sysWORXX CTR-700

System Manual
Version 1.6

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Changes

Date/Version	Section	Changes	Author/Editor
22.05.2018	-	Initial version	C. Sc. A. Di.
28.06.2018	6.2, 6.4.1	Table 8: Add service for docker container engine Add section 7.2 and 7.4.1	A. Di. C. Sc.
21.01.2019	3, 6.16, 6.5, 8, 10, 11.3, 11.5, Appendix B	Add section 7.16 (TeamViewer IoT Agent) Table 8: Add service for *containerd* runtime Sections 12.3, 12.5: Counter input and A/B encoder are now available Add section 7.5 (Wi-Fi Adapter) Add section 11 (Python example) Add section 3 (Safety Guidelines) Add Safety Guidelines in sections 5 and 6 Change to Section 9 Add hardware information to Appendix B	B. Sc. A. Di. C. Sc.
12.04.2019	5.2, 5.4, 5.5, 6.7.1	Update to the following sections: 6.3, 6.4, 6.5, **Fehler! Verweisquelle konnte nicht gefunden werden.**, 6.8 Add section 7.7.1	C. Sc.
20.05.2019	Appendix B	Update information in Appendix B	C. Sc.
01.12.2020	All	Update all Sections Add Section 14	C. Sc.
23.06.2022	6.2	Description for Boot Mode switch changed	A. Su.

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1 Introduction

Thank you for choosing the SYS TEC sysWORXX CTR-700. This product provides to you an innovative, Linux-based and high-capacity compact controller to process standard industrial signals. Due to its numerous in- and outputs and communication interfaces it is well-suitable as central control in distributed automation appliances.

Please take some time to read through this manual carefully. It contains important information about the commissioning, configuration and programming of this device. It will assist you in getting familiar with the functional range and usage. This document is complemented by other manuals, e.g for the OpenPCS IEC 61131 programming system. Table 1 in section 2 lists relevant manuals for this device. This table also references documentation to other software components and programming languages which are supported, such as Node-RED, C# or Java. Please also refer to those complementary documents.

For more information, optional products, updates et cetera, we recommend you to visit our website: https://www.systec-electronic.com. The content of this website is updated periodically and provides you with downloads of the latest software releases and manual versions.

2 Overview

Table 1 lists up all relevant manuals for the device.

Table 1: Overview of relevant manuals

Information about…	In which manual?
Basic information about the device (configuration, administration, process image, connection assignment, firmware update, reference designs et cetera)	In this manual
Basics about the *OpenPCS* IEC 61131 programming system	Brief instructions for the programming system (Entry "*OpenPCS Dokumentation*" in the *OpenPCS* program group of the start menu) (Manual no.: L-1005)
Complete description about the *OpenPCS* IEC 61131 programming system, basics of PLC programming according to IEC 61131-3	Online help about the *OpenPCS* programming system
Command overview and description of standard function blocks according to IEC 61131-3	Online help about the *OpenPCS* programming system
SYS TEC extension for IEC 61131-3: - String functions - UDP function blocks - SIO function blocks - FB for RTC, Counter, EEPROM, PWM/PTO	User Manual *"SYS TEC-specific extensions for OpenPCS / IEC 61131-3"* (Manual no.: L-1054)
CANopen extension for IEC 61131-3 (network variables, *CANopen* function blocks)	User Manual *"CANopen extension for IEC 61131-3"* (Manual no.: L-1008)
Textbook about PLC programming according to IEC 61131-3	IEC 61131-3: Programming Industrial Automation Systems John/Tiegelkamp Springer-Verlag ISBN: 3-540-67752-6 (a short version is available as PDF on the *OpenPCS* installation CD)

One can also use Node-RED, Java or C# to program the device. The following table provides links to the websites of those projects. On these sites you will also find guides and references on how to use these programming environments for developing applications. Getting started with these environments is described in this document.

Project	**Website**
Node-RED	https://nodered.org/
Mono / C#	http://www.mono-project.com/
OpenJDK / Java	http://openjdk.java.net/

Section 6 Describes **electric connections** of the product and their application; moreover, it documents their **internal structure**.

Section 7 Makes available **details about the configuration**, e.g. the configuration of Ethernet and CAN interfaces, the configuration of Linux services and the selection of the firmware version. In addition, the **administration** is explained, e.g. the login to the system, the user administration and the execution of software updates.

Section 8 Provides basic information on how to enable Node-RED and how to use the custom nodes to access digital inputs and outputs, or to access OpenPCS variables.

Section 9 Provides information on how to develop and debug Mono/C# applications in form of a step-by-step guide of a sample project, which uses the I/O driver for the device.

Section 10 Provides information on how to develop and debug Java applications in form of a step-by-step guide of a sample project, which uses the I/O driver.

Section 12 Includes details about the **usage of the device**, e.g. the **setup of the process image**, the **meaning of control elements** and this section provides basic information about programming the module. Furthermore, it gives information about the usage of CAN interfaces in combination with **CANopen**.

Section 13 Covers information about data exchange between a PLC program and a user-specific C/C++ application via **shared process image**.

3 Safety Guidelines

This product may only be operated by personnel qualified for the specific task in accordance with the corresponding documentation for this specific task. This relates in particular to its warning notices and safety instructions. Qualified personnel are those who, when working with these products, are capable of identifying risks and avoiding potential hazards.

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. These notices shown below are graded according to the degree of danger.

DANGER

Danger signs warn for potential life-threatening situations. There may be occur damage not only to the device and its surroundings, but also to the operating personnel. **Do under no circumstance ignore these warnings!**

WARNING

Warnings show, when certain situation could permanently damage the device or its surroundings. Make sure to always follow the instruction, to not harm any parts of the hardware.

NOTICE

Notices describe, which things could inflict potentially harmful things to the device. There is no imminent danger to personnel or the surrounding hardware, but the functionality of the device could be permanently impaired.

4 Intended use

The device is designed for use in the industrial sector (EN 61000-6-2:2005 & EN 61000-6-4:2007 + A1:2011) only.

NOTICE

The approvals are voided, if certain modifications are made

- The device was opened.
- The device was physically modified, for example, additional openings were created.
- Cables are routed from the inside out of the device or from the outside into the device, for example, to connect additional peripherals.
- The specified cable lengths for the interfaces must not be exceeded.

Under certain conditions one can use the device for residential purposes and for commercial operations, if that does not significantly impact the residential purpose. In that case, one must comply with the radio frequency interference limits of the generic standard EN 61000-6-3.

Please contact us, if there is the need to use the device in any condition or sectors, which are not specified in this document.

5 Product Description

The sysWORXX CTR-700 extends the SYS TEC electronic AG product range within the field of IoT and control applications. It is an innovative, Linux-based compact controller for universal processing purposes of standard industrial signals. The controller module provides to the user numerous local in- and outputs as well as versatile communication interfaces. Due to CAN and Ethernet interfaces, it is suited for realizing decentral control tasks in distributed fieldbus systems of automation technology. With all these tools and interfaces, one is able to write their own applications for their specific needs and purposes.

Figure 1: Top view of device

These are some significant features of device:

- Linux-based compact PLC for industrial controls
- High-capacity CPU kernel (Freescale i.MX7 series Dual ARM Cortex-A7 Core 1GHz, Real-time Core Cortex-M4 200MHz)
- Up to 1024 MiB RAM, 8GiB eMMC FLASH Memory
- 1x USB 2.0 Host interface
- 2x 10/100 Mbps Ethernet LAN interface
- 2x CAN 2.0B interface, usable as CANopen Manager (CiA 302-conform)
- 3x asynchronous serial ports (UART), usable as RS-232 or RS-485
- 16 digital inputs 24VDC, galvanic isolated
  - Alternate function: 1 high-speed counter input, galvanic isolated
  - Alternate function: 1 A/B-Encoder
- 16 digital outputs 24VDC/500mA, galvanic isolated, short-circuit-proof
  - Alternate function: 2 PWM/PTO[1] outputs 24VDC/500mA 1KHz
- 2 Relay outputs (2x change-over relay)
- 4 analog inputs 0-10VDC or 0-20mA with 12-Bit resolution
- RTC (with buffer capacitor)
- 2 temperature sensors, CPU and System temperature
- On-board software: Linux, PLC firmware with CANopen Master, Node-RED, HTTP and SFTP server
- Programmable according to IEC 61131-3, C/C++, C#, Java and Python
- Function block libraries for communication (CANopen, Ethernet and UART)
- Function block libraries for hardware components (RTC, Counter, PWM/PTO)

[1] PTO functionality is not implemented yet. It will be available in a future release. The PWM functionality is already available.

- Linux-based (other user programs are executable in parallel)
- Easy, HTML-based OpenPCS configuration via web browser
- Remote login via SSH
- Dimensions: 162 x 91 x 60mm
- Temperature 0° … 55°C
- Suitable for DIN top hat rail mounting

The default hardware comes with a Linux operating system. This base system can be used to program in different programming languages and also provides the Node-RED programming environment. To identify each individual device, the manufacturer, revision, serial and order number are be printed on a label on the right side of the device. Some additional hardware and software components are also available:

Order no.: **16061002**:	sysWORXX CTR-700 with basic Debian/GNU Linux installation, including microUSB cable for serial terminal via SERVICE plug
Order no.: **16062000**:	Meshnet Extension sysWORXX SRN-GW1
Order no.: **240011**:	Runtime license OpenPCS RT sysWORXX CTR-700
Order no.: **240012**:	Runtime license OPC-UA basis server sysWORXX CTR-700

One can also buy the sysWORXX CTR-700 BSP KIT which includes all products for an easy entry point to developers.

Order no.: **KIT-177**: sysWORXX CTR-700 BSP KIT IoT, which includes:

- 16061000: sysWORXX CTR-700
- 192016: USB-Stick with virtual machine incl. Compiler / Demos
- 193006: sysWORXX phase tester
- L-2199: Download Instructions
- L-1190: ESD Handling Instructions

This device is an all-round PLC for complex industrial control tasks. As Linux-based compact controller, the module is programmable in C/C++, C#, Java and Python and in IEC 61131-3. Also, the Node-RED node editor is available. All of these options allow highly efficient software development for this module. The on-board firmware of contains the entire PLC runtime environment including CANopen connection with CANopen Master Functionality. Thus, the module is able to operate control tasks such as linking in- and outputs or converting rule algorithms. Data and occurrences can be exchanged with other nodes (e.g. superior main controller, I/O slaves and so forth) via CANopen network, Ethernet (UDP protocol) and serial interfaces (UART). The numerous in- and outputs that the module provides can be decentrally extended by CANopen devices. CANopen IO modules of *sysWORXX Automation Series* are well-suited for this. Those modules are also designed for processing industrial standard signals (24VDC, 0-10VDC, 0-20mA etc.).

Programming the device takes place according to IEC 61131-3 using the programming system *OpenPCS* of the company infoteam Software GmbH (http://www.infoteam.de). This programming system has been extended and adjusted for this device by the company SYS TEC electronic AG. Hence, it is possible to program the device graphically in KOP/FUB, AS and CFC as well as textually in AWL or ST. Downloading the PLC program onto the module takes place via Ethernet or CANopen – depending on the firmware configuration. Addressing in- and outputs and creating a process image follows the SYS TEC scheme for compact control units. Hence, PLC programs developed by the user can be operated on different SYS TEC control modules without adjustments. Like all other SYS TEC controls, this device supports backward documentation of the PLC program as well as the debug functionality including watching and setting variables, single cycles, breakpoints and single steps.

This device uses Debian GNU/Linux as operating system. This allows for an execution of other user-specific programs while PLC firmware is running. If necessary, those other user-specific programs may interchange data with the PLC program via the process image or the Node-RED nodes for reading and writing of variable values. More information about this is provided in section 8 and 13.

The Linux applied is licensed under GNU General Public License, version 2. **Appendix C** contains the license text. All sources of Linux BSP are included in the software package 3912005 ("Oracle VM VirtualBox-Image of the Linux development system"). If you require the Linux BSP sources independently from the Oracle VirtualBox-Image of the Linux development system, please contact our support:

support@systec-electronic.com

The PLC system and the PLC-, C# and C/C++ programs developed by the user are **not** subject to GNU General Public License!

6 Interface of the Device

6.1 Pin Assignment

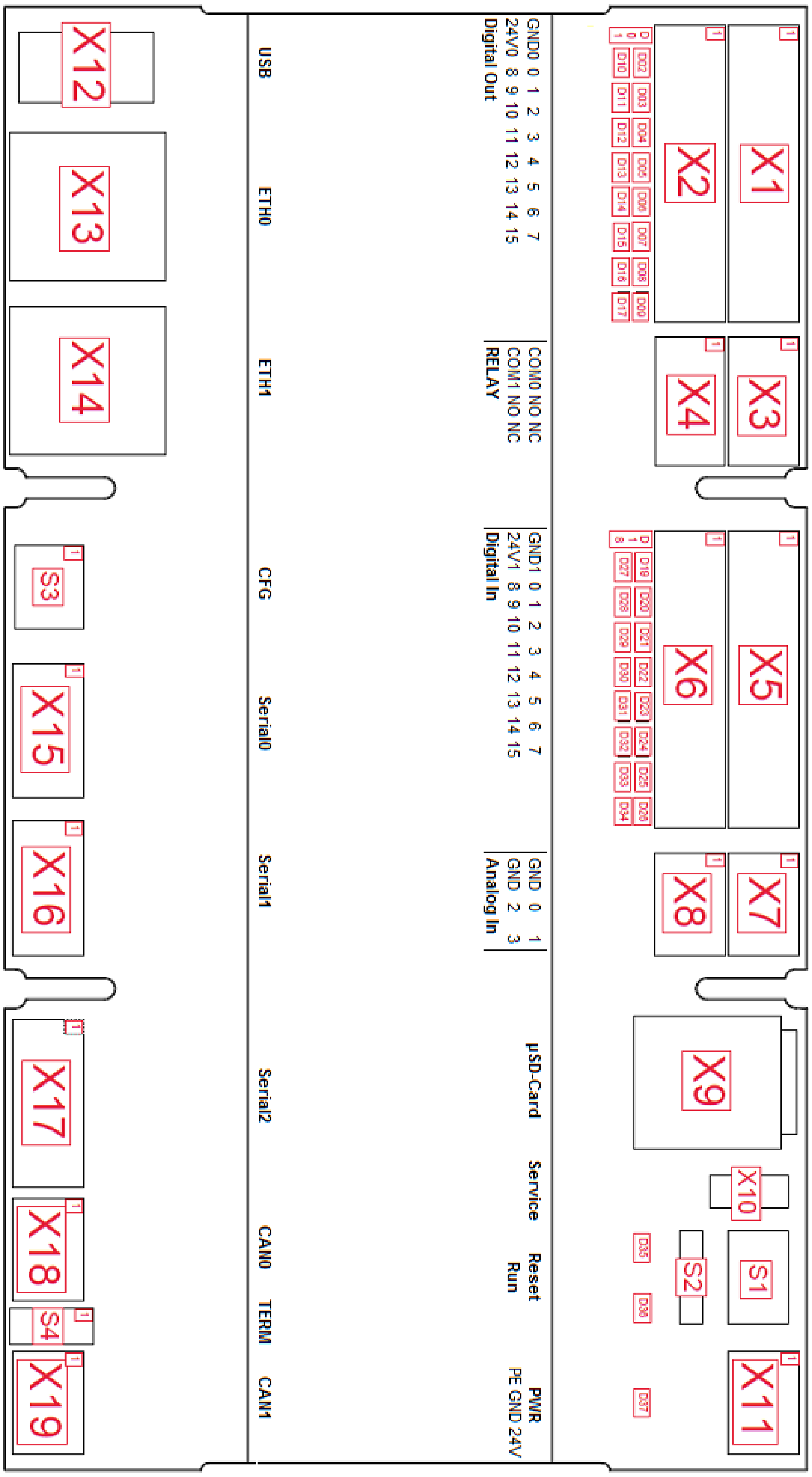

Figure 2: Interface and connector assignment

Figure 2 shows the positioning of connectors on the device as an overview. Table 2 lists all connectors in detail.

Table 2: Pin assignment

Terminal	Port	Signal name	Remark
Digital Outputs X1	1	GND0	24V
	2 … 9	DO0 … DO7	
Digital Outputs X2	1	24V0	
	2 … 9	DO8 … DO15*	
Relay 0 X3	1	COM0	230V
	2	NO	
	3	NC	
Relay 1 X4	1	COM1	230V
	2	NO	
	3	NC	
Digital Inputs X5	1	GND1	24V
	2 … 9	DI0 … DI7	
Digital Inputs X6	1	24V1	
	2 … 9	DI8 … DI15	
Analog Inputs X7	1, 2	AIN 0, AIN 1	0 … 10V/0 … 20mA
	3	GND	
Analog Inputs X8	1, 2	AIN 2, AIN 3	
	3	GND	
µSD-Card-Holder X9	-	-	-
µUSB (console) X10	-	-	-
Power X11	1	PE	24V
	2	GND	
	3	24VDC	
USB-Host X12	-	-	-
Ethernet 0 X13	-	-	-
Ethernet 1 X14	-	-	-

Serial Interface 0 X15	1	RX	RS-232
	2	-	
	3	TX	
	4	GND	
	1	A/D0	RS-485/Modbus RTU
	2	B/D1	
	3	-	
	4	GND	
Serial Interface 1 X16	1	RX	RS-232
	2	-	
	3	TX	
	4	GND	
	1	A/D0	RS-485/Modbus RTU
	2	B/D1	
	3	-	
	4	GND	
Serial Interface 2 X17	1	RX	RS-232
	2	CTS	
	3	TX	
	4	RTS	
	5	GND	
	1	A/D0	RS-485/Modbus RTU
	2	B/D1	
	3	-	
	4	-	
	5	GND	
CAN 0 X18	1	HIGH	-
	2	LOW	
	3	GND_CAN0	
CAN 1 X19	1	HIGH	-
	2	LOW	
	3	GND_CAN1	

NOTICE

Damage through additional/improper system expansions

The installation of additional expansions (sensors, actuators, …) may damage the device or machine. Device and system expansions may also violate safety rules and regulations regarding radio interference suppression. If you install or exchange system expansions and damage your device, you void your warranty.

Install only expansions or devices which are specified to be used with this device. When in doubt contact your local technical support team or the SYS TEC electronic support at support@systec-electronic.com

NOTICE

Limitation of liability

Technical specifications and approvals of this device only apply, if expansion components with a valid CE approval are used.
Also, the installation conditions for expansion components, described in the associated documentation, must be followed.
SYS TEC electronic is not liable for functional limitations caused by the use of third-party devices or components.

6.2 User Interface

Table 3: Description Switches

Switch	Port	OFF	ON
S1	-	-	RESET
S2	-	Position = left (see Figure 2) PLC stop (outputs deactivated)	Position = right (see Figure 2) PLC run (program re-starts)
S3[2]	1	**SERIAL0:** RS-485: Bus termination off RS-232: Must be set!	**SERIAL0:** RS-485: Bus termination on RS-232: Do not set!
	2	**SERIAL1:** RS-485: Bus termination off RS-232: Must be set!	**SERIAL1:** RS-485: Bus termination on RS-232: Do not set!
	3	**SERIAL2**: RS-485: Bus termination off RS-232: Must be set!	**SERIAL2:** RS-485: Bus termination on RS-232: Do not set!
	4	Configuration: **ON**	Configuration: **OFF**
	5	Normal Booting	Boot in U-Boot Bootloader CLI
	6	Boot mode: SD-Card	Boot mode: eMMC
S4	1	CAN0: Termination off	CAN0: Termination on
	2	CAN1: Termination off	CAN1: Termination on

Table 4: Description LEDs

LED	Color	Feature
D01	Green	Status of the power supply for the DO's
D02 … D17	Yellow	Signal status of the DO's (on = high; D02 = DO0, D03 = DO1, …)
D18	Green	Status of the power supply for the DI's
D19 … D34	Yellow	Signal status of the DI's (on = high; D19 = DI0, D20 = DI1, …)
D35	Green	Status of the PLC: **RUN** f=1 Hz; **STOPP** f=0.5 Hz
D36	Red	ERROR-LED, signals an occurring (PLC or IO-driver) error
D37	Green	Status of the power supply for the device

[2] The switches for the serial interfaces are in reversed order (2, 1, 0) on all devices labeled as prototype.

6.3 Mounting

NOTICE

Mounting

This device is intended to be mounted on DIN rail. It is designed to be attached horizontally only (orientation does not matter). Mounting it vertically may disturb the air flow and can cause over-heating of the internal components.

6.4 Power Supply

The device features three power supply inputs (24VDC ±20%) for CPU unit and two peripheries. The connector supplies the CPU unit, the digital in- and outputs. This input has reverse polarity protection. If the device experiences a power fail (< 14,9V), there is a 10 ms time window to act accordingly, for example to safe your data. During this 10 ms, the device will work normally then shuts down. To access the power fail signal, one has to use the driver library in a separate program (see Sections 8, 9, 10, 11).

6.5 Galvanic Isolation

Figure 3 shows the galvanic isolation of the different interfaces and system components.

Digital Out 0..15	24V0 GND0	Relais 0	CAN1	ETH0	Analog In USB Serial 0..2 System Power
Digital In 0..15	24V0 GND0	Relais 1	CAN0	ETH1	

Figure 3: Galvanic isolation

6.6 Cable types and maximum cable lengths

The following table shows, which cable types are recommended for the different interfaces:

Table 5: Recommended cable lengths, types and wire cross section

Interface	Cable length	Recommended cable types	Wire cross section
Digital outputs, Relais	<30m	Any cable suitable to the specific usage.	0,2 - 1,5mm² or AWG24 - 16
Digital inputs	<30m	Any cable suitable to the specific usage.	0,2 - 1,5mm² or AWG24 - 16
Analog inputs	<30m	Shielded twisted pair	
CAN0/1	<30m	Shielded twisted pair	
Serial0/1/2	RS232: <15m Modbus RTU: <30m	Shielded twisted pair	
Ethernet0/1	<30m	S/FTP Cat 6	-
USB, Service	<3m	USB standard cable	-
PWR	<30m	Any cable suitable to the specific usage.	1mm² - 1,5mm² or AWG17 - 16

6.7 In- and Outputs for Industrial Standard Signals

6.7.1 Digital Inputs

The device features 16 digital inputs (DI0 ... DI15). The inputs are galvanically isolated. Each sixteen inputs have the same supply potential (DI0 ... 7, DI8 ... DI15). The inputs are high active with the following switching threshold:

- Input voltage > 15 VDC: is shown as '1' in the process image
- Input voltage < 5 VDC: is shown as '0' in the process image

Digital inputs DI0 ... DI15 have the internal structure as shown in Figure 4.

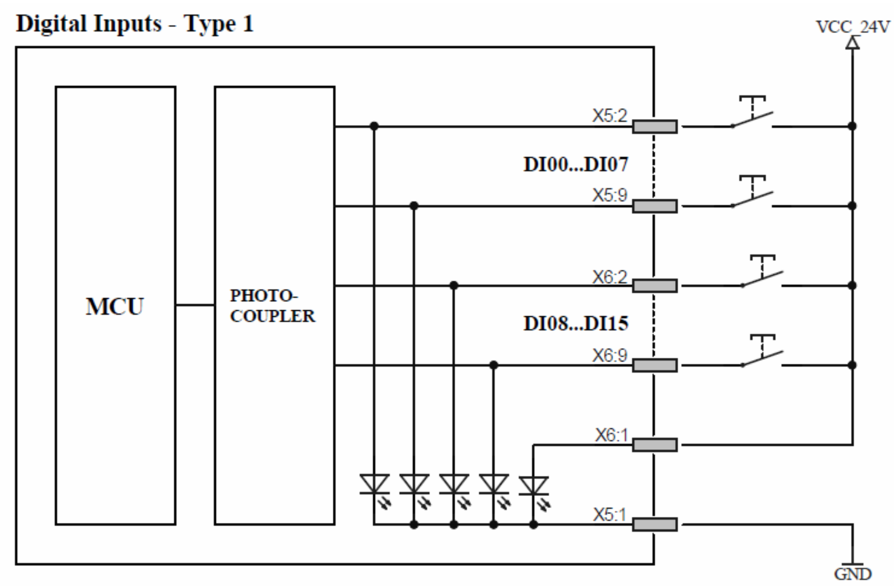

Figure 4: Setup of digital inputs

The digital inputs in a PLC program are accessible via the process image (see Table 11 in section 12.3.1).

6.7.1.1 Alternate function DI14, DI15: Counter input C0, Step Direction

The device features a high-speed counter input (C0) which is galvanically isolated from the CPU kernel. The counter input C0 has the same internal structure as the digital inputs DI0 ... DI15 shown in Figure 4 and is also high active, with the same switching thresholds.

The counter inputs in a PLC program are accessible via process image (see Table 11 in section 12.3.1) as well as via function block *"CNT_FUD"* (see manual *"SYS TEC-specific extensions for OpenPCS / IEC 61131-3"*, manual no.: L-1054).

To use the Counter without a PLC program, one has to use the I/O-driver for the device. The documentation to the API can be found in under ***"/usr/include/<device>drv/<device>drv.h"***.

6.7.1.2 Alternate function: DI14, DI15: A/B Encoder C0

The device features a high-speed A/B-Encoder input which is galvanically isolated from the CPU kernel. The A/B-Encoder has the same internal structure as the digital inputs DI0 ... DI15 shown in Figure 4 and are also high active, with the same switching thresholds.

