LAPORAN MIKROKONTROLLER

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A. Program Blink:

```
#define LED 2

void setup() {
 pinMode(LED,OUTPUT);
} void loop() {  delay(500);
 digitalWrite(LED,HIGH);
delay(500);
 digitalWrite(LED,LOW);
}
```

Kode ini adalah program sederhana untuk mengendalikan LED menggunakan **Arduino**. Berikut adalah penjelasan detail untuk setiap bagian dari kode:

1. Pendefinisian Konsta

```
#define LED 2
```

•Baris ini mendefinisikan konstanta bernama `LED` dengan nilai `2`.

•Konstanta `LED` digunakan untuk merepresentasikan pin **digital** nomor 2 pada board Arduino.

2. Fungsi `setup()`

```
void setup() {  pinMode(LED,OUTPUT);
```

•Fungsi `setup()` dijalankan satu kali saat Arduino pertama kali dinyalakan atau di-reset.

•`pinMode(LED,OUTPUT);` mengatur pin 2 (yang didefinisikan dengan `LED`) sebagai **output**, sehingga dapat mengontrol perangkat seperti LED.

3. Fungsi `loop()`

```
void loop() {  delay(500);  digitalWrite(LED,HIGH);  delay(500);
 digitalWrite(LED,LOW);
}
```

Fungsi `loop()` dijalankan terus-menerus selama Arduino aktif. •**`delay(500)`**`;` : Menunggu selama 500 milidetik (0.5 detik) sebelum menjalankan instruksi berikutnya.

•**`digitalWrite(LED,HIGH);`** **:** Mengirim sinyal HIGH ke pin 2, yang menyalakan LED.

•**`delay(500);`** : Menunggu selama 500 milidetik (0.5 detik) lagi.

•**digitalWrite(LED,LOW)**`;` : Mengirim sinyal LOW ke pin 2, yang mematikan LED.

OutPut

LED yang terhubung ke pin 2 akan menyala selama 0.5 detik, kemudian mati selama 0.5 detik, dan pola ini akan terus diulang selama Arduino menyala.

Prinsip Kerja

•`HIGH`: Menghubungkan pin ke tegangan tinggi (biasanya 5V), sehingga LED menyala.

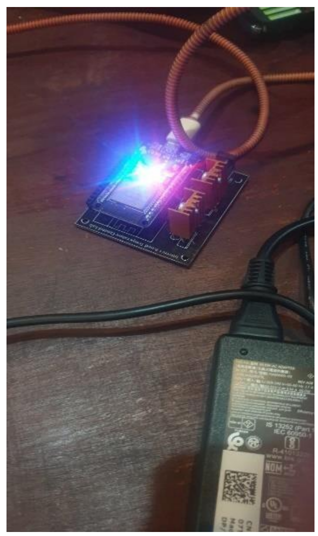
•`LOW`: Menghubungkan pin ke ground (0V), sehingga LED mati.

•Fungsi `delay()` menambahkan jeda untuk menghasilkan efek nyala-mati secara teratur.

Kegunaan

Program ini cocok untuk membuat LED berkedip (blinking) sederhana, yang sering digunakan sebagai contoh dasar pemrograman Arduino.

Foto Hasil



B. ITCLab-1:

```
#include <Arduino.h>

// constants
const int baud = 115200;     // serial baud rate

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;       // T1 const int pinT2   = 35;       // T2
const int pinQ1   = 32;       // Q1 const int pinQ2   = 33;       // Q2
const int pinLED  = 26;       // LED

// setting PWM properties const
int freq = 5000; //5000 const int
ledChannel = 0;
```

```
const int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

float cel, cel1, degC, degC1;
const float upper_temperature_limit = 55;

// global variables
float Q1 = 0;         // value written to Q1 pin float Q2 = 0;
// value written to Q2 pin int iwrite_max = 255;      // integer
value for writing int iwrite_min = 0;       // integer value for
writing
 void setup() {
 // put your setup code here, to run once:
Serial.begin(baud);   while (!Serial) {
  ;// wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled   ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled   ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled   ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
ledcWrite(ledChannel,0);
}
void Q1on(){
  ledcWrite(Q1Channel,iwrite_max/255*100);
  //Q1 = iwrite_max/255*100;
  //Serial.println(Q1);
}
void Q1off(){
  ledcWrite(Q1Channel,iwrite_min/255*100);
  //Q1 = iwrite_min/255*100;
  //Serial.println(Q1);
}
void Q2on(){
  ledcWrite(Q2Channel,iwrite_max/255*100);
  //Q2 = iwrite_max/255*100;
  //Serial.println(Q2);
```

```
}
void Q2off(){
  ledcWrite(Q2Channel,iwrite_min/255*100);
  //Q2 = iwrite_min/255*100;
  //Serial.println(Q2);
}
void ledon(){
  ledcWrite(ledChannel,iwrite_max);
}
void ledoff(){
  ledcWrite(ledChannel,iwrite_min);
}
void cektemp(){
 degC = analogRead(pinT1) * 0.322265625 ;  // use for 3.3v AREF   cel =
degC/10;
 degC1 = analogRead(pinT2) * 0.322265625 ;  // use for 3.3v AREF   cel1 =
degC1/10;

 Serial.print("Temperature: ");
 Serial.print(cel);  // print the temperature T1 in Celsius
 Serial.print("°C");
 Serial.print(" ~ "); // separator between Celsius and Fahrenheit
 Serial.print(cel1);  // print the temperature T2 in Celsius
 Serial.println("°C");
}
void loop() {
 // put your main code here, to run repeatedly:  cektemp();
 if (cel > upper_temperature_limit){
Q1off();    ledon();
 } else {
Q1on();
ledoff();
 }
 if (cel1 > upper_temperature_limit){
Q2off();    ledon();
 } else {
Q2on();
ledoff();
 }
 delay (100);
}
```

Kode ini adalah program berbasis Arduino yang menggunakan **iTCLab Shield** untuk mengukur suhu melalui sensor suhu (T1 dan T2), mengendalikan output PWM (Q1 dan Q2), dan LED. Berikut adalah penjelasan detail dari kode tersebut:

1. Header dan Konstanta

```
#include <Arduino.h>
```

Header ini digunakan dalam platform Arduino IDE untuk memastikan kompatibilitas fungsi.

```
const int baud = 115200;    // serial baud rate
```

Kecepatan komunikasi serial (baud rate) diatur ke 115200 bps untuk pengiriman data melalui Serial Monitor.

```
const int pinT1  = 34;     // T1 const int pinT2
= 35;     // T2 const int pinQ1  = 32;     // Q1
const int pinQ2  = 33;     // Q2 const int
pinLED  = 26;     // LED
```

•Pin **T1** dan **T2** adalah input analog untuk membaca suhu dari sensor.

•Pin **Q1**, **Q2**, dan **LED** adalah output digital dengan fungsi PWM.

```
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15
```

•Frekuensi PWM diatur ke 5 kHz dengan resolusi 8-bit (nilai 0-255).

•**upper_temperature_limit** adalah batas suhu maksimum untuk tindakan otomatis.

2. Variabel Global

```
float Q1 = 0;         // value written to Q1 pin float Q2 = 0;
// value written to Q2 pin int iwrite_max = 255;     // integer
value for writing int iwrite_min = 0;      // integer value for
writing
```

Variabel ini digunakan untuk mengontrol dan menyimpan data PWM serta nilai suhu.

3. Fungsi setup()

```
void setup() {
 // put your setup code here, to run once:
Serial.begin(baud);  while (!Serial) {
  ; // wait for serial port to connect.  }
```

Memulai komunikasi serial dengan baud rate 115200 dan menunggu koneksi serial.

```
 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1, Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2, Q2Channel);

 // configure pinLED PWM functionalitites
```

```
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
 ledcWrite(ledChannel,0);
}
```

Pin Q1, Q2, dan LED dikonfigurasi sebagai output PWM menggunakan kanal masing-masing.

4. Fungsi Pengendalian

Menghidupkan/Mematikan Q1, Q2, dan LED:

```
void Q1on(){
  ledcWrite(Q1Channel,iwrite_max/255*100);
  //Q1 = iwrite_max/255*100;
  //Serial.println(Q1);
}
void Q1off(){
  ledcWrite(Q1Channel,iwrite_min/255*100);
  //Q1 = iwrite_min/255*100;
  //Serial.println(Q1);
}
void Q2on(){
  ledcWrite(Q2Channel,iwrite_max/255*100);
  //Q2 = iwrite_max/255*100;
  //Serial.println(Q2);
}
void Q2off(){
  ledcWrite(Q2Channel,iwrite_min/255*100);
  //Q2 = iwrite_min/255*100;
  //Serial.println(Q2);
}
void ledon(){
  ledcWrite(ledChannel,iwrite_max);
}
void ledoff(){
  ledcWrite(ledChannel,iwrite_min);
}
```

Fungsi ini digunakan untuk mengontrol status PWM (0 untuk mati, nilai maksimum untuk hidup). **Membaca Suhu dari Sensor:**

```
void cektemp(){
 degC = analogRead(pinT1) * 0.322265625 ;  // use for 3.3v AREF   cel = degC/10;
 degC1 = analogRead(pinT2) * 0.322265625 ;  // use for 3.3v AREF   cel1 = degC1/10;

 Serial.print("Temperature: ");
 Serial.print(cel);  // print the temperature T1 in Celsius
 Serial.print("°C");
 Serial.print(" ~ "); // separator between Celsius and Fahrenheit
```

```
 Serial.print(cel1); // print the temperature T2 in Celsius
 Serial.println("°C");
}
```

`analogRead` membaca nilai ADC dari pin sensor suhu dan dikonversi ke derajat Celsius menggunakan faktor skala.

5. Fungsi `loop()`:

```
void loop() {
 // put your main code here, to run repeatedly:  cektemp();
 if (cel > upper_temperature_limit){
Q1off();    ledon();
 }  else {
Q1on();
ledoff();
 }
 if (cel1 > upper_temperature_limit){
Q2off();    ledon();
 }  else {
Q2on();
ledoff();
 }
 delay (100);
}
```

Fungsi ini:

- Membaca suhu T1 dan T2 menggunakan `cektemp()`.
- Jika suhu T1 melebihi batas, Q1 dimatikan, dan LED dihidupkan.
- Jika suhu T2 melebihi batas, Q2 dimatikan, dan LED dihidupkan.
- Jika suhu berada di bawah batas, Q1 dan Q2 dinyalakan, dan LED dimatikan.

Output

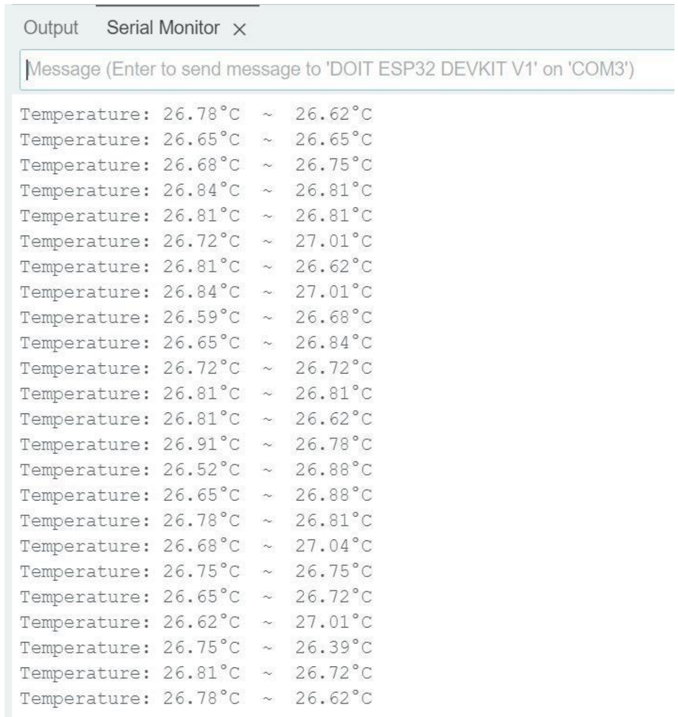
- Serial Monitor akan menampilkan suhu T1 dan T2 secara real-time.
- Jika suhu melebihi 55°C:
  - Output Q1 atau Q2 akan dimatikan.
  - LED akan menyala sebagai indikator peringatan.
- Jika suhu di bawah 55°C:
  - Output Q1 dan Q2 akan hidup.
  - LED akan mati.

Kegunaan

Kode ini dapat digunakan dalam sistem kontrol suhu otomatis seperti pendingin, pemanas, atau peringatan suhu tinggi.

Screenshot

Hasil



C. ITCLab-2

```
// the number of the LED pin const
int ledPin = 26;

// setting PWM properties
const int freq = 5000; const int
ledChannel = 0; const int
resolution = 8;

void setup(){
 // configure LED PWM functionalitites  ledcSetup(ledChannel,
freq, resolution);

 // attach the channel to the GPIO to be controlled  ledcAttachPin(ledPin,
ledChannel);
}
void loop(){
 // increase the LED brightness
 for(int dutyCycle = 0; dutyCycle <= 255; dutyCycle++){
  // changing the LED brightness with PWM
ledcWrite(ledChannel, dutyCycle);   delay(20);
 }

 // decrease the LED brightness
 for(int dutyCycle = 255; dutyCycle >= 0; dutyCycle--){
  // changing the LED brightness with PWM
ledcWrite(ledChannel, dutyCycle);    delay(20);

 }
}
```

Kode ini adalah program sederhana untuk mengontrol kecerahan sebuah LED menggunakan PWM (Pulse Width Modulation) pada ESP32 atau mikrokontroler serupa. Berikut adalah penjelasan per bagian:

1. Variabel Global

```
const int ledPin = 26;
```

Menentukan pin GPIO yang terhubung ke LED. Dalam hal ini, pin 26.

2. Properti PWM

```
const int freq = 5000; const
int ledChannel = 0; const
int resolution = 8;
```

- Frekuensi PWM yang akan digunakan, yaitu 5000 Hz.
- Saluran PWM yang digunakan (ESP32 mendukung beberapa saluran PWM).
- Resolusi PWM dalam bit, yaitu 8-bit (nilai PWM antara 0 hingga 255).

3. Fungsi `setup()`

Konfigurasi PWM pada LED:

```
ledcSetup(ledChannel, freq, resolution);
```

Mengatur properti PWM (frekuensi dan resolusi) untuk saluran yang ditentukan.

Melampirkan Saluran PWM ke GPIO:

```
ledcAttachPin(ledPin, ledChannel);
```

Mengaitkan saluran PWM ke pin GPIO yang terhubung dengan LED.

4. **Fungsi `loop()`**

Tujuan: Mengontrol LED untuk secara bertahap menjadi lebih terang dan kemudian lebih redup dalam sebuah siklus. **Meningkatkan Kecerahan LED**

```
for(int dutyCycle = 0; dutyCycle <= 255; dutyCycle++){
  // changing the LED brightness with PWM
ledcWrite(ledChannel, dutyCycle);    delay(20);
 }
```

Proses:

- `for` loop menaikkan nilai `dutyCycle` dari 0 ke 255.
- `ledcWrite(ledChannel, dutyCycle);` : Menulis nilai PWM ke saluran yang ditentukan untuk mengubah tingkat kecerahan LED.
- `delay(20);` : Menambahkan jeda 20 ms antara setiap perubahan kecerahan agar transisinya halus.

Menurunkan Kecerahan LED

```
for(int dutyCycle = 255; dutyCycle >= 0; dutyCycle--){
  // changing the LED brightness with PWM
  ledcWrite(ledChannel, dutyCycle);      delay(20);
 }
```

Proses:

- `for` loop menurunkan nilai `dutyCycle` dari 255 ke 0.
- Sama seperti sebelumnya, `ledcWrite` mengatur nilai PWM untuk membuat LED perlahan menjadi lebih redup.

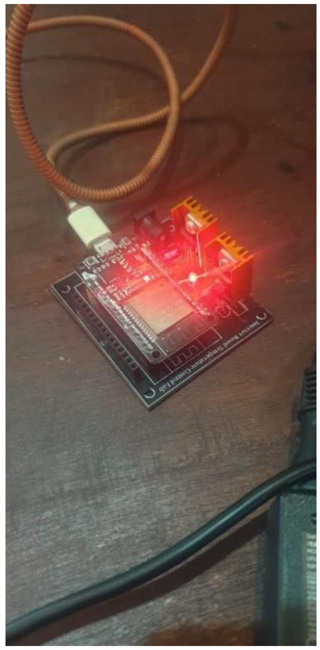
Output

- LED akan perlahan menjadi lebih terang hingga mencapai kecerahan maksimum (nilai PWM = 255).
- Setelah itu, LED akan perlahan menjadi lebih redup hingga mati (nilai PWM = 0).
- Siklus ini akan berulang terus-menerus.

Kegunaan

Kode ini menunjukkan bagaimana menggunakan fitur PWM pada ESP32 untuk menghasilkan efek fading pada LED. Nilai resolusi 8-bit memberikan tingkat kontrol hingga 256 langkah (0-255), dan loop dalam kode memberikan perubahan bertahap pada kecerahan LED dengan efek yang terlihat halus.

Hasil Foto



D. ITCLab-3

Di ITCLab ke-3 ada tiga kode yaitu, kode Arduino, Python, dan Notebook Jupyter.

```
#include <Arduino.h>

// constants
const String vers = "1.04";  // version of this firmware const
int baud = 115200;    // serial baud rate const char sp = ' ';
// command separator const char nl = '\n';      // command
terminator

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1  = 34;      // T1 const int pinT2  = 35;      // T2
const int pinQ1  = 32;      // Q1 const int pinQ2  = 33;      // Q2
const int pinLED  = 26;      // LED

//Q1 32 - T1 34
//Q2 33 - T2 35

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

const double upper_temperature_limit = 59;

// global variables
char Buffer[64];         // buffer for parsing serial input  String
cmd;            // command   double pv = 0;          // pin value float
level;            // LED level (0-100%) double Q1 = 0;          // value
written to Q1 pin double Q2 = 0;          // value written to Q2 pin
int iwrite = 0;          // integer value for writing float dwrite = 0;
// float value for writing
int n = 10;          // number of samples for each temperature measurement

void parseSerial(void) {
 int ByteCount = Serial.readBytesUntil(nl,Buffer,sizeof(Buffer));  String
read_ = String(Buffer);  memset(Buffer,0,sizeof(Buffer));

 // separate command from associated data
int idx = read_.indexOf(sp);  cmd =
read_.substring(0,idx);  cmd.trim();
cmd.toUpperCase();

 // extract data. toInt() returns 0 on error   String
data = read_.substring(idx+1);  data.trim();
 pv = data.toFloat();
}

// Q1_max = 100%
// Q2_max = 100%
```

```
 void dispatchCommand(void) {
if (cmd == "Q1") {
   Q1 = max(0.0, min(25.0, pv));     iwrite =
int(Q1 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
   ledcWrite(Q1Channel,iwrite);
   Serial.println(Q1);
 }
 else if (cmd == "Q2") {
   Q2 = max(0.0, min(25.0, pv));     iwrite =
int(Q2 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
ledcWrite(Q2Channel,iwrite);
   Serial.println(Q2);
 }  else if (cmd == "T1") {
float mV = 0.0;     float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT1) * 0.322265625;        degC = degC
+ mV/10.0;
   }
   degC = degC / float(n);

   Serial.println(degC);
 }  else if (cmd == "T2") {
float mV = 0.0;     float
degC = 0.0;
   for (int i = 0; i < n; i++) {
       mV = (float) analogRead(pinT2) * 0.322265625;         degC = degC
+ mV/10.0;
  }    degC = degC / float(n);
   Serial.println(degC);
 }
 else if ((cmd == "V") or (cmd == "VER")) {
   Serial.println("TCLab Firmware Version " + vers);
 }
 else if (cmd == "LED") {
   level = max(0.0, min(100.0, pv));     iwrite =
int(level * 0.5);
   iwrite = max(0, min(50, iwrite));        ledcWrite(ledChannel, iwrite);
   Serial.println(level);
 }
 else if (cmd == "X") {     ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);     Serial.println("Stop");
 }
}
// check temperature and shut-off heaters if above high limit void
checkTemp(void) {
   float mV = (float) analogRead(pinT1) * 0.322265625;
   //float degC = (mV - 500.0)/10.0;     float
degC = mV/10.0;
   if (degC >= upper_temperature_limit) {      Q1 =
0.0;
```

```
    Q2 = 0.0;
    ledcWrite(Q1Channel,0);     ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 1 (> upper_temperature_limit): ");
    Serial.println(degC);
  }
  mV = (float) analogRead(pinT2) * 0.322265625;
  //degC = (mV - 500.0)/10.0;    degC
= mV/10.0;
  if (degC >= upper_temperature_limit) {
    Q1 = 0.0;      Q2 =
0.0;
    ledcWrite(Q1Channel,0);     ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 2 (> upper_temperature_limit): ");
    Serial.println(degC);
  }
}

// arduino startup void
setup() {
 //analogReference(EXTERNAL);
 Serial.begin(baud);  while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
}

// arduino main event loop
void loop() {  parseSerial();
dispatchCommand();
 checkTemp();
}
```

Kode ini adalah program firmware untuk **Arduino** yang digunakan untuk mengontrol dan memonitor perangkat keras melalui komunikasi serial. Program ini mengontrol elemen seperti LED dan dua saluran kontrol (Q1 dan Q2), serta membaca dua sensor suhu (T1 dan T2). Berikut penjelasan detail setiap bagian kode:

1. **Konstanta dan Pin**
   - `vers`: Versi firmware.
   - `baud`: Kecepatan komunikasi serial (115200 bps).
   - `sp` dan `nl`: Separator (`sp` = spasi) dan terminator (`nl` = newline) untuk memproses perintah serial.
   - Pin:
     - `pinT1`, `pinT2`: Pin input untuk sensor suhu.
     - `pinQ1`, `pinQ2`: Pin output PWM untuk kontrol. `pinLED`: Pin output PWM untuk kontrol LED.
   - PWM:
     - Frekuensi dan resolusi saluran PWM untuk LED (`ledChannel`) dan kontrol (`Q1Channel`, `Q2Channel`).
2. **Variabel Global**
   - `Buffer`: Buffer untuk menyimpan data input dari serial.
   - `cmd` dan `pv`: Menyimpan perintah dan nilai yang diproses dari input serial.
   - `Q1`, `Q2`: Nilai kontrol output PWM untuk saluran Q1 dan Q2.
   - `level`: Nilai kontrol untuk LED (0-100%).
   - `n`: Jumlah pengukuran untuk menghitung rata-rata suhu dari sensor.
3. **Fungsi**

   `parseSerial()`
   - Membaca data serial hingga ditemukan terminator (`\n`).
   - Memisahkan data input menjadi:
     - `cmd`: Perintah.
     - `pv`: Data numerik (misal, tingkat PWM atau nilai suhu).

   `dispatchCommand()`
   - Mengeksekusi perintah berdasarkan nilai `cmd`:
     - Q1/Q2: Mengatur output PWM untuk Q1 atau Q2, dengan batas nilai 025%.
     - T1/T2: Membaca suhu dari sensor T1/T2 dalam derajat Celsius.
     - V/VER: Mengirim versi firmware melalui serial.
     - LED: Mengontrol intensitas LED (0-100%).

- X: Mematikan Q1 dan Q2.

`checkTemp()`

- Memeriksa suhu dari T1 dan T2:
  - Jika suhu melebihi batas (`upper_temperature_limit = 59`), Q1 dan Q2 dimatikan untuk keamanan. **`setup()`**
- Inisialisasi:
  - Serial komunikasi.
  - Saluran PWM untuk Q1, Q2, dan LED.
  - Menyambungkan saluran PWM ke pin masing-masing.

`loop()`

- Fungsi utama yang terus berjalan:
  - Membaca perintah serial (`parseSerial()`).
  - Mengeksekusi perintah sesuai input (`dispatchCommand()`).
  - Memantau suhu dan mematikan kontrol jika suhu terlalu tinggi (`checkTemp()`).

```
import sys import
time import numpy
as np
 try:   import
serial except:
import pip

   pip.main(['install', 'pyserial'])     import serial
from serial.tools import list_ports
 class iTCLab(object):
    def __init__(self, port=None, baud=115200):         port
= self.findPort()         print('Opening connection')
       self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()        self.sp.flushOutput()        time.sleep(3)
       print('iTCLab connected via Arduino on port ' + port)
    def findPort(self):        found = False        for port in
list(list_ports.comports()):
          # Arduino Uno          if port[2].startswith('USB
VID:PID=16D0:0613'):
              port = port[0]               found = True          # Arduino HDuino
if port[2].startswith('USB VID:PID=1A86:7523'):               port =
port[0]              found = True              # Arduino Leonardo          if
port[2].startswith('USB VID:PID=2341:8036'):               port = port[0]
found = True             # Arduino ESP32            if port[2].startswith('USB
VID:PID=10C4:EA60'):               port = port[0]
```

```
            found = True
        # Arduino ESP32 - Tipe yg berbeda            if port[2].startswith('USB
VID:PID=1A86:55D4'):                port = port[0]                found = True
if (not found):            print('Arduino COM port not found')
        print('Please ensure that the USB cable is connected')            print('---
Printing Serial Ports ---')            for port in list(serial.tools.list_ports.comports()):
print(port[0] + ' ' + port[1] + ' ' + port[2])            print('For Windows:')
        print('  Open device manager, select "Ports (COM & LPT)"')            print('  Look for COM
port of Arduino such as COM4')            print('For MacOS:')
        print('  Open terminal and type: ls /dev/*.')
        print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')            print('For Linux')
        print('  Open terminal and type: ls /dev/tty*')
        print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')            print('')
        port = input('Input port: ')            # or hard-
code it here
        # port = 'COM3' # for Windows
        # port = '/dev/tty.wchusbserial1410' # for MacOS        return port
    def stop(self):        return
self.read('X')
    def version(self):        return
self.read('VER')

   @property    def T1(self):        self._T1 =
float(self.read('T1'))        return self._T1

   @property    def
T2(self):
      self._T2 = float(self.read('T2'))        return self._T2
    def LED(self, pwm):
      pwm = max(0.0, min(100.0, pwm)) / 2.0
self.write('LED', pwm)        return pwm
    def Q1(self, pwm):
      pwm = max(0.0, min(100.0, pwm))
self.write('Q1', pwm)        return pwm
    def Q2(self, pwm):
      pwm = max(0.0, min(100.0, pwm))
self.write('Q2', pwm)        return pwm

   # save txt file with data and set point
   # t = time
   # u1,u2 = heaters
```

```
    # y1,y2 = tempeatures     # sp1,sp2 = setpoints     def save_txt(self, t, u1, u2, y1, y2, sp1, sp2):
data = np.vstack((t, u1, u2, y1, y2, sp1, sp2))  # vertical stack
        data = data.T  # transpose data
        top = 'Time (sec), Heater 1 (%), Heater 2 (%), ' \               + 'Temperature 1
(degC), Temperature 2 (degC), ' \
              + 'Set Point 1 (degC), Set Point 2 (degC)'
        np.savetxt('data.txt', data, delimiter=',', header=top, comments='')
    def read(self, cmd):         cmd_str =
self.build_cmd_str(cmd, '')          try:
self.sp.write(cmd_str.encode())            self.sp.flush()
except Exception:            return None
        return self.sp.readline().decode('UTF-8').replace("\r\n", "")
    def write(self, cmd, pwm):
        cmd_str = self.build_cmd_str(cmd, (pwm,))         try:
self.sp.write(cmd_str.encode())            self.sp.flush()
except:            return None
        return self.sp.readline().decode('UTF-8').replace("\r\n", "")
    def build_cmd_str(self, cmd, args=None):         if args:
args = ' '.join(map(str, args))         else:            args = ''
        return "{cmd} {args}\n".format(cmd=cmd, args=args)
    def close(self):         try:
self.sp.close()
            print('Arduino disconnected successfully')         except:
            print('Problems disconnecting from Arduino.')            print('Please unplug
and reconnect Arduino.')         return True
```

Kode ini merupakan implementasi kelas Python yang digunakan untuk berkomunikasi dengan perangkat keras berbasis Arduino melalui port serial. Perangkat ini tampaknya digunakan untuk pengendalian dan pemantauan suhu serta pengaturan elemen pemanas (heater). Berikut adalah penjelasan rinci:

1. Impor dan Instalasi Modul

- `serial`: Modul untuk komunikasi serial. Jika belum terinstal, skrip akan mencoba menginstalnya menggunakan `pip`.
- `numpy`: Digunakan untuk mengolah data (termasuk menyimpan data dalam bentuk file teks).

