![KNX logo] Smart home and building solutions.
Global. Secure. Connected.

KNX BASICS

INTRODUCING BUS SYSTEMS

Intelligent bus systems make buildings more cost-effective to operate, safer, more flexible, more energy-efficient and – above all – more comfortable and convenient. The KNX standard occupies a large share of the market for building automation systems.

Past, present and future

People live differently from how they did just a decade or two ago. We get money from cash dispensers, buy and sell goods and services over the internet, phone friends all over the world from our mobile phones, and start to moan if an MMS or e-mail takes more than 5 minutes to reach a destination in the USA. In our cars we are guided around by sat navs, and we lock and unlock the doors remotely without a key. The interior light goes on the moment we step inside, then after a while slowly dims down again. In short, for quite some time we have been enjoying cutting-edge developments in the areas of communication, entertainment and automotive technology. If we look at how technology in buildings has developed over the same period, it's a very different story. We still open our flat doors with conventional keys; and if we can't find our keys fast enough, the staircase light timer switches the lights off and plunges us into darkness. True, while we're out working all day, the heating automatically keeps our homes at a pleasant temperature – but it doesn't notice whether we left the living room window open when we went out. Only the electricity meter, ticking away quietly in a switch cabinet, notices that. Before going away for the weekend, it is wise to turn down the temperature in our hot water tanks and to turn off all those electrical appliances on standby. But no one actually does – at least, not reliably. It takes too long.

Time to do some catching up

So electrical installations in buildings have some substantial catching up to do. Networked sensors and actuators have long since been a standard feature of motor cars; buildings, on the other hand, are lagging some way behind. A change of mindset is needed, not least because of the long service life of an electrical installation. Today's new buildings will have to adapt to numerous changes over the next few decades. Now, more than ever, buildings need to be flexible and capable of accommodating networked building services. In technical terms, all of this is already entirely feasible *(Fig. 1)*.

Figure 1. "Smart" houses that adapt to users' needs? It sounds like something from a sci-fi novel, but it is already a reality. Intelligent buildings incorporating networks of sophisticated devices that control the building as needed already exist, and are making life easier for their occupants on a day-to-day basis.

More networking

The key to making a building "intelligent" is to equip it with networked sensors and actuators. There are several different ways of doing this:

Conventional methods
The immediately obvious solution is to employ a star topology, i. e. an arrangement where every socket outlet circuit, ceiling or wall outlet, and light switch is linked by its own (ideally five-core) NYM cable to a central distribution board in which the logical relationships are created by contactors, switch relays, and a programmable logic controller (PLC). This works well in reasonably small dwellings. However, the size of the house only needs to increase by a fairly small amount before the extent of the wiring work and size of the power distribution boards required becomes excessive. In a star topology, adding to or extending the system is also very time-consuming in terms of installation and programming.

Bus technology
A far better solution is to link all sensors and actuators in the building with a "data cable", and enable them to share information with each other *(Fig. 2)*. Each device can then communicate with every other device, for example: a light switch can "talk" to a dimmer and tell it how bright to set the ceiling light; a motion sensor can tell the actuator for the corridor lighting that someone has entered the corridor, or tell the room thermostat that there is no one in the room any more, so it can turn down the temperature.

Figure 2.
A bus system is a system of
sensors and actuators joined
together by a "bus cable".
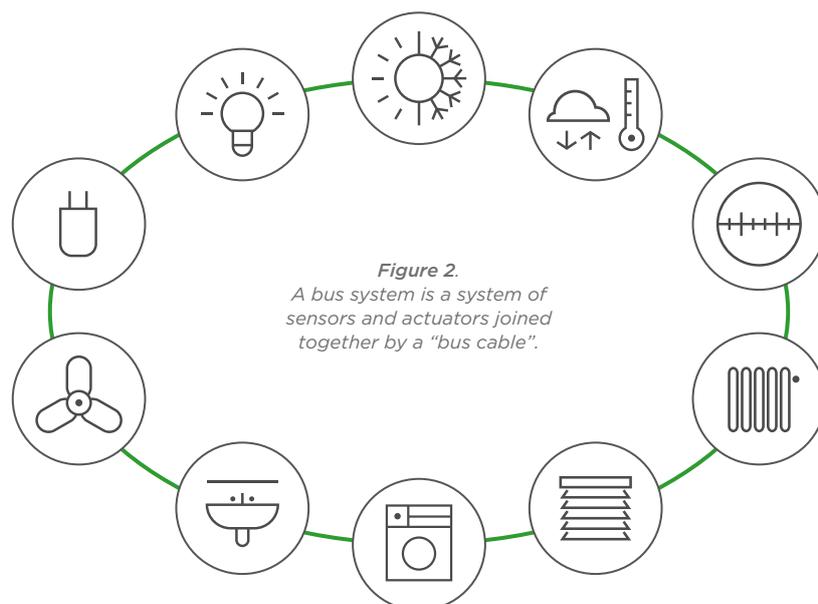
The following are examples of sensors that can send information to the bus:

Light switches

Dimmer switches

Motion sensors

Presence detectors (which can detect whether there is a person in a room even if they are not moving)

Window and door contacts (for security and heating control)

Doorbell buttons for front doors

Water, gas, electricity and heat meters

Overvoltage sensors

Temperature sensors for indoor and outdoor air

Temperature sensors in heating and hot water circuits

Modules for preselecting room temperature setpoints

Brightness sensors for indoors and outdoors, e.g. for constant lighting control

Wind sensors for controlling blinds

Fault and system status messages for white goods (washing machine, clothes dryer, dishwasher, cooker, etc.)

Leak sensors, e. g. in laundry room

Level measurements e. g. for rain water tank, oil tank, wood pellet store

Radio receivers for door locks

Receivers for infrared remote controls

Fingerprint modules and card readers for access control

The following are examples of actuators that can be controlled via the bus:

Relays for switching room lights on and off

Dimmers and DALI-gateways

Electric thermostatic radiator valves

Temperature displays

Drive mechanisms for awnings, blinds, curtains and garage doors

Drive mechanisms for windows

Circulator pumps for heating systems

Valve control systems, e.g. for solar thermal installations

Alarms (lights and buzzers)

Information displays and indicator LEDs

Relays for making and breaking socket outlet circuits (standby cut-off)

Well pumps

Air conditioning systems

Ventilation systems (toilet / bathroom extractor fans, controlled ventilation for living areas)

Control of washing machine, dryer, dishwasher

Consumer electronics

Trigger signals for alarm systems

Telephone systems

Electric door openers and door locking systems

Examples of functional modules (may be self-contained or integrated in devices):

Room temperature controllers

Timer functions

Freely-programmable logic modules

PLCs with KNX interface

Constant lighting control modules

Alarming and alerting

Telephone switchboards connected to the bus

Media control

Heating control

Pump control

Presence simulation

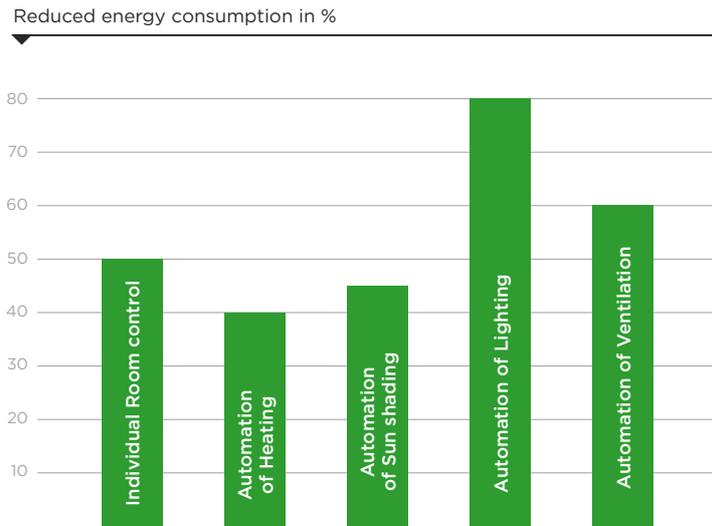Displays and user interfaces

Modules for connecting bus with telephone

Modules for automatically sending warning messages by text

Modules for accessing building data from outside via the internet or a phone

Reduced energy consumption in %

Figure 3.
A study conducted by the Institute for Building and Energy Systems at Biberach University of Applied Sciences, entitled "The potential offered by modern electrical installations for saving energy", has revealed that the use of a KNX-based, networked home and building control system can reduce energy consumption by as much as 50 %.

Why KNX?

There are several bus technologies on the market. All of them are beneficial and appropriate for certain areas of application. But no other bus system is supported by as many different manufacturers as KNX. This is because:

- All strong brands in the building installation sector are pushing KNX technology
- KNX was developed specifically to meet the needs of electrical installations in buildings
- KNX devices are installed, programmed and parameterised by fully qualified system integrators
- KNX is well-established and can accommodate a huge range of functions
- There are several thousand KNX-certified product groups available, covering every conceivable field of application
- KNX products are tested for conformity by an independent third party test laboratories
- KNX products are compatible with products from all manufacturers (interworking)
- End customers benefit from an extensive network of specialist tradesmen with solid KNX skills accredited by KNX-certified training centres
- The PC software ETS can be used to plan, design and commission installations of KNX-certified products from any manufacturer
- KNX supports all communication media: TP (based on a standalone 2-wire bus cable), PL (Powerline), RF (Radio Frequency), and IP/Ethernet/WLAN
- KNX is standardised in Europe, the USA, China and internationally, through e. g. CENELEC EN 50090 (Europe), EN ISO 22510 (Europe), ISO/IEC 14543-3 (International), GB/T 20965 (China), and ANSI/ASHRAE 135 (USA).

More than 450 KNX members in 45 countries manufacture products according to the KNX standard. Because the technology is standardised, KNX products are all mutually compatible and KNX installations can be easily modified or extended at a later stage.

Do bus installations make sense financially?

This is one of the first questions that building owners and tradespeople ask when considering bus technology. As so often – it depends. At first glance, bus systems appear more expensive than conventional installations. But appearances can be very deceptive! What need to be considered are the benefits offered by a system over its entire service life. Depending on the building type, the following may be compelling arguments for choosing a bus system:

- In situations where the customer wants a large number of different functions, a bus system will be easier and cheaper to install than an equivalent conventional installation
- In situations where the customer wants a large number of different functions, a bus system will also be less complex than a traditional installation
- Continuous energy savings and hence lower operating costs
- Greater comfort and convenience
- Easier to operate for older people/conducive to senior-friendly living
- Flexible, future-proof installations
- Safety/security (presence simulation, alarms in case of break-in attempts, freezer door alarms, panic buttons with telephone link, etc.)

Electrical installations are changing. Customers need to be shown the benefits of a future-proof KNX installation, in order to make an informed decision about whether the initial higher investment is justified by the long-term reduction in operating costs.

Already, new commercial and institutional buildings, in other words schools, events venues, offices, hotels, doctors' surgeries, law firms and production sites, are generally equipped with KNX bus installations. In these buildings bus technology often costs less than a conventional electrical installation even in the wiring stage. The benefits of bus technology are undeniable *(Fig. 3)*.

