

I&C Work Assignment - Quadratic RTD Conversions

Problem Definition

Resistance Temperature Detectors (RTDs) are used to measure the temperature in a plant. The applied temperature change causes a resistance change for a precision resistor and this resistance change is then measured to provide an indication of the process temperature.

RTD's very closely follow a quadratic relationship when the corresponding resistance versus temperature values are plotted. Industrial resistance temperature transmitters provide a 1:1 current signal in proportion to this resistance change. However, once the computer reads in these signal values (voltage developed by current flow through a specified dropping resistor), further errors could be introduced depending upon the numerical conversion method used.

In this work example, we will consider a temperature measurement application in which a *linear conversion* algorithm is utilized in the computer to read temperature signals obtained from an RTD installation. However, it is found during commissioning that the errors introduced by this linear conversion are not acceptable and so a software change to use a *quadratic solution* must be implemented. It is assumed that the computer installation has a quadratic algorithm available and so all that needs to be done is to specify the quadratic equation coefficients necessary to provide acceptable conversion accuracy (say +/- 0.5% full span error) for the temperature conversion application.

Background Technical Information

- The measured process temperature range is 0-320 C.
- The RTD is a precision 100 ohm platinum resistor which is described by the following function:

$$R_T = R_0 \{ 1 + a [T - S(-1.0 + T/100.0)]^2 \}$$

where

R_0 = 100 ohms, R_T = resistance at temperature T

a = 0.0039125

S = 1.447

- A **4-20 mA** signal is developed proportional to the 0-320 C measurement.
- A **225 ohm** dropping resistor provides the voltage input signal for the ADC.
- The ADC develops **6400 counts** for **each volt** applied as an input signal.
- The linear conversion routine used in the computer is made directly as a function of the counts read.

Deliverables

1. As Found:

Write a software routine to table the following values: **Process Temperature** in degrees C (incrementing in 10 C steps from 0-320 C), computed **RTD resistance** in Ohms based on the manufacturers given equation, transmitter **4-20 mA** signal, dropping resistor **V dc** signal, computer **ADC counts** obtained, and the **linearized computer temperature** displayed from given counts conversion. Calculate one additional value - the percentage full span error which results from the difference between the applied temperature value and the indicated temperature. If we require this indication to be within 0.5% of full span, is this conversion acceptable or not?

2. Quadratic Unit Conversion Routine

Write a quadratic equation solving routine that can accept specific 3 point calibration data input (temperature and counts for 0, 50 & 100% of measured temperature scale - but this can be flexible, say 10, 55 and 95 % as you think is important) and use this data to solve for the standard quadratic equation coefficients - A, B & C.

Once the quadratic coefficients are solved, use these coefficients to calculate the resulting quadratic temperature for a specified count value. That is, use the coefficients obtained to repeat the table temperature values from question #1 to show the improvement over the linear solution. Does this conversion method meet the specified criteria?

INSTRUMENT CALIBRATION SHEET

INSTRUMENT NUMBER 63333-TT2, TT4, TT9A,B,C

MEASUREMENT RANGE = 0-350°C

FROM REF 1.

$$R_T = R_0 \left\{ 1 + \alpha \left[T - \delta \left(\frac{T}{100} - 1 \right) \frac{T}{100} \right] \right\}$$

WHERE $\alpha = 0.0039125$

$\delta = 1.447$

R_T = RTD RESISTANCE @ $T^\circ\text{C}$

R_0 = RTD RESISTANCE @ 0°C

FROM REF 2

$R_0 = 100 \Omega$

$$R_{350} = 100 \left\{ 1 + 0.0039125 \left[350 - 1.447 \left(\frac{350}{100} - 1 \right) \frac{350}{100} \right] \right\}$$

$$= \underline{231.984 \Omega}$$

R/I CONVERTER IS TO OUTPUT 4-20 mA CORRESPONDING TO A RESISTANCE INPUT OF $100 - 231.984 \Omega$, i.e. A MEASUREMENT RANGE OF 0-350°C

REFERENCES:

1. MEMO Y.C. KAN (AECL) TO W. KIPWA
1994 JUNE 5.
FILE 138-60442-330-00
2. REF DWG HK38-D2N-60442-9001-001
3. CALIBRATION SHEET
X411-63333-3007 SHT 2

E730

CT

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21/13/94

R/I CONVERTERS

63333-TT2, TT4, TT9A,B,C

CALIBRATION SHT 1 OF 2



Ontario Hydro

Design & construction branch
instrumentation and control

850-10

Feb 20-95

N.T.S.

HK38 X411-63333-3007 SHT 1 OF 2

INSTRUMENT CALIBRATION SHEET

IDENTIFY NUMBER 63333-TT2 TT4 TT9ABC

TEMP °C	RESISTANCE Ω	EXPECTED OUTPUT mA	VOLTA	ACTUAL OUTPUT mA	
0	100	4.582	0.9	3.37	5905 4852
35	113.286	5.60		5.04	7857.6 12.5
70	127.509	7.20		6.84	9849.6
105	141.052	8.80		8.55	12812.0
140	154.454	10.40		10.24	14745.6
175	167.218	12.00	2.7	11.36	17280 17078.4
210	180.844	13.60		13.57	19442
245	193.833	15.20		15.19	21673.6 21466.4
280	206.686	16.80		16.81	23860.8
315	219.402	18.40		18.40	26096
350	231.984	20.00	4.5 with	19.98	28352 28171.2

NOTE: TRANSMITTERS ARE CALIBRATED TO ALLOW FOR MAX. ACCURACY IN THE 250°C TO 310°C RANGE WITHIN THE MEASUREMENT RANGE OF 0°C TO 350°C.

OTHER NOTES, SEE SHT. 1

TEST COUNTS octal 63120 → 26192 30.4

with 520-2880

K₂ 0151909 -1

T₂ K4C -87.5 = 310.55

E-730
67

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RT CONVERTERS
63333-TT2, TT4, TT9A, B, C
CALIBRATION SHT 2 of 3



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M.T.S.

10130 X411A 3393-9001 310.55

UNICON conversion check

enter ZERO SCALE Temp T(0) & counts to computer 0.0, 4833.0 ✓

enter MID SCALE Temp T(1) & counts to computer 245.0, 21873.0 ✓

enter FULL SCALE Temp T(2) & counts to computer 300.0, 28771.0 ✓

Answers auto

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775 ✓

counts to check 26496

quadratic temperature = 315.0042 ✓

test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 26190

quadratic temperature = 310.3074 ✓

test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 26206

quadratic temperature = 280.1442

test another count? 1 yes else end

+ .144°C error

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 21873

quadratic temperature = 245 ✓

test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 19540

quadratic temperature = 210.2331

test another count? 1 yes else end 1

+ .23°C error ✓ (Previously 0.65°C error)

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 17070

quadratic temperature = 173.95

test another count? 1=yes else end 1

-1.05°C (Previous 3.06°C error)

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18775

counts to check 14741

quadratic temperature = 139.9147 ✓

test another count? 1 yes else end

90-04-13 intentionally skew conversion toward top end to compensate for special RTD converter calibration.

*3.37-19.98mA
0 350°C with custom 250-350°C L.T.*