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Design of Vehicle Tunnel Illumination Measurement Device Based on STC12C5A60S2 Single-Chip Microcomputer

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Abstract: In order to measure tunnel illumination with high efficiency and accuracy, a vehicle-mounted tunnel illumination measurement device is designed in this paper. The device comprises a measurement module, a control module, a display module, and a power module. The measurement module is composed of a BCE illuminance sensor and an inductive proximity switch, which can realize a single illuminance measurement within a fixed distance. The control module, i.e., the STC12C5A60S2 single-chip microcomputer, sends the single measurement data to the storage module to realize dynamic automatic measurement. The display module is an LCD1602 liquid crystal display, which displays the measured tunnel mileage and real-time illumination. The whole device is fed by the powered module. The man–machine exchange interface of the Visual Basic (VB) host computer and Access database are used to display and store the previous illuminance measurement data, respectively. Extensive experiments show that the device has the advantages of a simple structure, convenient installation, stable operation, and accurate and efficient measurement, and can realize an automatic measurement of illumination in a long tunnel.

Keywords: tunnel illumination; vehicle-mounted; single-chip microcomputer; dynamic automatic measurement; VB host computer; access database

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1. Introduction

Tunnel lighting plays an important role in highway traffic. The "black hole effect" and "white hole effect" [1] caused by the difference in illumination inside and outside the tunnel and the insufficient lighting environment [2] will have effects on drivers and driving safety. Pan Fuquan et al. analyzed the characteristics of drivers' eye movements at the entrance and exit of an undersea tunnel and the variation law of vehicle speed, discussed the relationship between eyelid closure, blink frequency, fixation duration, vehicle speed, illumination, and gradient, and established the mathematical model in [3]. In [4], Qiao Jiangang et al. qualitatively and quantitatively analyzed the relationship between the distance of the expressway tunnel entrance and the light intensity, the speed, and the driver's physiological response and established a multiple regression safety evaluation model for the tunnel entrance section, providing a theoretical reference for the design of the expressway tunnel entrance lighting parameters and traffic safety management.

In order to achieve accurate tunnel illumination control and reduce lighting energy consumption while ensuring traffic safety, it is necessary to accurately measure the illumination in the tunnel. The traditional manual point-by-point measurement is inefficient, the later data processing is cumbersome, and the road needs to be closed. Therefore, it is urgent to design a measuring device to realize the dynamic and efficient measurement of highway tunnel illuminance.

Sun Yaoyuan et al. analyzed the principle of illuminance and brightness detection and the structure of the illuminometer and luminance meter in detail and systematically analyzed the control requirements of tunnel lighting in [5]. Ma Yangye briefly introduced the detection and calculation of expressway tunnel lighting and accumulated experience in the detection of expressway tunnel lighting in [6], and in [7], Zhang Jianxiong discussed the detection method of tunnel illumination with reference to relevant specifications, and detection examples provided a reference for highway tunnel illumination detection. Song Changyu introduced the detection method and calculation process of highway tunnel illuminance in [8] and analyzed the data processing in combination with the detection examples to provide a reference for relevant construction personnel. Li Weiping et al. introduced the numerical calculation method of tunnel lighting in [9], which included the calculation of illuminance, brightness, and uniformity. In view of the deficiencies in Chinese tunnel lighting standards and the problems existing in the design and operation of tunnel lighting, Zhao Hanwen proposed an improvement scheme for the ground lighting at the entrance of the tunnel and used DIALux to model the tunnel entrance section and the middle section in [10]. Liang Bo et al. carried out a series of tunnel lighting energy-saving tests based on the concept of reflective light storage in [11], which included an indoor simulation test, physical tunnel test, and field test, and discussed the laws of tunnel energy-saving lighting. Wang Xiang et al. studied the illuminance change rate of drivers' visual adaptation at the tunnel entrance through the design illuminance test experiment and proposed a calculation method for the length of the tunnel entrance dimming component combined with the relevant tunnel interior lighting specifications in [12]. Bao Yifan et al. proposed two design ideas for the light–dark alternation phenomenon at the entrance and exit of the tunnel in [13], which are, respectively, used to alleviate the light–dark effect at the entrance and exit of the tunnel group, eliminate the light–dark effect, and alleviate the visual fatigue caused by long-time driving. In [14], quantitative analysis was made on the light and dark adaptation rule of drivers at the tunnel entrance and exit sections and the influence of sunshade on the maximum pupil change rate, providing theoretical support for the construction of a comfortable light environment at the tunnel entrance and exit sections.

