# DETERMINATION OF THE DEVIATION OF THE ON-BOARD COMPUTER IN THE VEHICLE WHEN DETERMINING THE AVERAGE FUEL CONSUMPTION

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## Abstract

Fuel consumption measurement itself is a demanding process and it is difficult to determine the exact consumption of a vehicle. Fuel consumption can be determined in various ways. One way to determine consumption is through driving tests. We know several types of driving tests. Nowadays, most vehicles and all new vehicles can provide a wealth of data to the driver directly during vehicle operation. One of them is the data on the consumption of the vehicle also through the on-board computer located in the vehicle. The information provided to the driver may not reflect reality. In most cases, they are inaccurate and do not correspond to reality. Therefore, the subject of the research will be to verify the accuracy of the provided data on vehicle consumption by the on-board computer. The aim of the research will be to determine the extent to which consumption data are true. Vehicle consumption, as well as measurements are performed on one vehicle in every day traffic. This will ensure that it is possible to compare the measured data with each other.

**Keywords:** fuel consumption; vehicle; on-board computer; service station; measurement uncertainty

## 1. Introduction

The driver can significantly influence the car's fuel consumption with his driving technique [3, 7, 25]. This consumption can ultimately also influence the amount of emissions produced [16, 18, 24].

Determining the vehicle's consumption as well as determining the amount of emissions produced is a very demanding activity. We can never express the exact consumption of a car with certainty [27]. We often come into conflict between the actual consumption of a car and the consumption declared by the manufacturer. This can be caused by the driving technique, the load on the vehicle or even a different way of monitoring fuel

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consumption. Much research is currently underway to assess vehicle consumption and emissions from non-combustion vehicles [10, 17, 22].

A very discussed topic is also the comparison of electric vehicles with vehicles that are powered by an internal combustion engine. First of all, care must be taken to ensure that the production of exhaust emissions during operation is as low as possible. Electric vehicles produce almost no emissions while driving [9, 19]. It is therefore necessary to examine the emissions from the production of electricity that is supplied to the places where vehicles are charged. It is this production of electricity that is associated with air pollution in connection with the operation of electric cars [4, 17, 28].

There are several ways in which car consumption can be determined and subsequently observed [1, 11, 15]. In any case, it is a driving test, which is based on a pre-processed methodology. This methodology sets out the measurement conditions, the measurement procedure, so that it results in the most objective expression of the vehicle's consumption [2, 8, 26].

When operating a motor vehicle in normal traffic, we often encounter monitoring of fuel consumption. Such consumption control is introduced especially in the business environment, in company vehicles, which are provided to users for business purposes. Company vehicles can be equipped with various devices that can monitor and record the increase and decrease of fuel in the vehicle's tank over time. It is introduced mainly for the purpose of an overview of fuel management. Monitoring the increase or decrease of fuel in the tank can be provided in several ways:

- **Level probe** – consumption is calculated based on the measurement of fuel loss in the tank. Its advantage is that it can also alert the operator to fuel loss from the tank (theft).
- **Flow meter** – used in places where the shape and location of the tank does not allow the use of a level probe. A flow meter is a simple device that detects the amount of fuel leaked per unit time. The disadvantage is the impossibility of detecting refuelling or loss of fuel (theft).
- **Data collection from the control unit via CAN/FMS/COTEL bus** – used to visualize the flow of fuel to the engine, the fuel level in the tank. It can also provide data on tachometer status, temperature, speed, braking, cruise control and many other operating characteristics.

In connection with this issue, there are several companies on the market that deal with the provision of these services through their own software [6, 23, 29].

## 2. Regulations related to consumption measurement

Fuel consumption can be measured using various methods. These are further subdivided and depends on which measurement will be followed. We can look at the measurement of vehicle consumption itself from several points of view:

- Measurement method:
- volume measurement,

- mass measurement,
- measurement based on emissions,
- other (internal diagnostics, etc.).

