A Novel Track Detection Program for Accurate Position Location of Freescale Smart-Cars

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Abstract **— To solve the problem that Freescale electromagnetic smart-car correctly identifies the track, the distribution of the magnetic field intensity around straight current-carrying wires is analyzed to deduce the relationship between coils induced electromotive force (emf) and horizontal distance from wires. Three lay-out models of sensor coils have been setup with devices to detect deviation from the track and indicates by positive or negative emf on both sides of sensor coils. This is capable of judging the accurate direction and distance if the axis of smart-car moves off wires. A related control circuit is designed to detect and send signals to a software filter to collect and process data into simplified and normalized form. Feedback values of the three sensors have the ability to judge the shape of the track. The result indicate the feasibility of the novel program where Freescale smart-car identifies a variety of different tracks precisely.**

Keywords - bias tunnel; Freescale smart-car; electromagnetic; sensor; detection

I. INTRODUCTION

The Freescale smart-car competition requires that the racing car can effectively identify the track which is made up of electromagnetic wires with specific frequency and size, and finish the whole distance with the faster speed according to the shape of track. Due to the differences of track elements, if we want to complete the competition in the light of the shape of track, the track elements must be identified effectively to finish the competition rapidly and efficiently.

Different from photo electricity group and camera group, the prospect of electromagnetic group is relatively slim. The number of sensors and its rational distribution directly influences the correctness of collecting signals, thus affecting the judging ability for track condition. Synthesizing the previous experiences and the situation of own experimental tests, there are several schemes as follows:

(1) Sensors are distributed equally in the front-back rows, each row with 4 sensors. The advantage is that it can detect the track especially the bends. But the shortcoming is unconformity of sensor return value and ideal value owing to the serious interruption between sensors. So the value must be calibrated through multiple data collection. Besides, the signal strength is easily influenced;

(2) Four sensors are distributed equally in a row. The advantage is intense signal strength and smoothing curve. While the disadvantage is undesirability for bend control due to the mutual interruption between sensors.

(3)There are two sensors in the front row and three in the back row. The merit is that the handling ability for signal becomes stronger, which can process the track signal by processor in advance. But the sensors in the front row will produce interruption when entering and existing the bends.

To improve the system security and solve signal jitter problem, the scheme that three sensors are positioned horizontally in one row is studied and designed. It has little signal interference between sensors and fits smoothing curve so it would not appear the phenomenon about the misjudgment of curve and greatly improve the ability of information processing.

II. ELECTROMAGNETIC PRINCIPLE

The current through the wire of racing car is alternating current with current of 100mA and frequency of 20 kHz. The position of racing track relative to the racing car is determined by the surrounding electromagnetic field which needs to be detected through sensor coil. According to Maxwell electromagnetic field theory, alternating current produces alternating electromagnetic field around it. Because the track wire and size of car are far less than the wave length λ of electromagnetic wave, and the radiant energy of electromagnetic field is not so much, the energy inducted from electromagnetic wave is very small.

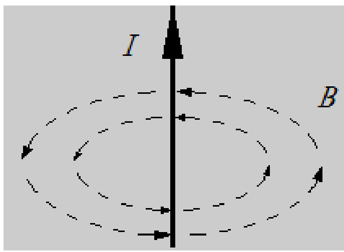

Figure 1. Distribution of the magnetic field intensity around straight current-carrying wires

Therefore, the changing magnetic field around the wire can be approximate to slowly varying magnetic field, and the magnetic field distribution around wire is obtained in the light of the method of detecting static magnetic field. If the inductance coil is put in the magnetic field, electromagnetic induction can produce alternating current in the coil. Under the established conditions of wire position and current in

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wire, the induced current in the coil belongs to function about spatial position for position detection.

Based on electromagnetic principle, if there is a wire with infinite length and the changing current I is switched on in the wire, the place around wire will produce magnetic field B with the changing of current, as shown in Fig.1.

Put inductance coil in the magnetic field, and the inductance will produce induced electromotive force E with the changing of magnetic field.

