Motion Sensing with mCube iGyro™
Delivering New Experiences for Motion Gaming and Augmented Reality for Android™ Mobile Devices

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Every high-end smartphone and tablet today contains three sensing devices that enable true motion gaming and augmented reality experiences. Two of these devices, the accelerometer and magnetometer, can be produced at very low cost and also consume very little power. The third component, which is commonly known as the gyroscope or gyro, provides true rotation, but is significantly more expensive and consumes more power than both the accelerometer and magnetometer combined.

When built into consumer hand-held devices, accelerometers and magnetometers are typically three-axis components that produce three-dimensional vector measurements of the accelerations and magnetic fields being experienced by the device. Together, these field measurements are used to determine the orientation of an electronic device relative to a locally level coordinate system. In many devices, this combination of sensing and processing is known as an “orientation sensor.” A shortcoming of an orientation sensor is that the instantaneous output can be significantly distorted by magnetic fluctuations and small motions of the device that deflect the gravity vector. In a precision orientation estimation system, a gyro is needed to stabilize outputs from the orientation sensor, which significantly reduces these distortions and provides true motion sensing needed for gaming and other applications.

While the gyro’s functionality significantly enhances the user experience for gaming on mobile devices, the cost, power consumption and board space required has limited its applicability to only the most expensive mobile devices. mCube has solved that limitation by developing the first software-based gyro that can bring 9DoF motion gaming and augmented reality experiences for Android mobile devices. The new mCube MC7010 solution, featuring the iGyro™ virtual rotation sensor, is an enhancement to the MC6450 electronic compass (“eCompass”) hardware package that uses accelerometer and magnetometer measurements to estimate rotational rates about all three axes. This solution can be used to substitute for gyro measurements in a mobile system, or to monitor gyro measurements in a system where signal integrity has to be maintained using an independent source of rotational rate sensing.
Rotation Sensors

The advent of mobile devices as preferred gaming platforms, combined with an explosion of applications that present information on mobile displays as overlays to real-time camera imagery for augmented reality, has made spatial awareness a critical technology. Initially, device orientation came from basic arithmetic on the sensed gravity and magnetic field vectors, allowing roll, pitch and heading to be estimated by knowing where “down” and “north” are relative to the device itself. Because this process produced inherent jitter, developers often added basic filters to the incoming data stream, or to the orientation values themselves, in order to stabilize the jitter. However, these filters also led to delays, discontinuities and odd behavior in certain device orientations where conventional descriptions of orientation encountered numerical processing problems. To overcome these obstacles, more sophisticated developers began taking advantage of increasingly popular gyro sensors because they could very accurately measure the instantaneous rotation rate around all three axes. By combining a hardware gyro with a conventional orientation sensor, developers were able to produce an orientation estimate that was both very smooth and very responsive with minimal latency. While this was the desired result, the downside was that the gyro sensor had a higher initial bill-of-materials cost, for the part itself and for the physical support it must have from the platform, and consumed significantly more power than other MEMS sensors being used for motion processing. This limited its use to just high-end tablets and phones, leaving mainstream and entry-level phones and tablets without a sufficient motion sensing solution. Without an expensive gyroscope, mainstream mobile phone users were forced to drag their finger on the phone’s touch screen to move in the desired location rather than simply turning or rotating the phone like a gyro would enable them to do. Clearly, a different solution was needed to deliver acceptable levels of motion sensing functionality with extended battery life to support applications designed to consume gyro measurements.

**Figure 1:** Mobile gamers, with particular focus on first-person shooters and driving simulators, will rotate a device around all 3 axes, and nearly all rotation information from a hardware gyro requires less than a 4Hz bandwidth for proper motion capture. Augmented reality applications require even less bandwidth since the user is typically doing more steady focus and less rapid targeting.

