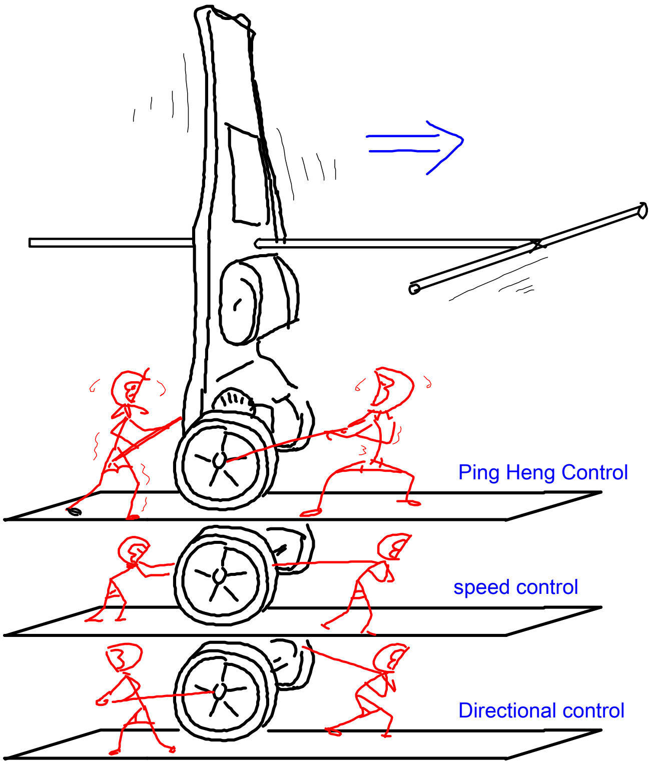
Seventh National College "Freescale Cup" smart car race

Electromagnetic driving reference set upright design

(Version 2.0)


Ping Heng Control
speed control
Directional control

Competition Secretariat

2012-3-1

Eye record

Eye record.. 2
Chart index 3
I. Introduction.. 7
Second, the principle articles 9
2.1 Upright task decomposition 9
2.2 Cars upright control 11
2.3 Cars angle and angular velocity measurements 19
2.3 Cars speed control 26
2.4 Cars directional control 33
2.6 Cars upright total control algorithm of FIG 36
Third, the circuit design articles 37
3.1 Overall circuit block diagram 37
3.2 DSC Introduction and smallest single-chip system 39
3.3 Tilt sensor circuit 42
3.4 Motor drive circuit 44
3.5 Speed sensor circuit 45
3.6 Wire detection circuit 46
3.7 .... angle calculation circuit 50
3.8 Cars full control circuit of FIG 55
Fourth, the mechanical design articles 57
4.1 Cars simplify conversion 57
4.2 Sensor mounting 59
4.3 Precautions.. 63
Fifth, software development articles 64
5.1 Software function and framework 65
5.2 DSC Hardware resources 68
5.3 The main algorithm and its implementation 69
Six Cars commissioning articles 82
6.1 Debugging parameters 82
6.2 Debugging condition 85
6.3 Desktop static parameters debugging 91
6.4 Site debugging dynamic parameters 101
6.5 Programs to improve the overall level of car models and increase 101
VII Conclusion 102
appendix : 103

List of Figures

Chapter One

Map 1-1 Cars run mode set upright electromagnetic 7

Map 1-2 Reference design content 8

Map 1-3 Cars produced roadmap 9

Chapter two

Map twenty one Cars break down .... control tasks 10

Map twenty two Cars inclination will cause changes in vehicle speed 10

Map twenty three .... cooperate between three control 11

Map twenty four Feedback control to maintain an upright stick 12

Map 2-5 Cars held upright by the motion of the wheel 12

Map 2-6 Cars simplified inverted pendulum 13

Map 2-7 Ordinary pendulum force analysis 13

Map 2-8 Pendulum motion under different damping force 14

Map 2-9 Cars in the frame of reference on the wheel Mechanical Analysis 14

Map 2-10 Cars two control coefficients action 16

Map 2-11 Cars equations of motion 16

Map 2-12 Was added after the system block diagram of differential feedback ratio 17

Map 2-13 Motor speed at different voltage curves 18

Map 2-14 Acceleration sensor principle 19

Map 2- 15 MMA7260 Axis acceleration sensor 20

Map 2-16 Cars exercise-induced acceleration signal fluctuations .... twenty one

Map 2-17 Actual measurement MMA7260Z Axis signal .... twenty one

Map 2-18 Cars exercise-induced acceleration Z Axis signal changes .... twenty two

Map 2-19 The angular velocity sensor and the reference amplifier circuit .... twenty two

Map 2-20 Angle obtained by integrating the angular velocity .... twenty three

Map 2-21 Angular velocity integration drift .... twenty three

Map 2-22 It is corrected by a gravitational acceleration gyro drift angle .... twenty four

Map 2-23 Cars double angular acceleration sensor obtained 25

Map 2-24 Angle control block diagram 25

Map 2-25 Motor speed detection 26

Map 2-26 Cars inclination given 27

Map 2-27 Cars camber control the speed of the positive feedback 28

Map 2-28 Cars tilt control analysis 28

Map 2-29 Cars simplified model velocity control 29

Map 2-30 Increase the system after the differential control 30

Map 2-31 Improved differential control 30

Map 2-32 Cars angle and speed control block diagram 31

Map 2-33 Improved angular velocity control scheme 32

Map 2-34 The improved speed and angle control scheme 32
Map 2-35 Wire detection center of the road way 33
Map 2-36 By the motor drive voltage differential control car models direction 34
Map 2-37 Cars rotational speed detecting gyro 34
Map 2-38 Impact angle inductor induced electromotive force 35
Map 2-39 Cars directional control algorithm 35
Map 2-40 Cars general block diagram of the motion control 36

third chapter

Map 3-1 Cars overall block diagram of the control circuit upstanding 39
Map 3- 2 56F8013 .... diagram of internal resources 40
Map 3- 3 F8013 Minimum system circuit 41
Map 3- 4 F8013 Minimum physical system circuit 42
Map 3-5 A gyroscope, an acceleration sensor circuit 43
Map 3-6 Cars tilt sensor circuit of FIG physical 43
Map 3-7 Dual motor driving circuit 44
Map 3-8 Unipolar PWM Bipolar PWM 45
Map 3-9 Two 33886 A motor driving circuit 45
Map 3-10 Speed sensor circuit 46
Map 3-11 Amplifying electromagnetic signal detection circuit based on transistor 47
Map 3-12 Amplifying transistor-based electromagnetic detector circuit physical map 48
Map 3-13 use RR Amplifier amplifies the electromagnetic signal detecting 49
Map 3- 14 LMV358 Amplifying the detection output waveform 49
Map 3-15 based on LMV358 FIG physical amplifying detector circuit 50
Map 3-16 Double angular velocity acceleration measurement circuit 51
Map 3-17 Dual accelerometer measuring angular waveform diagram 51
Map 3-18 An angular velocity simplified circuit 52
Map 3-19 Found Cars angular velocity signal waveform 52
Map 3-20 An angle signal processing circuit 53
Map 3-21 An angular velocity ratio of the output waveform under different circumstances 53
Map 3-22 Angle calculation link transfer function 54
Map 3-23 An operational amplifier to achieve angle calculation 54
Map 3-24 different P1 Output waveform corresponding to the resistance 55
Map 3-25 Angle and the angular velocity simplified processing circuit 55
Map 3-26 Cars full control circuit of FIG 56

Chapter Four

Map 4-1 complete C Type chassis .... Cars 57
Map 4-2 Simplified C Type chassis .... Cars 57
Map 4-3 And hot melt adhesive used to fix the motor car models chassis bracket 58
Map 4-4 After removing the rear wheel chassis Cars 58
Map 4-5 .... motor lead adapter plate 59
Map 4-6 Composite glue fixed optical encoder disk 59
Map 4-7 Good fixing photoelectric encoder and the photodetector tube 60
Map 4-8 Electromagnetic sensor holder 61

Map 4-9 Cars full assembly of FIG 64

chapter Five

Map 5-1 The main program framework 65
Map 5-2 Interrupt service routine 66
Map 5-3 Task interruption time waveform 67
Map 5-4 A block diagram of the software algorithm associated with the control function 70
Map 5-5 Call control functions and parameter passing relationship 71
Map 5-6 Program variable naming 72
Map 5-7 Motor dead-time compensation 78

Chapter Six

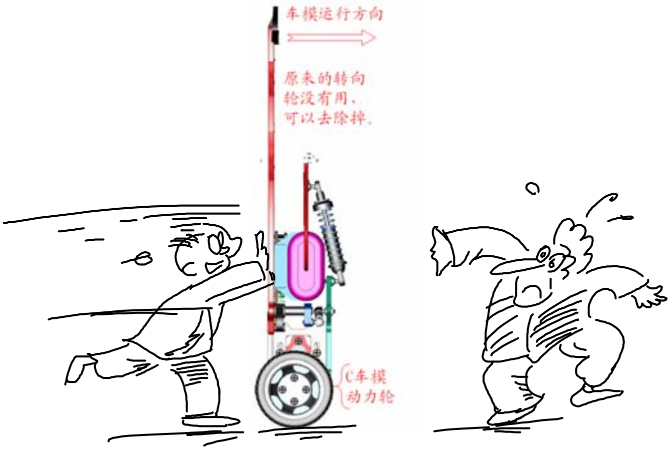
Map 6-1 Cars debugging complex and critical parameters 82
Map 6-2 We need to adjust the parameters and associated units 84
Map 6-3 Cars sport coordinates defined 85
Map 6-4 Check the power 86
Map 6-5 Serial Communication 86
Map 6- 6 PWM Signal output 87
Map 6-7 Recording the motor photoelectric encoder signal 87
Map 6-8 A gyroscope, an acceleration sensor AD Acquire the Signal... 88
Map 6-9 Cars static parameters to adjust the desktop 88
Map 6-10 Cars dynamic parameter testing site 89
Map 6-11 Monitoring software interface 89
Map 6-12 Wireless remote control switch 90
Map 6-13 The wireless communication module parameter monitoring 90
Map 6- 14 F8013 internal FLASH Applications division 91
Map 6-15 Setting sensor parameters required 91
Map 6-16 Cars held vertically stationary 92
Map 6-17 Extreme measuring acceleration sensor 92
Map 6-18 Measuring the scale factor of the gyro sensor, an angle compensation loop disconnect 93
Map 6-19 Several different scale factor of the gyro angle output 94
Map 6-20 Cars control parameters 95
Map 6-21 Angle parameter adjustment procedure 96
Map 6-22 Speed parameter adjustment process 97
Map 6-23 Direction parameter adjustment procedure 98
Map 6-24 .... angle compensation time constant adjusting 99
Map 6- 25 Z Additional axis signal analysis 100
Map 6-26 Deadband constant adjustment 100

appendix

Map 7-1 Reference design for video capture 103
Map 7-2 Parameter Tuning and Debugging Guide 104
Map 7-3 Software control algorithm full picture 106
Map 7-4 Referring to Scheme circuit of FIG full 107

The first chapter, Introduction

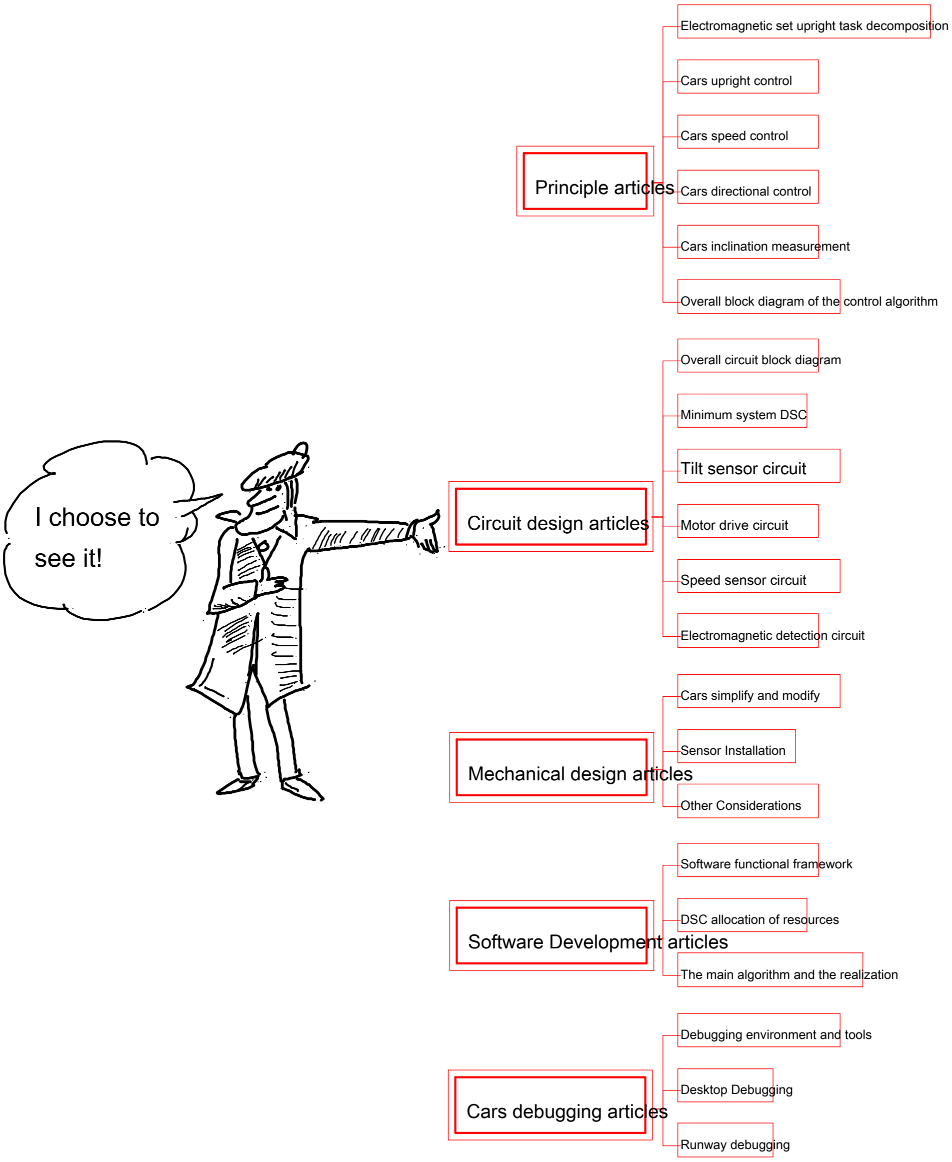
In order to improve the country car race smart students innovative and fun, inspire college students to participate in the competition Hing Fun, improve the abilities of students, innovation and the ability to accept the challenge, smart car race committee will group than electromagnetic Cars predetermined game is upright, as shown in 1-1 Fig. Cars of walking two other groups remain unchanged.


车模运行方向
原来的转向轮没有用，可以去除掉。
C车模动力轮

Map 1-1 Electromagnetic operation mode set upright Cars

Cars walk upright game is modeled on two traveling mode requires self-Ping Heng electric vehicle, so car models with two rear wheels Driving of walk upright. In recent years, two self-Ping Heng electric vehicle running its flexible, convenient, energy-saving features to give A lot of development. There are many domestic and international research in this area, but also the appropriate product. In the electromagnetic's race, using The original C Type dual rear-wheel drive car models characteristics, to achieve self-Ping Heng two walking. Compared with the traditional four-wheeled vehicle trave Modeling contest mode, scale models to walk upright in hardware design, control software development and on-site commissioning and put forward higher Requirements. In order to be able to help participating students made car models as soon as possible participate in the competition, the competition secretariat has p Li reference design walking. Team members can be on this basis, further improve the hardware and software solutions to improve The level of competition.

To accommodate beginners, the program describes the process, the derivation formula to minimize the use of scientific language popular media Shao control theory and method, given C The core part of the process of making the type of car models. The main content of the paper is organized as shown 1-2 Fig.

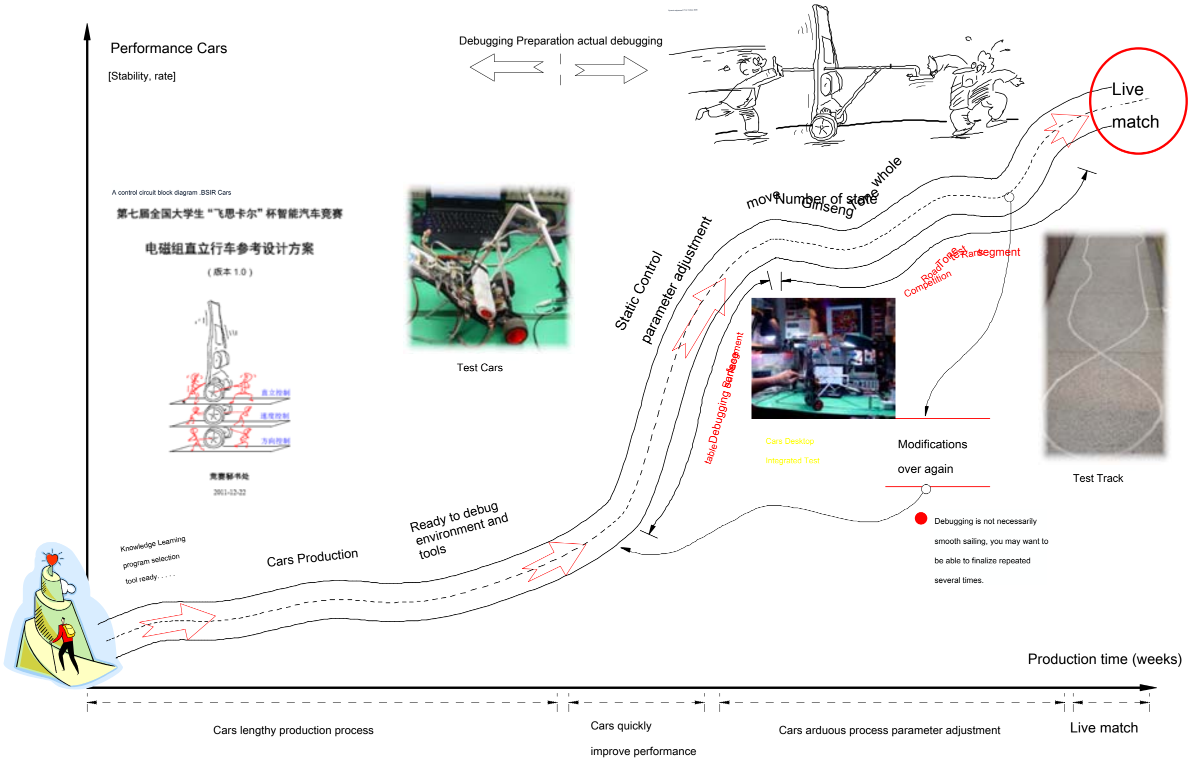

I choose to see it!
Principle articles
Electromagnetic set upright task decomposition
Cars upright control
Cars speed control
Cars directional control
Cars inclination measurement
Overall block diagram of the control algorithm
Circuit design articles
Overall circuit block diagram
Minimum system DSC
Tilt sensor circuit
Motor drive circuit
Speed sensor circuit
Electromagnetic detection circuit
Mechanical design articles
Cars simplify and modify
Sensor Installation
Other Considerations
Software Development articles
Software functional framework
DSC allocation of resources
The main algorithm and the realization
Cars debugging articles
Debugging environment and tools
Desktop Debugging
Runway debugging

Map 1-2 Reference design content

After the actual reference design verification testing, please download the test run video on the competition website.

Given in the Appendix to the competition website address for downloading data and related information can be downloaded.

Cars produced roughly divided into program determined, making Cars, Cars commissioning three stages, as shown in 1-3 Fig. due to Numerous electromagnetic upright car models involved algorithm parameters, so much the commissioning phase proportion. Cars not only for debugging Cars to improve performance is very important, but also the understanding of the principle of control car models, improve the ability to use the knowledge, training sit Important stage of practical skills.


Performance Cars
[Stability, rate]
Debugging Preparation actual debugging
A control circuit block diagram .BSIR Cars
第七届全国大学生“飞思卡尔”杯智能汽车竞赛
电磁组直立行车参考设计方案
（版本 1.0）
直立控制
速度控制
方向控制
竞赛秘书处
2011-12-22
Test Cars
Static Control
parameter adjustment
Number of state
whole
Debugging
Cars Desktop
Integrated Test
Modifications
over again
Competition
segment
Test Track
Live
match
Debugging is not necessarily smooth sailing, you may want to be able to finalize repeated several times.
Knowledge Learning
program selection
tool ready.....
Cars Production
Ready to debug environment and tools
Production time (weeks)
Cars lengthy production process
Cars quickly
improve performance
Cars arduous process parameter adjustment
Live match

Map 1-3 Cars produced roadmap

To help students perform debugging car models, Appendix 4 Cars are given guidelines - and the related video site. Cars can get an intuitive feel as soon as possible by adjusting the parameters of such information.

Chapter II, Part principle

2.1 Upright task decomposition

Cars match the requirements set electromagnetic performed in an upright state along a track to match two wheels, as compared to four The ground state, the task is more complex control car models. In order to facilitate the solution to the problem can be found, first of all complex Problem into simple questions for discussion.

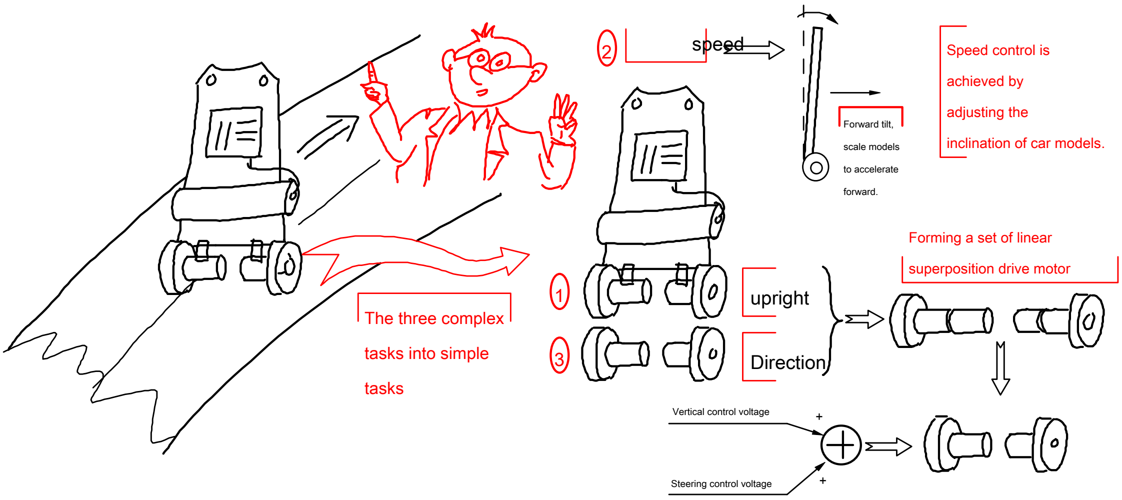
The rules of the game required to maintain car models may be able to design many upright of the program, the program is assumed that the reference dimens Cars held upright, the power running car models are derived from the two wheels. The rear wheel is driven by two DC motors. Therefore, from a control standpoint, as a control target car models, which is a control input of the rotational speeds of the two electrodes. Cars motion control tasks may be decomposed into the following three basic control tasks as twenty one Below:

(1) Ping Heng control Cars: Cars upright holding reverse motion to the Ping Heng state by controlling two motors;

(2) Speed control car models: Cars speed control is achieved by adjusting the angle of the car models, in fact, finally

To control the evolution of the wheel speed is achieved by controlling the motor speed.

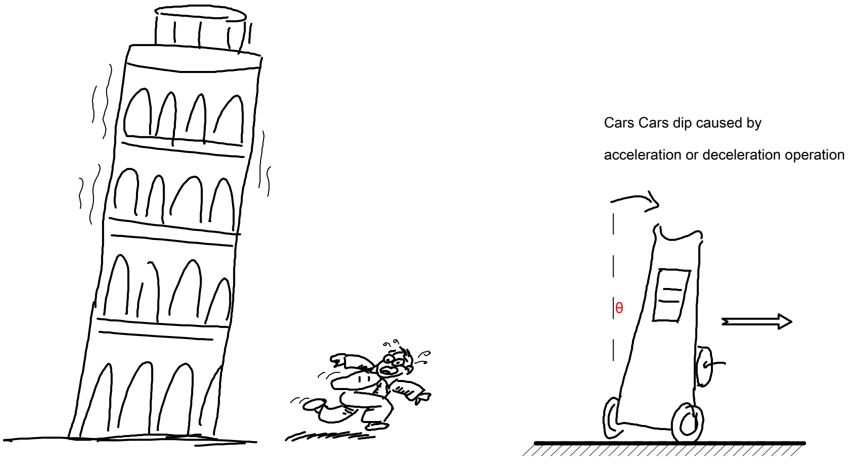
(3) Direction control Cars: Cars steering control is achieved by controlling the rotational speed differential between the two motors.


②
speed
Forward tilt, scale models to accelerate forward.
Speed control is achieved by adjusting the inclination of car models.
Forming a set of linear superposition drive motor
The three complex tasks into simple tasks
①
③
upright
Direction
Vertical control voltage
Steering control voltage
+
+

Map twenty one Cars control task decomposition

Cars vertical direction and two control tasks are directly controlled by the rear-wheel drive motor car models completed. Assume car Mode virtual machine can be broken down into two different functions of the drive motor, which are connected coaxially, respectively, to control the linear Cars Li Ping Heng, the left and right direction. In actual control, the control signal is superimposed and controls vertical direction with car models plus Upload motor, as long as the motor in the linear state to complete the above two tasks simultaneously.

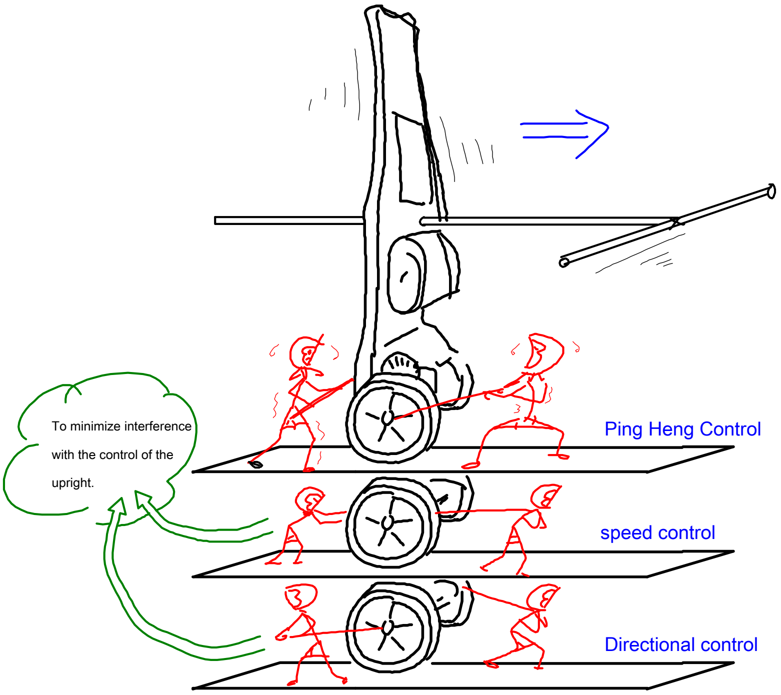
Cars speed by adjusting the inclination to complete car models. Different car models inclination causes acceleration and deceleration of the car models, So as to control the speed of.


Cars Cars dip caused by acceleration or deceleration operation
θ

Map twenty two Cars inclination will cause changes in vehicle speed

After the task decomposition three independently controlled. As the final are on the same electrical control object (car models Machine) is controlled, there is a coupling between them. For analytical purposes, it is assumed in the analysis of one of the other Control objects have stabilized. For example, in the speed control, it is necessary to control car models have been able to stay upright; square When the control requires speed car models and can maintain a constant Ping Heng; Similarly, when the Ping Heng control car models, need Speed and direction control has reached a plateau. These three tasks remain Cars balance is the key. Since the car models as well as by Effect of the three control, from the point of view of Ping Heng control car models, it becomes the other two control interference. therefore Controlling the speed of the car models, the direction should be kept smooth to reduce interference to the balance control. Speed adjustment For example, the need to change the set value of the inclination Cars Cars Ping Heng control, thereby changing the inclination angle of the actual car models. for The Ping Heng control to avoid the impact of car models, car models change this inclination need be very slow. This will be after Face velocity control is discussed in detail.

FIG mating between the three twenty three Fig.


To minimize interference with the control of the upright.
Ping Heng Control
speed control
Directional control

Map twenty three Mutual cooperation between the three control

The following three implementations are discussed control task decomposition car models.

2.2 Cars Ping Heng control

Cars Ping Heng of control and intuitive experience from daily life experience. The average person through simple exercises you can

Let a straight stick upright on the fingertips. This requires two conditions: one is the palm holding the stick may be moved;

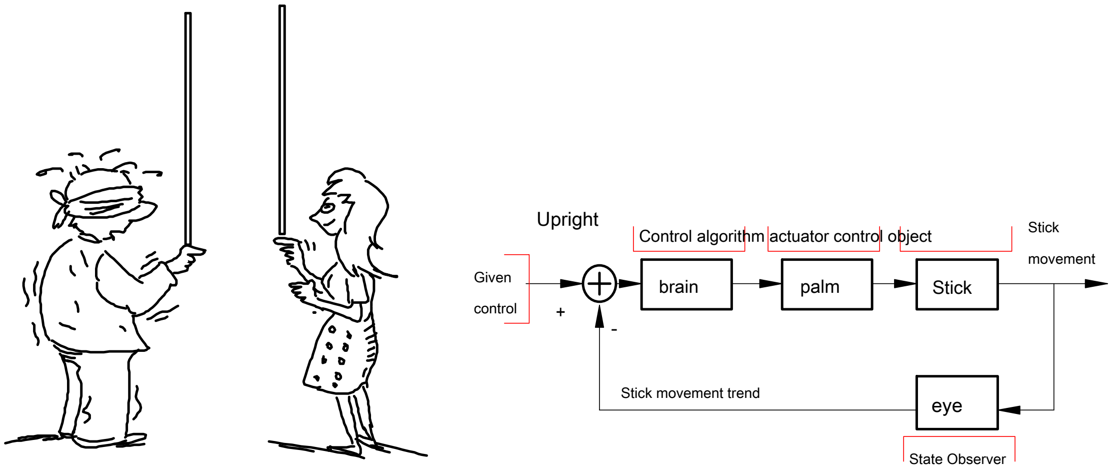
Another can observe the eye inclination angle and the inclination tendency of the stick (angular velocity). Offset by moving palm tree

And the inclination angle of the rod tendency to stick in the upright. These two conditions are indispensable, in fact, in control

The negative feedback mechanism, see Fig. twenty four .

No genius a blindfolded acrobat can make stick upright on his fingertips in the world, because

For the eyes observed no negative feedback.

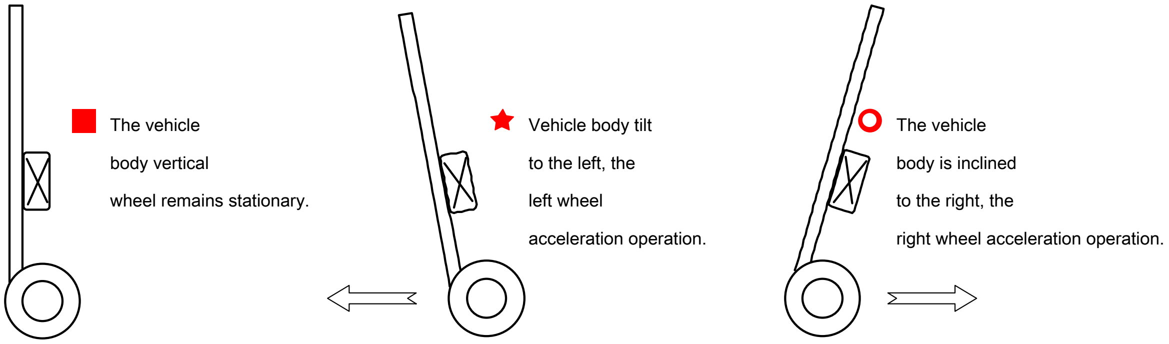

Upright
Control algorithm
actuator control
object
Stick
movement
Given
control
+
-
brain
palm
Stick
eye
Stick movement trend
State Observer

Map twenty four Feedback control to maintain an upright stick

Cars Ping Heng control is achieved through negative feedback, maintains the upright stick above comparison is relatively simple. because

Cars for the two wheels touch the ground, the body will only tilted on wheels rolling direction. Controlling rotation of the wheel, offset

In one dimension sloping trend can keep the body balanced. Figure 2-5 Fig.


■ The vehicle
body vertical
wheel remains stationary.
★ Vehicle body tilt
to the left, the
left wheel
acceleration operation.
○ The vehicle
body is inclined
to the right, the
right wheel acceleration operation.

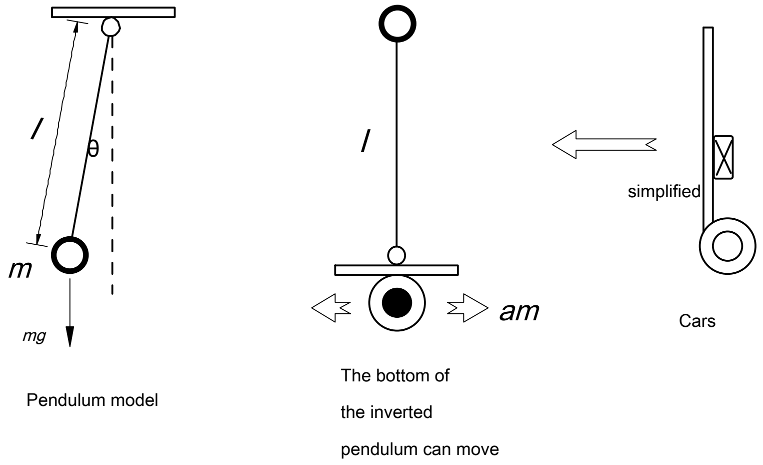
Map 2-5 Cars by motion of the wheel to maintain Ping Heng

So how the wheels run, finally be able to maintain the body Ping Heng and stability? To answer this question, you can

Cars establish mathematical models of kinematics and dynamics, design feedback control to ensure Ping Heng of the car models. In order to make the students

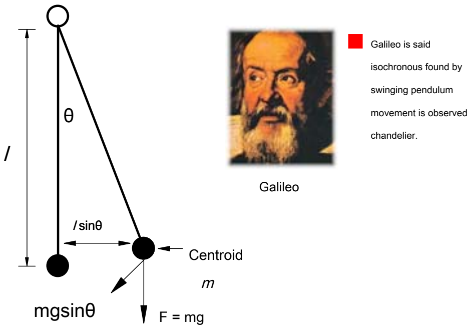
We were able to more clearly understand the physical processes of them. Cars now be described to maintain balance control by comparing the pendulum model System of law.

Gravitational field with fine, suspended pendulum model was simplified focus will form idealized. Cars can be of upright To be left in place as an inverted pendulum on the mobile platform. Figure 2-6 Fig.


l
θ
m
mg
Pendulum model
l
am
The bottom of the inverted pendulum can move
simplified
Cars

Map 2-6 Cars simplified inverted pendulum

FIG ordinary pendulum Mechanical Analysis 2-7 Fig.


θ
l
l sinθ
Centroid
m
mgsinθ
F = mg
Galileo
Galileo is said isochronous found by swinging pendulum movement is observed chandelier.

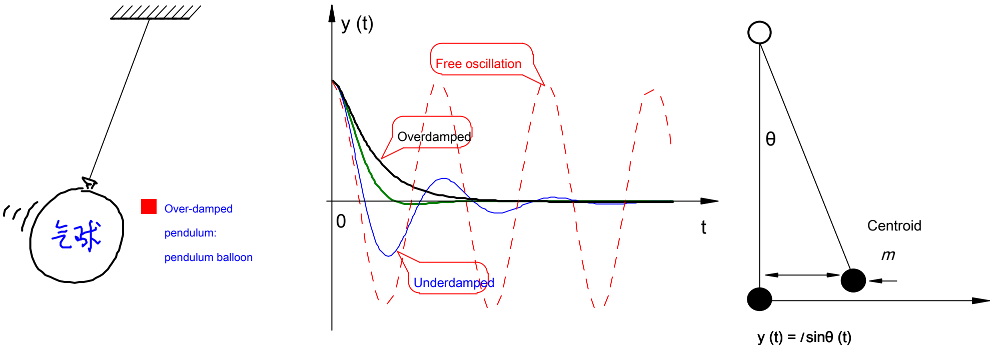
Map 2-7 Ordinary pendulum Stress Analysis

When the object away from the vertical equilibrium position will be subject to the action of gravity and force of the suspension wires, driving reply weight Ping Heng position. This force is referred to as a restoring force, the size of

$$F = -mg \sin\theta \approx - mg\theta$$

In the offset angle is small, and the return force is proportional to the angular deviation between the magnitude in the opposite direction. here Restoring force, the pendulum will conduct periodic motion. Pendulum motion in the air, due to the damping force of the air, Pendulum eventually stops in a vertical Ping Heng position. Pendulum damping force proportional to the velocity of the air, in the opposite direction. Block Larger damping force, the pendulum will be stabilized in the vertical position as soon as possible. Map 2-8 Exhibit different damping, pendulum

Motion profile.



Map 2-8 Pendulum motion under different damping force

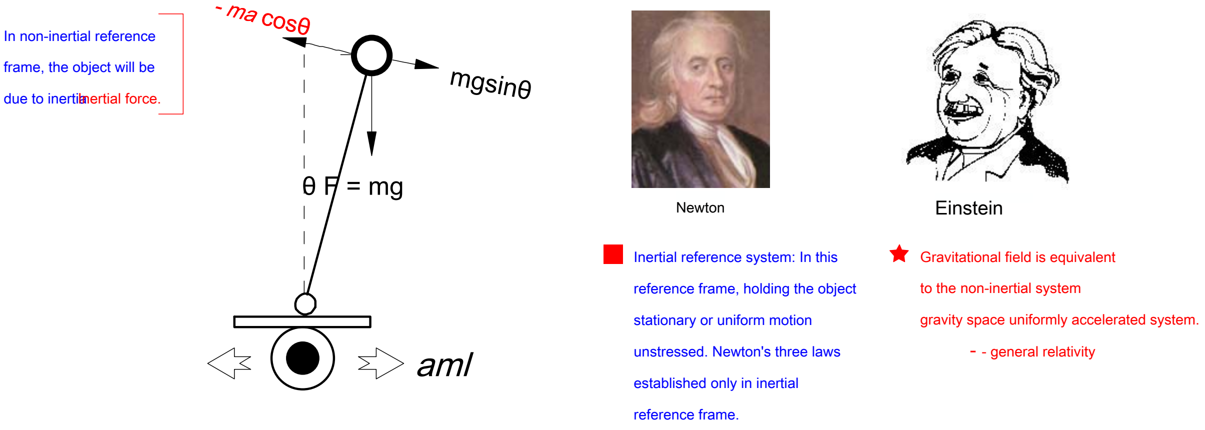
Summary pendulum can be stabilized in the vertical position of the two conditions:

(1) By the displacement (angle) opposite to the restoring force;

(2) Opposite to the damping force by velocity (angular velocity).

If no damping forces, the pendulum swings around a vertical position. Pendulum damping force will make the final stop in Vertical position. The damping force is too small (less damping) makes the pendulum oscillates back and forth in the attachment position of Ping Heng. The d Large (overdamped) will be such that the Ping Heng position of the pendulum reaches longer time. Thus there is a critical damping coefficient, the At the time was the shortest pendulum stable equilibrium position.

Why pendulum in a vertical position, when subjected to external disturbances, we can not maintain stability? Minute Analysis of the inverted pendulum force, as 2-9 Fig.



In non-inertial reference frame, the object will be due to inertial force.

🟥 Inertial reference system: In this reference frame, holding the object stationary or uniform motion unstressed. Newton's three laws established only in inertial reference frame.

★ Gravitational field is equivalent to the non-inertial system gravity space uniformly accelerated system.
- - general relativity

Map 2-9 Cars in the frame of reference on the wheel Mechanical Analysis

The reason is not inverted pendulum like a pendulum in the vertical position as can be stabilized, because of its deviation from Ping Heng position When restoring force and displacement suffered the same direction, rather than vice versa! Thus, the inverted pendulum will deviate from the vertical acceleration

Position until the fall.

How can control such as an inverted pendulum pendulum as stable in the vertical position it? To achieve this goal, Only two ways: one is to change the direction of gravity; the other is the additional force, so that restoring force and displacement In the opposite direction the job. The second method is clearly only be able to do.

The bottom of the inverted pendulum control wheels, so that it An accelerated. Such carts standing (non-inertial reference frame, the wheel for The origin of coordinates) Analysis pendulum force, it would be an additional inertial force, the force and direction of the wheel acceleration phase Instead, proportional to the size. Such inverted pendulum restoring force suffered as:

$$F = mg\sin\theta - ma\cos\theta \approx mg\theta - mk_1\theta \qquad (2\text{-}1)$$

Where, due to the θ Small, so it was linearized. Negative feedback control is assumed that the wheel acceleration a and angle θ Positively Ratio, ratio. If the ratio $k_1 > g$, (the acceleration of gravity g) so restoring force to facilitate the displacement direction relative to a direction Inverted.

