## 5. Experimental Contents

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7) Measure temperature properties of a voltage-mode integrated temperature sensor (LM35).

## 6. Experimental Procedures

6.1 Measure temperature properties of a platinum resistance temperature sensor (Pt100)

1) Constant current method:

Connect the constant current source, check if the current on $R_1$ is 1 *mA* (i.e. $U_1$ = 1.000 *V*, $R_1$ = 1.00*K*).

Insert the temperature control sensor Pt100 (with 3 leads) into the central well of the dry well furnace. Insert the tested Pt100 sensor (with 2 leads) into any other one well.

Start from room temperature, set the temperature controller at higher values with step size 10 °C till 100 °C to do measurement. Note: wait 2 minutes after temperature getting stable to record data.

Use formula (2) to calculate the resistance of the Pt100 platinum resistance. Record data in the table below.

The result is acquired by fitting the line with the least square fitting method.

Temperature coefficient *A* = Correlation coefficient *r* =

| No. | *T* (°C) | $R_t$ (Ω) |
|---|---|---|
| 1 | 30 | |
| 2 | 40 | |
| 3 | 50 | |
| 4 | 60 | |
| 5 | 70 | |
| 6 | 80 | |
| 7 | 90 | |
| 8 | 100 | |
| 9 | 0 | |

Note: 0°C is freezing point (ice-water mixture). Put the tested temperature sensor into an insulation cup of pre-prepared ice-water mixture to do measurement at 0°C.

2) DC bridge method:

Connect the power source (+2V) to the bridge.

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested Pt100 sensor into another well.

Start from room temperature, set the temperature controller at higher values with step size 10 °C till 100 °C to do measurement.

At each temperature point, adjust the resistance box $R_3$ to make the bridge balance (i.e. output voltage zero). Note: wait 2 minutes after temperature getting stable to record data.

Use formula (1) to calculate the resistance of the Pt100 platinum resistance. Record data in the table below.

The result is acquired by fitting the line with the least square fitting method.

Temperature coefficient $A_1$ = Correlation coefficient $r$ =

| No. | T (°C) | $R_x$ (Ω) | $R_t$ (Ω) |
|---|---|---|---|
| 1 | 30 | | |
| 2 | 40 | | |
| 3 | 50 | | |
| 4 | 60 | | |
| 5 | 70 | | |
| 6 | 80 | | |
| 7 | 90 | | |
| 8 | 100 | | |
| 9 | 0 | | |

Note: Use a precision resistance box for $R_x$.

6.2 Measure temperature properties of thermistor NTC

1) Constant current method:

Same as the previous experiment for Pt100 measurement, connect the constant current source, check if the current on $R_1$ is 1 $mA$ (i.e. $U_1 = 1\ V$, $R_1 = 1.00K$).

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested thermistor NTC1K into another well.

Start from room temperature, set the temperature controller at higher values with step size 10 °C till 100 °C to do measurement. Note: wait 2 minutes after temperature getting stable to record data.

Use formula (2) to calculate the resistance of the NTC1K thermistor. Record data in the table below.

The result is acquired by fitting the line with the least square fitting method.

Temperature coefficient $B$ = Correlation coefficient $r$ =

| No. | $T$ | $R_t$ (Ω) |
|---|---|---|

| | (°C) | |
|---|---|---|
| 1 | 20 | |
| 2 | 30 | |
| 3 | 40 | |
| 4 | 50 | |
| 5 | 60 | |
| 6 | 70 | |
| 7 | 80 | |
| 8 | 90 | |
| 9 | 100 | |
| 10 | 0 | |

2) DC bridge method:

Connect the power source (+2V) to the bridge.

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested thermistor NTC1K into another well.

Start from room temperature, set the temperature controller at higher values with step size 10 °C till 100 °C to do measurement.

At each temperature point, adjust the resistance box $R_3$ to make the bridge balance. Note: wait 2 minutes after temperature getting stable to record data.

Use formula (1) to calculate the resistance of the thermistor NTC1K. Record data in the table below.

The result is acquired by fitting the line with the least square fitting method.

Temperature coefficient $A$ = Correlation coefficient $r$ =

| No. | $T$ (°C) | $Rx$ (Ω) | $Rt$ (Ω) |
|---|---|---|---|
| 1 | 20 | | |
| 2 | 30 | | |
| 3 | 40 | | |
| 4 | 50 | | |
| 5 | 60 | | |
| 6 | 70 | | |
| 7 | 80 | | |
| 8 | 90 | | |
| 9 | 100 | | |
| 10 | 0 | | |

6.3 Measure temperature properties of a PN junction temperature sensor

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested PN junction temperature sensor into another well.

Connect wires according to requirements. Start from room temperature, set the temperature controller at higher values with step size 10 °C till 100 °C to do measurement.

At each temperature point, measure the forward voltage $U_{be}$ of the PN junction. Note: wait 2 minutes after temperature getting stable to record data. Record data in the table below.

| T (°C) | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| $U_{be}$ (V) | | | | | | | | | |

This experiment connects a 51$K$ ohm resistor to the constant voltage source (DC 5V) in series, this way to approximately achieve an effect of constant current source. If directly using the included constant current source, please skip the 51$K$ resistance. Try the two methods to test and compare the correlation coefficients.

