



# PROGRAMMABLE POWER USAGE ANALYZER FOR LOAD SURVEY APPLICATIONS

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**ABSTRACT-** The Programmable Power Usage Analyzer for Load Survey Applications is engineered to monitor, measure, and evaluate electrical energy consumption of diverse loads with reliability and efficiency.

In order to better understand load behavior and increase overall energy efficiency, this system focuses on delivering precise real-time data on voltage, current, power, and energy use. It is especially helpful in commercial, industrial, and residential settings where thorough load analysis is necessary for early defect identification, system optimization, and performance enhancement. The proposed system utilizes an Arduino-based architecture to continuously acquire electrical parameters through suitable sensing units.

Instantaneous and cumulative power consumption are calculated by processing the input data obtained from the electrical load using voltage and current sensors. Because the Arduino is programmable, customers may set critical parameters like load thresholds, sample intervals, and operational restrictions to suit particular needs. Because of its adaptability, the system may be used for a variety of purposes, including major industrial load surveys and small-scale home monitoring.

The system also includes a display module that provides real-time visualization of measured electrical parameters. This makes it simple for users to track changes in voltage, current, and power, assisting them in spotting use trends and unusual swings. The analyzer has data logging capabilities to save past energy usage data over time in addition to real-time monitoring. Conducting thorough load assessments, determining peak demand times, and carrying out energy audits all depend heavily on this recorded data. Additionally, it facilitates more effective load control techniques and improved planning.

**Keywords-** Power Monitoring, Load Survey, Energy Measurement, Arduino, Electrical Load Analysis, Energy Consumption, Data Logging, Power Quality.



## I. INTRODUCTION

An essential tool for measuring, tracking, and analyzing electrical energy usage across various load types is the Programmable Power Usage Analyzer for Load Survey Applications. Because of growing demand, rising operating costs, and the requirement for sustainable power management, effective energy consumption has become a crucial issue in contemporary electrical systems. Load survey plays a vital role in understanding how electrical energy is consumed over time, helping engineers and users to evaluate system performance and identify opportunities for improvement.

Depending on consumption trends, operational circumstances, and environmental variables, electrical loads in the residential, commercial, and industrial sectors can differ greatly. It becomes challenging to spot excessive energy use, times of peak demand, or unusual operating circumstances without adequate monitoring. A dependable system that can continually monitor and record electrical characteristics including voltage, current, power, and energy consumption is therefore required. The programmable power usage analyzer addresses this need by providing accurate and real-time measurement of these parameters, allowing detailed analysis of load behavior.

Through programmable features, the system is made to be flexible, allowing users to specify operational limitations, set measurement intervals, and tailor data collection to particular needs. Because of its versatility, the analyzer may be used for a variety of tasks, such as load profiling, energy audits, and electrical equipment performance evaluation.

The system assists in recognizing trends and patterns in energy usage, which are crucial for effective planning and decision-making, by gathering and storing data over time. The system's capacity to increase the dependability and security of electrical systems is another crucial feature. System failures and equipment damage can result from abnormal situations such as overloading, voltage fluctuations, and abrupt changes in load.

## II. OBJECTIVES

- Develop an accurate power monitoring system
- To enable real-time monitoring of electrical loads
- Perform effective load survey and analysis
- Incorporate data logging for historical analysis
- Design a cost-effective and user-friendly system

### III. SYSTEM OVERVIEW

A microcontroller-based energy monitoring system built using the 8051 series microcontroller is shown in the block diagram. This system is particularly made to reliably and efficiently monitor, process, and display electrical energy usage. Because digital components and programmable logic are integrated, this system provides higher control, flexibility, and precision than traditional analog energy monitoring techniques. The transformer, which is essential to lowering the high AC mains voltage to a lower and safer level appropriate for electronic circuits, is where the system begins to function. Since most electronic components cannot withstand high voltages directly, this step-down process ensures both safety and compatibility. The reduced AC voltage is then supplied to the rectifier, which converts the alternating current (AC) into pulsating direct current (DC). However, the output of the rectifier is not smooth and contains ripples, making it unsuitable for sensitive electronic devices. The pulsing DC is sent through a voltage regulator to get around this problem. The regulator produces a steady and controlled DC output by stabilizing the voltage and eliminating fluctuations. The microprocessor and other system components cannot operate properly without this power source. Regulation is a crucial step in the system design since any change in voltage might result in erroneous readings or circuit malfunction.

