Possibilities of implementing a monitoring system for road transport using a dimensions basis approach

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Abstract: - In nowadays, the development of production force and the sharpening of labour division, the development of production and the movement of goods, have conducted to the enhancement of resources and ways of transportation, which have become internal elements of a global transportation system. Romania, due to its geographical position, is situated at the intersection of communication ways that links north and south, and east to the west of Europe. This means an important benefit related to the transportation. However, in order to ensure an adequate transportation system, Romania has to create a proper infrastructure for all transportation ways. Because roads represent one of the most important transportation ways that has recorded a signified enhancement during the past 100 years, a modern infrastructure, at European standards, is needed. The study proposes a solution with a punctual approach (refers to a transportation way) for watching the traffic flow on the main national roads using a monitoring system, which can be extended through telecommunications systems and becoming a system with a global traffic flow image. Gathering traffic flow information leads to fundamental decisions to improve Romanian auto transportation condition.

Key-Words: - vehicle, ultrasound transducers, transfer characteristic, monitoring, auto traffic, and traffic flow.

1 Introduction

Traffic flow on the network national roads has encountered a special evolution. The average annually daily traffic is double in 2000 compared to the 80s and the prediction for 2015 is that it is going to double compared to 2000. This traffic increase has been determined by the goods and persons transported by vehicles using a direct meaning of transportation, compared to others ways of transportation.

The monitoring principle this system stands on is illustrated in figure 1, which shows three auto transportation vehicles arranged by their dimensions. Is presented only one transportation way. Transducer T is fixed on a frame transversal on the monitoring road at a height that allows to measure distances d_1, d_2 and d_3. These measurements are the input data (Voltages) that are read either through a data acquisition system or through a controller, on a numeric calculator(C).

In order to be able to handle the auto transportation monitoring for a certain road we must strictly divide the interrogation interval of the transducer. In case that under the transducer there is none vehicle than the transducer will indicate d_0, that corresponds to electrical measurement of the transducer. In case that under the transducer there is a vehicle, than the transducer will indicate an electrical result that is related to the vehicle height. Taking into consideration that vehicle sizes are variable with the vehicle maker I will choose three dimensions d_1, d_2, d_3 that are edificatory for the following examples. It can be considered that any measurement that gives a magnitude in a small interval $[d_1-p, d_1+p]$ belongs to category vehicle d_1, similar for d_2 we have $[d_2-p, d_2+p]$ and for d_3 we have $[d_3-p, d_3+p]$. Figure 2 represents a diagram for the distance variation with time -measured by transducer T.

It can be observed that time interval for transducer T interrogation is constant and it has Δt value. The vehicles have passed in the following order:

1. Vehicle category d_3
2. Vehicle category d_2
3. Vehicle category d_3
4. Vehicle category d_1

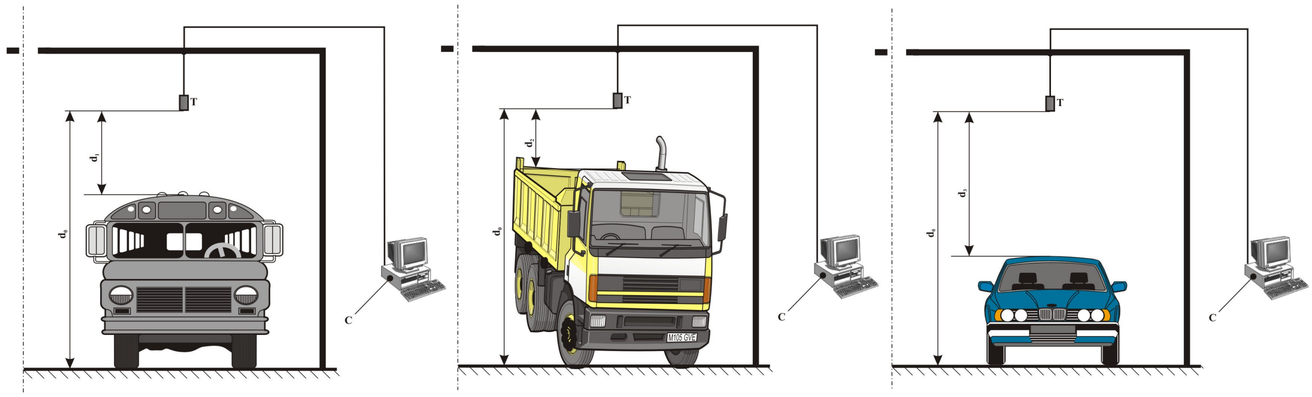

Fig.1 Monitoring different transportation vehicles: bus, heavyweight truck and compact car

