**Design of a Detection and Diagnosis Equipment**

**Yong Wu**, Yong Guo Xu, Jianhu Zhang, Xiaoyan Ruan and Jun Zhang

1. Introduction
During the operation and use of a certain type of equipment, regular inspection and maintenance are needed. Because of its complex structure and high technical content, it is difficult to detect and diagnose. At present, only simple parameters of the equipment can be tested. In order to improve the technical support ability of this type of equipment and realize its fast and accurate fault diagnosis, a portable detection and diagnosis equipment is designed. The system has the advantages of simple operation, high test precision and high detection efficiency.

2. System hardware
As shown in Figure 1, the hardware architecture of the system is centered on the control unit (MCU). The functional modules are relatively independent in the circuit, and they coordinate under the control of the control unit.

The communication module is used to complete the data communication with the host computer, mainly through the USB port for data communication. Data storage module is used to store detection data and metadata. Resistance detection module is used to detect the insulation resistance and on-resistance of the tested equipment. Keyboard input module is used for human-computer interaction, input meta-information or function selection. Real-time clock module is used to provide real-time clock for the system. The system is powered by lithium batteries. The working power supply module mainly uses “Jin-sheng-yang” power supply module, which is used to generate all kinds of voltage needed by each module. The charging module is used for charging control and display of lithium batteries.
2.1. Micro controller
The Cortex-M3 microcontroller of NXP semiconductor LPC1778 has a high integrated frequency of 120 MHz and is designed for low power embedded applications [1]. Main features: 1. Functional replacement of LPC23XX and 24XX series devices; 2. The ARM Cortex-M3 processor runs at frequencies up to 120 MHz; 3. Nested Vector Interrupt Controller (NVIC) is built in Cortex-M3 of ARM; 4. Multilayer AHB matrix interconnection provides an independent bus for each AHB host; 5. Splitting APB bus allows higher throughput; 6. Cortex-M3 system rhythm timer, including external clock input options. The MCU of NXP Cortex-M3 also includes ultra-low power real-time clocks with independent battery power supply and up to 165 universal I/O pins. It is very suitable for eMetering, lighting, industrial network, alarm system, household appliances and motor control applications.

2.2. Voltage Conversion and Overcurrent Protection Circuit
The test equipment needs a positive and negative 110V voltage excitation signal. The 110V voltage is generated by the voltage conversion circuit, and the -110V voltage is obtained by converting the input polarity. As shown in Figure 2, we mainly use the “Jin-sheng-yang” Voltage Conversion Module HRB12110D-6w, the input voltage is 12V, and the input voltage is from M1’s 1 or 2 feet and the output voltage is from 7 or 8 feet.
As shown in Figure 3, the over-current protection circuit is used to complete the over-current 110V protection with Figure 2. Figure 2 comparator U1 outputs to Figure 3’s R7. The monostable flip-flop is composed of SA555 chip (M2) and peripheral circuit. The U1 amplifier acts as a comparator, and the reverse input is divided by R5 and R6.

555 timer is a medium-scale integrated circuit. It combines analog function with logic function on the same chip. It can be used as both timer and oscillator. It only needs a small number of resistor and capacitor components, so it can easily form monostable flip-flop, Schmidt flip-flop and multi-resonator pulse generation and conversion circuit. 555 timer is widely used in automatic detection and control, instrumentation, signal generation and transformation, timing and alarm, household appliances and other fields. The function of 555 timer is mainly determined by two voltage comparators [2-4]. The output voltage of the two voltage comparators controls the state of RS flip-flop and VT of discharge tube. Among them, three 5kΩ resistors constitute a voltage divider between the power supply voltage and the ground. When the CO of the control voltage input is suspended, the reference voltage of the in-phase input terminal of the voltage comparator is 2Vcc/3, and the reference voltage of the inverted input terminal is 1Vcc/3.

Normally SA555 is in steady state, no output, E3, E4 cut off, output 110V_OVER_SIGNAL high level to MCU, control power stop. At the same time, 110V_EN has no voltage signal to ensure that the power supply has no input. When overcurrent occurs, the voltage of U1 forward input is too high, and U1 output is high. The monostable circuit composed of 555 triggered by R7 enters the transient state. The over-current signal 110V_OVER_CURRENT triggers the NMOS Q1 through R9 and R10, thus lowering the E3’s two legs and making the E3 work. The output 110V_EN outputs high level to E1. Similarly, E4 starts to work, outputs 110V_OVER_SIGNAL low level to MCU, and controls the power supply.

