Enhancement of Automotive Battery life by Quiescent Current Detection

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ABSTRACT

The use of electronics in the automobiles is particularly concentrated on the improvement of performance parameters, comfort and safety conditions. The more complexity in circuits may cause failures. The energy perspective for the application of the electronics in automobiles is targeted on the battery as the battery is the only source of power in the idle condition. The common issue faced by the automobile industry is the energy loss in battery due the Quiescent current. The Quiescent current is the fact that represents the loading on the battery even when all loads are put off. The immediate effect of the Quiescent current is the ignition problem. The passive effects mainly include the loss in Ampere-Hours. This paper is dealt with the design of a conceptual circuit to detect the presence of faults and suitably indicate the failures in the electronic devices in the automobile by various perspectives

Keywords---Troubleshooting, Quiescent current, passive loading, battery backup life

I. INTRODUCTION

THE auto industry is one of the largest industries around the globe. It is one of the key sectors of the economy. The industry comprises of automobile and the auto component sectors and encompasses commercial vehicles, multi utility vehicles, passenger cars, two-wheelers, three-wheelers, tractors and related auto components. The industry has shown great advances since delicensing and opening up of the sector to foreign direct investment (FDI) in 1993. It has deep forward and backward linkages with the rest of the economy, and hence, has a strong multiplier effect. This results in the auto industry being the driver of economic growth.

The automotive industry is the industry that focuses on designing, developing and manufacturing, marketing and selling the motor vehicles. In the year 2008, more than seventy million motor vehicles were produced worldwide including cars and other commercial vehicles. In the year 2007, the total number of new automobiles sold is more than seventy one million [1].

The automobile industry is going through a technological change where each firm is engaged in changing its processes and technologies to sustain the competitive advantage and provide customers with the optimized products and services. Starting from the two wheelers, trucks, and tractors to the multi utility vehicles, commercial vehicles and the luxury vehicles, the automobile industry has achieved tremendous amount of success in the recent years. In the current decade, the recent trend of increasing sophistication and empowerment of the consumer has led automakers to identify new and more specialized markets within saturated markets with diverse customer bases. Another trend is to infiltrate new emerging markets, which has further motivated the establishment of production facilities overseas and the establishment of global alliances and commercial strategic partnerships with foreign automakers.

The invention of electronics has made the technology more advanced. The principle behind electronics is the flow of electrons in a semi conductor. Very large and complex control systems can be easily integrated into a small chip by using electronic components. The primary advantage of electronics is the size and cost. The electronic components are also programmable which extends its application in wide ranges and mostly in every possible sector.

Safety applications have the goal to ensure that no harm is done to humans in or around the vehicle. The safety applications are built into the vehicle, so even if safety applications target individuals it is a set of vehicle centric services. Applications aiming at the handling and dynamics of the car are generally referred to as drive-by-wire systems. Some of these aim at improving the drivers' feel for the vehicle; others aim at improving vehicle dynamics like braking range and stopping range. By-wire control applications include systems like non-locking brakes (ABS), electronic stability programs (ESP) and electronic control of combustion in engines. Navigation/Driver support applications have the goal to assist the driver with tasks associated with driving the vehicle. Navigation applications have exploded from the introduction of the GPS-system. Communication applications have been around for a while in the shape of cellular phones and computer networks. The goal of these applications is to get and send information between individuals, which classifies them as back-seat applications. The infotainment applications are back-seat services that integrate consumer electronics in the automotive environment. Cars can include video screens, game consoles and audio systems, almost anything that you can find in your home.

The immediate effects of electronic faults are mainly ignition problems and failure of components. These faults have their effect on the battery which is used as the source of power for all the components. The effect of fault on a battery is the loss of energy from the battery of passive loading. The main objective of this thesis is to design a conceptual circuit to identify any fault in the electronic components in an automobile.

II. Electronic Faults Detection

The primary problem in the application of electronics in automobile systems is the occurrence of faults. The faults in the electronic components are mainly identified by their increased current consumption during working conditions or by the quiescent current at the vehicle off conditions.

