Development of Energy Measurement System for Electrical Vehicle Battery Using Arduino

Peeyush Garg, Deepika Bansal, Souvik Khan, and Siddharth Bhattacharya

Abstract Automobile sectors are shifting toward battery-powered electric vehicles from of fuel-based vehicles. Major drawbacks of fuel based vehicles are air pollution, sound pollution and uneven hike in petrol–diesel's prices. These tend the automobile sector to an alternate solution as electrical vehicles. The battery-based vehicles are free from air and sound pollution. The electric battery supplies energy to electrical motor, tends to move the vehicle. The existing e-bike and e-car are using diverse types of battery as source of power. Varieties of batteries have been used in electrical vehicle. The operating DC voltage and current in EVs are generally high, so an efficient system is required for current, voltage, power, and energy measurement. Present work is to create an electrical energy measurement device, which measures instantaneous voltage, current and power consumed, which is apparently supplied by the electrical battery. The voltage Arduino-based measurement system is used to acquire electrical variables with the help of arrangement of voltage sensor and current sensors. In addition, a temperature measurement sensor is used to measure battery temperature as a safety parameter. All electrical and physical variables are displayed on LCD screen, also can be used for further recording and analysis.

Keywords EV battery · Current sensor · Voltage sensor · Energy measurement · Arduino

1 Introduction

Due to regular uses of petrol and diesel-operated automobile produce a lot of carbon dioxide and other pollutant gasses, these gasses are discharged to the atmosphere, which causes pollution and greenhouse gasses. Also causes various serious health and

P. Garg (✉) · S. Khan · S. Bhattacharya
Department of Electrical Engineering, Manipal University Jaipur, Jaipur, Rajasthan, India
e-mail: peeyush01garg@gmail.com

D. Bansal
Department of Electronics and Communication Engineering, Manipal University Jaipur, Jaipur, Rajasthan, India

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environment issue. So, electric vehicles are being considered as a best alternative to the traditional IC engine vehicles and an effective measure in the direction of saving our mother earth and creating a pollution free environment for the future generation. The electric vehicles are being developed because they produce zero pollution and are cost-effective as compared to other vehicles and due to advancement of battery technology in past few years and efficiency of motors. Now, EV's are moving toward to become a reliable mean of transportation. Varieties of batteries such as lithium ion (Li-ion), molten salt ($Na\text{-}NiCl_2$), nickel metal hydride (Ni–MH), and lithium sulfur (Li-S) used in electric vehicle now a days. Lithium-ion battery is grasping the market due to effective performance and capacity [1, 2].

Electric vehicle generally excited by high-voltage lithium-ion battery sets. These batteries have higher energy density than other batteries, also have some risk factors of catching fire under uncommon situations. It is important to operate the EV batteries in defined safe limits to guarantee the protection of users and the vehicles.

In general, an electrical vehicle comprises different electrical component like battery, power electronics, electric motor, high voltage cable, and integration of on-board charging units [3, 4]. The energy measurement of these component is very crucial for reducing energy losses and can enhance the performance of the battery charging. The electric vehicle battery energy can utilize in best way by digitally monitoring each component energy. The overall performance of the EV is depending on how the vehicle been driven. The EV charging station is not available like petrol, diesel, and gas pumps, so the measurement of the battery energy is especially important for reaching the destination based on energy available in the battery [5].

2 Methodology

The simplified electrical vehicle system comprises the battery unit, motor unit, and wheel arrangement as shown in Fig. 1. The battery unit comprises the battery, electric cables, and integration of on-board charging units. The motor unit has power electronics, electric motor. The wheel arrangement is responsible for the movement of vehicle. The battery unit provides electrical power to the motor unit; motor unit converts electrical energy to mechanical energy. Then, the rotational mechanical energy provides to wheel unit.

The proposed system is energy measurement unit, which is connected after the battery unit and before motor unit as shown in Fig. 2. The proposed system is an additional attachment in between the battery unit and the plug. The system is portable,

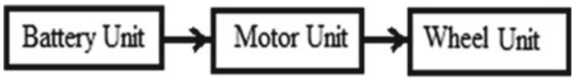

Fig. 1 General block diagram of electrical vehicle system

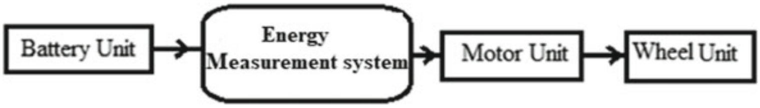

Fig. 2 Block diagram of proposed energy measurement unit

durable, and easy to use. The controller used in measurement system is Arduino Uno. The systematic pin diagram of Arduino Uno board is shown in Fig. 3.

