Design and Implementation of a Portable Experimental Platform for Electrical Foundation Courses

Yang Song*[1], Bo Zhou[2], Dongmei Zhao[3]

{*songyang0047@126.com[1], 1280788943@qq.com[2], zhaodongmei871201@126.com[3]}

Dept. of Basic Sciences, Dalian Naval Academy, Dalian, China

Abstract. To comprehensively implement the teaching philosophy of "integrating theory with practice and combining the virtual with the real" in electrical foundation courses, addressing issues such as limited experimental class hours, constraints on physical space, and insufficient autonomy and innovation, this paper presents a design solution for a portable experimental platform. The portable experimental platform of foundation courses possesses advantages such as portability and strong scalability. It can meet students' needs for various electrical foundation experiments and innovative projects, supporting teachers in conducting smart classrooms, flipped classrooms, and other teaching activities. Together with theoretical instruction, it forms a multidimensional, stereoscopic teaching model of "teaching, learning, doing, and researching," stimulating interest in learning, enhancing practical innovation abilities, and cultivating well-rounded individuals with advanced thinking skills.

Keywords: Electrical Basics, Portable, Experimental Platform.

1 Introduction

Electrical foundation courses belong to engineering practice courses, aiming at solving practical problems. The knowledge system is complex and abstract, with strong logic, engineering, practicability and application. Therefore, in addition to the study of theoretical knowledge, it is more necessary to combine theoretical knowledge with practice through corresponding experimental projects to improve students' hands-on, practical and innovative abilities.

At present, the theory and practical teaching of electrical foundation courses are carried out separately. The theoretical teaching is carried out in the classroom, and the experimental courses are completed on the experimental boxs in the laboratory. The following problems exist in this teaching mode[1]:

1. The connection between theory and practice is not close, and students' enthusiasm for learning is not high.

2. The practical activities are limited by time and space, and the students do not explore deeply.

3. The implementation project is solidified and simple, and the students lack the consciousness of independence and innovation.

In order to solve the above problems existing in the practice of electrical foundation courses, to enrich teaching activities and teaching methods, to develop the "student-centered" mixed

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teaching mode, to provide students with independent, innovative and flexible experimental platforms, and to expand the concept of traditional laboratory time and space, the portable experimental platform came into being [2].

The development and application of the portable experimental platform is of great benefit to the cultivation of students' knowledge, skills and ability [3]:

1. Promote the connection between theory and practice.

2. Improve the scalability of experimental projects.

3. Extend the experiment space and time.

4. Improve the learning and problem research ability.

5. Help design and develop solutions.

6. Improve your ability to use modern tools.

7. Develop communication and cooperation skills.

There are two main channels for the acquisition of portable experimental platforms, which are purchased by electronic companies or independently developed by schools. The experimental platforms purchased directly from the companies have the advantages of strong versatility, stable product performance, and in line with industry standards, but because of the different curriculum requirements of different universities, these products may not meet the teaching requirements of the courses; The experimental platforms independently developed by the schools highlight the advantages of customization, its functions and operability are more in line with the teaching requirements of the school [4]. At present, the portable experimental platforms on the market need to use laptop computers for virtual experiments, and the students in military universities are limited in using information equipments. Therefore, this paper proposes a new design scheme of a portable experimental platform for electrical foundation courses.

2 Overall program design

To provide students with richer circuit resources and complete as many experimental projects as possible, considering the upgrading and secondary development issues brought about by the gradual reform of electrical foundation course content and teaching modes [5, 6], this experimental platform includes three parts: the experimental baseboard, development board and consumables box.

The development board is the board on which students build circuits. Considering that experimentation is a continuous improvement and creativity process, the development board needs to meet the flexibility, creativity, autonomy, scalability, and repeatability required. The breadboard is a versatile universal experimental board with low price, strong scalability, and no need for welding. It is very suitable for the assembly, debugging and training of electronic circuits. Therefore, the breadboard is selected for the development board.

The consumables box contains commonly used components in electrical foundation courses, additional functional elements, and general material tools. Common electronic components can be listed and purchased centrally based on course content and stored in various storage boxes. The physical diagram of the development board and the consumable box is shown in Figure 1.

Fig. 1. Physical diagram of the development board and the consumable box.

Common DC power supplies, instruments, and other components are integrated into a circuit board, serving as the baseboard for a portable experimental platform. The development of the baseboard involves both hardware circuit development and software development. During the design process, while ensuring safe usage, the hardware circuit aims to minimize size without excessively pursuing parameters, meet the requirements for daily experimental use, and facilitate portability and operation. The following focuses on the hardware design of the experimental baseboard.

