Enabling Next-Generation Avionics Systems

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Recent generations of MEMS technology are now providing highly robust, critical performance to avionics equipment, with significant advances in size, weight, power (SWAP), and cost.

Within the avionics industry, and other equally demanding applications, traditional solutions based on prior generation MEMS, or other inertial technology, have a proven track record of meeting performance objectives. However, those same technologies have struggled to make significant generational advancements on cost and other economies. Newer generation avionics systems face increasing pressure to improve on these fronts, leaving equipment manufacturers with challenging development goals and without more optimized technology choices. A critical dilemma facing avionics equipment integrators today is to maintain performance, while also improving SWAP/cost.

Surveying inertial MEMS components in production today across the entire electronics industry, there are three primary and distinct pedigrees of the technology. The solutions have originated from one of these main application focuses: military, automotive, or consumer. Decades old military origin technology is highly robust, but inflexible in SWAP and cost. Consumer origin technology meets aggressive cost goals, but with notable and limiting trade-offs in performance and ruggedness. However, technology originally targeted at the automotive industry was specifically optimized to meet demanding goals on all key parameters: performance, ruggedness, cost, size, weight, and power. Just as significantly, there are notable differences in the roadmap/potential of each of these for further development; see Figure-1.

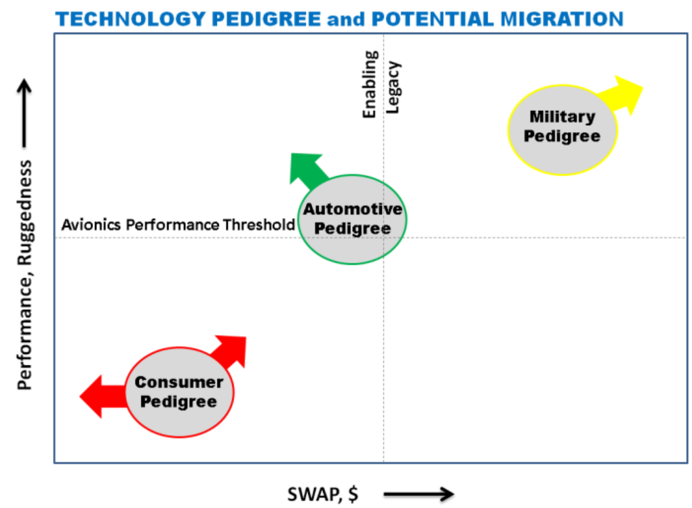

Figure 1. ADI MEMS Technology, Originally Focused on Automotive Requirements, Is Uniquely Capable of Performance Advancements While Also Improving SWAP and Cost

Next-generation avionics platforms flow down the specification goals listed in Table-1 to inertial sensing systems:

Inertial Sensor, Stability	**<10 °/hr, <100 micro *g***
Bandwidth	**>100 Hz**
Environment	**DO-160**
Reliability	**>20,000 hours**
Design Assurance	**DO178/254**

Table 1. Critical Avionics Goals for Inertial Systems

An essential element of ADI MEMS technology's ability to meet these requirements is its highly robust quad-core gyro sensing structure, depicted in Fig-2. This structure serves to reject shock and vibration influences on the angular sensing mechanism, and has a proven track record in avionics, automotive, medical, and smart munitions programs. The symmetry of the dual pair of antiphase resonators provide a high level of common-mode rejection for nonrotational inputs and the high resonator and demodulation frequency (approximately 18 kHz) has been leveraged to offer superior rejection of out-of-band signals. Robust linear-acceleration/vibration analysis has been performed on the core sensor, including sweeps above its resonance frequency, demonstrating its ability to reject this influence.

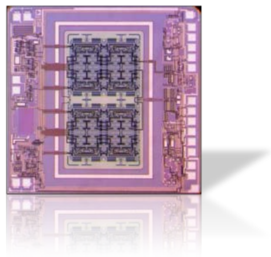

Figure 2. Industry-Leading Shock and Vibration Rejection with Proprietary Quad-Core Sensing

Beyond robust sensor core design, equally important is well matched and optimized sensor signal conditioning. Fundamentally, the sensor element is capturing a real life motion (that is, structure rotation) and translating it to a measurable electronic signal (that is, voltage). This translation and subsequent processing could have opportunity for inaccuracies without proper attention to bandwidth, timing, phase, sampling rates, resolution, and other drift characteristics such as temperature and voltage stability. These all rely on advanced and robust sensor signal conditioning. Analog Devices has distinguished itself in the high performance MEMS community by successfully marrying its proprietary MEMS IP with its industry leading signal processing.