Furthermore, the system includes setup push buttons that serve as user input interfaces. These buttons allow users to interact with the system by performing functions such as resetting the energy reading, calibrating the device, or adjusting system parameters. When a button is pressed, the microcontroller detects the input and executes the corresponding function based on its programmed logic. Overall, this microcontroller-based energy monitoring system offers significant advantages over traditional systems. It provides higher accuracy, improved safety through isolation, and greater flexibility due to programmable features. The use of digital processing allows easy calibration, reliable measurement, and efficient monitoring, making the system suitable for modern energy management applications.

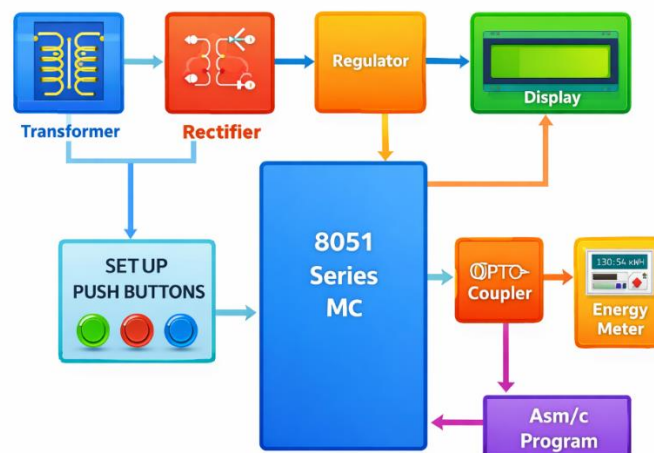


Fig.1- System Design



## HARDWARE COMPONENTS

- **Arduino UNO**

One of the most well-liked and extensively utilized microcontroller boards in the Arduino series is the Arduino UNO. It is based on the ATmega328P microcontroller and is intended to make it simple for engineers, enthusiasts, and students to create embedded systems and automation applications. The board's software and hardware designs are publicly accessible since it is open-source. Because the Arduino UNO is open-source, users may alter and personalize it to suit the needs of their projects. It is perfect for both novices and experts due to its user-friendly design and straightforward programming environment.

### Functions of Arduino UNO

The **Arduino UNO** is a versatile microcontroller board that serves as the brain of embedded and automation systems. Its primary functions in electronic projects include:

1. **Input Processing:** Arduino UNO can read signals from various input devices such as **sensors, switches, IR modules, and potentiometers**. In the Power Usage Analyzer system, it reads signals from IR sensors detecting vehicles near U-turns.
2. **Decision Making:** The board processes input data according to programmed instructions. It can make real-time decisions, such as determining whether a U-turn is safe or if an alert should be triggered.
3. **Output Control:** Arduino UNO controls output devices like **LEDs, buzzers, motors, relays, and displays**. In the U-turn system, it activates green/red LEDs, buzzers, and LCD messages to warn drivers.

- **Relay**

Relays are simply electrically driven switches. A modest control current that activates the relay's coil creates a magnetic field that moves an armature, opening or closing one or more contacts. More specifically: A metal core is encircled by an electromagnet coil. The moveable armature is drawn to the magnetic field when control voltage or current passes through the coil. Depending on the design, the armature movement can cause normally open (NO) contacts to shut or normally closed (NC) contacts to open. The spring resets the contacts and restores the armature to its starting condition when the coil is de-energized. Through electromagnetic switching, a higher power circuit (such switching shunt capacitor banks) may be operated by a low power control circuit (like a microcontroller) with galvanic isolation.

- **Transformer**

A transformer operates on the principle of Faraday's Law of Electromagnetic Induction, which states:

“When a changing magnetic flux links with a coil, an electromotive force (EMF) is induced in that

coil.” In a transformer, alternating current (AC) in the primary winding produces an alternating magnetic flux in the core, which induces a voltage in the secondary winding. A transformer works by using electromagnetic induction to change voltage, based on its **transformation ratio**, which is the ratio of the number of turns in the secondary coil

$$\frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$$

$K = V_2/V_1 = E_2/E_1 = N_2/N_1$  equals the fraction with numerator cap V sub 2 and denominator cap V sub 1 end-fraction equals the fraction with numerator cap E sub 2 and denominator cap E sub 1 end-fraction equals the fraction with numerator cap N sub 2 and denominator cap N sub 1 end-fraction

$$K = V_2/V_1 = E_2/E_1 = N_2/N_1$$

### Working

1. AC supply is applied to the primary winding.
2. The alternating current produces an alternating magnetic flux in the core.
3. This flux links both primary and secondary windings.

