Developing of automatic lap counting system for electric vehicle at Shell Eco-marathon competition

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Abstract. The article shows the development of a closed circuit track counting system made from a prototype electric car that was specifically developed for the Shell Eco Marathon. The system records the laps made by transmitting and receiving radio waves (RF). The entire electronic system was built on the Arduino microcontroller platform and one-way radio frequency transceiver modules. The design of the system was developed using Catia V5 3D modeling software. Additive technology was used to reduce the mass of the system.

1. Introduction
Shell Eco-Marathon is a unique competition that challenges students from all over the world to design, construct, and compete with the most energy-efficient cars. The competition develops the innovative thinking of students to solve problems and tasks related to energy efficiency and environmental problems. The initial project was based on two working purples: the design, manufacturing of prototype battery electric vehicle (PBEVs) and the participation in a few of the competitions held annually in Europe [1, 2]. Both purples are closely connected. First, the design of the vehicle is carried out according to the regulations of these competitions, which limit many of its features such as physical dimensions, engine power, battery type, etc. and they also have very strict specifications and regulations regarding safety such as the characteristics of the braking system, safety switches, etc [3]. On the other hand, the involvement in races is an ideal benchmark to evaluate the performance of the designed and manufactured vehicles.

The experience gained in these races is used to identify problems and needs and to seek solutions for them, which will be tested and analyzed again in future races. In the Shell Eco-marathon, the teams are used to record the number of laps on the track, which is positioned in a certain part of the track determined by the race organizers. This method of reporting laps predisposes to errors due to various factors (such as distraction of the persons involved in the reporting, poor visibility from the place of reporting, engaging the pilot’s attention during reporting, etc.). The construction of a system for counting the laps is necessary, from the point of view of eliminating the human factor. Improper lap counting can lead to pilot leaving the runway earlier or later. These mistakes lead to disregard for the laps made according to the rules of the competition. In the lap counting system, the pilot receives information from the system for the exact time of his last lap. This information allows the pilot to adjust his finishing time.
by reducing or increasing his speed on the runway. All of this has an impact on energy consumption at laps, which is the other important factor requiring the design of the lap counting system.

2. Construction of the electronic part of the lap counting system
The system consists of two separate parts, transmitting and receiving. The emissive part of the system is placed near the start-finish line of the track, from where the transmitter sends a constant signal, which is intercepted by the receiving part when the electric vehicle is passing, where the receiving part of the system is located.

The SYN115 / SYN480R transceiver pair was chosen for one-way communication (Table 1) due to its low cost, small size and relatively low frequency of radiation, which allows the waves to spread more smoothly in space and also low energy consumption. In addition, broadcasting of radio waves is in the range of 15-20 meters from the transmitter to the receiver. This allows the counting of the laps to take place only in the area of the start-finish line (Figure 1).

| On-board single-chip module | SYN115 (transmitter) | SYN480R (receiver) |
|-----------------------------|----------------------|--------------------|
| Module transmitting frequency | 433MHz | 433MHz |
| Module output power:         | <10dBm | -107dBm |
| The module transmission rate | <10kbps | 2.5kbps (SWP), 10kbps (FIXED) |
| The module supply voltage    | 1.8-3.6V | 3.3-5.5V |
| PCB size:                   | 15*11.8(mm) | 17.2*11.8(mm) |

![Figure 1. Positioning of the emitter in relation of the runway](image1.png)

![Figure 2. Components of the electrical part of the emitter](image2.png)

(a) Arduino microcontroller; (b) 9V power supply battery; (c) transmitter chip module SYN115 / F115; (d) antenna
The emitting part consists of four main components: Arduino microcontroller (Figure. 2, a), 9V power supply battery (Figure. 2, b), SYN115 / F115 emitting chip module (Figure. 2, c) and antenna (Figure. 2, d).

The Arduino Nano microcontroller control requires a supply voltage of 5V via its USB port, which means that it can also be powered via a portable powerbank. It is also possible to supply from 6 to 12V, when connecting the positive terminal of the power supply, in this case using a 9V battery, to the VIN pin of the board (red wire).

Figure 3 shows the connection diagram of the signal emitting part of the system. The signal emitting chip requires a power supply of 1.8 to 3.6V, for this reason it is connected to the 3.3V pin on the board (orange wire), and the ground of the battery (black wire) is used as ground. The generated signal is transmitted from the TX1 pin of the microcontroller to the emitting chip (green wire), the signal is being transmitted by radio waves. As an antenna, a copper wire with a cross-sectional diameter of 0.6 mm is used, which is connected directly to the emitting chip (blue wire). It is encased in an aluminium shell in order to direct the distribution of radio waves.

The receiving part of the system is located in the steering wheel housing. This is done in order to reduce the length of the wires and to avoid unwanted electromagnetic interference resulting from the operation of the electric motor, which is located in the rear of the electric vehicle. This part of the automatic lap counting system consists of three main components: Arduino Due microcontroller (Figure 4, a), SYN480R chip receiving module (Figure 4, b) and antenna (Figure 4, c).

