VIETNAM NATIONAL UNIVERSITY, HO CHI MINH CITY
HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY
FACULTY OF COMPUTER SCIENCE AND ENGINEERING

Electrical Electronic Circuits - CC03

Report for Final Project

Le Tuan Hung - 2052508

1 Objectives

In this project, you are required to use the Altium Designer to design and layout a circuit that synthesize many knowledge that you have learnt in this course. There is something new, but no worries, we support you.
The project will include

- how to design a digital input switches,
- how to use a diode to prevent a short-circuit,
- how to use a transistor generating a high current signal,
- how to use an opamp as a buffer and a low-pass filter before reading an ADC signal, and
- how to connect all the input and output signals to a micro-controller.

2 Specifications

In this project, you aim to design a circuit that is able

- to measure the current of an 220V AC signal,
- to set an address to distinguish with other similar circuits, up to 16,
- to measure the maximum current either up to 5A or up to 10A,
- to send data to a gateway via RS485 or Wifi or Bluetooth,
- (optional) to display on 7 segment LEDs using IC 74HC595.

3 Solution

To fulfill the requirements above, one of the solutions that we can think of is that

- We will use a current sensor [1] to measure the current of the AC signal. The sensor should support to measure up to 5A or up to 10A. There are many current sensors that are available in the market, we recommend you to use TA12 [2] for 5A maximum and TA17 for 10A maxumun. They are cheap and easy to use.
- We will use 4 slide switches to set a board address.
- We will use an IC that can convert from UART signals to RS485 signals [3] for transferring data via RS485.
- We will use a micro-controller (MCU) board, namely ESP32-WROOM-32 [4] as a main processor. ESP32-WROOM-32 is a powerful, generic WiFi and Bluetooth MCU module which is suitable to many IoT application.

Now we list all the part that is required for our circuit. Based on the solution above, the circuit should include

- A power supply input with the range of 5V - 36V,
- A regulator 3.3V to supply power to the module ESP32-WROOM-32,
- A microcontroller board ESP32-WROOM-32,
- A TA12/TA17 sensor that supports up to 5A or up to 10A,
- Slide switches for a board address,
- LEDs for display status,
- a RS485 circuit,
- and some capacitors for filtering noise.

4 Guidance

In this section, we give you some guidance to draw a circuit with the solution above.

4.1 Design a 3.3V regulator

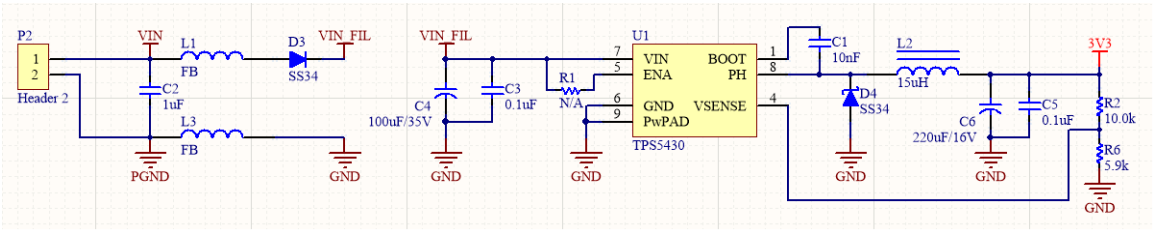


Figure 1.1: Power supply 3.3V regulator

Figure 1.1 shows a power supply part for this circuit. It generates a 3.3V output for our circuit from input from 5V-36V to 3.3V. On the left, P2 is a input header which 5-36V input is coming. The input power supply goes through a LC circuits (L1, L3 and C2) to filtering the high frequency noises. Then it goes though a diode D3 which is used to prevent the error from input at P2. Finally, we use IC TPS5430 [5] to generate a voltage 3.3V output.

