Development of Electrical Fault Detection System for Low-End Light Motor Vehicle

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Abstract **- In modern cars, there more electrical components, sensors and less mechanical components. It is very much necessary for those electrical sensors to function properly every time for safe driving and understanding of vehicle condition. Due to increase in these electronics and electrical it has become difficult to identify and diagnose any fault in the electrical circuit and sensors as it is more complicated and delicate unlike previous age vehicles. Fault detection system is integrated in cars to automatically identify and diagnose problems related to electronics and electrical component, but it is available in high-end cars. The aim of the project is to make a fault detection system, which will indicate the faulty sensors on engine to the driver by a device named "Feedback return pulse system" (FRPS), so that the user would know exactly which sensor is not functioning in the engine compartment. In addition, project aims a designing of a cheap fault detection system, which can be integrated in low-end LMV vehicles.**

Keywords **- Fault detection, electrical circuit, Sensors, FRPS, and Low-end LMV**

I. INTRODUCTION

Fault detection system is a branch of control engineering, which is used for monitoring a fault, identifying what is actual fault, and pinpointing the type of fault and the location. Our system mainly focus on the low-end vehicle where driver and the passenger does not know the actual problem. This system used in vehicle is to recognize the problem has occurred, even if driver or passenger do not know the root cause. In low-end vehicle most of time driver or passenger does not know the actual problem of the vehicle to detect the location or actual problem, device is used.

The system approaches the fault by two method. A direct pattern recognition of sensors readings that indicate a fault and to analysis of the similarity between the sensors reading. In later, the fault is detected then the LED. In most of vehicle, sensors failures are among the most common failures. So major focus of our system is to recognizing sensors problem as well as process problem. Sensors includes process monitoring the flow, level, pressure, temperature, power, etc. If there is any problem in sensors or process it will be detected by our device FRPS.

II. PROBLEM DEFINITION

A. Conceptual and Technical Problem

New vehicles are loaded with advanced technology designed to keep drivers not in the breakdown lane. A new study by the American Automobile Association found that technology, including maintenance reminders and other safety alerts, has not reduced the number of drivers stranded on the roadside. Breakdowns are actually happening more than ever. AAA rescued a record-breaking 32 million drivers in 2015[1], with more battery problem, engine malfunction etc. this can be because of the failure of sensors and other electrical problems to which driver does not have knowledge of and keeps the car running until breakdown. Engine malfunction is one of top 10 reasons for car breakdowns and this can happen because of not functioning of sensors which gives readings and feedbacks to the ECU from which engine is controlled.

Fault detection system as discussed earlier are devices, which connects to the engine and keep it running to check where and what the fault is. These devices are far expensive for example; a kit of OBD II can cost around two lakhs to 2.5 lakhs of rupees. In addition, now days there are some high-end cars, which have integrated electrical and electronic devices fault indicator system, but such automobiles are of-course expensive. Our project aims at developing a system, which integrates in low-end light motor vehicles for indicating fault in sensors of engine and electrical lines.

Our technical problem was to do the electrical connections taking feedback from the sensors to the ECU. As the automotive wiring and harnessing system, I quiet complicated, it was necessary for us to check the continuity of each wire of the sensors as well as other electrical since some of the sensors were dependent to other sensors or electronics. In addition, the colour coding of each wire is different such as multiple colour codes, etc.

B. Public Survey

When a car breaks down most of the driver and the passengers do not know the problem and end up being stuck in the middle of the road. They have to approach to the nearest

garage, get the car towed or take lift from other vehicles passing by. Here, we took a small survey asking people some questions related to their experience when the car stopped functioning and how many times they actually had knowledge of the cause of breakdown. The survey was conducted by sending a google form online limited to residents of nearby cities which are Mumbai, Navi Mumbai and Thane. Total 258 people took part for the survey and the results we found out is given by the following data. Most of the driver's age was between 20 – 25 years

.As shown in Fig. 1, about 30% of the people did not know at all what the fault was during their car breakdown. It is very important for us to know such statistic as it is helpful for us to create a device for a common passenger car.

