

ONE FOR ALL

Preprocessing and digitising of sensorsignals.

In many applications in almost all areas of technology it is necessary to convert sensorsignals into useable electrical, and now a-days digital, signals to be processed in microcontrollers. The traditional way of converting sensorsignals was by using operational amplifiers, A/D convertors, etc. Long distance applications were solved in an analogue way by using standard 0-10 V. or 4 –20 mA. current loops.

The new released product of SMARTEC BV. will solve these problems in one step. One integrated circuit will be the only interface between the sensor and the digital input of the microcontroller.

The increasing complexity of electronic systems has caused a growing demand to interface possibilities to connect all kind of sensorelements to microcontrollers. Sensorelements like PT100, PT1000 and all kind of bridge sensors have to be preprocessed before they can be connected to microcontrollers. Circuitry to perform this are complex and will cost in general a lot of design complexity.

Next to this, powerconsumption will be a main issue for the future and complex interface-circuitry will use complex powersupplies especially where battery or explosion proof requirements are needed. For Smartec the main reason to develop a chip that gives an answer to all these complex circuits. Also the questions of calibration and adjustments are solved by using a special (patented) way of signalprocessing.

The Universal Transducer Interface(UTI) is a very simple and low cost solution to all these problems.

The UTI is a complete front-end to all kind of sensors. The UTI converts the low level signal of the sensor to a microcontroller compatible signal and has an internal autocalibration. The offset and gain will automatically be calibrated.

The Universal Transducer Interface(UTI) is a sensor to time converter and is based on a period modulated oscillator. The sensor can be connected directly to the UTI without any circuitry in between. The only need is a reference element of the same kind of the sensor element. For instance measuring a PT100 resistor needs only a stable reference resistor of about 100 Ω .

The UTI supports the below stated sensors:

PT100, PT500 and PT1000 resistive thermal elements,

Capacitive sensors in the range of 0-2 pF untill 0 – 300 pF.

Thermistor, NTC elements from 1 K Ω to 25 K Ω

Resistive bridges from 250 Ω to 10 K Ω with an imbalance of 0,25 or 4 %

Potentiometers in the range between 1 K Ω to 50 K Ω .

All the sensorelements are excited with an AC signal in the range of 5 to 20 KHz. A special technology is designed to suppress low frequency interference. In all the applications the offset and gain will be calibrated on a continuous base.

Three-Signal Technique.

To get a high accuracy and stable measurement of the sensorsignal a reference signal and the offset of the chip will be measured on the same way as the sensorsignal is measured. These signals are measured on exactly the same way after each other. This way of signal processing is called the Three Signal Technique. The first signal is the offset, the second signal is the reference signal and the third signal is the sensor output signal. The time frame of these three signals is about 100 ms(slow mode).

The three signal technique will be used to eliminate the effects of unknown offset and gain errors in a linear system. In order to apply this technique, in addition to the measurement of the sensor signal, two reference signals are required to be measured in an identical way. Suppose a system has a linear transfer function of

$$M_i = kE_i + M_{off} \quad (1)$$

The measured three signals are:

$$\begin{aligned} M_{off} &= M_{off} \\ M_{ref} &= kE_{ref} + M_{off} \\ M_x &= kE_x + M_{off} \end{aligned} \quad (2)$$

Then the measuring result is the ratio

$$M = \frac{M_x - M_{off}}{M_{ref} - M_{off}} = \frac{E_x}{E_{ref}} \quad (3)$$

When the system is linear, then in this ratio the influence of the unknown offset M_{off} and the unknown gain K of the measurement system is eliminated. To build up a system based on this three signal technique a memory is required. The solution for this is the use of a microcontroller which can perform data storage and some calculations as well as the measurement of the period modulated signals. These kind of systems, where the sensor, the UTI and a microcontroller is used, can be considered as a smart sensor system. Below some examples of such a smart sensor system is described.

The measurement of temperature using Platinum resistors PT100 (PT1000).

The measurement of temperature with platinum resistors can be considered as the most common method to measure temperatures.

In the UTI two methods are designed to measure platinum resistors:

MODE 5 Measurement of one PT100(PT1000) element in 2-, 3-, or 4 wires.

MODE 7 Measurement of two or three PT100(PT1000) elements.

MODE 5 will give a good example about the way of processing in the UTI. In fig 1. the different setups are given.

