TALLINNA TEHNIKAÜLIKOOL
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Chair of Quality Engineering and Metrology

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Deceleration measurement system used for measuring vehicle braking parameters

Master's Thesis

Author applying for
master's sciences of technical
academic degrees

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2016

(The reverse of the title page)

AUTHOR'S DECLARATION

I hereby declare that this thesis is the result of my independent work.
On the basis of materials not previously applied for an academic degree.
All materials used in the work of other authors are provided with corresponding references.

The work was completed .... guidance

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The author

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The work meets the requirements for a master's work.

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Supervisor

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Permit to defense

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TUT Department of Mechatronics
Chair of Mechanosystem Components

MASTER'S THESIS SHEET OF TASK'S

Year 2016, semester 4

Student: Ramanjit Singh, MAHM 144749
Curricula: MAHM 02/13
Speciality: Mechatronics
Supervisor: Professor, Edi Kulderknup

MASTER'S THESIS TOPIC:
(in English) Deceleration measurement system used by vehicle braking parameter measurement
(in Estonian) Sõidukite pidurdamise aeglustuse mõõtesusteem

Thesis tasks to be completed and the timetable:

Nr	Description of tasks	Timetable
1.	Finding of braking parameter measurement instrument based on deceleration measurement	**18/.03.2016**
2.	Working up the decelerometer suitable for use in vehicle periodic inspection	**20.03.2016**
3.	Theoretical design of decelerometer with required accuracy.Working up the composite scheme and general technical drawing. Used microprocessor program development. Design of measurement data transmission through wifi.	**19.04.2016**
4.	Development of the decelerometers calibration procedure with uncertainty estimation. Required expanded uncertainty max 2% from measurement result	**29.04.2016**
5.	Safety and financial problems solution	**8.05.2016**

Solved engineering and economic problems:
Developing a theoretical design for Decelerometer. During the development the work is divided into subtasks. Each substasks are analyzed and finally a suitable design is proposed.

Additional comments and requirements: ……………………………………..............................

Language: English

Application is filed not later than: 16.05.2016

Deadline for submitting the theses: 20.05.2016

Student: Ramanjit Singh /signature/ ……….............. date ………

Supervisor: Edi Kulderknup /signature/ ………................ date………

Contents

LIST OF FIGURES

LIST OF TABLES

Kokkuvõte

Antud magistritöö ülesandeks on arendada sõidukite pidurduse effektiivsuse mõõtur, mis põhineb pidurduse aeglustuse mõõtmisel. Antud mõõtevahend on vajalik praktikas sõidukite perioodilisel tehnilisel ülevaatusel üle kogu Euroopa Liidu. Pidurduse aeglustuse mõõtur, mis näitab otse pidurduse effektiivsust, on ettenähtud ka direktiiviga 2014/45/EC, mis käsitleb sõidukite tehniliste seisukorda. Ülesande lahendamiseks on vajalik mitme alamülesande rakendaamine. Esmalt oli vajalik läbi viia olemasolevate sõidukite pidurduse effektiivuse mõõtevahendite analüüs. Pidurduse effektiivsust on võimalik mõõta mitme meetodiga, milledest rakendatuim on otse mõõta ratastelt pidurdujõudu, mis on aga kallis ja viiakse läbi sõiduki paigaloleku tingimustes, mitte liikumisel, nagu tavaolukorras. Sõiduki aeglustuse mõõtmine annab reaalsele lähedasemad andmed sõiduki pidurduse tehnilisest seidukorrast, kuivõrd toimub sõiduki liikumisel. Aeglustuse mõõtmine võimaldab läbi viia pidurduse katse ja mõõta keskmise aeglustuse kogu pidurduse tsükli ajal reaalsetes tingimustes. Samuti on aeglustuse anduri kasutamine hinnalt odav, kuid kindlustab vajaliku täpsustaseme. Seega on aeglustuse mõõturi, mis näitab mõõtetulemuse pidurduse effektiivsusena, arendamine uudne, praktiliselt vajalik ja innovatiivne. Antud töös esitatud pidurduse effektiivsuse mõõtur aeglustuse alusel koosneb mehhaanilise struktuuri, milles asetsevad mõõtevahendi komponendid, arendusest. Tuleb arvestada, et mehhaaniline struktuur peab olema vastupidav. Järgnevalt on esitatud mõõtevahendi üldkompositsioon, mis omab esmast tähtsust. Komponentide valik sisaldas aeglustuse anduri, ADC konverteri ja mikrokontrolleri leidmist. Autori poolt oli leitud sobiv aeglustuse andur ja mikrokontroller, mis sisaldas ka ADC konverteri. Valitud oli Arduino Uno mikrokontroller. Seda mikrokontrollerit on lihtne programmeerida ja võimalik on kasutada andmete ülekandmiseks wify abil. Mikrokontrolleri abil toimub aeglustuse mõõtetulemuste ümberarvutamine pidurduse effektiivsuseks. Lisada tuleb sõiduki massi andmed eelnevast mõõtmisest. Autor soovitab akasutada 7 voldist toitepinget. Järgnevalt on antud mõõtevahendi elektriline ühendusskeem. Antud on mikrokontrolleri programmi lahendusskeem.

Mõõtevahendite puhul on oluline mõõtetulemuse tõendus ja selleks on autori poolt esitatud kalibreerimise metoodika koos mõõtemääramatuse hinnanguga. Kalibreerimismetoodika võimaldab laiendmääramatuse U pidurduse effektiivsuse % des. Käsitletud on mõõteseadme hinnaaluseid ja vajalikke katseid, tõendamaks mõõtevahendi kasutuskõlblikkust.

FOREWORD

This thesis was written for my Master degree in Mechatronics at the Tallinn University of Technology. The work was executed at the Tallinn University of Technology. The work consists of electronic, mechanical, data communication and software field integration. The purpose of the research is to design decelerometer with the braking efficiency indication. I would like to thank the people, without whose help and support this thesis would not have been possible. First, I like to show my gratitude to the people of my departments of Mechatronics. My supervisor Edi Kulderknup for his suggestions, encouragements, and guidance in writing the thesis and approaching the different challenges during the thesis. I would also like to thank my sister and brother for their support and help. Finally, I would like to thank my parents and my friends for their constant support during the time I studied.

Tallinn, May 2016,
Ramanjit Singh

INTRODUCTION

This topic relates to the deceleration measurement instrument used for measuring vehicle braking parameter. This topic is proposed by my supervisor and he has the working experience of more than 20yrs in the field of metrology. There is very few equipment which are used for measuring braking parameters. Mostly rollerbench technique is used, but there are few companies which manufacture decelerometer for measuring braking efficiency. I have researched that the current decelerometer does not provide the satisfactory result. There is always an error limit. The techniques which are used. The calibration and uncertainty estimation procedure for the decelerometer has to be developed. The data cannot be shared through Wi-Fi. The target object would be improved decelerometer design. Author is designing the decelerometer that would be displayed braking efficiency in % with time and date. It has the feature of Wi-Fi for transmission of the data to the desired server. The Author has done some research, compared several decelerometer and has developed an improved new design.

The main problem of measuring the braking parameter is the accurate efficiency measurement in %, but in most technique average value of the deceleration generated during braking is calculated so this needs to be improved. Another problem is the accuracy, most of the available decelerometer are not accurate, there is still left an error limit in them. To get the right result the vehicle braking operation uncertainty of the measured result has to be considered. The tasks of this thesis include comparing the available instrument used for measuring the braking perimeter of the vehicle, what are their drawbacks, evaluate their mechanisms and finally propose the new design. To solve these problems a decelerometer has to be design which has the best accuracy with improved calibration procedure and based on it the uncertainty of the result is estimated to get the right result and the expanded uncertainty max 2% of measurement result can be estimated. The program has to be developed for calculating the braking efficiency and the data can also be shared through the internet wifi with the desired server. . For better accuracy the better calibration procedure has to be developed. Since the results always has the uncertainty factor involved. So an efficient method for calibration and uncertainty estimation has to be developed. These are the main focuses of my thesis.

1. EU DIRECTIVES ON ROADWORTHINESS TEST FOR VEHICLES

Roadworthiness testing is a part of the wider regime designed to ensure that vehicles are kept in a safe and environmentally acceptable condition during their use. Road vehicles should technically maintain.Therefore the periodic inspection of road vehicle is very necessary. Each country has his own directive, which should be followed during the inspection and they also specified the standards to be followed. EU follows the directive 2014/45/EC for the periodic inspection of the vehicles [1]. There are several things which should be kept in mind while having a test. The test center should be a certified center to carry out such test. The certified equipment should be used for such tests. Vehicles with the malfunctioning technical system have an impact on road safety and may contribute to road accidents. This impact can be reduced by improving the roadworthiness testing system.

During the inspection of any vehicle the most important parameter which has to be measured are the braking parameters. For measuring the braking parameters means we are measuring the deceleration of the vehicle. Deceleration means a reduction in speed by a certain speed value in meters per second for each second. The instruments which are used to measure these braking parameters are called as decelerometer. The main purpose of the decelerometer is the measurement of braking parameters.

There are few companies which are manufacturing the decelerometer. Which is the main focus of my thesis. There are several instruments available in the market for measuring these parameters. The circumstances in which the measurements are performed are more important because it gives the measurement process stability and accuracy. For this good quality of measurement instruments should be used.

The main parameters for the inspections of the vehicle is to measure braking parameters which include braking force, performance and efficiency of brakes, equality of braking force on every wheel. There are always permissible error limits while measuring these braking parameters. There are several current problems with the available decelerometers which needs to be improved.

The main problem of measuring the braking parameter is the efficiency and performance factors which need to be improved. Another problem is the accuracy, most of the available decelerometer are not accurate, there is still left an error limit in them. To get the right result the vehicle braking operation uncertainty of the measured result has to be used.

According to the directives of 2014/45/EC.For the efficiency with the decelerometer should generate the braking efficiency. If the vehicle exceeds the mass of more than 3,5 tonnes then it has to be checked by the ISO 21060 method. Road tests should always be carried out under a dry conditions on a flat, straight road [1].

2. VEHICLE BRAKING PARAMETER FOR INSPECTION

During the roadworthiness testing of vehicles there are several parameters which plays an important role during the inspection of vehicles. Among these the most important is the vehicle braking parameter which means measuring the efficiency of the brakes. When one apply brakes, how efficiently the brakes are working that needs to be tested. According to the standard defined the braking efficiency for road vehicle should be minimum 60% to pass the test. Braking efficiency is proportional to the braking force divided by the mass of the vehicle.

