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Smart Street Lighting Using Piezoelectricity

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ABSTRACT: The natural resources used for powering purposes are limited resources and getting diminished day by day as the demand for it is rising. In developing countries, Amount of generated electrical energy is unable to keep up with the demand, and also there is scarcity of raw materials for producing the energy. In countries like India, 1/5th of energy consumption is through street lighting. The conventional street lights are still designed according to old standards of reliability. Because of this, large amount of energy is wasted and it puts a lot of stress on the natural resources used for generating electricity. Alternative sources are now explored to prepare for the future dearth of traditional energy sources. A well designed energy efficient street light system should permit traffic and pedestrian to travel at night with great visibility in safety and comfort while reducing energy consumption and cost. The main aim of our project is to make use of the energy generated as the result of movement of vehicles on road to control the street lighting and thereby increasing their efficiency and also automating their process.

KEYWORDS*:* Piezoelectricity, Energy harvesting and storage, Automation, Innovative energy source.

I. INTRODUCTION

Smart Street Lighting aims at increasing the efficiency of street lights by automating their control, as and when, required, without using any external supply. The vehicles moving on the road tends to vibration of the piezoelectric material placed below the road due to deformation, caused by the pressure of vehicle passing. Piezoelectricity is an electric charge that accumulates in certain solid materials (such as crystals, certain ceramics) in response to applied mechanical stress. The electricity generated from one piezo is quite small and not useful for practically, thus we have an array of piezoelectric transducers. Considering the large number of piezo arrays and huge pressure applied by heavy vehicles, the electricity generated increases. The electricity generated from these transducers is further rectified and regulated using, energy harvesting circuit. Now this instantaneous energy is not used directly but the electricity generated throughout the day is stored in batteries. Hence, the cumulative amount of electricity stored in the battery is high enough for powering of street lights. There is also an automation circuit which controls the street lights, according to, whether it is day or night, and also changes the intensity of street lights on the basis of density of vehicles, at any given time. Street lights will be off in the day and will turn on automatically at night. At night street lights will glow with high density if there is a fair amount of traffic, else street lights will glow at low intensity, further saving the energy.

II. LIMITATIONS OF THE EXISTING TECHNOLOGY

The existing Street Lighting system has various limitations. First of all, Controlling of street lights is done manually. So it involves human interaction and that may cause errors in control. We have seen that Street lights are sometimes on even in daylight, while sometimes street lights are not turned on even when the darkness has settled in. If street lights are on, even during the daylight, large amount of energy is wasted. Also, the existing system makes use of sodium vapour lamps. Sodium vapour lamps consume much larger energy and they also heat up, thereby leading to high power dissipation.

III. ADVANTAGES OF THE PROPOSED SYSTEM

The most important advantage of the proposed system is Powering and controlling of street lights is done without use of any external supply. The proposed system is completely automatic and it eliminates any manual control, thereby reducing the chances of error in controlling. Another advantage is use of LED lamps, instead of sodium vapour lamps. LED lights have high luminescence and power consumption is less, as compared to sodium vapour lamps. The intensity

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control of street lights in night time, based on density of traffic is also prominent feature. The proposed system is eco-friendly as well.

IV. BLOCK DIAGRAM

There are four major blocks in our project as given below. The first block is the piezo block. This block is the source of energy generation. This block consists of piezoelectric material like PZT. These materials are embedded within road so as to convert pressure exerted by moving vehicles into electrical energy. Next block is energy harvesting and boost circuit. The energy so generated is rectified and boosted so as to become of practical purpose. Next block is of energy storage consisting of battery, the main function of which is to store the energy for further use. The final block is the automation circuit. This may be called the brain of the circuit, as it determines the daytime and night time, and also according to the traffic, controls the intensity of street lights, and hence street lights are used efficiently.

