

The next generation of piezo actuators - robust and stronger

Comparing N-Stacks and the CuX Series from piezosystem jena

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Introduction and Background

Piezoelectric actuators are essential components in nanopositioning, nanotechnology, optics, life sciences, and semiconductor manufacturing. Their ability to offer sub-nanometer resolution, fast response times and play-free behavior makes them superior to conventional actuators in many high-tech applications. Compared to alternative technologies, such as electromagnetic motors, voice coil actuators and screw-driven systems, piezo actuators offer several beneficial advantages. Unlike electromagnetic motors, which typically suffer from mechanical play, limited resolution, and slower dynamic response, piezo actuators offer direct drive, eliminating the need for gears or transmission elements and thus eliminating backlash and wear. Voice coil actuators are capable of fast movements but require a continuous power supply for positional holding and often lack the resolution and energy efficiency of piezoelectric systems. Screw-driven actuators are strong and reliable for coarse positioning, but cannot compete with the compactness, speed, or precision of piezo-based solutions. As industry demands ever-higher levels of performance, reliability, and mechanical strength, the next generation of piezo actuators must offer more than just precision. They must also be mechanically robust and able to withstand high loads and harsh environmental conditions. Advanced designs such as the CuX series already combine piezoelectric performance with

new designs to meet the requirements of modern industrial and aerospace applications. By combining ultra-fine motion control with robust durability, piezo actuators are establishing themselves as the first choice for next-generation motion technologies. The significant innovation at piezosystem jena, a leading manufacturer of piezo-based motion technologies, sets new standards in this field: the CuX piezo stack actuators series. This white paper compares this product line with the N-Stack series, i.e., conventional PZT stacks, and evaluates their respective strengths, differences, and optimal areas of application.

Technology Overview

N-Stacks – Performance Meets Precision

Piezosystem jena has been offering the N-Stack series for many years and continues to form the basis for nanopositioning systems with high transmission ratios. An N-Stack can be described as a multilayer piezoelectric actuator that has been specially developed for the use in high-precision positioning applications. These actuators consist of ultra-thin piezoelectric ceramic layers and offer exceptional performance in a compact design. They can generate forces of up to 3,500 Newtons while maintaining response times in the sub-millisecond range, making them ideal for dynamic environments with limited space. A key advantage of N-Stacks is their high stroke-to-length ratio, which allows for significant displacement in a small area. They are characterized by fast response with minimal hysteresis, ensuring reliable and precise motion control. In combination with control systems, they also offer excellent sub-nanometer resolution and, as a result, repeatability in the single-digit nanometer range, which is crucial for applications that require consistent and precise positioning. Thanks to these characteristics, N-Stacks

are frequently used in various demanding fields such as nanopositioning, adaptive optics, scanning systems, precise measurement technology, and microfabrication. Their combination of performance, speed, and precision makes them a versatile solution for advanced technological applications.

CuX Series – Strength and Robustness Redefined



Figure 1: Picture of the CuX-Series from piezosystem jena.

The CuX series (Figure 1.) sets new standards for applications that require mechanical robustness and long-term durability. Similar to the N-Stack series, these actuators feature a multi-layer piezoelectric composite structure. The difference here lies in the composition of the copper-based electrode materials integrated between the piezoceramic layers and the minimization of inactive zones. The innovative design improves the mechanical strength, durability, and heat resistance of the actuator, making it ideal for applications with high forces in challenging environments. Another feature is the improved stroke-to-length ration, which is 20% higher than conventional PZT actuators, allowing integration into smaller installation spaces. In order to achieve higher temperature resistance, an alternative PZT ceramic with a Curie temperature of 340 °C is used. Furthermore, CuX stacks exhibit

excellent resistance to moisture and other environmental influences, ensuring reliable performance. Tests were conducted at 85 %RH, 85 °C, a preload of 27 MPa and a frequency of 17 Hz and were terminated after one hundred million cycles due to the absence of failures. Thanks to their already mentioned advantages, CuX actuators are the ideal choice for industrial automation, aerospace applications, high-performance positioning systems, micro-dispensing valves and active vibration and noise control in harsh or mission-critical environments. Their design strikes a thoughtful balance between the precision of piezoelectric motion and the mechanical demands of real-world applications.

Comparative Analysis – N-Stacks vs. CuX Series

When selecting a piezo actuator for a specific application, it is important to understand the differences in performance characteristics, mechanical load capacity, and environmental resistance. The N-Stack and CuX series from piezosystem jena represent two technologically advanced but fundamentally different approaches to high-performance actuation, each tailored to specific operating requirements. Thanks to their low-outgassing materials and optional protective coatings, the N-Stack series can be adapted for operation under vacuum conditions, cryogenic temperatures and in clean room environments. Due to the lower capacity of N-stacks compared to CuX-stacks, N-stacks are slightly better suited for applications with very high frequencies. However, the mechanical robustness of both actuator series in the form of the bare stack is moderate. For applications involving mechanical shocks or high mechanical loads, external protective measures or system-level risk mitigation strategies are recommended, such as implementing a preload or additional housing for the actuator, such as a stage based on solid-

state joints. The technology behind the CuX series is the inactive zone in the multilayer structure of the ceramic stacks has been minimized from the conventional 400 µm to just 100 µm. The structure of a CuX series actuator is shown in Figure 2. Furthermore, the use of copper-based electrode material instead of the conventional silver-palladium alloy results in lower migration of the electrode material and thus a more durable piezo actuator.