The braking efficiency measurement process has various factors which have influenced during the inspection of vehicles. Among these the one factor is the measurement method how the test is being carried out. There are several other factors also. The condition of the road surface on which the test is being carried out. It has an impact on the braking condition. The techniques used during the inspection to the test the braking parameters by using a roller bench or by using decelerometer. Vehicle condition is also an important factor that needs to be considered a special vehicle braking condition during the inspection. Person carry out the test. Theoretically the measurement uncertainty should be upto 3 to 5 times more than measuring device uncertainty.
There are several other parameters which are considered during measuring the braking condition of the vehicle and those are listed below

Adhesion coefficient *(k)*
Adhesion coefficient depends on the road surface and its condition due to which certain value of this coefficient is achieved, which determines the maximum achievable braking deceleration.derived from [2].
Max. Achievable deceleration = gravity.

$$\text{Adhesion coefficient} \quad = g.\, K\,\mathrm{m/s^2} \qquad (2.1)$$

Table 2.1. Shows adhesion coefficients k on different road conditions [2].

Road surface	Dry	Wet clean	Wet slippery
Concrete, granite	0.7	0.6	Approx 0.4

Tar macadam	0.6	0.5	Approx, 0.3
Asphalt	0.6	0.5	Approx. 0.25
Blue basalt cobbles	0.55	0.3	0.1 – 0.2
Snow	0.2	0.1	0.1
Black ice	0.1	0.1	0.1

By using these values of the adhesive coefficient according the surface on which test is being carried out. The maximum deceleration which can be achieved on such type of the surface is calculated.

For example, if a braking process is carried out on the surface of snow then

$$a_{max} = 10\frac{m}{s^2}.0{,}2 = 2\frac{m}{s^2} \qquad (2.2)$$

This means if the adhesion coefficient is 0.2 then maximum achievable values is $2\frac{m}{s^2}$.

The whole process of braking

There are several parameters which are involved during the braking process of the vehicle. Which means when the brakes are applied and from the time it is applied till the vehicle stops, there are several parameters which are described below. The maximum deceleration which can be achieved during the braking process is not affected by the total time taken by the vehicle from the time when the brakes are being applied and finally when the vehicle stops. Because when the brakes are applied till vehicle stops there are several processes which are involved during this whole process of the braking, the process first passes through the response time t_a and the pressure build up time t_s .

The responds time (t_a) Is defined as the time in which the brake pedal is being actuated and then till it reaches to the point of maximum braking performance.

In the second stage of the process, then the other parameter is involved, which is called as the pressure build-up timet_s This is defined as the time which in-between the point of the braking performance and the moment when maximum braking deceleration has been achieved.

Braking deceleration period ($t_{a_{max}}$) The period from the time of maximum braking deceleration and the moment when the vehicle finally stopped.

Total Braking Period(t_{tot}) The period from the beginning when the brakes are being pressed and the time till the vehicle finally stops. In this whole process drivers thinking and reaction time is not included.

Actuating period(t_f) It is the period when brake pedal, which is being pressed and the moment its when it reaches to its end
The Braking Ratio The percentage ratio of the braking forces generated by the current weight force of the vehicle. [2]

$$Braking\ ratio\ in\ \% = \frac{vehicle\ stotal\ braking\ force}{vehicle\ test\ weight}.100 \quad (2.3)$$

$$Z = \frac{F}{G_p}.100\ \% \quad (2.4)$$

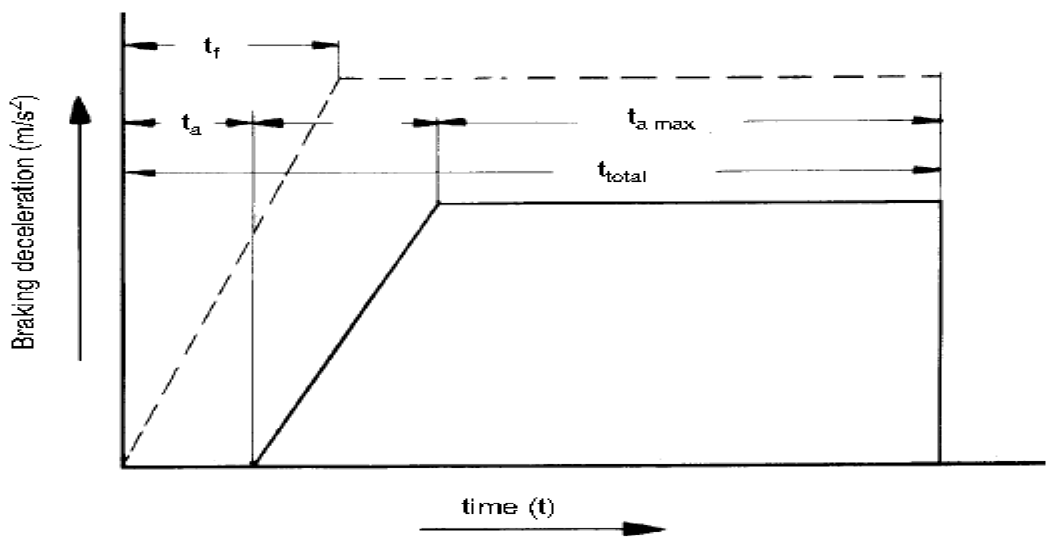

Figure 2.1 concept of Braking process of the vehicle[2]

There is an direct relation between the braking deceleration amax and the braking ratio which is explained below:

$$a_{max} = \frac{F.g}{G_p} = z.g \quad (2.5)$$

Which allows the braking deceleration(a_{max}) obtained to be expressed as the percentage of braking ratio(z) .

Table 2.2. Braking ratio proportional to braking deceleration [2]

Braking Ratio(z)	Exact braking deceleration
10 efficiency %	0.981m/s^2
20 efficiency %	1.962 m/s^2
30 efficiency %	2.943 m/s^2
40 efficiency %	3.924 m/s^2
50 efficiency %	4.905 m/s^2
60 efficiency %	5.886 m/s^2
70 efficiency %	6.867 m/s^2
80 efficiency %	7.848 m/s^2
90 efficiency %	8.829 m/s^2
100 efficiency %	9.810 m/s^2

3. INSTRUMENTS USED FOR MEASURING THESE PARAMETER

There are several instruments by which the braking parameter of the vehicle can be measured. Among these the most popular is the roller bench technique. For the road test decelerometer is used. There are three common techniques which are used for measuring braking system of the vehicle.

3.1. Roller bench brake testing system

It is a method which is used for testing, braking parameters of the vehicle which is measured directly on the rollerbench with weighing instrument which is the basic principle of working. In this method the force on each axle is measured and imbalance among all axles of the vehicle is also checked.

Figure 3.1. Roller tester for braking efficiency measurement concept [3].

It usually measures the braking force by hydraulic pressure or air and the resulting display is braking force overtime. This technique is used to know the braking condition of the vehicle. It can be used to measure the braking condition of heavy vehicles and light vehicles. It is a most common techniques which are in use for measuring braking system of the vehicle.

3.2. Plate brake tester

This is also a technique which is used to measure the braking parameters of the vehicles. But it is not so common nowadays. It's an old technique which is not in practice nowadays. The principle which this technique follows is that it consists of two parallel plates which are moving and placed on the transducer so when the vehicle passes over these plates and the brakes are being applied. By this the braking force generated during the braking process is calculated. The whole process of braking results in the forward movement of the plates by which the braking force is calculated.

Figure 3.2. Concept of plate braking testing system [4]

It can also be measured by the difference in voltage measure on each force transducer. The result is not so accurate, by using such kind of techniques.

3.3. Decelerometer

The use of decelerometer for measuring the braking efficiency of the vehicle is the best way to know the braking efficiency of the vehicle. This instrument is used for measuring the braking parameter during the road test. It has an inbuilt sensor which generates the value of the braking force g generated during the braking process of the vehicle. The direction of travel while using a decelerometer is always forward and there is a sign also made on the top of every decelerometer with an arrow mark which means it is always placed in the vehicle with the arrow pointing forward movement. This calculates the braking process from the time of brakes being applied till the vehicle stops. This generates data in form graph through which the braking efficiency of the vehicle is calculated and how efficient are the braking system of the vehicle is displayed on the screen of the decelerometer.

Figure 3.3. Decelerometer for testing brake system [5]

4. NEED FOR MEASURING THESE PARAMETERS

Road vehicles should be technically maintained and approved if are used on the public roads. Therefore the technical inspection should be carried out in a prescribed time period, which is for heavier vehicles is one year and also depend on the condition of the vehicles. Vehicle inspection is defined as the process to perform mandatory inspection, including any associated testing and measurements, of the road vehicles on the basis of defined directives for the periodical inspection of vehicles. Vehicle inspection is used mainly 5-6 measurements. The most important parameter which shows the vehicle condition are brakes correct working indicators which are braking force and braking efficiency and differentiate of braking force of various wheels on the same axle. Therefore, it is very important to measure the braking parameter of any vehicle.

For the safety of the road vehicles and to prevent accidents there is always a need to ensure that the vehicle should have the periodical inspection. During the inspection of vehicle these tests are carried under the defined category and by following the procedure according to the directives of the roadworthiness which defined under the European commission. If the vehicles are being inspected from time to time, then the reduction in the number of accidents can be observed and moreover, it also creates an responsibility among individual that these parameters should should be inspected on define them to reduce the risk involves while driving the vehicle if these parameters are not working properly.

When road vehicles are technically maintained and approved, then only are allowed to be used on the roads. The inspection period for any vehicle depend on the age and condition of the vehicles. The inspected body can be public or private, but it should be authorized by the government, which means the testing should also be done by the registered center then only the test result will be considered valid. By measuring the braking parameter of any vehicle it can be observed how efficient this vehicle is for the use of the road and the owner of the vehicle also get aware and then can change the brakes, if required or do the necessary repair and can solve the problem before any damage may happen. There are several other parameters that need to be remembered when designing any brake testing instrument used for the vehicles. The mass of the vehicle whose efficiency has to be tested should not be more than 3500kg and should minimum has a vehicle weight of at least 300kg. The braking force should have the range of 1500N to 15000N which is equivalent to 100kg......1500kg. The range for measuring the braking efficiency of vehicle the minimum should be 10% and maximum should be 100%. For the 10% the g force generated would be equal to.1g and for the 100% it should be 1g. So based on these parameters the decelerometer can be designed. The vehicle to have correct braking system, it must have the braking efficiency of at least 60%, then it can be said that the brakes of the vehicle are efficient enough to be used. To achieve these estimated parameter certain calculations has to be done. To calculate the braking efficiency. The mass of the vehicle should be known whose efficiency has to be tested. The formula used to calculate braking efficiency is

4.1. Table showing braking efficiency per g force and deceleration value

	G force		Deceleration m/s2		Braking efficiency %
1	0.1		0.981		9.624
2	0.2		1.962		19.247
3	0.3		2.943		28.871
4	0.4		3.924		38.494
5	0.5		4.905		48.118
6	0.6		5.886		57.742
7	0.7		6.867		67.365
8	0.8		7.848		76.989
9	0.9		8.829		86.612
10	1		9.81		96.236

From equation (2.3)

$$\text{Braking efficiency} = \frac{B_F}{M} . 100$$

This equation is derived from [17].

$$B_F = Mag \tag{4.1}$$

$$M = \text{Total mass of vehicle (kg)}$$

$$a = \text{deceleration (g units)}$$

$$g = \text{acceleration due to gravity m/s}^2$$

The mass of the vehicle has been approximately estimated to calculate the value of braking efficiency so these parameters which are considered by those values shown in table 4.1.

