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Design and Implementation of Synchronously Emergency Lights

[1] Misheck Bweupe, [2] Godfrey Benjamin Zulu
[1] Department of Electrical Electronics, Information and Communications University, Lusaka, Zambia
[2] Department of Information and Technology, Information and Communications University, Lusaka, Zambia

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Corresponding Author: **Misheck Bweupe**

Abstract
This research investigates the development and deployment of synchronously blinking emergency lights, which deliver a distinct and uniform visual warning in high -pressure situations. By synchronizing the blinking pattern, these lights effectively grab attention, mitigate accident risks, and enhance safety. Improved visibility and awareness facilitate quicker response times, reduced downtime, and ultimately, minimized economic losses.
The implementation of synchronously blinking emergency lights can significantly impact safety and efficiency in various settings, including emergency response situations, industrial environments, and public spaces. These lights reduce confusion and panic, facilitating more effective response and decision making. The standardized and easily recognizable visual signal provided by synchronously blinking emergency lights enables seamless communication and coordination in emergency situations.
This study highlights the importance of designing and implementing reliable and efficient lighting systems that prioritize safety and efficiency. By adopting synchronously blinking emergency lights using a programmable logic controller (PLC), LED lights, and relay modules, individuals and organizations can enhance their emergency response capabilities, reducing risks and improving outcomes. The findings of this research have implications for the development of more effective emergency lighting systems, which can ultimately save lives and reduce economic losses. Overall, synchronously blinking emergency lights are a crucial component of emergency response systems, providing a dependable and efficient way to alert individuals of potential hazards and critical situations.

Keywords: Synchronous, Emergency, LED Lights, PLC, Relay Modules

1. Introduction
Research into synchronously blinking emergency lights using a programmable logic controller (PLC) focuses on enhancing safety and communication beyond simple, random flashing [5]. The primary motivations are to eliminate the disorienting stroboscopic effect of unsynchronized lights, which can trigger seizures, and create more effective, attention-grabbing visual signals [8].
The core research involves **Human Factors**- determining optimal flash patterns and sequences that best capture human attention and convey specific warnings [17, 23].
Technically, the study centers on using a PLC as a robust, industrial – grade brain to generate precise timing signals. The PLC executes a programmed logic sequence, sending commands to actuators like the solid-state relays, ensuring all lights operate in perfect unison [43].
The key findings confirm that a PLC- based synchronized system offers:

- Improved awareness through directional patterns, reduced neurological risks, high reliability and flexibility to easily reprogram patterns for different emergencies [10].

This approach transforms basic warning lights into intelligent, coordinated safety system.

2. Background of Study
The study of synchronously blinking emergency lights involves designing and developing lighting systems that provide reliable and efficient illumination during emergency situations. This field of study focuses on creating systems that can automatically activate during power outages or other emergencies, ensuring safety and visibility [1, 7, 8].

3. Motivation of Study
The motivation behind lies on their potential to significantly enhance safety, response times and overall emergency management. Improved safety outcomes can reduce the risks of accidents and fatalities when the emergency blinking sends the signal to the public in order to alert them [17]. Enhanced Emergency Response times by these lights provides a quick response by the public there by reducing Economic losses and downtime [15, 17, 21]. Studying the synchronously emergency blinking lights drives innovation in lighting technology [19].
The use of synchronized LED lights decrease confusion and panic, enabling more effective response and decision-making [17, 20].
Understudying the benefits of these lights helps organizations meet safety regulations and standards [17, 22].

4. Significance of study
The study of synchronously blinking emergency lights is crucial for ensuring safety and visibility during emergency situations, providing reliable illumination, reducing the risk of accidents and injuries, and enhancing safety in buildings, public spaces, and other areas. By understanding the design, development, and application of these lights, researchers and practitioners can create optimized systems that meet safety regulations and standards, such as those set by the National Fire Protection Association (NFPA) or the International Building Code (IBC). This study can lead to innovative solutions, such as energy-efficient lighting systems or smart emergency lighting systems that can adapt to different situations, and can be integrated with other safety systems, like fire alarms or security systems, to enhance overall safety and response. The practical applications of synchronously blinking emergency lights include emergency response situations, public safety, and building safety, where they can provide critical illumination during power outages or other emergencies, reducing the risk of accidents and injuries. Ultimately, the study of synchronously blinking emergency lights is essential for ensuring safety, compliance, and effective emergency response, and can lead to the development of safer and more reliable emergency lighting systems [12, 13].