![Figure 3. 110V Overcurrent Protection Circuit](image)

2.3. Micro controller AC and DC Signal Detection Circuit
As shown in Figure 4, after DC-IN signal is divided by a voltage dividing network composed of R20, R21 and R22, OP07 chip is used in the latter stage. The chip has very low input offset voltage, does not need additional zero-setting measures, and has the characteristics of low offset and high open-loop gain. The DC-OUT signal is generated by the follower composed of OP07 amplifier and sent to the AD acquisition port of MCU for data acquisition and analysis [5].
Figure 4. DC Detection Circuit

The detection of AC signals is shown in Fig. 5. The core part of the system consists of three amplifiers. The first amplifier is a proportional amplifier. The AC output signal is separated by C10. The AC-IN signal is scaled up by a proportional amplifier composed of R30, R31, R32 and U3. The absolute value circuit composed of U4 and U5 reverses the negative value of the input signal and obtains the AC-OUT signal, which is sent to the AD acquisition port of MCU for data acquisition and analysis.

Figure 5. AC Detection Circuit

2.4. Switching circuit
The switching circuit is designed because of the large resistance to be detected. MAX4638 multiplexer with switching speed in microsecond level is adopted. MAX4638 is an 8-choice 1 Analog multiplexer. It uses +1.8 V to +5.5 V single power supply; switching time is only 7 ns. The constant current source circuit is used to provide the standard test current. The output of the constant current source circuit is added to the cable to be tested by driving the multi-channel switch to transmit the voltage difference between the two ends of the test cable to the instrument amplifier. Instrument amplifier converts and amplifies the signal to the A/D port of microcontroller for A/D conversion. According to Ohm's law, the resistance of on-resistance is calculated by voltage value. Through the program to determine whether the test results are normal, and display on the screen.

3. System Software Architecture
The host software of detection and diagnosis equipment is developed in C language, and the uC/OSII operating system is adopted. The uC/OSII operating system, provided by Micrium, is a portable,
solidified, tailorable, preemptive multitasking real-time kernel. It is suitable for a variety of microprocessors and digital processing chips. At the same time, the source code of the system is open, clean, consistent, detailed and suitable for system development. We have tailored and transplanted the uC/OSII operating system.

Its workflow is shown in Figure 6. The main processes are hardware initialization, operating system initialization, creating start tasks and opening multi-tasks.

![Software flow chart](image)

**Figure 6.** Software flow chart

AppTaskStart is the first task of system startup, and other tasks are created by it. The main tasks include: UsbTask, PcCmdTask, TestSelfTask, EggTask, CableTask, FlwTask, DatChkTask, DateTask, MainMenuTask, and ChargeTask.

### 3.1. Embedded Operating System Porting

The main modifications of system transplantation are as follows: 1. Compiler environment IAR and KEIL are different, especially in the recognition of assembly instructions; 2. although both LPC1778 and STM32F107 belong to M3, the transplanted platform ARM Cortex-M3 has some differences in implementation. A new Keil project was established. The assembly files cpu_a.asm, os_cpu_a.asm, startup_LPC177x_8x.s to be modified.

### 3.2. Upper Computer Program Architecture

The host computer program is developed with VC++ 6.0. It can control the function of the host computer, provide time, read data, and manage the received data. The main functions include: instrument self-test, cable test, performance parameter test, current monitoring and so on. The upper computer program uses MFC Dialog template to create executable program, and introduces EasyUSB23xx.dll and sqlite3.dll dynamic Link libraries, which are used for data communication and data storage respectively.

### 4. Conclusion

This type of testing and diagnosing equipment can check the main electrical parameters of the equipment to improve the safety and reliability of the equipment used. It can supervise and inspect the quality monitoring situation and effect of the inspected equipment, and improve the maintenance and support ability of the inspected equipment.
References

[1] Xu Shimin, Fan Xiaoming, Li Bo. Research on Six-way RS485 Bus Coal Mine Safety Monitoring Substation Based on LPC1778, J. Electronic world, 2014, (23): 27-28.

[2] Zou LAN. Typical Circuit of 555 Timer and Its Practical Application, J. Chemical automation and instrumentation, 2017, 44 (4): 406-409.

[3] Chen Yong Fu. Classical Application Example of Multifunctional Integrated Circuit 555, M. Beijing: Electronic Industry Press, 2011.

[4] Li Xiaoyong, Huang Junhua, Wu Xiaole. Ballistic Burst Analysis of 555 Timing Control Self-destruction Circuit Under Condition of Unstable Power Supply, J. Ordnance Industry Automation, 2016, (9): 35-37.

[5] Zhang Weifeng, Zhang Yanhui, Luo Huan. A Simple AC Voltage Detection Circuit, J. Microcomputer and Its Application, 2017, (5): 32-34.