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# Design and Realization of Embedded System in Dangerous Chemical Warehouse Monitoring System

Jun Xiao

Xi'an Aeronautical University, Xi'an, Shaanxi 710077, China
rechardxa@126.com

Dangerous chemical storage warehouse is one of the important links in the production safety of chemical enterprises. It stores a lot of raw materials, intermediates, finished products, etc., which leading to dangerous chemical warehouse is the most dangerous place, besides most of the chemical raw materials are flammable, explosive, toxic or high voltage storage. Therefore, it is very important to monitor the state parameters of the raw materials and the surrounding environment of the warehouse. This paper mainly designs the embedded remote monitoring system for liquid ammonia reservoir area. The design adopts ARM processor and Linux system as the core, combined with automatic positioning technology, modern sensing technology, to real-time monitoring the chemical parameters such asstorage pressure, storage level, ammonia concentration, temperature and others of liquid ammonia reservoir. The research results are of great practical significance for the establishment of the remote monitoring system and the dangerous alarm mechanism in the scattered dangerous chemical reservoir area.

## 1. Introduction

The reservoir area is not only an important part of the chemical industry, but also is the most dangerous place, most of the chemical raw materials are flammable, explosive, toxic or high pressure storage. It is necessary to monitor the liquid level, pressure, temperature and other parameters of the chemical raw material in reservoir as well as the site environment of the reservoir area (Chiodo et al., 1994; Xu et al., 2016). The traditional wired monitoring method has the disadvantages of high cost, long construction time and inconvenient for large-scale use. Compared with the wired monitoring, the wireless remote monitoring is more flexible, has the advantages of less cost, simple maintenance and short construction time (Zhang et al., 2003). More importantly, the usage of wireless remote monitoring is also conducive to the future expansion of enterprise scale or the expansion and upgrading of the system in production structure adjustment.

Nowadays, embedded system technology is constantly developing and is widely used in various fields. Embedded microprocessors, development tools, operating systems are become more and more mature. Especially embedded system based on ARM-Linux is more and more favored by researchers (Chakraborty et al., 2003). ARM microprocessor has the advantages of small size, low power consumption, low cost and high performance, which makes ARM become the most popular choice of embedded microprocessors. Linux is a free operating system which can run on a variety of hardware platforms. At the same time with the development of communication technology, the coverage of GSM / GPRS network is more and more widely, the application is also very popular (Pimentel et al., 2006). GPRS wireless transmission can achieve multi-location and real-time monitoring of the scattered chemical reservoir area. GPRS wireless network transmission has the advantages of low cost, simple equipment installation, short construction period and low requirement for installation environment.

In recent years, more and more researchers in the field of security have integrated the GPRS wireless network technology and the embedded technology to realize the embedded remote monitoring system. The development and maturity of Embedded system technology (Alur et al., 1993), GPRS wireless communication technology, modern detection and sensing technology and voice chip technology, provides excellent conditions to the transforming and upgrading of the dangerous chemical reservoir's monitoring system and alarm system. In this paper, uses the ARM processor-Linux system as the core, combined with GPRS

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technology, modern sensor technology and voice chip to achieve embedded remote monitoring system, furthermore to achieve remote monitoring and dangerous alarm for the scattered dangerous chemical warehouse (Edwards et al., 2002).

## 2. Brief introduction of ARM-Linux in embedded system

Embedded system regards application as the center, based on computer technology, adapts to specific application systems, it is a dedicated computer system which has strict requirements of function, reliability, cost, size, power consumption(Ravi et al., 2004). Broadly speaking, the embedded system is a designed dedicated system for a specific application function, and the system is equipped with microprocessors, peripheral hardware and software (Gajski et al., 1998), hardware and software can be designed according to the needs of users. Embedded system consists of hardware and software the two main parts. The hardware part mainly includes the microprocessor and various peripherals and interfaces (Sangiovanni and Martin, 2001). The software part mainly includes embedded operating system which is support multi-task operation and user application program.

### 2.1 Instruction set and operating mode of Microprocessor

ARM is a 32-bit microprocessor architecture, is widely used in embedded systems, ARM processor using simplify instruction set (RISC), generally using three-address format and fixed-length instructions to support seven operating modes, specific operating mode As shown in Table1, the system automatically switches between these operating modes according to the peripheral and system environment (Jejurikar et al., 2004).

