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IOT Based Battery Management System

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Abstract

Battery is the most essential component of any vehicle. So perfect maintenance of any battery is very much essential for it to function properly. Lead Acid batteries which are more commonly used in the vehicular batteries, need to be efficiently monitored, for it to perform better under all circumstances. So, a more systematic battery management system needs to be implemented so that the performance of the battery can be monitored continuously. When it comes to battery, the two most important parameters are the State Of Charging (SoC) and State of Health (SoH) of the battery. There are several coherent methods to calculate these parameters. But these methods cannot provide correct results, as the battery materials, atmosphere surrounding the battery, the load put on to the battery, will affect these parameters. Overcharging of the battery leads to emission of gases like Hydrogen, Oxygen etc. This Battery Management System (BMS) aims at detecting the emission of these gases from the battery, when it is overcharged, and monitors the other basic parameters such as Voltage, Current, Temperature of the battery using STM controller and sensors. It is also equipped with GPS module, which enables tracking of vehicles. Also these values are displayed in Cloud, which brings the concept of Internet of Things (IoT).

Keywords: Battery Management System, Hydrogen emission, IoT, Overcharging, STM controller

INTRODUCTION

The State of Charge of the battery is the measure of charge that the battery can hold or in other words it indicates the level of charge that the battery currently holds. There are several methods of measuring the SoC parameter of the battery. All these measures have their own disadvantages [1]. If the percentage is correctly measured, there will not be a possibility of overcharging the battery. But since they all have their limitations, there can be situations where the battery is overcharged. In case of car batteries too, the alternators will contain an internal voltage regulator that can provide constant voltage. In case of failure, there can be several hazardous consequences.

As a result of overcharging, there can be emission of gases like Hydrogen, Oxygen, etc. They are produced by evaporation of aqueous solution of the electrolyte [2], which is sulphuric acid. Also there is a great possibility of emission of hydrogen sulphide gas also. These gases are inflammable and create harmful working conditions in industrial areas. In case of a light spark in the vicinity of these gases can create explosion of the battery. Therefore it becomes essential for detection of these gases, in case they are emitted and creating an alert to prevent the battery from overcharging, and thus prevent any hazards. The same scenario can be observed inside a car battery also. So in addition to gas detection system, and the basic parameters like voltage, current, temperature monitored continuously [3], we can also integrate a GPS tracker inside it helps us to track the vehicle wherever it goes. We also enable storing these values in the Cloud, so that it can be retrieved later for analysis and can be viewed anytime in our mobile phone.

MQ-8 HYDROGEN SENSOR

MQ-8 Hydrogen gas sensor is an electrochemical gas sensor that is sensitive to hydrogen gas present in the atmosphere. It can detect various concentrations of hydrogen in the atmosphere and produce accurate results [4]. It offers more resistance when exposed to fresh air. When it is exposed to Hydrogen, the resistance decreases and as a result the sensitivity of the sensor is high. The output voltage can be traced by the change in resistance offered by the sensor when exposed to hydrogen.

Variable load resistance can be achieved with the help of potentiometer. With the help of the sensitivity curve of MQ-8 Hydrogen gas sensor, which is a graph plotted between ppm (at X-Axis) and the ratio R_s/R_0 (at Y-axis) we can determine the concentration of the Hydrogen gas emitted in ppm. The sensor should be properly calibrated before exposing it to fresh air and the gas. The voltage across the sensor is determined by connecting the sensor output to the Analog Input of the Micro-controller. The digitally converted analog value is the output voltage of the sensor. As the output voltage is analogous to the change in resistance of the sensor, by using a simple voltage division rule of two series resistances, we can calculate the sensor resistance. This sensor resistance is calculated with respect to the sensor output when exposed to fresh air as well as when exposed to Hydrogen gas. Here the resistance offered by the gas sensor when exposed to fresh air is R_0 and the resistance offered by the gas sensor when exposed to Hydrogen gas is R_s. The voltage division rule states that, when two resistances say R1 and R2 connected in series, then the voltage across R2 is given by:

$$V_{R2} = (Applied\ Voltage * R2) / (R1+R2) \quad \ldots\ldots (1)$$

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The following figure shows the circuit diagram of a gas sensor:

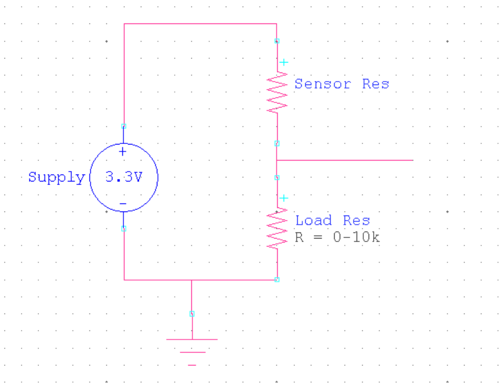

Figure 1. Circuit diagram of a gas sensor

In our case R1 is the sensor resistance and R2 is the load resistance. The load resistance is fixed at some value by varying the potentiometer. When the sensor is exposed to fresh air, then the resistance $R1=R_0$ and hence the output voltage is measured as a digital value with digital resolution bits equal to 10, which means the output value '1023' refers to maximum voltage 3.3Volts of the analog to digital converter present in the micro-controller and the output value '0' refers to the minimum voltage 0 Volts. The value of R_0 can be found by rearranging (1), where $V_{R2}=V_0$, the digital output from the analog to digital converter present in the microcontroller when the sensor is exposed to fresh air, R_L is the fixed potentiometer load resistance which should be undisturbed. The applied voltage is restricted to 3.3 V which is mapped to the digital value 1023 and let the output voltage of the ADC be V_0, then

$$R_0 = ((1023 / V_0)-1) * R_L \quad (2)$$

When the sensor is exposed to the Hydrogen gas, its resistance gets reduced and hence the value R_0 changes to R_s and hence calculated in the same way as in (2). So we get the ratio R_s / R_0 and hence by finding the correlation points [5] from the calibration curve of Hydrogen gas, we can obtain the corresponding concentration of hydrogen in parts per million (ppm). The points in the calibration curve are given in logarithmic scale. So we have to take the antilogarithm of the obtained value of ppm to the corresponding R_s/R_0. Let,

$X1 = \log (R_s/R_0)_{\text{obtained}}$ $X2 = \log (R_s/R_0)_{\text{initial}}$

$X3 = \log (R_s/R_0)_{\text{final}}$, $X4 = \log (\text{initial ppm})$

$X5 = \log (\text{final ppm})$

Then, the concentration of Hydrogen in ppm (parts per million) is given by:

$$\log (ppm) = [(X1 – X2) / \{ (X3-X2) / (X5-X4) \}] + X4 \quad (3)$$

The amount of hydrogen emitted for different amounts of charging voltages is given as follows:

Table 1. Overcharging voltage and corresponding hydrogen emission

Overcharging Voltage for a cell (Charging period = 1Ah)	**Hydrogen emission**
14 Volts	226.02 ppm
14.4 Volts	554.72 ppm
16 Volts	947.65 ppm
16.5 Volts	1171.47 ppm
18 Volts	1624.36 ppm
18.6 Volts	2257.14 ppm
19 Volts	3251.25 ppm
20.5 Volts	3622.59 ppm
22 Volts	5714.97 ppm
23.6 Volts	8201.03 ppm
24 Volts	9106.32 ppm
24.4 Volts	9737.19 ppm
25 Volts (ALERT ISSUED)	10001.23 ppm (1% in air)

MEASUREMENT OF BASIC PARAMETERS OF BATTERIES:

When it comes to Battery Management System, monitoring the basic parameters of the battery is very much essential. The basic parameters of the battery include voltage, current, temperature of the battery [6]. These parameters are very important and needs to be measured periodically.

Measurement of Voltage and Current:

As the battery is charging, the voltage of the battery by any means, will not provide the charging status or charging voltage of the battery. The charging voltage and the voltage measured across the terminals of the battery need not be the same. A dead battery which is not connected to any load can show an approximate voltage of 12.5 Volts (in case of Lead Acid Batteries). We need some complex circuitry to measure the charging voltage, or we can use any voltage detection module to measure the voltage across the terminals of the battery.

