

# K230 Color Tracking

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### 1. Software-Hardware

### 2. Brief Principle

#### 2.1 Hardware Schematic Diagram

#### 2.2 Physical Connection Diagram

#### 2.3 Control Principle

### 3. Code Analysis

### 4. Experimental Operation

### 5. Experimental Phenomena

This tutorial is a comprehensive experiment combining multiple peripherals. You can understand individual peripherals before conducting this experiment.

## 1. Software-Hardware

- KEIL5

- MSPM0G3507 Robot Development Board

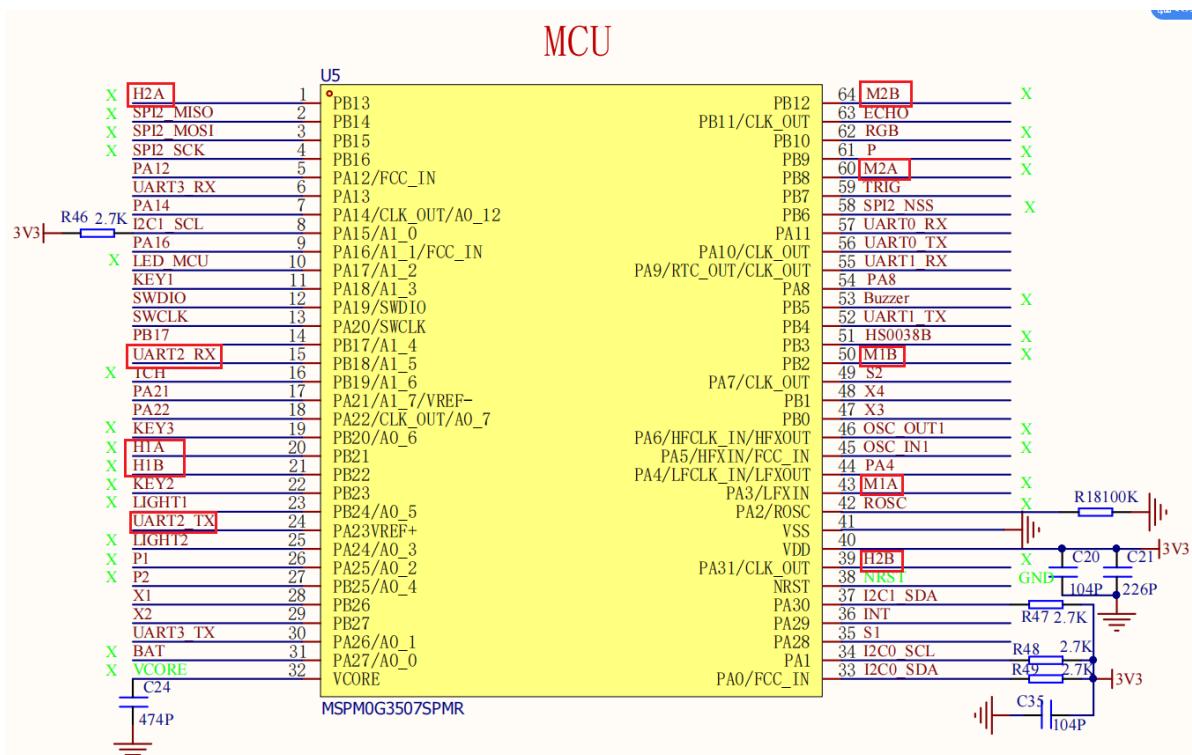
k230 Module: External

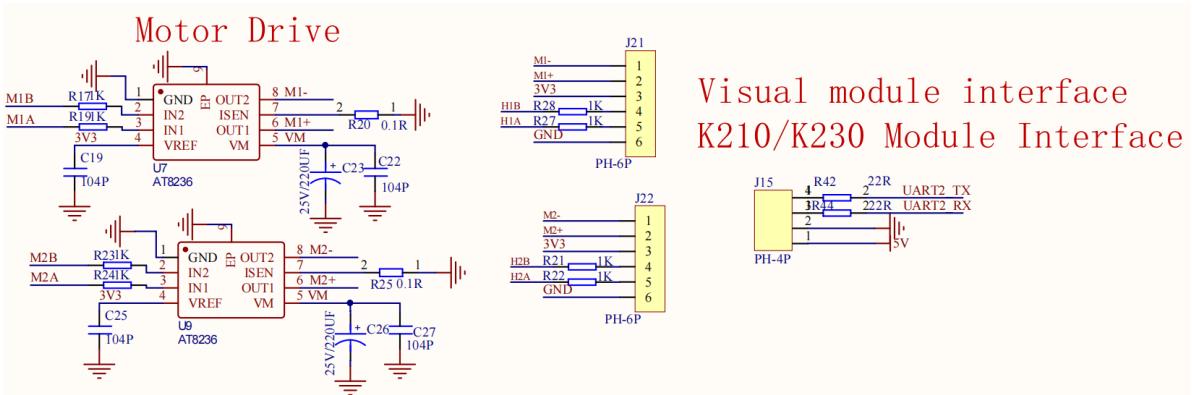
