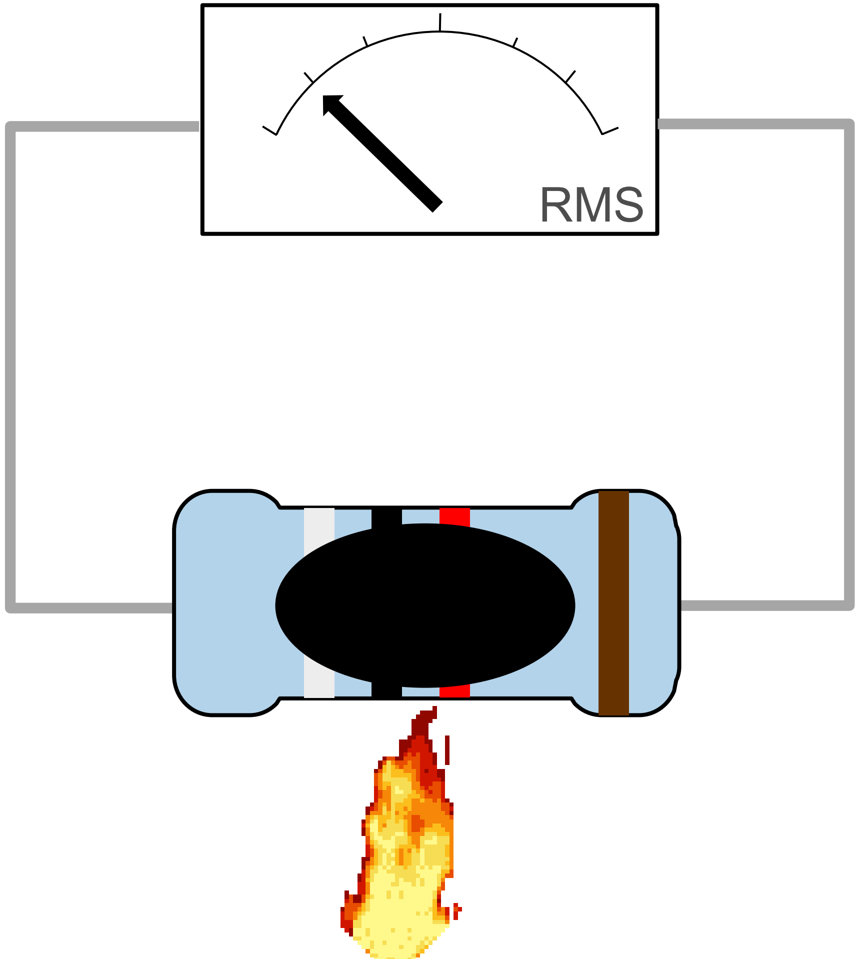
Progress in the Development of Primary (Johnson Noise) Thermometer

