NON-CONTACT ACCELERATION MEASUREMENT IN ORTHOGONAL DIRECTIONS

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ABSTRACT

In this work, determination of acceleration (using a non-contact device) in three mutually perpendicular directions (X, Y and Z) is carried out using M E M S. A Tri- axial Accelerometer ADXL335 sensor and a Bluetooth module are used to find the accelerations at a point where measuring the acceleration is normally not achievable due to inaccessibility of a small area where three accelerometers cannot be located to measure in all the three directions. They are sensed by the accelerometer sensor and the corresponding signal is transmitted to a PC or a laptop or a Wi-Fi-supported mobile. Using the Bluetooth/Wi-Fi module which involves the IOT (Internet of Things) concept is applied through MEMS here. It is possible to use these components for further processing and applications which shall be discussed depending on a few factors, they are like sensitivity, thresholds, range, rise time, precision, calibration- friendliness of the signals etc. A range of possible applications of this method is discussed. A very adequate, robust electronic packaging should entail too with MEMS connected to Wi-Fi mother boards of any fitting type inclusive of blue tooth.

Key words: Parallelepiped of acceleration, applications and extensions, demonstration experiments, Accelerometer, Bluetooth, and wide range of possible applications in different fields

1. INTRODUCTION

Measurement of accelerations in multi-directions is important in many engineering applications. Piezo electricity based Accelerometers using quartz, barium titanate etc., are known. Scientists and engineers across the globe are working for over seven decades on this topic. Traditional measurement of acceleration is normally in single direction(X-Y-or Z-axis). Using MEMS (Micro Electro Mechanical Sensors) it is possible to measure the acceleration in all the three directions simultaneously.

Piezo sensors have wide range of applications. Manufacturing and industrial uses could be the highest share. Medical instruments like CT scan, patient orientation-automation occupy very attractive long time-tested applications. Currently, industrial and manufacturing sector is the largest application market for piezoelectric devices, followed by the automotive industry. Heavy demands are also conspicuous in information and telecommunications. Realizing that each and every smart phone, tablet or pad needs six sensors for requisite self-orientation, we can see demands keep increasing. Reputed and easily available sources like Wikipedia projected values of these sensors in world market even in 2010 around US $ 15 billion. As of today, the actual figures and their growth rate will be much higher. This is more so with the advent of MEMS and Wi-Fi applications around Internet of Things (IOT). [1]

Accelerations can be measured from about 0.1g to more than 10g using piezo devices and MEMS. Rise times will be in micro seconds. This is illustrated in ultrasonic applications and military devices like mixers, elevators, mechanical handling equipment, conveyors, handled materials, information handling devices like pads, phones etc., Where jerk or acceleration rate plays a role, machines where there is importance attached to measuring the acceleration in all the three components i.e., (X,Y and Z axes respectively). MEMS use the latest methodology which is available to sense the acceleration in the 3-directions such as a wireless tri-axial accelerometer like Bean Device AX-3DS, BZ-TECH wireless accelerometer. These available wireless accelerometers in the market are cost effective in comparison to the project cost. As the bulk needs increase, the price comes down with increasing manufacturing capabilities owing to the deployment of MEMS. While doing away with the needs of experiments that cost very high Arduino platform and MEM sensors will achieve the same purpose in the applications mentioned in a very effective way. In order to avoid the high cost experimental needs, this work uses the Arduino platform and the sensors.

2. LITERATURE REVIEW

MEMS gave rise to a lot of applications and advancements. They involve / miniaturization, process improvements in quality and quantity etc., [2]. The rapidly growing innovations, interest in ever growing measuring techniques especially wireless based, network friendly, easy to adopt without compromise on precision and reliability all make this highly interdisciplinary activity an attraction to many specialists.

Hardly spanning from micrometers to millimeters in size, each piece of MEMS permits possibility of production in large numbers like thousands. Batch processing techniques help in specifications and variety change.

Being of full help in detection, control and passing on decisions related to actions there on, MEMS with wireless facilitation have become real tech-assets. This is sudden and unexpected turn in industries which is almost invisible, notwithstanding the reality of it. This is in the past one decade. Construction and manufacturing industries receive all these advantages.

