A Digital Wireless LED Light Source Controller for Machine Vision

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Abstract. Interconnecting wires is sometimes difficult, inconvenient and even impossible when the light source controller is installed in the industrial field. In order to solve the problem above, a digital wireless LED light source controller for machine vision is proposed in this paper. Firstly, the hardware modules, including host computer software, embedded control unit program, power supply module, embedded control unit, display module, light source driving circuit, wireless serial communication module, infrared remote controller and infrared receiver, are described in detail to build the hardware platform. Secondly, the host computer software and its interface are introduced in detail, which are used to transmit the control instructions from the host computer. Finally, the control instructions are analyzed by the embedded control unit program, and according to the results of analysis, the embedded control unit adjusts the duty cycle of the PWM wave, so as to adjust the brightness of LED light source. This kind of light source controller with small heat productivity and reasonable structure can accurately and stably control the four channels of LED light source modules at the same time. And it inputs control instructions by no-contact way, which is useful in cases where interconnecting wires is difficult, inconvenient and even impossible and makes it easier to be used in the actual installation process. The digital wireless LED light source controller for machine vision is mainly applied into the industrial field on machine vision system.

1 Introduction

Machine vision system has been widely used in industry, agriculture, medicine and other fields, such as automatic production, detection of product defects and medical imaging, etc. Machine vision system obtains images of objective things by machine instead of human eyes, and then analyses and recognizes the required image by computer and image processing technology [1][2]. It consists of lighting, lens, camera, frame grabber and visual processor, each part of which can affect the results of image processing and even result in the instability of the system [3][4]. Among these components of machine vision system, the light source controller is one of the most important sections, which is used to provide different lighting patterns and adjust the brightness of LED light source, in order to obtain high quality images.

The commonly used light source controllers for machine vision in the market are mainly divided into two kinds, i.e. analog controller and digital controller. The analog controller achieves continuous adjustment of brightness by changing the value of LED forward current, but it has obvious heating because of the use of power electronic devices. And the color shift phenomenon of LED would produce if the LED forward current becomes large enough, which would lead to the consequence that the analog controller can't meet the requirements of adjusting accuracy. The digital controller adopts the PWM technology (Pulse-Width Modulation technology), and adjust the brightness of LED light source by controlling conducting time. It just changes the conducting time not the current's value of LED light source, so the color shift phenomenon of LED would not produce when using the digital controller to adjust brightness of LED light source.

The existing light source controller has obvious heat productivity and the wiring trouble between control instructions input module and controller. In the industrial field, due to the restrictions of the installation environment, control instructions input module which is used to input control instructions

of adjusting brightness of LED light source sometimes need to be installed separately from the other modules of light source controller.

In order to solve the problem that the light source controller has obvious heat productivity and the wiring trouble between control instructions input module and controller, a digital wireless LED light source controller for machine vision is introduced in this paper. The light source controller uses the wireless and serial interface communication technology to achieve the wireless input of control instructions, which is useful in cases where interconnecting wires is difficult, inconvenient and even impossible and makes it easier to be used in the actual installation process. At the same time, it uses the PWM technology to adjust brightness, which would reduce heat productivity of light source controller and not cause the color shift phenomenon of LED. In this paper, the software's flowchart and the hardware modules of the digital wireless LED light source controller for machine vision are described in detail.

2 Hardware modules

The hardware modules of digital wireless LED light source controller for machine vision are comprised by power supply module, embedded control unit, display module, light source driving circuit, wireless serial communication module, infrared remote controller and infrared receiver. The block diagram of the hardware modules is shown in Fig. 1.

