WEINZIERL ENGINEERING GMBH
Dr. Y. Kyselytsya, Dr. Th. Weinzierl
D-84558 Tyrlaching
Phone +49 (0) 8623 / 987 98 - 03
Web: www.weinzierl.de

# Implementation of the KNX Standard

## Abstract

KNX is the world's only open standard for home & building control.

KNX has developed into one of the most important systems for home & building control. While the KNX market is still dominated by EIB, twisted pair with PC configuration, the KNX standard currently offers a wide variety of media and configuration modes. KNX now covers the full range of in-house communication options, including twisted pair, powerline, radio frequency and even Ethernet media.

Especially the combination of various media has made it possible to implement new solutions for building powerful networks. For example, radio frequency and twisted pair or twisted pair and IP can be incorporated in a single installation.

Another aspect is the combination of various configuration modes. While it is not recommendable to mix different modes within one installation, it is possible to build devices that support several modes in parallel. For example, a TP1 device can be developed that can be configured in system mode and easy mode. Such a device can be integrated in system mode as well as in easy mode installations.

For manufacturers, this flexibility is an opportunity as well as a cost factor. To reduce costs for software, training and tools, it is essential that solutions come from one source. This article gives an overview of cost effective solutions to implement KNX devices.

# 1 The diversity of KNX

The complete KNX landscape is thoroughly defined in the KNX handbook [1] – which contains several thousands of pages of documentation.

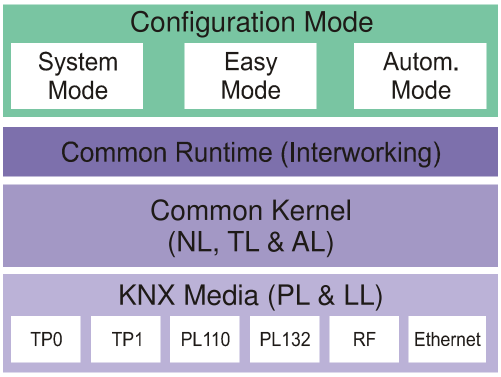


Figure 1: The KNX landscape

Figure 1 shows the relationship between the different communication media and the configuration modes in the KNX standard. The following sections describe the diversity of KNX regarding the communication media, configuration modes and device models.

## 1.1 Media in KNX

Different applications require different solutions. This is especially true of communication media. While twisted pair is a system with maximum reliability, powerline is applicable if an existing power grid is to be used for communication. If no grid is available at the installation location, radio frequency is the only choice. Ethernet is invaluable for high bandwidth solutions. In KNX the full range of media is available.

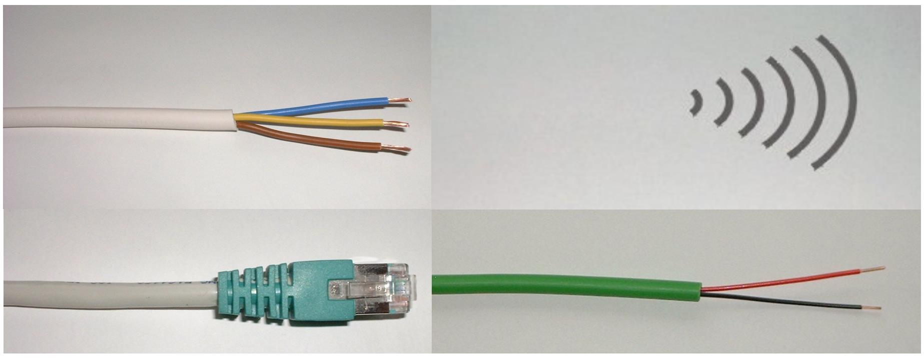

Figure 2: KNX media

**Twisted pair TP0** was taken over by Batibus and is popular in France. It is expected that this communication medium will disappear in the future since most manufacturers are switching to TP1.

**Twisted pair TP1** was introduced with the EIB and is used by more that 90 percent of current KNX products. KNX TP1 combines high quality transmission with low cost hardware. The topology of TP1 is very flexible: linear, star, tree or a combination thereof. For the physical transfer of the data, balanced baseband signal encoding is used with a data rate of 9600 baud. Devices connected to the TP1 can be supplied over the bus.

