

# APAC15-000 Simulation and Experimental Results on Study of Automotive Airflow Meter Swappability

Van Dung Do, Thanh Thuong Tran, Ba Hai Nguyen  
University of Technical Education HCMC

1) Ho Chi Minh University Technical Education, Vietnam  
2) College of Transportation N.3, Vietnam

## Abstract

This article presents the application of LabVIEW for simulating mathematic models of the replacement of automotive airflow sensors. Moreover, the combination of this simulated model and the computer communication program created by LabVIEW language is used to carry out the semi-experiment and the experiment of this project. The mathematic models allow us to learn and investigate the possibility of the project's solutions. It also allows the authors to predict the characteristic of airflow sensors and the airflow sensors' characteristic converter before the final products are produced. Beside that, the simulation processes help us to reduce time and finance due to the quick modifications of programs and control algorithms, and the lack of hardware as well as the prototype circuits.

**Keywords:** Automotive airflow meter sensor, converter, sensor replacement, swappability.

## 1. INTRODUCTION

Electronic components are the core parts of automobiles. The benefits of electronics are compact, flexible, clean and so on. Challenged by the severe hot and dank climate in Vietnam, automotive electronic components, in particular, the airflow meter (AM) sensors have been corrupted. Therefore, the vehicles equipped these sensors produce much contaminants in their exhaust emission. The engine power is also reduced. And, fuel economy is decreased. Moreover, once the sensors are corrupted the users must wait several weeks or months to find imported sensors at high price. In serious cases, users may not find new sensors used in the old car models. As the result, spare sensors will not be replaced.

To solve this problem, Do et. al. have proposed a novel solution which replace original airflow meter sensor with different types of airflow meter sensors provided by various vendors. The initial research was done in [6]. In this paper, a software-based tool is developed to conveniently and quickly carry out several experiments thereby, a number of airflow meter characteristics can be obtained. Based on sensors' characteristics, several reference maps can be preprogrammed in the converter. Therefore, the acquired characteristics from airflow meter sensors are one of the most important factors required in development of the converters. In addition, a simulation in LabVIEW is developed to test the possibility of the algorithm of automotive airflow meter swappability.

This paper is organized as follows. The detailed processes to develop a data acquisition tool for building reference maps in converters are presented in section 2. simulation of algorithm of automotive airflow meter swappability is described in section 3.

## 2. DEVELOPMENT OF DATA ACQUISITION TOOL

### 2.1 Experiment overview

Figure 1 illustrates experimental testbed. An engine 1 is used to intake air 4 from environment through an intake pipe 2. The AM sensor is attached to measured airflow taken into the engine. The AVL hardware and NI USB 6009 are used to acquire intake air mass or volume.

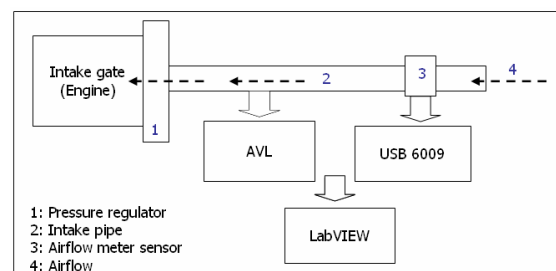


Figure 1 Experimental setup

The main task now become developing a suitable and fast software-based tool which allows users to acquire AM sensors' signal as well as engine dynamics. To conduct experiment, firstly, the engine's

speed is adjusted through a throttle controller. Air is taken to the engine. The NI USB 6009 card and AVL measure volume or mass of airflow as well as the ambient temperature. Those signals then automatically recorded in text file using LabVIEW. A graphical user interface displays all the data acquisition process in real-time.

## 2.1 Hardware and software

To easily handle the mass production and multiform of airflow meter sensors, the research group has decided to develop the data acquisition tool based on LabVIEW environment and USB-based NI hardware. LabVIEW is powerful to perform measurement tasks, hardware connectivity as well as simulation techniques. Detailed description of hardware and software are provided in the followings.

### 2.1.2 The experimental engine

To produce airflow at different operating condition of engine, a Toyota Camry 2.0L engine is used. The engine has 4 cylinders. Speed range is from 600 to 7000rev/min. AM sensor is MAP type.

### 2.1.3 NI USB 6009 (14-Bit, 48 kS/s low-cost multifunction DAQ board)

The National Instruments USB-6009 shown in figure 2 provides basic data acquisition functionality for applications such as simple data logging, portable measurements, and academic lab experiments. It is affordable for student use and powerful enough for more sophisticated measurement applications. Every NI USB data acquisition device includes a copy of NI LabVIEW SignalExpress LE so you can quickly acquire, analyze, and present data without programming. In addition to LabVIEW SignalExpress, USB data acquisition modules are compatible with the following versions (or later) of NI application software –LabVIEW 7.x, LabWindows™/CVI 7.x, or Measurement Studio 7.x. USB data acquisition modules are also compatible with Visual Studio .NET, C/C++, and Visual Basic 6.