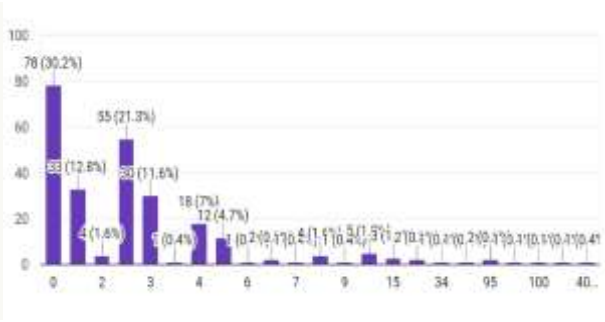

Fig. 1. Fault knowledge graph

About 83% of the people said that they need a system or a device, which will indicate them about such faults and make them aware of it before the car stops working or gives some problem while driving, as shown in Fig. 2.

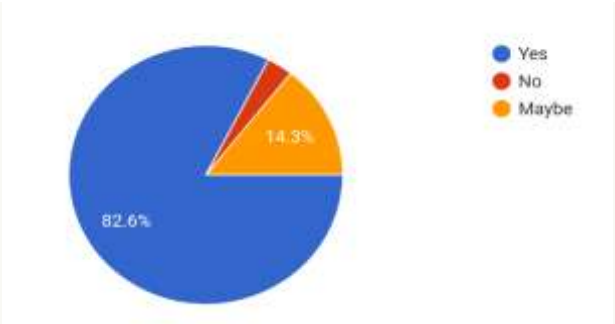

Fig. 2. Surveyors View

We asked all of our surveyors that what such device should cost which will show them electrical engine faults on-board in their vehicles. About 52% of the people said that they would be willing to give money between 1000 – 2000 rupees range. The results are in Fig. 3.

C. Objective

Thus, in this project we aim to design and fabricate a sensor's fault detection device that will indicate the non-working sensor by switching OFF the illuminated LED of the respective sensor thus showing it to the driver for immediate service of the car. The main objectives of Development of electrical fault detection system in low-end LMV are:

- Integrating Electrical Fault detection device for low-end vehicles.

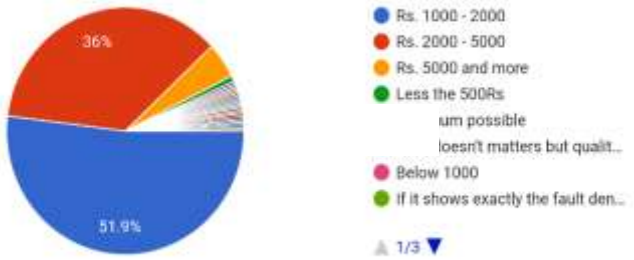

Fig. 3. Cost Review

- To detect the electrical sensors fault in engine compartment of vehicle.
- System, which will make the wiring, fault detection easy.
- To locate, Identify and indicate the fault to any individual.
- To make a cost effective device based on peoples view.

III. METHODOLOGY

A. Starting of Engine

The first and foremost challenge in front of us was the Engine. Since it was only an Engine along with all its other components and the wire harness of the complete vehicle, we first had to understand the colour coding used in the vehicle, location of all the wires, Tracking of the wires and sort the wires accordingly. Once the layout was understood, we initiated working on how to start the Engine. After thorough inspection, we diagnosed the faults, which were Faulty Fuse, Leaked Fuel Pipe Line, Faulty Fuel Relay, Non-Working Speedometer, Odometer, Dashboard Console, Jammed Fuel Pump, Low Coolant Level, No sparks in the Cylinders, Damaged Ignition Coil. The faults were rectified. After all the Efforts, it was identified that the Ignition Coil was the Fault for non-operation of the Engine. After many attempts, we were unable to get a new Ignition coil of that sort hence we could not start the Engine but we knew what the fault is.

B. Checking Continuity of Wire

For tracking the wires from Sensors to ECU, we used a multi-meter [2] and a continuity wire. This was necessary because the wires when passing from the Sensors are sometimes, linked

with other sensors also in order to get Data from the sensor. All the Sensors and Devices in the Automobile are conned to each other via CAN Protocol which is handled by the ECU. The wire layout from the sensor to the ECU is not as simple as it looks in the Diagram but it is far more complex.