*Table 1: Operating mode of ARM Microprocessor*

| Processor operating mode | Illustration |
|---|---|
| User Mode | Normal operation of Processor |
| Fast terminal | Data transmission and channel processing |
| Externalinterruption | Interrupt processing |
| Abort | Protecting stored data |
| System mode | Run operating system instructions |

### 2.2 Embedded Linux operating system

Embedded Linux system is based on their own system performance requirements, optimal configuration and tailoring the complete Linux operating system (Avissar et al., 2002). In general, we will divided Linux system into three layer structure, the hardware layer, kernel layer and application layer. The user interacts directly with the application layer (Henzinger and Sifakis, 2006), and the call of the application is realized through the kernel-level system. Linux system structure and the relationship between the each part shown in Figure 1:

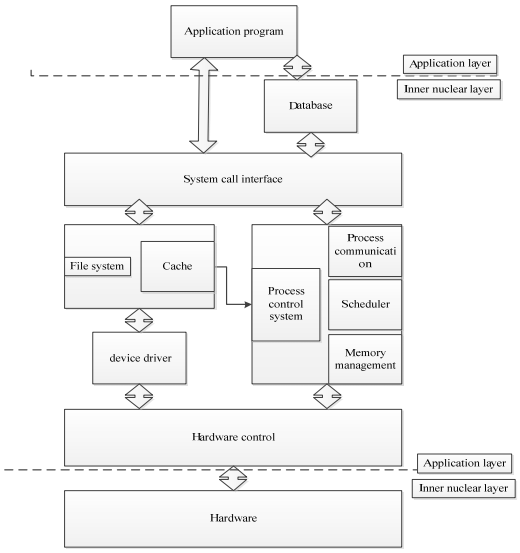



*Figure 1: System structure drawing*

## 3. Overall functional design of dangerous chemical products monitoring system

In order to expand the scale of production and meet production needs, a new liquid ammonia reservoir area is built on a small hill next to production solvent preparation workshop, the reservoir storage is used to store liquid ammonia with capacity of 2400m$^3$. Liquid ammonia is a dangerous chemical, whether it is from transport, unloading, storage are all required strictly control. Taking into account the liquid ammonia reservoir is a major hazard source, we must design an effective monitoring system, to real-time collecting the level and pressure, ammonia concentration and temperature and other chemical indicators of liquid ammonia storage in the chemical plant.

### 3.1 Main functions of dangerous chemicals monitoring system

The design mainly to achieve the following functions:

1) Using remote monitoring system, the reservoir level, pressure, ammonia concentration, temperature and other chemical indicators are collected by sensor at the liquid ammonia storage area site, liquid ammonia reservoir area pictures are collected by remote camera, and then the GPRS network transmitting data and pictures to a remote data monitoring center.

2) The remote data monitoring center is responsible for receiving the indicators of chemical products, saving the data, and displaying in the graphical interface based on Qt.

3) When the liquid level, pressure, temperature and the concentration of ammonia and other dangerous chemicals indicators in the reservoir area exceeding the upper limit, the site issuing a voice alarm to drawing the site monitoring personnel attention, and notifying security management by text messages.

### 3.2 Overall structure of dangerous chemical monitoring system

The system consists of the following parts:

1) Signal acquisition input part: detection of level, pressure and the reservoir area of ammonia concentration in chemical plant liquid ammonia storage, temperature, through the corresponding standard current or voltage analog signal sensor to realize acquisition and collection of indicators and through the camera to achieve area scene pictures collection.

2) Data transmission processing and transmission part: the collected analog signal through the A/D converter is converted to digital signals then sent to the ARM processor, processed by the ARM microprocessor, through the GPRS network transmitted to the data monitoring center.

3) Alarm part: ARM microprocessor control voice alarm module for voice alarm and control GPRS fortext message alarm.

4) Control Part: control pressure relief valve in the liquid ammonia storage, liquid ammonia inlet shut-off valve and spray water outlet valve and other external equipment, mainly are the solenoid valve.

5) Data display part: remote data monitoring center, using Qt for graphical interface design, display the transmitted data.

### 3.3 System structure scheme of dangerous chemicals

The system is mainly based on ARM-Linux embedded system, combined with GPRS communication module, data acquisition module, voice alarm module to realize the real-time monitoring, dangerous alarm and safety interlock of chemical dangerous liquid ammonia storage area. The whole system uses the upper computer and the lower computer two-layer structure, which are the embedded monitoring terminal and the remote data monitoring center respectively. The overall structure is shown in Figure 2.

