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DIGITAL PID REGULATOR FOR HEATING OBJECTS - USING A MICROCONTROLLER

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ABSTRACT
Although many controllers have been successfully applied in industrial control systems, the PID regulator is still an extremely important regulator in most control systems. The PID regulator is widely applied and popular because of its simple and easy-to-apply control algorithm. Along with the development of science and technology, digital is using in many fields and one of them is applied to Digital PID regulator. With the digital PID control algorithm, it will be loaded into the microcontroller to improve the quality of the Heating object.

Keywords:
Digital PID, Arduino,Heating object, Feedback.

INTRODUCTION

Traditional heating systems often use analog systems, the weakness of this system is that they are sensitive to changes in noise and component life, and it is difficult to upgrading and expand the system.Therefore, digital control structures overcome all the above disadvantages by using programmable microprocessors. Upgrading easily made by softwares.High-speed digital signal processors allow us to perform numerical control problems that require high resolution, speed and large amounts of computation.In the article, Arduino microcontroller is used to adjust the temperature of the heating object.The rest of the paper is structured as follows: Experimental system of temperature control for heating objects. Control methodsand mathematical models. Experimental results. Conclusion

EXPERIMENTAL SYSTEM FOR ADJUSTING HEATING OBJECT

The heater experimental object as shown in Figure 1 requires that the temperature can be adjusted from 0-100oC, the temperature sensor uses a K-type thermocouple. Disturb affects the heated object using a 12 VDC DC fan and AC 220/240V fan with 38W capacity. Fotek Model DSC-240 single-phase AC-AC converter to regulate AC voltage applied to heater equipment. The digital PID regulator is programmed on the Arduino microcontroller as shown in Fig 2.

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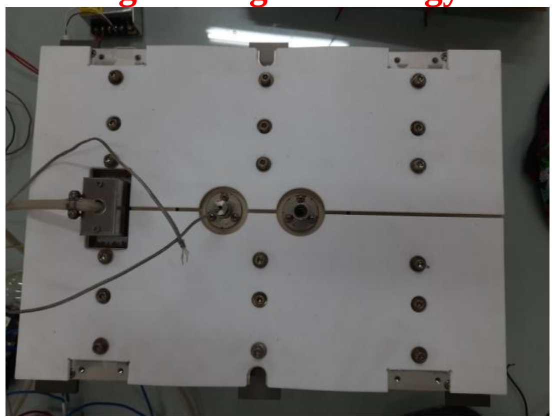

Fig 1:Heating object

Fig 2: Pair heating object with arduino

CONTROL METHOD AND OBJECT MATHEMATICAL MODEL

a. **Control method**

The block diagram of the digital control system is shown in the figure:

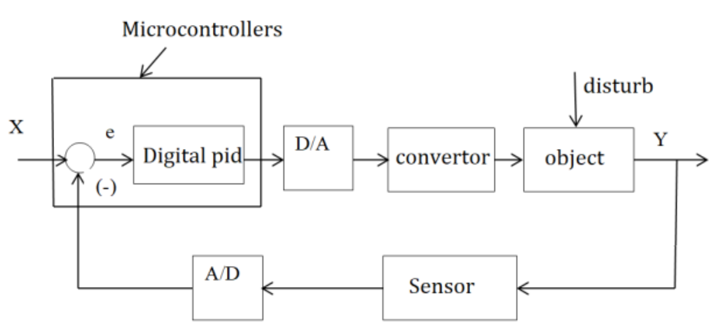

Fig3: Structure of the digital control system

The digital PID regulator has the following algorithm:

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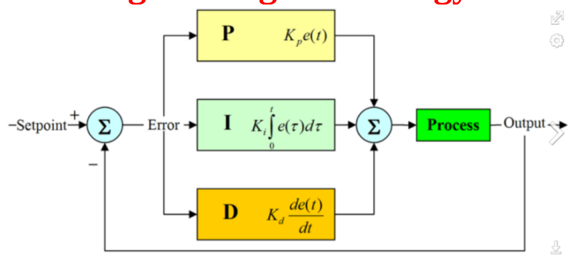


