Design of an Intelligent Leakage Prevention System for High pressure Injector

Zhengdong LI1,*, Xiuling LI2, Haimei XU3,*, Juan CAI1, Xiaoling XU1, Yan HE1

1Track Electrical Department, Chongqing Vocational College of Public Transportation, Chongqing, 402247, China
2Communication NCO Academy, Army Engineering University of PLA, Chongqing, 400035, China
3Big Data and Digital Media College, Chongqing Telecommunication Polytechnic College, Chongqing, 402247, China

*Corresponding author’s e-mail: gusi@foxmail.com

Abstract. In order to solve the problem of liquid leakage due to high injection pressure and fast injection speed in the current medical high pressure injector, a set of intelligent anti-leakage diversion alarm system for high pressure injector was designed by using TI microcontroller MSP430F4619, precision electronic FS2050 pressure sensor and Nordic company’s NRF24L01+ wireless transmission chip. The system can monitor the process of high pressure injection in real time. Once the leakage of drug solution is detected, wireless acousto-optic alarm will be given immediately and diversion switch will be made quickly. This system not only overcomes the disadvantage of the previous mechanical design scheme which is easy to be loosened, but also increases the function of diversion switch which can effectively reduce the pain of patients. The results of animal experiments show that the intelligent diversion alarm system is stable, reliable and highly sensitive, which can effectively reduce the leakage of drug solution in high pressure injector.

1. Introduction
As an important auxiliary equipment in radiology diagnosis and treatment system, high pressure injector is widely used in clinical cardiovascular angiography, CT enhanced angiography and MR enhanced scanning. In clinical application, the problem of leakage of drug solution is often caused by the high injection speed and pressure of high pressure injector when injecting drug solution [1-8]. Although the high pressure injector itself has a pressure monitoring system, this indirect monitoring method sometimes fails to detect hydraulic leakage into the patient’s skin because the system measures the pressure inside the high pressure injection tube. Sometimes, even by the time of monitoring, the patient’s skin has developed severe swelling. In order to overcome the above shortcomings, some relevant mechanical devices have been studied abroad to monitor the arm pressure of patients. However, due to the characteristics of mechanical devices, their service life is short, and at the same time, these devices cannot complete the corresponding guiding function. So it is still impossible to avoid the appearance of skin swelling. In this paper, TI microcontroller MSP430F4619[9], [10] and precision electronic FS2050[11] pressure sensor were used to design a set of intelligent leakage prevention system for high pressure injector. This system can monitor the process of high pressure injection in real time. Once the
leakage is detected, wireless acousto-optic alarm will be given immediately, and the diversion will be switched quickly, so as to effectively avoid the leakage of the liquid of high pressure injector.

2. Microcontroller MSP430FG4619

The Texas Instruments MSP430 family of ultra low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6 us. The MSP430FG4619 is a microcontroller configurations with two 16-bit timers, a high-performance 12-bit A/D converter, dual 12-bit D/A converters, three configurable operational amplifiers, one universal serial communication interface (USCI), one universal synchronous/asynchronous communication interface (USART), DMA, 80 I/O pins, and a liquid crystal display (LCD) driver with regulated charge pump. In view of these advantages, the system uses the MSP430FG4619 as the main controller. The architecture of MSP430FG4619 is shown in Figure 1.

![Figure 1. Architecture diagram of the MSP430FG4619](image)

3. Architecture of System

The intelligent anti-leakage system of high pressure injector mainly consists of the following two parts: the master control system and the terminal control system. Among them, the main control system is composed of pressure sensor module, microcontroller module, sound-light alarm module, switching diversion module and wireless communication module. The terminal system is composed of microcontroller module, wireless communication module and acousto-optic alarm module. Master control system can real-time detect patient arm microcontroller module injection pressure value, if there is leakage of liquids, the pressure of the pressure sensor value will increase rapidly, micro control module immediately launched the acousto-optic alarm, training module, at the same time send information through wireless transmission module in a timely manner to terminal control system, through the terminal control system, the timely processing of medical staff patients the wound and close the high pressure injector.

