ABSTRACT

This article main has discussed the design and the manufacturing of integrating Local Interconnect Network (LIN) and the Adaptive Front-lighting System (AFS); in the headlamp controller part we have applied the LIN2.0 Single-Master/Multi-Slave framework. In this experiment we use the host controller as Master’s node, and the right & left headlamps and the auxiliary angle lamp to play the Slave duty. In addition, sensors installed in the car’s system include the steering-wheel turning angle using the Controller-Area-Network (CAN2.0) interface and the automobile’s horizontal sensing signal. Therefore, the main controller of headlamp is the gateway of CAN and LIN, applied to exchange information between the different networks.

INTRODUCTION

The automobile lamps is the important automobile initiative safety part, especially when night driving, that can provide the suitable illumination function on particular while make turn at night, if driver cannot promptly see the coming vehicles run in the opposite side, it might make serious traffic accident. According to overseas statistical demonstration, although the traffic flow loading at night is less than 1/5 of daytime one, yet, the traffic accidents occurred at night share 1/4 of the total traffic accidents, in which the accidents made at curved road sect has always occupied the major part. So far the solution adopted has two kinds, the first way is by enhancing the light bulb brightness, for example, use the high illuminance xenon light bulb; the other way is by using the intelligent active turn-type headlamp to enhance the security at night driving.

Horizontal adjusting ability At present because the gas-discharge type headlamp (HID) source are popular day by day because its high brightness characteristic lets the driver security at night driving improved significantly; yet, if without the manual/automatic control headlamp system to make the light direction adjustment, it would affect other passenger’s vision in front/rear direction, such as dazzling, and dizzy phenomenon and thus rises up quite opposite feeling against HID headlamp vehicles. That is why the market now is modifying the cars not installing the automatic horizontal system yet.

Besides the discharge lamp source, the HID headlamp’s reflection layer design and the horizontal lighting control is the important parameter influencing street passengers, but HID headlamp sets sold in the market actually have nothing but the HID light bulb and stabilizer only, it will have serious light- distraction state if not coordinated to the reflector Therefore, the HID headlamp equipped in domestically produced vehicles have to make overall headlamp design by following the enactments and codes and incorporate with the horizontal control system to eliminate the street passenger's present complaint. At present Also, domestic has the same problem too. Therefore, the Ministry of Telecommunications and Communications now has drafted the enactment asking domestic vehicles to have the headlamp height regulating system if equipped by the HID headlamp.

In order not to let HID only make car driver looks clearly yet other car drivers near it are dazzling that would affect driving safety, we thus have discussed with the cooperated vendor upon the feasibility of producing automatic headlamp adjusting system, co-build the controller and sensor standard and arrange the vehicle's electronic environment and electromagnetic compatibility (EMI) test according to correlated international laws and regulations; the goal is in the hope that the domestic road safety is based on user’s basic demand rather than the lowest standard defined in the enactments. By means of this concept mentioned, the adaptive headlamp control system will contain the two-dimensional movement control (up-down and turn-angle). On one hand this design will meet the safety need, and on the other hand it will increase uses street passenger's visible range.

VEHICLE NETWORK (LIN& CAN)

In order to coordinate with the fast development of vehicles electronics, the use pf electrical devices is increasing too. It thus makes the wire bundle add weight, the cost increase the geometry & manufacturing arrangement difficult and the contact failure rate is elevated, thus, the reduces the automobile reliability is
lowered down in consequence. Now the worldwide big automotive factories, research units, automobile assembly/parts suppliers and instrument manufacturers are unceasingly seeking for the responding countermeasures to solve for this problem, and thus have created the Local Area Network (LAN) product that include the information and control formats.

The industrial control network has, from the variation of data- transmission protocols, CANOpen, DeviceNet, ARCNET and GPIB, etc. And among the vehicle control network types, the "CAN" communication protocol developed by German BOSCH Corporation is mostly emphasized and applied by automotive factories, such as 10.4/41.6Kb/s in GM-LAN, VPW (Variable Pulse Width), and single wire self-controlled network protocol. To effectively use the common communication protocol and make the vehicles communication more convenient, CAN and LIN already have been widely and commonly used in European, American and Japanese vehicles, the domestic vehicle factories also have started to study and experiment on it as well.

