Dynamic Detection of PPG(Photo Plethysmography) Signals Using Mems Self Designed Sensors

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Abstract

Objectives: To design Micro Electro Mechanical System (MEMS) based sensor with novel design considerations to detect/ identify PhotoPlethysmography(PPG) signals when the person is in dynamic mode. To simulate the above design using COMSOL Multiphysics and evaluate the results with the existing methodologies. **Methods/Statistical Analysis:** A MEMS based sensor with a four T-shaped cantilever with middle load hanged structure is designed in COMSOL Multiphysics and after attaining the required resonant frequency of PPG, by using capacitive actuation technique the acquired mechanical signals are evaluated and digitised. **Findings:** PPG sensors optically recognize changes in tidal volume of blood (i.e., changes in the force of light perceived) in the vascular bed of little scale tissue by reflection from or transmission through the tissue. If the person is in static mode it is very easy to detect blood flow rate. If suppose the person is not in rest, i.e., may be dynamic we will observe many variations in blood flow rate. So it is very difficult to estimate the blood flow rate. This Patch type device easily measures the blood flow rate. **Application/Improvements:** Mainly these type of devices are useful to detect variations in blood flow rate in human whether in static condition or in dynamic condition. In future we are planning to develop implantable sensors with reporting system to doctor in particular intervals of time. This may be helpful to doctors to cater the needs of human society at right time whenever it is needed.

Keywords: Capacitive Actuation, Dynamic, Implantable, MEMS, PPG, Static

1. Introduction

1.1 Principle of PPG

The guideline of PPG rapidly elucidates here. Light experiencing characteristic tissue can be devoured by distinctive substances, joining shading into the skin, bones and veins and venous blood¹. Most changes in the circulatory system fundamentally happen in supply routes and arterioles (however not veins). For instance, the veins contain more blood volume amidst the cardiovascular cycle systolic period amidst the diastolic stage². PPG sensors optically recognize changes in tidal volume of blood (i.e., changes in the force of light perceived) in the vascular bed of little scale tissue by reflection from or transmission through the tissue. Photo Plethysmographic wave structure, contrasting Direct Current (DC) and alternating current (AC). The DC current shape PPG wave alludes to the optical sign recognized transmitted or reflected from the tissue, and depends on the structure of the tissue and the typical blood volume of both veins and the venous blood³. Note that the DC section progressively changes with relaxing. Fragment AC indicates changes in the blood volume going between the systolic and diastolic periods cardiovascular cycle; the key recurrence of the AC section depends on the velocity and heart overlies DC portion.

2. Factors Affecting PPG Recordings

Past research has perceived a few components affecting recordings PPG, including the site of estimate (i.e., site

test connection), power contact, mechanical ancient rarities of development, stance theme, and breathing, and encompassing temperature expansion.

2.1 PPG Sensing When the Subjects are Still

PPG recognizing when the subjects are still. Distinctive LED driving current is utilized as a major aspect of this tradition. The LED drive current extends from 1-24 mA to 4 mA-increases, and after it was lessened again to 1 mA⁴. This is to watch the effect of hysteresis. For sensor and - AR, there were two treatment frameworks sensor, i.e., protecting (really worn and secured by a dull domain) or settling (assurance, and a headband immobilize the handset against auricular skin). Every test keeps on going <1 min, this respectably brief time guarantees that the body states of subjects, for instance, positions, levels of blood perfusion and skin temperature remained for the most part predictable.

Crude PPG signal specimens beneath (obliterated) that is 50 for every channel Sps were taken before the pattern (DC) location and separating band-pass with a pass-band of 0.5-4 Hz⁵. The handled sign is envisioned and found the normal estimation of pulsatile portion of the prepared sign (aerating and cooling) was assessed. This is to survey the exactness of the PPG signal in the particular territories and perceive a tasteful sensor LED current practices for e-AR sensor.

Cantilever sensors have an essential piece of over 10 years because of its high affectability, execution and acknowledgment of target segments. The fundamental rule is that the cantilever sensor responds mechanically when there is change in outside parameters, for example, temperature, adsorption atom. Cantilever having a settled end and the other side is versatile⁶. Most bars which are readied utilizing silicon were utilized as sensors. It cannot be measured by measuring changes in the resonance frequency of defecation.

Distinctive as the static mode, dynamic mode, the thermal mode, the hot spectroscopy photo, change recognition, and the revelation of attractive strengths⁶. There is appraisals mode. For the most part around the static and element modes. In the static mode, amidst the adsorption of the atom or target molecule in the surface layer, there will be no strain in the surface layer. In the dynamic mode, as appeared by adsorption of iota particles or destination or desorption of the surface of the cantilever pillar, the shaft is swung at its thunderous recurrence and is seen with the settings in the resounding recurrence⁷. The response cantilevered MEMS sensor can be checked utilizing different strategies, for example, piezoelectric, Piezo-resistive, optical, and so forth⁸. Cantilever sensors can find their applications in various applications as the discovery of concoction and natural recognizable pieces of proof as a result of its high affectability, likewise the expense is low⁹.

