The Rook™ Automatic Voltage Adjustment

TECHNICAL NOTE

Applicable Products	The Rook™		
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Purpose

This document is intended to explain how The Rook™ cryogenic nanopositioner automatically adjusts voltage, why voltage needs to be adjusted in piezo stages operated at cryogenic temperatures, and how The Rook™ simplifies the user experience.

Background

As a user varies temperature, piezoelectric phenomena in a piezo stage can be reduced or changed. Normally, to maintain optimal operating parameters of the piezo stages, the user needs to manually increase voltage settings for the stages as temperature decreases. The exact adjustment can vary based on the piezoelectric material used in the stage but can generally be found using the equation in the section below (given that other parameters of charge and capacitance are known or can be measured).

Applicable Theory

The following equation shows the relationship between charge, Q, voltage, V, and capacitance, C. As temperature decreases, capacitance is also decreased at lower temperatures due to decreased permittivity in the piezo actuator. The capacitance decrease requires an increase in voltage to maintain the same charge. Without the adjustment, movement of the stage will become increasingly limited. In the worst case, the stage will not be able to move at all.

Voltage, V, equation, where:

- Q is charge
- C is capacitance

$$V = \frac{Q}{C}$$

The relationship between stroke length of a piezo actuator and temperature is shown in Figure 1. Figure 2 demonstrates the relationship between voltage and temperature.

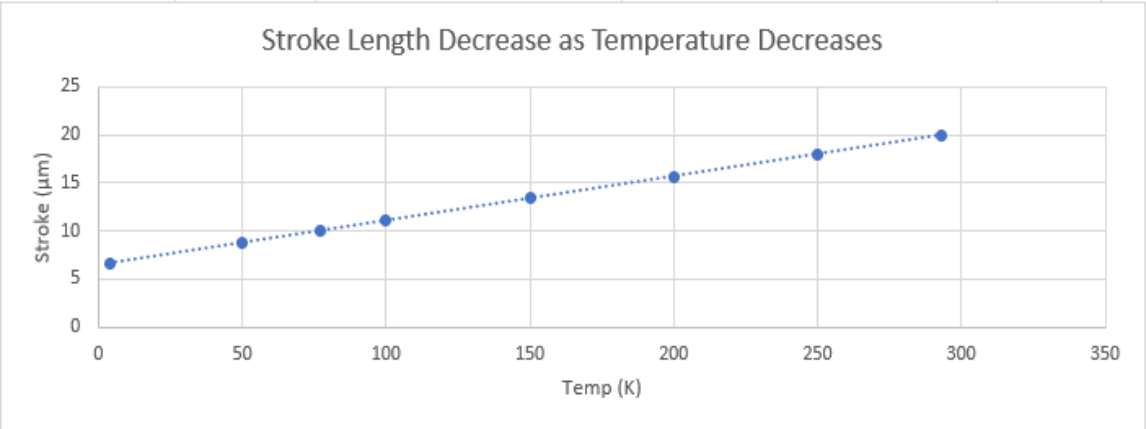

Figure 1: Stroke length decrease in piezo actuator as temperature decrease.

Data from CTS Corp.

