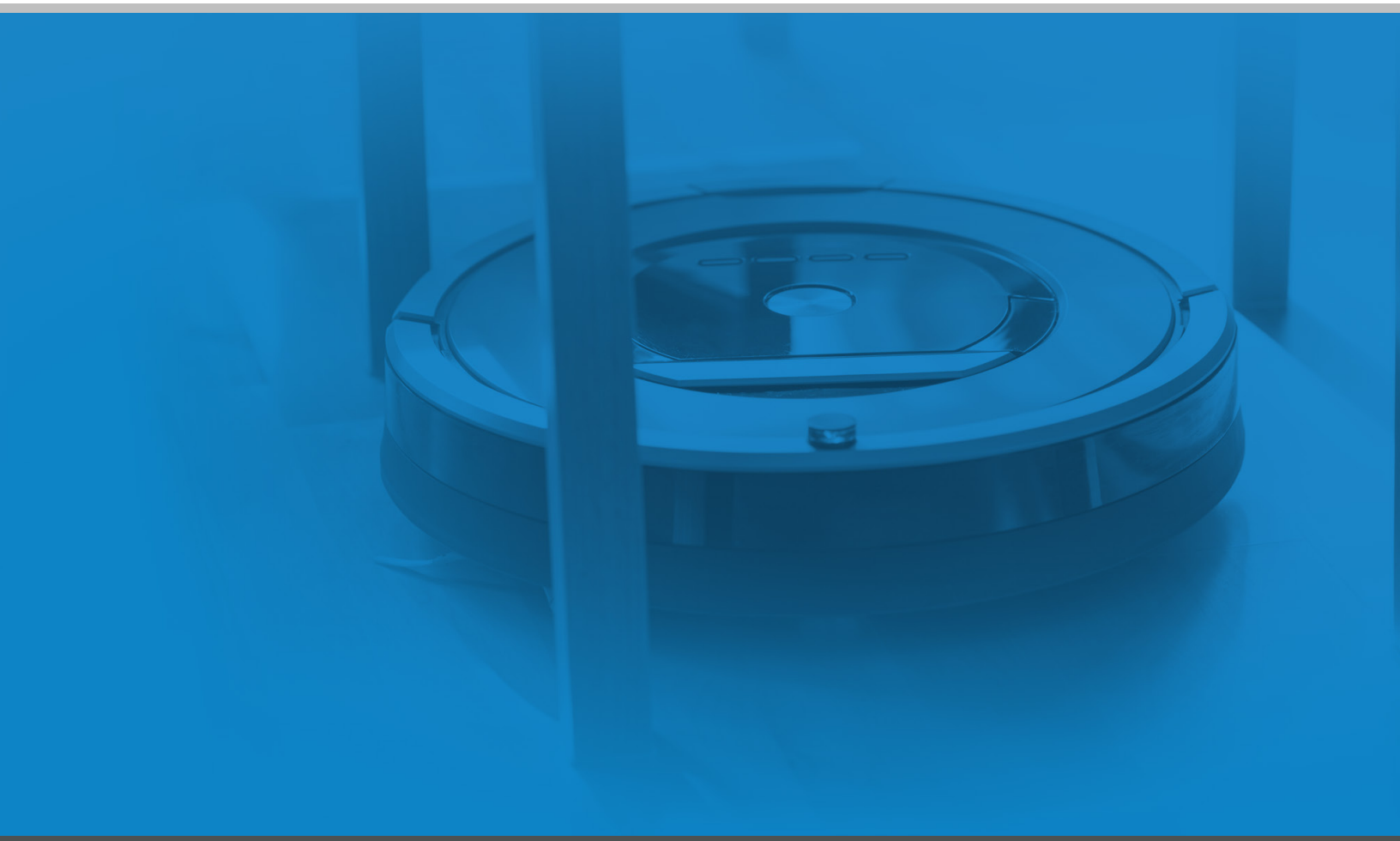
UNLOCKING THE ROBOTIC CLEANER OF TOMORROW

3 WAYS MULTI-AXIS MOTION SENSORS GIVE ROBOTIC CLEANERS A COMPETITIVE EDGE



