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Bachelor's thesis

Light Column System

May 2021

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of ICT and Natural Sciences

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Kunnskap for en bedre verden

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IE303612 - Bachelor Thesis

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Summary: This thesis concerns research and development of a Light Column System (LCS) for Vard Electro AS. The LCS is a clustered audio and optical notification system for alarms on vessels. The project consists of design and developing a prototype Light Column Unit (LCU), and show the concept of the system. The system include redundant communication between LCUs, displaying visual alarm symbols and siren tones. A configuration interface is developed for configuring the system in the field and troubleshooting. Based on given design criteria, the project is successful.

This thesis is written by students at NTNU in Ålesund.

Preface

The assignment is to research and develop a Light Column System for the company Vard Electro AS. This assignment includes several topics the group have learned during all of the courses the last three years. This includes PLC programming, micro controllers and electrical aspects. The group found it interesting to develop a new product that can help the company develop a complete system that can be used on vessels in the future.

This report is written for the Bachelor Thesis from the study Automatisering-steknikk (Automation Engineering) at NTNU in Ålesund. The project was started January 2021 and finished in May 2021. The group consists of three students, where two of the group members has certificate of apprenticeship as electrician from Vard Electro AS.

A demonstration video was created, that shows the most important aspects of the system. The video can be found here.

Acknowledgement

During the project, there have been a lot of contributors that have helped with different subjects. We would like to thank:

- Main supervisor Kai Erik Hoff at NTNU for guidance during the project.
- Supervisor Ottar Laurits Osen at NTNU for guidance during the project.
- Vard Electro AS who provided the assignment. Vard Electro AS have also helped with different subjects and problems.
- Anders Sætersmoen at NTNU who have provided a lot of components from the labs and ordered components if needed.
- Torgeir Sundet, Kristian Syversen and Håkon Skaug Ingebritsen from WAGO Support Norway for very good support with PLC, Modbus and communication.
- Fellow students for many helpful discussions through the project.

Summary

This thesis concerns research and development of a Light Column System (LCS) for Vard Electro AS. The LCS is a clustered audio and optical notification system for alarms on vessels, and are placed in noisy areas of the vessel to notify the crew if anything needs attention. The project consists of research, design and development of a prototype Light Column Unit (LCU), and show the concept of the system. The system include redundant communication between LCUs, displaying visual alarm symbols and siren tones. A configuration interface is developed for configuring the system in the field and troubleshooting.

The thesis includes the methods and results used to achieve a reliable LCS, that is scalable and easy to install and configure. The system is reliable with a redundant master/slave architecture of the PLCs, which are the main controllers of each LCU. The installation and configuration of the LCS is simplified by the development of a 'one-box-for-all' solution. There are no external components other than the LCUs and the Ethernet network. The optical indication of alarms is reinvented using LED modules to display alarm symbols and a warning light to indicate alarms.

The project achieved all of the critical criteria according to the design criteria given by Vard Electro. There are still improvements for both software and hardware that can be done for making the system complete for usage on vessels.

Contents

Terminology

Abbreviations

AOS - Audio and Optical notification System
FBD - Function Block Diagram
IAS - Integrated Automation System
IDE - Integrated Development Environment
IL - Instruction List
IMO - International Maritime Organization
I/O - Input / Output
IP - Internet Protocol
LCS - Light Column System
LCU - Light Column Unit
LD - Ladder Diagram
LED - Light-emitting Diode
MCU - Microcontroller Unit
PLC - Programmable Logical Controller
SFC - Sequential Function Chart
SRtP - Safe Return to Port
ST - Structured Text
TCP - Transmission Control Protocol
UDP - User Datagram Protocol

Notations

dB - Desibel
Hz - Hertz
ms - Milliseconds
M - Mega
s - Seconds
V - Volt
VAC - Volt Alternating Current
VDC - Volt Direct Current
Struct - Structure

Terms

Modbus - Communication protocol for PLCs
IP-rating - Ingress Protection Rating
Structure - A set of variables in Structured Text
Query - Block with information and data

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1 Introduction

1.1 Project Description

Vessels are normally equipped with a Audio and Optical notification System (AOS) to indicate/notify the crew in noisy areas of the vessel if anything needs attention. This could be fire alarm, engine alarm, man overboard alarm etc. The AOS is regulated by purpose of the ship, class and governmental rules. These different AOS alarms can be installed separately and serving only one purpose (one AOS pr. system), or it can be clustered together and programmed by logic to serve multiple purposes, light column system (LCS). (Appendix: B)

The objective of the project is to develop a new LCS with design criteria given by Vard Electro AS.

1.2 Today's System

Vard Electro AS are using both methods of the AOS. However, the LCS used are not scalable or configurable for the installer or operator. This creates a change order or an update that is very difficult to execute.

Normal installation and configuration contain:

- Light for each main system accord to class rules
- Siren with dB level above ambient noise level
- Air typhoon with magnetic valve

1.3 New Design Criteria

Vard Electros design criteria for the project. The criteria are listed below.

- Standard full design with X numbers of lights and X number of sirens according to rules and regulations.
- Simplified change in design/number of parts, program to recognize the removed/added part and inhibit the output and available selection in configurator.
- Simplified installation of system - system to use an Ethernet network (System LAN) for linking the LCUs.
- Master and Slave architecture, with one LCU acting as Master, one as Redundant Master, and the rest as Slaves.
- No external system components except the LCUs them self.
- One-box-for-all solution - All LCUs to be same hardware, but have different roles (Master/Slaves).
- PLC and relay must be of WAGO type.
- Program must be of Codesys.
- Alarm output to Vessel alarm system (IAS) (broken relay output/power failure/ PLC error).
- Scalable with more relay stack's.

(Appendix: B)

1.4 Vard Electro AS

Vard Electro AS is a leading system integrator and supplier for electrical systems for vessels. They are a part of VARD Group. The main office is located in Tennfjord, Møre og Romsdal in Norway and have around 900 employees globally. The products delivered from Vard Electro AS contains automation systems, bridge systems, electrical systems, propulsion, diesel-electrical systems and NavCom packs. They do also deliver services such as installation, engineering and service on board. Since the year 2000, Vard Electro AS have delivered systems to over 400 vessels.

1.5 Report content

The sections below is the main structure for how the report is written.

1 Introduction	-	Introduction for the report, design criteria and Vard Electro AS.
2 Theoretical Basis	-	Theory behind different aspects of the system.
3 Materials	-	Complete list of materials that are used for building the system, including software and libraries used in the development.
4 Method	-	Methods that is used for developing the project.
5 Results	-	The results of the system, including tests.
6 Discussion	-	Discussion of results and solutions, including group experiences.
7 Conclusion	-	Conclusion of how the project went.

2 Theoretical Basis

In the following sub-sections the theoretical basis behind all decisions and solutions will be explained.

2.1 Programmable Logic Controller

A Programmable Logic Controller (PLC) is an industrial computer controller system that continuously monitors the state of input devices and makes decisions based upon a custom program to to control the state of output devices.

2.1.1 IEC 61131-3

IEC 61131 is an International standard for PLC. It consist of 5 parts, where part 3 dealt with programming languages. The IEC 61131-3 standard, which is now more or less followed by most major manufacturers, comprises 5 different programming languages: [13]:

- Structured Text - ST
- Function Block Diagram - FDB
- Ladder Diagram - LD
- Instruction List - IL
- Sequential Function Chart - SFC

2.1.2 WAGO WebVisu

WAGO WebVisu is a web-based visualization client that is created in e!Cockpit programming environment. This makes it easy to access WAGO PLCs with a remote computer and be able to control or monitor the PLC systems in the field.

2.1.3 Persistent Variables

Persistent Variables are variables stored in the memory of the PLC. With this mechanism, the variable retains the value even after cold reset, warm reset or even a power failure.

2.2 LED Module

A LED module display module is a large, low-resolution form of dot-matrix display whose values are determined by the current inputs.

The LED module display is comprised of LED chips, shift registers. Each color of each LED is driven by one bit of a shift register and all of the shift registers are then daisy-chained together.

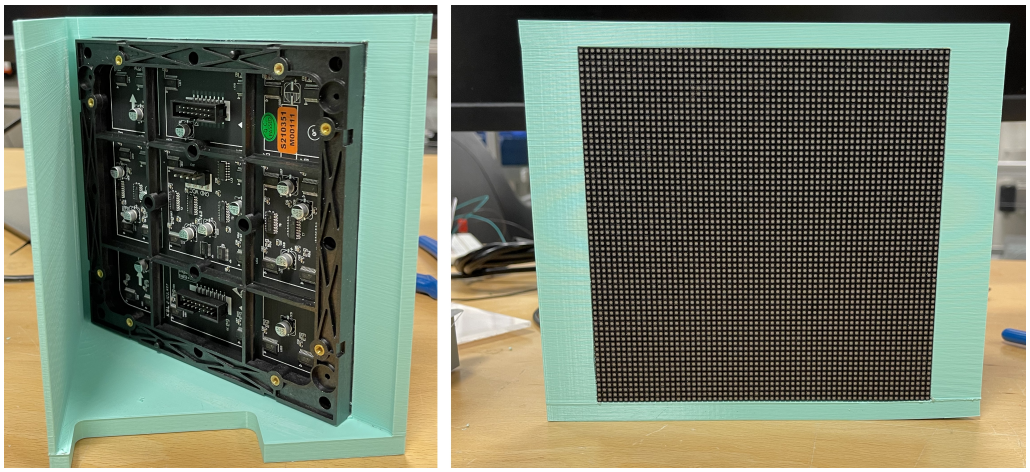


Figure 1: 64x64 RGB LED module

2.2.1 Shift register

Shift Register is a group of flip flops used to store bits of data. The bits stored in shift registers can move within the registers and in/out of the registers with the help of a clock pulse signal [24].

To drive LED modules all of the bits for the LEDs gets clocked in high or low bits for the red, green, and blue LEDs individually.

2.2.2 HUB75 interface

HUB75 interface connector that is most common for interfacing RGB LED modules. It is a 16 pin connection that sends pixel data from the LED module driver to the LED modules [15].

2.2.3 RGB565 Matrix

RGB565 specifies the color depth of the image, 2 bytes or 16 bits per pixel. See Figure 2.

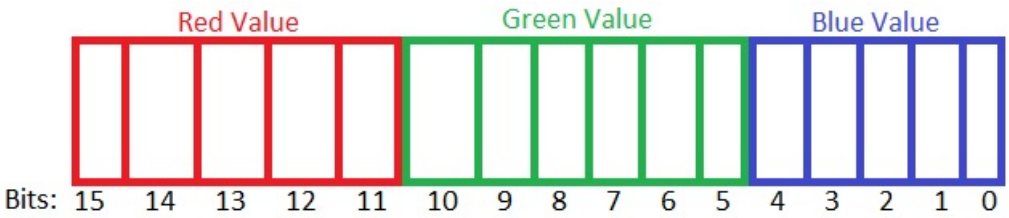


Figure 2: RGB565 Bit Values

2.3 Maritime Safety

Important maritime safety protocols that are taken into account in the project will be described below.

2.3.1 SOLAS

SOLAS (Safety of Life at Sea) is an international maritime security agreement by UNs maritime department and is a convention of IMO (International Maritime Organisation). The SOLAS agreement is contains different chapters of how things should be done at sea to achieve the highest possible security. [43]

2.3.2 IMO-Vega

The IMO-VEGA database jointly developed by IMO and DNV-GL is an indispensable database of IMO instruments including IMDG CODE, SOLAS, MARPOL, IAMSAR and Colregs. It also incorporates essential historical data. Vega is essential tool for everyone working with vessels, providing all the key information applicable to individual needs in one place. [14]

2.3.3 SRtP

Safe Return to Port refers to SOLAS regulations that became effective July 2012. SRtP have become a criteria for every vessel that have a total length of minimum 120 meters, have three or more vertical zones or have the capacity to held more than 240 people. [18]

2.3.4 IAS

The integrated automation system is a system used in vessels. The system is redundant and provides secure and fast communication between devices. The IAS integrates the functions of control, monitoring and alarming of all automation systems on the ship. [17]

2.3.5 Main Vertical Zones

Ships being built today are divided into vertical zones. This is for safety measures to reduce the risk of danger spreading to other parts of the ship. With partitions and fireproof doors, they isolate the danger and reduce the extent of damage to a single zone. Zones with critical systems are designed redundant and can in the event of an emergency look at the zone as lost without any further consequences for the ship's functionality [5]

2.4 Redundancy

Redundancy is a concept that consists of duplication of critical devices in a system. This is a criteria in a lot of industrial systems, even alarm systems. If a critical device fails, for example losing power or connection, an identical standby device will take over the control and ensure that the system does not shut down. In most cases, a redundant device will only have the control when the main device is down. This means that when the main device is up and running again, the redundant device does not control the system any more. [45]

2.4.1 PLC redundancy

PLC redundancy systems can be configured as warm standby or hot standby configuration. [32]

2.4.1.1 Warm Standby

Warm redundancy is a standard used when time and response is not critical for the system, but it's important. In this standard the main processor and the second processor runs an identical software where they are sharing a heartbeat signal. When the heartbeat signal stops for a certain amount of time, the secondary processor may take control for the system until the main processor is up and running again. With warm redundancy, the system can tolerate seconds or some minutes of interruption as long as the system can operate as usual automatically.

2.4.1.2 Hot Standby

Hot redundancy is a standard used when time and response is critical for the system. Both processors runs their program and scans synchronized. When one processor fail, the other one will take control immediately.

2.4.2 Network redundancy

Redundancy in networks helps to eliminate single points of failure to ensure better network stability and uptime in the face of events that would otherwise take the network offline. A reliable network is crucial on board vessels.

2.5 Network architecture

Networks can mainly be divided into two types, campus network and ring network. They both are explained below.

2.5.1 Campus network

A campus network is a network architecture that is set up in multiple layers. The first and lowest layer are often computers or end users. Layer number two do often contain edge switches, which is smaller switches. The next layer are often bigger switches or routers. In these layers, the switches are cores of the entire network. The number of layers in a campus network varies of the size of the network. Figure 3 shows an example of a campus network.

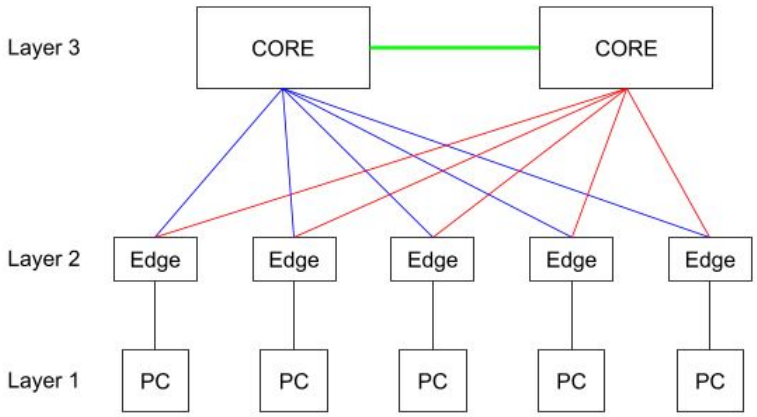


Figure 3: Example of a campus network

2.5.2 Ring network

A ring network is a network architecture where all of the nodes in the network a coupled in one ring or loop. This means that one node is connected to the next, which is connected to the next again. This goes all the way to the last node is connected to the first node. Figure 4 shows an example of a ring network.

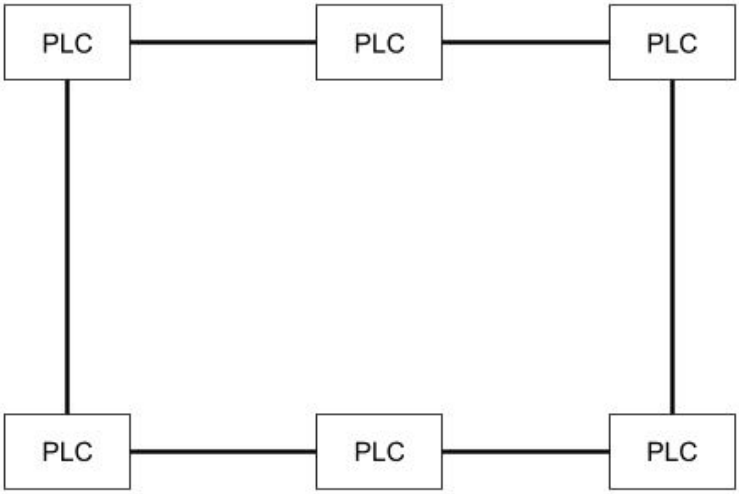


Figure 4: Example of a ring network

2.6 Communication Protocols

The communication protocols is used for sending bits between computers and PLC. Below, it is explained two communication protocols which is used for the LCS.

2.6.1 TCP/IP

TCP is a communication standard that defines how to create and maintain network communication between application that provides the ability to exchange data. It is based on IP, which is a protocol that describes how data packets is being sent between network devices. The advantage with TCP/IP is that it provides reliable data transfer because the receiver confirms that the data is received. This makes it possible to send a big amount of data without loosing packets during the sending.

2.6.2 Modbus TCP

Modbus TCP is a communication protocol developed for PLCs. It is Ethernet based, which means is uses Ethernet as transport layer. Modbus TCP is a master/slave protocol where the master node must poll the other devices, or slaves, continuously. The data sent between Modbus TCP devices as four different object types:

- Coils - 1 bit, read-write
- Discrete inputs - 1 bit, read-only
- Input registers - 16 bit, read-only
- Holding registers - 16 bit, read-write

Modbus data is sent from the master to slaves as queries with information. The slaves do automatically respond.

2.6.2.1 Query

A query is a request for information. In the Modbus communication, the query contains an ID for the slave, a function code (read, write, read-only etc.) and data.

2.7 Master/Slave Architecture

A Modbus TCP system consists of a master/slave architecture. The figure 5 shows an image of how a network with a master, redundant master and slaves can look like. Below the figure, the different roles are described.

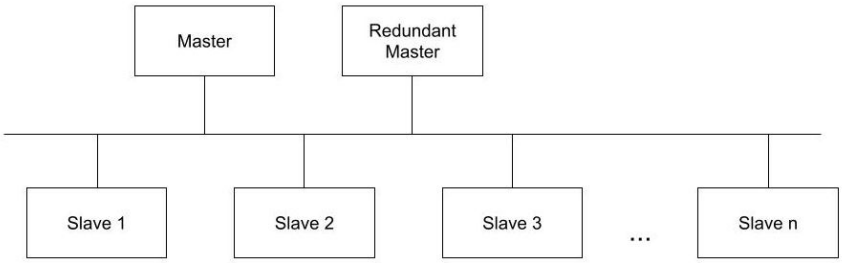


Figure 5: Example Modbus TCP architecture

2.7.1 Master

The master PLC controls the slave PLCs. A master PLC can control one or multiple slaves. The master sends a query to the slaves with information for what the slave should do.

2.7.2 Redundant Master

A redundant master operates as a slave until it looses connection to the master PLC, when the redundant master don't get information from the master it will switch mode to and operate as a master. This is to make the system more reliable, so that the system can still run if the main master disconnects.

2.7.3 Slave

A slave is listening for requests from the master. The slaves does not send any requests to the master or any other slave. Each slave has its own IP-address, responding to the master only when addressed by the master.

2.8 Programming language

The programming language used to solve this project is described below.

2.8.1 Structured Text

Structured text is a text-based programming language. It makes the language easy to read and several operations can be executed with a simple command line. Structured text makes it easy to program with logical expressions and is therefore very suitable for PLC [13].

2.8.2 Arduino (C++)

Arduino C++ is the programming language used in the Arduino IDE. This programming language is a framework built on top of the language C++. This programming language is a general-purpose programming language which can be used for a lot of microcontrollers.

3 Materials

This section of the report contains a list and information for the most critical components used in the project. It does also contains the software, libraries and other tools that have been used for developing the LCS.

3.1 List of Materials

A list of materials used in the project can be seen in Table 1. The list shows all critical materials that has been used during the project. Items which has been tested, but not used in the final product is exempted from the list.

No.	Component	Details/Specifications	Quantity
1	WAGO PLC	750-8100 PFC100	4
2	WAGO 16 Channel Input Module	750-1405	4
3	WAGO 8 Channel Output Module	750-530	8
4	WAGO 24 VDC Module	750-602	4
5	WAGO End Module	750-600	4
6	WAGO Power supply	787-602	4
7	Power supply	DR-60-5	1
8	Siren	VTB-32E Sounder/beacon	1
9	MCU	ESP-32	1
10	P2. 5-160*160MM- INDOOR	LED module	2
11	Base unit + cover for modular tower lights	Base	1
12	Illuminated unit for modular tower lights	Green	1
13	Illuminated unit for modular tower lights	Yellow	1
14	Illuminated unit for modular tower lights	Red	1
15	Cabinet	RS PRO Steel Wall Box	1
16	Relays	Phoenix PLC-BSC-24DC/21	6
17	WAGO 3-conductor through terminal block	Terminal Through Block	18
18	WAGO 4-conductor ground terminal block	Terminal Ground Block	2

Table 1: Material list

3.2 Programmableogic Controller

The PLCs used in the project is of the type WAGO 750-8100. This is a PLC from the PFC100 series and is a compact PLC for the modular WAGO I/O System. The PLC can be seen in Figure 6.

Figure 6: WAGO 750-8100 PLC [34]

3.3 WAGO Modules

The PLC need different types of modules for using inputs and outputs. It is also necessary to use power supply modules and end modules. The modules which is used in this project can be seen below.

3.3.1 Input Module

The WAGO 750-1405 module is an 16-channel digital input module. The WAGO 750-1405 module can be seen in Figure 7.

Figure 7: WAGO 750-1405 16-channel Input Module [35]

3.3.2 Output Module

The WAGO 750-530 module is an 8-channel digital output module. The WAGO 750-530 module can be seen in Figure 8.

Figure 8: WAGO 750-530 16-channel Output Module [36]

3.3.3 Power Supply Module

The WAGO 750-602 is an 24VDC Module which is needed for powering the I/O-modules. The WAGO 750-602 module can be seen in Figure 9.

Figure 9: WAGO 750-602 24VDC Power Supply Module [38]

3.3.4 End Module

The WAGO 750-600 module is an end module which ensures correct data flow and completes the internal data circuit. The WAGO 750-600 module can be seen in Figure 10.

Figure 10: WAGO 750-600 End Module [37]

3.4 Power Supply

The following power supplies were used in the project. The WAGO 787-602 and WAGO 787-1002 is used for the PLCs, and the MW DR 60-5 power supply is used for powering the LED modules and the MCU. NTNU provided all of the power supplies used in the project.

3.4.1 WAGO 787-602

A 24 VDC switched-mode Power Supply used for powering the PLCs. The WAGO 787-602 power supply can be seen in Figure 11.

Figure 11: WAGO 787-602 Power Supply, Output 24VDC [39]

3.4.2 MW DR 60-5

Power supply used for powering the LED modules. This power supply have 100-240 VAC input and 5V output. The Mean Well DR-60-5 power supply can be seen in Figure 12.

Figure 12: MW DR 60-5 5V Power Supply [42]

3.5 Switch

The switch that is used in the project is a D-Link switch. This switch have 5 ports. Figure 13 shows an image of the switch used in the project.

Figure 13: Switch [9]

3.6 Siren

The siren used in the project is a VTB-32E Sounder/Beacon. This is a siren with the support of continuous or varying sound. The siren is provided from Vard Electro. The used siren can be seen in the Figure 14.

Figure 14: Siren [11]

3.7 Microcontroller Unit

The MCU in the LCUs are used for driving the LED modules. The used MCU is seen below. The ESP32 32D is a MCU which have support for WiFi and Bluetooth. This is a fast MCU and has a CPU clock frequency up to 240MHz. NTNU have provided the ESP-32. The used MCU can be seen in Figure 15.

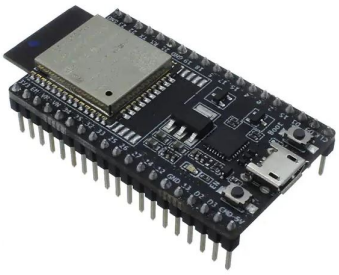


Figure 15: ESP32 [6]

3.8 LED Module

A LED module which consists of 64x64 LEDs. In the project, this LED module is used to indicate all the alarm symbols that is needed, this includes twelve different symbols. The P2.5-160*160MM LED module can be seen in Figure 16.

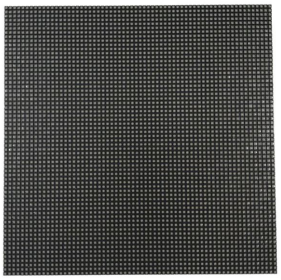


Figure 16: LED module [2]

3.9 Warning Light

It is used a warning light on top of the LCU to indicate the types of alarms that is active. The Warning light is built out of four different pieces. One base unit and 3 color units which is green, yellow and red.

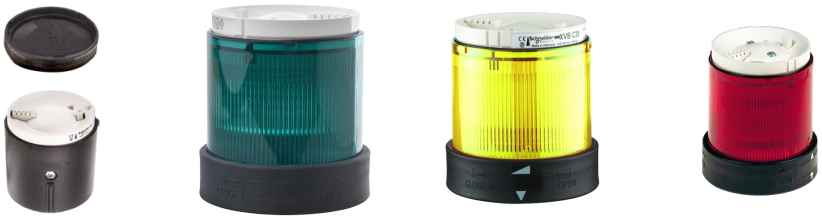


Figure 17: Base [26], Green Light[27], Yellow Light[29], Red Light [28]

3.10 Cabinet

The cabinet is of the type RS PRO Steel Wall Box. This is a cabinet that have the IP-rating of IP66, which fulfills the criteria for the capsule according to the DNV-GL IP-Rating table from the offshore standard for electrical installations, chapter 2 section 10. (Attachment: G) [7]. The cabinet have a size of 500mm x 400mm x 150mm. The used cabinet can be seen in Figure 18.

Figure 18: Cabinet [19]

3.11 Relay

A 6.2 mm PLC interface relay module designed to be mountable on DIN rail NS 35/7.5. Featuring a basic terminal block with screw connection and a plug-in miniature power relay [16].

Figure 19: Relay [16]

3.12 Terminal blocks

3.12.1 Terminal Through Block

The 3-conductor Terminal Through Block is used to connect multiple wires and can house different sizes up to 2,5mm^2. This terminal is used to set on a DIN-rail. This Terminal Block is equipped with a "cage clap" which is to easily connect wires. Figure 20 shows a image of a Terminal Through Block.

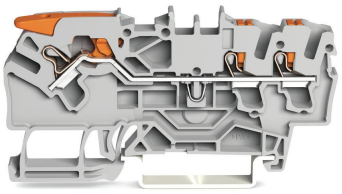


Figure 20: Terminal Through Block [41]

3.12.2 Terminal Ground Block

The 4-conductor Terminal Ground Block is used to connect multiple grounding wires and can house different sizes up to 2,5mm^2. This terminal is used to set on a DIN-rail. The color is yellow and green which indicates that it is used for grounding. Figure 21 shows a image of a Terminal Ground Block.

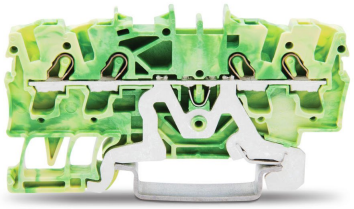


Figure 21: Terminal Ground Block [40]

3.13 Tools

During the project, the group had to use different tools for developing the physical system.

3D-printer
It was used a Prusa MK3s 3D-printer for printing enclosure for the LED modules and mounting for warning light.

Laser Cutter
A laser cutter from the labs at NTNU was used to cut Plexiglas that are mounted in front of and to protect the LED modules.

Oscilloscope
When the MCU signals was not appropriate, it was used a oscilloscope. The use of a oscilloscope makes it easier to troubleshoot signal.

Multimeter
A multimeter was used for testing electrical components and circuits.

3.14 Software and software libraries

Below is a list of different software and libraries used during the project.

3.14.1 Software

Overleaf - Overleaf is a free web-based tool for writing LaTeX. With Overleaf it is possible to add text, pictures, tables etc. and make stylish documents. It do also have cloud storage which makes it easy for the project group to write in real-time [22].

Figure 22: Overleaf

Arduino IDE - The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. This software can be used with any Arduino board [3].

Figure 23: Arduino

e!Cockpit - e!Cockpit is WAGOs own software for developing WAGO systems. It is based on CODESYS 3. e!Cockpit do also have support for making visualization.

Figure 24: e!Cockpit

WAGO Ethernet Settings - A software that let the user connect to the PLC with Ethernet or USB for configuring the network settings for the PLC [33].

Figure 25: WAGO Ethernet Settings

Rilheva Modbus Poll - Rilheva Modbus Poll is a free software for checking Modbus TCP- and Serial-communication. With a Slave ID and an IP-address it is easy to connect to a Modbus TCP device for checking registers [25].

Figure 26: Rilheva Modbus Poll

Diagram.net - Free web-based software for drawing diagrams, such as flow charts. Google Drive [12] do have support for diagrams.net which provide cloud storage for diagrams [8].

Figure 27: Diagrams.net

TeamGantt - TeamGantt is an online gantt diagram creation tool meant for easy project scheduling online [31].

Figure 28: TeamGantt

Paint.net - A program for drawing images. Support for multiple layers. Used for drawing 64x64 pixel images for the LED modules [23].

Figure 29: Paint.net

LCD-image-converter - A software that can convert a bitmap image to an array of color bits [30].

Figure 30: LCD-Image-Converter

PC-Schematic Automation - Is a software specially developed for complete documentation of projects in electrical/ automation.

Figure 31: PC Schematic

Autodesk Fusion 360 - Fusion 360 is a cloud-based CAD/CAM tool for collaborative product development [10].

Figure 32: Autodesk Fusion

Prusa Slicer - A software from Prusa which converts a 3D model to a g-code file which can be used for a Prusa 3D-printer.

Figure 33: Prusa Slicer

3.14.2 e!Cockpit Libraries

From the Library Manager in e!Cockpit, is it possible to import libraries which can be used for developing the system. The libraries used in this project is listed below.

WagoAppPlcModbus - A library which can be used for developing communication between PLC with using the Modbus fieldbus. The library have support for ModbusTCP, ModbusUDP and ModbusRTU.

WagoAppConfigTool - A library that contains a lot of configuration features for WAGO PLCs. With this library it is easy to implement time, get IP addresses, set address and a lot of other features.

WagoAppTime - WagoAppTime is a library that contains some functions for time for the PLCs.

WagoAppString - A library that contains a lot of string functions. Example can be a format conversion or a function that finds the length of the string.

Util - A library which contains some useful utilities when programming PLC software.

3.14.3 Arduino Libraries

PxMatrix - A library used to drive LED modules with ESP32 or ESP8266 [1].

4 Method

The method section of the report is about how the group have approached the project, and describes how the group have come up with a solution for the project.

4.1 Project Approach

All of the group members was given different main tasks at the beginning of the project. With every member having the responsibility of different tasks, it is easy to have an overview of the current situation in the project. The appendix E shows how different tasks is distributed to each member. The gantt diagram do also visualize how the group was going to work with the tasks and how long time which is estimated for each task.

Every Friday during the project, it was written a progress report which contained the status for different subjects, problems and further work. This progress reports was sent to the supervisors attached with an updated gantt diagram.

The main tasks for the project is described in the Pre-Project Report (Appendix A). The list below is a list of the main tasks:

- Concept Design
- Physical Visual System
- Network
- Redundancy
- PLC Program
- Physical Audio System
- Prototype
- Configuration Interface

4.2 Approach due to Covid-19

In a period where the coronavirus has radically transformed the lives of masses of people around the world, including students, much of daily life has been effected. Much of the communication has been virtual when working with this project to prevent the spreading of virus. To reduce the spreading of the virus, the group worked a lot from home, where each member had tasks to work with. The communication went thru the application Discord.

Because of the coronavirus outbreak in Norway in March this year, it was introduced a lockdown and restrictions in the municipality which closed the most of the community. The laboratories at the university were still open but was closed at 17:00 each day. With these restrictions, the work with the prototype was held back.

4.3 Alarms

The alarms for the LCS follows IMO-VEGA Code on Alerts and Indicators [21]. Code on Alerts and Indicators specifies how visual and audible presentation of indicators should be in noisy areas of the vessel.

Visual Presentation
For visual presentation of alarms Code on Alerts and Indicators, Section 6.1 to 6.4, specifies:

1. Be clearly visible and distinguishable.
2. Be of color and symbol according to Table 7.1.1 to 7.1.3 in Code on Alerts and Indicators.
3. Instead of individual flashing lights a single flash or rotating white light in addition to a permanent individual indication may be used for light columns.
4. Be of high light intensity.
5. Flashing indicators and calls should be illuminated for at least 50% of the cycle and have a pulse frequency in the range of 0.5 Hz to 1.5 Hz.
6. Visual indicator symbols should be arranged in columns for ready identification from all directions.

Audible Presentation

For audible presentation of alarms Code on Alerts and Indicators, Section 5.1 to 5.11, specifies:

1. In noisy areas of the vessel, it is permitted to install common audible signal devices supplemented by visual indicators identifying the meaning of the audible signal.
2. Audible signals and calls should have characteristics in accordance with Table 7.1.1 to 7.1.3 and 7.2 in Code on Alerts and Indicators.
3. System automatically overrides any other alarm input when an emergency alarm is required.
4. Audible signals should have a signal frequency between 200 Hz and 2500 Hz.

4.3.1 List of Alarms

Figure 34 is an excerpt from Code on Alerts and Indicators Table 7.1.1 Emergency Alarms, Table 7.1.2 Alarms and Table 7.1.3 Call Signals. Since the LCS is made for crew areas and should be installed in noisy areas, it was chosen a certain amount of alarms for this project. The chosen alarms can be seen below or in the Appendix H. The list includes an audible code which describes the tone of each alarm, the tones is described in (Section 4.3.2).

Function	IMO instruments	Audible	Color	Symbol	Remarks
General Emergency Alarm	LSA 7.2.1 SOLAS III/6.4 SOLAS II-2/7.9.4	1.b	Green		Used for summoning the crew to the boat stations.
Fire Alarm	SOLAS II-2/7.9.4 FSS 9.2.5.1	2	Red		Used for summoning the crew to the fire stations on passenger ships.
Fire-extinguishing pre-discharge alarm	FSS 5.2.1.3	2	Red	CO_2	Audible signal distinct from all others.
Machinery Alarm		3	Amber		Horn in machinery space, buzzer elsewhere.
Steering Gear Alarm	SOLAS II-1/29.5.2 II-1/29.8.4 II-1/29.12.2 II-1/30.3	3	Amber		Horn in machinery space, buzzer elsewhere.
Activation of fixed local Application Fire-extinguishing system	SOLAS II-2/10.5.6.4	2	Red		
Telephone	SOLAS II-1/50	3.a	White		
Engine room telegraph	SOLAS II-1/37	2 or 3.a	White		
Water ingress detection main-alarm	SOLAS XII/12.1, 12.2 and II-1/23-3	2	Red		For cargo holds used for water ballast and the ballast tanks, an alarm overriding device may be installed.
Water ingress detection pre-alarm	SOLAS XII/12.1, 12.2 and II-1/23-3	2	Amber		For cargo holds used for water ballast, an alarm overriding device may be installed.
Bilge alarm	SOLAS II-1/48	3	Amber		
Engineers' alarm	SOLAS II-1/38	3	Amber		

Figure 34: List of Alarms according to IMO [21]

4.3.2 Audible alarms

The table below is from Table 7.2 Audible signal and call waveforms from the IMO-VEGA Code on Alerts and Indicators [21]. The table includes the audible code, shows how the waveform is and describes each audible tone.

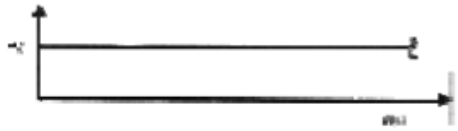
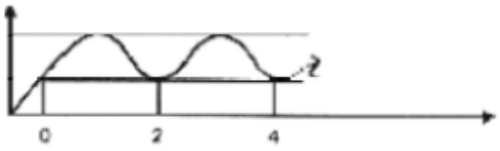
Audible code	Waveform	Remarks
1.a		General emergency alarm.
2		Continuous until silenced or acknowledged.
3.a		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz
3.b		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz
3.c		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz
3.d		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz

Figure 35: List of Siren Tones according to IMO [21]

4.4 Redundancy

The purpose of redundancy is to prevent any disruption of system operation in the case of a technical failure or disaster by maintaining a continuity of service.

One of the critical challenges of the project is to make the system redundant, as one of the design criteria states (Section 1.3). Since the alarm inputs from the IAS will only be connected to the master and redundant master LCUs, redundancy is necessary to ensure that the entire system respond to alarms. This method eliminates direct alarm inputs from the IAS to each of the LCUs in the system, which results in less complexity and less expensive cabling.

The type of redundancy for the LCS is a warm standby. Only one LCU in the system will act as active master at a time. The temporary outage with this type of redundancy will be a few seconds, which is considered acceptable. To achieve this type of redundancy the heartbeat method was used. The active master LCU is sending alarm updates continuously to all connected devices in the LCS network. The continuous alarm update, which happens several times a second, is used as a heartbeat for the master LCU. The redundant master is monitoring this heartbeat. If the heartbeat stops longer than configured master timeout period, the redundant master instantly takes control of the system as active master.

Both master and redundant master are monitoring the system. The master and redundant master will automatically give a system error output to IAS if LCUs are not responding to requests. This means that the LCU is effectively disconnected from the system. The error can then be troubleshooted by logging into the configuration interface for the LCU acting as active master.

4.5 PLC Implementation

The PLC programming of the system is done in e!Cockpit. All PLCs in the LCUs got the same hardware and software. The system is designed in a way which make every LCU have the support to act as a master, redundant master or a slave. This was done by implementing different programs and function blocks in e!Cockpit project.

Each LCU should have the same program uploaded, therefore they need to be configured after system is installed. The configuration interface is created in WAGO WebVisu in e!Cockpit. This makes it easier to configure the system in the field (Section 4.6).

See Appendix L for complete PLC code.

4.5.1 Master/Slave Architecture

One of the design criteria was to use a master/slave architecture for the system. The implementation of master/slave architecture is done with e!Cockpit library WagoAppPlcModbus. This library enables the program to be easily scalable with multiple masters and slaves. The LCS is designed to have one master, one redundant master and n number of slaves.

Modbus TCP uses Ethernet as medium, which results in easy installation and scalability of the network.

4.5.1.1 Master

The master code uses the function block FbMbMasterTcp from the WagoAppPlcModbus library. The master receives inputs from the structure typMasterTcp which is explained further below (Section 4.5.6.1). As seen in Figure 36 below, the master needs a query. This query is the data to be sent, and is triggered by the boolean variable xTrigger. Once a query is sent to a slave, the xTrigger variable is reset and the master can send a new query (Section 4.5.6.2).

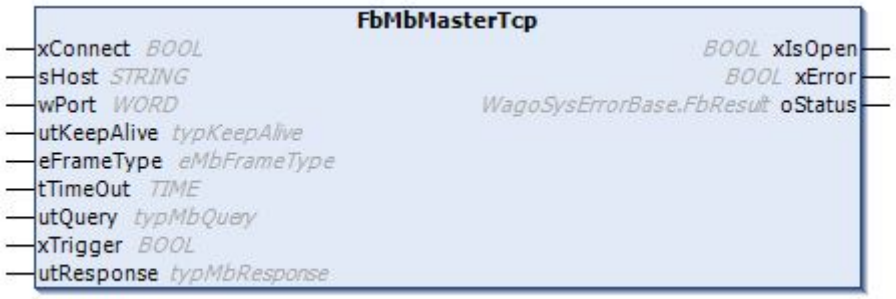


Figure 36: FbMbMasterTcp function block from the WagoAppPlcModbus library

4.5.1.2 Slave

A slave is often called a server in the Modbus terminology. The slave code is using the FbMbSimpleServerTcp function block from the WagoAppPlcModbus library. Figure 37 shows the inputs and outputs for the slave. This slave have an ID, which is set in the query, it receives arrays with data from the master. The slave will automatically set xIsOpen to TRUE if it has established connection with the master. The output oStatus is possible to use on the master side for checking the connection between the master and the slave.

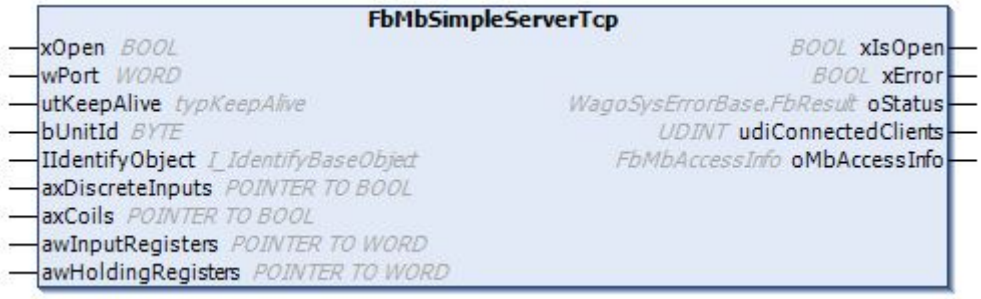


Figure 37: FbMbSimpleServerTcp function block from the WagoAppPlcModbus library

The data input for the slave function block are arrays of different Modbus object types. In this project, the 'axCoils' is the only one that is used. All off these object types are required for the function block to work. In this case, it is made four arrays that can correspond with these four object types, where three of them have the array limits set to 0.

4.5.2 PLC I/O

The LCU has several I/Os to receive alarms from IAS and to control the LED modules, warning lamp and the siren. Table 2 is a list for all of the I/O signals for the PLC.

Input
The Digital Input module consist of 16 channels, which is considered enough inputs for the system. The master and the redundant master receives alarm inputs from IAS.

Output
The two Digital Output modules has a total of 16 channels of output. Four outputs for signal to LED driver, two outputs for signal to siren, three outputs for signal to warning lamp and one output to IAS in case of error.

Address	Symbol	I/O Type	Description
%IX2.0	xGeneralEmergency	DI	General Emergency Alarm
%IX2.1	xFire	DI	Fire Alarm
%IX2.2	xFireExtinguishing	DI	Fire-extinguishing Pre-discharge Alarm
%IX2.3	xMachinery	DI	Machinery Alarm
%IX2.4	xSteeringGear	DI	Steering Gear Alarm
%IX2.5	xActivationFireExtinguishing	DI	Activation of Fixed Local Application Fire-extinguishing system
%IX2.6	xTelephone	DI	Telephone Alarm
%IX2.7	xEngineRoomTelegraph	DI	Engine Room Telegraph Alarm
%IX3.0	xWaterIngressDetectionMain	DI	Water Ingress Detection Main-alarm
%IX3.1	xWaterIngressDetectionPre	DI	Water Ingress Detection Pre-alarm
%IX3.2	xBilge	DI	Bilge Alarm
%IX3.3	xEngineers	DI	Engineers‘ Alarm
%IX3.4		DI	SPARE
%IX3.5		DI	SPARE
%IX3.6		DI	SPARE
%IX3.7		DI	SPARE
%QX0.0	xSignalLampBit0	DO	Signal to MCU (Bit 0)
%QX0.1	xSignalLampBit1	DO	Signal to MCU (Bit 1)
%QX0.2	xSignalLampBit2	DO	Signal to MCU (Bit 2)
%QX0.3	xSignalLampBit3	DO	Signal to MCU (Bit 3)
%QX0.4	xSirenCont	DO	Signal to siren
%QX0.5	xSirenTone	DO	Signal to siren
%QX0.6	xSystemError	DO	Error output to IAS
%QX0.7		DO	SPARE
%QX1.0	xWarningLightRed	DO	Red Light Warning Lamp
%QX1.1	xWarningLight Amber	DO	Amber Light Warning Lamp
%QX1.2	xWarningLightGreen	DO	Green Light Warning Light
%QX1.3		DO	SPARE
%QX1.4		DO	SPARE
%QX1.5		DO	SPARE
%QX1.6		DO	SPARE
%QX1.7		DO	SPARE

Table 2: I/O List for LCS

4.5.3 Global Variables

The use of global variables makes it easy to use a specific variable in several programs. Therefore, it was created one global variable for each alarm, for each output and for the array of structure typMasterTcp (Section 4.5.6.1).