### Function

- To transfer electrical energy between two circuits through magnetic induction.
- To change voltage levels (step-up or step-down) while keeping frequency constant.

To isolate circuits for safety

- **Rectifier**

An electrical device that changes alternating current (AC) into direct current (DC) is called a rectifier. Diodes' unidirectional conduction feature, which permits current to flow only in one direction (forward-biased) and blocks it in the other (reverse-biased), is the foundation of their operation. Principle: Rectification uses semiconductor diodes to convert AC (bidirectional) to DC (unidirectional).

### Construction

A basic full-wave bridge rectifier consists of:

1. Four diodes (D1–D4) arranged in a bridge configuration.
2. Step-down transformer (e.g., 230 V AC → 12 V AC).
3. Load resistor or electronic circuit (Arduino and sensors in this project).
4. Filter capacitor to smooth the pulsating DC output.
5. Voltage regulator (e.g., 7805) to provide a stable 5 V DC output.

### Working

The full-wave bridge rectifier as used in project:

1. Step-down transformer reduces the AC mains voltage (230 V AC) to a lower value (12 V AC).

During the positive half-cycle of AC: Diodes D1 and D3 conduct (forward-biased), allowing current through the load in one direction.

- **Electronic Energy Meter**

The conventional Ferraris wheel meter is functionally inferior to an Electronic Energy Meter (EEM). One significant benefit of EEM is that, compared to traditional mechanical meters, its electronic measurement is more reliable and its metering is more precise under nonlinear loads. There are three main ways that EEM helps the power companies.

1. With electronic designs and prepayment interfaces, it lowers the cost of theft and corruption on the electrical distribution network. 2. Phase and neutral line currents are measured by an electronic energy meter, which uses the bigger of the two currents to determine power usage. 3. Electricity distribution is more affordable and of higher quality thanks to EEM.

### **Opto-Coupler**

The Programmable Power Usage Analyzer for Load Survey Applications requires an opto-coupler, also known as an opto-isolator, to provide electrical isolation between the system's high-voltage and low-voltage portions. It guarantees secure signal transmission while shielding delicate equipment from electrical defects, noise, and voltage spikes. The opto-coupler is usually utilized in the energy metering section's pulse output stage. The opto-coupler transfers the energy meter's pulses, which are proportionate to energy consumption, to the control and processing unit. The opto-coupler's internal components are a phototransistor and a light-emitting diode (LED) that are positioned near to one another yet electrically separated. The LED emits light in response to the strength of the supplied input signal. The phototransistor conducts and generates a matching output signal when this light strikes it. In this manner, there is no direct electrical connection and the signal is sent visually.

