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Piezoelectric Exercise Monitor

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***Abstract*-- This paper presents an exercise monitor system for walking or jogging application. A piezoelectric principle based mechanism is proposed, which is composed of a module of four piezoelectric discs mounted inside the shoes of the person undertaking exercise. The potential generated as a result of applied pressure by the person is used to detect the number of footsteps of the person. The walking or jogging motion is analyzed. Depending upon this analysis, number of calories burnt by the person is determined and displayed. A prototype of the exercise monitoring module with compact size and low power consumption has been developed and performance tests have been conducted. The experimental results demonstrate that this system has characteristics such as excellent repeatability, high efficiency and no complex control logic.**

***Index Terms*- Embedded system, piezoelectric discs, Relation between footsteps and calories burnt.**

I. INTRODUCTION

The word piezoelectricity means electricity resulting from pressure. Piezoelectricity is the charge that accumulates in certain solid materials in response to applied mechanical stress. The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in some crystalline materials with no inversion symmetry. The piezoelectric effect is the process of internal generation of electrical charge resulting from an applied mechanical force. The capacity of piezoelectric materials to receive any vibration and to convert that into electric signal attracted many researchers who tried to implement circuits and systems for converting pressure and vibrations into electric power. [1], [2]

Examples of such piezoelectric crystalline structures are Quartz, Rochelle salt, Topaz, Tourmaline, Cane sugar, Berlinite ($AlPO_4$), Tendon, Silk, Enamel, Dentin, Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Potassium Niobate ($KNbO_3$), Lithium Niobate ($LiNbO_3$) etc. [3]

There are two types of piezoelectric effect, direct piezoelectric effect and inverse piezoelectric effect. The direct piezoelectric effect is derived from materials generating electric potential when mechanical stress is applied and the inverse piezoelectric effect implies materials deformation when an electric field is applied. This project of Footsteps counter via piezoelectricity uses direct piezoelectric effect.

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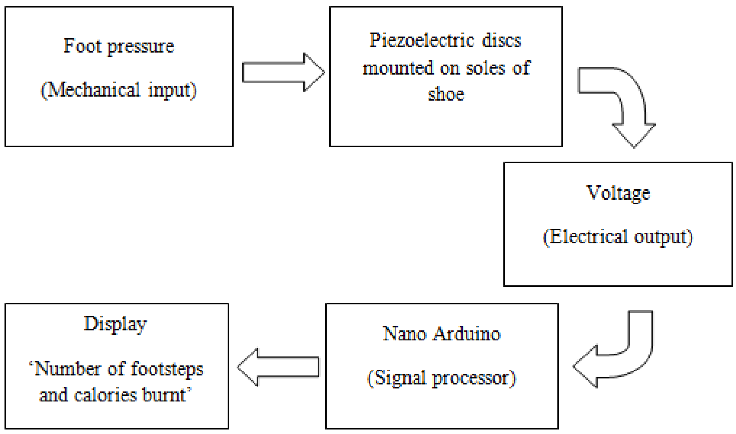


Figure1. Functional Block Diagram

II. THE SYSTEM OVERVIEW

A. Piezoelectric material

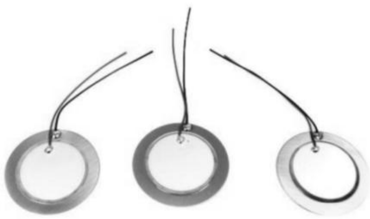


Figure2. Piezoelectric discs used

The Piezoelectric ceramic plate sensor used here is manufactured by Murata Manufacturing Co. Ltd [6]. It is a Piezoelectric Diaphragm as shown in Fig.2. This is a family of low cost pressure transducers. These are active transducers and hence the sensitivity and linearity are not affected by input voltage fluctuations.
Piezoelectric sensors have to be positioned in two main parts of the sole where the maximum pressure is applied. Single sensor is capable of generating 0.5 to 1.5V on application of pressure.

B. Nano Arduino

Nano Arduino with AT Mega 328 is used to detect whether the voltage fluctuation generated is a valid footstep or not, to store the count and to calculate the calories burnt.

Power:
The Arduino Nano can be powered via the Mini-B USB connection, 6 to 20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). This project uses pin 30 as battery used is of 9V [7].

Input and Output:
Each of the 14 digital pins operates at 5V. Each pin can provide or receive a maximum of 40mA and has an internal pull-up resistor of 20 to 50 kΩ.

