Journal of Computing and Electronic Information Management
ISSN: 2413-1660 | Vol. 11, No. 1, 2023

Design and study of a hydrogen concentration online monitoring system

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Abstract: This paper designs a hydrogen concentration online monitoring system, mainly completes the construction of the software and hardware platform, select the I.MX6ULL embedded processor as the core hardware platform and embedded Linux system transplantation, root file system construction, hardware peripherals driver design, complete the human-computer interface based on QT application framework and save the collected data to the memory of the embedded motherboard and send to the cloud in real time through the network port.

Keywords: Hydrogen leakage; Embedded; Human-computer interaction; Linux system.

1. Introduction

Hydrogen as a kind of combustible gas, improper use of combustion and explosion, so in the use of hydrogen as energy must ensure the safety of operation, fight hydrogen leakage, so need to monitor the change of the hydrogen concentration by comparing with the background value to determine whether the hydrogen leakage, once the hydrogen concentration significantly over the background value and continue to increase, the hydrogen leakage the safety measures immediately [1].

In addition to the higher requirements for the accuracy, resolution and stability of hydrogen monitoring instruments, people also need to add the monitoring of temperature and humidity as auxiliary variables. In addition, due to the development of embedded technology and communication technology, it is completely possible to realize manual remote online monitoring, and the measured real-time data is uploaded to the cloud, which provides a reliable guarantee for the security of hydrogen monitoring personnel. Therefore, it is of great practical significance to develop a good human-computer interaction function and real-time online hydrogen leakage monitoring device through the network [2].

2. Hardware design

2.1. Overview of the hardware scheme

The overall design scheme of this system is shown in Figure 1. Its core components include hydrogen sensor unit, temperature and humidity sensor unit, power supply unit, suction pump unit, and embedded system main board.

The power supply unit is mainly composed of AC / DC switching power supply, which is responsible for converting 220V AC power into low-voltage DC power required by each sensor unit and its main board, and the suction pump unit is responsible for sending the gas to be measured into the hydrogen sensor unit with a certain flow rate to improve the response speed of the hydrogen sensor. Hydrogen sensor unit, temperature and humidity sensor unit mainly through the RS485 unit and the embedded system motherboard communication, embedded motherboard is responsible for the hydrogen sensor and temperature and humidity sensor data processing, storage and the main interface display, the Ethernet communication interface and USB interface respectively responsible for data upload and download, LCD touch screen instrument interface display and human-computer interaction function. Embedded system motherboard

To ensure the development time and improve the stability of the instrument. The CPU of this system selects the mature embedded development board on the market and meets the development requirements. The embedded development board has high stability and rich peripheral interface resources, which can be perfectly adapted to the system. Alalpha development board based on I.MX6ULL main controller. Alpha development board has rich peripheral interface resources. The master core board expands 512MB bytes of DDR 3 L memory and 8GB of EMMC FLASH storage, with four-way USBHost interface and supports USB2.0 protocol. Users can download and save the data stored in the development board memory through the USB interface. With 2 Ethernet interfaces for network communication, the communication rate is up to 100M. With a RGB LCD interface for connecting the RGB display screen for image display and human-computer interaction. An RS485 interface is used to realize communication between the development board and the sensor. It has a road TF card interface for the data storage of the development board, system startup and other functions.

2.2. Embedded system motherboard

The data acquisition module is mainly composed of hydrogen sensor unit and temperature and humidity sensor unit. The hydrogen sensor adopts PDM200 palladium alloy thin film hydrogen sensor (as shown in Figure 2). The sensor mainly uses the catalytic decomposition of gas by metal film [3]. Hydrogen molecules are adsorbed to the surface of the alloy film. Under the catalytic action of the palladium alloy film, the hydrogen molecules decompose into two hydrogen atoms. The hydrogen atoms diffuse into the palladium alloy lattice, causing lattice expansion and phase change, resulting in the conductivity of the alloy film. According to this principle, the measurement of hydrogen is realized. The advantages of this sensor are its high stability, strong anti-

interference ability, and no increased measurement error due to the presence of other gases. The accuracy of the sensor is less than 5%F. S, the repeatability is less than or equal to 2%F. S, and the zero-point drift is less than or equal to ±0.5%F. S/12h;