The encoder value in a PLC program are accessible via process image (see Table 11 in section 12.3.1) as well as via function block *"CNT_FUD"* (see and manual *"SYS TEC-specific extensions for OpenPCS / IEC 61131-3"*, manual no.: L-1054).

To use the A/B-Encoder without a PLC program, one has to use the I/O-driver for the device. The documentation to the API can be found in under ***"/usr/include/<device>drv/<device>drv.h"***.

6.7.2 Digital outputs

The device features 16 digital high-side switch outputs (DO0 ... DO15). The outputs each connect the supply voltage Vcc of the appliance (switching positively). The maximum load current for each 24V output is 0.5A for ohmic, inductive or capacitive load. The outputs are short-circuit-proof and galvanically isolated from the CPU unit. The outputs are protected against excess voltage, reverse polarity and excess temperature. The outputs are accessed high active:

- '1' in process image: output transistor active, appliance connected with Vcc
- '0' in process image: output transistor inactive, appliance disconnected from Vcc

The digital transistor outputs DO0 ... DO15 have the internal structure as shown in Figure 5. At and after powerup and reset the outputs are in off state.

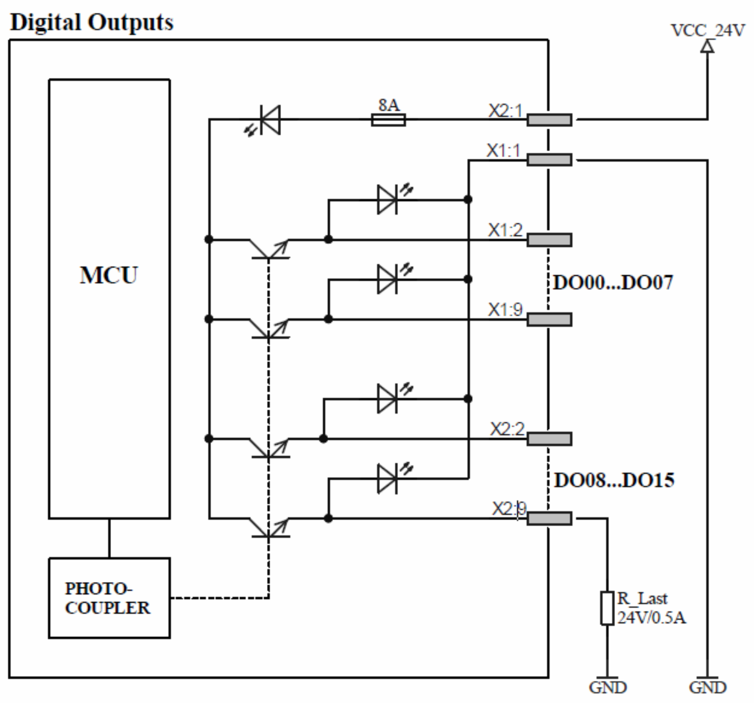

Figure 5: Setup of digital outputs

The digital outputs in a PLC program are accessible via the process image (see Table 11 in section 12.3.1).

6.7.2.1 Alternate Function: DO14, DO15: Pulse outputs P0 and P1

The device features two Pulse outputs (P0 and P1) to output PWM and PTO signal sequences. The maximum load current for each 24V output is 0.5 A for ohmic, inductive or capacitive load. The outputs are short-circuit-proof and galvanically isolated from the CPU unit. The performance drivers used are protected against excess voltage, reverse polarity and excess temperature. The transistor outputs are also activated low active.

Pulse outputs P0 and P1 use the same internal structure as the digital outputs DI14/DI15 shown in Figure 5.

In a PLC program, the PWM/PTO functionality of Pulse outputs is accessible via function block *"PTO_PWM"* (see manual *"SYS TEC-specific extensions for OpenPCS / IEC 61131-3"*, manual no.: L-1054).

6.7.3 Relay Outputs

The device features two Relay outputs. Outputs REL0 and REL1 are change-over relay contacts. The Relays are high active:

- ‘1’ in process image: contact is closed
- ‘0’ in process image: contact is open / contact is closed

Relay outputs REL0 and REL1 have the internal structure as shown in Figure 6.

⚠	**DANGER: Electrical Shock** **Life-threatening currents and voltages are present with an open control cabinet.** When you install the device in a control cabinet, beware that some areas or components in the open control cabinet may be carrying life-threatening voltages currents. Touching these areas or components may kill you. Switch off the power supply to the cabinet before opening it.

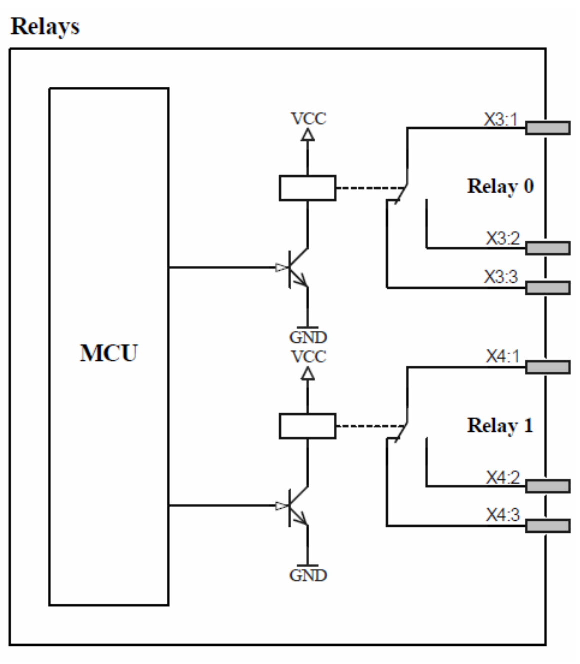

Figure 6: Setup of Relay outputs

Attention! Country-typical technical standards for the usage of power supply voltage must be taken into consideration.

The Relay outputs are in a PLC program accessible via the process image (see Table 11 in section 12.3.1).

6.7.4 Analog Inputs

In its default configuration the device features up to 4 analog inputs for a voltage range of 0 … +10 V and a resolution of 12-bit. Alternatively, these inputs can be configured to current inputs of 0 ... 20 mA. The configuration of the ADC mode after bootup is described in section 7.5 .

The inputs are protected against overvoltage.

Analog inputs AI0 … AI3 have the same internal structure as shown in Figure 7.

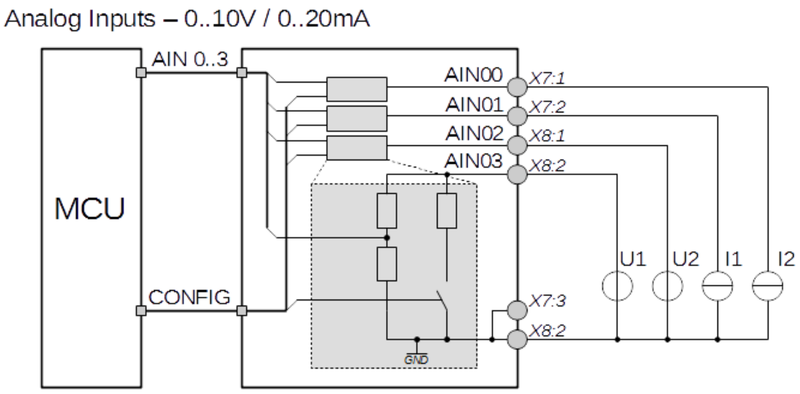

Figure 7: Setup of analog inputs

The analog inputs in a PLC program are accessible via the process image (see Table 11 in section 12.3.1).
Process image and I/O user space driver give a 16-bit signed value for the ADC (two's complement). In case this device only positive values will be returned. Thus only 15-bit with a theoretical range of 0 to 32765 are used. The value range and further information about the analog inputs can be found in the technical specifications in the Appendix.

To get the real value for the voltage or current measurement, the LSB has to be multiplied by the measured digits, like the following calculation shows:

Example for voltage measurement:

U = 1 LSB * DIGIT
U = 355,225µV * 28151 = 9,999V

6.8 Communication Interfaces

6.8.1 Serial Interfaces

This device features one service and three serial interfaces (X10, X15 … X17).

Table 6: Serial interface to Linux device node path

Interface	Linux-Device (*INTERFACE*)
SERIAL0	/dev/ttymxc6
SERIAL1	/dev/ttymxc5
SERIAL2	/dev/ttymxc1
SERVICE [3]	/dev/ttymxc0

SERVICE (X10)
Interface Service serves as service interface to administer the device. The connection to a computer is established via Micro-USB.

SERIAL0 and SERIAL1 (X15 and X16)
Interface Serial 0 can be used for data exchange under control of the PLC program. RS-232 signals Rx, Tx and GND or RS-485 signals D0, D1 and COM are available at a X15, X16 connector. Additionally, the configuration for the RS-485 has to be added to the source code of an application. When used as RS-485, termination resistors can be activated via the DIP-Switch (see Table 3: Description Switches). The termination should only be used, if the device is the last in line. By default, the interface uses RS-232 signals.

SERIAL2 (X17)
Interface Serial 2 can be used for data exchange under control of the PLC program. R-232 signals Rx, Tx, RTS, CTS and GND or R-485 signals D0, D1 and COM are available at a X17 connector. Additionally, the configuration for the RS-485 has to be added to the source code of an application. When used as RS-485, termination resistors can be activated by the DIP-Switch (see Table 3: Description Switches). The termination should only be used, if the device is the last in line. By default, the interface uses RS-232 signals.

[3] The **SERVICE** interface is used as the default Linux console for serial access to the device. Do not use this for custom applications unless you really know how to handle this without any conflicts.

Setting up a serial interface for RS-485

RS-485 is available for the serial interfaces **SERIAL0**, **SERIAL1** and **SERIAL2**. To set up an interface for RS-485, the following configuration has to be executed. Substitute **INTERFACE** with the targeted interface (see Table 6):

```
#include <stdio.h>
#include <string.h>
#include <strings.h>
#include <unistd.h>
#include <errno.h>
#include <stdlib.h>
#include <fcntl.h>
#include <termios.h>
#include <sys/select.h>
#include <sys/ioctl.h>
#include <linux/serial.h>

int main() {
    int iInterface = open("INTERFACE", O_RDWR | O_SYNC);

    struct serial_rs485 RS485;

    ioctl(iInterface, TIOCGRS485, &RS485);
    RS485.flags |= SER_RS485_ENABLED;
    RS485.flags &= ~SER_RS485_RX_DURING_TX;
    ioctl(iInterface, TIOCSRS485, &RS485);

    close(iInterface);
}
```

This code has to be put into a C-file, compiled and can then be executed.
Hint: After the device is restarted, this configuration has to be repeated!

6.8.2 CAN Interfaces

The device features 2 CAN interfaces (CAN0 and CAN1). Those two CAN-Bus-Transceivers are galvanically isolated to one another and to the CPU. The transceivers are supplied via two on-board DC/DC converter. CAN-Bus signals CAN0 HIGH, CAN0 LOW, CAN1 HIGH, CAN1 LOW and CAN0 GND/CAN1 GND are available from withdrawable terminal-block connectors.

Section 12.8 provides detailed information about the usage of both CAN interfaces in connection with CANopen.

CAN cable: The CAN-Bus usually is a twisted pair line. At both ends of the cable, a termination resistor of **120 Ohm termination** is necessary **between CAN_H and CAN_L**. CiA (CAN in Automation) must use CAN-GND in CiA DRP 303-1. For more information please refer to the appropriate CiA standards.

Both CAN interfaces also support the use of an internal termination resistor for one end of the CAN bus. The DIP-switch to make use of these resistors is described in Table 3.

6.8.3 Ethernet Interfaces

The device features up to two Ethernet interfaces (ETH0 and ETH1) which are designed as 10Base-T/100Base-TX.

The Ethernet interface serves as service interface to administer the device and it can be used for data exchange with any other devices.

6.8.4 USB-Host

The device features a USB 2.0 host interface (X12).

7 Configuration and Administration

7.1 System Requirements and Necessary Software Tools

The administration requires any Windows or Linux computer that has available an Ethernet or USB interface. These allow a connection to administer the device via a Linux command line-interface.

All examples referred to in this manual are based on an administration using a Windows computer. Procedures using a Linux computer would be analogous.

To administrate the device the following software tools are necessary:

Terminal program

A Terminal program allows the communication with the **command shell** via **the integrated USB-to-UART bridge (USB service console) of the** device. This is required for the Ethernet configuration as described in section 7.4. After completing the Ethernet configuration, all further commands can either be entered in the Terminal program or alternatively in an SSH client (see below).

A suitable Terminal program would be *"TeraTerm",* which is available as Open Source Software (*BSD* License). The project page is located at: http://ttssh2.osdn.jp/.

Secure Shell (SSH)

SSH allows the encrypted communication with **command shell** via **Ethernet**. Using SSH requires a completed Ethernet configuration of the device according to section 7.4. As alternative solution to SSH, all commands can be used via a Terminal program.

Suitable as SSH client would be *"PuTTY"* or *"TeraTerm",* which can also be used as Terminal program (see above). "*PuTTY*" is licensed under *MIT*-License and can be downloaded at: https://www.chiark.greenend.org.uk/~sgtatham/putty/.

SFTP client

An SFTP client allows file transfer between the device and the computer. This allows for example **editing configuration files** by transferring those onto the computer where they can be edited and get transferred back to the device. Downloading files is also necessary to **update the PLC firmware**. (Advice: The update of *PLC firmware* is not identical with the update of the *PLC user program*. The PLC program is directly transferred to the module from the *OpenPCS* programming environment. No additional software is needed for that.)

Suitable as SFTP client would be *"WinSCP"* which is available as Open Source Software (GNU GPL).

For programs that communicate via Ethernet interface, such as SFTP client or TFTP server, it must be paid attention to that rights in the Windows-Firewall are released. Usually Firewalls signal when a program seeks access to the network and asks if this access should be permitted or denied. In this case access is to be permitted.

7.2 Connection Over the Serial Interface

Setting up a connection over the serial interface needs a Terminal Program like *"TeraTerm"* (see 7.1) and the *"Silicon Labs USB to UART Bridge"* driver installed on the computer. The driver can be found here: https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers

Additionally, the USB host interface (SERVICE, see section 6) of the device has to be connected to the computer with a µUSB cable.

If both are installed and the device is connected to the computer, *"TeraTerm"* must be started and configured as follows (see Figure 8):

- 115200 Baud
- 8 Data bit
- 1 Stop bit
- no parity
- no flow control

Note: The Port has to be the COM-interface installed with the Silicon Labs driver. This is depending on the computer on which it was installed. COM3 as shown in Figure 8 is only an example, the real number of the COM interface can vary on other computers.

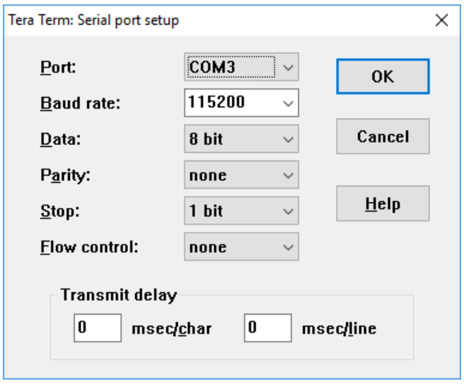

Figure 8: Terminal configuration using the example of "TeraTerm"

Clicking on OK will start the command shell. After pressing any key, the login screen should be visible and the user is able to interact with the device (see Figure 9).

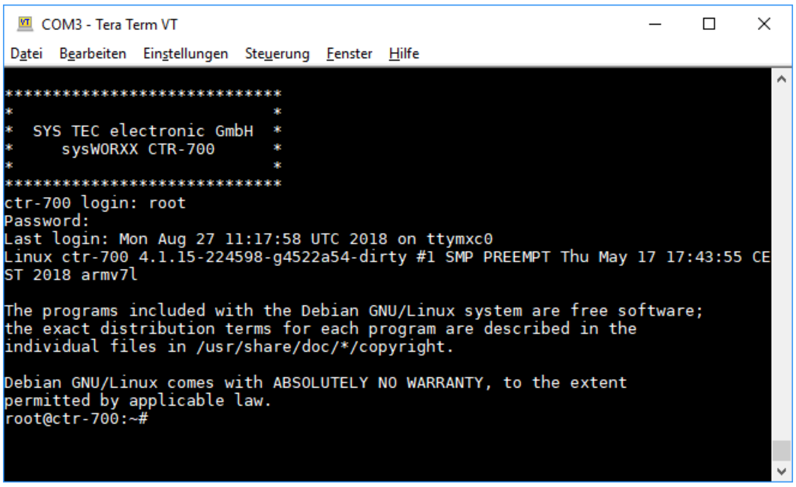

Figure 9: Login screen TeraTerm

For the login you need a valid user account. There are predefined and ready to use accounts already available (see section 7.9). In this example, the user *"root"* was used.

7.3 Activation/Deactivation of Linux Auto-Boot

During standard operation mode, the bootloader "U-Boot" automatically starts the Linux operating system of the module after a reset (or power-on reset). Afterwards, the operating system loads all enabled services such as OpenPCS runtime or Node-RED (see section 7.8.3 on how to enable system services). For certain service tasks it may be required to access the "U-Boot" command prompt instead.

Communicating with the bootloader "U-Boot" only takes place via the serial interface “Service”. To disable the auto-boot, the corresponding DIP-Switch has to be set (see Table 3). After the switch is set and the system is rebooted, the “U-Boot” command prompt is activated.

7.4 Ethernet Configuration

The device has up to two ethernet interfaces ETH0 and ETH1.The main ethernet configurations are saved in the configuration file in */etc/network/interfaces.* By default, only ETH0 is used and configured to use DHCP and the interface ETH1 has no configuration. The following configuration examples below use “ethX” as placeholder. Substitute “ethX” with the targeted network interface *eth0* or *eth1*. Modifications are adopted upon the next reboot.

Advice: After the configuration is finished, the serial connection between PC and the device is no longer necessary.

7.4.1 Get the Current IP Address

To get the current IP addresses of the device, one has to set up a connection with a Terminal program (see 7.1). After login one can use the following command, to get a list of IP addresses:

```
ifconfig eth0
```

The parameter *eth0* is optional. If not given, *ifconfig* will print the IP addresses of all interfaces.

The following example shows the IP address *192.168.10.134* for the network interface *eth0*:

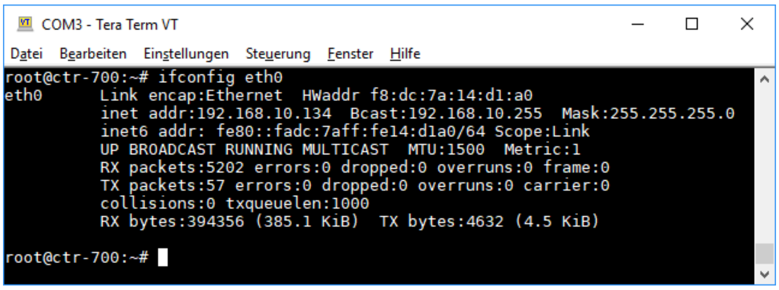

Figure 10: Example – get the IP address for eth0

7.4.2 DHCP Configuration

Add the configuration options listed below to the configuration file, to change the network interface to DHCP.

```
allow-hotplug ethX
iface ethX inet dhcp
```

7.4.3 Static IP Address Configuration

Add the configuration options listed below to the configuration file, to change the network interface to static. Use the proper configuration for your network infrastructure.

```
allow-hotplug ethX
iface ethX inet static
      address 192.168.0.100
      netmask 255.255.255.0
```

```
      network 192.168.0.0
      broadcast 192.168.0.255
      gateway 192.168.0.1
```

7.5 Setting Up a USB Wi-Fi Adapter

The device is capable of using a wide range of USB Wi-Fi Adapters. There are several vendors and products available. This section will describe the steps necessary to setup of a Wi-Fi adapter based on the RTL8192CU chip. Check the Linux kernel configuration, which Wi-Fi adapters are supported.

Open a terminal session via serial service interface or SSH and plug the adapter to the USB-Host plug. Check with *lsusb* if the Wi-Fi adapter is the right one. In this case it must be the *RTL8192CU 802.11n WLAN Adapter*. If this is the case, install the *wpasupplicant* and *firmware-realtek* packages.

```
apt install wpasupplicant firmware-realtek
```

Setup the SSID and PSK of the wireless network by issuing the following command. (replace the placeholders <SSID> and <PSK> to your network configuration)

```
wpa_passphrase <SSID> <PSK> > /etc/wpa_supplicant.conf
```

Add the following lines to the end of */etc/wpa_supplicant.conf*.

```
update_config=1
ctrl_interface=DIR=/var/run/wpa_supplicant
```

Put the rtl8192cu module on the blacklist, to force the kernel to use another driver module. Otherwise the kernel will mistakenly try to use this one, which will not work as expected.

```
echo "blacklist rtl8192cu" > /etc/modprobe.d/rtl8192cu-blacklist.conf
```

Restart Wi-Fi adapter by replacing the interface <WLAN> to your Wi-Fi interface name.

```
ip link set <WLAN> down
ip link set <WLAN> up
```

Start the *wpa_supplicant* with Wi-Fi interface in background and run the DHCP client.

```
wpa_supplicant -i <WLAN> -B -c /etc/wpa_supplicant.conf
dhclient <WLAN>
```

Now the network / internet should be working smoothly. This can be tested by pinging to an IP address in the internet or your local network.

```
ping <SOMEIPADDRESS>
```

To automatically connect to the network after booting, add the following lines to the file */etc/network/interfaces* and replace <WLAN>, <SSID> and <PSK> with the correct settings.

```
auto <WLAN>
iface <WLAN> inet dhcp
      wpa-ssid <SSID>
      wpa-psk <PSK>
```

7.6 Configuration of ADC Inputs for Voltage / Current Measurements

ADC inputs (“ANALOG IN”) can be configured for voltage measurements (default) as well as for current measurements. The configuration will be loaded at startup of the Linux system as a system service. This service is enabled by default. The configuration can be changed by using a text editor when some sort of terminal command line is connected or up-/download of the configuration file via SFTP.

The path of the configuration file: */etc/systec/adc_modes*

By default, all channels are configured for voltage measurements. The following example shows how to configure ADC input 2 (AI2) for current measurements and all other channels are configured for voltage measurements:

```
# Possible values for ADC modes are "voltage" or "current"
AI0_MODE="voltage"
AI1_MODE="voltage"
AI2_MODE="current"
AI3_MODE="voltage"
```

The configuration can also be changed by the I/O driver (e.g. “libctr700drv”) too. This driver is installed as a Debian package on the device.

7.7 PLC configuration

7.7.1 OpenPCS License Key Handling

For the usage of the PLC functions, the device needs an installed OpenPCS license key. If ordered that way, the key is normally pre-installed. To check, if a key is installed, the following command can be used:

```
cat /vendor/device
```

This command outputs not only the license key, but also other device and vendor information, such as the device specific serial number. If the line for the “LicKey” is empty, no license key is installed.

The key can also be installed, after purchase. For that, please contact us and we provide you with the license key for OpenPCS. With the following command, it can be installed (or deleted):

```
vedor_setup vendor
```

During the following setup, the device specific serial number and the license key has to be added. After that, reboot the device. The service for OpenPCS can now be used as described below.

7.7.2 PLC configuration via WEB-Frontend

After finishing the Ethernet configuration (see section 7.4), all further adjustments can take place via the integrated WEB-Frontend. The frontend service is disabled by default. To enable it, run the following command as described in section 7.8.3:

```
systemctl enable openpcs-lighttpd
```

To configure the deviec via WEB-Frontend it needs a WEB-Browser on the PC (e.g. Microsoft Internet Explorer, Mozilla Firefox, etc.). To call the configuration page, prefix *"http://"* must be entered into the address bar of the WEB-Browser prior to entering the IP address of the device as set in section 7.4, e.g. *"http://192.168.10.193"*. Figure 11 exemplifies calling the CTR-700 configuration page in the WEB-Browser.

The standard setting (factory setting) requires a user login to configure the device via WEB-Frontend. This is to prevent unauthorized access. Therefore, user name and password must be entered (see Figure 11). On delivery of the module, the following user account is preconfigured (see section 7.9):

User: PlcAdmin
Password: Plc123

Figure 11: User login dialog of the WEB-Frontend

All configuration adjustments for the device are based on dialogs. They are adopted into the file ***"/home/plc/bin/<device>.cfg" (e.g. "/home/plc/bin/ctr-700.cfg")*** by activating the pushbutton "Save Configuration" (also compare section 7.7.3). After activating Reset starts automatically using the active configuration. Figure 12 shows the configuration via WEB-Frontend.