Measuring point:
- laboratory,
- road test.

Methodology (standard) used according to the measurement procedure
- Slovak technical standards (STN 30 0510, STN 30 0515),
- European standards (ECE Regulation No 101),
- self-measurement.

Any measurement carried out in accordance with the above regulations must comply with them and meet the conditions set out therein.

Measurements according to STN 30 0510 and STN 30 0515 are dealt with by several companies. All these companies are also accredited by SNAS (Slovak National Accreditation Service) for the performance of official measurement of fuel consumption of motor vehicles and mechanisms. Such measurements shall be carried out when the vehicle consumes are more than the consumption stated in the registration certificate. This is because the fuel consumption stated in the vehicle registration certificate is determined in laboratory conditions where it is not possible to achieve real operating conditions. The result of this measurement is a certificate of official measurement, which fully replaces the values stated in the certificate of registration.

In our research, the vehicle's consumption was assessed based on journeys made over a longer period. During this period, the vehicle was driven in normal operating conditions, but with the difference that the data on the number of kilometres travelled and the fuel pumped were recorded throughout the research. Based on these facts and findings, we were able to draw a conclusion. The whole course of measurement as well as the methodology itself is described in the following text.

## 3. Determination of the accuracy of the performed measurement

The final value of the fuel consumption of the measured vehicle is a demanding activity. The resulting value of vehicle consumption depends on several data (number of kilometres travelled, volume of fuel consumed, etc.). Each of these values needs to be determined in some way.

In our measurements, we relied on the accuracy of other measuring devices. When calculating the distance travelled, it was an odometer on the measured vehicle, when determining the volume of fuel pumped, it was a flow meter on the dispenser. As we know, each device has a maximum permissible error from the manufacturer. This means that none of the devices used in such measurements is able to provide the user with an accurate result. The fault tolerance specified by the manufacturer of these devices will always play a role there. This error is usually given in % [14, 21].

Each dispenser at filling stations is equipped with a designated meter, i.e. it is subject to regular inspections (official verification of the specified meter). According to Annex 15 of the Decree of the Office for Standardization, Metrology and Testing of the Slovak Republic on measuring instruments and metrological control, it belongs to the group of measuring instruments: volumetric flow meters for liquids other than water. The wording of this annex states that the maximum permissible error of the instrument is 0,5% of the measured quantity. This verification must be repeated every 2 years. According to the above-mentioned law, only Slovak legal metrology can perform such activities on the territory of the Slovak Republic [5, 13].

## 3.1. Measurement uncertainty

The measurement uncertainty is a parameter characterizing the interval of the values of the measured quantity around the measurement result, which is expected to contain the actual value of the quantity. It is a quantitative indicator of the result and expresses the quality of the measurement. Uncertainty, we can denote it as ux, determines the interval of values $(x - u_x, x + u_x)$, which we will write $(x \pm u_x)$.

Measurement uncertainty can be expressed in several ways. In common practice, we distinguish 2 types of measurement uncertainties [12, 20].

**Type A standard uncertainties** – denoted $u_A$ – are obtained from repeated measurements of the quantity by statistical analysis of the measured values. A characteristic feature of $u_A$ is that it decreases with an increasing number of measurements. When measuring one quantity, $u_A$ is equal to the standard deviation of the arithmetic mean

As mentioned in the previous section, the uncertainty of type A is equal to the standard deviation of the average n of measurements of the same quantity by the same measuring instrument and under the same measurement conditions. Thus, type A uncertainty expresses a certain "instability" of the measurement caused in general by random errors of the measuring instrument, unspecified changes in measurement conditions, noise, and the like. It is manifested by obtaining different values of the measured quantity during repeated measurements, while from the researcher's point of view the same measurement conditions were observed.