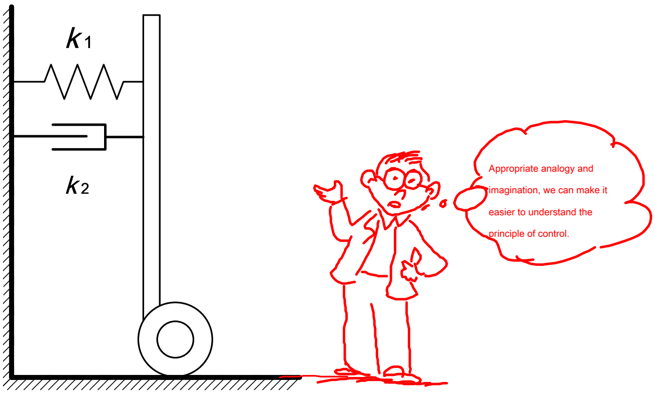
Further, in order that the inverted pendulum can be stabilized as quickly as possible in a vertical position, but also necessary to increase the damping force. a There is an air damping force and frictional force, the damping force is relatively small. Therefore it requires an additional control damping force. increase Adding a damping force proportional to the speed and the angle, in the opposite direction. Therefore formula (2-1) May become

$$F = mg\theta - mk_1\theta - mk_2\theta' \qquad (2\text{-}2)$$

According to the above control method, the inverted pendulum model becomes pendulum model can be stabilized in a vertical position. therefore, Control algorithm may have control of the wheel acceleration

$$a = k_1\theta + k_2\theta' \qquad (2\text{-}3)$$

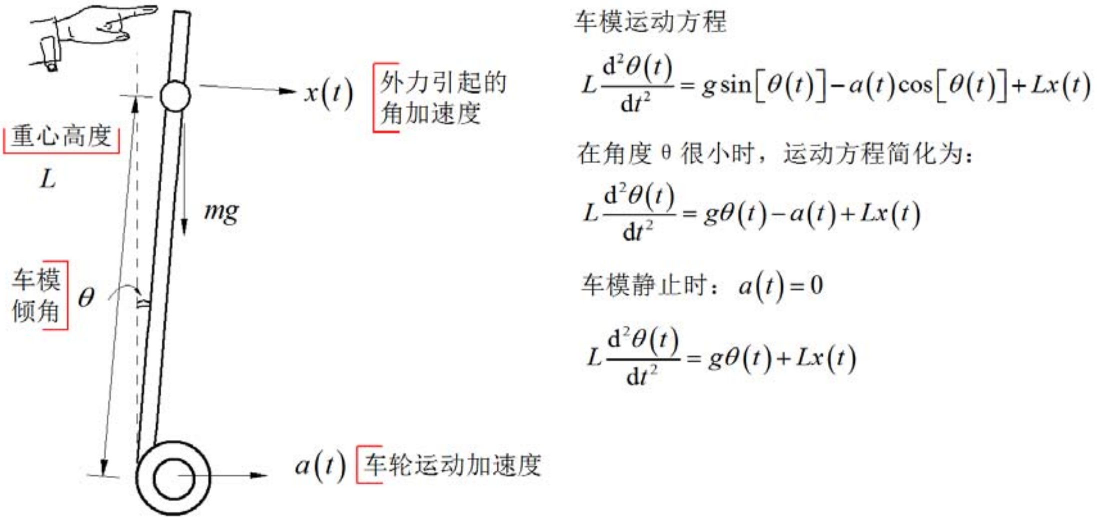
In the formula, θ Cars of inclination; θ' Angular velocity; k_1 , k_2 Are scale factor; after adding two wheel acceleration as The amount of control. Just make sure $k_1 > g$, $k_2 > 0$ Under conditions, such as car models as the pendulum is maintained in an upright state. Wherein there are two control parameters k_1, k_2, k_1 determine whether the car model can be stabilized to a vertical Ping Heng position, it must be greater than the weight Acceleration force; k_2 determines the vertical position back to the car model damping, the damping coefficient may be selected to ensure proper Cars Stable in the vertical position as soon as possible. The role of these two coefficients Map 2-10 Fig.


k_1
k_2
Appropriate analogy and imagination, we can make it easier to understand the principle of control.

Map 2-10 Cars two control coefficients action

In the above simple analysis, obtained by analogy with the inverted pendulum control scheme upstanding car models. Below the inverted car models Simple mathematical modeling, the ratio of the speed differential and the establishment of negative feedback control, control theory to discuss the basic car models Maintaining stable conditions by closed loop control.

Simplifying assumptions inverted car models with a height of L , The quality of m The simple pendulum, it can be placed around the moving The wheel. Suppose disturbance caused by the angular acceleration produced $x(t)$. Model cars to be forced direction perpendicular site Analysis can be obtained with the inclination motion of the wheel acceleration $a(t)$ car models and acceleration disturbance $x(t)$ movement between the parties Cheng. Figure 2-11 Fig.


$x(t)$
外力引起的角加速度
重心高度
L
mg
车模倾角
θ
$a(t)$
车轮运动加速度
车模运动方程
$L\frac{d^2\theta(t)}{dt^2}=g\sin[\theta(t)]-a(t)\cos[\theta(t)]+Lx(t)$
在角度θ很小时，运动方程简化为：
$L\frac{d^2\theta(t)}{dt^2}=g\theta(t)-a(t)+Lx(t)$
车模静止时：$a(t)=0$
$L\frac{d^2\theta(t)}{dt^2}=g\theta(t)+Lx(t)$

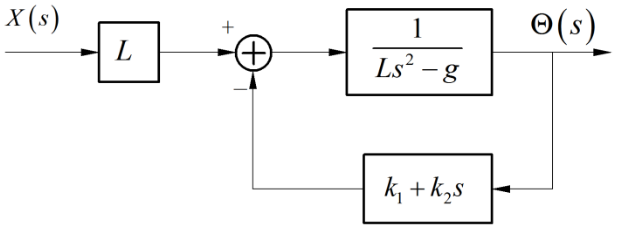
Map 2-11 Cars equations of motion

When the corresponding stationary car models, the transfer function of the system inputs and outputs:

$$H(s)=\frac{\Theta(s)}{X(s)}=\frac{1}{s^2-\frac{g}{L}}$$

In this case the system has two poles $p = \pm\sqrt{\frac{g}{L}}$. A pole at s flat

Right half-plane, car models and therefore unstable. Cars proportionality, after the differential feedback system as shown below:



Map 2-12 System block diagram of the proportional and differential feedback is added

The system transfer function is: $H(s) = \frac{\Theta(s)}{X(s)} = \frac{1}{s^2 + \frac{k_2}{L}s + \frac{k_1 - g}{L}}$. At this time, two system poles in:

$s_p = \frac{-k_{\text{two}} \pm \sqrt{k_2^{\text{twenty}} - 4L(k_1 - g)}}{L}$. The system requires two stable poles are located s The left half plane. To meet

This requires $k_1 > g, k_2 > 0$. It can be concluded, when $k_1 > g, k_2 > 0$ When upright car models can be stabilized.

This and the previous analysis is consistent with the conclusions reached by.

Feedback control the angle, and the angle is proportional to the control amount called proportional control; control proportional to the angular velocity

Differential control system referred to the amount (the angular velocity is a differential angle). The above k_1, k_2 therefore proportional and derivative coefficients are referred

System parameters. Wherein the differential parameter corresponds to the damping force, the shock can be effectively suppressed car models. By differential inhibiti

The idea is also applicable in the latter the speed and direction control.

Cars are summarized upright stable control conditions were as follows:

(1) To accurately measure the inclination Cars θ The size and the angular velocity θ' the size of;

(2) May control the acceleration of the wheel.

The first condition, that is, how to measure tilt angle and the speed of the car models θ, θ', See the next section "Cars angle measurement."

How to determine the control parameter k_1, k_2 adjustment parameters see "Debugging chapter" in the. The following first discuss the implementation of the second conditio

I.e., acceleration of the wheel control.

Cars speed and acceleration is achieved by controlling the speed of the wheel, two rear wheels by the motor car models by

Driven by a reduction gear box, motion control can be achieved by controlling the motor speed of the wheel.

Movement of the motor control serves three purposes:

(1) Achieved by a motor acceleration control Cars stable Ping Heng. Wherein the control law is given by one;

(2) By the motor speed control, constant speed running and stationary car models. Although there are no rules to this game

Cars seeking constant speed, there is no requirement to maintain a stationary state after Cars crossed the line and before the game. By speed Control, stability can be improved car models. In the future the game, if the rule increases the static requirements, or need to pass When over-bridges and other obstacles, speed control will play a role.

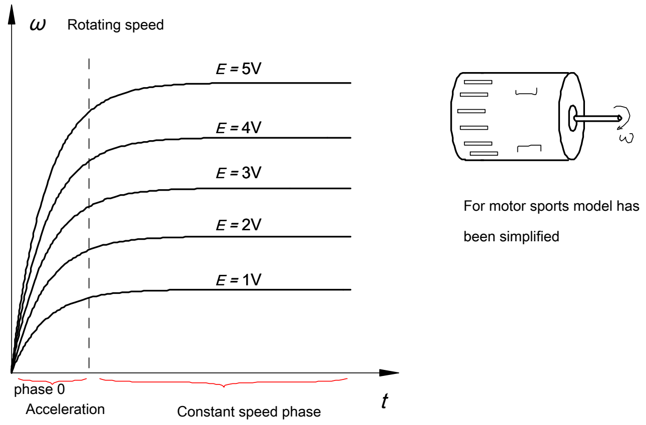
(3) By a motor differential speed control, direction control can be realized car models. Differential control method see below "car Direction control mode. "

Motor motion control by changing the magnitude of the voltage applied to the driving achieved. For electromagnetic mode of the motor Type, and the dynamics model kinetic model of car models and simplify the analysis, the motor speed may be applied thereon The relationship between the voltage reduced to the following first-order inertia model. Applying a step voltage to the motor, $Eu(t)$

Motor speed variation curve

$$\omega(t) = Ek_m\left(1 - e^{-\frac{t}{T_1}}\right)u(t) \qquad (2\text{-}4)$$

In the formula, E Voltage; a $u(t)$ step function; is the time constant T_1 of inertia; motor speed is constant k_m number. Corresponding to different voltages, the motor speed curve in FIG. 2-13 Fig.



Map 2-13 Motor speed variation at different line voltages

From Fig. 2-13 As can be seen, the motor is significant in two stages: The first stage is the acceleration stage; a second Stage for the constant speed phase. Wherein the acceleration stage, driven by the motor car models rear wheel acceleration, acceleration approximation And is proportional to the voltage applied to the motor, the length of time depends on the time constant T_1 of the acceleration phase. This constant by a motor Moment of inertia, the reduction ratio of the reduction gear box, the moment of inertia of the car models, typically in more than ten to hundreds of milliseconds. In con Speed stage, motor driven rear wheel Cars constant speed, the speed is proportional to the voltage applied to the motor.

Cars angle adjustment control cycle is very short, typically a few milliseconds of time, much less than the time constant T_1. At this time, electric

Machine runs substantially during the acceleration phase. by(2-3) Acceleration control amount calculation a obtained is multiplied by a scale factor,

Is the control voltage applied to the motor, so that it can control the car models is upright.

Acceleration of the motor is actually determined by the electromagnetic torque produced by the motor current. Taking into account the motor current

The control requires a higher speed, so in this motor control scheme can be simplified.

2.3 Cars angle and angular velocity measurements

Introduced in a control algorithm for controlling the upright car models, the car controlled by measuring the inclination angle and the speed of the car models

Wheel acceleration mode to eliminate the inclination of the car models. Thus, scale models and measuring the inclination angle becomes a speed control car models

The key upright. Cars and inclination angle measurement speed can be mounted on car models by an acceleration sensor and a gyro

achieve.

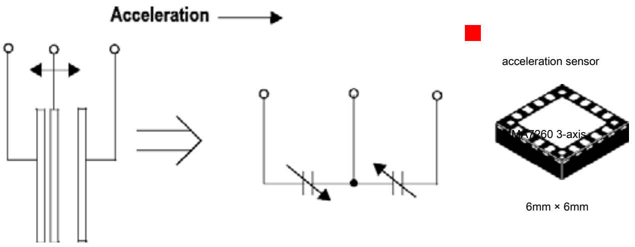
(1)Accelerometer

The acceleration sensor may measure gravitational acceleration due to the Earth movement of the object or produced. Contest rules governing

Freescale given the acceleration sensor generating acceleration sensor if the car models must be used. The series pass

A semiconductor sensor using surface micromachining and integrated circuit technology, small sensor size and light weight. Its basic

Principle is shown 2-14 Fig.



Map 2-14 Acceleration sensor principle

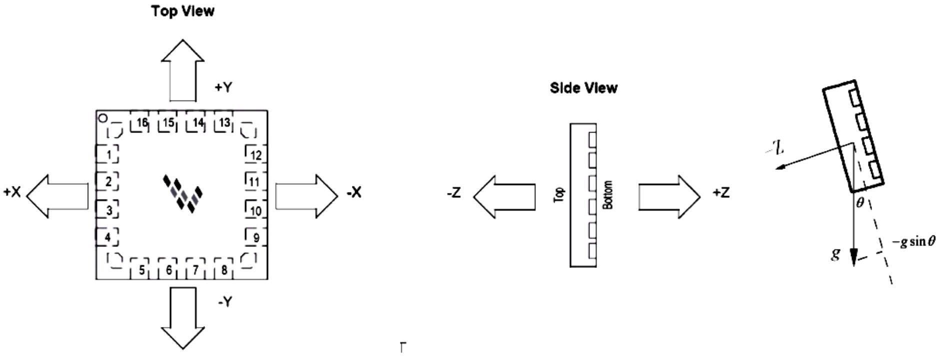
By micromachining technology mechanically processed to form a cantilever on a silicon wafer. It is formed of two adjacent electrodes

Capacitors. Since the acceleration that the distance between the two electrodes and the cantilever mechanical changes, thus changing the two electrical

Yung parameters. The integrated switched capacitor amplifier circuit changes the capacitance measured parameter, proportional to the acceleration of the formed

The voltage output. MMA7260 It is a three-axis low g The semiconductor accelerometer, the output can be applied simultaneously in the three directions

An analog velocity signal, as shown in 2-15 Fig.



Map 2- 15 MMA7260 Axis acceleration sensor

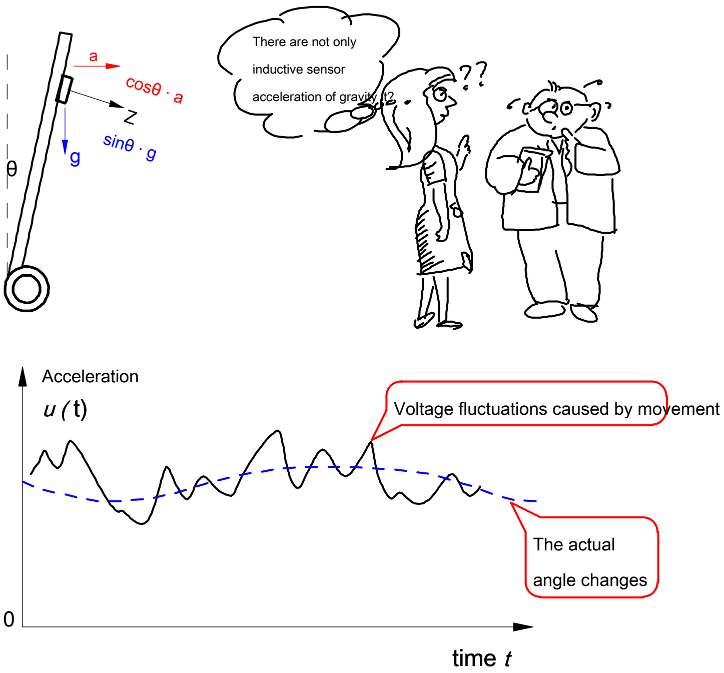
By setting such that MMA7260 The maximum signal output for each axis of sensitivity 800mV / g This signal need not To zoom is performed, you can directly be sent to the microcontroller AD Conversion. In fact, there are more lines Freescale Low column g Values of an acceleration sensor, in particular a sensor with a digital interface may be designed to facilitate single-chip interface.

Measuring acceleration values only in one direction wherein the angle can be calculated car models, such as the use Z Axis Upward acceleration signal. Cars When upright, fixed acceleration in Z Axis in the horizontal direction, then the output signal is zero bias Voltage signal. Cars occurs when the inclination, the acceleration of gravity g Will be in Z Axis direction acceleration component is formed, so that the lead Since the output voltage variation of the shaft. Change is the law

$$\Delta u = kg \sin\theta \approx kg\theta$$

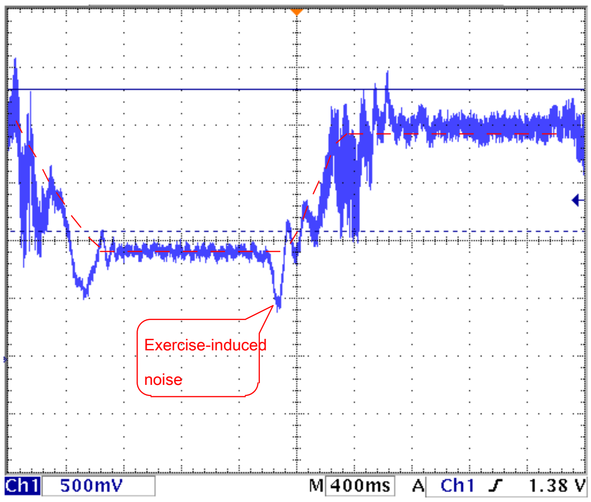
Where is the g acceleration of gravity; θ Cars of inclination; k acceleration sensor sensitivity coefficient of the coefficient. When dumping angle θ When a relatively small change in output voltage may be approximately proportional to the inclination angle.

It seems only acceleration inclination can get car models, and then the signal can be obtained by differentiating this inclination speed degree. However, in actual operation of car models, car models acceleration due to the swing itself produced will have a lot of interference Signal, which is superimposed on the measurement signal such that the output signal can not accurately reflect the inclination of the car models as 2-16 The Shows.


a
cosθ · a
Z
sinθ · g
g
θ
There are not only inductive sensor acceleration of gravity ?
??
Acceleration
u (t)
Voltage fluctuations caused by movement
The actual angle changes
0
time t

Map 2-16 Cars exercise-induced acceleration signal fluctuations

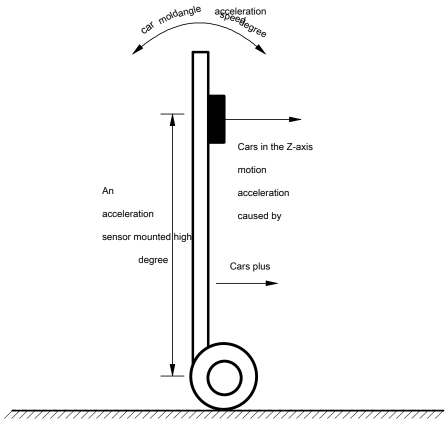
The figure is actually mounted on the measuring car models MMA7260 of Z Axis signal. Cars angle is too angular positions in two Crossing angle variation signal seen in addition, there is a voltage fluctuation due to the motion caused by the voltage fluctuations with Cars become very large movement speed increase.



Map 2-17 Actual measurement MMA7260Z Axis signal

The following simple analysis of the interference signal generated by the motion. An acceleration sensor mounted on the car model, the height from the axle for. r Cars having a rotation angular acceleration θ' Motion acceleration a. Then the acceleration sensor Z Since the emergence of the shaft Exercise-induced acceleration of car models $h\theta' + a$, As 2-18 Fig. In order to reduce the interference caused by the movement, acceleration

Sensor installation height as low as possible, but not completely eliminate the impact of the movement of the car models.

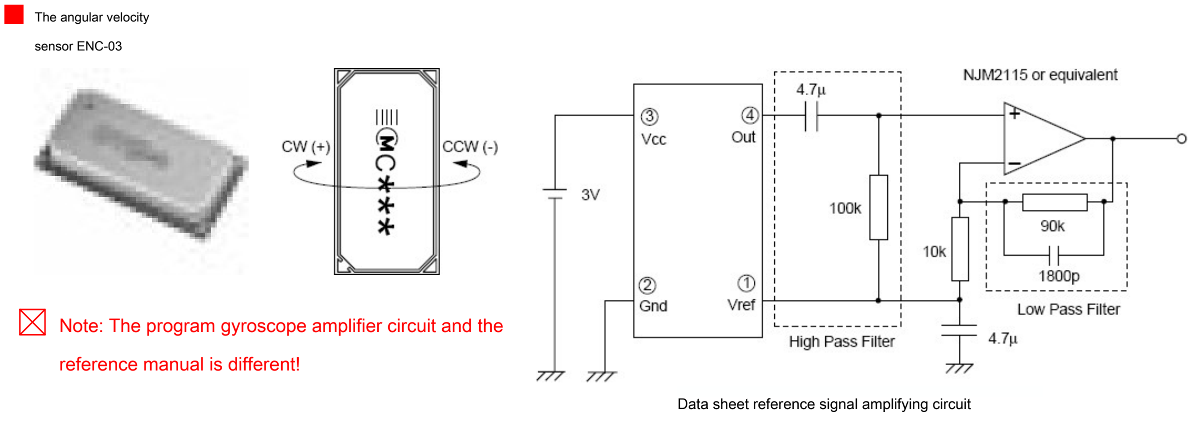

car moldangle
acceleration speedegree
Cars in the Z-axis motion acceleration caused by
An acceleration sensor mounted high degree
Cars plus

Map 2-18 Cars exercise-induced acceleration Z Axis signal changes

Cars motion acceleration generated so that the output voltage ripple voltage in the vicinity of the actual tilt angle. These fluctuations can noise By smoothing data which is filtered off. However, smoothing one hand so that the signal can not reflect real-time inclination becomes Cars , Thereby slowing wheel control for car models. Cars on the other hand will also change the angular velocity information filtered out. These two parties Filtering effect such that the surface of the car model can not maintain Ping Heng. Thus inclination information required for controlling the vertical car models need pa It is obtained through another device, that is, the angular velocity sensor - a gyroscope.

(2) The angular velocity sensor - gyroscope

Gyroscopes for measuring rotational angular velocity of the object. Competition allows the choice of Murata produced ENC-03 system An acceleration sensor columns. It utilizes the principle of a rotating coordinate system will be the object of the Coriolis force, in the device A piezoelectric vibrating element is made of ceramic. When the rotation of the device will change to reflect the vibration frequency of the rotation angular velocity of th degree. ENC-03 An angular velocity sensor including a reference to the amplifier circuit in FIG. 2-19 Fig.

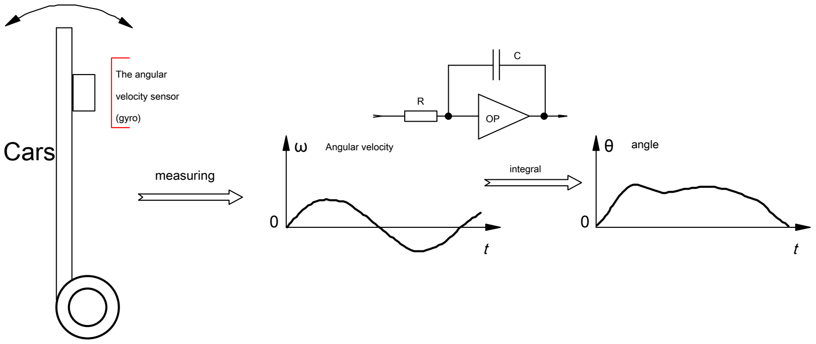

The angular velocity sensor ENC-03
CW (+)
CCW (-)
MC***
③ Vcc
④ Out
② Gnd
① Vref
3V
4.7μ
100k
High Pass Filter
NJM2115 or equivalent
+
−
90k
10k
1800p
Low Pass Filter
4.7μ

☒ Note: The program gyroscope amplifier circuit and the reference manual is different!

Data sheet reference signal amplifying circuit

Map 2-19 The angular velocity sensor and reference amplifier circuit

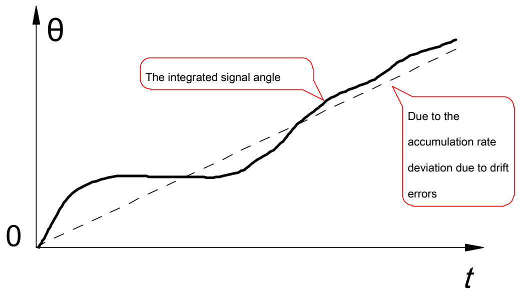
A gyroscope mounted on a car model, car model may be measured inclination angular velocity, the angular velocity signal can be integrated to give The inclination of the car models. Figure 2-20 Fig.



Map 2-20 Angle obtained by integrating the angular velocity

Since the output of the gyroscope is the angular velocity of car models, is not affected by body movement, so that the noise in the signal Small. Cars angle is obtained by integrating the angular velocity, which may further smooth the signal, so that the angle of the letter No more stable. Cars therefore necessary for the control angle and the angular velocity of the gyroscope signal can obtained.

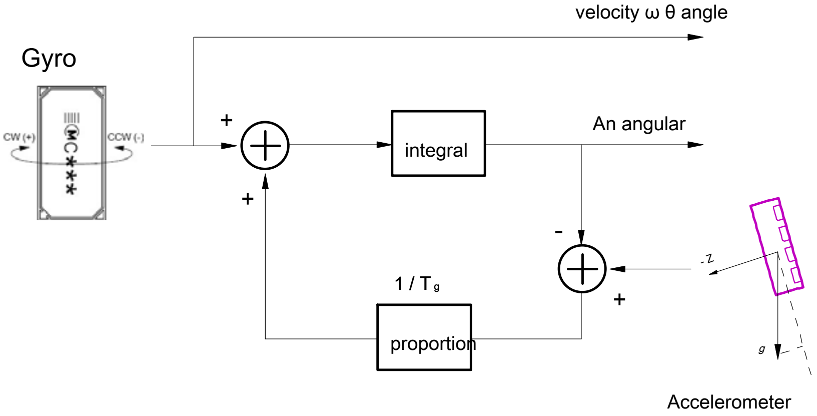
Since the angle information obtained from the angular velocity gyro, need to go through integral operation. If there is a slight angular velocity signal The bias and drift, after integration operation, change their cumulative error. This error will gradually with time Increases, eventually leading to the saturation circuit, the signal can not form right angles, as shown in 2-20 Fig.



Map 2-21 Angular velocity integration drift

How to eliminate the accumulated error of it?

A simple method is obtained by the above angle information of the acceleration sensor to correct this. by Comparative integrating the angular acceleration of gravity resulting angle obtained using the deviation therebetween changes gyroscope Output, so that the integration phase angle tracking the angle of the acceleration sensor is obtained. Figure 2-22 Fig.



Map 2-22 The gyroscope to correct the drift angle by gravitational acceleration

In the above-described embodiment, an accelerometer using the angle information θ_g obtained And the angle of the gyroscope integration θ For comparison Representing, through the comparison of the proportional $1/T_g$ signal After amplification and then into the angular velocity signal is superimposed after the output of the gyroscop Line points. For a given angular accelerometer θ_g, After proportional, integral part of the generated angle θ Would ultimately equal θ_g.

Write map 2-22 System transfer function can be seen that the output angle contains two first-order inertia. among them The first is the acceleration due to gravity Z Axis corresponds to the angle, the second gyroscope inertia value after acceleration. system Pure integrator system no longer exists, so that small deviations do not form rate gyro error accumulation. Where the parameter T_g Determines the time constant of these two aspects of inertia. T_g The larger, the tracking angle output Z The slower the output shaft, but can have Noise suppressing effect on gravity accelerometer. T_g Is too large, the gyro output error will be enlarged. The parameters need to Cars actual operating results adjusted, the latter method described in "Cars debugging chapter" in the.

In order to avoid the output angle θ Tracking time is too long, you can take measures following two aspects:

(1) Careful adjustment of the amplifier circuit of the gyroscope, the bias so that it is as close to zero set value, and stable set.

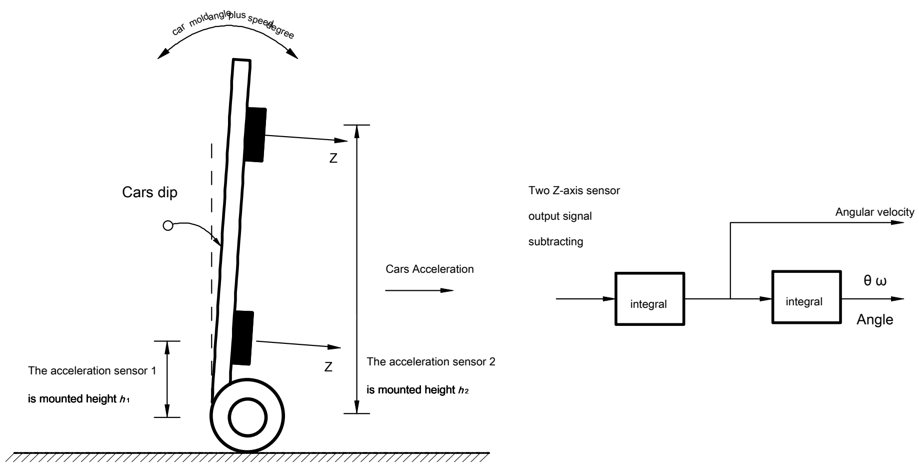
(2) And the start of the control circuit running, keep car models in an upright state, so the outset Such that the output angle θ versus θ_g equal. Thereafter, the output of the accelerometer only cancel the offset of the integrator, the output angle will not Great deviation.

An accelerometer to correct the gyro drift is only a method in which integration. Car model can also be measured by Speed and acceleration of the gyroscope to correct the drift of the integrator, so that the acceleration device can be omitted. This control party

Method of speed control are given later.

(3) Double angle of the acceleration sensor and the angular velocity obtained

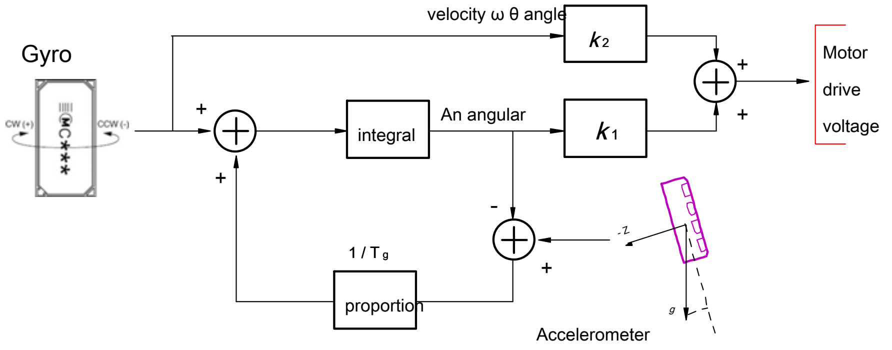
In Fig. 2-18 The acceleration sensor shown Z Addition to the output axis signal caused due to the acceleration of gravity, further Car model information including angular movement and an acceleration generated. In the conventional car models on the basis of the parameters, the signals There is not much difference in terms of amplitude, frequency, etc., are added together can not separate them. If on the other car models Add the outer one acceleration sensor, the acceleration sensor mounting two different heights, then through two The difference signal is determined angular acceleration of the car models. Figure 2-23 Fig.


car moldangleplus speeddegree
Cars dip
Z
Z
The acceleration sensor 1
is mounted height h_1
Cars Acceleration
The acceleration sensor 2
is mounted height h_2
Two Z-axis sensor
output signal
subtracting
integral
Angular velocity
integral
θ ω
Angle

Map 2-23 Double angular acceleration sensor obtained Cars

Two vertical acceleration sensors by subtracting the output signals, it can be obtained Cars angle acceleration. For this Signal integrated twice, you can get the angular velocity and the angle of inclination of the car models. For product integration may bring Points drift can still eliminate gravity accelerometer compensation method above.

The first two sections introduces Cars angle control and angle measurements, can be obtained Cars angle control block scheme Fig.


Gyro
CW (+)
CCW (-)
MC***
velocity ω θ angle
k_2
+
+
integral
An angular
k_1
+
Motor
drive
voltage
+
-
-z
1 / T_g
+
proportion
g
Accelerometer

Map 2-24 The angle control block

The program used by the gravitational acceleration and gyroscope fusion complementary way to obtain an angle and the inclination angular velocity Cars Degree, by the two proportional constant weight, to control the motor drive voltage such that the respective car models generated acceleration is maintained Upright car models.

In this scenario, it is necessary to ensure that the accelerometer is mounted Z Cars vertical axis strictly perpendicular axis. Such as If the angle deviation occurs, the actual result of the control is not strictly perpendicular to the ground car models, but there is a corresponding inclination. Under the action of gravity, scale models will accelerate progress toward one aspect. In order to maintain a constant speed or stationary car models This movement needs to eliminate installation errors. The actual car models in the production process requires mechanical adjustment and parameter setting softwar Home. Further stability required to achieve speed control by the speed of the software.

Cars in Cars angle deviation angle control such that the acceleration generated in the direction of car models inclined. This one The results can be used to control the speed of the car models. The next section will use this principle to regulate the speed of the car models.

2.3 Cars speed control

For controlling the speed with upstanding car models for controlling the speed of an ordinary car model is more complex. Because of the speed control It is necessary to always maintain Ping Heng during car models, and therefore can not directly control the speed of car models by changing the motor speed Lysaght Now. The following car models to analyze the reasons what caused the speed of change.

Cars in the above assumed vertical adjustment has been able to control the balance, but due to mounting error sensor The actual measured angular deviation angle car models, and therefore is not actually holding Cars perpendicular to the ground, but there is a inclination. Under the influence of gravity, will accelerate progress towards Cars inclined. Map twenty two It shows this relationship. control As long as the system speed by controlling the angle of the car models can be achieved. Concrete realization of the need to address three questions:

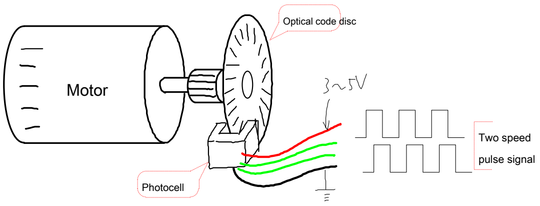
(1) How to measure the speed of car models?

(2) How to achieve vertical control by changing the angle of the car models car models?

(3) How to control the angle of the car models based on the speed error?

The first problem can be measured by the wheel speed car models installed in the optical code wheel motor output shaft. Such as

Map 2-25 Fig.



Map 2-25 Motor speed detection

The control counter measures the number of microcontroller fixed time interval velocity electrical pulse signal may reflect

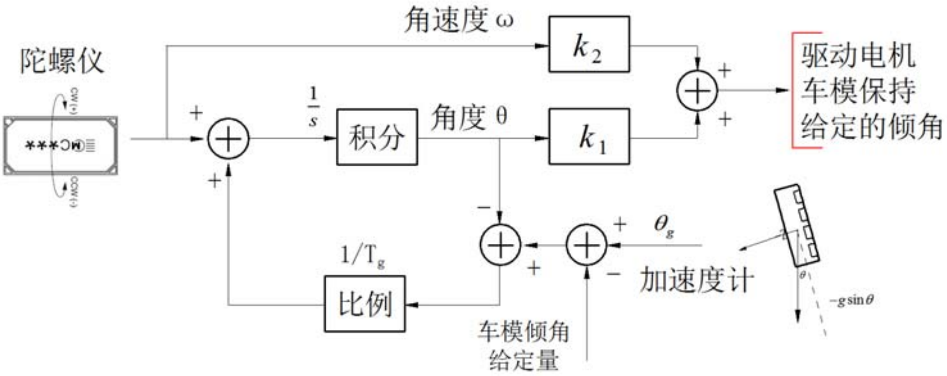
Machine speed.

The second problem can be solved by controlling the angle of a given value. Cars upstanding given setpoint control, the angle

Under the control of regulating, car models automatically maintained at an angle. Standing in front of car models control algorithm may know, the car

The final track is the acceleration of gravity tilt module Z The angle of the shaft. Therefore, the inclination car models given value and the acceleration of gravity Z Axi

Subtraction, we can finally decided inclination car models. Figure 2-26 Fig.



Map 2-26 Cars inclination given

Analysis chart 2-22 Cars in the angle between the control law can be seen a large change in the amount of car models car models inclination angle set

Body presents a first-order inertia $\frac{1}{T_z s + 1}$ When the application needs, this conclusion in the following speed control.

The third problem is relatively difficult to analyze them, than the speed intuitively analyze complex negative feedback. First, a

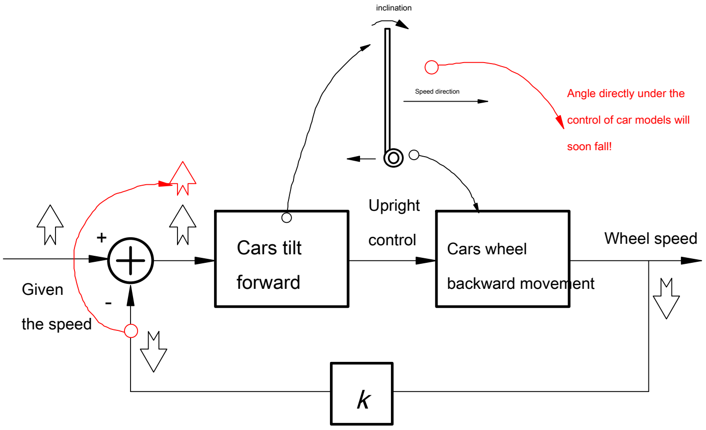
A simple example for analysis. Cars began to assume remain stationary, and then increase the given speed, which requires car models forward

Tilt in order to obtain acceleration. Under the control of car models upright, in order to have a forward tilt angle of the wheel needs

Backward movement, this will cause the wheel speed decreases (since the wheel to the negative direction). Due to the negative feedback, so that

Cars need more forward tilt. This cycle, scale models will soon be dumped. Originally the use of negative feedback for speed control

It has become a "positive" feedback. Figure 2-27 Fig.


inclination
Speed direction
Angle directly under the control of car models will soon fall!
Upright control
Cars tilt forward
Cars wheel backward movement
Wheel speed
+
-
Given the speed
k

Map 2-27 Cars inclination to control the speed of positive feedback

Why negative feedback control failure here of it? The original car models in an upright controlled speed and angle of Cars Between the non-minimum phase transfer function having a characteristic (here omitted analysis), not likely to cause a feedback control system in the stability. However, based on actual experience, speed control car models can tilt control. In order to get a reasonable Conclusion The experience of control, we need to speed in front of negative feedback control problem simplify the modeling analysis. Simplifying assumptions made as follows:

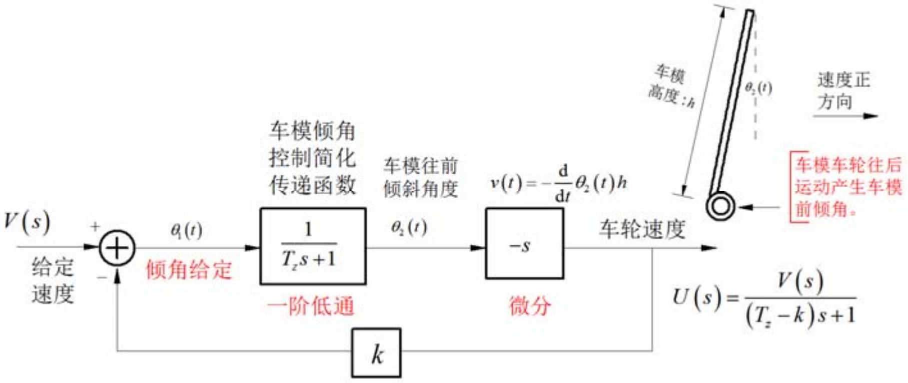
(1) Cars angle reduced to a first order transition under control of the upright $\frac{1}{T_z s+1}$. See the previous section of this Finally, the conclusion of two problems.

(2) Cars tilt motion is generated by the wheels, so the wheel speed is multiplied by the derivative variable inclination Cars length.

(3) Ignore Cars dip caused by the wheel acceleration. Since the beginning of this discussion only control short transition phase For segment, this time due to the relatively small car models angle, causing the rate of change is small.

(4) Systems, the speed ratio of the negative feedback.

Simplified model of FIG. 2-28 Fig.


车模
高度:h
$\theta_2(t)$
速度正
方向
车模车轮往后
运动产生车模
前倾角。
车模倾角
控制简化
传递函数
车模往前
倾斜角度
$v(t)=-\frac{d}{dt}\theta_2(t)h$
$V(s)$
+
-
给定
速度
$\theta_1(t)$
倾角给定
$\frac{1}{T_z s+1}$
一阶低通
$\theta_2(t)$
$-s$
微分
车轮速度
$U(s)=\frac{V(s)}{(T_z-k)s+1}$
k

Map 2-28 Cars tilt control analysis

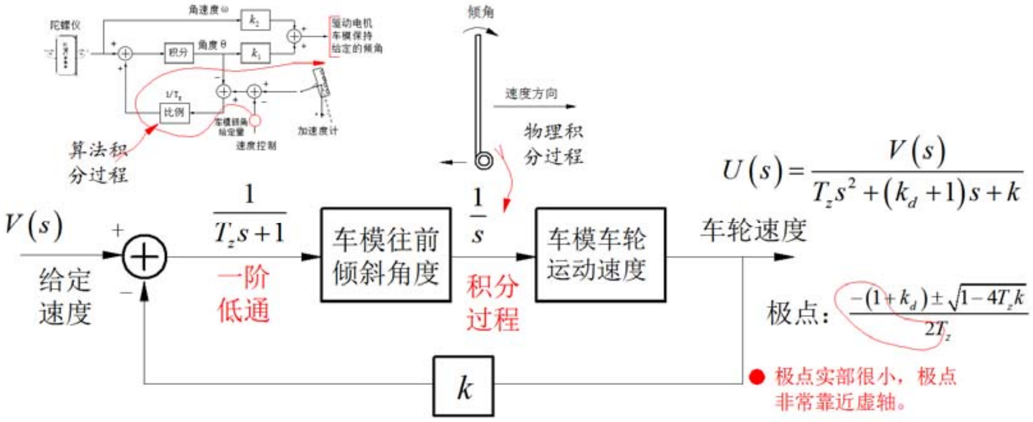
Transfer function analysis system simplification, having a first-order pole $-\frac{1}{T_z k}$ - - . To ensure system stability, need

To meet. This $T_z k$ requires adjustment of tilt Cars larger the time constant T_z, slow and smooth speed adjustment, while

Feedback proportional speed k is smaller. This conclusion is consistent with the actual experience.