THE KNX BUS SYSTEM

Intelligent bus systems make buildings more cost-effective to operate, safer, and more flexible. The KNX standard occupies a large share of the market for building automation systems.

Where does the name KNX come from?

The KNX building automation system was originally known as the European Installation Bus (EIB), and was developed and marketed by the EIB Association (EIBA). In 1999, EIBA, Batibus Club International (BCI, France) and the European Home Systems Association (EHSA, Netherlands) amalgamated, the name KNX was adopted, and the Brussels-based KNX Association was set up. The technology used in modern KNX devices is compatible with that of the old EIB system, so all devices bearing either the KNX or the EIB logo are mutually compatible.

Figure 4. *Sensor/actuator principle*

What is the KNX system?

The KNX system is a bus system for building control. This means that all devices in a KNX system use the same transmission method and are able to exchange data via a common bus network. This has the following consequences:
• Access to the bus network needs to be clearly regulated (bus access method)
• Most of the data transmitted are not payloads (e. g. light on / light off signals), but address information (i. e. where have the data come from? Where are they going to?)

Another important feature of the KNX bus system is its decentralised structure: there is no need for a central control unit, because the "intelligence" of the system is spread across all of its devices. Centralised units are possible, however, for realising very specialised applications. Every device has its own microprocessor. A major advantage of KNX's decentralised structure is that, if one device fails, the others continue to function. Only those applications dependent on the failed device will be interrupted. Generally in a KNX system, devices fall into three categories: system devices (power supply, programming interface, etc.), sensors, and actuators. Sensors are devices that detect events in the building (e.g. someone pressing a button, someone moving, a temperature falling above or below a set value, etc.), convert these into telegrams (data packets), and send them along the bus network. Devices that receive telegrams and convert the commands embedded in them into actions are known as actuators. Sensors issue commands, while actuators receive them *(Fig. 4)*.
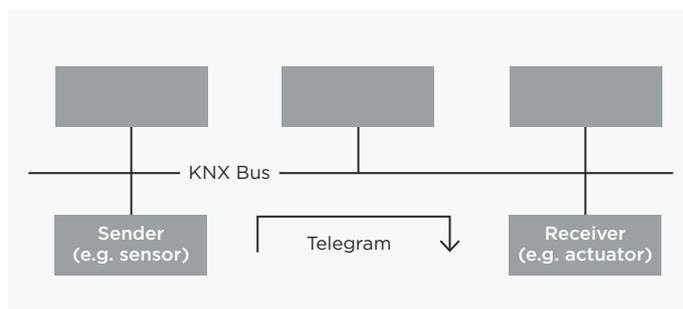
How big can a KNX system be?

Thanks to their decentralised structure, KNX bus systems can be modified and added to exactly as required. The smallest possible KNX application is a system linking two bus devices: a sensor and an actuator. This basic system can later be upgraded with as many devices as necessary to perform the desired control tasks. Theoretically a KNX system can consist of more than 50,000 devices. When extending a KNX system it is necessary to adhere to a specific topology.

What communication media are available?

Various communication media (and hence transmission methods) can be used for the exchange of data between devices in a KNX system:

KNX Twisted Pair (KNX TP)
communication via a twisted pair data cable (bus cable)

KNX Powerline (KNX PL)
uses the existing 230 V mains network

KNX Radio Frequency (KNX RF)
communication via radio signal

KNX IP
communication via Ethernet

KNX COMMUNICATION MEDIA

Bus systems need to be very convenient to install, add to, and in general to work with. The wide selection of KNX communication media available means that whatever the requirements, KNX can meet them – for example when retrofitting bus devices in even the most labyrinthine of buildings.

KNX Twisted Pair (TP)

A two-core twisted pair data cable (bus cable) is the most common communication medium for KNX installations. Here all devices are connected with one another via the bus cable. Twisted pair cables are cost-effective to buy and easy to install.

Power supply

In KNX TP the bus cable supplies all bus devices with both data and power. The rated voltage of the bus system is 24 V, while the voltage provided by the power supplies is 30 V. The bus devices work without error at voltages between 21 V and 30 V, so a tolerance range of 9 V is available to compensate for voltage drops in the cable, and contact resistance. In the devices, the DC supply voltage is first of all separated from the data-carrying AC voltage. The DC supply voltage is created by a capacitor, while a transformer decouples the data-carrying AC voltage. In transmitting devices, the transformer also serves to superimpose the outgoing data onto the bus voltage.

Data rate and signal shape

The data transfer rate is 9,600 bit/s, and the data travel serially, one byte at a time, via asynchronous data transfer. When a logical zero is transmitted, the voltage drops briefly and then, after no more than 104 µs, increases again to even out at the original voltage. This is due to the inductor effect of the choke. The transmission of logical ones corresponds to the idle state of the bus (Fig. 5). An important feature of communication via KNX TP is that the signals are coupled symmetrically onto the bus, i.e. the data cable has no fixed reference point against earth. This kind of communication is known as symmetrical, non-earthed transmission. The receiver does not register the voltage to earth in an individual data cable (like e.g. in the USB port), but instead evaluates changes in the voltage difference between the two data cables (Fig. 6). This means that, without any significant additional hardware, stability against coupled interference signals increases significantly, because e.g. the interference signals on both cores counterbalance each other (differential). The transmitter creates the AC voltage corresponding to the logical zero by only sending a half-wave, which it does by lowering the voltage on the pair of cores in the data cable by around 5 V. After approximately half a bit period, the sender cancels this voltage drop again. The rest of the system – the bus cable, transformers and charging capacitors of all bus devices, and – very importantly – the choke of the power supply, then generates a positive compensating pulse (resonator).
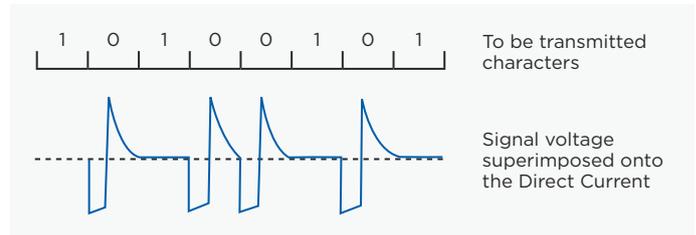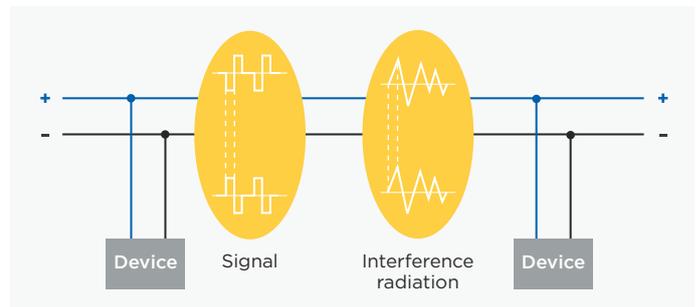

Figure 5. Signal shape in KNX TP

Figure 6. Symmetrical data transfer

Telegram structure

Information is exchanged between bus devices in the form of so-called telegrams. A telegram consists of a sequence of characters, with each character consisting of eight zeros and ones, in other words eight bits, or one byte. Often several characters are combined with one another to form a field. KNX TP telegrams have four fields (Fig. 7):

Control field
The control field defines the priority of the telegram and whether or not transmission of the telegram was repeated (if the receiver did not respond)

Address field
The address field specifies the Individual Address of the sender and the destination address (Individual Address or Group Address) of the receiver

Data field
The data field, which can be up to 16 bytes long, contains the telegram's payload

Checksum field
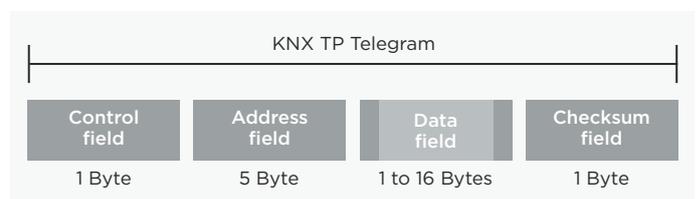The checksum field is used for parity checks

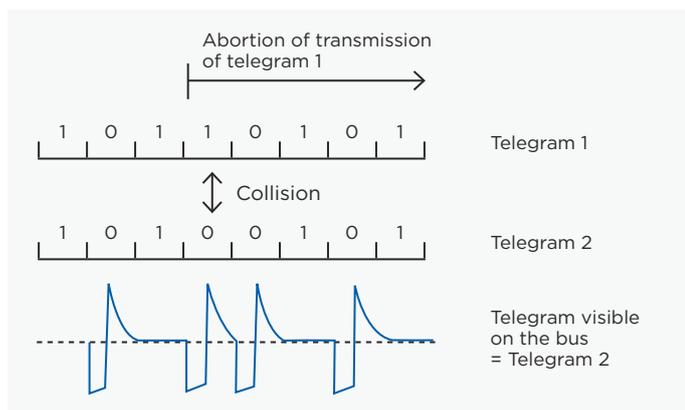Figure 7. Telegram structure in KNX TP

Figure 8. Collision avoidance in KNX TP

Bus access method

Access to the KNX bus, like several other bus systems, is random and event-driven. A telegram can only be transmitted if no other telegram is being transmitted at the same time. To prevent collisions during transmission, the priorities of the various sending devices are regulated by the CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance) method *(Fig. 8)*. Each transmitting device listens in to every bit of data transfer along the bus. If two devices are sending a telegram at the same time, then inevitably (and no later than at the moment of transmission of the sender address in the address field), one sender will transmit a 0 while the other wants to transmit a 1. The device sending the 1 "hears" that a 0 is being transmitted along the bus, and detects the collision. It is obliged to abort its own data transmission and give priority to the other trans- mission. After the transmission taking priority is complete, the aborted data transmission recommences. A telegram's level of priority can be defined in its control field; this enables the designer of the system to specify which telegrams have "right- of-way" in case of collision. If two telegrams have the same level of priority, which telegram is allowed to be sent first is deter- mined by its physical address (0 has priority over 1).

Connection of bus devices

Bus devices are connected to the data cable via components known as bus terminals – plug-in terminals able to accommo- date up to four KNX cables. The bus terminals make it possible to disconnect devices from the bus without interrupting the bus line. This represents a key benefit of the KNX bus system: removing a single bus device from the system does not stop the other devices from communicating with one another *(Fig. 9)*.
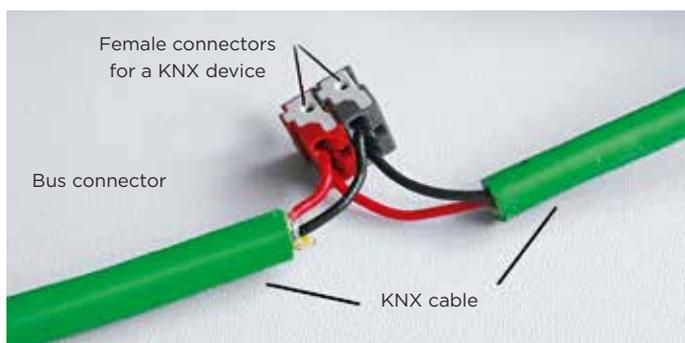

Figure 9. Bus terminal with incoming and outgoing bus cable

KNX Powerline (PL)

Using the existing electricity cables in a building as the KNX communication medium is a cost-effective way of retrofitting a building with KNX. In KNX Powerline (KNX PL) there is no need to lay a dedicated bus cable: the electricity cables already installed (one of the three phases + the neutral wire) themselves become the communication medium. The data signals are superimposed onto the mains voltage.

