Tentamen 2015-01-19 : solutions

Ex 1

a) Active sensors : generate energy that depends on a physical phenomenon. Examples: piezo-electric sensors, thermocouples

Passive sensors : they require an external voltage, which is used to detect changes in the electrical properties of the sensor. Examples : Pt100, strain gauges.

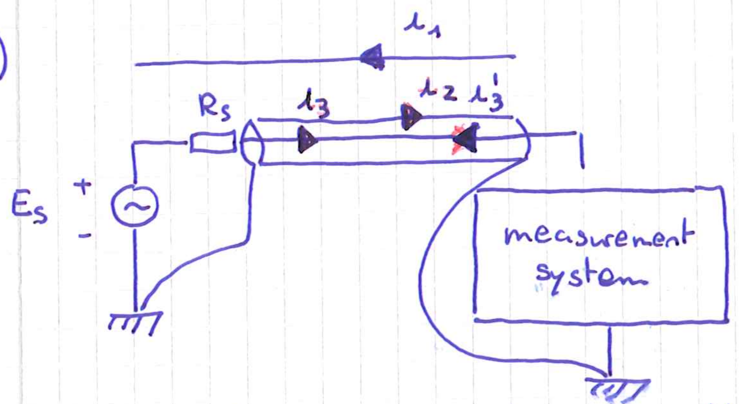
b) Higher sensor constant (twice as large).
Temperature compensation

c) If directly connected to a multimeter, the piezo-electric sensor discharges itself very fast (less than microseconds)
The charge amplifier avoids ~~that~~ it.

d)
+ cheap
+ quick
+ possible to integrate

- nonlinear
- require calibration
- limited range

e)



i_1 generates a current on the wire (i_3) but also a current on the shield (i_2), provided that the shield is connected at both ends. Furthermore, the current on the shield generates another current on the wire (i_3') in the opposite direction of i_3.

Ex 2

a) The voltage at the input of the AD converter must be between $\emptyset$ and 5 Volt. This means that the output voltage of the thermocouple must be between $\emptyset$ and 5 mV. Let's call this output U_S.

Then

$$U_S = U_{AB}(T \to \emptyset^\circ) - \underbrace{U_{AB}(T \to 15^\circ)}_{0{,}589 \text{ mV}}$$

$\Rightarrow$ $U_{AB}(T \to \emptyset^\circ)$ must be between 0,589 mV and 5,589 mV

$\Rightarrow$ T must be between 15°C and 127°C

b) The minimum voltage variation corresponding to an increase of 1°C in the interval 15°C – 127°C is 0,011 mV. $\Rightarrow$ The resolution of the ADC must be at least 0,011 V

$$\Rightarrow \frac{U_{ref}}{2^n} = \Delta U \qquad \Rightarrow \frac{5}{2^n} = 0{,}011$$

$\Rightarrow$ $n \approx 7$ bit

Ex 3

a) $f_s > 2 f_{max} \Rightarrow$ ~~[illegible]~~ $f_s = 1\ GHz$

b) $\emptyset \leqslant u(t) \leqslant 5 \Rightarrow U_{ref} = 5V$

c) $\Delta U = 1 mV \Rightarrow \Delta U = \frac{U_{ref}}{2^n}$

$\Rightarrow 1 mV = \frac{5V}{2^n} \Rightarrow n \simeq 13$ bit

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Ex 4

$$F_{NM} = \frac{2V}{2mV} = 1000$$

$$F_{CM} = \frac{0{,}02V}{10V} = 2 \cdot 10^{-3}$$

$$CMRR = 20 \log_{10} \frac{1000}{2 \cdot 10^{-3}} = 114\ dB$$

Ex 5

a) $f_0 = \emptyset$ $f_1 = 50\ Hz$ $f_2 = 200\ Hz$

$$N = \frac{0{,}2}{10^{-3}} = 200$$

$$\Delta f = \frac{f_s}{N} = \frac{1000}{200} = 5\ Hz$$

$\Rightarrow k_0 = \emptyset$ $k_1 = \frac{f_1}{\Delta f} = 10$ $k_2 = \frac{f_2}{\Delta f} = 40$

and then peaks also at $N - k_1 = 190$ and

$N - k_2 = 160$

b) $|X(k)| = N \frac{A_k}{2}$, $k \neq 0$

$|X(k)| = N A_k$, $k = 0$

Hence,

Ex 6 a) $t_{out} = \sqrt{t_{in}^2 + t_{amp}^2 + t_{osc}^2}$

$\Rightarrow \quad t_{in} = \sqrt{t_{out}^2 - t_{amp}^2 - t_{osc}^2}$; $t_{out} = 29$ ns

