Implementation of VLC transmitter using MCU for promotion lighting ID services

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Abstract— **In this paper, we propose a MCU-based signal generating method and a physical layer frame format for promotion lighting ID services using visible light communication (VLC) technology. The proposed method and format for VLC services are possible to be simply implemented by updating the firmware of existing MCU which is in the LED lighting for dimming function. We get the potential of performing visible light communication using MCU through the experiments.**

Keywords— **Dimming, LED, Lighting ID, MCU, VLC**

I. INTRODUCTION

Traditional luminaires such as fluorescent and incandescent are being replaced with energy-efficient LED (Light Emitting Diode) lightings in these days. The propagation of LED lightings is able to bring on IT (Information Technology) fusion technology[1-2]. As one of those areas, studies on visible light communication (VLC) using LED lighting have being performed actively. Whereas typical wireless communication use radio frequency to transmit and receive data, VLC use visible light as carrier frequency.

The advantages of LED lighting, unlike traditional lighting controlling the brightness of the light by changing the supplied voltage, can provide digital dimming. Digital dimming light uses PWM (Pulse Width Modulation) signal to control the brightness of the light. In ON section of PWM signal, LED light is turned ON. By changing the pulse width of PWM signal, brightness of LED light is controlled. We use MCU (Main Control Unit) which generates control signal to change the pulse width of PWM in LED lighting.

Usually On-Off Keying (OOK) modulation is used in VLC. OOK signal is similar to PWM signal in case the physical appearance of signal. So we can generate VLC signal using similar method generating PWM signal in MCU. This method can give VLC service through already installed lighting by updating the firmware in MCU. But MCU-based VLC is suitable only for short message transmission due to limit of processing power.

In case of combining VLC and LED lighting, some problems such as flickering and dimming control may occur. Occasionally VLC systems use line code including Manchester code, 4B6B for rejecting flickering and VPPM (Variable Pulse Position Modulation) modulation. Random data prevent dimming-control in LED lighting. This paper proposes a solution to solve these problems of the VLC transmitter using MCU in LED lighting. In addition, we also propose the PHY frame format to control dimming and reject flickering. And also, we propose the PHY frame format that can control dimming and reject flickering.

The proposed VLC system can transfer only short data such as promotion lighting ID (Identification) associated with a product information. In the proposed VLC system, promotion lighting ID is transferred to user device with VLC receiver. User device displays multimedia contents related with received ID. We have tested the proposed VLC system in commercial mart and described the test environment and the results in this paper.

II. VLC SIGNAL GENERATION

Typically traditional luminaires control the brightness of lighting by changing the supplied voltage such as zero-ten base. Dimming in digital lighting systems including LED lighting is based on PWM signal, as shown in Figure 1. Brightness of lighting is dependent on pulse width of PWM signal. In the figure 1, T_s is the period of PWM signal and T_c is ON section of the period. Supplied voltage, V is supplied to PN junction of LED during time T_c in period T_s and LED turns on. Doubling the ON section, the brightness of lighting is twice brighter.

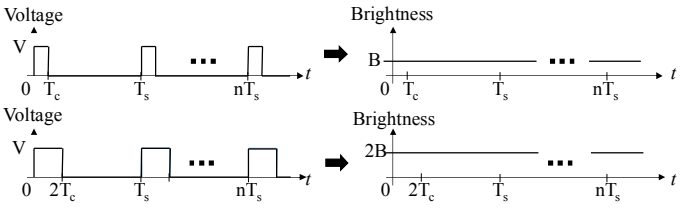

Figure 1. Digital dimming by PWM

A. MCU based PWM Signal Generation

Typically MCU has a GPIO (General Purpose Input Output) pins and can generate PWM signal using GPIO pin. GPIO pin outputs the decided logic value in MCU at TTL (Transistor-Transistor Logic) voltage level. GPIO pin is connected to the pin for LED driving shown as figure 2.

