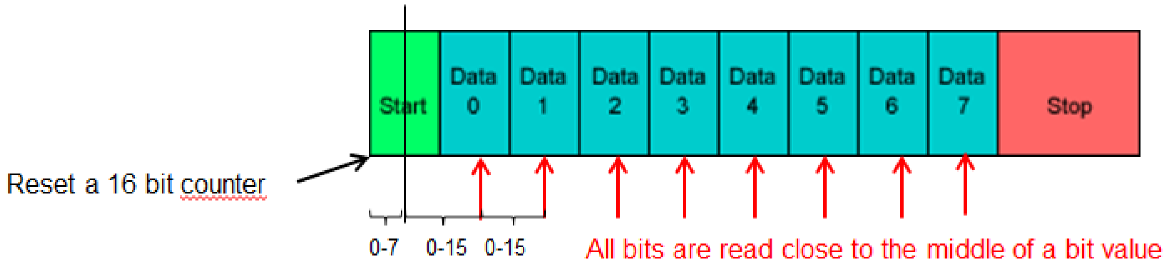
Exam 2018 – solution

Problem 1

a) Asynchronous transfer means that the information is not sent in predefined time slots. **Data transfer can start at any given time and it is the task of the receiver to detect when a message starts and ends**. Data is sent upon request using **handshake signals**. Tx and Rx have internal clocks but **no clock is shared.** Therefore **the receiver must adjust its clock to the transmitter's clock frequency and phase** (clock recovery /clock synchronization based on the data transfer) in order to read the data bits correct.

More details not required for full score:
One example is UART devices, using start bit and stop bit.



Reset a 16 bit counter

All bits are read close to the middle of a bit value

A clock 16 times faster than the bit clock is used as input to the counter

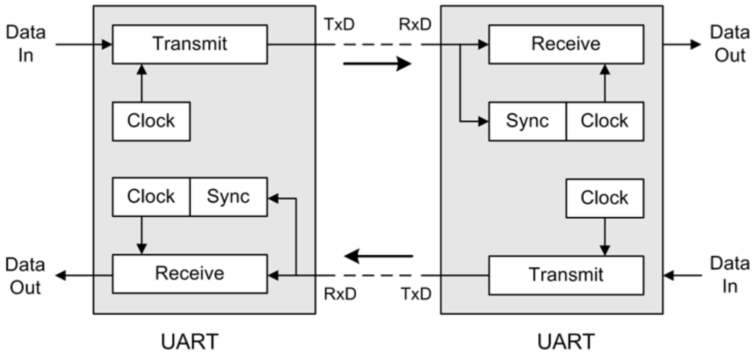


Figure 2-38. Asynchronous serial interface

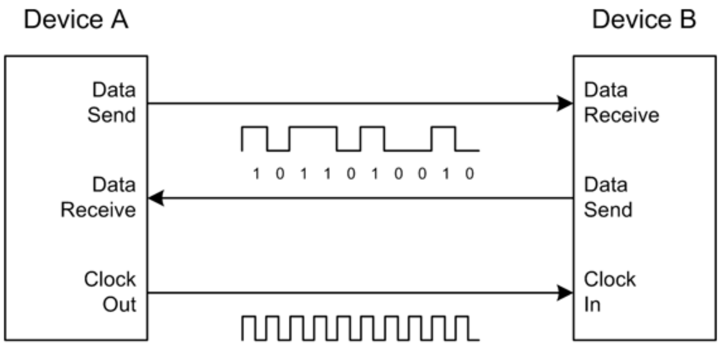
b) SPI is a **synchronous serial data** communication. Transmitter and receiver **share clock** (using a clock line/signal). It the transmitter put new data on the data line on the rising clock edge the receiver should read the data on the falling clock edge (read in the middle of the bit). The SPI interface use **four lines** (should mention at least 1-3)

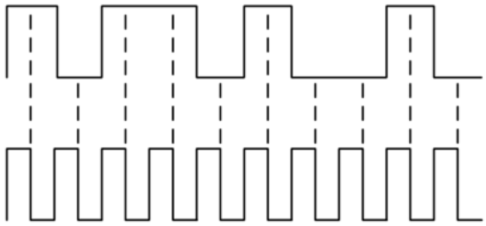
1. Serial Clock
2. Serial Data In
3. Serial Data Out

4. CS (chip select)

More details not required for full score:

- Full duplex
- Communicate in master/slave mode
- Short distance communication





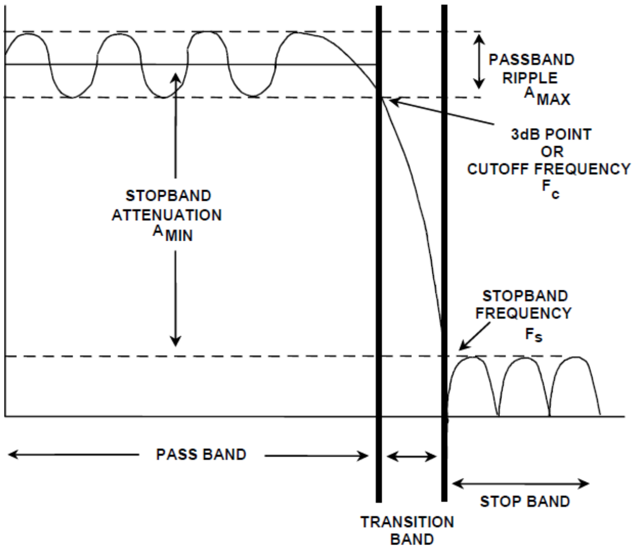
Data is valid on the falling edge of the clock signal.

c) In **protected mode**, there are four **privilege levels or rings, numbered from 0 to 3**, with ring 0 being the most privileged and 3 being the least. The use of rings allows for system software to **restrict tasks from accessing data or executing privileged instructions**. In most environments, the operating system and device drivers run in ring 0 and applications run in ring 3. **A device driver in ring 0 is needed in order to allow hardware I/O operations from application programs.**

d) If the PC has three or more CPU cores the VIs *Filter*, *Spectral Measurements*, and *Curve Fitting* will be executed in parallel (at the same time), and when they have all finished the VI *Write to Measurement File* will be executed.

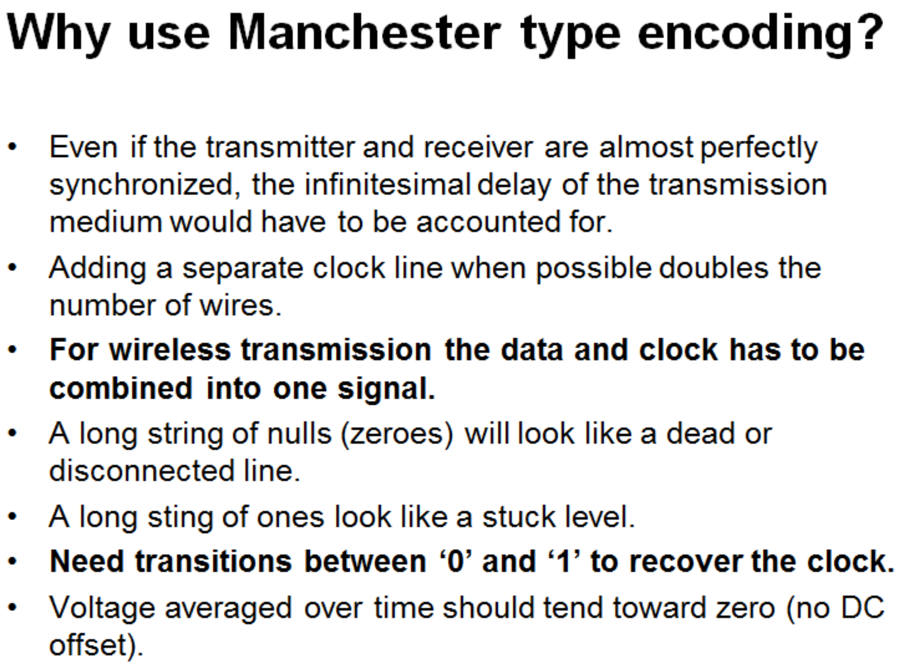
e) **Sample as fast as possible** (oversampling) to make the delay between each channel as small as possible. (The result will be limited by the maximum sample frequency of the ADC). A better solution is to **use a known time delay between the sampling of each channel and align the channels in software** (e.g. in post-processing).

f) **A filter will affect the phase of a signal, as well as the amplitude.** It is usually a tradeoff between a small transition band and ripple (in pass/stop band) and phase distortions/delay. In a DAQ system we usually do not want **ripple** in the pass band, and then a Butterworh characteristic is good. However, if it is more important to have a small **transition band** (to reduce sample frequency requirements) we could consider using an Elliptic filter. In other DAQ applications we might require **linear phase** (same delay for all frequencies), and then a Bessel filter could be a solution.



