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MICROPROCESSOR-BASED DIMMABLE DRIVER DESIGN FOR LED FLAT PANEL LIGHTING

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Abstract. *Lightning devices consume the majority of the power in a home electrical system. Enhanced control technology for saving power in green home lighting devices can reduce home power consumption. Therefore, we present a microprocessor-based power driver of an LED flat panel light with network control. Using the open firmware design technique, the proposed LED flat panel light can become a network control device with dimmable functions, to further improve the power efficiency of home lighting system.*
Keywords: DC/DC converter, LED flat panel lighting, LED dimmable driver

1. **Introduction.** In recent years, due to the general improvement of the economy as well as the national standard of living, the demand for energy is rapidly increasing, especially the electrical power. However, limited global energy and depletion of oil sources result in high price of the petroleum and electric power. Therefore, power saving and power-usage reduction become popular research topics. Lighting device consumes majority of the power in home electrical system. Enhanced control technology for saving power in green home lighting devices can reduce home power consumption. The LEDs are no longer used just for indicator lights on electronic equipment. Advances in technology have allowed LEDs to be used in illumination applications since LEDs have the benefits of long life, durability and efficiency. Switching-mode power supply (SMPS) has higher power conversion efficiency and is substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. These circuit topologies can be adopted to regulate electrical current of LEDs used in dimmable lighting applications [1]. However, SMPS also bring some drawbacks, such as more complicated circuit design, electrical high frequency noise problems, ripple voltage at the switching frequency, and harmonic frequencies. In order to maintain the advantages while reducing the drawbacks of SMPs, some control techniques have been considered and applied in the SMPS, including proportional-integral-derivative controller (PID) [2], sliding-mode control [3], and optimal control methods [4]. Classical PID control method can be designed to offer a good transient response as well as steady response when the system model is clearly specified and the value of the load is also known. Nevertheless, the system stability and adaptability of PID controllers can be improved by firmware program design and feeding back current and voltage signal through the use

of the Analog-to-Digital converter integrated chip [5-7]. Control of LED usually does not focus on controlling the supplied voltage since the brightness of the LED is related to its current flow. In order to have sufficient brightness, LED will generally be driven in the biggest allowable current value. The key issue is the current-voltage characteristics curve of LED diode in the range with a very steep slope of the working area. In this area, there will be a large current change rate associated with a small voltage rate change, and vice versa [8]. Therefore, in order to avoid exceeding the current limit value of the allowable LED current, the constant current drive mode is considered to be the more appropriate method [9].

Since the lighting system consumes the majority of power in home, LED illumination devices can be developed to further reduce power consumption. This paper will propose a dimmable drive design for LED flat panel lighting with network control. The LED brightness can be achieved by controlling the applied constant voltage through the feedback control of switched-mode power supply analogy circuit and microprocessor interference. The proposed LED driver architecture is simple and low cost. Furthermore, the use of switch-mode power supply controlled by microprocessor will provide a fast transient control performance compared with the digital switch-mode power supply.

2. **LED Dimmable Driver Design.** Dr. Shuji Nakamura at Nichia Chemical Company in Japan has successfully developed the blue LED to solve problem of producing a white LED due to the lack of Blue-ray [10]. With the advancement of new technology, high-wattage and high-brightness white LEDs are continually being developed for many applications, such as the white LED energy saving light bulbs, ultra-white LED flashlight, and high-brightness white LED backlight. However, home, office and commercial lightings require many different types of LED lamps for different applications. For the application of the ceiling light, the flat panel LED lamp plays an important role. In general, a flat panel LED lamp requires a dedicated drive controller.

After disassembling LED panel light, its structure and lighting principle can be analyzed and shown in Figure 1. The LED flat panel lamp is composed of a lamp frame, edge-lighting LED strip, diffuser lens panel, light guide plate, reflective sheeting, and integrated aluminum back plate for efficient thermal control. LED flat panel lighting technology is manufactured by embedding energy-efficient, high output LEDs along the edges of acrylic panel. Laser-etched channels evenly distribute light across the face of the panel, providing uniform light distribution for seamless backlighting of translucent glass or resin panels. The specifications of the common used products are 36V/1.2A LED flat panel light with 6000K color temperature as well as standard quick connector. The LED driver can be chosen to have dis-dimming or dimming function. However, its driving method is usually applied by flyback buck converter with constant voltage drive and transformer isolation circuit.