A. Quiescent current

The Quiescent current is the current consumed from the battery at vehicle off conditions by the components that have any fault. The expected reasons for the passive loading on the battery is influenced by the following reasons

- Temperature
- Idle state of alternator
- Comfort devices
- Audio systems
- Mishandling of control units

The other reasons for discharge from the battery are due to the passive loading of the components. The presence of quiescent current in any electronic component leads to the following problems

- Ignition problems
- Sulfation
- Electrolyte depletion
- Energy loss in battery
- Failure of electronics

The basic principle of the fault detection module is to detect the current consumption by the electronic component while the off conditions of the vehicle. The current is detected by using a current sensor. The current sensor senses any small current signals in the load (electronic component) and generates a signal. This signal is to be fed into a microcontroller or any programmable device. The programmable device determines the magnitude of the sensed current. The basic flow diagram is shown in Figure 1.

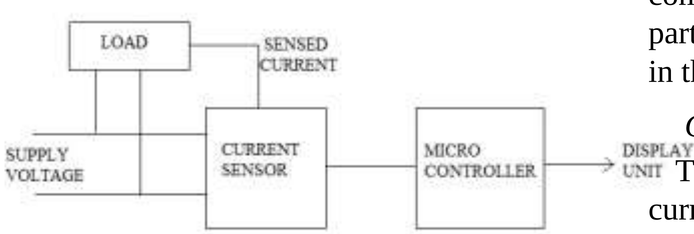


Fig. 1 Basic flow diagram of the fault detection module

The sensed current may be either the current consumed due to the fault or the off state current consumption of the device. For checking whether the detected current is fault current, the current value is to be compared with the tolerance value specified for the particular component. When the sensed current value is more than the tolerance value then a signal is generated from the microcontroller and sent to a suitable display unit to indicate the presence of fault.

III. Selection Of Current Sensor

The current sensor is the main component that is used in this circuit. The sensor should be carefully selected for the purpose considering several factors.

A. Electrical Ratings:

The operating voltage and the current consumed by the sensor should be as low as possible, as the only source of power for the various devices is the battery when the vehicle is in off conditions. When the sensing unit itself consumes more power the battery has to supply power only for this device. Therefore care is taken that the sensing unit consumes low power.

B. Effects of temperature:

Maintaining accuracy over the automotive temperature range of -40 to 125°C can be a challenge for a number of reasons. Additionally, the failure rate of many components accelerates at high temperatures, particularly if there is significant self-heating in the device.

C. Offset stability:

The suitability of a sensor to measure small currents accurately (as well as high currents) is dependent on the stability of the offset voltage. As mentioned above, temperature changes cause offset shift, but a significant contributor is shifts due to remanence effects in the magnetic circuit of the sensor. Reasonably good material can cause a 0.5% shift of output after a significant current excursion. The greater the excursion, the greater the shift of output. Very special material may be twice as good and leave 0.25% of remanent shift. Both open and closed-loop sensors are equally affected by remanence. Only an air circuit exhibits zero remanence.

D. Dynamic range:

The range of the sensor is another important parameter considered. The sensor should withstand the tolerance limits for the specified components. The upper limit should be as low as possible while the lower limit being very low. The dynamic range includes not only the sensing range, but also the operating range of the sensor.

E. Frequency response:

Frequency response is the measure of system's output spectrum in response to an input signal. The operating frequency in this case should be compatible with the oscillator frequency of the microcontroller.

IV. OPERATION OF SENSOR CIRCUIT

The fault in the component is sensed by the quiescent current consumed by it during the off condition of the vehicle. The input for the current sensor is the voltage at the supply terminals of the electronic component during vehicle off conditions. The functional block diagram of the current sensor is shown in Figure 2.

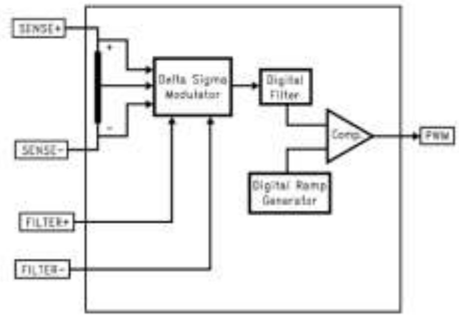


Fig. 2 Functional block diagram of LM3812 and LM3813

The current is sampled by the delta-sigma modulator, as illustrated in Figure 4.1. The pulse density output of the delta-sigma modulator is digitally filtered. The digital output is then compared to the output of a digital ramp generator. This produces a PWM output. The duty cycle of the PWM output is proportional to the amount of current flowing. A duty cycle of 50% indicates zero current flow. If the current is flowing in positive direction, the duty cycle will be greater than 50%. Conversely, the duty cycle will be less than 50% for currents flowing in the negative direction. A duty cycle of 95.5% (4.5%) indicates the current is at I_{MAX} ($-I_{MAX}$). The IC can sense currents from $-I_{MAX}$ to $+I_{MAX}$. Options for I_{MAX} are 1A or 10A. The sense current is given by:

$$I_{SENSE} = 2.2\,(D - 0.5)\,(I_{MAX}) \quad (1)$$

where D is the duty cycle of the PWM waveform
I_{MAX} is the full scale current (1A or 10A).
Similarly, the duty cycle is given by:

$$D = [I_{SENSE}/(2.2\,I_{MAX})] + 0.5 \quad (2)$$

In this IC from(1) and (2), the current is averaged over 50 msec time slots. Hence, momentary current surges of less than 50 msec are tolerated. This is a sampled data system which requires an antialiasing filter, provided by the filter capacitor. The delta-sigma modulator converts the sensed current to the digital domain. This allows digital filtering, and provides immunity to current and noise spikes. This type of filtering would be difficult or impossible to accomplish on an IC with analog components. In the connection of the sensing unit with the component, the suitable IC should be selected based on the operation voltage and current specification of the component. For a high side application LM3812 is selected and for low side application LM3813 is selected. The high side operation is selected in the case to demonstrate the operation. The working is considered in the off conditions of the vehicle. The component should draw zero current from the battery at this condition. In the case of fault, the will be a voltage at the supply terminals. The sensing unit is given input separately from the battery. The input for the I_{SENSE} terminal is taken from the component while consuming current. The presence of such current indicates the existence of a fault and thus activating the sensor (fig 3).

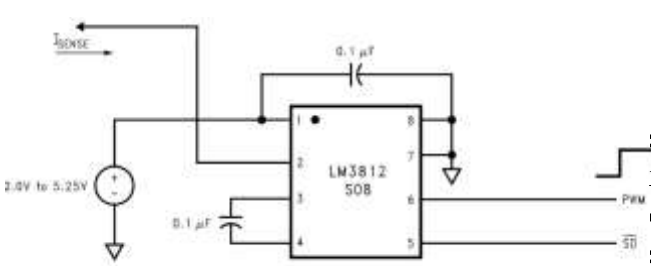


Fig. 3 Application circuit of LM3812

A. Connection details:

The pin 1 is where the supply voltage for the operation of the IC is to be given. The voltage range is usually from 2V to 5.25V.

A bypass capacitor if 0.1 uF is provided across the pins 1 and 8 and grounded.

The pin 2 is connected with the component for which the quiescent current is to be detected.

A filtering capacitor of 0.1 uF is provided across pins 3 and 4

The pin 5 is supplied with a shutdown signal

The pin 6 is from where the PWM output is obtained

The pin 7 is grounded.

B. Calculation procedure of the output value

The input is given through the current sensor. The input to the sensor generates a PWM of a particular duty cycle. The duty cycle can be converted into current using the conversion table for the IC.A sample value of the component with rated current 10 A is selected for evaluation. The voltage input at the terminals is 2 V. Under fault conditions there will be a current discharge from the battery to the component. The unknown value of the current is calculated from the duty cycle generated.

Supply Voltage - 2 V
Rated Current - 10 A
Duty Cycle - 55%

I_{SENSE} = 2.2 X (0.52 – 0.5) X 10
= 0.44 A.

V. CONTROLLER CIRCUIT

A controller circuit is used to evaluate the sensed current whether it is a fault current or it is within tolerance limits. The controller circuit detects the duty cycle of the PWM signal and concerts it into the current equivalent. The ideal tolerance value of the component and the detected value of the component are compared for magnitude variations. When the sensed current value is within the tolerance limit, there will be a null signal. When the sensed value is more than the tolerance value, the comparator sends as positive value. This positive signal is suitably displayed to the personnel in the automobile.

C. Functional block diagram of the controller

A programmable microcontroller is selected for detection of the PWM signal and for the calculations of the sensed current and other values. An ATmega processor AT89S52 is selected. The basic operation of the processor is shown in Fig 4.The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications.