3 Hardware design of the experimental baseboard

3.1 Overall hardware design of the experimental baseboard

The design of the experimental base plate of the portable experimental platform adheres to the design principles of "cost-effective, reliable, accurate, and enough." The so-called "cost-effective" means that the circuit cost is controlled to the maximum extent so that all students can configure and use it; "Reliable" means that the circuit is hard to damage under various abnormal use conditions; "Accurate" means that the function of the instrument must have a specific dynamic range and accuracy to meet the needs of various experiments and innovations; "Enough" means taking into account the actual situation of students' learning and innovation, and not excessively pursuing high indicators.

The experimental baseboard adopts the modular design idea, which contains all the peripheral modules needed for the actual experiment content, composed of four parts: power module, input module, measurement and output module, and connection module.

1. The power module for the experimental baseboard to provide the required DC power supply.

2. The input module includes the signal generator that can produce sine wave signals, rectangular wave signals, and triangle wave signals, the clock pulse source that can produce continuous or single clock pulse signals, and the logic level switch that can input high and low levels.

3. The measurement and output module can display the circuit output and measurement results, including an oscilloscope, a multimeter and sound and light display circuits of a logic pen, a BCD decoding display, logic level indication circuits, a buzzer.

4. The connection module includes the connection between each module, each module leads out of the pin, pin holder, and so on.

3.2 Hardware design of each module of the experimental baseboard

3.2.1 Hardware design of the power module

The power module provides the DC power supply to the portable experimental platform, including AC to DC converter and DC voltage regulator module. The AC to DC converter can convert 220V power grid voltage to DC, and the DC regulator module can provide the DC power such as 24V, 12V, 9V, and 5V for the experiments. A 9V DC power supply is set as an adjustable DC power supply to expand the application and meet more experimental needs [7, 8, 9].

The AC to DC module adopts a 30W ultra-small series module power supply, which has the advantages of global input voltage range, low-temperature rise, low power consumption, high efficiency, high reliability, high safety isolation, etc.

The DC voltage regulator module uses LM2596S multi-channel buck voltage regulator DC-DC switching power supply chip. The LM2596 switching voltage regulator is a step-down power management monolithic integrated circuit, capable of output up to 3A drive current while having good linearity and load regulation characteristics. 12V, 9V, and 5V DC power supplies are designed and realized by using the DC voltage regulator module with LM2596S multi-channel buck voltage regulator DC-DC switching power supply chip, in which 12V and 5V are fixed DC power supplies, and 9V is adjustable DC power supplies. The schematic diagram of the power module is shown in Figure 2.

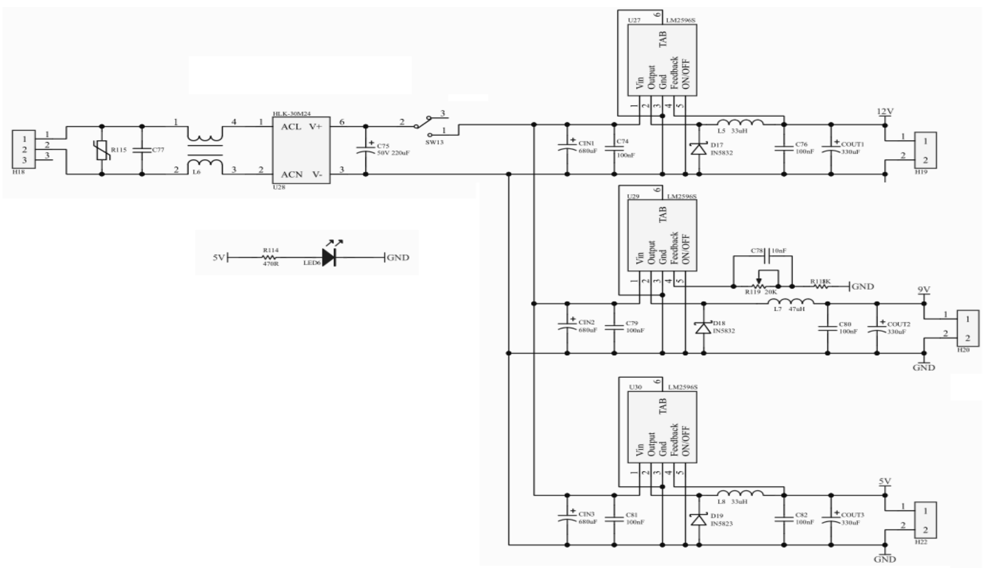


Fig. 2. Schematic diagram of the power module.

