



IOT Based Return Part Analysis for Automotive Exhaust Gas Sensor

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ABSTRACT: The vehicles are increasing in alarming rate every year. This increase in number of vehicles has an adverse effect on mankind and natural environment due to emission of hazardous gases from their exhaust system. To detect the amount of different gases that are emitted from the exhaust system different types of sensors are installed in the tail pipe of the exhaust system. Some of the harmful gases are CO, HC, and NOx. NOx gases are produced from the reaction of nitrogen and oxygen which will usually occur in car engines during the combustion of fuels especially at high temperature. The NOx sensor used to detect the amount of nitrogen oxide content in the exhaust gas chamber and the NOx sensor is installed in upstream and downstream of the exhaust flow depending upon application. But in present scenario if we want to test or monitor sensor of vehicle then we have the dependency on set of hardware and PC all the time and person should present physically all the time. It includes need of CAN monitoring devices along with licensed software installed and it is more expensive. So IOT concept can be used here to reduce the testing effort as well as dependency. So that anyone can perform test or monitor sensor remotely. The Idea is to test or monitor sensor data remotely by using an android mobile APP and a small hardware connected with the sensor. SCU/Sensor needs to connect with smart CAN to Wi-Fi Hardware which will record SCU data and put into the server (or directly to mobile). User will access sensor data using smart CAN-APP which can trigger commands from and can also show live data graphically. User can perform Return Part Analysis remotely and final analysis report will be generated automatically.

KEYWORDS: CAN, Automotive Exhaust Gas Sensors, IOT, SCU

I. INTRODUCTION

Vehicles are the main important aspect for the day to day life. World without the vehicle is impossible to imagine in these days as everyone has to reach their destination with comfort, safety and with less time. Due to its importance in present days, automotive industries are rapidly growing. The automotive industries are increasing day by day. The components of vehicle will be manufactured by different companies all around the world. Each automotive industry will be manufacturing particular component of the vehicle based on the requirements and applications. The automotive industries were using some traditional techniques for various functions.

Automation plays a crucial role in automotive manufacturing. It equips the interior suppliers with necessary tools and helps them remain flexible and relevant in this modern era. The vehicles are increasing in alarming rate every year. This increase in number of vehicles has an adverse effect on mankind and natural environment due to emission of hazardous gases from their exhaust system. To detect the amount of different gases that are emitted from the exhaust system different types of sensors are installed in the tail pipe of the exhaust system. Some of the harmful gases are CO, HC, and NOx. NOx gases are produced from the reaction of nitrogen and oxygen which will usually occur in car engines during the combustion of fuels especially at high temperature. The NOx sensor used to detect the amount of nitrogen oxide content in the exhaust gas chamber and the NOx sensor is installed in upstream and downstream of the exhaust flow depending upon application. But in present scenario if we want to test or monitor sensor of vehicle then we have the dependency on set of hardware and PC all the time and person should present physically all the time. It includes need of CAN monitoring devices along with licensed software installed and it is more expensive. So IOT concept can be used here to reduce the testing effort as well as dependency. So that anyone can perform test or monitor sensor remotely. The Idea is to test or monitor sensor data remotely by using an android mobile APP and a small hardware connected with the sensor. SCU/Sensor needs to connect with smart CAN to Wi-Fi Hardware which will record SCU data and put into the server (or directly to mobile). User will access sensor data using smart CAN-APP which can trigger commands from and can also show live data graphically. User can perform Return Part Analysis remotely and final analysis report will be generated automatically.

II. OBJECTIVES OF PROPOSED WORK

The main objectives of system are:

- ❖ The objective is to test or monitor sensor data remotely by using an android mobile APP and hardware connected with the sensor.
- ❖ SCU/Sensor needs to connect with smart CAN to Wi-Fi Hardware which will record SCU data and put into the server (or directly to mobile).

III. METHODOLOGY

In this Chapter the implementation of proposed concept is explained in detail. The block diagram of proposed concept and process flow at each node is shown.

A. BLOCK DIAGRAM

In the proposed block diagram as shown in fig. there are many components and mobile APP which plays a key role in functioning of proposed concept. The main components are CAN controller, CAN Transceiver, DB9 Connector, Sensor/SCU, Power Supply, Wi-Fi Module, Mobile APP, Server etc.

