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Research on Temperature Control System Based on WeChat Remote Operation

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***Abstract*—In this paper, a temperature control system using WeChat remote operation is designed, including a design of the connection method, circuit and improved PID control algorithm. Besides, the STM32f103 control board with ENC28J60 Ethernet transceiver chip, WeChat server, connection and data exchange mode of WeChat official account are introduced. At the same time, the usage of WeChat open interface will be introduced. The control instructions can be sent to the temperature control motherboard by users or researchers through WeChat official account, and the current temperature and historical temperature of the temperature control box can be inquired by accessing the device server.**

Keywords—WeChat remote operation; integral separation; anti-integration saturation; ZigBee

I. INTRODUCTION

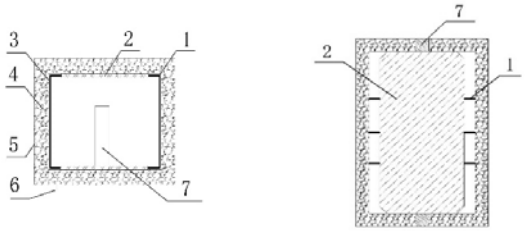
In the field of modern scientific research, ambient temperature is often an important test point that need to take into consideration, which is also an important factor that affects the experimental results. In many experimental environments, the ambient temperature can be more sensitive to the experimental requirements in a long time. Under the condition of dangerous test environments and long test period, the need emerges that temperature control system can be intelligent and can be controlled. In addition, the system can record the test temperature anytime and anywhere makes the system more usable [1-2].

With the development of the ZigBee[3-7], this concept is introduced to the field of instrument science gradually. S. Amendola used RFID for remote temperature control[8]. Genuine remote control is not realized because of the limited operating distance of RFID. X. X. Zheng proposed a remote temperature control system based on GSM[9]. The amount of data to transmiss by GSM is limited, and it is difficult to realize cloud processing. WeChat platform itself has three very friendly basic conditions: the first is the mature platform technology, the second is the huge user group, and the third is the open user platform. These three conditions make WeChat become the ideal control terminal of the intelligent device system for users[10].

In this design, the APP is not a necessity while the user only need to subscribe to the WeChat official account and input device number, temperature value in the official account. WeChat official account sends the data to the WeChat server. Then WeChat server sends the data to the ENC28J60 Ethernet transceiver chip through the URL interface. ENC28J60 Ethernet transceiver chip send data to the STM32f103 through the serial port. After that, STM32f103 adjust the temperature by operating silicon rubber heating plate or refrigeration compressor witch modified PID algorithm. In this process, the control instructions can be sent to the temperature control motherboard by users or researchers through WeChat official account, and the current temperature and historical temperature of the temperature control box can be inquired by accessing the device server.

II. SYSTEM COMPOSITION

The temperature control box containing silicone rubber plate for heating, refrigeration compressor for refrigeration whose type is Kangpu QD35, a small AC compressor. The box is made of two layers of iron - nickel alloy steel plate, and the steel plate is filled with adiabatic material, the size of the box is 30mm*25mm*45mm. The door of box can be opened in the front of box, with hinges linked between them, and the installation of the handle on the door is convenient for the installation of the test device. The Silicone rubber heating plate is installed in the front and back of the wall of the box, and compressor heat pipe is winded around inner layer of box. The compressor is installed on the rear side of the box to ensure that the radiator is well ventilated. The lower wall slotting on the box to the front wall is easy for the temperature control box to install on the stress loader. (The appearance of the temperature control box is shown in FIGURE I.)



(a)THE MAIN VIEW PROFILE (b) THE LEFT VIEW PROFILE

1. Condensing copper pipe of compressor; 2. Silicone rubber heating plate; 3. Inner layer iron nickel alloy steel plate; 4. Aerogel felt; 5. Outer layer iron nickel alloy steel plate; 6. Handle; 7. Mounting hole of stress loader.