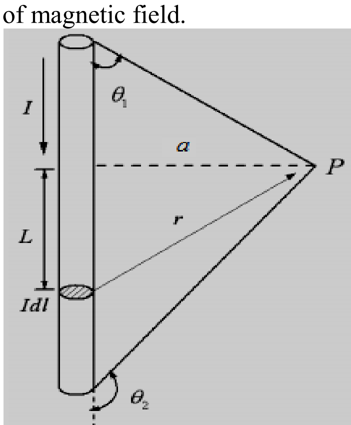

Figure 2. Magnetic field intensity calculating of straight current-carrying wires.

According to Biot-Savart law [1,2], let the magnetic flux density be B at the point P where the distance from the straight wire is a. Now partition the straight wire into infinite multiple current elements. Let the length of each current element and single current element be dl and Idl respectively. All current elements produce magnetic field at the point P, as shown in Fig.2.

So the produced magnetic field of single current element is $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$. (1)

Where, μ_0 is permeability of vacuum and the value is set to $\mu_0 = 4\pi \times 10^{-7} N / A^2$; and r represents the distance of single current element from the point P.

Take the integral of all produced magnetic flux density by current elements from wire, and get $B = \int dB = \int \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$.

Transformations for formula relation are as follows:

$$\begin{cases} r = \dfrac{a}{\sin\theta} \\ l = -actg\theta \\ dl = \dfrac{a}{\sin^2\theta}d\theta \end{cases}$$

Rearrange the above formula can be described as follow:

$$B = \frac{\mu_0 I}{4\pi a}\int_{\theta_1}^{\theta_2}\sin\theta d\theta = \frac{\mu_0 I}{4\pi a}(\cos\theta_1 - \cos\theta_2) \quad (2)$$

In which θ_1 is the included angle between the starting point of current-carrying straight conductor and point P, and θ_2 is the included angle between the terminal point and point P. If the conductor is infinite long, $\theta_1 = 0, \theta_2 = \pi$, so the magnetic flux density of point P is $B = \frac{\mu_0 I}{2\pi a}$. The direction of straight wire is taken as the tangential direction of circumference. The directions of point P and current form right-hand screw rule.

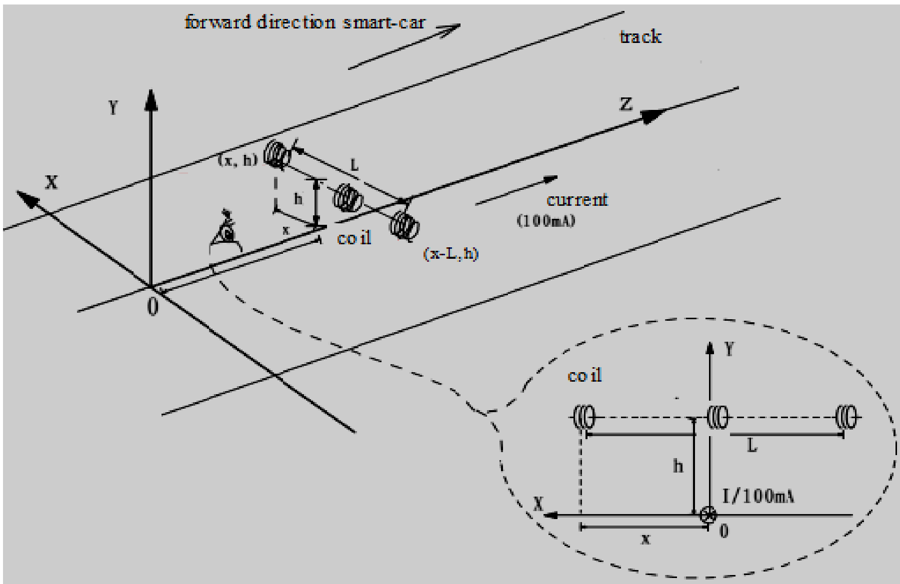

Figure 3. Lay-out modes of sensor coils.

III. DETECTION MODULE

A. Detection Principle.

If current intensity I in the energized wire makes changes according to certain rules, the magnetic field intensity B around the wire will change, and a certain amount of electromotive force E will be inducted in the coil. According to Faraday's electromagnetic induction law, induced electromotive force E is proportional to the magnetic flux $\Phi(t)$ through conductor circuit: $E = -\frac{d\Phi(t)}{t}$, and the direction of induced electromotive force can be ascertained by Lenz's law.