A simple voltage division network, by putting correct values of resistance, regulating it and then using signal conditioning mechanism that is nothing but using an analog to digital converter, we could easily measure the voltage with the help of the Microcontroller and measure the output. By connecting the battery to a known value of load resistance, we can measure the current produced from the battery. The following figure shows the circuit setup for the measurement of voltage and current of the battery:

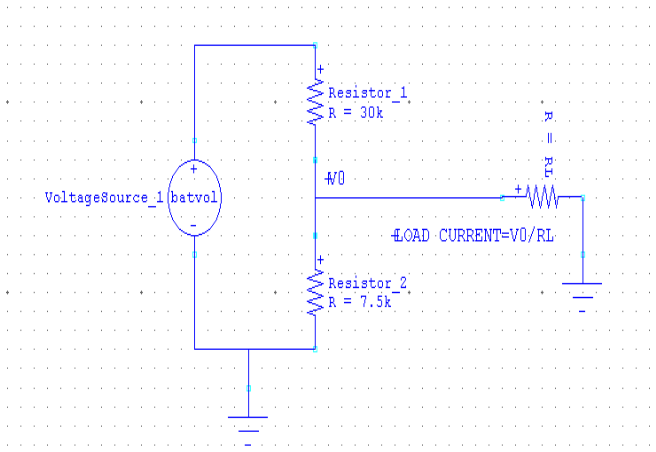

Figure 2. Circuit setup to measure Voltage and Current

We can also implement Hall Effect Current Sensor Module which is ACS712. With the principle of Hall Effect, from the voltage developed when electric and magnetic field cross each other, the current flowing from the battery can be found out. Again by using the analog to digital converter, regulating the input voltage properly, we can give to the Microcontroller and obtain the output in usable form. If V_0 is the output of the ADC, then using the sensitivity of the current sensor, we can calculate the Current offered by the battery at that particular voltage and a particular load. The maximum current sensitivity of the ACS712 is given as 185 mV/A, the current is given by:

$$I = (V_0 - (2^{\text{Resolution Bits}})/2) / 0.185 \text{ Amperes} \ldots\ldots\ldots\ldots\ldots \quad (4)$$

Measurement of Temperature:

The temperature of the battery is a very important parameter, as it decides the current state of the battery. If the temperature of the battery is high, it is a clear indication of the instability of the battery or to be more precise, it depicts the behaviour the battery under abnormal conditions. In order to measure the temperature, we go for the thermistor. The thermistor is a device, whose resistance changes with temperature. Here a negative temperature coefficient thermistor is used, which exhibits a resistance of 10 kilo ohms, under room temperature. This is connected with a series resistance in an voltage divider network and the change in resistance is mapped with the change in voltage between the two resistances, which in turn is analogous to the temperature. This is given as input to the Analog to Digital converter of the Microcontroller and then by using Steinhart-Hart equation, the temperature of the battery is found out. The Steinhart-Hart equation is given as:

$$T \text{ (in K)} = 1 / (A + B * \ln (R) + C * [\ln (R)]^3) \ldots\ldots\ldots\ldots \quad (5)$$

where A,B,C are Steinhart's Coefficients which depends on the type of thermistor used and 'R' is the resistance of the thermistor that is obtained using the same formula as (2). This temperature data is collected and is given to the cloud. The graph plotted below shows the relationship between charging voltage and temperature of the battery:

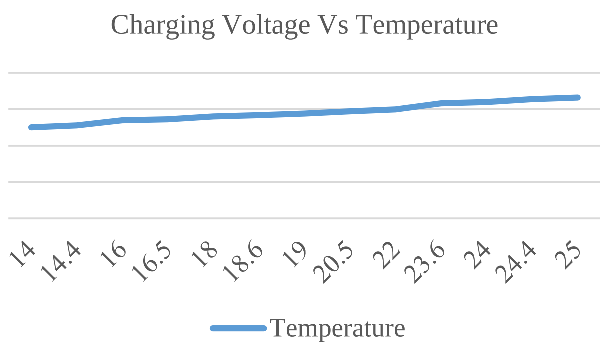

Figure 3. Relationship between charging voltage and temperature

VEHICLE TRACKING USING GPS:

When implemented in a car battery management system, vehicle tracking enables us to track the location of the vehicle by getting the latitude and longitude of the travelling car. In case of a battery mal function, live tracking enables us to find the exact location of the car [7]. The GPS Module used is the U-Blox Neo-6M V2 module. This module is convenient to be used inside the car. Even if our phone is not around, we can easily find out the location of the car. If the GPS is not getting a valid fix, it shows invalid data in the NMEA (National Marine Electronics Association) commands. It is indicated by a series of commas, and a value 'A' in most of its commands. Once it gets under three plus satellites, a blue LED will start blinking.