Mass of the vehicle = 1250 kg

Mass of person = 83 kg

Sum = 1333

Gravity 9.81

Based on these parameters the braking efficiency is calculated.

5. DECELEROMETER

Decelerometer is used for the measurement of the overall brake deceleration of the traffic vehicles. The value of the deceleration is measured, as well as its dependence on the controlling force applied to the brake pedal or its dependence on the air pressure in the air pressure brakes. The results of measurements are: graphical record time related, the numerically calculated average value of overall deceleration.

5.1. The principle of measurement

The measurement is based on simultaneous recording of vehicle brake deceleration and recording of the vehicle deceleration..All data are stored in the internal memory after the button Start has been applied. The measurement of the deceleration, is realised with the build-in deceleration sensor. At the end of the measurement the maximal values are shown on the display, then the average value of the overall deceleration is calculated.

At the beginning of the measurement, the recording interval has to be set. The range of
The setting is from 1 to 50 seconds, which differ from decelerometer to decelerometer. The recording clearly shows whether the measured smallest average value of the overall deceleration is as prescribed.

5.2. How decelerometer is used for measuring braking efficiency of the vehicle

The Decelerometer is placed in the vehicle, according to the direction of the arrow marked on the g meter which is always pointing in forward direction. The decelerometer should show the tilt within 20% of the road surface. and be positioned so that it cannot move under hard braking. The instrument is self-aligning, providing its direction of travel arrow roughly coincides with the actual direction of travel (within ±45 degrees) no error will be introduced. Press and hold the button, both decimal points will illuminate to confirm that the button press has been sensed. After 1 second, it will appear on the display to indicate that it is ready to proceed. Release the button, after a short pause the instrument will determine its tilt within the vehicle and complete its configuration. The display indicates go when it is ready to proceed. The vehicle can now be accelerated to speed and the brake test carried out, g-meter will automatically sense the beginning and end of the test and afterwards retain the Braking efficiency reading on its display.

6. DECELEROMETERS IN MARKET

With the following market research the already available decelerometer are brought out and compared. Main processes are: how the test is being carried out. The processes arise from the following questions. How efficient, these decelerometer are?

There are several decelerometer manufacturers and each manufacturer has a different model of decelrometer but with the same working principle.processor. The main and more known are turney decelerometer and monwok decelerometer.

Author uses the product specifications to provide explanatory details.

6.1. Turnkey decelerometer

This decelerometer is used to measure the g force generated when the brakes are being applied in the vehicle. It is suitable for vehicle which are defined in the category of classI and class II. It is an certified product which is used for measuring braking efficiency of the vehicle.

. Figure 6.1. Turnkey Decelerometer [7]

Table 6.1. Technical specification of turnkey decelerometer

Sensing Principle	Multiple axis decelerometer
Measurement Range	0-2g G=9. 81m/s/s
Accuracy	Better than ±3%g
LED Resolution	1%g 0.1 meters/Sec/Sec
Display	2 digits, 7 segment LED Readable in sunlight
Peak reading time constant	0.2 seconds
Tilt Compensation	2.5 degrees per g
Battery	V PP3 alkaline MN1604 or 6LR61 CR2032 Lithium cell
Interface	RS232C
Memory	3 tests
Size	122mm octagon 24mm deep
Weight	300 grams
Calibration	Multipoint calibration, UKAS traceable

6.2. Bowmonk Decelerometer

This a modern version of the decelerometer which is very common now a day. It has good features. It is a digital decelerometer which display the braking efficiency of the vehicle. The principle which this device follows for calculating the braking efficiency is by calculating the braking force generated during the whole cycle of the braking process. It is used to test the performance of any kind of the vehicle. This decelerometer is a VOSA approved product. It uses rechargeable Nickel Cadmium batteries which has long last life. It has an 2 year calibration certificate.

Figure 6.2. Bowmonk decelerometer. [8]

This the portable and light weigh decelerometer and needs the calibration in every two years, but it has a disadvantage that the data cannot be transmitted through wifi and it also involves the cost factor.

7. PROBLEMS WITH EXISTING DECELEROMETER

There are several problems with an existing decelerometer among them the major ones are

1. Calibration
2. Accuracy
3. Uncertainty Estimation

7.1. Calibration

The results which are obtained by using these decelerometer are not so accurate there is still uncertainty. It The instrument which are used for checking are not so the better calibration procedure has to be developed. Which should also satisfy these standard conditions. The decelerometer should be traceable to a national physical standard and should be certified by a UKAS accredited laboratory, or an equivalent European laboratory, that it is traceable to a national physical standard.

7.2. Accuracy

While measuring the braking parameter during the inspection of vehicle's braking performance there is always an error limit in the reading. It may be due to the influence of several other factors, so this needs to be improved and the brake performance readings should always be accurate when it lies within; +/- 3% of the true value. But it is not the case with the available decelerometer so this needs to be improved.

7.3 Uncertainty Estimation

This problem arises because there is a lack of equipment producer data. There are several influencing factors which include the temperature and cleanliness of the working conditions, testing people skills, measuring instrument. Theoretically the measurement uncertainty should be

3 up to 5 times more than the measuring device uncertainty. The vehicle braking parameter measurement is a great number of influential factors involved and some of them can give exaggerated uncertainty if we're not limiting and it can reach upto6-8. So for this an better procedure has to be developed to solve this problem.

The decelerometer which are available in the market most of them do not display braking efficiency in percentage. The result is being displayed which consist of the average value of the deceleration achieved during the braking process of the vehicle which is calculated on the bases of the graph in which the whole process when the brakes applied and till the vehicle stops. So the result is not so accurate because the average value is being taken.

8. PROPOSED DESIGN FOR DECELEROMETER

8.1. Overview of the proposed design

The Author has proposed a designed for decelerometer which will be used to measure the braking efficiency when the brakes are applied in the vehicle. The aim of this decelerometer is to measure the braking efficiency of the vehicle. It has several features which include showing the time and date when the road test has been carried out. There is a special feature in this decelerometer which makes it different from the other measuring instrument, that it shows the percentage of the braking efficiency of the vehicle and once the result is being displayed on the LCD. It can be transferred through the wifi because it has a wifi shield which is being used for this special feature.

8.2. Working principle of proposed decelerometer

The main principle of the working of the authors decelerometer is based on calculating the braking efficiency on the basis of Braking Force generated when the brakes being applied divided by the mass of the vehicle whose braking efficiency has to be measured.

The author has used Analog sensor which is connected to the Arduino UNO based microcontroller. When the brakes are applied this sensor receives g forces and as the output of this sensor is in Volts. It generates 100 measurements in each one second and the Micrcontroller is programmed so that each msec it asks from the sensor to give the data and the total duration of the process for calculating braking efficiency is 10secs.This means during this time the person should accelerate the vehicle and apply brakes. So the total data which the microcontroller receives from sensor consists of 1000 measurements. Now the microntroller calculates the maximum deceleration achieved during the braking process.. Finally, on the LCD the braking efficiency is being displayed. The temperature of the working environment can also be seen. As this Arduino UNO microcontroller is connected to the Arduino wifly shield because of which the data can be transmitted through the wireless internet wifi.

8.3. Design for decelerometer

The author has used a concept of box design for decelerometer design. The approach was the box should be designed in such a way that all the components which will be used for decelerometer manufacturing can be easily placed. As the proposed decelerometer is a portable device so by using a box means it easily to be carried. The author has designed the box with some features like on the top of the box an arrow is being made. The author has provided the special arrow mark on the top of the box, which means this decelerometer should always be kept in the vehicle with the arrow point towards the front movement of the vehicle.

Controlling a device with this design is easy..The author has design only the box with the feature mention above. All the components which are used for designing decelerometer are taken from the standard catalog.

Figure 8.1. When the case is closed

This drawing shows how all the components are placed in this box

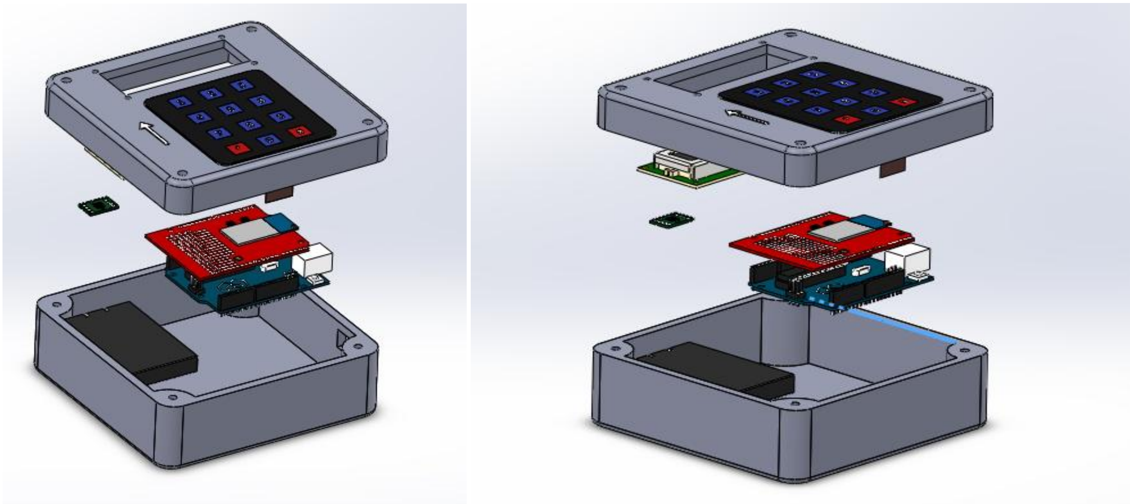

Figure 8.2 shows a different angle of view of the complaint in the case

It. Clearly shows the exact position of the each component which are placed in the box. All components which are used for building a decelerometer can be seen in this box. It also shows the exact position of the components, showing how they are being placed. This is an angle from the side view.

