Introducing *ATONA* for TIMS – A paradigm shift in signal amplifier technology.

Technical Note T30182

Isotopx Ltd, Dalton House, Dalton Way, Middlewich,
Cheshire, CW10 0HU, UK.

Introduction

Over the past 20 years improvements in resistor amplification technology have slowed. The marginal gains that have been made are largely offset by the practical limitations. The newly developed *ATONA* (aA to nA) amplification technology from Isotopx has eliminated the need for a “feedback resistor”. The outcome is a significant reduction in amplifier noise, a dramatic increase in dynamic range, rapid amplifier decay, and improved baseline and calibration stability. In practice, this means analysis of signal sizes from 100’s cps up to 1nA (equivalent to 100V on $1e^{11}\Omega$ resistor amplifier), with lower noise than any resistor based amplifier, <0.2 seconds amplifier decay time and ultimate baseline stability of <10 cps 1SD over 10 hours of analysis time. In addition, calibration of the amplifiers is stable to ~1ppm with no apparent drift over time.

Noise

Amplifier noise directly impacts on the precision of a measurement. The noise performance of a resistor based amplifier improves with increased integration time, but is theoretically limited by the Johnson-Nyquist noise of the specified resistor. By eliminating the “feedback resistor”, Isotopx *ATONA* amplifier surpasses the theoretical Johnson-Nyquist noise of a $1e^{13}\Omega$ resistor after 10 seconds of integration. After 100 seconds of integration the noise approaches the theoretical limit of $1e^{14}\Omega$ resistors. Unlike other amplification systems, these noise properties are applicable across the entire dynamic range and improve linearly with integration time.

Dynamic Range

In contrast to conventional resistor-based technology, *ATONA* amplification can detect signal sizes from 10’s cps to 1nA (100V in reference to $1e^{11}\Omega$ resistor amplifier) without any electronic or software switching throughout the entire dynamic range. This is of particular use in applications where large isotopic abundance ratios are present (e.g., Ca, Pb, U) Furthermore, the extreme dynamic range, in conjunction with low noise, enables measurement of unknowns with optimal precision regardless of isotopic composition.

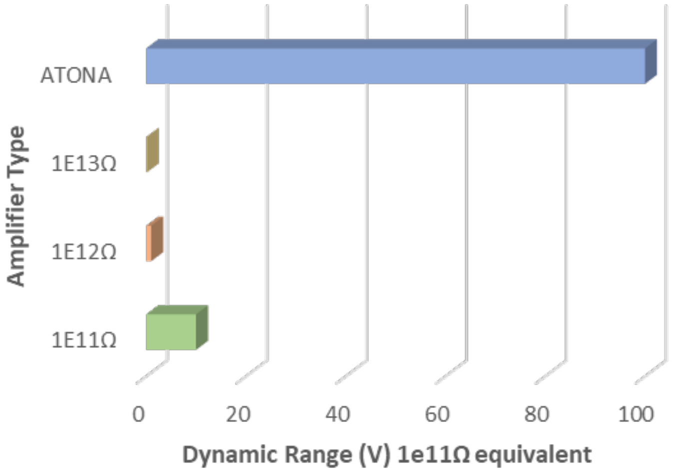

Figure 2. Comparison of $1e^{11}\Omega$, $1e^{12}\Omega$ theoretical $1e^{13}\Omega$ and ATONA dynamic range reference to $1e^{11}\Omega$ amplifier.