FIGURE I. STURCTURE OF TEMPERATURE CONTROL BOX

The circuit connection of the system is shown in FIGURE II. Among them, the solid-state relay whose type is SSR-D3805HK-E will be isolated by optical coupled isolator to prevent electromagnetic interference generated by AC 220V to STM32f103ZET6, and to prevent damaging motherboard due to the improper insulation. The temperature heated by the

silicon rubber heating plate is controlled through the opening and closing process of the solid-state relay at a certain frequency. The digital potentiometer whose type is X9C103S controls the rotating speed of the compressor by controlling the conduction angle of the Silicon controlled voltage regulator whose type is BTA16-600B, through changing of the resistance, in which case, the low temperature can be adjusted accordingly.

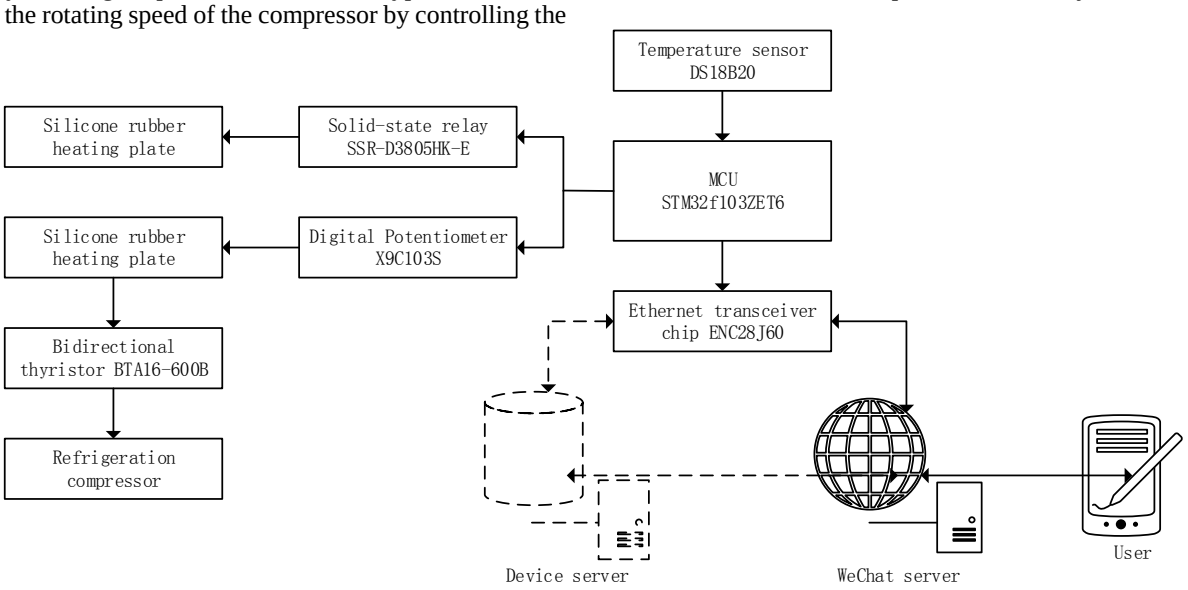


FIGURE II. CIRCUIT CONNECTION BLOCK DIAGRAM

The device server, whose role is to restore data for cloud operations is optional, and ENC28J60 can communicate directly with the WeChat server or communicate with the WeChat server through a device server. If the device server is required to provide data storage and query functions, it can be implemented by Linux on PC virtual machines or embedded devices such as ARM series. The Ethernet module can be replaced with a WIFI module to achieve good mobility

The WeChat server is a relay between the user and the device, and the WeChat public provides a good man-machine interface and a good operating experience. Users can send messages to WeChat official account conveniently through mobile devices such as mobile phones and pad. Messages of WeChat official account sent by users will be transmitted to the MCU by WeChat server, thus remote control and state query for devices can be realized. However the WeChat open platform only provides message forwarding services, and customized service system is required for a variety of custom function, in this case, equipment server or very be necessary to realize efficient remote control.