4.2 Design a ESP32-WROOM-32 part

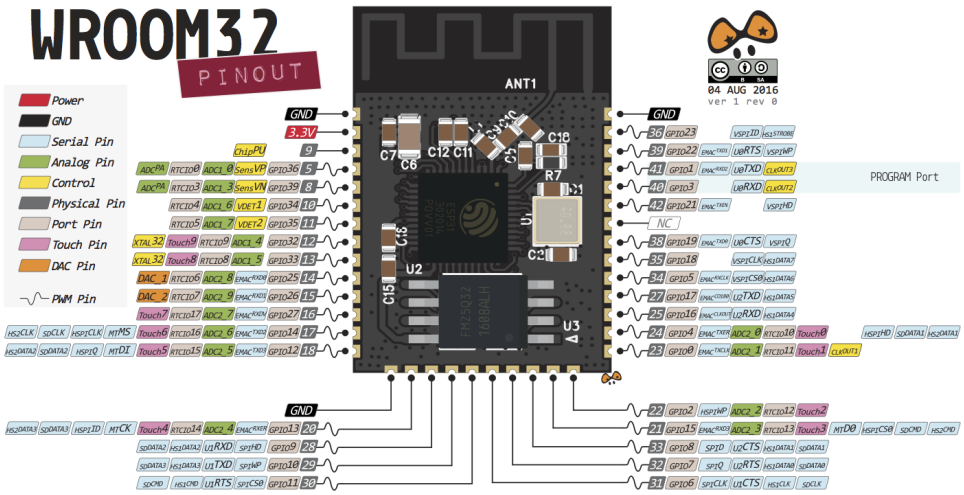


Figure 1.2: ESP32-WROOM-32 pinout

Figure 1.2 shows the pinout of the board ESP32-WROOM-32. It has on board 18 Analog to digital conversions (ADCs). Each ADC is 12 bit SAR technology based. 2 digital to analog conversion (DACs). It integrates 9 touch sensors. For communication, it has 2 UART communications channels, 2 I2C communications interfaces, two I2S channels and one CAN communication interface. It has 16 pulse width modulation channels. It also has a cryptographic hardware acceleration module for various cryptographic algorithms like RSA, AES.

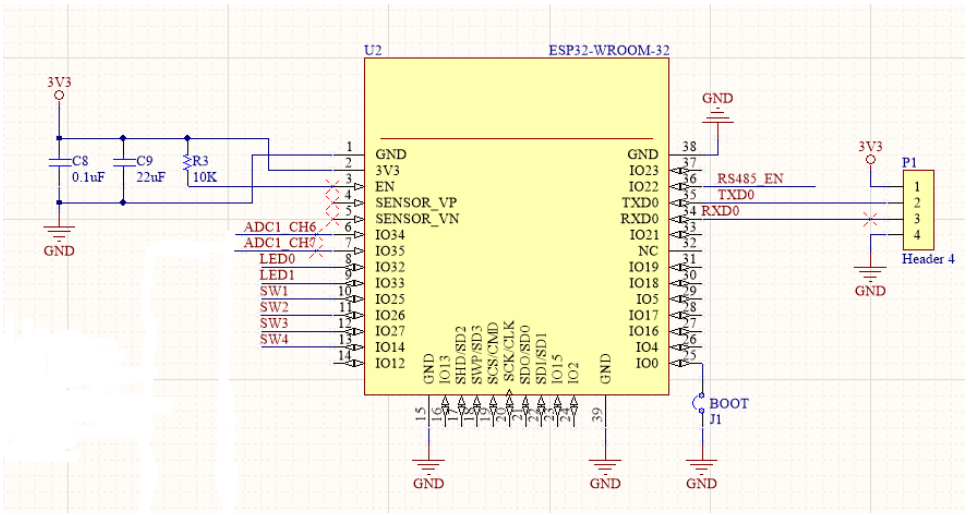


Figure 1.3: ESP32-WROOM-32

To fulfill the solution above, we will use 2 pins for ADC inputs, 2 pins for LEDs, 4 pins for switches and 3 pins for RS485 as shown in Figure 1.3.

4.3 Interfacing Slide Switch with an MCU

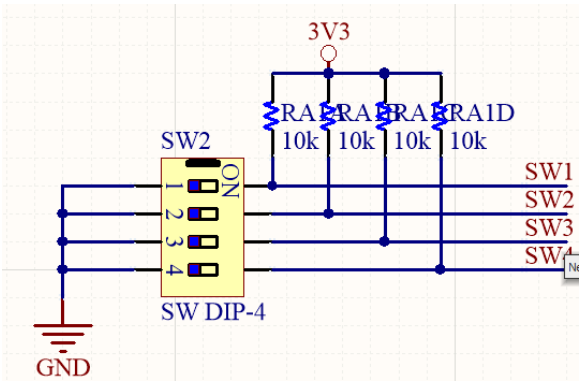


Figure 1.4: Switches

We use a SW DIP-4 for 4 switches which each switch has two terminals. One terminal connects with ground and the other connects with a resistor to 3.3V power supply and connects to the MCU pins. For resistors you can use 4 single resistors or you can use a RAID including 4 resistors inside.

4.4 Current sensor circuit

In this sensor part, we use two opamps which are packed in one IC LM358. IC LM358 includes two opamps. We use one to create a reference voltage, while we connect the second opamp with two current sensor TA12 and TA17 as shown in Figure 1.5.

