System Manual
sysWORXX CTR-700

User Manual

Version 1.5

Edition May 2019

Document No.: L-2137e_05

SYS TEC electronic AG   Am Windrad 2   D-08468 Heinsdorfergrund
Telefon: +49 (3765) 38600-0   Telefax: +49 (3765) 38600-4100
Web: https://www.systec-electronic.com   Mail: info@systec-electronic.com

Revision History

Version	Date	Author	Changes
01	22.05.2018	C. Sc. A. Di.	Initial version
02	28.06.2018	A. Di. C. Sc.	Table 8: Add service for docker container engine Add section 6.2 and 6.4.1
03	21.01.2019	B. Sc. A. Di. C. Sc.	Add section 6.16 (TeamViewer IoT Agent) Table 8: Add service for *containerd* runtime Sections 11.3, 11.5: Counter input and A/B encoder are now available Add section 6.5 (Wi-Fi Adapter) Add section 10 (Python example) Add section 3 (Safety Guidelines) Add Safety Guidelines in sections 4 and 5 Change to Section 8 Add hardware information to Appendix B
04	12.04.2019	C. Sc.	Update to the following sections: 5.2, 5.4, 5.5, 5.6, 5.7 Add section 6.7.1
05	20.05.2019	C. Sc.	Update information in Appendix B

Inform yourselves:

Contact	
Address:	SYS TEC electronic AG Am Windrad 2 D-08468 Heinsdorfergrund GERMANY
Ordering Information:	+49 (0) 37 65 / 38 60 00 sales@systec-electronic.com
Technical Support:	+49 (0) 37 65 / 38 60 00 support@systec-electronic.com
Fax:	+49 (0) 37 65 / 38 60 0 41 00
Web Site:	https://www.systec-electronic.com/

5th Edition May 2019

Table of Contents

1 Introduction 6

2 Overview 7

3 Safety Guidelines, Standards and Approvals...9

3.1 Safety Guidelines 9

3.2 Standards und approvals...9

4 Product Description 11

5 Interface of the CTR-700 14

5.1 Pin assignment 14

5.2 User interface 17

5.3 Mounting 17

5.4 Power supply 18

5.5 Galvanic Isolation 18

5.6 In- and outputs for industrial standard signals.. 18

5.6.1 Digital inputs DI0 - DI15 19

5.6.2 Digital outputs DO0 - DO15 21

5.6.3 Relay outputs REL0 and REL1 22

5.6.4 Analog inputs AI0 - AI3 23

5.7 Communication interfaces 24

5.7.1 Serial interfaces 24

5.7.2 CAN interfaces CAN0 and CAN1 26

5.7.3 Ethernet interface ETH0 and ETH1 26

5.7.4 USB-Host 26

6 Configuration and Administration...27

6.1 System requirements and necessary software tools 27

6.2 Connection over the serial interface 28

6.3 Activation/Deactivation of Linux auto-boot 29

6.4 Ethernet configuration 29

6.4.1 Get the current IP address.. 29

6.4.2 DHCP configuration 30

6.4.3 Static IP address configuration 30

6.5 Setting up a USB Wi-Fi Adapter 30

6.6 Configuration of ADC inputs for voltage / current measurements 31

6.7 PLC configuration 32

6.7.1 OpenPCS License key handling 32

6.7.2 PLC configuration via WEB-Frontend.. 32

6.7.3 Setup of the configuration file "ctr-700.cfg" 34

6.8 Service configuration and boot scripts 36

6.8.1 Extend shell script in /etc/rc.local 37

6.8.2 Add custom systemd services 37

6.8.3 Configure Services 37

6.9 Predefined user accounts... 38

6.10 Remote access 39

6.10.1 Remote login to the command shell 39

6.10.2 Login to the SFTP server... 40

6.11 Adding and deleting user accounts 41
6.12 How to change the password for user accounts 42
6.13 Setting the system time and time zone 42
6.14 File systems 44
6.15 Software installation and update 44
6.15.1 Updating the PLC firmware 44
6.15.2 Install Debian GNU/Linux to a SD Card for update/recovery 46
6.15.3 Install/Update Debian GNU/Linux to EMMC 47
6.16 TeamViewer IoT Agent 48

7 Node-RED programming environment 50
7.1 Running Node-RED 50
7.2 Creating a demo application 51

8 Mono/C# 56
8.1 Create a C# application 56
8.2 Run the application 58

9 Java 59
9.1 Create a Java Project 59
9.2 Run the Java application 62
9.3 Debug the Java application 63

10 Python 65
10.1 Create a Python application 65
10.2 Run the Python application 66
10.3 Debug the Python application 66

11 PLC functionality of the CTR-700 67
11.1 System start of the CTR-700 67
11.2 Programming the CTR-700 67
11.3 Process image of the CTR-700 68
11.3.1 Local In- and Outputs 68
11.3.2 Network variables for CAN1 69
11.4 Communication interfaces 69
11.4.1 Serial interfaces 69
11.4.2 CAN interfaces 70
11.4.3 Ethernet interface 70
11.5 Specific peripheral interfaces 70
11.5.1 Counter inputs 70
11.5.2 Pulse outputs 70
11.6 Control and display elements 71
11.6.1 Run/Stop switch 71
11.6.2 Run-LED (green, D035) 71
11.6.3 Error-LED (red, D036) 72
11.7 Local deletion of a PLC program 72
11.8 Using CANopen for CAN interfaces 72
11.8.1 CAN interface CAN0 74
11.8.2 CAN interface CAN1 74

12 Data exchange via shared process image 78
12.1 Overview of the shared process image 78
12.2 API of the shared process image client 82

12.3 Creating a user-specific client application 85
12.4 Example for using the shared process image 87

Appendix A: Firmware function scope of CTR-700 93

Appendix B: Technical Specification 99

Appendix C: Third Party Software Components 102

Appendix D: Declaration of EMC-Conformity 154

Appendix E: Declaration of RoHS-Conformity 155

Index 156

1 Introduction

Thank you that you have decided for 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 sysWORXX CTR-700. It will assist you in getting familiar with the functional range and usage of the sysWORXX CTR-700. 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 sysWORXX CTR-700. This table also references documentation to other software components and programming languages which are supported by the sysWORXX CTR-700 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 to you downloads of latest software releases and manual versions.

2 Overview

Table 1 lists all manuals relevant for CTR-700. To program the CTR-700 as PLC according to IEC 61131-3, the programming environment *OpenPCS* is used. There are also some manuals for *OpenPCS* that describe the usage and SYS TEC-specific extensions. Those are part of the software package *"OpenPCS"*.

Table 1: Overview of relevant manuals for the CTR-700

Information about…	**In which manual?**
Basic information about the CTR-700 (connections, configuration, administration, process image)	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 CTR-700. 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 on the sysWORXX CTR-700 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 5 Describes **electric connections** of CTR-700 and their application; moreover, it documents their **internal structure**.

Section 6 Makes available **details about the configuration of CTR-700**, 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 of CTR-700** is explained, e.g. the login to the system, the user administration and the execution of software updates.

Section 7 Provides basic information on how to enable Node-RED on the CTR-700 and how to use the custom nodes to access digital inputs and outputs, or to access OpenPCS variables.

Section 8 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 sysWORXX CTR-700.

Section 9 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 for the sysWORXX CTR-700.

Section 11 Includes details about the **usage of CTR-700**, 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 12 Covers information about data exchange between a PLC program and a user-specific C/C++ application via **shared process image**.

3 Safety Guidelines, Standards and Approvals

3.1 Safety Guidelines

The sysWORXX CTR-700 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.

3.2 Standards und approvals

CE-approval:

The CTR-700 fulfills the requirements and safety regulations of the following EC directives and complies with the harmonized European standards (EN) for programmable logic controllers in the journals of the European Community:

- 2014/30/EG "electromagnetic compatibility" (EMC directive):
  The CTR700 fulfills the EMC requirements of the harmonized European standard EN 61131-2:2007 (chapter 8, zone B).

See declaration of conformity in Appendix D or the product information on the SYS TEC electronic web site

- 2011/65/EG "restriction of hazardous substances" (RoHs directive)

  See declaration of conformity in Appendix E or the product information on the SYS TEC electronic web site

The EC declarations of conformity will be available to the competent authorities held at:

SYS TEC electronic AG
Am Windrad 2
D-08468 Heinsdorfergrund

Use in the industrial sector

The CTR-700 is designed for use in the industrial sector (EN 61000-6-2:2005 & EN 61000-6-4:2007 + A1:2011).

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.

4 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, the CTR-700 is suited for realizing decentral control tasks in distributed fieldbus systems of automation technology.

Figure 1: Top view of CTR-700

These are some significant features of CTR-700:

- 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

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

- Function block libraries for communication (CANopen, Ethernet and UART)
- Function block libraries for hardware components (RTC, Counter, PWM/PTO)
- 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 CTR-700 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 RFG-2.4
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

The CTR-700 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 CTR-700 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 CTR-700 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 the CTR-700 by the company SYS TEC electronic AG. Hence, it is possible to program the CTR-700 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, the CTR-700 supports backward documentation of the PLC program as well as the debug functionality including watching and setting variables, single cycles, breakpoints and single steps.

The CTR-700 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 7 and 12.

The Linux applied to CTR-700 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!

5 Interface of the CTR-700

5.1 Pin assignment

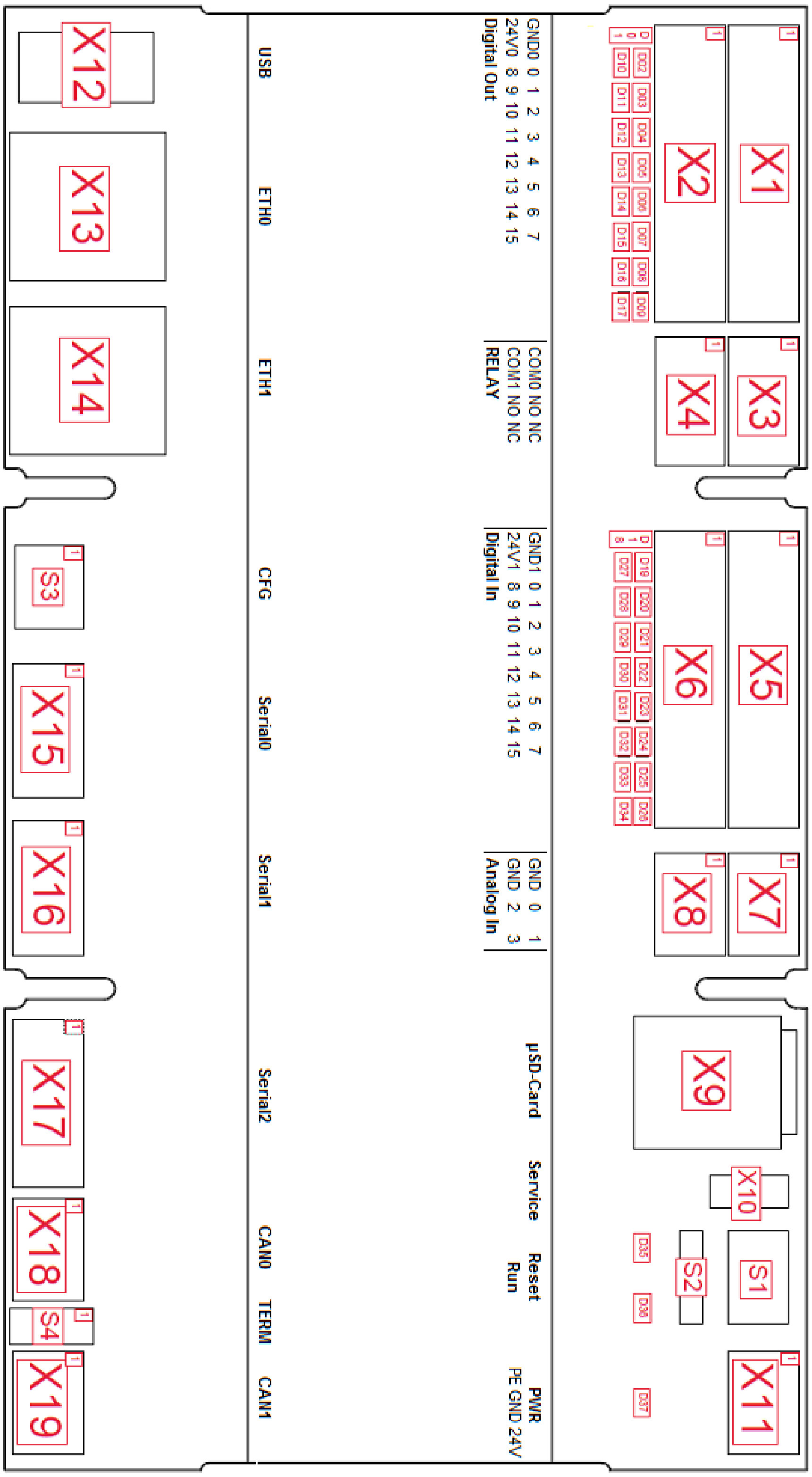


Figure 2: Interface and connector assignment of CTR-700

Figure 2 shows the positioning of connectors on CTR-700 as an overview. Table 2 lists all connectors in detail.

Table 2: Pin assignment of CTR-700

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	

5.2 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: EMMC	Boot mode: SD-Card
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

5.3 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 overheating of the internal components.

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

5.4 Power supply

The CTR-700 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 10ms time window to act accordingly, for example to safe your data. During this 10ms, the device will work normally then shuts down. To access the power fail signal, one has to use the driver library of the CTR-700 in a separate program (see Sections 7, 8, 9, 10).

5.5 Galvanic Isolation

Figure 3 shows the galvanic isolation of the different interfaces and system components of the CTR-700.

<table>
<tr><td>Digital Out
0..15</td><td>24V0
GND0</td><td>Relais 0</td><td>CAN1</td><td>ETH0</td><td rowspan="2">Analog In
USB
Serial 0..2
System
Power</td></tr>
<tr><td>Digital In
0..15</td><td>24V0
GND0</td><td>Relais 1</td><td>CAN0</td><td>ETH1</td></tr>
</table>

Figure 3: Galvanic isolation

5.6 In- and outputs for industrial standard signals

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.

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	<30m	Any cable suitable to the specific usage.	0,2 - 1,5mm² or AWG24 - 16
Digital inputs	<30m		
Analog inputs	<30m	F/UTP S/UTP SF/UTP F/FTP S/FTP SF/FTP F/STP S/STP SF/STP	
CAN	<30m		
Serial	RS232: <15m Modbus RTU: <30m		
Ethernet	<30m	F/FTP S/FTP SF/FTP F/STP S/STP SF/STP	-
USB	<3m	USB standard cable	-

5.6.1 Digital inputs DI0 - DI15

The CTR-700 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.

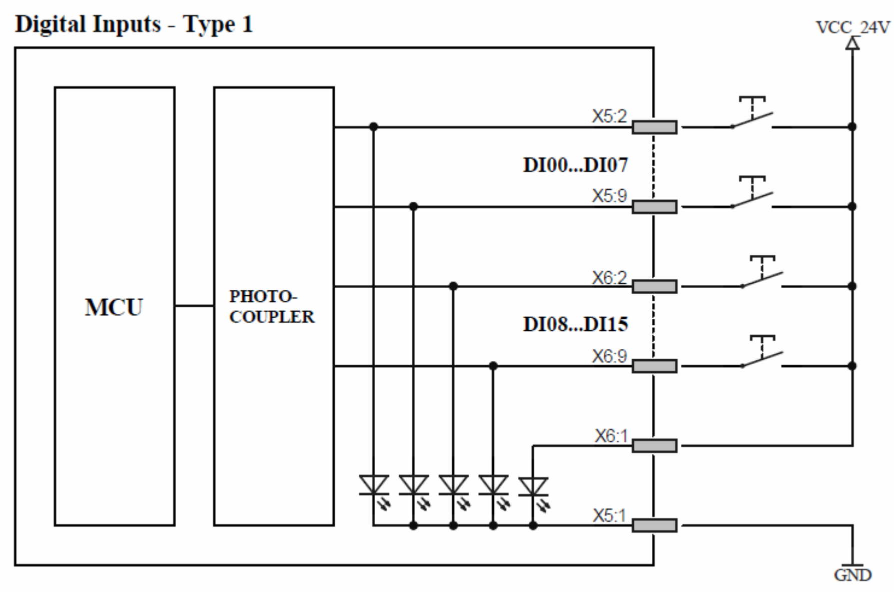


Figure 4: Setup of digital inputs DI0 ... DI15

The digital inputs in a PLC program are accessible via the process image (see Table 11 in section 11.3.1).

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

The CTR-700 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 11.3.1) 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 CTR-700. The documentation to the API can be found in ***"/usr/include/ctr700drv/ctr700drv.h"***.

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

The CTR-700 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 11.3.1) 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 CTR-700. The documentation to the API can be found in ***"/usr/include/ctr700drv/ctr700drv.h"***.

5.6.2 Digital outputs DO0 - DO15

The CTR-700 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

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.

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.

5.6.2.1 Alternate function: DO14, DO15: Pulse outputs P0 and P1

The CTR-700 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).

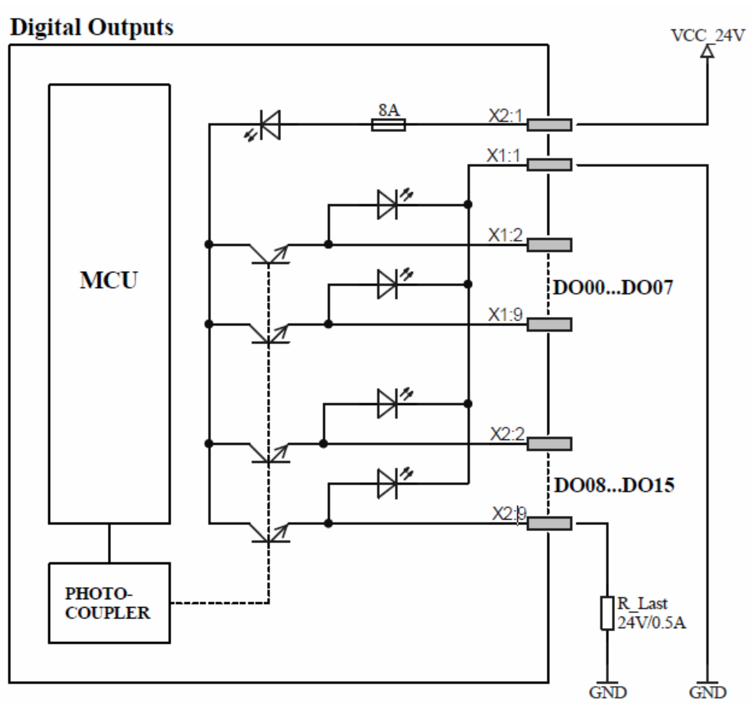


Figure 5: Setup of digital outputs DO0 ... DO15

The digital outputs in a PLC program are accessible via the process image (see Table 11 in section 11.3.1).

5.6.3 Relay outputs REL0 and REL1

The CTR-700 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.

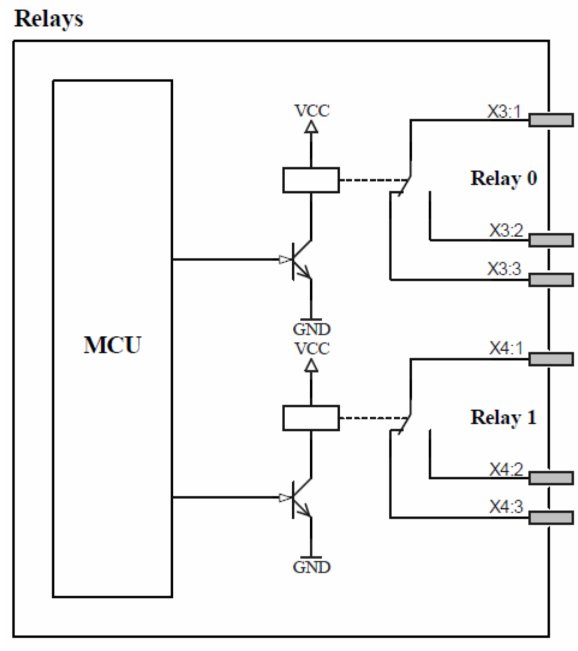


Figure 6: Setup of Relay outputs REL0 and REL1

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 11.3.1).

5.6.4 Analog inputs AI0 - AI3

In its default configuration, the CTR-700 features 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 6.5.

The inputs are protected against overvoltage.

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

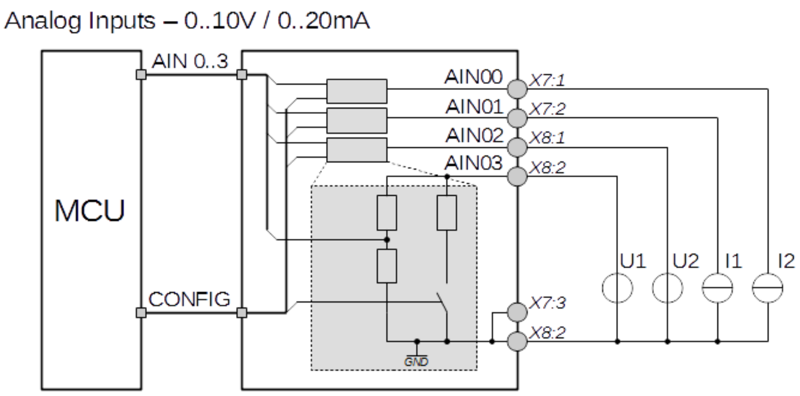


Figure 7: Setup of analog inputs AI0 ... AI3

The analog inputs in a PLC program are accessible via the process image (see Table 11 in section 11.3.1).

Process image and I/O user space driver give a 16-bit signed value for the ADC (two's complement). In case of CTR-700 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

5.7 Communication interfaces

5.7.1 Serial interfaces

The CTR-700 features one service and three serial interfaces (X10, X15 … X17).

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.

SERVICE (X10)
Interface Service serves as service interface to administer the CTR-700. The connection to a computer is established via Micro-USB.