Arduino Due is used in this section of the microcontroller system. This is the first Arduino board based on a 32-bit ARM core (Atmel SAM3X8E ARM Cortex-M3 CPU) with 54 digital input / output
and 12 analog pins [4]. It is chosen because of the many calculations it has to make based on the input signals. This board provides faster performance than other boards, which increases the number of data processing cycles. It performs the function of receiving a signal for reading the laps, but also for receiving and processing data based on the set data of the route, as well as the path, speed and time travelled by the electric vehicle. As after processing this data, they are visualized in an easily perceptible form on a 3.5” TFT LCD display with a 16-bit parallel port.

The Arduino Due microcontroller can be powered by its USB port (5V), which means that it can be powered via a portable powerbank. The control is also equipped with a power socket, which allows a voltage of 6 to 12V. In this case, a voltage transformer is used because the power supply of the electric car, which has a voltage of 48V, is used [5].

Figure 5 shows the connection diagram of the receiving part of the system. GND pins on the board (black wire) are used for the table. The requirements of the technical characteristics of the receiving chip (SYN480R) - a voltage between 3.3 and 5.5V, which allows it to be connected directly to the 5V pin of the board (red wire). The transmitted signal is received by means of a small antenna, because the whole chip module and antenna are placed directly in the steering wheel, and the antenna is connected directly to the receiving chip module. The signal is received by the antenna, and the signal processing is performed by the receiving chip module, which pass on the processed signal to the RX0 pins of the Arduino Due board (green wire).

Figure 5. Wiring diagram of the receiving part of the system

3. Construction of a housing for the radiating part of the system

The production of individual components in the automotive industry is obstructed by a many factor. These factors are monitored from the initial design, during their construction and verification of their functionality until the moment they enter into exploitation. Due to the complexity of their work, some elements require additional upgrades, which cost a lot of resources and time for the manufacturers [6, 7, 8]. This necessitates the use of software product with a high degree of flexibility [9]. The French company Dassault Systems provides the exact CAD software. The architecture of CATIA V5 is based on a modular principle and it includes a set of modules, which correspond to specific engineering tasks or processes [10]. Because of the common user interface on all platforms, the cost is minimized and the efficiency of introducing new opportunities for expanding the scope of use is maximized. To build the body of the radiating part of the system in a virtual environment, the 3D modeling software CATIA V5 is used [11]. In the construction of such a housing, the dimensions of the components, such as the antenna, the microcontroller control, the radiating chip module and the battery, are of key importance, as well as the possibility of the transmitter housing being easy to disassemble, making it easily portable. Another important aspect in the modeling of the case is the possibility to build it using FDM technology for 3D printing, i.e. to be consistent with the technical capabilities of the 3D printer.
As is well known, a system of three points in space describes a planar surface. The housing stand itself is in contact with the ground at three fulcrums (Figure 6), which ensure the stability of the housing at all times.

![Figure 6. Overall view of the designed housing of the transmitting part](image)

To activate the signal transmission, it is necessary to turn on the circuit breaker (Figure 7, b), which connects the electric battery (9V) with the Arduino Nano microcontroller. To confirm the operation of the system, the controller sends signals to an RGB LED (Figure 7, a), which is tested by simultaneous transmission in the three spectra (red, blue and green), emitting visible white light for a period of 1 second, after which the emission of light ceases. As it is permissible for the control to work smoothly from 6V to 12V, when the battery voltage drops below 7V, the LED indicates by flashing a bright red light. To avoid the need to replace the battery during operation, a small hole is made that provides access to the mini USB port of the Arduino Nano (Figure 7, c). Thus, by means of an external battery (powerbank), the transmitter can continue to operate smoothly.

![Figure 7. The body of the radiating part viewed from behind and below](image)

In the main body of the transmitter are placed all the components necessary for the signal broadcasting (Figure 8).
Figure 8. Arrangement of the components inside the body
a- Antenna support; b- antenna winding; c- battery holder; d- battery; e- Arduino Nano microcontroller control; f- switch

As mentioned, the design of the case allows it to be disassembled for more compact and easy carrying. The housing is divided into several main parts, which can be assembled and disassembled in a few seconds. The main body is connected to the stem by means of a bolt assembly with a nut, which allows to choose an inclination under which to fix the main body. And the stem is connected to the base to which 3 legs are mounted by pressure (Figure 9).

Figure 9. Representation of the way of assembling all the main components
4. Conclusion

The system was implemented in the latest prototype electric car DTT-3 by team “Team Avtomobilist”. Experiments have shown that:

1. The system uses a minimum amount of energy for its operation;
2. Thanks to the system, the pilot concentrates his full attention on the runway, because of the fact that it is not necessary for him to monitor the laps made;
3. The system provides up-to-date information to the pilot about the laps he has made and the exact time of the last lap;
4. The design of the housing of the transmitting part allowed its easy transportation in disassembled form in a box with dimensions 250x100x120mm.
5. The design allows assembly to take place within 30 seconds.

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