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STC89C52 microcontroller-based infusion vial monitoring device and design

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Abstract: These In this paper, in view of the problems existing in the process of modern medical intravenous infusion, a full-featured, lightweight and portable infusion vial monitoring device is designed, which is mainly controlled by the STC89C52 microcontroller for the main control, and the LCD1602 liquid crystal display is used for real-time displaying the speed of the droplets' lowering, the alarm of the buzzer, and the stepping motor automatically blocking the flow of the liquid, etc. The device is equipped with a slot of the cell phone card, which is capable of Notify family members through cell phone communication. The progress of the patient's infusion is obtained through sensors, realizing real-time sensing and monitoring of the infusion process, reducing the burden of healthcare personnel, and improving the quality of life and convenience of patients.

Keywords: Intravenous infusion; monitoring device; microcontroller; buzzer; stepping motor.

1. Introduction

Intravenous infusion is one of the common therapeutic and nursing operations in clinical practice. It was found that the utilization rate of intravenous infusion in hospitalized patients was 93.13%, and the average number of infusion bottles (bags) used per bed per day was 3.76 bottles[1] . During infusion therapy, patients and their families and nurses need to closely observe the infusion situation in order to replace the infusion or end the infusion in a timely manner, to avoid the return of blood to the infusion line, extravasation of drugs, or air input into the blood vessels resulting in air embolism and other adverse consequences[2] .

In medical practice, careful monitoring and management by healthcare professionals has been relied upon to ensure that patients receive safe and effective treatment. However, there are many problems with traditional infusion monitoring methods, such as relatively outdated technology, single function, insufficient measurement accuracy, low sensitivity, poor reliability, as well as a lack of automation and intelligence, and other features, which have constrained the efficiency and accuracy of infusion monitoring and increased the workload of healthcare professionals.

With the continuous advancement of medical technology and the high priority given to patient safety, there is an increasing demand for infusion monitoring devices. The aim of this study is to introduce a new infusion sling monitoring device that fully integrates mechanical circuits and medical scenarios to provide an innovative solution for medical infusion. The goal of the device is to monitor key parameters during infusion, such as drip rate, flow rate, and infusion progress, and to automatically cut off fluid delivery at the end of the infusion, as well as to provide timely end-of-treatment alerts by sending alerts to healthcare professionals and family members.

Although the domestic intelligent infusion alarm device can detect whether the drip is completed or not, the precise control of the infusion drip rate still needs to be improved. Such devices are relatively lagging behind in technology, single-function, low precision, and lack of intelligent features, and thus show insufficient reliability in practical applications. Against this background, this study aims to fill the gap in this field by developing a fully functional, portable and lightweight infusion vial monitoring device.

The results of this research include a number of functions such as automatic alarm, drip cut-off, flow rate detection, infusion progress judgment, automatic heating, and communication connection. This will not only reduce the workload of healthcare workers, but also improve the safety and reliability of treatment, making patients and their families feel more at ease. In addition, the wide application of the device will help promote the development of smart healthcare in China and bring positive impact to the medical field.

In the next section, the design, working principle and performance characteristics of this innovative infusion vial monitoring device will be introduced in detail, as well as its application prospects in actual medical scenarios. This work provides safer, more efficient and intelligent infusion monitoring solutions for the medical industry and promotes the continuous progress and innovation in the medical field.