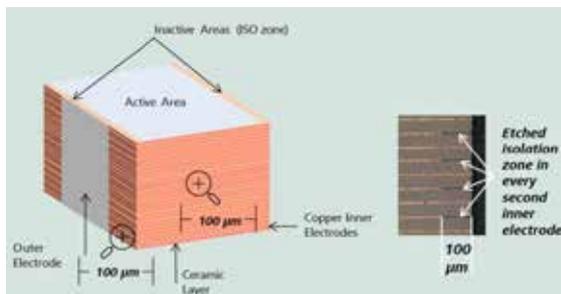


Figure 2: Structural design of a CuX stack.

This allows the actuator to maintain stable performance during continuous operation or high-duty cycles. Thanks to its new technology, the CuX series delivers exceptionally high blocking forces (up to 51 N/mm²) in comparison with the conventional N-stacks (13 N/mm²) and is optimized for use in environments where durability is particularly important. This higher blocking force of CuX actuators in relation to their surface area is particularly advantageous in industrial and aerospace applications, where easy integration and mechanical reliability are essential. Other comparable properties, such as stroke in relation to actuator length or stiffness, are listed in Table 1. Furthermore, the CuX series is designed to withstand challenging environmental conditions, including humidity, mechanical vibration and shock. This makes it a reliable choice for field-deployed systems and rugged industrial environments. The robustness of the CuX series makes them ideal for applications such as valve control, heavy-load positioning, aerospace mechanisms and vibration compensation in outdoor or high-stress settings. Besides ultra-fine precision,

the actuators of the CuX series value reliable performance under real mechanical demands. In summary, the CuX series represents a modern advancement of the N-Stack series. It was developed specifically for precision-oriented applications that require higher stroke with the same installation space, sub-nanometer accuracy, and optimal adaptation to the respective environment. In summary, the CuX series is particularly suitable for applications where a longer lifecycle, high blocking force and excellent resistance to environmental influences are crucial. Deciding between N-stacks and CuX stacks ultimately depends on the respective priorities. Whether precision, power or robustness are the main considerations.

Table 1: comparison of N-Stack (N 35/S5) and CuX-Stack (CuX-M).

	N 35/S5	CuX-M
max. stroke	41 µm	55 µm
stiffness	20 N/µm	25 N/µm
blocking force	850 N (13 N/mm ²)	1400 N (51 N/mm ²)
capacitance	3,6 µF	3,4 µF
recommended preload	~85 N	~150 N
voltage range	-20...130 V	-10...180 V
Curie Temperature	~145 °C	~340 °C
Length	7 mm	5.2 mm
Width	9 mm	5.2 mm
Height	36 mm	30 mm

Conclusion & Outlook – Choosing the Right Actuator

Both the N-Stacks and CuX series are at the forefront of modern piezoelectric drive technology but they are designed for different technical requirements. When selecting the right solution, it is crucial to consider the respective strengths. It is therefore always worth taking a closer look at the application. N-Stacks and the CuX series can perform precise movements with high repeatability. However, the capacity, and

thus also the resonance frequency, of the N-Stacks is slightly higher than that of the CuX series, making them more suitable for fast applications. The CuX series is also specially designed for extreme operating conditions where mechanical strength, environmental resistance, and easy integration are crucial. These actuators prove their strengths in demanding industrial environments where consistent performance is required even under high loads, shocks, or in humid conditions. The choice between N-Stacks and CuX actuators ultimately depends on the priorities of your application, i.e., whether precision and adaptability or robustness and reliability are the main considerations.

Future Trends in Piezo Technology

With advances in areas such as automation, robotics, aerospace, and quantum technology, the importance of piezoelectric actuators is continuously increasing. In addition, environmental robustness is becoming increasingly important. Piezo actuators must not only work reliably in controlled laboratory environments, but also under practical conditions with extreme temperatures, vibrations, humidity, and contamination. Performance requirements are increasingly exceeding established limits and leading to new technological approaches. A key development path is the combination of the high precision of N-Stacks with improved robustness, which resulted in the introduction of the CuX series. This series combines fine control and durability in a compact unit. Another focus is on integration into solid-state joints and coupling them with intelligent functions. Embedded sensor technology and real-time feedback loops enable self-monitoring systems with adaptive behavior that increase precision and reliability under changing operating conditions. At the same time, miniaturization is being advanced by using the CuX series stacks in newly

developed stages. The aim is to offer compact and more efficient actuators and stages with high force output and structural stability in order to open up new applications in medical technology, micro robotics and space-critical instruments. piezosystemjena is consistently pursuing these development paths, positioning itself as a leading technology provider for demanding applications in various industries.

Contact and Consultation

Are you planning to use N-Stacks or stacks from the CuX series? For straightforward testing, we recommend the demo package from piezosystemjena. It includes a stack in all five available sizes and a matching amplifier that makes it easy to control the stacks. Our experts will be happy to assist you in selecting suitable products, designing bias concepts and implementing appropriate protective measures. Tailored to your application and especially for larger project volumes

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References

All information used to create this white paper can be found on the piezosystemjena website.