MEMS: Re-Inventing Wireless Applications

It's not just for automotive applications anymore.

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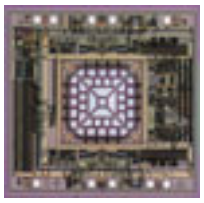
Micro Electrical Mechanical Systems (MEMS) technology has exploded onto the wireless scene; in fact, In-Stat/MDR estimates that MEMS consumer electronics sales will hit $1.5 Billion by 2005. Additionally, the company forecasts that revenues for MEMS devices within the wireless industry will grow from $102.7 million in 2001 to $852.2 million in 2006.



Why the boom? For years, wireless manufacturers have been intrigued with the miniature size of MEMS sensors and the range of new possible features they enable but, high unit costs have significantly stunted the penetration of MEMS sensors in wireless applications.

Manufacturers of wireless devices find themselves turning more frequently to a new generation of MEMS devices to add a wide array of functionality to products such as cell phones, PDAs, handheld GPS/Compass, handheld gaming, pedometers and to the products that combine all of the above (i.e. PDA/phone, Gaming/phone, GPS/Compass/phone, Pedometer/phone).

These new MEMS devices are tilt and motion sensors, commonly known as accelerometers, and are constructed with no moving parts. The principle of operation is based on differential thermal sensing of a heated gas inside a hermetic part. Constructing this sensor in a standard CMOS process has significantly lowered the cost and begun to open up wireless applications. Additionally, with no moving parts, this thermal-based sensor is capable of surviving the high shocks experienced by wireless devices, both in the field and during production, since it eliminates the traditional problems of stiction and particle issues associated with capacitive-based MEMS accelerometers.

Cell Phones and/or PDAs

The combination of Interactive Sensing Techniques &#151 which utilizes MEMS-based accelerometers and Scalable Vector Graphics (SVG) &#151 eliminates the need for conventional switches, button and thumb wheels for scrolling, and zooming and panning of web pages, e-books and spreadsheets.

Cell phones and PDAs feature small display screens and limited graphic capabilities, which Interactive Sensing Techniques address through the use of the accelerometer. Acting as a tilt/motion sensor, it detects basic human movement as the input for display orientation and simplifies how the end user views the downloaded pages. The user moves through the web pages or pans through maps by simply tilting the device in any direction required; if the user needs to zoom in or out, they only need to move the device closer or further away. This is achievable with accelerometers that have the capability to detect tilt (angular changes relative to constant acceleration of gravity) and to sense linear accelerations.

A single MEMS accelerometer can measure accelerations along two orthogonal axes. So, two dual axis accelerometers positioned orthogonal with each other can provide complete three axis motion information. Three axes are necessary if a cell phone/PDA is to provide scrolling, zooming, and panning features. Alternatively, one dual axis accelerometer could be used for scrolling and panning.

Scrolling and panning can be controlled with an accelerometer that is positioned so that its sensing axes are parallel to the cell phone/PDA display. In this configuration, the scrolling can be controlled by either forward motion or by the up/down tilt (or pitch angle) of the device. The panning can be controlled by either lateral motion or by the left/right tilt (or roll angle).

If using tilt to control scrolling or panning, one must note that the output of the accelerometer due to tilt input is not a linear function. The output follows a sine function. Consider that when the accelerometer sensing axis is horizontal, the input acceleration or gravity is at 90 degrees. So in this configuration tilt angle is:
Tilt angle = $\sin^{\&\#150\ 1}$ (Accelerometer output in units of g)

So the scrolling and panning sensitivity to tilt motion will depend on the initial orientation of the cell phone/PDA. For example, if someone is holding the cell

phone/PDA device near vertical, more tilt will be necessary to make it scroll or pan. If scrolling and panning based on tilt motion is desired, it may be necessary to account for the non-linear function.

Scrolling, panning and zooming based on forward/backward, lateral and inward/outward motion present a different challenge. A desirable signal from the MEMS motion sensor would be the X,Y coordinates of the position that could be directly scaled to represent display coordinates. But the MEMS device provides an acceleration measurement, not a position measurement. To convert acceleration into position, signal processing of double integration is necessary. But when performing double integration, very small errors in acceleration translate into very large errors in position, even over short integration time periods. One way to overcome this issue is to have a single button that enables scrolling panning and zooming only when depressed. With this single button, the integrators can be reset at the beginning of each operation.

The need for graphic features in portable devices is an ongoing challenge for hardware and software engineers; however, the evolution of two separate worlds coming together offers a viable solution to the problem.

MEMS for Wireless Pedometers

A MEMS application increasing in popularity is pedometers, which are used to measure the speed or distance traveled by an individual on foot. The mechanical translatory motion of an individual walking is in the vertical plane, and can be detected from the accelerometer output. The accelerometer output will be a periodic signal describing the vertical plane motion. The peak amplitude of the signal will depend on the orientation and the location of the accelerometer. In order to accumulate an accurate count of the periodic step event, a signal processing algorithm is necessary. A simple approach is a peak detection algorithm. Since the amplitude will vary with the location of the pedometer and there will be a gravity vector present, two signal processes can be applied prior to peak detection: high pass filter and some form of output gain control based on the signal rms level. In this fashion, the peak detection algorithm can be tweaked to provide the best results.

One commercially available version of a pedometer that uses a MEMS accelerometer goes beyond just measuring steps. The wireless pedometer is worn on the shoe, and it communicates to a wrist watch to display its measurements. This pedometer provides athletes with a complete training tool. The signal processing necessary to obtain distance and velocity also involves integration. The fast error building due to integration was corrected with a clever algorithm that resets the integrator at the end of every step, recognizing that the foot has hit the ground and it stands still. This type of pedometers benefit from the thermal accelerometer, because the new thermal technology can withstand the rigorous, continuous shock environment.

MEMS: Making GPS more precise

Personal and Vehicle navigation systems use GPS receivers to pinpoint position and provide route guidance. With any GPS system, the signal reception is not always 100% reliable; however, with the help of MEMS-based accelerometers, the loss of a signal can be supplemented with a dead reckoning approach that will keep track of distance traveled. To implement dead reckoning, not only is it necessary to know distance traveled, but also the direction traveled. An electronic compass is used to provide the direction.

Regardless of the position of the handheld receiver, an accurate heading from an electronic compass can be obtained using a thermal accelerometer. One embodiment of such a solution is the Honeywell HMC1055 chipset which is composed of three sensors packaged as integrated circuits for tilt compensated electronic compass applications. These three sensors are composed of a Honeywell HMC1052 two-axis magnetic field sensor, a Honeywell HMC1051Z one-axis magnetic sensor, and the MEMSIC MXS3334UL two-axis accelerometer. Traditionally, compassing is done with a two-axis magnetic sensor held level (perpendicular to the gravitational axis) to sense the horizontal vector components of the earth's magnetic field from the south pole to the north pole. By incorporating a third axis magnetic sensor and the two-axis accelerometer to measure pitch and roll (tilt), the compass is able to be electronically &quotgimbaled&quot and can point to the north pole regardless of level.

One of the issues that manufacturers of handheld GPS systems are concerned with is how the device holds up under adverse handling conditions. These systems need to be reliable and will experience high impact shock. In many cases, accelerometers today are unable to survive the shock levels experienced in these tough environments. As a response to the need in the industry, MEMSIC recently designed an ultra low noise accelerometer that offers a shock rating with 50,000g's survivability.

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