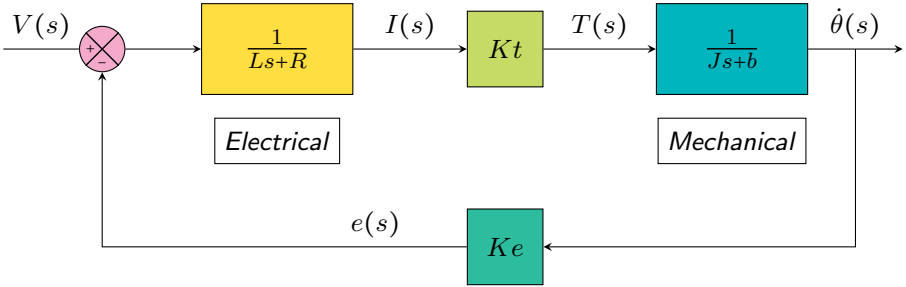


Diagram Blok Plant Motor DC

Struktur motor DC dengan parameter-parameter sebelumnya memiliki diagram blok sebagai berikut:



Fungsi Alih

Diagram blok *plant* motor DC menghasilkan persamaan fungsi alih berikut:

$$\frac{\dot{\theta}(s)}{V(s)} = \frac{Kt}{(Js+b)(Ls+R)+KtKe} \qquad \left[\frac{rad/sec}{V}\right] \tag{1}$$

Persamaan di atas merupakan fungsi alih kecepatan motor DC. Dengan mengintegralkan fungsi alih tersebut, maka diperoleh fungsi alih untuk posisi motor DC:

$$\frac{\theta(s)}{V(s)} = \frac{Kt}{s((Js+b)(Ls+R)+KtKe)} \qquad \left[\frac{rad}{V}\right] \tag{2}$$

State Space

Kecepatan:

$$\frac{\delta}{\delta t}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} = \begin{bmatrix}-\frac{b}{J} & \frac{Kt}{J}\\ -\frac{Ke}{L} & -\frac{R}{L}\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix} + \begin{bmatrix}0\\ \frac{1}{L}\end{bmatrix}V \qquad (3)$$

$$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\dot{\theta}\\ i\end{bmatrix}$$

Posisi:

$$\frac{\delta}{\delta t}\begin{bmatrix}\theta\\ \dot{\theta}\\ i\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & -\frac{b}{J} & \frac{Kt}{J}\\ 0 & -\frac{Ke}{L} & -\frac{R}{L}\end{bmatrix}\begin{bmatrix}\theta\\ \dot{\theta}\\ i\end{bmatrix} + \begin{bmatrix}0\\ 0\\ \frac{1}{L}\end{bmatrix}V \qquad (4)$$

$$y = \begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}\theta\\ \dot{\theta}\\ i\end{bmatrix}$$

Perancangan Kendali PID Motor DC

Apa Itu Kendali PID?

- PID=**Proportional-Integral-Derivative**
- Kendali mekanisme umpan balik yang biasanya dipakai pada sistem kontrol industri
- Secara kontinu menghitung nilai kesalahan sebagai beda antara setpoint yang diinginkan dan variabel proses terukur. Persamaan:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \tag{5}$$

Mengapa Kendali PID?

Kendali PID berfungsi untuk meminimalkan nilai kesalahan (*error*) setiap waktu dengan penyetelan variabel kontrol, seperti posisi, kecepatan, damper, daya, dan lain sebagainya.
Contoh perbandingan sistem dengan dan tanpa PID:

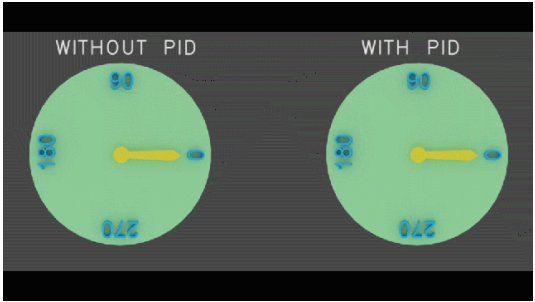
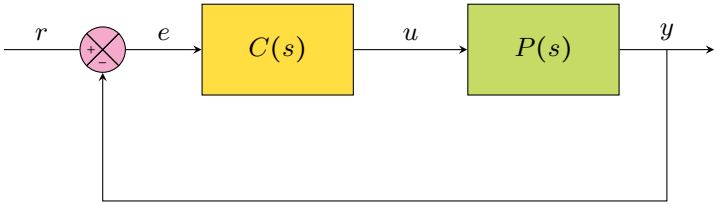


Diagram Blok Kendali



Keterangan:

$C(s)$	:	*Controller*
$P(s)$	:	*Plant*
$r(s)$	:	*Output* yang diinginkan
$e(s)$	:	Nilai *error*
$u(s)$	:	Sinyal kendali
$y(s)$	:	*Output* sesungguhnya

Diagram Blok Kendali PID Motor DC: Kecepatan

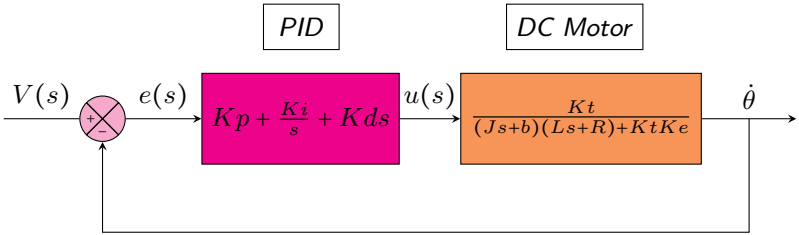
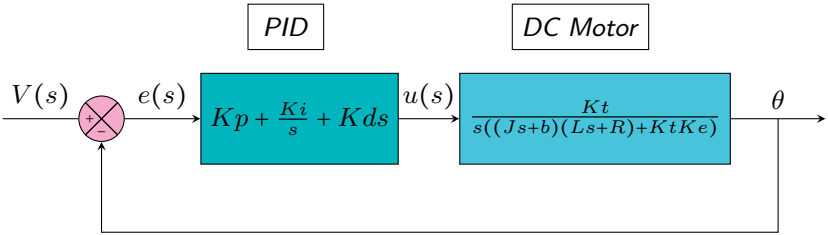


Diagram Blok Kendali PID Motor DC: Posisi



Simulasi Kendali PID

Uji Perbandingan Sistem *Open-loop* dengan *Closed-loop* Motor DC

Program *Open-loop*:

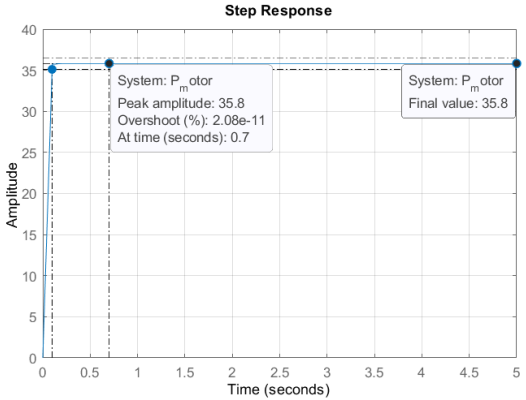
```
J = 3.2284E-6;
b = 3.5077E-6;
Kt = 0.0274;
Ke = 0.0274;
R = 4;
L = 2.75E-6;;
s = tf('s');
P_motor = Kt/((J*s+b)*(L*s+R)+Kt*Ke);
rP_motor = 0.1/(0.5*s+1)
ltiview('step', P_motor, 0:0.1:5);
```

Program *Closed-loop*:

