OAK RIDGE NATIONAL LABORATORY FACT SHEET
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

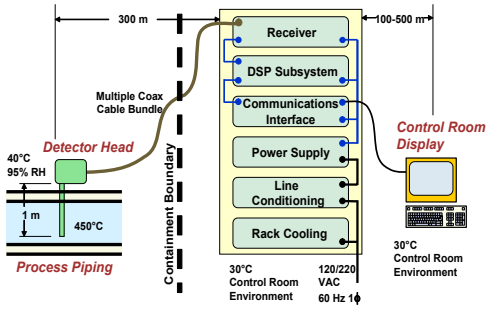
No Calibration Temperature Measurement

Johnson Noise Measurement Become a Reality

Existing Technology Falls Short of Industrial Needs

The theory and fundamental design elements for a practical Johnson noise temperature measurement system have been in development over the last 20 years but technology to successfully implement the design has only recently become practical. Inexpensive, high-speed, computer-based data acquisition and advanced signal processing software, the most important enabling technologies, are now up to the task. Additionally, electronic microcircuit components to accomplish low-noise signal amplification have improved in performance while remaining low in cost.

Using modern circuit design and computer software processing, we developed an architecture that measures temperature rapidly while maintaining calibration continuously throughout the instrument's life. The system consists of three major subsystems: (1) instrument head, (2) receiver, and (3) signal processing. The instrument head contains analog amplifier components. The receiver and signal processing subsystems can be located remotely from the head, away from a radiation or other contaminated zone. Interconnection between head and receiver is made by a bundle of shielded cables that extends their separation up to 300 meters.



Johnson Noise Temperature Measurement for Industrial Environments

Thermal Noise Is Johnson Noise

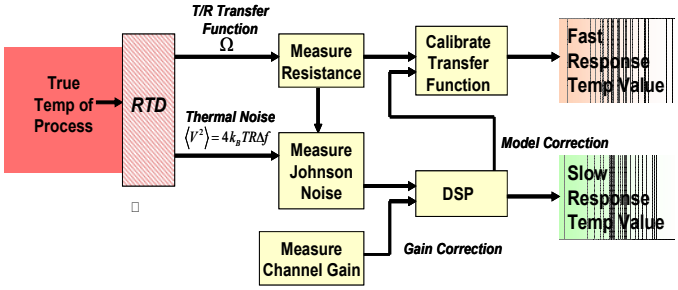
Johnson noise, caused by the random thermal motions of electrons in a conductor, generates an open-circuit voltage across any resistance, which is random with zero mean. The relationship between temperature, resistance, and voltage generated is given by the fundamental physics of the Nyquist relation:

$$\langle V^2 \rangle = 4k_B TR\Delta f$$

Our system measures process temperature using a standard resistance device (RTD) that gives fast time response. However, integrating the Johnson noise-derived temperature allows the system to continuously calibrate the rapid temperature signal. Drift and long term degradation (even effects from cable attenuation) are eliminated by Johnson noise and innovative features that we have included.

Features

- Fast response temperature measurement without drift or need for further calibration
- Full temperature range (0 to 450°C), 0.2% of reading
- Prototype field demonstration being built in next year
- System components can be made small and rugged



Functions Performed By Johnson Noise Temperature Measurement System

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