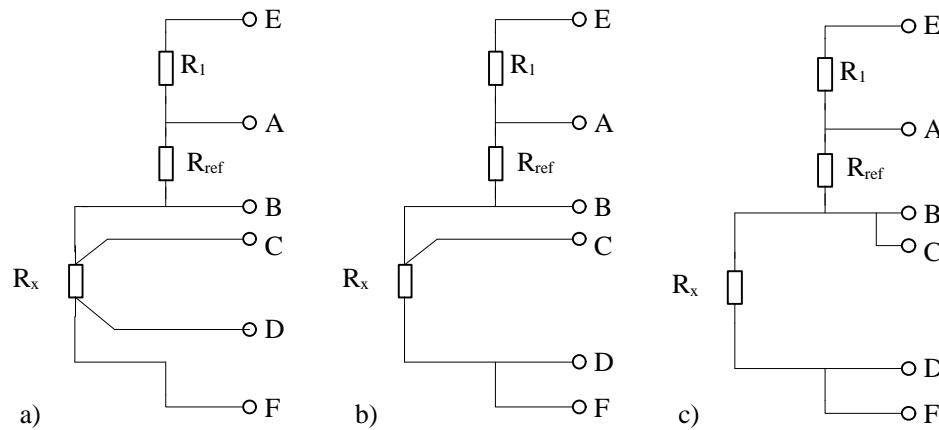


Fig 1. Different possibilities for a setup to measure PT100(PT100) elements.

The measurement period counts 4 phases. These phases contain the time information of the 2-,3- or 4 wire connection. As given before the measurement cycle time is about 100 ms or in the fast mode 10 ms. In figure 2 a measurement setup is given for a 4-wire connection of the PT100(PT1000) temperature sensor.

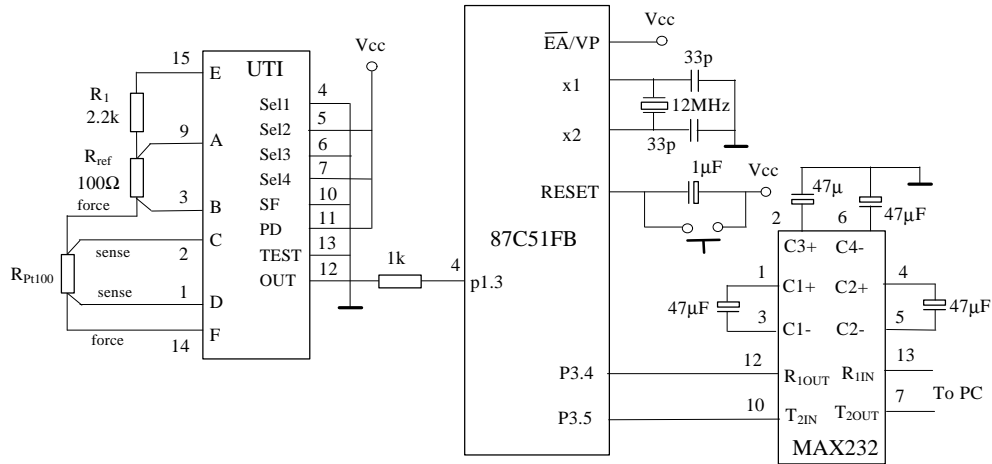


Fig. 2 Measurement setup for 4-wire measurement on a PT100(PT1000).

The output of the UTI is connected to the microcontroller (87C51) and can be connected with the serial interface to a PC. When using the 4-wire technique also at the reference resistor, the resistance of the wires can be eliminated. The sensor current flows from point E of the UTI to point F of the UTI. The resistor R1 is chosen for the current limitations and selfheating of the PT100(PT100) element.. The SF is connected to GND and the pin Power Down (PD) is set on 5Vcc. The period modulated outputsignal is given in figure 3.

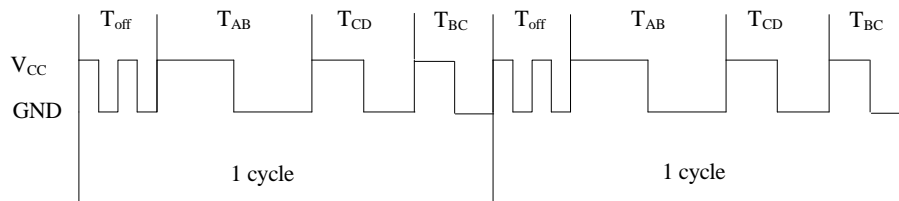


Figure 3. Output signal of the UTI in MODE 5.