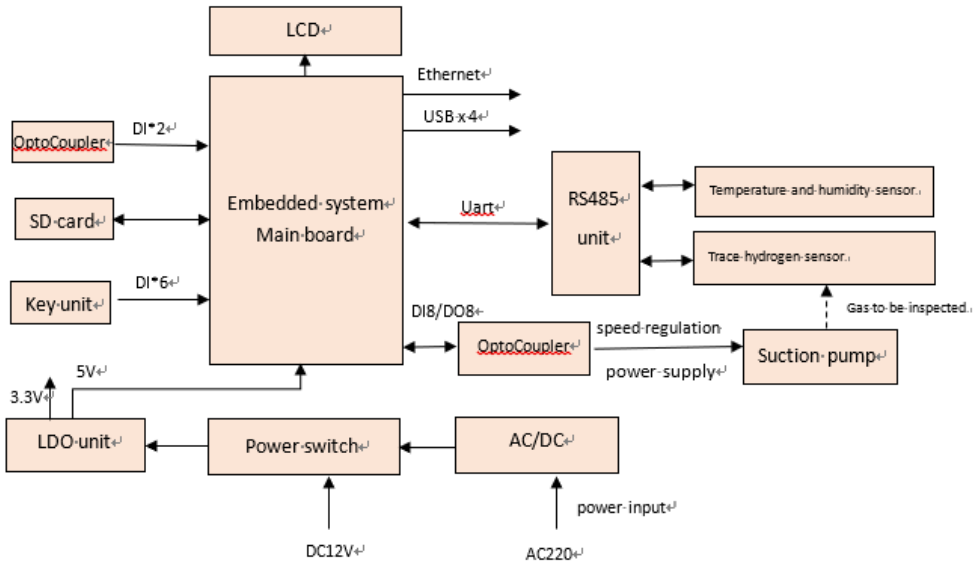


Fig. 1 Block diagram of the instrument hardware scheme

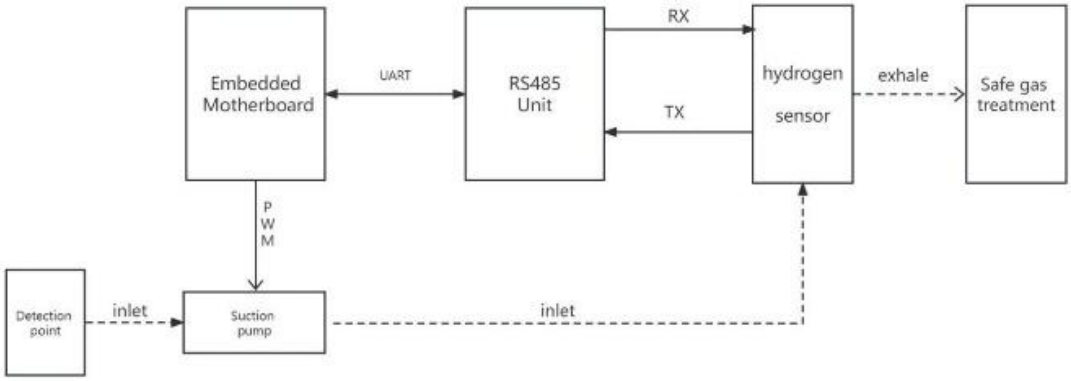


Fig. 2 Schematic diagram of the acquisition module

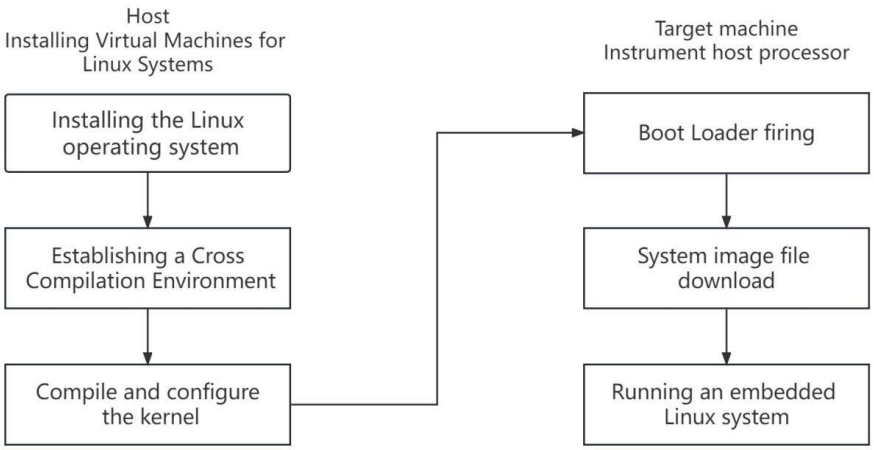


Fig. 3 Flow chart of the system development platform construction

3. Software system design

This chapter mainly explains the work of the software part of the device, including the construction of embedded development platform, Linux system transplantation, the driver construction of embedded platform, and the design and implementation of human-computer interaction interface.

