Wireless Communication System Design in Pipeline Monitoring

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Abstract

This paper presents a wireless communication system used in pipeline leakage monitoring and based on ARM and ZigBee. The system also contains keyboard, liquid crystal display and temperature sensor. The system provides a wireless measurement and control device with the advantages of multi-channel signal acquisition, highly general application, wireless communication and high anti-interference ability. For the whole system is modular designed, the system can be widely used in complex industrial sites.

Keywords: ARM, ZigBee, Pipeline Leakage Monitoring, Lab VIEW, Wireless Measurement And Control

1. Introduction

Pipeline leakage wireless monitoring is a difficulty to be solved for a long time in the field of transport pipeline monitoring. Now most transport pipeline companies use wired monitoring devices. Studies in this field focus on how to use fewer wires. However, due to cost of technology, the results of studies have not been applied in industrial sites now [1, 2]. Wireless monitoring system can be used in many kinds of complex conditions, and can monitor pipelines effectively, reduce the hidden danger greatly and ensure pipelines working normally [3]. Besides, the wireless monitoring system can save the expense of wiring and reduce the cost of transport pipeline company [4]. The system in this paper involves upper computer, lower computer and the communication between them in Figure1.

Figure 1. Transport pipelines model
2. Principle and System Structure

The system allows multi-channel signal acquisition, has a general application and a high anti-interference ability. The system consists of upper computer and lower computer. The main hardware of the system includes microcontroller, wireless communication device, keyboard, liquid crystal display, temperature sensor and so on. The upper computer consists of PC and ZigBee module, and the lower computer consists of microcontroller and some other equipment. In addition, microcontroller ARM7 is connected to the port of PLC. The system structure is shown in Figure2 as follows.

The process that messages are sent from lower computer to upper computer: the collected signals (such as flow and pressure signals) are sent to PLC to make A/D converting, and then sent to microcontroller. The microcontroller packages the messages into a data bag according to a ruled form. After that the ZigBee module in lower computer reads the data bag and sends it to upper computer in the method of wireless communication. The ZigBee module in upper computer releases the data bag to console. The software of upper computer unpacks the data bag, picks up each parameter and displays some parameters. The process that messages are sent from upper computer to lower computer: the software of upper computer packages them into a data bag according to the form. The ZigBee module in upper computer sends this data bag to lower computer. The ZigBee module in lower computer releases the data bag to the microcontroller. The microcontroller picks up each message and sends these messages to PLC input-and-output port. PLC finishes operations in industrial sites. Besides, the 4*4 keyboard can help users to check the lower computer and set some parameters. The liquid crystal display is convenient for users to check parameters and the temperature sensor helps users to measure temperature of industrial sites. The system has following functions:

1. Displaying pressure, flow and temperature immediately.
2. Setting or changing parameters, such as pressure and flow.
3. Controlling the opening of electromagnetic valve and changing rotary speed of pump.
4. Displaying the change of each parameter in curve graphs.
5. Inquiring historical data of each parameter.
6. Setting alert parameters, namely upper limit and lower limit.
7. Automatic alerting. When a parameter exceeds its safe range, the system will alert automatically.

3. System Hardware Design

3.1. Microcontroller ARM7LPC2138

Microcontroller ARM7LPC2138 is based on ARM7TDMI-S Core and has advantages of lower power consumption, single power supply, and a higher cost performance. It can be applied to small-size and high-performance embedded products. It has JTAG boundary scan and ISP programming functions. ARM7LPC2138 a 32 bit ARM7TDMI-SCPU microcontroller supporting real-time simulation and tracking, and has 512KB embedded high-speed Flash memory. 128 bit of the memory interface and unique accelerator structures make 32 bit codes run at the maximum clock rate. The application uses 16 bit Thumb mode and reduces the scale of codes 30% with little loss in system performance. It is quite appropriate for industrial control and medical system, because it has four 32 bit timers, two 10bit ADCs, one 10 bit DAC, six PWM outputs, forty-seven GPIOs, and nine kinds of internal interrupt.

![Figure 3. ARM photo](image)

3.2 Wireless Communication Device

The wireless communication device of the pipeline monitoring system consists of ZigBee module, RS-232 circuit and debugging plate. The ZigBee module is connected with RS-232 chip, and debugging plate is connected with console, which is used to exchange messages with upper computer. ZigBee debugging plate is connected with microcontroller through serial port, which is used to exchange messages with lower computer. The two ZigBee modules can communicate with each other wirelessly. SZ05 series of embedded wireless communication module includes microprocessor and RF (radio frequency) transceivers. The wireless communication has advantages of long distance, high anti-interfere ability, stability and reliability [5, 6].
The wireless communication ports include TTL level translate ports and standard RS-232 serial ports. Besides general point-to-point communication, it can realize communication among several points. The use of serial port is convenient and can reduce the embedded time process greatly. In this system, RS-232 serial port includes Tx, Rx, GND. The baud rate between ZigBee communication module and ARM is 9600bps. The power of receiving and sending is -27dBm-25dBm, the frequency of receiving and sending is 2.405GHz~ 2.480GHz [7].

