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Development of a Portable Process Data Acquisition System

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Thema der Diplomarbeit

Entwicklung eines portablen Systems zur Prozessdaten Erfassung

Stichworte

Datenlogger, Daten Monitoring, Daten Controlling, Potenzial Analyse, Energie Diensleistungen, GPRS Kommunikation

Kurzzusammenfassung

Der Nutzen von der Erfassung von Prozessdaten ermöglicht eine Basis für das Auffinden von Einsparpotenzialen und die Beurteilung von Optimierungsmaßnahmen. Aus diesem Grund steigt die Bedeutung von Systemlösungen, die die Aufzeichnung verschiedener Datenquellen ermöglichen. Dieses Projekt beschreibt ein Design, das die Erstellung einer ganzheitlichen Systemlösung zum Ziel hat.

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Title of the paper

Development of a Portable Process Data Acquisition System

Keywords

Data Logger, Data Monitoring, Data Controlling, Potential Analysis, GPRS Communication

Abstract

The advantage of recording process data stems from its ability to create a basis for the finding of saving potentials and the valuation of optimization measures. For that reason system solution offering the acquisition of different data sources becomes more important. This project discusses with a design focusing the creation of a portabel intregrated system solution.

Acknowledgment

I sincerely would like to thank Prof. Dr.-Ing. Franz Schubert for giving me the opportunity to perform this interesting and challenging work in his department. Special thanks to Prof. Dr.-Ing. Michael Röther for his interest in providing the co-corrector for this thesis. My other special appreciation goes to the management of the Envidatec GmbH, specifically to Dipl.-Ing. Thomas Frank and Dr. Stefan Kuck for providing me with the challenge to carry out my research work within the company. Last but not least, I want to express my gratefulness to my family and friends for their support during the making of this thesis and the whole study.

Contents

List of Tables

List of Figures

1. Introduction

The present thesis was created within the Envidatec GmbH, in Hamburg. The Envidatec GmbH provides energy services and energy management. Their major business area is the finding and analysing of saving potentials. Therefore, the collection and the evaluation of energy consumption information in customer's properties are essential. To work with a high information resolution, an automated application to acquire data and to make different data rows accessible is a fundamental need.

Existent tools in the company are able to realize immobile data monitoring installations. But Furthermore, the inquiries for temporary installation, e.g. to evaluate the benefit of an immobile installation first, are increasing. To confront the rising inquiries for the energy analyses and the energy efficiency measures, a new portable process data acquisition system is necessary.

The main purpose of this project is the design of an integrated system solution for the portable acquisition of process data. Different data sources can be connected to the system peripherals and are stored locally. A new mobile communication structure allows a reasonable remote maintenance and provides a secure readout of aquired data. The design is based on the VIDA350 software, resulting out a previous student research project.[1] Creating a new system based on prior achievements, follows the Envidatec's strategy to minimize the effort for soft- and hardware development, by improving synergy effects between different products.

Before going into the discussion, some formal declarations are made:

1. All included english texts are written in accordance with american english orthography.
2. Unit prefixes followed by an "i" are binary prefixes referring to a base of 1024 (2^{10}), e.g. 1 KiByte means 1024 byte.
3. Commands, variables and special programming statements are highlighted by a type writer font style.
4. All program source codes are stored at the Hochschule für Angewandte Wissenschaften (HAW) Hamburg accessible at the office of Prof. Dr.-Ing. Franz Schubert.

1.1. Motivation

Recently, the climate change becomes an omnipresent topic in all domains of the modern society. While the world climate has always varied naturally, the majority of scientists agrees that the increasing concentrations of greenhouse gases in the atmosphere are a result of the economic and demographic growth. In contrast to the natural variability, the consequences of the human-caused boost of emissions leads to a potentially irreversible climate change. The required research of the causes as well as the immediate implementation of strategies dealing with the consequenses, will be a big global challenge in the ongoing 21st century.

For the saving of the world for future generations, the global society has to come to a conclusion in counteracting the climate change. In 1997, international governments adopted the Kyoto Protocol in addition to the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto protocol sets a landmark, constraining greenhouse gas emissions with innovative meachanisms aimed reducing of emissions. Today, the Kyoto Protocol is legally-binding in 186 countries beeing part of the UNFCCC.[2]

In order to fulfill the international agreement, the number of national regulations within the member countries is increasing. Examples for such regulations are for instance:

- The adoption of a new Eco-tax regulation, in 1999 and the Renewable-Energy-Law in 2000, in Germany. Both regulations aim to control the energy costs for the improvement of climate, the so called green energies.
- The international standardization of the establishment of an energy management system described in the DIN EN 16001 and ISO 50001. In the near future, a certified energy management system may become an obligation for energy intensive companies, e.g. for the refund of the Eco-tax provision.

The variety of new regulations and the rising energy costs lead to new economical challenges. These demands gain new interests in energy efficiency services and create new business areas.

- The creation of Joint Implementation (JI) and Clean Development Mechanism (CDM) projects according to the Kyoto Protocol. JI and CDM projects allow the trade of saved carbon emissions among countries being part of the UNFCCC, focused on the improvement of international technology and know-how transfer.
- The establishment of Public-Private-Partnership (PPP) projects, offering an increased cooperation between research and economic development.

Against the background, the motivation of this thesis is centered in the development of a universal integrated solution enabling the analyses of saving potentials. The central point of interest is the development of a versatile product, dealing with the multisided demands of the described project types.

2. Background

2.1. Envidatec GmbH

The Envidatec GmbH located in Harburg south of Hamburg, was founded in 2001 out of the E.ON competence center for energy efficiency. Since then the Envidatec GmbH operates as an independent company and combines expertise from the fields of energy services, energy and operational data management, energy efficiency, general bus systems and automation. The major business area of the Envidatec GmbH is the detection of saving potentials with operation data controlling and energy management both with the energy services as well as with cooperating system solutions. This ensures that each assignment is analyzed according to the individual needs of the establishment. In addition to pose the necessary knowledge concerning energy efficient technology the Envidatec GmbH also has the expertise in methods that allow to identify energy-saving potentials, such as hard- and software solutions.[3]

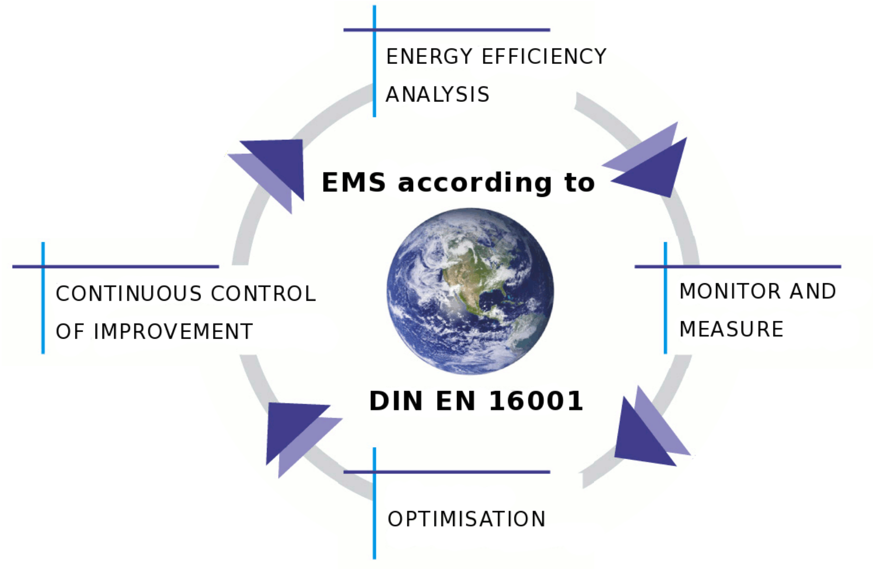


Figure 2.1.: Plan-Do-Check-Act (PDCA) cycle of an energy management system[3]

Energy efficiency analyses that are in accordance with legal regulations or necessary for the refund of the Eco-tax provision are part of the repertoire of internal audits offered by the

Envidatec GmbH. The new requirements of ISO 50001 and DIN EN 16001 will be the main concern of the Envidatec GmbH in the next decade.

"By reducing the energy consumption in companies we are making a significant contribution to reducing CO_2-emissions. We see this as our contribution to achieve the climate protection targets of the Kyoto Protocol." - Thomas Frank, Envidatec GmbH CEO

Recently the international inquiries for the Envidatec GmbH energy services are increasing. For this reason the Envidatec GmbH proceeds in expanding its network of competence constantly by establishing a global network of cooperating partners. The Envidatec GmbH established corporations in Vienna in 2007 and Yekaterinburg/Moscow in 2010. Thus the product management is focused on standardized products customized for the international market.

The main interest of the Envidatec GmbH in the development process of a portable data acquisition system is the creation of a versatile tool

- for the implementation of national energy efficiency advice and assessment of measures deployed,
- for the analysis of potential savings in international projects in accordance with ISO 50001 or the Kyoto Protocol,
- as a basis for training focusing the improvement of the know-how transfer for the extension of the competence network.

2.2. Data Monitoring

Monitoring is a generally used term describing a concept to acquire and observe a process. The substantial interest of a monitoring implementation is to increase the transparency of specific processes taking place in an organization. Because of the wide-ranging nature of processes found in an organization, the term is expanded to the term data monitoring to point on the aim to acquire technical process data recorded by appropiate metering installation. The economical interest in data monitoring is to display the dependency between processes or building a basis for business decisions. This can be realized by benchmarking of different processes. According to the experience of energy managers the initiation of an energy process data monitoring system and the implementation of solely organizational measures will typically effect 5% up to 15% of enhancement in energy efficiency.

A simple data monitoring can be realized by a periodical manual acquisition, e.g. by noting the counter reading of an electricity meter once a month. Because of the high dynamics of technical processes, such a low resolution of available data will not offer the desired illustration. In order for a significant illustration, the resolution, actuality, and availability are the key standards of quality for the process data. To match with these demands, a continuous aquisition with a high data resolution realized by automatic systems results in an economic profit in the majority of cases. An automatic system with a short data refresh time, enables a clear process overview and allows a immediate detection and reaction on erratic process behaviors.

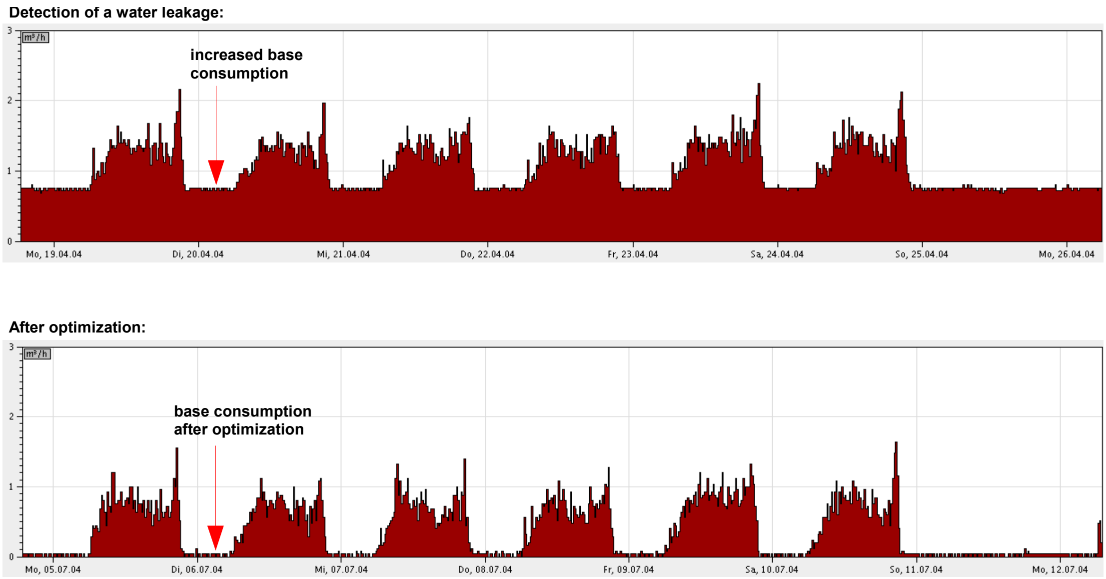


Figure 2.2.: The visual detection of a water leakage as an example for process controlling using data monitoring

The detection of a broken water valve, shown in figure 2.2, demonstrates a typical benefit of a data monitoring system.

2.3. My-JEVis System

The My-JEVis is a server based overlaying system for data processing and data visualization provided by the Envidatec GmbH. The general functionality of the My-JEVis system is partitioned into

- the readout of data gateways,
- the storage and allocation of data into a data base structure,
- the continuously processing of data such as individual calculations and alarming,

- the visualization of data onto the My-JEVis web frontend.

The My-JEVis stands in connection with all installed data gateways using several ways of communication. Referring to the My-JEVis system topology, a data gateway is any generic data device. This can be a FTP-server, a building control system, or field device supporting a My-JEVis system compatible data readout interface. The data gets fetched periodically and is stored into an Oracle-based data base structure. The raw data imported by the readout of the data gateways, are interpreted and continuously processed.