Put the detecting coil horizontally, establish X-axis along the direction vertical to the energized straight wire, then move it along the direction of X-axis [3,4]. Let the horizontal distance from sensor center to energized straight wire be $x = 15cm$, and vertical distance E_d, then the distance from sensor center to energized straight wire is:

$$a = \sqrt{h^2 + x^2}$$

as shown in Fig.3.

According to Faraday's law of electromagnetic induction, the induced electromotive force E can approximate:

$$E = -\frac{d\Phi(t)}{t} = \frac{K}{\bar{a}}\frac{dI}{dt},$$

where K is related to the coil placement method, coil size and physics and can be tested by actual measurement; $\bar{a}$ is the effective distance of the magnetic field line through the coil. Because the coil is placed horizontally, the induced electromotive force is related to the component of magnetic field line in horizontal direction. According to the distance relation between coil and straight line, it can be expressed as:

$$E = \frac{Kh}{h^2 + x^2}\frac{dI}{dt}.$$

It can be seen that the size of induced electromotive force is in inverse proportion to the distance a from coil to straight line. That is to say, the farther the distance from inductance coil to wire was, the lower the tested magnetic flux density B as well as the produced induced electromotive force E in the inductance would be. Let h=5cm and L=30cm, so the variation x is (−15, +15) cm. If only single coil is used, the relation between the tested induced electromotive force E and the horizontal distance x from the center of inductance coil to energized straight wire is shown in Fig.4.

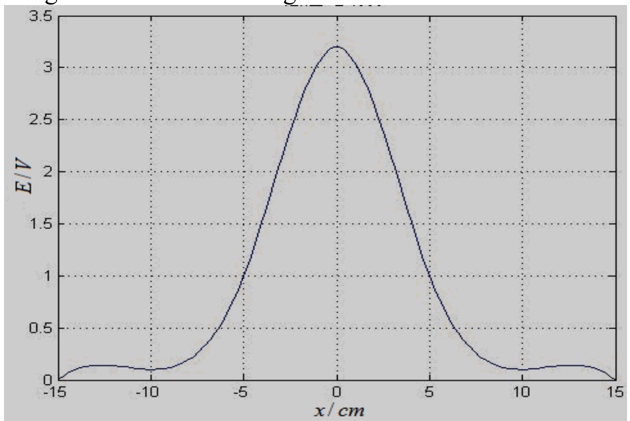

Figure 4. The relation between coils induced electromotive force and horizontal distance of wires.

Because the single coil can only distinguish the size of induced electromotive force, but cannot distinguish the position of on the left or right, the scheme about using three coils is adopted. The specific scheme is: three sensor coils are placed horizontally, and sensor coil 1 is put in the middle as the reference coil of testing induced electromotive force. Sensor coils 0 and 2 are placed at both ends, and the distance between them is $L = 30cm$. So the difference value of induced electromotive force between these two coils 0 and 2 is:

$$E_d = E_0 - E_2 = \left(\frac{h}{h^2 + x^2} - \frac{h}{h^2 + (x-L)^2}\right)\frac{KdI}{dt} \quad (3)$$

The difference value of their induced electromotive forces Ed is shown in Fig.5.

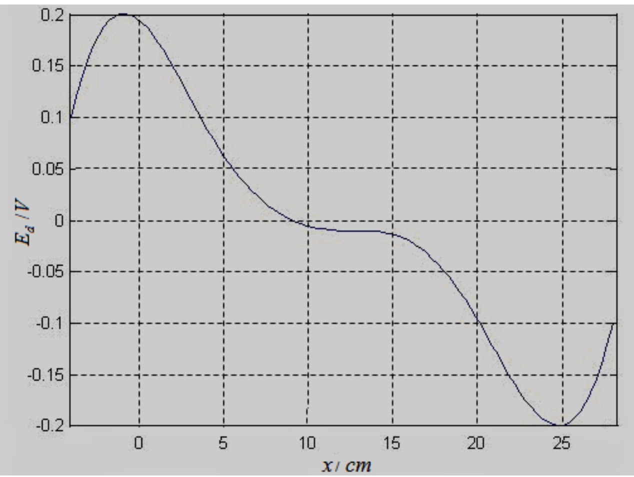

Figure 5. The relation between difference values of coils induced electromotive force and horizontal distance of wires