2. **Kelas `ITCLab`**

Kelas ini menangani komunikasi dengan Arduino melalui port serial. Berikut penjelasan metode dan atributnya:

Inisialisasi (`__init__`)

- Menghubungkan ke perangkat Arduino melalui port serial.
- Memanggil metode `findPort` untuk mendeteksi port serial yang terhubung ke Arduino.
- Mengatur baud rate komunikasi (default: 115200).
- Menunggu beberapa saat agar perangkat siap (`time.sleep(3)`).

Metode `findPort`

- Mendeteksi port serial Arduino berdasarkan VID (Vendor ID) dan PID (Product ID) yang umum digunakan oleh perangkat Arduino.
- Jika tidak ditemukan port yang cocok, pengguna akan diminta memasukkan port secara manual.
- Memberikan panduan cara menemukan port di Windows, MacOS, dan Linux.

Metode `stop` dan `version`

- `stop()`: Mengirimkan perintah "X" untuk menghentikan perangkat.
- `version()`: Mengirimkan perintah "VER" untuk mendapatkan versi firmware Arduino.

Properti `T1` dan `T2`

- Membaca suhu dari sensor suhu pada Arduino: `T1`: Membaca suhu dari sensor pertama.
   `T2`: Membaca suhu dari sensor kedua.

Metode untuk Mengontrol Perangkat

- `LED(pwm)`: Mengontrol LED pada Arduino dengan nilai PWM (0-100).
- `Q1(pwm)`: Mengontrol pemanas pertama dengan nilai PWM (0-100).
- `Q2(pwm)`: Mengontrol pemanas kedua dengan nilai PWM (0-100).

Metode `save_txt`

- Menyimpan data dalam file teks (`data.txt`).
- Data yang disimpan meliputi waktu, pengaturan heater, suhu dari sensor, dan setpoint (nilai target suhu).

Metode `read` dan `write`

- `read(cmd)`: Mengirimkan perintah ke Arduino dan membaca balasan.

- `write(cmd, pwm)`: Mengirimkan perintah beserta nilai (PWM) ke Arduino dan membaca balasan. **Metode `build_cmd_str`**
- Membuat string perintah yang dikirim ke Arduino.
- Format perintah: `{cmd} {args}\n` (misalnya: "Q1 50\n").

Metode `close`

- Menutup koneksi serial dengan Arduino.
- Menampilkan pesan jika koneksi berhasil atau jika ada masalah saat memutuskan koneksi.


```
{
 "cells": [
  {
   "cell_type": "code",
   "execution_count": 4,
   "metadata": {},
   "outputs": [
    {
     "name": "stdout",
     "output_type": "stream",
     "text": [
      "Opening connection\n",
      "iTCLab connected via Arduino on port COM9\n",
      "LED On\n",
      "LED Off\n",
      "Arduino disconnected successfully\n"
     ]
    },
    {
     "data": {
      "text/plain": [
       "True"
      ]
     },
     "execution_count": 4,
     "metadata": {},
     "output_type": "execute_result"
    }
   ],
   "source": [
    "import itclab\n",
    "import time\n",
    "# Connect to Arduino\n",
    "a = itclab.iTCLab()\n",
    "print('LED On')\n",
    "a.LED(100)\n",
    "# Pause for 1 second\n",
    "time.sleep(1.0)\n",
    "print('LED Off')\n",
    "a.LED(0)\n",
    "a.close()"
```

```
  ]
 },
 {
  "cell_type": "code",
  "execution_count": 2,
  "metadata": {},
  "outputs": [
   {
    "name": "stdout",
    "output_type": "stream",
```

```
   "text": [
    "Opening connection\n",
    "iTCLab connected via Arduino on port COM9\n",
    "<bound method iTCLab.version of <itclab.iTCLab object at 0x0000023679324520>>\n",
    "LED On\n",
    "LED Power 100\n",
    "LED Power 90\n",
    "LED Power 80\n",
    "LED Power 70\n",
    "LED Power 60\n",
    "LED Power 50\n",
    "LED Power 40\n",
    "LED Power 30\n",
    "LED Power 20\n",
    "LED Power 10\n",
    "LED Power 0\n",
    "Arduino disconnected successfully\n"
   ]
  },
  {
   "data": {
    "text/plain": [
     "True"
    ]
   },
   "execution_count": 2,
   "metadata": {},
   "output_type": "execute_result"
  }
 ],
 "source": [
  "import itclab\n",
  "import time\n",
  "\n",
  "# Connect to Arduino\n",
  "a = itclab.iTCLab()\n",
  "\n",
  "# Get Version\n",
  "print(a.version)\n",
  "\n",
  "# Turn LED on\n",
  "print('LED On')\n",
  "a.LED(100)\n",
  "\n",
  "# Taper LED off\n",
  "for i in range(100,-1,-10):\n",
  "    print('LED Power ' + str(i))\n",
  "    time.sleep(0.5)\n",
  "    a.LED(i)\n",
  "\n",
  "a.close()"
 ]
},
```

```
{
 "cell_type": "code",
 "execution_count": 10,
 "metadata": {},
 "outputs": [
  {
   "name": "stdout",
   "output_type": "stream",
```

[redacted]

```
    "text": [
     "Arduino disconnected successfully\n"
    ]
   },
   {
    "data": {
     "text/plain": [
      "True"
     ]
    },
    "execution_count": 10,
    "metadata": {},
    "output_type": "execute_result"
   }
  ],
  "source": [
   "a.close()"
  ]
 },
 {
  "cell_type": "code",
  "execution_count": null,
  "metadata": {},
  "outputs": [],
  "source": []
 }
],
"metadata": {
 "anaconda-cloud": {},
 "kernelspec": {
  "display_name": "Python 3 (ipykernel)",
  "language": "python",
  "name": "python3"
 },
 "language_info": {
  "codemirror_mode": {
   "name": "ipython",
   "version": 3
  },
  "file_extension": ".py",
  "mimetype": "text/x-python",
  "name": "python",
  "nbconvert_exporter": "python",
  "pygments_lexer": "ipython3",
  "version": "3.11.6"
 },
 "widgets": {
  "state": {
   "43a770e6b0524d899f4a1126019a0c2f": {
    "views": [
     {
      "cell_index": 1
     }
```

```
    ]
   }
  },
  "version": "1.2.0"
 }
},
"nbformat": 4,
"nbformat_minor": 4
```

```
}
```

Kode ini adalah kode Notebook Jupyter dalam format JSON, berisi skrip Python yang digunakan untuk mengontrol perangkat Arduino melalui komunikasi serial dengan modul Python. Berikut adalah penjelasan mendetail untuk setiap bagian dari kode ini:

1. Cell1: Mengontrol LED Sederhana

```
"import itclab\n",
   "import time\n",
   "# Connect to Arduino\n",
   "a = itclab.iTCLab()\n",
   "print('LED On')\n",
   "a.LED(100)\n",
   "# Pause for 1 second\n",
   "time.sleep(1.0)\n",
   "print('LED Off')\n",
   "a.LED(0)\n",     "a.close()"
```

- Impor Library: `itclab` adalah library yang mendukung komunikasi dengan perangkat Arduino, sementara `time` digunakan untuk mengatur jeda waktu.
- Koneksi ke Arduino: Objek `a` adalah instance dari kelas `iTCLab`, yang menginisialisasi koneksi serial dengan Arduino.
- Mengontrol LED:
  - Menyalakan LED dengan nilai PWM maksimum (100%).
  - Menunggu selama 1 detik (`time.sleep(1.0)`). Mematikan LED dengan nilai PWM 0%.
- Menutup Koneksi: Fungsi `a.close()` menutup koneksi serial ke Arduino.

2. Cell 2: Variasi LED dan Pembacaan Versi

```
"import itclab\n",
   "import time\n",
   "\n",
   "# Connect to Arduino\n",
   "a = itclab.iTCLab()\n",
   "\n",
   "# Get Version\n",
   "print(a.version)\n",
   "\n",
   "# Turn LED on\n",
   "print('LED On')\n",
   "a.LED(100)\n",
   "\n",
   "# Taper LED off\n",
   "for i in range(100,-1,-10):\n",
   "    print('LED Power ' + str(i))\n",
   "    time.sleep(0.5)\n",
   "    a.LED(i)\n",
   "\n",
```

```
"a.close()"
```

- Impor Library: Sama seperti cell sebelumnya.
- Membaca Versi Firmware:
  - `print(a.version)` digunakan untuk mendapatkan versi firmware Arduino.
  - Hasilnya mungkin berupa string seperti "`iTCLab v1.0`".
- Menyalakan LED: LED dinyalakan dengan nilai PWM 100%.
- Variasi Kekuatan LED:
  - Loop `for i in range(100, -1, -10)` menurunkan kekuatan PWM dari 100 ke 0 dengan langkah 10.
  - Pada setiap langkah, kekuatan LED dicetak, dan fungsi `time.sleep(0.5)` digunakan untuk menunggu 0,5 detik sebelum menyesuaikan nilai PWM berikutnya.
- Menutup Koneksi: `a.close()` menutup koneksi ke Arduino.

3. Cell 3: Menutup Koneksi

```
"a.close()"
```

Menutup koneksi serial ke Arduino. Jika ada koneksi terbuka dari cell sebelumnya, fungsi ini memastikan tidak ada konflik saat menggunakan Arduino lagi.

E. ITCLab-4


```
{
 "cells": [
  {
   "cell_type": "code",
   "execution_count": 1,
   "id": "4d63608e",
   "metadata": {},
   "outputs": [],
   "source": [
    "import numpy as np\n",
    "%matplotlib inline\n",
    "import matplotlib.pyplot as plt\n",
    "from scipy.integrate import odeint\n",
    "import ipywidgets as wg\n",
    "from IPython.display import display"
   ]
  },
  {
   "cell_type": "code",
   "execution_count": 4,
   "id": "7382d42e",
   "metadata": {},
```

```
 "outputs": [
  {
   "data": {
    "application/vnd.jupyter.widget-view+json": {
     "model_id": "18f0584c06094245be5bfad0a176d921",
     "version_major": 2,
     "version_minor": 0
```

```
     },
     "text/plain": [
      "interactive(children=(FloatSlider(value=0.1, description='Kc', max=1.0, min=-0.2, step=0.05), FloatSlider(valu…"
     ]
    },
    "metadata": {},
    "output_type": "display_data"
   },
   {
    "data": {
     "text/plain": [
      "<function __main__.pidPlot(Kc, tauI, tauD)>"
     ]
    },
    "execution_count": 4,
    "metadata": {},
    "output_type": "execute_result"
   }
  ],
  "source": [
   "n = 100 # time points to plot\n",
   "tf = 20.0 # final time\n",
   "SP_start = 2.0 # time of set point change\n",
   "\n",
   "def process(y,t,u):\n",
   "    Kp = 4.0\n",
   "    taup = 3.0\n",
   "    thetap = 1.0\n",
   "    if t<(thetap+SP_start):\n",
   "        dydt = 0.0  # time delay\n",
   "    else:\n",
   "        dydt = (1.0/taup) * (-y + Kp * u)\n",
   "    return dydt\n",
   "\n",
   "def pidPlot(Kc,tauI,tauD):\n",
   "    t = np.linspace(0,tf,n) # create time vector\n",
   "    P= np.zeros(n)          # initialize proportional term\n",
   "    I = np.zeros(n)         # initialize integral term\n",
   "    D = np.zeros(n)         # initialize derivative term\n",
   "    e = np.zeros(n)         # initialize error\n",
   "    OP = np.zeros(n)        # initialize controller output\n",
   "    PV = np.zeros(n)        # initialize process variable\n",      "    SP = np.zeros(n)        #
initialize setpoint\n",
   "    SP_step = int(SP_start/(tf/(n-1))+1) # setpoint start\n",
   "    SP[0:SP_step] = 0.0     # define setpoint\n",
   "    SP[SP_step:n] = 4.0     # step up\n",
   "    y0 = 0.0                # initial condition\n",
   "    # loop through all time steps\n",
   "    for i in range(1,n):\n",
   "        # simulate process for one time step\n",
   "        ts = [t[i-1],t[i]]         # time interval\n",
   "        y = odeint(process,y0,ts,args=(OP[i-1],))  # compute next step\n",
   "        y0 = y[1]                  # record new initial condition\n",
```

```
"        # calculate new OP with PID\n",
"        PV[i] = y[1]               # record PV\n",
"        e[i] = SP[i] - PV[i]       # calculate error = SP - PV\n",
"        dt = t[i] - t[i-1]         # calculate time step\n",
"        P[i] = Kc * e[i]           # calculate proportional term\n",
"        I[i] = I[i-1] + (Kc/tauI) * e[i] * dt  # calculate integral term\n",
"        D[i] = -Kc * tauD * (PV[i]-PV[i-1])/dt # calculate derivative term\n",
```

```
    "        OP[i] = P[i] + I[i] + D[i] # calculate new controller output\n",     "        \n",
    "    # plot PID response\n",
    "    plt.figure(1,figsize=(15,7))\n",
    "    plt.subplot(2,2,1)\n",
    "    plt.plot(t,SP,'k-',linewidth=2,label='Setpoint (SP)')\n",
    "    plt.plot(t,PV,'r:',linewidth=2,label='Process Variable (PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,2)\n",
    "    plt.plot(t,P,'g.-',linewidth=2,label=r'Proportional = $K_c \\; e(t)$')\n",
    "    plt.plot(t,I,'b-',linewidth=2,label=r'Integral = $\\frac{K_c}{\\tau_I} \\int_{i=0}^{n_t} e(t) \\; dt $')\n",
    "    plt.plot(t,D,'r--',linewidth=2,label=r'Derivative = $-K_c \\tau_D \\frac{d(PV)}{dt}$')
\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,3)\n",
    "    plt.plot(t,e,'m--',linewidth=2,label='Error (e=SP-PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,4)\n",
    "    plt.plot(t,OP,'b--',linewidth=2,label='Controller Output (OP)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.xlabel('time')\n",
    "    \n",
    "Kc_slide = wg.FloatSlider(value=0.1,min=-0.2,max=1.0,step=0.05)\n",
    "tauI_slide = wg.FloatSlider(value=4.0,min=0.01,max=5.0,step=0.1)\n",     "tauD_slide =
wg.FloatSlider(value=0.0,min=0.0,max=1.0,step=0.1)\n",
    "wg.interact(pidPlot, Kc=Kc_slide, tauI=tauI_slide, tauD=tauD_slide)"
   ]
  },
  {
   "cell_type": "code",
   "execution_count": null,
   "id": "9d5b3b16",
   "metadata": {},
   "outputs": [],
   "source": []
  }
 ],
 "metadata": {
  "kernelspec": {
   "display_name": "Python 3 (ipykernel)",
   "language": "python",
   "name": "python3"   },
  "language_info": {
   "codemirror_mode": {
    "name": "ipython",
    "version": 3
   },
   "file_extension": ".py",
   "mimetype": "text/x-python",
   "name": "python",
   "nbconvert_exporter": "python",
   "pygments_lexer": "ipython3",
   "version": "3.11.6"
  }
```

 },
 "nbformat": 4,
 "nbformat_minor": 5
}

Kode yang diberikan adalah sebuah Notebook Jupyter dalam format JSON, yang dirancang untuk simulasi kontrol PID (Proportional-Integral-Derivative) menggunakan Python. Berikut penjelasan dari isi notebook:

1. **Impor Modul**

   Di cell pertama, modul berikut diimpor:

   - `numpy`: Untuk manipulasi array dan perhitungan numerik.
   - `matplotlib`: Untuk membuat plot dan visualisasi.
   - `scipy.integrate.odeint`: Untuk menyelesaikan persamaan diferensial secara numerik.
   - `ipywidgets`: Untuk membuat widget interaktif.
   - `IPython.display`: Untuk menampilkan elemen interaktif.

2. **Fungsi untuk Model Proses**

   - Parameter Proses:
     - `Kp`: Gain (penguatan) proses.
     - `taup`: Waktu tunda proses.
     - `thetap`: Waktu mati (dead time)
   - Fungsi ini menggunakan persamaan diferensial pertama untuk merepresentasikan respons proses terhadap input kontrol `u`. Ada penundaan waktu mati sebelum proses bereaksi terhadap perubahan input.

3. **Fungsi Simulasi PID**

   Fungsi pidPlot(Kc, tauI, tauD) melakukan simulasi respons kontrol PID:

   - Parameter:
     - `Kc`: Penguatan proporsional.
     - `tauI`: Konstanta waktu integral.
     - `tauD`: Konstanta waktu derivatif.
   - Langkah-langkah:
     1) Inisialisasi variabel untuk waktu, error, keluaran kontrol, dan respons proses.
     2) Setpoint (SP):
        - Awalnya 0.
        - Berubah menjadi 4 setelah waktu tertentu.
     3) Untuk setiap langkah waktu:

- Solusi persamaan diferensial numerik menggunakan odeint untuk menghitung respons proses.
- Menghitung kontribusi PID:
  - P: Proporsional terhadap error.
  - I: Integral dari error terhadap waktu.
  - D: Derivatif dari perubahan proses
- Menentukan output kontrol `OP` sebagai kombinasi P, I, dan D.

4) Menampilkan 4 subplot:
   - Setpoint vs. respons proses (PV).
   - Komponen P, I, D.
   - Error.
   - Output kontrol (OP).

4. Widget Interaktif

Bagian akhir kode menggunakan modul ipywidgets untuk membuat slider interaktif untuk parameter PID:

- `Kc_slide`: Slider untuk nilai `Kc`.
- `tauI_slide`: Slider untuk nilai `tauI`.
- `tauD_slide`: Slider untuk nilai `tauD`.

Widget interaktif ini memungkinkan pengguna untuk mengubah parameter PID secara real-time dan melihat pengaruhnya pada respons sistem menggunakan fungsi `wg.interact`.

Output

Ketika kode ini dijalankan di Jupyter Notebook:

- Visualisasi Simulasi PID:
  - Pengguna dapat melihat pengaruh parameter PID terhadap respons sistem.
  - Grafik menunjukkan hubungan antara setpoint, error, output kontrol, dan respons proses.
- Interaktivitas:
  - Pengguna dapat menyesuaikan parameter PID (Kc, tauI, tauD) dengan slider untuk mengeksplorasi kinerja kontrol.

Kegunaan

Kode ini digunakan untuk:

- Belajar Konsep PID: Memahami bagaimana pengontrol PID bekerja.
- Simulasi: Mengetes dan menyetel parameter PID sebelum diterapkan pada sistem nyata.
- Pengajaran: Memberikan cara visual dan interaktif untuk memahami kontrol PID.

F. ITCLab-5

```
#include <Arduino.h>

// constants
const int baud = 115200;    // serial baud rate

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1  = 34;      // T1 const int pinT2  = 35;     // T2
const int pinQ1  = 32;      // Q1 const int pinQ2  = 33;     // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15
 float cel, cel1, degC, degC1;
float P, I, D, Kc, tauI, tauD;
float KP, KI, KD, opo, ophi, oplo, error, dpv; float
sp = 35, //set point  pv = 0,     //current
temperature  pv_last = 0,  //prior temperature  ierr
= 0,   //integral error
dt = 0,     //time between measurements  op = 0;
//PID controller output  unsigned long ts = 0,
new_ts = 0; //timestamp  const float
upper_temperature_limit = 58;

// global variables
float Q1 = 0;          // value written to Q1 pin  float Q2 = 0;
// value written to Q2 pin  int iwrite_value = 25;     // integer
value for writing  int iwrite_led = 255;      // integer value for
writing  int iwrite_min = 0;      // integer value for writing
 void setup() {
 // put your setup code here, to run once:

 ts = millis();

 Serial.begin(baud);   while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled   ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites   ledcSetup(Q2Channel,
freq, resolutionQ2Channel);
```

[redacted]

```
 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
ledcWrite(ledChannel,0);
}
void Q1on(){
   ledcWrite(Q1Channel,iwrite_value);
   //Serial.println(Q1);
}
void Q1off(){
   ledcWrite(Q1Channel,iwrite_min);
   //Serial.println(Q1);
}
void Q2on(){
   ledcWrite(Q2Channel,iwrite_value);
   //Serial.println(Q2);
}
void Q2off(){
   ledcWrite(Q2Channel,iwrite_min);
   //Serial.println(Q2);
}
void ledon(){
   ledcWrite(ledChannel,iwrite_led);
}
void ledoff(){
   ledcWrite(ledChannel,iwrite_min);
}
void cektemp(){
 degC = analogRead(pinT1) * 0.322265625 ;  // use for 3.3v AREF   cel =
degC/10;
 degC1 = analogRead(pinT2) * 0.322265625 ;  // use for 3.3v AREF   cel1 =
degC1/10;

 Serial.print("Temperature T1: ");
 Serial.print(cel);  // print the temperature T1 in Celsius
 Serial.print("°C");
 Serial.print(" ~ "); // separator between Celsius and Fahrenheit
 Serial.print("Temperature T2: ");
 Serial.print(cel1);  // print the temperature T2 in Celsius
 Serial.println("°C");
} float pid(float sp, float pv, float pv_last, float& ierr, float dt) {  float
Kc = 10.0; // K / %Heater   float tauI = 50.0; // sec
```

```
 float tauD = 1.0; // sec  //
PID coefficients  float KP
= Kc;  float KI = Kc / tauI;
float KD = Kc*tauD;
 // upper and lower bounds on heater level
float ophi = 100;  float oplo = 0;  // calculate
the error  float error = sp - pv;
 // calculate the integral error  ierr =
ierr + KI * error * dt;  // calculate the
measurement derivative  float dpv = (pv -
pv_last) / dt;  // calculate the PID output
 float P = KP * error; //proportional contribution
float I = ierr; //integral contribution  float D = -KD *
dpv; //derivative contribution  float op = P + I + D;
 // implement anti-reset windup  if
((op < oplo) || (op > ophi)) {
   I = I - KI * error * dt;
   // clip output
   op = max(oplo, min(ophi, op));
 }
 ierr = I;
 Serial.println("sp="+String(sp) + " pv=" + String(pv) + " dt=" + String(dt) + " op=" +
String(op) + " P=" + String(P) + " I=" + String(I) + " D=" + String(D));  return op;
} void loop() {
new_ts = millis();
 if (new_ts - ts > 1000) {

 // put your main code here, to run repeatedly:  cektemp();
 if (cel > upper_temperature_limit){
Q1off();    ledon();
 } else {
Q1on();
ledoff();
 }
 if (cel1 > upper_temperature_limit){
Q2off();    ledon();
 } else {
Q2on();
ledoff();
 }  pv = cel;  // Temperature T1
dt = (new_ts - ts) / 1000.0;  ts =
new_ts;
 op = pid(sp,pv,pv_last,ierr,dt);
ledcWrite(Q1Channel,op);  pv_last = pv;
```

```
 delay (200);
 }
}
```

Kode di atas merupakan program untuk mikrokontroler berbasis Arduino, digunakan untuk mengontrol suhu menggunakan metode PID (Proportional-Integral-Derivative) pada perangkat keras tertentu. Berikut adalah penjelasan terperinci:

1. **Konfigurasi Awal**

   Konstanta dan Pin:
   - `baud`: Kecepatan komunikasi serial dengan PC (115200 bps).
   - `pinT1` dan `pinT2`: Pin input analog untuk membaca suhu dari sensor suhu T1 dan T2.
   - `pinQ1` dan `pinQ2`: Pin output PWM untuk kontrol aktuator terkait (misalnya, pemanas).
   - `pinLED`: Pin output PWM untuk kontrol LED.

   Properti PWM:
   - `freq`: Frekuensi PWM (5 kHz).
   - `resolution`: Resolusi PWM (8 bit, nilai 0-255).

2. **Fungsi `setup`**
   - Mengatur komunikasi serial dan inisialisasi PWM untuk pin kontrol (Q1, Q2, LED).
   - Semua kanal PWM (Q1Channel, Q2Channel, ledChannel) diatur dengan frekuensi dan resolusi yang sama, kemudian dihubungkan ke pin masingmasing.

3. **Fungsi untuk Kontrol Aktuator**
   - `Q1on` / `Q1off`, `Q2on` / `Q2off`: Mengatur keluaran PWM ke pin Q1 dan Q2, masing-masing untuk menghidupkan dan mematikan aktuator.
   - `ledon` / `ledoff`: Menghidupkan atau mematikan LED dengan mengatur keluaran PWM.

4. **Fungsi untuk Membaca Suhu** `cektemp`

   :
   - Membaca nilai analog dari sensor suhu (T1 dan T2) melalui pinT1 dan pinT2.
   - Mengkonversi nilai analog menjadi suhu dalam derajat Celsius menggunakan faktor skala `0.322265625`.

- Mencetak suhu T1 dan T2 ke serial monitor.

5. **Fungsi PID**
    - Fungsi PID mengontrol keluaran aktuator berdasarkan error (selisih antara set point `sp` dan suhu aktual `pv`).
    - Komponen PID:
        - Proportional (`P`): Berbanding lurus dengan error.
        - Integral (`I`): Akumulasi error untuk memperbaiki kesalahan jangka panjang.
        - Derivative (`D`): Mengurangi efek perubahan cepat pada error.
    - Membatasi output (anti-reset windup) agar tetap dalam rentang oplo hingga ophi.