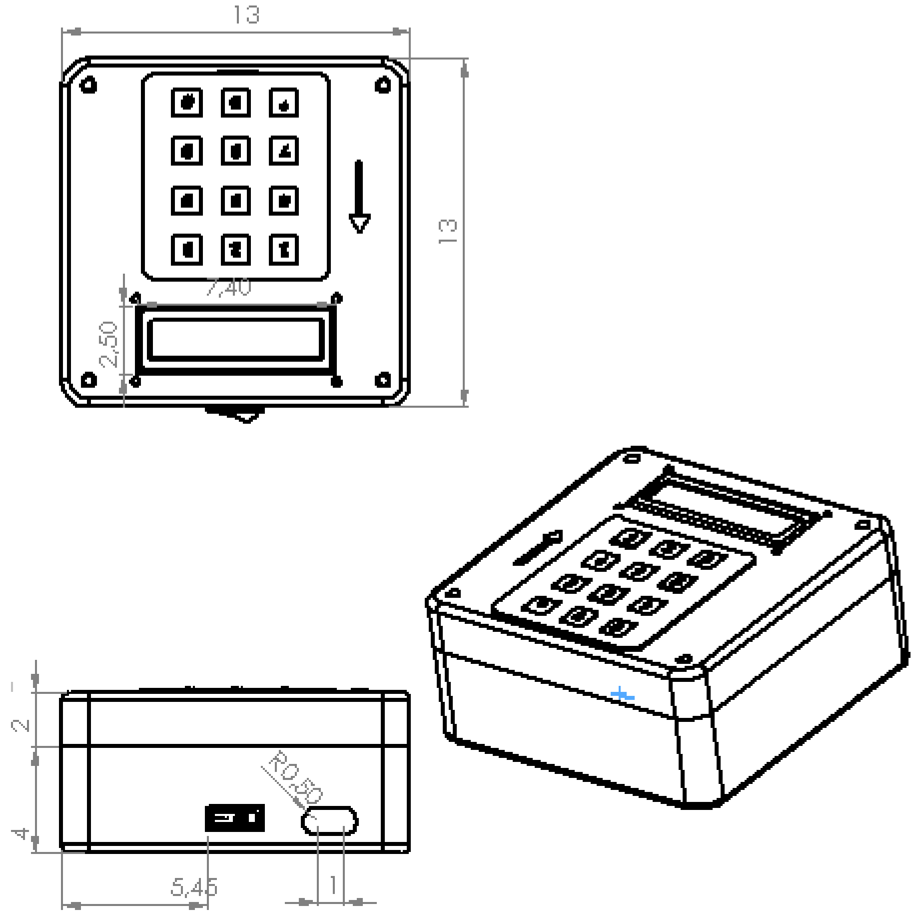

Figure 8.3. Dimensions of the designed box

Dimension of the designed box

The box has the dimension of 13cm x 13cm. All the component dimensions are made considering all other dimensions of the components which has to be placed in it. This is the design of the box concerning the dimension which include point for charging and for the interfacing of this keypad the box is providing the space on top from where the keypad interfacing will be done.

8.4. Material selection in the box

The author will be using the Wiska WIB1 junction box. It is always better to use plastic material when the electronic components are being involved. So it is best to use thos Wisa WIB 1junction box for the decelerometer manufacturing. It has several advantages. It is a non conductor of electricity, so change of any shock. It is cheap and in all it is cost effective. To manufacture such king box is always easy. This box has a material which is thermoplastic and it is waterproof. This box has mounting plates which can be screwed. The weight of the box is very light so it is easy to carry such box containing all components for decelerometer manufacturing. As our deceleromenter is portable device so such kind of weight boxes should be used.

Figure 8.4. Proposed box material [9]

According to our design of decelerometer we need this kind of the box which can easily be screwed. Because we have to make holes in the box. For LCD it has to be cut according to the size of the LCD so that it fits easily into the box and will have a display screen view from top of the box..So as it is easy to make hole in this kind of box and it has several advantages which are described. It can be used as a box for the decelerometer.

9. COMPOSITE SCHEME OF DECELEROMETER

This scheme defines how the components are being placed in the designed box. The Arduino UNO which is the microcontroller based on the ATmega328P. This microcontroller is placed in the base, according to its dimensions the box is being designed. On the top of this microcontroller the ordinal wifly shield is placed and the connections are being soldered. The sensor is placed near the wifly shield and then at the end the LCD is placed. Top of the box is cut according to the dimensions of the LCD the Arduino board in such a way that the sensor X axis always faces towards the front of the box that is why an error is also shown along the box so that the user used. This scheme defines how the components are being placed in the designed box. The Arduino UNO which is the microcontroller based on the ATmega328P. This microcontroller is placed in the base according to it dimensions the box is being designed.On the top of this microcontroller the ardino wifly shield is placed and the connections are being soldered

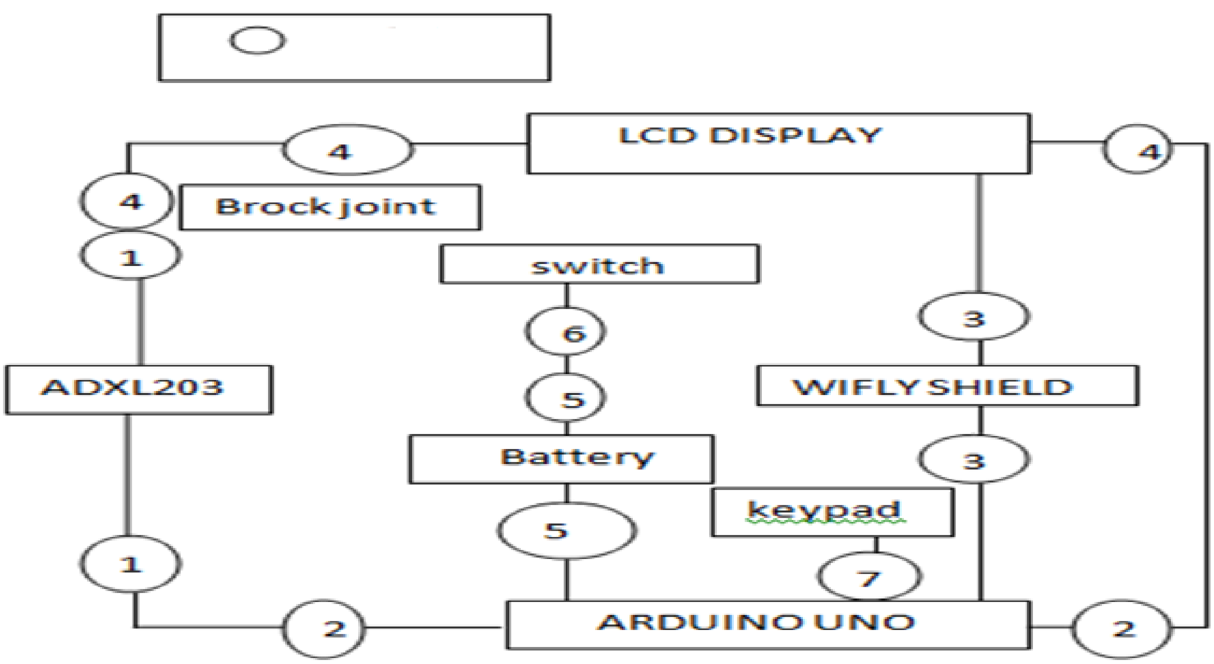

Figure 9.1. Composite scheme of the design

Table 9.1 Component used in the scheme

S.NO.	Item	Part no.	Size	Fitting position	distributor
1	ADXL203 sensor	ADXL203EB	5mm x 5mm	1	verical
2	Arduino uno	A000046	68.6mm x 53.4mm	2	Farnell
3	Arduino wifly shield	A000058	28.5mm x 20mm	3	Digi-key electronics
4	LCD	LCD1602	69.5mm x 14.5mm	4	TME electronics components
5	Battery	17670-7.2v-A	70mm x 60mm	5	Alibaba.com
6	On-off switch	Kcd3-101	10mm x 10mm	6	Alibaba.com
7	Membrane 3 x4 matrix keypad	Product ID 419	70mm x 77mm	7	Adafruit.com

This scheme defines how the components are being placed in the designed box. The Arduino UNO which is the microcontroller based on the ATmega328P. This microcontroller is placed in the base according to it dimensions the box is being designed.On the top of this microcontroller the ardino wifly shield is placed and the connections are being soldered.The sensor is placed near the wifly shield and then at the end the LCD is placed.Top of the box is cut according to the dimensions of the LCD the arduino board in such a way that the sensor X axis always faces towards the front of the box that is why an arror is also shown along the box so that user used know the box should be placed at the time of test.As this sensor is self algin so it automatically align towards the movement of the vehicles.

9.1.1. Sensor ADXL 203

This accelerometer has been used to measure the g force generated during the braking process of the vehicle.use. It has a range of $\pm 1.7g$ For the design of decelerometer maximum g which can be produced during braking is 1g.It is capable of measuring the dynamic acceleration. The bandwidth of this sensor can be adjusted so it is a plus point for this sensor. Which means noise factor can be reduced easily. It Works at a supply voltage of 5V so it is compatible to use this sensor with Arduino union which has same voltage requirements.

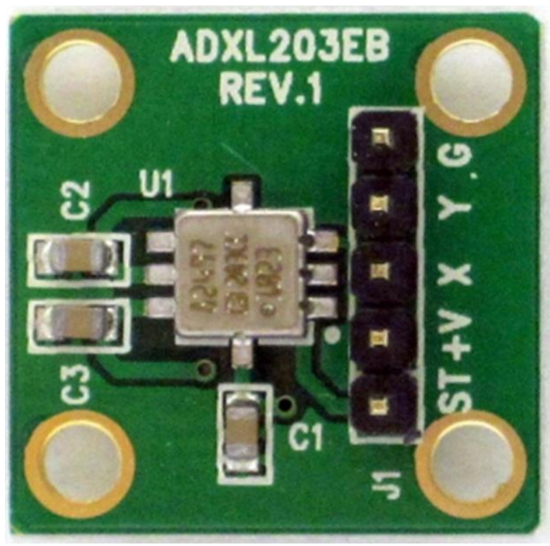

Figure 9.2. ADXL203 sensor [10]

It has capacitive filters inbuilt because of which noise can be easily reduced.

