A Peristaltic Pump Controller Design with Wireless Communication

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***Abstract*—With the development of wireless communication and computer networks, wireless network has a very wide range of applications on instruments to improve information acquisition and processing capabilities. A peristaltic pump controller with MCU is designed. The controller is constructed with the working network of ZigBee to realize multiple peristaltic pump monitoring and collaborative work. The controller adjusts the speed with index movement frequency according to the torque-frequency characteristic of step motor. And the controller uses the DC motor to control the pump head angle to make the peristaltic pump more convenient to use. The H-bridge circuit is used to control the DC motor steering, and short brake can make DC motor brake fleetly. This controller has good stability and control accuracy, strong practicability.**

Keywords-peristaltic pump; MCU; zigbee; speed adjustment; h-bridge

I. INTRODUCTION

Peristaltic pump is a kind of liquid conveying appliance which can control the flow direction and flow velocity, and it consists of the driver, pump head and tube. With the rotary roller extrusion tube, the liquid in the tube move with the rotation of the roller. Because peristaltic pump has advantages of good sealing, no pollution, high precision, it applies to medical, pharmaceutical and food. Micro Controller Unit (MCU) is regarded as processor in the peristaltic pump controller. The liquid flow direction and flow velocity are set and the peristaltic pump working status is controlled by key module. MCU processes settings, executes instructions and completes controls the peristaltic pump. In addition, MCU does also driver display module to monitor the work style and state of the peristaltic pump. In the peristaltic pump applications, the liquid flow velocity control is the key design, and the liquid flow velocity is directly related to the peristaltic pump roller, i.e. the flow velocity is proportional to the rotational speed of the roller. The roller driving motor is step motor to accurately control the rotational speed of the roller. The step motor is driven by drive module, and the pulse into the drive module input terminal can accurately control the step motor speed. Index movements frequency is selected to control motor speed. The method makes the speed change fast and smooth. The peristaltic pump is low requirement in work angle, so it is controlled in Direct Current (DC) motor. Relays constitute the bridge arm of the H-bridge circuit, and relay contacts achieve short braking. Because peristaltic pump more work in the room, a star network is built with ZigBee. Computer simultaneously monitors a plurality of peristaltic pumps to improve processing capability.

II. CONTROLLER PRINCIPLE

A. Step Motor Step Pulse Frequency Modulation Method

When the step motor starts at a high frequency, the motor can not start, and even it stalls that can not run. When the step motor stops from a higher frequency, the motor may occur to overshoot phenomenon due to the inertia [1]. Thus in the process of controlling the step motor, it is necessary to gradually adjust step motor control frequency in accordance with its torque-frequency characteristics. Two common control methods of step motor acceleration-deceleration are linear movements frequency and index movements frequency.

Linear movements frequency defines that speed is raised or lowered at a constant acceleration. At low frequencies the larger torque of the motor can not be taken full advantage of, while at high frequencies motor is easy to be out of step. According to the torque-frequency characteristic, when the frequency is low, the torque is large, angular acceleration is larger, so the increment rate of the pulse frequency can also be more. Conversely, when the frequency is high, the torque and angular acceleration are small, so the increment rate of pulse frequency should be lower. Therefore, increasing frequency process should follow the “first fast after slow” principle. Therefore, step motor is controlled with index movements frequency.

B. ZigBee Network Configuration

ZigBee is a Low-Rate Wireless Personal Area Network (LR-WPAN) specification on the basis of Physical Layer (PHL) and Media Access Control (MAC) defined by IEEE802.15.4. According to the communication capability of the equipment, the device can be divided into Full Function Device (FFD) and Reduced Function Device (RFD). FFDs, FFD and RFD can communicate with each other, but RFDs can not communicate with each other. Depending on the device network tasks, ZigBee network device is divided into the network coordinator, network routers and network terminal device. Coordinator and router usually consist of FFD, and terminal equipment is composed of RFD [2, 3].

ZigBee can build a star network or a peer-to-peer network. In a star network, all devices communicate with network coordinator, and network routers do not have a role in routing. When building a stat network, started FFD broadcasts network coordinator request. If there is no response, the FFD

automatically becomes a network coordinator and selects a different identifier with the others in the region. After selecting the identifier, the network coordinator will be able to add other network devices. In peer-to-peer network, any two devices can communicate directly, so it can be built into Mesh network. In the network, every FFD can be used as a network router, but only one FFD can be used as a network coordinator which is responsible for the network establishment and configuration.

III. PERISTALTIC PUMP CONTROLLER DRIVE IMPLEMENTATION

A. Controller Hardware

Controller is mainly responsible for the liquid flow direction and flow velocity, peristaltic pump working angle control and peristaltic pump working network construction. In order to make the rotational speed of the peristaltic pump rollers can be accurately controlled, the roller driving motor is step motor. Further, in the network building part, the star network is built with ZigBee, because the form of the star network is simple and the star network is suitable for using in small-scale indoor. Through the above analysis, the controller is divided into six parts: MCU, step motor drive module, DC motor driver, display module, key and ZigBee module. Block diagram of the controller is shown in figure 1.

