TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol.12, No.7, July 2014, pp. 5629 ~ 5635
DOI: 10.11591/telkomnika.v12i7.5658

A Study of a New Intelligent Key System for Substation

Dan Chen*, Yefei Yue, Hongfen Jiang, Xiaorong Zhao, Liyuan Wang
School of Computer Engineering, Jiangsu University of Technology,
Changzhou, Jiangsu, China, 213001, Telp: 086-13776878588
*Corresponding author, e-mail: adair_cd@163.com

Abstract

Aiming at the demand of production management of power system, a new intelligent key system applied to substation is created and established. Based on the operating mode of the system, the paper puts forward the design of intelligent key based on RFID technology. It expounds the hardware of the system, which adopts advanced ARM technology to develop an intelligent key system, combined with RF signal recognition technology, OLED display, data storage, keyboard input and other functions, in order to meet the functional requirements for intelligence. Its software uses the embedded μC/OS-□to achieve the signal reception of the new intelligent key system. After tested, the key works well. The system is characterized by more portability, large storage capacity, more functions, friendly interface and other noticeable features.

Keywords: *intelligent key system, ARM, radio frequency identification, embedded μC/OS-Ⅱ*

1. Introduction

With the development of power systems, power production management gradually is intensified, and a transport inspection center generally needs to manage more than a dozen to hundreds of substations. In order to ensure the safety of production, the partition management of equipment is adopted, which results in a variety of locks and locking devices, various jobs for the designed site such as routine inspections, switching operations, maintenance operations and eliminating defects. In these production operations, we must be based on the work need and use the corresponding keys to unlock. Because of the various types of keys [1], operational efficiency is seriously reduced. Worse still, there will be serious accidents such as mistakenly entering the charged rooms and so on.

In order to meet the growing demand for electricity, to effectively reduce and prevent the occurrence of human errors, and to improve the reliability of grid operating stably, a new type of intelligent key system comes into being. The study presents a new intelligent key system scheme applied to substation and elaborates the key technologies - the structure of intelligent key system, the composition theory and implementation techniques of its hardware and software.

RFID is widely used as a non-contact automatic identification technology [2]. It consists of 3 parts: RFID tags (tag), the reader (reader) and antenna (antenna). The role of intelligent key system is to receive the RFID tag of the primary system, embed a reader in the key, and realize the control of the device through RFID electronic codec and the mechanical locking of original locks [3]. Figure 1 illustrates the appearance of intelligent key and its use objects. RFID tags is ISO/IEC15693 protocol-based and the operating frequency is 125KHz read-only passive tags. It is designed in a round button shape, a diameter of about 14mm, mainly by the induction coil, read-only memory, RF transceiver and associated circuits. RFID tags are embedded in the lock core door of the device of each substation.

Therefore, intelligent key system is to accept the instruction of the primary system, i.e. a sequence of substation equipment operations, and, according to a substation equipment running, to lift device latch correctly and allow the operators to perform the switching operation, thus ensuring the correctness for the maintenance personnel to run a substation equipment operation, and finally returning the important information about the device operation to the host.

Received January 22, 2014; Revised March 16, 2014; Accepted April 9, 2014

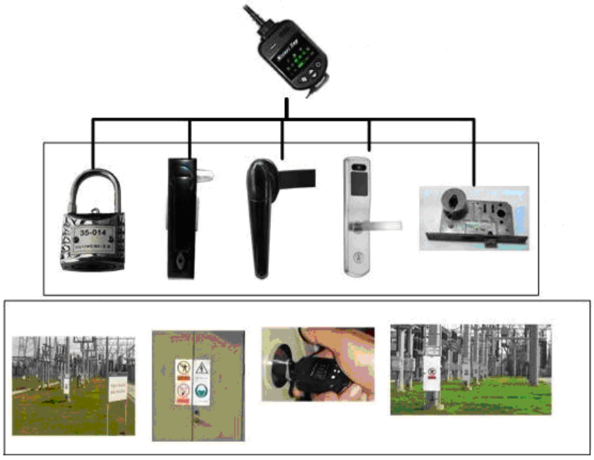

Figure 1. Intelligent Key Appearance and use Objects

2. System Design

The intelligent key system requires a microcontroller to make a real-time communication with external modules through a variety of bus [4-6], and RFID-based intelligent key is a mobile device which has more stringent requirements on power consumption, so the intelligent key system mainly contains the main control circuit, OLED display interface circuits, RF signal recognition circuit, a power circuit, data storage, keyboard input module and so on. Main control circuit composed of STM32F103VET6 and its peripheral interface circuit is the core part of the system and it deals with the main transmission and processing of the data. The signal collected by RF signal recognition circuit EM4095, is converted to the real-time data by a processor and then makes the real-time display through OLED display circuit after reprocessed by the processor. Data storage module uses EEPROM AT24C64 to store intelligent key operational states, large-capacity SD card stores label data and the GBK font, icons and other data for display.

