Research of Dynamic Steering Headlamps System Based on LIN Bus

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Abstract—Adaptive Front-lighting System (AFS) technology is the next generation of automotive adaptive headlights system. It enables driver to see the bend of the road fully before turning, improving the road safety and the pedestrians’ safety. With the LIN communication module, MASTER node angle collection module and steering gear control module, the system implements the AFS. The MASTER is responsible for obtaining the angle signal using the angle sensor KMA200 and initiating communication while the SLAVE node is responsible for adjusting of the Front-light. The Master will load information into the data field and send it to the SLAVE. Messages are filtered and the message of which the ID field and the local ID is consistent, data field will be read, as a PWM control of the steering gear parameters. Experimental results show that the AFS system has a satisfactory accuracy and it can be used in the Citrus Orchards. The system can improve the safety of the citrus conveyors at night and in any bad weather.

Index Term—AFS, LIN bus, Angle sensor, PWM, Control

I. INTRODUCTION

With the current economic development, China has experienced an unprecedented rise in the number of vehicles on the roads. This has brought about new concerns about driving safety. Improvement of lighting and visibility while making turns has been seen as a way of reducing accidents and improving the safety of the driving and the pedestrians. As a result the Adaptive Front-lighting System (AFS) technology has been implemented though mainly for luxury cars. Unfortunately it has not been extended to the mid-and-low end car market because of the high cost of installation. Meanwhile, statistics show that, about 13.7% of the traffic jams at night in China are under conditions of poor visibility [1].

The AFS is an intelligent lighting system which will automatically changes the lighting mode to adapt to the changing of driving conditions. It is not only a new technology but also an active safety system [2].

The light servo steering system is the integration of the optical and electrical system which is technically feasible and most practical. With auto safety being in the public’s attention, it can be able to bring about better visibility when vehicles are making turns at night hence improving safety.

LIN is a simple protocol and low-cost communicate network, whose specification has been aimed at low-end microcontrollers that have a USART or USI peripheral. Many body control functions are often simple digital on/off operations and are considered soft requirement. Real time systems can be considered as a low-speed communication network. At present, a lot of body control solutions using CAN low-speed networks to achieve communication. Recently a number of car manufacturers and semiconductor companies have jointly developed a low-speed network communications standard LIN to make the car more comfortable and more convenient. LIN-based generic SCI-UART interface, it does not need a dedicated CAN controller and LIN is a single line transmission system. So it has a lower communication cost than CAN. For certain cases some functions of CAN system are being replaced by LIN. It can not only reduce system costs but also improve system performance [3].

Foreign countries have made great headway in AFS system research and in foreign countries have made great headway and are becoming more and more mature. In Japan, Europe and other countries, which are well-known in car manufacture, have launched their own AFS system and standards in its high-end cars. The AFS system is even listed as optional models in the mid-range models and sedan such as Audi A8, and Toyota Crown and so on. The domestic research in this area is still relatively small, and further introduction of AFS systems for most

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manufacturers have to take in consideration that the domestic of Japan and Europe road conditions are quite different with characteristics and the road topography. Consequently the AFS System not been very effective in China [4]. Koito Toyota Ruizhi has already completed the development of AFS system and an AFS system for the new Toyota Camry has completed too. However, it has not been used in mass production of vehicles.

The aim of this paper is to design a cheap, compatible LIN which can link the car with the AFS system

II. TO THE ESTABLISHMENT OF THE MODEL

A. Establishment of the model

When braking while travelling in a curve headlight need to rotate into the curve, then to ensure a long line of sight of the road to ensure that the obstacle is seen at the earliest time. Generally speaking, from the time an obstacle be seen in the road to the time brakes are applied usually takes 1.5s.