6. Fungsi `loop`

Dieksekusi secara terus-menerus untuk membaca suhu, menghitung keluaran PID, dan mengontrol aktuator.

- Membaca Suhu:
    - Memanggil `cektemp` untuk membaca suhu T1 (`cel`) dan T2 (`cel1`).
- Logika Kontrol:
    - Jika suhu T1 atau T2 melebihi batas atas (`upper_temperature_limit`), aktuator dimatikan (`Q1off` atau `Q2off`) dan LED dihidupkan.
    - Jika tidak, aktuator dihidupkan dan LED dimatikan.
- PID Control:
    - Nilai suhu T1 (`pv`) digunakan untuk perhitungan PID.
    - PID menghasilkan nilai keluaran (`op`) yang kemudian digunakan untuk mengatur keluaran PWM di Q1.
- Pengaturan Waktu:
    - `dt` dihitung sebagai waktu antara pengukuran, digunakan dalam perhitungan PID.

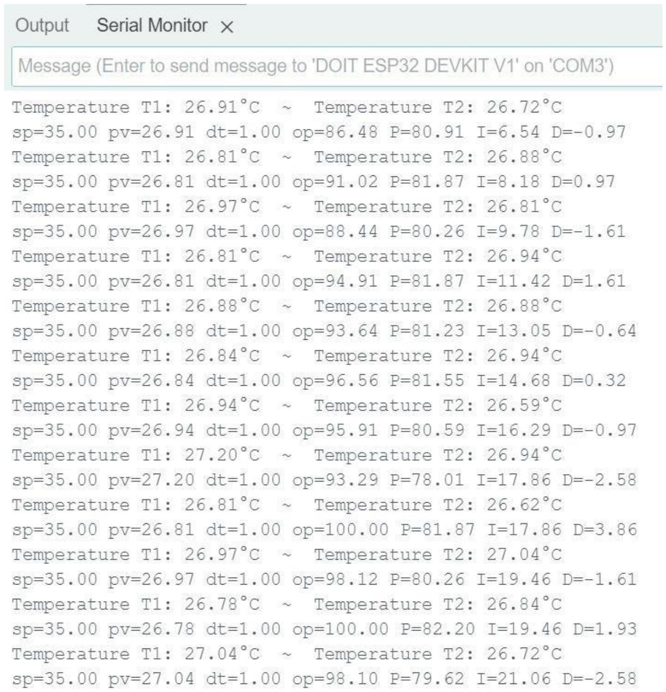
Kegunaan

Kode ini bertujuan untuk:

- Membaca suhu dari sensor (T1 dan T2).
- Menggunakan metode PID untuk mengontrol aktuator berbasis suhu (Q1).
- Menjaga suhu dalam batas tertentu dengan logika kontrol sederhana.

- Memberikan umpan balik melalui LED dan serial monitor untuk memantau kinerja sistem.

Hasil Screenshot



Output   Serial Monitor ×

Message (Enter to send message to 'DOIT ESP32 DEVKIT V1' on 'COM3')

```
Temperature T1: 26.91°C  ~  Temperature T2: 26.72°C
sp=35.00 pv=26.91 dt=1.00 op=86.48 P=80.91 I=6.54 D=-0.97
Temperature T1: 26.81°C  ~  Temperature T2: 26.88°C
sp=35.00 pv=26.81 dt=1.00 op=91.02 P=81.87 I=8.18 D=0.97
Temperature T1: 26.97°C  ~  Temperature T2: 26.81°C
sp=35.00 pv=26.97 dt=1.00 op=88.44 P=80.26 I=9.78 D=-1.61
Temperature T1: 26.81°C  ~  Temperature T2: 26.94°C
sp=35.00 pv=26.81 dt=1.00 op=94.91 P=81.87 I=11.42 D=1.61
Temperature T1: 26.88°C  ~  Temperature T2: 26.88°C
sp=35.00 pv=26.88 dt=1.00 op=93.64 P=81.23 I=13.05 D=-0.64
Temperature T1: 26.84°C  ~  Temperature T2: 26.94°C
sp=35.00 pv=26.84 dt=1.00 op=96.56 P=81.55 I=14.68 D=0.32
Temperature T1: 26.94°C  ~  Temperature T2: 26.59°C
sp=35.00 pv=26.94 dt=1.00 op=95.91 P=80.59 I=16.29 D=-0.97
Temperature T1: 27.20°C  ~  Temperature T2: 26.94°C
sp=35.00 pv=27.20 dt=1.00 op=93.29 P=78.01 I=17.86 D=-2.58
Temperature T1: 26.81°C  ~  Temperature T2: 26.62°C
sp=35.00 pv=26.81 dt=1.00 op=100.00 P=81.87 I=17.86 D=3.86
Temperature T1: 26.97°C  ~  Temperature T2: 27.04°C
sp=35.00 pv=26.97 dt=1.00 op=98.12 P=80.26 I=19.46 D=-1.61
Temperature T1: 26.78°C  ~  Temperature T2: 26.84°C
sp=35.00 pv=26.78 dt=1.00 op=100.00 P=82.20 I=19.46 D=1.93
Temperature T1: 27.04°C  ~  Temperature T2: 26.72°C
sp=35.00 pv=27.04 dt=1.00 op=98.10 P=79.62 I=21.06 D=-2.58
```

G. ITCLab-6

Di ITCLab ke-6 ada tiga kode yaitu, kode Arduino, Python, dan Notebook Jupyter.

```
#include <Arduino.h>

// constants
const String vers = "1.04";   // version of this firmware const
int baud = 115200;     // serial baud rate const char sp = ' ';
// command separator const char nl = '\n';      // command
terminator

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;      // T1 const int pinT2   = 35;      // T2
const int pinQ1   = 32;      // Q1 const int pinQ2   = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

const double upper_temperature_limit = 59;

// global variables
char Buffer[64];         // buffer for parsing serial input String
cmd;             // command  double pv = 0;          // pin value float
level;             // LED level (0-100%) double Q1 = 0;         // value
written to Q1 pin double Q2 = 0;         // value written to Q2 pin
int iwrite = 0;         // integer value for writing
```

```
float dwrite = 0;        // float value for writing
int n = 10;          // number of samples for each temperature measurement

void parseSerial(void) {
 int ByteCount = Serial.readBytesUntil(nl,Buffer,sizeof(Buffer));  String
read_ = String(Buffer);  memset(Buffer,0,sizeof(Buffer));

 // separate command from associated data
int idx = read_.indexOf(sp);  cmd =
read_.substring(0,idx);  cmd.trim();
cmd.toUpperCase();

 // extract data. toInt() returns 0 on error  String
data = read_.substring(idx+1);  data.trim();
 pv = data.toFloat();
}

// Q1_max = 100%
// Q2_max = 100%
 void dispatchCommand(void) {
if (cmd == "Q1") {
   Q1 = max(0.0, min(25.0, pv));    iwrite =
int(Q1 * 2.0); // 10.? max    iwrite = max(0,
min(255, iwrite));
   ledcWrite(Q1Channel,iwrite);
   Serial.println(Q1);
 }
 else if (cmd == "Q2") {
   Q2 = max(0.0, min(25.0, pv));    iwrite =
int(Q2 * 2.0); // 10.? max    iwrite = max(0,
min(255, iwrite));
ledcWrite(Q2Channel,iwrite);
   Serial.println(Q2);
 }  else if (cmd == "T1") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT1) * 0.322265625;       degC = degC
+ mV/10.0;
   }
   degC = degC / float(n);

   Serial.println(degC);
 }
 else if (cmd == "T2") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
       mV = (float) analogRead(pinT2) * 0.322265625;        degC = degC
+ mV/10.0;
  }
   degC = degC / float(n);
   Serial.println(degC);
 }
 else if ((cmd == "V") or (cmd == "VER")) {
```

```
Serial.println("TCLab Firmware Version " + vers);
```

[redacted]

```
 }
 else if (cmd == "LED") {
   level = max(0.0, min(100.0, pv));     iwrite =
int(level * 0.5);
   iwrite = max(0, min(50, iwrite));       ledcWrite(ledChannel, iwrite);
   Serial.println(level);
 }
 else if (cmd == "X") {    ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);    Serial.println("Stop");
 }
}
// check temperature and shut-off heaters if above high limit void
checkTemp(void) {
  float mV = (float) analogRead(pinT1) * 0.322265625;
  //float degC = (mV - 500.0)/10.0;    float
degC = mV/10.0;
  if (degC >= upper_temperature_limit) {
    Q1 = 0.0;      Q2 =
0.0;
    ledcWrite(Q1Channel,0);      ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 1 (> upper_temperature_limit): ");
    Serial.println(degC);
  }
  mV = (float) analogRead(pinT2) * 0.322265625;
  //degC = (mV - 500.0)/10.0;    degC
= mV/10.0;
  if (degC >= upper_temperature_limit) {
    Q1 = 0.0;      Q2 =
0.0;
    ledcWrite(Q1Channel,0);      ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 2 (> upper_temperature_limit): ");
    Serial.println(degC);
  }
}

// arduino startup void
setup() {
 //analogReference(EXTERNAL);
 Serial.begin(baud);  while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled
ledcAttachPin(pinQ2, Q2Channel);
```

```
 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
}

// arduino main event loop
void loop() {  parseSerial();
dispatchCommand();
 checkTemp();
}
```

Kode ini adalah firmware untuk Arduino yang digunakan untuk mengontrol dan memantau perangkat berbasis iTCLab Shield. Berikut adalah penjelasan elemen-elemen utama dalam kode ini:

1. **Konstanta dan Konfigurasi**
   - `vers`: Menyimpan versi firmware.
   - `baud`: Menentukan kecepatan baud untuk komunikasi serial (115200 bps).
   - `sp` dan `nl`: Separator dan terminator untuk parsing perintah serial.
   - Pin konfigurasi:
     - Pin analog `pinT1` dan `pinT2` untuk membaca suhu dari sensor.
     - Pin PWM `pinQ1`, `pinQ2`, dan `pinLED` untuk mengontrol output sinyal (heater dan LED).
   - Konfigurasi PWM:
     - Frekuensi PWM diatur ke 5000 Hz dengan resolusi 8 bit.
     - Tiga kanal PWM digunakan: satu untuk LED, dua untuk output Q1 dan Q2.
   - Batas suhu maksimal (`upper_temperature_limit`): Digunakan untuk pengamanan agar perangkat mati jika suhu terlalu tinggi.

2. **Variabel Global**
   - `Buffer`: Menyimpan input serial yang diterima.
   - `cmd`: Perintah yang diterima melalui serial.
   - `pv`: Nilai yang dikaitkan dengan perintah.
   - `level, Q1, Q2`: Nilai yang akan diterapkan pada LED dan heater (Q1, Q2).
   - `n`: Jumlah sampel untuk pengukuran suhu rata-rata.

3. **Fungsi Parsing Serial** `parseSerial()`
   :
   - Membaca data serial hingga menemukan terminator (`nl`).
   - Memisahkan perintah dan data (dengan menggunakan separator `sp`).
   - Mengubah perintah menjadi huruf besar untuk standardisasi.
   - Mengonversi data menjadi nilai numerik (`toFloat()`).

4. **Fungsi Eksekusi Perintah**
   `dispatchCommand()`:
   - Mengatur respons terhadap perintah yang diterima:
     - `Q1` dan `Q2`: Mengontrol nilai heater dalam kisaran 0-25%. Nilai ini dikonversi ke skala PWM (0-255).
     - `T1` dan `T2`: Membaca suhu dari sensor pada pin T1 atau T2, menghitung nilai rata-rata, dan mencetaknya ke serial.
     - `V` atau `VER`: Menampilkan versi firmware.
     - `LED`: Mengatur tingkat kecerahan LED dalam kisaran 0-100%.
     - `X`: Menghentikan output Q1 dan Q2 (mematikan heater).

5. **Fungsi Pengamanan Suhu**
   `checkTemp()`:
   - Membaca suhu dari sensor T1 dan T2.
   - Jika suhu melebihi batas (`upper_temperature_limit`), output heater (Q1 dan Q2) dimatikan untuk mencegah kerusakan.

6. **Fungsi `setup()`**
   - Menginisialisasi komunikasi serial dengan baud rate yang ditentukan.
   - Mengatur kanal PWM untuk Q1, Q2, dan LED serta mengaitkannya ke pin masing-masing.
   - Memastikan semua output PWM dimulai dari 0 (mati).

7. **Fungsi `loop()`**
   - `parseSerial()`: Membaca dan memproses perintah dari serial.
   - `dispatchCommand()`: Mengeksekusi perintah yang diterima.
   - `checkTemp()`: Memantau suhu dan mengambil tindakan pengamanan jika suhu melebihi batas.

```
import sys import
time import numpy
as np try:
  import serial
except:
```

```
  import pip
  pip.main(['install','pyserial'])   import serial
from serial.tools import list_ports
    class
iTCLab(object):
   def __init__(self, port=None, baud=115200):       port
= self.findPort()       print('Opening connection')
    self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()       self.sp.flushOutput()       time.sleep(3)
    print('iTCLab connected via Arduino on port ' + port)
      def findPort(self):       found = False       for port
in list(list_ports.comports()):
      # Arduino Uno        if port[2].startswith('USB
VID:PID=16D0:0613'):
        port = port[0]             found = True          # Arduino HDuino
if port[2].startswith('USB VID:PID=1A86:7523'):              port =
port[0]
        found = True
      # Arduino Leonardo         if port[2].startswith('USB
VID:PID=2341:8036'):              port = port[0]              found = True
# Arduino ESP32        if port[2].startswith('USB
VID:PID=10C4:EA60'):              port = port[0]              found = True
      # Arduino ESP32 - Tipe yg berbeda       if
port[2].startswith('USB VID:PID=1A86:55D4'):              port = port[0]
found = True       if (not found):
      print('Arduino COM port not found')
      print('Please ensure that the USB cable is connected')          print('---
Printing Serial Ports ---')                     for port in
list(serial.tools.list_ports.comports()):              print(port[0] + ' ' + port[1] + '
' + port[2])          print('For Windows:')
      print('  Open device manager, select "Ports (COM & LPT)"')          print('  Look for
COM port of Arduino such as COM4')          print('For MacOS:')
      print('  Open terminal and type: ls /dev/*.')
      print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')          print('For Linux')
      print('  Open terminal and type: ls /dev/tty*')
      print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')          print('')
      port = input('Input port: ')
      # or hard-code it here
      #port = 'COM3' # for Windows
      #port = '/dev/tty.wchusbserial1410' # for MacOS     return
port
```

[redacted]

```
  def stop(self):            return
self.read('X')
     def version(self):      return
self.read('VER')

  @property   def T1(self):       self._T1 =
float(self.read('T1'))       return self._T1

  @property   def T2(self):       self._T2 =
float(self.read('T2'))       return self._T2
        def LED(self,pwm):       pwm =
max(0.0,min(100.0,pwm))/2.0
     self.write('LED',pwm)       return
pwm
   def Q1(self,pwm):       pwm =
max(0.0,min(100.0,pwm))
     self.write('Q1',pwm)       return
pwm
        def Q2(self,pwm):       pwm =
max(0.0,min(100.0,pwm))
     self.write('Q2',pwm)       return
pwm

  # save txt file with data and set point
  # t = time
  # u1,u2 = heaters
  # y1,y2 = tempeatures  # sp1,sp2 = setpoints  def
save_txt(self,t,u1,u2,y1,y2,sp1,sp2):       data =
np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack      data = data.T
# transpose data       top = 'Time (sec), Heater 1 (%), Heater 2 (%), ' \          +
'Temperature 1 (degC), Temperature 2 (degC), ' \          + 'Set Point 1 (degC), Set Point
2 (degC)'
     np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
   def read(self,cmd):       cmd_str =
self.build_cmd_str(cmd,'')       try:
self.sp.write(cmd_str.encode())
self.sp.flush()       except Exception:          return
None
     return self.sp.readline().decode('UTF-8').replace("\r\n", "")
     def write(self,cmd,pwm):
     cmd_str = self.build_cmd_str(cmd,(pwm,))       try:
       self.sp.write(cmd_str.encode())
self.sp.flush()       except:          return None
     return self.sp.readline().decode('UTF-8').replace("\r\n", "")
```

```
 def build_cmd_str(self,cmd, args=None):
    """
    Build a command string that can be sent to the arduino.

    Input:         cmd (str): the command to send to the arduino, must not
contain a % character
       args (iterable): the arguments to send to the command
    """     if args:         args = ' '.join(map(str,
args))     else:         args = ''
    return "{cmd} {args}\n".format(cmd=cmd, args=args)
      def close(self):
try:         self.sp.close()
      print('Arduino disconnected successfully')      except:
      print('Problems disconnecting from Arduino.')         print('Please
unplug and reconnect Arduino.')       return True
```

Kode ini adalah implementasi Python yang dirancang untuk mengontrol perangkat keras yang terhubung ke Arduino, seperti LED, pemanas (heaters), dan sensor suhu (temperatures), melalui komunikasi serial. Kelas utama dalam kode ini disebut `iTCLab`.

1. Import Module

```
import sys import
time import numpy
as np try:   import
serial except:
  import pip
  pip.main(['install','pyserial'])   import serial
from serial.tools import list_ports
```

- Mengimpor modul standar Python dan modul tambahan:
  - `serial`: Untuk komunikasi serial.
  - `numpy`: Untuk manipulasi data numerik, digunakan untuk menyimpan data dalam bentuk file.
- Jika modul `serial` belum terinstal, akan diinstal secara otomatis menggunakan `pip`.

2. Kelas iTCLab

Kelas ini merepresentasikan perangkat keras yang dikendalikan melalui Arduino. **a) Konstruktor (`__init__`)**

```
def __init__(   ,    =    ,    =115200):
        =    .        ()
        ('Opening connection')
    self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)      self.sp.flushInput()
self.sp.flushOutput()      time.sleep(3)
    print('iTCLab connected via Arduino on port ' + port)
```

- Port: Menentukan port serial yang digunakan oleh Arduino.
- Baudrate: Kecepatan komunikasi serial (115200 bps).
- Memanggil metode `findPort` untuk mendeteksi port otomatis.
- Menginisialisasi komunikasi serial dengan Arduino.
- `time.sleep(3)`: Memberikan waktu bagi Arduino untuk siap.

b) Pendeteksian Port (`findPort`)

```
def findPort(self):      found = False      for port in
list(list_ports.comports()):
      # Arduino Uno       if port[2].startswith('USB
VID:PID=16D0:0613'):
        port = port[0]          found =
True
```

- Tujuan: Menemukan port Arduino secara otomatis berdasarkan ID perangkat (VID:PID).
- Jika tidak ditemukan, memberikan petunjuk kepada pengguna untuk menginput port secara manual.

c) Metode Utama

- Komunikasi Dasar
  - `read(cmd)`: Membaca data dari Arduino berdasarkan perintah (`cmd`).
  - `write(cmd, pwm)`: Mengirimkan perintah dengan nilai parameter PWM.
- Kontrol Perangkat
  - `LED(pwm)`: Mengatur intensitas LED (dalam skala 0-100%).

- Q1(pwm) dan Q2(pwm): Mengatur tingkat pemanasan heater 1 dan 2 (dalam skala 0-100%).

- Pengambilan Data Sensor
  - T1 dan T2: Membaca suhu dari sensor suhu 1 dan 2.
- Fungsi Lain
  - stop(): Menghentikan operasi.
  - version(): Membaca versi firmware Arduino.

d) Penyimpanan Data (save_txt)

```
def save_txt(self,t,u1,u2,y1,y2,sp1,sp2):
    data = np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack      data =
data.T          # transpose data      top = 'Time (sec), Heater 1 (%), Heater 2
(%), ' \        + 'Temperature 1 (degC), Temperature 2 (degC), ' \        + 'Set Point 1
(degC), Set Point 2 (degC)'
    np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
```

Menyimpan data waktu, pemanasan, suhu, dan setpoint dalam format CSV (data.txt) untuk analisis lebih lanjut.

e) Penutupan Koneksi

```
def close(self):      try:
self.sp.close()
      print('Arduino disconnected successfully')      except:
print('Problems disconnecting from Arduino.')        print('Please
unplug and reconnect Arduino.')
```

Menutup koneksi serial dengan Arduino dengan aman.

```
import itclab import
numpy as np import time
import matplotlib.pyplot as plt from
scipy.integrate import odeint

######################################################
# Use this script for evaluating model predictions   #
# and PID controller performance for the TCLab       #
# Adjust only PID and model sections                 # ######################################################

######################################################
# PID Controller                                     #
######################################################
# inputs -----------------------------------
# sp = setpoint
# pv = current temperature
# pv_last = prior temperature
# ierr = integral error
# dt = time increment between measurements
# outputs ----------------------------------
# op = output of the PID controller
# P = proportional contribution
# I = integral contribution # D =
derivative contribution def
pid(sp,pv,pv_last,ierr,dt):     Kc   = 10.0
# K/%Heater     tauI = 50.0 # sec
tauD = 1.0  # sec
    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)     op0 = 0
```

[redacted]

[redacted]

```
    I = ierr     D = -KD * dpv
op = opo + P + I + D
    # implement anti-reset windup     if op
< oplo or op > ophi:         I = I - KI * error *
dt
        # clip output
        op = max(oplo,min(ophi,op))
    # return the controller output and PID terms     return [op,P,I,D]

######################################################
# FOPDT model                                        #
######################################################
Kp = 0.5      # degC/% tauP = 120.0  # seconds
thetaP = 10   # seconds (integer)
Tss = 23      # degC (ambient temperature)
Qss = 0       # % heater

######################################################
# Energy balance model                               #
######################################################
def heat(x,t,Q):     # Parameters
    Ta = 23 + 273.15   # K     U = 10.0           #
W/m^2-K     m = 4.0/1000.0     # kg
    Cp = 0.5 * 1000.0  # J/kg-K         A = 12.0 /
100.0**2 # Area in m^2     alpha = 0.01       # W / %
heater     eps = 0.9          # Emissivity     sigma =
5.67e-8    # Stefan-Boltzman

    # Temperature State
    T = x[0]

    # Nonlinear Energy Balance     dTdt =
(1.0/(m*Cp))*(U*A*(Ta-T) \
            + eps * sigma * A * (Ta**4 - T**4) \
            + alpha*Q)     return dTdt

######################################################
# Do not adjust anything below this point            #
######################################################
# Connect to Arduino a =
itclab.iTCLab()
```

[redacted]

[redacted]

```
# Temperature
# set point (degC)
Tsp1 = np.ones(loops) * 25.0
Tsp1[60:] = 45.0
Tsp1[360:] = 30.0
Tsp1[660:] = 35.0
T1 = np.ones(loops) * a.T1 # measured T (degC) error_sp =
np.zeros(loops)

Tsp2 = np.ones(loops) * 23.0 # set point (degC)
T2 = np.ones(loops) * a.T2 # measured T (degC)

# Predictions
Tp = np.ones(loops) * a.T1 error_eb =
np.zeros(loops) Tpl = np.ones(loops)
* a.T1 error_fopdt = np.zeros(loops)

# impulse tests (0 - 100%)
Q1 = np.ones(loops) * 0.0
Q2 = np.ones(loops) * 0.0

print('Running Main Loop. Ctrl-C to end.')
print('  Time     SP     PV     Q1   =  P   +  I  +   D') print(('{:6.1f} {:6.2f} {:6.2f} ' + \
       '{:6.2f} {:6.2f} {:6.2f} {:6.2f}').format( \
           tm[0],Tsp1[0],T1[0], \
           Q1[0],0.0,0.0,0.0))

# Create plot
plt.figure(figsize=(10,7)) plt.ion()
plt.show()

# Main Loop
start_time = time.time() prev_time
= start_time # Integral error ierr =
0.0 try:     for i in range(1,loops):
        # Sleep time         sleep_max = 1.0
        sleep = sleep_max - (time.time() - prev_time)         if
sleep>=0.01:             time.sleep(sleep-0.01)         else:
            time.sleep(0.01)

        # Record time and change in time
```

[redacted]

[redacted]

```
    Tp[i] = Tnext[1]-273.15

    # Simulate one time step with linear FOPDT model         z = np.exp(-
dt/tauP)
    Tpl[i] = (Tpl[i-1]-Tss) * z \
        + (Q1[max(0,i-int(thetaP)-1)]-Qss)*(1-z)*Kp \                  + Tss

    # Calculate PID output
    [Q1[i],P,ierr,D] = pid(Tsp1[i],T1[i],T1[i-1],ierr,dt)
    # Start setpoint error accumulation after 1 minute (60 seconds)         if i>=60:
error_eb[i] = error_eb[i-1] + abs(Tp[i]-T1[i])             error_fopdt[i] = error_fopdt[i-1] +
abs(Tpl[i]-T1[i])             error_sp[i] = error_sp[i-1] + abs(Tsp1[i]-T1[i])
    # Write output (0-100)
    a.Q1(Q1[i])
    a.Q2(0.0)

    # Print line of data
    print(('{:6.1f} {:6.2f} {:6.2f} ' + \
          '{:6.2f} {:6.2f} {:6.2f} {:6.2f}').format( \
              tm[i],Tsp1[i],T1[i], \
              Q1[i],P,ierr,D))

    # Plot         plt.clf()
    ax=plt.subplot(4,1,1)         ax.grid()
    plt.plot(tm[0:i],T1[0:i],'r.',label=r'$T_1$ measured')
plt.plot(tm[0:i],Tsp1[0:i],'k--',label=r'$T_1$ set point')         plt.ylabel('Temperature
(degC)')         plt.legend(loc=2)         ax=plt.subplot(4,1,2)         ax.grid()
    plt.plot(tm[0:i],Q1[0:i],'b-',label=r'$Q_1$')
plt.ylabel('Heater')         plt.legend(loc='best')
ax=plt.subplot(4,1,3)         ax.grid()
    plt.plot(tm[0:i],T1[0:i],'r.',label=r'$T_1$ measured')         plt.plot(tm[0:i],Tp[0:i],'k-
',label=r'$T_1$ energy balance')         plt.plot(tm[0:i],Tpl[0:i],'g-',label=r'$T_1$ linear
model')         plt.ylabel('Temperature (degC)')         plt.legend(loc=2)
ax=plt.subplot(4,1,4)         ax.grid()
    plt.plot(tm[0:i],error_sp[0:i],'r-',label='Set Point Error')
plt.plot(tm[0:i],error_eb[0:i],'k-',label='Energy Balance Error')
plt.plot(tm[0:i],error_fopdt[0:i],'g-',label='Linear Model Error')
```

[redacted]

[redacted]

```
    # Save figure
    plt.savefig('test_PID.png')

# Allow user to end loop with Ctrl-C
except KeyboardInterrupt:     # Disconnect
from Arduino
    a.Q1(0)
    a.Q2(0)
    print('Shutting down')     a.close()
    plt.savefig('test_PID.png')

# Make sure serial connection still closes when there's an error except:
    # Disconnect from Arduino
    a.Q1(0)
    a.Q2(0)
    print('Error: Shutting down')
    a.close()
    plt.savefig('test_PID.png')     raise

a.close()
```

Kode ini adalah implementasi simulasi dan pengendalian sistem menggunakan **PID controller** (Proportional-Integral-Derivative) pada perangkat keras **TCLab** (Temperature Control Laboratory). Tujuan utamanya adalah untuk mengevaluasi performa model sistem dan pengendalian PID dalam mengatur suhu berdasarkan setpoint yang berubah seiring waktu. Berikut adalah penjelasan detail dari setiap bagian:

1. **Import Library**
    - `itclab`: Berisi antarmuka untuk mengendalikan perangkat keras TCLab (misalnya, membaca suhu dan mengontrol heater).
    - `numpy`, `time`, dan `matplotlib.pyplot`: Digunakan untuk komputasi numerik, pengukuran waktu, dan visualisasi data.
    - `scipy.integrate.odeint`: Digunakan untuk menyelesaikan persamaan diferensial numerik.

