Electrocardiogram using Piezo-Electric Sensor

Applying Open-Source to Biomedical Instrumentation.

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***Abstract*— Utilization of open-source hardware and software for the production of cost efficient Electrocardiogram using piezo-electric sensor.**

Keywords—Arduino Uno, Processing, Piezo-sensor, ECG.

INTRODUCTION

"Open Source is the new democracy"- is a tag line we many a times see adorning the tee-shirts of Computer Science undergrads and grads. But this democracy seems to have rooted itself in the world of hardware as well,diversifying itself from the world of software, Unix and Linux. Arduino is presently the leader in the world of open source microcontoller boards and its offerings have taken the world by storm with many new projects spurting up with each passing day, only to showcase the power and versatality of the ATMega based boards. No wonder it has been nicknamed "Engineer's microcontroller".

Processing is an open source programming language and integrated development environment(IDE) heavily working in graphics. It was initiated by Casey Reas and Benjamin Fry in 2001. They both were formerly of Asthetics and Computation Group at the MIT Media Lab.

Processing has been extensively in use by both professionals and amateurs to prepare their graphics projects. Most extensive use of processing has been seen in maping serial communication data from microcontrollers onto the computer screen.

Arduino, in conjuction with the Processing IDE has been used to display the output of the sensors on the computer screen . Together they form a combination where the microcontroller can be used by only interfacing the output screen without knowing the complex structure or the programming involved with the microcontroller.

This fact has been utilized here to produce an instrument wich can easily provide ECG without the hassle of complex and costly machinery.

Hundreds of thousands of people die every year due to lack of proper medical facilities and treatment. As engineers , it is our consistent endeavour to battle this plage by inventing newer and more affordable medical instrument to doctors and patients all around the world.

We were also taken into this new league of open source freedom and directed our efforts at venturing into this new realm. And it was there that we bumped across the project of providing cheap and economically friendly Electrocardiogram to everyone in dire need of it.

I. EQUIPMENTS

The components used for the construction of the circuit are all easy to find and assemble. The components utilized for the project are listed as follows :

- Arduino Uno
- Piezo Electric Sensor
- 10 kilo-Ohm Resistor
- Jumper wires
- Breadboard for prototyping
- Copper clad perforated board for soldering the circuit
- Soldering iron
- Solder wire
- Soldering flux

A. Abbreviations and Acronyms

The following abbreviations have been used in the paper. Their full forms are provided along with their acronyms.

1. ECG – Electrocardiogram
2. PES – Piezo Electric Sensor
3. EMF – Electromotive force
4. 10k - 10 kilo Ohm resistor
5. IR – Infrared

B. Units

No formal measurements have been performed in the experiment. The only precaution that has been maintained is that the input current to any of the Arduino pins should not exceed 40 milli Ampere. This calculation was taken care of by adding a 10 K-Ohm resistor in series with the analog input.

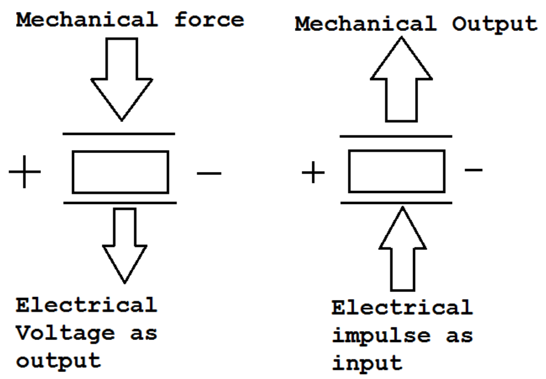
All of these are in SI units.

II. STEPS INVOLVED

The arduino is the central processing unit of the project. The piezo electric sensor acts as the medium which translates the force of the blood flow when the heart pumps as an analog input , which then is used as the input for the ECG plot. The operation of the PES is as follows.

The piezo electric substance is any substance that reacts to any electrical input by producing a mechanical output (in the form of vibration) or to any external mechanical input (for example, pressure applied on it) with an EMF as its output.

