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SCADA Lab Work

Supervisory Control and Data Acquisition

Hans-Petter Halvorsen

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Introduction SCADA Project

Hans-Petter Halvorsen

Lab Overview

In this Lab we will create a SCADA System from scratch

USB-6008

Air Heater

Process Plant

MV

PV

Control System

PV, MV

Matrikon OPC Simulation Server

OPC Server

PV, MV

Network

Datalogging System

PV, MV

Microsoft SQL Server

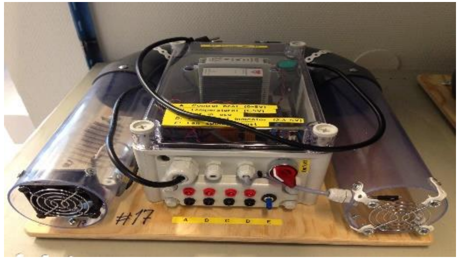
SQL Database

Alarm Trigger

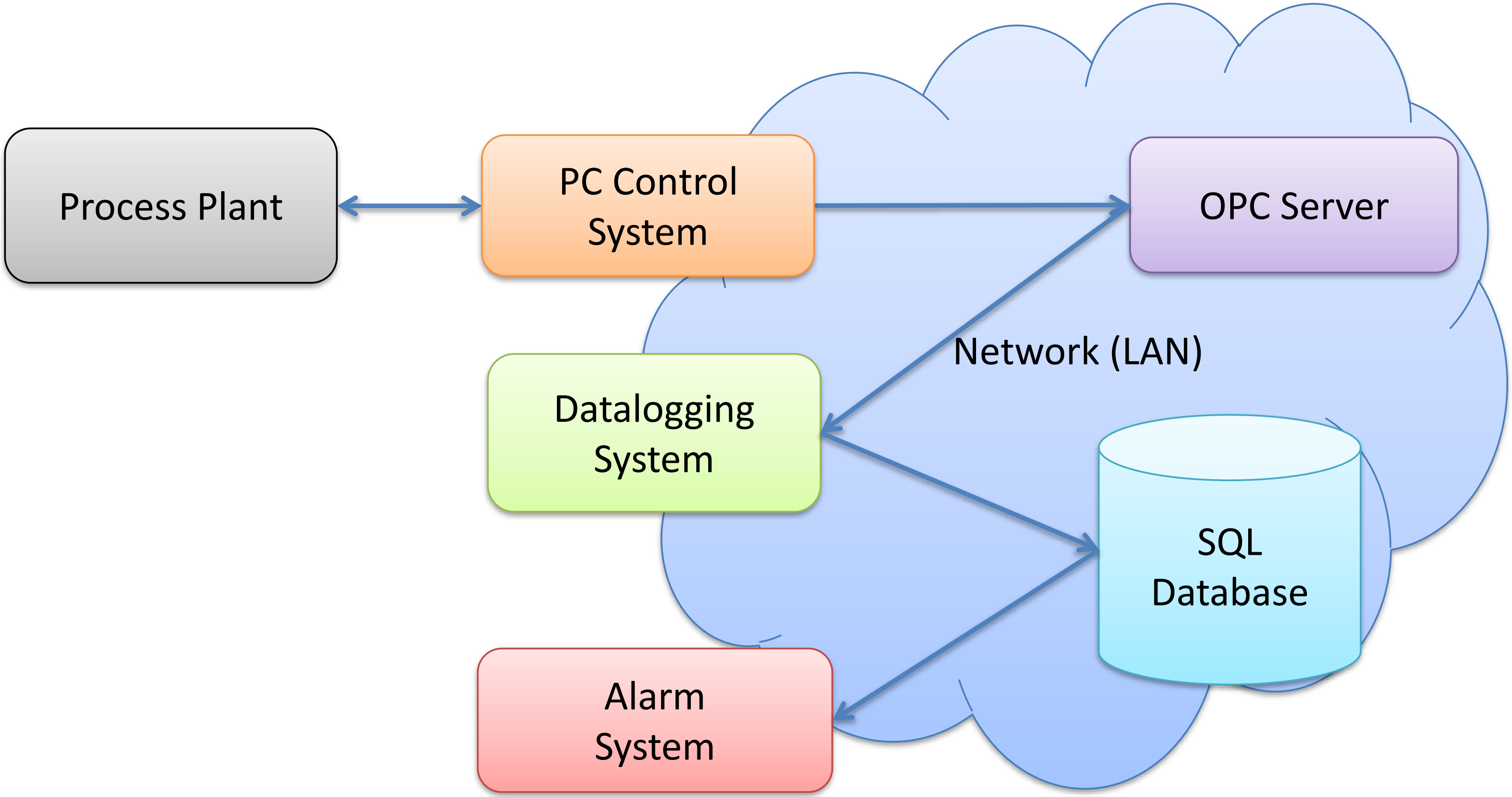
LL, L, H, HH

Alarm System

Simulator/Real Process



The SCADA system should be distributed, meaning that the different components could be located on different computers in a network

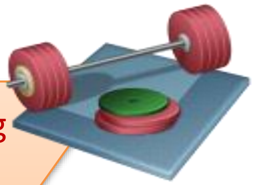

Process Plant
PC Control System
OPC Server
Network (LAN)
Datalogging System
SQL Database
Alarm System

Lab Assignment

- Assignment: Create a SCADA System from scratch
- In this Assignment you will need “everything” you have learned in Lectures and previous Lab Assignments
- Make sure to read the whole assignment before you start to solve any of the problems.
- If you miss assumptions for solving some of the problems, you may define proper assumptions yourself.
- It is assumed you use proper “System Design” principles as learned in the Lectures
- The suggested Tasks are somewhat loosely defined and more like guidelines, so feel free to interpret the Tasks in your own way. Add Value and Creativity!
- Feel free to Explore! – and add more value to the suggested examples and solutions

Lab Assignment Overview

All Programming shall be done with **Visual Studio/C#**



A. Design the Database using **ERwin**

B. Implement the Database using **SQL Server**

C. Create a **Control System** and send data to **OPC** Server.
   - Start with a model of the system. ~~When the Simulations works, use the the real system~~
   - You should create and use your own PI(D) controller and Lowpass Filter from Scratch (there is no built-in PID in C#)

D. **Datalogging System**: Read Data from OPC Server and Log the Data to a SQL Server Database

E. **Alarm System**: Create an Alarm Generation and Monitoring System

F. **Cyber Security**

Learning Goals

- Learn key concepts within SCADA systems
- Learn more about Database Systems, OPC and HIL
- Learn practical skills and implementation of SCADA systems
- Learn more C# Programming
- Learn about Hardware-Software Interactions
- Learn Practical Skills and Implementations in general
- Learn Software Installation in general, which can be cumbersome with many pitfalls
- Learn to use and create Software in general

Necessary Software

ERwin Academic Edition, free download from Internet

You can download Visual Studio from Microsoft Imagine

You can download SQL Server Express for Free either from Internet or DreamSparks

Measurement Studio

MatrikonOPC Server for Simulation

You can download MatrikonOPC Server for Simulation for Free from Internet

Make sure to install the necessary Software before you go to the laboratory!

Hardware

Your Personal Computer

USB-6008

Not part of SCADA Lab 2020 due to Covid-19

Air Heater

The teacher have not done all the Tasks in detail, so he may not have all the answers! That's how it is in real life also!

Very often it works on one computer but not on another. You may have other versions of the software, you may have installed it in the wrong order, etc...
In these cases Google is your best friend!

The Teacher dont have all the answers (very few actually ☹)!! Sometimes you just need to “Google” in order to solve your problems, Collaborate with other Students, etc. Thats how you Learn!

Troubleshooting & Debugging

Visual Studio

Use the **Debugging Tools** in your Programming IDE.
Visual Studio, LabVIEW, etc. have great Debugging Tools! Use them!!

Use available Resources such as User Guides, Datasheets, Text Books, Tutorials, Examples, Tips & Tricks, etc.

My System is not Working??

Multimeter, etc.

“Google It”!

You probably will find the answer on the Internet

Another person in the world probably had a similar problem

Check your electric circuit, electrical cables, DAQ device, etc. Check if the wires from/to the DAQ device is correct. Are you using the same I/O Channel in your Software as the wiring suggest? etc.

Lab Assignment Guidelines

- Make sure to read the whole assignment before you start to solve any of the problems.
- If you miss assumptions for solving some of the problems, you may define proper assumptions yourself.
- The Tasks described in the Assignment are somewhat loosely defined and more like guidelines, so feel free to interpret the Tasks in your own way with a personalized touch.
- Feel free to Explore! Make sure to Add Value and Creativity to your Applications!
- Try to add some extra value and be creative compared to the simplified examples given by me, in that way you learn so much more.

Lab Assignment Guidelines

- Think about the Lab Assignment as a small real-life industrial Project, and not a set of tasks or exercises.
- What does the company that hire you expect from you when you deliver this project? What kind of Quality is expected?
- Try to see your work in a larger context than just a Lab Assignment or a set of exercises.
- Try to see the big picture. The tasks within the assignment are just small building blocks that ends up with a fully working system.
- It is recommended that you make a Work Plan and a System Sketch that gives you an overview of WHAT you should do and WHEN you should do it.

Lab Work Requirements

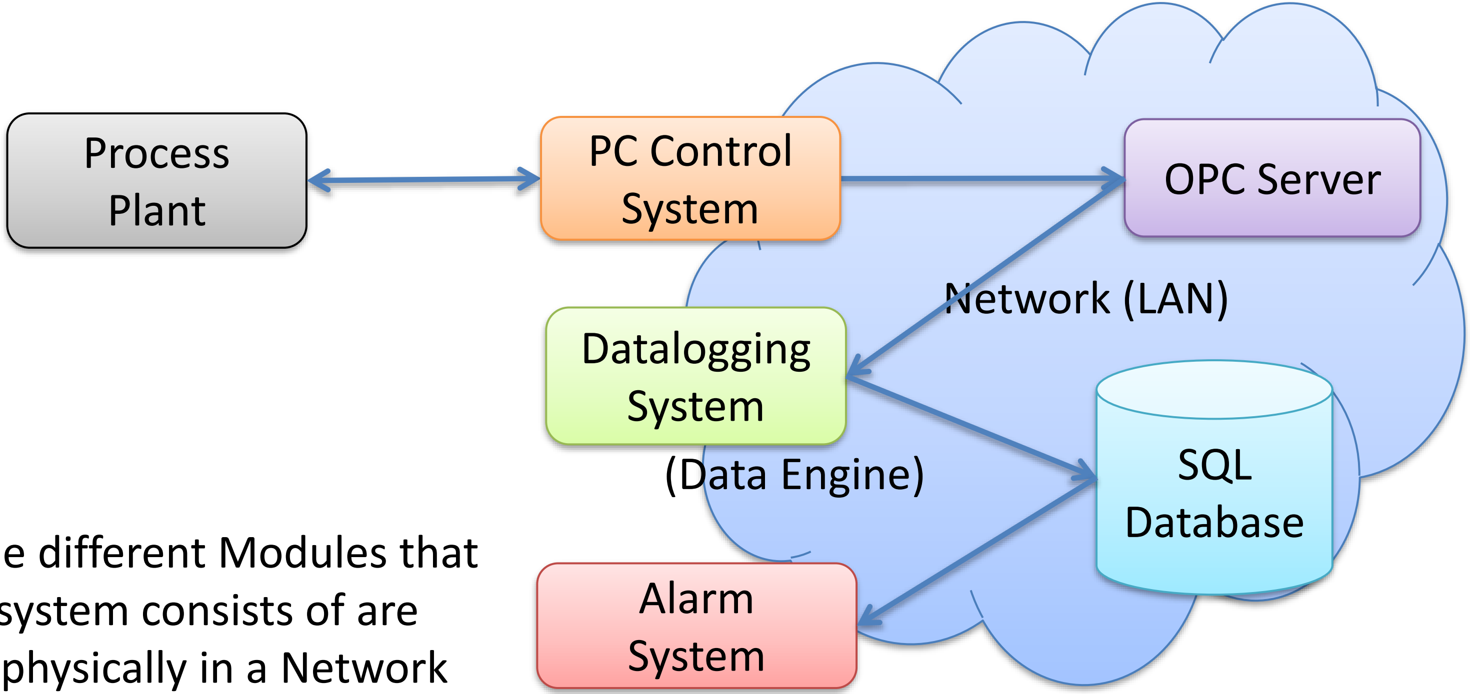
- Make sure to see the "**big picture**" – you don't need to document every single step you have made. Focus on what's important.
- **Your GUIs is important!** - make sure to make them user friendly and intuitive. You create this on behalf of someone that are going to use your applications.
- Make sure to always add **units** in your GUI, charts, documentation, etc.
- **Presenting values with 4+ decimals makes no sense!** E.g., a temperature sensor is not that accurate. You can easily change number of decimals that you present in your GUI in LabVIEW, C#, etc.
- **The quality of the code is important.** Make sure to use "straight lines" in your LabVIEW code, etc. The LabVIEW code should also flow from left to right, not opposite direction. You create this on behalf of someone that are going to use your applications. Neat code makes it easier to develop, maintain, find code errors, etc.
- **In general, make sure that you take some pride in your applications and the work that you do.** It's not about getting finished as soon as possible. The mission is to learn as much as possible within a given timeframe. Try to change the mindset.
- To improve the LabVIEW code, please see this video: **LabVIEW Applications using State Machine**: https://youtu.be/-b9St8wNhpQ

Introduction to SCADA

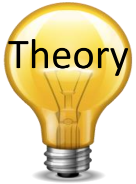
Supervisory Control and Data Acquisition