Johnson Noise



Johnson Noise

- JNTs use the Johnson-Nyquist equation

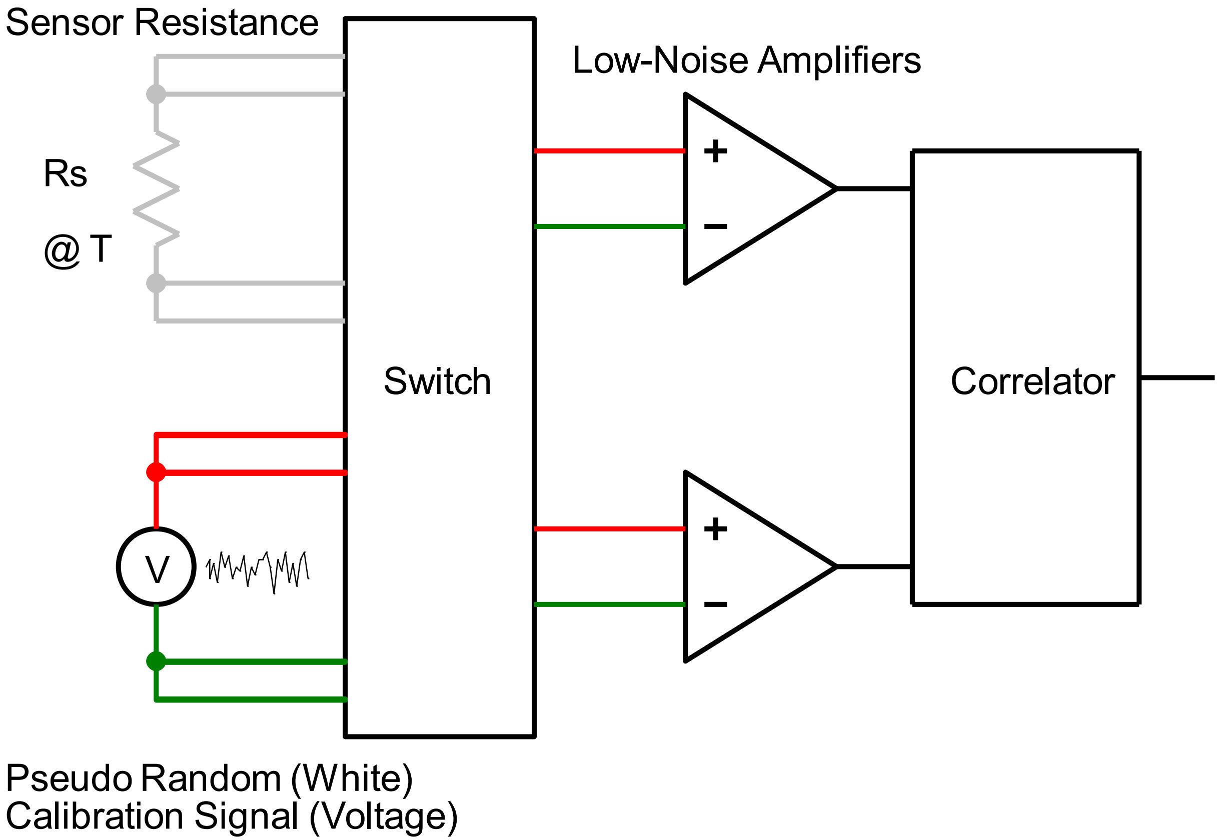
$$v_n = \sqrt{4kTR\Delta f}$$

Johnson Noise

- JNTs use the Johnson-Nyquist equation

$$T = \frac{1}{4k}\left\{ \frac{v_n^2}{R} \Big/ \Delta f \right\}$$

Prior Art JNTs



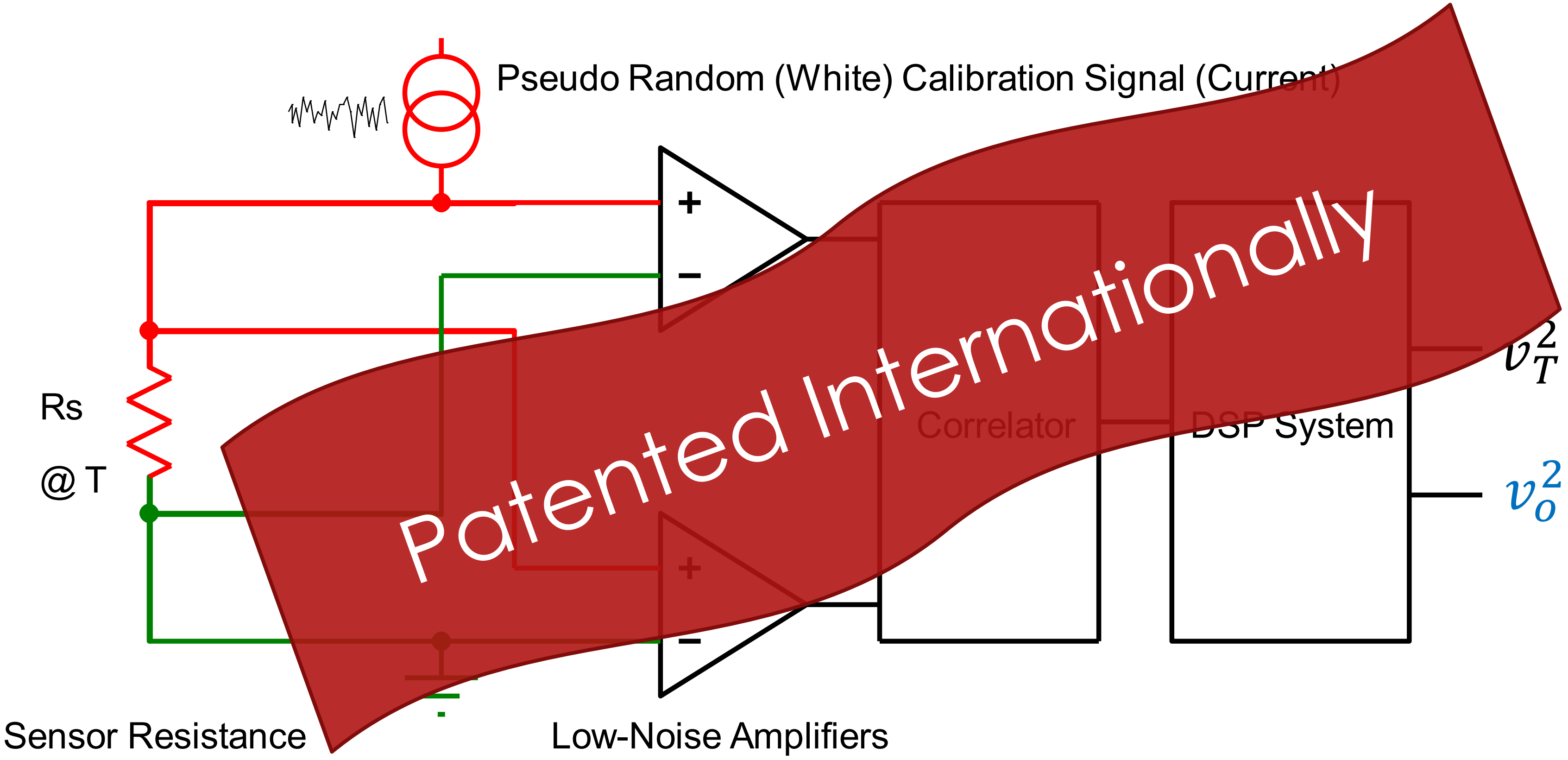