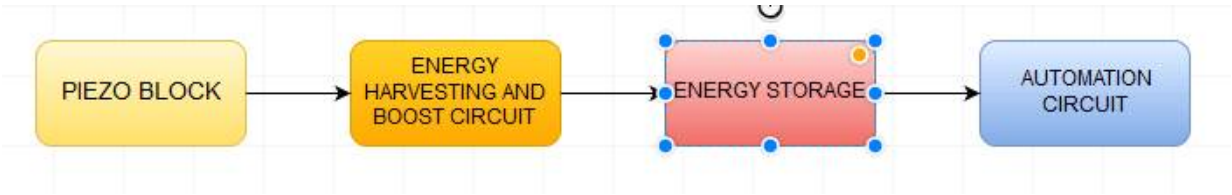

Figure 1: Main Block diagram of Smart Street Lighting using piezoelectricity

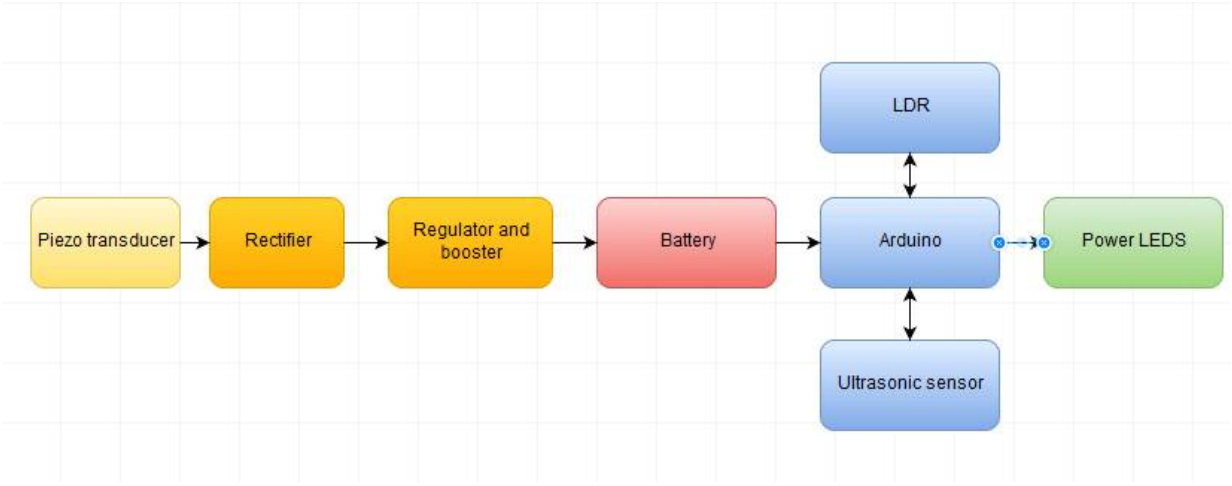

Figure 2: Detailed Block diagram of Smart Street Lighting using piezoelectricity

V. COMPONENTS USED AND ITS SPECIFICATIONS

The major components used in our project are listed below. All the components are selected after carefully analysing their specifications. The main components along with their relevant specifications are given below.

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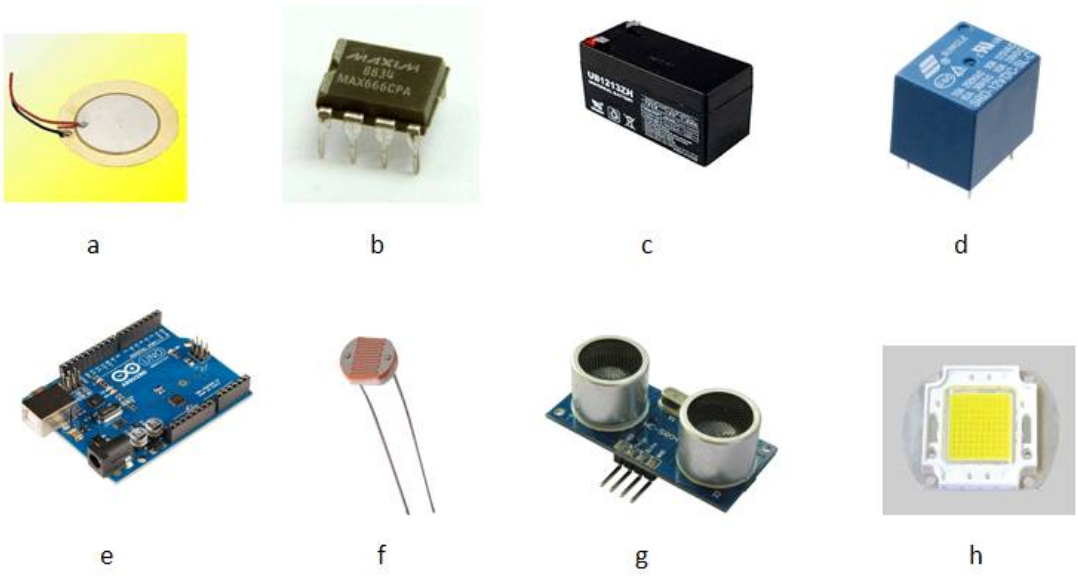

Figure 3: Main components used Smart Street Lighting System - (a) Piezoelectric Transducers (b) max666 ic (c)12V rechargeable battery (d) 12V Relay (e) Arduino (f) Light Dependent resistor (g) ultrasonic sensor (h) Power LEDs.

