Research Paper Engineering

Accelerometer in mobile

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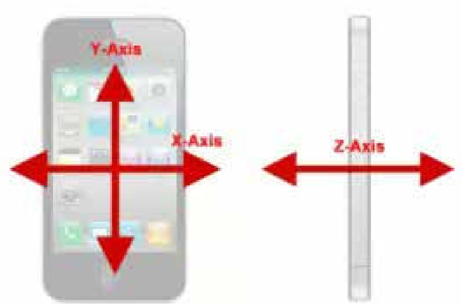
ABSTRACT

A mobile device which has an accelerometer is used to detect acceleration on two or three axes, allowing it to sense motion and orientation. A three-dimensional accelerometer can calculate pitch and roll and can be used in flight or driving simulation applications. It is an electronic component that measures tilt and motion. A device with an accelerometer is used to detect the angle the device is held. It can also measure movements such as rotation and motion gestures such as swinging, shaking, and flicking. One common use in phones it to detect whether the phone is upright or side ways, and automatically rotate the graphics on the screen accordingly. Another common use is controlling games and other applications (such as music player) by moving or shaking the phone.

Keywords: MOTION, ORIENTATION, ACCELERATION, TILT, ANGLE OF THE DEVICE, ROTATION.

Introduction

The implementation of onboard accelerometers on mobile phones different for each manufacturer, but the bottom line is to improve the user experience. For example, some mobile games have been adapted to make use of the gyro sensors that can detect motion on multiple axes. So you can "drive" a car in-game by tilting the phone left or right. Nokia also has tap-for-time and turn-to-mute features built into some of its handsets. The latter lets you silence an incoming call by turning the handset to face down. That requires an accelerometer as well. But the most common use of an accelerometer in a phone is perhaps for the auto rotation of screen displays. So when you turn the phone sideways to landscape mode, the accelerometer automatically adjusts the screen to the correct orientation. In my opinion, the iPhone could be the most ideal handset out there that lets you experience what an accelerometer can do on a phone. There are tons of games and apps on the Application Store, most of which are free, which you can download and try out for yourself. The accelerometer lets the smart phone measure the acceleration of an object. In smart phones, it's used to determine your phone's orientation and depending on the operating system (OS), lets you view items on the screen in either portrait or landscape mode. It's also used in games as an additional control scheme, depending on whether the developer has added the functionality. Games like Real Racing 2 let you steer your vehicle by tilting the smart phone. Other uses of the accelerometer include augmented reality apps and alarm clock apps that wake you up when it senses the sleeper's body moving.



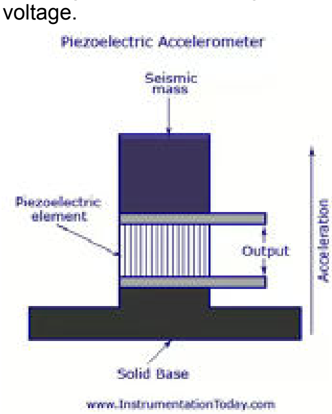
Working Principle

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer.

An accelerometer is a device which is used to detect acceleration through a micro-electromechanical system (MEMS). Due to this effect, there is change in electrical properties and these changes are translated into signals, which are sent to the appropriate software for processing.

There are various types of accelerometers used in phone:

Piezoelectric Accelerometer: It is devices which rely on the piezoelectric crystals, which react to forces exerted on the phone by generating an electrical charge, which subsequently creates a voltage.



Micro-electromechanical System (MEMS): These are tiny mechanical structures that change when forces are applied to them, subsequently changing an electrical property.

Capacitive Accelerometer: This is a MEMS device in which a net force is applied to the mechanical system results in a change in the system's capacitance.

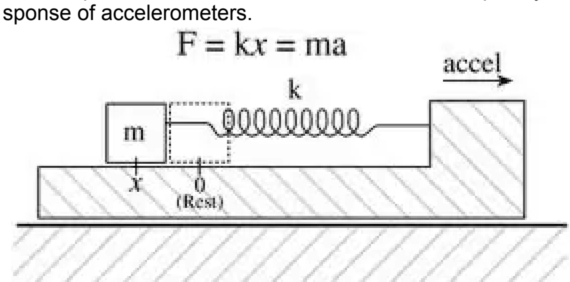
An accelerometer is a device that detects its own acceleration and is used in mobile phones to determine the phone's orientation. Once the orientation is determined, the phone's software can react accordingly, such as by changing its display from portrait to landscape.

A typical mobile device has an accelerometer that can detect acceleration on two or three axes, allowing it to sense motion and orientation. A three-dimensional accelerometer can calculate pitch and roll and can be used in flight or driving simulation application.

