

# Piezo Based Self Sustainable Traffic Light System

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**Abstract**— This paper describes a traffic light system that is based on piezoelectric power and its switching is automatically controlled depending upon the amount of traffic passing. Often road accidents occur due to human controlling and traffic light systems[7] fail in case of power failure like the one that occurred in India in July 2012. So, this traffic light system will not only generate power from traffic to power its components and LEDs but will also provide effective traffic control by eliminating any human interference from the system. The system uses piezoelectric films placed on road for power generation and a signal conditioning circuit[1] to optimise the power generated. This generated power will be stored in batteries which will further power the components of the system and traffic light LEDs[2]. A microcontroller will control the switching of lights by using an algorithm whose basis will be the amount of traffic passing on the road. Since no components of the systems are fragile and the system is self powered, the working of the system will be independent of the weather conditions and power failure.

**Index Terms**— Microcontroller, Light Emitting Diodes, Piezoelectricity, Young's Modulus, Step Down Converter, Ultra-capacitor, Rectifier, Buck Converter, PVDF.

## 1 INTRODUCTION

PIEZOELECTRICITY has always been a keen area of interest for researchers and scientists. Since early ages, piezoelectricity is being used by human beings knowingly or unknowingly. With the acknowledgement of piezoelectricity as a research area, developments in this field have been massive. Currently, piezo based instruments are being used in a large chunk of industries of the world. Industrial production of piezoelectric sensors and instruments has already started on a wide scale and their demand has been increasing day by day. The biggest advantage of piezoelectric sensors is that they are active sensors and provide output without any external excitation.

The motivation of energy harvesting through piezoelectric elements comes from the fact that they produce electric impulses whenever external excitation is provided to them. These output pulses can be conditioned to harvest energy then which will be a free form of energy. One of the major drawbacks of energy harvesting through piezoelectricity was its low output. The unconditioned output voltage and current provided by the piezoelectric crystals is so low that they cannot be used for the desired uses. Hence, in this paper, we will try to propose some methods which can provide a remedy to this problem. Output, if properly conditioned and harvested, this energy will not only drive the signal conditioning circuit but will also harvest energy for other uses like LED based sign boards, advertisement hoardings, street lights, pedestrian lights, turn lights, signal termination lights and so on. Since lot of work has already been done on the basic model of a piezo based energy harvesting system [3], [4], [5], [6], we will directly use some of the results and proceed further with inference from them. We will try to deduce useful conclusions from these and implement them in our model to design a piezo based self

sustainable traffic light system.

## 2 THEORY

A vibrating piezoelectric device differs from a typical electrical power source in the way that its internal impedance is capacitive rather than inductive in its nature, and hence may be driven by mechanical vibrations of varying amplitude and frequency. The piezoelectric elements convert mechanical stress into electric impulses. *The mechanical stress can be applied on the piezoelectric elements in the form of vehicles moving on the road.* Further, there is need of a rectifier to filter out sudden surges and a step down converter circuit to adjust the voltage produced by the elements into the optimum range. Thus, the impulses produced by the piezoelectric elements are first fed into the above circuitry and the optimum voltage produced is connected to the capacitor which stores energy in the form of  $\frac{1}{2}CV^2$ .

This energy is further transferred to a battery which accumulates the charge and can be used to power the traffic light system.

Each road on a crossroad will have its individual circuitry which will store a charge corresponding to the amount of traffic passed. The voltage generated in the battery due to this charge will be measured and compared with the voltages of other roads on the crossroad to give a feedback to the traffic light system. The timers on each road will operate according to the change in voltage of the batteries. The power for the LEDs and timers of the traffic light as well as the signal conditioning circuitry will be provided by the battery itself. Hence, the system becomes self sustaining and controls the dynamic behaviour of traffic.

### 3 THEORITICAL PERFORMANCE ESTIMATION

The following conditioning and storage circuit(Figure 1) will be connected with the piezoelectric elements(ref. Power Electronics, IEEE, VOL. 18, NO. 2, MARCH 2003).