3.1. Construction of the embedded development platform

Embedded platforms have limited computational resources due to their limited memory space, but they often have high

requirements for hardware resources when using the compilation tool chain. Therefore, cross-compilation is often used by building the development environment required for the embedded platform on the 64-bit computer platform and generating the executable code on the embedded platform. The computer is also known as the host of the embedded platform, and the embedded platform is called the target machine, by generating the executable code on the embedded platform on the host host. The construction of embedded Linux system software development platform includes the establishment of cross compilation environment of host and embedded platform, cropping and porting of Linux kernel, transplantation of Bootloader, installation file system and other [4]. In the development process, the system program is compiled on the host, the 64-bit computer platform, and then the executable file generated on the host is then burned to the embedded platform through SD card, Ethernet, or USB interface, namely the system Flash of the target machine. The flowchart of the embedded system development platform is shown in Figure 4.



Fig. 4 Human-computer interaction main interface

3.2. Edevice driver routine

Embedded Linux system can realize convenient management and use of embedded mainboard resources. Not only can it give full play to the advantages of Linux system in system management resources, but it also provides a smooth software running platform for developers. Embedded Linux system includes BootLoader, system kernel and root file system in storage devices. Therefore, porting embedded Linux system is mainly for porting BootLoader, system kernel, root file system and other contents.

3.3. Device driver

Device driver is a special form of software application to interact the kernel and hardware device. The three categories of drivers in Linux are: character device drive, block device drive and network device drive, among, Character device drive is relatively simple to develop, In this design, Character device driver is the most common class of driver, Including the common LED lights, I2C, SPI, serial port, LCD and other equipment drive; Block device drive and network device drive are a bit more complex than character device drive, The block device driver is actually the driver of the storage device, Including EMMC, NAND, SD card and U disk and other storage devices drive; Network device drive is the most complex, Including all wireless and wired networks. The device drivers described in this paper are all character devices, storage devices and network devices, and we directly use the corresponding device drive provided by the official.

3.3.1. Serial port driver

Linux Also provides the serial port drive frame, we only need to write the driver according to the corresponding serial port frame. There is no host terminal and device terminal for serial port drive, but only one serial port drive, and this drive has been officially written by NXP. What we really need to do is to add the serial port node information to be used in the device tree. The uart _ driver structure in the serial port drive framework represents the UART drive, and a uart _ driver is defined in each serial port drive. When the driver loads, the uart _ register _ driver function registers the uart _ driver with the system, and the uart _ unregister _ driver function when the driver is cancelled. In addition, uart _ port represents a specific port, the ops member variable in uart _ port is important, because ops contain a specific driver function for UART, Linux, the system sending and receiving data finally calls the function in ops, and ops is the structure pointer variable of type uart _ ops. Modify the node information of the serial port through the above operation.

3.3.2. LCD touch screen driver

In this design, the LCD driver NXP of i.MX6ULL has also been written, so we do not need to modify the specific code of the driver part to modify the device tree according to the LCD parameters we use. There are three parts that need to be modified: first, the IO configuration used by the LCD; second, the LCD screen node is the modification and the corresponding attribute value to replace the LCD screen parameters used by us; third, the LCD backlight node information is modified, and the corresponding device node information should be modified according to the actual backlight IO.

3.4. Human-computer interaction interface design

The development of the software program is based on C + + language in the application framework of Qt Creator. Compared with the process-oriented C language, the object-oriented C + + is more suitable for embedded software development, system development and other application scenarios. C + + has high efficiency and flexibility in games, servers and performance demanding applications; Qt Creator

is a cross-platform C + + graphical user interface library running on Windows, Linux, and macOS desktop operating systems. It provides the first integrated development environment (IDE) specifically designed to support cross-platform development, and ensures that first-time developers of the Qt framework can start and operate quickly.

