Project Towards a true 8-digit digitiser

Workshop, 15 May 2026

IPQ, Lisbon

Characterization of passive components for use in a precision integrating analogue-to-digital converter

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Outline

Motivation:

Need for exact characterisation of critical components

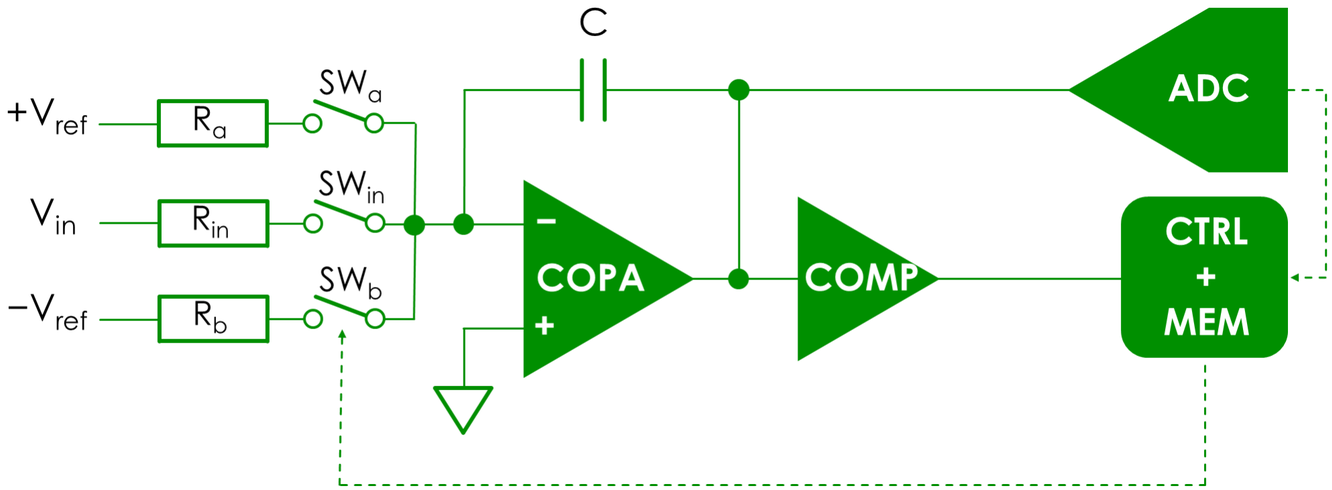
Testing the temperature and humidity sensitivity of

- Precision resistance arrays
- Capacitors

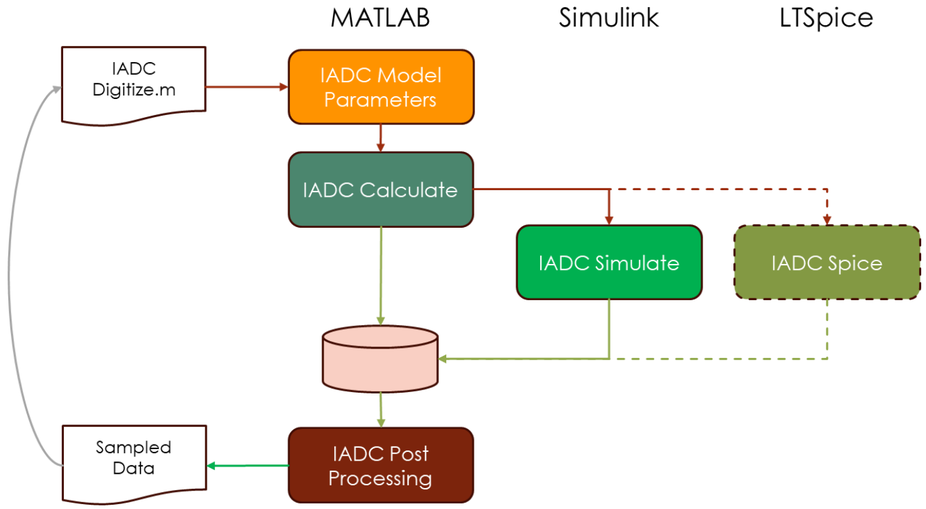
Testing the dielectric absorption of capacitors