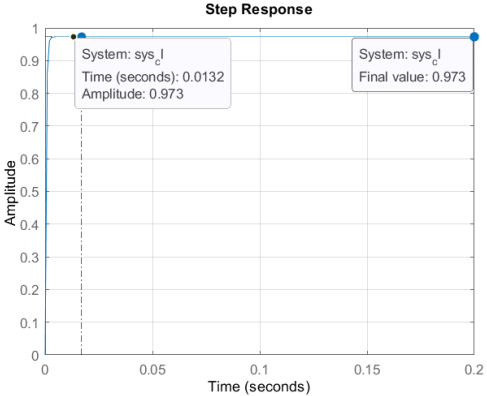
```
J = 3.2284E-6;
b = 3.5077E-6;
Kt = 0.0274;
Ke = 0.0274;
R = 4;
L = 2.75E-6
s = tf('s');
P_motor = Kt/((J*s+b)*(L*s+R)+Kt*Ke);
t = 0:0.001:0.2;
sys_cl = feedback(P_motor,1)
step(sys_cl,t)
```

Uji Perbandingan Sistem *Open-loop* dengan *Closed-loop* Motor DC

Hasil *Open-loop*:



Hasil *Closed-loop*:



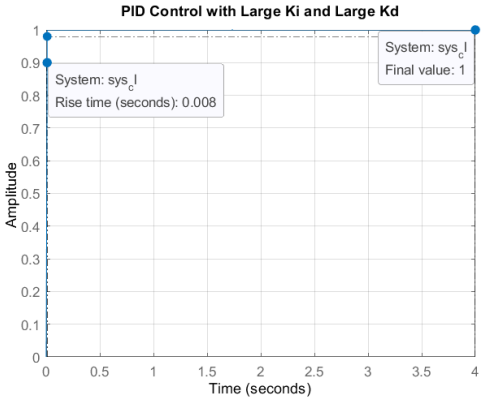
Kendali PID: Kecepatan

Program:

```
J = 3.2284E-6;
b = 3.5077E-6;
Kt = 0.0274;
Ke = 0.0274;
R = 4;
L = 2.75E-6;
s = tf('s');
P_motor = Kt/((J*s+b)*(L*s+R)+Kt*Ke);

Kp = 100;
Ki = 200;
Kd = 10;
C = pid(Kp,Ki,Kd);
sys_cl = feedback(C*P_motor,1);
step(sys_cl, 0:0.01:4)
grid
title('PID Control with Large Ki and Large Kd')
```

Hasil:



Kendali PID: Posisi

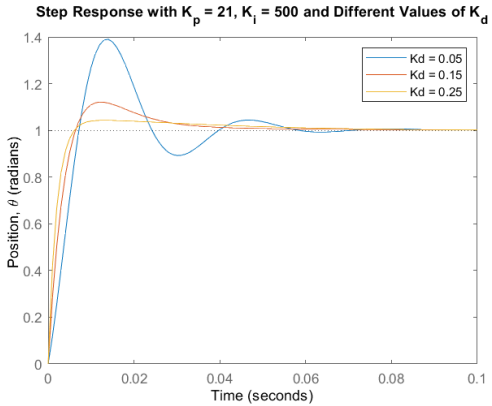
Program:

```
J = 3.2284E-6;
b = 3.5077E-6;
K = 0.0274;
R = 4;
L = 2.75E-6;
s = tf('s');
P_motor = K/(s*((J*s+b)*(L*s+R)+K^2));
Kp = 21;
Ki = 500;
Kd = 0.05;

for i = 1:3
  C(:,:,i) = pid(Kp,Ki,Kd);
  Kd = Kd + 0.1;
end

sys_cl = feedback(C*P_motor,1);
t = 0:0.001:0.1;
step(sys_cl(:,:,1), sys_cl(:,:,2), sys_cl(:,:,3), t)
ylabel('Position, \theta (radians)')
title('Step Response with K_p = 21, K_i = 500 and
      Different Values of K_d')
legend('Kd = 0.05', 'Kd = 0.15', 'Kd = 0.25')
```

Hasil:



Simulink

Diagram Blok Simulink

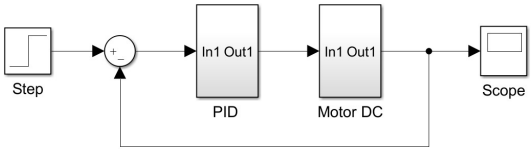
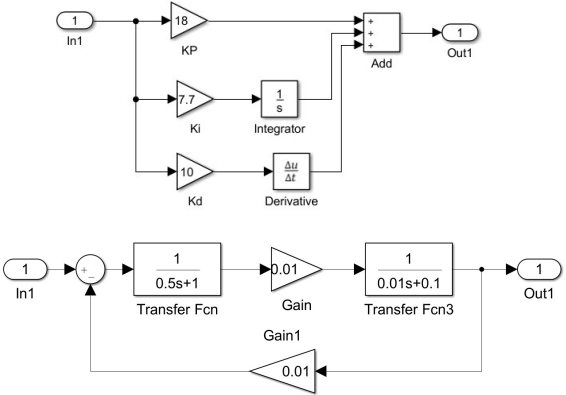
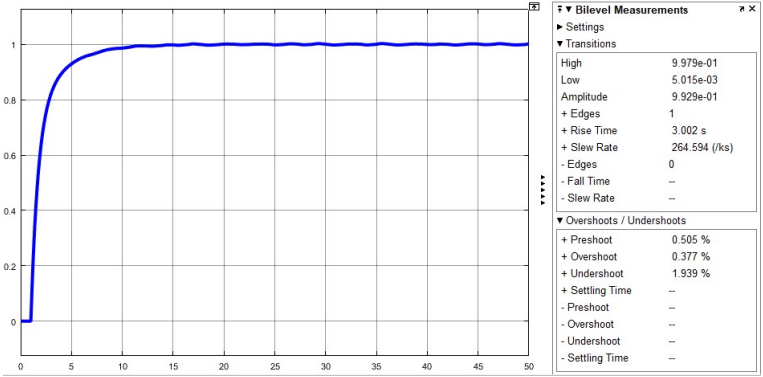