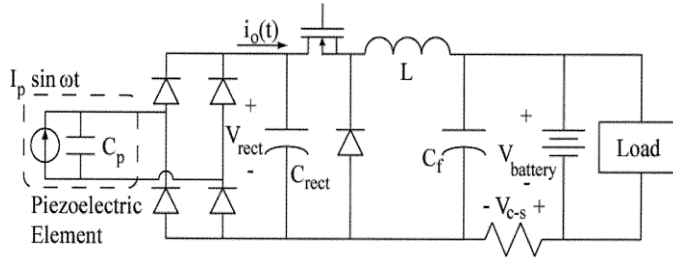


Figure 1

The electrical characteristics of a vibrating piezoelectric element can be modelled as a sinusoidal current source  $i(t)$  in parallel with its electrode capacitance  $C$ . The magnitude of the polarization current depends on the mechanical excitation level of the piezoelectric element. An ac-dc converter is fed with the output of piezoelectric element which produces a dc output and apparent peak output power is calculated when the rectifier voltage is maintained at one-half the open circuit voltage of the piezoelectric element.

A dc-dc step-down converter is placed between the rectifier and the electronic load as shown in fig above to change the output voltage of the rectifier as the mechanical excitation changes to achieve and maintain the maximum power flow. A battery is used to provide the energy storage which can be further used as a stiff power supply for the traffic light system. The change in battery voltages is monitored using a microcontroller which is programmed to control the traffic light switching as shown in Figure 2.

### 4 CIRCUIT IMPLEMENTATION

We will be using a DT1-028K piezoelement made up of PVDF (Polyvinylidene fluoride) which have the below specified technical specifications -

Output Voltage by piezoelectric element:  $12 \times 10^{-3} \text{V}$  per microstrain

Young Modulus of PVDF:-2-4

Area:12x30 mm

Thickness: 0.0640mm

Maximum applied force 6-9kgF yields output voltage of 830 to 1275v.

Thus, by using the above mentioned details we estimate that approximately 2kgF of force can produce 250 Volts of electricity at the piezoelectric element. This high voltage impulse will be first passed through rectifier which will convert this impulse signal into the dc signal. Then further the output of this rectifier will be fed to the dc-dc step down converter also known as a buck converter. Hence the dc signal will be stepped down to the 2.5 Volt increasing the amount of current which in turn also increases the amount of charge which will be stored in an **ultracapacitor** having capacitance approximately 200 Farads. This ultracapacitor allows us to store power approximately of 625 watts. Thus, once a capacitor gets charged, it will be further used to charge a battery. As soon as the capacitor starts discharging another impulse coming from a piezoelement after passing through the whole circuitary will charge the ultracapacitors.

A bank of capacitors will be created so as to ensure the continuous flow of charge in the circuit which will help in increasing the efficiency of our system. This charged battery will be used as a power supply to our traffic signal system.

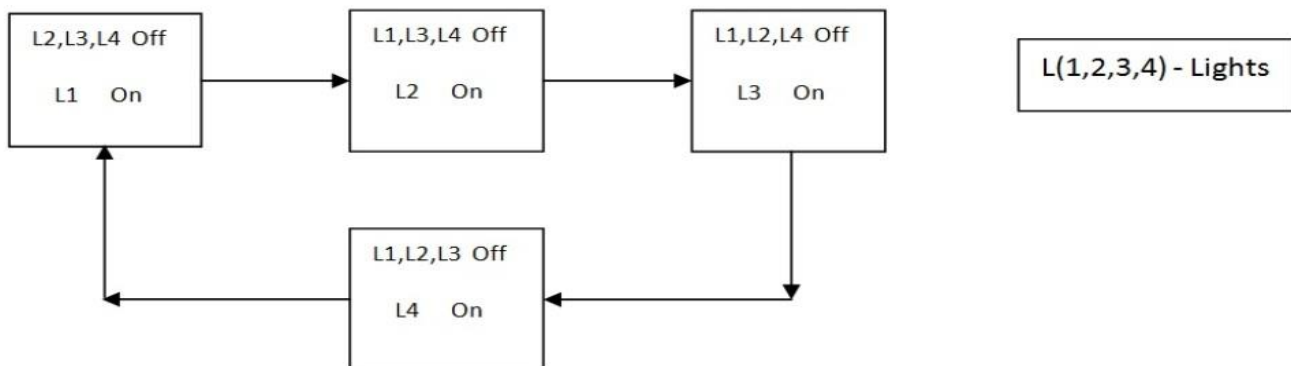


Figure 2

Based on actual meter readings over a period of four months, the power consumption of an intersection fitted with LEDs, including all hardware to operate the intersection, ranged from 103 kWh to 126 kWh per month with an average of 111 kWh(ref. Little Rock city survey). An intersection has 4 approaches with 6 lenses per approach (2 red, 2 green, 2 yellow) and two pedestrian heads per street, which is typical.

