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Design of Multi-functional Remote-control Terminal for IoT

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Abstract: The quality of smart home control applications and software is currently uneven. Faced with redundant functions such as open-screen advertising, manual control is more convenient. How to obtain a more convenient device control experience has become an urgent problem. Integrated with various standard communication control protocols, the multi-functional remote-control terminal of IoT focuses on the remote control of equipment. It simplifies the remote-control operation and has no redundant operation. Communicating with the smart car through the 2.4G wireless communication module, the terminal can remotely control the movement of the smart car and the on/off of the LED lamp on it by the LCD. With the built-in ESP-NOW function of the ESP32 microcomputer, the intelligent device equipped with an ESP chip can be controlled. The fan, light, and temperature and humidity display on the ESP intelligent device can be controlled by LCD. With the set temperature threshold of the ESP intelligent device, the start/stop of the fan can be automatically controlled. With the Wi-Fi function built-in ESP32 microcomputer, the system can be connected to the Wi-Fi, and the lights or windows of IoT devices can be controlled over the Internet.

1. Introduction

In the development process of science, technology is constantly improving, and people's expectations for daily life are gradually increasing. How to get a safer, more intelligent, and more convenient remote-control experience has become a problem [1-5]. The current remote controller is mainly divided into the photoelectric remote controller and the radio remote controller. The photoelectric remote controller controls the device by emitting digitally encoded infrared light waves, and the radio remote controller controls the device by radio waves. These two types of remote controllers have unique characteristics and application scenarios and have been widely used in modern life. The main advantage of the photoelectric remote controller is that it will not interfere with the surrounding environment or other electrical equipment. However, due to its limited power, the infrared light wave emitted by it cannot penetrate the wall, so its control range is limited. In contrast, radio remote control has a longer control distance and stronger penetration ability to control remote devices without interference from physical obstacles.

The traditional infrared remote controller is widely used in the family because of its simple operation. With technological advancement, it is gradually being replaced by wireless remote controllers and intelligent remote-control terminals with more advanced functions [6-10]. The IoT multi-functional remote-control terminal is an electronic control device based on advanced microcomputer and wireless communication technology. It has the intelligent perception function of the surrounding environment. It can monitor the parameters of the environment, such as temperature and humidity, and analyze the data. The intelligent remote control of home appliances, lights, windows, and shading facilities can be conducted with wireless transmission technology. The IoT multi-functional remote-control terminal improves the convenience of life and saves energy to a certain extent [11-15].

2. System working principle

Taking the ESP32 microcomputer as the main control chip of the system, the peripheral circuit is composed of an automatic download and reset circuit, USB to the serial port circuit, key circuit, power management circuit, 2.4G communication module circuit, LCD screen circuit, capacitive touch screen circuit, and EEPROM storage circuit. The ESP32 microcomputer has ESP-NOW and Wi-Fi communication functions as the main control chip. The human-computer interaction is realized by displaying relevant information on the LCD screen and the user's input on the capacitive touch screen. The domestic Si24R1 wireless transceiver RF chip is selected for the 2.4G communication module. Its frequency is 2.4-2.5GHz universal ISM band, and ESP32 uses SPI to interact with it. The power management circuit has the functions of charging, voltage and current detection, and step-down, and it can provide a stable and safe power supply.

The working principle of this design is as follows. ESP32 is responsible for the overall control of the system circuit module, such as the display and the interaction of the LCD screen, the communication of the 2.4G communication module, the display of the clock, and the lithium battery management. The 2.4G wireless communication module communicates with the smart car, and the movement of the smart car and the on/off of the LED lights can be remotely controlled by the screen interaction. The ESP-NOW function built in the ESP32 microcomputer is used to control the intelligent device equipped with the ESP chip. The fans and lights of the ESP intelligent device can be controlled by the screen, and the temperature and humidity of the intelligent device can be displayed. The temperature control threshold of the ESP intelligent device can be set to control the fan's start and stop. Using the built-in Wi-Fi function of the ESP32 microcomputer to connect the Wi-Fi, the lights or windows in the IoT can be controlled over the Internet.

