Adiabatic continuous stirred tank reactor

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Adiabatic Continuous Stirred Tank Reactor

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1 Introduction

The present report documents the adiabatic CSTR experimental setup after it was refurbished in September 2017.

The goal of the refurbishment was firstly to enable computer control of the experiment using the Open Process Control Unified Architecture (OPC-UA) standard, and secondly to improve the experiment for use in course 28845 Chemical Reaction Engineering Laboratory.

Initially the experimental setup is described in terms of programmable logic controller (PLC) hardware, laboratory apparatus and software. This is followed by a description of how to connect to the PLC via OPC-UA.

The appendix contains an experimental guide for use in course 28845, step-by-step instructions on how to control the setup with a computer, sample code and datasheets.

2 Experimental Setup

Sodium thiosulfate and hydrogen peroxide are stored at approximately 0°C in a freezer. A single peristaltic pump with two heads pump the reactants into the adiabatic continuously stirred tank reactor. The flow rate of one of the feeds is measured with a magnetic flow meter. The influent temperatures as well as the temperature of the reaction mixture are measured with thermocouples. The effluent is collected as waste. A process instrumentation diagram (PI&D) of the adiabatic CSTR experiment is presented in Figure 1.

In summary, the experiment offers three temperature measurements, a flow
Section 2. Experimental Setup

rate measurement and a single manipulated variable being the rotational speed of the pump. The equipment is described in Section 2.1 while the software is described in Section 2.2.

2.1 Laboratory Apparatus

The equipment comprises the process equipment listed in Table 1 and the PLC equipment listed in Table 2. A computer with an ethernet connection is required in order to connect to the PLC via. OPC-UA or to program the PLC.

The pump has to be in analog mode in order for the control system to be able to actuate it. The pump mode may be changed by pushing the “mode” button on the pump such that the display reads “ana”, indicating that the pump is in analog mode.

Table 1: Equipment.

<table>
<thead>
<tr>
<th>PID Id.</th>
<th>Brand</th>
<th>Model</th>
<th>IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI1, TI2, TI3</td>
<td>Generic</td>
<td>K-type</td>
<td>–</td>
</tr>
<tr>
<td>Pump</td>
<td>Watson Marlow</td>
<td>323u</td>
<td>0 – 10 V</td>
</tr>
<tr>
<td>FI</td>
<td>ISOIL</td>
<td>MS 501, MI 210</td>
<td>4 – 20 mA</td>
</tr>
<tr>
<td>Reactor</td>
<td>–</td>
<td>3-neck round bottom flask, 105 mL</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 2: PLC components, all of which are Siemens S7-1200 brand.

<table>
<thead>
<tr>
<th>Model</th>
<th>IO</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU 1212c</td>
<td>Ethernet, 8 digital inputs, 2 analog inputs, 6 relay outputs</td>
</tr>
<tr>
<td>SM 1234</td>
<td>4 analog inputs, 2 analog outputs</td>
</tr>
<tr>
<td>SM 1231</td>
<td>4 thermocouples</td>
</tr>
<tr>
<td>HMI KTP400 Basic</td>
<td>Ethernet, 4” touch screen</td>
</tr>
</tbody>
</table>

2.2 Software

Interaction with the experimental equipment is possible through the graphical user interface on the human machine interface (HMI) or through an OPC-UA interface as described in the following. The PLC may be programmed in the Siemens TIA v14 Basic software, this is also described briefly.

The PLC offers the following functionality:

1. Access to analog sensor and actuator values on dimensional scales.

2. Pump start/stop.

3. Pump pulse function where the pump is on for a certain amount of time.
Section 2. Experimental Setup

HMI Graphical User Interface

The graphical user interface on the HMI device consists of four screens:

1. PI&D diagram annotated with measurements and actuators.
2. Trend plot showing measurement and actuator values.
3. Large display of measurement and actuator values, and pump pulse function.
4. USB drive connect/disconnect.

There is a menu on every screen with buttons to go to any of the above mentioned screens. Additionally there are buttons to enable or disable the pump and to set the pump to its maximum speed.

The four screens are presented in Figure 2.

Figure 2: Graphical user interface.
Section 2. Experimental Setup

The HMI device is a touch screen hence it is easy to navigate. Input variables may be changed by touching the text field indicating its current value.

The HMI also offers a USB port which may be used to log data to a USB drive (FAT formatted). The current time, the temperature measurements, flow rate measurement and pump set point are logged every second and are saved in a text file format. The Python script listed in Appendix D.2 may be used to convert the data to a Matlab format.

OPC-UA

The process variables which are available via OPC-UA are listed in Table 3. The OPC-UA server is written in Python and the code is listed in Appendix D.1. A guide on how to install and run the OPC-UA server is presented in Appendix C.

Table 3: OPC-UA tags.

<table>
<thead>
<tr>
<th>OPC-UA Tag</th>
<th>PLC Tag</th>
<th>Unit</th>
<th>PLC Address</th>
<th>Size (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI1</td>
<td>TI1R</td>
<td>°C</td>
<td>MD:114</td>
<td>4</td>
</tr>
<tr>
<td>TI2</td>
<td>TI2R</td>
<td>°C</td>
<td>MD:118</td>
<td>4</td>
</tr>
<tr>
<td>TI3</td>
<td>TI3R</td>
<td>°C</td>
<td>MD:122</td>
<td>4</td>
</tr>
<tr>
<td>FI</td>
<td>FIR</td>
<td>mL min(^{-1})</td>
<td>MD:126</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>PR</td>
<td>RPM</td>
<td>MD:130</td>
<td>4</td>
</tr>
<tr>
<td>P_DISABLE</td>
<td>P_DISABLE</td>
<td>Boolean</td>
<td>Q:0.4</td>
<td>1</td>
</tr>
</tbody>
</table>

Programming the PLC and HMI

The PLC and HMI can be programmed using the Siemens TIA v14 Basic software on a Windows computer. The license key is loaded from the Siemens USB drive shown in Figure 3. The latest version of the PLC software is also stored on this USB drive in the “Adiabatic CSTR” folder.
Section 2. Experimental Setup

(a) License box.  
(b) Siemens USB drive.

Figure 3: The Siemens USB drive is in the license box.

The devices are programmed over an ethernet connection which should be established according to steps 2 and 3 as listed in Appendix C. The IP address of the PLC is 192.168.0.10 and the IP address of the HMI is 192.168.0.11.

2.3 Pump Calibration

The volumetric flow rate through the pump at a given set-point may be calibrated using the bucket-stopwatch method. A linear fit to such data where the intercept is forced through the origin is presented in Figure 4.

Figure 4: Linear fit of volumetric pump calibration data.
The linear approximation appears reasonable and offers the relationships in Equation (1) between the volumetric flow rate $Q$ in mL min$^{-1}$ and the corresponding set-point $S$ in RPM

$$Q = S^{2.02}$$ (1)

Another calibration method is to pulse the pump at a constant flow rate for a precise amount of time and then to measure e.g. the accumulated mass from the pump effluent. The flow rate is then the ratio of accumulated volume to the pulse length. A linear fit to such data where the intercept is forced through the origin is presented in Figure 5. The data is listed in Table 4.

Table 4: Pump calibration data. Confidence intervals represent two standard deviations.

<table>
<thead>
<tr>
<th>Speed [RPM]</th>
<th>Period [s]</th>
<th>Mass [g]</th>
<th>Flow rate [mL min$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trial 1</td>
<td>Trial 2</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
<td>28.80</td>
<td>28.54</td>
</tr>
<tr>
<td>25</td>
<td>60</td>
<td>42.28</td>
<td>42.02</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>89.73</td>
<td>89.06</td>
</tr>
<tr>
<td>75</td>
<td>60</td>
<td>137.56</td>
<td>137.94</td>
</tr>
<tr>
<td>100</td>
<td>60</td>
<td>185.28</td>
<td>185.88</td>
</tr>
<tr>
<td>125</td>
<td>60</td>
<td>226.26</td>
<td>226.49</td>
</tr>
<tr>
<td>150</td>
<td>60</td>
<td>271.15</td>
<td>270.63</td>
</tr>
<tr>
<td>175</td>
<td>60</td>
<td>323.22</td>
<td>324.34</td>
</tr>
<tr>
<td>200</td>
<td>60</td>
<td>381.23</td>
<td>381.15</td>
</tr>
<tr>
<td>225</td>
<td>60</td>
<td>432.33</td>
<td>431.13</td>
</tr>
<tr>
<td>250</td>
<td>30</td>
<td>238.59</td>
<td>237.57</td>
</tr>
<tr>
<td>275</td>
<td>30</td>
<td>264.46</td>
<td>264.70</td>
</tr>
<tr>
<td>300</td>
<td>30</td>
<td>291.77</td>
<td>292.29</td>
</tr>
<tr>
<td>325</td>
<td>30</td>
<td>317.47</td>
<td>317.69</td>
</tr>
<tr>
<td>350</td>
<td>30</td>
<td>346.95</td>
<td>347.67</td>
</tr>
<tr>
<td>375</td>
<td>30</td>
<td>367.39</td>
<td>369.69</td>
</tr>
<tr>
<td>400</td>
<td>30</td>
<td>392.87</td>
<td>391.52</td>
</tr>
</tbody>
</table>
Figure 5: Linear fit of massic pump calibration data.

Again, the linear approximation appears reasonable. The proportionality in Equation (2) is obtained with similar units as for Equation (1).

\[ Q = S \cdot 1.94 \]  

(2)

3 Computer Control

Computer control of the process is possible using the OPC-UA standard. Minimal code examples which show how to connect, read and write variables are presented in the following for both Matlab and Python. Matlab only offers OPC-UA connectivity on Windows whereas Python offers OPC-UA on any platform. An elaborate example of a Python OPC-UA client with live plotting capabilities is listed in Appendix D.4.
3.1 Minimal Code Examples

Matlab 2017a, OPC-UA

```matlab
% Connect to OPC-UA server
ua = opcua('opc.tcp://127.0.0.1:4840/adiabatic_cstr/');
connect(ua);
% The ua.browseNamespace function opens a GUI where the
% namespace may be browsed.
AdiabaticCSTR = findNodeByName(ua.Namespace,'AdiabaticCSTR');
TI1 = findNodeByName(AdiabaticCSTR,'TI1');
TI2 = findNodeByName(AdiabaticCSTR,'TI2');
TI3 = findNodeByName(AdiabaticCSTR,'TI3');
FI = findNodeByName(AdiabaticCSTR,'FI');
P = findNodeByName(AdiabaticCSTR,'P');
P_DISABLE = findNodeByName(AdiabaticCSTR,'P_DISABLE');
% Read value of TI1
readValue(TI1)
% Write value to P
writeValue(P,0);
% Disconnect
disconnect(ua);
```

Python, OPC-UA

```python
from opcua import Client
# Connect to OPC-UA server
ua = Client('opc.tcp://127.0.0.1:4840/adiabatic_cstr/')
ua.connect()
# You may browse the namespace in a
# GUI using the opcua-client software.
objects = ua.get_root_node().get_child('0:Objects')
AdiabaticCSTR = objects.get_child('2:AdiabaticCSTR')
TI1 = AdiabaticCSTR.get_child('2:TI1')
TI2 = AdiabaticCSTR.get_child('2:TI2')
TI3 = AdiabaticCSTR.get_child('2:TI3')
FI = AdiabaticCSTR.get_child('2:FI')
P = AdiabaticCSTR.get_child('2:P')
P_DISABLE = AdiabaticCSTR.get_child('2:P_DISABLE')
# Read value of TI1 [deg C]
print(TI1.get_value())
# Write value to P [RPM]
P.set_value(0)
# Disconnect
ua.disconnect();
```
4 Simulation OPC-UA Server

A simulation OPC-UA server which emulates the actual process is implemented in Python to aid the development of regulators communicating using the OPC-UA standard, the code is listed in Appendix D.3. Mock measurements are generated using a mathematical model of the process. The only discrepancy in comparison with the OPC-UA server offered by the actual process is a “RESET” tag. If the tag is written a value besides “0” then the server will reset to its initial state.
References

Appendix 1. Experiment Guide: Multiple Steady States

A Experiment Guide: Multiple Steady States

This experiment guide describes the backmix reactor experimental part of Exercise 3 in course 28845 Chemical Reaction Engineering Laboratory.

A.1 Objective

Determine steady states of Equation 3 in an adiabatic stirred tank reactor and reproduce the results by Vejtasa and Schmitz [1] as illustrated in Figure 6.

![Figure 6: Steady states determined by Vejtasa and Schmitz [1].](image)

A.2 Background

Sodium thiosulfate is oxidized by hydrogen peroxide to form sodium trithionate according to reaction 3:

$$\text{Na}_2\text{S}_2\text{O}_3 + 2\text{H}_2\text{O}_2 \rightarrow \frac{1}{2}\text{Na}_2\text{SO}_4 + \frac{1}{2}\text{Na}_2\text{S}_3\text{O}_6 + 2\text{H}_2\text{O} \quad (3)$$

The reaction is known to exhibit multiple steady states when it takes place in an adiabatic stirred tank reactor due to the interaction between the temperature dependent reaction rate and the exothermic reaction. Reaction 3 is irreversible and the rate of reaction is given in Equation 4:

$$-r_{\text{Na}_2\text{S}_2\text{O}_3} = -\frac{1}{2}r_{\text{H}_2\text{O}_2} = C_{\text{Na}_2\text{S}_2\text{O}_3} C_{\text{H}_2\text{O}_2} A \exp \frac{-B}{T} \quad (4)$$
Appendix 1. Experiment Guide: Multiple Steady States

Reaction parameters are stated in Table 5 where the enthalpy of reaction is on a \( \text{Na}_2\text{S}_2\text{O}_3 \) basis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A )</td>
<td>( \exp(24.6) \text{ L (s mol)}^{-1} )</td>
</tr>
<tr>
<td>( B )</td>
<td>8500 K</td>
</tr>
<tr>
<td>( \Delta H_R )</td>
<td>( -552 \text{ kJ mol}^{-1} ) to ( -573 \text{ kJ mol}^{-1} )</td>
</tr>
</tbody>
</table>

A.3 Experiment

Solutions of hydrogen peroxide and sodium thiosulfate have been prepared the day before the experiment is to be conducted and are kept cold in a freezer. The concentrations are approximately 2.4 M and 1.6 M respectively and are to be determined precisely by titrimetric analysis.

Check the following before you start the experiment:

1. Check that the solution recipient tank is empty or has enough space left for the entire experiment.

2. Check that there are sufficient amounts of chemicals in the containers in the freezer.

3. Power on equipment.
   (a) Power on the magnetic stirrer.
   (b) Power on the flow meter.
   (c) Power on the peristaltic pump.
   (d) Power on the electrical cabinet.

4. Ensure that the stirrer operates reliably at the highest possible rotational speed.

5. Ensure that the pump is in analog mode by pushing the “mode” button on the pump so that the display reads “ana”.

6. If you wish to record experimental data to a USB Drive:
   (a) Insert a USB drive (FAT formatted) into the USB port on the electrical cabinet.
   (b) Follow the instructions on screen F4 on the HMI.
Appendix 1. *Experiment Guide: Multiple Steady States*

(c) Wait 10 seconds, then stop logging.
(d) Check that data was actually logged to the USB drive.
(e) Repeat steps (a) and (b).

7. Set the pump speed to the maximum to remove air pockets that may be trapped in the tubes.

8. Await a steady indication of the effluent temperature and note the value.

I: Stable Steady States

A number of runs are made to measure the steady state effluent temperature for different residence times. The objective is to determine steady states outside the region with multiple steady states.

1. Determine stable steady states for long residence time corresponding to low flow rates.

2. Determine stable steady states for short residence time corresponding to large flow rates.

Try to determine precisely the two discontinuities. Note that close to the ignition point the reactor temperature initially changes very slowly prior to ignition. Be sure not to terminate a measurement close to the ignition point before it is quite certain that the temperature has not started a slow rise.

II: Unstable Steady States

The stable branches of the $(\tau, T)$-diagram have now been established. Perform a few measurements in the region with multiple steady states to approach the unstable states by intermittently turning off/increasing the pump speed. This can be done as follows:

1. Choose a relatively small residence time between the extinction-ignition limits.

2. Shortly turn off the pump and observe the temperature rise in the reactor.

3. Turn on the pump again after a slight temperature increase (2 to 4°C) and observe whether the temperature begins to return to the former level or continues to rise to the ignited state.
Appendix 1. *Experiment Guide: Multiple Steady States*

(a) If the temperature begins to return to the extinguished state, then turn off the pump to give zero flow until the temperature again has increased a few degrees. Then turn on the pump again.

