Electronic Ballast of the Electrode-less Lamp for the Group Lighting System

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Abstract

This Paper presents RF modem based remote controlled electronic ballast for electrode-less lamps. In order to control the power of lamp driven by high-frequency electronic ballast, remote control is necessary. For the group lighting system, especially, wireless remote control using RF modem is proper. In this paper, 2.4-GHz ISM band RF modem based remote controlled electronic ballast is proposed. However, the cost of RF modem is relatively expensive as compare with the cost of electronic ballast. For the economic realization, one-ballast two-lamps system is proposed. And the proposed control circuit of the ballast is implemented with fully digital circuit using low cost 16-bit DSP and small size EPLD. Detailed algorithms for the power control and protections for the commercial electronic ballast are described. Finally, the wire and wireless linked group lighting system using the proposed ballast is introduced.

1. Introduction

Since the electrode-less lamp(sometimes it called by induction lamp) has no electrodes, it has very long lifetime more than 60,000 hours. The electrode-less lamp, therefore, is usually used in the case where the system maintenance is difficult such as high ceiling lighting system. Electrode-less lamp is driven using by a high-frequency resonant inverter and its driving frequency is over several hundreds of kilo-hertz. Therefore, the remote control is needed for the dimming of the electrode-less lamp. Especially in the group lighting system, the wireless remote control using RF modem is proper. There is a problem, however, that the cost of RF modem is relatively expensive as compare with the cost of electronic ballast. [1-5]

In this paper, one-ballast two-lamps system is the proposed to solve the expenses problem in adopting the RF modem for the remote controlled electronic ballast for the electrode-less lamp. In the proposed ballast, there are two high frequency resonant inverters for two electrode-less lamps. However, PFC circuit and EMI filter in the ac/dc converter stage are commonly used for two resonant inverters. Of course the modem and controller are also commonly used. And the proposed control circuit of the ballast is implemented with fully digital circuit using low cost 16-bit DSP and small size EPLD. [6, 7]

Detailed algorithms of the power control and protections for the dimmable commercial electronic ballast are described in this paper. And an application of the group lighting system which is linked with the Ethernet based long distance communication network and the RF modem based local wireless communication network is presented to show the usefulness of the proposed RF modem based remote controlled electronic ballast for the electrode-less lamp.

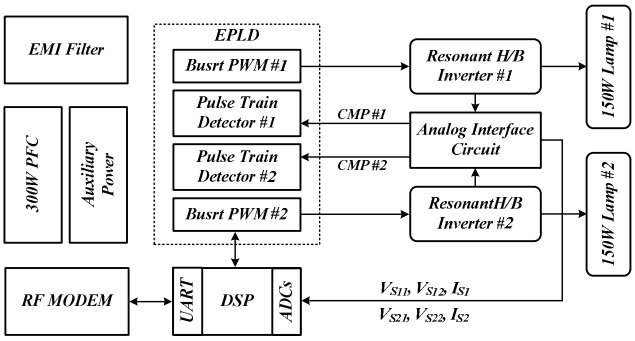


Fig. 1. Overall system configurations of the proposed ballast

2. Proposed New Electronic Ballast for the Electrode-less Lamp

2.1. Overall system configurations of the proposed electronic ballast

Fig. 1 shows the overall system configurations of the proposed electronic ballast. The proposed ballast can drive two electrode-less lamps simultaneously. Total power capacity of the proposed ballast is 300-W and is fed by a PFC circuit. Auxiliary power is 5V/12V output small converter for the controller and gate drive circuits. A novel burst PWM algorithm for power control and lamp fault protection algorithm are implemented using an EPLD. In order to drive two lamps, two high-frequency resonant half-bridge inverters are equipped. Each lamps are simultaneously controlled by a DSP, which is linked with the 2.4GHz RF modem.

2.2. Proposed one-ballast two-lamps system

Electrode-less lamp is driven using a high-frequency resonant inverter and its frequency is over several hundreds of kilo hertz and up to several Giga hertz. Fig. 2 shows the circuit of the proposed one-ballast two-lamps system. Two half-bridge resonant inverters are driven by a DC link. V_{S11}, V_{S12}, V_{S21}, and V_{S22} are used for dc link voltage monitoring, fuse status monitoring, and over/under voltage protection. I_{S1} and I_{S2} are used for used for dc current monitoring and power calculation of

each inverter. v_{L1} and v_{L2} are used for protection of switching devices in the ignition state and lamp fault state.

