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# REALIZATION OF MULTI-FUNCTIONAL TRAFFIC LIGHTS BY FULL-COLOR LED ARRAY

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Abstract. *The paper uses a full-color LED array to realize a multi-functional traffic light display. Hardware structure consists of both host and slave modules. The planning of the light for every module includes two screens: one is a pattern sign; the other is a countdown sign. The host module is used to display the road signals, generate synchronous signals, and deliver the messages to the slave module. The slave module receives the messages from the host module, and displays the corresponding sign. Two modules can be phased in sequence at the same time, to allow road traffic flow become more fluent. Each of the modules consists of an Arduino microprocessor, RGB control boards, full-color LED arrays, and a wireless communication circuit. The traffic light has a pattern sign that can allow citizens who suffer from color-blindness to understand the signaling situation. The traffic light also has advantages that integrate features, integrate mass traffic light displays, allow cars and people understand the traffic situation better, and finally, create a smoother and safer traffic flow. The paper can provide a reference for the study of traffic light systems.*
**Keywords:** Traffic light, Full-color LED array, Arduino

1. **Introduction.** According to statistics of the Transportation Ministry, over 80% of traffic accidents occur at crossroads, where more than 60% are caused by non-compliance with traffic signals. Thus, most of traffic accidents occur at crossroads. Any bustling city has a large number of crossroads, so it is very important that traffic signs control both people and vehicles at intersections. A variety of different control systems have been used to accomplish this. Some traffic signs are combined with detectors. Sensors inform the controller processor whether vehicles or other road users are present. This system adjusts signal timing and phasing within the limits set by the controller's programming. It can give more time to an intersection in heavy traffic, or shorten time in little or no traffic waiting for a green light, reducing collisions and waiting time for both vehicles and pedestrians [1]. More recently methods have been employed. Video cameras or sensors buried in the pavement can be used to monitor traffic patterns. Reducing unnecessary stopping and starting of traffic. This reduces fuel consumption, air and noise pollution, and vehicle wear and tear [2,3].

Traffic signs face at least three problems: countdown, picture design, and simplification, as follows [4]. The above accidents may be reduced by providing enough time for situations. In the green light countdown, it can help a distant vehicle to determine whether there is enough time to pass through the intersection. In the yellow light countdown, it can help the vehicle with sufficient information to determine whether to speed through the intersection, or wait for the next green light, which can assist in reducing impetuous rush causing vehicular accidents. In the red light countdown, it can help the driver to turn off the car engine following the current policy. If there is more than a 60 second delay at a red light, the driver can turn off the engine, and then restart the car 3-5 seconds before the green light activates. This can not only reduce carbon dioxide emissions and reduce fuel consumption, but can mitigate the dilemma that every time the red light stops command signals, vehicle emissions are reduced as well.

According to statistics, there is 8% of people color-blind in the world. Some color blindness conditions mean that those affected are not completely unable to see colors, such as deuteranopia and tritanopia, but they would be unable to distinguish between similar colors. Regardless, they still comply with the traffic rules as pedestrians according to the signal commands to cross the crosswalk or stop. Thus, it makes the color-blind feel confused, if they just refer to color display traffic signs [5]. If graphics were used for display, it would help color-blind people understand the situation of the road.

Nowadays, many traffic light signals appear at the same time, where there might be 3-5 signals, and especially at large intersections, many signals display at the same time. Some situations occur where the driver can even turn left or right at a red light. Such a complex situation can confuse drivers; therefore, the more simple the traffic signal is, the clearer the driver is, the faster the judgment is, reducing the chance of misjudgment, thereby reducing vehicular accidents [6].

In view of the complex situation of traffic lights, this paper uses a full-color LED array to develop a set of traffic lights. It uses just two screens to replace the current complex traffic light system, integrates disordered traffic lights, and allows the drivers of vehicles to understand the traffic situation better, ensuring safety.

2. **Signs Design.** The design sign system of the paper is composed of two modules: the host and slave modules. Each module has two screens: one displays a pattern sign; the other displays a countdown. The host module can also deliver a message to the slave module. When the slave module receives signals from the host, it will display a corresponding sign.

Since the traffic lights do not exit alone, they need to be coordinated with the intersection sign. Thus, the paper achieves a set of traffic lights as a target, with east-west as direction host, and south-north direction as slave, as shown in Figure 1. The host additionally displays road signal and conveys a synchronization command. The slave receives these commands from the host and displays the signs as it should be. Two modules can thereby achieve coordination. In this paper, two screens replace the complex traffic lights as shown in Figure 2.