$t_{amp} = \frac{0{,}35}{30 \text{ MHz}} = 11{,}7$ ns ; $\quad t_{osc} = \frac{0{,}35}{100 \text{ MHz}} = 3.5$ ns

$\Rightarrow t_{in} = 26{,}32$ ns

b) $\tau = \frac{t_{in}}{2{,}2} = 11{,}96$ ns

7.

a) A while loop executes the code it contains until the condition terminal receives a specific Boolean value.

b)

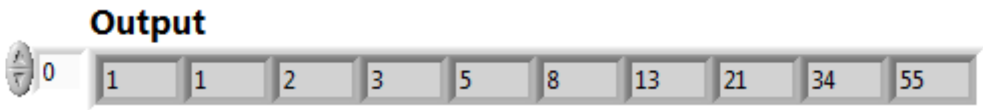
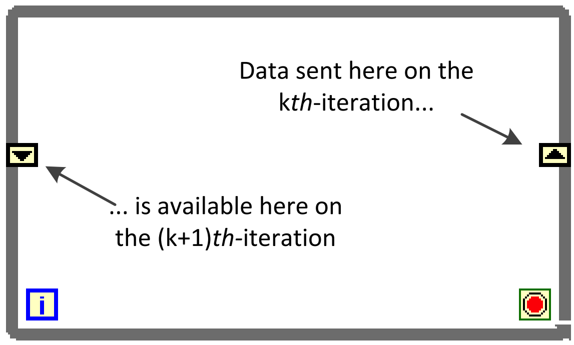


Figure 1: Exercise 7

c) A shift register is used to pass data between loop iterations. A shift register appears as a pair of terminals on the vertical sides of the loop border . A shift register transfers the data connected to the terminal in the right side of the register to terminal in left side in the next iteration.



8.

a) It presets and makes a 4-wire ohm measurement.

b) Wiring an error cluster through GPIB blocks ensures that they are executed in the right order; it also allows one to track the error messages.

c) A stacked sequence, a for loop, a case structure and a formula node.

d) It is saved in two columns, where the first column contains the time and the second column contains the temperature in Celsius.

9.

a) A stacked sequence consists of one or more sub diagrams/frames that execute sequentially. Stacked sequences are used to ensure that the sub diagrams are executed in the right order.

b) See Figure 2.

c) See Figure 2.

d) See Figure 2.

e) See Figure 2.