The above two points may be smoothed by filter changes the control period, the control parameter is reduced, the method implemented in the program signal Wave etc. to achieve. Specific can be found in Part V software code.

After achieving the above two points, and then analyze the stability of the moving speed car models. To simplify the analysis, first of all ignored Cars speed due to changes caused by the tilt control. Cars speed final acceleration generated by the inclination of the decision, because This will dip by integrating the speed of movement will be able to get car models. At this time, the speed control block diagram in FIG Cars 2-29 The Shows.


陀螺仪
角速度 ω
k_2
角度 θ
积分
k_1
驱动电机
车模保持
给定的倾角
1/T_z
比例
车模倾角
给定量
速度控制
加速度计
算法积
分过程
倾角
速度方向
物理积
分过程
$V(s)$
给定
速度
+
−
$\frac{1}{T_z s+1}$
一阶
低通
车模往前
倾斜角度
$\frac{1}{s}$
积分
过程
车模车轮
运动速度
$U(s)=\frac{V(s)}{T_z s^2+(k_d+1)s+k}$
车轮速度
极点: $\frac{-(1+k_d)\pm\sqrt{1-4T_z k}}{2T_z}$
k
● 极点实部很小，极点
非常靠近虚轴。

Map 2-29 Cars simplified model velocity control

To ensure the above analysis found that the system is stable, the inclination car models often take a large time T_z constant control. This will

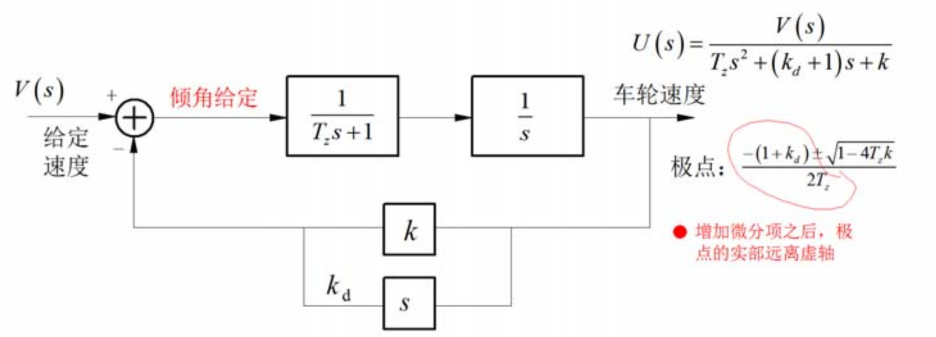
It will cause the system to produce two conjugate poles, and real pole becomes small, so that the speed control system will generate

Shock phenomenon. This phenomenon can be observed in real time parameter tuning. So how to eliminate the speed control process

The shock of it?

To solve the problem of control shock, has been the experience in front of the car models angle control, that is in the control feedback

Increase the speed differential control. Figure 2-30 Shown

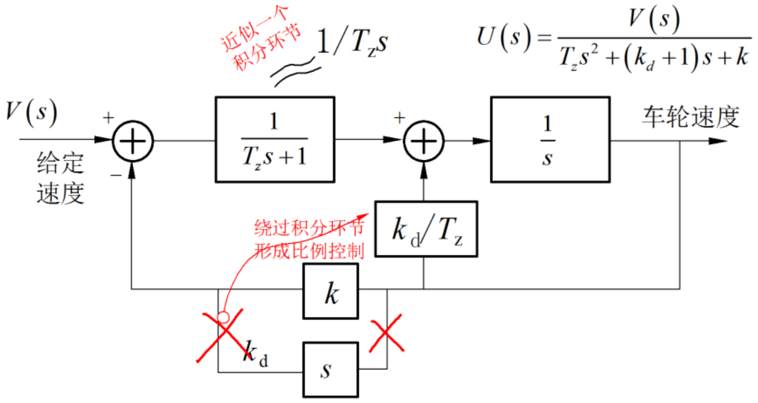

$V(s)$
给定
速度
+
−
倾角给定
$\frac{1}{T_z s+1}$
$\frac{1}{s}$
$U(s)=\frac{V(s)}{T_z s^2+(k_d+1)s+k}$
车轮速度
极点：$\frac{-(1+k_d)\pm\sqrt{1-4T_z k}}{2T_z}$
● 增加微分项之后，极点的实部远离虚轴
k
k_d
s

Map 2-30 Increase the system after the differential control

At this time the real pole of the transfer function of the system becomes large, convergence speed of the system.

Since the wheel speed feedback signal often there is noise, the speed differential operation will further increase the noise Impact sound. This requires improvements to the above control method. The original system time constant inclination adjustment process is often very Large, the system can be approximated by an integrator. The original part of the differential and integral part of this merger, Forming a proportional control link. This keeps the system control transfer function unchanged, while avoiding differential calculation.

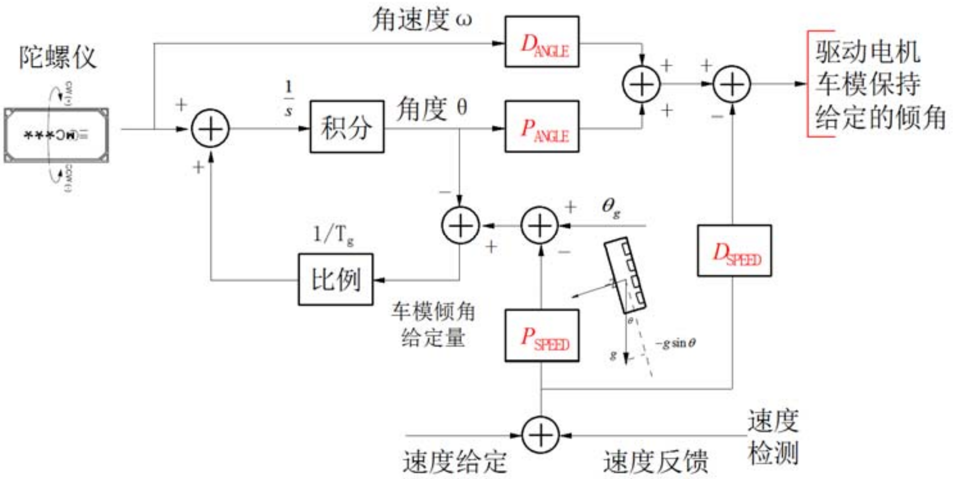
Specific improvements in FIG. 2-31 Fig.


近似一个积分环节
$1/T_z s$
$U(s)=\frac{V(s)}{T_z s^2+(k_d+1)s+k}$
$V(s)$
给定
速度
+
−
$\frac{1}{T_z s+1}$
+
$\frac{1}{s}$
车轮速度
绕过积分环节形成比例控制
k_d/T_z
k
k_d
s

Map 2-31 Improved differential control

These improvements can be avoided for the differential velocity feedback signal, the feedback control, the feedback signals but using The proportional and derivative, integral error no interest, so in the end the speed control is controlled residuals. But a direct quote The error integral control link, will increase the complexity of the system, for the integral control is no longer increased, but by the angle Performing the improved control of the combination.

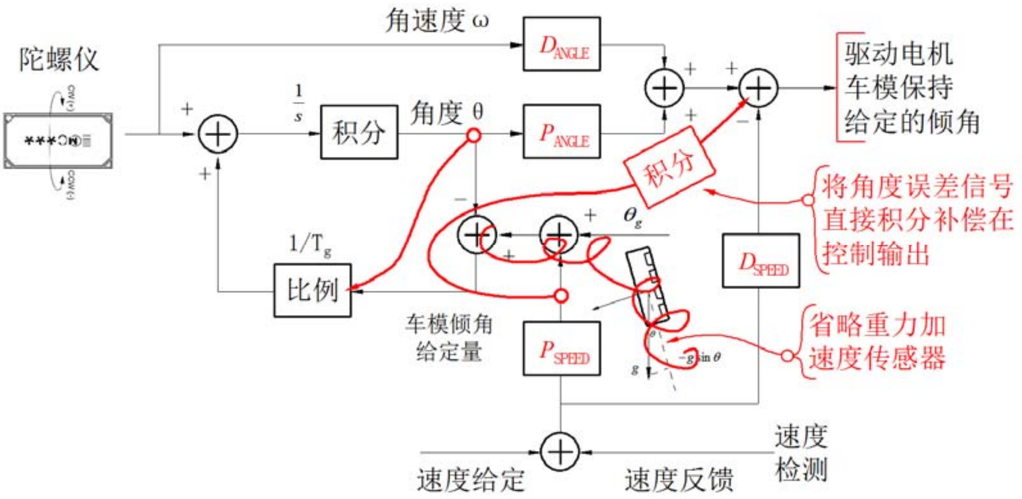
Connection with FIG. 2-26 Cars angle control angle given gives a block diagram of the FIG. 2-31 After introduction of an angle formed Cars And speed control block diagram. Figure 2-32 Below:



Map 2-32 Cars angle and speed control block

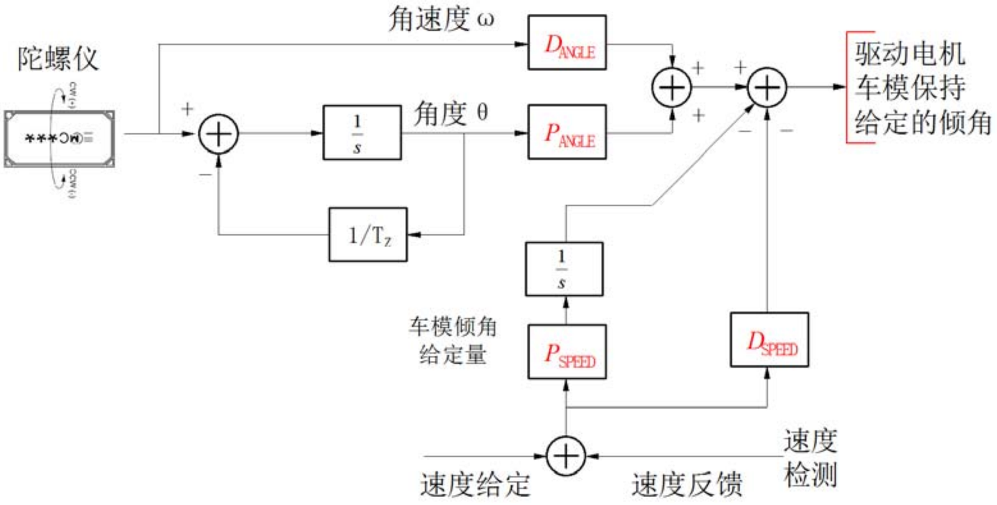
In the figure, the angle control requires two control parameters, the control parameters are the proportional P_{ANGLE} and differential control parameter number D_{ANGLE}. Speed control also has two parameters, the control parameters are the proportional and differential P_{SPEED} control parameter D_{SPEED} . In both of the differential control they are used to control the aim of increasing the angle and speed of the car models stability, Control to prevent overshoot. This experience still applies in the direction of control in the back of the car models.

Below for FIG. 2-30 Control program for a further two points into improved. First, FIG. 2-32 Control scheme is given for Integrating the speed error is not controlled, so that the final velocity is not strictly equal to the set value. Cars such as the requirement in the original Stop, speed 0 . However, due to the use of proportional control, if at this time the gyro drift, or acceleration Sensor mounting error, the final car models without the final adjustment to the inclination 0 , Scale models will run inclined towards constant speed Down. Note that this time will not be like no speed control car models that run faster, but speed is not final 0 . for This error elimination can be integrated directly Cars tilt compensation amount is set at an angle in the control output, which would Toru Bottom elimination rate control error. Second, due to the addition of the speed control, which compensates for the gravitational acceleration and gyroscope Drift and errors. Therefore, the accelerometer at this time is not actually necessary. The sensor may thus go Out, but still retains the proportion of negative feedback loop, which is used to overcome the integration gyro drift. Comprehensive improvement on two points, Map 2-32 It may be modified as shown in FIG.


角速度 ω
陀螺仪
D_{ANGLE}
1/s
积分
角度 θ
P_{ANGLE}
驱动电机
车模保持
给定的倾角
积分
将角度误差信号
直接积分补偿在
控制输出
θ_g
$1/T_g$
比例
D_{SPEED}
车模倾角
给定量
P_{SPEED}
省略重力加
速度传感器
−g sin θ
g
速度
检测
速度给定
速度反馈

Map 2-33 Improved angular velocity control scheme

The improved angle and speed control scheme shown below:


角速度 ω
陀螺仪
D_{ANGLE}
1/s
角度 θ
P_{ANGLE}
驱动电机
车模保持
给定的倾角
$1/T_z$
1/s
车模倾角
给定量
P_{SPEED}
D_{SPEED}
速度
检测
速度给定
速度反馈

Map 2-34 Improved speed and angle control scheme

Map 2-34 No gravitational acceleration sensor, a speed control loop can compensate for the error sensors. At this point Cars When the control starts, it is necessary to maintain a vertical position of car models. At this time, the angle of the gyro integrator is also initialized 0 . Of course, if the circuit has been included in the accelerometer, this part may be retained, thereby improving the stability of the car models Qualitative. In the latter given final control scheme, the control circuit retains this section.

In Fig. 2-34 Through speed control error directly proportional integral and superimposed on the motor control amount. Speed control When discussing the start is achieved by adjusting the inclination car models, simplified and improved by the above performed, and finally in FIG. 2-34 It has been turned into a direct control of the motor. Please note two points: the first point is the amount of pole speed control A negative resistance, and the polarity of the normal speed feedback control. " **On the contrary** "This is because the control scheme is adjusted from Cars

Design angle feedback and modifications obtained. The second point is that two control parameters correspond to the product of the error signal

Points and the proportion of value, so in some cases may be referred to these two parameters is integral and proportional control parameters.

2.4 Cars directional control

Cars achieve directional control is the key to the car models along a road race competition. Cars upright electromagnetic group resides

There is a paved road centerline enameled wire, inside pass there 100mA of 20kHz Alternating current. Therefore, in the center of the road

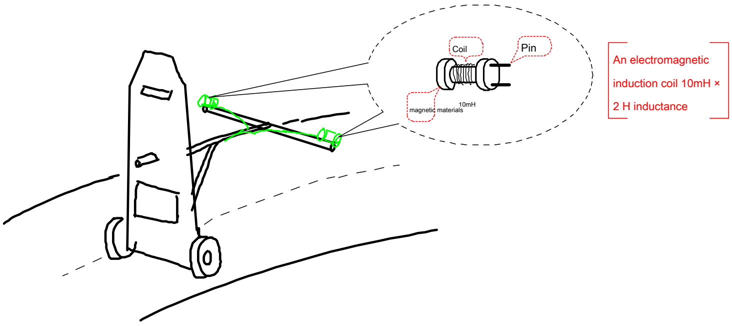
A generating line around an alternating magnetic field. By road centerline deviation detecting electromagnetic motor and differential control to achieve directional con

System, thus further ensuring Cars on the track. In the following we will be introduced separately.

(1) Deviation detecting electromagnetic road centerline

Electromagnetic road centerline detection method can be a simple two by electromagnetic induction coil mounted in front of the real car models

Now. Coils commonly used 10mH The H inductance. Figure 2-35 Fig.



Map 2-35 Wire detection center of the road way

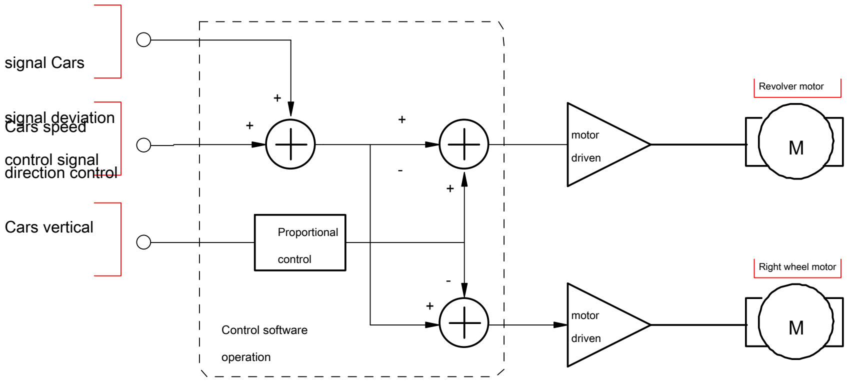
Detailed reference design please see documentation "electromagnetic group race car model reference designs, 2010 . " behind

It gives the specific circuit design of circuit design.

(2) Motor differential control

Wire using the deviation detection signals and speed control signals for car models, plus and minus, forming left and right wheel differential control

System voltage, so that the left and right wheels running car models inconsistent further control the angular velocity of the direction of car models. Figure 2-36 Fig.

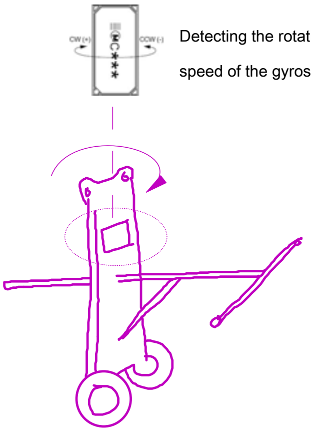

signal Cars
signal deviation
Cars speed
control signal
direction control
Cars vertical
+
+
+
-
+
-
+
Proportional
control
Control software
operation
motor
driven
motor
driven
Revolver motor
Right wheel motor
M
M

Map 2-36 Differential voltage through the motor drive control direction Cars

(3) Direction control algorithm

Direction of the control algorithm to generate the electromagnetic induction voltage differential control of the motor car models in accordance with the detectio Cars driving speed difference steering to eliminate the deviation from the center of the road car models. By adjusting the direction of car models, coupled with the veh Line movement, you can gradually eliminate the difference in distance from the center line of the car models. This process is a process of integration, so car Differential control mode typically requires only a simple proportional control can be done to control the direction of car models. However, because this car models Body mounted relatively heavy object such as a battery, has a large moment of inertia appears during adjustment car models oversteer Overshoot, if unchecked, will make the car models off the track. The foregoing angle and speed control experience for The elimination of car models in the direction of control overshoot, need to increase the differential control.

Derivative control is based on a rate of change of the direction of car models differential control amount for correcting the motor control, so Necessary to increase the rotational speed detection sensor car models. It can be detected using a gyro sensor, FIG. 2-37 The Shown in FIG. 2-37 Cars gyroscope detecting rotational speed. Cars are also used in the gyro tilt detection.



Detecting the rotational speed of the gyroscope Cars

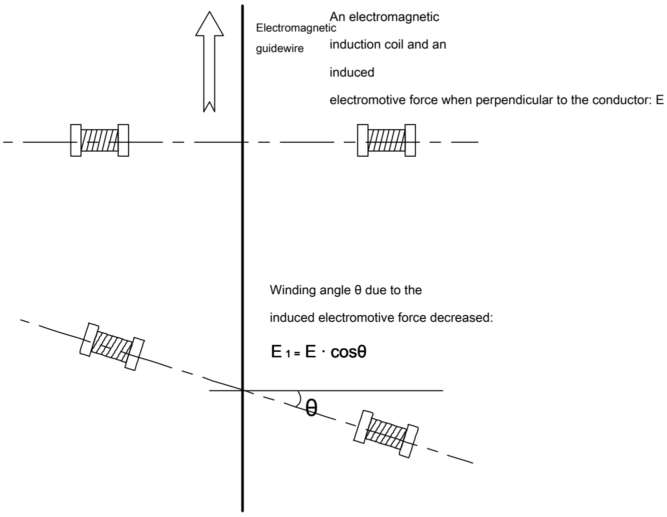
Map 2-37 Detecting the rotational speed of the gyroscope Cars

Since the distance and direction of the magnetic field strength of the electromagnetic detection coil guide wire have a relationship. When the direction of the d

When large, such as occur when a sharp turn in front of car models, the electromagnetic coil and the detection axis is no longer perpendicular to the guide wire,

A great angle deviation. At this time, the induced electromotive force of the two detection coils are lowered. Map 2-38 This is illustrated

Case.


Electromagnetic guidewire
An electromagnetic induction coil and an induced electromotive force when perpendicular to the conductor: E
Winding angle θ due to the induced electromotive force decreased:
$E_1 = E \cdot \cos\theta$
θ

Map 2-38 Angle inductor induced electromotive force of the impact

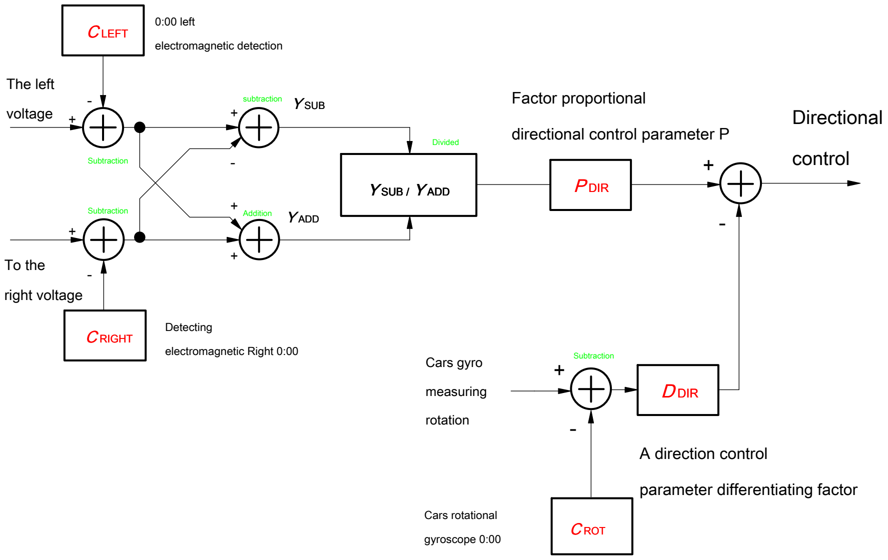
In order to more accurately reflect the differences in distance from the center of gravity of the car models electromagnetic cables, to avoid the image angle sic

To control, using an induced electromotive force difference of about two coils around two coils divided by the sum of the induced electromotive force, the use of

The ratio of the directional control. This eliminates the influence of the angle detection coil.

In summary, the algorithm control block diagram obtained Cars direction, as shown in 2-39 Fig. Wherein the direction of the differential control section

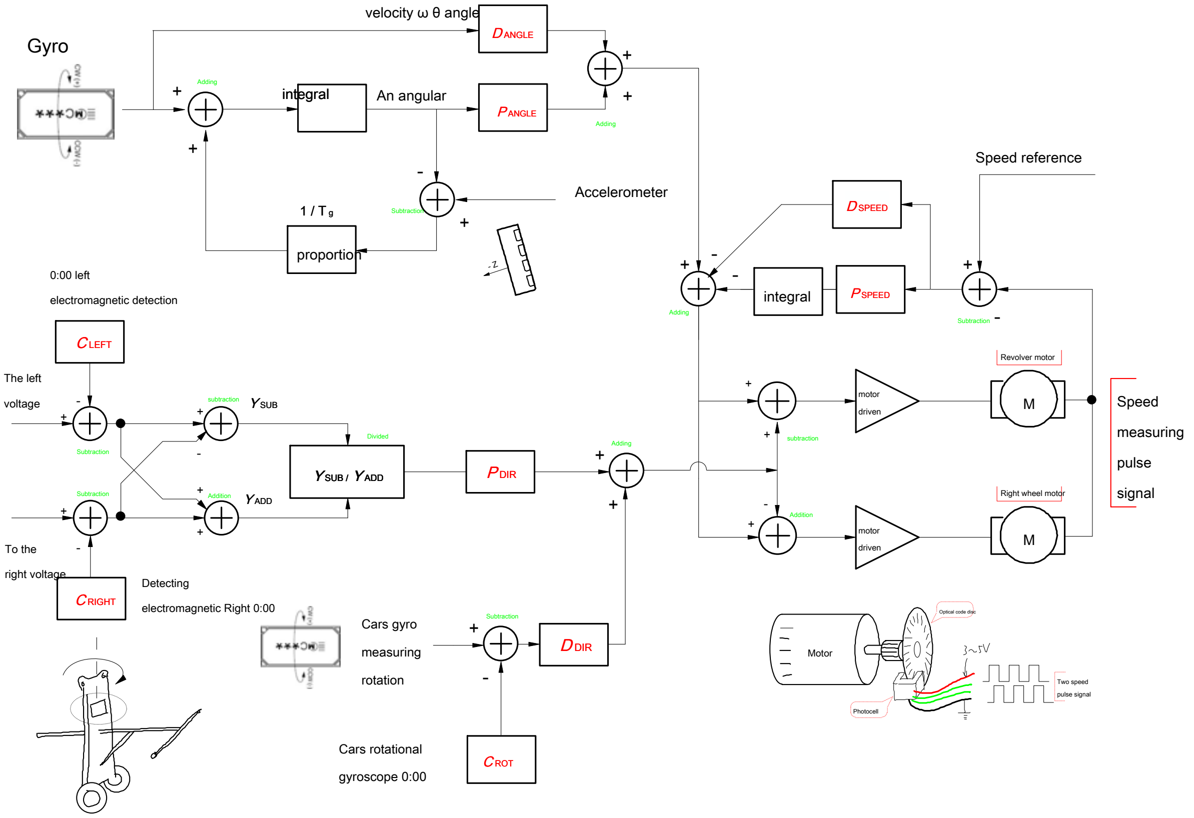
The situation can be omitted, which can further reduce the complexity of control.


C_{LEFT}
0:00 left electromagnetic detection
The left voltage
+
-
Subtraction
subtraction
Y_{SUB}
+
-
Divided
Y_{SUB} / Y_{ADD}
Factor proportional directional control parameter P
P_{DIR}
Directional control
+
-
Subtraction
+
Addition
Y_{ADD}
+
+
-
To the right voltage
C_{RIGHT}
Detecting electromagnetic Right 0:00
Cars gyro measuring rotation
+
Subtraction
-
D_{DIR}
A direction control parameter differentiating factor
Cars rotational gyroscope 0:00
C_{ROT}

Map 2-39 Cars directional control algorithm

2.6 Cars upright overall control algorithm of FIG.

By the above description, the car models upright main control algorithm together, in conjunction with FIG. 2-34 And 2-39 Forming a control block diagram of the overall algorithm as 2-40 Fig.


Gyro
velocity ω θ angle
D ANGLE
Adding
integral
An angular
P ANGLE
Adding
Speed reference
Accelerometer
1 / T g
Subtraction
proportion
-z
D SPEED
integral
P SPEED
Adding
Subtraction
0:00 left
electromagnetic detection
C LEFT
The left
voltage
Subtraction
subtraction
Y SUB
Divided
Y SUB / Y ADD
P DIR
Adding
Revolver motor
motor
driven
M
subtraction
Speed
measuring
pulse
signal
Subtraction
Addition
Y ADD
Right wheel motor
Addition
motor
driven
M
To the
right voltage
C RIGHT
Detecting
electromagnetic Right 0:00
Cars gyro
measuring
rotation
Subtraction
D DIR
Cars rotational
gyroscope 0:00
C ROT
Motor
Optical code disc
Photocell
3~5V
Two speed
pulse signal

Map 2-40 Motion general block diagram Cars

Map 2-40 Or maintained in the gravitational acceleration sensor, in complete control of car models, which can be controlled by the speed Partial replacement system.

To achieve the upright car models to be collected the following signals:

(1) Cars velocity gyro angle signal, and the angular velocity obtained inclination car models.

(2) Gravitational acceleration signal (z Axis signal), the gyro drift compensation. The signal can be omitted, the speed Control instead.

(3) Cars motor speed pulse signal obtained Cars velocity, speed control.

(4) Cars electromagnetic deviation signal (two-way) to obtain a positional deviation from the center line of car models, the direction control system.

(5) Cars gyro rotational speed signal, the steering angular velocity obtained Cars, directional control.

The above signal acquisition can be simplified and the signal out of the gravitational acceleration Cars rotational speed gyro signal.

Cars upright control, speed control and direction of the three links are used proportional differential (PD)control, The three final output of the control algorithm is done by superimposing motion by a motor.

(1) Cars upright control: inclination car models PD (Proportional, derivative) control;

(2) Cars speed control: PD (Proportional, derivative) control;

(3) Cars direction control: PD (Ratio, differential) control.

The control algorithm may be implemented by the microcontroller software.

After the above control process, the control and direction of the angle control car models are superimposed on the output voltage direct electrical control Machine speed achieved. Cars and speed control by adjusting the angle of inclination is essentially implemented car models, car models is due A non-minimum phase system, and the feedback proportional control if the speed is too large, it is easy to form a positive feedback, so that Cars out of control, resulting in instability of the system. Therefore, the adjustment speed of the process requires very slow and smooth.

The control block diagram schematically illustrate only the control relationship. In the software implementation process, also taking into account the need to A collection volume ratio of the polar and the zero point value and the signal. In Fig. 2-40 In the directional control has been added zero Correction process. The same procedure for controlling the angle of gyroscope and accelerometer acquisition channels need be. Signals Installation polarity relationship with the sensor, such as car models used in car models steering control steering gyroscope Z Axis and up Down, corresponding to the opposite polarity of the angular velocity of the steering car models, thus affecting control of the car models direction proportional control a The relationship between the amount of addition and subtraction system. Subtraction relationship other portions are the same with this.

Appendix detailed block can 5 The algorithm block diagram.

The third chapter, circuit design articles

3.1 Overall circuit block diagram

Cars circuit design a control system, firstly the need to analyze the system input and output signals, and then select the appropriate The core embedded control computer (SCM), circuit design of each sub-module gradually, and finally form a complete electrical control road.

Input and output system comprising:

(1) AD Conversion interface (at least 5 road)

a) Electromagnetic detection: two left, two right and left induction coil for measuring the voltage.

b) Gyro: two-way. Cars for detecting the inclination angular velocity all the way, the way for detecting a rotational angular velocity Cars degree.

c) Accelerometer: one measuring acceleration Z Axis output voltage.

d) Assisted debug :(spare) 1 To 3 Road, Cars for debugging, setting role.

(2) PWM interface(4 road)

a) Control electrodes around two sides to run. Since the unipolar PWM drive requires four PWM interface. If bipolar PWM driver, two may be used.

(3) Timer interface (2 road)

a) Two measuring motor speed, timer pulse requires two input ports.

(4) Communication interface (standby)

a) SCI (UART): One for program download and debug interface;

b) I2C Alternate :() If Freescale digital accelerometer, can I2C Direct Interface Then reads acceleration values.

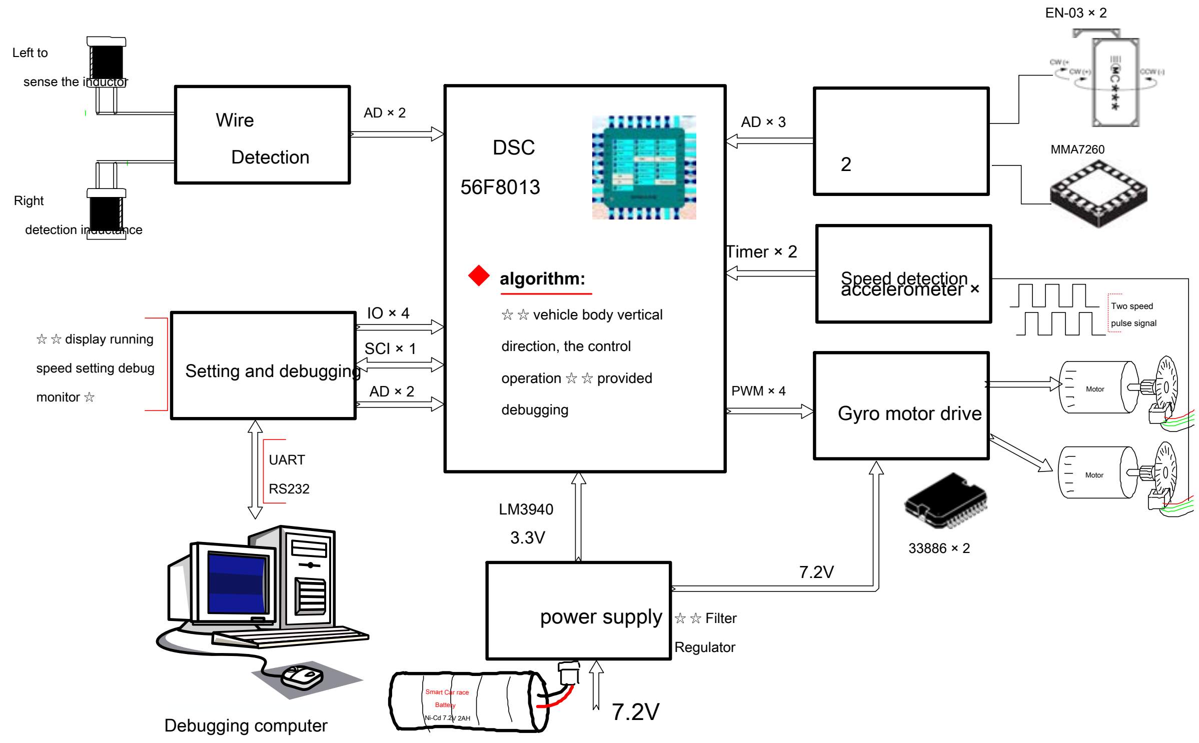
(5) **IO interface** (spare)

4 To 8 Input Output, status display application running car models, function settings and the like.

Said interface, the gravity acceleration sensor and a gyro rotational speed car models may be simplified omitted.

Competition allows the use of Freescale's processor family, the vast majority are able to meet the control requirements above.

Reference in the present embodiment selection Freescale DSC 16 Bit processor MC56F8013 As the core of the control processor Design. Cars overall block diagram of a control circuit in FIG. 3-1 Fig.


Left to
sense the inductor
Right
detection inductance
Wire Detection
AD × 2
DSC
56F8013
algorithm:
☆☆ vehicle body vertical
direction, the control
operation ☆☆ provided
debugging
AD × 3
2
EN-03 × 2
MMA7260
Timer × 2
Speed detection
accelerometer ×
Two speed
pulse signal
☆☆ display running
speed setting debug
monitor ☆
Setting and debugging
IO × 4
SCI × 1
AD × 2
PWM × 4
Gyro motor drive
Motor
Motor
33886 × 2
UART
RS232
LM3940
3.3V
7.2V
power supply
☆☆ Filter
Regulator
Smart Car race
Battery
Ni-Cd 7.2V 2AH
7.2V
Debugging computer

Map 3-1 A control circuit block diagram of the overall upright Cars

According to FIG. 3-1 The control circuit is divided into the following sub-modules:

(1) Smallest SCM system: comprising DSC Processor, download the program debugging interface;

(2) Magnet wire Detection: comprising two identical amplifying the electromagnetic induction signal detection circuit;

(3) Gyroscope and accelerometer: attitude sensor signal amplifier comprises three filtering circuit;

(4) Speed detection: detection photoelectric encoder motor pulse frequency, in fact, only the sensor comprises two photoelectric encoder of

Device. ;

(5) Motor drive: two electrodes operating power driving circuit;

(6) Power: the power supply voltage conversion switch, voltage regulator, a filter circuit;

(7) Set and Debug: displays system status, speed setting, download and monitoring.

We are given below with reference to design the circuit of the above embodiment.

3.2 DSC Introduction and smallest single-chip system

Freescale microcontroller selection DSC MC56F8013 It small size (32PIN TQFP), Low power consumption (3.3V Operating voltage), the operational speed (32MIPS , DSP Structure), with a broad peripheral module, suitable for control

Cars run. Its main peripherals include:

(1) PWM : 6 aisle;

(2) AD converter: 6 aisle, 12bit ;

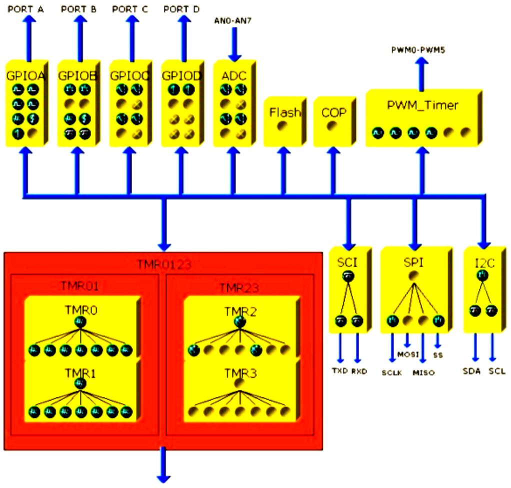
(3) Timer: 16bit , 4 aisle;

(4) Rich external serial interfaces: SCI , I2C , SPI ;

(5) IO Population: up to provide 26 Way, the device can be directly connected to 5V.

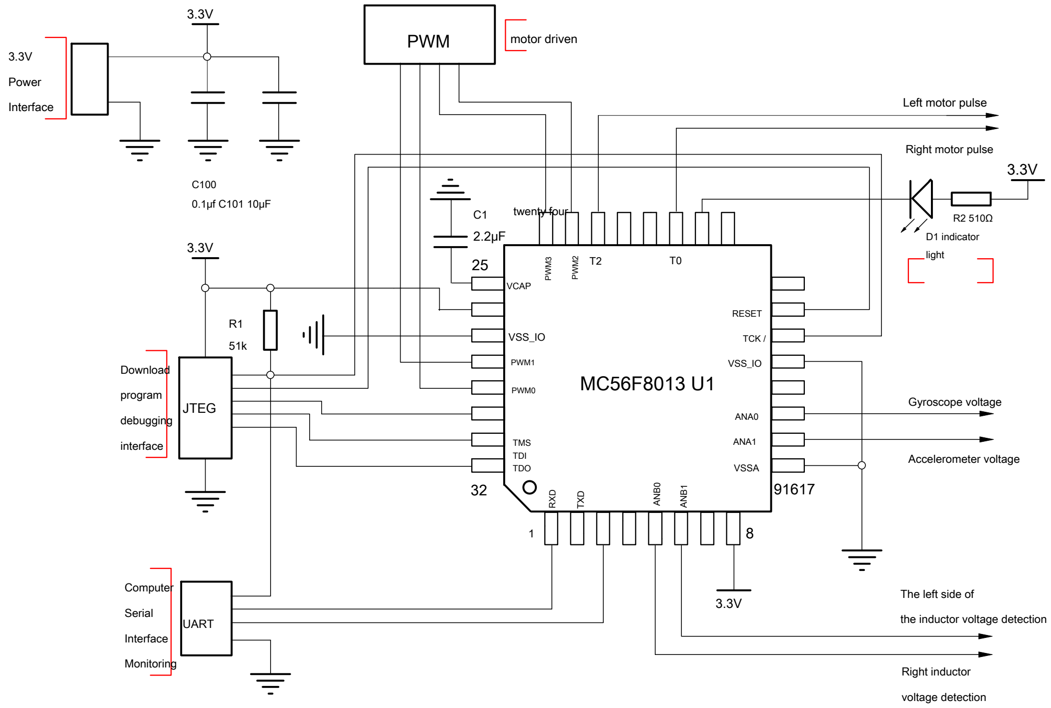
In addition, the internal clock of the integrated circuit, a power detection circuit and watchdog circuit.

Internal memory resources include: 16k program Flash , 4k data RAM . Map 3-2 Show the internal resources of the microcontroller Source situation.


PORT A
PORT B
PORT C
PORT D
AN0-AN7
PWM0-PWM5
GPIOA
GPIOB
GPIOC
GPIOD
ADC
Flash
COP
PWM_Timer
TMR0123
TMR01
TMR23
TMR0
TMR1
TMR2
TMR3
SCI
SPI
I2C
TXD
RXD
MOSI
SS
SCLK
MISO
SDA
SCL

Map 3- 2 56F8013 Schematic diagram of internal resources

Since the microcontroller already contains the clock and reset circuit, the minimum circuit microcontroller system is very simple. Figure 3-3 Fig.


3.3V
3.3V
Power
Interface
C100
0.1μf C101 10μF
PWM
motor driven
Left motor pulse
Right motor pulse
3.3V
R2 510Ω
D1 indicator
light
C1
2.2μF
twenty-four
25
PWM3
PWM2
T2
T0
VCAP
RESET
TCK /
VSS_IO
VSS_IO
PWM1
PWM0
MC56F8013 U1
ANA0
ANA1
VSSA
TMS
TDI
TDO
32
91617
RXD
TXD
ANB0
ANB1
1
8
3.3V
R1
51k
Download
program
debugging
interface
JTEG
Gyroscope voltage
Accelerometer voltage
Computer
Serial
Interface
Monitoring
UART
The left side of
the inductor voltage detection
Right inductor
voltage detection

Map 3- 3 F8013 Minimum system circuit

Used F8013 MCU resources include:

(1) Detecting analog interfaces

a) ANA0 (PIN12): Cars angle gyroscope detecting voltage;

b) ANA1 (PIN11): Accelerometer voltage;

c) ANB0 (PIN5): Right inductor detection voltage;

d) ANB1 (PIN6): Left inductance detection voltage;

e) ANB2 (PIN7): Voltage detecting Cars gyro rotation;

(2) Motor speed pulse interface

a) T0 (PIN19): Photoelectric encoder pulse motor on the right;

b) T2 (PIN22): Left photoelectric encoder pulse motor;

(3) Motor PWM Driver Interface

a) PWM0-3 (PIN23,24,28,29):motor driven.

(4) Download Debugging JTEG interface

a) TDI (PIN30);

b) TDO (PIN32);

c) TMS (PIN31);

d) TCK (PIN14);

e) / RESET (PIN15) .

(5) Serial Monitoring UART interface:

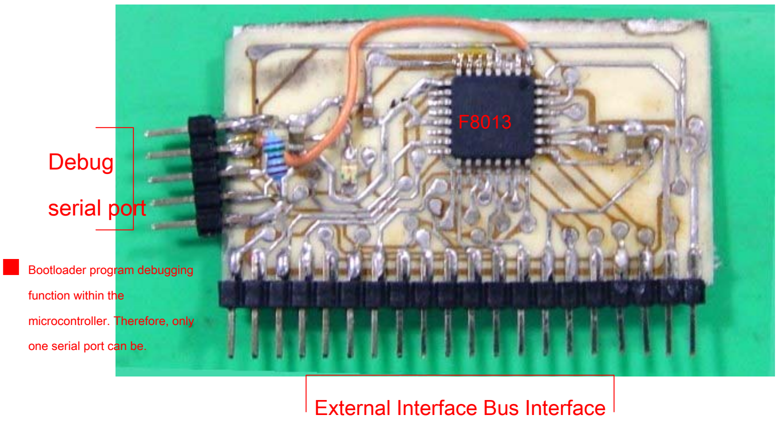
a) RXD (PIN1);

b) TXD (PIN3).