After inspecting and tracking all the wires from the sensors and the ECU and inspecting all the wires in the Prototype, we selected some Sensors, which will be used for Demonstrating the Working of our Device. Those are Manifold Absolute Pressure sensor, Throttle position sensor, temperature sensor, ignition sensor, actuator sensor, oxygen sensor. Depending upon the type of sensor and its use, the number of pins in a sensor is defined; it can vary from 1-5 pins per sensor.Table 1 shows the colour codes of wires at each pin of sensors.

TABLE 1
Colour Codes of Various Sensor Wires

Sr. No	Sensors	Colour Codes			
		Pin 1	Pin 2	Pin 3	Pin 4
1	MAP Sensor	Green-Yellow	White-Black	Red-White	Green-Black
2	Throttle Position Sensor	Black-Red	Green-Red	Green-Black	
3	Temperature Sensor	Red-Yellow	Green	Green-Blue	
4	Ignition Sensor		Green	Black	
5	Actuator Sensor				
6	Oxygen Sensor	White			

C. Development of FDS using IC of NOR and NAND Gate

The early plan for installation of our Device was inside the Occupant cabin in front of the driver. Since it was going to be in front of him, the glowing of the device at all time may result as a cause for accidents. Hence, we tried a different approach for the functioning of our Device. For our purpose, we had 2 options of having a NAND Logic Gate or a NOR Logic Gate.

TABLE 2
NAND Truth Table

Input		Output
A	B	NAND
0	0	1
0	1	1
1	0	1
1	1	0

For incorporating a NAND Gate in our device, we shorted the output and the input of the Sensor and provided it to INPUT A. Hence, there were only two cases possible now:

(0, 0) ⟶ 1

(1, 1) ⟶ 0

According to this logic, the Device would glow when there is no input from the Sensor and it would not glow when there is Feedback from the Sensor.[4]

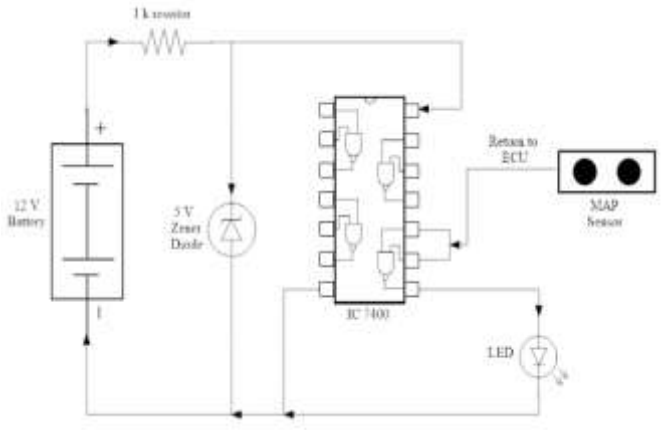

Fig. 4. Circuit Diagram for using NAND gate

As shown in Fig. 4. Four sensors can be attached to one IC, making the device less complex. Pin 1(A1) and Pin 2 (B1) are given a common input from the sensor and the output Pin 3(Q1) is given to one terminal to the LED inside the Device and the other terminal is grounded. In this manner all the inputs from the Sensors are given to the IC. The power to the IC is provided by the battery whose +ve terminal is given to Pin 14 (Vcc) and the –ve of the battery is given to Pin 7 (GND).

TABLE 3
NOR Truth Table

Input		Output
A	B	NAND
0	0	1
0	1	0
1	0	0
1	1	0

Yet another Option for the same purpose could be met. The procedure is same as used in NOR Logic.[5] Table No. 3 shows the truth table for NOR gate.

(0, 0) ⟶ 1
(1, 1) ⟶ 0

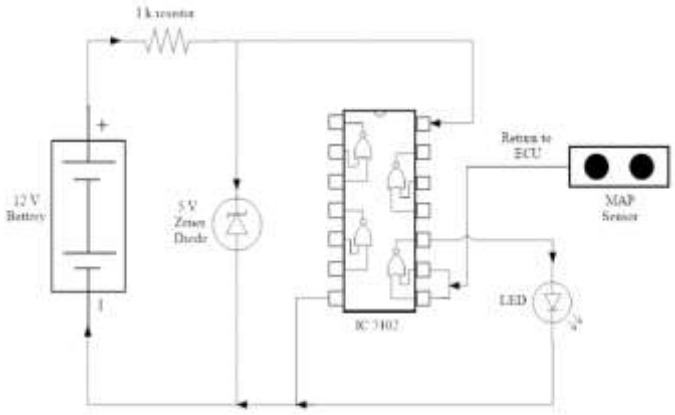

Fig. 5. Circuit Diagram for using NOR gate

The output of the gate is to be sent to one terminal inside the device and the other terminal is to be grounded for the Device to work.

