Design of a smart Solar Street Lamp

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Contents

Abstract. China is a country with a shortage of energy. Energy conservation awareness has penetrated into every aspect of our lives. Green and low-carbon environmental protection is our unremitting pursuit. In this paper, a solar street lamp controller with both time control and light control functions is designed. The micro control system 51 Series (MCS 51) MCU is used to realize the photoelectric control. After the sunlight reaches the set intensity, the lithium battery is charged through the battery board. Once the light intensity is weaker than the set value, when a pedestrian passes the LED lamp, the Pyroelectric Infrared Ray Sensor (PIR for short) outputs a signal to control the microcontroller to turn on the LED lamp, the LED lamp will turn off after some period of delay. The brightness can also be adjusted dynamically through the Bluetooth module.

This design implements the following features:

1) Solar maximum power point tracking (MPPT for short) is used to make the photovoltaic panel output more power, and judge the external lighting conditions based on the output voltage of the solar panel.

2) Both lithium battery overcharge and overvoltage protection and constant charging current are taken into account.

3) Dynamically adjust LED brightness via Bluetooth module.

4) After the mobile phone and the Bluetooth module are connected to communicate, the four working states of the LED (induction, constant light, flicker, and off) are controlled through the adapted "Aurora" APP.

After physically adjusting, the solar multifunctional LED lamp has excellent performance from external effects to internal mechanisms, and has strong practicability.

Key words: Solar energy; LED; PIR; Constant current; Lithium batteries; MCU

Preface: In recent years, energy and related environmental issues have become the hotspots of most countries around the world, and all countries are dealing with energy and environmental issues based on their own national conditions. As a large developing country, China’s per capita energy resources (especially oil, gas, and water) are scarce, its environmental capacity as well as resources are limited, and its ecology is fragile in the western region. This problem is particularly serious. Development has become an important issue for China's economic development. In the past few years, China's GDP has developed at a rate of 10% per year, energy consumption has increased dramatically, and energy consumption per unit of GDP far exceeds that of the Western developed countries such as the United States. The environment and ecology are deteriorating. This kind of natural, disorderly and predatory issue is practical, which has caused very serious and irreversible consequences. The natural punishment to human beings has been serious and will continue to worsen. In such a severe situation, energy saving has become the theme of our social life.

1. Tasks and Requirements of the System

1） It can be powered by solar energy.
2） Dynamic sensing of the human’s coming .
3） When someone passes the lamp, the lamp turns on and then turns off after delaying a period of time.
4） The working mode can be set.

2. Principles of the System

When there is the sun, the solar panel converts solar energy into electrical energy and stores it in the lithium battery. Overcharge protection is set to prevent damage caused by overcharging the battery. When it is detected that the light is not strong enough, light will switch to night mode (or use a Bluetooth module to manually adjust). At this time, the solar panel no longer supplies power to the lithium battery, and the PIR is turned on. When a person passes by, the LED lamp will be turned on. The lamp can be adjusted remotely through the Bluetooth module, and it will be turned off after a delay.

3. The Design Plan of the System

3.1 Hardware

3.1.1 The System Hardware Frame Diagram

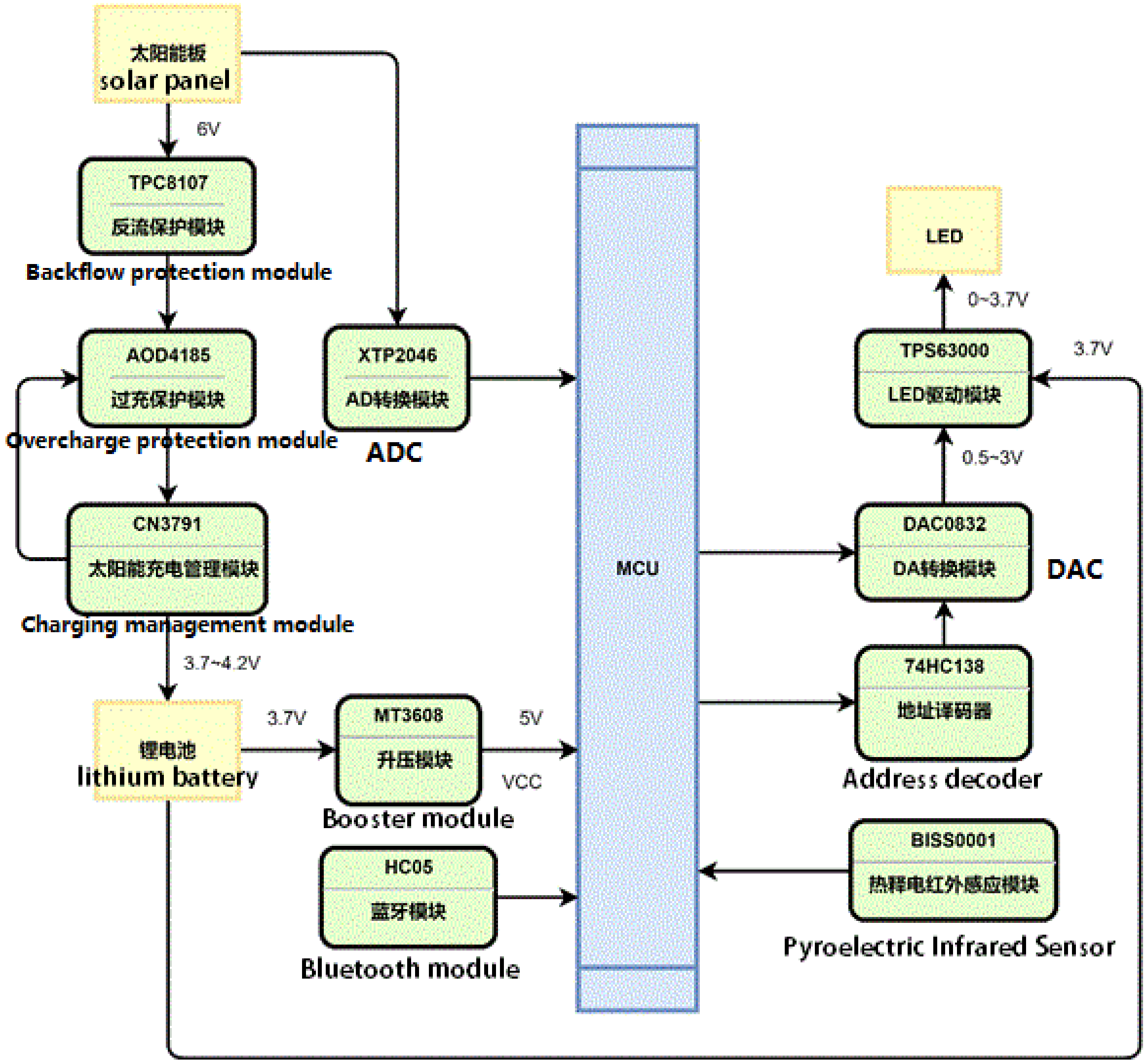


Figure 3-1 the System Hardware Frame Diagram

3.1.2 Core Chips

1．Solar Charging Management Chip：CN3791

CN3791 is a single lithium battery charging management integrated circuit that can be powered by solar panels in PWM step-down mode, which can independently manage single lithium battery charging, and can realize maximum power point tracking, and has the advantages, such as small packaging appearance, few peripheral components and simple use. Its symbol is shown in the figure below

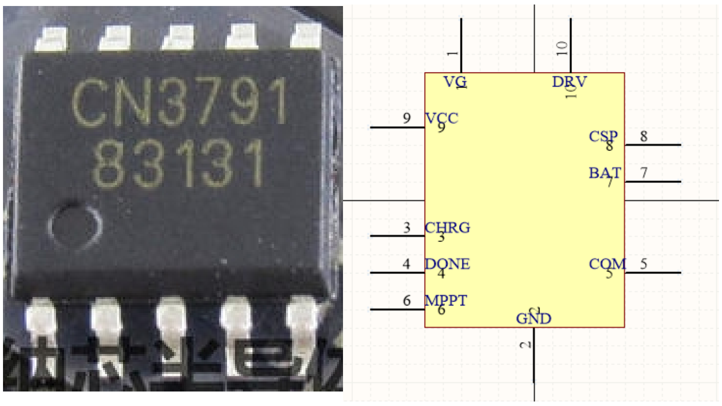


Figure 3-2 CN3791 Schematic symbol

Its characteristic is：

(1) The voltage input range from 4.5v to 28V

(2) PWM switching frequency is 300KHz

(3) Constant voltage charging voltage: 4.2v ±1%

(4)Operating temperature: -40℃ to 80℃.

1) Charging management function

CN3791 has trickle, constant current and constant voltage charging modes. In constant voltage charging mode, the CN3791 modulates the battery voltage at 4.2v; In constant current charging mode, the charging current is set through an external resistor. When the current output capacity of the input power supply is reduced, the internal circuit can automatically track the maximum power point of the solar panel to maximize the use of the output power of the solar panel. For lithium batteries with deep discharge, when the battery voltage is lower than 66.5%(typical value) of the constant voltage charging voltage, CN3791 uses 17.5% of the set constant current charging current to charge the battery trickle-down. In the constant voltage charging phase, the charging current gradually decreases, and when the charging current drops to 16% of the constant current charging current, the charging ends.

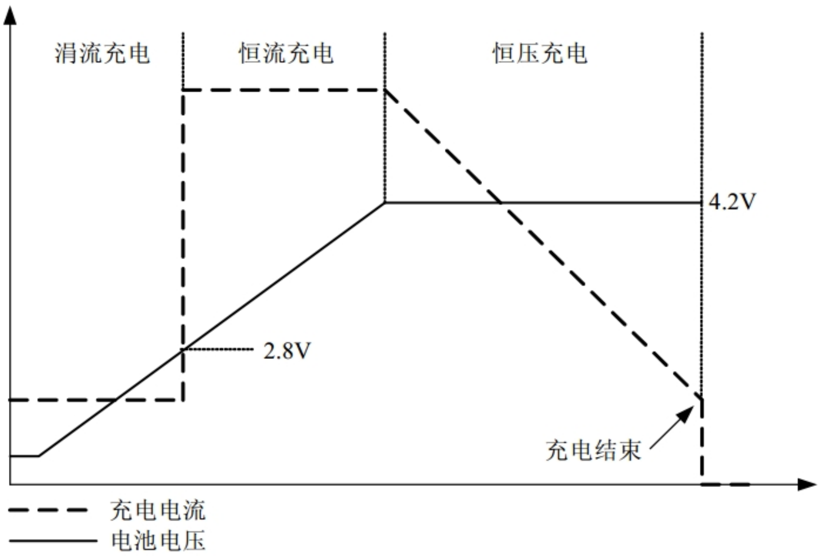


Figure 3-3 sketch map of the charging process

At the end of the charging state, if the battery voltage drops to 95.5% of the constant voltage charging voltage, the new charging cycle will start automatically. When the input power fails or the input voltage is lower than the battery voltage, the CN3791 automatically enters sleep mode.

2) Overvoltage protection and low voltage latch function

The circuit is set to PMOS (AOD4185). When the charging current decreases to 16% of the constant charging current, the charging ends and the DRV pin outputs a high level. At this time, PMOS is turned off and the charging current drops to 0 to prevent the battery from overcharging.

If the voltage of the battery (BAT) pin rises to 1.07 times of the constant voltage charging voltage, the overvoltage comparator will start to turn off the p-channel MOS Field effect transistor, and the charger will stop temporarily until the voltage of the battery pin returns to less than 1.02 times of the constant voltage charging voltage.

The low-voltage latch circuit inside the chip monitors the input voltage. When the input voltage is lower than 3.6V (the typical value), the internal circuit is shut down and the CN3791 is prohibited from working.

3) MTTP Maximum Power Point Tracking

Maximum Power Point Tracking (known as MTTP for short) is a control method that enables the solar panel to output more electricity by adjusting the working state of the electrical module. CN3791 chip adopts the mode of constant voltage regulation, that is, the output voltage of fixed solar panel, to achieve the function of maximum power output. When the current output capacity of the input power supply decreases, the internal circuit of the CN3791 can automatically tracks the maximum power point of the solar panel.

4）Signal Indicating Function

The CN3791 has two open-drain state indicator outputs: the CHRG pin and the DONE pin. In the charging state, the CHRG pin is pulled down by the internal transistors to a low level, while in other states the CHRG pin is in a high impedance state. At the end of charging state, the DONE pin is pulled down by the internal transistors to the low level; at other states, the DONE pin is in the high impedance state.

When the battery charger is not received, CN3791 will be charged to the constant voltage output capacitance charging voltage or slightly higher, and into the charging end state, because the BAT pin the working current of the output capacitor discharge effect, BAT pin voltage will slowly descend to recharge threshold, CN3791 again into the charging status, so the BAT pin to form a sawtooth waveform, at the same time CHRG output pulse signal indicates no install batteries.