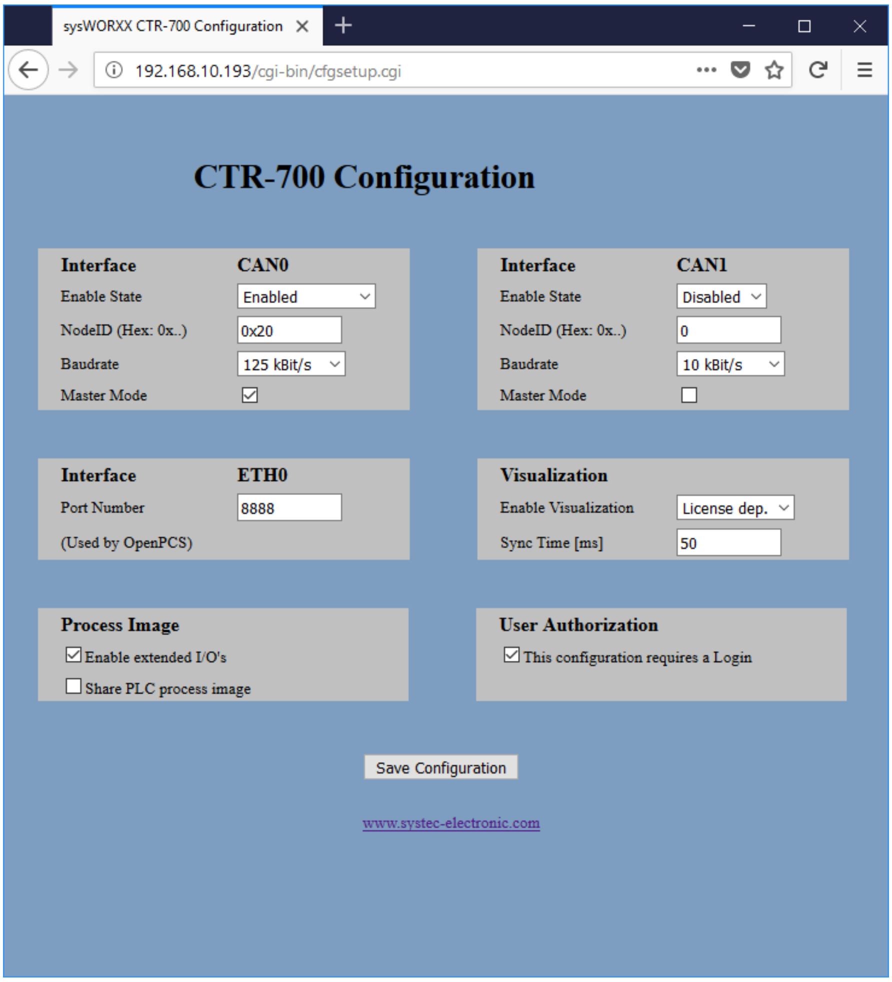

Figure 12: PLC configuration via WEB-Frontend

The standard setting (factory setting) requires a user login to access the WEB-Frontend. Therefore, only the user name indicated in configuration file ***"/home/plc/bin/<device>.cfg" (e.g. "/home/plc/bin/ctr-700.cfg")*** is valid (entry *"User="* in section *"[Login]"*, see section 7.7.3). Procedures to modify the user login password are described in section 7.12. To allow module configuration to another user, an appropriate user account is to be opened as described in section 7.11. Afterwards, the new user name must be entered into the configuration file ***"/home/plc/bin/<device>.cfg" (e.g. "/home/plc/bin/ctr-700.cfg")***. Limiting the user login to one user account is cancelled by deleting the entry *"User="* in section *"[Login]"* (see 7.7.3). Thus, any user account may be used to configure the module. By deactivating control box *"This configuration requires a Login"* in the field *"User Authorization"* of the configuration page (see Figure 12) free access to the module configuration is made available without previous user login.

7.7.3 Setup of the Configuration File

The configuration file ***"/home/plc/bin/<device>.cfg"*** allows for comprehensive configuration of the device. Although, working in it manually does not always make sense, because most of the adjustments may easily be edited via WEB-Frontend (compare section 7.7.1). The setup of the configuration file is similar to the file format "Windows INI-File". It is divided into "*[Sections]*" which include different entries "*Entry=*". Table 7 lists all configuration entries.

Table 7: Configuration entries of the CFG file

Section	Entry	Value	Meaning
[CAN0]	Enabled	0, 1	0: Interface CAN0 is deactivated 1: Interface CAN0 is activated, configuration takes place via entries of the configuration file below
	NodeID	1 … 127 or 0x01 … 0x7F	Node number for interface CAN0 (decimal or hexadecimal with prefix "0x")
	Bitrate in Kbit/s	10, 20, 50, 125, 250, 500, 800, 1000	Bitrate for interface CAN0
	MasterMode	0, 1	1: Master mode is activated 0: Master mode is deactivated
[CAN1]	Enabled	0, 1	0: Interface CAN1 is deactivated 1: Interface CAN1 is activated, configuration takes place via entries of the configuration file below
	NodeID	1 … 127 or 0x01 … 0x7F	Node number for interface CAN1 (decimal or hexadecimal with prefix "0x")
	Bitrate in Kbit/s	10, 20, 50, 125, 250, 500, 800, 1000	Bitrate for interface CAN1
	MasterMode	0, 1	1: Master mode is activated 0: Master mode is deactivated
[ETH0]	PortNum	Default Port no: 8888	Port number for the communication with the Programming-PC and for program download
[ProcImg]	EnableSharing	0, 1	0: No sharing of process image 1: Sharing of process image is enabled (see section 13)
[Login]	Authorization	0, 1	0: Configuration via WEB-Frontend is possible without user login 1: Configuration via WEB-Frontend requires user login
	User	Default Name: PlcAdmin	If entry *"User="* is available, only the user name defined is accepted for the login to configure via WEB-Frontend. If the entry is not available, any user registered on the device (see section 7.11) may login via WEB-Frontend.

The configuration file ***"/home/plc/bin/<device>.cfg"*** includes the following factory settings:

```
[Login]
Authorization=1
User=PlcAdmin

[CAN0]
Enabled=1
NodeID=0x20
Baudrate=125
MasterMode=1

[CAN1]
Enabled=0
NodeID=0x30
Baudrate=125
MasterMode=0

[ETH0]
PortNum=8888

[ProcImg]
EnableExtIo=1
EnableSharing=0
```

7.8 Service Configuration and Boot Scripts

The Debian GNU/Linux installed on the device uses “systemd” for managing services. Besides the default services of the operating system, there are some additional services available. For executing simple commands on bootup of the system, one can also extend the old-fashioned *rc.local* start script.

7.8.1 Extend Shell Script in /etc/rc.local

The start script */etc/rc.local* will be executed automatically at startup of the system. This file can be altered by the user to execute additional shell commands. One has to keep in mind to not block the execution of the script for a long time or start long running commands in background.

7.8.2 Add Custom Systemd Services

A much more flexible way to execute applications on boot-up or running Linux daemons, is to use “systemd” services. Users can add custom services on their own. System service files have to be added in */etc/systemd/system/<YOUR_ SERVICE>.service*. The service-file has to contain at least the following options:

```
[Unit]
Description=<YOUR_SERVICE_DESCRIPTION>
[Service]
ExecStart=/usr/bin/YOUR_SERVICE_EXECUTABLE
[Install]
WantedBy=multi-user.target
```

Description is the name for the service and *ExecStart* is the path to the executable file or script.
The service can be started automatically at boot-up with the following command:

```
systemctl enable YOUR_SERVICE
```

One can also disable it with the following command:

```
systemctl disable YOUR_SERVICE
```

As more in-depth examples, one could look up the service files of *OpenPCS* or *Node-RED*. The official documentation can be found in the provided man-pages or on the project site of *systemd*.
Important man-pages regarding system services:

```
man systemd
man systemd.unit
man systemd.service
```

Additional information can be found on the project homepage: https://www.freedesktop.org/wiki/Software/systemd/

7.8.3 Configure Services

The devicecomes with a few "systemd" services such as *OpenPCS, OPC UA Basis Server* or *Node-RED*. There are two ways to run these services:

1. The following commands are used to manually start or stop *OpenPCS* services:
   ```
   systemctl start openpcs-z5
   systemctl stop openpcs-z5
   ```

2. There is also the possibility to start the *OpenPCS* services automatically on power-on reset or reboot. These are the same commands as mentioned in Section 7.8.2:
   ```
   systemctl enable openpcs-z5
   ```
   To disable the automatic start, the following command is used:
   ```
   systemctl disable openpcs-z5
   ```

Table 8 shows a list of services, which can be configured by the user. Use the commands as above to run each of the services by substituting the name of the service.

Table 8: systemd services

Service file / name	Enabled by default	Description
adc-modes.service	Yes	Oneshot service, which sets up the ADC configuration from */etc/systec/adc_modes*
node-red.service	No	Enables the Node-RED programming tool, listens by default on port 1880
openpcs-lighttpd.service	No	Web configuration frontend for OpenPCS
openpcs-z4.service	No	OpenPCS RT, uses the CANopen (CAN0) for communication to OpenPCS on the PC **Hint:** This service can only be started if "openpcs-z5.service" is not running.
openpcs-z5.service	No	OpenPCS RT, uses ethernet (UDP) for communication to OpenPCS on the PC **Hint:** This service can only be started if "openpcs-z4.service" is not running.
docker.service	No	Docker container engine
containerd.service	No	Container runtime

7.9 Predefined User Accounts

All user accounts listed in Table 9 are predefined upon delivery. Those allow for a login to the command shell and at the SFTP server of the device.

Table 9: Predefined user accounts

User name	Password	Remark
root	root	Predefined root user for the administration (system configuration, user administration, software updates etc.)
user	user	Main user account
PlcAdmin	Plc123	Administration user for OpenPCS (root user alias; provided for compatibility reasons to older products)

Hint: To secure the device, users have to change all predefined passwords (see 7.12). If users are not needed, they can be disabled or removed except the “root” user. Additionally, SSH can be configured for public key authentication for even better security.

7.10 Remote Access

7.10.1 Remote Login to the Command Shell

In some cases, the administration requires the ability to typing shell commands manually. Therefore, the user must be directly logged in at the module. There are two different possibilities:

- Logging in is possible with the help of a **Terminal program** (e.g. TeraTerm, see section 7.1) via the serial interface **SERVICE**.
- Alternatively, the login is possible using an **SSH client** (e.g. PuTTY or also TeraTerm) via the Ethernet interface **ETH0**.

For logging in with SSH via PuTTY or TeraTerm, the IP address provided in section 7.1 must be used.

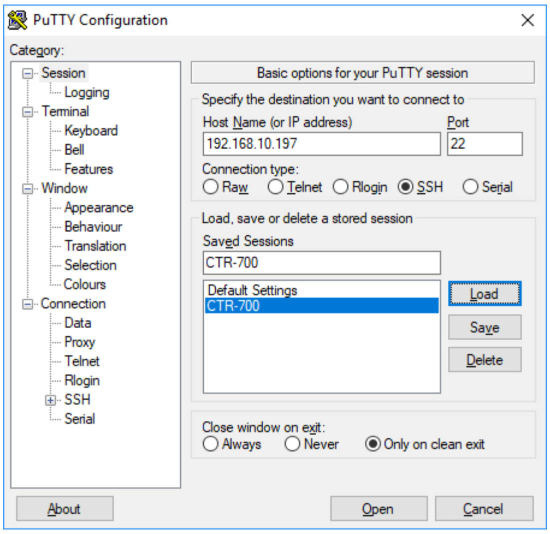

Figure 13: SSH login PuTTY

Logging in is possible in the Terminal window (if connected via Service) or in the SSH window (if connected via ETH0). The following user account is preconfigured for the administration of the module upon delivery (also compare section 7.9):

User: *root*
Password: *root*

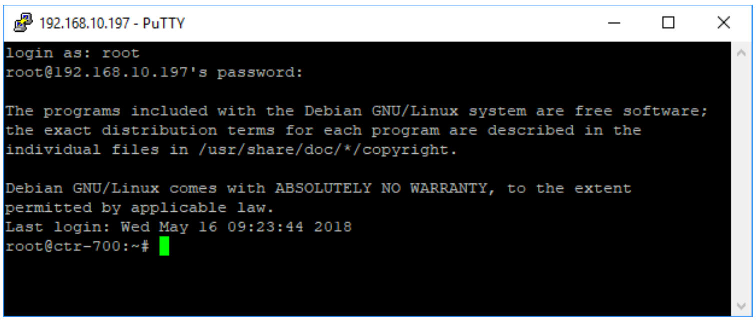

Figure 14: Login to the device

Figure 14 shows the login using PuTTY.

7.10.2 Login to the SFTP Server

The device has available a SFTP server that allows file exchange with any computer (up- and download of files). *"WinSCP"* - which is available as open source - is suitable as SFTP client for the computer (see section 7.1). It consists of only one EXE file, needs no installation and may be started immediately. After program start, dialog *"WinSCP Login"* appears (see Figure 16) and must be adjusted according to the following configurations:

File protocol: SFTP
Host name: IP address for the device as set in section 7.4
User name: *root* (for predefined user account, see section 7.9)
Password: *root* (for predefined user account, see section 7.9)

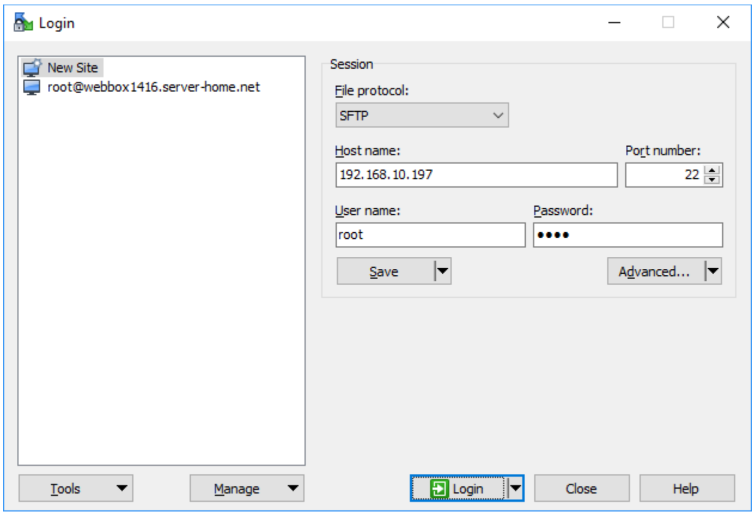

Figure 15: Login settings for WinSCP

After using pushbutton *"Login"*, the SFTP client logs in to the device and lists up the active content of directory *"/root"* in the right window. Figure 16 shows SFTP client *"WinSCP"* after successful login to a device.

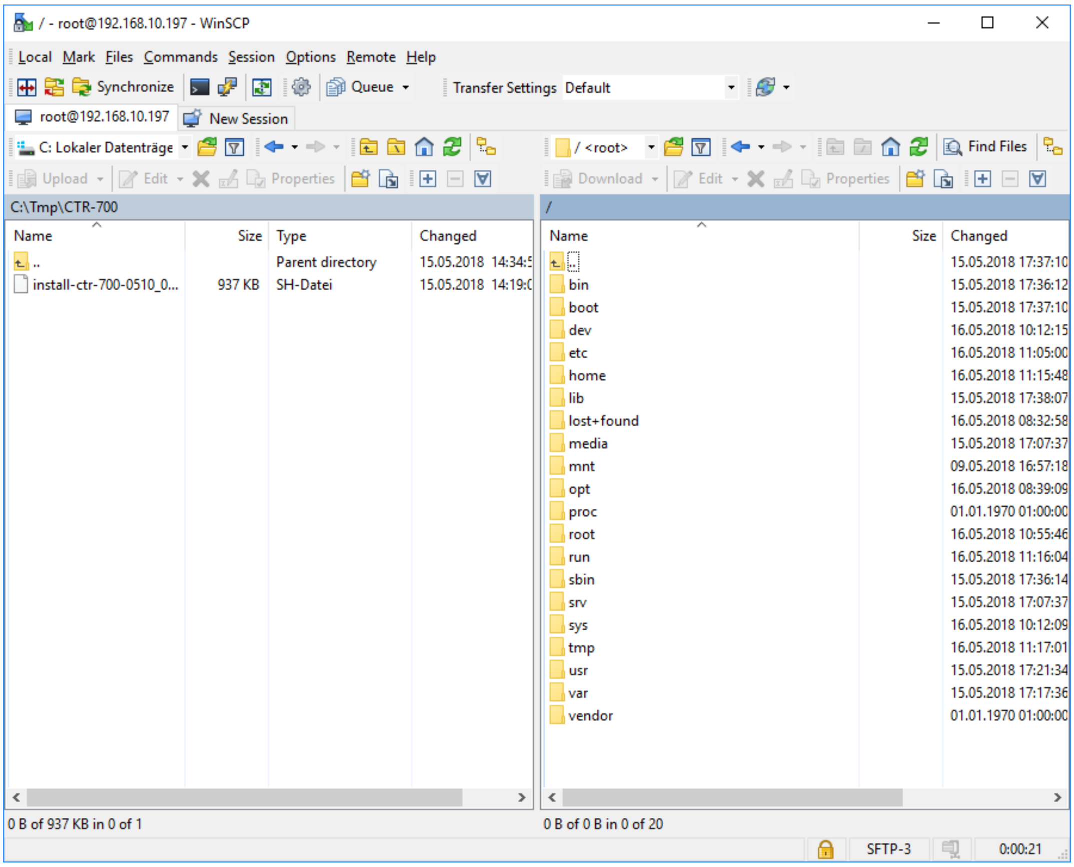

Figure 16: FTP client for Windows "WinSCP"

After successful login, configuration files on the device may be edited by using pushbuttons *"F4"* or *"F4 Edit"* within the SFTP client *"WinSCP"* (select transfer mode *"Text"*). With the help of pushbutton *"F5"* or *"F5 Copy"*, files may be transferred between the computer and the device, e.g. for data backups or to transfer installation files for firmware updates (select transfer mode *"Binary"*).

7.11 Adding and Deleting User Accounts

Adding and deleting user accounts requires the login as described in section 7.10.1.

Adding a new user account takes place via Linux command *"useradd"*. To create a new user, one can use the command *"useradd"* as follows:

```
useradd [options] [username]
```

Advice:	**If the new user account shall be used to access web frontend, the user name must be entered into the configuration file (for details about logging in to WEB-Frontend please compare section 7.7.1 and 7.7.3).**

To **delete** an existing user account from the device, Linux command *"userdel"* plus the respective user name must be used:

```
userdel [options] [username]
```

To get a full list of options for one of the commands, run it with the "--*help*" argument.

7.12 How to Change the Password for User Accounts

Changing the password for user accounts requires login as described in section 7.10.1.

To change the password for an existing user account, Linux command *"passwd"* plus the respective user name must be entered:

```
passwd <username>
```

Figure 17
exemplifies the password change for a user named *"testuser"*.

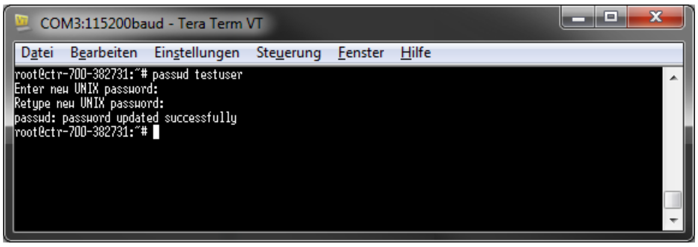

Figure 17: Changing the password for a user account

7.13 Setting the System Time and Time Zone

Setting the system time requires login to the device as described in section 7.10.1.

The current date and time must be set using the Linux command "timedatectl set-time". Linux command *"timedatectl set-time"* is structured as follows:

```
timedatectl [options] set-time "YYYY-MM-DD hh:mm:ss"
```

Example:

```
timedatectl set-time "2017-12-01 10:20:55"
```

The current system time is displayed by entering Linux command *"timedatectl"* (without parameter). Figure 18 exemplifies setting and displaying the system time.

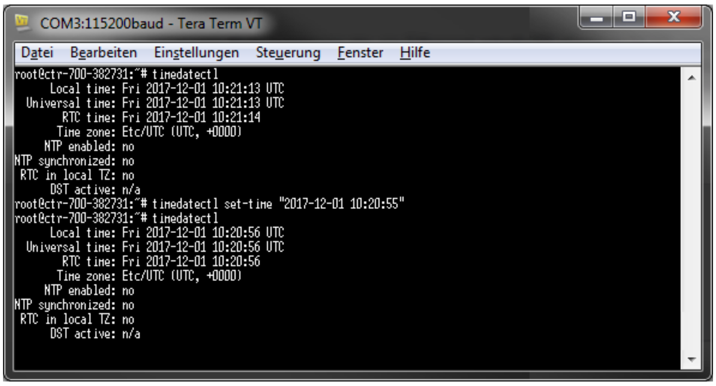

Figure 18: Setting and displaying the system time

Upon start of the device, date and time are taken over from the RTC and set as current system time of the module.

The current time zone must be set using the Linux command “timedatectl set-timezone”. Linux command ″ timedatectl set-timezone″ is structured as follows:

```
timedatectl [options] set-timezone [TIMEZONE]
```

Example:

```
timedatectl set-timezone Europe/Berlin
```

Figure 19 exemplifies setting and displaying the time zone setting.

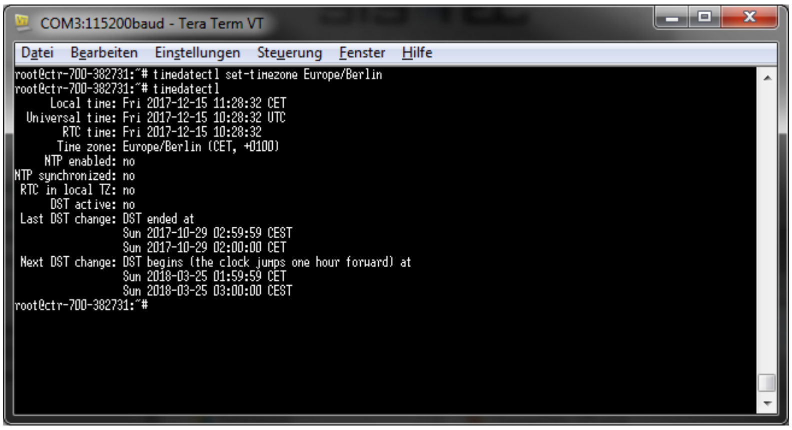

Figure 19: Setting and displaying the system time

With the following command, all available time zones can be looked up:

```
timedatectl list-timezones
```

7.14 File Systems

Table 10 lists the default filesystems and mountpoints of the device.

Table 10: File system configuration

Path	Size	Description
/	8 GiB / size of SD Card	Root filesystem where the Linux is installed to. The content of this partition is stored on the eMMC or SD Card depending on the current Boot-Mode (see Table 3)
/mnt	-	Target for mounting remote directories
/vendor	4 MiB	Read only configuration data of the device. These data should not be altered by the user. The content is stored on one of the general-purpose partitions (aka. “boot0”) to keep its contents event after a firmware update.

Size, usage and path of file systems which are mounted can be identified by using Linux command "df" ("disk free").

Advice: The general purpose eMMC partitions *“/dev/mmcblk2boot0”* and *“/dev/mmcblk2boot1”* contain vendor specific data. These partitions should **not** be used or altered by customers. Otherwise the device will not work as expected!

Particular information about the system login and handling the Linux command shell is given attention in section 7.10.

7.15 Software Installation and Update

All necessary firmware components to run the device are already installed on the module upon delivery. Hence, firmware updates should only be required in exceptional cases, e.g. to input new software that includes new functionality.

7.15.1 Updating the PLC Firmware

PLC firmware represents the run time environment of the PLC. The ***PLC firmware*** can only be generated and modified by the producer; **it is not identical with the PLC user program** which is created by the PLC user. The PLC user program is directly transferred from the *OpenPCS* programming environment onto the module. No additional software is needed.

Updating the PLC firmware requires login to the command shell as described in section 7.10.1 and login to the SFTP server as described in section 7.10.2.

Updating the PLC firmware takes place via a self-extracting firmware archive that is transferred onto the device via SFTP. The respective firmware archive can be transferred into directory *"/tmp"* (see Figure 20).

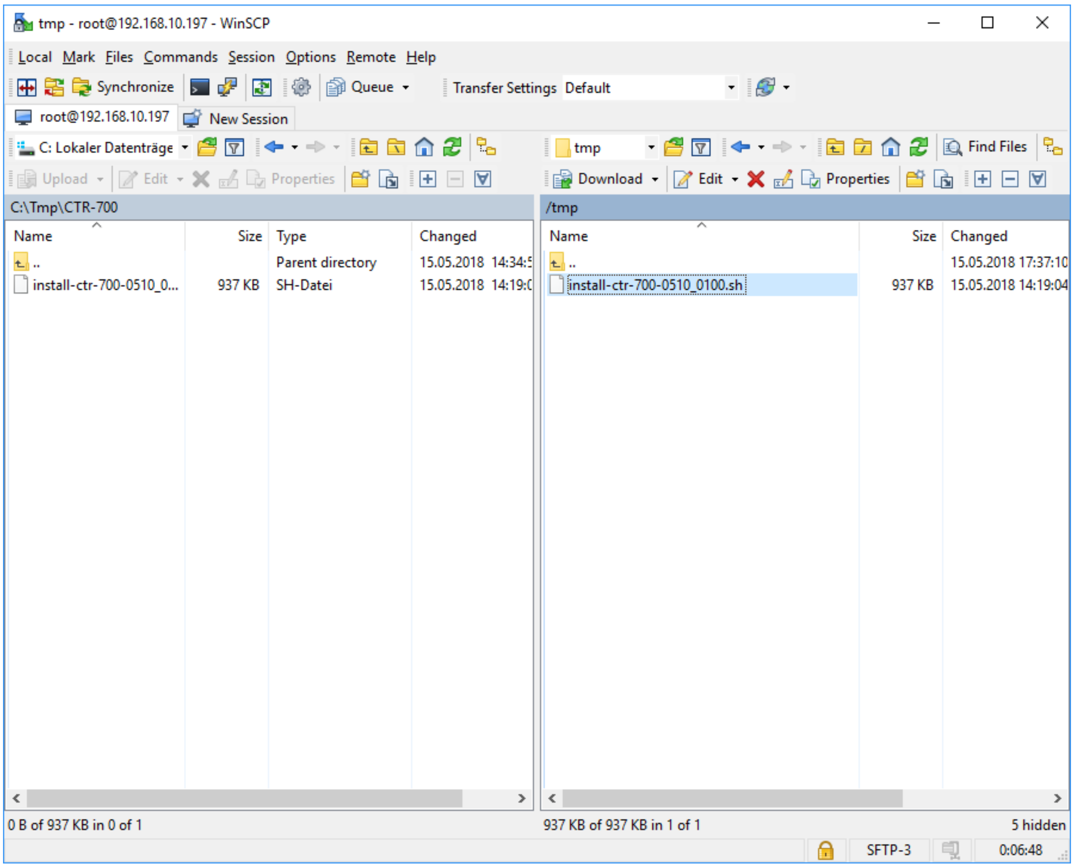

Figure 20: File transfer in SFTP client "WinSCP"

Important: To transfer the firmware archive via SFTP, transfer type “Default” or *"Binary"* must be chosen. If SFTP client *"WinSCP"* is used, the appropriate transfer mode is to be chosen from the menu bar. After downloading the firmware archive, it must be checked if the file transferred to the device has the exact same size as the original file on the computer (compare Figure 20). Any differences in that would indicate a mistaken transfer mode (e.g. *"Text"*). In that case the transfer must be repeated using transfer type *"Binary"*.

