15. PID control of robot motion

15.1. Purpose of the experiment

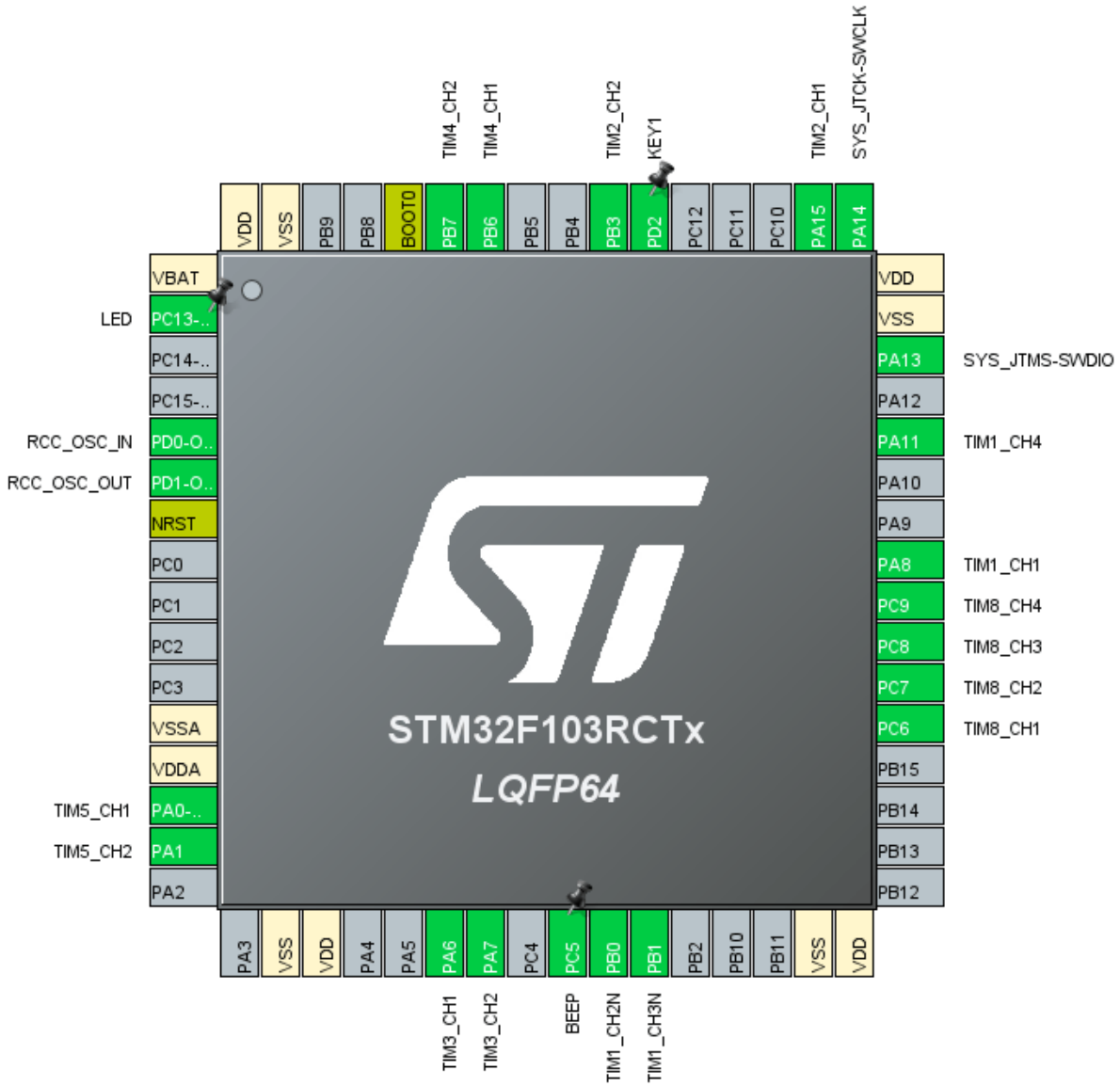
To control the robot motion and control the running speed of the robot by PID algorithm.

Since different models require different drive codes, here we only take the McNamee wheeled cart as an example for demonstration.