The **maximum cable length** for the SERVICE interface is **3m**.

SERIAL0 and SERIAL1 (X15 and X16)

Interface Serial 0 can be used for data exchange between the CTR-700 and other field devices 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 between the CTR-700 and other field devices 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.

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):

```
iInterface = open("INTERFACE", O_RDWR | O_SYNC);

ioctl(iInterface, TIOCGRS-485, &RS-485);
RS-485.flags |= SER_RS-485_ENABLED;
RS-485.flags &= ~SER_RS-485_RX_DURING_TX;
ioctl(iInterface, TIOCSRS-485, &RS-485);

// Configure baud rate
tcgetattr(iInterface, &Termios);
memset(&Termios, 0, sizeof(struct termios));
Termios.c_lflag &= ~(ICANON | ECHO | ISIG);
Termios.c_oflag  = 0;
Termios.c_cflag  = (CLOCAL|CREAD);
Termios.c_iflag  = 0;

Termios.c_cflag |= CS8;
Termios.c_cflag &= ~CSTOPB;
Termios.c_cflag &= ~PARENB;
Termios.c_cc[VMIN] = 0;
Termios.c_cc[VTIME] = 0;

cfsetispeed(&Termios, B115200);
cfsetospeed(&Termios, B115200);
tcsetattr(iInterface, TCSANOW, &Termios);

close(iInterface);
iInterface = open("INTERFACE", O_RDWR | O_SYNC);
```

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

5.7.2 CAN interfaces CAN0 and CAN1

The CTR-700 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 11.8 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.

5.7.3 Ethernet interface ETH0 and ETH1

The CTR-700 features two Ethernet interfaces (ETH0 and ETH1) which are designed as 10Base-T/100Base-TX.

The Ethernet interface serves as service interface to administer the CTR-700 and it can be used for data exchange with any other devices.

5.7.4 USB-Host

The CTR-700 features a USB 2.0 host interface (X12).

The **maximum cable length** for the USB-host interface is **3m**.

[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.

6 Configuration and Administration

6.1 System requirements and necessary software tools

The administration of the CTR-700 requires any Windows or Linux computer that has available an Ethernet or USB interface. These allow a connection to administer the CTR-700 via a Linux command line-interface.

All examples referred to in this manual are based on an administration of the CTR-700 using a Windows computer. Procedures using a Linux computer would be analogous.

To administrate the CTR-700 the following software tools are necessary:

Terminal program

A Terminal program allows the communication with the **command shell** of the CTR-700 via **the integrated USB-to-UART bridge (USB service console) of the** CTR-700. This is required for the Ethernet configuration of the CTR-700 as described in section 6.4. 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** of the CTR-700 via **Ethernet**. Using SSH requires a completed Ethernet configuration of the CTR-700 according to section 6.4. 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 CTR-700 and the computer. This allows for example **editing configuration files** by transferring those from the CTR-700 onto the computer where they can be edited and get transferred back to the CTR-700. Downloading files onto the CTR-700 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.

6.2 Connection over the serial interface

Setting up a connection to the CTR-700 over the serial interface needs a Terminal Program like *“TeraTerm”* (see 6.1) 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 5) of the CTR-700 has to be connected to the computer with a µUSB cable.

If both are installed and the CTR-700 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.

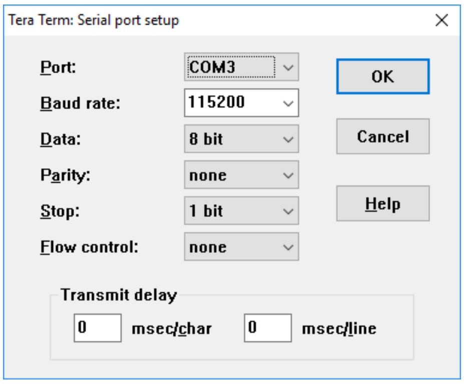


Figure 8: Terminal configuration using the example of "TeraTerm"

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 CTR-700 (see Figure 9).

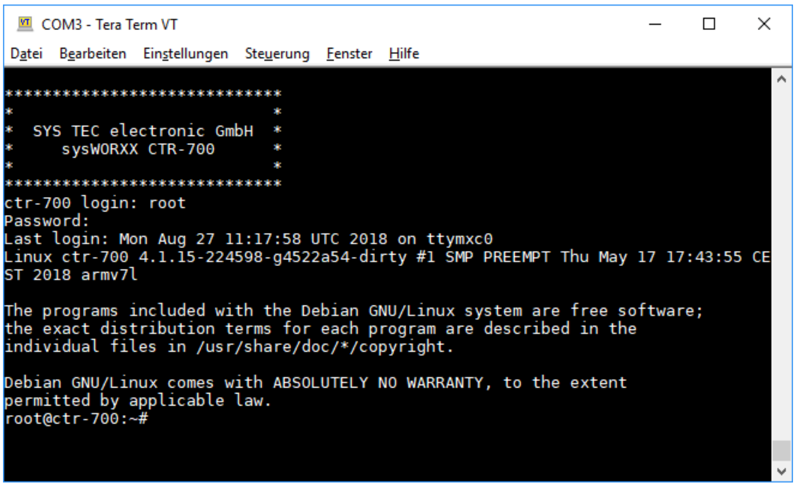


Figure 9: Login screen TeraTerm

To log into the CTR-700 you need a valid user account. There are predefined and ready to use accounts already available (see section 6.9). In this example, the user *"root"* was used.

6.3 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 6.8.3 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" of the CTR-700. 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.

6.4 Ethernet configuration

The CTR-700 has 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 of the CTR-700.

Advice: After the configuration is finished, the serial connection between PC and CTR-700 is no longer necessary.

6.4.1 Get the current IP address

To get the current IP addresses of the CTR-700, one has to set up a connection with a Terminal program (see 6.1). 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*:

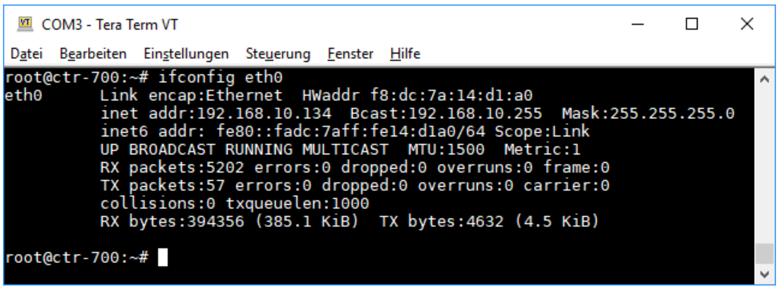


Figure 10: Example – get the IP address for eth0

6.4.2 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
```

6.4.3 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
```

6.5 Setting up a USB Wi-Fi Adapter

The sysWORXX CTR-700 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 of your CTR-700. 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 the CTR-700, 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>
```

6.6 Configuration of ADC inputs for voltage / current measurements

ADC inputs (“ANALOG IN”) of the sysWORXX CTR-700 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 “libctr700drv” too. This driver is installed as a Debian package on the CTR-700.

6.7 PLC configuration

6.7.1 OpenPCS License key handling

For the usage of the PLC functions, the CTR-700 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) on any CTR-700:

```
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.

6.7.2 PLC configuration via WEB-Frontend

After finishing the Ethernet configuration (see section 6.4), all further adjustments can take place via the integrated WEB-Frontend of the CTR-700. The frontend service is disabled by default. To enable it, run the following command as described in section 6.8.3:

```
systemctl enable openpcs-lighttpd
```

To configure the CTR-700 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 CTR-700 as set in section 6.1, 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 CTR-700 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 6.9):

User: PlcAdmin
Password: Plc123

Figure 11: User login dialog of the WEB-Frontend

All configuration adjustments for the CTR-700 are based on dialogs. They are adopted into the file ***"/home/plc/bin/ctr-700.cfg"*** of the CTR-700 by activating the pushbutton "Save Configuration" (also compare section 6.7.3). After activating Reset the CTR-700 starts automatically using the active configuration. Figure 12 shows the configuration of the CTR-700 via WEB-Frontend.

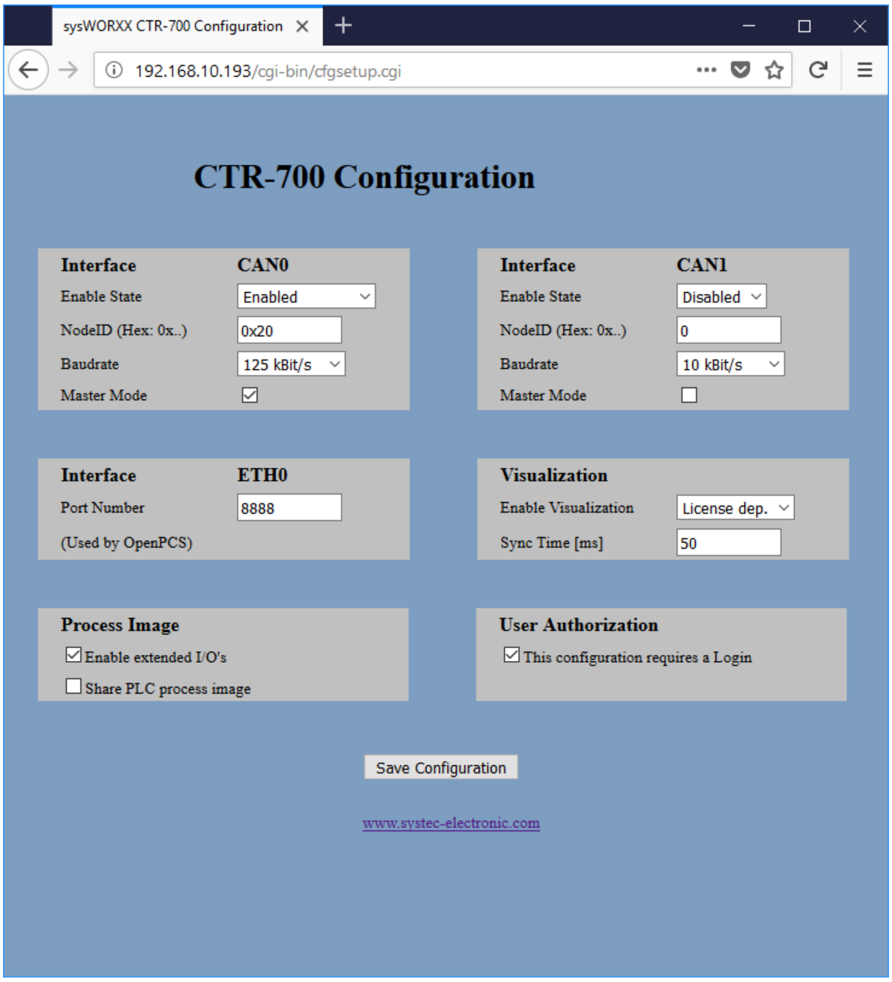


Figure 12: PLC configuration via WEB-Frontend

The standard setting (factory setting) of the CTR-700 requires a user login to access the WEB-Frontend. Therefore, only the user name indicated in configuration file ***"/home/plc/bin/ctr-700.cfg"*** is valid (entry *"User="* in section *"[Login]"*, see section 6.7.3). Procedures to modify the user login password are described in section 6.12. To allow module configuration to another user, an appropriate user account is to be opened as described in section 6.11. Afterwards, the new user name must be entered into the configuration file ***"/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 6.7.3). 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.

6.7.3 Setup of the configuration file "ctr-700.cfg"

The configuration file ***"/home/plc/bin/ctr-700.cfg"*** allows for comprehensive configuration of the CTR-700. Although, working in it manually does not always make sense, because most of the adjustments may easily be edited via WEB-Frontend (compare section 6.7.1). 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 (only for CTR-700/Z5, order number 3090002)
[ProcImg]	EnableSharing	0, 1	0: No sharing of process image 1: Sharing of process image is enabled (see section 7)

[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 CTR-700 (see section 6.11) may login via WEB-Frontend.

The configuration file ***"/home/plc/bin/ctr-700.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
```

6.8 Service configuration and boot scripts

The Debian GNU/Linux installed on the CTR-700 uses “systemd” for managing services. Besides the default services of the operating system, there are some additional services for the CTR-700 available. For executing simple commands on bootup of the system, one can also extend the old-fashioned *rc.local* start script.

6.8.1 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.

6.8.2 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/

6.8.3 Configure Services

The CTR-700 comes 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 on the CTR-700:
   ```
   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 6.8.2:
   `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 for the CTR-700

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

6.9 Predefined user accounts

All user accounts listed in Table 9 are predefined upon delivery of the CTR-700. Those allow for a login to the command shell and at the SFTP server of the CTR-700.

Table 9: Predefined user accounts of the CTR-700

User name	Password	Remark
root	root	Predefined root user for the administration of the CTR-700 (system configuration, user administration, software updates etc.)
user	user	Main user account of the CTR-700
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 6.12). 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.

6.10 Remote access

6.10.1 Remote login to the command shell

In some cases, the administration of the CTR-700 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 6.1) via the serial interface **SERVICE** of the CTR-700.
- Alternatively, the login is possible using an **SSH client** (e.g. PuTTY or also TeraTerm) via the Ethernet interface **ETH0** of the CTR-700.

For logging in to the CTR-700 with SSH via PuTTY or TeraTerm, the IP address provided in section 6.1 must be used.

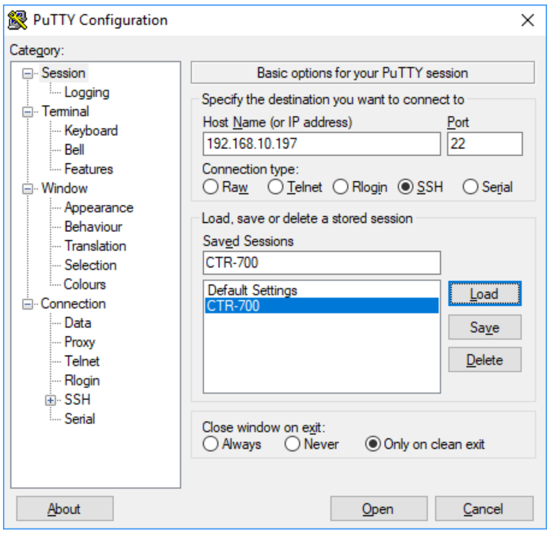


Figure 13: SSH login PuTTY

Logging in to the CTR-700 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 of the CTR-700 (also compare section 6.9):

User: *root*
Password: *root*

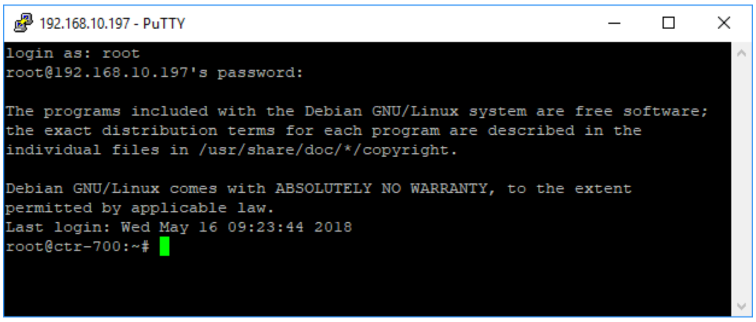


Figure 14: Login to the *CTR-700*

Figure *14* shows the login to the CTR-700 using PuTTY.

6.10.2 Login to the SFTP server

The CTR-700 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 6.1). 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 CTR-700 as set in section 6.4
User name:	*root* (for predefined user account, see section 6.9)
Password:	*root* (for predefined user account, see section 6.9)

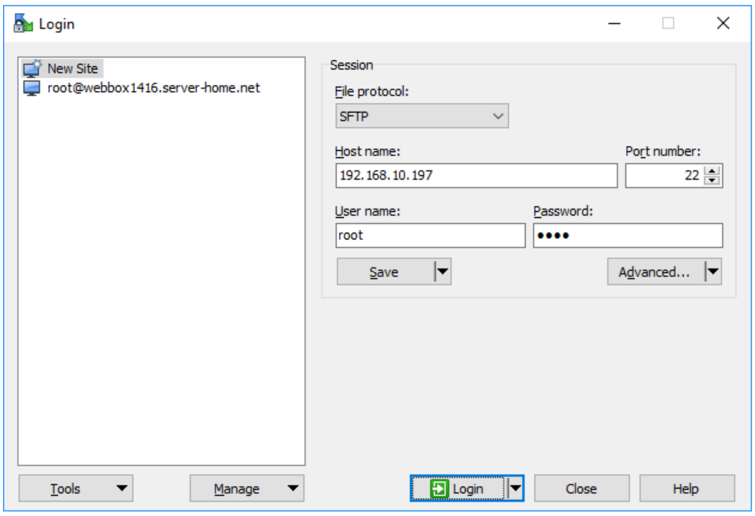


Figure 15: Login settings for „WinSCP“

After using pushbutton *"Login"*, the SFTP client logs in to the CTR-700 and lists up the active content of directory *"/root"* in the right window. Figure 16 shows SFTP client *"WinSCP"* after successful login to the CTR-700.

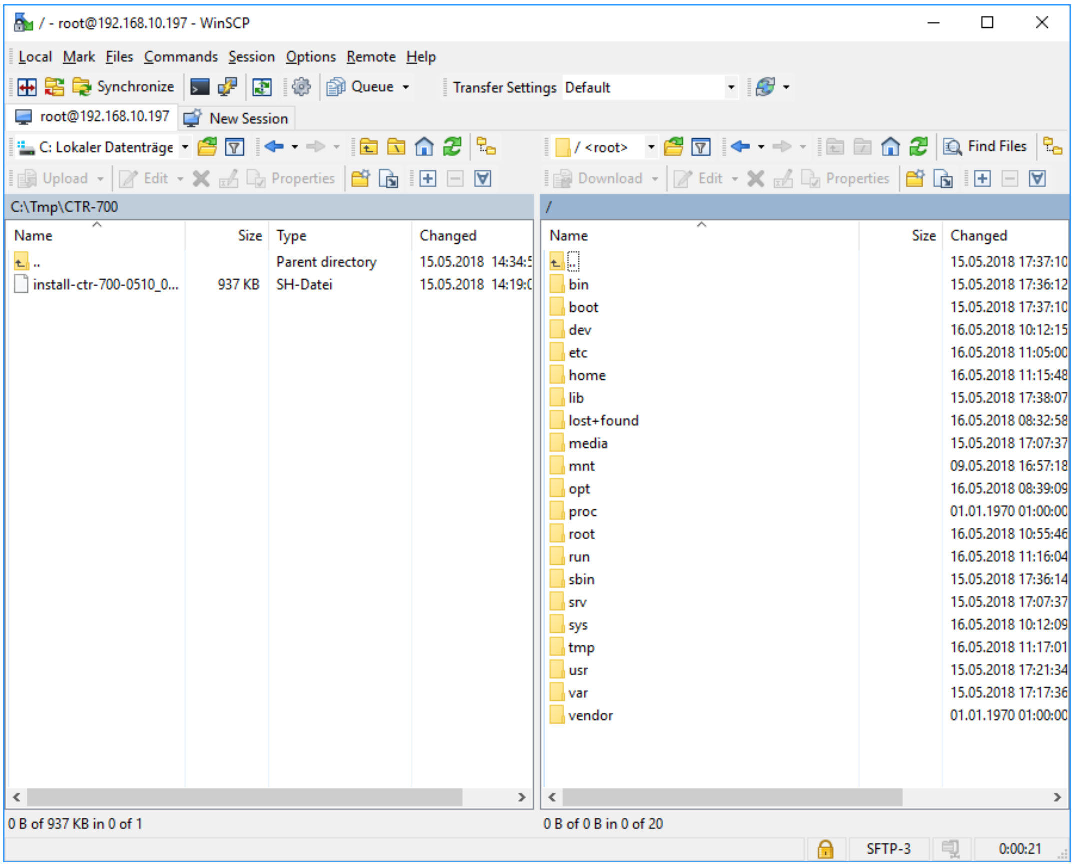


Figure 16: FTP client for Windows "WinSCP"

After successful login, configuration files on the CTR-700 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 CTR-700, e.g. for data backups of the CTR-700 or to transfer installation files for firmware updates (select transfer mode *"Binary"*).

6.11 Adding and deleting user accounts

Adding and deleting user accounts requires the login to the CTR-700 as described in section 6.10.1.

Adding a new user account takes place via Linux command *"useradd"*. To create a new user on the CTR-700, 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 *"ctr-700.cfg"* (for details about logging in to WEB-Frontend please compare section 6.7.1 and 6.7.3).**

To **delete** an existing user account from the CTR-700, 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.

6.12 How to change the password for user accounts

Changing the password for user accounts requires login to the CTR-700 as described in section 6.10.1.

To change the password for an existing user account on the CTR-700, Linux command *"passwd"* plus the respective user name must be entered:

```
passwd <username>
```

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

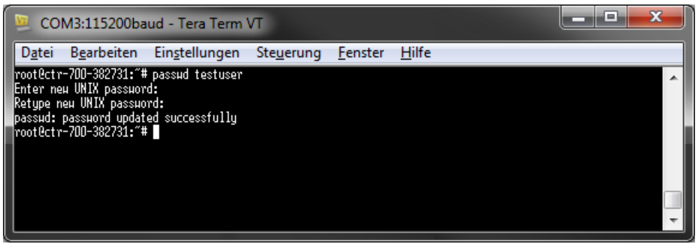


Figure 17: Changing the password for a user account

6.13 Setting the system time and time zone

Setting the system time requires login to the CTR-700 as described in section 6.10.1.

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.

