

## **A Review on the Use of Accelerometers for Motion Detection in Sleep Monitoring**

### **Introduction**

The increasing trend in system miniaturization has allowed for the introduction of IC sized motion detecting devices to be included in packages small enough to be wearable. Accelerometers have become ubiquitous in mobile devices due to their low power consumption, accurate readings and the simplicity and flexibility of the data that allows for precise calculations. Sleep monitoring technology has a strong interest in movement detection, given that a variety of sleep disorders are associated with involuntary movements during sleep. This paper reviews the technology behind accelerometers and their use as motion detectors in sleep monitoring devices.

### **Commercial Use of Accelerometers in Sleep Monitors**

Sleep monitoring can happen in either a medically controlled environment such as a sleep clinic where brain waves are measured with EEGs, or at home using less intrusive devices that rely on motion, sound and light detection. An actigraph is a non-invasive device that measures and records data related to sleep activity and is usually worn on the wrist. The top seven commercially available actigraphs contain at least one triple axis accelerometer used for motion detection [1]. The price of these devices vary from USD 100 to USD 300 depending on their software features and their popularity, but at their core they record movement data obtained from the accelerometer and do signal processing to extract sleep quality markers.

Accelerometers have become standard not only in sleep monitors but also in any device that benefits from motion detection such as smartphones. Smartphone manufacturers and operating system developers have made it possible to interact and interface with the accelerometer during mobile application development, and there has been a raise in smartphone based sleep monitoring apps that take advantage of the accelerometer already included in the phone [2]. The applications rely on software and signal processing, and are still considered significantly less thorough and complete solutions to sleep quality monitoring.

Accelerometers benefit from advanced microelectronics and MEMS manufacturing processes, and their prices have gone down significantly. They are manufactured by the semiconductor manufacturers, and their prices range from USD \$0.5 for basic two axis accelerometers to USD \$2 for advanced triple axis analog accelerometers [3]. These prices are meant for device manufacturers, and are priced for bulk purchasing of at least 1000 units.

## **Accelerometer Technology and their Motion Detecting Properties**

Accelerometers detect a change in motion by the use of piezoelectric material. The accelerometer consist of a mass, springs and a piezoelectric material. The piezoelectric crystal will then get pressured by the mass when a vibration or movement happens, and exert an electrical charge based proportional to the force applied to it [4]. Both digital and analog outputs accelerometers are available, with analog devices providing a voltage that correlates to a specific amount of acceleration detected and digital devices providing their outputs to a microcontroller or microprocessor. Moreover, triple and double axis accelerometers are in the market, with the number of axis determining the number of dimensions that the accelerometer is able to detect motion in. Specifications such as size, frequency range, acceleration amplitude range and different mounting options and interfaces vary individually with each accelerometer.

## **Hardware and Software Implementation of Accelerometers for Sleep Monitoring**

In the context of sleep monitoring, both hardware and software implementations of accelerometers play a critical role in successful data collection and interpretation. An accelerometer used for sleep monitoring purposes will output data for a constant period of time, making power consumption an important variable to reduce when doing hardware implementation. A software solution to this has been presented, which consist of data extrapolation and a limited duty cycle to the accelerometer [5]. This will limit the amount of time the accelerometer is on, saving a fraction of power each cycle that is directly related to the duty cycle. The solution proved to be 20% more power efficient than filter based approaches, maintain a maximum error rate of 1%, while increasing memory requirements to acceptable levels for low end devices

Since accelerometers will only provide acceleration data over a period of time, algorithms must be implemented to generate data such as velocity and position vectors, as well as calibration algorithms to generate accuracy and reliability. These algorithms focus on filtering mechanical and electrical noise, while implementing numerical integration to generate position and velocity data [6]. Most of these algorithms are provided by the same semiconductor manufacturers and have been tested to produce high fidelity data with 95%+ accuracy.

Sleep monitoring especially benefits from position and velocity data, as time spent sleeping in different poses and amount of physical activity are markers to score sleep quality. The relative position of the accelerometer with regard to a reference point yields the sleeping pose, while the amount of physical activity or movement is measured by peaks in acceleration. By coupling a tri-axial accelerometer with a pressure sensor, quantifiers such as heart rate, respiration, sleep stage and sleep time were able to get extracted to determine the sleep quality of patients [7].

## References:

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