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# An Automatic Light Monitoring System with Light-to-Frequency Converter for Flower Planting

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***Abstract –*** *In this paper, an automatic light monitoring system with light-to-frequency converter for flower planting is newly proposed. Based on the requirements for flower planting, the proposed light monitoring system is thus analyzed and designed. Besides, the designed light transducer, which is implemented as a light-to-frequency converter, is attractive due to that a digitized signal is produced without realizing the analog to digital converter. Hence, the hardware cost could be reduced. All the functions and performance of the proposed light monitoring system are successfully proven through measurement results. The proposed light monitoring system is rather suitable for the needs in a large flower planting area.*

***Keywords –*** *Light monitoring system, light-to-frequency converter, flower planting.*

## I. INTRODUCTION

Recently, environment monitors for agriculture are an important issue, and also have the urgent demands to be developed. This kind of agriculture is called the controlled environment agriculture (CEA). The main objects of the CEA are to adaptively control the environment condition for growing animals and plants and then to increase the output quantities and qualities. To achieve the function of the intelligent control of the CEA, some environment factors should always be detected and obtained in real-time. Among the CEA, an important filed is about the flower planting. Some systems in flower planting had been developed, such as Priva of Netherlands and Q-com of U.S.A. However, they are just suitable for temperature control in the indoor flower planting. They are not suitable for lighting control in the outdoor flower planting. Besides, the cost of the whole system setup is higher. In the traditional outdoor flower planting as shown in Fig. 1, the control algorithm of lighting control is rather simple, and the light can just be digitally turned on and off. That means that it can not adjust the light in real-time and varied in analogy according to the various environment conditions. Thus, in this paper, the automatic lighting control for outdoor flower planting is focused and researched.

Fig. 1. Traditional outdoor flower planting.

In order to fit the demands of the commercial market for flower planting, the light transducer, which is implemented as a light-to-frequency converter, has the low cost feature. It is due to that a digitized signal is produced without realizing the analog to digital converter. Hence, the hardware cost could be reduced. Besides, the output signal of the light transducer is a pulse stream, it could be easily sent over a wide range of transmission media, such as PSN, radio, optical, IR, ultrasonic, and etc. Hence, the output signal could easily be received and processed by the receiver terminal, such as receiver in the systems of wireless sensor network. Until now, several achievements [1]-[4] had been developed. However, they are not suitable for flower planting due to their applications, such as microspectrometer [3] and microfluidic systems [4]. Hence, the light transducer needs to be redesigned. To satisfy all the requirements for flower planting, which are to monitor and adjust the light variations in real-time, to cost down the system setup, and to achieve the monitoring functions without human efforts, an automatic light monitoring system with light-to-frequency converter for flower planting is inspired.

In this paper, all the system design and measurement results are discussed in detailed and demonstrated. In the section II, it describes the proposed automatic light monitoring system overview. Section III displays measurement results. Section IV gives conclusions and future works.

## II. THE PROPOSED AUTOMATIC LIGHT MONITORING SYTEM OVERVIEW

In Fig. 2, the proposed automatic light monitoring system for flower planting is presented. It consists of four circuit diagrams, which are a light-to-frequency converter, a wireless transmission media, a programmable controller, and a digital to analog converter (DAC)-to-lighter circuit. The light-to- frequency converter receives the light coming from both the environment and the lighter, and then transforms the received light into a pulse stream. Hence it can be easily transmitted and processed as a sequence of binary bits to the programmable controller. In order to fit the needs in a large flower planting area, the proposed system can handle both the local and global light changes. By using the multiplexer, the programmable controller receives either the local data via wires or the global data via the wireless transmitter. Then the programmable controller can analyze and judge the lightness of the received data. Finally, the DAC-to-lighter circuit will adaptively adjust the lightness of the lighter according to the output signals performed by the programmable controller. With the feedback path, the proposed light monitoring system can automatically lighten or darken the light through the DAC-to- lighter circuit and instantaneously react to fit the environment variations, such as sunrise, sunset, raining, and etc.

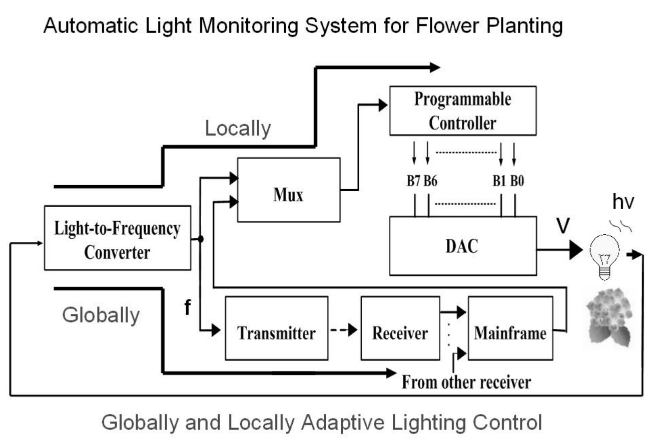


Fig. 2. Block diagram of the proposed automatic light monitoring system for flower planting.