Hans-Petter Halvorsen

SCADA System Overview



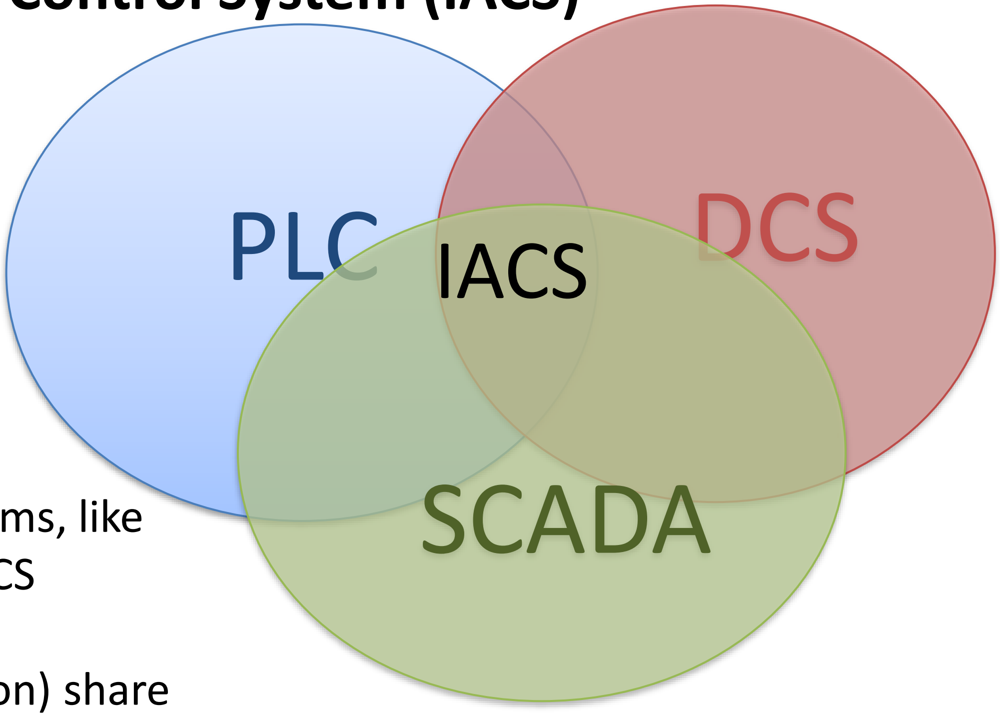
Typically, the different Modules that the SCADA system consists of are distributed physically in a Network (local network or over Internet)



SCADA System

SCADA (Supervisory Control And Data Acquisition) is a type of **Industrial Automation and Control System (IACS)**

Industrial Automation and Control Systems (IACS) are computer controlled systems that monitor and control industrial processes that exist in the physical world.



Industrial Automation and Control Systems, like PLC (Programmable Logic Controller), DCS (Distributed Control System) and SCADA (Supervisory Control And Data Acquisition) share many of the same features

Industrial Control Systems (ICS)

Theory

Industrial Control Systems are computer controlled systems that monitor and control industrial processes that exist in the physical world

cRIO

LabVIEW

Programmable Automation Controller (PAC) 4

1

I/O Module

5

Industrial PID Controller

PC based Control System/SCADA System (Supervisory Control And Data Acquisition)

2 Distributed Control Systems (DCS)

DeltaV

PLC (Programmable Logic Controller) 3

Siemens PLC

PC-based Control System

Theory

Industrial PID Controller

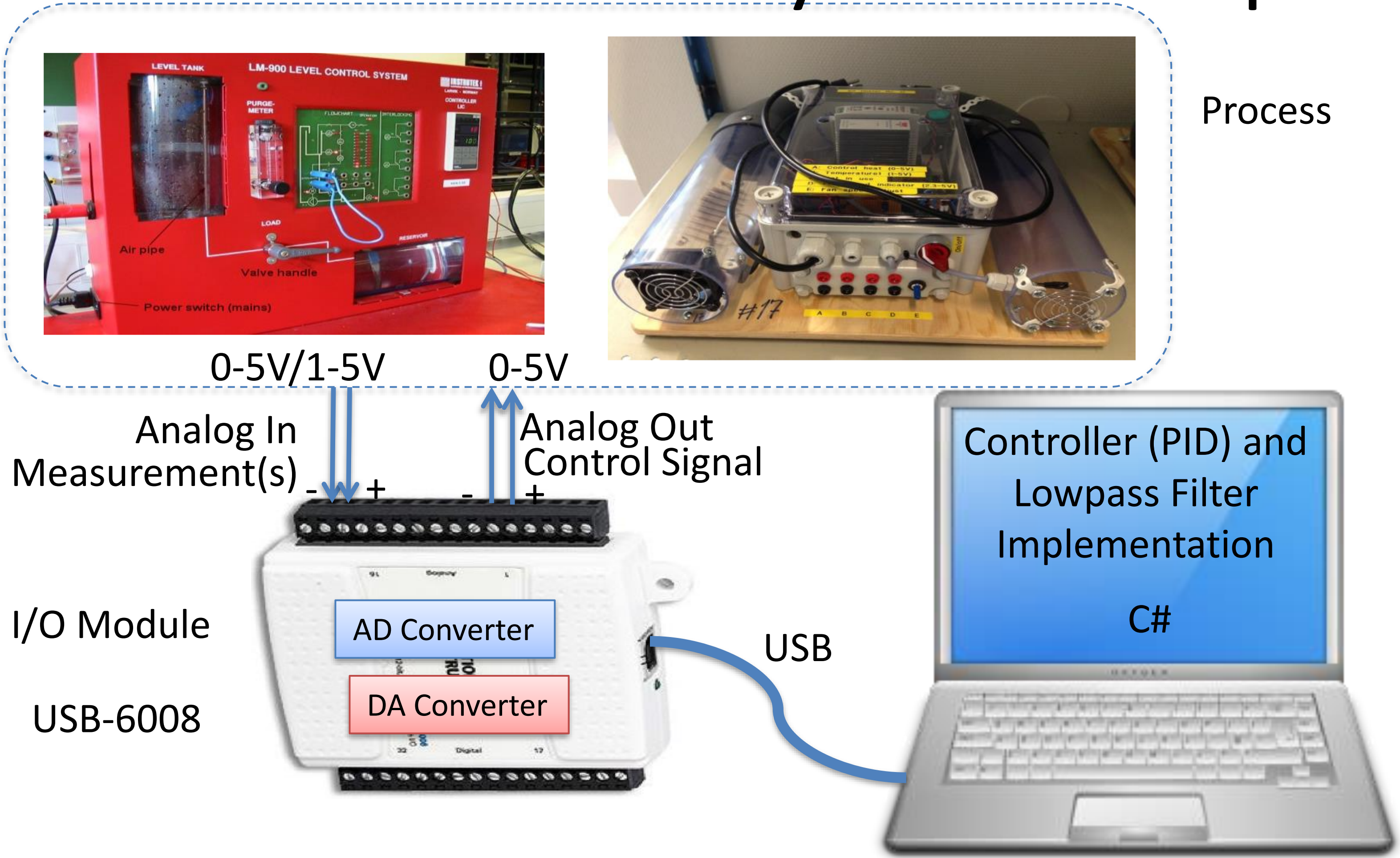
Embedded system with built-in PID algorithm, etc.

PID Control using PC and I/O Module

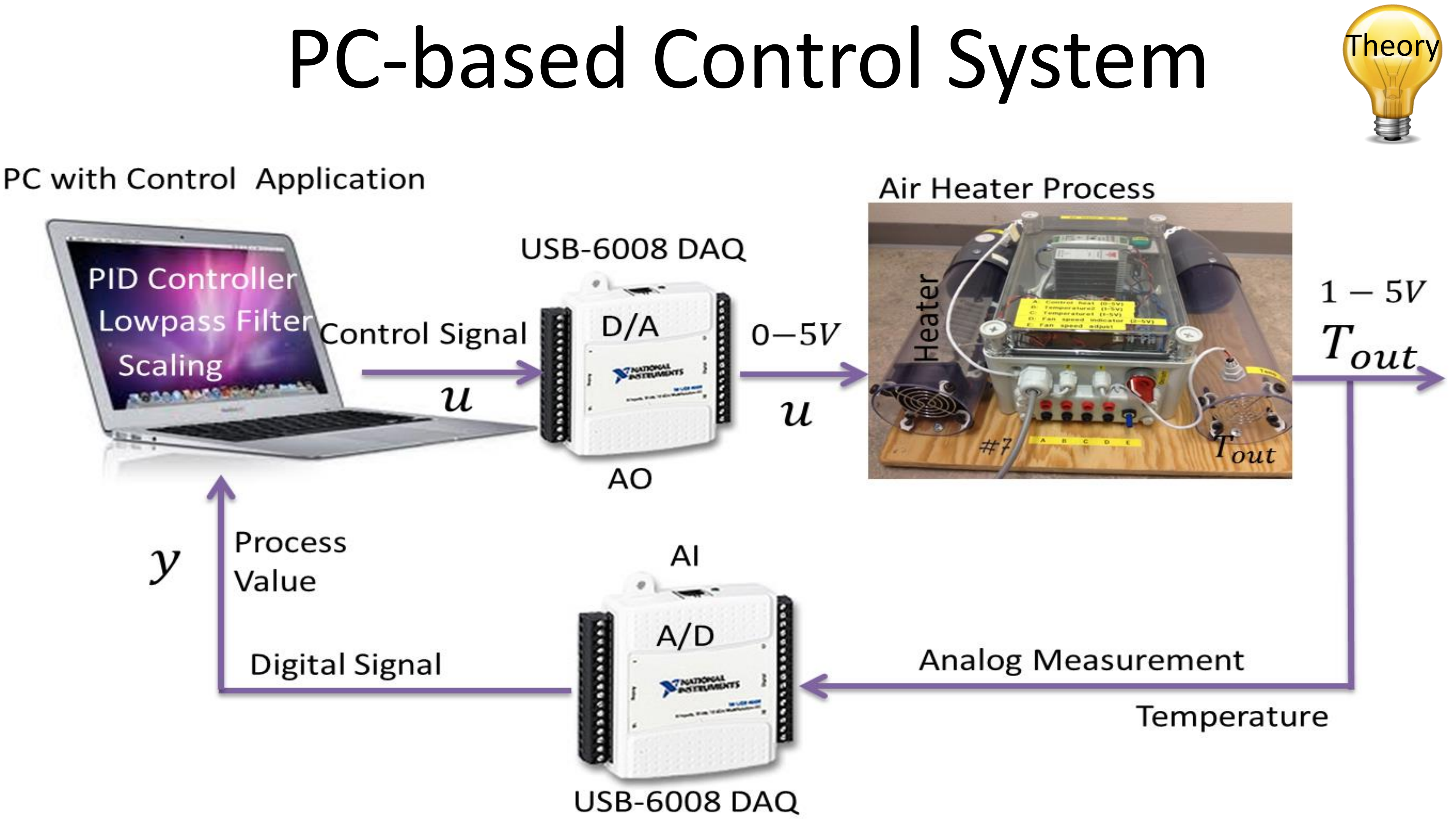
I/O Module

PC-based Control System Example

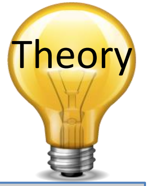
Theory

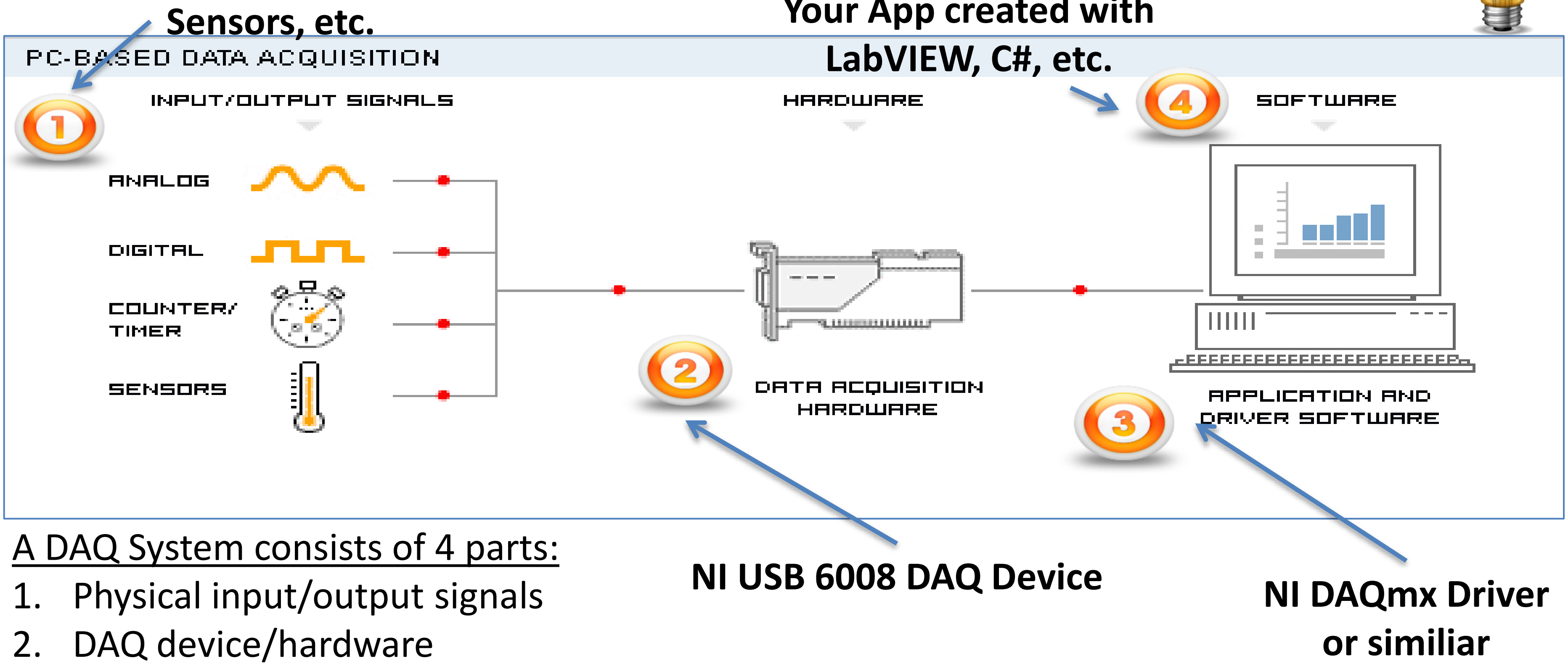


PC-based Control System



DAQ – Data Acquisition





<u>A DAQ System consists of 4 parts:</u>

1. Physical input/output signals
2. DAQ device/hardware
3. Driver software
4. Your software application (Application software)

SCADA System

- The SCADA system typically contains different modules, such as:
  1. OPC Server
  2. A Database that stores all the necessary data
  3. **Control System**
  4. **Datalogging System**
  5. **Alarm System**
- Note! They should be implemented as <u>separate</u> applications because they should be able to run on different computers in a network (distributed).