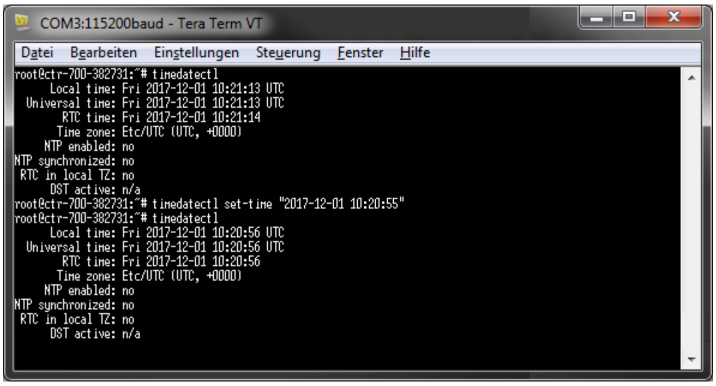


Figure 18: Setting and displaying the system time

Upon start of the CTR-700, 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.

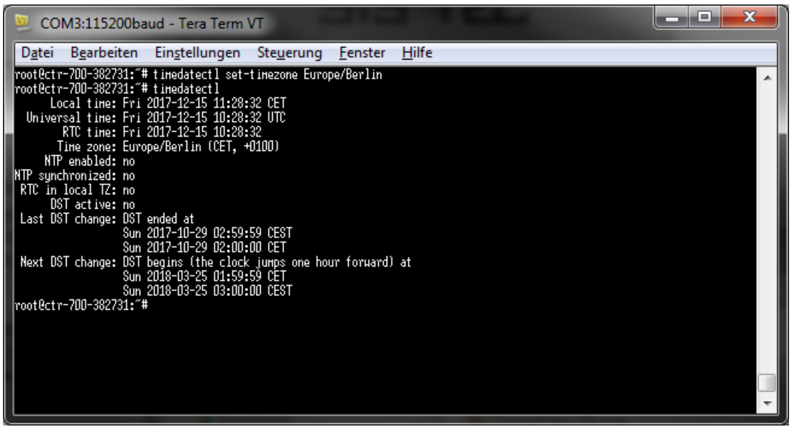


Figure 19: Setting and displaying the system time

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

```
timedatectl list-timezones
```

6.14 File systems

Table 10 lists the default filesystems and mountpoints of the CTR-700.

Table 10: File system configuration of the CTR-700

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 CTR-700. 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 of the CTR-700 is given attention in section 6.10.

6.15 Software installation and update

All necessary firmware components to run the CTR-700 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.

6.15.1 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 of the CTR-700 as described in section 6.10.1 and login to the SFTP server as described in section 6.10.2.

Updating the PLC firmware takes place via a self-extracting firmware archive that is transferred onto the CTR-700 via SFTP. The respective firmware archive can be transferred into directory *"/tmp"* of the CTR-700 (see Figure 20).

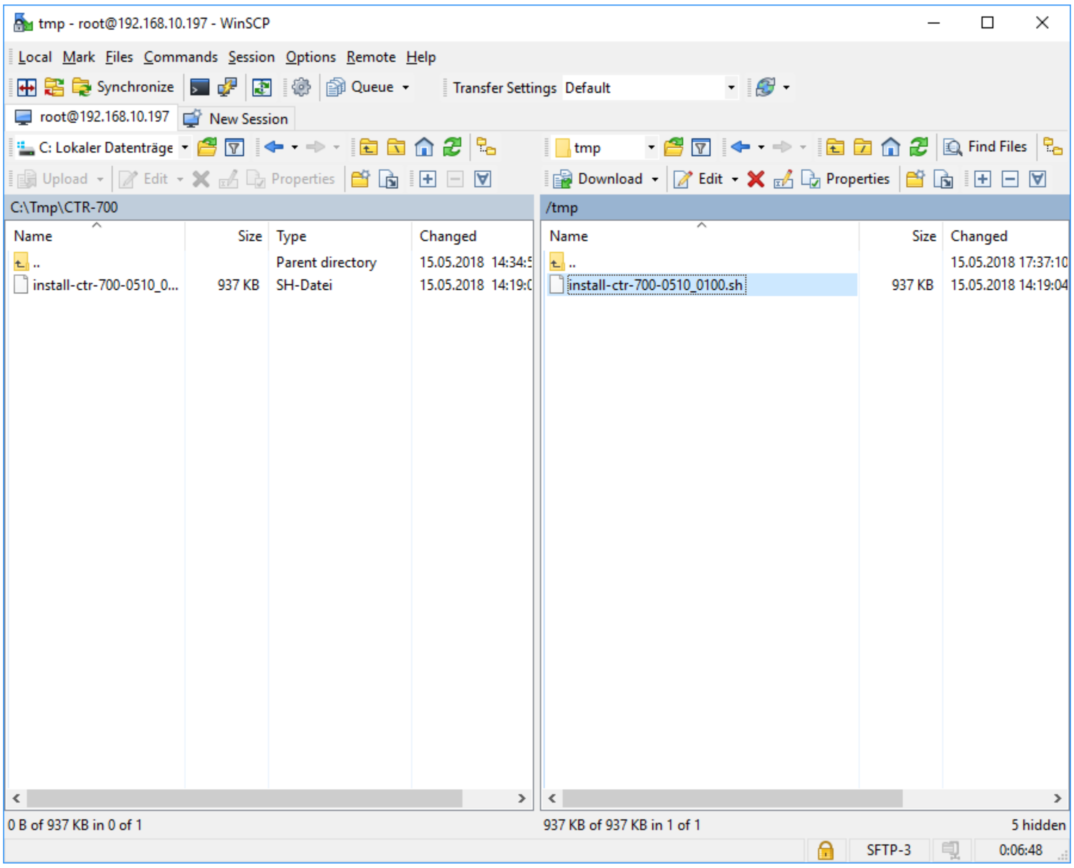


Figure 20: File transfer in SFTP client "WinSCP"

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 CTR-700 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 CTR-700. 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 of the CTR-700 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.

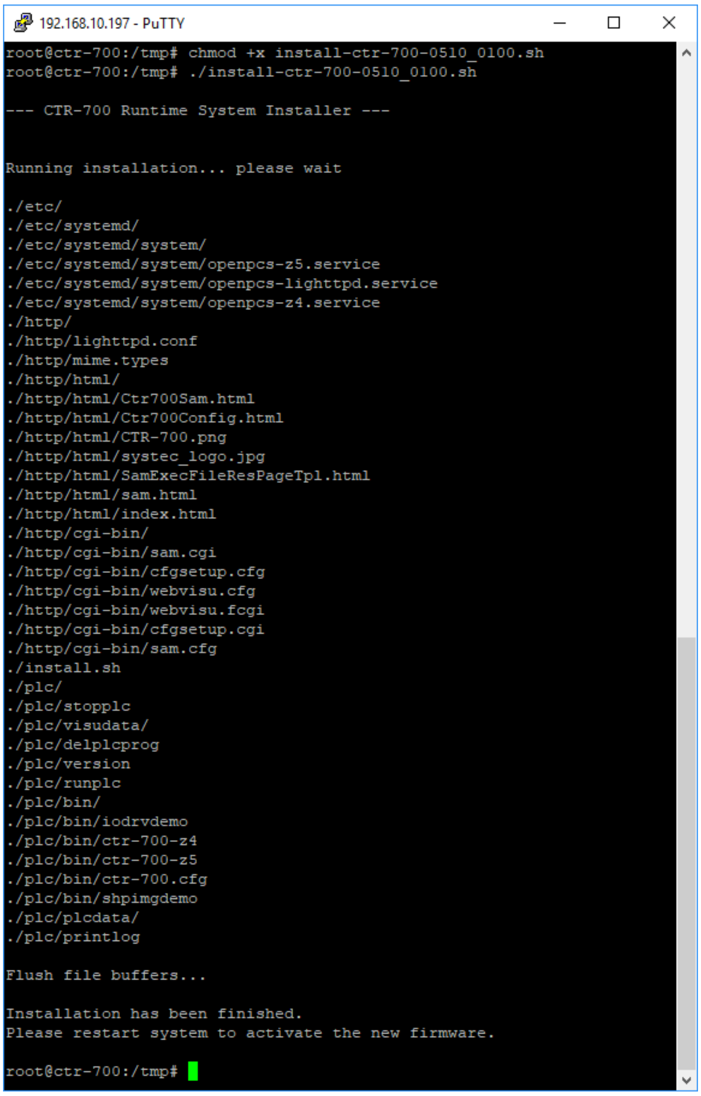


Figure 21: Installing PLC firmware on the CTR-700

Figure 21 shows the installation of PLC firmware on the CTR-700. After reboot the module is started using the updated firmware.

Advice:	**If the PLC firmware is updated, the configuration file *"/home/plc/bin/ctr-700.cfg"* is overwritten. This results in a reset of the PLC configuration to default settings. Consequently, after an update, the configuration described in section 6.7 should be checked and if necessary it should be reset.**

6.15.2 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 CTR-700 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 of the CTR-700. 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

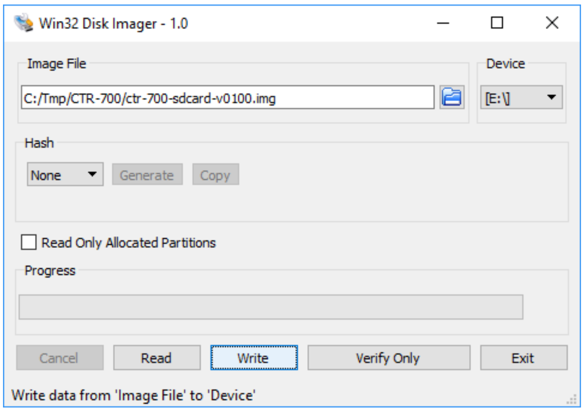


Figure 22: Write SD Card Image using Win32 Disk Imager

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 6.10.1 to work with the new firmware.

6.15.3 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 CTR-700, one has to create an SD Card as described in section 6.15.2.

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 6.10.1
   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 CTR-700 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.

6.16 TeamViewer IoT Agent

The CTR-700 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

6.16.1.1 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 CTR-700 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 6.8.3:

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

6.16.1.2 Enable Remote Terminal

The TeamViewer IoT Agent provides Remote Terminal access to CTR-700. 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
```

7 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 CTR-700 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 CTR-700 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 CTR-700 together with some custom Nodes. These nodes can be used to access inputs and outputs of the CTR-700. 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 CTR-700 nodes for the I/O Driver.

7.1 Running Node-RED

As described in section 6.8.3, 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 CTR-700. 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/

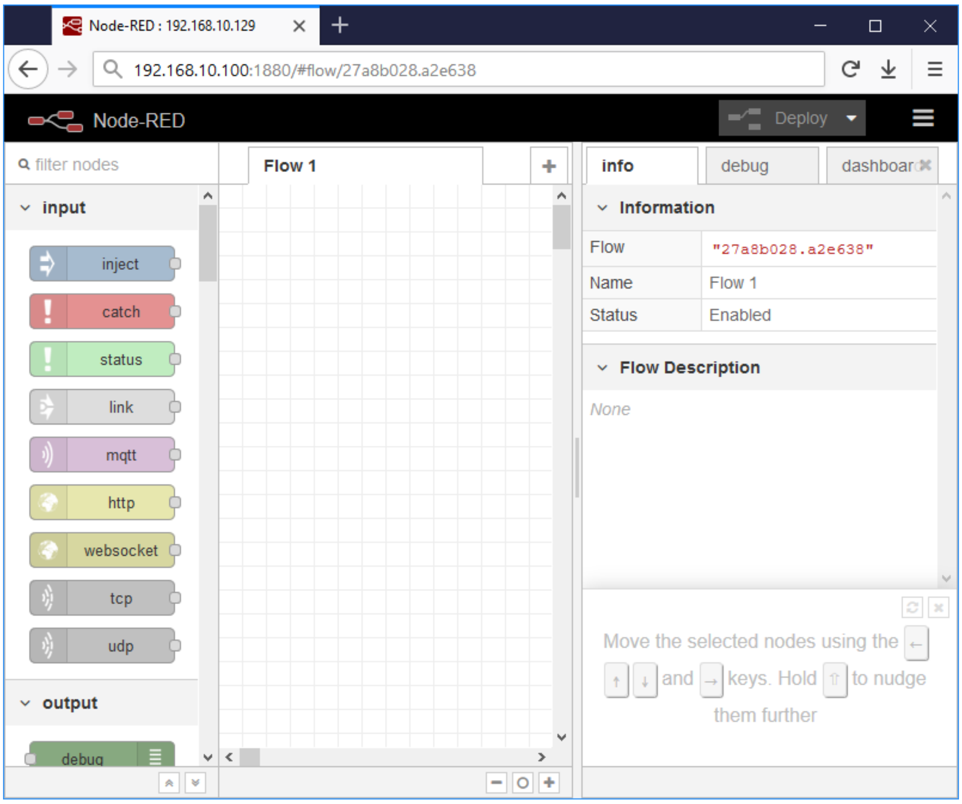


Figure 23: Node-RED editor in the web browser

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/

7.2 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 CTR-700 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.

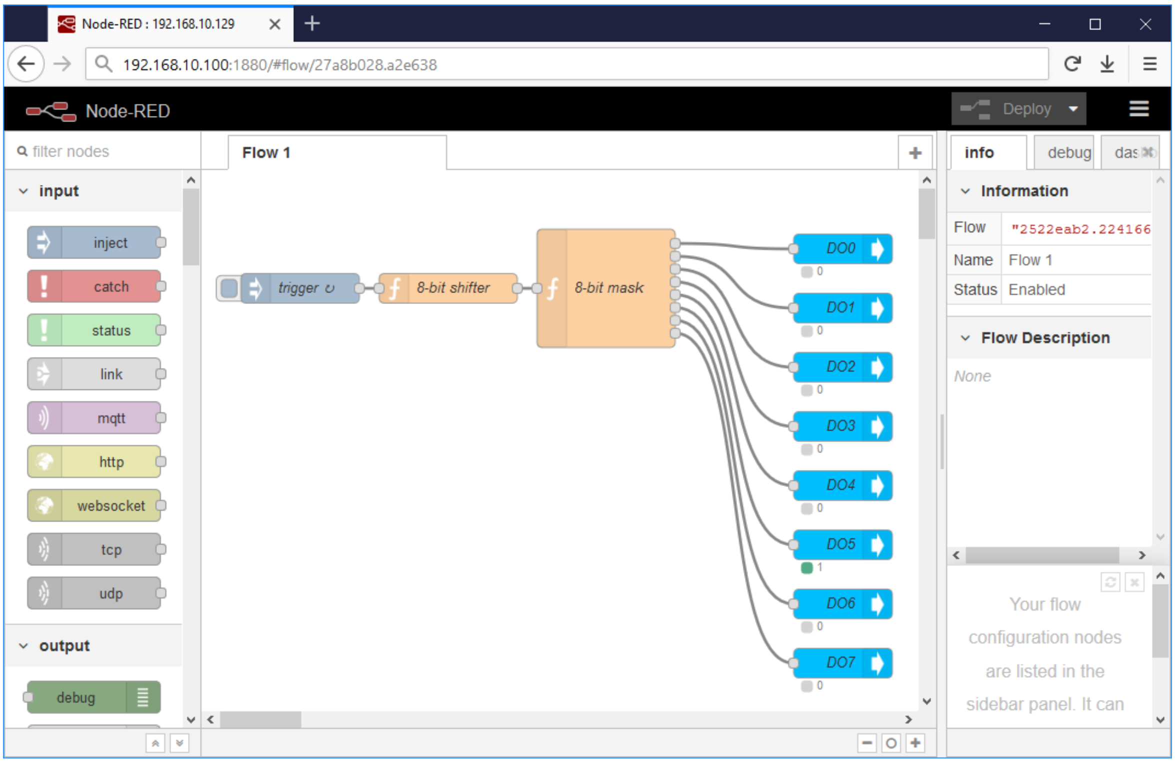


Figure 24: Node-RED demo application

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

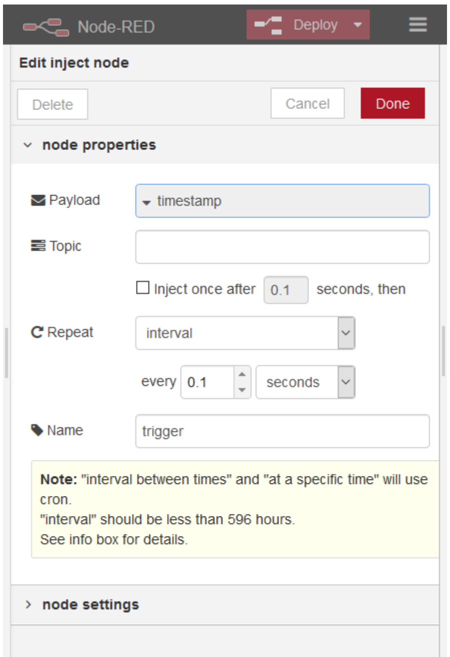


Figure 25: Node: “trigger”

- 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;
// ------------------------------------------------------------------
```

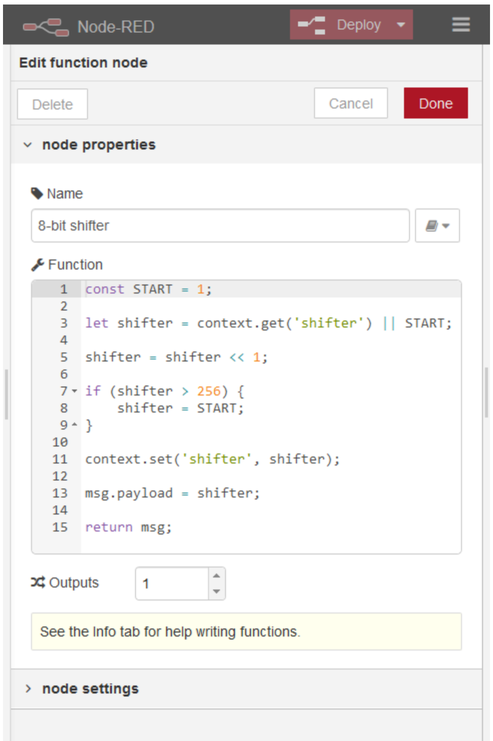


Figure 26: Node: "8-bit shifter"

- 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;
// -----------------------------------------------------------------
```

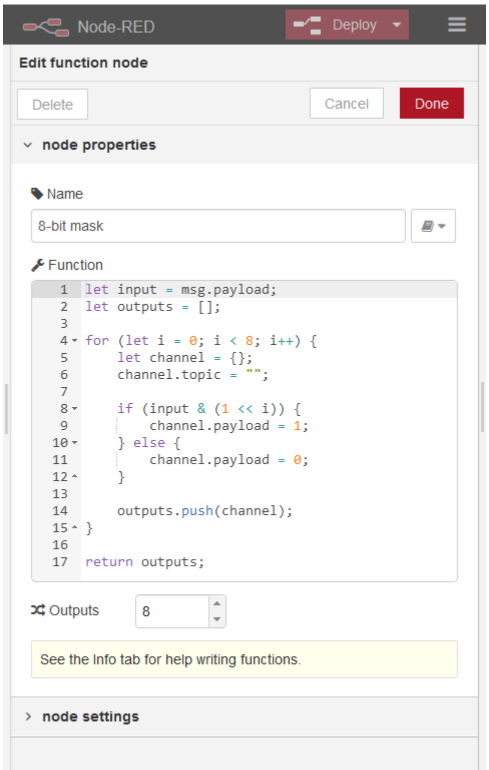


Figure 27: Node: "8-bit mask"

- 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:

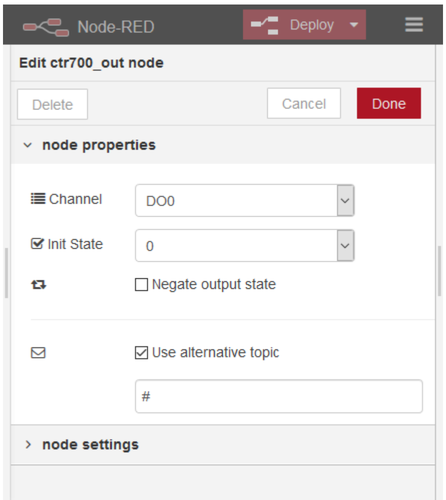


Figure 28: Node: “DO0”

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

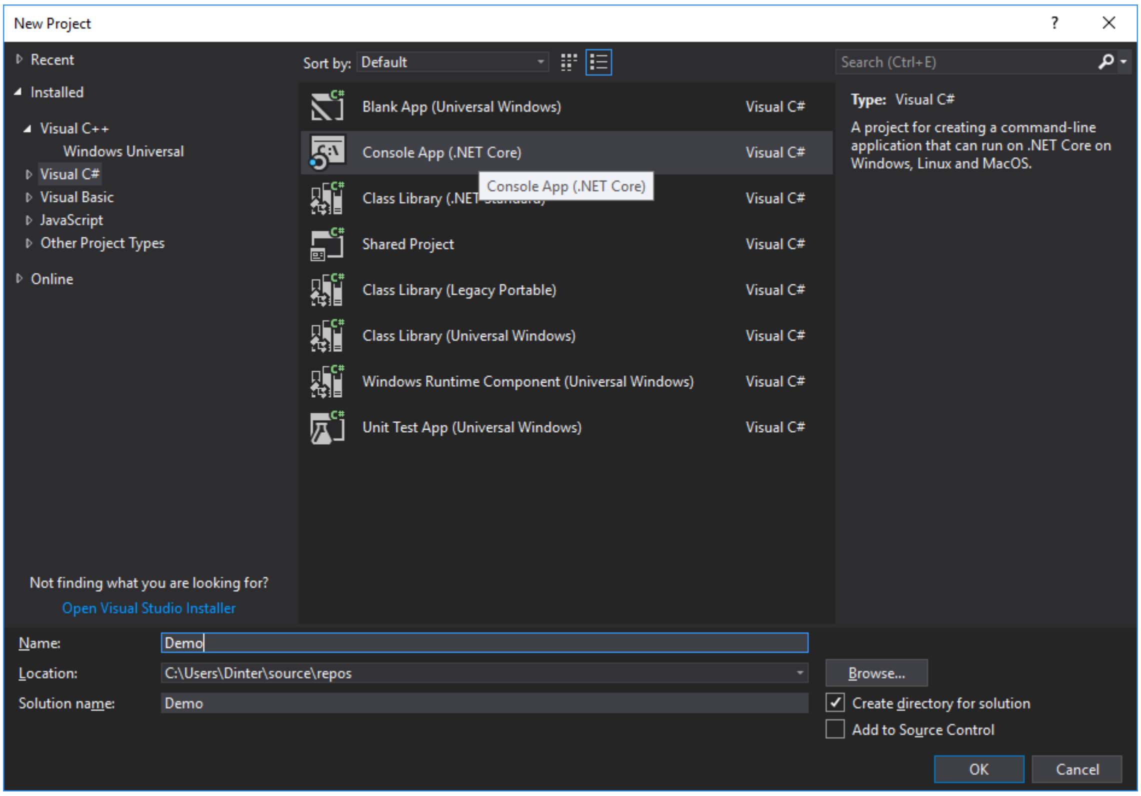
Copy the output node for *DO0* multiple times for each output until *DO7* and adjust the settings for each digital output. Connect all nodes as shown in Figure 24. Now the application is complete. To start it, click on the *Deploy* button in the top right corner of the editor interface. The output LED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

8 Mono/C#

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

8.1 Create a C# application

Create a console application as shown in the screenshot below:



The bindings to the CTR-700 I/O Driver are located in the *Oracle VM VirtualBox* provided for the CTR-700. (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/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.*

8.2 Run the application

To run the application on the target, copy the build Demo.exe in the projects output directory to the CTR-700. This can be done by using SFTP (see section 6.10.2). Login the CTR-700 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
```

9 Java

The CTR-700 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 CTR-700. (3912005 "Oracle VM VirtualBox-Image of the Linux development system") The application will implement a simple run light for digital outputs 0 to 7.

