1.Transistor circuit

-guess and sketch the waveform of V_A and V_B

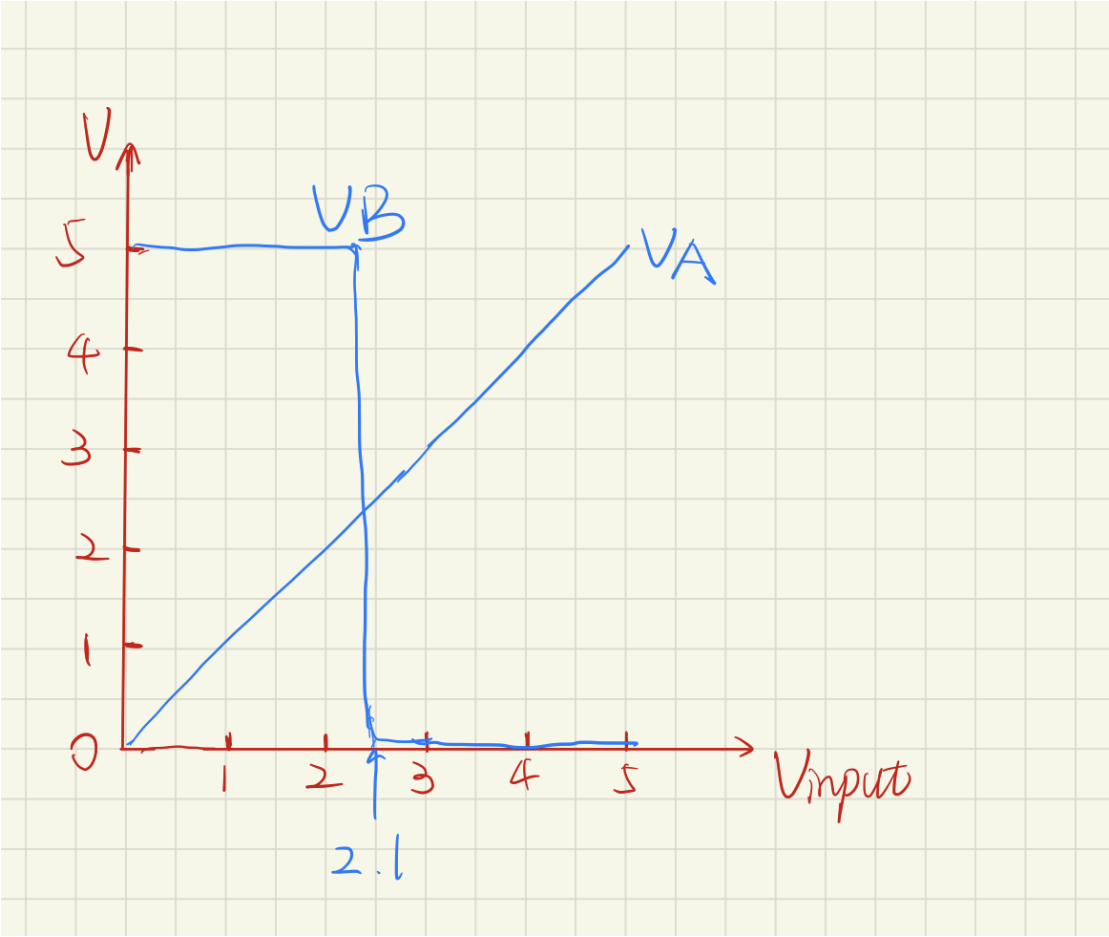


Table 4. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	I_D = 250 µA, V_{GS} =0	60			V
I_{DSS}	Zero gate voltage drain current (V_{GS} = 0)	V_{DS} = max rating V_{DS} = max rating, T_C = 125 °C			1 10	µA µA
I_{GSS}	Gate-body leakage current (V_{DS} = 0)	V_{GS} = ± 18 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 250 µA	1	2.1	3	V
$R_{DS(on)}$	Static drain-source on resistance	V_{GS} = 10 V, I_D = 0.5 A V_{GS} = 4.5 V, I_D = 0.5 A		1.8 2	5 5.3	Ω Ω

