PRACTICE 6 -Flow meter

AUTOTRONICS

Abril 14th, 2024

Jheny Huanca Cerezo.*
jheny.huanca@ucb.edu.bo

Abigail Belen Lopez Tarqui.*
abigail.lopez.t@ucb.edu.bo

Samuel Pasquier Rios*
samuel.pasquier@ucb.edu.bo

Fabrizio Lazo de La Vega. *
rolando.lazodelavega@ucb.edu.bo

Diego Calvimontes Vera.*
diego.calvimontes@ucb.edu.bo

***Abstract*—In this laboratory, the characteristic curves of two types of sensors were tested and obtained: the MAP (Mass Air Pressure Sensor) and the MAF (Mass Air Flow Sensor), using an oscilloscope and a multimeter. It was observed that the MAP sensor primarily responds to changes in vacuum pressure, while the MAF sensor is more sensitive to changes in airflow. Both sensors are important for measuring different aspects of airflow in an engine system, but the MAF stands out for its precision and versatility. Tables of values were generated to create the curve and compare their behavior with the theoretical.**

I. Introduction

In contemporary automotive industry, it is crucial to have precise measurement of airflow and vacuum pressure to optimize both engine performance and efficiency. This goal is achieved through the utilization of various sensors, each designed with specific characteristics and applications. In this laboratory study, the focus was on two of these fundamental sensors: the MAP sensor (Mass Air Pressure Sensor) and the MAF sensor (Mass Air Flow Sensor).

The MAP sensor detects fluctuations in intake manifold pressure, providing essential data for engine control systems. On the other hand, the MAF sensor records the amount of air entering the engine, which provides crucial information about fuel injection and combustion optimization.

Throughout the experiment, the aim was to deeply understand the behavior and peculiarities of these sensors by obtaining their characteristic curves. Using an oscilloscope and a multimeter, a series of tests were conducted to analyze each sensor's response to variations in airflow and vacuum pressure. Additionally, tables of values were created to compare experimental results.

II. General objective

The objective of this laboratory is to test and obtain the characteristic curves of two types of sensors: the MAP (Mass Air Pressure Sensor) and the MAF (Mass Air Flow Sensor), using an oscilloscope and a multimeter.

III. Specific Objectives

- Record the output values of the MAP sensor using an oscilloscope and a multimeter.
- Generate a characteristic curve that shows the relationship between the airflow rate and the output of the MAF sensor.

IV. Materials

material for practice

- MAP Sensor (Mass Air Pressure)
- MAF Sensor (Mass Air Flow)
- Oscilloscope
- Multimeter
- Vacuum gun
- Connection cables

V. Background

A. MAF Sensor (Mass Airflow Sensor)

The MAF sensor, or mass airflow sensor, utilizes a hot wire to measure the mass of air passing through it. It is known for its precision in measuring airflow and its ability to detect both positive and negative cycles [1].

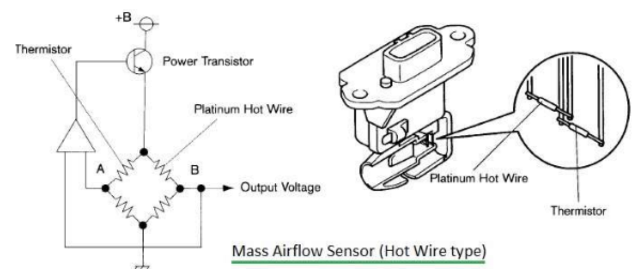

Fig. 1. Vane Air Flow Sensor circuit

B. OPertaion of the MAF Sensor

The Mass Air Flow (MAF) sensor operates with a thin platinum wire inside, also known as a "hot wire", which heats up to 200 degrees when the engine is running. This temperature must remain constant. Depending on whether the engine receives more or less air, this temperature will tend to decrease more or less due to the cooling effect caused by the airflow (more air leads to more cooling) [2].

C. Types of MAF Sensor

1) Hot Wire Sensor: : This sensor uses a heated wire element to measure the airflow. As the air flows over the wire, it cools it down, which causes a change in electrical resistance.