Power supply

No additional power supplies are needed for KNX PL; the power required by the bus devices comes from the 230 V mains electricity grid. Phase couplers are used to ensure that data communication can take place via all three phases, while band- stop filters prevent the propagation of data signals through the building connection towards the mains grid. Alternatively, instead of phase couplers, system couplers can be used.

Data rate and signal shape

In KNX PL the data transfer rate is 1,200 bit/s. Logical zeros and ones are transmitted via spread frequency shift keying (S-FSK). A signal of frequency 105.6 kHz sent by a transmitter corre- sponds to a logical zero, while a logical one is represented by a frequency of 115.2 kHz *(Fig. 10)*. The signals are superimposed onto the mains voltage. Thanks to comparative techniques and an intelligent corrective procedure, signals received can be evaluated even when interference is present. The centre frequency of the two wave motions is 110 kHz, which is why the KNX PL system is also known as PL110. The transmission power of the superimposed signals is often equal to the level of noise on today's highly noise-polluted mains networks. As a result they can only be evaluated using special digital signal process- ing methods, in which the transmission power and receptive sensitivity of the bus devices are constantly adapted to the network conditions.
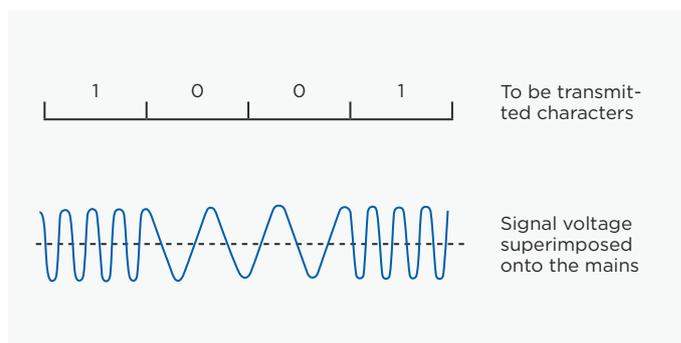

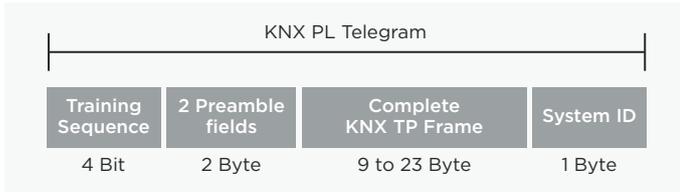*Figure 10. Signal shape in KNX PL*

KNX PL Telegram			
Training Sequence	2 Preamble fields	Complete KNX TP Frame	System ID
4 Bit	2 Byte	9 to 23 Byte	1 Byte

Figure 11. *Telegram structure in KNX PL*

Telegram structure

KNX PL telegrams are essentially extended KNX TP telegrams. KNX PL telegrams have four fields *(Fig. 11)*:

Training field
The training field synchronises and sets the levels of senders and receivers

Preamble fields
The preamble fields indicate the start of transmission, control access to the bus, and are needed to prevent telegrams from colliding

Third field
The third field contains the KNX TP telegram

System ID field
The system ID field contains an ID for keeping the signals of different KNX PL systems separate, so that only devices using the same system ID can communicate with one another.

Bus access method

Like KNX TP, KNX PL requires the use of a bus access method to prevent collisions between telegrams. This can only be done by delaying the sending of telegrams by bus devices. The default state of all bus devices is receive mode; only if certain conditions are met are they able to switch to sending mode. If a device detects the bit string of a preamble, this indicates to it that the bus is occupied by another device. A differentiation is made between the two states Bus occupied and Bus blocked. If a device receives a Bus occupied signal, the transmission of its telegram is postponed until a later point in time, chosen at random from one of seven possible options. This hugely reduces the likelihood of collisions occurring.

Connection of bus devices

In KNX PL, bus devices are connected directly to the 230 V mains network.

KNX Radio Frequency (RF)

Radio is always an appropriate KNX communication medium in those situations where it is not possible to lay new cables in the building (e. g. for sensors in inaccessible areas). KNX RF is also particularly suitable for extending existing KNX TP installations. Theoretically KNX RF could allow all technology in a building to be controlled wirelessly, but this will remain the exception rather than the rule.

Power supply

To enable RF sensors to be positioned where they do not have access to mains power, they are generally fitted with batteries. This is only possible if these devices do not need to be in a permanent ready-to-receive state. To help here, a unidirectional device model has been defined in KNX that only sends telegrams when needed, and does not contain a receiver. Actuators, on the other hand, need to be able to receive at all times, so need to be bidirectional. RF actuators therefore generally take their power from the 230 V mains. In KNX all receivers must also be able to transmit. The unique capabilities of KNX shine through when considering the performance of the system as a whole.

Data rate and signal shape

Radio technology works by modulating a carrier wave with the information that needs to be sent. This can be done by modulating either its amplitude (amplitude modulation), frequency (frequency modulation), phase (phase modulation), or a combination thereof. The modulated signal is sent to the receivers which then demodulate it, i. e. recover the information from it. KNX RF uses frequency modulation *(Fig. 12)*. The logical states zero and one are produced by slightly modifying the frequency of the carrier wave, also known as the centre frequency. Choosing the correct centre frequency is an important factor in determining the transmission performance. There are two upwards-compatible versions of KNX RF – KNX RF Ready and KNX RF Multi.
In KNX Ready the centre frequency is 868.3 MHz, and only one communication channel is available. However, radio communication in which only one channel is available is vulnerable to interference from non-KNX radio systems in the same or adjacent band that use different methods for accessing the communication medium.
KNX RF Multi overcomes this interference by enabling devices to switch from an occupied channel (e. g. F1, which is identical to the channel used by KNX RF Ready) to a different radio channel, i. e. ideally two other fast channels (F2 and F3), or two slow channels (S1 and S2). The fast channels are intended for applications operated by humans, e. g. lights, blinds, etc., while the slow channels are for devices that do not need to be permanently in receive mode, e. g. HVAC control systems. Fast channels have a data rate of 16.384 kbps, slow channels only half of that.
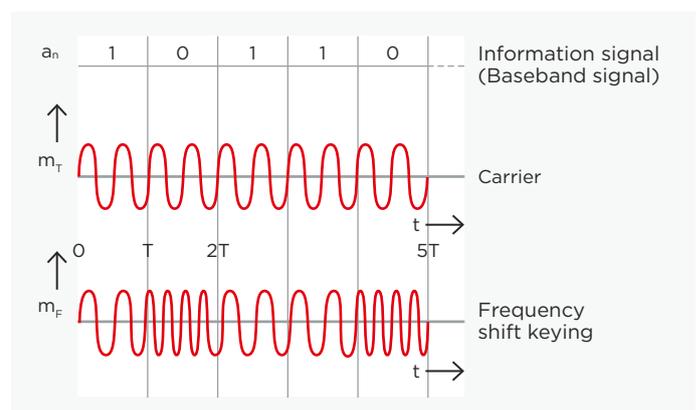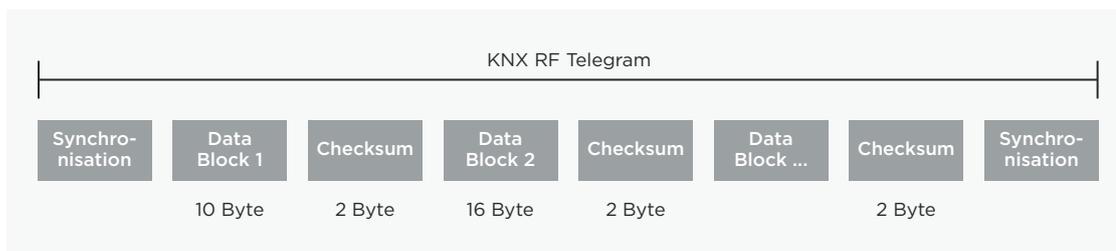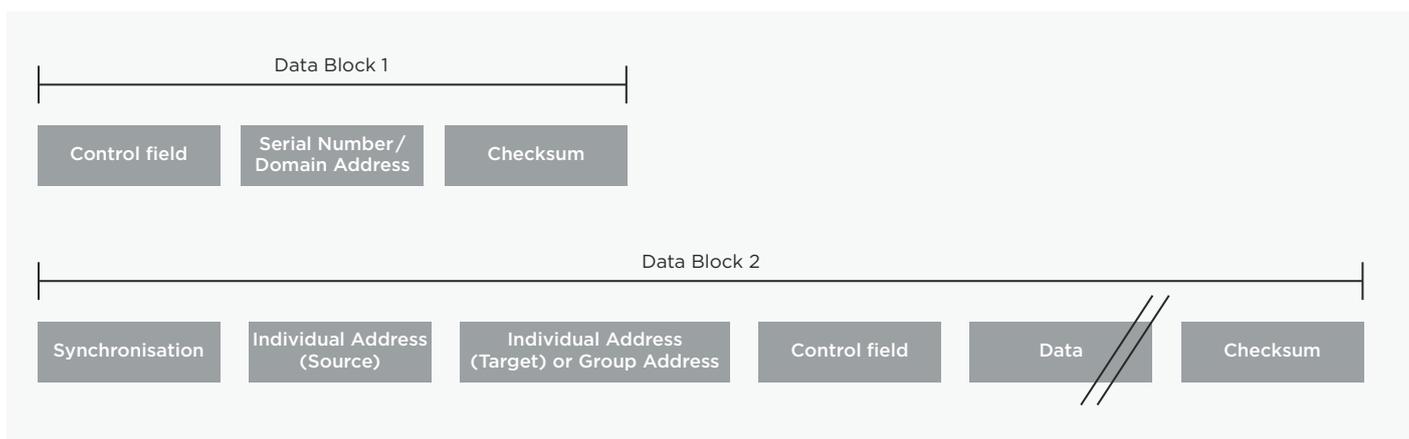

Figure 12. *Frequency modulation and signal in KNX RF*

While the data transfer rate (duty cycle) in F1 and F2 can only be 1 % or 0.1 % at a maximum of 25 mW, for channels F3 and S1 it can be increased to 100 % at a maximum of 5 mW (but between 5 and 25 mW again only 1 %). The data transfer rate in channel S2 is limited to 10 % at a maximum of 25 mW. Although devices are always capable of sending telegrams, they are switched to sleep mode to reduce their consumption by up to 80 % for fast channels and as much as 99 % for slow channels, waking up only periodically in order to receive telegrams. To ensure compatibility between single and multi-channel devices, a compatibility scheme has been developed, whereby newly-developed single-channel devices now need to use longer preambles. It must be possible for multi-channel devices to be downgraded to single-channel devices.