$$v_o^2$$

$$T = \frac{1}{4k}\left\{\frac{{v_T}^2/R_s}{\Delta f_1}\right\}$$

$$To = \frac{1}{4k}\left\{\frac{{v_0}^2/R_O}{\Delta f_2}\right\}$$

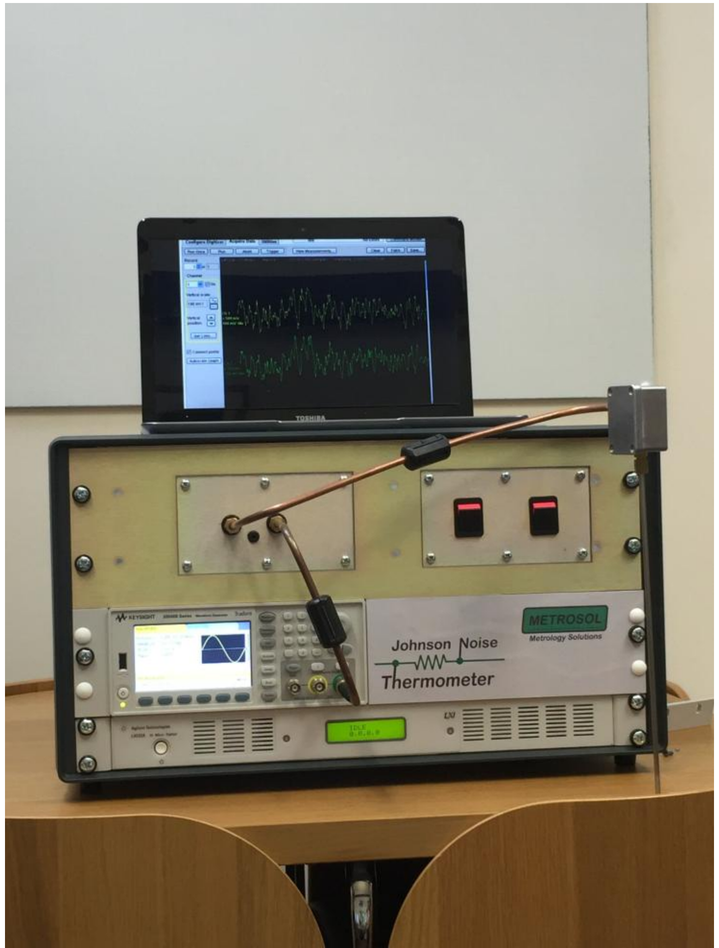
$$\boxed{T = T_O \frac{v_T^2 \; R_O}{v_0^2 \; R_s} \quad \text{if } \Delta f_1 = \Delta f_2}$$

Metrosol's JNT