As can be seen from the figure, it belongs to monotone function about the relation between difference values of electromotive force E_d and displacement x. When the displacement of coil 0 is $x = 15cm$, the induced electromotive force E_d is 0. At the moment, the centers of these coils are above the wire. If E_d >0, it indicates that coil 0 is closer to the wire; if E_d <0, it illustrates that coil 0 is farther away from the wire. Therefore, on the basis of the size and plus-minus of E_d, what can be determined are the distance and direction that car deviates from energized straight wire. Then control system is adjusted to guarantee that the central position of car is close to the center line of the track.

B. Detection Method

Cars can detect induced electromotive force from different positions by coil sensors, and single-chip restores the real situation of track by processing the return value. So it is the core of track detection. Due to the weaker electromagnetic signal and interruption, the effective signals must be magnified and the interference signals should be filtered [5,6,7,8]. The track electromagnetic wire whose current is identically equal to 100mA produces magnetic field whose frequency is 20KHz. Place the sensor horizontally above the track 15cm, and turn on the voltage +5V, then catch the electromagnetic signal through 10mH inductance, so the useless signals are filtrated through 6.8NF capacitor filter. Later input the effective signals into operational amplifier LM358, after the signals are amplified 100 times through amplifier, use output pin to output the amplified signals into AD ports of single-chip for processing. And the amplification factor of effective signals can be adjusted by revolving rheostat. Besides, sensors can indicate the signal intensity according to the light and shade degree of red LED indicator light. The circuit is shown in Fig.6.

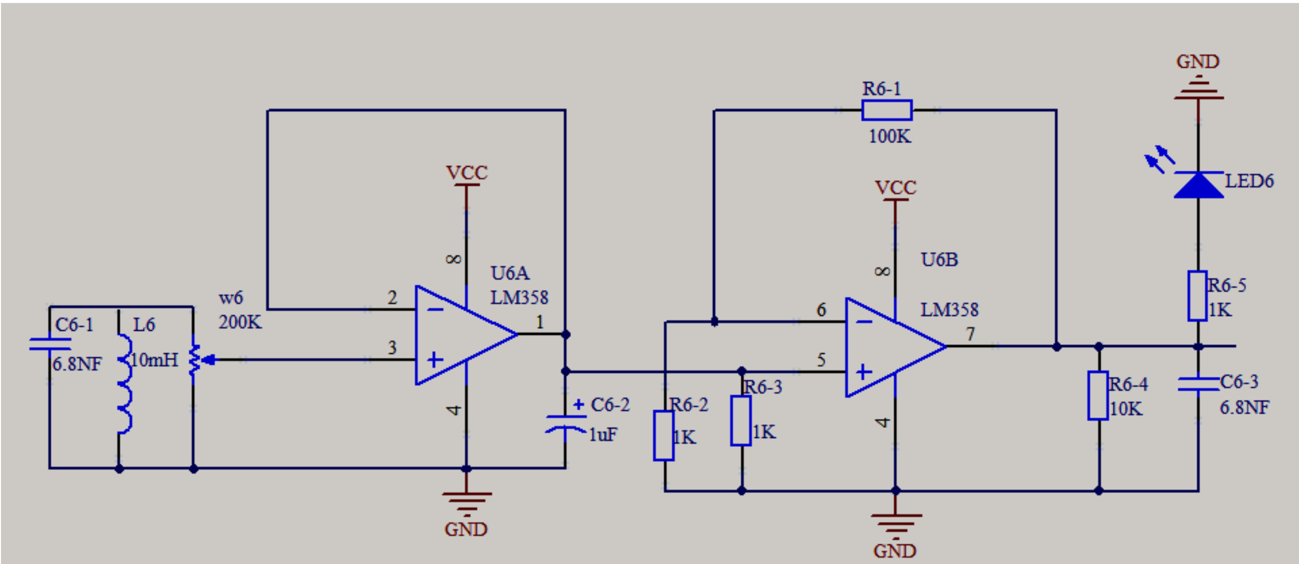

Figure 6. The amplify circuit of sensors.

