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Advanced and Automatic Smart Street Light using Dimming Control and Motion Sensor

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Abstract

Our project for developing a Advanced and Automatic LED street light system with dimming control and smart sensor is reviewed. In this project, the street light system, in which lights on when needed and light-off when not needed. Currently, in the whole world, enormous electric energy is consumed by the street lamps, which are automatically turn on when it becomes dark and automatically turn off when it becomes bright. This is the huge waste of energy in the whole world and should be changed. Our smart street light system consists of a LED light, a brightness sensor, a motion sensor, and a short-distance communication network. The lights turn on before pedestrians and vehicles come and turn off or reduce power when there is no one. It will be difficult for pedestrians and drivers of vehicles to distinguish our smart street lamps and the conventional street lights, since our street lamps all turn on before they come. The present status and the future prospects of our smart start light project will be reviewed.

Keywords: Light Dependent Resistor (LDR); Street Light; Microcontroller; Illumination Enhanced Safety; Adaptive Lighting and Reduce light pollution

Introduction

This Project gradually woks on Smart street light refers to a network-connected street light. Each street light is equipped with an outdoor lamp controller, internet of things device, and/ or sensors. A smart street light automatically regulates the light intensity based on sunset/ sunrise times, daily schedule, human presence, traffic, and/ or weather situation. Thereby saving considerable energy and lowering the maintenance costs. Smart street lights also capture and transmit data in near real-time to a central management system, so that street light operator gets:

- Total control over each luminaire.
- Insight into the state of public lighting.
- Access to a range of lighting applications and service.

Objective

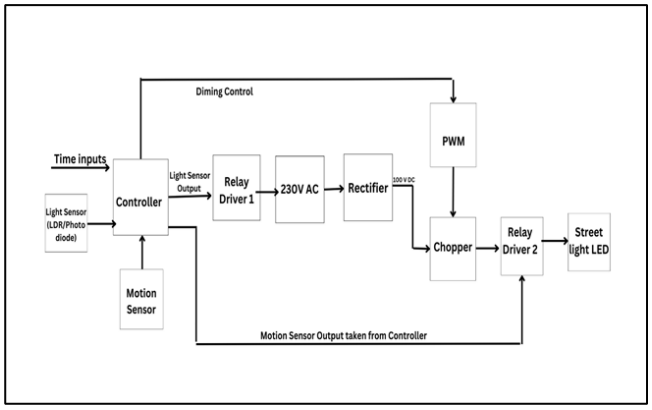
A smart street light automatically regulates the light intensity based on sunset/

sunrise times, daily schedule, human presence, traffic, and/or weather situation. Thereby saving considerable energy and lowering the maintenance costs.

Literature Survey[1–9]

- Advanced and Automatic LED Street light system with dimming control and smart sensor using light dependent resistor (LDR) removes manual works. The street lights are automatically switched ON when the sunlight goes below the visible region of our eyes. It automatically switches OFF the street lights under illumination by sunlight. The component used for light sensing is a Light. Dependent Resistor. By using the LDR we can operate the streetlight automatically, when ample amount of light is available the streetlight will be in the OFF state and when it is dark the light will be in ON state, it means LDR resistance is inversely proportional to light falling on it. It exploits the working of a transistor in saturation region and cut-off region to switch ON and switch OFF the lights at appropriate time with the help of an electromagnetically operated switch.
- While not focused solely on street lighting, this survey paper discusses the role of wireless sensor networks in smart grids, which are essential for advanced street lighting systems. It covers various sensor types and their applications in energy management. There are numerous patents related to advanced street lighting systems with dimming control and smart sensors. These patents cover various aspects, such as sensor integration, wireless communication, and energy-efficient lighting technologies.
- Government Initiatives and Case Studies: Some literature may discuss real-world implementations of smart street lighting systems in different cities and regions. These case studies often highlight the energy and cost savings achieved through the deployment of advanced LED street lighting with sensor-based controls. Please keep in mind that the field of smart street lighting is continuously evolving, and new research may have emerged since my last update in September 2021. Therefore, I recommend conducting a more recent literature search to find the most up- to-date information and developments in this area.

Block diagram of the project



Light Sensor/LDR: The light sensor is a passive device that converts the light energy into an electrical signal output. Light sensors are more commonly known as Photoelectric Devices or Photo Sensors because they convert light energy (photons) into electronic signal (electrons). This resistor works on the principle of photo conductivity. It is nothing but, when the light falls on its surface, then the material conductivity reduces and also the electrons in the valence band of the device are excited to the conduction band.

Controller: A controller is a piece of equipment that controls the operation of an electrical device. An adjustable speed drive might consist of an electric motor and controller that is used to adjust the motor's operating speed. smart street light controllers help upgrade regular street lights to smart street lights. Quick to install, our street light controllers (outdoor light controllers/luminaire controllers) help monitoring and controlling public lighting on individual basis as well as on group basis. The controller we used are microcontroller/Arduino/Raspberry Pi.

