A Micro Oven-Control System for Inertial Sensors

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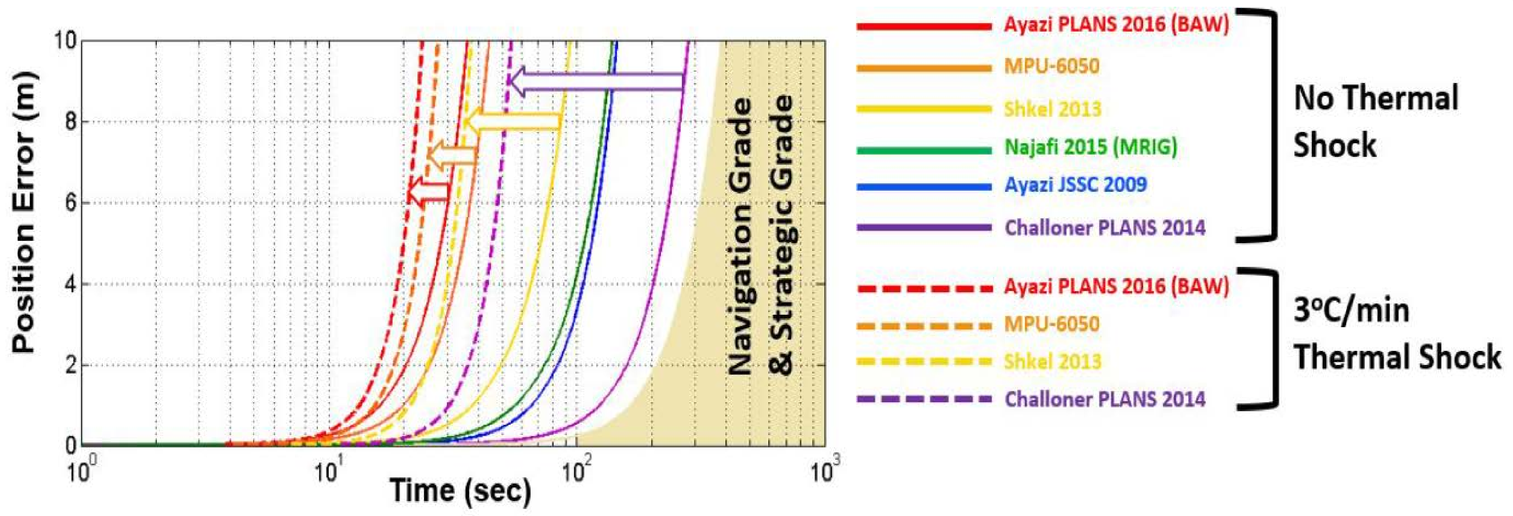
Problem Definition

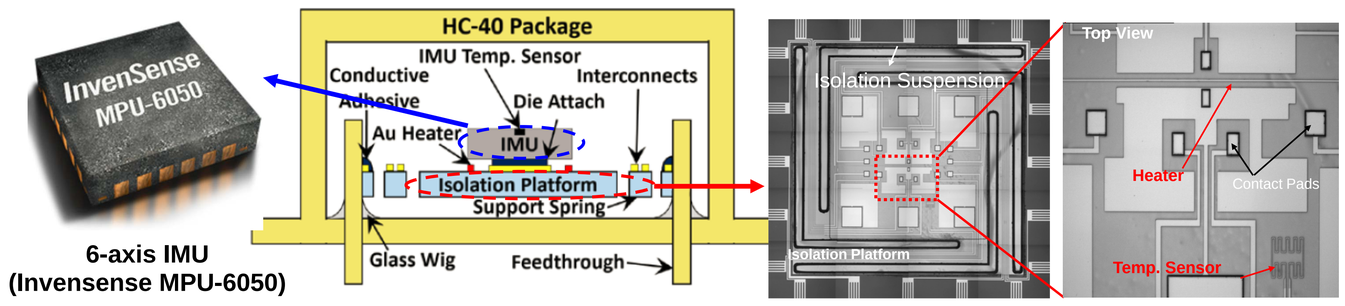
- Navigation system using MEMS inertial sensors greatly suffers from temperature change
- For example, position error of one of the best MEMS gyroscopes, Challoner PLANS 2014, is < 1m at 100s at RT, while it increased to > 50m at 100s with 3°C/min thermal shock
- Other inertial sensors show much degraded performances with thermal shock