$$T = \frac{{v_T}^2}{{v_0}^2} \frac{{i_0}^2 R_S}{4\,k}$$

JNT1 Proof of Principle Prototype: 2016



TEMPMEKO 2016 (JNT1):

- 35kg & 70L
- -20 to+120°C

Progress of JNT2 Programme

TEMPMEKO 2019 (JNT2):

- <1kg & <1L
- -100 to 1,000°C

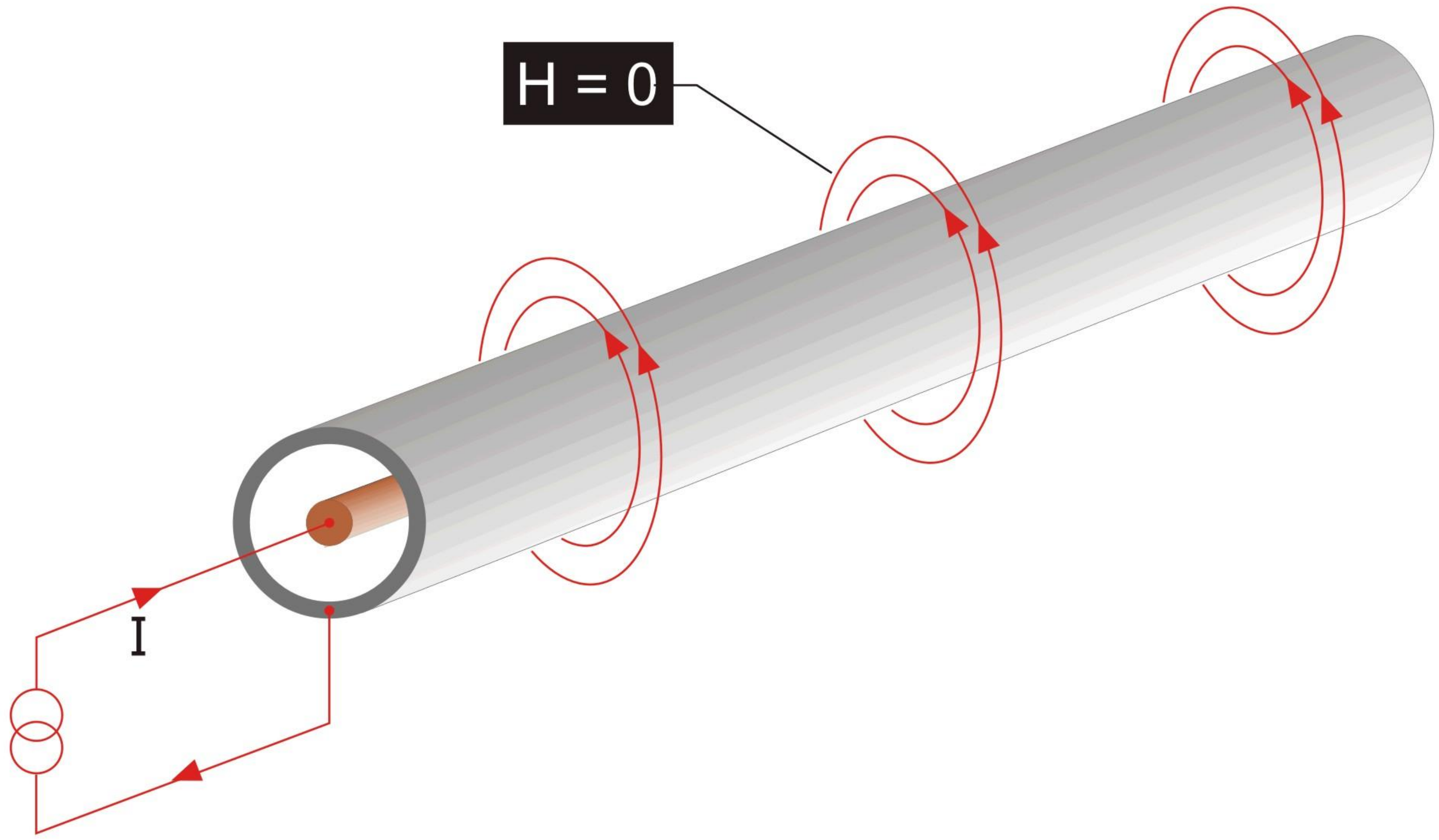
EMC (immunity to EM Interference)

