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Designing a KNX-house Automation System for a private residence

Helsinki Metropolia University of Applied Sciences

Bachelor of Engineering

Automation Engineering

Bachelor's Thesis

March 12, 2015

Author(s) Title Number of Pages Date	Osmo Sarjakoski Designing a KNX-house Automation system for a private residence 32 pages + 5 appendices March 12, 2015
Degree	Bachelor of Engineering
Degree Programme	Automation Engineering
Specialisation option	Manufacturing Automation
Instructor(s)	Kari Vierinen, Principal Lecturer Tiina Järvinen, Project Manager

The objective of this Bachelor's thesis was to design, document and program a house automation system based on KNX-protocol. The target was a private client's residence undergoing restoration.

The project was started by predefining the functions the client wanted to integrate into the home automation system. When the functions were outlined in adequate detail, the potential system components were selected from different manufacturers, and preliminary plans were made. The plans were specified as the project progressed.

As a result of this thesis, comprehensive and detailed documentation was produced. The documents describe the functions extensively and will help all participants during subsequent planning and implementation. Due to residence renovation delays, the implementation and programming stages were not included in this thesis.

Keywords	KNX, House Automation, Sensors , Measurement and Control system

Tekijä(t) Otsikko Sivumäärä Aika	Osmo Sarjakoski KNX-taloautomaatiojärjestelmän suunnittelu omakotitaloon 32 sivua + 5 liitettä 12.3.2015
Tutkinto	Insinööri (AMK)
Koulutusohjelma	Automaatiotekniikka
Suuntautumisvaihtoehto	Kappaletavara-automaatio
Ohjaaja(t)	Kari Vierinen Yliopettaja Tiina Järvinen, projektipäällikkö

Tämän insinöörityön tarkoituksena oli suunnitella, dokumentoida ja ohjelmoida KNX-protokollaan perustuva kotiautomaatiojärjestelmä remontoitavaan omakotitaloon. Työ tehtiin yksityiselle henkilölle.

Työ aloitettiin kartoittamalla huonekohtaisesti asiakkaan toivomat toiminnot, jotka hän halusi osaksi kotiautomaatiojärjestelmää. Kun toiminnot oli määritelty tarpeeksi kattavasti, valittiin mahdolliset komponentit eri valmistajilta ja tehtiin alustavat suunnitelmat. Projektin edetessä suunnitelmia tarkennettiin entisestään.

Työn tuloksena saatiin aikaan dokumentit, jotka kuvaavat toiminnot kattavasti ja auttavat eri osapuolia jatkosuunnittelussa ja käyttöönotossa. Koska talon remontoinnissa tuli viivästyksiä, lopputyössä ei päästy käsittelemään käyttöönottoa tai ohjelmointia.

Avainsanat	KNX, kiinteistöautomaatio, anturit, mittaus ja säätöjärjestelmä

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Table of Contents

Appendices

Nomenclature

Actuator	A bus listening device, mostly an interface between an appliance (e.g. light switch) and KNX.
Backbone	A line connecting multiple sub-systems into one single system
Bus	A transmission path, multiple devices can be connected to, all communicating together.
Bus device	A device which connects the bus cable and has at least one bus coupling unit.
Choke	Decouples a KNX line from the respective KNX power supply.
Device	Sending or receiving point for all couplings related to the communication system.
Scene	Preset functions are performed simultaneously, including temperature, ventilation, lightning, etc.
Sensor	A bus information feeding device, mostly an interface between a user (e.g. push button) and KNX.
Telegram	In communication technology, a bit string containing all the necessary information for device recognition and data convoying.

1 INTRODUCTION

Tiina Järvinen contacted Helsinki Metropolia University of Applied Sciences on the subject of their new home and its restoration. The 340 m^2 house was built in 1965 and needed a complete renovation to meet all modern standards.

The assignment was to design a house automation system that would integrate all the different systems from the floor heating to window pane sensors. The system was to be controlled and monitored from one touchscreen monitor and multiple other control points.

Additionally, the commission included assisting with the implementation of the system before and during the installation. The system was to be documented in a detailed way that would support all parties involved with the various stages of the project.

The client had already extensive preliminary plans for the home automation system design. In these plans, the protocol chosen was the KNX automation system.

I had no prior experience of KNX or any other home automation system.

In this thesis, from the applicable data transfer media, only the twisted pair cable will be described in more detail as it is the most commonly used in Finland and since it is applied in this project.

2 KNX Standard

2.1 KNX briefly

KNX, also known as Konnex, is an open international building control standard. It is a successor of three previous standards, European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB). The KNX standard is administered by the KNX Association which was founded in 1990. As of June 2010, the KNX Association has over 200 manufacturing members. [1]

2.2 Benefits of KNX

The need for building automation has increased progressively over the years. Like some other building automation systems, KNX can provide

- energy savings
- comfort and convenience
- security.

But unlike its rivals, KNX is an open standard. In this context, it means that devices from different manufacturers are compatible with one another. Therefore, a customer will not be dependent on a single supplier. This is guaranteed by a certification that is granted by the KNX Association. To get a device certified, a manufacturer has to comply with the quality management standard ISO 9001 and pass tests executed by the Association.

As the standard is long-standing, it provides backwards compatibility for over 20 year old installations.

Unlike conventional hardwired systems, KNX devices are linked digitally by a bus. Each device has its own microcontroller. In practice, KNX is a network of microcontrollers. With KNX it is easier to implement more complex features. For example, a so called panic button turning on all the lights in a building would require a great amount of wiring to be implemented with hardwiring. If there was another control point, it would make things even more complex with additional expenses, whereas for the KNX bus system it is just a matter of programming.

An important advantage of the KNX bus is that the KNX system can be optimally adjusted to any special requirements of building control.

In a KNX automation system, there is only one software tool for configuring KNX devices, ETS (Engineering Tool Software). It is manufacturer-independent, and compatibility with devices is assured via product certification. [1; 2] If additional systems, for example DALI (Digital Addressable Lighting Interface), are integrated to the KNX system, additional software might be required, such as DGS software tool.

3 KNX-SYSTEM

With KNX, it is possible to combine various types of building applications such as lightning, shutters and blinds, HVAC (heating, ventilating, and air conditioning), security, metering, energy management, entertainment systems, white goods etc. Additionally, it is possible to link third party devices to the automation system, such as tablets and smartphones. These devices can be used for visualization of the system, and also as alternative control points. [3]

3.1 Principle of operation

KNX is a bus-based system. Devices communicate independently without a central computer or a control system. The communication is accomplished by telegrams transmitted on the bus. With the same bus cable, the power is distributed to the bus devices. Below an illustration of a simple KNX system, the green line is the KNX bus and the red line is a 230 VAC line. (Figure 1.)

