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A Device to Measure the Internal Resistance of an Automobile Battery

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Abstract— Battery and battery parameters are very important as far as the automobiles are concerned. Automotive batteries are designed to give high current especially at the time of starting of the engine. Battery parameters like State of Charge (SOC) and State of Health (SOH) are crucial for proper functioning of the vehicle. Internal resistance of the battery at a particular temperature is yet another important parameter for a battery. In this paper, a new device is discussed which calculates the battery internal resistance in a very small interval of time. It is designed as a handheld device and no external power supply is needed for the operation. All the power needed for the operation of device is derived from the battery to be tested. It works on the principle of two pulse discharge method. The battery receives a brief discharge lasting for few milliseconds. The test results conducted in Lead Acid batteries are found to be accurate and repeatable. The response time of the device is less than 100ms.

Index Terms—Circuit Simulation, dip voltage, internal resistance, MOSFET switch, multivibrator, state of charge, state of health
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1 INTRODUCTION

Internal resistance is an important parameter for the performance of batteries. It primarily decides the amount of voltage drop when a given load is connected across the terminals of a battery. Internal resistance also gives information about State of Charge (SOC). SOC can be estimated from the internal resistance if the information about battery internal temperature and age is available [1], [2]. State of Health (SOH) can also be calculated from internal resistance with additional mathematical model, if the battery is conditioned and operating at a specified temperature [3], [4]. The internal resistance will increase with the battery aging and decreases as the battery is getting charged [5]. Unlike consumer electronics batteries, automobile batteries are designed to deliver high load current. So the internal resistance of these batteries will be a few milliohms. The most commonly available solution calculates the internal resistance by discharging the battery for longer duration. This will cause the battery to discharge and thus makes it not suitable for online measurement. A novel device is designed and developed to measure the internal resistance of any high capacity battery based on the pulse discharge method. The battery is discharged twice for smaller time duration in tens of milliseconds. This device gives faster information compared to the similar devices in [6], [7]. It is capable of giving the result within 100ms when the test button is pressed. The double discharge of the battery improves internal resistance measurement by reducing the effect of accumulated surface charge in the battery.

2 PRINCIPLE OF MEASUREMENT

A battery can be modelled in different ways. The simple model is the battery internal resistance model, depicted in Fig.1. Compared to Randless model [5], the capacitive and inductive effects are omitted in the internal resistance model. It helps in measuring the pure internal resistance of the battery. It consists of internal battery voltage V_i in series with battery internal resistance R_i. V_t is the battery terminal voltage. If the battery is not connected to a load the internal resistance will not affect the terminal voltage because there is no current flow. When a load is connected, there will be a drop in voltage depending on the amount of current flowing. This voltage drop is named as dip voltage. This dip voltage is used for the measurement of the internal resistance.

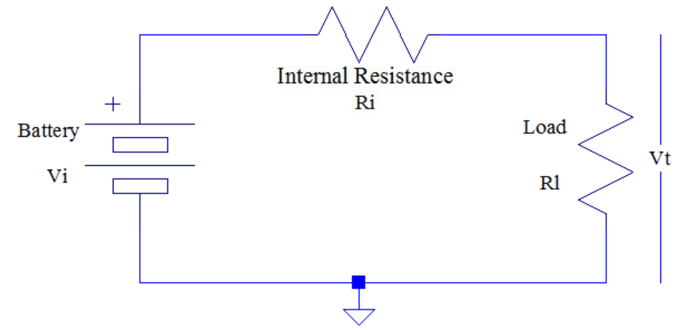

Fig. 1 Battrey internal resistance model

In this work, a new method is used to discharge battery. Instead of single discharge the battery is discharged twice [5], initially for low current (about 25Amp) and then for high current (selectable 150-250Amp). The discharge time can be varied from 10 to 50ms. The Fig. 2 shows the typical battery voltage profile at the discharge. The initial dip voltage is less due to low current and the final dip is more due to high current.

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Dual discharge helps to improve the results since the voltage and current profiles are evaluated under two different load conditions. It also avoids the effect of accumulated surface charge in the measurement [8].