2. **Fungsi PID**

    Fungsi `pid` adalah implementasi dari PID controller.
    - Input:
        - `sp` (setpoint): Suhu target.
        - `pv` (process variable): Suhu saat ini.

- `pv_last`: Suhu sebelumnya.
- `ierr`: Kesalahan integral sebelumnya. `dt`: Interval waktu.

- Output:
  - `op`: Output pengendali (persentase daya heater).
  - `P, I, D`: Kontribusi masing-masing komponen PID.
- Parameter:
  - `Kc, tauI, tauD`: Parameter pengendali PID (gain, waktu integral, waktu derivatif).
- Logika:
  - Menghitung kesalahan (`error`), kesalahan integral (`ierr`), dan derivatif perubahan suhu (`dpv`).
  - Menghitung kontribusi P, I, D, dan hasil akhirnya (`op`).
  - Anti-reset windup: Menjaga agar `op` tetap dalam batas 0-100%.

3. Model Sistem

- FOPDT Model (First Order Plus Dead Time): Parameter:
  - o `Kp`: Gain proses. o `tauP`: Konstanta waktu.
  - o `thetaP`: Waktu mati (dead time).

   Simulasi suhu linier berdasarkan model matematika.
- Energy Balance Model:
  - Persamaan termal non-linier berdasarkan energi masuk/keluar (konduksi, konveksi, radiasi).
  - Fungsi `heat` menyelesaikan laju perubahan suhu dengan metode `odeint`.

4. Loop Utama

- Inisialisasi:
  - `a = itclab.iTCLab()`: Menghubungkan ke perangkat TCLab.
  - `loops`: Jumlah iterasi berdasarkan waktu simulasi.
  - `Tsp1, T1, Q1`: Setpoint, suhu aktual, dan output heater.
- Iterasi (Setiap Detik):
  - Membaca suhu aktual dari TCLab.

- Menjalankan simulasi model linier (FOPDT) dan non-linier (energy balance).
- Menghitung output PID berdasarkan suhu aktual dan setpoint.
- Memperbarui cumulative error (kesalahan kumulatif).
- Mencetak data dan memperbarui plot secara real-time.

- Penanganan Akhir:
    - Jika program dihentikan (Ctrl-C atau error), heater dimatikan dan koneksi ditutup.

5. **Visualisasi**

   Membuat empat subplot:

   - Temperatur: Suhu aktual vs setpoint.
   - Heater: Output daya heater.
   - Prediksi Model: Perbandingan antara suhu aktual, model energi, dan model linier.
   - Kesalahan Kumulatif: Kesalahan antara suhu aktual, prediksi, dan setpoint.

H. ITCLab-7

Di ITCLab ke-7 ada 2 kode yaitu, kode Arduino dan Python.

```
#include <Arduino.h>

// constants
const String vers = "1.04";   // version of this firmware  const
int baud = 115200;     // serial baud rate  const char sp = ' ';
// command separator  const char nl = '\n';       // command
terminator

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;      // T1  const int pinT2   = 35;      // T2
const int pinQ1   = 32;      // Q1  const int pinQ2   = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

const double upper_temperature_limit = 59;

// global variables
char Buffer[64];         // buffer for parsing serial input  String
cmd;             // command   double pv = 0;          // pin value  float
level;           // LED level (0-100%)  double Q1 = 0;         // value
written to Q1 pin  double Q2 = 0;         // value written to Q2 pin
int iwrite = 0;         // integer value for writing  float dwrite = 0;
// float value for writing
int n = 10;           // number of samples for each temperature measurement

void parseSerial(void) {
```

```
 int ByteCount = Serial.readBytesUntil(nl,Buffer,sizeof(Buffer));   String
read_ = String(Buffer);   memset(Buffer,0,sizeof(Buffer));

 // separate command from associated data
int idx = read_.indexOf(sp);   cmd =
read_.substring(0,idx);   cmd.trim();
cmd.toUpperCase();

 // extract data. toInt() returns 0 on error   String
data = read_.substring(idx+1);   data.trim();
 pv = data.toFloat();
}

// Q1_max = 100%
// Q2_max = 100%
 void dispatchCommand(void) {
if (cmd == "Q1") {
   Q1 = max(0.0, min(25.0, pv));     iwrite =
int(Q1 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
   ledcWrite(Q1Channel,iwrite);
   Serial.println(Q1);
 }
 else if (cmd == "Q2") {
   Q2 = max(0.0, min(25.0, pv));     iwrite =
int(Q2 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
ledcWrite(Q2Channel,iwrite);
   Serial.println(Q2);
 }  else if (cmd == "T1") {
float mV = 0.0;     float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT1) * 0.322265625;        degC = degC
+ mV/10.0;
   }
   degC = degC / float(n);

   Serial.println(degC);
 }  else if (cmd == "T2") {
float mV = 0.0;     float
degC = 0.0;
   for (int i = 0; i < n; i++) {
       mV = (float) analogRead(pinT2) * 0.322265625;         degC = degC
+ mV/10.0;
  }
   degC = degC / float(n);
   Serial.println(degC);
 }
 else if ((cmd == "V") or (cmd == "VER")) {
   Serial.println("TCLab Firmware Version " + vers);
 }
 else if (cmd == "LED") {
```

```
level = max(0.0, min(100.0, pv));     iwrite =
int(level * 0.5);
```

```
   iwrite = max(0, min(50, iwrite));       ledcWrite(ledChannel, iwrite);
   Serial.println(level);
  }
  else if (cmd == "X") {    ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);    Serial.println("Stop");
  }
}
// check temperature and shut-off heaters if above high limit void
checkTemp(void) {
   float mV = (float) analogRead(pinT1) * 0.322265625;
   //float degC = (mV - 500.0)/10.0;    float
degC = mV/10.0;
   if (degC >= upper_temperature_limit) {
     Q1 = 0.0;      Q2 =
0.0;
     ledcWrite(Q1Channel,0);      ledcWrite(Q2Channel,0);
     //Serial.println("High Temp 1 (> upper_temperature_limit): ");
     Serial.println(degC);
   }
   mV = (float) analogRead(pinT2) * 0.322265625;
   //degC = (mV - 500.0)/10.0;    degC
= mV/10.0;
   if (degC >= upper_temperature_limit) {
     Q1 = 0.0;      Q2 =
0.0;
     ledcWrite(Q1Channel,0);      ledcWrite(Q2Channel,0);
     //Serial.println("High Temp 2 (> upper_temperature_limit): ");
     Serial.println(degC);
   }
}

// arduino startup void
setup() {
  //analogReference(EXTERNAL);
  Serial.begin(baud);   while
(!Serial) {
   ; // wait for serial port to connect.
  }

  // configure pinQ1 PWM functionalitites
  ledcSetup(Q1Channel, freq, resolutionQ1Channel);

  // attach the channel to the pinQ1 to be controlled   ledcAttachPin(pinQ1,
Q1Channel);

  // configure pinQ2 PWM functionalitites
  ledcSetup(Q2Channel, freq, resolutionQ2Channel);

  // attach the channel to the pinQ2 to be controlled   ledcAttachPin(pinQ2,
Q2Channel);

  // configure pinLED PWM functionalitites
  ledcSetup(ledChannel, freq, resolutionLedChannel);
```

```
// attach the channel to the pinLED to be controlled
```

```
 ledcAttachPin(pinLED, ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
}

// arduino main event loop
void loop() {  parseSerial();
dispatchCommand();
 checkTemp();
}
```

Kode ini adalah program untuk Arduino yang dirancang untuk mengontrol perangkat keras, seperti **heater**, **LED**, dan **sensor suhu**, dengan menggunakan modul PWM (Pulse Width Modulation) pada papan Arduino yang kompatibel, seperti ESP32. Program ini juga menyediakan antarmuka serial untuk menerima perintah dan memberikan respon yang sesuai. Berikut adalah penjelasan terperinci:

1. **Konstanta dan Pin Konfigurasi**
   - `vers`: Versi firmware (v1.04).
   - `baud`: Kecepatan komunikasi serial (115200 bps).
   - `sp` dan `nl`: Separator dan terminator untuk parsing perintah.
   - `pinT1`, `pinT2`, `pinQ1`, `pinQ2`, `pinLED`: Nomor pin untuk sensor suhu (T1, T2), heater (Q1, Q2), dan LED.
   - PWM Properties:
     - Frekuensi PWM diatur pada 5000 Hz.
     - Resolusi PWM adalah 8-bit (nilai antara 0-255).
     - Terdapat tiga channel PWM untuk Q1, Q2, dan LED.

2. **Variabel Global**
   - Buffer: Buffer untuk menyimpan input serial.
   - cmd: Perintah yang diterima.
   - pv: Nilai data dari perintah.
   - Q1, Q2: Nilai output PWM ke heater Q1 dan Q2.
   - `level`: Level intensitas LED dalam persen.
   - `n`: Jumlah sampel untuk pembacaan rata-rata suhu.

3. **Fungsi Utama**

   `parseSerial()`

- Membaca input serial hingga menemukan karakter `nl` (`\n`).
- Memisahkan input menjadi perintah (`cmd`) dan data (`pv`).
- Mengubah perintah menjadi huruf besar untuk konsistensi.

`dispatchCommand()`

- Mengeksekusi perintah berdasarkan nilai `cmd`. Perintah yang didukung:
  - Q1: Mengontrol nilai PWM untuk heater Q1. Nilai maksimum dibatasi pada 25% (50 PWM dari 255).
  - Q2: Mengontrol nilai PWM untuk heater Q2 dengan cara serupa.
  - T1 dan T2: Membaca suhu dari sensor analog (T1 atau T2) dan mengembalikan nilai rata-rata dalam derajat Celsius.
  - V atau VER: Mengembalikan versi firmware.
  - LED: Mengontrol intensitas LED (0-100%).
  - X: Mematikan heater (Q1 dan Q2) dengan menulis nilai PWM 0.

`checkTemp()`

- Membaca suhu dari sensor T1 dan T2.
- Jika suhu melebihi batas atas (59°C), heater Q1 dan Q2 dimatikan untuk mencegah overheating.

`setup()`

- Menginisialisasi komunikasi serial.
- Mengatur channel PWM untuk heater dan LED, serta menghubungkannya ke pin masing-masing.
- Menulis nilai awal 0 ke semua channel PWM.

`loop()`

- Mengulangi tiga fungsi utama:
  - `parseSerial()`: Membaca perintah dari serial.
  - `dispatchCommand()`: Menjalankan perintah yang diterima.
  - `checkTemp()`: Memastikan suhu aman.

4. Detail Perintah

- Perintah Q1/Q2:
  - Nilai input (pv) dibatasi antara 0-25%.
  - Nilai PWM dihitung sebagai pv * 2.0 untuk menghasilkan skala 0-50 (mewakili hingga 25% dari 255).

- Perintah T1/T2:
  - Sensor analog membaca nilai dalam miliVolt (mV), di mana 1 unit ADC setara dengan 0.322 mV.
  - Suhu dihitung sebagai mV / 10.0 dalam Celsius.
- Perintah LED:
  - Level intensitas LED (0-100%) dikonversi ke nilai PWM skala 0-50.
- Keamanan:
  - Jika suhu melebihi 59°C, semua heater dimatikan dengan menulis 0 ke channel PWM heater.

5. **Penggunaan**
   - Hubungkan Arduino ke komputer atau perangkat lain.
   - Kirim perintah melalui antarmuka serial (misalnya, `Q1 10` untuk mengatur Q1 ke 10%).
   - Perangkat akan merespon perintah sesuai logika dalam fungsi `dispatchCommand()`.

```
import sys import
time import numpy
as np try:
  import serial
except:   import
pip
  pip.main(['install','pyserial'])   import serial
from serial.tools import list_ports
     class
iTCLab(object):
   def __init__(self, port=None, baud=115200):       port
= self.findPort()       print('Opening connection')
     self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()       self.sp.flushOutput()       time.sleep(3)
     print('iTCLab connected via Arduino on port ' + port)
        def findPort(self):       found = False       for port
in list(list_ports.comports()):
       # Arduino Uno        if port[2].startswith('USB
VID:PID=16D0:0613'):            port = port[0]            found = True
# Arduino HDuino        if port[2].startswith('USB
VID:PID=1A86:7523'):            port = port[0]
          found = True
       # Arduino Leonardo        if port[2].startswith('USB
VID:PID=2341:8036'):
          port = port[0]            found = True        # Arduino ESP32
if port[2].startswith('USB VID:PID=10C4:EA60'):            port =
port[0]            found = True
       # Arduino ESP32 - Tipe yg berbeda        if
port[2].startswith('USB VID:PID=1A86:55D4'):
          port = port[0]            found =
True
```

```
    if (not found):          print('Arduino COM port not
found')
        print('Please ensure that the USB cable is connected')          print('---
Printing Serial Ports ---')                     for port in
list(serial.tools.list_ports.comports()):                print(port[0] + ' ' + port[1] + '
' + port[2])          print('For Windows:')
        print('  Open device manager, select "Ports (COM & LPT)"')          print('  Look for
COM port of Arduino such as COM4')          print('For MacOS:')
        print('  Open terminal and type: ls /dev/*.')
        print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')          print('For Linux')
        print('  Open terminal and type: ls /dev/tty*')
        print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')          print('')
        port = input('Input port: ')          # or
hard-code it here
        #port = 'COM3' # for Windows
        #port = '/dev/tty.wchusbserial1410' # for MacOS     return
port
      def stop(self):       return
self.read('X')
      def version(self):       return
self.read('VER')

  @property    def T1(self):        self._T1 =
float(self.read('T1'))       return self._T1

  @property    def T2(self):        self._T2 =
float(self.read('T2'))       return self._T2
         def LED(self,pwm):        pwm =
max(0.0,min(100.0,pwm))/2.0
      self.write('LED',pwm)       return
pwm
   def Q1(self,pwm):
      pwm = max(0.0,min(100.0,pwm))
self.write('Q1',pwm)       return pwm
         def
Q2(self,pwm):
      pwm = max(0.0,min(100.0,pwm))
self.write('Q2',pwm)       return pwm

  # save txt file with data and set point
  # t = time
  # u1,u2 = heaters
  # y1,y2 = tempeatures   # sp1,sp2 = setpoints   def
save_txt(self,t,u1,u2,y1,y2,sp1,sp2):       data =
np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack      data = data.T
# transpose data
```

[redacted]

[redacted]

```
= 'Time (sec), Heater 1 (%), Heater 2 (%), '
    + 'Temperature 1 (degC), Temperature 2 (degC), ' \      + 'Set Point 1
(degC), Set Point 2 (degC)'
   np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
  def read(self,cmd):      cmd_str =
self.build_cmd_str(cmd,'')      try:
self.sp.write(cmd_str.encode())
self.sp.flush()      except Exception:        return
None
   return self.sp.readline().decode('UTF-8').replace("\r\n", "")
   def write(self,cmd,pwm):        cmd_str =
self.build_cmd_str(cmd,(pwm,))      try:
self.sp.write(cmd_str.encode())        self.sp.flush()
except:
     return None
   return self.sp.readline().decode('UTF-8').replace("\r\n", "")
   def build_cmd_str(self,cmd, args=None):
   """
   Build a command string that can be sent to the arduino.

   Input:       cmd (str): the command to send to the arduino, must not
contain a % character
     args (iterable): the arguments to send to the command
   """     if args:        args = ' '.join(map(str,
args))     else:        args = ''
   return "{cmd} {args}\n".format(cmd=cmd, args=args)
     def close(self):
try:
     self.sp.close()
     print('Arduino disconnected successfully')      except:
     print('Problems disconnecting from Arduino.')        print('Please
unplug and reconnect Arduino.')      return True
```

Kode ini adalah implementasi sebuah kelas Python yang berfungsi untuk mengontrol perangkat berbasis Arduino melalui komunikasi serial. Berikut adalah penjelasan detail dari masing-masing bagian kode:

1. Import Library

```
mport sys import time
import numpy as np
try:
  import serial
except:
  import pip
  pip.main(['install','pyserial'])    import serial
from serial.tools import list_ports
```

Kode ini mengimpor modul standar Python seperti `sys` dan `time`, bersama dengan modul `numpy` untuk pengolahan data. Jika modul `serial` (dari pustaka `pyserial`) tidak diinstal, maka kode akan mencoba menginstalnya secara otomatis.

2. Kelas iTCLab

Kelas ini mendefinisikan metode untuk berkomunikasi dengan Arduino menggunakan port serial.

Inisialisasi (`__init__`)

```
def __init__(self, port=None, baud=115200):
      port = self.findPort()        print('Opening
connection')
      self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()        self.sp.flushOutput()        time.sleep(3)
      print('iTCLab connected via Arduino on port ' + port)
```

- Mencari port serial Arduino menggunakan metode `findPort`.
- Membuka koneksi serial pada port yang ditemukan dengan baud rate 115200.
- Membersihkan buffer input/output serial.
- Menunggu 3 detik agar perangkat siap. **Metode findPort**

```
def findPort(self):        found = False        for port in
list(list_ports.comports()):
        # Arduino Uno        if port[2].startswith('USB
VID:PID=16D0:0613'):
            port = port[0]              found = True          # Arduino HDuino
if port[2].startswith('USB VID:PID=1A86:7523'):
            port = port[0]
            found = True
        # Arduino Leonardo        if port[2].startswith('USB
VID:PID=2341:8036'):
            port = port[0]              found = True          # Arduino ESP32
if port[2].startswith('USB VID:PID=10C4:EA60'):
            port = port[0]              found =
True
        # Arduino ESP32 - Tipe yg berbeda        if
port[2].startswith('USB VID:PID=1A86:55D4'):
            port = port[0]
found = True        if (not found):
        print('Arduino COM port not found')
        print('Please ensure that the USB cable is connected')
```

```
                ('--- Printing Serial Ports ---')
```

```
        for port in list(serial.tools.list_ports.comports()):            print(port[0] + ' ' +
port[1] + ' ' + port[2])           print('For Windows:')
        print('  Open device manager, select "Ports (COM & LPT)"')           print('  Look for
COM port of Arduino such as COM4')           print('For MacOS:')
        print('  Open terminal and type: ls /dev/*.')
        print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')           print('For Linux')
        print('  Open terminal and type: ls /dev/tty*')
        print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')           print('')
        port = input('Input port: ')
        # or hard-code it here
        #port = 'COM3' # for Windows
        #port = '/dev/tty.wchusbserial1410' # for MacOS     return
port
```

- Mendeteksi port serial Arduino berdasarkan VID:PID USB yang terdaftar.
- Jika tidak ditemukan, meminta pengguna untuk memasukkan nama port secara manual.

Metode Pembacaan dan Penulisan

- `read`: Membaca data dari Arduino berdasarkan perintah (`cmd`) yang dikirim.
- `write`: Menulis data ke Arduino, seperti mengatur nilai PWM pada perangkat keras (misalnya, pemanas atau LED).

Properti dan Metode untuk Kontrol

- `T1` dan `T2`: Membaca suhu dari sensor 1 dan 2.
- `LED`: Mengontrol intensitas LED (0-100%).
- `Q1` dan `Q2`: Mengontrol pemanas (heater) 1 dan 2 menggunakan PWM (0100%).

Fungsi Penyimpanan Data

```
def save_txt(self,t,u1,u2,y1,y2,sp1,sp2):
    data = np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack       data = 
data.T            # transpose data       top = 'Time (sec), Heater 1 (%), Heater 2 
(%), ' \         + 'Temperature 1 (degC), Temperature 2 (degC), ' \         + 'Set Point 1 
(degC), Set Point 2 (degC)'
    np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
```

- Menyimpan data pengukuran ke file teks (`data.txt`) dalam format CSV.
- Data yang disimpan mencakup waktu, nilai heater, suhu, dan setpoint.

Menutup Koneksi

```
def close(    ):      try:
   .  .     ()
          ('Arduino disconnected successfully')       except:
          ('Problems disconnecting from Arduino.')              ('Please 
unplug and reconnect Arduino.')       return
```

- Menutup koneksi serial secara aman.
- Memberikan notifikasi jika terjadi masalah saat memutuskan koneksi.

Kegunaan

Kode ini dirancang untuk eksperimen atau pengendalian perangkat berbasis Arduino, seperti pengendalian suhu menggunakan heater dan LED, yang mungkin digunakan dalam aplikasi laboratorium atau pembelajaran IoT.

I. ITCLab-8

```
#include <WiFi.h>
#include <PubSubClient.h> #include
<Arduino.h>

const char* ssid = "wifi_name"; // Enter your WiFi name
const char* password =  "wifi_password"; // Enter WiFi password
#define mqttServer "broker.hivemq.com"
#define mqttPort 1883

WiFiServer server(80);
WiFiClient espClient;
PubSubClient client(espClient);

String Topic;
String Payload;

// constants
const int baud = 115200;     // serial baud rate

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;      // T1 const int pinT2   = 35;      // T2
const int pinQ1   = 32;      // Q1 const int pinQ2   = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

float cel, cel1, degC, degC1;
const float upper_temperature_limit = 58;

// global variables
float Q1 = 0;          // value written to Q1 pin float Q2 = 0;
// value written to Q2 pin int iwrite_value = 25;      // integer
value for writing int iwrite_min = 0;       // integer value for
writing
 void setup() {
 // put your setup code here, to run once:
```

```
    .    (    );  while
(!    ){
  ;// wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
        (         ,    ,                 );

 // attach the channel to the pinQ1 to be controlled
```

```
 ledcAttachPin(pinQ1, Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
ledcWrite(ledChannel,0);

 // Connect to WiFi network
 Serial.println();
 Serial.println();
 Serial.print("Connecting to ");
 Serial.println(ssid);
 WiFi.begin(ssid, password);

 while (WiFi.status() != WL_CONNECTED) {
delay(500);    Serial.print(".");
 }
 Serial.println("");
 Serial.println("WiFi connected");
 // Connect to Server IoT (CloudMQTT)  client.setServer(mqttServer,
mqttPort);  client.setCallback(receivedCallback);

 while (!client.connected()) {
  Serial.println("Connecting to CLoud IoT ...");
```

```
//    if (client.connect("ESP32Client", mqttUser, mqttPassword )) {
if (client.connect("iTCLab Suhu On/Off")) {
```

```
        .       ("connected");
        .     ("Message received: ");

  } else {
        .     ("failed with state ");
     .    (      .    ());          (2000);   }
       .          ("heater1bas");
     .          ("heater2bas");
 }
} void     (){
        (          ,          );
  //Q1 = iwrite_value/255*100;
  //Serial.println(Q1);
}
```

```
void Q1off(){
   ledcWrite(Q1Channel,iwrite_min);
   //Q1 = iwrite_min/255*100;
   //Serial.println(Q1);
}
void Q2on(){
   ledcWrite(Q2Channel,iwrite_value);
   //Q2 = iwrite_value/255*100;
   //Serial.println(Q2);
}
void Q2off(){
   ledcWrite(Q2Channel,iwrite_min);
   //Q2 = iwrite_min/255*100;
   //Serial.println(Q2);
}
void ledon(){
   ledcWrite(ledChannel,iwrite_value);
}
void ledoff(){
   ledcWrite(ledChannel,iwrite_min);
}
void cektemp(){
  degC = analogRead(pinT1) * 0.322265625 ;   // use for 3.3v AREF   cel =
degC/10;
  degC1 = analogRead(pinT2) * 0.322265625 ;   // use for 3.3v AREF   cel1 =
degC1/10;

  Serial.print("Temperature: ");
  Serial.print(cel);  // print the temperature T1 in Celsius
  Serial.print("°C");
  Serial.print(" ~ "); // separator between Celsius and Fahrenheit
  Serial.print(cel1);  // print the temperature T2 in Celsius
  Serial.println("°C");
}
void receivedCallback(char* topic, byte* payload, unsigned int length) {
```

```
/* we got '1' -> Q1_on */ if
((char)      [0] == '1') {
       ();
       .      ("Q1 On");
 }

/* we got '2' -> Q1_off */ if
((char)      [0] == '2') {
       ();
       .      ("Q1 Off");
 }

/* we got '3' -> Q2_on */ if
((char)      [0] == '3') {
    ();
       .      ("Q2 On");
 }

/* we got '4' -> Q2_off */
```

```
 if ((char)payload[0] == '4') {
      Q2off();
      Serial.println("Q2 Off");
 }
} void loop() {
char suhu1[4];
char suhu2[4];
client.loop();

 // put your main code here, to run repeatedly:   cektemp();
 if (cel > upper_temperature_limit){
Q1off();     ledon();
 }  else {
Q1on();
ledoff();
 }
 if (cel1 > upper_temperature_limit){
Q2off();     ledon();
 }  else {
Q2on();
ledoff();
 }
 delay (100);


 Serial.print("Temperature T1: ");
 Serial.print(cel);
 Serial.print(" Celcius ");
 Serial.println(" send to Broker MQTT");

 dtostrf(cel, 1, 0, suhu1);   client.publish("Suhu1",suhu1);

 delay (200);
```

```
  .       ("Temperature T2: ");
  .       (     );
  .       (" Celcius ");
  .          (" send to Broker MQTT");
    (     , 1, 0,          );
 .          ("Suhu2",          );
  (200);
```

}

Kode ini adalah program untuk ESP32 yang mengontrol pemanas menggunakan sensor suhu dan mengirim data suhu ke broker MQTT (Message Queuing Telemetry Transport). Berikut adalah penjelasan untuk setiap bagian:

1. **Header dan Konstanta**
   - Library yang digunakan:
     - `WiFi.h`: Untuk koneksi WiFi.
     - `PubSubClient.h`: Untuk komunikasi dengan broker MQTT. `Arduino.h`: Fungsi dasar Arduino.
   - Konstanta WiFi dan MQTT:
     - `ssid` dan `password`: Nama dan kata sandi WiFi untuk koneksi internet.
     - `mqttServer` dan `mqttPort`: Server dan port broker MQTT (`broker.hivemq.com`).
   - Konstanta lainnya:
     - `baud`: Kecepatan baud untuk komunikasi serial (115200 bps).
     - Pin untuk sensor suhu, pemanas, dan LED (`pinT1`, `pinT2`, `pinQ1`, `pinQ2`, `pinLED`).
     - PWM properties (frekuensi dan resolusi PWM).