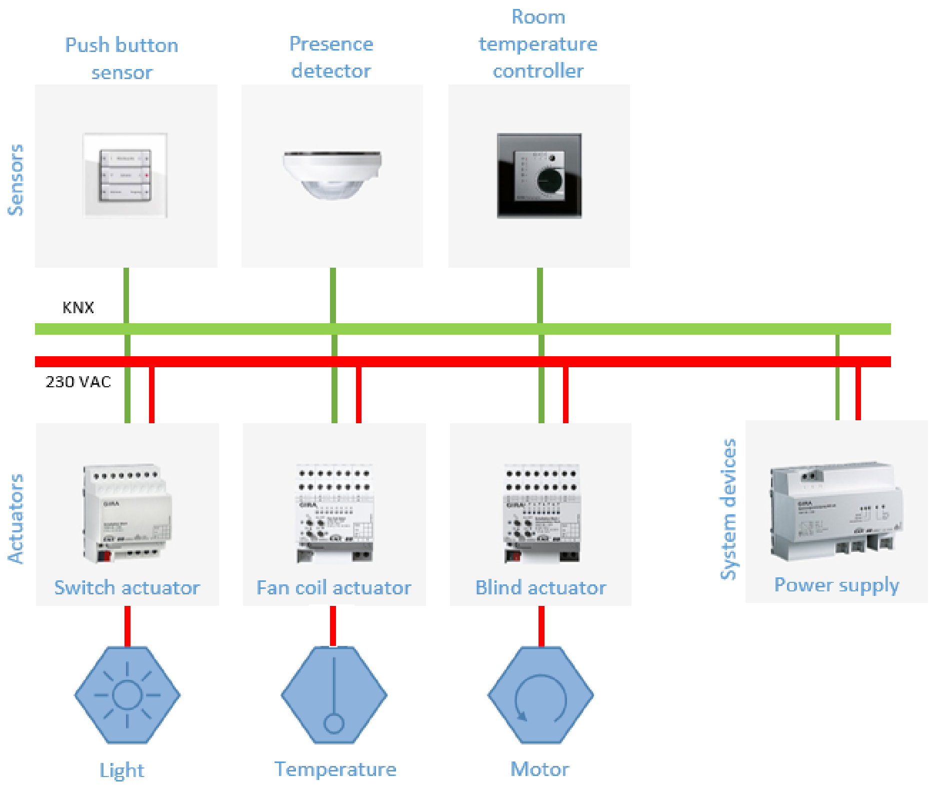

Figure 1. Principle of operation

In a KNX system, a device which feeds information within the bus, for example a push button, is called a sensor. A bus listening device, for example a light dimmer, is called an actuator. The information is available for all devices, but only the ones the telegram is allocated for, handle it.

3.2 Data transfer media

The versatility of KNX is based not only on its protocol, but also on the broad range of available data transfer media. A bus can consist of a combination of media described in this section.

3.2.1 Twisted pair cabling

KNX TP is the term used when twisted pair (TP) cables are utilized as a KNX-medium.

Twisted pair cabling is considered to be the best data transfer medium for KNX as it offers free topology. It is moderately low-cost and easy to install as the devices can be connected to each other without any hubs or switches. The data and energy for the devices are transmitted by the same twisted pair cable. The relatively slow baud rate (9600 bit/s) enables use of long cables and free topology. It is totally sufficient for transmitting telegrams on a line. The slow clock rate also reduces the power consumption of the devices, as microcontroller power consumption is heavily dependent on the clock rate. [4; 5]

3.2.2 Powerline cabling

KNX PL is the term used when a powerline (PL) cable is utilized as a KNX-medium.

Powerline is typically used in renovation works when installing new cables is not practical. Powerline, as the name reveals, uses 230 VAC cables as a data transfer medium. The powerline devices need only the phase and the neutral conductors. As the devices are supplied with 230 VAC, there is no need for separate power supplies. The powerline devices are about identical in size and in usage with twisted pair cabling components. There can be 255 devices connected to a line. The topology of powerline is similar to the twisted pair cabling topology. There is no defined length for powerline cabling. [4]

3.2.3 Internet Protocol

KNX IP is the term used when the Internet Protocol (IP) is utilized as a KNX-medium.

The benefits of Ethernet as a data transfer medium are: high bandwidth (100 Mbit/s), more or less cheap components, and widespread use. It can be used in automation systems, even though originally it was developed for communications solutions. Today Ethernet has evolved into a universal communication solution and is used in offices, homes and industry.

Ethernet cannot replace the twisted pair cable due to the low-bandwidth nature of the KNX bus. Together, they form an ideal solution for building automation. Ethernet can be used as a backbone for inter-system communication when the system is extensive, and twisted pair cabling can be used for local control. The telegrams of KNX, internet usage, multimedia, and computer networking can be transmitted over the same LAN (Local Area Network). With Ethernet, the building networking has a hierarchical architecture. There can be 255 devices connected to Ethernet on a KNX line. [6; 5]

3.2.4 Wireless Network System (WNS)

KNX RF is the term used when the Radio Frequency (RF) is utilized as a KNX-medium.

A radio network is a suitable option when a twisted pair cable cannot be used as a communication medium. With radio frequency, there is no hierarchical structure to follow as long as the sensors and coupling units are located within the radio signal range. The radio range cannot be determined precisely as also devices linked to another KNX-radio network can receive data messages. The structures such as walls and roofs do shorten the range. With additional repeaters it is possible to get the signal through thick obstacles. There are no restrictions on how or where a device can be installed, but it is necessary to take into consideration if the device should need a battery or mains power to function. The devices communicate on the frequency of 868 MHz. [4]

3.3 Topology

In this chapter, only topology for twisted pair cabling is reviewed.

The topology of a KNX bus can be one of the following: line, tree, star, or a combination of them, but it cannot be circular.

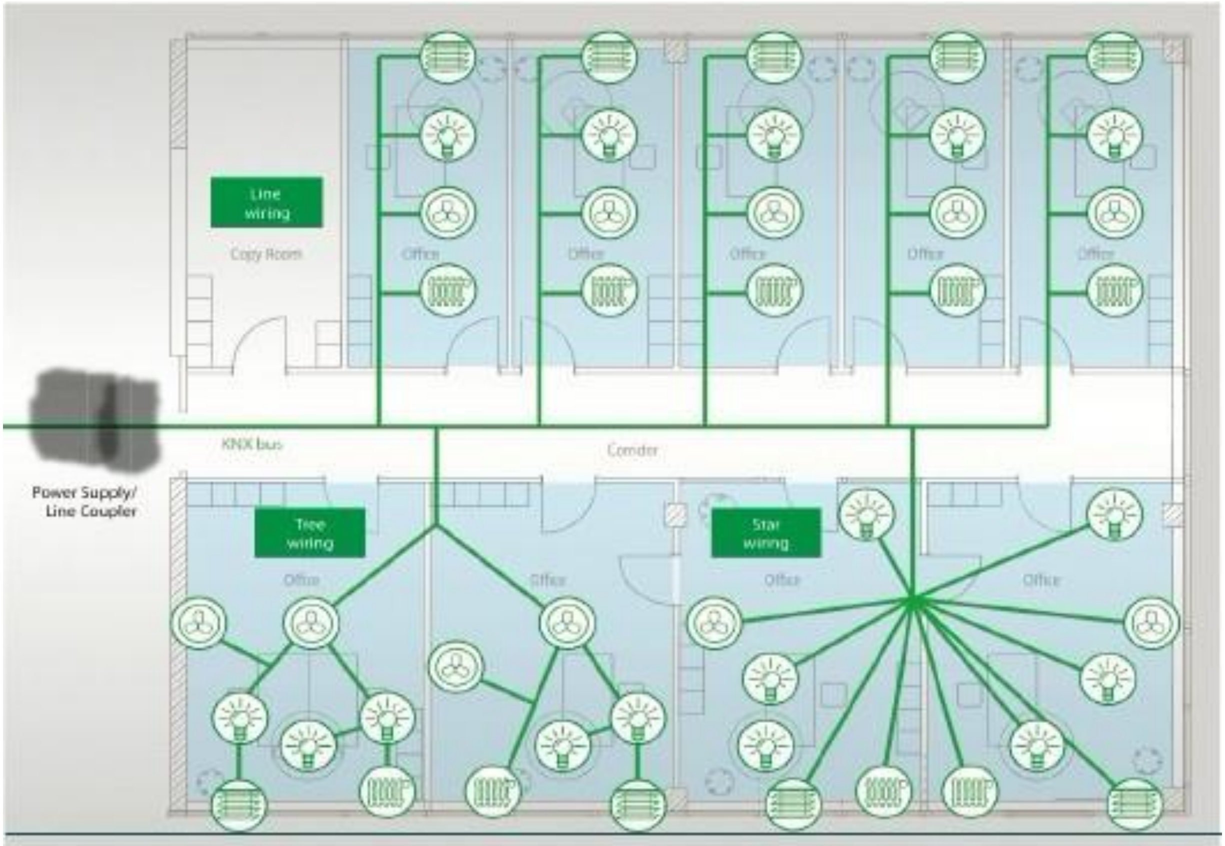

Figure 2. The topologies [7]

When twisted pair cabling or powerline is used as a communication medium, the KNX system consists of lines and areas.