Motion Sensor: A motion sensor, in the context of electronics and technology, is a device that is used to detect the presence or movement of objects or people within its field of view. Motion sensors are commonly employed in various applications, including security systems, lighting control, home automation, and industrial automation. They work by sensing changes in their surroundings and generating an electrical signal or output when motion is detected. A street light motion sensor is a smart device mounted on a street light that detects human movement and adapts luminaire's illumination accordingly.

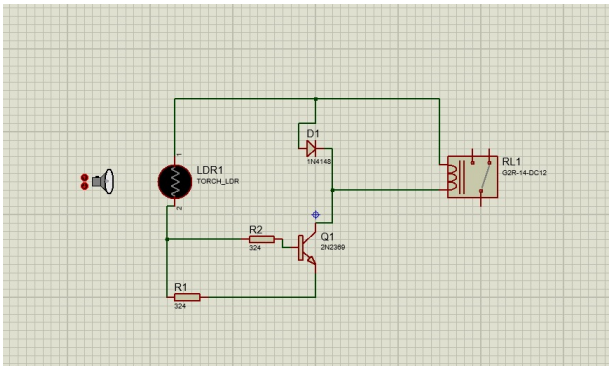
Relay Driver: A relay driver in electronics is a circuit or device used to control or interface a relay with other electronic components or systems. Relays are electromagnetic switches that can be used to control high-power or high-voltage devices using a low-power signal. They are commonly used in applications where a low-voltage and low-current control signal, such as one from a microcontroller or a digital

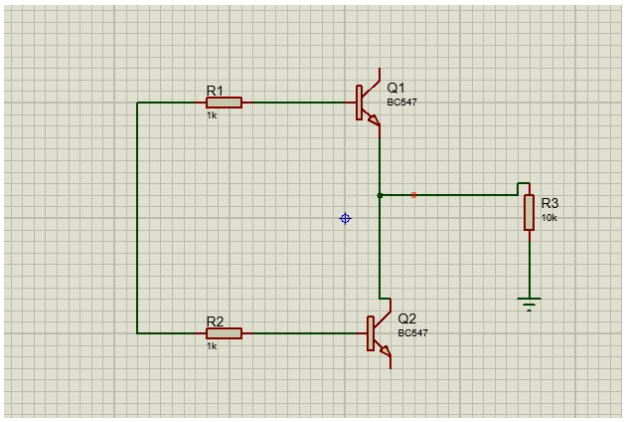
logic circuit, needs to control a higher-voltage or higher-current load. There are two relay drivers used in this Circuit. A relay is an electromagnetic switch that is used turn on and turn off a circuit by a low power signal, or where several circuits must be controlled by one signal accordingly to the conditions. Relay 1 is used to provide cutoff 230V mains supply to rectifier and relay 2 is used to provides chopper output with respect to dimming controls and also motion sensor output.

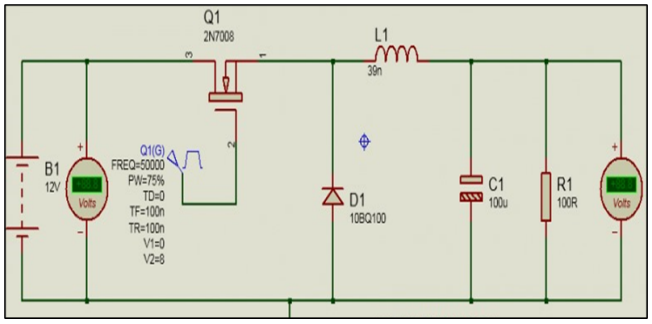
PWM: PWM, or Pulse Width Modulation, is a commonly used technique in electronics and control systems to control the average voltage or current supplied to a load, such as a motor, LED, or other devices. It is a method of varying the width (duration) of a pulse within a fixed time period while keeping the frequency constant. This modulation technique is particularly useful for tasks like speed control of motors, dimming LEDs, generating analog -like signals from digital systems, and more. In this work, the power efficiency has been achieved through PWM by switching the brightness of the LED from 100% to 20% based on the vehicle traffic. Based on the vehicle traffic per hour, the duty cycle has been adjusted which inherently changes the width of the pulse.

Chopper: chopper typically refers to a device or circuit that is used to control the duty cycle or switching of a signal, usually a voltage or current. Choppers are commonly used in power electronics and voltage regulation applications to convert a continuous voltage or current into a pulsed or chopped waveform. A chopper is a device that converts fixed DC input to a variable DC output voltage directly.