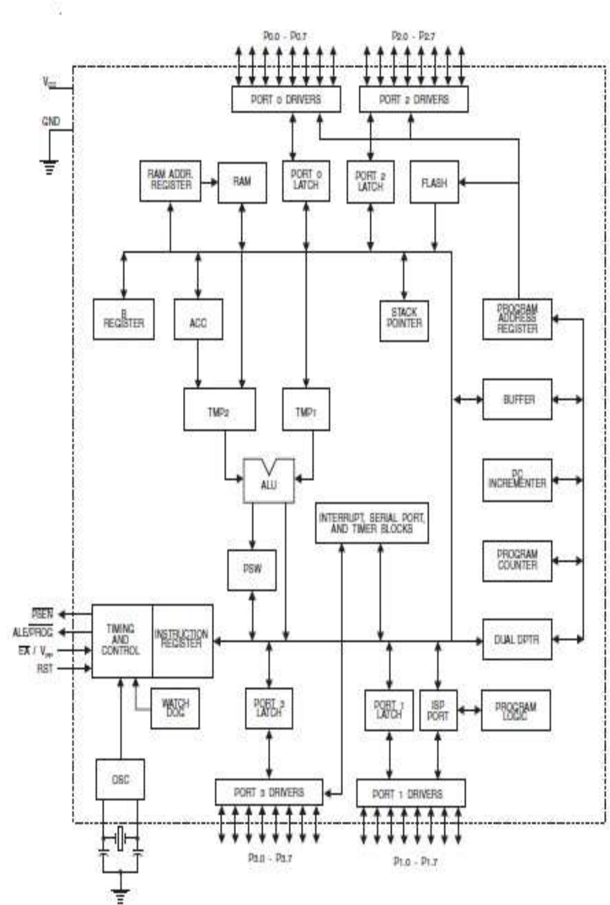


Fig. 4 Functional Block Diagram of AT89S52

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

D. Programming the controller

The device specific values at vehicle off conditions are defined first. The required values are maximum operating current, the current consumption at sleep mode of the device and the tolerance limit are first stored in the controller

The sampling time of the current sensor defines the operating period of the controller. The operation period is the period for which the clock pulse is generated. The clock pulse is generator is a crystal oscillator at a suitable frequency. The frequency of the oscillator is determined by the formula

$$f = 1 / (\text{sampling time})$$

The PWM signal input is fed into a suitable input port of the microcontroller and the on period of the signal is determined.

From the value of T_{ON} the duty cycle of the PWM signal is determined by the formula

$$\text{Duty cycle} = T_{ON} / (\text{sampling time})$$

After determining the duty cycle, this value is used for detecting the sensor current. The current in the sensor input is calculated by using the formula

$$I_{SENSE} = 2.2 \text{ X } (\text{Duty cycle} - 0.5) \text{ X } I_{MAX}$$

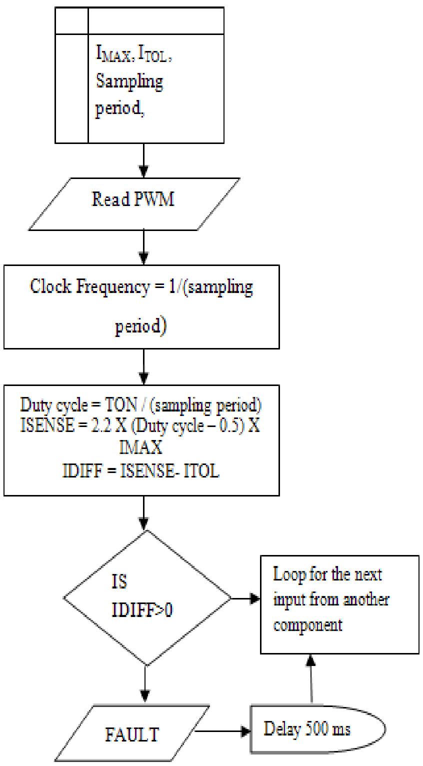


Fig. 5 Flow Diagram Showing Commands

The sensed current in the component may either be the fault current or the off state current consumption of the particular device. The difference between the sensed current and the current consumption at sleep mode of the device or the tolerance limit is to be determined. If the sensed current value is less than the tolerance limit or the off state current consumption value the device is proper. If a higher value is found then there is a presence of fault. When a positive value of the differential current is returned a suitable display unit is activated to indicate the presence of the fault. The algorithm is looped for integration of various components to the microcontroller and the outputs are displayed in the display using a suitable delay program

For the calculation of the fault current, certain values are to be preset into the microcontroller and the current sensor. The maximum operation current I_{MAX}, the tolerance limit I_{TOL} and the sampling period are to be programmed into the microcontroller registry.