3.2.2 Hardware design of the input module

The input module includes a signal generator that can generate sine wave, rectangular wave, and triangle wave signals, a clock pulse source that can generate continuous or single clock pulse signals and a logic level switch that can input high and low levels.

The signal generator is primarily composed of the ICL8038 precision oscillator integrated circuit, TL082 is a dual operational amplifier that amplifies the output waveform signal, and the circuit design includes a 78L09 series voltage regulator and a TC7660S voltage inverter for dual power supply to the TL082 amplifier. A multivibrator is constructed by using LMC555 and components such as resistors and capacitors to realize a single and continuous clock pulse source. The logic level switch circuit consists of 16 logic switches and their corresponding switch level output ports, providing logic high and low levels to digital circuits. The schematic diagram of the input module is shown in Figure 3.

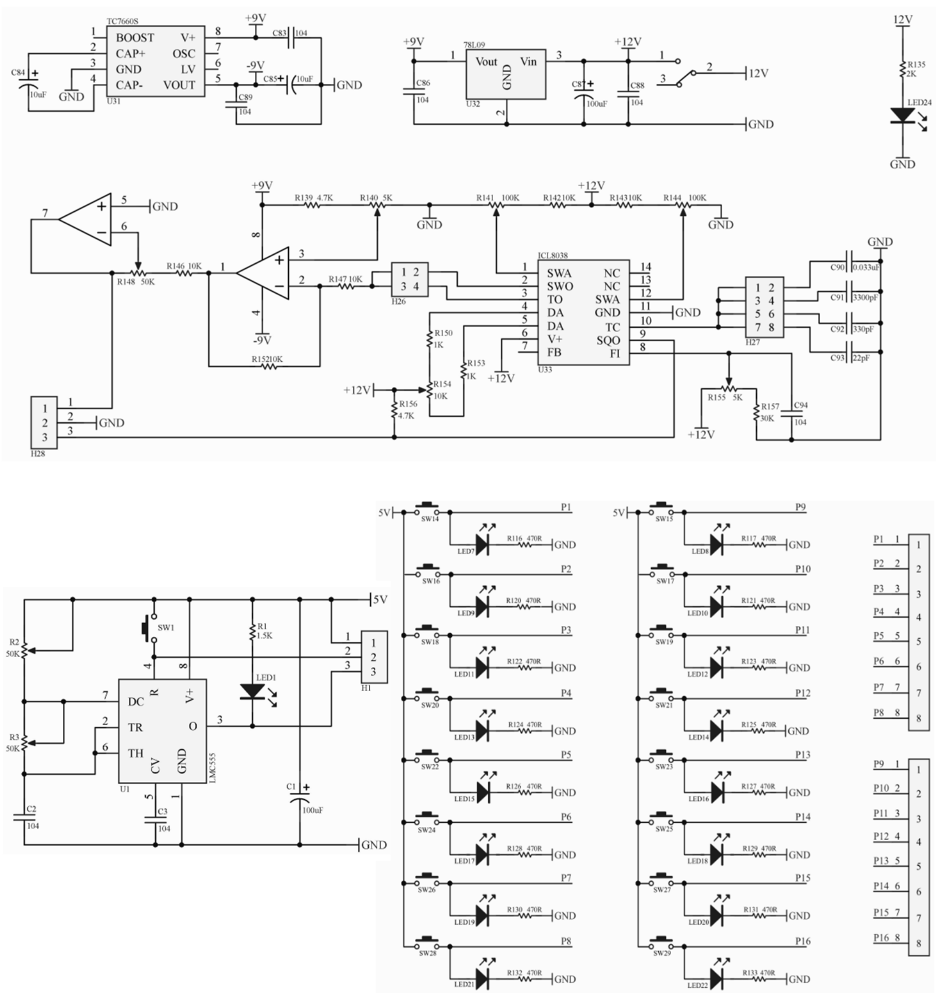


Fig. 3. Schematic diagram of the input module.

3.2.3 Hardware design of the measurement and output module

The measurement and output module can display the circuit output and measurement results, including an oscilloscope, a multimeter, sound and light display circuits of a logic pen, a BCD decoding display, logic level indication circuits, and a buzzer.