The GPIO pin is controlled by MCU main clock, so the smallest pulse width of PWM is decided by the main clock. The input and output rate of GPIO pin is controlled by the main clock. In case the input and output rate of GPIO pin is 4 Mbps, the smallest pulse width of PWM, T_c is 0.25us.

Programmed MCU can change the output of GPIO pin every step T_c.

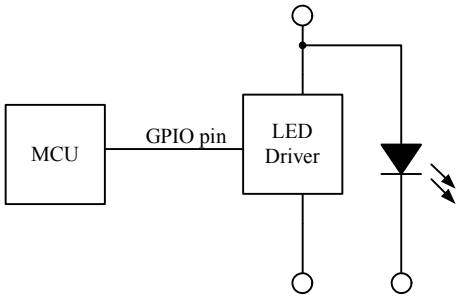

Figure 2. Connection between MCU and LED driver using MCU GPIO pin

B. VPPM Symbol

VPPM symbol is defined as in Table 1. Logical data '0' is mapped to VPPM symbol transited from 'high' to 'low', and logical data '1' is mapped to VPPM symbol transited from 'low' to 'high'. Schematic mechanism for VPPM in IEEE 802.15.7 standard is shown as figure 3[3].

TABLE 1. DEFINITION OF DATA MAPPING FOR VPPM

Logical value	**Physical value** d is the VPPM duty cycle ($0.1 \leq d \leq 0.9$)	
0	High	$0 \leq t < dT$
	Low	$dT \leq t < T$
1	High	$0 \leq t < (1-d)T$
	Low	$(1-d)T \leq t < T$

The brightness of VPPM symbol is same for both case of logical data '1' and '0', because both signals have the same ON section of pulse. The difference between logical data '0' and '1' is the type of transition. So VLC receiver can detect logical data '0' and '1' from the type of transition.

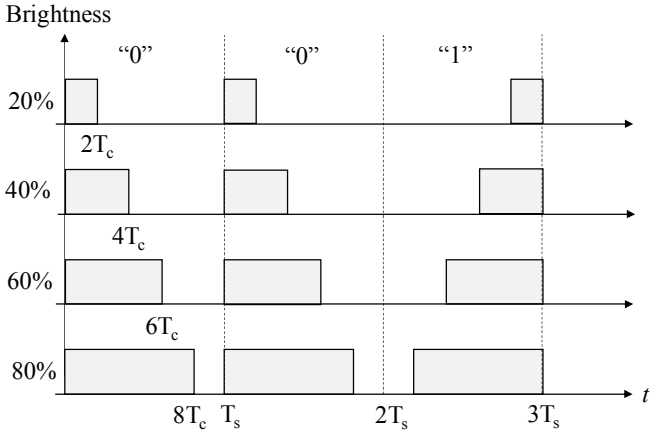

Figure 3. Schematic mechanism for VPPM signal

C. MCU based VPPM Symbol Generation

VPPM symbol has ON section and OFF section. The width of each section is controlled according to the brightness of lighting. For example, if dimming step of lightening is 10% of maximum brightness, the ON section time of VPPM symbol is T_c. In case that the VPPM symbol is 0% and 100% of the maximum brightness, the symbol has not the transition of signal, so that the symbol cannot be used as a communication signal.

If the time duration of one VPPM symbol is T_s and dimming step is 10% of maximum brightness, T_s equals to 10 T_c. As MCU changes the output of GPIO every T_c, MCU can generate one VPPM symbol every T_s. For the condition that logical data is '0' and dimming step is 10% and the brightness is 10% of maximum brightness, the VPPM symbol is generated by C program as shown in the figure 4. We know that the duration of VPPM symbol is decided by the main clock of MCU.

