PSK Method for Controlling LED Pool Lighting Systems: An Innovative Path to Enhance User Experience

Karthik Hosavaranchi Puttaraju

khosavaranchi@gmail.com

Abstract

The pool lighting industry commonly employs a method of cycling power (turning lights off and on) to change lighting sequences or colors, which negatively impacts the customer experience. This paper proposes the implementation of Phase-Shift Keying (PSK) as a solution for more seamless control. PSK enables communication between the controller and the LED lights without requiring power cycling, maintaining a continuous power supply. This can improve the user experience while preserving the two-wire system with Class 2 isolation, ensuring both electrical safety and reliable performance.

Keywords: Pool lighting, LED lighting, Pool management, LED Controller, Pool customer, phase shift keying, power line communication.

INTRODUCTION

Swimming pools have been a symbol of luxury and served as a focal point for relaxation and social gatherings in residential and commercial environments. As the modern business world evolves and technology evolves, so do the customer expectations for more sophisticated and efficient pool management systems. Pool lighting is a key to enhancing the aesthetic appeal and enhancing the customer experience. Traditionally, pool lighting systems are simple and controlled by basic ON/OFF mechanisms. This mechanism not only causes discomfort in the customer experience but also limits the utilization of the system as a whole, limiting it from creating ultimate customer delight. This is mainly because the pool lighting system sits away from the home environment, making it a separate stand-alone system. With advancements in LED lighting adaptations, modern pool lighting systems rely heavily on LED technology for energy efficiency and vibrant color effects. This opens up the opportunity to implement more advanced control systems that can fully leverage the capabilities that LED can offer.

This paper proposes applying techniques used in other fields, such as communications and automotive, to advance the LED pool lighting industry. Phase Shift Keying (PSK), a digital modulation technique used in communications to encode digital data, has great potential to provide solutions to the pool lighting industry's challenges. This system would also help with precision color management, energy efficiency, and single-power installation.

This paper aims to provide an overview of the pool lighting system's current state and limitations while explaining the PSK concept and how it can help capture the opportunity. It also highlights the potential benefits and challenges of implementing such systems in the aquatic environment. This paper aims to contribute to the knowledge of smart lighting systems by investing the PSK application in LED pool lighting systems and demonstrating how to enhance efficiency and user experience.

LITERATURE REVIEW

A. Current Pool Lighting Control Systems

Pool lighting systems have significantly evolved over the past decade, transitioning from incandescent bulbs to energy-efficient LED systems. However, the control mechanism has not caught up with the advancement of light technology. Many pool lights work on the 2-wire concept, where the two wires are used to power the LED light and control the light mode. The other method is 4-wire; two wires are used to power LED lights, while the other two are used to control the light modes. In the four-wire systems, the 2-wire used to power LED lights carry AC power, while the other two wires used to control the light modes carry DC voltage. The challenge is to carry DC voltage for long range. In Figure 1, the Switch after GFCI acts as a pool light controller.

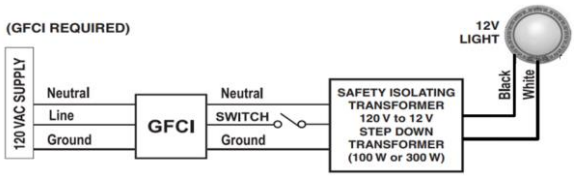

Figure 1: Typical Wiring of Pool light system

Additionally, the current systems use a class 2 isolated 12V transformer as a means of isolation; this adds additional points of failure and cost for both development and maintenance. Even with the 2-wire isolated systems, the control of LED is done with On/OFF switching. Figure 2 shows the selection of the third color in the sequence.

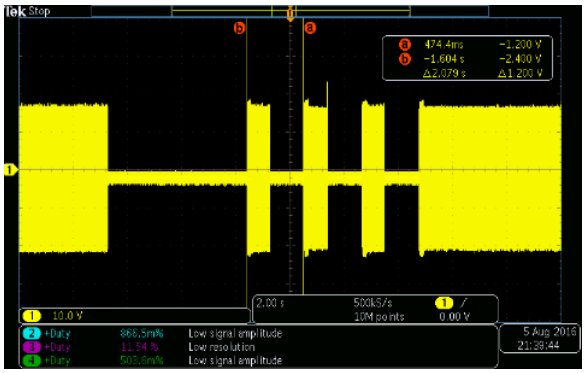

Figure 2: Shows the signal to select the third color

B. LED Technology in Pool Lighting

The adoption of LED in pool lighting systems has not only enhanced customer experience but also opened up opportunities for manufacturers to utilize the knowledge available in the indoor lighting environment and apply it to the outdoor environment. This potentially solved the challenges that the outdoor lighting industry faces and helped increase their profit while making the pool lighting affordability lower for the customers, thereby increasing the industry market size.

LED technology meets many of the requirements needed in the pool environment. From energy efficiency to Instant on/off, from longevity to color versatility, LED technology has proven its potential. It also brings in protocols such as Dali, DMX, z-wave, etc., which are used in other industries that can be leveraged.