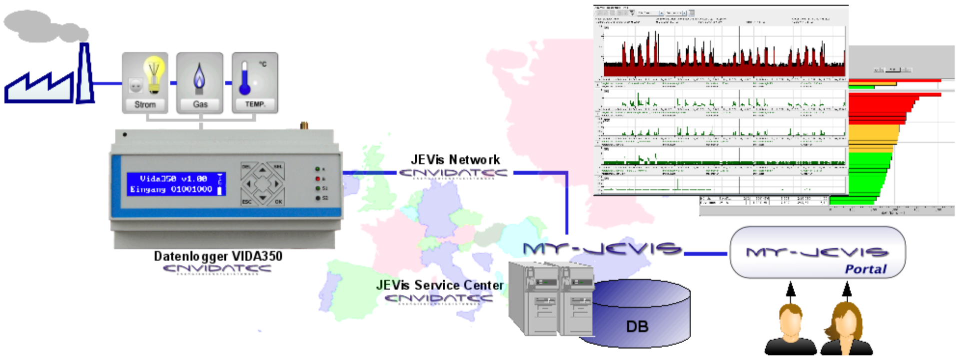


Figure 2.3.: My-JEVis system overview[4]

The My-JEVis system provides a Java-based web frontend[1] exclusively developed by the Envidatec GmbH. The My-JEVis web frontend offers a central data monitoring solution focused on the visualization of acquired data. To match with this, the My-JEVis system comes with web applications allowing a contemporary overview on all available data rows.[4]

A significant advantage of the My-JEVis system is the applicability for a multitude of different data sources and the web based monitoring software running in any standard Java compatible web browser. The most common used web applications are the

- JEChart
- JEBench

software modules.

The JEChart module is a graphical user interfaces (GUI) offering the illustration and comparison of data rows such as consumptions, switching states or costs. JEChart allows the drawing of line and bar charts and supports different additional graphical options such as zooming and color highlighted threshold visualization, see figure 2.4.

[1] http://www.my-jevis.com

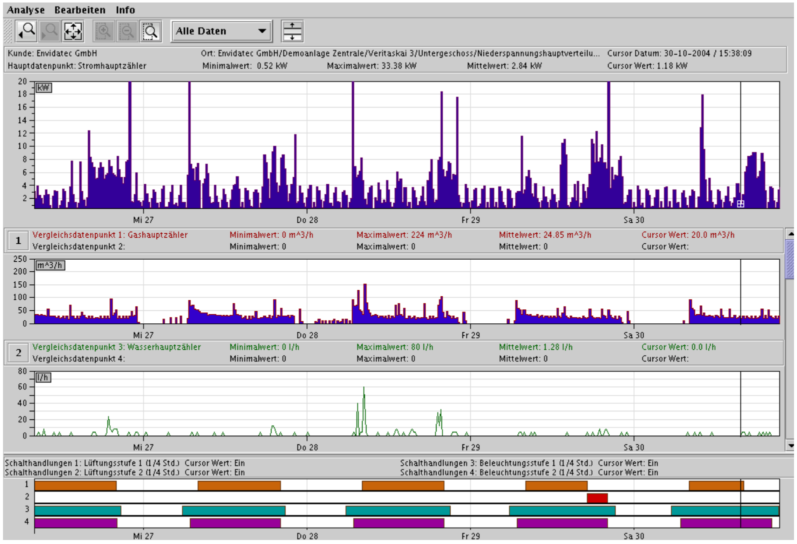


Figure 2.4.: The My-JEVis Java-based web application JEChart, allowing the drawing of line- and bar-charts

Another component of the My-JEVis web frontend is the JEBench benchmarking tool. The JEBench module allows to create rankings over a wide range of data rows, e.g. for the ranking of a series of buildings.

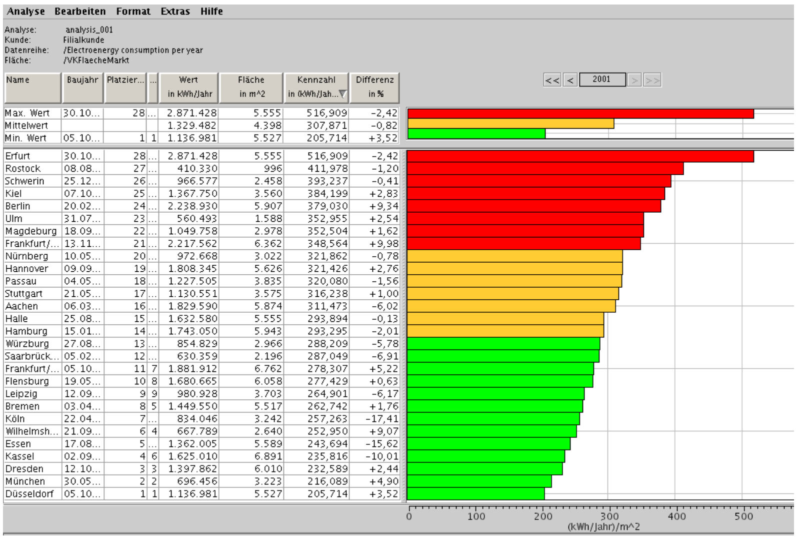


Figure 2.5.: The My-JEVis Java-based web application JEBench, offering the ranking and sortation of data rows

3. System Requirements

The development of a multi-purpose portable process data acquisition system, has to deal with a multitude of different requirements. Creating a full integrated system solution puts several challenges on the system design. The system design has to handle different software requests such as: input control, data storage, and communication as well as the mechanical demands, and the need of a suitable infrastructure for remote operating.

The following partitioning will give an survey on the main design challenges and the involved requests.

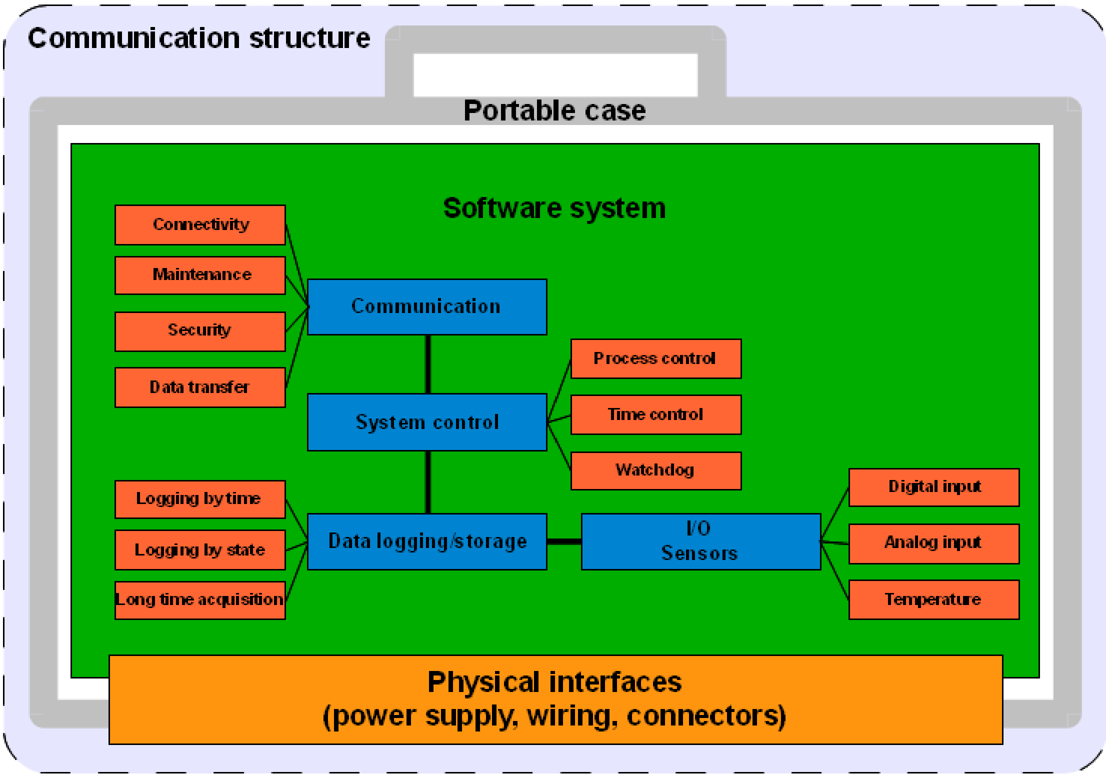


Figure 3.1.: Overview on the system requirements

3.1. Data Input

In creating an data acquisition system the main point of interest is the recording of data. To accommodate for this, the system design has to support different interfaces to get data from a process. The following subsections present the different interfaces and their applicability. All provided data inputs should be acquirable in a reasonable time resolution. With the focus on a central maintainability and an unproblematic exchangeability of devices, all data is stored in raw data. The interpretation of the referring values is perfomed on a higher level in the My-JEVis system.

3.1.1. Digital States

A lot of processes in a facility can be monitored using digital states. In many cases the information about a process state becomes essential to evaluate the impact of different processes. Accommodate to this, the system should provide the recording of different switch states, e.g.monitoring the run-time of a production machine. The state control should provide a periodically recording of event as well as the detection of state changes in real time.

3.1.2. Pulse Counter

A multitude of processes need special metering installations that involve specific counters to measure consumptions. Modern consumption meters for industrial use allow different methods for direct digital counter reading. For a wide-ranging coverage of applicability the design will focus on the pulse interface, so called S0-interface, according to the DIN 43864. The S0-interface is widely-used by different types of

- electric,
- gas,
- water,
- oil,
- steam,
- heat,
- and compressed-air

consumption meters. The main principle of the pulse interface is based on a fixed number of current pulses referring to the metering value relating to a defined time window. The pulses get generated by using potential-free contact circuit based on an optocoupler which is applied by the external device.

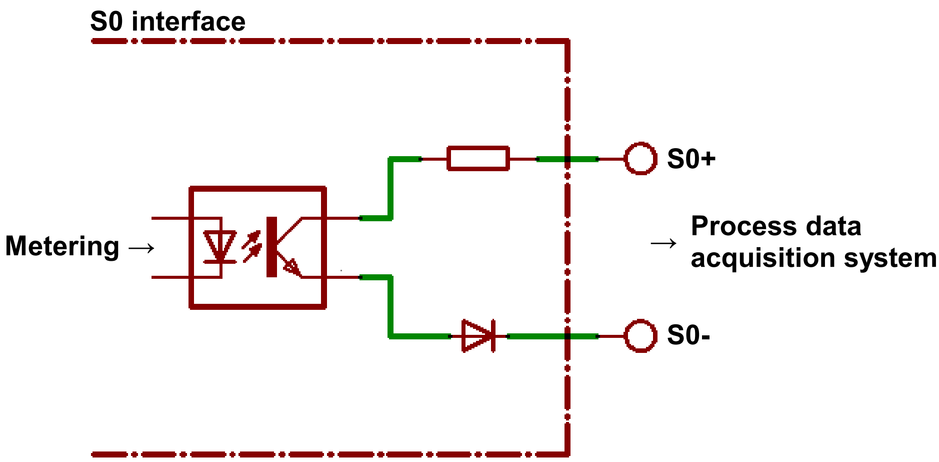


Figure 3.2.: Illustration of a S0-interface according to DIN 43684

The specific relation of pulses referring to the metering value depends on the counter and is given as a $\frac{pulses}{unit}$ factor.

3.1.3. Analog Values

The amount of different sensors providing the measurement of physical quantities is huge. A majority of sensors convert the actual measured value into an analog voltage or current value. The branch of analog sensors for industrial use is very multisided. Analog sensors are often used for very special operation areas, for instance exhaust emission sensors. Due to this, the system should support the recording of analog values.

3.1.4. Temperatures

In a wide range of technical applications temperature is of big importance. For the benchmarking of such processes a relating temperature is essential. Therefore, an acquisition of different temperatures should be supported by the system design.

3.2. Data Logging and the Storage of Data

To make the acquisition of data possible the software design has to include an event handler. The event handler is responsible for the triggering of data storages. Following the demands described in the data input requirements, the design should support the control of log events

- triggered by different time events,
- triggered by different digital state conditions.

In order to provide a variable system, a free configurable time control, and adjustable resolution in minute and second values is required. In order to handle a big amount of data, the data storage design should support a possibility to save a lot of data for a reasonable hold-back time. Additionally, the data storage design should include a well structured method to save system parameters and software settings in a non-volatile way.

3.3. Communication

Another main point in the system design is the remote communication. A faultless communication between the field device and the control center is paramount for a plurality of system features. The availability of data depends on the remote accessability of the system. In consequence of this relation, the communication design should focus on an always-online solution. To accommodate for the data confidentiality a secured communication is required. To fulfill the demand of an international applicable system, the design should prefer the usage of a well developed technology.

Referring to the demand of getting data out of a monitoring installation, the communication design should offer a remote data transfer interface. The data readout interface should support a My-JEVis compatible data format.

A lot of projects have to deal with changing demands during the project run-time, e.g. a modification or an upgrading of the metering installation. In order to an economic maintenance, the communication design has to support the modification of all relevant parameters by remote control. To increase the options of remote error diagnostic by remote control, the design should also support the remote readout of general system states.

3.4. Case Design

A wide applicability comes up with different requirements focused on the case design. To cope with the demands of industrial use the case design has to characterize itself by a robust case exposure. In addition to the entitlement to create a portable system, the design should feature a suitable dimension and an efficient wiring for temporary installations.

4. Programmable Hardware

Since the foundation in 2001, the Envidatec GmbH has developed several hard- and software applications. Out of the experience from the early concern history, the development of hardware devices became more and more insignificant in the main business concept. Since 2007, the development of field devices is completely based on the use of programmable hardware combined with a custom-designed software developed by the Envidatec GmbH. The first data logger based on a programmable hardware manufactored by the danish Logic IO[1], named VIDA88 was developed in 2007.

In 2009 Logic IO has realeased a new, so called x32-architecture, hardware design. The x32-architecture is a dynamic hardware design presenting a generic core for actual and intended Logic IO products. Therefore, the basic VIDA88 functionality was adapted on the Logic IO RTCU DX4 pro unit within a student project resulting the new VIDA350 version 1.00 application.[1]

Figure 4.1.: Logic IO RTCU DX4 pro DIN rail device[5]

To improve synergies for future data logger development, the software design will be based on the VIDA350 software version 1.00. The achievements of the software design developed in this thesis will result the VIDA350 2.00 software version.