- Type-C Data Cable or DAP-Link

For program download or simulation to the development board

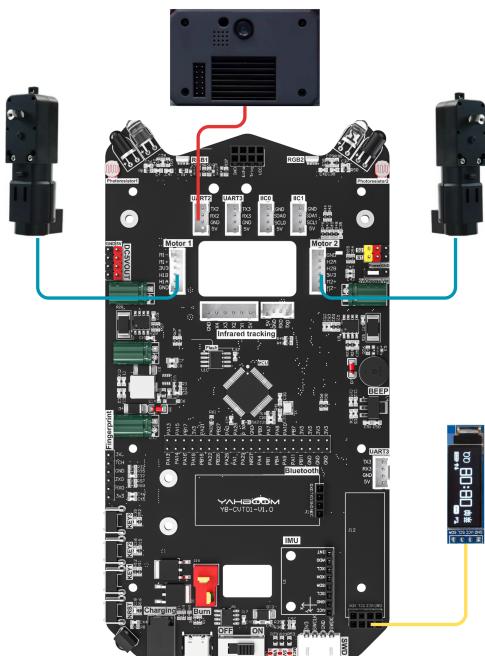
## 2. Brief Principle

### 2.1 Hardware Schematic Diagram





## 2.2 Physical Connection Diagram



### Wiring Pins

**Motor Wiring** (Note: The wiring in the diagram below is for position reference only. We provide dual-head PH2.0 6Pin all-black cables with anti-mistake design, so you don't need to worry about wiring issues)

TT Encoder Motor	MSPM0G3507
Motor Wire-	M1-
Motor Wire+	M1+
Encoder Power	3V3
Encoder Output B Phase	H1B
Encoder Output A Phase	H1A
Encoder Ground	GND