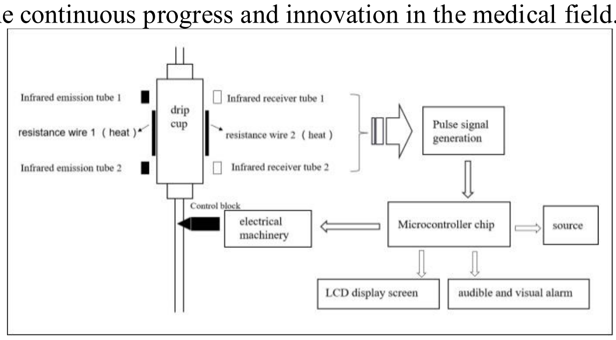

Fig. 1 General design of infusion vial monitoring device

2. Design proposalt

The infusion monitoring device adopts the design scheme combining the main module and sub-module. The main module is a minimum system board based on STC89C52 microcontroller, which contains the main chip and crystal circuits and reset circuits. The sub-module, on the other hand, consists of an infrared pair tube module, a buzzer alarm module, an LCD module, a stepping motor module and a wireless network communication module. The operation of the system involves the interconnection of the modules, i.e., a sub-master-sub-module communication architecture is adopted, in which the sub-modules transmit the collected data to the master module, which processes the data and passes it on to the other sub-modules. Specifically, the infrared pair of tubes module is used to measure the infusion safety status such as the current drip rate of the infusion, whether or not the infusion is completed, and whether or not blockage occurs. The module collects pulse signals through U-shaped photoelectric sensors and passes these signals to the main module. The main module performs analog-to-digital conversion, converts them to digital signals, and transmits the results to the LCD module. At the same time, the main module sends commands to the buzzer alarm module and the stepper motor module to trigger alarms and take measures to block the liquid in the hose. Abnormal conditions are also transmitted to the patient's family to alert the relevant personnel. As shown in Fig. 1, the design scheme of the infusion monitoring device covers the collaboration between the main module and several sub-modules. The system realizes the monitoring and safety control of the infusion process through infrared technology, LCD display, alarms and control of stepper motors.

2.1. Hardware Design

This design firstly receives the signal through the U-type photoelectric sensor, subsequently, the signal is transferred to the microcontroller through photoelectric conversion, and then the microcontroller carries out the operation and the realization of the main control function. In the synchronized state, the droplet speed module implements the microcontroller-based multiplexing management through serial communication, which converts the droplet speed into high and low levels and is controlled by the microcontroller. If the drop is not detected by the U-type photoelectric sensor, it will cause the diode to light and the buzzer to sound.

The infusion vial monitoring device includes a detachable device housing attached to the outside of a drip pot, with a main chip, an infrared pair of tube module, a buzzer alarm module, a stepping motor module, a liquid crystal display module, and a wireless network communication module housed inside.

The IR-to-tube module consists of two U-shaped photoelectric sensors that are fixedly attached to the unit's housing, arranged in parallel above and below, and staggered front to back. This module can effectively and accurately determine three types of infusion conditions: normal infusion, abnormal infusion (e.g., no flow due to obstruction of the hose underneath), and completed infusion.

The system utilizes a five-step, four-phase stepping motor, including a stepping motor connected to a main chip and a tube clamping mechanism connected to the output shaft of the stepping motor. The stepper motor slides back and forth along the length direction of the guide rail by driving a push rod, thereby realizing the clamping or releasing operation of the dropper by the clamping mechanism.

The schematic diagram of some of the module circuits is shown in Figure 2.

