Application Note of UTI
the measurement of Pt100/Pt1000 with a very long cable wire

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1. Introduction

The UTI is a complete front end for many types of passive sensors, such as resistive, resistive-bridge and capacitive sensors. This application note describes a way to use the UTI for the measurement of Pt100/Pt1000 with a long cable wire.

2. Some non-idealities

1) Parasitic capacitance due to long cable wire

Figure 1 shows some parasitic capacitors when long cable wires are used to connect the Pt100 to the UTI. Combining with the resistances (R_{BIAS}, R_{ref} and R_{Pt100}), these parasitic capacitances will form a time constant RC. According to the design of the UTI, when this time constant is 500 ns, it will cause a non-linearity of about 45 ppm.

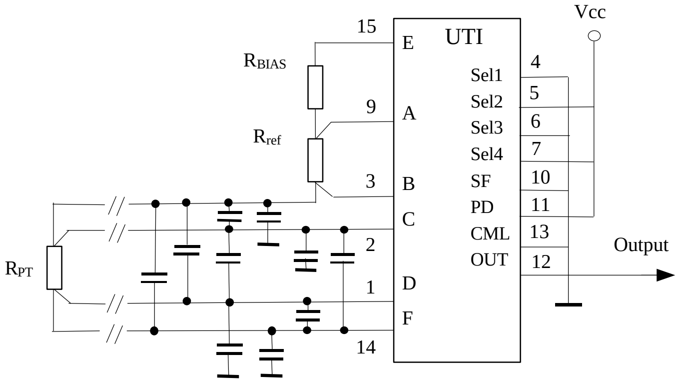


Figure 1 The parasitic capacitors effect.

When all parasitic capacitances are equal, the largest time constant is $6C_p(R_{PT}/(R_{BIAS}+R_{ref})$. For instance, when the parasitic capacitance is 2 nF which is equivalent to a cable wire with a length of 20 m, and R_{BIAS} = 2.2 kΩ, $R_{ref} = R_{PT}$ = 100 Ω, then, the time constant is about 1.15 us. This time constant will result in a non-linearity of about 1.29%.

2) Common mode effect

According to the working principle of the UTI, the applied chopping technique results in a large CM AC signal on the measurand. This CM signal is different in the magnitude for R_{ref} and R_{PT}, respectively. This causes the problem of unequal offset voltages for both of the measurements.

3. Measurement principle

To implement an accurate measurement of the Pt100 with a long cable wires, these two critical problems described above must be solved. The proposed solutions are:

1) For the effect of long cable wire, instead of the square wave AC driving signal for the Pt100, a DC driving signal is used for the Pt100. Meanwhile, the chopping technique of the UTI is implemented using the extra switches.
2) To reduce the common mode effect, a multiple offset measurement technique is used. In this technique, the offsets corresponding to the different measurand are measured in the same way as that measurand, respectively.

Figure 2 shows a simplified circuit diagram for the measurement of the Pt100 using the Pt mode of the UTI. It is shown that the resistor R_{pt}, is measured in a 4-wire setup as well as a reference resistor R_{ref}. In this circuit, the multiplexer MUX is used to select the measured signals, R_{pt} and R_{ref}. The commutator S_{COM}, which is controlled by the signals E and/or F from the UTI, implements the chopping signal for the measured signal. A microcontroller is used to measure the signal from the UTI output, to control the multiplexer and current switch Sc, and to communicate with other digital world.

