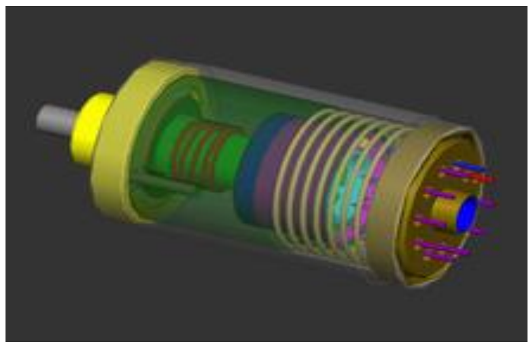
A

SEMINAR REPORT

ON

Accelerometer



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CERTIFICATE

This is to certify that **Mr. Milin C. Joshi** of B. E. Semester V (Computer Engineering) has completed his seminar work titled "**ACCELEROMETER"** satisfactorily in partial fulfillment of requirement of Bachelor of Engineering degree course, GUJARAT TECHNOLOGICAL UNIVERSITY, Ahmedabad, in the year 2011.

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Abstract

Accelerometer is the device that is responsible for motion sensing. Accelerometer is basically made up of a container inside which a test mass is kept on a spring so that it performs damped motion. Accelerometer is a device that measures acceleration experienced by the test mass. So according to that acceleration experienced , the decisions with outer devices are made. Accelerometer uses the container in which it is kept as the frame of reference. The force related with this acceleration is called G-force.

With improving 21st century's technology, the use of accelerometer has increased. Accelerometer is used in smartphones, digital cameras, tablet PCs . If we tilt a smartphone, its screen adjusts itself to landscape view or portrait view. Well known examples are apple iPhones, Blackberry Storm and Nokia N95.

Accelerometers are also used in transport i.e. in some cars. Cars come with airbag deployment system. With instant braking applied in cars, the accelerometer experiences G force and the airbags come out.

1. Introduction

An **accelerometer** is a device that measures proper acceleration. This is *not necessarily* the same as the coordinate acceleration (change of velocity of the device in space), but is rather the type of acceleration associated with the phenomenon of weight experienced by a test mass that resides in the frame of reference of the accelerometer device. For an example of where these types of acceleration differ, an accelerometer will measure a value when sitting on the ground, because masses there have weights, even though they do not change velocity. However, an accelerometer in gravitational free fall toward the center of the Earth will measure a value of zero because, even though its speed is increasing, it is in a frame of reference in which it is weightless.

An accelerometer thus measures **weight per unit of (test) mass**, a quantity also known as specific force, or g-force. Another way of stating this is that by measuring weight, an accelerometer measures the acceleration of the free-fall reference frame (inertial reference frame) relative to itself (the accelerometer).

Most accelerometers do not display the value they measure, but supply it to other devices. Real accelerometers also have practical limitations in how quickly they respond to changes in acceleration, and cannot respond to changes above a certain frequency of change.

Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration (or g-force), as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration (so long as it produces g-force or a change in g-force), vibration, shock, and falling (a case where the proper acceleration changes, since it tends toward zero). Micromachined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input.

Pairs of accelerometers extended over a region of space can be used to detect differences (gradients) in the proper accelerations of frames of references associated with those points. These devices are called gravity gradiometers, as they measure gradients in the gravitational field. Such pairs of accelerometers in theory may also be able to detect gravitational waves.

1. Physical principles

An accelerometer measures proper acceleration, which is the acceleration it experiences relative to freefall and is the acceleration felt by people and objects. Put another way, at any point in space, time the equivalence principle guarantees the existence of a local inertial frame, and an accelerometer measures the acceleration relative to that frame. Such accelerations are popularly measured in terms of g-force.

An accelerometer at rest relative to the Earth's surface will indicate approximately 1 g *upwards*, because any point on the Earth's surface is accelerating upwards relative to the local inertial frame (the frame of a freely falling object near the surface). To obtain the acceleration due to motion with respect to the Earth, this "gravity offset" must be subtracted and corrections for effects caused by the Earth's rotation relative to the inertial frame.

The reason for the appearance of a gravitational offset is Einstein's equivalence principle, which states that the effects of gravity on an object are indistinguishable from acceleration. When held fixed in a gravitational field by, for example, applying a ground reaction force or an equivalent upward thrust, the reference frame for an accelerometer (its own casing) accelerates upwards with respect to a free-falling reference frame. The effects of this acceleration are indistinguishable from any other acceleration experienced by the instrument, so that an accelerometer cannot detect the difference between sitting in a rocket on the launch pad, and being in the same rocket in deep space while it uses its engines to accelerate at 1 g. For similar reasons, an accelerometer will read *zero* during any type of free fall. This includes use in a coasting spaceship in deep space far from any mass, a spaceship orbiting the Earth, an airplane in a parabolic "zero-g" arc, or any free-fall in vacuum. Another example is free-fall at a sufficiently high altitude that atmospheric effects can be neglected.

