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Reliability of Raspberry Pi 3 temperature sensor at low voltage

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Abstract

An important variable in performing precise measurements is the power source. This paper shows the influence of low power on the measuring accuracy of the operation of the Raspberry Pi device and its sensor, and whether the obtained measurement uncertainties can be used for the measurements' relevance. To achieve the measurement result, the sensor and the device have a connection to a source with a variable power source that can simulate the desired voltage drop on the converter or a decrease in battery capacity simulation. Raspberry Pi model 3 and Sunfounder DS18b20 heat sensor have been used in the practical part of the work. The operating speed of the Raspberry device has been decreased by reducing the voltage, and the sensor provides temperature reading curves under constant conditions. In the practical part of the work, measurements have been repeated at constant different temperatures. For the relevance of the measurement, the measurement cycle has been performed in a short time interval, which applies the measure of repeatability and reproducibility. The measured results have been presented in tables that we use for mathematical representation measurement uncertainties.

Keywords

Raspberry Pi4, sensors, low voltage, measurable insecurity

Introduction

Raspberry Pi is a single-board computer with a wide range of applications in the world of technology. Due to its characteristics, it is easy to use and maintain, easily accessible, and its versatility enables a wide range of applications. Raspberry Pi is a popular platform for developing microcomputer-based projects, used in various fields such as IoT (Internet of Things), home automation, and research experiments [1].

The power supply plays a crucial role in the functioning of the Raspberry Pi device and its sensors, necessitating a stable and dependable power source for optimal performance. Our analysis will delve into the fundamental principles of powering Raspberry Pi devices and sensors, encompassing the necessary voltage and current specifications. This study will explore the impact of an unstable power supply on the operation of sensors connected to the Raspberry Pi device, supported by practical examples and experimental findings using a variable power supply. In this way, we will better understand this issue and provide guidelines for efficient power management in projects that include the Raspberry Pi device and its sensors. Possible problems arising from a faulty power supply, such as voltage instabilities and lack of current capacity, will be investigated. For the relevance of the measurement, the measurement cycle has been performed in a short time interval, which applies the measure of repeatability and reproducibility. Namely, two sets of measurements have been sampled on two different days [2].

1. Raspberry Pi

The main features of the Raspberry device are a 64-bit quad-core processor, and support for displays up to 4K resolution via a pair of micro-HDMI ports. It supports hardware video decoding up to 4Kp60, up to 8 GB of RAM, dual-band Wireless LAN 2.4/5.0 GHz, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE option (via a separate PoE HAT accessory). Dual-band wireless LAN and Bluetooth have modular conformances that allow the board to be turned into a final product with significantly less conformance testing, reducing costs and shortening the time to market [3].

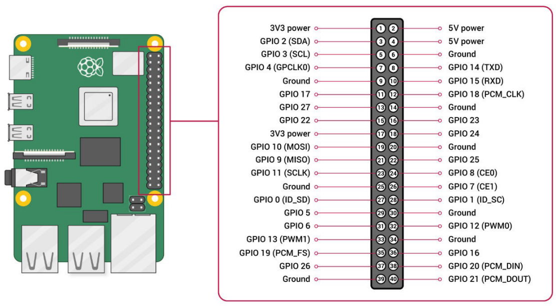
Raspbian is a Debian-based system maintained by a community whose goal is to port as many Debian packages as possible to Raspbian. Raspberry Pi OS is a free Debian-based operating system optimized for Raspberry Pi hardware. It is the recommended operating system for usual Raspberry Pi use. The operating system includes more than 35,000 packages, which are precompiled software packages in a nice format for easy installation on your Raspberry Pi.

Raspberry Pi with ARM processors, apart from the Pico microcontroller, works on all Raspberry Pi models. The Raspberry Pi OS uses a custom LXDE desktop environment with an Openbox stacking window manager as well as a custom theme [4].

2. GPIO and 40-pin Header

A great feature of the Raspberry Pi is the row of GPIO (general purpose input/output) pins along the board's top edge. The 40-pin GPIO (Figure 1) header is on all current Raspberry Pi boards (exposed on Raspberry Pi Zero, Raspberry Pi Zero W, and Raspberry Pi Zero 2W). Before the Raspberry Pi 1 Model B+ (2014), these boards had shorter 26-pin headers. The GPIO headers on all boards, including the Raspberry Pi 400, have a pin spacing of 0.1 inch (2.54 mm).