**Powerline PL110** was also taken over by EIB. Today only a few manufacturers support PL110 but they continue to offer a full range of devices for lighting, blinds and heating control. Powerline uses the electrical power distribution network that is usually already installed in buildings. The data signal is modulated with spread frequency shift keying (SFSK) with a data rate of 1200 baud. This medium is a very good alternative for the renovation market wherever the laying of twisted pair is not feasible.

**Powerline PL132** was inherited from EHS (European Home System) and is currently only being employed by a few manufacturers of white goods. It also uses the power distribution network for data transfer, but with minimum shift keying (MSK) modulation and a data rate at 2400 baud. Since practically no products currently exist for this medium, PL132 may disappear in the future.

**Radio frequency RF** is still a relatively new aspect of the KNX specification. Although it is as of yet only supported by a few manufacturers, new products from additional manufacturers will be launched soon. KNX RF uses frequency shift keying (FSK) with a center frequency of 868.30 MHz and a typical deviation of 50 kHz for data modulation. With a data rate of 16384 baud, a similar number of frames can be transmitted as with TP1. The KNX RF medium will play a major role in the future. It lends itself well to the extension of existing wired KNX installations and for the renovation market where high costs prohibit rewiring.

**Internet protocol KNXnet/IP** was only recently specified as a KNX medium and promises to become very important for the future growth of KNX. It opens doors to top level communication systems in buildings (e.g. telecommunications, multimedia, etc.) and simultaneously creates a standard gateway into the KNX installation.

Thus, KNX offers a complete set of media for in-house control systems. TP1 will remain the most important medium. KNX RF is very well suited to accommodating the demands for wireless connection in installation technology. PL110 will continue to be a solution specifically for the renovation market. The bridge to high bandwidth digital communication like audio, video or telecommunications has already been established via KNXnet/IP.

## 1.2 Configuration modes

After KNX devices are connected to the medium, they are configured to integrate them into the KNX installation. An additional strength of KNX is the number of configuration modes it supports.

**System mode** was the first configuration mode to be established and was already specified in EIB. It needs a PC tool (ETS) to carry out the configuration process. It is a very powerful mode and can be applied to very complex installations. For system mode configuration, the manufacturer must provide a product database for each device. System mode requires specially trained personnel with system knowledge in the configuration of KNX networks.

**Easy mode** is a new configuration mode that was recently introduced into KNX. It does not require a PC tool. The properties of the installed devices can be read out over the bus, making it independent of a product database. Instead, a mechanism is defined on the basis of so-called functional blocks, channels and connection codes, which describe the functionality of the device. Easy mode configuration is divided into different sub-modes. The easy controller mode and the easy pushbutton mode will be important in the future. As the name indicates, the easy controller mode requires a controller device in the KNX network that carries out the configuration process according to the defined connection rules. The easy pushbutton mode configuration does not require auxiliary tools or devices and can be performed by each individual device. For this, each device is equipped with the necessary pushbuttons and adjustments.

**Automatic mode** was also newly specified in KNX. It offers a plug-and-play configuration process without user interaction. Since automatic mode has a very limited functionality, devices that support this mode are not currently available on the market.

### 1.3 Device models

The system software for KNX, which must be present in every device, is generally called KNX stack. When referring to a stack for KNX, we usually think of the layers (i.e. the modules) of the OSI/ISO reference model. And this is indeed the core of every stack implementation. However, implementing a full-fledged KNX device requires more than individual layers. On the application layer there are services such as *memory read* and *property value write*. But what does writing to a dedicated memory location mean? This is defined by the device model. A device model in KNX specifies which services must be supported and what function they perform. It describes the management procedures, i.e. which telegram sequences are used to configure a device. In the KNX handbook, different device models are defined as profiles for various media. Each KNX stack of Weinzierl Engineering GmbH corresponds to one of these device models and is certified accordingly. A device model can simultaneously support various configuration modes.

## 2 Implementation of KNX devices

The first step in designing KNX devices is to decide which medium, which configuration modes and, in addition, which device model should be used and implemented. While the choice of medium is generally prescribed by the application, the decision on hardware, configuration mode and device model is more difficult.