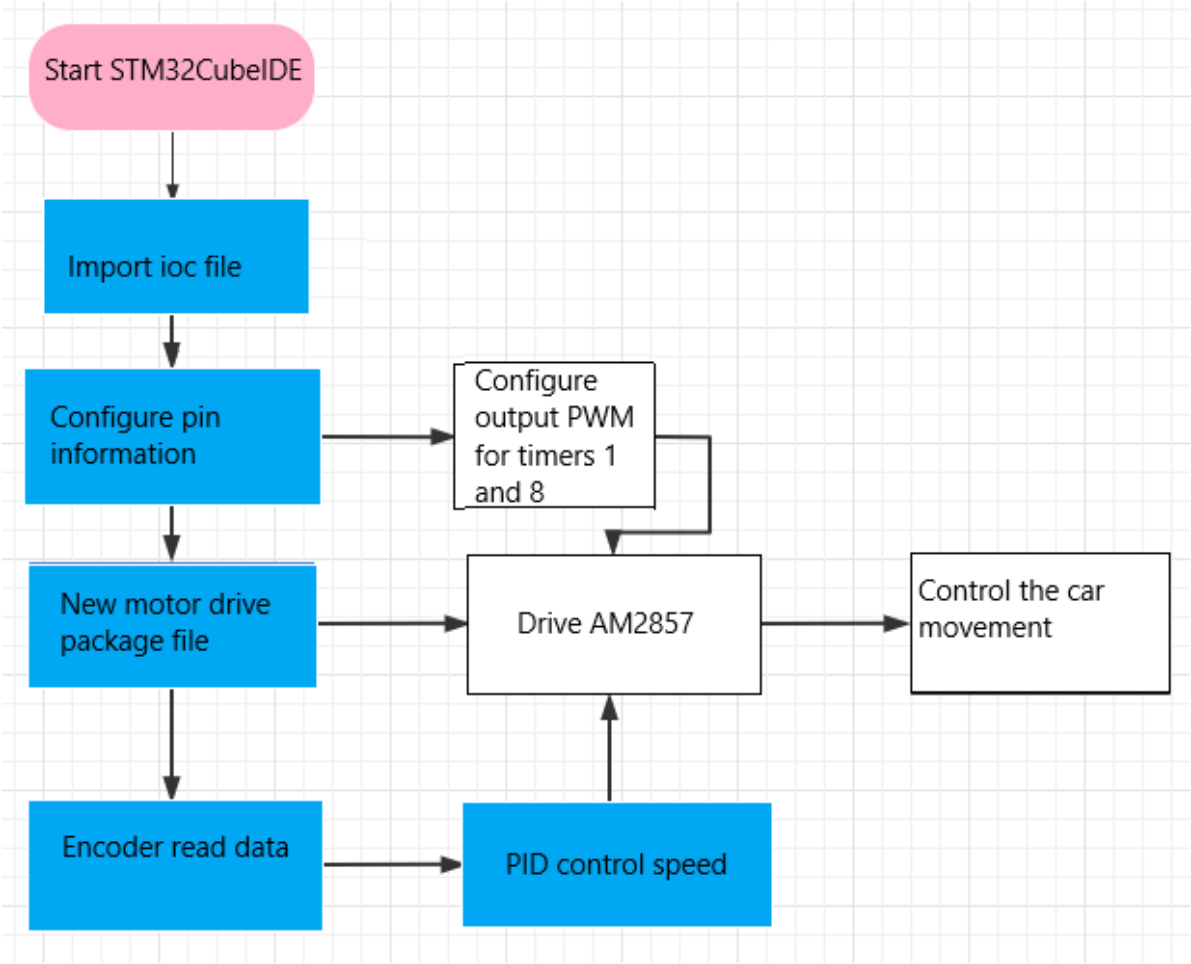
15.2. Configure the pin information

1. Import the ioc file from Encoder's project and name it Car_Motion.

There is no need to add extra content, and finally the chip configuration pins are shown below:



15.3. Experimental flowchart analysis



15.4. Core Code Explanation

1. Create a new bsp_pid.h and bsp_pid.c, and add the following to bsp_pid.h:

```
typedef struct _pid_t
{
    float target_val;                   //目标值
    float pwm_output;                   //PWM输出值
    float Kp,Ki,Kd;                     //定义比例、积分、微分系数
    float err;                          //定义偏差值
    float err_last;                     //定义上一个偏差值

    float err_next;                     //定义下一个偏差值，增量式
    float integral;                     //定义积分值，位置式
} motor_pid_t;

typedef struct _motor_data_t
{
    float speed_mm_s[4];        // Input value, encoder calculation speed 输入值，编码器计算速度
    float speed_pwm[4];         // Output value, PID calculates PWM value 输出值，PID计算出PWM值
    int16_t speed_set[4];       // Speed setting value  速度设置值
} motor_data_t;


void PID_Param_Init(void);
void PID_Calc_Motor(motor_data_t* motor);
void PID_Set_Motor_Target(uint8_t motor_id, float target);
void PID_Clear_Motor(uint8_t motor_id);
void PID_Set_Motor_Parm(uint8_t motor_id, float kp, float ki, float kd);
```