4.5.3.1 Global constant variables

Some variables were also declared as constant, then they are never being changed. Total number of alarms and the maximum number of slaves the LCS can have are declared as constant variables. Some variables for the query are also declared as constants.

4.5.4 Programs

The following programs was implemented:

- MainProgram()
- ModbusMaster()
- ModbusMasterRun()
- ModbusRedMaster()
- ModbusSlave()
- SignalLampVisualization()
- VisualizationProgram()

4.5.4.1 MainProgram

MainProgram is the main program, which runs on all LCUs. The main task of this program is to ensure that each LCU run their role specific program, and to write to PLC outputs. If not any role is configured to the LCU, it will by default act as a slave in the system. See Figure 38 on how the MainProgram works.

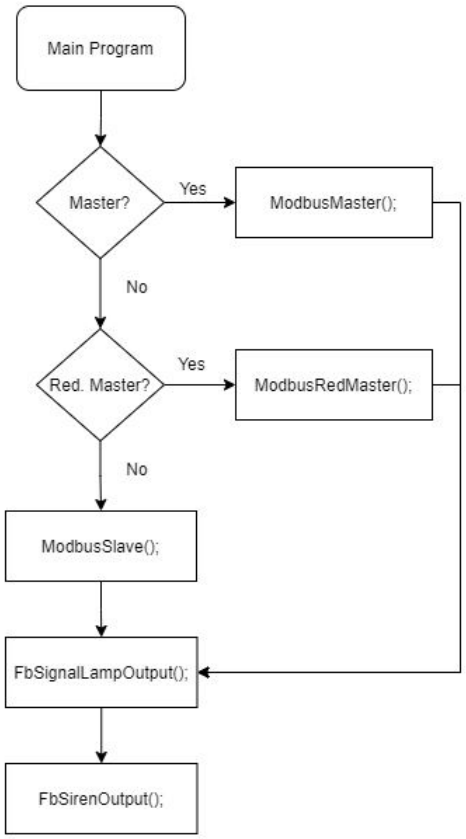


Figure 38: Flow chart of MainProgram

4.5.4.2 ModbusMaster

This is the program that handles the logic for the master PLC. The ModbusMaster program reads the alarm inputs from IAS through the input module and writes to outputs using the function blocks FbSignalLampOutput (Section 4.5.5.3) and FbSirenOutput (Section 4.5.5.4).

Based on alarm inputs it uses the function block FbMbAlarmInputToData (Section 4.5.5.1) to convert the alarm inputs to data suitable for using "Write multiple coils" command for Modbus. This data is then set to the query ready to be sent to slaves. The ModbusMaster program runs the ModbusMasterRun (Section 4.5.4.3) program, which handles the Modbus master communication with each slave. See Figure 39 on how ModbusMaster program works.

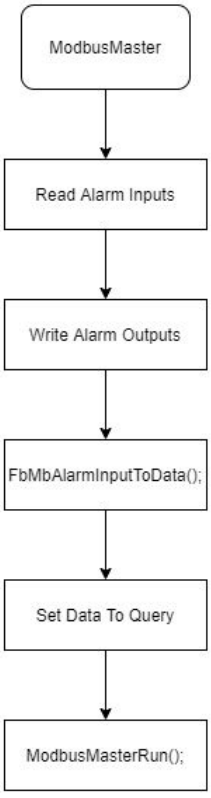


Figure 39: Flow chart of the ModbusMaster program

4.5.4.3 ModbusMasterRun

ModbusMasterRun handles the connection and requests for every slave in the system. The LCS is designed in a way that the master PLC creates a master structure for every slave added in the system, and puts the necessary variables from the structure into the FbMbMasterTcp function block (Section 4.5.6.1). The program contains a switch case that have multiple cases which represents different states in a Modbus connection. Figure 40 is an overview of how the master communicate with a slave in the system. The switch case is wrapped in a for-loop that loops through all of the master blocks for each slave. The different states for the switch case is listed below:

Idle	-	Waits for activation signal
Open connection to slave	-	Tries to connect to the slave
Response after request	-	Sends a query to the slave
Delay before new request	-	Waits a certain amount of time before next request
Monitor activation signal	-	Check if the activation signal is activated
Error Handling	-	Handles errors if needed

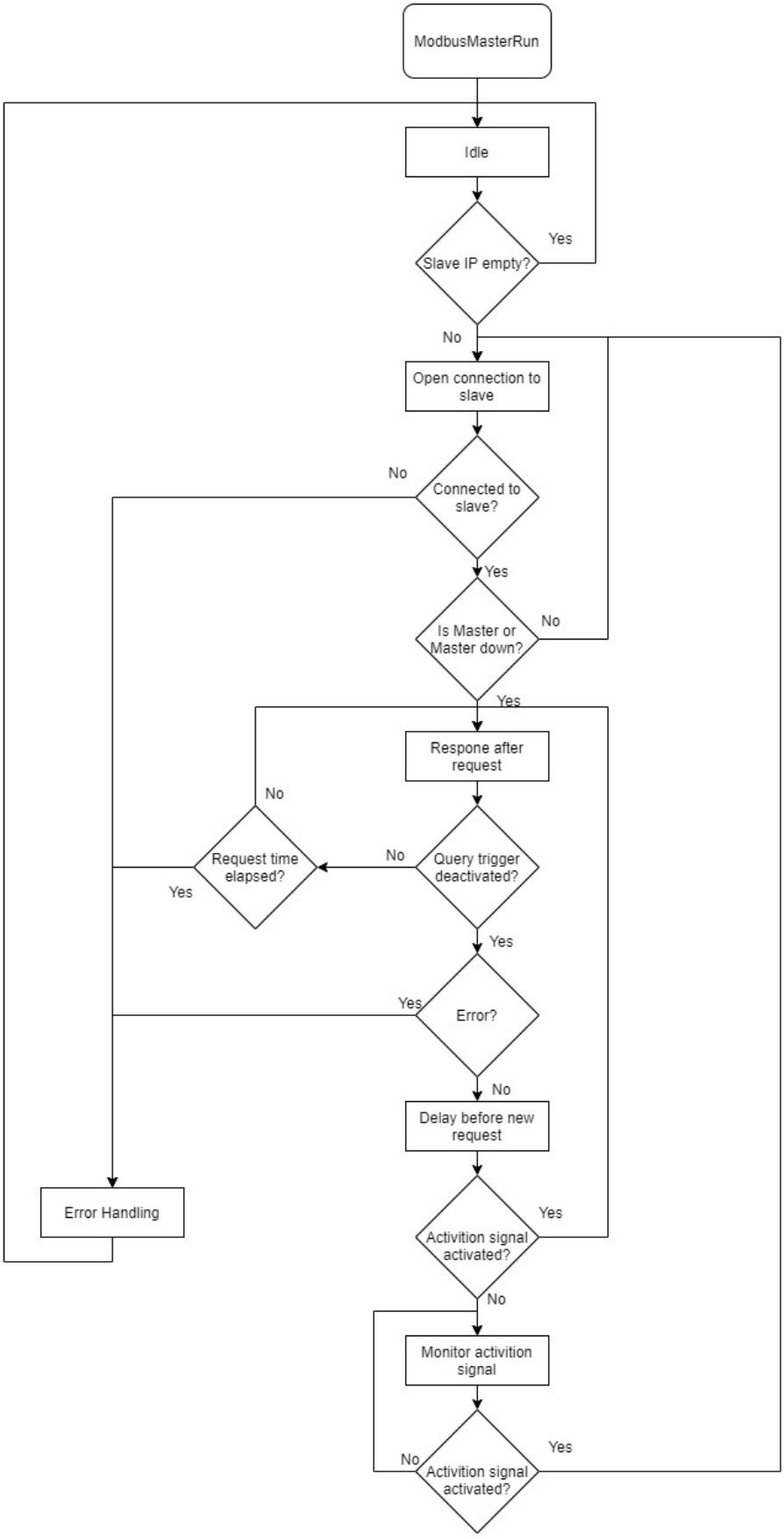


Figure 40: Flow chart of the ModbusMasterRun program

4.5.4.4 ModbusRedMaster

ModbusRedMaster is the program that runs the redundant master code. As seen in Figure 41, the redundant master runs both ModbusMaster() and ModbusSlave(), but will not send any queries to the slaves when master PLC is operating as normal. The redundant master PLC is effectively working as a slave until the main master is disconnected or lost from the system, for example when losing network connection. When redundant master detects that the master is disconnected, it will take over as active master and begin to send queries to the slaves.

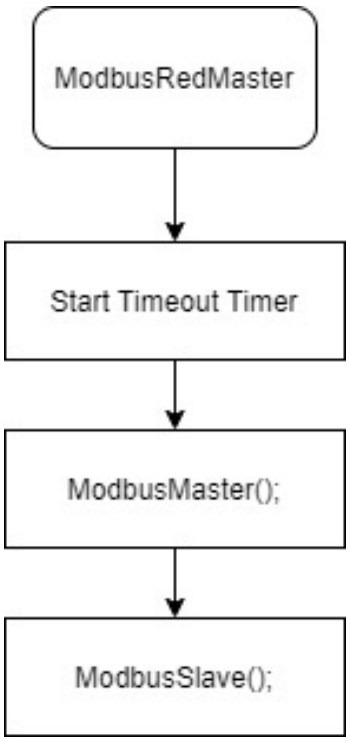


Figure 41: Flow chart of the ModbusRedMaster program

When the redundant master acts as a slave, it will get information continuously from the master. The successful queries from then master is used as a heartbeat for the master. For every successfully received request from the master, a counter from the slave function block is increased (Section (4.5.1.2). This counter can be used to start a timer. If the counter does not increase after a certain amount of time, that is an indication that the master is not acting as normal and the redundant master takes over the role. This means that the master is disconnected from the system. When this happen, the ModbusRedMaster program can now send queries to the slaves. When the master is connected in the system again, the redundant master will sense the heartbeat signal and acts as a slave again. The master timeout can be changed as desired in the configuration interface.

4.5.4.5 ModbusSlave

This program handles the slave connection. The master sends queries to the slaves with information and data, mainly to update alarms. ModbusSlave uses the FbMbSimpleServerTcp function block (Section 4.5.1.2). The queries sent from the master contains boolean values for each, which tells the slave the status for each alarm. Each alarm represent an index of the array. The slave sets the alarm outputs depending on each alarm. Figure 42 shows how the ModbusSlave program works.

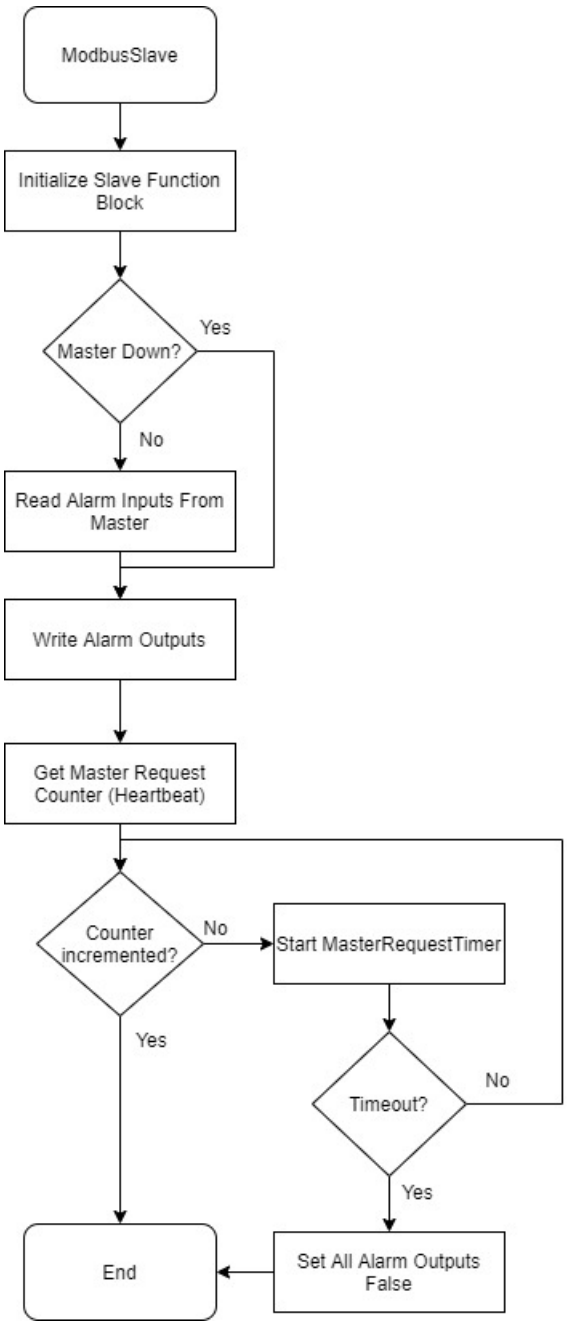


Figure 42: Flow chart of the ModbusSlave program

The slave sets output based on the queries from the master. If the last query received from master contains active alarms and the master disconnects, the active alarms will stay the same. To prevent this issue, a counter value increases every time a successful request is received from the master. If that counter does not increase during a certain amount of time, the connection between the master and the slave is lost and the slave will reset all of the alarm outputs.

4.5.4.6 SignalLampVisualization

This program runs the simulation for the alarm symbols. It was implemented to simulate the alarm symbols that are displayed on the LED modules, therefore it has the same logic to display symbols as the LED driver (See Figure 51). The output alarm is then displayed in the Home page in the configuration interface.

4.5.4.7 VisualizationProgram

This program was implemented to run visualization specific operations. All of the code used for the configuration interface runs in the VisualizationProgram. There are different subjects in this program:

- Home Tab
- Device Tab
- Settings Tab

Read more about how the configuration interface is implemented in Section 4.6.

4.5.5 Function Blocks

The following function blocks was implemented:

- FbMbAlarmInputToData()
- FbPulseTimer()
- FbSignalLampOutput()
- FbSirenOutput()

4.5.5.1 FbMbAlarmInputToData

This function block converts alarm inputs to data, which is used to input data to query. See Figure 43.

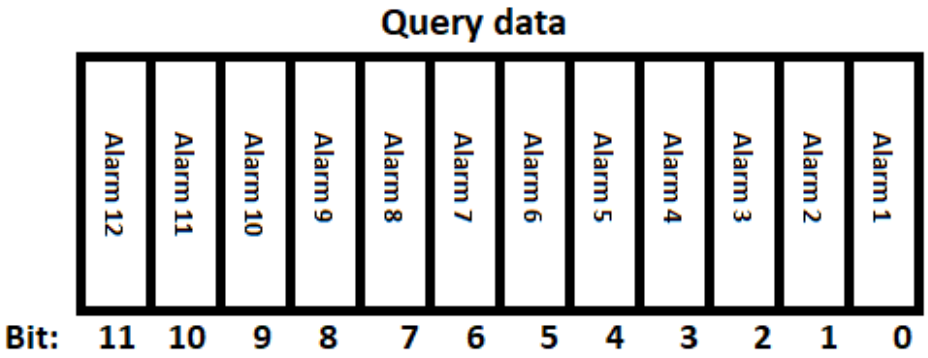


Figure 43: First 12 bits of the query data

FbMbAlarmInputToData does bit manipulation to store the alarm input value from alarm 1 to 12 as bits in a variable of the data type Word. This is done by looping through all alarms and setting the data bit high if the alarm is active, otherwise the bit is set low. The output of this function block is set to data input of the query in the ModbusMaster program.

4.5.5.2 FbPulseTimer

This function block is using the BLINK() function block from the library Util. FbPulseTimer is the same as the BLINK() function block but with a different name and different name for variables, so it can correspond with a relevant situation in the LCS. The BLINK() function block needs a bool input for enabling the timer, a time for the output to be high, and a time for the output to be low. The output is also a bool variable.

4.5.5.3 FbSignalLampOutput

This function block handles the output signal to the MCU LED Driver and the warning light. This uses the alarm inputs and determines what alarm symbol should be displayed and which warning lamps should light up.

Output to LED Driver

The LED module can only display one symbol at the time. In the case of multiple alarms a solution would be to display one symbol after the other at a constant time interval.

There are four outputs from the PLC to the MCU LED Driver. The four outputs represent four bits, which results in 16 different values of output.

The function block loops through the alarm list once every second and if there is an active alarm, the outputs are set accordingly. When there is an active alarm, the alarm number is converted to a binary number and the outputs are set. See Figure 44.

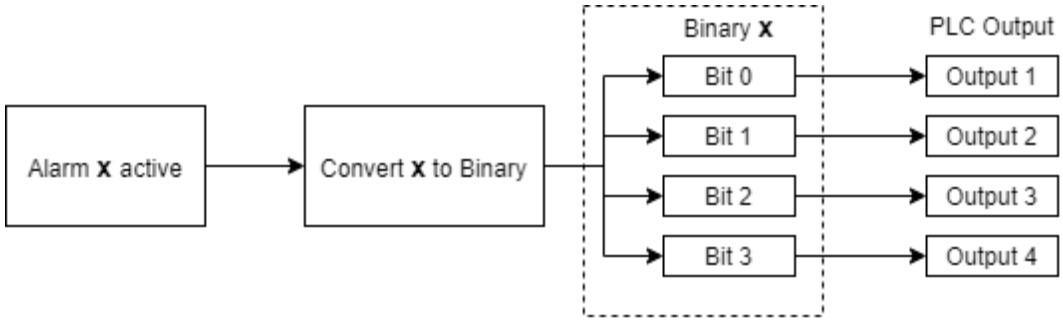


Figure 44: Active alarm to PLC output

Output to Warning Light

The warning light have three outputs. One for each color. The outputs for the warning light is activated for every alarm that is activated. The alarm list seen in Figure 34 shows the colors for every alarms. With the use of the function block FbPulseTimer (Section 4.5.5.2) the warning lights will blink with a constant interval, 1 second on and 250ms off. There are two alarms that have the color white, but the warning light does only have red, green and amber. For showing the concept, these alarms turns on the amber warning light.

4.5.5.4 FbSirenOutput

The FbSirenOutput function block handles the output signal to the siren. From Appendix H, every alarm have an siren tone. The siren have two outputs from the PLC system; one for tones and one for continuous sounds. With the use of FbPulseTimer function block, it is created three timers. The reason for that is that there are three types continuous siren tones which is relevant for the project according to the alarm list.

4.5.6 Structures

4.5.6.1 typMasterTcp

It is created a structure for the master Modbus function block. This structure contains a set of variables that is used for the master function block. In this case, it is supposed to create one master for every slave. With the use of a structure, it is possible to change values for every master independently. It is made an array of this structure so every slave can get a master structure. This makes it easy to loop through the slaves, write alarms to all of the slave etc.

4.5.6.2 utQuery

This structure contains variables for the queries that are sent from the master to the slaves. The FbMbMasterTcp function block must have the query to work. The query contains an unit ID, function code, read/write addresses and query read/write quantities. In this project, the master is only writing coil variables to the slave. This means that there are only one Modbus function code needed for this system, function code 15 (FC15) [44].

4.5.7 Persistent Variables

In the PLC system, there where used some persistent variables (Section 2.1.3). The main reason for using the persistent variables is for example if the master PLC loses power, it should operate similarly when it's turned on again. The following variable are declared as persistent variables:

- **xMaster** - Bool variable used in the Settings page in the configuration interface. The LCU is a master when this variable is active.
- **xRedundantMaster** - Bool variable used in the Settings page in the configuration interface. The LCU is a redundant master when this variable is active.
- **asSlaveIp** - Array of strings that is used for the IP addresses for the connected LCUs in the system.
- **iSlaveIpIndex** - Integer variable that is used for the current chosen LCU in the Device List.

- **iTimeoutIndex** - The current number for what timeout to choose for the redundant master.
- **tMasterTimeout** - The timeout should always be the same when the redundant master is restarted.

When installing the system, the chosen master PLC needs to be set up as a master with the use of the xMaster variable. As soon this is done, the master needs to be connected to the slaves with the use of asSlaveIp, an array of strings that always will have the same values in the array elements even if the master PLC loses power. The same operation must be done on the chosen redundant master PLC. After installing the system, the master PLC can lose power and redundant master will take the control of the system after a given amount of time, tMasterTimeout. The use of persistent variables helps the system to achieve redundancy.

4.6 Configuration Interface Implementation

The configuration interface is created in WAGO WebVisu. Each LCU have their own configuration interface. The configuration interfaces main task is to let the user set roles to different LCUs and connect slaves to the master and the redundant master. It will also show active alarms, alarm history and a list of slaves with connection status, which can be used for debugging purposes. See Appendix L page 23 to see how the configuration interface was made.

4.6.1 Main Layout

The configuration interface was made with the Visualization tool in e!Cockpit. The main layout consists of a main working area and a header, which lets the user choose different tabs to configure and see status of the system. See Figure 45. The header will constantly be on the top of the page. The header also contains the IP address for the current LCU, date and time in top right corner and the role for the current LCU.

Figure 45: Header in Configuration Interface

4.6.1.1 Time and Date Field

In a configuration interface, date and time are very often visualized. This system uses the library WagoApptime. From the library, the function FuGetLocalDateAndTime(), which returns a DATE_AND_TIME variable (DT). This variable can be converted to a String with the use of the function FuDTToString() from the library WagoAppString. This function needs a format ID and the DT variable.

4.6.1.2 IP Address Field

The IP address for the device will be visible in the configuration interface. For getting the IP address for the device, it is used a function block from the WagoAppConfigTool library. The function block FbGetIpAddress returns the IP address for this device as a String.

4.6.1.3 Role Field

The current role of the connected device is visible on the bottom right in the header. The variable sRole from VisualizationProgram is set to this text field.

4.6.2 Home Page

Home page is the first page the user will see when logging into the configuration interface of the LCU. The home page contains an alarm panel that shows which alarms are active, a list of alarms that show the active alarms including timestamps, and a section for visual simulation of alarm symbols.

4.6.2.1 Alarm List: Alarm Configuration

The alarm list is used for showing several alarms simultaneously. The list will show a timestamp when the alarm was activated. When an alarm is active the row will switch from grey to yellow color and an alarm message will appear as shown in Figure 46. When the alarm is deactivated, the row will switch back to grey color.

Figure 46: Alarm Table in Configuration Interface

To implement the table, an Alarm table from Visualization ToolBox is added to the Visualization. To use this table it is necessary to add an Alarm Configuration to the e!Cockpit project. In the Alarm Configuration all alarm variables are set to trigger an alarm, including an alarm message. An 'Alarm History'-button is added to show the history of active alarms.

4.6.2.2 Alarm Panel

The alarm panel is used to indicate which of the alarms are active and what type of alarm it is with different colors of the lamp. This can be used to monitor the system when signed in to the configuration interface.

The panel contains all of the alarms according to the Alarm List (Section 4.3.1), where each alarm has a lamp with the correct color. Figure 47 shows how the alarm panel looks like with two active alarms.

Figure 47: Alarm Panel with active alarms

4.6.2.3 Signal Lamp Visualization

The Signal Lamp Visualization shows the symbol of the current alarm that is active. If there is multiple alarms active at the same time the image will switch between the alarms. This is implemented for the user to see the symbol of the alarm that is also showing on the LED module.

Figure 48: Alarm Symbol Visualization

4.6.3 Device Page

The Device Page shows the device list which includes all the IP addresses of the slaves connected to the current LCU and a status message that indicates whether the slave is connected or not. Buttons are added to the Device page that allows the user to either remove devices or update the list. At last there is a button called WebVisu that enables quickly switching to the WebVisu any of the connected devices on the list.

4.6.3.1 Device List

Each device has its own IP address. The IP addresses are stored in an array of String in the Persistent Variables list (Section 4.5.7). To add a LCU to the system, the user will have to update the list with the LCUs IP address. This fulfills the design criteria about scalability of the system.

The device list is a table from the Visualization Toolbox in e!Cockpit, and contains a two dimensional array. The first dimension represents the array for IP addresses, and the other dimension is the status message for each LCU. The index of the device list is also a persistent variable.

4.6.3.2 WebVisu Button

In the Visualization tool in e!Cockpit, it is possible to make a button execute a command which takes the user to a web address. This makes it easy to change between devices in the WebVisu (Section 2.1.2). The command to execute is the 'NavigateURL', which needs the whole web address for the given device.

A typically WebVisu address looks like this: *'https://<IP Address>/webvisu/webvisu.htm*. To make this button execute the correct IP address for each slave, it is created two string variables, sHttps and sWebVisu. One that contained the *'https://'* part and the other that contained *'/webvisu/webvisu.htm'* part. The functoin CONCAT is a function that takes two strings as input and return the concatenated string [20]. To use this function in this case, use the function twice:

```
sFirstPart := CONCAT(sHttps, sIP);
sFinalPart := CONCAT(sFirstPart, sWebVisu);
```

If the IP address of the device is '158.38.140.120', after the use of the CONCAT function, the web address will be: *'https://158.38.140.120/webvisu/webvisu.htm*. The button in the configuration interface will then execute the command 'NavigateURL' with the web address.

4.6.3.3 Update Button

The string for the IP addresses for the slaves is based on what is typed in the device list. When setting a new IP address to that field, a trigger is used for update the list, which is the 'Update' button. This makes it easy to change the IP address for an unit if the user types the wrong IP address before connecting the unit to the system.

4.6.3.4 Remove Button

The 'Remove' button is used for removing a LCU from the device list. If the remove button is pressed, the program takes the string for the IP address for the chosen LCU in the list and set it as an empty string. Then the master doesn't have any IP address to send the query to. This makes it possible to disconnect a LCU from the system.

4.6.4 Settings Page

The settings page is used for configuring the roles for the LCUs. There is a 'Master' and 'Redundant Master' toggle button on the page. Only one of the buttons can be active at once.

4.6.4.1 Master Toggle Button

When 'Master' button is clicked, it will toggle the role for the current LCU to either master or not master. When the master button is activated, the current LCU will be running the ModbusMaster program (Section 4.5.4.2).

4.6.4.2 Redundant Master Toggle Button

When activating the 'Redundant Master' button, the current LCU will act as a redundant master, and run the ModbusRedMaster program (Section 4.5.4.4). When the redundant master button is activated, the timeout selection will be visible. Read more about the timeout below.

4.6.4.3 Master Timeout

When 'Redundant Master' button is activated, a drop-down menu for setting the master timeout will be visible. The drop-down menu is limited from 2 to 10 seconds and is connected to the persistent variable 'iTimeoutIndex'. It is a persistent variable because the timeout should not change value if the redundant master is shut down, for example power failure.

4.7 Physical Visual System

The Physical Visual System (PVS) consists of mainly two parts, the warning light and the LED modules. See Figure 49. The LED modules objective is to display various alarm symbols and the warning light flashes the color of alarm according to the Alarm List (See Section 4.3.1).

Figure 49: Prototype of PVS: Warning light on top, LED modules on bottom

4.7.1 LED Module

The LED modules will display the alarm symbol for each alarm. The two LED modules are arranged in a 90 degree V shape orientation to cover a large visible area. See Figure 50. The modules are connected in parallel, and therefore will display the same alarm symbols.

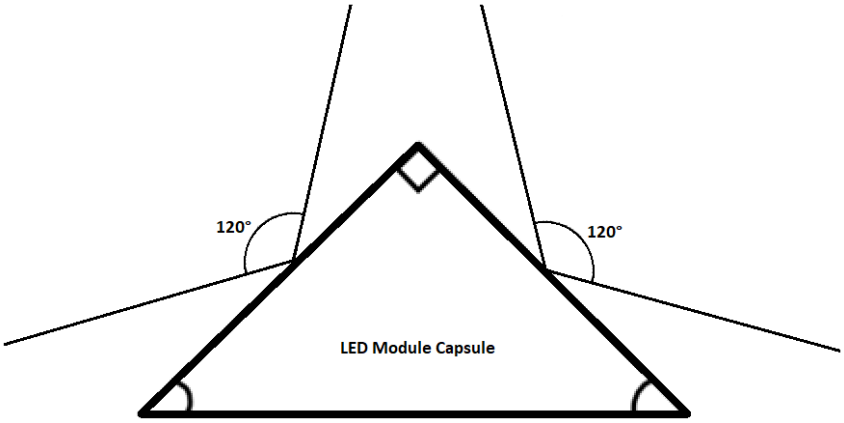


Figure 50: The LED module capsule seen from above and the viewing angles of the LED modules

4.7.2 LED Module Modification

Out of the box the LED modules are not usable with the LED driver library PxMatrix. There are two connection points on the back of the module, input and output. The LED modules consists of 6 shift registers. On the input of the module there are inputs to; shift registers (R1, R2, G1, G2, B1, B2), address inputs A,B,C,D and E, a latch enable input (LAT/STB), a clock input (CLK) and output enable (OE). On the output of the module there are the identical signals to the input connector, except R1, R2, G1, G2, B1 and B2 which are outputs of the shift registers on the module [1].

To drive these modules it needs modification, that is jumper wires between input connector and output connector which chains all the shift registers to one big shift register (Appendix J p. 8). This enables the modules to be driven using a MCA and the Arduino PxMatrix library.

4.7.3 LED Driver

A driver is required for displaying alarm images on the LED module. ESP32 and Arduino IDE was used to develop the code to drive the LED modules. The ESP32 is fast and has enough storage to hold all the alarm symbols in flash.

The logic for what alarm symbol to display is simple. The PLC determines which alarm symbol should be displayed.

4.7.3.1 Driver Input

The MCU LED driver takes four digital inputs from the PLC and show corresponding alarm symbol based on a state machine. The four inputs to the MCU from the PLC is connected according to the electrical drawing (Appendix J p. 6-7). By using four digital inputs from the PLC to the MCU and bit manipulation, an integer is created. The integer will be a value between 0 and 15, which results in 16 different states. The first input is the least significant bit and the fourth input is the most significant bit. Each states task is to display its alarm symbol. See figure 51.

4.7.3.2 Driver Output

The LED module needs ten inputs from the MCU LED driver. The ten inputs to the LED module from the MCU is connected according to the electrical drawing (Appendix J p. 7-8). The connection between ESP32 and LED module is specified in the PxMatrix library documentation [1].

4.7.3.3 Arduino Program Implementation

To display images on the 64x64 LED module, PxMatrix Arduino library is used. In PxMatrix library documentation, it is described how to set up the Arduino sketch for several types of LED modules.

The LED module outputs are defined as PxMatrix library specifies:

- P_LAT - pin 22
- P_A - pin 19
- P_B - pin 23

- P_C - pin 18
- P_D - pin 5
- P_E - pin 15
- P_OE - pin 16

The LED module in the code is defined by using **PxMATRIX display**(<myMatrixWidth>, <myMatrixHeight>, P_LAT, P_OE, P_A, P_B, P_C, P_D, P_E). The LED module for this project need all address lines A to E.

All the alarm symbol images are defined as arrays of unsigned 16-bit integers. The array contains 64x64 unsigned 16-bit integers. How these arrays are created see Section 4.7.4. (Appendix M l. 102-916)

Before updating the display the images must be drawn. A draw images function was taken from PxMatrix example code, and was modified to support 64x64 unsigned 16-bit integer array (Appendix M l. 956).

Setup Function

The Arduino Setup function runs once at startup which initializes and sets the initial values (Appendix M l. 921).

The LED module is initialized by using **display.begin**(<moduleScanRate>).

The text "Light Column System" is printed in the LED module for 3 seconds. This is done by first setting the color of the text by using **display.setTextColor**(<myColor>), the position of the text on the LED module by using **display.setCursor**(x, y), and then printing the text on the LED module by using **display.print**("My Text Here").

The inputs from the PLC are initialized in the setup. It uses the MCUs internal pull-up resistor, which means the signal is connected to ground when input is active. This is done by using **pinMode**(<myInput>, INPUT_PULLUP) for the four inputs from the PLC.

Loop Function

The Loop function loops consecutively through the code (Appendix M l. 970). In the loop the inputs from the PLC are read, and by bit manipulation an integer is created. This integer determines the state in the Switch Statement. Each state has one task, which is to draw alarm images to the LED module. See Figure 51.

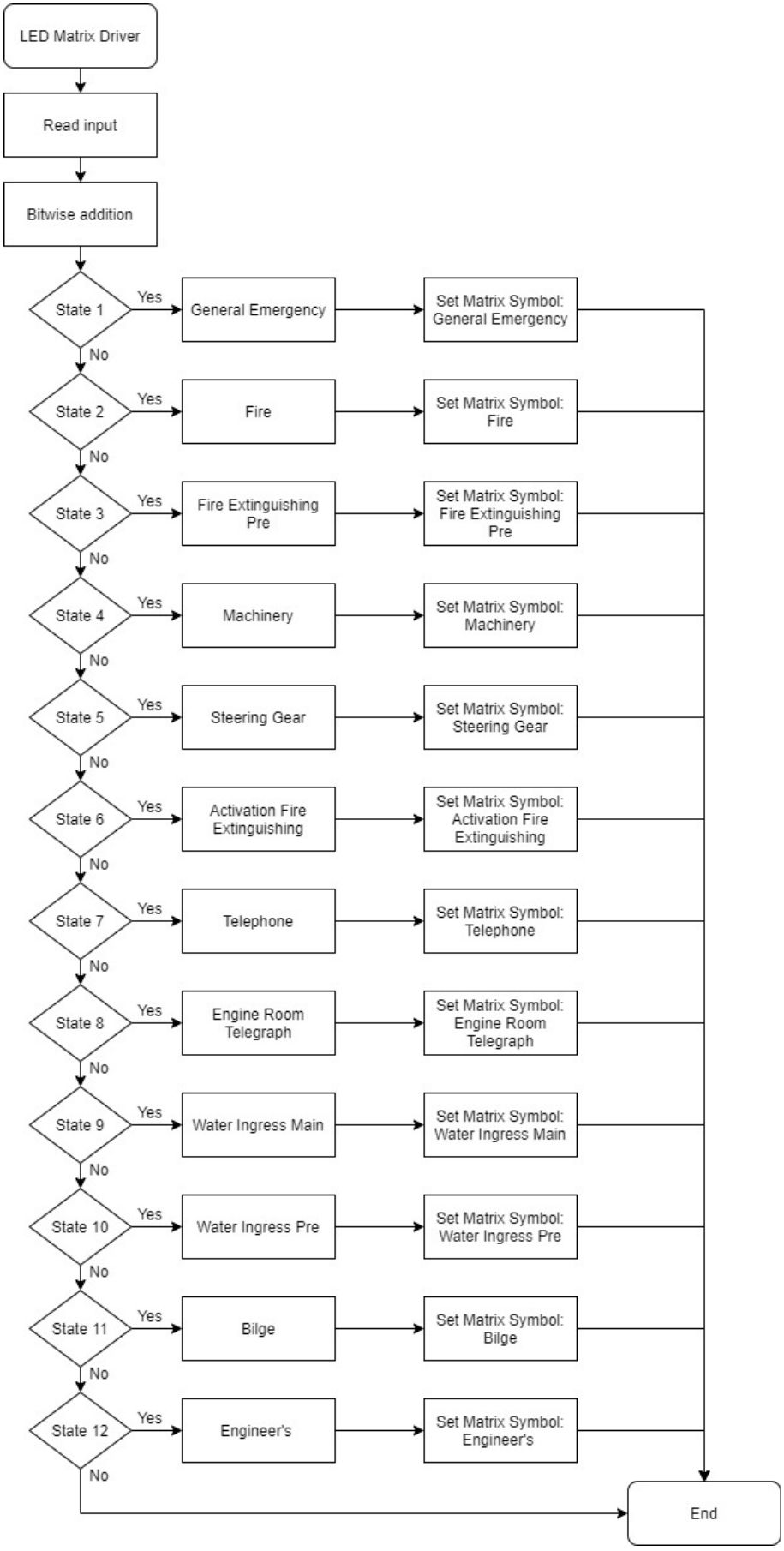


Figure 51: Flow chart of MCU LED driver

4.7.4 Alarm Images

In this section the process of making the alarm images for the LED modules is described.

4.7.4.1 Create alarm images

The driver of the LED modules need an array of color bits to draw the alarm symbols. For drawing these alarm symbols, the program Paint.net was used. This was done by capturing a screenshot of the alarm image from the Alarm List (Section 4.3.1). Example for this is the Fire Alarm. See Figure 52.

Figure 52: Screenshot from Alarm List

The alarm symbol images were pasted into Paint.net and used as a template to draw the symbols. The alarm image needs the correct color according to the alarm list. Figure 53 shows the finished drawing of the fire alarm symbol in the Paint.net application.

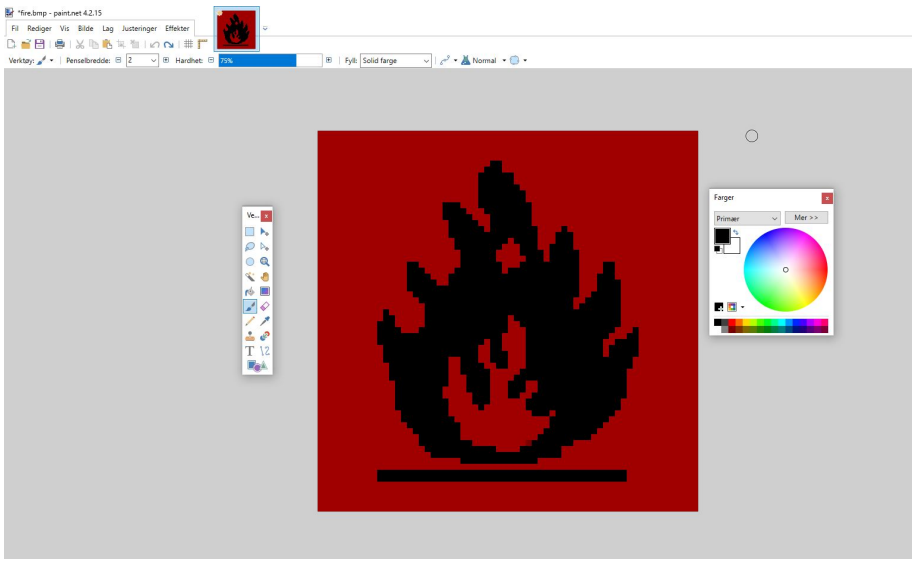


Figure 53: Paint.net during drawing the alarm image

When the alarm image is drawn, it is saved as a bitmap file (.bmp) and is ready to be converted to an array of color bits.

4.7.4.2 Converting alarm images to a color matrix

For converting a bitmap into an array of color bits, the software LCD-image-converter was used. The alarm images were opened in the application. In the Conversion page under 'Options' lets the user chose several conversion options. Figure 54 shows how the conversion page looks like.

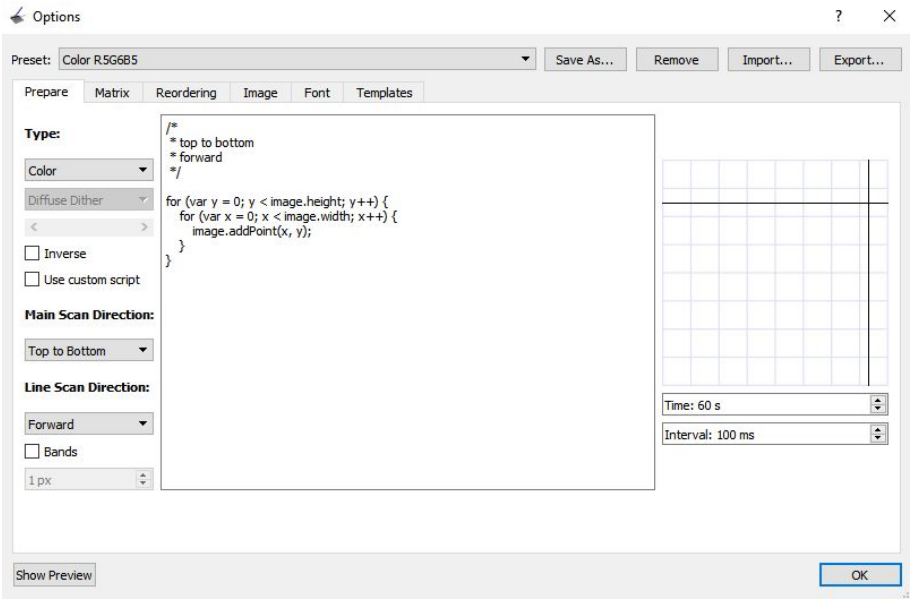


Figure 54: Conversion of bitmap to color matrix

For getting the desired color image, 'color' must be chosen under 'Type', and under the page 'Image', choose the desired size of the color bits. In this project, 16 bits color image is used. Change the 'Preset' to 'Color R5G6B5'. 'Show Preview' displays an array color bits that can be used for setting an image to the LED module. The preview can be copied and used as an array in the code for the MCU. Below, the Figure 55 shows a part of the color bits for the Fire Alarm.

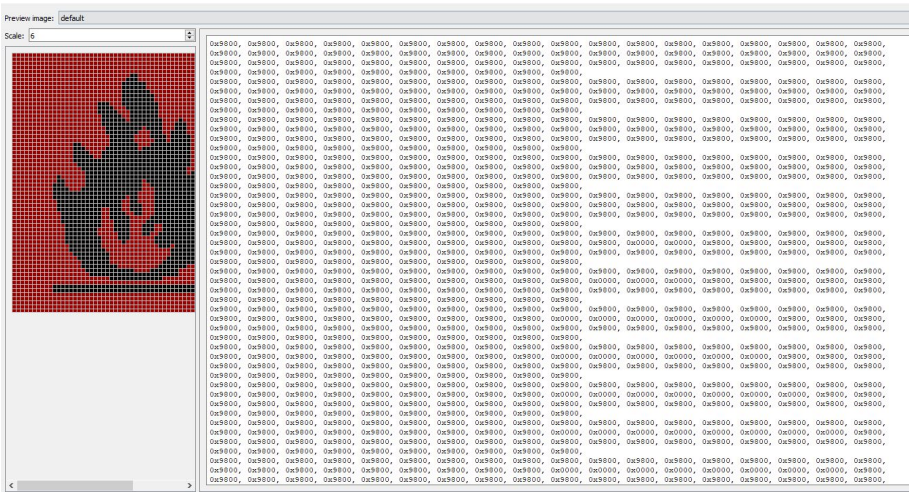


Figure 55: Part of Fire Alarm color matrix

In Figure 56 is the fire alarm symbol displayed on one of the LED modules. The LED module shows the correct colors, but the camera used to take images of the LED modules does not represent the real colors of the LED modules.