3.3.1 Line

A line consists of up to 4 line segments, and each segment of up to 64 connected devices. Each segment requires its own power supply. In theory, a line can comprise up to 256 devices but, for example, due to certain limitations of power supply qualities, the number of actual devices is fewer.

In the figure below, an illustration of a line with a power supply with a choke (PS/CH), a sensor (S1), and an actuator (A1). [3]

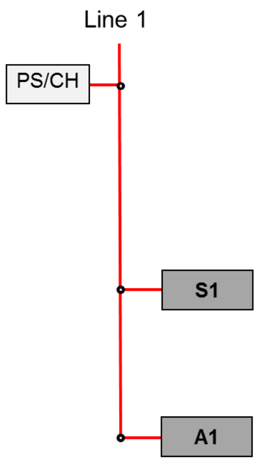

Figure 3. Hierarchy, a line [3]

There are a couple of limitations when using a twisted pair cable bus:

- The maximum length for a line segment is 1000 m.
- The maximum distance between a power supply and a bus device is 350 m
- The minimum distance between two power supplies with chokes is 200 m.
- The maximum distance between two bus devices is 700 m.
- If a line needs to be continued with a line repeater (LR) to a line segment, the maximum total length of the line segment is 1000 m.
- Each one of the line segments has to have its own suitable power supply.
- The maximum number of line repeaters installed on parallel on a line is three. [4]

3.3.2 Area

If the capacity of the line is exceeded by the number of the devices connected to it or if it's practical to divide the automation system into smaller sections, areas can be utilized. It is possible to connect up to 15 lines to a main line with line couplers (LC). The maximum number of 64 devices connected to a main line is reduced by the number of line couplers connected to it as they are counted as devices. The main line has to have its own power supply with a choke, and cannot be continued with a line repeater. If timing is critical for the automation system, the main line should be implemented with IP technology to provide a data highway. [4; 8; 3]

In the figure below, an illustration of an area with two lines which are connected to a main line with line couplers (LC1/LC2).

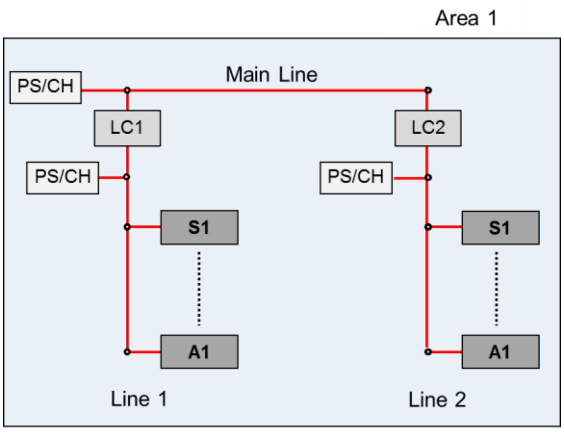

Figure 4. Hierarchy, an area [3]

3.3.3 Multiple areas

Several areas can be connected to a backbone line with a backbone coupler (BC). The maximum number of devices connected to a backbone line is reduced by the number of backbone couplers connected to it as they are counted as devices. With maximum of 15 areas, more than 58 000 devices can be connected to the bus. The backbone line has to have its own power supply with a choke. If the automation system is extensive, the main lines and backbone should be implemented with IP technology to provide data highways. [4; 8; 3]

In the figure below, an illustration of multiple areas connected to a backbone with a backbone coupler (BC1/BC2).

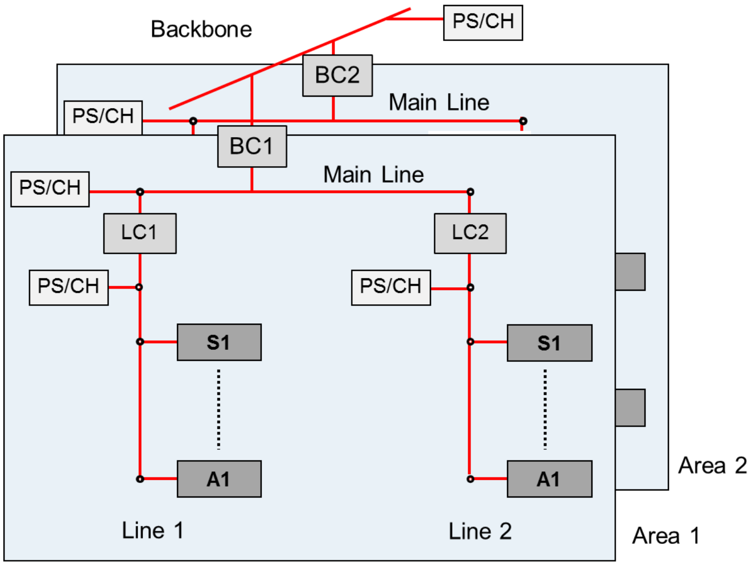

Figure 5. Hierarchy, multiple areas [3]

By dividing the bus installation into lines and areas, the functional reliability is increased considerably as every line has its own power supply, and the lines are galvanically isolated. If one line should have a fault, that would not affect to the rest of the system. With separated areas, the data communication is localized as telegrams are not sent to areas where they are not relevant, thus conserving the capacity of the bus. Furthermore, it gives a clear image of the system during implementation, diagnosis and maintenance.

Even though different kinds of lines are described above, a backbone line is also a regular line. The backbone couplers, line couplers and line repeaters do not differ physically either. Their functionality is defined by programming. [4; 8; 3]

3.4 Communication technology

Signals and other information data between two separate bus devices are delivered as telegrams. The communication technology related to controlling bus speed and impulse transmission and reception is designed in such a way that the bus line does not need impedance matching and any form of topology is possible. [4]

3.4.1 Symmetrical transmission

The data is transmitted symmetrically over the bus cable cores. The bus device evaluates voltage deviations between the cores.