Use of wireless tracking commensurate with their material handling systems is another area where applications are expected to increase.

Many techniques and technologies have emerged in computing and sensor networking providing potential for data acquisition like RFID and GPS. [3] Development of MEMS will continue in technology. With NEMS added it still remains as an emerging area.

Material handing technology is deriving advantages like reliability and extra cost effectiveness etc., MEMS standout, especially fostered by wireless techniques, as the most encouraging area to be explored in several machine operations and industry as a whole.

A good mixture of microelectronics associated with micro-machining also in the manufacture of house hold and industrial products appears to be the forerunner in 21st century.

[4] It shows the incipient and immense potential of MEMS, NEMS and IoT. Technological ventures reckon them with all emphasis in the fortress of strides ahead.Many semiconductor device fabrication technologies have been benefitted. Use of MEMS had due significance in their development. [5] Automotive, telecommunications, IT sector, electronics, medical and life sciences, domestic electrical appliances, industrial process control, aerospace, defence and homeland security are only some areas where role of MEMS is observed and conspicuous in some areas. Amongst most of the materials, polymers play a vital role for the development of the bio-medical applications because of their biocompatibility, cost-effectiveness and ease of prototyping at increasingly faster rates.

3. PROBLEM STATEMENT & METHODOLOGY

Measurement of acceleration in orthogonal directions is difficult in very limited spaces because of occupying large volumes, an example can be from cutting tool dynamometer, though not exactly meant for measuring the orthogonal force components and measurement of acceleration may be useful to give an idea about those forces. Conventionally digital vibro- meters, pen like devices measuring DVAJ (Displacement, Velocity, Acceleration and Jerk) are available in the market with their ratings and ranges specified. A wireless signal obtained from MEMS going through an IOT motherboard can be displayed on a screen. This screen can be a laptop or a desktop or a mobile phone having access to the internet. The simplicity involved in the signals obtained like this may not be exaggerated. The numerical values can be further processed (computed) and further derived values can be utilized for many other purposes in technology. That is what is exactly done in the industries mentioned in the introduction part.

In this work, it is aimed to measure acceleration of a pendulum bob when it is a simple pendulum as well as when it is a conical pendulum. The central idea is to sense the main acceleration component out of X, Y, Z- axes. There can be minor contributions in the other two orthogonal directions. They vary from simple pendulum to conical pendulum and to all other pendulums.

In numerous applications like concrete mixers, lifts, mechanical handling equipment, it is hard to quantify the parameters like displacement, speed, acceleration, jerk and so on because of inaccessibility, unfeasibility etc., all due to lack of the exactly required technology. The scene has changed very rapidly in the past decade. MEMS are available for over a decade. Bluetooth, IoT platform/motherboards of different makes are also available in the market for almost the same period. The growing realization that economy, efficiency, speed and change over from the present system to a smarter system can be also achieved in numerous applications is prompting works like the present one. Suitable understanding of this can help in calibration work, Machine to Machine (M2M) communication, diagnostics etc.

For conducting the experiments the accelerometer is put into a ball made up of plastic material which in the proper electronic packaging finally looks like a sphere. [6]

Figure 1 Complete electronic packaged ball

The output given by the accelerometer is normally a voltage signal but through appropriate programming in the Arduino software, the voltage obtained is converted into the required acceleration outputs.

This sphere or the pendulum bob when in motion, MEMS senses the acceleration in orthogonal directions which in turn is sent to the Arduino motherboard. It sends signal to the Bluetooth module for conversion into the wireless signals. This Bluetooth module transmits the signal to the mobile phone with the help of an app known as 'Bluetooth Graphics'.

Arduino

Arduino board is an open source platform which consists of a Micro-controller that can be used to make interaction possible among devices. It is a very simple device which can be easily programmed for required applications that is most commonly used by the people for their requirements. The technical specifications of Arduino board are Atmega 328P microcontroller [7] which has an operating voltage of 9V and its dimensions are 68.6 mm in length, 53.4 mm in width and 25g in weight. The Arduino board is connected to the PC or a laptop using a USB cable for software programming.

