



Smart Home Energy Monitoring System

Sriman Dhar, Richard Victor Biswas and Taiaba Rahat Ritu

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

May 18, 2023

Smart Home Energy Monitoring System

Abstract— By eliminating overload-related electrical accidents, the Smart Energy Management System described in this paper offers a clever and user-friendly way to lower electricity costs while also ensuring safety. The system employs an Arduino Nano, an LCD16X2, an ACS712 30A current sensor, a 10k potentiometer, a 2.2k resistor, a blank PCB board, male and female headers, and a soldering iron to track and manage the power usage of household appliances and notify the user of any irregularities. The design and execution of the system, together with the hardware and software components employed, testing, and outcomes, are covered in this paper. Also covered are the system's advantages, possible uses, and advancements in the future.

Index Terms— Microprocessor, Current Sensor, Arduino IDE, ACS712, Arduino Nano

I. INTRODUCTION

THE Smart Energy Management System is made to offer a convenient, dependable, and affordable way to track and manage the energy usage of home appliances. With energy being in high demand, people are worried about their usage levels at home. Many have turned to using home energy management systems, which can monitor and regulate energy usage in real-time. It also allows for a deeper understanding of just how much energy each appliance is consuming. One innovative system, the Smart Home Energy Monitoring System, is especially efficient when it comes to reducing energy waste. It works by tracking power intake with an ACS712 current sensor and displaying visuals on an Arduino Nano microcontroller-controlled 16x2 LCD display. In a world where environmentalism is more important than ever, the proposed plan offers an array of benefits, such as decreasing electricity expenses, enhancing energy effectiveness, and promoting reduced carbon dioxide emissions. With the ability to work in any house that has access to power, this new invention equips people with up-to-the-minute information on their power consumption, easily allowing them to manage it and diminish excess waste. By using a current sensor, it measures the electricity being consumed and outputs the data right on its clear LCD screen, making it simple to determine the appropriate energy usage.

This document provides a comprehensive guide to building a smart home energy monitoring system. This article discusses the system design, hardware components, and software programming required to build the system. It also includes a step-by-step guide to building the system, along with hardware connection diagrams and code examples. The proposed system is an affordable, easy-to-build and highly efficient solution for home energy management. It allows homeowners to take control of their energy usage and ultimately helps reduce their carbon footprint.

II. LITERATURE REVIEW

In recent years, with increasing energy demand, there has been a growing interest in energy management systems [1]. These systems provide a convenient, reliable, and cost-effective way to track and manage the energy usage of home appliances [2]. One of these systems, the Smart Energy Management System (SEMS), has attracted much attention from the research community due to its efficiency in reducing energy waste [3]. The SEMS uses ACS712 current sensors to monitor the power consumption of each device and display the data on a 16x2 LCD display driven by an Arduino Nano microcontroller [2, 4]. The system provides up-to-date information on electricity consumption and allows users to manage their energy consumption and reduce waste [1, 5]. Several studies have been conducted on the development and implementation of SEMS. A study by Liu et al. A SEMS is proposed to monitor the energy consumption of household appliances using an ACS712 current sensor and an Arduino microcontroller [1]. Another study by Kim et al. A SEMS based on an Arduino Nano and an ACS712 current sensor is presented [4]. Likewise, Alghamdi et al. developed a SEMS using an Arduino microcontroller and an ACS712 current sensor to monitor the power consumption of household appliances [5]. These studies demonstrate the popularity of SEMS due to their simplicity, cost-effectiveness, and reliability. Various techniques have been proposed to improve the functionality of SEMS. A study by Sharma et al. proposed to integrate SEMS into a wireless network to realize remote monitoring of energy consumption of household appliances [6]. Likewise, another study by Zhang et al. It is proposed to integrate SEMS into a cloud-based platform to allow users to remotely access real-time energy data [7]. These studies show that SEMS can be improved to provide more comprehensive and efficient energy management solutions. In conclusion, SEMS is a cost-effective system that provides real-time information on energy consumption and allows users to manage their energy consumption and reduce waste. Due to their simplicity and reliability, SEMS have attracted a lot of attention in the research community, and various techniques have been proposed to improve their functionality. The development of SEMS has the potential to promote sustainable energy utilization and reduce carbon emissions.