9.1 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*.

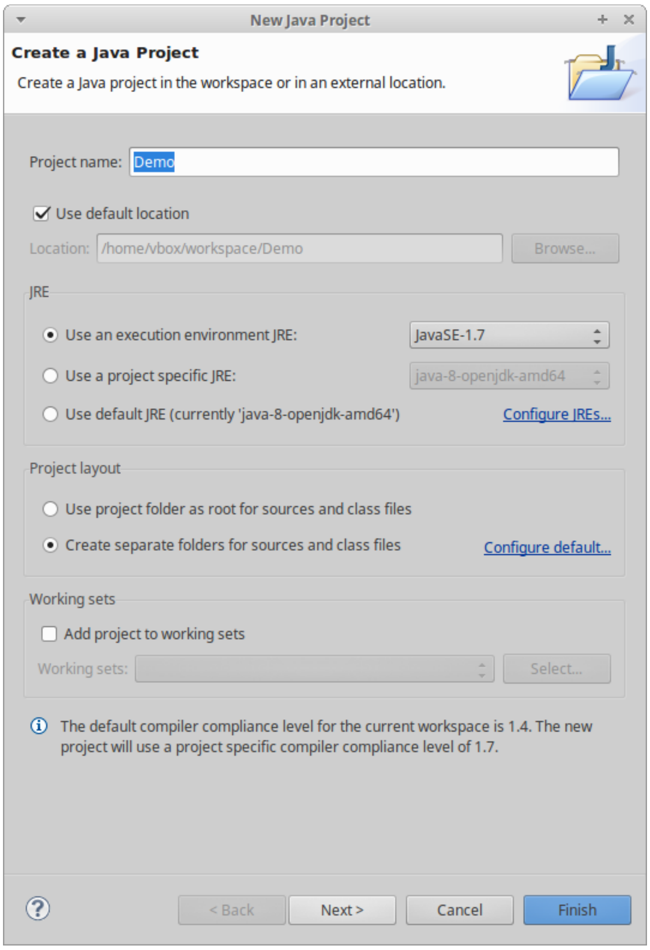


Figure 29: Java Demo: Project setup

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:

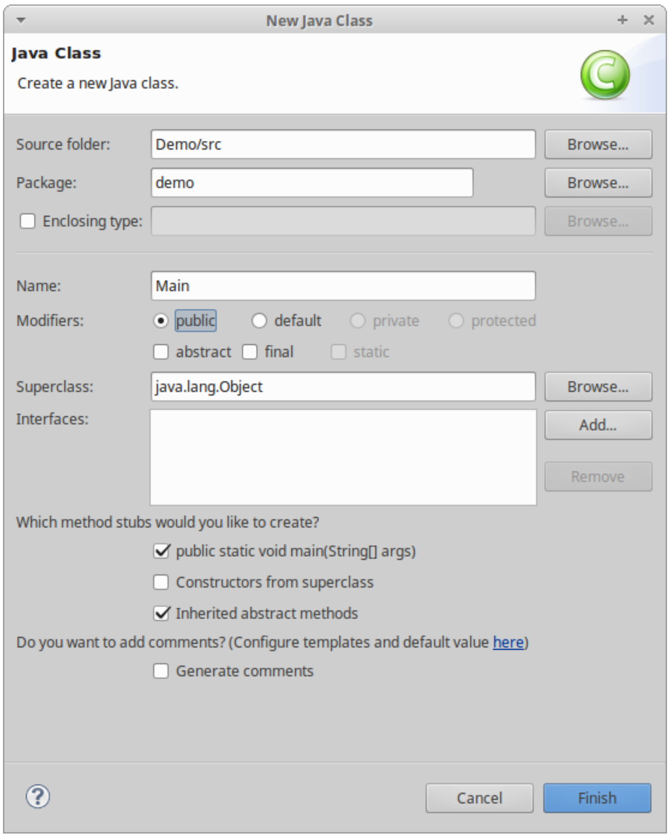


Figure 30: Java Demo: Main class

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.*

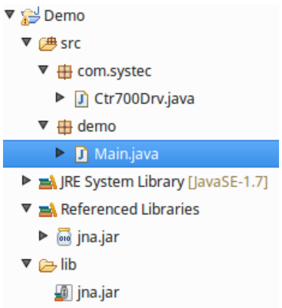


Figure 31: Java Demo: Project structure

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.

9.2 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*.

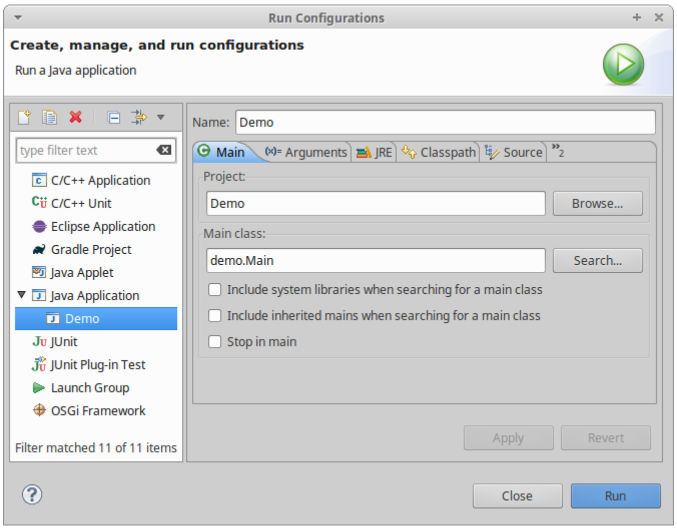


Figure 32: Java Demo: Run configuration

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.

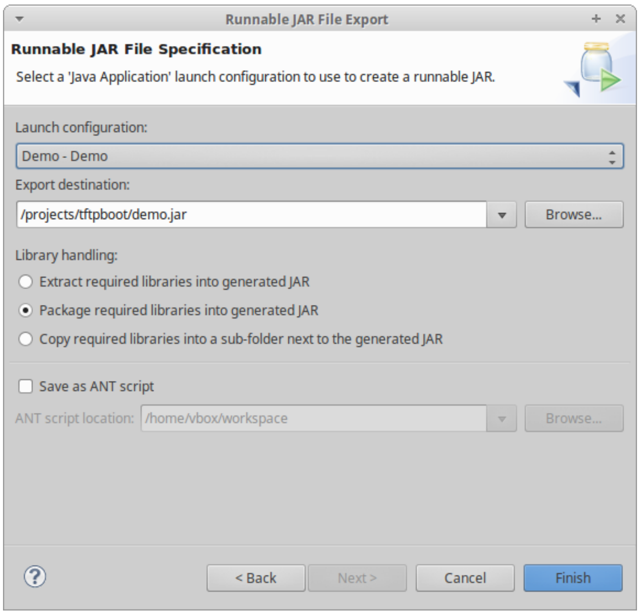


Figure 33: Java Demo: Export Java JAR archive

Copy the created JAR file to the CTR-700 by using SFTP for example. This is described in section 6.10.2. Login the CTR-700 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.

9.3 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 CTR-700. After this click on *Debug* to start the debugging session.

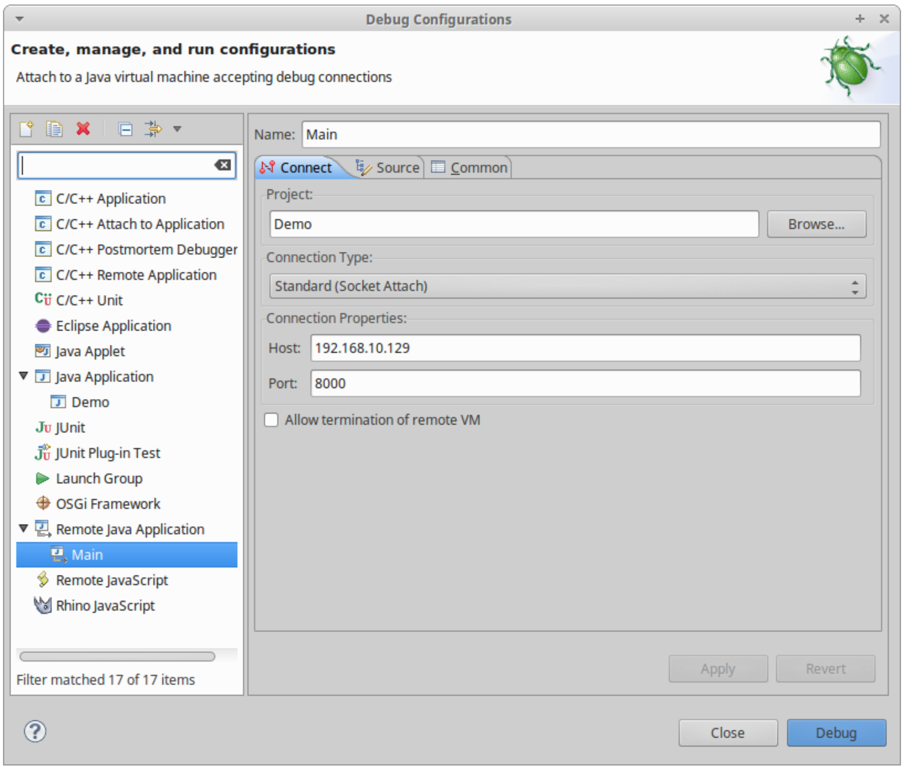


Figure 34: Java Demo: Debug configuration

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.

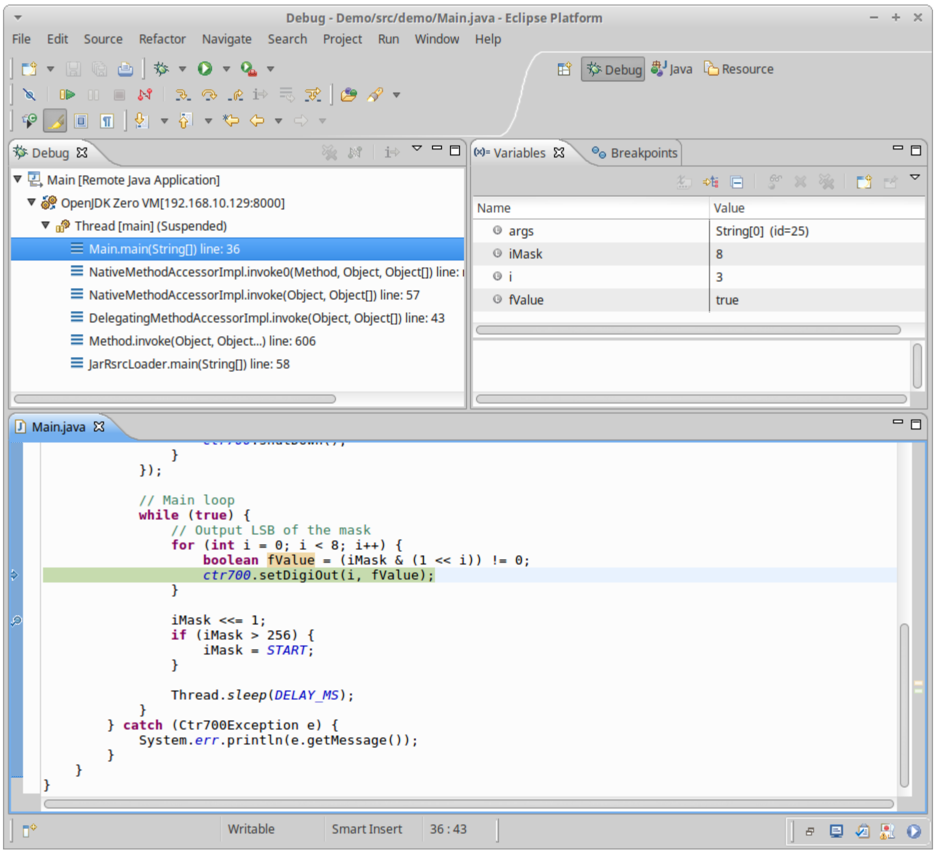


Figure 35: Java Demo: Debug example

10 Python

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

10.1 Create a Python application

The bindings to the CTR-700 I/O Driver are located in the *Oracle VM VirtualBox* provided for the CTR-700. (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 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. 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.

10.2 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 CTR-700. This can be done by using SFTP (see section 6.10.2). Login the CTR-700 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.

10.3 Debug the Python application

To debug the application, the built-in debugger *pdb* can be used. Execute the following commands on the CTR-700 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.

11 PLC functionality of the CTR-700

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

11.1 System start of the CTR-700

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 6.8.3.

If enabled, the CTR-700 loads all necessary firmware components upon power-on or reset and starts running the PLC program afterwards (if enabled). Hence, the CTR-700 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.

11.2 Programming the CTR-700

The CTR-700 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 for the CTR-700 are listed in Table 1.

CTR-700 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 11.3) as well as the functionality of control elements (DIP-Switch, Run/Stop switch, Run-LED, Error-LED).

Depending on the firmware version used, CTR-700 firmware provides numerous function blocks to the user to access communication interfaces. Section 6.8.3 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 CTR-700. Detailed information about using the CAN interfaces in connection with CANopen is provided in section 11.8.

11.3 Process image of the CTR-700

11.3.1 Local In- and Outputs

Compared to other SYS TEC compact control systems, the CTR-700 obtains a process image with identical addresses. All in- and outputs listed in Table 11 are supported by the CTR-700.

Table 11: Assignment of in- and outputs to the process image of the CTR-700

I/O of the CTR-700	Address and Data type in the Process Image	
DI0 ... DI7	**%IB0.0** %IX0.0 … %IX0.7	as Byte with DI0 … DI7 as single Bit for each input
DI8 ... DI15	**%IB1.0** %IX1.0 … %IX1.7	as Byte with DI8 … DI15 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** counter input: DI14 (%IX1.6), direction: DI15 (%IX1.7)	31Bit + sign (-2^{31} - 2^{31} -1)
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** %QX0.0 … %QX0.7	as Byte with DO0 … DO7 as single Bit for each output
DO8 … DO15	**%QB1.0** %QX1.0 … %QX1.7	as Byte with DO8 … DO15 as single Bit for each output
REL0 and REL1 (corresponds to DO16 … DO17)	**%QB2.0** %QX2.0 … %QX2.1	as Byte with REL0 and REL1 as single Bit for each Relay
DO Mask	**%QD1984.0** a bitmask of digital outputs, which will **not** be written from process image to hardware registers. (LSB relates to DO0, MSB relates to DO15)	Mask of digital outputs
AI0 Configuration	**%QW1928.0** 0: keep configuration, 1: set to voltage measurement, 2: set to current measurement	Configuration of AI0
AI1 Configuration	**%QW1930.0** see AI0 Configuration	Configuration of AI1
AI2 Configuration	**%QW1932.0** see AI0 Configuration	Configuration of AI2
AI3 Configuration	**%QW1934.0** see AI0 Configuration	Configuration of AI3

Advice: The CTR-700 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 of the CTR-700 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.

11.3.2 Network variables for CAN1

Contrary to interface CAN0, interface CAN1 of the CTR-700 is designed as static object dictionary. Thus, at interface CAN1 the CTR-700 acts as a CANopen I/O device. All static network variables for CAN1 are accessible via the marker section of the process image.

Section 11.3.2 includes more detailed information about CAN interface CAN1 and the network variables that are provided by it in the marker section.

11.4 Communication interfaces

11.4.1 Serial interfaces

The CTR-700 features one service and three serial interfaces (X10, X15 … X17). Details about hardware activation are included in section 5.7.1.

SERVICE (X10)

Interface Service serves only as service interface to administer the CTR-700. The connection to a computer is established via Micro-USB.

SERIAL0 and SERIAL1 (X15 and X16)

Interface Serial 0 and 1 are disposable and support data exchange between the CTR-700 and other field devices kept under control of the PLC program.

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).

SERIAL2 (X17)

Interface Serial 2 is disposable and **modem-compatible**. It supports data exchange between the CTR-700 and other field devices kept under control of the PLC program.

The interface 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).

11.4.2 CAN interfaces

The CTR-700 features two CAN interfaces (CAN0 and CAN1). Details about the hardware activation are included in section 5.7.2.

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

11.4.3 Ethernet interface

The CTR-700 features 2 Ethernet interface (ETH0 and ETH1, also termed as ETHERNET). Details about the hardware activation are included in section 5.7.3

The Ethernet interface serves as service interface to administer the CTR-700 and it enables data exchange with other devices. 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.

11.5 Specific peripheral interfaces

11.5.1 Counter inputs

The CTR-700 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 11.3.1) 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

11.5.2 Pulse outputs

To release PWM and PTO signal sequences, the CTR-700 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 11.3.1). 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

11.6 Control and display elements

11.6.1 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.

11.6.2 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"*

11.6.3 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.

11.7 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 CTR-700 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!

11.8 Using CANopen for CAN interfaces

The CTR-700 features 2 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 6.7.

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 of the CTR-700.

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 the CTR-700, the usage of PDO-based network variables is different for each CAN interface CAN0 and CAN1. Sections 11.8.1 and 11.8.2 provide more detail on this.

In a CANopen network, exchanging PDOs only takes place in status *"OPERATIONAL"*. If the CTR-700 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. The CTR-700 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 6.7.

As CANopen Manager, the CTR-700 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.

11.8.1 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 CTR-700.

11.8.2 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 CTR-700 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 36 shows the positioning of network variables for CAN1 within the marker section.

CAN1 Input Variables

	CAN1 IN0	CAN1 IN1	CAN1 IN2	CAN1 IN3	CAN1 IN4	CAN1 IN5	CAN1 IN6	CAN1 IN7	...	CAN1 IN244	CAN1 IN245	CAN1 IN246	CAN1 IN247	CAN1 IN248	CAN1 IN249	CAN1 IN250	CAN1 IN251
BYTE / SINT, USINT	%MB 0.0 (Byte0)	%MB 1.0 (Byte1)	%MB 2.0 (Byte2)	%MB 3.0 (Byte3)	%MB 4.0 (Byte4)	%MB 5.0 (Byte5)	%MB 6.0 (Byte6)	%MB 7.0 (Byte7)		%MB 244.0 (Byte244)	%MB 245.0 (Byte245)	%MB 246.0 (Byte246)	%MB 247.0 (Byte247)	%MB 248.0 (Byte248)	%MB 249.0 (Byte249)	%MB 250.0 (Byte250)	%MB 251.0 (Byte251)
WORD / INT, UINT	%MW 0.0 (Word0)		%MW 2.0 (Word1)		%MW 4.0 (Word2)		%MW 6.0 (Word3)		...	%MW 244.0 (Word122)		%MW 246.0 (Word123)		%MW 248.0 (Word124)		%MW 250.0 (Word125)	
DWORD / DINT, UDINT	%MD 0.0 (Dword0)				%MD 4.0 (Dword1)					%MD 244.0 (Dword61)				%MD 248.0 (Dword62)			

CAN1 Output Variables

	CAN1 OUT0	CAN1 OUT1	CAN1 OUT2	CAN1 OUT3	CAN1 OUT4	CAN1 OUT5	CAN1 OUT6	CAN1 OUT7	...	CAN1 OUT244	CAN1 OUT245	CAN1 OUT246	CAN1 OUT247	CAN1 OUT248	CAN1 OUT249	CAN1 OUT250	CAN1 OUT251
BYTE / SINT, USINT	%MB 256.0 (Byte0)	%MB 257.0 (Byte1)	%MB 258.0 (Byte2)	%MB 259.0 (Byte3)	%MB 260.0 (Byte4)	%MB 261.0 (Byte5)	%MB 262.0 (Byte6)	%MB 263.0 (Byte7)		%MB 500.0 (Byte244)	%MB 501.0 (Byte245)	%MB 502.0 (Byte246)	%MB 503.0 (Byte247)	%MB 504.0 (Byte248)	%MB 505.0 (Byte249)	%MB 506.0 (Byte250)	%MB 507.0 (Byte251)
WORD / INT, UINT	%MW 256.0 (Word0)		%MW 258.0 (Word1)		%MW 260.0 (Word2)		%MW 262.0 (Word3)		...	%MW 500.0 (Word122)		%MW 502.0 (Word123)		%MW 504.0 (Word124)		%MW 506.0 (Word125)	
DWORD / DINT, UDINT	%MD 265.0 (Dword0)				%MD 260.0 (Dword1)					%MD 500.0 (Dword61)				%MD 504.0 (Dword62)			

Figure 36: 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 the CTR-700)			
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 the CTR-700)			
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 CTR-700 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"*.