Reason:

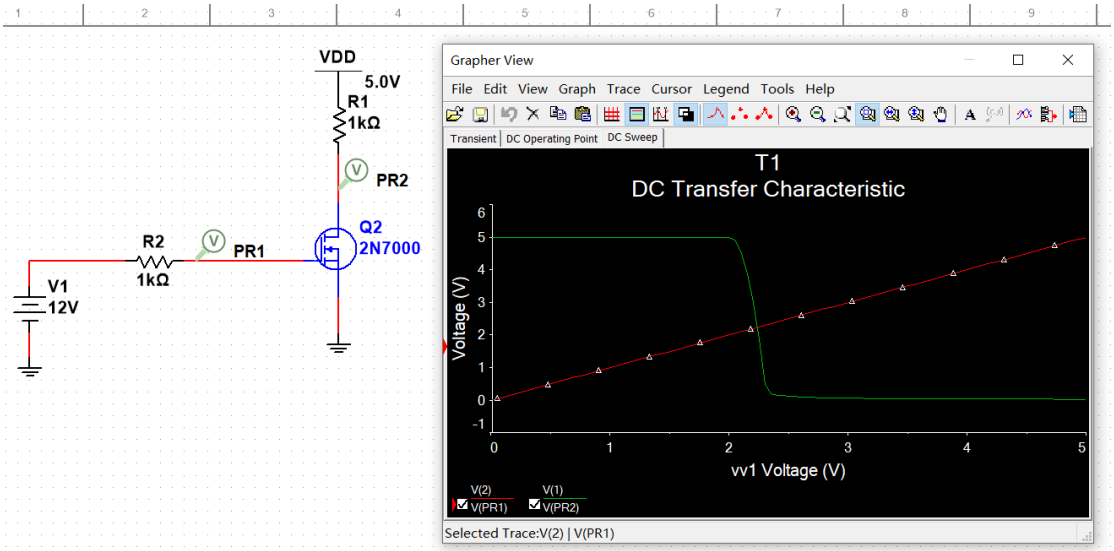
Query the datasheet and we could find that the gate threshold voltage is about 2.1V.

VA is always almost equal to the input voltage.

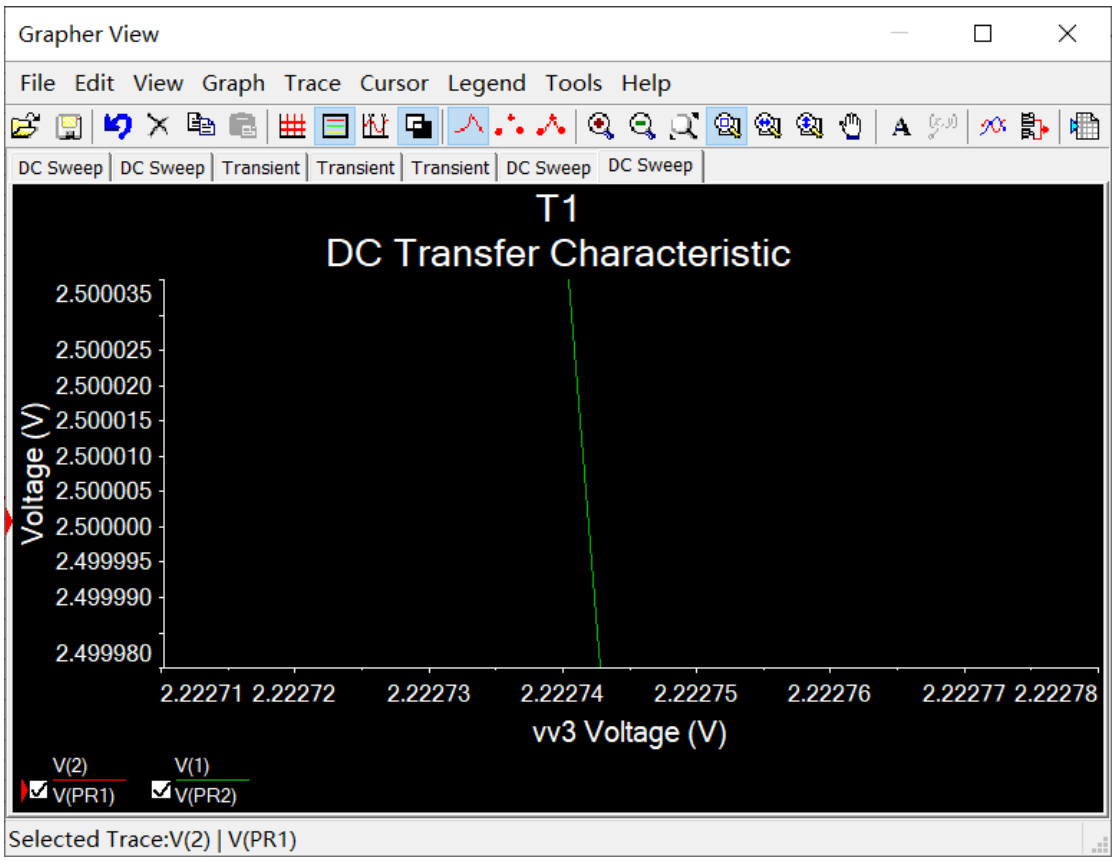
When the input voltage < 2.1V, the NMOS is on, so VB=VDD=5V.