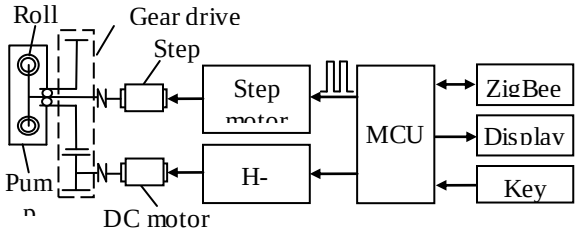

FIGURE I. BLOCK DIAGRAM OF THE CONTROLLER

B. H-bridge DC Motor Steering Control Circuit

H-bridge driver circuit can control the steering. In the H-bridge circuit, DC relay is a current-driven device. Relay contacts constitute the bridge arms of H-bridge, and a pair of contacts on the diagonal is a group. When the same group of contacts is simultaneously turned on, current flows through the DC motor from left to right or from right to left to control the motor steering. However, different groups of contacts can not be turned on, otherwise it will cause short circuit to burn power. A relay has a normally open contact and a normally closed contact, and these two contacts can be used as bridge arms of H-bridge, so an H-bridge driver requires only two relays. Because the normally open contacts and the normally closed contacts of the same relay can not pull in, it avoids the different groups of switches to turn off at the same time.

After DC motor outage, due to inertia the motor will not stop immediately. This phenomenon affects the control accuracy of DC motor. In order to improve the control accuracy of the DC motor, motor brakes with short connection, i.e. the input of the motor is shorted after motor outage. Because due to the inertia the motor works in a state of power generation, short equals to that output of power generation shorts out, and a reverse current is produced in the loop. The reverse current causes the motor to generate a reverse torque and it counteract the inertia to make the motor fast brake. H-bridge driver circuit is shown in figure 2.

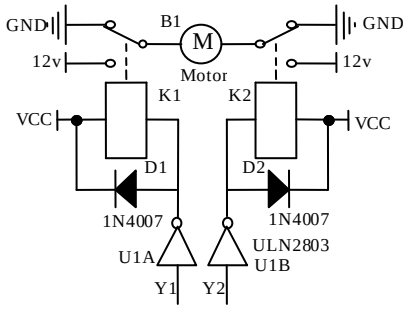

FIGURE II. H-BRIDGE DRIVER CIRCUIT

H-bridge drive circuit consists of relay continuous current circuit, relay driver circuit and relay. U1A and U1B are two channels of Darlington transistor ULN2803. When MCU output is '1', the Darlington transistor driver circuit is turned on, and the normally open contact is closed. Otherwise, the normally closed contact is closed. After the relay is power off, the coil will continue to maintain a larger current [4]. If there is no current release circuit, the current is applied to the driver to make the driver damage. So a reverse diode is paralleled to make coil discharge.

When the state of combination input Y1 and Y2 is '10', the current direction is from left to right. When the input state of Y1 and Y2 is '01', the current direction is from right to left. When the input state of Y1 and Y2 is '00', the input of the motor is shorted to achieve short braking.

IV. MCU SOFTWARE DESIGN

A. The Rise-and-Fall-Frequency Method Implementation

Producing a series of pulse whose frequency is adjustable is an essential part of the step motor speed control. The methods MCU producing pulse are software delay and hardware timer. Software delay is achieved by delay subroutine. This method reduces the efficiency of MCU. Therefore, hardware timer is used. Programmable Counter Array (PCA) module of MCU operates in the high-speed pulse output mode. The output pulse frequency is changed by changing the time constant of internal register. This method occupies fewer software resources, saves instruction time and improves the MCU efficiency.

According to the speed-up/down curve, increasing frequency process approximates an exponential curve, and the software calculation method to obtain the time constant will take a lot of the MCU resources. Therefore, the various discrete points of speed corresponding to the time constant of the timer is stored in Read Only Memory (ROM), the desired time constant is looked up through look-up table method while the system is running. The method reduces the MCU running time and improves system responsiveness. Step motor deceleration process is the reverse process of the acceleration process. Therefore, they can share a data table, i.e. the table must reverse lookup for deceleration. The rise-and-fall-frequency software flow chart is shown in figure 3.