1. Hardware design of the oscilloscope

The hardware design of the oscilloscope includes a power supply, LCD screen, MCU, input circuit, and download/debugging sections. The main components of the power supply are 78L05, 79L05 to provide ±5V DC voltage for the circuit, LM1178-3.3 to provide +3.3.V DC voltage for the circuit. The LCD screen is a 2.4-inch high-definition TFT screen of the HT024SQV330NH model. The MCU is STM32F103, a commonly used 32-bit ARM microcontroller produced by ST. The input circuit is the circuit that the external input signal sending to the MCU, including the voltage follower and the amplifier circuit. The download/debugging part of the oscilloscope is the processor STM32F103 connected to the port of the downloader. In summary, the schematic diagram of the oscilloscope is shown in Figure 4.

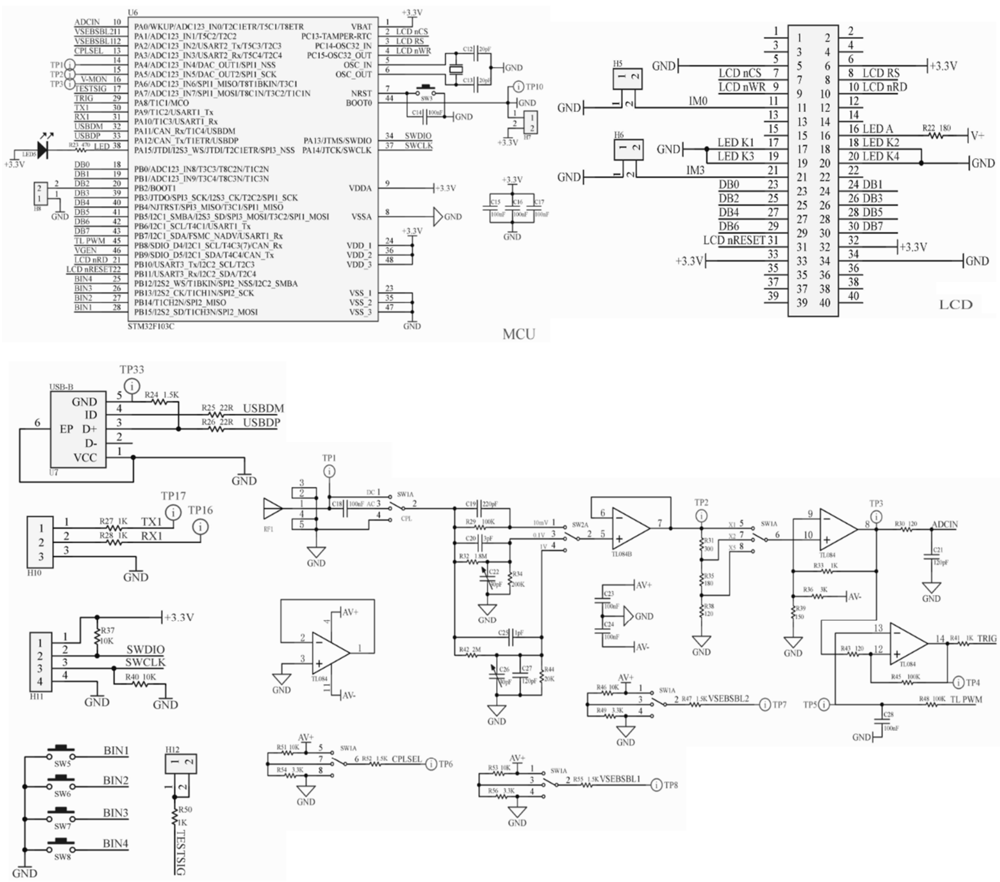
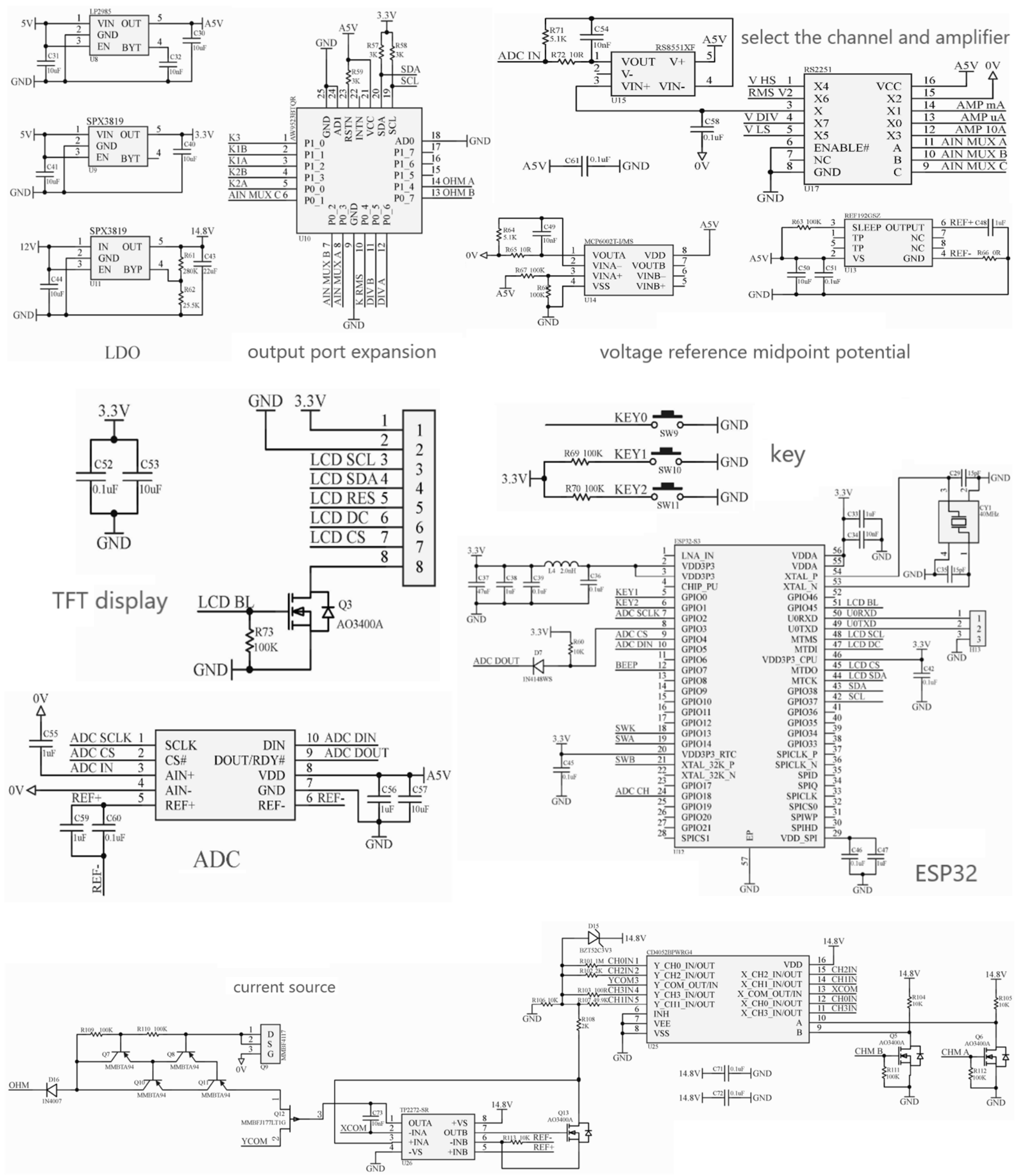