Conventional headlights and traffic direction light maintain the same direction, so inevitably there is the blind spot in the lighting. In a case of obstacles in the corners, the driver may not see them in time as it is still in the dark and will only be visible once the car has turned giving him very little time to react to prevent an accident. The AFS on the other hand rotates the headlight into the corner and as it enters a curve, it rotates the light more towards the road eliminating any blind spots in the lighting of the road in front of the vehicle. The driver will then concentrate on the road in front and not on the roadside glare caused by other road users.

Under different conditions like the vehicle speed, the road conditions, the car loads and the tires, the characteristics of the vehicle when braking in a turning are different and very difficult to predict. So accurately calculation of the steering angle of the light is very difficult.

![Figure1. Limited steering angle lights](image)

A car with AFS there is an asymmetry of light that the head-lamps shines as the car turns to the left or the right. When it is turning to the left, headlamp turns more angles to the left than the right as can show in Fig 1. The aim of this is to ensure that is much road as possible in front of the vehicle is illuminated. The greater of the angle rotation will turn when it is limit required by the above formula location. And turn left when the left light is less than the angle of rotation, the left auxiliary lights work, smaller rotation.

For absence of pre-generated special optical light and in order to make the demonstration effect and Servo Steering is easy be observed, so when the cars turn left the light of the left and right’s extreme angles were set at 45° and 30°. Similarly, when the car turn right, left and right extreme angles of light is set to 30° and 45°.

The only remaining problem about turning is to obtain the vehicle turning radius. There are two options. The First one is using a lateral acceleration sensor with the speed then calculated turning radius and the other one is using the steering wheel angle sensor combined with the speed then calculated turning radius [5-6].

Because acceleration is a transient parameter and cannot accurately reflect the driving conditions, therefore the program has given priority to the latter. Directly obtaining the signal about the wheel speed from one wheel speed sensor is not sufficient because the speeds on the four wheels are not necessarily the same. Therefore, the speed signal can only obtained from the processed signal in ABS's ECU.

The angle of rotation of the steering wheel is 3 revolutions, while the steering at a fixed front wheel drive driven through a transmission varies within about 45°. Taking into account the steering wheel free travel is 5°-15°, when the vehicle is traveling in a straight line the steering wheel is in the middle of the equilibrium position. If turn left or right in either direction still in the free angle, the wheel will not follow. So the AFS do not turn with the turn signal. When the magnet sensor of angle is turning greater than 35°, the system will automatically light up auxiliary lights, traffic light in the direction of expansion of about 90°, and it is become easier to drive at night and bad weather conditions or at the intersection of city and rural roads.

![Figure2. AFS work with the relationship between steering angle and vehicle speed](image)
The AFS’s working scope depends on the steering angle and vehicle speed as shown Fig 2. The system starts working when the steering angle is above 12° and stop when it is less than 9°. And it will working on the speed over 30km/h but stop less than 5km/h. The system provides the scope of work while turning street intersections in the city and the bar across the street pavement line identification must also be light.

In high speed highway driving, the road ahead should be lit for 3S in advance, more so when the vehicle turning small radius. The system has a switch installed to turn the system off when the circumstances do not permit its use. Nissan Motor Company has used similar devices, the German Mercedes-Benz and BMW preparing to use the system.

B. Mechanical Design Solutions

As NXP KMA200 angle sensor range is from 0° to 180°, while the wheel can turn about 1080°. Thus using 1:6 gear transmission mode, connect a small gear M1 with 11 teeth of the shaft end to the steering wheel for easy to control, then connect a large gear M1 with 66 teeth of the shaft the other end to the magnet. When turning the steering wheel, the gear transmission driving the magnet to rotate and resulting changes in the magnetic field, then the rotation angle of the shaft can be detected by the KMA200 magnetic[7].

III. System Design and Implementation

A. System Structure

AFS system can be divided into three parts. The first part is a sensor for measuring the parameters of driving conditions and building the corresponding mathematical model. The second part is aim to input the sensor signal to the electronic control unit. The role of electronic control units is to connect input and output units, deal with input signals and output control signals. The third part is the implementations of the output devices, including the Master for lighting to adjust optical switches for intelligent-conditioning systems.

