ECSA-12
2025
Conference

The 12th International Electronic Conference on Sensors and Applications

12–14 November 2025 | Online

Impact of Electrical Noise on the Accuracy of Resistive Sensor Measurements Using Sensor-to-Microcontroller Direct Interface

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INTRODUCTION & AIM

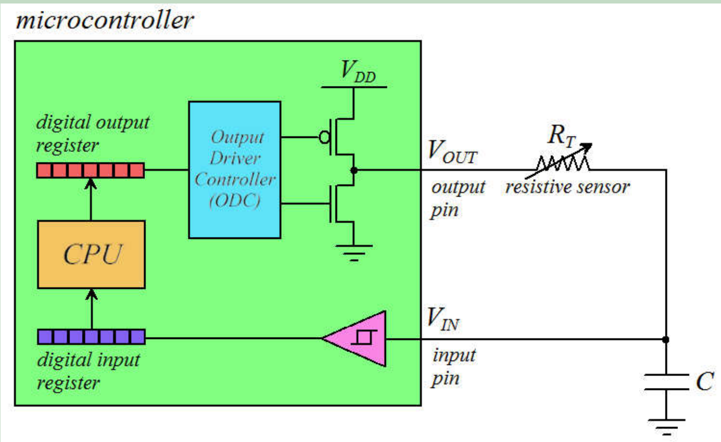
Wireless sensor networks (WSNs) implemented in the paradigm of the Internet of Things (IoT) are characterized by a large number of distributed sensor nodes that make measurements in-the-field.

Sensor-to-microcontroller direct interface (SMDI) is a technique used for the measurement of resistive sensors without the use of an ADC. In SMDI based measurements, the sensor is directly interfaced with the digital input-output pins of the general purpose input output (GPIO) interface of microcontrollers and FPGAs. Compared with the measurements performed with an ADC, SMDI is characterized by lower cost and lower power consumption.

The impact of electrical noise on the accuracy of resistive sensor measurements using SMDI is investigated and compared with the reference case of measurements carried out with a 12-bit ADC.

METHOD

SMDI exploits the Schmitt triggers integrated in the GPIO interface of microcontrollers to create an astable oscillator whose period is measured to estimate the resistive sensor value R_T.



Electrical level simulations with Spice were carried out for seven values of R_T, nine values of the peak-to-peak voltage ($V_{noise,PP}$) and two measurement setups:

1) SMDI based measurements (using a Schmitt trigger with threshold voltages V_H = 1.9V and V_L = 1.4V).

2) ADC based measurements (using the 12-bit differential input ADC LTC2311-12).

RESULTS & DISCUSSION

In SMDI measurements, the average value of R_T decreases linearly with the increase of $V_{noise,PP}$ and deviates from its nominal value as $V_{noise,PP}$ increases.

The relative deviation (in percent) of the measured resistance R_T from its nominal value can be defined by:

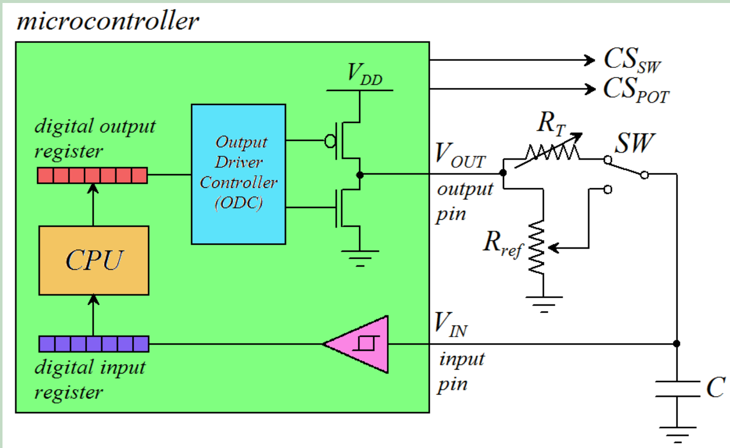
$$\Delta_{ERROR} = 100 \times \left| \frac{R_{T,meas} - R_T}{R_T} \right|$$

where $R_{T,meas}$ is the measured value of the resistive sensor while R_T is its nominal value. For low levels of noise ($V_{noise,PP}$=1.25 mV), SMDI achieves very good accuracy (Δ_{ERROR} < 1%, i.e. better than ADC). For high levels of noise ($V_{noise,PP}$=100 mV), SMDI achieves poor accuracy (Δ_{ERROR} > 10%, i.e. worse than ADC).

SMDI-based measurements	R_T						
	100Ω	250Ω	500Ω	1000Ω	2500Ω	5000Ω	10000Ω
$V_{noise,PP}$=1.25mV	1.004%	0.416%	0.178%	0.070%	0.068%	0.127%	0.155%
$V_{noise,PP}$=100mV	11.502%	14.239%	15.054%	15.803%	17.417%	18.746%	18.451%

ADC-based measurements	R_T						
	100Ω	250Ω	500Ω	1000Ω	2500Ω	5000Ω	10000Ω
$V_{noise,PP}$=1.25mV	2.477%	0.837%	0.947%	0.301%	1.398%	0.505%	2.601%
$V_{noise,PP}$=100mV	6.965%	3.276%	2.130%	1.550%	2.025%	2.463%	4.481%

A novel measurement setup is proposed, that features a digital potentiometer R_{ref} and an analog switch SW. It can be used to characterize the noise signal and to compensate the measured value of R_T.



CONCLUSION

The accuracy of resistive sensor measurements by SMDI in presence of high levels of noise can not be improved by averaging on multiple samples.

A possible solution to mitigate the impact of noise was proposed using a new measurement setup.