3. Hardware circuit design

3.1. ESP32 main control module

The circuit of the main control module is based on the ESP32-WROOM-32UE module of the ESP32 chip. As shown in Figure 1, the C11 and C12 capacitors in the upper left corner of the circuit are used as the coupling filter circuit of the power input, which provides stable and reliable power input and signal loop for the ESP32 chip. The peripheral circuit on the left side is the reset circuit, and the R1 resistor provides the pull-up level to the EN pin. The C13 capacitor can prevent false reset caused by electronic interference. The RST1 button is used as the reset key, and the reset operation can be performed by pressing it. The peripheral circuit on the right side is the pull-up circuit of the I2C bus. Since I2C communication uses the on-off output mode, providing a high-level signal with the pull-up resistor is necessary. The peripheral circuit in the lower right corner is the startup mode selection circuit. Press the circuit switch when the system is started, and the ESP32 chip will enter the download mode. Otherwise, it will enter the normal operation mode.

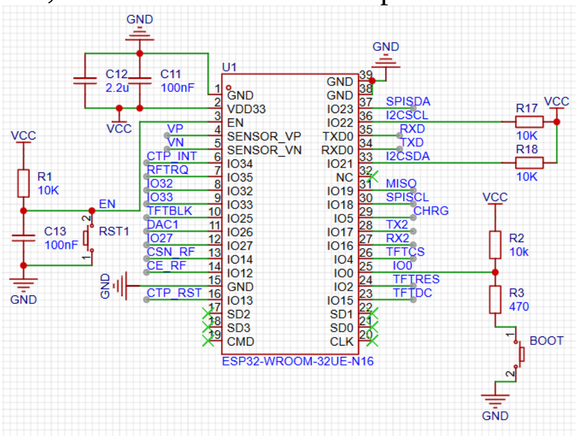

Figure 1: ESP32 minimum system.

3.2. Automatic download and reset circuit module

The automatic download and reset circuit is based on the USB to serial port circuit. The USB to serial port function is the communication medium between the terminal and the computer. It is also the interface to download and burn the software program. As shown in Figure 2, the circuit can be connected to the computer with the external data cable to realize the function of USB to serial port and external power input. The power chip of the circuit uses the XC6206 linear step-down chip, which can reduce the 5V input voltage of the USB circuit to 3.3V for the system power supply. When the USB cable is unplugged, CH340 is disconnected, and the power supply circuit's power consumption is close to 0W. The CH340 has six connection wires. TX and RX are cross-connected to the RX and TX pins of ESP32. DP and DN are connected to the DP and DN of the TYPE-C interface. RTS and DTR are connected to the automatic download and reset circuit.

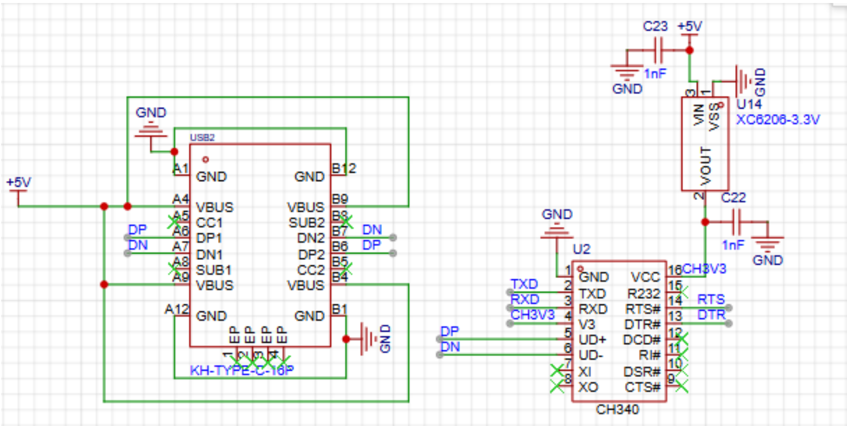

Figure 2: USB to serial port circuit.

As shown in Figure 3, The automatic download and reset circuit mainly comprises two resistors and two NPN transistors. The RTS and DTR network tags are extracted from the CH340, and the IO0 network tag is the ESP32 boot mode pin. When ESP32 is started, if IO0 is at a high level, ESP32 enters normal operation mode. Otherwise, it enters code download mode. The EN network tag is the enabling pin of the ESP32 chip. The microcomputer can be started at high levels, and the chip is closed at low levels.

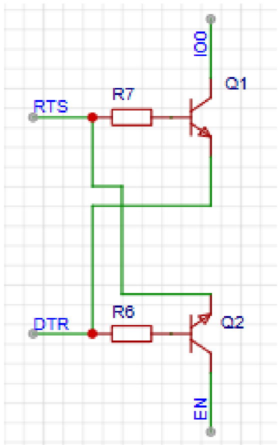

Figure 3: Automatic download and reset circuit.