B. LIN Protocol Specifications

This design was done using Master and Slave nodes. The Master deals with the speed input interface and the steering angle sensor real-time processing. The Master communicates with the Slave through LIN message. The Slave is responsible for regulating headlamp’s angle. Communication was initiated by the Master. The Master loads the deflection angle data into the data field and sends to the Slave. Slave filters through packet then read the message’s ID which is consistent with the machine ID from ID field. This is as the parameters for PWM control of the servo motors [8]. The corner model was shown as Fig 3.

C. The steering wheel angle gathering module

Steering wheel model is shown in Fig 4.
magneto resistive angle sensor. Option Three use NXP KMA200 magneto resistive angle sensor, which is both accurate and reliable. And its angle measurement can be achieved to 180°, without loss of non-contact operation. Operation precision can’t be influenced by mechanism error as well as the magnetic field deflection. Moreover, it can operate under a wide temperature range, cost-effective and very suitable for a variety of demanding automotive electronics applications.

The sensor’s working principle is to place a bar magnet material to the steering wheel so that the KMA200 can detect the rotation angle. While testing, the support surface of MR-SENSOR must parallel with the magnetic field.

KMA200 has analog interface and digital SPI interface and applications can select one of the interfaces. This program is using default standard analog output mode. Programming default set $\alpha_{\text{max}} = 180^\circ$.

Taking the cost, accuracy and reliable stability as the design criteria, option 3 was chosen.

D. AD Conversion Circuit

Using ADC0831 8bit single channel AD converter chip, which has a simple SPI interface and is easy to program and control [9] Headlamps can light up manually or automatically at night. The design is using a photosensitive resistor, adjusting the partial pressure of the resistance in order to achieve automatic light headlamps at night.

E. Optical Switch Module

Headlamps can light up manually or automatically at night. The design is using a photosensitive resistor, adjusting the partial pressure of the resistance in order to achieve automatic light headlamps at night.

F. Servo Control Module

The MCU PWM signals are used to control the steering gear. The position servo is a servo motors as it needs to constantly change the angle and keep the control system. As the steering gear has power (VCC) and ground (GND) pins, so it can be only given control signal to the driver and can be directly used as control signal MCU port lines. And coupling two-way steering can be controlled through the MCU pin isolated output.

Servo control signals are the PWM signals, using the duty cycle change to change the steering position. Two tasks must be completed before the SCM system achieves the output angle of the steering control. First, create the basic PWM cycle signal and this design is to produce 20ms periodic signal; second, pulse width adjustment. It means that microcontroller analog output PWM signal and adjust the duty cycle. By adjusting the duty cycle, the servo steering gear control is realized.

G. LIN communication module

TJA1020 is the LIN Master / Slave protocol controller and LIN Bus interface between bodies, mainly used as a Vice-network, using the baud rate from 2.4 to 20kbits/s. Controller in the TXD input pin examines data stream and sends the RXD pin to the microcontroller.

Figure 5. Master program flow chart
IV. SOFTWARE DESIGN

A. Master software flow

Software development platform is using the KeilC51 language, while Master controller's software uses cycle way to scan the main switch state. When the state changes, the software will send the function and through LIN bus output the corresponding instruction. Master program controls the LIN Bus, such as LIN Bus initialization, launching packet headers. The Master will judge the receive data from Slave control unit and adjust accordingly after realizing the Slave state is abnormal. The Master software flow was shown as Fig 5.

V. SYSTEM TESTING

A. Move around the Corner with an Accuracy Tests

(1) Turning the steering wheel and the end of the magnet will turn according to drive ratio, and the angle sensor senses the angle corresponding;
(2) Through the AD conversion circuit input signals produce by the angle sensor to the Master;
(3) Master according the input angle signal, computing and obtained the control of steering angle value, then sent to left and right Slave through the LIN bus;
(4) The left and right Slave identified the ID signal, get different values and output a specific pulse width to control the steering gear;
(5) The photoelectric switch senses the conditions and decides whether to switch on the headlights or not. Speed button to simulate environments, so that steering at different speeds has different angle. "-" sign on behalf of counterclockwise rotation and "+" is clockwise rotation, values are showing in Table 1 to 3.