The layout of IC7402 is the Mirror Image of IC7400. I.e. Pin 2 and Pin 3 are given a common input from the sensor, the output Pin 1 is given to one terminal to the LED inside the Device, and the other terminal is grounded.

The power to the IC is provided by the battery whose +ve terminal is given to Pin 14 (Vcc) and the –ve of the battery is given to Pin 7 (GND).The only obstacle in implementing this Technique was the voltage given to the IC.The IC functions at 5V potential difference but the voltage coming from the battery 12V.

Hence, in order to decrease it to 5V, we used Resistors and a Zener Diode to regulate the Voltage.Since there are six Sensors indicated by the device and there can be many more in modern cars; it is not possible to construct gates for each and every sensor inside the Breadboard. It would just increase the Complexity of the Device.

However, we could not incorporate this method into the Final product of the Device Because of the Voltage limitations of the Sensors, which caused into just giving a pulse to the Device and not a continuous Feedback.

D. Development of Fault Detection by FRPS.

In FRPS, it uses sensor's return signal to detect fault. Is uses a simple wiring connection? As the circuit is complete, (i.e. the sensor is attached) the LED of that particular sensor will glow this means that there is no fault in the sensor and its connection. However, in case of faulty sensor or an improper wiring the Led of that particular sensor will not glow. This notifies the faulty sensor or faulty connections.

Each sensor is connected to a LED. The LEDs are connected such way that when the sensor's circuit is completed it will glow. This helps to know whether the sensor is working or not.

The 5V from the ECU act is input to the sensor and the reference is output. This if connected properly completes the circuit for LED to glow. For LED the Return signal from the sensor is the positive input and the other terminal of LED is directly grounded hence the circuit of LED is completed. In case of faulty sensor, the sensor will not give a Return pulse, this will not complete LED's circuit, and hence it will not glow notifying the fault. Even if there is loose, wiring connection the LED will not glow.

In case of Ignition sensor, a signal comes from ECU before the engine is ON and goes to relay completing the circuit. It reverses after the engine is ON. This signal coming from ECU is an input to LED and the other terminal of the LED is connected to the wire going to relay completing the circuit.

In case of O_2 sensor, when the sensor senses the oxygen in exhaust gas it provides a voltage signal which goes to ECU this signal acts as an input to LED which is connected to its return wire and the other terminal of LED is grounded completing the circuit.

In case of Temperature sensor, when the sensor senses the heat (i.e. rise in temperature) it gives the voltage signal which goes to ECU this signal acts as an input to LED which is connected to its return wire and the other terminal of LED is grounded completing the circuit.

In basic, FRPS is a simple, cheap and reliable fault-detecting device. It uses LEDs to notify the faulty sensors. Each sensor is connected to the LED. If the LED glows, it means there is no fault in the system and if a LEDs dose not glows this notifies that there is some fault in the respective sensor.

Components used: LEDs, low gauge single stand connecting wire, 1K resistor and sensors, 12 volts lead acid battery.

All these sensors have different connectivity and different number of wire and accordingly they function. Most of the sensors take 5volts input as reference from ECU and then accordingly give return voltage to ECU. This change in voltage is sensed by the ECU and accordingly ECU operates respective actuator. In sensors the circuit is completed between the 5V input reference and the return signal to ECU.