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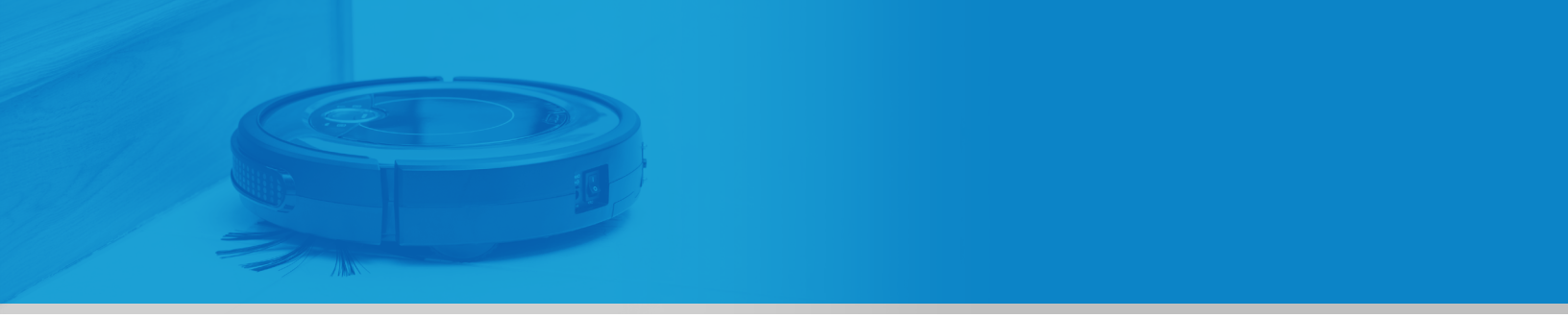
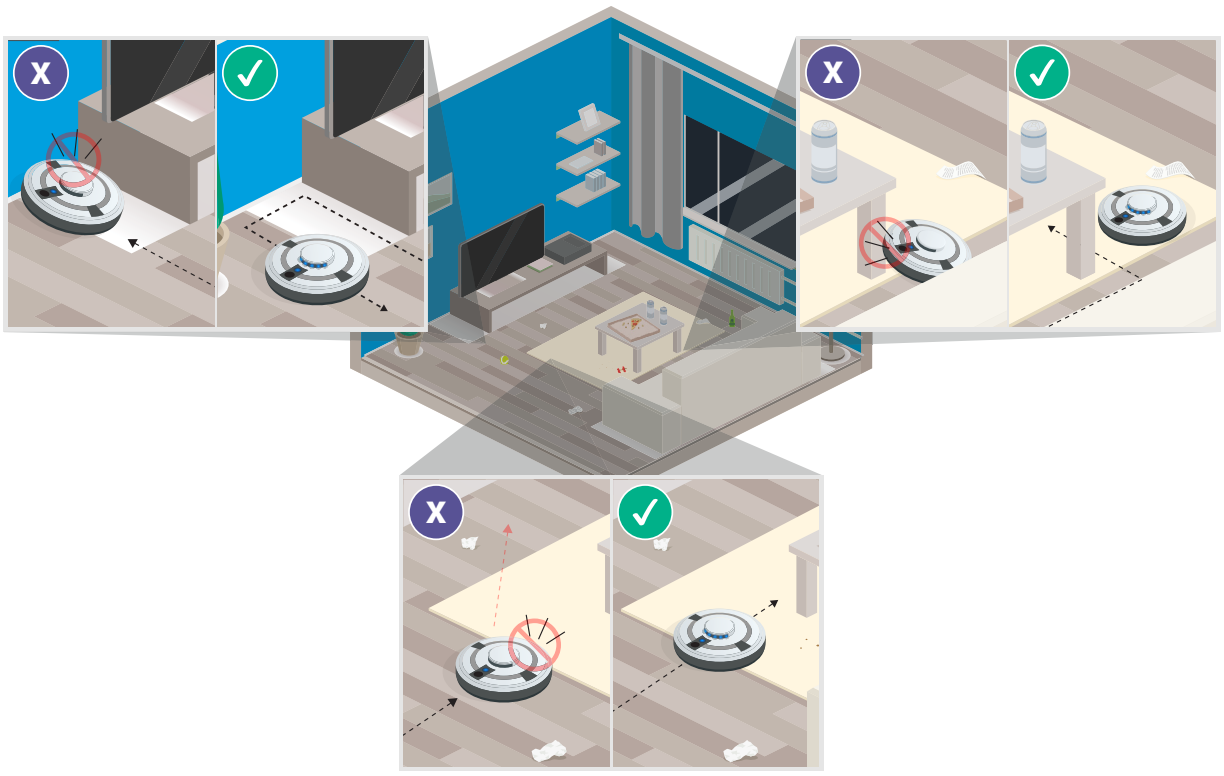