Depending on the features of more and more substation equipment and relatively high-value, intelligent key system substation in the overall design of the hardware should consider the following: high reliability, portability, storage capacity, easy expansion. The overall design of substation intelligent key system is shown in Figure 2.

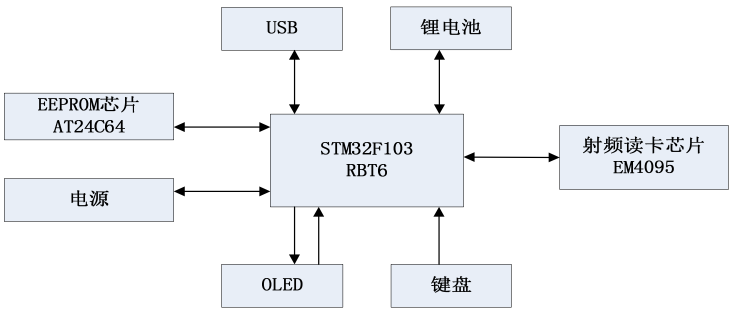

Figure 2. Overall Structure of the System

2.1. ARM Selection and Peripheral Interface

Based on the STM32 family, it is designed for the requirements of high-performance, low-cost, low-power embedded applications, specifically for ARM Cortex-M3 core. According to the performance, it is divided into two different series: "Enhanced" STM32F103 series and "basic" STM32F101 series [7]. This design uses the STM32 "Enhanced" STM32F103VET6, the clock frequency of 72MHz, executing code from flash; STM32 consumes 36mA, the lowest power consumption in the market of the product 32, which is equivalent to 0.5mA/MHz. It can achieve high-end computing, embedded 512KB FLASH program memory, supports a rich set of peripherals and communication bus with I^2C, SPI, USART serial interface and USB bus, I/O interfaces and other functions [8].

STM32F103VET6 communicates with RF chip, SD card by using 4-wire SPI bus mode and is connected to touch screen controller. For example, the feet 26 and 27 of the STM32 are respectively connected with the feet 13 and 14 of the EM4095 so as to complete the connection of processor and RF chip. STM32F103VET6 uses I^2C bus to communicate with the external EEPROM AT24C64. It is connected to display module by using 16-bit I/O interface to achieve the output of the system displays. It is connected to the keyboard by using 16-bit I/O interface and can support up to 64 keystrokes. It achieves programming and debugging programs by using USART serial interface. It realizes high-speed communication between USB and PC.

2.2. Display Interface Circuit

In the process of using the intelligent key, we need to send data to the RF tag and realize real-time data storage and communication with the host computer, which requires the input of data and the control of information, and the data and control information are visually displayed. From the use of performance requirements, it achieves both hand-held small size, as small as a car key, and intelligent human-machine interface. Therefore, an organic light emitting display screen with the 0.96' OLED is designed to display human-machine interface. The display device supports a two-ways input of touch screen and keyboard. The touch screen is mainly used for inputting control information, while the keyboard is mainly used for inputting data. The organic light emitting display OLED is the next-generation flat panel display technology, more advanced than LCD. Compared with LCD, it has superior features such as ultra-thin, high brightness, self-illumination, wide viewing angle, fast response, adaption to a wide temperature range and a strong earthquake, low power consumption and so forth.

The system uses OLED display module to display 64 lines, 128 rows, using a 64-line output line driver and two column drive controllers, and each column driver has 64 outputs. There is no relationship between line driver and control circuit STM32F103VET6, only to provide power to generate the drive signal and a synchronization signal. The connection between STM32F103VET6 and OLED uses I_0 common port with PC_0-PC_7 used as the data bus and the other used as a control port. The external signals of modules are only related to column driver. Column driver has a 64*64-bit built-in display memory. RAM is divided into 8 pages, 8 lines each page. The state of each pixel on the display corresponds to the data of display memory and the data of display memory directly acts as the drive signal of graphical display. "1" is displayed and "0" is not displayed.