III. CONTROL ALGORITHM

Traditional PID is a simple and efficient way to control which will have some defects through, one of which is that the integral link makes the dynamic characteristics of the system worse. This section will give a modified PID algorithm based on the system model. The control block diagram of the whole system is illustrated in FIGURE III.

Traditional PID expression is:

$$T_u(t) = K_p\left(T_{err}(t) + \frac{1}{T_i}\int_0^t T_{err}(\varsigma)d\varsigma + T_d\frac{dT_{err}(t)}{dt}\right) \quad (1)$$

Where, $T_{err}(t) = T_{set} - T_{now}(t)$ that means the dynamic error, $T_u(t)$ is the set value of the temperature, K_p, T_i and T_d are proportionality constants.

While d_t is initialized as $20ms$ which is produced by TIM3 of STM32f103ZET6, the formula can be discretized as:

$$\begin{aligned} T_u(k) &= K_p T_{err}(k) + K_i\sum_{n=0}^{k} T_{err}(n) \\ &\quad + K_d\left(T_{err}(k) - T_{err}(k-1)\right) \end{aligned} \quad (2)$$

Where, $K_i = 1/T_i$, $K_d = T_d$.

The purpose of introducing integral in PID control is to eliminate static error and improve control precision. However, in the process of setting the start and end or greatly increase or decrease, great deviation of output system within a short period of time will cause the integral accumulation of PID operation. For that reason, the ultima control volume exceeds the limit control corresponding to the maximum range of operation permitted by the executing agency, which results in larger overshoot and even greater oscillation.

Considering the integral separation, this formula can be rewritten as:

$$\begin{aligned} T_u(k) &= K_p T_{err}(k) \\ &\quad + K_i\sum_{n=0}^{k} T_{err}(n)\cdot\varepsilon\left(e_{max} - \left|T_{err}(k)\right|\right) \\ &\quad + K_d\left(T_{err}(k) - T_{err}(k-1)\right) \end{aligned} \quad (3)$$

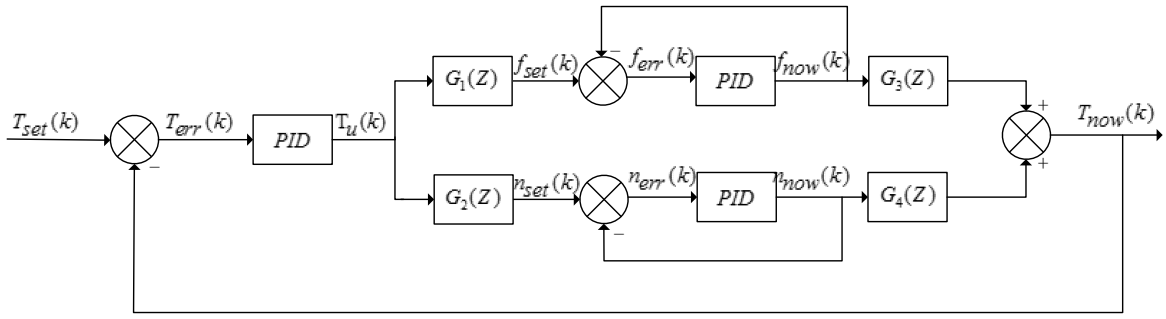


FIGURE III. THE CONTROL BLOCK DIAGRAM OF THE WHOLE SYSTEM

Where , $\varepsilon = (e_{max} - |T_{err}(k)|)$ is the step function, $e_{\max}$ is a constant that is related to the system.

The heating and cooling processes of the temperature control system are all highly time-dependent control processes; especially the nonlinearity of the relationship between motor speed and voltage is particularly evident in low voltage and high voltage areas.