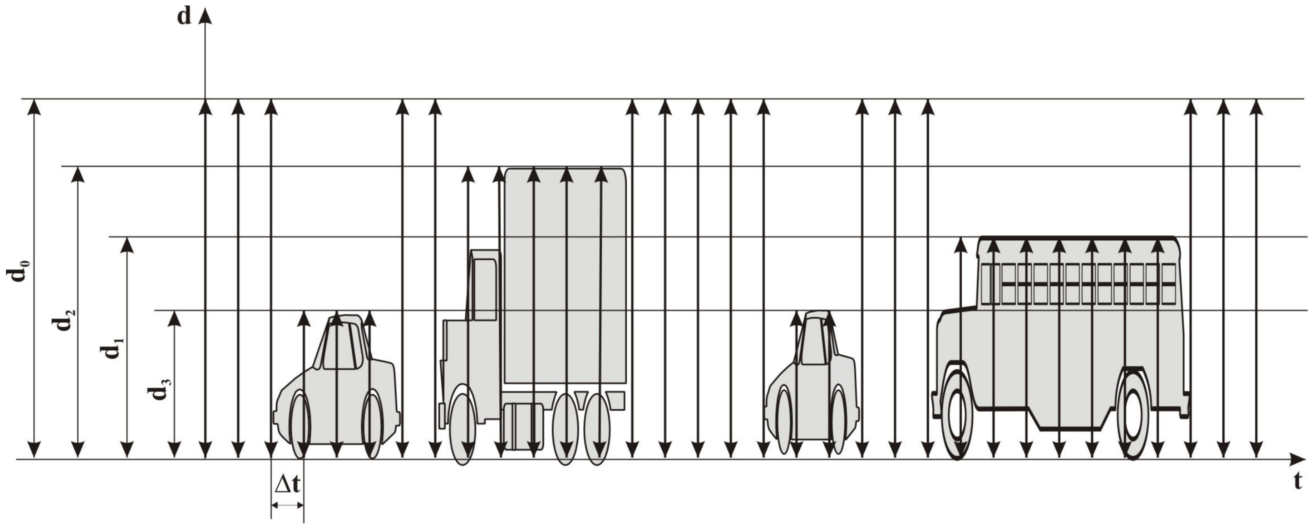

Fig.2 Variation with time of the transducer T measured distance diagram

During the interval taken into consideration two auto vehicle belonging to category d_3 have passed. The number of interrogations that correspond to those are not equal (3 interrogations for the first one and only two for the second) because the passing speeds are sensitive different (the second vehicle speed is higher than the first).

2 The ultrasound transducer Microsonar UT-212

To determine vehicles height we will use ultrasound transducers. Microsonar UT-212 (figure 3) is an ultrasound transducer that is used for detection and for measuring the distance there are those certain objects. Detection and measuring can be done if there are no objects between target vehicle and transducer and the target has to have a good surface to reflect the incident ultrasound beam. The technical specifications for this transducer type are presented in table 1.

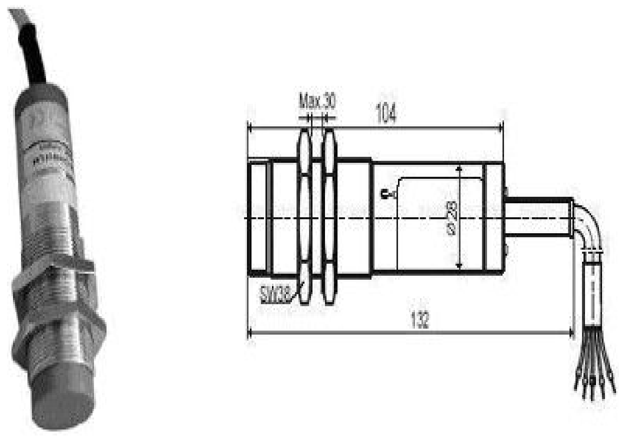

Fig.3 Ultrasound transducer Microsonar UT- 212

Table 1

Distance X_{min}	0,2 m
Distance X_{max}	7,0 m
Ultrasounds frequency	160 kHz
Incident beam maximum	5^o
Measured time T_p	25 ms
Resolution	0...25 mm
Output signal	0...10 V
Programming	contact PRG or with magnet
Working temperature	-20...70 ^oC
Supply voltage	10,8...30 V CC
Consumption Us=12 V	< 41 mA
Consumption Us=24 V	< 49 mA
Weight	400 g

This type of transducer can be used even in cases that spaces are limited. In this situation (fig. 4) the ultrasounds route can be diverted through a reflection surface, the condition of an acceptable limits measurement (table 1) being: $A+B>x_{min}$.