(b) If the temperature begins to decrease the procedure is repeated.

Be sure that the maximum temperature in each successive period with zero flow is a few degrees higher than in the foregoing. In this way it is possible gradually to encircle the position of the unstable steady state temperature at the given residence time. After an ignition, the extinguished state is recovered by “flushing” the reactor with a high flow rate.

4. The unstable steady state should also be determined by making analogous extinction experiments, starting on the “ignited” branch and instead of using periods with zero flow, periods with max flow should be used.

5. If possible, repeat this procedure for a couple of other values of the residence time between the extinction-ignition limits.

You have now recorded pairs of steady state values of the pump speed (P) and the reaction mixture temperature (TI3). These datapoints may be used to construct a $(\tau, T)$-diagram similar to Figure 6.
Appendix 2. **Installation of Python for OPC-UA Connectivity**

### B  Installation of Python for OPC-UA Connectivity

#### B.1  Windows


2. Install Anaconda. Use default options when prompted. For assistance, see [https://docs.continuum.io/anaconda/install/windows](https://docs.continuum.io/anaconda/install/windows).

3. Navigate to Start, Anaconda3 (64-bit) and run “Anaconda Prompt”.

4. In the prompt, issue the command[^1]
   
   ```bash
   conda install python=3.5
   ```

5. In the prompt, issue the command:
   
   ```bash
   conda install -c anaconda cvxopt
   ```

6. In the prompt, issue the command:
   
   ```bash
   pip install freeopcua opcua-client python-snap7
   ```

7. You have now set up Python. Always call Python code form the “Anaconda Prompt”.

#### B.2  Ubuntu


2. Install Anaconda. Use default options when prompted. For assistance, see [https://docs.continuum.io/anaconda/install/linux](https://docs.continuum.io/anaconda/install/linux).

3. Open a terminal window.

4. In the terminal window, issue the command:
   
   ```bash
   conda install -c anaconda cvxopt
   ```

5. In the terminal window, issue the command:
   
   ```bash
   pip install freeopcua opcua-client python-snap7
   ```

6. You have now set up Python.

[^1]: Downgrading to Python 3.5 is required because cvxopt (convex optimization solver) does not yet support Python 3.6 on Windows.
Appendix 2. *Installation of Python for OPC-UA Connectivity*

**B.3 macOS**


2. Install Anaconda. Use default options when prompted. For assistance, see [https://docs.continuum.io/anaconda/install/mac-os](https://docs.continuum.io/anaconda/install/mac-os).

3. Open a terminal window.

4. In the terminal window, issue the command:

   ```bash
   conda install -c anaconda cvxopt
   ```

5. In the terminal window, issue the command:

   ```bash
   pip install freeopcua opcua-client python-snap7
   ```

6. You have now set up Python.
C  Installing and Running the OPC-UA Server

1. Complete the steps listed in Appendix B for your operating system.

2. Connect your computer to the experimental setup with ethernet.

3. Configure your ethernet adapter.
   
   • Windows:
     3.1. Open a cmd window.
     3.2. In the cmd window, issue the command:
         ```
         netsh interface ipv4 show config
         ```
     3.3. Find the name of your ethernet connection in the output of the preceding command. It is typically called “Ethernet”.
     3.4. In the cmd window, issue the following command where NAME is replaced with the name found in the preceding step:
         ```
         netsh interface ipv4 set address name="NAME" static 192.168.0.5 255.255.255.0
         ```
     3.5. To restore the initial network configuration, issue the command:
         ```
         netsh interface ipv4 set address name="NAME" source =dhcp
         ```
   
   • Ubuntu or macOS:
     3.1. Open a terminal window.
     3.2. In the terminal window, issue the command:
         ```
         ifconfig
         ```
     3.3. Find the name of your ethernet connection in the output of the preceding command. It is typically called “eth0”.
     3.4. In the terminal window, issue the following command where NAME is replaced with the name found in the preceding step:
         ```
         sudo ifconfig NAME 192.168.0.5 netmask 255.255.255.0
         ```
     3.5. To restore the initial network configuration, issue the command:
         ```
         dhclient
         ```


5. Unzip the release zip.
Appendix 3. Installing and Running the OPC-UA Server

   - Windows:
     6.1. Find snap7.dll the release and copy it to C:\Windows\System32.  
   - Ubuntu:
     6.1. Open a terminal.
     6.2. Navigate to build/unix in the release.
     6.3. In the terminal, issue the command:
       `make -f x86_64_linux.mk`
     6.4. In the terminal, issue the command:
       `sudo make -f x86_64_linux.mk install`
   - macOS:
     6.1. Open a terminal.
     6.2. Navigate to build/osx in the release.
     6.3. In the terminal, issue the command:
       `make -f x86_64_osx.mk`
     6.4. In the terminal, issue the command:
       `sudo make -f x86_64_osx.mk install`

7. Open a terminal.
   7.1. Windows: Open “Anaconda Prompt”.
   7.2. Ubuntu or macOS: Open a terminal.

8. Navigate to the folder where you have saved the code listed in Appendix D.1.

9. In the terminal window, issue the command:

   `python s7_to_opcua.py`

10. The OPC-UA server is now running and you may connect to it on
    opc.tcp://127.0.0.1:4840/adiabatic_cstr/.

    Note: When the OPC-UA server is running the HMI should not be used.

11. To stop the OPC-UA server, issue CTRL-C.
Appendix 3. *Installing and Running the OPC-UA Server*

### C.1 Running the Sample Code

Install Python as described in Appendix B. Save the code listed in the Appendix D. Firstly the simulation server is started and then a client may be started.

To start the simulation server issue

```bash
python simulation_server.py
```

When the server is done starting up it will display “Server reset” to indicate that it has reset to the specified initial steady state and that it is ready for a client to connect. The Python client example (Appendix D.4) may be run by issuing

```bash
python client_template.py
```

A live plot will appear showing measurements as they are recorded from the OPC simulation server.
Appendix 4. Sample Code

D Sample Code

For comments on the code listed in the following, the reader is referred to the comments given in the code.
Appendix 4. Sample Code

D.1  s7_to_opcua.py

```python
# Name: s7_to_opcua.py
# Author: Eskild Schroll-Fleischer <esksch@dtu.dk>
# Date: 12th of September 2017
#
# Description:
# OPC-UA server exposing PLC endpoints. Data exchange with PLC
# using S7 protocol. Variables are read periodically from the
# PLC and published on the OPC-UA server.
# The writable OPC-UA tags are monitored for changes. When a change is
# caught then the new value is published to the PLC.
#
# The code is organized as follows:
# 1. Configuration
# 2. Connect to PLC with S7
# 3. Populate OPC-UA address space
# 4. Subscribe to datachanges coming from OPC-UA clients
# 5. Read all readables simultaneously from the PLC and update the OPC-UA variables
#
# L 609 in addressspace.py, python-opcua v 0.90.3

import time
from opcua import ua, Server

import snap7
from snap7.snap7types import S7AreaMK, S7AreaPA, S7WLWord

## 1. Configuration
OPC_UA_SERVER = 'opc.tcp://127.0.0.1:4840/adiabatic_cstr/
# Certificates may be generated on unix platforms by issuing:
# openssl req -x509 -newkey rsa:2048 -keyout private_key.pem -out certificate.pem -days 355 -nodes
# openssl x509 -outform der -in certificate.pem -out certificate.der
OPC_UA_CERTIFICATE = 'certificate.der'
OPC_UA_PRIVATE_KEY = 'private_key.pem'
OPC_UA_URI = 'http://dtu.dk'
SAMPLE_TIME = 0.1 # [s]
SNAP7_CLIENT = ('192.168.0.10', 0, 1,)

def read(c):
    data = c.read_area(snap7.snap7types.S7AreaMK, 0, 114, S7WLWord*5)
    TI1 = snap7.util.get_real(data,S7WLWord*(1-1)) # [deg C]
    TI2 = snap7.util.get_real(data,S7WLWord*(2-1)) # [deg C]
    TI3 = snap7.util.get_real(data,S7WLWord*(3-1)) # [deg C]
    FI = snap7.util.get_real(data,S7WLWord*(4-1)) # [mL/min]
    P = snap7.util.get_real(data,S7WLWord*(5-1)) # [RPM]
    #PULSE_DURATION = snap7.util.get_dword(data,S7WLWord*(6-1)) # [ms]
    P_DISABLE = snap7.util.get_bool(c.read_area(S7AreaPA, 0, 0, 1), 0, 4)
    return (TI1, TI2, TI3, FI, P, P_DISABLE,)

def write_p(c, RPM):
    data = bytearray(16)
    snap7.util.set_real(data, 0, RPM)
    c.write_area(S7AreaMK, 0, 130, data)

def pump_pulse(c):
    # The PULSE bit resides on M142.1.
    on = bytearray(1)
    snap7.util.set_bool(on, 0, 1, True)
    c.write_area(S7AreaMK, 0, 142, on)

def write_p_disable(c,b):
    d = bytearray(1)
    if b:
        snap7.util.set_bool(d, 0, 4, True)
    c.write_area(S7AreaPA, 0, 142, d)

class SubscriptionHandler(object):
    def __init__(self,n):
        self.i = 0
        self.n = n
        self.final_datachange_notification(self, node, val, data):
        node = node.get_path_as_string()[-1].split('/')[-1]
        # 'path_as_string' is a list of strings containing:
        # 0: 0:Root
        # 1: 1:Objects
        # 2: 2:OPC DA Server
```
# 3 and onwards: 3: [Step of path to node in OPC-DA]

```python
#snap7client_ = snap7.client.Client()
snap7client_.connect(*SNAP7_CLIENT)
if node == '/ts1P/'): write_p(snap7client_, val)
if node == '/DISABLE/): write_p_disable(snap7client_, val)
snap7client_.disconnect()
```

This function is called initially to catch the notifications from newly added nodes

```python
def datachange_notification(self, node, val, data):
    self.i = self.i + 1
    #print('Catching meaningless datachange notification')
    if self.i == self.n:
        #print('Finished catching meaningless datachange notifications')
        self.datachange_notification = self.final_datachange_notification
```

## 2. Connect to PLC with S7

```python
snap7client = snap7.client.Client()
snap7client.connect(*SNAP7_CLIENT)
```

## 3. Populate OPC-UA address space

```python
server = Server()
server.set_endpoint(OPC_UA_SERVER)
server.load_certificate(OPC_UA_CERTIFICATE)
server.load_private_key(OPC_UA_PRIVATE_KEY)
```

```python
idx = server.register_namespace(OPC_UA_URI)
```

```python
objects = server.get_objects_node()
```

```python
# 3. Populate OPC-UA address space
TI1, TI2, TI3, FI, P, P_DISABLE = read(snap7client)
acstr = objects.add_object(idx, 'AdiabaticCSTR')
TI1 = acstr.add_variable(idx, 'TI1', ua.Variant(TI1, ua.VariantType.Double))
TI2 = acstr.add_variable(idx, 'TI2', ua.Variant(TI2, ua.VariantType.Double))
TI3 = acstr.add_variable(idx, 'TI3', ua.Variant(TI3, ua.VariantType.Double))
FI = acstr.add_variable(idx, 'FI', ua.Variant(FI, ua.VariantType.Double))
P = acstr.add_variable(idx, 'P', ua.Variant(P, ua.VariantType.Double))
P_DISABLE = acstr.add_variable(idx, 'P_DISABLE', ua.Variant(P_DISABLE, ua.VariantType.Boolean))
P.set_writable()
P_DISABLE.set_writable()
```

```python
try:
    server.start()
```

## 4. Subscribe to datachanges coming from OPC-UA clients

```python
handler = SubscriptionHandler(2) # Two writable variables
sub = server.create_subscription(100, handler).subscribe_data_change([P, P_DISABLE])
```

```python
while True:
    time.sleep(SAMPLE_TIME)
```

## 5. Read all readables simultaneously from the PLC and update the OPC-UA variables

```python
[TI1, TI2, TI3, FI, P, P_DISABLE] = read(snap7client)
```

```python
[node.set_value(value) for node, value in zip([TI1, TI2, TI3, FI], [TI1, TI2, TI3, FI])]```

```python
finally:
    snap7client.disconnect()
```

server.stop()
Appendix 4. Sample Code

D.2 datalog_to_matlab.py

```python
# Name: datalog_to_matlab.py
# Author: Eskild Schroll-Fleischer <esksch@dtu.dk>
# Date: 12th of September 2017
#
# Description:
# Converts text file format of HMI device to Matlab file format
# which is convenient for data analysis and plotting.
# This file should be placed in the same directory as the input data file.
# The output data file may be loaded in Matlab and used to plot the data:
# % Load data
# load('OUTPUT_MAT', 'data');
# % Store data in named vectors
# t = data(:,1); % Time relative to first collected data [s]
# TI1 = data(:,2); % Temperature [deg C]
# TI2 = data(:,3); % Temperature [deg C]
# TI3 = data(:,4); % Temperature [deg C]
# FI = data(:,5); % Flow rate [mL/min]
# PUMP_DISABLE = data(:,7);
# PUMP_ENABLE = ~PUMP_DISABLE;
# P = data(:,6) .* PUMP_ENABLE; % Pump speed, respects PUMP_DISABLE setting [RPM]
# % Plot of temperature and pump speed
# figure(1);
# subplot(2,1,1);
# plot(t, [TI1 TI2 TI3]);
# ylabel('Temperature [deg C]');
# subplot(2,1,2);
# plot(t, P)
# xlabel('Time [s]'); ylabel('Pump [RPM]');

import csv, datetime, codecs
import numpy as np
import scipy.io as io

INPUT = 'Data log0.txt' # Change this
OUTPUT_MAT = 'data.mat'
INPUT_DATETIME_FORMAT = '%Y-%m-%d %H:%M:%S'

def string_to_datetime(s):
    return datetime.datetime.strptime(s, INPUT_DATETIME_FORMAT)

class Datapoint():
    def __init__(self):
        self.TI1 = None; self.TI2 = None; self.TI3 = None; self.FI = None; self.P = None; self.P_DISABLE = None

# Open file for reading
with codecs.open(INPUT, 'rb', 'utf-16') as f:
    # 'data' is a buffer for data read from the CSV
    data = {}
    # CSV file is tab-delimited and values are enclosed in quotation marks
    # Loop over rows in the CSV File
    for row in f:
        # This try-except will except if the row contains no timestamp
        try:
            t = string_to_datetime(row[1]).timestamp()
            key = row[0]
            value = float(row[2])
            # The the 'value' of 'key'. If the object does not already exist, create it.
            try:
                setattr(data[t], key, value)
            except:
                data[t] = Datapoint()
                setattr(data[t], key, value)
        except:
            pass

# Save data from buffer 'data' to a .mat file
matrix = np.zeros((len(data.keys()), 7))
t0 = None
i = 0
for timestamp, obj in sorted(data.items()):
    if t0 is None:
```

m
Appendix 4. Sample Code

```python
t0 = int(timestamp)
matrix[:,] = [int(timestamp)-t0, obj.TI1, obj.TI2, obj.TI3, obj.FI, obj.P, obj.P_DISABLE]
i = i + 1
# Remove rows containing 'nan'
matrix = matrix[~np.isnan(matrix).any(axis=1)]
# Save 'matrix' to .mat file.
io.savemat(OUTPUT_MAT, {'data':matrix})
```
Appendix 4. Sample Code

D.3 simulation_server.py

```python
# Name: simulation_server.py
# Author: Eskild Schroll-Fleischer <esksch@dtu.dk>
# Date: 12th of September 2017
#
# Description:
# Simulation server which emulates the adiabatic CSTR in B229 using a process model
to generate mock measurements. The server communicates according to the OPC-UA standard.
The state may be reset by writing anything but 0 to the RESET tag.
The server may be stopped by issuing CTRL-C.
#
# The code is organized as follows:
# 1. Configuration
# 2. First-principles model of the adiabatic CSTR
# 3. Populate OPC-UA address space
# 4. (a) If the RESET tag value is different from 0 then the server is reset to the initial state
# 4. (b) Check whether sample time has passed and if so, execute process functionality
# 4. (c) Simulate process model one sample time
# 4. (f) Publish results of simulation to OPC-UA server
#
# Import standard python packages
import time
from opcua import ua, Server
import numpy as np
from scipy.integrate import odeint