These decisions become even more complex when investments in system software (KNX stack), training and tools are also considered. In the long run, such decisions may influence the complete product line of KNX devices of a company. Clearly, the selection of an optimal development platform that is flexible and scalable is essential for effective development in the future.

As a commercial KNX system software supplier, Weinzierl Engineering GmbH has developed a flexible software model that meets these new demands.

To be able to effectively implement the KNX standard, a modular stack architecture was developed that permits changes to the hardware platform, the supported configuration modes and even the communication medium. Its modularity makes it possible to begin the development of a device with only one medium and configuration mode, e.g. implementing a device for TP1 using S-Mode configuration. Later on, the system software of the same device can be extended to support easy mode, if the application is suitable for this mode. An existing application can easily be transferred to other media without great expense. Reusable code saves development time and costs. Another aspect of the new software model is its high scalability, which allows for cost-effective implementation of simple as well as complex devices.

Cost reductions not only arise for large quantities but also for small series, which can be quickly and effectively implemented. Especially when many different applications need to be developed, the efficiency of our software models becomes apparent.

## 2.1 Solutions for TP1

The KNX stack of Weinzierl Engineering GmbH is the most successful implementation currently on the market. No other stack implementation today is used more often to implement new TP1 devices. An overview of our TP1 solutions follows.

### 2.1.1 Microcontroller

The Weinzierl KNX stack can be run on any microcontroller family as long as the minimum requirements are met. Our stack implementations are not dependent on specific controller architecture. To provide a “ready to start” solution for our customers, our software has already been optimized and certified for various controller families. Currently we support:

- **ATmega** (Atmel)
- **MSP430** (Texas Instruments)
- **78K0** (NEC)
- **ARM7** (Atmel)

The decision for a particular microcontroller depends on the application requirements and of course on developer preferences.

### 2.1.2 Bus access hardware

Special bus access hardware is required for communication with the KNX bus. The most significant pieces of hardware are the bit transceiver (FZE1065/FZE1066) and the TP-UART from Siemens. While a bit transceiver operates at the bit level, the TP-UART can be connected with a UART interface of the microcontroller. The appropriate choice of hardware depends on the application (timing constraints, current consumption, etc.). The stack implementation of Weinzierl Engineering supports both options. When hardware is designed, it is necessary to consider whether optical isolation is required. If so, the TP-UART is usually the better choice due to its limited timing requirements.

### 2.1.3 Device models

The following device models are available:

**0012**

This device model was introduced by the BCU1 many years ago. A lot of devices are still based on this model today. Because of its simple management procedures, the 0012 can be implemented with a very small footprint of about 10K of code and 1K of RAM. The drawbacks of this model are the very limited resources of 256 bytes of loadable memory for tables and parameters and a maximum count of 36 communication objects.

**0021**

This device model corresponds with BCU2 technology. It is rarely used today because it features complex management in conjunction with limited resources. Only 880 bytes can be programmed via the bus.

**0701 / 0705**

0701 is the most frequently used device model in new designs. This model is similar to 0021 in complexity but offers significantly more resources. Model number 0701 supports up to 255 communication objects and a loadable area of up to 30K. Model number 0705 is very similar to 0701 with some marginal improvements.

#### 2.1.4 Loadable code

For most devices it is advantageous to program the application during device production. In this case, ETS only writes the group addresses and the parameters. The benefit for the installer is a relatively fast download. For special uses (e.g. bug fixing or project business), it might be necessary to load a complete application program via ETS. Our stack with device model 0701/0705 make it possible to load an op-code of up to 30 Kbytes.

### 2.2 Solutions for PL110

Although the powerline medium is only used by a few manufacturers, a stack for PL110 is available from Weinzierl Engineering GmbH.

#### 2.2.1 Hardware

If low level signal coding and decoding are not carried out within the controller, the requirements for the PL110 microcontroller are not very high. We have implemented the PL110 stack on ATmega from Atmel.

A drawback of the PL110 medium is that no standard transceiver is available via a distributor. We have implemented the KNX stack based on an ASICS of one of our customers. In principle it is also available for other device manufacturers.

#### 2.2.2 Device models

Powerline devices are generally not as complex as solutions for TP1. One reason for this is the reduced baud rate compared to twisted pair. Therefore, device model 1012 is sufficient for most devices. It corresponds with BCU1 technology and is very similar to twisted pair model 0012.