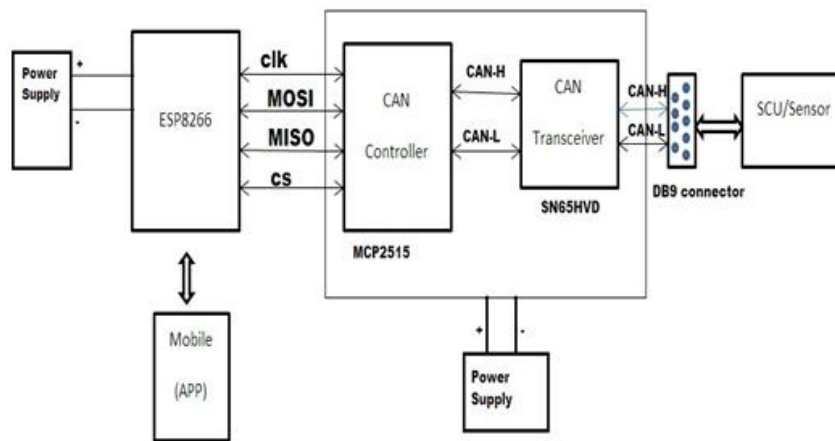


Fig 1 Block Diagram of Proposed work

B. CAN to Wi-Fi Module

CAN to Wi-Fi module plays a major role in the proposed concept which is used to receive the data from Sensor/SCU and transmit that data to the mobile APP or Server. A CAN to SPI concept is used while transmitting the data from the Wi-Fi module.



Fig 2. CAN to Wi-Fi Module

In the above CAN to Wi-Fi module there is 2 layered PCB which has the Wi-Fi module embedded in it. There are Power Supply Connector, CAN DB9 Connector, Power supply status LED, CAN Communication status LED, Network status LED. Working of each of the above-mentioned connectors and LED are explained in the working of CAN to Wi-Fi module. In the above module Power Supply connector are connected to power supply and ground of the external battery. CAN DB9 Connector is connected to the SCU/Sensor of NOx or PM.



C. PROCESS FLOW AT HARDWARE LEVEL

The explanation of process flow in Hardware at both Transmission and Reception level is shown here.

(1). Process Flow At Transmission Level

At Hardware level when SCU/Sensor got connected with implemented hardware and module powered up then CAN Controller goes to init mode. If there is data received from sensor then INT signal goes LOW and data will be read by the nodemcu. The received data will be converted into specified format and sent through Wi-Fi. This specified format can be done by reading the IDE bit of CAN frame. If the IDE is read 'HIGH' then it is 29-bit extended frame ID. If the IDE is read 'LOW' then it is 11-bit standard frame ID. After the data is made into specified format by reading the CAN data and ID this data is sent through Wi-Fi by making the WebSocket connection to the mobile APP or server.

(2). Process Flow At Receiver Level

At receiver level when the hardware receives data frame from the mobile or server, it is divided into frame ID and data. When the frame ID is read as 23-bit extended frame ID, the IDE bit is made as 'HIGH'. If the frame ID is read as 11-bit frame ID, then IDE bit made as 'LOW'. After the data and IDE bit are known then those are merged in specified format and sent to the CAN Controller. From there it is sent to the Sensor/SCU. According to the data sent as for requesting sensor for message frames, we get the message frame from Sensor.

D. ANDROID/IOS APP:

An Android or IOS App is developed to monitor or analyze the message signals. It is also used in sending the REQUEST frame to SCU/Sensor. There is always a need for Request frame to be sent to the SCU in background. There are different screens in Android App to analyze the signals easily. We can do maximum analyzing that we can do from Canalyzer using this APP. The screens are made user friendly to navigate to different features in the APP. There is INTERACTIVE GENERATION block in APP which can be used as IG block in CANalyzer. The Self-Diagnosis signals are shown in different screen which shows the internal errors of Sensor/SCU.

APP Layout:

Android Application designed to communicate with sensor using Can to Wi-Fi hardware

Features-

- Full duplex CAN data streaming (Rx + Tx)
- Auto variant detection.
- One click self-diagnosis
- Live real time data and graph
- Data logging and sharing

When the user opens the APP, it asks for username and password. After that, it searches for Wi-Fi networks and once it gets connected to CAN to Wi-Fi module it opens Home Screen And from that we can select the type of sensor whether it is NOx or PM sensor.

Once the sensor selected, it goes to select mode screen. Here we can select either Monitor sensor mode or Self-diagnosis mode.

After selection of mode, there will be appearance of Additional Details Screen which is used to verify the details of project variant, Software type, software version, CVN number, Hardware details. After the flash screen of Additional details appear, we can go back to see the data from sensor. There is a menu on top right side of the Data screen which is used to send dewpoint frame at background. If we want to see the additional details once again, we can click on the Additional Information menu. Here one more menu is added which is engineering mode which acts as equal to IG block in CANalyzer.

E. Process Flow

The process flow starts when the SCU/sensor connected to the DB9 connector of CAN to Wi-Fi module and power supply is given. As soon as power supply is given, the CAN to Wi-Fi hardware starts checking whether there is any data on CAN. If there is CAN data available, it checks whether APP connected to the Wi-Fi. If there is no CAN data available then connection with SCU/sensor has to be checked. If there is no connection established between CAN to Wi-Fi hardware and APP then connection has to be established.