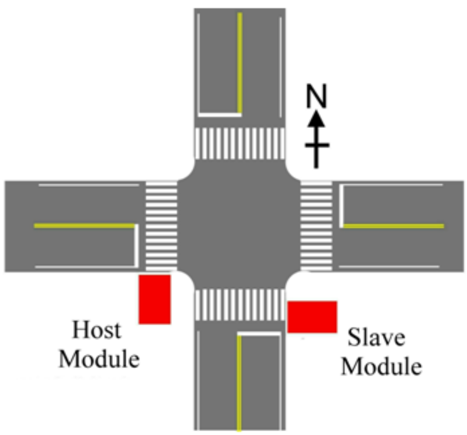
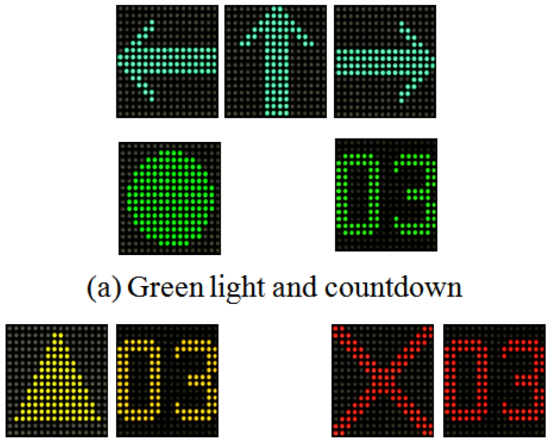



FIGURE 1. Traffic light location




(a) Green light and countdown

(b) Yellow light and countdown

(c) Red light and countdown

Figure 2. Sign design

2.1. **Pattern signs.** The first sign is pattern sign. It has the following characteristics [7].

(a) Use full-color LED to transform green, yellow, and red lights.
(b) Colorblindness population accounts for 8% in Taiwan. Considering their difficulty in identifying color, this paper sets ◯, △, × respectively to stand for green, yellow, and red lights. These patterns can help them identify the traffic light changes.
(c) Among green lights, the pattern ◯ stands for all pass, patterns ←, ↑, and → stand for only being allowed to turn left, straight, and turn right. It can be displayed on the same screen.

2.2. **Countdown.** The second screen is countdown, with the countdown at red, yellow, and green. It has the following characteristics [8].

(a) In the green light countdown, this lets distant vehicle driver determine if there is sufficient time to get through the intersection, or to gradually slow down to reduce energy waste.
(b) In the yellow light countdown, this lets the vehicle driver determine whether the intersection can be passed through, or whether to stop and wait for the next green light. This helps reduce accidents where drivers speed through the yellow light.
(c) In the red light countdown, this can let drivers know how much time remains for waiting, and help reduce the anxiety of waiting.

3. **Hardware Structure.** The structure in this paper is shown in Figure 3. This system includes a host and a slave modules. The host module and slave module consist of control circuits, RGB control panels, full-color LED arrays, and wireless communication circuits. Two modules are linked by wireless communication circuits. In the host module, the control circuit transfers the pattern number to the slave module via the wireless communications circuit, so that the pattern of the host module and slave module displays achieve coordination. The control circuit delivers data via $I^2C$ to the RGB control panel to display the patterns and the number demanded by the control circuit [9,10].