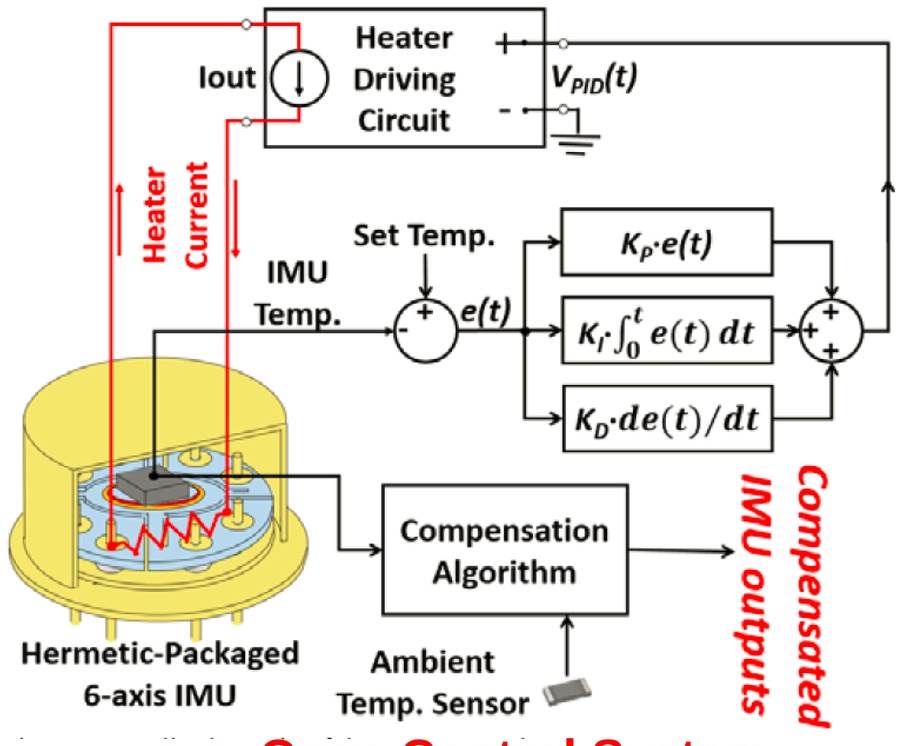
Methods & Materials

- Temperature of inertial sensors is controlled at 90°C at all time using a micro-machined glass isolation platform
- A heater and an RTD sensor are fabricated on the isolation platform
- Lease mean square (LMS) and random forest (RF) compensation algorithms are used to minimize residual bias errors
- Thermal circuit analysis is conducted to minimize power consumption