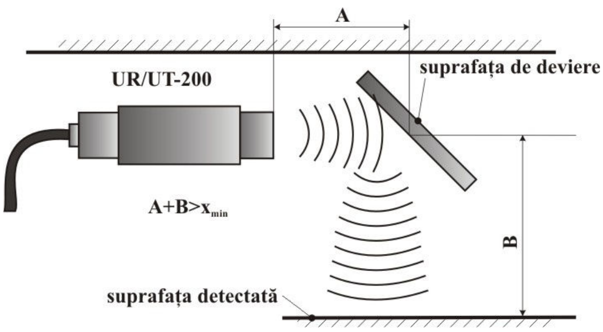

Fig. 4 The deviation of the ultrasounds route

In order to avoid the interference (fig. 5) between 2 or more ultrasounds transducers of this type, with respect to the way of placement, the condition: $B_{min}>$ 0.25m has to be followed.

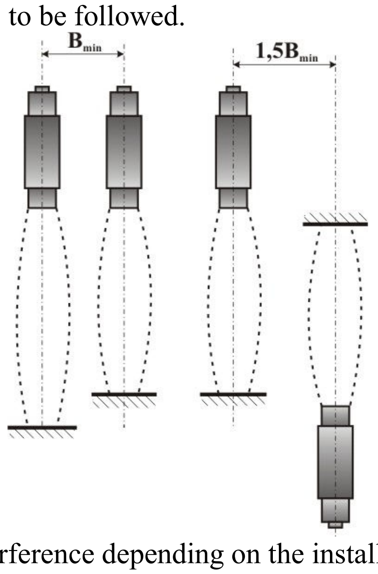

Fig. 5 Interference depending on the installation

2.1 Touch-Magnet Programming

The magnetic screwdriver (with its cap removed) should be put to the points on the enclosure marked up with **A** or **B** according to Figure 6. These steps will in the following be indicated by **A** or **B**.

Touch-Magnet Programming is only available if it is not disabled and the PRG wire is free. Disabling can be programmed both by Touch-Magnet Programming or by cable contacting, but it can only be released by cable contacting.

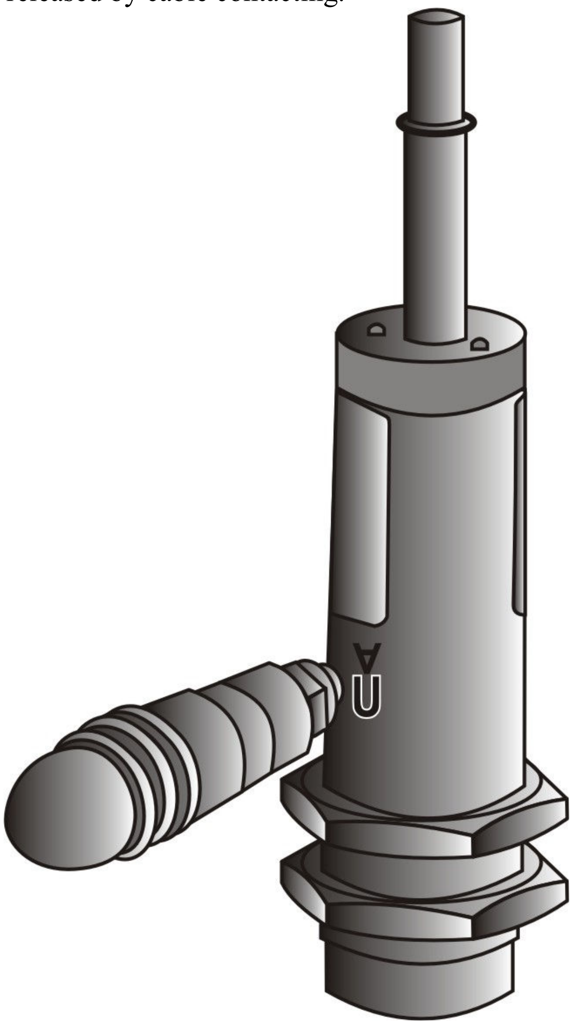

Fig.6 Touch-Magnet Programming

2.2 Programming with cable contact

The steps **A** or **B** A will be represented by connecting wire PRG with +US or GND respectively. These connections can be established by the use of switch or push buttons in accordance with Figures 7 and 8. or by simply connecting cables.

Different states within the programming procedure will be indicated by the three LEDs. Steps **A** and **B** (magnet touch, wire connection) should be maintained till the effect will be indicated by the relevant change of the LED status (figure 9).