After downloading the self-extracting archive, the PLC firmware must be installed on the device. Therefore, the following commands are to be entered in the SSH window. It must be considered that the file name for the firmware archive is labeled with a version identifier (e.g. “install-ctr-700-0510_0100.sh” for version 5.10.01.00). This number must be adjusted when commands are entered:

```
cd /tmp
chmod +x install-ctr-700-0510_0100.sh
./install-ctr-700-0510_0100.sh
```

Advice: The command shell is able to automatically complete names if the Tab key is used ("tab completion"). Hence, it should be sufficient to enter the first letters of each file name and the system will complement it automatically. For example, *"./ins"* is completed to *"./install-ctr-700-0510_0100.sh"* if the Tab key is used.

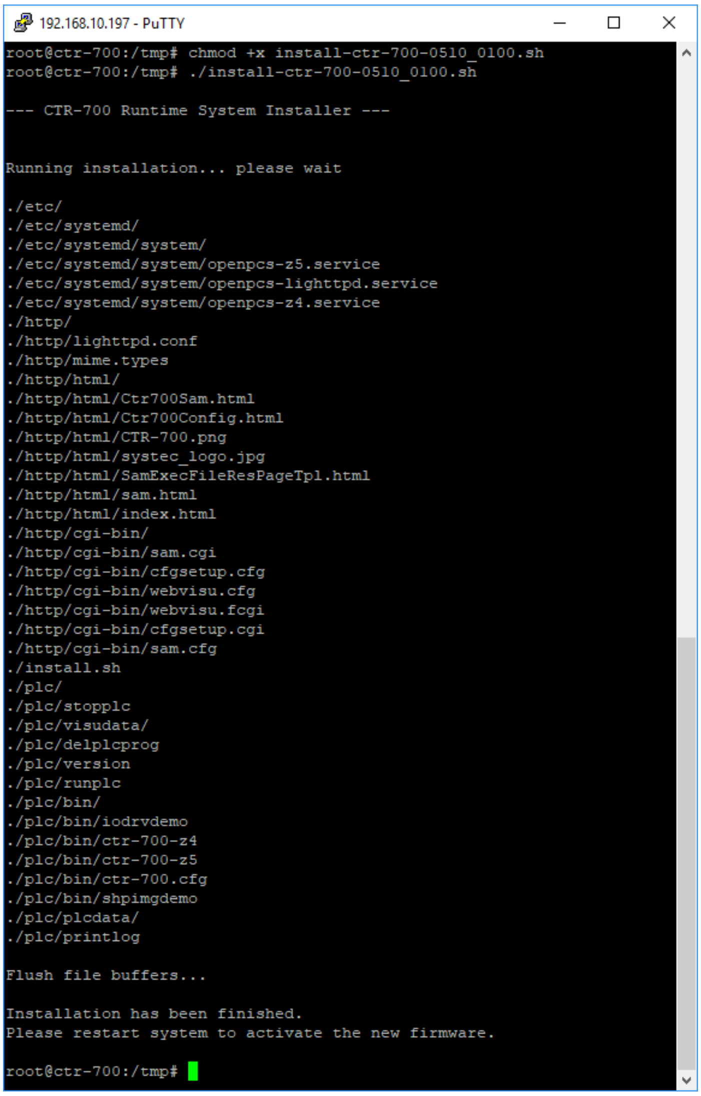

Figure 21: Installing PLC firmware

Figure 21 shows the installation of PLC firmware. After reboot the module is started using the updated firmware.

Advice: **If the PLC firmware is updated, the configuration file is overwritten. This results in a reset of the PLC configuration to default settings. Consequently, after an update, the configuration described in section 7.7 should be checked and if necessary it should be reset.**

7.15.2 Install Debian GNU/Linux to a SD Card for update/recovery

Advice: **Installing Debian GNU/Linux to the SD Card will format all partitions of the SD Card. This means all data on the device will be overwritten.**

The device supports to boot from SD Card as well as from eMMC. The following steps describe how to install a new firmware version to an SD Card and boot from it. This card can then be used to install Debian GNU/Linux to the internal eMMC. The SD Card has to have a size of at least 4 GiB. The SD Card software is provided as a compressed image, which contains the whole file system of the operating system.

The SD Card Image is provided by SYS TEC. The following steps assume the file *"ctr-700-sdcard-v0100.img.zip"* is used. Newer versions will have a slightly different file name. Follow the steps to install this file to an SD Card.

1. Unzip the file
2. Download the tool *"Win32 Disk Imager"*: https://sourceforge.net/projects/win32diskimager/
   This tool will be used to copy the image file to the SD Card image.
3. Insert your SD Card
4. Run *"Win32 Disk Imager"*
   a. Choose the uncompressed SD Card image
   b. Choose the drive letter of your SD Card
   c. Click on the "Write" button to write the image to your SD Card

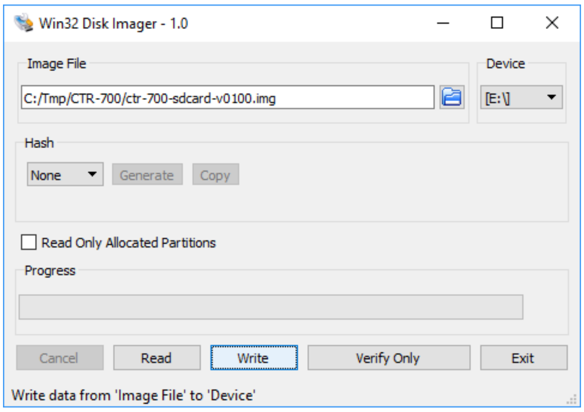

Figure 22: Write SD Card Image using Win32 Disk Imager

5. Insert the SD Card and switch the boot mode to SD Card (turn DIP-Switch 6 off, see Table 3)
6. Power-on the device

The device will now boot from the SD Card. Use a command shell as described in section 7.10.1 to work with the new firmware.

7.15.3 Install/Update Debian GNU/Linux to eMMC

Advice: Installing Debian GNU/Linux to the eMMC will format all partitions of the eMMC. This means all data on the device will be overwritten except vendor data partitions, which contain ADC calibration data or information of purchased licenses.

To be able to install Debian GNU/Linux to the internal eMMC of the device, one has to create an SD Card as described in section 7.15.2.

After a SD Card is available, follow the steps to install the Linux Image from SD Card to the eMMC and boot it afterwards:

1. Insert the SD Card and switch the boot mode to SD Card (turn DIP-Switch 6 off, see Table 3)
2. Start / boot the device
3. Login to a command line shell as described in section 7.10.1
   User: root
   Password: root
4. Execute the following command to install the Linux to the eMMC. This will take a few minutes to execute.

```
debian-emmc.sh
================================
 SYS TEC sysWORXX CTR-700

 Installing Debian to eMMC
================================

...
...
...

Debian Flashed. Press any key to continue...
```

5. Switch the boot mode to eMMC (turn DIP-Switch 6 on, see Table 3)
6. Reboot or shutdown the system. The device will now boot from eMMC.

```
reboot
```

Now the Debian GNU/Linux is installed to the eMMC memory and it can be booted. Using the eMMC has several benefits. The storage is most of the time faster than using an SD Card and it is more reliable in terms of durability.

7.16 TeamViewer IoT Agent

The device can be used with the TeamViewer IoT Agent. Separate licensing is required for the use of the agent. It has a command line user interface. All commands are available via the command line interface tool teamviewer-iot-agent.

The agent is not pre-installed by default and has to be loaded and activated separately. The full documentation and download instruction can be found on the TeamViewer website:
https://community.teamviewer.com/t5/TeamViewer-IoT-Labs/TeamViewer-IoT-for-the-CTR-700/td-p/44477

7.16.1.1 Start TeamViewer IoT Agent

To start the agent, execute the following command:

```
teamviewer-iot-agent start
```

The user will be prompted to enter his TeamViewer account credentials. Upon provisioning completion, the device will be assigned to the associated account and be added to the TeamViewer Contacts list. The device will be automatically added to the TeamViewer IoT Cloud.

It is possible to use the recent Windows TeamViewer Desktop to open a remote AppControl session. By default, the agent connects to a local web server on the device to port 1880. This is the default port of Node-RED. Therefore, the system service Node-RED has to be enabled as described in section 7.8.3:

```
systemctl enable node-red
systemctl start node-red
```

7.16.1.2 Enable Remote Terminal

The TeamViewer IoT Agent provides Remote Terminal access to the device. It is deactivated by default but it can be activated with the following commands:

```
teamviewer-iot-agent configure set EnableRemoteShell 1
```

```
teamviewer-iot-agent restart
```

8 Node-RED Programming Environment

The Node-RED programming environment allows a simple flow-driven approach to program *Internet of Things* applications in a web browser. This is based on a node editor, which provides nodes for:

- Inputs: These nodes have a single output and trigger a flow by sending a *msg* object. A trigger for an input node can be receiving a timer, a network packet, change of a digital input of the device and much more.
- Outputs: These nodes finish the flow execution and provide some reaction to the outside world. Possible reactions can be sending a network packet or tweet, setting a digital output of the device and much more.
- Functions: These nodes will operate on an input *msg* and provide some outputs. These are used to map data value, convert data or multiplex data. There are a lot of predefined nodes for common cases. For more advanced functionality they can also be programmed in *JavaScript*.

All nodes have zero or one Input and zero to n Outputs. SYS TEC provides Node-RED preinstalled on the device together with some custom Nodes. These nodes can be used to access inputs and outputs of the device. Additionally, nodes to access OpenPCS variables are provided.

The following section will provide information on the creation of a simple demo program, using the Node-RED programming environment and the nodes for the I/O Driver.

8.1 Running Node-RED

As described in section 7.8.3, Node-RED has to be started by issuing the following command in a command line shell:

```
systemctl enable node-red
systemctl start node-red
```

This will enable it permanently after boot-up and start the environment without the need for a reboot. Starting Node-RED may take a few seconds. After this, one is able to open the Node-RED editor in a web browser. To access the editor, one can use the hostname or the IP address of the device. In case the device is configured for DHCP, one can find the IP address by issuing the following command.

```
ifconfig
```

To get the hostname of the device use the following command:

```
hostname
```

Now use one of the following links to get access to the Node-RED editor.

http://192.168.10.100:1880/ (replace with your IP address)
or
http://ctr-700-000000:1880/

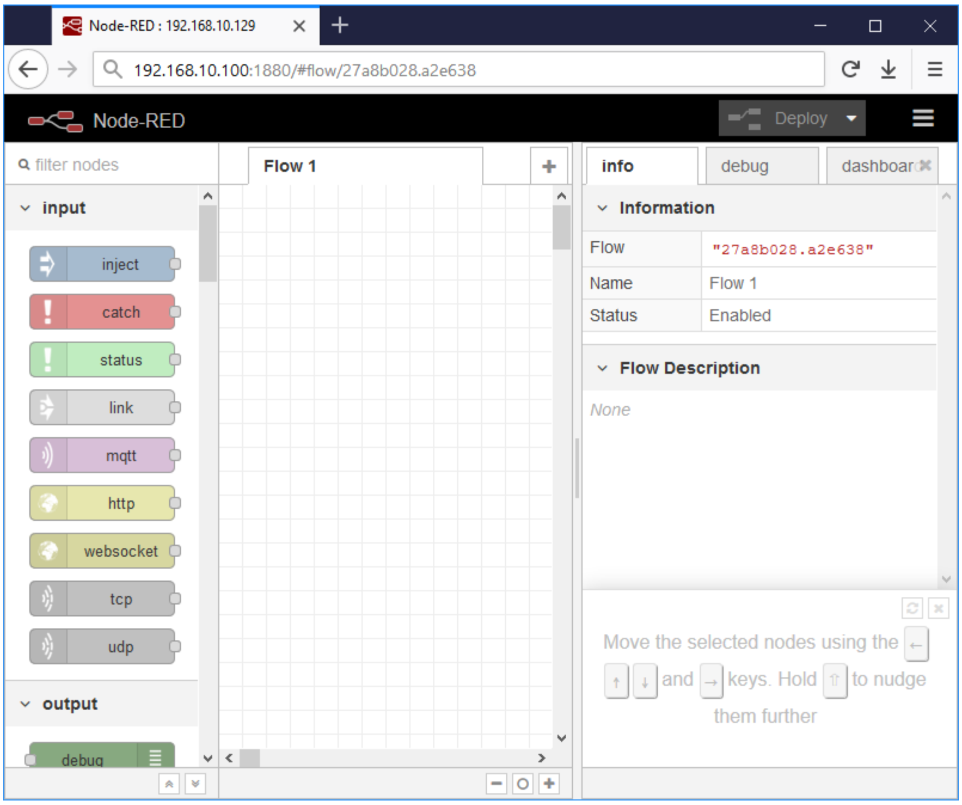

Figure 23: Node-RED editor in the web browser

Node-RED is configured for listening on port 1880 by default. This and the Node-RED configuration can be changed in the file */root/.node-red/settings.js.* The file contains a lot of comments describing the different options. For more documentation lookup the project site of Node-RED:

https://nodered.org/

8.2 Creating a demo application

This section describes the steps to create a simple run light application by using some of the default Node-RED nodes and the nodes from SYS TEC. Node-RED has to be running as described in the previous section.

The following figure shows the final application with all nodes. After a brief explanation of the setup the different settings of each node is explained in detail.

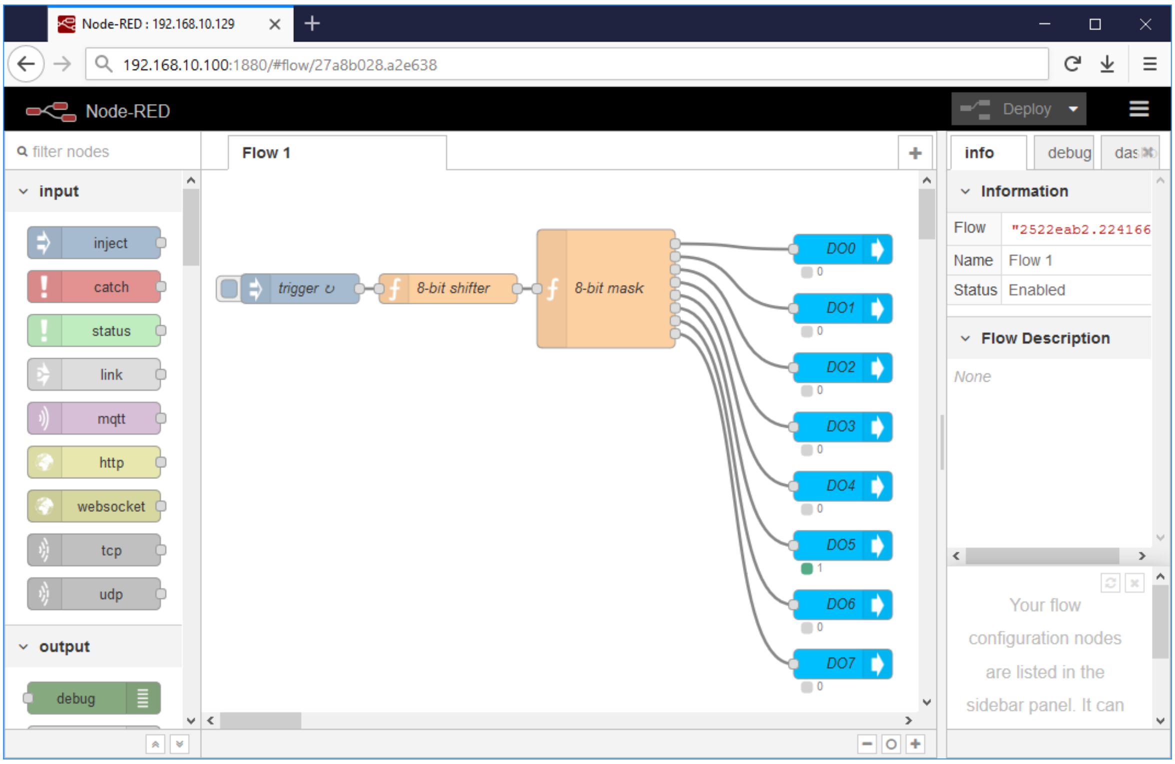

Figure 24: Node-RED demo application

The application contains 3 kinds of nodes starting from the left. The first node called "trigger" gives a repeating input signal, which triggers the execution of the flow. The second node "*8-bit shifter*" will shift a numeric value to the left at each incoming message and outputs the current value. The third node "*8-bit mask"* converts a numeric value (0-255) and provides an output for each value. The nodes "DO0" to "DO7" take the value 0 or 1 and set a digital output accordingly.

Setup the "*trigger*" node:

- Add a node of kind "*inject*" by dragging it to the editor pane and double click on it
- Set "Repeat" to interval, with a value of 0.1 seconds

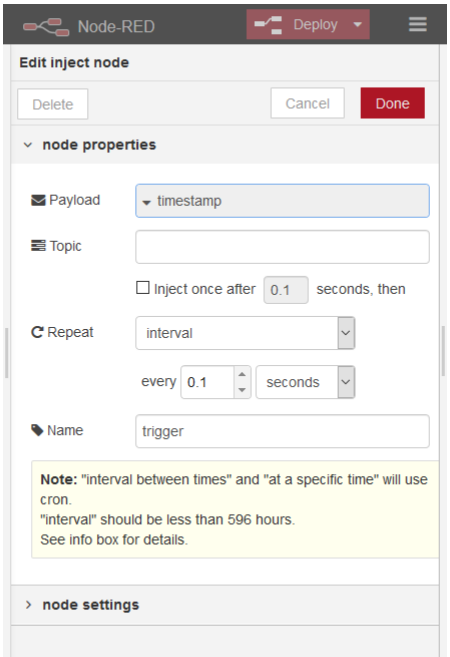

Figure 25: Node: "trigger"

- Click on "*Done*" to confirm the changes

Setup the “*8-bit shifter*” node:

- Add a node of kind “*function*” by dragging it to the editor panel and double click on it
- Copy the following code to the “*Function*” text area and adjust the settings as shown in the screenshot.

```
// -----------------------------------------------------------------
const START = 1;
let shifter = context.get('shifter') || START;

shifter = shifter << 1;
if (shifter > 256) {
    shifter = START;
}

context.set('shifter', shifter);
msg.payload = shifter;
return msg;
// -----------------------------------------------------------------
```

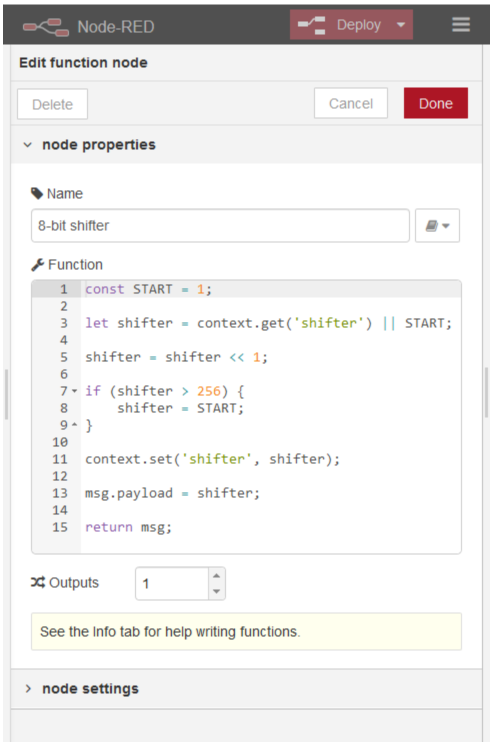

Figure 26: Node: “8-bit shifter”

- Click on “*Done*” to confirm the changes

Setup the “*8-bit mask*” node:

- Add a node of kind “*function*” by dragging it to the editor pane and double click on it
- Copy the following code to the “*Function*” text area, set *Outputs* to 8 and adjust the settings as shown in the screenshot.

```
// -----------------------------------------------------------------
let input = msg.payload;
let outputs = [];

for (let i = 0; i < 8; i++) {
    let channel = {};
```

```
    channel.topic = "";

    if (input & (1 << i)) {
        channel.payload = 1;
    } else {
        channel.payload = 0;
    }

    outputs.push(channel);
}

return outputs;
// -------------------------------------------------------------------
```

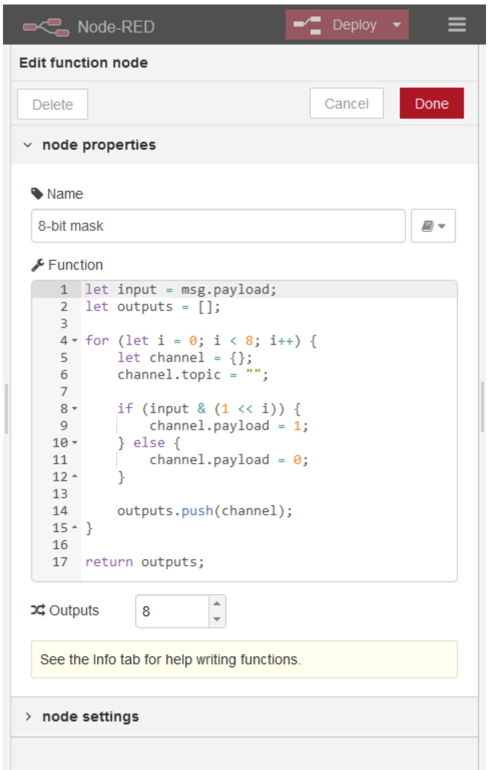

Figure 27: Node: “8-bit mask”

- Click on “*Done*” to confirm the changes

Setup the “*DO0*” node:

- Add a node of kind “*ctr700_out*” by dragging it to the editor pane and double click on it
- Set the *Channel* to DO0, the *Init state* to 0, select *Use alternative topic* and set it to “#” like shown in the screenshot below:

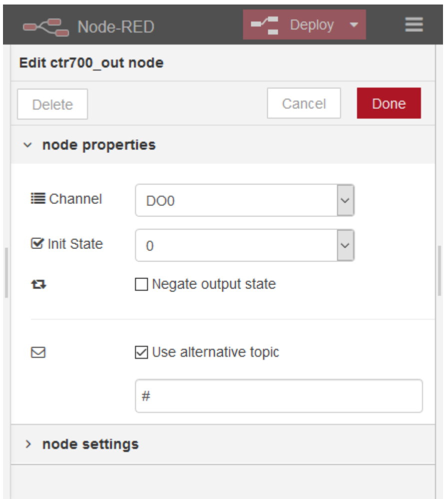

Figure 28: Node: “DO0”

- Click on “*Done*” to confirm the changes

Copy the output node for *DO0* multiple times for each output until *DO7* and adjust the settings for each digital output. Connect all nodes as shown in Figure 24. Now the application is complete. To start it, click on the *Deploy* button in the top right corner of the editor interface. The output LED should now show a run light on *DO0* to *DO7*.

9 Mono/C#

The device comes with the preinstalled mono package together with C# bindings for the I/O driver. This allows to write C# applications for the device in Microsoft Visual Studio 2017. The application will implement a simple run light for digital outputs 0 to 7. Here on the example of the CTR-700.