E. Fault current calculation

For a sample calculation a car stereo system is selected. The ratings as per the product specification are noted as follows.

I_{MAX} = 10 A
I_{TOL} = 0.8 A

The sampling period of the current sensor is noted from the datasheet

sampling period = 50 ms

To run the microcontroller for the specified time period, the suitable oscillator frequency must be set. The oscillator frequency for 50 ms is calculated as

oscillator frequency = 1 / sampling period
$= 1 / 50 \times 10^{-3}$
= 20 Hz

The PWM output from the current sensor is assumed to operate for 27 ms (for calculation). The duty cycle of the PWM signal is calculated as

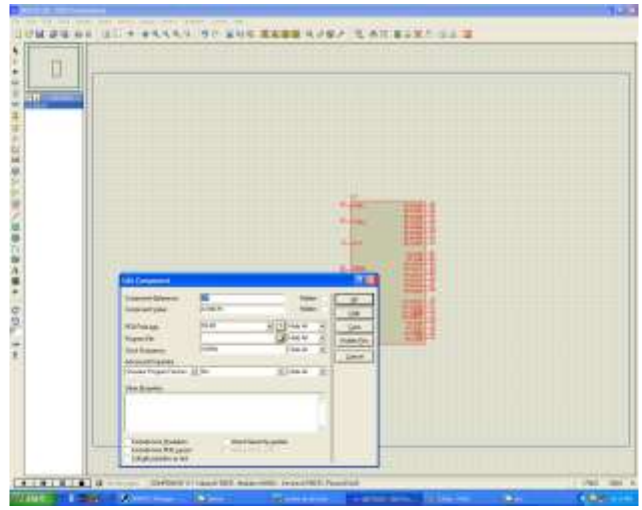
duty cycle = T_{ON} / sampling period
= 27 / 50
= 0.54

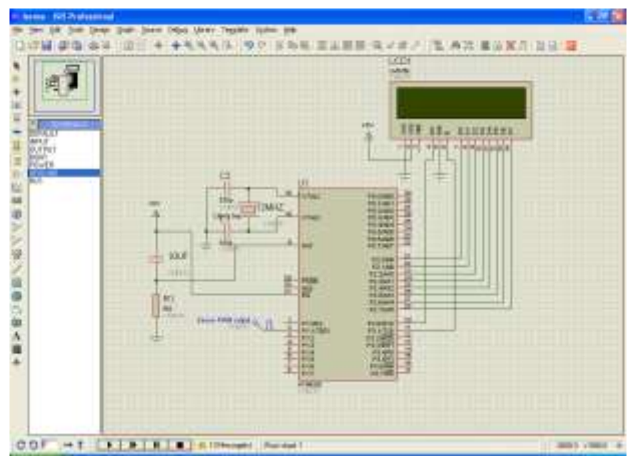
From the duty cycle, the sensor current is calculated as

$I_{SENSE} = 2.2 \times (\text{duty cycle} - 0.5) \times I_{MAX}$
$= 2.2 \times (0.54 - 0.5) \times 10$
= 0.88 A

The differential current is determined whether the detected current is fault current or not.

$I_{DIFF} = I_{SENSE} - I_{TOL}$





= 0.88 – 0.8

= 0.08

The differential current returns a positive value. This positive value is used to run a display to indicate the presence of a fault.

VI. SIMULATION

The The simulation is done using Proteus ISIS Professional software. The components required for the circuit are taken from the Library. The components are searched by keywords in the Library window. The C program to be embedded in the micro controller is previously written using AVR Studio. The saved file is loaded into the micro controller by editing the component properties.