KNX RF Multi also makes it possible to check that a telegram has been received correctly: fast, direct acknowledgement of receipt (Fast IACK) can be obtained from up to 64 individual receivers. If no Fast IACK is received, transmission of telegrams is automatically repeated.

In larger installations, retransmitters can be used to forward telegrams to distant installation locations. Media couplers can be used for coupling KNX RF systems with KNX TP systems.

Telegram structure

Like with all KNX communication media, in KNX RF the useful data are sent via multicast telegrams. This means that one telegram can be received by several bus devices simultaneously and so e.g. switch on several lights at once. KNX RF telegrams are made up of several data blocks separated by checksum (CRC) fields *(Fig. 13)*. The data blocks contain the actual payload as well as bus-specific information for addressing purposes. The first data block consists of three fields *(Fig. 14)*: the

first – the control field – contains information about the length of the telegram, the transmission quality (reception performance), the battery status of battery-operated KNX RF devices, and whether the device is unidirectional, while the second field contains either the KNX serial number or the domain address. The serial number is assigned by the manufacturer and cannot be changed.

In commissioning in E- Mode, the serial number is evaluated in the receiver together with the source address of the sender. In KNX RF S-Mode devices, the domain address is assigned in ETS (version 5 or higher), and serves to keep neighbouring RF systems separate from one another.

The third field, the checksum field, allows the receiver to determine whether or not a telegram has been sent without error. In addition to further control fields and checksum bytes, the second data block consists of fields containing the individual source address (physical address), the destination address, and the payload. The payload is the actual information that is to be sent. Depending on the length of the payload, a KNX telegram can also contain further data blocks.

Bus access method

Unidirectional devices only send telegrams when necessary. Because of the very small duty cycle (= the pulse duration as a percentage of the complete period) of 1 %, it is virtually impossible for telegrams to collide, even in KNX RF Ready. Bidirectional devices check before sending a telegram whether the radio channel is free. If the channel is occupied, the device waits until it is free again before sending the telegram. As already mentioned, in KNX RF Multi the sender can request acknowledgement of receipt of the telegram.

Connection of bus devices

KNX RF components can be flush-mounted, surface-mounted, or built-in. Flush-mounted devices are mainly inserts onto which operating buttons are mounted to enable lights to be switched on and off or dimmed, or drive mechanisms for blinds to be operated. The radio communication components can be integrated either in the push-on interface or in the device insert. Various sensors, actuators and combination units are available as surface-mounted / built-in devices suitable for mounting, gluing or integrating in any desired location and on any surface.
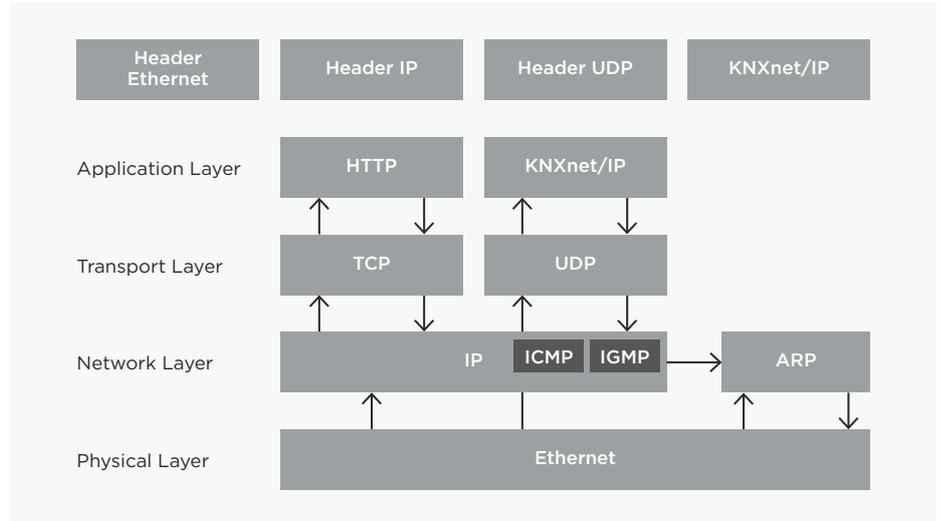

Figure 15. KNXnet/IP in the OSI reference model

KNX IP

Ethernet is an open (manufacturer-independent), high-performance, local and wide area network compliant with the international standard IEEE 802.3 (Ethernet). Ethernet is used for local networks, particularly in conjunction with the internet. Throughout the world there are a wide variety of different network structures. The Ethernet standard defines the physical areas (network engineers call them layers) – i. e. for example the following:

· What form the signals take in the cable
· What cables are used
· Cable pin configurations
· How the various devices can access a common system
· How the characters being sent are represented
· What data backup methods are used

For sending data between two devices, these definitions are generally not sufficient, however. Numerous other details concerning the protocols used also need to be defined; this is particularly important in large networks (internet). Protocols are needed in order for computers to communicate with one another in the network. TCP/IP – a group of protocols or rules (protocol family) introduced in 1984 – is currently very widely used. Although usually discussed in the form "TCP/IP", TCP (Transmission Control Protocol) and IP (Internet Protocol) are in fact two distinct protocols. Strictly speaking, the internet protocol suite TCP/IP also includes a third, equally important protocol: UDP (User Datagram Protocol). The base protocol, IP, serves to ensure that the data packets are sent from one device to another, and that in doing so they follow the optimal routes. This is made possible by so-called IP addresses. The TCP protocol is based on the IP protocol, and is used for a large number of common network applications, e. g. e-mail and surfing the internet. The TCP protocol establishes a permanent, error-checked connection and ensures that all data packets are sent in the correct order and successfully reconstructed by the receiver (connection-oriented protocol). The UDP protocol is used for applications (e. g. audio and video streaming) in which it is acceptable for data packets to occasionally go missing.

The connection is not error-checked, and the delivery of data packets is uncontrolled (connectionless protocol). UDP is considerably leaner and faster than TCP. In applications like the transmission of speech and video, it would also be counter-productive to resend – e. g. a second later – a packet that has gone missing. The UDP protocol is often used in building automation. Linking KNX to the Ethernet has the following advantages:

· The existing network infrastructure in the building can be used for the KNX main and backbone lines (higher speed, more cost effective, and more convenient)
· Buildings can be monitored and controlled via Ethernet from anywhere in the world
· Several individual sites can be observed and maintained from a central location over the internet
· KNX customer installations can be analysed and programmed remotely over the internet by the designer of the KNX system.

Protocol

The KNX system uses two Ethernet communication methods – tunneling and routing – both of which use the UDP protocol. Tunneling is used to access the bus from a local network or the internet for purposes of e. g. programming the KNX installation, while routing is used for exchanging telegrams over an Ethernet network, e. g. to couple two KNX TP systems via Ethernet. The KNX protocols for these two communication methods are called KNXnet/IP routing and KNXnet/IP tunneling. IP communication in KNX can be explained using the OSI reference model *(Fig. 15)*. Communication takes place via the application layer (which generates the KNXnet/IP telegram), the transport layer (UDP), the network layer (IP), and Ethernet – the physical layer. Like with the TP protocol, additional information for the respective layer (the header) is always added to the KNXnet/IP information.
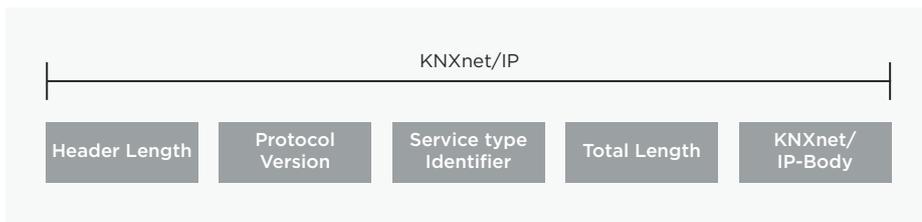
Figure 16.
KNXnet/IP telegram

Telegram structure

The KNXnet/IP telegram contains some further information in addition to that in the KNX TP telegram *(Fig. 16)*:

Header Length
The header length is always the same. This information is still sent, however, because the header length may change in a later version of the protocol. The purpose of the header is to identify the start of the telegram.

Protocol Version
This indicates what version of the KNXnet/IP protocol applies.

KNXnet/IP Service Type Identifier
The KNXnet/IP Service Type Identifier indicates the action that is to be carried out.

Total Length
This field indicates the total length of the KNXnet/IP telegram.

KNXnet/IP-Body
This field contains the payload.

KNXnet/IP tunneling

Tunneling is needed where ETS is to be used to send KNX telegrams in a connection-oriented manner within an IP framework *(Fig. 17)*. In principle this is always the case if a physical address is to be used as the destination address (e. g. when programming the physical address/downloading the application software for KNX devices). In tunneling, communication always takes place via the IP address of the KNXnet/IP device that is being used for tunneling.
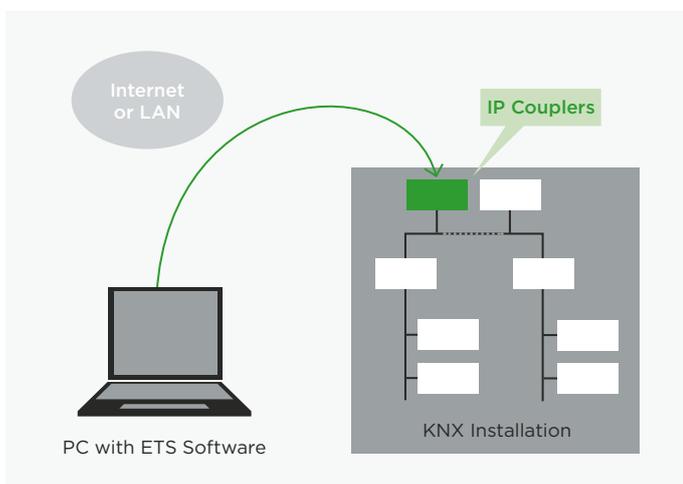
KNXnet/IP routing

Routing is needed for the simultaneous, connectionless transmission of KNX telegrams to several participants via a KNXnet/IP router *(Fig. 18)*. This is equivalent to group communication in e. g. KNX TP. Routing is used for e. g. coupling TP cables. A KNXnet/IP router serving as a line coupler for a KNX TP cable will only send a telegram to the IP side if the corresponding group address appears in the filter table of the KNXnet/IP router. All other KNXnet/IP routers serving as line couplers for other KNX TP lines will only transmit the telegram from the IP side to their KNX TP line provided that the relevant group address appears in the filter tables of the KNXnet/IP routers.