2) Cold Wire Sensor: : Similar to the hot wire type, this sensor measures the airflow using a wire element. However, in this case, the wire is maintained at a lower temperature than the surrounding air. The airflow heats the wire, resulting in a change in electrical resistance.

3) Vortex Type Sensor: : This sensor utilizes the principle of vortex generation to measure the airflow. As the air passes through a restricted area, it creates vortices, which are detected and measured to determine the airflow velocity.

4) Membrane Type Sensor: : This sensor employs a flexible membrane that deforms under the pressure of the airflow. The deformation of the membrane is then converted into an electrical signal to measure the airflow [3].

One of the distinguishing features of the MAF sensor is its hot wire technology, which allows for accurate measurement of airflow. This method provides precise readings, making the MAF sensor suitable for applications where precise airflow measurement is essential.
Unlike the VAF sensor, which relies on mechanical movement, the MAF sensor uses a hot wire to detect airflow. This technology enables the MAF sensor to detect both positive and negative cycles of airflow, providing comprehensive data for engine control systems.

D. Location

The flow meter is located in the intake system, right after the air filter. This positioning serves to prevent any external particles or dirt from entering and potentially damaging the meter. Despite being a highly reliable component, it's crucial to shield it from any potential harm, as even the smallest debris could compromise its functionality.

Fig. 2. MAF Sensor location

E. MAP Sensor

1) Function and Mechanism of the MAP Sensor: The MAP sensor measures the absolute pressure inside the intake manifold and converts this pressure into an electrical signal that the Engine Control Module (ECM) can interpret. This process is vital for the ECM to properly adjust the fuel injection parameters [4].

2) Types of MAP sensors: MAP sensors can be classified into two groups: intake manifold pressure sensors and boost pressure sensors. They provide immediate data to the ECU on manifold/boost pressure, measuring air pressure and performing fuel calculations, and on ignition calibration, which is essential to maintain engine efficiency [5].

3) Components of the MAP Sensor: The MAP sensor assembly generally includes an air temperature sensor (ACT) and a pressure transducer. The information provided by these sensors helps the electronic control unit (ECU) calculate the mass of air entering the engine, which is crucial for regulating the air-fuel mixture.

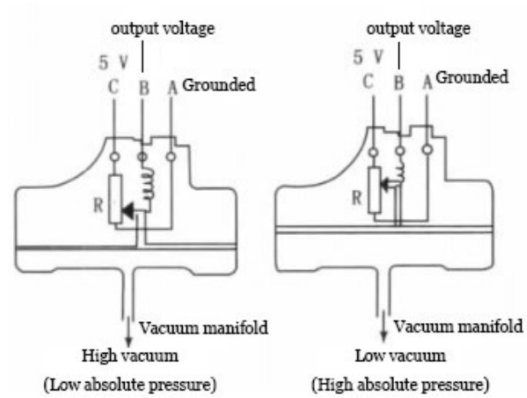

Fig. 3. MAP sensor functionality

4) Location and Connections of the MAP Sensor: The MAP sensor is located on the intake manifold, near the throttle body. This sensor includes three important connections: a ground connection, a power supply of about 5 volts, and an output that varies between 0.6 and 2.8 volts.

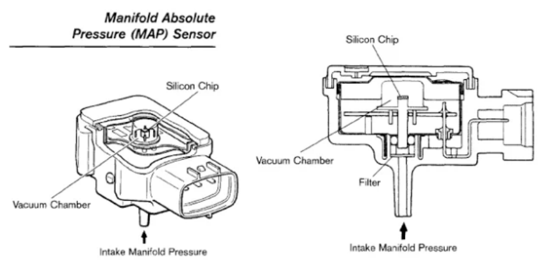

Fig. 4. Location for MAP sensor [6]

5) MAP Sensor Data Relationship Diagram: This diagram illustrates the relationship and data flow involving the Manifold Absolute Pressure (MAP) sensor within output signal.