By using the microcontroller the period modulated signal can be measured. The time signals Toff, Tab, Tcd and Tbc are counted to internal registers of the micro. N_{off} , N_{ab} , N_{cd} and N_{bc} are the counted values. By using the three signal technique the measurand is represented by:

$$R_{Pt100} = \frac{N_{CD} - N_{off}}{N_{AB} - N_{off}} \cdot R_{ref} \quad (4)$$

This formula is performed by the microcontroller. It is shown that the measured accuracy of R_{Pt100} is directly depended on the accuracy of R_{ref} .

Measurement of two or three PT100(PT1000).

In case more thermal PT elements has to be measured the UTI can be used in MODE 7. The connection to the microcontroller is the same and the connection of the element is according to figure 4.

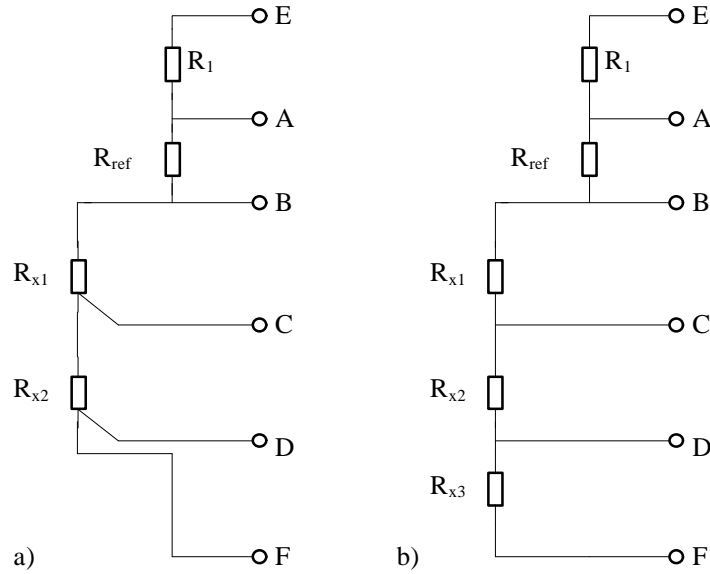


Fig. 4. A temperature measurement setup for two or three PT100(PT1000) sensor elements.

In MODE 7 the same restriction for the maximum current will yield as in MODE 5. The biggest difference between MODE 5 and MODE 7 is that in MODE 7 the output signal has 5 phases while in MODE 5 the output signal has only three phases.

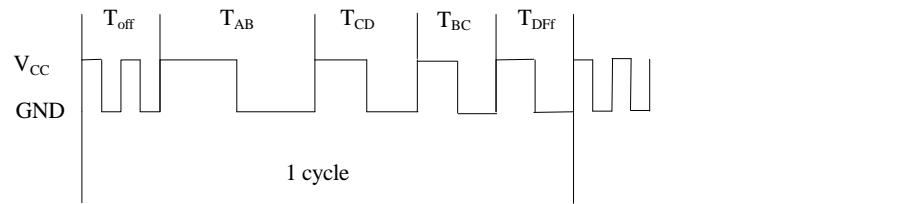


Fig 5. Output signal in MODE 7

In MODE 7 find with reference to the three signal technique the below stated representation of the measurand.

$$R_{x1} = \frac{N_{BC} - N_{off}}{N_{AB} - N_{off}} \cdot R_{ref} \quad (5)$$

$$R_{x2} = \frac{N_{CD} - N_{off}}{N_{AB} - N_{off}} \cdot R_{ref} \quad (6)$$

$$R_{x3} = \frac{N_{DF} - N_{off}}{N_{AB} - N_{off}} \cdot R_{ref} \quad (7)$$

Parameter ($V_{DD}=5V$)	Value
K_2	$56\mu s/V$
V_0	$0.36V$
R_1 (Pt100, self-heating for $200K/W=80mK$)	$2.2k\Omega$ (5%), $I=2mA$
R_1 (Pt1000, self-heating for $200K/W=80mK$)	$6.2k\Omega$ (5%), $I=600\mu A$
Offset	$10\mu V$
Nonlinearity	$150ppm$
Resolution SF=0 (Pt100, 2mA)	$7\mu V$ (9mK)

Table 1: Specification for the UTI in MODE 5 and MODE 7.

