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Design and Development of Sensor in Measuring Force

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Abstract: In this project, we are going to measure the force applied by a headphone on a human ear. For this, we are using FSR (Force Sensitive Resistor) to measure the force. The FSR is interfaced with Arduino Uno for the required purpose along with a 10 km ohm resistor (pull down resistor). The resistance offered is a sum of two resistances means FSR resistance + pull down resistor's resistance which fluctuates between 100 Kohm to 10 Kohm . Also a LCD display connected with a variable 10 Kohm resistor is used to display the force value in Newton. We have taken 2 readings of each different headset one is the maximum value observed and second is the minimum value observed. A mean is taken of these two values and an overall mean of all values of different headsets is taken. Hence the value got, is an average suitable value that a headphone should apply on human ears so that they can be worn for a longer period of time. (approx 4 to 5 hours)
Keywords: Force Resistive Sensors, Arduino Nano, Force Measurement.

I. INTRODUCTION

Force sensing resistrors are used to sense the force . They are basically made up of two layers and separated by spacer . In simple they are a resistor that changes resistive value depending on how much pressure is applied on the sensors surface. The force sensor can detect many mechanical quantities such as pressure , weight , strain and interior stress . Performance of force sensing resistrors are mostly and solely based on contact resistance. Drifts are present but the rheological models predicted that drift can be reduced by choosing an appropriate sourcing voltage . Another thing to reduce drift is that to use non aligned electrodes so that effects of polymer creep are minimised

II. OBJECTIVES

A. To design the headphone ergonomically good with the customer by measuring the optimum pressure force with the help of capacitive sensors.
B. To increase the product quality and rating by meeting the customer requirements

III. LITERATURE SURVEY

Sr no	Name Of Paper/journal	Authors Name	Year of published	Findings Of the Paper
1	Basics of capacitive sensing	David Wang	2014	In this paper we have found the following data:- Basics of Capacitance, capacitive sensing work Principle, Capacitive sensing v/s Capacitive touch. If distance between the plates is small compare to other dimensions of plate then field in capacitor for most of the area is uniform. The fringing effect occurs near the edges of the plate and depending on application, can affect the accuracy of measurement.
2	Capacitive sensors for detecting the thickness or Application of an automobile brake pad	Willian T. Anderson	2004	In this paper a capacitive sensor for sensing the thickness of an automobile brake pad is provided. The sensing capacitor includes a pair of parallel plates that are arranged such that brake pad wear reduces the size of one or both of the pads. The reduced size of the plate(s) is detectable as a change in capacitance between the plates. In one aspect a reference capacitor is also placed within the brake pad. The reference capacitor includes a pair of plates that do not change size during wear of the brake pad. The capacitance of the sensing capacitor can be compared to the capacitance of the reference capacitor for a more accurate indication of pad wear.

3	Results of tilted capacitive sensors to detect shear force	Sophan Somlor, Alexander Schmitz, Richard Sahala & Shigeki Subano	2015	The paper describes ways to arrange normal force transducer, so that they can sense shear force. Using a copper beryllium plate as a deformable element capacitive type force sensor can reduce hysteresis Capacitance to Digital Convertor (CDC) chips such as AD7147 are available which enables digitalisation in very limited space.
4	Application of FSR in design of pressure scanning system for plantar pressure measurement	N.K. Rana	2020	In this paper to estimate the peak pressure point on the foot sole a study was conducted on a healthy male group and using this and few other data shoe sole of different sizes were developed with 8 FSR placed in each sole and its connection to data acquisition system analysed information regarding diabetic foot ulceration and used for sole design.
5	Force sensing resistor (FSR): A brief overview and the low cost sensor for active compliance control	Jamaludin Jalani , J.A. Sukor	2016	This paper presented an overview application of FSR sensors also stated the comparison of flexi force sensor and interlink sensor which are basically two types of FSR sensors. In all the experiments for an effectiveness of FSR sensors was conducted

IV. COMPONENTS

A. FSR (Sensor)

When a force or pressure is applied to the sensor it's resistance changes .FSR are usually constructed by two film layers .The resistance of the circuit is high when their is no pressure , but when pressure is applied to the sensor resistance drops . Resistance drop is proportional to pressure being applied.

B. Arduino Uno

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.The Arduino Uno is a microcontroller board based on the ATmega328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI. USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

C. Breadboard

A breadboard or protoboard is a construction base for the prototyping of electronics.