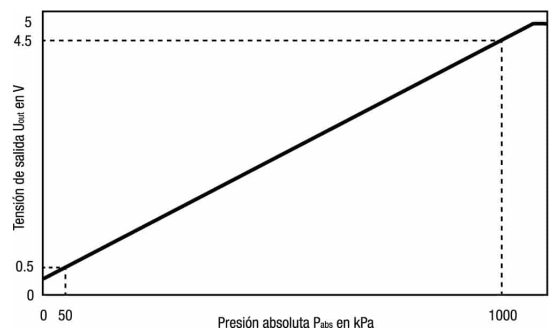

Fig. 5. MAP Sensor Data Relationship Diagram

The relationship between the components of the MAP sensor and its output can be described by the following equation [7]:

$$V_{out} = S \times P + Of \tag{1}$$

where:

- V_{out}: Output voltage (V).
- S: Sensitivity of the sensor, indicating how much the output voltage changes per unit of pressure change.
- P: Intake air pressure (kPa).

- Of: Offset, which is an adjustment constant to calibrate the sensor.

VI. Experimentation

A. MAP Sensor

To perform the experimental curve, the oscilloscope and the regulated 12V power supply were connected to the VAF sensor. Below, an image of the connection made is attached.

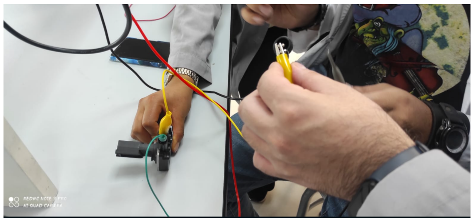

Fig. 6. Conection circuit implemented in MAP sensor

The practice involved blowing air onto the sensor and observing the changes generated on the oscilloscope. It was observed that when air pressure was applied to the sensor, it was reflected as a signal on the oscilloscope, as depicted in the image below. When changes

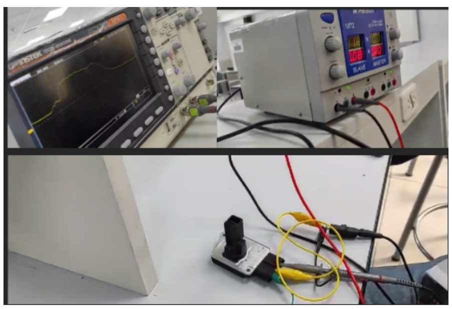

Fig. 7. Physic circuit implemented in VAF sensor

in air pressure occur, the diaphragm within the MAP sensor moves accordingly. This movement results in a change in the electrical output of the sensor, which is then utilized to measure the intake air volume entering the engine. The MAP sensor converts these changes in air pressure into an electrical signal, which is subsequently employed to regulate the fuel and air mixture within the engine, thereby enhancing its performance and efficiency.

Max Voltage (V)	**Min Voltage (mV)**
2.08V	360

TABLE I
Voltage Data

When analyzing the signal on the oscilloscope, two relevant pieces of information regarding voltage were identified. Both the maximum and minimum voltages provided by the sensor were recorded, which maintained a proportional relationship with the amount of airflow passing through the MAF sensor.

B. MAP sensor

The experimental setup began by adjusting the voltage of the power supply to a stable 5 volts Fig. 8, which is essential for ensuring consistent operating conditions for the sensor. After setting the voltage, the next step involved connecting the sensor to a specialized device engineered to generate vacuum pressure in Fig. 9. This device is critical for simulating various air pressure scenarios that the sensor might encounter in a real-world application.

Fig. 8. Voltage source

Following the setup of the vacuum generator, the sensor was simultaneously connected to the power source and an oscilloscope. This dual connection is crucial as it not only powers the sensor but also allows for real-time monitoring and visualization of the electrical signals output by the sensor. The oscilloscope is instrumental in capturing these signals, providing a visual representation of the sensor's response to changes in pressure.

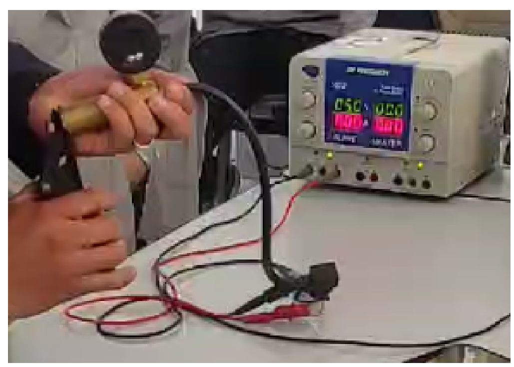

Fig. 9. Conection

As pressure was incrementally applied through the vacuum device, observations were made regarding the behavior of the sensor's output signals. It was noted that the sensor's response was linear, with the signal strength increasing proportionally to the amount of pressure exerted. This linear relationship indicates a consistent and predictable performance by the sensor, which is often critical in applications requiring precise measurements of pressure variations.