The above literature analyzed the importance of tunnel illuminance detection, gave the calculation method of tunnel illuminance, and proposed the lighting improvement scheme. However, it did not give a specific design method for the illuminance detection device.

In recent years, in order to replace manual standing point measurement, a variety of measuring devices and methods have emerged. Zhang Qingwen et al. proposed a method for detecting the lighting quality of the tunnel entrance section through field experiments on multiple tunnel entrance sections by using an advanced eye tracker system based on the "safe visual distance method" in [15]. This method requires drivers to wear eye tracker helmets and can only achieve illumination detection at the entrance section. Cheng Qingchun designed a vehicle-mounted long tunnel illuminance dynamic detection system based on the C8051F061 single-chip microcomputer in [16], which can meet the main technical requirements of a wide range of and fast signal acquisition speeds for long tunnel illuminance dynamic measurement. However, in order to achieve the specified number of measurements within a fixed interval, the vehicle needs to drive at a constant speed of 5 km/h, and the road should be closed during measurement to ensure road safety. Cheng Zhiqing et al. developed a vehicle-borne intelligent detection system for tunnel illumination in [17], which improved the detection efficiency and accuracy and greatly shortened the time for sealing the road during detection. However, much measuring equipment is required, and the overall system is expensive, which is not conducive to large-scale promotion in the country.

In view of the above problems, this paper designed a vehicle-mounted expressway tunnel illuminance detection device, which is composed of a measurement module, control module, display module, storage module, and power module. It is convenient to install, simple to operate, low in cost, low in speed control requirements, has no need to close the road during the measurement period, and can realize the dynamic automatic measurement of expressway long tunnel illuminance.

2. Working Principle and Hardware Design

2.1. Working Principle of Measuring Device

The vehicle tunnel illuminance measurement device designed in this paper consists of a measurement module, control module, display module, and power module. The installation mode of the device is shown in Figure 1. The illumination sensor, control module, display module, and power module in the measurement module are fixed on the car roof, and three illumination sensors are installed side by side at an interval of 1 m. The inductive proximity switch in the measurement module is installed above the vehicle wheels.

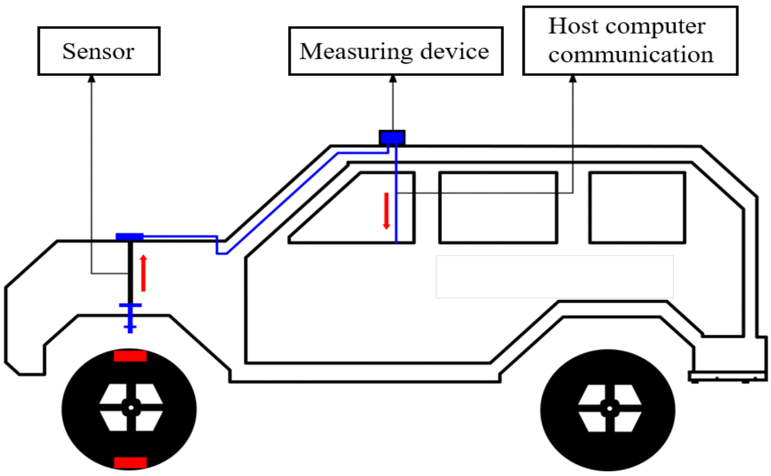

Figure 1. Schematic diagram of measuring device.

The hardware design principle block diagram of the device is shown in Figure 2. We know the wheel diameter range is 60~80 cm, and the device moves forward 0.94~1.26 m every half turn. At this time, the inductive proximity switch generates pulse signals by detecting two metal sheets installed at the central axis of the wheel. Every time a pulse signal is generated, the control module drives the illuminance sensor to measure the illuminance and transmits the measured data to the display module and the upper computer.