Task A

ERwin

Database Design/Modelling

Hans-Petter Halvorsen

Database Design & Modelling

- Design the Database using ERwin (ER diagram)
- Generate a SQL Script that can be used to create the tables in SQL Server

See next slides for details about Database Requirements

Database Requirements

Tag Configuration:

The TAG table(s) could e.g. have the following columns:

- TagId (int, Primary Key, Identity)
- TagName (varchar)
- ItemId (varchar) (OPC)
- ItemUrl (varchar) (OPC)
- Description (varchar)
- etc.

Here are some examples of functionality of the SCADA system and information that typically could be stored in the Database.

Tag Data:

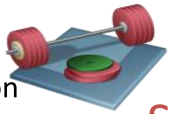
Create one or more tables used for logging the Tag Values into the Database. Example of information:

- Value
- Timestamp
- Status (e.g., “Active”, “Not Active”)
- Quality (e.g., “Good”, “Bad”)
- etc.

Alarm Configuration & Alarm Data:

Important fields in an alarm handling system could be:

- AlarmId
- Activation Time
- Acknowledge Time and Person
- Type of Alarm
- Which Tag
- Alarm Limits
- Textual Description
- etc.



Students: Design the the Tables according to the Requirements

Database Requirements

The alarm system will be responsible for the warnings and the alarms in a monitoring and control system. An alarm system contains different **Alarms** and **Warnings** like:

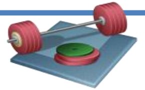
- Timeout; no input from a sensor or another computer system within a specific amount of time,
- High High (HH) or Low Low (LL) alarm; a critical alarm condition,
- High (H) or Low alarm (L)
- I/O device errors
- System device errors
- etc.

Make sure your Alarm tables and system can handle some of these kinds of alarms and warnings.

An Alarm System use different Alarm Devices, such as, e.g.,

- Screen; display the alarms
- Keyboard; alarm operations
- Horn; indicate an active alarm, or security alarm
- Lamp; indicate an active alarm, or an active alarm by blinking and an acknowledge alarm by a steady light
- Printer; logging of the alarm states
- SMS
- E-mail
- Etc.

Make use of one or more of these alarm devices in your Alarm Handling and Management System.



Students: Design the the Tables according to the Requirements

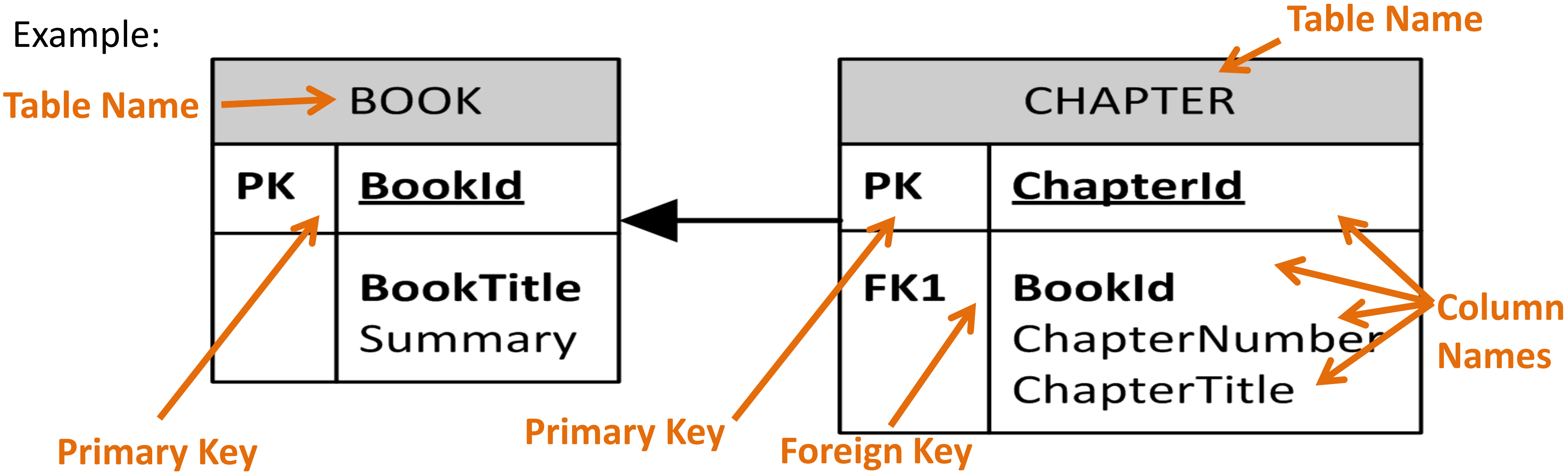
Database Design – ER Diagram

Theory

ER Diagram (Entity-Relationship Diagram)

- Used for Design and Modeling of Databases.
- Specify Tables and **relationship** between them (**Primary Keys** and **Foreign Keys**)

Example:



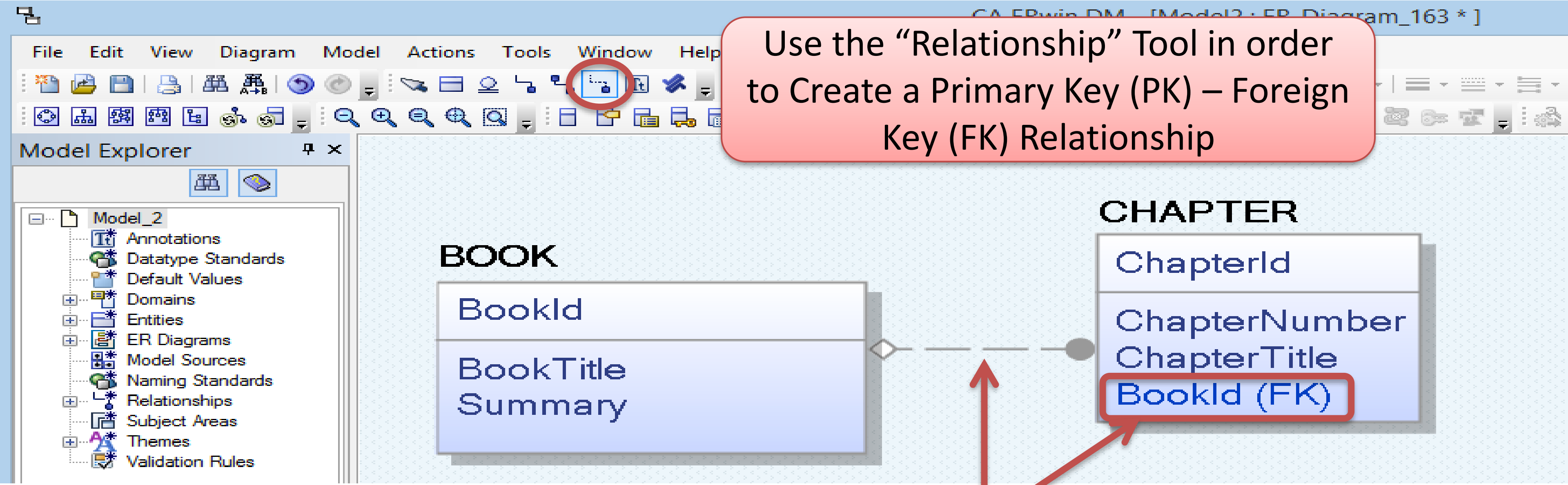
Relational Database. In a relational database all the tables have one or more relation with each other using Primary Keys (PK) and Foreign Keys (FK). Note! You can only have one PK in a table, but you may have several FK's.

Database - "Best Practice"

- **Tables**: Use upper case and singular form in table names – not plural, e.g., "STUDENT" (not "students")
- **Columns**: Use Pascal notation, e.g., "StudentId"
- **Primary Key**:
  - If the table name is "COURSE", name the Primary Key column "CourseId", etc.
  - "Always" use Integer and Identity(1,1) for Primary Keys. Use UNIQUE constraint for other columns that needs to be unique, e.g. "RoomNumber"
- Specify **Required** Columns (NOT NULL) – i.e., which columns that need to have data or not
- Standardize on few/these **Data Types**: *int*, *float*, *varchar(x)*, *datetime*, *bit*
- Use English for table and column names
- Avoid abbreviations! (Use "RoomNumber" – not "RoomNo", "RoomNr", ...)

Introduction to ERwin

How-To: Create Primary Key (PK) – Foreign Key (FK) Relationships:



Use the “Relationship” Tool in order to Create a Primary Key (PK) – Foreign Key (FK) Relationship

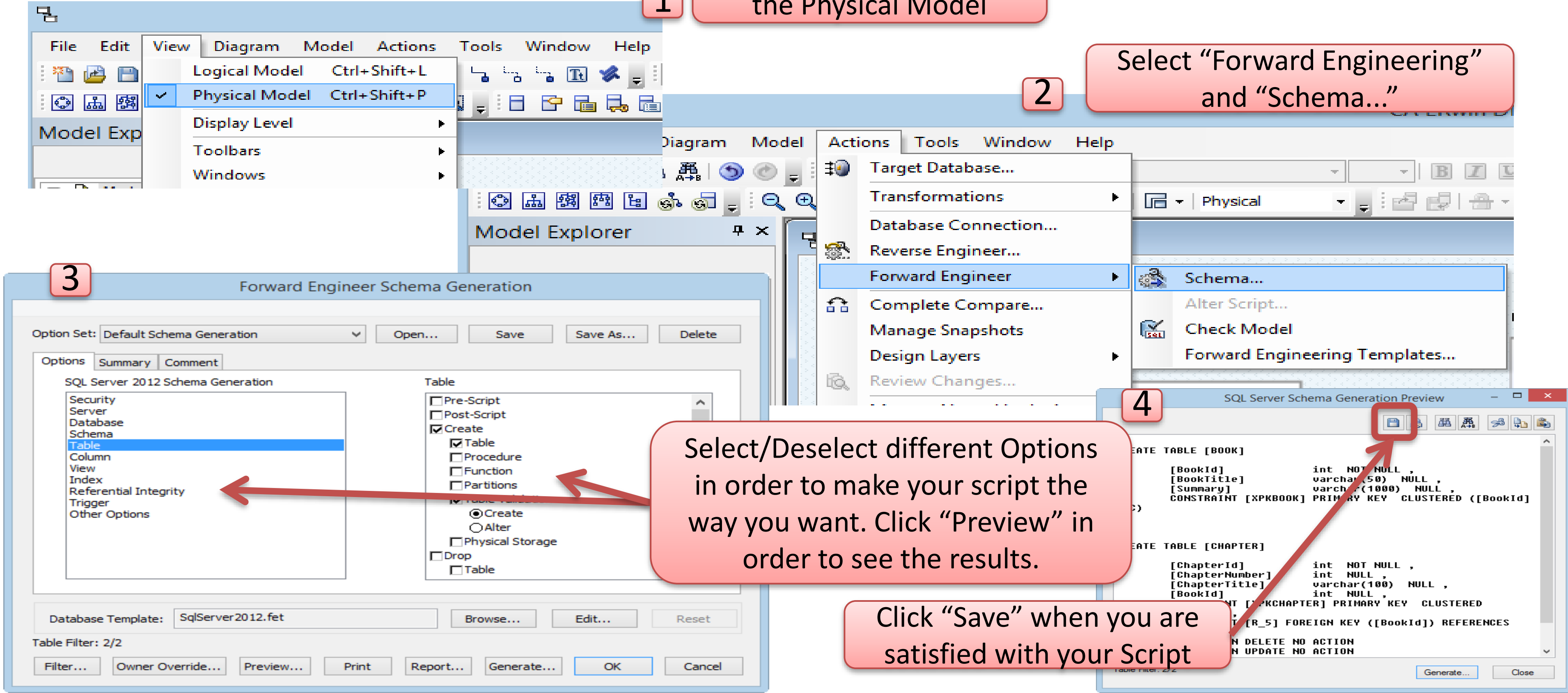
Click first on the PK table and then on the FK table using the “Relationship” Tool. The Relationship Connection and Foreign Key column are then Created Automatically

Introduction to ERwin

How-To: Create a SQL Script

1 Make sure you are using the Physical Model

2 Select “Forward Engineering” and “Schema...”



3 Select/Deselect different Options in order to make your script the way you want. Click “Preview” in order to see the results.