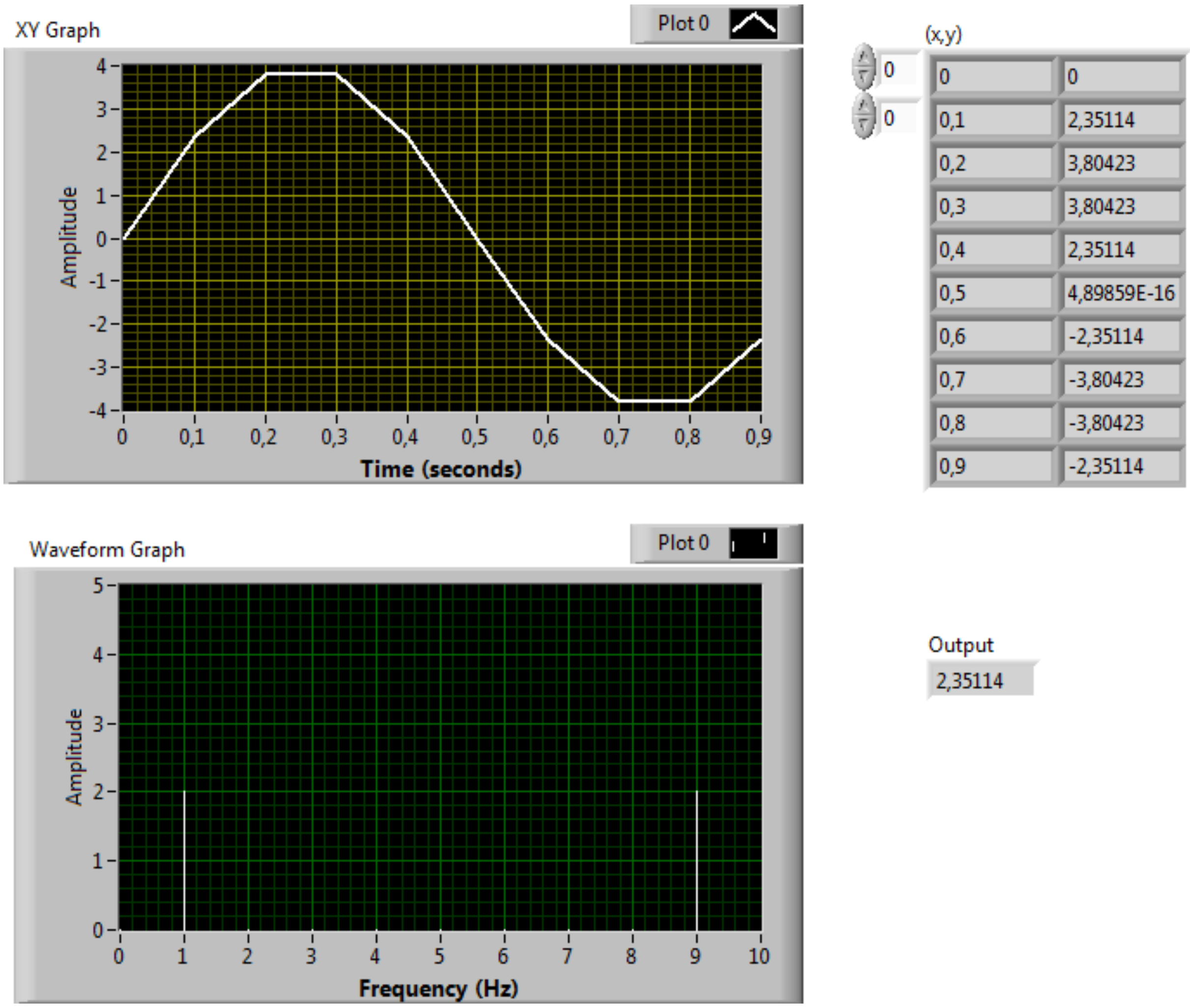


Figure 2: Exercise 9

Ex 10

a) $\hat{R} = 1137{,}6\ \Omega$

b) standard deviation $\hat{\sigma} = \sqrt{\frac{1}{N-1}\sum_{\ell=1}^{N}(R_\ell - \hat{R})^2} = 1{,}504\ \Omega$

$$u_A(R) = \frac{\hat{\sigma}}{\sqrt{N}} = 0{,}614\ \Omega$$

c) $R \in [\hat{R} - k\,u_A(R),\ \hat{R} + k\,u_A(R)]$

with $k = 2{,}57$.

Hence, the extreme points of the confidence interval are

$$(1137{,}6 \pm 1{,}6)\ \Omega$$

d) $\Delta R = \left(\frac{0{,}002}{100}\ 1137{,}6 + \frac{0{,}0005}{100}\ 1000\right)\Omega = 0{,}0277\ \Omega$

$$u_B(R) = \frac{\Delta R}{\sqrt{3}} = 0{,}016\ \Omega$$

$$\Rightarrow u(R) = \sqrt{u_A^2(R) + u_B^2(R)} = 0{,}614\ \Omega \approx u_A(R)$$

e) $R = R_0(1+\gamma T) \Rightarrow T = \frac{1}{\gamma}\left(\frac{R}{R_0} - 1\right)$

$$\hat{T} = 29{,}978\ °C$$

f) $u(\gamma) = 1{,}155 \cdot 10^{-5}\ °C$ $\qquad \left(u(\gamma) = \frac{\Delta\gamma}{\sqrt{3}}\right)$

$u(R_0) = 1{,}732\ \Omega$ $\qquad \left(u(R_0) = \frac{\Delta R_0}{\sqrt{3}}\right)$

$$c_R = \frac{\partial T}{\partial R} = \frac{1}{\gamma R_0} = 0{,}2178\ °C\,\Omega^{-1}$$

$$c_\gamma = \frac{\partial T}{\partial \gamma} = -\frac{1}{\gamma^2}\left(\frac{R}{R_0} - 1\right) = -6{,}53 \cdot 10^{+3}\ °C^2$$

$$u(T) = \sqrt{\left(c_R \cdot u(R)\right)^2 + \left(c_\gamma \cdot u(\gamma)\right)^2 + \left(c_{R_0} \cdot u(R_0)\right)^2}$$

$$= 0{,}456\,°C$$

$$\Rightarrow \quad T = (29{,}97 \pm 0{,}46)\ °C$$