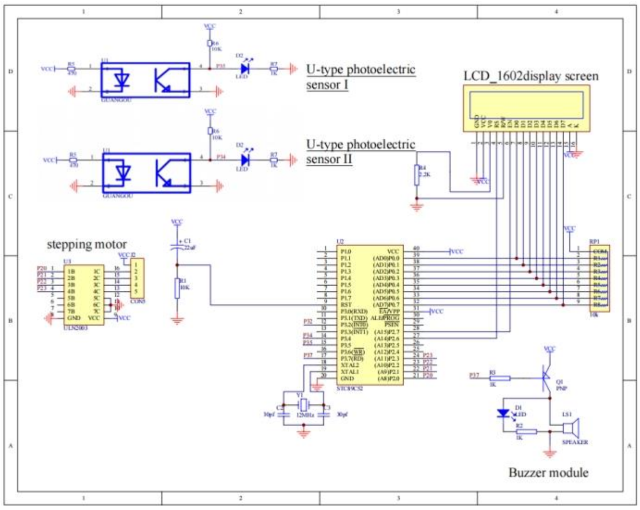

Fig. 2 Schematic diagram of some module circuits

(1) Infrared Pair Tube Module

The use of slot photoelectric switch (U-type photoelectric sensor), by the combination of infrared transmitter tube and infrared receiver tube, the transmitter and receiver are located on both sides of the U-shaped slot, forming a light column. When the medicine drops, the medicine in the drop produces diffuse reflection, absorption and scattering of infrared light, resulting in a large change in the intensity of the received light, which causes the photoelectric switch to produce a detected switching signal.

In order to solve the problem of inaccurate monitoring in the existing infusion alarm devices and to take into account the versatility and convenience, we introduced the double staggered infrared pair of tubes technology. In the drip pot part of the infusion device, we installed two U-shaped photoelectric sensors arranged in parallel above and below and staggered front and back. The upper U-shaped photoelectric sensor is used to detect the flow rate of the droplet, and the lower U-shaped photoelectric sensor is used to detect whether there is any liquid left. The infrared light between the transmitter and receiver tubes of the upper U-type photoelectric sensor propagates in the direction of the diameter of the cross-sectioned circular surface of the drop pot, while the infrared light between the transmitter and receiver tubes of the lower U-type photoelectric sensor intersects the cross-sectioned circular surface of the drop pot, forming a superior arc and a inferior arc. These two U-shaped photoelectric sensors are able to distinguish between the three situations during infusion:

1. Normal infusion: Both upper and lower U-type photoelectric sensors detect the liquid, and the upper U-type photoelectric sensor can detect the flow rate.

2. Abnormal infusion, such as the following hose obstruction caused by the non-flow of liquid, etc.: the upper U-type photoelectric sensor can not detect the liquid drop, but the lower U-type photoelectric sensor can detect the liquid, this time the device issued an abnormal alarm.

3. Completion of the infusion: no liquid is detected by either the upper or lower U-type photoelectric sensors, the device issues an alarm and performs a blocking operation on the infusion hose.

The IR-to-tube module unit connection is shown in Figure 3.

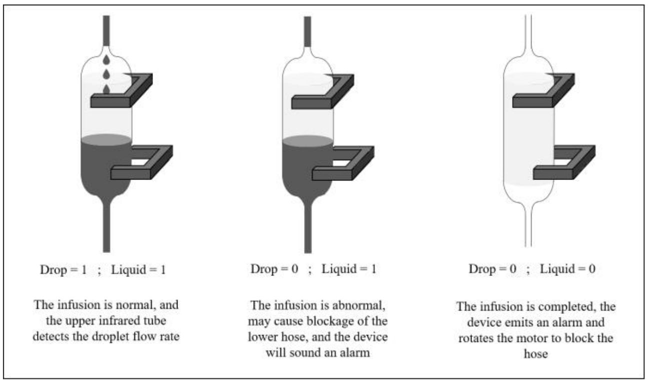

Fig. 3 Schematic diagram of infrared pair tube module

(2) Buzzer Alarm Module

In this design of alarm device, the active buzzer is powered by DC voltage, and this buzzer is widely used as an alarm device in electronic products such as electronic computers, electronic watches, printers, etc. Its sounding principle is through the current through the electromagnetic coil, generating a magnetic field which drives the vibrating membrane to emit sound.

In this design, the alarm threshold of the buzzer is designed based on the time the liquid is detected by the U-shaped photoelectric sensor below. When the time for which no liquid is detected exceeds the preset threshold, the buzzer sounds an alarm. The alarm will continue for a period of time and will stop if liquid is subsequently detected. If liquid is still not detected, the buzzer will continue to sound the alarm.