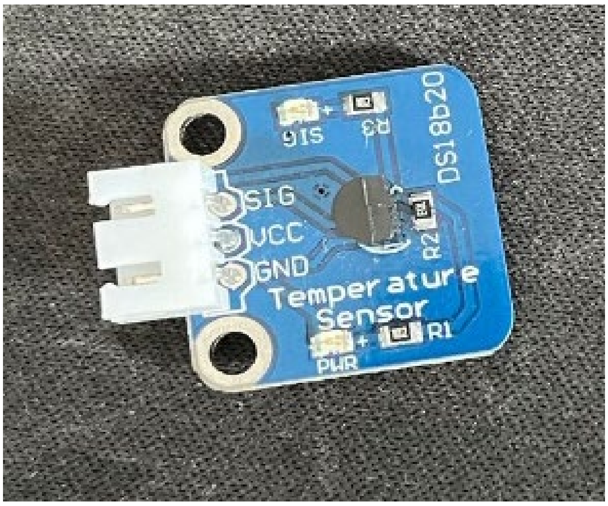
FIGURE 1: 40-PIN HEADER



Source: GPIO and the 40-pin header [5].

Furthermore, Figure 2 represents the Raspberries' temperature modul used for temperature sampling.

FIGURE 2: RASPBERRY PI TEMPERATURE SENSOR



Source: author

3. Raspberry Pi and Power Supply Connection

The Raspberry Pi power supply itself depends on the model. All models require a 5.1V power supply, but the current required generally depends on the model. In our study, Raspberry Pi specification is 5 volts (V) +/- 5% per USB 2.0 standard via micro-USB Power Supply. Some other variations of the Raspberry Pi power supply are shown in Table 1.

TABLE 1: POWER SUPPLY VALUES REPRESENTATION FOR RASPBERRY PI MODELS

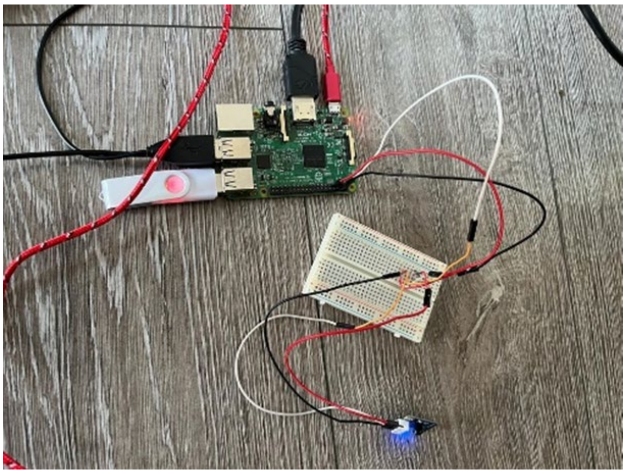
Model	Recommended power supply capacity	USB peripherals Maximum consumption	Motherboard consumption
Raspberry Pi 3 Model B	2.5 *A*	1.2 *A*	400 *mA*
Raspberry Pi 3 Model A+	2.5 *A*	Limited by a power supply, board, and connector rating	350 *mA*
Raspberry Pi 3 Model B+	2.5 *A*	1.2 *A*	500 *mA*
Raspberry Pi 4 Model B	3.0 *A*	1.2 *A*	600 *mA*

Source: GitHub - Power supply - raspberrypi/documentation [6].

All Raspberry Pi 3 models require a micro-USB connector for power, while the Raspberry Pi 4 and Raspberry Pi 400 use a USB-C connector. How much current (mA) the Raspberry Pi requires depends on what is connected to it [7].

There are two 5 V and two 3.3 V pins on the board and several 0 V pins for grounding. The previously mentioned pins cannot be configured, while the others are general-purpose (3.3 V).

FIGURE 3: RASPBERRY PI CONNECTION PRESENTATION



Source: author's supplemental from [7].

The remaining pins (general purpose pins) have tolerant inputs at 3.3 V, and outputs are set at 3.3 V.