Conclusion

General IADC structure

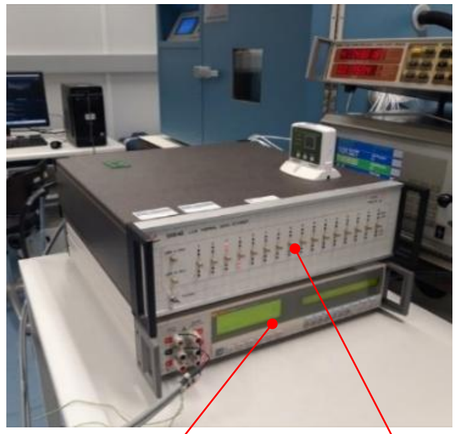


IADC MODEL AND SIMULATION
MATLAB & SIMULINK



Resistor networks ratio temperature and humidity dependence

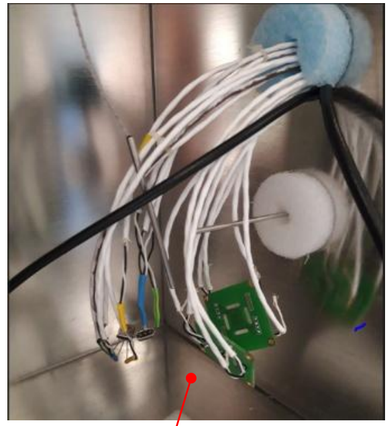
Setup



Multimeter
Fluke 8508A

Low Thermal Scanner Data Proof
6664B

Climatic Chamber
Thunder Scientific 2500



Resistor inside the climatic chamber

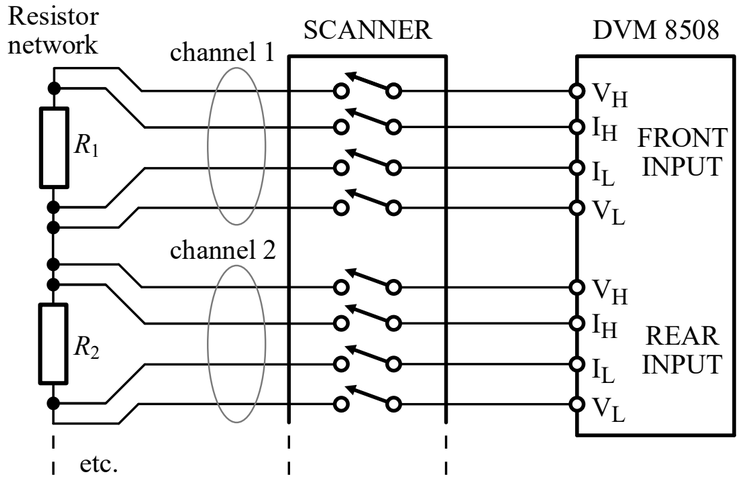
Three resistor networks with the same nominal ratio 1:1

- R_1 10 kΩ / 10 kΩ
Hermetic 3-pin (through-hole)

- R_2 4 x 10 kΩ

Plastic 8-pin (surface-mount)