Once the GPS gets a proper fix, the NMEA commands will start to have the value 'V' which depicts values from a proper fix. From a series of five NMEA commands, which are serially transmitted to the Microcontroller, the required command where the latitude, longitude is displayed is extracted. The latitude and longitude will be in degrees and minutes in fractional format. It is converted into accurate details with exact degrees, minutes and seconds and then sent to the cloud. This helps us to find the location of the car even without the help of our mobile phone. This module is advantageous because it can be interfaced easily with the Microcontroller and then it has got an inbuilt battery storage capability, that will make it convenient to use and interfaced easily.

The following figure shows the typical block diagram of GPS (Global Positioning System) and Microcontroller interface:

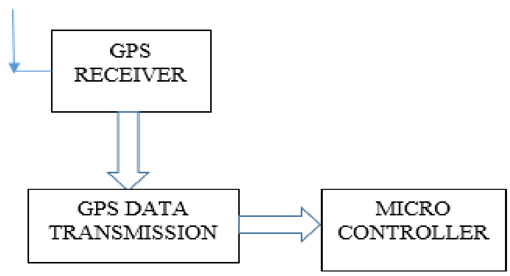

Figure 4. Block diagram of GPS and Microcontroller interface

SENDING DATA TO CLOUD

Internet of Things is a very fast growing technology. Integrating the battery management system with IoT enables us to view the data obtained from the batteries anywhere with the help of our Mobile phone or it can be saved in Cloud and retrieved anytime for analysis. This feature is enabled by using a GPRS module, which will collect the data from the controller and display it in cloud via any of the available bearer services. The GPRS can be checked by sending the AT commands to it.

By fixing appropriate delays, the request and response messages from the GPRS is fed to the Microcontroller and data is received from Microcontroller and sent to the GPRS. The values are posted in the website server, which is specified in the bearer services of the GPRS. Once the connection with the bearer is established, the data can be transferred to the website and then monitored online. We have to provide the URL of the website in which we need to post while configuring the GPRS. The GPRS module is powered by the 12 V adapter. The following figure shows the block diagram of the interfacing between GPRS module and the Microcontroller:

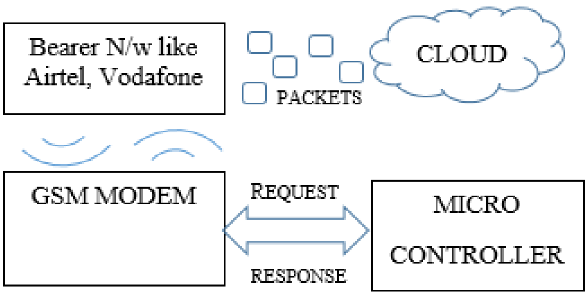

Figure 5. Block diagram of GPRS and Microcontroller interfacing

We need to first attach the GPRS and then give the connection type as GPRS and set the bearer parameters. Then we need to provide the IP address or URL of the website server. We then have to give the action that we need to perform with the GPRS, which is either GET or POST. Once everything is done perfect, the values obtained from the sensors and modules will be posted in the website server [8].

FUTURE SCOPE

The above architecture can be integrated with mobile phones and hence an Android application can be built to view this data. Also using a GSM Modem, we can collect this raw data and sent as an SMS message to mobile phones. With the help of mobile phones, the data can be collected and viewed even from remote locations, where Internet connection is weak. This prototype can also be extended for multiple battery monitoring system.

CONCLUSION

This paper has discussed about the detection of Hydrogen gas emitted from the batteries. It aims at providing a very safe atmosphere around the battery, which can help in having harmless environment. Also, the basic battery parameters help in monitoring the battery conditions. Incorporating Cloud and IoT into the Battery Management System will help in analysing the data. This BMS is also equipped with the GPS tracker that will enable tracking of vehicles and hence immediate attention can be provided. Thus, a prototype model was developed based on all these and successfully implemented and tested.

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