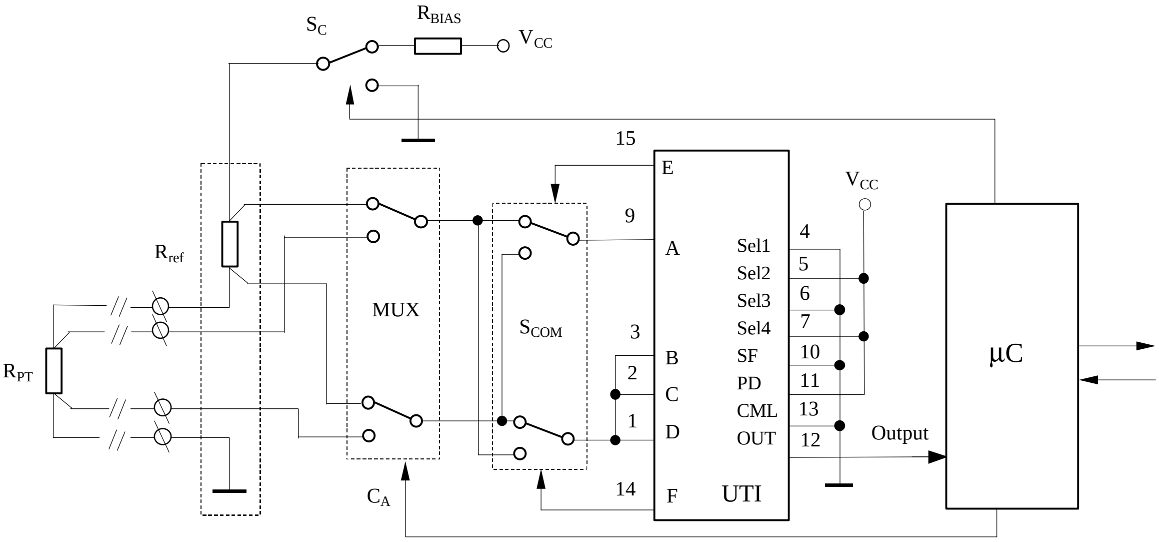


Figure 2 A simplified circuit diagram for the measurement of Pt100.

To implement a complete measurement for the circuit shown in Figure 2, four measurement cycles of the UTI are required. In these four cycles, four couples of signals are converted into time periods at UTI output and are measured: T_{PT} and $T_{off,PT}$, T_{ref} and $T_{off,ref}$, T_{PT0} and $T_{off,PT0}$, T_{ref0} and $T_{off,ref0}$. The output sequence of the UTI is listed in Table 1.

Table 1

Sequence	Switch control	UTI Output
1	$S_C = 1, C_A = 0$	$T_{off,PT}, T_{PT}, T_{CD}, T_{BC}$
2	$S_C = 1, C_A = 1$	$T_{off,ref}, T_{ref}, T_{CD}, T_{BC}$
3	$S_C = 0, C_A = 0$	$T_{off,PT0}, T_{PT0}, T_{CD}, T_{BC}$
4	$S_C = 0, C_A = 1$	$T_{off,ref0}, T_{ref0}, T_{CD}, T_{BC}$

Using these measured data, the measured result is given:

$$R_{PT} = \frac{(T_{PT} - T_{off,PT}) - (T_{PT0} - T_{off,PT0})}{(T_{ref} - T_{off,ref}) - (T_{ref0} - T_{off,ref0})} \cdot R_{ref} \qquad (1)$$

In this calculations, applying the substraction (T_i - $T_{off,i}$), (i = *PT, PT0, ref* and *ref0*), the effect of the common mode on the offset is eliminated. The subtraction (T - T_0) is used to reduce the effect of the leakage current through the MUX and the low-pass filter, and effect of the thermal voltage due to the connectors for the components. Where T is $T_j - T_{off,j}$ and T_0 is $T_{j0} - T_{off,j0}$ (j = *PT* or *ref*).

4. A practical example

Based on the measurement principle described above, Figure 3 shows a circuit diagram for actual application. A voltage regulater is used to supply a single voltage power supply of 5V. The multiplexers, MAX4559 and MAX4560 are used for the MUX, and S_{COM} and S_C, respectively. A resistor with high accuracy and low temperature coificient is used for the R_{ref}.