- Thermal (Johnson) Noise signals are very small. A change of 0.01°C at 1,000°C corresponds to a change in the (RMS) noise voltage of:

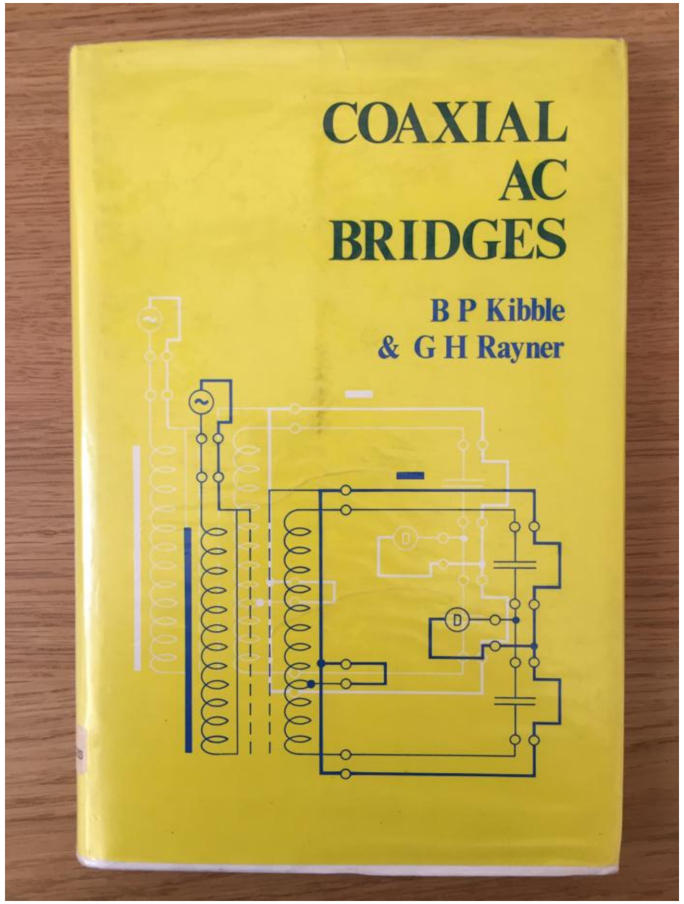
	Bandwidth = 100kHz	Bandwidth = 1MHz
Rsense = 100Ω	8.4nV	26.5nV
Rsense = 5kΩ	59.3nV	187.5nV