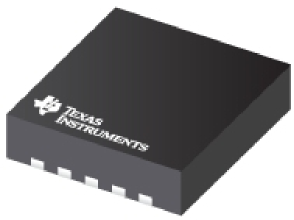
2. LED Dimming Driver Chip：TPS63000

The TPS63000 is a high-efficiency single-inductor buck-boost Boost chip with the following features:

(1) The input voltage ranges from 1.8v to 5.5v

(2) The output voltage ranges from 1.2 to 5.5v

(3) The maximum voltage in the step-down mode is 1200mA, and the maximum output voltage in the step-up mode is 800mA, which can automatically switch the up-and-down mode.



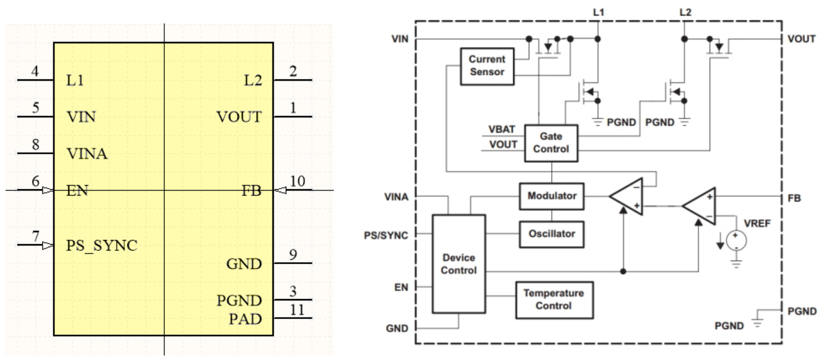


Figure 3-4

The control circuit of this device is based on average current mode control technology. The average inductance current is regulated by the fast current regulator loop controlled by the voltage control loop. The controller also uses input and output voltage feed forward. Changes in input and output voltages are monitored and the duty cycle in the modulator can be changed immediately to achieve a quick response to these errors. The voltage error amplifier takes the feedback input from the FB pin.

The topology of switch power circuit is divided into current mode control and voltage mode control. The current mode control has been widely used because of its advantages such as fast dynamic response, simplified compensation circuit, large gain bandwidth, small output inductance and easy current sharing. Current mode control is divided into peak current mode control and average current mode control. Peak current is the detection of the inductor current and voltage loop set PWM comparator compares the current value of input, average current method is to set the actual outer ring inductance current and voltage of the ideal current from a current error of high gain amplifier, through the current error amplifier and then received the PWM comparator, and a sawtooth wave of large values (that is, that the slope of the oscillator).

For peak-current mode control, due to the stability requirements of the circuit, and considering that there is a certain error between the peak inductive current and the average inductive current, slope compensation needs to be added to the circuit, which increases the complexity of the circuit.。

The average current mode control is provided by the crystal vibration amplitude to provide adequate compensation for the slope, so no compensation circuit is needed. Moreover, due to the high gain current amplifier, the average current can accurately track the current set value, which improves the dynamic voltage regulation accuracy of the chip. Therefore, in such a buck-boost voltage control chip, it is more appropriate to choose the average current mode control.

3. Analog-Digital Converter (ADC)：XPT2046

XPT2046 is a 4-wire touch screen controller containing a 12-bit 125KHz conversion rate approximation AD converter.

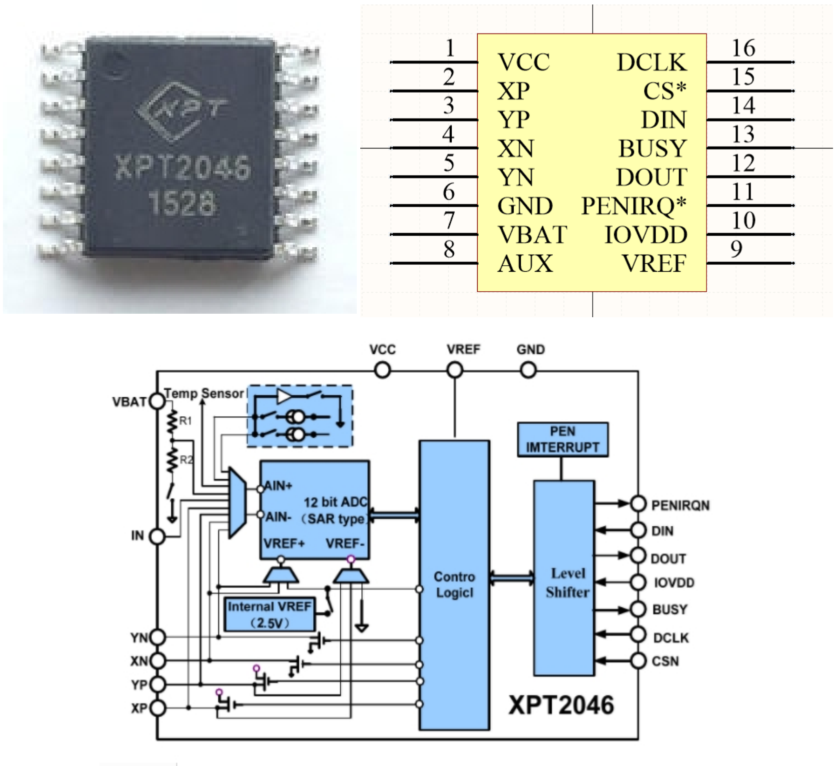


Figure 3-5

Its features include:

(1) Directly measure the power supply voltage (0V ~ 6V)

(2) Digital I/O ports supporting 1.5v ~ 5.25v levels

(3) Low power consumption (260 A)

(4) With a conversion rate of 125KHz

In this application, Tssop -16 package is adopted.

4. Voltage Regulating Module：MT3608

MT2608 is a DC-DC switch booster converter, and the MT3608 features automatic switching to pulse frequency modulation mode during light loads, including under-voltage locking, current limitation, and thermal overload protection.

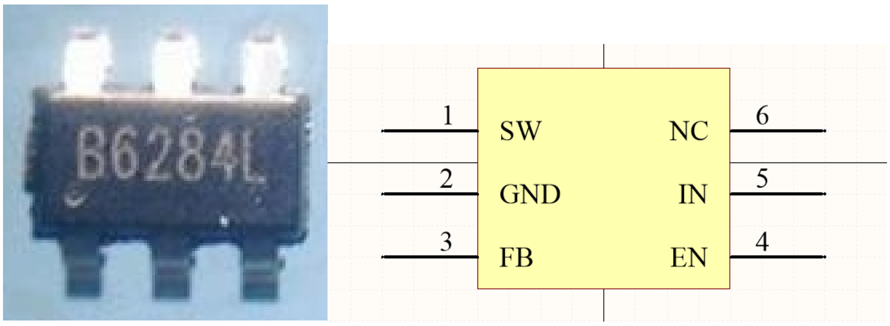


Figure 3-6

Its main features are:

(1) Input voltage from 2 to 24 V

(2) The maximum output voltage is 28v

(3) Maximum output current 2 A

5. Voltage Regulating Chip 7133-1

Internal structure diagram:

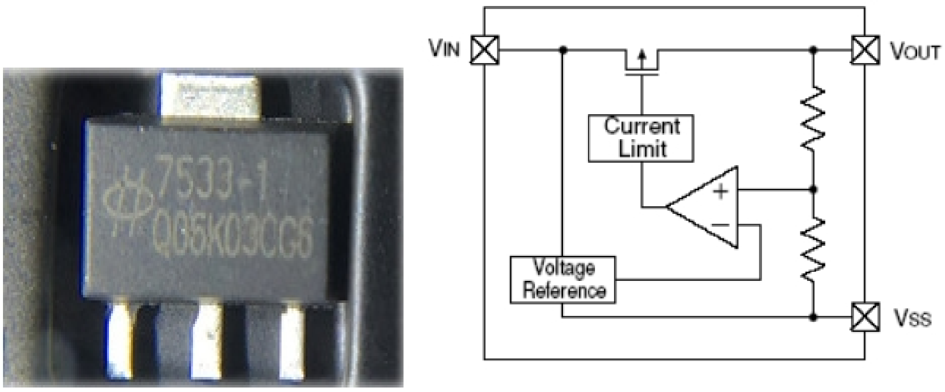


Figure 3-7 7133-1 Voltage regulating chip structure diagram

In essence, it is a partial voltage circuit, which takes the 24V high voltage partial voltage as the specified voltage output, and adds the negative feedback of the operational amplifier to make the output voltage stable without the interference of the input voltage fluctuation.

Its basic operating circuit is as follows:

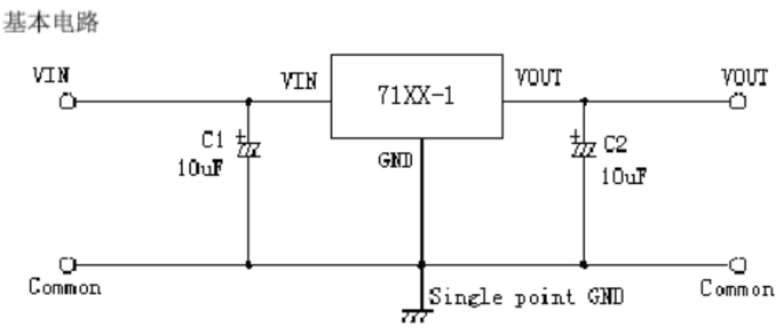


Figure 3-8 7133-1 Voltage regulating chip running circuit diagram

In the module I mainly use it to stabilize the input voltage fluctuation.

6. Pyroelectric Infrared Ray Sensor (PIR)：BISS0001

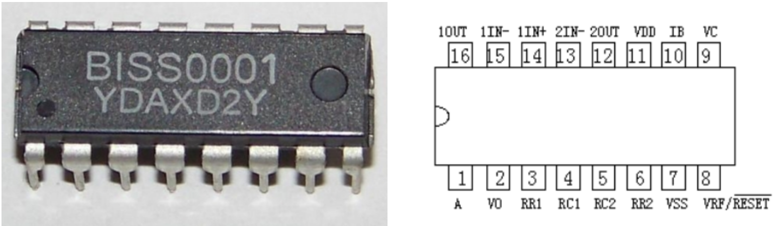


Figure 3-9 BISS0001 shape figure

The functions of each pin are as follows:

BISS0001 ELECTRICAL CHARACTERISTICS

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Vdd	SUPPLY VOLTAGE		3	5	6	V
Ist	STANDY CURRENT		0.9	1.0	1.2	mA
Idd	OPERATING CURRENT	1.8mA, TRIAC 2.5mA, RELAY	1.8		2.5	mA
Vref	STABLE VOLTAGE	Vdd>4.2V	3.0	3.2	3.4	V
Iref	SOURCE CURRENT OF Vref		200			uA
	RIPPLE OF Vref				0.5	mV
	INPUT AND OUTPUT REGULATION OF Vref				0.3%	
Ftb	TIME BASE OPERATING FREQUENCY		15	16	17	KHZ
Vt+	CDS OPERATING TRIGGER		1.3	1.7	2.1	V
Vt-	CDS OPREATING TRIGGER		0.6	0.9	1.1	V
Icds	CDS SOURCE CURRENT		2.6	3.5	4.4	uA
Isource	CDS OUTPUT SOURCE CURRENT		9	10.4	17.4	mA
Isink	CDS OUTPUT SINK CURRENT		11.6	13	21	mA
Irs	RELAY SOURCE CURRENT				5	mA
Irsink	RELAY SINK CURRENT				5	mA
Vro	RELAY OPERATING VOLTAGE	18.8V: RELAY ON 13.1V: RELAY OFF	13.1		18.8	V
Itsink	TRIAC SINK CURRENT				15	mA
Itsource	TRIAC SOURCE CURRENT				50	uA

table 3-10 BISS0001 Pin function

Its internal circuit is shown in figure：

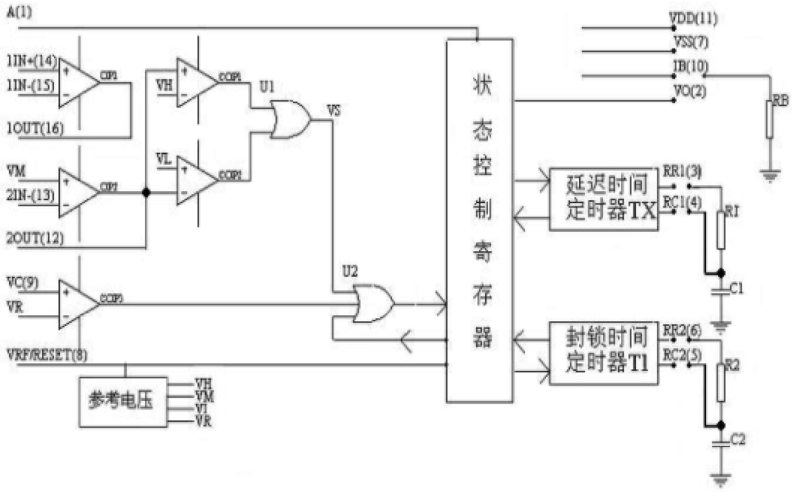
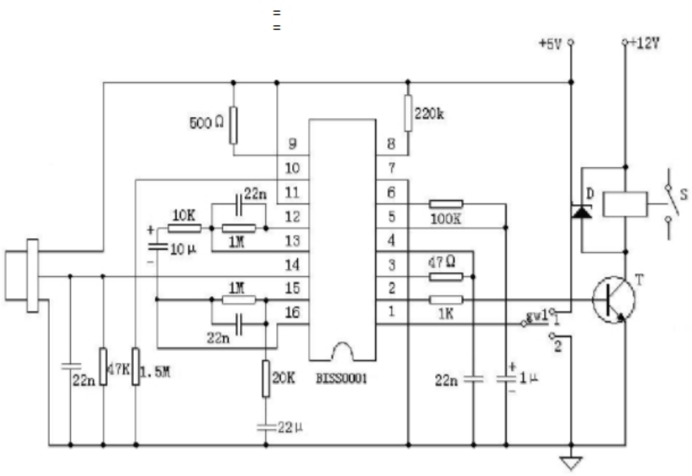