The automobile control network is somehow similar to the multi-works system that can effectively integrate all nodes in more efficient way, such like the information exchange among the computer, sensors and actuator in vehicle’s subsystems. Using multi-works operation has the following favors:

- Simplify circuit (reduces cost and increase reliability)
- Communicate among different equipment (easier to diagnose disorder).
- Reduce the sensor amount (because of data co-share).

In order to use multi-works way to transmit data, it must precisely to define the following 3 items:
- The representative signal transmission medium either the circuit line (optical fiber or electric cable line and so on).
- The representative signal on the media (voltage, current, light and so on).
- The data transmission protocol that defines the information transmitted in all equipment, such as the analog or digital transmission pattern, code pattern, address, transmission sequence and error detection, etc.

LIN BUS (Local Interconnect Network) network technology not only can reduce the system cost, it also has promoted the system reliability because it only uses three sets of circuits (the communication, power source, and ground cables) to connect each of the node points without providing circuit to each of them separately. In the situation of not needing CAN BUS bandwidth and the multi works, using LIN can greatly reduce cost. Although LIN BUS is initially designed to the automobile electronics application, however, it also may be widely applied to the industrial automation, sensor’s main line and popularly consumed product.

LIN BUS is composed by one master node and one or more slave nodes; and a complete signal format is divided by the main signal sent out by master node and the response signal sent out by slave node. The signal sent out by master node can also divided to the following columns: the synchronized interval column, synchronized column and labeled column; and from the responding signal sent by node we can divide to the following columns: data column and error inspection column. Refer to the communication form shown in Fig 1.

![Fig 1: LIN communication format](image)

One essential characteristics of LIN protocol is the synchronizing capacity of using the low cost oscillator’s slave node point; the LIN specification allows 15% of non- synchronized time pulse offset from slave node, once the time pulse deviation exceeds 15%, the master node then will transmit a zero byte and recognized as the “Sync Break” by the slave nodes. In order to fulfill correct communication, the slave node must have capability to re-synchronize and maintain stable within the time interval of LIN message frame (the synchronizing offset is lower than 2%).

The above function is a special attribute of LIN, it allows to the penetration subordinate node point resume time pulse without using quartz or the ceramic oscillator. Moreover, the LIN transceiver specification must follow the single tracks standards defined in ISO 9141; the maximum transmission speed is 20Kbps. This is made according to EMC and time-pulse synchronization request; and the time-pulse synchronization, simple UART communication and single- line interface is the primary factor of why LIN so far takes the superiority.

The main characteristics of LIN BUS can be summarized to:
- Low cost. Since using UART, therefore varied MCU can be applied.
- Very few signal lines required, as complying with ISO ISO9141 requirement.
- The transmission speed can be up to 20K bit/sec.
- Under multi-node state, the synchronization can be acquired without using quartz or the ceramic oscillator and thus would safe hardware cost.
- No need to change hardware or software in LIN slave node, which can add nodes in bus.
- Allow having up to 16 nodes in single LIN bus.

Fig 2 is shown the graphic example of applying LIN to vehicle. It mainly illustrates if LIN fulfills the fundamental network configuration.
Fig 2. The graphic example of applying LIN to vehicle

CAN (Controller Area Network) is in Multi-Master and Multicast configuration. It is two-line bus with built-in fault-tolerant ability. When one of the two lines has short-circuited or the disconnected, network will switch to the one-pattern continuing to operate. Therefore, CAN is extremely strong to properly process the extreme condition. And many chip vendors have provided the solution to enable the designer fast to use CAN. Table 1 is the application comparison of CAN and LIN; and Table 2 is the characteristics comparison of them. By these two tables we can comprehend the brief routine of selecting correct network type.

Table 1: Application comparison table of CAN and LIN

<table>
<thead>
<tr>
<th>Item</th>
<th>CAN</th>
<th>LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Allocated at important locations like engine, brake, ABS or various critical sensors</td>
<td>Process speed is slower than CAN; mainly applied to vehicle window, back mirror, instrument panel and door lock.</td>
</tr>
<tr>
<td>Network composition</td>
<td>Theoretically, multi-master has no node restriction nor fixed node location.</td>
<td>Maximum connecting node amount of single-master is 16; node’s location is fixed.</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>1Mbps</td>
<td>20kbps</td>
</tr>
<tr>
<td>Transmitting distance</td>
<td>1 km in max.</td>
<td>40m in max.</td>
</tr>
<tr>
<td>Receiver</td>
<td>Differential type</td>
<td>Comparing type</td>
</tr>
<tr>
<td>Communication way</td>
<td>Special hardware for Semi-duplicate type.</td>
<td>Special hardware &amp; software for Semi-duplicate type.</td>
</tr>
<tr>
<td>Oscillator</td>
<td>the allowable tolerance is within 1.5%.</td>
<td>allowable tolerance is within 0.5%.</td>
</tr>
<tr>
<td>Identification</td>
<td>Standard format: 2,048 types; extendable format: 236,870,912 types</td>
<td>64 types</td>
</tr>
</tbody>
</table>