The designed light-to-frequency converter is demonstrated in Fig. 3. $D_1$, $D_2$, and $D_3$ are the photodiodes built with SP-1KL, while $C_1$ is a capacitor, the comparator and the switching MOS are built with LM311P and IRF630A, respectively. Each photodiode induces the same photocurrent $I_{ph}$ under the same lightness. Now the circuit operations are addressed. In the first half period, the switching MOS is off, the capacitor $C_1$ is charged only by the photocurrent of $D_3$, $I_{ph}$. The generated voltage is with a positive voltage $V_H$. Once the voltage $V_H$ is higher than $V_{th}$, which is the threshold voltage of the comparator, the output of the comparator converts into logic high and turns on the switching MOS. The relationship between the oscillating frequency and the lightness can be derived as

$$V_H + V_L = \frac{1}{C_1}\int_0^{T_1} I_{ph}\ dt \qquad (1)$$

where $V_H$ and $V_L$ are the generated voltages when the capacitor $C_1$ is charged in two opposite directions of the photocurrent $I_{ph}$. With steady lightness, (1) can be rewritten as

$$V_H + V_L = \frac{I_{ph}T_1}{C_1}$$
$$\Rightarrow \quad T_1 = \frac{(V_H + V_L)C_1}{I_{ph}} \qquad (2)$$

In the second half period $T_2$, the switching MOS is turned on, the total photocurrent passes through $C_1$, the photocurrent $I'_{ph}$, will become

$$I'_{ph} = I_{ph} - 2I_{ph} = -I_{ph}$$

Then the capacitor $C_1$ is charged from $V_H$ to $-V_L$.

$$-V_L - V_H = \frac{1}{C_1}\int_0^{T_2} (-I_{ph})\ dt$$
$$\Rightarrow \quad T_2 = \frac{(V_H + V_L)C_1}{I_{ph}} \qquad (3)$$

Combined (2) and (3), the output frequency of the light-to-frequency converter is derived as

$$T = T_1 + T_2 = \frac{2(V_H + V_L)C_1}{I_{ph}}$$
$$f = \frac{1}{T} = \frac{I_{ph}}{2(V_H + V_L)C_1} \qquad (4)$$

According to (4), the relationship between the frequency and the photocurrent is directly proportional. Finally, the photocurrent $I_{ph}$ [2] is

$$I_{ph} = \frac{PA_j\lambda\eta_c}{\eta c} \qquad (5)$$

where P is optical power, $A_j$ the junction area, $\lambda$ the wavelength, $\eta_c$ the external quantum efficiency, $\eta$ the Plank's constant, and c is the speed of light. combined (4) and (5), the output frequency can be modified as

$$f = \frac{PA_j\lambda\eta_c}{2\eta c(V_H + V_L)C_1} \qquad (6)$$

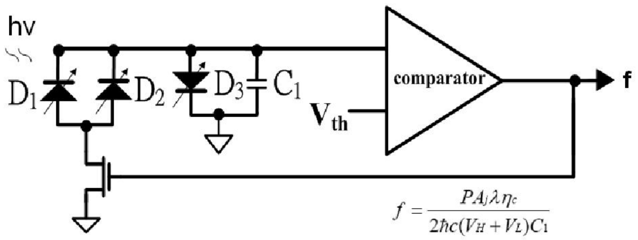


Fig. 3. Circuit schematic of the designed light-to-frequency converter.

Fig. 4 shows the block diagram of the programmable controller. There are two major circuit operations in this block diagram. The first one is to evaluate the frequency of the received data, and the second is to make the judgment to adaptively adjust the output signals according to the environment requirement, which is the reference lightness or reference frequency. According to the evaluated frequency of the first step, the comparator in the programmable controller will send a binary bit to the averaged buffer. The binary bit 1 is to represent that the generated frequency is higher than the reference frequency and 0 is to represent it is lower than the reference frequency. In order to reduce the effect of the environmental noise, the averaged buffer collects 100 compared results and takes into the averaging operations. After performing the circuit averaging and judging operations, the programmable controller will strengthen or weaken the lightness of the lighter. With the feedback path from the lighter to the light-to-frequency converter, the programmable controller repeatedly makes the adjustment to the output, and gradually achieves the reference frequency or reference lightness of the environment requirement. All the circuit operations are measured in section III.