1) Piezoelectric Transducers (35mm diameter discs).
2) Max666CPA IC (Programmable voltage regulator IC, Dual mode of operation: Fixed or variable).
3) 12V Lead Acid Rechargeable Battery (12V 1.3A-h rating).
4) 12V Relay (with 5 pins).
5) Arduino UNO development board.
6) Light dependent resistor.
7) Ultrasonic sensor module HC-SR04 with max range of 4m.
8) High Power LEDs (1W to 5W).

VI .WORKING

When the vehicle moves over the road, there is deformation of the road due to the pressure applied by the moving vehicle. In our project, we propose to place the arrays of piezoelectric materials placed below the surface of road. Hence, due to deformation of road, these piezoelectric materials vibrate up to some extent, thereby generating electricity because of the principle of piezoelectricity. The electricity generated from one piezo set is in very low, but the overall energy from arrays of piezo is considerable.

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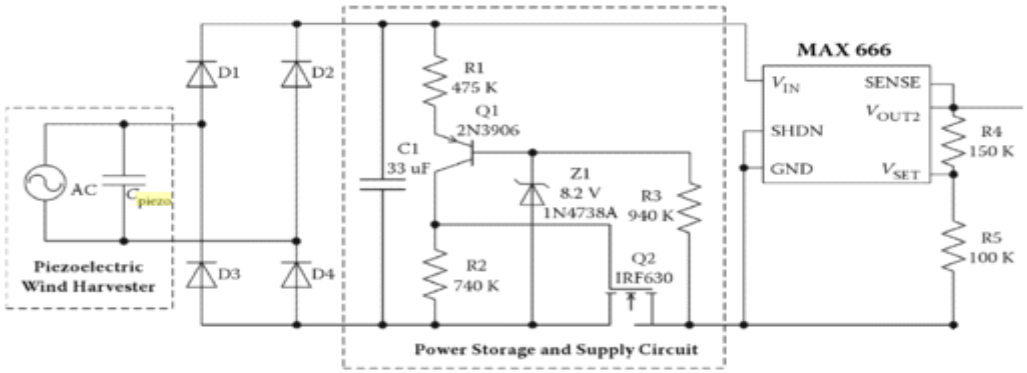
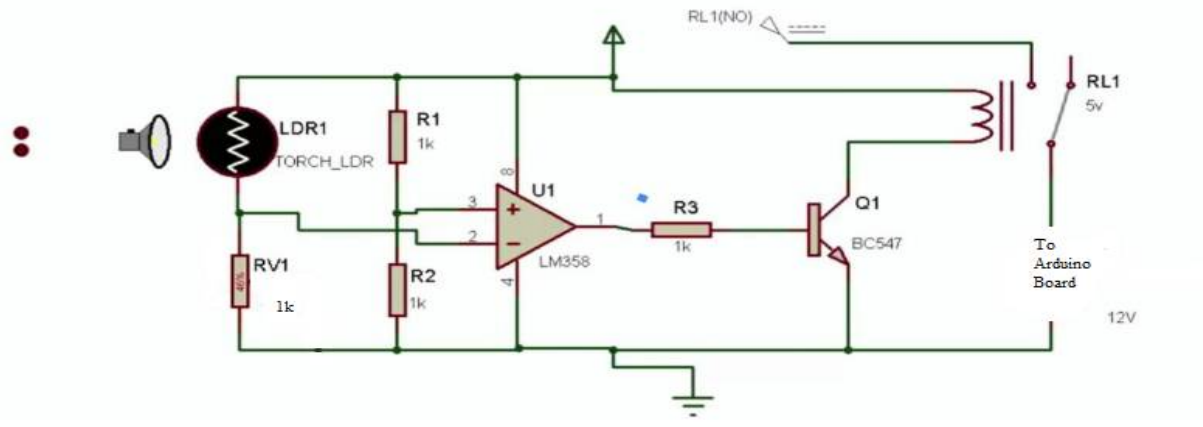


Circuit Diagram of Phase 1 of our proposed system

The electricity so generated is then given to the energy harvesting and boost circuit. The electricity from piezo is AC in nature and hence it is rectified to get the DC output voltage. As shown in circuit diagram, This DC voltage is then stored by the capacitor. The transistor 2N3906 and VN2222L are used as the switch state for controlling the flow of current. The zener diode used is of 12V. Initially, both the transistors are in cut-off state and hence, the capacitor keeps on charging. As soon as the voltage on capacitor exceeds zener diode voltage, the capacitor releases it's charge, switching the BJT, Q1, to the on position, and triggering the MOSFET, Q2, to pull the ground line down allowing C1 to discharge through the circuit. The MAX666CPA is low power voltage regulator. It can operate in two modes: fixed in which it gives 5V or variable in which output is decided on the basis of resistors value. We chose the value of resistors so that, we get constant 12V output voltage. Once Capacitor has discharged beyond certain low value of voltage, the MAX666 sends out a negative pulse that turns the Q1, off, allowing C1 to begin the process over and recharge. In the "off" state, the circuit has a high impedance allowing C1 to charge fast.