Table 2: Characteristic comparison table of CAN and LIN

<table>
<thead>
<tr>
<th>Item</th>
<th>CAN</th>
<th>LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main feature</td>
<td>1. Widely acceptable standard</td>
<td>1. Low cost, fulfilled by single circuit.</td>
</tr>
<tr>
<td></td>
<td>♦ EU vehicle industry standard.</td>
<td>2. Speed can be up to 20K bps.</td>
</tr>
<tr>
<td></td>
<td>♦ U.S. is gradually accepting it.</td>
<td>3. Single master / multiple slave concept.</td>
</tr>
<tr>
<td></td>
<td>♦ Can adequately handle the extreme situation.</td>
<td>5. Can self-synchronize without the assistance of quartz oscillator by means of slave nodes.</td>
</tr>
<tr>
<td></td>
<td>♦ Simple in design.</td>
<td>6. Can ensure the latency time of signal transmission.</td>
</tr>
<tr>
<td></td>
<td>♦ Well debug ability; grounded by single line that can be activated while shortage or power is off.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Support hardware/software in a wide variety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♦ Multiple driving programs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♦ Suitable to be the analysis/developing tool of bus.</td>
<td></td>
</tr>
</tbody>
</table>

By considering the factors of cost and actual operation speed on the headlamp control network system, the European automobile factories decide to use LIN (Local Interconnect Network) to acquire the advantage of low cost & low speed fundamental network protocol. Fig 3 is experiment framework of the headlamp system made in this article, parts in the headlamp include the right & left LIN slave controllers connected to the host controller’s (also is the gateway’s) LIN master; then, through CAN to read the data in the turn-angle and horizontal sensor back to host controller to control the headlamp position.
INTRODUCTION OF BIPOLAR STEPPER MOTOR DRIVE

The principle of electrical motor movement is that when the rotor is energized by electric current, from cutting the magnetic flux, the stator will produce rotation torque to drive the electrical motor rotor in rotation; so does the actuation principle of step motor. Yet, if observing it in the viewpoint of actuating signal, the driving voltage signal used by common DC motor and AC motor is continuous DC and AC signals in respective, whereas the step motor uses non-continuous pulse signal and excite the stator in sequence, in which we can apply the electronic phase-split exciting theory to use electronic technology to control the pulse voltage value & conducting time to make the motor's stepping angle more slighter and achieves the preciser positioning control.

Refer to Fig 4 for the bipolar step motor. It is the solid model of bipolar step motor that has the same framework of single-polar one except that the wiring way of two sets is somewhat relatively simple and do not have the central tapping. Although the motor structure is simplified, yet, each pair of motor actuation electrical circuit for reverse rotation has become more complex. Regarding each pair of wiring set, it needs an H-bridge type control circuit to be the actuation electrical circuit. In Fig 4 the right half part has applied L9935 bipolar driver application circuit to complete the up-down & turn-angle control of headlamp.

Other factor is the speed-lost of step motor; the so-called speed-lost means while the motor rotor's rotation speed is unable to follow the stator's exciting speed, it would cause the motor rotor stopping to rotate. The speed-lost phenomenon would occur at each kind of motors; in common motor application, the speed-lost condition often would cause the consequence that the winding coil is burnt down; however, when speed-lost condition occurs to step motor, it only would cause the motor stands still. Although coil still is in exciting status, yet, due to the pulse signal, it won't burn down the coil.

Another key point for step motor is the feedback; the actual current output of sensor amplifier is by a precise resistor or Hall effect device to sense out. This feedback circuit will compare the error made by non-contacted inductive current from the command one and actual one and corrects it in response. The actual devices and magnetic pole set refers to Fig 5; when the magnetic pole set revolves along with the rotation mechanism, the Hall IC will induce the EM density and generate the Hall voltage deviation output. We then can use this voltage value to judge the present headlamp's rotating position.