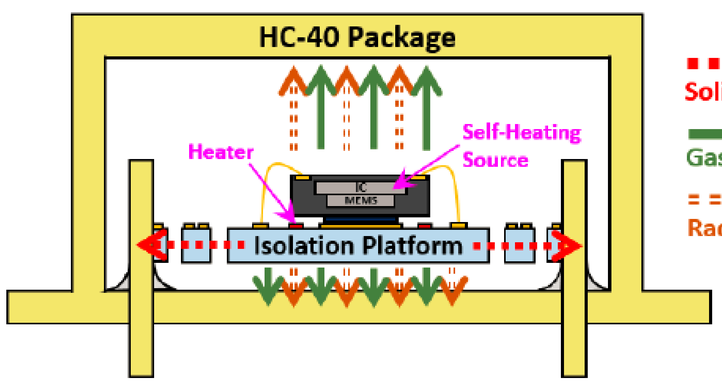
Hermatic-Packaged 6-axis IMU

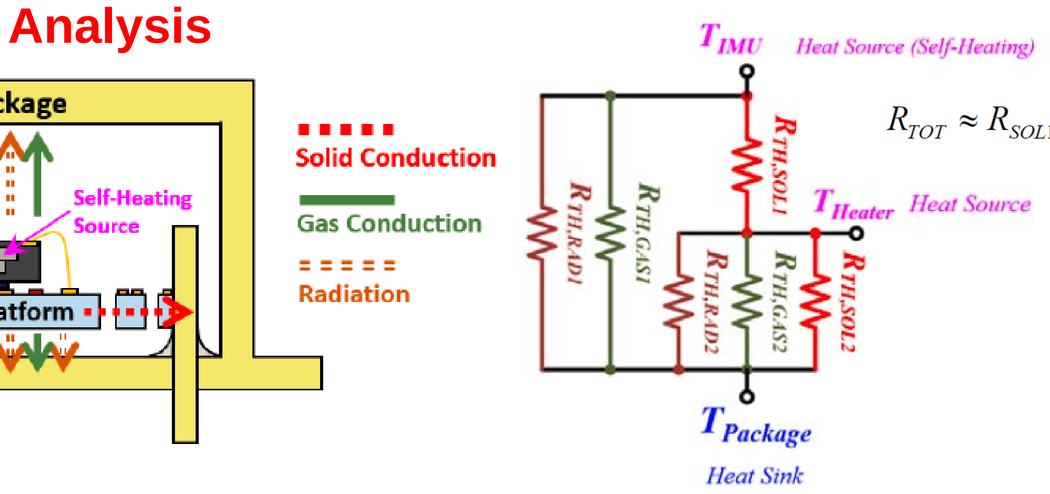


Oven-Control System Diagram



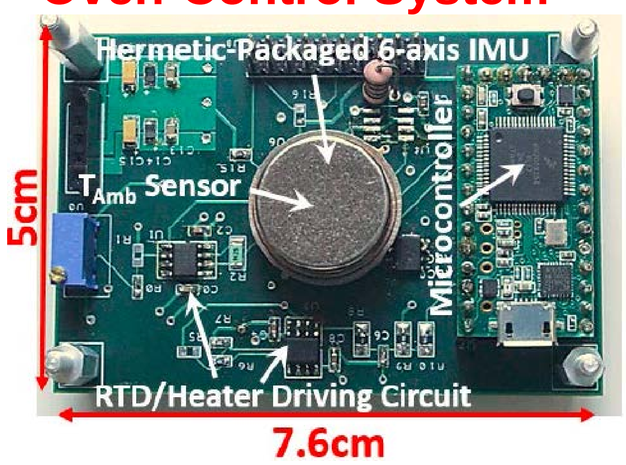
Thermal Circuit Analysis





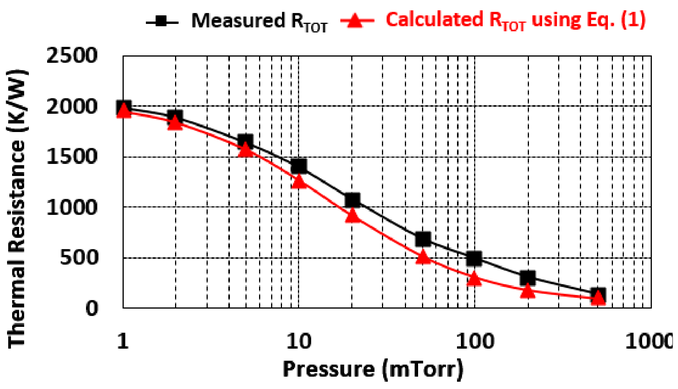
$$R_{TOT} \approx R_{SOL1} + (R_{SOL2} \,//\, R_{GAS2})$$

