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IC Design For Street Light Automation

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Abstract

In the pursuit of sustainable urban development and energy-efficient infrastructure, this project introduces a novel System-on-Chip (SoC) design for intelligent streetlight automation, integrating adaptive sensing, real-time decision-making, and energy-optimized actuation into a single IC. The architecture leverages a high-sensitivity photodiode array with embedded analog front-end (AFE) signal conditioning, enabling precise ambient light detection while compensating for environmental fluctuations such as weather and artificial light interference.A self-calibratingthresholdcomparator dynamically adjusts the activation threshold based on historical data trends, ensuring optimal performance across varying seasons and geographic locations. The control logic employs an ultra-low-power finite state machine (FSM) with adaptive dimming algorithms, allowing seamless transitions between illumination levels while minimizing flicker and abrupt brightness changes.To enhance energy efficiency, the design incorporates a hybrid PWM-CC (Pulse Width Modulation with Constant Current) LED driver, reducing switching losses and extending LED lifespan. Advanced EMI hardening techniques, including on-chip decoupling and spread-spectrum clocking, ensure robust operation in electrically noisy urban environments. Furthermore, the IC supports network-ready configurations for future smart city integration, enabling remote diagnostics and grid synchronization via a low-power wireless interface.By unifying precision sensing, intelligent control, and power-efficient driving in a single compact IC, this solution offers a scalable, maintenance-friendly, and eco-conscious approach to modern streetlight automation, paving the way for smarter, greener cities.

I.INTRODUCTION

To transform urban life through smarter, more responsive street lighting, our project pioneers an innovative approach that puts energy efficiency and reliability at its core. Instead of relying on outdated, manually controlled systems that often waste power and perform inconsistently, we've developed a specialized integrated circuit that brings together everything street lighting needs into one compact, efficient chip.At the heart of this design is a sensor interface that listens to the ambient world around it whether through a light-dependent resistor (LDR) or another type of photodetector. This sensor's analog signals are carefully processed and compared against set light thresholds using precision comparators built directly into the chip. The internal logic then smartly decides when to turn the lights on or off, ensuring that bright daylight doesn't waste energy and that dark nights bring safe illumination.In reimagining street lighting this way, we're not just reducing energy consumption; we're also cutting down on system complexity and improving overall reliability. By seamlessly integrating key functions like light sensing, signal conditioning, and output driving into a single chip, our design minimizes inefficiencies and parasitic losses that plague traditional systems, paving the way for a more sustainable and secure urban environment.

II.LITERATURE REVIEW

[1]. Mehra, D. A., Bhanderi, R. B., Hegade, A., & Choubey, C. K. (2024, August). Efficient Illumination: Arduino-Based Street Light Automation for Energy Savings. In *2024 International Conference on Emerging Techniques in Computational Intelligence (ICETCI)* (pp. 397-401). IEEE.

This research introduces an innovative Arduino-based solution to address energy wastage in street lighting, which activates lights autonomously in the presence of vehicles or pedestrians. The system, leveraging PIR sensors for vehicle detection and LDRs for day-night differentiation, dynamically adjusts LED brightness, ensuring optimal energy utilization. This dual-sensor approach extends the lifespan of street lamps and contributes to a more environmentally friendly urban landscape. The primary objective is to trigger and promote selective street lights, thereby promoting significant energy savings and cost reductions and a sustainable lighting infrastructure tailored to diverse community needs. This research addresses the imperative of resource conservation amid unprecedented population growth and escalating energy demand, offering a pioneering solution for metropolitan areas.

[2]. Mohanty, P., Pati, U. C., Mahapatra, K., & Mohanty, S. P. (2024). bSlight 2.0: Battery-free Sustainable Smart Street Light Management System. *IEEE Transactions on Sustainable Computing*.

Street lighting is one of the prominent applications that demand a massive amount of power and substantially contributes to the energy budget of a country. Light Emitting Diode (LED) and the advancement of Internet of Things (IoT) have significantly improved conventional street light technology. Nevertheless, the rapid growth of IoT devices has presented a formidable challenge in powering the vast array of IoT devices. In this manuscript, a sustainable, battery-free, low-power street light management system has been proposed which is powered from hybrid solar and solar thermal energy harvesting scheme integrated with an efficient power management unit. As a specific case study, the prototype has been implemented with an existing LED street light in India. The characteristics and performance of the prototype have been evaluated to ensure its seamless operation under real-world scenarios. The average power consumption of the system is measured as 2.088 mW when operating in real-time with 50% duty cycle, exhibiting high Quality of Service (QoS).