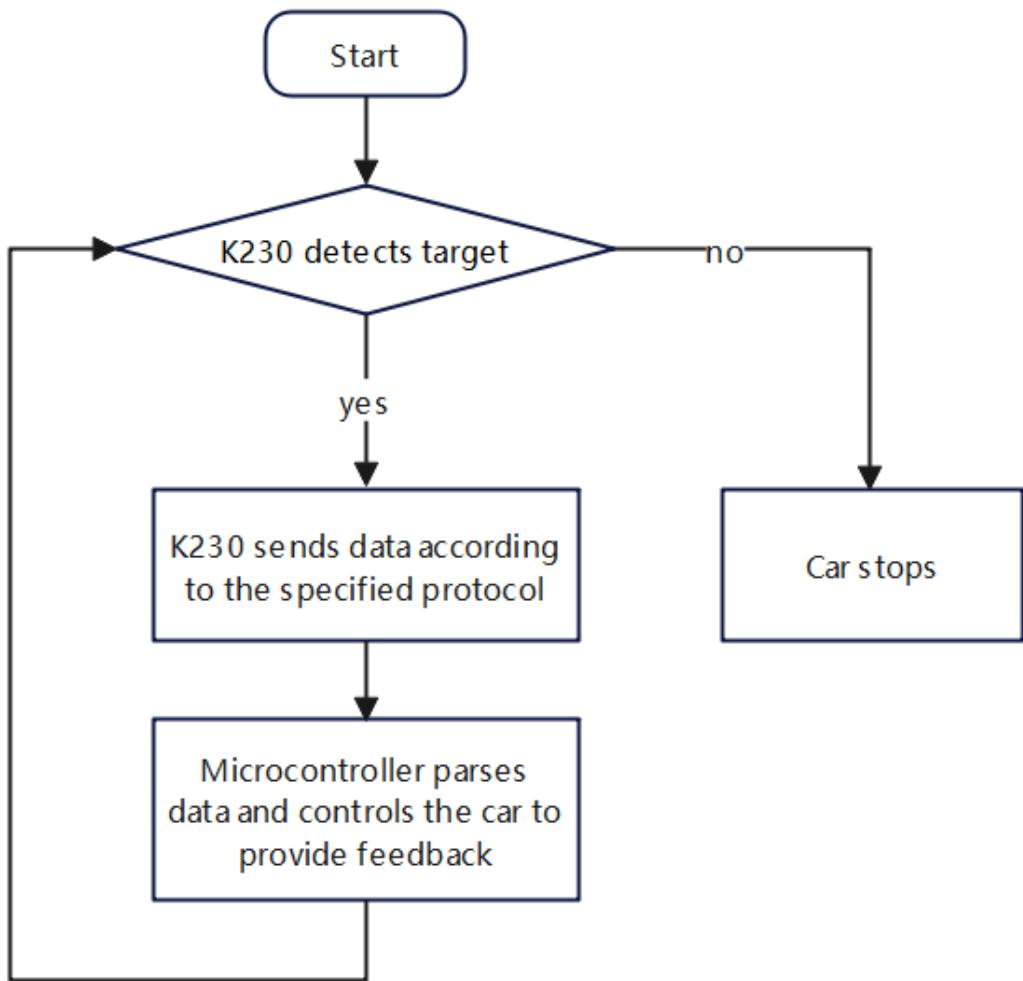
TT Encoder Motor	MSPM0G3507
Encoder Ground	GND
Encoder Output A Phase	H2A
Encoder Output B Phase	H2B
Encoder Power	3V3
Motor Wire+	M2+
Motor Wire-	M2-

**K230 Wiring** (Note: The wiring in the diagram below is for position reference only. We provide K230 dual-head PH2.0 4Pin all-black cables with anti-mistake design, so you don't need to worry about wiring issues)

K230	MSPM0G3507
RX	TX2
TX	RX2
GND	GND
5V	5V

## 2.3 Control Principle

- Program Flow Chart



### Control Principle:

#### PID Control

PID control is a commonly used closed-loop control algorithm that continuously adjusts the controller output to minimize the error between the system's actual output and expected output.

PID Parameters	Function	Purpose
P (Proportional)	Determines the response speed of PID controller output	Accelerate system response speed
I (Integral)	Determines the PID controller's response to cumulative error	Eliminate steady-state error
D (Differential)	Determines the PID controller's response to error change rate	Improve system steady-state performance

Module	Function
k230 Vision Module	Select the line you want to recognize, then send data to the microcontroller via serial port

### Communication Protocol:

When k230 recognizes the color track, it will send a data frame via serial port with the following format

Experiment Routine	Start Symbol	Length	Separator	Routine Number	Separator	x	Separator	y	Separator	w	Separator	h	End Symbol
Color Recognition	\$	XX	,	01	,	XXX	,	XXX	,	XXX	,	XXX	#

Microcontroller part:

Receive data sent by k230 via serial port and process each byte of data. Extract valid data from the data frame content and store it in an array. Then perform PID processing on the array data, and the microcontroller drives the motors based on the processed data to move along the track.