Fig. 10. Experimental plot 1

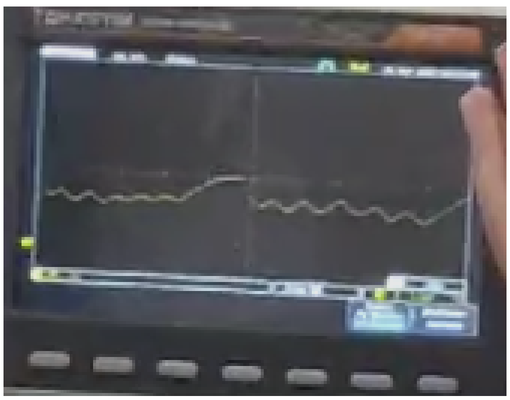

Fig. 11. Experimental plot 2

Fig. 12. Experimental plot 3

Fig. 13. Experimental plot 4

As part of the laboratory exercise, we aim to validate the data by comparing oscilloscope signals with the subsequent figure. This comparison demonstrates the behavioral relationship in action with a CMP sensor, where we also observe the behavior of the MAP sensor, which closely resembles the experimental results.

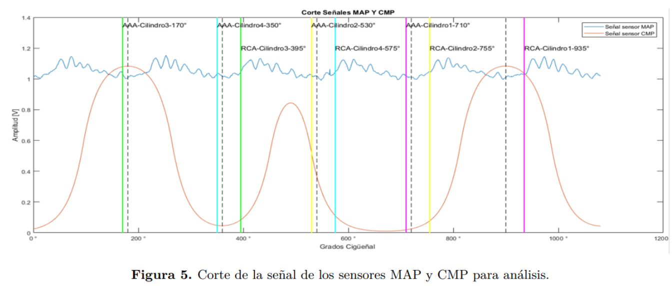

Fig. 14. Cutting off the signal from the MAP and CMP sensors for analysis [8]

1) Graphs: For plotting the signals, data from the Marelli-GM-Bosch sensor was utilized, and the signals were normalized using MATLAB. This process resulted in a fitted curve and an associated fitting error of 0.0254.

TABLE II
PRESSURE VS. VOLTAGE (MARELLI SENSOR)

Pressure (kPa)	Voltage (V)
0	4.8
2.5	4.2
5	3.6
7.5	3.2
10	2.8
12.5	2.4
15	1.9
17.5	1.5
20	1.1
22.5	0.8
25	0.5

Finally, the fitted model is shown in the Fig. 15 It must be considered that the data are plotted on axes other than the figure of the theoretical framework in order to adjust the data of the mathematical model.