4. Measurement and Measurement Uncertainty

Temperature sampling has been divided into two cycles to get different temperatures, and output voltage has been reduced from 5V to 3.5V in ten steps. After dropping below 3.5V, the module switches off. Table 2 represents samples of the two cycles of temperature measurements. Also, same results showed in figure 4

TABLE 2: TWO-CYCLE OF TEMPERATURE MEASUREMENTS UNDER CONTROLLED CONDITIONS

Output voltage (V)	Cycle 1 Temperatures (°C)	Cycle 2 Temperatures (°C)
5.0	19.51	26.81
4.8	19.45	26.75
4.6	19.38	26.69
4.5	19.33	26.63
4.4	19.26	26.56
4.2	19.21	26.50
4.0	19.14	26.44
3.8	19.08	26.38
3.6	18.98	26.25
3.5	18.89	26.19

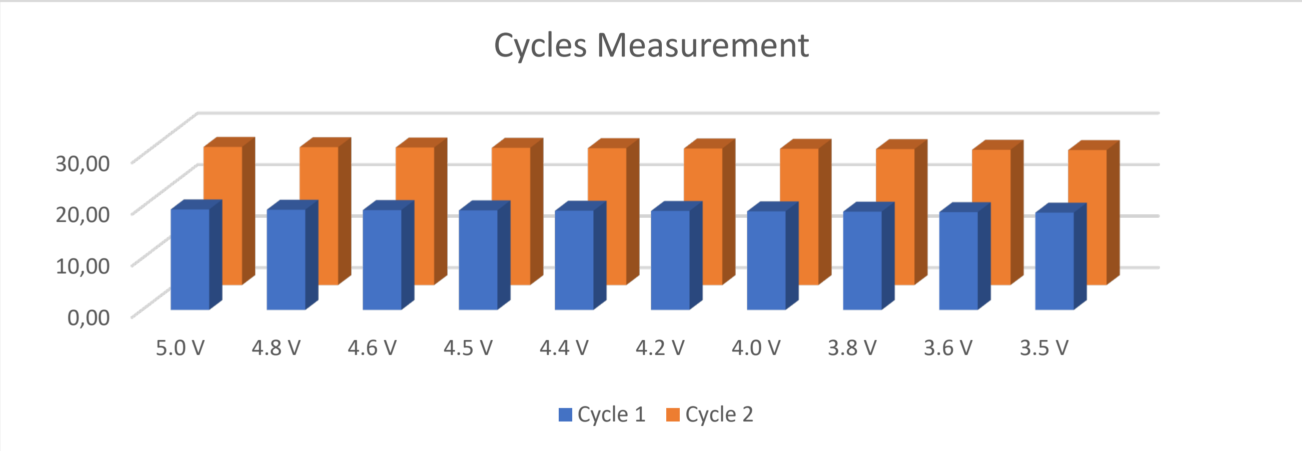
Source: author's supplemental from [8].

Measurement error occurs when there is a difference between the true value and the measured value. It is important to recognize that the measured value along with its statement of uncertainty characterizes the range of possible measured values. Since both the measured value and its uncertainty are only estimates, the true value is uncertain.

Uncertainty was a result of errors that led to variation around the estimated value of the quantity being measured, and reducing this variation decreases the uncertainty [9].

They are two components of measurement uncertainties. Type A measurement uncertainty is determined experimentally. It is necessary to carry out several consecutive measurements. Measurements are performed under equal conditions, and after the measurement, the arithmetic mean and standard deviation are calculated. The standard deviation of th

FIGURE 4: RASPBERRY PI CONNECTION PRESENTATION



Source: author

arithmetic mean and the deviation "s" from each measurement has been calculated. The standard deviation of the arithmetic mean represents the dispersion of the arithmetic means from all repeated measurements, while the deviation "s" from each measurement represents a measure of the dispersion of imprecision in each reading of the measured quantity [10].

Type A measurement uncertainty is determined by the following formulas:

$$S = \sqrt{\frac{1}{n-1}\sum_{n=1}^{n}(x_n - \bar{x})^2} \tag{1}$$

where n is the number of measurements, x_n is a single measurement, and x̄ is the mean value expressed by the following formula:

$$\bar{x} = \frac{x_1+x_1+x_3+\cdots x_n}{n} \tag{2}$$

Also, the standard deviation of individual measurements is:

$$U_A = S_x = \frac{s}{\sqrt{n}} \tag{3}$$

$$\mathrm{U_{A\%}} = \frac{\mathrm{U_A}}{\bar{x}} \cdot 100\% \tag{4}$$

Measurement uncertainties could be noted that the temperature range is -55 to 125°C and accuracy of ±0.5°C [11].