<table>
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<th>Steering angle (°C)</th>
<th>Magnet angle (°C)</th>
<th>Theory of left steering angle(°C)</th>
<th>Left actual steering angle(°C)</th>
<th>Absolute error (°C)</th>
<th>Relative error (%)</th>
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## Table 3. The Accuracy Test of the Slow Go Mode

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Experimental results show that at City model, the left and right Slave with an Absolute error is 0.587% and -0.23% and Relative error is 2.97% and 3.165%. At Country model the Absolute error is 0.203% and -0.017%, Relative error is 0.637% and 1.492%. At Go model the Absolute error is 0.2% and 0.083%, Relative error is 0.917% and 1.433%. The value shows that the system has a satisfactory accuracy.

### B. LIN Agreement Tests

**Kavaser LIN Bus Analyzer Analysis**

This design use Kavaser LIN Bus analyzer and Xtm software to measuring the output of the LIN bus message frame. After connected the circuit, click Consent, Trace in Xtm’s window.

Click Start to survey data and turn the steering wheel then sending and receiving data. As display in Fig 6.

![Figure 6. The initial data frame](image1)

Turn the steering wheel, and then sending and receiving data is display in Fig 7.

![Figure 7. System initializations message and initial data frame](image2)

**Portable Virtual Oscilloscope Analysis**

![Figure 8. Oscilloscope to observe the system initialization when the message frame](image3)
The timing of messages frame is observed through digital storage oscilloscope. Supply power and connect the oscilloscope probe to LIN output. And the result is as Fig 8. Experimental results show that the AFS system model can supply data receiving and sending in the LIN bus

VI. CONCLUSION

AFS system is a revolutionary technology in the control of the headlight for dramatically it increasing the security of driving at night, improved the situation of road lighting and greatly improved the comfort of the traffic lighting. According to LIN protocol, the system development and design of an intelligence Master node and Slave nodes and complete the hardware selection, circuit design, the program analysis and implementation. At last, the system will test with the accuracy of the rotation angle and analysis by Kavaser LIN Bus analyzer. Experimental results show that the AFS system model has a satisfactory accuracy, and it is less expensive compared to similar foreign products. Because a number of practical factors and lack of experience, the design of this paper still has some imperfections, and needs further research and deepening.

Finally, this system has been successfully used in the projects of Hill Citrus orchard in the citrus convey. Through the LIN bus and the control system, it can improve the safety of the working and make sure the citrus conveyers at night and in any bad weather.

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Prof. Wu is now an IEEE member. He received the title of outstanding graduates of Guangdong Province in China for twice, in 2004 and 2007. In 2006, he won Bronze Award of National Challenge Cup business competition. He was also recruited as science and technology consultant and agricultural delegate in Guangdong province since 2010.

Tiansheng Hong, Male, born in 1955, obtained his bachelor's degree in 1982 at South China Agricultural University. In 1987 and 1990, Professor Hong received his Master's and Ph.D degree in France. Afterwards, he has studied and worked in France and Canada as a senior visiting scholar. At present, Professor Hong holds concurrent positions as the Dean of College of Engineering in South China Agricultural University, Director and Chief Scientist of National Citrus Industry Technology Research System Machinery Laboratory. For his spare time, Professor Hong serves as member of the Science and Technology Committee in the Ministry of Agriculture of China, member of the Chinese Society of Agricultural Engineering, senior member for life in the Chinese Society for Agricultural Machinery, member of the editorial board of IJABE, and the editorial member of the Transactions of the Chinese Society for Agricultural Machinery etc.
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