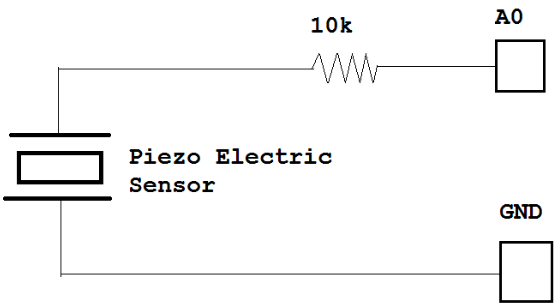
It is illustrated in figure below. The box in the center is used to represent the piezo sensor.



The most common application of the piezo substance is in guitar pickups.

The theory behind the ECG machine used here is - the mechanical vibration of the heart pumping blood across any vein near the surface of the body (for example, the artery near the wrist), is translated into an EMF which is passed onto the Arduino as an analog input. The Arduino reads the value of the input, and plots the values with a delay of 10 milli-seconds using the open-source graphics software Processing.

III. CIRCUIT DIAGRAM



In the above circuit diagram A0 acts as the analog input on the Arduino board. GND serves as the ground pin of the Arduino.

IV. CODE

```
int beatPin=0;

void setup()
{
  // Initialization
  Serial.begin(9600);
  pinMode(beatPin,OUTPUT);
}

void loop()
{
  // code to detect the pulse and recieve the value
  int val=analogRead(beatPin);
  if(val>=24 && val<=29)
  {//the drop of val for each pulse
    val=val*3;//magnifying the pulse
  }
  Serial.println(val);
  delay(10);
}
```

This is the code that needs to be uploaded in the Arduino.

The code that needs to be uploaded to the Processing to analyze and plot the serial communication data from the sensor connected to the Arduino is the following.