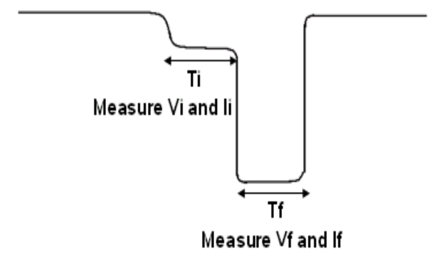


Fig. 2 Voltage dip during discharge

The initial voltage (V_i) and current (I_i) is measured at the last 10ms of initial discharge time (Ti) and final voltage (V_f) and current (I_f) is measured at the last 10ms of final discharge time (T_f). The samples taken at the last 10ms will improve the accuracy of the measurement [9].

The Internal Resistance is given by

$$R_i = \Delta V / \Delta I$$

$$R_i = (V_i - V_f) / (I_f - I_i)$$

The battery discharge profile is a square pulse [3]. The duration of pulse is very important in the accurate calculation of the internal resistance. Smaller time interval gives more accurate result. Typical discharge time of about 10ms gives the accurate information about the internal resistance [10].

3 DEVICE BLOCK DIAGRAM

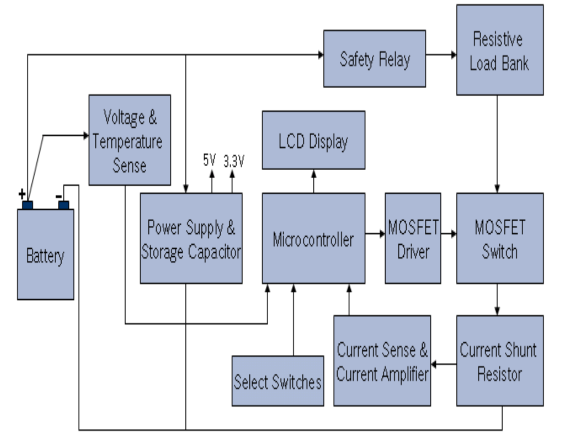


Fig. 3 Device block diagram

Initially the design was performed with the device block diagram, depicted in Fig.3. The device uses two battery clips to connect to battery. The positive clip consists of three wires and the negative clip consists of two wires. One pair of thick wires is used for battery discharge and the other thin wires are for powering up the device and sensing the voltage. Voltage is measured by tapping one wire at the battery terminal. The current is measured using shunt resistances connected in serried with the load. A provision is provided for battery internal temperature measurement by using either a thermistor or a resistance temperature detector (RTD).

The power supply for the device is derived from the battery itself. Both 5V and 3.3V are made using the regulators LM7805 and LM 317 respectively. Large Capacitor banks will provide the charge to operate the device while discharging the battery. Four switches and a 20x4 LCD display are available in the front panel. All the function is controlled by a 16 bit dspic33f microcontroller. The connected load across the battery is 50W Al Housed Resistors. The discharge time is achieved by MOSFET switches controlled by microcontroller. Voltage and current sensing signals are given to the 12 bit ADC pins of the microcontroller.

4 HARDWARE DESIGN

The battery is discharged using 50Watt Aluminium housed power resistors. The circuit in Fig. 4 shows the connection of the resistors to the battery. All the switches shown are MOSFET switches in actual circuit and will be turned on/off by the microcontroller. The 0.5ohm load is used for initial discharge and it will give a current of 25Amps. Three 0.05ohm loads are used for final discharge and it will give current ranging from 150 to 250Amps. The shunt resistor is connected in series with the load resistors.

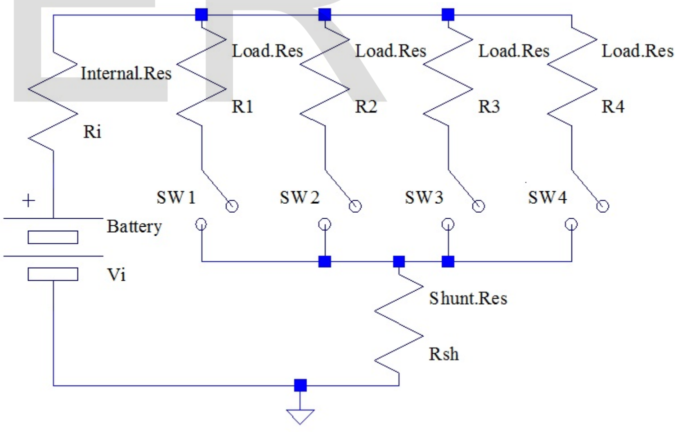
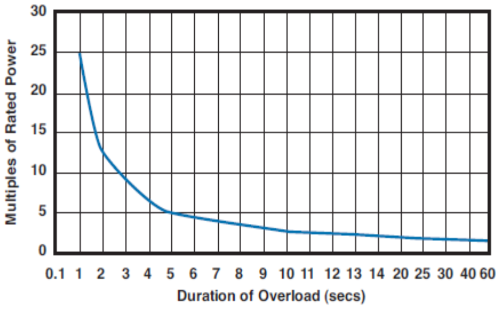


Fig. 4 Battery discharge circuit.