Diagram Blok PID dan Plant Motor DC

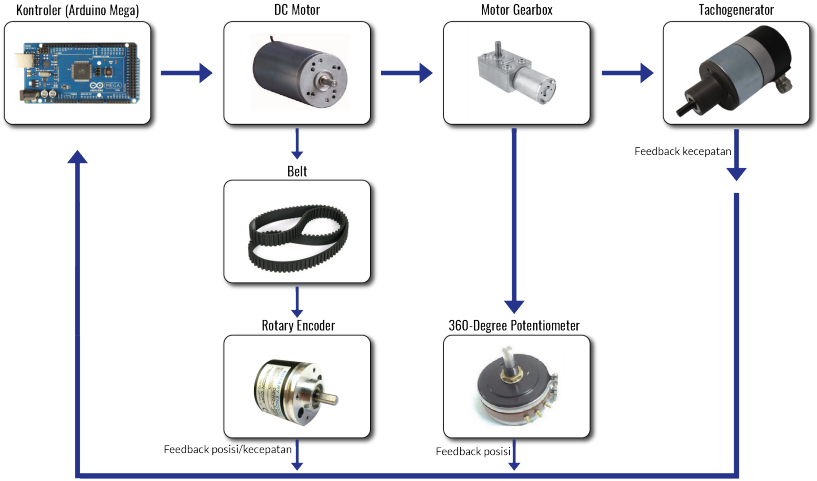


Hasil Simulink

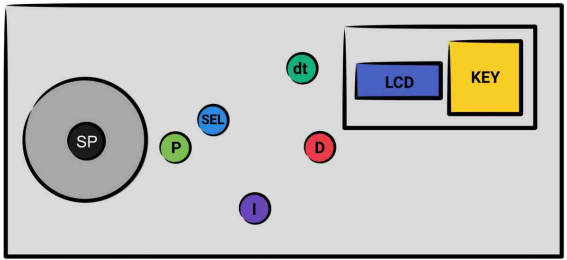


Sistem Mekanikal dan Elektrikal

Diagram Sistem



Konfigurasi Pin-Pin Arduino Mega

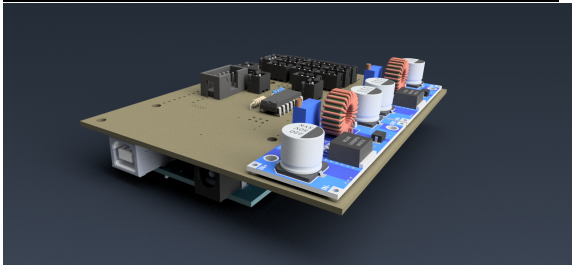


Kontroler

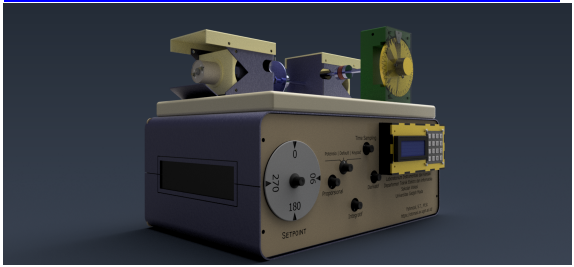
Input-Output	**Fungsi**	**Pin**
SP	Set Poin	A7
P	Proporsional	A5
I	Integral	A8
D	Derivatif	A6
SEL	*Selector*	34, 32, 30
dt	*Time Sampling*	A4
LCD	LCD	0, 1
KEY	Keypad	52, 50, 48, 46, 44, 42, 40, 38

Desain 3D

Board PCB

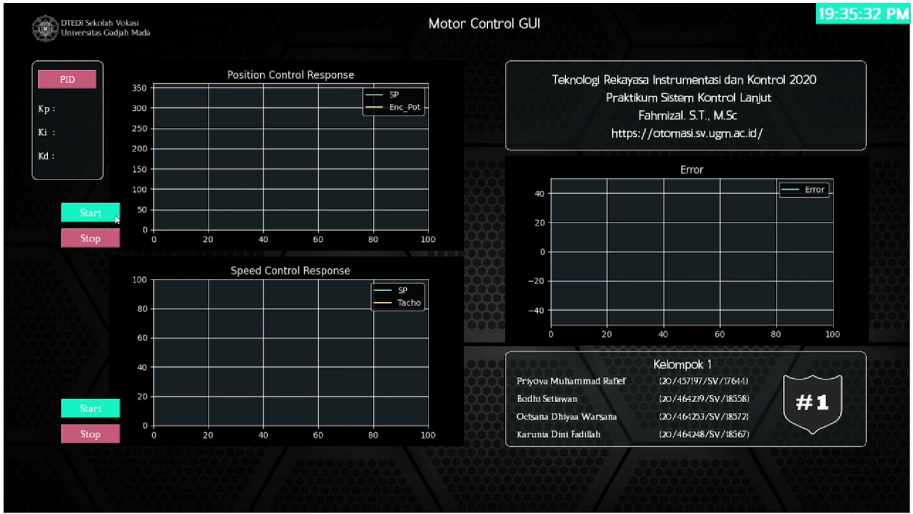


Alat



Desain GUI

Tampilan GUI



Kesimpulan

Daftar Pustaka

- *Control Tutorials for MATLAB and Simulink. "DC Motor Speed: System Modeling"*, (https://ctms.engin.umich.edu/CTMS/index.php?example=MotorSpeed+section=SystemModeling) [Waktu akses].
- *Control Tutorials for MATLAB and Simulink. "DC Motor Position: System Modeling"*, (https://ctms.engin.umich.edu/CTMS/index.php?example=MotorPosition+section=SystemModelin [Waktu akses].

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