[1] http://www.logicio.com

4.1. The Logic IO x32-family RTCU Hardware

The Logic IO x32-family RTCU product line is based on a 32-bit ARM7 processore with 1 MiByte RAM. The RTCU product line constitutes of a combination of programmable control-units with flexible digital- and analog I/0, GSM/GPRS quad-band communication, and provides several possibilities to store data. The x32-family units offer also the opportunity to expand the integrated peripherals by using the supported bus systems such as: Modbus, 1-wire, CAN or using the serial interfaces RS-232 and RS-485. All x32-family RTCU devices are equipped with a Li-Ion battery pack for uninterruptible power supply.[6]

The Logic IO RTCU devices are established and proven equipment compliance with specified demands of industrial applications referring to:

- Ingress Protection (IP) Code IP-20
  (according to the International Electrotechnical Commission (IEC) 60529)
- EN 61000-6-2 and EN 61000-6-3
  (according to the European Electromagnetic Compatibility (EMC) Directive)
- European CE marking conformity

The Logic IO RTCU units can be programmed using the custom-made high-level language VPL, which looks similar to Basic- or Pascal-syntax. To facilitate easy access to the many different features, the Logic IO units come with the Logic IO Standard Function Library (SFL). The Logic IO SFL provides a number of functions to be used by the programmer for developing a software application based on the available RTCU platform features without a detailed knowledge of the built-in hardware realization.[7]

4.2. The Logic IO RTCU IDE

The free available RTCU integrated development environment (IDE) is the main development tool which Logic IO offers to their customers. The RTCU IDE combines a common syntax highlighting editor and compiler bundle with a collection of useful tools to check and configure the state and behavior of the connected device. The RTCU IDE also provides the needed interfaces to program the device by uploading the compilation using a serial cable, direct data call, or GPRS connection.

To enhance the testability of new software, the RTCU IDE comes with additional simulator functionality. The simulator function consists of a collection of several software tools representing the different RTCU hardware functions such as in- and outputs, GSM/GPRS communication, real time clock, etc. seen in figure 4.3. For an intensive software analyzation the

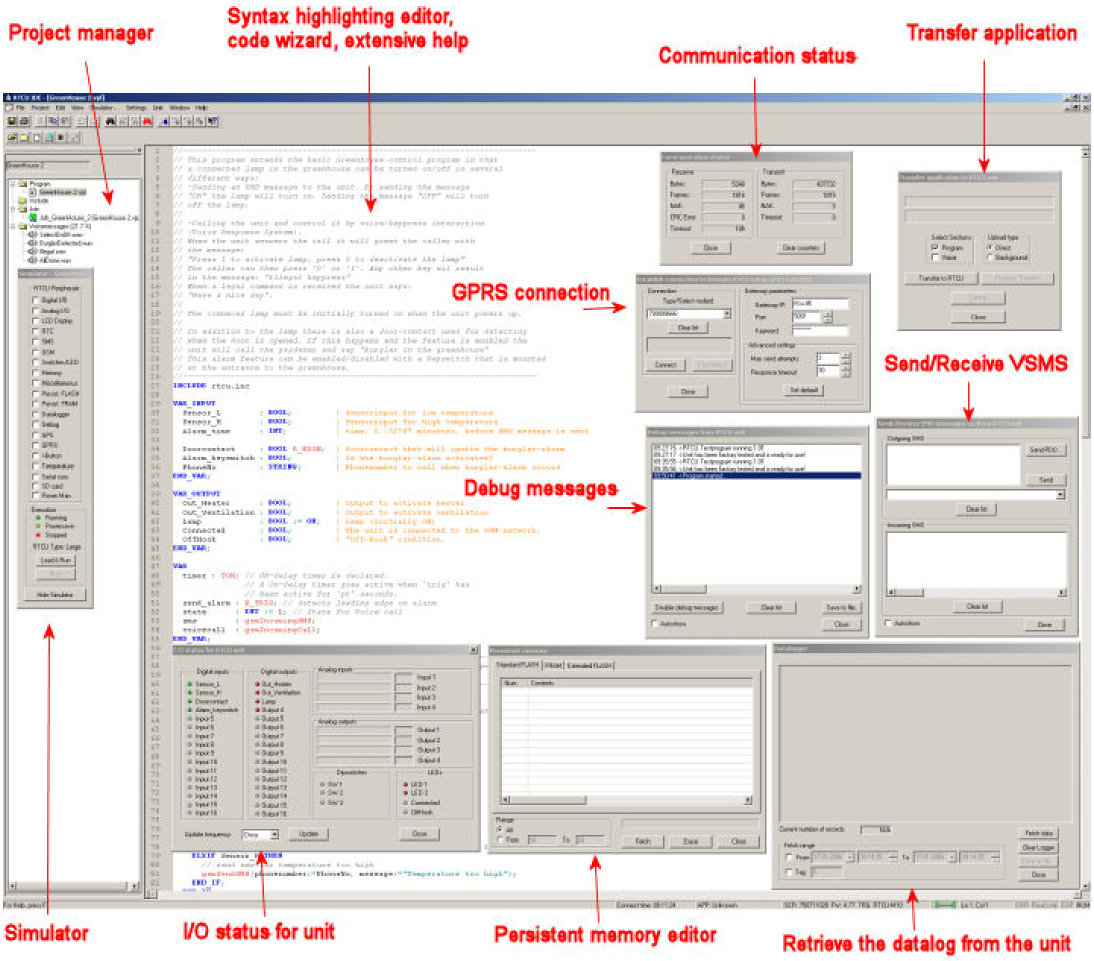


Figure 4.2.: The Logic IO RTCU IDE, providing several programming tools[7]

RTCU IDE integrated simulator supports simple ways for the manipulation of system settings and behavior to penetrate the system with possible fault cases.

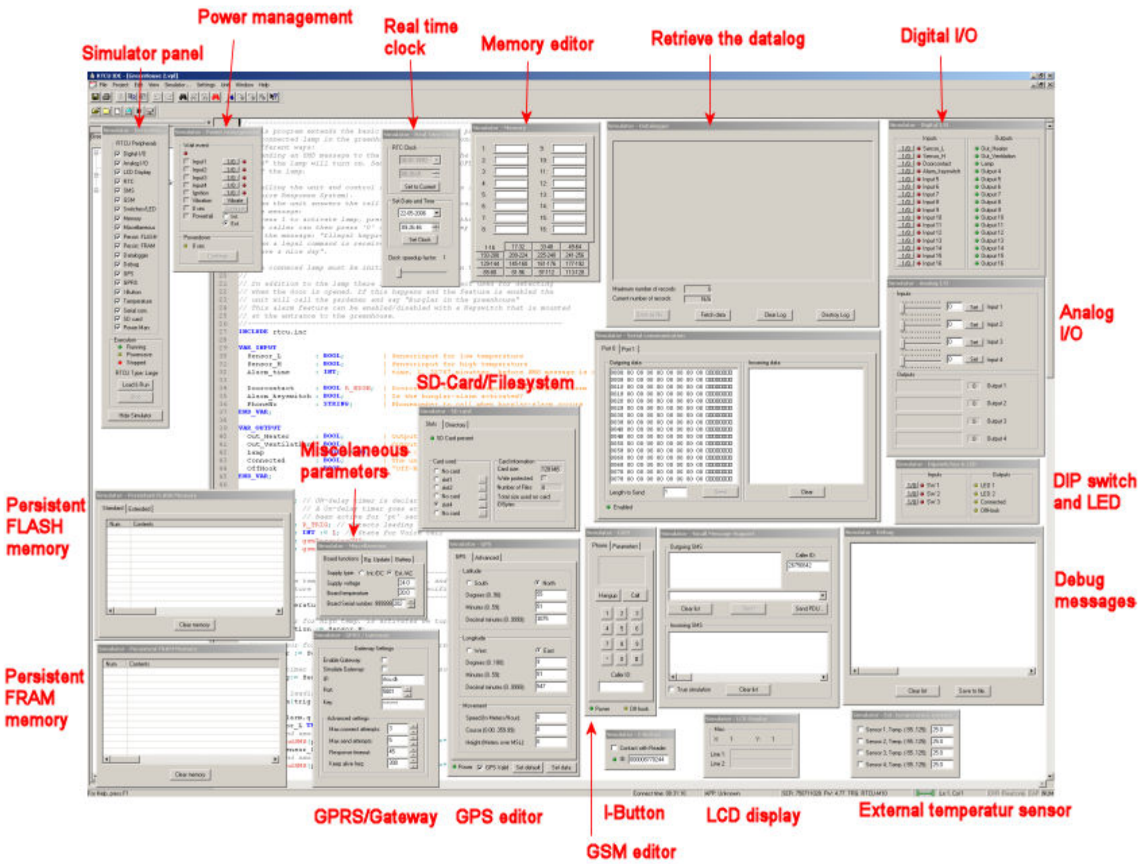


Figure 4.3.: The Logic IO RTCU IDE integrated simulator tool boxes[7]

4.3. Reusability of Code

To increase the efficiency in software development of the Envidatec GmbH, all results arising from this thesis should benefit the already established data logging products. In addition, the software design should constitute the universal basis for future RTCU based development. As a consequence of this aim, the design also attaches a great importance to the compatibility to other x32-based RTCU units such as the Mx- and the advertised Logic IO Cx- and Ax devices.

To ensure a wide reusability of code, the software realization will base on generic x32-compatible functions coming with the Logic IO SFL. All device specific parameters and functions, such as e.g. the number of I/O, special peripherals, etc. will be implemented using conditional compilation. Conditional compilation describes the usage of directives which get checked before any other compilation happen, so called preprocessor commands. The conditional directives allow the selectiv in- or exclusion of code for or from compilation depending on the specified conditions. The conditions could either be defined by the `#DEFINE` directive or could be defined in the RTCU IDE project settings. The code example in figure 4.4 will demonstrate the compiler behavior.

```
#DEFINE VIDA350

#IFDEF VIDA350 OR VIDA44M THEN
... this code will be included for both VIDA350 and VIDA44M
... compilation
#END_IF

#IFDEF VIDA44M THEN
... this code will be included only for VIDA44M compilation
#END_IF
```

Figure 4.4.: Exemplary conditional compiling structure, realized with preprocessor commands

This design aims to be compilable for the VIDA350 (based on the RTCU DX4 pro) and VIDA44M (based on the RTCU MX2i pro) product line and will change the parallel software development for two different products to one simultaneous development.

5. Data Input

Providing different input interfaces for the acquisition of process data is one of the most important system features. The digital and analog input of the RTCU device should be used in a multi-purpose way. In order to this, the design allows the definition of different data points relating to a single physical input.

5.1. Digital Input

The RTCU DX4 pro device provides eight DC-isolated digital inputs. The signal level is -5 to 3VDC for a logical "0" signal and 6 to 40VDC for a logical "1" signal level. The input state detection is based on the interrupt control functions featured by the Logic IO SFL. Each of the eight digital inputs will open up the three single data points

- digital state,
- continuous pulse counter,
- differential pulse counter,

beeing individually configurable.

5.1.1. Digital States

For the acquisition of switching operations, the digital state control monitors the digital input behavior. To come across to different monitoring interests the control allows to detect

- the actual state,
- if a input state changed,
- the state changing direction, thus if a falling or rising edge happened.

In consequence of the demand of providing three individual data points per physical input, the state control runs parallel, unaffecting an optional count of pulses.

5.1.2. Pulse Counter

According to the S0-interface standard, the count of pulses directly represents the energy consumption. The counter design presents two different counter models. Both counter models are synchronously available.

Continuous Pulse Counter

The continuous pulse counter model summates all incoming pulses, comparable to the functionality of a common counter reading display. Thus, the acquisition of continuous pulse counter by time come close to an automated alternative in opposition to the manual notation of counter readings.

The progressional summation of pulses comes with the negative characteristic of a possible counter wrap-around[1].

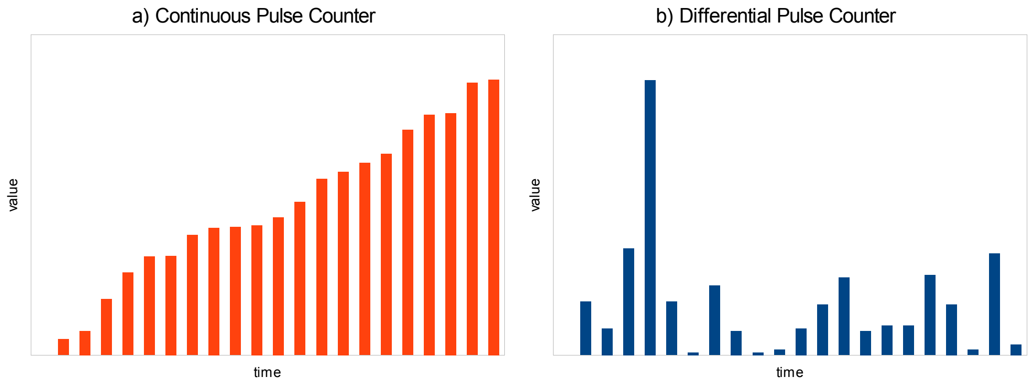


Figure 5.1.: Representation of the same pulse sequence in continuous and differential counting

Differential Pulse Counter

The differential pulse counter method works quite similar to the continuous pulse counter. Unlike the progressional counting, the differential pulse counter sums the pulses partitioned to a defined time window. In contrast to the continuous pulse counter method, the partitioned summation of pulses prevents a wrap-around behavior.

[1] wrap-around describes the effect of an overwrite of the value margin

5.2. Medaflex Clamp-on Ammeter Integration

Focused on an improved applicability for temporary metering installations, the data input design contains the adaptation of the Medaflex clamp-on ammeter made by the german producer MEDATEC[2]. The Medaflex clamp-on ammeter is equipped with a flexible metering coil which is placeable around a power line without opening a wire.[8] The metering principle of the Medaflex clamp-on ammeter is based on the rogowski effect, detecting the actual current by the interpretation of the inductive radiation field.