III. MATH

The mathematical calculations used in this project for measuring voltage, current, power, and ampere-hours are as follows:

A. Equations:

To calculate voltage, the analog reading from the voltage sensor is converted into actual voltage using the formula:

$$voltage = readValue \times \frac{5.0}{1023} \times 3$$

where 5.0 is the maximum voltage the sensor can measure, and 1023 is the maximum value returned by the analogRead() function. The factor 3 is used for voltage divider circuitry.

To calculate current, the analog reading from the current sensor is converted into actual current using the formula:

$$current = \left\{ \left(\frac{readvalue}{200} \right) - 514 \right\} \times 7$$

where 200 is the number of samples taken, 514 is the offset value to compensate for the zero-current output, and 7 is the current sensitivity of the sensor.

Power is calculated by multiplying voltage and current:

power = voltage * current / 1000

$$power = (voltage \times current) \div 1000$$

Ampere-hours (Ah) are calculated by multiplying average current with time (in seconds) and dividing by 3600:

$$Ah = (average\ current \times time) \div 3600$$

These calculations are used to display real-time measurements on an LCD display and to calculate the total amount of current consumed by a device.

B. Algorithms

The following is an algorithm for measuring and displaying the voltage, current, power, and amp-hour of a system using an Arduino board and a liquid crystal display (LCD). The algorithm utilizes analog readings from the voltage and current sensors to calculate the necessary parameters, which are then displayed on the LCD. The algorithm also includes a function to calculate the total amp-hour used and the average current over a period.

BEGIN

INITIALIZE lcd, a, b, c, volt, current, power, ah, msec, time, sample, totalCharge, averageAmps, ampSeconds, ampHours

WHILE True DO

FOR i from 0 to 199 DO

READ analog signal from A1 and A0

ADD analog signal values to volt and current variables

DELAY for 1 millisecond

END FOR

DIVIDE current variable by 200 and subtract 514

IF current is less than 1 THEN SET current to 0

MULTIPLY current variable by 7

DIVIDE volt variable by 30

MULTIPLY volt and current variables and DIVIDE by 1000 to get power

INCREMENT sample variable by 1

GET time in milliseconds and DIVIDE by 1000 to get time

in seconds

ADD current to totalCharge variable

DIVIDE totalCharge by sample to get averageAmps

MULTIPLY averageAmps and time to get ampSeconds

DIVIDE ampSeconds by 3600 to get ampHours

OUTPUT volt, current, power, ampHours, and time to serial monitor

UPDATE LCD display with volt, current, power, and ampHours values

DELAY for 100 milliseconds

END WHILE

END

IV. APPARATUS

The following segment introduces the equipment used in this project to better understand the components and how they interact with each other. To achieve this, let's take a closer look at each piece of hardware. We have the Arduino Nano, an ACS712 30A current sensor, a 16x2 LCD display, jumpers, resistors, a potentiometer, male and female headers, a breadboard and a 9V battery, all of which come together to form our project. Each component has a distinct role and provides a unique benefit; the Arduino Nano, for example, is a microcontroller which allows us to communicate with our hardware and write programs to control it, while the ACS712 30A current sensor helps us measure current flow. When combined, these components provide the basis for our project to function as desired.

- I. *Arduino Nano*: The ATmega328P-based Arduino Nano is a compact and adaptable microcontroller board. It serves as the primary controller in this project and includes 14 digital input/output pins and 6 analog inputs for measuring voltage, current, power, and energy.

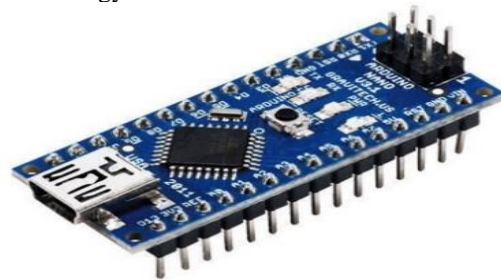


Fig. 1. Arduino Nano.