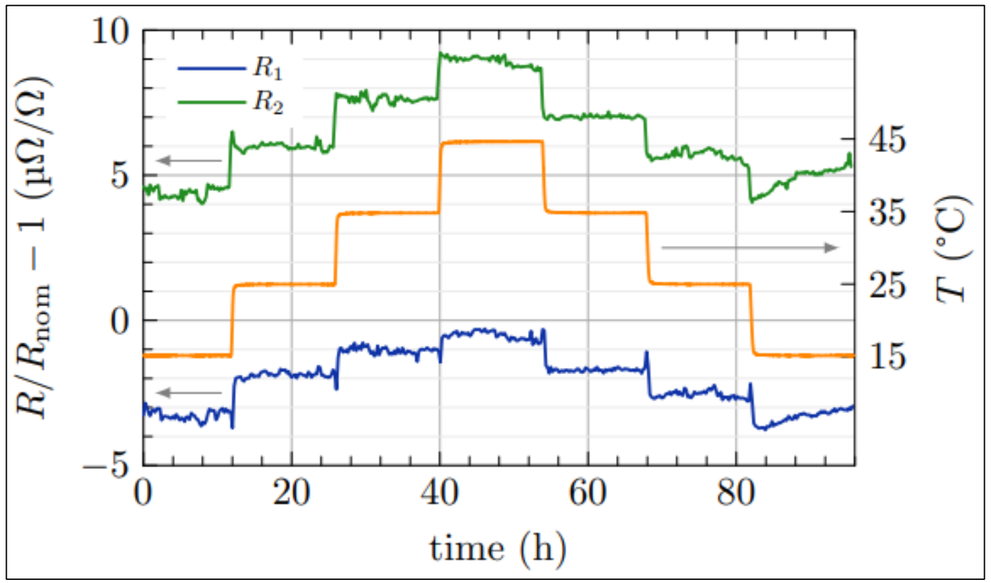
- R_3 10 kΩ / 10 kΩ
Plastic 3-pin (surface mount)



Ratio function of a high-resolution multimeter (Fluke 8508)

Sequential two-channel measurements and outputs the resistance ratio directly
Measurement uncertainty is dominated by short-term noise and ADC linearity
“True-ohm” function: measurements with reverse polarity

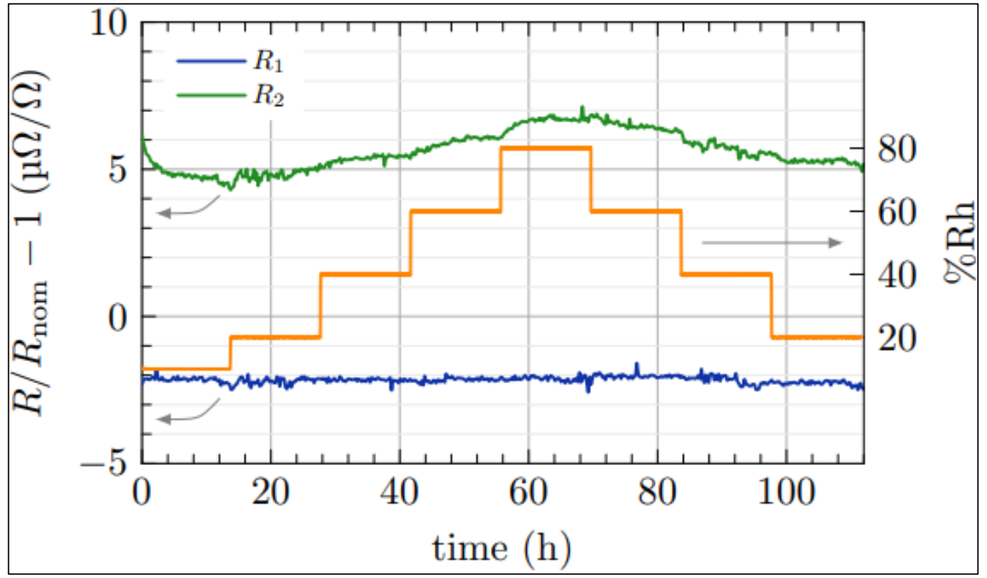
Validation: two matched 10 kΩ standards over six days -> standard deviation = 9×10^{-8}