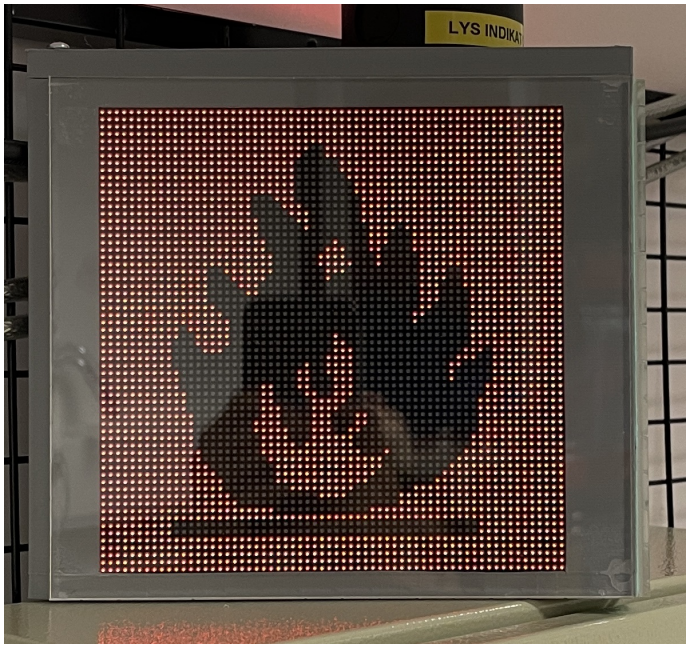


Figure 56: Fire alarm symbol on the LED module

4.8 Prototype Design

The prototype design consist of a electrical cabinet enclosure, siren mounted on the side and the PVS on the top of the cabinet. All of the critical control components are mounted inside of a cabinet enclosure. The internals consists of a PLC system with I/O modules, power supplies, terminal blocks, MCU and relays, along with cable channels for cable management. On top of the enclosure there are two LED modules in a prototype enclosure and a warning light with three colors; green, amber and red. The siren is mounted on the side of the cabinet enclosure. The signal, power and Ethernet cables enters the cabinet at the bottom through cable glands.

See Appendix J for the electrical drawing for the prototype LCU.

4.8.1 Cabinet Layout

The Figure 57 shows the layout of essential components inside the cabinet.

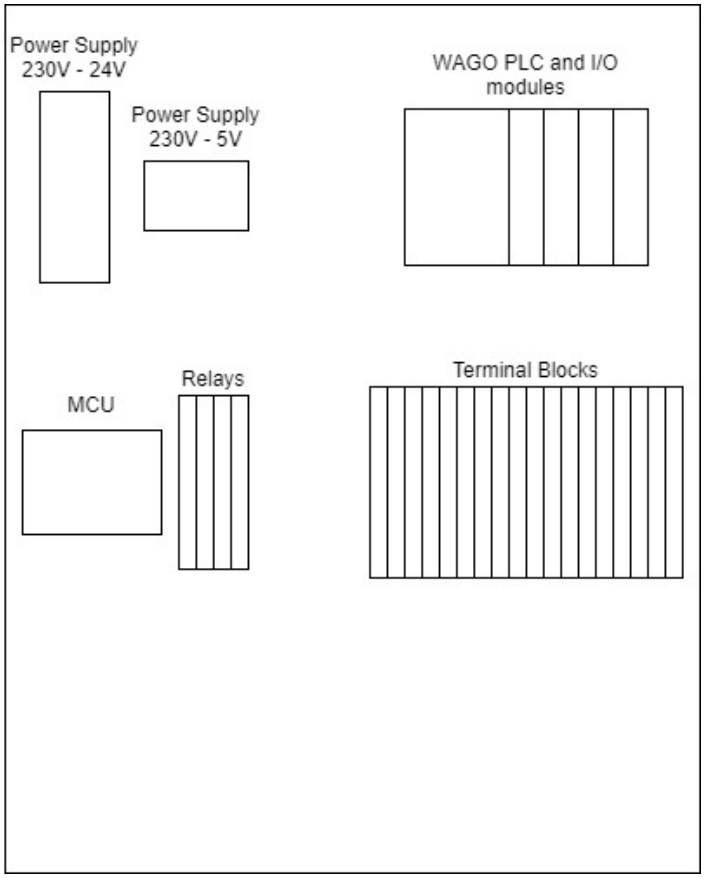


Figure 57: Cabinet layout for essential components

4.8.2 Cabinet

The detachable mounting plate that comes with the cabinet makes easy to add DIN rails in the cabinet. All of the critical components in the cabinet are attached to the DIN rails. See figure 58 for how the components are placed on the DIN rails.

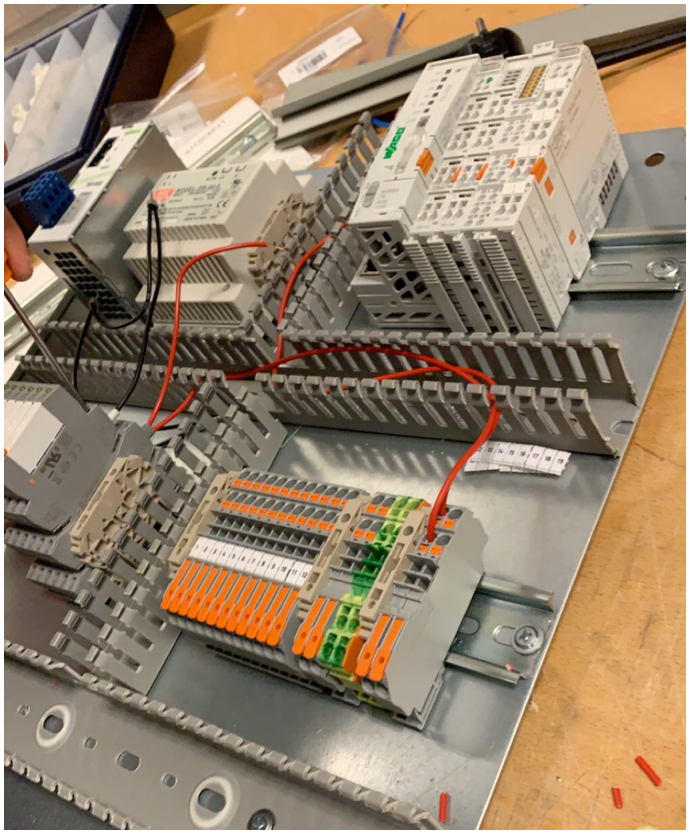


Figure 58: Components are placed on the mounting rails

4.8.3 Cabinet Terminal Blocks

The terminal blocks makes it easier to connect alarm signals and power to the LCU out in the field. Most of the wiring goes trough the terminal blocks, see Figure 59. To the right, there are terminal blocks for the 5V power supply and ground. Next there are terminal blocks for 24V power supply and ground. The external power supply cable connects in to L, N and ground terminal blocks. The numbered terminal blocks 1 to 12 are alarm inputs and number 13 is system error output to IAS.

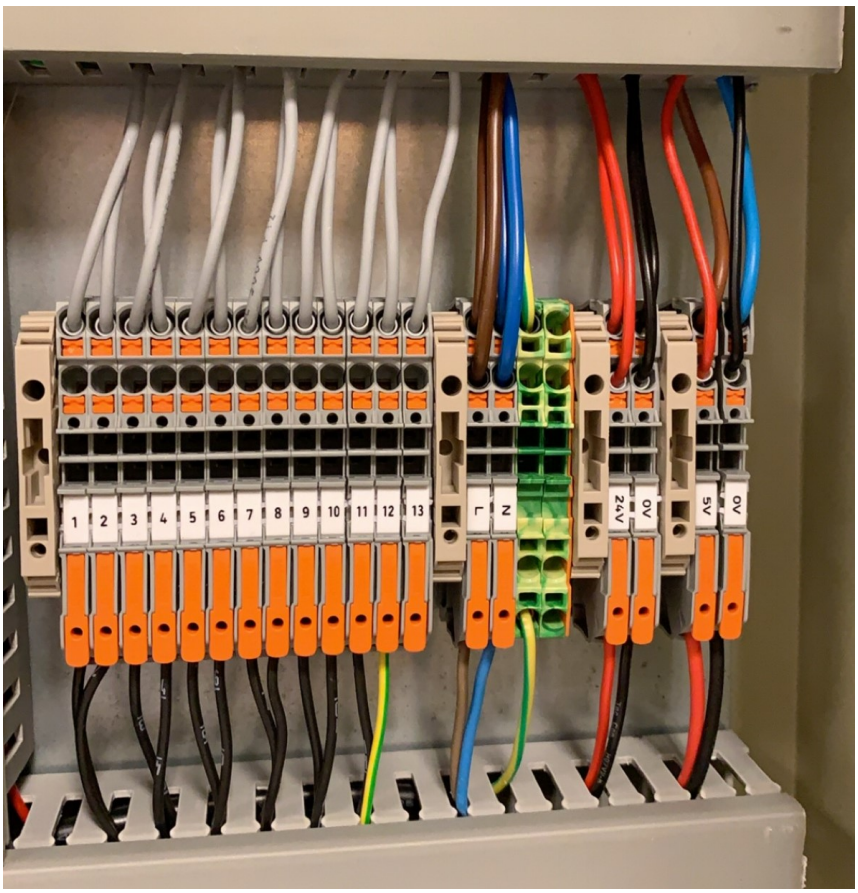


Figure 59: Terminal blocks mounted on DIN rails inside the cabinet

4.8.4 Cabinet Power Supply

The internal system components are powered by two different power supplies, see Figure 60. Both of the power supplies are powered from the 230V main power supply. The 24V power supply powers the PLC, siren and the warning light. The 5V power supply powers the MCU LED Driver and the LED modules.

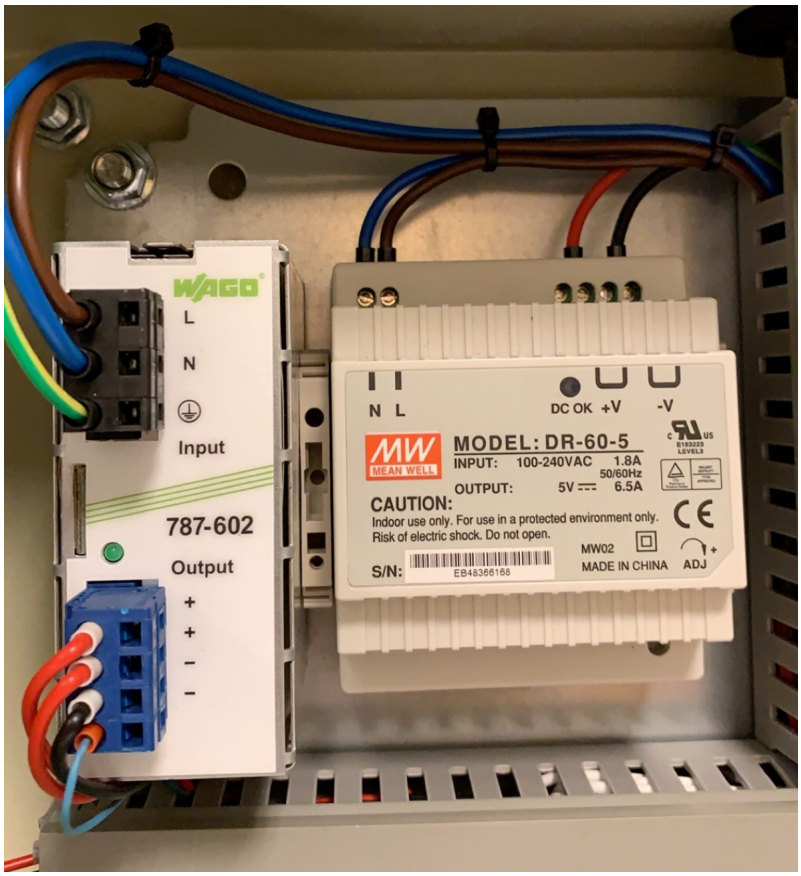


Figure 60: 24V and 5V Power Supplies

4.8.5 Cabinet PLC

The PLC is the main controller of the system. Figure 61 show how the PLC and the I/O modules are set up. The PLC are connected with two Ethernet cables and power from the 24V power supply. It is used two 8-channel output modules for siren output, warning light output and alarm output. The grey wires are alarm inputs which is connected to the terminal blocks.

Figure 61: PLC with I/O modules

4.8.6 Cabinet MCU LED Driver

The MCU LED Driver is set up with a protoboard, which makes it easy to connect cables to the MCU. See Figure 62. The MCU receives signals from the PLC and convert them to an alarm image which is shown at the LED modules.

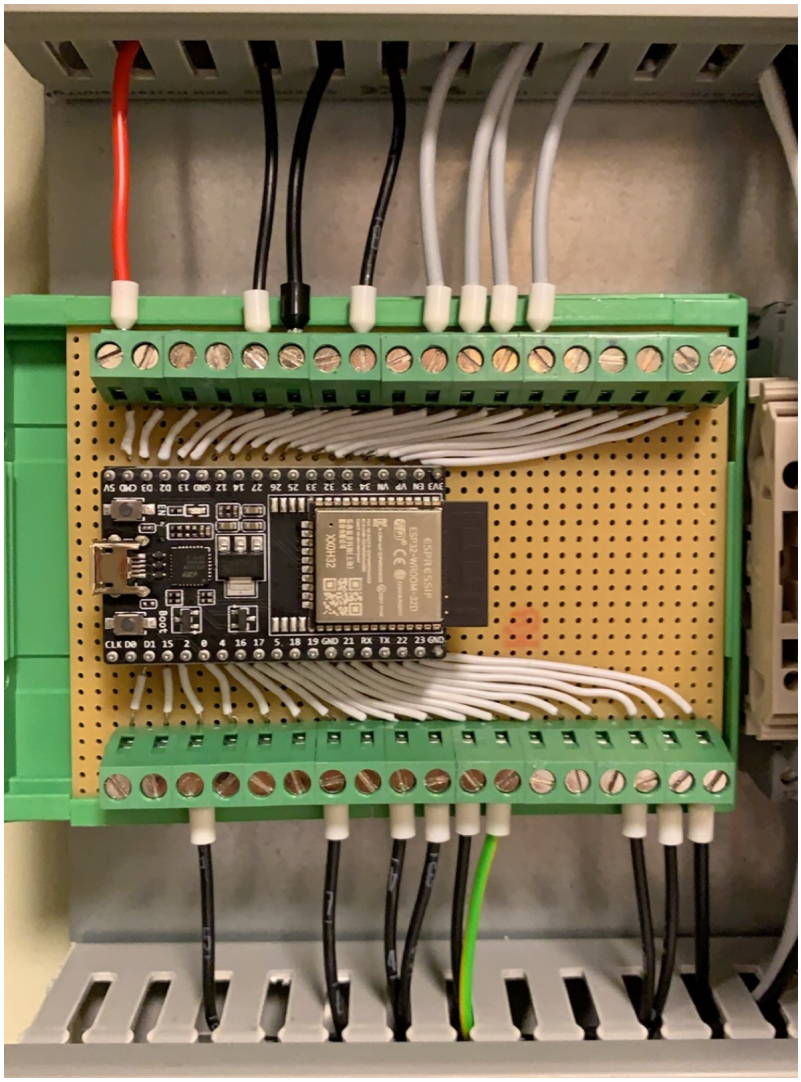


Figure 62: The MCU LED driver mounted on the protoboard

4.8.7 LED Module and Warning Light Enclosure

The LED modules and the warning light is mounted in a 3D printed prototype enclosure on top of the cabinet. Figure 63 show the 3D model of the LED module enclosure. The part was too big for the 3D printer, therefore the enclosure was printed in two parts and glued together.

The enclosure is in a V-shape to set the LED modules orientation in a V-shape. This makes the viewing angle great for the alarm symbols. See Figure 50 for the viewing angle.

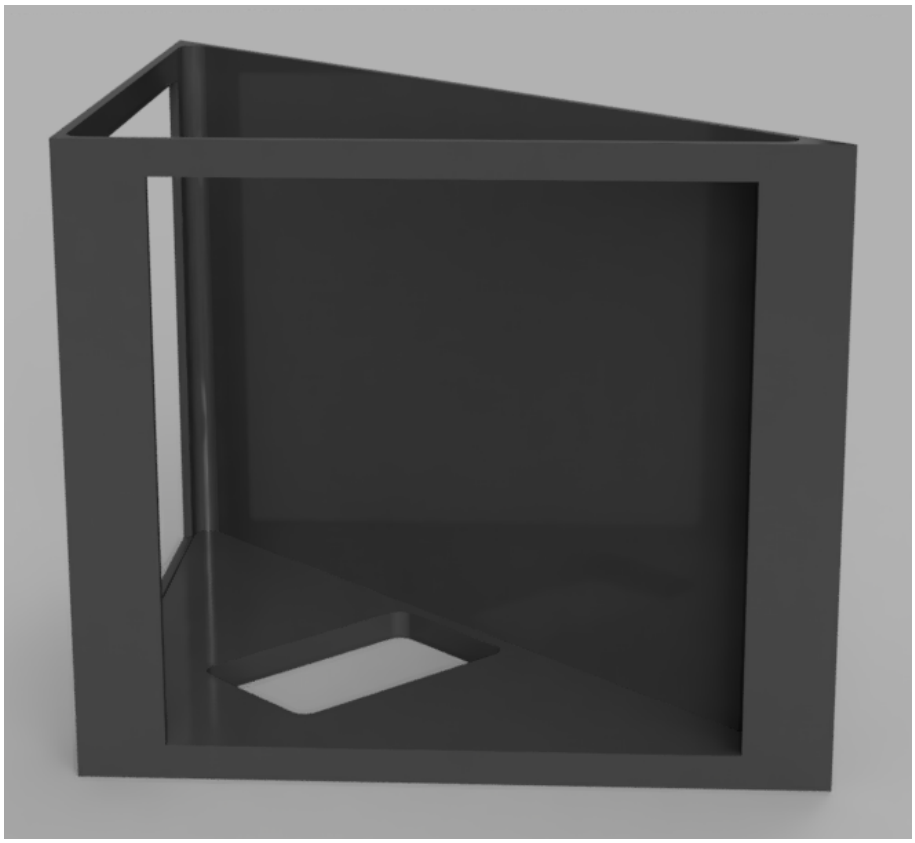


Figure 63: 3D-printed LED module Enclosure

The lid designed for the LED module enclosure makes is possible to open the enclosure if some changes are needed in the wiring of the LED modules. On top of the lid is the mounting for the warning light. See figure 64. There is a hole trough the warning light mounting for the signal cable for the warning light. The cable goes through the LED module enclosure and into the cabinet.

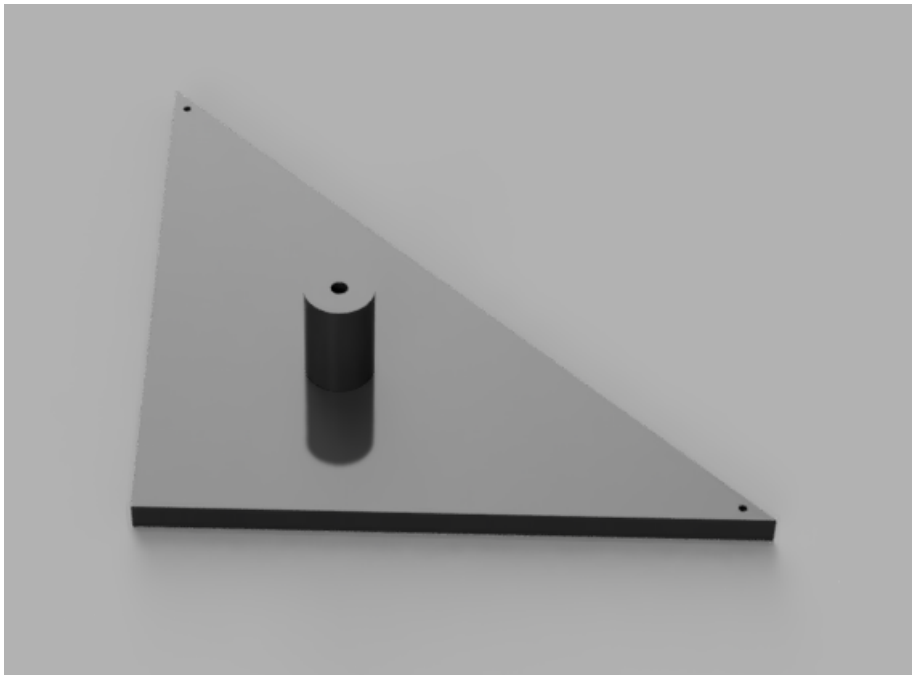


Figure 64: Lid for LED module enclosure with Warning Light Mounting

4.8.8 Simulated Alarm Inputs

The LCS receives alarm inputs from the IAS on board the vessels. In this project, the IAS is simulated with two WAGO 288-853 relay switch modules. These modules have 8 channels each, which gives the opportunity to have one switch for each alarm. From Figure 65, it is shown how the alarm input switches looks like.

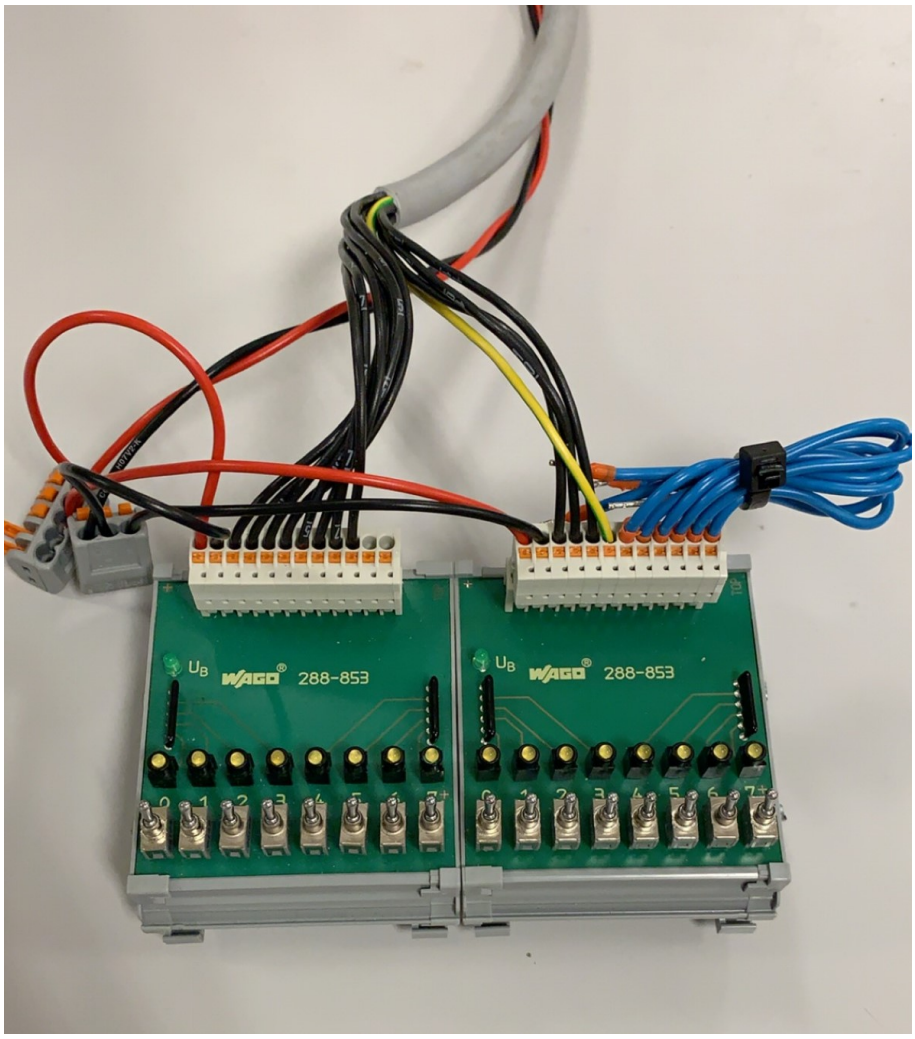


Figure 65: Simulated Alarm Inputs

4.8.9 Siren

The siren that is used on the prototype is of type Marine VTB-32EM Spatial Sounder/Beacon. The siren has DIP-switches on the inside that can manually be switched to different tones and volume. The tone which is set on the siren was of the General Emergency tone.

Figure 66: Siren

4.9 Testing

Several tests were established to prove the concepts of the project. Appendix I is a list for important tests for the LCS. The test methods for the different subjects are described below.

4.9.1 Alarm Testing

A list of tests and expected results for the prototype LCU was created. See Table 3.

No.	Test	Testing Method	Expected Result
1	Response to Alarm	Toggle on alarm from IAS to master LCU	The master and slaves should output the same on the I/O modules
2	Alarm on LED module	Toggle on alarm from IAS to master LCU	See corresponding alarm symbol on the LED modules
3	Alarm on Warning Light	Toggle on alarm from IAS to master LCU	See corresponding color on warning light
4	Alarm on Siren	Toggle on alarm from IAS to master LCU	Hear corresponding audio alarm
5	Handle multiple Alarms (Optical)	Toggle on multiple alarms from IAS to master LCU	See corresponding alarm symbols on the LED modules switching at a given time interval. See corresponding colors on warning lights.
6	Handle multiple Alarms (Audio)	Toggle on multiple alarms from IAS to master LCU	The audible alarm should be the most prioritized.

Table 3: List of tests of handling alarms

4.9.2 Configuration Interface Testing

Table 4 is a list of expected results of tests for the configuration interface.

No.	Test	Testing Method	Expected Result
1	Alarm Panel	Toggle on alarms from IAS and monitor the alarm panel.	The correct alarm according to IAS should light up on the alarm panel.
2	Alarm Table	Toggle on alarms from IAS and monitor the alarm table.	The correct alarms according to IAS should appear in the alarm table along with timestamps and error messages.
3	Alarm Table History	Toggle on and off alarms from IAS and click the "Alarm History"-button.	The correct alarm history should appear in the table along with timestamps and error message.
4	Alarm Symbol Simulation	Toggle on alarms from IAS and monitor the alarm panel.	The correct alarm symbol according to IAS should appear.
5	Add LCU to system	Add slaves to the device list and update. Monitor the status message	When new device is connected to the network and is added to the device list, the device should be connected and status message "Connected" should appear.
6	Remove LCU from system	Remove slaves from the device list and update. Monitor the status message.	When a device is removed from the network and is removed from the device list, the device should dissappear from the list.
7	Device List Status	Disconnect and connect devices to the network and monitor the status messages.	When devices are disconnected and connected to the network, the status message should update accordingly.
8	Device List Reboot	Restart the current device and check if the list is preserved.	After a device reboot, the device list containing all devices should be preserved.
9	WebVisu Shortcut	Choose any device in the device list and press the "WebVisu"-button.	When "WebVisu"-button is pressed, the configuration interface for the chosen device should appear in a new window.
10	Toggle Role	Toggle "Master"-button, check if the device asts as master. Restart device and check if the device still acts as master. The same procedure for "Redudant Master"-button.	When a role is selected, the role should be preserved even after a device reboot in case of power failure.

Table 4: List of tests for configuration interface

4.9.3 Redundancy Testing

Table 5 is a list of expected results for redundancy tests.

No.	Test	Testing Method	Expected Result
1	Slave Shutdown	Remove power of slave and monitor master behaviour. Connect back power and monitor master behaviour.	Master should detect when slave is shutdown and send notification to IAS. When slave is running again, master should detect this and stop notification to IAS.
2	Slave Disconnection	Disconnect slave from network and monitor master behaviour. Connect slave back to the network and monitor master behaviour.	Master should detect when slave is disconnected and send notification to IAS. When slave is connected back to network, master should detect this and stop notification to IAS.
3	Redundant Master Shutdown	Remove power of redundant master and monitor master behaviour. Connect back power and monitor master behaviour.	Master should detect when redundant master is shutdown and send notification to IAS. When redundant master is running again, master should detect this and stop notification to IAS.
4	Redundant Master Disconnection	Disconnect redundant master from network and monitor master behaviour. Connect redundant master back to the network and monitor master behaviour.	Master should detect when redundant master is disconnected from network and send notification to IAS. When redundant master is connected back to the network, master should detect this and stop notification to IAS.
5	Master Shutdown	Remove power of master and monitor redundant master behaviour. Connect back power and monitor redundant master behaviour.	Redundant master should detect when master is shutdown and become active master after master timeout has elapsed. Red. master sends notification to IAS when master is shutdown. When master is running again, red. master will become active slave again, and stop notification to IAS.
6	Master Disconnection	Disconnect master from network and monitor redundant master behaviour. Connect master back to network and monitor redundant master behaviour.	Redundant master should detect when master is disconnected from network and become active master after master timeout has elapsed. Red. master sends notification to IAS when master is disconnected. When master is connected back to network, red. master will become active slave again, and stop notification to IAS.
7	Timeout (Redundant Master)	Remove power of master and monitor redundant master behaviour.	When master is disconnected, check if the time for red. master to take control is correct.

Table 5: List of tests for LCS redundancy

4.9.4 Electrical Testing

Before connecting components to the system, all of the electrical components had to be tested. This is important to avoid damages or destroying the components. For testing the electrical components, it was used a multimeter. Electrical components can be tested with use of point to point testing for checking voltage or resistance, or use the beep function where the multimeter makes a beep sound if there is continuity through the connections.

4.9.5 Modbus TCP Testing

Before starting with the connection between master and slaves, some Modbus TCP testing was done. This test was done with the use of the software Rilheva Modbus Poll [25]. This software sets up an virtual slave, where the user connects with an IP address and port. By adding registers, it is possible to set different values on the PLC and read them on the virtual slave on the Rilheva Modbus Poll software. This test made it a bit easier to understand the use of the Modbus TCP protocol.

4.9.6 LED module Testing

The LED modules needed to be tested before they were set up on the prototype. With the use of the PxMatrix Arduino library, they could be tested with an example code. If the LED module ran the example code correctly, it was tested with one alarm symbol. With a correct test of the alarm symbol, the LED module were set up on the prototype, and wired correct to the MCU in the cabinet and tested with multiple alarms.

4.9.7 Protoboard Test

The MCU is placed on a protoboard in the cabinet. The protoboard was soldered by the group themselves and a test was necessary before connecting power and signal cables. The test was done with the beep function on a multimeter which is described in the electrical testing (Section 4.9.4). If the protoboard was soldered correctly, no of the pins should be soldered together and the board was ready to be used.

5 Results

The purpose of the system is to cluster AOS systems on vessels and notify the crew in noisy areas of the vessel if anything needs attention.

The most critical objectives of the project are stated below.

- Light Column System:
  - Simplified Installation of System - System to use an Ethernet network
  - Redundant Master/Slave Architecture
  - Reliable LCS, that is Scalable and Easy to Install and Configure
- Light Column Unit:
  - Standard Full Design
  - 'One-box-for-all' Solution - All LCUs to be same Hardware
  - No External System Components, except the LCUs them self
  - Simplified Change in Design/Number of parts
  - Light for Each Main System According to Class Rules
  - Siren with dB Level above Ambient Noise Level

The results of the project shows that the system has fulfilled all of the objectives above. The results of the project will be explained in the following sub-sections.

5.1 LCS Testing

In the sections Alarm Testing (Section 4.9.1), Configuration Interface Testing (Section 4.9.2) and and Redundancy Testing (Section 4.9.3) there was listed different types of tests for the LCS.

5.1.1 Alarm Testing

The Table 3 shows the list of tests for how each LCU should handle alarms. The results of these test were successful as expected.

5.1.2 Configuration Interface Testing

Table 4 shows the list for tests for the configuration interface. The configuration interface is successful in its tasks, and the functionalities were as expected.

5.1.3 Redundancy Testing

Table 5 shows the list of tests for system redundancy. The results of these test were successful as expected.

5.2 Final Results

The group have achieved multiple aspects with the complete system. A demonstration video was created that shows the most important aspects of the system. The video can be found here.

5.2.1 Prototype

The prototype is a standard full design 'one-box-for-all' solution, which means that the LCS can be built using the prototype LCUs and easily configure the system through the configuration interface. There are no external components. The LCUs connects to the LCS network and are added to the system through the configuration interface.

The sirens noise level is configurable to exceed ambient noise level when installed in machinery areas of the vessel. The visual presentation of alarms, with use of a warning light and LED modules, are done according to Code on Alerts and Indicators (Section 4.3).

Figure 67 shows the finished prototype of the LCU. With a siren mounted on the left side of the LCU. LED modules on top of the cabinet with warning lights at the very top. Figure 68 shows the layout for the prototype LCU.

Figure 67: Final Result of Prototype

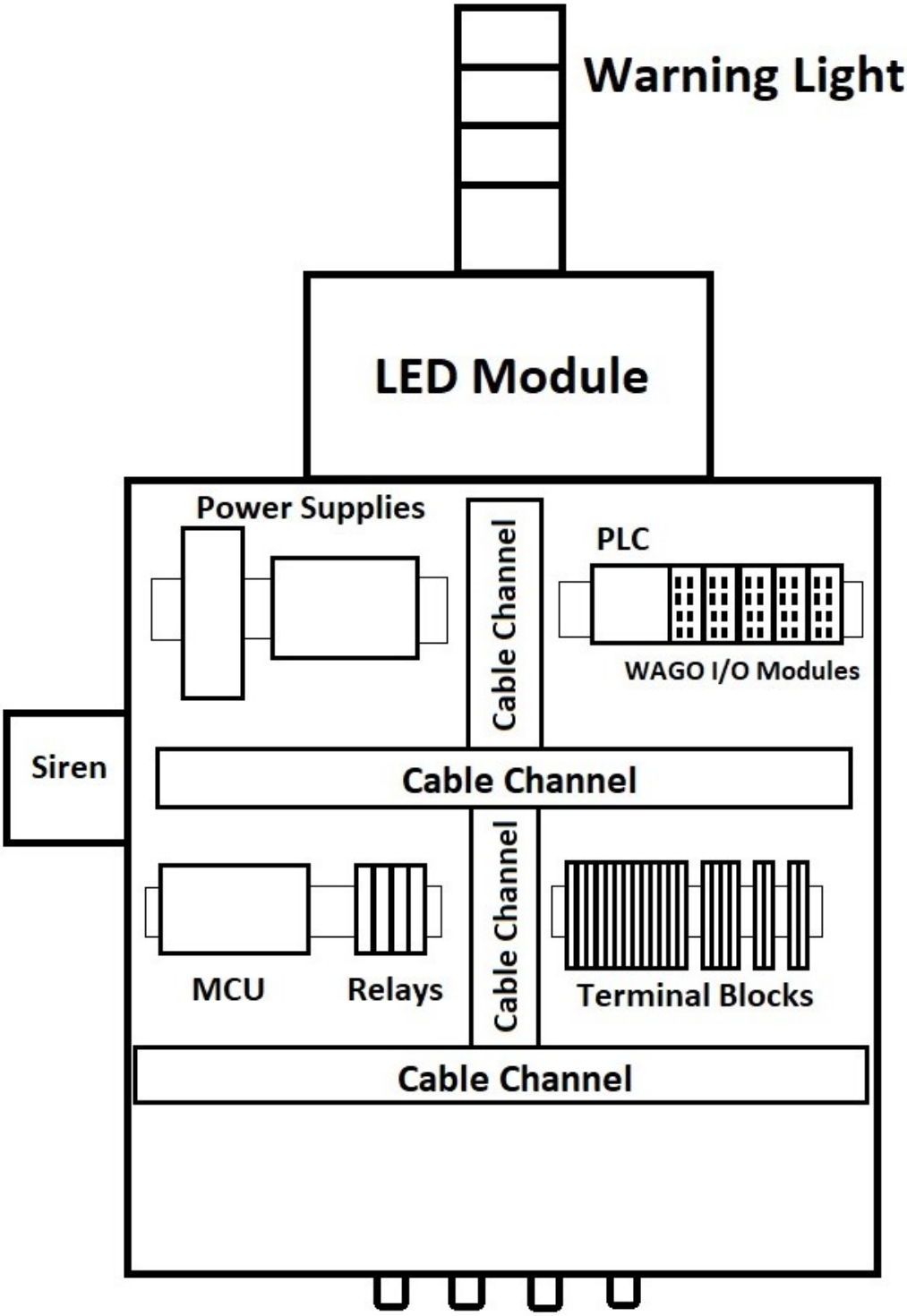


Figure 68: Cabinet Layout

5.2.2 System

The demonstration of the LCS for this project consists of four LCUs. The important concepts are proven in a realistic way. In a real system on board vessels, there are two LCUs that receives alarm inputs from the IAS, and this was taken into account when designing the system. With the use of Modbus TCP master/slave architecture, the LCUs are linked together through the Ethernet network. With four LCUs, it is possible to choose one master, one as redundant master and two slaves. As a criteria for the system, it is a scalable system and it is possible to choose desired LCUs to be master and redundant master.

There are 12 different alarms which is used in the system, but the simulated redundant master had only one relay switch module. This means that the redundant master only had eight different alarms to activate. That is enough for proving the concept for the system.

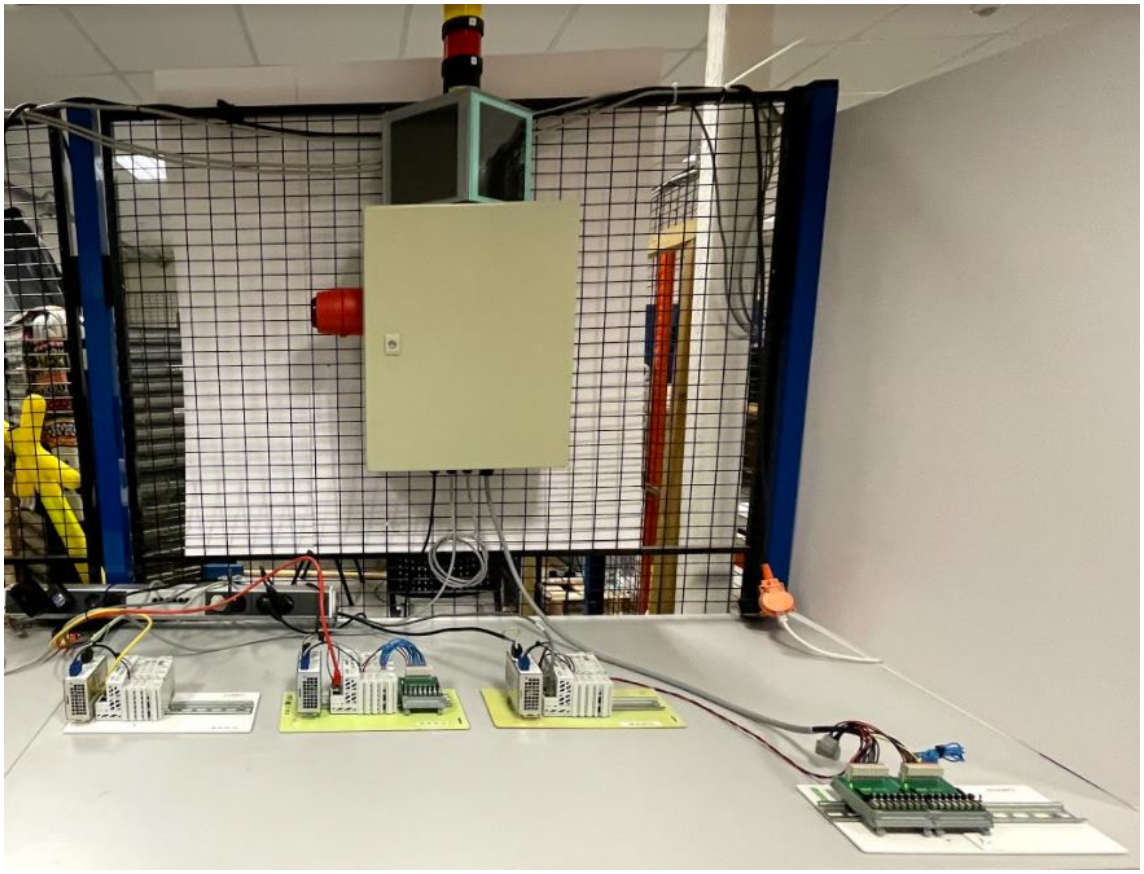


Figure 69: System Overview; Prototype LCU top middle, three simulated LCUs under, simulated alarm input from IAS at the bottom right

Figure 70 is a chart that shows the scalable system overview. The alarm signals are received to the LCS from IAS, to the master and redundant master LCUs. The alarm signals are forwarded by Modbus TCP, to all LCUs from slave 1 to the nth slave. If necessary, more LCUs can easily be connected and configured into the LCS.

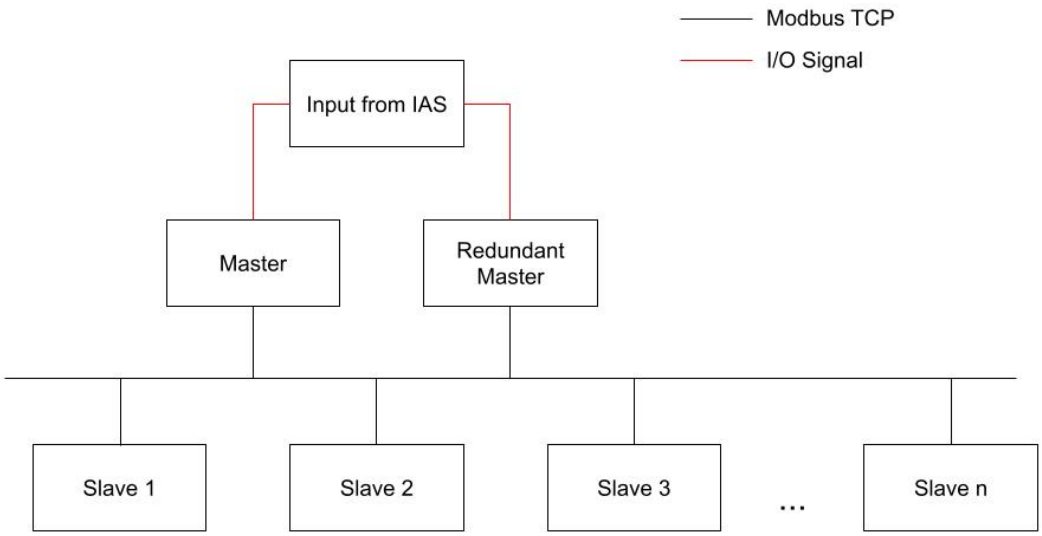


Figure 70: Overview of the the scalable LCS

5.2.3 Configuration Interface

The configuration interface was made with e!Cockpit. The configuration interface is working as intended with all functionality that was necessary for the project. With this configuration interface, the user can easily add as many LCUs as desired, choose role for the LCUs, and troubleshoot the system in case of system errors.

5.2.3.1 Home Page

Figure 71 shows the Home page where it will show a list of alarms that is activated or when it last was active. When an alarm is active, the table row will turn red. If the alarm is deactivated, the table row will change color to the original color of the row. All the alarms are listen on the left side of the page with a lamp indicating if the alarm is active. The current alarm will be visual on the right side of the page.