5. Scope of Study
The scope of study of synchronously blinking emergency lights includes design, development, safety, energy efficiency, integration with other systems, human factors, testing, and applications. Research aims to improve safety, efficiency, and compliance, leading to innovative solutions like smart lighting systems. It explores various settings, including buildings, public spaces, and industrial facilities [23].

6. Problem statement
The problem statement for synchronously blinking emergency lights is to design and develop a reliable, efficient, and safe lighting system that provides clear visibility and guidance to individuals during emergency situations, such as power outages, fires, or natural disasters, while minimizing energy consumption and ensuring compliance with relevant safety regulations and standards. This system should be capable of synchronizing multiple lights to create a cohesive visual signal, effectively guiding people to safety and reducing the risk of injuries and fatalities, while also being adaptable to various environments and applications, including buildings, public spaces, and industrial facilities [10].

7. Objectives
- **General Objectives**

The goal is to create an intelligent, safer evacuation system using a programmable controller that uses the synchronized patterns to effectively guide occupants to safety while also simplifying maintenance and testing.
- **Specific Objectives**
  1. To maximize visibility and alertness
  2. To create a clear and unambiguous signal
  3. To provide the capability for advanced programmable flash patterns.

8. Research Questions
1. How does synchronization affect visibility range in different conditions?
2. How does the implementation of standardized, synchronized light patterns affect the rate of ''moth to flame'' incidents or erratic driver behavior in the vicinity of emergency scenes?
3. What is the effect of implementing different scenario – specific PLC programmable light patterns?

9. Literature Review
1. Overview
Literature review shows that traditional emergency light systems use incandescent bulbs or fluorescent lights, which have limitations such as energy inefficient and short life span [29]. These systems also lack the capability to provide synchronized blinking, which is essential for effective emergency response. PLC based system offer improved reliability, flexibility, and stability compared to traditional system [32].
Light Emitting diodes (LEDs) have become increasingly popular in emergency light due to their energy efficiency, long life span and compact size [31]. LEDs can be easily controlled using PLCs or microcontrollers, making them an ideal choice for synchronously blinking emergency lights. Synchronously blinking of emergency light systems have been achieved using various control algorithms, including ladder logic programming and function block programming [34].
These algorithms ensure that the lights blink in unison, providing a clear and consistent visual alert. The reliability and maintenance of emergency lighting system have been improved using PLCs and LEDs, reducing downtime and maintenance costs [35]. The systems are essential for ensuring the safety and efficiency of emergency response.

10. Limitations of Synchronously Blinking Emergency Lights
Studies investigating synchronously blinking emergency lights face several key limitations that affect the applicability of their findings. These constraints, identified in academic literature, primarily arise from methodological compromise between scientific control and real- world complexity.
- **Ecological Validity**: many studies rely on driving simulators or controlled test tracks, which may not accurately replicate the stress and risk perception of actual emergency situations. This can alter participant's

behavior and responses making it challenging to generalize findings to real world scenarios [11].

- **Limited to participants**: Research often underrepresents vulnerable demographics, such as older drivers, who may have slower visual processing speeds and increased glare sensitivity. This can affect the effectiveness of synchronous emergency lights in real-world situations [11].
- **Subjectivity**: metrics like perceived glare or annoyance can be difficult to quantify consistently across potential measurements bias.
- **Long-term Effects:** Short - term studies may not capture potential habituation or reduced effectiveness overtime, which is a significant concern for real world implementation.
- **Ethical Constraints**: conducting true field experiments with unsuspecting drivers in genuine emergencies is impossible, meaning studies can only provide approximations of how these lighting systems would perform in actual crisis situations [11].

However, further research is needed to address these limitations and improve the effectiveness of synchronous emergency lights

11. Design and simulation of synchronously Blinking Emergency Lights

1. Project Design and approach

(i) Real Image of the Actual Prototype in OFF Position

Fig 1: When the blinking LED Light is in off position when the optical sensor detects no Danger

Figure 1: Shows a blinking light in off state. However, the bulb will only come on automatically and blink if there is an obstruction in between the optical sensor and the reflector. The sensor can capture anything (e.g. floods, fires etc.) within the radius of 15mtrs and alert the public through the emergency blinking lights.