## 2. Configuration
OPC_UA_SERVER = 'opc.tcp://127.0.0.1:4840/adiabatic_cstr/
# Certificates may be generated on unix platforms by issuing:
# openssl req -x509 -newkey rsa:2048 -keyout private_key.pem -out certificate.pem -days 355 -nodes
# openssl x509 -outform der -in certificate.pem -out certificate.ders
OPC_UA_URI = 'http://dtu.dk'
t_step = 0.2
# [s]
Q = 0.01*np.eye(ny)
# Measurement noise dispersion matrix
PUMP_CALIBRATION = 2.02
# [(mL/min)/RPM]

## Dimensions of variables
nx = 3
# TC3, Ca, Ch
ny = 1
# TC3
nu = 1
# P
nz = 1
# TC3
nd = 2
# TC1, TC2

## 2. First-principles model of the adiabatic CSTR
class AdiabaticStirredTankReactor:
def __init__(self, x0=None):
    '''Set initial conditions and plant parameters.''
    self.t = 0
    self.Cin = [0.9320625, 1.28125]
    # [mol/L]
    self.HR = -553000
    # [J/mol]
    self.v = [-1, -2]
    # Molar stoichiometry
    self.kA = 24.6
    # Corresponding to R in units [mol/L]
    self.kB = 8500
    # [K]
    self.V = 0.105
    # [L]
    self.cp = 4186.3
    # [J/(kg*K)]
    self.rho = 1.0
    # [kg/L]
    if x0 is None:
        self.x = np.concatenate(([-1.5], self.Cin))
    else:
        self.x = x0
def ode(self, x, t, u, d):
    if clusterdefaults[0] == 1:
        return self.x
    # Model parameters
    self.Cin = [0.9320625, 1.28125] # [mol/L]
    self.HR = -553000 # [J/mol]
    self.v = [-1, -2] # Molar stoichiometry
    self.kA = 24.6 # Corresponding to R in units [mol/L]
    self.kB = 8500 # [K]
    self.V = 0.105 # [L]
    self.cp = 4186.3 # [J/(kg*K)]
    self.rho = 0.9 # [kg/L]
    self.t = t
    self.C = self.x[0]
    self.T = self.x[1]
    return np.concatenate([[dT], [dC]])
```
```
Appendix 4. Sample Code

```python
def y(self, x):
    return x[0]
def step(self, dt, u, d):
    sol = odeint(self.ode, self.x, [0, dt], args=(u,d,))
    self.x = sol[1]  # Save final solution as current state
    self.t += dt
    return sol[1]
ACSTR = AdiabaticStirredTankReactor()
x0 = ACSTR.x
server = Server()
server.set_endpoint(OPC_UA_SERVER)
server.load_certificate(OPC_UA_CERTIFICATE)
server.load_private_key(OPC_UA_PRIVATE_KEY)
idx = server.register_namespace(OPC_UA_URI)
objects = server.get_objects_node()

## 3. Populate address space
acstr = objects.add_object(idx, '/AdiabaticCSTR/')[0]
reset_tag = acstr.add_variable(idx, '/RESET/').variant(1, ua.VariantType.UInt16)
reset_tag.set_writable()
TI1 = acstr.add_variable(idx, '/TI1/').variant(0, ua.VariantType.Double)  # [deg C]
TI2 = acstr.add_variable(idx, '/TI2/').variant(0, ua.VariantType.Double)  # [deg C]
TI3 = acstr.add_variable(idx, '/TI3/').variant(0, ua.VariantType.Double)  # [deg C]
FI = acstr.add_variable(idx, '/FI/').variant(0, ua.VariantType.Double)  # [mL/min]
P = acstr.add_variable(idx, '/P/').variant(0, ua.VariantType.Double)  # [RPM]
P_DISABLE = acstr.add_variable(idx, '/P_DISABLE/').variant(0, ua.VariantType.Double)  # [RPM]
P.set_writable()
server.start()

try:
    t0 = time.time()
    while True:
        # 4. (a) If the RESET tag value is different from 0 then the server is reset to the initial state
        if reset_tag.get_value() != 0:
            # Reset server
            ACSTR.x = x0;
P.set_value(0)
            TI1.set_value(0)
            TI2.set_value(0)
            reset_tag.set_value(0)
            print('Server reset')
            time.sleep(0.1)  # Update speed of the real system
        # 4. (b) Check whether sample time has passed
        if time.time() - t0_ >= t_step:
            t0_ = t0
            # Generate measurement noise
            v = np.random.multivariate_normal(np.zeros(ny),Q)
        # 4. (e) Simulate process model one sample time
        T = ACSTR.y(ACSTR.step(t0-t0_, P.get_value()*PUMP_CALIBRATION*P_ENABLE), [(TI1.get_value()+TI2.get_value()+273.15*2)/2]) + v -273.15
        # 4. (f) Publish results of simulation to OPC-UA server
        TI3.set_value(T[0])
finally:
    server.stop()
```

P
Appendix 4. Sample Code

D.4 client_template.py

```python
# Name: client_template.py
# Author: Eskild Schroll-Fleischer <esksch@dtu.dk>
# Date: 12th of September 2017
#
# Description:
# MPC regulator for the adiabatic CSTR in B229 at the Technical University of Denmark.
# Communicates with the process equipment using OPC-UA.
# Data acquisition, Kalman filter and MPC are executed in a background thread at regular
# intervals. The controller set point may be changed during operation using the r(x)
# function in the embedded prompt. A live plot may be started using the
# live_plot(data_queue) function, it may be closed by CTRL-C.
#
# The code is organized as follows:
# 1. Configuration
# 2. Prepare Kalman filter and MPC here
# 3. Connect to OPC-UA server and discover nodes
# 4. Open CSV file for logging
# 5. Establish time-zero and read current values
# 6. (a) Poll server for new measurements
# 6. (b) Read measurements, inputs and known disturbances
# 6. (c) Filtering and MPC execution here
# 6. (d) Update data for animation plot
# 7. Plot

import sys, time, datetime, csv, queue, atexit, threading
from opcua import Client
import numpy as np
from numpy.matlib import repmat
from scipy.optimize import fsolve
import matplotlib.pyplot as plt
# Use qt5 backend for more reliable plotting with matplotlib
import matplotlib.pyplot as p
p.switch_backend('Qt5Agg')

try:
    from IPython import embed
except ImportError:
    import code
def embed():
    vars = globals()
    vars.update(locals())
    shell = code.InteractiveConsole(vars)
    shell.interact()

## 1. Configuration
OPC_UA_SERVER = 'opc.tcp://localhost:4840/adiabatic_cstr/
LOG_FILE = 'log.csv'
# Length of discrete time step [s]
t_step = datetime.timedelta(seconds=1)
# Number of discrete time steps to keep in history
n_hist = 60
# Number of discrete time steps to forecast
n_horizon = 10

# Dimensions of variables
ny = 1
nu = 1
nz = 1
nd = 2

## 2. Prepare Kalman filter and MPC here

# Set these values!
y_s = np.array([0])
u_s = np.array([0])
d_s = np.array([0,0])
# Default to keeping current steady state
r_future = np.zeros((1,nz))
def regulator(data_queue):
```

```
Appendix 4. Sample Code

```python
# Get reference to current thread instance
thread = threading.currentThread()

# Preallocate measurement and estimate history matrices to be used in a ring-buffer scheme
r = np.zeros((n_hist+n_horizon,nz))
y_hist = np.empty((n_hist,ny))
y_est = np.empty((n_hist,ny))
y_pred = np.empty((n_horizon,ny))
u_hist = np.empty((n_hist,nu))
u_pred = np.empty((n_horizon,nu))
for array in [y_hist, y_est, y_pred, u_hist, u_pred]:
    array[:] = np.NAN

# 3. Connect to OPC-UA server and discover nodes
client = Client(OPC_UA_SERVER)
# Connect and discover nodes
client.connect()
root = client.get_root_node()
AdiabaticCSTR = root.get_child('/ts10:Objects/ts12:AdiabaticCSTR')
TI1 = AdiabaticCSTR.get_child('/ts12:TI1')
TI2 = AdiabaticCSTR.get_child('/ts12:TI2')
TI3 = AdiabaticCSTR.get_child('/ts12:TI3')
FI = AdiabaticCSTR.get_child('/ts12:FI')
P = AdiabaticCSTR.get_child('/ts12:P')
P_DISABLE = AdiabaticCSTR.get_child('/ts12:P_DISABLE')

# 4. Open CSV file for logging
logfile = open(LOG_FILE, 'a')
csvlog = csv.writer(logfile, delimiter=';', quoting=csv.QUOTE_MINIMAL)

try:
    # 5. Establish time-zero and read current values. The process is assumed to be in
    # steady state.
t0 = TI3.get_data_value().ServerTimestamp
    y0 = TI3.get_value()
    modifier = 1
    if P_DISABLE.get_value():
        modifier = 0
    u0 = P.get_value()*modifier
    t_start = t0
    while getattr(thread, 'do_run', True):
        # 6. (a) Poll server for new measurements and act when sufficient time has passed
        # time.sleep(0.1)
        t = TI3.get_data_value().ServerTimestamp
        if t-t0 >= t_step:
            t0 = t
        # 6. (b) Read measurements, inputs and known disturbances as well as extra
        # data not directly used by the regulator. Data is logged continuously.
        y = TI3.get_value()
        modifier = 1
        if P_DISABLE.get_value():
            modifier = 0
        u = P.get_value()*modifier
        d = [TI1.get_value(), TI2.get_value()]
        # Log data to disk
        csvlog.writerow([t-t_start].total_seconds()]+y+u+d)

        # Dimensional variables from deviation variables
        y = ys + (np.array(y)-y0)
        u = us + (np.array(u)-u0)
        **
        # 6. (c) Filtering and MPC execution here
        **
        # 6. (d) Update data for animation plot
        # Roll history and trajectory
        y_hist = np.roll(y_hist, -ny)
        u_hist = np.roll(u_hist, -nu)
        r = np.roll(r, -nz)
        y_hist[-1] = y
        u_hist[-1] = u
        r[-1] = r_future

        # Submit new data to queue for live_plot to consume
        data_queue.put((r, y_hist, y_est, u_hist, y_pred, u_pred))

finally:
```

---
Sample Code

```python
import queue
import matplotlib.pyplot as plt
import numpy as np
import time

def live_plot(data_queue):
    # Empty the queue of its contents
    while True:
        try:
            data_queue.get(block=False)
        except queue.Empty:
            break

    # Get data from queue
    r, y_hist, y_est, u_hist, y_pred, u_pred = data_queue.get()

    # Prepare time axis which is constant at all times
    t_hist = np.linspace(-(n_hist-1),0,n_hist) * t_step.total_seconds()
    t_hist_pred = np.linspace(-(n_hist-1),n_horizon,n_hist+n_horizon) * t_step.total_seconds()

    # Open plot window and clear it.
    f = plt.figure(1)
    f.clf()
    plt.ion()

    # Upper subplot
    plt.subplot(2,1,1)
    # Plot measurements
    p1 = plt.plot(t_hist, y_hist, ms=4, mfc='none')
    # Reset color order
    plt.gca().set_prop_cycle(None)
    # Plot filtered measurements
    p2 = plt.plot(t_hist_pred, np.concatenate((y_est,y_pred)))
    # Reset color order
    plt.gca().set_prop_cycle(None)
    # Plot set point
    p3 = plt.plot(t_hist_pred, r, '--')
    # Axis specification
    plt.ylim([-10,100])
    plt.xlim([-n_hist*t_step.total_seconds(), n_horizon*t_step.total_seconds()])
    plt.legend(['TI3'])
    plt.ylabel('Temperature [\textdegree{}C]')

    # Lower subplot
    plt.subplot(2,1,2)
    # Plot manipulated variable as stairs
    p4 = plt.plot(t_hist_pred, np.concatenate((u_hist,u_pred)), drawstyle='steps-pre')
    # Axis specification
    plt.ylim([0,400])
    plt.xlim([-n_hist*t_step.total_seconds(), n_horizon*t_step.total_seconds()])
    plt.legend(['P'],loc='lower left')
    plt.ylabel('Pump [RPM]')
    plt.xlabel('Time [s]')

    # Display plot
    plt.show()

    # Live update plot until keyboard interrupt (CTRL-C) is issued.
    try:
        while True:
            plt.pause(0.1)
            # Get latest data
            try:
                r, y_hist, y_est, u_hist, y_pred, u_pred = data_queue.get(True, 0.1)
            except queue.Empty:
                continue
            # Update the plots
            for i, p in enumerate(p1):
                p.set_ydata(y_hist[:,i])
                y_ = np.concatenate((y_est,y_pred))
                for i, p in enumerate(p2):
                    p.set_ydata(y_[:,i])
                for i, p in enumerate(p3):
                    p.set_ydata(r[:,i])
                    y_ = np.concatenate((u_hist,u_pred))
                    for i, p in enumerate(p4):
                        p.set_ydata(y_[:,i])
            except KeyboardInterrupt:
                plt.close(1)