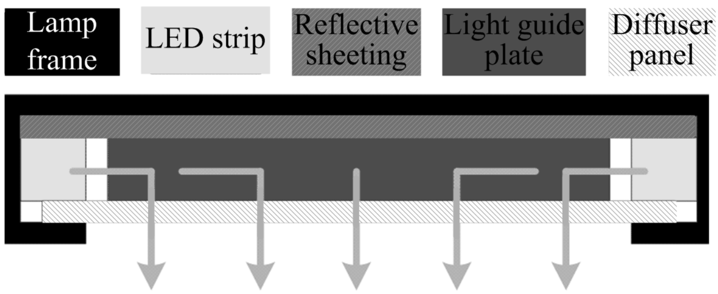

Figure 1. The structure of the LED flat panel light

2.1. **LED flat panel light driver design.** The proposed design of LED flat panel lighting driver is described in the function block diagram in Figure 2. Figure 3 depicts the overall design of the proposed driver in 4 portions, which are (1) the system power circuit, (2) microprocessor circuit, (3) LED light driving circuit, and (4) interface circuits of RS-485 and analog input for dimmable function. Figure 4 presents the system power circuit design, working in independent mode. When the power of DC 36V is supplied, the voltage level can be stepped down to DC 12V by the switching voltage regulator of LM2596, and then further stepped down to DC 3.3V by the high-efficiency linear regulator of LM086. DC 12V and DC 3.3V power source are respectively for relay circuit and microprocessor circuit. Figure 5 is the circuit diagram with the microprocessor chip of dsPIC33FJ09GS302, Microchip Technology Inc. Based on the firmware design, this microprocessor is responsible for detecting the inputs voltage, input current, output voltage and output current of the driver, serial peripheral interface (SPI) bus, enable/disable driver output, LED status indicators, reading the analog input signal of 0∼10V, and RS-485 communication for control network.

Figure 6 represents the enable circuit and flat panel lamp drive circuit. The PW-ON signal in Figure 6 is applied to enable or disable the operation of LM2596-ADJ chip. Then, the driver output voltage is regulated by feeding back the output voltage signal. Furthermore, the feedback signal can be controlled by the digital potentiometer of MCP41010 from SPI interface. It is simple to change the value of the digital potentiometer MCP41010 in order to control the output voltage of the driver using the interior functions of the simple switcher power converter LM2596-ADJ. That is, the brightness of the LED flat panel