9.1 Create a C# application

Create a console application as shown in the screenshot below:

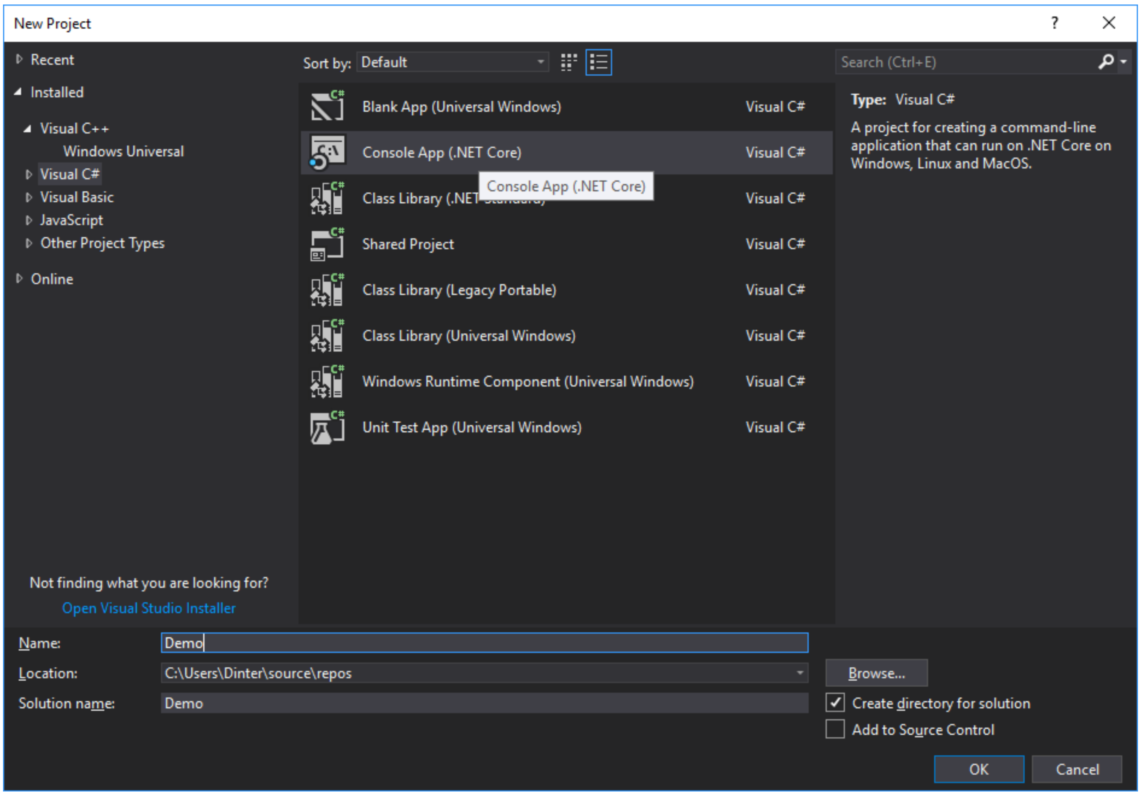

Figure 29: Visual Studio console application

The bindings to the I/O Driver are located in the *Oracle VM VirtualBox* provided for the device. (3912005 "Oracle VM VirtualBox-Image of the Linux development system") The source code of the bindings needs to be copied to the project. The path, for example for the CTR-700, to the bindings in the *Oracle VM VirtualBox* is:

/projects/CTR-700/driver/ctr700drv/Bindings/CSharp/Ctr700Driver/Ctr700.cs

The content of the file Program.cs needs to be replaced with the following source code:

```
using System;
using Systec.Ctr700Driver;
using Mono.Unix;
using Mono.Unix.Native;

namespace Demo
{
    class Program
    {
        static int Main(string[] args)
        {
            using (var ctr700 = new Ctr700())
            {
                MainLoop(ctr700);
            }
            return 0;
        }

        private static void MainLoop(Ctr700 ctr700)
        {
            const byte START = 1;
            const byte DELAY_MS = 100;
            byte bMask = START;
            UnixSignal sigint = new UnixSignal(Signum.SIGINT);

            while (!sigint.WaitOne(0))
            {
                bMask <<= 1;
                if (bMask == 0)
                {
                    bMask = START;
                }

                for (byte bChannel = 0; bChannel < 8; bChannel++)
                {
                    bool fValue = (bMask & (1 << bChannel)) != 0;
                    ctr700.SetDigitalOutput(bChannel, fValue);
                }

                System.Threading.Thread.Sleep(DELAY_MS);
            }

            for (byte bChannel = 0; bChannel < 8; bChannel++)
            {
                ctr700.SetDigitalOutput(bChannel, false);
            }
        }
    }
}
```

The application uses the class Ctr700Drv, which contains static methods to access the driver. This will be used to set the digital outputs of the CTR-700. The constructor for this class also deconstructs it. (see variable creation before calling the MainLoop-Method)

Inside the main loop a mask will be shifted and reset, if the value is zero. The value of the mask will be signaled by bitwise activating the digital outputs represented by the mask. Each loop cycle is finished by sleeping for 100 milliseconds.

Now the project can be built by clicking on *Build / Build Demo.*

9.2 Run the application

To run the application on the target, copy the build Demo.exe in the projects output directory to the device. This can be done by using SFTP (see section 7.10.2). Login the device with a command shell via SSH or a Terminal program. Run the application by running the following commands.

```
cd <DIRECTORY_CONTAINING_THE_DEMO>
mono Demo.exe
```

The application can be stopped by pressing CTRL-C. One can also directly execute applications without using mono explicitly if the binary is marked as executable file. The following commands show how to achieve this:

```
chmod +x Demo.exe
./Demo.exe
```

10 Java

The device comes with the preinstalled OpenJDK package and also with Java bindings for the I/O driver. The following section will describe how to setup a Java application in the Oracle VM VirtualBox provided for the device. (3912005 "Oracle VM VirtualBox-Image of the Linux development system") The application will implement a simple run light for digital outputs 0 to 7. Here on the example of the CTR-700.

10.1 Create a Java Project

The following steps describe the steps necessary to create the demo application. Start Eclipse, choose a workspace and create a new *Java Project*.

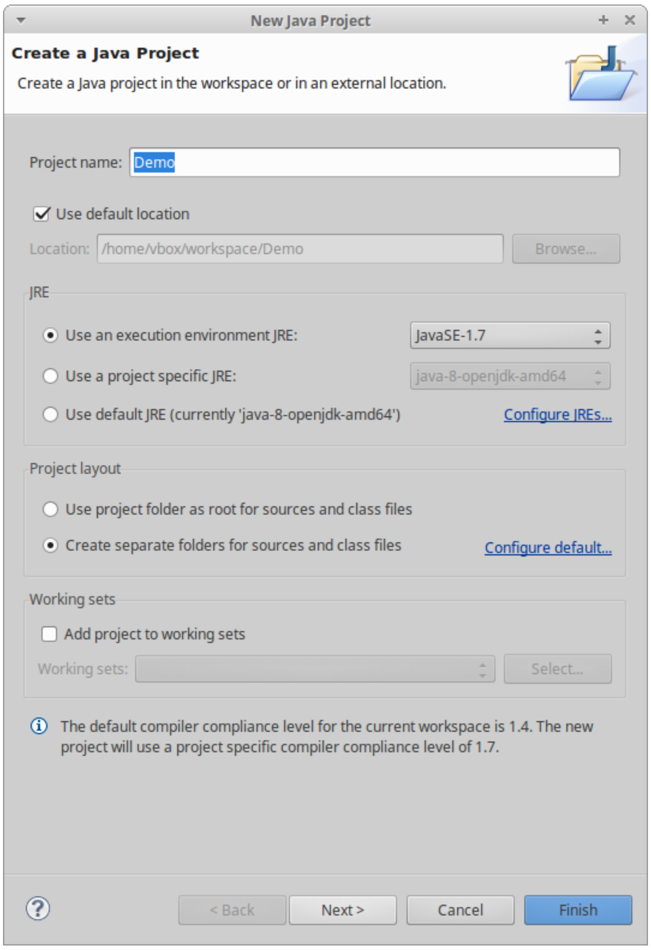

Figure 30: Java Demo: Project setup

Create the Project structure:
Open */projects/CTR-700/driver/ctr700drv/Bindings/Java/* in the file manager and copy the *lib* directory and the file *src/com/systec/Ctr700Drv.java* to the project. The file manager is not needed anymore and can be closed.
After this, one can use the auto-fix feature of *Eclipse* to move *Ctr700Drv.java* to the correct subdirectory of the project. By right clicking on *lib/jna.jar* in the *Package Explorer* and clicking on *Build Path / Add to Build Path* the JNA library can be used by the demo application.

Create a new class Main in the package demo by right clicking on *src* and then click *New / Class* and adjust setting as shown below:

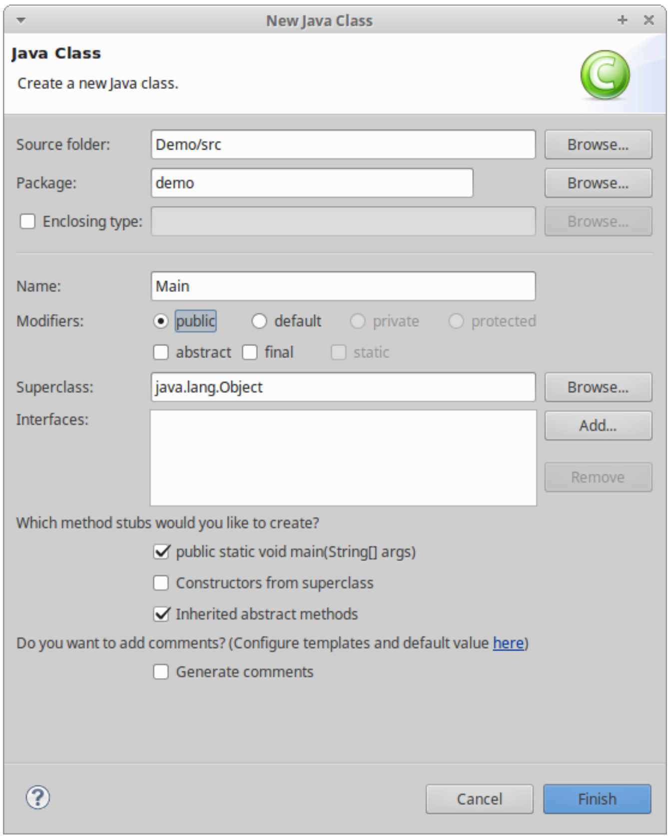

Figure 31: Java Demo: Main class

The structure in *Project Explorer* should now look like in the screenshot below. Both *Java* files have to exist under the *src* directory and the file *jna.jar* has to be a member of *Referenced Libraries.*

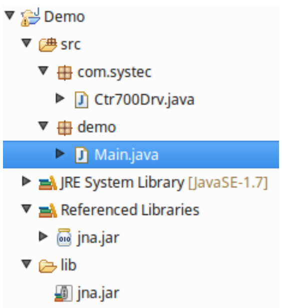

Figure 32: Java Demo: Project structure

Copy the following Java demo source code to Main.java:

```
package demo;
import com.systec.Ctr700Drv;
import com.systec.Ctr700Drv.Ctr700Exception;

public class Main {
      final static int START = 1;
      final static int DELAY_MS = 100;
      static Ctr700Drv ctr700;

      public static void main(String[] args) throws
                              InterruptedException {

            int iMask = START;

            try {
                  ctr700 = new Ctr700Drv();
                  ctr700.init();

                  Runtime.getRuntime().addShutdownHook(new Thread() {
                        @Override
                        public void run() {
                              for (int i = 0; i < 8; i++) {
                                    ctr700.setDigiOut(i, false);
                              }
                              ctr700.shutDown();
                        }
                  });

                  // Main loop
                  while (true) {
                        // Output LSB of the mask
                        for (int i = 0; i < 8; i++) {
                              boolean fValue =
                                    (iMask & (1 << i)) != 0;
                              ctr700.setDigiOut(i, fValue);
                        }

                        iMask <<= 1;
                        if (iMask > 256) {
                              iMask = START;
                        }

                        Thread.sleep(DELAY_MS);
                  }
            } catch (Ctr700Exception e) {
                  System.err.println(e.getMessage());
            }
      }
}
```

The application creates an object of Ctr700Drv. This will be used to set the digital outputs of the CTR-700. Before using it one needs to call the *init()*-Method. On exit of the application the *shutdown*()-Method should be called. Inside the main loop a mask will be shifted and reset, if the value is to large to show the enabled output(s). The value of the mask will be signaled by bitwise activating the digital outputs represented by the mask. Each loop cycle is finished by sleeping for 100 milliseconds.

The demo application is now complete and can be run or debugged.

10.2 Run the Java application

Create a new *Run Configuration* of kind "*Java Application*" and change the settings as shown in the screenshot below. *Apply* and *Close*.

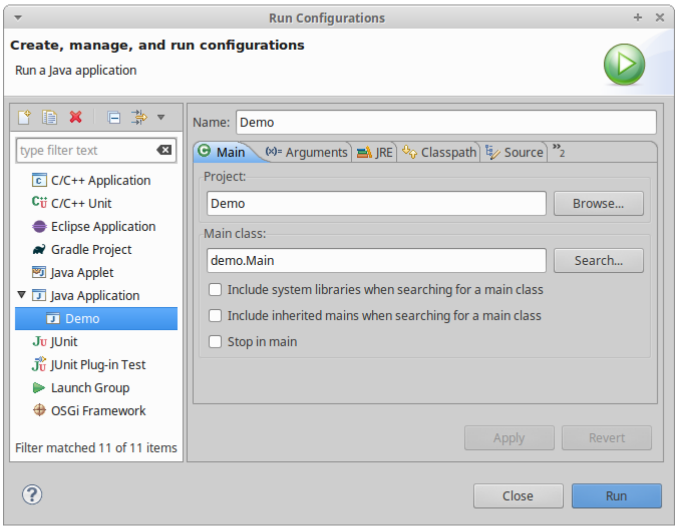

Figure 33: Java Demo: Run configuration

Export a runnable JAR file by *File / Export… / Runnable JAR file.* Click on *Next*, choose the created run configuration and choose a destination path to export the JAR file to. This JAR file will then contain the demo source with all dependencies packaged as a single file.

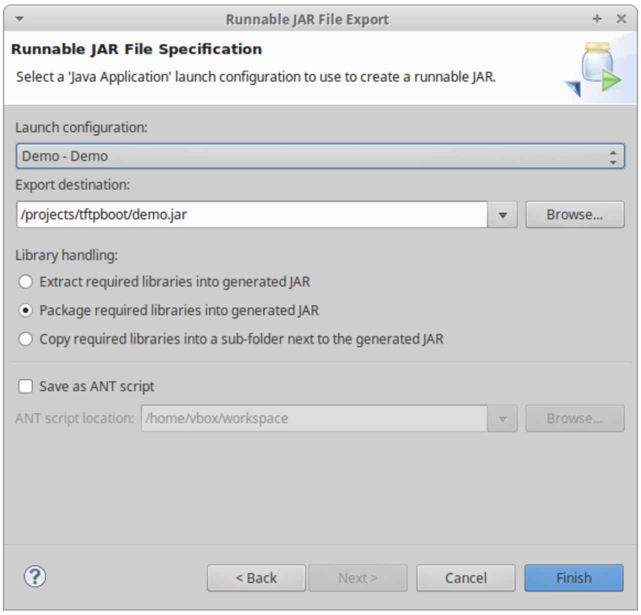

Figure 34: Java Demo: Export Java JAR archive

Copy the created JAR file to the device by using SFTP for example. This is described in section 7.10.2. Login to the device with a command shell via SSH or a Terminal program. Run the application by running the JVM with the JAR file as argument.

```
cd <DIRECTORY_CONTAINING_THE_JAR>
java -jar demo.jar
```

The application can be stopped by pressing CTRL-C.

10.3 Debug the Java application

Start the application on the target with some additional arguments to the JVM. This will start JVM in a debug mode, waiting for a remote to connect.

```
java  -Xdebug \
      -Xrunjdwp:transport=dt_socket,server=y,suspend=y,address=8000 \
      -jar demo.jar
```

In *Eclipse* create another *Run Configuration* for debugging a *Remote Java Application* as shown below but substitute the *Host* IP address with the one of your device. After this click on *Debug* to start the debugging session.

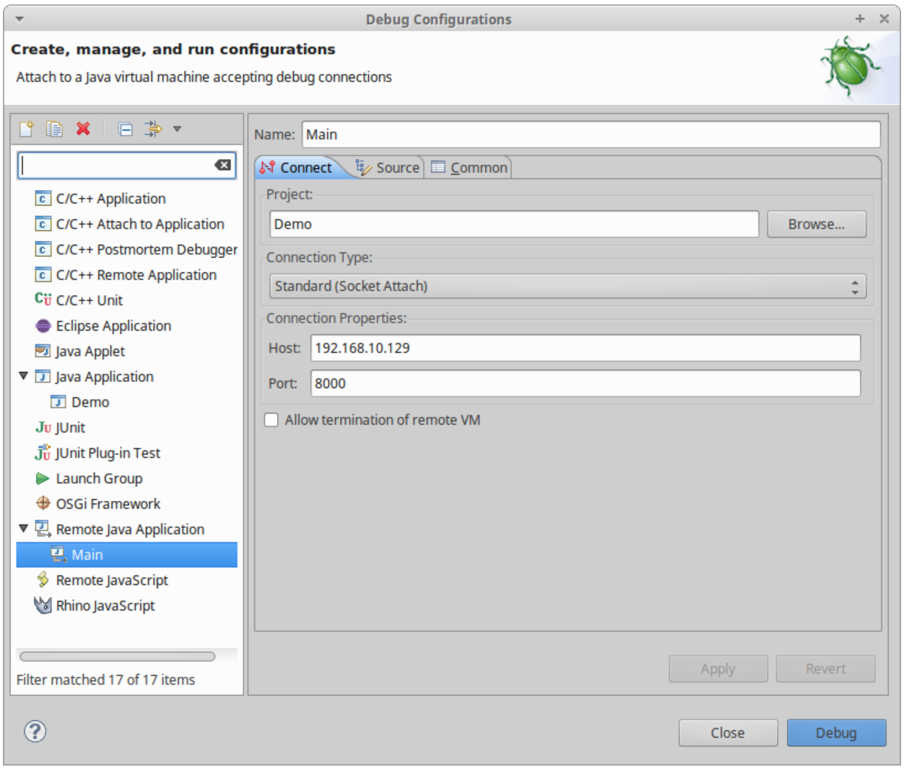

Figure 35: Java Demo: Debug configuration

Now all common debugging features can be used to debug the application. This includes features such as pause execution, stepping through your code, setting breakpoints, watching variable values and much more.

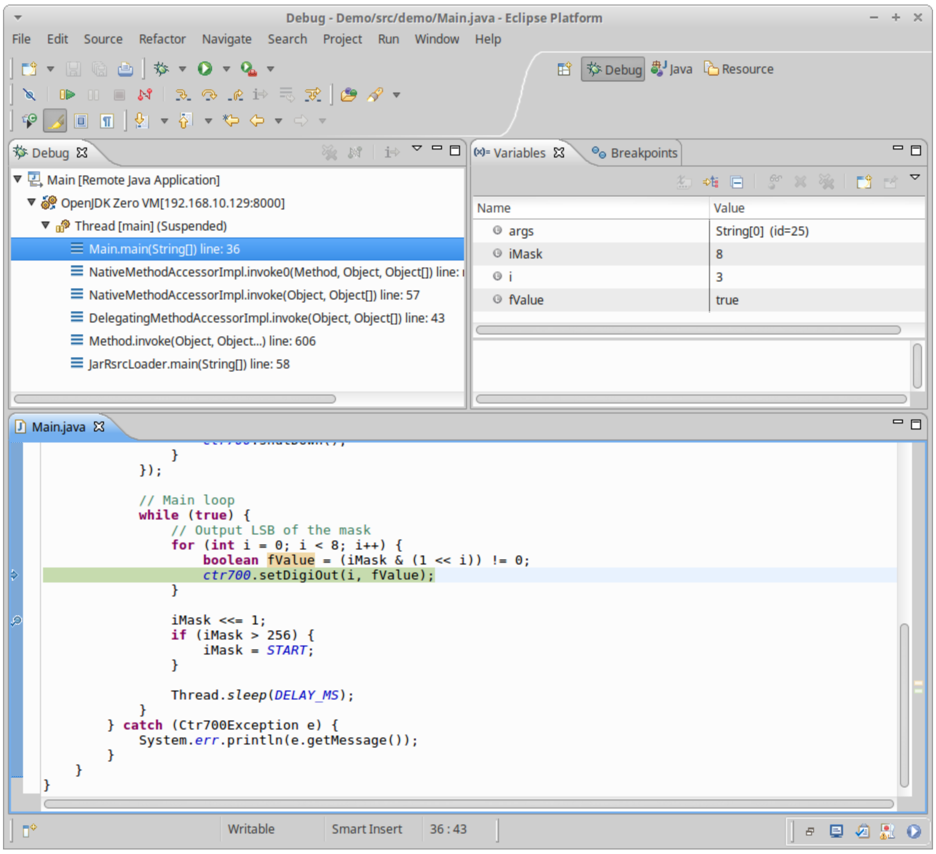

Figure 36: Java Demo: Debug example

11 Python

The device comes with Python 2 and Python 3 and provides Python bindings for the I/O driver. This allows to write Python applications for the device, which allow access to the low-level peripherals. The following application will implement a simple run light for digital outputs 0 to 7. Here on the example of the CTR-700.

11.1 Create a Python application

The bindings to the I/O Driver are located in the *Oracle VM VirtualBox*. (3912005 "Oracle VM VirtualBox-Image of the Linux development system") The source code of the bindings needs to be copied to the project. The path to the bindings in the *Oracle VM VirtualBox* is:

/projects/CTR-700/driver/ctr700drv/Bindings/Python/ctr700drv.py

Create a file demo.py and fill it with the following source code:

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-

import signal
import time
import sys
from ctr700drv import Ctr700Drv

# signal handler to intercept ctrl+c
def signal_handler(sig, frame):
    for uChannel in range(0, 8):
        ctr700.set_digi_out(uChannel, False)

    ctr700.shutdown()
    sys.exit(0)

signal.signal(signal.SIGINT, signal_handler)

if __name__ == "__main__":

    uDigiOut = 1

    ctr700 = Ctr700Drv()
    ctr700.init()

    while True:
        uDigiOut = (uDigiOut << 1 | uDigiOut >> (8 - 1)) & 0xff

        for uChannel in range(0, 8):
            if (uDigiOut & (1 << uChannel)):
                fDoState = True
            else:
                fDoState = False

            ctr700.set_digi_out(uChannel, fDoState)

        time.sleep(0.3)  # wait 300ms
```

The application uses the class Ctr700Drv, which contains methods to access the driver. This will be used to set the digital outputs of the device. Before using it, one needs to call the *init()*-Method. On exit of the application the *shutdown*()-Method should be called. Inside the main loop a mask will be shifted. The value of the mask will be signaled by bitwise activating the digital outputs represented by the mask. Each loop cycle is finished by sleeping for 300 milliseconds.

11.2 Run the Python application

To run the application on the target, copy the created demo.py together with the Python bindings ctr700drv.py to the device. This can be done by using SFTP (see section 7.10.2). Login with a command shell via SSH or a Terminal program.

It is necessary to install all mandatory python dependencies to run the application successfully. Therefore, copy the one of the Python setup files, which are located in */usr/share/libctr700drv/demo/python/* and execute it. The following steps will prepare to run it for Python 3. The same can be achieved for Python 2 by copying and using the file *setup_py2.sh* instead of *setup_py3.sh*.

```
cp  /usr/share/libctr700drv/demo/python/ setup_py3.sh .
chmod +x setup_py3.sh
./setup_py3.sh
```

After that, run the application by executing the following commands.

```
cd <DIRECTORY_CONTAINING_THE_PYTHON>
python demo.py
```

The application can be stopped by pressing CTRL-C.

11.3 Debug the Python application

To debug the application, the built-in debugger *pdb* can be used. Execute the following commands on the device to start a debugging session.

```
cd <DIRECTORY_CONTAINING_THE_PYTHON>
python -m pdb demo.py
```

Now the debugger is waiting for certain commands to control it. To get a list of all commands type *h* or *help*. A full reference of commands can be found in Python documentation: https://docs.python.org/3.5/library/pdb.html.

All common debugging features are available to debug the application. For example, a breakpoint can be set on line 27 with the following command.