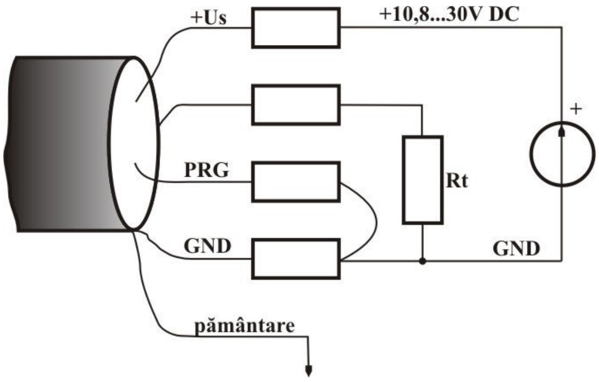

Fig. 7 Connections for measurement with Microsonar UT-212 transducer

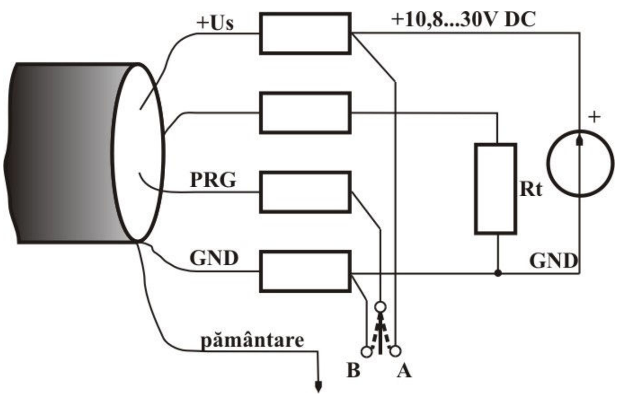

Fig. 8 Connections for programming of Microsonar UT-212 transducer

Fig.9 Arrangement of the LEDs and interpretation of markings

For entering programming mode: step **A** for 2 s.

For quitting programming mode: step **B.**

Programming mode entered: will be indicated by blinking of the red and going off the yellow and green LED s. While being in programming mode (with red LED blinking) every step **A** will change the Menu Points. The six different Menu Points are indicated by the combination of the states of the yellow and green LEDs. Selecting the Menu Point the unit will after 5 s automatically (without step **A** or **B)** be ready for programming, which will be indicated by the red LED. In the first four Menu Points learning should be initiated by step **A**. Blinking of the green LED indicates the measurement during the learning. On getting a valid echo the yellow LED will lit and the relevant numeric value of the measured distance appears on the output (for instance with measured distance of 0.4 m the output will be 0.4 mA or 0.4 V!) With repeated step **A** new distance can be learned and the old one will be overwritten. Step **B** will finalise learning and result in return to the Menu Point. Step **B** represents quitting Programming Mode.

Parameters **a** and **k** can be programmed in Menu Points 4 and 5.

Touch-Magnet programming can be enabled or disabled in Menu Point 6 by step **A**. Disabling of the Magnet-Touch Programming by the use of the magnet will be completed after quitting Programming Mode.

During Touch-Magnet Programming the Wire-Contact Programming is disabled and vice versa.
If the unit is left in Programming Mode by mistake it will automatically quit after 10 seconds.

2.3. The transfer characteristic

Transfer characteristic for Microsonar UT-212 transducer is showed in figure 10and 11.

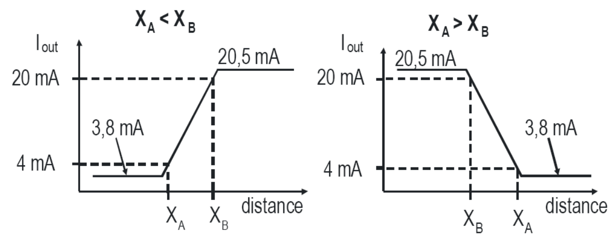

Fig. 10 Transfer characteristic of units with current output

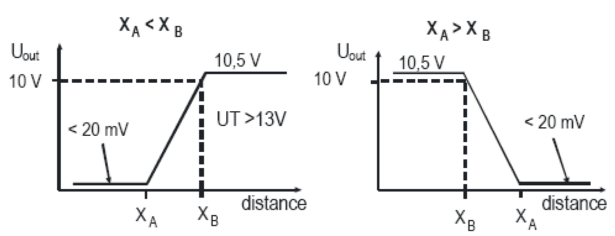

Fig.11 Transfer characteristic of units with voltage output

In conformity with target objects(figure 12) the measurement result will be presented in table 2.

Processing the transducer-generated signal can be adapted for various requirements and conditions.

The programmable parameters that influence processing signal are the average number and the removed echoes number.

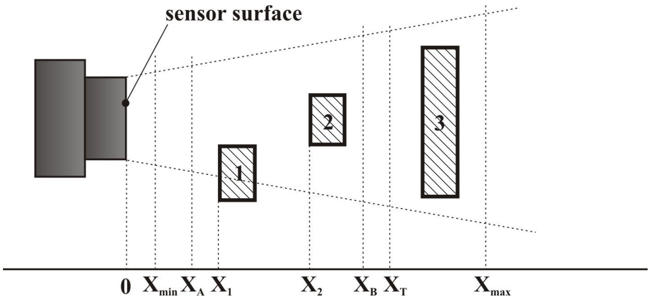

Fig. 12 Target objects positioning

Table 2

Targets present	Measured distance
1,2,3	X1
2,3	X2
3	Error

Distance parameters X_A, and X_B can be changed with programming by placing a good reflecting target at the distance to be programmed and by stepping to the relevant Menu Point. The unit will measure and store (learn) the distance.