3.3. Key circuit module

As shown in Figure 4, the key circuit module comprises a pull-up resistor and a key switch, which controls the display screen's opening and closing. The related functions can be realized when the display screen is turned on. When the display screen is turned off, it enters the low-power mode, which can significantly increase the system's standby time.

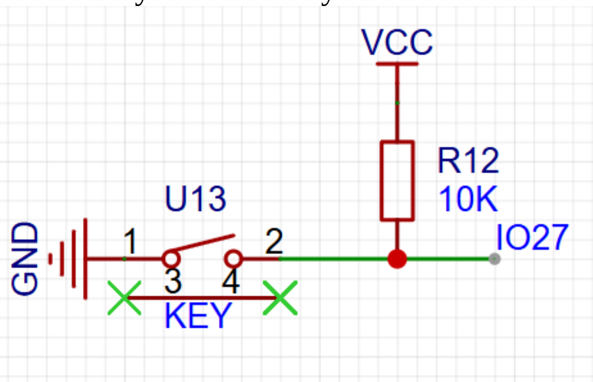

Figure 4: Key circuit.

3.4. Power management module

As the main power supply module, the module provides stable voltage for each chip and the peripheral circuit and manages the charging and discharging of the lithium battery. The module's circuit is divided into three parts: the lithium battery charging, voltage and current detection, and step-down power supply. As shown in Figure 5, The CHRG network tag is connected to the GPIO pin of ESP32 to realize the charging indication function. BATIN is connected to the lithium battery, and the +5V network tag is connected to the 5V pin of the TYPE-C interface. The R11 resistance is the set resistance of the charging current. The 1.65k resistance is used, and the charging current is 606mA.

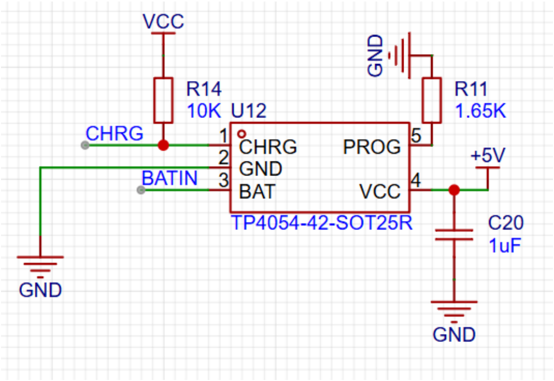

Figure 5: Lithium battery charging circuit.

As shown in Figure 6, the voltage and current detection part of the lithium battery uses INA219 as the detection chip of the lithium battery. The chip is a high-precision device that integrates the functions of current detection and power monitoring, and it can communicate with the outside with the I2C interface. The chip can monitor the voltage drop of the shunt resistor and the bus power supply voltage in real time. It has programmable conversion time and calibration functions, allowing users to adjust the measurement parameters flexibly according to specific needs. Using the built-in gain, INA219 can directly output accurate current readings, simplifying the circuit and improving the measurement accuracy. INA219 can directly calculate power by configuring the multiplication register, facilitating energy efficiency management, and battery monitoring. By using INA219 to detect the voltage and current state of the lithium battery, the accurate power of the lithium battery is calculated, providing effective parameter feedback for the low power consumption function.

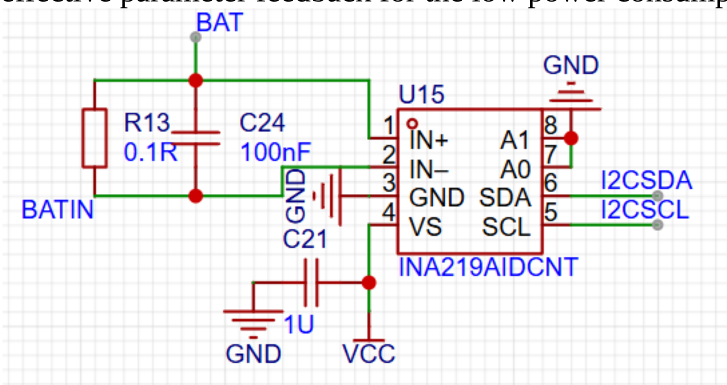

Figure 6: Lithium battery voltage and current detection circuit.