However this does not include a (non-free) fall in which air resistance produces drag forces that reduce the acceleration, until constant terminal velocity is reached. At terminal velocity the accelerometer will indicate 1 g acceleration upwards. For the same reason a skydiver, upon reaching terminal velocity, does not feel as though he or she were in "free-fall", but rather experiences a feeling similar to being supported (at 1 g) on a "bed" of uprising air.

Acceleration is quantified in the SI unit metres per second per second (m/s^2), in the cgs unit gal (Gal), or popularly in terms of g-force (*g*).

For the practical purpose of finding the acceleration of objects with respect to the Earth, such as for use in an inertial navigation system, a knowledge of local gravity is required. This can be obtained either by calibrating the device at rest,[3] or from a known model of gravity at the approximate current position.

2. Structure

Conceptually, an accelerometer behaves as a damped mass on a spring. When the accelerometer experiences an acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration.

In commercial devices, piezoelectric, piezoresistive and capacitive components are commonly used to convert the mechanical motion into an electrical signal. Piezoelectric accelerometers rely on piezoceramics (e.g. lead zirconate titanate) or single crystals (e.g. quartz, tourmaline). They are unmatched in terms of their upper frequency range, low packaged weight and high temperature range. Piezoresistive accelerometers are preferred in high shock applications. Capacitive accelerometers typically use a silicon micro-machined sensing element. Their performance is superior in the low frequency range and they can be operated inservo mode to achieve high stability and linearity.

Modern accelerometers are often small *micro electro-mechanical systems* (MEMS), and are indeed the simplest MEMS devices possible, consisting of little more than a cantilever beam with a proof mass (also known as seismic mass). Damping results from the residual gas sealed in the device. As long as the Q-factor is not too low, damping does not result in a lower sensitivity.

Under the influence of external accelerations the proof mass deflects from its neutral position. This deflection is measured in an analog or digital manner. Most commonly, the capacitance between a set of fixed beams and a set of beams attached to the proof mass is measured. This method is simple, reliable, and inexpensive. Integrating piezoresistors in the springs to detect spring deformation, and thus deflection, is a good alternative, although a few more process steps are needed during the fabrication sequence. For very high sensitivities quantum tunneling is also used; this requires a dedicated process making it very expensive. Optical measurement has been demonstrated on laboratory scale.

Another, far less common, type of MEMS-based accelerometer contains a small heater at the bottom of a very small dome, which heats the air inside the dome to cause it to rise. A thermocouple on the dome determines where the heated air reaches the dome and the deflection off the center is a measure of the acceleration applied to the sensor.

Most micromechanical accelerometers operate *in-plane*, that is, they are designed to be sensitive only to a direction in the plane of the die. By integrating two devices perpendicularly on a single die a two-axis accelerometer can be made. By adding an additional *out-of-plane* device three axes can be measured. Such a combination always has a much lower misalignment error than three discrete models combined after packaging.

Micromechanical accelerometers are available in a wide variety of measuring ranges, reaching up to thousands of *g*'s. The designer must make a compromise between sensitivity and the maximum acceleration that can be measured.

3. Applications

4.1 Engineering

Accelerometers can be used to measure vehicle acceleration. They allow for performance evaluation of both the engine/drive train and the braking systems.

Accelerometers can be used to measure vibration on cars, machines, buildings, process control systems and safety installations. They can also be used to measure seismic activity, inclination, machine vibration, dynamic distance and speed with or without the influence of gravity. Applications for accelerometers that measure gravity, wherein an accelerometer is specifically configured for use in gravimetry, are calledgravimeters.

Notebook computers equipped with accelerometers can contribute to the *Quake-Catcher Network* (QCN), a BOINC project aimed at scientific research of earthquakes.

4.2 Biology

Accelerometers are also increasingly used in the biological sciences. High frequency recordings of bi-axial or tri-axial acceleration (>10 Hz) allows the discrimination of behavioral patterns while animals are out of sight. Furthermore, recordings of acceleration allow researchers to quantify the rate at which an animal is expending energy in the wild, by either determination of limb-stroke frequency or measures such as overall dynamic body acceleration. Such approaches have mostly been adopted by marine scientists due to an inability to study animals in the wild using visual observations, however an increasing number of terrestrial biologists are adopting similar approaches. This device can be connected to an amplifier to amplify the signal.

