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A NETWORK CONTROL SYSTEM FOR SCENE ADAPTIVE SEMICONDUCTOR LIGHTING

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ABSTRACT

This paper presents a design for intelligent control system of scene adaptive semiconductor lighting. The new design contains the host computer and the terminal in a control network. The lighting effect patterns are edited by the software on the host computer, then the lighting scene data is transported to the terminal through network. The terminal is a sub-controller based on the embedded system which is consisting of the ARM920T architecture processor and FPGA programmable logic devices, to control the lighting effects of LEDs carried on it with DMX512 signal to realize digital light regulating. The control system can be applied to many kinds of semiconductor landscape lighting, such as the surfaces of buildings and indoor hall spaces, while it can realize remote scenery setting and LED screen real-time playing through combination with the lighting effects editing software in the host computer. It will contribute to the lighting control in the future.

Keywords: *Linux Embedded System (LES), Network System (NS), LED Lighting Scenes (LLS), Image processing (IP)*

1. INTRODUCTION

Scene lighting means the lighting environment made up of electric light source in relevant scene, the aim of which is to improve the quality of people's life in cities. It foils special atmosphere and makes beautiful landscape by changing the brightness and colour of light. The scene can be applied to many occasions such as parks, squares, buildings and bridges. The LED lighting technology is developing rapidly in recent years. Compared to the traditional techniques, it has features of various colors, good dynamic performance, long service life, great environmental adaption, high cost-effectiveness and small energy consumption, thus it is more and more widely used in a variety of lighting scenes. However, the LED lighting controller at present basically uses an 8-bit microcontroller as its control core [1]. With the expansion of the scale of lighting control, lots of limitations of the traditional lighting control system have been exposed in the LED lighting field, the 8-bit microcontroller is no longer suitable in the future.

The intelligent lighting control system the paper presents is to meet the growing demand of large semiconductor scene lighting in modern society. The control system is with network, based on the traditional lighting control, it combines Ethernet with DMX512 digital protocol standard [2]. The host computer of the control system is used to design the digital lighting effects, and transport the edit file with lighting data through Ethernet to the terminal. Terminal is the sub-controller which is based on embedded system. The sub-controller receives the lighting data delivered by the host computer, and packs the data in accordance with the DMX512 digital protocol standard. ARM9 processor and FPGA programmable logic devices are the cores of the sub-controller. ARM9 processor is aim to realize network communication and lighting data packing [3]. It is running the Linux operating system to support the function, to meet the demand of high-speed and quantity of data. FPGA is used for data buffering because of the high speed of lighting data, so that the terminal LEDs carried on the sub-controller are able to display fluent dynamic lighting effects, even play

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animation as a light array screen. Now there is a trend using LED lighting screen to decorate different lighting scene, due to the advantage of long lifetime and low cost compared to traditional light source [4][5].

With the new lighting control system, users are capable of editing the lighting scene according to their own ideas. The software on host computers is so human-oriented that general users can grasp the methods of application quickly with simple training, which favors the popularization of the system [6] [7].

2. SOFTWARE STRUCTURE OF SYSTEM

The software of the lighting control system consists of two parts: the LED scene edit part on the host computer and the embedded system software part [8].

The software of the LED scene edit system based on VC++ platform is divided into two parts. One is the scene edit part, and the other is the playback control part. Scene edit software is used to edit the arrangement of LEDs array. By importing the files of images, video, Flash, audio and other materials, it produces lighting effects files. From the lighting effects files, the system can get the RGB information for each pixel, then it communicates with the hardware, and finally sends the control information of each frame in real time [9]. It gets the protocol address and spatial location of every pixel from the LED screen outdoor, to establish a mapping between the pixel from multimedia files and the relevant LED on the outdoor screen (see Figure 1).