KNX IP and KNX TP compared

As communication via IP and Ethernet grows in significance, it is reasonable to ask whether the popularity of Ethernet will eclipse that of the current most popular, established KNX medium, TP. The answer is no. The main reasons for this are, firstly, the substantial cabling costs involved – because each terminal would need its own network cable. Secondly, networking KNX DIN rail modules in a switch cabinet via Ethernet would be too time-consuming, because of the very large number of network switches needed. Their high energy consumption furthermore means that they are not energy-efficient. IP does not pose a problem, however, if – by virtue of its function – a device has a network connection anyway (e. g. a KNX display). Thus, through the integration of KNX system software, any device with a network connection can be turned into a KNX device without any additional hardware costs. So while the hierarchical topologies will clearly continue to prevail, Ethernet will become
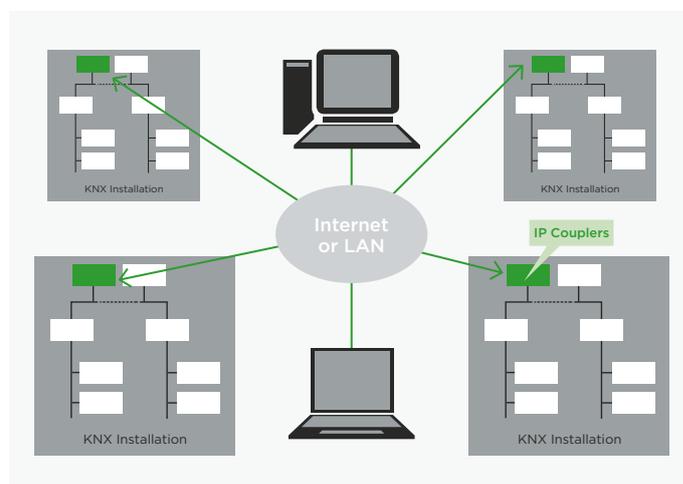

Figure 17. *Example of KNXnet/IP tunneling:*
programming of bus devices via Ethernet

Figure 18. *Example of KNXnet/IP routing:*
accessing several KNX installations at once via Ethernet

KNX TOPOLOGY

increasingly established as a high-performance backbone and a means of connecting complex (KNX IP) devices. The benefits of KNX TP, KNX PL and KNX RF can be clearly seen in their suitability for linking together separate sensors and actuators. KNX is the only bus system to offer such a wide variety of communication media.

Data transfer rates compared

Despite its various different communication media available, KNX constitutes a single bus system. KNX systems can be designed and commissioned with just one piece of software (ETS). KNX bus devices differ only in the type of connection they use; this does not affect the way the devices communicate with each other (the same Group Addresses apply throughout the system, components from different manufacturers are mutually compatible, etc.). The various media do differ considerably in their data transfer rates, however. In normal data traffic, KNX TP needs around 20 ms to send a telegram. Only during the programming of devices does this increase – to 40 ms. A KNX TP bus can send a maximum of 50 telegrams per second. KNX PL, in contrast, offers a data rate of six telegrams per second, due to the lower baud rate, longer telegram structure, and different access method of this medium.

KNX systems can be added to as desired, and can consist of several KNX subsystems based on different communication media (TP, PL, RF, IP). To ensure problem-free transmission of telegrams between individual bus devices, KNX systems must adhere to a specific topology.

KNX TP

Topology

The basic unit of a KNX TP installation is a line *(Fig. 19)*. A line includes a KNX power supply (including choke), and usually no more than 64 other bus devices. The power supply and twisted pair line (bus cable) perform two functions: they supply the bus devices with the power they need, and permit the exchange of information – i.e. the sending of telegrams – between those devices. The bus cable can be laid as desired, and branches can be added at any point. The resulting topology is a free tree structure, which allows a great deal of flexibility in terms of layout. Line Repeaters can be used to extend a line if more than 64 devices are needed. Sections added in this way are known as line segments. A line segment consists of a line repeater, a power supply (including choke), and no more than 64 further bus devices (line repeaters count as bus devices in the line). No more than three repeaters can be operated in parallel in a line, meaning the maximum number of bus devices is 255 *(Fig. 20)*. Another way of expanding the installation is to create new lines using Line Couplers. Because, in practice, line repeaters and Line Couplers (or Area Couplers) are often the same hardware, lines are not normally extended to their maximum size using line repeaters; new lines are generally created instead. On the one hand this makes the system more manageable, and on the other hand it reduces the number of telegrams travelling along each line (by taking advantage of the filter function of the line couplers). A Line Coupler will not send a telegram to a line for which it is not destined. Up to 15 lines can be operated via Line Couplers on a line – the main line – to form an area *(Fig. 21)*. The main line can likewise accommodate up to 64 devices. Line Repeaters cannot be used on the main line. Line Couplers in the
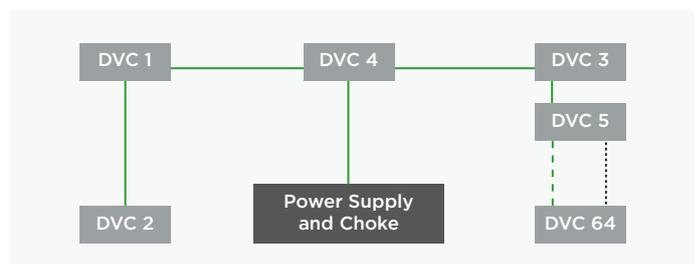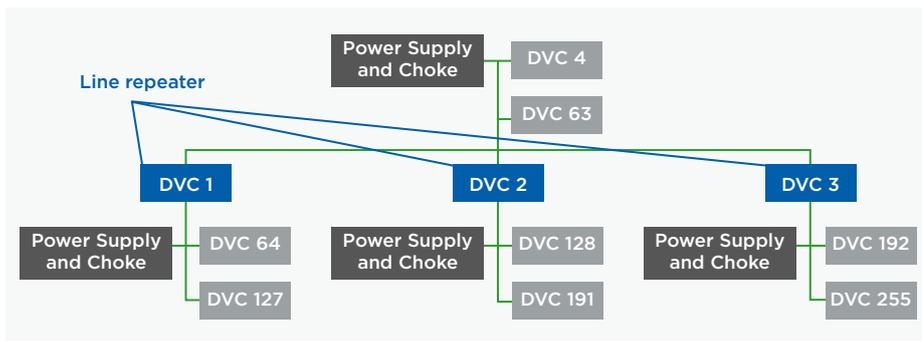

Figure 19. KNX TP line
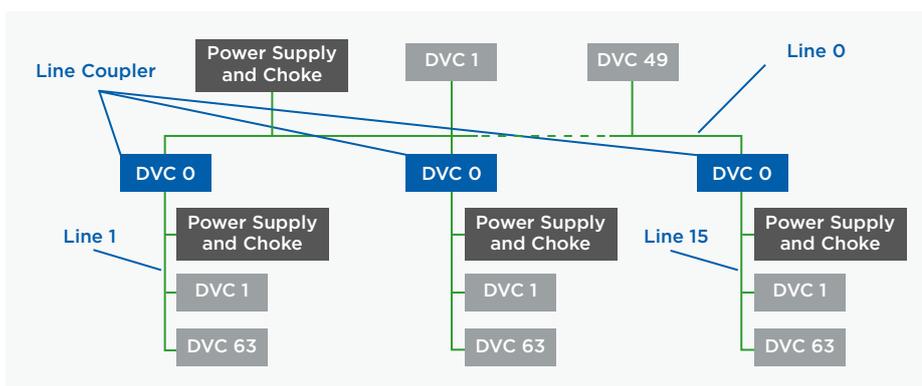
Figure 20.
Maximum length of a line in KNX TP

Figure 21.
An "area" in KNX TP:
up to 15 lines can be coupled
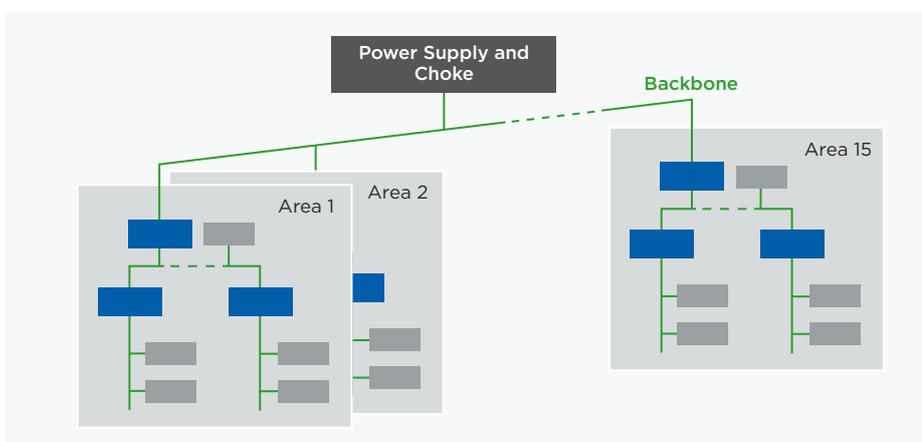*via a main line.*

Figure 22.
Up to 15 areas can be coupled via
area couplers (blue boxes) in KNX TP.

main line count as bus devices. Each line needs its own power supply (including choke). Up to 15 areas can be added to an area line via Area Couplers, to form a complete system *(Fig. 22)*. Just like the main line, the area line can accommodate up to 64 bus devices (not including Line Repeaters). Line Couplers on the area line count as bus devices. In practice, area coupling is typically performed using Line Couplers parameterised as area couplers. The area line is also called the backbone, so it also needs its own power supply.

The separation of the system into lines and areas has the following substantial benefits:

1. More reliable operation thanks to galvanic separation – lines and areas all have their own power supplies. The system as a whole continues to work even if individual power supplies fail.

2. Local data traffic on a line or area does not affect the data rate in other lines and areas.

3. The topology is logical and manageable for commissioning purposes.

Cable lengths

For signal formation reasons, and due to the maximum permissible propagation delay, distances in line segments are limited as follows:

Distance from power supply to device: max. 350 m
Distance between any two devices in a line: max. 700 m
Length of a line segment: max. 1,000 m
Distance between two power supplies (including choke) in a line: as per manufacturers' specifications.

Individual Addresses

Every device in a KNX system is assigned a unique, unambiguous number – its Individual Address. This consists of three numbers separated by dots. The numbers depend on the position of the bus device in the topology:

- The first number denotes the number of the area
- The second number denotes the number of the line
- The third number is a sequential number indicating the device's position in the line.

Physical addresses are needed in order to identify devices clearly, and also to program them. A special point to note is that, when attributing physical addresses, area/line couplers must always be given the number 0 as their sequential number.

Examples:

Physical address 1.1.0:
line coupler coupling the first line with the main line in the first area.

Physical address 2.3.20:
bus device 20 in the third line of the second area.

KNX PL

Topology

The topology in KNX PL is similar to that of KNX TP, and is made up of lines and areas. The basic unit of an installation is a line containing a maximum of 255 devices. An area is created by coupling 15 KNX PL lines using KNX TP; in PL the maximum number of areas is eight, however. Instead of line couplers, in KNX PL system couplers are used. The individual KNX PL lines need to be separated from one another using band-stop filters. System couplers, like all other couplers, have filter functions, which make it possible to reduce the number of telegrams in the various subsystems. Because the number of telegrams in a KNX PL installation is considerably smaller than in KNX TP, using KNX PL can be a necessary measure for preventing congestion in the bus system.