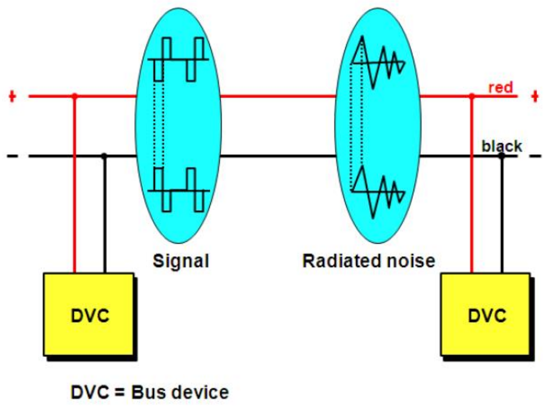

Figure 6. Symmetrical transmission [9]

Possible interferences affect all cores having the same polarity, and therefore they have no influence on the difference in the signal voltage. [4; 9]

3.4.2 Telegram

The telegrams consist of information transmitted on the bus, so called useful data, which comprises the event to be transmitted and the test data used for detecting transmission errors. The telegram is a character string. The information from the monitoring and checksum fields is necessary for undisturbed communication. The devices which are given an address evaluate data from these fields. [4]

3.4.3 Telegram collision

As multiple devices share the same bus, the telegrams are transmitted in series. The data exchange between bus devices is event-controlled as only one telegram can be transmitted at a time in the bus. To avoid collisions, the simultaneous sending of requests of several bus devices is controlled by the Carrier Sense Multiple Access with Collision Avoidance procedure (CSMA/CA). The collisions are detected by sending a bus reservation signal prior to the actual data. A bus device may start a transmission when it finds the bus to be unoccupied. With this reservation procedure it is assured that no data is lost and that the bus is used in the most efficient way. It also allows sending priority telegrams such as alarms and errors, which will be transmitted first. [4; 9]

3.4.4 Individual address

The individual address is a physical address indicating the area and line the device is installed in. The individual address is unique and used in commissioning, diagnosis, error rectification, and modification of the installation by reprogramming, but during normal operation it has no significance.

3.4.5 Group address

The devices which communicate with one another are defined by group addresses. The structure of the address can be one of the following:

- 2-level: main group, and subgroup
- 3-level: main group, middle group, and subgroup
- freely defined.

The structure can be changed in individual projects, but it is recommended that the selected group address pattern is followed in all projects. For example, the main group could indicate the floor, the middle group the functional domain, and the subgroup the function of a load or a group of loads.

Regardless of where the device is installed in the system, each group address can be assigned to the bus device as required. The sensors and actuators are assigned group addresses either with ETS, or automatically, if the function is integrated in the device.

Sensors can send only one group address per telegram; actuators, however, can listen simultaneously to several group addresses. The size of the device's memory limits the number of assigned group addresses to a sensor or actuator. [9]

4 THE DESIGN

4.1 The design process

The first step in the planning stage was to compile a list of general functions in each room to an excel sheet. As the client had comprehensive preliminary drafts done, this phase was rather fast. The excel sheet became the backbone for the project.

From this data, I started to supplement the function requirements in more detail. As neither I nor the client had any knowledge of KNX, this was the most time consuming phase. I needed to study what was possible to implement and how. One of the functions I could not find a solution for was how to embed a Jacuzzi control with KNX in some other way than through a relay control which does not provide full control.

After the design was essentially complete in principle, it was time to document how it should be implemented in practice. Up to this point, everything was defined in the excel sheet. As it has extensive range of information, the function cards were made to divide the information into smaller sections. Additionally, the layout was drawn. These were helpful as the client invited contractors and electric designers to bid. After thinking of how the home automation should work in practice, some of the functions were reduced.

4.2 Documents

4.2.1 Master file

The whole design was based on one excel file which included all the necessary information. Each device was listed and categorized by several attributes. From there, it was easy to analyze how many sensors and actuators were needed for each function.

4.2.2 Function cards

A function card was made for each room. Each card consist of the following sections: 1) proposed planning, where the general functions of the room are explained; 2) preplanning, where the functions and locations are explained in more detail; 3) commissioning planning, where the addresses of the devices are listed and programming information is given; and 4) function test and handover operational test tables. The function card is based on a ST 701.31 card. The ST 701.31 describes how a KNX system should be implemented and what kind of documents are produced.

The appended card is not complete as they are filled in during the commissioning.

4.2.3 Commissioning operating model

During commission, a commissioning operating model will be used to guide the installation and testing. The document is based on the thesis of Joonas Viljanen, titled "*KNX-järjestelmän käyttöönotto".* [10]

4.2.4 Test record

A supplementary test record was made to ensure correct installation. All the test points are summarized on the front page of the record. Following the list section, there is a separate section for each test point for filling in the details.

4.2.5 Plane representation

The plane representation is a document showing the position of devices and lights. As I did not have experience how these were to be drawn professionally, they were only preliminary schematic diagrams for the electric designer.

In the appendix, security-related devices are concealed.

4.3 Hardware

I made a list of main components from three different manufacturers: ABB, Gira and GVS. The client selected from the list the components that would be used.

The system components were mainly chosen from GVS's products, expected to have a good price/quality ratio. ABB's products were used to supplement the components as GVS had currently only a limited supply of products available on European markets.

The client wanted to purchase the devices by herself. By buying a whole system and its installation from a local contractor, the products would have had a guaranteed warranty, local representatives and technical support. It would have simplified the distribution of responsibility of the devices and their installation. Even though KNX is a standard and every device should function together, in case of malfunctioning it might be difficult to get assistance if something did not work accordingly.

4.3.1 Power supply unit

Power supply is used to produce a voltage of 30 VDC to the KNX-bus. Most power supplies have an integrated choke. The number of power supplies needed for the automation system is determined by the number of bus devices. Generally, a bus device consumes 10 mA.

Figure 7. GVS KP/D30.640.1 power supply [11]

For this project, the GVS KP/D30.640.1 was the chosen supply. It provides a current of 640 mA and has an integrated choke. [11] As the number of bus devices in the residence is between 64 and 124, two power supplies are needed as one power supply can support only 64 bus devices. The connection is made with the KNX bus terminal.

4.3.2 Line coupler

Line couplers enable connecting lines together.

As for the project, there is need for more than one power supply. A line can have only one power supply, so a line coupler is needed to connect these lines together.

Figure 8. GVS BNLC-00101.1 line coupler [12]

For this project, the GVS BNLC-00101.1 was the chosen line repeater. The device has a bus connection terminal for two lines.

4.3.3 IP interface unit

An IP interface is used to connect the KNX bus and the LAN and it serves as an interface between the KNX installation and IP networks. The KNX can be configured using a computer connected to the LAN.

Figure 9. GVS BTIC-01/00.1 IP interface unit [13]

For this project, the GVS BTIC-01/00.1 was the chosen IP interface unit. It has a RJ45 socket on top of it for LAN connection. The bus line is connected with a bus connection terminal. An additional 30 VDC power supply is required.

4.3.4 Logic module

A logic module is used to generate logic functions. For example, a brightness sensor can adjust the luminous intensity of a light source, and during the night, the lights will be dimmed automatically.

Figure 10. ABB ABL/S2.1 logic module [14]

For this project, the ABB ABL/S2.1 was the chosen logic module. It has the following features and functionalities:

- 254 inputs and outputs
- 50 logical functions, such as: AND, OR, One hot
- 50 unidirectional and bidirectional gates
- 30 timers with, such as: ON and OFF delays, pulse duration, staircase lightning functions
- 10 comparators
- 200 worksheets
- 250 flags [15]

4.3.5 Electricity consumption meter

Electricity consumption meters can be used to measure the total house electricity consumption, or only to measure consumption of single small appliances, such as an oven or a sauna stove.

Figure 11. ABB A43 111-100 meter [16]

For this project the whole house electricity consumption is measured with the ABB A43 111-100 meter. It is a direct connect three phase meter capable to measure 80 A [17]. Data from this meter can be shown on a ComfortTouch panel.

Figure 12. ABB ZS/S1.1 meter interface module [18]

The meter cannot be connected directly to the KNX bus. The meter needs the ABB ZS/S1.1 meter interface module. This is located next to the meter and is connected to it via an infrared interface, shown on the side of the module in the picture below.