In our research, we dealt with this type of uncertainty, as we performed repeated measurements and compared only one quantity, namely vehicle consumption. This means that the measurement uncertainty can be expressed by the standard deviation of the measured values. The standard deviation can be calculated using the following formula:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad (1)$$

where:
$\sigma$ – standard deviation,
$N$ – number of measurements performed,
$x_i$ – average value of a specific measurement,
$\overline{x}$ – mean deviation.

**Type B standard uncertainties** – denoted $u_B$ – are uncertainties determined other than statistically. Type B uncertainties are tied to known, identifiable sources, in contrast to type A uncertainties, where the causes of random errors are unknown.

Type B uncertainty is related to known, resp. identified and quantified sources that have been identified and quantified in the past. In the case of direct measurement of one quantity, the only source of type B uncertainty is the errors of the measuring instrument in reference conditions, the limits of which $\pm \Delta_{max}$ are declared (guaranteed) by the manufacturer of the measuring device.

The standard uncertainty of type B is calculated from:

$$u_B = \frac{\Delta_{max}}{\chi} \tag{2}$$

where the value of $\chi$ expresses the ratio between the maximum value of the error and the corresponding standard deviation. The value of $\chi$ depends on the course of the probability of errors of the measuring instrument in the interval $\pm \Delta_{max}$. Indeed, it is very difficult to estimate the probability of error of a measuring instrument. Therefore, when calculating, we can consider an even distribution, i. e. we assume that measurement errors occur equally often in the interval $\pm \Delta_{max}$. For uniform distribution, $\chi = \sqrt{3}$ and the standard uncertainty of type B is usually calculated from the maximum absolute error of the meter reading $\Delta_{max}$ according to a simpler relation which has the form:

$$u_B = \frac{\Delta_{max}}{\sqrt{3}} \tag{3}$$

## 4. Vehicle description and research methodology

We selected a Ford Focus II facelift (Figure 1) passenger car to perform the measurement.

When choosing a vehicle, we considered that the results of the research were usable and provided useful information for a wider range of readers (drivers, motor vehicle operators, etc.). The vehicle is commonly available and often encountered on the road. Driving characteristics and motorization are comparable to other vehicles that are used in road traffic.

During the individual measurements, the vehicle was used in normal road traffic. We did not take into account its load in specific measurements. We believe that it is in this way of the normal use of the vehicle that we have simulated the ideal state. By this state, we can understand the fact that the results of measurements will be fully applicable to the practice and normal operation of other vehicles. The information that will be the result of the research will form the basis or at least the possibility of informing other drivers, vehicle operators on the data provided by the on-board computer respectively.

Prior to the start of the measurement, the vehicle met the parameters specified by the manufacturer (Table 1). Prior to the test, no adjustment was made, the odometer reading was 229,000 km. We also verified that the vehicle is ready for measurement via OBD diagnostics by reading out the fault memory. No errors were detected by OBD diagnostics.

Fig. 1. Vehicle used for measurement. Source: authors

Tab. 1. Technical parameters of the measured vehicle. Source: authors

| Technical parameters of the measured vehicle | |
|---|---|
| Brand | Ford |
| Trade name | Focus |
| Engine code | G8DB |
| Number of cylinders | 4 |
| Cylinder displacement | 1,560 $cm^3$ |
| Highest engine power | 80.00 kW |
| Speed at max. moment | 4 000 $min^{-1}$ |
| Highest design speed | 188 $km.h^{-1}$ |
| Fuel type | Diesel |
| Length | 4,468 mm |
| Width | 1,839 mm |
| Height | 1,537 mm |
| Operating weight | 1,391 kg |
| Maximum permissible total weight | 1,885 kg |
| Size and type of tires | 205/55 R16 91H |

As mentioned above, one way to monitor fuel consumption is to have the vehicle's on-board computer. The accuracy of these devices varies. A computer in one vehicle can operate with 96% accuracy, while in another vehicle it operates with only 75% accuracy. In principle, these data are relatively accurate, but the vehicle operator must take them with caution.