2.3. Radiofrequency Signal Recognition Circuit

RFID (Radio Frequency Identification) technology is a communication technology using radio signals to identify specific target and read data without the establishment of a specific mechanical or optical contacts between recognition system and the target [9]. Door locks and device locks in power supply system uniformly adopt lock cylinder with electronic tags. There is RFID signal recognition circuit chips in the intelligent key to read when the lock is authorized and whether the key can open the door or not.

EM4095 is selected as RF chip. EM4095 is a dedicated RFID reader chip launched by Swiss EM Microelectronic Corporation. Figure 3 is for a schematic diagram EM4095. DEMOD_OUT pin is an output of AM demodulated signal; MOD acts as modulation control side, low level without modulation, the high level of 100% modulation; RDY/CLK output terminal is indicative of multiple features, or as ready to send instructions, or as a synchronous clock signal output indicating the reception. When the chip works to establish an internal phase-locked loop and the receiver circuit comes to work, RDY/CLK outputs a continuous clock signal synchronized with DEMOD_OUT data signal; when SHD is high-lever, EM4095 comes into power-saving sleep mode, and RDY/CLK is also set low.

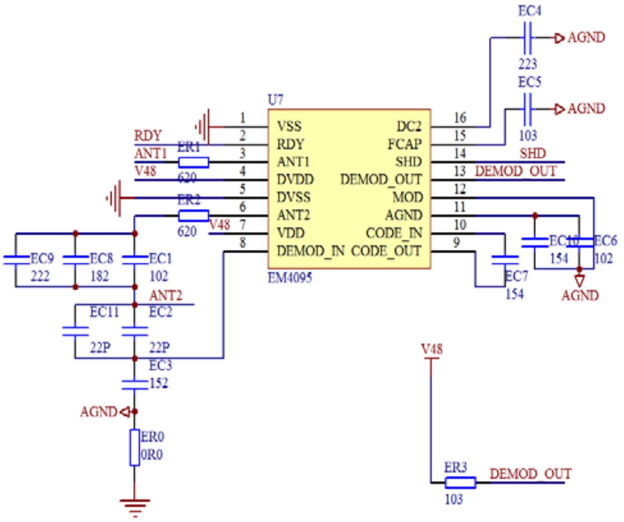

Figure 3. Schematic Diagram EM4095

As EM4095 provides only produce carrier and AM modulation and demodulation functions, the reader receives the transmission of encoding and decoding of data completely from the processor STM32F103VET6. The data rate of 125kHz RFID is usually 2-3.2kb/s. The transmission of encoding data is relatively simple as long as the port of controlling the transmission produces a timing output of specified data bit, and the decoding of the received data is relatively complex [10].

2.4. Power Circuit

Intelligent key is handheld, so it is necessary to provide mobile power. The design uses a lithium battery and provides charge and discharge protection circuit internally. USB port is used for charging, and OLED displays the charge status, battery power and other parameters. Charging chip adopts Shanghai Consonance CN3063; charge and discharge protection circuit uses classic circuit DW01 + 8205A. The circuit diagram is shown in Figure 4.

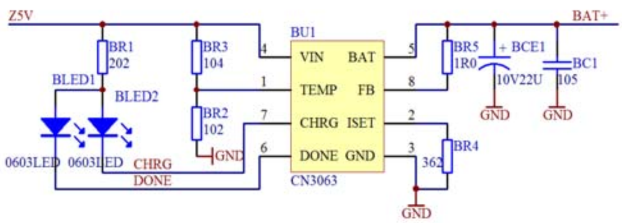

Figure 4. CN3063 Circuit Diagram

The system circuit also needs to provide 5V power supply to the OLED and EM4095 and +3.3V power supply to STM32F103VET6. For anti-interference, each supply pin of STM32F103VET6 is paralleled with 0.1μF coupled capacitor. These capacitors should be placed close to the power/ground pin, as close as possible. Boost DC/DC converter is MAX1687 chip and power supply chip is TPS7333Q.

2.5. Data Storage

As for internal storage resources, STM32F103VET6 contains 512KB SRAM and 64KB FLASH. In order to store the work status of intelligent key, the resource used for display and a large number of radio frequency identification data, Atmel AT24C64 EEPROM storage chip is used to meet the requirements of intelligent key working condition. The chip can store 64KB of data and communicate via the I2C bus with STM32F103VET6, including data line SDA and the clock line SCL. Calibration data of the touch screen is stored in AT24C64 to achieve coordinate transformation between touch screen and the OLED.