Circuit diagram of project







System Specifications

1) 7:00 pm - 12:00 (mid)
   Traffic: 100%
   Light intensity: 100%
   Energy Save: 0%
   2) 12:00 (mid) - 4:00 am
   Traffic: 20%
   Light intensity: 20%
   Energy Save: 80%
   3) 4:00 am - 5:30 am
   Traffic: 30-40%
   Light intensity: 50-60%
   Energy Save: 50-40%
   4) 5:30 am - 7:00 am
   Traffic: 70-80%
   Light intensity: 20%
   Energy Save: 30-20%

Results

- **Maintenance Cost Reduction:** Dimming the lights when not needed also prolongs the life of the luminaires, reducing the frequency of replacements and maintenance efforts. Additionally, these systems often include remote diagnostics and automatic fault reporting, which further decreases the need for manual inspections and reduces overall maintenance costs by up to 70%.

Enhanced Safety and Reduced Light Pollution: These smart street lighting systems enhance safety by ensuring that areas are well-lit when people or vehicles are present, deterring crime, and reducing the risk of accidents. At the same time, they help reduce light pollution, which benefits both human health and nocturnal wildlife by minimizing unnecessary light during periods of inactivity.

- **Real-Time Adaptation and Control:** The systems typically employ a combination of centralized and decentralized control. Centralized systems manage data collection and overall monitoring, while decentralized control allows individual lights to respond immediately to local sensor inputs. This ensures that lights in a certain area brighten up as soon as motion is detected, providing seamless illumination for moving vehicles and pedestrians without delays.
- **Environmental Benefits:** By significantly cutting down on energy consumption and extending the lifespan of lighting components, these systems contribute to reducing greenhouse gas emissions and combating climate change. They are an effective way for cities to move towards energy neutrality and sustainability.
- **Practical Implementations:** Several successful implementations of these systems have been reported globally. For instance, adaptive lighting solutions have been used in various cities to achieve substantial energy savings and improved safety. These systems have been praised for their efficiency and future-proof capabilities, making them a preferred choice for many municipalities.

Applications

- **Energy Efficiency:** The system can dynamically adjust the brightness of the LED lights based on the surrounding ambient light conditions. This feature helps to save energy during periods of low activity or when full brightness is not necessary.
- **Smart City Infrastructure:** Integration with Smart City Systems: The LED Street light system can be integrated into a larger smart city infrastructure. This integration allows for centralized monitoring, control, and management of street lights. For instance, lights can be dimmed or turned off remotely, contributing to overall energy conservation.
- **Reduced Light Pollution:** Automatic dimming can be programmed to lower the brightness during late-night hours when there is less activity. This helps in reducing light pollution, creating a more sustainable and environmentally friendly lighting solution.
- **Longevity of LED Lights:** LEDs are energy-efficient and have a longer lifespan compared to traditional street lights. The dimming feature further extends the lifespan of the LED lights, contributing to reduced maintenance costs.

Adaptive Lighting

- **Motion Sensors:** Integrating motion sensors into the system enables adaptive lighting. Lights can be automatically brightened when motion is detected, enhancing security and safety in the area. The lights can then return to a lower intensity when the activity subsides. Weather Conditions:
- **Adaptation to Weather Conditions:** The system can be programmed to adjust the brightness based on weather conditions. For example, during foggy or rainy weather, the lights can automatically increase in brightness to maintain visibility on the roads.

Data Collection and Analysis

- **Usage Statistics:** The system can collect data on energy usage, brightness levels, and other relevant parameters. This data can be analyzed to optimize the system's performance, identify potential issues, and make informed decisions for future urban planning.

Emergency Response

- **Integration with Emergency Systems:** The system can be integrated with emergency response systems to automatically increase the brightness in specific areas during emergencies, aiding first responders and enhancing public safety.

Community Engagement

- **Customizable Lighting Schedules:** The system can be programmed to adjust lighting schedules based on community events or specific needs, fostering community engagement and satisfaction.

Future Scope

The system can evolve to become a part of a larger Internet of Things (IoT) ecosystem, enabling seamless connectivity and communication between various urban systems. This integration can enhance data exchange, allowing for more intelligent decision-making and improved overall city management. Integration of energy-harvesting technologies, such as solar panels or kinetic energy harvesting from pedestrian movement, can make the LED street light system more self-sufficient and reduce dependency on the grid.

Conclusion

Smart street lighting systems using dimming control and motion sensors offer a range of substantial benefits, including

significant energy savings, cost reductions, enhanced safety, and environmental sustainability. By dimming lights during periods of inactivity and brightening them only when motion is detected, these systems can reduce energy consumption by up to 80%, which also helps lower greenhouse gas emissions. The extended lifespan of lighting components due to reduced usage results in maintenance cost savings of up to 70%, supported by remote diagnostics and automated fault reporting. Enhanced safety is achieved through improved visibility for pedestrians and drivers, which also helps deter crime. Additionally, these systems contribute to reduced light pollution, benefiting nocturnal wildlife and human health by minimizing disruptions to natural sleep patterns. Cities worldwide have successfully implemented these technologies, achieving impressive energy and cost savings while enhancing public safety. Overall, smart street lighting with dimming control and motion sensors represents a forward-thinking solution that aligns with the goals of sustainable urban development.

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