Microsonar will accept the echo coming from the reflecting surface (within the range) nearest to the unit. The range of the unit with Factory Setting extends between X_{min} and X_{max}. (Nominal range).

If the target is moving within narrower range it is advised to reduce the range by far-end blocking which should be done with programming X_T. Factory default:

$$X_T = X_{max} \tag{1}$$

The signal processing of the unit can be adapted for the most different requirements and conditions of the application. The two programmable parameters influencing signal processing are the averaging number and the number of discarded echoes.

Average number: a, can take following values: 1,4,8 or 16.

To avoid mistaken measurements the unit will not provide output on the basis of a single measurement but by taking the average of the last **a** number of distance samples.

Increasing averaging number will reduce small oscillation of the output signal born by the indefinite movement of the target or measurement error (caused by noise). On the other hand this will cause a target tracking failure depending on the speed of the target which will be mended after a Tb=a·Tp settling time or switching delay.

Number of discarded echoes: **k** (1, 3, 5 or 10)

Under disadvantageous conditions (air movement, not perpendicular or bad reflecting surface) some of the echoes may miss the sensor. Giving immediate attention to this, might lead to frequent error indication or measurement failures. Therefore the unit would check the measured distance for verifying that it is within the range.

Measured distance outside the range will be disregarded while calculating the average and leaves output signal unchanged. The unit can disregard **k** number of consecutive distance samples. After that error will be indicated. If due to bad reflection substantial number of echoes go astray and the number of invalid (incorrect) echoes, between two valid ones, is smaller than **k** the unit will work continuously i.e. without indicating error. The greater the value of **k** programmed, the less sensitive the unit to invalid echoes but the reaction time for indication of error will increase. To maintain continuous operation the programmed range is advised to keep as narrow as possible.

The greater the speed of the target the smaller should the averaging number be chosen. The worse the reflection of the target the higher value should be chosen for **k** (number of discarded echoes).

Steps that have to be followed for programming Microsonar U-212 transducer are showed in figure 13.

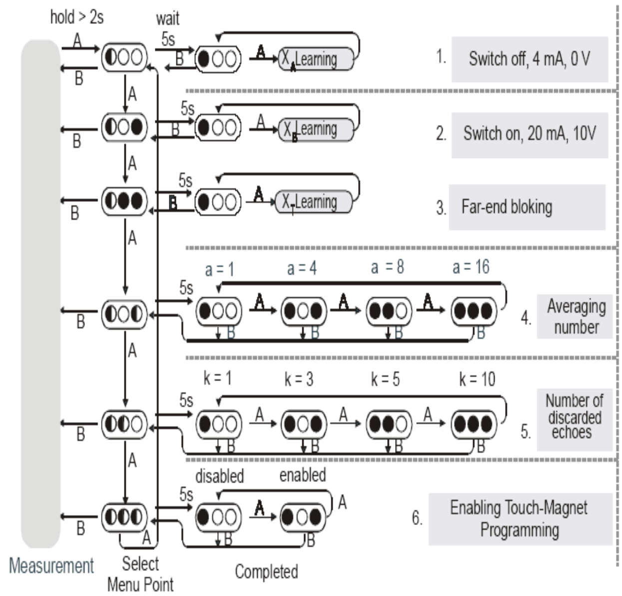

Fig.13. Programming Microsonar U212 transducer (modification of parameters)

3. Transducers voltages I/O reading card

In order to read the supplied voltages from Microsonar UT- 21 transducers it will be used an A/D – D/A type I/O card with a 12 bits resolution and a numerical calculator (figure 14).

This card allows 2 digital-analogical outputs (unipolar or bipolar) and 16 analog-digital inputs (simple) or 8 analogical-digital (differential) all of them having a 12 bits resolution.

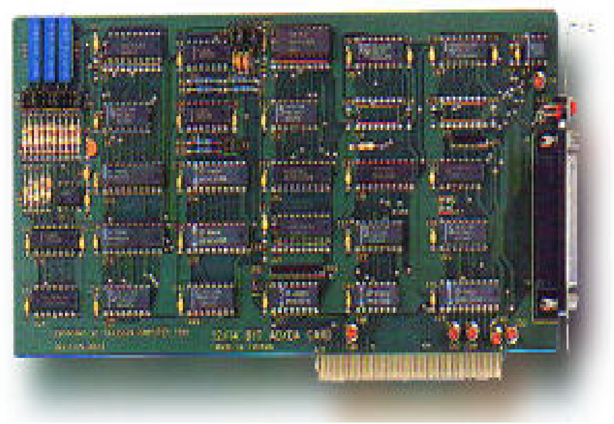

Fig.14 A/D – D/A 12 bits Card

The Technical data of this card are the following:

D/A

– resolution	12 bits;
– number of channels	2;
– power output:	
- unipolar output	0 at 2,5 V, 0 at 5 V, 0 at10 V;
- bipolar output	-2,5 at 2,5 V, -5 at 5 V, -10 at 10 V;
– conversion time	< 2 μs ;
– output impedance	> 2 kΩ ;

A/D:

– resolution	12 bits;
– power input	
- unipolar input	0 at 2,5 V, 0 at 5 V, 0 at 10 V;
- bipolar input	-2,5 at 2,5 , -5 at 5 V, -10 at 10 V;
– conversion time	< 22 μs (for each channel);
– maximum power allowed	12 V.