(ii) Real Image of the Actual prototype in ON Position

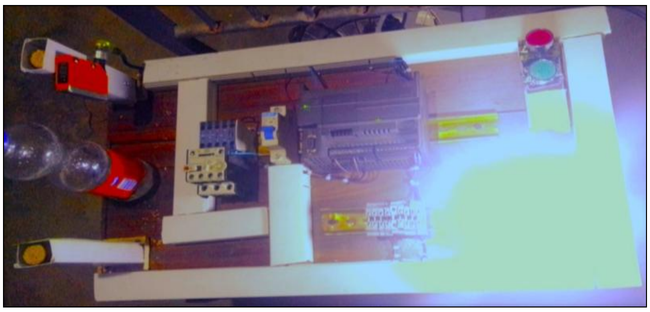

Fig 2: The blinking LED light is in ON position when the sensor captures an object

The optical sensors sends a signal to the PLC once an object be it metallic or non-metallic is detected to complete the circuit as it blocks a path of sensor laser light and sends the signal to the Programmable logic controller, which in turn commands the light to blink as shown in figure 2 above. Hence, alerting the public.

2. System Software Level Architectural Design

Figures 3, 4, 5, and 6 show how the lights blink when the internal delay on timers are ON and OFF. The software used is a Micro Win Programming Siemens S7 200 Simatic software. The Ladder Logic control is the method used to design this system.

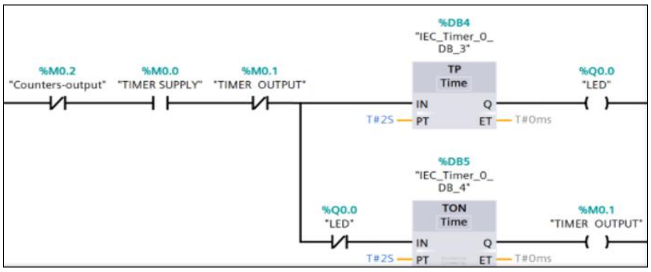

Fig 3: Shows the two internal timers in off position with normally closed and open contacts as interlock

Figure 4, shows the start button (I0.0), the normally closed contacts (NC) for both Q0.0 and M0.0 and the output Q0.0 in ON position.

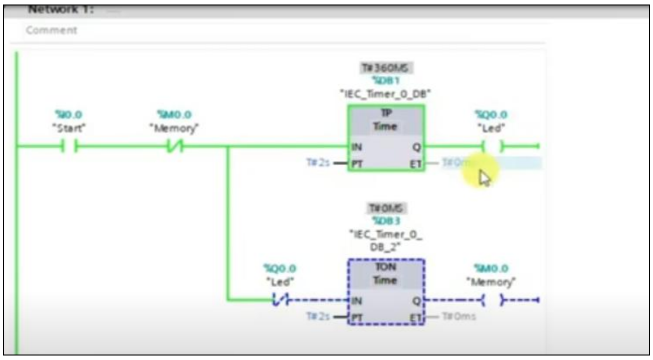

Fig 4: Blinking LED light ON

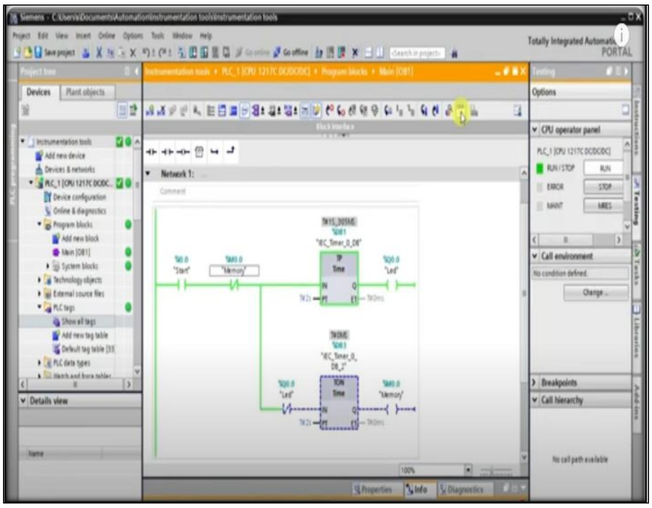

Fig 6: Shows TON Timer 1 with a pre-set value of 2s in ON position to control the output Q 0.0 (Light) and TON Timer 2 connected in parallel with TON Timer 1, in off position

12. Discussion of Results

Experiment 1

1. The preset value of 2s of the internal timer was used as an initial set point to determine how intelligent the system was in responding to emergency situation in the first experiment when an object was detected by the sensor.

The stopwatch timer also was used to record the actual time it was taking for the blinking LED light to respond when an object is detected.