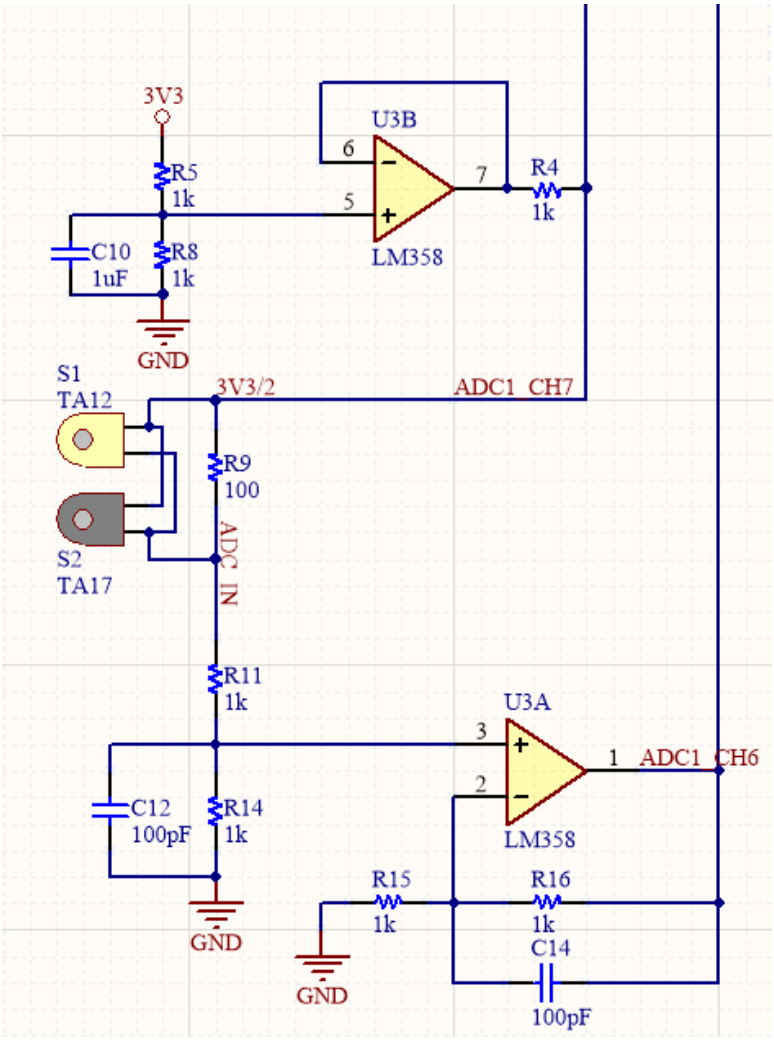


Figure 1.5: ADC Input

4.5 Design a RS-485 part

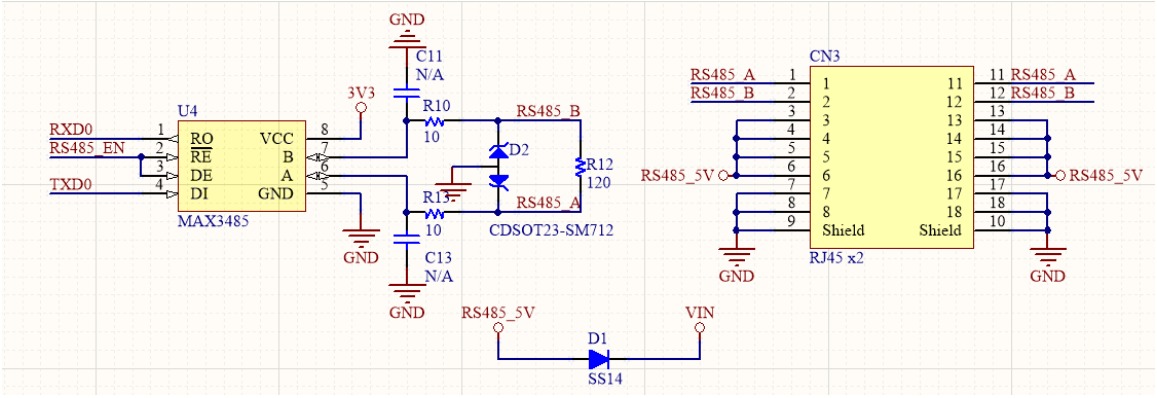


Figure 1.6: RS 485

For RS-485 part, we use an IC MAX485 to convert UART signal to 485 signal and vice versa. We also use a RJ45x2 to connect RS-485 signals. Last thing we need to consider for this part is that RJ45x2 is also supply 5V input, so we use D1 to prevent the current go through the RS485_5V pins.

4.6 Interface with high-current LEDs

Now, we design an output part which includes a 2-color LED as shown in Figure 1.7. In this part, we use two transistors to connect with the 2-color LED.