    # Use this function to manipulated set-point from cmd window
    def r(x):
        global r_future
        r_future = r_future + x
```

---

Appendix 4. Sample Code
def end_thread(thread):
    thread.do_run = False
    if thread.is_alive():
        thread.join()

if __name__ == '__main__':
    data_queue = queue.Queue()
    thread = threading.Thread(target=regulator, args=(data_queue,), daemon=True)
    thread.start()
    atexit.register(end_thread, thread)
    live_plot(data_queue)
    embed()
Appendix 5. Datasheets

E   Datasheets

E.1  Watson Marlow 323u
# 323U/ D and 323U/ 4D

## Metering and Transfer Pump

**Auto/ Manual Control**

**IP31 Wipedown Enclosure**

## Technical Information and Features

- **Flow rates from** 0.09 to 2000 mL/min (0.001-31.7 gph)
- **Operator friendly keypad offering:**
  - Start, stop, speed control, fwd/rev, control mode
  - Precise manual speed control from 3-400 rpm in 1 rpm increments
  - Large clear LCD display with accurate digital monitoring for clear RPM indication
  - “Auto-restart” and “keypad lock” functions
  - Memo Dose feature allows manually actuated repetitive discrete volume dispensing
- **133:1 speed control range**
- **Remote speed control via** 0-10VDC or 4-20mA analog speed input when in Analog mode
- **Remote start/stop capability via** dry contact closure or TTL switching
- **Remote direction control capability via** dry contact closure or TTL switching
- **Tough metal and ABS case with broad chemical resistance and IP31 wipedown enclosure**
- **Brushless DC motor** for excellent speed control, quiet operation, and no maintenance
- **Fitted easy loading flip-top three roller 313D or four roller 314D pumpheads**
- **Optional three roller 313X and four roller 314X extension pumpheads for up to 6 channels of flow**
- **313D and 314D and extension heads** accept tube sizes # 112, 13, 14, 16, 25, 17, and 18 (0.5-8.0 mm bore & 1.6 mm wall)
- **313D2 and 314D2 accept** thick wall tube sizes # 105, 108, 119, 120, 15, 24 (0.5-6.4 mm bore & 2.4 mm thick wall)
- **May be fitted with optional** four roller 314MC or eight roller 318MC five-channel microcassette pumpheads – stackable for up to ten channels of flow with manifold tubing

## Flow Rate Ranges (ml/ min*)

<table>
<thead>
<tr>
<th>1.6 mm Wall Tube #</th>
<th>112</th>
<th>13</th>
<th>14</th>
<th>16</th>
<th>25</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 mm Wall Tube #</td>
<td>105</td>
<td>108</td>
<td>119</td>
<td>120</td>
<td>15</td>
<td>24</td>
<td>N/A</td>
</tr>
<tr>
<td>Tube Bore</td>
<td>0.5mm</td>
<td>0.8mm</td>
<td>1.6mm</td>
<td>3.2mm</td>
<td>4.8mm</td>
<td>6.4mm</td>
<td>8.0mm</td>
</tr>
<tr>
<td></td>
<td>1/50”</td>
<td>1/32”</td>
<td>1/16”</td>
<td>1/8”</td>
<td>3/16”</td>
<td>1/4”</td>
<td>5/16”</td>
</tr>
<tr>
<td>313 Pumphead (3 Roll)</td>
<td>0.09-12</td>
<td>0.21-28</td>
<td>0.81-110</td>
<td>3.0-400</td>
<td>6.6-880</td>
<td>11-1440</td>
<td>15-2000</td>
</tr>
<tr>
<td>314 Pumphead (4 Roll)</td>
<td>0.09-12</td>
<td>0.18-24</td>
<td>0.75-100</td>
<td>2.6-340</td>
<td>5.7-760</td>
<td>9.0-1200</td>
<td>12-1600</td>
</tr>
</tbody>
</table>

## Maximum Number of Channels with 1.6mm Wall Tubing with 313 or 314 Extension Pumpheads, up to 30 psi

<table>
<thead>
<tr>
<th>Tube Bore</th>
<th>0.5mm</th>
<th>0.8mm</th>
<th>1.6mm</th>
<th>3.2mm</th>
<th>4.8mm</th>
<th>6.4mm</th>
<th>8.0mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicone</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Other Materials</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*1 gal = 3785.4 ml
Materials of Construction

**Pumphead**
- Pump Track & Lever: IXEF
- Rollers: Nylatron
- Spindles: Electroless nickel plated hardened steel
- Bearings: Bronze bush

**Drive**
- Drive Base: Powder coated aluminum casting
- Drive Top: ABS Plastic
- Bayonet Mounting Plate: IXEF

**Available Tubing Materials**

1. **1.6 mm wall for 313D & 314D**
   - Bioprene®
   - Marprene®
   - Silicone
   - Neoprene (excl. 0.5 mm)
   - Butyl (excl. 0.5& 0.8mm)
   - Tygon® (excl. 0.5& 0.8)
   - Sta-Pure™ (excl. 0.5& 0.8mm)
   - Chem-Sure™ (excl. 0.5& 0.8mm)

2. **2.4 mm wall for 313D2 & 314D2**
   - Bioprene® (excl. 0.5& 0.8mm)
   - Marprene® (excl. 0.5& 0.8mm)
   - Silicone
   - Sta-Pure™ (excl. 0.5& 0.8mm)
   - Chem-Sure™ (excl. 0.5& 0.8mm)

**Product Codes**

- 323U Drive, 400 rpm 036.3144.00A
- 313D 3 roller pumphead for 1.6 mm wall 033.3411.000
- 313X 3 roller extension pumphead for 1.6 mm wall 033.3431.000
- 314D 4 roller pumphead for 1.6 mm wall 033.4411.000
- 314X 4 roller extension pumphead for 1.6 mm wall 033.4431.000
- 313D2 3 roller pumphead for 2.4 mm wall 033.3511.000
- 314D2 4 roller pumphead for 2.4 mm wall 033.4511.000
- Complete 323U/D 030.3144.3DA
- Complete 323U/D2 030.3144.32A

**Specifications**
- Shipping Weight: 9.9lbs
- Maximum Power Consumption: 100VA
- Supply: 100-120/220-240V 50-60Hz (voltage selectable)
- Maximum Rotor Speeds: 400 rpm
- Enclosure: IP31 wipedown
- Operational Temperature Range: 4°C to 40°C (40°F to 104°F)
- Control Range: 133:1
- Noise: <70dBA at 1 meter
- Standards: Equipment complies with all applicable CE directives

**Watson-Marlow Bredel Pumps**
37 UPTON TECHNOLOGY PARK, WILMINGTON, MA. 01887-1018
TEL: 978-658-6168 / FAX: 978-658-0041
www.watson-marlow.com
support@wmbpumps.com

The information contained in this document is believed to be correct, but Watson-Marlow Bredel Pumps accepts no liability for any errors it contains, and reserves the right to alter specifications without notice.

Ssta-Pure and Chem-Sure are trademarks of W.L. Gore & Associates, Inc.

Tygon is a trademark of the Saint-Gobain Corporation. Fluorel is a trademark of 3M Corporation.
Appendix 5. Datasheets

E.2 ISOIL MS 501, ML210
Isoil Industria
a worldwide supplier
of electromagnetic
flowmeters

Total flow control. Accurate to the drop.
### SENSORS

<table>
<thead>
<tr>
<th>Description</th>
<th>“Microflow” Sensor</th>
<th>“Wafer” Sensor</th>
<th>Patented Wrapper Plastic Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Material</strong></td>
<td>Stainless Steel AISI304 (MS 501); Polypropylene (MS 600)</td>
<td>Carbon Steel Stainless Steel AISI304 (316 on request)</td>
<td>Polyurethane</td>
</tr>
<tr>
<td><strong>Diameter (mm)</strong></td>
<td>DN 3 = 20</td>
<td>DN 25 = 400</td>
<td>DN 20 = 80</td>
</tr>
<tr>
<td><strong>Pressure (bar)</strong></td>
<td>PN 16, PN 40 on request</td>
<td>PN 16, PN 40 for PTFE</td>
<td>PN 6</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>-20 ÷ 100 °C (PTFE/compact) -20 ÷ 130 °C (PTFE/remote) 0 ÷ 60 °C (Polypropylene liner)</td>
<td>0 ÷ 60 °C (Polypropylene liner) -5 ÷ 80 °C (Ebonite liner) -20 ÷ 100 °C (PTFE/compact) -20 ÷ 110 °C (PTFE/remote)</td>
<td>0 ÷ 50 °C</td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td>Threaded; Flanged; Sanitary DIN11851; Tri-clamp, Tri-clover, SMS...</td>
<td>Wafer</td>
<td>Metallic wrapper</td>
</tr>
<tr>
<td><strong>Liner</strong></td>
<td>PTFE, Polypropylene</td>
<td>Polypropylene, Ebonite, PTFE, others on request</td>
<td>Polyurethane</td>
</tr>
<tr>
<td><strong>Electrodes</strong></td>
<td>Stainless Steel AISI316L; Hastelloy C; Platinum, Tantalum, Titanium, etc...</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protection Rate</strong></td>
<td>IP68 for all sensors in separate version, for compact sensors depending on protection rate of converter connected</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Accuracy class</strong></td>
<td>Depending on converter</td>
<td>± 2% of measured value</td>
<td></td>
</tr>
</tbody>
</table>

### CONVERTERS

<table>
<thead>
<tr>
<th>Description</th>
<th>Fast Sampling Rate Converter (up to 400Hz)</th>
<th>4/20 mA Loop Powered Converter</th>
<th>Digital Converter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enclosure</strong></td>
<td>Stainless Steel AISI 304 (opt. AISI 316)</td>
<td>Nylon with Glass Fiber</td>
<td>Nylon with Glass Fiber</td>
</tr>
<tr>
<td><strong>Display</strong></td>
<td>No</td>
<td>2 lines x 16 characters</td>
<td>2 lines x 16 characters</td>
</tr>
<tr>
<td><strong>Protection Rate</strong></td>
<td>IP 67</td>
<td>IP 45 / IP 67</td>
<td>IP 65 / IP 67</td>
</tr>
<tr>
<td><strong>Outputs / Inputs</strong></td>
<td>1 digital output max 1250Hz Profibus / RS485 (opt.) 1 current output, passive (opt.) 5 digital input/output</td>
<td>1 digital output + 1 digital input + 4/20 mA two wire system</td>
<td>1 current output 2 digital output max 1250Hz Others on request (see additional modules)</td>
</tr>
<tr>
<td><strong>Special Functions</strong></td>
<td>Bidirectional, Dual Range, Diagnostic, Empty Pipe, Batch</td>
<td>Bidirectional, Diagnostic, Empty Pipe</td>
<td>Bidirectional, Dual Range, Diagnostic, Empty Pipe</td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
<td>10-33 Vdc</td>
<td>10-33 Vdc two wire</td>
<td>90-265Vac / 45-60Hz 10-63Vdc 15-45Vac / 45-66Hz</td>
</tr>
<tr>
<td><strong>Accuracy class</strong></td>
<td>± 0,2% of measured value</td>
<td>± 0,5% of measured value</td>
<td>± 0,8% (± 0,4% on request) of measured value</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td>Better than 0,1%</td>
<td>± 0,5%</td>
<td>± 0,2%</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>-20...+60°C</td>
<td>-20...+70°C</td>
<td>-10...+50°C</td>
</tr>
</tbody>
</table>

THE IDEAL FLOWMETERS FOR ANY APPLICATION
- from DN03 to DN2400
- wide range of process connections
- battery powered system
- GPRS wireless communication
### MS 2410 - MS 2500 - MS 3770 - MS 3810

<table>
<thead>
<tr>
<th>ML 210 – ML 211</th>
<th>ML 145 – ML 252</th>
<th>ML 255</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graphic Converter</strong></td>
<td><strong>Battery Powered Converter</strong></td>
<td><strong>Battery Powered Converter</strong></td>
</tr>
<tr>
<td><strong>Aluminium Die Casting</strong></td>
<td><strong>Aluminium Die Casting</strong></td>
<td><strong>Aluminium Die Casting</strong></td>
</tr>
<tr>
<td><strong>Stainless Steel on request</strong></td>
<td><strong>Stainless Steel on request</strong></td>
<td><strong>Stainless Steel on request</strong></td>
</tr>
<tr>
<td><strong>Graphic display 128x64 pixels, 8 lines x 16 characters</strong></td>
<td><strong>2 lines x 16 characters</strong></td>
<td><strong>Graphic display 128x64 pixels, 8 lines x 16 characters</strong></td>
</tr>
<tr>
<td><strong>IP 67</strong></td>
<td><strong>IP 67 / IP 68</strong></td>
<td><strong>IP 67 / IP 68</strong></td>
</tr>
<tr>
<td><strong>1 current output (+ 1 opt.)</strong></td>
<td><strong>2 digital output + 1 digital input (opt.)</strong></td>
<td><strong>2 digital output + 1 digital input (opt.)</strong></td>
</tr>
<tr>
<td><strong>2 digital output max 1250Hz (opt. at 12.5kHz); 1 digital input</strong></td>
<td><strong>1 current output (with external power supply only ML 145)</strong></td>
<td><strong>Others on request (see additional modules)</strong></td>
</tr>
<tr>
<td><strong>Others on request (see additional modules)</strong></td>
<td><strong>Bidirectional, Dual Range, Diagnostic, Empty Pipe, Batch</strong></td>
<td><strong>Bidirectional, Diagnostic, Energy Saving, Empty Pipe, Data Logger</strong></td>
</tr>
<tr>
<td><strong>90-265Vac / 45-60Hz</strong></td>
<td><strong>Lithium Battery (up to 6 batteries) + DC or solar panel (ML 145)</strong></td>
<td><strong>Lithium Battery (up to 6 batteries) + AC/DC or solar panel</strong></td>
</tr>
<tr>
<td><strong>± 0,2% of measured value</strong></td>
<td><strong>± 0,5% of measured value</strong>*</td>
<td><strong>± 0,4% of measured value</strong>*</td>
</tr>
<tr>
<td><strong>Better then 0.1%</strong></td>
<td><strong>Better then 0.4%</strong></td>
<td><strong>± 0,4%</strong></td>
</tr>
<tr>
<td><strong>-20…+60°C</strong></td>
<td><strong>-20…+60°C</strong></td>
<td><strong>-20…+60°C</strong></td>
</tr>
</tbody>
</table>

### MS 2410
- **"Sanitary" Sensor for Food/Pharmaceutical Applications**
- **Stainless Steel AISI304**
- **Stainless Steel AISI316 (on request)**
- **DN 3 ÷ 100**
- **PN 16 / PN 25 on request**
- **-20 ÷ 100 °C (compact) 130 °C with ML4F1**
- **-20 ÷ 150 °C (remote)**
- **Sanitary DIN11851, Tri-clamp, Tri-clover, SMS etc...**
- **PTFE**
- **Stainless Steel AISI316L; Hastelloy C, Platinum, Tantalum, Titanium, etc...**

### MS 2500
- **"Flanged" Sensor**
- **Carbon Steel**
- **Stainless Steel AISI304/316 (on request)**
- **DN 25 ÷ 2400**
- **PN 16, others on request**
- **-20 ÷ 100 °C (compact) 130 °C**
- **-20 ÷ 150 °C (remote)**
- **Sanitary DIN11851, Tri-clamp, Tri-clover, SMS etc...**
- **PTFE**
- **Stainless Steel AISI316L; Hastelloy C, Platinum, Tantalum, Titanium, etc...**

### MS 3770 - MS 3810
- **"Insertion" Sensor with or without Isolation Ball Valve**
- **Probe in Stainless Steel AISI304; 316 on request**
- **Probe in Stainless Steel AISI316 (MS 3810)**
- **DN80 ÷ DN8000**
- **PN 16 others on request (MS 3770 - PN 25 (MS 3810))**
- **-20 ÷ 100 °C (compact)**
- **-20 ÷ 130 °C (remote) only for MS 3770**
- **Sanitary DIN11851, Tri-clamp, Tri-clover, SMS etc...**
- **PTFE**
- **Stainless Steel AISI316L; Hastelloy C, Platinum, Tantalum, Titanium, etc...**

### Additional Modules
- **Graphic Converter**
- **Energy Meter (ML 211)**
- **Battery Powered Converter**
- **Aluminium Die Casting**
- **Stainless Steel on request**
- **Graphic display 128x64 pixels, 8 lines x 16 characters**
- **IP 67**
- **Lithium Battery (up to 6 batteries) + DC or solar panel (ML 145)**
- **-20…+60°C**

### Technical Specifications
- **Accuracy**: ± 2% of measured value*
- **Temperature Range**: -20 ÷ 100 °C (compact) 130 °C
- **Pressure**: up to 250 bar
- **Power Supply**: 90-265Vac / 45-60Hz
- **Protection Class**: IP 67
- **Input**: 1 current output (+ 1 opt.)
- **Output**: 2 digital output + 1 digital input (opt.)

*Higher accuracies, also at low flow rates, can be reached with special calibrations.
## Additional I/O Modules for Converters

<table>
<thead>
<tr>
<th>Modules</th>
<th>ML 51</th>
<th>ML 110</th>
<th>ML 210</th>
<th>ML 211</th>
<th>ML 145</th>
<th>ML 800*</th>
<th>ML 255</th>
<th>ML 252*</th>
<th>ML 4F1*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 additional outputs (n.1 at 12.5 KHz)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Serial Interface RS 485</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Serial interface RS 232</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Modbus</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>GPRS module</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<td>●</td>
</tr>
<tr>