12 Data exchange via shared process image

12.1 Overview of the shared process image

The CTR-700 is based on the operating system 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").

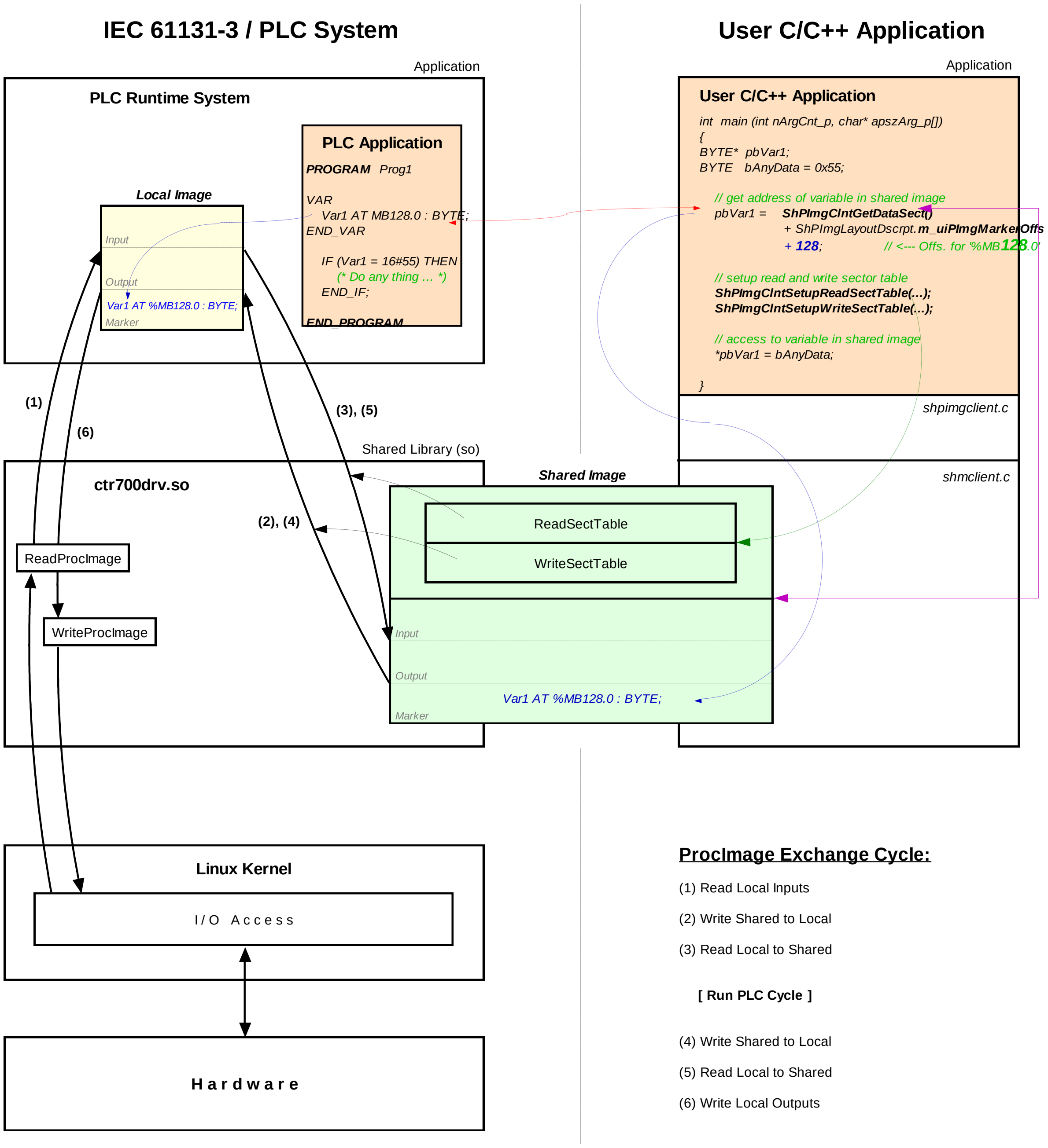


Figure 37: Overview of the shared process image

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 37, 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 37). 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 37). 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 6.7.1). Alternatively, entry *" EnableSharing="* can directly be set within section *"[ProcImg]"* of the configuration file ***"/home/plc/bin/ctr-700.cfg"*** (see section 6.7.3). 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 37). 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 37 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.

12.2 API of the shared process image client

As illustrated in Figure 37, 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 12.1). 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 12.1), 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 12.1).

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 12.1).

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 12.1). 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 12.1). 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 12.1). 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.

12.3 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 CTR-700. 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 37, 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* (*/projects/CTR-700/user/shpimgdemo*) contains the respective files. 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 for the CTR-700. 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"*:

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

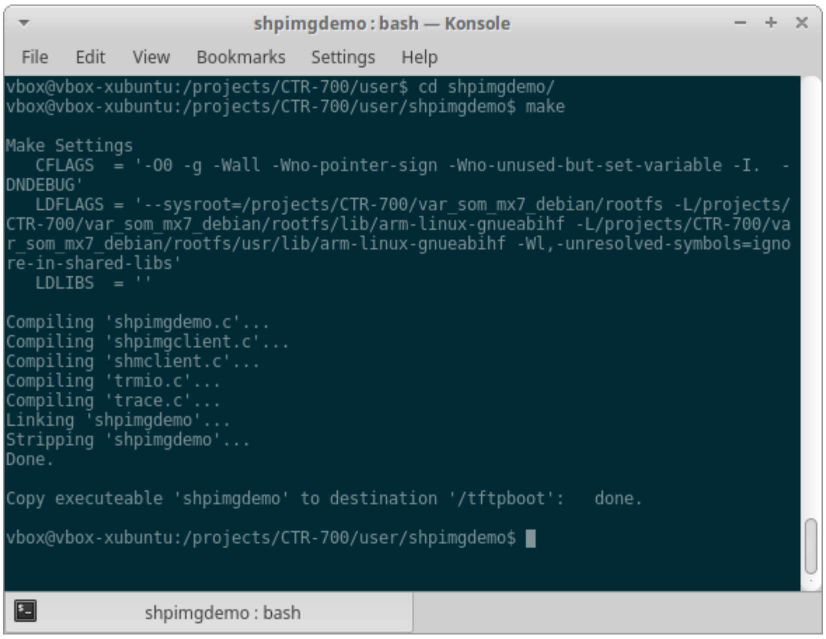


Figure 38: Generating the demo project "shpimgdemo" in the Linux development system

Section 12.4 describes the usage and handling of the demo project *"shpimgdemo"* on the CTR-700.

12.4 Example for using the shared process image

The demo project *"shpimgdemo"* (described in section 12.3) 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 on the CTR-700

To enable the execution of the *shared process image demo* without previous introduction into the Linux-based C/C++ programming for the CTR-700, 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 12.3) 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* on the CTR-700:

1. **Activate option *"Shared PLC process image"*** in the PLC configuration (see sections 12.1, 6.7.1 and 6.7.3).

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 *"SYSTEC – CTR-700"*

3. Select the network connection to the CTR-700 und download the program.

4. Start the PLC program on the CTR-700

5. Login to the command shell of the CTR-700 as described in section 6.10.1.

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

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

   The digital outputs of the CTR-700 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"* on the CTR-700, actual status information about the runlight is indicated cyclically in the terminal (see Figure 39).

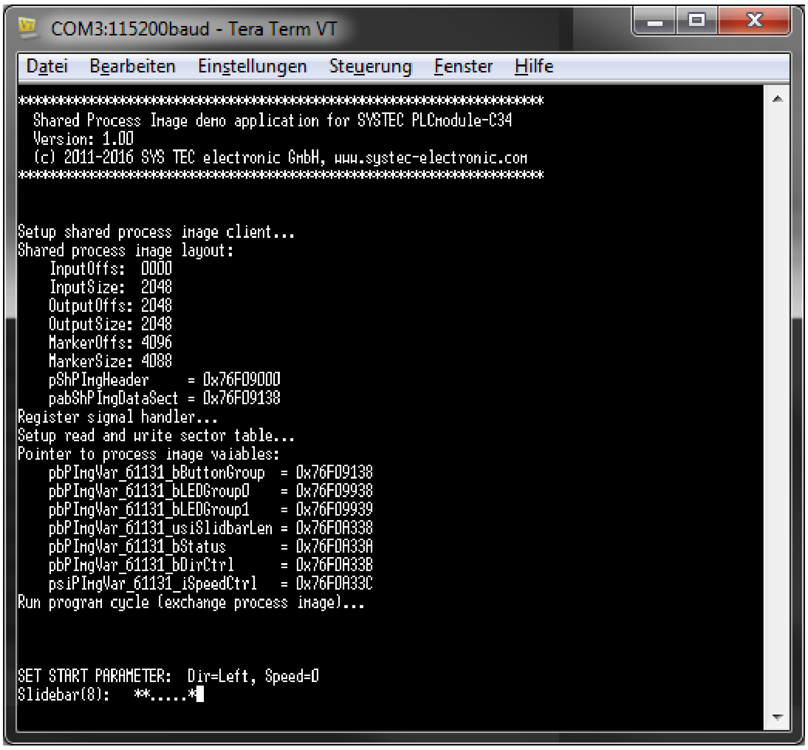


Figure 39: Terminal outputs of the demo program "shpimgdemo" after start

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 ↓).

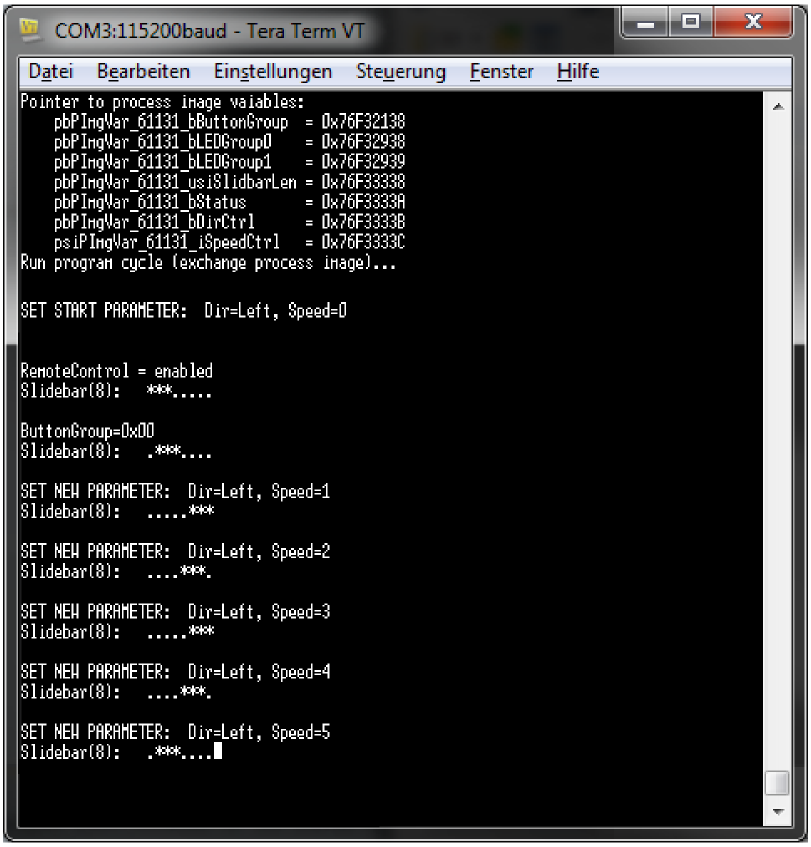


Figure 40: Terminal outputs of the demo program "shpimgdemo" after user inputs

Figure 40 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.

Appendix A: Firmware function scope of CTR-700

Table 19 lists all firmware functions and function blocks available on the CTR-700.

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 of CTR-700

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"* on the CTR-700. 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 CTR-700. 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 6.10.1).

(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 6.7.1), 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 *"/home/plc/bin/ctr-700.cfg*" (see section 6.7.3).

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.)	$100x10^6$	

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

	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	
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%[7]
	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[8]	
	Measurement error	0.23%	0.5%[7]
	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

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

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

Appendix C: Third Party Software Components

GNU General Public License

The Embedded Linux used on CTR-700 is licensed under GNU General Public License, version 2. The entire license text is specified below. A German translation is available from http://www.gnu.de/documents/gpl-2.0.de.html. Be advised that this translation is not official or legally approved.

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

GNU GENERAL PUBLIC LICENSE
Version 2, June 1991

Copyright (C) 1989, 1991 Free Software Foundation, Inc. 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software -- to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs; and that you know you can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the software.

Also, for each author's protection and ours, we want to make certain that everyone understands that there is no warranty for this free software. If the software is modified by someone else and passed on, we want its recipients to know that what they have is not the original, so that any problems introduced by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that redistributors of a free program will individually obtain patent licenses, in effect making the program proprietary. To prevent this, we have made it clear that any patent must be licensed for everyone's free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification follow.

GNU GENERAL PUBLIC LICENSE
TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License applies to any program or other work which contains a notice placed by the copyright holder saying it may be distributed under the terms of this General Public License. The "Program", below, refers to any such program or work, and a "work based on the Program" means either the Program or any derivative work under copyright law: that is to say, a work containing the Program or a portion of it, either verbatim or with modifications and/or translated into another language. (Hereinafter, translation is included without limitation in the term "modification".) Each licensee is addressed as "you".

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running the Program is not restricted, and the output from the Program is covered only if its contents constitute a work based on the Program (independent of having been made by running the Program). Whether that is true depends on what the Program does.

1. You may copy and distribute verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and give any other recipients of the Program a copy of this License along with the Program.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Program or any portion of it, thus forming a work based on the Program, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

a) You must cause the modified files to carry prominent notices stating that you changed the files and the date of any change.

b) You must cause any work that you distribute or publish, that in whole or in part contains or is derived from the Program or any part thereof, to be licensed as a whole at no charge to all third parties under the terms of this License.

c) If the modified program normally reads commands interactively when run, you must cause it, when started running for such interactive use in the most ordinary way, to print or display an announcement including an appropriate copyright notice and a notice that there is no warranty (or else, saying that you provide a warranty) and that users may redistribute the program under these conditions, and telling the user how to view a copy of this License. (Exception: if the Program itself is interactive but does not normally print such an announcement, your work based on the Program is not required to print an announcement.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Program, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Program, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Program.

In addition, mere aggregation of another work not based on the Program with the Program (or with a work based on the Program) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may copy and distribute the Program (or a work based on it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you also do one of the following:

a) Accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

b) Accompany it with a written offer, valid for at least three years, to give any third party, for a charge no more than your cost of physically performing source distribution, a complete machine-readable copy of the corresponding source code, to be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

c) Accompany it with the information you received as to the offer to distribute corresponding source code. (This alternative is allowed only for noncommercial distribution and only if you received the program in object code or executable form with such an offer, in accord with Subsection b above.)

The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

4. You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Program

(or any work based on the Program), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program), the recipient automatically receives a license from the original licensor to copy, distribute or modify the Program subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Program at all. For example, if a patent license would not permit royalty-free redistribution of the Program by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Program.

If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system, which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of this License, you may choose any version ever published by the Free Software Foundation.

10. If you wish to incorporate parts of the Program into other free programs whose distribution conditions are different, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

NO WARRANTY

11. BECAUSE THE PROGRAM IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

12. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

<one line to give the program's name and a brief idea of what it does.>
Copyright (C) <year> <name of author>

This program is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this program; if not, write to the Free Software Foundation, Inc., 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it starts in an interactive mode:

Gnomovision version 69, Copyright (C) year name of author
Gnomovision comes with ABSOLUTELY NO WARRANTY; for details type `show w'.
This is free software, and you are welcome to redistribute it under certain conditions;
type `show c' for details.

The hypothetical commands `show w' and `show c' should show the appropriate parts of the General Public License. Of course, the commands you use may be called something other than `show w' and `show c'; they could even be mouse-clicks or menu items -- whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

Yoyodyne, Inc., hereby disclaims all copyright interest in the program `Gnomovision' (which makes passes at compilers) written by James Hacker.

<signature of Ty Coon>, 1 April 1989
Ty Coon, President of Vice

This General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Library General Public License instead of this License.

Paho MQTT Embedded/C

The Eclipse Paho MQTT package is a client library for MQTT embedded devices.

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

Copyright and license:

Mono

Mono is an open source implementation of Microsoft's .NET Framework based on the ECMA standards for C# and the Common Language Runtime.

Project URL: https://github.com/mono/mono

```
License:

In general, the runtime and its class libraries are licensed under the
terms of the MIT license, and some third party code is licensed under
the 3-clause BSD license.  See the file "PATENTS.TXT" for Microsoft's
patent grant on the Mono codebase.

The Mono distribution does include a handful of pieces of code that
are used during the build system and are covered under different
licenses, those include:

Build Time Code
===============

This is code that is used at build time, or during the maintenance of
Mono itself, and does not end up in the redistributable part of Mono:

* gettext

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

* Benchmark Source Files

  Logic.cs and zipmark.cs are GPL source files.

* mono/docs/HtmlAgilityPack

  MS-PL licensed

* mcs/jay: 4-clause BSD licensed

* mcs/nunit24: MS-PL

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

Runtime Code
============

The following code is linked with the final Mono runtime, the libmono
embeddable runtime:

* support/minizip: BSD license.

* mono/utils/memcheck.h: BSD license, used on debug builds that use
Valgrind.

* mono/utils/freebsd-dwarf.h, freebsd-elf_common.h, freebsd-elf64.h
freebsd-elf32.h: BSD license.

* mono/utils/bsearch.c: BSD license.

* mono/metadata/w32file-unix-glob.c, w32file-unix-glob.h: BSD license

Class Library code
```

==================

These are class libraries that can be loaded by your process:

* mcs/class/RabbitMQ.Client: dual licensed in Apache v2, and Mozilla Public License 1.1

* mcs/class/Compat.ICSharpCode.SharpZipLib and
  mcs/class/ICSharpCode.SharpZipLib are GPL with class-path exception.
  Originates with the SharpDevelop project.

* mcs/class/System.Core/System/TimeZoneInfo.Android.cs

  This is a port of Apache 2.0-licensed Android code, and thus is
  licensed under the Apache 2.0 license

  http://www.apache.org/licenses/LICENSE-2.0

API Documentation
=================

The API documentation is licensed under the terms of the Creative Commons Attribution 4.0 International Public License

The Licenses
============

These are the licenses used in Mono, the files are located:

MIT X11 License

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.

Mozilla.MPL

MOZILLA PUBLIC LICENSE
Version 1.1

----

1. Definitions.

1.0.1. "Commercial Use" means distribution or otherwise making the Covered Code available to a third party.

1.1. "Contributor" means each entity that creates or contributes to the creation of Modifications.

1.2. "Contributor Version" means the combination of the Original Code, prior Modifications used by a Contributor, and the Modifications made by that particular Contributor.

1.3. "Covered Code" means the Original Code or Modifications or the combination of the Original Code and Modifications, in each case including portions thereof.

1.4. "Electronic Distribution Mechanism" means a mechanism generally accepted in the software development community for the electronic transfer of data.

1.5. "Executable" means Covered Code in any form other than Source Code.

1.6. "Initial Developer" means the individual or entity identified as the Initial Developer in the Source Code notice required by Exhibit A.

1.7. "Larger Work" means a work which combines Covered Code or portions thereof with code not governed by the terms of this License.

1.8. "License" means this document.

1.8.1. "Licensable" means having the right to grant, to the maximum extent possible, whether at the time of the initial grant or subsequently acquired, any and all of the rights conveyed herein.

1.9. "Modifications" means any addition to or deletion from the substance or structure of either the Original Code or any previous Modifications. When Covered Code is released as a series of files, a Modification is:

A. Any addition to or deletion from the contents of a file containing Original Code or previous Modifications.

B. Any new file that contains any part of the Original Code or previous Modifications.

1.10. "Original Code" means Source Code of computer software code which is described in the Source Code notice required by Exhibit A as Original Code, and which, at the time of its release under this License is not already Covered Code governed by this License.

1.10.1. "Patent Claims" means any patent claim(s), now owned or hereafter acquired, including without limitation, method, process, and apparatus claims, in any patent Licensable by grantor.

1.11. "Source Code" means the preferred form of the Covered Code for making modifications to it, including all modules it contains, plus any associated interface definition files, scripts used to control compilation and installation of an Executable, or source code differential comparisons against either the Original Code or another well known, available Covered Code of the Contributor's choice. The Source Code can be in a compressed or archival form, provided the appropriate decompression or de-archiving software is widely available for no charge.

1.12. "You" (or "Your") means an individual or a legal entity exercising rights under, and complying with all of the terms of, this License or a future version of this License issued under Section 6.1. For legal entities, "You" includes any entity which controls, is controlled by, or is under common control with You. For purposes of this definition, "control" means (a) the power, direct or indirect, to cause the direction or management of such entity, whether by contract or otherwise, or (b) ownership of more than fifty percent (50%) of the outstanding shares or beneficial ownership of such entity.

2. Source Code License.

2.1. The Initial Developer Grant.
The Initial Developer hereby grants You a world-wide, royalty-free, non-exclusive license, subject to third party intellectual property claims:

(a) under intellectual property rights (other than patent or trademark) Licensable by Initial Developer to use, reproduce, modify, display, perform, sublicense and distribute the Original Code (or portions thereof) with or without Modifications, and/or as part of a Larger Work; and

(b) under Patents Claims infringed by the making, using or selling of Original Code, to make, have made, use, practice, sell, and offer for sale, and/or otherwise dispose of the Original Code (or portions thereof).

(c) the licenses granted in this Section 2.1(a) and (b) are effective on the date Initial Developer first distributes Original Code under the terms of this License.

(d) Notwithstanding Section 2.1(b) above, no patent license is granted: 1) for code that You delete from the Original Code; 2) separate from the Original Code; or 3) for infringements caused by: i) the modification of the Original Code or ii) the combination of the Original Code with other software or devices.