```
b demo.py:27
```

To run the application until this breakpoint is reached, the *c* or *continue* command can be executed.

12 PLC Functionality

Further information about the supported PLC functionalities, e.g. retain variables or function blocks, can be found in the documents referenced inTable 1.

12.1 Starting the PLC Runtime

The PLC runtime is not enabled by default. To activate the automatic start, one has to enable the services *“openpcs-z4”* or *“openpcs-z5”* as described in section 7.8.3.

If enabled, the device loads all necessary firmware components upon power-on or reset and starts running the PLC program afterwards (if enabled). Hence, the device is suitable for the usage in independent control systems. In case of power breakdown, such systems resume the execution of the PLC program independently and without user intervention.

12.2 Programming the Device

The device is programmed with IEC 61131-3-conform *OpenPCS* programming environment. There exist additional manuals about *OpenPCS* that describe the handling of this programming tool. Those are part of the software package *"OpenPCS"*. All manuals relevant are listed in Table 1.

The firmware is based on standard firmware for SYS TEC's compact control units. Consequently, it shows identical properties like other SYS TEC control systems. This affects especially the process image setup (see section 12.3) as well as the functionality of control elements (DIP-Switch, Run/Stop switch, Run-LED, Error-LED).

Depending on the firmware version used, it provides numerous function blocks to the user to access communication interfaces. Section 7.8.3 describes the selection of the appropriate firmware version.

Table 19 in **Appendix A** contains a complete listing of firmware functions and function blocks that are supported by the device. Detailed information about using the CAN interfaces in connection with CANopen is provided in section 12.8.

12.3 Process Image of the Device

12.3.1 Local In- and Outputs

Compared to other SYS TEC compact control systems, this device obtains a process image with identical addresses. All supported in- and outputs listed in Table 11.

Table 11: Assignment of in- and outputs to the process image

I/O of the device	Address and Data type in the Process Image
DI0 ... DI7	**%IB0.0** as Byte with DI0 … DI7 %IX0.0 … %IX0.7 as single Bit for each input
DI8 ... DI15	**%IB1.0** as Byte with DI8 … DI15 %IX1.0 … %IX1.7 as single Bit for each input
AI0	**%IW8.0** 15Bit + sign (0 … +32767)
AI1	**%IW10.0** 15Bit + sign (0 … +32767)
AI2	**%IW12.0** 15Bit + sign (0 … +32767)
AI3	**%IW14.0** 15Bit + sign (0 … +32767)
C0	**%ID40.0** 31Bit + sign (-2^{31} - 2^{31} -1) counter input: DI14 (%IX1.6), direction: DI15 (%IX1.7)
CPU Temperature Sensor	**%ID72.0** 31Bit + sign as 1/10000 °C
System Temperature Sensor	**%ID76.0** 31Bit + sign as 1/10000 °C
DO0 ... DO7	**%QB0.0** as Byte with DO0 … DO7 %QX0.0 … %QX0.7 as single Bit for each output
DO8 … DO15	**%QB1.0** as Byte with DO8 … DO15 %QX1.0 … %QX1.7 as single Bit for each output
REL0 and REL1 (corresponds to DO16 … DO17)	**%QB2.0** as Byte with REL0 and REL1 %QX2.0 … %QX2.1 as single Bit for each Relay
DO Mask	**%QD1984.0** Mask of digital outputs a bitmask of digital outputs, which will **not** be written from process image to hardware registers. (LSB relates to DO0, MSB relates to DO15)
AI0 Configuration	**%QW1928.0** Configuration of AI0 0: keep configuration, 1: set to voltage measurement, 2: set to current measurement
AI1 Configuration	**%QW1930.0** Configuration of AI1 see AI0 Configuration
AI2 Configuration	**%QW1932.0** Configuration of AI2 see AI0 Configuration
AI3 Configuration	**%QW1934.0** Configuration of AI3 see AI0 Configuration

Advice: The device works with Little-Endian format (“Intel-Notation). Consequently, and on the contrary to controls using Big-Endian (“Motorola-Notation), it is **possible** to sum up several BYTE variables of the process image to one WORD or DWORD and to access Bits above Bit7. The following example shows issue described:

```
bInByte0    AT    %IB0.0    :    BYTE;
bInByte1    AT    %IB1.0    :    BYTE;
wInWord0    AT    %IW0.0    :    WORD;

wInWord0.0 == bInByte0.0  due to Little-Endian: wInWord0.0 <> bInByte1.0
wInWord0.8 == bInByte1.0  due to Little-Endian: wInWord0.8 <> bInByte0.0
```

In- and outputs are not negated in the process image. Hence, the H-level at one input leads to value "1" at the corresponding address in the process image. Contrariwise, value "1" in the process image leads to an H-level at the appropriate output.

12.3.2 Network Variables for CAN1

Contrary to interface CAN0, interface CAN1 of the device is designed as static object dictionary. Thus, at interface CAN1 the device acts as a CANopen I/O device. All static network variables for CAN1 are accessible via the marker section of the process image.

Section 12.3.2 includes more detailed information about CAN interface CAN1 and the network variables that are provided by it in the marker section.

12.4 Communication Interfaces

12.4.1 Serial Interfaces

The device features one service and three serial interfaces (X10, X15 … X17). Details about hardware activation are included in section 6.8.1.

The interfaces may be used from a PLC program via function blocks of type *"SIO_Xxx"* (see manual *"SYS TEC-specific Extensions for OpenPCS / IEC 61131-3"*, Manual no.: L-1054).

12.4.2 CAN Interfaces

Both CAN interfaces allow for data exchange with other devices via network variables and they are accessible from a PLC program via function blocks of type *"CAN_Xxx"* (see *"User Manual CANopen Extension for IEC 61131-3"*, Manual no.: L-1008).

Section 12.3.2 provides detailed information about the usage of the CAN interfaces in connection with CANopen.

12.4.3 Ethernet Interface

Details about the hardware activation are included in section 6.8.3

The interface is accessible from a PLC program via function blocks of type *"LAN_Xxx"* (see manual *"SYS TEC-specific Extensions for OpenPCS / IEC 61131-3"*, Manual no.: L-1054).

The exemplary PLC program *"UdpRemoteCtrl"* illustrates the usage of function blocks of type *"LAN_Xxx"* within a PLC program.

12.5 Specific Peripheral Interfaces

12.5.1 Counter Inputs

The device features a fast counter input (C0). Prior to its usage, all counter inputs must be parameterized via function block *"CNT_FUD"* (see manual *"SYS TEC-specific Extensions for OpenPCS / IEC 61131-3"*, Manual no.: L 1054). Afterwards, in a PLC program the current counter value is accessible via the process image (see Table 11 in section 12.3.1) or via function block *"CNT_FUD"*. Table 12 lists the allocation between counter channels and inputs.

Table 12: Allocation between counter channels and inputs

Counter channel	Counter input	Optional direction input	Counter value in process image
C0	C0 (DI14) %IX1.6	DI15 %IX1.7	%ID40.0

12.5.2 Pulse Outputs

To release PWM and PTO signal sequences, the device features 2 pulse outputs (P0 and P1). Prior to its usage, all pulse outputs must be parameterized using function block *"PTO_PWM"* (see manual *"SYS TEC-specific Extensions for OpenPCS / IEC 61131 3"*, Manual no.: L 1054). After the impulse generator is started, it takes over the control of respective outputs. After the impulse generator is deactivated, the respective output adopts the corresponding value that is filled in the process image for this output (see Table 11 in section 12.3.1). Table 13 lists the allocations between impulse channels and outputs.

Table 13: Allocation between impulse channels and outputs

Impulse channel	Impulse output
P0	P0 (DO14) %QX1.6
P1	P1 (DO15) %QX1.7

12.6 Control and Display Elements

12.6.1 Run/Stop Switch

The Run/Stop switch makes it possible to start and interrupt the execution of the PLC program. Together with start and stop pushbuttons of the *OpenPCS* programming environment, the Run/Stop switch represents a "logical" AND-relation. This means that the PLC program will not start the execution until the local Run/Stop switch is positioned to *"Run"* **AND** additionally the start command (cold, warm or hot start) is given by the *OpenPCS* user interface. The order hereby is not relevant. A run command given by *OpenPCS* while at the same time the Run/Stop switch is positioned to *"Stop"* is visible through quick flashing of the Run- and Error-LED.

12.6.2 Run-LED (green, D035)

The Run-LED provides information about the activity state of the control system. The activity state is shown through different modes:

Table 14: Display status of the Run-LED

LED Mode	PLC Activity State
Off	The PLC is in state *"Stop"*: • the PLC does not have a valid program, • the PLC has received a stop command from the *OpenPCS* programming environment or • the execution of the program has been canceled due to an internal error
Quick flashing in relation 1:8 to pulse	The PLC is on standby but is not yet executing: • The PLC has received a start command from the *OpenPCS* programming environment but the local Run/Stop switch is still positioned to *"Stop"*
Slow flashing in relation 1:1 to pulse	The PLC is in state *"Run"* and executes the PLC program.
Quick flashing in relation 1:1 to pulse	The PLC is in mode *"Reset"*

12.6.3 Error-LED (red, D036)

The Error-LED provides information about the error state of the control system. The error state is represented through different modes:

Table 15: Display status of the Error-LED

LED Mode	PLC Error State
Off	No error has occurred; the PLC is in normal state.
Permanent light	A severe error has occurred: • The PLC was started using an invalid configuration (e.g. CAN node address 0x00) and had to be stopped or • A severe error occurred during the execution of the program and caused the PLC to independently stop its state *"Run"* (division by zero, invalid Array access, ...), see below
Slow flashing in relation 1:1 to pulse	A network error occurred during communication to the programming system; the execution of a running program is continued. This error state will be reset independently by the PLC as soon as further communication to the programming system is successful.
Quick flashing in relation 1:1 to pulse	The PLC is in mode *"Reset"*
Quick flashing in relation 1:8 to pulse	The PLC is on standby, but is not yet running: • The PLC has received a start command from the *OpenPCS* programming environment but the local Run/Stop switch is positioned to *"Stop"*

In case of severe system errors such as division by zero of invalid Array access, the control system passes itself from state *"Run"* into state *"Stop"*. This is recognizable by the permanent light of the Error-LED (red). In this case, the error cause is saved by the PLC and is transferred to the computer and shown upon next power-on.

12.7 Local Deletion of a PLC Program

PLC programs can only be deleted with an established connection via a terminal program, SSH or SFTP (see section 7.1). First, the device has to be stopped (S2 switched to left), then the file *PlcArchv.bin* found in ***"/home/plc/plcdata/"*** can be deleted. Only the file has to be deleted not the directory!

12.8 Using CANopen for CAN Interfaces

The device features two CAN interfaces (CAN0 … CAN1), both are usable as CANopen Manager (conform to CiA Draft Standard 302). The configuration of both interfaces (active/inactive, node number, Bitrate, Master on/off) is described in section 7.7.

Both CAN interfaces allow for data exchange with other devices via network variables and they are usable from a PLC program via function blocks of type *"CAN_Xxx"*. More details are included in *"User Manual CANopen Extension for IEC 61131-3"*, Manual no.: L-1008.

The CANopen services **PDO** (***P***rocess ***D***ata ***O***bjects) and **SDO** (***S***ervice ***D***ata ***O***bjects) are two separate mechanisms for data exchange between single field bus devices. Process data sent from a node (**PDO**) are available as broadcast to interested receivers. PDOs are limited to 1 CAN telegram and therewith to 8 Byte user data maximum because PDOs are executed as non-receipt broadcast messages. On the contrary, **SDO** transfers are based on logical point-to-point connections ("Peer to Peer") between two nodes and allow the receipted exchange of data packages that may be larger than 8 Bytes. Those data packages are transferred internally via an appropriate amount of CAN telegrams. Both services are applicable for interface CAN0 as well as for CAN1.

SDO communication basically takes place via function blocks of type *"CAN_SDO_Xxx"* (see *"User Manual CANopen Extension for IEC 61131-3"*, Manual no.: L-1008). Function blocks are also available for PDOs (*"CAN_PDO_Xxx"*). Those should only be used for particular cases in order to also activate non-CANopen-conform devices. For the application of PDO function blocks, the CANopen configuration must be known in detail. The reason for this is that the PDO function blocks only use 8 Bytes as input/output parameter, but the assignment of those Bytes to process data is subject to the user.

Instead of PDO function blocks, network variables should mainly be used for PDO-based data exchange. Network variables represent the easiest way of data exchange with other CANopen nodes. Accessing network variables within a PLC program takes place in the same way as accessing internal, local variables of the PLC. Hence, for PLC programmers it is not of importance if e.g. an input variable is allocated to a local input of the control or if it represents the input of a decentralized extension module. The application of network variables is based on the integration of DCF files that are generated by an appropriate CANopen configurator. On the one hand, DCF files describe communication parameters of any device (CAN Identifier, etc.) and on the other hand, they allocate network variables to the Bytes of a CAN telegram (mapping). The application of network variables only requires basic knowledge about CANopen.

For this device, the usage of PDO-based network variables is different for each CAN interface CAN0 and CAN1. Sections 12.8.1 and 12.8.2 provide more detail on this.

In a CANopen network, exchanging PDOs only takes place in status *"OPERATIONAL"*. If the device is not in this status, it does not process PDOs (neither for send-site nor for receive-site) and consequently, it does not update the content of network variables. The CANopen Manager is in charge of setting the operational status *"OPERATIONAL"*, *"PRE-OPERATIONAL"* etc. (mostly also called "CANopen Master"). In typical CANopen networks, a programmable node in the form of a PLC is used as CANopen-Manager. This device is able to take over tasks of the CANopen Manager at both CAN interfaces CAN0 and CAN1. How the Manager is activated is described in section 7.7.

As CANopen Manager, it is able to parameterize the CANopen I/O devices ("CANopen-Slaves") that are connected to the CAN bus. Therefore, upon system start via SDO it transfers DCF files generated by the CANopen configurator to the respective nodes.

12.8.1 CAN Interface CAN0

Interface CAN0 features a dynamic object dictionary. This implicates that after activating the PLC, the interface does not provide communication objects for data exchange with other devices. After downloading a PLC program (or its reload from the non-volatile storage after power-on), the required communication objects are dynamically generated according to the DCF file which is integrated in the PLC project. Thus, CAN interface CAN0 is extremely flexible and also applicable for larger amount of data.

For the PLC program, all network variables are declared as *"VAR_EXTERNAL"* according to IEC61131-3. Hence, they are marked as „outside of the control“, e.g.:

```
VAR_EXTERNAL
    NetVar1 : BYTE ;
    NetVar2 : UINT ;
END_VAR
```

A detailed procedure about the integration of DCF files into the PLC project and about the declaration of network variables is provided in manual *"User Manual CANopen Extension for IEC 61131-3"* (Manual no.: L-1008).

When using CAN interface CAN0 it must be paid attention that the generation of required objects takes place upon each system start. This is due to the dynamic object directory. "Design instructions" are included in the DCF file that is integrated in the PLC project. **Hence, changes to the configuration can only be made by modifying the DCF file.** This implies that after the network configuration is changed (modification of DCF file), the PLC project must again be translated and loaded onto the device.

12.8.2 CAN Interface CAN1

On the contrary to interface CAN0, interface CAN1 is provided as static object dictionary. This means that the amount of network variables (communication objects) and the amount of PDOs available are both strongly specified. During runtime, the configuration of PDOs is modifiable. This implies that communication parameters used (CAN Identifier, etc.) and the allocation of network variables to each Byte of a CAN telegram (mapping), can be set and modified by the user. Thus, only the number of objects (amount of network variables and PDOs) is strongly specified in the static object dictionary. Consequently, application and characteristics of objects can be modified during runtime. For this reason, at interface CAN1 the device acts as a CANopen I/O device.

All network variables of the PLC program are available through the marker section of the process image. Therefore, 252 Bytes are usable as input variables and also 252 Bytes as output variables. To enable any data exchange with other CANopen I/O devices, the section of static network variables is mapped to different data types in the object dictionary (BYTE, SINT, WORD, INT, DWORD, DINT). Variables of the different data types are located within the same memory area which means that all variables represent the same physical storage location. Hence, a WORD variable interferes with 2 BYTE variables, a DWORD variable with 2 WORD or 4 BYTE variables. Figure 37 shows the positioning of network variables for CAN1 within the marker section.

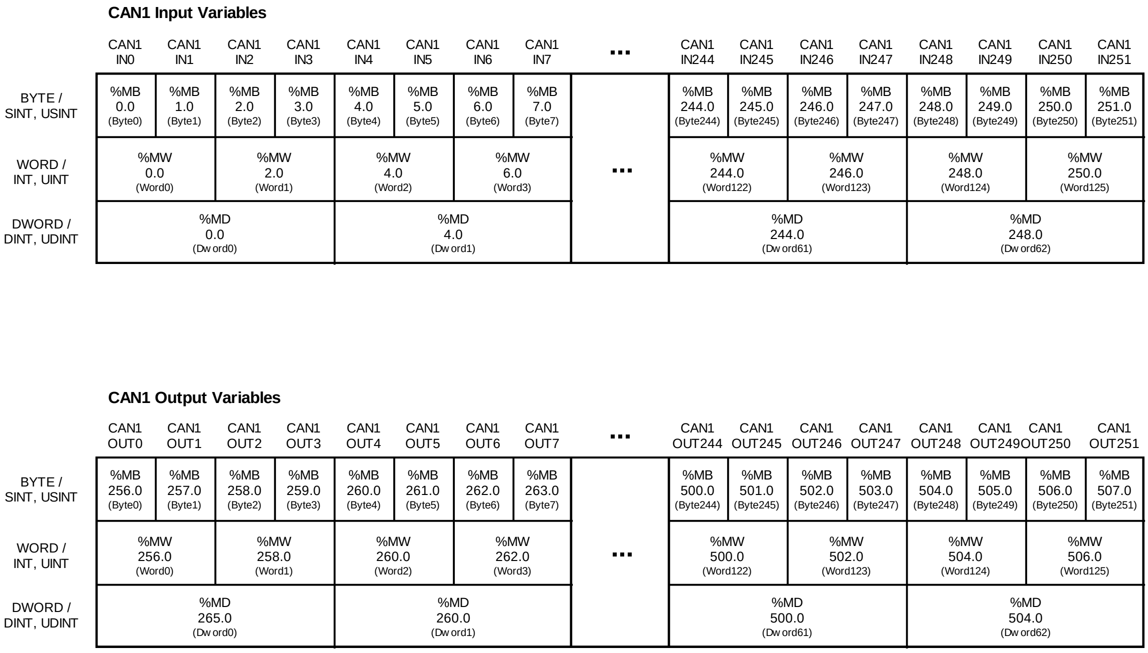

Figure 37: Positioning of network variables for CAN1 within the marker section

Table 16 shows the representation of network variables through appropriate inputs in the object dictionary of interface CAN1.

Table 16: Representation of network variables for CAN1 by entries in the object dictionary

OD section	**OD variable / EDS input**	**Data type CANopen**	**Data type IEC 61131-3**
Inputs (inputs for this device)			
Index 2000H Sub 1 … 252	CAN1InByte0 … CAN1InByte251	Unsigned8	BYTE, USINT
Index 2001H Sub 1 … 252	CAN1InSInt0 … CAN1InSInt251	Integer8	SINT
Index 2010H Sub 1 … 126	CAN1InWord0 … CAN1InWord125	Unsigned16	WORD, UINT
Index 2011H Sub 1 … 126	CAN1InInt0 … CAN1InInt125	Integer16	INT
Index 2020H Sub 1 … 63	CAN1InDword0 … CAN1InDword62	Unsigned32	DWORD, UDINT
Index 2021H Sub 1 … 63	CAN1InDInt0 … CAN1InDInt62	Integer32	DINT

Outputs (outputs for this device)			
Index 2030H Sub 1 … 252	CAN1OutByte0 … CAN1OutByte251	Unsigned8	BYTE, USINT
Index 2031H Sub 1 … 252	CAN1OutSInt0 … CAN1OutSInt251	Integer8	SINT
Index 2040H Sub 1 … 126	CAN1OutWord0 … CAN1OutWord125	Unsigned16	WORD, UINT
Index 2041H Sub 1 … 126	CAN1OutInt0 … CAN1OutInt125	Integer16	INT
Index 2050H Sub 1 … 63	CAN1OutDword0 … CAN1OutDword62	Unsigned32	DWORD, UDINT
Index 2051H Sub 1 … 63	CAN1OutDInt0 … CAN1OutDInt62	Integer32	DINT

The object dictionary of interface CAN1 in total has available 16 TPDO and 16 RPDO. The first 4 TPDO and RPDO are preconfigured and activated according to the Predefined Connection Set. The first 32 Byte of input and output variables are mapped to those PDOs. Table 17 lists all preconfigured PDOs for interface CAN1.

Table 17: Preconfigured PDOs for interface CAN1

PDO	CAN-ID	Data
1. RPDO	0x200 + NodeID	%MB0.0 … %MB7.0
2. RPDO	0x300 + NodeID	%MB8.0 … %MB15.0
3. RPDO	0x400 + NodeID	%MB16.0 … %MB23.0
4. RPDO	0x500 + NodeID	%MB24.0 … %MB31.0
1. TPDO	0x180 + NodeID	%MB256.0 … %MB263.0
2. TPDO	0x280 + NodeID	%MB264.0 … %MB271.0
3. TPDO	0x380 + NodeID	%MB272.0 … %MB279.0
4. TPDO	0x480 + NodeID	%MB280.0 … %MB287.0

Due to limitation to 16 TPDO and 16 RPDO, only 256 Bytes (2 * 16PDO * 8Byte/PDO) of total 504 Bytes for network variables in the marker section (2 252Bytes) can be transferred via PDO. Irrespective of that it is possible to access all variables via SDO.

The configuration (mapping, CAN Identifier etc.) of interface CAN1 typically takes place via an external Configuration Manager that parameterizes the object dictionary on the basis of a DCF file created by the CANopen configurator. By using default object inputs 1010H und 1011H, the device supports the persistent storage and reload of a backed configuration.

Alternatively, the configuration (mapping, CAN Identifier etc.) of the static object dictionary for interface CAN1 can take place from the PLC program by using SDO function blocks. Therefore, inputs *NETNUMBER* and *DEVICE* must be used as follows:

```
NETNUMBER := 1;           (* Interface CAN1 *)
DEVICE    := 0;           (* local Node     *)
```

The PLC program example *"ConfigCAN1"* exemplifies the configuration of interface CAN0 through a PLC program by using function blocks of type *"CAN_SDO_Xxx"*.

13 Data Exchange via Shared Process Image

13.1 Overview of the Shared Process Image

This device is using the operating system Debian, which is based on Linux. Thus, it is possible to execute other user-specific programs simultaneously to running the PLC firmware. The PLC program and a user-specific C/C++ application can exchange data by using the same process image (shared process image). Implementing user-specific applications **is based on the Software package** 3912005 ("Oracle VM VirtualBox-Image of the Linux development system").

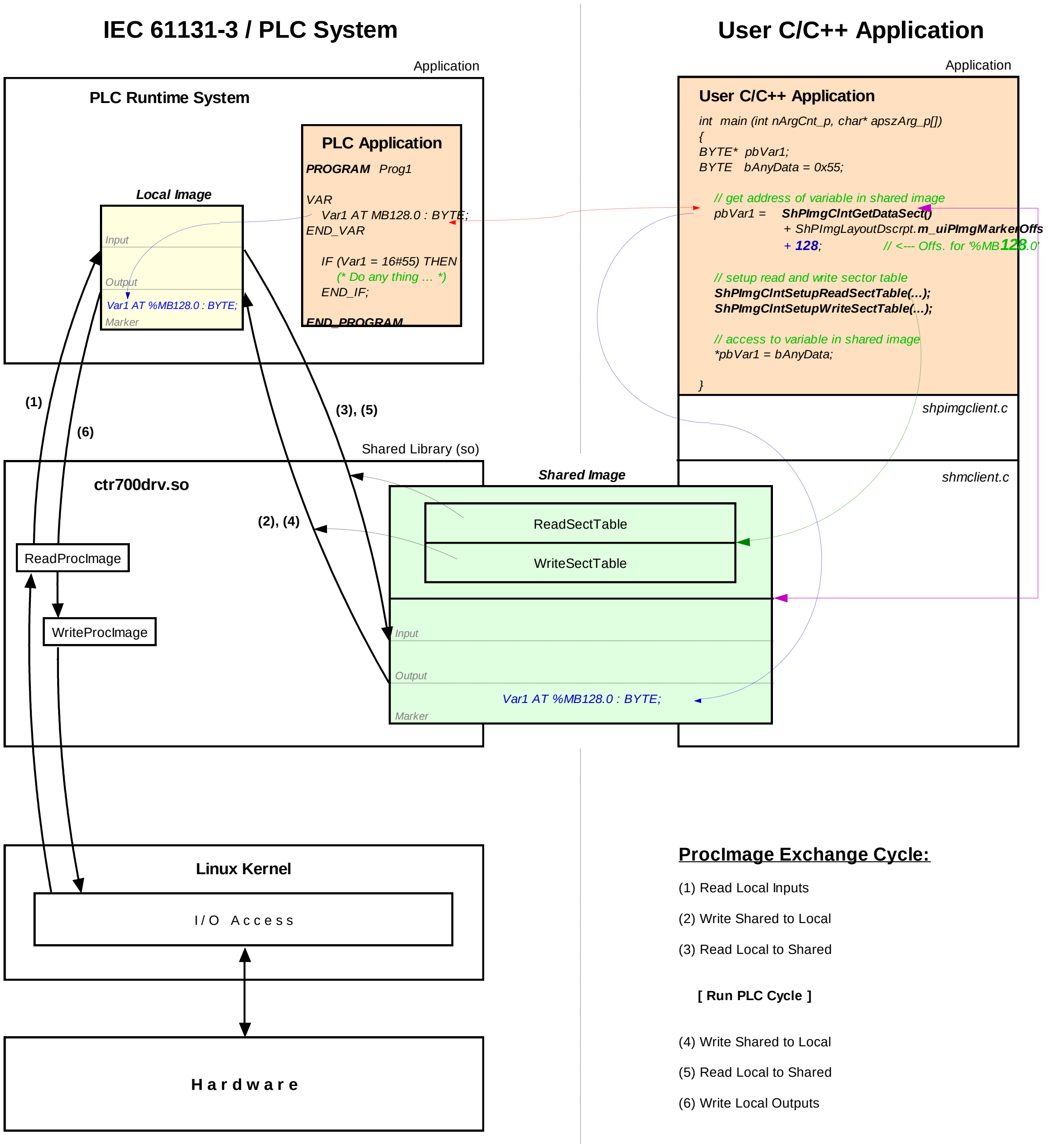

Figure 38: Overview of the shared process image

Not all variables are utilizable via the shared process image within a C/C++ application. Only those directly addressed variables that the PLC program generates within the process image. As shown in Figure 38, two separate process images are used for the data exchange with an external application inside of the PLC runtime system. This is necessary to meet the IEC 61131-3 requirement that the initial PLC process image may not be modified during the entire execution of one PLC program cycle. Thereby, the PLC program always operates with the internal process image that is locally generated within the PLC runtime system ("Local Image" in Figure 38). This is integrated within the PLC runtime system and is protected against direct accesses from the outside. On the contrary, the user-specific, external C/C++ application always uses the shared process image ("Shared Image" in Figure 38). This separation of two process images enables isolation between accesses to the PLC program and the external application. Those two in parallel and independently running processes now must only be synchronized for a short period of time to copy the process data.

An activation of **option *"Share PLC process image"*** within the PLC configuration enables data exchange with external applications (see section 7.7.1). Alternatively, entry *" EnableSharing="* can directly be set within section *"[ProcImg]"* of the configuration file (see section 7.7.3). The appropriate configuration setting is evaluated upon start of the PLC firmware. By activating option *"Share PLC process image"*, the PLC firmware creates a second process image as Shared Memory ("Shared Image" in Figure 38). Its task is to exchange data with external applications. Hereby, the PLC firmware functions as Server and the external, user-specific C/C++ application functions as Client.

ReadSectorTable and ***WriteSectorTable*** both control the copying of data between the two process images. Both tables are filled by the Client (external, user-specific C/C++ application) and are executed by Server (PLC runtime system). The Client defines ranges of the PLC process image from which it will read data (*ReadSectorTable*) or in which it will write data (*WriteSectorTable*). Hence, the terms *"Read"* and *"Write"* refer to data transfer directions from the viewpoint of the Client.

Sections to read and write may comprise all sections of the entire process image – input, output as well as marker sections. This allows for example that a Client application writes data into the input section of the PLC process image and reads data from the output section. Figure 38 shows the sequence of single read and write operations. Prior to the execution of a PLC program cycle, the physical inputs are imported into the local process image of the PLC (1). Afterwards, all sections defined in *WriteSectorTable* are taken over from the shared process image into the local process image (2). By following this sequence, a Client application for example is able to overwrite the value of a physical input. This may be used for simulation purposes as well as for setting input data to constant values (*"Forcen"*). Similarly, prior to writing the process image onto the physical outputs (6), sections defined in *WriteSectorTable* are taken over from the shared process image into the local process image. (4). Thus, a Client application is able to overwrite output information generated by the PLC program.

The PLC firmware provides the **setup of the process image**. The Client application receives information about the setup of the process image via function ***ShPImgClntSetup()***. This function enters start offsets and values of the input, output and marker sections into the structure of type *tShPImgLayoutDscrpt*. Function ***ShPImgClntGetDataSect()*** provides the start address of the shared process image. Upon defining a variable within the PLC program, its absolute position within the process image is determined through sections (%I = Input, %Q = Output, %M = Marker) and offset (e.g. %MB**128**.0). In each section the offset starts at zero, so that for example creating a new variable in the marker section would be independent of values in the input and output section. Creating a corresponding **pair of variables** in the PLC program as well as in the C/C++ application allows for data exchange between the PLC program and the external application. Therefore, both sides must refer to the same address. Structure *tShPImgLayoutDscrpt* reflects the physical setup of the process image in the PLC firmware including input, output and marker sections. This is to use an addressing procedure for defining appropriate variables in the C/C++ application that is comparable to the PLC program. Hence, also in the C/C++ program a variable is defined in the shared process image by indicating the respective section and its offset. The following example illustrates the creation of a corresponding variable pair in the PLC program and C/C++ application:

PLC Program