9.1.2. Arduino UNO

It is based on the ATmega328P. Arduino UNO is an open-source physical computing platform based on a simple microcontroller board and it has a specific development environment for writing software for the board, the “Arduino IDE”. This microcontroller is programmed to receive the acceleration data from the sensor then convert into the braking deceleration which is also known as braking efficiency of the vehicle

Figure 9.3. Arduino UNO board [11]

. For this special code has to be developed to achieve such a result. These code develop on the bases of calculating the braking parameter.

9.1.3. Arduino wifly shield

This wifly shield is used for the transmission of the data through the wireless network, which is the plus point of this decelerometer. This wifly shield equips the Arduino UNO ability to connect to 802.11b/g wireless networks and uses the same library. So it's easy to program. This shield includes the RN-131C, SC1615750 and the supporting components.

Figure 9.4. Wifly shield [12]

By using this wifi shield the data can be shared through the internet at the fastest speed and it is also a cost effective product.

9.1.4. LCD screen

There are other LCD also available, but this is selected because it is compatible to use this with Arduino UNO based microcontroller. It operates at 5V. It has a display format of 16 x 2 character.

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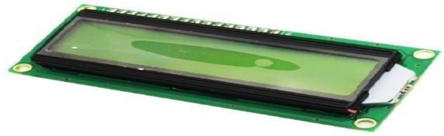


Figure 9.5. 1602LCD screen [13]

9.1.5. Matrix Keypad

The choice of this key is done because it's cost effective. It is easy to implement. It can further be used for future development of the product

Figure.9.6. 3x4 Matrix keypad [14]

9.1.6. Battery

The author decided to use the battery of 7.2V. Because of the following calculations which are as follows:

The formula used for calculating energy consumed is:

$$E = V.A.H$$

The total energy consumed by battery = 7,2. 280.180.1/60

Energy consumed for 3hrs = 33.62

Total current of the battery 3600 mah

Figure 9.7. 7.2 V battery [15]

For how many days such batteries can be used= 108days

So if the product is used only for 3hrs a day and if this battery is used, then it last for 108 days when it is recharged once.

Based on this calculation it is assumed that a 7v battery would have enough energy which will be required during the working of decelerometer.

9.1.7. On/off switch

The switch is needed to turn on the decelerometer. The advantage of using this switch it is made of good quality of material and the cost of this is also very less as compared to others which are available in the market. So it is right to use this switch for our product.

Figure 9.8. ON/OFF switch [16]

9.1.8. Charger for Battery

The charger is needed to charge the battery of the decelerometer. This charger is selected because it is compatible with the battery which is being used. Its also a cost effective product.

Figure 9.9. Battery charge [17]

So all these components are used in the designing of the decelerometer. In this section overall composite scheme of the proposed decelerometer design has been explained in the component description also.

10. ELECTRICAL SCHEME DESIGN OF DECELEROMETER

Electrical Scheme Design

The author has used the manual drawing to show the electrical schematic connection between the components. This drawing shows how the interface between the component is being done and it is easy to understand this design by through this sketch.

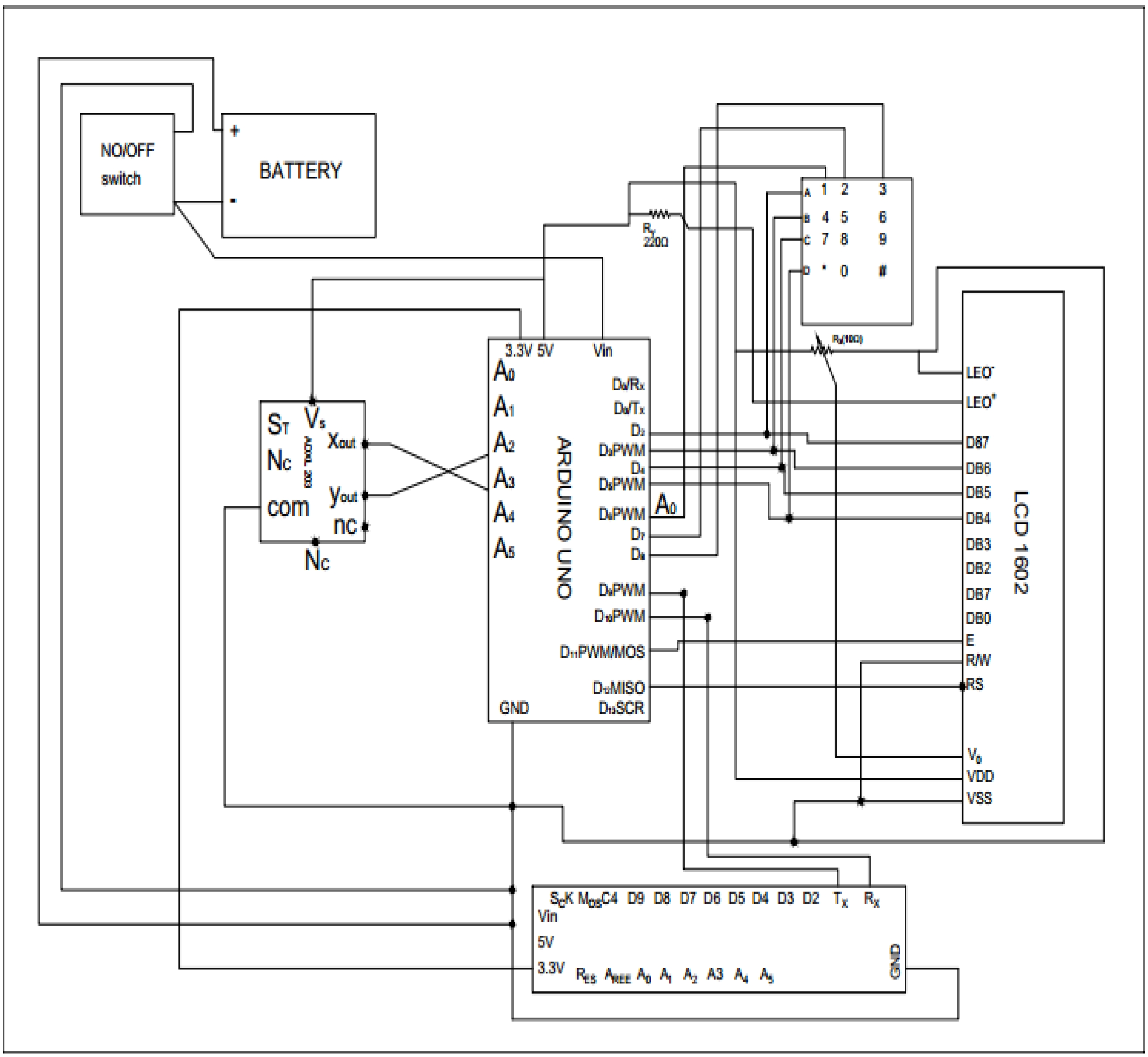


Figure 10.1. Electrical scheme of decelerometer

This is the electrical scheme diagram of the proposed decelerometer design. It clearly shows how the connections are being made.

The main circuit of the decelerometer is composed by the sensors (accelerometer), the Arduin UNO, Arduino wifly shield, matrix keypad, LCD, battery and switch. When we assemble this circuit, we need to make sure that the all GND (ground) pins are connected. And that we supply power to Arduino UNO board, through the Arduino UNO +5 V output. The wifly shield is connected to the 3.3 V power supply from the Arduino UNO board. All the component of the decelerometer receives the power through the Arduino UNO board. The analog output pins of the sensor are connected to the analog input pins of the Arduino UNO. In the accelerometer we are interested in read the values of x and y and so we connect them to pins A3 and A4 respectively. They are connected to the analog pins of the Arduino UNO because they are analog devices. We used 7.2 V the battery to power the Arduino UNO and the battery is connected with on/off switch.

From sensor output which is connected to the analog input of the microcontroller. The power is supplied through the microcontroller to all the components in the circuit. The battery of 7.2 volts is used which is sufficient to supply power to the controller. As the Arduino UNO microcontroller requires the power of only 5 V. But it is always advised to use the supply of the 7-12 V for Arduino UNO. It has inbuilt resistors which protects the microcontroller being damaged due to overflow of the current.

11. DEVELOPMENT OF PROGRAM FOR DECELEROMETER

Decelerometer has a sensor through which the microcontroller receives the data and then it calculate the braking efficiency of the vehicle on the bases of this data. First of all the weight of the vehicle is entered in the decelerometer and then the test is performed. Vehicle weight means the curb weight, which is always mentioned on the certificate of the vehicle plus the weight of the driver. It takes maximum 10 s to carry out the road test. To make it clearer we consider following example Suppose a vehicle whose mass is 240 kg is being considered for the road test, then we use this decelerometer then driven initially accelerates the speed once it reaches to 30 km/h. The brake is being applied.Then the sensor generates following the data.