IV. SOFTWARE ALGORITHM AND ITS IMPLEMENTATION

A. Software Filtering

Due to the design of hardware circuit, fluctuation of the size of track supply current and interruptions by other relevant factors, the return value of sensor may be affected. And the judgment of system for the road condition of track is directly influenced, which causes erroneous judgment or decreases the ability of judgment. To eliminate the deviation of sampling value caused by impulse interference, the system combines arithmetic average filter method and recursion average filtering method [9,10,11]. Collect data from AD ports of single-chip three times and evaluate the average value, then put into AD_datai[j]（i=0,1,2,; j=0~10）. For each sensor, 10 continuous sampling values are seen as a queue whose length is identically equal to 10. The elements in array use “first-in first-out” principle. Then according to “bubble sort” method, the maximum and minimum are deleted. Then the other 8 groups of data are made arithmetic mean operation. Later new smoothing result can be gained and put into the array AD_wData[i]（i=0,1,2).

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B. *Normalization Thought*

Due to the design reason of sensor and hardware reason caused by related electrical connection, the collected data are not unified. Use the normalization thought to eliminate the error of each sensor in the aspects of hardware and physical property [12,13]. The specific method is that place the sensor above the wire around 15cm; measure and record the maximum value of sensor; and repeat for several times to get the average value of maximum. Then put the same sensor into the margin of the track, measure and record the minimum value of sensor; and repeat for several times to get the average value of minimum. The maximum and minimum values of other two sensors are measured by using the same method. Later the maximum and minimum are placed into the arrays max_v[3] and min_v[3]. Normalization is dividing the value that current AD collected by the sensor minus the minimum by the difference between maximum and minimum. The numerical value of sensor_to_one[i]=((((float)(AD_wData[i]-min_v [i]) /max_v [i]- min_v [i])) * 100 * 0.98, (i=0,1,2), sensor_to_one[i] is the one between 0 and 100.

C. *Track Processing*

In the light of lane shape, the track can be classified into straight-line road, small S-shaped bent, large S-shaped bent, square bend, U-shaped bent and cross-loopback etc.. Because of the large-span returned value of the same sensor in different positions, especially in the situation that the sensor deviates from the track, to make use of effective value extents of each sensor, the system adopts different algorithms for the tracks with various shapes based on the numerical value from sensor and the relative position of sensor and magnetic induction line [14].

(1) When the numerical value of sensor 1 satisfies sensor_to_one[1]>65, and the numerical values of sensor 0 and 1 are sensor_to_one[0]<7, sensor_to_one[2]<7, the track belongs to straight-line road;

(2) When the numerical value of sensor 1 satisfies 65<sensor_to_one[1]<80, and the numerical values of sensor 0 and 1 are sensor_to_one[0]>20, sensor_to_one[2]>20, the track belongs to small S-shaped bent;

(3) When the numerical value of sensor 1 satisfies 27<sensor_to_one[1]<55, the track belongs to square bend;

When the numerical values of sensor 2 satisfy 7<sensor_to_one[2]<25 and sensor_to_one[1]<10, the track belongs to square bend, right-turn; When the numerical values of sensor 0 satisfy 7<sensor_to_one[0]<25 and sensor_to_one[1]<10, the track belongs to square bend, left-turn;

(4)When the numerical value of sensor 1 satisfies sensor_to_one[1]<10, and the numerical values of sensor 0 and 1 are sensor_to_one[0]<7, sensor_to_one[2]<7, the track belongs to large S-shaped bent.

V. CONCLUSIONS

The design practice verifies that using unique track processing algorithm can effectively utilize the return value of sensor to make racing car identify the track rapidly and effectively and does not appear the incidental faults such as track misjudgment and lane changing in the crossroad, etc. It also can effectively predict the time when the car is about to enter the bend, the curvature degree of bend as well as evident inscribe when the car enters the bend. Furthermore, it significantly optimizes driving trajectory and stability of cars to complete the competition stably, accurately and rapidly.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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