4 Click “Save” when you are satisfied with your Script

Congratulations! - You are finished with the Task

Task B

Database Implementation

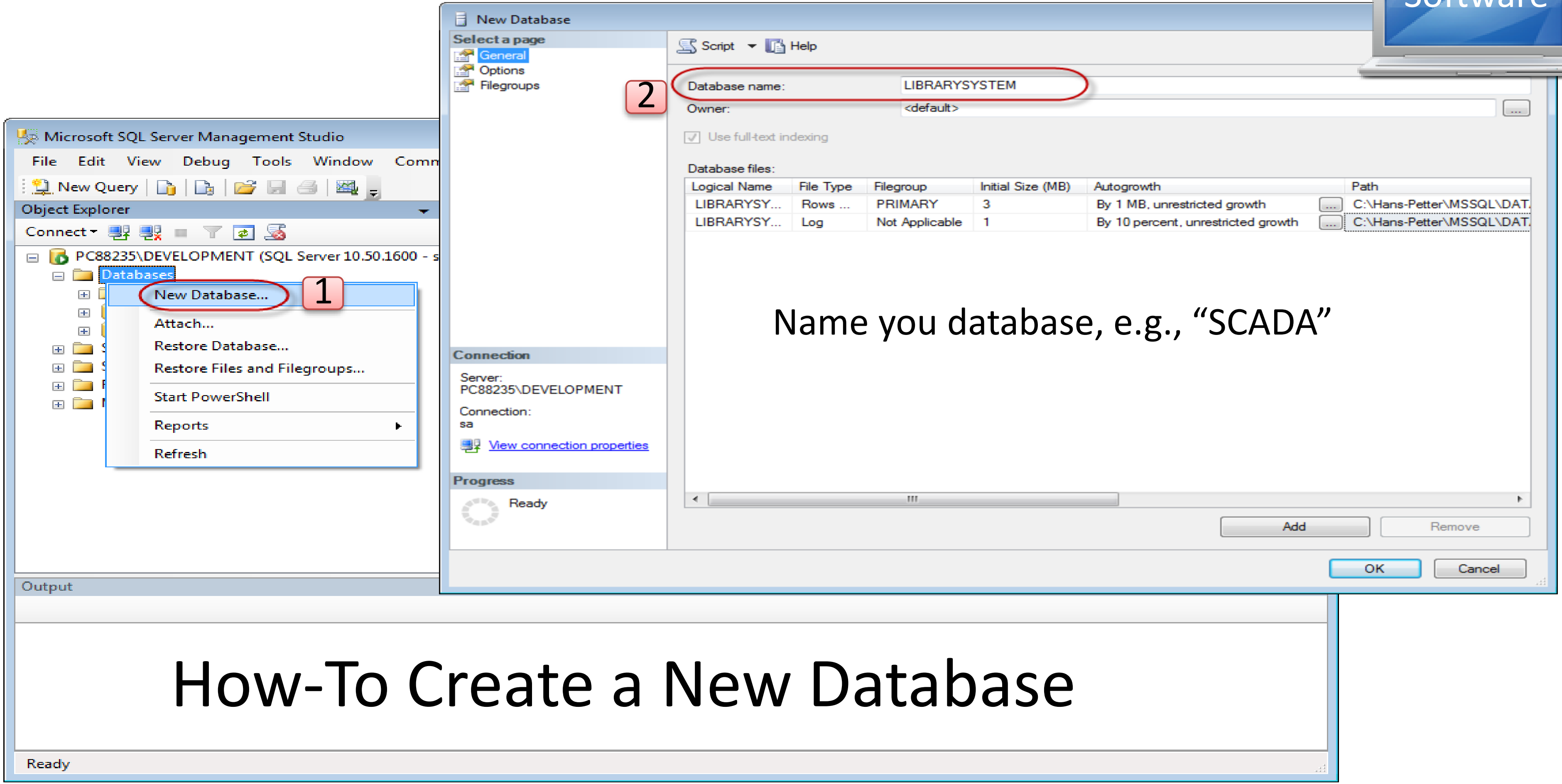
Hans-Petter Halvorsen

Database Implementation

- Implement the Database using SQL Server
- Make necessary Tables, Views, Stored Procedures, etc.
- You should insert the Tables based on the Script generated from ERwin.

Microsoft SQL Server

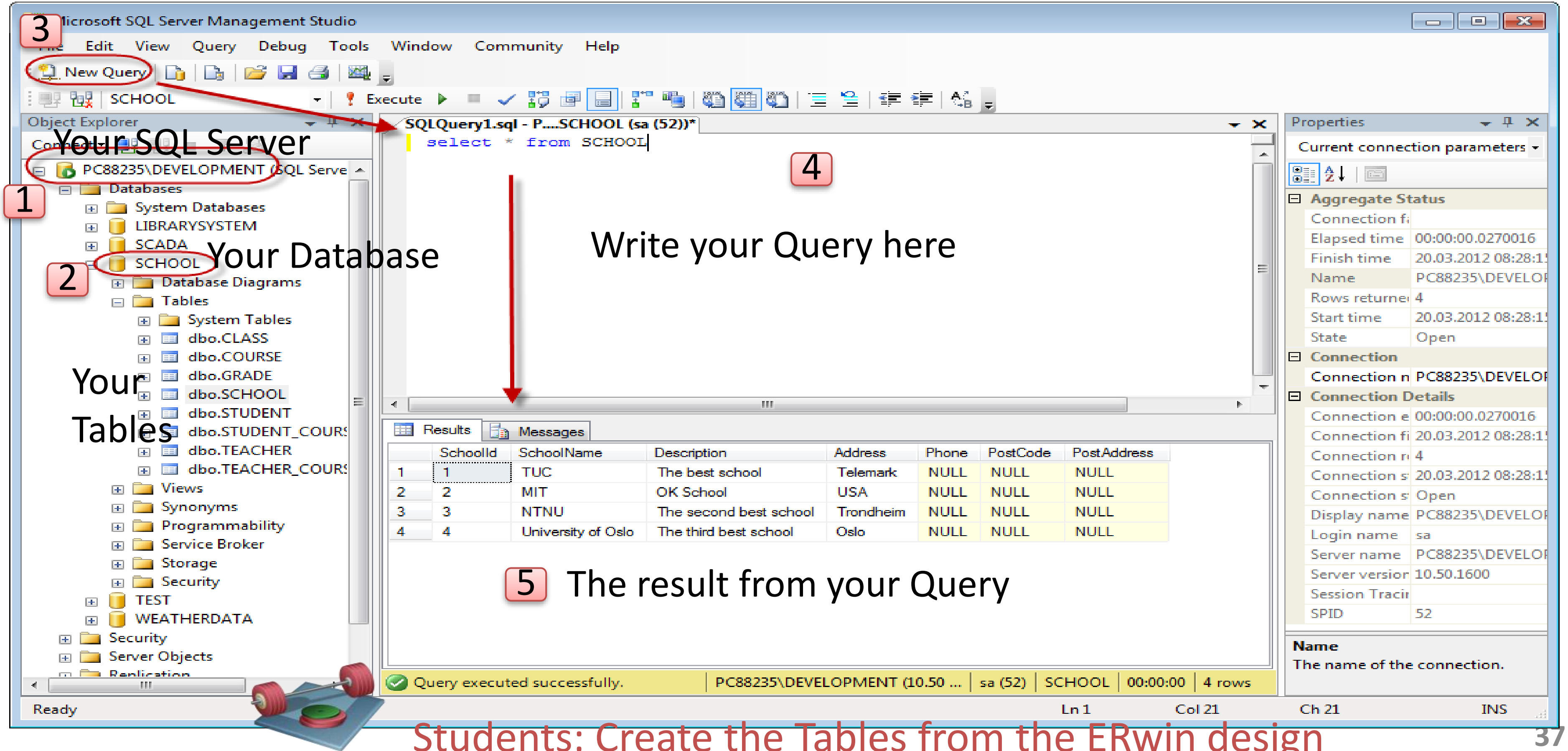
Software



Name you database, e.g., “SCADA”

How-To Create a New Database

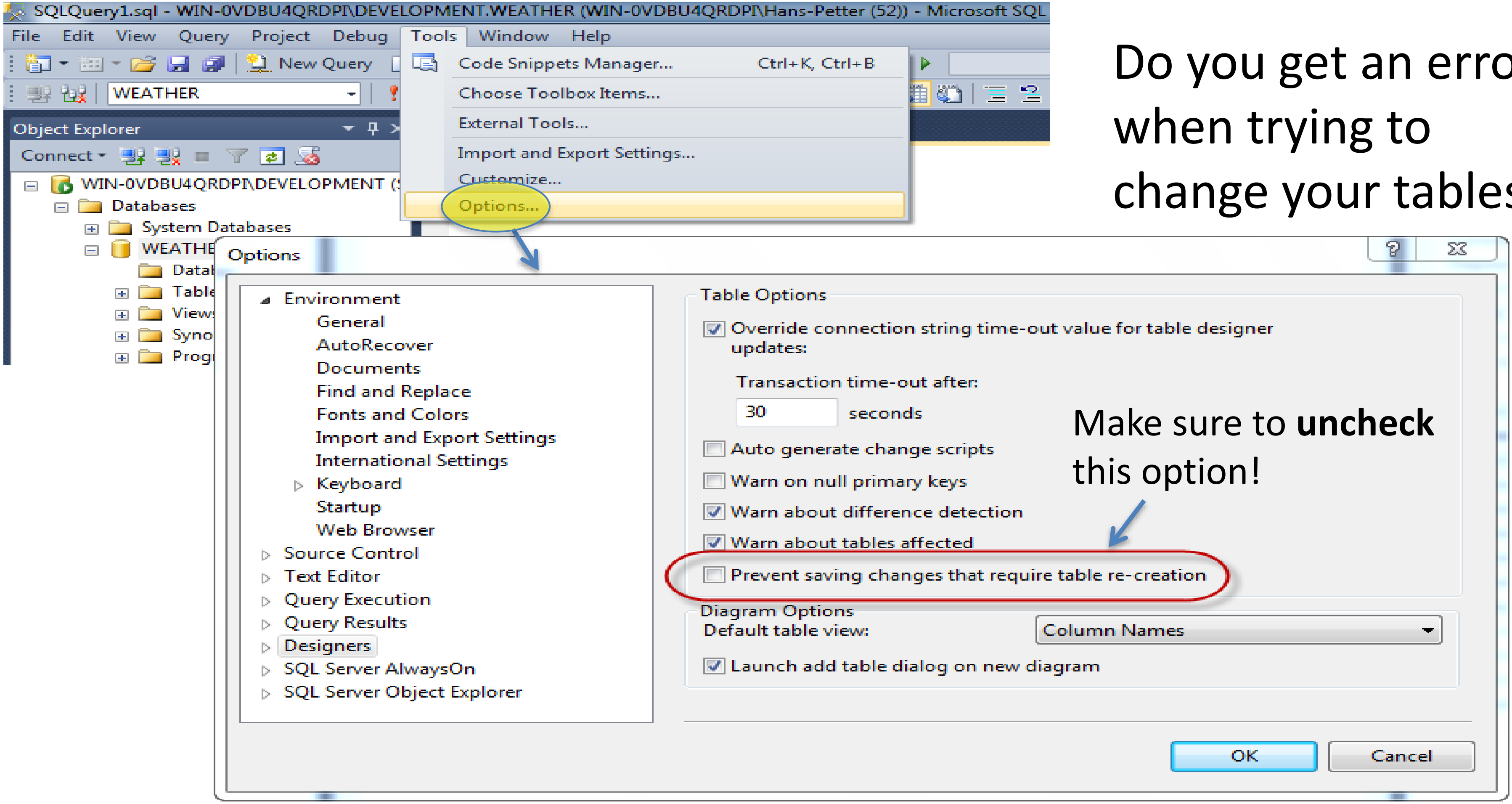
Microsoft SQL Server



Students: Create the Tables from the ERwin design

Microsoft SQL Server

Do you get an error when trying to change your tables?



Make sure to **uncheck** this option!