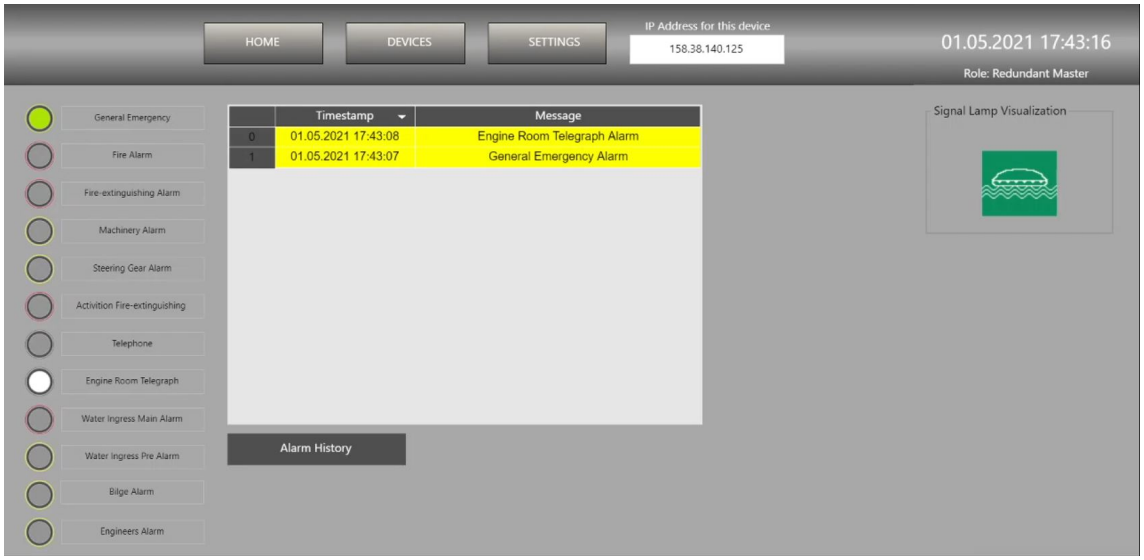


Figure 71: Home page

5.2.3.2 Device Page

In the Device page slaves can be added and removed from the system with simple buttons. It also shows the slaves IP addresses connected to the system and the status of each slave.

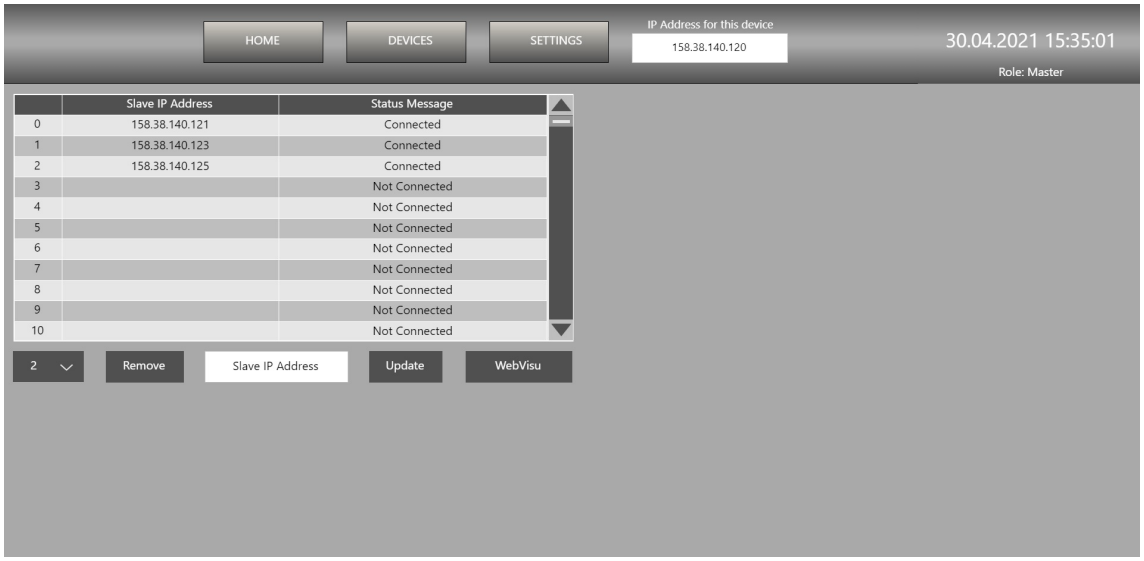


Figure 72: Device page

5.2.3.3 Settings Page

The last page is Settings. In this page you can choose whether the current LCU should be a master or a redundant master. The time before the redundant master takes over can be set in seconds.

Figure 73: Settings page

5.2.4 LED Module

The Figures 74, 75 and 76 show list of alarm symbols and the alarm images on the LED module. The camera used to take images of the LED modules does not represent the real colors of the LED modules.

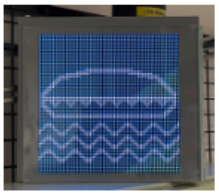
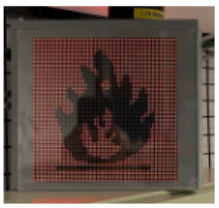
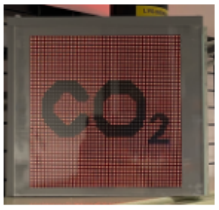
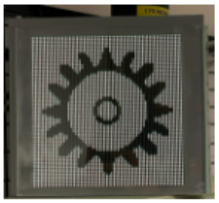
Function	Symbol	LED Module
General Emergency Alarm		
Fire Alarm		
Fire-extinguishing pre-discharge alarm	CO_2	
Machinery Alarm		
Steering Gear Alarm		

Figure 74: Alarm List with LED module images

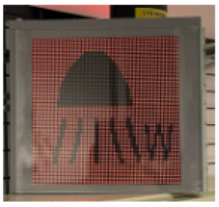
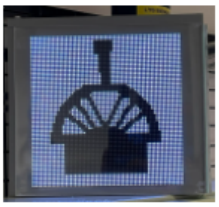
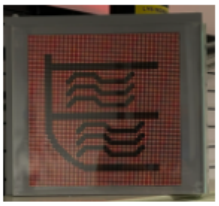
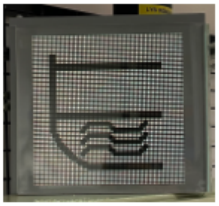
Activation of fixed local Application Fire-extinguishing system		
Telephone		
Engine room telegraph		
Water ingress detection main alarm		
Water ingress detection pre-alarm		

Figure 75: Alarm List with LED module images

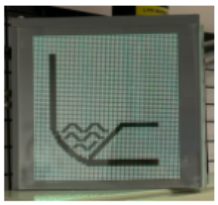
Bilge alarm		
Engineers' alarm		

Figure 76: Alarm List with LED module images

6 Discussion

This part of the project is about discussing the results, limits for system, or any other changes according to the plan. It do also contain experience the group have achieved during the project.

6.1 Concept Design

Modernization were taken in account when designing the LCS. As a criteria for the project, the system should be 'one-box-for-all' solution, which means that all the LCUs should have the same hardware, and it was not acceptable to have any other components except the LCUs themselves. With these criteria taken in account, a cabinet with all of the critical components inside, was a good solution.

6.1.1 Prototype

The prototype is a cabinet with a LED module, siren and warning light. As a criteria for this system was that there should not be any other components than the LCU itself. So a cabinet with the necessary components was a good solution for this system.

6.1.2 First Concept Design

It was early in the project made a drawing of a concept prototype for a LCU. The idea was a box like enclosure with the terminal blocks separated from the other important components. The installer of the LCU would open the bottom lid of the enclosure to expose the terminals, and then pull in the cables and connect. Figure 77 shows how the LCU was first drawn.

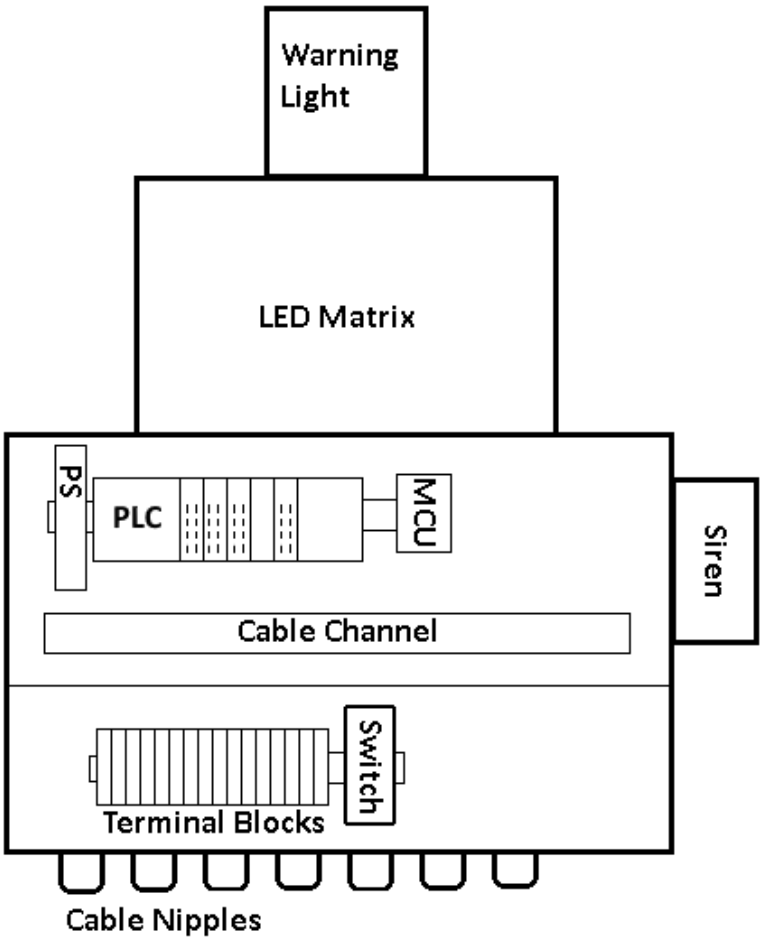


Figure 77: First drawing of the LCU

This solution was scraped because the group found it not acceptable to have one switch inside each LCU and it requires a custom enclosure.

The chosen solution have divided four different sections in the cabinet, as seen in figure 57 in section 4.8. The group found that solution more acceptable. The chosen solution is also tidier than the solution show above.

6.1.3 Visual System

It was at the beginning of the project discussed how the group wanted the visual system should be. It was discussed if the visual system should be of the type static or modular solution. The group wanted to modernize the LCU, and a LED module display was a good option for the solution. This makes the visual system static and easily scalable. The current LCU used by Vard is a modular design which means you have to physically remove or add modules from the LCU.

6.1.3.1 Warning Light

It was desired to use a 32x8 LED matrix for the warning light. With the use of a LED matrix as warning light, it is easy to set different colors for the warning light. Figure 78 shows an image of the LED module that was desired as a warning light. This plan had to be scrapped at the end of the project because of the LED matrix did not work with the LED module display used for the alarm symbols. There was no time left for research to fix it, and the group came up with the idea to use a 'traffic light' instead, which can be seen in figure 49. This type of traffic light only need three outputs from the PLC, and was easy to implement. This makes the warning light PLC dependent, rather than LED driver dependent.

Figure 78: Desired Warning Light

6.2 Redundancy

6.2.1 Redundancy Standard

When the group started to think about the redundancy for the system, it was discussed how the redundancy should be implemented for the system. The two options warm redundancy and hot redundancy were the two options (Section 2.4.1). The group found it best to go for the warm redundancy standard where the system can handle that the master PLC is down for a short amount of time, and it was not system critical that the redundant master should not take control immediately. This standard is a bit easier to implement, since it can use a heartbeat signal from the master PLC to the redundant master PLC.

6.2.2 Watchdog Timer

The group got information from supervisors that a watchdog timer was a possible solution to achieve more redundancy to the LCS. A watchdog timer is an external circuit that can observe and detect faults to a software [4]. For example if the PLC uses to long time to run the program, the watchdog timer can reset the program or stop the power for the PLC. Figure 79 shows an example of a Watchdog Timer. A watchdog timer could be added to the PLC or the MCU.

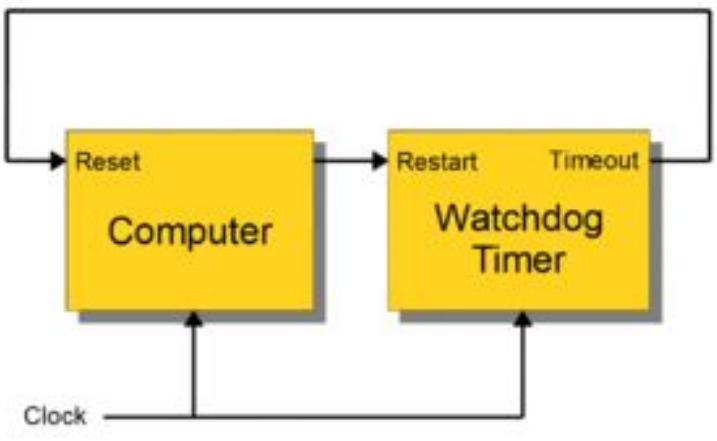


Figure 79: Example of Watchdog Timer

6.3 Network

Beginning this project the network was a discussion. What is the cheapest, most redundant and best of use on board vessels. It has also been taken in account that the new design criteria that the system should be easily scalable 1.3. The group ended up with a system that can be used with both Campus and Ring network. How the network was set up had no impact on the system's function. Both networks are redundant in their own way.

6.4 Communication Protocols

Modbus TCP is the chosen communication protocol data transfer between the LCUs. It is a communication protocol that easy makes the system scalable. The Modbus TCP protocol does provide reliable data transfer, which was highly desired. A possible solution was to use the Modbus UDP protocol, which can provide high-speed communication between devices, but the risk of loosing data was taken in account when deciding for which communication protocol to use. Therefore, the group found Modbus TCP the best solution for the LCS.

6.5 Choosing Alarms

The chosen alarms is taken from the alarm list from the IMO-VEGA document Code on Alerts and Indicators [21]. This document contains a list of a certain amount of alarms for vessels. The alarms listed is for alarms in both passengers and crew areas. The LCS is mainly developed for crew areas, so the group found it most important to use the alarms for the crew areas.

6.6 Improvements

Closing up to the end of this project the lack of time sat a limit of how much prevalence that could be achieved. The listed points below are possible suggestions for how to develop the LCS in the future.

- Software
  - Auto detect new LCUs on the network
  - Add a Watchdog Timer
- Hardware
  - Brighter warning light
  - RGB LED as warning light
  - More compact design
  - Custom enclosure

6.7 Group Experience

The group members have diverse backgrounds which facilitated good dynamics and a broad knowledge area, which has come in handy during the project. All the participants in the group have worked steadily and well with the project along the way. There has been good communication and cooperation between the group members, which has resulted in a nice and steady progress.

7 Conclusion

This thesis concerns the research and development of a clustered AOS (LCS) which is both scalable and easily configurable. A LCS aboard a vessel serves the benefit to notify crew in noisy areas in case of emergency from the vessels many AOS. Today's LCS are not scalable and configurable for the installer. The assignment was given by Vard Electro along with design criteria. This includes a 'one-box-for-all' solution with a redundant master/slave architecture.

One of the most important objectives for project was to make a reliable and functional LCS with multiple LCUs working seamlessly together in a redundant master/slave architecture. One LCU acting as master, one as redundant master, and the rest as slaves. The LCUs are linked together through the Ethernet network. The LCS is easily scalable and configurable, with the use of the user-friendly configuration interface.

A prototype was developed as part of the project to illustrate the visual and audible presentation of alarms, with a standard full design. The visual alarm symbols are displayed on LED modules placed on top of the prototype, and the warning light placed above flashes the color according to class rules. The audible presentation of alarms were done with the siren, mounted on the side of the prototype, that is configurable to above ambient noise level in machinery areas.

The project is mainly based on the design criteria from Vard Electro. The group considers all the design criteria as completed, except automatically recognize new LCUs in the network. Instead the user has to manually add new LCUs to the system through the configuration interface. Overall, the group considers the project as a success.

As mentioned before, there are improvements to be made (Section 6.6).

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Appendix

A Pre-Project Report

NTNU

Kunnskap for en bedre verden

Department of ICT and Natural Sciences

IE303612 - Bachelor Thesis

Light Column System

Pre-Project Report

Candidates:
Per-Stian Alvestad
Gustav Sørdal Hagen
Ole Jørgen Klemetsen Buljo

January 28, 2021

NTNU
Kunnskap for en bedre verden

Title:

Light Column System

Candidates:
Per-Stian Alvestad

Gustav Sørdal Hagen

Ole Jørgen Klemetsen Buljo

Date:	**Course Code:**	**Course:**	**Document Access:**
January 28, 2021	IE303612	Bachelor Thesis	Open

Study:	**Pages/Attachments:**
Automation Engineering	1of 15

Course Coordinator(s):

Kai Erik Hoff

Ottar Laurits Osen

Supervisor(s) (Roles):

Nermin Konjhodzic (Product Manager - Communications)

Andreas Hjellbakk (R&I Manager - Product)

Tommy Sønderland (Manager - Electrical Department)

Revision	**Date**
A	January 20, 2021
B	January 28, 2021

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1 Introduction

The group will research and develop a light column system for Vard Electro. A light column system is an audio and optical notification system for various alarms aboard a ship with purpose to warn the crew. The light columns are located in rooms with relatively high noise level, particularly within the area of engine room. The light column systems must follow specific safety rules and regulations, such as Code on Alerts and Indicators 2009 required by the SOLAS Convention[1]. The requirements for alarms for the light columns depend on the purpose of the ship, class and governmental regulations.

The light column systems installed aboard ships today are not scalable and hard to configure for the installer. To do changes on existing light column systems, it requires a lot of competence and there are no interface possibilities. The assignment is to design and develop a light column system that is easy to install, expand, re-configure and interface with. It is required that the system must be redundant and reliable.

2 Terms

LCS	Light Column System
LCU	Light Column Unit
PLC	Programmable Logical Controller
AOS	Audio and Optical Notification System
LAN	Local Area Network
IAS	Integrated Automation System
NTNU	Norwegian University of Science and Technology
I/O	Input/Output
GUI	Graphical User Interface
GA	General Arrangement

3 Project Organization

3.1 Project Group

Candidates:
Per-Stian Alvestad
Gustav Sørdal Hagen
Ole Jørgen Klemetsen Buljo

3.1.1 Tasks for Project Group - Organization

Role	**Student**
Manager	Gustav Sørdal Hagen
Secretary	Ole Jørgen Klemetsen Buljo
Worker	Per-Stian Alvestad

Table 1: Project Group with Role

3.1.2 Tasks for Project Manager

The project manager have the responsibility to have a overview of the entire project. The project manager do also have to work with tasks during the project, but at the same time:

- Look after that all tasks are being done according to progress plan.
- Responsibility to invite supervisors from NTNU and Vard Electro to meetings.

3.1.3 Tasks for Secretary

The secretary has the responsibility to:

- Write meeting reports for all meetings with management group.
- Make sure all group members documents the work they are doing.

3.1.4 Tasks for Other Members

All members in the project group has to work the tasks they are given according to the progress plan. All main tasks have been given a group member as charge, and rest of the group as available to help. All of the group members have the responsibility to work on their given tasks and write documentation for their own tasks. If the group can work with that standard, it will be easier to write the final report for the project.

3.2 Management Group (Supervisors and Contact person, Client)

NTNU have two representative persons for the project:

Supervisors:
Kai Erik Hoff
Ottar Laurits Osen

Vard Electro have three representative persons for the project:

Supervisors (Roles):
Nermin Konjhodzic (Product Manager - Communications)
Andreas Hjellbakk (R&I Manager - Product)
Tommy Sønderland (Manager - Electrical Department)

4 Appointments

4.1 Agreement with Vard Electro

The group will have a non-disclosure agreement with Vard Electro. Vard Electro have to specify what information is confidential.

4.2 Workplace and Resources

Due to the situation with Covid-19 it is not possible for the students to work with the Bachelor thesis at Vard Electro's offices in Tennfjord. Primary workplaces will be at the students homes, or laboratory on the NTNU campus Aalesund.

NTNU have a lot of tools and equipment that will come to use throughout the project. Vard Electro may also provide equipment if needed.

Vard Electro engineers are available to the group if we need advice throughout the assignment. Due to the Covid-19 situation they are able to help through Microsoft Teams or Zoom meetings.

4.3 Group Norms - Cooperation Rules - Attitudes

- The group should meet to agreed time everyday.
  - By exception, agree with the rest of the group.
- The students should behave well to the rest of the group.
- The students should be transparent with each other.
- Give constructive feedback to each other.
- Attend at all meetings
  - By exception, agree with the rest of the group.

5 Project Description

5.1 Problem Statement - Objective - Purpose

The vessels are normally equipped with AOS to indicate/notify the crew in noisy areas of the vessel if anything needs attention. This is usually engine alarms, fire alarm, telephone call, man overboard or abandon ship. The setup of this is regulated by purpose of the vessel, class and governmental rules.

The different AOS alarms on board can be installed as one AOS pr. system, or it can be clustered together and programmed by logic to serve multiple purposes. Thus, creating a LCS.

Today, the LCS used are not scalable or configurable for the installer or the client. This means that it is difficult for the user to change or update the system.

5.2 Requirements for Solution or Project Result - Specification

The group has received a assignment text from Vard Electro where new design criteria for the system are listed.

- Standard full design with X number of lights and X number of sirens according to rules and regulations.
- Simplified change in design/number of parts, program to recognize the removed/added part and inhibit the output and available selection in configurator.
- Simplified installation of system – system to use an Ethernet network (System LAN) for linking the units.
- Master and Slave architecture, with one LCU acting as Master, one as Redundant Master, and rest as Slaves.
- No external system components except the LCUs them self.
- One-box-for-all-solution – All LCUs to be same hardware, but have different roles (Master/Slave)
- PLC and relay must be of WAGO type.
- Program must be of Codesys.
- Alarm output to Vessel alarm system (IAS) (broken relay output/power failure/PLC error).
- Scalable with more relay stacks.

It is not a requirement from Vard Electro that a finished product must be made, but it is desirable that a prototype of the system should be made.

5.3 Planned Procedure for Development - Method

Progress
The group will use TeamGantt to document the progress through the project. The gantt diagram visually represents the project plan over time and who is responsible for each task.

PLC
The PLC will be developed in the WAGO software e!Cockpit. In e!Cockpit, it is possible to connect and write program in Codesys, connect I/Os to the I/O module, create connection to Modbus and create a Visualization.

Network
The group will design a network that is redundant and reliable. To achieve this the group must find a solution for the best possible network architecture.

Electronic
The electronic part will be designed and coupled according to documentation and drawings.

Prototype
There will be built a prototype based on the research and development in this project. All the necessary components should be ordered in early phase of the project.

5.4 Information Gathering - Performed and Planned

Most of the information will be gathered from previous courses and projects. The members in the project groups have had some relevant courses for this assignment.

The group does also have access to internet and people that can give information for some of the tasks. Datasheet for components are also some of the tools that can come in handy for the project.

5.5 Assessment - Analysis of Risk

From the Pre-Project Report is delivered, the group has about 4 months work on the project. The group is optimistic to be done with the project within the deadline.

It is a problem for the project group if the Covid-19 situation is getting worse during the project. The government can force NTNU to close the Labs. The group needs some equipment which the school have access to.

No.	Risk	Likelihood	Severity	Reduce Risk
1	Illness	1	2	Good hygiene and enough sleep
2	Loss of Data	1	2	Cloud storage
3	To Much Work	2	3	Work steadily
4	Component Failure	1	2	Proper use and testing
5	Component Delay	2	2	Plan ahead, early order
6	Short Circuit	1	3	Follow wiring diagram
7	Behind Schedule	1	3	Meet with supervisors
8	Covid-19 Infection	1	3	Good hygiene and few close contacts
9	Covid-19 Restrictions	2	2	Stay home and use masks.
10	School Closed	2	2	Bring components home if possible
11	Quarantine	1	2	Few close contacts

Table 2: Risk Table

The table above shows what risks the group can experience during the project. The likelihood is leveled from 1 to 3, where 1 is least likely and 3 is most likely to happen. Severity is leveled from 1 to 3, where 1 is least critical for the implementation and 3 is most critical for the implementation.

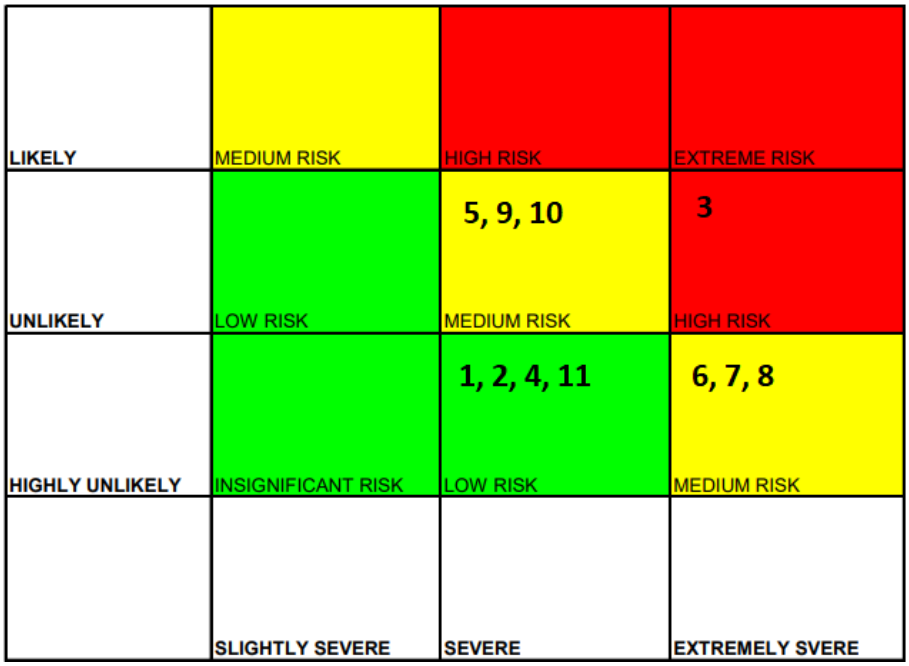

Figure 1: Risk Matrix

5.6 Main Activities in Further Work

The main activities is listed below. Changes may occur if needed:

Main Activity	**Responsible**
Project Initialization	All
Pre-project Report Draft	All
Pre-project Report Final	All
Physical Visual System	Ole Jørgen
Concept Design	All
Network System	Gustav
Main PLC Program	Per-Stian
Configuration Interface	Gustav
Physical Audio System	Per-Stian
Prototype of System	All
Weekly Project Meetings	Gustav
Meetings (updated for every meeting)	Gustav
Main Project Report	All
Presentation	All

Table 3: Main Activities with Responsible Student

5.7 Progress Plan - Project Management

5.7.1 Master Plan

Project Initialization
This is the phase where the project is started. The project started after there was a meeting with NTNU and Vard Electro. The project-planning part is also in this phase of the project. To be ended when this report is delivered.

Pre-project Report Draft
A report where the project is described. This is just the first draft and it should almost be done. To be delivered at Jan 20th.

Pre-project Report Final
The updated Pre-Project report where the project plan is finished. The group members has responsibility for the pre-project report. Planned to be delivered at Jan 28th.

Physical Visual System
Here is the visual part of the LCS being developed. Planned to start this phase when the Pre-Project report is delivered.

Concept Design
This part is about that the project group can come with different solutions for how to achieve the goal for the project. The group can find more than one solution and find out what is the best solution. Starts when the project group is starting the main project.

Network System
This part of the project is where the network system is being designed. Planned to be started at Jan 29th and should be finished at the end of the month. Changes can occur.

Main PLC Program
This part is about programming the main program for the PLC. The part contains research on PLC redundancy, plan I/O-modules and programming.

Configuration Interface
This main activity is about to create an interface that the operator can configure a specific LCU. This is one of the criteria for the project. Planned to start this activity when the building of the prototype is being started and planned to be finished within 14 days.

Physical Audio System
The audio-part of the LCS is to be started at Jan 28th.

Prototype of System
When the network system, visual system and audio system is done, the project group will start to build the prototype of a LCS.

Weekly Project Meetings
Every Friday the project group are going to have a meeting and write a status report where the group describes how the project is at the time.

Meetings (updated for every meeting)
This is the part where the project group invited the supervisors from both NTNU and Vard Electro for meeting if there are some part of the project where the project groups needs external input.

Main Project Report
This is the main report for the project. The main report should be updated continuous and be done around May 20th.

Presentation
When the main project report is done, the presentation is the last part of the project.

5.7.2 Project Management Tools

Tool	Usage
Google Drive	Cloud storage for files and documents
Google Documents	Writing meeting reports and status reports
Google Sheets	To make BOM-list and other lists
Google Drawings	Making Flow Charts and other drawings
TeamGantt	Making Gantt diagram
GitHub	Version Control for program code
Microsoft Teams / Zoom	Meetings with management group
Discord	Internal project meetings
Overleaf	LaTeXwith a modified template for "Template Project NTNU"

Table 4: Project Management Tools

5.7.3 Development Tools

Tool	Usage
e!Cockpit	WAGO Software for programming PLC
Arduino IDE	Develop LED-driver program for MCU
Autodesk AutoCAD	Drawing electrical wiring diagrams
Autodesk Fusion 360	Develop 3D models

Table 5: Development Tools

5.7.4 Internal Control - Evaluation

The group will have meetings every Friday where the group will discuss the past week and write a status report. In the meetings, there is also possible to plan if the group should work in the weekends.

The group will have continuous contact with each other. When a task is done, the project group will update the progress plan.

5.8 Decisions - Decision-making Process

If a group member have to make a decision, the whole group should be aware of the decision and eventually consequences of the decision.

6 Documentation

6.1 Reports and Technical Documents

6.1.1 Essential Documents for PLC System

- System overview and complete description of control operation
- Block diagram of the units in the system
- Complete list of every I/O, destination and number
- Wiring diagrams of I/O modules, address identification for each I/O point, and rack locations

6.1.2 Essential Documents for LAN System

- Wiring diagram for network
- Complete list of switches
- Complete list of address identification

6.2 Other Essential Documents

- Datasheet for components used in the project
- Documentation for the configuration interface
- Pre-project report
- BOM-list
- GA and wiring diagram

7 Scheduled Meetings and Reports

7.1 Meetings

7.1.1 Meetings with the Management group

The project group will invite to meetings with supervisors once a week.

7.1.2 Project Meetings

Scheduled project meetings each Friday:

Week	Date
Week 3	Friday 22.January
Week 4	Friday 29.January
Week 5	Friday 05.February
Week 6	Friday 12.February
Week 7	Friday 19.February
Week 8	Friday 26.February
Week 9	Friday 05.March
Week 10	Friday 12.March
Week 11	Friday 19.March
Week 12	Friday 26.March
Week 13	Friday 02.April
Week 14	Friday 09.April
Week 15	Friday 16.April
Week 16	Friday 23.April
Week 17	Friday 30.April
Week 18	Friday 07.May
Week 19	Friday 14.May
Week 20	Friday 20.May

Table 6: Planned Weekly Project Meetings

All project meetings to be online using the Discord app.

7.2 Progress Reports (included. Milestone)

The group will write a progress report on every project meeting each Friday. These progress report will be delivered to supervisors from NTNU.

8 Planned Deviation Management

If the project does not work out the way it should, the project group can edit the progress plan and find another solution to the project. This will be planned with the steering group.

9 Equipment Needs / Prerequisites for Implementation

Component	**Usage**
LED-Matrix	Visual indicator for alarm
MCU	LED-driver
Warning Light	Visual signal for alarm
Power Supply	Power to the system
Terminal Block	Connector between cables and components
PLC	Controller for the system
I/O-module	Connect components to controllers
Network switch	Communication between PLCs
Siren	Audio for the system

Table 7: Equipment

Bibliography

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B Project Assignment

Vard Electro AS

Bachelor assignment

LIGHT COLUMN SYSTEM

REV A

Date: 14 September 2020

CONTENT

ASSIGNEMENT

1.1 INTRODUCTIONS

The vessels are normally equipped with audio and optical notification system (AOS) to indicate/notify the crew in noisy areas of the vessel if anything needs attention.
This is usual: Engine alarms, fire alarm, telephone call, man overboard or abandon ship.
The setup of this is regulated by purpose of the ship and class, governmental rules.

These different AOS alarms can be installed separately and serving only one purpose (one AOS pr. system), or it can be clustered together and programmed by logic to serve multiple purposes. (Light Column System, LCS).

1.2 HOW IT WORKS TODAY

Pr. today Vard Electro are using both methods of AOS setup.
However, the LCS used are not scalable or configurable for the installer or the client, and this creates a change order or an update very difficult to execute.

Normal installation and configuration contain:

1. Light for each main system according to class rules
2. Siren with dB level above ambient noice level
3. Air typhone with magnetic valve

1.2.1 PRO:

- ”Off-the-shelf” product
- Easy to work with, if standard assembly

1.2.2 CONS:

- Not scalable
- Not configurable
- Needs high competance to re-program
- No interface posibilities, outside main purpose

2.1 NEW DESIGN CRITERIA

- Standard full design with X number of lights and X number of sirens according to rules and regulations.
- Simplified change in design/number of parts, program to recognize the removed/added part and inhibit the output and available selection in configurator.
- Simplified installation of system – system to use an ethernet network (System LAN) for linking the units
- Master and Slave architecture, with one LCS unit acting as Master, one as Redundant Master, and rest as Slaves
- No external system components except the LCS units them self
- One-box-for-all solution – All LCS units to be same HW, but have different roles (Master/Slave)
- PLC and relay must be of WAGO type.
- Program must be of Codesys
- Alarm output to Vessel alarm system (IAS) (broken relay output/power failure/PLS error)
- Scalable with more relay stack`s.

3. INFORMATION AND CONTACT

3.1

The student does not need to have electrical experience, Vard Electro will give the student technical information on how to solve the “electro” part of the task.
The student will have a contact person and a supervisor.
Vard Electro will provide the student with a work desk close to the engineers who will be the end users of the product.

Contact information:
Tommy Sønderland, tommy.sonderland@vard.com
Nermin Konjhodzic, nermin.konjhodzic@vard.com

C Meeting Reports

Light Column System
Meeting Report

Date and time:
Wednesday 13.01.2021 kl 10:30

Attendance (students):
Per-Stian Alvestad, Ole Jørgen Klemetsen Buljo, Gustav Sørdal Hagen

Attendance (supervisors):
Nermin Konjhodzic

Agenda:
Information meeting, questions from the students

Questions from students:

1. Are the students going to make a physical system
    a. Can be helpful to build a prototype
    b. Make a physical system with network and some light columns to prove the system
2. What does Vard Electro expect from the project group during the project?
    a. Vard Electro forventer at vi gjør det som NTNU forventer og at vi legg en god del arbeid i oppgaven.
    b. Vard Electro expects that the group does what NTNU expects and that the group puts in the work needed to achieve a desired result.
    c. Vard Electro is looking for a solution
3. In the assignment text from Vard Electro, it states that the group can work with the assignment at Vard Electro's office in Tennfjord. Is this still a real opportunity considering the Covid-19 situation?
    a. Due to the Covid-19 situation, it is not possible for the group to work with the assignment at Vard Electro's office.

Other subjects:

- The light column is a convoy system
- It is not blinking lights with multiple I/Os. There is a lot of security regulations.

- Design criteria
    - Scalable design with x number of lights and siren
        - Possible to add alarms for specific system
    - Easy to change the system to something else
    - Use LAN
        - Should be able to use remote control
        - Automatic setup of a unit that is connected
        - Easy to corporate with other systems onboard
    - Master/Slave architecture
        - Should not have a computer besides the system, but possible to connect a service-machine
        - Every single light column to have a own PLC
    - PLC have to be of WAGO, and use Codesys
        - Minimal configuration
        - Use a GUI for adding and remove parts of the system
    - Alarm output to IAS
    - Should be able to connect a relay stack if needed
- Proof of concept
- List of components, especially main components
- The students have to find rules for the system

Light Column System
Meeting Report

Date and time:
Tuesday 19.01.2021 - 12:15

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Bujo

Attendance (supervisors):
Ottar Osen, Kai Erik Hoff

Agenda:
Guidance meeting

Questions from students:

Other subjects:
Appointment with Vard Electro:

- NTNU do have some templates for appointment

Ottar sends the report from the group that had the same assignment in 2019

Light Column System
Meeting Report

Date and time:
Monday 25.01.2021

Attendance (students):
Ole Jørgen Klemetsen Buljo, Gustav Sørdal Hagen, Per-Stian Alvestad

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen

Agenda:
Pre-project report, general assignment, agreements with VE

Questions from students:
Appointment with NTNU and VE?

- Kai Erik and Ottar approved the appointments that the project group had signed.

Other subjects:
Pre-project report

- Draw risk matrix
- Gantt, more details for each task (Basic research, develop, testing, finalyze)

Agreements with VE:

- Approved NTNU NDA

Capture more design criterias from Vard, absolute requirements

- I/O
- Zone
- IP-rating
- Redundancy (CPU / network / I/O)

Design

- Multiple solutions for the system
    - Solution A
    - Solution B
    - Solution C
- Pros/cons with each solution
- Find the best solution

Watchdog

- What is watchdog?

WAGO

- Capture software/hardware support for redundancy

Light Column System
Meeting Report

Date and time:
Thursday 28.01 at 10:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Nermin Konjhodzic, Andreas Hjellbak

Agenda:
Questions from the students

Questions from students:

- What type of network structure should the project have?
    - Campus-network, core-system
    - Vard Electro is going to see if a ring-network can work
    - Network outside of the LC-units
    - Project group to research pros/cons of ring-network vs campus-network
- Siren
    - Vard Electro have siren the project group can use
- Capsule for the LC-units
    - Project group to put the electronics in capsule
    - Vard Electro said IP54
    - IP44, see IP-table from DNV
- Signal cable in/out for the LC-units
    - Signal from fire-alarm system, phone system
- Redundant power supply? Redundant network? Redundant CPU?
    - Focus on network
    - But think of backup system for master
- LED-matrices for indicating alarms, warning light?
    - Students to decide
    - Try to think of cost
    - Are there requirements for Lux?
- Making GA and wiring diagram

    - Use AutoCAD or Visio

Other subjects:

- Agreements between students and Vard Electro
    - Project group has sent agreements to Vard Electro
    - Answers on the agreements within short time

Light Column System
Meeting Report

Date and time:
Tuesday 09.02 at 10:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Nermin Konjhodzic, Andreas Hjellbakk, Artem Kornilov

Agenda:
Workshop Network Architecture

- Solve once and for all the question about network architecture
    - Ring network vs Campus network

Ring network

- A lot of work to expand the system

Campus network

- Easier to expand than a ring network

Questions from students:

Other subjects:
Cannot cross multiple firezones with network
Can only lose one network node

- The rest have to work

Light Column System
Meeting Report

Date and time:
Wednesday 10.02 at 10:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen

Agenda:
Progress meeting with coordinators from NTNU

- Weekly progress reports

Questions from students:

- Components
    - Budget for each bachelor group
        - 5000 NOK
    - Should order from Anders on the Labs
    - Find refund scheme on ntnu.no for refunding components that is ordered self

Other subjects:

- Network
    - Group deciding to use Campus Network
- LED-matrix
    - One LED-matrix pr LCU
- Find different solutions
    - Find the best
    - Write about different solutions in the final report
- The discuss part in the final report is important
    - Reflect on the different solutions

Light Column System
Meeting Report

Date and time:
Thursday 18.02 at 09:30

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen

Agenda:
Problems with I/O-modules
- Module 750-602 is the solution

Maybe work at campus
- Important to work together

Standard Appointments signed by Vard Electro
Holiday in China is a problem for delivering components

Questions from students:

Other subjects:

Light Column System
Meeting Report

Date and time:
Thursday 04.03 at 09:30

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff

Agenda:
Progress Meeting with supervisors from NTNU

- PLC
- Main PLC program
- Final Report
- LED-Matrix
    - Simulate LED-matrix can be a solution if delivery takes to much time

Questions from students:
A paragraph about Vard Electro in the Introduction part of the final report?

- Yes, some lines is possible

Other subjects:

Light Column System
Meeting Report

Date and time:
Monday 15.03 at 10:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff

Agenda:
Status meeting

- Not much work since last meeting due to lectures in the course Industry 4.0
- Problem with MCU
    - Will be worked on during this week

Questions from students:

Other subjects:

- Distribution of tasks
    - Distribution of tasks seems fine

Light Column System
Meeting Report

Date and time:
Thursday 25.03 at 10:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen

Agenda:
LED-Matrix

- Waiting for a new LED-Matrix
    - Last one did not work for this project
- LED-Matrix to use private after project

PLC

- Cleaned code
- Made a lot of progress on the master/slave program
- Redundancy
    - Redundant master is working
        - Will be improved
- Explained the functional PLC program to Kai Erik and Ottar

Cabinet

- The cabinet which was delivered first was to small
    - Could be planned better before ordering
- The group found a new cabinet at RS Online which is twice the size
    - Kai Erik approved to order it

Budget

- The group do have a total of 5000NOK
    - The group is far away from the limit at this point in the project.
    - Anders Sætersmoen at the labs will take the cabinet which was to small

Questions from students:

Other subjects:

Light Column System
Meeting Report

Date and time:
Monday 12.04 at 14:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff

Agenda:
Progress Meeting:

- Cabinet
    - Soon finished prototype
    - Waiting for LED-matrix to be delivered
- Report
- LED-matrix
- Functional Testing

Questions from students:

Other subjects:

Light Column System
Meeting Report

Date and time:
Monday 26.04 at 13:30

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen

Agenda:
LED-Matrix
- LED-Matrix have arrived
- Working as it should

Presentation
- Make a short video of the system

Report
- Done some writing on the main report

Redundancy
- Discuss what is redundant and not

Test procedures
- Document tests
- Explain them in the result part

Questions from students:
Code snippets in the report?
- Use a flow chart instead of code to explain

Other subjects:
Invite Vard Electro to progress meeting

Light Column System
Meeting Report

Date and time:
Tuesday 27.04 at 13:00

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Nermin Konjhodzic

Agenda:
Progress:

- PLC software
- LED-matrix
- Warning Light
- Alarm
- Configuration Interface

Vard Electro is impressed of the progress so far

Questions from students:

Other subjects:
Vard Electro will attend at next progress meeting with NTNU

- Planned at Monday 10.05

Light Column System
Meeting Report

Date and time:
Monday 10.05 at 13:30

Attendance (students):
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Attendance (supervisors):
Kai Erik Hoff, Ottar Laurits Osen, Nermin Konjhodzic

Agenda:
Status
- System is complete
- All criterias is reached
    - Some parts could be more optimized

Video for presentation
- A bit too long
- May add some voiceover for explaining different subjects

Report
- Group to deliver a draft at monday 10.05
- Add a short text for explaining different sections of the report

Vard Electro is looking forward to read the final report

A well-executed project

Questions from students:
Anders (at the labs) wondered if he gets back the traffic light
- Ottar should check if he wanted it

Other subjects:

D Progress Reports

Light Column System
Weekly Status Report

Week:
Week 3

Date:
Friday 22.01

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
The group delivered the first draft for the Pre-Project Report on wednesday Jan 20th.
We have done some research on the Physical Visual System (PVS), and we have some thoughts on how to develop that part of the system. We figured out that we are going for a LED-matrix that is controlled by a microcontroller unit (MCU) such as Arduino etc. We have ordered a 16x32cm LED-matrix for testing.
The group has reserved 4 PLC from the Electronic Lab at NTNU. These are the PLCs that we are going to work with through the whole project. They will also provide the group with licenses for e!Cockpit.
We have sent an email to Vard Electro where we asked if they had some sirens we can use during the project.

Problems:
No problems at the time of writing.

Further work:
Finish the final draft of the Pre-Project Report which is being delivered on wednesday Jan 27th.
Start researching the network system, physical audio system (PAS).
Start developing the PVS.
A meeting with Kai Erik and Ottar is planned Monday Jan 25th.

