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MDPI

Accuracy of NTC Thermistor Measurements Using the Sensor to Microcontroller Direct Interface

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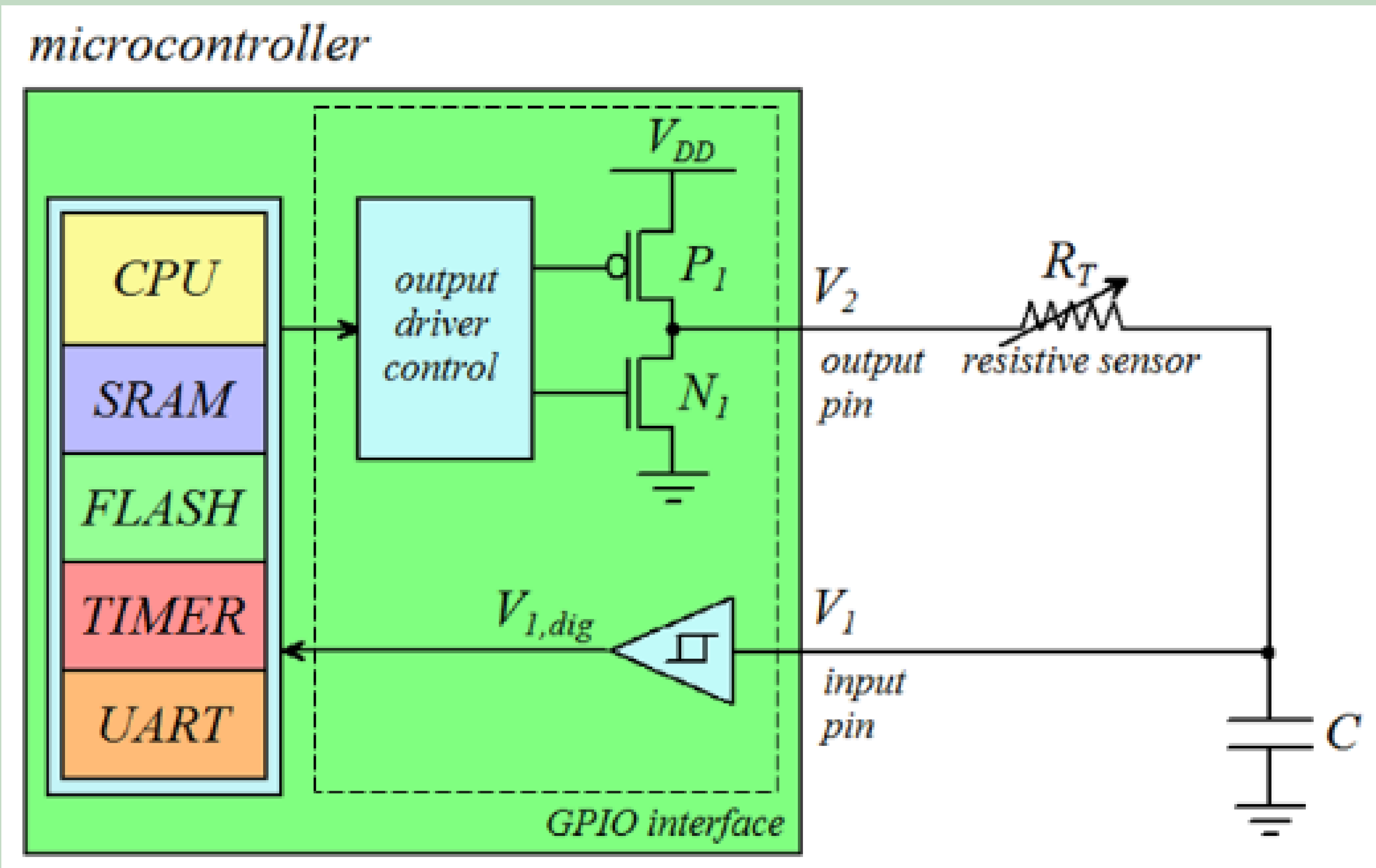
INTRODUCTION & AIM

Portable and wearable sensor systems are usually based on microcontrollers or FPGAs, where the sensors are measured using an analog-to-digital converter (ADC). An alternative solution, featuring lower cost and power consumption, is the sensor-to-microcontroller direct interface (SMDI), a technique where the sensor is measured exploiting the general purpose input output (GPIO) interface present on any microcontroller or FPGA.

In this paper, the measurement accuracy of a non-linear temperature sensor (NTC 3950) using SMDI was evaluated by means of LTSpice simulations in the temperature range from −10 °C to 80 °C. Two different models (Steinhart-Hart model and polynomial model) were used to estimate the temperature value from the measured sensor resistance and their impact on the measurement accuracy was compared.

METHOD

The circuit to measure the temperature sensor resistance using SMDI is presented in the figure.



The Schmitt trigger of the GPIO interface (with thresholds V_H and V_L) is used as analog comparator. Its output $V_{1,dig}$ is read by the CPU to drive the output pin as the complement of $V_{1,dig}$. An astable oscillator is created using two external components (R_T and C). The sensor resistance R_T can be determined by measuring the oscillator period T_P.

$$R_T = \frac{T_P}{C \cdot log\frac{V_H(V_{DD}-V_L)}{V_L(V_{DD}-V_H)}} \qquad (1)$$

RESULTS & DISCUSSION

The circuit used to measure the temperature sensor was simulated with LTSpice. The sensor resistance R_T was calculated with equation (1) by measuring the oscillation period T_P with a timer of frequency 64 MHz.