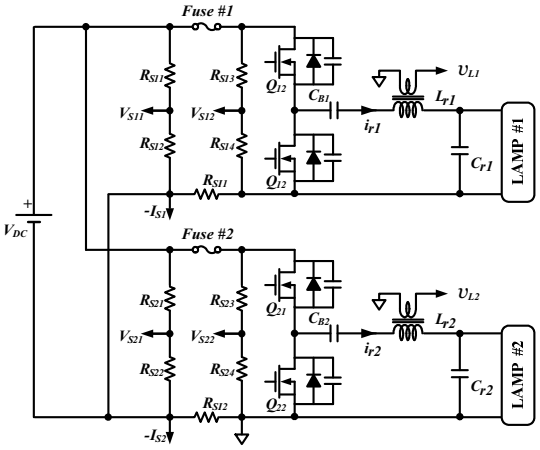


Fig. 2. Main circuit of the proposed ballast

2.3. Digital controller for the electrode-less lamp ballast

Fig. 3 presents block diagrams of the proposed fully digital dimming controller for one electrode-less lamp. 16-bit MCU is used for the main controller. Voltage and current of the dc link of the ballast are gathered by using built-in A/D converters in MCU and digitized data are transferred to the central monitoring host PC through the wire and wireless linked communication network. 115.2-kps UART interface is used for all information exchanges between the remote RF modem and MCU. A novel average burst duty control method is used for the dimming of the electrode-less lamp. The proposed control method can produce variable PWM duty with 1-% of steps. All functions are implemented by using small size EPLD. Fig. 4 shows the specific time chart of the proposed average burst PWM method and it is in the case of 58-% duty. Since 25-kHz of burst PWM frequency is adopted, the proposed averaging burst PWM method does not produce sound noise caused by PWM.

3. Wire and Wireless Linked Remote Controlled Group Lighting System Using Electrode-less Lamps

Since the electrode-less lamp has long life time, it is very useful especially in the fields of high ceiling and tunnel lighting system. Sometimes those lighting system needs controlling the illumination. For those cases, remote control system must be needed because induction lamps are driven at very high frequency. Therefore the wire and wireless linked remote control system for the group lighting system using electrode-less lamps is proposed in this paper.