Light Column System
Weekly Status Report

Week:
Week 4

Date:
Friday 29.01

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
PVS:
More research.

Network:
Research on WAGO Redundancy.
Research on Pros/Cons for Ring Network vs Star Network

PAS:
Research on alarms
Vard Electro have sirens which can be used during the project.

Problems:
No problems at the time.

Further work:
Continue Research on different main activities. Maybe starting to design a possible network architecture.
Waiting for LED-matrices and MCUs and start programming

Light Column System
Weekly Status Report

Week:
Week 5

Date:
Friday 07.02

Students:
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Status:
Due to a lot of work with the course Industry 4.0 it has not been that much work on the bachelor assignment this week.

We have started on the development for the LED-matrices. We are now able to put the colors of the LED-matrices in an array so we can make a LED picture.

We have started on the development for PLC.

Problems:
No problems at the current time.

Further work:
We are going to have a workshop with Vard Electro on Tuesday Feb 9th. We are going to work with network architecture.

Light Column System
Weekly Status Report

Week:
Week 6

Date:
Friday Feb 14th

Students:
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Status:
We have brought 4 PLCs home, so we can work from home with the communication between the LCUs.

We have picked up a siren from Vard Electro that we can use during the project.

Problems:
It might take some time for us to get the ordered LED-matrix because of the holiday in China

Further work:
Continue developing the network with PLC.
Continue developing the LED-matrix.

Light Column System
Weekly Status Report

Week:
Week 7

Date:
Friday 19.02

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Fixed problem with I/O-modules that occured this week.
- 750-602-module was needed for delivering power to the I/O-modules.

Progress on the modbus-communication
Progress on the main program
Made I/O-list

Problems:
Master TCP
- Contact WAGO support at monday next week

Further work:
Continue working with the communication
Continue developing the main program

Light Column System
Weekly Status Report

Week:
Week 8

Date:
Friday 26.02

Students:
Per-Stian Alvestad, Gustav Sørdal Hagen, Ole Jørgen Buljo

Status:
There is communication between master and slave
- WAGO Support have been very helpful

Continued working with the PLC main-program

Still waiting for the LED-matrix to be delivered.
- Tested the MCU in arduino

Problems:
Some problems with the MCU
- Does not upload code from Arduino to MCU

Further work:
Continue on the main PLC program
Continue with the master/slave program
Fix problem with arduino

Light Column System
Weekly Status Report

Week:
Week 9

Date:
Friday 05.03

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
- Not so much work was done this week due to lectures in the course Industri 4.0.
    - Will be the same next week (week 10)
- Done some writing on the final report

Problems:
The problem with arduino is still a case

Further work:
Continue with main PLC program
Continue writing report

Light Column System
Weekly Status Report

Week:
Week 10

Date:
Monday 15.03

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Due to the course Industri 4.0, it was not done work on the project

- Some writing on the report were done

Problems:
Same problems as last week

Further work:
Continue working on the main PLC program
Continue working with the communication
Continue working on the report

Light Column System
Weekly Status Report

Week:
Week 11

Date:
Friday 19.03

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
PLC
- Started working on the redundancy between PLC
- Connected siren and warning light to PLC slave

LED matrix
- LED matrix have arrived
    - Started working with that

Capsule
- Capsule have arrived

Problems:
Capsule is to small
- Working on finding a solution

Further work:
Continue working with the LED matrix to get it to work
Continue working with the redundancy
Find a solution on the capsule-problem

Light Column System
Weekly Status Report

Week:
Week 12

Date:
Friday 26.03

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
LED-Matrix
- Still waiting for new LED-matrices

Cabinet
- New cabinet is ordered

PLC
- Redundancy is working
    - Some bugs, will be worked on during easter
- Cleaned code and made some changes in the code

Configuration Interface
- Designed and made an interface which works quite good
    - Can add a slave and list it
    - Remove slave from the list
    - Decide roles

Problems:
- Some bugs with redundancy
- Current LED-matrix does not work

Further work:
- Fix the bugs with redundancy
- Work with configuration interface

Light Column System
Weekly Status Report

Week:
Week 14

Date:
Friday 09.04

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Almost done with prototype
- New cabinet is big enough

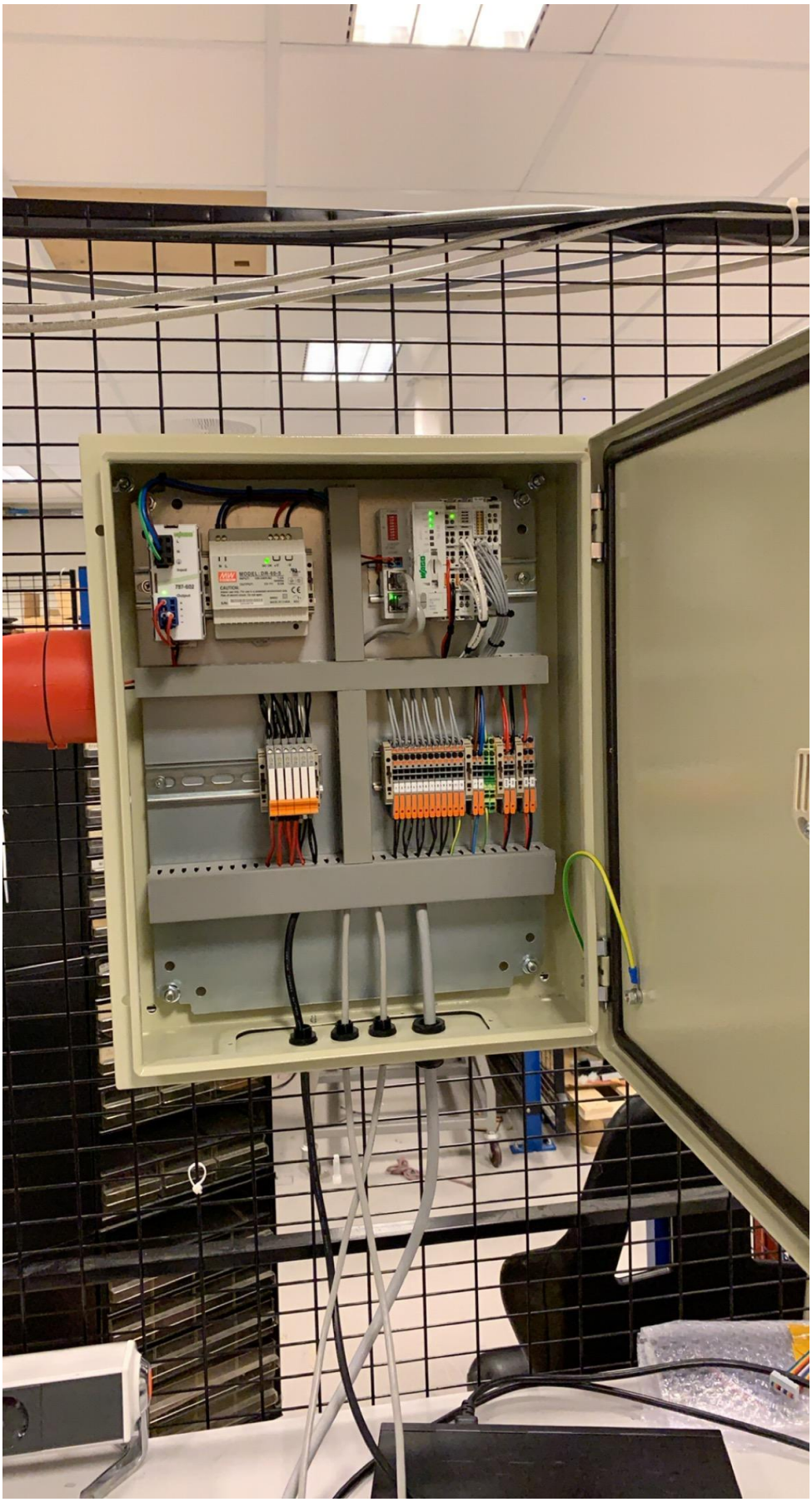
Cleaned a lot of code
- Refactored
- Optimized
- Commented

Still waiting for new LED-matrices
- Estimated delivery between april 10th and 19th
    - May simulate the images if it takes to long time to deliver

Problems:
No problems at the current time

Further work:
Finish the prototype
- Install MCU and LED-matrices

Writing report
Finish BOM-list
Electrical drawings



Light Column System
Weekly Status Report

Week:
Week 15

Date:
Friday 16.04

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Cleaned more code
- Comments
- Refactoring

Warning light
- Set up a LED-matrix as warning light
- Controlled by ESP32
- Working as it should

Report
- Some work on the report have been done

Made test procedure

Still waiting for LED-matrix to use with alarm symbols

Problems:
A bug with Master/Redundant Master
- Will be worked on next week

Further work:
Report
Finalize the prototype
Fix master/redundant master bug

Light Column System
Weekly Status Report

Week:
Week 16

Date:
Friday 23.04

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Report
- Started writing the report

PLC
- Optimized PLC code
- Done some changes with the master-slave connection

LED-matrix
- LED-matrix delivered at friday 23.04
    - Ole Jørgen started working with that

Problems:

Further work:
Write report
Make LED-matrix work
Build the complete prototype

Light Column System
Weekly Status Report

Week:
Week 17

Date:
Friday 30.02

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Meeting with Vard Electro
- Progress
- Inputs from Vard Electro

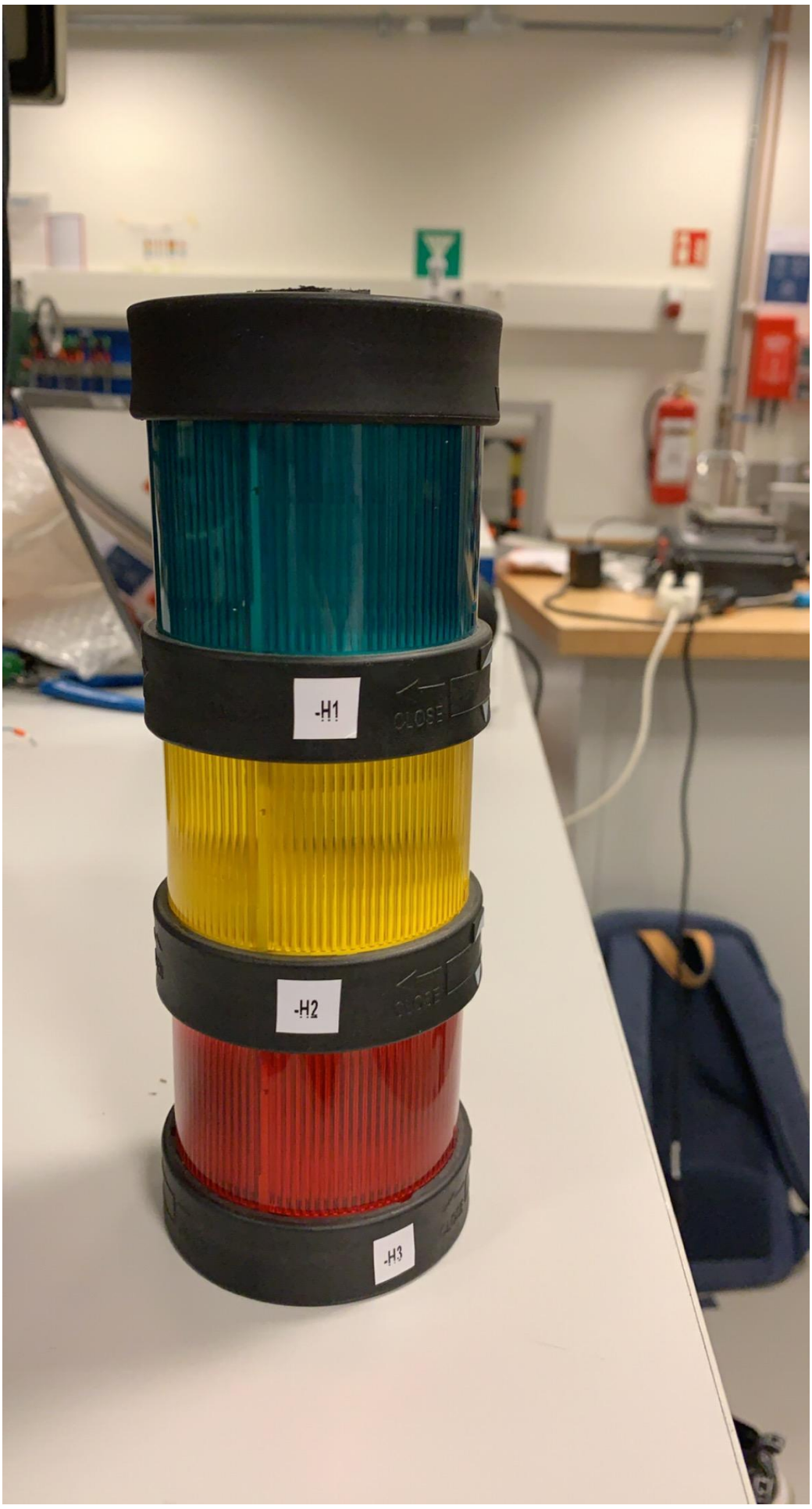
Prototype
- Almost complete installed
    - One 3D-printed part to be finished

LED-Matrix
- Installed at the prototype
- Works for every alarm

Warning light
- Removed from the prototype
    - Did not work
    - Not enough time to fix
- Replaced with a “Traffic light”, see image below

Problems:

Further work:
Write the final report
Complete the prototype


-H1
CLOSE
-H2
CLOSE
-H3

Light Column System
Weekly Status Report

Week:
Week 18

Date:
Friday 07.05

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Finalized the prototype

- Working as we wanted
    - Still some bugs that can occur
- LED-matrix works well
- Warning Light works well

Report

- Most of the time has been report

Problems:

Further work:
Finalize the report

Light Column System
Weekly Status Report

Week:
Week 19

Date:
Friday 14.05

Students:
Per-Stian Alvestad, Ole Jørgen Buljo, Gustav Sørdal Hagen

Status:
Held meeting with NTNU and Vard Electro

- Presentation of video to supervisors
    - Cut video a bit shorter
    - Maybe add voice-over
- Well executed project
    - All design criterias is achieved

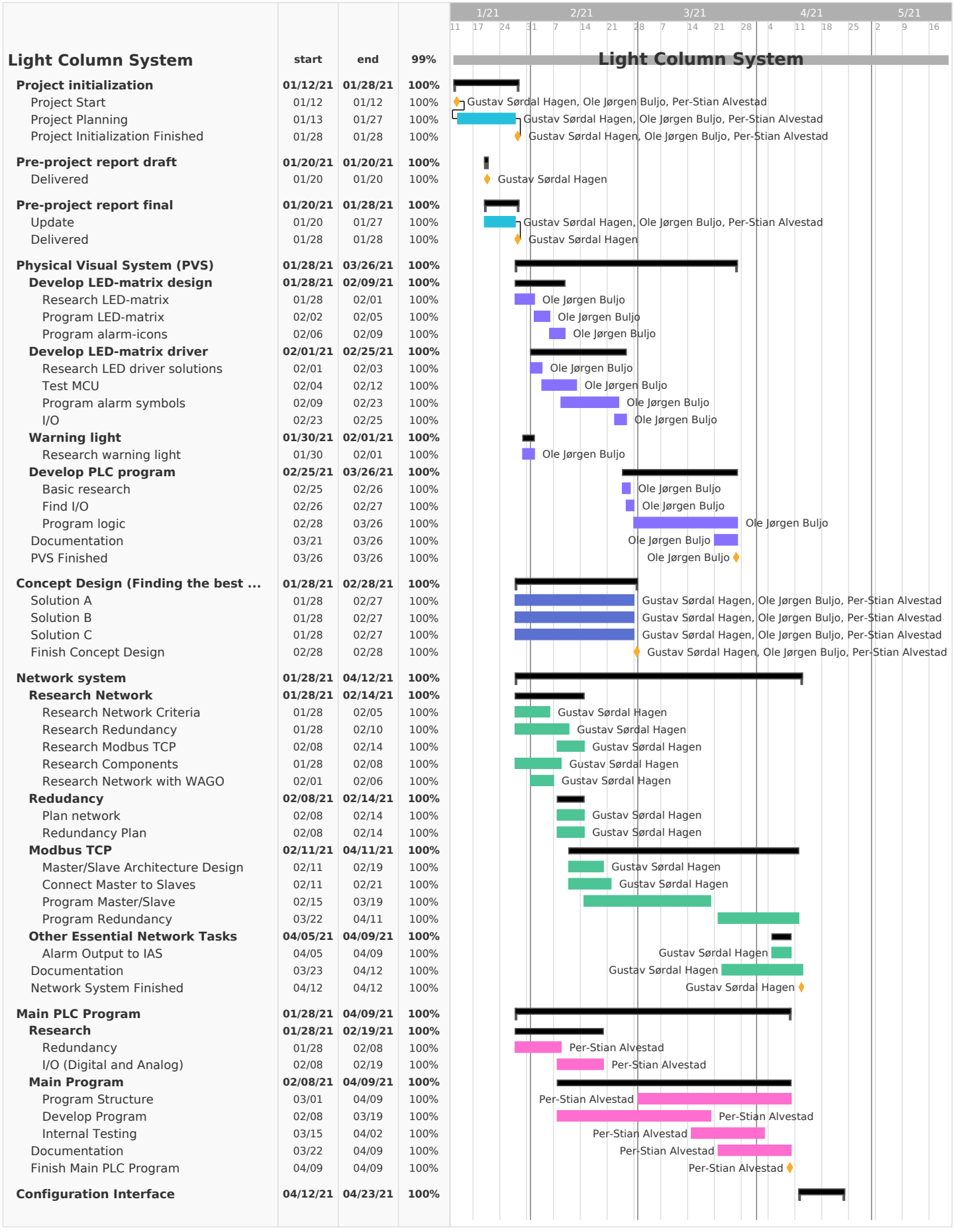
Report

- A lot of writing done
- Still some more writing to do

Problems:

Further work:
Finalize and deliver report

E Gantt Diagram



Light Column System	start	end	99%
Project initialization	**01/12/21**	**01/28/21**	**100%**
Project Start	01/12	01/12	100%
Project Planning	01/13	01/27	100%
Project Initialization Finished	01/28	01/28	100%
Pre-project report draft	**01/20/21**	**01/20/21**	**100%**
Delivered	01/20	01/20	100%
Pre-project report final	**01/20/21**	**01/28/21**	**100%**
Update	01/20	01/27	100%
Delivered	01/28	01/28	100%
Physical Visual System (PVS)	**01/28/21**	**03/26/21**	**100%**
Develop LED-matrix design	**01/28/21**	**02/09/21**	**100%**
Research LED-matrix	01/28	02/01	100%
Program LED-matrix	02/02	02/05	100%
Program alarm-icons	02/06	02/09	100%
Develop LED-matrix driver	**02/01/21**	**02/25/21**	**100%**
Research LED driver solutions	02/01	02/03	100%
Test MCU	02/04	02/12	100%
Program alarm symbols	02/09	02/23	100%
I/O	02/23	02/25	100%
Warning light	**01/30/21**	**02/01/21**	**100%**
Research warning light	01/30	02/01	100%
Develop PLC program	**02/25/21**	**03/26/21**	**100%**
Basic research	02/25	02/26	100%
Find I/O	02/26	02/27	100%
Program logic	02/28	03/26	100%
Documentation	03/21	03/26	100%
PVS Finished	03/26	03/26	100%
Concept Design (Finding the best ...	**01/28/21**	**02/28/21**	**100%**
Solution A	01/28	02/27	100%
Solution B	01/28	02/27	100%
Solution C	01/28	02/27	100%
Finish Concept Design	02/28	02/28	100%
Network system	**01/28/21**	**04/12/21**	**100%**
Research Network	**01/28/21**	**02/14/21**	**100%**
Research Network Criteria	01/28	02/05	100%
Research Redundancy	01/28	02/10	100%
Research Modbus TCP	02/08	02/14	100%
Research Components	01/28	02/08	100%
Research Network with WAGO	02/01	02/06	100%
Redudancy	**02/08/21**	**02/14/21**	**100%**
Plan network	02/08	02/14	100%
Redundancy Plan	02/08	02/14	100%
Modbus TCP	**02/11/21**	**04/11/21**	**100%**
Master/Slave Architecture Design	02/11	02/19	100%
Connect Master to Slaves	02/11	02/21	100%
Program Master/Slave	02/15	03/19	100%
Program Redundancy	03/22	04/11	100%
Other Essential Network Tasks	**04/05/21**	**04/09/21**	**100%**
Alarm Output to IAS	04/05	04/09	100%
Documentation	03/23	04/12	100%
Network System Finished	04/12	04/12	100%
Main PLC Program	**01/28/21**	**04/09/21**	**100%**
Research	**01/28/21**	**02/19/21**	**100%**
Redundancy	01/28	02/08	100%
I/O (Digital and Analog)	02/08	02/19	100%
Main Program	**02/08/21**	**04/09/21**	**100%**
Program Structure	03/01	04/09	100%
Develop Program	02/08	03/19	100%
Internal Testing	03/15	04/02	100%
Documentation	03/22	04/09	100%
Finish Main PLC Program	04/09	04/09	100%
Configuration Interface	**04/12/21**	**04/23/21**	**100%**

teamgantt
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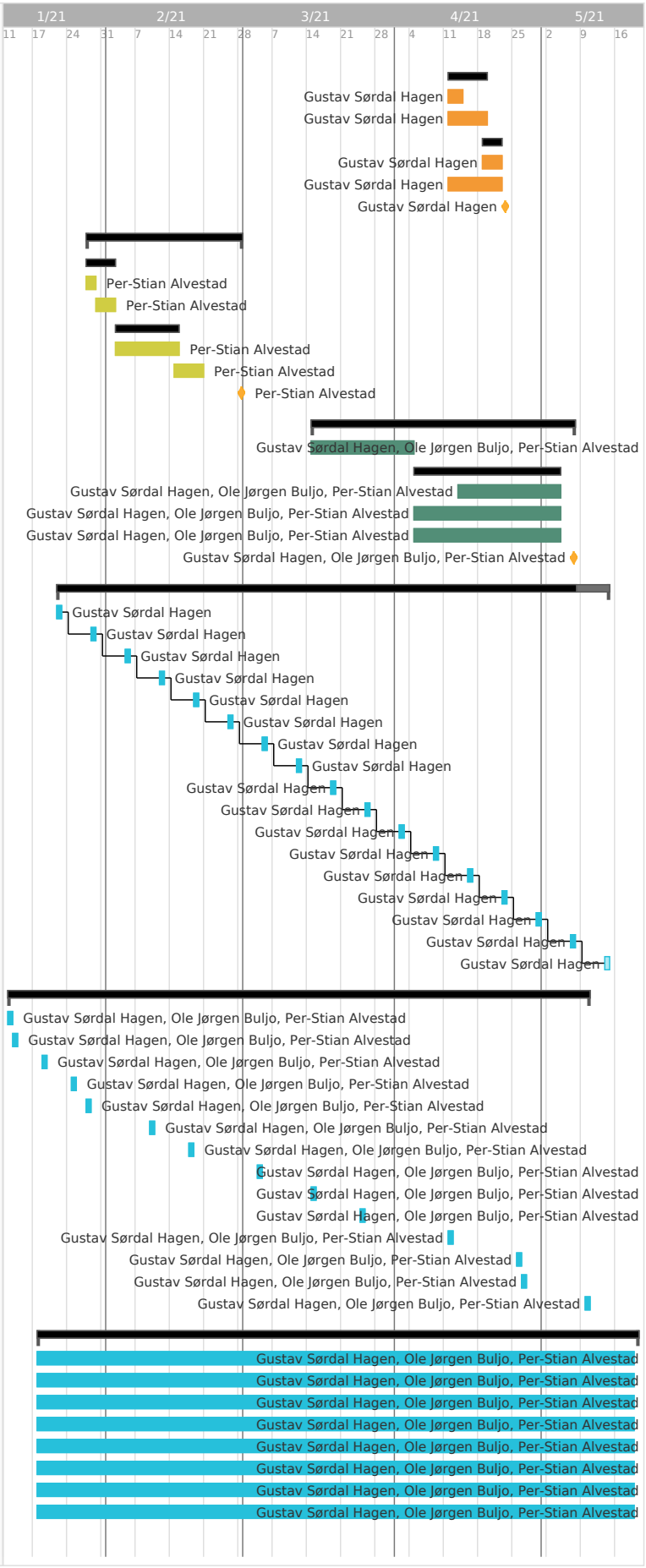


Visualization	**04/12/21**	**04/19/21**	**100%**
Design Configuration Interface	04/12	04/14	100%
Create Visualization	04/12	04/19	100%
WAGO PLC WebVisu	**04/19/21**	**04/22/21**	**100%**
Research WebVisu	04/19	04/22	100%
Documentation	04/12	04/22	100%
Finish Configuration Interface	04/23	04/23	100%
Physical Audio System (PAS)	**01/28/21**	**02/28/21**	**100%**
Research PAS	**01/28/21**	**02/02/21**	**100%**
Research Requirements	01/28	01/29	100%
Research Equipments	01/30	02/02	100%
Develop Siren	**02/03/21**	**02/15/21**	**100%**
Develop	02/03	02/15	100%
Documentation	02/15	02/20	100%
PAS Finished	02/28	02/28	100%
Prototype of system	**03/15/21**	**05/07/21**	**100%**
Build LCS prototype	03/15	04/04	100%
Testing LCS Prototype	**04/05/21**	**05/04/21**	**100%**
Test PLC with LED-matrix	04/14	05/04	100%
Test Redundancy	04/05	05/04	100%
Documentation	04/05	05/04	100%
Prototype Finished	05/07	05/07	100%
Weekly Project Meeting	**01/22/21**	**05/14/21**	**94%**
Week 3	01/22	01/22	100%
Week 4	01/29	01/29	100%
Week 5	02/05	02/05	100%
Week 6	02/12	02/12	100%
Week 7	02/19	02/19	100%
Week 8	02/26	02/26	100%
Week 9	03/05	03/05	100%
Week 10	03/12	03/12	100%
Week 11	03/19	03/19	100%
Week 12	03/26	03/26	100%
Week 13	04/02	04/02	100%
Week 14	04/09	04/09	100%
Week 15	04/16	04/16	100%
Week 16	04/23	04/23	100%
Week 17	04/30	04/30	100%
Week 18	05/07	05/07	100%
Week 19	05/14	05/14	0%
Meetings (Updated for every plann...	**01/12/21**	**05/10/21**	**100%**
Information Meeting (NTNU)	01/12	01/12	100%
Startup Meeting (NTNU, Vard Electro)	01/13	01/13	100%
Follow-up Meeting (NTNU)	01/19	01/19	100%
Pre-Project Finalize (NTNU)	01/25	01/25	100%
Question meeting (Vard Electro)	01/28	01/28	100%
Follow-up Meeting (NTNU)	02/10	02/10	100%
Follow-up Meeting (NTNU)	02/18	02/18	100%
Follow-up Meeting (NTNU)	03/04	03/04	100%
Follow-up Meeting (NTNU)	03/15	03/15	100%
Follow-up Meeting (NTNU)	03/25	03/25	100%
Follow-up Meeting (NTNU)	04/12	04/12	100%
Follow-up Meeting (NTNU)	04/26	04/26	100%
Status Meeting (Vard Electro)	04/27	04/27	100%
Follow-up Meeting (NTNU) (Vard Elec...	05/10	05/10	100%
Main Project Report	**01/18/21**	**05/20/21**	**100%**
Introduction	01/18	05/19	100%
Theoretical Basis	01/18	05/19	100%
Material	01/18	05/19	100%
Method	01/18	05/19	100%
Result	01/18	05/19	100%
Discussion	01/18	05/19	100%
Conclusion	01/18	05/19	100%
References	01/18	05/19	100%

Appendix	01/18	05/19	100%
Delivered	05/20	05/20	0%
Presentation	**05/10/21**	**05/20/21**	**48%**
Video	05/10	05/20	100%
Presentation	05/10	05/20	0%
Presentation	05/20	05/20	0%

F BOM-List

BOM-list for Prototype LCU

PLC

Name	Quantity	Comment	Article number
WAGP 750-8100 Controller PFC100	1	Programmable Logic Controller	750-8100
WAGO 750-1405 Digital Input Module 16ch	1	Digital Input Modul	750-1405
WAGO 750-530 Digital Output Module 8ch	2	Digital Output Modul	750-530
WAGO 750-602 Power Supply Module 24VDC	1	Power Supply	750-602
WAGO 750-600 End Module	1	End modul	750-600
WAGO 787-602 Power Supply	1	Power Supply	787-602
WAGO 288-853 Switch Relay Module	2	Switch Relay	288-853
PHoenix PLC-BSC-24DC/21	6	Relays	2966265

Visual System

Name	Quantity	Comment	Article number
MW DR 60-5 Power Supply	1	100-240VAC Input, 5VDC Output	712-7427
ESP32-DEVKITC-32UE	1	Micro Controller Unit	ESP32-DEVKITC-32UE
Base unit + cover for modular tower lights, plastic, black	1	Base unit	XVB21
Illuminated unit for modular tower lights, plastic, green	1	Green light	XVBC4M3
Illuminated unit for modular tower lights, plastic, yellow	1	Yellow light	XVBC4M4
Illuminated unit for modular tower lights, plastic, red	1	Red light	XVBC4M8
P2. 5-160*160MM LED matrix	1	LED matrix	

Cables

Name	Meters	Comment	Article number
Ethernet Cat5E - 24 AWG F/UTP	5	Cat 5E Cable	BC-5UG001F
Schuko Plug - Open Cable End 1.80m Black	1.8	Power Cable	PCPE18BK
Lapp OLFLEX CLASSIC 110 12 Core YY Controle Cable	1	Signal Cable	1119312

Other

Name	Quantity	Comment	Article number
Mild Steel IP Wall Box	1	Cabinet	775-5808
HTWD-PN-25X40 PVC GY7030	2	Cabel channel	300-63-514
HTWD-PN-40X40 PVC GY7030	2	Cabel channel	300-63-517
M20 Cable Gland With Locknut	2	M20 Nipple	822-9760
M16 Cable Gland With Locknut	3	M16 Nipple	669-4667
WAGO 3-conductor through terminal block	18	Terminal Through Block	2102-5301
WAGO 4-conductor ground terminal block	2	Terminal Ground Block	2002-1407
WAGO Steel Carrier Rail	4	Steel Rail	210-112
End Bracket for Terminal Block	8	End Bracket	295-9140
D-Link DGS-105	1	Switch	DGS-105/E
Marine VTB-32EM Spatial Sounder/Beacon	1	Sirene	623-6659
Mini DIN Rail Support Base Element	1	Support Element	150-18-536
MB310 PCB Terminal Block	18	Terminal Block	MB310-500M

G DNV GL IP Rating

Table 1 Enclosure types in relation to location

Location		*Switchgear and transformers*	*Luminaries*	*Rotating machines*	*Heating appliances*	*Socket outlets*	*Miscellaneous such as switches and connection boxes*	*Instrumentation components*
Engine and boiler rooms 15)	Above the floor	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44	IP 44
	Below the floor	N	IP 44	IP 44	IP 44	N	IP 44	IP 56
	Dry control rooms and switchboard rooms	IP 21 1)	IP 22	IP 22	IP 22	IP 22	IP 20	IP 20
	Closed compartments for fuel oil and lubrication oil separators	IP 44	IP 44	IP 44	IP 44	N	IP 44	IP 44
Fuel oil tanks 2)		N	N	N	N	N	N	IP 68
Ballast and other water tanks, bilge wells 2)		N	N	IP 68	IP 68	N	N	IP 68
Ventilation ducts		N	N 13)	IP 44 13)	N	N	N	13)
Deckhouses, forecastle spaces, steering gear compartments and similar spaces		IP 22 3)	IP 22	IP 22 3)	IP 22	IP 44	IP 44	IP44
Ballast pump rooms, columns below main deck and pontoons and similar rooms below the load line		IP 44 14)	IP 44	IP 44 14)	IP 44	IP 56 5)	IP 56 5)	IP 56 5)
Cargo holds 4)		N	IP 55	IP 44	N	IP 56 5)	IP 56 5)	IP 56 5)
Open deck, keel ducts 15)		IP 56	IP 55	IP 56 6)	IP 56	IP 56 5)	IP 56 5)	IP 56
Battery rooms, paint stores, gas welding gas bottle stores or areas that may be hazardous due to the cargo or processes onboard 7)		EX12)	EX 12)	EX 12)	EX 12)	EX12)	EX 12)	EX 12)
Dry accommodation spaces		IP 20	IP 20	IP 20	IP 20	IP 20	IP 20 8)	IP 20
Bath rooms and showers		N	IP 44 11)	N	IP 44	N 9)	IP 56 11)	IP 56 11)
Galleys, laundries and similar rooms 10)		IP 44	IP 44	IP 44	IP 44	IP 44	IP 44	IP 44

Table 1 Enclosure types in relation to location (Continued)

(N: Normally, not accepted for installation in this location.)

1) Switchboards in dry control rooms and switchboard rooms with IP 21 shall have a roof with eaves. If there is a chance of dripping water from piping, condensed water, etc. then a higher IP rating may be necessary. If there is no chance of dripping water, and the room is equipped with air conditioning system, the IP rating for control desks may be as required for dry accommodation spaces.
2) For cable pipes and ducts through fuel oil and water tanks, see [3.7].
3) Such equipment shall be provided with heating elements for keeping it dry when not in use, regardless if IP rating. The heating elements shall normally be automatically switched on when the equipment is switched off. Continuously connected heating elements may be accepted provided the maximum allowed temperatures are maintained when the equipment is in operation.
4) For enclosures in cargo holds, placed so that they are liable to come into contact with the cargo or cargo handling gear, see Sec.3 [4.1]. For truck battery charging arrangements, see Sec.2 [9].
5) IP 44 may be accepted, when placed in a box giving additional protection against ingress of water. Equipment for control and indication of watertight doors and hatches shall have watertightness based on the water pressure that may occur at the location of the component, if intrusion of water can affect the control or indication system.
6) Motors on open deck shall have ingress protection IP 56, and either:
   - be naturally cooled, i.e. without external cooling fan
   - be vertically mounted and equipped with an additional steel hat preventing ingress of water or snow into any external ventilator
   - or be equipped with a signboard requiring that the motor shall only be used in port, and be provided with additional covers (e.g. tarpaulins) at sea.
7) For arrangement and connection of batteries, see Sec.2. For installations in paint stores, welding gas bottle stores or areas that may be hazardous due to the cargo or processes onboard, the requirements in Sec.11 shall be complied with. Electrical equipment and wiring shall not be installed in hazardous areas unless essential for operational purposes.
8) Connection boxes may be accepted installed behind panels in dry accommodation spaces provided that they are accessible through a hinged panel or similar arrangement.
9) Socket outlets shall be so placed that they are not exposed to splash, e.g. from showers. Circuits for socket outlets in bathrooms shall either be fed from a double insulated transformer, or be equipped with earth fault protection with a maximum release current of 30 mA.
10) Stoves, ovens and similar equipment may be accepted with IP 22 when additionally protected against water splash by hose or washing of the floor.
11) Lower degree of protection may be accepted provided the equipment is not exposed to water splash.
12) Type of ingress protection shall be in accordance with the minimum requirements in Sec.11 or minimum requirements in this table, whichever is the strictest. Minimum explosion group and temperature class shall be one of those specified in Sec.11 (some national regulations may limit the choice of type of protection).
13) Luminaries and instrumentation components may be accepted after special consideration. It shall be observed that a ventilation duct may be a hazardous area, depending upon the area classification at the ends of the duct.
14) Electric motors switchgear and starting transformers for thrusters shall be equipped with heating elements for standstill heating. Provided the space will not be used as pump room for ballast, fuel oil etc., the thrusters motor may be accepted with IP22 enclosure type.
15) Electrical and electronic equipment and components located in areas or in the vicinity of areas protected by Fixed Water-Based Local Application Fire-Fighting Systems as required by SOLAS Ch. II-2/10 5.6 using fresh water shall be to a degree of protection not less than IP22.
16) When salt water is used, electrical and electronic equipment and components located in areas, or in the vicinity of areas, protected shall be to a degree of protection not less than IP44, unless the manufacturer of the electrical and electronic equipment or components submits evidence of suitability using a lower degree of protection (e.g. IP23, IP22, etc.) restricted to:
   - For the natural air cooled static power equipment (e.g. starter, distribution panel, transformer, lighting etc.) at least IP23 is required.
   - For the natural air cooled electronic equipment mounted or located on the protected system (e.g. sensors, actuators, etc.), at least IP44 is required.
   - For the rotating machinery and mechanically air cooled type equipment (e.g., rotating machinery, air cooled SCR panel, etc.) which needs the forced cooling air from outside the equipment, the lower degree than IP44 may be accepted if measures are taken, in addition to ingress, to prevent the ingest of water. The terminal boxes shall be of at least IP44.

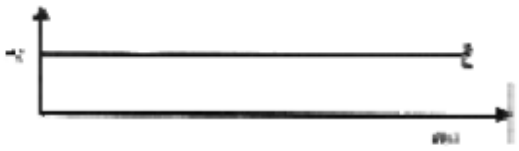
   Generators with a lower degree of protection as IP44 may be used if they are separated to each other in a way that the water used for the FWBLAFFS (e.g. watermist, waterdrops) will harm only the set concerned.
17) IP55 can be accepted if the equipment can not be subject to heavy seas.

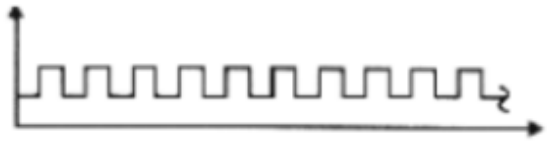
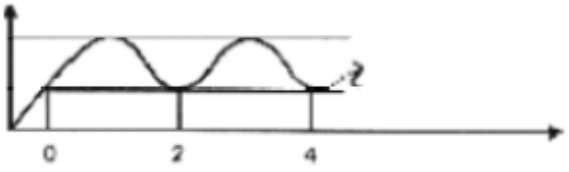
H List of Alarms

List of alarm for LCS

Function	IMO instruments	Audible	Color	Symbol	Remarks
General Emergency Alarm	LSA 7.2.1 SOLAS III/6.4 SOLAS II-2/7.9.4	1.b	Green		Used for summoning the crew to the boat stations.
Fire Alarm	SOLAS II-2/7.9.4 FSS 9.2.5.1	2	Red		Used for summoning the crew to the fire stations on passenger ships.
Fire-extinguishing pre-discharge alarm	FSS 5.2.1.3	2	Red	CO_2	Audible signal distinct from all others.
Machinery Alarm		3	Amber		Horn in machinery space, buzzer elsewhere.
Steering Gear Alarm	SOLAS II-1/29.5.2 II-1/29.8.4 II-1/29.12.2 II-1/30.3	3	Amber		Horn in machinery space, buzzer elsewhere.
Activation of fixed local Application Fire-extinguishing system	SOLAS II-2/10.5.6.4	2	Red		
Telephone	SOLAS II-1/50	3.a	White		
Engine room telegraph	SOLAS II-1/37	2 or 3.a	White		

Water ingress detection main alarm	SOLAS XII/12.1, 12.2 and II-1/23-3	2	Red		For cargo holds used for water ballast and the ballast tanks, an alarm overriding device may be installed.
Water ingress detection pre-alarm	SOLAS XII/12.1, 12.2 and II-1/23-3	2	Amber		For cargo holds used for water ballast, an alarm overriding device may be installed.
Bilge alarm	SOLAS II-1/48	3	Amber		
Engineers‘ alarm	SOLAS II-1/38	3	Amber		

Audible code	**Waveform**	**Remarks**
1.a		General emergency alarm.
2		Continuous until silenced or acknowledged.
3.a		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz
3.b		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz

3.c		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz
3.d		Optionals waveform to provide distinction between alarms. Pulse frequency between 0.5 Hz and 2.0 Hz

I System Tests

Communication Testing

Test	Failed/Pass	Comment
Slave Shutdown (Power)	Passed	Master know if slave is down and send notification to IAS
Slave Disconnection	Passed	Master knows if the slave is down and sends a notification to IAS. Slave must erase all signal outputs.
Redundant Master Shutdown (Power)	Passed	Master knows if the red. master is down and send notification to IAS
Redundant Master Disconnection	Passed	Master knows if the red. master is down and sends a notification to IAS. Red. master must erase all signal outputs.
Master Shutdown (Power)	Passed	Red. master takes control after a desired timeout and sends a notification to IAS.
Master Disconnection	Passed	Red. master takes control after a desired timeout and sends a notification to IAS. Master must erase all signal outputs.
Timeout (Redundant Master)	Passed	If the master is down, check if the time before red. master to take control is correct.

Functional Testing

Test	Failed/Pass	Comment
Toggle Alarms	Passed	If the active master controller receives an alarm input from IAS, toggle the same alarm on all of the connected LCUs.
Toggle Siren	Passed	If the active master controller receives an alarm input from IAS, toggle the same siren output on all of the connected LCUs.
Toggle Alarm LEDs	Passed	If the active master controller receives an alarm input from IAS, toggle the alarm LEDs on all of the connected LCUs.

Handle Multiple Alarms (Visual)	Passed	Show active alarm symbols one by one at a given time interval.
Handle Multiple Alarms (Audio)	Passed	Use audio for the prioritized alarm, ref List of Alarms.

Configuration Interface Testing

Test	Failed/Pass	Comment
Alarm Panel Lamps	Passed	Check if the correct alarm panel lamps are active according to active alarms.
Add LCU	Passed	Test for adding LCUs to the device list. This will connect a device to the system.
Remove LCU	Passed	Test for removing LCUs from the device list. This will disconnect a device from the system.
WebVisu Shortcut	Passed	Check if the WebVisu button directs to the correct LCU.
Roles	Passed	Check if the correct role is set to a LCU.