Oven-Control System



Test Results

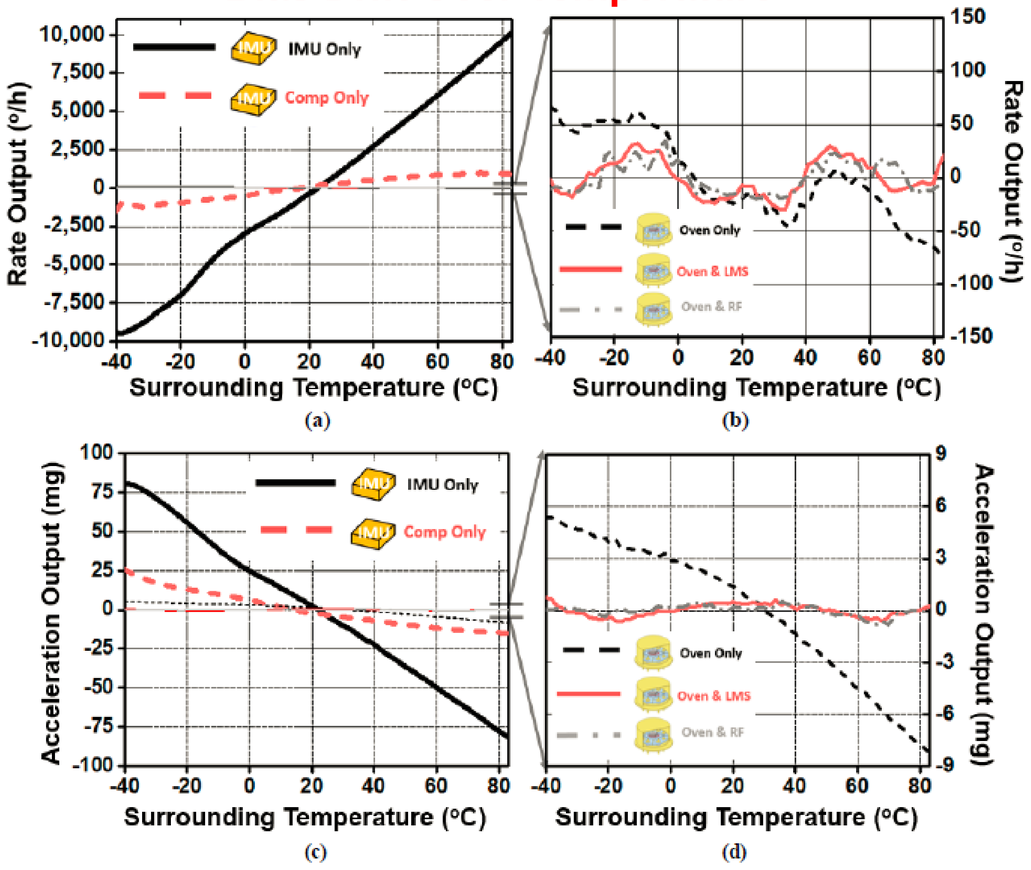
Thermal Resistance



Quantitative Comparisons

Combination		None	Oven-Control	
		Drift	Drift	Imp.
Gyro	X (°/h)	20610	54.54	378x
	Y (°/h)	6486	28.20	230x
	Z (°/h)	1288	12.78	101x
Acc	X (mg)	72.22	1.205	59.9x
	Y (mg)	14.91	0.6652	22.4x
	Z (mg)	170.6	1.339	127x

Bias Drift Over Temperature



Summary & Conclusion

- RSS bias changes of the three gyroscopes and the three accelerometers were reduced by 345 times (from 21645°/hr to 62.71°/hr) and 97 times (from 185.9mg to 1.920mg), respectively during the thermal-cycle test over 125°C surrounding temperature changes, from -40°C to 85°C with a 1°C/min rate of change.
- The platform has a thermal impedance of ~2,000°C/W.
- Low power consumption of < 100mW over temperature range from -40 to 85°C is achieved.
- The entire system measures 7.6cm x 5cm.

Future Works

- Possible future work will include:
  - analyzing and optimizing temperature-induced stress on IMU
  - analyzing run-to-run stability and repeatability of the oven-control system
  - implementing an oven-control system with lower power consumption
  - applying these oven-controlled IMUs to practical applications

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