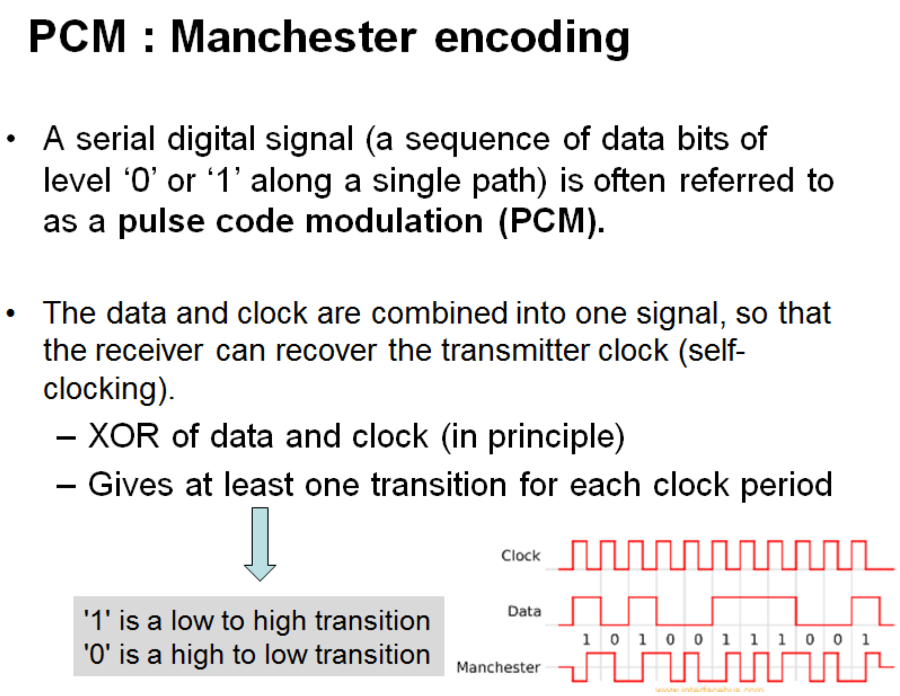
Problem 2

a) See slides below.



Why use Manchester type encoding?

- Even if the transmitter and receiver are almost perfectly synchronized, the infinitesimal delay of the transmission medium would have to be accounted for.
- Adding a separate clock line when possible doubles the number of wires.
- **For wireless transmission the data and clock has to be combined into one signal.**
- A long string of nulls (zeroes) will look like a dead or disconnected line.
- A long sting of ones look like a stuck level.
- **Need transitions between ‘0’ and ‘1’ to recover the clock.**
- Voltage averaged over time should tend toward zero (no DC offset).



PCM : Manchester encoding

- A serial digital signal (a sequence of data bits of level ‘0’ or ‘1’ along a single path) is often referred to as a **pulse code modulation (PCM).**
- The data and clock are combined into one signal, so that the receiver can recover the transmitter clock (self-clocking).
  - XOR of data and clock (in principle)
  - Gives at least one transition for each clock period

'1' is a low to high transition
'0' is a high to low transition

b)

- **Dedicated, high bandwidth** to each connected device
- **Serial bus** (with the advantages of serial buses)

c) **It is useful in order to provide a common and convenient interface to a physical USB port. Can also be used on computers that do not have a UART serial interface connector (RS-232), when such a port is required.** For instance if you have a motor or **motor controller with an RS-232 interface**. This also requires a hardware converter box that converts data between the required formats, for instance a USB-to-Serial converter. (Another example could be if you need to transmit RS-232 signals over a long distance. Writing to a virtual COM-port which converts the data to TCP/IP packages and transmits them over Ethernet only requires a hardware converter box at the receiver end that converts back to RS-232 signals).