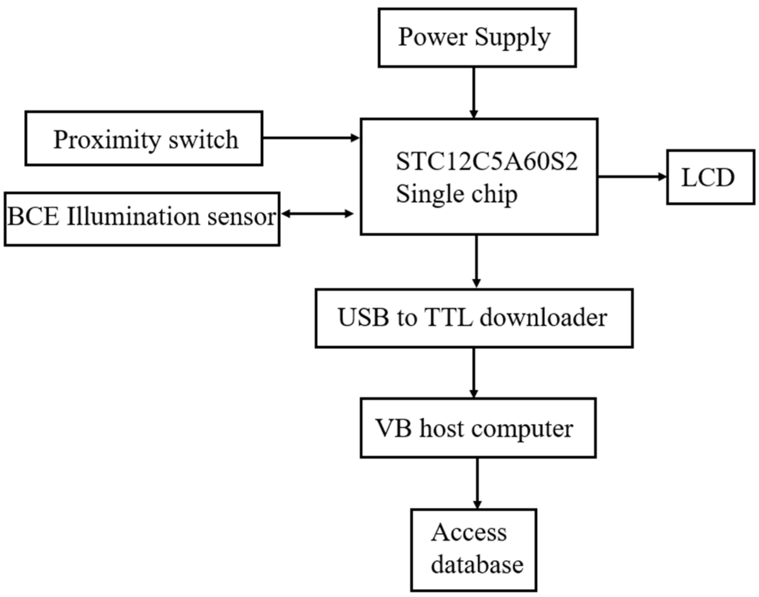

Figure 2. Hardware design principle block diagram of measuring device.

2.2. Measuring Module

The measurement module consists of 3 BCE illuminance sensors and an inductive proximity switch. It can simultaneously measure the illuminance data of three target measurement points in the tunnel, and the measured illuminance data are sent to the control module through the IIC communication interface. See Figures 1 and 2.

As shown in Figure 3, the BCE illuminance sensor has the same internal structure as the GY-30 BH1750 illuminance sensor. However, the BCE (BackChannel-Etching) illuminance sensor is equipped with an optical protective cover, which can also transmit light and seal internal components. Moreover, its hollow hemispherical structure has little impact on the directional error, good processability, and high mechanical strength. The working voltage of the illuminance sensor is 3~5 V, the working temperature is—40~85 °C, the storage temperature is—40~100 °C, and the data range is 0~65,535. Nonlinear: ≤0.2% FS; sensor sensitivity: ±3% FS; resolution: 10 Lux; circuit noise includes integrated PPG sensor front-end circuits, such as MAX30112. By combining these functions into a single cost-effective IC, the implementation of PPG is simplified. It drives the LED light source and samples the output of the photodetector. According to the selection of LED and photoelectric detector, the photocurrent involved ranges from sub nA to tens of μA. It is simple in structure, cheap in price, and suitable for complex tunnel environments [18,19].

Figure 3. BCE illuminance sensor.

The inductive proximity switch is installed above the car wheel as an external interrupt source, and the metal sheet on the side of the wheel is used as the detection body. When the wheel rotates half a circle, the device moves forward 0.94~1.26 m, the inductive proximity switch will be triggered once to generate a pulse signal and send it to the control module. The inductive proximity switch model is LJ12A3-4-Z/BX, the detection distance is 4 mm, the working voltage is DC 12~24 V [20], and it has strong anti-interference, stable performance, sensitive induction, and fast response. Its physical diagram is shown in Figure 4.

Figure 4. Physical drawing of inductive proximity switch.

2.3. Control Module

The device selects STC12C5A60S2 single-chip microcomputer as the core device of the control module, which has strong anti-interference and fast processing speed. After receiving the pulse signal generated by the inductive proximity switch, the control module drives the illuminance sensors to measure the illuminance and transmits the measured data to the display module and the upper computer. The physical diagram of the control module is shown in Figure 5.