Figure 3-11 BISS0001 Functional schematic diagram

First, according to the actual needs, the operational amplifier OP1 is used to form a sensor signal preprocessing circuit to amplify the signal. Then, it is coupled to operational amplifier OP2, and the second stage of amplification is carried out. At the same time, the DC potential is raised to VM (≈ 0.5vdd), and the output signal V2 is sent to the two-way amplitude discriminator composed of comparators COP1 and COP2 to detect the effective trigger signal Vs. Since VH≈ 0.7vdvl ≈ 0.3vdd, when VDD=5V, noise interference of ±1V can be effectively suppressed to improve the reliability of the system. COP3 is a conditional comparator. When the input voltage Vc (≈ 0.2vdd) is VR, COP3 output is low level, which seals the door U2 and forbids the transmission of trigger signal Vs to the lower level; while when Vc is VR, COP3 output is high level and enters the delay period. When terminal A is connected with low power, any change of V2 in Tx time is ignored until the end of Tx time, namely the so-called non-repeatable trigger mode of operation. When the Tx time is over, Vo will jump back to the low level and start the blocking time timer to enter the blocking cycle Ti. During the time of TI, no change of V2 can make Vo jump into the effective state (high level), which can effectively suppress all kinds of interference generated in the process of load switching.

When the waveform in the repeatable triggering mode is in the period of Vc= "0" and A= "0", the signal Vs cannot trigger Vo is in the valid state. When Vc= "1" and A= "1", Vs repeatable trigger Vo is A valid state, and can promote Vo to maintain A valid state throughout the Tx cycle. In Tx time, as long as the jump of Vs occurs, Vo will continue to extend the Tx period from the jump time of Vs. If Vs remains in the "1" state, Vo remains in the valid state. If Vs remains in the "0" state, it remains in effect throughout the Tx cycle. In Tx time, as long as the jump of Vs occurs, Vo will continue to extend the Tx period from the jump time of Vs. If Vs remains in the "1" state, Vo remains in the valid state. If Vs remains in the "0" state, Vo will return to the invalid state after the end of the Tx cycle, and also, no change in Vs can trigger Vo to be a valid state during the blocking time TI.

应用电路



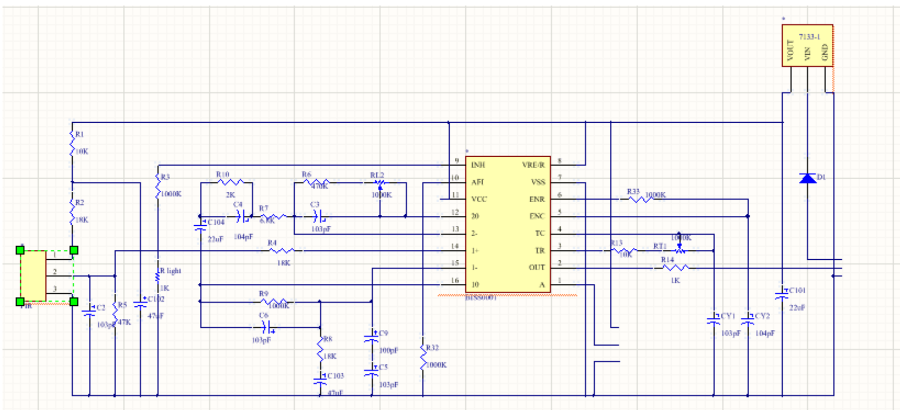


Figure 3-12 BISS0001 Internal Circle Diagram

Above, operational amplifier OP1 the PIR output signal of the first stage amplifier, and then by the C3 OP2 second-level amplification, coupled to the operational amplifier through the voltage comparator COP1 and COP2 after processing of two-way learning, so that the effective trigger signal detection Vs to startup latency timer, output signal Vo by transistor T1 amplifier drive relay connected to the load.

In the figure above, R3 is a photosensitive resistor used to measure ambient illumination. When used as lighting control, if the environment is bright, the resistance value of R3 will be reduced, keeping the input of pin 9 low, thus blocking the trigger signal Vs. SW1 is a selection switch for working mode. When SW1 is connected with terminal 1, the chip is in a repeatable triggering mode. When SW1 is connected with terminal 2, the chip is in non-repeatable triggering mode. In the figure, the size of the amplifier gain can be adjusted by R6. 10K is selected in the original drawing, but 3K can be used in actual use to improve the circuit gain and improve the circuit performance. The output delay time Tx is resized by the external R9 and C7, the trigger block time TI is resized by the external R10 and C6, the R9 and C7 are resized, the trigger block time TI is resized by the external R10 and C6, the R9/R10 can use 470 ohms, and the C6/C7 can choose 0.1U.

3.1.3 Detailed Description and Schematic Diagram of the Self-designed Circuits

In this design, I have completed the solar charging module, LED light adjusting and driving module, boost and voltage stabilizing module, infrared sensor module, AD conversion, DA conversion module.