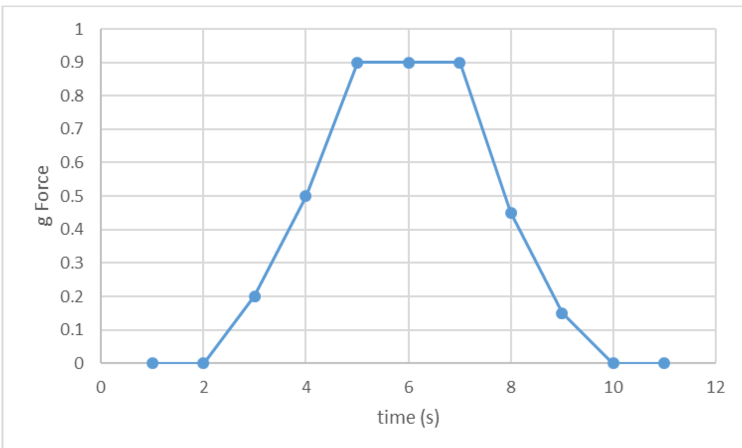
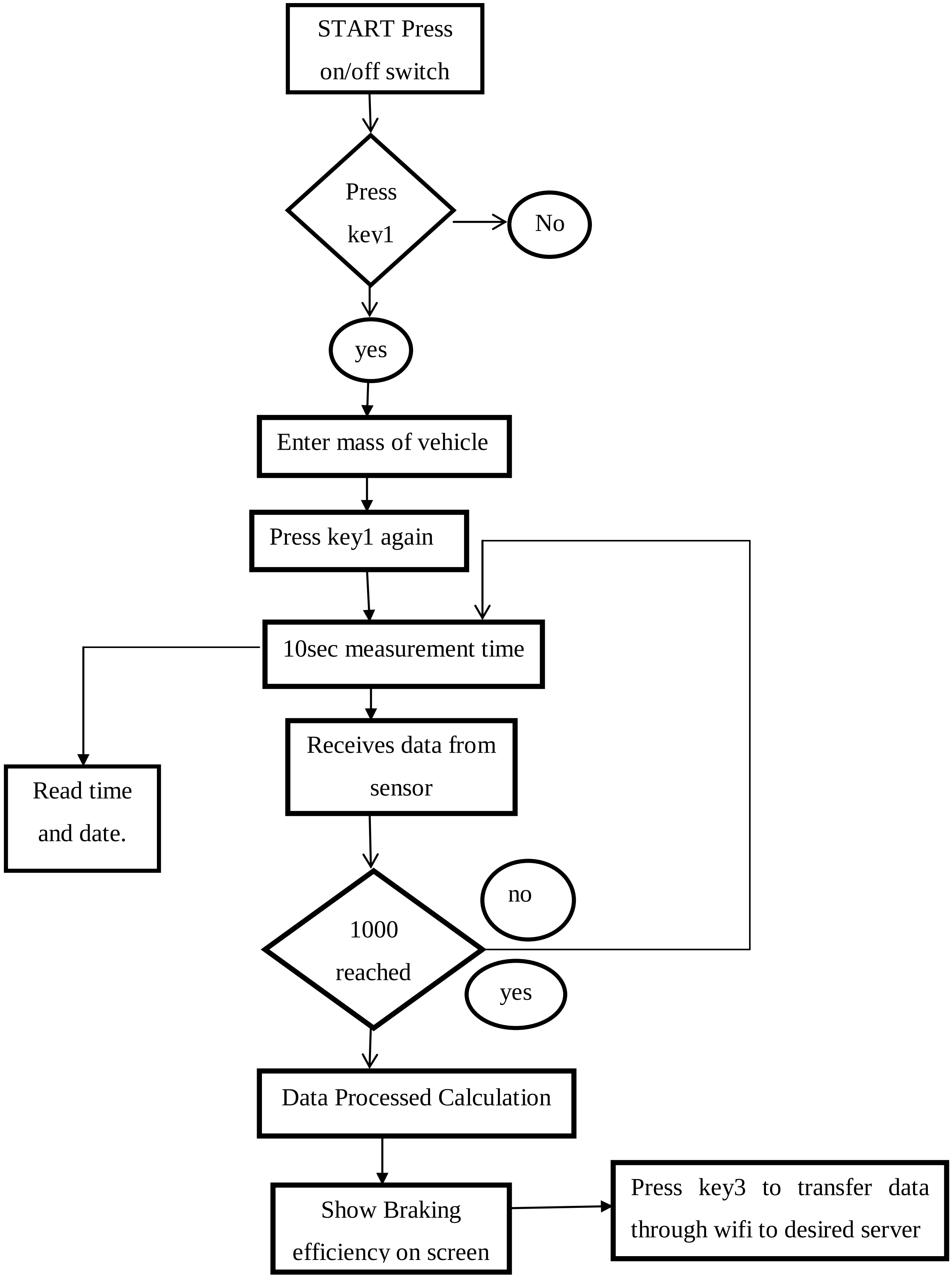


Figure 11.1 sensor values in g force

Table 11.1.

Measurement	Value
1	0
2	0
3	0.2
4	0.5
5	0.9
6	0.9
7	0.9
8	0.45
9	0.15
10	0

Microcontroller which is connected to this sensor receives the data from it and it is programmed for calculating the braking efficiency.



Description of the measurement, flow chart

The above flow chart describes the working of the authors decelerometer. To start the measurement the process key 1 has to be pressed then the mass of the vehicle whose braking efficiency has to be tested is entered by using the keypad on the decelerometer. Once the person entered the mass, then again key 1 is pressed. The total time for the measurement is 10 seconds. This means in this the person should accelerate the vehicle to normal speed of 30km/hr and then brakes should be applied. In this 10 seconds the sensor generates the data of 1000 values. From this the maximum g force which is achieved during braking is taken into the consideration for the calculation of the braking efficiency. For calculating braking force following equation is used [19].

Braking Force

$$B_F = Mag \tag{4.1}$$

Where $B_F = \text{Total braking force (N)}$

$M = \text{Total vehicle mass (kg)}$

$a = \text{deceleration (g)}$

$g = \text{acceleration due to gravity} (^{\text{m}}/_{s^2})$

By using this formula the microcontroller calculates the braking force. In the next step of the program microcontroller calculates braking efficiency by using equation (2.3)

$$Braking\ efficiency = \frac{Braking\ force}{Mass\ of\ \text{the vehicle}} . 100$$

According to the flow chart the person who wants to check the efficiency of his vehicle.The mass of the vehicle has to be entered before accelerating and applying brakes because if the mass of the vehicle is known then the braking efficiency of the vehicle is calculated.It gives the braking efficiency in percentage. So the microcontroller is programmed by using these equations to show the braking efficiency of the vehicle. This braking efficiency is then displayed on the LCD screen of a decelerometer.

Menu selection flow chart

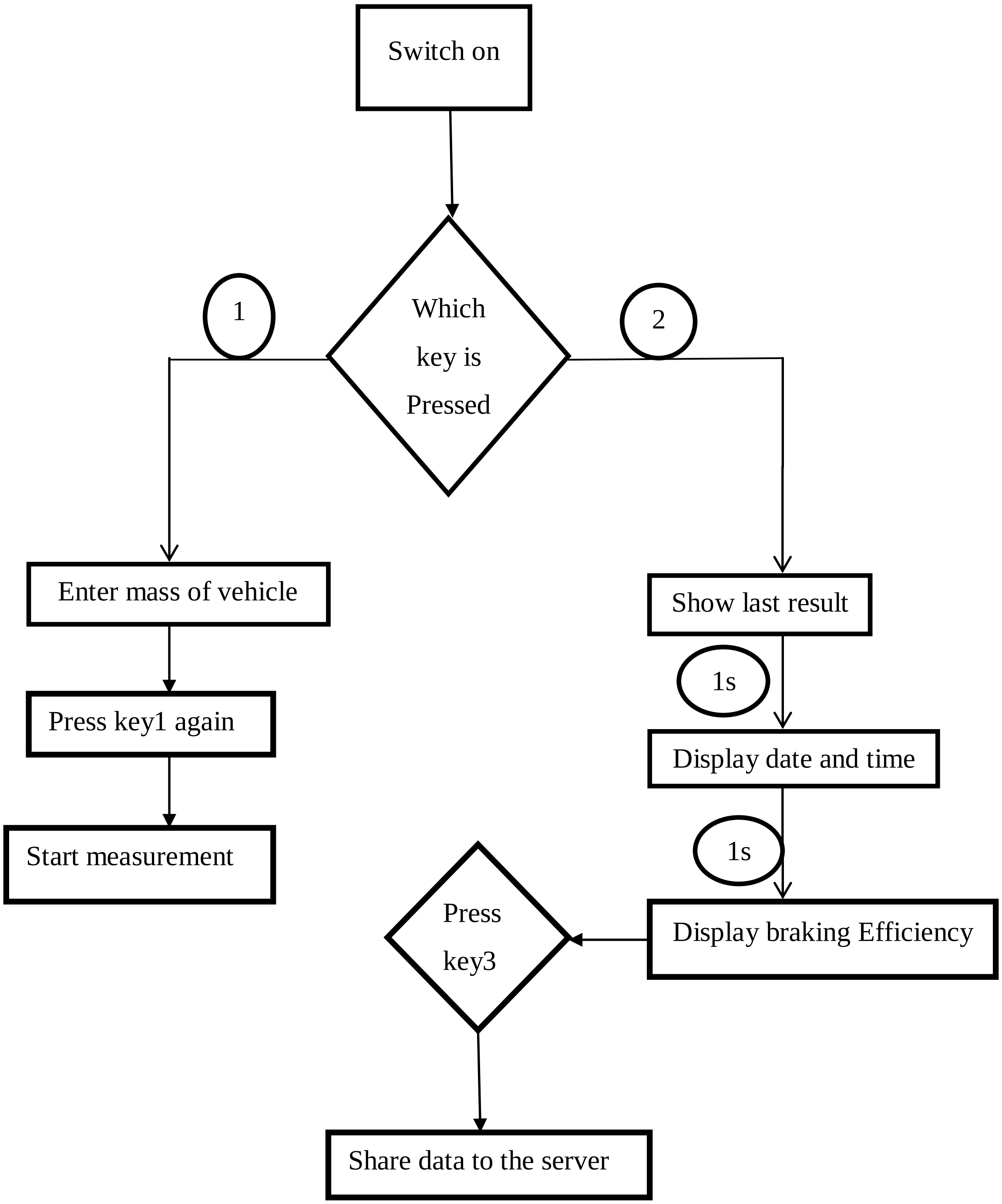


Figure 11.2. Menu selection flow chart

This flow chart describes the programming of microcontroller for the features which are proposed in the authors decelerometer. As this decelerometer has keypad so it has keys from 0-9. But the author has used key1 and key2. When the decelerometer is on then if key1 is pressed then the display of the decelerometer will show enter the mass. Then the mass of the vehicle whose braking efficiency has to checked is entered and after this again key1 is pressed to start the measurement process. When key 2 is pressed it shows the result of the last test which is being carried out by using this decelerometer.With the interval of 1sec the date ,time and braking efficiency of the vehicle is displayed on the LCD screen of the deceleromeer.

How sensor values are converted to the g Force in the microcontroller

10 seconds measurement time

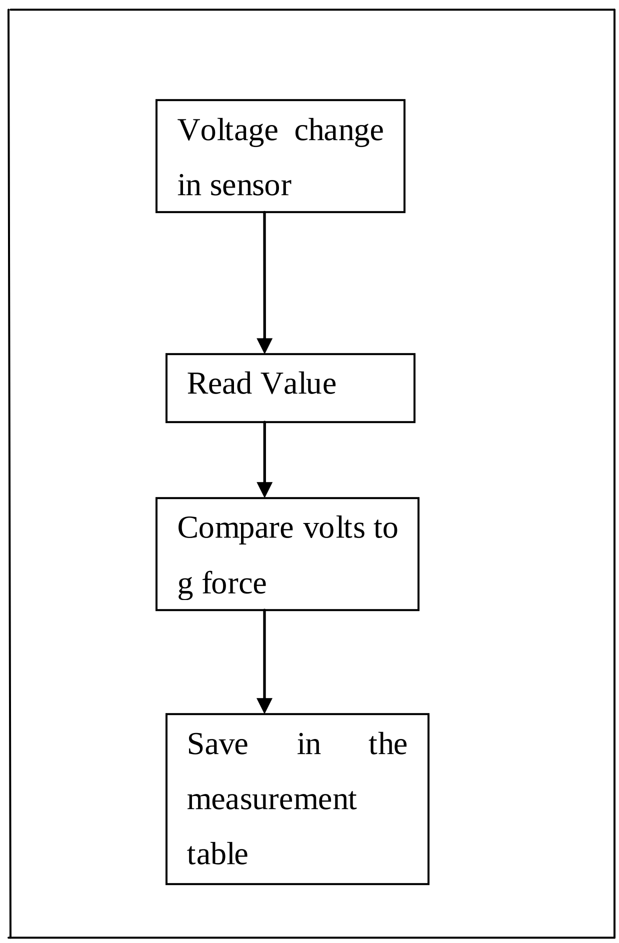


Figure 11.4. Conversion of sensor value in g force

The total time for the measurement process is 10seconds So during this time if there is any g force acting on the sensor then there is a change in the voltage. Microcontroller gets this feedback and receives the data and compare those values of voltage change in the defined g force value and save that value in the measurement table.