The system uses SD card to store character fonts, pictures and the data read from RF interface card. SD card is small-sized, with large capacity, widely used in mobile devices. SD card communicates with STM32F103VET6 via SPI bus with fast transfer rates, more than 2MB per second, to meet the requirements of the data transmission rate of the handheld intelligent key. In addition, the SD card can be easily removed from intelligent key, so we can use the general reader of the PC to read SD card so as to realize data exchange between intelligent key and PC.

3. System Software Development

The software of embedded GUI-based intelligent key system is developed by the following layers. The underlying layer is constituted by the μC/OS-Ⅱ kernel and drivers, which mainly provides support for a variety of hardware interfaces; the middle layer is an embedded μC/GUI library, which optimizes the operation of various graphics, without the demand of extra run-time support system, reducing CPU load, and which can be extended to the continuous upgrading; the top level is application of the system, which implements a specific function set of applications of intelligent key.

Since the system is a small intelligent key system for substation, to reduce development costs and cycles, we use the embedded real-time operating system μC/OS-Ⅱ, which is of higher cost-performance ratio. According to system development environment, RealView MDK-ARM 4.20 and STM32 compiler provides a hardware platform. In the need of development, some of the documents are revised when μC/OS-Ⅱ is transplanted [11]. The revised documents include: OS_CPU.H (C language header), OS_CPU_C.C (C source files), OS_CPU_A.ASM (Assembler source files) and the related configuration files.

μC/GUI is a graphical support system of the embedded application. It is designed to provide efficient OLED controller for using OLED display graphics applications, independent of the processor and the graphical user interface, so μC/GUI can be seen on μC/OS-Ⅱ embedded operating system written in a visual interface function library [12].

μC/OS-Ⅱ supports interrupt routines and multitasking [13]. To shorten the response time of the reader terminal and the inspection time of data comparison, the main function of the entire software system is designed as follows: motor driven, radio frequency processing, interface display, data storage and other modules. The intelligent key system terminal software is written in C language in KeiluVision4.0 compiler environment. The primary process is shown in Figure 5.

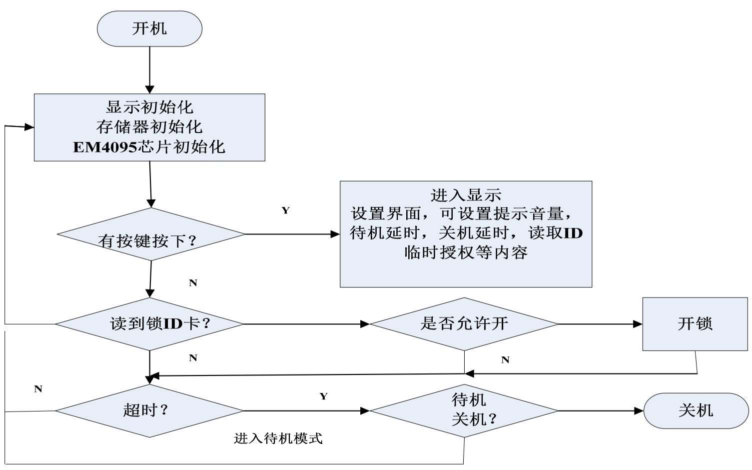

Figure 5. Software Design Diagram

Intelligent key system is composed of a 400mah lithium battery with an RFID chip embedded in the head of each lock. The lock is a magnetic one and has four marbles in irregular arrangement. Under normal circumstances, marbles are irregular and the key can not unlock. When the key is inserted to the lock cylinder, the EM4095 reads the corresponding ID card of the lock. When the ID card information is consistent with the key authorized, the key starts executing procedure which enables the marbles in a straight line, then we can unlock. It is requested that the more times the key unlock, the better. When starting the system, real-time clock initialization involves calling real-time clock RTC initialization and set the RTC clock function parameters.

```
void Clock_Init(void)
{
    if(BKP_ReadBackupRegister(BKP_DR1) != 0xA5A5)                  // Determine
whether the backup flag stored in the RTC registers has been configured
    {
            RTC_Config();
      // RTC initialization
            Time_Adjust();
              // Set RTC clock parameters
            BKP_WriteBackupRegister(BKP_DR1, 0xA5A5);                 // After the
RTC setting, the flag has been configured to write the backup data registers
    }
    else
    {
            if(RCC_GetFlagStatus(RCC_FLAG_PORRST) != RESET)                  //
Check for power failure restart
            {
                    //  a power-on reset
            }

            else if(RCC_GetFlagStatus(RCC_FLAG_PINRST) != RESET)    // Check if
reset reset
            {
                    //  an external pin RST reset
            }
            RTC_WaitForSynchro();
                    //  Wait RTC registers are synchronized
            RTC_ITConfig(RTC_IT_SEC, ENABLE);
           // Enable interrupt seconds
            RTC_WaitForLastTask();
                    // Wait for the write completion
    }
    RCC_ClearFlag();
                        // Clear reset flag
}
```