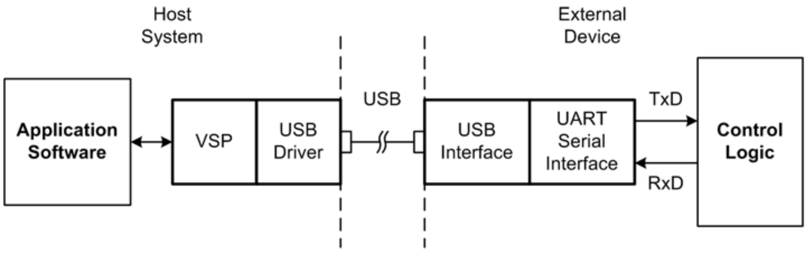


Figure 7-34. USB-to-serial interface

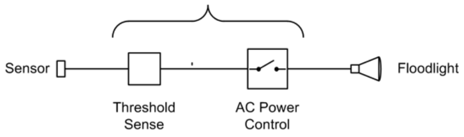
d) The two main problems with the software clock is **low accuracy due to drift** (drift away from the correct time) **and limited resolution** (about 1 ms).

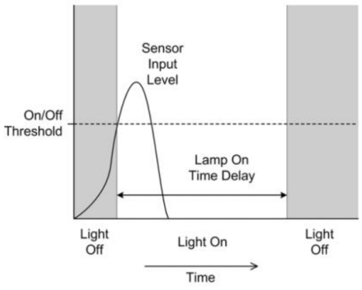
<u>More details not required for full score:</u>
The software clock is maintained by the operating system, based on the RTC (Real Time Clock**)** interrupts. Since the RTC hardware clock (an integrated circuit on the motherboard) use a <u>quartz crystal oscillator</u>, and some interrupts could be missing, the clock will drift.

e) International Atomic Time (TAI) is a weighted average of the time kept by over 300 atomic clocks in over 60 national laboratories worldwide. Coordinated Universal Time (UTC) is based on TAI but with **leap seconds** added at irregular intervals to compensate for the slowing of the Earth's rotation. GPS time is the atomic time scale implemented by the atomic clocks in the GPS ground control stations and the GPS satellites themselves. GPS time is not corrected for leap seconds, and remains at a constant offset of 19 seconds compared to TAI. So, GPS time is not equal to either UTC or TAI time.

Problem 3

a) Open-loop: **no feedback** (between controller output and input); e.g. an **automatic light switch**.





Closed-loop: **use feedback to determine the effect of the control** and based on this modify the control actions according to the “control law” (control algorithm). One closed-loop example is the fluid level controller.

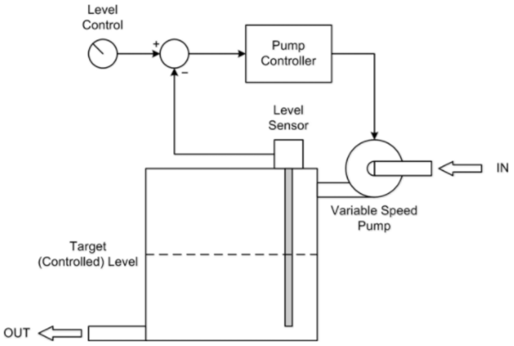


Figure 1-7. Closed-loop fluid level control

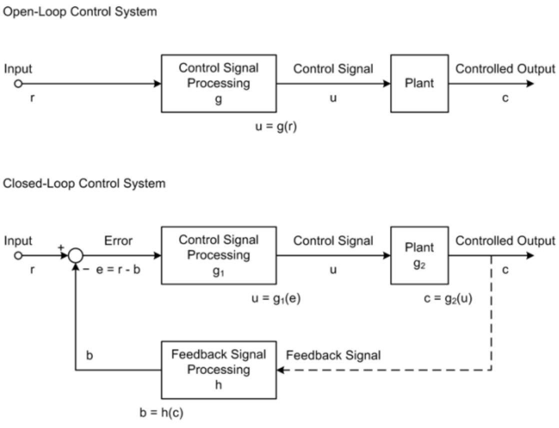


Figure 9-5. Control system block diagrams

b) On/off (bang-bang) nonlinear controller switches between two states; either completely on or completely off. Then hysteresis is useful t**o avoid the controller to turn on/off very often when it is close to the set point (due to noise or small input variations). For instance used for thermostats.**