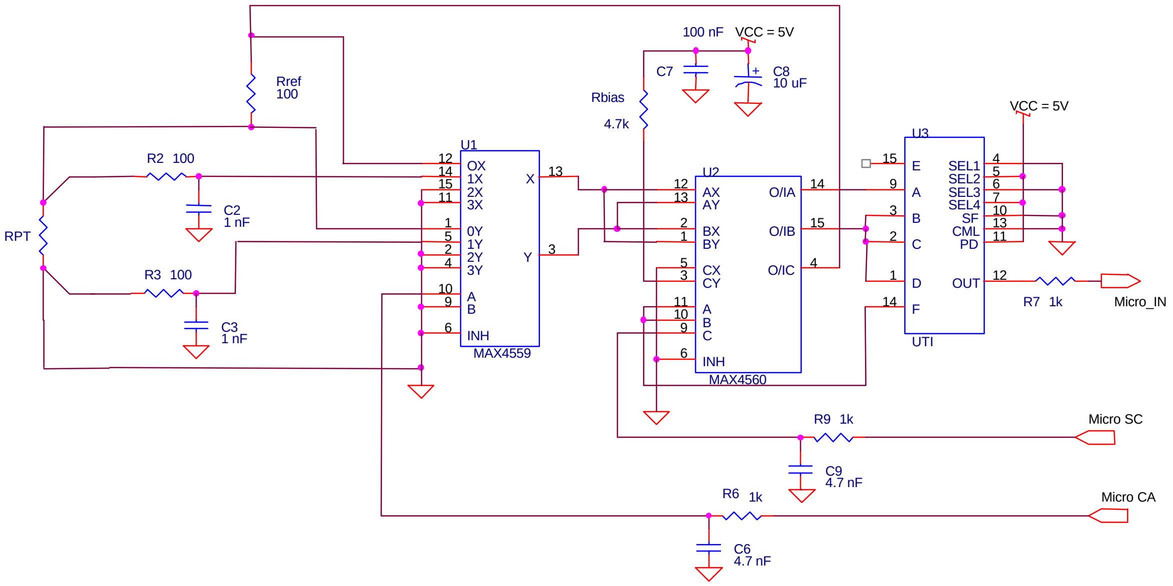


Figure 3 A testing circuit diagram.

To evaluate the effect of long cable wire, the 6-capacitance model is used when the multi-wire shielding cable is used for the four wires connecting the R_{PT} to the UTI. An equivalent model of the long cable wire is shown in Figure 4. Therefore, the effect of long cable wire can be tested by changing the capacitor value C_{ep}.