Fig. 4. Schematic diagram of the oscilloscope.

2. Hardware design of the multimeter

The hardware design of the multimeter includes the voltage regulator circuit, the output port expansion circuit, the MCU, the voltage reference midpoint potential circuit, the select channel amplifier circuit, the analog-to-digital conversion circuit, the display circuit, the key and pen terminal circuit, the AC measuring circuit, the current stop circuit, and current source circuit, the schematic diagram of the multimeter is shown in Figure 5.



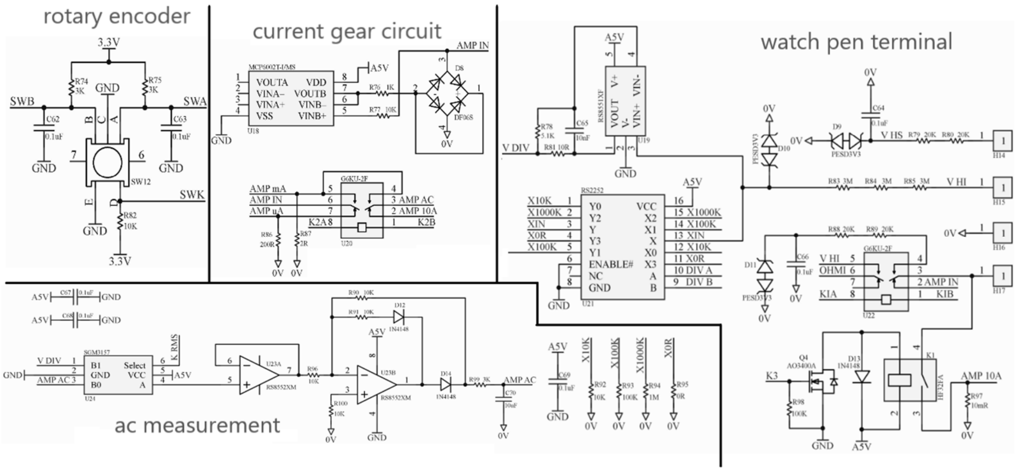
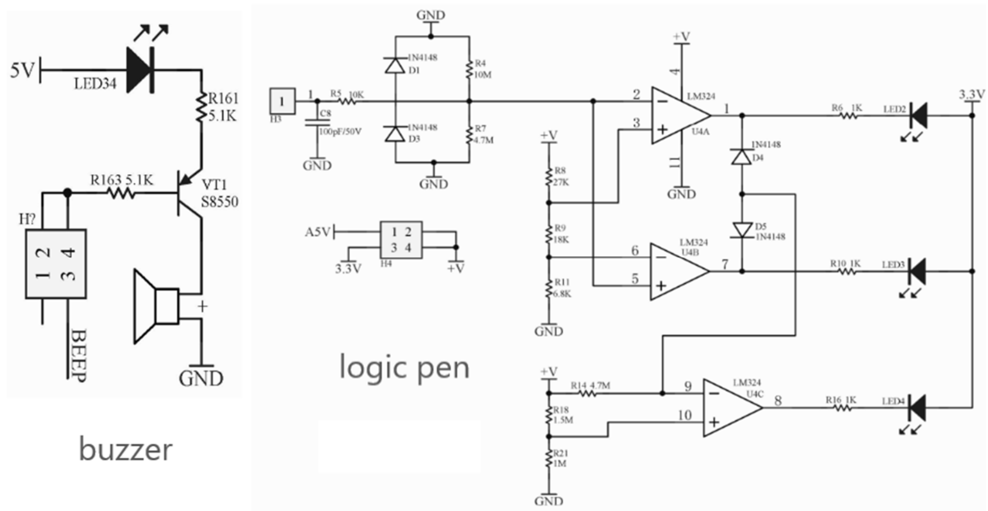


Fig. 5. Schematic diagram of the multimeter.

3. Hardware design of the sound and light display circuits

The sound and light display circuits include a logic pen, logic level detectors, digital display circuits, and a buzzer. The main function of the logic pen is to compare the input level with the set voltage, and the level comparison function of the logic pen is realized by using the LM324 four-way operational amplifier. The logic level detectors include 16 light-emitting diodes and their corresponding switching level input jacks. The function is to judge the input level by the corresponding light-emitting diodes' on-off state. The digital tube display circuits include digital tubes and a digital tube control circuit, and the digital tubes use two total cathode 4-bit integrated red LED digital tube SR420361N. The digital tube control circuit uses TM1640, a special LED drive control circuit. The buzzer is a commonly used electronic sound component. The schematic diagram of the sound and light display circuits is shown in Figure 6.



