

# Electronic Circuit for Temperature and Humidity measurements for the purpose of the Mini Robot Caterpillar

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## Summary:

The paper presents the design of an electronic circuit for temperature and humidity measurements for a Mini Robot Caterpillar. There are two types of circuits proposed: wired and wireless. The preliminary results of the integration of the thermoresistor into the 3D-printable body of the robot is presented, i.e. opportunities and limitations in the context of integrating a sensor with a 3D-printed movable structure. Additionally, the possible ways for miniaturizing the measuring system are discussed.

**Keywords:** thermoresistor, 3D printing, humidity sensor, circuit, wireless communication

## Introduction

The goal of the Mini Robot Caterpillar is the environmental monitoring in hard to reach places like ventilation shafts or fallen buildings. We were inspired by the other research of meso- or micro-scale soft robots that mimicked nature, such as a bioinspired footed robot [1] or a shape-changing crawling robot [2]. The robot, we aimed to develop, must fulfill the following restrictions: 1) to be 10 mm long so that its body can fit in tiny spaces, 2) to measure temperature in the range of 20-200°C. Its movement is based on the remote thermal actuation. For this, the body of the caterpillar was 3D-printed in a hybrid form from a developed composite and the commercial UV-sensitive resin. By incorporating, e.g. temperature or gas sensor, the robot could ensure safety of workers and rescuers.



*Fig. 1. The schematic illustration of the Mini Robot Caterpillar.*

Except for the electronic circuit to serve for temperature measurements, the assembly trials were conducted to integrate the thermoresistor into the 3D-printable component similarly to work reported in [3], where embedding components using an additive process was demonstrated on a 0201 LED. In this paper, we propose designs of two circuit types - wired and wireless with the latest being expanded about wireless communication.

## Circuits for temperature measurements

For the wired circuit, its control was provided by the microcontroller raspberry pi pico (Raspberry Pi Foundation, UK). As the sensor we chose a thermoresistor PT-1000 (RS PRO, PL), with a 4-wire connection eliminating measurement error that comes from the wire resistance, as presented in Fig.2b-c. In order to confirm the wired circuit functionality, a reference PT-500 was connected to a digital multimeter SDM3045XI (SIGLENT Technologies, CPR). Both sensors were put on a hot plate, in the ambient air, hence they were simultaneously exposed to set different temperatures (23°C, 100°C, 150°C and 200°C). Figure 2a presents the results of the measured temperature by the sensors in the wired circuit. There is a linear dependency, as expected, and a slight difference in acquired temperatures, for 150°C. and 200°C.

For the wireless version, a two in one digital sensor was selected, i.e. measuring the humidity and the temperature, DHT11 (D-Robotics UK). The circuit also included the transponder. It consisted of a transmit antenna module RF 433 MHz and a microcontroller Arduino UNO R3 module that was programmed in the ArduinoIDE. Meanwhile, the receiver was composed of a microcontroller Arduino Nano, a receiving antenna module and an LCD display. The measurement data was superimposed on the carrier wave using amplitude-shift keying (ASK). The ASK signal was then transmitted via a 433 MHz electromagnetic wave. The signal in the receiver was then demodulated, filtered and amplified, resulting in data being converted into a readable format. The information was then

displayed on the LCD screen as presented in Fig. 2d.

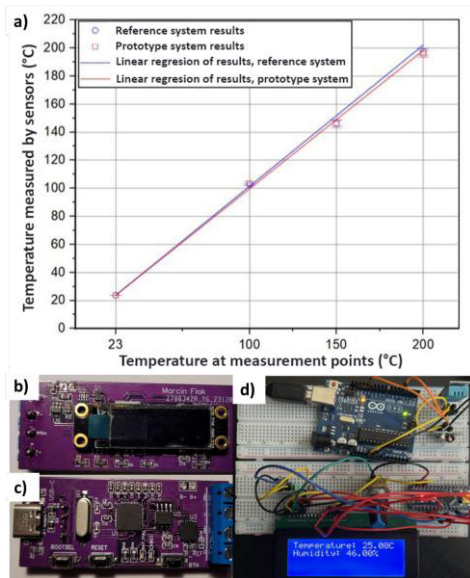


Fig. 2. The temperature measurements: a) the graph of the reference temperature vs. the temp. measurements received by the wired circuit; b-d) the digital photographs of the PCB circuits of the wired version - top (b) and bottom (c) views, respectively, and the wireless version (d);

### Assembly of the sensors with the 3D printable component

The Mini Robot Caterpillar was designed based on the preliminary study of the 3D-printed hybrid composite structure, i.e. the cantilever. To conduct trials to assemble the sensor to the 3D printed cantilever, its design was modified; inside lengthwise the cantilever the channels (dia. 350  $\mu\text{m}$ ) were included through which copper wires (dia. 50  $\mu\text{m}$ ) were interwoven. Next, the PT-1000 sensor was soldered (Fig.3a).

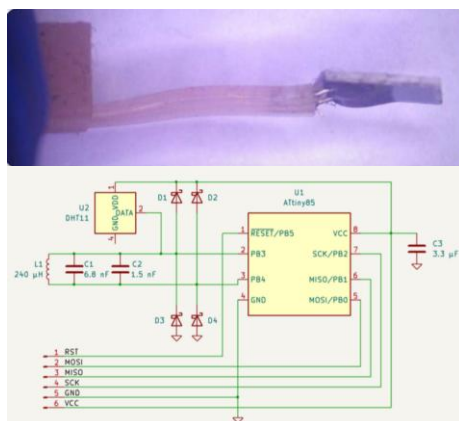


Fig. 3. The further development proof-of-concept for the Mini Robot Caterpillar: a) a digital photograph showing the integration of the temperature sensor in the 3D-printed structure b) the miniaturized transponder circuit.

The result of combining the sensor with the cantilever raised questions about its compatibility; the structure was bent due to the gravitational force. This significantly disrupts the bending of the cantilever, hence the movement of the Mini Robot. Because of the incompatibility in size between the transponder and the Mini Robot, a radio transmission with a dedicated LC circuit was proposed. Figure 3b presents the scheme of the circuit. Here, the Arduino module was replaced by a smaller ATtiny85 microcontroller (Atmel Corporation, USA). As a result, this transponder could also work as a passive power supply making the Mini Robot to be driven autonomously.

### Conclusions and Perspectives

We present the work related to the project of the remotely actuated Mini Robot Caterpillar. Our aim is to integrate with the Robot the temperature and humidity sensors. Two circuit types to enable sensor measurements and suitable for the Mini Robot Caterpillar were presented - a wired version and a wireless alternative. Moreover, for future development, it is necessary to challenge two issues: 1) a mismatch in size of the transponder and the mini robot, and 2) the sensor's integration with the Robot's body. For this, a dedicated LC circuit was proposed that is lighter and scaled down in size. This opens a new perspective in the integration of the sensors with the 3D-printed robot.

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### References

- [1] X. Wang et al. "Bioinspired footed soft robot with unidirectional all-terrain mobility.", *Materials Today* 35 (2020): 42-49.
- [2] B. A. Trimmer, V. Vishesh, P. Templeton, "Design and control of a soft, shape-changing, crawling robot.", arXiv:1509.07569.
- [3] S. Lungen, T. Tiedje, K. Meier, K. Nieweglowski and K. Bock, "Reliability of 3D additive manufactured packages," 2018 7th Electronic System-Integration Technology Conference (ESTC), Dresden, Germany, 2018, pp. 1-5, doi: 10.1109/ESTC.2018.8546417.