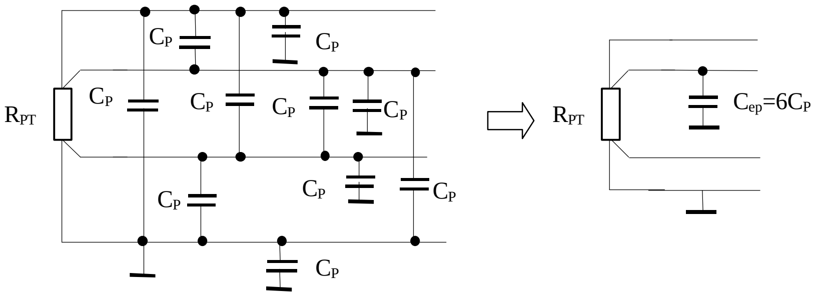
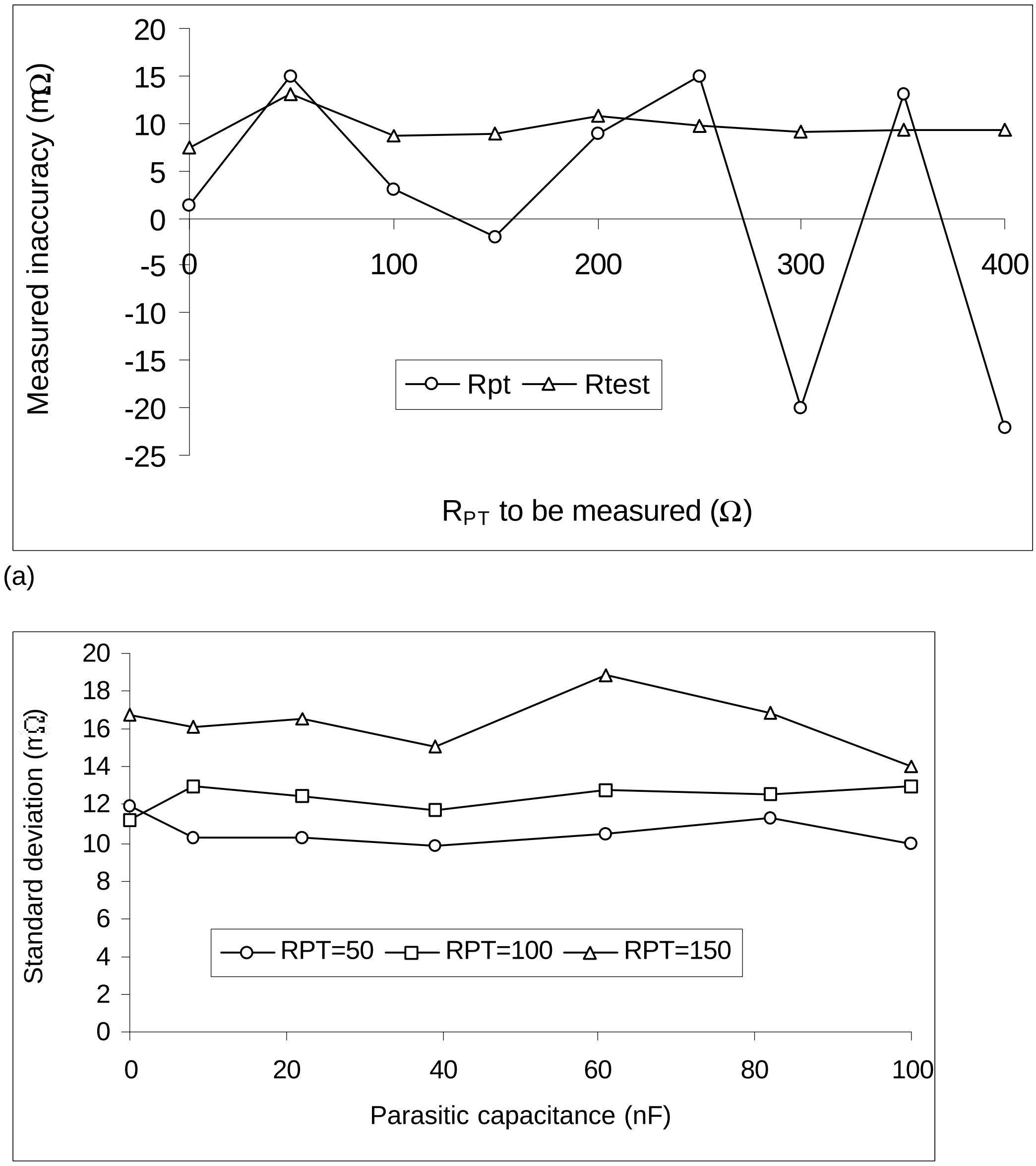


Figure 4 An equivalent model of long cable wire.

Figure 5 show that the effect of the parasitic capacitance C_{ep} on the measurement of R_{PT}. In this measurement, the resistor R_{ref} has a constant value of 104.0625 Ω and a temperature coefficient less than 1 ppm. R_{PT} is changed with three values: 50 Ω, 100 Ω and 150 Ω. The biasing current for R_{PT} amounts to 1 mA. The parasitic capacitance C_{ep} is changed from 0 to 100 nF, which corresponds to the cable wire with a length of 0 to 170 m.



F*igure 5 The effect of parasitic capacitance on the measurement of* R_{PT}*, a) accuracy, b) standard deviation.*

From the Figure 5, it is shown that the parasitic capacitance up to 100 nF has almost not affected the measured accuracy and standard deviation. According to the design, the value of parasitic capacitance is not limited so long as its leakage current is small enough.