For example

Volts	g
1.1	0.024
1.2	.048
1.3	.072
1.4	.094
1.5	.118

How microcontroller calculates the biggest value of g force generated during braking process

For the calculation the biggest value of g force generated is needed to calculate the braking efficiency of the vehicle. For this the microcontroller has to be programmed so the following flow chart describes the process of calculating the biggest value of g force generated during braking of the vehicle.

Drung the measurement process microcontroller recieves the value and convert those values in the g force described in the program. After that it saves those values in the table. In the table if the first value is considered to be X then it compares the each value. Then X is compared with the next biggest value. This process continues till the biggest value is not found. After getting the biggest value of g force generated during braking process. This value is further used by the microcontroller for calculating the braking efficiency. By using the formula from the equation. Finally the braking efficiency of the brake is displayed on the screen of the LCD.

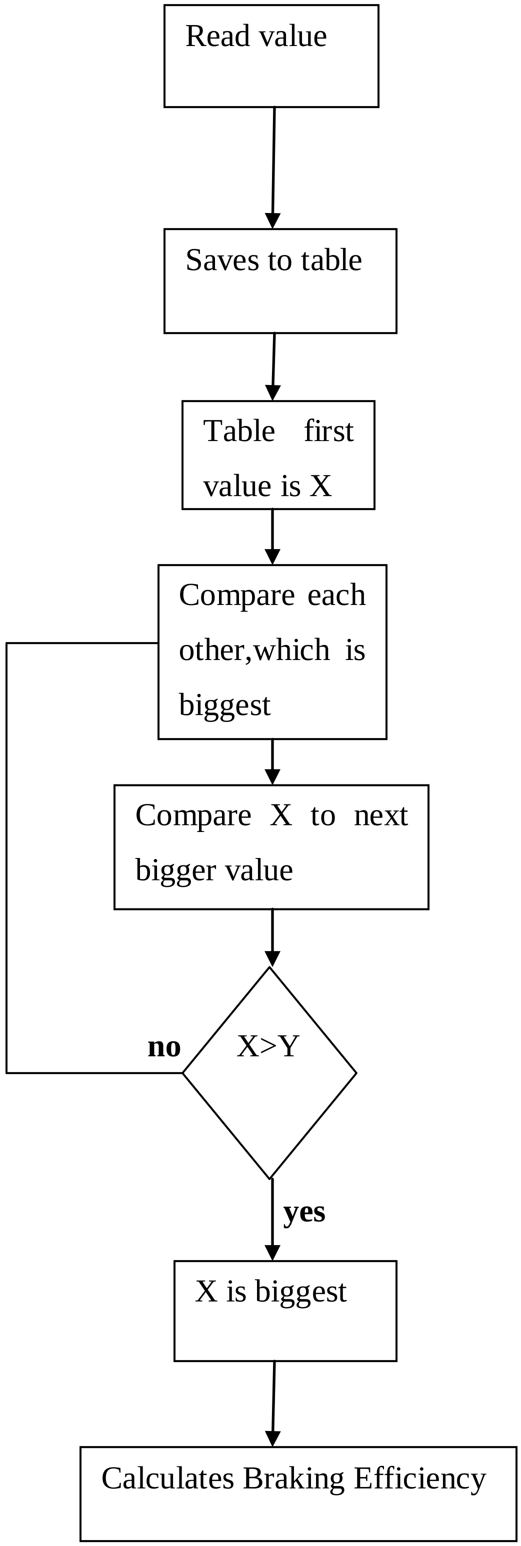


Figure 11.5. Flow chart for calculating the biggest value of g force

How the Data is transmitted after calculating the braking efficiency

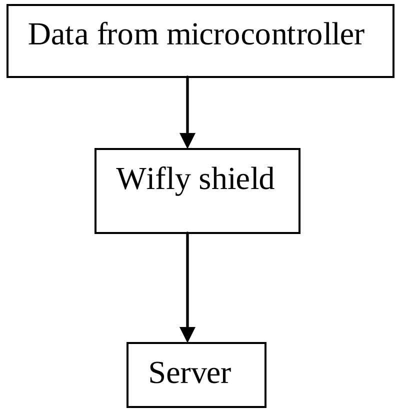


Figure 11.6. Showing transmission of data from the microcontroller

When the decelerometers shows the braking efficiency of testing vehicle. Then this data is transferred to the desired server with the help of the wifly shield mounted on the Arduino UNO. In this process the microcontroller has to be programmed. The flow chart above describes how the data from the microcontroller is transmitted to the server.

12. CALIBRATION PROCEDURE FOR DECELEROMETER

Object: Objective of this procedure is decelerometer with braking efficiency indication.

Scope of use: Procedure can be used for calibration of decelerometer and its indication parameters braking efficiency, date and time.

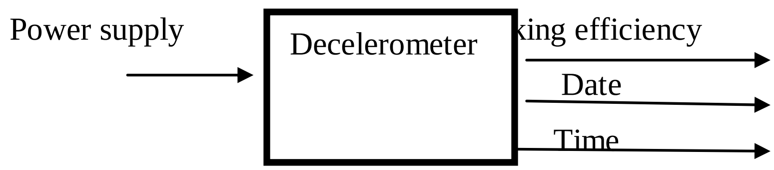


Figure 12.1. Simple block diagram of decelerometer with output results

Decelerometer measuring instrument is used for measuring the braking efficiency of the vehicles. For the calibration method the decelerometer braking efficiency indications with the standard decelerometer values. For the calibration result is estimated measurement uncertainty.

Standard measuring instrument should be prepared according to the producers instructions. Environment conditions Temperature shall be (20±3)ºC. Temperature should change during the calibration over 1ºC per 1 hour.Before calibration the measurement instruments, standards and equipment should be kept in above environment conditions, so that they get adjusted to the temperature as environment.Do not use in flammable or explosive environment.Decelerometer parts and insulations should be without damage and corrosion.In box all components should be placed according to the composite

Determination of meteorological parameters

A sensor which is used to measure Braking efficiency should be placed in the direction, such that the x axis of sensor is always in the forward direction because it will always be considered as direction of travel. So proper care has to be taken regarding this. Otherwise decelerometer will show errors.

During calibration shall be compared standard decelerometer values.Calibration should be carried out beginning from the min range indication up to max range indication. In between them shall be taken 3 to 5 more readings.Then this has to be compared with standard decelerometer values.

Estimation of measurement uncertainty

Calibration result has uncertainty which is caused by various influential factors. Uncertainty estimation has to be calculated on standard deviation level and are summarized to have the combined uncertainty u. Combined uncertainty has statically calculated component u_A known as component A and experimentally estimated component u_B which is also known as B component[20] ,

Then $u = \sqrt{u_A^2 \ \ + u_B^2}$.

In the case of this decelerometer there is no u_A component because there is no repeated values.Only a particular value is being considered for estimating the uncertainty.

Braking efficiency $E_f = \frac{Force\ F\ (kg)}{Mass\ M} . 100$

Minimum of Efficiency $Ef_{Min} = 10\%\ eff. \quad \pm 3\%\ eff.$

Maximum of Efficiency $Ef_{Max} = 100\%\ eff. \quad \pm 5\%\ eff.$

Deviation as relative value

Minimum. $\pm 3\%\ /10\%\text{eff.} = 30\%$ relative value

Maximum $\pm 5\%\ /100\%\text{eff.} = 5\%$ relative value

Same relation will be followed for the deceleration

Minimum deceleration $= -1,0\ \text{m/s}^2$

Relative deviation $= -1,0\ \text{m/s}^2 . 30\% = 0,3\ \text{m/s}^2$

Maximum deceleration $= -10\ \text{m/s2}$

Relative deviation $= -10 \frac{\text{m}}{\text{s}^2} . 5\% = 0.5\ \text{m/s}^2$

Uncertainty by calibration from [21]

$$Ef. = \frac{F}{M.g}.100[\%]efficiency$$

Partial differential differentiation of above equation

$$u_{Ef} = \sqrt{(dEf/dF)^2.u_F^2 + (dEf/dM)^2.u_M^2}$$

$$correlated\ 100\%\ to\ u_{deceleration}$$

$$-u_{STANDARD}$$

$$-u_{READING}$$

$$-u_{METHOD}$$

$u_{STANDARD}$ $-$should be more than 3 times decelerometer efficiency

Deceleration for MIN 30% rel. $\pm(-0.3m/s^2)$ standard $u_{st} = \frac{0.3}{3} = -0.1\text{m/s}^2$

Deceleration for MAX 5% rel. $\pm(-0.5m/s^2)$ standard $u_{st} = \frac{0.5}{5} = -0.1\text{ m/s}^2$

When K=1 $u_{ST} = -\frac{0.1}{2} = -0{,}05m/s$ K=2 U_{ST}

$$u_{READING} = \frac{scale\ interval\ for\ decelerometer}{\sqrt{3}}$$

$$scale\ interval = \frac{0.1m}{s^2}$$

$$u_{READING} = 0.05$$

The uncertainty of the method includes several factors which are road condition, vehicle velocity.

The expert says it will be 2 to 3 times more than the scale interval for decelerometer

$$u_{METHOD} = 0.25\text{ m/s}^2$$

So the combined uncertainty

$$u = \sqrt{C_{STANDARD}^2\, u_{STANDARD}^2 + C_{READ}^2\, u_{READ}^2 + C_{METHOD}^2\, u_{METHOD}^2}\quad \frac{\text{m}}{\text{s}^2}$$

Where $C_{STANDARD}$, C_{READ}, C_{METHOD}

These are sensitivity coefficient in this case equal to 1,0.