Fig. 6 Loading the program into the micro controller

Fig. 7 Simulation circuit

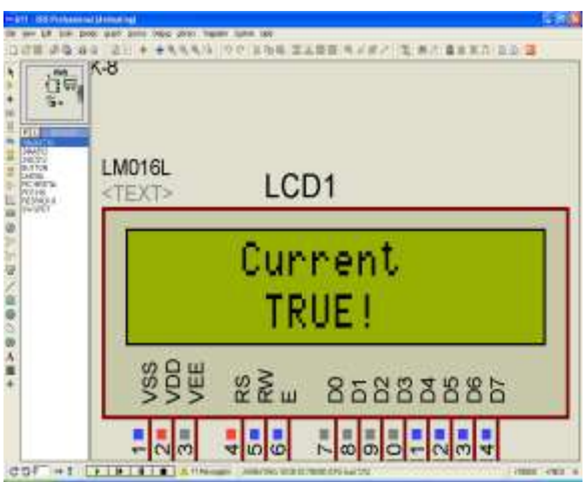


Fig. 8 Simulation under no-fault condition

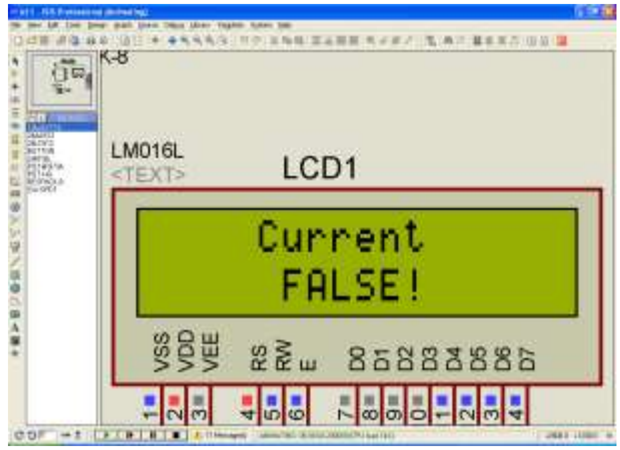


Fig. 9 Simulation under fault condition

VII. HARDWARE IMPLEMENTATION

After obtaining required output values from the software simulation, the proposed circuit is then implemented practically using the hardware components specified in the circuit.

A. Circuit Explanation

The hardware circuit consists of two main parts, the current sensing unit and the controlling unit. The load is connected to the current sensing unit and a display arrangement is made to observe the condition of the system.

Fig.10 Quiescent current detection module

B. No Fault Condition

When there is no fault in the system, the LCD displays "NO-FAULT" and a green light glows to indicate the status of the system. Figure 6.2 shows the system under No-Fault condition. The load used here is a simple lighting. When the system is connected, the load is turned on and the supply to sensing and controlling units are switched on. The system at no-fault condition is identified by the glowing up of green light at the controlling unit and the display at the LCD.

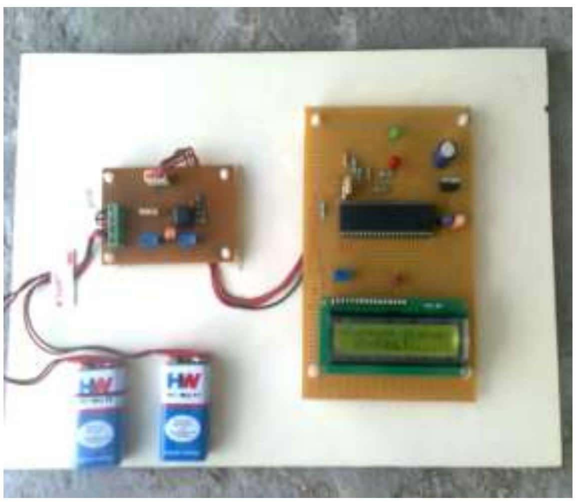


Fig. 11 No-Fault condition

Fig. 12 Display Unit under No-Fault condition

C. Fault Condition

When there is fault in the system, the LCD displays "FAULT" and a red light glows to indicate the status of the system. Figure 6.4 shows the system under Fault condition. The load used here is a simple lighting. When the system is connected, the load is turned on and the supply to sensing and controlling units are switched on. An additional load is applied to the battery to create a fault. The system at fault condition is identified by the glowing up of red light at the controlling unit and the display at the LCD.

Fig. 13 Fault condition

Fig. 14 Display Unit under Fault condition

VIII. CONCLUSION

A basic design of a fault detection module has been framed to determine electronic fault. The design provided here is applicable for an individual component. This simple module easily detects the presence of fault in the device. The further process of development of this thesis in the integration of the module with all the components in the car. The simulation of the current sensor is partly performed till date. The projected work is to simulate the full operations of the current sensor and the microcontroller circuits. The programming of the microcontroller module is coded by using C Program. The validation of the program can be done by compiling using other recent advanced techniques.

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