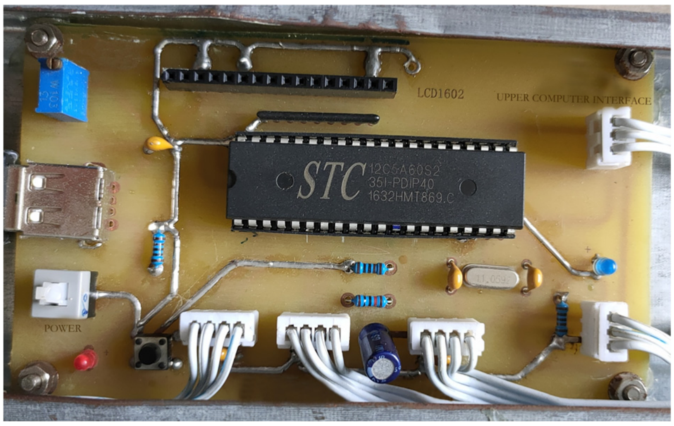

Figure 5. Physical drawing of control module.

2.4. Display Module

LCD1602 LCD is selected as the display module, which is connected with the IO port of the control module to display the illuminance data measured by the illuminance sensors in a single time and the mileage data of the completed illuminance measurement, and this is compared with the data received by the upper computer in the later stage to facilitate the commissioning of the device. If the upper computer fails, the control module cannot communicate with the upper computer. The module displays the measurement data and can also measure the tunnel illumination [21].

2.5. Power Module

Considering that the device is vehicle-mounted, the running of the vehicle will inevitably bring a certain degree of mechanical vibration to the device, so the design of the entire device must be compact enough to reduce mechanical vibration and ensure the stable operation of the device. Based on the above analysis, this paper designs an independent and portable power module based on a 12 V lithium polymer battery and DC 5 V regulated power supply. The module has 5 V/2 A output capacity, stable voltage, reverse connection, overcurrent, and over temperature protection. The power module is also equipped with a charger. The measuring device is equipped with a lithium battery charging interface, which is convenient for charging. It can continuously measure the illuminance for 10 h when fully charged, which can meet the working requirements of actual tunnel illuminance measurement. The actual power module is shown in Figure 6.

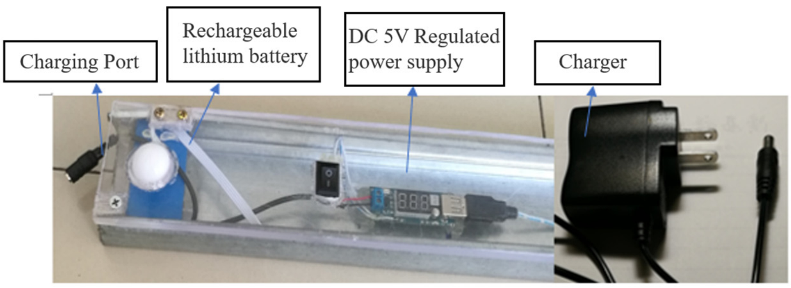

Figure 6. Physical drawing of power module.

3. Measuring Device Software Design

As shown in Figure 7, the software of the device includes the software of the single-chip microcomputer and the upper computer. MCU (Microcontroller Unit) program is written in C language, and the software writing platform is Keil5. The upper computer program is written in Visual Basic language, and the platform is Microsoft Visual Basic 6.0. The software of MCU includes the main program design, serial port sending program, and BCE illuminance measurement program. The upper computer program includes the main interface design, upper computer data receiving and processing program design, etc.