No other use IO And analog port can be used as the status display, and an auxiliary operational settings for the debug use.

Rapid plate making method using the smallest SCM system, such as the physical map

Map 3-4 Fig.


F8013
Debug
serial port
Bootloader program debugging
function within the
microcontroller. Therefore, only
one serial port can be.
External Interface Bus Interface

Map 3- 4 F8013 Minimum physical system circuit

Map 3-4 The actual circuits shown, each of the external ports required by way of a bus lead, through a unified

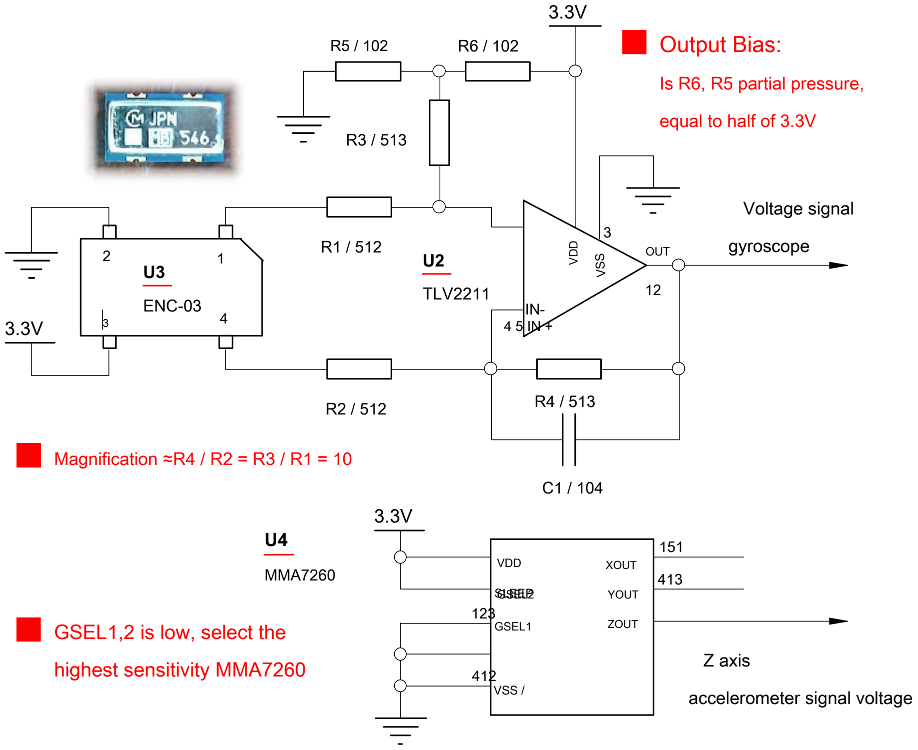
Each backplane connector interface to other sub-circuits.

The above circuit board nor JTEG The program interface. Program development mainly through internal microcontroller Bootloader Program to complete the process of downloading and debugging, so the smallest single-chip system only needs a UART interface It can be carried out without additional Debugger. Introduce relevant information can be found in Freescale's website.

3.3 Tilt sensor circuit

Cars The main circuit is a tilt sensor gyro signal amplifying and filtering. Since the acceleration sensor is employed low g Sensor value MMA7260 , Its output signal is large, no further amplification. A circuit diagram of FIG. 3-5 The

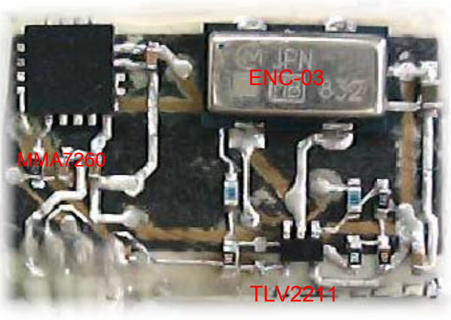
Shows.


3.3V
R5 / 102
R6 / 102
■ Output Bias:
Is R6, R5 partial pressure,
equal to half of 3.3V
JPN
546
R3 / 513
Voltage signal
gyroscope
2
1
U3
ENC-03
3
4
3.3V
R1 / 512
U2
TLV2211
VDD
VSS
3
OUT
12
IN-
4 5 IN +
R2 / 512
R4 / 513
■ Magnification ≈R4 / R2 = R3 / R1 = 10
C1 / 104
3.3V
U4
MMA7260
VDD
XOUT
YOUT
ZOUT
GSEL2
GSEL1
VSS /
151
413
123
412
■ GSEL1,2 is low, select the
highest sensitivity MMA7260
Z axis
accelerometer signal voltage

Map 3-5 A gyroscope, an acceleration sensor circuit

Figure above, the output signal of the gyroscope enlarged 10 Around times, the bias voltage is adjusted to zero and the working electrode The source of half (1.65V)about. Magnification requires root According to the selected design of the sensor output sensitivity can be selected 5 to 10 Fold range control car models to meet all needs.

The above circuit is made into a single small circuit board, can be more easily placed in the most stable position of car models. real Inter circuit diagram of FIG. 3-6 Fig.


ENC-03
MMA7260
TLV2211

Map 3-6 Cars physical inclination sensor circuit of FIG.

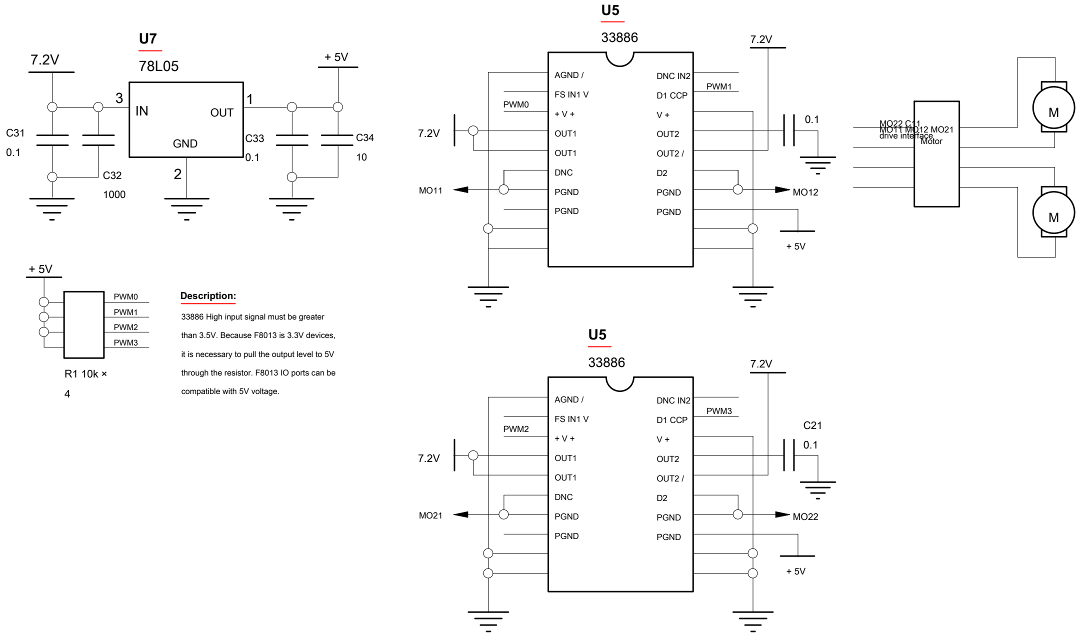
The signal from the sensor circuit over only the enlargement processing is performed, the angle and angular acceleration calculation rely on single

Machine software to complete. Angle signal processing may also be achieved by a hardware circuit, this part See 3.7 Content section. in 3.7 Also given section using only two MMA7260 Acceleration sensor will be able to get car Mold Angle and the angular velocity of the circuit.

Involved in the above circuit and the measuring circuit gyroscope Cars steering angle of the gyro is the same as the control circuit of. Just install the steering Tuo Lo, when the gyro is mounted vertically, thereby measuring the angular velocity of the steering car models. Thereof will be omitted here.

3.4 Motor drive circuit

Since the two rear-wheel drive motor car models, it is necessary electric motor driving two axle road. Map 3-7 Selected two Freescale sheet dedicated motor driver chip 33886 A motor driving circuit composition.


U7
78L05
7.2V
+ 5V
3
1
IN
OUT
GND
2
C31
0.1
C32
1000
C33
0.1
C34
10
+ 5V
PWM0
PWM1
PWM2
PWM3
R1 10k ×
4
U5
33886
AGND /
FS IN1 V
+ V +
OUT1
OUT1
DNC
PGND
PGND
DNC IN2
D1 CCP
V +
OUT2
OUT2 /
D2
PGND
PGND
PWM0
PWM1
7.2V
7.2V
0.1
MO11
MO12
+ 5V
U5
33886
PWM2
PWM3
7.2V
7.2V
C21
0.1
MO21
MO22
+ 5V
MO22 C11
MO11 MO12 MO21
drive interface
Motor
M
M

Description:

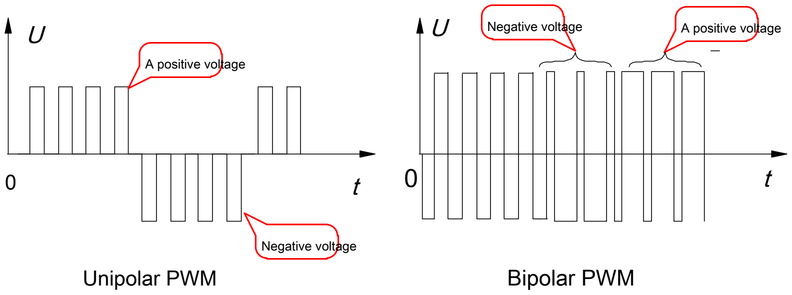
33886 High input signal must be greater than 3.5V. Because F8013 is 3.3V devices, it is necessary to pull the output level to 5V through the resistor. F8013 IO ports can be compatible with 5V voltage.

Map 3-7 Dual-motor drive circuit

Map 3-7 middle DSC F8013 Yes 3.3V Device, its IO Highest output voltage 3.3V Not reach the 33886 For high-level must be greater than 3.5V Requirements, so the circuit specifically designed 5V Power, 33886 Driving The signal to pull 5V . due to F8013 of IO Port can be tolerated 5V Voltage, so that the above circuit can 3388 6 The drive signal voltage reaches 5V .

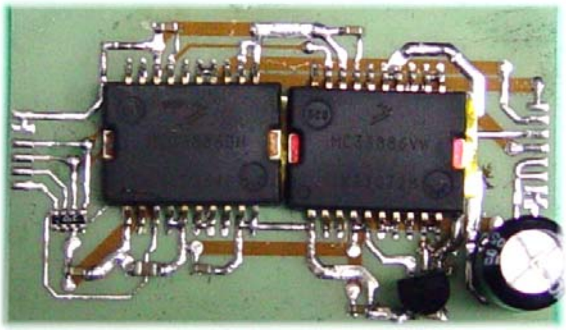
In order to improve the efficiency of the power application, the drive motor PWM Unipolar driving waveforms using square formula. It

It is in a PWM Cycle, the voltage applied to the motor as a voltage, FIG. 3-8 Fig.


U
A positive voltage
0
t
Negative voltage
Unipolar PWM
U
Negative voltage
A positive voltage
0
t
Bipolar PWM

Map 3-8 Unipolar PWM Bipolar PWM

So each way in order to achieve positive inversion motor, requires two P WM signal. A total of two motors 4 road PWM signal. A drive circuit specific implementation of FIG. 3-9 Fig.

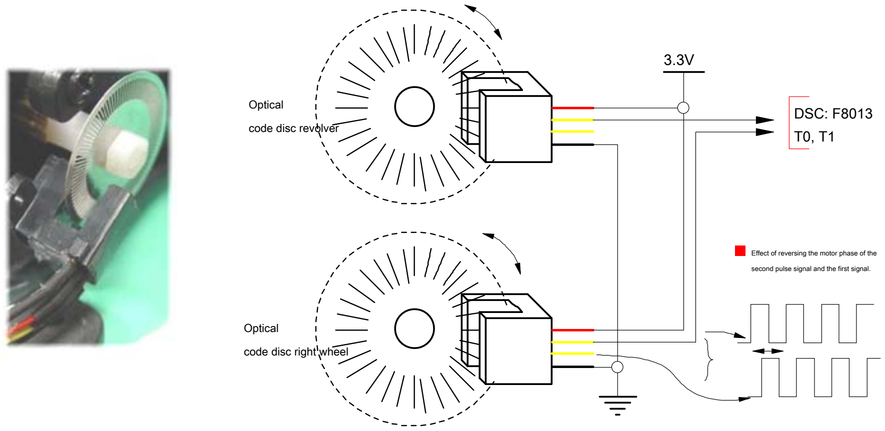


Map 3-9 Two 33886 A motor drive circuit

Map 3.9 In order to prevent the output current of the motor For the impact power, in the power input board (7.2V) A parallel port 1000 Microfarads capacitance.

3.5 Speed sensor circuit

So that the motor speed sensor Used in fixed optical encoder of the motor output shaft and on the photoelectric device cooperating Element, FIG. 3-10 Fig.


Optical
code disc revolver
3.3V
DSC: F8013
T0, T1
Effect of reversing the motor phase of the second pulse signal and the first signal.
Optical
code disc right wheel

Map 3-10 Speed sensor circuit

Since the pulse signal is directly output digital photocell device, can be connected directly to the pulse signals monolithic Machine counter port.

Each phototube outputs two pulse signals which are the same waveform, but out of phase 90 °. If the motor is transferred, The second pulse behind 90 [Deg.]; If reverse, the second pulse lead 90 °. This relationship can be judged by Whether reversing the motor. In the actual circuit, only one pulse signal is detected, the motor obtained by measuring its frequency Speed. A steering motor is determined by applying a negative voltage to the motor. Although the existence of inertia Cars In possible at low motor speed, the rotational direction of the motor and the voltage applied to its positive and negative may be different, Causing the inaccuracy motor speed. As the racing game game, in general, the motor is running at high speed like The state, the steering direction and the motor voltage is the same. Experimental verification by this method can effectively determine the motor Rotational direction and speed control.

3.6 Wire detecting circuit

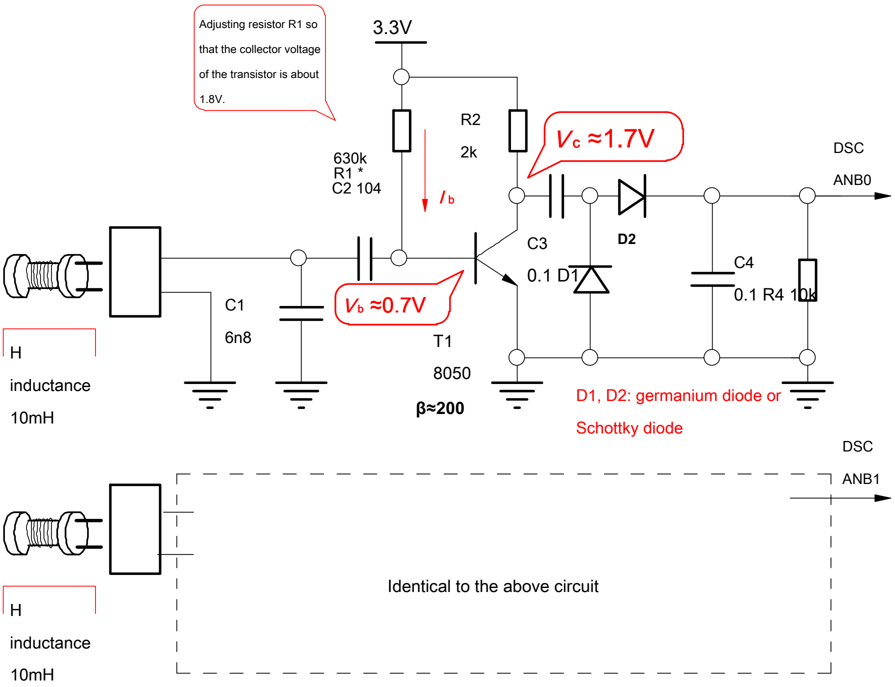
(1) Discrete components amplifying electromagnetic detector circuit

Wire road centerline detection is to ensure car models capable of running on the track. Since the electromagnetic group in the fifth race It has been set up, in 2010 In the competition secretariat published a reference design magnet wire detection. Detailed design principles See reference circuit and appendix.

Map 3-11 It shows a circuit diagram of its programs. The program uses a single-stage amplifying circuit of the transistor is electrically detected cascode Magnetic signal amplification stage is a voltage doubler rectifier circuit for detection can be obtained about the detected two induction coils The intensity of the magnetic field. In order to improve the sensitivity of the circuit, the transistor is greater than the cut-off frequency should be used 100MHz Current

Magnification greater than 200 Triode. Rectifying diodes are pressed using a low forward voltage of a germanium diode, or

Who Schottky diode.


Adjusting resistor R1 so that the collector voltage of the transistor is about 1.8V.
3.3V
R2
2k
630k
R1 *
C2 104
I_b
V_c ≈1.7V
DSC
ANB0
C3
0.1 D1
D2
C4
0.1 R4 10k
C1
6n8
V_b ≈0.7V
T1
8050
β≈200
H
inductance
10mH
D1, D2: germanium diode or Schottky diode
DSC
ANB1
Identical to the above circuit
H
inductance
10mH

Map 3-11 Detector circuit based on an electromagnetic signal amplifying transistor

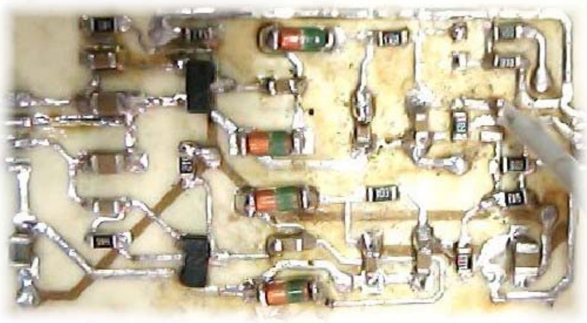
In order to ensure that the signal amplifying transistor amplifier dynamic range is large enough, the collector of the transistor need to be

In about half of the pressure regulating circuit voltage: $V_c = 3.3/2 = 1.65\ V$. This requires the base of the transistor by adjusting a bias electrode

In resistors R_1 Completed. The R_1 value may be calculated from the formula: $R_1 = \frac{V_{cc} - V_b}{I_b} = \frac{V_{cc} - V_b}{I_c / \beta}$ Wherein the collector current

$I_c = \frac{V_{cc} - V_c}{R_2}$. The circuit parameters into the computer can be obtained $R_1 \approx 630\ k\Omega$.

According to the above circuit diagram of the circuit fabricated as shown in FIG 3-12 Fig.



Map 3-12 Electromagnetic amplification transistor based physical map detector circuit

(2) Integrated operational amplifier amplifying an electromagnetic detector circuit

Amplifying triode electromagnetic detector circuit is simple and practical, it has been widely used in the game. If you need to enter Further improve the sensitivity of detection may add a transistor amplifier. Using discrete components triode Amplifying detector circuit has some drawbacks:

(1) To adjust the operating point of the voltage is complicated;

(2) Depends on the magnification circuit transistor current amplification factor and base-resistance, etc., more dispersed;

(3) Due to the forward voltage of the detection diode for the detection can not be performed very weak electromagnetic signals.

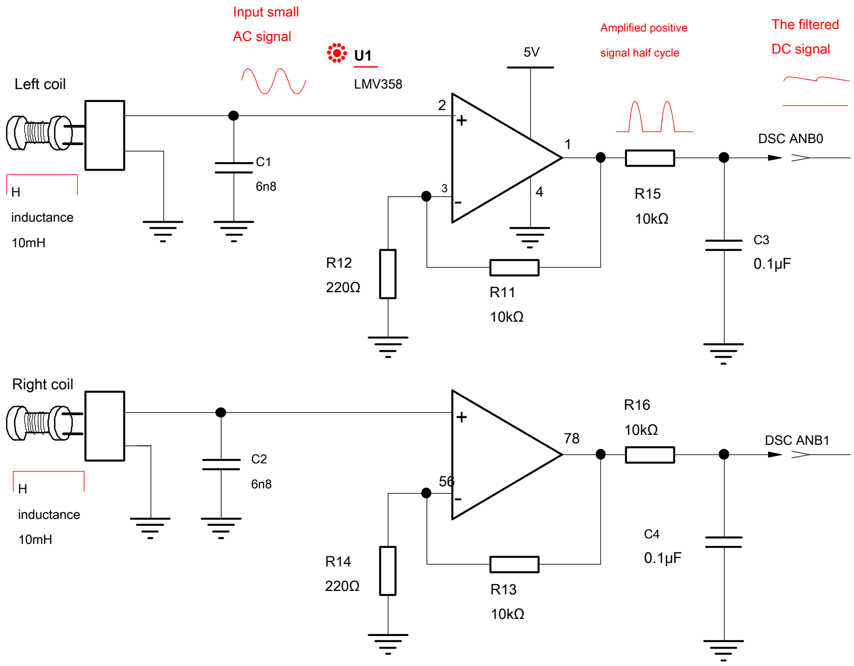
An integrated circuit can be simplified amplifier design, improve the performance of the circuit. Based on the output is given below Full voltage range (Rail-to-Rail, Electromagnetic rail to rail) amplifying operational amplifier detector circuit.

RR Amplifier generally operates in a single power supply, the output voltage range substantially close to the supply voltage and ground. Common-mode input voltage range. Commonly used to RR Including op amps LMV321 , LMV358 , LMV324 , AX4451 Wait. Please note that the previous names are three kinds of op amp LMV These op amps are prefixed LM Corresponding to models of the op amp. LMV And op amp LM Same op amp package pins, but LMV Full-scale output voltage of the output full voltage range. form 3-1 Gives LMV358 The main electrical properties, its common mode input voltage range may be lower than 0V .

form 3- 1 LMV358 Key Features

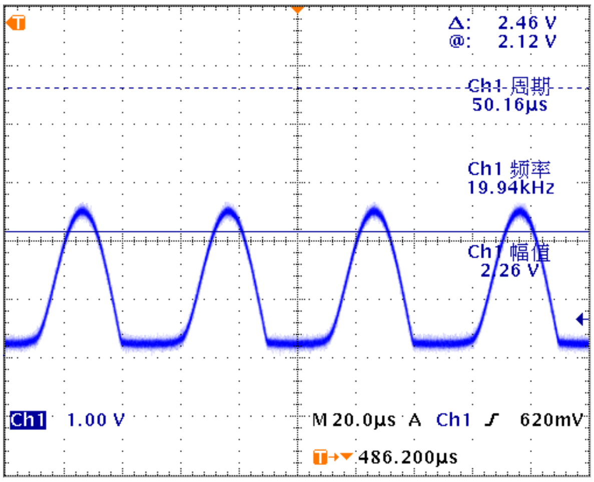
parameter	Test Conditions	Ranges	unit
Vcc : Working voltage (single power supply)		2.7 to 5.5	V
Vicr: Common-mode input range CMRR> 50db		-0.2 to 1.9	V
Output voltage range	RL = 10k	60 to Vcc-10	mV
B1: Unity gain bandwidth	CL = 200pF	1	MHz
Vio: Input offset voltage		1.7	mV

Map 3-13 It is based on RR Op amp LMV358 Amplifying electromagnetic detector circuit.


Input small
AC signal
U1
LMV358
5V
Amplified positive
signal half cycle
The filtered
DC signal
Left coil
H
inductance
10mH
C1
6n8
2
+
3
-
1
4
R15
10kΩ
DSC ANB0
C3
0.1μF
R12
220Ω
R11
10kΩ
Right coil
H
inductance
10mH
C2
6n8
+
56
-
78
R16
10kΩ
DSC ANB1
C4
0.1μF
R14
220Ω
R13
10kΩ

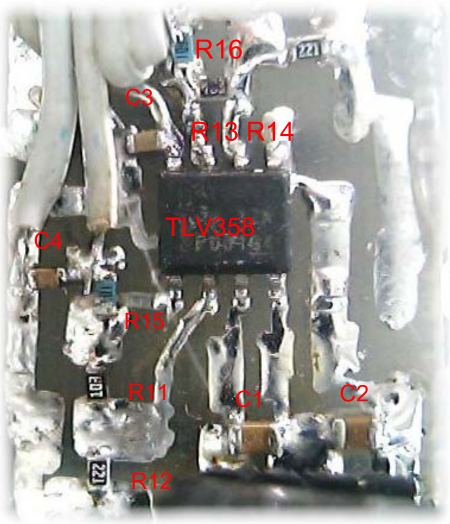
Map 3-13 use R-R Op amp amplifies an electromagnetic signal detector

In this circuit, the midpoint of the op amp is intentionally provided 0V , Amplifier signal into only the positive half cycle of the input signal Amplification line, the negative half cycle of the signal can not be amplified. Amplifier for amplifying a signal also completed with detector (half Week detection). After the detection signal RC Filtering the signal obtained after the DC component, to detect the microcontroller. Map 3-14 It is a circuit for amplifying the detection waveform.


Δ: 2.46 V
@: 2.12 V
Ch1 周期
50.16μs
Ch1 频率
19.94kHz
Ch1 幅值
2.26 V
Ch1 1.00 V
M 20.0μs A Ch1 ∫ 620mV
486.200μs

Map 3- 14 LMV358 Amplifying the detection output waveform

The figure is based on LMV358 FIG detector circuit amplifying two physical channels electromagnetic induction design.



Map 3-15 based on LMV358 FIG detector circuit amplifying two physical channels

Since the operational amplifier common mode input voltage range may be less than 0V , So that the weak signals for a circuit with a very good The amplification and detection performance. Magnification is determined by the feedback resistor circuit network, stable. Since the detection field Direct access to the resonant circuit inductor positive input terminal of the operational amplifier, very high input impedance, thereby improving the product of the reso The quality factor (Q Value), such that the input frequency selection capability greatly enhanced.

Since the half-wave detection signal when the output signal, the maximum value of the output signal does not exceed half of the power operational amplifier. In order to improve the dynamic range of the signal amplifying circuit voltage of the op amp is selected 5V .

Since the frequency of the signal is 20kHz So choose RR Op amp's unity gain bandwidth must be large enough, this For samples in order to ensure 20kHz Signal amplification capability, it is recommended operational amplifier unity gain bandwidth greater than at least 1MHz .

3.7 Angle calculation circuit

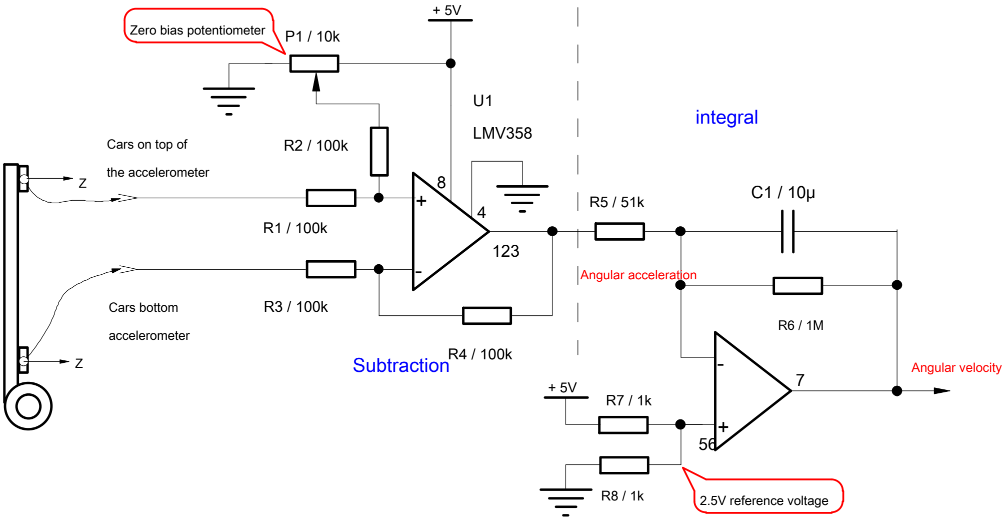
In principle, there are two control car models car models described in chapter angle and angular velocity measurement method, by first gyroscope And an acceleration sensor device is achieved, the second may be achieved by two acceleration sensors. After the angular velocity feedback Points can obtain a smooth angle signal coincides with the acceleration sensor. This signal processing section may be performed by the microcontroller Software to complete the operational amplifier circuit may be implemented by an external. This section shows that part of the signal processing circuit implementatio formula.

(1) Was calculated from the acceleration sensor an angular velocity double

according to 2.3 Cars introduced angle measuring section, mounted on the top and bottom of the car models two acceleration sensors

MMA7260 of Z Axis signal through subtraction, it is possible to obtain the angular acceleration of the car models. This signal can be integrated

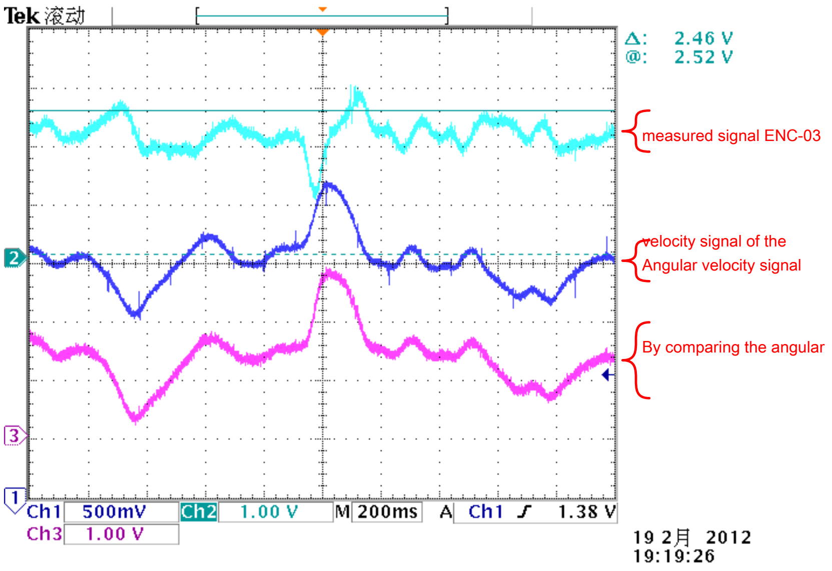
To obtain an angular velocity of car models. Map 3-16 It shows implementation of.


Zero bias potentiometer
P1 / 10k
+ 5V
U1
LMV358
integral
Cars on top of
the accelerometer
R2 / 100k
Z
8
+
R5 / 51k
C1 / 10µ
4
R1 / 100k
123
Angular acceleration
-
Cars bottom
accelerometer
R3 / 100k
R6 / 1M
Z
R4 / 100k
Subtraction
-
7
Angular velocity
+ 5V
R7 / 1k
+
56
R8 / 1k
2.5V reference voltage

Map 3-16 Double angular velocity acceleration measurement circuit

The above circuit diagram consists of two parts, first part is to achieve signal subtraction to obtain the angular acceleration of the car models. The first

The second part is integral calculation to obtain the angular velocity of car models. The figure is a waveform diagram of the actual signal.



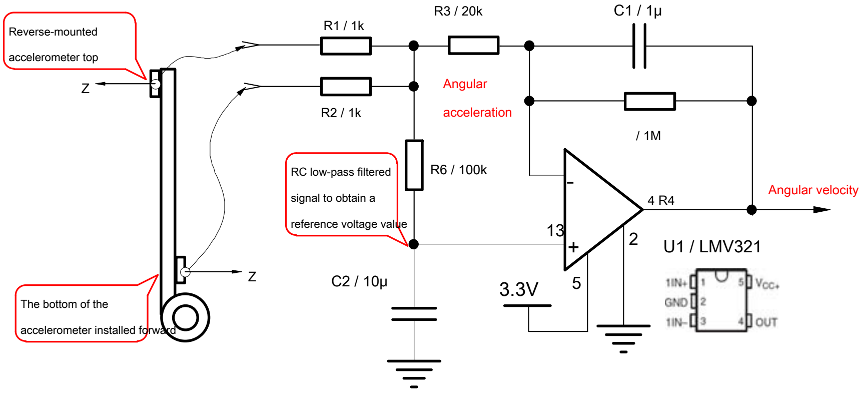
Map 3-17 Dual accelerometer waveform diagram measured angle

In order to verify the performance of the circuit, FIG. 3-17 Also mounted on the simultaneous acquisition of car models ENC-03 The measurement signal.

As can be seen from the waveform of the wave angular velocity obtained by the acceleration sensor and the angular velocity of the car models integrating gyro meas

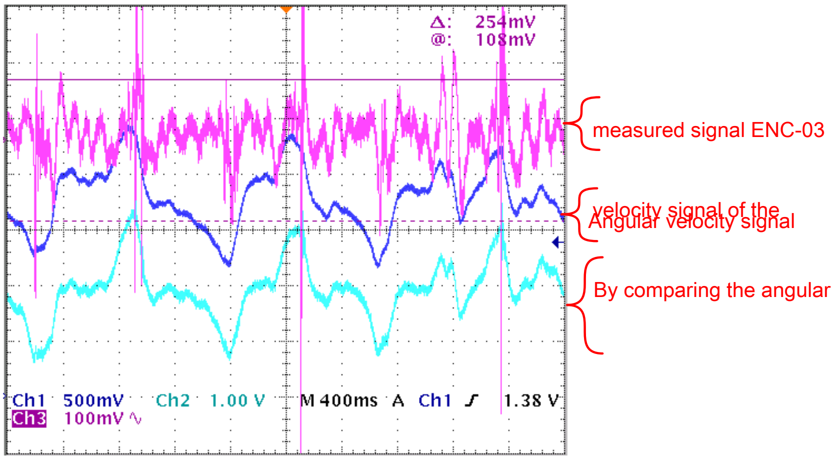
Shape is the same, the method is validated.

To further simplify the circuit, the acceleration sensor may be mounted on top of car models reverse, so the top of the sensor Device Z Variable axis signal and then the bottom of the acceleration sensor signal symbol contrast, as long as the two overlapping signals through a resistor Together subtraction signal can be realized, whereby the circuit can be further simplified as 3-18 Fig.


Reverse-mounted accelerometer top
Z
R1 / 1k
R2 / 1k
R3 / 20k
C1 / 1μ
Angular acceleration
/ 1M
R6 / 100k
RC low-pass filtered signal to obtain a reference voltage value
Angular velocity
4 R4
13
2
5
U1 / LMV321
C2 / 10μ
3.3V
Z
The bottom of the accelerometer installed forward
1IN+
GND
1IN-
1
2
3
5
4
VCC+
OUT

Map 3-18 An angular velocity simplified circuit

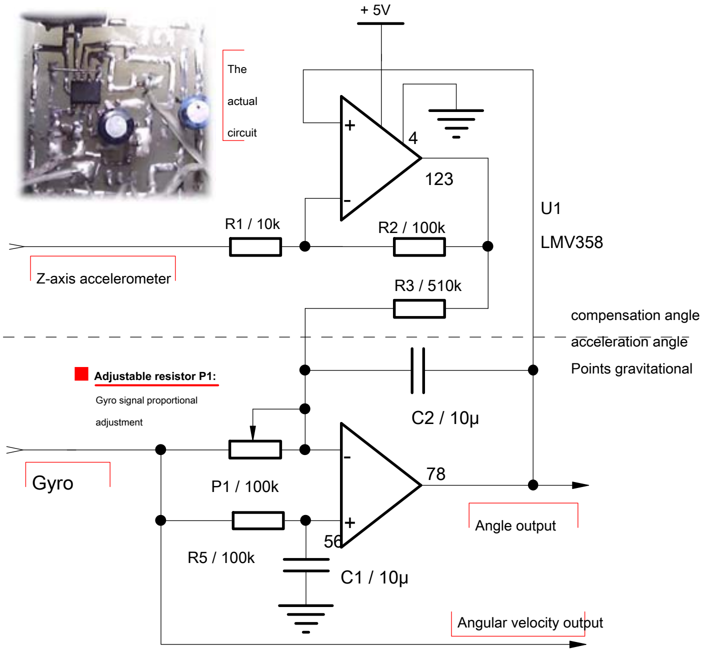
The following figure is an observed signal to each part of the simplified circuit oscilloscope, fixed on the same car model ENC-03 Comparison of the output signal, can verify the correctness of the simplified circuit of acceleration.



Map 3-19 Found an angular velocity signal waveform Cars

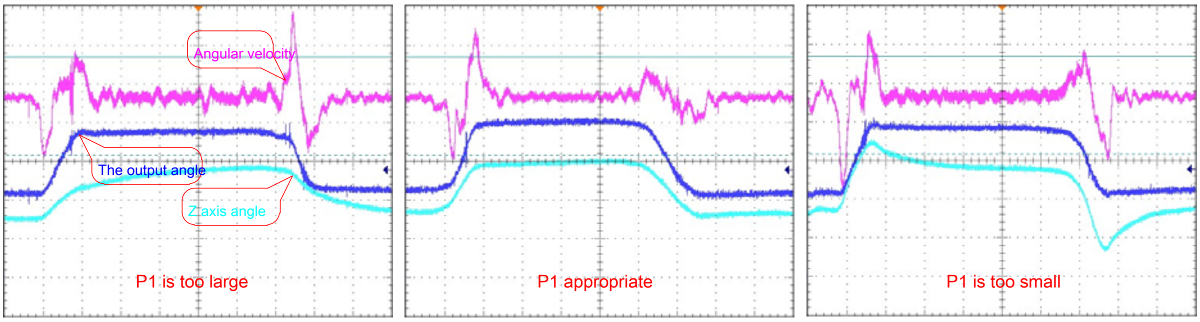
(2) Angle calculation circuit

according to 2.3 Described in section, by integrating the angular velocity signal can be obtained Cars angle. In order to suppress Drift and the drift of the angular velocity signal of the integrating circuit, the acceleration sensor according to the need to give the Z Angular axis signal Correction of the signal. Map 3-20 Circuit is to obtain an angle signal processing circuit block diagram of a signal processing according to the previously described.


+ 5V
The actual circuit
+
-
4
123
U1
LMV358
R1 / 10k
R2 / 100k
Z-axis accelerometer
R3 / 510k
compensation angle
acceleration angle
Points gravitational
Adjustable resistor P1:
Gyro signal proportional adjustment
C2 / 10μ
Gyro
P1 / 100k
-
+
78
Angle output
R5 / 100k
56
C1 / 10μ
Angular velocity output

Map 3-20 An angle signal processing circuit

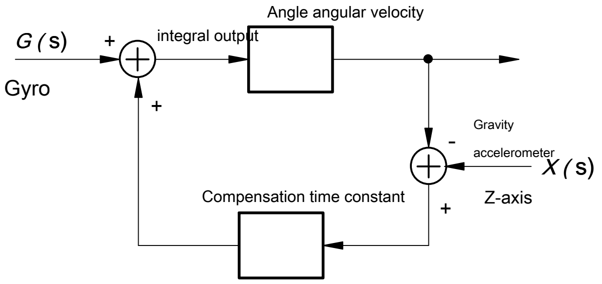
The circuit consists of two parts, the angular integration compensation circuit and the gravitational acceleration. Potentiometer P1 Size can be changed VARIABLE PROPORTION angular velocity. P1 Larger proportion of the angular velocity value is smaller; P1 The smaller the value the greater the ratio of the angula Overshoot P1 So that the angle of the output of the acceleration sensor can be well tracked Z Signal output shaft. The following figure shows the different of P1 Angle of the output value corresponding circuit trace Z Axis signal of the case. P1 Is too large, the output angle tracking Z Axis slow. P1 Is too large, the output angle tracking Z Axis overshoot. P1 When adjusted to the appropriate value, and can output an angle Z Output shaft Consistency, while the signal is very smooth.



Map 3-21 An angular velocity ratio of the output waveform under different circumstances

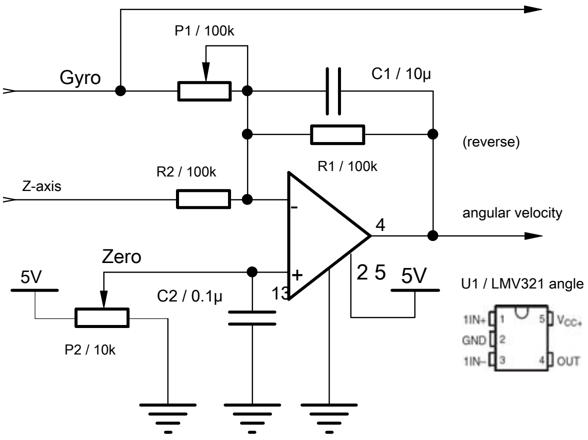
To further simplify the circuit implementation, analysis angle calculation part transfer function (FIG. 3-22 Shown). angle The count output by the accelerometer and a gyroscope Z Axis signal through a first-order inertia superposition. So you can just use An op amp can complete the calculation of the angle, the above circuit can be simplified, the simplified circuit of FIG. 3-23

Fig.


G(s)
Gyro
+
+
integral output
Angle angular velocity
Gravity
accelerometer
-
X(s)
Z-axis
+
Compensation time constant

Map 3-22 Angle calculation link transfer function

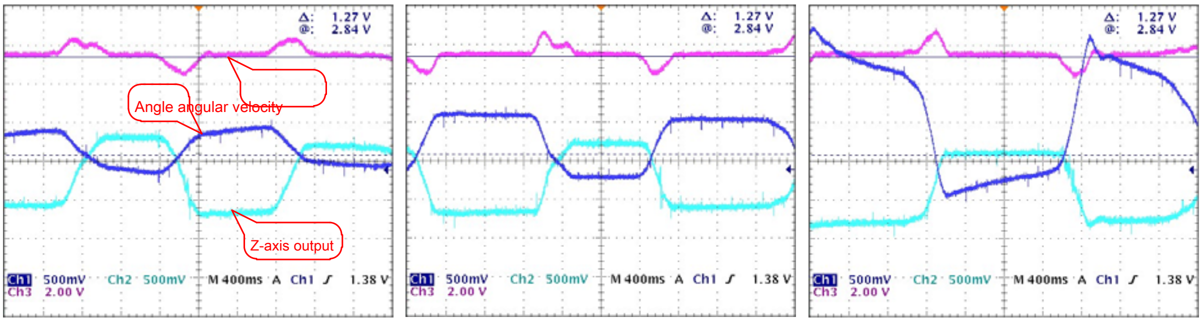
The following figure shows the use of an operational amplifier circuit calculates an angle. And function of the circuit of FIG. 3-22 The same one of. Wherein the potentiometer P1 Ratio can be adjusted gyroscope factor.