Increased blinking LED rate was observed when the programmed timer value was reduced.

2. Scan Time Calculations

Scan time is calculated as follows:

Absolute error = stop watch timer actual value – programmed timer preset value.

Therefore, absolute error= 2.03s -2.00s= 0.03s

Percentage error = (actual value- preset value/ actual value) x 100%

= 2.03-2=0.03/2.03=0.01477x100=1.47%

However, experiment 1 showed that the percentage error was minimal hence; the system was intelligent enough to respond to any emergency.

Experiment 2

In experiment 2, the preset value of the internal timer was reduced from 2s to 500ms to test how the system could respond in case an emergency to avoid panic and confusion. The stopwatch was used to record the scan time or the absolute error. The results are as follows:

Absolute error = stop watch timer actual value – programmed timer preset value.

Therefore, absolute error= 501ms -500ms= 0.1ms

Percentage error= (actual value- preset value/ actual value) x 100%

= 501ms-500ms=1ms/501ms=x100=0.0199%.

However, the system responded much faster than in experiment 1 and the time it took for the blinking light to respond when an optical sensor detected an object was very, minimal than in experiment.

Experiment 3

In this experiment, the preset value was reduced further from 500ms to 200ms. Here, the blinking rate gradually increased more than in experiment 1 and in experiment 2 when an object was detected by the sensor as shown below.

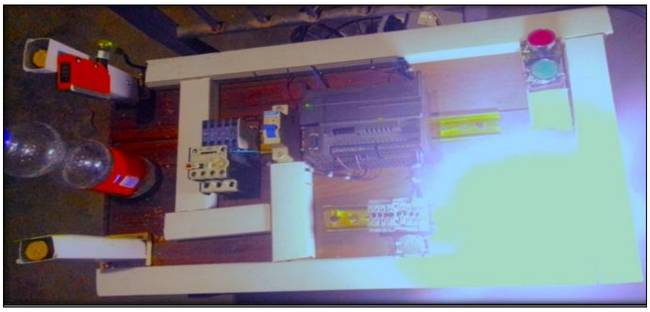

Fig 6: The blinking LED light is ON when an object is detected by the sensor

Calculations of the scan time and the percentage error in experiment 3

Absolute error= stop watch timer actual value – programmed timer preset value.

Therefore, absolute error= 200.5ms -200ms= 0.5ms

Percentage error = (actual value- preset value/ actual value) x 100%

= 200.5ms-200ms=0.5ms/200.5ms=x100=0.005% In experiment 3, the light responded faster with high blinking rate signaling how effective the system is.

Comparison between preset value and the actual value

The table below shows the comparison between the preset value and the stopwatch value when an object was detected by the sensor.

Table 1: Comparison of results between the preset value and the stopwatch value

Prog Timer (seconds/mille seconds)	Stop Watch Timer (S/ms)	Absolute Error	Percentage Error (%)	Blinking Rate
2 s	2.03s	0.03s	1.47	Low
500ms	501ms	0.01ms	0.19	Slightly High
200ms	200.5ms	0.5ms	0.005	High

The results above showed the following:

1. High Accuracy: System readings showed a maximum error of 0.03s compared to manual measurements.
2. The optical sensor successfully sent signal to the PLC for all critical events (LAMP ON, LAMP OFF) with a typical network delay of 0.5ms -0.03 seconds.
3. Reliable Control: LED light switched ON/OFF consistently at the defined set points.
4. The system met all design objectives, proving to be accurate, reliable, and effective.
5. The project was successfully designed, developed, and implemented a fully functional synchronized emergency.

13. Conclusion

Number XI. has outlined the different methods of connecting synchronously emergency lights using the internal timers. It has also detailed the solutions to all the control problems and explained the learning objectives, concepts and knowledge required to solve the control problems designed.

14. General Conclusion

This paper has successfully presented a series of experiments of how synchronously blinking emergency lights operates using the programmable logic controller. This paper highlights the importance of using the PLC to control the emergency lights as the best method.

On number XI, we have designed and demonstrated how the programmable logic controller (PLC) works, for it to control the blinking light using the internal timers, the push buttons, and optical sensor. The sensor automatically, captures and detects the fault within the range of 0-15mtrs by reflecting back a beam of lights to the object and hence allowing the 24V to be sent to the blinking lights. The algorithm used is the Ladder logic algorithm to control the blinking light.

We hope this information would be helpful to the public in order to stay alert whenever there is an interruption e.g. floods, fires and earthquake.

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