<td>Profibus DP</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>HART</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>1 0/4–20 mA output + n.2 On/Off prog. Outputs + n. 1 ON/OFF input</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>1 RS232 serial interface + n.1 0/4–20 mA + n.2 On/Off prog. outputs</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2 relay outputs (each with 1 NO/NC contact, 2A – 250 Vac, 60W 125V)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2 PT100 input + 1 additional 0/4–20 mA output + n.1 ON/OFF input + 1 ON/OFF output (programmable function)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>4-20 mA output</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2 pressure or level inputs</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>1 pressure or level input + 1 CPM input</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

* Blind version only.

### NOMINAL FLOWS

<table>
<thead>
<tr>
<th>DN</th>
<th>Min full scale (v=0.4\ m/s)</th>
<th>Max full scale (v=10\ m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0 10 l/h</td>
<td>0 250 l/h</td>
</tr>
<tr>
<td>6</td>
<td>0 40 l/h</td>
<td>0 1000 l/h</td>
</tr>
<tr>
<td>10</td>
<td>0 120 l/h</td>
<td>0 2800 l/h</td>
</tr>
<tr>
<td>15</td>
<td>0 240 l/h</td>
<td>0 6000 l/h</td>
</tr>
<tr>
<td>20</td>
<td>0 300 l/h</td>
<td>0 11500 l/h</td>
</tr>
<tr>
<td>25</td>
<td>0 0,72 m³/h</td>
<td>0 18 m³/h</td>
</tr>
<tr>
<td>30</td>
<td>1,16 m³/h</td>
<td>0 29 m³/h</td>
</tr>
<tr>
<td>35</td>
<td>1,80 m³/h</td>
<td>0 45 m³/h</td>
</tr>
<tr>
<td>40</td>
<td>2,68 m³/h</td>
<td>0 72 m³/h</td>
</tr>
<tr>
<td>45</td>
<td>4,30 m³/h</td>
<td>0 120 m³/h</td>
</tr>
<tr>
<td>50</td>
<td>7,20 m³/h</td>
<td>0 180 m³/h</td>
</tr>
<tr>
<td>55</td>
<td>11,20 m³/h</td>
<td>0 280 m³/h</td>
</tr>
<tr>
<td>60</td>
<td>18,00 m³/h</td>
<td>0 450 m³/h</td>
</tr>
<tr>
<td>65</td>
<td>25,60 m³/h</td>
<td>0 660 m³/h</td>
</tr>
<tr>
<td>70</td>
<td>45,20 m³/h</td>
<td>0 1130 m³/h</td>
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<tr>
<td>75</td>
<td>70,80 m³/h</td>
<td>0 1770 m³/h</td>
</tr>
<tr>
<td>80</td>
<td>100,80 m³/h</td>
<td>0 2520 m³/h</td>
</tr>
<tr>
<td>85</td>
<td>138,00 m³/h</td>
<td>0 3450 m³/h</td>
</tr>
<tr>
<td>90</td>
<td>180,00 m³/h</td>
<td>0 4500 m³/h</td>
</tr>
<tr>
<td>95</td>
<td>228,80 m³/h</td>
<td>0 6720 m³/h</td>
</tr>
<tr>
<td>100</td>
<td>284,00 m³/h</td>
<td>0 7100 m³/h</td>
</tr>
<tr>
<td>105</td>
<td>349,80 m³/h</td>
<td>0 10000 m³/h</td>
</tr>
<tr>
<td>110</td>
<td>560,00 m³/h</td>
<td>0 14000 m³/h</td>
</tr>
<tr>
<td>115</td>
<td>720,00 m³/h</td>
<td>0 18000 m³/h</td>
</tr>
<tr>
<td>120</td>
<td>920,00 m³/h</td>
<td>0 23000 m³/h</td>
</tr>
<tr>
<td>125</td>
<td>1140,00 m³/h</td>
<td>0 28500 m³/h</td>
</tr>
<tr>
<td>130</td>
<td>1600,00 m³/h</td>
<td>0 40000 m³/h</td>
</tr>
<tr>
<td>135</td>
<td>2200,00 m³/h</td>
<td>0 55000 m³/h</td>
</tr>
<tr>
<td>140</td>
<td>2800,00 m³/h</td>
<td>0 72000 m³/h</td>
</tr>
<tr>
<td>145</td>
<td>3640,00 m³/h</td>
<td>0 91000 m³/h</td>
</tr>
<tr>
<td>150</td>
<td>4520,00 m³/h</td>
<td>0 113000 m³/h</td>
</tr>
<tr>
<td>155</td>
<td>5600,00 m³/h</td>
<td>0 140000 m³/h</td>
</tr>
</tbody>
</table>

**Procedure**

Determine the d/D ratio, velocity range, and calculate the pressure loss on the monogram.
COMPACT SOLUTIONS: CONVERTER + SENSOR

<table>
<thead>
<tr>
<th>Model Type</th>
<th>MS 3900</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Ultracompact flowmeter</td>
</tr>
<tr>
<td><strong>Body Material</strong></td>
<td>PTFE coated zinced Steel</td>
</tr>
<tr>
<td><strong>DN</strong></td>
<td>10/15/20/32/40/50 mm</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>1600 KPa</td>
</tr>
<tr>
<td><strong>Medium temperature</strong></td>
<td>–10 °C to 100 °C</td>
</tr>
<tr>
<td><strong>Ambient temperature</strong></td>
<td>–10 °C to 60 °C</td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td>Thread male UNI 338/NPT</td>
</tr>
<tr>
<td><strong>Liner</strong></td>
<td>PTFE</td>
</tr>
<tr>
<td><strong>Electrodes</strong></td>
<td>Stainless Steel AISI316L</td>
</tr>
<tr>
<td><strong>Protection Rate</strong></td>
<td>IP67</td>
</tr>
<tr>
<td><strong>Display</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Output/Inputs:</strong></td>
<td>N. 2 outputs for Volume/alarms; N. 1 freely programmed as input or output N. 1 current output</td>
</tr>
<tr>
<td><strong>Temperature measurement</strong></td>
<td>–10 °C to 100 °C, accuracy ±2 °C</td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>18-30 VDC</td>
</tr>
<tr>
<td><strong>Accuracy class</strong></td>
<td>±1,5% of measured value</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Type</th>
<th>MS 3790</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Ultracompact insertion Flowmeter</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>AISI 304 full construction</td>
</tr>
<tr>
<td><strong>DN</strong></td>
<td>up to DN 65</td>
</tr>
<tr>
<td><strong>Medium temperature</strong></td>
<td>0 °C to 100 °C</td>
</tr>
<tr>
<td><strong>Ambient temperature</strong></td>
<td>–10 °C to 60 °C</td>
</tr>
<tr>
<td><strong>Protection rate</strong></td>
<td>IP67</td>
</tr>
<tr>
<td><strong>Display</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Output/Inputs:</strong></td>
<td>N. 1 channel freely programmable as INPUT or OUTPUT for volume pulses/alarms</td>
</tr>
<tr>
<td><strong>Special features</strong></td>
<td>1 additional digital output; 4-20 mA</td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>18-30 VDC</td>
</tr>
<tr>
<td><strong>Accuracy class</strong></td>
<td>±2% of measured value</td>
</tr>
</tbody>
</table>

ML 155 DATA LOGGER

ML 155 is a battery operated powerful universal data logger with integrated GPRS.
The instrument is designed to be integrated to, or to retrofit, meters which do not have a GPRS transmission.

The instrument can log up to 3 external signals in different combinations and also drive 2 pressure/level sensors or CPM (Corrosion Protection Module).
**ACCESSORIES**

**ISOCAL** – Completely automatized flow meter advanced check up, measures the electrical conditions of the sensor and compares the results with the reference stored. Full verification of all converter I/O. Emission of report with reference and actual data.

**IF2 CABLE** – Cable to connect all ISOMAG meters to a laptop, including ISOCON software.

**CPM** – Corrosion Protection Module additional measuring module able to continuously monitor the electrical potential of the line, giving to user real time information on cathodic protection efficiency. For ML 255 and ML 155.

**ISOCHECK** – Flow simulator is a simple device to be connected to ML 110 or ML 210 converters, making a verification of the electrical and measurement characteristics of the converter.

**BIV** – Built in verificator, on request for ML 255, consists in a software that automatically and periodically makes a check of the vital electrical characteristics of the sensor, sending an alarm in case of result outside specification and generating a printable report.

**ISOCON** – User friendly interface software for an easy access to all meters programmable functions.

**PREAMPLIFIER** – Useful tool to be mounted on top of the meter when converter must be placed far from a sensor. Maximum distance 500 meters (1640 ft.). It works with ML 210 only.

**SEPARATION KIT** – Several kits for the transformation of the instruments from compact to separate and vice versa.

**APL** – Solar panel with external accumulator and electronic for power management, suitable for battery converters.

**IN SITU VERIFICATION**
## THE RIGHT FLOWMETER FOR YOUR APPLICATION

**Converter Model**

<table>
<thead>
<tr>
<th>Water &amp; Wastewater</th>
<th>ML 51</th>
<th>ML 110</th>
<th>ML 210</th>
<th>ML 211</th>
<th>ML 145</th>
<th>ML 235</th>
<th>ML 232</th>
<th>ML 4F1</th>
<th>ML 800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water distribution</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Water treatment</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Sludge/Sewage</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>NRW/DMAs</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Irrigation</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>General Industry</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Chemical</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pulp &amp; Paper</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Food &amp; Beverages</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Dosing/Batching</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Filling machines</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>HVAC</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

**Sensors**

<table>
<thead>
<tr>
<th>MS 501</th>
<th>MS 600</th>
<th>MS 1000</th>
<th>MS 2410</th>
<th>MS 2500</th>
<th>MS 3770</th>
<th>MS 3790</th>
<th>MS 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

Note: the above are the suggested combinations. For any particular application please contact your local distributor.
Isoil flow meters are tested on ISO 17025 certified benches when leaving the factory, the original accuracy can be granted for years when the meter is working within its specifications.

Thanks to the Accredited Calibration Laboratory named Libra, conforming to UNI EN ISO/IEC 17025 standard (ACCREDIA CERTIFICATE LAT 237), Isoil can offer Calibration service for liquid flow meters for any type of flow meters in volume and volumetric flow. Currently on the 7 testing lines benches can be calibrated sensors up to DN800, the eighth line for bigger diameters is under construction.

**FLOW METERS FOR HEAT CALCULATION**

MS 2500 sensors coupled to ML 210 or to ML 110 or ML 255 converters are suitable for custody transfer. Lining materials used on Isomag® sensors are suitable for drinking water and conform to NSF and/or WRAS.

<table>
<thead>
<tr>
<th>SENSOR SIZE</th>
<th>mm</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>100</th>
<th>125</th>
<th>150</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3</td>
<td>m³/h</td>
<td>16,00</td>
<td>25,00</td>
<td>40,00</td>
<td>63,00</td>
<td>100,00</td>
<td>160,00</td>
<td>250,00</td>
<td>400,00</td>
<td>630,00</td>
<td>1000,00</td>
<td>1600,00</td>
</tr>
<tr>
<td>Q1, R=100</td>
<td>m³/h</td>
<td>0,16</td>
<td>0,25</td>
<td>0,40</td>
<td>0,63</td>
<td>1,00</td>
<td>1,60</td>
<td>2,50</td>
<td>4,00</td>
<td>6,30</td>
<td>10,00</td>
<td>16,00</td>
</tr>
<tr>
<td>Q1, R=400</td>
<td>m³/h</td>
<td>0,04</td>
<td>0,06</td>
<td>0,10</td>
<td>0,16</td>
<td>0,25</td>
<td>0,40</td>
<td>0,63</td>
<td>1,00</td>
<td>1,58</td>
<td>2,50</td>
<td>4,00</td>
</tr>
</tbody>
</table>

Q2/Q1 = 1,6

Q4/Q3 = 1,25

**TEST BENCH AND ISO17025 CALIBRATION LABORATORY**

Isoil flow meters are tested on ISO 17025 certified benches when leaving the factory, the original accuracy can be granted for years when the meter is working within its specifications.

Thanks to the Accredited Calibration Laboratory named Libra, conforming to UNI EN ISO/IEC 17025 standard (ACCREDIA CERTIFICATE LAT 237), Isoil can offer Calibration service for liquid flow meters for any type of flow meters in volume and volumetric flow. Currently on the 7 testing lines benches can be calibrated sensors up to DN800, the eighth line for bigger diameters is under construction.
Appendix 5. Datasheets

E.3 Siemens S7-1200 CPU 1212c
# SIMATIC S7-1200, CPU 1212C, COMPACT CPU, AC/DC/RLY, ONBOARD I/O: 8 DI 24V DC; 6 DO RELAY 2A; 2 AI 0 - 10V DC, POWER SUPPLY: AC 85 - 264 V AC AT 47 - 63 HZ, PROGRAM/DATA MEMORY: 50 KB

## Display
- **with display**: No

## Supply voltage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated value (AC)</td>
<td>Yes</td>
</tr>
<tr>
<td>- 120 V AC</td>
<td>Yes</td>
</tr>
<tr>
<td>- 230 V AC</td>
<td></td>
</tr>
<tr>
<td>Permissible range, lower limit (AC)</td>
<td>85 V</td>
</tr>
<tr>
<td>Permissible range, upper limit (AC)</td>
<td>264 V</td>
</tr>
</tbody>
</table>

## Line frequency
- Permissible frequency range, lower limit: 47 Hz
- Permissible frequency range, upper limit: 63 Hz

## Input current

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current consumption (rated value)</td>
<td>80 mA at 120 V AC; 40 mA at 240 V AC</td>
</tr>
<tr>
<td>Inrush current, max.</td>
<td>20 A; at 264 V</td>
</tr>
</tbody>
</table>

## Encoder supply

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 V encoder supply</td>
<td>Permissible range: 20.4V to 28.8V</td>
</tr>
</tbody>
</table>

## Output current

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current output to backplane bus (DC 5 V), max.</td>
<td>1 000 mA; Max. 5 V DC for SM and CM</td>
</tr>
</tbody>
</table>

## Power losses

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power loss, typ.</td>
<td>11 W</td>
</tr>
</tbody>
</table>

## Memory

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of memory</td>
<td>EEPROM</td>
</tr>
<tr>
<td>Feature</td>
<td>Specification</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Usable memory for user data</td>
<td>75 kbyte</td>
</tr>
<tr>
<td>Work memory</td>
<td></td>
</tr>
<tr>
<td>● Integrated</td>
<td>50 kbyte</td>
</tr>
<tr>
<td>● expandable</td>
<td>No</td>
</tr>
<tr>
<td>Load memory</td>
<td></td>
</tr>
<tr>
<td>● Integrated</td>
<td>1 Mbyte</td>
</tr>
<tr>
<td>● Plug-in (SIMATIC Memory Card), max.</td>
<td>2 Gbyte; with SIMATIC memory card</td>
</tr>
<tr>
<td>Backup</td>
<td></td>
</tr>
<tr>
<td>● present</td>
<td>Yes; maintenance-free</td>
</tr>
<tr>
<td>● without battery</td>
<td>Yes</td>
</tr>
<tr>
<td>CPU processing times</td>
<td></td>
</tr>
<tr>
<td>for bit operations, typ.</td>
<td>0.085 µs; / Operation</td>
</tr>
<tr>
<td>for word operations, typ.</td>
<td>1.7 µs; / Operation</td>
</tr>
<tr>
<td>for floating point arithmetic, typ.</td>
<td>2.3 µs; / Operation</td>
</tr>
<tr>
<td>CPU-blocks</td>
<td></td>
</tr>
<tr>
<td>Number of blocks (total)</td>
<td>DBs, FCs, FBs, counters and timers. The maximum number of addressable blocks ranges from 1 to 65535. There is no restriction, the entire working memory can be used</td>
</tr>
<tr>
<td>OB</td>
<td>Limited only by RAM for code</td>
</tr>
<tr>
<td>Data areas and their retentivity</td>
<td></td>
</tr>
<tr>
<td>retentive data area in total (incl. times, counters, flags), max.</td>
<td>10 kbyte</td>
</tr>
<tr>
<td>Flag</td>
<td></td>
</tr>
<tr>
<td>● Number, max.</td>
<td>4 kbyte; Size of bit memory address area</td>
</tr>
<tr>
<td>Address area</td>
<td></td>
</tr>
<tr>
<td>I/O address area</td>
<td></td>
</tr>
<tr>
<td>● Inputs</td>
<td>1 024 byte</td>
</tr>
<tr>
<td>● Outputs</td>
<td>1 024 byte</td>
</tr>
<tr>
<td>Process image</td>
<td></td>
</tr>
<tr>
<td>● Inputs, adjustable</td>
<td>1 kbyte</td>
</tr>