## 2.3 Solutions for KNX RF

Currently, Weinzierl Engineering is the only vendor who offers a stack implementation for KNX RF. The first devices based on our RF stack will be released in late 2006.

### 2.3.1 Hardware

KNX RF does not require dedicated hardware. Various microcontroller and RF transceivers that are suitable for implementing the KNX RF protocol are available on the market.

Figure 3:
Bidirectional
KNX RF device

Figure 4:
Unidirectional
KNX RF device

The MSP430 microcontroller family from Texas Instruments was selected because of its very low power consumption. For the RF interface we use components from Chipcon. With this combination it is possible to produce powerful wireless devices with low power consumption at low cost. Especially unidirectional devices (Figure 4) can be produced very inexpensively. Because of the modular structure of the KNX stack, it is possible to use alternative RF components.

### 2.3.2 Device models

The KNX-RF standard differentiates between unidirectional (send only) and bidirectional devices, which also contain a receiver. Since unidirectional devices lack a receiver that is permanently active, they can be operated with very low power consumption and are suitable for battery driven devices. Actuators, of course, are always bidirectional and are in most cases powered by the mains. The following device models are defined for KNX-RF.

**2010 (bidirectional)**

Our bidirectional stack for KNX RF requires about 20 Kbytes of flash memory and less than 1 Kbyte of RAM. It supports S-Mode and E-Mode simultaneously. The easy pushbutton mode is an especially interesting configuration method for small installations and even for the do-it-yourself market.

**2011 (unidirectional)**

The unidirectional stack can be run on a 4 Kbyte controller with 256 bytes of RAM. In spite of its small size, this stack offers a complete platform for sensor applications including the support of energy saving modes for the transmitter and microcontroller. Device model 2011 can also be used for S-Mode and E-Mode.

## 2.4 Platform for KNXnet/IP

Weinzierl Engineering GmbH was one of the first companies to implement the system software for KNXnet/IP devices. The software was developed in parallel with corresponding hardware. The result is the new *KNX EtherGate* platform.

### 2.4.1 Hardware

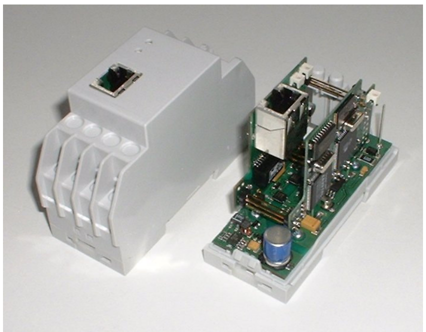

Figure 5: KNX EtherGate platform for KNXnet/IP devices

The KNX EtherGate hardware is a cost-effective circuit specifically designed for this application. The core of the device is a microcontroller that simultaneously communicates with a network chip and a KNX chip.

Power can be drawn from an external power source of 12-24 V AC or up to 30 V DC. In addition, the gateway also supports power supply via the *power-over-Ethernet* standard (PoE, IEEE 802.3af).

### 2.4.2 Software

A lean operating system was specially designed for KNX EtherGate (Figure 5). It is the basis for a wide variety of device types. The protocols listed below are available for application development.

- IP with ARP, DHCP
- UDP for KNXnet/IP
- TCP for Object Server or Web Server
- KNXnet/IP Core Services
- KNXnet/IP Tunnelling
- KNXnet/IP Routing
- KNX Object Server
- HTTP (Web Server)
- KNX Stack (Common Kernel)