And when the input voltage > 2.1V, the NMOS is off, so VB=0V.

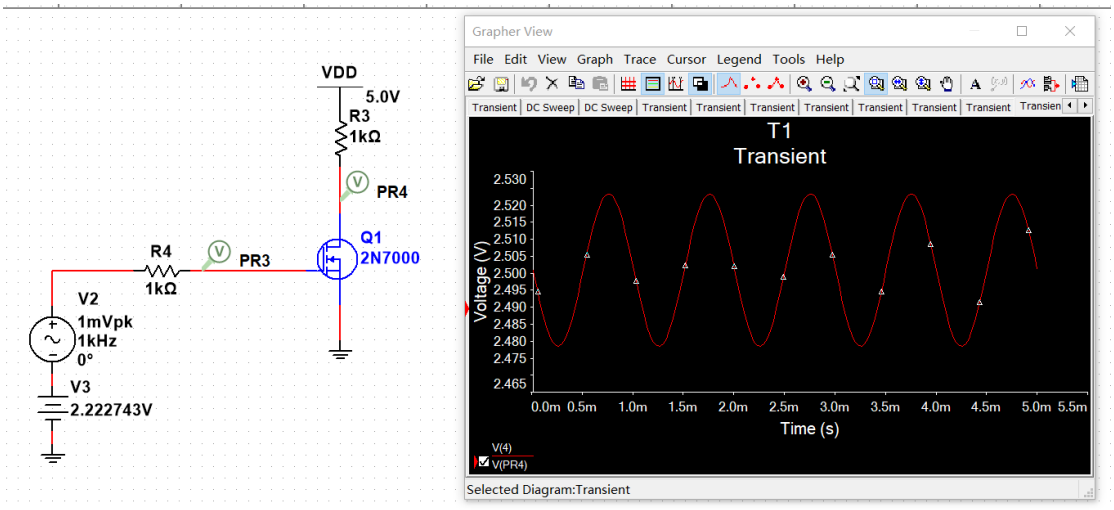
- Build the circuit in Multisim, use ‘DC sweep’ or ‘transient’ simulation to validate your guess.



- Find the output waveform of VB, and calculate the voltage gain.



Enlarge the wave of VB, we could find that when VB≈2.5V, the input voltage≈2.222743V.
So let the input voltage=2.222743V, and print the waveform of VB.