<tr>
<td>● Outputs, adjustable</td>
<td>1 kbyte</td>
</tr>
<tr>
<td>Hardware configuration</td>
<td></td>
</tr>
<tr>
<td>Number of modules per system, max.</td>
<td>3 comm. modules, 1 signal board, 2 signal modules</td>
</tr>
<tr>
<td>Time of day</td>
<td></td>
</tr>
<tr>
<td>Clock</td>
<td></td>
</tr>
<tr>
<td>● Hardware clock (real-time clock)</td>
<td>Yes</td>
</tr>
<tr>
<td>● Deviation per day, max.</td>
<td>+/- 60 s/month at 25 °C</td>
</tr>
<tr>
<td>● Backup time</td>
<td>480 h; Typical</td>
</tr>
<tr>
<td>Digital inputs</td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>Specification</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td>Number of digital inputs</td>
<td>8; Integrated</td>
</tr>
<tr>
<td>of which, inputs usable for technological</td>
<td>6; HSC (High Speed Counting)</td>
</tr>
<tr>
<td>functions</td>
<td></td>
</tr>
<tr>
<td>integrated channels (DI)</td>
<td>8</td>
</tr>
<tr>
<td>m/p-reading</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of simultaneously controllable inputs</td>
<td></td>
</tr>
<tr>
<td>all mounting positions</td>
<td></td>
</tr>
<tr>
<td>— up to 40 °C, max.</td>
<td>8</td>
</tr>
<tr>
<td>Input voltage</td>
<td></td>
</tr>
<tr>
<td>• Rated value (DC)</td>
<td>24 V</td>
</tr>
<tr>
<td>• for signal &quot;0&quot;</td>
<td>5 V DC at 1 mA</td>
</tr>
<tr>
<td>• for signal &quot;1&quot;</td>
<td>15 VDC at 2.5 mA</td>
</tr>
<tr>
<td>Input current</td>
<td></td>
</tr>
<tr>
<td>• for signal &quot;1&quot;, typ.</td>
<td>1 mA</td>
</tr>
<tr>
<td>Input delay (for rated value of input voltage)</td>
<td></td>
</tr>
<tr>
<td>for standard inputs</td>
<td></td>
</tr>
<tr>
<td>— Parameterizable</td>
<td>0.1 / 0.2 / 0.4 / 0.8 / 1.6 / 3.2 / 6.4 / 10.0 / 12.8 / 20.0 μs; 0.05 / 0.1 / 0.2 / 0.4 / 0.8 / 1.6 / 3.2 / 6.4 / 10.0 / 12.8 / 20.0 ms</td>
</tr>
<tr>
<td>— at &quot;0&quot; to &quot;1&quot;, min.</td>
<td>0.1 μs</td>
</tr>
<tr>
<td>— at &quot;0&quot; to &quot;1&quot;, max.</td>
<td>20 ms</td>
</tr>
<tr>
<td>for interrupt inputs</td>
<td></td>
</tr>
<tr>
<td>— Parameterizable</td>
<td>Yes</td>
</tr>
<tr>
<td>for counter/technological functions</td>
<td></td>
</tr>
<tr>
<td>— Parameterizable</td>
<td>Yes; Single phase: 3 at 100 kHz &amp; 3 at 30 kHz, differential: 3 at 80 kHz &amp; 3 at 30 kHz</td>
</tr>
<tr>
<td>Cable length</td>
<td></td>
</tr>
<tr>
<td>• Cable length, shielded, max.</td>
<td>500 m; 50 m for technological functions</td>
</tr>
<tr>
<td>• Cable length unshielded, max.</td>
<td>300 m; For technological functions: No</td>
</tr>
<tr>
<td>Digital outputs</td>
<td></td>
</tr>
<tr>
<td>Number of digital outputs</td>
<td>6; Relays</td>
</tr>
<tr>
<td>integrated channels (DO)</td>
<td>6</td>
</tr>
<tr>
<td>short-circuit protection</td>
<td>No; to be provided externally</td>
</tr>
<tr>
<td>Switching capacity of the outputs</td>
<td></td>
</tr>
<tr>
<td>• with resistive load, max.</td>
<td>2 A</td>
</tr>
<tr>
<td>• on lamp load, max.</td>
<td>30 W with DC, 200 W with AC</td>
</tr>
<tr>
<td>Output delay with resistive load</td>
<td></td>
</tr>
<tr>
<td>• &quot;0&quot; to &quot;1&quot;, max.</td>
<td>10 ms; max.</td>
</tr>
<tr>
<td>• &quot;1&quot; to &quot;0&quot;, max.</td>
<td>10 ms; max.</td>
</tr>
<tr>
<td>Switching frequency</td>
<td></td>
</tr>
<tr>
<td>• of the pulse outputs, with resistive load,</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Pixel outputs</td>
<td></td>
</tr>
<tr>
<td>• Max. number of relay outputs, integrated</td>
<td>6</td>
</tr>
</tbody>
</table>
### Number of relay outputs
- 6
- Number of operating cycles, max. mechanically 10 million, at rated load voltage 100,000

### Cable length
- Cable length, shielded, max. 500 m
- Cable length unshielded, max. 150 m

### Analog inputs
- Number of analog inputs 2
- Integrated channels (AI) 2; 0 to 10 V
- Input ranges
  - Voltage Yes
- Input ranges (rated values), voltages
  - 0 to +10 V Yes
  - Input resistance (0 to 10 V) \( \geq 100 \text{k ohms} \)
- Cable length
  - Cable length, shielded, max. 100 m; twisted and shielded

### Analog outputs
- Number of analog outputs 0

### Analog value creation
- Integration and conversion time/resolution per channel
  - Resolution with overrange (bit including sign), max. 10 bit
  - Integration time, parameterizable Yes
  - Conversion time (per channel) 625 \( \mu \text{s} \)

### Encoder
- Connectable encoders
  - 2-wire sensor Yes

### 1. Interface
- Interface type PROFINET
- Physics Ethernet
- Isolated Yes
- Automatic detection of transmission speed Yes
- Autonegotiation Yes
- Autocrossing Yes

### Functionality
- PROFINET IO Device Yes
- PROFINET IO Controller Yes

### Communication functions
- Prioritized startup supported
  - Number of IO Devices, max. 16
### S7 communication
- supported: Yes
- as server: Yes
- As client: Yes

### Open IE communication
- TCP/IP: Yes
- ISO-on-TCP (RFC1006): Yes
- UDP: Yes

### Web server
- supported: Yes
- User-defined websites: Yes

### Test commissioning functions
#### Status/control
- Status/control variable: Yes
- Variables: Inputs/outputs, memory bits, DBs, distributed I/Os, timers, counters

#### Forcing
- Forcing: Yes

#### Diagnostic buffer
- present: Yes

#### Traces
- Number of configurable Traces: 2; Up to 512 KB of data per trace are possible

### Integrated Functions
- Number of counters: 4
- Counter frequency (counter) max.: 100 kHz
- Frequency meter: Yes
- controlled positioning: Yes
- PiD controller: Yes
- Number of alarm inputs: 4
- Number of pulse outputs: 4

### Galvanic isolation
#### Galvanic isolation digital inputs
- 500V AC for 1 minute
- between the channels, in groups of: 1

#### Galvanic isolation digital outputs
- Relays
- No
- between the channels, in groups of: 1

### Permissible potential difference
between different circuits: 500 V DC between 24 V DC and 5 V DC
## EMC

### Interference immunity against discharge of static electricity

- Interference immunity against discharge of static electricity acc. to IEC 61000-4-2
  - Test voltage at air discharge: 8 kV
  - Test voltage at contact discharge: 6 kV

### Interference immunity to cable-borne interference

- Interference immunity on supply lines acc. to IEC 61000-4-4: Yes
- Interference immunity on signal lines acc. to IEC 61000-4-4: Yes

### Surge immunity

- On the supply lines acc. to IEC 61000-4-5: Yes

### Immunity against conducted interference induced by high-frequency fields

- Interference immunity against high-frequency radiation acc. to IEC 61000-4-6: Yes

### Emission of radio interference acc. to EN 55 011

- Limit class A, for use in industrial areas: Yes; Group 1
- Limit class B, for use in residential areas: Yes; When appropriate measures are used to ensure compliance with the limits for Class B according to EN 55011

### Degree and class of protection

- Degree of protection to EN 60529
  - IP20: Yes

### Standards, approvals, certificates

- CE mark: Yes
- UL approval: Yes
- cULus: Yes
- RCM (formerly C-TICK): Yes
- FM approval: Yes
- Marine approval: Yes

### Ambient conditions

#### Free fall

- Drop height, max. (in packaging): 0.3 m; five times, in dispatch package

#### Ambient temperature in operation

- During operating phase, minimum: -20 °C; maximum: 60 °C
- Horizontal installation, minimum: -20 °C; maximum: 60 °C
- Vertical installation, minimum: -20 °C; maximum: 50 °C

#### Storage/transport temperature
### Min. -40 °C

### max. 70 °C

<table>
<thead>
<tr>
<th><strong>Air pressure</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation, min.</td>
<td>795 hPa</td>
</tr>
<tr>
<td>Operation, max.</td>
<td>1 080 hPa</td>
</tr>
<tr>
<td>Storage/transport, min.</td>
<td>660 hPa</td>
</tr>
<tr>
<td>Storage/transport, max.</td>
<td>1 080 hPa</td>
</tr>
<tr>
<td>Permissible operating height</td>
<td>-1000 to 2000 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Relative humidity</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation, max.</td>
<td>95 %; no condensation</td>
</tr>
<tr>
<td>Permissible range (without condensation) at 25 °C</td>
<td>95 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Vibrations</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibrations</td>
<td>2G wall mounting, 1G DIN rail</td>
</tr>
<tr>
<td>Operation, checked according to IEC 60068-2-6</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Shock test</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>checked according to IEC 60068-2-27</td>
<td>Yes; IEC 68, Part 2-27 half-sine: strength of the shock 15 g (peak value), duration 11 ms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pollutant concentrations</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO2 at RH &lt; 60% without condensation</td>
<td>S02: &lt; 0.5 ppm; H2S: &lt; 0.1 ppm; RH &lt; 60% condensation-free</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Programming</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming language</td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td>Yes</td>
</tr>
<tr>
<td>FBD</td>
<td>Yes</td>
</tr>
<tr>
<td>SCL</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cycle time monitoring</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>can be set</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Dimensions</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>90 mm</td>
</tr>
<tr>
<td>Height</td>
<td>100 mm</td>
</tr>
<tr>
<td>Depth</td>
<td>75 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Weights</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, approx.</td>
<td>425 g</td>
</tr>
</tbody>
</table>

**last modified:** 05.02.2015
Appendix 5. Datasheets

E.4   Siemens S7-1200 SM 1234
## SIMATIC S7-1200, ANALOG I/O SM 1234, 4 AI / 2 AO, +/-10V, 14 BIT RESOLUTION OR 0(4) - 20 MA, 13 BIT RESOLUTION

### Supply voltage

<table>
<thead>
<tr>
<th>Rated value (DC)</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 V DC</td>
<td></td>
</tr>
</tbody>
</table>

### Input current

<table>
<thead>
<tr>
<th>Current consumption, typ.</th>
<th>60 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>from backplane bus 5 V DC, typ.</td>
<td>80 mA</td>
</tr>
</tbody>
</table>

### Power loss

<table>
<thead>
<tr>
<th>Power loss, typ.</th>
<th>2 W</th>
</tr>
</thead>
</table>

### Analog inputs

<table>
<thead>
<tr>
<th>Number of analog inputs</th>
<th>4; Current or voltage differential inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>permissible input voltage for current input (destruction limit), max.</td>
<td>± 35 V</td>
</tr>
<tr>
<td>permissible input voltage for voltage input (destruction limit), max.</td>
<td>35 V</td>
</tr>
<tr>
<td>permissible input current for voltage input (destruction limit), max.</td>
<td>40 mA</td>
</tr>
<tr>
<td>permissible input current for current input (destruction limit), max.</td>
<td>40 mA</td>
</tr>
<tr>
<td>Cycle time (all channels) max.</td>
<td>625 µs</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td><strong>Input ranges</strong></td>
<td></td>
</tr>
<tr>
<td>● Voltage</td>
<td>Yes; ±10V, ±5V, ±2.5V</td>
</tr>
<tr>
<td>● Current</td>
<td>Yes; 4 to 20 mA, 0 to 20 mA</td>
</tr>
<tr>
<td><strong>Input ranges (rated values), voltages</strong></td>
<td></td>
</tr>
<tr>
<td>● -10 V to +10 V</td>
<td>Yes</td>
</tr>
<tr>
<td>● Input resistance (-10 V to +10 V)</td>
<td>≥9 MOhm</td>
</tr>
<tr>
<td>● -2.5 V to +2.5 V</td>
<td>Yes</td>
</tr>
<tr>
<td>● Input resistance (-2.5 V to +2.5 V)</td>
<td>≥9 MOhm</td>
</tr>
<tr>
<td>● -5 V to +5 V</td>
<td>Yes</td>
</tr>
<tr>
<td>● Input resistance (-5 V to +5 V)</td>
<td>≥9 MOhm</td>
</tr>
<tr>
<td><strong>Input ranges (rated values), currents</strong></td>
<td></td>
</tr>
<tr>
<td>● 0 to 20 mA</td>
<td>Yes</td>
</tr>
<tr>
<td>● Input resistance (0 to 20 mA)</td>
<td>280 Ω</td>
</tr>
<tr>
<td>● 4 mA to 20 mA</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Analog outputs</strong></td>
<td></td>
</tr>
<tr>
<td>Number of analog outputs</td>
<td>2; Current or voltage</td>
</tr>
<tr>
<td>Output ranges, voltage</td>
<td></td>
</tr>
<tr>
<td>● -10 V to +10 V</td>
<td>Yes</td>
</tr>
<tr>
<td>Output ranges, current</td>
<td></td>
</tr>
<tr>
<td>● 0 to 20 mA</td>
<td>Yes</td>
</tr>
<tr>
<td>● 4 mA to 20 mA</td>
<td>Yes</td>
</tr>
<tr>
<td>Load impedance (in rated range of output)</td>
<td></td>
</tr>
<tr>
<td>● with voltage outputs, min.</td>
<td>1 000 Ω</td>
</tr>
<tr>
<td>● with current outputs, max.</td>
<td>600 Ω</td>
</tr>
<tr>
<td><strong>Analog value generation for the inputs</strong></td>
<td></td>
</tr>
<tr>
<td>Measurement principle</td>
<td>Differential</td>
</tr>
<tr>
<td>Integration and conversion time/resolution per channel</td>
<td></td>
</tr>
<tr>
<td>● Resolution with overrange (bit including sign), max.</td>
<td>12 bit; + sign</td>
</tr>
<tr>
<td>● Integration time, parameterizable</td>
<td>Yes</td>
</tr>
<tr>
<td>● Interference voltage suppression for interference frequency f1 in Hz</td>
<td>40 dB, DC to 60 V for interference frequency 50 / 60 Hz</td>
</tr>
<tr>
<td><strong>Smoothing of measured values</strong></td>
<td></td>
</tr>
<tr>
<td>● parameterizable</td>
<td>Yes</td>
</tr>
<tr>
<td>● Step: None</td>
<td>Yes</td>
</tr>
<tr>
<td>● Step: low</td>
<td>Yes</td>
</tr>
<tr>
<td>● Step: Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>● Step: High</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Analog value generation for the outputs</strong></td>
<td></td>
</tr>
<tr>
<td>Integration and conversion time/resolution per channel</td>
<td></td>
</tr>
</tbody>
</table>
## Resolution (incl. overrange)

| Voltage: 14 bits; Current: 13 bits |

### Errors/accuracies

| Temperature error (relative to input range), (+/-) | 25 °C ±0.1%, to 55 °C ±0.2% total measurement range |
| Temperature error (relative to output range), (+/-) | 25 °C ±0.3%, to 55 °C ±0.6% total measurement range |

#### Basic error limit (operational limit at 25 °C)

| • Voltage, relative to input range, (+/-) | 0.1 % |
| • Current, relative to input range, (+/-) | 0.1 % |
| • Voltage, relative to output range, (+/-) | 0.3 % |
| • Current, relative to output range, (+/-) | 0.3 % |

#### Interference voltage suppression for f = n x (f1 +/- 1 %), f1 = interference frequency

| • Common mode voltage, max. | 12 V |

### Interrupts/diagnostics/status information

| Alarms | Yes |
| Diagnostic functions | Yes |

#### Alarms

| • Diagnostic alarm | Yes |

#### Diagnostic messages

| • Monitoring the supply voltage | Yes |
| • Wire-break | Yes |
| • Short-circuit | Yes |

#### Diagnostics indication LED

| • for status of the inputs | Yes |
| • for status of the outputs | Yes |
| • for maintenance | Yes |

### Potential separation

| Potential separation analog outputs | No |