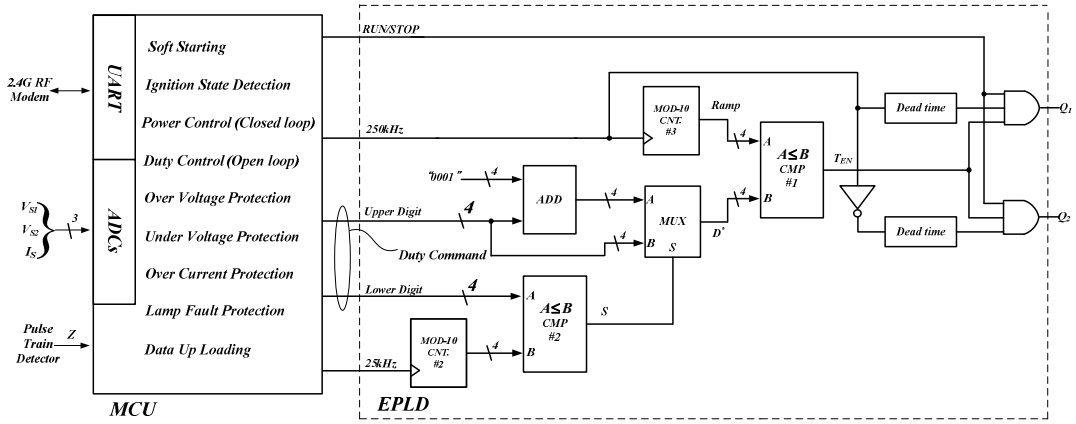


Fig. 3. Block diagrams of the digital controller for one lamp

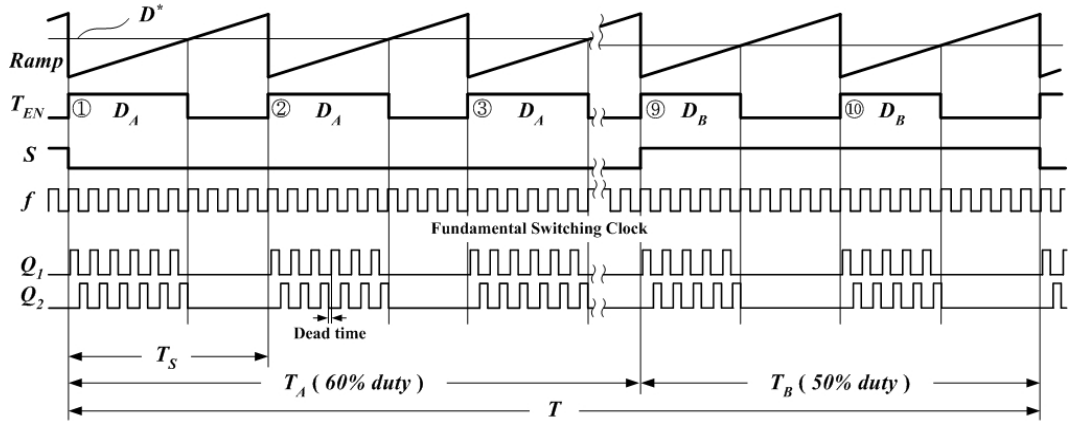


Fig. 4. Timing charts of average burst duty control method (in case of 58% duty)

Fig. 5 shows the overall system configurations of the proposed remote lighting control system. In order to use Internet network or local area network for the main long distance communication network, the main network is designed with Ethernet based network. Therefore the system management can be easily achieved by using personal computer to handle the proposed system. And the commercial mobile communication network can be also combined with the proposed system. In that case, the system manager can handle the lighting system with mobile devices such as cellular phone and/or PDA which loaded application soft-ware to control and monitor the system. For the local area communication between the main network and the each ballast, wireless network is more proper than wired network. 2.4-GHz RF network is built in the proposed system. We need, therefore, two kinds of RF modem. Ethernet interfaced master modem and UART interfaced local modem linking the wireless main network and ballasts. Therefore ballast includes the local modem. In the future, to work with another management system such as IBS, standard protocol like a ZigBee is more proper for the proposed system. In this stage, however, simple user protocol is adopted in the proposed system.

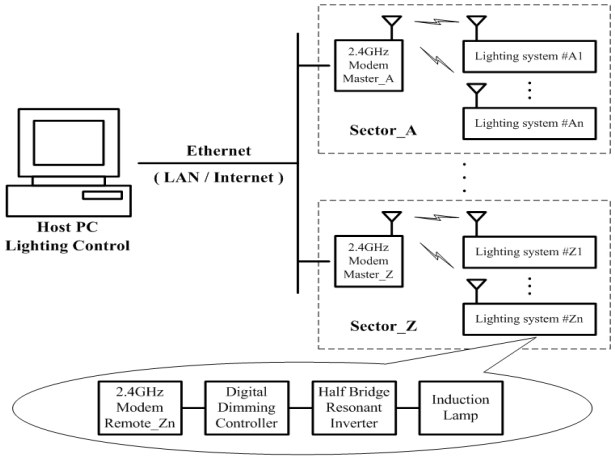


Fig. 5. Configurations of the proposed group lighting system

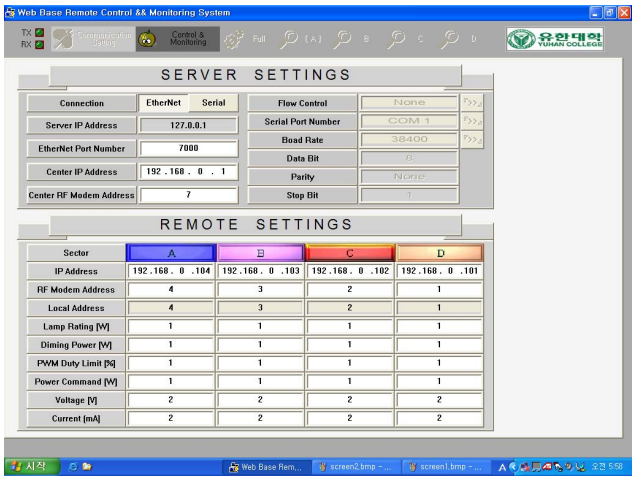
4. Experimental Results

For the experimentation, proto lighting system is constructed, which is composed of four sectors. Each sector is composed with four ballasts. In actual application system, the number of sectors is not limited and the number of lamps is dependent on addressable capability of the RF modem. In the experimental setup, 150-W electrode-less lamps manufactured by OSRAM are used.