[3]. Mondal, s., deyashi, d., mukherjee, d., &sarker, k. (2024). Advancing sustainability and comfort through smart sensors and iot: a comprehensive analysis of automatic light control systems in residential and commercial environments. *i-manager's Journal on Electrical Engineering*, *17*(3).

Automatic light control systems have garnered significant attention for their potential to enhance energy efficiency and user convenience across various settings. This paper provides a comprehensive overview of these systems, elucidating their principles, components, applications, and associated benefits. The primary objective of automatic light control systems is to intelligently regulate lighting levels based on environmental factors such as occupancy, ambient light, and time of day. Various sensors, including Passive Infrared (PIR), ultrasonic, and photoresistors, are commonly employed to detect changes in the surroundings and trigger appropriate lighting adjustments. Advanced control algorithms and communication protocols facilitate seamless integration with building automation systems, enabling centralized management and optimization of lighting across diverse zones. Moreover, the advent of smart lighting solutions leveraging Internet of Things (IoT) platforms enables remote monitoring and control, empowering users to personalize lighting preferences and further optimize energy consumption. The paper critically reviews the key features, benefits, and challenges associated with automatic light control systems, underscoring their pivotal role in promoting sustainability, comfort, and cost-effectiveness in both residential and commercial environments. Additionally, the paper discusses future research directions, highlighting opportunities for innovation in sensor technology, data analytics, and human-centric lighting design to propel the capabilities and adoption of these systems.

[4]. Agramelal, F., Sadik, M., Moubarak, Y., &Abouzahir, S. (2023). Smart street light control: a review on methods, innovations, and extended applications. *Energies*, *16*(21), 7415.

As urbanization increases, streetlights have become significant consumers of electrical power, making it imperative to develop effective control methods for sustainability. This paper offers a comprehensive review on control methods of smart streetlight systems, setting itself apart by introducing a novel light scheme framework that provides a structured classification of various light control patterns, thus filling an existing gap in the literature. Unlike previous studies, this work dives into the technical specifics of individual research papers and methodologies, ranging from basic to advanced control methods like computer vision and deep learning, while also assessing the energy consumption associated with each approach. Additionally, the paper expands the discussion to explore alternative functionalities for streetlights, such as serving as communication networks, environmental monitors, and electric vehicle charging stations. This multidisciplinary research aims to be a pivotal resource for both academics and industry professionals, laying the groundwork for future innovation and sustainable solutions in urban lighting.

[5]. Omar, A., AlMaeeni, S., Attia, H., Takruri, M., Altunaiji, A., Sanduleanu, M., ... & Al Hebsi, G. (2022). Smart city: Recent advances in intelligent street lighting systems based on IoT. *Journal of Sensors*, *2022*(1), 5249187.

Street lighting is a core infrastructure piece in urban and semiurban cities. It provides a number of advantages such as improving safety for drivers and pedestrians. Nowadays, street lighting accounts for about 13–14% of the world's electricity annual production [1–4], and the market is continuously growing. It is expected that by 2027, there will be about 363 million street lights around the world [5]. Consequently, enormous energy is consumed by the street lights, which makes it imperative to work on solutions to reduce street light consumption.

[6]. SITAPURA, J. (2022). ***Automatic Road Light System for Highway*** **(Doctoral dissertation, RAJASTHAN TECHNICAL UNIVERSITY, KOTA).**

The primary thought in the current field advancements is Automation, Power utilization cost viability. Mechanization is expected to lessen labor with the assistance of wise frameworks. Power saving is the principal thought always as the wellspring of the power (Thermal, Hydro and so on) are getting lessened because of different reasons. The principal point of the undertaking is programmed road power saving framework with LDR, this is to save the power. We need to save power naturally as opposed to doing manual. Making cost effectiveness is simple. This saved power can be utilized in a few different cases. In towns, towns we can plan savvy frameworks for the use of streetlamps. Needs no manual activity for turning ON and OFF. At the point when there is need of light. It distinguishes itself climate there is need for light or not When obscurity ascends to a specific worth then naturally streetlamp is exchanged the responsiveness of the streetlamp can likewise be changed. In our task we have involved four L.E.D for sign of bulb however for high power exchanging one can associate Relay (electromagnetic switch) at the result of pin 3 of I.C 555. Then it will be feasible to turn ON/OFF any electrical machines associated the entire way through hand-off.