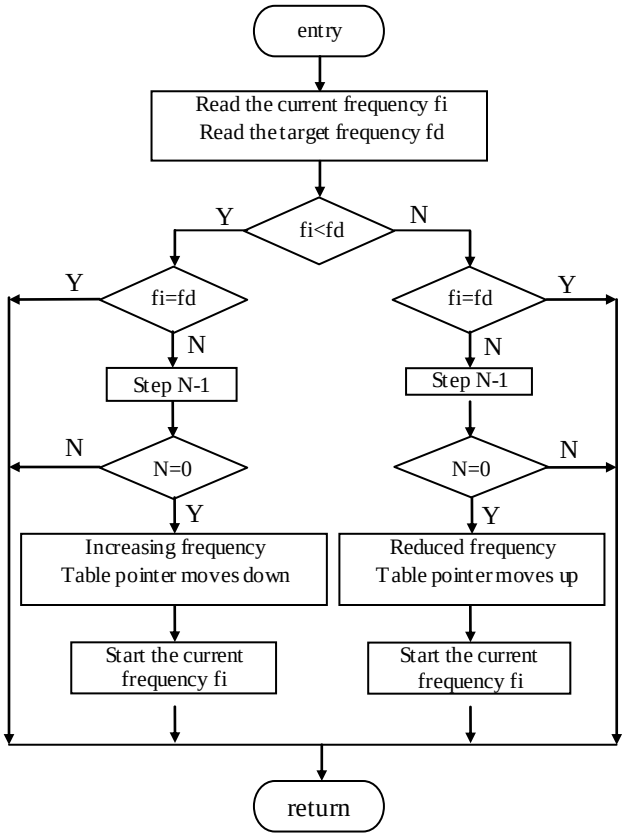

FIGURE III. RISE-AND-FALL-FREQUENCY SOFTWARE FLOW CHART.

B. *Display Data Processing Method*

Display module is a intelligent human-machine interface system, and it can drive colorized screen and process the data. MCU completes display data transmission and the page control through serial ports. In order to adapt to the operator's operation habit, the method of multilevel menu display is adopted [5].

Firstly, display information file is established, and the content displayed in each screen, parent page information, current page information and subordinate page information are written in the file display.h according to a certain format. A structure page is established. Structure variables combine different types of variables to a combination variable, as follows.

```
struct page
{
void (*op[4])();   //key function pointer array
unsigned char dat[10];  //display data
unsigned char ppage;   // parent page information
unsigned char cpage;   // current page information
unsigned char spage[10]; // subordinate page information
};
struct page page1={//the first page display information
{add1,add2,add3,add4},// key function addresses
{5,0,5,360},//display data
0, // parent page number
1, // current page number
{4,5,6}          };// subordinate page number
```

There are five variables in a structure. Each menu corresponds to a number, so according to the number the data is displayed on the display module. Different key function is performed in different pages to complete the page switching, data display, equipment monitoring and other functions.

C. *The Main Control Flow Design*

The controller completes device initialization, ZigBee wireless communication, the data transmission with the display module, keys scanning and controlling the motor operation state. In the design, the cyclic scan is used to achieve the above functions. A star network is established by ZigBee, and different device address is assigned to each child device. In addition, the computer with strong data processing ability is a network coordinator to complete monitoring peristaltic pumps and forwarding network data. MCU communicates with display module through point-to-point form. Two communication buffers are set up in register to store the communication data, and the data in the register will be transmitted in each scan cycle. Keys scanning and motor control are completed through the I/O. In order to ensure the reliability of input and output, input and output data register is established, and all of the I/O ports are read and written in every cyclic. System is periodically scanned with MCU timer interrupt. MCU communication function and I/O port read write functions are activated in timer interrupt. After the functions are completed, the main function is returned and the next scan cycle is waited for. Waiting for the timer interrupt, the key performance function is executed. In each performance function, registers are operated instead of serial and I/O ports. The controller control sequence diagram is shown in figure 4.

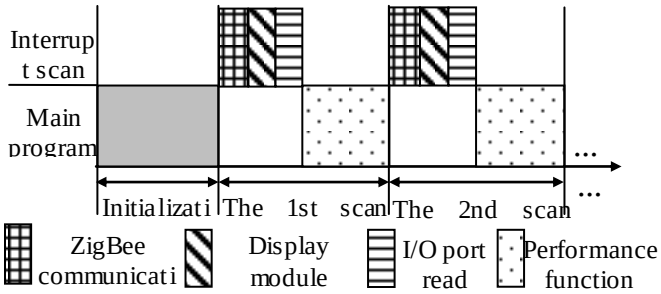

FIGURE IV. THE CONTROLLER CONTROL SEQUENCE DIAGRAM.

V. CONCLUSION

The ZigBee technology is applied to the peristaltic pump controller with the computer as the network coordinator and peristaltic pumps as the network terminal equipments which together constitute a star network. This kind of network can improve the peristaltic pump information acquisition and processing ability to ensure the whole equipment monitoring and collaborative work. The peristaltic pump controller is designed based on MCU. The key is responsible for setting the liquid flow direction and flow velocity and controlling the

working state. At the same time, the working state is displayed on the display module. Step motor rotational speed is adjusted with index movement frequency. This method can take full advantage of effective torque and improve the regulation speed. The hardware timer generates pulse whose frequency is adjusted with look-up table method. The H-bridge circuit designed with relays can effectively control the pump head rotary motor steering and brake, which can accurately control the working angle of the pump head. The controller has good performance and a strong practical.

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