The 12V output coming out of the phase 1 of the circuit is stored in 12V lead acid rechargeable battery. During day, battery only does the work of charging itself. The second phase of the circuit consists of automation circuit. For demonstration purpose, this phase consists of Arduino UNO, Light Dependent Resistor and Ultrasonic sensor. Battery and arduino are connected with relay and LDR circuit. This circuit serves the important function of determining whether it is daytime or night time.



Isolation circuit betweeen arduino and battery

Light dependent resistor is the resistor whose resistance decreases with increasing light and provides high resistance when it is dark. The relay and LDR circuit is so designed such that, in the daytime, energy from battery is not used by

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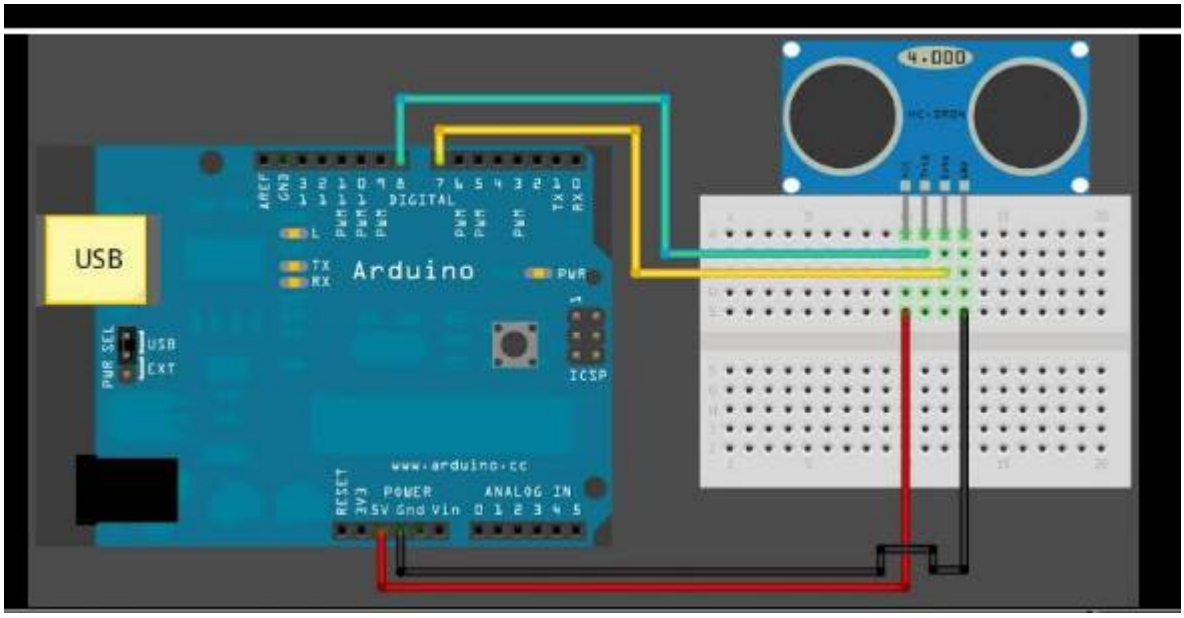
arduino or other peripherals and hence energy is stored in the battery without getting discharged. In the night time arduino will be powered by the battery. The working of the relay circuit is based on the principle of comparator. LDR and resistors are arranged in form of voltage divider. One pair serves as the input for the inverting input while other for non-inverting input. The resistance of LDR changes according to the light intensity. Accordingly, At day time, output of comparator is low and transistor is not on. Relay isolates arduino from battery. In night time, comparator gives high output turning transistor on, and relay connects battery to the arduino.



Arduino acts as the controlling system for the street lights (power LEDs). Arduino is interfaced with power LEDs and ultrasonic sensors. So the power LEDs will be on only during night time. Further if ultrasonic sensor detects the passer-by or vehicle, the corresponding street light glows at the high intensity. As soon as, the vehicle pass away LED will switch to low intensity. This will further save energy and will be particularly of great importance after midnight time, when traffic is not too heavy.