The system mainly realizes human-computer interaction function through touch screen (the human-computer interaction interface is shown in Figure 5). Including the display of hydrogen concentration, temperature and humidity measurement results, the real-time curve display of hydrogen concentration, instrument information display and setting, user information display and setting, network information display and setting, etc. The real-time curve display function of hydrogen concentration is realized by using the class QCustomPlot in QT, while the user setting, parameter setting, network setting and other functions are realized by using the signal and slot mechanism in QT, QFile, QTextStream and other technologies.

4. System testing

4.1. Precision test of hydrogen concentration

The accuracy test of this system is made by comparing the standard value of hydrogen concentration with the measured actual value. Seven sampling points were selected for testing, and the 10 data measured from these seven sampling points were averaged to obtain the average hydrogen concentration of the 7 sampling points. The data are shown in Table 1. The means of test data versus standard values are shown in Figure 6. While the absolute error and accuracy of the hydrogen concentration in the 7 data points can be calculated according to the average value, the accuracy is the ratio of the absolute error and the maximum range. The precision analysis of hydrogen concentration is shown in Table 2.

After data analysis, it can be concluded that the hydrogen concentration data collection accuracy of the system is less than or equal to ±5%F.S, which is within the allowable error range.

Table 1. Hydrogen concentration fixed-point data sampling(ppm)

Theoretical	14260	28490	41100	57170	**71310**	**85610**	99550
Sample point 1	18421	32462	49511	58404	78841	90192	90121
Sample point 2	18481	29942	47101	62102	69401	85772	94051
Sample point 3	19110	30460	45540	59750	79990	815422	100004
Sample point 4	17645	33011	45564	59994	70462	94014	90984
Sample point 5	13465	31161	40161	61144	74842	90114	94254
Sample point 6	16972	29991	48814	62231	77022	93561	94484
Sample point 7	10044	37647	39461	59924	67552	90004	96801
Sample point 8	18841	32002	46401	65022	73991	84993	100001
Sample point 9	13101	28641	37997	56143	79573	87651	94492
Sample point 10	18792	34432	41104	61195	76010	91464	100001

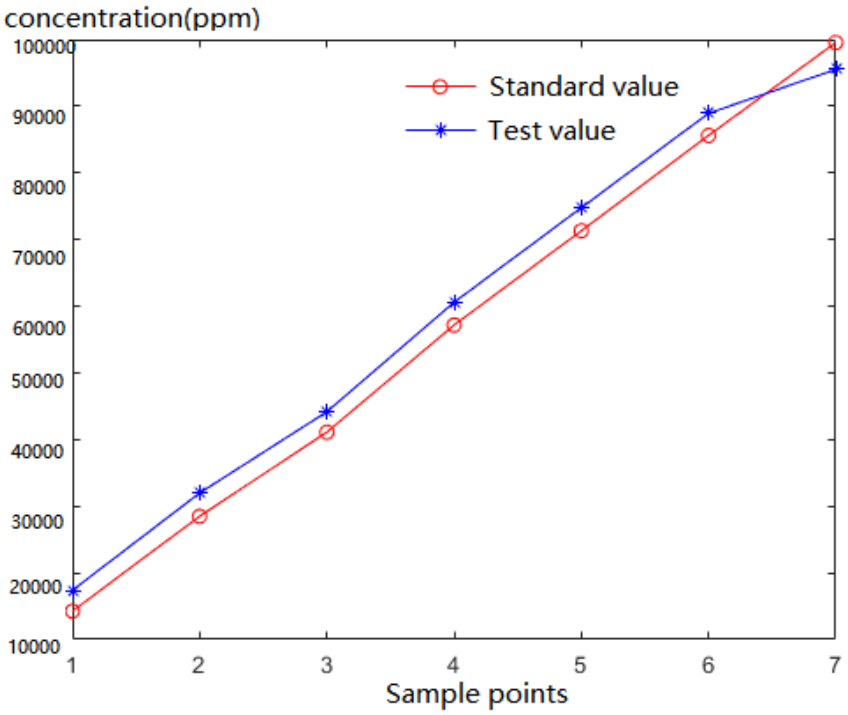


Fig. 5 Curve of standard values and sample site test means

Table 2. Error analysis results of hydrogen concentration

Theroetical(ppm)	Test value(ppm)	Absolute error(ppm)	accuracy(%F.S)
14260	17382	3122	3%
28490	31973	3483	3%
41100	44161	3061	3%
57170	60583	3413	3%
71310	74763	3453	3%
85610	88927	3317	3%
99550	95510	4040	4%