D. Jumper wire

Also known as jumper or Dupont wire is a normal electric wire or group of them with a pin at each end.They are normally used to interconnect the components of a breadboard internally or with other components.

E. LCD Display

We have used 16x2 LCD Display.These displays are mainly used for multi segment light emitting diodes and seven segments.These displays are simply programmable and there are no limitations for displaying customer character.

F. Resistors

We have used two resistors :

1) *10 k ohm Variable Resistor:* This resistor is used so that the electrical resistance value can be changed on demand .They are used to control voltage or current within a circuit
2) *10 k ohm Resistor:* A resistor is a passive two terminal electrical component that uses electrical resistance as an element of circuit . They are used to reduce current flow , adjust signal levels , terminate transmission lines among other uses .

V. WORKING

The simple working setup is shown in fig. below the set-up includes sensors (FSR-Force Sensitive Resistor), Arduino Uno and 10k ohm resistor. As we apply force on the FSR the resistance changes and hence this change in resistance is measured and then converted into force in Newton. Along with this the change in current as well as change in current and voltage is also measured for reference purpose.

For our example we are showing it with a 5V supply but we can also use this with a 3.3v supply just as easily. In this configuration the analog voltage reading ranges from 0V (ground) to about 5V (or about the same as the power supply voltage).The way this works is that as the resistance of the FSR decreases, the total resistance of the FSR and the pulldown resistor (10k ohm) decreases from about 100Kohm to 10Kohm. That means that the current flowing through both resistors increases which in turn causes the voltage across the fixed 10K resistor to increase.

This table indicates the approximate analog voltage based on the sensor force/resistance 5V supply and 10K ohm pulldown resistor.

Force (lb)	Force (N)	FSR Resistance	(FSR + R) ohm	Current thru FSR+R	Voltage across R
None	None	Infinite	Infinite!	0 mA	0V
0.04 lb	0.2 N	30 Kohm	40 Kohm	0.13 mA	1.3 V
0.22 lb	1 N	6 Kohm	16 Kohm	0.31 mA	3.1 V
2.2 lb	10 N	1 Kohm	11 Kohm	0.45 mA	4.5 V
22 lb	100 N	250 ohm	10.25 Kohm	0.49 mA	4.9 V

VI. ACTUAL WORKING SETUP

The actual setup was made by making connections between the sensor, Arduino and breadboard. The results or values of force applied by the headphone where recorded when the setup was tested in real life.

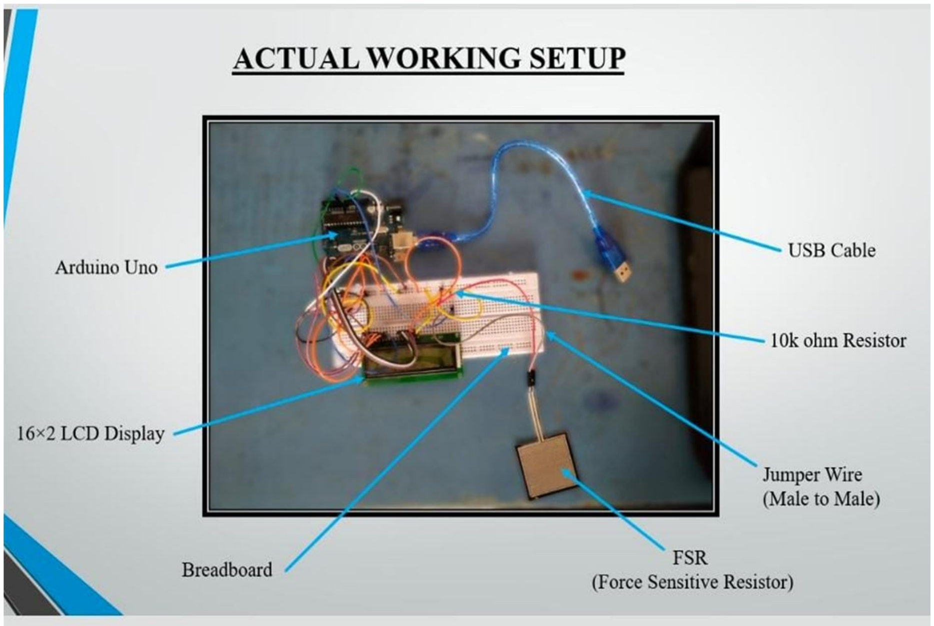

FIG 1 (Actual Working Setup)