Fig4: Structure of the PID regulator

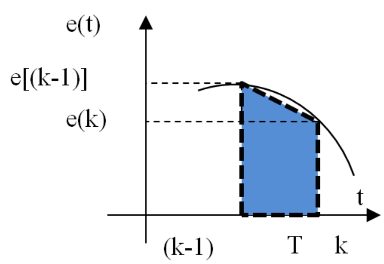
With: $$u_{dk}(t) = K_P\, e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} \tag{1}$$

$$W(s) = \frac{U_{dk}(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D.s = K_P(1 + \frac{1}{T_I s} + T_D.s) \tag{2}$$

$$T_I = \frac{K_P}{K_I} \quad (3) \qquad\qquad T_D = \frac{K_D}{K_P} \quad (4)$$

Thedifference equationof the PID regulator

$$u_{dk}(t) = u_p(t) + u_I(t) + u_D(t) \tag{5}$$



Switching to differential equations:

Proportional component: $u_p(t) = K_p e(t)\,;\;\; u_p(k) = K_p e(k)$ (6)

Integral component: $u_I(t) = K_p \frac{1}{T_I}\int e(t)dt$ (7)

Trapezoid Integral we have: $u_I(k) = K_p \frac{1}{T_I}\frac{T}{2}\left[e(k) + e(k-1)\right]$ (8)

Derivative component: $u_D(t) = K_p T_D \frac{d\,e(t)}{dt}$ (9)

$$u_D(k) = K_p T_D \frac{\left[e(k) - e(k-1)\right]}{T} = K_p T_D \frac{1}{T}\left[e(k) - e(k-1)\right] \tag{10}$$

$$u_{dk}(k) = K_p\, e(k) + K_p \frac{0.5T}{T_I}\left[e(k) + e(k-1)\right] + K_p T_D \frac{1}{T}\left[e(k) - e(k-1)\right] \tag{11}$$

This is the difference equation describing the programming algorithm for the digital PID regulator

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b. **Object mathematical model**

There are many methods applied to parameter adjustment of the PID regulator in the control system. The paper applies the Ziegler-Nichols method 1

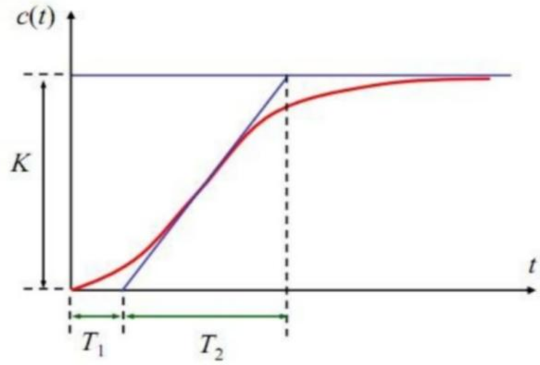

Fig 5 : Feature line of the object

Table 1: The parameters of the PID regulator designed according to of Ziegler-Nichols method 1 .

Control law	Proportional constant (KP)	Integral time constant(T_I)	Derivative time constant (T_D)
P	$\frac{T_2}{K.T_1}$	-	-
PI	$\frac{0,9.T_2}{K.T_1}$	$\frac{T_1}{0,3}$	-
PID	$\frac{1,2.T_2}{K.T_1}$	2.T1	0,5.T1

For simplicity, in this content we use the method of object model recognition by experiment. Then synthesize the PID regulator parameter..

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object identification:

The author sets the control voltage Udk = 1.7 [V] DC, the input AC voltage for the water heater is stable at 40 [V] AC AC voltage.

After reaching the set temperature. We add the load is an AC fan with voltage parameters: AC 220 / 240V, Frequency: 50 / 60H, current: 0.22A, power: 38W into the system

In order to clearly observe the changing process of the control voltage, the changing temperature.The author sets "#define cycle 200000 // sample time (ms)", we obtain the following experimental characteristics:

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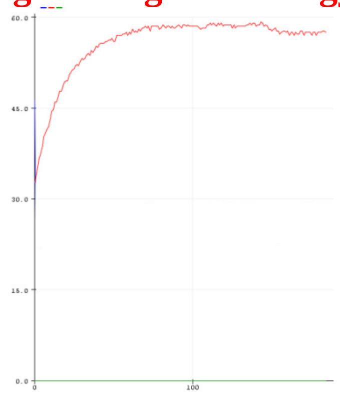


Fig 6: The object characteristic

The result of determining the mathematical description of the object:

$$W(s) = \frac{25}{1 + 3.10^3 s} \tag{12}$$

In the process of using the microcontroller as a regulator that outputs PWM pulses to the buffer, the microcontroller must perform the work of synthesizing the set signal and the feedback signal taken from the temperature sensor. arduino circuit board:

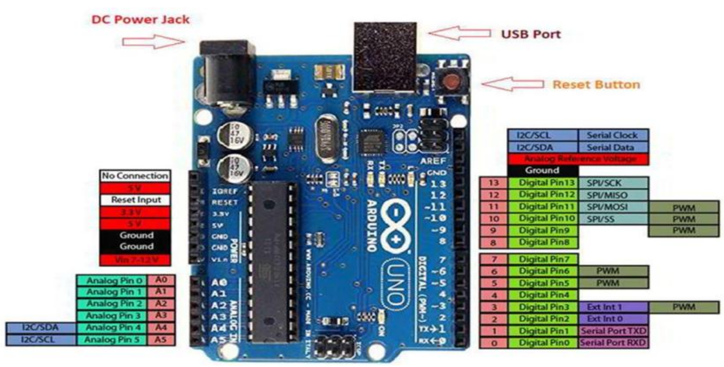
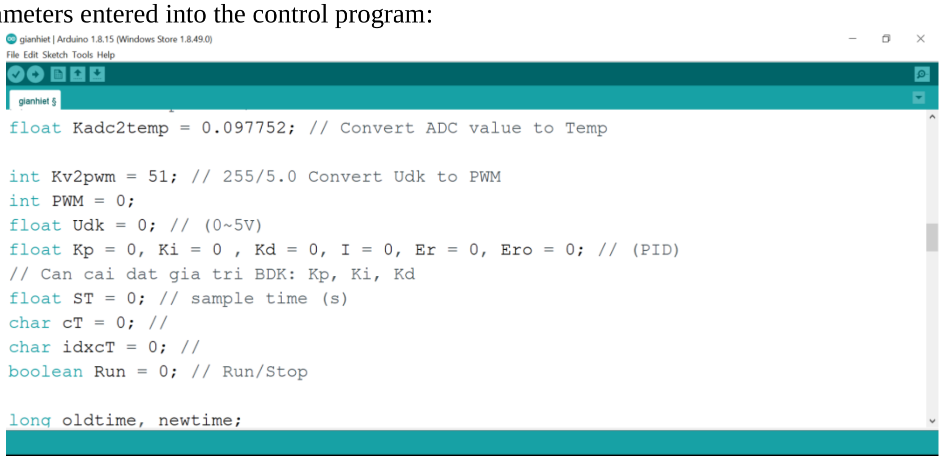


Fig 7 : arduino circuit board

Regulator parameters entered into the control program:



```
float Kadc2temp = 0.097752; // Convert ADC value to Temp

int Kv2pwm = 51; // 255/5.0 Convert Udk to PWM
int PWM = 0;
float Udk = 0; // (0~5V)
float Kp = 0, Ki = 0 , Kd = 0, I = 0, Er = 0, Ero = 0; // (PID)
// Can cai dat gia tri BDK: Kp, Ki, Kd
float ST = 0; // sample time (s)
char cT = 0; //
char idxcT = 0; //
boolean Run = 0; // Run/Stop

long oldtime, newtime;
```

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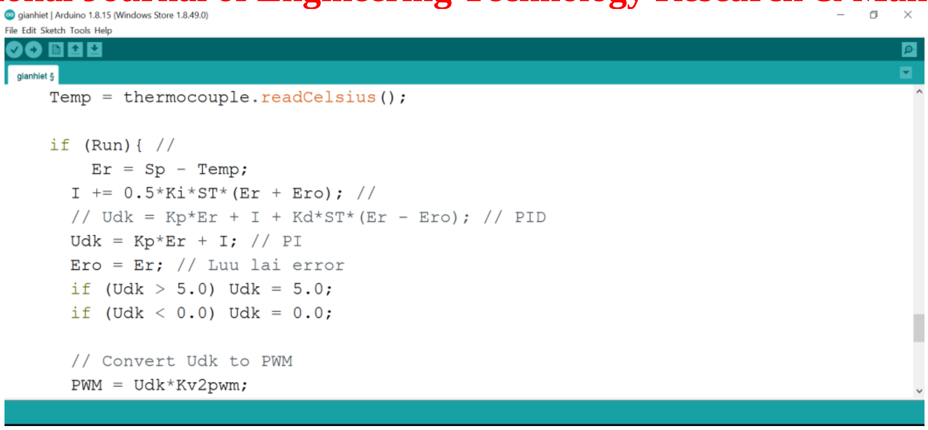

```
gianhiet | Arduino 1.8.15 (Windows Store 1.8.49.0)
File Edit Sketch Tools Help
gianhiet §
    Temp = thermocouple.readCelsius();

    if (Run){ //
        Er = Sp - Temp;
      I += 0.5*Ki*ST*(Er + Ero); //
      // Udk = Kp*Er + I + Kd*ST*(Er - Ero); // PID
      Udk = Kp*Er + I; // PI
      Ero = Er; // Luu lai error
      if (Udk > 5.0) Udk = 5.0;
      if (Udk < 0.0) Udk = 0.0;

      // Convert Udk to PWM
      PWM = Udk*Kv2pwm;
```