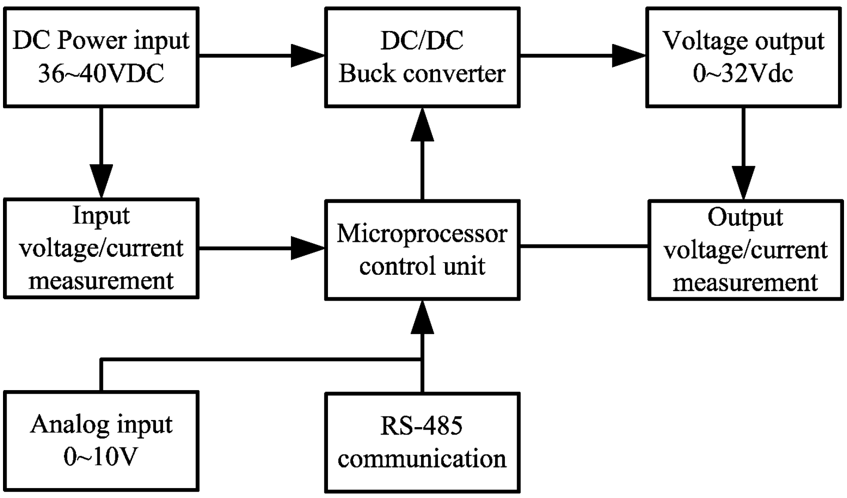

Figure 2. The function block diagram of the LED driver

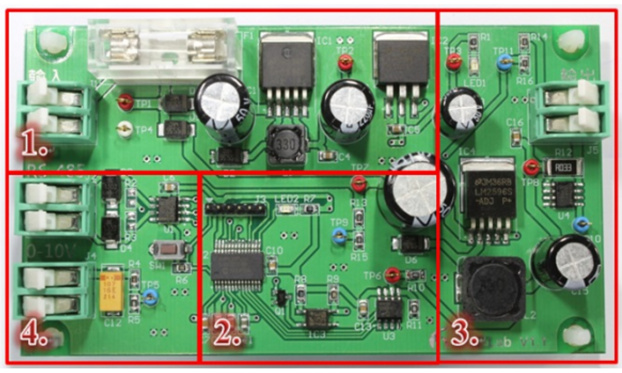

Figure 3. The proposed LED driver

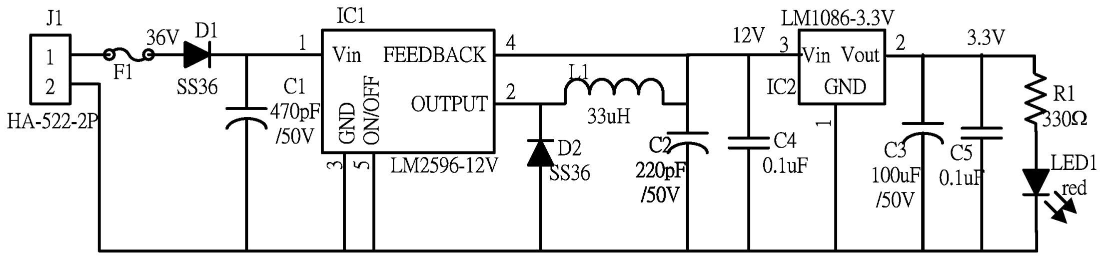

Figure 4. The system power circuit

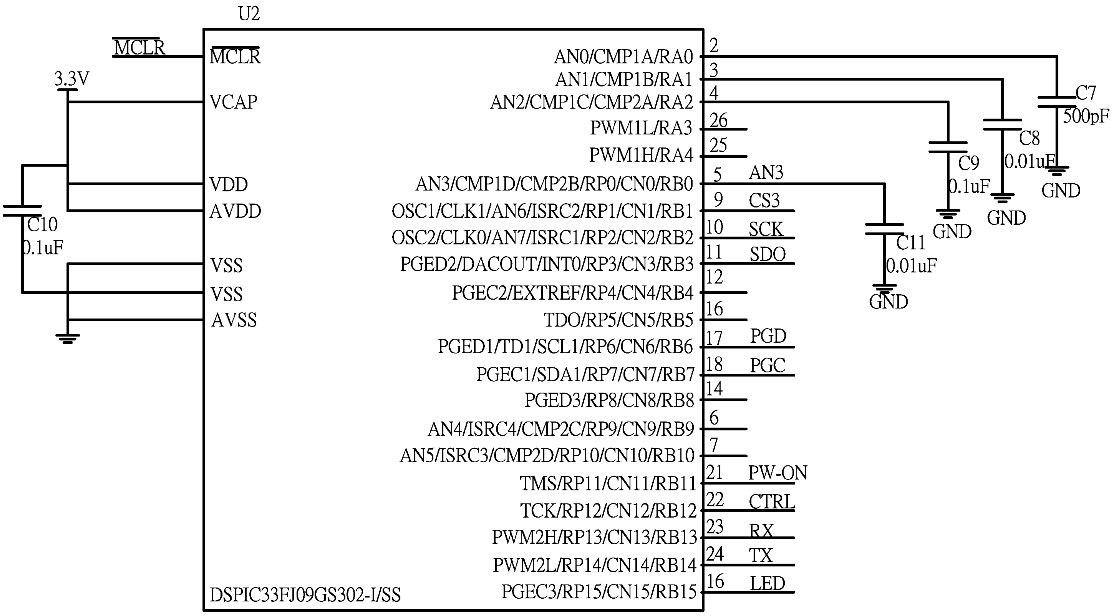

Figure 5. The microprocessor circuit with interface

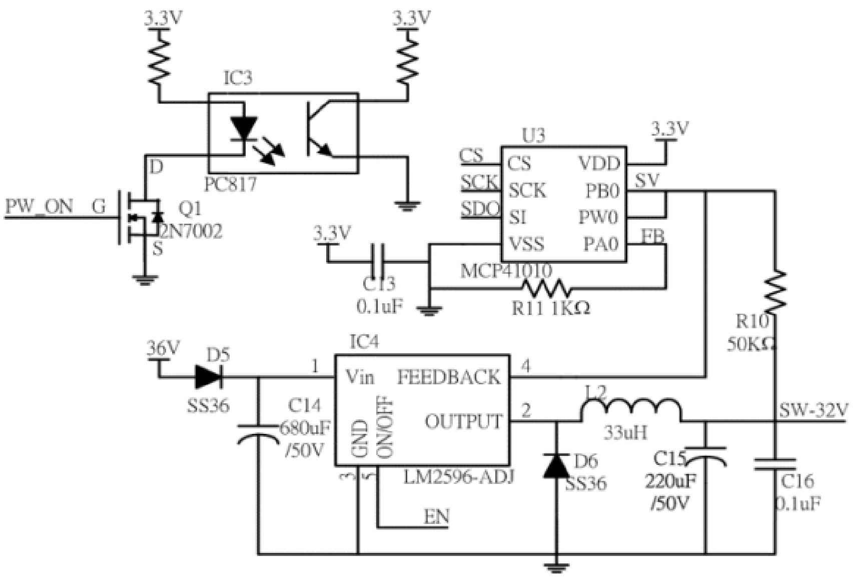

Figure 6. The LED driving circuit with interface

light can be dimmed by the microprocessor, based on analog input signal (0∼10V) and RS-485 communication commands.

2.2. **Firmware design for LED flat panel lighting driver.** Figure 7 demonstrates the developing flow chart of the firmware program for LED driver. The MPLAB integrated development environment (IDE) provided by Microchip Technology can be applied to support project management, code editing, debugging and programming of Microchip 8-bit, 16-bit and 32-bit PIC microcontrollers in personal computer through the PICkitTM3 in circuit debugger and C programming language. Figure 8 presents the control block diagram of the LED flat panel light. When the system is powered on, the microprocessor of dsPIC33FJ09GS302 will be launched in the initial stage for writing the parameters of the designated functions into the corresponding registers. After the initialization, the embedded system will go into the selection mode of the dimmable and non-dimmable driving. If non-dimmable mode is selected, the embedded system will only drive the LED