## 3. Code Analysis

### Main Function Analysis

#### Function: Pto\_Loop

Function Prototype	<b>void Pto_Loop(void)</b>
Function Description	Main function for running the program
Input Parameters	None
Output Parameters	None

### Partial Function Analysis

- main.c

```
colorMode color_mode = 2; //1:巡线、2:跟踪 1: Patrol, 2: Tracking

int main(void)
{
    bsp_init(); //需要的外设初始化 / Required peripheral initialization
    Control_RGB_ALL(OFF);
    delay_ms(100);

    OLED_ShowString(0,0,"pid_output:",8,1);
    OLED_ShowString(0,20,"pid_output1:",8,1);

    OLED_Refresh();

    while (1)
    {
        Pto_Loop();
        OLED_ShowSNum(75,0, pid_output, 3, 8, 1);
        OLED_ShowSNum(75,20,pid_output1,3,8,1);
        OLED_Refresh();
    }
}
```

```
    }
}
```

color\_mode: Use 1 when running vision line tracking case, use 2 when running color tracking case

BSP\_init: Hardware initialization

pto\_Loop: Continuously processes received K230 messages.

- `yb_protocol.c`

```
/***
* @Brief: 数据分析 Data analysis
* @Note:
* @Parm: 传入接收到的一个数据帧和长度      Pass in a received data frame and length
*
* @Retval:
*/
void Pto_Data_Parse(uint8_t *data_buf, uint8_t num)
{
    uint8_t pto_head = data_buf[0];
    uint8_t pto_tail = data_buf[num-1];

    //校验头尾  Check head and tail
    if (!(pto_head == PTO_HEAD && pto_tail == PTO_TAIL))
    {

        return;
    }

    uint8_t data_index = 1;
    uint8_t field_index[PTO_BUF_LEN_MAX] = {0};
    int i = 0;
    int values[PTO_BUF_LEN_MAX] = {0};
    char msgs[] [PTO_BUF_LEN_MAX] = {0};

    //分割字段  Split Field
    for (i = 1; i < num-1; i++)
    {
        if (data_buf[i] == ',')
        {
            data_buf[i] = 0;
            field_index[data_index] = i;
            data_index++;
        }
    }

    //解析长度与功能ID  Parse length and function ID
    for (i = 0; i < 2; i++)
    {
        values[i] = Pto_Char_To_Int((char*)data_buf+field_index[i]+1);
    }
```

```

    uint8_t pto_len = values[0];
    uint8_t pto_id = values[1];

    ParseCommonFields(pto_id,data_buf,pto_len,field_index,data_index,values,msgs);

}

```

Parse the received protocol-compliant data to obtain the function ID number and data information in the data, and execute the corresponding function processing function. This project uses a metadata parsing method. The core idea is to separate the protocol format description (field position, type, etc.) from the parsing logic, define the protocol format through data structures (such as struct arrays), and the parsing function automatically processes data according to these descriptions.

Different types of data contained in the protocol can also be parsed. If you want to understand the implementation details, you can study it yourself. No excessive explanation will be provided. This function has been adapted to all K230 communication protocols in our store. You don't need to fully understand it to use it normally.

- bsp\_PID\_motor.c

```

// PID单独计算一条通道 / PID calculation for a single channel
float PID_Calc_One_Motor(uint8_t motor_id, float now_speed)
{
    if (motor_id >= MAX_MOTOR)
        return 0;

    return PID_Location_Calc(&pid_motor[motor_id], now_speed);
}

void Set_PID_Motor(float set_l ,float set_r,float turn_out)
{
    l_pid_out = PID_Calc_One_Motor(0, set_l);
    r_pid_out = PID_Calc_One_Motor(1, set_r);

    PWM_Control_Car(l_pid_out+turn_out , r_pid_out-turn_out );
}

// 位置式PID计算方式 / Positional PID calculation method

float PID_Location_Calc(PID_t *pid, float actual_val)
{
    /*计算目标值与实际值的误差*/ /*calculate error between target value and actual
    value*/
}