2. **Variabel Global**
   - `cel`, `cel1`: Variabel untuk menyimpan suhu dari sensor T1 dan T2.
   - `upper_temperature_limit`: Batas suhu atas (58°C) untuk mengontrol pemanas.
   - Variabel `Q1`, `Q2`: Nilai output PWM ke pemanas.
   - `iwrite_value`, `iwrite_min`: Nilai PWM (dalam skala 0-255) untuk mengontrol intensitas.

3. **Fungsi `setup()`**
   - Koneksi Serial:
     - Menginisialisasi komunikasi serial pada baud rate 115200.

- Konfigurasi PWM:
    - Mengatur properti PWM (frekuensi dan resolusi) untuk pin pemanas (`pinQ1`, `pinQ2`) dan LED (`pinLED`).
    - Mengikat saluran PWM dengan pin terkait. Menetapkan nilai awal PWM ke 0 (mati).
- Koneksi WiFi:
     Menghubungkan ESP32 ke jaringan WiFi dengan `WiFi.begin`. Looping hingga koneksi berhasil (`WiFi.status()`).
- Koneksi ke Broker MQTT:
    - Mengatur server MQTT dan callback untuk menerima pesan. Looping hingga koneksi berhasil.
    - Berlangganan ke topik `heater1bas` dan `heater2bas`.

4. **Fungsi Kontrol**
    - Kontrol Pemanas dan LED:
        - `Q1on()`, `Q1off()`, `Q2on()`, `Q2off()`: Menghidupkan/mematikan pemanas dengan menulis nilai PWM.
        - `ledon()`, `ledoff()`: Menghidupkan/mematikan LED.

5. **Fungsi `cektemp()`**
    - Membaca nilai analog dari sensor suhu (`pinT1`, `pinT2`), mengkonversi ke suhu dalam °C.
    - Menggunakan konstanta `0.322265625` untuk kalibrasi berdasarkan AREF 3.3V.
    - Menampilkan suhu di serial monitor.

6. **Callback MQTT**
   `receivedCallback(char* topic, byte* payload, unsigned int length)`
    - Mengevaluasi pesan yang diterima dari broker MQTT.
    - Pesan berupa angka yang menentukan tindakan:
        - `'1'`: Menghidupkan `Q1`. `'2'`: Mematikan `Q1`.
        - `'3'`: Menghidupkan `Q2`.
        - `'4'`: Mematikan `Q2`.

7. **Fungsi `loop()`** Loop Utama:
    - Memeriksa suhu sensor menggunakan `cektemp()`.
    - Membandingkan suhu dengan batas atas: Jika suhu > batas: ○ Matikan pemanas, nyalakan LED.
         Jika suhu <= batas:
            ○ Hidupkan pemanas, matikan LED.
    - Mengirim data suhu (`cel` dan `cel1`) ke broker MQTT pada topik `Suhu1` dan `Suhu2`.
    - Penundaan (`delay`) untuk interval pengiriman data.

Kegunaan

Kode ini digunakan untuk:

- Mengontrol pemanas berdasarkan suhu.
- Mengirim data suhu ke broker MQTT untuk monitoring.
- Menerima perintah kontrol manual dari broker MQTT.

J. ITCLab-9

```
#include <WiFi.h>
#include <PubSubClient.h> #include
<Arduino.h>

const char* ssid = "wifi_name"; // Enter your WiFi name
const char* password =  "wifi_password"; // Enter WiFi password
#define mqttServer "broker.hivemq.com"
#define mqttPort 1883

WiFiServer server(80);
WiFiClient espClient;
PubSubClient client(espClient);

String Topic;
String Payload;

// constants
const int baud = 115200;     // serial baud rate

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;      // T1  const int pinT2   = 35;      // T2
const int pinQ1   = 32;      // Q1  const int pinQ2   = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

float cel, cel1, degC, degC1; float P, I,
D, Kc, tauI, tauD;
float KP, KI, KD, op0, ophi, oplo, error, dpv; float
sp = 35, //set point  pv = 0,     //current
temperature
```

```
      = 0, //prior temperature     = 0,
//integral error
```

```
dt = 0,     //time between measurements  op = 0;
//PID controller output unsigned long ts = 0,
new_ts = 0; //timestamp const float
upper_temperature_limit = 58;

// global variables
float Q1 = 0;          // value written to Q1 pin float Q2 = 0;
// value written to Q2 pin int iwrite_value = 25;     // integer
value for writing int iwrite_led = 255;      // integer value for
writing int iwrite_min = 0;       // integer value for writing
 void setup() {
 // put your setup code here, to run once:

 ts = millis();

 Serial.begin(baud);   while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
ledcWrite(ledChannel,0);

 // Connect to WiFi network
 Serial.println();
 Serial.println();
 Serial.print("Connecting to ");
 Serial.println(ssid);
 WiFi.begin(ssid, password);

 while (WiFi.status() != WL_CONNECTED) {
delay(500);    Serial.print(".");
 }
 Serial.println("");
```

```
Serial.println("WiFi connected");
// Connect to Server IoT (CloudMQTT)
```

```
. ( , ); . ( );
```

```
 while (!client.connected()) {
  Serial.println("Connecting to MQTT Broker ...");

   if (client.connect("PID-iTCLab Monitoring Using IoT...")) {
    Serial.println("connected");
    Serial.print("Message received: ");

  } else {
    Serial.print("failed with state ");
Serial.print(client.state());     delay(2000);
  }
  //client.subscribe("heater1");
  //client.subscribe("heater2");
 }
}
void Q1on(){
  ledcWrite(Q1Channel,iwrite_value);
  //Q1 = iwrite_value/255*100;
  //Serial.println(Q1);
}
void Q1off(){
  ledcWrite(Q1Channel,iwrite_min);
  //Q1 = iwrite_min/255*100;
  //Serial.println(Q1);
}
void Q2on(){
  ledcWrite(Q2Channel,iwrite_value);
  //Q2 = iwrite_value/255*100;
  //Serial.println(Q2);
}
void Q2off(){
  ledcWrite(Q2Channel,iwrite_min);
  //Q2 = iwrite_min/255*100;
  //Serial.println(Q2);
}
void ledon(){
  ledcWrite(ledChannel,iwrite_led);
}
void ledoff(){
  ledcWrite(ledChannel,iwrite_min);
}
void cektemp(){
 degC = analogRead(pinT1) * 0.322265625 ;  // use for 3.3v AREF   cel =
degC/10;
 degC1 = analogRead(pinT2) * 0.322265625 ;  // use for 3.3v AREF   cel1 =
degC1/10;

 Serial.print("Temperature T1: ");
  Serial.print(cel);  // print the temperature T1 in Celsius
```

```
.    ("°C");
.    (" ~ "); // separator between Celsius and Fahrenheit
```

```
  Serial.print("Temperature T2: ");
  Serial.print(cel1);  // print the temperature T2 in Celsius
  Serial.println("°C");
}
float pid(float sp, float pv, float pv_last, float& ierr, float dt) {  float Kc
= 10.0; // K / %Heater   float tauI = 50.0; // sec   float tauD = 1.0;  // sec
// PID coefficients   float KP = Kc;   float KI = Kc / tauI;   float KD =
Kc*tauD;
 // upper and lower bounds on heater level
float ophi = 100;  float oplo = 0;  // calculate
the error   float error = sp - pv;
 // calculate the integral error   ierr =
ierr + KI * error * dt;   // calculate the
measurement derivative   float dpv = (pv -
pv_last) / dt;  // calculate the PID output
 float P = KP * error; //proportional contribution
float I = ierr; //integral contribution   float D = -KD *
dpv; //derivative contribution   float op = P + I + D;
 // implement anti-reset windup   if
((op < oplo) || (op > ophi)) {
   I = I - KI * error * dt;
   // clip output
   op = max(oplo, min(ophi, op));
 }
 ierr = I;
 Serial.println("sp="+String(sp) + " pv=" + String(pv) + " dt=" + String(dt) + " op=" +
String(op) + " P=" + String(P) + " I=" + String(I) + " D=" + String(D));  return op;
}

void receivedCallback(char* topic, byte* payload, unsigned int length) {
/* we got '1' -> Q1_on */  if
((char)payload[0] == '1') {
Q1on();
      Serial.println("Q1 On");
 }

/* we got '2' -> Q1_off */  if
((char)payload[0] == '2') {
      Q1off();
      Serial.println("Q1 Off");
 }

/* we got '3' -> Q2_on */  if
((char)payload[0] == '3') {
      Q2on();
      Serial.println("Q2 On");
   }
```

```
/* we got '4' -> Q2_off */
```

```
 if ((char)payload[0] == '4') {
     Q2off();
     Serial.println("Q2 Off");
 }
} void loop() {
new_ts = millis();
 if (new_ts - ts > 1000) {

 char suhu1[4];  char
suhu2[4];  char
SetPoint[4];  char
Nilai_op[4];  char
Nilai_P[4];  char
Nilai_I[4];  char
Nilai_D[4];

 client.loop();

 // put your main code here, to run repeatedly:   cektemp();
 if (cel > upper_temperature_limit){
Q1off();    ledon();
 }  else {
Q1on();
ledoff();
 }
 if (cel1 > upper_temperature_limit){
Q2off();    ledon();
 }  else {
Q2on();
ledoff();
 }
 //delay (100);
  pv = cel;  // Temperature T1   dt
= (new_ts - ts) / 1000.0;   ts =
new_ts;
 op = pid(sp,pv,pv_last,ierr,dt);
ledcWrite(Q1Channel,op);  pv_last = pv;

 dtostrf(cel, 1, 0, suhu1);  client.publish("Suhu1",suhu1);

 dtostrf(sp, 1, 0, SetPoint);
 client.publish("SetPoint",SetPoint);

 dtostrf(op, 1, 0, Nilai_op);
 client.publish("Nilai_op",Nilai_op);
  delay (200);
 dtostrf(cel1, 1, 0, suhu2);
```

```
.        ("Suhu2",       );
```

```
delay (200);
 }
}
```

Kode ini merupakan implementasi dari sistem IoT berbasis ESP32 yang mengontrol suhu menggunakan PID (Proportional-Integral-Derivative) controller. Kode memanfaatkan WiFi untuk koneksi internet, PubSubClient untuk komunikasi MQTT (Message Queuing Telemetry Transport), serta pengukuran suhu melalui pin analog dan pengendalian perangkat keras menggunakan PWM (Pulse Width Modulation). Berikut adalah penjelasan rinci setiap bagian:

1. **Header File dan Konstanta**
   - Library:
     - `WiFi.h` dan `PubSubClient.h` digunakan untuk koneksi WiFi dan komunikasi MQTT.
     - `Arduino.h` adalah library dasar Arduino.
   - Konstanta WiFi dan MQTT:
     - `ssid` dan `password`: Nama dan password jaringan WiFi.
     - `mqttServer` dan `mqttPort`: Server MQTT (HiveMQ) dan port (1883).

2. **Pin Konfigurasi dan PWM**
   - Pin Konfigurasi:
     - Pin `T1` dan `T2`: Sensor suhu analog.
     - Pin `Q1`, `Q2`: Perangkat keluaran yang dikendalikan (misal: pemanas).
     - Pin `LED`: Indikator visual.
   - PWM Konfigurasi:
     - Frekuensi PWM `freq` ditetapkan pada 5000 Hz.
     - Resolusi PWM ditetapkan pada 8 bit.

3. **Variabel Global**
   - Variabel seperti `cel`, `sp`, `pv`, `ierr`, dan `op` digunakan untuk menghitung suhu, setpoint, error, dan output PID.

- `upper_temperature_limit`: Batas suhu atas, digunakan untuk menghidupkan/mematikan pemanas.

4. Fungsi `setup()`

- Menginisialisasi:
  - Serial komunikasi untuk debugging.

- PWM pada pin `Q1`, `Q2`, dan `LED`.

- Koneksi WiFi:
  - Menghubungkan ESP32 ke WiFi dengan SSID dan password.
- Koneksi MQTT:
  - ESP32 dihubungkan ke broker MQTT, dan callback `receivedCallback` ditetapkan untuk menangani pesan masuk.

5. Fungsi Utama Fungsi Kontrol:

- `Q1on(),Q1off(),Q2on(),Q2off()`: Menyalakan atau mematikan pin PWM.
- `ledon(,ledoff()`: Menyalakan atau mematikan LED. **Pembacaan Suhu:**
- `cektemp()`: Membaca suhu dari pin analog (T1 dan T2) dan mencetak nilainya ke serial monitor.

Fungsi PID:

- `pid()`: Menghitung output berdasarkan kontrol PID: Error: Selisih antara setpoint dan suhu saat ini.
  - Proportional: Mengalikan error dengan `Kc`.
  - Integral: Mengakumulasikan error untuk respon lambat.
  - Derivative: Memperkirakan perubahan error untuk respon cepat.

Callback MQTT:

- `receivedCallback()`: Mengolah pesan masuk dari broker MQTT. Pesan dapat berupa:
  - `'1'`: Menyalakan `Q1`. `'2'`: Mematikan `Q1`.
  - `'3'`: Menyalakan `Q2`.
  - `'4'`: Mematikan `Q2`.

6. Fungsi `loop()`

- Pemrosesan Periodik:
  - Memeriksa waktu menggunakan `millis()` untuk iterasi PID setiap 1 detik.
- Pengendalian Suhu:

- Jika suhu melebihi batas, pemanas dimatikan dan LED menyala. Jika suhu normal, pemanas dinyalakan dan LED mati.
- PID Kontrol:
  - Menghitung output PID untuk menyesuaikan keluaran PWM.
- Komunikasi MQTT:
  - Mengirim data suhu (`T1`, `T2`), setpoint, dan nilai PID ke broker MQTT.

Kegunaan

Kode ini cocok untuk aplikasi pengendalian suhu seperti inkubator atau oven pintar. Sistemnya modular, mendukung komunikasi IoT melalui MQTT, dan mengintegrasikan algoritma PID untuk pengendalian suhu yang presisi.

K. ITCLab-10

```
#include <WiFi.h>
#include <PubSubClient.h> #include
<Arduino.h>

const char* ssid = "wifi_name"; // Enter your WiFi name
const char* password =  "wifi_password"; // Enter WiFi password
#define mqttServer "broker.hivemq.com"
#define mqttPort 1883

WiFiServer server(80);
WiFiClient espClient;
PubSubClient client(espClient);

String Topic;
String Payload;

// constants
const int baud = 115200;     // serial baud rate

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1   = 34;      // T1  const int pinT2   = 35;      // T2
const int pinQ1   = 32;      // Q1  const int pinQ2   = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15
 float   ,    ,      ,      ;
float  , ,  ;
float   ,   ,   ,    ,    ,    ,    ,   ;

float   = 30, //set point    = 0,
//current temperature       = 0,  //prior
temperature     = 0,   //integral error    =
```

```
0,    //time between measurements    = 0;
//PID controller output

int       = 0; // autoSet = 1 otomatis sesuai Default
//float Kc = 0;
```

```
//float tauI = 0;
//float tauD = 0;

// Default = autoset = 1 otomatis sesuai Default
float Kc = 10.0; // K / %Heater  float tauI = 50.0; //
sec  float tauD = 1.0; // sec
 unsigned long ts = 0, new_ts = 0; //timestamp
const float upper_temperature_limit = 58;

// global variables
float Q1 = 0;         // value written to Q1 pin float Q2 = 0;
// value written to Q2 pin int iwrite_value = 25;     // integer
value for writing int iwrite_led = 255;      // integer value for
writing int iwrite_min = 0;       // integer value for writing
 void setup() {
 // put your setup code here, to run once:
  ts = millis();
Serial.begin(baud);
while (!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);

 ledcWrite(Q1Channel,0);  ledcWrite(Q2Channel,0);
```

```
       (         ,0);

// Connect to WiFi network
    .     ();
    .     ();
    .    ("Connecting to ");
    .     (   );
   .    (   ,        );

while (    .    () !=                ) {
```

```
    (500);       .    (".");
}
    .     ("");
```

```
 Serial.println("WiFi connected");
 // Connect to Server IoT (CloudMQTT)   client.setServer(mqttServer,
mqttPort);  client.setCallback(receivedCallback);

 while (!client.connected()) {
   Serial.println("Connecting to MQTT Broker ...");

   if (client.connect("PID-iTCLab Controlling Using IoT...")) {
     Serial.println("connected");
     Serial.print("Message received: ");

   } else {
     Serial.print("failed with state ");
Serial.print(client.state());      delay(1000);
   }
   client.subscribe("autoSet");    client.subscribe("SetPoint");
client.subscribe("Nilai_Kc");    client.subscribe("Nilai_tauI");
client.subscribe("Nilai_tauD");
 }
}
void Q1on(){
   ledcWrite(Q1Channel,iwrite_value);
   //Q1 = iwrite_value/255*100;
   //Serial.println(Q1);
}
void Q1off(){
   ledcWrite(Q1Channel,iwrite_min);
   //Q1 = iwrite_min/255*100;
   //Serial.println(Q1);
}
void Q2on(){
   ledcWrite(Q2Channel,iwrite_value);
   //Q2 = iwrite_value/255*100;
   //Serial.println(Q2);
}
void Q2off(){
   ledcWrite(Q2Channel,iwrite_min);
```

```
  //Q2 = iwrite_min/255*100;
  //Serial.println(Q2);
} void
     (){
          (           ,          );
} void      (){
        (           ,          ); } void
       (){
     =           (     ) * 0.322265625 ;  // use for 3.3v AREF
```

```
  cel = degC/10;
  degC1 = analogRead(pinT2) * 0.322265625 ;  // use for 3.3v AREF   cel1 =
degC1/10;

}
float pid(float sp, float Kc, float tauI, float tauD, float pv, float pv_last, float& ierr, float dt) {
 // PID coefficients
float KP = Kc;  float KI =
Kc / tauI;  float KD =
Kc*tauD;
 // upper and lower bounds on heater level
float ophi = 100;  float oplo = 0;  // calculate
the error  float error = sp - pv;
 // calculate the integral error   ierr =
ierr + KI * error * dt;   // calculate the
measurement derivative  float dpv = (pv -
pv_last) / dt;  // calculate the PID output
 float P = KP * error; //proportional contribution
float I = ierr; //integral contribution  float D = -KD *
dpv; //derivative contribution  float op = P + I + D;
 // implement anti-reset windup  if
((op < oplo) || (op > ophi)) {
   I = I - KI * error * dt;
   // clip output
   op = max(oplo, min(ophi, op));
  }
  ierr = I;
  Serial.println("sp="+String(sp) + " pv=" + String(pv) + " dt=" + String(dt) + " op=" +
String(op) + " P=" + String(P) + " I=" + String(I) + " D=" + String(D));  return op;
}
void receivedCallback(char* topic, byte* payload, unsigned int length) {  Topic =
topic;  char autoS[60];  int i;
 for (i=0;i<length;i++){    autoS[i] =
payload[i];
  }
  autoS[i] = '\0';
  Payload = String(autoS);
```

```
} void    (){
      =     ();

 if (       -   > 1000) {
 char      [4];
char      [4];  char
       [4];  char
         [4];  char
         [4];  char
          [4];  char
           [4];
```

```
client.loop();

// put your main code here, to run repeatedly:   cektemp();
if (cel > upper_temperature_limit){
Q1off();    ledon();
} else {
Q1on();
ledoff();
}
if (cel1 > upper_temperature_limit){
Q2off();    ledon();
} else {
Q2on();
ledoff();
}    if(Topic=="autoSet"){
autoSet=Payload.toInt();
}  if(Topic=="Nilai_Kc"){
Kc=Payload.toFloat();
}  if(Topic=="Nilai_tauI"){
tauI=Payload.toFloat();
}  if(Topic=="Nilai_tauD"){
tauD=Payload.toFloat()/6;
}  if(Topic=="SetPoint"){
sp=Payload.toFloat();
}
Serial.println("<------------------------->");
Serial.print("autoSet: ");
Serial.println(autoSet);
Serial.print("SetPoint: ");
Serial.println(sp);
Serial.print("Nilai_Kc: ");
Serial.println(Kc);
Serial.print("Nilai_tauI: ");  Serial.println(tauI);
Serial.print("Nilai_tauD: ");
Serial.println(tauD);
```

```
  .      ("<-------------------------->");
  (   , 1, 0,       );
.       ("Suhu1",      );

 (    , 1, 0,       );       .       ("Suhu2",      );
  (   , 1, 0,            );
.       ("Tampil_SP",           );
```

```
 ( , 1, 0, );
. ("Tampil_Kc", );
```

```
 dtostrf(tauI, 1, 0, Tampil_tauI);
 client.publish("Tampil_tauI",Tampil_tauI);

 dtostrf(tauD, 1, 0, Tampil_tauD);
 client.publish("Tampil_tauD",Tampil_tauD);
  if(autoSet==1){
sp = 35;
   Kc = 10.0; // K / %Heater
tauI = 50.0; // sec      tauD = 1.0;
// sec

 }else if(autoSet == 0){
  // bisa diubah2, sesuai yg muncul terakhir, dan setelah diubah2
 }     pv = cel;  // Temperature T1
dt = (new_ts - ts) / 1000.0;      ts =
new_ts;

   op = pid(sp,Kc,tauI,tauD,pv,pv_last,ierr,dt); // PID Process

   ledcWrite(Q1Channel,op);      pv_last =
pv;

   dtostrf(op, 1, 0, Nilai_op);
   client.publish("Nilai_op",Nilai_op);
 }
}
```

Kode di atas merupakan program untuk mengontrol suhu menggunakan PID (Proportional-Integral-Derivative) dengan bantuan ESP32 yang terhubung ke jaringan WiFi dan MQTT (Message Queuing Telemetry Transport) untuk komunikasi IoT.

1. Fungsi Utama

- Koneksi WiFi dan MQTT:
  - Program menghubungkan ESP32 ke jaringan WiFi menggunakan kredensial `ssid` dan `password`.
  - Menggunakan broker MQTT (`broker.hivemq.com`) pada port 1883 untuk komunikasi data.
  - Topik MQTT yang digunakan mencakup:
    - o `autoSet` untuk mengatur mode otomatis. o `SetPoint` untuk menetapkan suhu target.

- Nilai_Kc, Nilai_tauI, dan Nilai_tauD untuk parameter PID.

- Konfigurasi Pin dan PWM:
  - Pin tertentu (Q1, Q2, LED) dikonfigurasi untuk kontrol PWM (Pulse Width Modulation) dengan frekuensi 5000 Hz dan resolusi 8 bit.
  - Pin T1 dan T2 digunakan untuk membaca suhu dari sensor analog.
- Logika Kontrol Suhu:
  - Suhu diukur menggunakan fungsi `cektemp()` yang membaca nilai analog dari sensor suhu.
  - Jika suhu melebihi batas tertentu (`upper_temperature_limit`), pemanas (Q1 dan Q2) dimatikan, dan LED menyala sebagai indikator.
- Kontrol PID:
  - Fungsi `pid()` digunakan untuk menghitung nilai kontrol berdasarkan suhu target (SetPoint) dan suhu saat ini (Process Variable, `pv`).
  - Parameter PID (Kc, tauI, tauD) digunakan untuk menyesuaikan respons kontrol.
  - Nilai keluaran PID (`op`) menentukan intensitas pemanas melalui PWM.
- Komunikasi MQTT:
  - Callback MQTT (`receivedCallback`) memproses pesan masuk untuk memperbarui nilai `autoSet`, `SetPoint`, atau parameter PID.
  - Data suhu dan parameter kontrol dikirimkan kembali ke broker MQTT untuk pemantauan.
- Fungsi AutoSet:
  - Jika `autoSet` bernilai 1, program menggunakan parameter default:
    - SetPoint = 35
    - Kc = 10.0
    - tauI = 50.0
    - tauD = 1.0
  - Jika `autoSet` bernilai 0, parameter dapat diatur secara manual melalui MQTT.

2. Rincian Variabel

- PID Variables:
    - `sp` (SetPoint): Suhu target.
    - `pv` (Process Variable): Suhu saat ini. `Kc`, `tauI`, `tauD`: Parameter kontrol PID.
    - `op`: Output PID untuk mengontrol pemanas.
- Global Variables:
    - `cel`, `cel1`: Suhu yang dibaca dari sensor (dalam Celsius).
    - `ierr`: Kesalahan integral untuk kontrol PID.
    - `ts`, `new_ts`: Penanda waktu untuk menghitung durasi antara pengukuran.

Kegunaan

Program ini merupakan implementasi sistem kontrol suhu berbasis IoT yang fleksibel. Dengan kombinasi PID dan MQTT, pengguna dapat mengatur dan memantau sistem dari jarak jauh.