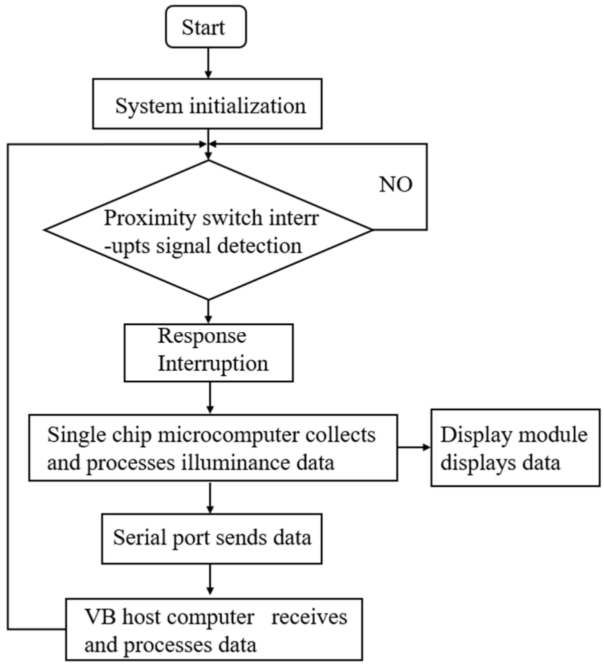

Figure 7. Single-chip microcomputer program flow chart.

3.1. *Single-Chip Microcomputer Program*

The MCU program adopts a modular programming scheme, which consists of the main program, serial port initialization program, proximity switch program, delay program, BCE illumination sensor measurement program, LCD1602 LCD display program, etc. Its flow chart is shown in Figure 8. When the proximity switch triggers the interrupt, the MCU receives the interrupt signal, and sends the measured illuminance data and detection distance to the upper computer and LCD1602 through the serial port.

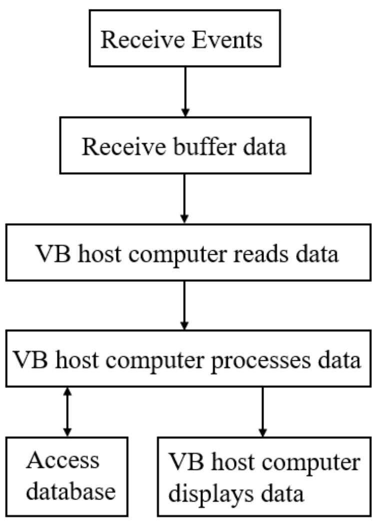

Figure 8. Program framework of host computer.

3.2. Upper Computer Program

The upper computer continuously queries the data in the buffer area through the timer, and the query time interval is far less than the transmission time interval of the illuminance measurement data. Whenever there is a frame of data in the receiving buffer area, the OnComm event of the MSComm control in VB is used to capture and process the communication event so as to ensure that the upper computer can timely detect all of the measurement data sent by the control module, and the measured values of each of the three illuminance sensors and the accumulative detection distance of the completed measurement are displayed on the host computer main interface. In addition, the measurement data can be stored in the Access database associated with the upper computer for the convenience of querying historical data for analysis. The upper computer program framework is shown in Figure 8.

The main interface of the upper computer mainly includes three areas, namely, the serial port area, the illumination display area, and the data recording area. Setting the serial port area mainly realizes the function of selecting and opening the serial port. Then the upper computer program can be started. After opening the serial port, the drop-down list will display the available serial ports on the PC to establish the connection. The illumination display area can simultaneously display the illumination data collected by the left, middle, and right illumination sensors. The main function of the data recording area is to display the historical illuminance measurement records saved in the Access database, including measurement time, serial number, illuminance value of the left illuminance sensor, illuminance value of the middle illuminance sensor, illuminance value of the right illuminance sensor, and measured mileage. In addition, the main interface includes buttons related to data operations, such as “Delete”, “Save”, and “Turn Page”, so that the measurer can conduct objective and standard data analysis.

4. Joint Debugging of Hardware and Software

4.1. Simulated Environment Test

The initial measurement and debugging were carried out in a simulated environment. This method requires three testers, two of whom move the horizontal measuring device in parallel, and the other one holds the proximity switch and an iron nail with both hands and makes the same movement. When the measuring device moves about 1 m, the tester holding the proximity switch touches the proximity switch and the iron nail once to generate a low-level interrupt signal. At this time, the measuring device measures the illuminance once. It has been verified many times that the device has good performance, stable operation, sensitive response, and can measure illuminance data with a wide range of changes. The illuminance measurement Access database history interface in different time periods is shown in Figures 9–11.