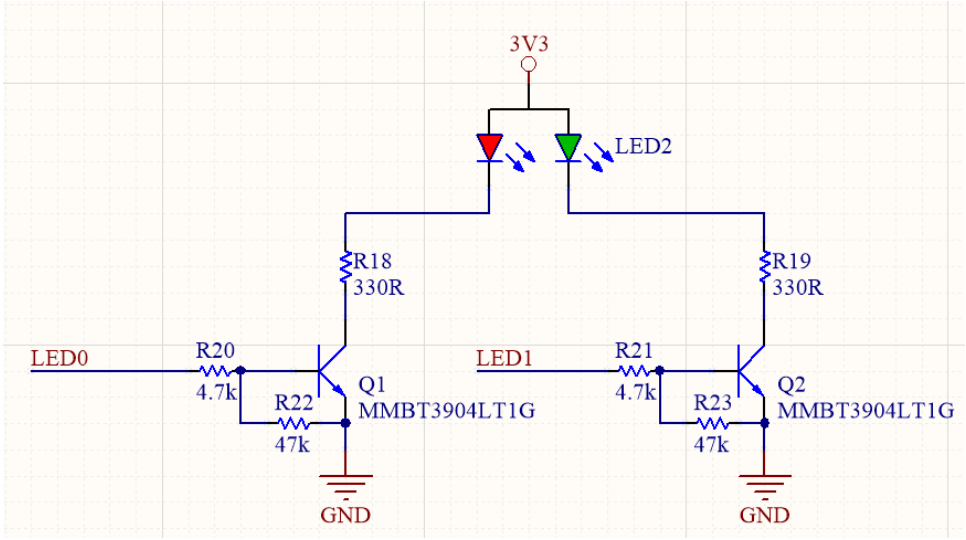


Figure 1.7: LED display

5 Example of a final result

Here is the sample of final result that you can use as a reference.