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```
import processing.serial.*;
Serial myPort; // The serial port
int xPos = 1; // horizontal position of the graph
float oldHeartrateHeight = 0; // for storing the previous reading
void setup () {
size(1000, 500);
frameRate(25);
println(Serial.list());
myPort = new Serial(this, Serial.list()[0], 9600);
background(0);
}
void draw () {
}
void serialEvent (Serial myPort) {
String inString = myPort.readStringUntil('\n');
if (inString != null) {
inString = trim(inString);
println(inString);
int currentHeartrate = int(inString);
float heartrateHeight = map(currentHeartrate, 0, 1023, 0, height);
stroke(0,255,0);
line(xPos - 1, height - oldHeartrateHeight, xPos, height - heartrateHeight);
oldHeartrateHeight = heartrateHeight;
if (xPos >= width) {
xPos = 0;
background(0);
}
else {
xPos++;
} } }
```

V. SETUP AND PERFORMANCE

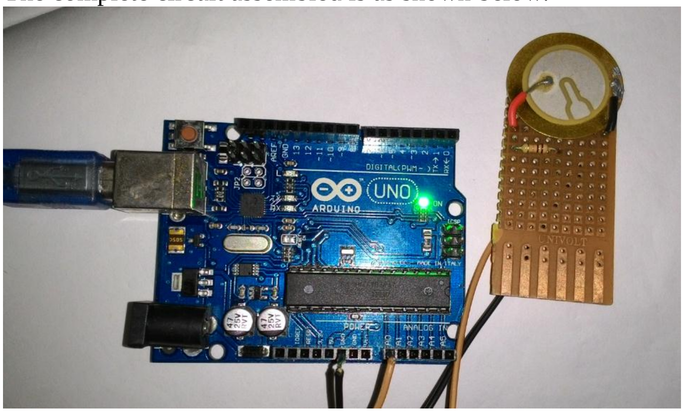
The circuit has to assembled onto a copper clad vero-board and the terminals soldered into position.

Two terminals come out of the board. One wire goes to the ground pin on the Arduino, while the other goes to the analog pin A0.

It is assembles as shown in figure below.

Here, orange is the live wire while the black serves as the ground.

The complete circuit assembled is as shown below.

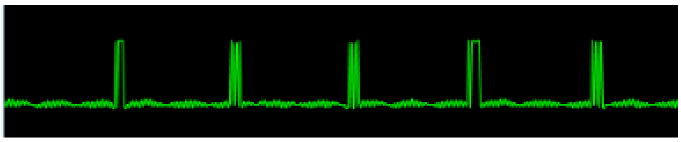


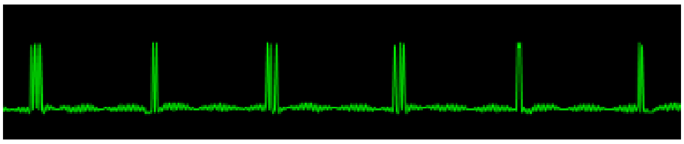
Now the program is uploaded to the Arduino. The sensor starts sending in data to the Arduino , which can be seen from the Serial Monitor. The Serial Monitor can be accessed from the Tools menu of the Arduino IDE.

Next , the Processing program is uploaded and run. A terminal window opens which shows a steady zero value, corresponding to no input.

The piezo sensor is the placed near the wrist from where the pulse can be checked. Pressure is applied to keep the sensor in place. The vibration of the pulse travel to the surface of the body , near which the sensor is placed. This sensor now receives the mechanical vibration and the piezo transmits an electrical impulse corresponding to the pulse. This forms the basis of the ECG.

A trial was performed whose output was as shown below in the Fig.





We observe from the above ECG that each spike corresponds to the pulse.

VI. PRECAUTION

Precaution need to be maintained during the assembly and soldering. No short circuit should be allowed as the maximum current current rating of the Arduino board is 40 milli Amperes.

Care should be taken during operation so as not to damage the sensor. The rest of the circuit is mostly rugged.

VII. CONCLUSION

The device provides the user ECG at a very pocket friendly price. The entire equipment is robust and any damage can easily be addressed to without the involvement of much cost.

The primary object in working on such a project is providing the needy and the poor with better medical facilities. All around the world, mostly in underdeveloped and developing countries, ECG is a costly affair. This devices eliminates the cost associated with such medical procedures and provides a cheap and easily affordable ECG to everyone who needs it.

The cost involved with the production of such an equipment is enlisted as follows. The pricing can be cross checked easily on the internet. All prices are in Indian Rupees (Rs.)

- Arduino Board - Rs. 590
- Piezo Electic Sensor - Rs. 10
- 10k Ohm resistor - Rs. 1
- Vero board - Rs. 10
- Jumper wire - Rs. 10
- Cost of soldering - Rs. 10

Total costing involved = Rs.631.00/-

All the prices are from a consumer end and not from a manufacturer's end. In mass production the equipment can be manufacture in Rs.100.00 approx.

The entire objective of utilizing a piezo electric sensor comes from the idea of applying it to amplifying guitar sounds by converting the mechanical sound wave into electrical impulses. This idea of utilizing pressure gradient to produce analog signal was the inspiration of applying the same philosophy to detech pulse rate.

Other alternatives could be infrared emitter and detection. But the greatest advantage of using piezo sensor is the availability of a constant zero when not attached to the body of the user. The high rate of fluctuation of the infrared signal is the reason to shift to the utilization of piezo sensors.

The circuit can be easily operated by anyone without any prior knowledge of the hardware and the software involved.

As all of the software and hardware are open source there is ready support in the form of forums and available schematics from the manufactures, in case of maintenance and repair.

VIII. AFFILIATIONS

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We were heavily influenced by the extensive work on utilizing infrared sensors in performing ECG , easily available on the web. But we are mostly indebted to Mr.Collin Cunningham's video on IR pulse sensor on the 'Make' page on 'YouTube'.

X. REFERENCES

- Makezine – Collin's Lab – IR pulse sensor. *makezine.com/2009/11/30/collins-lab-infrared-heart-sensor*