By substituting the value of each parameter from the above equations

The uncertainty of the deceleration is estimated.

$$u = \sqrt{0.1^2 + 0.05^2 + 0.25^2}$$

$$u = \sqrt{0.075}$$

$$u = .27\ m/s^2$$

The statically component u_A do not involved because there are not repeated measurements for one result.

u_{MASS} - practically 2% from the measured mass

M=1000kg so $u_m = 20$ kg

If Force = 8000 N then deceleration indication

$$u_{eff.} = \sqrt{(1.100/M.g)^2.u_F^2 + (F.100/g.M^2)^2.u_M^2}$$

$$\text{force} = 8000\text{ N and deceleration indication } d_i = -8\ \frac{m}{s^2}$$

$$u_{eff.} = \sqrt{100^2/1000^2.10^2\ \ .160^2 + 8000^2.100^2/10^2 1000^4\ \ .20^2}$$

$$= \sqrt{10^4/10^8.3.10^4 + 64.10^6.10^4/10^2.10^{12}.400}$$

$$u_{eff.} = \sqrt{2{,}5.\frac{10^{14}}{10^{14}} + 3}$$

$$u_{eff.} = \sqrt{6} = 2{,}5\ eff.$$

$k = 2$ expanded uncertainity

$u_{eff.} = k.u_{eff.} = 2.u_{eff.}$

$u_{eff.} = 2.2{,}5 = 5\ \%$

Table 12.1. Summary of the factors involved in uncertainty estimation.

Influence factor	Sensitivity coefficient	Statistically distribution	value
u_{ST}	1,0	Normal	-0,05 m/s
u_{RES}	1,0	Rectangular	0,05 m/s
u_{MET}	1,0	Rectangular	0,25 m/s^2
u_F	1,0	Normal	160

Table 12.2. Summary of uncertainty estimation for the braking efficiency

Factor	Sensitivity coefficient	Statistical distribution	Value
u_F	(def/dF)	Normal	160 N
u_m	(def/dm)	Normal	20 kg
$u_{eff\,.}$			2,5 %

13. NOVALITY OF THE PRODUCT

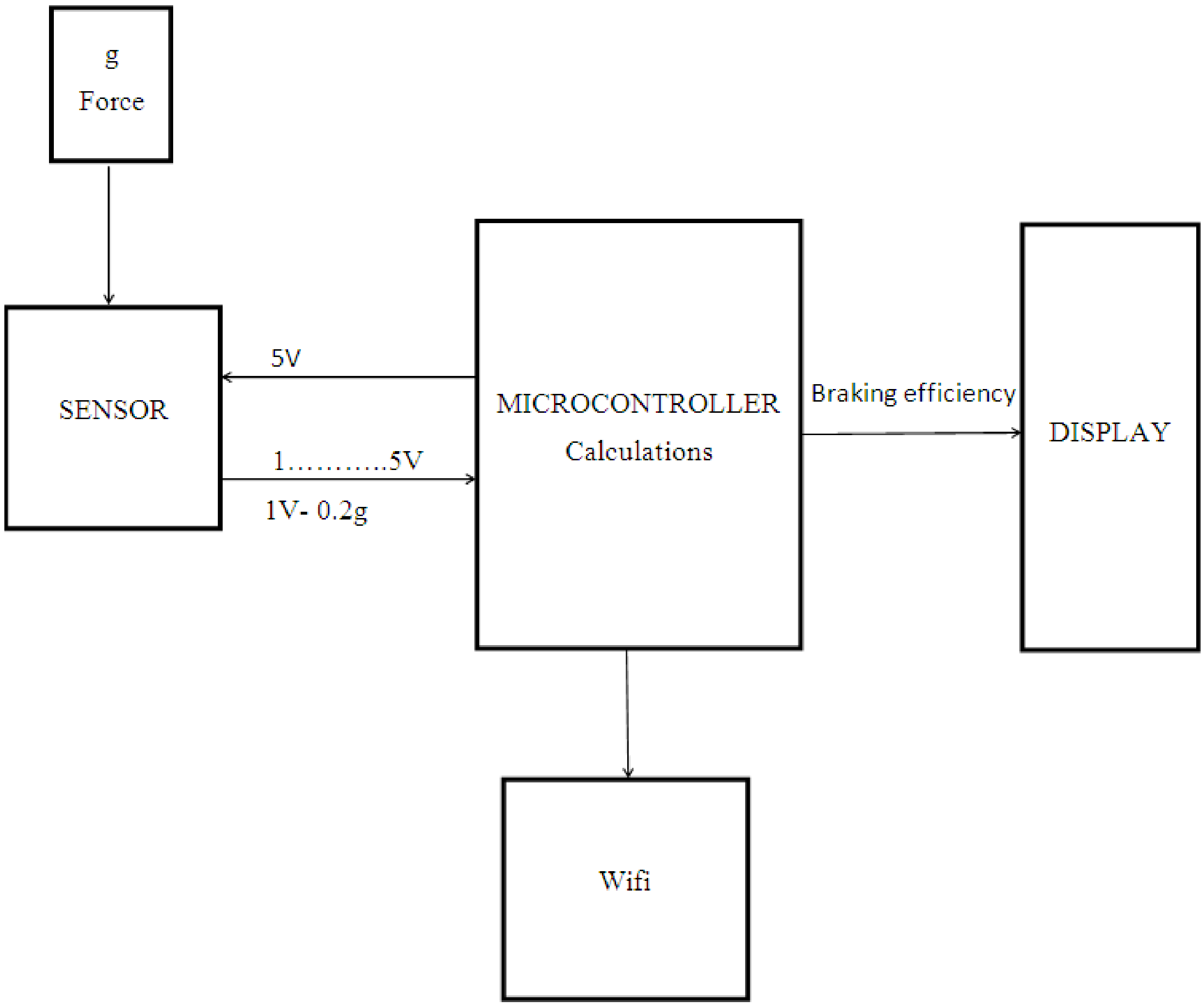


Figure 13.1. Showing novality of decelerometer

The decelerometer which is being proposed by the author has a special feature which makes it different than those which are available in the market. The braking efficiency is displayed in the percentage when the test is being carried out.It consist of an sensor adxl203 which has analog output volts and this is connected to the microcontroller which in msec ask from the sensor to give data.The maximum measurement time is 10sec. So after that the microcontroller is programmed in such a way that by using this data and then using the formulas mentioned in the above equation it calculates braking efficiency of the vehicle. Once the result is being displayed on the LCD then it can be transferred by using the wifi. These features describe the novelty of the author's product.

When there is any g force acting on the sensor the microcontrol gets the feedback. Then microcontroller recievesthis data values and convert these values into the g force. Then by using the value of the g force and the formula for calculating the braking efficiency. The microcontroller display the result of the calculation on the LCD in the form of the braking efficiency of the vehicle in percent.

14. COST ESTIMATION AND SAFETY OF DECELEROMETER

The cost of the proposed decelerometer is being calculated on the bases of the component required to design this decelerometer and the cost of calibration procedure is also included in the total cost of the product.

Table 14.1. Estimation of cost for manufacturing decelerometer

Components	Units needed	Price
AXDL203 Sensor	1	33Euro
Arduino UNO	1	26Euro
Ardiuno wifly shield	1	44Euro
LCD 1602	1	9Euro
Matrix 3x4 Keypad	1	3Euro
Battery	1	21Euro
Charger	1	10Euro
Calibration Procedure	1	50Euro

This cost is an estimation for manufacturing one decelerometer. The total cost for building one decelerometer is 196 Euro for one decelerometer which is very less as compare to those which are available in the market. So, it is a cost effective product with the better inbuilt feature which clearly specify the % of braking efficiency of the vehicles. This the novelty of this product

In European union two directives should be considered before manufacturing of any electronic product. For the safety of the electronics products several tests have to be carried out.

Damp heat steady test

In this test the product is exposed to a reference temperature of 20 °C and a relative humidity of 50 %. The test is carried out at five different test loads. The product is also tested at high temperature range specified and the relative humidity of 85 % . All functions should operate as designed.

Performance test for Disturbances

The error, if exist in the device should be set to zero before carry out the test. The environmental conditions at which the test is carried out should be realized. The changes in the no load indications during any test conditions should be recorded and the load indication should be corrected with the weighing result. There is not much influence of these parameters on the proposed design of the decelerometer.

SUMMARY

The main aim of this thesis work is to develop a braking efficiency meter of the vehicle which based on the measurement of deceleration. This topic is needed for real measurements by vehicle technical periodical inspection through over the European Union. This use of the decelerometer showing directly braking efficiency is required by the directive 2014/45/EC which relates to road worthiness inspection. There are several subtasks which needs to be done. To begin with first to analyze the instruments which are available in the market for measuring the braking efficiency of the vehicle. There are several techniques which are used to check the efficiency of braking. Main of those is to measure directly the force presented by the tyres. The method is expensive and the vehicle is not moving. Measurement of the deceleration gives more realistic data about the vehicle's brake condition. Measurement using decelerometers allows to carry out brake test and they generate the average value of the overall deceleration achieved during braking. Use of deceleration sensor is inexpensive, but gives required accuracy level. So to design the decelerometer which display braking efficiency is quite challenging and includes moments of novelty. Several parameters are considered for its design. The braking efficiency meter based on decelerometer design is proposed in this thesis work which includes the design of the mechanical case where all components of the measuring instrument situated. Shall be taken into account that the mechanical structure shall be durable. After this step the composite scheme for the measuring instrument is proposed. To select suitable components for design is also an important task. This includes sensor, ADC converter and microcircuit selection. First the author has found the suitable sensor of deceleration which can be used to measure the g force which will be generated during the braking process. Then the suitable microcontroller is selected author has used Arduino UNO. This microcontroller is easy to program and used for transmission of data through wifi. It is compatible to connect the Arduino UNO with Arduino Wify shield which shares the same library for programming. To calculate the braking efficiency of the vehicle the microcontroller has to be programmed. For this the author has proposed the flow charts which describe the program cycle, which is done while measuring the braking efficiency. The adafruit keypad is used because to calculate the braking efficiency of the vehicle the mass of the vehicle has to be enter. The Author has proposed to use the 7.2 volt battery to supply the current to the Arduino board with which all other components connect. On/off switch is used to on the decelerometer

which is connected to the battery. Proposed is a microcontrollers programming flowchart. The electrical schematic of the whole design is also proposed by the author in this thesis work. After this the author has developed a specific calibration procedure with the uncertainty estimation procedure. The method allows expanded uncertainty (k=2) of maximum 2 % (percentage is as braking efficiency). Handled are cost estimation and required testing of the measuring instrument assuring the stability by measurements.

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APPENDICE

Appendice 1

Dimensions of parts used