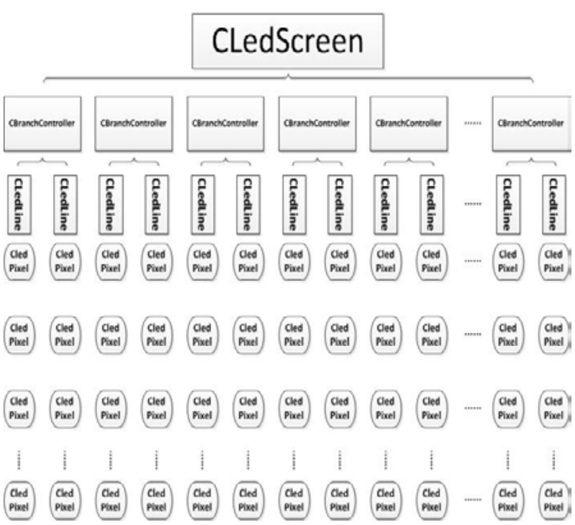

Fig. 1 The Mapping Between Screen And Multimedia Files

The parsing of multimedia files and the mapping with large-screen is implemented by OpenCV. The playback control software is mainly used for the simulation of outdoor scenes in PC and the demonstration of playback effect in real-time. The main purpose is to monitor the playback status of the lighting scenes in real-time [10] [11]. At the same time, this software can control the playing of the LED scene, realizing its pause, stop, resume and effects files' transition.

Figure 2 shows the structure of the host computer software. The functions which the software can realize are below:

1. Editing the number and display layout of LEDs under the limitation of hardware configuration, and saving the data to the database.
2. The light arrangement files of AutoCAD format can be imported and the 3D scene of light arrangement is achieved.
3. The materials of multimedia files can be analyzed to frame data for the effect files.
4. Supporting the object-oriented single frame edit, so that users are capable of designing the whole scene with drawing every frame.
5. Supporting the 3D preview of effect files. It's useful for users to check their design of lighting.
6. Being provided with the hardware interface, so that the software has a means of communicating with hardware, which enable users to apply their design to the real lighting scene.

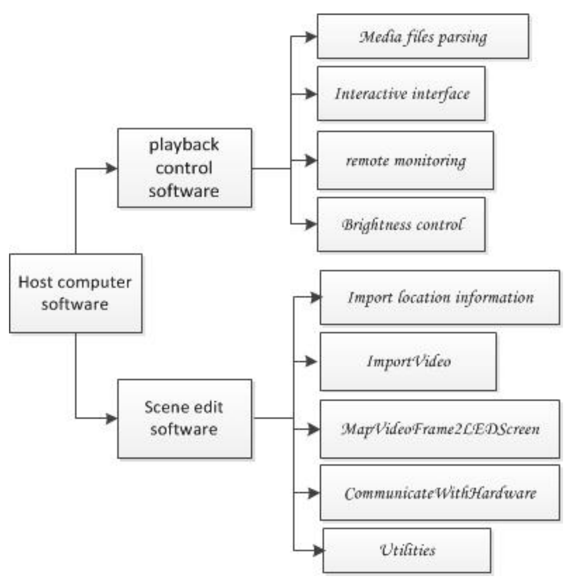

Fig. 2 The Structure Of The Software On The Host Computer

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3. CONTROL PROTOCOL AND CONTROL MODE

3.1 DMX512 Digital Protocol Standard

DMX512 Digital Protocol Standard is used as the carrier to transport brightness adjustment data from sub-controller to dimmers, and the decoder with dimmers translate the signal from which the useful information is picked up to change the LED current to realize brightness adjustment. This Standard describes a method of digital data transmission between controllers and lighting equipment and accessories, including dimmers. It covers electrical characteristics, data format, data protocol, connector type, and recommended cable types. It uses a simple asynchronous eight-bit serial protocol consisting of an untyped byte stream produced by standard UARTs, The physical media is normally, but not exclusively, a two-pair cable, with each pair serving as a data link. The media is driven using ANSI/TIA/EIA-485-A-1998 balanced data transmission techniques. Physical connection at devices is via 5-pin XLR connectors or by "hard-wiring" to terminals.