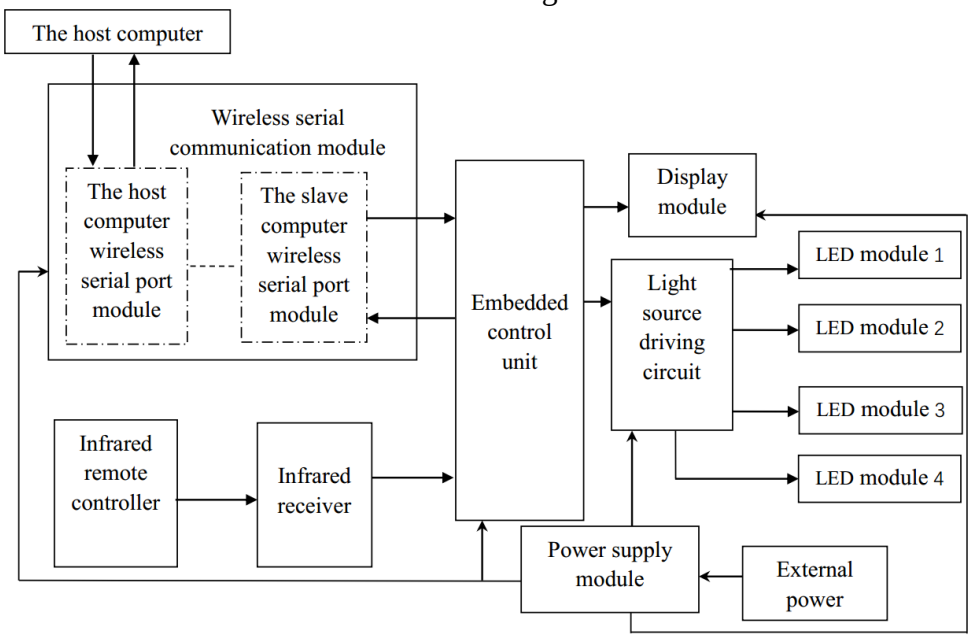

Figure 1. The block diagram of the hardware modules

The power receive end of the power supply module is connected with an external power supply which is normally 220V and 50HZ. AC (alternating current) of 220V and 50HZ would become ripple DC (direct current) voltage through the EMI (Electromagnetic Interference) filter and the single-phase full bridge rectifier circuit. And then a smooth and stable 24V DC voltage can be got through the filter circuit and the voltage regulator circuit [5]. 24V DC voltage can become a 5V DC voltage through the DC buck circuit. The power supply end of the power supply module is connected with the power receive end of embedded control unit, the power receive end of display module, the power receive end of light source driving circuit and the power receive end of wireless serial communication module, in order to provide the required voltage for these four modules to ensure their normal operation.

Display module is composed of a digital tube display circuit and connected with embedded control unit. It is used to display the channel number and the corresponding channel's gray value of the LED light source.

Light source driving circuit, which is used to supply voltage for four LED light source modules, is composed of a high-frequency switch circuit and a driving circuit. It uses saturated current limiting

method to drive LED light source. The current of some electronic devices, such as Zener diode, is almost changeless with output voltage rising. So if LED light source is in series with these electronic devices, the current flowing through the LED would be limited, namely saturated current limiting method. High-frequency switch circuit uses IRF520 power MOS tube as high-frequency switching device, which could be controlled by PWM wave to determine whether to be conducted [6]. The output ports of light source driving circuit are connected to the power receive end of LED light source modules, and its input ports are connected with embedded control unit's PWM output ports.

Infrared remote controller is a device for generating and transmitting the infrared control signal, which is used to generate and transmit control instructions of adjusting brightness of LED light source. The infrared receiver is used to receive these infrared control signal from infrared remote controller, and then turn them into electrical signals. At last, it sends electrical signals to embedded control unit [7]. According to the received electrical signals from the infrared receiver, the embedded control unit would determine which channel of LED light source should be controlled and whether to increase brightness of LED light source or not. It is a unidirectional communication between infrared receiver and embedded control unit.

Wireless serial communication module adopts nRF905 as wireless transmission chip. Chip nRF905 can work at ISM frequency band of 433/866/915MHz. Inner of chip integrates power supply management, crystal oscillator, low noise amplifier, frequency synthesizer, power amplifier, etc. It has a strong anti-interference ability, and could be suitable to many industrial applications. And the maximal effective distance for transmitting and receiving is 1000 meters when used at an open field [8][9]. The nRF905 wireless transceiver module is connected with the MCU, and the serial conversion part adopts MAX232 chip.

Wireless serial communication module is divided into two parts, i.e. one is the host computer wireless serial port module, and the other one is the slave computer wireless serial port module. Both of them are made up of a MCU, a serial conversion part and a wireless transceiver module. The MCU in the host computer wireless serial port module receives control instructions from the host computer, and then set TRX_CE and TX_EN to 1, which would enable the nRF905 wireless transceiver module to transmit control instructions. The MCU in the slave computer wireless serial port module receives control instructions by setting TRX_CE to 1 and setting TX_EN to 0, and then send them to the embedded control unit through the MAX232 serial conversion part [10]. The process of sending data from the embedded control unit to the host computer is similar to the process described above. It is the half duplex mode to transmit and receive data between the host computer and the embedded control unit. In addition, the hardware structure of wireless serial communication module is simple, which can save the cost effectively.