As shown in Figure 7, the lithium battery step-down power supply circuit uses ME6217 as the step-down chip, which has the characteristics of low voltage difference and high output current. Based on advanced CMOS technology, the chip has the advantages of high precision and low current consumption. The chip integrates low-on-resistance transistors, effectively realizing low-dropout operation and significant current output. The chip has a built-in over-current protection mechanism, which can protect the circuit from damage when the load current is abnormal. ME6217 integrates the intelligent on/off control circuit to extend battery life and improve equipment endurance.

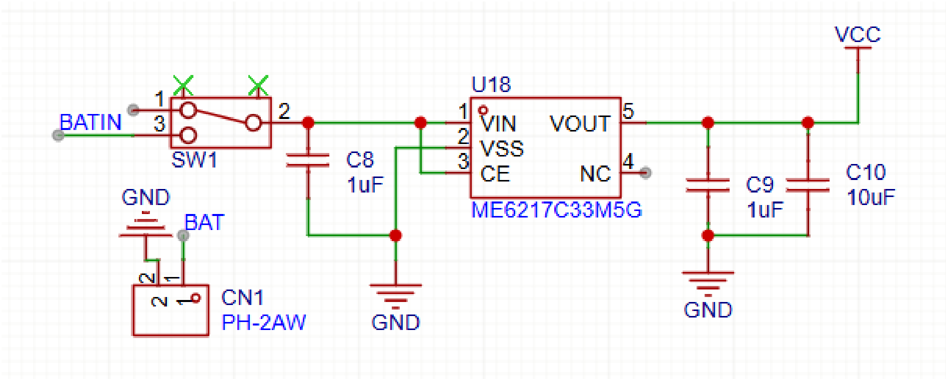

Figure 7: Lithium battery step-down power supply circuit.

3.5. 2.4G communication module

As shown in Figure 8, the 2.4G communication circuit uses the G01-SPIPX communication module equipped with the SI24R1 as the communication chip. Based on SI24R1, the PA power amplifier chip is added to make the transmission power up to 20 dBm and the transmission distance up to 1km. The 2.4G communication module communicates with the microcomputer using the SPI bus protocol, and the communication frequency is up to 10MHz.

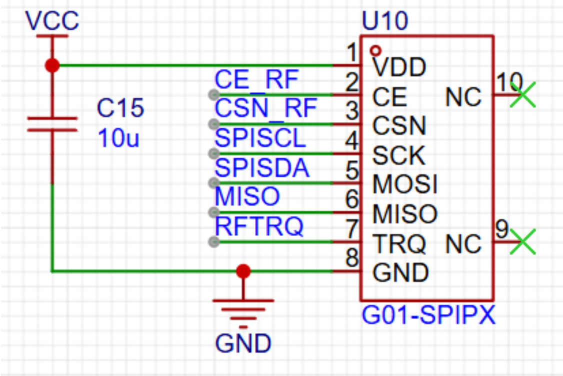

Figure 8: 2.4G communication circuit.

3.6. LCD screen module

The LCD screen is mainly composed of two FPC connectors. One FPC connector is connected to the ST7789 display chip, and the other to the FT6336U capacitive touch chip. As shown in Figure 9, the FPC connector with the component identification of U3 is connected to the FPC cable of the display chip. TFTDC, TFTRES, TFTCS, SPICL, and SPISDA are respectively connected to the SPI bus pin of ESP32. The TFTBLK is the backlight control pin of the LCD screen. It is connected to the GPIO25 pin of ESP32, and the brightness control of the LCD screen can be performed by the transistor control circuit.

The FPC connector with the component identification of U8 is connected to the FPC cable of the capacitive touch screen chip. In addition to connecting the power supply, I2CSCL and I2CSDA are respectively connected to the GPIO22 and GPIO21 pins of the ESP32 I2C bus. The CTP_INT is the interrupt signal cable of the capacitive touch screen chip. It is connected to the GPIO34 pin of ESP32 to provide the touch interrupt signal for the system and improve the touch response speed. The CTP_RST is the reset function pin of the capacitive touchscreen chip, and it is connected to the GPIO13 pin of ESP32.

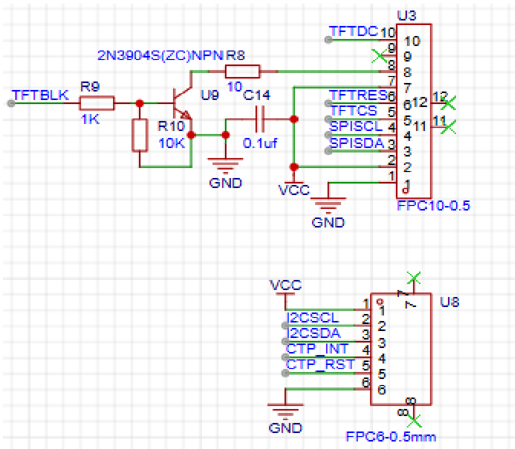

Figure 9: LCD screen circuit.