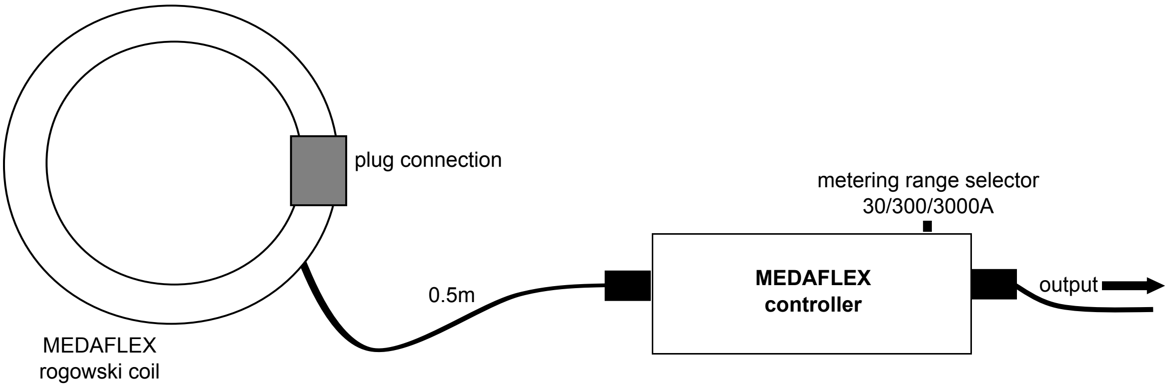


Figure 5.2.: MEDATEC Medaflex scheme

The Medaflex core is based on a microcontroller circuit converting the rogowski coil values into digital or analog output signals. The output mode can be selected by an analog voltage reference.

Mode select voltage U_m	Mode
0V <= U_m <= 12V	analog output in VAC
12V < U_m <= 18V	digital pulse output
18V < U_m <= 24V	debug mode

Table 5.1.: Medaflex current sensor modes

Operating in digital pulse mode, the Medaflex controller acts similar to common pulse meters. But unlike common pulse counter implementations, the Medaflex controller perform a low signal level of 3.3VDC for a logic "1" signal. For the purpose of the signal adaption, the system design will contain an extra source driver[9] to support a signal level corresponding

[2] http://www.medatec.com

to the RTCU device logic level. To allow three-phase current analyses, the adaption module supports the connection of up to three Medaflex rogowski coils to the acquisition system.

The Medaflex controller operates with a 5VDC power supply, provides three switchable metering ranges (30/300/3000A) and is equipped with a four pole connector.

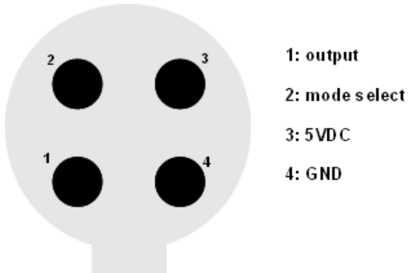


Figure 5.3.: Four pole connector comming from the Medaflex controller

In order to provide a 5VDC supply and an additional voltage referring to the operation mode, the module will contain a DC/DC power supply based on the well-developed L200 voltage- and current regulator IC.[10] For more flexibility and an increased possibility of reuse, both supplied voltages will be scaleable using an onboard potentiometer. The schematic and board layout is designed via the CadSoft[3] EAGLE version 5.10 layout software.

5.3. Analog Input

The analog inputs of the x32-family RTCU can be configured individually to work either as voltage or current measurement input selectable by an onboard jumper. The measurement range in voltage mode is 0 to 10VDC and in current mode it is 0 to 20 mA. In standard setup the analog inputs are set to voltage measurement. With an A/D-converter resolution of 10 bit, the system will display the value with 1023 if the input voltage is 10V, respectively 512 if the voltage is 5V.[5] The analog input values are sampled in real time and get averaged over an array of the last 32767 elements for stabilization.

5.4. 1-Wire Temperature Sensors

The 1-Wire bus system was designed by Dallas Semiconductors Corporation as a communication solution for small devices. The name 1-Wire may lead to some misunderstandings because the 1-Wire technology need at least two wires (ground and data line). The power

[3] http://www.cadsoft.de

supply can be realized with the data line, via the so called parasite power, or with an external DC power supply. The 1-Wire communication standard is similar to I^2C but operating with a lower data rate and comes with the possibility to bridge a longer overall length for communication.[11]

The Logic IO x32-family RTCU comes with an 1-Wire bus interface and additional standard functions to interact with the Dallas Semiconductor DS18B20 1-Wire temperature sensor. The DS18B20 temperature sensor is a well developed sensor which can be found in a multitude of applications. The DS18B20 perform a measuring range from -55°C up to 124°C. For the operation above 100°C, an external voltage supply is recommend, as described in the sensor documentation. This specification is caused by the limited power input being supplied from a 800pF capacitor, charged by the data line when operating with parasite power.[12]

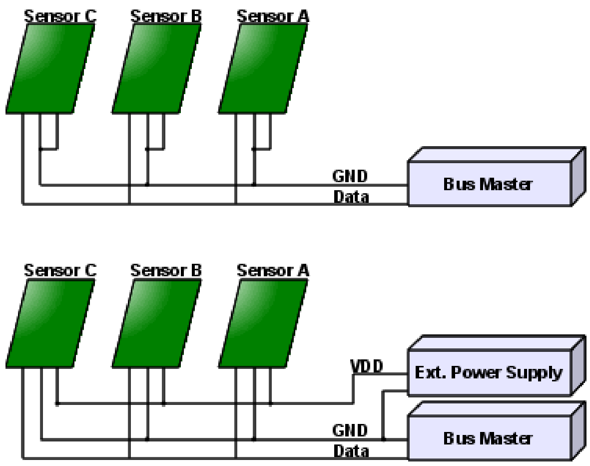


Figure 5.4.: 1-Wire sensor power supply possibilities

To point out which outstanding improvements come along with this new design, the advantages in comparison to temperature measurement using analog sensors should be clarified.

An 1-Wire temperature sensor includes an analog temperature sensor, a communication bus according to the 1-Wire standard, and performs a compensated conversion into digital values. All featured peripherals are integrated in a single integrated circuit (IC). As a direct profit an additional error compensation, that was realized in the past with a combined soft- and hardware solution, is not needed. Extra installation costs and efforts caused by the compensation hardware, the need for extensive three- or four-conducter wiring, and an individual calibration droped out. As known from other bus systems, the 1-Wire standard allows different options in bus wiring and affords a more flexible installation.[13]

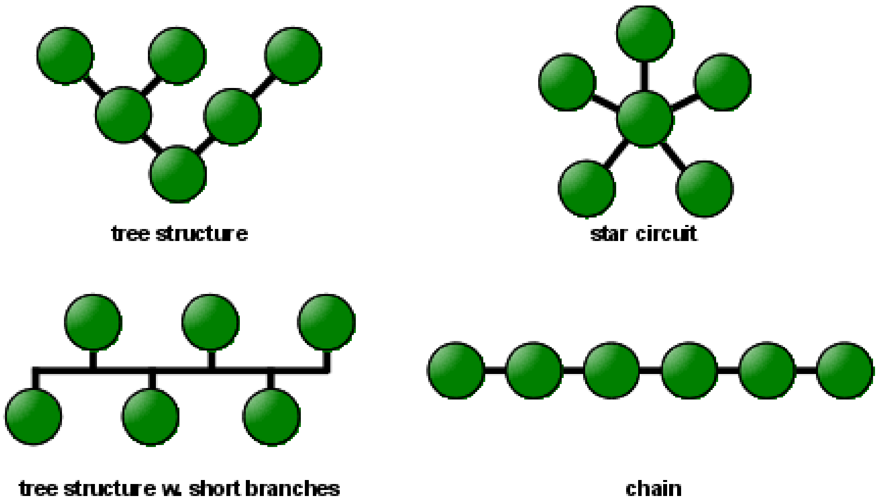


Figure 5.5.: Illustration of the available 1-Wire bus wiring structures

Wiring Type	**Recommendation**
Tree Structure	Max. 100m overall length, only confined for small installations (num. senors <= 20)
Tree Structure w. short branches	Max. 300m overall length, efficient utilization in length
Chain	Max. 300m overall length, optimum utilization in length
Star Circuit	Max. 100m overall length, only confined for small installations (num. senors <= 20)

Table 5.2.: Describtion of different 1-Wire wiring types

To offer a well structured bus communication every 1-Wire sensor has an explicit ID number comparable to the Media-Access-Control (MAC) addresses, well known from ethernet devices. The design will provide up to 18 installed DS18B20 1-Wire sensors at the same time. The temperature sensors need no extra hardware and do not occupy any analog input.

The software design offers an automatic sensor detection. The relation between installed sensors and the data point map is stored in an extra configuration string, to provide a fixed binding even restarting the system. In order to prevent command timeouts on the 1-Wire bus caused by an inactive sensor, a not accessible sensor is ignored after a defined number of connection time outs.

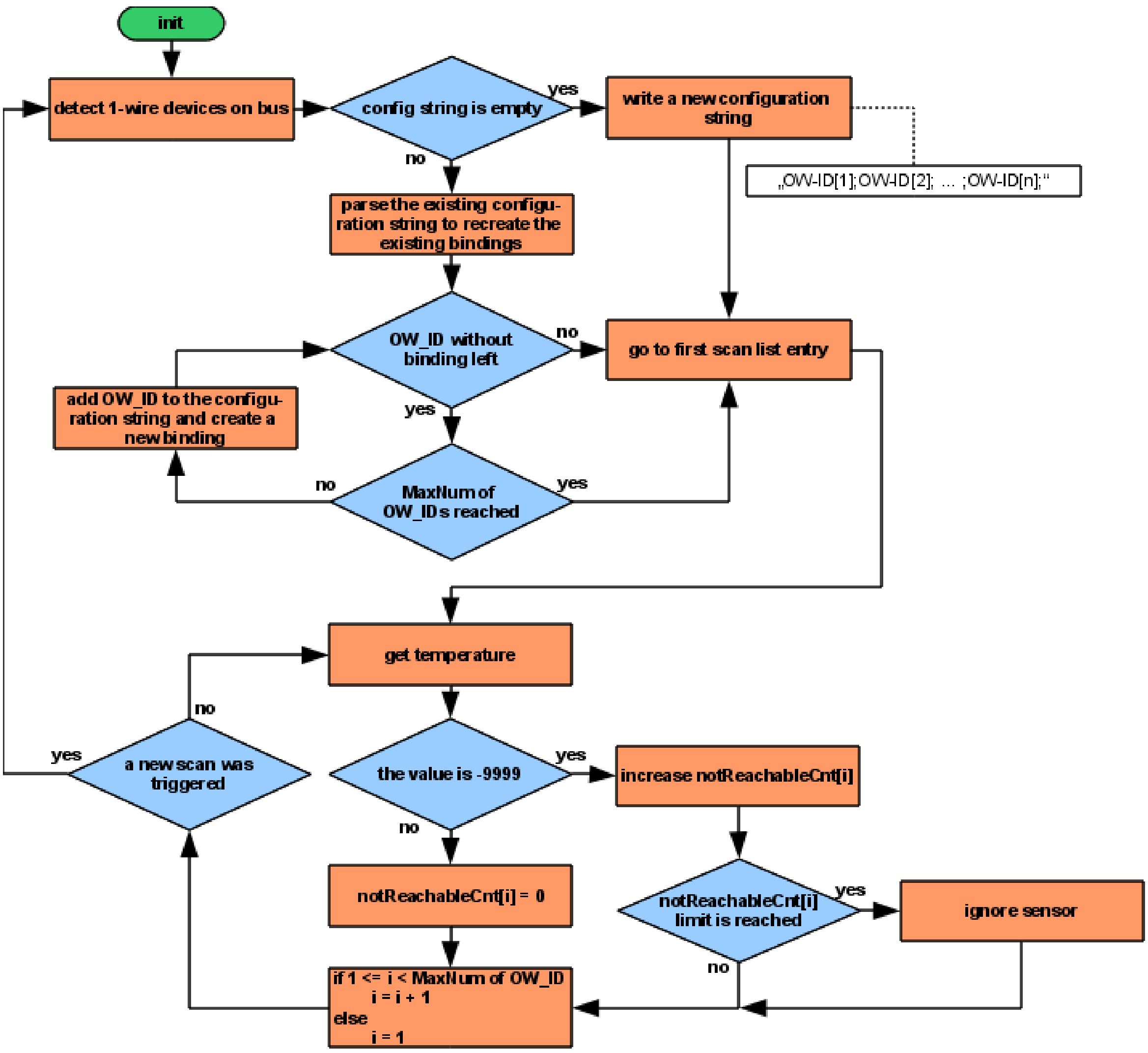


Figure 5.6.: 1-Wire sensor control scheme

6. Data Logging and the Storage of Data

In order to meet the demands of an automated data acquisition system, the log event control and the storage design become an important point in the system architecture. With the requirements arise a variety of challenges on the data storage design. Referring to the system requirements discussed in chapter 3.2, the following subchapter presents the data storage design, including the storage of system paramters and different types of data logging, just as well as the control of data logging events.

6.1. Data Storage

The spectrum of requirements coming with the demand of creating an universal data acquisition system for a wide range of projects, causes a big challenge on the data storage design. The design aims to afford a suitable compromise between

- non-volatile storage of system and program parameters,
- storage of a multitude of data points,
- data acquisition with long hold-back times,
- practicable data format for end-user data processing,
- economically justifiable memory life-time

without restricting the user options of configuring.

The x32 RTCU unit type offers two different possibilities to save data in a non-volatile way. The internal FLASH memory on one hand and the optional use of the SD memory card on the other. Both memory models come with different pro and contra aspects made clear in the comparison, presented in table 6.1.