Data on the primary data link is sent in packets of up to 513 slots. The first slot is a START CODE, which defines the information in the subsequent slots in the packet. The interoperability of equipment complying with the standard is largely due to the use of the NULL START Code by transmitting devices. A NULL START Code is one that contains eight data bits all of zero value and indicates that all subsequent data within the packet is sequentially numbered bytes of uncategorized data. Proper function is dependent upon the receiving devices isolating the pertinent data for processing from each transmitted packet.

Figure 3 reveals the timing diagram of the DMX512 standard signal.

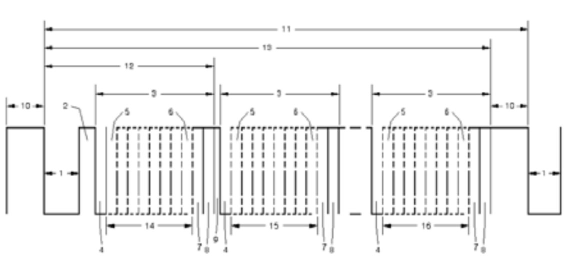

Table 7 - Timing Diagram Values

Designation	Description	Min	Typical	Max	Unit
-	Bit Rate	245	250	255	kbit / s
-	Bit Time	3.92	4	4.08	µs
-	Minimum Update Time for 513 slots	–	22.7	–	ms
-	Maximum Update Rate for 513 slots	–	44	–	/ s
1	"SPACE" for BREAK	88	–	–	µs
2	"MARK" After BREAK (MAB)	8	–	< 1.00	µs s
9	"MARK" Time between slots	0	–	< 1.00	s
10	"MARK" Before BREAK (MBB)	0	–	< 1.00	s
11	BREAK to BREAK Time	1196	–	– 1.00	µs s
13	DMX512 Packet	1196	–	– 1.00	µs s

Fig. 3 Timing Diagram of DMX512 Standard

This Standard performs no error checking of NULL START Code packets. It's not sure that all DMX512 packets will be delivered. It is common practice for merge units and protocol convertors to drop packets that they cannot process in a timely manner.

3.2 Embedded Operating System Application

The core of the sub-controller is the embedded operating system application, which builds up the function of the terminal controller. The ARM module is the most important part of the controller, which plays a role of connecting the host computer and the terminal. Embedded Linux operating system is running on the ARM9 processor, and the application software on it is developed by C language. The processor carries DM9000 driver so that it is capable of communicating with the host computer through Ethernet. The brightness data packed according to UDP protocol standard is transported to the processor and saved in the SD card. The processor gets and analyses the data, decodes and picks up the useful brightness information, and writes the 8-bit data into FPGA [12]. FPGA is carried on the processor as a character device, which enables the processor to write data byte by byte into it. Application on FPGA is developed by Verilog HDL. The first function is that it imitates a dual-port RAM to receive data written by the processor and store it in the RAM block of FPGA, then processor and other modules of FPGA are able to get the data by address. The outstanding feature of dual-port RAM is the shared storage data. It has two sets of data bus, address bus and read-and-write control bus, and it enable two independent CPUs to asynchronously access storage units, so it is called shared multi-port memory. A simulant dual-port RAM is used here to ensure the high-speed and reliability of information communication between two processors [13]. In the FPGA, One port of the RAM is connected with the data bus of the ARM processor, and the other one connects the inner

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module of FPGA, so it increases the efficiency of data transmission. Another part of the application on FPGA is the DMX512 communication module. It takes the brightness data from the simulant dual-port RAM and packs according to DMX512 protocol standard, so that the dimmer below can recognize the brightness information.