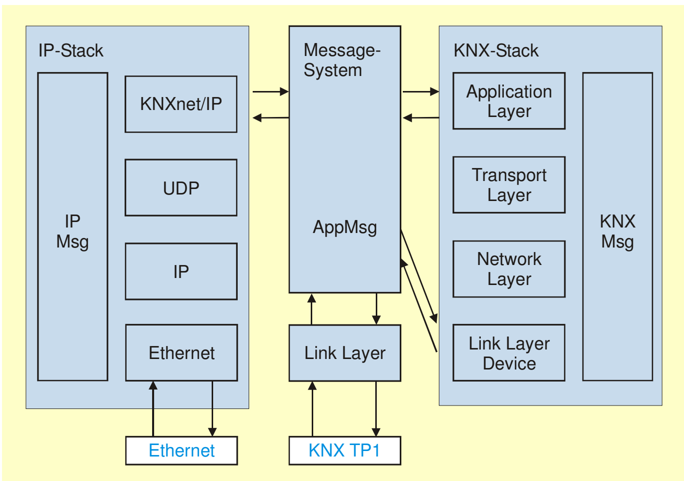


Figure 6: Software structure of the KNX EtherGate platform

### 2.4.3 Device model

Until now only one device model has been defined for KNXnet/IP devices.

**091A**

Device model 091A describes the KNXnet/IP router for the TP1 medium. A KNX IP router is capable of routing KNX telegrams between two or more KNX TP1 lines using Ethernet as a fast backbone. In our implementation, this device model is used as one possible application of KNX EtherGate. Other modules (e.g. object server, web server) are available for further applications.

## 2.5 Development tools

The quality of development depends primarily on the tools used. KNX manufacturers have a great advantage if they can use the same set of tools for the entire standard. A uniform user interface and consistent operation of the tools saves on developing time and costs.

### 2.5.1 Debug support using TraceMon

A major advantage of our unified software model is the universal debug concept. In addition to every available debugger (e.g. JTAG), the KNX system software also offers further debug support. The developer has access to a software debugging system that traces debug information via, for instance, an on-chip UART of the microcontroller.

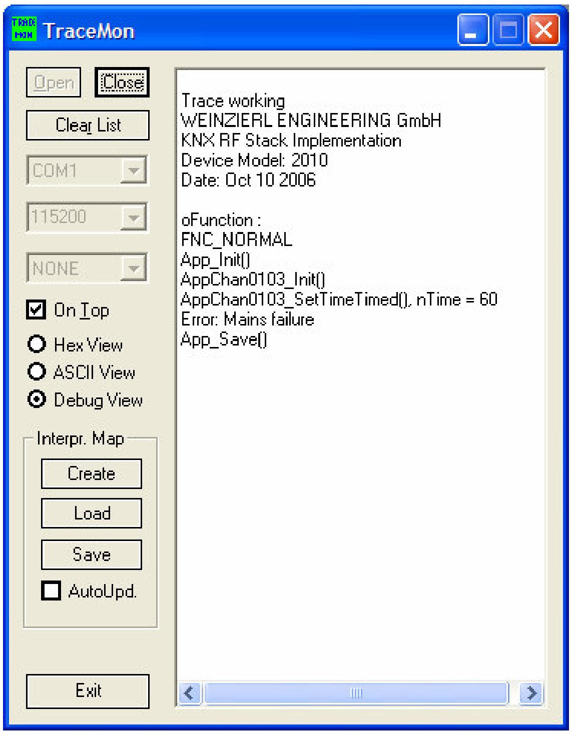


Figure 7: The TraceMon tool

The level of debug information (e.g. errors, warnings) can be set separately for each software module or turned off completely. The same debugging concept is integrated in all of our KNX stacks. The TraceMon software tool (Figure 7) is included in our package to enable the viewing of debug output on a PC.

### 2.5.2 Bus monitor and Net'n Node analysis tool

When developing components for a bus system, it is important to have a detailed overview of each device's process and of the complete system. To be able to analyze the actions and reactions of a bus device, or the inner-workings of the system, a bus monitor is required.

The Net'n Node software (Figure 8) is a comprehensive tool for KNX developers. It is not only a bus monitor program but also a very effective tool to analyze bus devices or the inner-workings of the entire system. It supports all standard device models currently defined. Net'n Node can be used for TP1, PL110, RF and for KNXnet/IP.