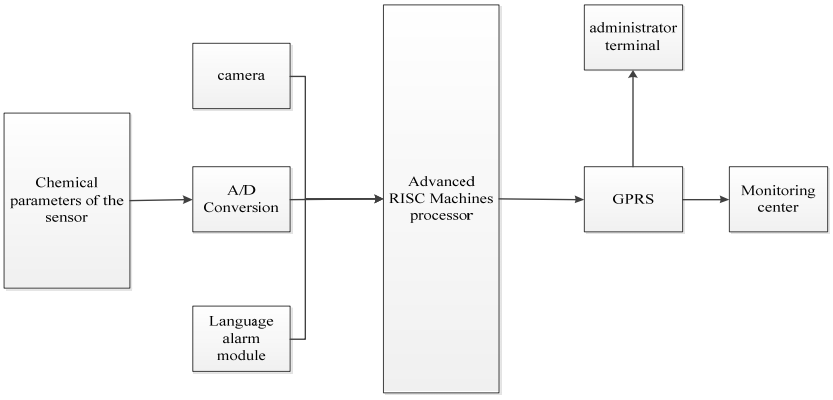



*Figure 2: System operation schematic diagram*

Site embedded monitoring terminal, mainly to complete data acquisition of the parameters in the liquid ammonia reservoir, voice and text message alarm, wireless data transmission. Information acquisition is completed by the pressure sensor, ammonia concentration sensor to collect standard analog signals, then the collected the standard analog signals through the A/D conversion chip are converted to digital signals, afterwards data analysis and processing is done by ARM processor. When the chemical pressure, liquid level, temperature or air ammonia concentration reaches the alarm value, then trigger the ARM processor to control the site voice module for voice alarm and control GPRS module to sent text message alarm to the security management staff.

## 4. Hardware design of dangerous chemical monitoring system

### 4.1 Design of power supply module

The system is designed to use 3.3V and 1.8V DC voltage, thus it is necessary to voltage reduction processing. This design uses LM1117 voltage reduction chip plus an external 5V power supply, obtained 3.3V and 1.8V DC voltage that the system needs, as shown in Figure 3.

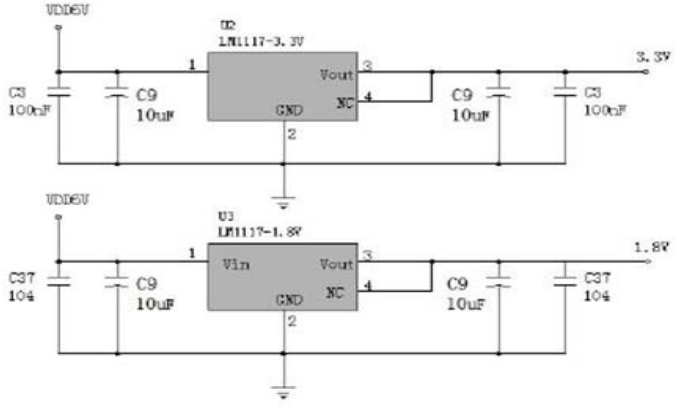



*Figure 3: Power supply circuit*

### 4.2 Extension of Storage Module

The system adopts NOR FLASH, which can randomly accesses data at any address. Therefore, by using of NOR FLASH, the system does not need to copy the code to the memory to implement, can implement directly in the NOR FLASH. The system selects NANDFLASH chip which type is K9F1208 as the system memory, to storing the bootstrap program, operating system and application programs, the chip connection circuit is shown in Figure 4.

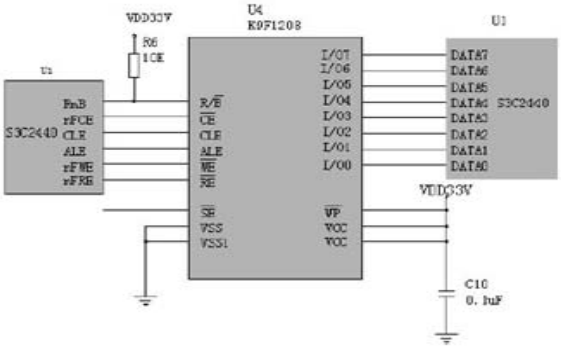



*Figure 4: NAND FLASH connected to the processor*

### 4.3 Design of voice chip and interface

Chip memory can store 128k of voice information, the address space shown in Table 2. The recording and playback start at the start address set by A0-A7. At the end of the recording, the chip will automatically insert the end marker (EOM) at the end of the segment voice and the playback while the (EOM) marker occurs, the chip stops playback.