INTRODUCTION OF CONTROLLER FUNCTIONS

Host controller Gateway uses PIC18F258 CAN controller interface and MCP2551 Transceiver to achieve CAN communication with the sensor system. On the other end LIN applies UART interface and MCP201 Transceiver to send out the control order on headlight position. Fig 6 is the example of CAN-IN integrated circuit on electric car lock; by this chart we can see that the automobile body control is under the CAN framework, whereas the doors & windows and door lock are under LIN framework. Therefore, it needs a gateway to achieve the signal transformation and fulfill the communication task. From this we may extend to the AFS system, the headlamp control network is LIN structure, in order to integrate the CAN we need to complete the master control, normally in the LIN Master end, which is responsible to filter and analyze the sensing data and sends it into the algorithmic program and then deliver to the right & left headlamp to control the up-down & left-right movement. The entire experimental framework is shown in Fig 7.
Since the headlamp controller has the same function, therefore, after receiving the up-down & left-right movement commands against headlamp, it will process the network communication and the motor control tasks in the single chip and feedbacks the present headlamp turning position to the Master in order able to provide the newest information; therefore, the hardware will be identical.

The two angle lamps (right & left one) performs two purposes: the first one is to timely assist on illuminating blind point, the other one is to make up the problem of slow response on the turning mechanism of headlamp. The installation angle and altitude must be determined according to the vehicle’s size.

The turning signal of steering wheel is produced by applying the turning sensor manufactured by Bosch Corporation, its transmission interface is the CAN2.0B specification, installed at the column of steering wheel to transfer the turning state to relevant systems, such as the dynamic control system of vehicle stability and etc. as for AFS, it can receive the turning signal and turning speed and provide to the program design for use.

The automobile body’s horizontal sensor is the most important components of the automatic adjusting headlamp system; on particular the domestic HID luminance sources are increasing day by day, by counting the security assurance the headlamp’s horizontal automatic adjustment ability would effectively eliminate the dazzling light problem coming from the car running from the opposite direction. And because domestic market does not have any vendor to manufacture this sort of sensors, therefore, we use the market-provided vehicle components to carry on re-equipping process and add the CAN interface to link the network system.

RELEVANT LIN2.0 DESIGN

LIN bears the goal of providing auxiliary function to the present automobile network (for example, CAN BUS). LINbus uses non-synchronized series port (UART) on the point-to-point computer and the multi-communication bus type driver, then we adds the LIN bus communication protocol to constitute the inexpensive in-series bus type control system, LIN bus is high-end communication bus, while needing not the CAN bus bandwidth and function occasion, such like the gate, window, rear view and mirror control, and communication between the intelligent sensor and brake, using LIN bus can greatly save the cost.

The difference of edition 2.0 software from the former edition is that it has reinforced the software processing ability; the outstanding part contains the diagnosis mechanism, event triggers and adding or revising inspection & checksum. Since LIN is basing on the UART/SCI single line serial communication protocol, therefore, there are certain odd points in LIN specification. For example:

1. Transmits break field (master task): The regulation is that the translation must be no less than 13 TBIT. In order to make UART/SCI conform to the LIN
specification, it must make some extra processing task to the software. The solution methods are various; here we provide two examples for reference. The first method is by adjusting the UART/SCI baud rate before transmitting break field; the second method is by canceling UART/SCI function and use GPIO to output low horizontal.

(2) Detect break field (slave task): Since there is break field transmission it should also have the break field detection in response. Normally ECU has the external interruption function, use this external interruption and timer's time computation we then are able to confirm the break field.

In the inspection and checksum portion, version 2.0 has been sorted to two computing modes; the first one is the traditional inspection and classic checksum, the computing mode is same with the former edition, used exclusively to the diagnosing mechanism; the second one is the enhanced inspection and enhanced checksum; except the diagnosis, all others must use this computing mode. What the difference from classic checksum is that the enhanced checksum has contained the protector Identifier computation in it. The following flowchart has briefly interpreted the behavior pattern of master/slave task:

Master Task: Master task mainly is responsible to transmit HEADER out, whereas the content of the ID Field is decided by the Schedule Table. After transmitting out HEADER, it must wait for the completion of message frame to continue HEADER transmission. Refer to the work flowchart shown in Fig 8.