ROBOTIC VACUUM CLEANER CHALLENGES PERSIST

Adapting technology to customer needs is the essential marker of who thrives and who disappears in a fast-paced, ever-changing consumer landscape. The robotic vacuum industry has seen major innovation over the past decade: the use of sensors to detect obstacles, improved suction, and the emergence of multi-function devices that can both mop and vacuum. In fact, several products are already in their sixth generation.

But critical challenges still persist. Today's robotic vacuums still run the risk of getting stuck in corners, on obstacles like table legs, or when transitioning from one floor type to another. And they still take inefficient routes through a room and miss areas of the floor. This leads to lengthy cleaning times and high battery consumption.



TRENDS SHAPING THE MARKET

Consumers are ready for robotic vacuums that can perform autonomously. These five trends in robotic vacuum cleaner development are paving the way[1,2]. The right sensor products will help you capitalize on these trends so you can meet—and exceed—customer needs.

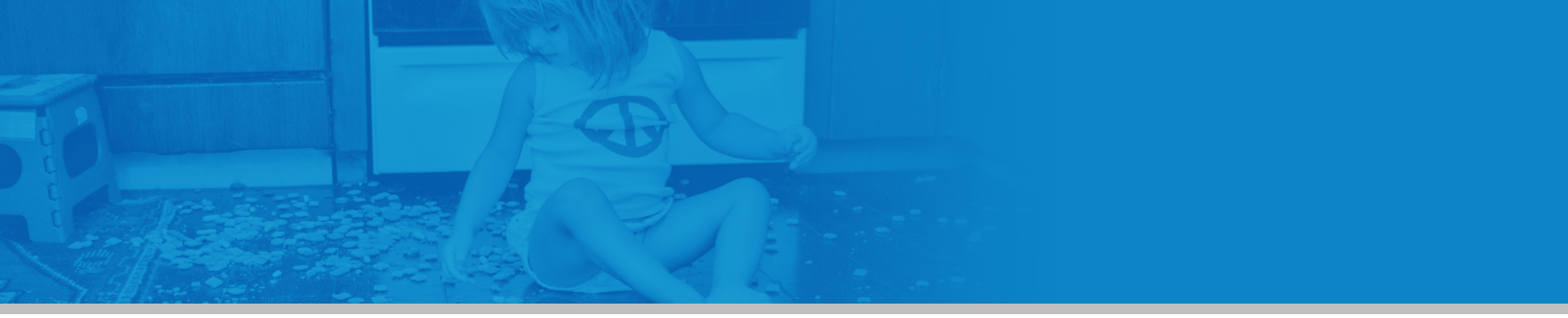
1. **Remembering efficient routes and room size monitoring:** Several of today's navigation challenges (missed areas, long cleaning cycles) can be addressed through efficient route planning. Mapping the floorplan of a house and "remembering" which room is where is a goal worth attaining.

2. **Location-specific commands:** Don't cry over spilled chips. Let the robot take care of it! As-needed spot cleaning can tackle high-traffic areas and on-demand accidents. Conversely, it can establish "no-go" zones where robots won't dare tread.