This was expressed in the form *of:*

$$t = 180.0 \pm 0.5\ °C$$

where further the expression is:

$$t = 180.0\ (1 \pm 0.0028)\ °C$$

$$t = 180.0\ (1 \pm 0.000028\%)\ °C$$

In this case, if the manufacturer provides the standard uncertainty, it is used directly and percentage error is also B measurement uncertainties [12].

$$U_b = s_b = \frac{G}{\sqrt{3}} \tag{5}$$

$$U_{b\%} = \frac{U_b}{\bar{x}}\ 100 \tag{6}$$

Furthermore, standard measurement uncertainties are expressed by:

$$U_{\%} = \sqrt{{U_{a\%}}^2 + {U_{b\%}}^2} \tag{7}$$

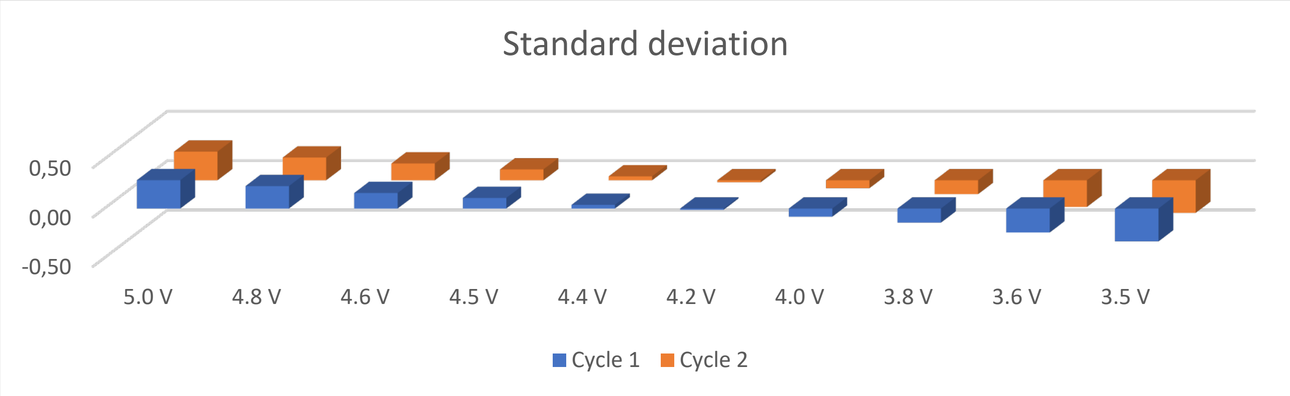
Then, with these data, all components of measurement uncertainty have been calculated, and Table 3 can be filled in. Standard deviation both cycles have showed in figure 5.

TABLE 3: MEASUREMENTS UNCERTAINTY

Uncertainty	Cycle 1	Cycle 2
Type B standard uncertainty	0,333%	0,248%
Type B standard uncertainty	1,502%	1,089%
Standard uncertainty	1,538%	1,116%

Source: author

FIGURE 5: RASPBERRY PI CONNECTION PRESENTATION



Source: author

5. Conclusion

An unstable power supply can cause damage to the device and its sensors. After multiple measurements, it has been proved that an unstable and faulty power supply can interfere with the Raspberry Pi and its sensor's functionality. It has been observed that when the output voltage dropped to 4.2 V, the LED lamp on the Raspberry Pi device stopped lighting, while the Raspberry Pi and the sensor continued to function. Further reduction in the input voltage has been monitored to assess the accuracy of the sensor readings. Reducing the voltage from 5 V to 4.8 V, the operating system of the Raspberry Pi device issued a notification of a faulty power supply. Gradual reduction of the voltage resulted in other peripherals losing their functionality. When the voltage decreased to around 3.5 V, the sensors lost their accuracy, and other peripherals (e.g., mouse, keyboard) occasionally lost contact and stopped working.

Nevertheless, while the power supply has been in the range from 3.5 to 5V, the measurement uncertainty of the sampled measurements under controlled conditions was between 1.11% and 1.54%. This level of uncertainty is acceptable for a device intended for commercial use.

This research and experimentation highlight the importance of a proper power supply when using Raspberry Pi devices in projects that require precise and reliable sensor readings.

Through research, it has been proven that voltage changes, whether an increase or decrease, can result in inaccurate or unreliable sensor reading.

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