Once the CAN data available and connection between the APP and hardware module established then Home page of the APP gets splashed. In the home Screen user can select the type of sensor to be tested. Once the sensor gets selected, it moves to "mode selection" whether user want to perform "Monitor Sensor Data" or "Self-Diagnosis". If it is "Monitor sensor Data" then the data is received to APP is decoded and frame ID is derived and based on it



CVN,CALID is requested and in return data is decoded to get the CVN ,CALID and other sensor related data. Once the data is derived an Additional Info screen is splashed which contain the Customer Details, Software Type, Software Version, and Operating voltage, CVN, CALID and other sensor related information. After going through the Additional Info when the user presses the back button the Real-Time measurement signals can be seen with respective to the particular sensor. In background, there is dewpoint signal is sent parallel for every 100ms to get the valid data from the sensor. If user presses the back button the APP goes to the “Mode Selection” again.

Once the CAN data available and connection established, if the user going to perform “Self-diagnosis mode” then there is always dewpoint and self-diagnosis request frames are sent in parallel. The requested frames sent to the sensor makes the sensor go through diagnosis mode and after certain period the self-diagnosis frames are sent to the APP and displays all the error signals status of the particular sensor. If the user press the back button it goes to the “Mode Selection” again.

The above mentioned process flow is only related to the “Self-diagnosis mode” and the “Monitor Sensor data mode”. Along with this, there are many features in the APP which are almost similar CANalyzer/CANoe software. The features like Interactive generator block and logging data are implemented in the APP similar to that of CANalyzer/CANoe.

F. Engineering Mode

In CANalyzer/CANoe application there is an INTERACTIVE GENERATOR called IG block. Through this IG block, user can communicate with the sensor by sending request frames. User can send the frames with his own choice by giving the frame-ID, data and duration of the time in milliseconds to send the frames at particular interval.

Similar to the IG block there is a feature implemented in APP called “Engineering Mode”. This feature works like an IG block and user can communicate to the sensor through Engineering Mode. As in IG block, user can create a profile by giving the profile name, frame ID, Data and duration time in milliseconds to create a profile. Once the profile created successfully then user can press the run button to send the frames to the SCU/sensor and can stop by clicking on the same button.

G. Logging

In CANalyzer/CANoe there is availability of Logging the data which is being received in Trace window. By saving this log file, sensor data can be used whenever tester want to perform analysis. Similar to the logging in CANalyzer/CANoe, there is separate feature in the APP for saving the log file. In Monitor sensor data mode, at bottom there is a button called “Start Logging”. When the user press this button, it will take to different screen where user can give the duration of log file to be saved and also can save the log file with unique name or can scan QR code of SCU/sensor for saving the log file with that ID.

IV. TESTING

In this chapter, the test set up and how the sensors of different variants were tested is explained in detail. For reliable product, thorough testing is required. Different variants with different versions of software has to be tested for both NOx and PM sensors.The test set up requires power supply, SCU/sensor, CAN to Wi-Fi hardware module and a mobile device with Sensor APP. As shown in below figure, SCU/sensor and CAN to Wi-Fi module has to be connected with the power supply. The CAN lines of SCU/sensor has to be connected with DB-9 connector of CAN to Wi-Fi hardware.

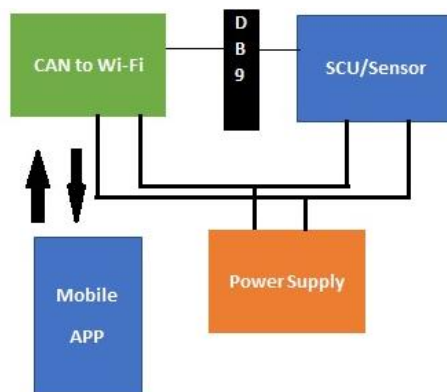


Fig 3: Test setup



After the test setup is established, APP should be connected to the CAN to Wi-Fi hardware. Once the connection is established, the setup is ready to test. While testing the implemented concept, there is a need to check whether it is working according to the requirement as well as real time data is received correctly. For this reason the traditional test setup what we are replacing with our concept has to run in parallel to verify the results. The data that receives in the implemented concept has to match with the data that we get in traditional CANalyzer hardware and software setup. The traditional test setup contains PC with licensed CANalyzer/CANoe software and CANalyzer/CANoe hardware.