2.2. Contributor Grant.
Subject to third party intellectual property claims, each Contributor hereby grants You a world-wide, royalty-free, non-exclusive license

(a) under intellectual property rights (other than patent or trademark) Licensable by Contributor, to use, reproduce, modify, display, perform, sublicense and distribute the Modifications created by such Contributor (or portions thereof) either on an unmodified basis, with other Modifications, as Covered Code and/or as part of a Larger Work; and

(b) under Patent Claims infringed by the making, using, or selling of Modifications made by that Contributor either alone and/or in combination with its Contributor Version (or portions of such combination), to make, use, sell, offer for sale, have made, and/or otherwise dispose of: 1) Modifications made by that Contributor (or portions thereof); and 2) the combination of Modifications made by that Contributor with its Contributor Version (or portions of such combination).

(c) the licenses granted in Sections 2.2(a) and 2.2(b) are effective on the date Contributor first makes Commercial Use of the Covered Code.

(d) Notwithstanding Section 2.2(b) above, no patent license is granted: 1) for any code that Contributor has deleted from the Contributor Version; 2) separate from the Contributor Version; 3) for infringements caused by: i) third party modifications of Contributor Version or ii) the combination of Modifications made by that Contributor with other software (except as part of the Contributor Version) or other devices; or 4) under Patent Claims infringed by Covered Code in the absence of Modifications made by that Contributor.

3. Distribution Obligations.

3.1. Application of License.
The Modifications which You create or to which You contribute are governed by the terms of this License, including without limitation Section 2.2. The Source Code version of Covered Code may be distributed only under the terms of this License or a future version of this License released under Section 6.1, and You must include a copy of this License with every copy of the Source Code You distribute. You may not offer or impose any terms on any Source Code version that alters or restricts the applicable version of this License or the recipients' rights hereunder. However, You may include an additional document offering the additional rights described in Section 3.5.

3.2. Availability of Source Code.
Any Modification which You create or to which You contribute must be made available in Source Code form under the terms of this License either on the same media as an Executable version or via an accepted Electronic Distribution Mechanism to anyone to whom you made an Executable version available; and if made available via Electronic Distribution Mechanism, must remain available for at least twelve (12) months after the date it initially became available, or at least six (6) months after a subsequent version of that particular Modification has been made available to such recipients. You are responsible for ensuring that the Source Code version remains available even if the Electronic Distribution Mechanism is maintained by a third party.

3.3. Description of Modifications.
You must cause all Covered Code to which You contribute to contain a file documenting the changes You made to create that Covered Code and the date of any change. You must include a prominent statement that the Modification is derived, directly or indirectly, from Original Code provided by the Initial Developer and including the name of the Initial Developer in (a) the Source Code, and (b) in any notice in an Executable version or related documentation in which You describe the origin or ownership of the Covered Code.

3.4. Intellectual Property Matters

(a) Third Party Claims.
If Contributor has knowledge that a license under a third party's intellectual property rights is required to exercise the rights granted by such Contributor under Sections 2.1 or 2.2, Contributor must include a text file with the Source Code distribution titled "LEGAL" which describes the claim and the party making the claim in sufficient detail that a recipient will know whom to contact. If Contributor obtains such knowledge after the Modification is made available as described in Section 3.2,

Contributor shall promptly modify the LEGAL file in all copies Contributor makes available thereafter and shall take other steps (such as notifying appropriate mailing lists or newsgroups) reasonably calculated to inform those who received the Covered Code that new knowledge has been obtained.

(b) Contributor APIs.
If Contributor's Modifications include an application programming interface and Contributor has knowledge of patent licenses which are reasonably necessary to implement that API, Contributor must also include this information in the LEGAL file.

(c) Representations.
Contributor represents that, except as disclosed pursuant to Section 3.4(a) above, Contributor believes that Contributor's Modifications are Contributor's original creation(s) and/or Contributor has sufficient rights to grant the rights conveyed by this License.

3.5. Required Notices.
You must duplicate the notice in Exhibit A in each file of the Source Code. If it is not possible to put such notice in a particular Source Code file due to its structure, then You must include such notice in a location (such as a relevant directory) where a user would be likely to look for such a notice. If You created one or more Modification(s) You may add your name as a Contributor to the notice described in Exhibit A. You must also duplicate this License in any documentation for the Source Code where You describe recipients' rights or ownership rights relating to Covered Code. You may choose to offer, and to charge a fee for, warranty, support, indemnity or liability obligations to one or more recipients of Covered Code. However, You may do so only on Your own behalf, and not on behalf of the Initial Developer or any Contributor. You must make it absolutely clear than any such warranty, support, indemnity or liability obligation is offered by You alone, and You hereby agree to indemnify the Initial Developer and every Contributor for any liability incurred by the Initial Developer or such Contributor as a result of warranty, support, indemnity or liability terms You offer.

3.6. Distribution of Executable Versions.
You may distribute Covered Code in Executable form only if the requirements of Section 3.1-3.5 have been met for that Covered Code, and if You include a notice stating that the Source Code version of the Covered Code is available under the terms of this License, including a description of how and where You have fulfilled the obligations of Section 3.2. The notice must be conspicuously included in any notice in an Executable version, related documentation or collateral in which You describe recipients' rights relating to the Covered Code. You may distribute the Executable version of Covered Code or ownership rights under a license of Your choice, which may contain terms different from this License, provided that You are in compliance with the terms of this License and that the license for the Executable version does not attempt to limit or alter the recipient's rights in the Source Code version from the rights set forth in this License. If You distribute the Executable version under a different license You must make it absolutely clear that any terms which differ from this License are offered by You alone, not by the Initial Developer or any Contributor. You hereby agree to indemnify the Initial Developer and every Contributor for any liability incurred by the Initial Developer or such Contributor as a result of any such terms You offer.

3.7. Larger Works.
You may create a Larger Work by combining Covered Code with other code not governed by the terms of this License and distribute the Larger Work as a single product. In such a case, You must make sure the requirements of this License are fulfilled for the Covered Code.

4. Inability to Comply Due to Statute or Regulation.

If it is impossible for You to comply with any of the terms of this License with respect to some or all of the Covered Code due to statute, judicial order, or regulation then You must: (a) comply with the terms of this License to the maximum extent possible; and (b) describe the limitations and the code they affect. Such description must be included in the LEGAL file described in Section 3.4 and must be included with all distributions of the Source Code. Except to the extent prohibited by statute or regulation, such description must be sufficiently detailed for a recipient of ordinary skill to be able to understand it.

5. Application of this License.

This License applies to code to which the Initial Developer has attached the notice in Exhibit A and to related Covered Code.

6. Versions of the License.

6.1. New Versions.
Netscape Communications Corporation ("Netscape") may publish revised and/or new versions of the License from time to time. Each version will be given a distinguishing version number.

6.2. Effect of New Versions.
Once Covered Code has been published under a particular version of the License, You may always continue to use it under the terms of that version. You may also choose to use such Covered Code under the terms of any subsequent version of the License published by Netscape. No one other than Netscape has the right to modify the terms applicable to Covered Code created under this License.

6.3. Derivative Works.
If You create or use a modified version of this License (which you may only do in order to apply it to code which is not already Covered Code governed by this License), You must (a) rename Your license so that the phrases "Mozilla", "MOZILLAPL", "MOZPL", "Netscape", "MPL", "NPL" or any confusingly similar phrase do not appear in your license (except to note that your license differs from this License) and (b) otherwise make it clear that Your version of the license contains terms which differ from the Mozilla Public License and Netscape Public License. (Filling in the name of the Initial Developer, Original Code or Contributor in the notice described in Exhibit A shall not of themselves be deemed to be modifications of this License.)

7. DISCLAIMER OF WARRANTY.

COVERED CODE IS PROVIDED UNDER THIS LICENSE ON AN "AS IS" BASIS, WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, WITHOUT LIMITATION, WARRANTIES THAT THE COVERED CODE IS FREE OF DEFECTS, MERCHANTABLE, FIT FOR A PARTICULAR PURPOSE OR NON-INFRINGING. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE COVERED CODE

IS WITH YOU. SHOULD ANY COVERED CODE PROVE DEFECTIVE IN ANY RESPECT, YOU (NOT THE INITIAL DEVELOPER OR ANY OTHER CONTRIBUTOR) ASSUME THE COST OF ANY NECESSARY SERVICING, REPAIR OR CORRECTION. THIS DISCLAIMER OF WARRANTY CONSTITUTES AN ESSENTIAL PART OF THIS LICENSE. NO USE OF ANY COVERED CODE IS AUTHORIZED HEREUNDER EXCEPT UNDER THIS DISCLAIMER.

8. TERMINATION.

8.1. This License and the rights granted hereunder will terminate automatically if You fail to comply with terms herein and fail to cure such breach within 30 days of becoming aware of the breach. All sublicenses to the Covered Code which are properly granted shall survive any termination of this License. Provisions which, by their nature, must remain in effect beyond the termination of this License shall survive.

8.2. If You initiate litigation by asserting a patent infringement claim (excluding declatory judgment actions) against Initial Developer or a Contributor (the Initial Developer or Contributor against whom You file such action is referred to as "Participant") alleging that:

(a) such Participant's Contributor Version directly or indirectly infringes any patent, then any and all rights granted by such Participant to You under Sections 2.1 and/or 2.2 of this License shall, upon 60 days notice from Participant terminate prospectively, unless if within 60 days after receipt of notice You either: (i) agree in writing to pay Participant a mutually agreeable reasonable royalty for Your past and future use of Modifications made by such Participant, or (ii) withdraw Your litigation claim with respect to the Contributor Version against such Participant. If within 60 days of notice, a reasonable royalty and payment arrangement are not mutually agreed upon in writing by the parties or the litigation claim is not withdrawn, the rights granted by Participant to You under Sections 2.1 and/or 2.2 automatically terminate at the expiration of the 60 day notice period specified above.

(b) any software, hardware, or device, other than such Participant's Contributor Version, directly or indirectly infringes any patent, then any rights granted to You by such Participant under Sections 2.1(b) and 2.2(b) are revoked effective as of the date You first made, used, sold, distributed, or had made, Modifications made by that Participant.

8.3. If You assert a patent infringement claim against Participant alleging that such Participant's Contributor Version directly or indirectly infringes any patent where such claim is resolved (such as by license or settlement) prior to the initiation of patent infringement litigation, then the reasonable value of the licenses granted by such Participant under Sections 2.1 or 2.2 shall be taken into account in determining the amount or value of any payment or license.

8.4. In the event of termination under Sections 8.1 or 8.2 above, all end user license agreements (excluding distributors and resellers) which have been validly granted by You or any distributor hereunder prior to termination shall survive termination.

9. LIMITATION OF LIABILITY.

UNDER NO CIRCUMSTANCES AND UNDER NO LEGAL THEORY, WHETHER TORT (INCLUDING NEGLIGENCE), CONTRACT, OR OTHERWISE, SHALL YOU, THE INITIAL

DEVELOPER, ANY OTHER CONTRIBUTOR, OR ANY DISTRIBUTOR OF COVERED CODE, OR ANY SUPPLIER OF ANY OF SUCH PARTIES, BE LIABLE TO ANY PERSON FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OF ANY CHARACTER INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF GOODWILL, WORK STOPPAGE, COMPUTER FAILURE OR MALFUNCTION, OR ANY AND ALL OTHER COMMERCIAL DAMAGES OR LOSSES, EVEN IF SUCH PARTY SHALL HAVE BEEN INFORMED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION OF LIABILITY SHALL NOT APPLY TO LIABILITY FOR DEATH OR PERSONAL INJURY RESULTING FROM SUCH PARTY'S NEGLIGENCE TO THE EXTENT APPLICABLE LAW PROHIBITS SUCH LIMITATION. SOME JURISDICTIONS DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THIS EXCLUSION AND LIMITATION MAY NOT APPLY TO YOU.

10. U.S. GOVERNMENT END USERS.

The Covered Code is a "commercial item," as that term is defined in 48 C.F.R. 2.101 (Oct. 1995), consisting of "commercial computer software" and "commercial computer software documentation," as such terms are used in 48 C.F.R. 12.212 (Sept. 1995). Consistent with 48 C.F.R. 12.212 and 48 C.F.R. 227.7202-1 through 227.7202-4 (June 1995), all U.S. Government End Users acquire Covered Code with only those rights set forth herein.

11. MISCELLANEOUS.

This License represents the complete agreement concerning subject matter hereof. If any provision of this License is held to be unenforceable, such provision shall be reformed only to the extent necessary to make it enforceable. This License shall be governed by California law provisions (except to the extent applicable law, if any, provides otherwise), excluding its conflict-of-law provisions. With respect to disputes in which at least one party is a citizen of, or an entity chartered or registered to do business in the United States of America, any litigation relating to this License shall be subject to the jurisdiction of the Federal Courts of the Northern District of California, with venue lying in Santa Clara County, California, with the losing party responsible for costs, including without limitation, court costs and reasonable attorneys' fees and expenses. The application of the United Nations Convention on Contracts for the International Sale of Goods is expressly excluded. Any law or regulation which provides that the language of a contract shall be construed against the drafter shall not apply to this License.

12. RESPONSIBILITY FOR CLAIMS.

As between Initial Developer and the Contributors, each party is responsible for claims and damages arising, directly or indirectly, out of its utilization of rights under this License and You agree to work with Initial Developer and Contributors to distribute such responsibility on an equitable basis. Nothing herein is intended or shall be deemed to constitute any admission of liability.

13. MULTIPLE-LICENSED CODE.

Initial Developer may designate portions of the Covered Code as "Multiple-Licensed". "Multiple-Licensed" means that the Initial Developer permits you to utilize portions of the Covered Code under Your choice of the NPL or the alternative licenses, if any, specified by the Initial Developer in the file described in Exhibit A.

EXHIBIT A -Mozilla Public License.

``The contents of this file are subject to the Mozilla Public License Version 1.1 (the "License"); you may not use this file except in compliance with the License. You may obtain a copy of the License at http://www.mozilla.org/MPL/

Software distributed under the License is distributed on an "AS IS" basis, WITHOUT WARRANTY OF ANY KIND, either express or implied. See the License for the specific language governing rights and limitations under the License.

The Original Code is ______________________________________.

The Initial Developer of the Original Code is ________________________.
Portions created by ______________________ are Copyright (C) ______ _______________________. All Rights Reserved.

Contributor(s): ______________________________________.

Alternatively, the contents of this file may be used under the terms of the _____ license (the "[___] License"), in which case the provisions of [______] License are applicable instead of those above. If you wish to allow use of your version of this file only under the terms of the [____] License and not to allow others to use your version of this file under the MPL, indicate your decision by deleting the provisions above and replace them with the notice and other provisions required by the [___] License. If you do not delete the provisions above, a recipient may use your version of this file under either the MPL or the [___] License."

[NOTE: The text of this Exhibit A may differ slightly from the text of the notices in the Source Code files of the Original Code. You should use the text of this Exhibit A rather than the text found in the Original Code Source Code for Your Modifications.]

Microsoft Public License

Microsoft Permissive License (Ms-PL)

This license governs use of the accompanying software. If you use the software, you accept this license. If you do not accept the license, do not use the software.

1. Definitions

The terms “reproduce,” “reproduction,” “derivative works,” and “distribution” have the same meaning here as under U.S. copyright law.
A “contribution” is the original software, or any additions or changes to the software.
A “contributor” is any person that distributes its contribution under this license.
“Licensed patents” are a contributor’s patent claims that read directly on its contribution.

2. Grant of Rights

(A) Copyright Grant- Subject to the terms of this license, including the license conditions and limitations in section 3, each contributor grants you a non-exclusive, worldwide, royalty-free copyright license to reproduce its contribution, prepare derivative works of its contribution, and distribute its contribution or any derivative works that you create.

(B) Patent Grant- Subject to the terms of this license, including the license conditions and limitations in section 3, each contributor grants you a non-exclusive, worldwide, royalty-free license under its licensed patents to make, have made, use, sell, offer for sale, import, and/or otherwise dispose of its contribution in the software or derivative works of the contribution in the software.

3. Conditions and Limitations

(A) No Trademark License- This license does not grant you rights to use any contributors' name, logo, or trademarks.

(B) If you bring a patent claim against any contributor over patents that you claim are infringed by the software, your patent license from such contributor to the software ends automatically.

(C) If you distribute any portion of the software, you must retain all copyright, patent, trademark, and attribution notices that are present in the software.

(D) If you distribute any portion of the software in source code form, you may do so only under this license by including a complete copy of this license with your distribution. If you distribute any portion of the software in compiled or object code form, you may only do so under a license that complies with this license.

(E) The software is licensed "as-is." You bear the risk of using it. The contributors give no express warranties, guarantees or conditions. You may have additional consumer rights under your local laws which this license cannot change. To the extent permitted under your local laws, the contributors exclude the implied warranties of merchantability, fitness for a particular purpose and non-infringement.

(F) If you distribute the software or derivative works with programs you develop, you agree to indemnify, defend, and hold harmless all contributors from any claims, including attorneys' fees, related to the distribution or use of your programs. For clarity, you have no such obligations to a contributor for any claims based solely on the unmodified contributions of that contributor.

(G) If you make any additions or changes to the original software, you may only distribute them under a new namespace. In addition, you will clearly identify your changes or additions as your own.

Infozip BSD

This is version 2009-Jan-02 of the Info-ZIP license. The definitive version of this document should be available at ftp://ftp.info-zip.org/pub/infozip/license.html indefinitely and a copy at http://www.info-zip.org/pub/infozip/license.html.

Copyright (c) 1990-2009 Info-ZIP. All rights reserved.

For the purposes of this copyright and license, "Info-ZIP" is defined as the following set of individuals: Mark Adler, John Bush, Karl Davis, Harald Denker, Jean-Michel Dubois, Jean-loup Gailly, Hunter Goatley, Ed Gordon, Ian Gorman, Chris Herborth, Dirk Haase, Greg Hartwig, Robert Heath, Jonathan Hudson, Paul Kienitz, David Kirschbaum, Johnny Lee, Onno van der Linden, Igor Mandrichenko, Steve P. Miller, Sergio Monesi, Keith Owens, George Petrov, Greg Roelofs, Kai Uwe Rommel, Steve Salisbury, Dave Smith, Steven M. Schweda, Christian Spieler, Cosmin Truta, Antoine Verheijen, Paul von Behren, Rich Wales, Mike White.

```
This software is provided "as is," without warranty of any kind,
express or implied. In no event shall Info-ZIP or its contributors be
held liable for any direct, indirect, incidental, special or
consequential damages arising out of the use of or inability to use
this software.

Permission is granted to anyone to use this software for any purpose,
including commercial applications, and to alter it and redistribute it
freely, subject to the above disclaimer and the following
restrictions:

Redistributions of source code (in whole or in part) must retain the
above copyright notice, definition, disclaimer, and this list of
conditions.

Redistributions in binary form (compiled executables and libraries)
must reproduce the above copyright notice, definition, disclaimer, and
this list of conditions in documentation and/or other materials
provided with the distribution. Additional documentation is not needed
for executables where a command line license option provides these and
a note regarding this option is in the executable's startup
banner. The sole exception to this condition is redistribution of a
standard UnZipSFX binary (including SFXWiz) as part of a
self-extracting archive; that is permitted without inclusion of this
license, as long as the normal SFX banner has not been removed from
the binary or disabled.

Altered versions--including, but not limited to, ports to new
operating systems, existing ports with new graphical interfaces,
versions with modified or added functionality, and dynamic, shared, or
static library versions not from Info-ZIP--must be plainly marked as
such and must not be misrepresented as being the original source or,
if binaries, compiled from the original source. Such altered versions
also must not be misrepresented as being Info-ZIP releases--including,
but not limited to, labeling of the altered versions with the names
"Info-ZIP" (or any variation thereof, including, but not limited to,
different capitalizations), "Pocket UnZip," "WiZ" or "MacZip" without
the explicit permission of Info-ZIP. Such altered versions are further
prohibited from misrepresentative use of the Zip-Bugs or Info-ZIP
e-mail addresses or the Info-ZIP URL(s), such as to imply Info-ZIP
will provide support for the altered versions.

Info-ZIP retains the right to use the names "Info-ZIP," "Zip,"
"UnZip," "UnZipSFX," "WiZ," "Pocket UnZip," "Pocket Zip," and "MacZip"
for its own source and binary releases.

### License Creative Commons 2.5

// Copyright 2006 James Newton-King
// http://www.newtonsoft.com
//
// This work is licensed under the Creative Commons Attribution 2.5 License
// http://creativecommons.org/licenses/by/2.5/
//
// You are free:
//    * to copy, distribute, display, and perform the work
//    * to make derivative works
//    * to make commercial use of the work
//
// Under the following conditions:
```

// * For any reuse or distribution, you must make clear to others the license terms of this work.
// * Any of these conditions can be waived if you get permission from the copyright holder.

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.

The CC license has the following clause: Any of the above conditions can be waived if you get permission from the copyright holder.

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

Regards,
James

Creative Commons Attribution 4.0 International Public License

Attribution 4.0 International

===

Creative Commons Corporation ("Creative Commons") is not a law firm and does not provide legal services or legal advice. Distribution of Creative Commons public licenses does not create a lawyer-client or other relationship. Creative Commons makes its licenses and related information available on an "as-is" basis. Creative Commons gives no warranties regarding its licenses, any material licensed under their terms and conditions, or any related information. Creative Commons disclaims all liability for damages resulting from their use to the fullest extent possible.

Using Creative Commons Public Licenses

Creative Commons public licenses provide a standard set of terms and conditions that creators and other rights holders may use to share original works of authorship and other material subject to copyright and certain other rights specified in the public license below. The following considerations are for informational purposes only, are not exhaustive, and do not form part of our licenses.