Internal FLASH Memory	**SD Memory Card**
• fused on-board	• optional mountable
• max. 512 KiByte capacity	• up to 2 GiByte capacity
• expensive to replace	• easy to replace
• difficult to access	• easily accessible

Table 6.1.: Comparison of the different x32 RTCU memory models

To gain a maximum benefit out of the different memory models, the data storage functions will be allocated as shown in the following schedule.

The internal FLASH memory will be used for:

- system- and program-paramters
- basic data logging

The SD memory card will be (optionally) used for:

- advanced data logging
    - logging periods given in seconds
    - long time data acquisition

To guarantee a continuous data logging, all data storage services are implemented as a circuit buffer design.

6.1.1. Internal FLASH Memory

All x32-family RTCU units come with a 512 KiByte non-volatile FLASH memory. The Logic IO firmware devides the FLASH memory into five different allocation areas. The figure 6.1 shows the memory map of the FLASH memory in a x32-family RTCU unit.

The upper addresses in FLASH memory are always locked in size and position. This memory area is subdivided into reserved memory for system contents coming with the Logic IO firmware and into the so called persistant memory. The lower adresses in FLASH memory are flexible. The voice memory is located at the bottom of the FLASH memory and has at least the size of 1 KiByte including the directory information for optional voice messages. The data logger memory is addressed below the persistant memory. The memory between the data logger memory and the voice memory is used for the program code. The range of program memory is scalable, offering to allocate more memory for data logger or voice messages.

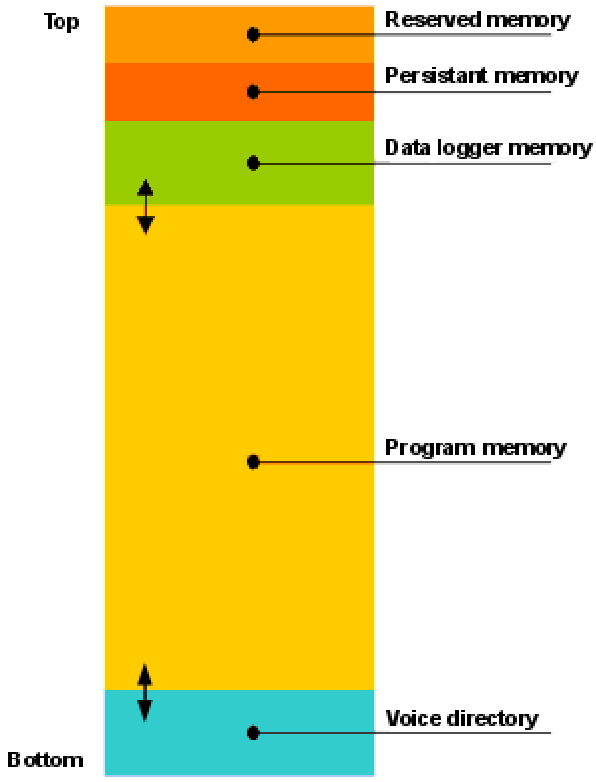


Figure 6.1.: Logic IO x32-family RTCU memory map[7]

For the actual application requirements no voice messages are needed, thus the memory range for voice messages is set to the minimum, while the rest of memory is arranged similarly for data logger and program code.

Configuration Strings

For a flexible software design which is applicable to the specification depending on the project, a configurable system setup is essential. To keep the system parameters save during a long time without power supply, the system configuration is stored into the persistant memory area of the internal FLASH memory. The Logic IO SFL comes with functions to separate the persistant memory into up to 192 strings with a maximum length of 255 characters. Each string is equipped with an index to specify the location in the persistant FLASH memory to read from or write to.

To store the system configuration, the persistant memory strings are arranged with serially numbered indexes. Starting with index number 1, the so called configuration strings contain all needed system parameters. In order to have a clear view on the different software parameters, the configuration string is sorted by functionality. The configuration string arrangement starts with general system parameters at the lower index numbers, followed by parameters for extended system functions. The end of the persistant memory is used for the higher index numbers for an individual configuration string for each data point, the so called data point map. According to this structure, the software configuration can be done by storing several configuration strings in the FLASH memory of the device. The specific items of a string are separated by semicolons. After clearing a string, it will be filled with default configuration data at the next reset of the device.

Index	**Configuration**	**Description**
1	Location String	Name of the device, it is part of the alarm SMS
2	Minute Time Intervals	Configuration of up to 8 minute time intervals
3	Second Time Intervals	Configuration of up to 8 second time intervals
4	Local Time Offset	Difference between UTC and local time
5	GPRS	Configuration of the GPRS communication
6	Port Map	Port configuration of the TCP services
7	SD Card	SD Card configuration
8	System Control	System status control configuration
9	Temperature IDs	Temperature sensor ID configuration
10	Synchronization	Synchronization parameters
11	Heating Control	Configuration of the heating control
12	Cooling Control	Configuration of the cooling control
13	Clock Timer 1	Controls a digital output (controller is coupled with the heating control)
14	Clock Timer 2	Controls a digital output (controller is coupled with the heating control)
15	Clock Timer 3	Controls a digital output
16	Clock Timer 4	Controls a digital output
17 - 32	Alarm	Configuration of 16 alarm controllers
33+	Data Point Map	Data point configuration

Table 6.2.: Configuration string table demonstrating the available system parameters

Data Point Map

The data point map is a special group of configuration strings. In contrast to the ordinary configuration strings, that have always the same structure, the data point map depends on the specific x32-family RTCU platform. The data point map consists of a configuration string for every data point describing the individual behavior on log events. The data point configuration starts with the abbreviation "DP" in combination with a serial numeration and a short describtion followed by the log event behaviors. A typical configuration string defining the data point map looks like:

```
DP9 Differential Counter 1; 0; 0;
```

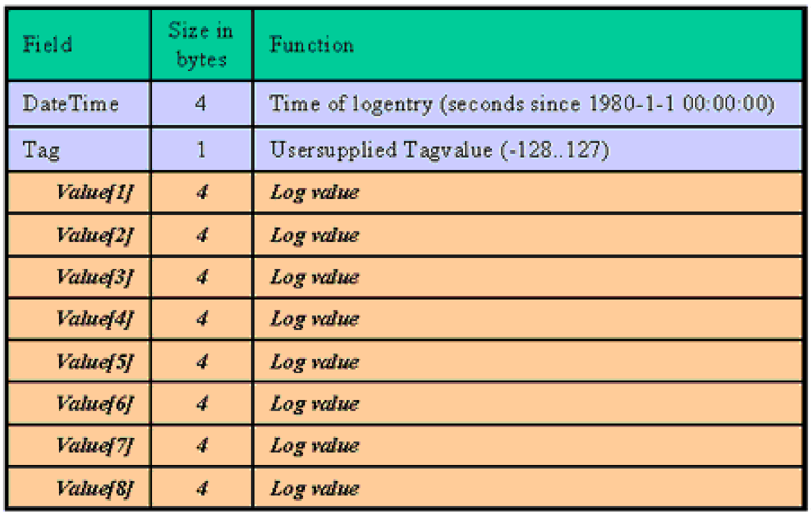
Table 6.3 presents an overview of the data point map on the supported RTCU platforms. As seen, the VIDA44M relating MX2i RTCU platform supports an additional Global Positioning System (GPS) module. Apart from this, both devices differ only in the number of I/Os. Because the system design is based on the VIDA350 software core, the GPS implementation is not further discussed in this thesis.

DP Index	VIDA350	DP Index	VIDA44M
1- 8	Continuous Counter 1 - 8	1 - 4	Continuous Counter 1 - 4
9 - 16	Differential Counter 1 - 8	5 - 8	Differential Counter 1 - 4
17 - 24	Digital Input 1 - 8	9 - 12	Digital Input 1 - 4
25 - 42	Temperature 1 - 18	13 - 30	Temperature 1 - 18
43	System Temperature	31	System Temperature
44 - 47	Analog Input 1 - 4	32 - 33	Analog Input 1 - 2
		34	GPS Latitude
		35	GPS Longitude
		36	GPS Speed
		37	GPS Height
		38	GPS Course
48+	MODBUS I/O Extension	39+	MODBUS I/O Extension

Table 6.3.: Overview on the data point map structure of the software, including both VIDA350 and VIDA44M compilation versions

Data Logger

To get access to the data logger memory within the internal FLASH chip, the Logic IO SFL provides functions for initialization, read and write operations. The data logger has a circuit buffer structure replacing the oldest log entry with a new value, if the data logger memory capacity is completely in use. The number of data point values stored per log entry depends on the datalogger initialization.



Field	Size in bytes	Function
DateTime	4	Time of logentry (seconds since 1980-1-1 00:00:00)
Tag	1	Usersupplied Tagvalue (-128..127)
Value[1]	*4*	*Log value*
Value[2]	*4*	*Log value*
Value[3]	*4*	*Log value*
Value[4]	*4*	*Log value*
Value[5]	*4*	*Log value*
Value[6]	*4*	*Log value*
Value[7]	*4*	*Log value*
Value[8]	*4*	*Log value*

Figure 6.2.: Logic IO SFL datalogger initialization[7]

The system design provides an initialization with one value per log entry, providing a dynamic system with individually configurable data points. The tag value, seen in figure 6.2, will be equal to the data point number and refers to the data point map.

A general disadvantage of FLASH memory is a physically limited number of erase cycles until the memory looses the integrity of the storage. The life time duration of FLASH memory is in direct relationship with the number of values stored per log entry. This correlation is based upon the absolute size in memory per value.

In consequence of the design, the initialization allows up to 51968 log entries into the data logger memory, until the oldest log entry is replaced. A minimum number of over 3 million write operations are guaranteed by the manufacturer.[14]

In regard to the limited number of erase cycles, the internal FLASH memory data logger is only be used to store data with a logging resolution given in minutes. The result is a reasonable hold-back time. An exemplary hold-back time is 54 days for ten data points with a resolution of 15 minutes.

Log-values per. log-entry	Total number of log-entries	Number of logWrite() operations
1	51968	3090655
2	35840	4480000
3	26880	5973333
4	21504	7466666
5	17920	8960000
6	16128	9955555
7	14336	11200000
8	12544	12800000

Figure 6.3.: Limitation of FLASH memory write operations depending on the data logger initialization[7]

6.1.2. SD Memory Card

The Secure Digital (SD) memory card technology was developed by Panasonic, SanDisk and Toshiba and is well known from mobile devices such as digital cameras, handheld computers, or mobile phones. Generally, the SD memory card technology follows the principles of FLASH memory. Therefore, the SD memory has the same limitation of erase cycles. But counterbalanced by the size of up to 2 GiByte, that is supported by the x32-family architecture, makes the SD memory card become an interesting optional data storage device for special logging setups. In addition to this, File Allocation Table (FAT) compatible SD memory cards have an intelligent file system, which allows to increase the life-time using features like marking corrupted clusters instead of using them. Further the SD memory card comes with big commercial advantages, for instance the low memory costs and an economical replaceability. The SD memory card becomes a good option for the storage of a large amount of data balancing life-time and economic necessities.

In order to optimize the settings for a long time data acquisition or a high resoluted data acquisition, two different operation modes are designed.

1. Synchron Mode:

   This operating mode uses the SD memory card synchron to the internal FLASH data logger for long time data acquisition. Thus the system will synchronously log all log events coming from the internal data logger to the SD memory card. The hold-back time is depending on the chosen data format, and can be increased up to many years.

2. Asynchron Mode:

   This operating mode uses the SD memory card asynchron to the internal FLASH data logger, making it possible to acquire data points with a high logging resolution. Setting up the system to this operation mode will enable a logging behavior on the SD memory card which is independent from the internal data logger configuration. Thus making it possible, to log data periodical with time intervals given in seconds.

To prevent problems, caused by writing all data into a single file, the system writes separated files during fixed periods.

6.1.3. Data Formats

The chosen data format is directly related to the needed data space per logged data point. There are two principle ways to write data into a file, writing binary data or writing American Standard Code for Information Interchange (ASCII) characters.

In order to create a system with a high degree of freedom both modes are implemented.

ASCII Data Format

The big advantage of the ASCII data format is the readability. An ASCII format is characterized by a clear structure aimed for intuitive human readability, using only a simple text editor. An unobstructed data importing into standard spreadsheet software, such as Microsoft Excel or OpenOffice Calc is a key advantage. In order to achieve the compatibility to the Envidatec My-JEVis system import interfaces, the design contains an implementation of an already exisiting data format.

The format is structured line-by-line where every line represents a single data point. The line content is specified as

```
<time stamp>,<data point number>,<value>
```

where the `<time stamp>` represents the logging time formated in Universal Time Coordinated (UTC) standard as

```
DD.MM.YYYY hh:mm:ss
```

seperated by comma, followed by the specific data point number and the referring value.[15] A correct formatting is shown in the example below:

Caused by the human readable formatting, a single logged data point reserves at least 23 byte in memory. The needed memory for additional data points is linear, e.g. at least 230 byte in memory for a setup of ten synchron data points.

```
29.04.2010 14:45:00,1,12.23
29.04.2010 14:45:00,2,169.13
29.04.2010 14:45:00,3,26.00
30.04.2010 15:00:00,1,13.12
30.04.2010 15:00:00,2,169.80
30.04.2010 15:00:00,3,26.20
```

Binary Data Format

The big advantage of using a binary data format instead of an ASCII format is the considerably reduced memory space needed. The minimization of redudant information and formatation, is achieved by:

- identic time stamps are saved only once
- no formatation characters like seperators or new line are needed
- each variable has a fixed size unafflicted by the specific content

The advantages in memory usage when writing data binary into a file comes with the loss that the processing of data is only possible with an extra interpretation software. The complexity of the data format should be minimized to enable an easy data conversion. Due to this, the binary data format will contain only two different types of data frames.

1. Set frame
   The set frame content describes the active data point log events referring to the data point map configuration. The payload is a 16 byte long bit stream where every single bit represents the active (1) or inactive (0) setting for each data point, starting with 1 up to 128.
2. Data frame
   The data frame contains the data point values referring to the order described in the valid set frame.