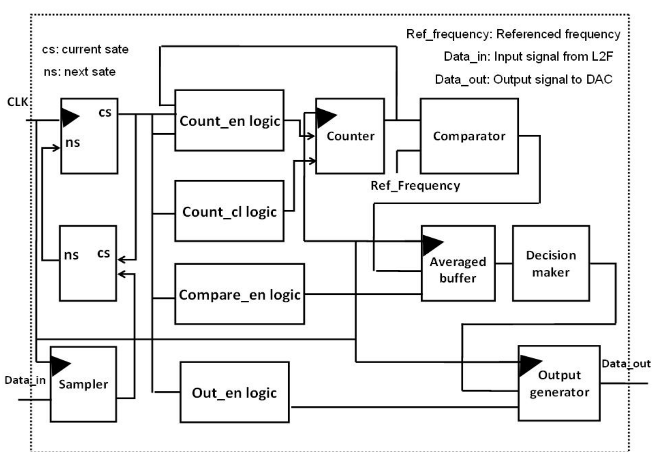


Fig. 4. Block diagram of the programmable controller.

## III. MASUEMET RESULTS

Fig. 5 demonstrates the measurement results of photodiodes under the illuminance varied from 100 to 1100 lux. The oscilloscope traces of the designed light-to-frequency converter are demonstrated in Fig. 6. As shown, the light-to-frequency converter is successfully performed and matched to (6). The larger the illuminance will increase the output frequency, and this is observed. The corresponding frequencies of 200 lux, 400 lux, 600 lux, and 800 lux are 1.825 kHz, 2.315 kHz, 2.571 kHz, and 2.786 kHz, respectively. The sensitivity of the light-to-frequency converter is 1.875 Hz/lux.

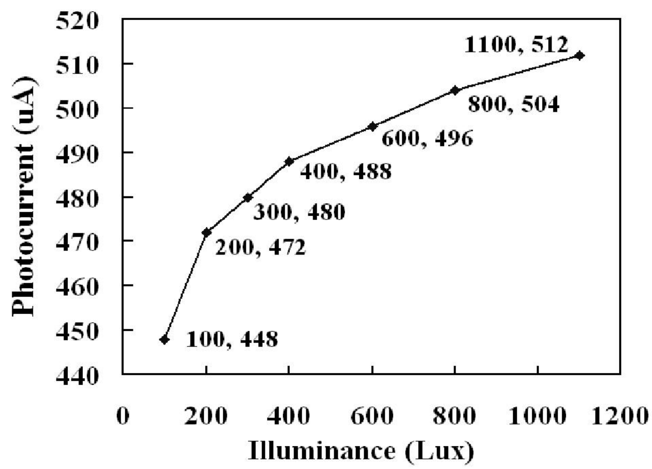


Fig. 5. Measurement results of the photodiodes under the illuminance varied from 100 to 1100 lux.

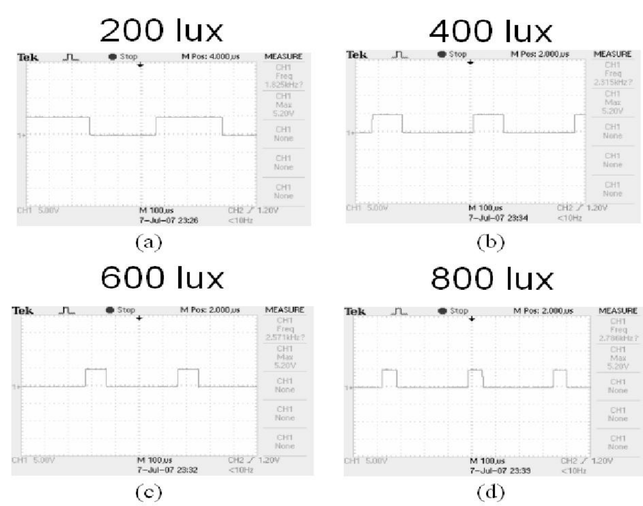


Fig. 6. Measurement results of the oscilloscope traces of the designed light-to-frequency converter under the illuminance at (a) 200 (b) 400 (c) 600 (d) 800 lux.