Ratio sensitivity

R_1: 9×10^{-8} K^{-1}
R_2: 14×10^{-8} K^{-1}
R_3: -5×10^{-8} K^{-1}

R_1: 0.3×10^{-8} %rh^{-1}
R_2: 3×10^{-8} %rh^{-1}
R_3: -5×10^{-8} %rh^{-1}

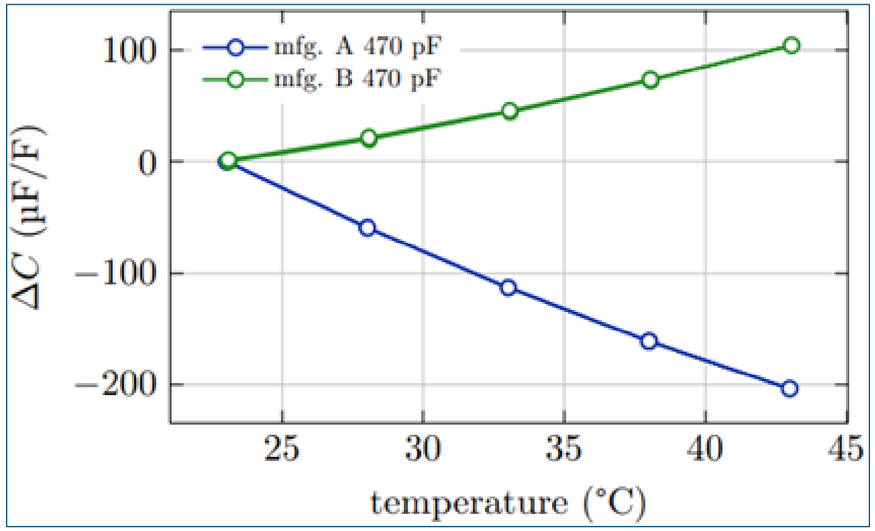


Mean value and standard deviation of the mean for the **relative error of the measurement ratio**

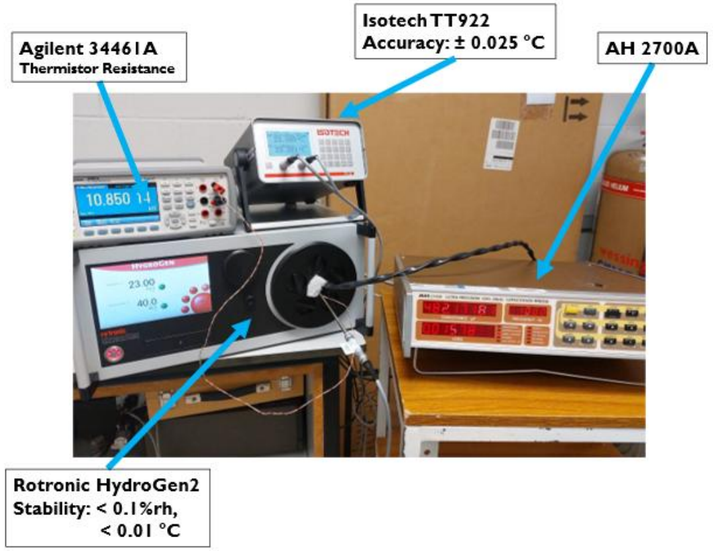
T (°C)	δr(R_1) (μΩ/Ω)	σ (μΩ/Ω)	δr(R_2) (μΩ/Ω)	σ (μΩ/Ω)	δr(R_3) (μΩ/Ω)	σ (μΩ/Ω)
15	–3.31	0.02	4.36	0.03	–27.22	0.04
25	–1.85	0.02	5.99	0.02	–27.25	0.03
35	–1.06	0.02	7.59	0.02	–28.01	0.03
45	–0.48	0.02	8.95	0.02	–28.47	0.03
35	–1.71	0.01	7.02	0.01	–28.60	0.01
25	–2.53	0.02	5.75	0.02	–27.80	0.03
15	–3.30	0.02	4.96	0.03	–26.81	0.03