J LCS Diagrams

1 2 3 4 5 6 7 8

A

B

C

D

E

F

Skoleversion

Light Column System

PCSCHEMATIC Automation

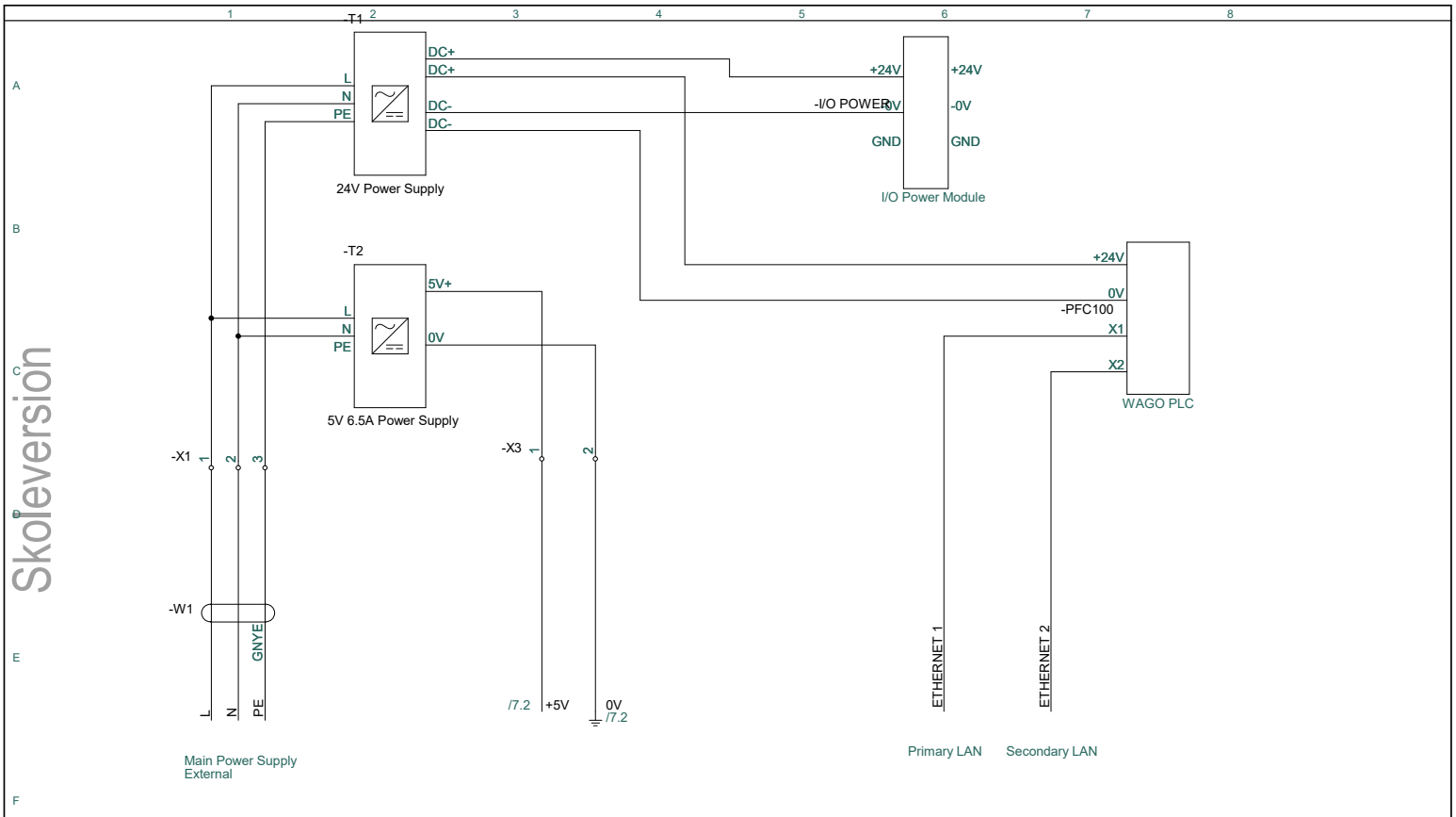
PC | SCHEMATIC

Project title:	**Light Column System**	**Project no.:**	**800.420**	**Project rev.:**	**'**	**Page**	**1**
Customer:	Bachelor Assignment	DCC:				Scale:	1:1
Page title:	Front page	Dwg. no.:		Page rev.:		Previous page:	
File name:	Aa Light Column System	Eng. (proj/page):	OJB	Last print:	10.05.2021	Next page:	2
Page ref.:		Appr. (date/init):		Last edit:	07.05.2021	Total no. of pages:	10

Skoleversion

Light Column System

Diagrams



PCSCHEMATIC Automation

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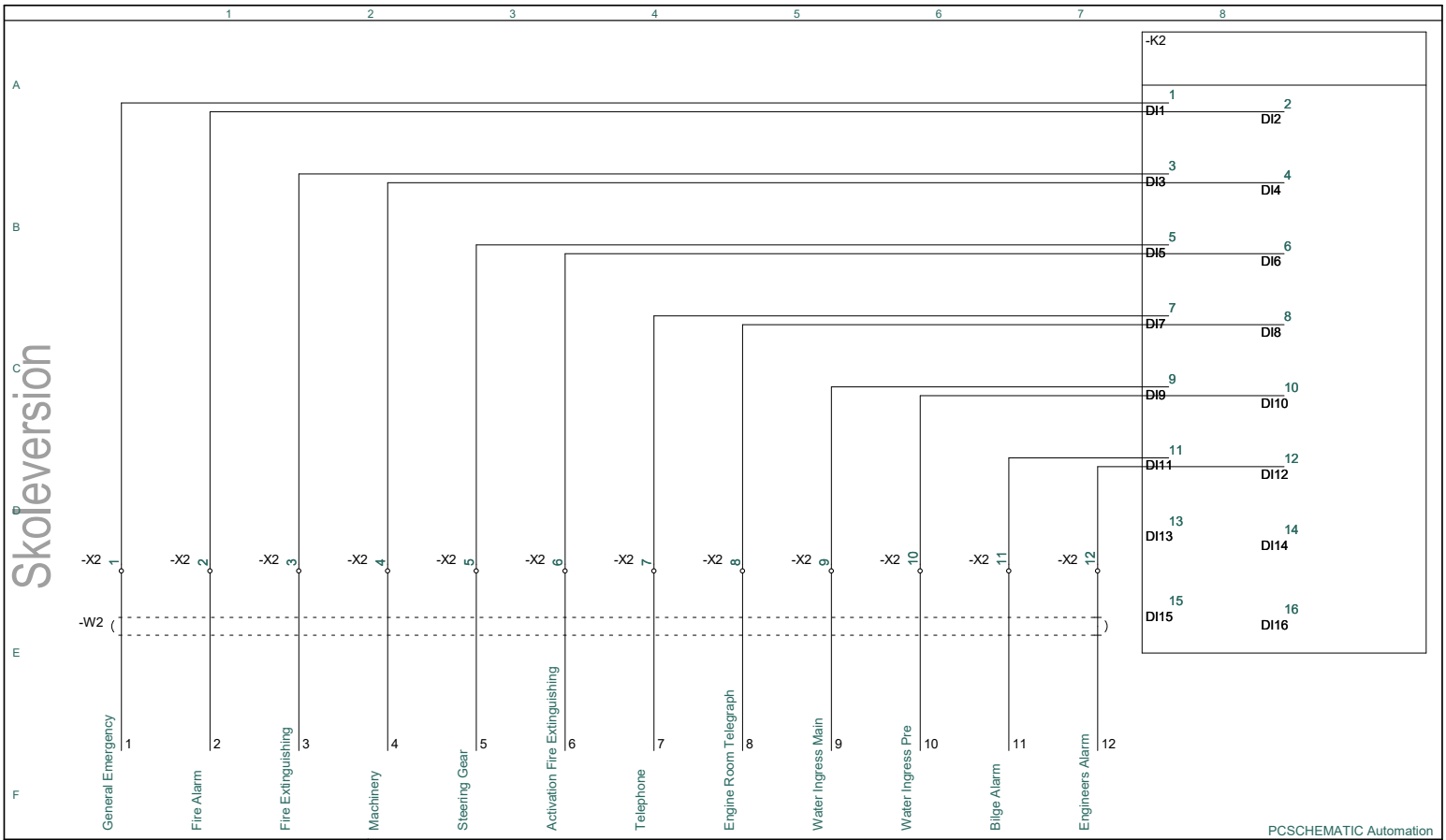

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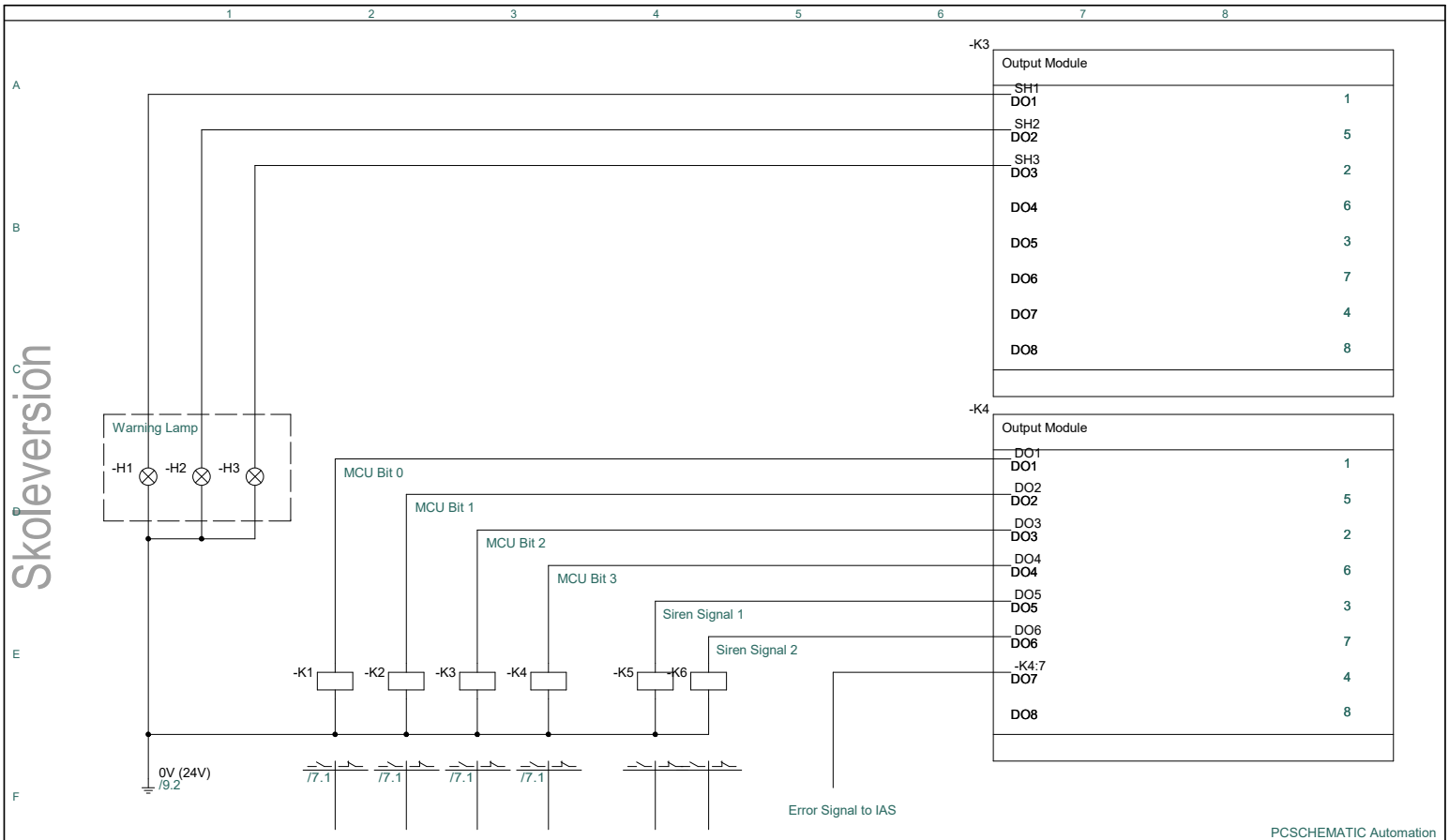

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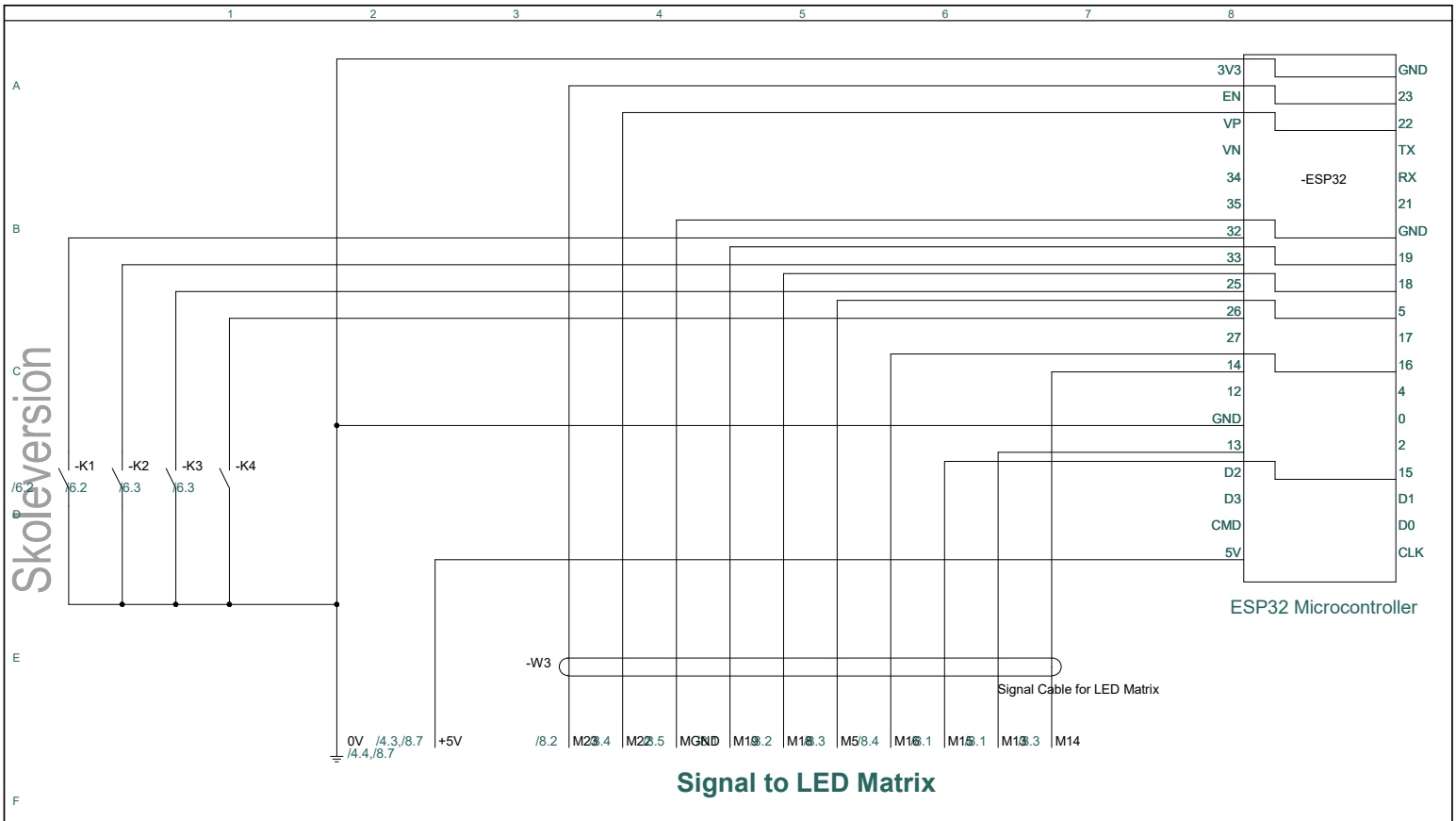

PCSCHEMATIC Automation

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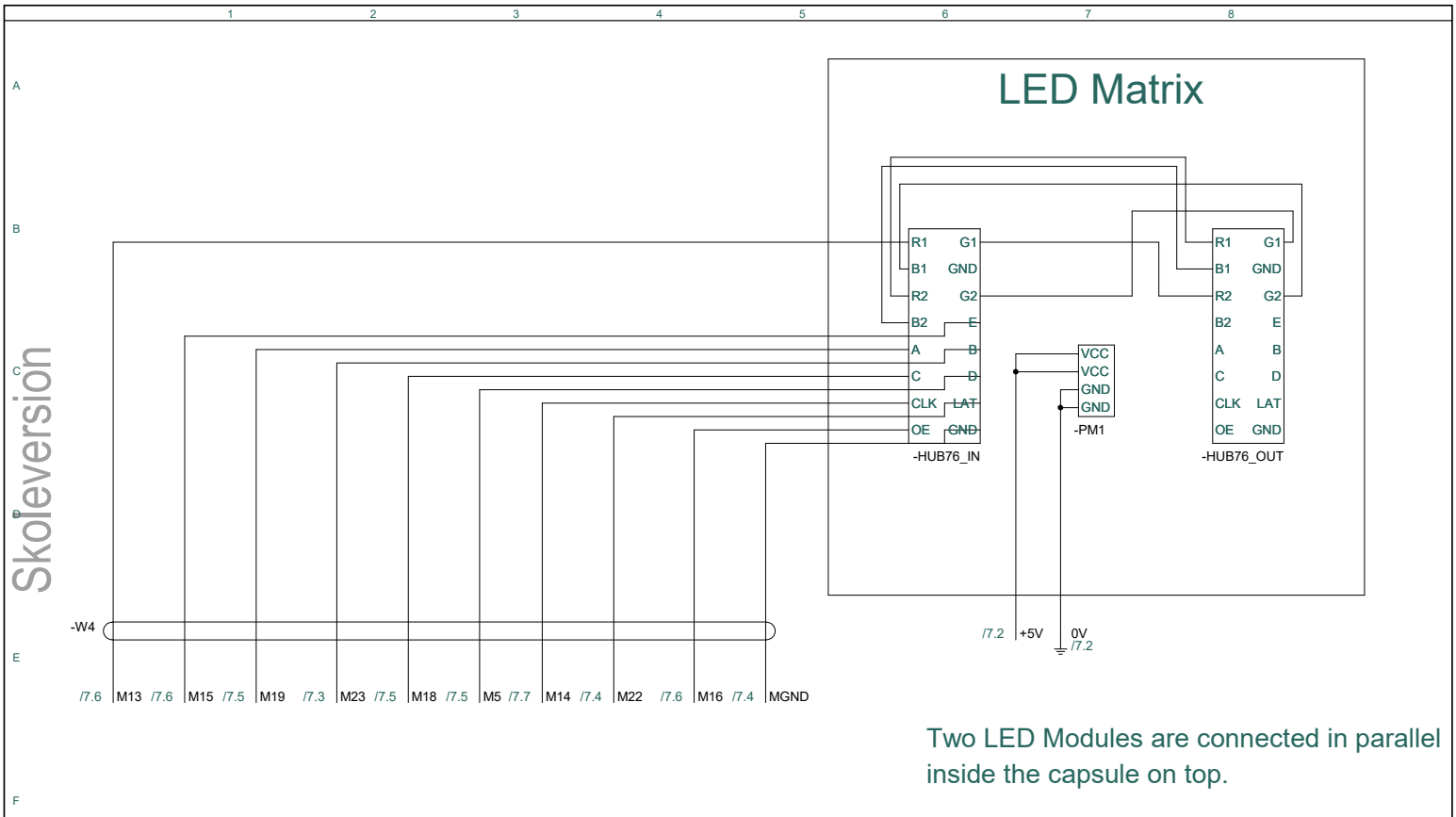

Two LED Modules are connected in parallel inside the capsule on top.

PCSCHEMATIC Automation

PC SCHEMATIC	**Project title:**	**Light Column System**	**Project no.:**	**800.420**	**Project rev.:**	'	**Page** **8**
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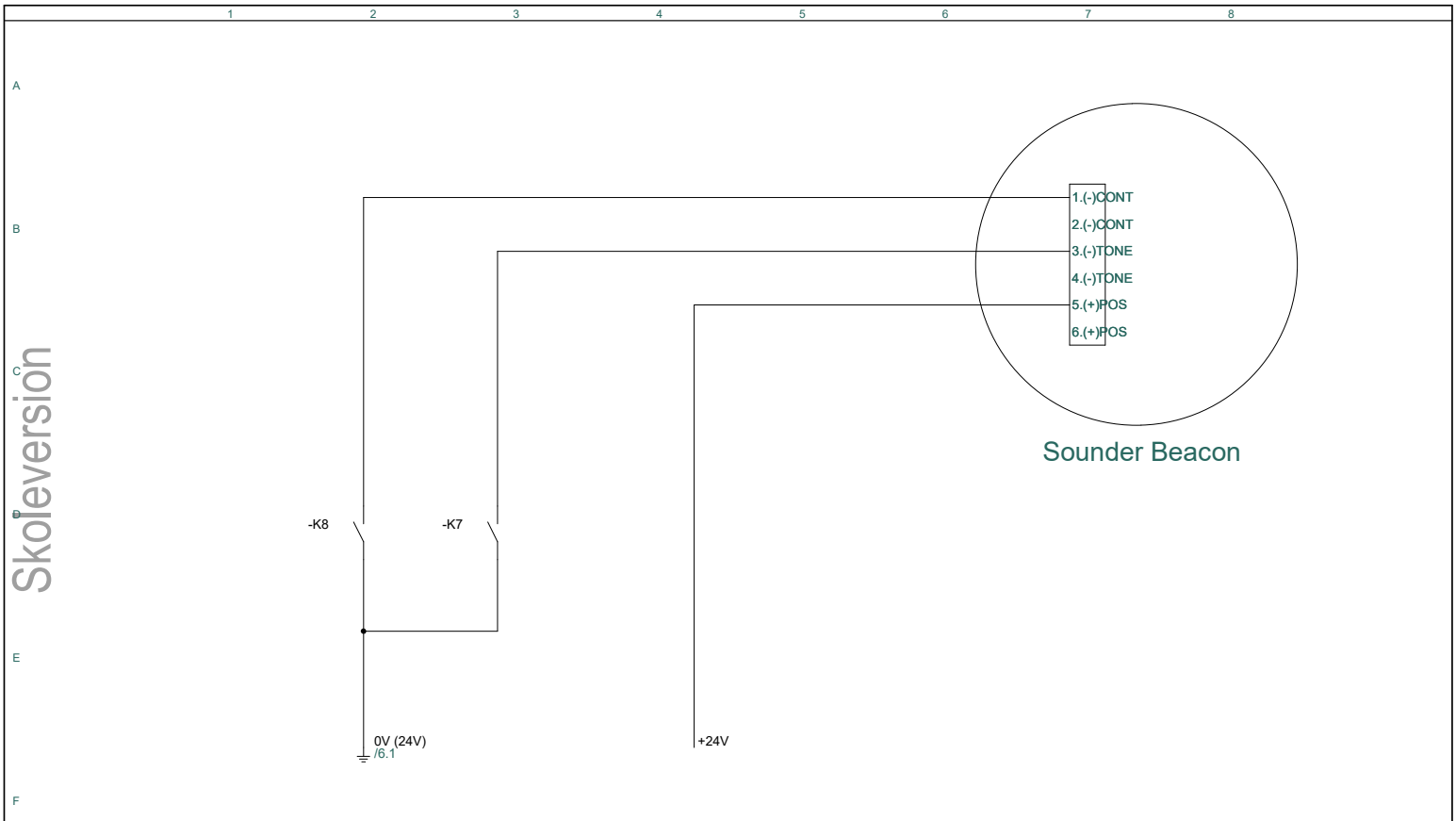

Skoleversion

PCSCHEMATIC Automation

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	Page ref.:		Appr. (date/init):		Last edit:	10.05.2021	Total no. of pages: 10

K Siren Datasheet

NTNU
Kunnskap for en bedre verden

VTB spatial sounder/beacon 24Vdc

EN54 part 3 approved

The VTB EN54 part 3 approved sounder beacon is part of the VTG family of products designed for use with conventional fire alarm systems including SAV-WIRE® two wire.

The sounder function like all VTG family of products comes as standard with 32 tones. The beacon function has been designed for maximum all round visibility coupled with low power consumption utilising an array of energy efficient LED's.

The sounder function features a two-stage alarm override which is activated by a third negative wire from the fire panel.

Both the sounder and beacon functions are fully synchronised. The sounder function has been fully approved to EN54 part 3 by Intertek on tones 1, 3, 8, 11, 25 and 27. The product can also be used as a beacon only which is easily selected by a dil switch at the time of installation.

- sounder function fully approved to EN54-3
- 32 tones plus a selectable override tone
- shallow base IP21C and deep base IP33C versions available
- designed to work with both conventional and two-wire (SAV-WIRE®) systems
- switch selectable beacon only feature
- unique twist and lock bayonet mounting system
- removable cover on deep base for surface wiring
- features base locking system as standard

TECHNICAL

voltage range (Vdc)	21 - 28	
number of tones	32	
operating frequency (Hz)	440 - 2900	
temperature range (°C)	-20 to +70	
flash rate	c. 1Hz	
monitoring	reverse polarity	
protection rating	IP21C (shallow)	IP33C (deep)
boxed weight (kg)	0.22 (shallow)	0.25 (deep)
body colours available	red or white (ABS fire retardant plastic)	
lens colours available	red or amber	

PERFORMANCE

volume setting	high	med	low
sound output, typical (dBA)	99.1	95.4	79.7
sound output, anechoic chamber (dBA)	98.0	94.3	78.5
sound output, reverberation chamber (dBA)	113.6	110.2	96.0
max. current consumption @ 24Vdc (mA)	34.4	19.9	10.8
power consumption @ 24Vdc (mW)	826	478	259

NB: see tone list performance for more accurate current consumption figures

ORDERING INFORMATION

red body, 32 tone, shallow base, red lens	511-095L
red body, 32 tone, shallow base, amber lens	511-099L
red body, 32 tone, deep base, red lens	511-097L
red body, 32 tone, deep base, amber lens	511-101L
white body, 32 tone, shallow base, red lens	511-096L
white body, 32 tone, shallow base, amber lens	511-100L
white body, 32 tone, deep base, red lens	511-098L
white body, 32 tone, deep base, amber lens	511-102L

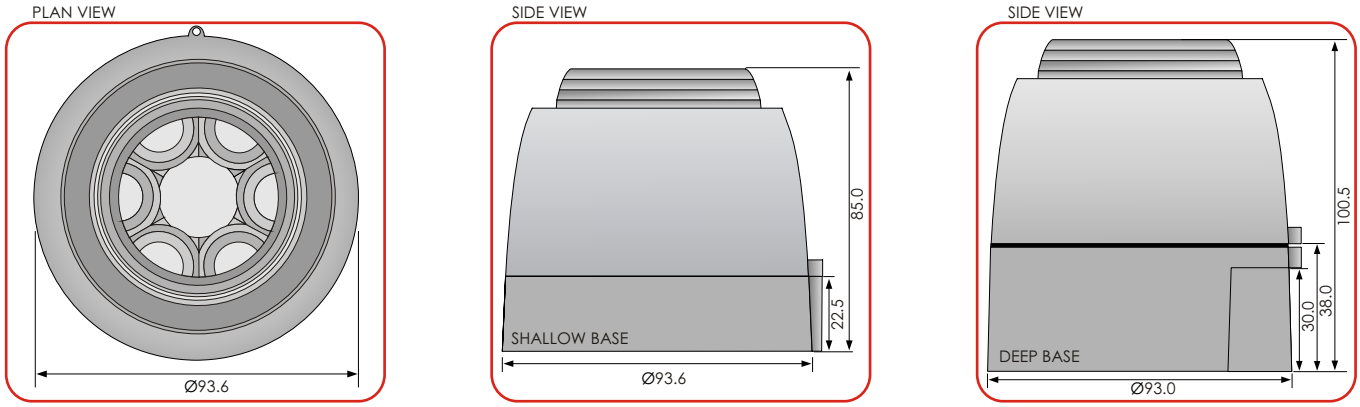
APPROVALS INFORMATION

EN54-3

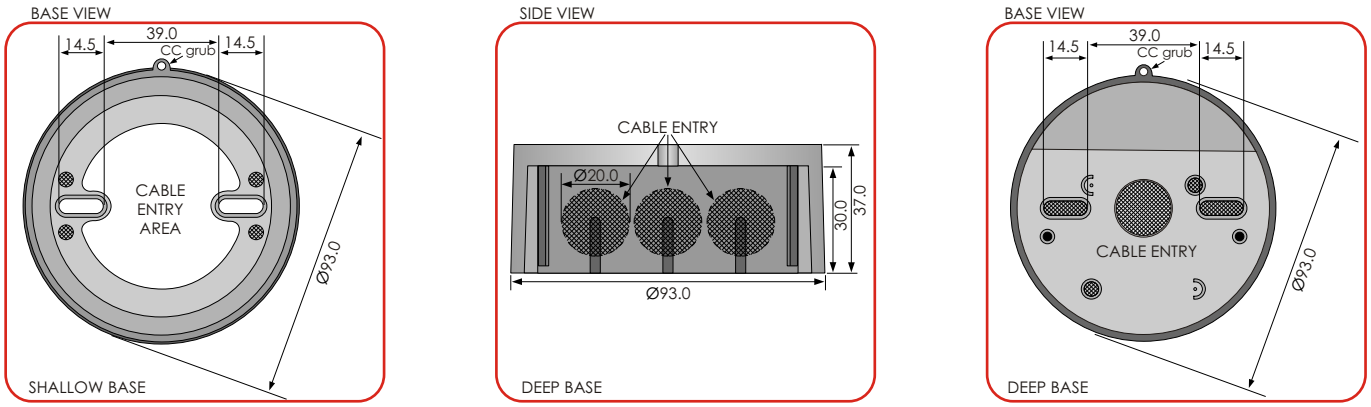
CE
0359-CPR-00060

Intertek

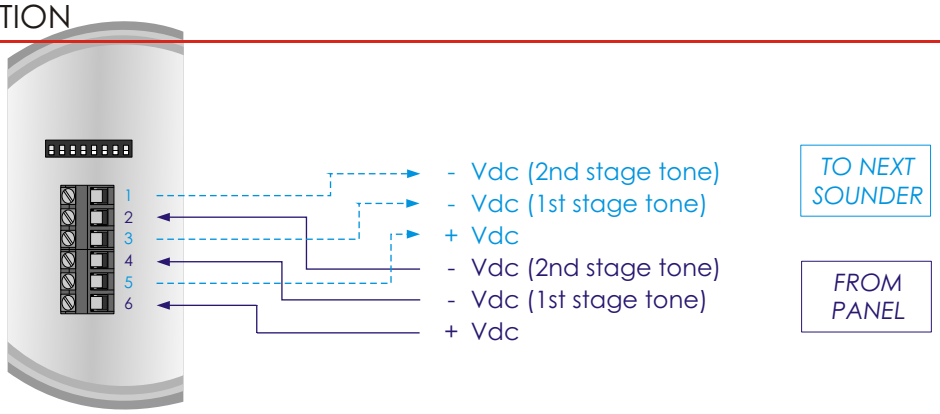
DIMENSIONS



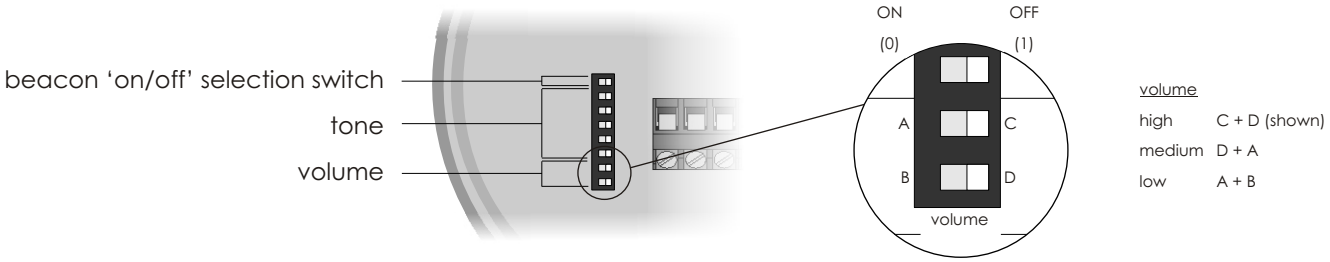
PRODUCT MOUNTING & CABLE ENTRY



WIRING CONFIGURATION



TONE & VOLUME SELECTION



volume

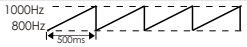
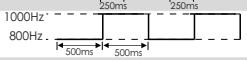
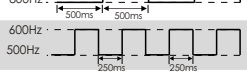
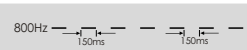
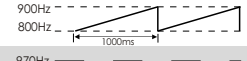
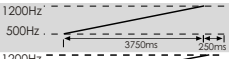
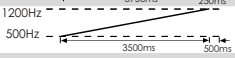
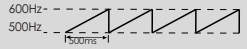
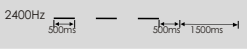
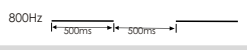
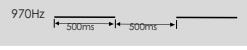
high	C + D (shown)
medium	D + A
low	A + B

innovationdesignmanufacture

00 44 (0)1420 592444 sales@cranfordcontrols.com

TONE LIST - GRAPHICAL

Tones 1,3,8,11(Second Stage Tone),25 & 27 Approved to EN54-3

no.	name	1st stage frequency	1st stage graphical	2nd stage frequency	2nd stage graphical
1	**LF Sweep (Cranford sweep)**	**800-1000Hz swept every 500ms (2Hz)**		800Hz continuous	
2	Alternative warble BS	800Hz for 250ms, then 960Hz for 250ms		800Hz continuous	
3	**Warble Tone BS**	**800Hz for 500ms, then 1000Hz for 500ms**		800Hz continuous	
4	Alternative warble BS	500Hz for 250ms, then 600Hz for 250ms		500Hz continuous	
5	HF Back up Interrupted	2800Hz for 1000ms, then off for 1000ms		2800Hz continuous	
6	LF Back up Alarm	800Hz for 150ms, then off for 150ms		800Hz continuous	
7	HF Back up Interrupted (fast)	2800Hz for 150ms, then off for 150ms		800Hz continuous	
8	**LF Continuous tone BS5839**	**800Hz continuous**		800Hz continuous	
9	Sweep - 1Hz	800-900Hz swept every 1000ms (1Hz)		800Hz continuous	
10	Australian slow whoop	970Hz for 625ms, then off for 150m		500-1200Hz for 3250ms, then off for 250ms	
11	**Dutch sweep**	970Hz continuous		**500-1200Hz for 3500ms, then off for 500ms**	
12	Analogue sweep	500-600Hz swept every 500ms (2Hz)		500Hz continuous	
13	Sweep - 3Hz	800-970Hz swept every 333ms (3Hz)		800Hz continuous	
14	Alternate HF slow sweep	2350-2900Hz swept every 333ms (3Hz)		2400Hz continuous	
15	Fast HF sweep	2400-2800Hz swept every 143ms (7Hz)		2400Hz continuous	
16	US Temporal Pattern LF	950Hz for 500ms on, 500ms off (x3), then 1500ms off		800Hz continuous	
17	Interrupted BS	800Hz for 500ms, then off for 500ms		800Hz continuous	
18	ISO 8201 LF BS5839 Pt 1	970Hz for 500ms, then off for 500ms		970Hz for 500ms, then off for 500ms	
19	Interrupted medium	1000Hz for 250ms, then off for 250ms		800Hz continuous	
20	ISO8201 HF	2850Hz for 500ms, then off for 500ms		2850Hz for 500ms, then off for 500ms	
21	Continuous	1000Hz continuous		1000Hz continuous	
22	LF Buzz	800-950Hz swept every 9ms (110Hz)		800Hz continuous	
23	HF Continuous	2800Hz continuous		2800Hz continuous	
24	Sweep	800-970Hz swept every 111ms (9Hz)		800Hz continuous	
25	**German DIN tone**	**1200-500Hz swept every 1000ms (1Hz)**		800Hz continuous	
26	Swedish Fire signal	660Hz for 150ms, then off for 150ms		660Hz for 150ms, then off for 150ms	
27	**French tone AFNOR**	**554Hz for 100ms, then 440Hz for 400ms**		800Hz continuous	
28	Swedish all clear signal	660Hz continuous		660Hz continuous	
29	US Temporal Pattern HF	2900Hz for 500ms on, 500ms off (x3), then1500ms off		2900Hz continuous	
30	Siren 2 way ramp (short)	500-1200Hz rising for 250ms, then falling for 250ms		800Hz continuous	
31	FP1063.1-Telecom	800Hz for 250ms, then 970Hz for 250ms		800Hz continuous	
32	Siren 2 way ramp (long)	500-1200Hz rising for 3000ms, then falling for 3000ms		800Hz continuous	

TONE LIST - PERFORMANCE

Tones 1,3,8,11(Second Stage Tone),25 & 27 Approved to EN54-3

				typical current (mA)			typical sound output (dBA)		
no.	name	1st stage frequency	switch (2345)	low	medium	high	low	medium	high
1	**LF Sweep (Cranford sweep)**	**800-1000Hz swept every 500ms (2Hz)**	11111	10.2	14.8	23.0	80.1	95.6	99.9
2	Alternative warble BS	800Hz for 250ms, then 960Hz for 250ms	11110	9.9	14.6	19.2	80.4	95.7	100.0
3	**Warble Tone BS**	**800Hz for 500ms, then 1000Hz for 500ms**	11101	9.9	14.7	18.9	79.7	94.7	98.5
4	Alternative warble BS	500Hz for 250ms, then 600Hz for 250ms	11100	9.1	12.7	14.9	80.0	95.8	99.1
5	HF Back up Interrupted	2800Hz for 1000ms, then off for 1000ms	11011	12.4	19.4	28.9	79.2	93.7	101.0
6	LF Back up Alarm	800Hz for 150ms, then off for 150ms	11010	10.7	15.0	18.2	78.6	93.6	97.2
7	HF Back up Interrupted (fast)	2800Hz for 150ms, then off for 150ms	11001	11.8	19.4	28.8	78.3	92.9	99.9
8	**LF Continuous tone BS5839**	**800Hz continuous**	11000	9.6	14.0	17.4	79.8	94.7	98.4
9	Sweep - 1Hz	800-900Hz swept every 1000ms (1Hz)	10111	9.9	14.8	19.2	80.2	95.6	99.8
10	Australian slow whoop	970Hz for 625ms, then off for 150m	10110	9.9	15.6	19.5	80.2	95.5	99.9
11	**Dutch sweep**	970Hz continuous	10101	10.1	15.0	19.6	80.2	95.5	100.1
12	Analogue sweep	500-600Hz swept every 500ms (2Hz)	10100	9.1	12.6	14.7	80.2	94.8	97.8
13	Sweep - 3Hz	800-970Hz swept every 333ms (3Hz)	10011	9.9	15.0	19.0	80.2	95.7	100.0
14	Alternate HF slow sweep	2350-2900Hz swept every 333ms (3Hz)	10010	11.4	19.3	34.5	83.7	95.7	104.6
15	Fast HF sweep	2400-2800Hz swept every 143ms (7Hz)	10001	11.4	19.6	34.4	82.6	97.1	104.2
16	US Temporal Pattern LF	950Hz for 500ms on, 500ms off (x3), then 1500ms off	10000	10.4	15.1	19.6	80.6	96.0	100.5
17	Interrupted BS	800Hz for 500ms, then off for 500ms	01111	9.2	15.1	18.4	79.6	94.5	98.3
18	ISO 8201 LF BS5839 Pt 1	970Hz for 500ms, then off for 500ms	01110	9.2	14.6	20.5	80.1	95.4	99.9
19	Interrupted medium	1000Hz for 250ms, then off for 250ms	01101	11.0	16.0	20.2	78.5	93.8	98.0
20	ISO8201 HF	2850Hz for 500ms, then off for 500ms	01100	12.1	17.5	28.3	79.4	93.4	100.7
21	Continuous	1000Hz continuous	01011	10.2	15.1	20.1	78.9	94.2	98.7
22	LF Buzz	800-950Hz swept every 9ms (110Hz)	01010	9.8	14.7	18.9	79.9	95.3	99.5
23	HF Continuous	2800Hz continuous	01001	11.3	18.6	29.3	79.3	93.8	101.1
24	Sweep	800-970Hz swept every 111ms (9Hz)	01000	9.7	14.6	18.9	80.1	95.5	99.7
25	**German DIN tone**	**1200-500Hz swept every 1000ms (1Hz)**	00111	9.7	13.5	20.9	79.5	95.0	99.0
26	Swedish Fire signal	660Hz for 150ms, then off for 150ms	00110	10.4	14.3	17.0	76.0	91.9	95.6
27	**French tone AFNOR**	**554Hz for 100ms, then 440Hz for 400ms**	00101	9.1	11.9	15.6	76.9	93.1	95.9
28	Swedish all clear signal	660Hz continuous	00100	9.3	13.2	16.2	77.1	93.1	96.8
29	US Temporal Pattern HF	2900Hz for 500ms on, 500ms off (x3), then1500ms off	00011	11.3	18.3	28.9	79.2	93.1	100.4
30	Siren 2 way ramp (short)	500-1200Hz rising for 250ms, then falling for 250ms	00010	9.4	13.6	17.6	79.2	94.6	98.7
31	FP1063.1-Telecom	800Hz for 250ms, then 970Hz for 250ms	00001	9.8	15.9	19.6	80.2	95.5	100.0
32	Siren 2 way ramp (long)	500-1200Hz rising for 3000ms, then falling for 3000ms	00000	9.9	15.0	19.7	81.0	95.9	100.2

EN54-3 APPROVED MINIMUM SOUND OUTPUT AT 1 METRE - LOW VOLUME

Tone 1 - Cranford Sweep

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	66.54	69.64	15°	65.94	69.14
45°	72.44	75.54	45°	72.24	75.34
75°	72.54	75.64	75°	72.44	75.64
105°	72.54	75.74	105°	72.44	75.54
135°	72.44	75.54	135°	73.24	76.34
165°	65.74	68.94	165°	66.14	69.24

Tone 8 - Continuous 800Hz Tone

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	62.14	64.54	15°	61.14	64.24
45°	69.14	72.14	45°	68.74	71.84
75°	70.94	74.04	75°	70.84	73.94
105°	71.64	74.64	105°	70.74	73.74
135°	68.24	71.24	135°	69.84	72.94
165°	60.94	64.04	165°	59.94	63.14

Tone 11 - Dutch Sweep Tone

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	66.34	69.54	15°	66.04	69.14
45°	72.44	75.54	45°	72.34	75.34
75°	73.64	76.74	75°	73.14	76.24
105°	73.24	76.44	105°	73.44	76.54
135°	72.34	75.44	135°	72.74	75.74
165°	65.94	69.04	165°	66.14	69.34

Tone 25 - German DIN Tone

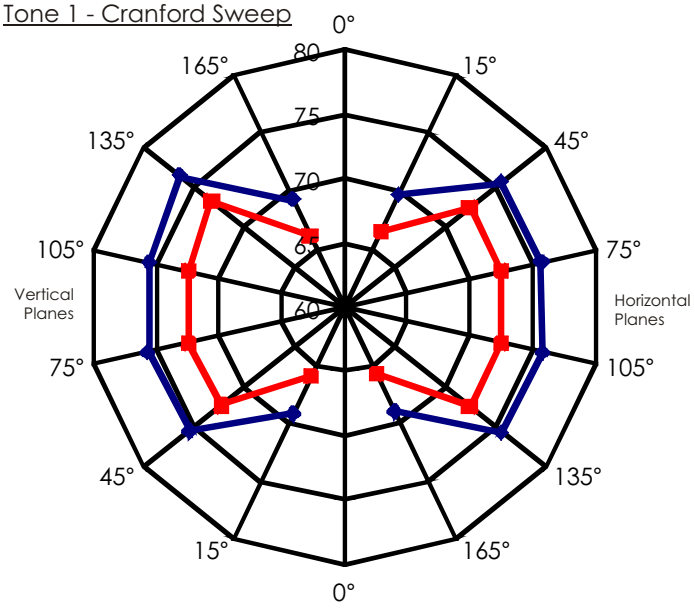
Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	64.44	67.54	15°	63.94	67.04
45°	71.14	74.14	45°	70.94	74.04
75°	71.74	74.84	75°	71.34	74.54
105°	71.54	74.74	105°	71.54	74.74
135°	70.64	73.74	135°	71.14	74.34
165°	63.94	67.04	165°	64.24	67.34