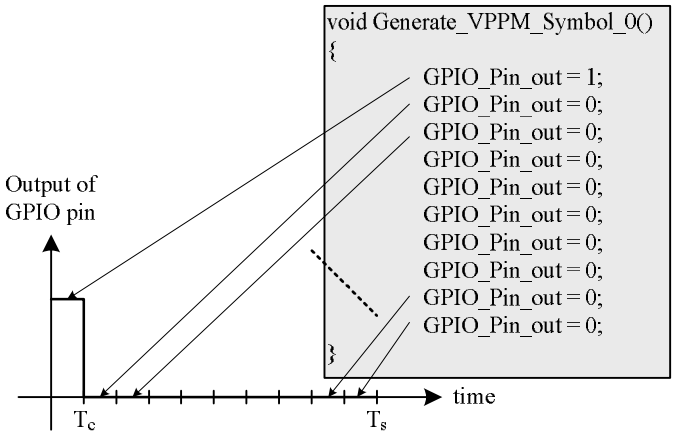

Figure 4. VPPM symbol generation using C program

VPPM symbols generated in MCU are used as the transmission signal in a visible light communication. To receive the data without error at the receiver, the symbol period of the transmitting signal must be always same. However, the swing of symbol period prevents receiver from maintaining symbol synchronization. In order to always keep the symbol period of the transmitting signal, MCU should not perform other tasks. Other task of MCU should be performed after delivery of a single physical layer frame.

III. VLC PHY FRAME FORMAT

Figure 5 shows the structure of the VLC transmitter implemented by using a MCU. Out signal from GPIO pin of the MCU is applied to the LED driver. The MCU has a role to make VLC PHY frame and generate transmitting signal which is applied to the LED driver. In detail, the MCU includes the following function blocks. A function block reads the memory with a given ID. Another function block makes the VLC PHY frame with these data. The third block modulates the frame with the VPPM symbol mapping function.

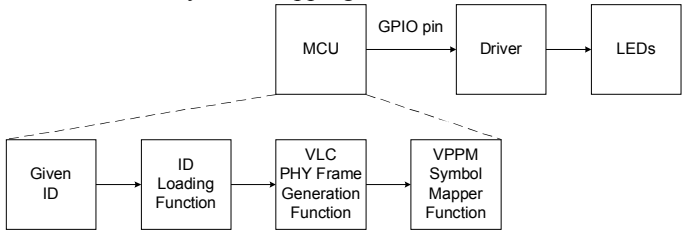

Figure 5. Structure and function of VLC transmitter using MCU

A. VLC PHY Frame

Frame structure for the promotion lighting VLC proposed in this paper is shown in Figure 6. The frame starts with a preamble field to indicate the starting point of the frame. The data field following the preamble field includes the predetermined value that is assigned for promoting lighting. The CRC field is generated by using a generator polynomial CRC-5 to check the error in a frame. The CRC-5 polynomial which is used in the system is given by x ^ 5 + x ^ 2 +1.

Fields	Preamble	~Preamble	Data	CRC
# of bit	11 bits	11 bits	5 bits	5 bits
Value	11100010010	00011101101	01100	11001

Figure 6. VLC PHY Frame format of promotion lighting service

For promotion lighting, the data depends on light ID and then the contents of the frame are fixed if the light ID is not changed. Therefore, once the CRC value related to light ID is determined, the value can be reused for all frames. In the receiver side, the starting point of the frame can be detected by using this preamble which is predetermined values.

The proposed VLC system has been developed in ATMEGA128 8-bit processor. To maintain the duty cycle of transmit signal for logic data '0' and '1', physical layer frame is consisted of 32 bits. To extend the ID length is achieved by reducing the length of preamble and CRC, but it causes the performance of communications to worse. If lighting does not support dimming function, we can use Manchester code instead of VPPM. If Manchester code is used, the transmitter sends 4 times faster than VPPM-based transmitter sends data. Also if flicker is not considered as problem, no coding scheme is needed in VLC system.

B. Flickering in VLC

Flicker is defined as periodic or non-periodic changes in the brightness of the light source which human eye can detect. When the output of the LED lighting have different averages of brightness about each of data bit '0' and bit '1' as shown figure 7, flicker protection technology is needed on the inside of the frame. VPPM symbol mapping is a flicker protection technology which can support dimming simultaneously.