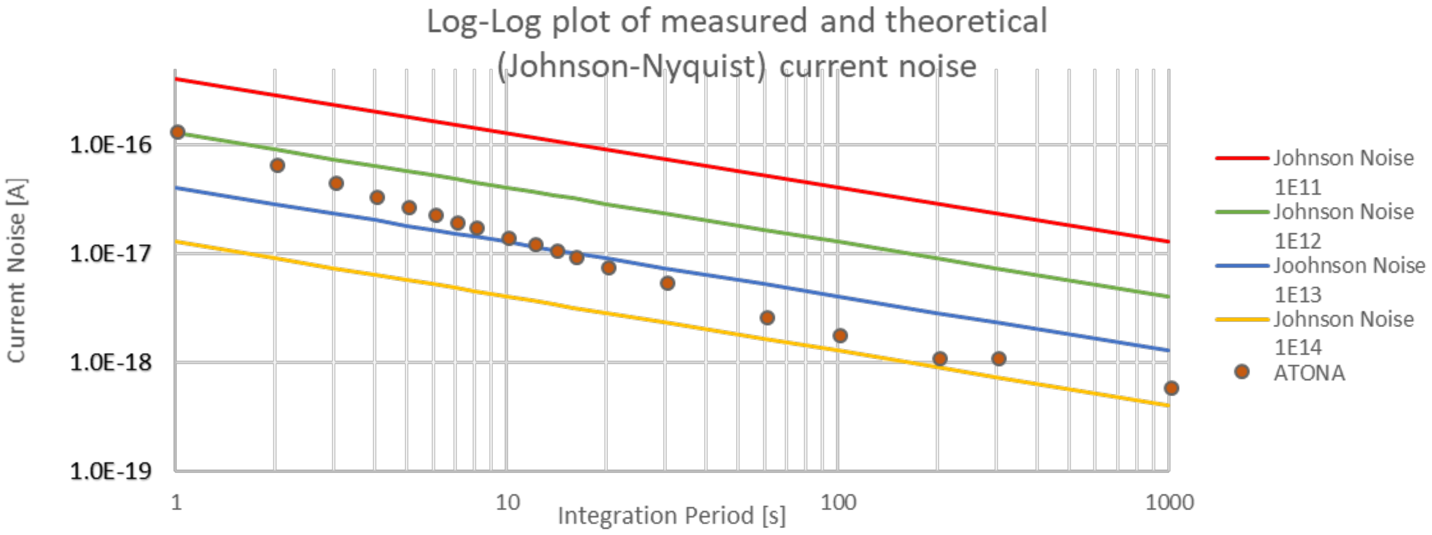

Figure 1. Log-Log plot of measured ATONA noise [A] against theoretical (Johnson-Nyquist) noise across different integration times [s].

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Amplifier Decay

The time for an amplifier to return to baseline following measurement of a signal has always presented a significant challenge to resistor based designs. Lengthy amplifier decay reduces “on-peak” measurement time, ultimately leading to fewer ions being collected and lower analytical precision. Higher resistance amplifiers are characterized by prolonged amplifier decay times, i.e., for $1e^{13}\Omega$ resistor amplifier the time would be several seconds, making any peak hopping methodology difficult. With *ATONA* amplification, amplifier decay time is <0.2 seconds, faster than any commercially available resistor amplification, and requiring no artificial correction. Amplifier decay is therefore not a limiting analytical factor using *ATONA*.

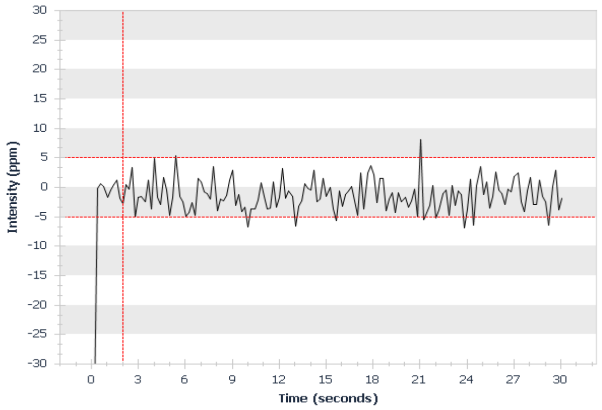

Figure 3. 25 x 200ms integrations of on peak 8V signal measured, magnet moved 0.5 AMU and baseline measurements taken for 30 seconds of 200ms integrations.

Baseline Stability

Long term baseline stability has been measured at significantly less than 10 cps 1SD using 1000 second integrations. This results in a quantification limit (defined as 5 x 2SD) less than 100 cps. This emphasizes potentially how low the cross over point is between ion counting and *ATONA* amplification. This stability in combination with low noise offers the possibility of static Faraday measurement with *ATONA* yielding comparable precision to peak hopping on an ion counter in the 100’s cps range.

Inter-channel Gain stability

Long term inter-channel gain stability for *ATONA* amplification is exceptional. Using a completely novel gain calibration technique, amplifier gain stability is ~1ppm over 2 days. The data displayed no apparent long term drift or trends during the measurement period. Frequent amplifier calibration therefore becomes unnecessary.

	Mean	1SD	1RSD [ppm]
L5	**1.0078**	**9.3E-07**	**0.92**
L4	1.0188	7.7E-07	0.75
L3	1.0029	7.6E-07	0.76
L2	1.0025	8.8E-07	0.88
Ax	0.9944	5.7E-07	0.57
H1	0.9985	1.0E-06	1.05
H2	0.9945	7.4E-07	0.74
H3	1.0016	1.0E-06	1.04
H4	1.0144	9.5E-07	0.93

Figure 4. 48 hours of gain calibration based on 1 hour integration time.

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