Embedded control unit utilizes ARM LPC2148 as the kernel control chip. LPC2148 is the 32-bits high-speed processor of Philip company, which is based on TDMI ARM7 kernel and contains 2 PLL (Phase Locked Loop) modules, 6 channels of PWM wave output, 2 UART, etc. [11]. The embedded control unit could analyze and deal with the control instructions that are transmitted by the host computer through wireless serial communication module or by the infrared remote controller. And then according to the results of analysis, the embedded control unit could output required duty cycle of PWM wave to adjust the brightness of LED light source. At the same time, embedded control unit can control the display module to display the channel number and the corresponding channel's gray value of the LED light source. In addition, embedded control unit can independently output four channels of PWM wave with different duty cycle, and can also adjust the duty cycle of the PWM wave in real time, so as to achieve the purpose of adjusting the brightness of the four channels of LED light source modules in real time independently.

3 Software design

The software of the digital wireless LED light source controller for machine vision includes the host computer software and the embedded control unit program.

The host computer software is composed of the initialization of GUI, serial port initialization, selecting LED light source channel and sending control instructions. At first, the software interface and serial port need to be initialized. After the initialization has been completed, whether the serial port has been switched on would be determined. If the serial port has been switched on, then select the channel number of LED light source and send the control instructions of adjusting the brightness of the LED light source. But if the serial port hasn't been switched on, whether the serial port is switched on should be detected again. The flowchart of the software of the host computer is shown in Fig. 2.

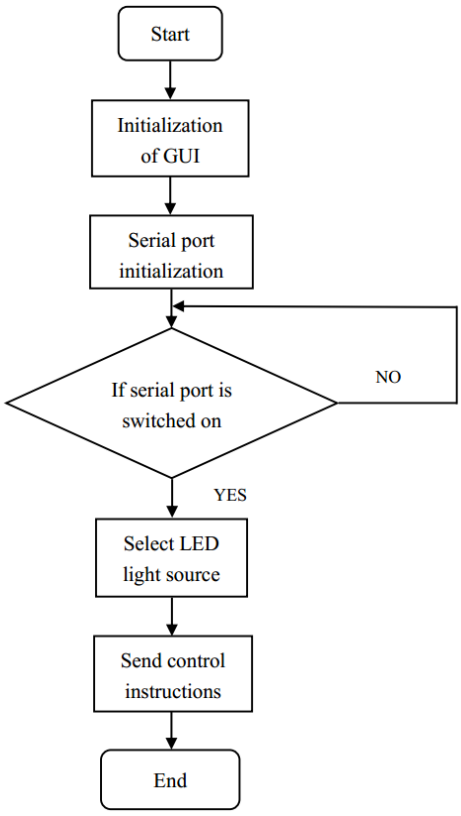

Figure 2. The flowchart of the software of the host computer

The interface of host computer software includes LED light source gray value manual input bar, LED light source gray value sliding input bar, LED light source channel selection bar, serial port switch, status bar, send data bar and baud rate selection bar. The operator could use baud rate selection bar to set the serial communication rate selection and switch on the host computer's serial port through serial port switch, and then select the channel of LED light source through LED light source channel selection bar, and input the gray value through LED light source gray value manual input bar or sliding block up and down. After these operations above, click on the send data bar to send the control instructions for adjusting the brightness of the LED light source. In addition, the status of serial port and channel of LED light source is shown in the status bar. The interface of host computer software is shown in Fig. 3.

The embedded control unit program includes initialization, detecting control instructions, analyzing control instructions and adjusting the duty cycle of the PWM wave. At first, I/O port, PLL, infrared port, serial port and PWM output port are initialized, and then detect whether the serial port and infrared pins have the input of the control instructions. If control instructions are not input through serial port or infrared pins, whether control instructions are input should be detected again. However, if the input of the control instructions has been detected, the embedded control unit would analyze and deal with the control instructions. According to the results of analysis and processing, the embedded control unit adjusts the duty cycle of the PWM wave. The flowchart of the embedded control unit program is shown in Fig. 4.

In this LED light source controller, the frequency of Crystal Oscillator is 12MHZ. When initializing the PLL0, PLLCFG register is set to 0x24 to provide 60MHz system clock frequency for LPC2148 chip. The system clock frequency can be given by the following equation:

$$f_{cclk} = f_{osc} \times M. \tag{1}$$

$$f_{cco} = f_{cclk} \times 2 \times P. \tag{2}$$

Where f_{cclk} is the system clock frequency for LPC2148 chip, f_{osc} is the frequency of Crystal Oscillator which ranges from 10MHz to 25MHz, f_{cco} is the frequency of current controlled oscillator (CCO) which ranges from 156MHz to 320MHz, M is the PLL multiplier values of the MSEL bit in the PLLCFG register, P is the PLL divider values of the PSEL bit in the PLLCFG register.