3. **Cleaning all floor types:** Why be limited to cleaning only carpets? The robot cleaner of the future (and even a few today) can clean whatever surface it finds—carpet, tile, wood—and switch dynamically as needed.

Common Approaches to Robotic Cleaner Navigation

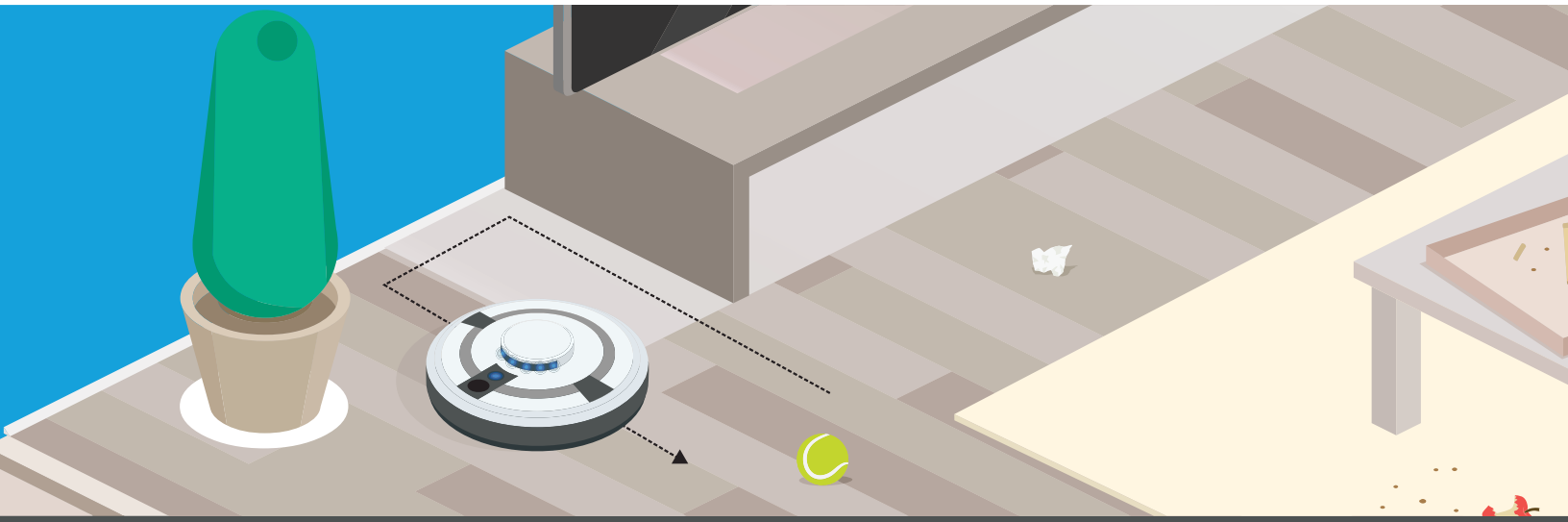
- **Random Walk:** No navigation sensors. The robotic device just wanders around the room until it eventually covers all of it. This is typical in the low-end models.
- **Intelligent Walk:** An Inertial Measurement Unit provides heading to drive the robot in straight lines and assist staying on track after getting around obstacles.
- **Visual SLAM:** Visual Simultaneous Localization and Mapping uses an IMU with a camera to map the room and intelligently plan the robot's navigation path.
- **LiDAR:** Light Detection and Ranging uses a laser sensor often paired with an IMU to map similarly to Visual SLAM, but enables higher accuracy in room mapping, albeit in one dimension.



4 **Identifying common obstacles:** Even if not fully mapping the house, the robotic vacuum can identify common obstacles. Distance sensors already tell the robots when they approach a drop-off, like the top of stairs, or are about to run into a wall. But distance sensors can be fooled into thinking that they are farther away than they are, based on the angle that their beams reflect from the surface. A robotic cleaner should be able to differentiate between a steep drop and a harmless flooring change.