Amplitude of the VB's wave is 2.523V-2.501V=0.022V

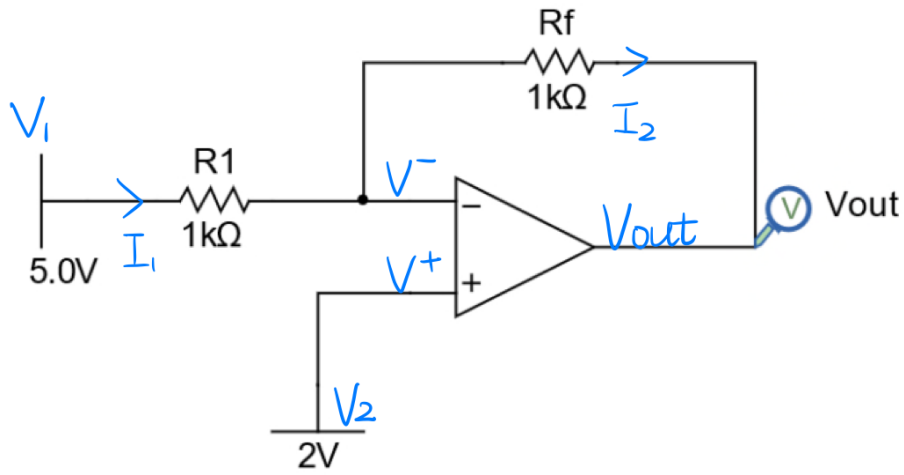
And the Amplitude of the peak voltage is 1mV=0.001V

So the voltage gain is (2.523-2.501)/0.001=22

The voltage gain=22.

2.Operational amplifier

Circuit #1



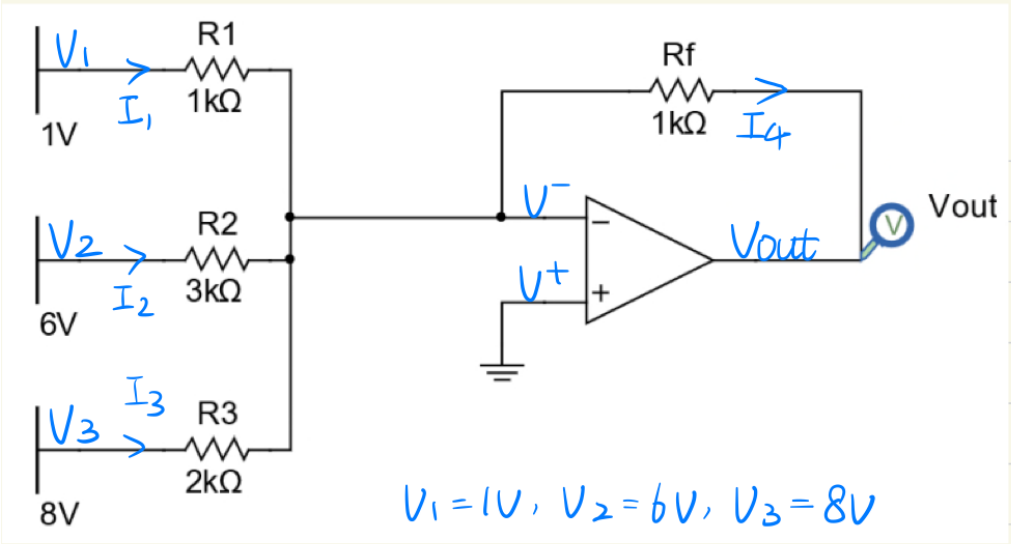
$V^- = V^+ = V_2 = 2V$ $\quad V_1 = 5V$

$I_1 = \frac{V_1 - V^-}{R_1} = \frac{5-2}{1k\Omega} = \frac{3}{1k\Omega}$ $\quad I_2 = \frac{V^- - Vout}{Rf} = \frac{2-Vout}{1k\Omega}$

$I_1 = I_2 \quad \therefore \frac{3}{1k\Omega} = \frac{2-Vout}{1k\Omega} \quad \therefore Vout = -1V$