Congratulations! - You are finished with the Task

Task C

Control System

Computer

I/O Module

Air Heater

Hans-Petter Halvorsen

Control System

- Create an Application in **C#** that controls the Air Heater Temperature. Use standard **PI**(D) control.
- Start using a **Simulator** created from scratch in C#
- You need to create an **HMI** (Human Machine Interface) for your application.
- The process data should be sent to an **OPC** Server. You should write the Control Signal (*u*) and the Process Value (*y*) to the OPC Server
- You should create and use your own **PI**(D) **controller** + **Lowpass Filter**

Air Heater Mathematical Model

$$\dot{T}_{out} = \frac{1}{\theta_t}\{-T_{out} + [K_h u(t - \theta_d) + T_{env}]\}$$

Example of Model Parameters:

Note! You need to make a discrete version of this model and implement in C#

$$\theta_t = 22\ sec$$

Where:

Use, e.g., these values:

$$\theta_d = 2\ sec$$

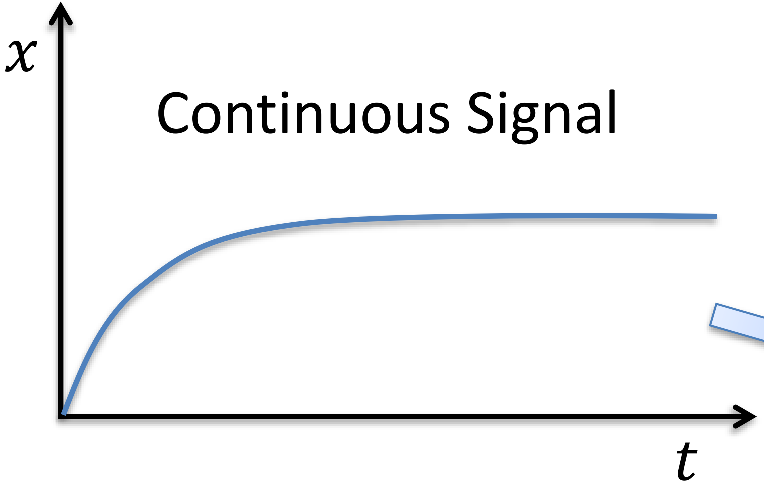
$$K_h = 3.5\ \frac{°C}{V}$$

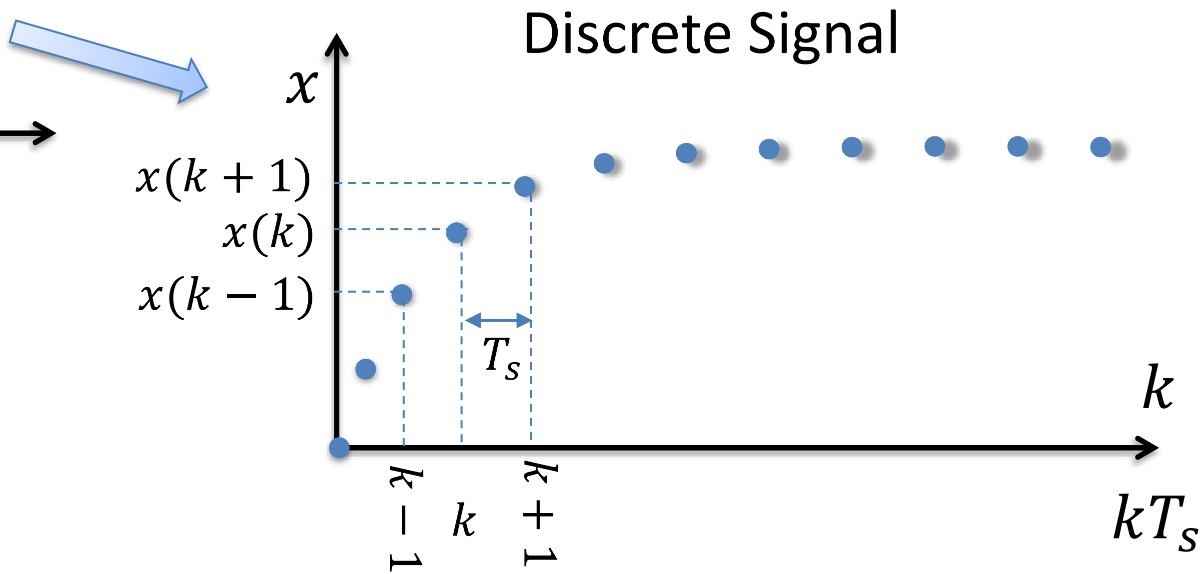
$$T_{env} = 21.5\ °C$$

- T_{out} is the air temperature at the tube outlet
- $u\ [V]$ is the control signal to the heater
- $\theta_t\ [s]$ is the time-constant
- $K_h\ [deg\ C\ /\ V]$ is the heater gain
- $\theta_d\ [s]$ is the time-delay representing air transportation and sluggishness in the heater
- T_{env} is the environmental (room) temperature. It is the temperature in the outlet air of the air tube when the control signal to the heater has been set to zero for relatively long time (some minutes)

Continuous vs. Discrete Systems

A computer can only deal with discrete signals





T_s - Sampling Interval

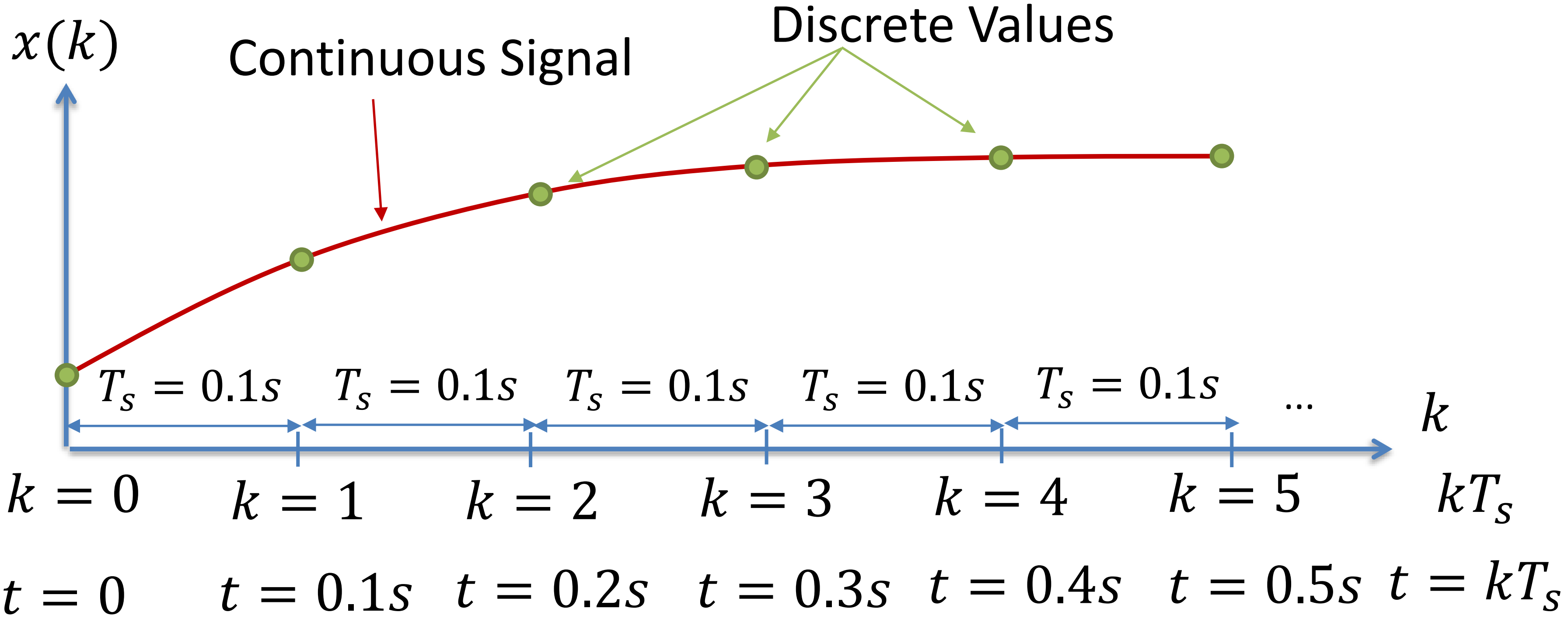
$x(k-1)$ - Previous Value

$x(k)$ - Current Value

$x(k-1)$ - Next Value

Continuous vs. Discrete Systems - Example

In this Example we have used Sampling Interval $T_s = 0.1s$



Discretization

Continuous Model:

$$\dot{T}_{out} = \frac{1}{\theta_t}\{-T_{out} + [K_h u(t - \theta_d) + T_{env}]\}$$

We can use e.g., the Euler Approximation in order to find the discrete Model:

$$\dot{x} \approx \frac{x(k+1) - x(k)}{T_s}$$

T_s - Sampling Time

$x(k)$ - Present value

$x(k+1)$ - Next (future) value

The discrete Model will then be on the form:

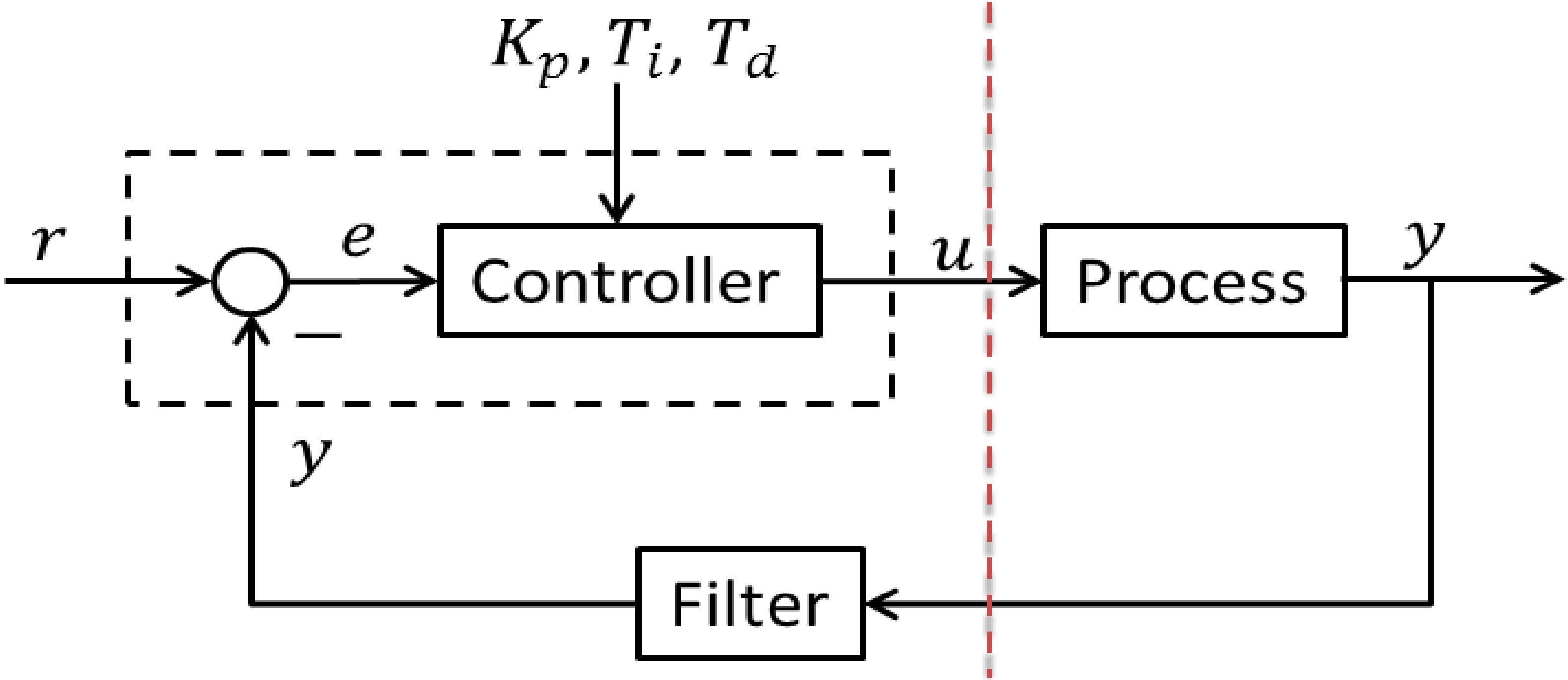
$$x(k+1) = x(k) + \ \ldots$$

We can then implement the discrete model in C#

Control System Example

Theory

While the real process is continuous, normally the Controller and the Filter is implemented in a computer.



Visual Studio

Control System in C#

Hans-Petter Halvorsen

Timer

In Visual Studio you may want to use a Timer instead of a While Loop in order to read values at specific intervals.

1

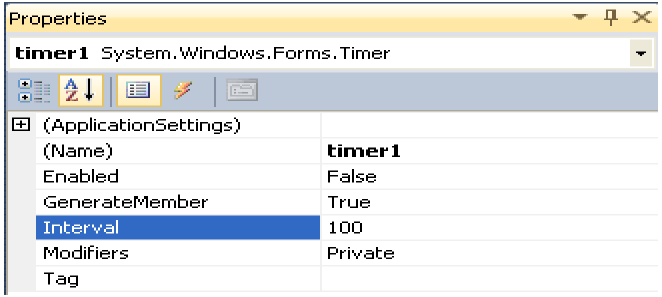
Select the “Timer” component in the Toolbox

2 **Initialization:**

```
public Form1()
    {
        InitializeComponent();
        timer1.Start();
    }
```

Double-click on the Timer object in order to create the Event

Properties: 3



You may specify the Timer Interval in the Properties Window

4 **Timer Event:**

```
private void timer1_Tick(object sender, EventArgs e)
    {
        ... //DAQ
        ... //Scaling
        ... //Control
        ... //Plot Data
        ... //Write to OPC
    }
```

Structure your Code properly!! Define Classes and Methods which you can use here

Example

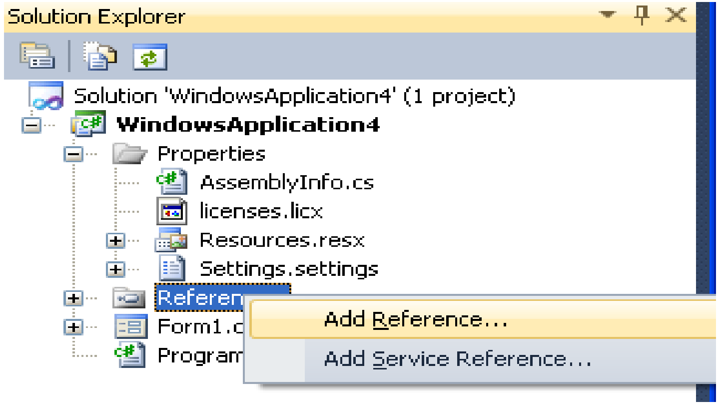
Not part of SCADA Lab 2020 due to Covid-19