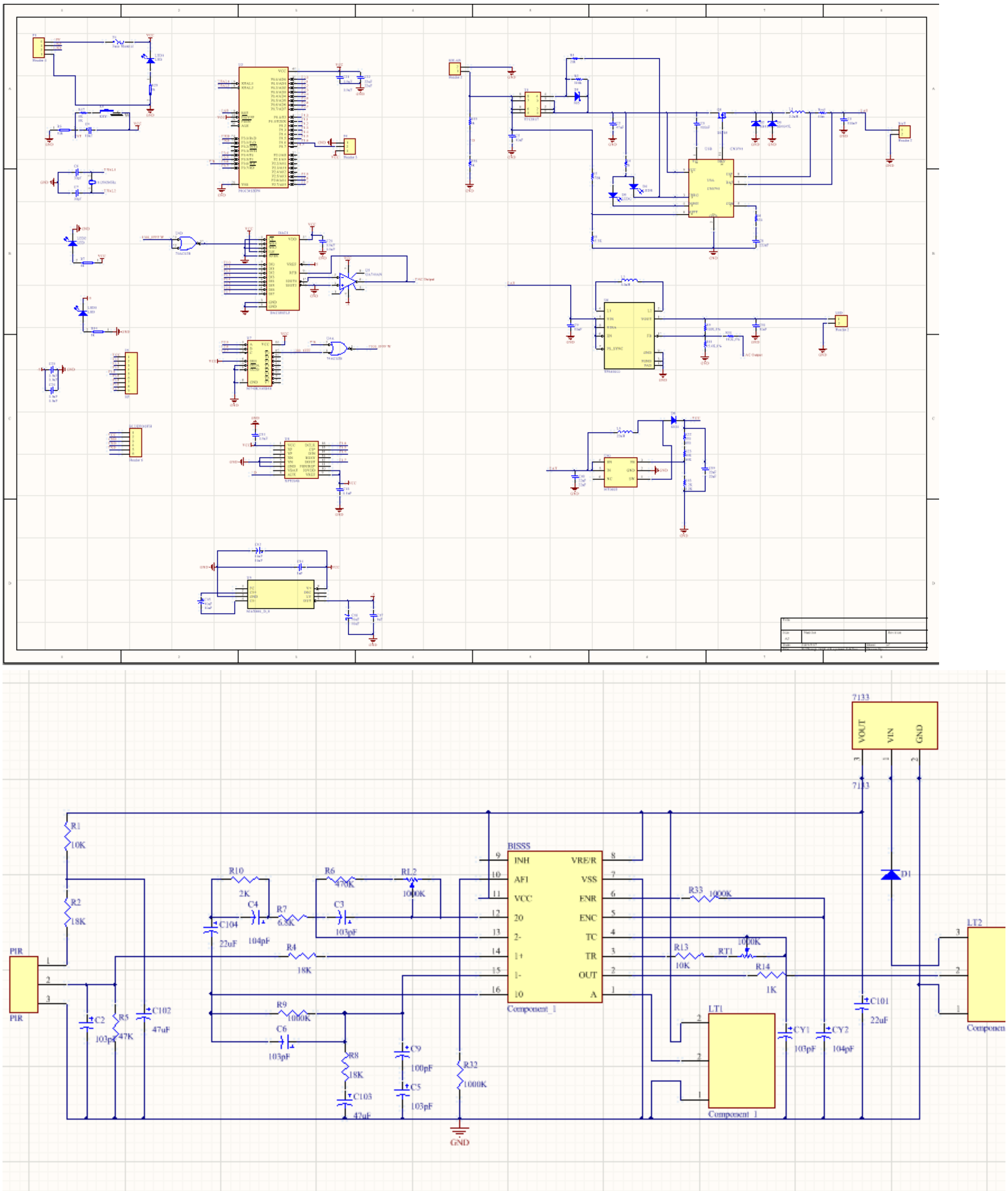


Figure 3-13 Circuit diagram

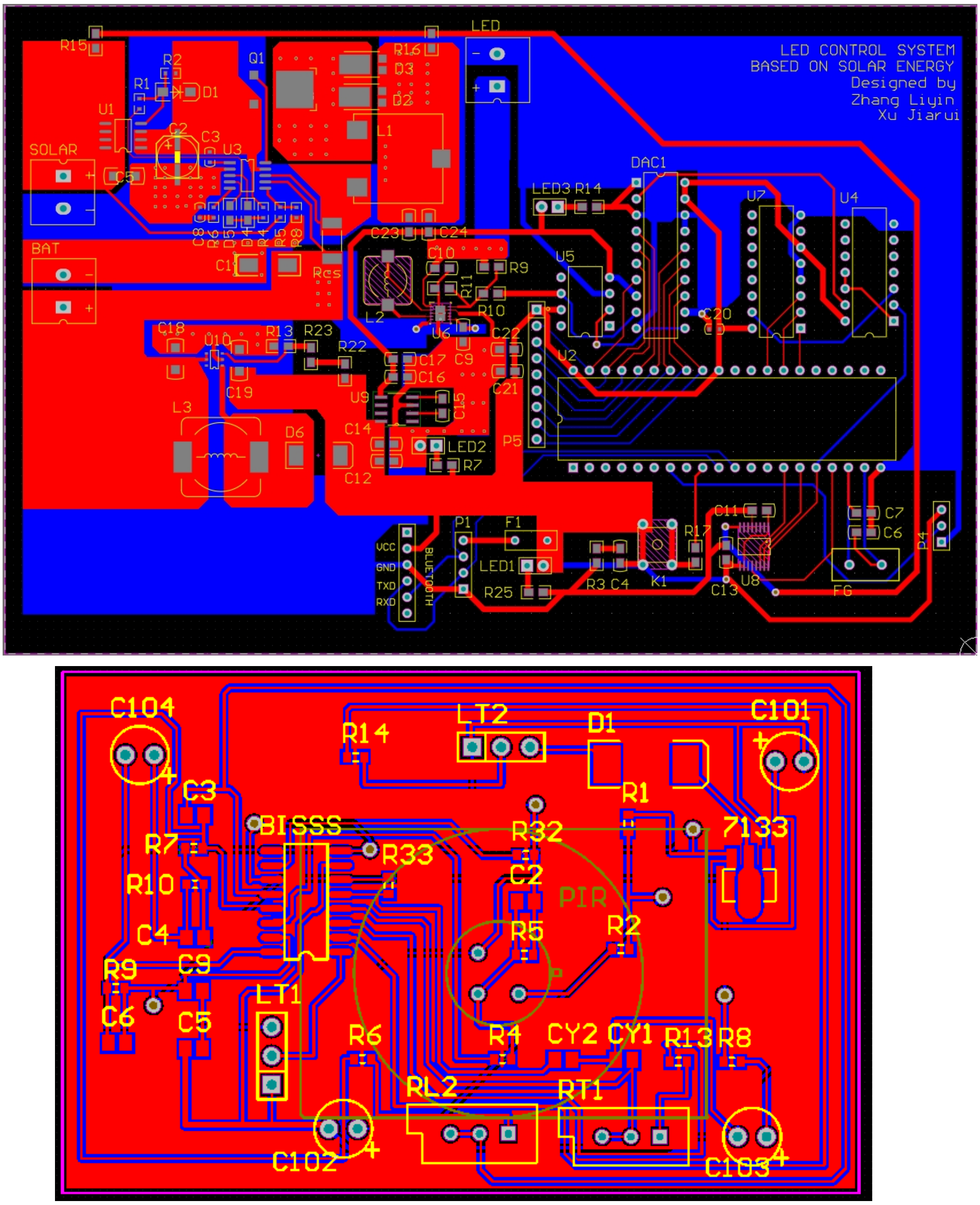


Figure 3-14 PCB design diagram

1. Solar charging management module

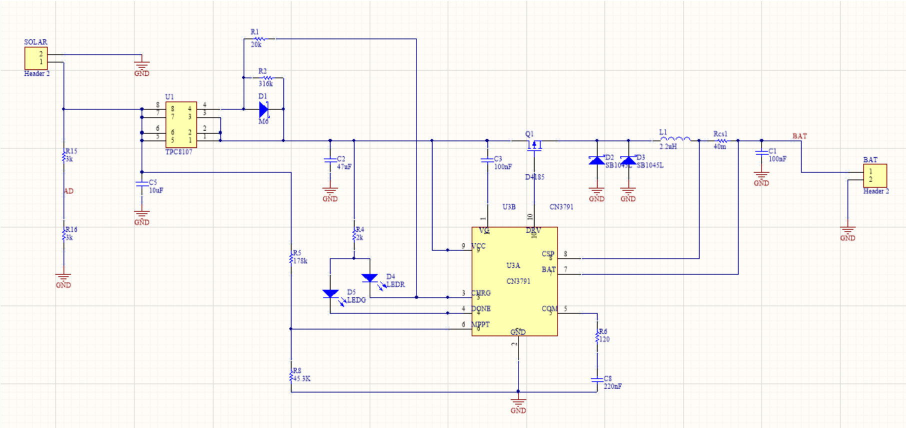


Figure 3-15 Circuit diagram of solar charging management module

The solar management module connects the solar panel to the lithium battery, transmitting the power generated by the solar panel to the lithium battery and providing overcharge protection.

In the figure, no. 3 and no. 4 pins are the indicator pins for charging status, and the output is open-circuit drain, so a pull-up resistor is required after the LED is connected. 5 for the loop compensation input, in order to guarantee the stability of the current modulation circuit and voltage modulation circuit, need to cascade connection between from COM to a 120 Ω resistance and a 220 nf ceramics capacitors.

No. 6 pin is the maximum power tracking terminal of the solar panel, and the voltage is modulated at 1.205v. With the partial voltage network composed of two resistors outside the chip (R5 and R8 in the schematic diagram), the maximum power point of the solar panel can be tracked. The standard voltage of the solar panel we chose was 6V, while under normal working light, the actual V_{OC}= 7.3v. According to the data, when the constant voltage tracking method was adopted, the tracking voltage was

$$\mathrm{V_{MPPT}} = 0.8V_{OC} = 5.84\ \mathrm{V}$$

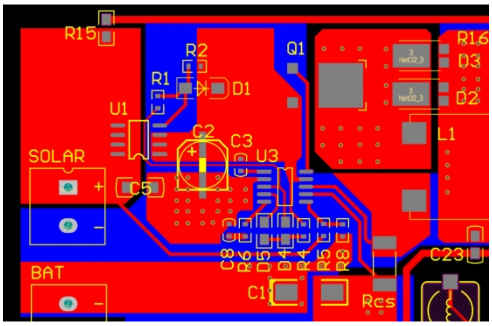
Considering the error of the device itself and the standard system of SMD resistance, take $\mathrm{R_5} = 178\ k\Omega$, $\mathrm{R_8} = 45.3\ k\Omega$, according to the manual chip technology available

$$\mathrm{V_{MPPT}} = 1.205\left(1 + \frac{R_5}{R_8}\right) = 5.94\ V$$

No. 7 and No. 8 pins are the positive connection end of the battery and the positive and negative input end of charge current detection respectively. The two pins provide the voltage at both ends of the measuring current detection resistance $\mathrm{R_{CS}}$ and feedback the voltage signal to CN3791 for current modulation. Constant current charge current is

$$\mathrm{I_{CH}} = \frac{120}{R_{CS}}$$

Take the discharge rate of the battery C=0.3, $\mathrm{I_{CH}} = 3\ A$; therefore, $\mathrm{R_{CS}} = 40\ m\Omega$.



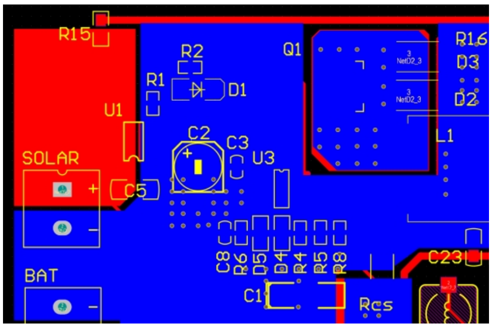


Figure 3-16 PCB Front and back

PCB Design considerations：

(1) The positive pole of the input filter capacitor should be close to the source pole of the p-channel MOS pin;

(2) The diode D1 and D2 shall be close to the inductance, and the current detection resistance shall be close to the inductance;

(3) The output capacitance shall be close to the current detection resistance;

(4) Input filter capacitor, p-channel MOS pin, diode D1 and D2, inductance, current detection resistance and output filter capacitor should be as short as possible;

(5) In CN3791, the grounding terminals of the GND pin and COM pin compensation components of the circuit shall be connected to the system ground separately, so as to avoid the influence of switching noise on the stability of the circuit. The ground terminal of the input capacitor, the positive terminal of diode D2 and the ground terminal of the output capacitor should be connected to the same copper skin before returning.

At the input end, I used a p-type MOS tube TPC8107 to complete the reflux protection. Just after power on, the parasitic diode of the MOS tube conducts, and the power supply and load form a circuit, so the s-pole potential is vin-0.6v, while the g-pole potential is 0V. The PMOS tube conducts, and the current from D to S shorts the diode. When the power supply is inverted, the G pole is high level and the PMOS tube does not conduct. Protect circuit security. And TPC8107 resistance is very small, only 5 m Ω, will not result in a high voltage loss.

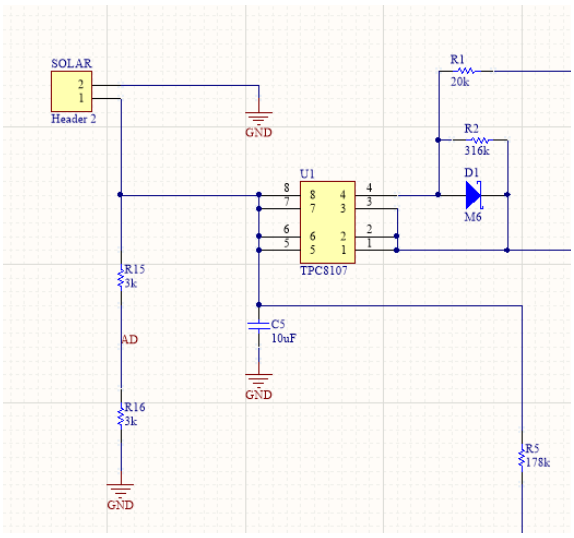


Figure 3-17 TPC8107 Circuit Diagram

2．LED Dimming control circuit

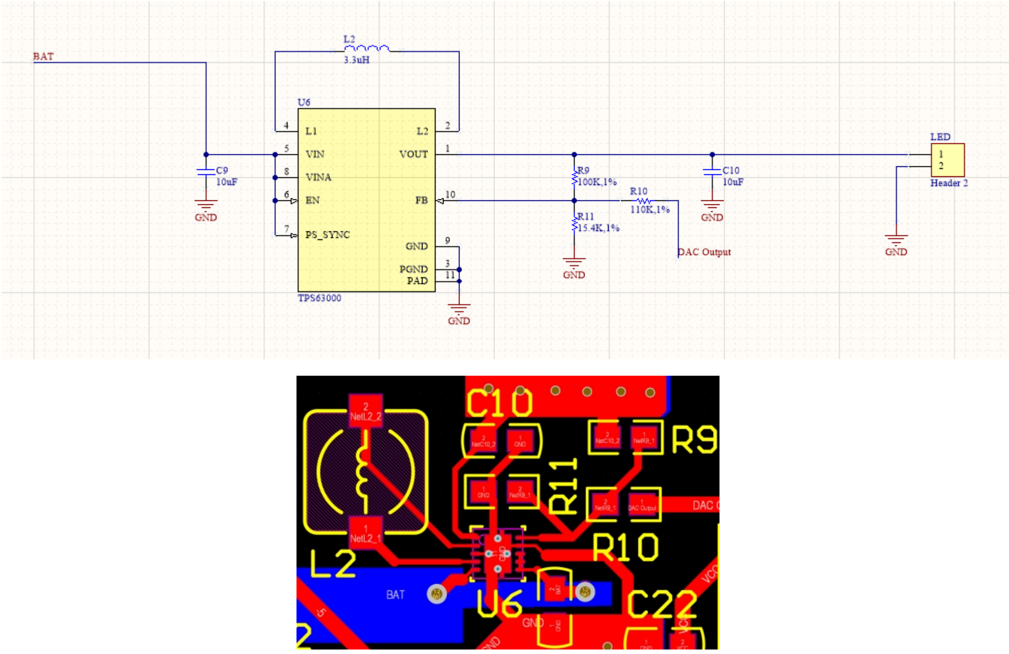


Figure 3-18 LED Dimming Control Circuit Diagram and PCB Design

This circuit is a typical application circuit provided by TPS63000. Its function is to dynamically adjust the output voltage through the input DAC. First, we determine the desired output range and the input range that the DAC can provide, and from this range we can calculate the resistance in the circuit.

$$\mathrm{R}_{11} = -V_{FB} \times R_9 \times \frac{(V_{DACL} - V_{DACH})}{(V_{OUTL} - V_{OUTH} + V_{DACL} - V_{DACH}) \times V_{FB} - (V_{DACL} \times V_{OUTL}) + (V_{DACH} \times V_{OUTH})}$$

$$\mathrm{R}_{10} = R_{11} \times R_9 \times \frac{(V_{DACH} - V_{FB})}{(R_{11} \times V_{FB}) + (R_9 \times V_{FB}) - (R_{11} \times V_{OUTL})}$$

According to the parameters：

$$\mathrm{V_{IN}} = 3\,V\ to\ 4.2\,V$$

$$\mathrm{V_{OUT}} = 1.2\,V \text{ to } 4.2\,V$$

$$\mathrm{V_{DAC}} = 0\,V \text{ to } 3.3\,V$$

$$\mathrm{R}_9 = 100\ \mathrm{k\Omega}$$

Can obtain

$$\mathrm{R}_{10} = 110\ k\Omega$$

$$\mathrm{R}_{11} = 15.4\ k\Omega$$

According to the input DAC curve, the output voltage curve can be simulated:

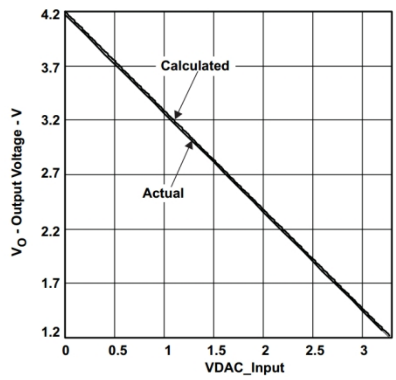


Figure 3-183-19 DAC Output Voltage Curve

3．AD Conversion module

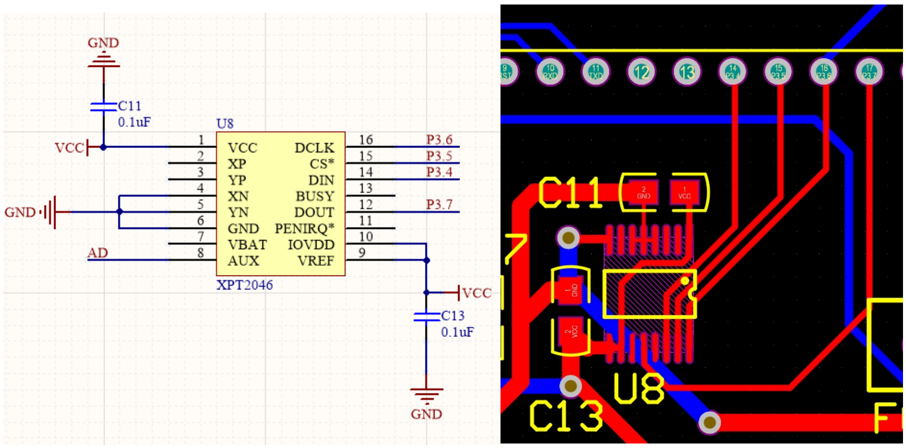


Figure 3-20 AD Conversion Circuit Diagram and PCB Design

XPT2046 includes a 12-bit 125KHz conversion rate progressive approximation A/D converter that supports a low voltage I/O interface from 1.5v to 5.25v. The so-called progressive approximation type refers to the input of an analog quantity, which is compared with the analog quantity corresponding to 100,000,000,000 with a high value of 1 and a low value of 0. This idea is equivalent to a halving query, so I can determine all values from high to low in order to determine the digital quantity corresponding to the analog quantity.