The principal parameters of the experimental setup are as follows:

- DC link voltage, V_{DC} : 400 [V]
- Switching frequency, f_s : 250 [kHz]
- Burst PWM frequency, f_b : 25 [kHz]
- Blocking capacitance, C_B : 100 [nF]
- Resonant inductance, L_r : 232 [uH]
- Resonant capacitance, C_r : 2.2 [nF]
- Switching devices : IRF840
- Starting frequency (for soft ignition) : 500 [kHz]
- Successful ignition determining time : 0.5 [Sec]
- Over voltage protection level : 450 [V]
- Under voltage protection level : 350 [V]
- Over current protection level : 500 [mA]

Fig. 6 shows some images of the prototype server management program screen. Fig. 6(a) is a screen for the parameter settings such as IP address of the center modem, local address of the remote modem, and some gains of the control/monitoring factors. Fig. 6(b) is a screen for overall system control and monitoring screen.



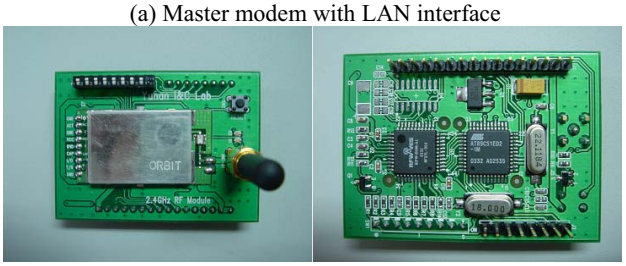
(a) Screen for parameter setting

(b) Screen for controlling and monitoring

Fig. 6. Images of the prototype management program screen

Fig. 7 shows some images of master RF modem with Ethernet interface and local RF modem with UART interface used in the prototype system. The RF modem uses 2.4-GHz ISM band radio frequency and the RF power is 10-mW. The data transfer rate of the RF modem is 1-Mbps. The RF modem is worked by using the direct sequence spread spectrum modulation method. Since CSMA/CA, automatic re-transmission, and CCITT 16bit CRC algorithms are implemented in the MAC protocol level, reliable communication can be achieved. The data transfer rate of UART interface is up to 115.4-kbps.

(a) Master modem with LAN interface



(b) Remote modem with UART interface

Fig. 7. Images of modems

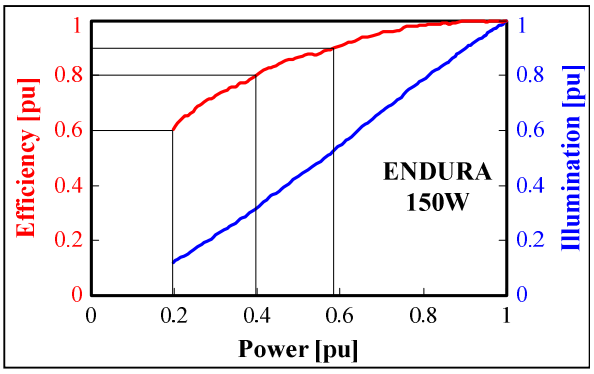
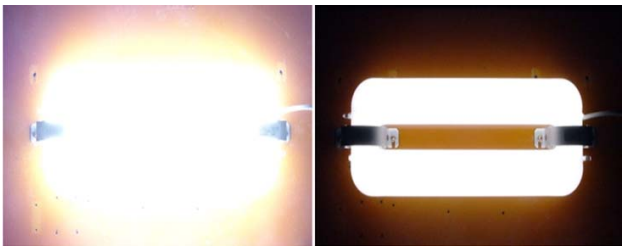


Fig. 8. Illumination and Efficiency according to the power



a) A case of 100% power (b) A case of 30% power

Fig. 9. Images of lighting according to the power

Fig. 8 represents variations of illumination and efficiency according to the various power. In the wide power range, over 60-% efficiency is achieved and it is very good result. Under 20-% power, the lamp could not be driven. For the stable lighting, above 30-% of power control range is proper.

Finally, images of the lighting lamp at various powers are shown in Fig. 9. Since the rating of lamp power is 150-W, 100-% power and 30-% power mean 150-W and 45-W, respectively.

5. Conclusions

This paper proposes new electronic ballast for electrode-less lamps. Fully digital controlled average burst PWM power control algorithm is proposed for dimming and the controller is composed with an MCU and EPLD. Since the proposed PWM method can produce the output with the 1-% of duty resolution and with the 25-kHz burst frequency, the lamp power is stably controlled without sound noise. For the remote controlling and monitoring the group lighting system, Ethernet based communication and 2.4-GHz RF communication are constructed. The proposed ballast equipped RF modem and one-ballast two-lamps system is implemented. With the result of experimentation using prototype setup, the usefulness of the proposed remote control system and effectiveness of the proposed dimming method for the electrode-less lamp are confirmed and verified.

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