For measuring thermistors the same requirements yields as for these PT100 measurements. The resistor for the current limitation can be zero and Rref has to be adapted..

Measurement of resistive bridges.

Resistive bridges are often used to measure pressure, acceleration, force, etc. In the UTI six modes (MODE 9-14) are available to measure the resistive bridge signals. Here the MODE 9 is employed to demonstrate the application of the UTI in the measurement of the resistive bridge signal. In MODE 9 the maximum imbalance of the bridge is maximum 4% while the maximum imbalance in MODE 10 is 0.25 %. The circuitry of the resistive bridge is given in Figure 6.

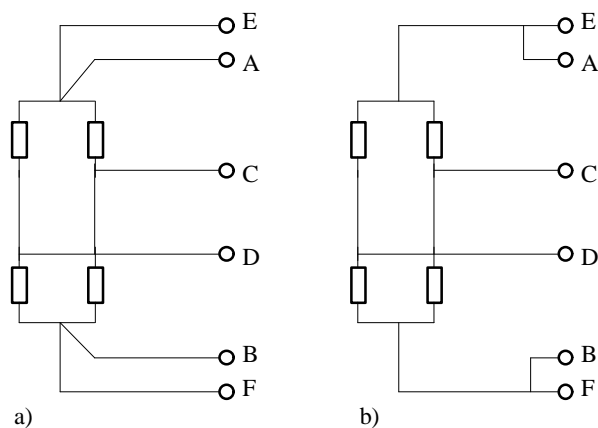


Fig 6. A measurement circuit for resistive bridge signals.

The executing terminals of the resistive bridge are connected to the UTI in a 4-wire setup, then the effect of the lead resistances is completely eliminated. The period modulated output signal from the UTI is shown in figure 7.

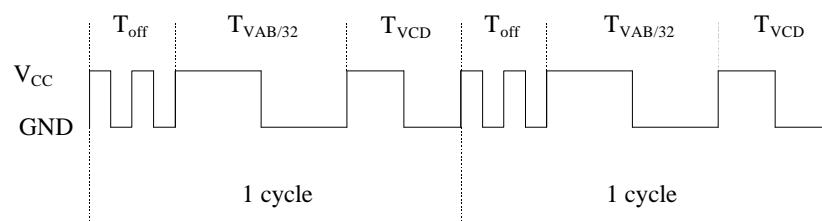


Fig. 7 Output signal of the UTI in MODE 9.

During the second phase the bridge Voltage is measured. An on-chip divider divides this voltage by 32. After this division the voltage V_{ab} is measured on the same way as the V_{cd} . The measured imbalance of the bridge is represented by:

$$M = \frac{V_{CD}}{V_{AB}} = \frac{1}{32} \cdot \frac{N_{VCD} - N_{off}}{N_{VAB/32} - N_{off}} \quad (8)$$

Measurement of capacitor values..

There are five modes (MODE 0-4) for capacitive measurement. This measurement is performed in the same way as in the way resistors are measured. The only difference is that the offset capacitor has to be connected externally while the offset in the resistive modes are internally on-chip. A general measurement setup is given in figure 8.

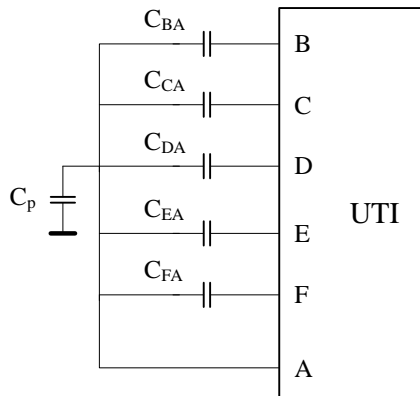


Fig 8. General measurement setup for measuring capacitors.

The capacitor C_p represents the parasitic capacitance. This capacitor can be relatively high in comparison with the capacitance that has to be measured. By means of a multiplexer (also a Smartec product) multiple capacitor values can be measured.

In the last decade there is a high demand for sensor-applications. Many new sensorelements are available for the market especially in process industry and in consumer-goods. At the same time the design time for these products has to be smaller and smaller. By means of the recent released product, the UTI, Smartec thinks to have an answer for preprocessing sensorsignals and to build within a short time sensorsystems. For easy and quick development there is also a design-in kit available on which the user can connect directly his sensor-application with a direct output presentation on a personal computer. The UTI is available in DIL 16 and in SOIC housing. For further information please contact us in Holland.