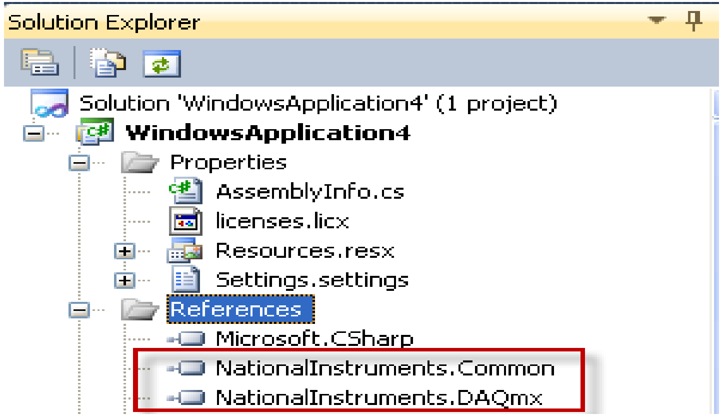
DAQ in C#

Hans-Petter Halvorsen

Add References to the **DAQmx** Driver in Visual Studio

Example





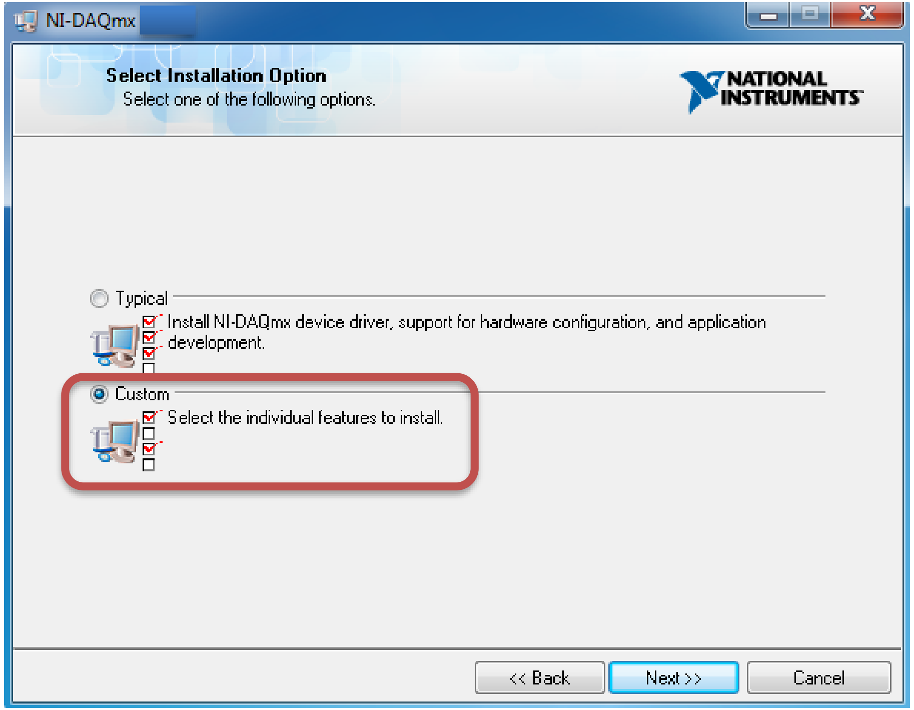

```
NationalInstruments.Common.dll
NationalInstruments.DAQmx.dll
```

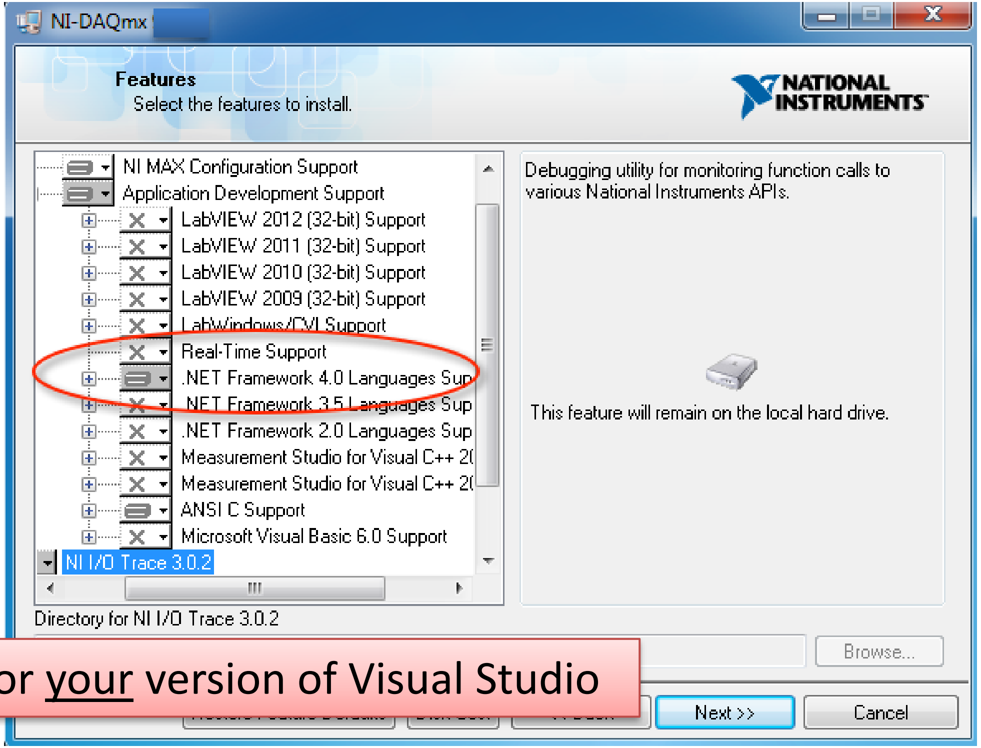
We also need to add the following Namespaces:

```
using NationalInstruments;
using NationalInstruments.DAQmx;
```

Support for .NET Framework with DAQmx Driver

Note! Also included with Measurement Studio





Make sure to add .NET Framework support for <u>your</u> version of Visual Studio

Simple **DAQ** in C# with DAQmx


```
private void btnGetAnalogIn_Click(object sender, EventArgs e)
        {
            Task analogInTask = new Task();

            AIChannel myAIChannel;

            myAIChannel = analogInTask.AIChannels.CreateVoltageChannel(
                "dev1/ai0",
                "myAIChannel",
                AITerminalConfiguration.Differential,
                0,
                5,
                AIVoltageUnits.Volts
                );

            AnalogSingleChannelReader reader = new
             AnalogSingleChannelReader(analogInTask.Stream);

            double analogDataIn = reader.ReadSingleSample();

            txtAnalogIn.Text = analogDataIn.ToString();
        }
```

Analog In Example

Simple **DAQ** in C# with DAQmx

```
private void btnWriteAnalogOut_Click(object sender, EventArgs e)
        {
            Task analogOutTask = new Task();

            AOChannel myAOChannel;

            myAOChannel = analogOutTask.AOChannels.CreateVoltageChannel(
                "dev1/ao0",
                "myAOChannel",
                0,
                5,
                AOVoltageUnits.Volts
                );

            AnalogSingleChannelWriter writer = new
             AnalogSingleChannelWriter(analogOutTask.Stream);

            double analogDataOut;
            analogDataOut = Convert.ToDouble(txtAnalogOut.Text);

            writer.WriteSingleSample(true, analogDataOut);
        }
```

Analog Out Example

Example

Visual Studio

Discrete PI (D) Controller

Hans-Petter Halvorsen

Discrete PI Controller Example

Continuous PI Controller:

$$\boxed{u(t) = u_0 + K_p e(t) + \frac{K_p}{T_i}\int_0^t e d\tau}$$

$$\dot{u} = \dot{u}_0 + K_p \dot{e} + \frac{K_p}{T_i} e$$

We use the Euler Backward method:

$$\dot{x} = \frac{x_k - x_{k-1}}{T_s}$$

$$\frac{u_k - u_{k-1}}{T_s} = \frac{u_{0,k} - u_{0,k-1}}{T_s} + K_p \frac{e_k - e_{k-1}}{T_s} + \frac{K_p}{T_i} e_k$$

$$\boxed{u_k = u_{k-1} + u_{0,k} - u_{0,k-1} + K_p(e_k - e_{k-1}) + \frac{K_p}{T_i} T_s e_k}$$

We may set:

$$\Delta u_k = u_k - u_{k-1}$$

This gives the following discrete PI algorithm:

$$e_k = r_k - y_k$$

$$\Delta u_k = u_{0,k} - u_{0,k-1} + K_p(e_k - e_{k-1}) + \frac{K_p}{T_i} T_s e_k$$

$$u_k = u_{k-1} + \Delta u_k$$

This algorithm can be easly implemented in a Programming language

Students: Create a PI(D) Controller in C#

Visual Studio

Simple Discrete **PI Controller** – C#


```
class PidController
{
        public double r;
        public double Kp;
        public double Ti;
        public double Ts;
        private double z;

        public double PiController(double y)
        {
            double e;
            double u;

            e = r - y;
            u = Kp * e + (Kp / Ti) * z;
            z = z + Ts * e;
            return u;
        }
}
```

Note! This is just a simple Example

Visual Studio

Discrete Lowpass Filter

Hans-Petter Halvorsen

Discrete Lowpass Filter Example

Lowpass Filter Transfer function:

$$H(s) = \frac{y(s)}{u(s)} = \frac{1}{T_f s + 1}$$

Inverse Laplace the differential Equation:

$$\boxed{T_f \dot{y} + y = u}$$

We use the Euler Backward method:

$$\dot{x} = \frac{x_k - x_{k-1}}{T_s}$$

This gives:

$$T_f \frac{y_k - y_{k-1}}{T_s} + y_k = u_k$$

$$\downarrow$$

$$y_k = \frac{T_f}{T_f + T_s} y_{k-1} + \frac{T_s}{T_f + T_s} u_k$$

We define:

$$\frac{T_s}{T_f + T_s} \equiv a$$

This gives:

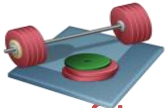
$$\boxed{y_k = (1-a) y_{k-1} + a u_k}$$

Filter output

Noisy input signal

$$T_s \leq \frac{T_f}{5}$$

This algorithm can be easly implemented in a Programming language



Students: Create a Lowpass Filter in C#

Discrete **Lowpass** Filter – C#


```
class Filter
{
        public double yk;
        public double Ts;
        public double Tf;

        public double LowPassFilter(double yFromDaq)
        {
            double a;
            double yFiltered;

            a = Ts / (Ts + Tf);
            yFiltered = (1 - a) * yk + a * yFromDaq;
            yk = yFiltered;
            return yFiltered;
        }
}
```

Note! This is just a simple Example

Congratulations! - You are finished with the Task

Write Data to OPC Server in C#

Hans-Petter Halvorsen

Measurement Studio 2019

- Measurement Studio is an add-on to Visual Studio.
- Measurement Studio is used for development of measurement, control and monitoring applications using .NET and Visual Studio.
- Measurement Studio has a library (NetworkVariable) that makes it possible to communicate with OPC DA servers that we will use is this lab work
- Download Software here: https://www.ni.com/download

Measurement Studio

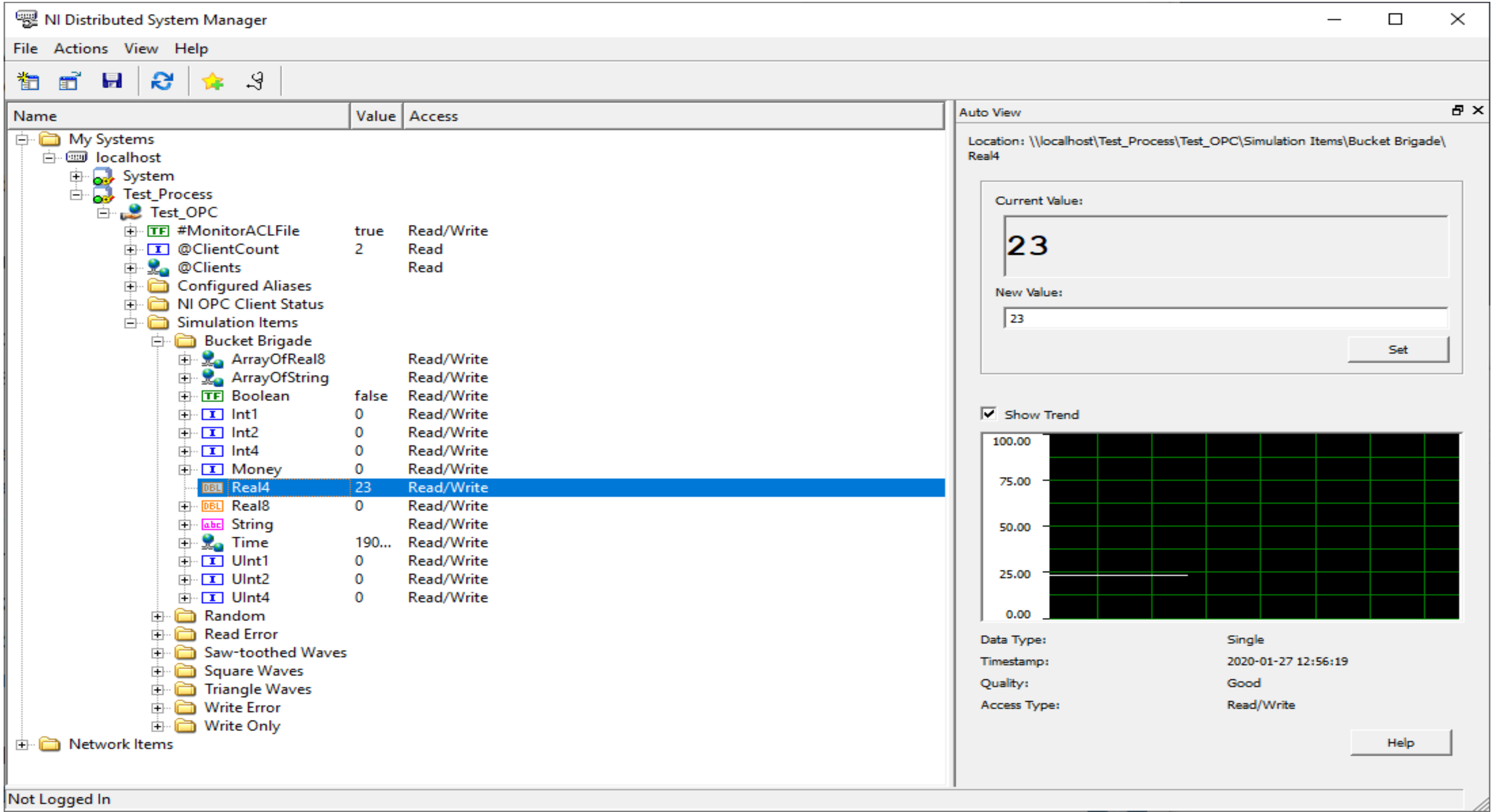
OPC with NetworkVariable

The following paragraphs explain how to use NetworkVariable with an OPC server using the LabVIEW DSC Run-Time System.