Intelligent key system is low-power consumption. When the key does not touch the button for a long time, the key turns off the backlight to close the booster circuit, and finally turns off the power. After turning off the power lithium battery will not lose power until the next re-boot.

4. System Testing

A PCB board of RFID-based intelligent key system is designed, with its motherboard about 16CM*9CM, which can meet the portable demand of handheld intelligent key. When testing, it uses ISP download tools of STM32F103VET6 to download through USART serial, and uses this RFID-based intelligent key to read RF tag which meets the ISO/IEC15693 standard. The operating distance is not less than 8CM. Reader and display speed meet the needs. The resulting reader data will be stored to an SD card and sent to PC via the USB bus. PC can receive the card number, sector, data and other information for further data processing.

As a result, after the test the intelligent key system is more flexible to use, easier to carry and operate than the ordinary substation key, and it can be used normally.

5. Conclusion

From the ARM software and hardware design, the novel study is the development of a substation intelligent key system. It is a highly visual interface intelligent key and has information query and memory function to achieve the integration of the anti-locking system and error monitoring system closely. It fully combines and utilizes integrated features and resources to improve the degree of automation mislock system, to make the structure more streamlined, more reliable and easier to maintain. With the development of electronic technology, the requirements for the intelligent key are getting higher and higher, so portability, large storage capacity, more features, friendly user interface are all taken into account.

Acknowledgements

The work is supported by National Natural Science Foundation of China (No. 61142007). Furthermore, we are indebted to the support and encouragements received from the staff and colleagues of Cloud Computing and Intelligent Information Processing Laboratory of Chang zhou (No. CM20123004).

References

[1] Xiaoqin Zhang. On the Intelligent Key Management System in Substation. *New technologies and products*. 2012; (16): 6-6.
[2] Dobkin DM. The RF in RFID: UHF RFID in Practice. Waltham: Newnes. 2012: 189-201.
[3] Lehpamer H. RFID design principles. Norwood: Artech House. 2012: 77-94.
[4] Liu Ying, Zhu Yantao, Li Yurong, Ni Chao. The embedded information acquisition system of forest resource. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(7): 1843-1848.
[5] Chen YL, Chiang CY. *Embedded vision-based nighttime driver assistance system.* Proceedings of Computer Communication Control and Automation (3CA). Tainan. 2010; 2: 199-203.
[6] Shiguang ZXQXL, Biao RYQ. Design of electric power data acquisition system based on STM32. *Electronic Measurement Technology*. 2010; 11: 023.
[7] Brown G. Discovering the STM32 Microcontroller. *Cortex.* 2012; 3: 34.
[8] STM32F101xxandSTM32F103xx advaneed ARM-based 32-bit MCUs Reference manuals microelectronics. 2008.
[9] Wen W. An intelligent traffic management expert system with RFID technology. *Expert Systems with Applications*. 2010; 37(4): 3024-3035.
[10] Namboodiri V, Gao L. Energy-aware tag anticollision protocols for RFID systems. *IEEE Transactions on Mobile Computing.* 2010; 9(1): 44-59.
[11] Xin Z, Guo Y, Hu L. Research on the Implementation of Porting uC/OS-II on the STM32F103 chip. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(7): 3897-3904.
[12] Tian LG, Guan BB, Chen ZL, et al. Design of μC/GUI Interface Based on STM32 Embedded System. *Applied Mechanics and Materials*. 2013; 303: 1485-1488.
[13] Shi J, Guo M. Embedded Digital Oscilloscope Based on STM32 and μC/OS-II. *Applied Mechanics and Materials*. 2012; 190: 1129-1135.