DCLK pin is connected to the MCU clock P3.7, and controls the chip selection signal with P3.5. DIN is the serial input terminal, and P3.4 is connected to it, which is used for starting conversion, addressing, setting ADC resolution, configuration and power loss control of XPT2046. DOUT is the serial output terminal, which is connected to P3.6 and written into the MCU.

4．Voltage Regulating Module

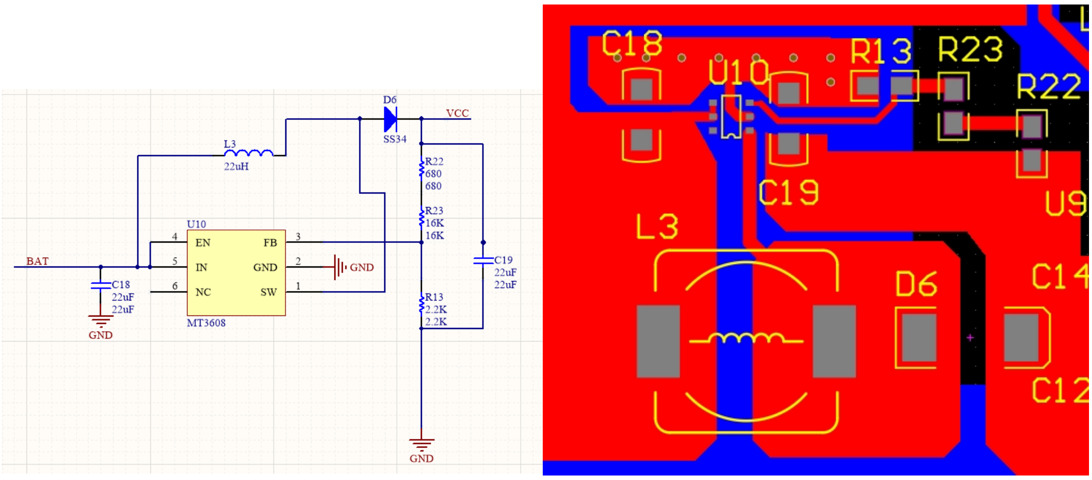
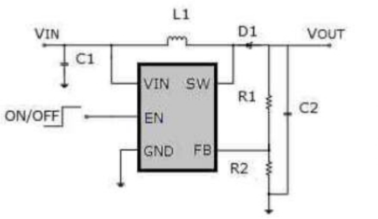


Figure 3-21 Voltage Regulating Module Circuit Diagram and **PCB** Design

As shown in the figure, the typical application circuit of MT3608 is adopted.



Where, according to the formula:

$$\mathrm{V_{OUT}} = V_{REF}(1 + \frac{R_1}{R_2})$$

Within it, $\mathrm{V_{REF}} = 0.6\,V$, take $\mathrm{R_1} = 16.68\,k\Omega$, $\mathrm{R_2} = 2.2\,k\Omega$, get $\mathrm{V_{OUT}} = 5.15V$,

Meet the requirements.

PCB design points:

(1) The input and output capacitors must be close to the chip and directly grounded.

(2) The grounding terminal shall be connected to a strong ground to ensure heat dissipation.

(3) The main lines should be as short and wide as possible.

(4) Feedback devices should rely on the chip as far as possible, away from noise interference.

5. PIR Module

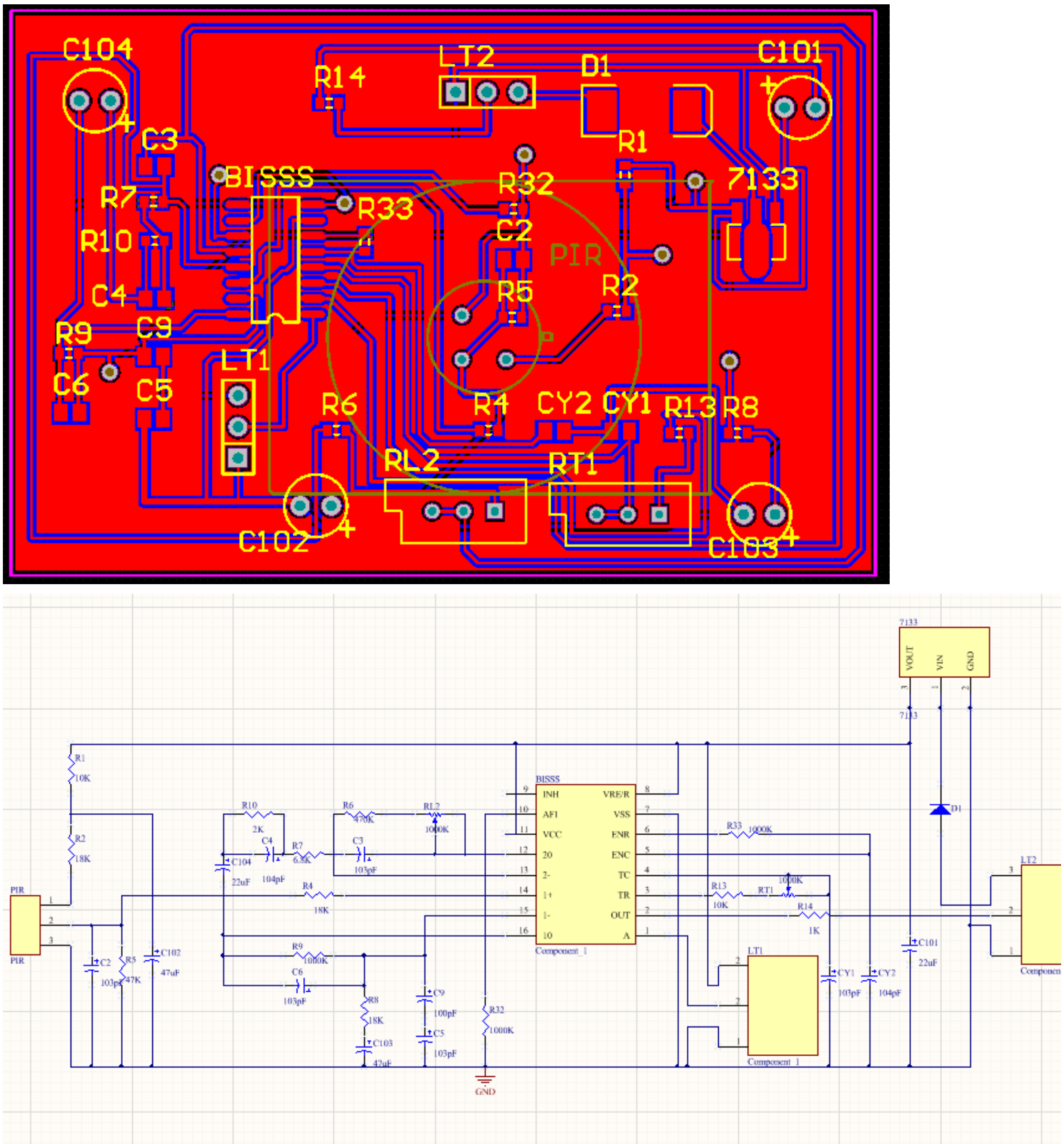


Figure 3-22 Circuit Diagram and PCB Design of PIR Module

The operational amplifier OP1 amplifies the output signal of the PIR at the first stage, and then couples C3 to the operational amplifier OP2 to perform the second stage amplification. The effective trigger signal Vs is output to start the delay time timer, and the output signal Vo is amplified by the transistor T1 to drive the relay to turn on the load.

In the figure above, R3 is a photosensitive resistor used to measure ambient illumination. When used as lighting control, if the environment is bright, the resistance value of R3 will be reduced, keeping the input of pin 9 low, thus blocking the trigger signal Vs. SW1 is a selection switch for working mode. When SW1 is connected with terminal 1, the chip is in a repeatable triggering mode. When SW1 is connected with terminal 2, the chip is in non-repeatable triggering mode. In the figure, the size of the amplifier gain can be adjusted by R6. 10K is selected in the original drawing, but 3K can be used in actual use to improve the circuit gain and improve the circuit performance. The output delay time Tx is resized by the external R9 and C7, the trigger block time TI is resized by the external R10 and C6, the R9 and C7 are resized, the trigger block time TI is resized by the external R10 and C6, the R9/R10 can use 470 Ω, and the C6/C7 can choose 0.1U.

3.2 Software

3.2.1 The Structure Diagram and Software Flow Diagram

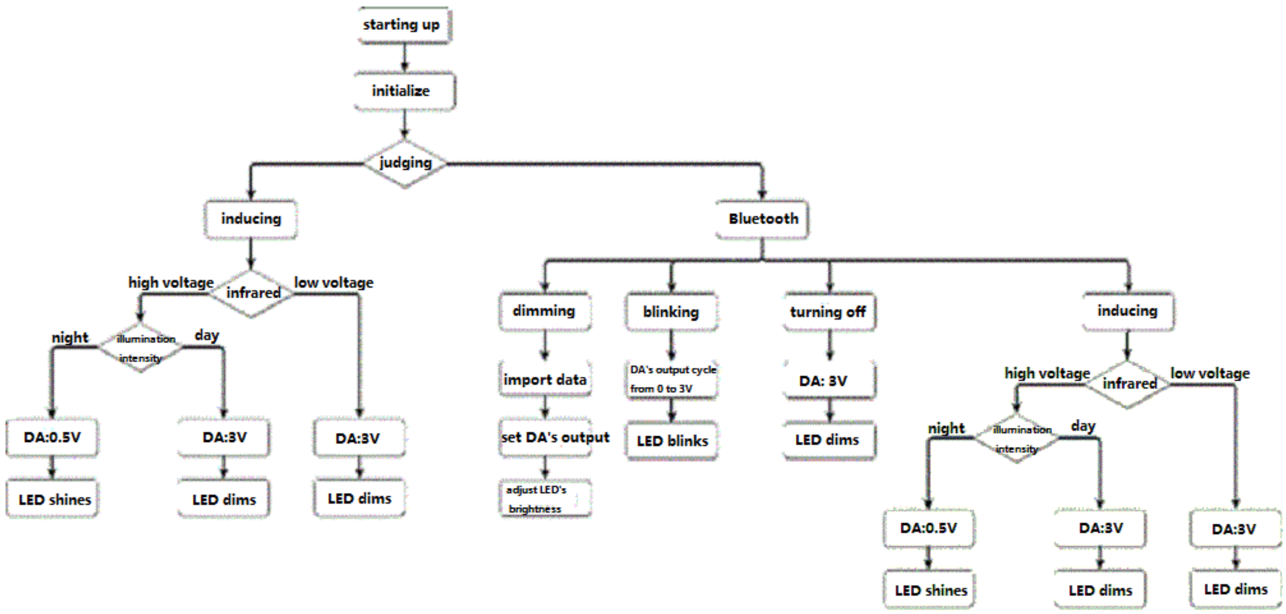


Figure 3-23 the Structure Diagram and Software Flow Diagram

3.2.2 Program Implementation Method of Key Modules

1. Analog-Digital Converter (ADC)

XPT2046 Pin functions are as follows:

PARAMETER	CONDITION	XPT2046			UNITS
		MIN	TYP	MAX	
ANALOG INPUT					
Full-Scale Input Span	Positive Input−Negative Input	0		V_{REF}	V
Absolute Input Range	Positive Input	-0.2		+VCC+0.2	V
	Negative Input	-0.2		+0.2	V
Capacitance			25		pF
Leakage Current			0.1		μA
SYSTEM PERFORMANCE					
Resolution			12		Bits
No Missing Codes		11			Bits
Integral Linearity Error				±2	LSB[1]
Offset Error				±6	LSB
Gain Error	External VREF			±4	LSB
Noise	Including Internal VREF		70		μV_{rms}
Power-Supply Rejection			70		dB
SAMPLING DYNAMICS					
Conversion Time				12	CLK
Acquisition Time		3			Cycles
Throughput Rate				125	CLK
Multiplexer Settling Time			500		Cycles
Aperture Delay			30		KHz
Aperture Jitter			100		ns
Channel-to-Channel Isolation	$V_{IN}=2.5V_{pp}$, fs=50KHz		100		ns
					ps
					dB
SWITCH DRIVERS					
On-Resistance					
YP、XP			5		Ω
YN、XN			6		Ω
Drive Current(2)	Duration 100ms			50	mA
REFERENCE OUTPUT					
Internal Reference Voltage		2.45	2.50	2.55	V
Internal Reference Drift			15		ppm/℃
Quiescent Current			500		μA

REFERENCE INPUT					
Range		1.0		VCC	V
Input Impedance			1		GΩ
	$SER/\overline{DFR}=0$, $PD1=0$				
	Internal Reference Off		250		Ω
	Internal Reference On				
BATTERY MONITOR					
Input Voltage Range		0.5		6.0	V
Input Impedance					
Sampling Battery			10		KΩ
Battery Monitor Off			1		GΩ
Accuracy	V_{BAT}=0.5V~5.5V, ExternalV_{REF}=2.5V	-2		+2	%
	V_{BAT}=0.5V~5.5V, Internal Reference	-3		+3	%
TEMPERATURE ASUREMENT					
Temperature Range		-40		+85	℃
Resolution	Differential Method(3)		1.6		℃
	TEMP0(4)		0.3		℃
Accuracy	Differential Method(3)		±2		℃
	TEMP0(4)		±3		℃
DIGITAL INPUT/OUTPUT					
Logic Family			CMOS		
Capacitance	All Digital Control Input Pins		5	15	pF
V_{IH}	$\vert I_{IH}\vert \le +5\mu A$	IOVDD*0.7		IOVDD+0.3	V
V_{IL}	$\vert I_{IL}\vert \le +5\mu A$	-0.3		0.3*IOVDD	V
V_{OH}	$I_{OH}=-250\mu A$	IOVDD*0.8			V
V_{OL}	$I_{OL}=250\mu A$			0.4	V
Data Format			Straight Binary		
POWER-SUPPLYREQUIREMENTS					
+VCC (5)	Specified Performance	2.7		3.6	V
	Operating Range	2.2		5.25	V
IOVDD (6)		1.5		VCC	V
Quiescent Current (7)	Internal Reference Off		280	650	μA
	Internal Reference On		780		μA
	fSAMPLE = 12.5kHz		220		μA
	Power-Down Mode with (CS=DCLK=DIN=IOVDD)			3	μA
Power Dissipation	VCC=+2.7V			1.8	mW
TEMPERATURE RANGE		-40		+85	℃
Specified Performance					

Table 3-24 XPT2046 Pin function

The serial data output is DOUT (16 pins), which is our final digital quantity. The serial data input is DIN (2 pins), which is the mode control input. We use No. 12 pin, input a voltage value externally, and perform AD conversion on it. The DCLK pin is an external clock input port that controls serial input and output.

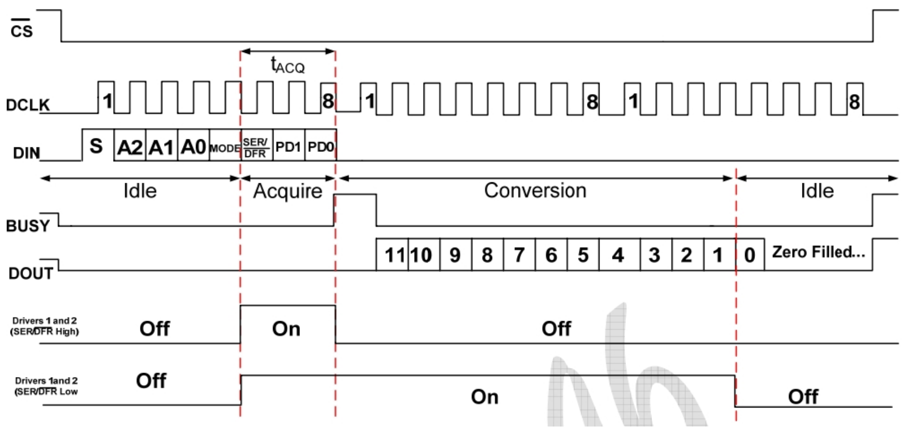


Figure 3-25 Time Series Charts

First of all, CS is chip selection, low active. Input a DIN, but because it is a serial input, bit operations are used to extract it one by one and then input it to the DIN pin. Input occurs at the rising edge of the clock and at the falling edge of the clock to end the input.

Write the pattern input program in this format:

(1) get the char mode numeric quantity

(2) DCLK = 0

(3) extract the high value and assign it to DIN

(4) DCLK = 1. The current value is locked

(5) cycle 8 times

To detect the analog signal on AIN3 channel, the control word command register value is 0xE4, write a command to XPT2046 through SPI_Write(CMD), and let XPT2046 work in the specified working mode. After writing the command to XPT2046, it can start working normally:

```
void SPI_Write(uchar dat)
{
    uchar i;
    CLK = 0;
    for(i=0; i<8; i++)
    {
        DIN = dat >> 7;    // Place the highest bit
        dat <<= 1;
        CLK = 0;           // The rising edge places the data
        CLK = 1;
    }
}
```

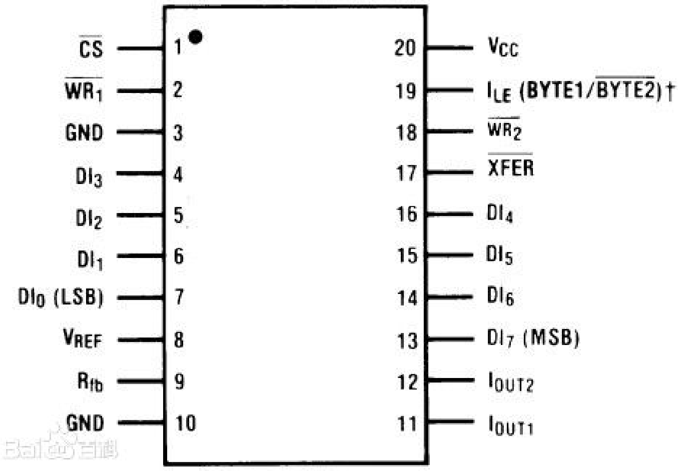
Then the chip goes into the busy phase, and I need to give it a little delay to do the AD conversion, and then I need to give another clock pulse to clear the busy. The next step is to read the value of DOUT, the same principle as DIN input.

AD transfer function：

```
uint Read_AD_Data(uchar cmd)
{
    uchar i;
    uint AD_Value;
    CLK = 0;
    CS  = 0;           // Chip select, active low
    SPI_Write(cmd);// Write control command word
    for(i=6; i>0; i--);   // Delay waiting for conversion result
    CLK = 1;      // Send one clock cycle, clear BUSY
    _nop_();
    _nop_();
    CLK = 0;
    _nop_();
    _nop_();
    AD_Value=SPI_Read();//Read the DOUT pin to get the final digital quantity function
    CS = 1;
    return AD_Value;
}
```

2. Digital-Analog Converter (DAC)

DA conversion module integrates two DAC0832, which can realize log / analog conversion.



DAC0832 is a 20 pin dual - line insert chip. The characteristics of each pin are as follows：

CS——Chip selection signal, and allow the lock signal ILE combination to determine whether the effect, active low.

ILE——Allows latching signals, active high.

WR1——Write signal 1, as the first latched signal, the input data is latched to the input register (at this time, it must be valid with ILE),active low.

WR2——Write signal 2 to send the data stored in the input register to the DAC register for latching (at this point, the transmission control signal must be valid),active low.

XFER——Transmit control signals,active low.

DI7~DI0——8-bit data input.

IOUT1——Analog current output terminal 1. When all the DAC registers are 1, the output current is the maximum; when all the DAC registers are 0, the output current is 0.

IOUT2——Analog current output terminal 2. IOUT1+IOUT2= Constant.

Rfb——The feedback resistor leads out. The DAC0832 already has an internal feedback resistor, so the RFB terminal can be directly connected to the output of the external operational amplifier. This is equivalent to connecting the feedback resistor between the input and output of the operational amplifier.

VREF——Reference voltage input. The accessible voltage range is ±10V. The external standard voltage is connected to the t-type resistance network by VREF.

VCC——chip supply voltage end. The range is +5V~+15V, and the optimal working state is +15V.

AGND——analog ground, that is, analog circuit ground terminal.

DGND——digital ground, that is, the ground end of digital circuit.

Its internal structure is as follows:

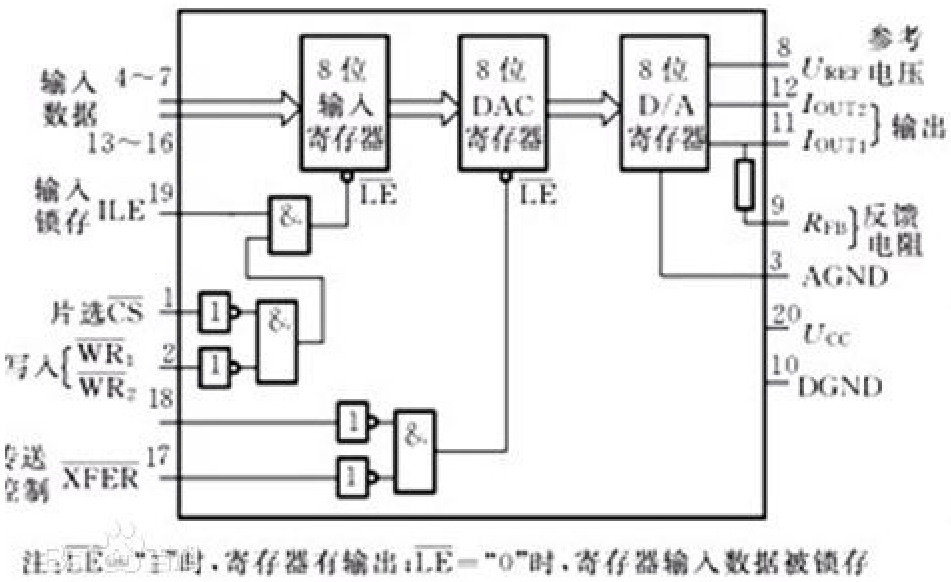


Figure 3-26 Structure Chart

There are two levels of registers inside, namely the input register and the DAC register. Each register is controlled by a set of logic signals.

The DAC0832 operates in three modes, depending on the circuit design.

1) single-buffer mode: let the input register and the DAC register receive data at the same time, or connect the DAC register into a pass-through mode using only the input register. This method is suitable for only one analog output or several analog outputs that appear asynchronously.

2) double-buffer mode: control the input register to receive data first, and then control the output of the input register to the DAC register, that is, lock the input data twice. This method is suitable for simultaneous output of multiple D/A transformations.

3) pass-through mode: the pass-through mode means that the data does not pass through the latches of two-stage latches, that is, /CS, /XFER, /WR1*, /WR2 are all grounded, and high level is connected to ILE. This method is suitable for continuous feedback control circuits and control system without CPU.

For power circuits：

1）+5V power supply

The DAC0832 module needs to be externally provided with +5V voltage. There are two ways to obtain power supply, namely power supply through J5 and J6 connectors respectively. The following sections describe the usage and definition of these two connectors in detail.

J6 is a headphone socket that connects the J12 to the computer USB port via a dedicated cable, which powers the DAC0832 module.

J5 is a molex-4 connector that connects the J11 to the external power supply via a dedicated cable, which powers the DAC0832 module.

Either of the above two connectors can power the module.

F1 is a self-recovery fuse in the power circuit. When the circuit current is too large, the fuse will be automatically disconnected to ensure the safety of the chip.

C3 and C4 in the module are filter capacitors, which are used to filter the interference brought by external power supply and guarantee the power supply quality.

2）-5V power supply

The DAC0832 module requires -5v dc power for the use of the DAC0832 and uA741, and the -5v power is generated by the MAX660 power chip on the DAC0832 module.