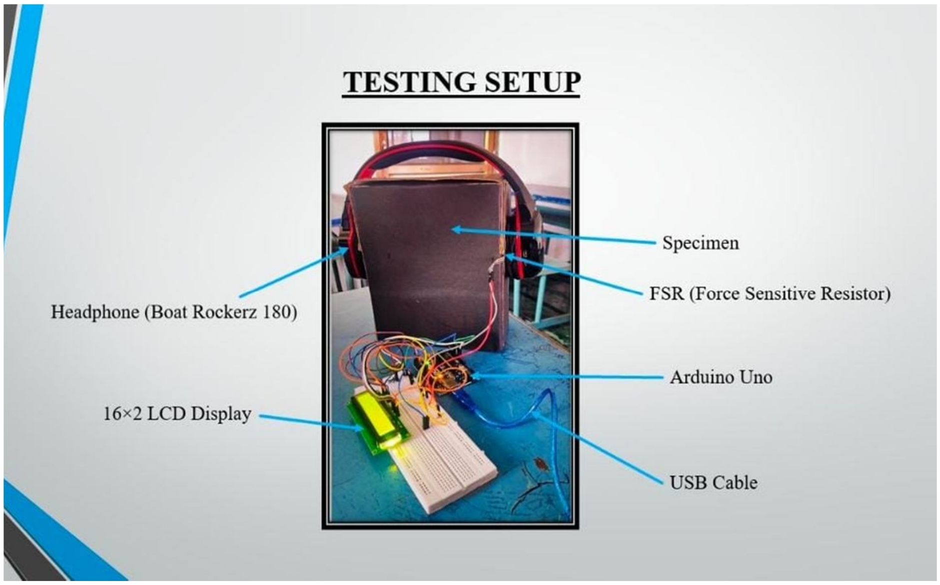

FIG 2 (Testing Setup)

VII. RESULTS AND CONCLUSION

The sample of an experimental readings are recorded also the sensors are calibrated as required for the experimental purpose. Four different types of headphones are used for performing the experiment. Also, for each headphone 4 readings are taken i.e. (2 readings for Left ear cup and 2 readings for Right ear cup). First reading is the maximum amount of force recorded and second reading for minimum amount of force recorded.

A. Force Measurement Readings

boAt Rockerz 518

Sr. No.	Analog Reading	Voltage Reading in mV	FSR Resistance in Ohms	Conductance in micro ohms	Force in Newton
LEFT EAR CUP					
1	728	3558	4052	246	3
2	3502	1720	19069	52	0
Mean Value	904	2639	11560.5	149	1.5
RIGHT EAR CUP					
4	766	3743	3358	297	3
5	590	2883	7343	136	1
Mean Value	678	3313	5350.5	216.5	2

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Tribit X Free Go

Sr. No.	Analog Reading	Voltage Reading in mV	FSR Resistance in Ohms	Conductance in micro ohms	Force in Newton
LEFT EAR CUP					
1	782	3822	3082	324	4
2	516	2521	9833	101	1
Mean Value	649	3171.5	6457.5	212.5	2.5
RIGHT EAR CUP					
4	847	4139	2080	480	6
5	464	2267	12055	82	1
Mean Value	655.5	3203	7067.5	281	3.5

VIII. CALCULATIONS

[BOAT ROCKERZ 518]

$$F_{avg} = \frac{\left\{ \text{mean Value (Left Ear Cup)} + \text{mean Value (Right Ear Cup)} + \text{[TRIBTT X FREE GO] mean value (Left Ear Cup)} + \text{mean Value (Right Ear Cup)} \right\}}{4}$$

$$F_{avg} = \frac{1.5 + 2 + 2.5 + 3.5}{4}$$

$$\boxed{F_{avg} = 2.375\ N}$$

IX. FUTURE SCOPE

As per our system concerned we can take more readings by using large and small head sizes in order to get more accurate value of force. Moreover, an advancement can also be done in the headphones depending upon the comfort level needed by the consumer.