## **IV. WORKING PRINCIPLE**

**Circuit Diagram: -**

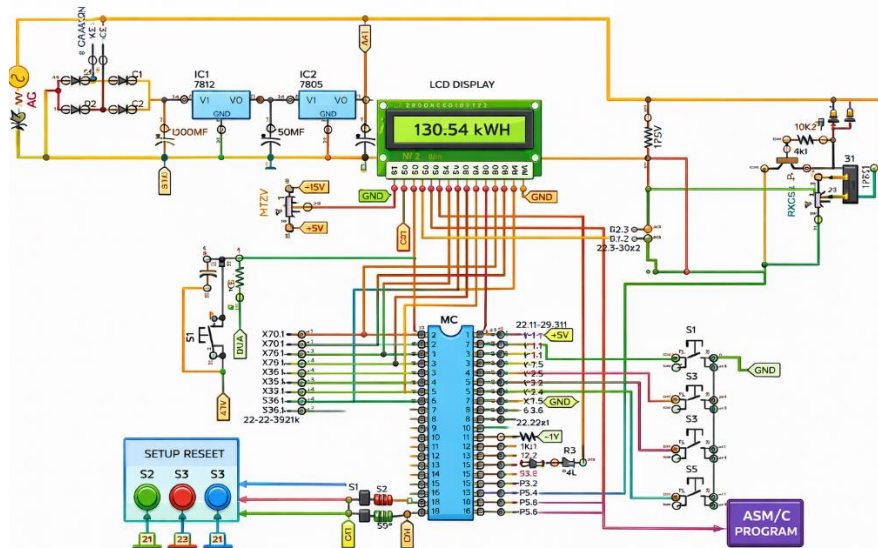


Fig.2- Circuit Diagram

The given circuit diagram represents a microcontroller-based energy monitoring and display system that measures electrical energy consumption in kilowatt-hours (kWh) and displays it on an LCD. The circuit begins with an AC supply input, which is the primary source of power. This AC voltage is first stepped down using a transformer (not explicitly shown but implied through the AC input stage), and then it is passed through a bridge rectifier composed of diodes (D1, D2, D3, and D4). The rectifier converts the alternating current (AC) into pulsating direct current (DC). To smooth out the ripples in the rectified output, large filter capacitors (such as the 1000µF capacitor) are used. These capacitors store charge and provide a more DC voltage. Following the rectification and filtering stage, voltage regulators IC1 (7812) and IC2 (7805) are used. The 7812-voltage regulator provides a constant +12V DC output, which may be used for components requiring higher voltage, while the 7805 regulator provides +5V DC supply, which is essential for powering the microcontroller and other digital components. Small capacitors (like 50µF) are connected at the input and output of these regulators to improve stability and reduce noise in the power supply.

At the center of the circuit is the microcontroller (MC), which acts as the brain of the system. It receives input signals, processes them, and controls the output devices. The microcontroller is powered by the regulated +5V supply and is connected to multiple input and output pins. The analog or digital signals representing voltage and current are fed into the microcontroller through input pins. These signals are typically derived from sensors or measurement circuits connected to the AC line. The microcontroller calculates energy consumption based on these inputs by integrating power over time.

### Flow Chart of the System

The Programmable Power Usage Analyzer for Load Survey Applications flow chart uses a logical Yes/No decision-making procedure to guarantee ongoing system monitoring and safe operation. The system first determines whether or not the power source is accessible during the start

condition. The system powers on and initializes all internal components if the response is yes; else, it stays in an inactive state until power is restored. Once power is available, the system goes to initialization, where it checks that all modules and settings are configured correctly. The system proceeds if initialization is successful (Yes); if not (No), the initialization procedure is repeated.

The system then moves on to the sensing step, where measurements are made on the voltage and current signals. It determines if the voltage signal is there; if it is, it records and transmits it; if not, it waits for the signal to be detected continually. In a similar manner, it confirms if current is there; if it is, the current is measured; if not, the system continues to monitor. After both signals are acquired, they are sent to the signal conditioning step, where the system determines if the signals are noise-free and within acceptable bounds. If Yes, the signals are processed further; if No, conditioning is repeated until proper signals are obtained.

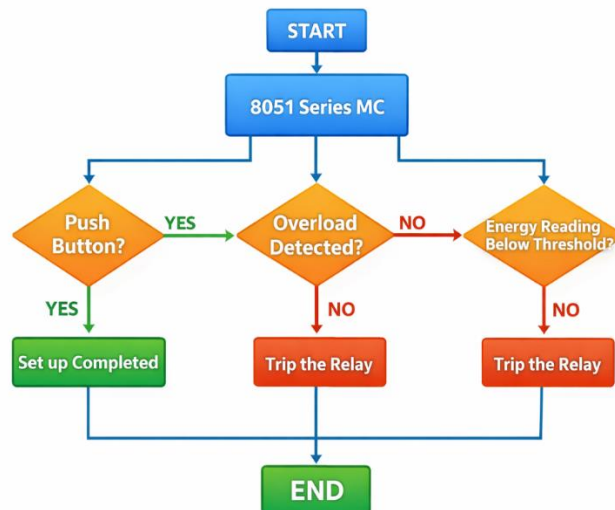


Fig.3- Flow Chart of the proposed system

Following signal conditioning, the system proceeds to the processing step, where it verifies the accuracy of the voltage and current calculations. If the answer is "yes," the system calculates power and energy usage; if the answer is "no," the signals are reprocessed. The system then determines if the measured values are within safe operating bounds in the decision stage. If the answer is "yes," the system keeps running normally; if the answer is "no," a fault situation is detected and the protective mechanism is triggered. When a defect occurs, the system determines if the anomalous state continues. If so, the system resumes regular monitoring; if not, alarms or preventative measures are initiated.