Hence the power stored is sufficient to power the whole traffic light system and our system is self sustaining. The change in battery voltages can be compared with the help of a microcontroller to control the traffic light switching and thus controlling the traffic conditions dynamically without any manual interference as shown in figure 3.

### 5 ROUGH COST ESTIMATES

Piezoelectric elements = Rs. 40,000  
Signal Conditioning and Feedback Circuit= Rs. 20,000  
Total cost = Rs. 60,000(approx.)

The cost of ultracapacitors depends on their charge holding capacity. These capacitors are generally expensive but the cost can be brought down significantly if produced in bulk.

This system, besides, has a vast business potential too. If major automation companies start manufacturing this system on a wide scale, it can be sold to developed countries, developing countries and energy deficient countries at high prices. This system has a long life and does not break down easily. Hence, in the long run, it will be a profitable deal for the buyers as well. Also, in places which are frequently affected by snow storms and other natural calamities.

As more multinational conglomerates along with indigenous start ups enter production, the cost of the system will reduce and efficiency will improve.

### 6 CONCLUSION

This paper has summarized the results of our concepts development for a piezo based self sustainable traffic light system. On this basis, we propose the following baseline for its technical implementation:

- Piezoelectricity should be targeted as an alternative energy source of the future.
- To maximize the power output of the system, bridge rectifier followed by step down dc to dc converter should be used along with the filter circuit.
- The charge levels in battery must be continuously monitored to estimate the traffic passing per cycle of traffic light switching.
- Ultracapacitors should be used for better storage capacity.
- Fabrication of the circuit should be done with low power components and ICs to minimize the power loss in the circuit and lower the generation of heat as well.

Preparation of the roadmap for wider adoption of this system calls for research activities addressing its technical feasibility as well as its application and business issues.

The research on the technical feasibility should cover both low traffic and high traffic areas and the optimization of circuits accordingly.

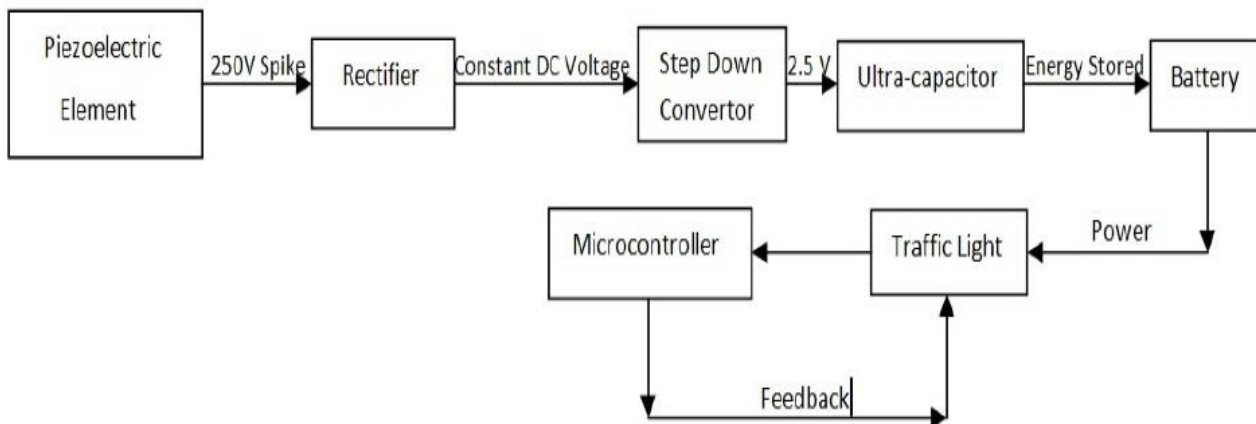


Figure 3

Specific research issues include the following:

- Maximising the output of piezoelectric elements without compromising the safety of the circuit from spikes and fluctuations.
- An alternate or improved version of step down dc to dc converter which converts vibration spikes into steady dc signal.
- Standard resonator circuits which will consume low power and provide adequate frequency vibrations which could match with that of the input signal.
- Switching of harvested energy for emergency cases such as medical surveillance during a catastrophe.

If adequate research be done in this field, it can also be used in military operations in remote areas and may even some day be used to power low power GPS devices.

## 7 REFERENCES

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