C. Shoe sole

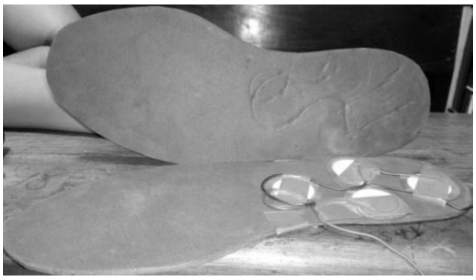


Figure3. Shoe sole

Piezoelectric discs are mounted onto the shoe sole as shown in Fig. 3 such that maximum pressure is obtained to yield maximum voltage

D. General Purpose Board

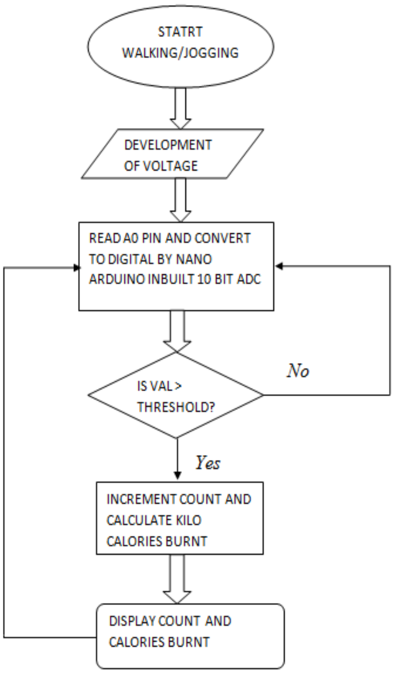
GPB is soldered with the components Nano arduino, connections from the discs mounted on shoe sole, LCD, pull down resistor of value 500kΩ for AREF pin of nano arduino in order to avoid keeping it open.

The entire assembly is mounted onto a box as shown in Fig 4.

Figure4. Experimental Setup

The analog value of 0.5V corresponds to digital value of 100 and 1.5V corresponds to digital value of 300. Thus, a pulse of range 100 to 300 will be counted as a successful footstep.

III. ALGORITHM



IV. RELATION BETWEEN CALORIES AND FOOTSTEPS

For initial calibration, method given by Harvard Health publications [9] has been used. For casual walking, which is 3.2 kmph (i.e. about 2 mph) the relation between footsteps and calories can be established as -

Step 1
Multiply the weight of the person by 1.26 (for weight 'w' in kg) to calculate how many calories the person burns in 1.6km (i.e. about 1mile).

Calories burned = 0.7875*w calories per km.

Step 2
Walk casually for exactly 1km while wearing the foot step counter. Record the number of steps it took the person to walk. Let the number of steps be 'n'.

Step 3
Divide the number of calories the person burns per km by 'n'. The result is a unique conversion factor which can be used to calculate the number of calories burnt.

In our experiment, weight = 59kg and n=1032.
Conversion factor = (0.7875*59)/1032 = 0.045 calories per foot step.

This is implemented as shown in Fig. 5.

```
#include <LiquidCrystal.h>
#define THRESHOLD 200       // for 500kohm
LiquidCrystal lcd(12,11,5,4,3,2);
int val, count=0; float calories;
void setup() {
 Serial.begin(9600);
 pinMode(13,OUTPUT);
 analogWrite(6,15);
 lcd.begin(16,2);
}
void loop() {
 delay(750);
 val=analogRead(A0);

  if(val>THRESHOLD)
       count++;

    calories= 0.045*count;
    lcd.setCursor(0, 0);
    lcd.print("count  :" );
    lcd.print(count);
    lcd.setCursor(0,1);
    lcd.print("calories  :" );
    lcd.print(calories);
   }
}
```

Figure5. Code Snippet

V. MECHANICAL DESIGN AND PRODUCT AESTHETICS

A wearable product should have the following significant properties.

1. The components used should not be bulky.
2. The components should be easily installable and removable from the existing set up.
3. The display should be clear.

The final setup of foot step counter is mounted on the shoe as shown in Fig 6.

Figure6. Final Module mounted on shoe

VI. RESULT ANALYSIS

1. The number of footsteps displayed on LCD and the actual footsteps are in good agreement (With accuracy of around 90%).
2. Thus considering the formula for the conversion, the number of calories burnt can be displayed up to 90% accuracy.

VII. CONCLUSION

This method of using piezoelectricity principle has been successfully incorporated to monitor the exercise at run time in terms of walking / jogging performed by a person. Thus, the number of calories burnt is obtained as a result.

On fly, the target for the day can be set and current number of calories burnt against the required can be displayed.

Thus, this will be extremely useful for athletes, professional sportspersons and even in gymnasiums for people participating in weight loss programs.

VIII. FUTURE WORK

The proposed work portrays the concept of Piezoelectric Exercise Monitor System and the results obtained are encouraging. Future work relating to energy harvesting idea encompasses further amplification of the disc output to a greater extent.

Future lies in the inclusion of advanced material used to design the piezoelectric crystal which further amplifies the crystal output in terms of voltage as well as current. A study could be carried out from the variety of piezoelectric crystals and after comparing the results, the choice of the optimum material for the best performing crystal could be devised.

An array of piezoelectric sensors can be connected in series to get larger voltage and in parallel to get larger current. The appropriate combination can be used depending upon the desired application. Piezoelectric energy harvesting can be used as a cleanest form of alternate energy source in future. This work is an example illustrating one of its applications.

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