(3) Stepper Motor Modules

The stepper motor module in this design is used to perform the liquid blocking operation on the infusion tube. It works in synchronization with the alarm module. When the U-type photoelectric sensor does not detect the liquid, the microcontroller will control the stepper motor to rotate at a certain angle, thus squeezing the dropper and preventing the air from entering by driving the attachment to rotate together.

The pipe clamping mechanism consists of a linkage, a pusher and a guide rail. The stepper motor and guide rail are fixed in the housing of the device and they are arranged perpendicular to each other. The guide rail is located next to the dropper, and the push rod can slide along the length of the guide rail. One end of the connecting rod is connected to the output shaft of the stepper motor and the other end is connected to the push rod.

On the push rod, there is a fixed swivel pin, while the connecting rod has an elongated through-hole set along its length. The rotating pin passes through this through-hole. Thus, when the stepper motor is activated, the rotation of the connecting rod drives the push rod to slide back and forth on the guide rail, thereby compressing the dropper to block the flow of liquid or moving the push rod out of the way to maintain the through-hole.

Additionally, a fixed blocking block can be mounted in an extended position on the guide rail, which is attached to the device housing, on either side of the dropper. In this way, the actuator only needs to provide a small amount of travel to squeeze the dropper in conjunction with the blocking block without having to squeeze against the inner wall of the device housing.

The working schematic of the stepper motor module is shown in Figure 4.

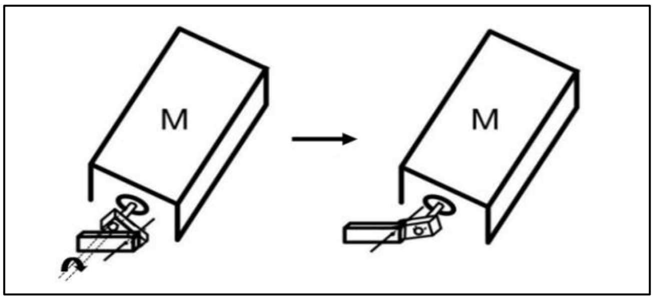

Fig. 4 Working principle diagram of stepper motor module

(4) Liquid Crystal Display Module

The LCD1602 display is employed to accurately display the liquid flow rate (in drops/minute) and the real-time temperature of the drug solution (in °C). It is characterized by visual comfort, simple structure, economical price and easy operation.

(5) Wireless Network Communication Module

A GSM module is used and communicates with the microcontroller through a serial communication interface (e.g. TTL or RS232). The module is powered by a regulated 5V power supply. The data is encoded into a format understandable by the modem at the time of sending and then transmitted to the GSM network. On receiving the data, it is decoded and transmitted to the microcontroller. The communication protocol defines details such as the format and rate of the data as it is transmitted to ensure accuracy and reliability of data transmission

2.2. Software design

The system software is mainly developed in Keil uVision5 development environment for compiling and debugging STC89C52 microcontroller. The main program includes infrared pair tube module, buzzer alarm module, stepper motor module and wireless network communication module.

The main program is developed according to the design requirements of each module and the system flow is shown in Figure 5. Once the device is installed and activated, it first monitors the situation inside the infusion tube through two photoelectric sensors, and the detection of a drop or column of liquid indicates that the device is working properly. During normal operation, the program detects the number of drops every five seconds to calculate the drip rate and displays the result on the LCD screen.

When the program does not detect any droplets or columns of liquid, i.e. when the infusion is abnormal or finished, the program will first control the stepper motor to cut off the infusion tube and then trigger the buzzer to sound an alarm. If the alarm continues for a period of time and no action is taken, the program will control the GSM module to send an SMS or make a phone call to the family to remind them to deal with the abnormality in time. This dual alarm mechanism ensures that infusion abnormalities can be handled in a timely manner.