**Figure 2:** Binning all three axes of gyro motion during a gaming scenario shows that outputs in excess of 300 degrees per second are very infrequent, so a sensor optimized for gaming could ignore larger outputs.
Motion Sensing

The motion sensor system is complex, but through extensive MEMS expertise and careful processing, developers can extract rotation information by monitoring changes in the gravitational and magnetic fields sensed in the coordinate frame of the mobile device. Intelligent filters and signal processing can be built to properly exclude errors due to magnetic fluctuations and disturbances, translational motion that distorts the gravitational measurement, sensor noise, and biases. The resulting measurements can then be used to synthesize an output that very closely approximates what would be output by a hardware gyro. This processing, generally referred to as a “virtual gyro,” focuses on the behaviors of a gyro that are most important to a mobile device user. This estimate can then be used interchangeably with the hardware gyro output, either to augment or replace the gyro, using the same interface to programs and applications.

By focusing on the most common uses, the virtual gyro’s rotation rate processing can discard higher bandwidth sensor behavior and realize lower noise and an optimized responsiveness for the types of motion they are interested in for their gaming and augmented reality applications.

The Next Evolutionary Step in Motion Sensing

The reality is that a gyro sensor on a typical consumer handset is capable of far more motion sensing than a user needs. Bandwidths in the tens or hundreds of hertz realm are common, as are output rates in the thousands of degrees per second, due largely to the wide range of end-user installations that most MEMS manufacturers need to consider during product design. As a result, much of the capability of a gyro on a mobile device goes to waste. For a typical “gamer” playing a first-person shooter or a driving/pilot simulation game on a phone or tablet, most of the information from a gyro exists at less than a four-hertz bandwidth, and output measured rotation rates very seldom exceed 300 degrees per second on any axis.

The realization that the gyro is being under-utilized, or not needed at all, has paved the way for the next evolutionary step in motion sensing, which is to develop a virtual gyro that delivers the level of performance that mobile users are actually using. If high-end phones don’t need the power of a hardware gyro, the market will look to a software solution that meets the price, performance and power consumption while delivering the right level of motion sensing performance.

“As the number of applications taking advantage of motion continues to explode, there is an increasing demand for 9DoF motion sensors across all mobile device segments,” said Kai Chen, General Partner at SK Telecom (China) Ventures. “mCube’s iGyro bridges the gap by bringing motion games capability to all types of phones and tablets.”
The mCube iGyro

The mCube MC7010 iGyro is the industry’s complete “virtual” gyroscope, delivering immersive, 9DoF motion gaming and augmented reality experiences to mainstream phone and tablet users, while cutting the power, cost and board space in half compared to hardware-based solutions. This solution delivers an 80 percent reduction in power consumption, costs 50 percent less than equivalent discrete hardware 9DoF solutions and features pin compatibility to simplify customers’ board designs with flexible configurations.

The physical sensors in the mCube MC7010 provide high-rate three-axis measurements of specific force/acceleration and magnetic field that support computation of rotation rates to synthesize a virtual gyro. This turns a highly capable six degree-of-freedom electronic compass into a full nine degree-of-freedom motion package with significantly lower power consumption and cost than a sensor package incorporating a traditional hardware gyro. The mCube MC7010 iGyro supports gaming (FPS and other first-person perspective such as driving/flying), racing games with gyro smoothing, and augmented reality applications on mobile devices. It offloads optimal rotation/orientation processing from applications, enabling it to be used as a drop-in replacement at the Android Application Programming Interface (API) level for a hardware gyro, and provide estimates of three-axis rotation rate. Since the proprietary iGyro algorithms share time on the device application processor, the additional power required over a basic electronic compass sensor is minimal, offering significant benefits in power consumption, footprint and initial part costs compared to a traditional hardware gyro.

Further, the iGyro uses both the instantaneously detected device orientation and the rates of change on the outputs of the accelerometer and magnetometer to tailor its filter properties in real time. This enables it to adapt to fine targeting maneuvers and large panning maneuvers as needed to ensure a mix of smoothness and responsiveness that exceeds what is achievable by filtering the native raw orientation of the device.