L. ITCLab-11

```
{
 "cells": [
  {
   "cell_type": "markdown",
   "id": "49922eca",
   "metadata": {},
   "source": [
    "# XOR Gate Programming using Deep Learning"
   ]
  },
  {
   "cell_type": "raw",
   "id": "6e239ded",
   "metadata": {},
   "source": [
    "By: IO-T.NET Team (https://io-t.net/itclab)"
   ]
  },
```

```
{
 "cell_type": "code",
 "execution_count": 1,
 "id": "4aeddbdf",
 "metadata": {},
 "outputs": [],
 "source": [
  "# Library yg dibutuhkan\n",
  "import numpy as np"
 ]
},
{
 "cell_type": "code",
 "execution_count": 2,
 "id": "312606b1",
 "metadata": {},
 "outputs": [],
 "source": [
  "# Pasangan data latih\n",
  "\n",
  "XOR_X = np.array([\n",
  "    [0, 0],\n",
  "    [0, 1],\n",
  "    [1, 0],\n",
  "    [1, 1]\n",
  "])\n",
```

[redacted]

[redacted]

```
    "### Arsitektur Deep Learning\n",
    "Arsitektur Deep Learning dengan Dua Masukan dan Satu Keluaran"
   ]
  },
  {
   "cell_type": "markdown",
   "id": "cf5a0863",
   "metadata": {},
   "source": [
    "![arsitektur_DL](Gerbang_XOR.jpg)"
   ]
  },
  {
   "cell_type": "code",
   "execution_count": 3,
   "id": "2b875363",
   "metadata": {},
   "outputs": [
    {
     "name": "stdout",
     "output_type": "stream",
     "text": [
      "WARNING:tensorflow:From
C:\\Users\\USER\\AppData\\Local\\Programs\\Python\\Python311\\Lib\\site-
packages\\keras\\src\\losses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecated. Please use
tf.compat.v1.losses.sparse_softmax_cross_entropy instead.\n",
      "\n",
      "WARNING:tensorflow:From
C:\\Users\\USER\\AppData\\Local\\Programs\\Python\\Python311\\Lib\\site-
packages\\keras\\src\\backend.py:873: The name tf.get_default_graph is deprecated. Please use
tf.compat.v1.get_default_graph instead.\n",
      "\n"
     ]
    }
   ],
   "source": [
    "# Impor `Sequential` dari` keras.models`\n",
    "from keras.models import Sequential\n",     "\n",
    "# Impor `Dense` dari` keras.layers`\n",
    "from keras.layers import Dense\n",
    "\n",
```

```
"# Inisialisasi konstruktor\n",
"model = Sequential()\n",
"\n",
"# Tambahkan lapisan masukan \n",
"model.add(Dense(2, activation='sigmoid', input_shape=(2,)))\n",
```

[redacted]

[redacted]

```
awal."    ]
  },
  {
   "cell_type": "code",
   "execution_count": 4,
   "id": "c72c87b8",
   "metadata": {},
   "outputs": [
    {
     "name": "stdout",
     "output_type": "stream",
     "text": [
      "Model: \"sequential\"\n",
      "_________________________________________________________________\n",
      " Layer (type)                Output Shape              Param #   \n",
      "=================================================================\n",
      " dense (Dense)               (None, 2)                 6         \n",
      "                                                                 \n",
      " dense_1 (Dense)             (None, 2)                 6         \n",
      "                                                                 \n",
      " dense_2 (Dense)             (None, 1)                 3         \n",
      "                                                                 \n",
      "=================================================================\n",
      "Total params: 15 (60.00 Byte)\n",
      "Trainable params: 15 (60.00 Byte)\n",
      "Non-trainable params: 0 (0.00 Byte)\n",
      "_________________________________________________________________\n"
     ]
    },
    {
     "data": {
      "text/plain": [
       "[array([[ 0.88105714,  1.120653  ],\n",
       "        [-1.0473598 ,  0.37149537]], dtype=float32),\n",
       " array([0., 0.], dtype=float32),\n",
       " array([[ 0.55942726, -0.02052712],\n",
       "        [-1.1376439 ,  0.07940733]], dtype=float32),\n",
       " array([0., 0.], dtype=float32),\n",
       " array([[ 0.2318461 ],\n",
       "        [-0.25704885]], dtype=float32),\n",
```

```
    " array([0.], dtype=float32)]"
   ]
  },
  "execution_count": 4,
  "metadata": {},
  "output_type": "execute_result"
```

```
   ]
  },
  {
   "cell_type": "markdown",
   "id": "57d2a1b5",
   "metadata": {},
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C:\\Users\\USER\\AppData\\Local\\Programs\\Python\\Python311\\Lib\\sitepackages\\keras\\src\\optimizers\\__init__.p
y:309: The name tf.train.Optimizer is deprecated.
Please use tf.compat.v1.train.Optimizer instead.\n",
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C:\\Users\\USER\\AppData\\Local\\Programs\\Python\\Python311\\Lib\\sitepackages\\keras\\src\\utils\\tf_utils.py:492:
The name tf.ragged.RaggedTensorValue is deprecated.
Please use tf.compat.v1.ragged.RaggedTensorValue instead.\n",
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C:\\Users\\USER\\AppData\\Local\\Programs\\Python\\Python311\\Lib\\sitepackages\\keras\\src\\engine\\base_layer_uti
ls.py:384: The name tf.executing_eagerly_outside_functions is deprecated. Please use
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    "4/4 [==============================] - 0s 1ms/step - loss: 0.6934 - accuracy: 0.5000\n",      "Epoch 191/1000\n",
0s 0s/step - loss: 0.6933 - accuracy: 0.5000\n",
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    "4/4 [==============================] -
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"4/4 [==============================] - 0s 3ms/step -  - accuracy: 0.5000\n",
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"4/4 [==============================] -  \n",
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 \n",
"4/4 [==============================] -  -  -  \n",
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"4/4 [==============================] - 0s 3ms/step -                                   - accuracy: 0.5000\n",
                          \n",
"4/4 [==============================] -                                                               \n",
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"Epoch 198/1000\n",
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"Epoch 216/1000\n",
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                                                0s 3ms/step - loss: 0.6934 - accuracy: 0.5000
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"4/4 [==============================] -                  -              -                  \n",
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"4/4 [==============================] - 0s 3ms/step -                     - accuracy: 0.5000\n",
                  \n",
"4/4 [==============================] -                                             \n",
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                  \n",
"4/4 [==============================] -               -             -              \n",
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"4/4 [==============================] - os 3ms/step -                                   - accuracy: 0.5000\n",
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"4/4 [==============================] -                                                                \n",
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"4/4 [==============================] - os 3ms/step - loss: 0.6933 - accuracy: 0.5000\n",
"Epoch 250/1000\n",
"4/4 [==============================] - os 3ms/step - loss: 0.6933 - accuracy: 0.5000\n",    "Epoch 251/1000\n",
                                                  os os/step - loss: 0.6934 - accuracy: 0.5000
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                              \n",
"4/4 [==============================] -                    -                -                 \n",
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"4/4 [==============================] - 0s 3ms/step -                    - accuracy: 0.5000\n",
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"4/4 [==============================] -                                                       \n",
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                  \n",
"4/4 [==============================] -              -            -            \n",
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"4/4 [==============================] - 0s 3ms/step -                                   - accuracy: 0.5000\n",
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"4/4 [==============================] -                                                                    \n",
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"4/4 [==============================] -                     -                -                  \n",
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"4/4 [==============================] - 0s 3ms/step -                          - accuracy: 0.5000\n",
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"4/4 [==============================] -                                                  \n",
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                   \n",
"4/4 [==============================] -                   -              -                 \n",
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                                \n",
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                                \n",
    "4/4 [==============================] -                  -               -                   \n",
                                \n",
    "4/4 [==============================] -                  -               -                   \n",
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    "4/4 [==============================] -                                                      \n",
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    "Epoch 293/1000\n",
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    "4/4 [==============================] -                  -                  - accuracy: 0.2500\n",
                                \n",
    "4/4 [==============================] -                  -                  - accuracy: 0.2500\n",
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    "4/4 [==============================] -                  -                  - accuracy: 0.2500\n",
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    "4/4 [==============================] -                  -                  - accuracy: 0.2500\n",
                                \n",
    "4/4 [==============================] -                  -                  - accuracy: 0.2500\n",
                                \n",
```

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"4/4 [==============================] - 0s 3ms/step -                    - accuracy: 0.2500\n",
              \n",
"4/4 [==============================] -               -             - accuracy: 0.2500\n",
              \n",
"4/4 [==============================] -                                          \n",
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              \n",
"4/4 [==============================] -               -           -             \n",
```

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"4/4 [==============================] - 0s 3ms/step -                    - accuracy: 0.2500\n",
                \n",
"4/4 [==============================] -              -             - accuracy: 0.2500\n",
                \n",
"4/4 [==============================] -                                        \n",
```

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"Epoch 325/1000\n",
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"Epoch 326/1000\n",
"4/4 [==============================] - 0s 1ms/step - loss: 0.6933 - accuracy: 0.2500\n",     "Epoch 327/1000\n",
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                                                0s 2ms/step - loss: 0.6933 - accuracy: 0.2500
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                \n",
"4/4 [==============================] -              -           -               \n",
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"4/4 [==============================] - 0s 3ms/step -                              - accuracy: 0.2500\n",
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"4/4 [==============================] -                      -                     - accuracy: 0.2500\n",
                         \n",
"4/4 [==============================] -                                                       \n",
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                         \n",
"4/4 [==============================] -                      -            -                 \n",
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"4/4 [==============================] - 0s 3ms/step -                    - accuracy: 0.2500\n",
              \n",
"4/4 [==============================] -               -                 - accuracy: 0.2500\n",
              \n",
"4/4 [==============================] -                                                    \n",
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              \n",
"4/4 [==============================] -               -            -                       \n",
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"4/4 [==============================] -                    -                  - accuracy: 0.2500\n",
                   \n",
"4/4 [==============================] -                    -                  - accuracy: 0.2500\n",
                   \n",
"4/4 [==============================] -                                                     \n",
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                   \n",
"4/4 [==============================] -                    -               -                \n",
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"4/4 [==============================] -                                -                              - accuracy: 0.2500\n",
                                \n",
"4/4 [==============================] -                                -                              - accuracy: 0.2500\n",
                                \n",
"4/4 [==============================] -                                                                                  \n",
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```
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"4/4 [==============================] - 0s 3ms/step -                          - accuracy: 0.5000\n",
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```
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    "4/4 [==============================] -               -               -08 - accuracy:
1.0000\n",
                    \n",
    "4/4 [==============================] -               -               -08 - accuracy:
1.0000\n",
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```

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```

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```

```
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```
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   "from sklearn.metrics import mean_squared_error\n",
   "from math import sqrt\n",
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   "rmse2 = sqrt(mean_squared_error(XOR_Y, Hasil_Prediksi_Keras))\n",
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   "print('RMSE =',rmse2)"
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```

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M. ITCLab-12

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    "pengendali PID menggunakan Deep Learning"    ]
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  "    [1.2, 0.1],\n",
```

```
  "    [1, 0.1]\n",
  "])\n",
  "\n",
  "# Label untuk Data Latih.\n",
  "y = np.array([\n",
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  "    [0.2, 4.1, 0.1],\n",
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  "model = Sequential()\n",
  "\n",
  "# Tambahkan lapisan masukan \n",
  "model.add(Dense(2, activation='sigmoid', input_shape=(2,)))\n",      "\n",
  "# Tambahkan satu lapisan tersembunyi\n",
  "model.add(Dense(3, activation='sigmoid'))\n",
  "\n",
  "# Tambahkan lapisan keluaran\n",
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    "                                                                 \n",
    " dense_4 (Dense)             (None, 3)                 9         \n",
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    " dense_5 (Dense)             (None, 3)                 12        \n",
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     "        [-0.9043672 ,  0.6550486 , -0.40327096],\n",
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```

```
   "\n",
   "# Ringkasan model\n",
   "model.summary()\n",
   "\n",
   "# Konfigurasi model\n",
   "model.get_config()\n",
   "\n",
   "# Buat daftar semua tensor bobot \n",
   "model.get_weights()"
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     " [0.24446805 0.8346314  0.18357222]\n",
     " [0.24636793 0.83322346 0.18463148]]\n"
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[redacted]

[redacted]

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 },
```

```
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```
"#plt.xlabel('Kc, tauI, tauD');\n",
"#plt.legend((result_Kc, result_tauI, result_tauD), ('Kc', 'tauI', 'tauD'))\n",     "\n",
"plt.legend(loc='upper left')\n",
"#pylab.ylim(-1.5, 2.0)\n",
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   "tf = 50.0 # final time\n",
   "SP_start = 2.0 # time of set point change\n",
   "\n",
   "def process(y,t,u):\n",
   "    Kp = 4.0\n",
```

[redacted]

[redacted]

```
    "\n",
    "def pidPlot(Kc,tauI,tauD):\n",
    "    t = np.linspace(0,tf,n) # create time vector\n",
    "    P= np.zeros(n)          # initialize proportional term\n",
    "    I = np.zeros(n)         # initialize integral term\n",
    "    D = np.zeros(n)         # initialize derivative term\n",
    "    e = np.zeros(n)         # initialize error\n",
    "    OP = np.zeros(n)        # initialize controller output\n",
    "    PV = np.zeros(n)        # initialize process variable\n",
    "    SP = np.zeros(n)        # initialize setpoint\n",
    "    SP_step = int(SP_start/(tf/(n-1))+1) # setpoint start\n",
    "    SP[0:SP_step] = 0.0     # define setpoint\n",
    "    SP[SP_step:n] = 4.0     # step up\n",
    "    y0 = 0.0                # initial condition\n",
    "    # loop through all time steps\n",
    "    for i in range(1,n):\n",
    "        # simulate process for one time step\n",
    "        ts = [t[i-1],t[i]]         # time interval\n",
    "        y = odeint(process,y0,ts,args=(OP[i-1],))  # compute next step\n",
    "        y0 = y[1]                  # record new initial condition\n",
    "        # calculate new OP with PID\n",
    "        PV[i] = y[1]               # record PV\n",
    "        e[i] = SP[i] - PV[i]       # calculate error = SP - PV\n",
    "        dt = t[i] - t[i-1]         # calculate time step\n",
    "        P[i] = Kc * e[i]           # calculate proportional term\n",
    "        I[i] = I[i-1] + (Kc/tauI) * e[i] * dt  # calculate integral term\n",
    "        D[i] = -Kc * tauD * (PV[i]-PV[i-1])/dt # calculate derivative term\n",
    "        OP[i] = P[i] + I[i] + D[i] # calculate new controller output\n",     "        \n",
    "    # plot PID response\n",
    "    plt.figure(1,figsize=(15,7))\n",
    "    plt.subplot(2,2,1)\n",
    "    plt.plot(t,SP,'k-',linewidth=2,label='Setpoint (SP)')\n",
    "    plt.plot(t,PV,'r:',linewidth=2,label='Process Variable (PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,2)\n",
    "    plt.plot(t,P,'g.-',linewidth=2,label=r'Proportional = $K_c \\; e(t)$')\n",
    "    plt.plot(t,I,'b-',linewidth=2,label=r'Integral = $\\frac{K_c}{\\tau_I} \\int_{i=0}^{n_t} e(t) \\; dt $')\n",
    "    plt.plot(t,D,'r--',linewidth=2,label=r'Derivative = $-K_c \\tau_D \\frac{d(PV)}{dt}$')
\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,3)\n",
    "    plt.plot(t,e,'m--',linewidth=2,label='Error (e=SP-PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,4)\n",
    "    plt.plot(t,OP,'b--',linewidth=2,label='Controller Output (OP)')\n",
    "    plt.legend(loc='best')\n",
```

```
"    plt.xlabel('time')\n",
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"Kc_slide = result_Kc\n",
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   "SP_start = 2.0 # time of set point change\n",
   "\n",
   "def process(y,t,u):\n",
   "    Kp = 4.0\n",
   "    taup = 3.0\n",
   "    thetap = 1.0\n",
   "    if t<(thetap+SP_start):\n",
   "        dydt = 0.0  # time delay\n",
   "    else:\n",
   "        dydt = (1.0/taup) * (-y + Kp * u)\n",
   "    return dydt\n",
   "\n",
   "def pidPlot(Kc,tauI,tauD):\n",
   "    t = np.linspace(0,tf,n) # create time vector\n",
   "    P= np.zeros(n)          # initialize proportional term\n",
   "    I = np.zeros(n)         # initialize integral term\n",
   "    D = np.zeros(n)         # initialize derivative term\n",
   "    e = np.zeros(n)         # initialize error\n",
   "    OP = np.zeros(n)        # initialize controller output\n",
   "    PV = np.zeros(n)        # initialize process variable\n",
   "    SP = np.zeros(n)        # initialize setpoint\n",
   "    SP_step = int(SP_start/(tf/(n-1))+1) # setpoint start\n",
   "    SP[0:SP_step] = 0.0     # define setpoint\n",
   "    SP[SP_step:n] = 4.0     # step up\n",
   "    y0 = 0.0                # initial condition\n",
   "    # loop through all time steps\n",
   "    for i in range(1,n):\n",
   "        # simulate process for one time step\n",
   "        ts = [t[i-1],t[i]]         # time interval\n",
   "        y = odeint(process,y0,ts,args=(OP[i-1],))  # compute next step\n",
   "        y0 = y[1]                  # record new initial condition\n",
   "        # calculate new OP with PID\n",
   "        PV[i] = y[1]               # record PV\n",
   "        e[i] = SP[i] - PV[i]       # calculate error = SP - PV\n",
   "        dt = t[i] - t[i-1]         # calculate time step\n",
   "        P[i] = Kc * e[i]           # calculate proportional term\n",
   "        I[i] = I[i-1] + (Kc/tauI) * e[i] * dt  # calculate integral term\n",
```

```
"        D[i] = -Kc * tauD * (PV[i]-PV[i-1])/dt # calculate derivative term\n",
"        OP[i] = P[i] + I[i] + D[i] # calculate new controller output\n",     "        \n",
"    # plot PID response\n",
"    plt.figure(1,figsize=(15,7))\n",
"    plt.subplot(2,2,1)\n",
"    plt.plot(t,SP,'k-',linewidth=2,label='Setpoint (SP)')\n",
"    plt.plot(t,PV,'r:',linewidth=2,label='Process Variable (PV)')\n",
```

```
    "    plt.plot(t,I,'b-',linewidth=2,label=r'Integral = $\\frac{K_c}{\\tau_I} \\int_{i=0}^{n_t} e(t) \\; dt $')\n",
    "    plt.plot(t,D,'r--',linewidth=2,label=r'Derivative = $-K_c \\tau_D \\frac{d(PV)}{dt}$')
\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,3)\n",
    "    plt.plot(t,e,'m--',linewidth=2,label='Error (e=SP-PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,4)\n",
    "    plt.plot(t,OP,'b--',linewidth=2,label='Controller Output (OP)')\n",
    "    plt.legend(loc='best')\n",
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"plt.plot(result_tauD, 'bo', label='tauD')\n",
"\n",
"#plt.xlabel('Kc, tauI, tauD');\n",
"#plt.legend((result_Kc, result_tauI, result_tauD), ('Kc', 'tauI', 'tauD'))\n", "\n",
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  "n = 100 # time points to plot\n",
  "tf = 50.0 # final time\n",
  "SP_start = 2.0 # time of set point change\n",
  "\n",
  "def process(y,t,u):\n",
  "    Kp = 4.0\n",
  "    taup = 3.0\n",
  "    thetap = 1.0\n",
  "    if t<(thetap+SP_start):\n",
  "        dydt = 0.0  # time delay\n",
  "    else:\n",
  "        dydt = (1.0/taup) * (-y + Kp * u)\n",
```

```
"    return dydt\n",
"\n",
"def pidPlot(Kc,tauI,tauD):\n",
"    t = np.linspace(0,tf,n) # create time vector\n",
"    P= np.zeros(n)          # initialize proportional term\n",
"    I = np.zeros(n)         # initialize integral term\n",
"    D = np.zeros(n)         # initialize derivative term\n",
"    e = np.zeros(n)         # initialize error\n",
"    OP = np.zeros(n)        # initialize controller output\n",
"    PV = np.zeros(n)        # initialize process variable\n",
"    SP = np.zeros(n)        # initialize setpoint\n",
"    SP_step = int(SP_start/(tf/(n-1))+1) # setpoint start\n",
```

```
    "        y = odeint(process,y0,ts,args=(OP[i-1],))  # compute next step\n",
    "        y0 = y[1]                  # record new initial condition\n",
    "        # calculate new OP with PID\n",
    "        PV[i] = y[1]               # record PV\n",
    "        e[i] = SP[i] - PV[i]       # calculate error = SP - PV\n",
    "        dt = t[i] - t[i-1]         # calculate time step\n",
    "        P[i] = Kc * e[i]           # calculate proportional term\n",
    "        I[i] = I[i-1] + (Kc/tauI) * e[i] * dt  # calculate integral term\n",
    "        D[i] = -Kc * tauD * (PV[i]-PV[i-1])/dt # calculate derivative term\n",
    "        OP[i] = P[i] + I[i] + D[i] # calculate new controller output\n",     "        \n",
    "    # plot PID response\n",
    "    plt.figure(1,figsize=(15,7))\n",
    "    plt.subplot(2,2,1)\n",
    "    plt.plot(t,SP,'k-',linewidth=2,label='Setpoint (SP)')\n",
    "    plt.plot(t,PV,'r:',linewidth=2,label='Process Variable (PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,2)\n",
    "    plt.plot(t,P,'g.-',linewidth=2,label=r'Proportional = $K_c \\; e(t)$')\n",
    "    plt.plot(t,I,'b-',linewidth=2,label=r'Integral = $\\frac{K_c}{\\tau_I} \\int_{i=0}^{n_t} e(t) \\; dt $')\n",
    "    plt.plot(t,D,'r--',linewidth=2,label=r'Derivative = $-K_c \\tau_D \\frac{d(PV)}{dt}$')
\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,3)\n",
    "    plt.plot(t,e,'m--',linewidth=2,label='Error (e=SP-PV)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.subplot(2,2,4)\n",
    "    plt.plot(t,OP,'b--',linewidth=2,label='Controller Output (OP)')\n",
    "    plt.legend(loc='best')\n",
    "    plt.xlabel('time')\n",
    "    \n",
    "Kc_slide = result_Kc\n",
    "tauI_slide = result_tauI\n",
    "tauD_slide = result_tauD\n",
    "wg.interact(pidPlot, Kc=Kc_slide, tauI=tauI_slide, tauD=tauD_slide)"
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N. ITCLab-13

Di ITCLab ke-13 ada tiga kode yaitu, kode Arduino, Python, dan Notebook Jupyter.

```
#include <Arduino.h>

// constants
const String vers = "1.04";  // version of this firmware const
int baud = 115200;    // serial baud rate const char sp = ' ';
// command separator const char nl = '\n';     // command
terminator

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1  = 34;     // T1 const int pinT2  = 35;     // T2
const int pinQ1  = 32;     // Q1 const int pinQ2  = 33;     // Q2
const int pinLED  = 26;     // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

const double batas_suhu_atas = 59;

// global variables
char Buffer[64];        // buffer for parsing serial input String
cmd;            // command  double pv = 0;          // pin value float
level;            // LED level (0-100%) double Q1 = 0;          // value
written to Q1 pin double Q2 = 0;          // value written to Q2 pin
int iwrite = 0;         // integer value for writing float dwrite = 0;
// float value for writing
int n = 10;           // number of samples for each temperature measurement

void parseSerial(void) {
 int ByteCount = Serial.readBytesUntil(nl,Buffer,sizeof(Buffer));  String
read_ = String(Buffer);  memset(Buffer,0,sizeof(Buffer));

 // separate command from associated data
int idx = read_.indexOf(sp);  cmd =
read_.substring(0,idx);
```

```
 cmd.trim();  cmd.toUpperCase();

 // extract data. toInt() returns 0 on error   String
data = read_.substring(idx+1);  data.trim();
 pv = data.toFloat();
}

// Q1_max = 100%
// Q2_max = 100%
 void dispatchCommand(void) {
if (cmd == "Q1") {
   Q1 = max(0.0, min(25.0, pv));    iwrite =
int(Q1 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
   ledcWrite(Q1Channel,iwrite);
   Serial.println(Q1);
  }
  else if (cmd == "Q2") {
   Q2 = max(0.0, min(25.0, pv));    iwrite =
int(Q2 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
ledcWrite(Q2Channel,iwrite);
   Serial.println(Q2);
  }  else if (cmd == "T1") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT1) * 0.322265625;       degC = degC
+ mV/10.0;
   }
   degC = degC / float(n);

   Serial.println(degC);
  }  else if (cmd == "T2") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT2) * 0.322265625;       degC = degC
+ mV/10.0;
   }    degC = degC / float(n);
   Serial.println(degC);
  }
  else if ((cmd == "V") or (cmd == "VER")) {
   Serial.println("TCLab Firmware Version " + vers);
  }
  else if (cmd == "LED") {
   level = max(0.0, min(100.0, pv));    iwrite =
int(level * 0.5);
   iwrite = max(0, min(50, iwrite));       ledcWrite(ledChannel, iwrite);
   Serial.println(level);
  }
  else if (cmd == "X") {    ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
```

```
   Serial.println("Stop");
  }
}
// check temperature and shut-off heaters if above high limit void
checkTemp(void) {
  float mV = (float) analogRead(pinT1) * 0.322265625;
  //float degC = (mV - 500.0)/10.0;    float
degC = mV/10.0;
  if (degC >= batas_suhu_atas) {
    Q1 = 0.0;      Q2 =
0.0;
    ledcWrite(Q1Channel,0);     ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 1 (> batas_suhu_atas): ");
    Serial.println(degC);
   }
  mV = (float) analogRead(pinT2) * 0.322265625;
  //degC = (mV - 500.0)/10.0;    degC
= mV/10.0;
  if (degC >= batas_suhu_atas) {
    Q1 = 0.0;      Q2 =
0.0;
    ledcWrite(Q1Channel,0);     ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 2 (> batas_suhu_atas): ");
    Serial.println(degC);
   }
}

// arduino startup void
setup() {
 //analogReference(EXTERNAL);
 Serial.begin(baud);  while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled   ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled   ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled   ledcAttachPin(pinLED,
ledChannel);
```

```
 ledcWrite(Q1Channel,0);  ledcWrite(Q2Channel,0);
}

// arduino main event loop
```

```
void loop() {  parseSerial();  dispatchCommand();
 checkTemp();
}
```

Kode ini adalah firmware untuk sebuah mikrokontroler berbasis Arduino. Firmware ini mengontrol perangkat keras yang tampaknya memiliki fungsi pemanas, pembaca suhu, dan LED. Berikut adalah penjelasan terperinci dari berbagai bagian kode:

1. **Konstanta dan Pin Setup**
    - Konstanta
        - `vers`: Versi firmware (`1.04`).
        - `baud`: Baud rate untuk komunikasi serial (`115200`).
        - `sp`: Separator untuk perintah serial (`spasi`).
        - `nl`: Terminator untuk perintah serial (`\n`).
    - Pin Setup
        - Pin Sensor Suhu (T1, T2): `pinT1` (34) dan `pinT2` (35).
        - Pin Output (Q1, Q2): `pinQ1` (32) dan `pinQ2` (33).
        - Pin LED: `pinLED` (26).
    - PWM Properties
        - Frekuensi PWM ditetapkan ke 5000 Hz.
        - Resolusi PWM untuk semua kanal adalah 8 bit (nilai maksimum 255).

2. **Variabel Global**
    - `Buffer`: Buffer untuk menyimpan data input serial.
    - `cmd`: Perintah yang diterima melalui serial.
    - `pv`: Nilai dari perintah serial (dalam bentuk angka).
    - `level`: Tingkat intensitas LED (0-100%).
    - `Q1`, `Q2`: Nilai output ke pin Q1 dan Q2 (maksimum 25).
    - `n`: Jumlah sampel untuk pengukuran suhu.

3. **Fungsi Utama**
    `parseSerial()`
    - Membaca data dari serial hingga karakter terminator (`nl`).
    - Memisahkan perintah (`cmd`) dan data nilai (`pv`) menggunakan pemisah (`sp`).
    - Data nilai dikonversi menjadi float.

`dispatchCommand()`

Menginterpretasikan perintah dan menjalankan fungsi terkait:

- `Q1`, `Q2`: Mengontrol output PWM untuk pin Q1 dan Q2 dengan nilai maksimum 25.
- `T1`, `T2`: Membaca nilai suhu dari sensor (T1 atau T2), mengonversinya ke derajat Celsius.
- `V` atau `VER`: Menampilkan versi firmware.
- `LED`: Mengontrol intensitas LED (0-100%).
- `X`: Menghentikan semua aktivitas (set Q1 dan Q2 ke nol).