2. Create the following new contents in the bsp_pid.c file:

Initialize the PID parameters:

```
// Example Initialize PID parameters 初始化PID参数
void PID_Param_Init(void)
{
    for (int i = 0; i < MAX_MOTOR; i++)
    {
        pid_motor[i].target_val = 0.0;
        pid_motor[i].pwm_output = 0.0;
        pid_motor[i].err = 0.0;
        pid_motor[i].err_last = 0.0;
        pid_motor[i].err_next = 0.0;
        pid_motor[i].integral = 0.0;

        pid_motor[i].Kp = PID_DEF_KP;
        pid_motor[i].Ki = PID_DEF_KI;
        pid_motor[i].Kd = PID_DEF_KD;
    }
}
```

3. The formula for incremental PID.

```
// Incremental PID calculation formula  增量式PID计算公式
float PID_Incre_Calc(motor_pid_t *pid, float actual_val)
{
    pid->err = pid->target_val - actual_val;
    pid->pwm_output += pid->Kp * (pid->err - pid->err_next)
                    + pid->Ki * pid->err
                    + pid->Kd * (pid->err - 2 * pid->err_next + pid->err_last);
    pid->err_last = pid->err_next;
    pid->err_next = pid->err;
    if (pid->pwm_output > MOTOR_MAX_PULSE)  pid->pwm_output = MOTOR_MAX_PULSE;
    if (pid->pwm_output < -MOTOR_MAX_PULSE) pid->pwm_output = -MOTOR_MAX_PULSE;
    return pid->pwm_output;
}
```

4. Set the target value.

```
// Set PID target speed, unit: mm/s  设置PID目标速度，单位为：mm/s
void PID_Set_Motor_Target(uint8_t motor_id, float target)
{
    if (motor_id > MAX_MOTOR) return;

    if (motor_id == MAX_MOTOR)
    {
        for (int i = 0; i < MAX_MOTOR; i++)
        {
            pid_motor[i].target_val = target;
        }
    }
    else
    {
        pid_motor[motor_id].target_val = target;
    }
}
```

5. PWM output value by PID calculation.

```
// PID Calculates the output value  PID计算输出值
void PID_Calc_Motor(motor_data_t* motor)
{
    for (int i = 0; i < MAX_MOTOR; i++)
    {
        motor->speed_pwm[i] = PID_Incre_Calc(&pid_motor[i], motor->speed_mm_s[i]);
    }
}
```

6. Clear PID parameter data.

```
// Clearing PID Data  清除PID数据
void PID_Clear_Motor(uint8_t motor_id)
{
    if (motor_id > MAX_MOTOR) return;

    if (motor_id == MAX_MOTOR)
    {
        for (int i = 0; i < MAX_MOTOR; i++)
        {
            pid_motor[i].pwm_output = 0.0;
            pid_motor[i].err = 0.0;
            pid_motor[i].err_last = 0.0;
            pid_motor[i].err_next = 0.0;
            pid_motor[i].integral = 0.0;
        }
    }
    else
    {
        pid_motor[motor_id].pwm_output = 0.0;
        pid_motor[motor_id].err = 0.0;
        pid_motor[motor_id].err_last = 0.0;
        pid_motor[motor_id].err_next = 0.0;
        pid_motor[motor_id].integral = 0.0;
    }
}
```

7. New bsp_motion.h and bsp_motion.c files.

```
// 停止模式，STOP_FREE表示自由停止，STOP_BRAKE表示刹车。
typedef enum _stop_mode {
    STOP_FREE = 0,
    STOP_BRAKE
} stop_mode_t;


typedef struct _car_data
{
    int16_t Vx;
    int16_t Vy;
    int16_t Vz;
} car_data_t;


void Motion_Stop(uint8_t brake);
void Motion_Set_Pwm(int16_t Motor_1, int16_t Motor_2, int16_t Motor_3, int16_t Motor_4);
void Motion_Ctrl(int16_t V_x, int16_t V_y, int16_t V_z);

void Motion_Get_Encoder(void);
void Motion_Set_Speed(int16_t speed_m1, int16_t speed_m2, int16_t speed_m3, int16_t speed_m4);

void Motion_Handle(void);

void Motion_Get_Speed(car_data_t* car);
float Motion_Get_Circle_MM(void);
float Motion_Get_APB(void);
```