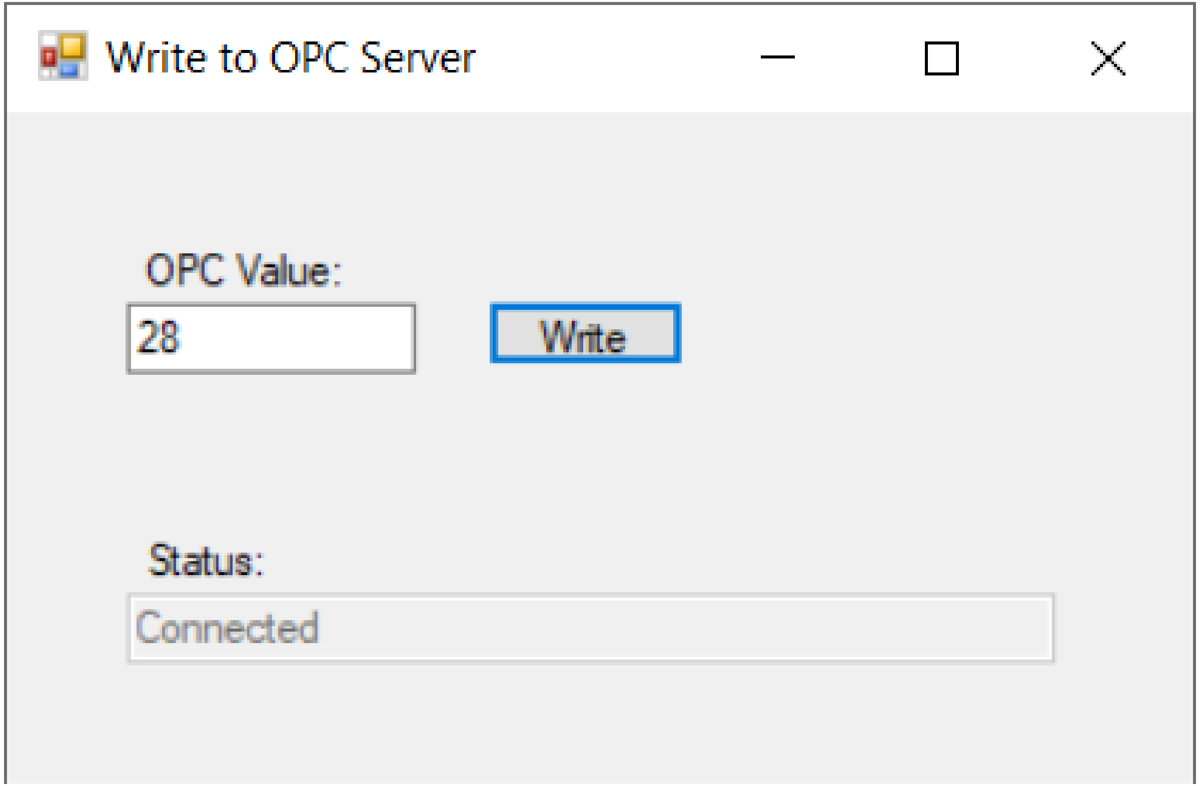
1. **Install LabVIEW Datalogging and Supervisory Control (DSC)** Run-Time System.
2. **Install your OPC server**. Only OPC2 and higher are supported by LabVIEW DSC Run-Time System.
3. Select Start»All Programs»National Instruments»**Distributed System Manager** to launch the application.
4. Right-click localhost and select **Add Process** to create a new process. Type Test_Process in the Add Process dialog box and click OK. Grouping variables by process allows you to organize your variables. You can start and stop processes independently, which allows you to easily manage your variables.
5. Right-click on Test_Process and select **Add I/O Server**.
6. For the I/O Server Type, **select OPC Client** and click Continue.
7. Type Test_OPC in the **Enter IO Server Name** dialog box and click OK.
8. **Select the OPC server** that you want to access through the Network Variable API from the list of Registered OPC Servers you installed in step 3 and click OK.
9. Right-click on Test_Process and select **Add Variable** to launch the **Shared Variable Properties** dialog box.
10. In the Shared Variable Properties dialog box, select the **Enable Aliasing** checkbox and click the Browse button.
11. In the Browse for Variable dialog box, select one of the OPC items from the OPC I/O server you configured in step 6.
12. Click OK to **bind the new variable to the OPC source**.
13. Click OK to return to NI Distributed System Manager. Use the new variable as you would any other shared variable. You can access the variable you have configured through the .NET **NetworkVariable class library**, as you would any other network variable.

http://zone.ni.com/reference/en-XX/help/375857B-01/mstudionetvar/netvar_opc/

Distributed System Manager



C# Application – Write to OPC Server



Write to OPC Server C# Example

```
using NationalInstruments.NetworkVariable;
namespace OPCExample
{
    public partial class Form1 : Form
    {
        private NetworkVariableWriter<double> _writer;
        private const string NetworkVariableLocation = @"\\localhost\OPCProcess\Temperature";

        public Form1()
        {
            InitializeComponent();
            ConnectOPCServer();
        }
```

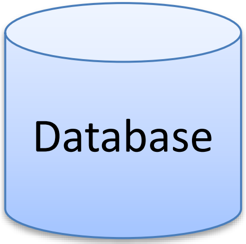
```
        private void btnWriteData_Click(object sender, EventArgs e)
        {
            double temperature;
            try
            {
                temperature = Convert.ToDouble(txtOpcData.Text);

                _writer.WriteValue(temperature);
            }
            catch (TimeoutException)
            {
                MessageBox.Show("The read has timed out.", "Timeout");
                return;
            }
        }
```

```
        private void ConnectOPCServer()
        {
            _writer = new NetworkVariableWriter<double>(NetworkVariableLocation);

            _writer.Connect();

            txtStatus.Text = _writer.ConnectionStatus.ToString();
        }
```

```
        private void Form1_FormClosing(object sender, FormClosingEventArgs e)
        {
            _writer.Disconnect();
        }
```

Task D

Datalogging System



Microsoft SQL Server

Hans-Petter Halvorsen

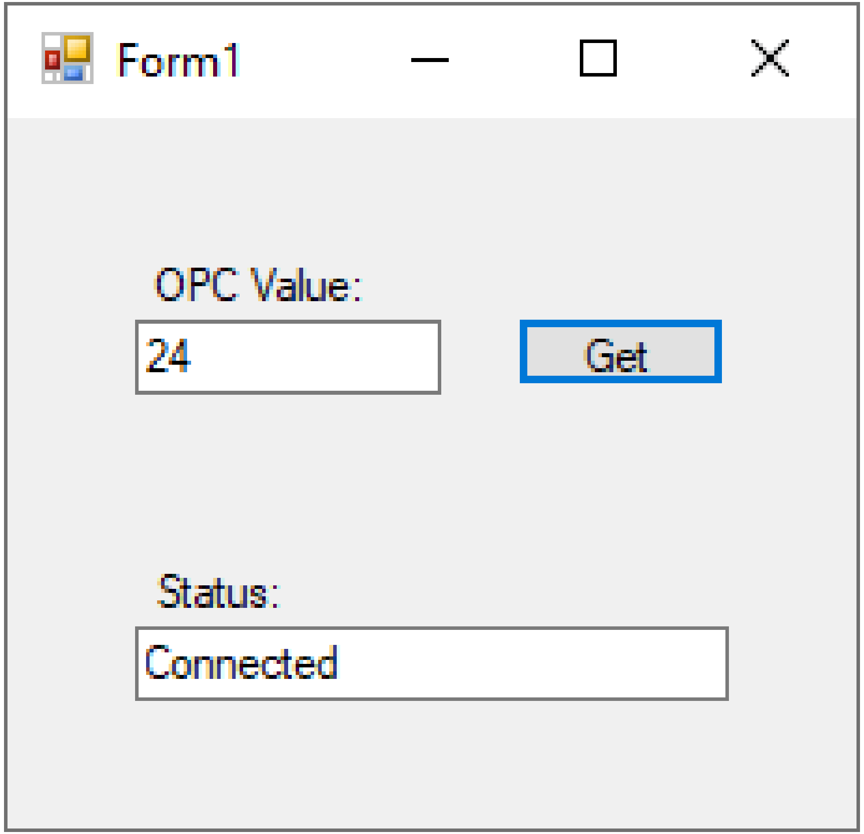
Datalogging System

- Create an application in C# that reads the values from the **OPC** Server and store them in the **SQL Server**.
- You should create a **Stored Procedure** that saves the data into the Database. This Stored procedure should be used from the C# Application

Read Data from OPC Server

Hans-Petter Halvorsen

C# Application – Read from OPC Server



```
using NationalInstruments;
using NationalInstruments.NetworkVariable;

namespace OPCExample
{
   public partial class Form1 : Form
   {
      private NetworkVariableReader<float> _reader;
      private const string NetworkVariableLocation = @"\\localhost\Test_Process\opctempdata";

      public Form1()
      {
         InitializeComponent();

         ConnectOPCServer();
      }

      private void btnGetData_Click(object sender, EventArgs e)
      {
         NetworkVariableData<float> opcdata = null;
         try
         {
            opcdata = _reader.ReadData();

            txtOpcData.Text = opcdata.GetValue().ToString();
         }
         catch (TimeoutException)
         {
            MessageBox.Show("The read has timed out.", "Timeout");
            return;
         }
      }
...
```


```
....

      private void ConnectOPCServer()
      {
         _reader = new NetworkVariableReader<float>(NetworkVariableLocation);

         _reader.Connect();

         txtStatus.Text = _reader.ConnectionStatus.ToString();
      }

      private void Form1_FormClosing(object sender, FormClosingEventArgs e)
      {
         _reader.Disconnect();
      }

   }
}
```

Note! This Code Snippet reads only one value once when clicking the button. You can use e.g. a **Timer** in order to read values at specific intervals.