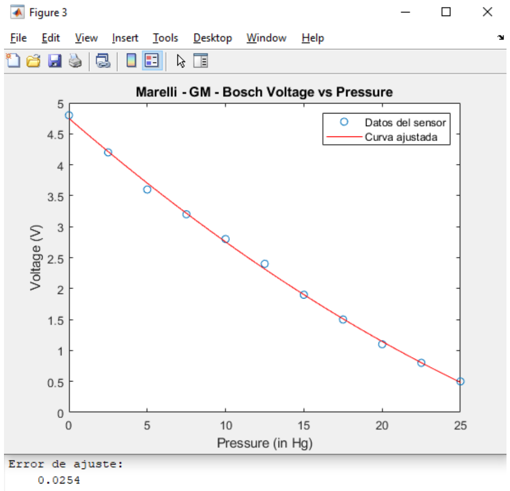

Fig. 15. Marelli - GM - Bosch Voltage vs Pressure

VII. CONSLUSIONS

- A direct relationship between the voltage produced by the sensors and the pressure in the case of MAP or the airflow in the case of MAF was observed. This confirms that these sensors are designed to convert physical changes into proportional electrical signals.
- The data obtained from the oscilloscope can be compared with manufacturer specifications to determine if the sensors are calibrated correctly and providing accurate readings. Any significant deviation could indicate the need for recalibration or sensor replacement.
- The waveform generated by the sensors on the oscilloscope can provide additional information about the system's status and health. For example, changes in amplitude, frequency, or waveform shape could indicate specific problems that require attention.
- A direct correlation was observed between the voltage output of MAP sensors and the pressure within the intake manifold, or the airflow in the case of MAF sensors. This observation underscores the role of these sensors in converting physical changes into proportional electrical signals, essential for engine management.
- The responsiveness of MAP and MAF sensors to alterations in pressure or airflow emerged as pivotal for engine efficiency. Real-time monitoring through oscilloscopes facilitated the optimization of engine performance and the detection of operational irregularities.
- Comparison of oscilloscope data with manufacturer specifications enabled the assessment of sensor calibration and accuracy, signifying potential recalibration needs or sensor replacements in case of significant deviations.
- Analysis of sensor-generated waveforms provided supplementary insights into system functionality and health, with variations in amplitude, frequency, or waveform shape serving as indicators of specific underlying issues demanding resolution.
- MAF sensors were observed to gauge the mass of air entering the engine, enabling the engine control unit to optimize fuel injection for efficient combustion. Furthermore, the diverse types of MAF sensors, including hot wire and thin-film variants, were noted for their distinct advantages.
- Insights into MAP sensors revealed their role in measuring absolute pressure within the intake manifold, furnishing crucial data on engine load and air density. This information is indispensable for fine-tuning fuel injection and ignition timing to achieve optimal combustion efficiency.
- The laboratory encompassed functional assessments of both MAF and MAP sensors, involving their connection to oscilloscopes and power supplies. These tests simulated airflow and pressure variations, yielding graphical data essential for understanding sensor behavior in practical scenarios.

REFERENCES

[1] Bosch Automotive, "Hot-film air-mass meter, type hfm 2," Technical datasheet, date accessed. [Online]. Available: http://www.meeknet.co.uk/e64/HFM.pdf

[2] I. y Mecánica Automotriz, "¿qué es el sensor maf y cómo funciona en el vehículo?" https://www.ingenieriaymecanicaautomotriz.com/que-es-el-sensor-maf-y-como-funciona-en-el-vehiculo/, fecha de acceso.

[3] M. Sequeda Celis, "Sensores que miden o indican la cantidad de aire que ingresa al motor: Maf, map y vaf," *Ficha técnica*, 2023, ficha: 2025683.

[4] M. L. Paida Puente, "AnÁlisis de los sensores map y maf en un motor a gasolina," Trabajo de graduación previo a la obtención del Título de Ingeniero en Electrónico, Universidad del Azuay, Cuenca, Ecuador, 2007, director: Ing. Hugo Torres Salamea. [Online]. Available: https://www.yourlink.com/monica-lorena-paida-puente-thesis

[5] NITERRA. (2018) Sensores map/maf. [Online]. Available: https://www.ngkntk.com/es/productos/sensores-mapmaf/#:~:text=Tipos%20de%20sensores%20MAP%2FMAF&text=Estos%20sensores%20MAF%20no%20tiene,sensores%20de%20presin%20de%20sobrealimentacin.

[6] Quarktwin. (2023, April 11) Map sensor - working principles, features and types comparison. [Online]. Available: https://www.quarktwin.com/blogs/sensor/map-sensor-working-principles-features-and-types-comparison/84

[7] FAE, "Sensores de presión," https://www.fae.es/productos/sensores-de-presion, 2024, accessed: 2024-04-14.

[8] W. C. Urgilés, J. M. Ortega, and R. L. Japa, "Application of feed-forward backpropagation neural network for the diagnosis of mechanical failures in engines provoked ignition," *Ingenius*, vol. 21, pp. 32–40, January-June 2019, available at ORCID: http://orcid.org/0000-0003-2300-9457, http://orcid.org/0000-0002-3846-2599, http://orcid.org/0000-0003-2142-3769. [Online]. Available: https://doi.org/10.17163/ings.n21.2019.03