There are many different ways to make an accelerometer! Some accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which cause a voltage to be generated. Another way to do it is by sensing changes in capacitance. If you have two microstructures next to each other, they have a certain capacitance between them. If an accelerative force moves one of the structures, then the capacitance will change. Add some circuitry to convert from capacitance to voltage, and you will get an accelerometer. There are even more methods, including use of the piezoresistive effect, hot air bubbles, and light.

Principle of Operation

Most accelerometers are Micro-Electro-Mechanical Sensors (MEMS). The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion (**F = ma**), as an acceleration is applied to the device, a force develops which displaces the mass. The support beams act as a spring, and the fluid (usually air) trapped inside the IC acts as a damper, resulting in a second order lumped physical system. This is the source of the limited operational bandwidth and non-uniform frequency response of accelerometers.



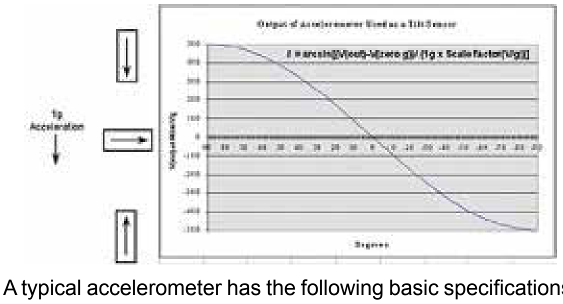
Effect of Tilt in Accelerometer:

[1] DC response sensors measure tilt. Mounting errors are therefore significant
[2] 1 degree tilt in the 0g position creates an output error equivalent to a10 degree tilt in the +1g or -1g positions
[3] 0g is the most sensitive to mounting errors

The sensitivity of device to tilt in 0g orientation is because

at 0g orientation, there is change in 1 tilt which causes 57x bigger change in sensor output versus 1g or +1g orientation 1°.

Effect of Tilt on DC Accelerometer:



A typical accelerometer has the following basic specifications:

Analog vs. digital: The most important specification of an accelerometer for a given application is its type of output. Analog accelerometers output a constant variable voltage depending on the amount of acceleration applied. Digital accelerometers output a variable frequency square wave, a method known as pulse-width modulation. A pulse width modulated accelerometer takes readings at a fixed rate, typically 1000 Hz (though this may be user-configurable based on the IC selected). The value of the acceleration is proportional to the pulse width (or duty cycle) of the PWM signal. For use with ADCs commonly used for music interaction systems, analog accelerometers are usually preferred.

Number of axes: Accelerometers are available that measure in one, two, or three dimensions. The most familiar type of accelerometer measures across two axes. However, three-axis accelerometers are increasingly common and inexpensive.

Output range: To measure the acceleration of gravity for use as a tilt sensor, an output range of ±1.5 g is sufficient. For use as an impact sensor, one of the most common musical applications, ±5 g or more is desired.

Sensitivity: An indicator of the amount of change in output signal for a given change in acceleration. A sensitive accelerometer will be more precise and probably more accurate.

Bandwidth: The bandwidth of a sensor is usually measured in Hertz and indicates the limit of the near-unity frequency response of the sensor, or how often a reliable reading can be taken. Humans cannot create body motion much beyond the range of 10-12 Hz. For this reason, a bandwidth of 40-60 Hz is adequate for tilt or human motion sensing. For vibration measurement or accurate reading of impact forces, bandwidth should be in the range of hundreds of Hertz. It should also be noted that for some older microcontrollers, the bandwidth of an accelerometer may extend beyond the Nyquist frequency of the A/D converters on the MCU, so for higher bandwidth sensing, the digital signal may be aliased. This can be remedied with simple passive low-pass filtering prior to sampling, or by simply choosing a better microcontroller.

Amplitude stability: This is not a specification in itself, but a description of several. Amplitude stability describes a sensor's change in sensitivity depending on its application, for instance over varying temperature or time.

Output: An accelerometer output value is a scalar corresponding to the magnitude of the acceleration vector. The most common acceleration, and one that we are constantly exposed to, is the acceleration that is a result of the earth's gravitational pull. This is a common reference value from which all other accelerations are measured (known as g, which is ~9.8m/s^2).

Temperature range: The maximum ambient temperature the accelerometer will encounter must not exceed the sensor's operating temperature range (212°F, 100°C). Inside a closed vehicle, solar heat-soak temperatures can exceed 1408F (60°C). Inside the engine compartment, a hot exhaust manifold or catalytic converter can drive temperatures over 100°C.For hot spots, charge-mode accelerometers can operate at temperatures up to 254 °C if you place your signal-processing electronics in a cooler area. Packaging methods and a piezoelectric element's Curie-point temperature define temperature limits.

Packaging: Depending on its location, an accelerometer may get splashed with (or immersed in) hot or cold hostile fluids ranging from fresh-water or saltwater, oil, and hydraulic fluids to engine coolants and battery acids or bases. Many accelerometers feature waterproof hermetic seals and titanium, stainless steel, or plastic packaging. So, choose appropriately for the test's chemical environment. Chemical exposure can also damage cables and connectors. Avoid using delicate laboratory-rated accelerometers in a field-measurement environment.