In order to solve this problem, anti-integral saturation is needed. The cooling inner ring is designed as:

$$\begin{aligned} n_u(k) &= K_p n_{err}(k) \\ &+ K_i\left(\sum_{n=0}^{k-1} n_{err}(n) + \Delta'(k)\right) \\ &+ K_d\left(n_{err}(k) - n_{err}(k-1)\right) \end{aligned} \tag{4}$$

$$\begin{aligned} \Delta'(k) = n_{err}(k) \cdot (&\varepsilon(n_{min} - n_{err}(k)) - \varepsilon(n_u(k) - n_{max})) \\ &\cdot \varepsilon(n_{max} - |n_{err}(k)|) \end{aligned} \tag{5}$$

Where, $n_u(k)$ is expected speed, $n_{err}(k)$ is the speed error, n_{max} is the maximum speed of approximate linear region , n_{min} is the minimum speed of approximate linear region.

When the temperature T_{now} is lower than $T_{set} - \Delta T$, the solid-state relay is enabled and the silicon rubber heating plate begins to work. The difference in temperature is converted to the frequency of the opening and closing of the solid-state relay. Here, a cycle is composed of Opening and closing time, and the opening time occupies 50% of the entire cycle. The trigger frequency of the solid-state relay can be described as:

$$f_{relay} = T_u(k) \cdot \mu \tag{6}$$

Where, μ is a frequency product constant set before which depends on the thermal efficiency of the silicon rubber heating plate and the maximum allowable trigger frequency of the solid state relay, f_{relay} is usually limited between the range that $0 < f_{relay} < 100Hz$.(High f_{relay} will exceed the allowable frequency of the solid-state relay and cause damage.)

ΔT is set up to prevent overshoot caused by rapid oscillation considering that an inert interval can slow down the oscillation. When the temperature T_{now} is higher than $T_{set} + \Delta T$, the refrigeration compressor start working. The rotational speed n of the refrigeration compressor can be described as:

$$\begin{aligned} n_u(k) &= \frac{9550P}{T} \\ &= \frac{9550P \times \omega_1[(R_s + \frac{R_r'}{S})^2 + \omega_1^2(L_{ls} + L_{lr}')^2]}{\frac{3n_p U_S^2 R_r'}{S}} \\ &= \frac{9550P \times \omega_1[(R_s + \frac{R_r'}{S})^2 + \omega_1^2(L_{ls} + L_{lr}')^2]}{\frac{3n_p \times \sum_{n=0}^{k}(\sqrt{2}U_i \sin\frac{\delta T_u(k)}{R_{sum}}) \times R_r'}{S}} \end{aligned} \tag{7}$$

Where, δ is the product constant for calculating the setting resistance of the digital potentiometer whose type is X9C103, P is power supplied, U_i is the effective value of the input voltage, ω_1 is the circumferential frequency of power supply, s is the transfer rate, n_p is rated speed, T_{sum} is the total resistance of the digital potentiometer, R_s, R_r', L_{ls}, L_{lr}' are structural parameters of the motor.

Cascade PID control is adopted in the system both in heating and refrigeration link. The integral separation and integral saturation theory are used for each PID controller. The outer ring is a temperature ring and the inner ring is the ring of the solid-state relay and the speed ring of the compressor. $T_u(k) \cdot G_i(Z)$ obtained by the outer ring is the target value of the inner ring. $f_{now}(k)$, $n_{now}(k)$ are the feedback of the inner ring, respectively.

In this model, $G_1(Z) = \mu$ as described above. $G_2(Z)$ can be described as:

$$G_2(Z) = \frac{\mathcal{L}[Q(k)]}{\mathcal{L}[T_u(k)]} \tag{8}$$

$$Q(k) = \frac{(9550P \cdot \omega_1[(R_s + \frac{R_r^{'}}{S})^2 + \omega_1^2 (L_{ls} + L_{lr}^{'})^2])}{\frac{3n_p \cdot \sum_{n=0}^{k} (\sqrt{2}U_i \sin \frac{\delta T_u(k)}{R_{sum}})^2 \cdot R_r^{'}}{S}} \quad (9)$$

The transfer function $G_3(Z)$ and $G_4(Z)$ are related to many factors such as the performance of the equipment, the heat transfer rate and the temperature outside the box. The accurate transfer function of $G_3(Z)$ and $G_4(Z)$ can not be calculated, and specific analysis is not given here due to their complexity and uncertainty.