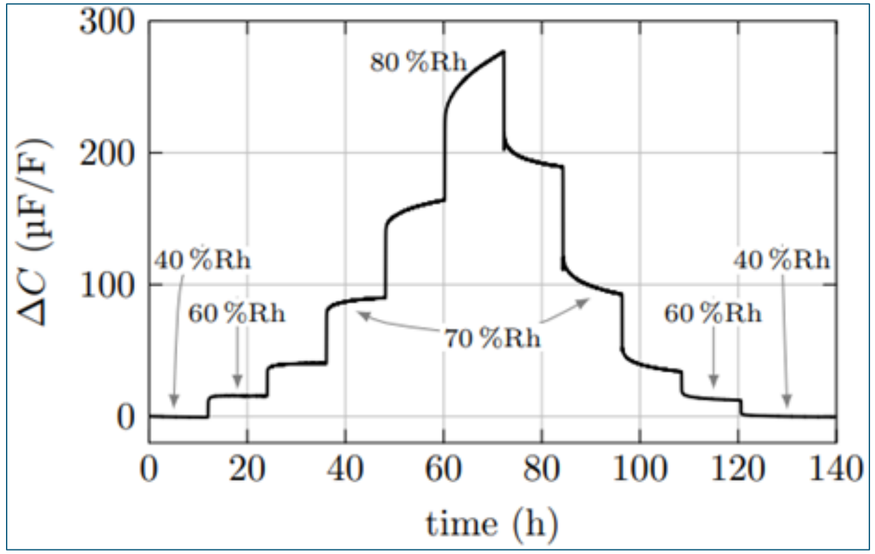
RH (%rh)	δr(R_1) (μΩ/Ω)	σ (μΩ/Ω)	δr(R_2) (μΩ/Ω)	σ (μΩ/Ω)	δr(R_3) (μΩ/Ω)	σ (μΩ/Ω)
20	–2.22	0.02	4.78	0.02	–26.68	0.05
40	–2.17	0.01	5.41	0.01	–28.25	0.02
60	–2.14	0.01	5.95	0.02	–29.12	0.01
80	–2.12	0.01	6.71	0.01	–29.43	0.02
60	–2.03	0.01	6.44	0.01	–27.96	0.03
40	–2.20	0.03	5.65	0.03	–27.19	0.03
30	–2.24	0.01	5.29	0.01	–26.48	0.01

Capacitor Temperature and humidity dependence

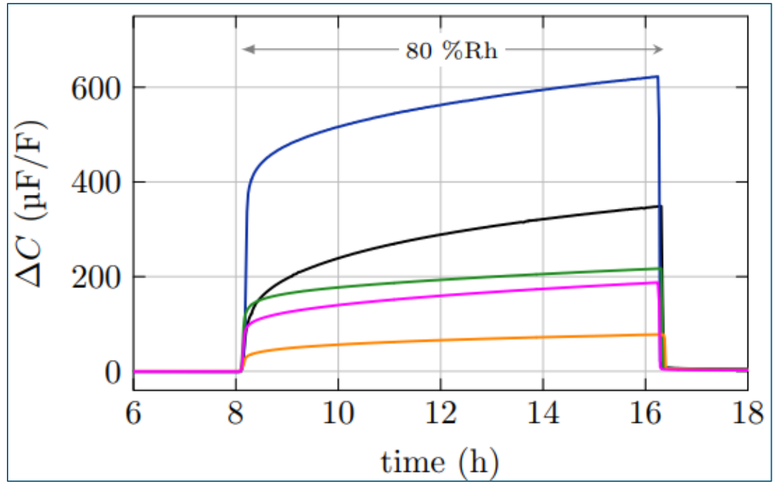


A (batch 1)	- 12.2 ×10^{-6} K^{-1}
A (batch 2)	-12.6 ×10^{-6} K^{-1}
B	3.1×10^{-6} K^{-1}