Individual Addresses

System couplers (like Area and Line Couplers) are assigned the sequential number 0. All other PL devices are assigned a Individual Address corresponding to their position in the topology.

Examples:

Individual Address 1.5.0
system coupler coupling the fifth PL line with the TP main line in the first area.

Individual Address 2.3.20
PL bus device with sequential number 20 in the third line of the second area.
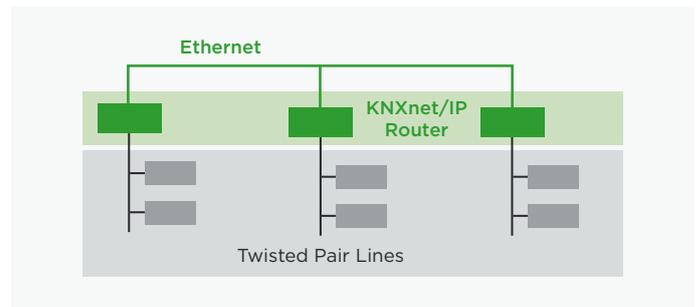

Figure 23. *Coupling of KNX TP lines with KNXnet/IP routers*

KNX RF

Topology

The devices in a KNX RF installation do not need to be arranged hierarchically, and can be installed virtually anywhere. Provided that they are within range of one another, any sensor can communicate with any actuator. It is not possible to limit the range of RF radio signals geographically, i. e. KNX RF telegrams can be received by devices in other, nearby KNX RF installations. It therefore needs to be ensured that neighbouring installations cannot interfere with one another. Telegrams sent by KNX radio transmitters always include the serial number / domain address of the device as a unique identifier. Only those receivers paired with the transmitter are able to process telegrams sent by it. A KNX system can be purely a radio network, or can combine radio with another communication medium (e. g. KNX TP). Media Couplers are used for coupling purposes.

Individual Addresses

Media couplers are assigned physical addresses corresponding to their position in the system topology.

Example:

Physical address 2.3.20
media coupler with sequential number 20 in the third line of the second area.

KNX IP

Topology

KNX IP can be used in place of main and area lines. This requires the use of KNXnet/IP routers. On the "top" of KNXnet/IP routers is an Ethernet port and a KNX TP connection. The routers forward KNX telegrams to other KNXnet/IP routers using the routing method. The availability of Ethernet as a further communication medium increases yet further the flexibility of KNX system topologies. KNXnet/IP routers can be used both as Line Couplers *(Fig. 23)* and Area Couplers *(Fig. 24)*. Like all couplers, KNXnet/IP routers are also able to filter telegrams. KNXnet/IP routers also make it possible to program devices in different lines. Some manufacturers of KNXnet/IP routers additionally support the filtering of telegrams with Individual Addresses, to prevent programming across different lines or areas if desired. During operation, KNXnet/IP routers communicate with one another and with the other KNX devices in the
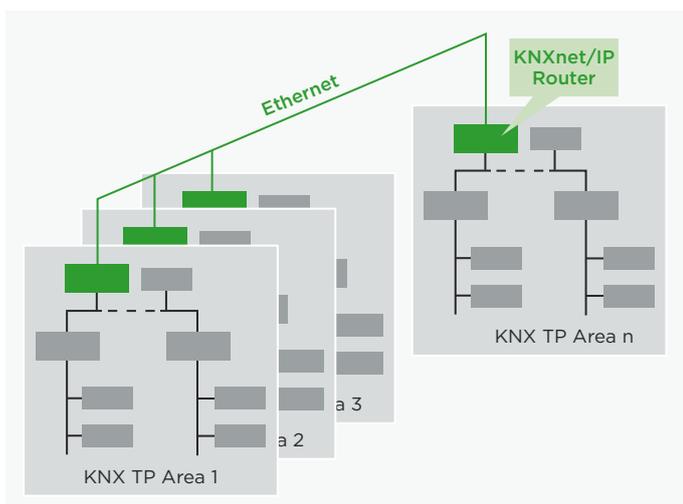
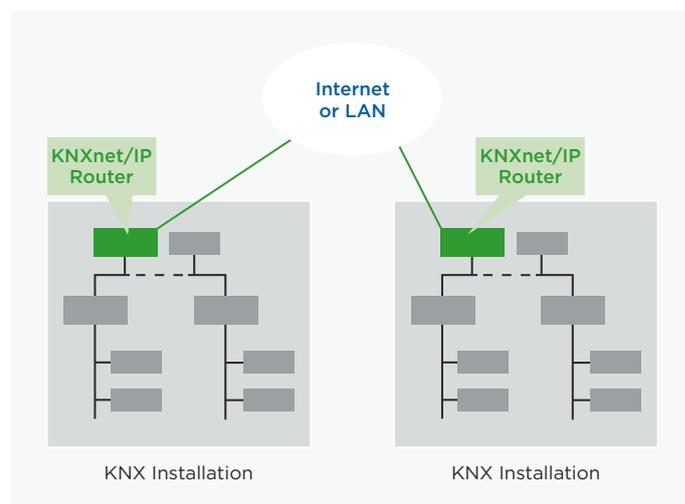*Figure 24. Coupling of KNX TP areas with KNXnet/IP routers*

Figure 25. Coupling of two KNX systems at separate locations

system via Ethernet, using routing as a communication method. Most KNXnet/IP routers also support tunneling, i. e. they can also be used as an IP programming interface for ETS. KNXnet/IP routers can additionally be used to connect entire separate systems with one another via Ethernet *(Fig. 25)*. This can be useful if e. g. two buildings are each equipped with a KNX twisted pair system, and these two installations need to be combined into a single system. If there is already an Ethernet connection between the two buildings (which will often be the case in commercial and institutional buildings), then there is no need to lay a new cable between them. KNX IP can also be used to network KNX devices, e. g. KNX displays, with one another. Software is available for communicating with KNX systems via KNXnet/IP.

Cable lengths

Ethernet installations are connected using network cables. Various types of network cable are available, each using a different method for shielding the cable cores. It is generally not permitted for these cables to be longer than around 100 m. For longer installations, special network components are needed to join together individual network segments. In residential buildings cable length is not usually an issue. As already mentioned, in commercial and institutional buildings the existing network infrastructure can be used.

Individual Addresses

KNXnet/IP routers (routing) are given the sequential number 0 (like area and line couplers). KNX IP interfaces (tunneling) can be given any sequential number.

Examples:

Individual Address 1.5.0
KNXnet/IP router acting as a line coupler, coupling the fifth line with the main line in the first area.

Individual Address 2.3.20
KNX IP programming interface with sequential number 20 in the third line of the second area.

Mixed topology

All of the topologies for the various communication media (TP, PL, RF and IP) can be used in combination with one another if desired *(Fig. 26)*.
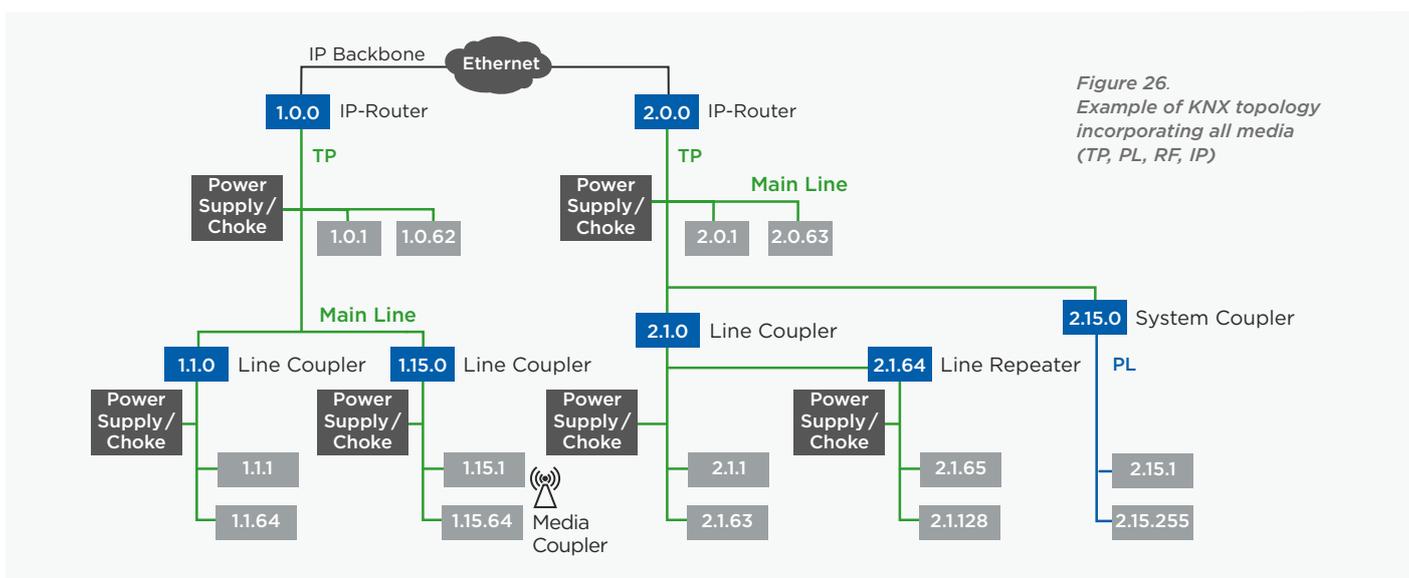

Figure 26. Example of KNX topology incorporating all media (TP, PL, RF, IP)

KNX DEVICES

There are two kinds of devices in a KNX system: system devices and end devices. System devices can be e. g. power supplies, couplers or programming interfaces, while end devices are e. g. sensors and actuators.

Sensors, actuators and bus coupling units

Components of bus devices

All standard bus devices are made up of two parts – the bus coupling unit (BCU) and the application module *(Fig. 27)*. If these two components are separable, they are connected via a standardised, 10 or 12-pin physical external interface (PEI). If a device was assembled in the factory – as is the case with built-in devices and most devices designed for DIN-rail mounting – it will not be possible to access the PEI.