The frames are distinguished by the leading byte.

	Mode	**Payload Content**
Set Frame	0x00	16 byte describing the active data point map
Data Frame	0xFF	Time stamp followed by logged data in order and as desribed in the set frame

Table 6.4.: Data frame types in the binary data format

The result of this design, is a compact data format reducing the reserved data space per logged data point, scaling down with a raising number of active log events. This design allows to store a great amount of data over a long time. Ten data points with a resolution of 1 second can be stored about two years without overwriting an older value. A setup of ten 32-bit counter will cause a fixed memory usage of 40 byte and a set frame of 17 byte. With only one time setup, the set frame is only stored once per file.

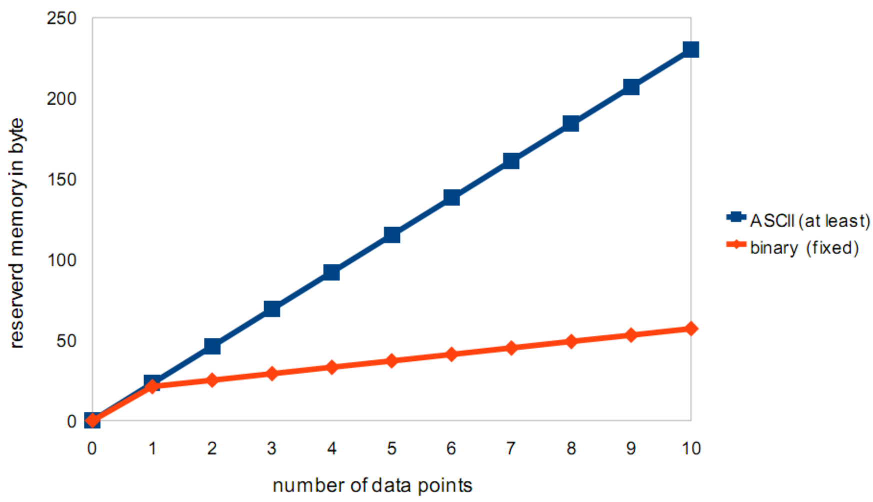


Figure 6.4.: The memory usage of the binary format compared to the ASCII format

To guarantee a faultless interpretation, two specifications must be defined:

1. Every correct file has to start with a set frame.
2. The specific data point variable size must be known for correct data interpretation.

The system will arrange a structure following the principle of one data directory per day, to implement a clear directory structure.

6.2. Log Event Handling

The system has to handle several conditions to trigger a data storage. The faultless detection of log events depending on time or state is an important system process. To come up on this high priority, the log event handling function gets triggered as often as possible, in the so called real time.

6.2.1. State Control

For the logging of digital states an asynchron log event detection has to be realized. The log event handle process directly polls the values of the variable referring to the digital states, as described in the chapter 3.1.1 Digital Input.

6.2.2. Time Control

The system offers an individual time interval configuration for the continuous data acquisition by time. To provide a system with a large degree of freedom, the system design supplies up to eight free programmable time intervals, respectively for second and minute resolution.

Two configuration strings are reserved for the time intervals given in minutes and accordingly for the time intervals given in seconds. Each configuration string has eight values separated by semicolons. The user is free in choosing a integer value for the time interval, where a "0" value means that the programmable interval is not in use.

Default values for intervals given in minutes:

```
1;5;10;15;30;60;0;0;
```

Default values for intervals given in seconds:

```
1;2;5;10;15;20;30;60;
```

The time intervals running synchronously with the internal real time clock (RTC) are described by an eight bit mask. Each bit represents the state of one time interval, where "1" symbolizes a match. The state of the first time interval up to the state of the eighth time interval are arranged from the least significant bit (LSB) to the most significant bit (MSB). The interval preferences are loaded from the according configuration string at run-time.

The several time intervals are compared with the system time by using a `MODULO`[1] operation. This comparison is repeated continuously once per minute, respectively once per second. The state of the time bit mask is updated by a bitwise `OR`[2] operation.

[1] The MODULO operation finds the remainder of division of one number by another.
[2] A logical OR operation results true whenever one or more of its operands are true.

Time hh:mm	**[8]**	**[7]**	**[6]**	**[5]**	**[4]**	**[3]**	**[2]**	**[1]**
**:02	0	0	0	0	0	0	0	1
**:05	0	0	0	0	0	0	1	1
**:45	0	0	0	0	1	0	1	1
**:50	0	0	0	0	0	1	1	1
**:00	0	0	1	1	1	1	1	1

Table 6.5.: Five examples demonstrating the different time bit mask results referring to the default minute interval configuration

In order to prevent difficulties with different time zones, the system time should always be in UTC standard. UTC is based on the International Atomic Time (TAI) and corresponds to Greenwich Mean Time (GMT) without a clock change for summer time. The persistant memory includes a configuration string to define an offset between the local time zone and UTC, e.g. to display the local time onto the included Liquid Crystal Display (LCD) of the RTCU DX4 pro device. Unaffected by the local offset, the data acquisition and other time based functions always run synchronously to the system RTC being set to the UTC standard.

Figure 6.5 gives an overview of the log event handler behavior.

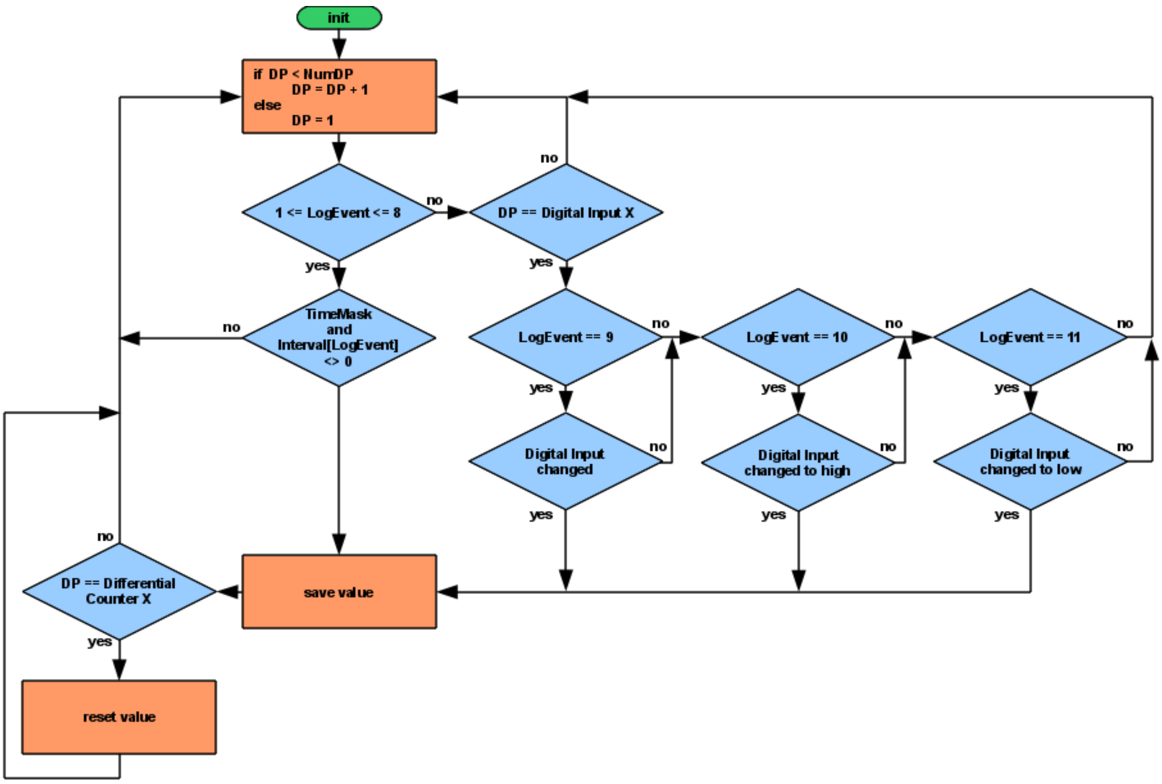


Figure 6.5.: Log event handling scheme

The event handler behavior is verified by a bitwise `AND`[3] operation between the actual time bit mask and the referring data point configuration. An example is shown in figure 6.6.

Time	**[8]**	**[7]**	**[6]**	**[5]**	**[4]**	**[3]**	**[2]**	**[1]**
LogEvent[DP]	0	0	0	0	1	0	0	0
TimeMask	0	0	0	0	1	0	1	1
Result	0	0	0	0	**1**	0	0	0

Table 6.6.: Demonstration of the generation of a time log event using a bitwise AND operation

[3] A logical AND operation results true when all operands are true, otherwise the operation results false.

7. Communication

A sophisticated communication design is the basis to meet for several challenges, such as data readout and remote maintenance. As described in chapter 3.3, for a portable data acquisition system a good communication design is characterized by:

- connectivity
- reachability
- security

To come up to this requirements, the communication design is realized by using mobile telemetric standards and is integratable into existing network structures. Past communication designs are based on the Global System for Mobile Communications (GSM) using direct data call connections.

7.1. IP via GPRS

The General Packet Radio Service (GPRS) is a packet-oriented mobile data service based on the GSM network. The technical innovation of GPRS in relation to classic GSM is the use of principle of packet-switched communication. The main benefit is an always-online communication charged per data volume in contrast to classic circuit-switched communication, where data transfer is billed per minute. Additionally, using GPRS instead of classic GSM makes modem hardware superfluous on the control center side. The GPRS network standard comes with all typical features of digital communication, such as encoding and digital error checking. The communication is based on using the standard Internet Protocol (IP). In opposition to further advanced communciation standards, such as the Universal Mobile Telecommunications System (UMTS), the availability of GPRS is well developed world wide. GPRS comes with a wider bandwith (56 - 114 kbit/s) than GSM (9.6 kbit/s) and allows a more fault-tolerant communication, especially at low signal strength. The GPRS tariff price level is comparable with classic GSM communication costs.[16]

The always-online infrastructure of GPRS allows

- increasing actuality of data,
- continuous automated maintenance,
- a short reaction time for problem solutions.

Additionally the GPRS modem should perform a common 24 hour automatic reconnect to increase the communication system stability.

The variety of advantages are accompanied by two particular disadvantages linked with typical GPRS communication.

1. Only unidirectional communication, initiated by the Subscriber Identity Module (SIM) client, is possible. A communication initiated from another side is not possible, because the client network address is located behind a routing device on the side of the internet service provider (ISP), running a network address translation (NAT).
2. All communication takes place via the public internet, transparent for and unprotected from third parties.

7.2. Virtual Private Network

Virtual Private Network (VPN) generally describes a software based solution to connect several physical networks (e.g. Ethernet and GPRS) to a collective network without any barriers in IP communication. VPN does not stand for a standardized protocol, VPN is rather a technical solution, which can be realized in several ways. Depending on the VPN implementation, there are different possiblities to encrypt the transferred data. As a benefit from an encrypted data transfer, the communication is secured from man-in-the-middle[1] or manipulation attacks from third parties and can be established through an insecure network, such as public internet, without increased security risks. In this case the VPN technology will be used to connect the ISP with the Envidatec IT structure, using a secure VPN tunnel realized by the Internet Protocol Security (IPSec) standard, a so called Site-to-Site-VPN.[17]

To realize this Site-to-Site-VPN setup, the SIM cards have access to a specific customer access point name (APN) in stead of connecting to the typical public ISP's APN. The SIM client users are authenticated by password or by SIM card ID. All data transfer coming from a successful authenticated SIM user is forwarded from a specific ISP router, the so called VPN terminator. The data is encrpyted by the IPSec protocol and forwarded to the Envidatec VPN concentrator. All SIM cards getting forwarded through the IPSec tunnel have a fixed

[1]The man-in-the-middle method describes an attack based on the redirection of data streams to spy out or even manipulate data

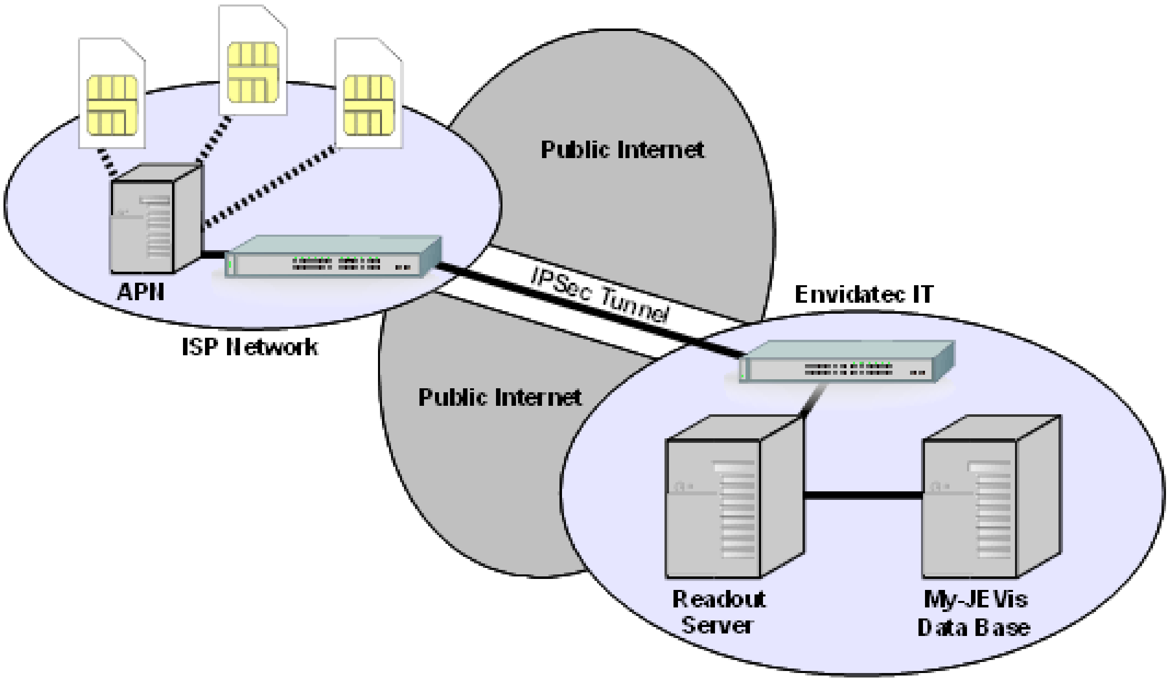


Figure 7.1.: Site-to-Site-VPN structure between the Envidatec GmbH and the ISP network structure

IP address, which is bound to the user authentication. The result of this architecture is a full service IP network, which combines different physical interfaces. The design follows state-of-art security aspects and has the possibility to be expandthe network further.