Tone 27 - French AFNOR Tone

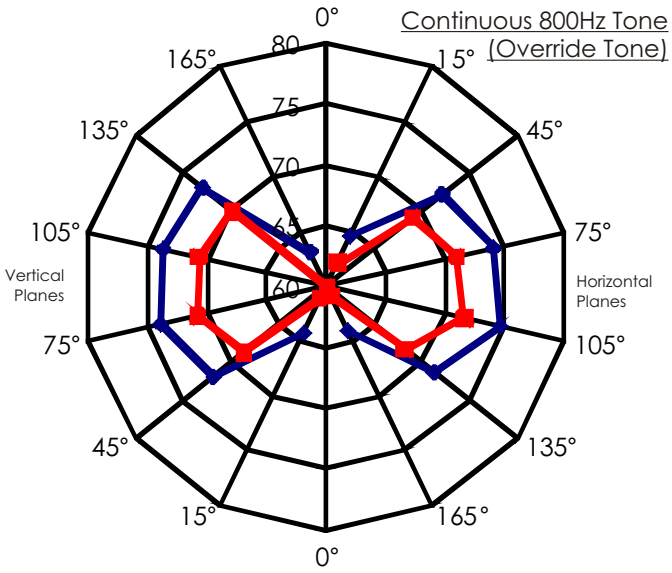
Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	61.54	64.64	15°	60.44	63.34
45°	69.14	72.14	45°	68.84	71.84
75°	68.54	71.64	75°	68.34	71.34
105°	68.54	71.54	105°	68.84	71.84
135°	68.24	71.24	135°	69.44	72.44
165°	61.64	64.74	165°	61.74	64.74

EN54-3 APPROVED POLAR DIAGRAMS - LOW VOLUME

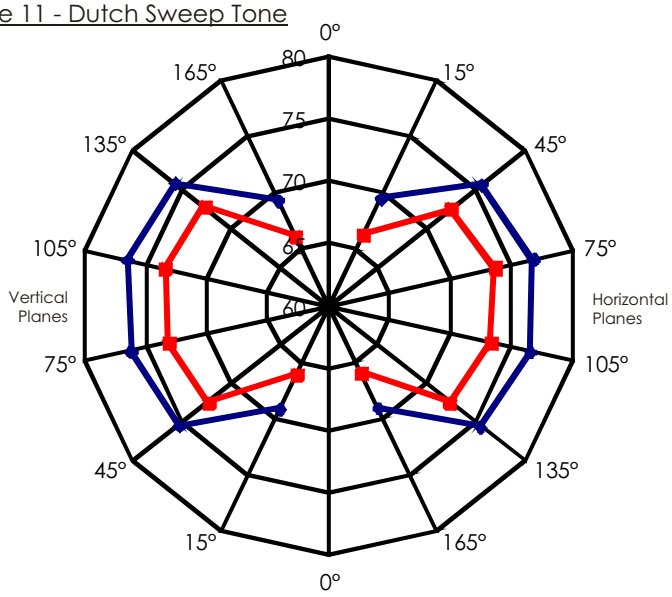
Tone 1 - Cranford Sweep



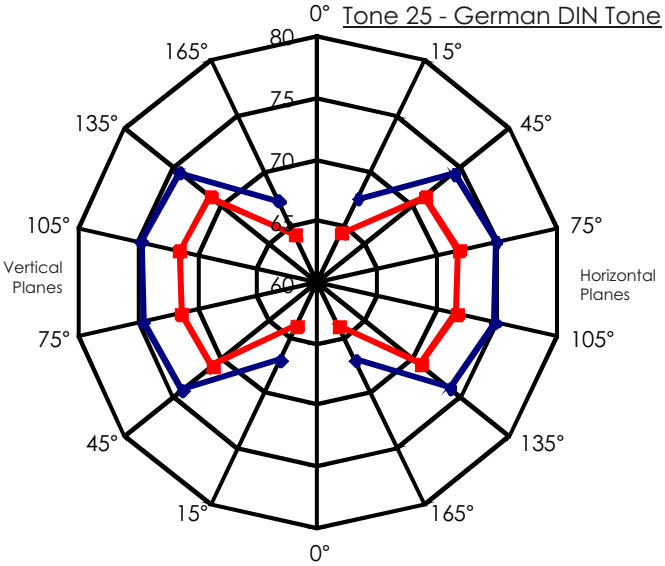
Continuous 800Hz Tone (Override Tone)



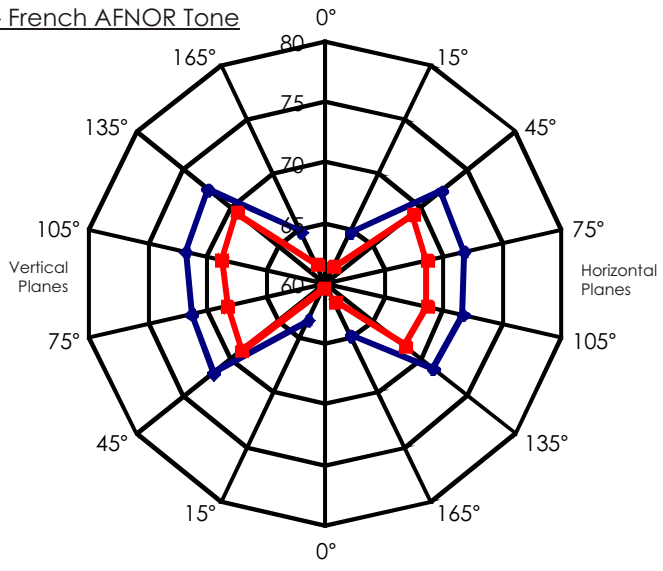
Tone 11 - Dutch Sweep Tone

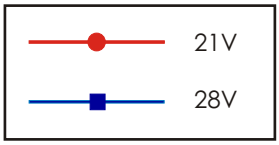


Tone 25 - German DIN Tone



Tone 27 - French AFNOR Tone





EN54-3 APPROVED MINIMUM SOUND OUTPUT AT 1 METRE - HIGH VOLUME

Tone 1 - Cranford Sweep

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	89.14	91.44	15°	88.64	91.04
45°	94.44	96.64	45°	94.14	96.44
75°	94.94	97.24	75°	94.84	97.24
105°	94.84	97.24	105°	94.94	97.14
135°	94.34	96.64	135°	95.14	97.34
165°	88.24	90.54	165°	88.54	90.84

Tone 8 - Continuous 800Hz Tone

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	81.04	83.44	15°	82.14	84.54
45°	89.74	91.94	45°	89.24	91.54
75°	91.14	93.44	75°	91.24	93.54
105°	92.44	94.64	105°	91.34	93.54
135°	89.04	91.24	135°	90.54	92.84
165°	81.94	84.24	165°	81.34	83.64

Tone 11 - Dutch Sweep Tone

Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	89.14	91.44	15°	88.84	91.14
45°	94.34	96.64	45°	94.34	96.64
75°	95.14	97.44	75°	94.94	97.24
105°	95.04	97.34	105°	95.04	97.34
135°	94.44	96.64	135°	94.44	96.64
165°	88.44	90.64	165°	88.64	90.94

Tone 25 - German DIN Tone

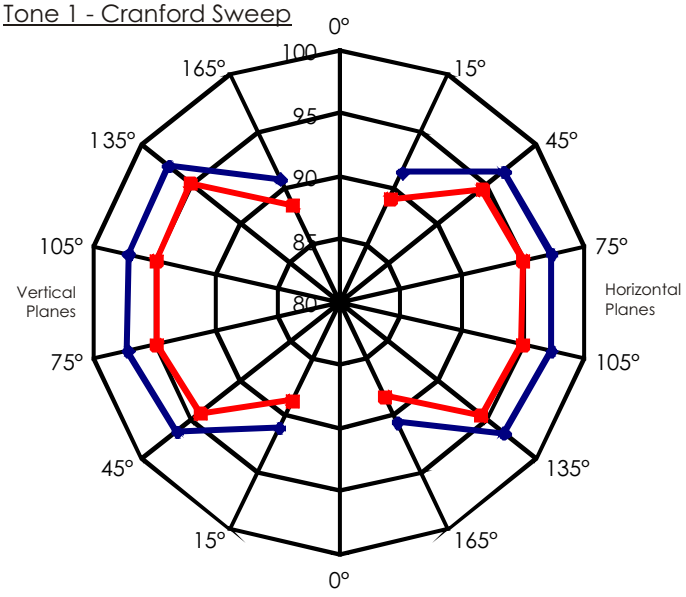
Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	86.84	89.14	15°	86.44	88.74
45°	92.64	94.84	45°	92.54	94.84
75°	93.64	95.94	75°	93.44	95.74
105°	93.54	95.84	105°	93.54	95.84
135°	92.34	94.54	135°	92.84	95.14
165°	86.24	88.44	165°	86.44	88.74

Tone 27 - French AFNOR Tone

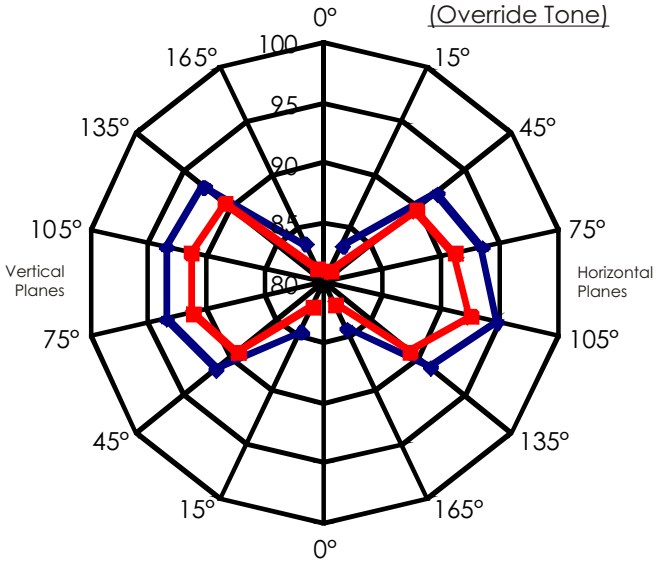
Horizontal Plane			Vertical Plane		
Angle	21V	28V	Angle	21V	28V
15°	82.84	85.04	15°	81.74	83.94
45°	89.84	92.04	45°	89.84	91.94
75°	89.74	91.94	75°	89.34	91.64
105°	89.84	92.14	105°	89.84	92.14
135°	89.24	91.34	135°	90.44	92.54
165°	82.74	85.04	165°	82.84	85.04

EN54-3 APPROVED POLAR DIAGRAMS - HIGH VOLUME

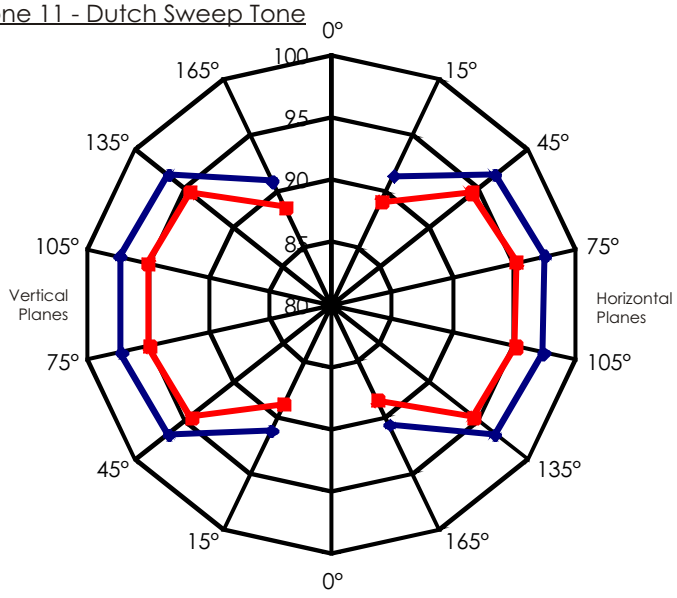
Tone 1 - Cranford Sweep



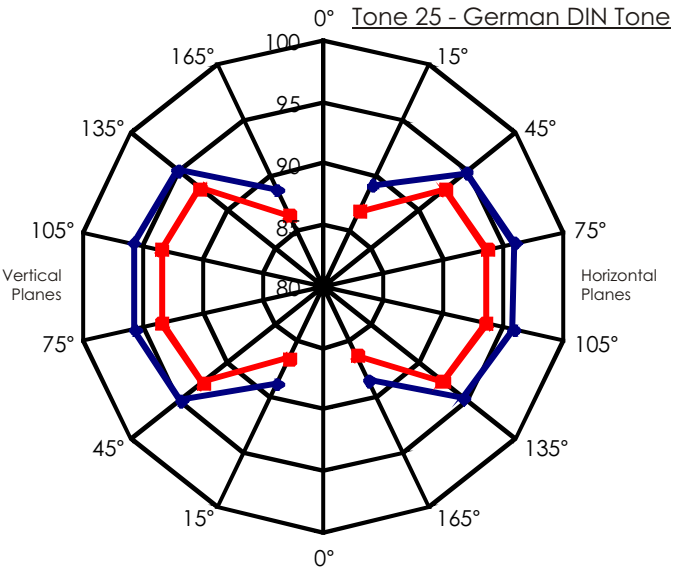
Continuous 800Hz Tone (Override Tone)



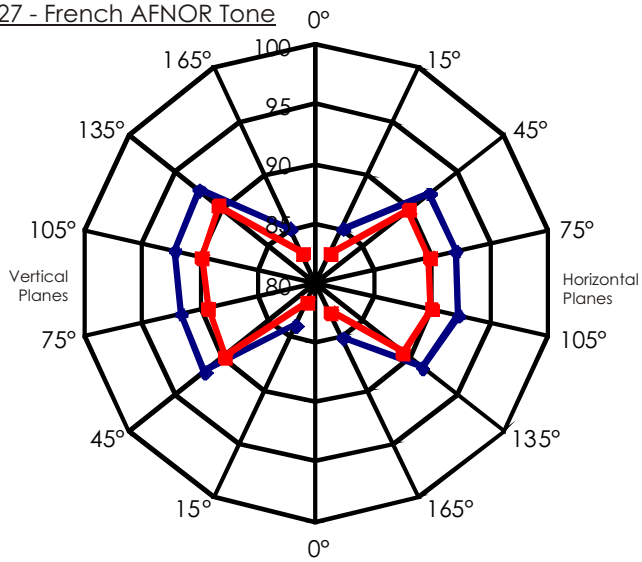
Tone 11 - Dutch Sweep Tone

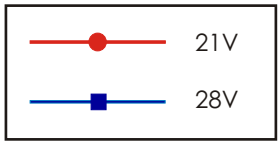


Tone 25 - German DIN Tone



Tone 27 - French AFNOR Tone





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L PLC Project w/ code

Project Documentation

File: LCS_Final.ecp

Date: 5/12/2021

Profile: e!COCKPIT

Table of contents

1 Device: Main_Program_Controller

Users and Groups

Users:

Groups:

Access Rights

View
Modify
Execute
Add/remove children

Symbol Rights

Parameters

Parameters:

Name:	Type:	Value:	Default Value:	Unit:	Description:
Processor Load Lower Limit	DWORD	80	80		
Processor Load Upper Limit	DWORD	90	90		
Processor Load Processor Share	DWORD	90	90		
Processor Load Should Throw ProcessorLoadWatchdog_Exception	bool	FALSE	FALSE		
Keep output values in stop	bool	FALSE	FALSE		
Keep output values in exception	bool	FALSE	FALSE		

Information

Name:	750-8100 PFC100 2ETH ECO
Vendor:	WAGO
Categories:	PLCs
Type:	4096
ID:	1006 1101
Version:	5.15.4.20
Order number:	0750-8100
Description:	Programmable Ethernet controller

1.1 PLC Logic: Plc Logic

1.1.1 Application: Application

1.1.1.1 DUT: typMasterTcp

```
1   (* A Type for a Master that contains a structure *)
2   TYPE typMasterTcp :
3   STRUCT
4       FbMbMasterTcp                   : WagoAppPlcModbus . FbMbMasterTcp ;
                // A Master Function block
5       oMbStatus                       : WagoAppPlcModbus . WagoSysErrorBase .
    FbResult ;   // Status message
6
7       utMbKeepAlive                   : typKeepAlive ;            //
    Keep-Alive
8       eMbFrameType                    : eMbFrameType ;            // Frametype
9       utMbQuery                       : typMbQuery ;          // Query to be
    sent to slave
10      utMbResponse                    : typMbResponse ;       // Response from
    slave
11
12      sMbHost                         : STRING ;              // IP Address
13
14      xMbConnect                      : BOOL ;                    // Connects
    to slave
15      xMbTrigger                      : BOOL ;                    // Triggers
    query
16      xMbIsOpen                       : BOOL ;                    //
    Connection is open
17      xMbError                        : BOOL ;                    // Error
18      xMbAccessEnable                 : BOOL := TRUE ;            // Enables
    access
19
20      wAccessState                    : WORD ;                    // State
    value used in switch-case
21      wMbPort                         : WORD ;                    // Port
    number
22
23      TON_MbConnectMonitor            : TON ;                 // Timer used
    when connection to a slave
24      TON_MbRequestMonitor            : TON ;                 // Timer used
    for receiving a request
25      TON_MbRequestSchedule           : TON ;                 // Timer for
    sending a new request
26
27      tMbConnectMonitor               : TIME := T#1S ;            // Time used
    for TON_MbConnectMonitor
28      tMbRequestMonitor               : TIME := T#200MS ;         // Time used
    for TON_MbRequestMonitor
29      tMbRequestInterval              : TIME := T#200MS ;         // Time used
```

```
    for TON_MbRequestSchedule /500ms
30      tMbTimeOut                  : TIME ;                    // Timeout
31
32      dwMbConnectErrorCnt         : DWORD := 0 ;          // Number of
    connection errors
33      dwMbConnectSuccessCnt       : DWORD := 0 ;          // Number of
    succeeded connections
34      dwMbRequestErrorCnt         : DWORD := 0 ;          // Number of
    request error
35      dwMbRequestSuccessCnt       : DWORD := 0 ;          // Number of
    succeeded requests
36      dwMbRestartCnt              : DWORD := 0 ;          // Number of
    restarts
37  END_STRUCT
38  END_TYPE
39
```

1.1.1.2 Global Variable List: GVL_LCS

```
1   {attribute 'qualified_only'}
2   VAR_GLOBAL
3       // An array of struct for creating master function blocks
4       aTypMasterTcp  : ARRAY [ 0 .. GVL_LCS_Const . iMaxSlaves ]  OF  typMasterTcp
    ;
5
6       // The used alarms accoring to IMO
7       xGeneralEmergency           : BOOL ;        // Genreal Emergency
    Alarm
8       xFire                       : BOOL ;        // Fire Alarm
9       xFireExtinguishing          : BOOL ;        // Fire-Extinguishing
    pre-discharnge Alarm
10      xMachinery                  : BOOL ;        // Machinery Alarm
11      xSteeringGear               : BOOL ;        // Steering Gear Alarm
12      xActivationFireExtinguishing    : BOOL ;    // Activition of local
    Application Fire-extinguishing system
13      xTelephone                  : BOOL ;        // Telephone
14      xEngineRoomTelegraph        : BOOL ;        // Engine Room Telegraph
15      xWaterIngressDetectionMain  : BOOL ;        // Water Ingress
    detection main alarm
16      xWaterIngressDetectionPre   : BOOL ;        // Water Ingress
    detection pre alarm
17      xBilge                      : BOOL ;        // Bilge alarm
18      xEngineers                  : BOOL ;        // Enigneer's Alarm
19
20      // Outputs
21      xSignalLampBit0     : BOOL ;        // Signal output 1
22      xSignalLampBit1     : BOOL ;        // Signal output 2
23      xSignalLampBit2     : BOOL ;        // Signal output 3
24      xSignalLampBit3     : BOOL ;        // Signal output 4
25      xSirenTone          : BOOL ;        // Siren Tone output
26      xSirenCont          : BOOL ;        // Siren Continuous output
27      xSystemError        : BOOL ;        // System Error output
28      xWarningLightGreen  : BOOL ;        // Warning Light Green Output
29      xWarningLightAmber  : BOOL ;        // Warning Light Amber Output
30      xWarningLightRed    : BOOL ;        // Warning Light Red Output
31  END_VAR
32
```

1.1.1.3 Global Variable List: GVL_LCS_Const

```
{attribute 'qualified_only'}
VAR_GLOBAL CONSTANT

    iMaxSlaves              : INT  := 100 ; // Max number of slaves
    iMaxAlarms              : INT  := 12 ;  // Max number of alarms

    aiMaxDiscreteInputs     : INT  := 0 ;       // Max number of discrete
inputs from the master
    aiMaxInputRegisters     : INT  := 0 ;       // Max number of input
registers from the master
    aiMaxHoldingRegisters   : INT  := 0 ;       // Max number of holding
bits from the master
    aiMaxHoldingBits        : INT  := 20 ;  // Max number of holding bits
from the master

    (* TypMasterTcp Variables *)
    wMbPort                       : WORD  := 2000 ;
                                             // The port for the slaves
    xKeepAliveEnable              : BOOL  := TRUE ;
                                             // Enables the KeepAlive
    tKeepAliveMaxIdleTime         : TIME  := T#5S ;
                                             // Max idle time for KeepAlive
    tKeepAliveInterval            : TIME  := T#2S ;
                                             // The time interval for the
KeepAlive
    udiKeepAliveProbes            : UDINT  := 5 ;
                                            // Number of probes to try
    tMbTimeOut                    : TIME  := T#100MS ;
                                           // The timeout time
    eMbFrameType                  : eMbFrameType  := WagoAppPlcModbus .
eMbFrameType . ETHERNET ;     // Frametype for the communication
    bQueryUnitId                  : BYTE  := 1 ;
                                             // UnitID for the slave
    bQueryFunctionCode            : BYTE  := 15 ;
                                            // Function code for query
    uiQueryReadAddress            : UINT  := 0 ;
                                             // Number of Read address
    uiQueryReadQuantity           : UINT  := 0 ;
                                             // Number of Read quantity
    uiQueryWriteAddress           : UINT  := 0 ;
                                             // Number of Write address
    uiQueryWriteQuantity          : UINT  := 12 ;
                                            // Number of Write quantity


    // Alarm bits
    iAlarmBit0  : INT  := 0 ;
    iAlarmBit1  : INT  := 1 ;
    iAlarmBit2  : INT  := 2 ;
    iAlarmBit3  : INT  := 3 ;
END_VAR

```

1.1.1.4 POU: FbMbAlarmInputToData

```
FUNCTION_BLOCK FbMbAlarmInputToData
VAR_INPUT
END_VAR
VAR_OUTPUT
    wSendData : WORD; // Data for Modbus query
END_VAR
VAR
    axAlarms : ARRAY[1..GVL_LCS_Const.iMaxAlarms] OF BOOL; // Boolean array for alarms
    awDataToSend : ARRAY[1..GVL_LCS_Const.iMaxAlarms] OF WORD := [1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048]; // Data to send for each alarm
    awSendData : ARRAY[1..GVL_LCS_Const.iMaxAlarms] OF WORD; // Array for data to send

    iAlarmIndex : INT; // Alarm index used in for-loops
END_VAR
```

```
// Set alarms to the array of all alarms
axAlarms[1] := GVL_LCS.xGeneralEmergency;
axAlarms[2] := GVL_LCS.xFire;
axAlarms[3] := GVL_LCS.xFireExtinguishing;
axAlarms[4] := GVL_LCS.xMachinery;
axAlarms[5] := GVL_LCS.xSteeringGear;
axAlarms[6] := GVL_LCS.xActivationFireExtinguishing;
axAlarms[7] := GVL_LCS.xTelephone;
axAlarms[8] := GVL_LCS.xEngineRoomTelegraph;
axAlarms[9] := GVL_LCS.xWaterIngressDetectionMain;
axAlarms[10] := GVL_LCS.xWaterIngressDetectionPre;
axAlarms[11] := GVL_LCS.xBilge;
axAlarms[12] := GVL_LCS.xEngineers;

wSendData := 0;
// Loops through all of the alarms
FOR iAlarmIndex := 1 TO GVL_LCS_Const.iMaxAlarms DO
    IF axAlarms[iAlarmIndex] THEN
// If a alarm with a given index is active
        awSendData[iAlarmIndex] := awDataToSend[iAlarmIndex];
// Set the dat to send to the awSendData with a given index
        ELSE
            awSendData[iAlarmIndex] := 0;
// If no alarms, awSendData is equal to 0
    END_IF
END_FOR

FOR iAlarmIndex := 1 TO GVL_LCS_Const.iMaxAlarms DO
    wSendData := wSendData + awSendData[iAlarmIndex];
// Adds the data to send to the output
END_FOR
```

```
28
29
30
```

1.1.1.5 POU: FbPulseTimer

```
1   FUNCTION_BLOCK FbPulseTimer
2   VAR_INPUT
3       xEnabled : BOOL ;               // Bool to enable the tone timer
4       tTimeLow : TIME ;               // The time the pulse will be low
5       tTimeHigh : TIME ;              // The time the pulse will be high
6   END_VAR
7   VAR_OUTPUT
8       xOutput : BOOL := FALSE ;       // Flag for toggle the tone
9   END_VAR
10  VAR
11      FbTimer : BLINK ;               // Timer function block
12
13  END_VAR
14
```

```
1   FbTimer ( ENABLE := xEnabled , TIMELOW := tTimeLow , TIMEHIGH := tTimeHigh
    ) ;
2   xOutput := FbTimer . OUT AND xEnabled ;
3
```

1.1.1.6 POU: FbSignalLampOutput

```
1   FUNCTION_BLOCK FbSignalLampOutput
2   VAR_INPUT
3   END_VAR
4   VAR_OUTPUT
5   END_VAR
6   VAR
7       // Function blocks for timing an output signal on and off
8       FbTimer                     : FbPulseTimer ;
9       FbWarningLightPulseGreen    : FbPulseTimer ;
10      FbWarningLightPulseRed      : FbPulseTimer ;
11      FbWarningLightPulseAmber    : FbPulseTimer ;
12
13      axAlarms : ARRAY [ 1 .. GVL_LCS_Const . iMaxAlarms ] OF BOOL ;    //
    Contains all alarms in array of bools
14
15      xOrAllAlarms    : BOOL ;                // Bool for all alarms Ored
    together
16      xTimerPulse     : BOOL ;                // Trigger the signal output
    handling
17
18      tPulseTimeLow   : TIME := T#1S ;        // Pulse time low
19      tPulseTimeHigh  : TIME := T#1MS ;  // Pulse time high
20
21      iOffset             : INT ;         // Offset
22      iCurrentAlarmIndex  : INT ;         // Current alarm to check
23      iNewIndex           : INT ;         // The new alarm to check
24
```

```
25          xGreenLight      : BOOL ;                // Green light for the warning
        light
26          xRedLight        : BOOL ;                // Red light for the warning
        light
27          xAmberLight      : BOOL ;                // Amber light for the warning
        light
28      END_VAR
29
30
```

```
 1      (* This Function Block handles the output signals for signal lamps.
 2       It can handle multiple active alarms, and shuffle between them
 3       at a constant time interval. It does also handle the warning lights.
        *)
 4
 5      // Set alarms to the array of all alarms
 6      axAlarms [ 1 ]  :=  GVL_LCS . xGeneralEmergency ;
 7      axAlarms [ 2 ]  :=  GVL_LCS . xFire ;
 8      axAlarms [ 3 ]  :=  GVL_LCS . xFireExtinguishing ;
 9      axAlarms [ 4 ]  :=  GVL_LCS . xMachinery ;
10      axAlarms [ 5 ]  :=  GVL_LCS . xSteeringGear ;
11      axAlarms [ 6 ]  :=  GVL_LCS . xActivationFireExtinguishing ;
12      axAlarms [ 7 ]  :=  GVL_LCS . xTelephone ;
13      axAlarms [ 8 ]  :=  GVL_LCS . xEngineRoomTelegraph ;
14      axAlarms [ 9 ]  :=  GVL_LCS . xWaterIngressDetectionMain ;
15      axAlarms [ 10 ]  :=  GVL_LCS . xWaterIngressDetectionPre ;
16      axAlarms [ 11 ]  :=  GVL_LCS . xBilge ;
17      axAlarms [ 12 ]  :=  GVL_LCS . xEngineers ;
18
19      // Start pulse timer that triggers the for-loop every second
20      FbTimer ( xEnabled  :=  TRUE ,  tTimeLow  :=  tPulseTimeLow ,  tTimeHigh  :=
        tPulseTimeHigh ,  xOutput  =>  xTimerPulse ) ;
21
22      IF  xTimerPulse  THEN                                                    //
        If the pulse is trigged
23          // Sets all signal outputs to false
24          GVL_LCS . xSignalLampBit0     :=  FALSE ;
25          GVL_LCS . xSignalLampBit1     :=  FALSE ;
26          GVL_LCS . xSignalLampBit2     :=  FALSE ;
27          GVL_LCS . xSignalLampBit3     :=  FALSE ;
28          GVL_LCS . xWarningLightGreen      :=  FALSE ;
29          GVL_LCS . xWarningLightAmber      :=  FALSE ;
30          GVL_LCS . xWarningLightRed    :=  FALSE ;
31
32          FOR  iOffset  :=  1  TO  GVL_LCS_Const . iMaxAlarms  DO              //
        Loop through all of the alarms
33              iNewIndex  :=  iCurrentAlarmIndex  +  iOffset ;
34
35              IF  iNewIndex  >  GVL_LCS_Const . iMaxAlarms  THEN           // If
        new alarm index is bigger max number of alarms
36                  iNewIndex  :=  iNewIndex  -  GVL_LCS_Const . iMaxAlarms ;       //
        Sutract the number of alarms
37              END_IF
38
39              IF  axAlarms [ iNewIndex ]  THEN                                //
```

```
        If one or more alarms is active
40                  iCurrentAlarmIndex  := iNewIndex ;                        // Sets
        the current alarm index to the new alarm index
41
42                  // Sets signal outputs to the given alarm index
43                  GVL_LCS . xSignalLampBit0  := iNewIndex . 0 ;                   //
        Sets the first bit of iNewIndex to signal output
44                  GVL_LCS . xSignalLampBit1  := iNewIndex . 1 ;                   //
        Sets the second bit of iNewIndex to signal output

45                  GVL_LCS . xSignalLampBit2  := iNewIndex . 2 ;                   //
        Sets the third bit of iNewIndex to signal output
46                  GVL_LCS . xSignalLampBit3  := iNewIndex . 3 ;                   //
        Sets the fourth bit of iNewIndex to signal output
47                  EXIT ;
48              END_IF
49          END_FOR
50      END_IF
51
52      // If General Emergency is active, turn on green warning light
53      IF GVL_LCS . xGeneralEmergency THEN
54          xGreenLight  := TRUE ;
55          ELSE
56              xGreenLight  := FALSE ;
57      END_IF
58      // If Fire, Fire Extinguishing, Activition Fire Extinguishing or Water
        Ingress Main is active, turn on red warning light
59      IF GVL_LCS . xFire OR GVL_LCS . xFireExtinguishing OR GVL_LCS .
        xActivationFireExtinguishing OR GVL_LCS . xWaterIngressDetectionMain THEN
60          xRedLight  := TRUE ;
61          ELSE
62              xRedLight  := FALSE ;
63      END_IF
64      // If Machinery, Steering Gear, Teleponhe, Engine Room Telegraph, Water
        Ingress Pre, Enigneers or Bilge is active, turn on red warning light
65      IF GVL_LCS . xMachinery OR GVL_LCS . xSteeringGear OR GVL_LCS . xTelephone
        OR GVL_LCS . xEngineRoomTelegraph OR GVL_LCS . xWaterIngressDetectionPre OR
        GVL_LCS . xEngineers OR GVL_LCS . xBilge THEN
66          xAmberLight  := TRUE ;
67          ELSE
68              xAmberLight  := FALSE ;
69      END_IF
70
71      // Turn on the different warning lights with a interval
72      FbWarningLightPulseGreen ( xEnabled := xGreenLight ,     tTimeLow := T#250MS
        , tTimeHigh := T#1S , xOutput => GVL_LCS . xWarningLightGreen ) ;
73      FbWarningLightPulseRed ( xEnabled := xRedLight ,     tTimeLow := T#250MS ,
        tTimeHigh := T#1S , xOutput => GVL_LCS . xWarningLightRed ) ;
74      FbWarningLightPulseAmber ( xEnabled := xAmberLight ,     tTimeLow := T#250MS
        , tTimeHigh := T#1S , xOutput => GVL_LCS . xWarningLightAmber ) ;
75
```

1.1.1.7 POU: FbSirenOutput

```
1   FUNCTION_BLOCK FbSirenOutput
2   VAR_INPUT
3   END_VAR
4   VAR_OUTPUT
5   END_VAR
6   VAR
7       // Creates three different tones, based on the FbSirenTone function
    block
8       Tone3a : FbPulseTimer;
9       Tone3b : FbPulseTimer;
10      Tone3c : FbPulseTimer;
11  END_VAR
12
```

```
1   // Create three different siren tones
2   Tone3a(xEnabled := TRUE, tTimeHigh := T#500MS, tTimeLow := T#500MS);
        // One tone each seond
3   Tone3b(xEnabled := TRUE, tTimeHigh := T#500MS, tTimeLow := T#250MS);
        // Active for 500ms and inactive for 250ms
4   Tone3c(xEnabled := TRUE, tTimeHigh := T#250MS, tTimeLow := T#250MS);
        // Two tones each second
5
6   (* Tone output for each alarm according to rules and regulations *)
7
8   // If General Emergency alarm is active, Siren Tone is active
9   IF GVL_LCS.xGeneralEmergency THEN
10      GVL_LCS.xSirenTone := TRUE;
11      GVL_LCS.xSirenCont := FALSE;
12
13      // Continous alarm if Fire Alarm, Fire Extinguishing Alarm, Activation
    Fire Extinguishing Alarm, Engine Room Telegraph Alarm, Water Ingress
    Detection Main Alarm, Water Ingress Detection Pre Alarm
14      ELSIF GVL_LCS.xFire OR GVL_LCS.xFireExtinguishing OR GVL_LCS.
    xActivationFireExtinguishing OR GVL_LCS.xEngineRoomTelegraph OR GVL_LCS.
    xWaterIngressDetectionMain OR GVL_LCS.xWaterIngressDetectionPre THEN
15          GVL_LCS.xSirenCont := TRUE;
16          GVL_LCS.xSirenTone := FALSE;
17
18      // If Machinery Alarm or Steering Gear Alarm is active, continous alarm
    with one tone each second
19      ELSIF GVL_LCS.xMachinery OR GVL_LCS.xSteeringGear THEN
20          GVL_LCS.xSirenCont := Tone3a.xOutput;
21          GVL_LCS.xSirenTone := FALSE;
22
23      // If Telephone Alarm or Engineers Alarm is active, continous alarm that
    is active for 500ms and inactive for 250ms
24      ELSIF GVL_LCS.xTelephone OR GVL_LCS.xEngineers THEN
25          GVL_LCS.xSirenCont := Tone3b.xOutput;
26          GVL_LCS.xSirenTone := FALSE;
27
28      // If Bilge Alarm is active, continous alarm with two tones pr second
29      ELSIF GVL_LCS.xBilge THEN
```

```
30              GVL_LCS . xSirenCont  :=  Tone3c . xOutput ;
31              GVL_LCS . xSirenTone  :=  FALSE ;
32
33          // Silent if no alarm
34          ELSE
35              GVL_LCS . xSirenCont  :=  FALSE ;
36              GVL_LCS . xSirenTone  :=  FALSE ;
37      END_IF
38
```

1.1.1.8 POU: Main_Program

```
1       PROGRAM  Main_Program
2       VAR
3           // Function blocks for handling signal and siren outputs
4           FbSignalLampOutput   :  FbSignalLampOutput ;
5           FbSirenOutput        :  FbSirenOutput ;
6       END_VAR
7
```

```
1       (* The main program for the LCS. This program runs the ModbusMaster,
        ModbusRedMaster
2        and the ModbusSlave according to what role the PLC has.
                                                                    *)
3
4       // If the master switch is enabled, run the ModbusMaster program
5       IF  PerVar . xMaster  THEN
6           ModbusMaster ( ) ;
7           PerVar . xRedundantMaster  :=  FALSE ;
8
9           // If the redundant master switch in enabled, run the ModbusRedMaster
        program
10          ELSIF  PerVar . xRedundantMaster  THEN
11              ModbusRedMaster ( ) ;
12              PerVar . xMaster  :=  FALSE ;
13
14          // If no one of the role switches is enabled, run the ModbusSlave
        program
15          ELSE
16              ModbusSlave ( ) ;
17      END_IF
18
19      // Signal output and siren output
20      FbSignalLampOutput ( ) ;
21      FbSirenOutput ( ) ;
22
23      // Runs the visualization program
24      VisualizationProgram ( ) ;
25
```

1.1.1.9 POU: ModbusMaster

```
PROGRAM ModbusMaster
VAR
    // Function blocks for the master
    FbSignalLampOutput      : FbSignalLampOutput ;
    FbMbAlarmInputToData    : FbMbAlarmInputToData ;
    FbSirenOutput           : FbSirenOutput ;

    // INT used in the for-loops
    i : INT ;

    // Variables for reading data from the slaves if needed
    // iReadData        : INT;
    // aiReadData        : ARRAY[0..9] OF INT;

    // Variables for sending data over Modbus
    awCoils     : ARRAY [ 0 .. 124 ] OF WORD ;        // Coils data to send
    wSendData   : WORD ;                              // Data to send as worrd

    // Alarm inputs
    xGeneralEmergency               AT %IX2.0   : BOOL ;
    xFire                           AT %IX2.1   : BOOL ;
    xFireExtinguishing              AT %IX2.2   : BOOL ;
    xMachinery                      AT %IX2.3   : BOOL ;
    xSteeringGear                   AT %IX2.4   : BOOL ;
    xActivationFireExtinguishing    AT %IX2.5   : BOOL ;
    xTelephone                      AT %IX2.6   : BOOL ;
    xEngineRoomTelegraph            AT %IX2.7   : BOOL ;
    xWaterIngressDetectionMain      AT %IX3.0   : BOOL ;
    xWaterIngressDetectionPre       AT %IX3.1   : BOOL ;
    xBilge                          AT %IX3.2   : BOOL ;
    xEngineers                      AT %IX3.3   : BOOL ;

    // Alarm outputs
    xSignalLampBit0     AT %QX0.0   : BOOL ;
    xSignalLampBit1     AT %QX0.1   : BOOL ;
    xSignalLampBit2     AT %QX0.2   : BOOL ;
    xSignalLampBit3     AT %QX0.3   : BOOL ;
    xSirenCont          AT %QX0.4   : BOOL ;
    xSirenTone          AT %QX0.5   : BOOL ;
    xSystemError        AT %QX0.6   : BOOL ;
    xWarningLightRed    AT %QX1.0   : BOOL ;
    xWarningLightAmber  AT %QX1.1   : BOOL ;
    xWarningLightGreen  AT %QX1.2   : BOOL ;

    iCnt  : INT ;
END_VAR
```

```
(* This program handles the master code. It runs the ModbusMasterRun
program.
 It also prints a status message to the Device list in the Visualization
             *)
```

```
3
4       // Sets the alarm inputs to the Global Variables
5       IF PerVar.xMaster OR ModbusRedMaster.xMasterDown THEN
6           GVL_LCS.xGeneralEmergency              := xGeneralEmergency;
7           GVL_LCS.xFire                          := xFire;
8           GVL_LCS.xFireExtinguishing                 := xFireExtinguishing;
9           GVL_LCS.xMachinery                         := xMachinery;
10          GVL_LCS.xSteeringGear                  := xSteeringGear;
11          GVL_LCS.xActivationFireExtinguishing   := xActivationFireExtinguishing
        ;
12          GVL_LCS.xTelephone                         := xTelephone;
13          GVL_LCS.xEngineRoomTelegraph           := xEngineRoomTelegraph;
14          GVL_LCS.xWaterIngressDetectionMain         :=
        xWaterIngressDetectionMain;
15          GVL_LCS.xWaterIngressDetectionPre      := xWaterIngressDetectionPre;
16          GVL_LCS.xBilge                             := xBilge;
17          GVL_LCS.xEngineers                         := xEngineers;
18          GVL_LCS.xSystemError                   := xSystemError;
19      END_IF
20
21      // Sets global output variables to the alarm outputs
22      xSignalLampBit0      := GVL_LCS.xSignalLampBit0;
23      xSignalLampBit1      := GVL_LCS.xSignalLampBit1;
24      xSignalLampBit2      := GVL_LCS.xSignalLampBit2;
25      xSignalLampBit3      := GVL_LCS.xSignalLampBit3;
26      xSirenCont           := GVL_LCS.xSirenCont;
27      xSirenTone           := GVL_LCS.xSirenTone;
28      xWarningLightGreen   := GVL_LCS.xWarningLightGreen;
29      xWarningLightAmber   := GVL_LCS.xWarningLightAmber;
30      xWarningLightRed     := GVL_LCS.xWarningLightRed;
31
32      FbMbAlarmInputToData();
33
34      // Write the data provided from the FbMbWriteMultipleCoils function block
35      awCoils[0] := FbMbAlarmInputToData.wSendData;
36
37      // Writes the coils to the query for the master
38      // May be moved to ModbusMasterRun
39      FOR i := 0 TO GVL_LCS_Const.iMaxSlaves DO
40          GVL_LCS.aTypMasterTcp[i].utMbQuery.awWriteData[0] := awCoils[0]
        ;
41      END_FOR
42
43      // If IP address is not empty and a slave has disconnected
44      FOR i := 0 TO GVL_LCS_Const.iMaxSlaves DO
45          IF (VisualizationProgram.asSlaveStatus[1,i] = 'Not Connected') AND
         (PerVar.asSlaveIp[i] <> '') THEN
46              iCnt := iCnt + 1;          // Increase counter for disconnected
        slaves
47          END_IF
48      END_FOR
49      // IF counter for disconnected slaves is greater than 0
50      // Set activate system error
51      IF iCnt > 0 THEN
52          xSystemError := TRUE;
53          ELSE
```

```
54              xSystemError  :=  FALSE ;
55      END_IF
56      iCnt  :=  0 ;          // Resets counter
57
58      // Uncomment if reading data from the slaves if needed
59      // iReadData := GVL_Master.aTypMasterTcp[1].utMbResponse.awData[0];
60      // FOR i := 0 TO 9 DO
61      //        aiReadData[i] :=
        GVL_Master.aTypMasterTcp[2].utMbResponse.awData[i];
62      // END_FOR
63
64      // Runs the ModbusMasterRun code
65      ModbusMasterRun ( ) ;
66
```