Certain policies and procedures must be followed to verify the accuracy of the on-board computer. We also followed these procedures when performing the measurement. During the measurement, we quantified the actual consumption of the vehicle, which we then compared with the consumption data on the on-board computer. The procedure for quantifying real consumption is simple and, ultimately, very accurate.

1) In the first step, it is crucial to choose a gas station where we will pump fuel during the entire measurement period. At this gas station, we will choose a specific stand with a refuelling gun. The reason for such an action is the difference (error rate) of refuelling pistols when refuelling a full tank. The choice of the filling station must be observed due to the quality of fuel, which varies depending on the manufacturer.

2) When refuelling for the first time, it is necessary to reset the odometer. This figure will later play a key role in determining consumption. During the measurement, we zeroed the entire contents of the on-board computer to compare the data for individual refuelling cycles.

3) The condition of measurement is that we always pump a full tank. The refuelling pistol was secured after being placed in the neck of the tank and we waited for it to switch off automatically. It is important to keep this procedure throughout the measurement.

4) In such a measurement, the principle applies, the more kilometres travelled, the better (the measurement will be more accurate). During our measurement, the vehicle was driven outside the city.

5) It is necessary to follow this procedure when refuelling again. We refuelled a full tank again and wrote off the volume of pumped fuel from the stand.

6) This figure (labelled X) gives me information about how much fuel we have consumed. Divide it by the number of kilometres travelled (marked Y) and then multiply by the number 100.

$$Fuel\ consumption = \frac{X\ [l]}{Y\ [km]} \cdot 100 = XY\ l/100\ km \tag{4}$$

7) The resulting value represents the real average fuel consumption for the vehicle. In our measurements, we did more of such draws so that the deviation found was as accurate as possible. We then compared the detected consumption with the data on the on-board computer for a specific period.

**Tab. 2. Verification of the accuracy of the on-board computer of the measured vehicle. Source: Author**

| measurement number | pumped fuel [l] | mileage [km] | fuel consumption [l/100 km] | | DEVIATION [l/100 km] | DEVIATION [%] |
|---|---|---|---|---|---|---|
| | | | board computer | real | | |
| 1 | 32.20 | 583.5 | 5.2 | 5,518 | 0.318 | 6.5 |
| 2 | 30.00 | 500.4 | 5.6 | 5.995 | 0.395 | 16.2 |
| 3 | 48.50 | 835.9 | 5.5 | 5.802 | 0.302 | 11.2 |
| 4 | 42.00 | 717.9 | 5.5 | 5.852 | 0.352 | 3.5 |
| 5 | 49.15 | 828.4 | 5.6 | 5.933 | 0.333 | 2.1 |
| 6 | 52.00 | 794.9 | 6.2 | 6.542 | 0.342 | 0.6 |
| | | | Mean deviation | | 0.34 | 6.683 |
| | | | Measurement uncertainty | | **0.029** | |

It is clear from Table 2 that the on-board computer on the measured vehicle operates with a deviation (error rate). This fact was confirmed to us by finding the difference when comparing the vehicle consumption provided by the on-board computer and the consumption determined by the refuelling method. The inaccuracy of the on-board computer can be understood as the average value of the differences found when performing the comparison.

From the research we can deduce the following: The average deviation of the on-board computer on the measured vehicle is 0.34 l/100 km. To make the measurement more accurate and to provide readers with full-fledged information, we also stated the value of the measurement uncertainty for the calculation. As we wrote above, the degree of measurement uncertainty determines the value by which the calculated result may differ. This means that the final value of our measurement represents the interval in which the final deviation of the on-board computer is located. Since this is a standard type A uncertainty, its magnitude can be calculated by the standard deviation. The size of the standard deviation and the measurement uncertainty is 0.029 in our case. In summary, the consumption information provided by the vehicle's on-board computer ranges with an error ranging from 0.311 l/100 km to 0.369 l/100 km. This interval is determined based on the measurement uncertainty (0.34 ± 0.029). In percentage terms, it is 6.68 %. It is also possible to notice that with a higher increase in mileage, the measurement is more accurate, and the deviation is lower. We can therefore confirm our assumption that the on-board computer does not actually provide accurate information on the vehicle's consumption. From the measurements performed, however, we can notice that it works with a constant error, which means that the vehicle operator will already have this information and can calculate it in the future. For a better presentation of the described information, a graphical representation of the results of the detected measurements is available (Figure 2).