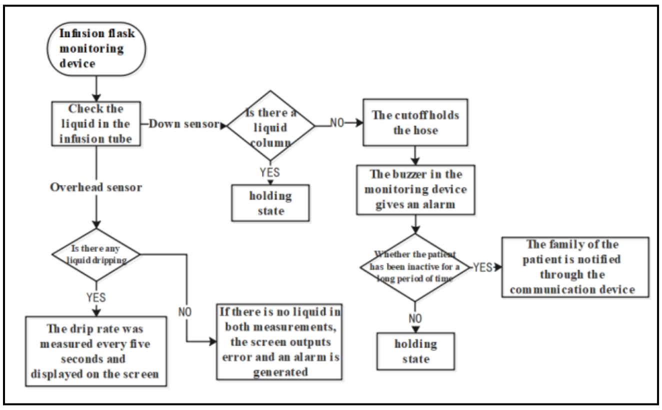

Figure 5 System software main program flow chart

3. Literature References

Table 1. Various response times of the device at different drop rates

Drip rate Drip/min	Average time 1/s	Average time 2/s	Average time 3/s	Average time4/s
40	2.63	2.67	6.07	3.67
60	2.67	2.59	5.53	3.52
80	2.59	2.58	6.20	3.57

Average time 1: the time it takes from a blocked hose to sound the alarm

Average time 2: the time taken from the end of the infusion until the alarm is raised

Average time 3: the time required from the end of the infusion to the rotation of the motor

Average time 4: Time taken from the end of the infusion until the family receives the text message

The three sets of experiments are the time required for the device to respond to various situations (including hose blockage and end of infusion) and make corresponding initiatives when the drop rate is slow, fast and rapid respectively. It can be found that, regardless of the droplet speed is faster or slower, the time needed from the hose blockage to the alarm is stable around 2.6s, which indicates that the device reacts more quickly and steadily when it detects such abnormal situations. The alarm is issued after the device detects the abnormal situation or the infusion is completely finished, and the time is stable at about 2.6s, and the stepping motor rotation time is 3.5s after the alarm after the data monitoring, while the family members receive the SMS and the alarm is only 1s. (The time is affected by the network signal: when the signal is stronger, the time is shorter; when the signal is weaker, the time is longer.) The fluctuation of the test data is small, which means that the infusion process under the control of the system device is more rapid and the response time is stable. The infusion process under the control of the system device is highly stable and more secure

4. Conclusion

This paper presents an innovative infusion vial monitoring device designed to enhance the safety and efficiency of medical infusion. The device adopts a design scheme that combines a master module and a sub-module; the master module is based on the STC89C52 minimum system version, while the sub-modules include several components such as an infrared pair of tubes module, a buzzer alarm module, an LCD module, a stepper motor module, and a wireless network communication module. Collaboration between these modules is realized through the interconnection of sub-masters to ensure the comprehensiveness and accuracy of infusion supervision.

In this design, the infrared tube module measures the drip rate of medicine, detects the completion of infusion and recognizes the safety status such as infusion blockage through the U-type photoelectric sensor, and transmits the relevant data to the main module, which is processed and displayed on the liquid crystal display module. At the same time, the main module can send commands to the alarm and stepper motor to realize the alarm and block the liquid in the hose, and notify the patient's family of the abnormal situation. The core of this design lies in the signal reception of the U-type photoelectric sensor, the operation and processing of the microcontroller, and the serial communication of the drip speed module, which realizes the multiplexed management and the accurate control of the speed of the liquid droplets.

In addition, this system uses a five-step, four-phase stepping motor to perform clamping or unclamping operations on the drip irrigation through a clamping mechanism to ensure smooth infusion. The entire unit has a removable housing, making it suitable for a variety of infusion scenarios.

In summary, this innovative infusion vial monitoring device integrates several key modules to provide comprehensive infusion supervision functions while taking into account safety and portability. Through the wide application of this device, we are expected to realize a higher level of infusion supervision in the medical field, provide patients with safer and more reliable treatment, and promote the development of smart medical technology in China.

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