

**TS100**

**RTD - PT100 - Temperature Sensor**

March, 2017

**YEPKIT** 

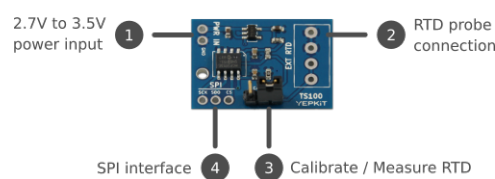
## Contents

|  |          |
|--|----------|
| <b>1 Overview</b>                                      | <b>2</b> |
| <b>2 Get readings from TS100</b>                       | <b>2</b> |
| 2.1 Use the MCU SPI to read from TS100 . . . . .       | 3        |
| 2.2 Connect the SPI with just two wires . . . . .      | 4        |
| <b>3 Convert sensor readings to temperature values</b> | <b>4</b> |
| <b>4 Calibrate the sensor</b>                          | <b>5</b> |
| <b>A Revisions</b>                                     | <b>6</b> |

## 1. Overview

TS100 is a temperature sensor board for PT100 Resistive Temperature Detector (RTD). It uses a precision instrumentation circuit, which can achieve  $\pm 0.1^{\circ}\text{C}$  accuracy and  $\pm 0.01^{\circ}\text{C}$  measurement resolution for a temperature range of  $-200^{\circ}\text{C}$  to  $+800^{\circ}\text{C}$ . This precision is attainable with a single point calibration.

Readings are fetched from the sensor using a SPI<sup>TM</sup> serial interface. The interface wiring can be set-up with three or two wires.



1. 2.7V to 5.5V power input
2. RTD probe connection pins
3. Calibrate or RTD measure mode select jumper
4. SPI interface

## 2. Get readings from TS100

Typically a Microcontroller (MCU) is used to fetch readings from TS100. Nonetheless any board or system with SPI or digital I/O's can be used to get readings from TS100.

The following picture illustrates the serial interface connection to a MCU using a three wire setup.

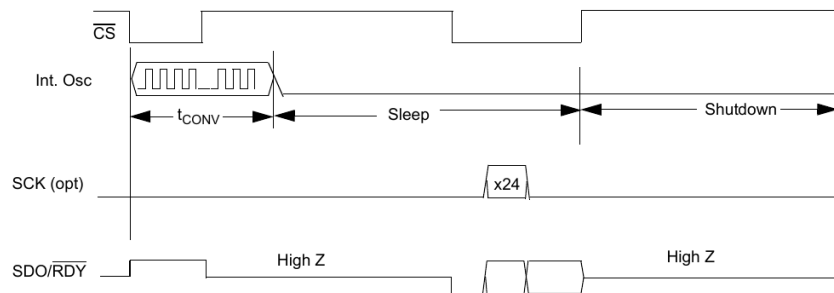


There are two modes of operation:

1. Single Acquisition
2. Continuous Acquisition

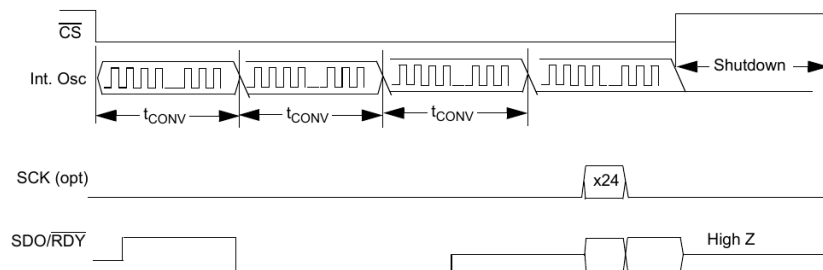
In Single Acquisition mode the sensor performs a single measure. Once complete the acquired value is placed in the output buffer, and the ADC goes into sleep and shutdown mode. If a new reading is required it can only be done after the value, of the previous reading, in the output buffer is clocked out (e.g., read by the MCU).

The following timing diagram illustrates the Single Acquisition mode serial communication.



TS100 enters into Single Acquisition mode when a rising edge of Chip Select signal ( $\overline{CS}$ ) occurs during the conversion interval ( $t_{CONV}$ ). Otherwise, if no rising edge of  $\overline{CS}$  occurs, the sensor stays in Continuous Acquisition mode.

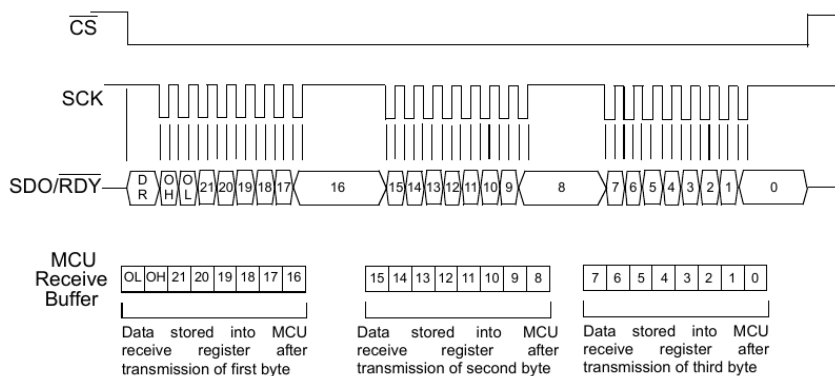
In Continuous Acquisition mode the sensor keeps on performing measures and refreshing the output buffer with the latest acquired value. The following timing diagram illustrates the Continuous Acquisition mode serial communication.