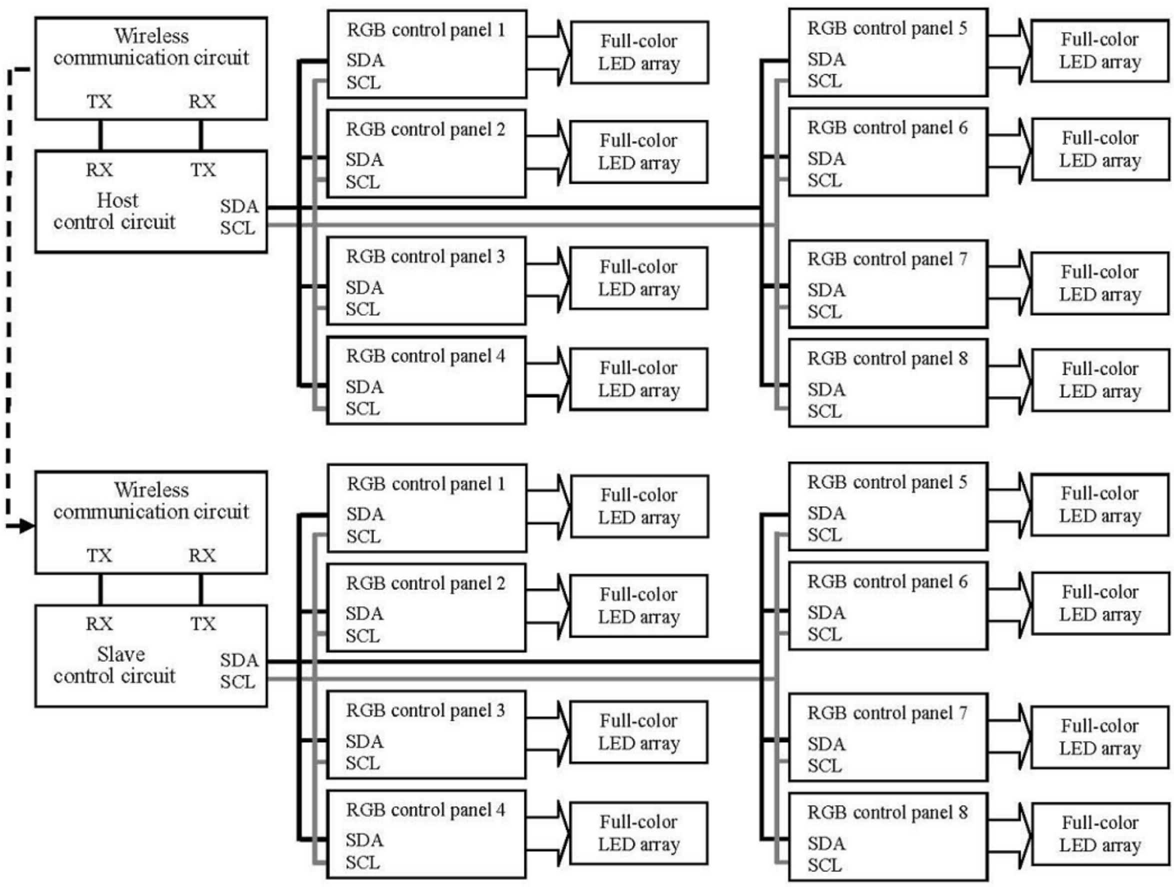



Figure 3. Hardware structure

## 4. Software Structure.

### 4.1. Pattern design.
In graphic display, the host and slave control circuits display the format signals (pattern, color) to eight RGB control panels via $I^2C$ port. Control signals are received by the specified RGB and perform patterns and colors displayed. The paper has illustrated a total of 26 pictures; each picture contains a number and a pattern, in which 26 pictures contain 13 red images, 8 green images, and 5 yellow images. The program compiles a set of 26 images, and sequentially displays patterns in every one second. It could accomplish a complete cycle in 26 seconds, as follows:

The host module and slave module contain two screens. One displays pattern of ◯, △ and ×, on behalf of the green, red and yellow lights. And the other screen displays countdown. When the east-west signal lights are green and yellow, the north-south lights must be red. When the north-south lights go to green and yellow, the red lights are shown in the east-west direction. These two modules are equipped with UART, so that the wireless communication can be achieved between modules. The host module sends signals to the slave modules via wireless communication, so that the slave module can display the corresponding signs. When the host module starts running, this module not only shows the pattern and countdown, but also passes the signal to the slave module. When the slave module receives the signal, this module shows the corresponding pattern and countdown.

### 4.2. Color control.
Traffic lights signal lights with red, green and yellow. Full-color LED consists of red, green, and blue colors. The red and green colors are the primary colors of the full-color LED. However, the yellow is not the primary color, and it need be mixed by primary colors. The yellow is mixed by the red and green. The proportion

of red and green can be adjusted by pulse width modulation (PWM). PWM can decide the light emission duty cycle. When the duty cycle is longer, more LED can be made to emit light, which looks brighter. Whereas when the low duty cycle, the less time LED can light emitting, which looks darker. Using this method, a variety of colors can be mixed by these three primary colors. When the pulse inputs to full-color LED, the flashing should happen in vision. For the human eye's persistence of vision, it looks no flicker will lead the way.

4.3. **Host module control flow chart.** The control flow of host module control circuit is as follows.

Step 1. Set the pattern number $i = 1$.
Step 2. The pattern number $i$ is transmitted out by the wireless communication circuit.
Step 3. The display formats of pattern $i$ are transferred to the eight RGB control boards by $I^2C$.
Step 4. Set the next pattern number ($i = i+1$); if $i$ exceeds the maximum, then $i$ is reset ($i = 1$).
Step 5. Delay.
Step 6. Return to Step 2.

4.4. **Slave module control flow chart.** The control flow of the slave control circuit is as follows.

Step 1. The control circuit receives the signal pattern number $i$ for a period of time.
Step 2. If the slave does not receive a pattern number $i$, the control circuit of the slave displays standby graphics. The display formats are transferred to the eight RGB control boards by $I^2C$. And back to Step 1.
Step 3. If slave receives pattern number $i$, then the display formats of pattern $i$ are transferred to the eight RGB control boards by $I^2C$.