The reading, interpreting and display of monitored values program was realized in C language on a DOS platform using the next algorithm:

Analogue-digital conversion:

1) select the channel to be read
   OUT port, channel
2) cancel the parameters
   OUT (port+1),1
3) start conversion
   FOR I=1 to 6
      A=INP (port+12)
   NEXT I
   FOR I=1 to 8
      A=INP (port+8)
   NEXT I
4) read the above octet (4 bits)
   C=INP (port+3)
   HB=(C/16 – INT(C/16))*16
5) read the below octet (8 bits)
   LB=INP(port+2)
6)measure the value
   A/D=HB*256+LB

Analogue-digital conversion:

1) write the above octet on the channel 1 (4 bits)
   OUT (port + 5), Hdata
2) write the below octet on channel 1 (8bits)
   OUT(port+4),Ldata
3) write the above octet on channel 2 (4 bits)
   OUT (port + 7), Hdata
4) write the below octet on channel 2 (8 bits)
   OUT(port+6),Ldata

The pins assignation for A/D –D/A card is presented in table 3.

Table 3

Pin	Function	Pin	Function
1	+12 V	14	-12V
2	D/A-CH2 OUT	15	D/A-CH1 UT
3	GND	16	A/D-CH15
4	A/D-CH14	17	A/D-CH13
5	A/D-CH12	18	A/D-CH11
6	A/D-CH10	19	A/D-CH9
7	A/D-CH8	20	A/D-CH7
8	A/D-CH6	21	A/D-CH5
9	A/D-CH4	22	A/D-CH3
10	A/D-CH2	23	A/D-CH1
11	A/D-CH0	24	GND
12	GND	25	-5V
13	+5V		

4. Controller µChameleon

As can be seen in Figure 15 this controller has a compact design. It can perform the functions of table 4.

Values from ultrasound transducer (voltages) are transmitted via the connector 1 system to controller 2, and from this controller through the USB interface are covered in numerical computer 3.

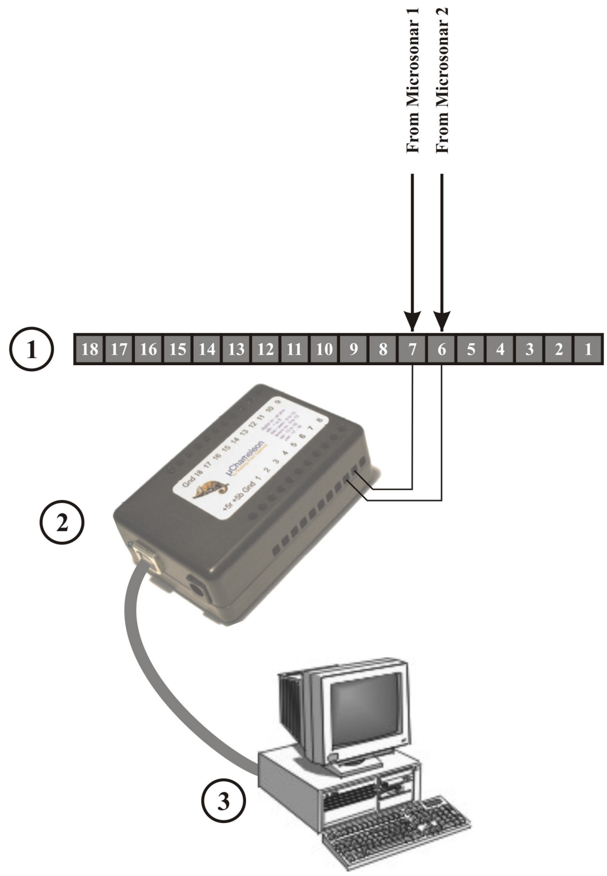

Fig. 15 Controller arrangement

Table 4

Function	Corresponding Pin
Digital I/O	All pins
Analogical inputs	1 to 8
Analogical outputs	9 to 12
Timer	9 to 12
Output PWM (Pulse-width modulation)	9 to 12
Input pull-ups	9 to 16
SPI (Serial Peripheral Interface Bus)	13 to 16
UART (Universal asynchronous receiver/transmitter)	17 to 18

Each controller pins can be individually programmed as digital inputs or outputs, each state can be set or read. As shown in Table 3 analysis some pins may have special functions such as analogical input, analogical output, frequency generator or frequency modulation.