Slave Task: Slave Task mainly has two works to attend: the first task is to detect the break and sync to make baud rate synchronization and ensure correctly receiving ID Field; the second task is to hand frame that contains receiving/sending data bytes and computing checksum. Refer to the work flowchart shown in Fig 9.

Fig 9 : Slave task frame handling flowchart

In the hardware arrangement, as shown in Fig 10, the LIN 2.0 spec has defined the resistance value of exterior promotion resistor as displayed in Table 3. Certainly, the exteriorly series-connected diode has been involved into the compulsory component added.

Table 3 : LIN resistor promoting parameter table

<table>
<thead>
<tr>
<th>Property</th>
<th>Min.</th>
<th>Typical</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>900</td>
<td>1000</td>
<td>1100</td>
<td>Ω</td>
</tr>
<tr>
<td>Slave</td>
<td>20</td>
<td>30</td>
<td>60</td>
<td>KΩ</td>
</tr>
</tbody>
</table>

Fig 10 : LIN BUS hardware layout diagram

Vector, the development vendor, has launched the developing tool of Embedded Software Components for LIN, named CANbedded LIN Generation Tool. It can follow the LDF format (LIN Description Files) in LIN2.0 spec to describe the network configuration and communication data format, then, carry out the LIN network by applying the program producer. Since the µC used in this experimental framework has no support and we tend to deeply comprehend the LIN communication protocol, therefore, in this article, we have written the LIN function database and schedule handler to conform to the software procedure of communication protocol. And by referring to the applied electric circuit of LIN Transceiver manual, we have completed the hardware circuit design and use it to complete the LIN 2.0 communication protocol under low developing cost, applied to headlamp control system; which can meet the technical level of foreign LIN vehicle network application.
and headlight integration, under the prospect of fast fulfilling local interconnect network (LIN) task.

In the R&D initial period development, the brief framework of using LIN Schedule Designer to design LIN BUS is outlined in Fig 11; in which the time lag between two messages is 12ms, this Schedule Table is applied to general control use that has divided to four slots: Slot0-Light Control (0X2D), the main goal is to control work each slave node’s activity; the master node would send out the command; Slot1-Light Response (0X2E), is the left headlamp controller’s current state; Slot2-Right Response (0X2F), is the right headlamp controller’s current state; and Slot3-Clight Response (0X30) is the left & right headlamp controller’s current state. After carrying out hardware configuration, Fig 12 shows the practical oscilloscope display on measuring LIN BUS.

After the approximate function has been completed, we hereby have carried out the LIN BUS verification process. Fig 13 is the statistic chart of measured BUS data made by using CANoe. We acquire more correct data from it and perform verification therewith. For example: the BUS load factor, data frame per sec and so on. Also, we may use the trace function, which is shown in Fig 14, to timely observe each Message Identifier, DLC and Data, and deeper to verify problems that exist in BUS but actually not easy to discover.

**CONCLUSION**

Along with the rapid development of information technology, the automobile electronic product’s application proportion is bigger and bigger; and the automobile electronic technology gradually becomes one of automobile high-tech characteristics. Local interconnect network (LIN) can be treated as the most outstanding technology breakthrough in the sensor and the controller domain. Bosch Corporation, the giant plant of control system, has proposed the CAN standard since 1991, in which we hereby can see the importance. And on the LIN BUS2.0 edition published in 2004 it has is worthy of looking at its importance. Has strengthened up the software mechanism, event trigger and checksum functions that is a sort of low-cost serial communication network now has been widely applied to carry on the distributed electronic systems control in automobile. On particular the connection and integration with CAN, using the current foreign vehicle’s networks framework can verify the importance of the two network protocols specified in this article.
This experiment’s framework has applied the newest LIN2.0 and CAN2.0B network technology to the adaptive illumination headlamp system; simultaneously it also has fulfilled the information exchange work made by gateway in two different network protocols. At present it in the local interconnect network (LIN) era, LIN has become the basic requirement of automobile parts; we hope that through this study result we could make certain effort to the correlated vehicles industry, on particular in the design carryout of local interconnect network (LIN) aspect.

ACKNOWLEDGMENTS

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

CAN : Controller Area Network
LIN : Local Interconnect Network
AFS : Adaptive Front-lighting System