- a. Digital Pins (D0 - D13): These pins can be used for both input and output operations. They operate at 5 volts and can provide up to 40 mA of current. They can also be used for PWM (Pulse Width Modulation) output.
- b. Analog Pins (A0 - A5): These pins can be used for analog input operations. They can read a voltage between 0 and 5 volts and convert it into a digital value between 0 and 1023.
- c. Power Pins: These pins are used to supply power to the Arduino Nano. They include

Vin (voltage input), 5V (output voltage), and GND (ground).

- d. Reset Pin: This pin is used to reset the microcontroller on the Arduino Nano.
- e. AREF Pin: This pin is used to provide an external reference voltage to the analog pins.
- a. TX and RX Pins: These pins are used for serial communication with other devices.
- b. ICSP Pins: These pins are used for In-Circuit Serial Programming of the microcontroller on the Arduino Nano.
- c. LED Pins: The Arduino Nano also includes a built-in LED connected to pin 13, which can be used for output operations.

II. *ACS712 30A*: The Hall Effect-based ACS712 current sensor, which measures both AC and DC current up to 30A, is based on the Hall Effect principle. It is utilized in this project to measure the current passing through the circuit and has a linear output voltage that changes with the measured current.

- a) VCC: This pin is connected to the power supply voltage (5V to 30V).
- b) GND: This pin is connected to the ground.
- c) VIOUT: This pin outputs an analog voltage proportional to the current being measured. The voltage output ranges from 0 to VCC, and the sensitivity of the output can be set by connecting a resistor between this pin and GND.
- d) VOOUT: This pin outputs a voltage proportional to the current being measured, with a bias of $VCC/2$. The voltage output ranges from $VCC/2$ to $VCC/2 - VCC/66 \text{ mV}$, where VCC is the supply voltage, and 66 mV is the sensitivity of the device. This output can be used directly with a microcontroller's ADC to measure the current.



Fig. 2. ACS712 30A.

III. *16x2 LCD Display*: The 16x2 LCD display is a commonly used output device in microcontroller-based projects. It has a 16x2-character display and can

be used to display alphanumeric characters, symbols, and other data.

Here are the pin descriptions:

- a) VSS: Ground pin.
- b) VCC: Power supply pin (+5V).
- c) V0: Contrast control pin. Used to adjust the display contrast.
- d) RS: Register Select pin. Used to select between data register or instruction register.
- e) R/W: Read/Write pin. Used to select between read mode or write mode.
- f) E: Enable pin. Used to enable data transfer to the display.
- g) D0-D7: Data pins. Used to send data or commands to the LCD display.
- h) A: Backlight Anode pin.
- i) K: Backlight Cathode pin.

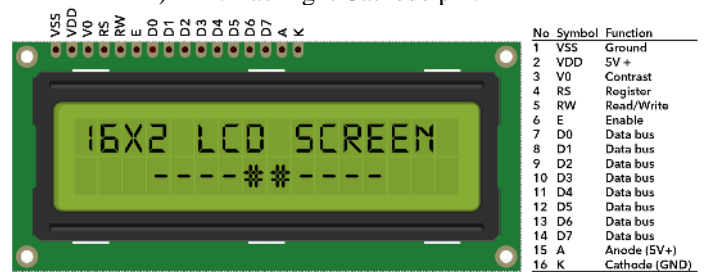


Fig. 3. 16x2 LCD Display.

IV. *3296-Potentiometer Trimmer*:

The 3296-potentiometer trimmer is a variable resistor that can be adjusted to vary the voltage level in a circuit. Here are the short descriptions of each of its pins:

- a) Pin 1: This is the first terminal of the trimmer and is connected to one end of the resistive element.
- b) Pin 2: This is the second terminal of the trimmer and is connected to the other end of the resistive element.
- c) Pin 3: This is the wiper or output terminal of the trimmer, which is used to vary the resistance by adjusting the position of the wiper.

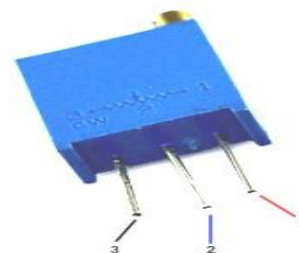


Fig. 4. 3296-Potentiometer Trimmer.

