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:

$R_T = R_0 \{ 1+a [T-S(-1.0 + T/100.)* T/100.0]\}$

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 Ç), 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 fiexible, say 10, 55 an 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 improvment 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°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 Ω, i.e. A MEASUREMENT RANGE OF 0 - 350°C

REFERENCES:

1. MEMO Y.C.WAN (AECL) TO W.KHOWA 1994 JUNE 5. FILE: 38-60442-330.00
2. REF DWG NK38-D2N-60442-9001-001
3. CALIBRATION SHEET X4H-63353-3007 SHT 2

E730
C7

DARLINGTON G.S. 'A' | 2 | 13 | 4

R/I CONVERTERS
63333-TT2, TT4, TT9A,B,C
CALIBRATION SHT 1 OF 2

Ontario Hydro
design & construction branch
instrumentation and control

650-19
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NK38 X4H-63333-3001 SHT 1 REV 1

INSTRUMENT CALIBRATION SHEET

INSTRUMENT NUMBER 63333-TT2, TT4, TT9ABC

TEMP °C	RESISTANCE Ω		EXPECTED OUTPUT mA	Voltage	ACTUAL OUTPUT mA		
0	100	.1582	4	0.9	3.37	5960	4852
35	113.286		5.60		5.04	7257.6	12' sec
[illegible]	127.509		7.20		6.84	9849.6	
105	141.052		8.80		8.55	12312.0	
140	154.454		10.40		10.24	14745.6	
175	167.218		12.00	2.7	11.86	17280	17078.4
210	180.844		13.60		13.57	195408	
245	193.833		15.20		15.19	21873.6	[illegible]
[illegible]	206.686		16.80 16.17		16.81	24166.4	
[illegible]	219.402		18.40		18.40	26496	
[illegible]	231.984		20.00	4.5 with.	19.98	28800	28771.2

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 actual 63120 → 26192 ... 30.4

Counts 5960 28800

K = .015909 -1

T = K+C -37.5 = 310.59

	E730
	C7
DARLINGTON G.S. 'A'	21 3 4
R/I CONVERTERS 63333-TT2, TT4, TT9 A,B,C CALIBRATION SHT 2 OF 2	
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NK38 X4H 63333-9007 SHT 2	00

DIST. ... ADDED FOR ... 63333-...

UNICON conversion check
enter ZERO SCALE Temp T(0) & counts to computer 0.0,4033.0 ✓
enter MID SCALE Temp T(.5) & counts to computer 245.0,21873.0 ✓
enter FULL SCALE Temp T(1) & counts to computer 300.0,[illegible] ✓

quad solution: A= 3.45754E-08 ✓ B= 1.347077E-02 ✓ C=-66.18795 ✓

counts to check 26496
quadratic temperature = 315.0068 ✓
test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18795

counts to check 24192
quadratic temperature = [illegible] ✓
test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18795

counts to check 24206
quadratic temperature = 280.1442 + .144°C error.
test another count? 1 yes else end

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18795

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=-66.18795

counts to check 17540
quadratic temperature = 210.2221 +.23°C error ✓ (Previously 0.65°C error)
test another count? 1 yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18795

counts to check 17070
quadratic temperature = 173.95 -1.05°C (Previous 3.56°C error)
test another count? 1=yes else end 1

quad solution: A= 3.45754E-08 B= 1.347077E-02 C=-66.18795

counts to check 14740
quadratic temperature = 139.9607 ✓
test another count? 1 yes else end

90-04-18 intentionally skew conversion toward top end to compensate for special RTD converter calibration.

3.37 - 19.98mA with the custom 250-300°C [illegible].
0 350°C