4.3.6 Water consumption meter

A water consumption meter can be used to measure for example how much the residence is using cold and hot water.

Figure 13. Arcus-EDS Water Meter [19]

There was a low supply of water consumption meters. The only found meter with a direct KNX interface was the NZR Arcus-EDS. It has an inbuilt impulse module and a counter. As it has the KNX bus interface, the stored data can be shown on a ComfortTouch panel.

4.3.7 Switch actuator

A switch actuator is used to control loads that do not need to be adjusted. In this project, the following were connected to switch actuators:

- lights that were not to be dimmed
- sockets for kitchen appliances and for entertainment electronics such as TV
- magnet valves for dishwasher and washing machine
- heating cables on roadways
- sauna stove

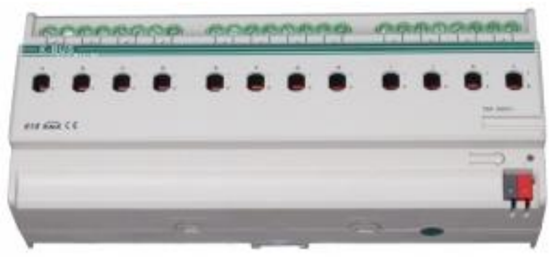

Figure 14. GVS KA/R1216.1 12 channel switch actuator [20]

For this project, the GVS KA/R1216.1 was the chosen switch actuator. It has twelve independent 16 A channels that can switch the AC loads or the three-phase loads on/off. An AC power supply is directly connected to the switch actuators instead of an extra voltage supply. [21]

4.3.8 DALI gateway

Lights are one of the biggest elements of the project. There are 274 individual light points which are divided into 65 dimmable groups and 25 on/off groups. As the number of dimmable lights is so vast, using a DALI light system is more practical than having KNX dimmers.

> DALI (Digital Addressable Lighting Interface) is a data protocol and transport mechanism that was jointly developed and specified by several manufacturers of lighting equipment. The common platform of DALI enables equipment from different manufacturers to be connected together.
>
> DALI is a step on from the DSI protocol, which is used by HF fluorescent ballasts. One of the main advantages that DALI has over earlier systems is that each device on a segment of data cable can be separately addressed, as DSI and 1-10V devices are not separately addressable and can only be controlled as a group. The net result is that to achieve similar control functionally, DALI requires less complex (and therefore less expensive) wiring topology than DSI or 1-10V devices.
>
> DALI devices include fluorescent HF ballasts, low voltage transformers, PE cells, motion detectors, wall switches and gateways to other protocols. There can be up to 64 DALI devices on a single DALI network. Sites requiring more than 64 devices are implemented by having multiple separate DALI networks, each with up to 64 devices. These separate networks are then linked together with DALI gateways and a data backbone running a high level protocol, such as Dynalite’s DyNet. [22]

DALI gateway is used to connect DALI bus to the KNX bus and convert telegrams between the two of.

Figure 15. GVS BTDG - 01 /00.1 DALI gateway [23]

For this project, the GVS BTDG - 01 /00.1 was the chosen DALI gateway.

4.3.9 Binary input unit

Binary input is used to connect conventional sensors and switches to indicate a certain status such as open doors and windows. As the security system used in this project is a separate and closed system, there was no use for binary input units.

4.3.10 Shutter actuator

Shutter actuator is a bit false tittle as in general they are used to control motors. Most common application is shade position control.

Figure 16. GVS AWBS-04/00.1 four channel shutter actuator [24]

For this project, the GVS AWBS-04/00.1 was the chosen blind actuator. It has four channels for 230 VAC drives. The maximum current is 6 A. The shutter actuator constantly determines the current position of the shades. [25]

4.3.11 Electronic switch actuator and electrothermal valve drive

Electronic switch actuator is used to control floor heating via an electrothermal valve drive.

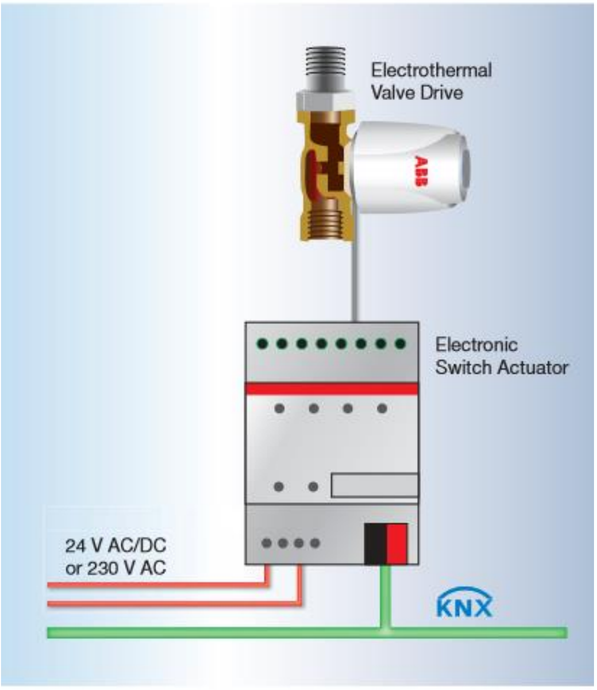

Figure 17. Electro thermal valve drive connected to KNX bus via electronic valve drive [26]

Above an illustration of the connection. The switch actuator is supplied with either DC or AC voltage. The electro thermal valve drive is operated through the output.

Figure 18. ABB ES/S4.1.2.1 four channel electronic switch actuator [27]

For this project, the ABB ES/S4.1.2.1 was the chosen electronic switch actuator. It has four channels. Unlike the other KNX system components, electronic switch actuators were not to be located to the KNX cabinet. The house has four manifolds across the house and each of them has its own actuator. This way, it is easy to observe the operation when using the manual buttons in a possible diagnostic situation. The contractor provides Empur 24 V electronic valve drives.

4.3.12 Analog sensor interface

Analog sensor interface is used to connect analog sensors.

Figure 19. ABB AE/S4.2 four channel analog sensor interface [28]

For this project, the ABB AE/S4.2 was the chosen analog sensor interface. It has four channels. In this project, the following were connected to analog sensor interface:

- water sensors under the dishwasher and the washing machine
- water sensors under the manifolds
- temperature sensors for sauna, Jacuzzi and storage room

4.3.13 Air quality sensor

Air quality sensor is used to sense characteristics of the air.

Figure 20. Gira 210403-PWG-1 air quality sensor [29]

For this project, the Gira 210403-PWG-1 was the chosen air quality sensor. It can sense the level of CO_2 (carbon dioxide), temperature, and humidity. The CO_2 content in the air can be measured between the range of 0 to 2000 ppm (parts per million). The relative humidity can be measured between the range of 10% to 95%.Temperature can be measured between 0 °C to +45 °C. [30]

These sensors were positioned in the humid rooms and the most frequently used rooms. The connection is made with the KNX bus terminal. There are air ventilation machines for both floors. The air quality sensors will provide the set point for these machines.

4.3.14 KNX interface for air conditioner

There are three ways an air conditioner can be connected to the KNX system.

- The AC unit is KNX compatible.
- The AC unit is connected to the KNX system via a wired interface unit.
- The AC unit is connected to the KNX system via an infrared interface unit.

Figure 21. DAIKIN AC interface [31]

The residence has two air conditioners. They are integrated to the automation system with a wired interface module. The AC units are not yet decided, but for example Intesis offers interfaces for DAIKIN, LG, Mitsubishi and Panasonic AC units.