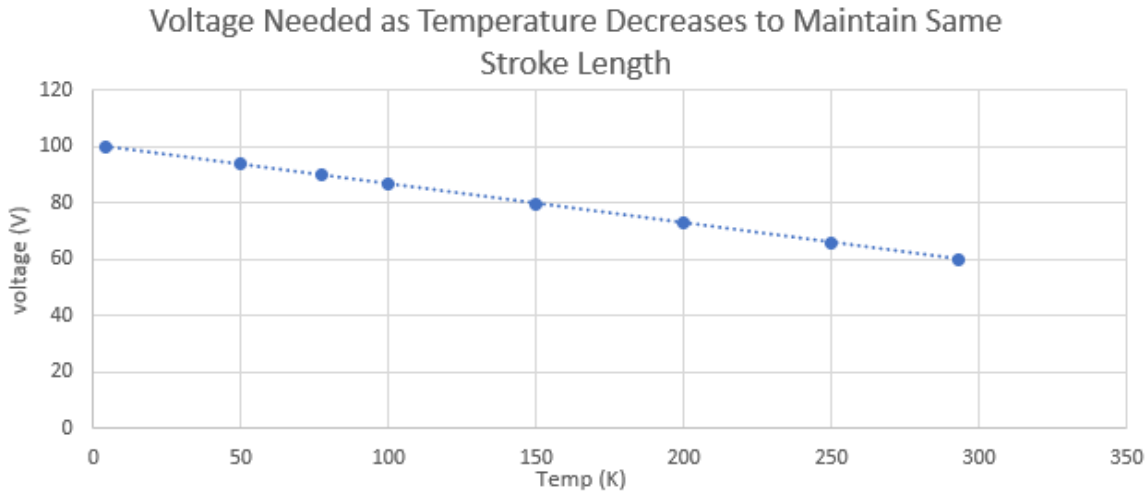

Figure 2: Voltage required as temperature decreases to maintain 10 µm stroke length of piezo actuator.

Data from CTS Corp.

During development of The Rook™ a lookup table of required voltage vs temperature was created to simplify the user experience in operating at cryogenic temperatures. The following block diagram provides a system overview of The Rook™ automatic voltage adjustment.

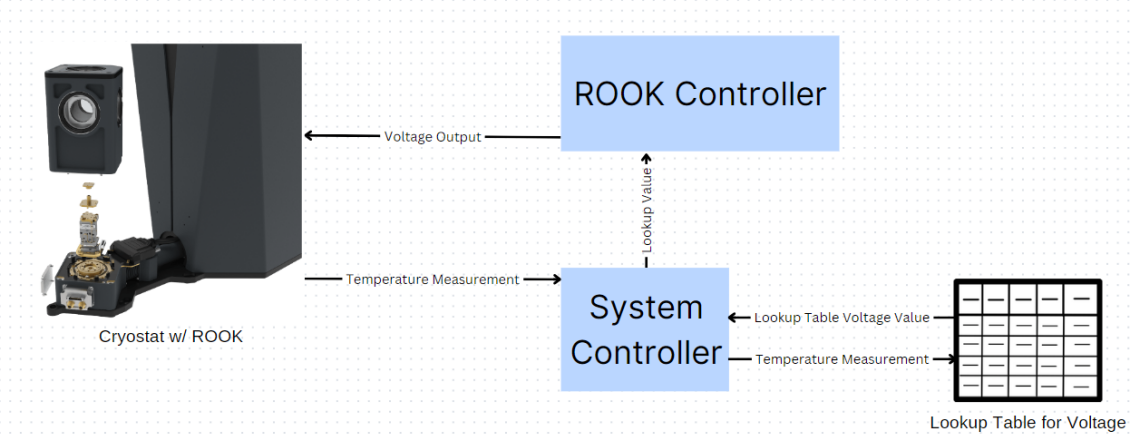

Figure 3: Block Diagram of how The Rook™ automatically adjusts voltage as temperature changes.

Summary

Piezo stages operating in cryogenic environments need to have voltage adjusted as temperature changes to maintain proper operation. This can become quite cumbersome for users who vary their temperatures frequently. The Rook™ automatically adjusts the piezo stage voltage as temperature changes within the cryostat sample space, allowing for seamless use of the 3-axis nanopositioner at any operating temperature.

References

[1] https://www.sciencedirect.com/science/article/pii/S0032386119302046
[2] https://eng.libretexts.org/Bookshelves/Materials_Science/Supplemental_Modules_(Materials_Science)/Electronic_Properties/Piezoelectricity#:~:text=In%20the%20case%20of%20piezoelectric%20materials%2C%20when%20stress,the%20crystal%20the%20stress%20is%20being%20applied%20on.
[3] https://ntrs.nasa.gov/api/citations/20090029957/downloads/20090029957.pdf
[4] https://www.ctscorp.com/resource-center/tutorials/piezo-basics/#:~:text=The%20piezoelectric%20effect%20is%20actually%20non-linear%20in%20nature,linear%20constitutive%20equations.%20Piezoelectric%20coefficients%20are%20temperature%20dependent.