5. **Result and Discussion.** Figure 4 shows the actual operation of the lights system. The light of host module is started with green. The colors of the light will switch according to the time setting. Corresponding to the host module, the slave module shows a red light and the countdown. When the countdown is finished, the red will switch to the green.

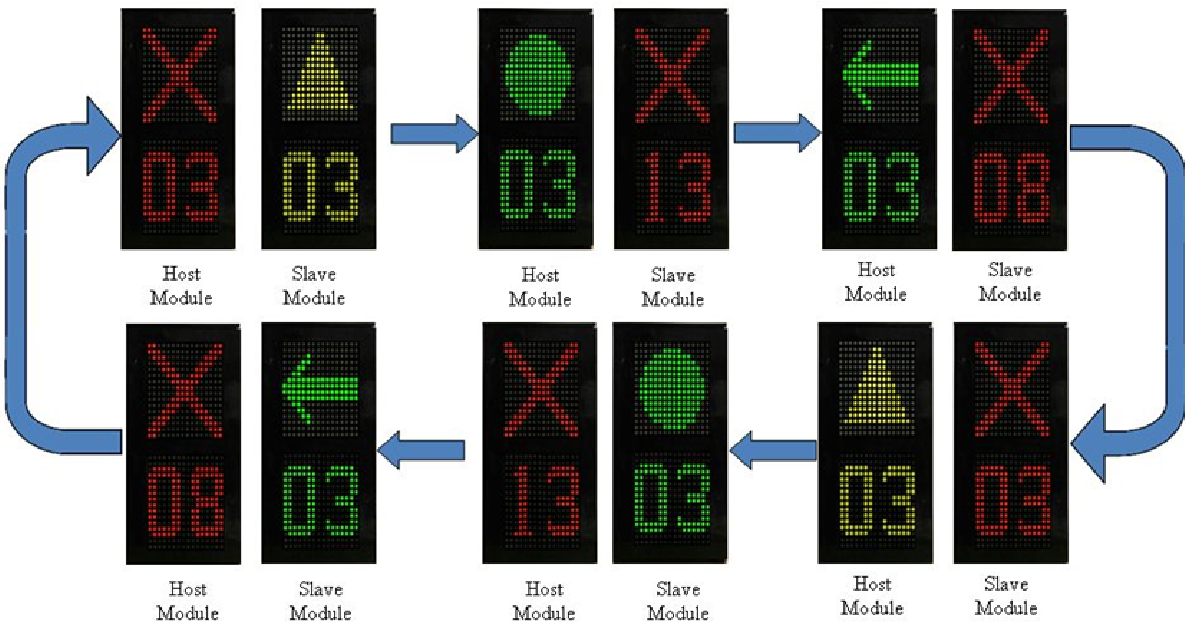



FIGURE 4. Traffic lights operating situation

Based on the design, when the light turns green into yellow, the yellow light maintains several setting seconds. The host module will switch to red light and its countdown when the yellow-light countdown is finished, the signal will be received from the host module; the time will go 0; lights turn green, followed by re-timing. The seconds of the countdown can be adjusted by the control circuit. In green pattern section, the user can insert a left-turn arrow pattern, a right-turn arrow pattern or a straight arrow pattern according to requirement. With coordination from the host module and slave module, this system accomplishes demands of the signal lights on the intersection.

In field test, the transmission distance of wireless is up to 100 M, which is competent for general intersections. The data transmission between the host and slave modules is one document per second via the UART port, which is without causing delays and errors. For the $I^2C$ port application, the circuit can significantly reduce the complexity of wiring. $I^2C$ port can connect with 112 nodes in one bus, which is ideal for use in the system. Standard mode of $I^2C$ can reach 100 Kbit/sec, and makes the display of the results will not have any delay. The screen of this system is $16 * 16$ points, which can display character for special occasions. The system shows 26 pictures of the cycle for example, and the future can be changed according to the application of different patterns.

6. **Conclusion.** In this paper, full-color LED has achieved a fully functional traffic light system. The architecture includes a host module and a slave module. Each module contains two screens: one for pattern and the other for countdown. This system owns advantage of mobility in application, which fills the bill of many environmental cases. Thus, this traffic light system offers great advantage both intersection traffic and mobile traffic control systems.

The design of full-color LED array in this system is agreed with characters display. Therefore, it very much suits to develop the application for special events, especially during working hours of a major factory, sports, exhibitions, or emergency exit indication. This system has advantages in these part-time operations.

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