4.3.15 Motion detector

Motion detector is used to sense movement in a space. Most common application is to turn on lights. It can also be used to alarm for intruders when the resident is away.

Figure 22. GVS CSBP-02/00.1 motion detector [32]

For this project, the GVS CSBP-02/00.1 was the chosen motion detector to indoor areas. Additionally, it is used as a brightness sensor. Movement can be detected in high sensitivity within a 4 – 5 m radius, and low sensitivity within a 5 – 7 m radius. The connection is made through a bus connection terminal. [33]

Figure 23. Esylux RC 230i motion sensor [34]

For this project, the Esylux RC 230i was the chosen motion detector to outdoor areas. It has a 230° sensing area up to a distance of 10 m. The operating temperature is between -25°C and +55 °C. [34]

4.3.16 Outdoor brightness and temperature sensor

For this project, the ABB 6146/10 was the chosen brightness and temperature sensor to outdoor areas. It is used to set the value of the heating cables on roadways and brightness of automatic light. It can measure luminosity between 1 and 100 000 lux. The operating temperature is between -40 and + 70 °C. The connection is made through a bus connection terminal.

Figure 24. ABB 6146/10 brightness and temperature sensor [35]

4.3.17 Control panel

For this project the ABB Busch-ComfortTouch 9” touchpanel is used as a central control panel where the entire premises is controllable. For example, room temperature and lightning can be alternated, scenes can be selected, and feed from IP cameras can be observed.

Figure 25. ABB Busch-ComfortTouch [36]

With the Busch-ComfortTouch mobile, application smartphones and tablets can be used as remote controllers.

4.3.18 Switches

Switches are used to perform everyday tasks, for example to switching lights, set preset scenes, and adjust position of blinds.

Two switch series were selected, Basalte Sentido and Berker K.1.

Basalte Sentido series has 4- and 2-way switches. Each section has a function, but touching multiple sections the preset lights will turn on and off. By long pressing of multiple sections, scenes can be changed. The background RBG led is used to inform which scene is selected.

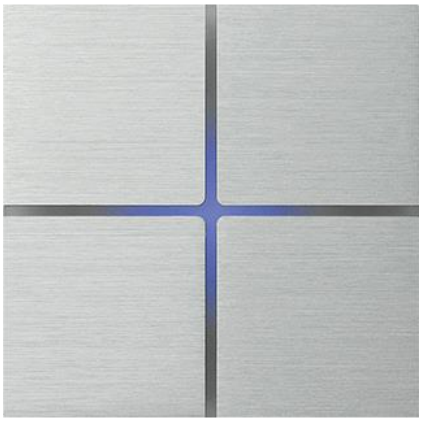

Figure 26. Basalte Sentido 4-way switch [37]

Berker K.1 series has a broad selection of switches. For this project, 1-, 2- and 2-way with screen switches were used.

Figure 27. Berker K.1 2-way switch with screen [38]

4.3.19 PoE switch

In this project, a PoE switch (power over Ethernet) is used as the main switch of the residence, and it will constitute the LAN.

As it is a PoE switch, IP cameras can be powered via a CAT-5 rated Ethernet cable less than 100 meters in length. Therefore, there is no need for extra power adapters. The video feed from the cameras can be viewed from the ComfotTouch -central panel.

For this project, the Zyxel ES1100-16P was the chosen switch. It has 16 ports from which eight supports PoE with a total power budget of 130 W.

5 COMMISIONING

Due to some delays, implementation will not be a part of this thesis as it will take some time to reach that stage.

With the help of the produced documents, the client will invite contractors and electrical designers to bid.

6 CONCLUSIONS

Automation can offer useful and convenient functions for buildings. For example, to turn off all the lights from a single control point is easy to implement and will help the daily life of a busy family. The most important functions are those that can save energy and provide security.

As a building automation system, KNX has proved to be a great option. KNX has existed for a long time and become a standard. There is a wide range of products, offered by over 300 manufacturers. They will provide devices for almost every desired function.

Minor modifications can be easy to implement as they might not need any wiring, only reprogramming. At the time of construction, it could be practical to wire up some extra cables to locations where bigger modifications might be required.

The design process was started ahead of time. This was an advantage because the project is extensive and the lack of knowledge caused several major changes over the time. One change was caused by the fact that it is not common to control each room’s ventilation individually instead of a whole floor. If I have had some experience, it would have been easier to set specific goals during the process. Now the design process was somewhat ineffective.

The building has a wide range of functions, so in the future, the system cannot be extended much. I would have preferred to integrate the security and door communication systems to the automation system; now they are separate systems.

As for any project, it is important to document what you want and what has been done. I believe the created documents will help those who will continue with the project.

The client wanted to purchase the devices by herself. I would have preferred to buy a whole system and its installation from a local contractor. This way, the products would have had a guaranteed warranty, local representatives and technical support. It would have simplified the distribution of responsibility of the devices and their installation.

As the selected products were not from one manufacturer only, I found it hard to ask advice on a bigger scale, only for specific products. Fortunately, there is a lot of material available, such as webinars organized by the KNX association.

As a result of this thesis, the client is satisfied with the produced documents and selected components. Unfortunately, due to delays, the implementation is not part of this thesis. However, I will be following the project and participate in the programming when it becomes actual. I have learned a lot about home automation from which I had no prior experience.

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Part of the master file

Details									Scenes					
Room	Device	Specification	Location in the room	Quantity	Grouping	Connected to the bus outside of the KNX centre	Sensor / actuator	Control	Away: air ventilation to minimal, lights and sockets off, shades down when dark outside	*Homecoming: air ventilation to normal, selected lights on if dark outside*	*Night: air ventilation to low, lights and sockets off, selected lights on by motion detector*	*Morning: air ventilation to normal, shades up when not dark outside*	*Day: air ventilation to normal*	*Evening: air ventilation to normal, shades down when dark outside*
Living room on first floor														
Living room on first floor	Air quality sensor	Humidity + CO2 + temperature	On the edge of duct casing on the wall of the lobby			b	s							
Living room on first floor	Motion detector		-			b	s							
Living room on first floor	Motion detector		-			b	s							
Living room on first floor	Switch	4-gang switch, Berker K.5	Next to the doorway from lobby			b	s	1. Ceiling spot group 2. Dimmable socket 1 3. Dimmable socket 3 4. Shades						
Living room on first floor	Switch	1-gang switch, Berker K.1	Next to the utility services room			b	s	1. Ceiling spot group						
Living room on first floor	Floor heating						a	Air quality sensor / scene / CTouch	19 C°	22 C°	21 C°	22 C°	22 C°	22 C°
Living room on first floor	Controllable socket	Entertainment electronics	On the diagonal wall	4			a	Scene	Off		Off			
Living room on first floor	Light	Ceiling spot group	In front of the fireplace	10			a	Switches / scene / CTouch	Off		Off			
Living room on first floor	Light	Dimmable socket 1	At the corner of window wall next to the lobby	1			a	Switches / scene / CTouch	Off	40 %	Off			
Living room on first floor	Light	Dimmable socket 2	At the corner of window wall next to the workroom	1			a	Scene / CTouch	Off	40 %	Off			
Living room on first floor	Light	Dimmable socket 3	Left side of the fireplace	1			a	Switches / scene / CTouch	Off	40 %	Off			
Living room on first floor	Light	Dimmable socket 4	Integrated spots in the cabinet	2			a	Motion detector / scene / CTouch	Off		50 %			
Living room on first floor	Light	LED strip	On the window wall behind curtain cover	1			a	Scene / CTouch	Off		Off			
Living room on first floor	Shade motor			1	SMG 1		a	Switches / scene / CTouch	Brightness sensor	Brightness sensor	Down	Brightness sensor	Up	Brightness sensor
Living room on first floor	Shade motor			1	SMG 1		a	Switches / scene / CTouch	Brightness sensor	Brightness sensor	Down	Brightness sensor	Up	Brightness sensor

Function card

KNX-FUNCTION CARD
[Project name]
[Project address]
Drawing: [reference drawing number/name]
Page 1/3

Type:

Room control	☒	Room: Lobby
General control	☐	
Interface	☐	

Usage:

Lobby and staircase control.