In summary the design of IP based communication via GPRS in addition with overlaying VPN technology comes with the advantages of

- a separated, private IP address range outside the public internet address range
- fixed client IP relations
- bidirectional communication
- full IP network administration privilegs
- IPSec based encrypted communication

which allows a functionality comparable with a local area network (LAN).

7.3. Data Readout Interface

The GPRS/VPN communication design offers a bidirectional IP communication that can be used to realize a remote data readout. To transmit data from the data acquisition system to the data base server, a communication protocol, implemented on both sides, is essential. To avoid the effort for a new transfer protocol, this design aims to implement standard protocol, which also minimizes the complexity of the implementation. The chosen transfer protocol is the Hypertext Transfer Protocol (HTTP) 1.0 standard, which is easily accessible using a standard like web browser or a command line client.

To readout data from the device, a minimal HTTP daemon performing a `GET` method implementation is sufficient. The HTTP `GET` method is the common function to get contents out of the world wide web. Everytime a web page is opened by standard web browser, the browser connects to the HTTP service addressed by the Uniform Resource Locator (URL) and sends a `GET` command, to request a data transfer, e.g. `GET /index.html`.

In contrast to common web applications the HTTP service sends logged data to the responding client. The HTTP daemon has to addressed in the following way:

```
<IP address>:<port>
```

If the port is set to the default value common HTTP clients will not need an explicit `<port>` statement. The requested information is assigned by a slash followed by a string, the so called HTTP query. If the request is related correctly the HTTP starts sending a HTTP header according to the HTTP/1.0 standard and the data transfer is initiated. The specific `<Content-Type>` parameter depends on the transfered data format, e.g. an ASCII CSV file or a binary data file. Contrary to a correct request an unresolvable request will cause an error, according to the HTTP/1.0 standard, shown in table 7.1.[18]

HTTP/1.0 200 OK response	HTTP/1.0 404 Not Found response
`HTTP/1.0 200 OK`	`HTTP/1.0 404 Not Found`
`Server: VIDA HTTP-DAEMON`	`Server: VIDA HTTP-DAEMON`
`Connection: close`	`Connection: close`
`Content-Type: text/csv`	
`Content-Length: (size in byte)`	

Table 7.1.: Implemented HTTP responses

The internal data acquisition and the optional SD card acquisition follow different methods in saving data. Caused by this circumstance the data is available in several forms. All data saved to the SD memory card is already formatted after logging and is sent in a ASCII or respectively binary data file. In contrast to the SD card data storage, values saved in the internal FLASH memory are stored unformatted. To transfer data relating to a request, the data has to be formatted into a structured file format. To fulfill this intention, the same formatting function implemented for ASCII mode in the SD memory design can be used.

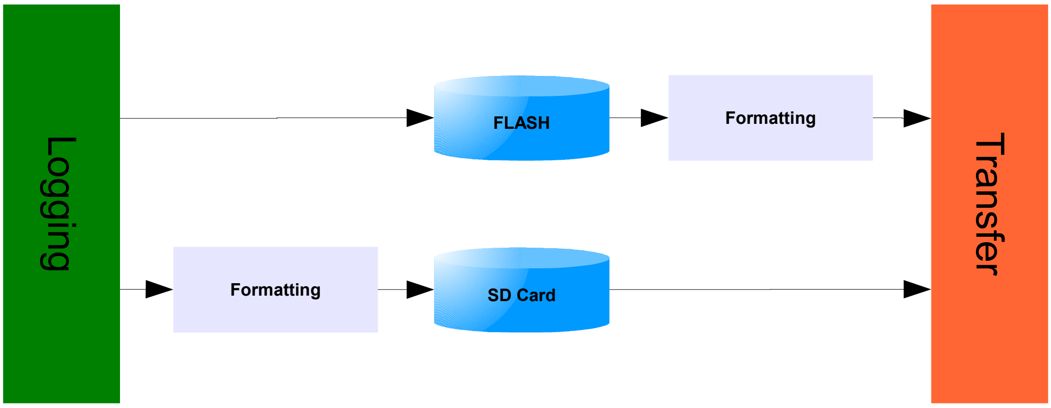


Figure 7.2.: Data write- and readout operation scheme

For the post-storage formatting, another ASCII data format used by common Envidatec applications is implemeted. The format starts with a preceding file header containing two lines:

```
<description line>
<caption 1>;<caption 2>;<caption 3>
```

I is followed by an arbitrary number of data lines, as shown below.

```
<value>;<time>;<date>
```

A complete example of a data file:

```
Env HQ - Metering Station 1
Value;Time;Date
219,28;20:45:00;05.06.2009
207,6;21:00:00;05.06.2009
208,8;21:15:00;05.06.2009
```

This implementation is a practicable solution, being compatible to the existing My-JEVis system and enables the query for a single data point (DP) request. Table 7.2 illustrates the valid HTTP queries.

Function	**HTTP-Query**
Single DP from int. FLASH without time range	`/DPx` where `x` stands for the DP number
Single DP from int. FLASH with time range	`/DPx-<start time>-<end time>` where `x` stands for the DP number
All DPs from int. FLASH without time range	`/DPall`
All DPs from int. FLASH with time range	`/DPall-<start time>-<end time>`
All DPs from opt. SD card without time range	`/SD`
All DPs from opt. SD card with time range	`/SD-<start time>-<end time>`

Table 7.2.: Valid HTTP query content

The time formatting is defined without any seperators in the format: `DDMMYYYYhhmmss`, e.g. the date 2009-12-21 11:12:13 is stored as `21122009111213`.

7.4. Remote Maintenance

Based on the IP communication, the communication design contains a primary remote control service. The remote control design is compatible to commonl software, e.g. a telnet clientand supporting a direct IP socket communication as well. The remote service allows the reading and writing of all system parameters. Additionally, the remote service offers the possibility to get several status informations out of the device and supports a time synchronization. The service port is configurable and is running by default on telnet standard port number 23.

To improve the availability, a redundant remote control is implemented. The redundant remote control uses classic GSM, based on a direct circuit-switched data call, to access the device. The GSM fallback is realized with the Logic IO firmware and allows a direct serial connection by using the RTCU IDE.

8. Case Design

The basic idea for design is based on the integration of DIN rail components into a portable case. Another important point is the creation of a clear user interface.

8.1. Peli Case

Peli Products is the trading name of Pelican Products Inc. in Europe. Peli Products is a producer of protection cases for military or industrial use. The Peli Case 1400, made of high quality plastic material, has the dimensions L:339 x W:295 x H:152 mm.[19]

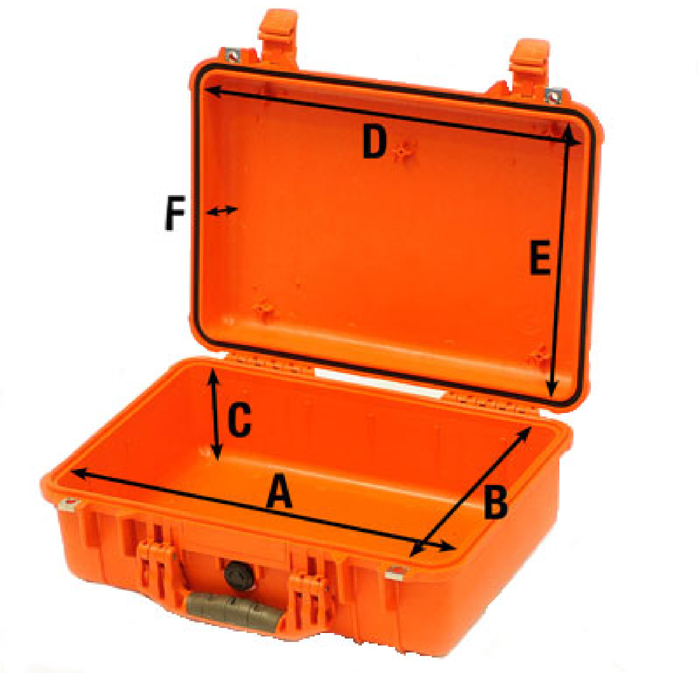


Figure 8.1.: Peli Case 1400 [19]

Base Length (A)	Base Width (B)	Base Depth (C)	Lid Length (D)	Lid Width E	Lid Depth F	Total Depth
306 mm	234 mm	100 mm	306 mm	234 mm	30 mm	130 mm

Table 8.1.: Peli Case 1400 internal dimensions [20]

If closed, the Peli Case 1400 is watertight and dustproof, certificated according to the IP67 standard. The Peli Case 1400 is robust and has a lifetime guarantee.

For the electronical installation a solid mounting plane is integrated into the Peli Case. Upon the mounting plane a built-in DIN rail allows an installation of DIN rail components. The external 230VAC power is realized with a BELDEN[1] IP67 power connector. For safety reasons the mounting plane, including the DIN rail, is connected to the protective earth conductor of the external power supply. Additionally, the electronic system is secured by an extra fuse.

8.2. Front Panel

Peli Products offers a mounting bracket to install electronic or instrumentation panels. The front panel made of anodized aluminum material provides a clear view on the functions. All necessary connectors are integrated in the front panel. The front panel layout is realized with the program Frontplatten Designer Version 4.01, provided by the Schaeffer AG[2].

To provide a quick and easy installation the front panel is equipped with screw clamps which allow to connect wires and pin plugs the same way. The programming interface is accessible using a common RS-232 connector. Contrary to the common connector concept, digital input 1 to 3 is equipped with a four pole connector suitable to the Medaflex clamp-on ammeter. The DIN rail components can be operated through a cut-out in the center. For the electric security the front panel is also connected to the protective earth conductor.

The finalized front panel is ordered and manufactured by transferring the layout file to the Schaeffer AG.

[1]BELDEN, prior Hirschmann, is a producer for electronical equipment. http://www.belden.com
[2]http://www.schaeffer-ag.de

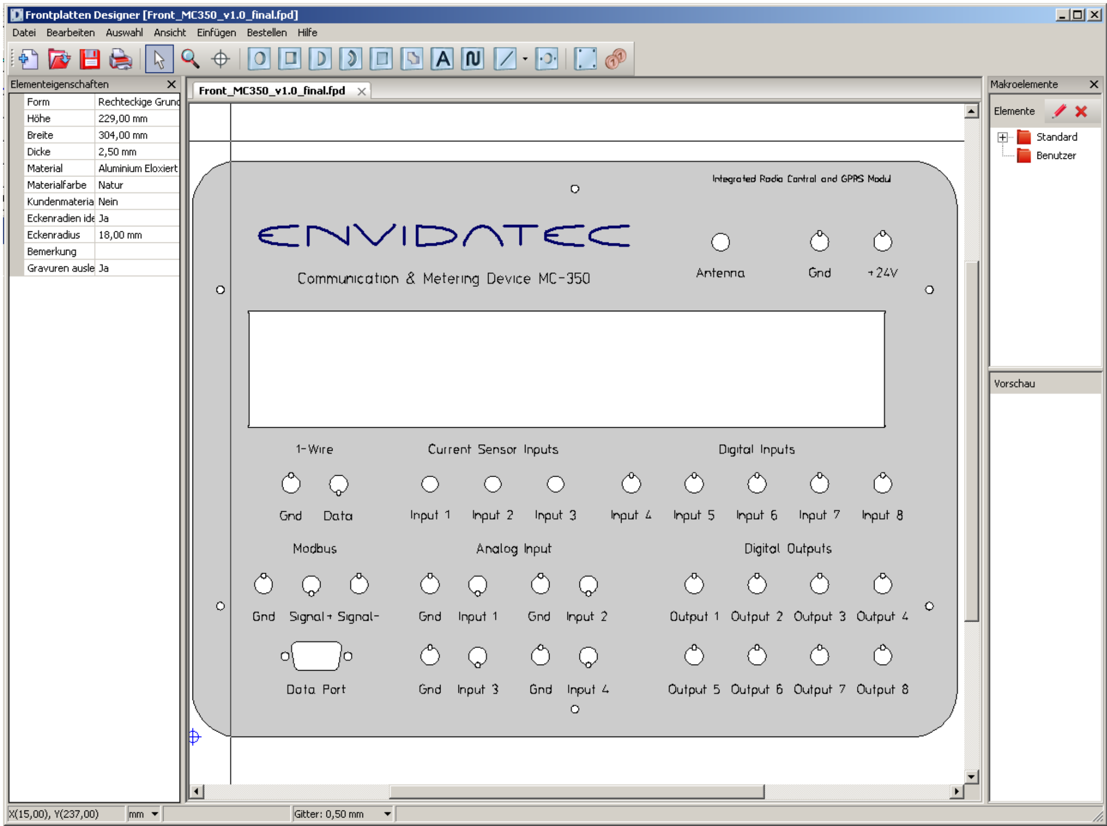


Figure 8.2.: Schaeffer AG Frontplatten Designer version 4.01

9. Realization

The following chapter shows the realization of the developed design. The resulting product is named MC-350. The chapter starts with a gerneral overview on the MC-350 and further discusses different setup possibilities.

As described in the case design, all system components are integrated into a robust Peli Case. With all components, the case weighs about 4kg. In the closed state, the internal is well protected against external exposur.