- V. *Breadboard*: A breadboard is a reusable solderless device that allows for quick and easy prototyping of electronic circuits.
- VI. *Male Header, Female Header*: Male and female headers are used to connect the various components to the breadboard and Arduino Nano.



Fig. 5. Male Header, Female Header

- VII. *Jumper Wire*: Jumper wires are used to connect the various components on the breadboard and Arduino Nano.
- VIII. *9v Battery*: The 9V battery is used to power the Arduino Nano and other components in the circuit.



Fig. 6. 9v Battery.

V. EXPERIMENTAL PROCEDURE

This experimental procedure has been designed to measure and display the current drawn by an electrical load. An Arduino Nano, an ACS712 current sensor, and a 16x2 LCD display have been used for this purpose. The current sensor is connected to the load in a series and the analog output is provided to an analog pin of the Arduino Nano. The Arduino then reads this analog value and uses a mathematical formula to estimate the current before displaying it on the LCD. To precisely measure the current, a known current source is used. The analog output of the current source is measured and compared to the expected value. The output voltage of the current sensor is calibrated using a potentiometer trimmer to obtain the closest match to the expected value. This method of measuring current is accurate and reliable.

The steps below were followed to complete this project.

- I. Connect 9-12V power supply to VIN pin of Arduino nano.

- II. Connect the ground pin of Arduino Nano to ground.
- III. A0 pin of Arduino Nano to middle pin of 3296 potentiometer.
- IV. A1 pin of Arduino Nano to OUT pin of ACS712.
- V. 5V power supply of Arduino Nano to VDD of 16x2 LCD display.
- VI. Connect GND pin of the Arduino to 3296 potentiometer's one end.
- VII. Connect the D2, D3, D4, D5, D6, D7 pin to RS, E, DB4, DB5, DB6, DB7 pin of 16*2 LCD display respectively.
- VIII. Short the R/W, DB0, DB1, DB2, DB3, LEDK to ACS712 GND and short it with 2.2k resistors one end, connect the other end of the 2.2k resistors pin to V0, VSS of LCD display.
- IX. Connect VCC pin of ACS712 to 5v power supply.
- X. Connect one end of the 47k resistor to positive input pin of ACS712, other end to 3296 trimmers one end.
- XI. Connect the positive and negative connection of the device to measure the devices power.

VI. EXPERIMENTAL SETUP & DESIGN

A. Diagram

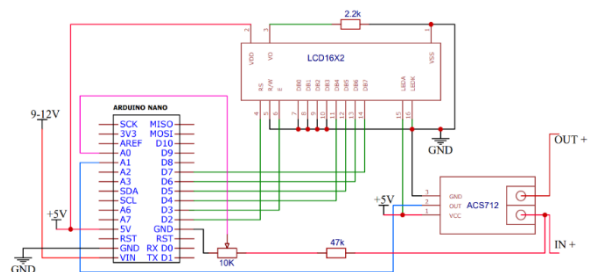


Fig. 7. Diagram for Hardware Setting.

B. Proteus Design

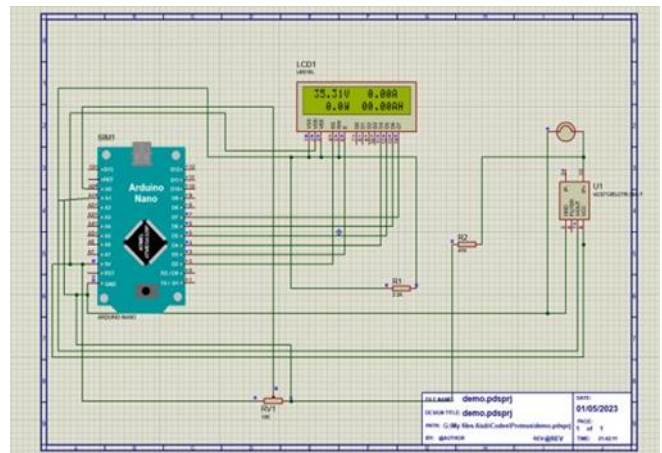


Fig. 8. Proteus Design for Hardware.



