Data Acquisition I

- Architecture of DAQ systems
- Signal conditioning
- Aliasing

Signal conditioning

- Instrumentation amplifiers
- Filters
- Integrators/differentiators

Example

A sensor outputs a voltage from −2.4 to −1.1V. For interface to ADC converter with range 0–2.5V. Develop the required signal conditioning.

Solution

Vout=mVin+Vo

0=-2.4m+Vo

2.5=-1.1m+Vo

Vo=4.615 & m=1.923

Vout=1.923Vin+4.625 using standard op-amp circits

Vout= 1.923(Vin+2.4)

Using INA with gain 1.923

Example

Temperature is to be measured in the range of 250-450 C with the accuracy ±2C. The sensor is a resistance that varies linearly from 280-1060Ω for the temperature range. Power dissipation must be kept below 5mW. Develop analog signal conditioning that provides a voltage varies linearly from -5 to +5 V for the temperature range.

Measured variable parameters

- Range
- Accuracy
- Noise

Sensor Signal

- Parameter
- Transfer function
- Time Response
- Range
- Power

Signal Conditioning

- Parameter
- Range
- Input Impedance
- Output Impedence

Solution

The accuracy of ±0.8% at the low end and of ±0.44% at the high end. Therefore we will keep 3 significant figures to provide 0.1% on values selected.

$$P = I^2 R$$

$$.005 = I^2 R$$

$$I_{MAX} = \sqrt{\frac{.005}{1060}} = 2.17mA$$

Keep current below 2mA

$$V_{out} = mR_s + V_o$$

$$-5 = 280m + V_0$$

$$+5 = 1060m + V_o$$

$$Vout = .0128R_s + -8.58$$

Inverting amplifier with the sensor on feedback following by an inverting summer. The fixed input voltage and input resistance of the first opamp have been selected to satisfy 5mW dissipation. By sing input voltage 1V and 1KΩ the current will be 1mA.

Significant Figures

- Digital multimeter measures current through 12.5KΩ resistor as 2.21mA using 10mA scale. Instrument accuracy is ±0.2% FS . Find the voltage across the resistor with the uncertainty in the values obtained.

- Accuracy becomes uncertainty in current of ±0.02mA
- V=I R =27.625volts.

With significance figures it is 27.6V

The accuracy means the the current could vary from 2.19 to 2.23 mA which introduces an uncertainty of ±0.25volt. Thus complete answer is 27.6±0.3 volts because we must express the uncertainty so that our significance is not changed.

In calculations one must be careful not to obtain a result that has more significance than the numbers employed in the calculation

Rules for deciding the number of significant figures in a measured quantity:

(1) All nonzero digits are significant:

1.234 g has 4 significant figures,
1.2 g has 2 significant figures.(2) Zeroes between nonzero digits are significant:
1002 kg has 4 significant figures,
3.07 mL has 3 significant figures.(3) Leading zeros to the left of the first nonzero digits are not significant; such zeroes merely indicate the position of the decimal point:
0.001 ^{o}C has only 1 significant figure,
0.012 g has 2 significant figures.(4) Trailing zeroes that are also to the right of a decimal point in a number are significant:
0.0230 mL has 3 significant figures,
0.20 g has 2 significant figures.(5) When a number ends in zeroes that are not to the right of a decimal point, the zeroes are not necessarily significant:

190 miles may be 2 or 3 significant figures,
50,600 calories may be 3, 4, or 5 significant figures.The potential ambiguity in the last rule can be avoided by the use of standard exponential, or "scientific," notation. For example, depending on whether the number of significant figures is 3, 4, or 5, we would write 50,600 calories as:

5.06×10^4 calories (3 significant figures)

5.060×10^4 calories (4 significant figures), or

5.0600×10^4 calories (5 significant figures).

By writing a number in scientific notation, the number of significant figures is clearly indicated by the number of *numerical figures* in the 'digit' term as shown by these examples. This approach is a reasonable convention to follow.

Rules for mathematical operations

In carrying out calculations, the general rule is that the accuracy of a calculated result is limited by the least accurate measurement involved in the calculation.

(1) In addition and subtraction, the result is rounded off to the last common digit occurring furthest to the right in all components. Another way to state this rule is as follows: in addition and subtraction, the result is rounded off so that it has the same number of digits as the measurement having the fewest decimal places (counting from left to right). For example,

100 (assume 3 significant figures) + 23.643 (5 significant figures) = 123.643,

which should be rounded to 124 (3 significant figures). Note, however, that it is possible two numbers have no common digits (significant figures in the same digit column).

(2) In multiplication and division, the result should be rounded off so as to have the same number of significant figures as in the component with the least number of significant figures. For example,

3.0 (2 significant figures) $\times$ 12.60 (4 significant figures) = 37.8000

which should be rounded to 38 (2 significant figures).

Rules for rounding off numbers

(1) If the digit to be dropped is greater than 5, the last retained digit is increased by one. For example,

12.6 is rounded to 13.

(2) If the digit to be dropped is less than 5, the last remaining digit is left as it is. For example,

12.4 is rounded to 12.

(3) If the digit to be dropped is 5, and if any digit following it is not zero, the last remaining digit is increased by one. For example,

12.51 is rounded to 13.

(4) If the digit to be dropped is 5 and is followed only by zeroes, the last remaining digit is increased by one if it is odd, but left as it is if even. For example,

11.5 is rounded to 12,

12.5 is rounded to 12.

This rule means that if the digit to be dropped is 5 followed only by zeroes, the result is always rounded to the even digit. The rationale for this rule is to avoid bias in rounding: half of the time we round up, half the time we round down.

Sample problems on significant figures

Instructions: print a copy of this page and work the problems. When you are ready to check your answers, go to the next page.

1. $37.76 + 3.907 + 226.4 = ?$
2. $319.15 - 32.614 = ?$
3. $104.630 + 27.08362 + 0.61 = ?$
4. $125 - 0.23 + 4.109 = ?$
5. $2.02 \times 2.5 = ?$
6. $600.0 / 5.2302 = ?$
7. $0.0032 \times 273 = ?$
8. $(5.5)^3 = ?$
9. $0.556 \times (40 - 32.5) = ?$
10. $45 \times 3.00 = ?$
11. What is the average of 0.1707, 0.1713, 0.1720, 0.1704, and 0.1715?
12. What is the standard deviation of the numbers in question 11?
13. $3.00 \times 10^5 - 1.5 \times 10^2 = ?$ (Give the exact numerical result, and then express that result to the correct number of significant figures).

Answer key to sample problems on significant figures

1. $37.76 + 3.907 + 226.4 = 268.1$
2. $319.15 - 32.614 = 286.54$
3. $104.630 + 27.08362 + 0.61 = 132.32$
4. $125 - 0.23 + 4.109 = 129$ (assuming that 125 has 3 significant figures).
5. $2.02 \times 2.5 = 5.0$
6. $600.0 / 5.2302 = 114.7$
7. $0.0032 \times 273 = 0.87$
8. $(5.5)^3 = 1.7 \times 10^2$
9. $0.556 \times (40 - 32.5) = 4$
10. $45 \times 3.00 = 1.4 \times 10^2$