The architecture block diagrams of main control system and terminal control system are shown in Figure 2 and Figure 3 respectively.
3.1. Module of Pressure Sensor
Pressure sensor FS2050 is developed by Measurement Specialties Inc (MEAS). The FS2050 is a low compression force sensor that creates new markets previously unrealizable due to cost and performance constraints. Its range of operating voltage is 3.3V ~ 5V. When the operating voltage is 5V, the range of output voltage can reach 1V ~ 4V. The range of pressure is 0.5kgf ~ 1.5kgf. Furthermore, FS2050 is embedded amplifier module, which make it is easy to measure the force. Meanwhile, FS2050 also has small size, low noise, high overload capacity and reliability, and quick response. The main function of pressure sensor is to translate the pressure to voltage.

3.2. Module of Main Control System
Low-power microprocessor MSP430FG4619 is the core of the system, which can complete signal detection and processing. MSP430FG4619 is embedded 12-bit A / D converter module, and the maximum conversion rate is up to 200ksps. The system offers the real-time monitoring for the output voltage of pressure sensor, and will start sound & light alarm, switch diversion immediately once the sensor voltage is higher than the threshold voltage. MSP430FG4619 can drive 2-mux, 3-mux, 4-mux LCD screen directly. In this paper, 4-mux LCD screen is selected to display real-time voltage of the pressure sensor and threshold voltage. Meanwhile, doctors can modify the related data of the threshold voltage according to clinical applications.
3.3. Module of Sound & Light Alarm
According to the settings, LED alarm and buzzer alarm are used as two kinds of sound & light alarm mode, which can effectively help the medical staff find the occurrence of leakage of high pressure injector in good time and respond accordingly.

3.4. Module of Diversion Switching
By comparing the results of tests, the servo motor meets the requirements, whose speed is between 0.18 sec/60 ° and 0.16 sec/60 °, whose torque is 15kg, and whose working voltage is between 5v and 7.2v. In this paper, this type of servo motor is used to drive three-way valve, and complete diversion of switch.

3.5. Module of Wireless Communication
The nRF24L01+ is a single chip 2.4GHz transceiver with an embedded baseband protocol engine (Enhanced ShockBurst™), suitable for ultra low power wireless applications[12]. The nRF24L01+ is designed for operation in the world wide ISM frequency band at 2.400 - 2.4835GHz. We can operate and configure the nRF24L01+ through a Serial Peripheral Interface (SPI). The register map, which is accessible through the SPI, contains all configuration registers in the nRF24L01+ and is accessible in all operation modes of the chip. The embedded baseband protocol engine (Enhanced ShockBurst™) is based on packet communication and supports various modes from manual operation to advanced autonomous protocol operation. Internal FIFOs ensure a smooth data flow between the radio front end and the system’s MCU. The radio front end uses GFSK modulation. It has user configurable parameters like frequency channel, output power and air data rate. nRF24L01+ supports an air data rate of 250 kbps, 1 Mbps and 2Mbps. The high air data rate combined with two power saving modes make the nRF24L01+ very suitable for ultra-low power designs. The circuits of wireless communication module is shown in Figure 4.

4. Structure of Program
When the power is on, the program will set up the registers of timers, A / D module and the LCD module and so on. At regular intervals, the microcontroller will begin A / D conversion, test the voltage of the pressure sensor. Once the output voltage of the pressure sensor exceeds the threshold, the
microcontroller will start the sound & light alarm, and export the PWM (Pulse-Width Modulation) wave, which can control the servo motor to switch the three-way valve. The structure diagram of program is shown in Figure 5.

![Figure 5. The structure of the program](image-url)

5. Conclusions
In this paper, aiming at the problem of occasional leakage of drug solution in high pressure injector in clinical application, a smart leakage proof and intelligent diversion alarm system for high pressure injector was designed with the microcontroller MSP430F4619 of TI company as the core. The system can detect whether the liquid is leaking in real time, and then, once the liquid leakage is found, it will send a wireless sound-light alarm, start the motor for diversion, and timely inform the medical staff to deal with the leakage, so as to effectively reduce the pain of patients. Experimental results on rabbits with high pressure injection show that the system is safe and stable, which can effectively solve the leakage of high pressure injector and has high clinical application value.

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