III.EXISTING SYSTEM

Street light automation projects frequently incorporate a robust IC design that harnesses analog sensor networks and comparator-based logic to control lighting based on ambient conditions. Typically, these systems use an LDR arranged in a voltage divider circuit, where varying resistance due to changes in brightness produces a corresponding voltage shift. This voltage is then compared to a predefined referenceoften set using a potentiometerby a comparator like the LM358 op-amp. When the ambient light falls below a specific threshold, the output of the comparator changes state, which then activates a transistor to drive a relay that switches the street light on; a diode is used to protect the circuit from back EMF when the relay coil is de-energized. Feedback hysteresis is commonly introduced to stabilize the circuit, preventing rapid on-off cycling during fluctuating light conditions. While this traditional analog approach is valued for its simplicity, reliability, and cost-effectiveness, modern upgrades often integrate microcontrollers and additional sensors such as PIR detectors to further optimize energy efficiency and responsiveness, thereby enhancing overall system robustness and scalability.

IV.PROPOSED SYSTEM

Our proposed system for a modern street light automation project integrates advanced sensing, control, and communication components into a cohesive and scalable solution. At its core, the system utilizes a dual-sensor module comprising an LDR to continuously monitor ambient light levels and a PIR sensor to detect the presence of pedestrians or vehicles. Sensor outputs are processed in real time by an embedded microcontroller (for example, an Arduino-based platform) which runs a customized algorithm to decide when to activate the street lights. When the ambient light drops below a predefined threshold and motion is detected, the controller triggers a MOSFET-based switching circuit to power energy-efficient LEDs while employing flyback diodes and other protective measures to safeguard the circuit against voltage spikes. Additionally, a built-in IoT communication module allows the system to relay operational data to a central management platform for remote monitoring, predictive maintenance, and adaptive brightness control. This design not only ensures optimal energy conservation and safety by switching lights on only when needed but also supports integration with renewable energy sources like solar panels, making it a cost-effective and future-proof solution for urban infrastructure.

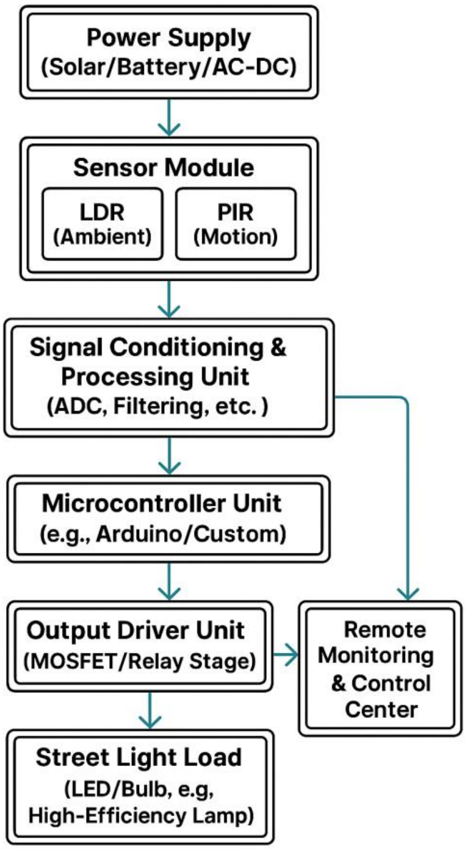

Fig.1.Block Diagram

A. Components Used:

1. Attiny 85 IC: The ATtiny85 is a compact yet powerful 8-bit microcontroller from Microchip, based on the AVR RISC architecture. Despite its small size, this microcontroller offers robust features, making it highly popular in DIY electronics and embedded systems. It has 8 pins, with 6 GPIO pins that can be used for digital input/output, pulse width modulation (PWM), and analog-to-digital conversion (ADC). The device includes 8KB of Flash memory, 512 bytes of SRAM, and 512 bytes of EEPROM, allowing storage of program code and non-volatile data. Operating at voltages between 1.8V and 5.5V, it is ideal for low-power applications, and its various sleep modes further enhance power efficiency.