5 **Moving outdoors:** Robotic sensor technology is moving outdoors to lawn care, but their navigation capabilities leave much to be desired. Many robots are still facing the same types of challenges in navigating obstacles, which is only exacerbated by the high degree of variance in terrain and the increased number of obstacles when dealing with the great outdoors.

To give their products the competitive edge, robotic cleaner manufacturers need the best technology, and that starts with accurate, configurable motion sensors and elegant sensor fusion technology.



3 STEPS TO A BETTER ROBOTIC CLEANER

Highly accurate multi-axis sensors with powerful sensor fusion calibrated to your application is the key to taking your robotic vacuum to the next level. Follow these three steps to get there.

#1: Configure the right sensor set:

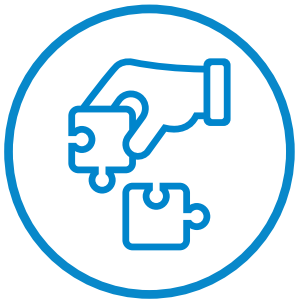
Many robotic cleaners rely on single-axis gyros for navigation. This works for planar heading and has been the traditional technology of choice. However, single-axis gyros won't provide the depth of context that's needed for robots to tackle variations in floor types and other common real-world scenarios. Single-axis gyros lead to robots that get stuck on chair legs. They just don't provide enough data about their environment to realize that they're inadvertently "popping a wheelie".

The solution to get these robots "unstuck" is a multi-axis IMU (inertial measurement unit), with a 3-axis accelerometer and a 3-axis gyroscope. This configuration delivers relative orientation or tilt information (pitch and roll), as compared to previous orientation. This orientation context is what allows your robot to realize that it's scaling an obstacle when it shouldn't be.

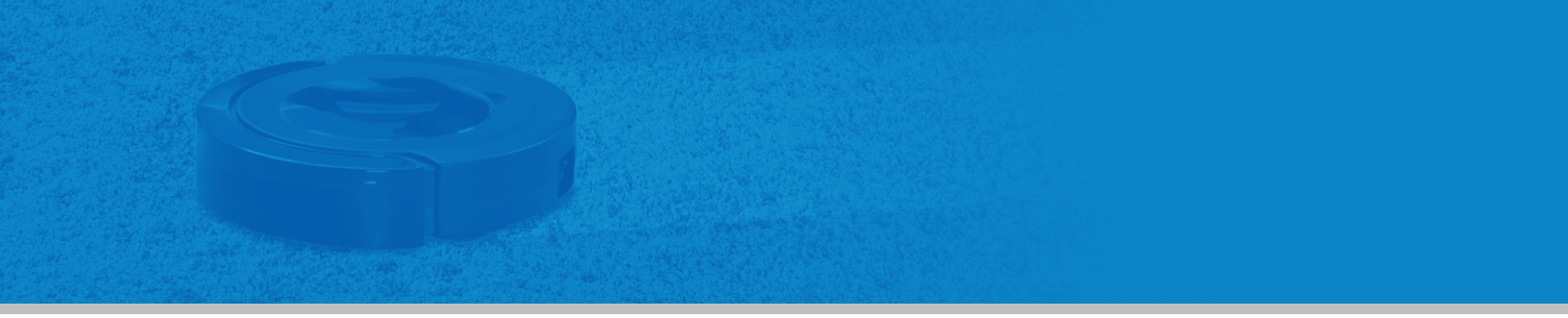
This 6-axis configuration delivers highly accurate relative heading. This means that your robot will understand its change as compared to its previous heading, so it will stay on course while getting itself unstuck when it makes acquaintances with a chair.

With relative heading, however, the output can drift, reducing accuracy over time. Having an absolute heading can help with that. Adding a magnetometer to this 6-axis configuration allows for a global reference point of the Earth's magnetic field. Problem solved…or is it?

The issue is that magnetometers can be affected by various magnetic fields present in the average household (all sorts of common electronic devices or even a building's structure). This significantly reduces the ability of the magnetometer to correctly find the direction of Earth's magnetic North. This is further exacerbated by changing magnetic objects (picking up a phone from the coffee table, moving a tablet), which further confuses the magnetometer.