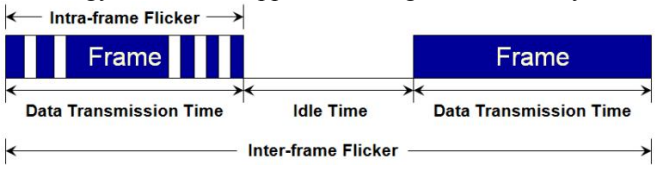

Figure 7. Intra-frame flicker and inter-frame flicker in VLC

The output of the LED lights in aspect of the average brightness is different between idle time and data-transferring time. And then, other technologies to prevent the inter-frame flicker another technique are also required. However, we don't consider inter-frame flicker because the proposed VLC system transmits packets continuously without idle time.

C. VPPM Symbol mapping

As shown in Figure 6, the proposed VLC frame consists of 32-bit binary values and each bit is transmitted during 8 time slots. The flicker effect occurs in case that all of values during 8 time slots are same. As shown in Figure 8, to prevent this flicker effect, Manchester coding taking value-transition is applied in this system.

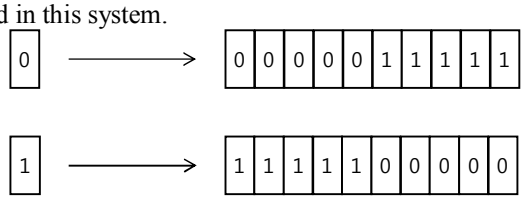

Figure 8. Structure and function of VLC transmitter using MCU

VLC symbol mapping is implemented using the look-up table (LUT). According to the input data, the system reads the corresponding values in the LUT and transfers this value to FEM during 8 time slots. Figure 9 describes the process of transferring the VLC frame to FEM. Output of PB5 pin that is one of the MCU GPIO pins is connected to FEM input. Depending on the value of the input signal, FEM part is driving the LED module (ON / OFF control).

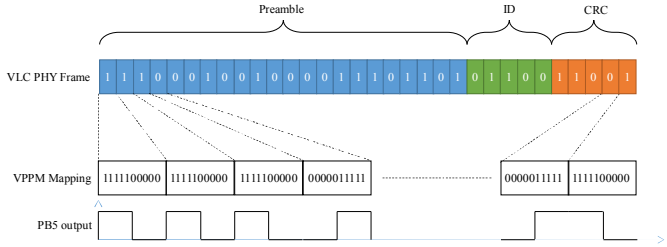

Figure 9. Structure and function of VLC transmitter using MCU

D. MCU Main Program

The main function of the MCU is implemented with a simple structure. After the initialization routine is performed, the same data is sent infinitely repeated. Once the promotion lighting is power on, initialization routine to clear the PB5 port is performed. In this implementation, PB5 is one of the ATMEGA128 MCU's PORT is connected to LED lighting. All interrupt functions are disabled to avoid the scattering of the transmitting time-slots due to any interrupt function.

Whenever a particular variable value is '0', PB5 is clear by the data transmission routine. In contrast, a particular variable value is '1', PB5 is set. PB5 out signal controls the LED lighting in the form of ON/OFF[4].

Figure 10 shows the operation of main function for VLC data transmission. VLCData is already initialized to the pre-determined values, mapped to VPPM symbol and is transmitted sequentially. Transmit interval in the infinite loop always must have the same processing time. If this is not guaranteed, duty cycle of data changes. Clock synchronizer of receiver cannot be performed appropriately because of irregular duty cycle.

VLCData of index *i* is passed to PB5 through the send() function. After sending the VLCData, index *i* is increased. Maximum value of index *i* is 255. In an 8 bit processor, when index *i* is 255, if *i* is automatic increasing, *i* returns to 0. Therefore transmitter transmits VLCData from index 0. As a

result, VLC transmitter can infinitely broadcast VLC PHY frame with short message ID.