4.2. Precision test of hydrogen concentration

Repeatability is the most important parameter to measure the stability of the instrument. The repeatability of the measurement system refers to "the ability of the measurement system to repeat the same measurement and provide the same value under the same measurement conditions".(The same measurement conditions include: " The same measurement procedure, the same observer, using the same measurement equipment under the same conditions, repeated in the same place for a short time.) Reflect the degree of dispersion of the measured results, the repeatability is usually expressed by the CV value of the coefficient of variation, which is as follows.

$$CV = \frac{\sigma}{\bar{X}} * 100\%$$

Where σ represents the sample standard deviation, and $\bar{X}$ represents the sample mean. The smaller the calculated CV value is, the more stable the measurement repeatability of the instrument is.

For the repeatability test of hydrogen concentration in this system, the test was tested at a fixed time for 2min during a week, and a sampling rate was 10s / time. By calculating the average of the daily test data, the experimental data shown in Table 3 below were obtained.

Table 3. Error analysis results of hydrogen concentration

week	1	2	3	4	5	6	7	average value
Test value(ppm)	28821	27483	28731	28920	28054	28911	28165	28444

According to the above table, the standard deviation σ: 55.25, the repetitive coefficient of variation CV: 1.94%, and CV <± 2%, which meets the requirements of the system.

4.3. Repeatability test of hydrogen gas concentration

The stability of the hydrogen concentration data of the instrument refers to the stability of the whole instrument to the basic response in the continuous working time, which mainly depends on the zero-point drift and the interval drift. In this paper, the simple evaluation of the stability of the instrument is completed by testing the zero-point error in a relatively short time. The test was carried out at room temperature and pressure. By connecting 99.999% of argon standard gas directly into the instrument inlet, the test began for 12 hours with a sampling rate of 1min / time. Figure 7 below is the zero drift test data curve.

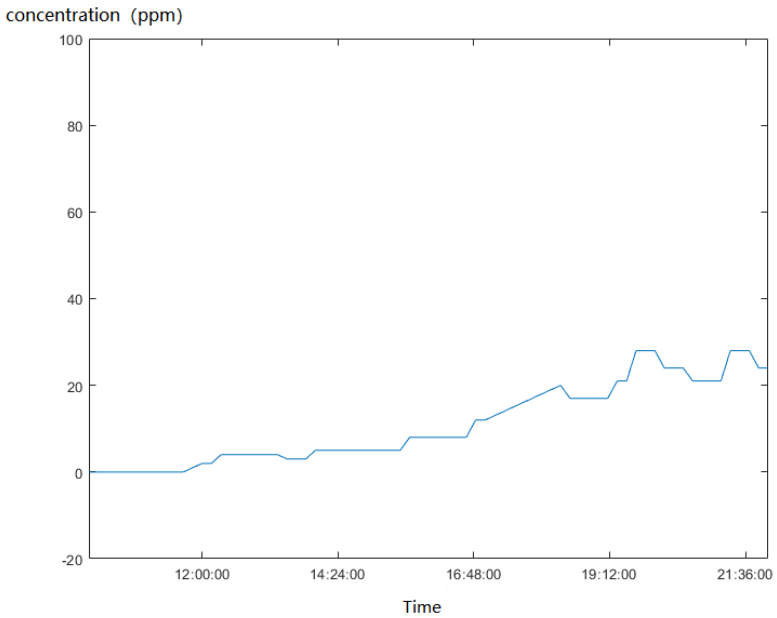


Fig. 6 Zero-point drift curve of the hydrogen gas concentration

According to the figure above, the hydrogen concentration data of the instrument did not exceed 50ppm within 12 hours. That is, the 12-hour zero-point drift value of the instrument is less than ±0.5%F. S, which meets the requirements of the

system design.

5. Conclusion

An online monitoring system of hydrogen concentration was designed. The embedded motherboard with NXP I.MX6ULL processor as the central processing unit is used as the host hardware platform. Software platform construction: complete the construction of embedded development environment, transplantation of embedded Linux system and the configuration of hardware driver, use C + + language in the Qt Creator development environment, provide a stable and reliable platform for the operation of the instrument host; display the collected hydrogen concentration data and graph to the instrument interface, and send and save it to the memory of embedded motherboard via Ethernet. The experimental platform and environment have proved the feasibility and practicability of the system.

Acknowledgements

This work was supported by the Intelligent Information Technology and Application Engineering Research Center of Gansu Province.

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