P1 / 100k
Gyro
C1 / 10μ
(reverse)
R1 / 100k
R2 / 100k
Z-axis
-
4
angular velocity
Zero
5V
+
C2 / 0.1μ
13
2 5
5V
U1 / LMV321 angle
P2 / 10k
1IN+
GND
1IN−
1
2
3
5
4
VCC+
OUT

Map 3-23 Angle calculating an operational amplifier to achieve

Map 3-24 It gives a different P1 Corresponding resistance circuit output. P1 Value is too large, a small proportion of the corresponding accelerometer angles Tracking of output Z The output shaft is relatively slow. in case P1 We had only a small, corresponding to a large proportion of the accelerometer, the output angle ov

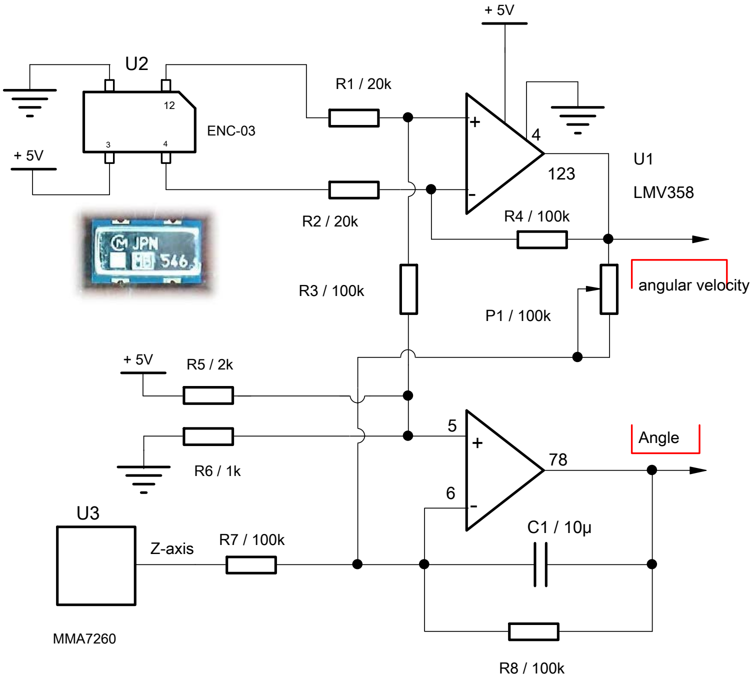
By adjusting P1 Tracking angle output can be obtained faster without overshoot. Since only one op amp, so Polarity opposite to the angle and the angular velocity of the output circuit, so when the microcontroller requires software processing by software changes The polarity of the angular velocity.



P1 value is too large P1 moderate value P1 value is too small

Map 3-24 different P1 Output waveform corresponding to the resistance

According to the previous design, the angle of measurement and signal processing can be combined to form a unified to simplify the circuit. Figure 3-25 Fig. The circuit may output the angular velocity values and the angle of car models. Angle signal through hardware processing, You can simplify programming and debugging, improve software reliability, speed up the process of making car models for beginners. So this part Cars circuit for beginners.

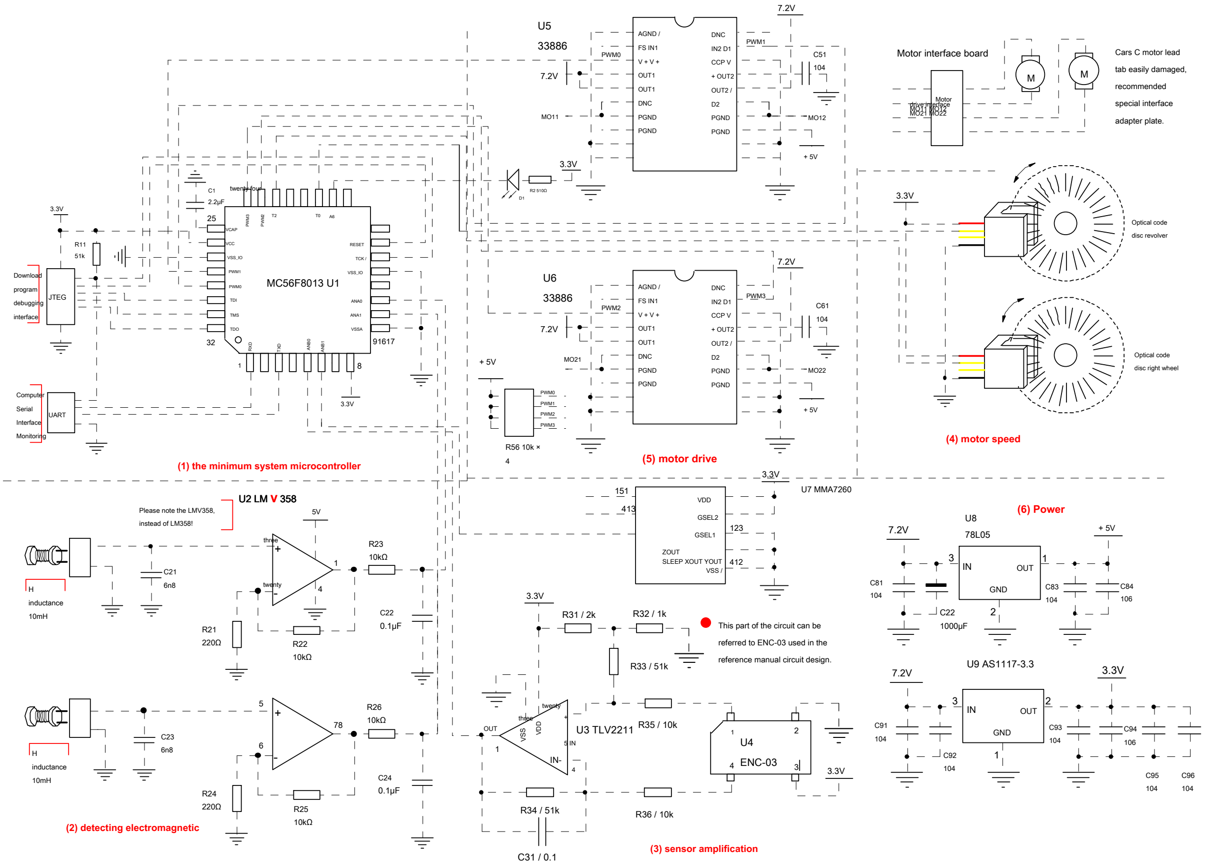

+ 5V
U2
12
3
4
ENC-03
+ 5V
R1 / 20k
R2 / 20k
+
-
4
123
U1
LMV358
R4 / 100k
R3 / 100k
P1 / 100k
angular velocity
+ 5V
R5 / 2k
R6 / 1k
5
+
6
-
78
Angle
U3
Z-axis
R7 / 100k
C1 / 10μ
MMA7260
R8 / 100k

Map 3-25 Simplified processing circuit angle and the angular velocity

Circuits through the above parts actually, the upright may be achieved in the control of car models.

3.8 Cars full control circuit of FIG.

Summary circuit design of the various parts of the front, the final selection of a full car models control circuit shown in Figure 3-26 Fig.


U5
33886
7.2V
PWM0
MO11
AGND /
FS IN1
V + V +
OUT1
OUT1
DNC
PGND
PGND
DNC
IN2 D1
CCP V
+ OUT2
OUT2 /
D2
PGND
PGND
PWM1
C51
104
MO12
+ 5V
3.3V
D1
R2 510Ω
Motor interface board
Motor
Drive interface
MO11 MO12
MO21 MO22
M
M
Cars C motor lead tab easily damaged, recommended special interface adapter plate.
3.3V
R11
51k
C1
2.2μF
25
twenty-four
Download program debugging interface
JTEG
MC56F8013 U1
32
1
8
91617
RESET
VCAP
VCC
VSS_IO
PWM1
PWM0
TDI
TMS
TDO
TCK /
VSS_IO
ANA0
ANA1
VSSA
3.3V
Computer Serial Interface Monitoring
UART
(1) the minimum system microcontroller
U6
33886
7.2V
PWM2
MO21
PWM3
C61
104
MO22
+ 5V
PWM0
PWM1
PWM2
PWM3
R56 10k ×
4
(5) motor drive
Optical code disc revolver
Optical code disc right wheel
(4) motor speed
U2 LM V 358
Please note the LMV358, instead of LM358!
5V
three
twenty
1
4
R23
10kΩ
C21
6n8
H
inductance
10mH
R21
220Ω
R22
10kΩ
C22
0.1μF
5
6
78
R26
10kΩ
C23
6n8
H
inductance
10mH
R24
220Ω
R25
10kΩ
C24
0.1μF
(2) detecting electromagnetic
3.3V
151
413
VDD
GSEL2
GSEL1
ZOUT
SLEEP XOUT YOUT
VSS /
123
412
U7 MMA7260
3.3V
R31 / 2k
R32 / 1k
R33 / 51k
This part of the circuit can be referred to ENC-03 used in the reference manual circuit design.
OUT
VSS
VDD
U3 TLV2211
R35 / 10k
U4
ENC-03
3.3V
R34 / 51k
R36 / 10k
C31 / 0.1
(3) sensor amplification
(6) Power
U8
78L05
7.2V
+ 5V
IN
OUT
GND
C81
104
C22
1000μF
C83
104
C84
106
U9 AS1117-3.3
7.2V
3.3V
C91
104
C92
104
C93
104
C94
106
C95
104
C96
104

Map 3-26 Cars full control circuit of FIG.

The control circuit includes a digital circuit and an analog circuit, a small signal circuit and power circuit. When designing a circuit board, All integrated circuit may be implemented in a circuit board, the block can be broken down into several circuits were produced. From circuit Schematic design of the circuit board, not only the attention of the logic function circuit board traces, the circuit board also need to consider cloth Line, to prevent mutual interference between the various parts of the circuit, the circuit to ensure stable and reliable.

Not related to the debug circuitry associated with the above circuits, the following debugging in fact used to Microcontroller serial port, the other two AD Input port (ANA2, ANB2) And other resources. We can according to their own The commissioning program design is complete contents of this section

Map 3-26 Angle calculation circuit circuit is not for angle measurement part is performed by the internal microcontroller software.

Above gives the main control circuit of the circuit design of car models, in addition to the need to design a power management circuit, parameter setting The monitoring circuit is set, and operation program debugging interface circuit. Students can contest the previous technical report in accordance with Off design.

The fourth chapter, mechanical design articles

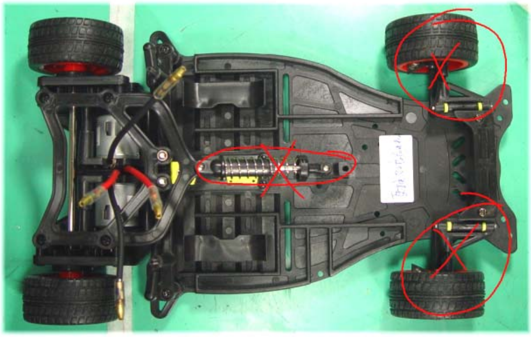
Good mechanical design and production of car models, car models for stable operation, security debugging is very important. As far as Cars simplify modification and the sensor mounting two aspects discussed.

4.1 Cars simplify modification

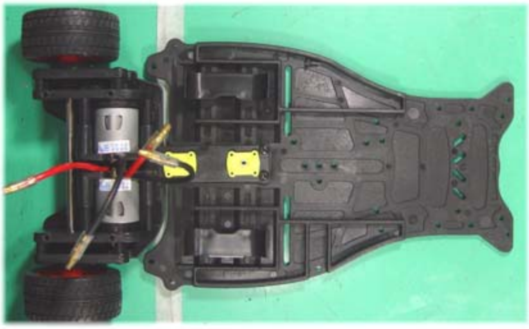
Since this year, the original use of the electromagnetic group race car models C Type of car models, which is a two-wheel drive, front wheel steering servos Sport mode, and competition regulations C Cars upright type, so the front car models and some associated components may be simplify. Specific reference to the following modified steps:

(1) And remove the front wheel support member, a buffer to remove the rear wheel suspension bracket

Where disassembled as shown in FIG.



Map 4-1 complete C Type chassis Cars

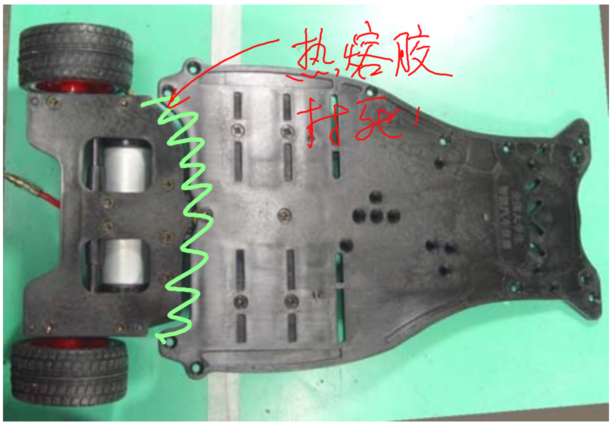


Map 4-2 Simplified C Type chassis Cars

(2) Fixed to the chassis and the rear wheel bracket Cars

In order to alleviate the existing car models rear impact vibration of the vehicle body, using a movable connecting between the bracket and the rear wheel cha Access way. However, to ensure the stability of the vehicle body upright car models, it requires the original car models with the rear wheel bracket to the site together. The most convenient way is to use hot melt adhesive at the gap between the rear bracket and the chassis are bonded. This

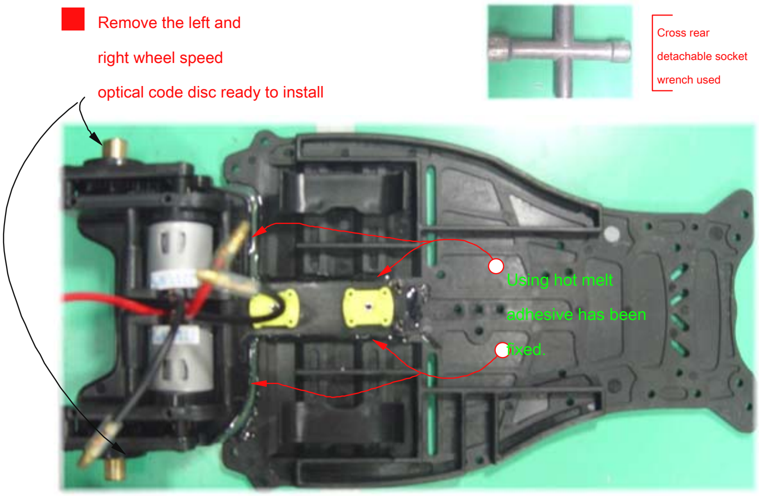
Between the vehicle body and the wheel-like forming a rigid, upright facilitate control. Map 4-3 It shows the position of the hot melt adhesive.



Map 4-3 And hot melt adhesive used to fix the motor car models chassis bracket

(3) To remove the rear wheel, the motor speed ready to install an optical code disc

Removable rear cross socket wrench can be used with the original car models. FIG disassembled Cars 4-4 Fig.


🟥 Remove the left and
right wheel speed
optical code disc ready to install

Cross rear
detachable socket
wrench used

Map 4-4 After removing the rear wheel chassis Cars

In Fig. 4-4 Please note that the use of hot melt adhesive fixing bracket and the rear wheel chassis car models.

After installing the speed sensor, and then again two rear wheels mounted to the rear bracket.

Please note that the rules of the game change for car models chassis limitations do not allow the use of other materials into the chassis for Cars

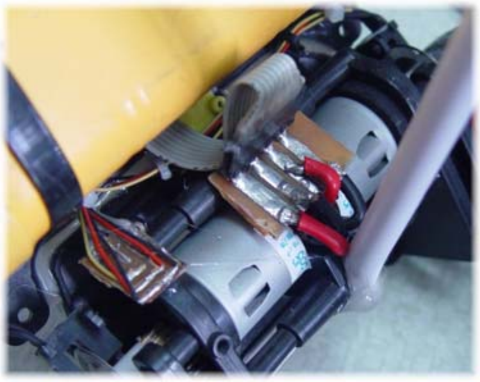
Line larger changes.

(4) Reinforced motor lead

C Cars rear wheel motor lead pin is very thin, easily broken after repeatedly shaking from the roots, causing no motor

Method to use. It proposed to add a motor adapter plate, welding the first lead of the motor adapter plate and the adapter plate solid

It does not cause breakage of the motor lead when held on the motor car models or scaffold floor, disassembly of such a circuit board.



Map 4-5 Motor lead adapter plate

Of course, the composite may be used as hot melt adhesive or glue for fixing the motor lead pin encapsulation, may be

It can protect the motor leads.

Further, the metal shaft coaxially with the drive motor in fact there is not much effect, if the installation for other purposes

You can also remove them.

4.2 Sensor Installation

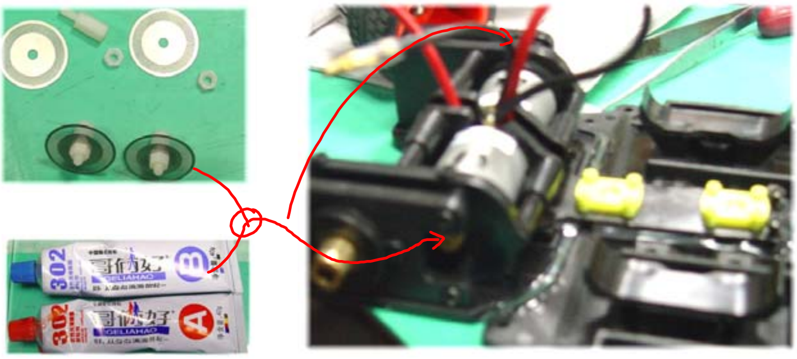
Cars in the sensor comprising: a speed sensor, an attitude sensor Cars (gyroscopes, accelerometers) to

And detecting an electromagnetic induction coil. The following describes the installation of these sensors.

(1) Speed sensor mounted

The speed sensor is mounted on the output shaft of the drive motor and optical encoder for cooperating photoelectric tube. Fixed light

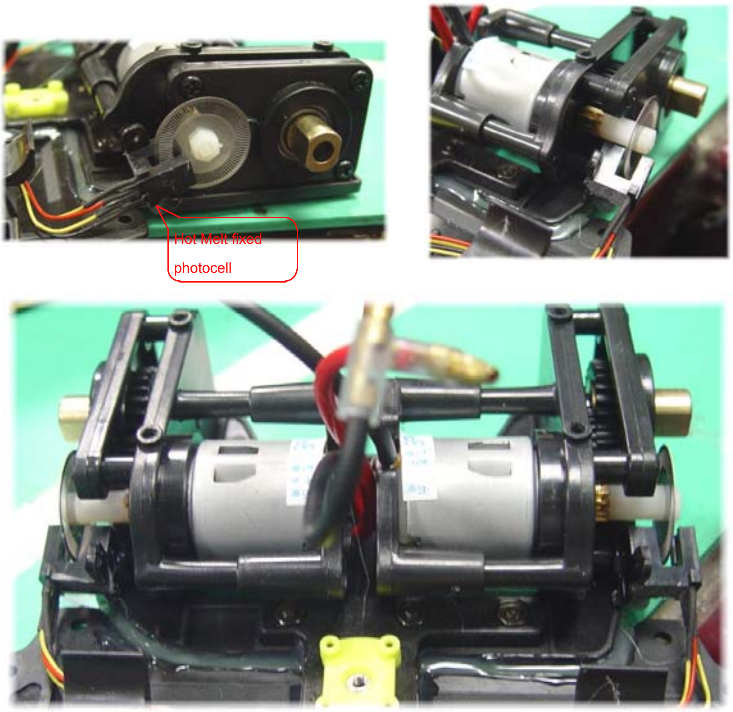
Code disc may use composite glue, the plastic shaft the output shaft of the motor photoelectric encoder adhesive. Figure 4-6 Fig.



Map 4-6 Composite glue fixed optical encoder disk

After bonding code disc, and then fixed on the photoelectric detector. The hot melt adhesive may be used on the photoelectric fastened to the rear bracket

Fixed photoelectric tube, such that the optical encoder of the intermediate tube by a gap. Figure 4-7 Fig.



Map 4-7 Good fixing photoelectric encoder and the photodetector tube

Please note that the fixed code disc must be better use of the thermal stability of the composite glue, such as "two brothers." due to

Motor heat during operation, and the large vibrations, so do not use hot melt adhesive fixed code disk.

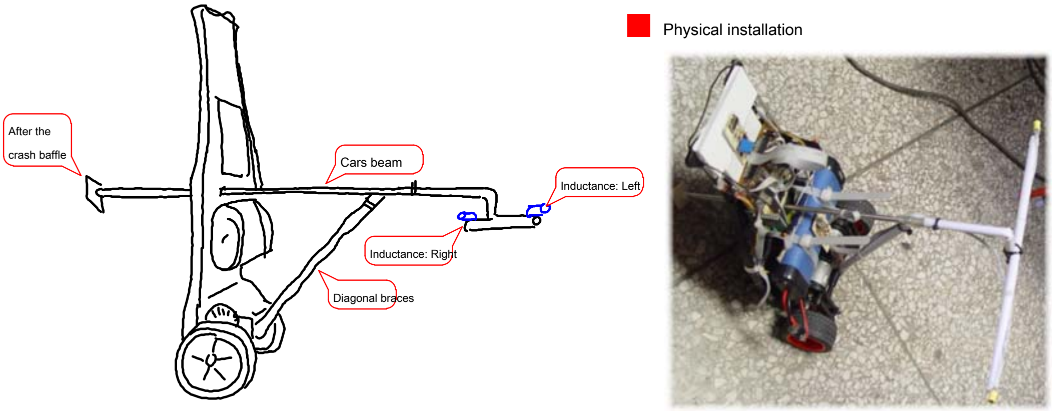
After completion of the above-described fixed speed sensor, a rear wheel can be re-mounted to the rear bracket.

(2) Electromagnetic sensor mounted

An electromagnetic sensor of the present embodiment designed for the two I-shaped 10 MH inductance. In order to better detected before

Road surface, generally the two I-shaped inductance as possible installed in front of the local car models run farther. due to

Cars run upright, the program may be considered as follows with reference to FIG. 4-8 Fig.



Map 4-8 Electromagnetic sensor holder

Please note that the competition rules to limit the dimensions of the car models. Since the tournament only limits the width of the car models,

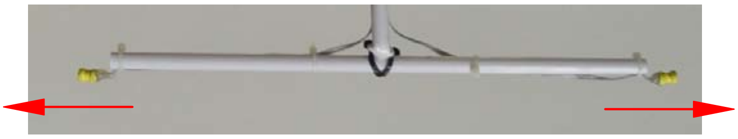
To less than 25 cm. For Cars no length and height restrictions.

Because the tournament does not require car models automatically stop at three meters on the track after the race finished after its implementation, and there

Without detecting the starting line of the permanent magnet track.

To avoid the influence of car models by crossed lines through the mouth, the two induction coils fixed time,

Try to keep the two coils in a horizontal position, and in a straight line, as shown below.

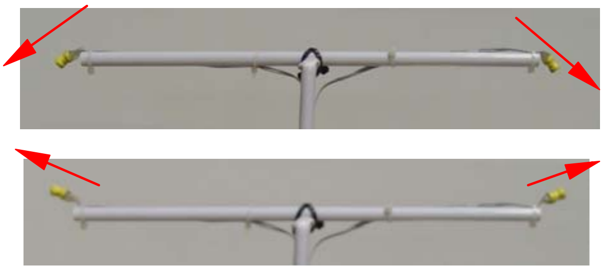


Map 4-9 An electromagnetic coil mounted horizontally

If the electromagnetic coil is mounted not on the same horizontal line, then the cross car models when crossing an intersection, the level of

In the wire direction of the magnetic field induced electromotive force is generated on the additional two coils. The electromotive force will cause the car

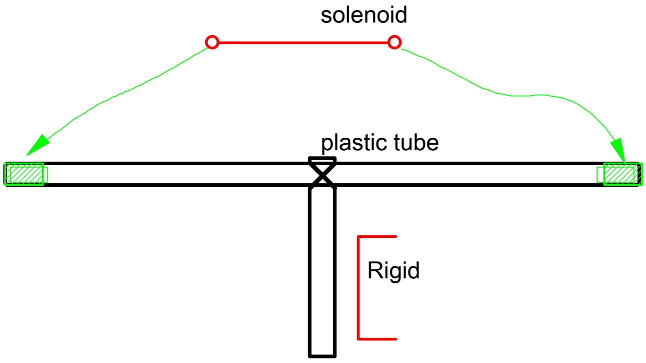
Direction control mode instability.



Map 4-10 An electromagnetic coil mounted not on the same horizontal line

Since the electromagnetic coil at the forefront of car models, we ran out of control track car models after striking other objects were first

An electromagnetic induction coil is broken. In order to protect the electromagnetic induction coil, such that they can at the same time in a horizontal linear Line, can be used hard plastic tube solenoid packaged together. As shown below:



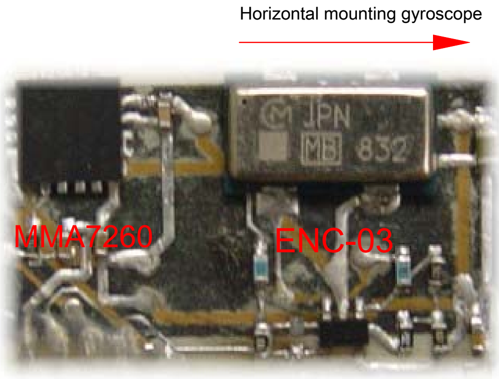
Map 4-11 Plastic pipe with a hard package electromagnetic induction coil

If more than two magnetic detection coil, also conceivable to use other bracket way to increase sensor Strength of the stent.

(3) Cars tilt sensor

Cars tilt sensor includes a gyroscope and an accelerometer. They are surface-mount components, generally fixed at the same potential Road board. The board is recommended with a gyroscope and an accelerometer fixed in position throughout the middle car models centroid, Or bottom of the car models, thus reducing interference with the measurement by vibrating the inclination Cars run maximally.

Should try to ensure that when a gyro sensor is mounted horizontally mounting angle of the sensor circuit board.



Map 4-12 Horizontal mounting gyroscope

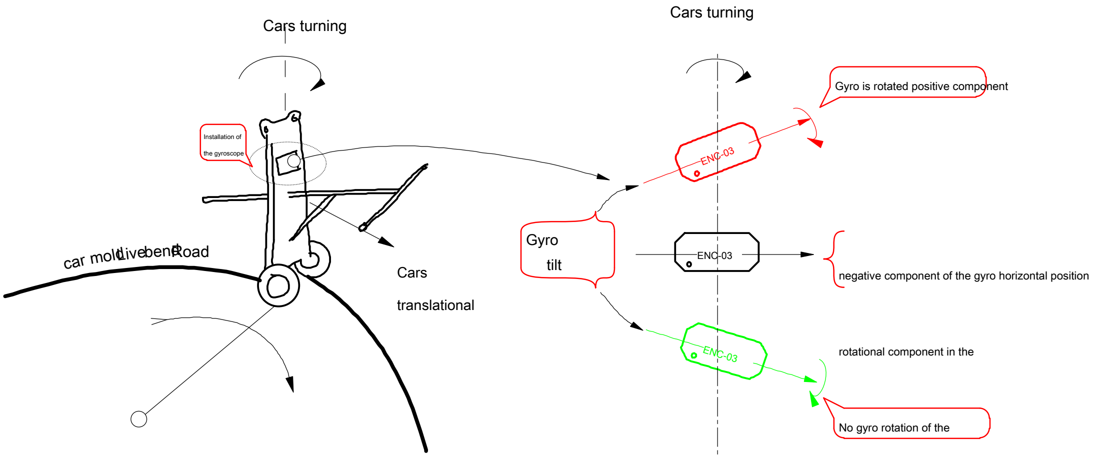
If the gyro installation is not able to guarantee the level, it will affect car models over speed corners. The performance of car models in the past When the curve becomes faster or slower speed. Analysis has both car models such that movement in the corners, the corners in Cars

Motion: translation and rotation. Which will lead to the rotation gyroscope rotation. If the gyro installation is not the absolute level, that

What will be in the rotation gyroscope Z There is a component of the axial direction. According to the gyro different inclination, this

There may be a positive component, there may be negative. Cars will be controlled so that the "feel as if the uphill or downhill"

Causing slow speed car model or faster.


Cars turning
Cars turning
Installation of the gyroscope
car mold
Live
bend
Road
Cars translational
Gyro tilt
ENC-03
ENC-03
ENC-03
Gyro is rotated positive component
negative component of the gyro horizontal position
rotational component in the
No gyro rotation of the

Map 4-13 Cars influence gyro installation angle the corners

4 , Steering speed gyroscope Cars

Cars steering speed sensor is used to control the differential direction, a direction to eliminate the overshoot control.

The gyroscope rotation shaft and a vertical longitudinal axis gyroscope requires consistent. If the steering does not require car models

Differential control, then this sensor can be omitted.

4.3 Precautions

Cars run since the upright, in the production of a circuit board to reduce the size of the circuit board as far as possible, on the one hand to facilitate solid

Set, on the other hand can reduce the inertia of car models.

Fixing the circuit board to be close to the chassis as car models, it is possible to secure.

In order to avoid during the pouring operation Cars, Cars and broke the circuit board, when in the mechanical design of car models,

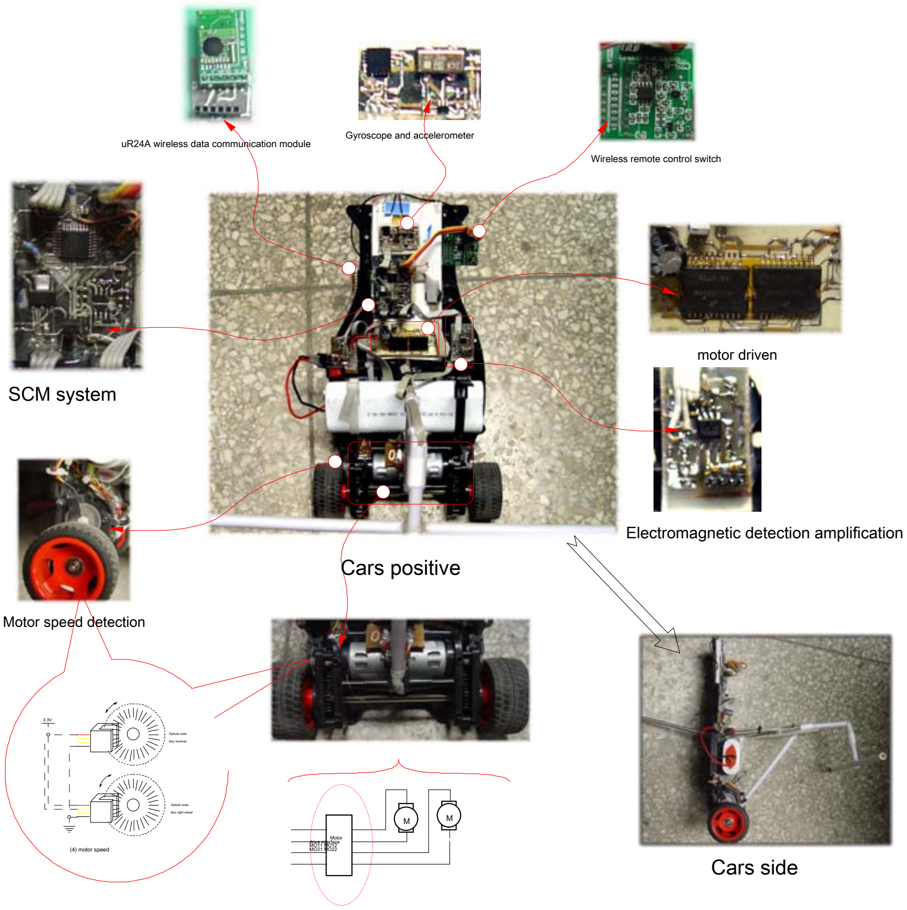
Cars need to be considered before and after the mounting bracket or the anti-collision cushion, once out of control or dump car models, the stent may crash

To protect the safety of car models machinery.

In addition, the car models may be mounted on the fall collision detection switch holder, once poured car models, the control circuit will be established

That is, stop running. Wireless remote control switch may also be used, such car models can emergency brake, thereby avoiding runaway due Cars

Impact damage. Map 4-9 Shows a case where the reference test design after assembly of car models.


uR24A wireless data communication module
Gyroscope and accelerometer
Wireless remote control switch
SCM system
motor driven
Electromagnetic detection amplification
Cars positive
Motor speed detection
Cars side
3.3V
(4) motor speed
M
M

Map 4-9 Cars assembled full image

Chapter V, software development articles

By the foregoing description, the control circuit production and installation of car models have been completed. Cars whether the normal high-speed stability Run, you need to control the software debugging and car models by writing to complete. The main tasks include the development of software:

(1) Established software engineering, configuration DSC Resources, the preparation of the preliminary program of the main frame;

(2) The preparation of PC monitoring software, build software to compile, download, debug environment;

(3) Prepared to achieve each sub-module, and test the functional correctness of each sub-module;

(4) By the initial debugging program, verify the correctness of the control circuit board.

Freescale Development 56800 / E series DSC SCM application can use CodeWarrior integrated Development environment (CodeWarrior for 56800 / E Digital Signal Controllers , The current version v5.9). And other Version of CodeWrrior same, DSC Version CodeWarrior Also provides Processeor Expert Function modules, To produce a microcontroller through project configuration is very easy to various peripheral initialization code and interface program to help develop

It will focus on application development.

5.1 Software function and framework

The main features of the software include: (1) Acquiring sensor signals, the process;

(2) Motor PWM Output;

(3) Cars run control: vertical control, speed control, direction control;

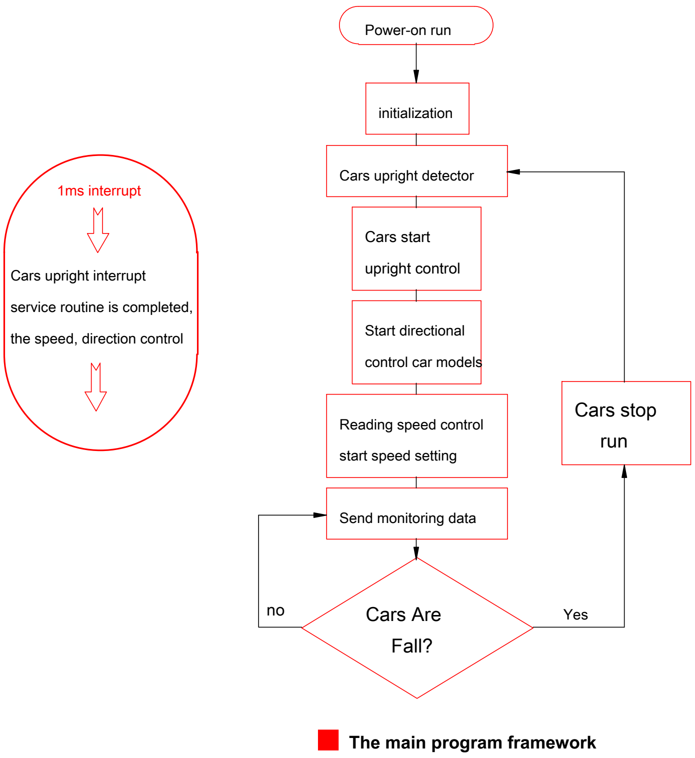
(4) Cars run process control: program initialization, start and end car models, car models status monitoring;

(5) Cars display setting information and parameters: status display, PC monitor, parameter settings and the like.

The above-described functions may be divided into two categories:

The first category includes 1-3 Function, they are in need of precise time period of execution, a timing cycle can be Interruption in the completion. The second category includes 4-5 Features. It does not require precise execution time period. It can be placed in the program The main program is completed. We can communicate with each other through the global variables between these two types of tasks.

The main program frameworks such as **error! Reference source not found.** Fig.


1ms interrupt
Cars upright interrupt service routine is completed, the speed, direction control
Power-on run
initialization
Cars upright detector
Cars start upright control
Start directional control car models
Reading speed control start speed setting
Send monitoring data
Cars Are Fall?
no
Yes
Cars stop run
🟥 The main program framework

Map 5-1 The main program framework

error! Reference source not found. After, the power to run the program, then initialize the microcontroller. Initialization work

It comprises two parts, one for each application to initialize the module microcontroller. This part of the code consists of

CodeWarrior Integrated Environment ProcessorExpert Tool generates. The second part is the application initialization is

Cars in the application to the control program values of variables are initialized.

After initialization, the upright first enters Cars detection subroutine. The program read by the accelerometer value determination

Cars off is in an upright state. Once in the upright position if the starting upright Cars control, direction control, and

speed control.

Continuously monitoring data transmission program in the primary cycle, is sent to the host computer through the serial port is monitored. Also check

Cars whether the fall. Fall can be determined by determining whether the tilt angle exceeds a certain range of car models, or by mounting

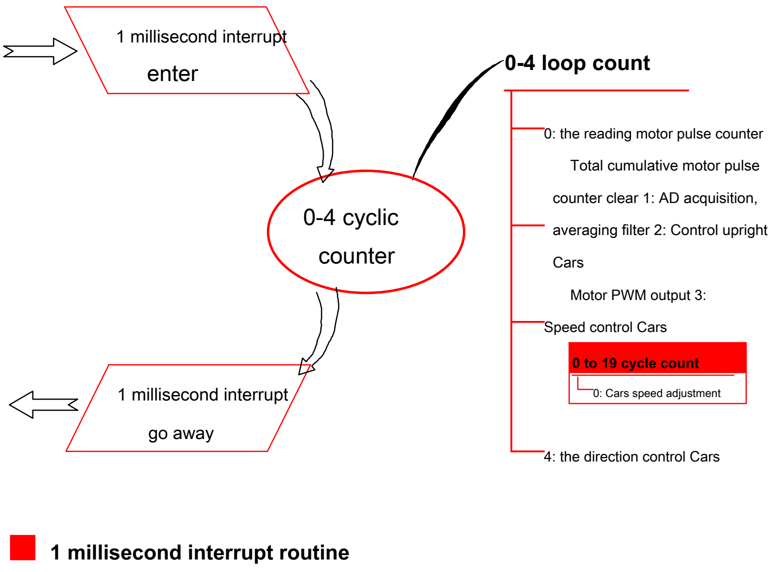
Cars before and after the micro switch holder on a collision is determined. Cars must fall, stop the car model run. Including Cars

Vertical control, speed control and direction control. Then re-enter the car models upstanding determination process.

Car models upstanding control, speed control and direction control is done in the interrupt program. By global flag change

Determine whether the amount of these closed-loop control.

Interrupt program framework shown in Figure 5.2 Fig.


1 millisecond interrupt
enter
0-4 loop count
0: the reading motor pulse counter
Total cumulative motor pulse
counter clear 1: AD acquisition,
averaging filter 2: Control upright
Cars
Motor PWM output 3:
Speed control Cars
0 to 19 cycle count
0: Cars speed adjustment
4: the direction control Cars
0-4 cyclic
counter
1 millisecond interrupt
go away
1 millisecond interrupt routine

Map 5-2 Interrupt service routine

Map 5-2 Using DSC A timer, generating a millisecond periodic interrupt. Interrupt service routine tasks

Is uniformly distributed 0-4 It interrupts fragment. So each cycle interrupt task execution segment is 5 Ms, frequency

Was 200Hz .

The task assigned to different interrupt segment, on the one hand to prevent the accumulation of these tasks take longer than 1 millisecond, Disrupt a millisecond timing interruption, while also taking into account the time between the order of these tasks. Of course, it can be the Some interrupt tasks are combined, using a 5 Ms interrupt to complete.

These tasks include:

(1) Reads the motor speed pulse counter cleared. Cumulative motor rotation angle. Cumulative motor speed, after Cars speed control provides the average surface;

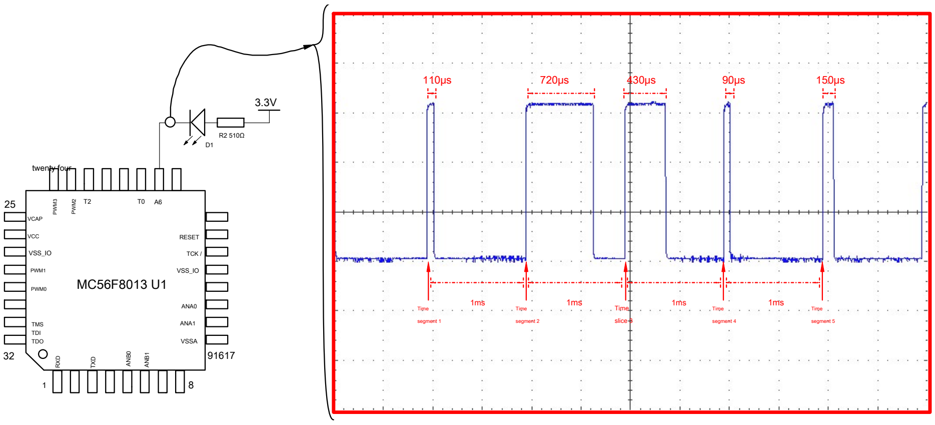
(2)start up AD Conversion. get on 20 Analog acquisition times, and calculates an average value of each analog channel. This process is carried out for the low-pass filtered analog signal.