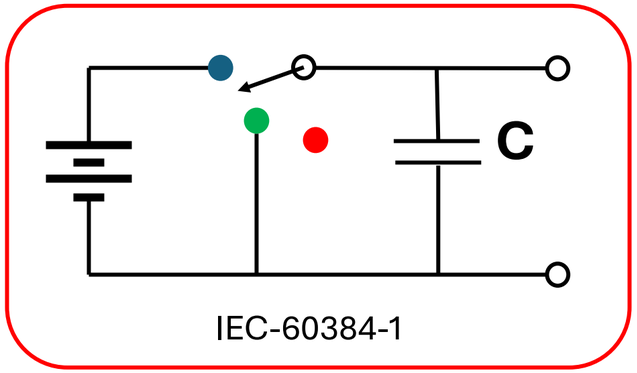


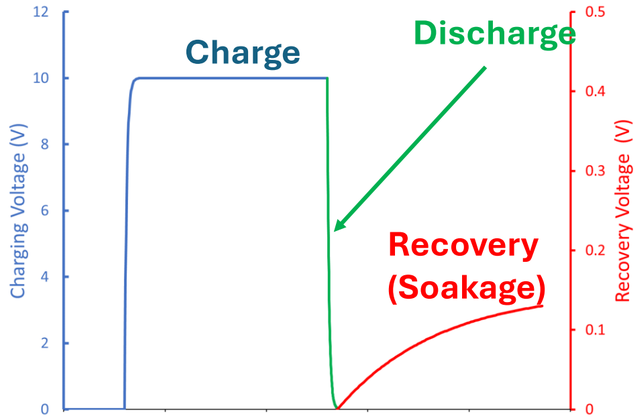
Increasing sensitivity with higher humidity and noticeable hysteresis



Batch of five manufacturer B 470 pF capacitors

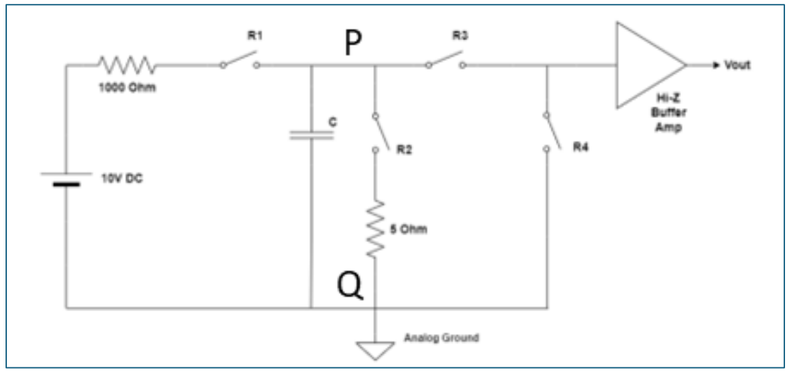
Measurement of the dielectric absorption of capacitors





Measurement of recovery voltage

Fluke 8588A DMM

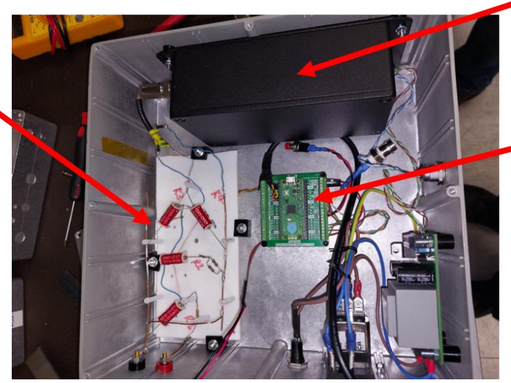


Relay Board

COTO Guarded
Glass-encapsulated relays
mounted on Teflon base

Buffer Amplifier

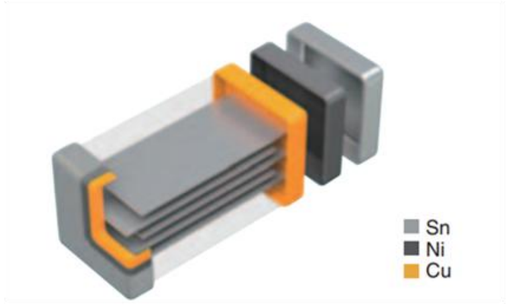
ADA4530-1 Op amp
Triaxial input with guarding