Resolution: A minimum-resolution specification of 0.02 g, which corresponds to a voltage of 200 mV, establishes a lower sensitivity limit analogous to a "noise floor."

Difference between a gyro and an accelerometer

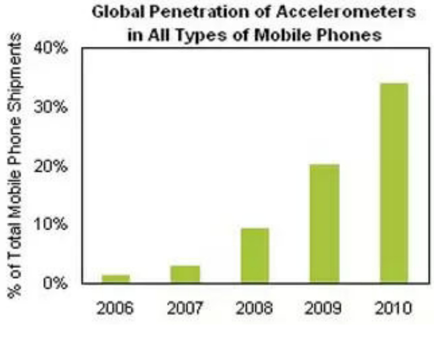
An accelerometer measures acceleration. A 3-axis accelerometer will tell you the orientation of a stationary platform relative to earth's surface, once that platform starts moving; however, things get more complicated. If the platform is in free-fall, it will show zero acceleration. If it is accelerating in a particular direction, that acceleration will simply be added to whatever acceleration is being provided by gravity, and you will not be able to distinguish. A 3-axis accelerometer in an aircraft in a properly coordinated turn with a 60 degree angle of bank, for instance, will show 2 G "vertical" acceleration in the aircraft, despite the fact that the aircraft is tilted 60 degrees relative to the horizon. So, accelerometers alone can't be used to keep in an aircraft in a particular orientation.

A gyro measures rate of rotation around a particular axis. If a gyro is used to measure the rate of rotation around the aircraft roll axis, it will measure a non-zero value as long as the aircraft is rolling, but measure zero if the roll stops. So, a roll gyro in an aircraft in a coordinated turn with a 60 degree bank will be measure a rate of zero, same as an aircraft flying straight and level. You can approximate the current roll angle by integrating the roll rate over time, but you can't do so without some error creeping in. Just to make life more interesting, gyros drift with time, so additional error will accumulate over a period of minutes or even seconds, and eventually, you'll have a totally inaccurate idea of your current roll angle relative to the horizon. So, gyros alone can't be used to keep in an aircraft in a particular orientation.

Accelerometers are right in the long term but wrong (noisy) in the short term. Gyros are right in the short term but wrong (drifting) in the long term.

Uses

The acceleration measurement has a variety of uses. The sensor can be implemented in a system that detects velocity, position, shock, vibration, or the acceleration of gravity to determine orientation. A system consisting of two orthogonal sensors is capable of sensing pitch and roll. This is useful in capturing head movements. A third orthogonal sensor can be added to the network to obtain orientation in three dimensional spaces. This is appropriate for the detection of pen angles, etc. The sensing capabilities of this network can be furthered to six degrees of spatial measurement freedom by the addition of three orthogonal gyroscopes. As a shock detector, an accelerometer is looking for changes in acceleration. This jerk is sensed as an over damped vibration.



Accelerometers use a quartz crystal mounted between a fixed point and a free floating mass. The mass puts pressure on the crystal and generates a tiny voltage (some work on resistance or capacitance change). As the direction of gravity's pull changes, so does the force of the crystal and the signal it generates. Most accelerometers are designed to sense movement in only one direction, so true 3D position sensing must use three crystals mounted in different orientations each with their own floating mass.

In the past this technology was very expensive and reserved for the scientific markets, but recently they have dropped in cost a lot and have excellent filtering. Traditionally you would need a large mass to sense the gross movements of a cell phone, but smaller units can be used with heavily signal filtering as long as low accuracy results are tolerable.

The iPhone's accelerometer measures the linear acceleration of the device so that it can report its roll and pitch, but not its yaw. If you are dealing with an iPhone 3GS, which has a digital compass, you can combine the accelerometer and magnetometer readings to have roll, pitch, and yaw measurements.

Application areas

By measuring the amount of static acceleration due to gravity, you can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, you can analyze the way the device is moving. At first, measuring tilt and acceleration doesn't seem all that exciting. However, engineers have come up with many ways to make really useful products with them.

Summary:

Acceleration is a measure of how fast the speed of something is changing

- It is used as an input to control systems
- Sensor voltage output should be determined as a percentage of voltage input for consistency
- The device is sensitive to tilt in the 0g position
- – 1otilt in 0g = 10oof tilt in the +1g and -1g positions

Typical Accelerometer Applications

- Tilt / Roll
- Vibration / "Rough-road" detection
- – Can be used to isolate vibration of mechanical system from outside sources
- Vehicle skid detection
- – Often used with systems that deploys "smart" braking to regain control of vehicle
- Impact detection
- – To determine the severity of impact, or to log when an impact has occurred
- Input / feedback for active suspension control systems
- Keeps vehicle level

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