The main concern in the hardware design is the overrating of the components to withstand the high current. The two components which are rated for high current are MOSFET switches and 50W resistors. With reference to the datasheet, for 1 sec the power overload is 25 times.

For 50 Watts, it will be 1250Watts. Maximum current flowing through a 0.05ohm resistance will be 150A. This will be 1125Watts which is less than 1250 Watts. The maximum time for which it will be on is 100millisec. To turn on each load, two MOSFETs are connected in parallel. So the maximum current flowing through a MOSFET will be less than 100 Amps. For 100 Amps, the Power dissipation will be 80 Watts. The used MOSFET is rated for 200Watts.



This graph indicates the amount that the rated power (at 20°C) of the standard HS Series resistor may be increased for overloads of 100mS to 60S

Fig. 5 Rated Power for small time period HS series 50W Al housed resistor

For safety reason, a hardware monitoring circuit using a monostable multivibrator is designed, which allows the resistive load to be connected only for a pre defined time (Set to 100ms). A high current relay is connected in the main power line for emergency shutdown.

Fig. 6 Assembled PCB

5 SOFTWARE DESIGN

The flowchart in Fig. 7 shows the sequence of the program when battery test is selected. There is an option for selecting surface charge removal, load to be connected across the battery and discharge time. The software is designed in such a way that the previous five test results and settings can be stored in the device itself. So after testing, the device can be taken to the work bench and the data can be downloaded through USB. CAN interface is provided to send the data to ECU while testing. The program C code comprises of 2922 lines.

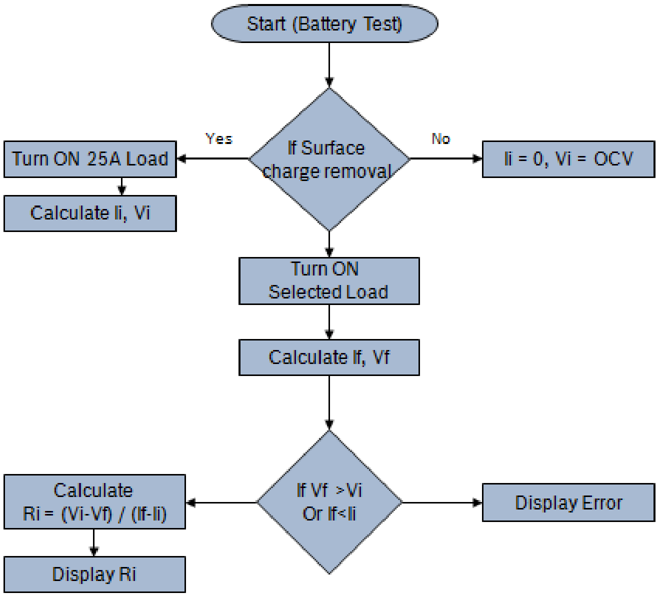


Fig. 7 Flowchart when battery test is selected

6 TEST SETUP

The testing is conducted with different batteries for the validation of the device. Fig.8 shows the set up for offline test at 25^{0}C. The device is connected to the battery using two battery clips. Test is conducted on two EXIDE conservo 60AH batteries.

Fig. 8 Test Setup conducted in EXIDE conservo battery

7 RESULTS AND DISCUSSION

Before testing the battery, the circuit is simulated in LT Spice software. The battery used in the circuit simulation has an internal resistance of 5 milliohm. The simulation result is shown in Fig. 9. Examining this voltage and current profile will give a voltage dip of 1.25V and the current variation of 250Amps. The results are the average value of the last 10 millisecond samples. From the readings, ΔV=1.25V and ΔI=250 Amps. That is internal resistance R_i= 0.05ohms.