<table>
<thead>
<tr>
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<th>mCube 9DoF MC7010 iGyro</th>
<th>Other Discrete 9DoF Sensor Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>0.26mA</td>
<td>3.6mA</td>
</tr>
<tr>
<td>Relative Cost</td>
<td>1x</td>
<td>2x</td>
</tr>
<tr>
<td>Sensor Foot Print</td>
<td>9mm²</td>
<td>22mm²</td>
</tr>
<tr>
<td>Pin Compatibility</td>
<td>3, 6 and 9 axis options possible with one board design (using mCube 3-axis accelerometer and 6-axis eCompass)</td>
<td>Needs new PCB board each for 3, 6 and 9 axis models</td>
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Key Characteristics

- No rotation rate bias, great bias stability.
- Adaptive gains support very stable, low-noise output during slow and precise movements, and more responsive tracking during faster or larger movements.
- Corrective trace-distortion capability to counteract interference from high acceleration events. No need to power up another piece of hardware – iGyro processing runs on the same application processor that is already running a user’s gaming or augmented reality app.
The proprietary mCube iGyro software algorithms yield a very good match to hardware gyro outputs for large motions, while providing a low-noise rotation detection capability for fine aiming and pointing, as showcased in the output comparisons below, respectively.

iGyro sensor fusion algorithm also provides a corrective trace-distortion capability to counteract interference from high acceleration events, providing a comfortable user experience especially for gaming applications.

Fast Movement Output Tracking in All Three Axes Between Hardware Gyro and iGyro

Subtle Slow Movement Output Tracking Between Hardware Gyro and iGyro

Figure 3: Rapid movement in all three axes shows that mCube’s iGyro tracks hardware gyro well for large motions in gaming.

Figure 4: The mCube iGyro very accurately tracks more subtle motion for fine aiming and targeting with very low noise, in both the tilt (up and down) and pan (back and forth) directions.

The iGyro engine runs on the application processor (or other available general purpose CPU) of a mobile device, and will convert three-axis magnetometer and accelerometer data into three-axis rotation rate data that is a direct drop-in replacement for a hardware gyro, employing the exact same API that developers would invoke to employ a hardware gyro. In Android, the iGyro will show up when a developer or user retrieves the sensor list for the device as a gyro sensor type, and the data structure and physical units are otherwise identical. The design is such that all processing and additional API calls are offloaded to the mCube iGyro engine, and that application developers can make full use of its capabilities without having to give any extra thought to what’s going on under the hood.
Gaming Examples

In order to demonstrate the capabilities of the iGyro, mCube provides customers with sample gaming applications free of charge, which focus on the two most common themes in mobile gaming that require accurate rotational information and spatial awareness: first-person shooters (for which supported applications are numerous) and flying/driving games.

In the game “Ice Ball”, a user must use his mobile device to aim and target penguins emerging from the sea, and launch ice balls and other objects to push them back into the sea before they reach the player’s location and eat all the fish.

In the game “Bee Garden”, a user controls the flight path of a bee as it seeks out flowers in a 3D world to gather nectar from the flowers while avoiding objects and hazards in flight. Both of these mCube games are available for the Android operating system and can be run on smartphones and tablets that are equipped with the mCube MC7010 iGyro.

Conclusion

While hardware gyros have become standard components in every high-end handset and tablet today, they deliver far more motion sensing performance than a user needs for their mobile device applications. The mCube MC7010 iGyro delivers 9DoF sensor functionality on all mobile devices, enabling users to play sophisticated motion games, with very low power consumption, low cost and a small footprint. Now, mobile phone and tablet users will be able to enjoy motion sensing functionalities that were previously only available in high-end products.

“The growing tablet market definitely needs a cost effective 9DoF solution,” said Joe Chen, GM of MediaTek Home Entertainment Business Unit. “According to an IDC report, with an available tablet market estimated to be 270.6 million units by 2014 and increasing to 386.3 million units by 2017, we believe that there is tremendous potential opportunity for mCube’s iGyro solution.”

ABOUT MCUBE
mCube makes the smallest motion sensors in the world. As a technology leader, mCube aspires to be the enabler for the Internet of Moving Things by putting a MEMS motion sensor on anything that moves, improving the way consumers live and interact with technology. mCube is backed by leading investors and has already shipped over 60M units. For more information, visit www.mcubemems.com. Follow mCube @mcubemems.

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