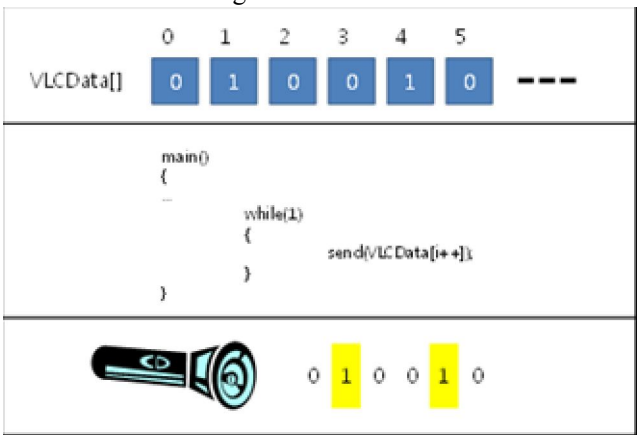

Figure 10. MCU main function for VLC transmitter

IV. Test and Results

The proposed VLC system transferring only short data such as promotion lighting ID (Identification) associated with a product information was tested for proving the proposed physical layer frame and MCU transmitter. Proposed MCU-based method for promotion lighting VLC system broadcasts ID to the user terminal. User terminal receiving ID plays the contents mapped to it. User picks the promotion information for product mapped to ID.

ATMEGA128 MCU is used for VLC transmitter. Typically ATMEGA128 MCU is used for PWM dimming in LED lighting. For MCU firmware updating, AVR Studio 4 development environment and C programming language were used. GPIO pin of the MCU, PB5 sends a digital signal to deriver in the FEM. Depending on the value set for PB5, LED is ON or OFF. Data bits is fixed to 5 in current physical frame, but VLC system can transfer longer data by changing the frame structure able to be applied to high-performance MCU.

Figure 11 shows the test environments for proposed VLC system in laboratory. For experiments, two built-in MCU lighting are used. Each MCU firmware saves each other ID. To generate the CRC, MCU can perform CRC calculation in real time. But we don't perform CRC calculation in real time, because ID value isn't changed in real time. Each MCU based VLC transmitter transmits each pre-calculated physical layer frame.

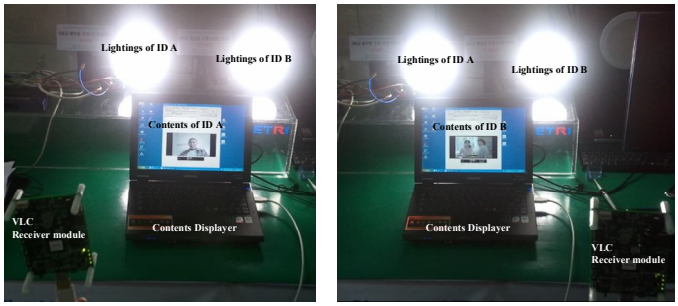

Figure 11. Demonstration of proposed VLC system

VLC receiving part is consisted of VLC receiving module and user terminal for displaying multimedia contents mapped to ID. VLC receiving module receives physical frame that is transmitted by VLC transmitter and gives the received physical frame to user terminal. The application of user terminal checks CRC from physical frame and gets ID.

As the test result of the proposed VLC system, depending on the location of the VLC receiving module, the application of user terminal displays the multimedia contents mapped to the received ID. User terminal display the multimedia contents of lighting closer to the VLC receiving module. By using the proposed VLC system, various services including indoor navigation, notification on risk areas and location dependent game service can be developed.

V. Conclusions

In this paper, we designed visible light communication system for transmitting short message such as promotion ID. We implemented the MCU based VLC transmitter applying the method used to generate PWM dimming signal. The designed MCU based VLC transmitter is able to support the dimming function and VLC transmitting at the same time. Also, we have proved that implemented VLC system provide the service scenario for promoting products.

According to results of this paper, location information service can be provided. Lighting IDs from LED lightings which exist all over the building can be used in indoor navigation. We will propose the structure of receiver for MCU based VLC transmitter in next paper.

Acknowledgment

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References

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