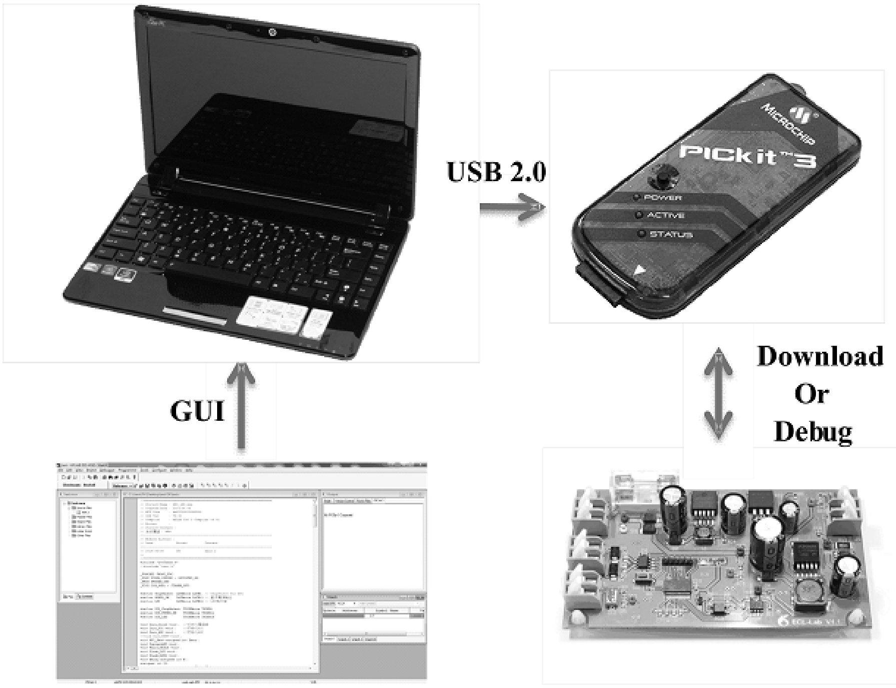

Figure 7. The firmware program development

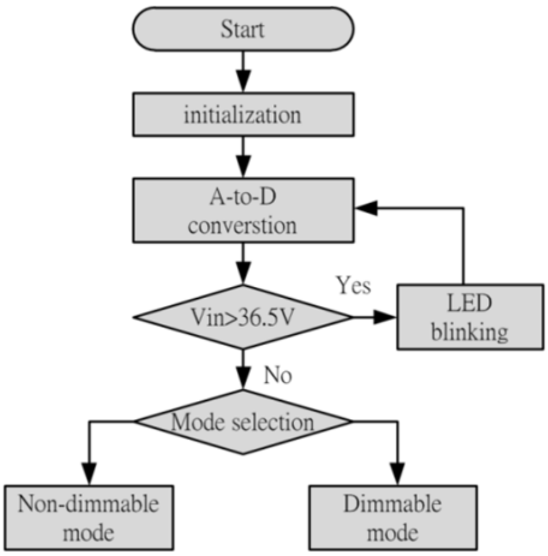

Figure 8. The control program flow chart

in fully light and dark states, based on the control input. On the other hand, when the system is working in the dimmable mode, the driver output voltage will be controlled according to the command from the RS-485 or analog input, in order to vary the lighting from 0 to 100%. When the system is working, the voltage and current information in the input and output sides of the driver will always be accessed in order to diagnose the system. When the input voltage > 36.5Vdc, dimming voltage > 10.2Vdc, the output voltage > 30Vdc and the output current > 1.25A has occurred, the embedded system will go into an infinite loop and blink the LED rapidly to express that an error has occurred in the system with no driving voltage output.

3. **Experimental Results.** The experimental system is as demonstrated in Figure 7. Here, the controllable dual voltage output channels of a DC power supply are applied directly to the LED drive. A set of 32Vdc output is the supply source and another output of 0∼10Vdc is the dimming signal to control the brightness of the LED panel lighting. The oscilloscope and digital multi-meters are applied to capture the output/input voltage and current. Figures 9 and 10 show the voltage output waveform of the LED flat panel light drive, captured by the digital oscilloscope. Figure 9 presents the voltage output waveform of the drive when the LED flat panel light is turned on. The output voltage signal can be controlled to the desired level in very short time (< 500ms). In addition, the controlled DC voltage output is fairly stable and the ripple phenomenon has not occurred. Figure 10 shows the voltage waveforms form when the dimmable control signal is triggered. The output voltage in AC coupling has the transient response when each dimmable trigger