![ZIGBEE Module Circuit Graph](image)

**Figure 4. ZIGBEE Module Circuit Graph**

### 3.3 4*4 Keyboard

Matrix keyboard is also called rank keyboard, and it consists of four I/O lines as rows and four I/O lines as column lines. There is a button on the intersection of each line and each row. So the total number of buttons on the keyboard is 4*4. 4*4 keyboard uses only 8 lines to provide 16 different signals. There are two advantages: 1 saving foot resource, such structure can increase utilization rate of I/O feet in ARM effectively. 2. Simplifying system and reducing the scale of circuits. Particularly considering insufficient resource, it is a practical method to our system, which has a strict limit of cost.

![4*4 Keyboard Circuit Graph](image)

**Figure 5. 4*4 Keyboard Circuit Graph**

### 3.4 Liquid Crystal Display (LCD)

SMG12864ZK is a liquid crystal display module containing Chinese standard GB2312 simplified Chinese words(16*16 dots matrix), 128 chars(8*16 dots matrix) and 64*256 dots matrix display RAM. It can be connected with microcontroller directly in two types: 8 bits parallel or serial. It provides multi-functions: cursors display, picture shift and sleep mode. In this system, liquid crystal display is connected with ARM through serial port.
In this system, liquid crystal display can display each parameter immediately. The administrator can observe each parameter through liquid crystal display to ensure system to operate normally.

![Connection Circuit Graph among ARM, LCD and Keyboard](image)

**Figure 6.** Connection Circuit Graph among ARM, LCD and Keyboard

Digital temperature sensor DS18B20 has advantages of connecting with CPU port conveniently, outputting digital signals directly and providing 12bits temperature information. There is only one line between microcontroller ARM and DS18B20.

DS18B20 can set 9-12bits resolutions, and its accuracy is ±0.5 °C. Users can choose smaller encapsulation and broader voltage range. Resolution and alarming temperature are stored in EEPROM, and will not be lost after power off. The working range of DS18B20 is -55 °C +125 °C [8, 9].

![Temperature Sensor Circuit Graph](image)

**Figure 8.** Temperature Sensor Circuit Graph

3.5 Temperature Sensor
4. System Software Design

4.1 Upper Computer Software Design

The console in upper computer receives data bag from lower computer through ZigBee module. The software of upper computerunpacks the data bag and picks up several commands and data. The console will judge whether the data is in the setting range. If data exceed range, the alarm device will run, and indicating light turns red. Otherwise, the alarm device will not run, and indicating light remains green. Besides displaying parameters and alerting, the upper computer has other functions such as setting safe working range, recording work diary, printing report forms, loading in database and so on [10,11].

The functions of upper computer are shown in Figure 10 as follows.

4.2 Lower Computer Software Design

When lower computer works, micro controller packages digital signals into a data bag and sends it to upper computer by ZigBee module. Also, the ZigBee module of lower computer receives a data bag and releases it to microcontroller. The microcontroller picks up commands and data and sends them to PLC through RS-485 Bus [12].

Figure 9. Connection Circuit Graph among ARM, ZigBee, Temperature Sensor and PLC Port

Figure 10. Functions of Upper Computer
4.3 Communication Format

The form of a data bag is as follows.

<table>
<thead>
<tr>
<th>Table 1. Communication Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting sign</td>
</tr>
<tr>
<td>First pressure</td>
</tr>
<tr>
<td>Second pressure</td>
</tr>
<tr>
<td>First flow</td>
</tr>
<tr>
<td>Second flow</td>
</tr>
<tr>
<td>Rotary speed</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
<tr>
<td>Ending sign</td>
</tr>
</tbody>
</table>

5. Communication Process

There are two types of communication.

When lower computer sends messages to upper computer, there are four procedures:
1. PLC converts the collected analog signals in industrial sites to digital signals, and sends them to microcontroller through RS-485 Bus.
2. Microcontroller packages the received digital signals into a data bag, and sends it to upper computer by ZigBee module.
3. ZigBee module of upper computer picks up effective messages and releases them to console.
4. The software of upper computer receives effective messages and displays some parameters.

When upper computer sends messages to lower computer, there are four procedures:
1. The software of upper computer packages data and commands into a data bag and sends the data bag to lower computer by ZigBee module.
2. ZigBee module of lower computer releases the data bag to microcontroller.
3. Microcontroller unpacks the data bag, picks up each command and data, and sends them to PLC through RS-485 Bus.
4. PLC finishes the corresponding operations in industrial sites.
This system uses LabVIEW Software as a programming environment of upper computer [13, 14] The system can detect and control pressure, flow, rotary speed and some other parameters. The upper computer can communicate with the lower computer through wireless system [15]. After replication experiment, the system is safe and reliable, and can be used in complex industrial sites.

6. Conclusion

This system uses ARM and ZigBee embedded wireless communication module to realize detection of signals and pipeline monitoring in industrial sites. Wireless communication is much more convenient than wired network. The system can monitor and control equipment running. It can realize data acquisition, measurement, adjusting parameters and alerting. Besides, it can provide statistical support for production and management. For the whole system is modular designed, the system can be widely used in complex industrial sites. It can realize real distant wireless intelligent control.

7. References