Accelerometer

Figure 2 Arduino UNO

Accelerometer is a device which can sense and convert the acceleration into the voltage using piezoelectric effect. The quartz crystals present inside the accelerometer sense the slightest change in the acceleration and there by change in the voltage will be obtained. The output obtained can be of digital or analog type. [8] The accelerometer ADXL-335 of low power 3- axis with a range of +/- 3g is used in this work. Its dimensions are 4mm x 4 mm x1.45 mm.

Figure 3 (a) Accelerometer front side

Figure 3 (b) Accelerometer rear side

Bluetooth Module

Bluetooth module is a device connected to the Arduino which can receive the information from the Arduino Board and send it to the PC or a laptop or a cell phone through either software or an app installed in the cell phone. The Bluetooth module of low power around 3.3V, frequency of 2.4-2.524 GHz with an in-built antenna is used in this work. [9] Its dimensions are 30mm x 14 mm x 2.2 mm.

Bluetooth Terminal / Graphics

Bluetooth Graphics is an application which contains graphics displaying the data sent by the Arduino and also there is serial monitor in it. This app can be used with the Arduino or a microcontroller to get the real time graphics of the data produced. This helps in displaying the data without any wires connected between the PC / mobile phone and Arduino board.

4. ELECTRONIC PACKAGING

Numerous nations over the globe have officially distinguished the need of the electronic packaging at this point. But, the advancement level and the development techniques for electronic packaging are still not up to the standards. This has been a lagging factor in the microelectronics field. The electronic packaging involves several fields like mechanics, electronics, physics, and chemistry. Also, in the case of heat transfer, mechanical analysis, transmission of signals etc., electronic packaging plays a significant role.

Generally any electrical and electronic devices generate some sort of signal which has a capability to interfere with the normal working of some other nearby electronic equipment's. This phenomenon is coined as Electro Magnetic Interference. EMC (Electro Magnetic Compatibility) is to be achieved for eliminating the EMI, in which Electronic packaging is one of the methods. In this work, MEMS equipment is made to fit into a ball made up of a plastic material through which the compactness and also the compatibility is achieved which helps in protection from the hazards like mechanical damage, exposure to the outside weather conditions, thermal shocks/fluctuations, EMI(Electro Magnetic Interference).

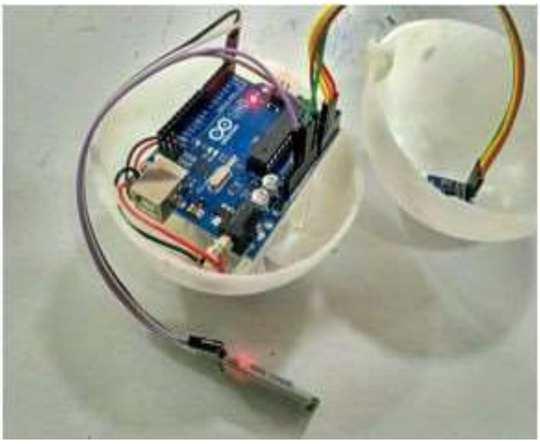


Figure 4 (a) Electronic packaging

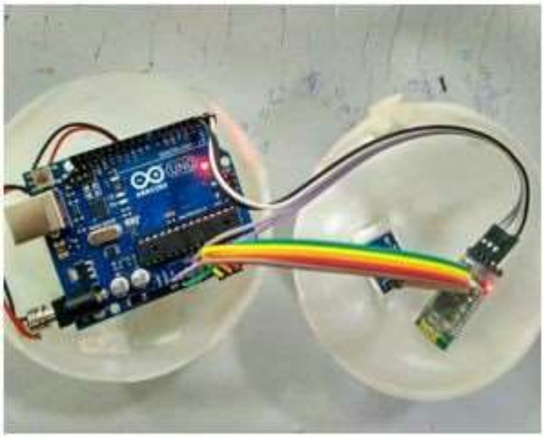


Figure 4 (b) Electronic packaging

5. EXPERIMENTS CONDUCTED & CALIBRATION

Output of any instrument to a standard known input at various points is Calibration. This process can be implemented if only standard or theoretically acceptable inputs are available. We have simple pendulum for theoretical quantities. This is made use in the Calibration. We use conical pendulum for testing purpose.