Figure 2 USB-based NI Multifunction Data Acquisition Board

### 2.1.2 NI LabVIEW

LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. LabVIEW offers unrivaled integration with thousands of hardware

devices and provides hundreds of built-in libraries for advanced analysis and data visualization. The LabVIEW platform is scalable across multiple targets and operating systems, and since its introduction in 1986 has become an industry leader.

### 2.1.4 AVL testbed

The main goal of component testing is to test the various engine parts as regards their functionality and durability. AVL defines engine components like valve timing drive, valve train, and variable valve timers, measurement of speed and torque, measurement temperature and pressure and intake airflow.

### 2.3 Development of data acquisition tool

A software-based tool for data acquisition is developed to build sensors' characteristic map. The program is able to automatically save file in both text and Exel format. Analog signals can be measure from -10 to 10V at 14bits resolution and 47Ks/s. Beside saving file function, the developed program is able to display acquired data in real-time.

## 3. SIMULATION OF ALGORITHM OF AUTOMOTIVE AIRFLOW METER SWAPPABILITY

### 3.1 Theoretical principles of automotive airflow meter swappability

Assume that characteristics of two arbitrary sensors are known as  $f_1^*(x)$  and  $f_1(x)$ . Where  $f_1(x)$  is the relationship of input and output of original sensor in normal condition. And,  $f_1^*(x)$  is a different type of airflow meter sensor which will be used to replace the original one if there is error in original sensor. Based on the proposed converter, function  $f_1^*(x)$  will be changed to  $f_1(x)$ . Therefore, the ECU will act in the same manner when the original sensor is replaced.

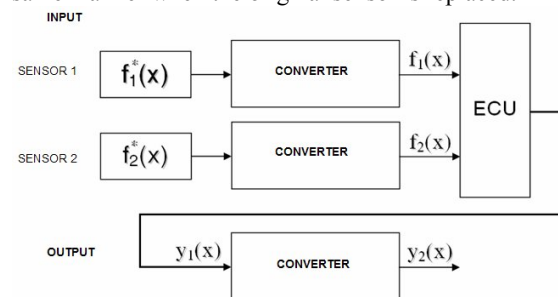


Figure 2 Principle structure of converter for general applications

In this research, the vane airflow meter sensor replaced with hot wire airflow meter sensor is chosen as demonstration for this research.

Before develop a circuit for the converter. The Theoretical principles of automotive airflow meter swappability is simulated in LabVIEW. The main task is to make output voltage of hot wire AM sensor must be exactly equal to the output of the original AM sensor (vane airflow meter sensor). That means there is no modification or firmware update in the main ECU (electronic control unit). To simulate the swappability algorithm, two characteristic functions of these two sensors are provided.

Characteristic functions of hot wire AM sensor used in Toyota Altis:

$$y = A * X^B \quad (2.1)$$

where, A = 0,6666; B = 0,2955

Characteristic functions of vane AM sensor (decreasing type):

$$y = A \times x^B \quad (2.2)$$

where A = 8,9007; B = - 0,4938

Replacement scheme in the simulation is shown in figure 3. Simulation result is provided in figure 4.

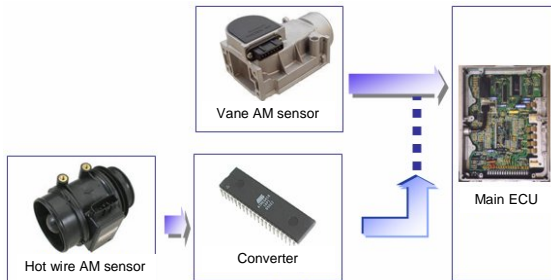


Figure 3 Replacement scheme

Simulated signal is from 0 to 200m<sup>3</sup>/hour. This simulated signal can be replaced with measure signal from AM sensors using NI USB 6009 in the experimental step.

### 3.2 Simulation of algorithm of automotive airflow meter swappability

Figure 4 shows the flowchart of the simulation of algorithm of automotive airflow meter swappability. The simulation requires several functions included simulated signal generator, arithmetic operator, chart, graph, while loop, array, case structure, and so on. Once the program is started, output voltage of replaced AM sensor (hot wire AM sensor) is read, the A,B of characteristic functions are typed using keyboard, the airflow signal is simulated and the converting algorithm is performed.