Relay Control Board

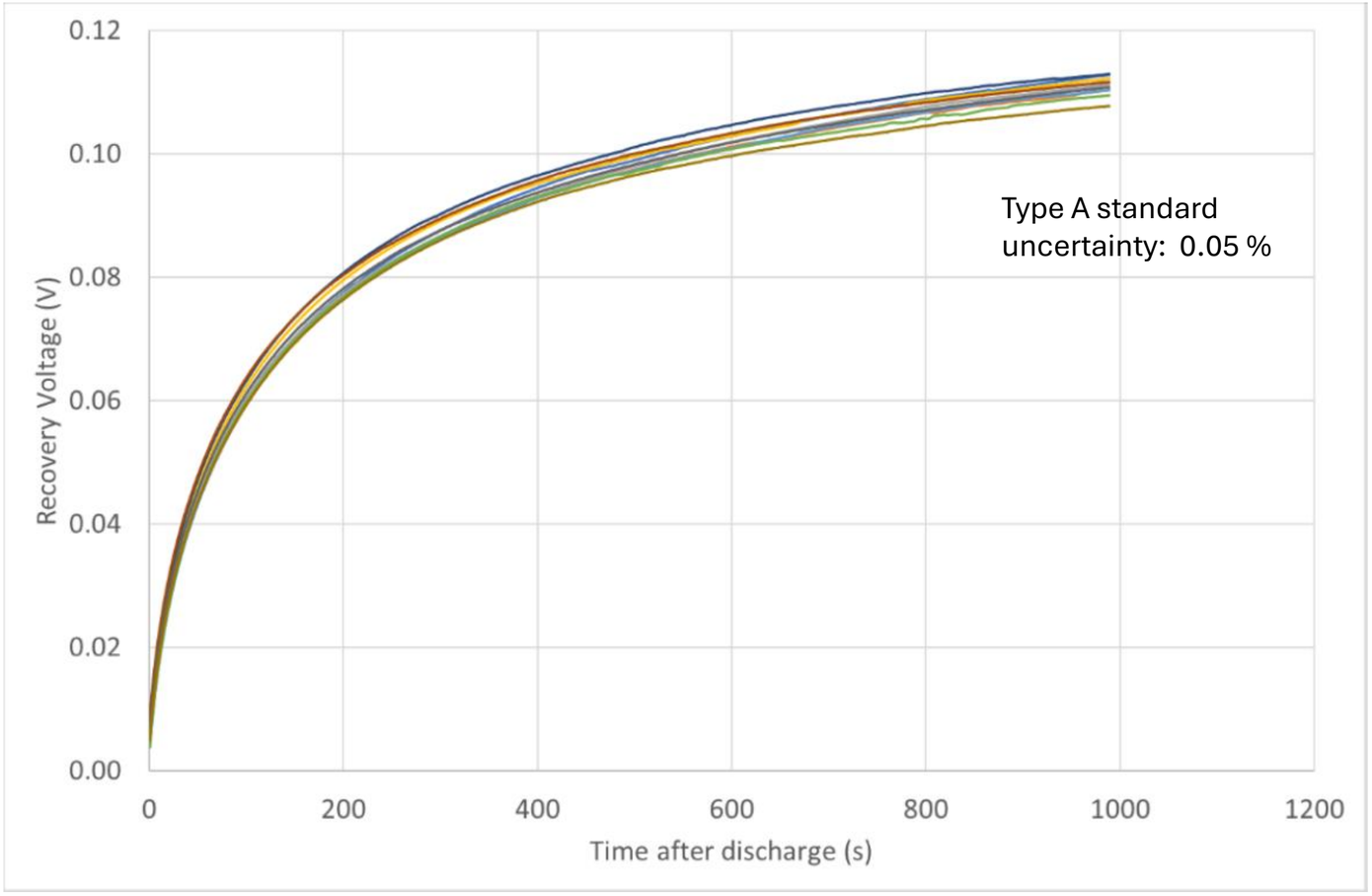
Rasp. Pi PICO
CircuitPython

Measurement of the dielectric absorption of capacitors

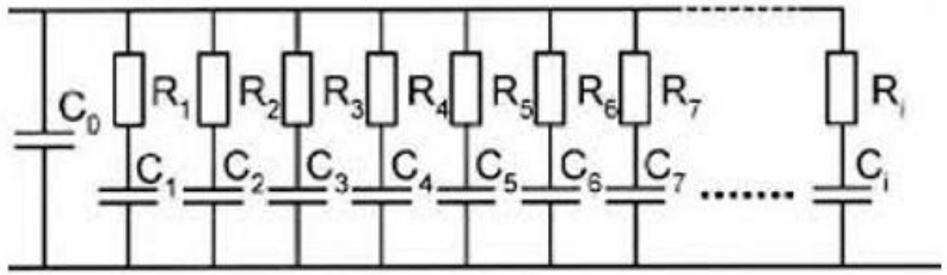


TDK 470 pF SMD Ceramic NP0

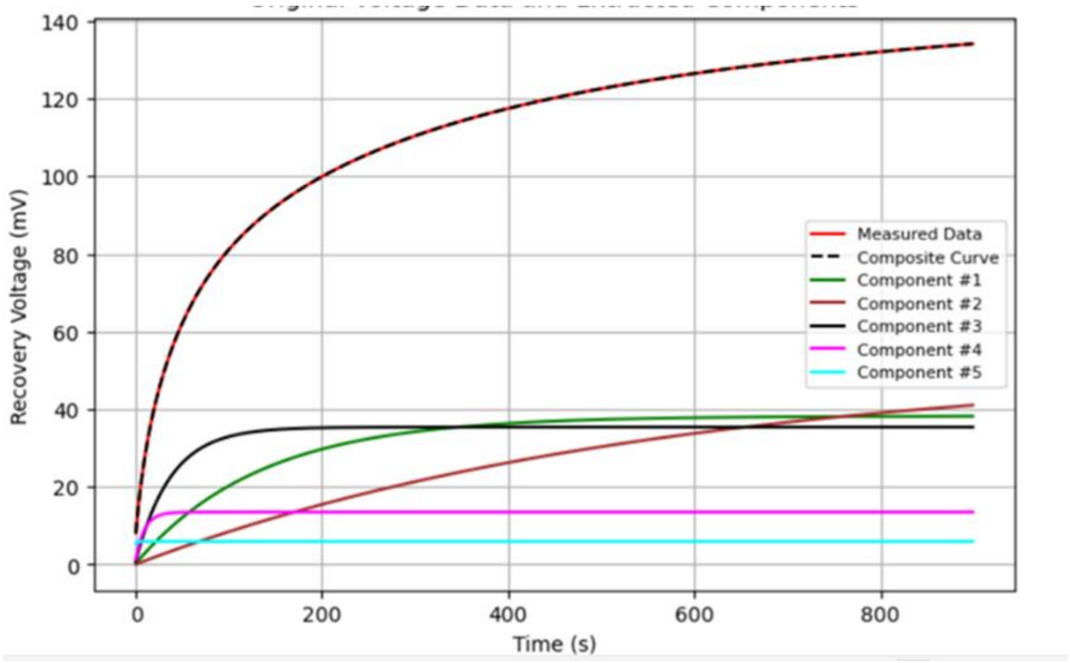
Charging voltage:	10 V
Charging time:	900 s
Discharge :	1 s



Model of the dielectric absorption of capacitors



$$V_{recovery}(t) = \sum_{i=1}^{n} V_i(t) = \sum_{i=1}^{n} a_i \cdot \left(1 - e^{-b_i \cdot t}\right)$$



Component	R_i	C_i
	(Ω)	(F)
1	8.25 x 10^{13}	1.78 x 10^{-12}
2	2.55 x 10^{14}	2.41 x 10^{-12}
3	2.56 x 10^{13}	1.62 x 10^{-12}
4	1.81 x 10^{13}	5.71 x 10^{-13}
5	1.61 x 10^{13}	3.10 x 10^{-14}

Conclusions

It was demonstrated the possibility to characterize passive componentes

- using traceable measurements
- with an uncertainty level useful to modeling ADC circuit

For some devices **humidity was found to induce larger** and more variable effects **than temperature**

Dielectric absorption in ceramic capacitors was measured

- with high resolution and
- modelled using a five-element RC network, offering a useful tool for IADC design simulations.

Thank you for your attention

For details: https://true8digit.eu/

Acknowledgement
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