Considerations for licensors: Our public licenses are intended for use by those authorized to give the public permission to use material in ways otherwise restricted by copyright and certain other rights. Our licenses are irrevocable. Licensors should read and understand the terms and conditions of the license they choose before applying it. Licensors should also secure all rights necessary before applying our licenses so that the public can reuse the material as expected. Licensors should clearly mark any material not subject to the license. This includes other CC-licensed material, or material used under an exception or

limitation to copyright. More considerations for licensors:
wiki.creativecommons.org/Considerations_for_licensors

Considerations for the public: By using one of our public licenses, a licensor grants the public permission to use the licensed material under specified terms and conditions. If the licensor's permission is not necessary for any reason--for example, because of any applicable exception or limitation to copyright--then that use is not regulated by the license. Our licenses grant only permissions under copyright and certain other rights that a licensor has authority to grant. Use of the licensed material may still be restricted for other reasons, including because others have copyright or other rights in the material. A licensor may make special requests, such as asking that all changes be marked or described. Although not required by our licenses, you are encouraged to respect those requests where reasonable. More_considerations for the public:
wiki.creativecommons.org/Considerations_for_licensees

===

Creative Commons Attribution 4.0 International Public License

By exercising the Licensed Rights (defined below), You accept and agree to be bound by the terms and conditions of this Creative Commons Attribution 4.0 International Public License ("Public License"). To the extent this Public License may be interpreted as a contract, You are granted the Licensed Rights in consideration of Your acceptance of these terms and conditions, and the Licensor grants You such rights in consideration of benefits the Licensor receives from making the Licensed Material available under these terms and conditions.

Section 1 -- Definitions.

a. Adapted Material means material subject to Copyright and Similar Rights that is derived from or based upon the Licensed Material and in which the Licensed Material is translated, altered, arranged, transformed, or otherwise modified in a manner requiring permission under the Copyright and Similar Rights held by the Licensor. For purposes of this Public License, where the Licensed Material is a musical work, performance, or sound recording, Adapted Material is always produced where the Licensed Material is synched in timed relation with a moving image.

b. Adapter's License means the license You apply to Your Copyright and Similar Rights in Your contributions to Adapted Material in accordance with the terms and conditions of this Public License.

c. Copyright and Similar Rights means copyright and/or similar rights closely related to copyright including, without limitation, performance, broadcast, sound recording, and Sui Generis Database Rights, without regard to how the rights are labeled or categorized. For purposes of this Public License, the rights specified in Section 2(b)(1)-(2) are not Copyright and Similar Rights.

d. Effective Technological Measures means those measures that, in the absence of proper authority, may not be circumvented under laws fulfilling obligations under Article 11 of the WIPO Copyright

Treaty adopted on December 20, 1996, and/or similar international agreements.

e. Exceptions and Limitations means fair use, fair dealing, and/or any other exception or limitation to Copyright and Similar Rights that applies to Your use of the Licensed Material.

f. Licensed Material means the artistic or literary work, database, or other material to which the Licensor applied this Public License.

g. Licensed Rights means the rights granted to You subject to the terms and conditions of this Public License, which are limited to all Copyright and Similar Rights that apply to Your use of the Licensed Material and that the Licensor has authority to license.

h. Licensor means the individual(s) or entity(ies) granting rights under this Public License.

i. Share means to provide material to the public by any means or process that requires permission under the Licensed Rights, such as reproduction, public display, public performance, distribution, dissemination, communication, or importation, and to make material available to the public including in ways that members of the public may access the material from a place and at a time individually chosen by them.

j. Sui Generis Database Rights means rights other than copyright resulting from Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, as amended and/or succeeded, as well as other essentially equivalent rights anywhere in the world.

k. You means the individual or entity exercising the Licensed Rights under this Public License. Your has a corresponding meaning.

Section 2 -- Scope.

a. License grant.

   1. Subject to the terms and conditions of this Public License, the Licensor hereby grants You a worldwide, royalty-free, non-sublicensable, non-exclusive, irrevocable license to exercise the Licensed Rights in the Licensed Material to:

      a. reproduce and Share the Licensed Material, in whole or in part; and

      b. produce, reproduce, and Share Adapted Material.

   2. Exceptions and Limitations. For the avoidance of doubt, where Exceptions and Limitations apply to Your use, this Public License does not apply, and You do not need to comply with its terms and conditions.

   3. Term. The term of this Public License is specified in Section 6(a).

   4. Media and formats; technical modifications allowed. The Licensor authorizes You to exercise the Licensed Rights in

all media and formats whether now known or hereafter created, and to make technical modifications necessary to do so. The Licensor waives and/or agrees not to assert any right or authority to forbid You from making technical modifications necessary to exercise the Licensed Rights, including technical modifications necessary to circumvent Effective Technological Measures. For purposes of this Public License, simply making modifications authorized by this Section 2(a)(4) never produces Adapted Material.

5. Downstream recipients.

    a. Offer from the Licensor -- Licensed Material. Every recipient of the Licensed Material automatically receives an offer from the Licensor to exercise the Licensed Rights under the terms and conditions of this Public License.

    b. No downstream restrictions. You may not offer or impose any additional or different terms or conditions on, or apply any Effective Technological Measures to, the Licensed Material if doing so restricts exercise of the Licensed Rights by any recipient of the Licensed Material.

6. No endorsement. Nothing in this Public License constitutes or may be construed as permission to assert or imply that You are, or that Your use of the Licensed Material is, connected with, or sponsored, endorsed, or granted official status by, the Licensor or others designated to receive attribution as provided in Section 3(a)(1)(A)(i).

b. Other rights.

1. Moral rights, such as the right of integrity, are not licensed under this Public License, nor are publicity, privacy, and/or other similar personality rights; however, to the extent possible, the Licensor waives and/or agrees not to assert any such rights held by the Licensor to the limited extent necessary to allow You to exercise the Licensed Rights, but not otherwise.

2. Patent and trademark rights are not licensed under this Public License.

3. To the extent possible, the Licensor waives any right to collect royalties from You for the exercise of the Licensed Rights, whether directly or through a collecting society under any voluntary or waivable statutory or compulsory licensing scheme. In all other cases the Licensor expressly reserves any right to collect such royalties.

Section 3 -- License Conditions.

Your exercise of the Licensed Rights is expressly made subject to the following conditions.

a. Attribution.

1. If You Share the Licensed Material (including in modified

form), You must:

a. retain the following if it is supplied by the Licensor with the Licensed Material:

    i. identification of the creator(s) of the Licensed Material and any others designated to receive attribution, in any reasonable manner requested by the Licensor (including by pseudonym if designated);

    ii. a copyright notice;

    iii. a notice that refers to this Public License;

    iv. a notice that refers to the disclaimer of warranties;

    v. a URI or hyperlink to the Licensed Material to the extent reasonably practicable;

b. indicate if You modified the Licensed Material and retain an indication of any previous modifications; and

c. indicate the Licensed Material is licensed under this Public License, and include the text of, or the URI or hyperlink to, this Public License.

2. You may satisfy the conditions in Section 3(a)(1) in any reasonable manner based on the medium, means, and context in which You Share the Licensed Material. For example, it may be reasonable to satisfy the conditions by providing a URI or hyperlink to a resource that includes the required information.

3. If requested by the Licensor, You must remove any of the information required by Section 3(a)(1)(A) to the extent reasonably practicable.

4. If You Share Adapted Material You produce, the Adapter's License You apply must not prevent recipients of the Adapted Material from complying with this Public License.

Section 4 -- Sui Generis Database Rights.

Where the Licensed Rights include Sui Generis Database Rights that apply to Your use of the Licensed Material:

a. for the avoidance of doubt, Section 2(a)(1) grants You the right to extract, reuse, reproduce, and Share all or a substantial portion of the contents of the database;

b. if You include all or a substantial portion of the database contents in a database in which You have Sui Generis Database Rights, then the database in which You have Sui Generis Database Rights (but not its individual contents) is Adapted Material; and

c. You must comply with the conditions in Section 3(a) if You Share all or a substantial portion of the contents of the database.

For the avoidance of doubt, this Section 4 supplements and does not replace Your obligations under this Public License where the Licensed Rights include other Copyright and Similar Rights.

Section 5 -- Disclaimer of Warranties and Limitation of Liability.

a. UNLESS OTHERWISE SEPARATELY UNDERTAKEN BY THE LICENSOR, TO THE EXTENT POSSIBLE, THE LICENSOR OFFERS THE LICENSED MATERIAL AS-IS AND AS-AVAILABLE, AND MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND CONCERNING THE LICENSED MATERIAL, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHER. THIS INCLUDES, WITHOUT LIMITATION, WARRANTIES OF TITLE, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NON-INFRINGEMENT, ABSENCE OF LATENT OR OTHER DEFECTS, ACCURACY, OR THE PRESENCE OR ABSENCE OF ERRORS, WHETHER OR NOT KNOWN OR DISCOVERABLE. WHERE DISCLAIMERS OF WARRANTIES ARE NOT ALLOWED IN FULL OR IN PART, THIS DISCLAIMER MAY NOT APPLY TO YOU.

b. TO THE EXTENT POSSIBLE, IN NO EVENT WILL THE LICENSOR BE LIABLE TO YOU ON ANY LEGAL THEORY (INCLUDING, WITHOUT LIMITATION, NEGLIGENCE) OR OTHERWISE FOR ANY DIRECT, SPECIAL, INDIRECT, INCIDENTAL, CONSEQUENTIAL, PUNITIVE, EXEMPLARY, OR OTHER LOSSES, COSTS, EXPENSES, OR DAMAGES ARISING OUT OF THIS PUBLIC LICENSE OR USE OF THE LICENSED MATERIAL, EVEN IF THE LICENSOR HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH LOSSES, COSTS, EXPENSES, OR DAMAGES. WHERE A LIMITATION OF LIABILITY IS NOT ALLOWED IN FULL OR IN PART, THIS LIMITATION MAY NOT APPLY TO YOU.

c. The disclaimer of warranties and limitation of liability provided above shall be interpreted in a manner that, to the extent possible, most closely approximates an absolute disclaimer and waiver of all liability.

Section 6 -- Term and Termination.

a. This Public License applies for the term of the Copyright and Similar Rights licensed here. However, if You fail to comply with this Public License, then Your rights under this Public License terminate automatically.

b. Where Your right to use the Licensed Material has terminated under Section 6(a), it reinstates:

   1. automatically as of the date the violation is cured, provided it is cured within 30 days of Your discovery of the violation; or

   2. upon express reinstatement by the Licensor.

   For the avoidance of doubt, this Section 6(b) does not affect any right the Licensor may have to seek remedies for Your violations of this Public License.

c. For the avoidance of doubt, the Licensor may also offer the Licensed Material under separate terms or conditions or stop distributing the Licensed Material at any time; however, doing so will not terminate this Public License.

d. Sections 1, 5, 6, 7, and 8 survive termination of this Public License.

GPL version 2

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software--to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs; and that you know you can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the software.

Also, for each author's protection and ours, we want to make certain that everyone understands that there is no warranty for this free software. If the software is modified by someone else and passed on, we want its recipients to know that what they have is not the original, so that any problems introduced by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that redistributors of a free program will individually obtain patent licenses, in effect making the program proprietary. To prevent this, we have made it clear that any patent must be licensed for everyone's free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification follow.

GNU GENERAL PUBLIC LICENSE
TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License applies to any program or other work which contains a notice placed by the copyright holder saying it may be distributed

under the terms of this General Public License. The "Program", below, refers to any such program or work, and a "work based on the Program" means either the Program or any derivative work under copyright law: that is to say, a work containing the Program or a portion of it, either verbatim or with modifications and/or translated into another language. (Hereinafter, translation is included without limitation in the term "modification".) Each licensee is addressed as "you".

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running the Program is not restricted, and the output from the Program is covered only if its contents constitute a work based on the Program (independent of having been made by running the Program). Whether that is true depends on what the Program does.

1. You may copy and distribute verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and give any other recipients of the Program a copy of this License along with the Program.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Program or any portion of it, thus forming a work based on the Program, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

a) You must cause the modified files to carry prominent notices stating that you changed the files and the date of any change.

b) You must cause any work that you distribute or publish, that in whole or in part contains or is derived from the Program or any part thereof, to be licensed as a whole at no charge to all third parties under the terms of this License.

c) If the modified program normally reads commands interactively when run, you must cause it, when started running for such interactive use in the most ordinary way, to print or display an announcement including an appropriate copyright notice and a notice that there is no warranty (or else, saying that you provide a warranty) and that users may redistribute the program under these conditions, and telling the user how to view a copy of this License. (Exception: if the Program itself is interactive but does not normally print such an announcement, your work based on the Program is not required to print an announcement.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Program, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Program, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Program.

In addition, mere aggregation of another work not based on the Program with the Program (or with a work based on the Program) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may copy and distribute the Program (or a work based on it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you also do one of the following:

a) Accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

b) Accompany it with a written offer, valid for at least three years, to give any third party, for a charge no more than your cost of physically performing source distribution, a complete machine-readable copy of the corresponding source code, to be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

c) Accompany it with the information you received as to the offer to distribute corresponding source code. (This alternative is allowed only for noncommercial distribution and only if you received the program in object code or executable form with such an offer, in accord with Subsection b above.)

The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

4. You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Program (or any work based on the

Program), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program), the recipient automatically receives a license from the original licensor to copy, distribute or modify the Program subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Program at all. For example, if a patent license would not permit royalty-free redistribution of the Program by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Program.

If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system, which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free

```
Software Foundation.  If the Program does not specify a version number of
this License, you may choose any version ever published by the Free
Software
Foundation.

  10. If you wish to incorporate parts of the Program into other free
programs whose distribution conditions are different, write to the author
to ask for permission.  For software which is copyrighted by the Free
Software Foundation, write to the Free Software Foundation; we sometimes
make exceptions for this.  Our decision will be guided by the two goals
of preserving the free status of all derivatives of our free software and
of promoting the sharing and reuse of software generally.

                            NO WARRANTY

  11. BECAUSE THE PROGRAM IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY
FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW.  EXCEPT WHEN
OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES
PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED
OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF
MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.  THE ENTIRE RISK AS
TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU.  SHOULD THE
PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING,
REPAIR OR CORRECTION.

  12. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING
WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR
REDISTRIBUTE THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES,
INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING
OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED
TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY
YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER
PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE
POSSIBILITY OF SUCH DAMAGES.

                     END OF TERMS AND CONDITIONS

            How to Apply These Terms to Your New Programs

  If you develop a new program, and you want it to be of the greatest
possible use to the public, the best way to achieve this is to make it
free software which everyone can redistribute and change under these terms.

  To do so, attach the following notices to the program.  It is safest
to attach them to the start of each source file to most effectively
convey the exclusion of warranty; and each file should have at least
the "copyright" line and a pointer to where the full notice is found.

    <one line to give the program's name and a brief idea of what it does.>
    Copyright (C) <year>  <name of author>

    This program is free software; you can redistribute it and/or modify
    it under the terms of the GNU General Public License as published by
    the Free Software Foundation; either version 2 of the License, or
    (at your option) any later version.

    This program is distributed in the hope that it will be useful,
    but WITHOUT ANY WARRANTY; without even the implied warranty of
    MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
    GNU General Public License for more details.
```

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it starts in an interactive mode:

```
    Gnomovision version 69, Copyright (C) year  name of author
    Gnomovision comes with ABSOLUTELY NO WARRANTY; for details type `show
w'.
    This is free software, and you are welcome to redistribute it
    under certain conditions; type `show c' for details.
```

The hypothetical commands `show w' and `show c' should show the appropriate parts of the General Public License. Of course, the commands you use may be called something other than `show w' and `show c'; they could even be mouse-clicks or menu items--whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

```
  Yoyodyne, Inc., hereby disclaims all copyright interest in the program
  `Gnomovision' (which makes passes at compilers) written by James Hacker.

  <signature of Ty Coon>, 1 April 1989
  Ty Coon, President of Vice
```

This General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Library General Public License instead of this License.

Link: https://github.com/mono/mono/blob/master/LICENSE

Microsoft Patent Promise for Mono

Microsoft Corporation and its affiliates (“Microsoft”) promise not to assert any Applicable Patents against you for making, using, selling, offering for sale, importing, or distributing Mono.

If you file, maintain, or voluntarily participate in any claim in a lawsuit alleging direct or contributory patent infringement by Mono, or inducement of patent infringement by Mono, then your rights under this promise will automatically terminate.

This promise is not an assurance that (i) any Applicable Patents are valid or enforceable or (ii) Mono does not infringe patents or other intellectual property rights of any third party. No rights except those expressly stated in this promise are granted, waived or received by Microsoft, whether by implication, exhaustion, estoppel or otherwise. This is a personal promise directly from Microsoft to you, and you agree as a condition of benefitting from it that no Microsoft rights are received from suppliers, distributors, or otherwise in connection with this promise.

Definitions:

“Mono” means those portions of the software development technology, as originally distributed by Xamarin, Inc. or the .NET Foundation under the name “Mono,” that implement .NET Framework Functionality, provided that such portions at a minimum implement all of the required parts of the mandatory provisions of Standard ECMA-335 – Common Language Infrastructure (CLI).

“.NET Framework Functionality” means any functionality in Microsoft’s .NET Framework as described in Microsoft’s API documentation on Microsoft’s MSDN website, including the functionality in Windowsbase.dll, but excluding all other functionality in the Windows Presentation Foundation component of .NET Framework.

“Applicable Patents” are those patent claims, currently owned by Microsoft and acquired in the future, that are necessarily infringed by Mono. For clarity, Applicable Patents do not include any patent claims that are infringed (x) by any underlying or enabling technology that may be used, combined, or distributed in connection with Mono (such as hardware, operating systems, or applications that run on Mono), (y) only as a consequence of modification of Mono, or (z) only by the combination of Mono with third party code.

Link: https://github.com/mono/mono/blob/master/PATENTS.TXT

Open JDK

The Eclipse Paho MQTT package is a client library for MQTT embedded devices.

Project URL: http://openjdk.java.net/

Copyright and license:

```
    the OpenJDK 6 code".

(3) Trademark Owner makes no warranties of any kind respecting the
    Name, and all representations and warranties, including any implied
    warranty of merchantability, fitness for a particular purpose or
    non-infringement are hereby disclaimed.

(4) Finally, this notice and the following legend are included in all
    copies of the Software or portions of it:

       Java and OpenJDK are trademarks or registered trademarks of
       Oracle and/or its affiliates.

Trademark Owner intends to revise this Notice as necessary in order to
meet the needs of the OpenJDK Community.  Revisions to this notice will
be announced on the public mailing list announce at openjdk.java.net, to
which you may subscribe by visiting http://mail.openjdk.java.net.  Please
send questions or comments about this Notice to the discuss list at the
same location.
```

Link: http://openjdk.java.net/legal/openjdk-trademark-notice.html

OpenJDK Assembly Exception

```
The OpenJDK source code made available by Oracle America, Inc. (Oracle) at
openjdk.java.net ("OpenJDK Code") is distributed under the terms of the GNU
General Public License <http://www.gnu.org/copyleft/gpl.html> version 2
only ("GPL2"), with the following clarification and special exception.

    Linking this OpenJDK Code statically or dynamically with other code
    is making a combined work based on this library.  Thus, the terms
    and conditions of GPL2 cover the whole combination.

    As a special exception, Oracle gives you permission to link this
    OpenJDK Code with certain code licensed by Oracle as indicated at
    http://openjdk.java.net/legal/exception-modules-2007-05-08.html
    ("Designated Exception Modules") to produce an executable,
    regardless of the license terms of the Designated Exception Modules,
    and to copy and distribute the resulting executable under GPL2,
    provided that the Designated Exception Modules continue to be
    governed by the licenses under which they were offered by Oracle.

As such, it allows licensees and sublicensees of Oracle's GPL2 OpenJDK Code
to build an executable that includes those portions of necessary code that
Oracle could not provide under GPL2 (or that Oracle has provided under GPL2
with the Classpath exception).  If you modify or add to the OpenJDK code,
that new GPL2 code may still be combined with Designated Exception Modules
if the new code is made subject to this exception by its copyright holder.
```

Link: http://openjdk.java.net/legal/assembly-exception.html

OpenJDK Designated Exception Modules

8 May 2007

For purposes of those files in the OpenJDK distribution that are subject to the Assembly Exception, the following shall be deemed Designated Exception Modules:

1. Those files in the OpenJDK distribution available at openjdk.java.net, openjdk.dev.java.net, and download.java.net to which Sun has applied the Classpath Exception,
2. Any of your derivative works of #1 above, to the extent you license them under the GPLv2 with the Classpath Exception as defined in the OpenJDK distribution available at openjdk.java.net, openjdk.dev.java.net, or download.java.net,
3. Any files in the OpenJDK distribution that are made available at openjdk.java.net, openjdk.dev.java.net, or download.java.net under a binary code license, and
4. Any files in the OpenJDK distribution that are made available at openjdk.java.net, openjdk.dev.java.net, or download.java.net under an open source license other than GPL, and your derivatives thereof that are in compliance with the applicable open source license.

Link: http://openjdk.java.net/legal/exception-modules-2007-05-08.html

GNU General Public License, version 2, with the Classpath Exception
The GNU General Public License (GPL)

Version 2, June 1991

Copyright (C) 1989, 1991 Free Software Foundation, Inc.
59 Temple Place, Suite 330, Boston, MA 02111-1307 USA

Everyone is permitted to copy and distribute verbatim copies of this license
document, but changing it is not allowed.

Preamble

The licenses for most software are designed to take away your freedom to share
and change it. By contrast, the GNU General Public License is intended to
guarantee your freedom to share and change free software--to make sure the
software is free for all its users. This General Public License applies to
most of the Free Software Foundation's software and to any other program whose
authors commit to using it. (Some other Free Software Foundation software is
covered by the GNU Library General Public License instead.) You can apply it to
your programs, too.

When we speak of free software, we are referring to freedom, not price. Our
General Public Licenses are designed to make sure that you have the freedom to
distribute copies of free software (and charge for this service if you wish),
that you receive source code or can get it if you want it, that you can change
the software or use pieces of it in new free programs; and that you know you
can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny
you these rights or to ask you to surrender the rights. These restrictions
translate to certain responsibilities for you if you distribute copies of the
software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for
a fee, you must give the recipients all the rights that you have. You must
make sure that they, too, receive or can get the source code. And you must
show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2)
offer you this license which gives you legal permission to copy, distribute
and/or modify the software.

