Evolution of a Compact TOF Mass Spectrometer from Space Exploration to the Internet of Things

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We present a new compact time-of-flight (TOF) mass spectrometer for the Internet of Things (IoT), which builds upon the heritage of three generations of similar instruments for space and stratospheric missions[1,2,3].

After an overview of the evolution of the reflectron-TOF architecture for ESA space missions, from RTOF/Rosetta to NIM/JUICE, we summarize the key design patterns that led to achieving a unique mix of performance, dimensions, and resources utilization (mass and power): reliance on electron-impact ionization using low-power (~1W) thermionic emitters, extraction and an optional mass blanking with fast (~2-3 ns) high-voltage pulsers, use of integrated metal-ceramic screen-printed ion optics, extreme optimization of fast (~0.5 ns) custom-build impedance-matched Micro-Channel Plates (MCP) detectors, and use of automated particle-swarm optimization algorithm to maximize the instrument performance[4]. Examples of implemented designs together with some key performance results are used to expose the key tradeoffs behind these design choices.

We then discuss how some key lessons learned and design patterns from the development of these space instrument's development have been implemented in a novel commercial IoT mass spectrometer by a spin-off from the same group. This new device is based on orthogonal-extraction reflectron TOF architecture and is compact (sensor: ~300 mm; electronics 238x165x105 mm). Early tests with residual and calibration gases showed 720 M/ΔM (at 44u, CO_2) mass resolution and 10^5 dynamic range, but 950 and 10^6 are at reach with further optimizations, considering SIMION results and achievable noise level targets (~1mV rms white noise).

Contrary to its predecessors, this commercial instrument has been designed for manufacturability and cost, yet with the advantage of using state-of-the-art electronics, such as high-performance FPGAs and commercial Systems-in-Package (SiP) that provide for higher flexibility, performance, and reduced development times. Moreover, an HTTP

API make it a true IoT device, allowing real-time control and data visualization via web browser and data storage to InfluxDB time-series database, allowing to envision new ConOps based on distributed system-of-systems architectures, for example in drinking water quality monitoring.

[1] H. Balsiger, K. Altwegg, P. Bochsler, P. Eberhardt, J. Fischer, S. Graf, A. Jäckel, E. Kopp, U. Langer, M. Mildner, J. Müller, T. Riesen, M. Rubin, S. Scherer, P. Wurz, S. Wüthrich, E. Arijs, S. Delanoye, J. De Keyser, E. Neefs, D. Nevejans, H. Rème, C. Aoustin, C. Mazelle, J.-L. Médale, J.A. Sauvaud, J.-J. Berthelier, J.-L. Bertaux, L. Duvet, J.-M. Illiano, S.A. Fuselier, A.G. Ghielmetti, T. Magoncelli, E.G. Shelley, A. Korth, K. Heerlein, H. Lauche, S. Livi, A. Loose, U. Mall, B. Wilken, F. Gliem, B. Fiethe, T.I. Gombosi, B. Block, G.R. Carignan, L.A. Fisk, J.H. Waite, D.T. Young, and H. Wollnik,"ROSINA - Rosetta Orbiter Spectrometer for Ion and Neutral Analysis," Space Science Review 128 (2007), 745-801.
[2] D. Abplanalp, P. Wurz, M. Wieser, and S. Barabash, "A Neutral Gas Mass Spectrometer to Measure the Chemical Composition of the Stratosphere," proceedings of the 19th ESA Symposium on Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 7-11 June 2009, edt. H. Lacoste, ESA SP-671 (2010), 153-158, on CD.
[3] R.G. Fausch, P. Wurz, M. Tulej, J. Jost, P. Gubler, M. Gruber, D. Lasi, C. Zimmermann, and T. Gerber, "Flight Electronics of GC-Mass Spectrometer for Investigation of Volatiles in the Lunar Regolith," IEEE Aerospace Conference (2018), 1-13, DOI: 10.1109/AERO.2018.8396788.
[4] A. Bieler, K. Altwegg, L. Hofer, A. Jäckel, A. Riedo, T. Sémon and P. Wurz, "Mass Spectrometer Optimization with the Adaptive Particle Swarm Algorithm," Jou. Mass Spectr. 46 (2011) 1143-1151.