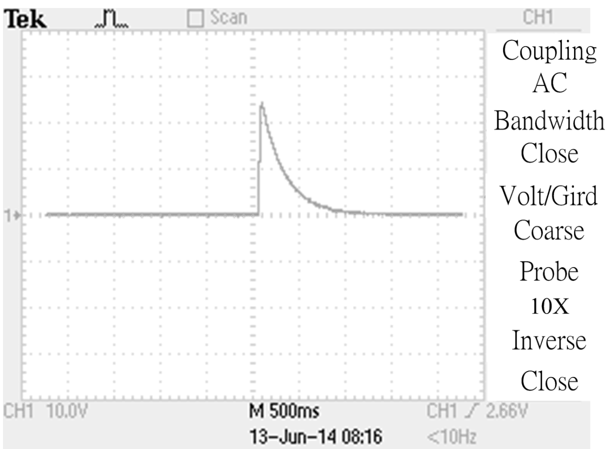

Figure 9. The driver DC coupling waveform during launching

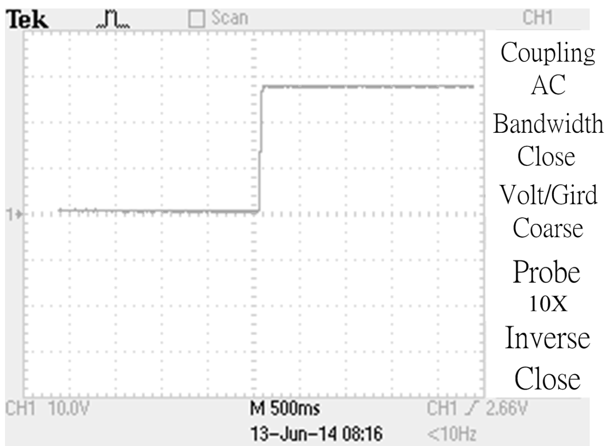

Figure 10. The driver AC coupling waveform during dimming action

Table 1. Experimental data for dimmable control

No.	Input voltage	Input current	Dimming command	Output voltage	Output current	Brightness %	Conversion efficient %
0	31.65	0.017	0.0	0	0	0	0
1	31.65	0.052	0.0	20.78	0	0	0
2	31.65	0.085	0.4	20.93	0.103	4	80.13
3	31.65	0.085	0.8	21.16	0.103	9	81.01
4	31.65	0.086	1.2	21.42	0.105	13	82.63
5	31.65	0.087	1.7	21.68	0.105	17	82.67
6	31.65	0.088	2.1	21.94	0.106	22	83.5
7	31.65	0.089	2.5	22.2	0.107	26	84.33
8	31.65	0.095	3.1	22.47	0.113	30	84.45
9	31.65	0.103	3.5	22.75	0.121	35	84.44
10	31.65	0.121	3.9	23.04	0.141	39	84.83
11	31.65	0.150	4.3	23.34	0.173	43	85.05
12	31.65	0.192	4.8	23.64	0.219	48	85.20
13	31.65	0.244	5.2	23.95	0.275	52	85.29
14	31.65	0.244	5.6	24.27	0.272	57	85.48
15	31.65	0.307	6.0	24.61	0.336	61	85.1
16	31.65	0.382	6.5	24.94	0.413	65	85.19
17	31.65	0.467	6.9	25.3	0.497	70	85.07
18	31.65	0.562	7.4	25.63	0.59	74	85.08
19	31.65	0.647	7.8	25.97	0.671	78	85.1
20	31.65	0.718	8.2	26.23	0.737	83	85.07
21	31.65	0.795	8.6	26.49	0.808	87	85.07
22	31.65	0.935	9.1	26.81	0.939	91	85.07
23	31.65	1.066	9.5	27.2	1.055	96	85.05
24	31.65	1.235	10	27.62	1.207	100	85.29

is applied. Table 1 presents the measured voltage and current by the digital multi-meter when the selected dimmable signal is applied. Dimmable control voltages with the corresponding brightness in percentage rates are also shown. The experimental data shows that the LED driver consumes 0.5 watts and 1.6 watts in saving mode and standby mode, respectively. In the dimmable mode, LED voltages $<$ 20.8Vdc cannot turn on the light because the LED diodes of the LED flat panel light are arranged in series. Table 1 also illustrates that the LED light has only 24 stages for dimming the lighting from 0 to 100%. In addition, the power conversion efficiency of the LED flat panel light is around 85%. This is due to MOSFET LM2596 having large internal resistance which results in more power depletion during the conversion process.

4. **Conclusions.** In this paper, we propose a power driver to achieve dimmable control of LED flat panel light with network communications based on integrated implementation of the hardware and firmware design. We have presented an embedded controller with the functions and interfaces of AC/DC transformation, local operation, remote supervisory control, lighting illumination indication, Modbus communications, power systems, system/distributing configuration, security settings, etc. Using the open firmware design technique, LED flat panel light can be enhanced to become a network control system with dimmable function to further enhance the power efficiency in home lighting system. When the system is operating, the microprocessor-based driver can monitor the system

current and voltage variation in order to protect the driver in abnormal situations. Furthermore, through use of the RS-485 communication interface, this driver can enable the LED flat panel light to become a network control dimmable lighting system for integrated applications in intelligent home automation systems.

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