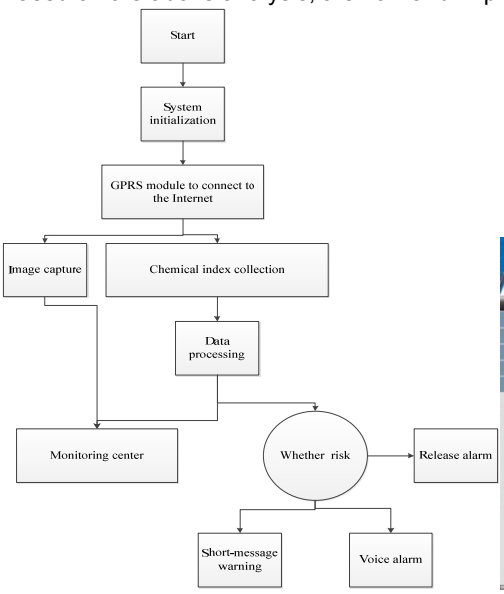
*Table 2: Voice chip address space*

| Decimalism | Binarysystem<br>A7 A6 A5 A4 A3 A2 A1 A0 | Time<br>0 |
|---|---|---|
| 0 | 0 0 0 0 0 0 0 0 | 0.125 |
| 1 | 0 0 0 0 0 0 0 1 | 2.5 |
| 20 | 0 0 0 1 0 1 0 0 | 5 |
| 40 | 0 0 1 1 1 1 0 0 | 7.5 |
| 60 | 0 1 0 1 0 0 0 0 | 10 |
| 80 | 0 1 1 1 1 0 0 0 | 12.5 |
| 100 | 0 1 1 0 0 1 0 0 | 15 |

As the alarm limit of the design is the chemical liquid ammonia storage pressure warning and upper limit alarm, liquid ammonia reservoir level warning and upper limit alarm, temperature warning and upper limit alarm, air ammonia concentration warning and upper limit alarm, a total of eight segments, so record eight voice messages. ARM microprocessor analyzes state parameters which collected by data acquisition module, to control the voice chip selecting voice segment which has been recorded and then alarming.

## 5. Design of the dangerous chemical monitoring software

Based on the above analysis, the flow and implementation of the whole program is shown in Figure 5.



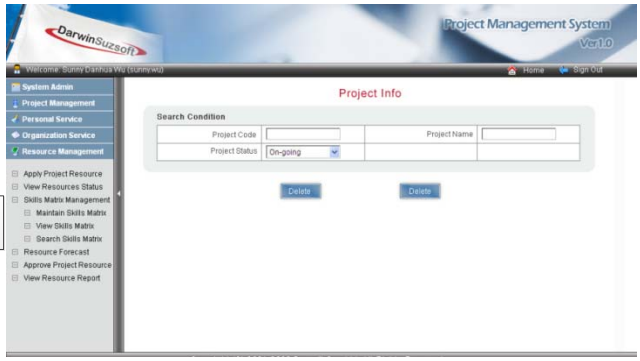




*Figure 5: Monitoring terminal program process*

*Figure 6: User Interface Modeling*

### 5.1 Design of graphical interface

When using the Qt Designer to design monitoring interface, drag the required controls to rational place, and then through QVBox Layout, QHBox Layout and QGrid Layout the three layout managers to realizing reasonable layout, the design of system interface shown in Figure 6.

### 5.2 My SQL database

Database is the core of the software, the design of system chooses the commonly used My SQL database. My SQL requires less memory, when it is running, so the cost is low, and My SQL can be ported to different hardware platforms. My SQL uses an optimized SQL query algorithm, in this way it effectively improves the query speed. After a successful connection to the database, we can query the database. My SQL data query takes advantage of QSql Query class's object to conduct operation, so we must create an object at first, and then we go to the implementation of QSql Query :: exec () function. The code is as follows:

```
QSql Query query;
query.exec("select * from State-Parameter-data ");
```

After the execution of exec () function, the system will locate QSql Query internal pointer to the place where before the first record. Then we can use the QSql Query:: next () function to locate the pointer to the first record. Then repeatedly execute next () function to access other records until a false value is returned. The

following code snippet uses the next () function to access the chemical index, pressure (P), temperature (T), level (L), and ammonia concentration (C).

```
while (query.next())
{
QString P=query.value(0).to String();
QString T=query.value(1).to String();
QString L=query.value(2).to String();
QString C=query.value(3).to String();
q Debug() << P << T << L << C;
}
```

## 6. Conclusions

In order to meet the requirements of a chemical enterprise to monitoring the liquid ammonia storage area, the embedded remote monitoring system based on ARM processor and Linux operating system combined with GPRS positioning is adopted. It is a very effective method which achieved real-time monitoring of the dangerous chemical liquid ammonia reservoir area. Innovation of the Research is mainly:

1) Applied embedded remote monitoring technology which based on ARM-Linux and GPRS to chemical reservoir monitoring system. The system is stable and reliable, low cost, small size.

2) Change the traditional audibleandvisualalarm, by using of voice alarm, the alarm is more intuitive.

3) Using Qt graphical interface to real-time display the state parameters of the reservoir area, the design is simple, easy to operate.

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