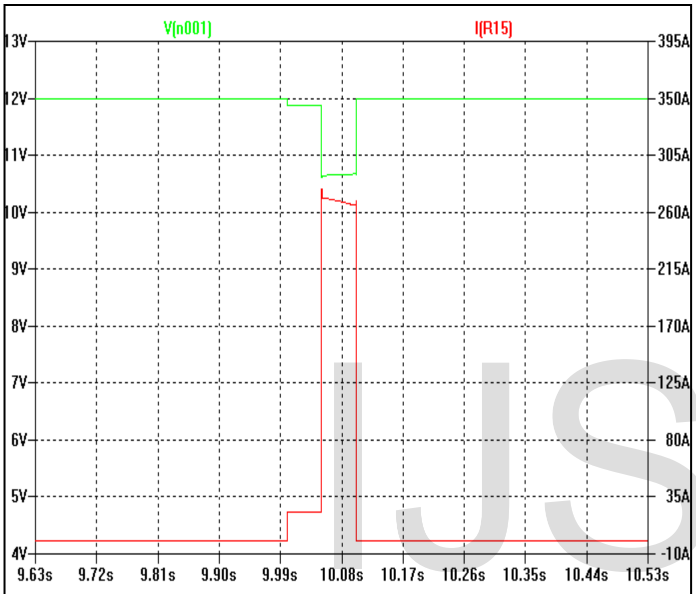


Fig. 9 Simulated current and voltage for 3 Load

The set up shown in Fig. 8 is used for actual testing. The device is connected to the battery using battery clips. It is very important that the contact resistance of the clip or terminal connector should be as low as possible to reduce the further error. While testing, to verify the device measured readings, a clamp meter is connected for the actual current measurement and an oscilloscope is used for the actual voltage measurement. These readings are shown in Fig. 10. It is used as the reference to cross check the device measured readings. The current and voltage measured by the device is shown in Fig.11. The battery is discharged for 20msec. The curves are more stable at the end of discharge pulse [11]. But discharge time is decreased and current is increased in converse to [11] to get more accurate the results. The samples are taken for last 10msec. The time delay between two discharges as in [5] is avoided to get quick and accurate result.