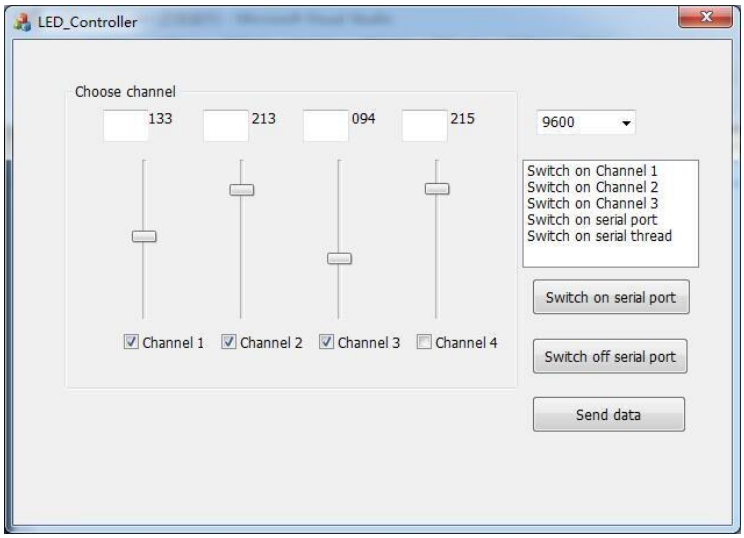

Figure 3. The interface of host computer software

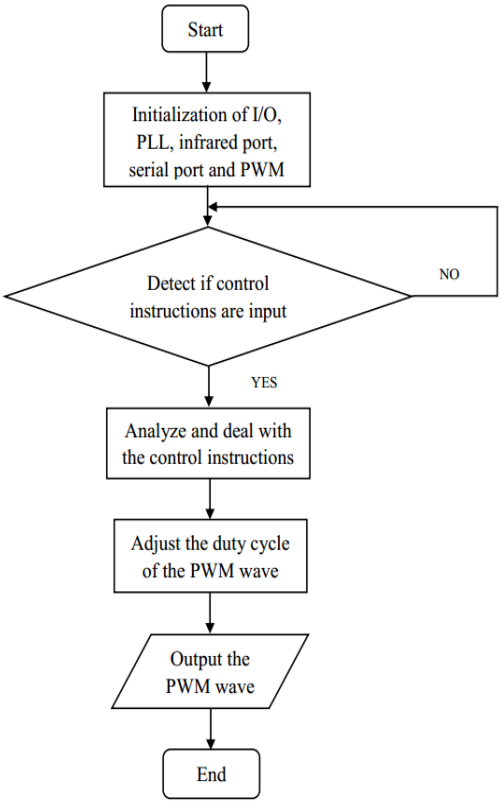

Figure 4. The flowchart of the embedded control unit program

The PWM wave is single edge-triggered, and is high level at the beginning. Its period would not be changed [12]. This LED light source controller sets PWMMR0 to 256, in order to output the PWM wave of 256 system clock periods. The value of system clock period can be got through the following equation:

$$T_{PWM} = n \times \frac{1}{f_{cclk}}. \tag{3}$$

Where $n = 256$, $f_{cclk} = 60MHz$, so $T_{PWM} \approx 4.27 \times 10^{-6} S$. According to $f = \frac{1}{T}$, the frequency of PWM wave is about $2.3 \times 10^{5} Hz$.

In this embedded control unit program, PWM match registers including PWMMR2, PWMMR4, PWMMR5, PWMMR6, are set to control the time of high level in each PWM cycle, which can change its duty cycle [13][14]. The values of PWMMR2, PWMMR4, PWMMR5, and PWMMR6 are given by the following equation:

$$PWMMR_i = \frac{PWMMR0}{256} \times N. \quad (4)$$

Where $i = 2,4,5,6$； $N = 0,1,2,3...255$。N is the LED gray value.

The duty cycle of the PWM wave is:

$$DutyRatio = \frac{PWMMR_i}{PWMMR0} = \frac{N}{256}. \quad (5)$$

According to Eq.5, the duty ratio can be adjusted from 0 to 255/256, so as to adjust the LED gray value from 0 to 255.

4 Conclusions

A PWM control technology is proposed to adjust the brightness of the LED light source in this paper. And the heating of this light source controller, which uses the proposed method, isn't obvious. In this proposed method, the frequency of PWM waves is up to $2.3\times10^5 Hz$, which is sufficient to accurately and stably control the brightness of LED light source module. So when obtaining images, the camera can't capture the phenomenon of LED light source's flickering. Compared with the existing light source controller, the light source controller in this paper inputs control instructions by no-contact way, which can solve the problem of wiring trouble and makes it easier to be used in the actual installation process.

5 Acknowledgment

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