- **Experimental Set up**

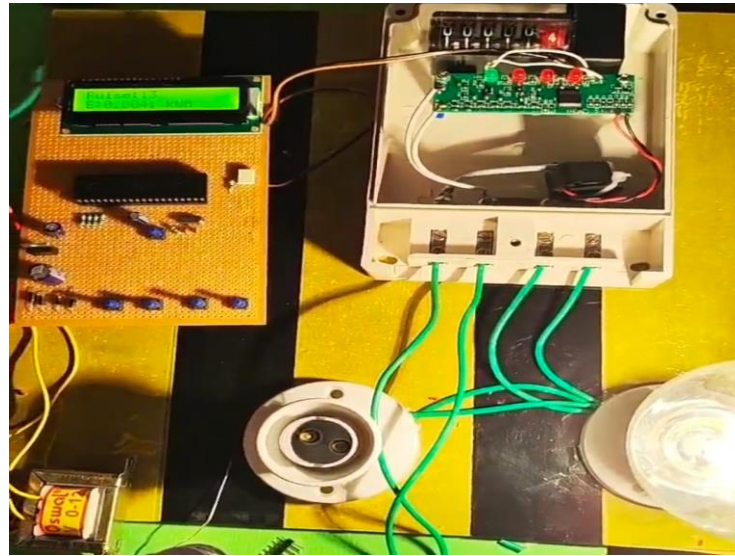


Fig.4- Experimental Set up

## V. RESULT AND CONCLUSION

Sr. No	Pulse Count	Voltage (V)	Energy (kWh)	Bill Amount (₹)
1	9	238	0.028	0.02
2	10	236	0.034	0.03
3	12	235	0.038	0.04
4	14	234	0.041	0.06
5	16	231	0.048	0.08

The Programmable Power Usage Analyzer's observed values show how well the device monitors electrical parameters during load survey applications. It is clear from the collected data that energy usage and the associated bill amount rise proportionately with an increase in pulse count. At a voltage of 238V, the initial reading showed a pulse count of 9, which translated into an energy usage of 0.028 kWh and a bill amount of ₹0.02. Similarly, in the second reading, the pulse count rose to 10 at 236V, resulting in a billing value of ₹0.03 and an energy usage of 0.034 kWh.

Additional measurements reveal a steady rise in power use. Twelve pulses at 235V with 0.038 kWh of energy consumption were recorded in the third reading, and fourteen pulses at 234V with 0.041 kWh and ₹0.06 in billing amount were recorded in the fourth reading. With 16 pulses at 231V, the fifth measurement showed the maximum load condition, resulting in 0.048 kWh of energy usage and ₹0.08 in bills. The pulse count and energy values verify precise load assessment, while the little voltage difference suggests typical supply variations. Overall, the system demonstrated its

applicability for load survey applications by effectively monitoring power usage, calculating energy consumption, and estimating billing.

An efficient and useful method for tracking, evaluating, and improving electrical energy use in a variety of settings is offered by the Power Usage Analyzer for Load Survey Applications project. Important electrical metrics including voltage, current, power, and energy consumption may be measured in real time by the system. The system is suitable for both small-scale and large-scale applications because it uses a programmable controller to assure correct data collecting, processing, and display. Users can quickly comprehend consumption patterns and spot inefficiencies thanks to the combination of sensor components, signal conditioning circuits, and a display unit.

The project's capacity to carry out continuous load monitoring and data logging is one of its main features. This aids in locating peak load situations, odd usage patterns, and possible system flaws. Users can thus take preventative measures to lessen energy waste and prevent equipment damage. Additionally, the system facilitates load survey analysis, which is crucial for companies and electrical boards to plan energy distribution, enhance load management, and create more effective tariff structures..

To sum up, the Power Usage Analyzer is a dependable and effective instrument for contemporary energy management. It supports sustainable development and energy reduction in addition to enhancing system performance and dependability. This study shows how technology may be applied successfully to real-world power monitoring and management problems..

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