6.4 Measure temperature properties of current-type IC temperature sensor (AD590)

Connect wires following the schematic diagram on the panel. Set the temperature controller to 30 °C (do P.I.D adaptive tuning at 30 °C to achieve ± 0.1°C accuracy at 30 °C).

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested temperature sensor AD590 into another well.

After the temperature is stable at 30 °C, check whether the voltage on the 1$K$ resistor (a metal film precision resistance) is 303.15 $mV$. (In this case, the room temperature must be lower than 30 °C. If not, select another proper temperature and do adaptive tuning accordingly.)

Start from 30 °C with step size 10 °C till 100 °C, respectively measure the voltage on the 1$K$ resistor. Record data in the table below. Note: wait 2 minutes after temperature getting stable to record data.

| $T$ (°C) | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| $U$ (V) | | | | | | | | | |
| $I$ (μA) | | | | | | | | | |

$I$ is the current flowing through the 1$K$ resistor which is calculated by using the measured voltage on it ($I = U/R$).

Using the least square fitting method to fit these data, we obtain:

Temperature coefficient $A$ = ______ $\mu A/K$ and correlation coefficient $r$ = ____.

6.5 Measure temperature properties of voltage-type IC temperature sensor (LM35)

Connect wires following the schematic diagram on the panel.

Insert the temperature control sensor Pt100 into the central well of the dry well furnace. Insert the tested temperature sensor LM35 into another well.

Start from room temperature with step size 10 °C till 100 °C, respectively measure the output voltage of LM35. Record data in the table below. Note: wait 2 minutes after temperature getting stable to record data.

| T (°C) | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| $U_0$ (V) | | | | | | | | | |

Using the least square fitting method to fit these data, we obtain:

Temperature coefficient $A$ = ______ and correlation coefficient $r$ = ____.

## 7. Examples of Data Recording and Processing

Note: the following data are for reference purposes only, not the criteria for apparatus performance.

7.1 Measure temperature properties of a platinum resistance temperature sensor (Pt100)

| Temperature (°C) | DC bridge method Resistance (Ω) | Constant current method Resistance (Ω) |
|---|---|---|
| 30.0 | 114.0 | 113.7 |
| 40.0 | 117.0 | 116.2 |
| 50.0 | 121.0 | 120.1 |
| 60.0 | 125.0 | 124.6 |
| 70.0 | 129.0 | 128.7 |
| 80.0 | 133.0 | 132.9 |
| 90.0 | 137.0 | 136.8 |
| 100.0 | 141.0 | 140.7 |

Results of straight line fitting:

DC bridge method: Temperature coefficient A=0.391 Ω/°C, correlation coefficient $r^2$=0.999.

Constant current method: Temperature coefficient A=0.398 Ω/°C, correlation coefficient $r^2$=0.997.

7.2 Measure temperature properties of thermistor NTC1K

| Temperature T(°C) | DC bridge method $R_1$ (Ω) | Constant current method $R_2$ (Ω) |
|---|---|---|
| 30.0 | 815.0 | 816.2 |
| 40.0 | 552.0 | 553.3 |
| 50.0 | 385.0 | 384.5 |
| 60.0 | 277.0 | 277.8 |
| 70.0 | 198.0 | 198.4 |

| | | |
|---|---|---|
| 80.0 | 145.0 | 144.6 |
| 90.0 | 108.0 | 107.8 |
| 100.0 | 82.0 | 80.8 |

DC bridge method $R_1=2041\ exp(-0.03T)$, correlation coefficient $r^2=0.997$.

Constant current method: curve equation $R_2=2060\ exp(-0.03T)$, correlation coefficient $r^2=0.997$.

7.3 Measure temperature properties of a PN junction temperature sensor

| T(°C) | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 |
|---|---|---|---|---|---|---|---|---|
| $U_{be}$ (mV) | 604.2 | 582.9 | 561.3 | 540.2 | 517.9 | 496.2 | 475.2 | 453.3 |

Results of curve fitting: curve equation $U_{be}=-2.157T+669.1$, correlation coefficient $r^2=1.000$.

7.4 Measure temperature properties of current-type IC temperature sensor (AD590)

| T(°C) | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 |
|---|---|---|---|---|---|---|---|---|
| U(V) | 0.3019 | 0.3125 | 0.3228 | 0.3330 | 0.3432 | 0.3535 | 0.3639 | 0.3744 |
| I(μA) | 301.9 | 312.5 | 322.8 | 333.0 | 343.2 | 353.5 | 363.9 | 374.4 |

Results of curve fitting: curve equation $I=1.031T+271.0$, correlation coefficient $r^2=1.000$.

7.5 Measure temperature properties of voltage-type IC temperature sensor (LM35)

| T(°C) | 30.0 | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 |
|---|---|---|---|---|---|---|---|---|
| $U_0$(mV) | 326.8 | 425.0 | 527.2 | 624.4 | 727.2 | 824.7 | 921.6 | 1020.3 |

Results of curve fitting: curve equation $U_0=9.92T+29.85$, correlation coefficient $r^2=1.000$.