Vout=-1V

Circuit #2



$V^- = V^+ = 0$

$I_1 = \frac{V_1 - V^-}{R_1} = \frac{1-0}{1k\Omega} = \frac{1}{1k\Omega}$ $I_2 = \frac{V_2 - V^-}{R_2} = \frac{6-0}{3k\Omega} = \frac{2}{1k\Omega}$

$I_3 = \frac{V_3 - V^-}{R_3} = \frac{8-0}{2k\Omega} = \frac{4}{1k\Omega}$ $I_4 = \frac{V^- - Vout}{Rf} = \frac{-Vout}{1k\Omega}$

$\because I_1 + I_2 + I_3 = I_4$ $\therefore \frac{1}{1k\Omega} + \frac{2}{1k\Omega} + \frac{4}{1k\Omega} = \frac{-Vout}{1k\Omega}$

$\therefore Vout = -7V$

Vout=-7V

3.Analog-to-digital converter (ADC)

let Vin compare with k
if Vin < k then $x_k = 1$
else $x_k = 0$

	x_1	x_2	x_3	x_4	B_1	B_0
$0 < V_{in} < 1$	1	1	1	1	1	1
$1 < V_{in} < 2$	0	1	1	1	1	0
$2 < V_{in} < 3$	0	0	1	1	0	1
$3 < V_{in} < 4$	0	0	0	1	0	0

the simplifications of digital circuit:

$$B_1 = x_1x_2x_3x_4 + \overline{x_1}x_2x_3x_4 = x_2x_3x_4$$

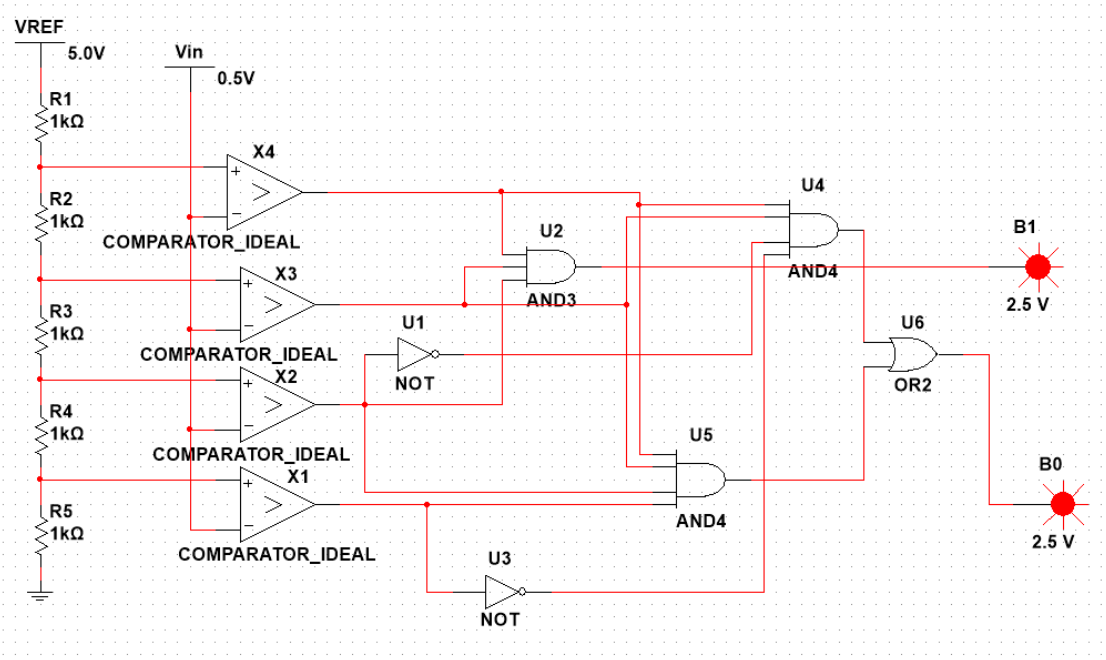
$$B_0 = x_1x_2x_3x_4 + \overline{x_1}\,\overline{x_2}x_3x_4$$

The circuit is as followed.