Experiments completed the MCU core program can realize in high level (daytime) within the scope of the lamp, low level lights (at night), and can be both a control level determine whether someone is coming, people to the output low level, bright lights, otherwise the last out the lamp, and to monitor the voltage, more or less allowed range when cut off the battery charging, at the same time, the design can be calculated during the day when the long timers, through digital tube display, although the final did not use in the finished product.

```
sbit P5=P2^0;
sbit P6=P1^7;
sbit P7=P1^6;
sbit P8=P1^3;
sbit P13=P2^1;

sbit LSA=P2^2;
sbit LSB=P2^3;
sbit LSC=P2^4;

#define GPIO_KEY P1

u8 code smgduan[17]={0x3f,0x06,0x5b,0x4f,0x66,0x6d,0x7d,0x07,
                    0x7f,0x6f,0x77,0x7c,0x39,0x5e,0x79,0x71};
u16 s;
u8 sec,mb[2];
                    int x;

void Timer0Init()
{
    TMOD|=0X01;
    TH0=0XFC;
    TL0=0X18;
```

```
    TR0=1;
}
```

The basic idea is to read the signal repeatedly using the Read_AD_Data function

```
uint Read_AD_Data(uchar cmd)
{
    uchar i;
    uint AD_Value;
    CLK = 0;
    CS  = 0;
    SPI_Write(cmd);
    for(i=6; i>0; i--);
    CLK = 1;
    _nop_();
    _nop_();
    CLK = 0;
    _nop_();
    _nop_();
    AD_Value=SPI_Read();
    CS = 1;
    return AD_Value;
}
```

And judge in the main function:

```
void main(void)
{
while(1)
{
    char a=0;
    Timer0Init();
    GPIO_KEY=0x0f;
```

```
if(GPIO_KEY!=0x0f||(!(datapros())))
{
    delay(1000);
    if(GPIO_KEY!=0x0f||(!(datapros())))
    {

        GPIO_KEY=0X0F;
        if(GPIO_KEY==0X07)//night
    {
        P5=1;
        P13=0;
        if(GPIO_KEY==0X0b)
        {
        P13=1;
        //delay(100000);
        }
        else{
        P13=0;
        }
        //delay(100000);
    }
    else{//day
        P5=0;
        P13=1;
        x=1;
        sec=0;
        while(x)
        {
            if(TF0==1)
```

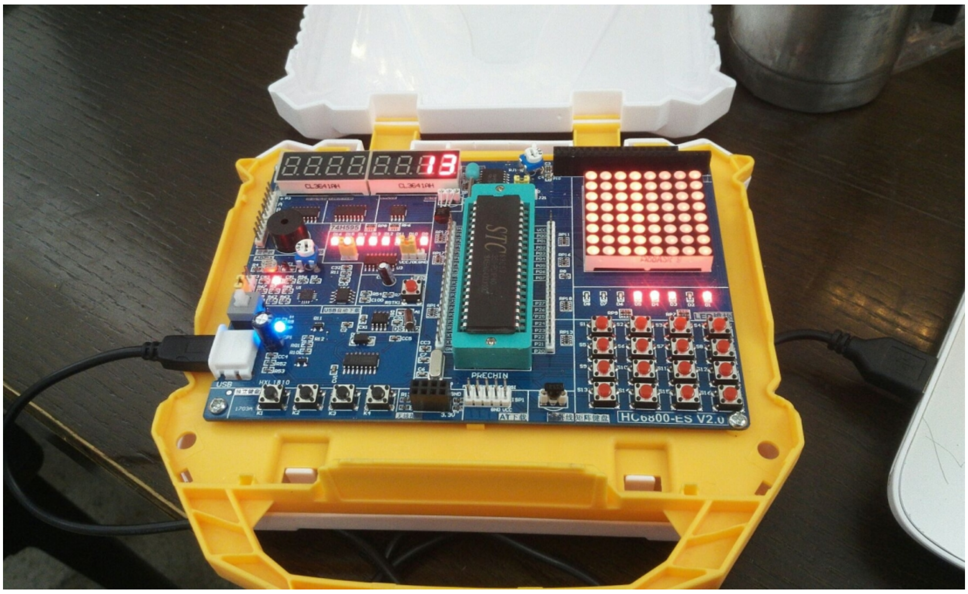
```
{
TF0=0;
TH0=0XFC;
TL0=0X18;
s++;
if((GPIO_KEY==0X0d)||(GPIO_KEY==0X07)||(!(datapros())))
{
    x=0;
    P5=0;
}
while(!(datapros()))
    {   x=1;
        P5=1;
        if(GPIO_KEY==0X07)
        {
            delay(1000);
            if(GPIO_KEY==0X07)
            {   break;}
        }
    }
    P5=0;
}

        if(GPIO_KEY==0X07)
        {
            delay(1000);
            if(GPIO_KEY==0X07)
            {   break;}
        }
```

```
        if(s==1000)
        {
        s=0;
        sec++;
        if(sec==100)sec=0;
        }
        mb[0]=sec%10;
      mb[1]=sec/10;
        DigDisplay();
      }

      }
        while((a<50)&&(GPIO_KEY!=0xf0))
        {
          delay(1000);
          a++;
        }
      }
    }
  }
  }
```

Finally, the DigDisplay() function is used to display the number and calculate the daytime time. The result is as follows



3. Bluetooth Module

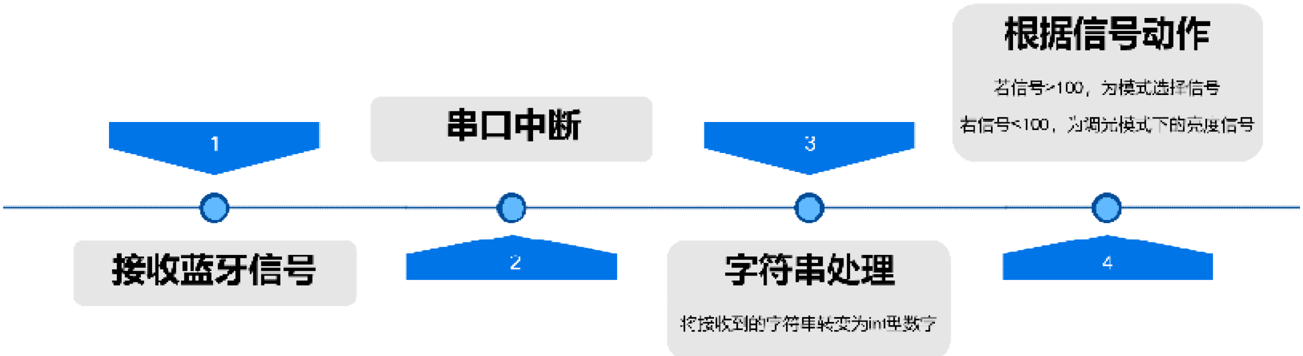


Figure 3-27 Block Diagram

First, enable the serial port interrupt and initialize the baud rate to 9600.

```
TMOD = 0x20;
PCON = 0x00;
SCON = 0x50;
TH1 = 0xFD;
TL1 = 0xFD;
TR1 = 1;
ES = 1;
EA = 1;
```

When receiving Bluetooth data, enter the serial port interrupt:

```
void UARTInterrupt(void) interrupt 4 // Serial port receiving characters
```

```
{
    if(RI)
    {
        RI = 0;
        r_buf = SBUF;
        Receive(r_buf);
    }
}
```

Since what is received is a string, it needs to be processed by the Receive () function:

```
void Receive(char x)  // Store received characters into a string
  {
  receiveDatas[j]=x           ;
  j++;
  if(j==3){
            j=0;
            result();//Follow up with result ()
   }
  }
```

4. Functions and Analysis of the Works

4.1 Functions

Our work provides a multi-functional LED lamp powered by solar energy. It has the following functions

(1) Power is supplied by the solar panel, and external lighting conditions can be judged by the output voltage of the solar panel;

(2) Communicate with mobile phone through Bluetooth module, and control the working state through supporting APP;

(3) Working state I: induction state: through PIR, it can sense the pedestrian passing by (the farthest distance is 6m), and then choose whether to illuminate after judging the combined lighting conditions;

(4) Working state II: under the state of constant light, the lighting intensity can be continuously adjusted artificially;

(5) Working state III: flicker state, LED brightness from 0% to 100% cycle;

(6) Working state IV: closed state, LED does not emit light.

4.2 Parameters

Polycrystalline silicon solar panel: standard pressure 6V, rated power 7W;
Polymer lithium battery: nominal voltage: 3.7v, full voltage: 4.2v, capacity: 8000mAh;
LED (single) : operating voltage: 3.7v-5v, rated power: 1W.
Relationship curve between light intensity and solar panel voltage:

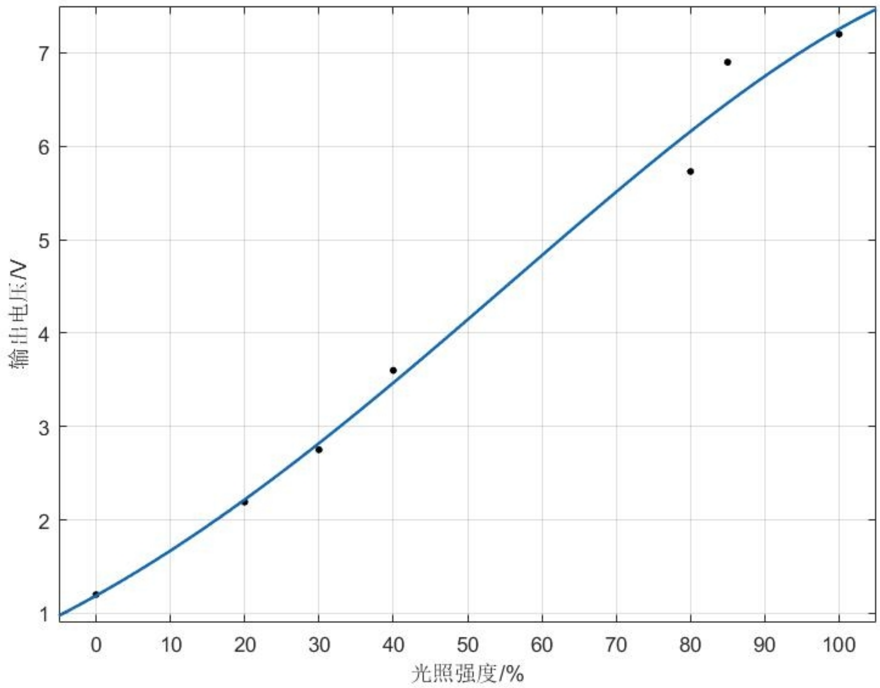


Figure 4-1 The relationship between light intensity and solar panel voltage

4.3 Running Process and Results

4.3.1 Operating Instructions of the System

（1）Configure Bluetooth module

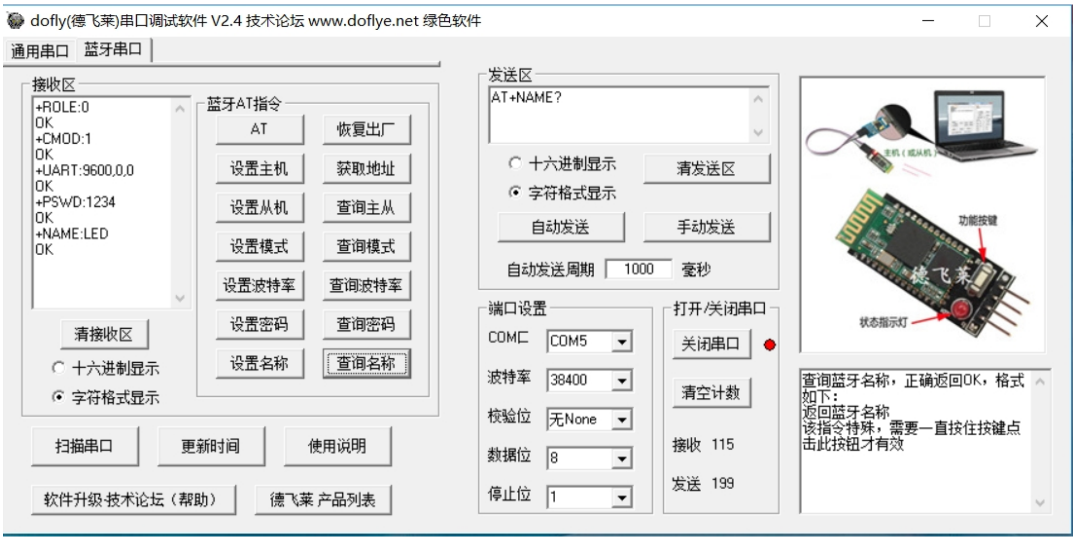


Figure 4-2

As shown in the figure, the Bluetooth module is set as a slave, the mode is 1, the connection password is 1234, and the name is LED.