(3) Cars upright control process. Cars angle calculation includes upstanding control calculation, the motor PWM Output.

(4) Cars speed control: in this time segment, and for 0-19 count. In the first of 0 Fragment, The speed PID adjust. Thus, the speed adjustment period 100 millisecond. That is per second adjust 10 Times.

(5) Cars directional control: electromagnetic field detector read previous value, a deviation value. Then calculate Motor control voltage differential value.

Each of these interrupt tasks occupy different time, when the program debugging, need to ensure that they are not more than 1 millisecond. Each specific task execution time can be displayed by the microcontroller ports. As it is through the microcontroller led Control port A6 , Showing each task execution. Upon entering the interrupt, A6 High output, launched Interrupted, A6 Output low. Figure 5-3 Waveform shown in FIG.



Map 5-3 Task interruption time waveform

Each task can be time consuming task from above interruption time waveforms:

table 5-1 Interrupt task execution time table

time Fragments	**Task execution time (Microseconds)**	**mission name**	**Remark**
1	110	Pulse rate	

2	720	AD Change	Conducted 20 Times 6 Analog Channel acquisition and averaged.
3	430	Cars angle control	
4	90	Cars speed control	Speed control period is 100 Hair second.
5	150	Cars directional control	

Quit after an interruption, the main program execution, monitoring and debugging run to complete the car models.

5.2 DSC Hardware resources

The following describes the procedures used DSC The module resources and their configuration. If other family of processors, Referring to these configuration settings.

1) Ms timer interrupt: TI1

Hardware modules: TMR2_Compare

In short cycle: Period: 1ms

trigger event: Event: Interrupt

2) Motor control PWM output: PWMC1

Hardware modules: PWM_Timer

Output frequency: Frequence: 10Khz

Output mode: PWM0,1,2,3 Independent

Dead time: Dead Time: 0

3) ADC Acquisition channels: ADC

Hardware modules: ANA0,12, ANB0,1 , 2

Range of values: Range: 0 - 0x7ff0

Conversion time: Conversion Time: 1.594us

Acquisition mode: Mode: Sequency

Conversion Resolution: Resolution: 12bit

4) Motor speed pulse counter: Counter1

Hardware modules: TMR0

Counting range: 16bit

Signal trigger edge: Rising Edge

5) Motor speed pulse counter: Counter2

Hardware modules: TMR1

Counting range: 16bit

Signal trigger edge: Rising Edge

6) monitor UART Serial ports

Hardware modules SCI

Communication speed: Baud: 117647 (Actual value)

7) Read MMA8452Q of I2C Bus (Alternate)

Hardware modules: I2C

Interrupt Mode: Interrupt Service: Disable I2C address:

Address: 4c

Communication speed: SCL Frequency: 200kHz

Note: This I2C The bus controller reads the acceleration sensor used in the Freescale digital interface.

Note: The above configuration mainly through CodeWarrior of Processor Expert (PE)To be done,

PE Automatically generate program code to initialize those modules and an interface code. Project files and directories

File Description See Appendix.

5.3 The main algorithm and its realization

Before designing and writing software control algorithms, make sure your control scheme. For beginners can read

In the appendix 4 Software algorithms given full map, cut and modify the control scheme according to their own understanding. The same control

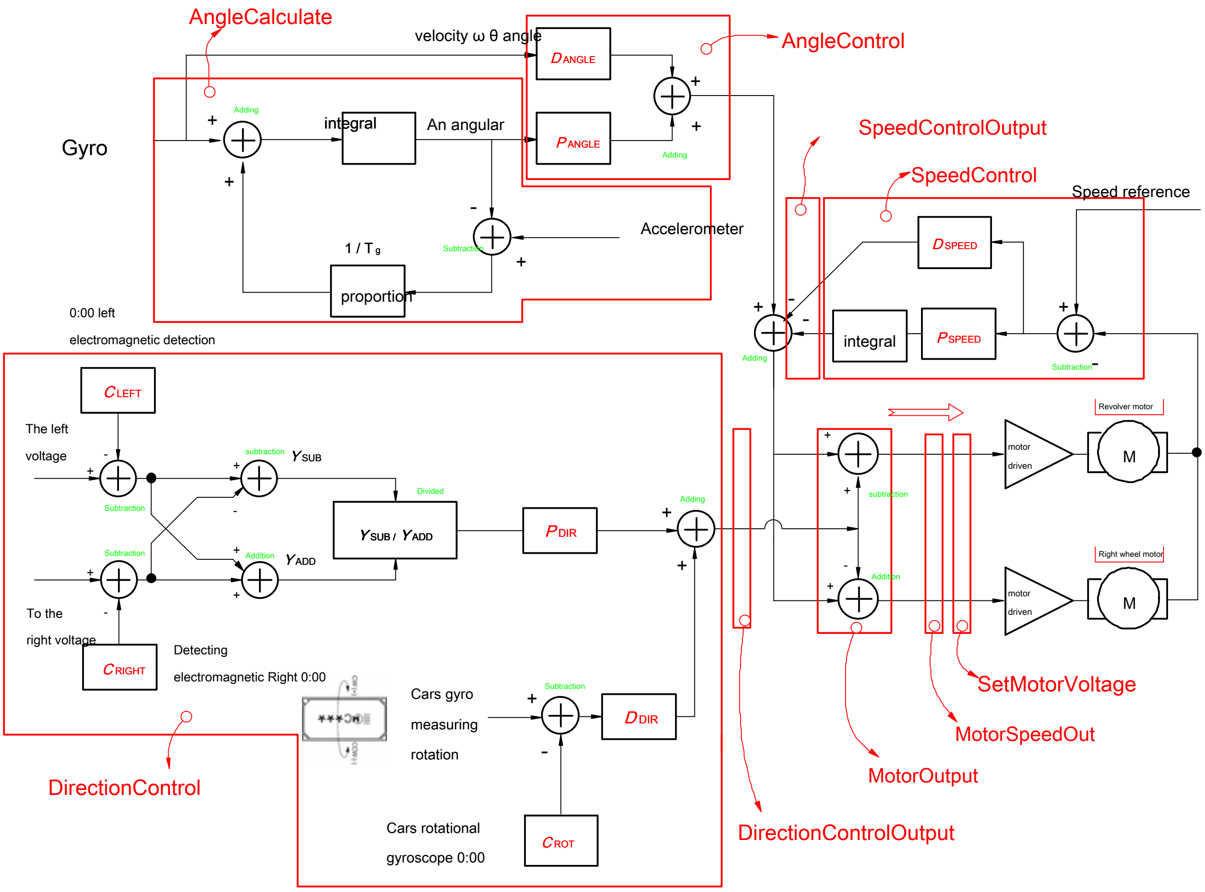
When implemented in software algorithm due to take different data structures, implementation C Language codes vary. early

Scholars may reference code software functions provided in this section, implementation, and optimization of their own code on this basis.

5.3.1. A block diagram of a control algorithm and a function

Complete software algorithm block diagram in Appendix 4 . Wherein associated with the control algorithm is shown below. The portions in the FIG.

Off series between the algorithm and software control function to write, to help you understand the relevant algorithms.


AngleCalculate
velocity ω θ angle
AngleControl
DANGLE
PANGLE
Gyro
Adding
integral
An angular
Adding
SpeedControlOutput
SpeedControl
Speed reference
1 / Tg
Subtraction
Accelerometer
proportion
DSPEED
PSPEED
integral
0:00 left
electromagnetic detection
Adding
Subtraction
CLEFT
The left
voltage
subtraction
YSUB
Subtraction
Divided
YSUB / YADD
PDIR
Adding
Subtraction
Addition
YADD
To the
right voltage
CRIGHT
Detecting
electromagnetic Right 0:00
Cars gyro
measuring
rotation
Subtraction
DDIR
Cars rotational
gyroscope 0:00
CROT
DirectionControl
Revolver motor
motor
driven
M
subtraction
Addition
Right wheel motor
motor
driven
M
SetMotorVoltage
MotorSpeedOut
MotorOutput
DirectionControlOutput

Map 5-4 A block diagram of the software algorithm associated with the control function

Map 5-4 Software functions associated with the control include:

1. AngleCalculate : Cars inclination calculation functions. The number of collected gravitational acceleration sensor and a gyro

   Cars angle and the angular velocity value calculation. If this part of the algorithm from the outside with an op amp, then get collected

   Is the direct angle and angular velocity of car models, this part of the algorithm can be omitted. This function is every 5 Ms called once.

2. AngelControl : Cars erect the control function. Cars motor control amount is calculated based on the angular velocity and the angle of car models.

   Control is upright 5 Ms called once.

3. SpeedControl : Cars speed control function. The car models collected motor speed and the set speed value, calculated

   The control amount of the motor. This function is 100 Ms called once.

4. SpeedControlOutput : Speed of the output smoothing function. Because speed is every 100 Ms calculated once. for

   Such that the smoother speed control, the speed of the output function will be evenly distributed to the change amount 20 step 5 Ms Control

   Cycle.

5. DirectionControl : Direction control function. The value of car models collected about two electromagnetic sensors of the meter

   Angle control amount is calculated. The function of each 10 Ms called once.

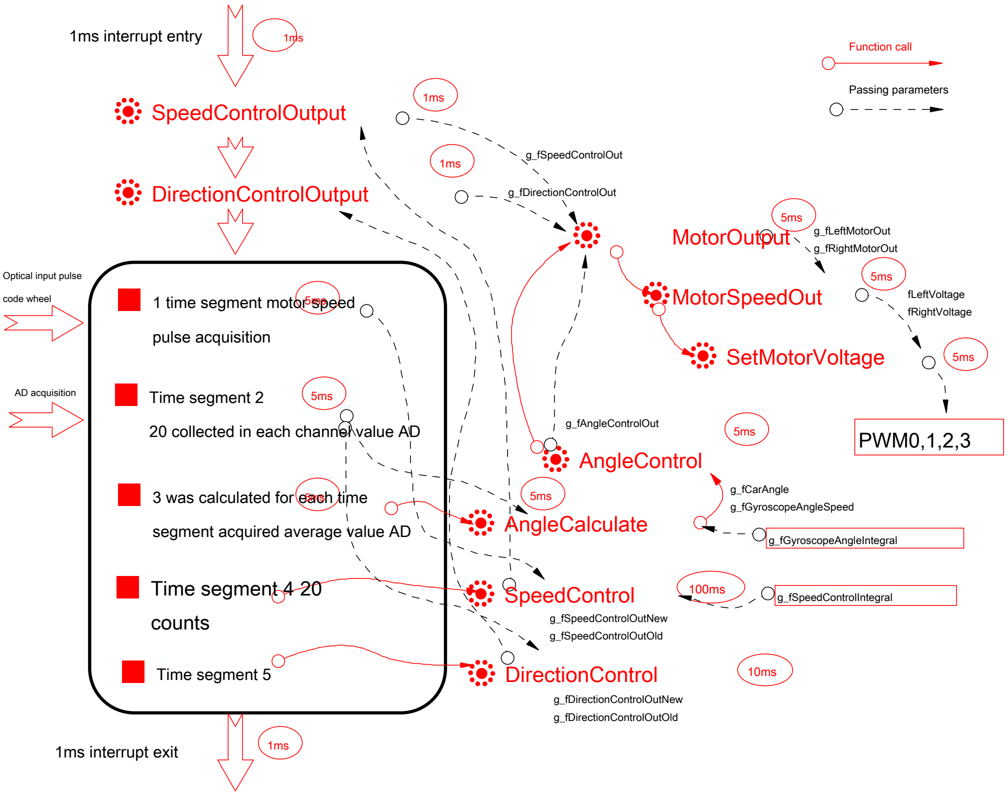
6. DirectionControlOutput : Direction control function output smoothing function. The change in output level of the direction control Is assigned to 2 step 5 Millisecond control cycle.

7. MotorOutput : Motor output function together. The front upright control, speed control and direction control of the Superposing a control amount obtained, respectively, to obtain the output voltage control amount of the left and right two electrodes. The output of the superim The amount of saturation processing. Function Call cycle 5 millisecond. Please note that this amount is superimposed speed control polarity It is negative.

8. MotorSpeedOut : Motor PWM Output calculation function. The output control of the left and right of the positive and negative electrodes Polarity, superimposed on a small dead zone value, to overcome the static friction Cars machinery. Function Call cycle 5 millisecond.

9. SetMotorVoltage : PWM Output function: The output of the two motors, is calculated PWM Control register The value is, four PWM Control value register. Function Call cycle 1 millisecond.

the above 9 Functions are in 1 Ms interrupt service performed is called mutual. The following figure shows the functions of Call transfer relationship between the parameters. In the vicinity of a function also shows the cycle call.


1ms interrupt entry
1ms
Function call
Passing parameters
SpeedControlOutput
1ms
g_fSpeedControlOut
1ms
g_fDirectionControlOut
DirectionControlOutput
MotorOutput
5ms
g_fLeftMotorOut
g_fRightMotorOut
5ms
MotorSpeedOut
fLeftVoltage
fRightVoltage
SetMotorVoltage
5ms
PWM0,1,2,3
Optical input pulse
code wheel
1 time segment motor speed
pulse acquisition
5ms
AD acquisition
Time segment 2
5ms
20 collected in each channel value AD
3 was calculated for each time
segment acquired average value AD
Time segment 4 20
counts
Time segment 5
g_fAngleControlOut
5ms
AngleControl
g_fCarAngle
g_fGyroscopeAngleSpeed
5ms
AngleCalculate
g_fGyroscopeAngleIntegral
SpeedControl
100ms
g_fSpeedControlIntegral
g_fSpeedControlOutNew
g_fSpeedControlOutOld
DirectionControl
10ms
g_fDirectionControlOutNew
g_fDirectionControlOutOld
1ms interrupt exit
1ms

Map 5-5 Call control functions and parameter passing relationship

The above function parameters are passed between some variables function call parameters, some are transmitted through the global variable of. All types of parameters are single precision floating point (float) . AngleCalculate , SpeedControl In the presence of

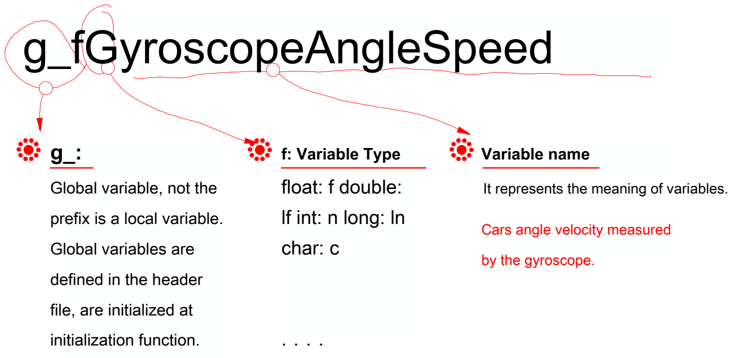
Integral calculation, these two functions also retained two global integration variable. In time segment 1,2 Collected in the velocity pulses

Information and analog information after cumulative average, an angle of the latter, controls the speed and direction of car models providing state variable

the amount.

In order to facilitate reading the following code, the program will be defined in the variable naming conventions will be briefly described,

Figure 5-6 Fig.


g_fGyroscopeAngleSpeed
g_:
Global variable, not the prefix is a local variable. Global variables are defined in the header file, are initialized at initialization function.
f: Variable Type
float: f double: lf int: n long: ln char: c
. . . .
Variable name
It represents the meaning of variables.
Cars angle velocity measured by the gyroscope.

Map 5-6 Program variable naming conventions

And understood variables follow certain naming, such that the program code has a "self-evident" feature, the program can be written

To reduce the annotation work, so as to avoid confusion. Described later in the program, each code block with the control algorithm

Figure been one correspondence, easy to understand and become familiar with the control algorithm to help students read the code, the program code does not nee

Any comments should be very clear.

5.3.2. The main control Function Description

This section will explain the main control functions. The function code in general are used C Language, single-precision floating-point operations.

Easy for beginners to understand and transplantation.

1. AngleCalculate : Angle calculation function

This program reads DSC of AD Numerical, and then calculate the tilt angle of the car models.

Values for gyroscope and accelerometer bias reading was subtracted value. This value need to be determined experimentally

set. Cars upright when stationary, the read values of the two channels, is the corresponding bias value. This value will take

There are some errors, such car models tend acceleration traveling in one direction. This error can be controlled by the speed of the latter

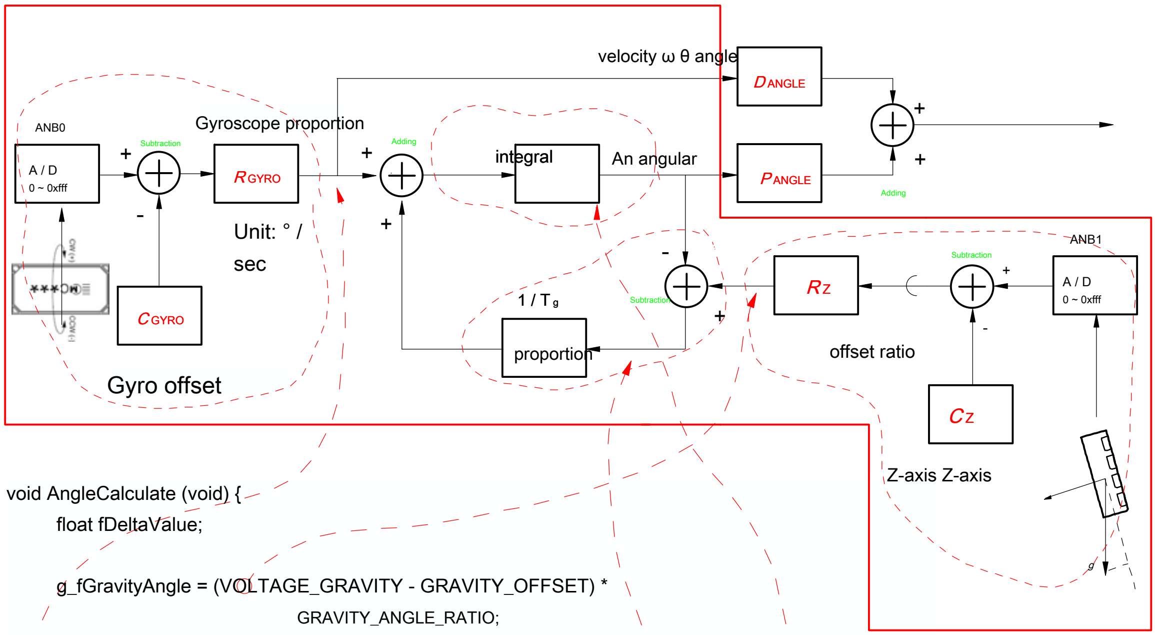
System to eliminate them.

For the accelerometer values obtained by a scaling factor (GRAVITY_ANGLE_RATIO) It

Normalized to - 90 to 90 Between this macro definition header file please everyone to read the project file. Similarly, the back of the Tuo

Spiro meter read data needs to be normalized by a scaling factor. This value is determined by experiment of. Specific ways to see the back of the debugging process.

Due to the time period of this function call 5ms . Detailed procedures, see the program - 1 Code:


velocity ω θ angle
DANGLE
PANGLE
Adding
ANB0
A / D
0 ~ 0xfff
Subtraction
Gyroscope proportion
RGYRO
Adding
integral
An angular
Unit: ° / sec
CGYRO
Gyro offset
1 / Tg
proportion
Subtraction
Rz
Subtraction
ANB1
A / D
0 ~ 0xfff
offset ratio
Cz
Z-axis Z-axis
CW(+)
CCW(-)
g

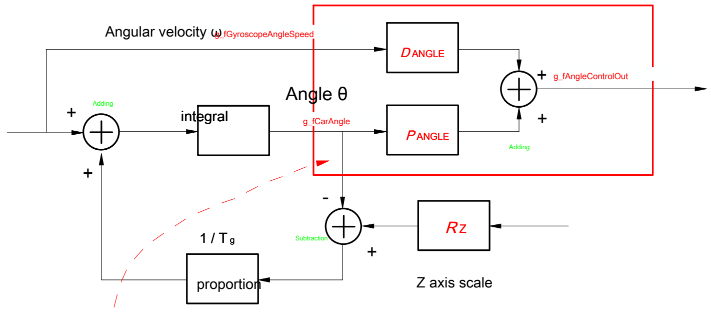
```
void AngleCalculate (void) {
        float fDeltaValue;

        g_fGravityAngle = (VOLTAGE_GRAVITY - GRAVITY_OFFSET) *
                                    GRAVITY_ANGLE_RATIO;
// g_fGravityAngle = 0;

        g_fGyroscopeAngleSpeed = (VOLTAGE_GYRO - GYROSCOPE_OFFSET) *
                                    GYROSCOPE_ANGLE_RATIO;

        g_fCarAngle = g_fGyroscopeAngleIntegral; fDeltaValue =
        (g_fGravityAngle - g_fCarAngle) /
                              GRAVITY_ADJUST_TIME_CONSTANT;

        g_fGyroscopeAngleIntegral + = (g_fGyroscopeAngleSpeed + fDeltaValue) /
                                            GYROSCOPE_ANGLE_SIGMA_FREQUENCY;
}
```

program - 1 Angle calculation function

Worthy of note is the angle calculation function can be performed by hardware, see Figure 3-25 Simplified angle and angular velocity Of the processing circuit, which can help us further understand the perspective of processing algorithms. If the actual circuit employed in FIG. 3-25 Program, this angle calculation function can be omitted, can be obtained directly by collecting the corresponding angle of Cars And angular velocity.

2 , AngleControl: Upright Control Function

Cars angle and the angular velocity multiplied by the respective coefficients can be obtained upstanding control output. See Cheng algorithm sequence- 2 Content.



```
void AngleControl (void) {
        float fValue;

        fValue = (CAR_ANGLE_SET - g_fCarAngle) * ANGLE_CONTROL_P +
                  (CAR_ANGLE_SPEED_SET - g_fGyroscopeAngleSpeed) *
                   ANGLE_CONTROL_D;

        if (fValue> ANGLE_CONTROL_OUT_MAX)
                fValue = ANGLE_CONTROL_OUT_MAX; else if (fValue
        <ANGLE_CONTROL_OUT_MIN)
                fValue = ANGLE_CONTROL_OUT_MIN;

        g_fAngleControlOut = fValue;}
```

These macros defined identically equal to 0

Output limiter processing, this section may be omitted

program - 2 Upright Control Function

There are two macros defined in this function CAR_ANGLE_SET , CAR_ANGEL_SPEED_SET We are

Defined header files 0 .

Angle limiter control section outputs code amount can be removed.

3 , SpeedControl: Speed control function

Speed control period 100 millisecond. Reading two electrodes optical encoder pulses accumulated by 100 Ms

It may reflect the number of pulses of the rotational speed of the motor car models. Cars using the average speed of the two electrode velocity.

In order to make a speed having a physical meaning, the obtained value for the motor speed required for the unit conversion.

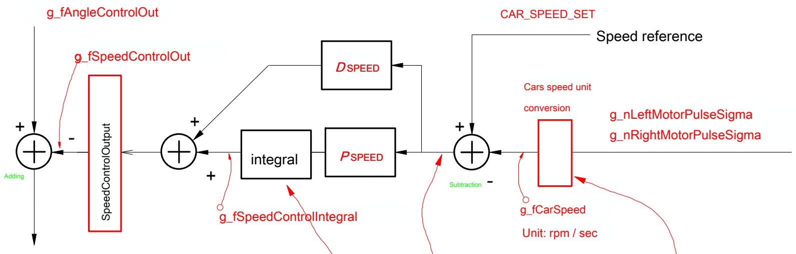
The physical meaning of the definition of the unit, the unit can determine the speed ratio of conversion values. In this procedure, the speed of the defined

A motor unit number of revolutions per second. Thus the ratio of the unit value (CAR_SPEED_CONSTANT) defined as:

```
#define OPTICAL_ENCODE_CONSTANT 100 // Number of notch optical encoder disc

#define SPEED_CONTRO_PERIOD                    100 // Speed control cycle, ms

#define CAR_SPEED_CONSTANT                     // Scale value conversion unit

            1000.0 / SPEED_CONTROL_PEIORD / OPTICAL_ENCODE_CONSTANT
```

To reduce the impact on the speed control car models upstanding control, the speed control is a function of the amount of change of the output

SpeedContorlOut Uniform distribution 20 The function of angular control period, which can ensure the stability of the car models.


g_fAngleControlOut
g_fSpeedControlOut
SpeedControlOutput
Adding
+
-
DSPEED
integral
PSPEED
g_fSpeedControlIntegral
CAR_SPEED_SET
Speed reference
Cars speed unit
conversion
g_nLeftMotorPulseSigma
g_nRightMotorPulseSigma
Subtraction
g_fCarSpeed
Unit: rpm / sec

```
void SpeedControl (void) {
        float fDelta; float fP,
        fI;

        g_fCarSpeed = (g_nLeftMotorPulseSigma +
                                g_nRightMotorPulseSigma) / 2;
        g_nLeftMotorPulseSigma = g_nRightMotorPulseSigma = 0; g_fCarSpeed * =
        CAR_SPEED_CONSTANT;

        fDelta = CAR_SPEED_SETfDelta - g_fCarSpeed; fP = fDelta *
        SPEED_CONTROL_P; fI = fDelta * SPEED_CONTROL_I;


        g_fSpeedControlIntegral + = fI;

        g_fSpeedControlOutOld = g_fSpeedControlOutNew; g_fSpeedControlOutNew =
    fP + g_fSpeedControlIntegral;}
```

Calculating the number average of the two electrodes of pulses, then the conversion units. Unit: rpm / sec

```
void SpeedControlOutput (void) {
        float fValue;
        fValue = g_fSpeedControlOutNew - g_fSpeedControlOutOld; g_fSpeedControlOut =
        fValue * (g_nSpeedControlPeriod + 1) /
                                        SPEED_CONTROL_PERIOD +
                                        g_fSpeedControlOutOld;
}
```

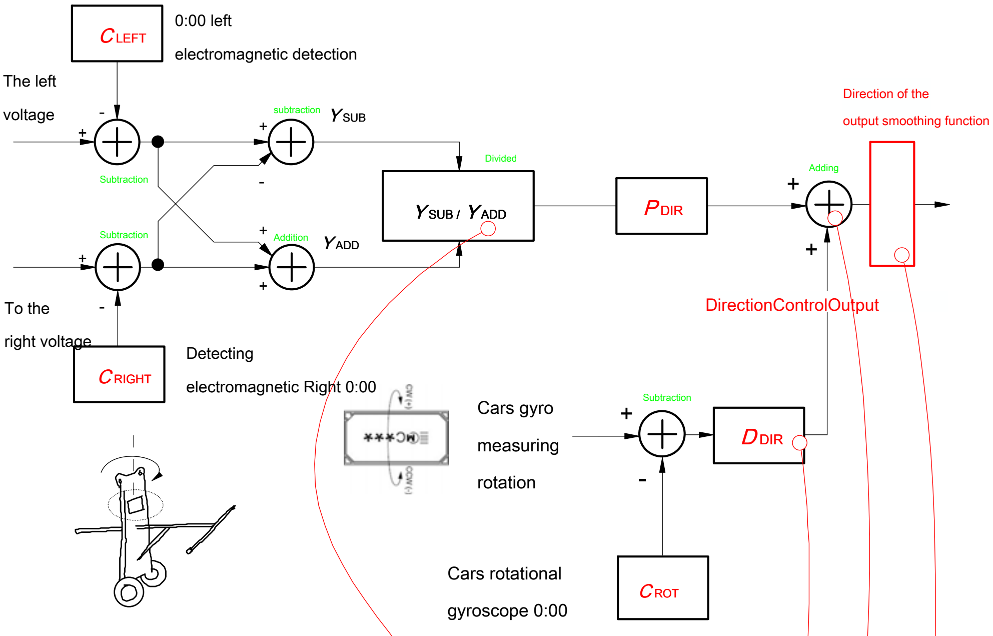
This function will change the amount of the average speed of the output 20 to the control period.

program --3 Speed control function

4 , DirectionControl: Direction control function

Cars left direction control using two solenoid induction voltage difference between the calculated driving motor car models difference Pressure. The front of the control principle described, specific procedures to achieve See Procedure - 4 . The function call period 10ms .

Also in order to reduce changes in the video, the directional control of the amount of control is also upstanding uniform distribution 2 A vertical control Cycle. By function DirectionControlOut to fulfill.


CLEFT
0:00 left
electromagnetic detection
The left
voltage
Subtraction
subtraction
YSUB
Divided
YSUB / YADD
PDIR
Adding
Direction of the
output smoothing function
Subtraction
Addition
YADD
To the
right voltage
CRIGHT
Detecting
electromagnetic Right 0:00
DirectionControlOutput
Cars gyro
measuring
rotation
Subtraction
DDIR
Cars rotational
gyroscope 0:00
CROT

```
void DirectionControl (void) {
        float fLeftRightAdd, fLeftRightSub, fValue; float fDValue; int
        nLeft, nRight;


        nLeft = (int) (g_fLeftVoltageSigma / = DIRECTION_CONTROL_COUNT); nRight = (int)
        (g_fRightVoltageSigma / = DIRECTION_CONTROL_COUNT); g_fLeftVoltageSigma = 0;
        g_fRightVoltageSigma = 0;


        fLeftRightAdd = nLeft + nRight; fLeftRightSub
        = nLeft - nRight;

        g_fDirectionControlOutOld = g_fDirectionControlOutNew;

        if (fLeftRightAdd <LEFT_RIGHT_MINIMUM) {
                g_fDirectionControlOutNew = 0;} else {

                fValue = fLeftRightSub * DIR_CONTROL_P / fLeftRightAdd;

                fDValue = DIR_CONTROL_D_VALUE-DIRECTION_OFFSET; fDValue * =
                DIR_CONTROL_D;

                fValue + = fDValue;

                g_fDirectionControlOutNew = fValue;}}


void DirectionControlOutput (void) {
        float fValue;
        fValue = g_fDirectionControlOutNew - g_fDirectionControlOutOld; g_fDirectionControlOut = fValue *
        (g_nDirectionControlPeriod + 1) /
                                    DIRECTION_CONTROL_PERIOD + g_fDirectionControlOutOld;
}
```

● g_fLeftVoltageSigma
g_fRightVoltageSigma zero offset value
has been subtracted in AD acquisition
channel, at the same time the average
cumulative

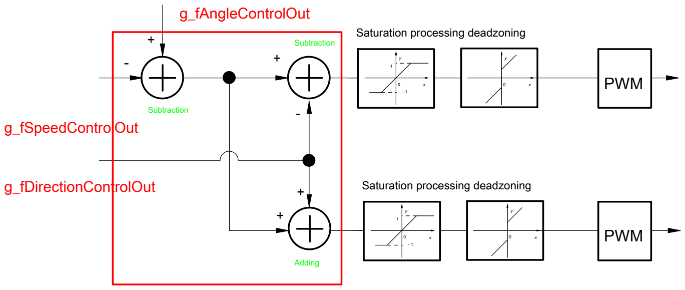
If the induced voltage is not detected around
the electromagnetic directional control amount is 0

program --4 Cars directional control

5 , MotorOut: Motor output function

Motor output function is very simple, just standing in front of the control, speed control, direction control output is

Overlapped to form the left and right drive control amount of the motor. See the program - 5 Motor output function.


g_fAngleControlOut
+
-
Subtraction
Subtraction
+
-
g_fSpeedControlOut
g_fDirectionControlOut
+
+
Adding
Saturation processing deadzoning
Saturation processing deadzoning
y
1
0
x
- 1
PWM
PWM

```
void MotorOutput (void) {
        float fLeft, fRight;

        fLeft = g_fAngleControlOut -
                        g_fSpeedControlOut
                g_fDirectionControlOut; fRight =
                g_fAngleControlOut -
                          g_fSpeedControlOut +
                          g_fDirectionControlOut;

        g_fLeftMotorOut = fLeft;
     g_fRightMotorOut = fRight;
     MotorSpeedOut ();}
```

program --5 Motor output function

In this function should be noted that the polarity of each control amount. Different physical coordinate system defined for each decision front

Relationship between the amount of positive and negative control of the overlay. Cars such as the definition of forward speed is positive, the angle Cars back angle is

Cars counter-clockwise rotation angle is positive. Cars in the control process should adhere to the definition of a unified physical coordinate system.

In Fig. 5-3 FIG, a predetermined coordinate system Cars motion parameters, if reference is made to FIG. 5-3 Coordinate system defining the motion,

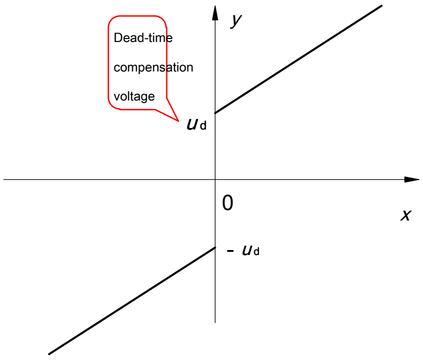
In the above-described function, the output polarity control speed is "negative", and a polarity opposite to the angle control amount.

6 , MotorSpeedOut: Motor PWM Calculation function

The output function is approximately two electrodes increases and the output saturation constant deadband process.

Cars drive mechanism due to this static friction, can increase a dead zone constant increase in car models under static

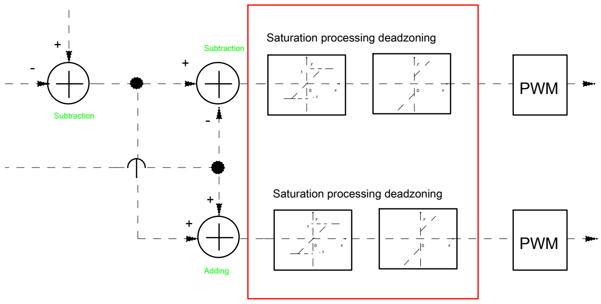
stability. This value needs to be determined by experimentation. Map 5-7 It shows the relationship between the dead zone compensation.



Map 5-7 Motor dead-time compensation

Output processing is to ensure the saturation output will not exceed PWM The full-scale range.

Reform program calls for the cycle 5 Ms See program 5-6.

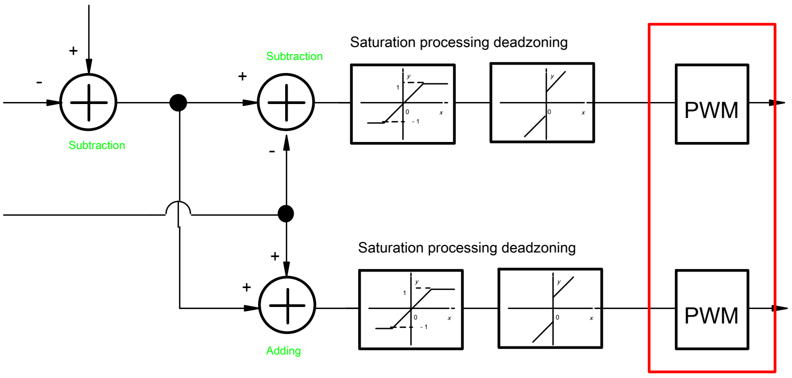

Saturation processing deadzoning
Saturation processing deadzoning
Subtraction
Subtraction
Adding
PWM
PWM
+
-
+
-
+
+

```
void MotorSpeedOut (void) {
        float fLeftVal, fRightVal;

        fLeftVal = g_fLeftMotorOut; fRightVal =
        g_fRightMotorOut;

        if (fLeftVal> 0)
                fLeftVal + = MOTOR_OUT_DEAD_VAL; else if
        (fLeftVal <0)
                fLeftVal - = MOTOR_OUT_DEAD_VAL;

        if (fRightVal> 0)
                fRightVal + = MOTOR_OUT_DEAD_VAL; else if
        (fRightVal <0)
                fRightVal - = MOTOR_OUT_DEAD_VAL;

        if (fLeftVal> MOTOR_OUT_MAX)
                fLeftVal = MOTOR_OUT_MAX; if
        (fLeftVal <MOTOR_OUT_MIN)
                fLeftVal = MOTOR_OUT_MIN; if
        (fRightVal> MOTOR_OUT_MAX)
                fRightVal = MOTOR_OUT_MAX; if
        (fRightVal <MOTOR_OUT_MIN)
                fRightVal = MOTOR_OUT_MIN;

        SetMotorVoltage (fLeftVal, fRightVal);}
```

program - 6 Motor PWM Calculation function

7 , SetMotorVoltage: PWM Output Settings function

The final signal is obtained by the motor drive microcontroller PWM Module generated. This function calculates two motors PWM Output duty cycle, and provided PWM Register module.


+
-
Subtraction
+
Subtraction
-
Saturation processing deadzoning
PWM
+
+
Adding
Saturation processing deadzoning
PWM

```
void SetMotorVoltage (float fLeftVoltage, float fRightVoltage) {
        short nPeriod; int
        nOut;

        nPeriod = (short) getReg (PWM_PWMCM);

        if (fLeftVoltage> 0) {
                setReg (PWM_PWMVAL1, 0); nOut = (int)
             (fLeftVoltage * nPeriod); setReg (PWM_PWMVAL0,
             nOut);} else {

                setReg (PWM_PWMVAL0, 0); fLeftVoltage =
              -fLeftVoltage; nOut = (int) (fLeftVoltage * nPeriod);
              setReg (PWM_PWMVAL1, nOut);}



        if (fRightVoltage> 0) {
                setReg (PWM_PWMVAL2, 0); nOut = (int)
             (fRightVoltage * nPeriod); setReg (PWM_PWMVAL3,
             nOut);} else {

                setReg (PWM_PWMVAL3, 0); fRightVoltage =
              -fRightVoltage; nOut = (int) (fRightVoltage * nPeriod);
              setReg (PWM_PWMVAL2, nOut);}



        MOTOR_SETLOAD; // Reload the PWM value}
```

program - 7 PWM Output function

8 Interrupt service routine

ISR finished car models angles, speed and direction control cycle call. See Figure 5-5 read

Read the following procedure.

```
void TI1_OnInterrupt (void) {
    int i;

    g_nSpeedControlPeriod ++;
    SpeedControlOutput ();

    g_nDirectionControlPeriod ++;
    DirectionControlOutput ();

    if (g_n1MSEventCount> = CONTROL_PERIOD) {
        g_n1MSEventCount = 0; GetMotorPulse ();   Two electrodes
      reading the pulse count} else if (g_n1MSEventCount == 1) {

        for (i = 0; i <INPUT_VOLTAGE_AVERAGE; i ++)
            SampleInputVoltage ();} else if
    (g_n1MSEventCount == 2) {
        GetInputVoltageAverage ();
        AngleCalculate (); AngleControl ();
        MotorOutput ();

    } Else if (g_n1MSEventCount == 3) {
        g_nSpeedControlCount ++;
        if (g_nSpeedControlCount> = SPEED_CONTROL_COUNT) {
            SpeedControl (); g_nSpeedControlCount
          = 0; g_nSpeedControlPeriod = 0;}


    } Else if (g_n1MSEventCount == 4) {
        g_nDirectionControlCount ++;
        DirectionVoltageSigma ();
        if (g_nDirectionControlCount> = DIRECTION_CONTROL_COUNT) {
            DirectionControl (); g_nDirectionControlCount
       = 0; g_nDirectionControlPeriod = 0;}}
```

program - 8 Interrupt service routine

In order to make the core control function readily understood that in all the function code given above, with the control algorithm will Irrelevant statements were properly cut, you can see the detailed code given in Annex DSC Project file CarSub.C, .H file. For the core control algorithm you will find the car models of the electromagnetic set upright algorithm also relatively It is very simple.

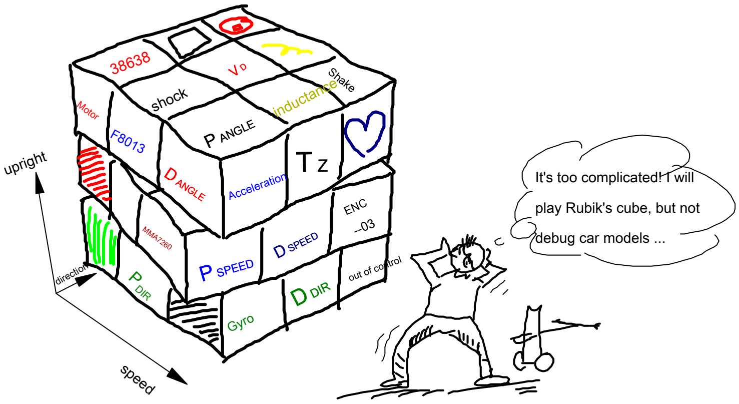
The core implements the algorithm just for car models walk upright foundation. Cars also need a high-speed running is stable feed Tuning and debugging line parameters. Software code should also include procedures for debugging car models. Cars such as running

Communication setting, detection and protection of car models abnormal operation, program parameters between a display state, and debugging PC And storage and so on. These auxiliary program is perfect, directly affect the accuracy and efficiency of the post-car models debugging. This Content can be found in section secretariat given DSC Correlation function project file, will not describe here.

Chapter VI, scale models debugging articles

Cars production and software development for the car models running the foundation, is running stable and rapid needs by car models Careful commissioning to complete. Debugging process also can make students deepen control algorithms for physical processes deep Engraved understanding, improve the ability to solve practical engineering problems, to find a basis for a more optimized design of car models. Tone Trial process is very important for the race car model production.

Cars are divided into Debug debugging preparation, the static parameter tuning, dynamic tuning parameters, scale models and competition policies mechanic The development of other links. Relates to the entire debugging parameters and components are very large, and there is a tight between these parameters Interaction dense. If the physical process in which the clear understanding that there is no proper commissioning steps, then tune Various errors phenomena that occur during the test will cover up for the right reasons, affect the entire commissioning process, and even shake system For confidence.


38638
VD
Shake
shock
inductance
Motor
F8013
P ANGLE
Tz
upright
D ANGLE
Acceleration
ENC
--03
MMA7260
P SPEED
D SPEED
direction
P DIR
out of control
Gyro
D DIR
speed
It's too complicated! I will play Rubik's cube, but not debug car models ...

Map 6-1 Cars debugging complex and critical parameters

This section describes the steps Cars tuning parameters as a reference.