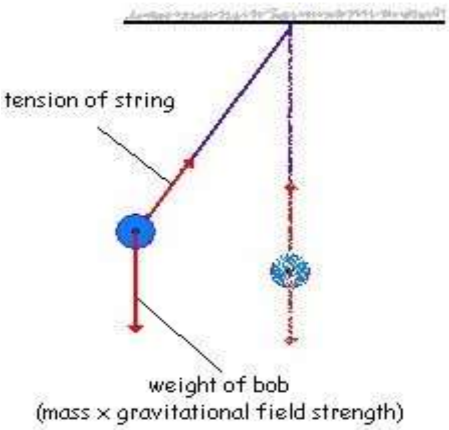
In this work, a tri-axial Accelerometer ADXL 335 along with Arduino UNO and Bluetooth module are connected using probes for the measurement of the changes in the acceleration of a moving part which has acceleration components in the three directions. The whole setup is made compact by proper electronic packaging and is mounted on the part on which the experiment is to be carried out. In this work, the connections are as follows:

- An external battery source of 9V is used as a power unit to the entire setup.
- The VCC of an accelerometer is connected to the 5.5V terminal of the Arduino, other three terminals are connected to the three components(x, y, z respectively) present on the Arduino which senses the slightest change in the acceleration. The other remaining terminal is grounded.
- Regarding the Bluetooth module, VCC is connected to the 3.3V terminal of the Arduino, the transmitting and receiving terminals are connected to TX and RX terminals respectively.

The instantaneous acceleration is sensed by the accelerometer connected to the Arduino board which transmits continuous signal to the PC/laptop or to the mobile phone using available Bluetooth module thus involving the concept of IoT (Internet of Things).

In this work, Simple pendulum experiment is carried out for calibration of MEMS. The MEMS setup is calibrated in such a way that it shows no acceleration when it is at rest. The compact MEMS setup ball acts like a pendulum bob. One end of an inextensible string of known length is tied to support the bob and the other end is fixed to a support. The ball is pulled to one side at an angle of 15^0 and then released. The time period is noted and the acceleration values are dynamically obtained in the Bluetooth Graphics App using the Bluetooth module mentioned in the methodology. This captured and the required graphs are plotted between the Acceleration and Time. Theoretically the acceleration values at certain angles are calculated and compared with the practical values using the below mentioned equations.

These equations [10] are obtained by resolving forces in X Y axes



$T\sin\theta = m*A_x$;

$T\cos\theta = mg$; $A_x =$

$g\tan\theta$;

Once the calibration part is completed, the same setup is utilized for the conical pendulum experiment. The required graphs are plotted between the acceleration and time which are shown in the results.

6. RESULTS

Calibration

Table 1 Comparison of theoretical and practical values of acceleration (a_x) of a simple pendulum

Angle(degree)	Theoretical(acceleration (A_X) in g)	Practical (acceleration(A_X) in g)
+/-15	0.267	0.24
+/-10	0.174	0.11
+/-5	0.087	0.07
0	0.000	0.01

Figure 9 (a) Simple pendulum-Acceleration (A_z) **Figure 9 (b)** Simple pendulum- Acceleration (A_x, A_y, A_z)

From the above plotted graphs for a simple pendulum experiment, it is inferred that acceleration component in X-axis (A_x) is periodic in nature. The other two components in Y- axis (A_y) and in Z-axis (A_z) are supposed to be constant theoretically, but in practical, the string is not inextensible, the mass is not uniformly distributed and other factors like air resistance, vibrations and spinning effect etc., affect the A_y and A_z components respectively.

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7. CONCLUSIONS

Using MEMS and connecting through Arduino and Bluetooth it is possible to obtain three accelerations that are Orthogonal, all simultaneously. Connecting to the Bluetooth Graphics enables obtaining the plots. In the case of Simple and Conical pendulums predominant acceleration/s obtained can be also suitably calibrated because of the possibility of theoretical evaluation of these accelerations.

Using of ICs that can integrate once, twice and thereby getting velocities and accelerations is also similarly possible. Here also theoretically well-established input quantities. The applications mentioned in the introduction may include sensors/display/computed results mentioned in this work in a suitable way where Tri-axial accelerations are needed quantitatively in time domain. If we have to extend to frequency domain the same signal outputs obtained on the final screen can be post-processed through FFT or any other DSP software.

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