2. LDR(Light Dependent Resistor): An **LDR (Light Dependent Resistor)**, also known as a **photoresistor**, is a passive component whose resistance varies with the intensity of light falling on it. In darker conditions, the LDR exhibits high resistance; under bright illumination, its resistance drops dramatically. This behavior makes it an ideal component for sensing ambient light levels in a vast range of applications. LDRs operate on the principle of **photoconductivity**. The sensor is typically made from semiconductor materials, most commonly **cadmium sulfide (CdS)**, although other materials like cadmium selenide can also be used. In the absence of light, very few charge carriers (electrons and holes) are present in the semiconductor, so the resistance is high. When photons hit the material, they provide enough energy to excite electrons from the valence band to the conduction band. This increase in charge carriers lowers the resistance.

3. Relay Module: A 5-volt relay module is a compact yet sophisticated device that marries low-power digital control with high-power electrical switching in a single unit. It contains an electromechanical relay a device that includes a coil, an armature, and a set of contacts integrated with a driver circuit that allows a microcontroller's simple 5V logic signal to control much larger currents. When the 5V control signal is applied, a transistor within the module is activated, allowing current to flow from the 5V supply through the relay's coil. This current flow generates a magnetic field that pulls the armature, a movable metal part, toward the coil, mechanically shifting the contacts from their default arrangement (typically connecting a common terminal to the normally closed contact) to connect the common terminal with the normally open contact instead.

4. Pic Programmer Kit:A PIC programmer kit is a specialized hardware and software bundle designed to enable users to program PIC microcontrollersa family renowned for their efficiency and versatility in embedded applications. At its core, the kit provides an interface between your computer and a removable PIC chip, allowing you to write, upload, verify, and erase firmware. Typically, the kit includes a PIC microcontroller (such as the popular PIC16F84A, which is electrically erasable, meaning that it can be programmed and reprogrammed repeatedly) alongside the programming hardware that connects directly to the computer's parallel port. This direct connection is crucial because it ensures that the voltage levels and timing signals necessary for proper programming are maintained, which is often not possible with converter cables or non-standard interfaces.

5. MOTION SENSOR: Motion sensors are devices designed to detect physical movement within an area by monitoring changes in their environment. They are a cornerstone of modern security systems, home automation, and energy-efficient lighting, among other applications. The core concept behind these sensors is to detect variationswhether in infrared radiation, sound waves, or microwave signalsthat signify the movement of objects or people. Advanced processing circuitry within the sensor then interprets these changes, triggering responses like activating lights, sounding alarms, or recording video.

V.CONCLUSION

The proposed street light automation project represents a significant evolution from traditional, manually operated or timer-based systems towards a smarter, more sustainable urban lighting solution. By integrating ambient light sensorslike the LDR for continuous monitoring of environmental brightnesswith motion detectors such as PIR sensors, the system ensures that street lights are energized only when needed. This not only reduces energy consumption but also enhances road safety by dynamically adapting to real-time conditions. At the heart of the system, a microcontroller processes conditioned sensor signals to make timely, automated decisions. When combined with a robust output driver circuit using MOSFETs or relays, and enhanced by IoT connectivity for remote monitoring and control, the design provides a scalable and cost-effective solution. This integration ensures predictive maintenance, streamlined operations, and potential for future upgradessuch as adaptive thresholds and advanced energy management featuresmaking the system both sustainable and capable of meeting modern urban infrastructure demands.

VI.REFERENCE

[1]. Mehra, D. A., Bhanderi, R. B., Hegade, A., & Choubey, C. K. (2024, August). Efficient Illumination: Arduino-Based Street Light Automation for Energy Savings. In *2024 International Conference on Emerging Techniques in Computational Intelligence (ICETCI)* (pp. 397-401). IEEE.

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[7]. Omar, A., AlMaeeni, S., Attia, H., Takruri, M., Altunaiji, A., Sanduleanu, M., ... & Al Hebsi, G. (2022). Smart city: Recent advances in intelligent street lighting systems based on IoT. *Journal of Sensors*, *2022*(1), 5249187.

[8]. SITAPURA, J. (2022). *Automatic Road Light System for Highway* (Doctoral dissertation, RAJASTHAN TECHNICAL UNIVERSITY, KOTA).
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