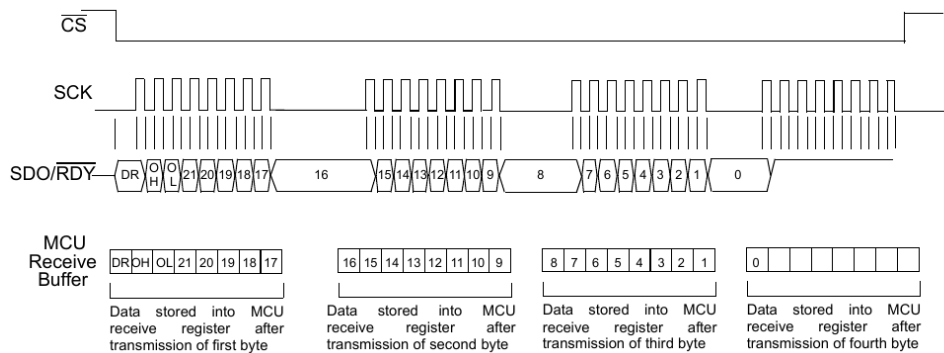
### 2.1. Use the MCU SPI to read from TS100

The microcontroller SPI port must be configured to clock-out data on the falling edge of the clock. Data must be latched on the rising edge of the clock.

The following timing diagram represents the read operation for a MCU using SPI mode 1,1.

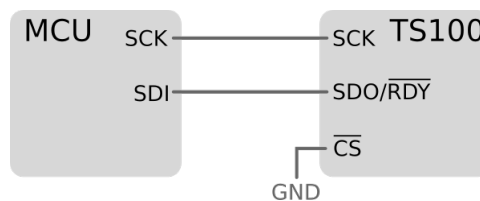


For a microcontroller using SPI mode 0,0 consider the following timing diagram.



## 2.2. Connect the SPI with just two wires

You can use two wires for the serial interface instead of three. To use only two wires for the communication tie  $\overline{CS}$  pin permanently to low (GND). With this setup the device is always operating in Continuous Acquisition mode and you can clock-out the sensor readings from the buffer using only the  $SDO/\overline{RDY}$  and  $SCK$  lines.



## 3. Convert sensor readings to temperature values

The process of getting from a TS100 reading to a temperature value in *Celsius* is the following:

1. Get TS100 sensor reading value (which is a 22 bit code);
2. Convert the reading value to the RTD resistance ( $R_T$ );
3. Calculate the temperature in *Celsius* using the formula expressed by equation (4).

In the previous sections we showed how to fetch a reading from the TS100 sensor board. Now let's see how to convert the reading value to the corresponding resistance value, and how to use this resistance value to calculate a temperature in *Celsius*.

To convert a sensor reading value, which is a 22 bit code, use the following equation.

$$R_T = R_A \left( \frac{Code}{2^{n-1} - Code} \right) \quad (1)$$

Where:

$Code$  is the TS100 sensor reading consisting on a 22 bit value.

$R_A$  is the TS100 biasing resistor wich is  $6.8k\Omega$ .

$n$  is the TS100 board ADC resolution in bits, which is 22 bits.

Using the DIN EN 60751 definitions the RTD resistance varies with temperature ( $T$ ) according to the following formulas.

For  $T \geq 0^\circ\text{C}$

$$R_T = R_0 \cdot (1 + a \cdot T + b \cdot T^2) \quad (2)$$

For  $T < 0^\circ\text{C}$

$$R_T = R_0 \cdot [1 + a \cdot T + b \cdot T^2 + c \cdot (T - 100^\circ\text{C}) \cdot T^3] \quad (3)$$

Where:

$R_T$  is the RTD resistance at temperature  $T$ .

$R_0$  is the RTD resistance at temperature  $0^\circ\text{C}$ .

$$a = 3.9083 \times 10^{-3}$$

$$b = -5.775 \times 10^{-7}$$

$$c = -4.183 \times 10^{-12}$$

For positive temperature the equation (2) can be solved in function of  $T$  to get the temperature.

$$T = \frac{-a \pm \sqrt{a^2 - 4b(1 - \frac{R_T}{R_0})}}{2b} \quad (4)$$

For PT100 probes  $R_0 = 100\Omega$ . Now use the value obtained from equation (1) on equation (4) to calculate the temperature in *Celsius*.

## 4. Calibrate the sensor

$$R_{A'} = \frac{100}{\frac{code_{cal}}{2^{n-1}} - code_{cal}} \quad (5)$$

Where:

$R_{A'}$  is the calibrated value for  $R_A$  to be used in equation (1).

$code_{cal}$  is the reading code obtained from TS100 with the calibration jumper in the position **CAL**.

$n = 22$ .

## A. Revisions

**Revision 1.0** Initial release.