ADI inertial measurement units (IMUs) address an additional challenge in implementing inertial sensors into complex avionics systems, which must rely on multiple sensor types in multiple dimensions to adequately discern the complex motion they experience. *i*Sensor® IMUs integrate up to 10 degrees of freedom sensing, with all necessary alignment, calibration, and first order sensor fusion, factory integration, and test.

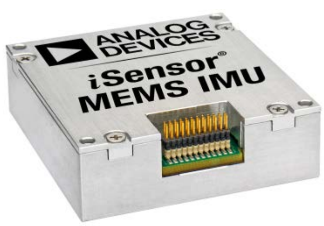

Figure 3. MEMS Inertial Measurement Unit

The ADIS16485/ADIS16488 *i*Sensor® MEMS inertial measurement units (IMUs) (Figure-3), for instance, are six and 10 degree of freedom sensors that are deployed in avionics systems today, meeting all performance and reliability (Table-2) goals, and providing up to an order of magnitude SWAP advantage.

System-Level Overview of ADI Avionics Grade Inertial Measurement Unit	
Inertial Sensor, Stability	**6 °/hr, 32 micro-*g***
Bandwidth	**330 Hz**
Linear-g Effect, Vibration Rectification	**9 mdps/sec; 0.1 mdps/g^2**
Tempco (Bias, Sensitivity)	**2.5 mdps/°C; 35 ppm/°C**
Temp/Vibration/Shock	**DO-160 G, Mil-Std-810 G**
Reliability	**>35,000 hours**
Design Assurance	**DO178/254**

Table 2. Demonstrated Avionics System Performance: Enabling Next-Generation Advancement with Industry-Leading SWAP/Cost Advantages

This MEMS technology has already proven itself against FOG inertial technology. A recent1 side-by-side comparison between ADI's ADIS16485 MEMS IMU and a $30k legacy FOG IMU clearly demonstrated similar performance levels. Additionally, the MEMS device offered an order of magnitude advantage in critical SWAP and cost parameters. Table-3 summarizes the results of this industry study, with the critical MEMS heading performance parameter being within ~5% of the $30k FOG device.

	FOG	**ADI MEMS**
Roll RMS Error (Deg)	**0.08**	**0.10**
Pitch RMS Error (Deg)	**0.08**	**0.10**
Heading RMS Error (Deg)	**0.13**	**0.14**

Table 3. ADI MEMS Technology Closes the Gap on Performance, with Substantial Economic Benefit Against FOG and Other Legacy Inertial Technology

MAINTAINING CRITICAL PERFORMANCE UNDER COMPLEX AND RUGGED CONDITIONS

There are three key elements of the MEMS IMU design that ensure rejection of erroneous motion artifacts related to vibration or other extraneous signal input. In each case, for the core sensor element, for the subsystem design, and for the signal processing, design requirements are specifically related to maintaining signal integrity under complex motion, via rejection of all unwanted motion artifacts. To further enhance performance, the *i*Sensor MEMS subsystem implementation uses multiple (of the quad resonator) sensors for each axis of measurement, with two sensors mechanically reoriented from a second pair, providing first order cancelation of systemic common nonrotational signals and sensitivities (thermal, supply, and residual acceleration sensitivity). Processing is performed at high data rates (sufficiently oversampled), in order to ensure preservation of the high performance established with the core sensor elements and subsystem design.

ADI has many years of sensor, signal processing, and applications expertise that is leveraged when developing MEMS IMU characteristics to meet performance and ruggedness requirements in hostile avionics, automotive, and military environments. The core sensors are in their third generation, with 10s of millions of units sold into high reliability and high performance end applications.

The ADIS16485 core sensor processing element will be certified to DO178/254 DAL-B. Hardware and software elements have followed rigorous specification, design, verification, and validation processes, which are tightly managed and under configuration control. ADI's core inertial sensing technology is in its third decade of production, with ADIS1648X IMUs anticipated to be in unit production well beyond 2030 based on the life cycle needs of existing and future design wins in avionics, defense, and industrial applications. In parallel, ADI continues to push its performance-leading SWAP and cost advantaged MEMS technology deeper into the realm of what used to be only the domain of fiber optic and legacy military inertial sensing.

REFERENCES

Goodall, Chris, Sarah Carmichael, Bob Scannell. "The Battle Between MEMS and FOGs for Precision Guidance." *EDN*, January 2013.

RESOURCES

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