All the measured results are plotted in Fig. 7. As the similar tendency of Fig. 5, the linear region of Fig. 7 successively certifies this relationship that (4) derives. Finally, Fig. 8 demonstrates the responses of the whole system for flower planting under different initial environment conditions. These results show that no matter what the initial illuminance is, the proposed adaptive light monitoring system would automatically pull the received lightness to the reference illuminance as the environment requirement. Taking the Fig. 8(b) and (c) as an example, when the initial lighting condition is larger than reference illuminance, the lighter is controlled to be gradually decreased to achieve the reference illuminance. Hence, the feedback path successfully functions in the adaptive light monitoring system. However, due to the effects of noise, there are some small oscillations in the stable situation. The oscillations are about one or two deviations among total 256 steps of the DAC. Each step is 19.5 mV. The sensitivity corresponding to the illuminance is 6.25 mV/lux. All measured results above have successfully proved the functions and performance of the proposed automatic light monitoring system for flower planting. The characteristics of the proposed automatic light monitoring system with light-to-frequency converter for flower planting are summarized in Table I.

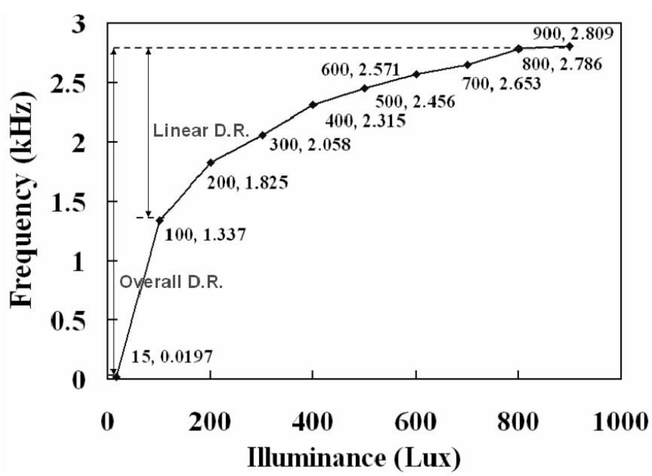


Fig. 7. Measurement results of the designed light-to-frequency converter under the illuminance varied from 15 to 900 lux.

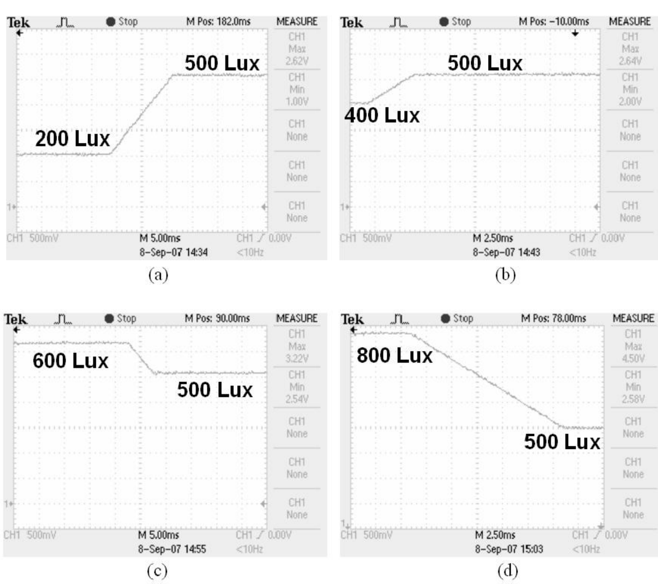


Fig. 8. Measurement results of the oscilloscope traces of the proposed automatic light monitoring system for flower planting under the initial environment illuminance at (a) 200 (b) 400 (c) 600 (d) 800 lux. The reference illuminance is 500 lux.

## IV. CONCLUSION

An automatic light monitoring system with light-to-frequency converter for flower planting is newly proposed. This proposed system can satisfy the requirements for flower planting, which are to monitor and adjust the light variations in real-time, to cost down the system setup, and to achieve the monitoring functions without human efforts. Besides, the designed light transducer has the low cost feature. It is due to that a digitized signal is produced without realizing the analog to digital converter. Hence, the hardware cost could be reduced. Moreover, the output signal of the light transducer is a pulse stream, it could be easily sent over a wide range of transmission media. All the functions and performance of the proposed light monitoring system for flower planting are successfully proven through measurement results. In the future research, this automatic light monitoring system will be applied in systems of wireless sensor network for globally adaptive lighting control.

Table 1. Summary on the characteristics of the proposed automatic light monitoring system with light-to-frequency converter for flower planting.

| | |
|---|---|
| Linear dynamic illuminance range | 100-900 lux |
| DAC resolution | 8 bits |
| Reference illuminance | 500 lux |
| Frequency range of light-to-frequency converter corresponding to linear D.R. range | 1.337 kHz-2.786 kHz |
| Sensitivity of light-to-frequency converter | 1.875 Hz/Lux |
| Sensitivity of DAC-to-lighter | 6.25 mV/lux |
| Application field | Traditional flower planting |


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