### Degree and class of protection

| Degree of protection acc. to EN 60529 | IP20 |

### Standards, approvals, certificates

| CE mark | Yes |
| CSA approval | Yes |
| FM approval | Yes |
| RCM (formerly C-TICK) | Yes |
| Marine approval | Yes |

### Ambient conditions

| Free fall |
| 0.3 m; five times, in product package |
### Ambient temperature during operation
- **min.** -20 °C
- **max.** 60 °C
- Horizontal installation, min. -20 °C
- Horizontal installation, max. 60 °C
- Vertical installation, min. -20 °C
- Vertical installation, max. 50 °C

### Ambient temperature during storage/transportation
- **min.** -40 °C
- **max.** 70 °C

### Air pressure acc. to IEC 60068-2-13
- **Operation, min.** 795 hPa
- **Operation, max.** 1 080 hPa
- **Storage/transport, min.** 660 hPa
- **Storage/transport, max.** 1 080 hPa

### Relative humidity
- Operation at 25 °C without condensation, max. 95 %

### Extended ambient conditions
#### Pollutant concentrations
- SO2 at RH < 60% without condensation
  - SO2: < 0.5 ppm; H2S: < 0.1 ppm; RH < 60% condensation-free

### Connection method
- **required front connector** Yes

### Mechanics/material
#### Enclosure material (front)
- Plastic Yes

### Dimensions
- **Width** 45 mm
- **Height** 100 mm
- **Depth** 75 mm

### Weights
- **Weight, approx.** 220 g

---

*last modified:* 07/31/2017
Appendix 5. *Datasheets*

**E.5 Siemens S7-1200 SM 1231**

at
## Supply voltage

<table>
<thead>
<tr>
<th>Rated value (DC)</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 V DC</td>
<td></td>
</tr>
</tbody>
</table>

## Input current

<table>
<thead>
<tr>
<th>Current consumption, typ.</th>
<th>40 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>from backplane bus 5 V DC, typ.</td>
<td>80 mA</td>
</tr>
</tbody>
</table>

## Power losses

<table>
<thead>
<tr>
<th>Power loss, typ.</th>
<th>1.5 W</th>
</tr>
</thead>
</table>

## Analog inputs

<table>
<thead>
<tr>
<th>Number of analog inputs</th>
<th>4; Thermocouples</th>
</tr>
</thead>
<tbody>
<tr>
<td>permissible input frequency for current input (destruction limit), max.</td>
<td>± 35 V</td>
</tr>
<tr>
<td>Technical unit for temperature measurement adjustable</td>
<td>Degrees Celsius/degrees Fahrenheit</td>
</tr>
</tbody>
</table>

## Input ranges

| Thermocouple | Yes; J, K, T, E, R, S, N, C, TXK/XK(L); voltage range: +/-80 mV |
| Resistance thermometer | No |
| Resistance | No |

## Input ranges (rated values), voltages

| -80 mV to +80 mV | Yes |
| Input resistance (-80 mV to +80 mV) | >= 1 MOhm |

## Input ranges (rated values), thermoelements

| Type B | Yes |
| Type C | Yes |
### Type E Yes
### Type J Yes
### Type K Yes
### Type N Yes
### Type R Yes
### Type S Yes
### Type T Yes
### Type TXK/TXK(L) to GOST Yes

#### Thermocouple (TC)
- **Permissible input voltage for voltage input (destruction limit), max.** +35 V
- **Temperature compensation**
  - Parameterizable No

#### Analog outputs
- **Number of analog outputs** 0

#### Analog value creation
- **Measurement principle** integrating

#### Integration and conversion time/resolution per channel
- **Resolution with overrange (bit including sign), max.** 15 bit; + sign
- **Integration time, parameterizable** No
- **Interference voltage suppression for interference frequency f1 in Hz** 85 dB at 50 / 60 / 400 Hz

#### Analog value generation (in isochronous mode)
- **Smoothing of measured values**
  - Parameterizable Yes

#### Errors/accuracies
- **Temperature error (relative to input range), (+/-)**...
- **Repeat accuracy in steady state at 25 °C (relative to output area), (+/-)** 0.5 %
- **Interference voltage suppression for f = n x (f1 +/- 1 %), f1 = interference frequency**
  - Common mode interference, min. 120 dB

#### Interrupts/diagnostics/status information
- **Alarms**
  - Parameterizable Yes
  - Diagnostic alarm Yes
- **Diagnostic messages**
  - Diagnostic functions Yes; Can be read out
  - Monitoring the supply voltage Yes
  - Wire break Yes
- **Diagnostics indication LED**
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>for status of the inputs</td>
<td>Yes</td>
</tr>
<tr>
<td>for maintenance</td>
<td>Yes</td>
</tr>
<tr>
<td>Degree and class of protection</td>
<td></td>
</tr>
<tr>
<td>Degree of protection to EN 60529</td>
<td></td>
</tr>
<tr>
<td>● IP20</td>
<td>Yes</td>
</tr>
<tr>
<td>Standards, approvals, certificates</td>
<td></td>
</tr>
<tr>
<td>CE mark</td>
<td>Yes</td>
</tr>
<tr>
<td>CSA approval</td>
<td>Yes</td>
</tr>
<tr>
<td>FM approval</td>
<td>Yes</td>
</tr>
<tr>
<td>RCM (formerly C-TICK)</td>
<td>Yes</td>
</tr>
<tr>
<td>Highest safety class achievable in safety mode</td>
<td></td>
</tr>
<tr>
<td>● SIL acc. to IEC 61508</td>
<td>none</td>
</tr>
<tr>
<td>Ambient conditions</td>
<td></td>
</tr>
<tr>
<td>Free fall</td>
<td></td>
</tr>
<tr>
<td>● Drop height, max. (in packaging)</td>
<td>0.3 m; five times, in dispatch package</td>
</tr>
<tr>
<td>Ambient temperature in operation</td>
<td></td>
</tr>
<tr>
<td>● Permissible temperature range</td>
<td>-20 °C to +60 °C horizontal mounting, -20 °C to 50 °C vertical mounting, 95% humidity, non-condensing</td>
</tr>
<tr>
<td>● Min.</td>
<td>-20 °C</td>
</tr>
<tr>
<td>● max.</td>
<td>60 °C</td>
</tr>
<tr>
<td>Ambient temperature during storage/transportation</td>
<td></td>
</tr>
<tr>
<td>● Min.</td>
<td>-40 °C</td>
</tr>
<tr>
<td>● max.</td>
<td>70 °C</td>
</tr>
<tr>
<td>Air pressure acc. to IEC 60068-2-13</td>
<td></td>
</tr>
<tr>
<td>● Operation, min.</td>
<td>795 hPa</td>
</tr>
<tr>
<td>● Operation, max.</td>
<td>1 080 hPa</td>
</tr>
<tr>
<td>● Storage/transport, min.</td>
<td>660 hPa</td>
</tr>
<tr>
<td>● Storage/transport, max.</td>
<td>1 080 hPa</td>
</tr>
<tr>
<td>Relative humidity</td>
<td></td>
</tr>
<tr>
<td>● Permissible range (without condensation) at 25 °C</td>
<td>95 %</td>
</tr>
<tr>
<td>Pollutant concentrations</td>
<td></td>
</tr>
<tr>
<td>— SO2 at RH &lt; 60% without condensation</td>
<td>S02: &lt; 0.5 ppm; H2S: &lt; 0.1 ppm; RH &lt; 60% condensation-free</td>
</tr>
<tr>
<td>Connection method</td>
<td></td>
</tr>
<tr>
<td>required front connector</td>
<td>Yes</td>
</tr>
<tr>
<td>Mechanics/material</td>
<td></td>
</tr>
<tr>
<td>Type of housing (front)</td>
<td></td>
</tr>
<tr>
<td>● plastic</td>
<td>Yes</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>45 mm</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>Height</td>
<td>100 mm</td>
</tr>
<tr>
<td>Depth</td>
<td>75 mm</td>
</tr>
</tbody>
</table>

**Weights**

<table>
<thead>
<tr>
<th>Weight, approx.</th>
<th>180 g</th>
</tr>
</thead>
</table>

*last modified:* 20.04.2015
Appendix 5. Datasheets

E.6 Siemens S7-1200 CSM 1277
### Data sheet

**Product type designation**

**CSM 1277**

COMPACT SWITCH MODULE CSM 1277 CONNECTION SIMATIC S7-1200 AND UP TO 3 FURTHER IND. ETHERNET USERS WITH 10/100 MBIT/S UNMANAGED SWITCH, 4 RJ45 PORTS, EXT. 24V DC POWER SUPPLY, LED DIAGNOSTICS, S7-1200 MODULE INCL. ELECTRONIC MANUAL ON CD

<table>
<thead>
<tr>
<th>Transmission rate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer rate</td>
<td>10 Mbit/s, 100 Mbit/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interfaces</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrical/optical connections</td>
<td>4</td>
</tr>
<tr>
<td>● for network components or terminal equipment / maximum</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interfaces</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrical connections</td>
<td>4</td>
</tr>
<tr>
<td>● for network components or terminal equipment</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interfaces</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of electrical connection</td>
<td>RJ45 port</td>
</tr>
<tr>
<td>● for network components or terminal equipment</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Interfaces / for communication / integrated</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of 100 Mbit/s SC ports</td>
<td>0</td>
</tr>
<tr>
<td>● for multimode</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Interfaces / others</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrical connections</td>
<td>1</td>
</tr>
<tr>
<td>● for power supply</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interfaces / others</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of electrical connection</td>
<td>3-pole terminal block</td>
</tr>
<tr>
<td>● for power supply</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supply voltage, current consumption, power loss</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of voltage / of the supply voltage</td>
<td>DC</td>
</tr>
</tbody>
</table>

---

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### Supply voltage
- external 24 V
- external 19.2 ... 28.8 V

### Product component / fusing at power supply input
Yes

### Fuse protection type / at input for supply voltage
0.5 A / 60 V

### Active power loss
- for DC / at 24 V: 1.6 W

### Permitted ambient conditions
#### Ambient temperature
- during operation: 0 ... 60 °C
- during storage: -40 ... +70 °C
- during transport: -40 ... +70 °C

#### Relative humidity
- at 25 °C / without condensation / during operation / maximum: 95 %

#### Protection class IP
IP20

### Design, dimensions and weight
#### Design
SIMATIC S7-1200 device design

#### Width
45 mm

#### Height
100 mm

#### Depth
75 mm

#### Net weight
0.15 kg

#### Mounting type
- 35 mm DIN rail mounting: Yes
- wall mounting: Yes
- S7-300 rail mounting: No
- S7-1500 rail mounting: No

### Product functions / management, configuration
#### Product function
- multiport mirroring: No
- switch-managed: No

### Standards, specifications, approvals
#### Standard
- for FM: FM3611: Class 1, Division 2, Group A, B, C, D / T.., CL.1, Zone 2, GP. IIC, T.. Ta
- for safety / from CSA and UL: UL 508, CSA C22.2 No. 142
- for emitted interference: EN 61000-6-4 (Class A)
- for interference immunity: EN 61000-6-2
Certificate of suitability

<table>
<thead>
<tr>
<th>CE marking</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Tick</td>
<td>Yes</td>
</tr>
<tr>
<td>KC approval</td>
<td>No</td>
</tr>
</tbody>
</table>

Marine classification association

| American Bureau of Shipping Europe Ltd. (ABS) | No |
| Bureau Veritas (BV)                          | No |
| Det Norske Veritas (DNV)                     | No |
| Germanische Lloyd (GL)                       | No |
| Lloyds Register of Shipping (LRS)            | No |
| Nippon Kaiji Kyokai (NK)                      | No |
| Polski Rejestr Statkow (PRS)                 | No |

MTBF / at 40 °C 273 y

Further Information / Internet Links

<table>
<thead>
<tr>
<th>Internet-Link</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>to website: Selector SIMATIC NET SELECTION TOOL</td>
<td><a href="http://www.siemens.com/snet">http://www.siemens.com/snet</a></td>
</tr>
<tr>
<td>to website: Industrial communication</td>
<td><a href="http://www.siemens.com/simatic-net">http://www.siemens.com/simatic-net</a></td>
</tr>
<tr>
<td>to website: Industry Mall</td>
<td><a href="https://mail.industry.siemens.com">https://mail.industry.siemens.com</a></td>
</tr>
<tr>
<td>to website: Information and Download Center</td>
<td><a href="http://automation.siemens.com/bilddb">http://automation.siemens.com/bilddb</a></td>
</tr>
<tr>
<td>to website: Image database</td>
<td><a href="http://www.siemens.com/cax">http://www.siemens.com/cax</a></td>
</tr>
<tr>
<td>to website: CAX Download Manager</td>
<td><a href="https://support.industry.siemens.com">https://support.industry.siemens.com</a></td>
</tr>
<tr>
<td>to website: Industry Online Support</td>
<td></td>
</tr>
</tbody>
</table>

Security information

Siemens provides products and solutions with industrial security functions that support the secure operation of plants, solutions, machines, equipment and/or networks. They are important components in a holistic industrial security concept. With this in mind, Siemens’ products and solutions undergo continuous development. Siemens recommends strongly that you regularly check for product updates. For the secure operation of Siemens products and solutions, it is necessary to take suitable preventive action (e.g. cell protection concept) and integrate each component into a holistic, state-of-the-art industrial security concept. Third-party products that may be in use should also be considered. For more information about industrial security, visit http://www.siemens.com/industrialsecurity. To stay informed about product updates as they occur, sign up for a product-specific newsletter. For more information, visit http://support.automation.siemens.com. (V3.4)

last modified: 14.04.2015
Appendix 5. Datasheets

E.7 Siemens HMI KTP400 Basic
## General information

<table>
<thead>
<tr>
<th>Product type designation</th>
<th>SIMATIC HMI KTP400 Basic</th>
</tr>
</thead>
</table>

### Display

- **Design of display**: TFT widescreen display, LED backlighting
- **Screen diagonal**: 4.3 in
- **Display width**: 95 mm
- **Display height**: 53.9 mm
- **Number of colors**: 65,536

#### Resolution (pixels)

- **Horizontal image resolution**: 480 Pixel
- **Vertical image resolution**: 272 Pixel

#### Backlighting

- **MTBF backlighting (at 25 °C)**: 20,000 h
- **Backlight dimmable**: Yes

### Control elements

#### Keyboard fonts

- **Function keys**
  - **Number of function keys**: 4
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of function keys with LEDs</td>
<td>0</td>
</tr>
<tr>
<td>Keys with LED</td>
<td>No</td>
</tr>
<tr>
<td>System keys</td>
<td>No</td>
</tr>
<tr>
<td>Numeric keyboard</td>
<td>Yes; Onscreen keyboard</td>
</tr>
<tr>
<td>Alphanumeric keyboard</td>
<td>Yes; Onscreen keyboard</td>
</tr>
<tr>
<td>Touch operation</td>
<td>Yes</td>
</tr>
<tr>
<td>Design as touch screen</td>
<td></td>
</tr>
<tr>
<td>Installation type/mounting</td>
<td></td>
</tr>
<tr>
<td>Mounting position</td>
<td>Horizontal, vertical</td>
</tr>
<tr>
<td>Mounting in portrait format possible</td>
<td>Yes</td>
</tr>
<tr>
<td>Mounting in landscape format possible</td>
<td>Yes</td>
</tr>
<tr>
<td>Maximum permissible angle of inclination</td>
<td>35°</td>
</tr>
<tr>
<td>without external ventilation</td>
<td></td>
</tr>
<tr>
<td>Supply voltage</td>
<td></td>
</tr>
<tr>
<td>Type of supply voltage</td>
<td>DC</td>
</tr>
<tr>
<td>Rated value (DC)</td>
<td>24 V</td>
</tr>
<tr>
<td>Permissible range, lower limit (DC)</td>
<td>19.2 V</td>
</tr>
<tr>
<td>Permissible range, upper limit (DC)</td>
<td>28.8 V</td>
</tr>
<tr>
<td>Input current</td>
<td></td>
</tr>
<tr>
<td>Current consumption (rated value)</td>
<td>125 mA</td>
</tr>
<tr>
<td>Starting current inrush I²t</td>
<td>0.2 A²·s</td>
</tr>