Principle of operation:

The following functions of the room are integrated to the home automation system: lightning, motion detection, ventilation, heating, blinds and the electric lock of the gate. Room management is executed by switches in the room, a ComfortTouch-user interface and general scenes of the building. The motion detector controls selected lights. Ventilation and heating are controlled automatically by an air quality sensor. The set point of the ventilation and heating can be changed with the ControlTouch-interface and through the general scenes of the building.

Proposal planning ends here

Implementation:

Lightning of the room is divided into the following control groups:

- Dimmable socket
- LED-strip 1
- LED-strip 2
- Ceiling spot group 1
- Ceiling spot group 2
- Ceiling spot group 3
- LED-strip 3, staircase
- Ceiling spot group 4, staircase

As external, the fence lights of the front garden are also controllable from this room.

Lights are connected to a dimmer actuator in the KNX-cabinet.

Positioned next to the main door, there is a 4-gang switch and a 2-gang switch. The switches are connected to the KNX-bus. The switch controls are the following:

Switch 1: Basalte Sentido 4-way -switch

1. Ceiling spot group 1
2. Ceiling spot group 2
3. Ceiling spot group 3
4. Both blinds of the hall

By long pressing of multiple sections: arrival / away -scene.

Switch 2: Basalte Sentido 2-way -switch

1. Electric gate lock
2. Fence lightning of the front garden

The motion detector activates the LED-strip 3. They are active for 15 minutes from the last detection. During the night scene, the lights in question are dimmed (30%) when activated. The motion detector is connected to the KNX-bus.

The air quality sensor controls an electrothermal valve drive via an electronic switch actuator, located in the space with manifold XX (location not yet defined). The air quality sensor is connected to the KNX-bus. The hall bathroom belongs to the same floor heating area as the hall. The settings of ventilation and heating in different situations are specified in the document ”Devices_and_controls.xlsx”.

The position of the blinds is controlled automatically by the outdoor brightness sensor. The motors of the blinds are connected to the shutter actuators in the KNX-cabinet. These can be controlled by the room switches and the ComfortTouch-interface.

Scenes:

- **Scene 1, arrival to home:** selected light groups are turned on, ventilation and heating are set higher.
- **Scene 2, away:** all indoor lights and controllable sockets are turned off, ventilation and heating are set lower. Selected outdoor lights are turned on by a brightness sensor. The lights of the hall are on for 5 minutes after setting the away-scene.

The general scenes of the building are defined in more detail in the document ”Devices_and_controls.xlsx”.

Preplanning ends here

KNX-FUNCTION CARD
[Project name]
[Project address]
Drawing: [reference drawing number/name]
Page 3/3

Programming information:

Device address	Channel	Type	Location of the KNX-component	Explanation

Included group addresses:

Group address	Explanation

Commissioning planning ends here

Handover test (Note! Electric designer defines test cases):

Method of testing	Date	Tested by	Result	Note

Operational test (Note! Electric designer defines test cases):

Test case	Date	Tested by	Result	Note

Commissioning operating model

Implementation of KNX building automation system

BASIC INFORMATION				
PROJECT				
ADDRESS				
Description	KNX home automation system device installation, programming and implementation.			
1. Line lenghts				
Cable length on line max. 1000 m	Line __.__		Meet the requirement	☐
Power supply – Bus device max. 350 m	Line __.__		Meet the requirement	☐
Power supply – Power supply min. 200 m	Line __.__		Meet the requirement	☐
Bus device – Bus device max. 700 m	Line __.__		Meet the requirement	☐
Comments				
2. Bus cable markings				
At the end of the bus cable, there has to be a distinct "KNX" print. It is recommended to mark also the area and line numbers.				
Cable markings	Line __.__		Meet the requirement	☐
	Line __.__		Meet the requirement	☐
	Line __.__		Meet the requirement	☐
	Line __.__		Meet the requirement	☐
Bus node physical address	Line __.__		Marked	☐
	Line __.__		Marked	☐
	Line __.__		Marked	☐
	Line __.__		Marked	☐
Comment				
3. CONNECTIONS				
Lines can only be connected together with line couplers. Branching in a same branching box with mains cable is prohibited, unless the box has separate sections.				
Bus connections checked				☐
The cable used in the KNX-cabinet is a shielded bus cable				☐
Comments				

Implementation of KNX building automation system

4. INSULATION RESISTANCE		
Insulation between cable and earth. Requirement ≥ 250 Ω. Measurement voltage 250 VDC. Overvoltage protectors should be removed before measurement.		
Meet the requirement		☐
5. POLARITY		
Check is done by pressing the programming button on the device. Check polarity of all devices.		
Polarity check	Completed	☐
Comment		
6. BUS VOLTAGE		
Voltage should be between 21 – 30 VDC. Voltage is checked from every bus node.		
Voltage measurement	Completed	☐
Comment		
7. BUS PROGRAMMING		
It is recommended that line couplers are programmed last.		
Check for unnecessary bus devices	Completed	☐
Separate line from the rest of the system	Completed	☐
Upload addresses to the devices	Completed	☐
Connect the line back to the system	Completed	☐
Comments		
8. TESTING		
Testing of the system	Completed	☐
Comments		
9. END USER INSTRUCTIONS		
User instructions Date:	Completed	☐

Implementation of KNX building automation system

10. DOCUMENTATION	
System diagram	☐
Connection point index	☐
Function cards	☐
Instructions	☐
Measurement records	☐
Recordings	☐
Digital copy of all documents	☐
Project file given digitally	☐
- Includes a list of the devices	☐
Connection groups	☐
Agreed rapports as PDF-files, digitally	☐