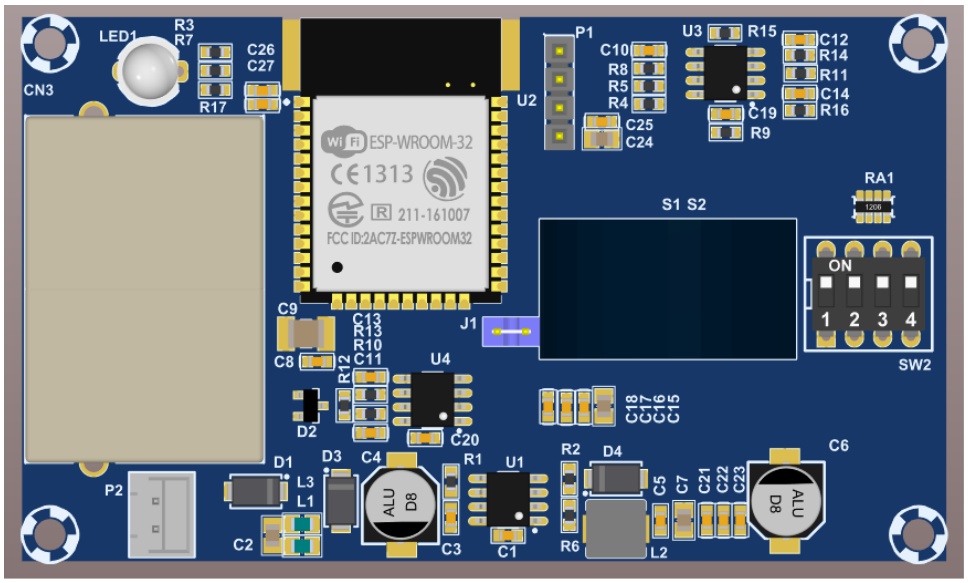


Figure 1.8: Final result 1

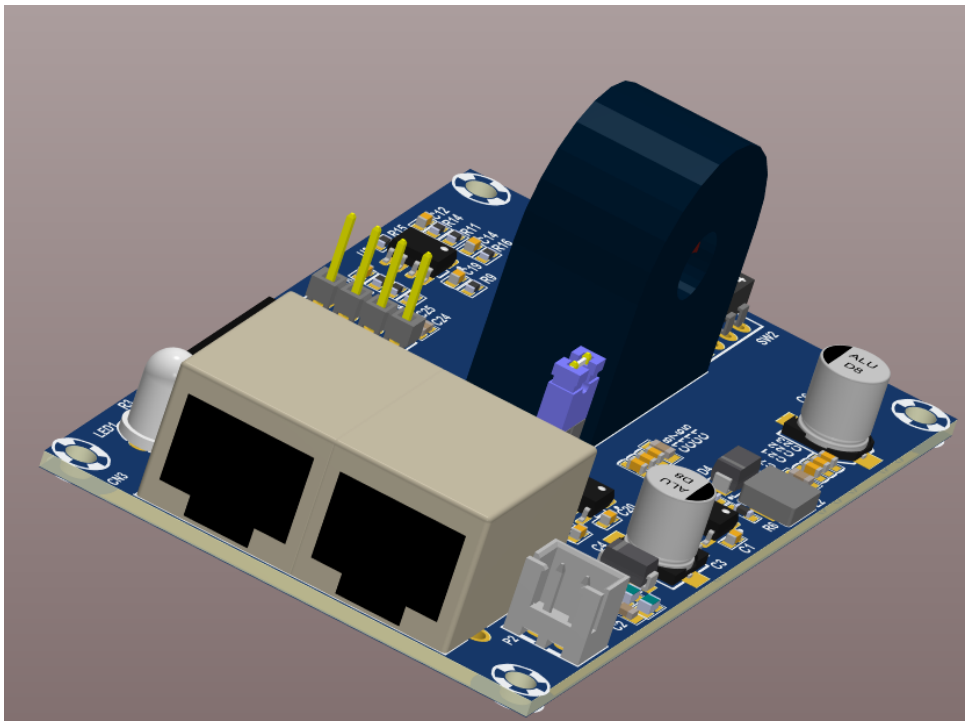
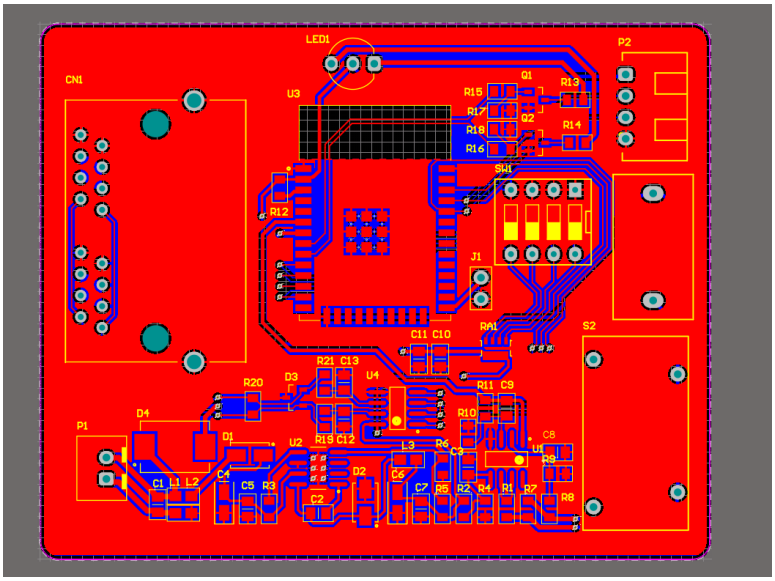
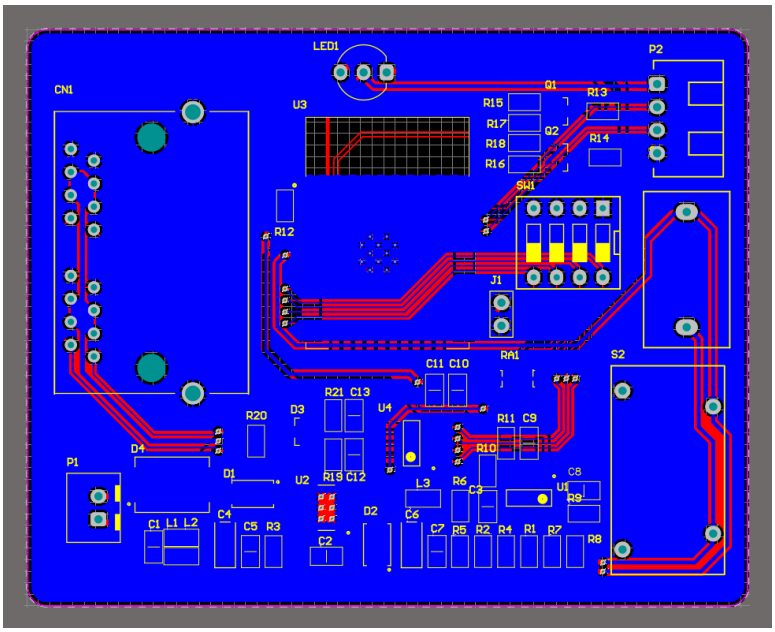