```
VAR
    Var1 AT MB128.0 : BYTE;
END_VAR
```

C/C++ Application

```
BYTE*  pbVar1;

pbVar1 =   ShPImgClntGetDataSect()
         + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs
         + 128;     // <--- Offset for '%MB128.0'
```

As described above, ***ReadSectorTable*** and ***WriteSectorTable*** manage the copy process to exchange variable contents between the PLC and the C/C++ program. Following the example illustrated, the Client (C/C++ application) must enter an appropriate value into the *WriteSectorTable* to transfer the value of a variable from the C/C++ application to the PLC program (*WriteSectorTable*, because the Client “writes” the variable to the Server):

```
// specify offset and size of 'Var1' and define sync type (always or on demand?)
WriteSectTab[0].m_uiPImgDataSectOffs = ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 128;
WriteSectTab[0].m_uiPImgDataSectSize = sizeof(BYTE);
WriteSectTab[0].m_SyncType           = kShPImgSyncOnDemand;

// define the WriteSectorTable with the size of 1 entry
ShPImgClntSetupWriteSectTable (WriteSectTab, 1);
```

If several variable pairs are generated within the same transfer direction for the data exchange between the PLC program and the C/C++ application, they should possibly all be defined in one coherent address range. Thus, it is possible to list them as one entry in the appropriate SectorTable. The address of the first variable must be set as the *SectorOffset* and the sum of the variable sizes as *SectorSize*. Combining the variables improves the efficiency and the performance of the copy processes.

For each entry of the *WriteSectorTable* an appropriate *SyncType* must be defined. It determines whether the section is generally taken over from the shared process image into the local image whenever there are two successive PLC cycles (***kShPImgSyncAlways***) or whether it is taken over on demand (***kShPImgSyncOnDemand***). If classified as *SyncOnDemand*, the data only is copied if the respective section before was explicitly marked as updated. This takes places by calling function ***ShPImgClntWriteSectMarkNewData()*** and entering the corresponding *WriteSectorTable*-Index (e.g. 0 for *WriteSectTab[0]* etc.).

kShPImgSyncAlways is provided as *SyncType* for the *ReadSectorTable* (the value of the member element *m_SyncType* is ignored). The PLC firmware is not able to identify which variables were changed by the PLC program of the cycle before. Hence, all sections defined in *ReadSectorTable* are always taken over from the local image into the shared process image. Thus, the respective variables in the shared process image always hold the actual values.

The PLC firmware and the C/C++ application both use the shared process image. To prevent conflicts due to accesses from both of those in parallel running processes at the same time, the shared process image is internally protected by a semaphore. If one process requires access to the shared process image, this process enters a critical section by setting the semaphore first and receiving exclusive access to the shared process image second. If the other process requires access to the shared process image at the same time, it also must enter a critical section by trying to set the semaphore. In this case, the operating system identifies that the shared process image is already being used. It blocks the second process until the first process leaves the critical section and releases the semaphore. Thereby, the operating system assures that only one of the two in parallel running processes (PLC runtime system and C/C++ application) may enter the critical section and receives access to the shared process image. To ensure that both processes do not interfere with each other too much, they should enter the critical section as less as possible and only as long as necessary. Otherwise, the PLC cycle time may be extended and runtime variations (Jitter) may occur.

The client application has available two functions to set the semaphore and to block exclusive access to the shared process image. Function ***ShPImgClntLockSegment()*** is necessary to enter the critical section and function ***ShPImgClntUnlockSegment()*** to leave it. The segment between both functions is called protected section, because in this segment the client application holds access to the shared process image without competition. The consistency of read or written data is only guaranteed within such a protected section. Outside the protected section, the shared process image may anytime be manipulated by the PLC runtime system. The following example shows the exclusive access to the shared process image in the C/C++ application:

```
ShPImgClntLockSegment();
{
    // write new data value into Var1
    *pbVar1 = bAnyData;

    // mark new data for WriteSectorTable entry number 0
    ShPImgClntWriteSectMarkNewData (0);
}
ShPImgClntUnlockSegment();
```

For the example above, *kShPImgSyncOnDemand* was defined as *SyncType* upon generating entry *WriteSectorTable*. Hence, taking over variable *Var1* from the shared process image into the local image can only take place if the respective section was beforehand explicitly marked as updated. Therefore, it is necessary to call function ***ShPImgClntWriteSectMarkNewData()***. Since function *ShPImgClntWriteSectMarkNewData()* does not modify the semaphore, it may only be used within a protected section (see example) – such as the code section between *ShPImgClntLockSegment()* and *ShPImgClntUnlockSegment()*.

The synchronization between local image and shared process image by the PLC runtime system only takes place in-between two successive PLC cycles. A client application (user-specific C/C++ program) is not directly informed about this point of time, but it can get information about the update of the shared process image from the PLC runtime system. Therefore, the client application must define a callback handler of the type *tShPImgAppNewDataSigHandler*, e.g.:

```
static  void  AppSigHandlerNewData (void)
{
    fNewDataSignaled_l = TRUE;
}
```

This callback handler must be registered with the help of function ***ShPImgClntSetNewDataSigHandler()***. The handler is selected subsequent to a synchronization of the two images.

The **callback handler of the client application is called within the context of a Linux signal handler** (the PLC runtime system informs the client using Linux function *kill()*). Accordingly, all common **restrictions** for the Linux signal handler also apply to the callback handler of the client application. In particular, it is only allowed to call a few operating system functions that are explicitly marked as reentrant-proof. Please pay attention to not make reentrant calls of local functions within the client application. As shown in the example, only a global flag should be set for the signaling within the callback handler. This flag will later on be evaluated and processed in the main loop of the client application.

13.2 API of the Shared Process Image Client

As illustrated in Figure 38, the user-specific C/C++ application exclusively uses the API (Application Programming Interface) provided by the s*hared process image client*. This API is declared in the header file *shpimgclient.h* and implemented in the source file *shpimgclient.c*. It contains the following types (partly defined in *shpimg.h*) and functions:

Structure *tShPImgLayoutDscrpt*

```
typedef struct
{
    // definition of process image sections
    unsigned int        m_uiPImgInputOffs;      // start offset of input section
    unsigned int        m_uiPImgInputSize;      // size of input section
    unsigned int        m_uiPImgOutputOffs;     // start offset of output section
    unsigned int        m_uiPImgOutputSize;     // size of output section
    unsigned int        m_uiPImgMarkerOffs;     // start offset of marker section
    unsigned int        m_uiPImgMarkerSize;     // size of marker section

} tShPImgLayoutDscrpt;
```

Structure ***tShPImgLayoutDscrpt*** describes the setup of the process image given by the PLC firmware. The client application receives the information about the setup of the process image via function *ShPImgClntSetup()*. This function enters start offsets and values of input, output and marker sections into the structure provided upon function calling.

Structure *tShPImgSectDscrpt*

```
typedef struct
{
    // definition of data exchange section
    unsigned int        m_uiPImgDataSectOffs;
    unsigned int        m_uiPImgDataSectSize;
    tShPImgSyncType     m_SyncType;             // only used for WriteSectTab
    BOOL                m_fNewData;

} tShPImgSectDscrpt;
```

Structure ***tShPImgSectDscrpt*** describes the setup of a *ReadSectorTable* or *WriteSectorTable* entry that must be defined by the client. Both tables support the synchronization between the local image of the PLC runtime system and the shared process image (see section 13.1). Member element *m_uiPImgDataSectOffs* defines the absolute start offset of the section within the shared process images. The respective start offsets of the input, output and marker sections can be determined through structure *tShPImgLayoutDscrpt*. Member element *m_uiPImgDataSectSize* determines the size of the section which may include one or more variables. Member element *m_SyncType* only applies to entries of the WriteSectorTable. It determines whether the section is generally taken over from the shared process image into the local image whenever there are two successive PLC cycles (***kShPImgSyncAlways***) or whether it is taken over on demand (***kShPImgSyncOnDemand***). If classified as *SyncOnDemand*, the data must be marked as modified by calling function *ShPImgClntWriteSectMarkNewData()*. It sets the member element *m_fNewData* to TRUE. The client application should never directly modify this member element.

Function *ShPImgClntSetup*

```
BOOL  ShPImgClntSetup  (tShPImgLayoutDscrpt* pShPImgLayoutDscrpt_p);
```

Function ***ShPImgClntSetup()*** initializes the *shared process image client* and connects itself with the storage segment for the shared process image which is generated by the PLC runtime system. Afterwards, it enters the start offsets and values of the input, output and marker sections into the structure of type *tShPImgLayoutDscrpt* provided upon function call. Hence, the client application receives notice about the process image setup managed by the PLC firmware.

If the PLC runtime system is not active when the function is called or if it has not generated a shared process image (option *"Share PLC process image"* in the PLC configuration deactivated, see section 13.1), the function will return with the return value FALSE. If the initialization was successful, the return value will be TRUE.

Function *ShPImgClntRelease*

```
BOOL  ShPImgClntRelease  (void);
```

Function ***ShPImgClntRelease()*** shuts down the s*hared process image client* and disconnects the connection to the storage segment generated for the shared process image by the PLC runtime system.

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

Function *ShPImgClntSetNewDataSigHandler*

```
BOOL  ShPImgClntSetNewDataSigHandler  (
      tShPImgAppNewDataSigHandler pfnShPImgAppNewDataSigHandler_p);
```

Function ***ShPImgClntSetNewDataSigHandler()*** registers a user-specific callback handler. This callback handler is called after a synchronization of both images. Registered callback handlers are cleared by the parameter NULL.

The **callback handler is called within the context of a Linux signal handler**. Accordingly, all common **restrictions** for the Linux signal handler also apply to the callback handler (see section 13.1).

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

Function *ShPImgClntGetHeader*

```
tShPImgHeader*  ShPImgClntGetHeader  (void);
```

Function ***ShPImgClntGetHeader()*** provides a pointer to the internally used structure type *tShPImgHeader* to manage the shared process image. The client application does usually not need this structure, because all data that it includes can be read and written through functions of the API provided by the *shared process image client*.

Function *ShPImgClntGetDataSect*

```
BYTE*  ShPImgClntGetDataSect  (void);
```

Function ***ShPImgClntGetDataSect()*** provides a pointer to the beginning of the shared process image. This pointer represents the basic address for all accesses to the shared process image; including the definition of sections *ReadSectorTable* and *WriteSectorTable* (see section 13.1).

Funktionen Functions *ShPImgClntLockSegment* and *ShPImgClntUnlockSegment*

```
BOOL  ShPImgClntLockSegment  (void);
BOOL  ShPImgClntUnlockSegment  (void);
```

To exclusively access the shared process image, the client application has available two functions - function ***ShPImgClntLockSegment()*** to enter the critical section and function ***ShPImgClntUnlockSegment()*** to leave it. The segment between both functions is called protected section, because in this segment the client application holds unrivaled access to the shared process image (see section 13.1). The consistency of read or written data is only guaranteed within such a protected section. Outside the protected section, the shared process image may anytime be manipulated by the PLC runtime system. To ensure that the client application does not interfere with the PLC runtime system too much, the critical sections should be set as less as possible and only as long as necessary. Otherwise, the PLC cycle time may be extended and runtime variations (Jitter) may occur.

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

Function *ShPImgClntSetupReadSectTable*

```
BOOL ShPImgClntSetupReadSectTable (
    tShPImgSectDscrpt* paShPImgReadSectTab_p,
    unsigned int uiNumOfReadDscrptUsed_p);
```

Function ***ShPImgClntSetupReadSectTable()*** initializes the *ReadSectorTable* with the values defined by the client. The client hereby determines those sections of the PLC process image from which it wants to read data (see section 13.1). Parameter *paShPImgReadSectTab_p* holds elements of the structure *tShPImgSectDscrpt* and must be transferred as start address of a section. Parameter *uiNumOfReadDscrptUsed_p* indicates how many elements the section has.

kShPImgSyncAlways is provided as *SyncType* for the *ReadSectorTable*.

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

Function *ShPImgClntSetupWriteSectTable*

```
BOOL ShPImgClntSetupWriteSectTable (
    tShPImgSectDscrpt* paShPImgWriteSectTab_p,
    unsigned int uiNumOfWriteDscrptUsed_p);
```

Function ***ShPImgClntSetupWriteSectTable***() initializes the *WriteSectorTable* with the values defined by the client. The client hereby determines those sections of the PLC process image from which it wants to write data (see section 13.1). Parameter *paShPImgWriteSectTab_p* holds elements of structure *tShPImgSectDscrpt* and must be transferred as start address of a section. Parameter *uiNumOfWriteDscrptUsed_p* indicates how many elements the section has.

For each entry in the *WriteSectorTable* the *SyncType* must be defined. This *SyncType* defines whether the section is always taken over into the local image between two PLC cycles (***kShPImgSyncAlways***) or only on demand (***kShPImgSyncOnDemand***). If taken over on demand, the respective section is explicitly marked as updated by calling *ShPImgClntWriteSectMarkNewData()*.

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

Function *ShPImgClntWriteSectMarkNewData*

```
BOOL  ShPImgClntWriteSectMarkNewData  (unsigned int uiWriteDscrptIdx_p);
```

For the content of a section that is held by the *WriteSectorTable*, function ***ShPImgClntWriteSectMarkNewData()*** marks this content as modified. This function is used (for sections with *SyncType* ***kShPImgSyncOnDemand***) to initiate the copy process of data from the shared process image into the local image of the PLC.

Function *ShPImgClntWriteSectMarkNewData()* directly accesses the header of the shared process image without setting a semaphore before. Hence, it may only be used within the protected section – in the code section between *ShPImgClntLockSegment()* and *ShPImgClntUnlockSegment()*.

If executed successfully, the function delivers return value TRUE. If an error occurs, it will deliver return value FALSE.

13.3 Creating a User-Specific Client Application

Software package 3912005 ("Oracle VM VirtualBox-Image of the Linux development system") is the precondition for the implementation of user-specific C/C++ applications. It contains a complete Linux development system in the form of a VirtualBox image. Hence, it allows for an easy introduction into the C/C++ software development for the device. Thus, the VirtualBox image is the ideal basis to develop Linux-based user programs on the same host PC that already has the *OpenPCS* IEC 61131 programming system installed on it. The VirtualBox image of the Linux development system includes the GNU-Crosscompiler Toolchain for ARM processors. Additionally, it includes essential server services that are preconfigured and usable for effective software development.

As illustrated in Figure 38, the user-specific C/C++ application uses the API (files *shpimgclient.c* and *shpimgclient.h*) which is provided by the *shared process image client*. The *shared process image client* is based on services provided by the *shared memory client* (files *shmclient.c* and *shmclient.c*). Both client implementations are necessary to generate a user-specific C/C++ application. The directory of the s*hared process image demo* contains the respective files. The path is depending on the device, e.g. */projects/**CTR-700**/user/shpimgdemo*. To create own user-specific client applications, it is recommended to use this demo project as the basis for own adaptations and extensions. Moreover, this demo project contains a Makefile with all relevant configuration adjustments that are necessary to create a Linux application. Table 18 lists all files of the directory *shpimgdemo* and classifies those as general part of the C/C++ application or as specific component for the demo project *"shpimgdemo"*.

Table 18: Content of the archive files "shpimgdemo.tar.gz"

File	Necessary for all C/C++ applications	In particular for demo *"shpimgdemo"*
shpimgclient.c	x	
shpimgclient.h	x	
shmclient.c	x	
shmclient.h	x	
shpimg.h	x	
global.h	x	
Makefile	draft, to be adjusted	
shpimgdemo.c		x
trmio.c		x
trmio.h		x
trace.c		x

The demo project can be built by calling command *"make".* Here on the example of the CTR-700:

```
cd  /projects/CTR-700/user/shpimgdemo
make
```

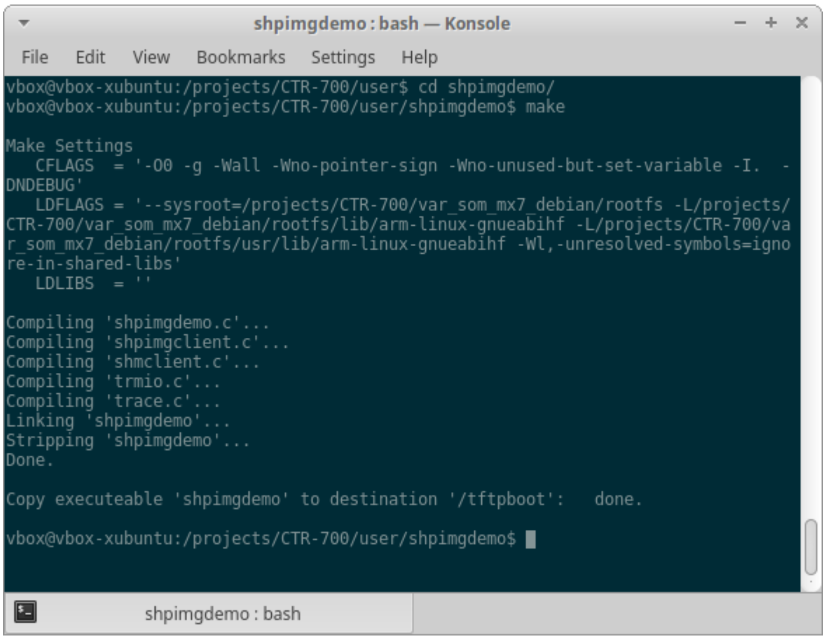

Figure 39: Generating the demo project "shpimgdemo" in the Linux development system

Section 13.4 describes the usage and handling of the demo project *"shpimgdemo"*.

13.4 Example for Using the Shared Process Image

The demo project *"shpimgdemo"* (described in section 13.3) in connection with the PLC program example *"RunLight"* both exemplify the data exchange between a PLC program and a user-specific C/C++ application.

Technical Background

The PLC program generates some variables in the process image as directly addressable variables. In a C/C++ application, all those variables are usable via the shared process image. For the PLC program example *"RunLight"* those are the following variables:

```
 (* variables for local control via on-board I/O's *)
bButtonGroup        AT %IB0.0    : BYTE;
iAnalogValue        AT %IW8.0    : INT;
bLEDGroup0          AT %QB0.0    : BYTE;
bLEDGroup1          AT %QB1.0    : BYTE;

(* variables for remote control via shared process image  *)
uiRemoteSlidbarLen  AT %MW512.0 : UINT;     (* out: length of slidebar          *)
bRemoteStatus       AT %MB514.0 : BYTE;     (* out: Bit0: RemoteControl=on/off *)
bRemoteDirCtrl      AT %MB515.0 : BYTE;     (* in:  direction left/right        *)
iRemoteSpeedCtrl    AT %MW516.0 : INT;      (* in:  speed                       *)
```

Variables of the PLC program are accessible from a C/C++ application via the shared process image. Therefore, sections must be generated for the *ReadSectorTable* and *WriteSectorTable* on the one hand and on the other hand, pointers must be defined for accessing the variables. The following program extract shows this using the example *"shpimgdemo.c"*. Function *ShPImgClntSetup()* inserts the start offsets of input, output and marker sections into the structure *ShPImgLayoutDscrpt*. Hence, on the basis of the initial address provided by *ShPImgClntGetDataSect()*, the absolute initial addresses of each section in the shared process image can be determined. To identify the address of a variable, the variable's offset within the particular section must be added. For example, the absolute address to access the variable *"bRemoteDirCtrl AT %MB515.0 : BYTE;"* results from the sum of the initial address of the shared process image (pabShPImgDataSect), the start offset of the marker section (*ShPImgLayoutDscrpt.m_uiPImgMarkerOffs* für *"%M…"*) as well as the direct address within the marker section which was defined in the PLC program (515 for "%MB515.0"):

```
    pbPImgVar_61131_bDirCtrl          =          (BYTE*)          (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 515);
```

The following code extract shows the complete definition of all variables in the demo project used for exchanging data with the PLC program:

```
// ---- Setup shared process image client ----
fRes = ShPImgClntSetup (&ShPImgLayoutDscrpt);
if ( !fRes )
{
    printf ("\n*** ERROR *** Init of shared process image client failed");
}

pabShPImgDataSect = ShPImgClntGetDataSect();


// ---- Read Sector Table ----
// Input Section:       bButtonGroup AT %IB0.0
{
    ShPImgReadSectTab[0].m_uiPImgDataSectOffs                                    =
                ShPImgLayoutDscrpt.m_uiPImgInputOffs + 0;
    ShPImgReadSectTab[0].m_uiPImgDataSectSize = sizeof(BYTE);
    ShPImgReadSectTab[0].m_SyncType           = kShPImgSyncAlways;

    pbPImgVar_61131_bButtonGroup         =          (BYTE*)          (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgInputOffs + 0);
}

// Output Section:      bLEDGroup0 AT %QB0.0
//                      bLEDGroup1 AT %QB1.0
{
    ShPImgReadSectTab[1].m_uiPImgDataSectOffs                                    =
                ShPImgLayoutDscrpt.m_uiPImgOutputOffs + 0;
    ShPImgReadSectTab[1].m_uiPImgDataSectSize = sizeof(BYTE) + sizeof(BYTE);
    ShPImgReadSectTab[1].m_SyncType           = kShPImgSyncAlways;

    pbPImgVar_61131_bLEDGroup0         =          (BYTE*)          (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgOutputOffs + 0);
    pbPImgVar_61131_bLEDGroup1         =          (BYTE*)          (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgOutputOffs + 1);
}

// Marker Section:      uiSlidbarLen AT %MW512.0
//                      bStatus      AT %MB514.0
{
    ShPImgReadSectTab[2].m_uiPImgDataSectOffs                                    =
                ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 512;
    ShPImgReadSectTab[2].m_uiPImgDataSectSize   =      sizeof(unsigned   short   int)
                                                  + sizeof(BYTE);
    ShPImgReadSectTab[2].m_SyncType           = kShPImgSyncAlways;

    pbPImgVar_61131_usiSlidbarLen   =   (unsigned   short   int*)   (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 512);
    pbPImgVar_61131_bStatus           =          (BYTE*)          (pabShPImgDataSect
               + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 514);
}
```

```
fRes = ShPImgClntSetupReadSectTable (ShPImgReadSectTab, 3);
if ( !fRes )
{
    printf ("\n*** ERROR *** Initialization of read sector table failed");
}