（2）Open the mobile Bluetooth, search for the Bluetooth module and match with it

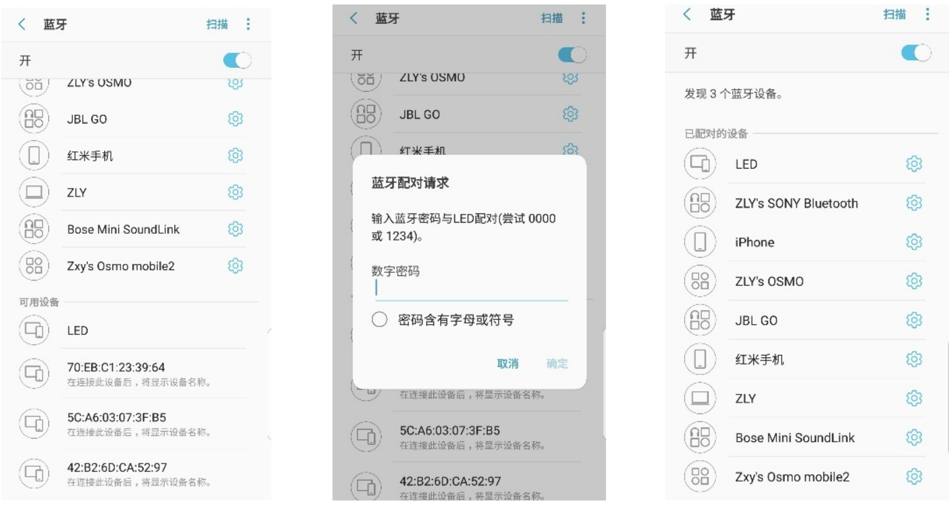


Figure 4-3

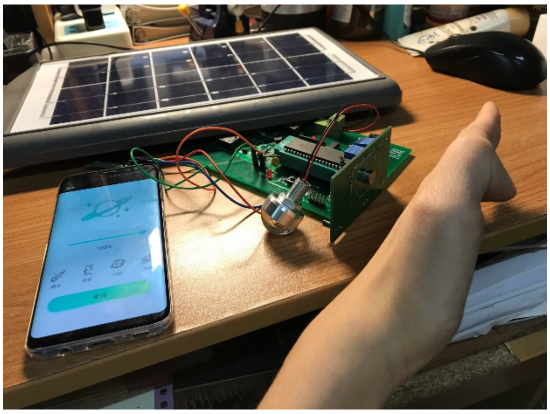
(3) Open the "aurora" APP, click "connect", select find device, and select the LED that has just been paired in the paired device.

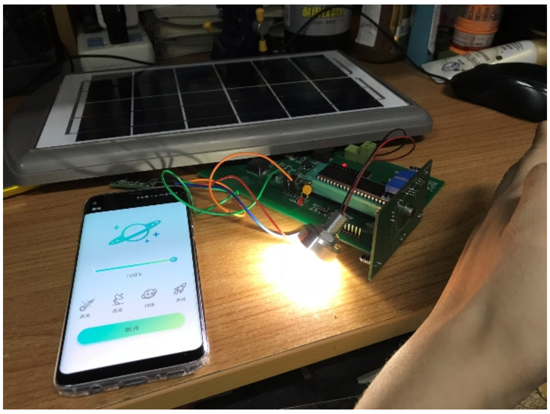
Figure 4-4

(4) When the lower button changes to "want to disconnect?", the connection is successful. Click the question mark in the upper right corner to enter the help page.

Figure 4-5

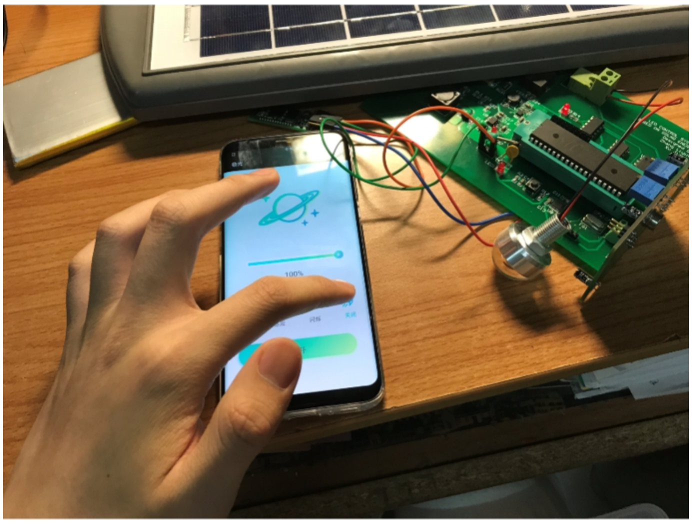
（5）Select the induction mode, when the external light intensity is high, the LED will not emit light; When the external light intensity is low and the pedestrian movement is sensed, the LED emits light.





（6）Select dimming mode and drag above Seekbar to continuously adjust LED brightness.

（7）Select off mode and the LED will not glow.



4.4 Comparison with design tasks

Design tasks:

NO.	Requirement	Completion status
1	Can be powered by solar energy	Completed
2	Dynamic sensing human body	Completed
3	When someone passes by, it's on. When someone leaves for a while, it's off	Completed
4	Working mode can be set	Completed

Table 4-6

Expanded functions:

(1) Maximum power point tracking of solar energy
(2)Lithium battery overvoltage protection
(3) Four working modes can be switched
(4) Dynamic adjustment of LED brightness
(5) Controlled through Bluetooth
(6) Mobile application with appropriate APP

4.5 Innovations

(1) Maximum power point tracking of solar energy

Maximum Power Point Tracking (MPPT) is a method to enable photovoltaic panels to output more Power by adjusting the working state of electrical modules.

(2) Lithium battery overcharge overvoltage protection

When the charging current decreases to 16% of the constant-current charging current, the charging ends and the over-charging can be prevented by turning off the MOS tube.

If the voltage of the battery (BAT) pin rises to 1.07 times of the constant voltage charging voltage, the overvoltage comparator will operate, turn off the P channel MOS pin outside the chip, and the charger will stop temporarily.

(3) Dynamic adjustment of LED brightness

(4) Communicate via Bluetooth and control with supporting APP.

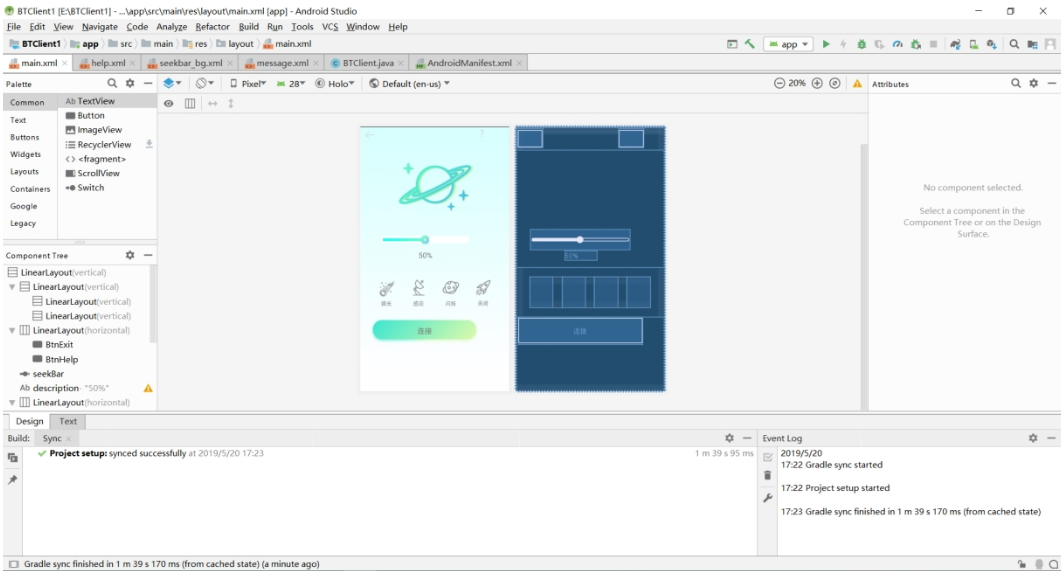


Figure 4-7

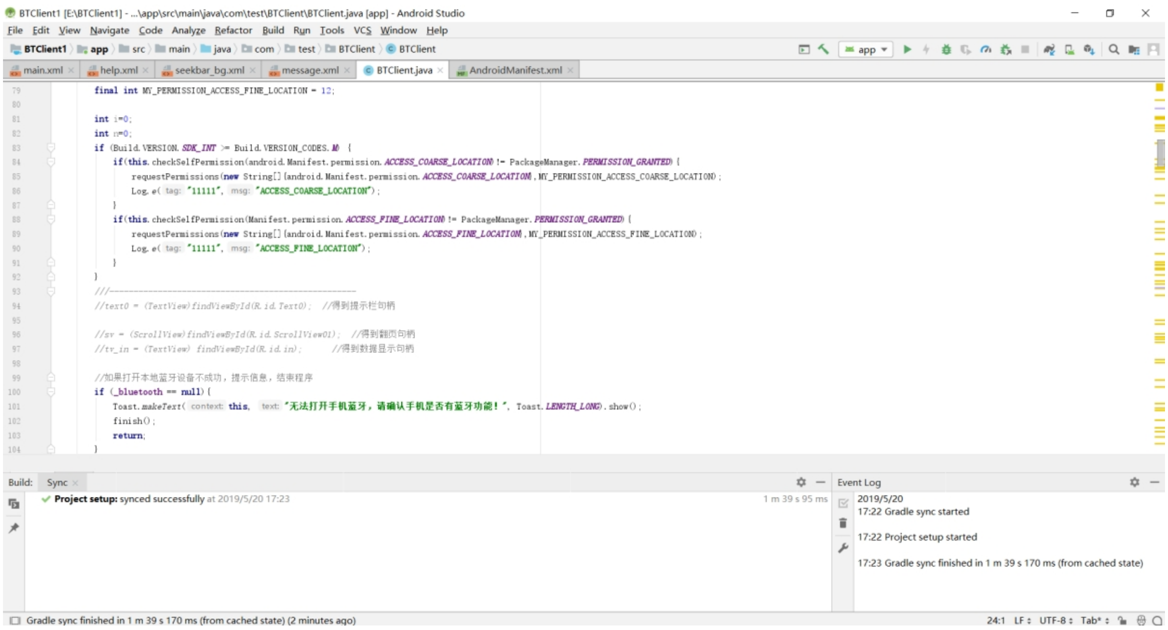


Figure 4-8

5. Process Recording

5.1 Experimental Process

(1) Learning the principles and basic knowledge of MCU; Learning to use Keil
(2) Analyzing the requirements of the topic and finding relevant information
(3) Determining the work indicators and functions, and selecting the chip to be used
(4) Learning the application circuit of the selected chip; Writing experimental program
(5) Learning Altuim Designer and drawing schematic diagrams and PCB
(6) Casting board and welding
(7) Debugging
(8) Developing supporting apps

5.2 Work Log

Date	Work details
Feb.25th	I determined the topic and expand ideas and learned the basics of MCU; Multi-function module use; running the lantern program
Feb.26	Experiment of interruption
Feb.27th	Determining the components of the solar lamp; I started designing specification parameters
Mar.4th	Timers and timer programs
Mar.5th	serial communication
Mar.6th	Determined the basic modules; Learned MPPT related knowledge; Started writing the DA conversion program
Mar.8th	Investigated the specifications of solar lamps on the market and determined the parameters; Chose batteries (lead-acid battery/lithium battery); Selected sensor type (radar induction/PIR)
Mar.9th	Investigation of lithium battery charger: ADI LT3652; Lithium battery protection chip: Ricoh
Mar.11th	Digital tube display, dynamic scan, key selection, single flashing
Mar.12th	Online battery monitoring

Mar.18th	Searched LED 5730 wick information; Found lithium battery information
Mar.22nd	Study on solar charger case: http://bbs.elecfans.com/jishu_357575_1_1.html
Mar.24th	Determined the required part of the chip, decided to test the TPS63000; Completed MCU core program can realize in high level (daytime) within the scope of the lamp, low level lights (at night), and can have a level control determine whether someone is coming, people to the output low level, bright light, otherwise the last out the lamp, and to monitor the voltage, more or less allowed range when cut off the battery charging, at the same time, the design can be calculated during the day when the long timers, through digital tube display, although the final did not use in the finished product.
Mar.26th	Read about TPS63000, CN3791 and BISS0001
Apr.1st	Drew the TPS63000 circuit diagram and Print Circuit Board
Apr.4th	Purchase of components; Designed circuit diagram of infrared sensor module
Apr.6th	Welding TPS63000 dimming module, tested (failed!)
Apr.7th	Welded again and analyzed the cause of welding plate burning
Apr.8th	Reselected inductor type-shielded power inductor
Apr.9th	The flying lead was retested and succeeded; the schematic diagram of the infrared sensor module and the PCB were started.
Apr.10th	Started drawing the schematics and PCB of the whole system
Apr.17th	Printed the broad of the PIR module
Apr.20th	Printed Circuit Board , purchase of components
Apr.28th	Finished welding and started debugging
May.2nd	Debugged Bluetooth module
May.6th	Started developing App
May.10th	Finished, began to prepare for the thesis writing
May.27th	Thesis defense

Table 5-1 Work log