Save Data to SQL Server

Hans-Petter Halvorsen

Stored Procedure Example

Create Stored Procedure:


```
IF EXISTS (SELECT name
                    FROM   sysobjects
                    WHERE  name = 'StudentGrade'
                    AND              type = 'P')
                  DROP PROCEDURE StudentGrade
OG

CREATE PROCEDURE StudentGrade
@Student varchar(50),
@Course varchar(10),
@Grade varchar(1)

AS

DECLARE
@StudentId int,
@CourseId int

select @StudentId=StudentId from STUDENT where StudentName = @Student

select @CourseId=CourseId from COURSE where CourseName = @Course

insert into GRADE (StudentId, CourseId, Grade)
values (@StudentId, @CourseId, @Grade)
GO
```

A Stored Procedure is like a Method in C# - it is a piece of code with SQL commands that do a specific task – and you reuse it

This part is not necessary – but if you make any changes, you need to delete the old version before you can update it

Procedure Name

Input Arguments

Internal/Local Variables
Note! Each variable starts with @

SQL Code (the "body" of the Stored Procedure)

Using the Stored Procedure:

```
execute StudentGrade 'John Wayne', 'SCE2006', 'B'
```

Saving Data to SQL from C#


```
public void CreateBook(string connectionString, Book book)
{
            try
            {
                using (SqlConnection con = new SqlConnection(connectionString))
                {
                    SqlCommand cmd = new SqlCommand("CreateBook", con);
                    cmd.CommandType = CommandType.StoredProcedure;

                    cmd.Parameters.Add(new SqlParameter("@Title", book.Title));
                    cmd.Parameters.Add(new SqlParameter("@Isbn", book.Isbn));
                    cmd.Parameters.Add(new SqlParameter("@PublisherName", book.PublisherName));
                    cmd.Parameters.Add(new SqlParameter("@AuthorName", book.AuthorName));
                    cmd.Parameters.Add(new SqlParameter("@CategoryName", book.CategoryName));

                    con.Open();
                    cmd.ExecuteNonQuery();
                    con.Close();
                }
            }
            catch (Exception ex)
            {
                throw ex;
            }
}
```

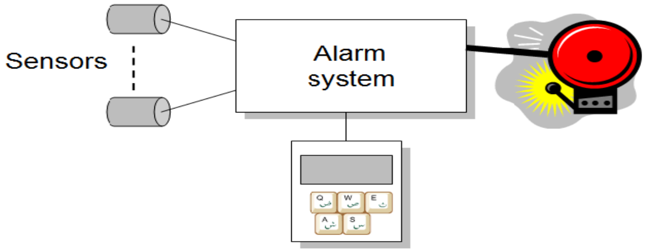
It is recommended to create and use a **Stored Procedure**.
It is also recommended that the Connection String is stored in **App.config**

Congratulations! - You are finished with the Task

Task E

Alarm System

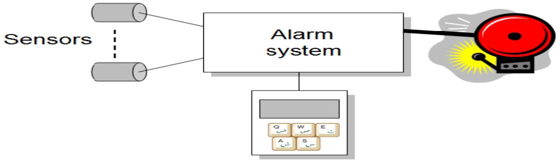
Alarm Generation and Alarm Monitoring



Hans-Petter Halvorsen

Alarm System

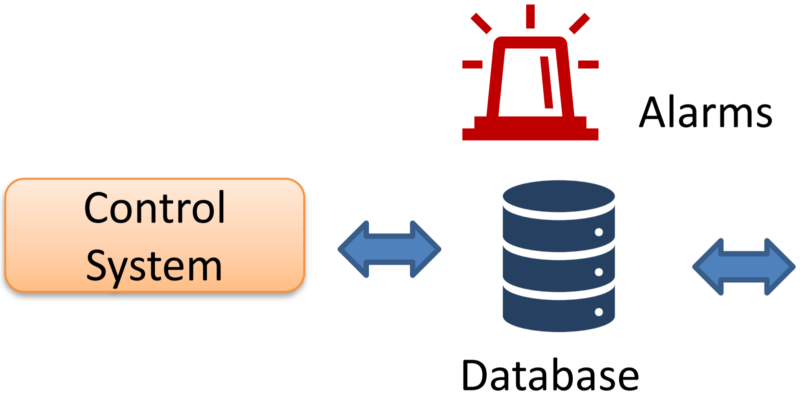
- The Alarm System should check for Alarms and saves the Alarm information in your Database.
- In addition you should have a User Interface that shows the Alarms (Alarm List).
- You could implement Alarm Logging in your SCADA system by using a Database **Trigger** on the table that stores the Tag Data.



Alarm System

- Create an **Alarm Application** (ASP.NET Core Web App) that shows all the Alarms in the system
- The operator should be able to see the Alarms and make some actions to these alarms, i.e. the operator should have the possibility to Acknowledge Alarms, Show Alarms with different Priorities, etc.
- A **Database Trigger** should be used in order to generate Alarms in the Database
- A Database **View** should be created and used to retrieve Alarm Data from the Database

Alarm System Example



Trigger that checks new Process values against Alarm Levels and generates Alarms

Alarms that need to be Acknowledged by the Operator

Alarm Application

Alarm List:

Operator: Nils-Olav

AlarmId	TagName	AlarmType	Priority	ActivitionTime	AckTime
5	Level	High	High	12:45	Ack
6	Temp	Low	Low	12:10	Ack
9	Pressure	High	Low	12:20	12:22
12	Level	Low	High	12:30	12:31
14	Pressure	High	Low	12:35	12:36
4	Level	HighHigh	High	12:40	12:42

Alarms that have been Acknowledged by the Operator

Create the Trigger:

Trigger Example

A Trigger is executed when you insert, update or delete data in a Table specified in the Trigger.

```
IF EXISTS (SELECT name
             FROM   sysobjects
             WHERE  name = 'CalcAvgGrade'
             AND        type = 'TR')
          DROP TRIGGER CalgAvgGrade
GO

CREATE TRIGGER CalcAvgGrade ON GRADE
FOR UPDATE, INSERT, DELETE
AS

DECLARE
@StudentId int,
@AvgGrade float

select @StudentId = StudentId from INSERTED

select @AvgGrade = AVG(Grade) from GRADE where StudentId = @StudentId

update STUDENT set TotalGrade = @AvgGrade where StudentId = @StudentId

GO
```

This part is not necessary – but if you make any changes, you need to delete the old version before you can update it

Name of the Trigger

Specify which Table the Trigger shall work on

Specify what kind of operations the Trigger shall act on

Internal/Local Variables

Inside the Trigger you can use ordinary SQL statements, create variables, etc.

SQL Code (The "body" of the Trigger)

Note! "INSERTED" is a temporarily table containing the latest inserted data, and it is very handy to use inside a trigger

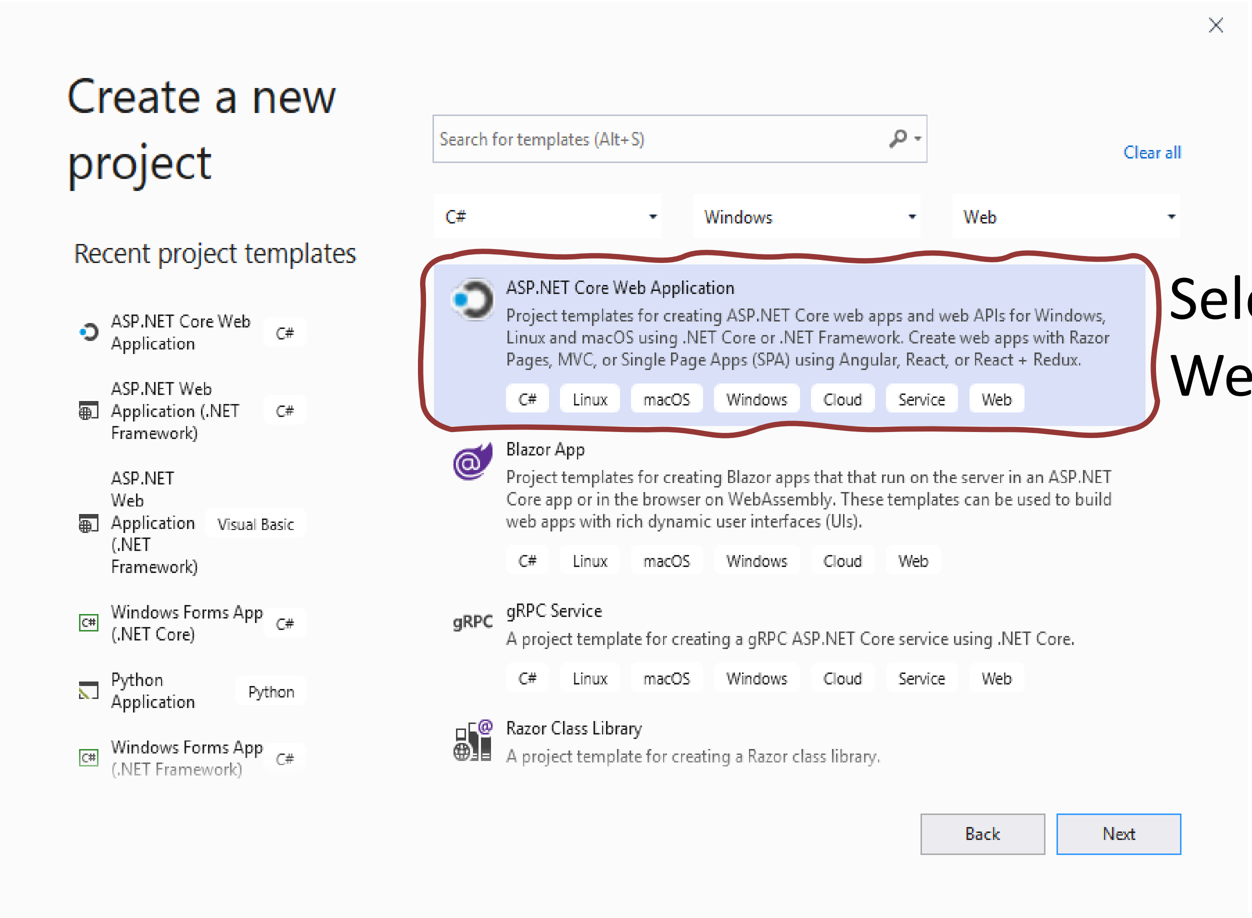
ASP.NET Core

Hans-Petter Halvorsen

ASP.NET Core Web Application

- ASP.NET is a Web Framework for creating Web Applications
- ASP.NET is integrated with Visual Studio and you will use the C# Programming Language
- .NET Core is cross-platform, meaning it will work on Windows, Linux and macOS.
- ASP.NET Core is Microsoft’s newest baby and it is the future of Web Programming

ASP.NET Core in Visual Studio



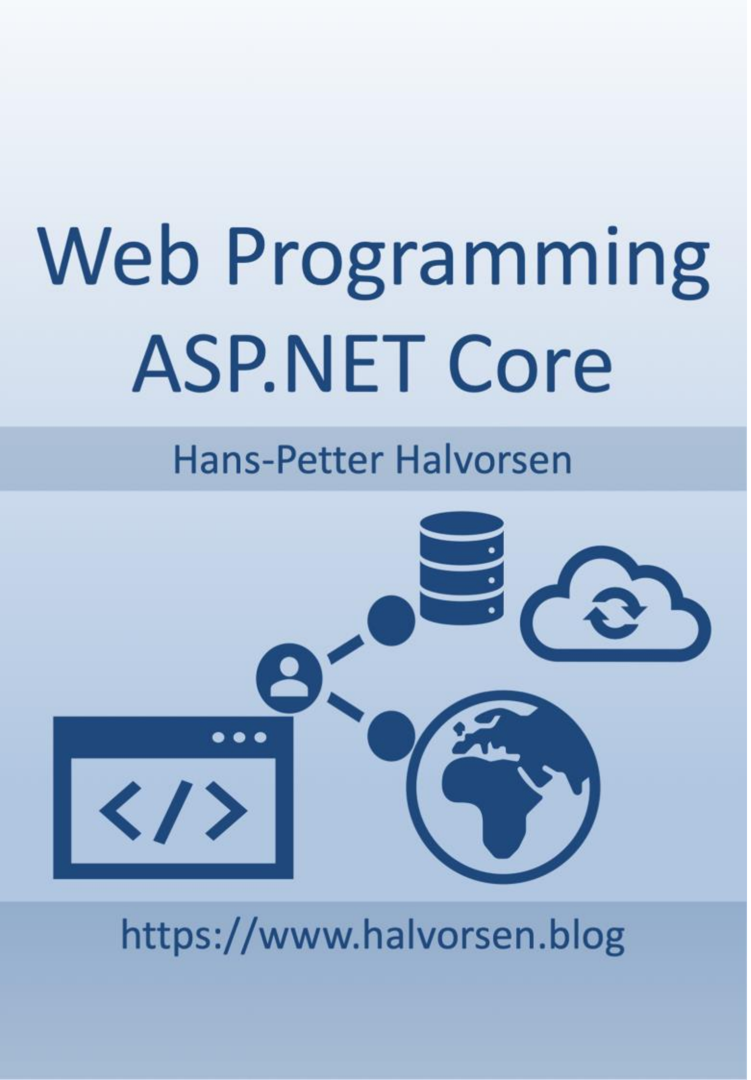
Select the ASP.NET Core Web Application Project

ASP.NET Core Examples

Recommended Videos:

- ASP.NET Core – Introduction: https://youtu.be/zkOtiBcwo8s
- **ASP.NET Core - Database Communication: https://youtu.be/0Ta3dQ3rxzs**
- ASP.NET Core - Database CRUD Application: https://youtu.be/k5TCZDwTYcE

Download Examples here: https://www.halvorsen.blog/documents/programming/web/aspnet



ASP.NET Core Resources

- Textbook
- Videos
- Tutorials
- Example Code

https://www.halvorsen.blog/documents/programming/web/aspnet

Congratulations! - You are finished with the Task

Task F

Cyber Security

Hans-Petter Halvorsen

Cyber Security in IACS Systems

- CSMS – Cyber Security Management System
- IACS – Industrial Automation and Control Systems
- Security is critical in IACS systems because a potential hacker can do great damage
- In the Norwegian energy and oil and gas sector alone, more than 50 cyber security incidents are detected the last year.*

Source: Norwegian National Security Authority

Cyber Attack

- In computers and computer networks an **attack** is any attempt to expose, alter, disable, destroy, steal or gain unauthorized access to or make unauthorized use of the system
- A **cyber attack** is any type of action that targets computer information systems, infrastructures, computer networks, or personal computer devices.
- An **attacker** is a person or process that attempts to access data, functions or other restricted areas of the system without authorization, potentially with malicious intent

https://en.wikipedia.org/wiki/Cyberattack

Cyber Security Standards

- To protect the cyber environment of a user or organization.
- This environment includes users themselves, networks, devices, all software, processes, information in storage or transit, applications, services, and systems that can be connected directly or indirectly to networks
- Reduce the risks and prevent Cyber Attacks
- IEC62443 – Cyber Security standard for IACS systems

https://en.wikipedia.org/wiki/Cyber_security_standards

Cyber Security in IACS Systems

- Explain Data & Cyber Security Issues regarding your SCADA Software.
- How can you secure your Software against threats and vulnerabilities?
- What kind of precautions have you done when implementing your system?
- What can/should you/have you done do to protect your Software?

Congratulations! - You are finished with the Task

Congratulations! - You are finished with <u>all</u> the Tasks in the Assignment!

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