11. Additional comments

Test record

Test record

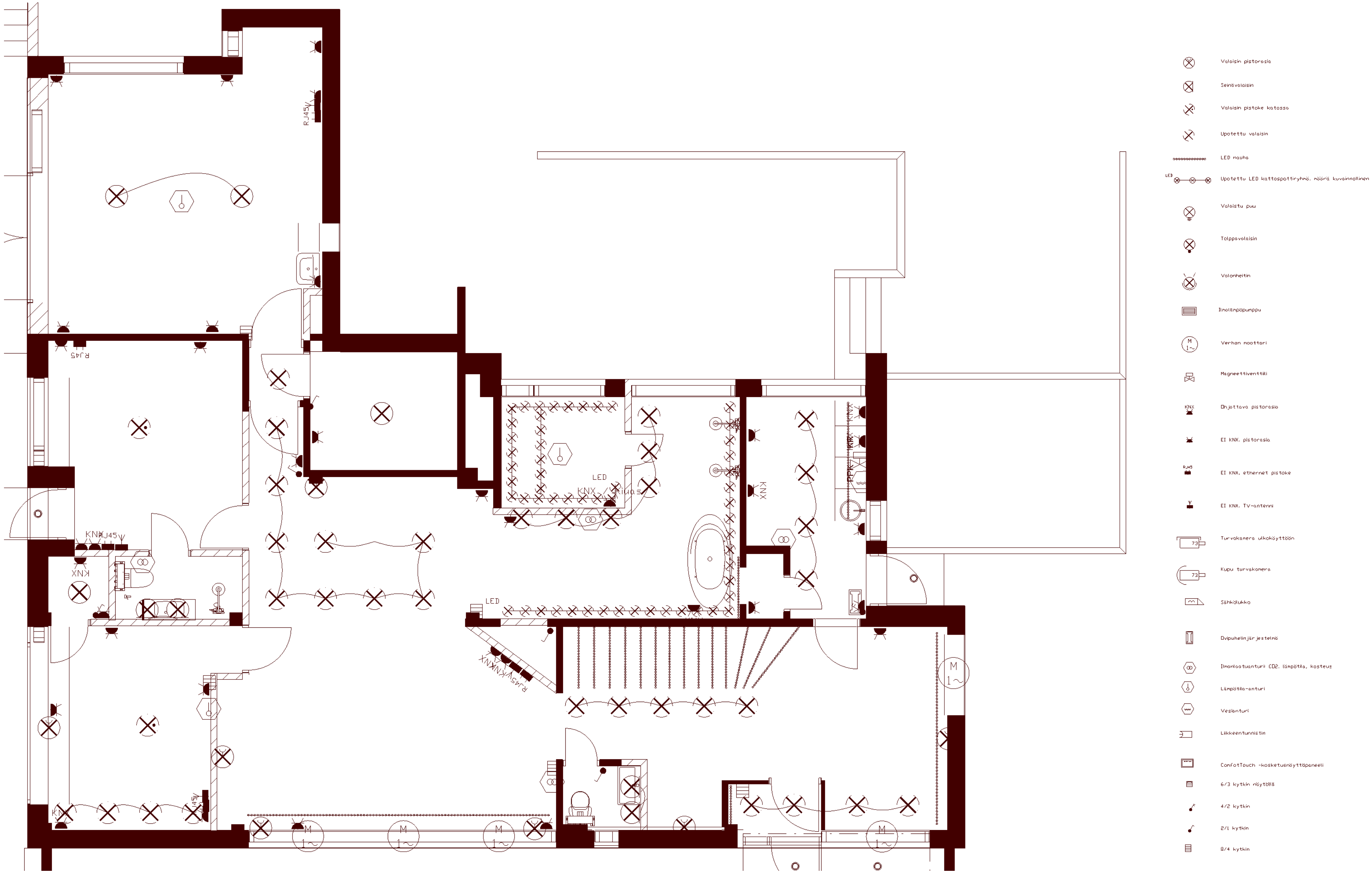
1 / 2

Measurement point	
Engineering and utility services room	☐
Measurement point 1	☐
Measurement point 2	☐
And so on, all the bus devices and branching points.	

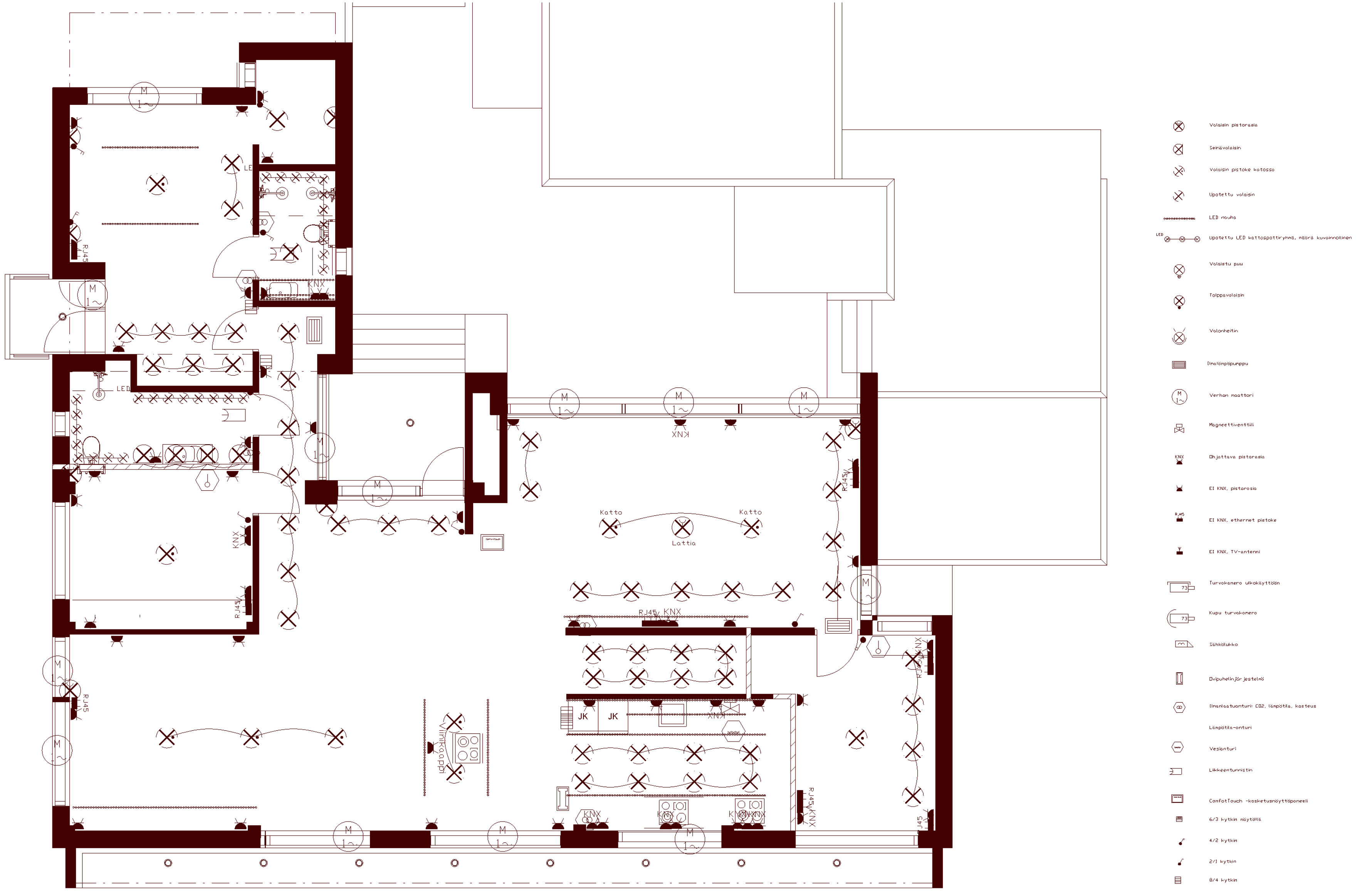
Test record

Measurement point		
Location: Engineering and utility services room		
Mounting box	☐	
Bus device	☐	
Distribution center	☐	
Checked		
Bus cable installation	OK ☐	
Continuity and polarity	OK ☐	
Measurements		
Bus cable insulation resistance		Measurement:
Bus voltage		Measurement:
Date:		
Signature		
Clarification of name		
Measurement point		
Location: Measurement point 2		
Mounting box	☐	
Bus device	☐	
Distribution center	☐	
Checked		
Bus cable installation	OK ☐	
Continuity and polarity	OK ☐	
Measurements		
Bus cable insulation resistance		Measurement:
Bus voltage		Measurement:
Date:	Signature	
Clarification of name		

Plane representation, 1st floor



Plane representation, 2[nd] floor



Plane representation, outside