`checkTemp()`

- Membaca suhu dari sensor T1 dan T2.
- Jika suhu melebihi batas (`batas_suhu_atas = 59` derajat Celsius), mematikan pemanas dengan mengatur Q1 dan Q2 ke nol.

4. Fungsi `setup()`

- Menginisialisasi komunikasi serial pada baud rate 115200.
- Menyiapkan fungsi PWM untuk pin Q1, Q2, dan LED.
- Mengatur semua output PWM awal ke 0.

5. Fungsi `loop()`

- Menjalankan tiga fungsi utama secara berulang:
  - `parseSerial()`: Membaca dan memproses perintah serial.
  - `dispatchCommand()`: Mengeksekusi perintah.
  - `checkTemp()`: Memeriksa suhu untuk perlindungan perangkat.

```
import sys import
time import numpy
as np try:    import
serial except:
   import pip
   pip.main(['install','pyserial'])    import serial
from serial.tools import list_ports
      class
iTCLab(object):
    def __init__(self, port=None, baud=115200):
       port = self.findPort()        print('Opening
connection')
       self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()        self.sp.flushOutput()        time.sleep(3)
       print('iTCLab connected via Arduino on port ' + port)
           def findPort(self):        found = False        for port
in list(list_ports.comports()):
         # Arduino Uno          if port[2].startswith('USB
VID:PID=16D0:0613'):
```

```
            port = port[0]               found = True          # Arduino HDuino
if port[2].startswith('USB VID:PID=1A86:7523'):              port =
port[0]
            found = True
         # Arduino Leonardo          if port[2].startswith('USB
VID:PID=2341:8036'):               port = port[0]              found = True
# Arduino ESP32         if port[2].startswith('USB
VID:PID=10C4:EA60'):               port = port[0]              found = True
         # Arduino ESP32 - Tipe yg berbeda        if
port[2].startswith('USB VID:PID=1A86:55D4'):              port = port[0]
found = True        if (not found):
         print('Arduino COM port not found')
         print('Please ensure that the USB cable is connected')           print('---
Printing Serial Ports ---')                    for port in
list(serial.tools.list_ports.comports()):              print(port[0] + ' ' + port[1] + '
' + port[2])           print('For Windows:')
         print('  Open device manager, select "Ports (COM & LPT)"')           print('  Look for
COM port of Arduino such as COM4')           print('For MacOS:')
         print('  Open terminal and type: ls /dev/*.')
         print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')            print('For Linux')
         print('  Open terminal and type: ls /dev/tty*')
         print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')           print('')
         port = input('Input port: ')
         # or hard-code it here
         #port = 'COM3' # for Windows
         #port = '/dev/tty.wchusbserial1410' # for MacOS     return
port
      def stop(self):
      return self.read('X')
      def version(self):
      return self.read('VER')

   @property   def
T1(self):
      self._T1 = float(self.read('T1'))       return self._T1

   @property   def T2(self):       self._T2 =
float(self.read('T2'))       return self._T2
         def
LED(self,pwm):
      pwm = max(0.0,min(100.0,pwm))/2.0
      self.write('LED',pwm)       return
pwm
```

```
def Q1(self,pwm):         pwm =
max(0.0,min(100.0,pwm))
      self.write('Q1',pwm)        return
pwm
         def Q2(self,pwm):         pwm =
max(0.0,min(100.0,pwm))
      self.write('Q2',pwm)        return
pwm

  # save txt file with data and set point
  # t = time
  # u1,u2 = heaters
  # y1,y2 = tempeatures   # sp1,sp2 = setpoints   def
save_txt(self,t,u1,u2,y1,y2,sp1,sp2):         data =
np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack        data = data.T
# transpose data        top = 'Time (sec), Heater 1 (%), Heater 2 (%), ' \           +
'Temperature 1 (degC), Temperature 2 (degC), ' \           + 'Set Point 1 (degC), Set Point
2 (degC)'
      np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
   def read(self,cmd):         cmd_str =
self.build_cmd_str(cmd,'')         try:
self.sp.write(cmd_str.encode())
self.sp.flush()         except Exception:            return
None
      return self.sp.readline().decode('UTF-8').replace("\r\n", "")
       def write(self,cmd,pwm):               cmd_str =
self.build_cmd_str(cmd,(pwm,))         try:
self.sp.write(cmd_str.encode())            self.sp.flush()
except:            return None
      return self.sp.readline().decode('UTF-8').replace("\r\n", "")
       def build_cmd_str(self,cmd, args=None):
      """
      Build a command string that can be sent to the arduino.

      Input:            cmd (str): the command to send to the arduino, must not
contain a % character
         args (iterable): the arguments to send to the command
      """        if
args:
         args = ' '.join(map(str, args))        else:
args = ''
      return "{cmd} {args}\n".format(cmd=cmd, args=args)
         def close(self):
      try:
         self.sp.close()
         print('Arduino disconnected successfully')        except:
```

```
        print('Problems disconnecting from Arduino.')
print('Please unplug and reconnect Arduino.')        return True
```

Kode ini adalah sebuah Python script yang digunakan untuk mengontrol perangkat Arduino melalui komunikasi serial. Perangkat Arduino yang dikontrol kemungkinan terhubung ke sistem fisik seperti laboratorium miniatur yang mengukur suhu, mengontrol pemanas, atau menjalankan LED, seperti pada eksperimen kontrol. Berikut adalah penjelasan detail dari setiap bagian kode:

1. Import dan Setup Library

```
import sys import
time import numpy
as np try:
   import serial except:
   import pip
   pip.main(['install','pyserial'])    import serial
from serial.tools import list_ports
```

- `serial`: Library untuk komunikasi serial.
- `list_ports`: Digunakan untuk mendeteksi port yang tersedia untuk perangkat yang terhubung.
- `time`: Digunakan untuk memberikan jeda waktu.
- `numpy`: Digunakan untuk memproses data numerik, seperti mengatur data dalam array dan menyimpannya ke file.
- `try-except`: Memastikan bahwa jika library serial tidak terinstal, akan diinstal secara otomatis menggunakan pip.

2. Kelas iTCLab

Kelas utama ini bertanggung jawab untuk mengontrol perangkat yang terhubung ke Arduino.

2.1. Konstruktor `__init__`

```
def __init__(self,        port=None, baud=115200):
```

- `port`: Port komunikasi serial. Jika tidak diberikan, akan dicari otomatis.
- `baud`: Baud rate untuk komunikasi (default: 115200).
- Membuka koneksi ke Arduino, menunggu selama 3 detik agar komunikasi siap, dan memberikan pesan sukses.

2.2. Metode `findPort`

```
def findPort(self):
```

- Mencari port yang sesuai dengan perangkat Arduino berdasarkan VID:PID (Vendor ID dan Product ID).
- Mendukung berbagai tipe Arduino seperti Uno, HDuino, Leonardo, dan ESP32.
- Jika port tidak ditemukan, memberikan panduan untuk menemukannya di berbagai sistem operasi (Windows, macOS, Linux).
-

2.3. Properti dan Fungsi Kontrol

- Properti `T1` dan `T2`: Mengembalikan suhu dari sensor 1 dan sensor 2.

```
@property   def T1(self):       self._T1 =
float(self.read('T1'))       return self._T1
```

- Fungsi `LED`, `Q1`, `Q2`: Mengontrol perangkat keras seperti LED dan pemanas (Heater 1 & Heater 2) dengan nilai PWM (0-100%).

```
def Q1(self,pwm):
    pwm = max(0.0,min(100.0,pwm))
    self.write('Q1',pwm)       return
pwm
```

2.4. Fungsi `save_txt`

```
def save_txt(self,t,u1,u2,y1,y2,sp1,sp2):
```

- Menyimpan data eksperimen ke file teks (`data.txt`).
- `t`: Waktu.
- `u1`, `u2`: Input ke pemanas.
- `y1`, `y2`: Suhu dari sensor.
- `sp1`, `sp2`: Set point (nilai target suhu).

2.5. Komunikasi Serial

- Fungsi `read`: Mengirim perintah ke Arduino dan membaca respon.

```
def read(self,cmd):       cmd_str =
self.build_cmd_str(cmd,'')       try:
        self.sp.write(cmd_str.encode())
self.sp.flush()       except Exception:
return None
    return self.sp.readline().decode('UTF-8').replace("\r\n", "")
```

- Fungsi `write`: Mengirim perintah dengan argumen (misalnya nilai PWM).

```
def write(self,cmd,pwm):            cmd_str =
self.build_cmd_str(cmd,(pwm,))      try:
        self.sp.write(cmd_str.encode())
self.sp.flush()      except:
        return None
     return self.sp.readline().decode('UTF-8').replace("\r\n", "")
```

- Fungsi `build_cmd_str`: Membuat string perintah dengan format tertentu untuk dikirim ke Arduino.

2.6. Fungsi Tambahan

- `version`: Mengembalikan versi firmware dari Arduino.
- `stop`: Menghentikan semua aktivitas.
- `close`: Menutup koneksi serial dengan Arduino.

```
import itclab import
numpy as np import time
import matplotlib.pyplot as plt from
scipy.integrate import odeint import random
# Machine Learning - Building Datasets and Model
# Impor `Sequential` dari` keras.models` from
keras.models import Sequential

# Impor `Dense` dari` keras.layers` from
keras.layers import Dense

# Inisialisasi konstruktor model =
Sequential()

# Tambahkan lapisan masukan
model.add(Dense(2, activation='sigmoid', input_shape=(2,)))
# Tambahkan satu lapisan tersembunyi model.add(Dense(3,
activation='sigmoid'))

# Tambahkan lapisan keluaran
model.add(Dense(3, activation='sigmoid'))

# Data Latih.
X = np.array([
    [1, 1],
    [0.4, 1.2],
    [1.2, 0.1],
    [1, 0.1]
])

# Label untuk Data Latih. y =
np.array([
    [0.25, 4.31, 0.20],
    [0.2, 4.1, 0.1],
    [0.1, 4.0, 0],
    [0.1, 4.0, 0]
])

# Bentuk keluaran model model.output_shape

# Ringkasan model model.summary()

# Konfigurasi model model.get_config()

# Buat daftar semua tensor bobot  model.get_weights()
model.compile(loss='binary_crossentropy',              optimizer='adam',
```

[redacted]

[redacted]

```
# PID Controller                                    #
###################################################
# inputs ---------------------------------
# sp = setpoint
# pv = current temperature
# pv_last = prior temperature
# ierr = integral error
# dt = time increment between measurements
# outputs --------------------------------
# op = output of the PID controller
# P = proportional contribution
# I = integral contribution # D =
derivative contribution def
pid(sp,pv,pv_last,ierr,dt):     Kc   = 10.0
# K/%Heater     tauI = 50.0 # sec
tauD = 1.0  # sec
    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)     op0 = 0
    # upper and lower bounds on heater level     ophi =
100     oplo = 0
    # calculate the error     error = sp-pv
    # calculate the integral error     ierr = ierr + KI *
error * dt
    # calculate the measurement derivative     dpv = (pv
- pv_last) / dt     # calculate the PID output
    P = KP * error
    I = ierr     D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup     if op
< oplo or op > ophi:        I = I - KI * error *
dt
        # clip output
```

[redacted]

[redacted]

```
    # calculate the error      error =
sp-pv      d_error = sp-pv_last
    delta_error = (error - d_error)

    outDL = model.predict(np.array([[error,delta_error]]))
    Kc = outDL[0,0]      tauI =
outDL[0,1]      tauD =
outDL[0,2]

    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)      op0 = 0
    # upper and lower bounds on heater level      ophi =
100      oplo = 0

    # calculate the integral error      ierr = ierr + KI *
error * dt
    # calculate the measurement derivative      dpv = (pv
- pv_last) / dt      # calculate the PID output
    P = KP * error
    I = ierr      D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup      if op
< oplo or op > ophi:         I = I - KI * error *
dt
        # clip output
        op = max(oplo,min(ophi,op))
    # return the controller output and PID terms      return [op,P,I,D]
#####################################################
# FOPDT model                                       #
##################################################### Kp
= 0.5      # degC/%
```

[redacted]

[redacted]

```
    T = x[0]

    # Nonlinear Energy Balance      dTdt =
(1.0/(m*Cp))*(U*A*(Ta-T) \
            + eps * sigma * A * (Ta**4 - T**4) \
            + alpha*Q)      return dTdt
######################################################
# Do not adjust anything below this point             #
######################################################
# Connect to Arduino a =
itclab.iTCLab()
#a.encode('utf-8').strip()#modification error
# Turn LED on print('LED
On')
a.LED(100)

# Run time in minutes run_time = 15.0

# Number of cycles loops =
int(60.0*run_time) tm =
np.zeros(loops)

# Temperature
# set point (degC)
Tsp1 = np.ones(loops) * 25.0
Tsp1[60:] = 45.0
Tsp1[360:] = 30.0
Tsp1[660:] = 35.0
T1 = np.ones(loops) * a.T1 # measured T (degC) error_sp =
np.zeros(loops)

Tsp2 = np.ones(loops) * 23.0 # set point (degC)
T2 = np.ones(loops) * a.T2 # measured T (degC)

# Predictions
```

```
Tp = np.ones(loops) * a.T1 error_eb =
np.zeros(loops) Tpl = np.ones(loops)
* a.T1
```

[redacted]

[redacted]

[redacted]

[redacted]

```
prev_time = start_time # Integral
error ierr = 0.0 try:     for i in
range(1,loops):
        # Sleep time         sleep_max = 1.0
        sleep = sleep_max - (time.time() - prev_time)         if sleep>=0.01:
            time.sleep(sleep-0.01)         else:
            time.sleep(0.01)

        # Record time and change in time         t =
time.time()         dt = t - prev_time         prev_time
= t
        tm[i] = t - start_time

        # Read temperatures in Kelvin
        T1[i] = a.T1
        T2[i] = a.T2

        # Simulate one time step with Energy Balance
        Tnext = odeint(heat,Tp[i-1]+273.15,[0,dt],args=(Q1[i-1],))         Tp[i] = Tnext[1]-273.15

        # Simulate one time step with linear FOPDT model         z = np.exp(-
dt/tauP)
        Tpl[i] = (Tpl[i-1]-Tss) * z \
                 + (Q1[max(0,i-int(thetaP)-1)]-Qss)*(1-z)*Kp \                  + Tss

        # Calculate PID Output (Choose one of them)
        # 1. Manually Choosen
#         [Q1[i],P,ierr,D] = pid(Tsp1[i],T1[i],T1[i-1],ierr,dt)
        # 2. Based on Deep Learning Result
        [Q1[i],P,ierr,D] = pid_dl(Tsp1[i],T1[i],T1[i-1],ierr,dt)
        # Start setpoint error accumulation after 1 minute (60 seconds)         if i>=60:
            error_eb[i] = error_eb[i-1] + abs(Tp[i]-T1[i])             error_fopdt[i] = error_fopdt[i-1] +
abs(Tpl[i]-T1[i])             error_sp[i] = error_sp[i-1] + abs(Tsp1[i]-T1[i])
```

[redacted]

[redacted]

```
        plt.plot(tm[0:i],Tsp1[0:i],'k--',label=r'$T_1$ set point')
plt.ylabel('Temperature (degC)')         plt.legend(loc=2)         ax=plt.subplot(4,1,2)
ax.grid()
        plt.plot(tm[0:i],Q1[0:i],'b-',label=r'$Q_1$')
plt.ylabel('Heater')         plt.legend(loc='best')
ax=plt.subplot(4,1,3)         ax.grid()
        plt.plot(tm[0:i],T1[0:i],'r.',label=r'$T_1$ measured')         plt.plot(tm[0:i],Tp[0:i],'k-
',label=r'$T_1$ energy balance')         plt.plot(tm[0:i],Tpl[0:i],'g-',label=r'$T_1$ linear
model')         plt.ylabel('Temperature (degC)')         plt.legend(loc=2)
ax=plt.subplot(4,1,4)         ax.grid()
        plt.plot(tm[0:i],error_sp[0:i],'r-',label='Set Point Error')
plt.plot(tm[0:i],error_eb[0:i],'k-',label='Energy Balance Error')
plt.plot(tm[0:i],error_fopdt[0:i],'g-',label='Linear Model Error')         plt.ylabel('Cumulative
Error')         plt.legend(loc='best')         plt.xlabel('Time (sec)')         plt.draw()
plt.pause(0.05)

    # Turn off heaters
    a.Q1(0)
    a.Q2(0)     # Save
figure
    plt.savefig('test_PID_dl.png')

# Allow user to end loop with Ctrl-C
except KeyboardInterrupt:     # Disconnect
from Arduino
    a.Q1(0)
    a.Q2(0)
    print('Shutting down')     a.close()
    plt.savefig('test_PID_dl.png')

# Make sure serial connection still closes when there's an error except:
    # Disconnect from Arduino
    a.Q1(0)
```

[redacted]

1. **Pembelajaran Mesin**

   Pada bagian ini, model pembelajaran mesin dibuat menggunakan Keras dengan struktur jaringan saraf tiruan (Artificial Neural Network). Model ini digunakan untuk memperkirakan parameter PID seperti Kc, tauI, dan tauD berdasarkan input dari kesalahan setpoint (error) dan perubahan kesalahan (delta_error).

   - Lapisan Input: Memiliki 2 neuron dengan fungsi aktivasi sigmoid.
   - Lapisan Tersembunyi: 3 neuron dengan fungsi aktivasi sigmoid.
   - Lapisan Keluaran: 3 neuron untuk memberikan output parameter PID.
   - Data Pelatihan (Training Data)
     - Input (X) adalah pasangan nilai untuk sistem kontrol.
     - Target/output (y) adalah nilai parameter PID.

2. **Pengendalian PID**

   Bagian ini berisi implementasi pengendali PID tradisional dan pengendali berbasis pembelajaran mesin:

   - PID Manual: Menggunakan parameter tetap seperti Kc, tauI, dan tauD.
   - PID Berbasis Deep Learning: Parameter PID dihitung oleh model pembelajaran mesin berdasarkan input dari kesalahan.

   Fungsi PID mengontrol keluaran (op) yang mengatur pemanas untuk menjaga suhu pada setpoint yang diinginkan.

3. **Simulasi Sistem Termal**

[redacted]

Sistem termal disimulasikan menggunakan model berikut:

- Persamaan Energi: Model termal nonlinier dengan parameter fisik seperti massa, luas permukaan, dan koefisien perpindahan panas.
- FOPDT Model: Model linier orde pertama untuk sistem termal dengan parameter seperti waktu tunda (thetaP) dan waktu konstanta (tauP).

Kegunaan

Kode menghasilkan grafik untuk menampilkan suhu aktual, setpoint, dan keluaran pengontrol dalam waktu nyata.

O. ITCLab-14

Di ITCLab ke-14 ada tiga kode yaitu, kode Arduino, Python, dan Notebook Jupyter.

```
#include <Arduino.h>

// constants
const          = "1.04";  // version of this firmware
```

```
const int baud = 115200;    // serial baud rate const char sp
= ' ';      // command separator const char nl = '\n';      //
command terminator

// pin numbers corresponding to signals on the iTCLab Shield
const int pinT1  = 34;      // T1 const int pinT2  = 35;      // T2
const int pinQ1  = 32;      // Q1 const int pinQ2  = 33;      // Q2
const int pinLED  = 26;      // LED

// setting PWM properties
const int freq = 5000; //5000
const int ledChannel = 0; const
int Q1Channel = 1; const int
Q2Channel = 2;
const int resolutionLedChannel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ1Channel = 8; //Resolution 8, 10, 12, 15 const int
resolutionQ2Channel = 8; //Resolution 8, 10, 12, 15

const double batas_suhu_atas = 59;

// global variables
char Buffer[64];        // buffer for parsing serial input String
cmd;             // command   double pv = 0;          // pin value float
level;           // LED level (0-100%) double Q1 = 0;         // value
written to Q1 pin double Q2 = 0;         // value written to Q2 pin
int iwrite = 0;         // integer value for writing float dwrite = 0;
// float value for writing
int n = 10;           // number of samples for each temperature measurement

void parseSerial(void) {
 int ByteCount = Serial.readBytesUntil(nl,Buffer,sizeof(Buffer));   String
read_ = String(Buffer);   memset(Buffer,0,sizeof(Buffer));

 // separate command from associated data
int idx = read_.indexOf(sp);   cmd =
read_.substring(0,idx);   cmd.trim();
cmd.toUpperCase();

 // extract data. toInt() returns 0 on error   String
data = read_.substring(idx+1);   data.trim();
 pv = data.toFloat();
}

// Q1_max = 100%
// Q2_max = 100%
 void dispatchCommand(void) {
if (cmd == "Q1") {
   Q1 = max(0.0, min(25.0, pv));    iwrite =
int(Q1 * 2.0); // 10.? max    iwrite = max(0,
min(255, iwrite));
ledcWrite(Q1Channel,iwrite);
   Serial.println(Q1);
  }
```

```
 else if (cmd == "Q2") {
   Q2 = max(0.0, min(25.0, pv));     iwrite =
int(Q2 * 2.0); // 10.? max     iwrite = max(0,
min(255, iwrite));
ledcWrite(Q2Channel,iwrite);
   Serial.println(Q2);
 }  else if (cmd == "T1") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
      mV = (float) analogRead(pinT1) * 0.322265625;        degC = degC
+ mV/10.0;
   }
   degC = degC / float(n);

   Serial.println(degC);
 }  else if (cmd == "T2") {
float mV = 0.0;    float
degC = 0.0;
   for (int i = 0; i < n; i++) {
       mV = (float) analogRead(pinT2) * 0.322265625;         degC = degC
+ mV/10.0;
  }    degC = degC / float(n);
   Serial.println(degC);
 }
 else if ((cmd == "V") or (cmd == "VER")) {
   Serial.println("TCLab Firmware Version " + vers);
 }
 else if (cmd == "LED") {
   level = max(0.0, min(100.0, pv));     iwrite =
int(level * 0.5);
   iwrite = max(0, min(50, iwrite));        ledcWrite(ledChannel, iwrite);
   Serial.println(level);
 }
 else if (cmd == "X") {    ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);    Serial.println("Stop");
 }
}
// check temperature and shut-off heaters if above high limit void
checkTemp(void) {
   float mV = (float) analogRead(pinT1) * 0.322265625;
   //float degC = (mV - 500.0)/10.0;    float
degC = mV/10.0;
   if (degC >= batas_suhu_atas) {
     Q1 = 0.0;      Q2 =
0.0;
     ledcWrite(Q1Channel,0);      ledcWrite(Q2Channel,0);
     //Serial.println("High Temp 1 (> batas_suhu_atas): ");
     Serial.println(degC);
   }
   mV = (float) analogRead(pinT2) * 0.322265625;
   //degC = (mV - 500.0)/10.0;    degC
= mV/10.0;
```

```
  if (degC >= batas_suhu_atas) {
    Q1 = 0.0;     Q2 =
0.0;
    ledcWrite(Q1Channel,0);     ledcWrite(Q2Channel,0);
    //Serial.println("High Temp 2 (> batas_suhu_atas): ");
    Serial.println(degC);
  }
}

// arduino startup void
setup() {
 //analogReference(EXTERNAL);
 Serial.begin(baud);  while
(!Serial) {
  ; // wait for serial port to connect.
 }

 // configure pinQ1 PWM functionalitites
 ledcSetup(Q1Channel, freq, resolutionQ1Channel);

 // attach the channel to the pinQ1 to be controlled  ledcAttachPin(pinQ1,
Q1Channel);

 // configure pinQ2 PWM functionalitites
 ledcSetup(Q2Channel, freq, resolutionQ2Channel);

 // attach the channel to the pinQ2 to be controlled  ledcAttachPin(pinQ2,
Q2Channel);

 // configure pinLED PWM functionalitites
 ledcSetup(ledChannel, freq, resolutionLedChannel);

 // attach the channel to the pinLED to be controlled  ledcAttachPin(pinLED,
ledChannel);
  ledcWrite(Q1Channel,0);
ledcWrite(Q2Channel,0);
}

// arduino main event loop
void loop() {  parseSerial();
dispatchCommand();
 checkTemp();
}
```

Kode di atas merupakan firmware untuk sebuah perangkat berbasis Arduino yang menggunakan modul atau shield yang disebut **iTCLab Shield**. Firmware ini bertujuan untuk mengontrol perangkat keras tertentu seperti LED, sinyal output PWM, dan membaca sensor suhu (Thermocouple atau sensor analog lainnya). Berikut adalah penjelasan mendetail dari setiap bagian kode:

1. Konstanta dan Variabel Global

- Konstanta:
  - `vers`: Versi firmware ("1.04").
  - `baud`: Baud rate komunikasi serial (115200).
  - `sp` dan `nl`: Karakter pemisah dan terminator untuk parsing perintah serial.
  - Pin Numbers: Pin yang digunakan untuk sinyal (T1, T2, Q1, Q2, LED).
  - PWM Properties: Properti PWM seperti frekuensi (5000 Hz), kanal PWM (0-2), dan resolusi (8-bit).
- Variabel Global:
  - `Buffer`: Buffer untuk membaca data serial.
  - `cmd`: Perintah yang diterima dari input serial.
  - `pv`: Nilai yang diambil dari perintah serial.
  - `Q1`, `Q2`: Nilai yang ditulis ke pin Q1 dan Q2. `n`: Jumlah sampel untuk pembacaan suhu.

2. Fungsi parseSerial()

Fungsi ini membaca data dari Serial hingga karakter terminator (`\n`), lalu memisahkan perintah (`cmd`) dan data (`pv`).

3. Fungsi `dispatchCommand()`

Fungsi ini memproses perintah yang diterima dan mengambil tindakan sesuai jenis perintah:

- Q1 & Q2: Mengatur keluaran PWM ke pin Q1 dan Q2, dengan nilai diatur dalam rentang 0-25.
- T1 & T2: Membaca sensor suhu yang terhubung ke pin T1 dan T2, mengonversinya ke derajat Celcius, lalu mencetak hasilnya.
- VER: Menampilkan versi firmware.
- LED: Mengatur tingkat kecerahan LED dalam rentang 0-100%.
- X: Mematikan semua output (Q1, Q2).

4. Fungsi checkTemp()

Fungsi ini memeriksa suhu dari sensor T1 dan T2 untuk memastikan bahwa suhu tidak melebihi batas maksimum (`batas_suhu_atas` = 59°C). Jika suhu melebihi batas:

- Nilai Q1 dan Q2 diatur ke 0.

- Output PWM ke pin Q1 dan Q2 dimatikan.
- Suhu yang melampaui batas dicetak ke serial.

5. **Fungsi `setup()`**

   Fungsi inisialisasi Arduino:
   - Menyiapkan komunikasi serial pada baud rate yang ditentukan.
   - Mengatur kanal PWM untuk pin Q1, Q2, dan LED.
   - Melampirkan kanal PWM ke pin terkait.
   - Memastikan semua output dimatikan pada awal.