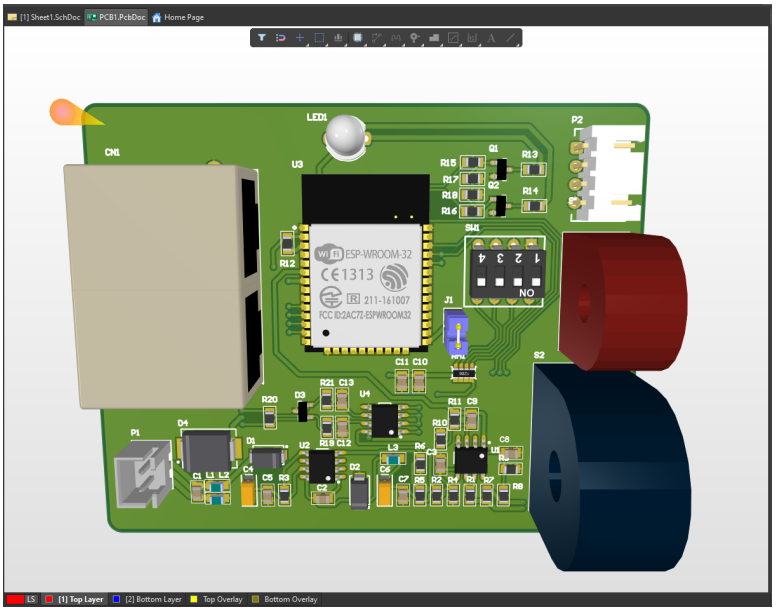
Figure 1.9: Final result 2

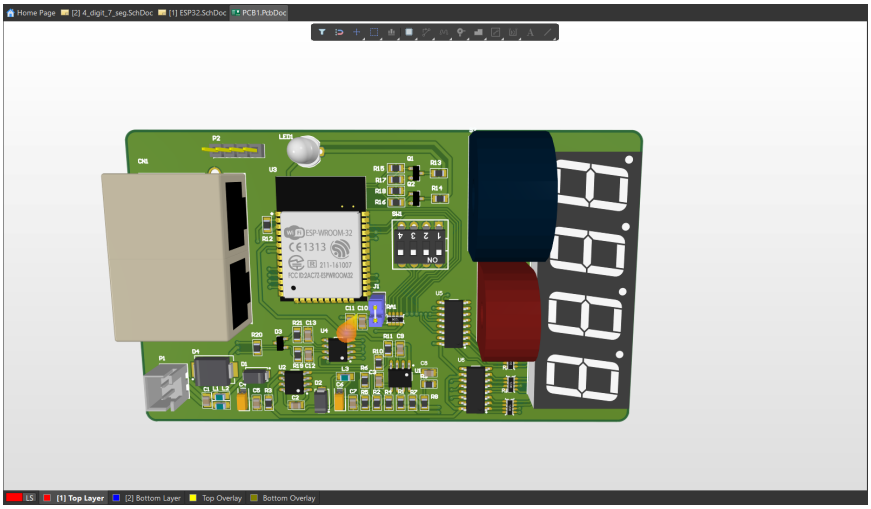
6 My final result





Here is my result with 4 digits 7-segments LED:





7 Requirements

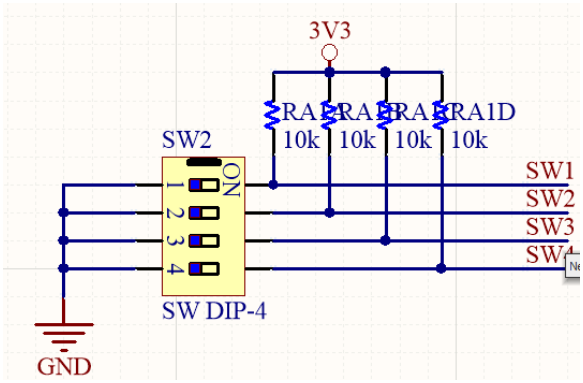
7.1 Questions to answer

[1] Research on the Internet and list 5 different current sensors that you can find. Along with each current sensor, please (1) give a reference source, (2) maximum current that the sensor can measure, and (3) how to obtain its values (e.g, using ADC, UART, I2C or SPI and so on).

Answer:
Both TA12, TA17 current sensors given above use ADC protocol (analog output).
WCM3720A current sensor, can measure up to 20A, digital output, can interface with MCU (UART communication).
TLI4970D025T4XUMA1 current sensor, measurement range up to ± 25(A), digital output, SPI interfacing.
Module PZEM-004T, measurement up to 100A, can interface with computer by UART.
IES5-1 measure up to 1000A, RS485 interfacing.
LMP92064, SPI interfacing, can measure up to 11mA.

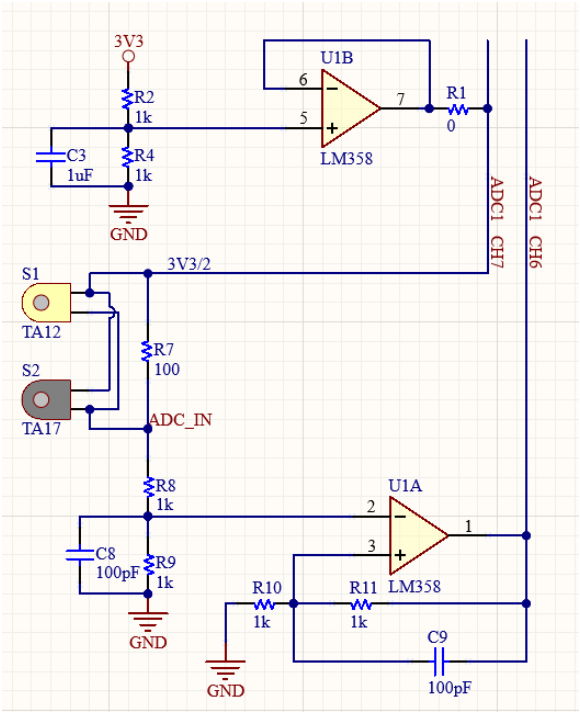
[2] In Figure 1.4, what is the voltage of SW1 when slide switch 1 is ON? and is OFF?

Answer:
When the SW1 ON, the current flow to the ground, so the voltage of SW1 is 0.
and when it is OFF, the voltage of SW1 is 3.3V.
[3] In Figure 1.5, what is the voltage of ADC1_CH7? of ADC1_CH6?



Answer:
Voltage of ADC1_CH7 is 1.65(V) because of voltage is divided by R2, R4
Input voltage of U1A = $\frac{1.65}{2.1}$ = 0.785, then the voltage of ADC1_CH6 is 1.57(V) (near 1.65V) because it is muliplied by R10 and R11.