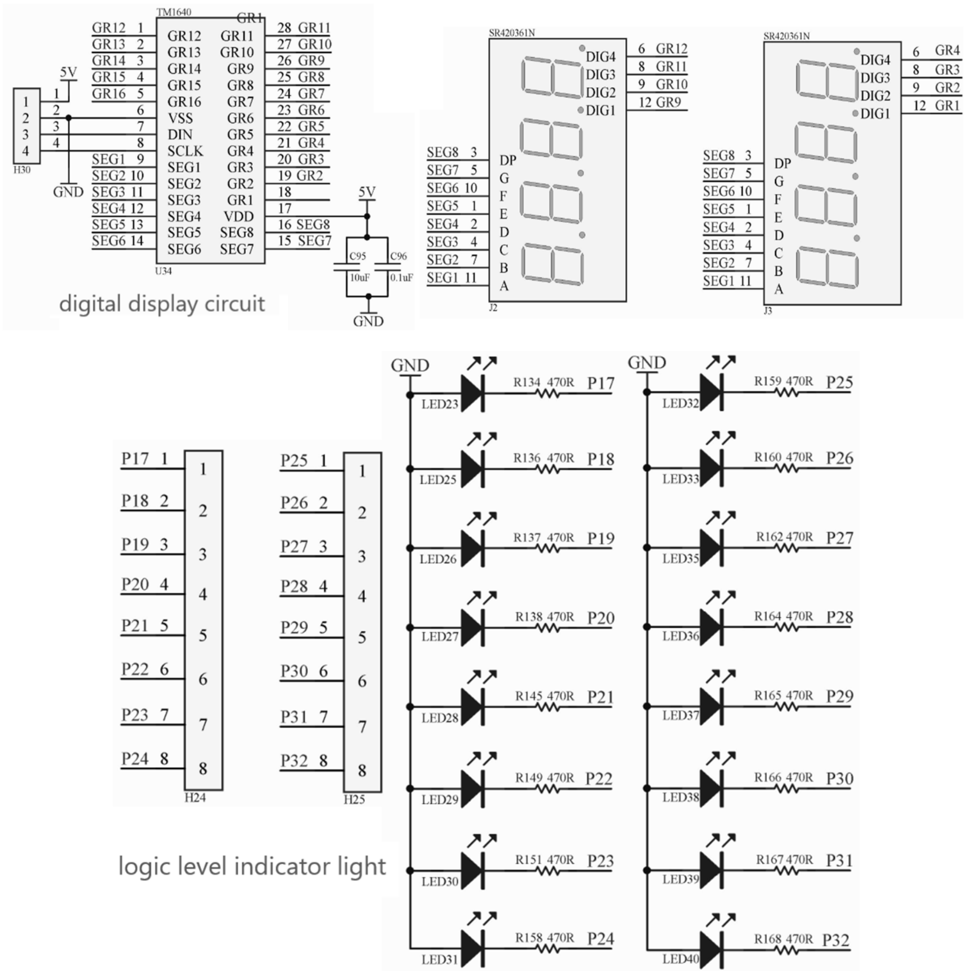


Fig. 6. Schematic diagram of the sound and light display circuits.

3.2.4 The experimental baseboard of the portable experimental platform

The PCB design and layout diagram of the experimental baseboard of the portable experimental platform for electrical foundation courses is shown in Figure 7, and Figure 8 demonstrates the physical diagram. The board integrates most instruments needed for basic and innovative experiments in electrical courses, with dimensions of 27 cm * 18 cm.

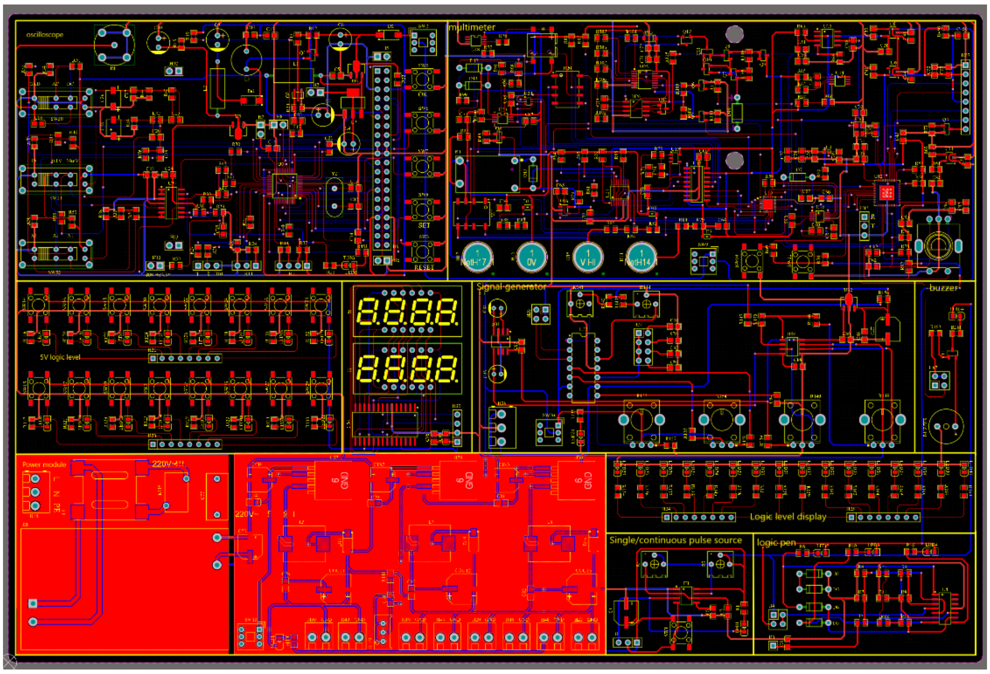


Fig. 7. PCB design and layout diagram of the experimental baseboard of the Portable Experimental Platform for Electrical Foundation courses.