6. **Fungsi `loop()`**

   Fungsi utama yang dijalankan terus-menerus:
   - `parseSerial()`: Membaca dan mem-parsing perintah dari serial.
   - `dispatchCommand()`: Memproses dan menjalankan perintah yang diterima.
   - `checkTemp()`: Memantau suhu dan mematikan output jika suhu terlalu tinggi.

7. **Fungsi PWM dan Pengontrolan**

   PWM digunakan untuk mengontrol keluaran pin Q1, Q2, dan LED:
   - Nilai PWM dihitung berdasarkan input (`pv`) dan dikonversi ke skala 8-bit (0255).
   - Metode `ledcWrite(channel, value)` digunakan untuk menulis nilai PWM ke pin tertentu.

8. **Fungsi Utama dan Fitur:**
   - Kontrol Output (Q1/Q2): Mengontrol output dengan nilai rentang 0-25.
   - Pengukuran Suhu (T1/T2): Membaca nilai analog dan mengonversinya ke suhu.
   - Kontrol LED: Mengatur kecerahan LED dengan rentang 0-100%.
   - Proteksi Suhu: Memastikan perangkat tidak melampaui suhu yang aman.

```
import sys import
time import numpy
as np try:    import
serial except:
   import pip
   pip.main(['install','pyserial'])    import serial
from serial.tools import list_ports
       class
iTCLab(object):
    def __init__(self, port=None, baud=115200):
       port = self.findPort()       print('Opening
connection')
       self.sp = serial.Serial(port=port, baudrate=baud, timeout=2)
self.sp.flushInput()       self.sp.flushOutput()
```

```
      time.sleep(3)
      print('iTCLab connected via Arduino on port ' + port)
          def findPort(self):        found = False        for port
in list(list_ports.comports()):
         # Arduino Uno         if port[2].startswith('USB
VID:PID=16D0:0613'):              port = port[0]              found = True
# Arduino HDuino         if port[2].startswith('USB
VID:PID=1A86:7523'):              port = port[0]
            found = True
         # Arduino Leonardo         if port[2].startswith('USB
VID:PID=2341:8036'):              port = port[0]              found = True
# Arduino ESP32         if port[2].startswith('USB
VID:PID=10C4:EA60'):
            port = port[0]              found =
True
         # Arduino ESP32 - Tipe yg berbeda       if
port[2].startswith('USB VID:PID=1A86:55D4'):              port = port[0]
found = True       if (not found):           print('Arduino COM port not
found')
         print('Please ensure that the USB cable is connected')           print('---
Printing Serial Ports ---')                     for port in
list(serial.tools.list_ports.comports()):              print(port[0] + ' ' + port[1] + '
' + port[2])           print('For Windows:')
         print('  Open device manager, select "Ports (COM & LPT)"')           print('  Look for
COM port of Arduino such as COM4')           print('For MacOS:')
         print('  Open terminal and type: ls /dev/*.')
         print('  Search for /dev/tty.usbmodem* or /dev/tty.usbserial*. The port number is *.')            print('For Linux')
         print('  Open terminal and type: ls /dev/tty*')
         print('  Search for /dev/ttyUSB* or /dev/ttyACM*. The port number is *.')           print('')
         port = input('Input port: ')           # or
hard-code it here
         #port = 'COM3' # for Windows
         #port = '/dev/tty.wchusbserial1410' # for MacOS     return
port
       def stop(self):
      return self.read('X')
       def version(self):
      return self.read('VER')

   @property   def
T1(self):
      self._T1 = float(self.read('T1'))        return self._T1

   @property   def
T2(self):
```

```
    self._T2 = float(self.read('T2'))        return self._T2
        def LED(self,pwm):        pwm =
max(0.0,min(100.0,pwm))/2.0
self.write('LED',pwm)        return pwm
    def Q1(self,pwm):        pwm =
max(0.0,min(100.0,pwm))
self.write('Q1',pwm)        return pwm
        def Q2(self,pwm):        pwm =
max(0.0,min(100.0,pwm))
self.write('Q2',pwm)        return pwm

  # save txt file with data and set point
  # t = time
  # u1,u2 = heaters
  # y1,y2 = tempeatures   # sp1,sp2 = setpoints   def
save_txt(self,t,u1,u2,y1,y2,sp1,sp2):        data =
np.vstack((t,u1,u2,y1,y2,sp1,sp2)) # vertical stack        data = data.T
# transpose data        top = 'Time (sec), Heater 1 (%), Heater 2 (%), ' \          +
'Temperature 1 (degC), Temperature 2 (degC), ' \          + 'Set Point 1 (degC), Set Point
2 (degC)'
    np.savetxt('data.txt',data,delimiter=',',header=top,comments='')
    def read(self,cmd):        cmd_str =
self.build_cmd_str(cmd,'')        try:
self.sp.write(cmd_str.encode())
self.sp.flush()        except Exception:          return
None
    return self.sp.readline().decode('UTF-8').replace("\r\n", "")
     def write(self,cmd,pwm):
    cmd_str = self.build_cmd_str(cmd,(pwm,))        try:
      self.sp.write(cmd_str.encode())
self.sp.flush()        except:          return None
    return self.sp.readline().decode('UTF-8').replace("\r\n", "")
     def build_cmd_str(self,cmd, args=None):
    """
    Build a command string that can be sent to the arduino.

    Input:
      cmd (str): the command to send to the arduino, must not              contain a % character
      args (iterable): the arguments to send to the command
    """        if args:          args = ' '.join(map(str,
args))       else:
```

```
        args = ''
     return "{cmd} {args}\n".format(cmd=cmd, args=args)
         def close(self):
try:         self.sp.close()
        print('Arduino disconnected successfully')       except:
print('Problems disconnecting from Arduino.')          print('Please
unplug and reconnect Arduino.')        return True
```

Kode ini adalah implementasi dalam Python untuk berkomunikasi dengan perangkat Arduino yang terhubung melalui port serial. Kode ini ditujukan untuk mengontrol perangkat keras, seperti modul termal (heaters), LED, dan membaca data suhu dari sensor. Berikut adalah penjelasan detail setiap bagian:

1. Impor Modul

```
import sys import
time import numpy
as np try:   import
serial except:
import pip
   pip.main(['install','pyserial'])    import serial
from serial.tools import list_ports
```

- `serial`: Digunakan untuk komunikasi serial antara Python dan perangkat Arduino.
- `numpy`: Digunakan untuk memproses dan menyimpan data.
- Jika `pyserial` tidak tersedia, modul akan diinstal secara otomatis.

2. Kelas `iTCLab`

Kelas ini menyediakan antarmuka untuk mengontrol perangkat keras yang terhubung ke Arduino.

- `__init__` Method
  - Memulai koneksi dengan Arduino melalui port serial.
  - Mencari port yang terhubung menggunakan metode `findPort`.
  - Menginisialisasi koneksi serial dengan baud rate default 115200 dan waktu tunggu 2 detik.
- `findPort` Method
  - Mendeteksi port yang terhubung dengan perangkat Arduino.

- Mencocokkan Vendor ID (VID) dan Product ID (PID) untuk berbagai tipe Arduino.
- Jika tidak ditemukan, meminta pengguna untuk memasukkan port secara manual.

3. **Kontrol dan Data**
   - Properti Suhu (`T1` dan `T2`)
     - `T1` dan `T2`: Membaca data suhu dari sensor melalui perintah `read`.
     - Mengembalikan nilai dalam tipe data float.
   - Kontrol Output (`Q1`, `Q2`, `LED`)
     - Metode ini mengontrol keluaran PWM (Pulse Width Modulation) dari heater atau LED:
       - `Q1`: Kontrol heater 1.
       - `Q2`: Kontrol heater 2.
       - `LED`: Kontrol intensitas LED.
   - Perintah Tambahan
     - `stop`: Mengirim perintah X untuk menghentikan operasi.
     - `version`: Membaca versi firmware Arduino.

4. **Penyimpanan Data**
   - `save_txt` Method
     - Menyimpan data ke file `data.txt` dalam format CSV.
     - Data yang disimpan:
       - Waktu (`t`)
       - Heater 1 dan Heater 2 output (`u1`, `u2`)
       - Suhu 1 dan 2 (`y1`, `y2`)
       - Set point untuk suhu 1 dan 2 (`sp1`, `sp2`).

5. **Komunikasi Serial**
   - `read` Method
     - Mengirim perintah ke Arduino dan membaca respon.
     - Respon di-decode dari byte ke string.
   - `write` Method
     - Mengirim perintah dengan parameter (misalnya nilai PWM).

- Menggunakan metode `build_cmd_str` untuk membangun format string perintah.

- `build_cmd_str` Method
  - Membentuk string perintah dengan format:
    Contoh: `Q1 50\n` untuk mengatur Heater 1 ke 50%.

6. Penanganan Koneksi

- `close` Method
  - Menutup koneksi serial dengan Arduino secara aman.

[redacted]

```
import itclab import
numpy as np import time
import matplotlib.pyplot as plt from
scipy.integrate import odeint import random
from paho.mqtt import client as mqtt_client # Machine
Learning - Building Datasets and Model
# Impor `Sequential` dari` keras.models` from
keras.models import Sequential

# Impor `Dense` dari` keras.layers` from
keras.layers import Dense

# Inisialisasi konstruktor model =
Sequential()

# Tambahkan lapisan masukan
model.add(Dense(2, activation='sigmoid', input_shape=(2,)))
# Tambahkan satu lapisan tersembunyi model.add(Dense(3,
activation='sigmoid'))

# Tambahkan lapisan keluaran
model.add(Dense(3, activation='sigmoid'))

# Data Latih.
X = np.array([
    [1, 1],
    [0.4, 1.2],
    [1.2, 0.1],
    [1, 0.1]
])

# Label untuk Data Latih. y =
np.array([
    [0.25, 4.31, 0.20],
    [0.2, 4.1, 0.1],
    [0.1, 4.0, 0],
    [0.1, 4.0, 0]
])

# Bentuk keluaran model model.output_shape

# Ringkasan model model.summary()

# Konfigurasi model model.get_config()

# Buat daftar semua tensor bobot  model.get_weights()
model.compile(loss='binary_crossentropy',              optimizer='adam',
```

[redacted]

[redacted]

[redacted]

[redacted]

```
# PID Controller                                    #
#####################################################
# inputs ---------------------------------
# sp = setpoint
# pv = current temperature
# pv_last = prior temperature
# ierr = integral error
# dt = time increment between measurements
# outputs ---------------------------------
# op = output of the PID controller
# P = proportional contribution
# I = integral contribution # D =
derivative contribution def
pid(sp,pv,pv_last,ierr,dt):     Kc   = 10.0
# K/%Heater     tauI = 50.0 # sec
tauD = 1.0  # sec
    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)     op0 = 0
    # upper and lower bounds on heater level     ophi =
100     oplo = 0
    # calculate the error     error = sp-pv
    # calculate the integral error     ierr = ierr + KI *
error * dt
    # calculate the measurement derivative     dpv = (pv
- pv_last) / dt     # calculate the PID output
    P = KP * error
    I = ierr     D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup     if op
< oplo or op > ophi:         I = I - KI * error *
dt
        # clip output
```

[redacted]

[redacted]

```
    # calculate the error      error =
sp-pv      d_error = sp-pv_last
    delta_error = (error - d_error)

    outDL = model.predict(np.array([[error,delta_error]]))
    Kc = outDL[0,0]      tauI =
outDL[0,1]      tauD =
outDL[0,2]

    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)      op0 = 0
    # upper and lower bounds on heater level      ophi =
100      oplo = 0

    # calculate the integral error      ierr = ierr + KI *
error * dt
    # calculate the measurement derivative      dpv = (pv
- pv_last) / dt      # calculate the PID output
    P = KP * error
    I = ierr      D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup      if op
< oplo or op > ophi:          I = I - KI * error *
dt
        # clip output
        op = max(oplo,min(ophi,op))
    # return the controller output and PID terms      return [op,P,I,D]
######################################################
# FOPDT model                                        #
###################################################### Kp
= 0.5      # degC/%
```

[redacted]

[redacted]

```
    T = x[0]

    # Nonlinear Energy Balance     dTdt =
(1.0/(m*Cp))*(U*A*(Ta-T) \
            + eps * sigma * A * (Ta**4 - T**4) \
            + alpha*Q)     return dTdt
# Connect to MQTT Broker for Monitoring broker
= 'broker.hivemq.com' port = 1883
client_id = f'python-mqtt-{random.randint(0, 1000)}'
 def connect_mqtt():
    def on_connect(client, userdata, flags, rc):         if rc == 0:
print("Connected to MQTT Broker!")         else:             print("Failed to
connect, return code %d\n", rc)

    client = mqtt_client.Client(client_id)
client.on_connect = on_connect
client.connect(broker, port)     return client
 client = connect_mqtt()
client.loop_start() Connected
to MQTT Broker!
######################################################
# Do not adjust anything below this point            #
######################################################
# Connect to Arduino a =
itclab.iTCLab()
#a.encode('utf-8').strip()#modification error
# Turn LED on print('LED
On')
a.LED(100)

# Run time in minutes run_time = 15.0
```

[redacted]

[redacted]

[redacted]

[redacted]

```
error_fopdt = np.zeros(loops)

# impulse tests (0 - 100%)
Q1 = np.ones(loops) * 0.0
Q2 = np.ones(loops) * 0.0

print('Running Main Loop. Ctrl-C to end.')
print('  Time     SP     PV     Q1   =  P   +  I  +   D') print(('{:6.1f} {:6.2f} {:6.2f} ' + \
      '{:6.2f} {:6.2f} {:6.2f} {:6.2f}').format( \            tm[0],Tsp1[0],T1[0], \
          Q1[0],0.0,0.0,0.0))

# Create plot
plt.figure(figsize=(10,7)) plt.ion()
plt.show()

# Main Loop
start_time = time.time() prev_time
= start_time # Integral error ierr =
0.0 try:     for i in range(1,loops):
       # Sleep time         sleep_max = 1.0
       sleep = sleep_max - (time.time() - prev_time)         if
sleep>=0.01:             time.sleep(sleep-0.01)         else:
           time.sleep(0.01)

       # Record time and change in time         t =
time.time()         dt = t - prev_time         prev_time
= t
       tm[i] = t - start_time

       # Read temperatures in Kelvin
       T1[i] = a.T1
       T2[i] = a.T2

       # Simulate one time step with Energy Balance
       Tnext = odeint(heat,Tp[i-1]+273.15,[0,dt],args=(Q1[i-1],))         Tp[i] = Tnext[1]-
273.15

       # Simulate one time step with linear FOPDT model         z = np.exp(-
dt/tauP)
       Tpl[i] = (Tpl[i-1]-Tss) * z \
               + (Q1[max(0,i-int(thetaP)-1)]-Qss)*(1-z)*Kp \
```

```
        # 2. Based on Deep Learning Result
        [Q1[i],P,ierr,D] = pid_dl(Tsp1[i],T1[i],T1[i-1],ierr,dt)
        # Start setpoint error accumulation after 1 minute (60 seconds)         if i>=60:
error_eb[i] = error_eb[i-1] + abs(Tp[i]-T1[i])             error_fopdt[i] = error_fopdt[i-1] +
abs(Tpl[i]-T1[i])             error_sp[i] = error_sp[i-1] + abs(Tsp1[i]-T1[i])
        # Write output (0-100)
        a.Q1(Q1[i])
        a.Q2(0.0)

        # Print line of data
        print(('{:6.1f} {:6.2f} {:6.2f} ' + \
              '{:6.2f} {:6.2f} {:6.2f} {:6.2f}').format( \
                  tm[i],Tsp1[i],T1[i], \
                  Q1[i],P,ierr,D))

        # Publish data to MQTT Broker
        pub_sp = client.publish('SetPoint', Tsp1[i])         pub_pv1 =
client.publish('Suhu1', T1[i])         pub_op = client.publish('Nilai_op',
Q1[i])

        # Plot         plt.clf()
        ax=plt.subplot(4,1,1)         ax.grid()
        plt.plot(tm[0:i],T1[0:i],'r.',label=r'$T_1$ measured')
plt.plot(tm[0:i],Tsp1[0:i],'k--',label=r'$T_1$ set point')         plt.ylabel('Temperature
(degC)')         plt.legend(loc=2)         ax=plt.subplot(4,1,2)         ax.grid()
        plt.plot(tm[0:i],Q1[0:i],'b-',label=r'$Q_1$')
plt.ylabel('Heater')         plt.legend(loc='best')
ax=plt.subplot(4,1,3)         ax.grid()
        plt.plot(tm[0:i],T1[0:i],'r.',label=r'$T_1$ measured')         plt.plot(tm[0:i],Tp[0:i],'k-
',label=r'$T_1$ energy balance')         plt.plot(tm[0:i],Tpl[0:i],'g-',label=r'$T_1$ linear
model')         plt.ylabel('Temperature (degC)')         plt.legend(loc=2)
ax=plt.subplot(4,1,4)         ax.grid()
        plt.plot(tm[0:i],error_sp[0:i],'r-',label='Set Point Error')
plt.plot(tm[0:i],error_eb[0:i],'k-',label='Energy Balance Error')
plt.plot(tm[0:i],error_fopdt[0:i],'g-',label='Linear Model Error')         plt.ylabel('Cumulative
Error')         plt.legend(loc='best')         plt.xlabel('Time (sec)')         plt.draw()
plt.pause(0.05)
```

```
# Allow user to end loop with Ctrl-C
except KeyboardInterrupt:     # Disconnect
from Arduino
    a.Q1(0)
    a.Q2(0)
    print('Shutting down')     a.close()
    plt.savefig('test_PID_dl.png')

# Make sure serial connection still closes when there's an error except:
    # Disconnect from Arduino
    a.Q1(0)
    a.Q2(0)
    print('Error: Shutting down')
    a.close()
    plt.savefig('test_PID_dl.png')     raise

a.close()
```

Kode ini merupakan kombinasi dari beberapa teknologi seperti Machine Learning, PID Controller, Simulasi Model Nonlinear dan FOPDT, serta komunikasi MQTT dengan perangkat keras melalui Arduino (iTCLab). Ini adalah penjelasan rincinya:

1. **Machine Learning**

   Bagian ini melibatkan pembuatan model Neural Network sederhana menggunakan Keras. Model ini digunakan untuk memprediksi parameter PID (Kc, τI, τD) berdasarkan data pelatihan.

   - Model Neural Network memiliki:
     - 1 lapisan masukan (2 neuron),
     - 1 lapisan tersembunyi (3 neuron),
     - 1 lapisan keluaran (3 neuron untuk menghasilkan parameter PID).
   - Data pelatihan (`X` dan `y`) dirancang untuk mengajarkan model memprediksi parameter PID berdasarkan error dan perubahan error.

2. **PID Controller**

- Controller PID digunakan untuk mengontrol suhu dengan parameter:
  - Proportional (P): Koreksi berdasarkan error saat ini.
  - Integral (I): Koreksi berdasarkan akumulasi error.
  - Derivative (D): Koreksi berdasarkan perubahan error.
- Ada dua metode:
  - PID Manual: Parameter PID diatur secara manual (`pid`).

- PID Deep Learning: Parameter PID diprediksi oleh model neural network (`pid_dl`).

3. **Model FOPDT dan Energi Nonlinear**
   - Model FOPDT (First Order Plus Dead Time):
     - Menggunakan parameter Kp, τP, dan θP untuk mensimulasikan sistem linier.
   - Model Energi Nonlinear:
     - Menghitung perubahan suhu berdasarkan energi konveksi, radiasi, dan daya pemanas.

4. **MQTT dan Arduino**
   - MQTT digunakan untuk komunikasi dengan broker (HiveMQ) untuk monitoring.
   - Arduino (iTCLab) digunakan sebagai perangkat keras untuk membaca suhu (`T1`, `T2`) dan mengontrol pemanas (`Q1`, `Q2`).

5. **Simulasi Utama**

   Simulasi mencakup langkah-langkah berikut:
   - Mengatur setpoint suhu:
     - Suhu target berubah pada waktu tertentu untuk menguji performa PID.
   - Menghitung output PID:
     - Baik manual maupun menggunakan model deep learning.
   - Memperbarui suhu:
     - Simulasi dilakukan menggunakan model energi nonlinear dan FOPDT.
   - Visualisasi:
     - Plot suhu aktual, setpoint, dan output kontrol.

6. **Kode Inti**

   Beberapa bagian penting dari kode:
   - Neural Network

```
model = Sequential()

# Tambahkan lapisan masukan
model.add(Dense(2, activation='sigmoid', input_shape=(2,)))
# Tambahkan satu lapisan tersembunyi model.add(Dense(3,
activation='sigmoid'))

# Tambahkan lapisan keluaran
model.add(Dense(3, activation='sigmoid'))

# Data Latih.
X = np.array([
    [1, 1],
    [0.4, 1.2],
    [1.2, 0.1],
    [1, 0.1]
])

# Label untuk Data Latih. y =
np.array([
    [0.25, 4.31, 0.20],
    [0.2, 4.1, 0.1],
    [0.1, 4.0, 0],
    [0.1, 4.0, 0]
])

# Bentuk keluaran model model.output_shape

# Ringkasan model model.summary()

# Konfigurasi model model.get_config()

# Buat daftar semua tensor bobot  model.get_weights()
model.compile(loss='binary_crossentropy',
optimizer='adam',               metrics=['accuracy'])

model.fit(X, y,epochs=10, batch_size=1, verbose=1)
```

- PID Controller Manual

```
def pid(sp,pv,pv_last,ierr,dt):     Kc   =
10.0 # K/%Heater     tauI = 50.0 # sec
tauD = 1.0  # sec
    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)     op0 = 0
    # upper and lower bounds on heater level     ophi =
100     oplo = 0
    # calculate the error     error = sp-pv
    # calculate the integral error     ierr = ierr + KI *
error * dt
    # calculate the measurement derivative     dpv = (pv
- pv_last) / dt     # calculate the PID output
    P = KP * error
    I = ierr     D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup     if op
< oplo or op > ophi:        I = I - KI * error *
dt
        # clip output
        op = max(oplo,min(ophi,op))     # return the controller
output and PID terms     return [op,P,I,D]
```

- PID Controller dengan Deep Learning

```
def pid_dl(sp,pv,pv_last,ierr,dt):

    # calculate the error     error =
sp-pv     d_error = sp-pv_last
    delta_error = (error - d_error)

    outDL = model.predict(np.array([[error,delta_error]]))
    Kc = outDL[0,0]     tauI =
outDL[0,1]     tauD =
outDL[0,2]

    # Parameters in terms of PID coefficients
    KP = Kc
    KI = Kc/tauI
    KD = Kc*tauD
    # ubias for controller (initial heater)     op0 = 0
    # upper and lower bounds on heater level     ophi =
100     oplo = 0

    # calculate the integral error     ierr = ierr + KI *
error * dt
    # calculate the measurement derivative     dpv = (pv
- pv_last) / dt     # calculate the PID output
    P = KP * error
    I = ierr     D = -KD * dpv
op = op0 + P + I + D
    # implement anti-reset windup     if op
< oplo or op > ophi:         I = I - KI * error *
dt
        # clip output
        op = max(oplo,min(ophi,op))
    # return the controller output and PID terms     return [op,P,I,D]
```

- Simulasi Nonlinier

```
def heat(x,t,Q):     #
Parameters
    Ta = 23 + 273.15   # K     U = 10.0
# W/m^2-K     m = 4.0/1000.0     # kg
    Cp = 0.5 * 1000.0  # J/kg-K         A = 12.0 /
100.0**2 # Area in m^2     alpha = 0.01       # W / %
heater     eps = 0.9          # Emissivity     sigma =
5.67e-8    # Stefan-Boltzman

    # Temperature State
    T = x[0]

    # Nonlinear Energy Balance     dTdt =
(1.0/(m*Cp))*(U*A*(Ta-T) \
```

```
+ eps * sigma * A * (Ta**4 - T**4) \
+ alpha*Q)     return dTdt
```

P. Kode yang Ditingkatkan (Blink Pola Morse)

```
#define LED 2

void dot() {
 digitalWrite(LED, HIGH);  delay(200); //
Durasi titik  digitalWrite(LED, LOW);
delay(200);
}
void dash() {
 digitalWrite(LED, HIGH);  delay(600); //
Durasi garis  digitalWrite(LED, LOW);
delay(200);
}
void setup() {
 pinMode(LED, OUTPUT);
} void loop()
{
 // SOS: ... --- ...   dot();
dot(); dot(); // S
delay(400);
 dash(); dash(); dash(); // O   delay(400);
 dot(); dot(); dot(); // S
 delay(1000); // Jeda sebelum ulangi
}
```

Kode ini adalah sebuah program Arduino sederhana yang membuat lampu LED berkedip dalam pola kode Morse untuk huruf SOS, yaitu tiga titik (...), tiga garis (---), dan tiga titik lagi (...). Berikut adalah penjelasan rinci:

1. Pendefinisian Pin LED

```
#define LED 2
```

- `#define` digunakan untuk mendefinisikan konstanta.
- `LED` diatur ke pin digital nomor 2 pada papan Arduino, tempat LED terhubung.

2. Fungsi dot()

```
void dot() {
 digitalWrite(LED, HIGH);  delay(200); //
Durasi titik  digitalWrite(LED, LOW);
delay(200);
```

```
}
```

- Fungsi ini membuat LED menyala selama 200 milidetik (titik), lalu mati selama 200 milidetik.

3. **Fungsi dash()**

```
void dash() {
 digitalWrite(LED, HIGH);  delay(600); //
Durasi garis  digitalWrite(LED, LOW);
delay(200);
}
```

- Fungsi ini membuat LED menyala selama 600 milidetik (garis), lalu mati selama 200 milidetik.

4. **Fungsi setup()**

```
void setup() {
 pinMode(LED, OUTPUT);
}
```

- Fungsi ini dijalankan sekali saat perangkat Arduino dihidupkan.
- `pinMode(LED, OUTPUT)` mengatur pin nomor 2 sebagai output, memungkinkan pin mengontrol LED.

5. **Fungsi `loop()`**

```
void loop() {
 // SOS: ... --- ...  dot();
dot(); dot(); // S
delay(400);
 dash(); dash(); dash(); // O  delay(400);
 dot(); dot(); dot(); // S
 delay(1000); // Jeda sebelum ulangi
}
```

- Fungsi ini terus-menerus dijalankan setelah `setup()`.
- Pola kode Morse untuk SOS diimplementasikan: Tiga titik (`dot(); dot(); dot();`) untuk S. Jeda antar huruf sebesar 400 milidetik.
   - Tiga garis (`dash(); dash(); dash();`) untuk O. Jeda antar huruf sebesar 400 milidetik.
   - Tiga titik (`dot(); dot(); dot();`) untuk S.
   - Jeda antar pola sebesar 1000 milidetik sebelum mengulangi.

Kegunaan

- Program ini cocok untuk demonstrasi sinyal darurat SOS menggunakan kode Morse pada LED.
- SOS adalah sinyal universal untuk permintaan bantuan.