The energy measurement unit is primarily used to measure the current through and voltage across the battery. Further, it is used to calculate the power and energy consumption. The instantaneous power is multiplication of instantaneous current and instantaneous voltage. The instantaneous energy is the accumulative power consumption over a period [6, 7].

$$p(t) = v(t) \times i(t)$$

$$E(t) = \int p(t)\mathrm{d}t$$

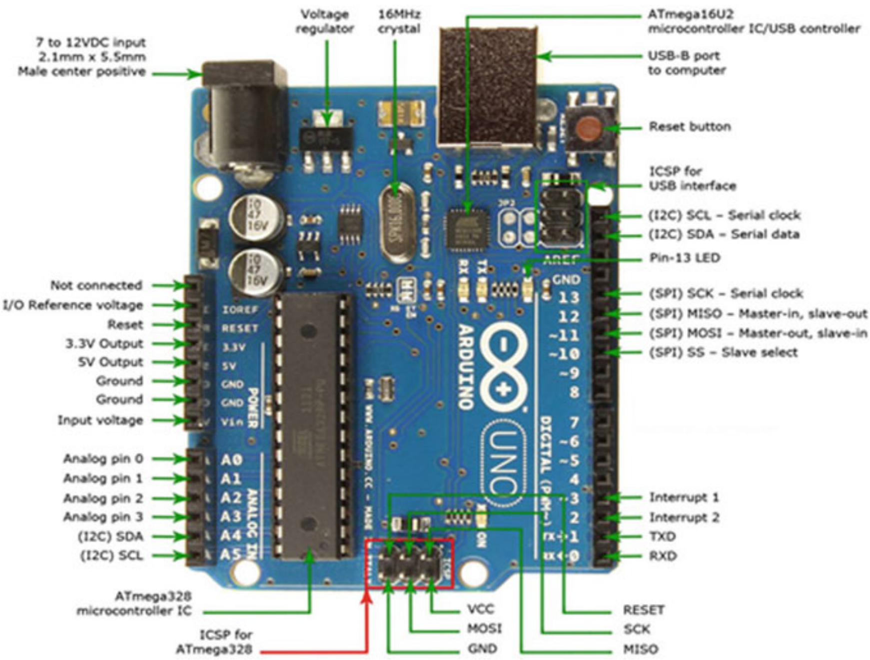

Fig. 3 Systematic pin diagram of Arduino Uno board [8]

The proposed system continuously measures system variables such as voltage, current, and temperature for the EV battery. This system can be further used to ensure the safe operation over the time by adjust cooling and triggering other safety schemes to close down operations and reduce the risk associated to battery or EV.

3 Implementation

The energy measurement unit uses Arduino Uno controller board, LCD panel, two voltage detector sensors, and two and more current sensors [5, 6]. The current sensors and voltage sensors are connected to Arduino Uno for battery current and battery voltage measurement, respectively. The voltage detector sensor is connected in parallel to the battery terminal, and the arrangement of current sensors is connected in series of the battery and motor unit. Along with these sensors, a temperature sensor is connected to measure the temperature of battery outer surface. The measured values or sensors outputs are fetched into Arduino Uno board. An LCD panel is connected to the digital pins of Arduino board to display the sensors outputs, temperature, and energy consumed, etc. A push button switch is connected to the digital pin of the Arduino board for the purpose of system reset and change the display screen of the LCD panel.

3.1 Controller Board—Arduino Uno

Arduino Uno uses ATmega328P, which is a microcontroller board. It comprises total 6 analog inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), and clock frequency of 16 MHz, one built-in LED and a reset button, etc. Arduino Uno is a perfect choice for various smart application such as data acquisition and home automation [8–10].

Availability of sufficient number of analog pins makes it a perfect choice for energy measurement device for EV battery system.

The four analog pins $A0$, $A1$, $A2$, and $A3$ are connected to output of voltage sensor, output of current sensor 1, output of current sensor 2, output of temperature sensor, respectively. These sensors are powered by +5 V, from available supply pins +5 V and GND on Arduino Uno board.

Along with these, a push button switch and LCD panel are connected to Arduino Uno board by mean of digital pins. LCD panel is used to display the measurement results.