```

```

pid->err = pid->target_val - actual_val;

/* 限定闭环死区 */ /* Limit closed-loop dead zone */

if ((pid->err >= -40) && (pid->err <= 40))
{
    pid->err = 0;
    pid->integral = 0;
}

/* 积分分离，偏差较大时去掉积分作用 */ /* Integral separation, remove integral
effect when deviation is large */

if (pid->err > -1500 && pid->err < 1500)
{
    pid->integral += pid->err; // 误差累积 / Error accumulation

    /* 限定积分范围，防止积分饱和 */ /* Limit integration range to prevent
integration saturation */
    if (pid->integral > 4000)
        pid->integral = 4000;
    else if (pid->integral < -4000)
        pid->integral = -4000;
}

/*PID算法实现*/ /*PID algorithm implementation*/
pid->output_val = pid->Kp * pid->err +
                    pid->Ki * pid->integral +
                    pid->Kd * (pid->err - pid->err_last);

/*误差传递*/ /*Error transmission*/
pid->err_last = pid->err;

/*返回当前实际值*/ /*Return current actual value*/
return pid->output_val;
}

```

Set\_PID\_Motor: Set target values for 2 motors and steering loop output value.

PID\_Calc\_One\_Motor: Calculate position loop PID value for one channel and return the calculated value.

PID\_Location\_Calc: Position loop PID calculation formula and complete position loop structure.

- bsp\_K230\_control.c

```

//颜色追踪 Color Tracking
void Color_Trace(int x,int w,int h)
{

    PID_TypeDef k230_pid;
    PID_param_init(&k230_pid);
    set_p_i_d(&k230_pid, k230_p3, 0, k230_d3);
    // set_p_i_d(&k230_pid, k230_p2, 0.001, k230_d2);
}

```

```

if(!Wait_Flag)
{
    delay_ms(1000);delay_ms(1000);delay_ms(1000); //delay 3s
    Wait_Flag = 1;
    return;
}

if(Wait_Flag && !SetTarget_Flag)
{
    SetTarget_Flag = 1;
    target_area = w*h/40;
}

int now_area = w*h/40;

int16_t err = 300 - x;

pid_output = PID_Calculate(&k230_pid,err); //计算差值的PID / calculate PID of
difference value

if(pid_output>70) pid_output=70; //对pid输出值进行限幅，防止小车跑过头 / Limit
PID output value to prevent car from overshooting
if(pid_output<-70) pid_output=-70;

int16_t err_area = target_area - now_area; //计算要追踪的面积差值 / Calculate
area difference to track

if(err_area<20 && err_area>-20)err_area=0; //设置要追踪的面积限幅，减少因为微弱变化
而引起小车频繁的抖动 / Set tracking area limit to reduce frequent car shaking
caused by small changes
pid_output1 = PID_Calculate(&k230_pid,err_area);

if(pid_output1>50) pid_output1=50; //对pid输出值进行限幅，防止小车跑过头 / Limit
PID output value to prevent car from overshooting
if(pid_output1<-50) pid_output1=-50;

Set_PID_Motor(-pid_output1 ,-pid_output1,pid_output);

}

```

Color\_Trace: After receiving data from K230, press the reset button, then wait for three seconds, then start calculating the tracking PID value, and finally control the car.

## 4. Experimental Operation

1. Wire according to the hardware wiring instructions in the tutorial.
2. Open the project used by MSPM0G3507. First, check the beginning part of the main.c file and modify color\_mode to 2. This enables tracking mode. After correct modification, compile and burn the program. Finally, reset or power on again.
3. Place Color\_Trace.py in the root directory of K230's SD card and rename it to main.py, then reset or power on again. If you are not clear about how to burn programs into K230, please first check the [K230 Vision Module](#) tutorial's [Quick Start] chapter.

4. Place the car in an open area, adjust the K230 module bracket to a suitable angle, and connect the power.
  5. When K230 initialization is successful, it will start recognizing the set color. Then press the car reset button, wait for three seconds, and the car will start tracking.

### Note:

`color_track.py` provides recognition of four preset colors: red, green, blue, and yellow. If the recognition effect is not good, you can check the K230 color recognition tutorial to learn how to replace LAB thresholds with thresholds suitable for your environment.