- All previous attempts have failed to achieve significant immunity
- Simply putting the electronics into a "screened box" is completely inadequate
- Extreme EMC hardening measures are required to achieve adequate immunity

Full Coaxial Design for EMC

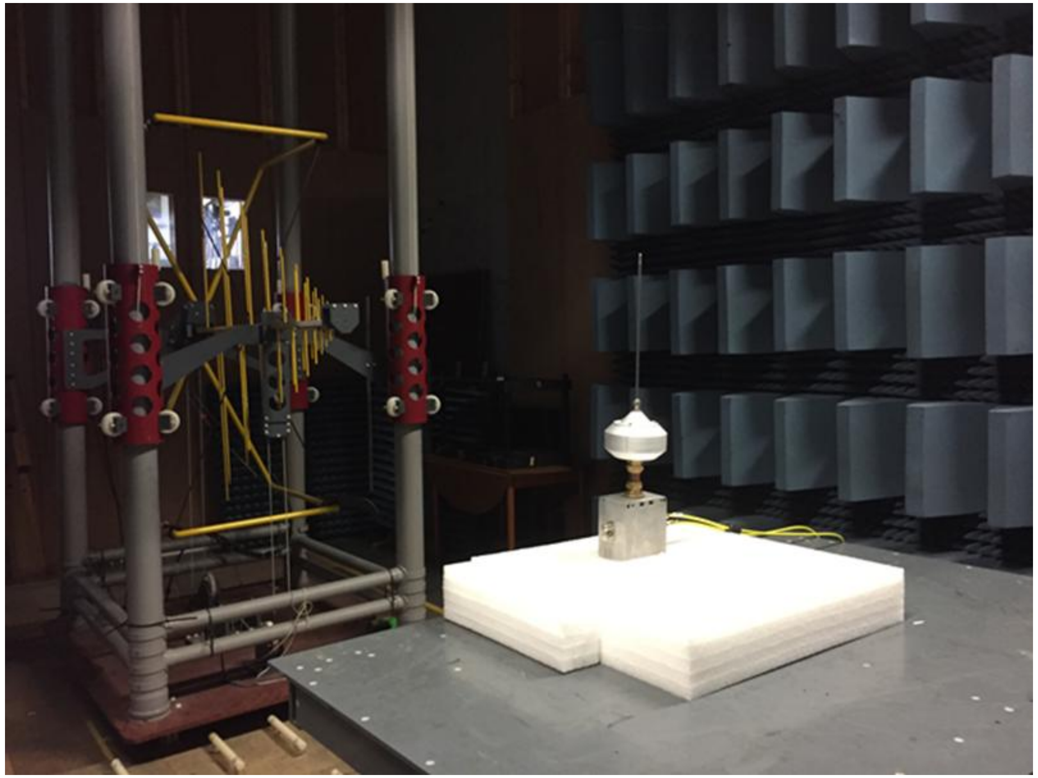


Full Coaxial Design for EMC

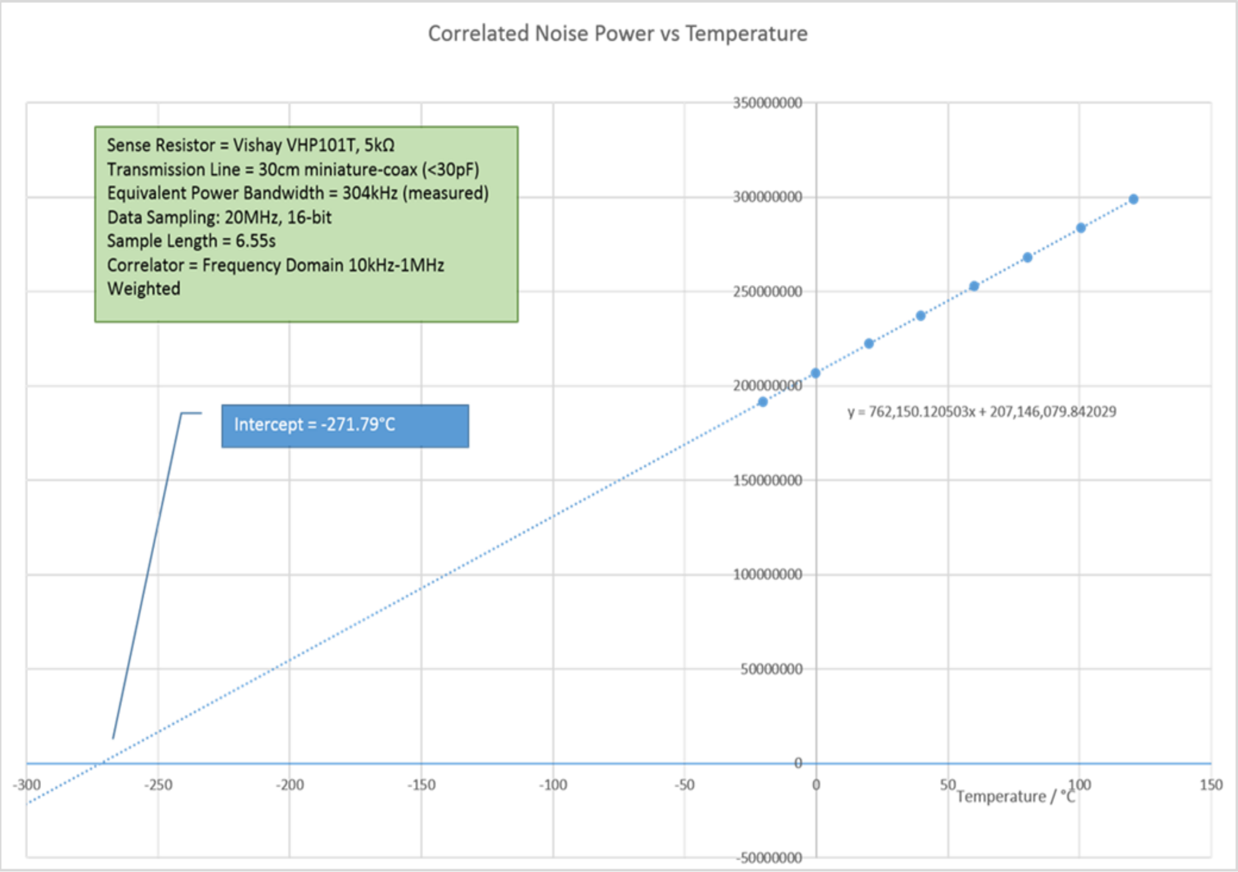


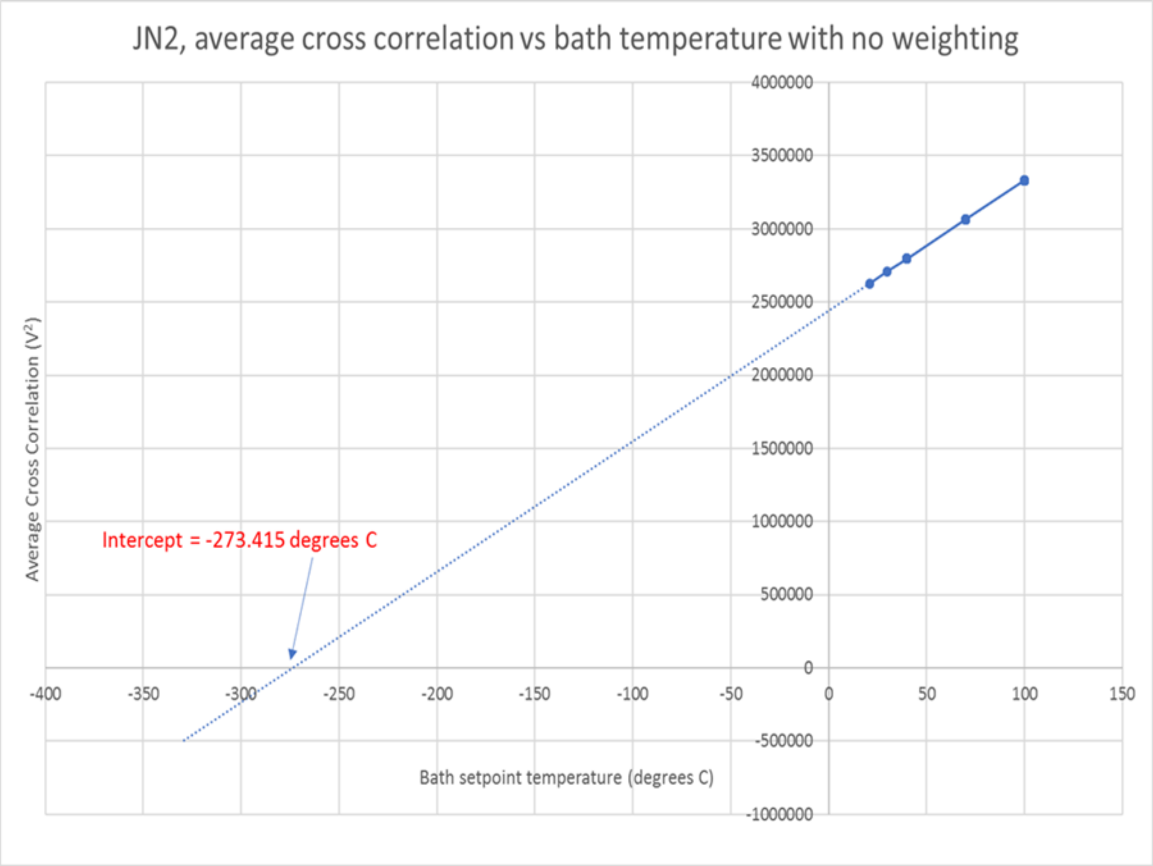
Immunity Tests at Test Laboratory

- 8^{th} May 2018: Passed EMC tests to EN61000-4 & EN55011:2009
- Tested to (harshest) Heavy Industrial level of immunity ($10Vm^{-1}$)



JNT2 Performance Improvements





JNT:JNT2 Performance Comparison

	Original JNT Project	JNT2 Project
Zero Offset	-1.36°C	+0.26°C
Noise (standard deviation for 6s samples)	0.14°C	0.24°C [1]