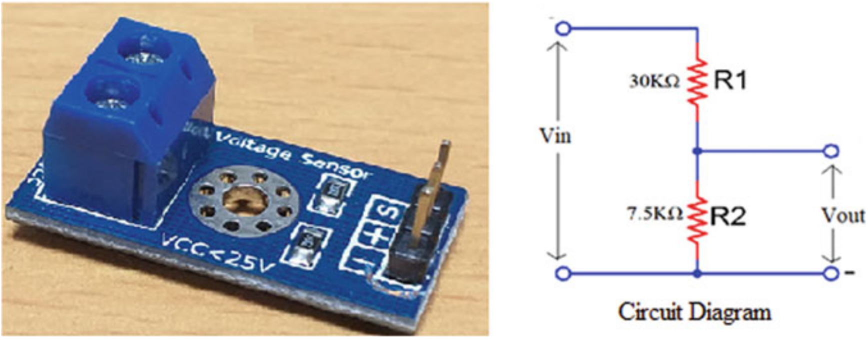

Fig. 4 Voltage detection sensor module

3.2 Voltage Measurement

Generally, existing electrical vehicle battery generates a voltage range of 48 V, and current is in range of 50–60 A for the battery of 3 kW. The battery voltage can be measured using voltage divider method, where the voltage range of 50 V is converted in to in the range of 2.5 V with the help of two voltage sensor of range 25 V. The first voltage sensor is connected in parallel of the battery terminal through plug, which convert the battery output in to divide by 5. Next, voltage sensor again used to measure the output voltage of first voltage sensor, means these two voltage sensor arrangement converts the battery voltage with the gain of 0.04 V/V. Then, the modulated signal of ranging 2 V is fed into analog pin *A*0 of Arduino Uno board. These voltage sensors arrangement also provides the over-voltage circuit protection (Fig. 4).

3.3 Current Measurement

The battery supplied DC current in the range of 50–60 A. In this paper, a parallel arrangement of two current sensors ASC712 of range 30 A is used. The two current sensors are connected in parallel, and the arrangement is connected in series of EV battery. The screw-type terminals of the ASC712 current sensor module are connected in parallel of each other, and arrangement is further cascaded with the motor and power supply unit as shown in Fig. 5.

The Vout pin of the current sensors is connected to analog pin (*A*1 and *A*2) of Arduino board. The maximum possible current in a branch of parallel current sensor arrangement is 30 A, which can effectively measure by a current sensor. The ASC712 works on the principle of Hall Effect and having internal overcurrent protection.

In place of ASC712, non-contact type of current sensor WCS1700 can also use for current measurement. It is an overcurrent detection sensor with short-circuit protection detection module. The current sensor module mainly comprises WCS1700

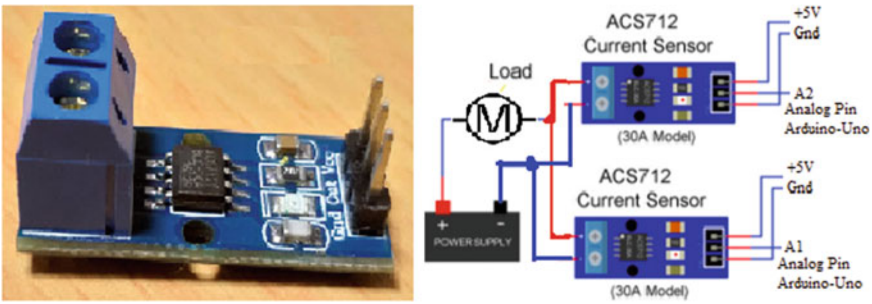

Fig. 5 Current sensor ASC712 and current measurement arrangement

and operational amplifier LM393. The range of current detection is DC ± 70 A AC: 50 A, and current measured resolution is 32 mV/A.

3.4 Temperature Measurement

The temperature sensor LM35 is place on the outer surface of battery to measure the battery temperature. The V_{out} pin of the sensor is connected on $A4$ port (analog pin) of the Arduino board. The sensor LM35 is powered by +5 V, and it is a precision integrated-circuit temperature device.

3.5 Display Unit

A 32 × 2 LCD is connected to Arduino board to display the results. Register select and enable pins of LCD are connected to the digital pins $D2$ and $D3$, respectively. Digital inputs of the LCD panels are connected from pin $D4$ to pin $D7$ digital I/O pin of Arduino board. A 10 KΩ POT is connected to pin 3 of LCD, and its V_{cc} is connected to +5 V, and GND is connected to GND terminal of board.

A digital switch $S1$ is also connected to the digital I/O pin 1 of Arduino board for the purpose of reset the LCD display and change the LCD display screen. The system is programmed in such a way that LCD screen can be changed by pressing digital switch $S1$. The details for the same are given in Table 1.

4 Results Discussion

The designed system is used to measure the real-time current through and voltage across the battery terminal and display on LCD panel initially as shown in Fig. 6. The

Table 1 Display modes on LCD panel

Switch mode	Descriptions
$M1$	Display instantaneous battery voltage and battery current
$M2$	Display time, power consumed, and total energy consumed
$M3$	Display battery temperature

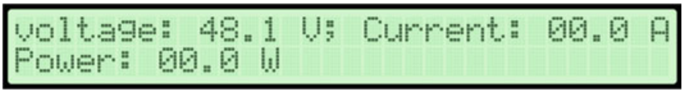

Fig. 6 LCD panel of energy measurement unit

LCD is used to display real-time current, voltage, temperature, power, and energy consumption. The designed energy measurement system is tested on lithium-ion battery, and result displayed on the LCD as shown in Fig. 6.

5 Conclusion

The energy measurement system can be used with any electrical vehicle with suitable sensors selection. The Arduino IDE environment provides a suitable method to acquire the measured values. The measured information can be easily stored and further used to analyze the battery health, alarming, and safety measures. In addition, the proposed system also measures the analog signals like temperature around motor and speed of motor with minor modifications.

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