On-board tunnel illumination measurement data record table

Time	Order Number	Left Illuminance Sensor	Intermediate Illuminance Sensor	Right Illuminance Sensor
10:27:24	1	40	3	5
10:27:36	2	6	3	5
10:27:42	3	40	3	5
10:27:43	4	40	3	5
10:27:44	5	40	3	5
10:27:46	6	40	3	5
10:27:49	7	40	3	5
10:53:14	8	54	141	9
10:53:16	9	54	141	9
10:53:17	10	54	141	9
10:53:19	11	54	141	9
10:53:35	12	53	139	9

Figure 9. Access database interface at 10:00.

On-board tunnel illumination measurement data record table

Time	Order Number	Left Illuminance Sensor	Intermediate Illuminance Sensor	Right Illuminance Sensor
13:06:00	1	23	69	1
13:06:02	2	23	69	3
13:06:03	3	23	69	1
13:06:04	4	23	69	1
13:06:05	5	23	68	1
13:06:06	6	23	68	1
13:06:07	7	23	68	1
13:06:08	8	23	66	1
13:06:42	9	23	69	1
13:06:43	10	24	69	3
13:06:44	11	24	69	3
13:06:45	12	24	69	3
13:07:50	13	24	69	3
13:07:55	14	24	69	3
13:08:01	15	6	69	1

Figure 10. Access database interface at 13:00.

On-board tunnel illumination measurement data record table

Time	Order Number	Left Illuminance Sensor	Intermediate Illuminance Sensor	Right Illuminance Sensor
18:52:48	1	21	3	3
18:52:54	2	21	3	3
18:53:03	3	59	22	7
18:53:07	4	59	22	7
18:53:08	5	59	22	7
18:53:09	6	59	22	7
18:53:11	7	59	22	7
18:53:12	8	59	23	7
18:53:13	9	59	23	7
18:53:14	10	59	23	7
18:53:15	11	59	23	7
18:53:17	12	59	23	7
18:53:18	13	59	23	7
18:53:20	14	59	23	7
18:54:10	15	61	25	7
18:54:20	16	21	3	3

Figure 11. Access database interface at 18:00.

After many debugging and testing attempts, the stability of the device was verified, and the real-time measurement can be realized with a high accuracy of the measured data. The upper computer interface can display the measured illuminance data in real time, and the data can be stored in the Access database in time. After the upper computer is started, the historical data can be viewed, and the page-turning operation can be realized on the upper computer interface. Each page can display multiple groups of data, and the function of viewing massive data on the upper computer interface can be realized through the page-turning operation. The device provides valuable data support for evaluating the tunnel lighting quality and timely regulation of the tunnel illumination so it is in a reasonable state. The hardware equipment of the device and the scenario of working with the software are shown in Figure 12.

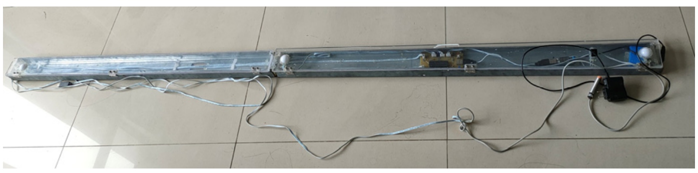

Figure 12. Hardware equipment of vehicle-mounted tunnel illumination detection device.