EMC Performance: Immunity Emmisions	Normal Lab (Unknown)	**Excellent** $10Vm^{-1}$ (heavy industrial limit) Below measurement limits

- Note 1: The improved design has better accuracy indicated by the reduced zero offset. Compromises necessary to improve some performance improvements were expected to incur to an acceptable 20% increase in the measurement noise. Actual measurement showed measurement noise increasing by 70%. This is being investigated to find the cause and solution so as to optimise the design.

World First: JNT Capable of working in electrically noisy environment

Why a Johnson Noise Thermometer?

- It's a primary thermometer, so:
  - It's completely insensitive to the condition of the sensor
  - So… it doesn't drift
  - Its calibration is traceable to electrical standards and not artefacts
  - Calibration will be much quicker (& so cheaper thermometers) since you only need to calibrate the electronics and not the sensor
  - Above 660°C it could replace noble metal thermocouples
  - Below 660°C it could be used to check sealed fixed point cells
  - It is a practical thermometer using the new Kelvin unit

JNT2 Programme – What Next

- Fully engineered production standard instrument by:
  - 29th September 2020 (currently running I week behind the plan)
- You can:
  - See existing (working) prototype on the Isotech stand here at Tempmeko
  - Follow our progress on:
    - Website: www.johnson-noise-thermometer.com
    - Facebook page: www.facebook.com/johnsonnoisethermometer

Thank you for coming, have a safe journey home… see you at the next TEMPMEKO!