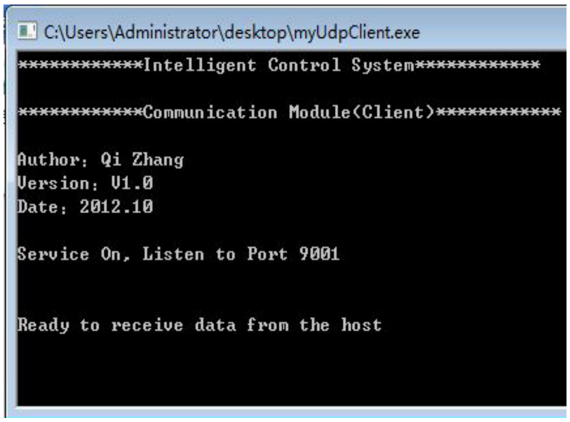

Fig. 4 Embedded Software Interface

Figure 4 shows the embedded system software interface, it is listening at a port to waiting for the data transported from the host computer [14]. Figure 5 shows the RTL design of the application on FPGA, the digital logic schematics do the job of data acquisition and data transmission.

4. HARDWARE STRUCTURE DESIGN FOR CONTROL PART

According to the needs of control, the hardware structure is divided into these parts below:

1. ARM processor core board.
2. SDRAM Synchronous dynamic random access memory interface circuit.
3. NOR Flash and NAND Flash interface circuit.
4. DM9000 Ethernet driver interface circuit.
5. SD storage card interface circuit.
6. Peripheral circuit of FPGA
7. DMX512 protocol communication module interface circuit.

ARM processor module is the core of the sub-controller. SAMSUNG S3C2440A embedded processor is chosen to be the platform for running the embedded operating system. S3C2440A is a 32-bit RISC microprocessor, based on ARM920T kernel, whose clock frequency is 400MHz. The processor has two coprocessors in it: CP14 and CP15. CP14 is used to debug control, and CP15 is regarded as the control of memory. It is gratifying that the integrated general function modules on chip enable us to design the peripheral interface circuit very easily.

The bootloader is running in NOR Flash, it is the bootstrap program of the embedded operating system, besides the kernel and the file system is running in NAND Flash. The processor receives data from the host computer and keeps it in SDRAM, and saves into SD card finally.

There are two methods for embedded network interface. One is making use of the processor with Ethernet interface inner, it is usually applied for network application, and network data is transported on internal bus. A more general approach is "embedded processor plus network driver chip", and it is the method chosen in our sub-controller hardware design. This paper used the mode of "S3C2440A+DM9000", and the network data is transported on external bus. DM9000 is a fast Ethernet controller from DAVICOM Corporation [15]. It can connect the processor with 8-bit or 16-bit mode, and automatically check the network connection. DM9000 is able to change the direction of transceiver pins so that the system can communicate normally regardless of the mode of the external cable, which is helpful for compatibility of our system.

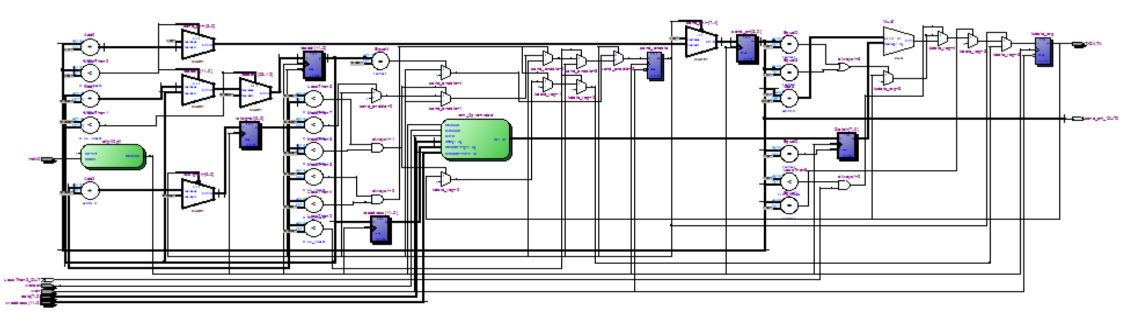

Fig.5 RTL Design Of FPGA Application

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The FPGA device on the sub-controller is the Cyclone III chip from Altera Corporation. In this control system the chip is regarded as an external character device, so the control command and data are transported to FPGA via data and address bus [16].