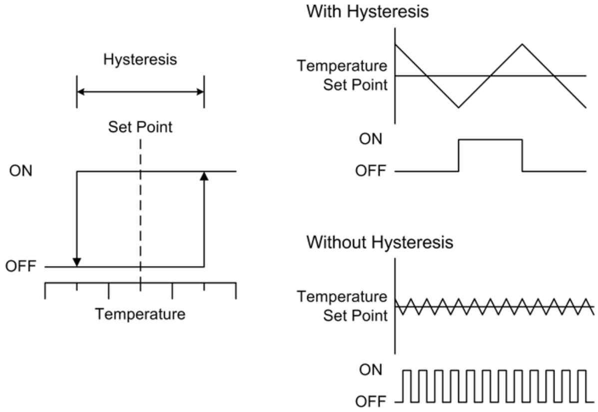


Figure 9-18. Hysteresis

c) The problem is that for this simple **open-loop control** implementation **the motor rotation rate will vary with load.** The controller can be improved by **adding a velocity feedback** (measurement of the motor rotation rate) and a **load feedback** (measurement of the current to the motor, to compensate for changing torque loads).

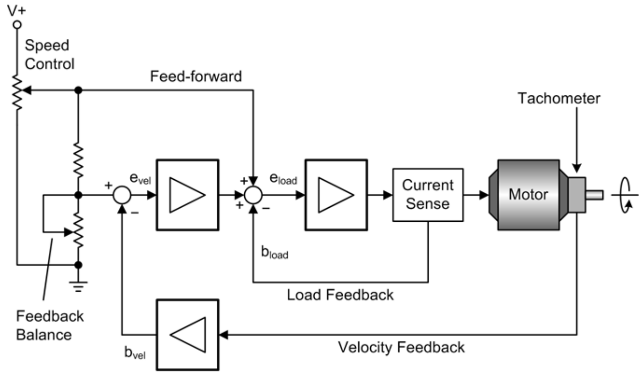
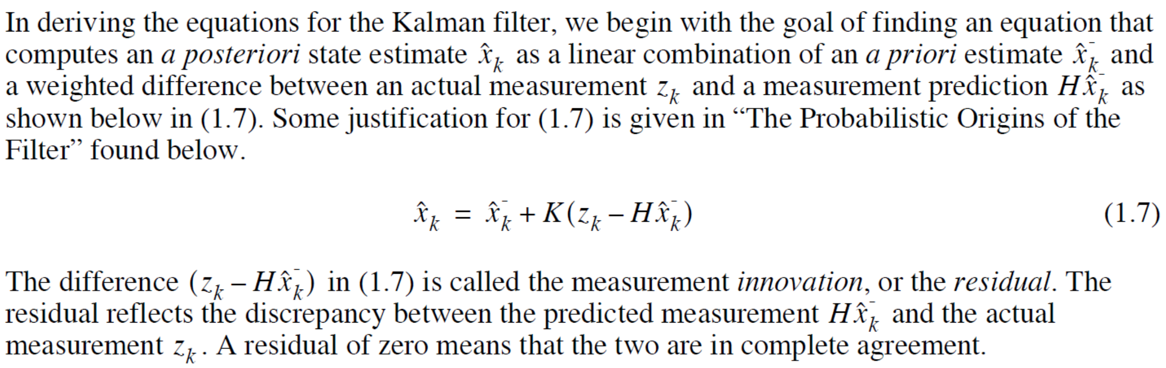


Figure 9-14. Feed-forward DC motor velocity controller

d) See e.g. the paper “An Introduction to the Kalman Filter”:



In deriving the equations for the Kalman filter, we begin with the goal of finding an equation that computes an *a posteriori* state estimate $\hat{x}_k$ as a linear combination of an *a priori* estimate $\hat{x}_k^-$ and a weighted difference between an actual measurement z_k and a measurement prediction $H\hat{x}_k^-$ as shown below in (1.7). Some justification for (1.7) is given in “The Probabilistic Origins of the Filter” found below.

$$\hat{x}_k = \hat{x}_k^- + K(z_k - H\hat{x}_k^-) \tag{1.7}$$

The difference $(z_k - H\hat{x}_k^-)$ in (1.7) is called the measurement *innovation*, or the *residual*. The residual reflects the discrepancy between the predicted measurement $H\hat{x}_k^-$ and the actual measurement z_k. A residual of zero means that the two are in complete agreement.

The weighting (gain) K tells how much to trust the measurement and how much to trust the predicted measurement (from the model). E.g. a small measurement error (variance) and a big uncertainty in the model (large variance) will give a large gain K to give a high weight to the measurement z.

Note: the different terms (x, z, H, K) should be explained.