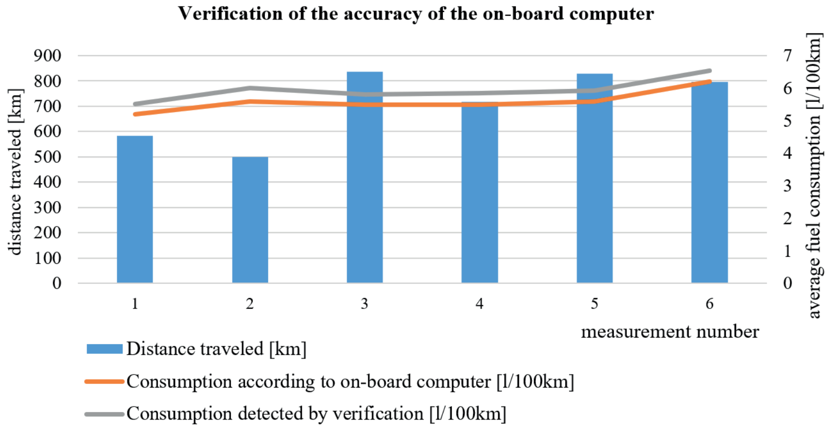


**Fig. 2. Verification of the accuracy of the on-board computer. Source: authors**

In Figure 2. it is possible to monitor the course of the curves that represent the consumption of the vehicle. Their difference is visible, which means that the on-board computer in the vehicle is working with an error. However, this difference between these curves (grey, orange) is almost constant. Simplistically, this means that the on-board computer in the measured vehicle operates with an error, but this error is always constant. As we wrote above, it is enough for the driver to determine this deviation once by such measurement and he can use it for calculation in the future. However, this method only applies when observing the average consumption provided by the on-board computer in the vehicle.

## 5. Conclusion

The practical part of the research fully confirmed our assumed theory [7]. Due to the performed measurements, we were able to evaluate and compare the measured values. The result of this research is proposals and recommendations, the use of which can be used to determine the average consumption of the vehicle and also to verify the accuracy of the on-board computer in the vehicle.

The practical part of the work was performed on a car. This means that the results and the final evaluation of the problem are fully usable in practice.

The output of the measurement is a comparison of vehicle consumption data. The research compares the veracity of the information provided on the average vehicle consumption to the driver. This information is provided by the on-board computer in the vehicle. Our task was to verify it. We have verified the extent to which the data provided in this way are true. It was for this inspection that we developed a methodology based on which we were able to calculate the average fuel consumption. The essence of the methodology is to determine the average consumption of the vehicle by its repeated refuelling. It was the case that we had consumption data at our disposal, which we could compare with each other and draw conclusions. A fact that many drivers are unaware of is the deviation of the on-board computer from the actual consumption of the vehicle.

Through research, we were able to determine the degree of unreliability of the on-board computer, which is commonly found in vehicles. In our Ford measuring vehicle, the error rate ranged from 0.311 l/100 km to 0.369 l/100 km. This means that we are able to determine the uncertainty of the measurement, which is 0.29, which means that the inaccuracy of the on-board computer is within the already mentioned interval. The reader must make sure that the measurement was performed on one vehicle. This means that the specific value of the on-board computer error is determined for a specific vehicle. However, it is highly probable that other vehicles work with a similar error and the method of determining it will be exactly the same.

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