The Design of Car Head-up Display System

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Abstract. In order to meet the requirements of driving safety and provide consumers with safer travel, this paper designs a car head-up display system. The system consists of two parts: circuit system and optical system. The circuit system is connected to the car through CANBus interface to realize data communication. Through the circuit system, the data of car driving can be obtained, and then the data can be displayed in front of the driver through the optical system, so that we can know the speed of driving, navigation and other related data without lowering our head. The test results show that the circuit system and optical system can run normally and steadily.

1. Introduction
Heads-up displays, which first appeared on fighter jets, displayed important information on a clear piece of glass in front of the plane so that pilots could focus without looking down at the instrument frequently. The technology was introduced in cars a few years ago, but few mass-produced cars come with the standard technology, which has poor display and high costs. With the continuous development of optical technology and electronic technology, head-up display plays an increasingly important role in car mounted products. The head-up display device enables drivers not to need to look down to check the display and data of the instrument, but to always keep the head up, reduce the fast change of the external environment between the head down and the head up, and reduce the delay and discomfort caused by the constant adjustment of eye focus, so as to improve driving safety.

This paper designs a head-up display system, including optical system and circuit system. The optical system uses highlighted TFT as the display light source to project the driving information to the distance in front of the car. NXP vehicle gauge platform is adopted in the circuit system, RGB888 display interface is used to connect to the display system, and CANBus is used to connect to the car to realize real-time display of car body data.

2. The structure of display system
2.1. The optical system
The optical system mainly realizes the magnified virtual image of the front of the car, which is composed of three parts: LCD, Mirror, Combiner. Refer to figure 1 for system schematic diagram.

a) LCD: In the optical system as a plane light source, in order to ensure visibility under strong light and interface permeability, LCD needs to meet the following conditions: LCD surface brightness needs to reach 30000cd/m2, The contrast is required to reach 1200, RGB888 interface is connected to the CPU unit of the circuit system.

b) Mirror: In order to ensure that the image is far enough, the object distance should also be large enough. The use of plane or curved mirror can effectively lengthen the object distance.
c) Combiner: A concave mirror is used to magnify and extend the plane light source. Image quality can be adjusted by adjusting the Angle of Mirror and the curvature of the X and Y axes of Combiner.

![Figure 1. Schematic diagram of optical system.](image)

The design parameters related to the optical system are shown in Table 1.

| Item               | Design parameters                  |
|--------------------|------------------------------------|
| TFT Size           | 1.8” 480×240                       |
| The virtual image size | > 7”                             |
| Virtual image distance | >1.6m                           |
| Down look angle    | < 6.5 degree                       |
| Eye relief         | 800mm                              |
| Combiner           | 116×102mm / R475(V) & R435(H)      |
| Mirror             | 110×36mm / Plate Plane             |

With optical simulation, Grid Distortion max -1.4939% meets the requirement of less than 2%. Simulation figure refers to figure 2.

![Figure 2. Optical simulation-Grid Distortion.](image)

TV Distortion Max is 1%, which meets the requirement of less than 2%. The actual UI simulation diagram is shown in figure 3.
MTF 0.42@2lp/mm, Simulation figure refers to figure 4.

According to the optical parameters in table 1, after simulation, the actual imaging size is 8 inches, and the virtual image is 1.99 meters away from the human eye.

2.2. The circuit system

The circuit system is mainly responsible for collecting information of CAN transceiver unit, including vehicle driving information, vehicle alarm information, navigation information, entertainment information and function setting information, which is presented to the driver in front through the display unit (optical system). Responsible for collecting the data of the automatic photosensitive unit and realizing the automatic adjustment of backlight with ambient light to ensure safer and more comfortable driving.

The circuit system is composed of five parts, as follows:

a) Display unit (optical system interface)
b) CAN transceiver unit
c) Automatic photosensitive unit
d) Hardware interface unit
e) Power supply unit

Circuit system diagram refers figure 5.
2.2.1. CPU unit

CPU uses NXP LPC4357 based on Arm ® architecture ®-M4/M0 kernel of high-performance microcontroller, integrated with asymmetric dual-core architecture of high performance and flexibility, as well as the serial connection, senior timer, simulation and high-speed connection, including high speed USB, CAN 2.0, 10/100 Ethernet, graphics LCD controller. Detailed block diagram refers to figure 6.

2.2.2. CAN transceiver unit

CAN transceiver module adopts NXP CAN transceiver chip TJA1042T/3, the main features are as follows:

a) Comply with ISO 11898-2 standard, suitable for 12V and 24V systems, with extremely low electromagnetic radiation characteristics and super anti-electromagnetic interference performance.

b) Standby mode with very low current, which can be awakened by the host bus. The power-off transceiver disconnects from the bus.

c) Protect the bus pin in the transient environment of the vehicle. Overheating protection.

As shown in figure 7, common mode inductance ACT45B-510-2P is used in the figure, mainly to suppress Electro Magnetic Compatibility (EMC) problems.
2.2.3. Automatic photosensitive unit

The light intensity of the environment will be collected by the automatic photosensitive unit in real time, and then fed back to the CPU unit through the I²C interface to achieve the purpose of adaptive ambient light. The relevant process is as follows, refers to figure 8.

a) The optical sensor module accepts the current ambient brightness.

b) The optical sensor module sends brightness to CPU through I²C interface.

c) after anti-shake, filtering and other relevant algorithms, the ambient brightness data received by CPU will finally output appropriate PWM to adjust the brightness of TFT backlight.

The automatic photosensitive unit uses the chip ISL29023IROZ as the receiver and communicates with the CPU through I²C. The circuit diagram refers to figure 9.
2.2.5. Power unit

The power supply unit is mainly responsible for supplying power to each module. There are three types of power supply: 12V, 5V, 3.3V. Power tree is shown in figure 11. The total power consumption of the system is 6W.

a) 5V power supply: transfer 12V to 5V CAN transceiver through DC-DC IC MPQ4423GQ-AEC1.

b) 3.3v power supply: transfer 5V to 3.3v for system CPU and IO port through LDO LM317AEMP.

3. System software design

The system software architecture consists of three layers: Linux Kernel layer, Framework layer, Application layer.

a) Linux Kernel layer: load peripheral drivers, responsible for mounting and communication of peripherals, and obtain relevant signals effectively.

b) Framework layer: get Kernel data and carry out relevant processing to provide API interface for Application layer.

c) Application layer: which realizes relevant functions of custom APP by calling API interface of Framework layer.

Refer to figure 12 for the system software architecture diagram.
4. Physical confirmation
According to the simulation result of optical system and the design of circuit system, the production of optical material and circuit system is carried out. The actual effect diagram is shown in figure 13. According to the measurement, the actual imaging size is 8.1 inches, and the virtual image is 2.1 meters away from the human eye. All functions can operate normally and steadily.

![Confirmation drawing of physical results.](image)

5. Conclusion
The car head-up display system displays the driving data and pictures of the car in front of the driver through the optical system and circuit system, and it can safely drive without lowering the head. The design scheme of the system has been verified to be stable and reliable by production. It is applicable to all types of vehicles and can meet the relevant requirements of vehicle manufacturers.

References
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