[4] In Figure 1.5, we apply a low pass filter to the signal ADC_IN. What is the cutoff frequency of this low pass filter? If we want to set a cutoff frequency is about 10kHz, what should we change in the circuit of U3A?



Answer:
Cutoff frequency is $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 1k \times 100p} \approx 1.6(MHz)$

We can change C9 from 100pF to 16nF to set the cutoff frequency to 10kHz, which based on this formula $f_c = \frac{1}{2\pi RC} \Rightarrow C = \frac{1}{2\pi R f_c}$

[5] How much do the currents go through each LED in Figure 1.7? What should we do if we want to control a 100mW LED?

Answer: We have the formula: $P = U.I$, so $I = \frac{P}{U}$

We have voltage drop of LED base on its color is: So, the current we need to go to green

color	voltage (Volts)
IR	1.5
red	2.0
orange	2.0
yellow	2.1
green	2.2
true green	3.3
blue	3.3
white	3.3
UV	3.3
blue (430 nm)	4.6

LED is $I_{RED} = \frac{100}{2.2} = 45(mA)$

The current we need to go to red LED is $I_{GREEN} = \frac{100}{2} = 50(mA)$

Following the figure, we have $I_B = I_{R_{15}} - I_{R_{17}} = \frac{3.3-0.7}{4.7k} - \frac{0.7}{47k} = 0.53(mA)$

Easily, we can find that the transistors Q1 and Q2 are in saturation mode with $V_{CE} = 0.2(V)$

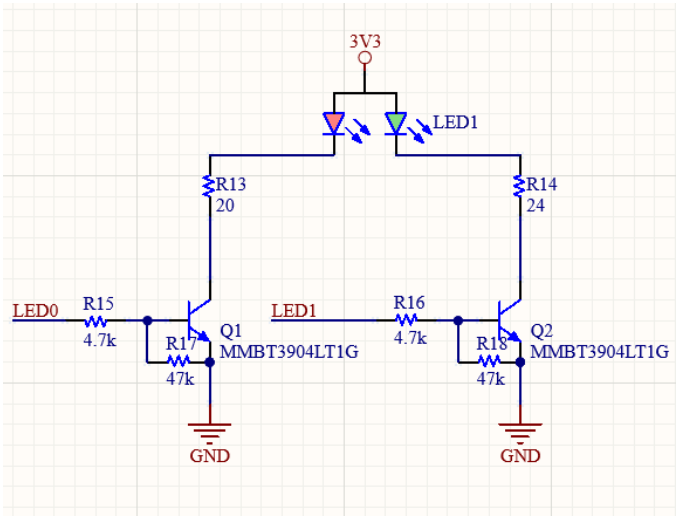
So the resistor we need to control the 100mW red LED is $R13 = \frac{3.3-2-0.2}{50} = 22(\Omega)$, i choose R13 = 24 Ω as it is available in market.

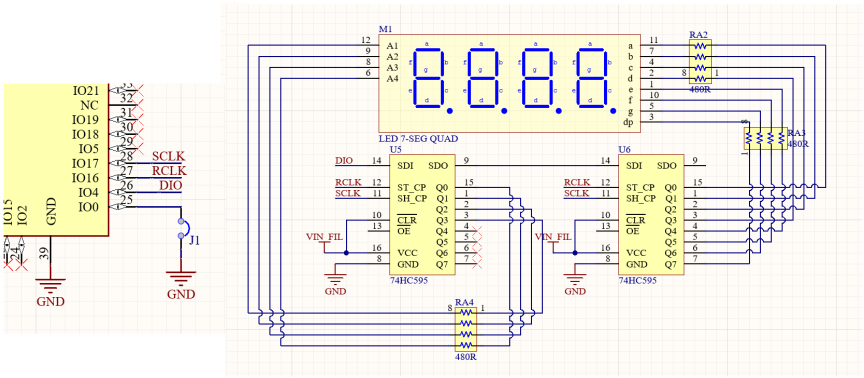
and for the green LED is $R14 = \frac{3.3-2.2-0.2}{45} = 20(\Omega)$

[6] What is the main purpose of D2 in Figure 1.6?