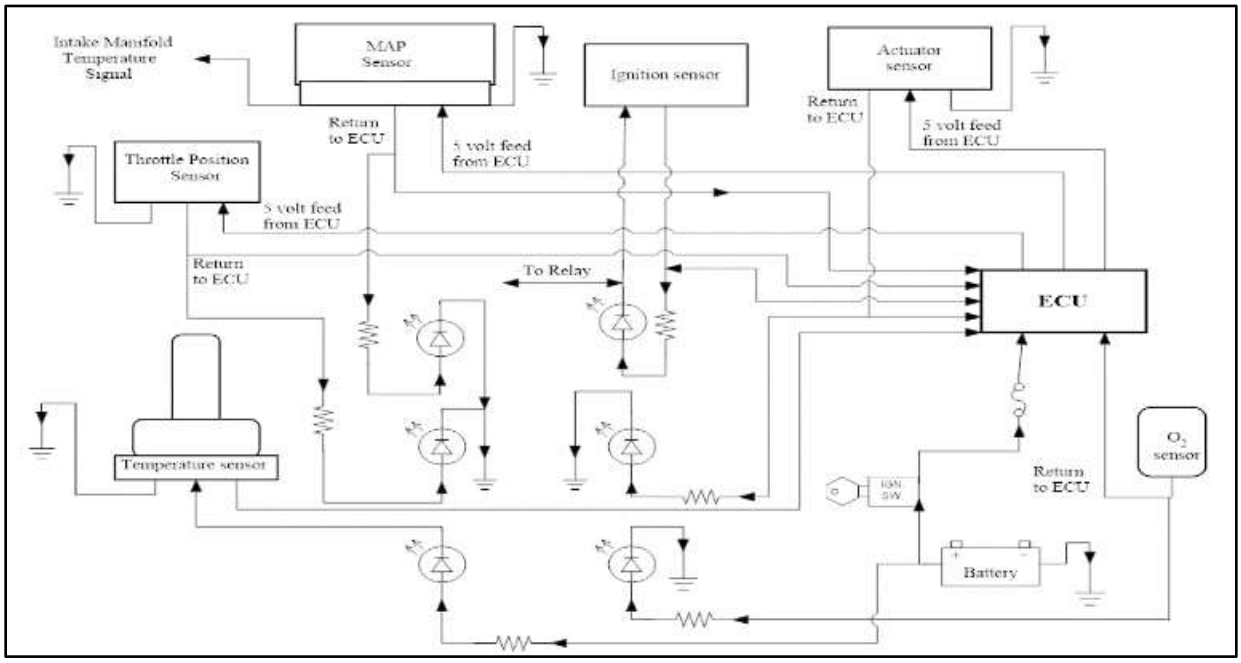

Fig. 6. FRPS Circuit Diagram

Fig. 6. Shows the whole circuit diagram of Feedback Return Pulse system.

IV. DESIGN AND FABRICATION OF FRPS

With the aim to make a low cost, efficient and reliable fault detection device for low end vehicles it was necessary that the device should be as compact as possible and as simple as possible so that any lay person can understand and can identify the fault. The electrical connections had to be concealed so that the device looks ethical. This device has electrical connections therefore the material used in making the device should be a bad conductor of electricity. Hence, selection of material was narrowed down to all insulating materials. A decision matrix [3] was made for various insulating materials based on the following criteria: 1. Cost; 2. Availability; 3. Life; 4. Machinability; 5. Durability; 6. Appearance as shown in Table 4. Hence, according to the decision matrix Acrylic was the vice choice.

TABLE 4
Decision Matrix

Material	1	2	3	4	5	6	Total
Wood	3	5	2.5	3.5	2.5	2.5	19
Acrylic	3	5	4.5	4	4	3.5	24
Polymer	1.5	1.5	5	2	5	4	19
Hard forms	2	2.5	3.5	3	3	2	16
Composites	1	1.5	5	2	5	5	19.5

To make the device portable and compact 3mm thick acrylic sheet was used. Red colour LEDs were used because of good visibility. The device was modelled with Ergonomics and Ethics in designing. The model is made by assembling small acrylic sheet parts. It is made up of all together 12 parts of acrylic. They are Base plate, Top plate, four side plates, Three-partition plate, onemiddle plate, two side plates for LEDs.

All the wiring is concealed between middle and base plate and is carefully insulated. The top plate has the names of sensors grooved according to the position of LED which is connected to that particular sensor. The middle plate has three partition plates which separates the lights of LEDs attached. LEDs are attached to two side plates, which are mounted on a middle plate.