The easiest way to communicate with this type of controller is based on using dynamic library D2XX.DLL, provided by the manufacturer, which includes library functions via the USB port through which can be transmitted commands and can be read information.

Analysing figure 15 shows 2 pins of the controller that must be set as pins for analogical inputs (1 and 2). Commands submitted to setting pins as were described above are presented in Table 5.

Table 5

Command	Set pins	Action
adc <n>; n=1,2	1 to 2	Sets pins 1 to 2 as analogical inputs

The controller has a resolution for analogical inputs and outputs of 8 bits. At such input is converted a voltage between 0 and 5 V on a single-byte. Measured voltage value is determined by the relationship:

$$V = \frac{n \cdot 5}{255} \quad (2)$$

where:
V- input voltage value,
n - the value corresponding byte read by the USB port of the controller.

We conclude that this type of controller compared to the card in paragraph 3, because of a lower resolution (8 bits), is a "tool" to measure less precisely. But the use of it in combination with a software developed on a Visual programming platform type makes it more attractive and easier to program.

5 Experimental researches to implement an auto transportation monitoring system using a dimensions basis approach

The experimental researches have been realised using an ultrasound transducer that has the maximum measuring distance of 1 m.

5.1 Drawing the transfer characteristic for UT 212 transducer

Using a Microsonar UT 212 transducer that has been fixed on a frame (figure 16), which allows the modification of distance compared to a plane surface, we'll draw the transfer characteristic for it. First there have been programmed (as per figure 14-Select 0V, Select 10V) the correlations between maximum (minimum) voltages and the their distances. Their values are presented in Table 6.

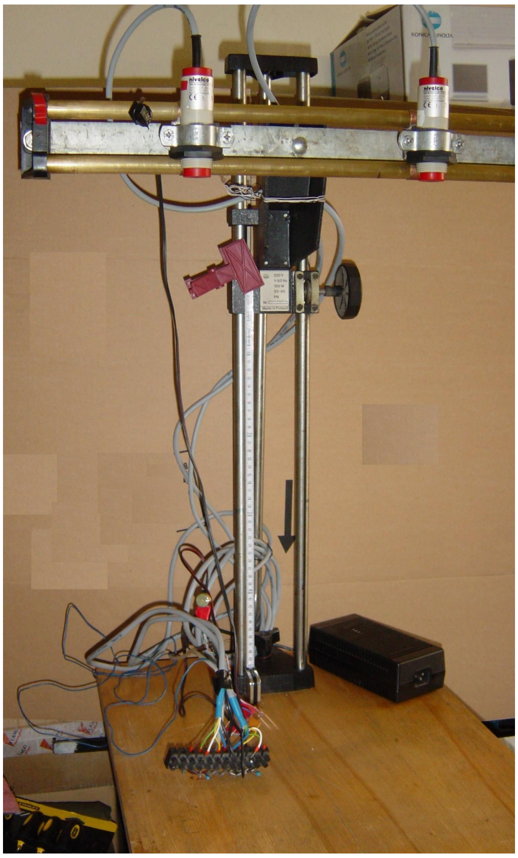

Fig.16 The transducers installed on the plane surface

Table 6

Distance to the reference surface [mm]	Measured voltage [V]
205	0.02
797	10

Figure 17 shows the transfer characteristic for the Microsonar UT 212 ultrasound transducer as well as the transfer straight-line equation corresponding to it. Establishing this characteristic has been done by modifying the transducers frame distance related to the base surface with a step of 50 mm and by measuring the corresponding voltage of the transducer. It can be seen that this characteristic has a linear shape in accordance with figure 11.

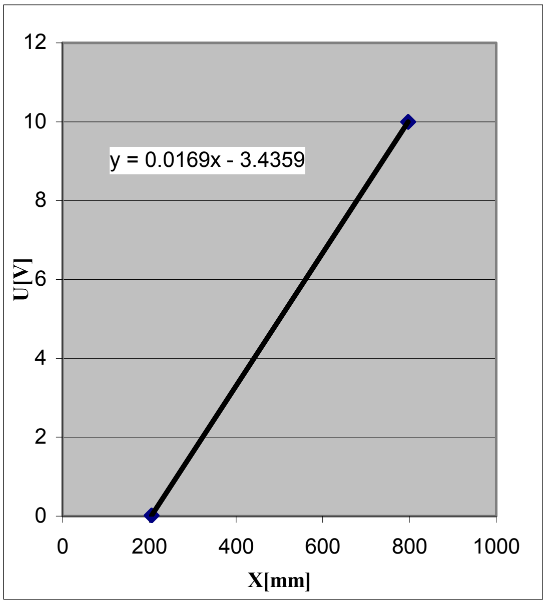

Fig. 17 Transfer characteristic for UT 212 transducer

5.2 Software application for traffic monitoring

To monitoring the traffic it has been developed a C application for DOS operating system. This program has to identify a target object that passes across the ultrasound transducer and to draw its shape in order to put it in one of the categories (d_1, d_2, or d_3).