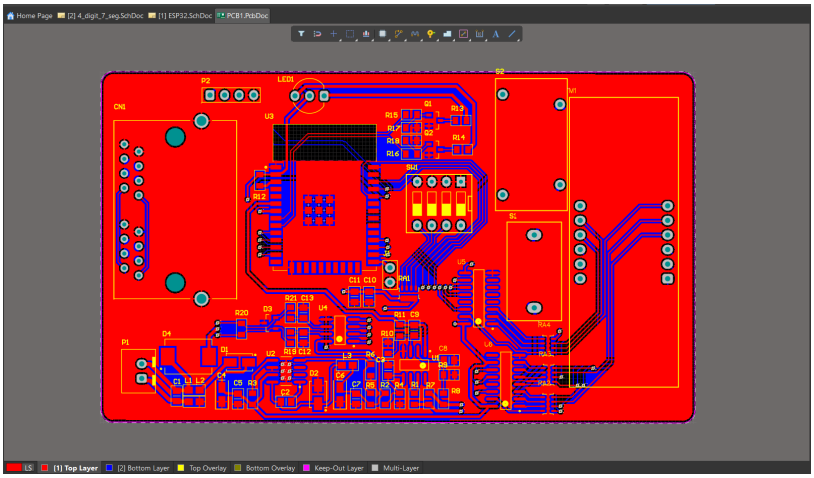
Answer:
D2 is a TVS Diode, it can be used to protect the circuit from spike voltages. The device operates by shunting excess current when the induced voltage exceeds the avalanche breakdown potential. It is a clamping device, suppressing all overvoltages above its breakdown voltage. It automatically resets when the overvoltage goes away but absorbs much more of the transient energy internally than a similarly rated crowbar device.

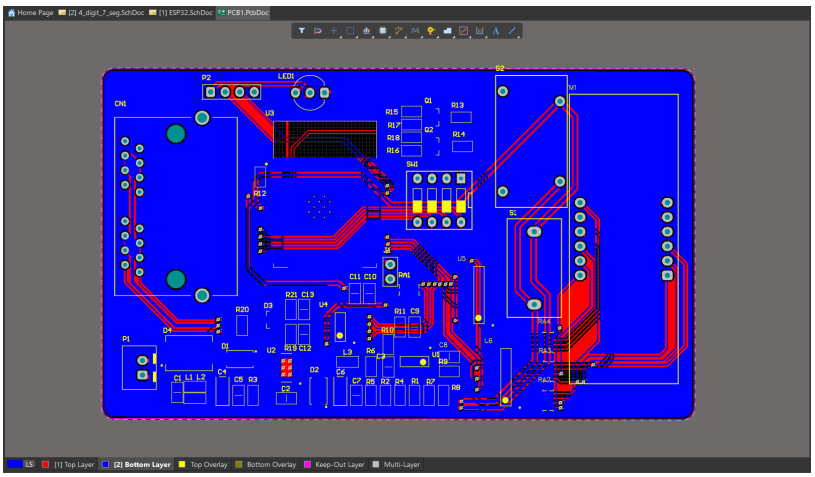
[7] (Optional) How to use IC 74HC595 to design a circuit to display value on 4 7-segment LEDs? First, we need 2 ICs 74HC595 to display 4 digits 7-segment LED
Then we make the connection like this

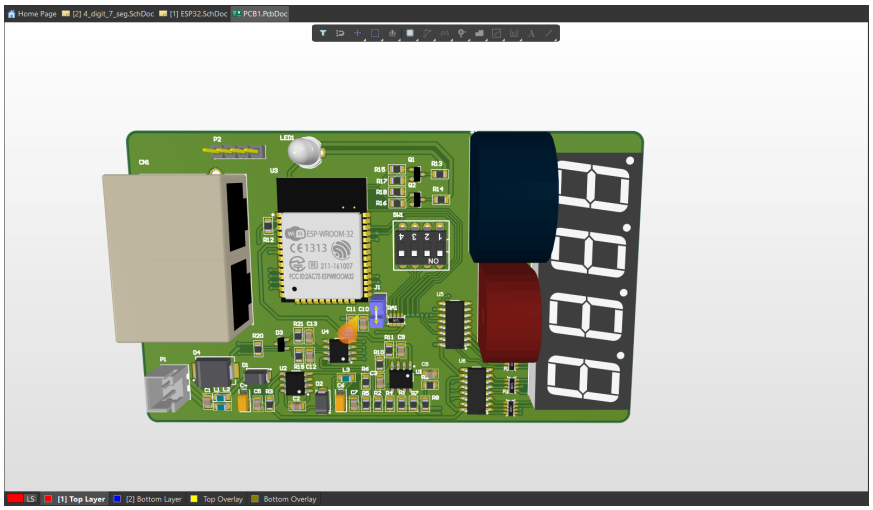




Finally, we connect 4 pins header to the PC, via UART to USB module, and define and program pins, we can use analogRead(); to read value from TA12 and TA17 current sensor. Then we define some LED pin and display value readed.







7.2 Requirements of your design and layout

1. Please download this rule **https://bit.ly/3bV7Vdy**, import it to your Altium Design project. Then you can place and route as normal.
2. Please note that the name of each component is shown in the figures above. You can use those information to search corresponding components on your project. All the components can be found in the **chipfc_altium_libs**, and also this library **https://drive.google.com/file/d/1JEiZ35lH3vG2xTBQqrG1bsEvJScXG6Eq/view?usp=sharing**
3. Please make the board as small as possible.

8 References

[1] https://en.wikipedia.org/wiki/Current_sensing
[2] http://www.electronicoscaldas.com/datasheet/TA12-TA12L-Series_YHDC.pdf
[3] https://en.wikipedia.org/wiki/RS-485
[4] https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.p
[5] https://www.ti.com/product/TPS5430