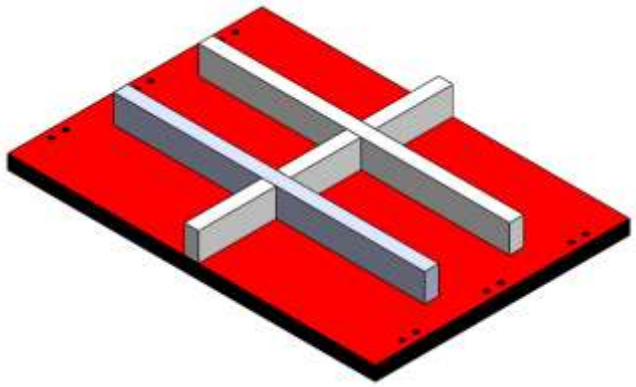

Fig 8. Partition over Middle plate

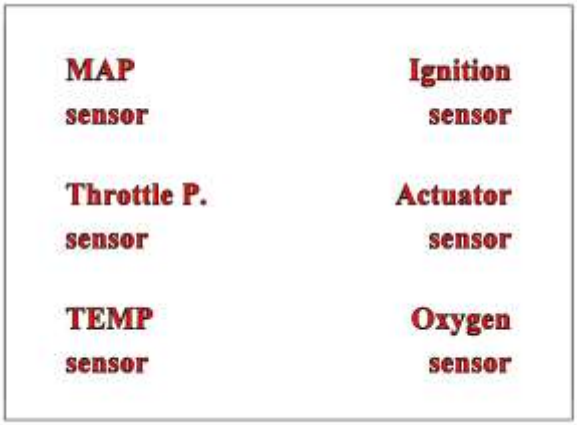

Fig. 9. Faulty Sensor Indicator

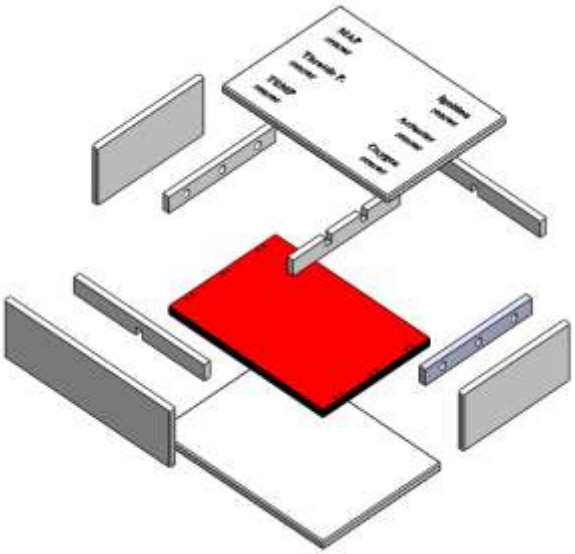

Fig. 10. Exploded View of Model

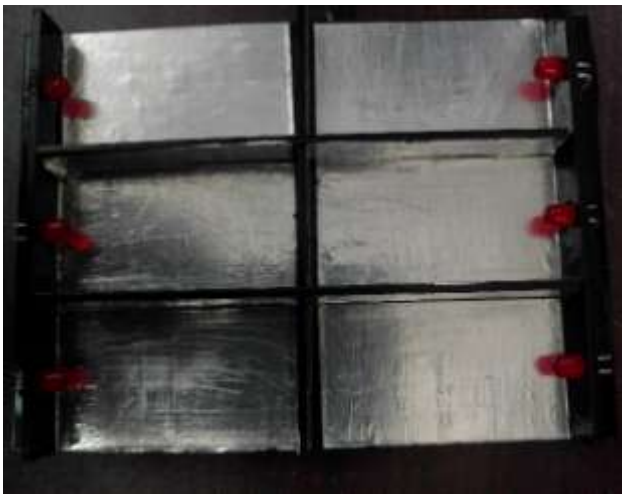

Fig. 11. LED fixed with grid plates and reflective material

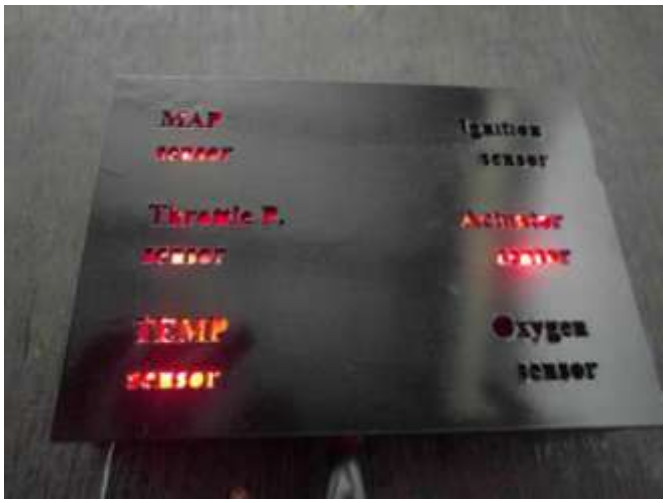

Fig 12. Working of device

V. TESTING OF FRPS

Since the engine was not working, the device was tested by the very basic method. To test the device all the connections were made through the ECU and relays. The power source is a 12V battery which is used to run the car as always.As soon as the ignition switch is turned ON, the lights of the MAP sensor, Actuator sensor and Temperature sensor glows up. Throttle position sensor works when acceleration is given to the pedal by the driver so, the LED glows when throttle is given to the engine and the sensor works based upon its feed. The very basic method for testing was to simply unplug the sensors from its connection on the engine and disconnecting it from any feed or reading. As soon as the sensor is unplugged the LED of respective sensor glows OFF or switches OFF indicating that the respective sensor is damaged or not working

VI. COST ESTIMATE

Since, our main objective was to make a device, which is cost effective and so we did the survey. Our focus was to design and fabricate a device, which can cost in between Rs.1000 to Rs.2000, which is according to surveyors cost review. Cost breakup in making of our device is shown in table no. 5.

Table 5
Cost breakup

Component	Cost in Rs.
Material	200
Machining	100
LED	12
Wires and connection	120
Consumable	20
TOTAL	452

The cost estimated here is the project cost but if the device goes for mass manufacturing it will be cheaper than this. Also, the future scope of this device which contains components like Arduinos, micro-controller, sophisticated model, etc. will increase the cost but still it will be under the mark of Rs. 2000 which will be according to the public review for this device. The device does not require an additional battery pack to keep on illuminating the LED light so, there is a cost cutting there as the connections of the model is directly connected to ECU, sensors and relay, which further are operated with the