4.2. Actual Tunnel Test

This actual tunnel test adopts the comparison method. First, 10 points are selected along the vehicle driving direction. We have provided the actual tunnel configuration here. Our data here are from the Qinling Zhongnanshan Road Tunnel. The Qinling Zhongnanshan Road Tunnel is designed with double holes and double lines. The clear height of the building clearance is 5 m, the clear width is 10.50 m, and the maximum longitudinal slope is 11%. The total length of a single hole is 18,020 m, the net width is 10.5 m, and the height limit is 5 m. The construction standards for two-way four lane and one-way two lane expressways are adopted, and the designed driving speed is 80 km per hour. The safety level is Class I, and the design reference period of the tunnel structure is 100 years. One emergency parking lot is set every 750 m in the upper and lower line tunnels, with an effective length of 30 m and a total length of 40 m. One cross passage is set every 500 m between the two tunnels, with a clear width of 4.5 m and a clear height of 5.97 m. One pedestrian cross passage is set every 250 m, with a clear width of 2 m and a clear height of 2.5 m. The tunnel entrance elevation is 896.9 m, and the exit elevation is 1025.4 m. Three special light belts with a length of 150 m are especially set in the Zhongnanshan Road Tunnel of the Qinling Mountains, and these are changed by different lights and slide patterns. The total traffic volume of the Qinling Zhongnanshan Road Tunnel is 287,398 vehicles (absolute traffic volume), the daily average traffic volume is 41,056 vehicles, and the traffic volume on 1 October was 52,818 vehicles. Each wheel turn can be positioned as a point. Each point can lead to three measuring points along the horizontal direction, which are the measuring positions of the three illuminance sensors on the left, middle, and right of the device, and they are numbered. For example, when the wheel turns for the first circle, the measuring position of the left sensor is marked as "measuring point 1-1"; the measuring position of the intermediate sensor is marked as "measuring point 1-2"; the measuring position of the right sensor is marked as "measuring points 1-3"; and so on. The vehicle tunnel illuminance measuring device and illuminometer are used to measure the illuminance of each measuring point, and then the data are compared to detect whether the illuminance value measured by the device is true and reliable [22,23].

It is known that the diameter of the car wheel participating in this field test was 60 cm, so every half turn of the wheel represents that the device moves forward 0.94 m. At this time, the MCU drives the sensor to measure the illumination. This process verifies that the system and the vehicle achieve linkage. After several attempts at measurements and the correction of the single-chip microcomputer illuminance conversion program, the illuminance data measured by the device and the illuminometer are basically the same, so the accuracy can be guaranteed. According to GB/T 5700-2008 «Lighting Measurement Methods», illuminometers of not less than one level shall be used for illuminance measurement. The illuminometers used in this test are shown in Figure 13, and the comparison tables of measured illuminance values are shown in Tables 1–3.

Our tunnel test data were measured by placing ten sensors in the tunnel; that is, ten sensors were deployed throughout the tunnel, and sensors were deployed at the tunnel entrance, middle of the tunnel, and exit. It can be seen from Tables 1–3 that if the illuminance data measured by the device and the illuminometer are in the same location and environment, the error is very small and can be ignored. The accuracy of the device can be guaranteed [24–26].

Figure 13. Illuminometer.

Table 1. Data comparison table of left illuminance sensor and illuminometer.

Measuring Point Serial Number	Left Sensor Data/(Lux)	Illuminance Meter Data/(Lux)	Relative Deviation
point1-1	31 Lux	28.7 Lux	7.7%
point 2-1	75 Lux	73.9 Lux	0.7%
point 3-1	914 Lux	917 Lux	−0.2%
point 4-1	51 Lux	53.8 Lux	−2.7%
point 5-1	49 Lux	48.0 Lux	1.0%
point 6-1	114 Lux	116.6 Lux	−1.0%
point 7-1	119 Lux	118.5 Lux	0.2%
point 8-1	78 Lux	79.1 Lux	−0.7%
point 9-1	71 Lux	74.2 Lux	−2.2%
point 10-1	65 Lux	67.7 Lux	−2.0%

Table 2. Data comparison table of intermediate illuminance sensor and illuminometer.

Measuring Point Serial Number	Intermediate Sensor Data/(Lux)	Illuminance Meter Data/(Lux)	Relative Deviation
point 1-2	28 Lux	25.5 Lux	4.7%
point 2-2	69 Lux	65.7 Lux	2.4%
point 3-2	890 Lux	893.8 Lux	−0.2%
point 4-2	46 Lux	45.6 Lux	0.4%
point 5-2	46 Lux	45.8 Lux	0.2%
point 6-2	90 Lux	93.4 Lux	−1.9%
point 7-2	120 Lux	118.5 Lux	0.6%
point 8-2	80 Lux	82.2 Lux	−1.4%
point 9-2	65 Lux	64.2 Lux	0.6%
point 10-2	58 Lux	57.7 Lux	0.3%

Table 3. Data comparison table of right illuminance sensor and illuminometer.