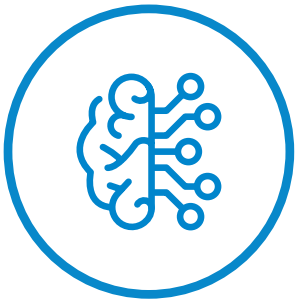
By writing algorithms to minimize the drift over time, and by utilizing additional sensors (like IR sensors to follow walls as a reference), a 6-axis solution will give a more consistent performance as compared to a 9-axis solution with a magnetometer.



Our Recommendations in Action: One huge benefit to using a multi-axis sensor as opposed to a single-axis gyro is that you'll get more data for context. This extra information can be mined to enable better AI decision making in your product. It also allows for additional "soft" sensors, such as bump detectors or tilt detection, that can address customer challenges and may result in a reduction in cost.

Of course, the sensor itself is only one part of the solution. Robust sensor fusion and dynamic sensor calibration are essential to opening up a multi-dimensional world of possibilities. With informational context and software, you'll be able to solve problems you haven't even considered tackling yet.

#2: Ensure intelligent sensor performance:



Intelligent sensor fusion, rigorous sensor testing and dynamic calibration will all help to differentiate your products from the competitors in your market.

Sensor fusion is the (scientific) art of combining data from each sensor in an IMU to create a more complete picture of a device's orientation and heading in the real world. For example, have you considered how you will account for bias in your IMU as their operating temperatures change? Do you know when to rely on accelerometer data versus gyroscope data and, just as important, how to blend that information? This is where sensor fusion will help optimize your performance.

Some robotics manufacturers attempt sensor fusion with in-house technology, but it can be very tricky to execute. Companies have lost significant R&D time and diverted critical engineer attention away from other projects while trying to get their sensor fusion to work. This increases costs, slows time to market, and puts your brand at risk of bad customer experiences. However, intelligent sensor fusion software provides the comprehensive data you need to elevate your products from good to great. Look to leverage the knowledge of experts on this critical piece of your product design.

In order to optimize performance, you also need sensors that have been rigorously tested. Both laboratory and real-world testing are essential to qualifying the performance of a sensor and determining how to optimize its sensor fusion algorithms based on the rich information discovered during testing. That data should be worked into algorithms for dynamic calibration as well as to enhance future generations. This lets you benefit from the years of real-world experience that have come before you.

Our Recommendations in Action: A dedication to testing has to be paramount. At At CEVA's Hillcrest Labs business unit, our R&D team has developed a proprietary Sensor Qualification Test System (SQTS) that collects data with statistically-significant spread (210 sensors at a time) all over a wide range of motions with varying environmental effects. By analyzing this wealth of information, we are able to update our sensor fusion algorithms to dynamically account for environmental impacts. The result is a more cost-effective sensor that performs as well as its more expensive counterparts.

#3: Choose the right sensor partner.

Having the right sensors with sensor fusion and optimized performance will get you only part of the way to the finish line. Look for vendors who offer deep expertise and flexible products that can be configured to your application's specific needs and integrated easily with your existing systems.

The right vendor will provide sensor options that map with each phase of your product development cycle, from modules for rapid prototyping to ready-to-integrate SiPs (system-in-package) for full-scale production. Configurable sensors will speed your time to market and free up your dev team to focus on what matters most—adding value to your products.

Flexibility is best matched with reliability. You'll want to look for signs that a vendor is proven in the field (based on real, delivered solutions) and dedicated to rigorous and robust testing. Even if a supplier had all of these pieces, they may not have the sensor in the right cost/performance ratio. Finding products that are sensor agnostic is also something to consider. If you find a vendor with products that deliver this flexibility, you'll be able to use whatever mix of sensors are best for your products.