The screenshot shows the CanMV IDE interface with the following details:

- File Menu:** File, Edit, Tools, Window, Help.
- Toolbar:** Includes icons for New, Open, Save, Print, Copy, Paste, Find, Replace, Undo, Redo, and others.
- Code Editor:** Displays the `color_track.py` script. A red box highlights the threshold definitions from line 17 to 28.

```
4     from media.media import *
5
6     from libs.YbProtocol import YbProtocol
7     from ybUtils.YbUart import YbUart
8     # uart = None
9     uart = YbUart(baudrate=115200)
10    pto = YbProtocol()
11
12
13    # 显示参数 / Display parameters
14    DISPLAY_WIDTH = 640 # LCD显示宽度 / LCD display width
15    DISPLAY_HEIGHT = 480 # LCD显示高度 / LCD display height
16
17    # LAB颜色空间阈值 / LAB color space thresholds
18    # (L Min, L Max, A Min, A Max, B Min, B Max)
19    THRESHOLDS = [
20        (40, 48, 31, 96, 21, 36), # 红 / Red light
21        (38, 34, -32, -7, 2, 24), # 绿 / green light
22        (59, 100, -20, 7, 51, 81), # 黄 / Yellow light
23        (21, 34, -4, 19, -54, -29), # 蓝色阈值 / Blue thres
24    ]
25
26
27
28]
29
30 def get_closest_rgb(lab_threshold):
31     """根据LAB阈值计算最近的RGB颜色 / Calculate closest RGB col
32     # 获取LAB空间的中心点值
```
- Status Bar:** Line: 1, Col: 1, Frame Buffer, Record, Zoom, Disable.
- Analysis Results:** A histogram titled "Histogram" and "RGB Color Space" showing "Res - No Image". The histograms for R, G, and B channels are empty. Below each histogram are summary statistics:

R	G	B
Mean 0	Mean 0	Mean 0
Min 0	Max 0	Min 0
Median 0	Median 0	Median 0
Mode 0	Mode 0	Mode 0
StDev 0	StDev 0	StDev 0
Q1 0	Q1 0	Q1 0
Q3 0	Q3 0	Q3 0
UQ 0	UQ 0	UQ 0

Here you can modify to the color you want to track:

The screenshot shows the CanMV IDE interface with the following details:

- Title Bar:** color\_track.py - CanMV IDE
- Menu Bar:** File Edit Tools Window Help
- Toolbar:** Includes icons for file operations, project management, and device connection.
- Code Editor:** Displays the `color_track.py` script. A red box highlights the line: `color_index = 0 # 可以修改这个值来选择检测不同的颜色 You can modify this value to select different colors`.
- Status Bar:** Line: 1, Col: 1, Frame Buffer, Record, Zoom, Disable
- Right Panel:** Shows three histograms for R, G, and B channels under "RGB Color Space". Each histogram has a grid from 0 to 240. Below each histogram are statistical values:

	R	G	B
Mean	0	0	0
Median	0	0	0
Mode	0	0	0
StDev	0	0	0
Min	0	0	0
Max	0	0	0
IQ	0	0	0
UQ	0	0	0
- Bottom Bar:** Search Results, Serial Terminal, Board: Sensor: Firmware Version: Serial Port: Drive: FFS:

If you are not satisfied with the line tracking effect, you can modify the PID values in the bsp\_PID\_motor.c file of the APP project.

```
#define k230_p3  (000.3f)
#define k230_i3  (0.00f)
#define k230_d3  (00.001f)
```

## 5. Experimental Phenomena

After successfully downloading the program, turn on the switch, K230 will enter color learning state. Put the color to be tracked in the center area of the screen. K230 will display the threshold learning progress in the upper left corner. After learning is complete, when a color target with the corresponding threshold appears within the camera range, the car will start following the specified color. Due to the limited camera collection range, the movement cannot be too fast, otherwise it will go out of frame and cannot follow the specified color.