In this system, the feedback for calculation $T_{err}(k)$ is realized by the temperature sensor DS18B20. The sensor will send data to MCU through the one-wire bus directly, in which case the system does not need to spend too much resources and time on the AD conversion. The accuracy of the system is determined by the accuracy of $T_{err}(k)$, so the system uses 3 sensors for median filtering and mean filtering to obtain accurate errors. As temperature measured is the ambient temperature simulated by equipment, three sensors must be effectively suspended in the air.

IV. Implementation of Remote Operation

The device server consists of STM32f103 and ENC28J60 Ethernet transceiver chips. The device server provides an interface URL to exchange data with the WeChat server. When accessing the WeChat platform API, URL, Token, and EncodingAESKey generated randomly are needed[11] (as shown in TABLE I).

TABLE I. MEANINGS OF NOUNS

Name	Meaning
URL	for receiving data from the server
Token	for the generation of a signature
Encoding AESKey	as a message body to decrypt the key

After providing the message, WeChat server will send GET request to the URL address to fill in, checking the signature sent by WeChat server to verify whether the message comes from WeChat server.

Access_token is the global unique interface call credential for the official account, and access_token is used when the WeChat official account call each interface. Developers need to be properly preserved. The storage of access_token must retain at least 512 character spaces.

When sending the request, three parameters required are grant_type, access_token and appid. The parameter grant_type is to obtain access_token to complete client_credential. The parameter appid is applied for third party certification and the parameter secret certificate is required for third party user key, i.e. appsecret. Normally, WeChat server will return the JSON packet to the official account.

After verification, the connection between WeChat server and user device server is effective. Users can realize remote control and status query indirectly through the communication between WeChat official account and devices. What the user needs is just a mobile device to realize this process.

When setting the temperature, users can choose the device and set the temperature through the menu bar at the bottom of the WeChat official account, which is visualized. After receiving the data sent by WeChat server, the message will be packed into a string, for example, "Device: 001, Temp: 20", and execute it strictly. When STM32f103ZET6 receives the data package, it will get the device number of temperature control box that is 001, and it needs to reach a constant temperature of 20 degrees. When the user need to query the current temperature of the temperature control box, a request is sent to the WeChat official account, such as "Device: 001, Query". After receiving a string send by the WeChat server, the device server saves the string firstly and then use the regular expression regular expression syntax to detect that whether the word “Query” is involved in the string. If the word does exists, the corresponding value will be find with key “001”. The temperature values sent to the device server by STM32f103ZET6 will be saved in the device server in the form of a dictionary in advance.

V. Conclusion

Combined with the example of this design, the improved PID algorithm is given based on the mechanical characteristic model of the motor and the heating model of the silicone rubber. The error of the temperature control box can be limited to 0.5˚C through the three loop cascade PID algorithm with integral separation and anti-integral saturation. Integral separation ensures the fast response of the system. The anti-integral saturation theory avoids the delay caused by the defect of asynchronous motor.

The development of the Internet of things and the use of the open platform of WeChat make the remote control and state query of the equipment be realized. A solution to the remote operation is given with a good use of the platform. Under the condition of dangerous test environment and the test which is long distance away or needs long period, users can control and monitor the temperature control box through the WeChat official account.

Besides, the cloud interfaces (such as the GIZWITS, http://www.gizwits.com/) provided by many vendors have also made the development of the Internet of things develop rapidly which can be an alternative to the device server. Cloud providers provide storage space for data, and of course, the interface of HTML control involved. With these cloud service platforms, users can query the previous temperature state and analyze the previous data. With these tools, MCU only needs to send data to a fixed URL to control and manage the device.

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