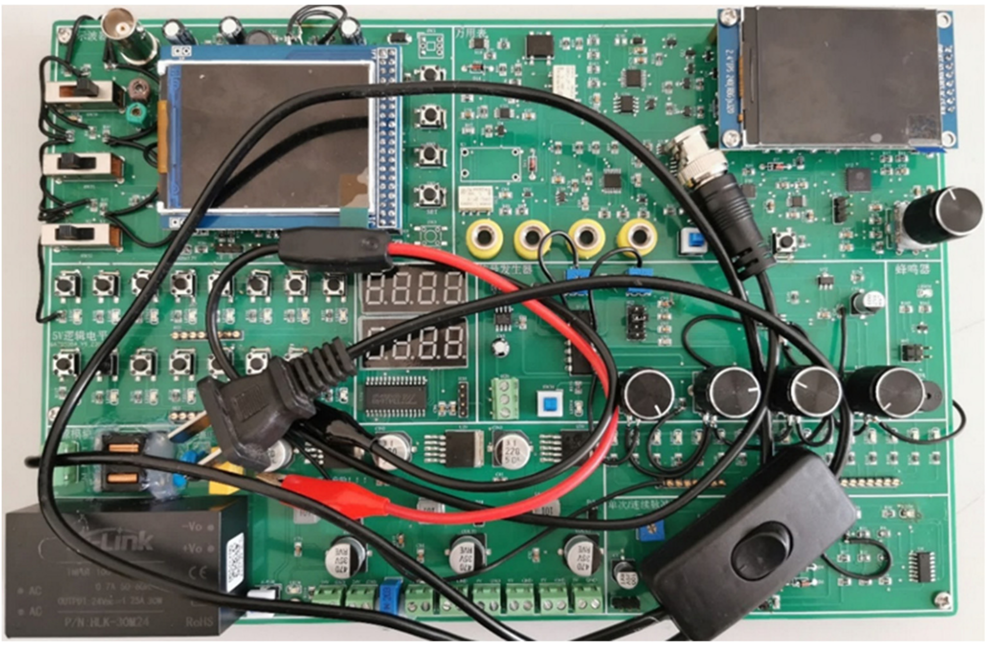
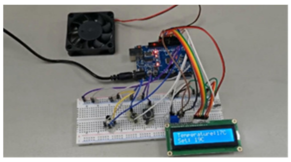


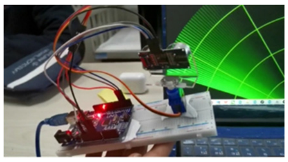
Fig. 8. Physical diagram of the experimental baseboard of the Portable Experimental Platform for Electrical Foundation courses.

4 Teaching application

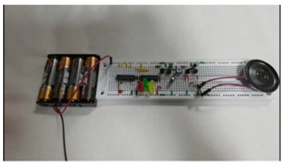
In order to cultivate students' ability of analysis, design, debugging, independent learning and solving practical problems, develop good engineering literacy and establish innovation awareness, the portable experimental platform has been applied to the teaching of digital circuit course in our university to assist students to complete the DIY open designs. By using the portable experimental platform, students consolidate and apply theoretical knowledge, expand the application, improve the innovative abilities and scientific research enthusiasm. Some students' DIY works are shown in Figure 9.



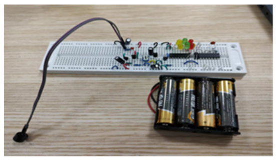
Arduino intelligent temperature control fan



Artificial radar



Acousto-optoelectronic sound simulator



Acousto-optoelectronic sound simulator

Fig. 9. Physical diagram of some students' DIY works.

5 Conclusion

The designed portable experimental platform for electrical courses, including the experimental baseboard integrated with almost all common instruments, a consumables box closely related to theoretical teaching content, and a development board, overcomes the drawbacks of traditional bulky experimental boxes. Students can independently conduct experiments anytime, anywhere, expanding the breadth and depth of teaching. The platform allows simultaneous theoretical learning and practical experimentation, making it a vital tool for interactive teaching, enhancing the quality and effectiveness of teaching, and fostering innovative talents.

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