Measuring Point Serial Number	Right Sensor Data/(Lux)	Illuminance Meter Data/(Lux)	Relative Deviation
point 1-3	29 Lux	26.5 Lux	4.5%
point 2-3	67 Lux	65.3 Lux	1.3%
point 3-3	881 Lux	877.9 Lux	0.2%
point 4-3	41 Lux	44.3 Lux	−3.9%
point 5-3	40 Lux	37.0 Lux	3.9%
point 6-3	120 Lux	118.4 Lux	0.7%
point 7-3	118 Lux	116.3 Lux	0.7%
point 8-3	76 Lux	77.4 Lux	−0.9%
point 9-3	69 Lux	66.5 Lux	1.8%
point 10-3	58 Lux	57.9 Lux	0.1%

In order to fully verify the practicability of the device, this actual tunnel survey not only compares it with the data measured by the illuminometer in the same environment and location, but also selects a standard section as the measurement area to test the dynamic measurement performance of the device. According to GB/T 5700-2008 «Lighting Measurement Methods», the traditional illuminance measurement method is the central distribution method, the measurement area is divided into a square grid, and the illuminance is measured at the grid center using the specified illuminometer. The dynamic measurement performance of the vehicle tunnel illuminance measuring device can be detected by measuring the illuminance of the measuring area according to this traditional method and comparing it with the data measured by the vehicle tunnel illuminance measuring device.

Because the three illuminance sensors of the device are installed on the roof, the measured illuminance is different from the horizontal road illuminance, it is necessary to measure the illuminance difference caused by different horizontal heights in advance, and the horizontal road illuminance can be obtained by subtracting the illuminance data measured by the device. Randomly select three measuring points in the measurement area, and mark them as "measuring point ①", "measuring point ②", and "measuring point ③", respectively. Measure the illuminance difference corresponding to each measuring point. The average value shows that the difference between the roof illuminance and the horizontal road illuminance is about 58 Lux. The comparison results are shown in Table 4. According to the conclusion in Table 4, another six measuring points are randomly selected and recorded as measuring points ④~⑨. The device is used to measure the corresponding roof illuminance of each measuring point. After subtraction, the device is compared with the illuminance data measured by the illuminometer. The results are shown in Table 5. The data are basically consistent, which proves that the device can achieve dynamic automatic measurement and has good performance.

Table 4. Table of comparison between horizontal illumination of vehicle roof and road surface.

Measuring Point Serial Number	Top Sensor Data/(Lux)	Illuminance Meter Data/(Lux)	Relative Deviation
point ①	234 Lux	156 Lux	78 Lux
point ②	142 Lux	89 Lux	53 Lux
point ③	101 Lux	57 Lux	44 Lux

Table 5. Data comparison table of the device and illuminometer.

Measuring Point Serial Number	Sensor Data/(Lux)	Illuminance Meter Data/(Lux)	Relative Deviation
point ④	185 Lux	188.9 Lux	−1.0%
point ⑤	93 Lux	89.3 Lux	2.0%
point ⑥	61 Lux	56.7 Lux	3.7%
point ⑦	77 Lux	74.1 Lux	1.9%
point ⑧	106 Lux	101.9 Lux	2.0%
point ⑨	158 Lux	165.4 Lux	−2.3%

The device is vehicle-mounted, and the data can be obtained only by driving through the tunnel during measurement, which reduces the interference of subjective factors caused by manual measurement, improves tunnel traffic safety, saves measurement time, and the VB upper computer located in the vehicle can display real-time measurement data and view historical data. The measurement process is convenient and fast and has more market promotion value compared with traditional manual measurement methods.

5. Summary

In this paper, a vehicle tunnel illuminance measurement device based on a STC12C5A60S2 microcontroller is designed, which can realize the dynamic real-time measurement of tunnel illuminance. It has the advantages of a fast measurement speed, high data accuracy, stability, reliability, and easy operation. It provides strong technical and equipment support for the on-site dynamic illuminance detection of long highway tunnels and has a certain promotion value.

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