Also, for each author's protection and ours, we want to make certain that
everyone understands that there is no warranty for this free software. If the
software is modified by someone else and passed on, we want its recipients to
know that what they have is not the original, so that any problems introduced
by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We
wish to avoid the danger that redistributors of a free program will
individually obtain patent licenses, in effect making the program proprietary.
To prevent this, we have made it clear that any patent must be licensed for
everyone's free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification
follow.

TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License applies to any program or other work which contains a notice

placed by the copyright holder saying it may be distributed under the terms of
this General Public License. The "Program", below, refers to any such program
or work, and a "work based on the Program" means either the Program or any
derivative work under copyright law: that is to say, a work containing the
Program or a portion of it, either verbatim or with modifications and/or
translated into another language. (Hereinafter, translation is included
without limitation in the term "modification".) Each licensee is addressed as
"you".

Activities other than copying, distribution and modification are not covered by
this License; they are outside its scope. The act of running the Program is
not restricted, and the output from the Program is covered only if its contents
constitute a work based on the Program (independent of having been made by
running the Program). Whether that is true depends on what the Program does.

1. You may copy and distribute verbatim copies of the Program's source code as
you receive it, in any medium, provided that you conspicuously and
appropriately publish on each copy an appropriate copyright notice and
disclaimer of warranty; keep intact all the notices that refer to this License
and to the absence of any warranty; and give any other recipients of the
Program a copy of this License along with the Program.

You may charge a fee for the physical act of transferring a copy, and you may
at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Program or any portion of it, thus
forming a work based on the Program, and copy and distribute such modifications
or work under the terms of Section 1 above, provided that you also meet all of
these conditions:

a) You must cause the modified files to carry prominent notices stating
that you changed the files and the date of any change.

b) You must cause any work that you distribute or publish, that in whole or
in part contains or is derived from the Program or any part thereof, to be
licensed as a whole at no charge to all third parties under the terms of
this License.

c) If the modified program normally reads commands interactively when run,
you must cause it, when started running for such interactive use in the most ordinary way, to print or display an announcement including an appropriate copyright notice and a notice that there is no warranty (or else, saying that you provide a warranty) and that users may redistribute the program under these conditions, and telling the user how to view a copy of this License. (Exception: if the Program itself is interactive but does not normally print such an announcement, your work based on the Program is not required to print an announcement.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Program, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Program, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Program.

In addition, mere aggregation of another work not based on the Program with the Program (or with a work based on the Program) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may copy and distribute the Program (or a work based on it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you also do one of the following:

a) Accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

b) Accompany it with a written offer, valid for at least three years, to

give any third party, for a charge no more than your cost of physically
performing source distribution, a complete machine-readable copy of the
corresponding source code, to be distributed under the terms of Sections 1
and 2 above on a medium customarily used for software interchange; or,

c) Accompany it with the information you received as to the offer to
distribute corresponding source code. (This alternative is allowed only
for noncommercial distribution and only if you received the program in
object code or executable form with such an offer, in accord with
Subsection b above.)

The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

4. You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Program (or

any work based on the Program), you indicate your acceptance of this License to
do so, and all its terms and conditions for copying, distributing or modifying
the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program),
the recipient automatically receives a license from the original licensor to
copy, distribute or modify the Program subject to these terms and conditions.
You may not impose any further restrictions on the recipients' exercise of the
rights granted herein. You are not responsible for enforcing compliance by
third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent
infringement or for any other reason (not limited to patent issues), conditions
are imposed on you (whether by court order, agreement or otherwise) that
contradict the conditions of this License, they do not excuse you from the
conditions of this License. If you cannot distribute so as to satisfy
simultaneously your obligations under this License and any other pertinent
obligations, then as a consequence you may not distribute the Program at all.
For example, if a patent license would not permit royalty-free redistribution
of the Program by all those who receive copies directly or indirectly through
you, then the only way you could satisfy both it and this License would be to
refrain entirely from distribution of the Program.

If any portion of this section is held invalid or unenforceable under any
particular circumstance, the balance of the section is intended to apply and
the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or
other property right claims or to contest validity of any such claims; this
section has the sole purpose of protecting the integrity of the free software
distribution system, which is implemented by public license practices. Many
people have made generous contributions to the wide range of software
distributed through that system in reliance on consistent application of that
system; it is up to the author/donor to decide if he or she is willing to
distribute software through any other system and a licensee cannot impose that
choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of this License, you may choose any version ever published by the Free Software Foundation.

10. If you wish to incorporate parts of the Program into other free programs whose distribution conditions are different, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

NO WARRANTY

11. BECAUSE THE PROGRAM IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND

FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE,
YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

12. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL
ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE
PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR
INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA
BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER
OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Programs

If you develop a new program, and you want it to be of the greatest possible
use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach
them to the start of each source file to most effectively convey the exclusion
of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

One line to give the program's name and a brief idea of what it does.

Copyright (C) <year> <name of author>

This program is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free
Software Foundation; either version 2 of the License, or (at your option)
any later version.

This program is distributed in the hope that it will be useful, but WITHOUT
ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for
more details.

You should have received a copy of the GNU General Public License along

    with this program; if not, write to the Free Software Foundation, Inc.,
59
    Temple Place, Suite 330, Boston, MA 02111-1307 USA

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it
starts in an interactive mode:

    Gnomovision version 69, Copyright (C) year name of author Gnomovision comes
    with ABSOLUTELY NO WARRANTY; for details type 'show w'. This is free
    software, and you are welcome to redistribute it under certain conditions;
    type 'show c' for details.

The hypothetical commands 'show w' and 'show c' should show the appropriate parts of the General Public License. Of course, the commands you use may be called something other than 'show w' and 'show c'; they could even be mouse-clicks or menu items--whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if necessary. Here is a sample; alter the names:

    Yoyodyne, Inc., hereby disclaims all copyright interest in the program
    'Gnomovision' (which makes passes at compilers) written by James Hacker.

    signature of Ty Coon, 1 April 1989

    Ty Coon, President of Vice

This General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Library General Public License instead of this License.

"CLASSPATH" EXCEPTION TO THE GPL

Certain source files distributed by Oracle America and/or its affiliates are subject to the following clarification and special exception to the GPL, but only where Oracle has expressly included in the particular source file's header

```
the words "Oracle designates this particular file as subject to the
"Classpath"
exception as provided by Oracle in the LICENSE file that accompanied this
code."

    Linking this library statically or dynamically with other modules is
making
    a combined work based on this library.  Thus, the terms and conditions
of
    the GNU General Public License cover the whole combination.

    As a special exception, the copyright holders of this library give you
    permission to link this library with independent modules to produce an
    executable, regardless of the license terms of these independent
modules,
    and to copy and distribute the resulting executable under terms of your
    choice, provided that you also meet, for each linked independent
module,
    the terms and conditions of the license of that module.  An independent
    module is a module which is not derived from or based on this library.
If
    you modify this library, you may extend this exception to your version
of
    the library, but you are not obligated to do so.  If you do not wish to
do
    so, delete this exception statement from your version.
```

Link: http://openjdk.java.net/legal/gplv2+ce.html

Node-RED

A visual tool for wiring the Internet of Things.

Project URL: https://github.com/node-red/node-red

Copyright and license:

submitted to Licensor for inclusion in the Work by the copyright owner
or by an individual or Legal Entity authorized to submit on behalf of the copyright owner. For the purposes of this definition, "submitted" means any form of electronic, verbal, or written communication sent to the Licensor or its representatives, including but not limited to communication on electronic mailing lists, source code control systems,
and issue tracking systems that are managed by, or on behalf of, the Licensor for the purpose of discussing and improving the Work, but excluding communication that is conspicuously marked or otherwise designated in writing by the copyright owner as "Not a Contribution."

"Contributor" shall mean Licensor and any individual or Legal Entity on behalf of whom a Contribution has been received by Licensor and subsequently incorporated within the Work.

2. Grant of Copyright License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form.

3. Grant of Patent License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable (except as stated in this section) patent license to make, have made, use, offer to sell, sell, import, and otherwise transfer the Work, where such license applies only to those patent claims licensable by such Contributor that are necessarily infringed by their Contribution(s) alone or by combination of their Contribution(s) with the Work to which such Contribution(s) was submitted. If You institute patent litigation against any entity (including a cross-claim or counterclaim in a lawsuit) alleging that the Work or a Contribution incorporated within the Work constitutes direct or contributory patent infringement, then any patent licenses granted to You under this License for that Work shall terminate as of the date such litigation is filed.

4. Redistribution. You may reproduce and distribute copies of the Work or Derivative Works thereof in any medium, with or without modifications, and in Source or Object form, provided that You meet the following conditions:

   (a) You must give any other recipients of the Work or Derivative Works a copy of this License; and

   (b) You must cause any modified files to carry prominent notices stating that You changed the files; and

   (c) You must retain, in the Source form of any Derivative Works that You distribute, all copyright, patent, trademark, and attribution notices from the Source form of the Work, excluding those notices that do not pertain to any part of the Derivative Works; and

   (d) If the Work includes a "NOTICE" text file as part of its distribution, then any Derivative Works that You distribute must include a readable copy of the attribution notices contained within such NOTICE file, excluding those notices that do not pertain to any part of the Derivative Works, in at least one of the following places: within a NOTICE text file distributed as part of the Derivative Works; within the Source form or documentation, if provided along with the Derivative Works; or, within a display generated by the Derivative Works, if and wherever such third-party notices normally appear. The contents of the NOTICE file are for informational purposes only and do not modify the License. You may add Your own attribution notices within Derivative Works that You distribute, alongside or as an addendum to the NOTICE text from the Work, provided that such additional attribution notices cannot be construed as modifying the License.

You may add Your own copyright statement to Your modifications and may provide additional or different license terms and conditions for use, reproduction, or distribution of Your modifications, or for any such Derivative Works as a whole, provided Your use, reproduction, and distribution of the Work otherwise complies with the conditions stated in this License.

5. Submission of Contributions. Unless You explicitly state otherwise, any Contribution intentionally submitted for inclusion in the Work by You to the Licensor shall be under the terms and conditions of this License, without any additional terms or conditions. Notwithstanding the above, nothing herein shall supersede or modify the terms of any separate license agreement you may have executed with Licensor regarding such Contributions.

6. Trademarks. This License does not grant permission to use the trade names, trademarks, service marks, or product names of the Licensor, except as required for reasonable and customary use in describing the origin of the Work and reproducing the content of the NOTICE file.

7. Disclaimer of Warranty. Unless required by applicable law or agreed to in writing, Licensor provides the Work (and each Contributor provides its Contributions) on an "AS IS" BASIS, WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied, including, without limitation, any warranties or conditions of TITLE, NON-INFRINGEMENT, MERCHANTABILITY, or FITNESS FOR A PARTICULAR PURPOSE. You are solely responsible for determining the appropriateness of using or redistributing the Work and assume any risks associated with Your exercise of permissions under this License.

8. Limitation of Liability. In no event and under no legal theory, whether in tort (including negligence), contract, or otherwise, unless required by applicable law (such as deliberate and grossly negligent acts) or agreed to in writing, shall any Contributor be liable to You for damages, including any direct, indirect, special, incidental, or consequential damages of any character arising as a result of this License or out of the use or inability to use the Work (including but not limited to damages for loss of goodwill, work stoppage, computer failure or malfunction, or any and all other commercial damages or losses), even if such Contributor has been advised of the possibility of such damages.

9. Accepting Warranty or Additional Liability. While redistributing the Work or Derivative Works thereof, You may choose to offer, and charge a fee for, acceptance of support, warranty, indemnity, or other liability obligations and/or rights consistent with this License. However, in accepting such obligations, You may act only

```
   on Your own behalf and on Your sole responsibility, not on behalf
   of any other Contributor, and only if You agree to indemnify,
   defend, and hold each Contributor harmless for any liability
   incurred by, or claims asserted against, such Contributor by reason
   of your accepting any such warranty or additional liability.

END OF TERMS AND CONDITIONS
```

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/

Copyright and license:

and issue tracking systems that are managed by, or on behalf of, the Licensor for the purpose of discussing and improving the Work, but excluding communication that is conspicuously marked or otherwise designated in writing by the copyright owner as "Not a Contribution."

"Contributor" shall mean Licensor and any individual or Legal Entity on behalf of whom a Contribution has been received by Licensor and subsequently incorporated within the Work.

2. Grant of Copyright License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable copyright license to reproduce, prepare Derivative Works of, publicly display, publicly perform, sublicense, and distribute the Work and such Derivative Works in Source or Object form.

3. Grant of Patent License. Subject to the terms and conditions of this License, each Contributor hereby grants to You a perpetual, worldwide, non-exclusive, no-charge, royalty-free, irrevocable (except as stated in this section) patent license to make, have made, use, offer to sell, sell, import, and otherwise transfer the Work, where such license applies only to those patent claims licensable by such Contributor that are necessarily infringed by their Contribution(s) alone or by combination of their Contribution(s) with the Work to which such Contribution(s) was submitted. If You institute patent litigation against any entity (including a cross-claim or counterclaim in a lawsuit) alleging that the Work or a Contribution incorporated within the Work constitutes direct or contributory patent infringement, then any patent licenses granted to You under this License for that Work shall terminate as of the date such litigation is filed.

4. Redistribution. You may reproduce and distribute copies of the Work or Derivative Works thereof in any medium, with or without modifications, and in Source or Object form, provided that You meet the following conditions:

   (a) You must give any other recipients of the Work or Derivative Works a copy of this License; and

   (b) You must cause any modified files to carry prominent notices stating that You changed the files; and

   (c) You must retain, in the Source form of any Derivative Works that You distribute, all copyright, patent, trademark, and attribution notices from the Source form of the Work, excluding those notices that do not pertain to any part of the Derivative Works; and

   (d) If the Work includes a "NOTICE" text file as part of its distribution, then any Derivative Works that You distribute must include a readable copy of the attribution notices contained within such NOTICE file, excluding those notices that do not pertain to any part of the Derivative Works, in at least one of the following places: within a NOTICE text file distributed as part of the Derivative Works; within the Source form or documentation, if provided along with the Derivative Works; or, within a display generated by the Derivative Works, if and wherever such third-party notices normally appear. The contents of the NOTICE file are for informational purposes only and do not modify the License. You may add Your own attribution notices within Derivative Works that You distribute, alongside or as an addendum to the NOTICE text from the Work, provided that such additional attribution notices cannot be construed as modifying the License.

   You may add Your own copyright statement to Your modifications and may provide additional or different license terms and conditions

```
   for use, reproduction, or distribution of Your modifications, or
   for any such Derivative Works as a whole, provided Your use,
   reproduction, and distribution of the Work otherwise complies with
   the conditions stated in this License.

5. Submission of Contributions. Unless You explicitly state otherwise,
   any Contribution intentionally submitted for inclusion in the Work
   by You to the Licensor shall be under the terms and conditions of
   this License, without any additional terms or conditions.
   Notwithstanding the above, nothing herein shall supersede or modify
   the terms of any separate license agreement you may have executed
   with Licensor regarding such Contributions.

6. Trademarks. This License does not grant permission to use the trade
   names, trademarks, service marks, or product names of the Licensor,
   except as required for reasonable and customary use in describing the
   origin of the Work and reproducing the content of the NOTICE file.

7. Disclaimer of Warranty. Unless required by applicable law or
   agreed to in writing, Licensor provides the Work (and each
   Contributor provides its Contributions) on an "AS IS" BASIS,
   WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or
   implied, including, without limitation, any warranties or conditions
   of TITLE, NON-INFRINGEMENT, MERCHANTABILITY, or FITNESS FOR A
   PARTICULAR PURPOSE. You are solely responsible for determining the
   appropriateness of using or redistributing the Work and assume any
   risks associated with Your exercise of permissions under this License.

8. Limitation of Liability. In no event and under no legal theory,
   whether in tort (including negligence), contract, or otherwise,
   unless required by applicable law (such as deliberate and grossly
   negligent acts) or agreed to in writing, shall any Contributor be
   liable to You for damages, including any direct, indirect, special,
   incidental, or consequential damages of any character arising as a
   result of this License or out of the use or inability to use the
   Work (including but not limited to damages for loss of goodwill,
   work stoppage, computer failure or malfunction, or any and all
   other commercial damages or losses), even if such Contributor
   has been advised of the possibility of such damages.

9. Accepting Warranty or Additional Liability. While redistributing
   the Work or Derivative Works thereof, You may choose to offer,
   and charge a fee for, acceptance of support, warranty, indemnity,
   or other liability obligations and/or rights consistent with this
   License. However, in accepting such obligations, You may act only
   on Your own behalf and on Your sole responsibility, not on behalf
   of any other Contributor, and only if You agree to indemnify,
   defend, and hold each Contributor harmless for any liability
   incurred by, or claims asserted against, such Contributor by reason
   of your accepting any such warranty or additional liability.

END OF TERMS AND CONDITIONS

Copyright 2013-2017 Docker, Inc.

Licensed under the Apache License, Version 2.0 (the "License");
you may not use this file except in compliance with the License.
You may obtain a copy of the License at

    https://www.apache.org/licenses/LICENSE-2.0

Unless required by applicable law or agreed to in writing, software
distributed under the License is distributed on an "AS IS" BASIS,
WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
See the License for the specific language governing permissions and
limitations under the License.
```

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*	....

SYS TEC
ELECTRONIC GmbH
Am Windrad 2
D-08468 Heinsdorfergrund
Tel.: 03765 38600-0 / Fax: 38600-4100
info@systec-electronic.com
www.systec-electronic.com

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.
type, article no.

16061001, Rev.1

die Anforderungen der EU-Richtlinie 2011/65/EU entsprechend erfüllt. Dieses Produkt erfüllt die derzeitigen Anforderungen der RoHS Direktive für alle 7 benannten Materialien (max. 0,1% des Gewichtes in homogenem Material für Blei, Quecksilber, sechswertiges
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:
and therefore, corresponds to the EU-directive:

RoHs-Richtlinie 2011/65/EU
RoHs-Directive 2011/65/EU

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*	

SYS TEC
ELECTRONIC GmbH
Am Windrad 2
D-08468 Heinsdorfergrund
Tel.: 03765 38600-0 / Fax: 38600-4100
info@systec-electronic.com
www.systec-electronic.com

Index

/

/home/plc/bin/ctr-700.cfg 33
/home/plc/plcdata/PlcPData.bin....................98
/tmp..44

A

Administration
  System Requirements...............................27
Autostart 67
AWL 13

B

Bitrate 34

C

CAN0 ....70, 74
CAN0, CAN1...26
CAN1 ....70, 74
  Network variables 69
  PLC program example 77
CANopen 13, 72
CANopen IO modules..................................12
CANopen Master 12
CE conformity 6
CFG File 34
Communication interfaces
  CAN..26, 70
  ETH...70
  Ethernet...26
ConfigCAN1...77
Configuration
  PLC 32
Configuration Mode 29
Control Elements
  Error-LED..72
  Run/Stop switch 71
  Run-LED 71
Counter input 70
ctr-700.cfg..33, 34, 46

D

Deletion of PLC Program..............................72
DHCP Configuration 30
DI0 … DI15..19
Digital inputs 19
Digital outputs 21
Dimensions 12
disk free 44
DO0 … DO15 21

E

Environmental Parameters 99
Error-LED 72
ETH0 .... 26, 70
  PLC program example 70
ETH1 26

F

FUB 13

G

GNU GPL 13, 102

K

KOP.. 13

L

limiting values 101
Linux... 13

M

Manuals
  Overview 7
Master Mode 34

N

Node Address 34

O

OpenPCS 13

P

P0 and P1 21
passwd 42
Pin assignment 15
Pinout 15
PLC program example
  CAN1 77
  ETH0 70
PlcPData.bin 98
Power Supply 18, 99
Predefined User Accounts 38
Process Image
  Layout and Addressing 68
Programming 67
Pulse outputs 21, 71

R

ReadSectorTable 79
REL0 and REL1 22

Relay outputs....22
Run/Stop switch....71
Run-LED....71

S

Serial 0....69
Serial 1....69
Serial 2....69
Service....24, 69
  Node-RED....37
  OPC UA....37
  OpenPCS....37
Service configuration
  Extended shell script....37
  System service....37
Setting the System Time....42
Setting Time Zone....42
SFTP
  Login to the CTR-700....40
SFTP Client....27
Shared Process Image
  Activation....79
  API Description....82
  Example....87
  Overview....78
  signaling....82
  Variable Pairs....80
ShPImgClntGetDataSect....84
ShPImgClntGetHeader....84
ShPImgClntLockSegment....84
ShPImgClntRelease....83
ShPImgClntSetNewDataSigHandler....83
ShPImgClntSetup....83
ShPImgClntSetupReadSectTable....84
ShPImgClntSetupWriteSectTable....85
ShPImgClntUnlockSegment....84
ShPImgClntWriteSectMarkNewData....85
shpimgdemo....86
shpimgdemo.tar.gz....86
Software Update
  PLC Firmware....44
SSH Client....27
ST....13
Static IP Configuration....30
System Start....67
sysWORXX Automation Series....12

T

Technical Specifications....101
Terminal Configuration....28
Terminal Program....27
timedatectl....42
tShPImgLayoutDscrpt....82
tShPImgSectDscrp....82

U

U-Boot Command Prompt
  Activation....28, 29
UdpRemoteCtrl....70
User Accounts
  Adding and deleting....41
  Changing Passwords....42
  Predefined....38
useradd....41
userdel....42

W

WEB-Frontend....32
WinSCP....40
WriteSectorTable....79

X

X10....24, 69
X15....69
X16....69
X17....69

Document:	System Manual sysWORXX CTR-700
Document number:	L-2137e_02, 2nd Edition August 2018

How would you improve this manual?

Did you detect any mistakes in this manual? Page

Submitted by:

Customer number:

Name:

Company:

Address:

Please return your suggestions to:

SYS TEC electronic AG
Am Windrad 2
D - 08468 Heinsdorfergrund
GERMANY
Fax : +49 (0) 37 65 / 38600 - 4100
Email: info@systec-electronic.com