3. Design of Cantilever Procedure

- Selecting Physics
- Defining geometry
- Defining materials
- Setting up physics
- Meshing
- Simulation
- Analysis of results

3.1 Selecting Physics

Here required physics is chosen i.e., solid mechanics, thermal stress etc.

3.2 Defining Geometry

In this level, measurements and required shape is defined to make cantilevers i.e., rectangular, square and so on., with required measurements in micro-meters.

3.3 Defining Materials

In this level, material is characterized to make a cantilever i.e., Silicon(c), SiO₂, P-silicon, n-silicon and so on., with their distinctive properties like young's modulus(E), Poisson's ratio(nu), density (nd) and so on.,

3.4 Setting up Physics

Here, required physical science is chosen i.e., Fixed Constraint, Body load, Pointload and so on.

3.5 Meshing

So as to accomplish the results precisely we have to utilise the element mesh regarding the measurements of the elements i.e., Fine, Finer, Coarse, Coarser and so on.

3.6 Simulation

In this step, Simulation is done according to the required specifications.



Figure 1. H-Shaped Structure 1st Eigen Frequency Mode.



Figure 2. Arc Length Versus Displacement at 1st Eigen Frequency Mode.



Figure 3. H-Shaped Structure With 2nd Eigen Frequency Mode.

3.7 Analysis of Results

Here results are observed through diagrams like point graph, line graph and so on.

4. Results and Discussion

An H-shaped cantilever shown in Figure 1 by an arrow is fixed in this mode. The corresponding First Eigen frequency and the displacement can be observed in this Figure 1. The respective graph for the displacement is shown in Figure 2.

In this mode, the other end of the H-shaped cantilever beam is fixed and the respective Eigen frequency and displacement is shown in Figure 3. The line graph for the above frequency for length and displacement is shown Figure 4.

Here in this level, the third Eigen Frequency was represented by Figure 5, there is no fixed end and the corresponding values can be observed in this Figure 6.

Here the fourth Eigen frequency is represented in Figure 7 and as shown above pointing an arrow is the fixed end and the respective Eigen frequency, displacement values are analysed and represented in Figure 8.







Figure 5. H-Shaped Structure With 3rd Eigen Frequency.



Figure 6. Arc Length Versus Displacement at 3rd Eigen Frequency.







Figure 8. Arc Length Versus Displacement at 4th Eigen Frequency.



Figure 9. H-Shaped Structure With 5th Eigen Frequency Mode.



Figure 10. Arc Length Versus Displacement at 5th Eigen Frequency.

In this step, the fixed end is represented by an arrow and the respective Eigen frequency 5 and is represented in Figure 9 and displacement values can be observed and represented in the Figure 10.

5. Capacitive Sensing Technique

Capacitive sensing is creating as an option choice for noticeable switches and controls interface gadgets and client applications show faceplate. The segment measuring capacitive detecting applications is a structure of a sensor cushion (a territory of conductive material) and spread conductive material, which is by and large a thickness of filler partition zone and condenser. The capacitance of a sensor appraisal is given by:

$$C = \frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{d}$$

Where A is the complete range of the whole sensor and related routing and d is the distance between the sensor routing and the encompassing conductors. As conductive objects, (for example, a finger) move in proximity to the sensor, they modify the electrical field lines of the capacitive sensor and change the capacitance that is measured by the control hardware.

6. Surface Capacitance

In this advancement, the glass is always secured with a conductive layer. Amidst the operation, a voltage sign

is associated with each of the four corners of the board, bringing about a uniform electrostatic field. The moment when a human finger touches the board, a capacitance where a plaque is the principle layer and the other is human finger shown in Figure 11 and 12. Contingent upon the domain of touch of a finger, current drawn from the four corners will be resolved and accordingly the capacitance seen by those corners will be so particular. This qualification can be utilized to choose the district cautious touch and is shown in Figure 13.



Figure 11. Surface Capacitance [Ref:6].



Figure 12. Sensor Pad on PCB [Ref:6].





This results in an increase in capacitance of the sensor from C_p to $C_p + C_f$

7. Measuring Capacitance Change

Regular frames dependent load estimation resonant capacitance or repeat time a RC (as is done in meters LCR). Moreover, these frameworks cannot be utilized particularly for the distinguishing proof of contacts, because of advances in the capacity of a sensor of this sort would generally be in the scope of a few tenths of pF. On the event that arrangements with measuring change time/ repeat booming charge in a capacitor as the utilization of a consistent current, there would be three concerns:

1. Measuring such a little capacitance would require a high frequency clock and/or a low current worth for an optimum estimation.

2. While measuring charging time, a larger part of the time would be spent in measuring the self (parasitic) capacitance of the sensor (which is generally in the order of several pF) and the required measurement of the change would constitute just a small amount of the measurement time, subsequently prompting unnecessary utilization of controller time and power.

3. The impact of noise on such a framework would be high.

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