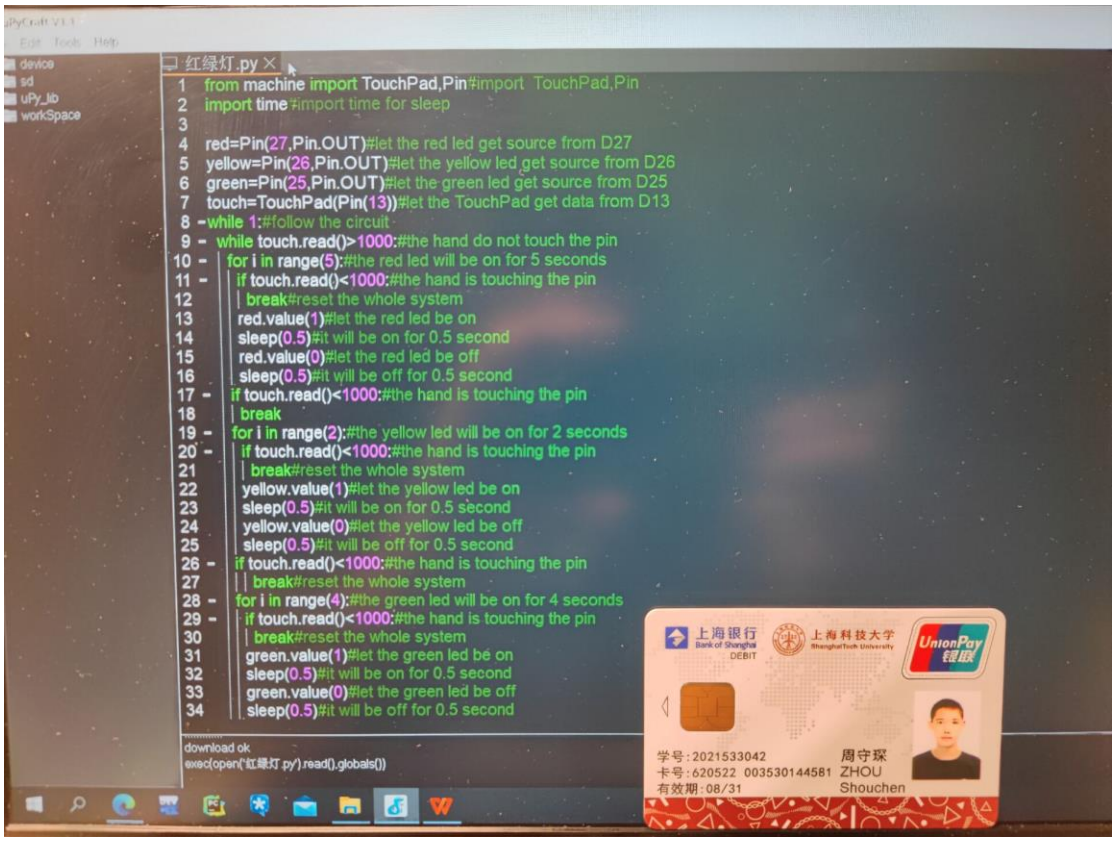
Change the value of Vin means the change of Vin.