<tr>
<td>Power</td>
<td></td>
</tr>
<tr>
<td>Active power input, typ.</td>
<td>3 W</td>
</tr>
<tr>
<td>Processor</td>
<td></td>
</tr>
<tr>
<td>Processor type</td>
<td>ARM</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
</tr>
<tr>
<td>Flash</td>
<td>Yes</td>
</tr>
<tr>
<td>RAM</td>
<td>Yes</td>
</tr>
<tr>
<td>Memory available for user data</td>
<td>10 Mbyte</td>
</tr>
<tr>
<td>Type of output</td>
<td></td>
</tr>
<tr>
<td>Acoustics</td>
<td></td>
</tr>
<tr>
<td>Buzzer</td>
<td>Yes</td>
</tr>
<tr>
<td>Speaker</td>
<td>No</td>
</tr>
<tr>
<td>Time of day</td>
<td></td>
</tr>
<tr>
<td>Clock</td>
<td></td>
</tr>
<tr>
<td>Hardware clock (real-time)</td>
<td>Yes</td>
</tr>
<tr>
<td>Software clock</td>
<td>Yes</td>
</tr>
<tr>
<td>Retentive</td>
<td>Yes; Back-up duration typically 6</td>
</tr>
<tr>
<td>Synchronizable</td>
<td>Yes</td>
</tr>
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</table>

6AV2123-2DB03-0AX0 Subject to change without notice
Page 2/9
08/14/2017 © Copyright Siemens
<table>
<thead>
<tr>
<th>Interfaces</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Number of industrial Ethernet interfaces</td>
<td>1</td>
</tr>
<tr>
<td>Number of RS 485 interfaces</td>
<td>0</td>
</tr>
<tr>
<td>Number of RS 422 interfaces</td>
<td>0</td>
</tr>
<tr>
<td>Number of RS 232 interfaces</td>
<td>0</td>
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<tr>
<td>Number of USB interfaces</td>
<td>1; Up to 16 GB</td>
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<tr>
<td>Number of 20 mA interfaces (TTY)</td>
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<tr>
<td>Number of parallel interfaces</td>
<td>0</td>
</tr>
<tr>
<td>Number of other interfaces</td>
<td>0</td>
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<tr>
<td>Number of SD card slots</td>
<td>0</td>
</tr>
<tr>
<td>With software interfaces</td>
<td>No</td>
</tr>
<tr>
<td>Industrial Ethernet</td>
<td></td>
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<tr>
<td>• Industrial Ethernet status LED</td>
<td>2</td>
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</table>

<table>
<thead>
<tr>
<th>Protocols</th>
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</thead>
<tbody>
<tr>
<td>PROFINET</td>
<td>Yes</td>
</tr>
<tr>
<td>Supports protocol for PROFINET IO</td>
<td>No</td>
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<tr>
<td>IRT</td>
<td>No</td>
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<tr>
<td>MRP</td>
<td>No</td>
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<tr>
<td>PROFIBUS</td>
<td>No</td>
</tr>
<tr>
<td>MPI</td>
<td>No</td>
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<table>
<thead>
<tr>
<th>Protocols (Ethernet)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• TCP/IP</td>
<td>Yes</td>
</tr>
<tr>
<td>• DHCP</td>
<td>Yes</td>
</tr>
<tr>
<td>• SNMP</td>
<td>Yes</td>
</tr>
<tr>
<td>• DCP</td>
<td>Yes</td>
</tr>
<tr>
<td>• LLDP</td>
<td>Yes</td>
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</table>

<table>
<thead>
<tr>
<th>WEB characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• HTTP</td>
<td>No</td>
</tr>
<tr>
<td>• HTML</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Further protocols</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• CAN</td>
<td>No</td>
</tr>
<tr>
<td>• EtherNet/IP</td>
<td>Yes</td>
</tr>
<tr>
<td>• MODBUS</td>
<td>Yes; Modicon (MODBUS TCP/IP)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interrupts/diagnostics/status information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic messages</td>
<td></td>
</tr>
<tr>
<td>• Diagnostic information readable</td>
<td>No</td>
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<table>
<thead>
<tr>
<th>EMC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission of radio interference acc. to EN 55 011</td>
<td></td>
</tr>
<tr>
<td>• Limit class A, for use in industrial areas</td>
<td>Yes</td>
</tr>
<tr>
<td>• Limit class B, for use in residential areas</td>
<td>No</td>
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</table>

<table>
<thead>
<tr>
<th>Degree and class of protection</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Feature</td>
<td>Specification</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>IP (at the front)</td>
<td>IP65</td>
</tr>
<tr>
<td>Enclosure Type 4 at the front</td>
<td>Yes</td>
</tr>
<tr>
<td>Enclosure Type 4x at the front</td>
<td>Yes</td>
</tr>
<tr>
<td>IP (rear)</td>
<td>IP20</td>
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### Standards, approvals, certificates

<table>
<thead>
<tr>
<th>Standard</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE mark</td>
<td>Yes</td>
</tr>
<tr>
<td>cULus</td>
<td>Yes</td>
</tr>
<tr>
<td>RCM (formerly C-TICK)</td>
<td>Yes</td>
</tr>
<tr>
<td>KC approval</td>
<td>Yes</td>
</tr>
<tr>
<td>Marine approval</td>
<td></td>
</tr>
<tr>
<td>Germanischer Lloyd (GL)</td>
<td>Yes</td>
</tr>
<tr>
<td>American Bureau of Shipping (ABS)</td>
<td>Yes</td>
</tr>
<tr>
<td>Bureau Veritas (BV)</td>
<td>Yes</td>
</tr>
<tr>
<td>Det Norske Veritas (DNV)</td>
<td>Yes</td>
</tr>
<tr>
<td>Lloyds Register of Shipping (LRS)</td>
<td>Yes</td>
</tr>
<tr>
<td>Nippon Kaiji Kyokai (Class NK)</td>
<td>Yes</td>
</tr>
<tr>
<td>Polski Rejestr Statkow (PRS)</td>
<td>No</td>
</tr>
<tr>
<td>Chinese Classification Society (CCS)</td>
<td>No</td>
</tr>
</tbody>
</table>

### Use in hazardous areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATEX Zone 2</td>
<td>No</td>
</tr>
<tr>
<td>ATEX Zone 22</td>
<td>No</td>
</tr>
<tr>
<td>IECEX Zone 2</td>
<td>No</td>
</tr>
<tr>
<td>IECEX Zone 22</td>
<td>No</td>
</tr>
<tr>
<td>cULus Class I Zone 1</td>
<td>No</td>
</tr>
<tr>
<td>cULus Class I Zone 2, Division 2</td>
<td>No</td>
</tr>
<tr>
<td>FM Class I Division 2</td>
<td>No</td>
</tr>
</tbody>
</table>

### Ambient conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suited for indoor use</td>
<td>Yes</td>
</tr>
<tr>
<td>Suited for outdoor use</td>
<td>No</td>
</tr>
</tbody>
</table>

### Ambient temperature during operation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation (vertical installation)</td>
<td></td>
</tr>
<tr>
<td>— For vertical installation, min.</td>
<td>0 °C</td>
</tr>
<tr>
<td>— For vertical installation, max.</td>
<td>50 °C</td>
</tr>
<tr>
<td>Operation (max. tilt angle)</td>
<td></td>
</tr>
<tr>
<td>— At maximum tilt angle, min.</td>
<td>0 °C</td>
</tr>
<tr>
<td>— At maximum tilt angle, min.</td>
<td>40 °C</td>
</tr>
<tr>
<td>Operation (vertical installation, portrait format)</td>
<td></td>
</tr>
<tr>
<td>— For vertical installation, min.</td>
<td>0 °C</td>
</tr>
<tr>
<td>— For vertical installation, max.</td>
<td>40 °C</td>
</tr>
<tr>
<td>Operation (max. tilt angle, portrait format)</td>
<td></td>
</tr>
<tr>
<td>— At maximum tilt angle, min.</td>
<td>0 °C</td>
</tr>
</tbody>
</table>
### Ambient temperature during storage/transportation
- min.: -20 °C
- max.: 60 °C

### Relative humidity
- Operation, max.: 90%; no condensation

### Operating systems
- proprietary: Yes
- pre-installed operating system: Windows CE, No

### Configuration
- Message indicator: Yes
- Alarm system (incl. buffer and acknowledgment): Yes
- Process value display (output): Yes
- Process value default (input) possible: Yes
- Recipe management: Yes

### Configuration software
- STEP 7 Basic (TIA Portal): Yes; via integrated WinCC Basic (TIA Portal)
- STEP 7 Professional (TIA Portal): Yes; via integrated WinCC Basic (TIA Portal)
- WinCC flexible Compact: No
- WinCC flexible Standard: No
- WinCC flexible Advanced: No
- WinCC Basic (TIA Portal): Yes
- WinCC Comfort (TIA Portal): Yes
- WinCC Advanced (TIA Portal): Yes
- WinCC Professional (TIA Portal): Yes

### Languages
- Online languages
  - Number of online/runtime languages: 10
- Project languages
  - Languages per project: 32

### Functionality under WinCC (TIA Portal)
- Libraries: Yes
- Applications/options
  - Web browser: Yes
  - SIMATIC WinCC Sm@rtServer: Yes; Available with WinCC (TIA Portal) V14 or higher
- Number of Visual Basic Scripts: No
- Task planner
  - time-controlled: Yes
  - task-controlled: Yes
- Help system: Yes
<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of alarm classes</td>
<td>32</td>
</tr>
<tr>
<td>Bit messages</td>
<td></td>
</tr>
<tr>
<td>— Number of bit messages</td>
<td>1,000</td>
</tr>
<tr>
<td>Analog messages</td>
<td></td>
</tr>
<tr>
<td>— Number of analog messages</td>
<td>25</td>
</tr>
<tr>
<td>S7 alarm number procedure</td>
<td>No</td>
</tr>
<tr>
<td>System messages HMI</td>
<td>Yes</td>
</tr>
<tr>
<td>System messages, other (SIMATIC S7, Sinumerik, Simotion, etc.)</td>
<td>Yes; System message buffer of the SIMATIC S7-1200 and S7-1500</td>
</tr>
<tr>
<td>Number of characters per message</td>
<td>80</td>
</tr>
<tr>
<td>Number of process values per message</td>
<td>8</td>
</tr>
<tr>
<td>Acknowledgment groups</td>
<td>Yes</td>
</tr>
<tr>
<td>Message indicator</td>
<td>Yes</td>
</tr>
<tr>
<td>Message buffer</td>
<td></td>
</tr>
<tr>
<td>— Number of entries</td>
<td>256</td>
</tr>
<tr>
<td>— Circulating buffer</td>
<td>Yes</td>
</tr>
<tr>
<td>— retentive</td>
<td>Yes</td>
</tr>
<tr>
<td>— maintenance-free</td>
<td>Yes</td>
</tr>
<tr>
<td>Recipe management</td>
<td></td>
</tr>
<tr>
<td>Number of recipes</td>
<td>50</td>
</tr>
<tr>
<td>Data records per recipe</td>
<td>100</td>
</tr>
<tr>
<td>Entries per data record</td>
<td>100</td>
</tr>
<tr>
<td>Size of internal recipe memory</td>
<td>256 kbyte</td>
</tr>
<tr>
<td>Recipe memory expandable</td>
<td>No</td>
</tr>
<tr>
<td>Variables</td>
<td></td>
</tr>
<tr>
<td>Number of variables per device</td>
<td>800</td>
</tr>
<tr>
<td>Number of variables per screen</td>
<td>100</td>
</tr>
<tr>
<td>Limit values</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiplexing</td>
<td>Yes</td>
</tr>
<tr>
<td>Structures</td>
<td>No</td>
</tr>
<tr>
<td>Arrays</td>
<td>Yes</td>
</tr>
<tr>
<td>Images</td>
<td></td>
</tr>
<tr>
<td>Number of configurable images</td>
<td>250</td>
</tr>
<tr>
<td>Permanent window/default</td>
<td>Yes</td>
</tr>
<tr>
<td>Global image</td>
<td>Yes</td>
</tr>
<tr>
<td>Pop-up images</td>
<td>No</td>
</tr>
<tr>
<td>Slide-in images</td>
<td>No</td>
</tr>
<tr>
<td>Image selection by PLC</td>
<td>Yes</td>
</tr>
<tr>
<td>Image number in the PLC</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Image objects
- Number of objects per image: 100
- Text fields: Yes
- I/O fields: Yes
- Graphic I/O fields (graphics list): Yes
- Symbolic I/O fields (text list): Yes
- Date/time fields: Yes
- Switches: Yes
- Buttons: Yes
- Graphic display: Yes
- Icons: Yes
- Geometric objects: Yes

### Complex image objects
- Number of complex objects per screen: 10
- Alarm view: Yes
- Trend view: Yes
- User view: Yes
- Status/control: No
- Sm@rtClient view: No
- Recipe view: Yes
- f(x) trend view: No
- System diagnostics view: Yes; System message buffer of the SIMATIC S7-1200 and S7-1500
- Media Player: No
- HTML browser: Yes
- PDF display: No
- IP camera display: No
- Bar graphs: Yes
- Sliders: No
- Pointer instruments: No
- Analog/digital clock: No

### Lists
- Number of text lists per project: 300
- Number of entries per text list: 100
- Number of graphics lists per project: 100
- Number of entries per graphics list: 100

### Archiving
- Number of archives per device: 2; One message and one process value archive
- Number of entries per archive: 10 000
- Message archive: Yes
- Process value archive: Yes
<table>
<thead>
<tr>
<th>Archiving methods</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>— Sequential archive</td>
<td>Yes</td>
</tr>
<tr>
<td>— Short-term archive</td>
<td></td>
</tr>
<tr>
<td>Memory location</td>
<td></td>
</tr>
<tr>
<td>— Memory card</td>
<td>No</td>
</tr>
<tr>
<td>— USB memory</td>
<td>Yes</td>
</tr>
<tr>
<td>— Ethernet</td>
<td>No</td>
</tr>
<tr>
<td>Data storage format</td>
<td></td>
</tr>
<tr>
<td>— CSV</td>
<td>No</td>
</tr>
<tr>
<td>— TXT</td>
<td>Yes</td>
</tr>
<tr>
<td>— RDB</td>
<td>No</td>
</tr>
<tr>
<td>Security</td>
<td></td>
</tr>
<tr>
<td>— Number of user groups</td>
<td>50</td>
</tr>
<tr>
<td>— Number of user rights</td>
<td>32</td>
</tr>
<tr>
<td>— Number of users</td>
<td>50</td>
</tr>
<tr>
<td>— Password export/import</td>
<td>Yes</td>
</tr>
<tr>
<td>— SIMATIC Logon</td>
<td>No</td>
</tr>
<tr>
<td>Character sets</td>
<td></td>
</tr>
<tr>
<td>— Keyboard fonts</td>
<td></td>
</tr>
<tr>
<td>— US English</td>
<td>Yes</td>
</tr>
<tr>
<td>Transfer (upload/download)</td>
<td></td>
</tr>
<tr>
<td>— MPI/PROFIBUS DP</td>
<td>No</td>
</tr>
<tr>
<td>— USB</td>
<td>No</td>
</tr>
<tr>
<td>— Ethernet</td>
<td>Yes</td>
</tr>
<tr>
<td>— using external storage medium</td>
<td>Yes</td>
</tr>
<tr>
<td>Process coupling</td>
<td></td>
</tr>
<tr>
<td>— S7-1200</td>
<td>Yes</td>
</tr>
<tr>
<td>— S7-1500</td>
<td>Yes</td>
</tr>
<tr>
<td>— S7-200</td>
<td>Yes</td>
</tr>
<tr>
<td>— S7-300/400</td>
<td>Yes</td>
</tr>
<tr>
<td>— LOGO!</td>
<td>Yes</td>
</tr>
<tr>
<td>— WinAC</td>
<td>Yes</td>
</tr>
<tr>
<td>— SINUMERIK</td>
<td>Yes; No access to NCK data</td>
</tr>
<tr>
<td>— SiMOTION</td>
<td>Yes</td>
</tr>
<tr>
<td>— Allen Bradley (EtherNet/IP)</td>
<td>Yes</td>
</tr>
<tr>
<td>— Allen Bradley (DF1)</td>
<td>No</td>
</tr>
<tr>
<td>— Mitsubishi (MC TCP/IP)</td>
<td>Yes</td>
</tr>
<tr>
<td>— Mitsubishi (FX)</td>
<td>No</td>
</tr>
<tr>
<td>— OMRON (FINS TCP)</td>
<td>No</td>
</tr>
<tr>
<td>— OMRON (LINK/Multilink)</td>
<td>No</td>
</tr>
<tr>
<td>— Modicon (Modbus TCP/IP)</td>
<td>Yes</td>
</tr>
</tbody>
</table>
- Modicon (Modbus) No

**Service tools/configuration aids**

- Backup/Restore manually Yes
- Backup/Restore automatically No
- Simulation Yes
- Device switchover Yes

**Peripherals/Options**

**Peripherals**

- Printer No
- SIMATIC HMI MM memory card: Multi Media Card No
- SIMATIC HMI SD memory card: Secure Digital memory card No
- SIMATIC HMI CF memory card Compact Flash Card No
- USB memory Yes
- SIMATIC IPC USB Flashdrive (USB stick) Yes
- SIMATIC HMI USB stick Yes

**Mechanics/material**

**Enclosure material (front)**

- Plastic Yes
- Aluminum No
- Stainless steel No

**Dimensions**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of the housing front</td>
<td>141 mm</td>
</tr>
<tr>
<td>Height of housing front</td>
<td>116 mm</td>
</tr>
<tr>
<td>Mounting cutout, width</td>
<td>123 mm</td>
</tr>
<tr>
<td>Mounting cutout, height</td>
<td>99 mm</td>
</tr>
<tr>
<td>Overall depth</td>
<td>33 mm</td>
</tr>
</tbody>
</table>

**Weights**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight without packaging</td>
<td>360 g</td>
</tr>
<tr>
<td>Weight incl. packaging</td>
<td>470 g</td>
</tr>
</tbody>
</table>

*last modified:* 08/12/2017