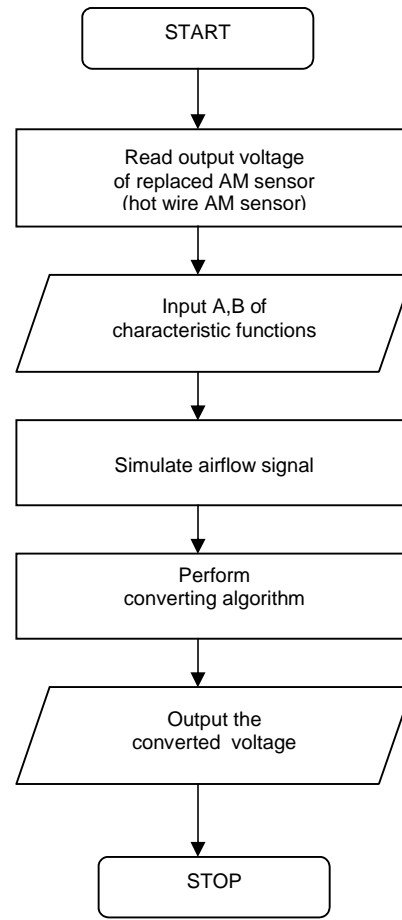


Figure 4 Flowchart of the simulation of algorithm of automotive airflow meter swappability

## 4. DEVELOPMENT AND SIMULATION RESULT

### 4.1 Result of development of data acquisition tool

A data acquisition tool shown in figure 5 is developed and matched with the requirements. In this tool, it allows users to adjust ADC range, channel, as well as saving mode (text or Exel format). Real-time chart is included to display history of measurement process.

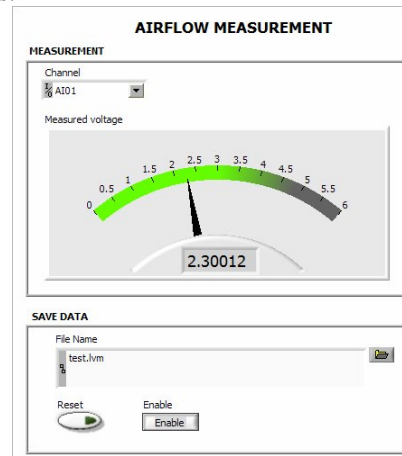


Figure 5 Developed tool for experimental process

## 4.2 Result simulation of algorithm of automotive airflow meter swappability

Result of the simulation is shown in figure 5. Simulated signal is changing from 0 to 200 m<sup>3</sup>/hour. In the figure 6, at the same airflow volume 120m<sup>3</sup>/h, the output voltage of vane AM sensor is 0.837 V compared to 2.881 V of output voltage of hot wire AM sensor. After the converting algorithm is done, the output voltage of vane AM sensor (yellow color) which is

calculated from hot wire AM sensor (white color), has the same value of original vane AM sensor (blue color). These values can be easily compared through voltage columns in the GUI (graphical user interface). As the result, there is no correction or modification in main ECU.

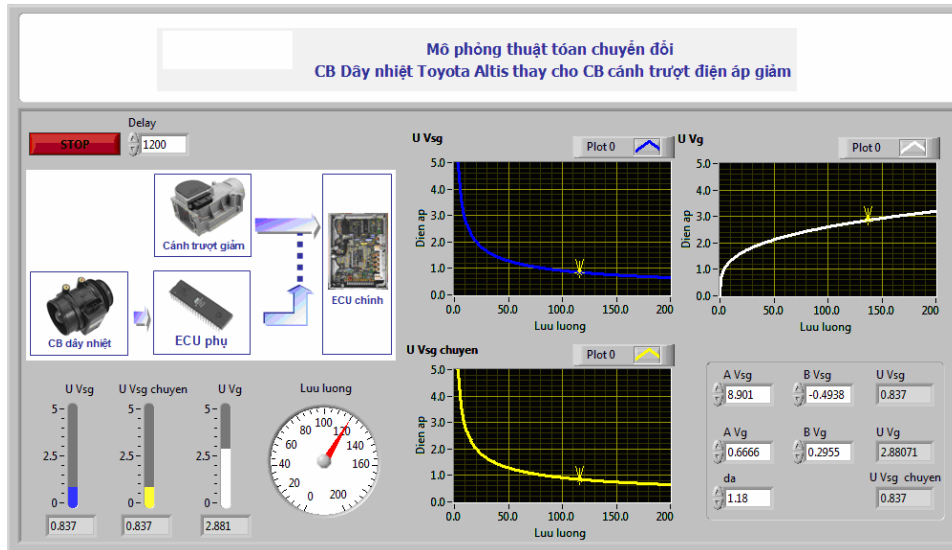


Figure 6 Replacement scheme

## 5. CONCLUSION

In this research, a tool for fast map building of AM sensors' characteristics was developed using LabVIEW. The tool allows users to easily perform a number of measurement tasks with minimum time and effort. The simulation of algorithm of automotive airflow meter swappability was carried out. The simulation results have shown that it is possible to develop a converter which allows users to replace corrupted AM sensors with different types of AM sensors thereby, the repair cost and time can be significantly reduced.

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