Components of bus coupling units

For bus coupling units that are permanently integrated into devices, manufacturers can use either a ready-made Bus Interface Module (BIM), or a KNX chipset. In those device types where the bus coupling unit is a separate device connected with the end device via the PEI, the bus coupling unit will be visible. A wide variety of different designs are available (flush-mounted, DIN-rail mounted, and printed circuit boards for integration into circuits), but all bus coupling units are essentially similar in structure, consisting of two functional modules: the bus coupling unit controller, and the transmission module *(Fig. 28)*. The transmission module determines the communication medium which the bus coupling unit will use. The most common bus coupling units are those with transmission modules for KNX TP (Twisted Pair) and for KNX PL (Powerline).
The functions of these two types of transmission module are as follows:

KNX TP
superimposing the data signal onto the DC supply voltage

KNX PL
superimposing the data signal onto the 230 V mains power

Both types of transmission module also contain a power supply for the bus coupling unit controller, and generate reset and save pulses for the microcontroller. The bus coupling unit controller is essentially a microcontroller – a chip incorporating a microprocessor and various memories and input and output peripherals. The microprocessor will be a standard e.g. NEC, ATMega or Texas Instruments controller with the following memories:
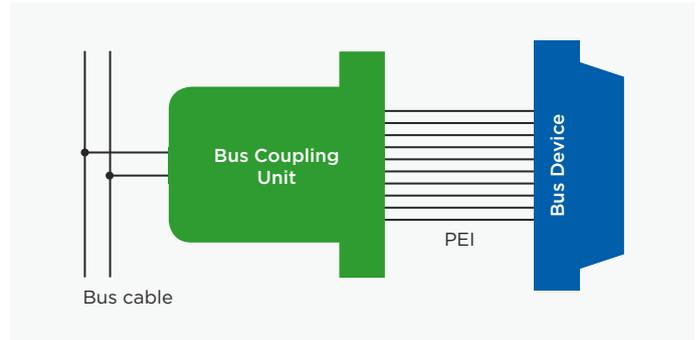

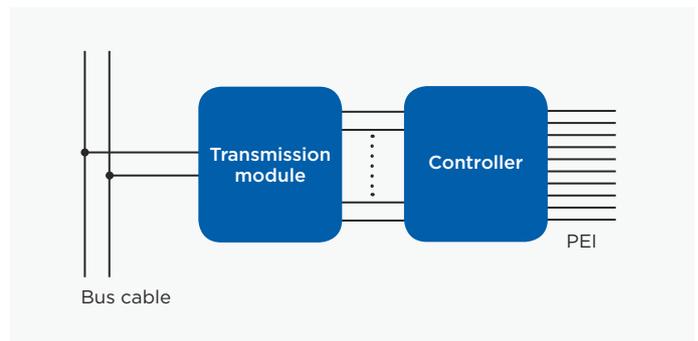*Figure 27*. Components of a bus device

Figure 28. Components of a bus coupling unit

RAM
the smallest memory. Variable parameters generated during operation of the device are stored here.

EEPROM or flash memory
the data (e.g. parameters, physical addresses and group addresses) input by the user in the application software are stored in this memory. The contents of this memory areis downloaded from the PC to individual devices, to be programmed, where the data is then stored.

ROM
the system software for the bus coupling unit is stored in this memory, during production of the chip. There are already several different development levels and versions, known as masks. A mask consists of two bytes of data, the first digit of which – y – indicates what medium is used (0 for TP, 1 for PL110, 2 for RF and 5 for KNXnet/IP). Not all profiles exist on all of these media.

The last digit, x, identifies the profile version.
The following masks serve to notify ETS of what system profile is used:
- y01xh: System 1
- y02xh: System 2
- y70xh: System 7
- y7Bxh: System B
- y300h: LTE
- 091xh: TP line/area couplers – repeaters
- 190xh: TP-PL110 media couplers
- 2010h: RF bidirectional Easy devices
- 2110h: RF unidirectional Easy devices

For a long time, System 1 was the most common profile. However, Systems 2, 7 and B – a progression on System 1 – are now gradually replacing System 1. They offer more memory and so allow a larger number of Group Objects and Group Addresses to be used. All functions required for e.g. alarm systems have additionally been revised (e.g. data access management via password protection). Application software developed for System 1 can be downloaded to devices with a System 2 mask. Many suppliers of KNX devices now no longer offer any System 1 devices. Advanced bus devices use System 7 or B, which offers considerably more memory than even System 2. The 10 or 12-pin connection between the bus coupling unit and the bus end device can be used in very different ways depending on the requirements. Depending on the end device used, the data exchanged via the contacts can take the form of binary signals, analogue signals, or a data stream via a serial interface. The way in which the contacts is used is determined on the basis of a resistor in the end device, which is measured by the bus coupling unit. Some end devices have their own "intelligence", possibly even in the form of another microcontroller. In this case the function of the bus coupling unit is often simply to manage the group addresses and ensure protocol-compliant data traffic. In rare cases it does not even manage the group addresses, acting – like the serial interface – merely as a gateway to the KNX bus.

System devices

KNX system devices are devices that perform primarily special functions, e. g.
- Facilitating adherence to the KNX topology
- Power supply
- Programming

KNX TP power supplies
KNX power supplies supply KNX TP lines with the necessary bus voltage, and provide the power needed for data transmission.

KNX TP USB interfaces
A KNX TP USB interface is needed in order to program the KNX system from a computer.

KNX TP line couplers/area couplers
These devices are used for the coupling of KNX TP lines and areas. They can also act as line repeaters.

KNX PL band-stop filters
KNX PL band-stop filters prevent powerline telegrams from leaving the intended propagation range. They are single-phase devices so should be fitted to all phases. Here it is important to adhere to the maximum current capacity of 63 A per device.

KNX PL phase couplers
In a three-phase network it should be ensured that KNX PL signals reach all three phases. If the three phases are routed in parallel in some sections, this will often take place automatically. If this is not the case, a phase coupler can help by providing capacitive coupling between the three phases of the 230 V network.

KNX PL system couplers
KNX PL system couplers can be used as repeaters for data signals in the 230 V network. They can also be used as line couplers for coupling several KNX PL lines, or as media couplers for coupling KNX PL systems with KNX TP systems.

KNX RF Media Couplers
KNX RF media couplers are used to couple KNX RF installations with KNX TP installations.

KNXnet/IP routers
KNXnet/IP routers support the protocols KNX IP routing and KNX IP tunneling, and can be used for coupling lines and areas. KNXnet/IP routers can also be used as a programming interface.

KNXnet/IP interfaces
KNXnet/IP interfaces are used for programming KNX systems from the Ethernet side.

KNX INSTALLATION REQUIREMENTS

A KNX installation is a standard electrical installation in the 230 V range, so all requirements applicable to standard installations (VDE 0100, etc.) also apply to KNX. There are also some KNX-specific aspects to consider.

KNX TP

No safety precautions are needed when installing / laying bus lines, because the bus voltage meets the requirements of safety extra-low voltage (SELV) and can therefore be touched. Because the absence of interference during the transmission of data between the individual bus devices depends on what cable is used, the KNX standard includes precise stipulations about what bus cables are acceptable. The cable must be a shielded twisted pair cable *(Table 1)*, and the shielding on the cable must not be contacted or connected to earth on any side – it functions purely as a metal cage. In KNX TP, mains cables must not be used as bus lines because of the risk of confusion and their non-compliance with the applicable communication requirements.

Second twisted pair

The most common bus cables also include a second, free twisted pair. The following guidelines apply with regard to the use of this free pair:
- Only extra-low voltages (SELV/PELV) are permitted
- Max. 2.5 A continuous current, overload protection required
- Cannot be used as a circuit for public telecommunications networks
- The second twisted pair is used to provide a separate power supply for particularly power-intensive KNX devices

Laying the cables

There are special issues to bear in mind wherever bus cables could come into contact with mains cables, e.g.
- In switch cabinets and distribution boards
- In branch boxes

Between the bus voltage and the 230 V network, double insulation capable of withstanding a test voltage of 4 kV is generally required. Minimum spacings apply, depending on the installation system used *(Fig. 29)*. If switch cabinets are used in which the mains section is fully separated from the installation bus (i.e. there must be no 230 V actuators present), then no special requirements apply. The shield of bus cables must continue right up to the terminals, and the use of shield bonding bars is not permissible. Mains and bus cables should be routed and/ or affixed in such a way that they do not touch. Special requirements apply for junction boxes only if both the bus cable and

RECOMMENDED BUS LINES

Cables typically used in Germany	Applicable constraints
YCYM 2 x 2 x 0.8 Test voltage: 4kV ("KNX cable")	Suitable for inside buildings
J-Y(St)Y 2 x 2 x 0.8 Test voltage: 2.5kV	Laid like YCYM, but note lower test voltage in proximity to 230 V mains
JH(St)H 2 x 2 x 0.8	Halogen-free cable, must however be installed at a distance from the existing 230 V installation
A-2Y(L)2Y or A-2YF(L)2Y	Used outdoors (linking separate buildings)

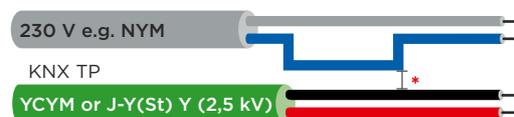**Table 1**. *What bus cable is used depends on the place of the installation.*

Insulated single core 230 V adjacent to the sheath of the bus cable
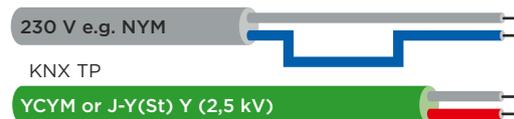
Insulated single core of the bus adjacent to the sheathed mains cable
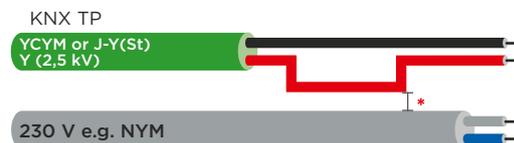
Exposure of two single cores

* > = 4 mm clearance space or additional insulation

Figure 29. *Minimum distances between bus cables and mains lines*

the 230 V cable are stripped. For branching, either separate boxes or a compartmentalised box with two separate chambers should be used. Special requirements apply for "combinations", i. e. where a bus component and a mains component are housed under the same cover, e. g. a flush-mounted actuator with a socket outlet controlled via the bus. When the common cover is removed, the mains side must remain covered, as is the case in socket outlets protected against direct contact. Bus cables should ideally be laid together with the mains and hence in the standard installation zones (for Germany see DIN 18015-3). There are several different methods for routing bus cables in individual rooms: they can be arranged in a star topology around a central distribution board, or a ring topology passing through all of the rooms, or a combination of the two. An important aspect to consider before undertaking a KNX installation is the extent to which a conventional installation and a KNX installation should, or indeed can, be combined, e. g. how appropriate it is to use KNX binary inputs in conjunction with conventional push buttons rather than KNX push-button sensors. This is particularly important if the customer has not yet fully decided on a KNX system, but would like to keep open the option of adding KNX components at a later stage. There are essentially two ways to proceed here:

- Lay a bus cable now but add KNX components later
- Use a star topology for the conventional installation (e. g. wire each push button individually up to the distribution board), to allow the system to be retrofitted with KNXcentrally in the distribution board.

It is therefore important to leave enough space in the distribution board.

KNX PL

Because KNX Powerline sends data along the existing mains network, no special KNX installation requirements apply here. Devices for limiting the transmission range (band-stop filters) and coupling the phases (phase coupling) are however needed. Circuit breakers or residual-current devices with rated currents of <10 A are not permissible in the signal circuit of a Powerline system; fuses must be used instead. Nor can shielded cables with an earthed shield or cables with core cross sections of more than 25 mm^2 be used for data transmission. All KNX PL devices have a connection for one phase and the neutral line. In actuators the connections for the load voltage and the signal cable are separate, so in installations with a very large amount of interference, it can make sense to separate the load and signal circuits.