6.1 Debugging parameters

Algorithm program exists many parameters given above, although the calculation of these parameters may be optimized in theory. However, due to the impact accuracy of the model car models, the resulting calculated parameters may also be used as a reference value only - Commissioning

Starting range. The actual optimization parameters required by certain steps to finalize the project, this process is called parameter tuning.

First determine the required control parameter tuning car models. In the appendix 5 A block diagram of the control algorithm is given, all the required Tuning parameters are marked in red. These parameters include two categories:

1 , Sensor parameters:

R_{GYRO}: Gyroscope scale. The gyroscope AD An angular velocity signal values into the acquisition unit is ° / sec.

C_{GYRO}: Gyroscope zero offset. When the gyroscope tranquility AD Collection volume.

C_Z: Gravitational acceleration Z Axis zero offset. When the accelerometer is stationary vertical Cars AD Collection volume.

Z_{MAX}: Gravitational acceleration Z Axis maximum acquisition value. When the back-up Cars Z axis AD Acquisition value.

Z_{MIN}: Gravitational acceleration Z The minimum acquisition value axis. When the front car models up Z axis AD Acquisition value.

C_{LEFT}: The left side of the electromagnetic induction coil zero offset. Externally 20kHz When the power is turned off, the left electromagnetic induction Coil should channel AD Acquisition value.

C_{RIGHT}: The right of the zero point offset electromagnetic induction coil. Externally 20kHz When the power is turned off, the right solenoid Channel induction coil AD Acquisition value.

C_{DIR}: Cars rotational speed gyro zero offset value. Cars at rest, the rotational speed measuring car models tuo Lo instrument AD Acquisition value.

2 Motion control parameters:

P_{ANGLE}: Angle proportional control parameter.

D_{ANGLE}: Angle differential control parameters.

P_{SPEED}: Speed proportional control parameter.

D_{SPEED}: Speed differential control parameters.

P_{DIR}: Direction proportional control parameter.

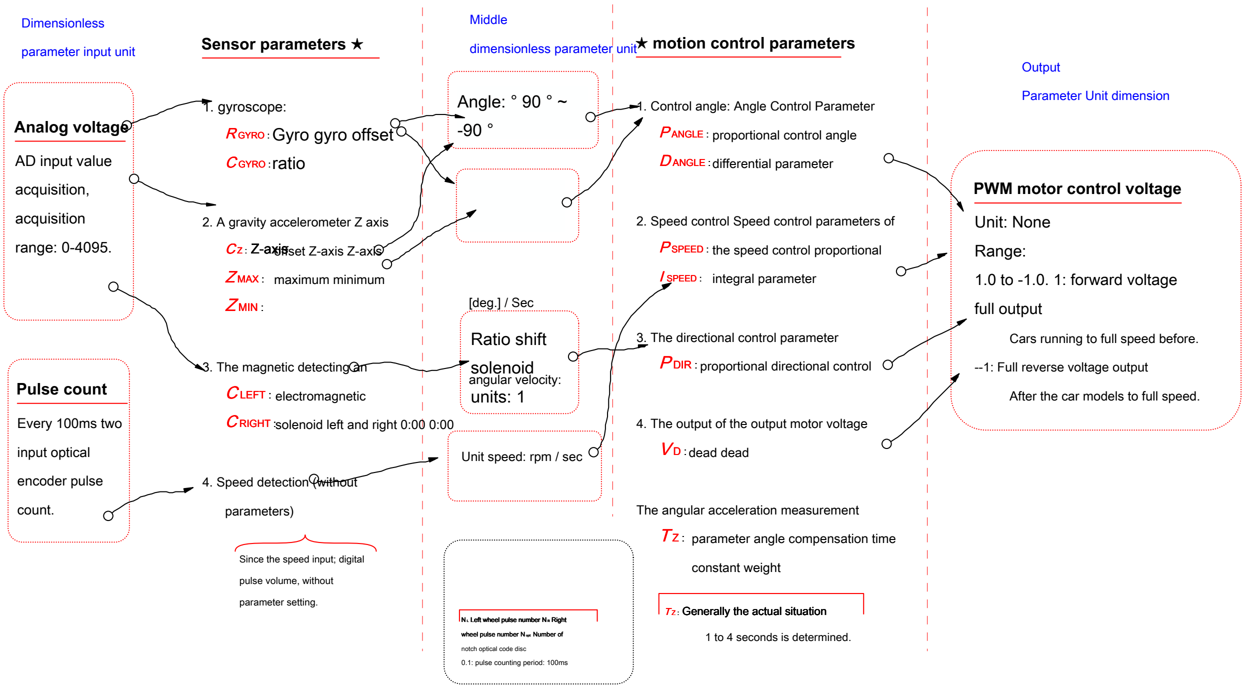
D_{DIR}: Direction differential control parameters.

T_Z: Gravitational acceleration compensation time constant. .

V_D: Motor output dead zone parameters.

These calibration parameters to consider input and output parameters of the unit dimension. The following figure shows the input and output parameters of ea

unit.


Dimensionless
parameter input unit
Sensor parameters ★
Middle
dimensionless parameter unit
★ motion control parameters
Output
Parameter Unit dimension
Analog voltage
AD input value acquisition, acquisition range: 0-4095.
1. gyroscope:
R_{GYRO}: Gyro gyro offset
C_{GYRO}: ratio
Angle: ° 90 ° ~ -90 °
1. Control angle: Angle Control Parameter
P_{ANGLE}: proportional control angle
D_{ANGLE}: differential parameter
PWM motor control voltage
Unit: None
Range:
1.0 to -1.0. 1: forward voltage full output
Cars running to full speed before.
--1: Full reverse voltage output
After the car models to full speed.
2. A gravity accelerometer Z axis
C_Z: Z-axis offset Z-axis Z-axis
Z_{MAX}: maximum minimum
Z_{MIN}:
2. Speed control Speed control parameters of
P_{SPEED}: the speed control proportional
I_{SPEED}: integral parameter
[deg.] / Sec
Ratio shift
solenoid
angular velocity:
units: 1
3. The magnetic detecting an
C_{LEFT}: electromagnetic
C_{RIGHT}: solenoid left and right 0:00 0:00
3. The directional control parameter
P_{DIR}: proportional directional control
Pulse count
Every 100ms two input optical encoder pulse count.
4. Speed detection (without parameters)
Unit speed: rpm / sec
4. The output of the output motor voltage
V_D: dead dead
The angular acceleration measurement
T_Z: parameter angle compensation time constant weight
Since the speed input; digital pulse volume, without parameter setting.
N_L Left wheel pulse number N_R Right wheel pulse number N_{opt} Number of notch optical code disc
0.1: pulse counting period: 100ms
T_Z: Generally the actual situation
1 to 4 seconds is determined.

Map 6-2 We need to adjust the parameters and associated units

If the design of the unit, and said unit is inconsistent, the corresponding parameters need to be unit conversion. ratio

Such as motor PWM Numerical control voltage range is - 128 ~ 127 , Then the value of the corresponding control parameters of movement are required

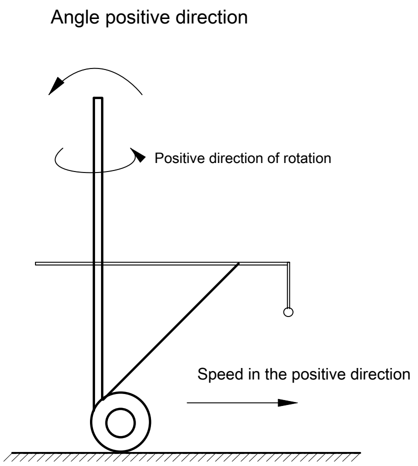
To expand 128 Times or so.

Individual parameters polarity (sign) to consider moving car models defined coordinate system. Cars sport includes three transport

Motion: translational car models, car models and car models Yang movable rotated.

Cars Cars positive direction is defined as the translation of the positive direction. Cars tilted backward direction is defined as positive Yang moving car models

Cars positive direction is defined as counterclockwise rotation of rotatable car models. Figure 6-3 Fig.


Angle positive direction
Positive direction of rotation
Speed in the positive direction

Map 6-3 Cars sport defined by the coordinates

When the predetermined coordinate car models in FIG. 6-3 Are different, the polarity of the corresponding parameters need to be changed.

6.2 Debugging condition

Cars assembled after installation, before the formal commissioning I need to prepare conditions:

1 , Scale models circuit initial commissioning: a power control circuit may correct, the microcontroller can download the program.

2 , Scale models debugging environment: the site must be debugged and auxiliary car models 20kHz Power supply.

3 , Hardware and software debugging aid Cars: Cars sport protection and parameter monitoring software.

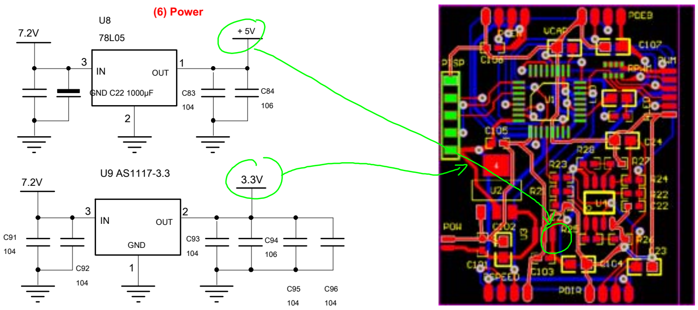
The above conditions can be made in the development of car models, debugging process gradually improved. The following describes these debugging Requirements and readiness conditions.

6.2.1. Cars preliminary circuit debugging

Cars preliminary circuit debugging lay the foundation for the back of the car models software parameters. Comprising five basic steps, namely Introduced. :

1 , Check the power supply

Plus circuit 7.2V After the battery voltage, the output value of the operating current measurement circuit and the voltage regulator circuit whether each Within a safe range.

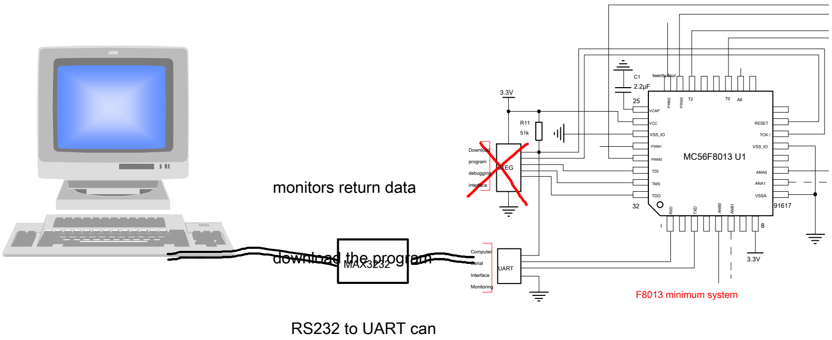

(6) Power
U8
78L05
7.2V
3
IN
OUT
1
GND C22 1000μF
2
C83
104
C84
106
+ 5V
U9 AS1117-3.3
7.2V
3
IN
OUT
GND
2
1
C91
104
C92
104
C93
104
C94
106
C95
104
C96
104
3.3V

Map 6-4 Check the power supply

Reference circuit design comprises 7.2V , 3.3V , 5V Three power. When static, the total power supply should work in 150mA about.

2 , Microcontroller program download and communication:

DSC 56F8013 Having in-system programming (ISP) ability. The microcontroller inside after playing there a bootstrap program (Bootloader) Program, through the UART Serial user will be able to download it. If the first download to go on Bootstrap program itself, but also has the function of all future programs will be able to download through UART get on. detailed introduction See Freescale Information on our web site. UART Not only can improve download the program, while in the upper strings Port monitoring program of assistance down to the character display serial port to send the program is running, easy to debug the program. Suggest F8013 of Bootloader Download and serial port monitor into a joint development of PC software, which will be done through the serial port To develop and debug the entire program of car models.


monitors return data
download the program
MAX3232
RS232 to UART can
Download
program
debugging
interface
JTEG
Computer
Serial
Interface
Monitoring
UART
3.3V
R11
51k
C1
2.2μF
twenty four
25
32
1
8
91617
PWM3
PWM2
T2
T0
A6
VCAP
VCC
VSS_IO
PWM1
PWM0
TDI
TMS
TDO
RESET
TCK /
VSS_IO
ANA0
ANA1
VSSA
RXD
TXD
ANB0
ANB1
MC56F8013 U1
3.3V
F8013 minimum system

Map 6-5 Serial Communication

MCU development also by means of JTEG And other development tools.

3 , PWM Export

In the SCM software can be downloaded on the basis of development, the preparation of SCM PWM Output control program. See also SetMotorVoltage Function code. By controlling the motor speed, to verify the correctness of the drive circuit. Determining two electrodes

Polarity of the voltage output. Guaranteed output PWM When a positive voltage, motor front drive car model line; PWM When the negative voltage output,

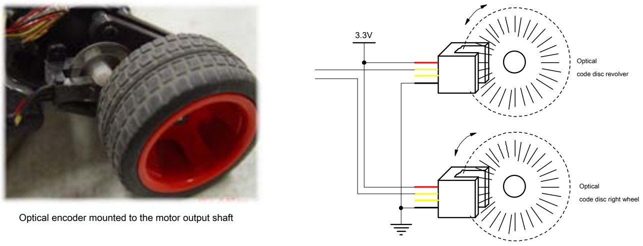
Cars underwent.

Output of the PWM
drive the motor.
Polarity adjustment
motor interface,
ensure that the output
voltage is positive, the
front row Cars;
negative output voltage, the trailing car models.

Map 6- 6 PWM Signal output

4 , Optical encoder pulse acquisition

Rotation of the output waveform of the time code wheel motor by an oscilloscope, and determining the frequency of the waveform amplitude. Writing pulse Acquisition program and displayed.

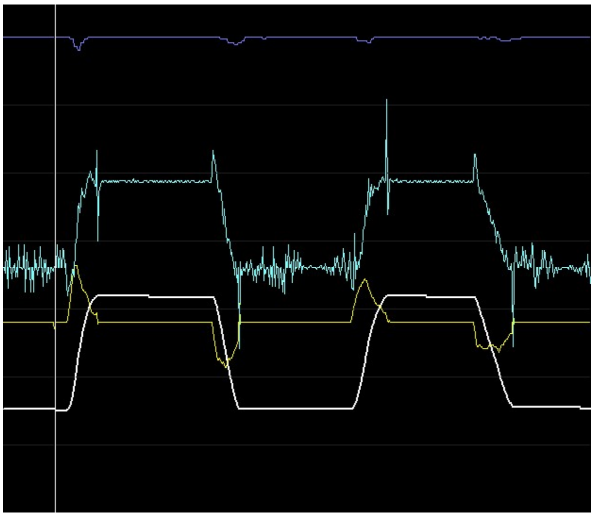

Optical encoder mounted to the motor output shaft

Map 6-7 Recording the motor photoelectric encoder signal

use PWM The output signal of the rotation drive motor, the number of motor pulse is obtained. Through the above two steps, To prepare a program of constant speed motors. by PID Adjustment situation is different in the outside of the motor resistance Lower, they are able to maintain a constant speed. Through this exercise can exercise DSC Develop the ability to debug programs, and Cars further verify the correctness of the input and output channels.

5 , Analog acquisition

F8013 It has six channels AD Conversion. Application of the reference design which five channels. write AD turn In other procedures, the collected values to a microcomputer for display. By observing the value of each acquisition channel, each sensing confirmation Operating condition, the influence of each channel signal dynamic range and noise. Preferably each channel can be acquired by the value Curve shows amplitude variation and noise can be compared directly observed signal. As is shown by the microcomputer Gyroscope and accelerometer waveform acquisition.



The analog channel signals microcontroller

Map 6-8 A gyroscope, an acceleration sensor AD Acquire the Signal

Each analog noise will have different proportions, the need for low-pass filtering each of the collection amount. Simple square

Law is to be achieved by the average multiple acquisitions. Map 6-8 Waveform data is displayed by 20 After an average of acquisitions

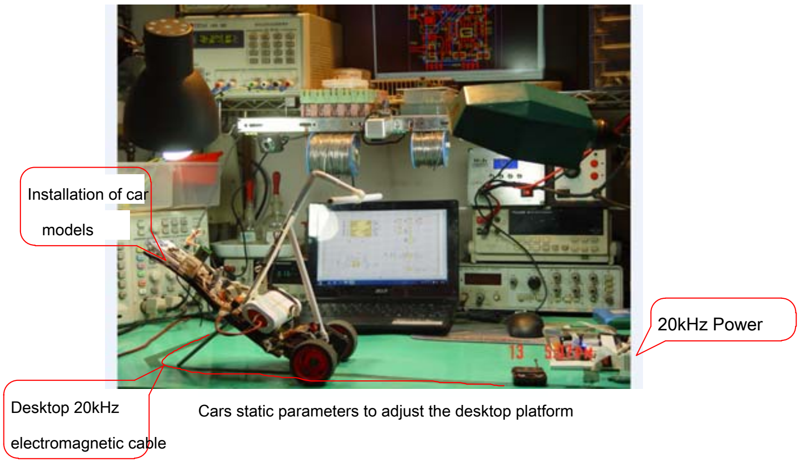
The data.

6.2.2. Cars debugging environment

1 Static parameters debugging Desktop

Cars static parameter adjustment can be done on the desktop. Therefore, there is need to prepare Shop 20kHz Electromagnetic guide wire debug tables

surface.


Installation of car models
20kHz Power
Desktop 20kHz electromagnetic cable

Cars static parameters to adjust the desktop platform

Map 6-9 Cars static parameters to adjust the desktop

2 Dynamic parameter testing site

To optimize the combination of the respective control parameters during operation of car models, and the sensor while the mechanical structure of an on car

Loaded adjustment. We need to prepare the runway with an electromagnetic cable. The scope and complexity of the shape of the provisions of the runway in the ga

The try rich track design elements, including at least a cross intersections and various corners.

Map 6-10 Cars dynamic parameter testing site

6.2.3 Cars hardware and software debugging aid

Saying, For good its power, its profits. Good aid debugging tools can greatly speed up the debugging process, can Enough to failure of accurate positioning.

1 Parameter setting and status monitoring software

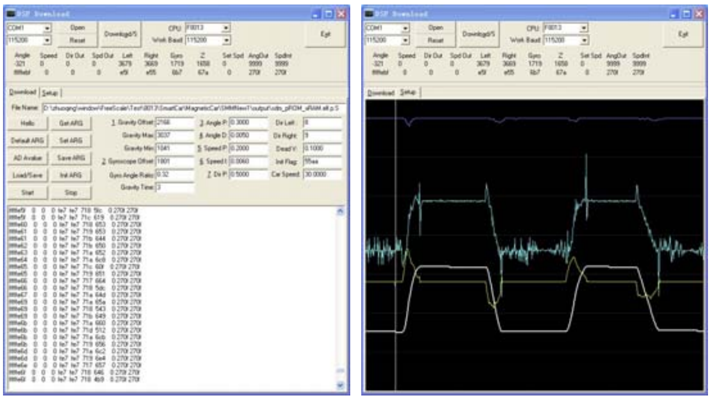
In order to ensure smooth commissioning, generally need to meet and host computer monitoring program, real-time display program running mining Set the various data, or the number displayed by the curve, to help determine the number of parameters to be determined, the program determines BUG , Speed up program debugging, to determine the value of the parameter control optimization.

Monitoring software features include:

1) Displays real-time parameters Cars returned;

2) Cars set various operating parameters;

3)have Bootloader Download Cars program.



Display operating parameters and download microcontroller program

Display motion parameter curve Cars

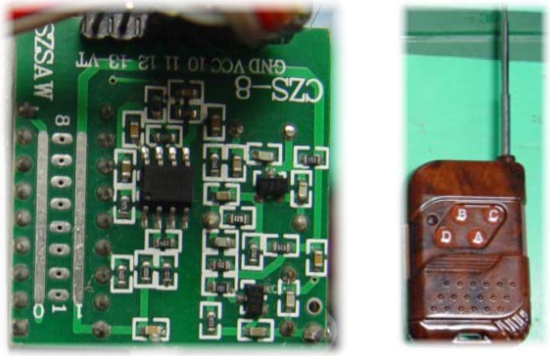
Map 6-11 Monitoring software interface

Monitoring software can choose their own familiar Windows Development tools for development.

2 , Wireless remote control switch

Cars easily ran wide at the beginning of the commissioning process. Cars in order to avoid damage due to an impact, mounted on the car models

A wireless remote control switch, can be timely stopped running car model, car models off the track to avoid impact damage.



Wireless remote control switch

Map 6-12 Wireless remote control switch

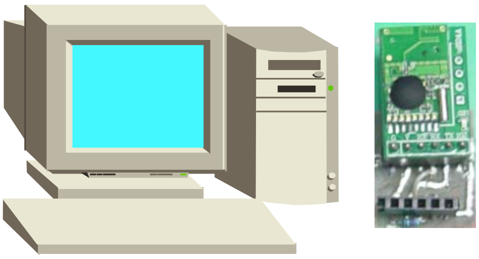
Wireless remote control switch can directly control the motor drive power car models, the microcontroller may control a switch to state

Signal, this signal is detected by the microcontroller to start or stop operation.

3 The wireless communication module

Can now choose a wireless serial communication module is very large, very convenient to use wireless communication module for dynamic operation

Cars line parameters to be monitored. Also can dynamically change the various parameters of motion control car models.



Monitoring and adjustment of computer

Map 6-13 Parameter monitoring wireless communication module

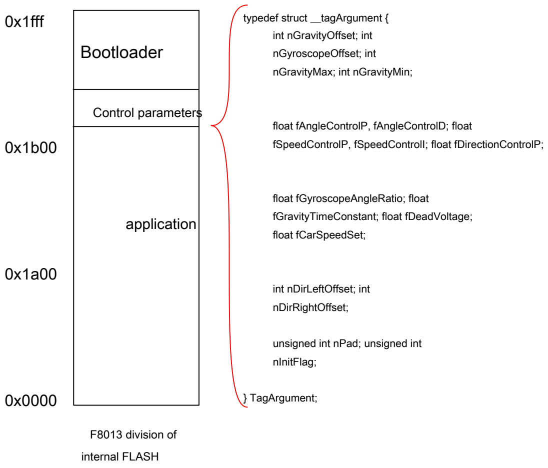
The main car models running state control parameters are determined. So all motion parameters is defined as a car models

A data structure stored in the internal microcontroller FLASH Each modification of these parameters only make changes to speed up the monolithic

Machine speed updates. Map 5-14 shown F8013 internal FLASH One application is divided. Wherein the control parameter storage

The 54 Control parameter bytes. These parameters can be downloaded directly to the microcontroller via the wireless communication module in the memory, to avoi

Avoid the cumbersome process of program updates.


0x1fff
Bootloader
Control parameters
0x1b00
application
0x1a00
0x0000
F8013 division of
internal FLASH

```
typedef struct __tagArgument {
        int nGravityOffset; int
        nGyroscopeOffset; int
        nGravityMax; int nGravityMin;


        float fAngleControlP, fAngleControlD; float
        fSpeedControlP, fSpeedControlI; float fDirectionControlP;


        float fGyroscopeAngleRatio; float
        fGravityTimeConstant; float fDeadVoltage;
        float fCarSpeedSet;


        int nDirLeftOffset; int
        nDirRightOffset;

        unsigned int nPad; unsigned int
        nInitFlag;

} TagArgument;
```

Map 6- 14 F8013 internal FLASH Applications division

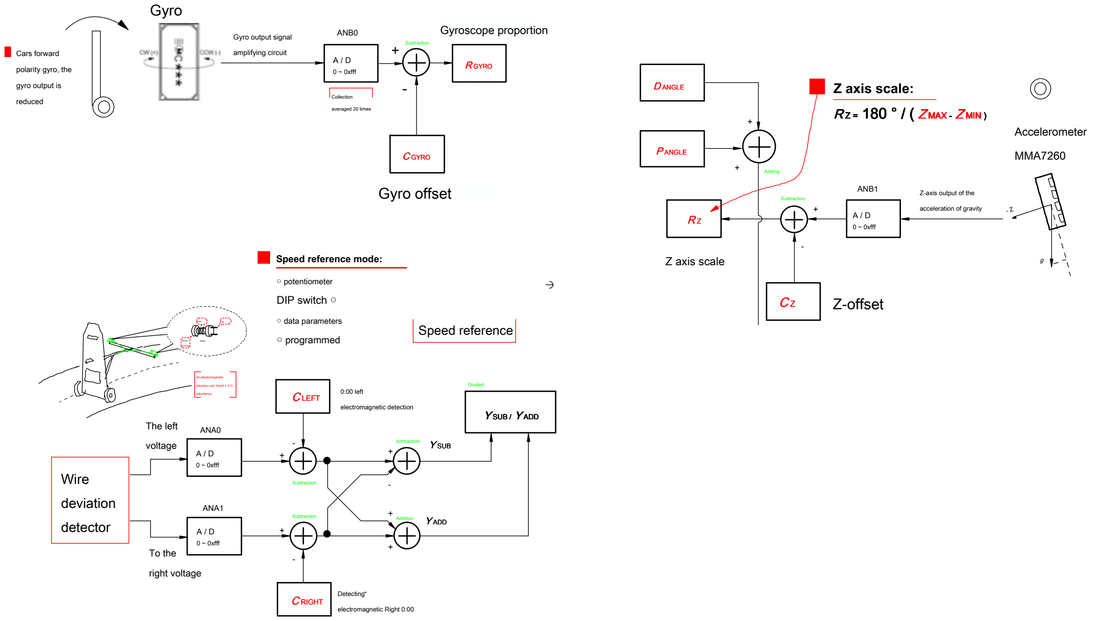
6.3 Desktop static parameters debugging

Desktop sensor parameters comprising static parameters and control parameters in the stationary state of the car models tuning.

6.3.1. Sensor parameters

Cars sensor measurement parameters include motion states of the respective car models car models stationary sensors at zero offset to

And the proportion of unit conversion values. In Fig. 5-15 These parameters will be marked out.


Gyro
Cars forward polarity gyro, the gyro output is reduced
CW (+)
CCW (-)
Gyro output signal amplifying circuit
ANB0
A / D
0 ~ 0xfff
Collection averaged 20 times
+
-
Subtraction
Gyroscope proportion
R_{GYRO}
C_{GYRO}
Gyro offset
D_{ANGLE}
P_{ANGLE}
+
+
Adding
Z axis scale:
$R_Z = 180° / (Z_{MAX} - Z_{MIN})$
Accelerometer
MMA7260
ANB1
Z-axis output of the acceleration of gravity
A / D
0 ~ 0xfff
Subtraction
-Z
g
R_Z
Z axis scale
C_Z
Z-offset
Speed reference mode:
○ potentiometer
DIP switch ○
○ data parameters
○ programmed
Speed reference
An electromagnetic induction coil 10mH × 2 H inductance
C_{LEFT}
0:00 left electromagnetic detection
Divided
Y_{SUB} / Y_{ADD}
The left voltage
ANA0
A / D
0 ~ 0xfff
Subtraction
subtraction
Y_{SUB}
Wire deviation detector
ANA1
A / D
0 ~ 0xfff
Subtraction
Addition
Y_{ADD}
To the right voltage
C_{RIGHT}
Detecting electromagnetic Right 0:00

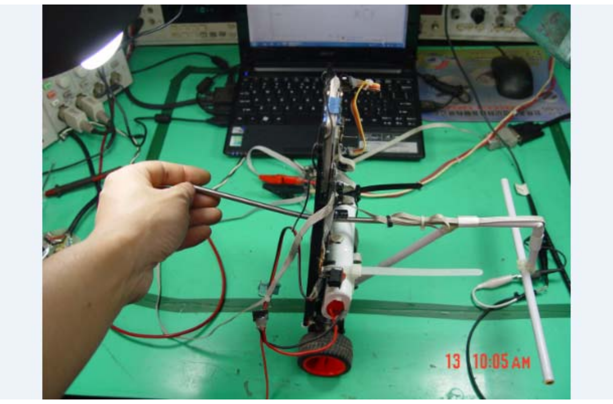
Map 6-15 Setting sensor parameters required

1 Measuring transducer zero offset

Debug table, holding Cars vertical stationary state, closed 20kHz Electromagnetic power supply. By SCM software acquisition

Each analog channel AD Value passed to the host computer for display. Determining the zero offset for each sensor:

C_{ANGLE} , C_Z, C_{LEFT} , C_{RIGHT} , C_{DIR} .

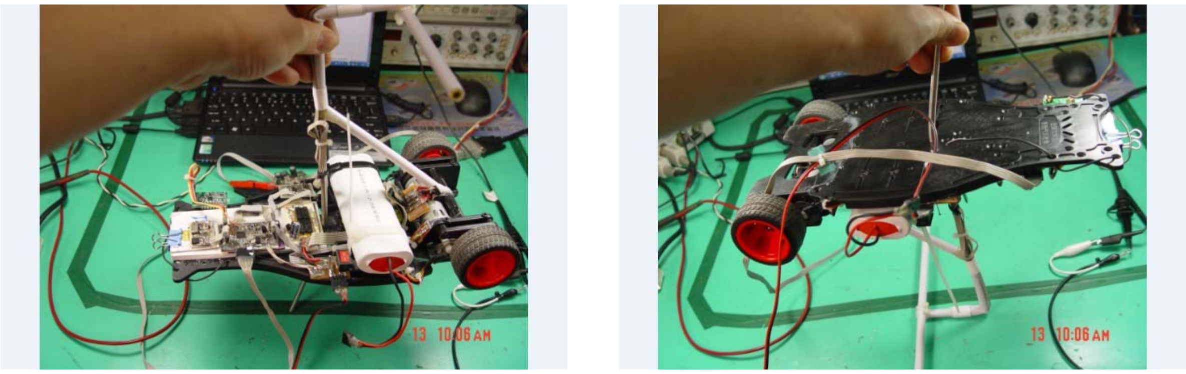


Map 6-16 Cars held vertically stationary

The average multiple acquisitions can be obtained by a more stable and accurate. In the reference embodiment, the acquisition of 1024 Times each through Channel average value as the zero point offset amount of the respective channels.

2 Measuring an acceleration sensor Z Axis maximum, minimum

Cars held stationary side up and tails can be measured Z Maximum and minimum axes.



Map 6-17 Measuring acceleration sensor extremum

Maximum and minimum values of the acceleration sensor may be used to determine an acceleration sensor Z Ratio corresponding to the angle of the shaft value: $R_Z = \frac{180}{Z_{MAX} - Z_{MIN}}$. This ratio may be accelerated by the sensor Z Axis signal into an angle signal, The unit is degrees.

3 , Gyro scale value calibration Cars

The scale determines the R_{GYRO} gyro angular rate gyroscope unit obtained by integrating a degree of acceleration of gravity and mass

Sensor is the same. This ratio can be calculated by the formula: $R_{GYRO} = \frac{R_{AD}}{R_G \cdot K}$. among them $R_{AD} = 3.3V/4096$,

Show AD Conversion factor. $R_G = 0.67\ mV \cdot$ deg / sec Gyro scale factor, the gyroscope data can manual

Found. $K = 5.1$ Gyro signal is magnification, the magnification can be calculated according to the preceding circuit parameters. will

Values into the above equation one can calculate the gyro scale factor: $R_{GYRO} = 0.24$. Since the existence of the above parameter

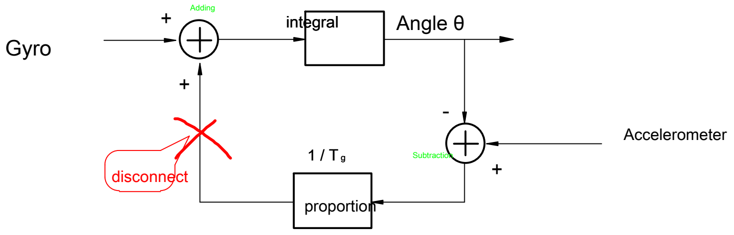
Errors, scale factor calculated above is only one reference value, we need to finalize the actual measured experimentally n

Determining the ratio value.

The method of experiment is the basic angle by changing an angle car models, comparison of the gyro obtained by integrating the amount of change

And the acceleration of gravity Z The amount of change is the same axis. Specific steps are as follows:

1) Algorithm first angle compensation circuit is opened;



Map 6-18 Measuring the scale factor of the gyro sensor, an angle compensation circuit is disconnected

2) Cars holding angle, measured Z And the output shaft angular acceleration integration angle output;

3) Cars changing the angle measurement Z Axis angle and the change in output angle variation acceleration integration;

in case Z Axis angle change amount of the gyro output angle variation are the same, then the current ratio gyroscope

Factor is correct. Otherwise, Z Angle change divided by two axis gyroscope angle variation, and then multiplied by the current ratio

Example factor can correct the gyro scale factor.

Since the existence of the integral gyro drift, so the above correction process needs fast. By repeatedly corrected, you can get

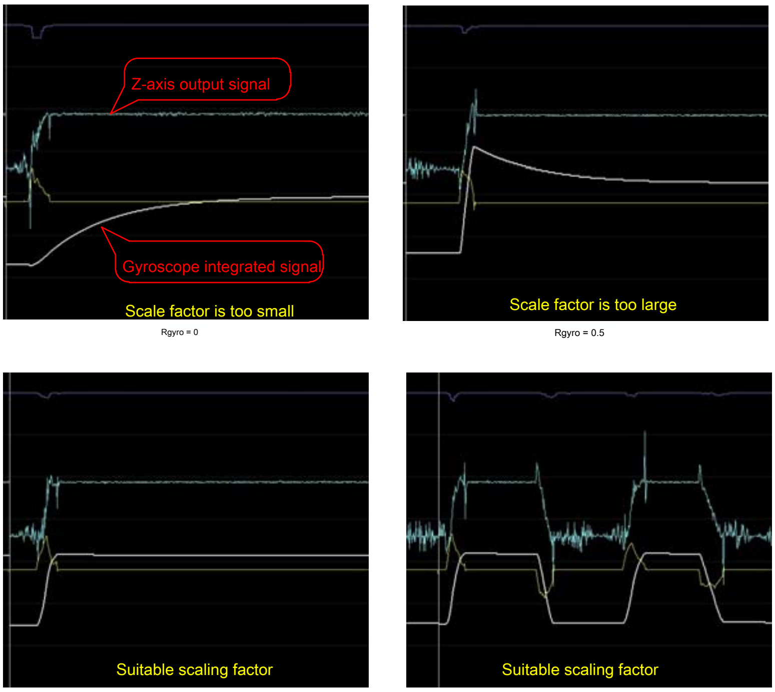
The exact scale factor of the gyroscope.

May not be the angle compensation circuit is disconnected, by the gyro output angle of the curve can also determine the ratio of the gyroscope

Factor is appropriate. If the small gyro scale factor, the gyro angle output will have a slow tracking process.

Conversely, if a large proportion of the factors gyroscope, the gyroscope will have an angle output overshoot. With a few adjustments, can

To give the correct scale factor of the gyroscope, the gyroscope so that the output angle of the gravitational acceleration can be tracked correctly Z Input shaft Signal. Map 6-19 Shows the case where the gyro output angle of several different scale factor of the gyroscope.



Rgyro = 0

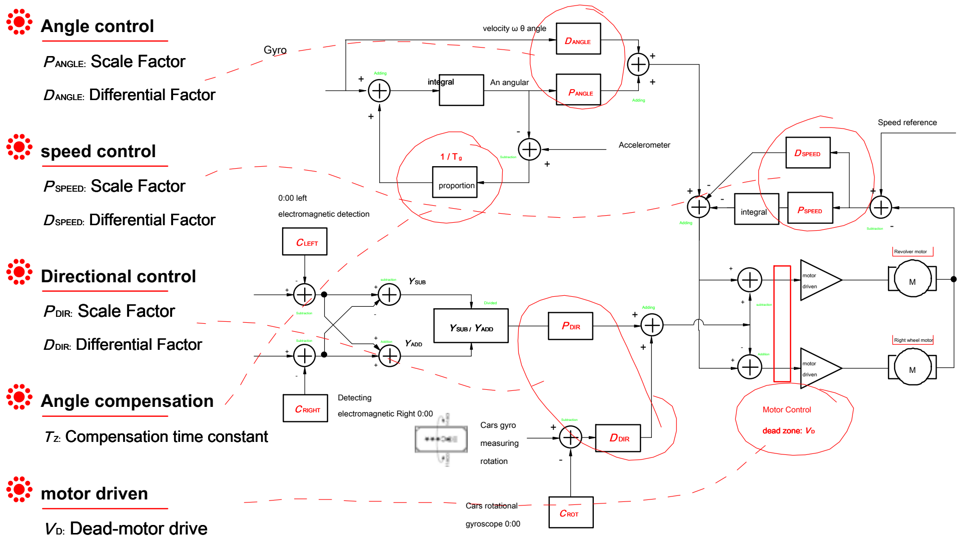
Rgyro = 0.5

Map 6-19 Several different scale factor of the gyro angle output

If a map 2-32 Without gravitational acceleration control scheme shown, the sensor can be greatly simplified parameters Tuning. Without gravity accelerometer sensor for measuring inclination of car models and car models gyroscope angle gyroscopes Scale factor can not be corrected, the final performance of the different sensors to compensate by controlling parameters.

6.3.2. Cars static debugging control parameters

Cars set speed 0 , The control parameters for each car model car models for debugging called static debugging. need FIG commissioning control parameter 6-20 :


Angle control
P_{ANGLE}: Scale Factor
D_{ANGLE}: Differential Factor
speed control
P_{SPEED}: Scale Factor
D_{SPEED}: Differential Factor
Directional control
P_{DIR}: Scale Factor
D_{DIR}: Differential Factor
Angle compensation
T_Z: Compensation time constant
motor driven
V_D: Dead-motor drive
Gyro
velocity ω θ angle
D_{ANGLE}
integral
An angular
P_{ANGLE}
$1/T_Z$
proportion
Accelerometer
Speed reference
D_{SPEED}
integral
P_{SPEED}
0:00 left
electromagnetic detection
C_{LEFT}
Y_{SUB}
Y_{SUB}/Y_{ADD}
Y_{ADD}
P_{DIR}
C_{RIGHT}
Detecting
electromagnetic Right 0:00
Cars gyro
measuring
rotation
D_{DIR}
Cars rotational
gyroscope 0:00
C_{ROT}
motor driven
Revolver motor
Right wheel motor
M
Motor Control
dead zone: V_D

Map 6-20 Control parameters Cars

These follow the order of parameter adjustment, the order of the angle, speed, direction of adjustment. In these three groups of parameters adjustment Process, and the time constant of the motor angle correction dead zone parameters are first set to a default value. For example, the angle Compensation time constant T_Z can choose 3 second. Motor options for the V_D dead 0 . After completion of the preceding three tuning parameters into a Further optimize these two parameters. It needs special emphasis has two aspects: The first aspect is the angle compensation constant T_Z It can not be too Small, analysis of the causes behind while adjusting the parameters. The second aspect is the zero point offset for each sensor as possible Amendment accurate energy. If during debugging below zero offset any sensor drift occurred, the need for timely Correction.

1 , The angle parameter setting

Angle proportional and derivative control parameters include two parameters. Scaling parameter (P_{ANGLE}) is equivalent to an inverted pendulum reply force. This parameter must be greater than the gravitational acceleration effect can be produced such that it remains upright car models. With this reference Gradually increase the number, scale models began to be able to stay upright. This parameter is further increased, scale models began to swing back and forth now Like. Differential parameter (D_{ANGLE}) corresponds to an inverted pendulum damping force, it can effectively suppress the swing car models. when When this parameter is too large, it will cause shock car models themselves. This is because the car model itself is not a rigid body, the body has a Given resonance frequency. Cars will be such that the time derivative parameter is too large resonance in the vehicle body driven by the motor.

Adjusting these two parameters can follow the process after the first derivative of proportion. First, adjust the scale parameter, such car models can be Upright and start swinging back and forth. A statement to this scale parameter image has been overcome gravity. Then gradually

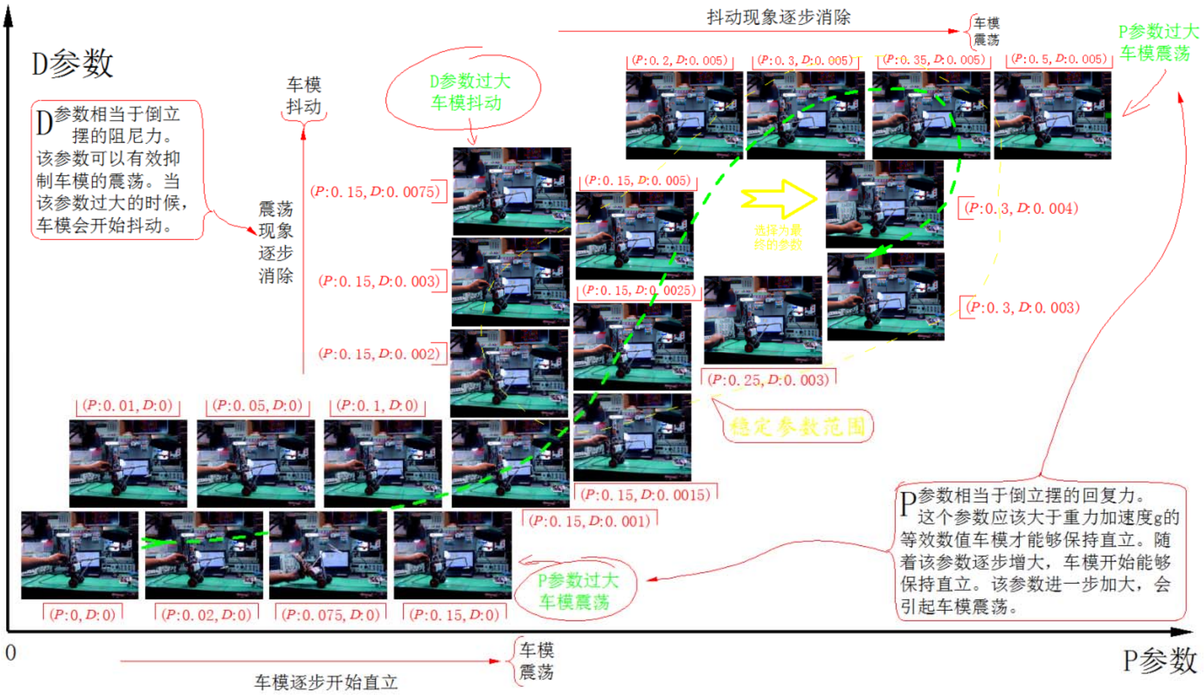
Increasing the differential parameters, scale models and gradually upright and stable. Cars began to increase the differential parameters until resonance, so that you

Determine the maximum value of the differential parameter. Differential parameter is then appropriately reduced, and then gradually increasing the proportion of para

He began to shock, so that we can determine the maximum proportion parameter. Then the appropriate reduction rate parameters. In these parameters

Tested several nearby until find a set of optimal control parameters Cars upright.