// ---- Write Sector Table ----
// Marker Section:      bDirCtrl    AT %MB515.0
//                      iSpeedCtrl AT %MB516.0
{
    ShPImgWriteSectTab[0].m_uiPImgDataSectOffs                                =
                  ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 515;
    ShPImgWriteSectTab[0].m_uiPImgDataSectSize = sizeof(BYTE) + sizeof(WORD);
    ShPImgWriteSectTab[0].m_SyncType           = kShPImgSyncOnDemand;

    pbPImgVar_61131_bDirCtrl          =          (BYTE*)          (pabShPImgDataSect
                + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 515);
    psiPImgVar_61131_iSpeedCtrl       =       (short      int*)       (pabShPImgDataSect
                     + ShPImgLayoutDscrpt.m_uiPImgMarkerOffs + 516);
}

fRes = ShPImgClntSetupWriteSectTable (ShPImgWriteSectTab, 1);
if ( !fRes )
{
    printf ("\n*** ERROR *** Initialization of write sector table failed");
}
```

Realization

To enable the execution of the *shared process image demo* without previous introduction into the Linux-based C/C++ programming for the device, the module comes with a preinstalled, translated and ready-to-run program version and PLC firmware (*"/home/plc/bin/shpimgdemo"*). The following description refers to this program version. Alternatively, the demo project can be newly-generated from the corresponding source files (see section 13.3) and can be started afterwards. As I/O-Simulator for practical controlling of the demo-program an I/O-Box is available from SYS TEC.

The following steps are necessary to run the *shared process image demo*:

1. **Activate option *"Shared PLC process image"*** in the PLC configuration (see sections 13.1, 7.7.1 and 7.7.3).

2. Open the PLC program example *"RunLight"* in the *OpenPCS* IEC 61131 programming system und build the project for a target hardware of the type, e.g. *"SYSTEC – CTR-700"*

3. Select the network connection to the device and download the program.

4. Start the PLC program on the device.

5. Login to the command shell as described in section 7.10.1.

6. Switch to the directory *"/home/plc/bin"* and call the demo program *"shpimgdemo"*:

   ```
   cd                                                   /home/plc/bin
   ./shpimgdemo
   ```

   The digital outputs of the device are selected as runlight. The speed is modifiable via the analog input AI0. With the help of digital inputs DI0 and DI1, the running direction can be changed. After starting the demo program *"shpimgdemo"*, actual status information about the runlight is indicated cyclically in the terminal (see Figure 40).

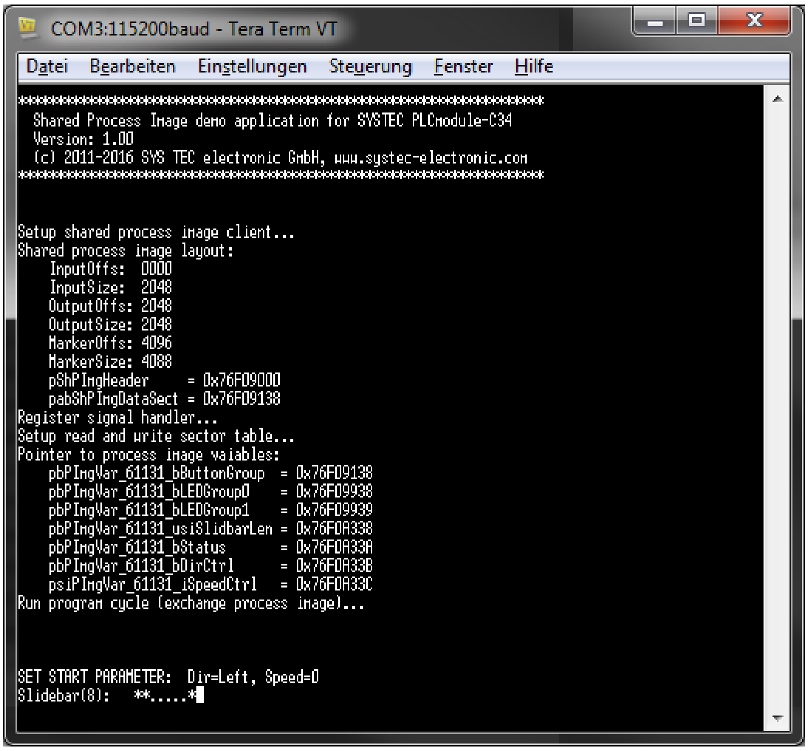

Figure 40: Terminal outputs of the demo program "shpimgdemo" after start

7. By activating of digital input DI3, the control of the runlight direction and speed is handed over to the demo program *"shpimgdemo"*. Afterwards, the running direction may be set by the C application by using the cursor pushbuttons left and right (← and →) in the terminal window and the speed may be changed by using cursor pushbuttons up and down (↑ and ↓).

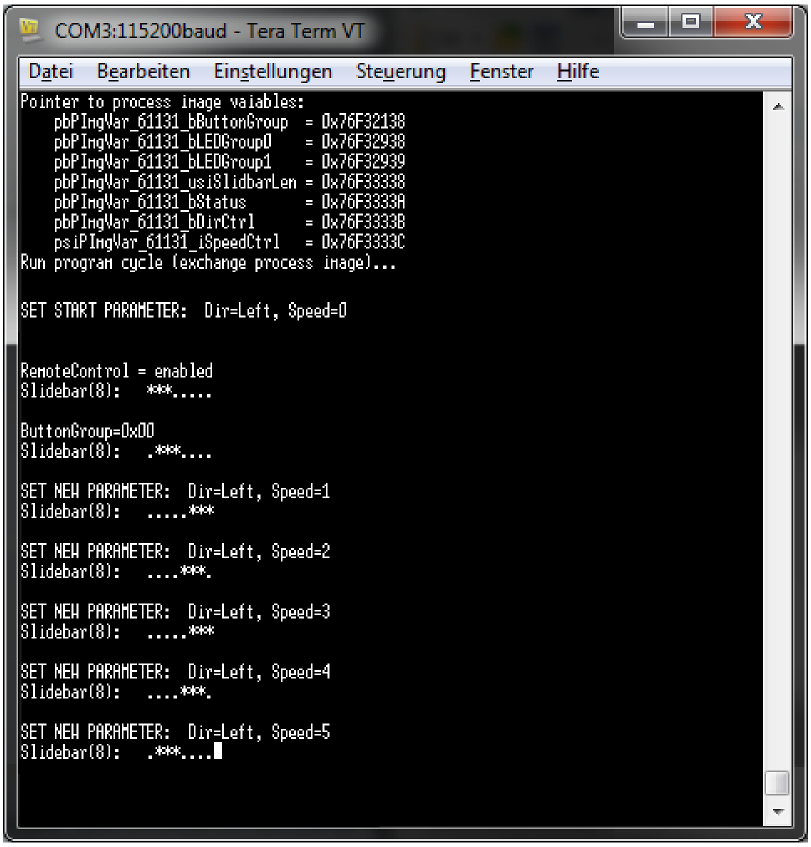

Figure 41: Terminal outputs of the demo program "shpimgdemo" after user inputs

Figure 41 shows the terminal outputs of the demo program *"shpimgdemo"* in answer to activating the cursor pushbuttons.

The demo program *"shpimgdemo"* may be terminated by pressing "Ctrl+C" in the terminal window.

14 Troubleshooting

If there are any problems with the device, which are not covered by this section or any other part of this document, please contact our support under +49 (0) 37 65 / 38 600-0 or support@systec-electronic.com.

Error Behavior:

The shown time or time zone on the device is wrong. This may include some applications like Node-RED.

Cause:

The device has no internal battery, which means after a certain time, some settings may get lost.

Solution:

If the device has access to the internet, the time will set itself on the next restart. If this is not the case, one has to set the time manually, described in Section 7.13.

Appendix A: Firmware Function Scope

Table 19 lists all firmware functions and function blocks available on the device.

Sign explanation:

FB	Function block
FUN	Function
Online Help	*OpenPCS* online help
L-1054	Manual *"SYS TEC-specific extensions for OpenPCS / IEC 61131-3"*, Manual no.: L-1054)
PARAM:={0,1,2}	values 0, 1 and 2 are valid for the given parameter

Table 19: Firmware functions and function blocks

Name	Type	Reference	Remark
PLC standard Functions and Function Blocks			
SR	FB	Online Help	
RS	FB	Online Help	
R_TRIG	FB	Online Help	
F_TRIG	FB	Online Help	
CTU	FB	Online Help	
CTD	FB	Online Help	
CTUD	FB	Online Help	
TP	FB	Online Help	
TON	FB	Online Help	
TOF	FB	Online Help	

Functions and Function Blocks for string manipulation			
ETRC	FB	L-1054	
PTRC	FB	L-1054	
GETVARPOINTER	FB	L-1054	
BIN_TO_STR	FUN	L-1054	
STR_TO_BIN	FUN	L-1054	
OBJ_TO_STR	FB	L-1054	
GETSTRINFO	FB	L-1054	
CHR	FUN	L-1054	
ASC	FUN	L-1054	
STR	FUN	L-1054	
VAL	FUN	L-1054	
LEN	FUN	L-1054	
LEFT	FUN	L-1054	
RIGHT	FUN	L-1054	
MID	FUN	L-1054	
CONCAT	FUN	L-1054	
INSERT	FUN	L-1054	
DELETE	FUN	L-1054	
REPLACE	FUN	L-1054	
FIND	FUN	L-1054	
STR_UPPER	FUN		
STR_LOWER	FUN		
STR_TRIM	FUN		
Functions and Function Blocks for OpenPCS specific task controlling			
GETVARDATA	FB	Online Help	
GETVARFLATADDRESS	FB	Online Help	
GETTASKINFO	FB	Online Help	
Functions and Function Blocks for handling of non-volatile data			
NVDATA_BIT	FB	L-1054	DEVICE:={0} see (1)
NVDATA_INT	FB	L-1054	DEVICE:={0} see (1)
NVDATA_STR	FB	L-1054	DEVICE:={0} see (1)
NVDATA_BIN	FB	L-1054	DEVICE:={0} see (1)
Functions and Function Blocks for handling of time			
GETTIME	FUN	Online Help	
GETTIMECS	FUN	Online Help	
TIME_TO_DINT	FUN		
DINT_TO_TIME	FUN		
DT_CLOCK	FB	L-1054	
DT_ABS_TO_REL	FB	L-1054	
DT_REL_TO_ABS	FB	L-1054	
DT_REL_TO_DT			
Functions and Function Blocks for counter inputs and pulse outputs			
CNT_FUD	FB	L-1054	CHANNEL:={0,1,2}
PTO_PWM	FB	L-1054	CHANNEL:={0,1}
PTO_TAB	FB	L-1054	CHANNEL:={0,1}
Function Block for PID regulator			
PID1	FB	L-1054	

Functions and Function Blocks for Serial interfaces			
SIO_INIT	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_STATE	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_READ_CHR	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_WRITE_CHR	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_READ_STR	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_WRITE_STR	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_READ_BIN	FB	L-1054	PORT:={0,1,2,3} see (2)
SIO_WRITE_BIN	FB	L-1054	PORT:={0,1,2,3} see (2)
Functions and Function Blocks for CAN interfaces / CANopen			
CAN_GET_LOCALNODE_ID	FB	L-1008	NETNUMBER:={0,1}
CAN_CANOPEN_KERNEL_STATE	FB	L-1008	NETNUMBER:={0,1}
CAN_REGISTER_COBID	FB	L-1008	NETNUMBER:={0,1}
CAN_PDO_READ8	FB	L-1008	NETNUMBER:={0,1}
CAN_PDO_WRITE8	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_READ8	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_WRITE8	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_READ_STR	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_WRITE_STR	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_READ_BIN	FB	L-1008	NETNUMBER:={0,1}
CAN_SDO_WRITE_BIN	FB	L-1008	NETNUMBER:={0,1}
CAN_GET_STATE	FB	L-1008	NETNUMBER:={0,1}
CAN_NMT	FB	L-1008	NETNUMBER:={0,1}
CAN_RECV_EMCY_DEV	FB	L-1008	NETNUMBER:={0,1}
CAN_RECV_EMCY	FB	L-1008	NETNUMBER:={0,1}
CAN_WRITE_EMCY	FB	L-1008	NETNUMBER:={0,1}
CAN_RECV_BOOTUP_DEV	FB	L-1008	NETNUMBER:={0,1}
CAN_RECV_BOOTUP	FB	L-1008	NETNUMBER:={0,1}
CAN_ENABLE_CYCLIC_SYNC	FB	L-1008	NETNUMBER:={0,1}
CAN_SEND_SYNC	FB	L-1008	NETNUMBER:={0,1}
CANL2_INIT	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_SHUTDOWN	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_RESET	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_GET_STATUS	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_DEFINE_CANID	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_DEFINE_CANID_RANGE	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_UNDEFINE_CANID	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_UNDEFINE_CANID_RANGE	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_READ8	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_READ_BIN	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_WRITE8	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_WRITE_BIN	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_UPDATE8	FB	L-1008	NETNUMBER:={0,1} see (3)
CANL2_MESSAGE_UPDATE_BIN	FB	L-1008	NETNUMBER:={0,1} see (3)

Functions and Function Blocks for Ethernet interfaces / UDP			
LAN_GET_HOST_CONFIG	FB	L-1054	NETNUMBER:={0}
LAN_ASCII_TO_INET	FB	L-1054	NETNUMBER:={0}
LAN_INET_TO_ASCII	FB	L-1054	NETNUMBER:={0}
LAN_GET_HOST_BY_NAME	FB	L-1054	NETNUMBER:={0}
LAN_GET_HOST_BY_ADDR	FB	L-1054	NETNUMBER:={0}
LAN_UDP_CREATE_SOCKET	FB	L-1054	NETNUMBER:={0}
LAN_UDP_CLOSE_SOCKET	FB	L-1054	NETNUMBER:={0}
LAN_UDP_RECVFROM_STR	FB	L-1054	NETNUMBER:={0}
LAN_UDP_SENDTO_STR	FB	L-1054	NETNUMBER:={0}
LAN_UDP_RECVFROM_BIN	FB	L-1054	NETNUMBER:={0}
LAN_UDP_SENDTO_BIN	FB	L-1054	NETNUMBER:={0}
Functions and Function Blocks for file access			
FILE_OPEN	FB	L-1828	
FILE_CLOSE	FB	L-1828	
FILE_READ	FB	L-1828	
FILE_READ_LINE	FB	L-1828	
FILE_WRITE	FB	L-1828	
FILE_SEEK	FB	L-1828	
FILE_SYNC	FB	L-1828	
FILE_STAT	FB	L-1828	
FILE_CHMOD	FB	L-1828	
FILE_TOUCH	FB	L-1828	
FILE_DELETE	FB	L-1828	
FILE_RENAME	FB	L-1828	
FILE_COPY	FB	L-1828	
FILE_SPLIT_PATH	FB	L-1828	
FILE_DIR_OPEN	FB	L-1828	
FILE_DIR_CLOSE	FB	L-1828	
FILE_DIR_READ	FB	L-1828	
FILE_GET_DIR	FB	L-1828	
FILE_SET_DIR	FB	L-1828	
FILE_MKDIR	FB	L-1828	
FILE_RMDIR	FB	L-1828	
FILE_MKFIFO	FB	L-1828	
FILE_EXEC_SYS_CMD	FB	L-1828	
FTYPE_TO_UINT	FUN	L-1828	
FSEEK_TO_UINT	FUN	L-1828	
FPERM_TO_STRING	FUN	L-1828	
SYSERR_TO_STRING	FUN	L-1828	

Functions and Function Blocks for Modbus communication			
MODBUS_OPEN_INSTANCE	FB	L-1829	
MODBUS_CLOSE_INSTANCE	FB	L-1829	
MODBUS_REGISTER_VAR_LIST	FB	L-1829	
MODBUS_READ_REGS	FB	L-1829	
MODBUS_WRITE_SINGLE_REG	FB	L-1829	
MODBUS_WRITE_MULTI_REGS	FB	L-1829	
MODBUS_READ_WRITE_REGS	FB	L-1829	
MODBUS_READ_INPUT_REGS	FB	L-1829	
MODBUS_READ_DISCR_INPUTS	FB	L-1829	
MODBUS_READ_COILS	FB	L-1829	
MODBUS_WRITE_SINGLE_COIL	FB	L-1829	
MODBUS_WRITE_MULTI_COILS	FB	L-1829	
MODBUS_RAW_PDU_REQUEST	FB	L-1829	
Functions and Function Blocks for Modbus communication			
MQTT_GET_CAPABILITIES	FB	Demo	
MQTT_CONNECT	FB	Demo	
MQTT_DISCONNECT	FB	Demo	
MQTT_GET_CONNECT_STATE	FUN	Demo	
MQTT_SUBSCRIBE	FB	Demo	
MQTT_UNSUBSCRIBE	FB	Demo	
MQTT_GET_ARRIVED_MESSAGE	FB	Demo	
MQTT_PUBLISH	FB	Demo	
Functions and Function Blocks for Modbus communication			
WPC_CONNECT	FB		
WPC_DISCONNECT	FB		
WPC_READ_FRAME	FB		
WPC_GET_STATE	FB		

(1) All nonvolatile data is filed into directory *"/home/plc/plcdata/PlcPData.bin"*. This file has a fix size of 32 KiB. By calling function blocks of type *NVDATA_Xxx* in a writing mode, the modified data is directly stored into file *"/home/plc/plcdata/PlcPData.bin"* ("*flush*"). Thus, unsecured data is not getting lost in case of power interruption.

(2) Interface SERVICE (PORT:=3) primarily serves as service interface to administer the device. Hence, this interface should only be used for sign output. The module always tries to interpret and execute sign inputs as Linux commands (see section 7.10.1).

(3) The usage of Function Blocks from type CANL2_Xxx is only possible, if the according CAN interface is not used already by CANopen. Due to its necessary to disable the according CAN interface in the PLC configuration (see section 7.7.1), otherwise the Function Blocks from type CANL2_Xxx can't be used. Alternatively, entry *"Enable="* can directly be set to 0 within section *"[CANx]"* of the configuration file (see section 7.7.3).

Appendix B: Technical Specification

Environmental Parameters		Typical	Minimum Maximum
Power Supply	V_{CPU}	24VDC	19.2…30VDC
	V_{IO}	24VDC	19.2…30VDC
	power fail level	18,2V	
	power fail delay time	10ms	
Current Consumption (inactive IOs)	I_{CPU}	100mA	
	I_{IO}	30mA	
Temperature Range	Storage temperature		-20..+70°C
	Operating temperature		0…55°C
MTTF	According to SN29500 at 40°C		> 373134 h
Protection class	Housing	IP20	
Weight	without any cable and packing	295g	
Dimensions	Width Height Depth		162mm 61mm 91mm
Connector type	Spring type connector		
Lowest cycle time for PLC		5 ms	

I/O-configuration (digital)		Typical	Maximum
Digital Outputs DO0 ... 15			
24VDC-Output (High Side Switch)	U_{OH} at I_{OH} = 500 mA	V_{IO}-0.12V < U_{OH} <V_{IO}	
	U_{OL} at I_{OL} = 0 mA		0.5 V
	Current limitation I_{OH_max}		700 mA
	Max. current		16x0,5A
	Impedance		0.11 Ohm
	$I_{OL(off)}$		10 µA
	t_{off} at I_{OH} = 500 mA	22 µs	27 µs
	t_{on} at I_{OH} = 500 mA	27 µs	45 µs
	Frequency	ca. 200 Hz	1 KHz[4]
PWM Output (DO14 + DO15)			
24VDC-Output (High Side Switch)	T_{jitter}		25 µs
	T_{on_min} and min. pulse width		800 ns
	Frequency		1 kHz
Digital Outputs RLY0/RLY1			
Relay output (N.O.)	Switching Voltage		220VDC 250VAC
	Switching Current		110VDC / 0.3A 30VDC / 2.0A 120VAC / 0.5A 240VAC / 0.25
	Contact rating		60W/62.5VA
	Durability (mechanical.)	$100x10^6$	
	Durability (electrical.) @12V/10mA @60V/500mA @30V/1000mA @30V/2000mA	 $5x10^7$ $5x10^5$ $1x10^6$ $2x10^5$	
	t_{on}	4ms	
	t_{off}	4ms	
	Isolation	1000Vrms	

[4] Frequency limit of hardware interface circuit. The actually frequency may vary due to software limitations.

Digital Inputs DI0 … 15			
24VDC- Inputs, plus switching	U_{IH}	13V	30V
	U_{IL}	-3V	12.3V
	I_{IH} (V_{IN}=6.7V)	1.3mA	
	I_{IH} (V_{IN}=30V)		3.5mA
	Input type according to IEC61131-2	Type 1	
	T_{DLY}		100ns
Counter Input and Step Direction (DI14 + DI15)			
24VDC- Inputs, plus switching	Min. pulse width		25 µs
	Frequency		10 kHz
A/B-Encoder (DI14 + DI15)			
24VDC- Inputs, plus switching	Frequency		10 kHz
	Phase Margin (A/B-Encoder)		±45°

I/O-configuration (analog)		Typical	Maximum
Analog Inputs AI0 ... 3			
0 ... 10V	Measurement range U_I	0…11.64V	
	Measurement error	0.23%	0.5%[5]
	Destructive voltage U_{I_max}	-	30V
	Input resistance R_I	97kΩ ±0.1%	
	Physical Resolution	-	12Bit
	LSB	355.23 µV	
	Cut off frequency	70Hz	
0 ... 20mA	Measurement range I_I	0…26.865mA[6]	
	Measurement error	0.23%	0.5%[5]
	Input resistance R_I	67Ω ±0.1%	
	Physical Resolution	-	12Bit
	LSB	819.87 nA	
	Cut off frequency	160Hz	

Communication Interfaces		Minimum	Maximum
CAN-Bus			
CAN1, CAN2	Baudrate	5kBaud	1Mbaud
	Max. number of nodes		64
	CAN-H, CAN-L short-circuit-proof towards 24V		
RS-232/RS-485			
SERIAL0	Baudrate	1200Baud	115200Baud
SERIAL1	Baudrate	1200Baud	115200Baud
SERIAL2	Baudrate	1200Baud	115200Baud
SERVICE	Baudrate	1200Baud	115200Baud
Ethernet			
ETH0	Bandwith	10Mbit/s	100Mbit/s
ETH1	Bandwith	10Mbit/s	100Mbit/s
Backplane Bus			
SERIAL1	Baudrate	1200Baud	115200Baud
SPI	Frequency		5MHz

Standards and approvals		
See the appendix or product folder on the website for the currently valid declaration of conformity		

[5] Value is defined over temperature range.
[6] Input is protected against overcurrent, max. voltage should not exceed 30V

Appendix C: Third Party Software Components

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Project URL: https://github.com/eclipse/paho.mqtt.embedded-c

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  m4 source files used to probe features at build time: GPL

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* mcs/class/I18N/mklist.sh, tools/cvt.sh: GNU GPLv2

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==================
```

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From:  james.newtonking@gmail.com  [mailto:james.newtonking@gmail.com]  On
Behalf Of James Newton-King
Sent: Tuesday, June 05, 2007 6:36 AM
To: Konstantin Triger
Subject: Re: Support request by Konstantin Triger for Json.NET

Hey Kosta

I think it would be awesome to use Json.NET in Mono for System.Web.Extensions.
```

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I can waive that statement for you and Mono. Would that be acceptable?

Regards,
James

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Docker CE (Community Edition)

The Docker CE package is an open source operating-system-level virtualization (containerization) application, which provides resource isolation of “containers” by using various features of the Linux kernel instead of running actual virtual machines (VMs).

Project URL: https://github.com/docker/docker-ce/

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Appendix D: Declaration of EMC-Conformity

EMV-KONFORMITÄTSERKLÄRUNG
DECLARATION OF EMC-CONFORMITY

Wir (Name des Herstellers)
We (name of the producer)

SYS TEC electronic GmbH

Adresse
address

Am Windrad 2
D-08468 Heinsdorfergrund

Erklären in alleiniger Verantwortung, dass das Produkt:
declare under sole responsibility, that the product:

sysWORXX CTR-700

Typ, Artikel-Nr.
type, article no.

16061001, Rev.1

die Anforderungen der folgenden harmonisierten Normen erfüllt /
fulfils the following harmonized standards

EN 61131-2:2007 **Chapter 8, zone B**	Speicherprogrammierbare Steuerungen – Teil 2: Betriebsmittelanforderungen und Prüfungen (IEC 61131-2:2007); Deutsche Fassung EN 61131-2:2007 *Programmable controllers – Part 2: Equipment requirements and tests (IEC 61131-2:2007); German version EN 61131-2:2007*

und damit folgender EU-Richtlinie entspricht:
and therefore, corresponds to the EU-directive:

EMV-Richtlinie 2014/30/EG
EMC-Directive 2014/30/EG

Diese Erklärung verliert ihre Gültigkeit, wenn Änderungen am Produkt vorgenommen werden.
This declaration loses its validity if the product gets modified.

Name / *name*	Siegmar Schmidt
Funktion / *title*	Chief Executive Officer
Datum / *date*	23.05.2018
Rechtsgültige Unterschrift / *authorized signature*	

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Appendix E: Declaration of RoHS-Conformity

RoHS-KONFORMITÄTSERKLÄRUNG
DECLARATION OF RoHS-CONFORMITY

Wir (Name des Herstellers)
We (name of the producer)

SYS TEC electronic GmbH

Adresse
address

Am Windrad 2
D-08468 Heinsdorfergrund

Erklären in alleiniger Verantwortung, dass das Produkt:
declare under sole responsibility, that the product:

sysWORXX CTR-700

Typ, Artikel-Nr.
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Chrom, polybromiertes Biphenyl (PBB), polybromierten Diphenylether (PBDE), Deca-BDE und max. 0,01% des Gewichtes für Cadmium).

complies with the requirements of the fulfils the EG directive 2011/65/EU This product is compatible with the current RoHS requirements for the 7 substances (max 0.1% by weight in homogeneous materials for lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), Deca-BDE and max 0.01% for cadmium).

und damit folgender EU-Richtlinie entspricht:
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Name / *name*	Siegmar Schmidt
Funktion / *title*	Chief Executive Officer
Datum / *date*	23.05.2018
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Do you have any suggestions for improving this manual?

Did you find any mistakes in this manual? **Page**

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