KNX RF

When planning KNX RF installations, the potential effects of building structures and other physical factors should be borne in mind. Under favourable conditions, the transmission range of a battery-powered device is approximately 100 m.

KNX IP

Network cables for KNX IP are subject to the same requirements as cables in IT networks.

THE ETS SOFTWARE

A single manufacturer-independent Engineering Tool Software is used to plan, design and commission KNX installations with KNX-certified products: ETS®. System integrators can use this tool for connecting products from different manufacturers and from different application domains to form a single installation.

A KNX installation can be programmed by one of the following two configuration modes:

Easy Mode (E-Mode)
Here the system is configured not via a PC, but using a handheld unit, push buttons, or other means. This configuration method is suitable for electricians with a basic knowledge of bus technology, but no software skills. S-Mode devices can still always be added to the installation at a later stage.

System Mode (S-Mode)
To configure S-Mode devices, a special program – the Engineering Tool Software (ETS) – is needed. ETS can also be used to connect and commission KNX devices.
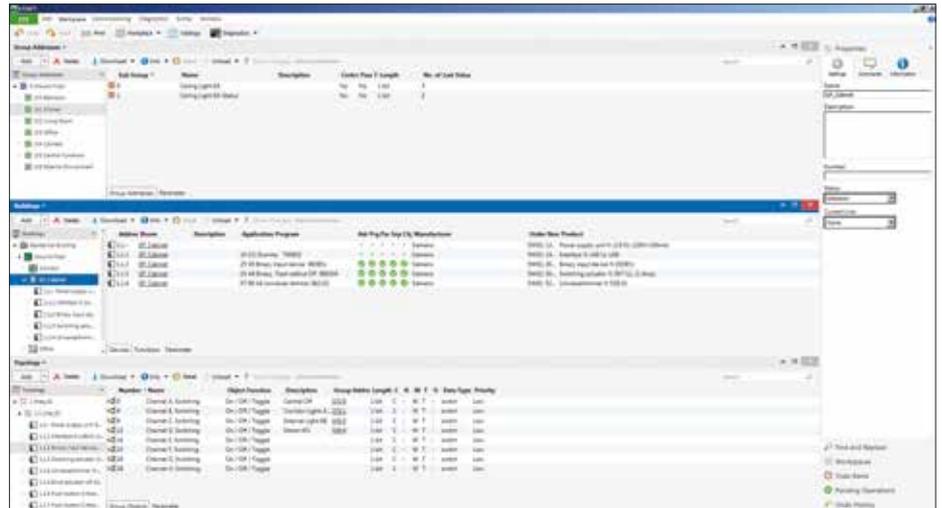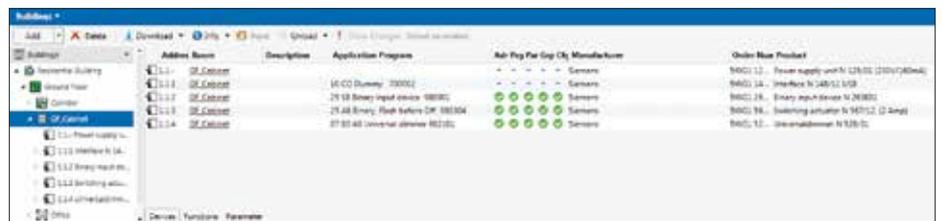
Figure 30. Various windows in ETS

Figure 31. Building layout and devices

Figure 32. Defining the parameters for a bus device

Figure 33. The Group Address window

Functions of ETS

A KNX installation is typically configured in S-mode, i. e. using a computer with ETS installed on it. ETS is used for processing the application software that manufacturers supply with their products. It can be used to perform e.g. the following tasks:

· Downloading manufacturers' application software from the internet (online catalogue) or reading in a manufacturer's database (e. g. as offered by the manufacturer via his website)
· Setting the parameters for the application software
· Using Group Addresses to link the Group Objects for of the individual Application Programs
· Downloading application software into KNX devices from ETS

In addition to design and commissioning tools, ETS also offers extensive assistance with diagnostics and troubleshooting.

ETS program structure

ETS has been created according to Windows design rules, so users who already work with Microsoft® products will not need long to learn how to use it. ETS has a number of windows, each representing a KNX installation in a different way *(Fig. 30)*:

Main window
The main window presents the installation from the point of view of the building, showing its various rooms and distribution boards. Devices can be assigned to individual rooms and distribution boards, making it easy to find a device in ETS on the basis of its location in the building.

Group Address window
The Group Address window shows the KNX installation from the point of view of the functions it offers. Here it is easy to see what devices in the building interact with each other in what way.

Topology window
The topology window shows the structure (Individual Addresses) of the KNX installation that is being edited.

Each window is divided into two halves, with the left-hand side providing a general overview of the installation in tree form, and the right-hand side presenting in list form individual sections of the tree structure selected in the left-hand part. Along the top edge of the window are menu bars from which individual functions can be called up. There are also toolbars providing quick, simple access to the program's most popular functions. The user can customise the appearance of the lists in the right-hand part of the window and the symbols in the toolbars, to adapt them to his or her personal working style.

Designing a KNX installation

To design a KNX installation, it is not enough to merely install ETS on a computer. The product data provided by the manufacturers of the various devices also need to be imported into the program. These data are available free-of-charge from manufacturers of KNX products, either online or directly from the manufacturer. They can also be accessed in the ETS Online KNX Product catalogue. Once these data have been imported into ETS, the design of the installation can commence. This involves the following steps:

Creating a project with the required data. The project can be later opened and edited again at any time via the attributed project name,

Depicting the layout of the building and the devices in it *(Fig. 31)*; defining the building structure and bus topology; defining the Individual Addresses of the devices

Defining the parameters for KNX products as required. In the case of a push button, for example, it is necessary to define whether the push button is to be a dimmer switch, a push-button for controlling blinds, or a simple push button for switching a light on and off *(Fig. 32)*. In the case of an actuator, these parameters determine how the actuator behaves, e. g. whether it should offer timer functions or, if it is a dimmer, how quickly the brightness should change from the previous to the new setting

Defining the functions of the system and the Group Addresses *(Fig. 33)*. Example: in an office there are two strips of lighting that work independently from one another. It should be possible to turn each light on and off individually, but it should also be possible to switch both lights on and off together, so the actuator needs to be programmed with three different functions. Three Group Addresses are therefore needed (strip light 1 on/off, strip light 2 on/off, and strip lights 1 and 2 on/off)

Linking the Group Objects of the KNX products via Group Addresses. This is done by connecting "virtual cables" in ETS between the devices' virtual inputs and outputs.
By linking Group Objects in this way, the user can define which sensors control which actuators

Specifying the trades to which the KNX devices in the installation relate (optional)

Checking that the installation has been designed correctly, printing documentation, and saving and backing up the project

Figure 34.
Programming button
for programming
the Individual Address

Commissioning

Commissioning is one of the most important functions of ETS. Each device first needs to be individually assigned a Individual Addresses, which the ETS user responsible for commissioning the installation does by pressing the programming button on the device; this tells the program that the address next in line to be issued should be assigned to that particular device *(Fig. 34)*. Special care is needed during this stage of the commissioning process, because errors at this point can lead to malfunctions later on, the correction of which can be very time-consuming. Once all devices have a Individual Addresses, it is time to download the software into them.

Diagnostic functions

ETS offers a number of diagnostic functions, for example for checking devices' Individual Addresses, or reading the status of a given bus device. This includes details of the device's manufacturer, any error bits in the bus coupling unit, and the operating status of the device. The operating status indicates whether the software is currently running. It is also possible to see whether there is an appropriate end device connected via the PEI to the bus coupling unit, and what Group Addresses are assigned to the objects of the device.

The bus and group monitor *(Fig. 35)* can be used to monitor all bus telegrams and hence observe activity on the bus. This makes it easy to diagnose and locate any errors. In addition to monitoring telegrams, it is also possible to send telegrams from a computer, and in this way to test actuators and initiate switching operations in the installation without the relevant sensors yet being installed. This is convenient for e.g. testing individual room controls, for example checking that the heating switches off when the windows are open (even though e.g. the relevant window contacts have not yet been fitted).

Installation and licensing

ETS is sold by KNX Association in the KNX Online Shop (www.knx.org). After purchase it can be downloaded directly from the internet, and can be installed on any computer. To work with ETS, users require a licence, of which there are several types available:

Software licence for ETS Professional
ETS Professional is the full version of ETS. The software licence is only valid for one computer.

Dongle licence for ETS Professional
A hardware dongle is also required; this is a portable licence that can be connected to a USB port on any computer. Thanks to the dongle, ETS can be used on any computer.

ETS supplementary licences
Up to two further licences can be bought for a small additional charge. This is particularly convenient for smaller companies

ETS Lite licence
inexpensive ETS trainee licences offering limited functionality are available for school pupils and students

Interfaces

For use in commissioning and diagnostics, ETS needs to be connected to the KNX bus. There are various ways of achieving this: the standard way is via a KNX USB port or KNXnet/IP interface (or KNXnet/IP router). If the network installation has a Wi-Fi connection, the bus can also be accessed wirelessly from a laptop.
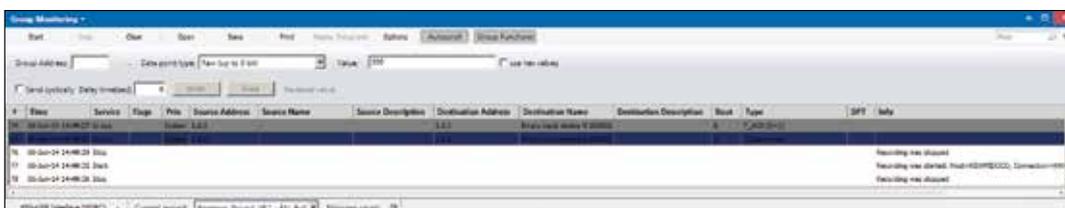

Figure 35.
The group monitor

Plug-ins

The configuration and commissioning of some KNX devices requires additional special software. In displays, for example, the page structure, texts that will be shown on the display, and link to events in the bus system are all defined by the person responsible for designing the installation. For this, a separate software plug-in is typically required. Plug-ins are automatically called up as soon as the user starts editing the device parameters in ETS.

ETS Apps

Apps are widely available for phones, smartphones and tablets – and now for ETS as well. ETS Professional offers generally all that is needed in order to work with a KNX installation. But, like mobile phone users, users of the KNX system also increasingly want access to a wide range of additional functions. By offering Apps for its Engineering Tool Software (ETS), KNX is responding to growing demand around the world for specialised solutions. Compatible Apps can increase the functions of ETS yet further. They allow KNX experts in particular to enjoy even greater transparency, and configure KNX installations more quickly than ever. Thanks to the Apps, ETS can be adapted to users' future wishes and to future technical developments. All Apps are designed by KNX Association and the KNX members. Validated by KNX Association, they are available to purchase from the KNX Online Shop.

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