The temperature T (in °C) is estimated from the sensor resistance R_T (in kΩ) using two different non-linear models, that are compared in terms of accuracy.

1. Steinhart-Hart model

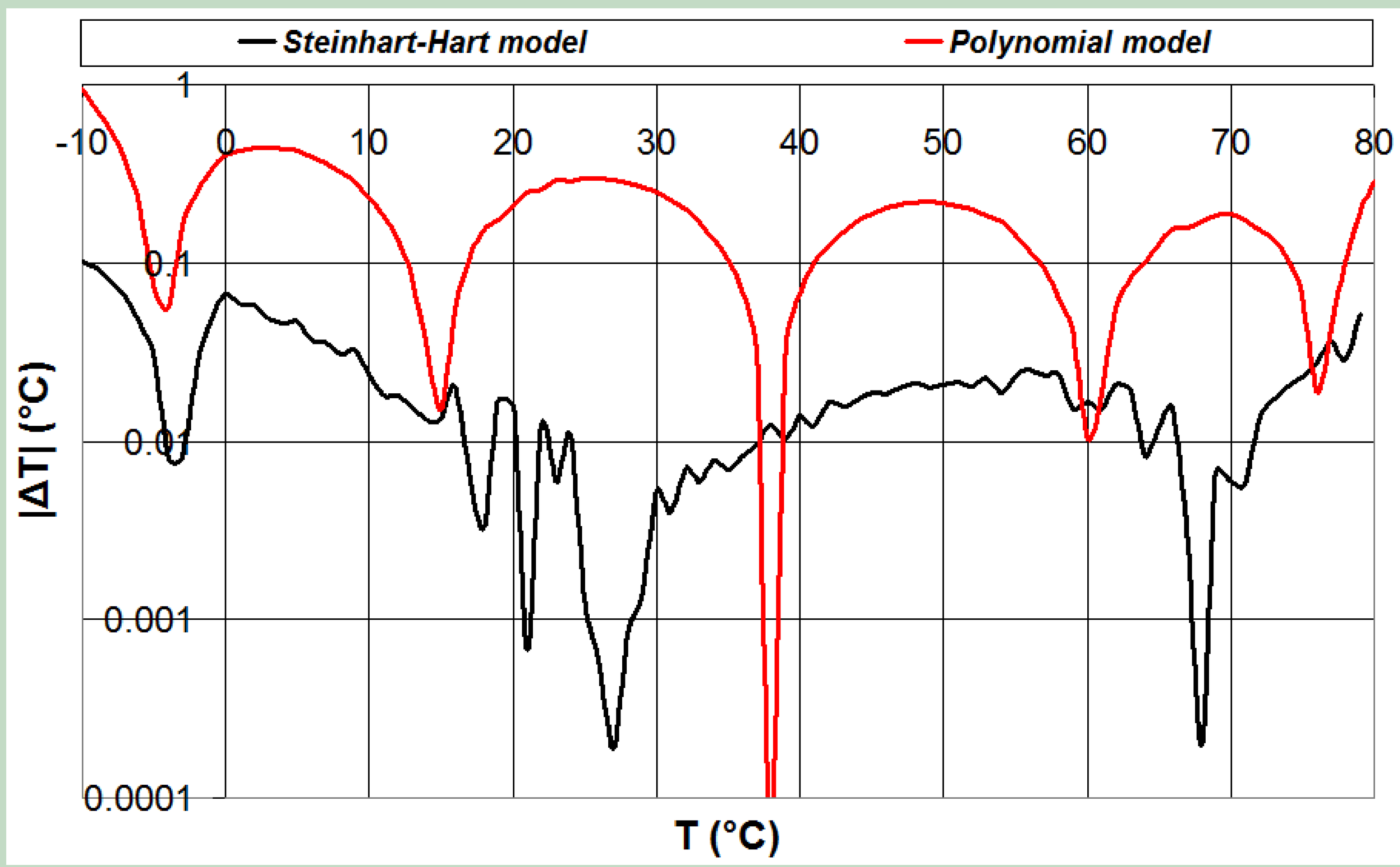
$$T = \frac{1}{k_1 + k_2 logR_T + k_3(logR_T)^3} - 273.15 \qquad (2)$$

where k_1, k_2 and k_3 are parameters used to fit the model with the experimental data.

2. Polynomial model

$$T = h_1 + h_2R_{eq} + h_3R_{eq}^2 + h_4R_{eq}^3 \qquad (3)$$

where the sensor resistance R_T in the measurement circuit is replaced by a resistance $R_{eq} = R_T \,||\, R_P$ with R_P = 5.41 kΩ. h_1, h_2, h_3 and h_4 are parameters used to fit the model with the experimental data.



Simulations were carried out with a white noise of peak values ±50mV superimposed to V_1 to simulate a real measurement scenario. The temperature estimation using the Steinhart-Hart model provides more accurate results (average error 0.078 °C).

CONCLUSION

Non-linear resistive temperature sensors can be measured with good accuracy using SMDI. The results have shown that the best accuracy can be obtained using the Steinhart-Hart model.