Future advancements that can be possible are:

1) Taking readings of two other head sizes i.e. large and small inorder to get a much more accurate value of force.
2) Finding out different headphone ear cups angles to design the headphones with adjustable ear cups opening angles. So, that the consumers can keep the ear cups of the headphones as per their requirement at the desired angle they need it to be.
3) One or more other sensors can also be used to design certain other parameters of headphones like motorized self-adjusting headphones, less force applying headphones, etc. making them more comfortable to wear for longer period of time.
4) Making the testing setup compact and much reliable to use.

Thus, these will be the advancements/adjustments that can be done in the future for finding out the value of force and thereby making the headphones more comfortable to wear for longer period of time without any issue.

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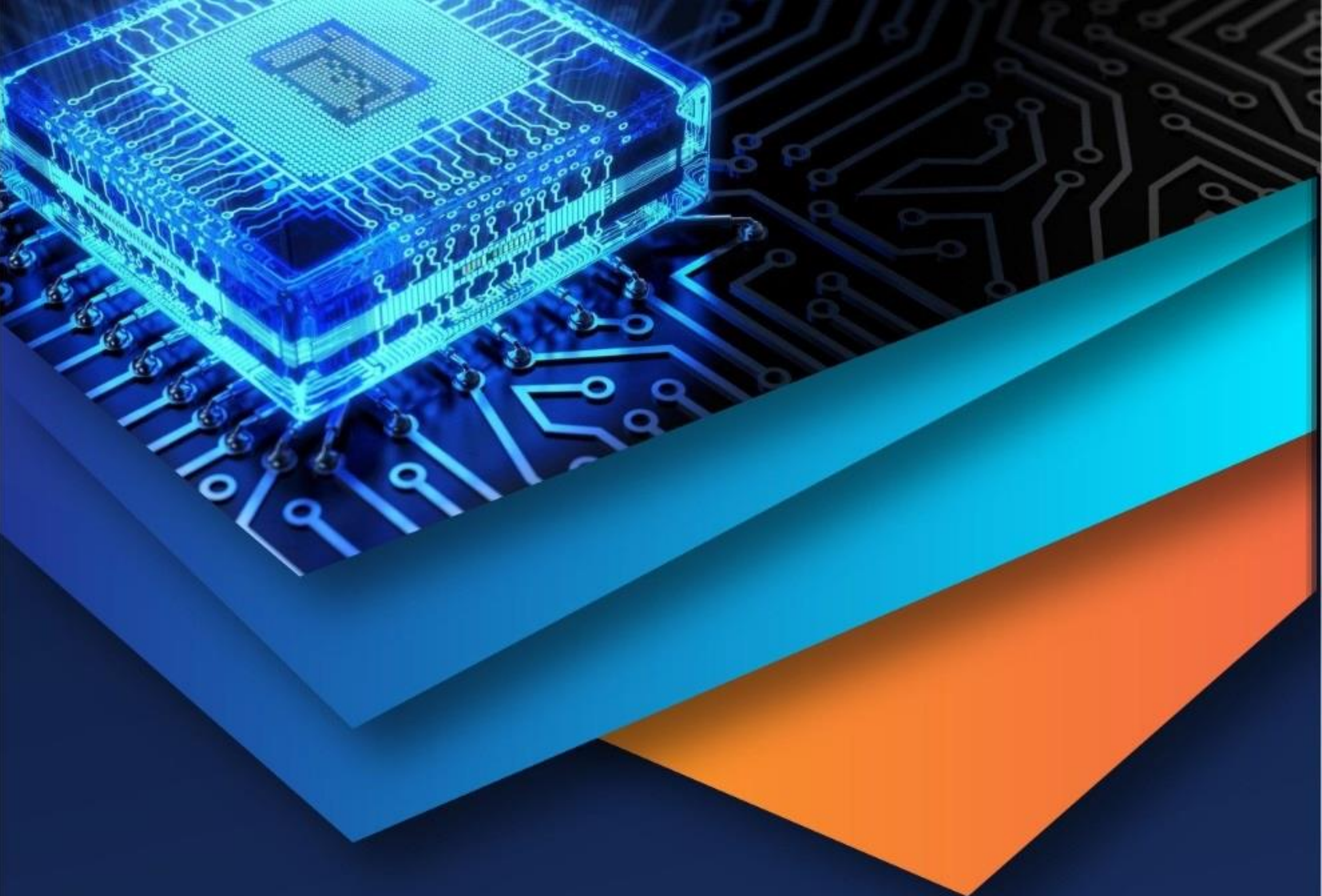

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