3.7. EEPROM storage module

The AT24C02 is used as the EEPROM storage chip to store the configuration parameters of the ESP32 central control module. It uses the I2C communication bus to connect to the ESP32's GPIO22 and GPIO21 pins. The EEPROM storage circuit is shown in Figure 10.

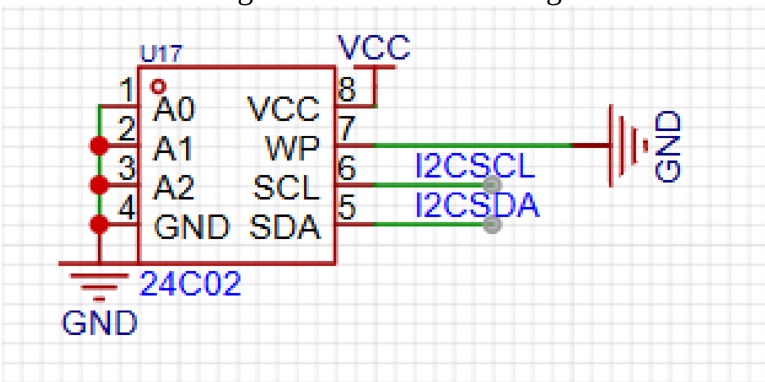

Figure 10: EEPROM storage circuit.

4. Physical production and debugging

The physical circuit board is designed and made into a PCB using EDA software. The components are manually welded with tin, and the shell is 3D printed by fused deposition modeling (FDM). The physical shape is shown in Figure 11. The program tasks are divided into initialization, system, and APP tasks. Moreover, the multi-task real-time operating system is the core. It dramatically simplifies the complexity of software development. The initialization tasks are used to initialize system functions, peripherals, peripheral sensors, system tasks, and APP tasks. The system tasks handle user UI operations, system time management, and peripheral device operations. The APP tasks can realize various remote control operations, such as smart car control, ESP-NOW smart device control, and IoT device control. The desktop UI is shown in Figure 12.

Figure 11: Physical shape. Figure 12: Desktop UI.

The smart car control APP can remotely control the smart car equipped with a 2.4G wireless communication chip. Controlled by the touch screen, the car can move forward and backward and turn left and right. The three switch buttons on the touch screen can control the LED light, automatic obstacle avoidance mode, and external controller mode of the smart car. In order to better control the intelligent car, the external controller mode is supported. The external controller is connected through the XH2.54_6PIN interface, and the controller is functional by pressing the external handle mode button on the touchscreen.

5. Conclusions

The commonly used microcomputer, wireless communication technology, and IoT platform are analyzed and compared, and the ESP32 is selected as the primary control microcomputer. Based on the development principle of ESP32, the ESP-NOW function and the STA mode of the Wi-Fi module are fully utilized. In the STA mode, the devices can connect with the AP, obtain the IP address, transmit and receive data, and scan other network devices. The Si24R1 communication chip is used, and the charging and discharging circuits of the lithium battery are designed. Based on the hardware and software design, the screen display and real-time touch control are realized with programming. Based on ESP32 and Si24R, three APP functions of the remote-control terminal are performed. (1) Car remote-control APP. Using the 2.4G communication function of the Si24R1 chip, the car equipped with the 2.4G wireless receiving module can be remotely controlled by the touch screen. The movement of the car and the on/off of the LED lights on the car can be controlled, and the movement of the car can be accurately controlled by the external controller. (2) ESP-NOW intelligent device control APP. The built-in ESP-NOW function of ESP32 is used to remotely control the intelligent device equipped with the ESP chip. The fans and LED lights on the device can be controlled, and the temperature and humidity information of the device can be obtained and displayed on the screen. The temperature threshold of the smart device can be set. When the temperature is higher than the threshold, the fan is started. When the temperature is lower than the threshold, the fan stops running. (3) IoT devices APP. Using the built-in Wi-Fi function of ESP32 to connect the IoT server, The IoT devices can be controlled, and the on/off of the lights and windows in IoT can be controlled.

Acknowledgments

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