Figure 9.1.: Top-view on the MC-350 in closed state

If opened the MC-350 is characterized by a functional user interface. All needed connectors are directly accessible on the front panel.

Figure 9.2.: Front panel of the MC-350

9.1. System Installation

To prepare the power supply of the MC-350, the included power connector is plugged to the MC-350, after removing the protection cap. The power supply is applied by an external 230VAC source. The integrated 24VDC power supply is activated by the included cutout switch. A green LED, indicates a faultess operation state.

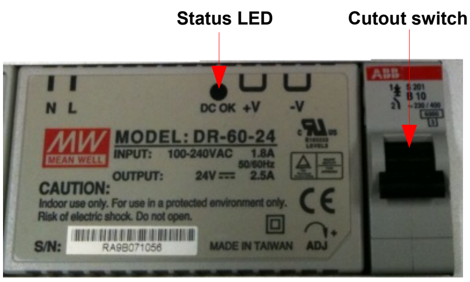


Figure 9.3.: MC-350 power 24VDC voltage supply, integrated in the right middle of the front panel

The boot process starts automatically when the power is switched on. While the boot process performs, the LCD shows the software version. If no configuration is loaded to the system memory, e.g. starting a new system, all system parameters will be set to the VIDA350 v2.00

default values. After initializating all system services, the LCD displays several system states. The LCD is divided into two lines, where the first line is reserved for variety system states. By pushing any navigation key next to the LCD, the integrated graphical system menu can be opened. The system menu provides several options to view actual system states or to set up basic system functions. The navigation keys are used to browse the menu, where OK confirms and respectively ESC discards changes.

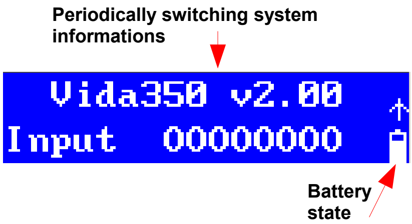


Figure 9.4.: Illustration of the LCD displaying the software version at startup

The MC-350 is equipped with an internal battery pack, allowing operations up to 12 hours without external power supply. The actual charging state is displayed by a battery symbol, located at the bottom right of the LCD. If operating with internal power supply the LCD turns off.

9.2. Establishment of Communication

In order to establish the mobile communication, the including GSM antenna has to be installed upon the antenna connector, located at the top right of the front panel. The MC-350 is equipped with a special SIM card, providing a flatrate tariff communication within 19 countries. All GPRS parameters are preset in the VIDA350 v2.00 firmware, thus no GPRS setup will be necessary to connect it to the My-JEVis network. The communication status is displayed by an antenna symbol located at the top right of the LCD. Additionally, the first display line periodically displays the actual signal strength in percent.

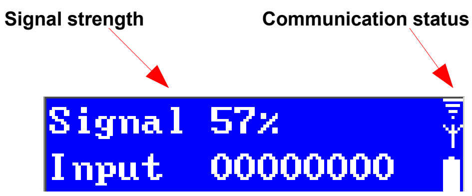


Figure 9.5.: LCD with communcation status and signal strength

The general GPRS configuration is accessible using the graphical system menu.

System Menu → Setup Menu → GPRS

After connecting to the My-JEVis network, the data readout is triggered by the My-JEVis system. Within the My-JEVis system a direct connection to the TCP/IP remote contro is possible, by using a standard telnet client.

The remote interface offers direct access to the system status and provides different functions, allowing an easy system configuration.

Figure 9.6.: IP connection for remote maintenance using a standard telnet client

The remote interface provides a direct access to the FLASH memory, allowing the modification of all configuration strings by using the hidden `saveString` command. The direct modification of configuration strings is recommended only for trained users.

9.3. Installation of a Digital Inputs

All digital inputs are low-pass filtered and transient protected.[5] The digital inputs 4 to 8 are equipped with screw clamp connectors, allowing the connection of 4mm plugs and conducters with a profile up to 1.5mm^2. To record a digital state, the signal line is directly connected to a digital input. The reference ground (GND) voltage is connected to the system GND, located at the top right of the MC-350.

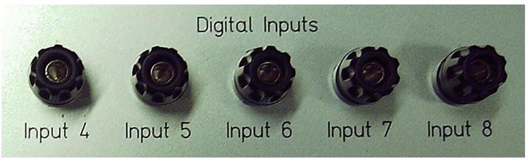


Figure 9.7.: MC-350 digital inputs 4 to 8

The second LCD line is reserved for the status report of the digital inputs. The eight digits corresponds to the eight digital inputs. The "0" indicates a logic low state and the "I" respectively the logic high state.

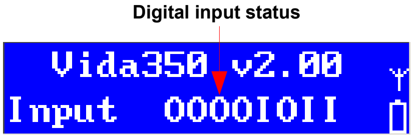


Figure 9.8.: Illustration of the LCD displaying the status of the digital inputs

9.4. Pulse Counter Installation

The digital input 4 up to 8 can be used to install a common pulse interface to the MC-350. Following the S0 working principle, the pulse interface is supplied by the MC-350. Therefore, the S0+ input of the pulse counter is connected to the 24VDC power supply. In order to record pulses coming from a meter, the S0- output has to be connected to one of the available digital inputs.

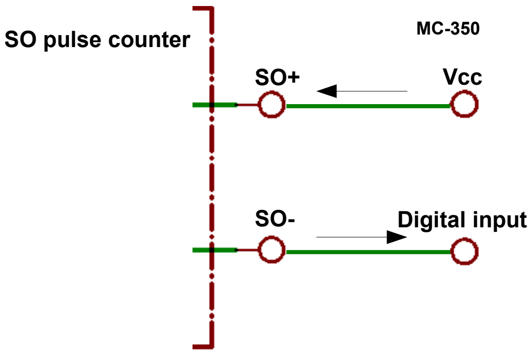


Figure 9.9.: Pulse counter installation according to DIN 43864

A basic pulse counter configuration is configured using the graphical system menu:

System Menu → Setup Menu → Data Points → Dig. Counter

9.4.1. Medaflex Clamp-on Ammeter Installation

Digital inputs 1, 2, and 3 are equipped with a suitable four pole connector, to support an easy installation of up to three Medaflex clamp-on ammeters. The input connector 1 to 3 is directly linked to the customized adaption module.

Figure 9.10.: Installation of a Medaflex clamp-on ammeter

The metering range can be 30, 300, or 3000A selected using the integrated switch of the Medaflex controller. The logging configuration is set according to the pulse counter, using counter 1 to 3.

9.5. Temperature Installation

The MC-350 supports the installation of up to 18 1-Wire temperature sensors. The sensors can be connected to the 1-Wire bus connectors at the bottom left of the front, using a star, tree, or chain wiring structure.

At the startup, the system performs a bus scan and automatically initializes all plugged in sensors. To ensure a correct assignment of temperature data points, even after restarting the system, the relation between installed sensors and referring data point is saved in a special configuration string. Therefore, a single system restart detects and configures all installed sensors.

A basic acquisition of temperatures can be configured using the graphical system menu:

System Menu → *Setup Menu* → *Data Points* → *Temperature*

A basic acquisition of temperatures can be configured using the graphical system menu.

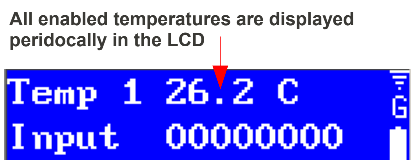


Figure 9.11.: The LCD displays the enabled temperature sensors

9.6. Installation of Analog Sensors

For the installation of an analog sensor, the input signal is connected between analog input and the relating analog GND reference. The GND has to be connected to the reference of the connected equipment. By using onlywires of the same length and profile the metering accuracy is improved.

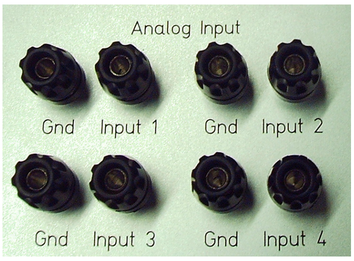


Figure 9.12.: Four analog inputs with associated GND provided by the MC-350

The analog inputs are sensible to elecontrical interference, so deviations may occur. To reduce deviations, avoid long unshielded wires and fast changing signals routed parallel to the analog signals. The impedance of the analog inputs is 40kΩ.[5]

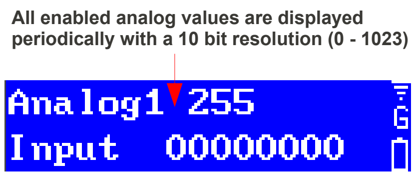


Figure 9.13.: The LCD displays analog values

9.7. Advanced Configuration

For an advanced configuration of all system settings, the MC-350 provides two possibilities to access the configuration strings directly.

1. Using the RTCU IDE tools, by a direct programming cable connection. To establish a programming cable connection a common serial cable is connected to the RS-232 data port, located at the bottom left of the front panel.
2. Access the configuration via the remote control interface.

Unafflicted by the chosen connection the user should be aware of the impacts, caused by the system modification.

10. Conclusion

Making process data visible is an essential measure for the implementation of projects focused on the increasing of energy efficiency. As shown in the beginning of this study the nature of aimed projects are widely spread. The present thesis discusses the concept of using programable hardware dealing with these versatile requirements. Based on the versatile system core, this design creates synergies between mobile and immobile applications.

The achievement of this thesis results in a prototype of a portable process data acquisition system, building a new product fitting into the existing product line and development interests of the Envidatec GmbH. The new product named MC-350 improves the prior VIDA350 software development and combines embedded customized software with modern communication structure, leading to an integrated system solution.

In June 2010, the first prototype was successfully tested in a training program in Istanbul and Bangkok. Out of the first experience the system present a new basis for the analysis and evaluation of process data, applicable in a wide range of projects. Additional tests in cooperation with an industrial customer are planed within July 2010. The feedback of these test results will be included into the further product development, to ensure the marketability. The recently aimed operation areas are for instance the establishment of JI projects in the Russian Federation or the control of the implementation of bio gas plants according to CDM placed in the Kingdom of Thailand.

An future refinement is the implementation of a Modbus interface and a development basic load management. These add-ons will allow the realization of interacting process controls and increasing the possibilities to adapt different data sources to the MC-350. Therefore, the present design already be aware of the allowance within the software and case design.

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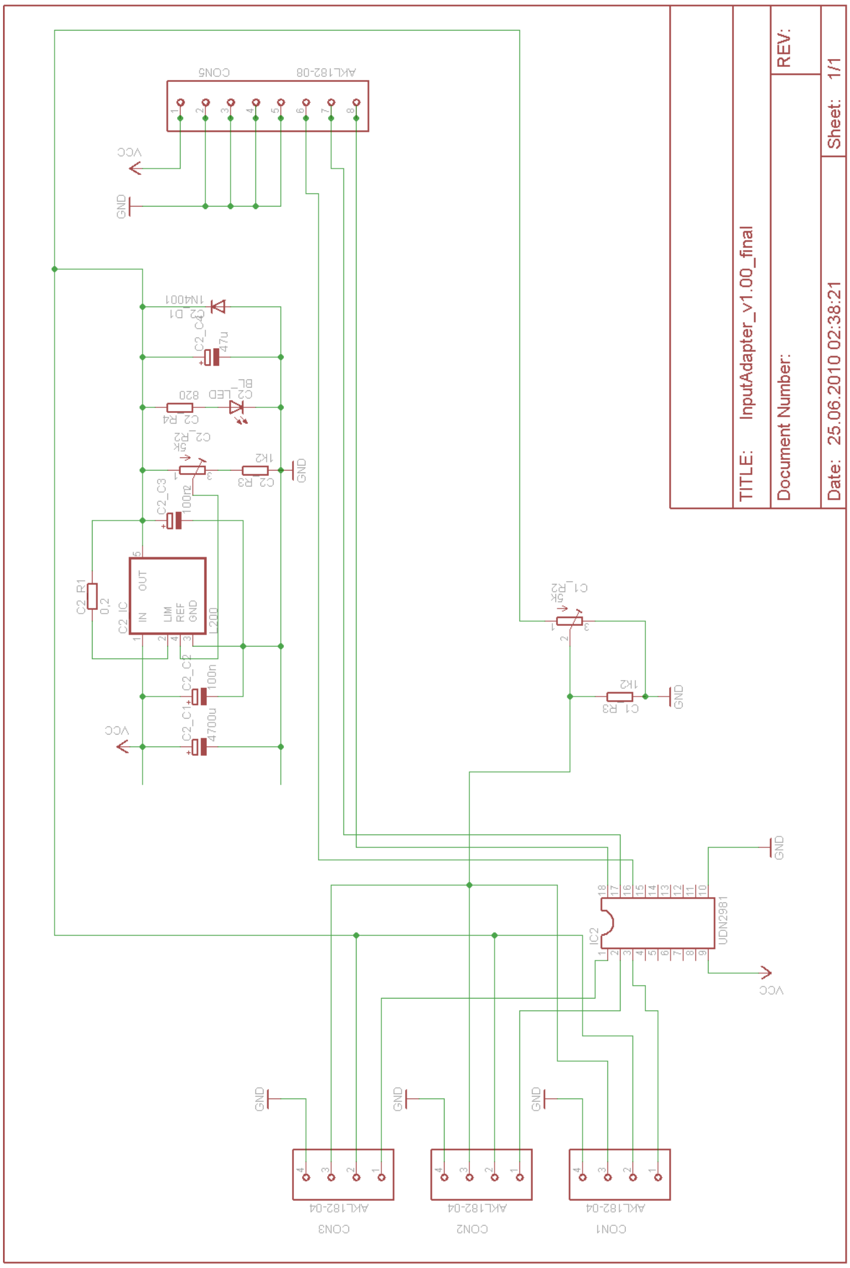
A. Input Adapter Module Schematic



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