In practical implementation of this project the values of voltage and current is much higher a1nd also components used will be of much greater load, for example, piezo discs are replaced by PZT materials. But the principle of operation remains same

VII. RESULTS

The results of various experiments we conducted are listed down in the table below. For demo purposes, these values of voltages and currents were recorded. However, for actual implementation of this project, the values of electrical voltage and current generated will be much higher because of tremendous pressure applied by the vehicles and also, for the practical purposes, the piezo disc will be replaced by PZT sheets, which have much stronger piezoelectric effect.

Parameters	Observations
1) AC voltage and current from piezo transducers	20-40V and 15-20uA
2) DC voltage and current obtained from bridge rectifier	2-4V and 10-15uA
3) Input and output voltage of MAX666	6-20V and 12-14V
4) Input and output current of MAX666	40uA and 500uA
5) Output voltage of comparator during night time	2-8V
6) Output voltage of comparator during day time	0.4V

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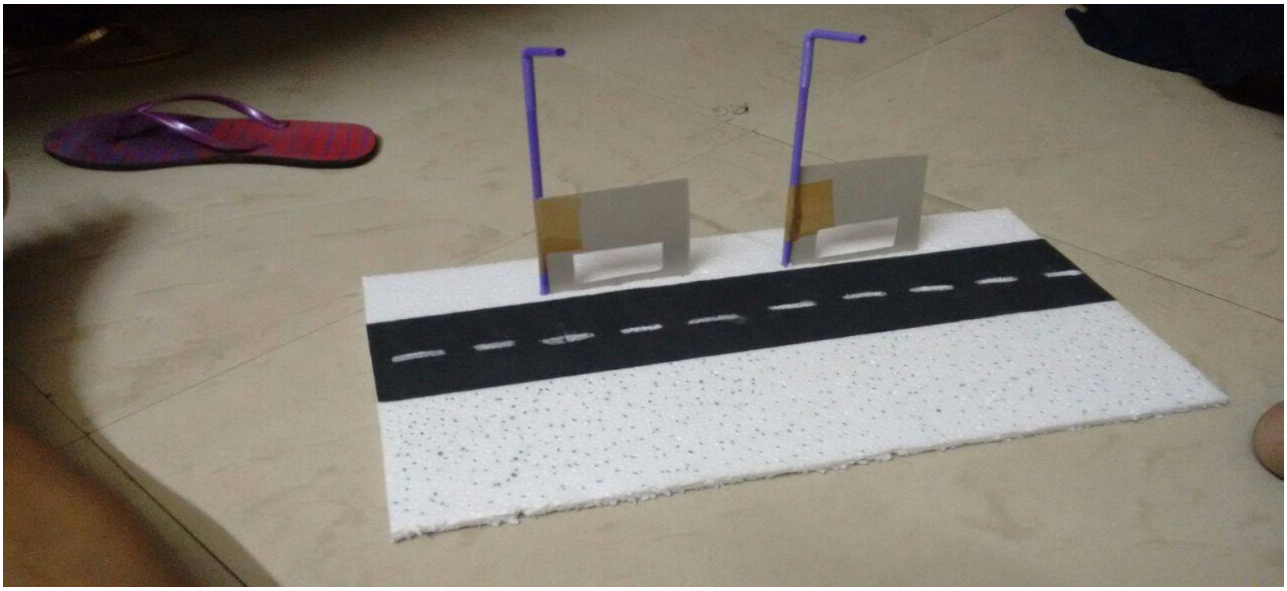
The images of some phases of the circuit which we made and demo setup images are shown below.

PCB1

PCB2



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VIII.SCOPE FOR FUTURE RESEARCH

1) Further, piezo knock sensors can also be taken into consideration.

2) Implementation of camera along with street lights for security purposes.

3) Bluetooth module can be interfaced so as to get the data regarding various street lights.

IX.CONCLUSION

LEDs are going to be vital lighting option in near future due to its peculiar low power consumption and cost effective nature. Our prototype will help in eliminating the current sodium vapour street lamps with better LED comprised lamps operated smartly using LDR, and piezoelectric material thereby increasing energy efficiency and reducing electricity costs. Harvesting energy from the environment is being considered as a viable option to replace the current power supplies for energy constrained embedded systems. The desire to use self-powered devices drives to achieve enormous growth in the field of energy harvesting. With the few limitations such as low amount of power generated using the power harvesters, the researchers are working towards generating new methods. These methods would help in placing the energy harvesters as one of the best sources to power portable devices in the field of wireless technology

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