Sensor Analysis of Uncertainty:

Motor Temperature:

Motor → KTY81-210 temperature sensor → Motor Controller →SCADA

Assuming no thermal error from the thermal circuit and positioning of the temperature sensor relative to the motor coils on the motor.

Assume error from the individual components is independent.

KTY81-210: https://emrax.com/wp-content/uploads/2018/08/KTY81-251.pdf

Datasheet gives temperature error in Kelvin as a function of ambient temperature. The motor is expected to operate over temperatures from 0 °C to 60 °C. The standard uncertainty of the KTY81-210 temperature sensor will be approximated by the RMS of temperature errors from -10 °C to 70 °C.

RMS of error = ±1.84 K

Emsiso emDrive 500 motor controller: eDrive_firmware_specifications_v1_1.pdf (page 70)

0x2025: Motor temperature reported to the nearest degree C. Assume there is no additional error introduced in the analog to digital conversion in the motor controller.

The motor controller passes this value to SCADA over CAN. SCADA reports this value without any additional calibration.

Uncertainty from quantization error = $\text{sqrt}(\Delta^2 /12) = \text{sqrt}(1^2/12) = \text{sqrt}(1/12) = 0.289$ °C

Standard uncertainty of motor temperature = RMS(known uncertainties) = 1.86 °C

Motor Controller Temperature:

Unknown temperature sensor → Motor Controller →SCADA

Assuming no thermal error from the thermal circuit and positioning of the temperature sensor inside the motor controller.

Assume error from the individual components is independent.

Emsiso emDrive 500 motor controller: eDrive_firmware_specifications_v1_1.pdf (page 70)

0x2026: Controller temperature reported to the nearest degree C. Assume there is no additional error introduced in the analog to digital conversion in the motor controller.

The motor controller passes this value to SCADA over CAN. SCADA reports this value without any additional calibration.

Uncertainty from quantization error = $\mathrm{sqrt}(\Delta^2 /12) = \mathrm{sqrt}(1^2/12) = \mathrm{sqrt}(1/12) = 0.289$ °C

Standard uncertainty of motor temperature = RMS(known uncertainties) = 0.289 °C

TSI Voltage Sensor:

Motor Controller Voltage and Accumulator side of AIRs Voltage

All voltages are divided by a 1/61 voltage divider with 1% resistors.

There are two op amp circuits set up to measure the differential voltage between HV+, HV- and MC+, HV-. The differential output is then measure on an 8-bit ADC operating from 0V to 5V. This gives a quantization step/resolution of 5V/255 = 0.02 V measured after the differential op amp.

Uncertainty from quantization = = sqrt(Δ^2 /12) = sqrt(0.02^2/12) = 0.00578 V

From the 1/61 voltage divider this becomes an uncertainty of 0.35 V.

GLV Standalone Multimeter Voltage

This meter has an operating range from 6.5 – 100 V and reports voltage within 1%.

Thus this meter has an uncertainty ranging from 0.065 V to 1 V.

The standard uncertainty can be approximated by the RMS of this uncertainty range.

This yields a standard uncertainty of 0.596 V.

$$\sqrt{\frac{1}{1-0.065}\int_{0.065}^{1} x^2\,dx} = 0.596999$$

GLV Standalone Multimeter Current

The meter has an operating range from 0 – 100A and reports current within 1%.

Thus this meter has an uncertainty ranging from 0 A to 1 A.

The standard uncertainty can be approximated by the RMS of this uncertainty range.

This yields a standard uncertainty of 0.577 A.

$$\sqrt{\frac{\int_0^1 x^2\,dx}{1-0}} = \frac{1}{\sqrt{3}} \approx 0.57735$$