EXPERIMENTAL RESULTS

Experimental results are obtained when installing with a PID regulator and a DC fan creating disturb. Set PID regulator parameter to K_p=5; K_i = 0,01; K_d= 0.

In order to clearly observe the changing process of the control voltage, the temperature changes. The author has put "#define cycle 2000 // sample time (ms)" at the beginning, set "#define cycle 600 // sample time (ms)" when the temperature is already close to the set temperature.

We obtain the following experimental characteristics:

In Fig 8, and Fig 9:Red line - shows actual temperature; green line - control voltage; blue line - set temperature.

When the load is an AC fan, we see that the temperature quickly returns to the set temperature, which proves that the negative temperature feedback has stabilized under load or disturb.

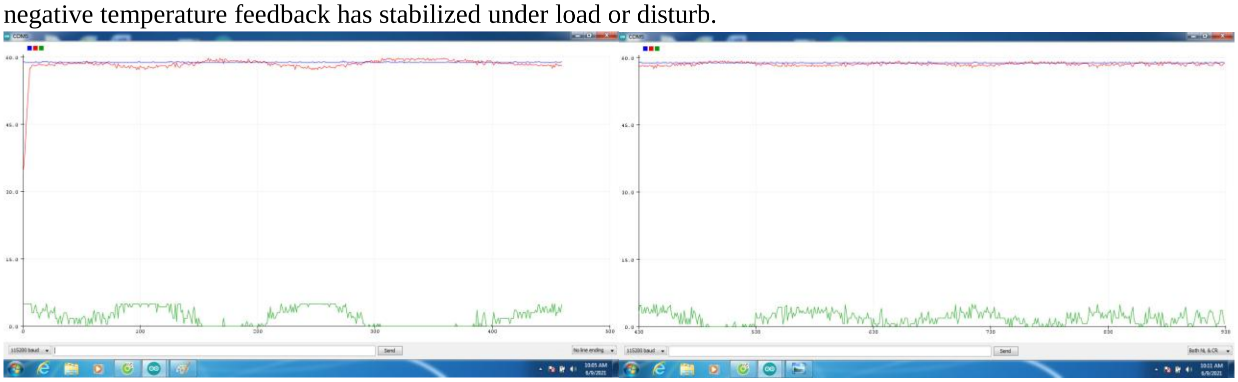

Fig 8: The object characteristicwhen there is a regulator

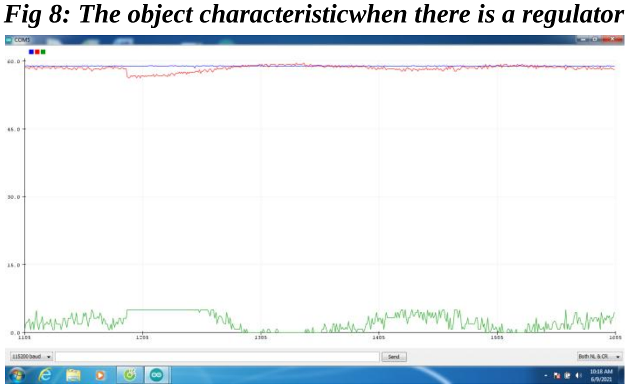

Fig 9: Feature line characteristics of the subject when there is a regulator after adding load

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CONCLUSION

The control object in the paper is the temperature of the heating object. With a temperature feedback control structure and a digital PID regulator, when using a microcontroller to control the heating object, we see that the system has met the requirements set forth: Faster transient time , less deviation, output stick to the set signal. However, because the heater system has a large inertia and a small setting, the output characteristic still has errors, but the error amount is small and meets the requirements.

ACKNOWLEDGEMENTS

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