Our Recommendations in Action: Know which types of vendors to look for. At Hillcrest Labs, sensors and sensor fusion have been our primary focus for more than 15 years. By now, we've pretty much seen it all, and know the industry inside and out. We understand the complexities of sensor development and deployment for robotic vacuum cleaners. And should you run into challenges during deployment of our sensors, we can help analyze performance logs, replicate issues, identify root causes and provide fixes.

But don't just take our word for it. Over 100 million products have shipped with our technology, enabling our customers to find their own market success. We developed our BNO085 with a long-time partner, Bosch Sensortec, and we have other long-term relationships with trusted brands like LG, Samsung, TCL and Sharp.

OVER
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BRANDS WHO HAVE USED OUR SENSOR FUSION PRODUCTS:

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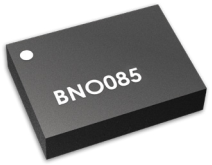
CLEAN UP THE COMPETITION

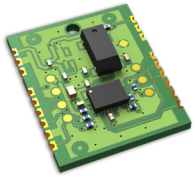
If you're ready to take advantage of the growth in this exciting market, then you need to get serious about selecting the right IMUs from the right vendor. Work with us to identify the right products and configure them for your application. All of our hardware components include our MotionEngine™ sensor fusion technology.

Our Recommended Sensors for Robotic Cleaners:

FSP200 – The FSP200 is a processor with embedded sensor fusion software designed for use in robotic navigation applications. The FSP200 integrates our high-performance sensor hub software stack into a low-power 32-bit ARM Cortex M3 MCU. With drivers for sensors from leading suppliers, the FSP200 allows you to choose the best fit for your product line. This component delivers faster time-to-market, simplified BOMs and the highest precision and quality.



BNO085 – The flexible BNO080/BNO085 SiP shortens development time and simplifies BOMs by combining a multi-axis sensor (configurable for 6- or 9-axis) with high performance sensor fusion capabilities in a single package. It addresses common sensor anomalies with proprietary algorithms that are continually perfected through rigorous testing.



FSM300 – The FSM300 is a self-contained 9-axis AHRS/IMU module (configurable for 6- or 9-axis) integrating a 3-axis accelerometer, 3-axis gyroscope, and 3-axis magnetometer, along with a low-power 32-bit ARM Cortex M0+ MCU running our high-performance sensor hub software stack. With the module form-factor, you'll speed your way through prototype testing with calibrated output the moment you drop it in.

3 KEY TAKEAWAYS:

- **Configure the right sensor set**
- **Ensure intelligent sensor performance**
- **Choose the right sensor partner**

Now that you know exactly what to look for, let's discuss the specifics of your robotic vacuum cleaner application. **Contact us today**.

1. https://ieeexplore.ieee.org/abstract/document/6249425
2. https://www.prnewswire.com/news-releases/cleaning-robot-market-to-2025--global-analysis-and-forecasts-by-type-floor-cleaning-lawn-cleaning-pool-cleaning-and-window-cleaning-300705931.html

ABOUT CEVA

CEVA is the leading licensor of wireless connectivity and smart sensing technologies. We offer Digital Signal Processors, AI processors, wireless platforms and complementary software for sensor fusion, image enhancement, computer vision, voice input and artificial intelligence, all of which are key enabling technologies for a smarter, connected world. We partner with semiconductor companies and OEMs worldwide to create power-efficient, intelligent and connected devices for a range of end markets, including mobile, consumer, automotive, robotics, industrial and IoT. Our ultra-low-power IPs include comprehensive DSP-based platforms for 5G baseband processing in mobile and infrastructure, advanced imaging and computer vision for any camera-enabled device and audio/voice/speech and ultra-low power always-on/sensing applications for multiple IoT markets. For sensor fusion, our Hillcrest Labs sensor processing technologies provide a broad range of sensor fusion software and IMU solutions for AR/VR, robotics, remote controls, and IoT. For artificial intelligence, we offer a family of AI processors capable of handling the complete gamut of neural network workloads, on-device. For wireless IoT, we offer the industry's most widely adopted IPs for Bluetooth (low energy and dual mode), Wi-Fi 4/5/6 (802.11n/ac/ax) and NB-IoT.