The application performs the following functions:

- Reads voltages generated by the ultrasound transducers, the reading can be done at time intervals chosen by user;
- Analogically displays the value of read voltage and digitally displays its value and the correspondence distance value (figure 18);
- Writes the read distances values in a file at user request;
- Allows, when a key is pressed, the engine step by step progress and the motion of an object which shape has to be determined.

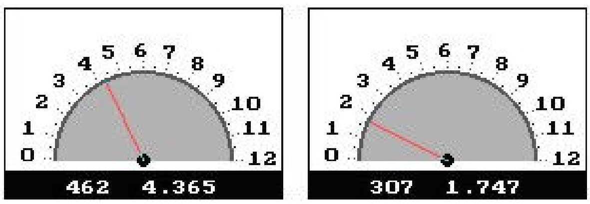

Fig. 18 Analogical display

The profile put in motion using a step-by-step engine is shown in figure 19.

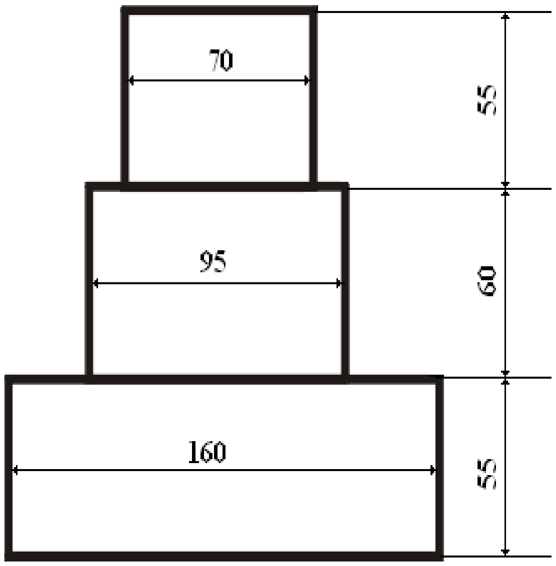

Fig. 19 Monitored profile

The outcome of the application is the profile presented in figure 20. There were two runs: one for k=1 and other for k=10.

It can be observed that the drawing profile for k=10 is more accurate than the one for k=1, the higher value of parameter k diminishes the reflection errors, the measuring being improved in these conditions.

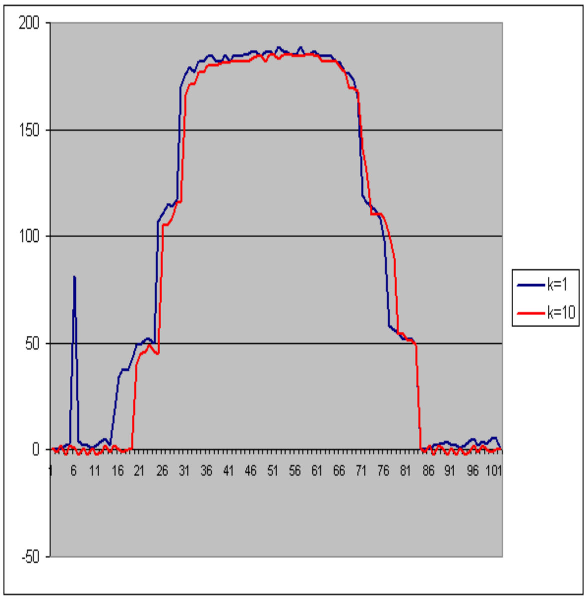

Fig. 20 Monitored result

4 Conclusion

In order to ensure an adequate transportation system Romania must ensure a proper infrastructure for all ways of transportation. Because roads represent one of the most important transportation ways that has recorded a signified enhancement during the past 100 years, a modern infrastructure, at European standards, is needed.

Romanian land transportation infrastructure is over fulfilled and it cannot support the traffic flow anymore. This reason makes it necessary to know the traffic flow on the most important national roads using a monitoring system.

The proposed solution in this study has a punctual approach (it refers to a single transportation way) but it can be extended using telecommunications systems and it can offer a global image of the traffic flow. Gathering traffic flow information allows elaborating fundamental decisions to improve the Romanian land transportation conditions.

The components that make this monitoring system to be viable and attractive are:

- Low cost price due to:
  - Ultrasound transducers are relatively cheap
  - Hardware resources needed for primary monitoring does not have to be top notch because the application is developed for MS-DOS platform
  - Instead of fixing transducers on a frame, bridges and upper gangways can be used
- Robustness
- Portability
- Elasticity- different transportation vehicles can be modified through number and dimension by altering the height
- Relatively easy to assemble
- Low maintenance costs
- Possibility to divide traffic for each type of transportation vehicle, compared to monitoring systems that use thermal sensors
- Possibility to signal rush hours.

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