8. Obtain and calculate the speed of the cart from the encoder.

```
// 从编码器读取当前各轮子速度，单位mm/s
// Read the current speed of each wheel from the encoder in mm/s
void Motion_Get_Speed(car_data_t* car)
{
    Motion_Get_Encoder();

    float circle_mm = Motion_Get_Circle_MM();

    float speed_m1 = (g_Encoder_All_Offset[0]) * 100 * circle_mm / (float)ENCODER_CIRCLE;
    float speed_m2 = (g_Encoder_All_Offset[1]) * 100 * circle_mm / (float)ENCODER_CIRCLE;
    float speed_m3 = (g_Encoder_All_Offset[2]) * 100 * circle_mm / (float)ENCODER_CIRCLE;
    float speed_m4 = (g_Encoder_All_Offset[3]) * 100 * circle_mm / (float)ENCODER_CIRCLE;
    float robot_APB = Motion_Get_APB();

    car->Vx = (speed_m1 + speed_m2 + speed_m3 + speed_m4) / 4;
    car->Vy = -(speed_m1 - speed_m2 - speed_m3 + speed_m4) / 4;
    car->Vz = -(speed_m1 + speed_m2 - speed_m3 - speed_m4) / 4.0f / robot_APB * 1000;

    if (g_start_ctrl)
    {
        motor_data.speed_mm_s[0] = speed_m1;
        motor_data.speed_mm_s[1] = speed_m2;
        motor_data.speed_mm_s[2] = speed_m3;
        motor_data.speed_mm_s[3] = speed_m4;
        PID_Calc_Motor(&motor_data);
    }
}
```

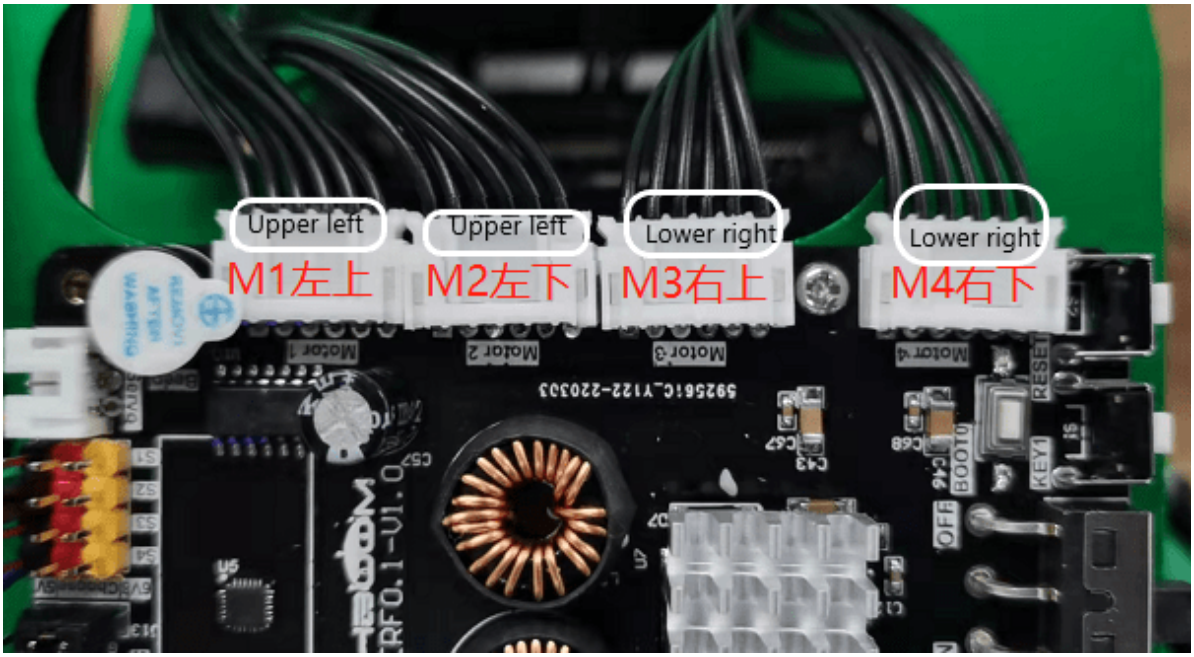
9. Re-update the PWM data of the motor according to the speed value, so as to achieve the function of speed regulation.

```
// 运动控制句柄，每10ms调用一次，主要处理速度相关的数据
// Motion control handle, called every 10ms, mainly processing speed related data
void Motion_Handle(void)
{
    Motion_Get_Speed(&car_data);

    if (g_start_ctrl)
    {
        Motion_Set_Pwm(motor_data.speed_pwm[0], motor_data.speed_pwm[1],
                motor_data.speed_pwm[2], motor_data.speed_pwm[3]);
    }
}
```

15.5 Hardware Connection

The motor connecting wires need to be connected to the corresponding motors as shown in the following figure, otherwise it may cause the problem that the program does not match the phenomenon. Motor 1 corresponds to the motor in the upper left corner of the body, Motor 2 corresponds to the motor in the lower left corner, Motor 3 corresponds to the motor in the upper right corner, and Motor 4 corresponds to the motor in the lower right corner.



Due to the relatively large power of the motor, the expansion board should not use USB 5V power supply directly, but must use DC 12V power supply.

15.6. Experimental effect

Since the motor will spin when it starts, please set up the cart before the experiment, with the motor wheels hanging in the air, to avoid running across the road.

After burning the program, the LED flashes every 200 milliseconds. Press the key KEY1, the cart advances, press KEY1 again the cart stops.