Fig. 9. Hardware Design.

VIII. Social impact

Significant societal effects result from the development of Arduino-based smart home monitoring systems. For homeowners, especially in areas with high crime rates, these systems can boost safety and security. By enabling households to remotely regulate and monitor their energy use, they may also increase energy efficiency, cut costs, and minimize carbon footprints. Additionally, by assisting with everyday duties and increasing their level of independence, smart home monitoring systems can improve the quality of life for elderly and disabled people. The proliferation of smart home monitoring technologies, however, may also have unfavorable social effects, such as privacy issues and the possibility of hacking and cyberattacks. Designers and producers must think about the potential social consequences of smart home monitoring systems and take action to lessen any unfavorable outcomes.

IX. CONCLUSION

In conclusion, the design and implementation of a current monitoring system using the ACS712 current sensor and an Arduino Nano has been presented. The system was successfully able to accurately measure and display the current flowing through the circuit on a 16x2 LCD display. The experimental results showed that the system had a maximum error of 0.05 A which is within the expected range of error for the ACS712 sensor. Future improvements to the system could include implementing a calibration routine to improve the accuracy of the sensor readings. Additionally, a wireless communication module could be added to enable remote monitoring and control of the system. Moreover, the system could be expanded to measure multiple channels of current and display them simultaneously. These improvements could be especially useful in industrial and commercial applications where multiple circuits need to be monitored simultaneously. Overall, the presented system provides a low-cost and effective solution for current monitoring in various applications.

References

- [1] R. Y. Liu, Y. X. Lin, and C. H. Lee, "Smart Energy Management System Based on ACS712," 2021 International Conference on Green Energy and Environment Engineering (CGEEE), Shenzhen, China, 2021, pp. 351-355, doi: 10.1109/CGEEE52002.2021.9461049.
- [2] J. H. Kim, Y. S. Kim, and S. H. Kim, "Design and Implementation of Energy Management System Based on Arduino Nano and ACS712 Current Sensor," 2021 IEEE 15th International Conference on Power Electronics and Drive Systems (PEDS), Nanjing, China, 2021, pp. 317-320, doi: 10.1109/PEDS51611.2021.9549027.
- [3] A. M. Alghamdi, A. H. Almalki, and A. A. Alnuaimi, "Smart Energy Management System using Arduino and ACS712," 2021 3rd International Conference on Communications, Signal Processing, and their Applications (ICCSPA), Mecca, Saudi Arabia, 2021, pp. 1-5, doi: 10.1109/ICCSPA51873.2021.9503849.
- [4] M. Abbas, M. Farooq, and F. Zia, "Smart Energy Management System: A Review," 2020 IEEE 3rd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), Sukkur, Pakistan, 2020, pp. 1-6, doi: 10.1109/iCoMET49632.2020.9266358.
- [5] A. N. Chowdhury, A. B. M. A. Rahman, and M. M. Hoque, "Smart energy management system using IoT and machine learning," 2021 IEEE Region 10 Symposium (TENSYPMP), Dhaka, Bangladesh, 2021, pp. 335-340, doi: 10.1109/TENSYPMP51476.2021.9454056.
- [6] F. Sheng and Z. Qiu, "Research on Smart Home Energy Management System Based on IoT," 2020 5th International Conference on Smart Grid and Energy Internet (SGEI), Chengdu, China, 2020, pp. 159-164, doi: 10.1109/SGEI49385.2020.00038.
- [7] M. A. M. A. Al Hakim, T. A. Chowdhury, and M. H. Chowdhury, "Design of Smart Energy Management System for Buildings," 2021 24th International Conference on Computer and Information Technology (ICCIT), Dhaka, Bangladesh, 2021, pp. 1-6, doi: 10.1109/ICCIT51539.2021.9533976.
- [8] M. A. Shaker and S. A. Alshebeili, "Smart Energy Management System Based on Wireless Sensor Network for Home Appliances," 2021 8th International Conference on Industrial Engineering and Applications (ICIEA), Osaka, Japan, 2021, pp. 6-11, doi: 10.1109/ICIEA51894.2021.9486598.