standard 12V battery of the vehicle. Incorporation of 42V technology is another factor for increase in cost of the FRPS as the whole wiring harness is changed for operation of each electrical and electronic components in the vehicle. However, it will be still cost effective as only the higher gauge wire will be required for making the connections.

VII. FUTURE SCOPE

It is almost impossible to detect the fault in low-end vehicle for the driver or passenger. Therefore, it is necessary to develop the fault detection in low-end vehicle and know the fault easy which occur in vehicle. As in present, our current automobile system has converted from mechanical linkages to electronics. Hence, in next four, five years our automobile system will convert from 12V to 42V technology. 42V technology will have 80% of electronic component replacing mechanical components. More the electrical system hence more trouble. Therefore, it is necessary that there have to be a fault-detecting device. More the number of electrical device more complicated will be the fault detection device.A device with digital display can be made for simplicity using Arduinos and microcontrollers. The device made using this technique can detect many sensors at the same time.

VIII. CONCLUSION

This system proves to be the cheapest and the easiest way for any owner to understand the faults occurring to his vehicle. Complex systems can be easily decoded and faults occurring in sensors can be easily detected by the use of Feedback Return Pulse System (FRPS) device. This can be proven as a boon for a layperson with minimum knowledge about automobile functioning and can be used as a guidance system to him before approaching the Garage for service or repairs. Because of this device's ability to work offline and On board availability with the vehicle, along with ease of information, it makes this device different from conventional fault detection devices. This device can be easily incorporated in any vehicle and should be made a standard optional device available from the manufacturers at no cost. Due to increased complexities in Automotive Systems now a days, this device can to be made more advanced which will be very well accompanied in the 42-Volt Technology in the near future.

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