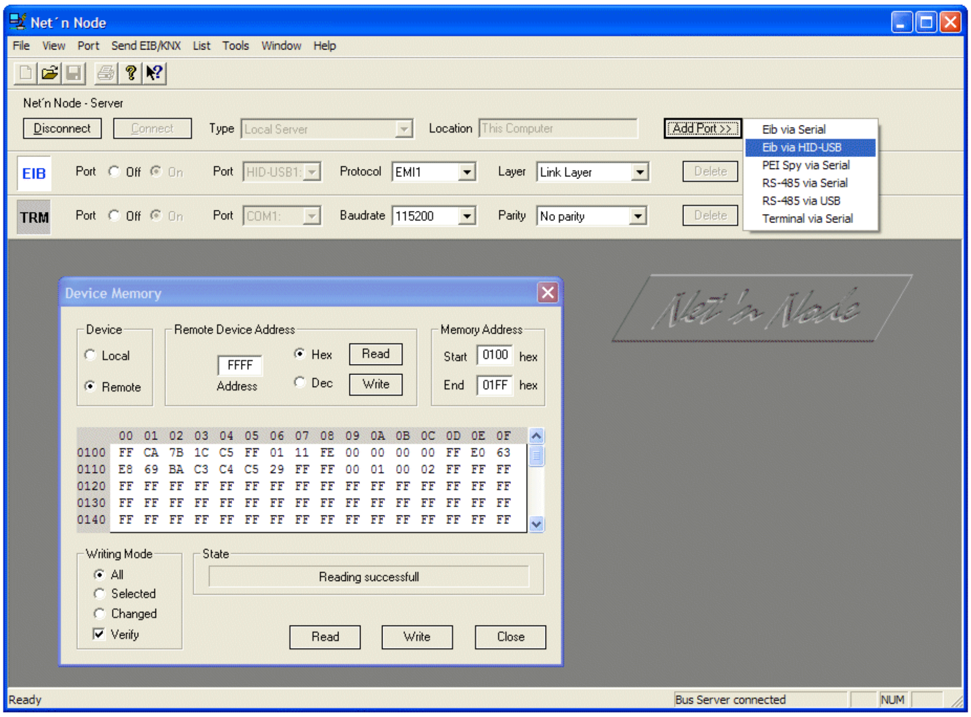


Figure 8: Net'nNode KNX tool

### 2.5.3 Evaluation hardware

The provided evaluation hardware is characterized by its standardized design concept. Figures 9 and 10 show the evaluation boards for KNX RF and KNX TP1 system software. Since their schematics are very similar, they can be used by the same application without requiring significant changes.

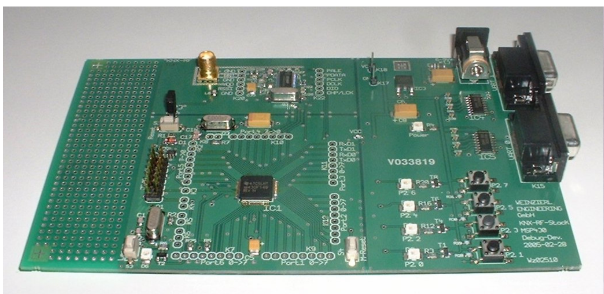

Figure 9: Evaluation board KNX RF

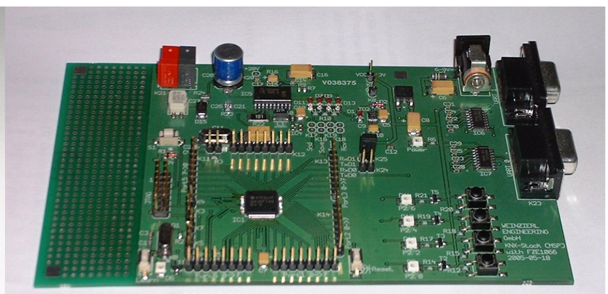

Figure 10: Evaluation board KNX TP1

# Conclusion

The diversity of KNX may be confusing at first. In reality, however, it represents a great opportunity for manufacturers whose products serve a variety of applications and markets. Developing the KNX standard into a comprehensive solution was a great challenge. Thanks to our success, KNX technology is now accepted as an international standard. KNX is the only building control system that is recognized as a standard by ISO/IEC, CEN and CENELEC. With the KNX system software described in this paper, Weinzierl Engineering GmbH offers a powerful and flexible solution for KNX device manufacturers.

Using software from a single source, it is now possible to implement various communication media and different configuration modes in a single device or in a complete device range. This development minimizes the risk of investing in system software and at the same time lets manufacturer prepare for future market demands and trends. One system – one solution!

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