Exam 2019 – solution

Problem 1

a) Explain why a start bit and a stop bit are used in the RS-232 standard (3 points).

There is no shared clock in RS-232 serial communication (asynchronous transfer) between the transmitter and the receiver. The start bit (0) shows the receiver the start of a new data word, by the falling edge of the data line. The stop bit (1) pull the data line high again, in order to guarantee that the signal line is high after the transmitted data word.

b) Explain the main differences between RS-232 and RS-485 (3 points).

RS-232	**RS-485**
Point-to-point connection (one transmitter and one receiver)	Multi-point connection (multiple transmitters and receivers)
Single-ended data transmission	Differential data transmission
Maximum cable length is about 15 m	Maximum cable length about 1200 meters

c) How can you communicate over RS-485 using a laptop with only USB and Ethernet connections? (3 points).

Use a **Virtual Serial Ports (VSP)**. A VSP-driver will then translate RS-485 ASCII commands to USB data or Ethernet packages. A hardware box is then used convert between different interfaces. Either USB to RS-485 or Ethernet to RS-485 in this case. See example below for USB to UART.

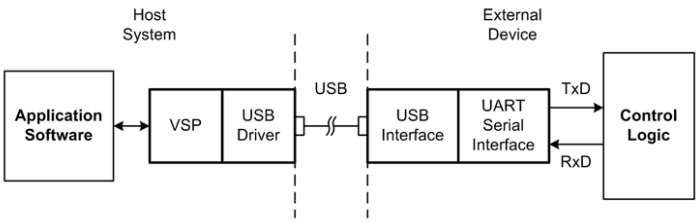


Figure 7-34. USB-to-serial interface

d) What is the typical maximum bus length for a point-to-point connection without any extension devices for (3 points):

i. USB — 5 meter or 3 meter, both answers are correct (3 meter used by USB 1.1 and recommended for 3.1)

ii. RS-485 — 1200 meter

iii. Ethernet — 100 meter

e) What is the bandwidth in GB/s for *PCI Express x16* of generation 3? (3 points).

16 GB/s.

f) Given that you do not have access to a hardware sensors or a DAQ-device used in your setup. How can you then test the entire DAQ-software you are making? (3 points).

Make a **simulator** in software of the sensor or hardware unit. (One example in the course was the simulated temperature sensor in lab0).

g) Explain the difference between array and cluster in LabVIEW (3 points).

An array must have the same data type for each element. In a cluster the elements can be of different data types.

h) Explain why queues should be used to communicate between software while loops / threads (3 points).

Queues provide **synchronization between loops**. This is important since different loops usually run at different speed. The **FIFO-buffer** in the queue **avoid data loss** between the loops. The loop synchronization using queues also **avoids reading the same data point multiple times**. Global variables can also create **race conditions** (uncertain result due to shared resources).

Problem 2 (18 points)

a) What is oversampling, and why is it a useful technique in data acquisition? (3 points)

Oversampling means to sample faster than the Nyquist rate $f_{nyquist}$, which is given by $f_{nyquist} = 2 * \Delta f$, where $\Delta f = f_{max} - f_{min}$. Oversampling

- allows a simple anti-aliasing filter before the ADC, and
- increase the signal-to-noise ratio (SNR) for a given number of bits, and
- accurately represents the shape of the signal and allows determination of peak maximum and peak location.

b) What are the problems of simple averaging of signals? Suggest another alternative digital filter for noise reduction (3 points).

Problems:

- Delay (shift in peak position).
- The amplitude of a time-varying signal is typically not preserved.

Alternative filter:

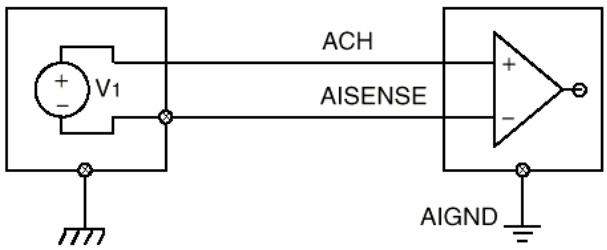
- In post-processing (non-real time) a **zero-phase digital filter** can be used.
- (A Savitzky-Golay smoothing filter can also be used, using a curve fitting technique based on minimizing the least squares error).

c) Given a sensor with an output resistance on 1 MΩ. If you require the measured voltage to be within 1 % error, what is the minimum input resistance of the pre-amplifier (front-end electronics) in the DAQ-system? (3 points).

Use the voltage divider equation: $V_{out}/V_{in} = R_L/(R_s + R_L) = 0.99$. Solving for the input resistance R_L gives $R_L = 99*Rs =$ **99 MΩ**

d) What is NRSE configuration for a DAQ system, and when can we use NRSE? (3 points).

Single-Ended means that only one signal wire is connected to the DAQ-system for each channel. **Non-Referenced Single-Ended (NRSE) means that the DAQ-system is not connected to ground. This configuration can be used for grounded signal sources**, as long as the signal level is sufficiently high and the external noise is small or take care of by short cables and cable shielding. NRSE can also be used for floating signal sources if a bias resistor to ground is added in the DAQ-unit.



e) What is the IEEE 1588 protocol? (3 points).

A **timing protocol** that provide sub-microsecond synchronization over Ethernet. Timing accuracy depends on the network.

f) Explain 8b/10b encoding, and give an example of where it is used (3 points).

8-bit symbols are encoded as 10-bit symbols to achieve **DC-balance** (equal number of '0' and '1' transmitted) and provide enough state changes to allow **clock recovery**. 8b/10b encoding is used in USB 3.0, SATA, PCI express and some Ethernet standards.

Problem 3 (12 points)

a) You are given the task to design a data acquisition and processing board for an embedded system. The design specification states that it should be able to keep track of time as accurate as possible also when indoor or when GPS is jammed. What kind of timing device would you include on your printed circuit board? (3 points).

A **Chip Scale Atomic Clock** (which provide two orders of magnitude better accuracy than an oven-controlled crystal oscillators).

b) What is the problem with an open loop controller? Explain (3 points).

No feedback means that it is not possible to correct the output. For instance, in an open loop motor controller the rotation rate will vary with the load.

c) Explain how a PI-controller works (3 points).

A PI controller continuously calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error over time, by adjustment of a control variable *u(t)*. The P term **is proportional to the error** while the I-tem is **proportional to the integral of the error**. In a PI-controller **the P and the I signals are added together** to produce *u(t)*.

d) Can you give an example of a predict-correct algorithm, and shortly explain how it works? (3 points).

The **Kalman filter (KF)** combines a prediction from mathematical models with a measurement correction (from sensor data). The process model describes how the states varies with time, and the measurement model describes how the measurements depend on the states. The five KF-equations calculate the estimated states (such as position and velocity) and their corresponding uncertainty (variance).