4.3 Industry

Accelerometers are also used for machinery health monitoring of rotating equipment such as pumps, fans, rollers, compressors, and cooling towers. Vibration monitoring programs are proven to save money, reduce downtime, and improve safety in plants worldwide by detecting conditions such as shaft misalignment, rotor imbalance, gear failure or bearing fault which can lead to costly repairs. Accelerometer vibration data allows the user to monitor machines and detect these faults before the rotating equipment fails. Vibration monitoring programs are utilized in industries such as automotive manufacturing, machine tool applications, pharmaceutical production, power generation and power plants, pulp and paper, food and beverage production, water and wastewater, hydropower, petrochemical and steel manufacturing.

3.4 Architecture

Accelerometers are used to measure the motion and vibration of a structure that is exposed to dynamic loads. Dynamic loads originate from a variety of sources including:

- Human activities – walking, running, dancing or skipping
- Working machines – inside a building or in the surrounding area
- Construction work – driving piles, demolition, drilling and excavating
- Moving loads on bridges
- Vehicle collisions
- Impact loads – falling debris
- Concussion loads – internal and external explosions
- Collapse of structural elements
- Wind loads and wind gusts
- Air blast pressure
- Loss of support because of ground failure
- Earthquakes and aftershocks

Measuring and recording how a structure responds to these inputs is critical for assessing the safety and viability of a structure. This type of monitoring is called Dynamic Monitoring.

4.5 Medical applications

Zoll's AED Plus uses CPR-D•padz which contain an accelerometer to measure the depth of CPR chest compressions.

Within the last several years, Nike, Polar and other companies have produced and marketed sports watches for runners that include footpods, containing accelerometers to help determine the speed and distance for the runner wearing the unit.

In Belgium, accelerometer-based step counters are promoted by the government to encourage people to walk a few thousand steps each day.

Herman Digital Trainer uses accelerometers to measure strike force in physical training.[23][24]

4.6 Navigation

An **Inertial Navigation System** (INS) is a navigation aid that uses a computer and motion sensors (accelerometers) to continuously calculate via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references. Other terms used to refer to inertial navigation systems or closely related devices include **inertial guidance system**, **inertial reference platform**, and many other variations.

An accelerometer alone is unsuitable to determine changes in altitude over distances where the vertical decrease of gravity is significant, such as for aircraft and rockets. In the presence of a gravitational gradient, the calibration and data reduction process is numerically unstable.

4.7 Transport

Accelerometers are used to detect apogee in both professional and in amateur rocketry.

Accelerometers are also being used in Intelligent Compaction rollers. Accelerometers are used alongside gyroscopes in inertial guidance systems.

One of the most common uses for MEMS accelerometers is in airbag deployment systems for modern automobiles. In this case the accelerometers are used to detect the rapid negative acceleration of the vehicle to determine when a collision has occurred and the severity of the collision. Another common automotive use is in electronic stability control systems, which use a lateral accelerometer to measure cornering forces. The widespread use of accelerometers in the automotive industry has pushed their cost down dramatically. Another automotive application is the monitoring of noise, vibration and harshness (NVH), conditions that cause discomfort for drivers and passengers and may also be indicators of mechanical faults.

Tilting trains use accelerometers and gyroscopes to calculate the required tilt.

4.8 Vulcanology

Modern electronic accelerometers are used in remote sensing devices intended for the monitoring of active volcanoes to detect the motion of magma

4.9 Consumer electronics

Accelerometers are increasingly being incorporated into personal electronic devices.

4.9.1 Motion input

Some smartphones, digital audio players and personal digital assistants contain accelerometers for user interface control; often the accelerometer is used to present landscape or portrait views of the device's screen, based on the way the device is being held.

Automatic Collision Notification (ACN) systems also use accelerometers in a system to call for help in event of a vehicle crash. Prominent ACN systems include Onstar AACN service, Ford Link's 911 Assist,Toyota's Safety Connect, Lexus Link, or BMW Assist. Many accelerometer-equipped smartphones also have ACN software available for download. ACN systems are activated by detecting crash-strength G-forces.

Nintendo's Wii video game console uses a controller called a Wii Remote that contains a three-axis accelerometer and was designed primarily for motion input. Users also have the option of buying an additional motion-sensitive attachment, the Nunchuk, so that motion input could be recorded from both of the user's hands independently. Is also used on the Nintendo 3DS system.