C. Phase Shift Keying in Communications

Phase shift Keying (PSK) is a digital modulation technique used in telecommunication. PSK is an encoding technique used to encode data by varying the phase of a reference Sine wave signal. Numerous combinations of the PSK can be achieved based on the precision of the detecting circuit design. However, the most cost-effective solution is binary phase shift keying (BPSK), which uses two phases of a sine wave separated by 180deg. Figure 3 shows a typical BPSK operation. Other methods include quadrature phase shift keying (QPSK), which uses four phases separated by 90deg. PSK has the potential to reach higher levels and the

ability to combine with other forms of shift keying like ASK and FSK. PSK forms a better option as it can offer high noise immunity and efficiency.

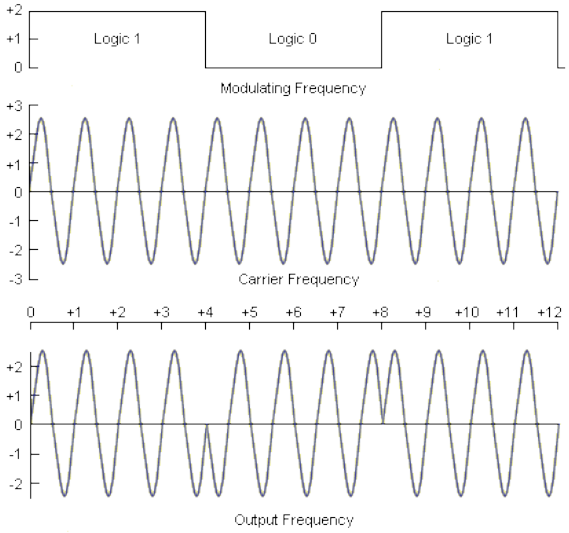

Figure 3: Binary Phase shift keying waveform (output)

CONCEPT

A. PSK-based pool light control

The proposed PSK-based LED light control is based on the principle of digital modulation to create a more efficient system to control the lights in a 2-wire system. The system uses phase shift keying to encode the control signals that determine and inform the LED lights with information including color selection, intensity, and dynamics.

B. System Architecture

The system architecture consists of the low pass filter, Rectifier, sinewave generator, LED light with phase sensor, pool light controller, and intelligence system with microcontroller. Most of these components exist in the current system, and the only addition is a sine wave generator.

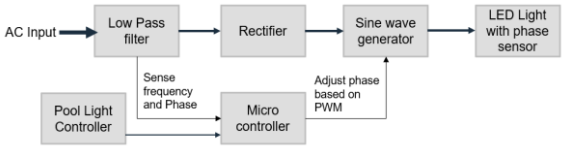

Figure 4: PSK based on Pool controller and LED'

A low-pass filter is used to sense the input voltage and understand the input voltage and current conditions. The input AC voltage is converted to the DC voltage with the help of a rectifier and a capacitor. A sine wave generator, typically a full bridge converter or a resonant converter, can generate the sine wave to power the LED driver. A microcontroller at the controller sets the input to the Full bridge converter by varying the PWM to the MOSFETs to generate the waveform as per Phase shift keying as per the preprogram. A phase detector circuit is embedded into the LED driver in lights to detect the input phase signal, and a microcontroller helps to decode and extract the information to take action.

Communication can be made more efficient by using a higher modulation level and Phase shift keying to establish numerous combinations of colors rather than the current set of color sequences. The system can also combine the concept of Amplitude shift keying and Phase shift keying to achieve a higher level of combination, but for a pool application, it would be an overdesign.

This system design allows easy retrofitting of the existing lights without the need for extensive rewiring. Additionally, it helps to have dimming capabilities in 2-wire systems, which was initially only possible in 4-wire systems. The proposed control system offers precision, efficiency, flexibility, and robustness compared to the old system.

C. Challenges and considerations

The main challenges in designing the PSK-based pool lighting system are:

Complexity: The proposed PSK system is more complex than the traditional system. Even though it does not affect the cost of the system, skilled design experience is required to design the system. The control loop in the backend of the system senses and sets the PWM to the half-bridge, which plays a vital role and needs to be calibrated properly.

Electromagnetic Compatibility: Care must be taken to ensure there is no interference with other electronic devices or disturbed by other electronic systems. The use of a half-bridge converter contributes to radiation and conducted noise. Appropriate filters need to be designed and implemented.

Standardization: Since the pool industry doesn't have a standardized approach in terms of system design, each company in the industry designs and develops its own system. When PSK is implemented in the system, it could tend to get complex for pool owners, constructs, builders, and distributors to understand the functionality. It is necessary to address this challenge industry rather than a single company.

CONCLUSION

Even with the advancement of LED technology in the Pool lights, the controllers lack the ability to change colors without turning off the LED light in a 2-wire system. This issue gave rise to a 4-wire system; however, this system was inefficient and costly due to its 4-wire and DC-based operations. The proposed concept of using PSK-phase shift keying offers solutions to these challenges while increasing efficiency, reducing maintenance, and increasing future possibilities. The PSK modulation could allow the LED controller to communicate; additionally, it enhances the customer experience, which is a key attribute in the luxury Pool industry.

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