The specific process can see the following FIG. 6-21 As shown in the graphic.


D参数
D参数相当于倒立摆的阻尼力。该参数可以有效抑制车模的震荡。当该参数过大的时候，车模会开始抖动。
车模
抖动
震荡现象逐步消除
D参数过大
车模抖动
抖动现象逐步消除
车模
震荡
P参数过大
车模震荡
(P:0. 2, D:0. 005)
(P:0. 3, D:0. 005)
(P:0. 35, D:0. 005)
(P:0. 5, D:0. 005)
(P:0. 15, D:0. 0075)
(P:0. 15, D:0. 005)
(P:0. 3, D:0. 004)
选择为最终的参数
(P:0. 15, D:0. 003)
(P:0. 15, D:0. 0025)
(P:0. 3, D:0. 003)
(P:0. 15, D:0. 002)
(P:0. 25, D:0. 003)
稳定参数范围
(P:0. 01, D:0)
(P:0. 05, D:0)
(P:0. 1, D:0)
(P:0. 15, D:0. 0015)
(P:0. 15, D:0. 001)
P参数相当于倒立摆的回复力。这个参数应该大于重力加速度g的等效数值车模才能够保持直立。随着该参数逐步增大，车模开始能够保持直立。该参数进一步加大，会引起车模震荡。
P参数过大
车模震荡
(P:0, D:0)
(P:0. 02, D:0)
(P:0. 075, D:0)
(P:0. 15, D:0)
0
车模逐步开始直立
车模
震荡
P参数

Map 6-21 Angle parameter adjustment process

Cars upright proportional and derivative control parameters of a considerable range. Cars were moving behind the

Parameter adjustment leaves room for amendment.

Since the gravitational acceleration sensor and the gyro drift error signal that has the mounting, the angle control parameter adjusted

The car models are not sophisticated stay at a certain point. It is inclined towards the angular direction acceleration traveling car models. During this process,

Adjusted for multiple car models and zero gravitational parameter gyroscope, the inclination angle may be gradually eliminate car models,

But in the end with the sensor drift, scale models or will accelerate the move. Cars remain stationary or constant speed operation needs to pass

Overspeed control to achieve.

2 Speed parameter setting

After the initial parameters determining the angle, the speed can be controlled tuning parameters. Speed ratio control parameter includes

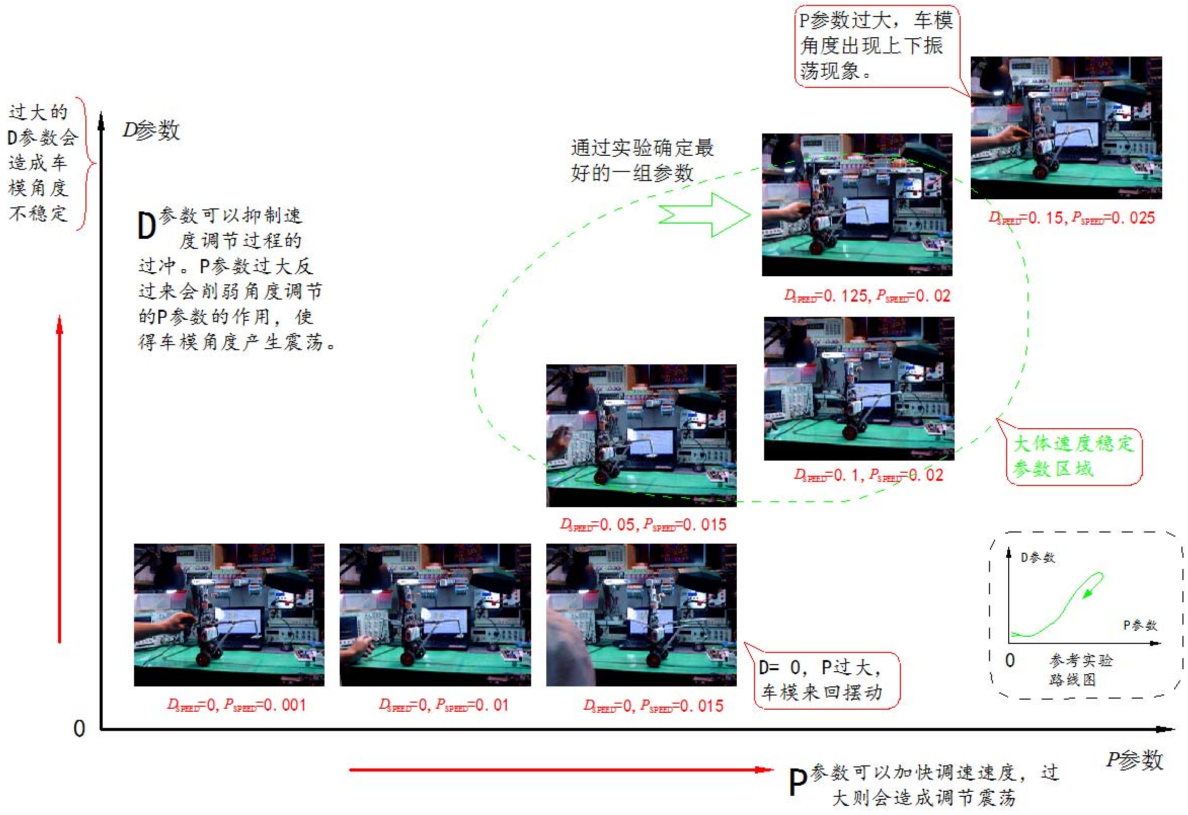
Example (P_{SPEED}) and differential (D_{SPEED}) two control parameters, where the proportional and derivative feedback means is defined speed

Statements. If the position feedback Cars (integral amount of speed) with respect to these two parameters can also be referred to as a product corresponding to each

Min () $_{SPEED}$ and the ratio () parameter P_{SPEED}.

Is achieved by adjusting the angle of the first car models Note that the speed modulation in nature. Map 2-38 Shows the Speed control link. Speed error proportional control parameter determines the ability to inhibit, but only proportional control, the speed of car models There will be a double integral control negative feedback control. The first integral is the integral of the error, the second is the integration of the inclination Cars Acceleration generated points. Therefore, the speed of the car models will be a shock phenomenon. The shock can be eliminated by differential control phenomenon.

When the adjustment, since the adjustment is static, therefore first speed setpoint speed control loop is set 0 . However After started to adjust the proportional and derivative parameters behind. The first specific debugging process can gradually scaling parameters, scale models can Be in the vicinity of Ping Heng point constant back and forth motion. Then gradually increase the differential parameter, scale models will soon remain in balance Out. Use external shocks car models, car models can quickly become stationary. And then gradually increase the proportional and derivative control parameters, Cars making resistance to external interference shocks gradually increase. Figure debugging process 6-22 Fig.


P参数过大，车模角度出现上下振荡现象。
过大的D参数会造成车模角度不稳定
D参数
通过实验确定最好的一组参数
D参数可以抑制速度调节过程的过冲。P参数过大反过来会削弱角度调节的作用，使得车模角度产生震荡。
D_{SPEED}=0. 15, P_{SPEED}=0. 025
D_{SPEED}=0. 125, P_{SPEED}=0. 02
D_{SPEED}=0. 1, P_{SPEED}=0. 02
D_{SPEED}=0. 05, P_{SPEED}=0. 015
大体速度稳定参数区域
D参数
P参数
0
参考实验路线图
D_{SPEED}=0, P_{SPEED}=0. 001
D_{SPEED}=0, P_{SPEED}=0. 01
D_{SPEED}=0, P_{SPEED}=0. 015
D= 0，P过大，车模来回摆动
0
P参数
P参数可以加快调速速度，过大则会造成调节震荡

Map 6-22 Speed parameter adjustment process

When the proportional and derivative parameters up to a certain value, scale models began to swing phenomenon. At this point we can know the ratio

Differential and general scope. Through several tests the optimum adjustment can be preliminarily determined within this range of speed control parameters combination.

3 , The direction parameter setting

A direction control includes two parameters: the proportional control parameter (P_{DIR}) and the differential control parameter (D_{DIR}). Adjustment

Direction parameter is to set the speed parameter 0 , Open the Desktop 20kHz Electromagnetic power supply. Proportional control parameter may cause

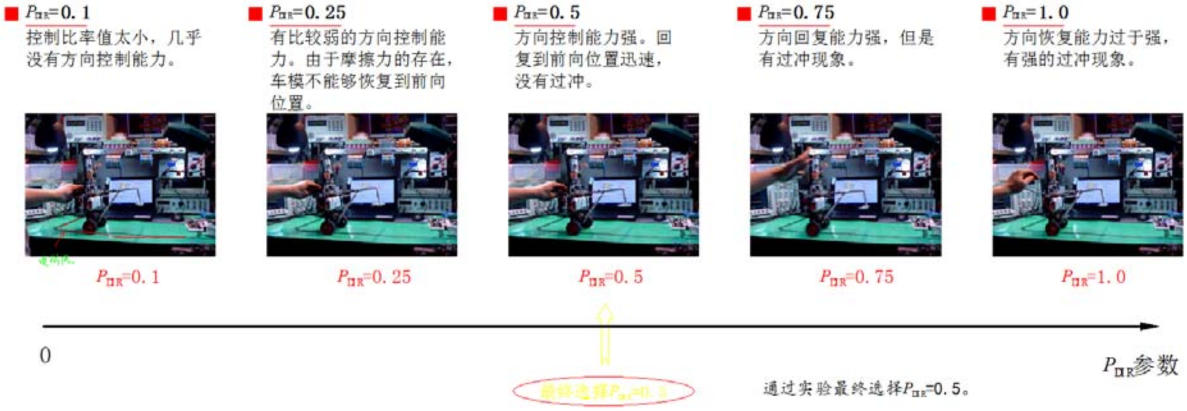
Cars restore the correct direction of the position. When this parameter is gradually increasing, scale models direction response rate gradually accelerated. When the

After several increases to a certain value, due to the rapid response car models direction, the direction will overshoot. This phenomenon can be

Through FIG. 5-23 display. At this time, the control parameters can be suppressed by increasing the differential of direction overshoot phenomenon. by

Combination of several tests can select an appropriate set of proportional control and differential control parameters that control the direction of car models quickly i.e.

It will not overshoot.


■ P_{DIR}=0. 1
控制比率值太小，几乎没有方向控制能力。
■ P_{DIR}=0. 25
有比较弱的方向控制能力。由于摩擦力的存在，车模不能够恢复到前向位置。
■ P_{DIR}=0. 5
方向控制能力强。回复到前向位置迅速，没有过冲。
■ P_{DIR}=0. 75
方向回复能力强，但是有过冲现象。
■ P_{DIR}=1. 0
方向恢复能力过于强，有强的过冲现象。
P_{DIR}=0. 1
P_{DIR}=0. 25
P_{DIR}=0. 5
P_{DIR}=0. 75
P_{DIR}=1. 0
0
P_{DIR}参数
最终选择P_{DIR}=0. 5
通过实验最终选择P_{DIR}=0. 5。

Map 6-23 Direction parameter adjustment process

If the directional control parameter adjustment is too large, it will affect the control car models angle. Therefore, in this process of debugging,

Cars need to balance the upright direction and both control stability.

The above three steps to adjust the angle of the car models, the speed and direction control. These parameters are stationary when the car models

Debugging. Have a mutual influence between them. Cars movement behind the front adjusted as compliance

Follow the principles and experience between them affect each other, and gradually optimizing these parameters such that during movement remains Cars

Stable and fast characteristics.

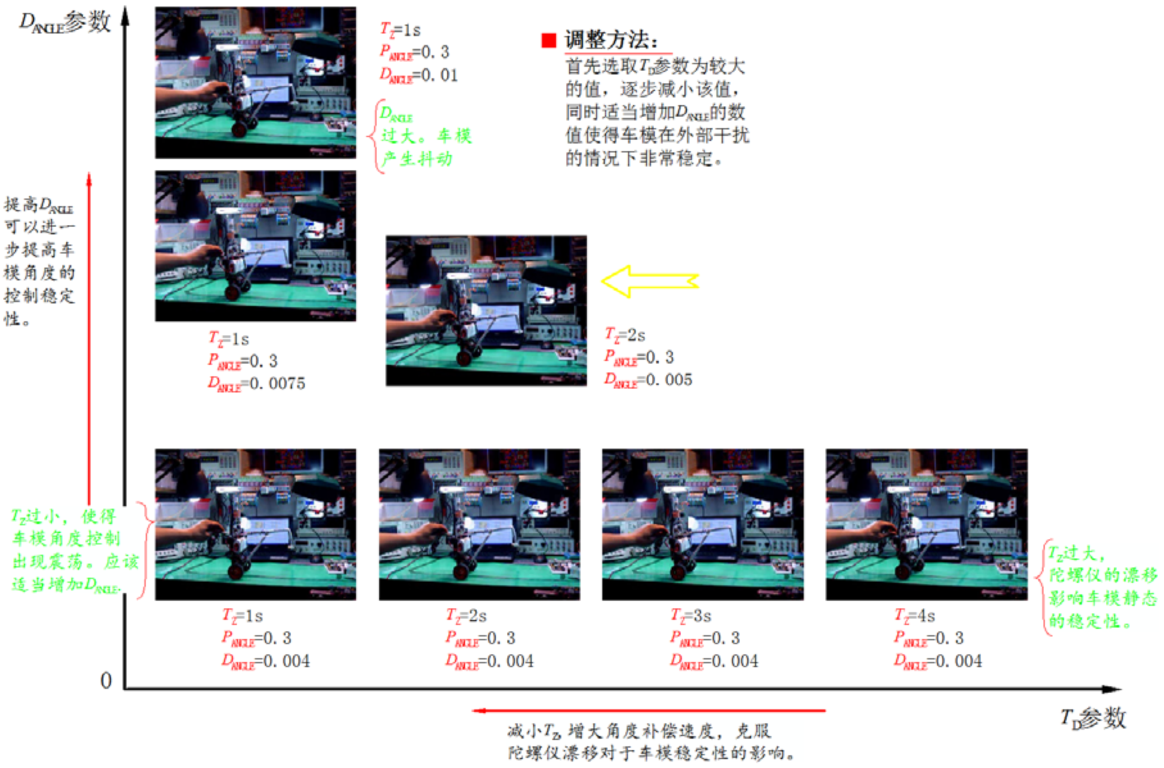
4 , Compensation time constant setting

Cars angle compensation time constant (T_z), determines the capacity of integrating gyro drift suppression, also determines the car

Speed control angle tracking mode speed, while the ability to determine the gravitational acceleration in the suppression of disturbing signals. Although it

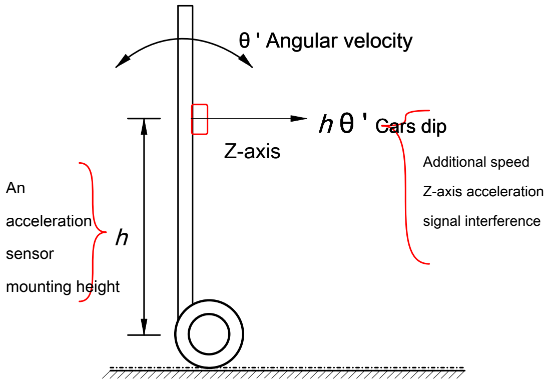
Only one parameter, but it will also affect the adjustment of the angle and speed control. Wherein for controlling the angle of impact Particularly evident.

Start adjusting the control parameters when the first three may be selected backoff time 3 to 4 Or so seconds. If Tuo Spiro instrument zero drift is small, the compensation can be increased time constant. If the gyroscope zero drift large, you can This gradually decreases the compensation time constant. Reduce the time constant when the compensation will find car models will now waggle Like. When this phenomenon and control the angle of car models, the oscillatory phenomenon of car models consistent scale value generated is too large. So you ca To increase the appropriate control parameters angle differential D_{ANGLE} parameter () to suppress the phenomenon of swing car models. See the debugging process Map 6-24 Fig.


D_{ANGLE}参数
T_Z=1s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 01
D_{ANGLE}过大。车模产生抖动
调整方法:
首先选取T_D参数为较大的值，逐步减小该值，同时适当增加D_{ANGLE}的数值使得车模在外部干扰的情况下非常稳定。
提高D_{ANGLE}可以进一步提高车模角度的控制稳定性。
T_Z=1s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 0075
T_Z=2s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 005
T_Z过小，使得车模角度控制出现震荡。应该适当增加D_{ANGLE}.
T_Z=1s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 004
T_Z=2s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 004
T_Z=3s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 004
T_Z=4s
P_{ANGLE}=0. 3
D_{ANGLE}=0. 004
T_Z过大，陀螺仪的漂移影响车模静态的稳定性。
0
减小T_Z，增大角度补偿速度，克服陀螺仪漂移对于车模稳定性的影响。
T_D参数

Map 6-24 Angle compensation time constant adjusting

Why angle compensation time constant is too small will cause car models swing it? FIG. 5-25 Carried on by the acceleration Forces can be known gravitational acceleration sensor is mounted having a certain height, angle changes at this time car models, it Will gravitational acceleration sensor Z Axis acceleration component appears. This inclination is proportional to the acceleration component of car models. Such as If at this time the compensation angle gravitational acceleration constant is too small, corresponding to the angle calculation loop analysis can know, at this time Z ax Since the signal of the acceleration caused by the angle of the car models exactly offset the differential angle control component in the original, so that the vehicle Mold will swing back and forth, therefore the need to increase the angle of the derivative component of the control to suppress the swing car models. Map 5-25 It shows the stress analysis of the accelerometer.


θ ' Angular velocity
h θ ' Cars dip
Z-axis
Additional speed
Z-axis acceleration
signal interference
An
acceleration
sensor
mounting height
h

Map 6- 25 Z Additional axis signal analysis

Cars swing elimination can be achieved by two methods, one is to increase the time constant of the compensation T_2, this solution also

To release the preceding claims when the compensation time constant adjustment parameter Why reason not be too small. The second way is through

Reducing the height of the angular velocity sensor to reduce the swing car models

5 The motor constant setting deadband

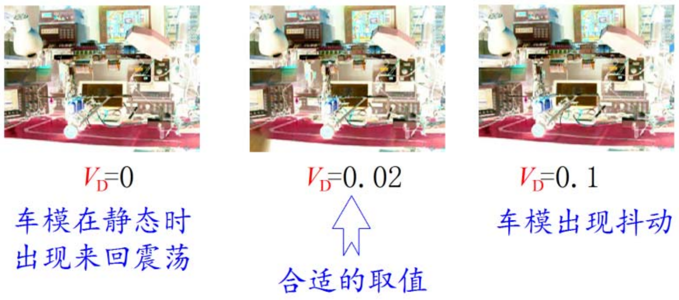
Cars in the drivetrain, all aspects of the existence of static friction, it will reduce car models static stability.

It can be overcome by increasing the voltage to the motor control a constant dead space.

When adjusting dead zone constant need to remain upright stationary car models. Deadband constant 0 When, scale models will be at rest

Back and forth back and forth movement of small amplitude appear. By gradually increasing the dead zone constant back and forth motion car models phenomenon

Dead time constant is too large, there will be car models motor vibration phenomenon. Figure 5-26 Fig.


V_D=0
车模在静态时
出现来回震荡
V_D=0. 02
合适的取值
V_D=0. 1
车模出现抖动

Map 6-26 Deadband constant adjustment

By gradual adjustment may determine a relatively modest deadband constant.

In the smart car competition it is, because it is the speed of the game. Deadband constant of the motor may be provided to 0 ,it

For car models did not affect the high-speed operation.

6.4 Site debugging dynamic parameters

By the above steps, determining the parameters of each phase of the control link. However, these parameters are the speed of the car models Remains 0 For debugging in the state. Are these parameters are in with a good run at high speed car models, but also "It is the mule is a horse, pull out yo." Therefore, the high-speed car models running on the race track again for each Control parameters are optimized, so that the car models run fast and stable.

Dynamic adjustment of the various parameters is generally based on the obtained static adjustment, gradually increase the speed set Cars Value observed at different car models operating speed setpoint, its angle, speed and direction control performance. In Bulgaria Cars under license angle and direction of stable conditions, and gradually increase the speed of the car models, observed phenomena appear, according to the Adjust control parameters preceding the interaction therebetween relationship obtained by adjusting parameters, such car models and can be Gu stability and speed.

Cars running on, adjust the control parameters are very complex. This process needs to be tested repeatedly. Tested Process, went off the track in order to avoid runaway Cars damaged hits an obstacle, it is recommended to increase in the wireless remote control car models Switch, can be stopped in an emergency car models.

Cars test track complex needs as much as possible under the conditions allow for racetrack elements that may arise Hope can be tested to find the optimal parameters of car models in a variety of extreme track conditions, as well as the fastest possible speed Degree setting, which is behind the development of competition policy to participate in a live game basis. When the game scene, often available on-site Debugging time does not allow players to race track complete test, therefore there is need to select the characteristics of the track section into Line testing, and finally given a reasonable control parameters. Select what part of the track for testing, usually you need to dynamically adjust The test of experience.

Cars dynamic debugging is not only adjusted for various control parameters, while the mechanical structure of the car models also measured Test and adjust. Within a predetermined range of the rules of the game, and arrange the center of gravity position of the sensor mounting position of car models, Improve the stability of the car models. In the fourth chapter describes the installation error will cause the gyroscope car models increase the speed when cornering c cut back. Thus, it is possible to adjust the mounting angle of the gyro car models by dynamic operation. After an additional electromagnetic Cars When crossing an intersection, by controlling the direction of car models electromagnetic sensor determines whether the installation is stable level.

6.5 Program improvement and improve the overall level of car models

Car models after production, programming, after commissioning, operation carried out in the real world, the existence of further errors are found, Optimization of the various control parameters, and gradually increase the running speed of the car models. Through continuous running, as amended, was an optim

Control Strategy.

In the test run, or we can make further improvements to the control algorithm. Cars increase state observations, which correction

Nonlinear links, improve stability and performance, the car models in the high-speed operation.

No Limit game, the endless pursuit. Debugging on the results already achieved, careful observation, careful thought, to

To the problems identified, the gradual improvement of the control scheme, breaking the limitations of existing ideas, seek more advanced perfect solution,

In order to win the next competition. Within the specified range of game technology, the pursuit of excellence. In the continuous improvement and real

Experiment, the harvest is not only the final race results, but also the ability and the courage to do it yourself spirit of exploration.

Chapter VII Conclusion

As used herein, the theoretical knowledge as few car models control scheme described with reference to upright walking. Through this square

Case, the students will feel to walk upright produced car models contest is not a difficult thing, but quite easy and fun

the process of.

By making, students can basically achieve complete race car models. Upon completion, students will gradually find

The shortcomings of the program, and thus improve the germination of the idea. To simplify the design of the control scheme, herein in many ways

It has been simplified. Cars need to realize such control is achieved by controlling the acceleration of the motor, at the start of presentation

Designate, for motor acceleration control is to alter the drive voltage of the motor. But the acceleration of the motor should be through

Wherein the electromagnetic torque generated by the current to achieve. This requires motor control circuit should be increased on the current control

Cars have a system which can ensure more stable performance. According to their knowledge and experience made, students can

Circuit design, control algorithms, mechanical adjustments can be found in many areas of improvement. In order to achieve these improvements

The idea, take out more of the relevant literature, learning advanced modern control theory knowledge and improve their theoretical level and

Practical ability, eventually produce automatic gain control for Qiang Lie professional interest, which is what the students deserve.

Cars made in the program of the competition, we should try to choose inexpensive, easy to buy the device. in order to avoid

Teams use expensive sensor device in terms of choice, the competition rules defined so that an acceleration sensor and a gyro

Model used. Taking into account changes in the future availability of sensor market, the organizing committee will expand the range of the sensor selected.

Please pay attention to the team members timely information published on the website of the competition.

Cars race this year to walk upright is first established, the students produced electromagnetic group walk upright running car models

Speed may be relatively slow, therefore limiting the length and difficulty of the race track in the competition rules. Meanwhile, in the game Process, does not require a static car models from two seconds to automatically start the race, was canceled at the end of the game Cars stopped at the starting Required track on-line within three meters. Competition Organizing Committee will be based on the specific circumstances of the students made car models, the elec Race track, rules of the game for further revision, the revised information will be promptly posted on the competition website.

appendix:

1 ,Copyright Notice

"Seventh National College" Freescale Cup "smart car race electromagnetic set of reference designs" Articles copyright Belonging to the smart car competition secretariat.

2 ,references

(1) Competition Secretariat "solenoid group race car models path detection reference designs" 2010-1, version 1.1

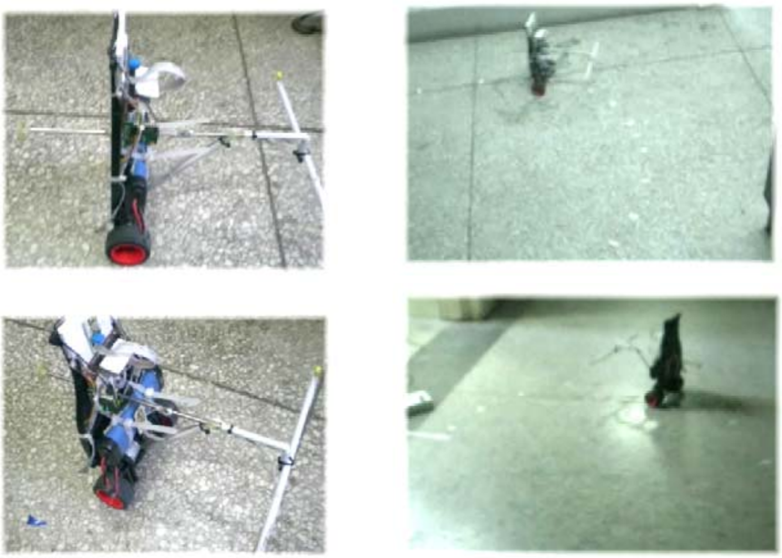
(2) "Fifth National Students Smart Car race 20kHz Power Design Reference "

Competition Secretariat Technology Group, version 1.1

3 Upstanding reference design video Cars

Reference design can be downloaded to the car models in this article in the demo video contest website:

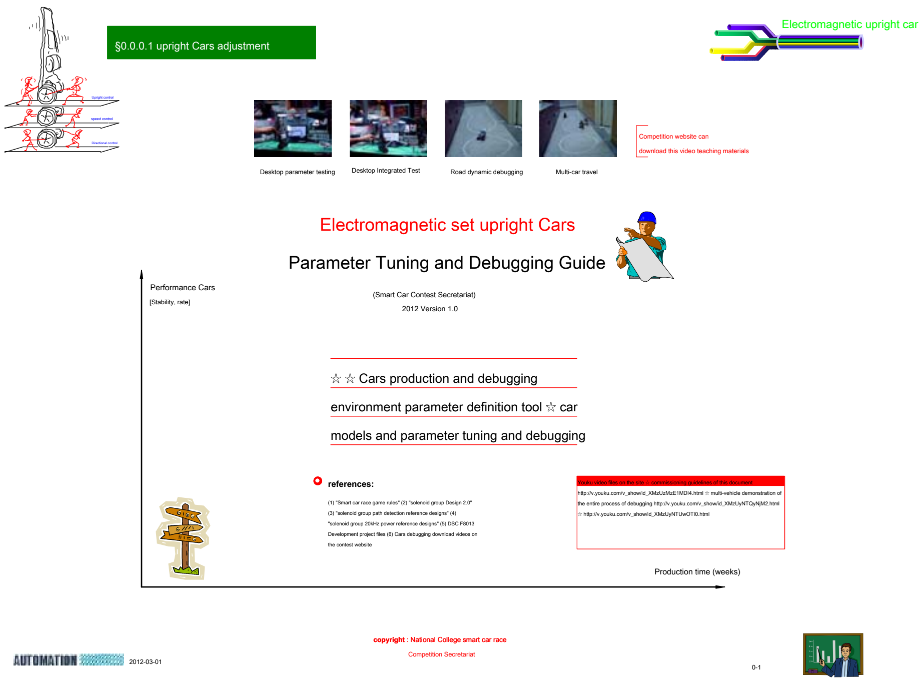
http://www.smartcar.au.tsinghua.edu.cn/web/index.jsp : "Cars upright video reference design"



Map 7-1 Reference design for video capture

4 Electromagnetic set upright Cars commissioning guide and video

Competition website can download this reference scenario upright Cars and Cars debug build guide manual debugging process of speaking Solutions for video file to watch the dynamics of the car models car models running debugging process.



§0.0.0.1 upright Cars adjustment

Desktop parameter testing

Desktop Integrated Test

Road dynamic debugging

Multi-car travel

Competition website can download this video teaching materials

Electromagnetic set upright Cars

Parameter Tuning and Debugging Guide

(Smart Car Contest Secretariat)

2012 Version 1.0

Performance Cars

[Stability, rate]

☆ ☆ Cars production and debugging environment parameter definition tool ☆ car models and parameter tuning and debugging

references:

(1) "Smart car race game rules" (2) "solenoid group Design 2.0" (3) "solenoid group path detection reference designs" (4) "solenoid group 20kHz power reference designs" (5) DSC F8013 Development project files (6) Cars debugging download videos on the contest website

Youku video files on the site ☆ commissioning guidelines of this document http://v.youku.com/v_show/id_XMzUzMzE1MDI4.html ☆ multi-vehicle demonstration of the entire process of debugging http://v.youku.com/v_show/id_XMzUyNTQyNjM2.html ☆ http://v.youku.com/v_show/id_XMzUyNTUwOTI0.html

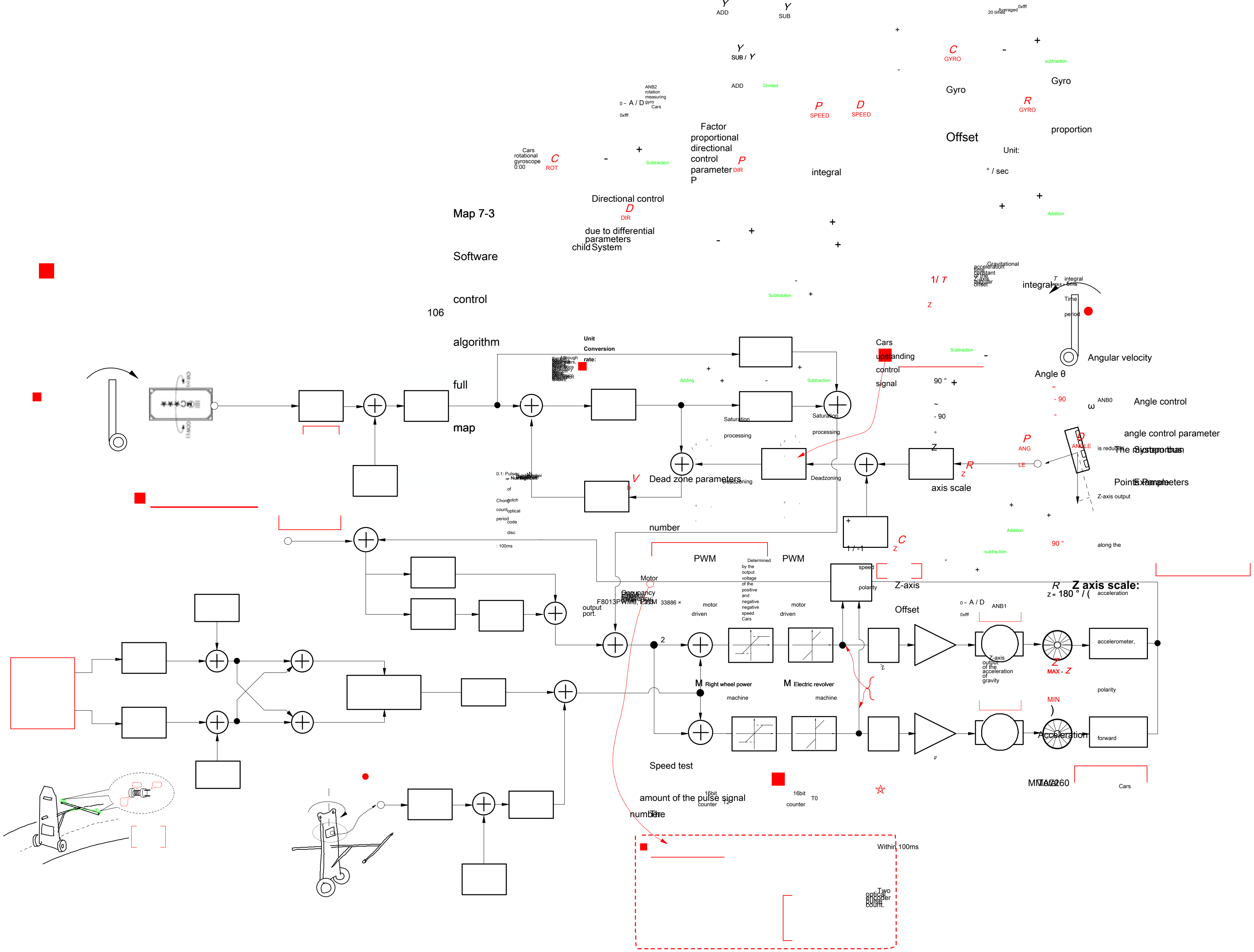
Production time (weeks)

AUTOMATION 2012-03-01

copyright : National College smart car race Competition Secretariat

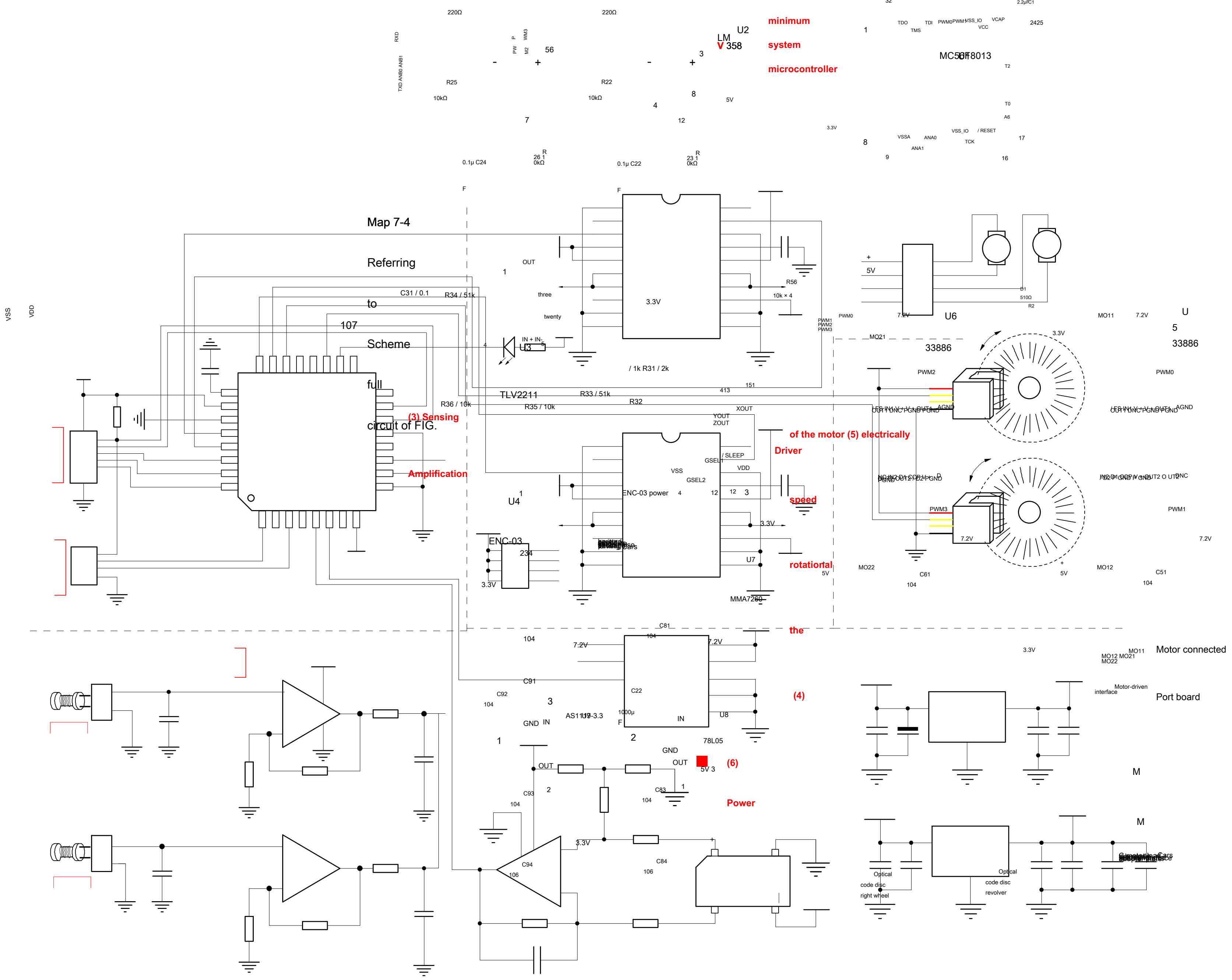
0-1

Map 7-2 Parameter Tuning and Debugging Guide



Map 7-3 Software control algorithm full map

Y ADD
Y SUB
Y SUB / Y
ADD
Divided
0 ~ A / D
0xfff
ANB2 rotation measuring gyro Cars
Cars rotational gyroscope 0:00
C ROT
Subtraction
Factor proportional directional control parameter P
P DIR
Directional control
D DIR
due to differential parameters child System
P SPEED
D SPEED
integral
C GYRO
Gyro
Offset
Averaged 20 times
0xfff
subtraction
Gyro
R GYRO
proportion
Unit:
° / sec
Addition
1/ T
Z
Gravitational acceleration
integral
T integral 5ms
Time period
Angular velocity
Angle θ
Cars upstanding control signal
Subtraction
90 °
- 90
ANB0
ω
Angle control
angle control parameter
P ANG
D ANGLE
The system has
Points Parameters
Z-axis output
R Z
axis scale
Unit Conversion rate:
Adding
Subtraction
Saturation processing
Deadzoning
V
Dead zone parameters
0.1: Pulses
Chong
count
period
optical code disc
: 100ms
number
PWM
PWM
Determined by the output voltage of the positive and negative negative speed Cars
Motor
F8013PWM0, 12, M 33886 ×
output port.
motor driven
motor driven
2
1 / -1
C Z
speed
polarity
Z-axis
Offset
0 ~ A / D
0xfff
ANB1
R Z axis scale:
Z = 180 ° / (
acceleration
accelerometer,
polarity
forward
Z-axis output of the acceleration of gravity
MAX - Z
MIN
Acceleration
M Right wheel power machine
M Electric revolver machine
Addition
subtraction
90 °
along the
Speed test
amount of the pulse signal
number
16bit counter
16bit counter
T0
MMA7260
Cars
Within 100ms
Two optical encoder pulse count.



Map 7-4 Referring to 107 Scheme full circuit of FIG.

minimum
system
microcontroller
U2
LM
V 358
MC56F8013
220Ω
220Ω
R25
10kΩ
R22
10kΩ
5V
3.3V
0.1μ C24
0.1μ C22
R 26 10kΩ
R 23 10kΩ
TDO
TMS
TDI
PWM0
VSS_IO
VCC
VCAP
2425
T2
T0
A6
VSSA
ANA0
ANA1
VSS_IO
/ RESET
TCK
17
16
RXD
TXD ANB0 ANB1
VSS
VDD
OUT
three
twenty
C31 / 0.1
R34 / 51k
R56
10k × 4
/ 1k R31 / 2k
IN + IN-
U3
TLV2211
R36 / 10k
R33 / 51k
R32
R35 / 10k
(3) Sensing
Amplification
413
151
XOUT
YOUT
ZOUT
/ SLEEP
GSEL1
VSS
GSEL2
VDD
ENC-03 power
U4
ENC-03
234
3.3V
U7
MMA7260
of the motor (5) electrically
Driver
speed
rotational
the
5V
U6
7.2V
33886
MO21
PWM0
PWM1
PWM2
PWM3
510Ω
R2
MO11
U
5
33886
PWM2
PWM0
PWM3
PWM1
7.2V
MO22
C61
104
MO12
C51
104
5V
OUT1 DNC FGND PGND
IN2 D1 OUT2 DNC
C81
104
7.2V
104
C91
C92
104
3
GND IN
AS1117-3.3
C22
1000μ
F
IN
U8
2
78L05
GND
OUT
5V 3
(4)
(6)
Power
1
OUT
C93
104
2
C83
104
3.3V
C94
106
C84
106
3.3V
MO12 MO21
MO22
MO11
Motor connected
Motor-driven
interface
Port board
M
M
Optical
code disc
right wheel
Optical
code disc
revolver

7 Reference design engineering design documents

This article can be downloaded to a reference design for software engineering documents on the competition website. "Reference design side upright Cars case DSC Software engineering documents. RAR . "

8 , DSC Project directory and file specification

(1) SMMNew1 \ Code Contents: kept by Codewarrior in PE Automatic generated DSC Each driver module program files.

(2) SMMNew1 \ AppCode Catalog: Save car models control algorithm file. among them:

CARSUB.C, .H: Cars full control functions, header files.

CONFIG.C, .H: Control parameters Cars FLASH Stored functions, header files.

DEBUG.C, .H: Cars serial debugging functions, header files.

F8013.C, .H: F8013 Underlying function files, header files.