Figure 6 presents the whole hardware structure of the control system.

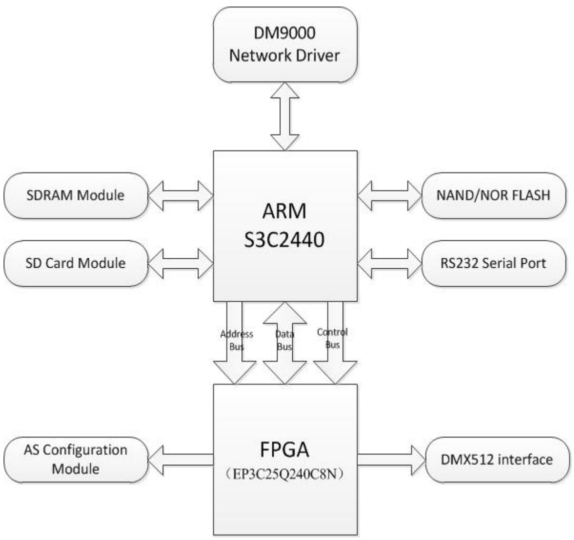

Fig.6 Hardware Structure for Control Part

5. HARDWARE STRUCTURE DESIGN FOR LED DRIVER

DMX512 decoders receive the data from the interface, then the processor in it start to work on the data: extracting information, analyzing content, and export LED control signal. The control signal is composed by an array of PWM signal. The main part of the LED driver is the switching power supply. Due to the low power need of the light, the construction of the supply is single-ended flyback. Circuit design displays in Figure 7 below.

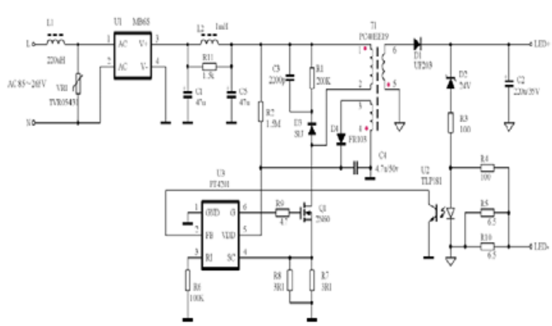

Fig.7 Hardware Structure For LED Driver

L1 is a inductance which is used for antisurge , while the voltage dependent resistor VR1 is for earth leakage protection. U1 is the bridge rectifier. PT4201 is used as the switching power supply chip which is the kernel of the structure. R1, C3 and D3 make up a RCD snubber to remove spike pulse noise. The driver will stabilize the output voltage and current so that LED arrays can be different modes. A MOSFET is connected with LED to control the brightness, with PWM voltage is on the grid. When the PWM signal is high level, the LED array is on. As a result of that, the higher the duty ratio of PWM is, the brighter LEDs are.

6. TEST EXPERIMENTAL RESULT

In this section, the whole control system is under functional test to examine its functional completeness.

The test begins with the host computer software, and the lighting edit function will be examined. Firstly users use AutoCAD to finish light information collection and generate the light arrangement file. Then the file is opened in the light edit window of the software for users to do some editing as their thoughts, such as increasing or decreasing the number of LEDs, drawing patterns and change the colour or brightness of outdoor LEDs. From the edit window we can see the image made by AutoCAD is analysed to abstract lattice, and users do the editing on it. Figure 8 is the edit effects preview part of the software. It shows the preview of the editing task on lighting so that users will confirm the design of lighting before it is applied into outdoor LEDs screen.