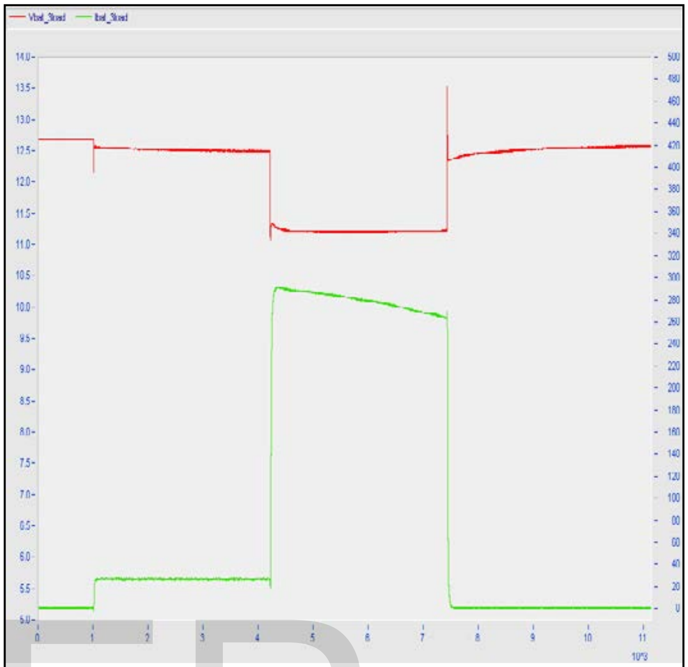


Fig. 10 Actual current and voltage for 3 Load

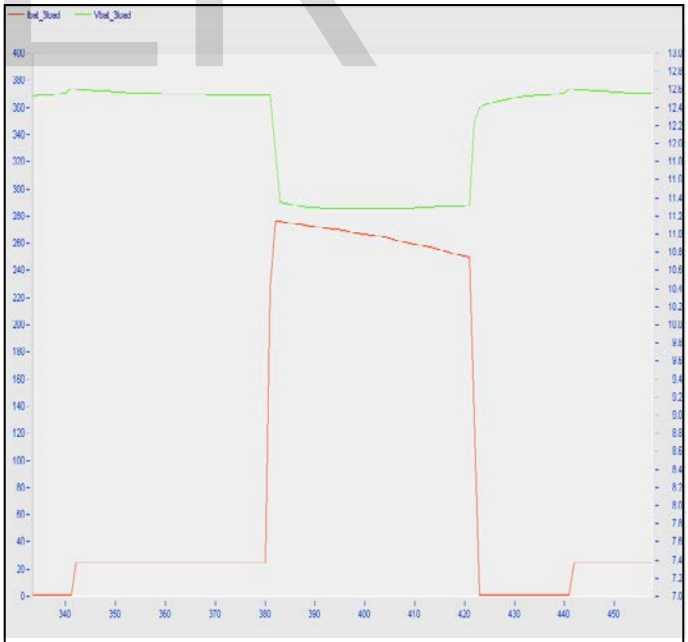


Fig. 11 Device measured current and voltage for 3 Load

From actual current and voltage, the voltage dip is 1.36V and current difference is 258A. So the internal resistance will be 5.27milliohm. The device measured readings giving a voltage dip of 1.35V and current difference of 254A and internal resistance is 5.31milliohm. The internal resistance values obtained are repeatable and depicted in Fig. 12. This test is repeated for both the batteries and is found to give stable results. For the battery1, the maximum deviation is 0.05milliohm. For battery2, the maximum deviation is 0.04 milliohm. There is no effect of surface charge as in the single pulse testing. All the test results are obtained within 100ms.

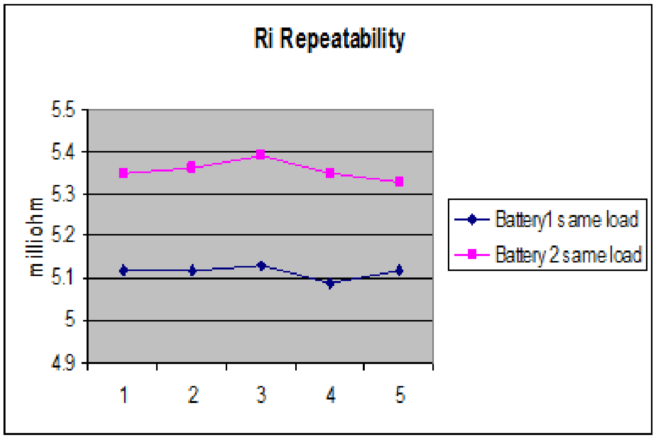


Fig. 12 Repeatability of Ri measurement

This device can also be used when the battery is getting discharged with other set of loads. The battery is tested in the vehicle with and without head lamp to simulate real time battery loads. The test result is given in Fig. 13. From this, it can be concluded that online testing is possible only when the battery discharge current is high. As the discharge current decreases, the error goes increases. For 150 Amps, the test result is showing a deviation of 0.6milliohms. But for 250Amps, the deviation is only 0.1milliohms. If the discharge current is large enough when compared to the other load current, then the device will give accurate information about internal resistance while online testing.

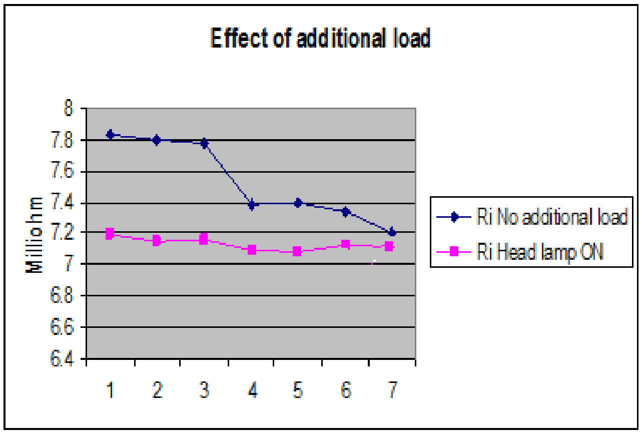


Fig. 13 Effect of additional load in the measurement

8 CONCLUSION

The device discussed in this paper measures the internal resistance of any automobile battery with high accuracy and repeatability. The response time of the instrument is less than 100ms. The device is developed using dspic33f microcontroller. Proper safety features are implemented in the device itself to avoid any hazardous condition while testing. For further development, provisions for temperature sensing, USB and CAN interface are provided in the hardware. The CAN interface can be implemented and used to communicate with the Electronic Control Unit (ECU). This will helps in online estimation of other parameters such as SOH, SOC from the measured internal resistance.

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