1.1.1.10 POU: ModbusMasterRun

```
1       PROGRAM  ModbusMasterRun
2       VAR
3           i  :  INT ;
4       END_VAR
5
```

```
1       (*        The code that runs the master code. The code uses a For-loop to
        iterate between
2              all of the slaves in the systems. The For-loop contains a switch case
        that is
3              controlled by the different states in a connection.
                                                        *)
4
5       FOR  i  :=  0  TO  GVL_LCS_Const . iMaxSlaves  DO
6           CASE  GVL_LCS . aTypMasterTcp [ i ] . wAccessState  OF
7               0 :      (*        Idle        *)
8                   // Does not connect to any slaves or send any queries
9                   GVL_LCS . aTypMasterTcp [ i ] . xMbConnect  :=  FALSE ;
10                  GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger  :=  FALSE ;
11                  // Resets connection and request timers
12                  GVL_LCS . aTypMasterTcp [ i ] . TON_MbConnectMonitor ( IN  :=  FALSE )
        ;
13                  GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor ( IN  :=  FALSE )
        ;
14
15                  // If the IP address for this slave is empty, don't enable
        xMbAccessEnable
16                  IF  GVL_LCS . aTypMasterTcp [ i ] . sMbHost  =  ''  THEN
17                      GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable  :=  FALSE ;
18                      ELSE
19                          GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable  :=  TRUE ;
20                  END_IF
21
22                  // Change to connection state if xMbAccessEnable is TRUE
23                  IF  GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable  THEN
24                      GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  1 ;
        // Changes state to "Open connection to slaves"
25                  END_IF
```

```
26
27              1 :          (*        Open connection to slaves        *)
28                  // Connects to the slaves and activate connection timer
29                  GVL_LCS . aTypMasterTcp [ i ] . xMbConnect  :=  TRUE ;
30                  GVL_LCS . aTypMasterTcp [ i ] . TON_MbConnectMonitor ( IN  :=  TRUE ,
    PT  :=  GVL_LCS . aTypMasterTcp [ i ] . tMbConnectMonitor ) ;
31
32                  // If connection is open, stop connection timer and increase
    number of succeed connections
33                  IF  GVL_LCS . aTypMasterTcp [ i ] . xMbIsOpen  THEN  // Connected til
    slave
34                      GVL_LCS . aTypMasterTcp [ i ] . TON_MbConnectMonitor ( IN  :=
    FALSE ) ;
35                      GVL_LCS . aTypMasterTcp [ i ] . dwMbConnectSuccessCnt  :=
    GVL_LCS . aTypMasterTcp [ i ] . dwMbConnectSuccessCnt  +  1 ;
36
37                      IF  PerVar . xMaster  OR  ModbusRedMaster . xMasterDown  THEN
38                          GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger  :=  TRUE ;
    // Trigger the query
39                          GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  2 ;
                // Changes state to "Response after request"
40                      END_IF
41
42                  // Increase number of failed connections if PT from connection
    timer has elapsed, could not connect
43                  ELSE  IF  ( GVL_LCS . aTypMasterTcp [ i ] . TON_MbConnectMonitor . Q  =
     TRUE )  THEN
44                      GVL_LCS . aTypMasterTcp [ i ] . dwMbConnectErrorCnt  :=  GVL_LCS
    . aTypMasterTcp [ i ] . dwMbConnectErrorCnt  +  1 ;
45                      GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  5 ;        //
    Changes state to "Error Handling"
46                  END_IF
47                  END_IF
48
49              2 :      (*        Response after request        *)
50                  // Activate request timer
51                  GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor ( IN  :=  TRUE ,
    PT  :=  GVL_LCS . aTypMasterTcp [ i ] . tMbRequestMonitor ) ;
52
53                  // Check if trigger is deactivated
54                  IF  GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger  =  FALSE  THEN
55                      // Deactivate the request timer
56                      GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor ( IN  :=
    FALSE ) ;
57
58                      // Changes state to "Delay before new request"
59                      GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  3 ;
60
61                      // If no error occured increase succeed request counter else
    increase request error counter
62                      IF  GVL_LCS . aTypMasterTcp [ i ] . xMbError  =  FALSE  THEN
63                          GVL_LCS . aTypMasterTcp [ i ] . dwMbRequestSuccessCnt  :=
    GVL_LCS . aTypMasterTcp [ i ] . dwMbRequestSuccessCnt  +  1 ;
64                      ELSE
65                          GVL_LCS . aTypMasterTcp [ i ] . dwMbRequestErrorCnt  :=
    GVL_LCS . aTypMasterTcp [ i ] . dwMbRequestErrorCnt  +  1 ;
```

```
66                          // Change state to "Error Handling"
67                          GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  5 ;
68                      END_IF
69
70                  // If the trigger is active for too long time
71                  ELSIF  GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor . Q  =
    TRUE  THEN
72                      // Deactivate the request timer
73                      GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor ( IN  :=
    FALSE ) ;
74
75                      // Increase the request error counter
76                      GVL_LCS . aTypMasterTcp [ i ] . dwMbRequestErrorCnt  :=  GVL_LCS
    . aTypMasterTcp [ i ] . dwMbRequestErrorCnt  +  1 ;
77
78                      // Change state to "Error Handling"
79                      GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  5 ;
80                  END_IF
81
82              3 :      (*        Delay before new request        *)
83                  GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestSchedule ( IN  :=  TRUE ,
     PT  :=  GVL_LCS . aTypMasterTcp [ i ] . tMbRequestInterval ) ;
84
85                  // If PT has elapsed, stop schedule timer
86                  IF  GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestSchedule . Q  =  TRUE
     THEN
87
88                      // Check if xMbAccessEnable is TRUE, reset schedule timer,
    toggle trigger and change state to "Response after request"
89                      // Else change state to "Monitor activition signal"
90                      IF  GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable  =  TRUE  AND
    ( PerVar . xMaster  OR  ModbusRedMaster . xMasterDown )  THEN
91                          GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestSchedule ( IN
    :=  FALSE ) ;
92                          GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger  :=  TRUE ;
93                          GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  2 ;
    // Changes state to "Response after request"
94                      ELSE
95                          GVL_LCS . aTypMasterTcp [ i ] . wAccessState  :=  4 ;
    // Changes state to "Monitor activition signal"
96                      END_IF
97
98                  END_IF
99
100             4 :      (*        Monitor activition signal        *)
101                 // As long as xMbAccessEnable is FALSE, only monitor activition
    signal
102                 GVL_LCS . aTypMasterTcp [ i ] . xMbConnect  :=  FALSE ;
103                 GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger  :=  FALSE ;
104
105                 // Reset connection and request timers
106                 GVL_LCS . aTypMasterTcp [ i ] . TON_MbConnectMonitor ( IN  :=  FALSE )
    ;
107                 GVL_LCS . aTypMasterTcp [ i ] . TON_MbRequestMonitor ( IN  :=  FALSE )
    ;
108
```

```
109                 // If the ip address for this slave is empty, don't enable
    xMbAccessEnable
110                 IF GVL_LCS . aTypMasterTcp [ i ] . sMbHost = '' THEN
111                     GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable := FALSE ;
112                     ELSE
113                         GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable := TRUE ;
114                 END_IF
115
116                 // If xMbAccessEnable is TRUE, open connection to slaves
117                 IF GVL_LCS . aTypMasterTcp [ i ] . xMbAccessEnable THEN
118                     GVL_LCS . aTypMasterTcp [ i ] . wAccessState := 1 ;
    // Changes state to "Open connection to slaves"
119                 END_IF
120
121             5 :     (*      Error Handling      *)
122                 // Increase restart counter and change state to Idle
123                 GVL_LCS . aTypMasterTcp [ i ] . dwMbRestartCnt := GVL_LCS .
    aTypMasterTcp [ i ] . dwMbRestartCnt + 1 ;
124                 GVL_LCS . aTypMasterTcp [ i ] . wAccessState := 0 ;
    // Changes state to "Idle"
125         END_CASE
126
127         (*      Execute master with given slave index       *)
128         GVL_LCS . aTypMasterTcp [ i ] . FbMbMasterTcp (
129                     xConnect        := GVL_LCS . aTypMasterTcp [ i ] . xMbConnect ,
                    // Connects to a slave
130                     sHost           := GVL_LCS . aTypMasterTcp [ i ] . sMbHost ,
                  // IP Address for the slave
131                     wPort           := GVL_LCS . aTypMasterTcp [ i ] . wMbPort ,
                  // Port
132                     utKeepAlive     := GVL_LCS . aTypMasterTcp [ i ] .
    utMbKeepAlive ,     // Keep-Alive
133                     eFrameType      := GVL_LCS . aTypMasterTcp [ i ] . eMbFrameType
    ,       // Frametype
134                     tTimeOut        := GVL_LCS . aTypMasterTcp [ i ] . tMbTimeOut ,
                    // Time for timeout
135                     utQuery         := GVL_LCS . aTypMasterTcp [ i ] . utMbQuery ,
                 // The query to be sent
136                     xTrigger        := GVL_LCS . aTypMasterTcp [ i ] . xMbTrigger ,
                    // Trigger
137                     utResponse      := GVL_LCS . aTypMasterTcp [ i ] . utMbResponse
    ,       // Response from slave
138                     xIsOpen         => GVL_LCS . aTypMasterTcp [ i ] . xMbIsOpen ,
                 // Checks if connection is opne
139                     xError          => GVL_LCS . aTypMasterTcp [ i ] . xMbError ,
                  // Error
140                     oStatus         => GVL_LCS . aTypMasterTcp [ i ] . oMbStatus
                   // Status from slave
141                     ) ;
142     END_FOR
143
```

1.1.1.11 POU: ModbusRedMaster

```
PROGRAM ModbusRedMaster
VAR
    udiMasterRequestCounter          : UDINT ;   // The counter value of
succesful master requests
    udiMasterRequestCounterShadow    : UDINT ;   // The shadow of the counter
value of succesful master requests

    tCurrentTime        : TIME ;                    // The current time
    tLastMasterRequest  : TIME  := T#0S ;           // The time since last
succesful master request

    xMasterDown         : BOOL  := FALSE ;      // TRUE if master has timed
out

END_VAR
```

```
(* This code runs the Redundant Master code. It uses the
udiWriteAccessCounter
 from the ModbusSlave.FbMbSimpleServerTcp function block fot checking
connection
 between the Redundant Master and the Master. Runs the ModbusSlave until the
 Master PLC is down. *)

// Get current time
tCurrentTime  := TIME ( ) ;

// Get connection counter value
udiMasterRequestCounter  := ModbusSlave . FbMbSimpleServerTcp . oMbAccessInfo .
udiWriteAccessCounter ;

// If counter value has changed, set the time since last master request
IF udiMasterRequestCounter  <> udiMasterRequestCounterShadow  THEN
    tLastMasterRequest  := tCurrentTime ;
END_IF

// Set shadow of the counter value of succesful master requests
udiMasterRequestCounterShadow  := udiMasterRequestCounter ;

// If time since last succesful master request is greater than timeout
value, then master is likely down
IF  ( ( tCurrentTime  -  tLastMasterRequest )  >  PerVar . tMasterTimeout )  THEN
    xMasterDown  := TRUE ;
ELSE
    xMasterDown  := FALSE ;
END_IF

// Runs the ModbusMaster program, but does not send any queries
// before the master is down
ModbusMaster ( ) ;
```

```
30
31      // Runs the ModbusSlave program
32      ModbusSlave ( ) ;
33
34
35
```

1.1.1.12 POU: ModbusSlave

```
1       PROGRAM  ModbusSlave
2       VAR
3           // Declare function blocks used for the Modbus slaves
4           FbMbSimpleServerTcp      :  FbMbSimpleServerTcp ;
5           FbSignalLampOutput       :  FbSignalLampOutput ;
6           FbSirenOutput            :  FbSirenOutput ;
7           FbMasterRequestTimer     :  FbPulseTimer ;
8
9
10          // Variables for the ModbusSlaveAct Action
11          xMbTcpOpen                   :  BOOL  :=  TRUE ;
12          wMbTcpPort                   :  WORD  :=  2000 ;
13          bMbTcpUnitId                 :  BYTE  :=  1 ;
14          xMbTcpIsOpen                 :  BOOL ;
15          xMbTcpError                  :  BOOL ;
16          oMbTcpStatus                 :  WagoSysErrorBase . FbResult ;
17          oMbTcpAccessInfo             :  FbMbAccessInfo ;
18          udiMbTcpConnectedClient      :  UDINT ;
19          utMbTcpKeepAlive             :  typKeepAlive  :=  ( xEnable  :=  TRUE ,
        tMaxIdleTime  :=  T#5S ,  tInterval  :=  T#2S ,  udiProbes  :=  5 ) ;
20
21          // Data arrays that is used in the ModbusSlaveAct action for the slaves
22          axDiscreteInputs             :  ARRAY [ 0 .. GVL_LCS_Const .
        aiMaxDiscreteInputs ]  OF  BOOL ;      // Boolean array for discrete inputs
23          awInputRegisters             :  ARRAY [ 0 .. GVL_LCS_Const .
        aiMaxInputRegisters ]  OF  WORD ;      // Word array for input registers
24          awHoldingRegisters           :  ARRAY [ 0 .. GVL_LCS_Const .
        aiMaxHoldingRegisters ]  OF  WORD ;    // Word array for holding registers
25          axMbHoldingBits              :  ARRAY [ 0 .. GVL_LCS_Const . aiMaxHoldingBits
        ]  OF  BOOL ;              // Boolean array for holding bits
26
27
28          // Output for the output lamps and siren
29          xSignalLampBit0      AT  %QX0.0   :  BOOL ;
30          xSignalLampBit1      AT  %QX0.1   :  BOOL ;
31          xSignalLampBit2      AT  %QX0.2   :  BOOL ;
32          xSignalLampBit3      AT  %QX0.3   :  BOOL ;
33          xSirenCont           AT  %QX0.4   :  BOOL ;
34          xSirenTone           AT  %QX0.5   :  BOOL ;
35          xWarningLightRed     AT  %QX1.0   :  BOOL ;
36          xWarningLightAmber   AT  %QX1.1   :  BOOL ;
37          xWarningLightGreen   AT  %QX1.2   :  BOOL ;
38
39
40          i  :  INT ;
41          sMasterIpAddress  :  STRING ;
42          sMasterIpAddressShadow  :  STRING ;
```

```
43          asMasterIpAddresses  :  ARRAY [ 1 .. 2 ]  OF  STRING ;
44
45          udiMasterRequestCounter  :  UDINT ;
46          udiMasterRequestCounterShadow  :  UDINT ;
47          TON_MasterRequestTimer  :  TON ;
48      END_VAR
49
```

```
1       (* This program runs the Modbus Slave code. It uses the
2       FbMbSimpleServerTcp function block from the WagoAppPlcModbus
3       library. *)
4
5       FbMbSimpleServerTcp (
6           xOpen               := xMbTcpOpen ,                    // Enables the
        slave function block
7           wPort               := wMbTcpPort ,                    // Port
8           utKeepAlive         := utMbTcpKeepAlive ,          // Keep-alive
9           bUnitId             := bMbTcpUnitId ,              // Unit ID
10          axDiscreteInputs    := axDiscreteInputs ,          // Array for
        Discrete Inputs
11          axCoils             := axMbHoldingBits ,               // Array for
        Holding Bits
12          awInputRegisters    := awInputRegisters ,          // Array for Input
        Registers
13          awHoldingRegisters  := awHoldingRegisters ,        // Array for Holding
        Registers
14          xIsOpen             => xMbTcpIsOpen ,              // Is Open Output
15          xError              => xMbTcpError ,               // Error Output
16          oStatus             => oMbTcpStatus ,              // Status for slave
17          udiConnectedClients => udiMbTcpConnectedClient ,   // Connected Clients
18          oMbAccessInfo       => oMbTcpAccessInfo ) ;        // Access Info
19
20      // Sets the alarm varibles to the Global Variables
21      IF   NOT  ModbusRedMaster . xMasterDown  THEN
22          GVL_LCS . xGeneralEmergency             := axMbHoldingBits [ 0 ] ;
23          GVL_LCS . xFire                         := axMbHoldingBits [ 1 ] ;
24          GVL_LCS . xFireExtinguishing                := axMbHoldingBits [ 2 ] ;
25          GVL_LCS . xMachinery                        := axMbHoldingBits [ 3 ] ;
26          GVL_LCS . xSteeringGear                 := axMbHoldingBits [ 4 ] ;
27          GVL_LCS . xActivationFireExtinguishing  := axMbHoldingBits [ 5 ] ;
28          GVL_LCS . xTelephone                        := axMbHoldingBits [ 6 ] ;
29          GVL_LCS . xEngineRoomTelegraph          := axMbHoldingBits [ 7 ] ;
30          GVL_LCS . xWaterIngressDetectionMain        := axMbHoldingBits [ 8 ] ;
31          GVL_LCS . xWaterIngressDetectionPre     := axMbHoldingBits [ 9 ] ;
32          GVL_LCS . xBilge                            := axMbHoldingBits [ 10 ] ;
33          GVL_LCS . xEngineers                        := axMbHoldingBits [ 11 ] ;
34      END_IF
35
36      // Set global variables to outputs
37      xSignalLampBit0     := GVL_LCS . xSignalLampBit0 ;
38      xSignalLampBit1     := GVL_LCS . xSignalLampBit1 ;
39      xSignalLampBit2     := GVL_LCS . xSignalLampBit2 ;
40      xSignalLampBit3     := GVL_LCS . xSignalLampBit3 ;
41      xSirenCont          := GVL_LCS . xSirenCont ;
42      xSirenTone          := GVL_LCS . xSirenTone ;
```

```
43      xWarningLightGreen   := GVL_LCS . xWarningLightGreen ;
44      xWarningLightAmber   := GVL_LCS . xWarningLightAmber ;
45      xWarningLightRed     := GVL_LCS . xWarningLightRed ;
46
47
48      // Get connection counter value
49      udiMasterRequestCounter  := ModbusSlave . FbMbSimpleServerTcp . oMbAccessInfo .
        udiWriteAccessCounter ;
50
51      // Start a master reqest timer
52      TON_MasterRequestTimer ( IN  := udiMasterRequestCounterShadow  =
        udiMasterRequestCounter ,  PT  := PerVar . tMasterTimeout  + T#1S ) ;
53      udiMasterRequestCounterShadow  := udiMasterRequestCounter ;
54
55      // Deactivate all alarms if master request timer have elapsed
56      IF  TON_MasterRequestTimer . Q  AND  NOT  PerVar . xRedundantMaster  THEN
57          GVL_LCS . xGeneralEmergency              := FALSE ;
58          GVL_LCS . xFire                          := FALSE ;
59          GVL_LCS . xFireExtinguishing                 := FALSE ;
60          GVL_LCS . xMachinery                         := FALSE ;
61          GVL_LCS . xSteeringGear                  := FALSE ;
62          GVL_LCS . xActivationFireExtinguishing   := FALSE ;
63          GVL_LCS . xTelephone                         := FALSE ;
64          GVL_LCS . xEngineRoomTelegraph           := FALSE ;
65          GVL_LCS . xWaterIngressDetectionMain         := FALSE ;
66          GVL_LCS . xWaterIngressDetectionPre      := FALSE ;
67          GVL_LCS . xBilge                             := FALSE ;
68          GVL_LCS . xEngineers                         := FALSE ;
69      END_IF
70
71
72
73
74
75
76
77
```

1.1.1.13 POU: SignalLampSimulation

```
1       PROGRAM  SignalLampSimulation
2       VAR
3           // Array of alarms
4           axAlarms  :  ARRAY [ 1 .. GVL_LCS_Const . iMaxAlarms ]  OF  BOOL ;
5
6           iAlarmNumber  :  INT ;        // Number for current alarm
7           iAlarmIndex  :  INT ;         // Index for current alarm
8       END_VAR
9
```

```
1       (* This program simulates the active alarms. This
2       program also controlling which alarms which are
3       shown in the Signal Lamp Visualization in the
4       Configuration Interface.                                    *)
5
```

```
6       iAlarmNumber.0 := GVL_LCS.xSignalLampBit0; // Sets the first
        bit in the alarm number to the first signal lamp bit
7       iAlarmNumber.1 := GVL_LCS.xSignalLampBit1; // Sets the second
        bit in the alarm number to the second signal lamp bit
8       iAlarmNumber.2 := GVL_LCS.xSignalLampBit2; // Sets the third
        bit in the alarm number to the third signal lamp bit
9       iAlarmNumber.3 := GVL_LCS.xSignalLampBit3; // Sets the fourth
        bit in the alarm number to the fourth signal lamp bit
10
11      // Loops through all of the alrams in the system.
12      FOR iAlarmIndex := 1 TO GVL_LCS_Const.iMaxAlarms DO
13          IF iAlarmIndex = iAlarmNumber THEN // If the alarm
        index is equal to the alarm number
14              axAlarms[iAlarmIndex] := TRUE; // Set the given
        alarm TRUE
15              ELSE
16                  axAlarms[iAlarmIndex] := FALSE; // Set the given
        alarm FALSE in any other case
17          END_IF
18      END_FOR
19
```

1.1.1.14 POU: VisualizationProgram

```
1       PROGRAM VisualizationProgram
2       VAR
3           // Function block for getting IP address for current LCU
4           FbGetIpAddress      : FbGetX1_ActualNetworkAddress;
5
6           // IP Address
7           sIpAddress : STRING;
8
9           xMasterChange           : BOOL := TRUE; // Toggles for-loop for
        declaring changes for the masters
10          xRemoveSlaveFromList    : BOOL;          // Bool varible for removing
        a device from the system
11          sRole                   : STRING;      // The current role for a LCU,
        seen in the configuration interface
12
13          // Time variables
14          dtPfcTime   : DATE_AND_TIME;
15          sLocalTime  : STRING;
16
17          // WebVisu variables
18          sWebAddressPart     : STRING;                       // The first
        part of the web address
19          sWebAddressFinal    : STRING;                       // The final
        part of the web address
20          sHTTPS              : STRING := 'https://';
21          sWebVisu            : STRING := '/webvisu/webvisu.htm';
22
23          // String Array for status message for the slaves
24          // The status message is listed in the Device page in the configuration
        interface
25          asSlaveStatus : ARRAY[0..1, 0..GVL_LCS_Const.iMaxSlaves] OF
        STRING;
```

```
26          atMasterTimeout      : ARRAY [ 0 .. 8 ] OF TIME := [ T#2S , T#3S , T#4S , T#5S , T#6S , T#7S , T#8S , T#9S , T#10S ] ; // Timeouts to select in Settings
27
28          // Ip address for the master
29          sMasterIpAddress  : STRING ;
30
31          xAlarmHistory  : BOOL ;       // Alarm History
32
33          // For-loop index
34          i  :  INT ;
35
36      END_VAR
37
```

```
 1      // Get local time, used in the configuration interface
 2      dtPfcTime  :=  WagoAppTime . FuGetLocalDateAndTime ( ) ;
 3      sLocalTime  :=  WagoAppString . FuDTToString ( bFormat := 13 , dtInput  := dtPfcTime ) ;     // Convert the date and time to a desirable format
 4
 5      // String manupilation for Device page in configuration
 6      // Gets the Web Address for the WebVisu for a given device
 7      sWebAddressPart  :=  '' ;
 8      sWebAddressFinal  :=  '' ;
 9      IF  PerVar . asSlaveIp [ PerVar . iSlaveIpIndex ]  <>  ''  THEN
                                // IF the IP address string is not empty
10          sWebAddressPart  :=  CONCAT ( sHTTPS ,  PerVar . asSlaveIp [ PerVar . iSlaveIpIndex ] ) ;   // Add the IP adrress to the sHTTPS string
11          sWebAddressFinal  :=  CONCAT ( sWebAddressPart ,  sWebVisu ) ;
                               // Add the new sHTTPS string to the sWebAddressPart to the final WebAddress
12      END_IF
13
14      // Gets the IP Address for the device
15      FbGetIpAddress ( xExecute  :=  TRUE ,  sIpAddress  =>  sIpAddress ) ;
16
17      // If a change have been done in the configuration, set the new settings for the device
18      IF  xMasterChange  THEN
19          FOR  i  :=  0  TO  GVL_LCS_Const . iMaxSlaves  DO
20              GVL_LCS . aTypMasterTcp [ i ] . sMbHost                    :=  PerVar . asSlaveIp [ i ] ;
21              GVL_LCS . aTypMasterTcp [ i ] . wMbPort                    :=  GVL_LCS_Const . wMbPort ;
22              GVL_LCS . aTypMasterTcp [ i ] . utMbKeepAlive . xEnable          :=  GVL_LCS_Const . xKeepAliveEnable ;
23              GVL_LCS . aTypMasterTcp [ i ] . utMbKeepAlive . tMaxIdleTime  :=  GVL_LCS_Const . tKeepAliveMaxIdleTime ;
24              GVL_LCS . aTypMasterTcp [ i ] . utMbKeepAlive . tInterval    :=  GVL_LCS_Const . tKeepAliveInterval ;
25              GVL_LCS . aTypMasterTcp [ i ] . utMbKeepAlive . udiProbes    :=  GVL_LCS_Const . udiKeepAliveProbes ;
26              GVL_LCS . aTypMasterTcp [ i ] . tMbTimeOut                 :=  GVL_LCS_Const . tMbTimeOut ;
27              GVL_LCS . aTypMasterTcp [ i ] . eMbFrameType               :=
```

```
        GVL_LCS_Const . eMbFrameType ;
28              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . bUnitId              :=
        GVL_LCS_Const . bQueryUnitId ;
29              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . bFunctionCode    :=
        GVL_LCS_Const . bQueryFunctionCode ;
30              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . uiReadAddress    :=
        GVL_LCS_Const . uiQueryReadAddress ;
31              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . uiReadQuantity   :=
        GVL_LCS_Const . uiQueryReadQuantity ;
32              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . uiWriteAddress   :=
        GVL_LCS_Const . uiQueryWriteAddress ;
33              GVL_LCS . aTypMasterTcp [ i ] . utMbQuery . uiWriteQuantity      :=
        GVL_LCS_Const . uiQueryWriteQuantity ;
34          END_FOR
35          xMasterChange  :=  FALSE ;
36      END_IF
37
38      // Removes a device from the device list in the configuration interface
39      IF  xRemoveSlaveFromList  THEN
40          PerVar . asSlaveIp [ PerVar . iSlaveIpIndex ]  :=  '' ;      // Set the IP
        Address to an empty string
41          xRemoveSlaveFromList  :=  FALSE ;
42      END_IF
43
44      // Devide visualization elements for each role
45      IF  PerVar . xMaster  THEN
46          sRole  :=  'Master' ;
47
48      ELSIF  PerVar . xRedundantMaster  THEN
49          sRole  :=  'Redundant Master' ;
50          // Sets timeout between 2 and 10 seconds
51          // Able to select the disired timout in the Settings page
52          IF  PerVar . iTimeoutIndex  =  2  THEN
53              PerVar . tMasterTimeout  :=  atMasterTimeout [ 0 ] ;
54              ELSIF  PerVar . iTimeoutIndex  =  3  THEN
55                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 1 ] ;
56              ELSIF  PerVar . iTimeoutIndex  =  4  THEN
57                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 2 ] ;
58              ELSIF  PerVar . iTimeoutIndex  =  5  THEN
59                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 3 ] ;
60              ELSIF  PerVar . iTimeoutIndex  =  6  THEN
61                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 4 ] ;
62              ELSIF  PerVar . iTimeoutIndex  =  7  THEN
63                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 5 ] ;
64              ELSIF  PerVar . iTimeoutIndex  =  8  THEN
65                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 6 ] ;
66              ELSIF  PerVar . iTimeoutIndex  =  9  THEN
67                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 7 ] ;
68              ELSIF  PerVar . iTimeoutIndex  =  10  THEN
69                  PerVar . tMasterTimeout  :=  atMasterTimeout [ 8 ] ;
70          END_IF
71          ELSE
72              sRole  :=  'Slave' ;
73              sMasterIpAddress  :=  ModbusSlave . FbMbSimpleServerTcp . oMbAccessInfo
        . sClientId ;
74      END_IF
75
```

```
76      // Prints the status message and the IP address for a slave to the device
        list
77      FOR i := 0 TO GVL_LCS_Const.iMaxSlaves DO
78          IF GVL_LCS.aTypMasterTcp[i].xMbIsOpen THEN
79              asSlaveStatus[1,i] := 'Connected';
80              ELSE
81                  asSlaveStatus[1,i] := 'Not Connected';
82          END_IF
83          asSlaveStatus[0,i] := PerVar.asSlaveIp[i];
84      END_FOR
85
86
87      // Simulate the alarm matrix symbols in vizualization
88      SignalLampSimulation();
89
```

1.1.1.15 Task Configuration: Task configuration

Max. number of tasks: 15
Max. number of cyclic tasks: 15
Max. number of freewheeling tasks: 15
Max. number of event tasks: 15
Max. number of external event tasks: 8
Max. number of status tasks: 15

System Events:

1.1.1.15.1 Task: AlarmManagerTask

Priority: 15
Type: Cyclic
Interval: 50 Unit: ms
Watchdog: Inactive
POUs: AlarmManager.Alarm_Prg

1.1.1.15.1.1 Program Call: AlarmManager.Alarm_Prg

1.1.1.15.2 Task: PLC_Task

Priority: 15
Type: Cyclic
Interval: t#50ms Unit: ms
Watchdog: Inactive
POUs: Main_Program

1.1.1.15.2.1 Program Call: Main_Program

1.1.1.15.3 Task: VISU_TASK

Priority: 15
Type: Cyclic
Interval: 100 Unit: ms
Watchdog: Inactive
POUs: VisuElems.Visu_Prg

1.1.1.15.3.1 Program Call: VisuElems.Visu_Prg

1.1.1.16 Persistent Variables: PerVar

```
1   {attribute 'qualified_only'}
2   VAR_GLOBAL PERSISTENT RETAIN
3       (* Persistent Variables for the LCS *)
4
5       xMaster             : BOOL ;
                                                    // Bool variable for
    master role for a LCU
6       xRedundantMaster    : BOOL ;
                                                    // Bool variable for
    redundant master role for LCS
7       asSlaveIp           : ARRAY [ 0 .. GVL_LCS_Const . iMaxSlaves ] OF STRING ;
              // The IP Addresses for every LCU in the system
8       iSlaveIpIndex       : INT := 0 ;
                                                // The index for each slave
9       iTimeoutIndex       : INT ;
                                                  // Index for what timeout
    that is chosen
10      tMasterTimeout      : TIME := T#4S ;
                                              // Time before master timeout
11  END_VAR
12
```

1.2 Device: Kbus

K-BUS Parameters

Parameters:

Name:	Type:	Value:	Default Value:	Unit:	Description:
k-bus cycle time	UINT(1..50)	10	10		cycle time in [ms]
k-bus event control 1					cycle offset and cycle number
offset	USINT	0	0		offset in number of cycles
cycle number	USINT	2	2		cycle number (disable event with zero)
k-bus event control 2					cycle offset and cycle number
offset	USINT	1	1		offset in number of cycles
cycle number	USINT	4	4		cycle number (disable event with zero)
k-bus event control 3					cycle offset and cycle number

offset	USINT	3	3	offset in number of cycles
cycle number	USINT	8	8	cycle number (disable event with zero)
k-bus event control 4				cycle offset and cycle number
offset	USINT	7	7	offset in number of cycles
cycle number	USINT	16	16	cycle number (disable event with zero)
program start interlock	BOOL	TRUE	TRUE	locks on configuration error

Information

Name: Kbus
Vendor: WAGO
Categories:
Type: 32778
ID: Wago 750-Series Local Bus Interface
Version: 1.4.0.2
Description: WAGO Kbus Interface

1.2.1 Device: _8DO_24_VDC_0_5A

K-BUS Parameters

Parameters:

Name:	Type:	Value:	Default Value:	Unit:	Description:
K-BUS module slot index	BYTE	1	0		K-BUS slot index of the module (1 indexed)
Optional module	BOOL	0	0		Mark module as optional
Module compare value	STRING	'UUUU8802UUUUUUUU'	'UUUU8802UUUUUUUU'		Desired value
Module attitude	STRING	0750-0530	0750-0530		Module attitude

Information

Name: 0750-0530
Vendor: WAGO
Categories:
Type: 32776
ID: 07500530
Version: 0.0.0.15
Order number: 0750-0530
Description: 8DO 24 VDC 0.5A

1.2.2 Device: _8DO_24_VDC_0_5A_1

K-BUS Parameters

Parameters:

Name:	Type:	Value:	Default Value:	Unit:	Description:
K-BUS module slot index	BYTE	2	0		K-BUS slot index of the module (1 indexed)
Optional module	BOOL	0	0		Mark module as optional
Module compare value	STRING	'UUUU8802UUUUUUUU'	'UUUU8802UUUUUUUU'		Desired value
Module attitude	STRING	0750-0530	0750-0530		Module attitude

Information

Name: 0750-0530
Vendor: WAGO
Categories:
Type: 32776
ID: 07500530
Version: 0.0.0.15
Order number: 0750-0530
Description: 8DO 24 VDC 0.5A

1.2.3 Device: _16DI_24_VDC_3ms

K-BUS Parameters

Parameters:

Name:	Type:	Value:	Default Value:	Unit:	Description:
K-BUS module slot index	BYTE	3	0		K-BUS slot index of the module (1 indexed)
Optional module	BOOL	0	0		Mark module as optional
Module compare value	STRING	'UUUU9001UUUUUUUU'	'UUUU9001UUUUUUUU'		Desired value
Module attitude	STRING	0750-1405	0750-1405		Module attitude

Information

Name: 0750-1405
Vendor: WAGO
Categories:
Type: 32776
ID: 07501405
Version: 0.0.0.14
Order number: 0750-1405
Description: 16DI 24 VDC 3ms

M Arduino Code

```
1  // Library
2  #include <PxMatrix.h>
3
4  // Pin mapping for ESP32
5  #define IN_BIT0      32   // Bit 0 signal from PLC
6  #define IN_BIT1      33   // Bit 1 signal from PLC
7  #define IN_BIT2      25   // Bit 2 signal from PLC
8  #define IN_BIT3      26   // Bit 3 signal from PLC
9
10 // Integer holding the 4 bit manipulated inputs from the PLC
11 int bitSum = 0;
12
13
14 // This is how many color levels the display shows - the more the slower the update
15 //#define PxMATRIX_COLOR_DEPTH 4
16
17 // Defines the speed of the SPI bus (reducing this may help if you experience noisy
   images)
18 //#define PxMATRIX_SPI_FREQUENCY 20000000
19
20 // Output pins for LED module
21 #ifdef ESP32
22 #define P_LAT   22     // Latch
23 #define P_A     19     // Address A
24 #define P_B     23     // Address B
25 #define P_C     18     // Address C
26 #define P_D     5      // Address D
27 #define P_E     15     // Address E
28 #define P_OE    16     // Output Enable
29 hw_timer_t * timer = NULL;
30 portMUX_TYPE timerMux = portMUX_INITIALIZER_UNLOCKED;
31 #endif
32
33 #ifdef ESP8266
34 #include <Ticker.h>
35 Ticker display_ticker;
36 #define P_LAT   16     // Latch
37 #define P_A     5      // Address A
38 #define P_B     4      // Address B
39 #define P_C     15     // Address C
40 #define P_D     12     // Address D
41 #define P_E     0      // Address E
42 #define P_OE    2      // Output Enable
43 #endif
44
45 #define matrix_width 64   // The width of the LED module
46 #define matrix_height 64  // The height of the LED module
47
48 // This defines the 'on' time of the display is us. The larger this number,
49 // the brighter the display. If too large the ESP will crash
50 uint8_t display_draw_time = 40; //30-70 is usually fine
51
52 // Setup for the LED module: width and height, output pins
53 PxMATRIX display(matrix_width, matrix_height, P_LAT, P_OE, P_A, P_B, P_C, P_D, P_E);
54
55 // Some standard colors
56 uint16_t myYELLOW =   display.color565(255, 255, 0);  // Yellow color
57 uint16_t myCYAN =     display.color565(0, 255, 255);  // Cyan color
58 uint16_t myMAGENTA =  display.color565(255, 0, 255);  // Magenta color
59
60 #ifdef ESP8266
61 // ISR for display refresh
62 void display_updater() {
63   display.display(display_draw_time);
64 }
65 #endif
66
67 #ifdef ESP32
68 void IRAM_ATTR display_updater() {
```

```
  // Increment the counter and set the time of ISR
  portENTER_CRITICAL_ISR(&timerMux);
  display.display(display_draw_time);
  portEXIT_CRITICAL_ISR(&timerMux);
}
#endif

/**
   Updates the LED module display

   @param is_enable   The boolean value for updating display
*/
void display_update_enable(bool is_enable) {
#ifdef ESP8266
  if (is_enable)
    display_ticker.attach(0.004, display_updater);
  else
    display_ticker.detach();
#endif

#ifdef ESP32
  if (is_enable) {
    timer = timerBegin(0, 80, true);
    timerAttachInterrupt(timer, &display_updater, true);
    timerAlarmWrite(timer, 4000, true);
    timerAlarmEnable(timer);
  } else {
    timerDetachInterrupt(timer);
    timerAlarmDisable(timer);
  }
#endif
}

// An array of 16 bits per pixel color of General Emergency alarm
const uint16_t GENERAL_EMERGENCY[] = {
  0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6,
  0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6,
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```

```
    0x02a6, 0x02a6, 0x02a6, 0x02a6,
    0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6, 0x02a6,
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0x02a6, 0x02a6, 0x02a6, 0x02a6
```

```
};

// An array of 16 bits per pixel color of Fire alarm
const uint16_t FIRE[] = {
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  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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  0x9800, 0x9800, 0x9800, 0x9800,
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  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
  0x9800, 0x9800, 0x9800, 0x9800,
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183     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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184     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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211     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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        0x9800, 0x9800, 0x9800, 0x9800,
212     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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213     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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214     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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215     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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216     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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217     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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218     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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219     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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220     0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
  0x9800, 0x9800, 0x9800, 0x9800
};

// An array of 16 bits per pixel color of Fire Extinguishing alarm
const uint16_t FIRE_EXTINGUISHING_PRE[] = {
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  0x9800, 0x9800, 0x9800, 0x9800
};

// An array of 16 bits per pixel color of Machinery alarm
const uint16_t MACHINERY[] = {
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    0xfde0, 0xfde0, 0xfde0, 0xfde0
};

// An array of 16 bits per pixel color of Steering Gear alarm
const uint16_t STEERING_GEAR[] = {
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391     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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420     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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421     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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422     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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423     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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424     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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425     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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426     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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427     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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428     0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0, 0xfde0,
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    0xfde0, 0xfde0, 0xfde0, 0xfde0
};

// An array of 16 bits per pixel color of Activation Fire Extinguishing alarm
const uint16_t ACTIVATION_FIRE_EXTINGUISHING[] = {
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  0x9800, 0x9800, 0x9800, 0x9800
};

// An array of 16 bits per pixel color of Telephone alarm
const uint16_t TELEPHONE[] = {
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  0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff,
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};

// An array of 16 bits per pixel color of Engine Room Telegraph alarm
const uint16_t ENGINE_ROOM_TELEGRAPH[] = {
  0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff,
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  0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff, 0xffff,
  0xffff, 0xffff, 0xffff, 0xffff
};

// An array of 16 bits per pixel color of Water Ingress Main alarm
const uint16_t WATER_INGRESS_MAIN[] = {
  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
  0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800, 0x9800,
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};

// An array of 16 bits per pixel color of Water Ingress Pre alarm
const uint16_t WATER_INGRESS_PRE[] = {
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    0xfde0, 0xfde0, 0xfde0, 0xfde0
};

// An array of 16 bits per pixel color of Bilge alarm
```

```
const uint16_t BILGE[] = {
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  0xfde0, 0xfde0, 0xfde0, 0xfde0
};

// An array of 16 bits per pixel color of Engineers alarm
const uint16_t ENGINEERS[] = {
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};

/**
   The standard Arduino setup function used for setup and configuration tasks.
*/
void setup() {
  // Initialize serial bus
  Serial.begin(115200);

  // Initialize LED module display
  display.begin(32);    // Initialize LED module

  // Set up starting display of the LED module
  display.setBrightness(50);         // Set brightness for LED module
  display.clearDisplay();            // Clear LED module display
  display.setTextColor(myCYAN);      // Color for text on LED display
  display.setCursor(12, 2);          // Position for text on LED display
  display.print("Light");            // Display text on LED display
  display.setTextColor(myMAGENTA);   // Color for text on LED display
  display.setCursor(12, 12);         // Position for text on LED display
  display.print("Column");           // Display text on LED display
  display.setTextColor(myYELLOW);    // Color for text on LED display
  display.setCursor(12, 22);         // Position for text on LED display
  display.print("System");           // Display text on LED display
  display_update_enable(true);       // Update display

  delay(3000);    // Delay for displaying text on LED module

  // Input configuration
  pinMode(IN_BIT0, INPUT_PULLUP);    // Utilizes MCUs internal pull-up resistor
  pinMode(IN_BIT1, INPUT_PULLUP);    // Utilizes MCUs internal pull-up resistor
  pinMode(IN_BIT2, INPUT_PULLUP);    // Utilizes MCUs internal pull-up resistor
  pinMode(IN_BIT3, INPUT_PULLUP);    // Utilizes MCUs internal pull-up resistor
}

/**
   Draws images on 64x64 LED module display.

   @param alarmSymbol[]   The array of 16 bit color values for each pixel
*/
void drawAlarmSymbol(const uint16_t alarmSymbol[]) {
  int counter = 0;
  for (int yy = 0; yy < 64; yy++) {
    for (int xx = 0; xx < 64; xx++) {
      display.drawPixel(xx + 0 , yy + 0, alarmSymbol[counter]);
      //display.drawPixel(xx + 0 , yy + 0, pgm_read_word_near(alarmSymbol + counter));
      // When using ESP8266 and adding image arrays to PROGMEM
      counter++;
    }
  }
}

/**
   The standard Arduino loop function used for repeating tasks.
*/
void loop() {
  // Reset input bit sum from PLC
  bitSum = 0;

  // Add input bits (4 bits, total 16 states).
  if (!digitalRead(IN_BIT0)) bitSet(bitSum, 0);   // First input to least significant
  bit of integer bitSum
  if (!digitalRead(IN_BIT1)) bitSet(bitSum, 1);   // Second input to second bit of
  integer bitSum
  if (!digitalRead(IN_BIT2)) bitSet(bitSum, 2);   // Third input to third bit of
```

```
    integer bitSum
978 if (!digitalRead(IN_BIT3)) bitSet(bitSum, 3);   // Last input to most significant bit
    of integer bitSum
979
980 // State machine based on input bits from PLC. Each state handles displaying an alarm
    symbol.
981 switch (bitSum) {
982   case 0:
983     // No input
984     display.clearDisplay();
985     break;
986   case 1:
987     // General Emergency Alarm
988     drawAlarmSymbol(GENERAL_EMERGENCY);
989     break;
990   case 2:
991     // Fire Alarm
992     drawAlarmSymbol(FIRE);
993     break;
994   case 3:
995     // Fire-Extinguishing Pre-Discharge Alarm
996     drawAlarmSymbol(FIRE_EXTINGUISHING_PRE);
997     break;
998   case 4:
999     // Machinery Alarm
1000    drawAlarmSymbol(MACHINERY);
1001    break;
1002  case 5:
1003    //Steering Gear Alarm
1004    drawAlarmSymbol(STEERING_GEAR);
1005    break;
1006  case 6:
1007    // Activation of Fixed Local Application Fire-extinguishing System alarm
1008    drawAlarmSymbol(ACTIVATION_FIRE_EXTINGUISHING);
1009    break;
1010  case 7:
1011    // Telephone Alarm
1012    drawAlarmSymbol(TELEPHONE);
1013    break;
1014  case 8:
1015    // Engine Room Telegraph Alarm
1016    drawAlarmSymbol(ENGINE_ROOM_TELEGRAPH);
1017    break;
1018  case 9:
1019    // Water Ingress Main Alarm
1020    drawAlarmSymbol(WATER_INGRESS_MAIN);
1021    break;
1022  case 10:
1023    // Water Ingress Pre Alarm
1024    drawAlarmSymbol(WATER_INGRESS_PRE);
1025    break;
1026  case 11:
1027    // Bilge Alarm
1028    drawAlarmSymbol(BILGE);
1029    break;
1030  case 12:
1031    // Engineers Alarm
1032    drawAlarmSymbol(ENGINEERS);
1033    break;
1034 }
1035}
1036
```