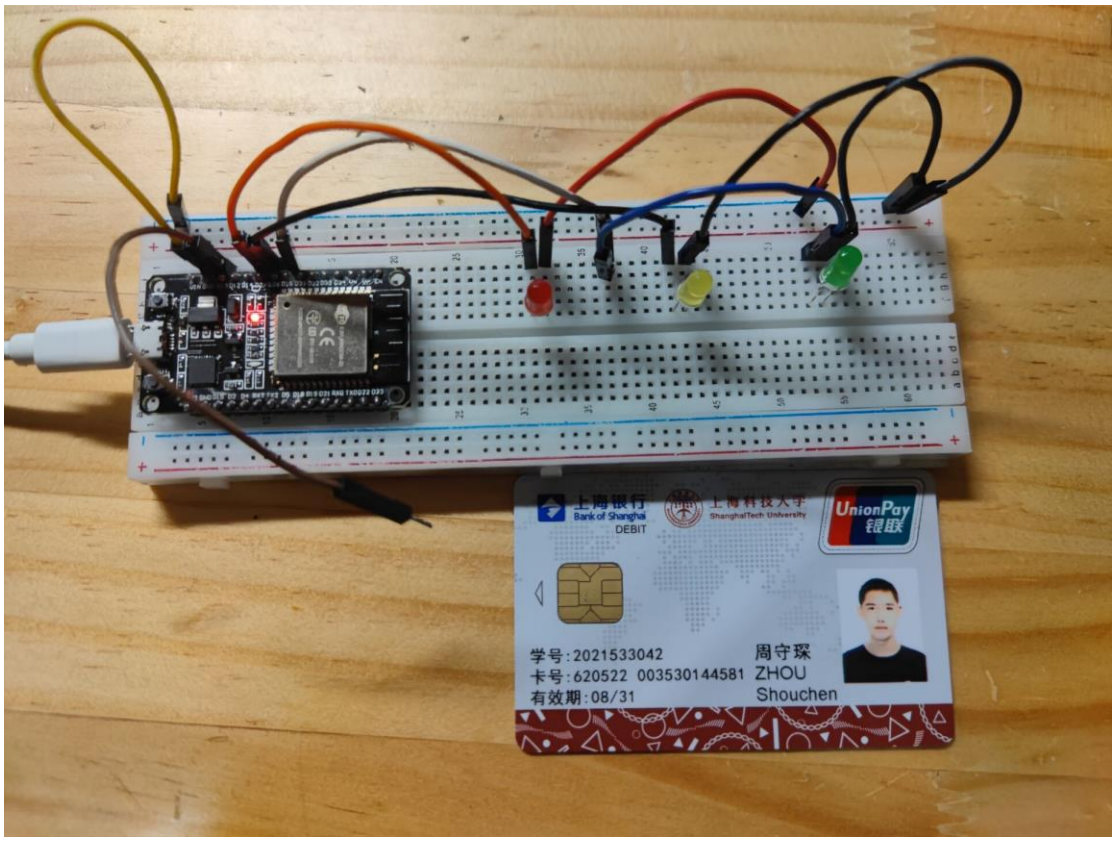
If B1/B0=1, then the corresponding light will light up.

If B1/B0=0, then the corresponding light will extinguish.



4.MCU development





```
from machine import TouchPad,Pin#import    TouchPad,Pin
import time#import time for sleep

red=Pin(27,Pin.OUT)#let the red led get source from D27
yellow=Pin(26,Pin.OUT)#let the yellow led get source from D26
green=Pin(25,Pin.OUT)#let the green led get source from D25
touch=TouchPad(Pin(13))#let the TouchPad get data from D13
while 1:#follow the circuit
    while touch.read()>1000:#the hand do not touch the pin
        for i in range(5):#the red led will be on for 5 seconds
            if touch.read()<1000:#the hand is touching the pin
                break#reset the whole system
            red.value(1)#let the red led be on
            sleep(0.5)#it will be on for 0.5 second
            red.value(0)#let the red led be off
            sleep(0.5)#it will be off for 0.5 second
        if touch.read()<1000:#the hand is touching the pin
            break
        for i in range(2):#the yellow led will be on for 2 seconds
            if touch.read()<1000:#the hand is touching the pin
                break#reset the whole system
            yellow.value(1)#let the yellow led be on
            sleep(0.5)#it will be on for 0.5 second
            yellow.value(0)#let the yellow led be off
            sleep(0.5)#it will be off for 0.5 second
        if touch.read()<1000:#the hand is touching the pin
                break#reset the whole system
        for i in range(4):#the green led will be on for 4 seconds
            if touch.read()<1000:#the hand is touching the pin
                break#reset the whole system
            green.value(1)#let the green led be on
            sleep(0.5)#it will be on for 0.5 second
            green.value(0)#let the green led be off
            sleep(0.5)#it will be off for 0.5 second
```