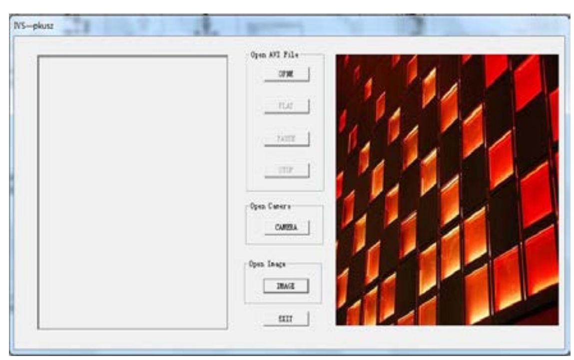

Fig.8 Light Edit Preview

After edit task is confirmed the software transports the edit file to the sub-controller via network cable. The processor receives the data and gets the brightness information, then writes it into FPGA. FPGA does the packing job of brightness data according to DMX512 protocol standard, then serially transports it into dimmers carried on the controller (See Figure 9). The “Datain” is data bus from dual-port RAM, and the “rdaddress” is the

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address bus. "TXDATA" is the serial communication interface, it is a one-bit data wire. Dimmers receive the serial data and change the circuit of LEDs according to it. At this point, the test is finished.

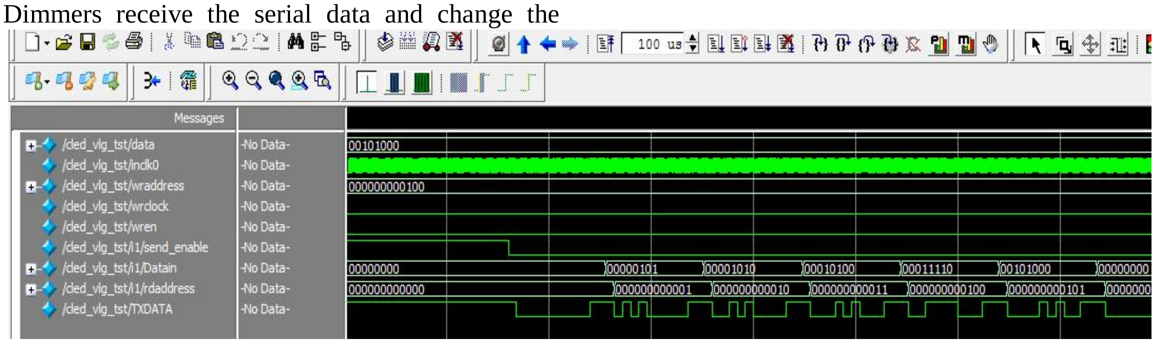

Fig.9 Dmx512 Signal Waveform Diagram

7. CONCLUSION

A new network control system for scene adaptive semiconductor lighting was presented in this paper to establish a new lighting control mode, which is composed of the host computer and the sub-controller. On the market there are many kinds of lighting controller, but most of them are based on 8-bit microcontroller and are not able to connect to the network. If users try to apply these traditional lighting controllers to their lighting environment, they must store the brightness data into SD cards or other memory in advance, while the controller is able to control the lighting system according to the data. It is very inflexible and inconvenient, and not propitious to real-time control. If users find that the lighting effect pattern is outdated and would like to change it, they must get the memory back and replace the brightness data in it. With the network control system, these problems can be perfectly solved. Users are capable of adding light into the control network randomly. They can edit lighting pictures on the host computer and transport the lighting edit file to the sub-controller so that they are able to control and monitor the whole lighting network indoors. Another advantage of the new control system is the host computer software, which makes the control system more intellectualized. Users can design light patterns according to their wishes, even design some animation on LEDs if the speed of data can meet the demand. The playback software enable users to preview the light pattern on computers. If they find the pattern is not their imagination, they will change the design conveniently on their not get the SD cards back and update the brightness data. The network control system can not only be applied to light control, but also be applied to various intelligent control modes, with a wide range of engineering application prospects.

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