The Sony PlayStation 3 uses the DualShock 3 remote which uses a three axis accelerometer that can be used to make steering more realistic in racing games, such as Motorstorm and Burnout Paradise.

The Nokia 5500 sport features a 3D accelerometer that can be accessed from software. It is used for step recognition (counting) in a sport application, and for tap gesture recognition in the user interface. Tap gestures can be used for controlling the music player and the sport application, for example to change to next song by tapping through clothing when the device is in a pocket. Other uses for accelerometer in Nokia phones include Pedometer functionality in Nokia Sports Tracker. Some other devices provide the tilt sensing feature with a cheaper component, which is not a true accelerometer.

Sleep phase alarm clocks use accelerometric sensors to detect movement of a sleeper, so that it can wake the person when he/she is not in REM phase, therefore awakes more easily.

4.9.2 Orientation sensing

A number of 21st century devices use accelerometers to align the screen depending on the direction the device is held, for example switching between portrait and landscape modes. Such devices include many tablet and some smartphones and digital cameras.

For example, Apple uses an LIS302DL accelerometer in the iPhone, iPod Touch and the 4th and 5th generation iPod Nano allowing the device to know when it is tilted on its side. Third-party developers have expanded its use with fanciful applications such as electronic bobbleheads. The BlackBerry Storm phone was also an early user of this orientation sensing feature.

The Nokia N95 and Nokia N82 have accelerometers embedded inside them. It was primarily used as a tilt sensor for tagging the orientation to photos taken with the built-in camera, later thanks to a firmware update it became available to other applications.

As of January 2009, almost all new mobile phones and digital cameras contain at least a tilt sensor and sometimes an accelerometer for the purpose of auto image rotation, motion-sensitive mini-games, and to correct shake when taking photographs.

4.9.3 Image stabilization

Camcorders use accelerometers for image stabilization. Still cameras use accelerometers for anti-blur capturing. The camera holds off snapping the CCD "shutter" when the camera is moving. When the camera is still (if only for a millisecond, as could be the case for vibration), the CCD is "snapped". An example application which has used such technology is the Glogger VS2,[34] a phone application which runs on Symbian OS based phone with accelerometer such as Nokia N96. Some digital cameras, contain accelerometers to determine the orientation of the photo being taken and also for rotating the current picture when viewing.

4.10 Device integrity

Many laptops feature an accelerometer which is used to detect drops. If a drop is detected, the heads of the hard disk are parked to avoid data loss and possible head or disk damage by the ensuing shock.

4.11 Gravimetry

A **gravimeter** or gravitometer, is an instrument used in gravimetry for measuring the local gravitational field. A gravimeter is a type of accelerometer, except that accelerometers are susceptible to all vibrations including noise, that cause oscillatory accelerations. This is counteracted in the gravimeter by integral vibration isolation and signal processing. Though the essential principle of design is the same as in accelerometers, gravimeters are typically designed to be much more sensitive than accelerometers in order to measure very tiny changes within the Earth's gravity, of 1 *g*. In contrast, other accelerometers are often designed to measure 1000 *g* or more, and many perform multi-axial measurements. The constraints on temporal resolution are usually less for gravimeters, so that resolution can be increased by processing the output with a longer "time constant".

4. Types of accelerometer

- Piezoelectric accelerometer
- Shear mode accelerometer
- Surface micromachined capacitive (MEMS)
- Thermal (submicrometre CMOS process)
- Bulk micromachined capacitive
- Bulk micromachined piezoelectric resistive
- Capacitive spring mass base
- Electromechanical servo (Servo Force Balance)
- Null-balance
- Strain gauge
- Resonance
- Magnetic induction
- Optical
- Surface acoustic wave (SAW)
- Laser accelerometer
- DC response
- High temperature
- Low frequency
- High gravity
- Triaxial
- Modally tuned impact hammers
- Seat pad accelerometers
- Pendulous integrating gyroscopic accelerometer

5. Conclusion

In conclusion, I'd like to say that the extent to which we have covered the topic in this seminar is just the tip of the iceberg. Accelerometer study is a massive field, & because of its relative novelty, the rate of growth of the same is bound to be extremely fast over the next few years. It is clearly going to be the technology of the future, & I hope that by means of this presentation, I have armed you with an understanding that will be both informative and interesting for you.

I would also like to thank you for making the time & effort to listen to my work, & would extend my sincere apologies too, in case I have offended anyone sitting here in any way.

Thank You.

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