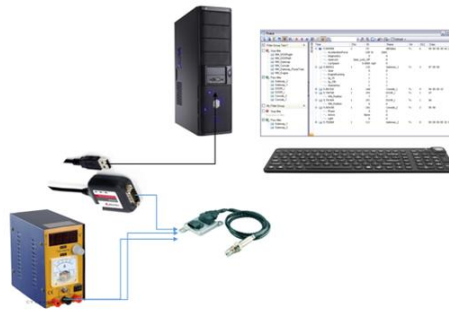


Fig4:Test with CANalyzer setup

Now the testing has to be started for both the traditional test set up and the implemented concept. The results of both the tests should be matched to conclude whether the implemented concept is working. The Canalyzer with the PC is set to on and in parallel the CAN to Wi-Fi hardware and App should also get connected. As soon as the Canalyzer software opened and run in PC, in trace window the received sensor data will be visible. To check the parameters of the signals respective CAN .dbc file should be added. There after signals with respective parameters can be seen in the trace window. In parallel to the traditional test, the implemented concept test also performed to check whether data received is real time. When the Monitor sensor data mode is selected from the sensor APP then the data displaying in the APP is verified with the data received in the traditional setup. From both the results we can conclude that the test of the implemented concept is passed. The below figure, shows the data received from sensor to the APP via CAN to Wi-Fi gateway.



Fig 5: Analysis with the Implemented concept

Similar to the above performed testing, different variants of both PM and NOx sensors were tested. There are many features in proposed concept which were tested in parallel to the traditional test. The Cyclonepro for Nox and Renesas flasher for PM are used in testing, for flashing different customer softwares in the respective SCU's. Testing phase is completed by thorough verification of details sent from SCU.

V. RESULTS

In this chapter the results of the implemented concept is shown in detailed figures. The results are shown in sequence of their flow and how they display the outputs for analysis. The customer related information is also shown in additional information screen with software type and software version.

Step by step results of the Sensor APP are shown in the below figures.

1. Selection of sensors
2. Selection of mode
3. Monitor sensor data
4. Self-Diagnosis

After allowing the permission and server is connected to APP there opens Home screen for the selection of sensor, on selecting the sensor (NOx or PM) select mode screen will be displayed.



Fig 6: Home Screen(selection of sensor)



Fig7 :Selection of mode

On selecting the Monitor sensor data(NOx or PM), Additional Info screen splashes with the customer name, software type, software version, CVN, CALID and other hardware specific details. After going through Additional Info details, by pressing back button it displays respective sensor data.

On top right side of the “Monitor sensor data” screen it shows a menu button where user can go to Additional Info once again. Also there are few more options in menu like “View Logs” and “Engineering Mode”



Fig 8: Monitor Sensor data Screen

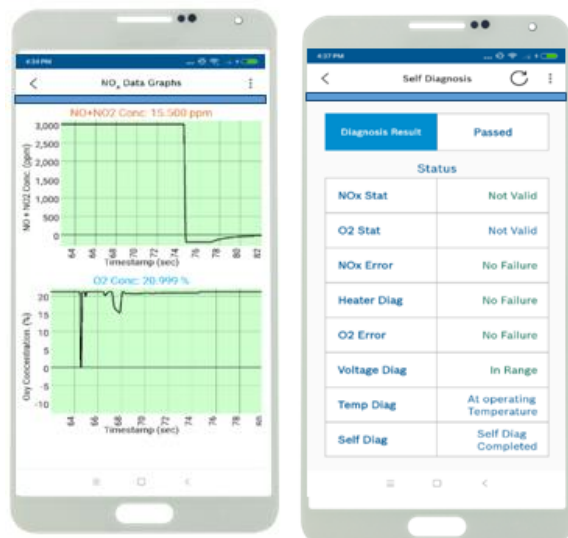


Fig 9 : Graph and Self-Diagnosis



VI. CONCLUSION

The criteria for the sensors to test as well as perform the return part analysis increased due to the emission legislations as well for proper accurate error detection. With the present methods, it consumes more time and manual effort to test and perform return part analysis for the automotive exhaust gas sensors but with implemented concept, it is verified that return part analysis can be performed within less time and no manual effort required. It has been proved in testing that implemented concept saves 90% of the time that consumed in traditional return part analysis and cost is almost reduced up to 98.5%. This implemented concept also helps in testing exhaust gas sensors from anywhere. The development of IOT based return part analysis of exhaust gas sensors with the unique functionality leads to a new approach and cost effective and easy error detection solution to the automotive industry for adapting Bharath stage VI emissions. Future scope is that in the automotive field the return part analysis can be adapted with other different type of sensors present in the exhaust tail pipe and also in the heat control unit. IOT based return part analysis can be implemented with any sensor that supports CAN protocol in future. In future, even secure flashing of SCU/sensor is possible. At server, data analytics can be done and log files can be generated and stored remotely.

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