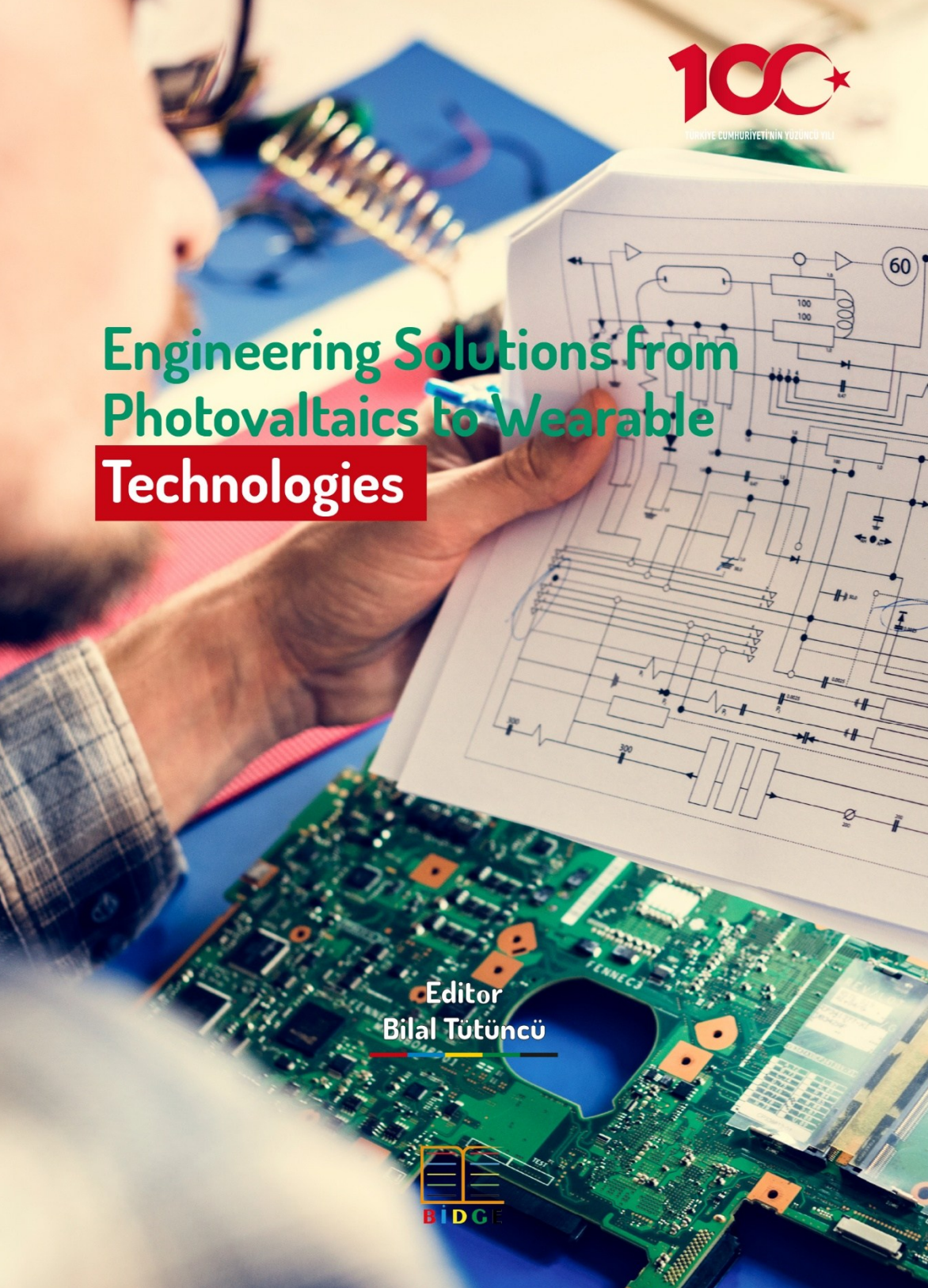


Engineering Solutions from Photovaltaics to Wearable Technologies

Editor
Bilal Tütüncü

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CHAPTER VIII

Innovative Approach in Technical Education: Hands-on Learning with KNX Building Automation Experiment Set for Students

Zühal POLAT[1]
Kübra Nur AKPINAR[2]

1. Introduction

With their remarkable comfort and energy-saving advantages, smart home systems have swiftly established themselves as a mainstay of contemporary living. By seamlessly integrating several sensors and gadgets, these systems optimize energy use, accommodate personal preferences, and improve home security. Smart homes reduce energy waste and improve quality of life by

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automating energy-intensive duties like lighting, heating, and cooling(Majeed et al., 2020). Internationally accepted standards that guarantee these systems' dependability, adaptability, and scalability are at their foundation. The KNX protocol is a well-known name in this industry and has established the benchmark for innovation in smart home technologies.

The KNX protocol is an internationally recognized open standard for home and building automation, enabling seamless communication among diverse systems such as lighting, HVAC, security, and energy management. As an ISO/IEC 14543-3-certified protocol, KNX guarantees interoperability across devices from different manufacturers, making it a cornerstone in smart home and industrial automation. It is a key enabler in integrating various building automation technologies into a cohesive, reliable system (Malhi & Apopei, 2022). At its core, KNX utilizes a decentralized communication architecture, ensuring that devices operate autonomously while maintaining network-wide synchronization. This decentralized nature enhances system reliability, allowing for robust control even if individual devices fail. Moreover, KNX supports various communication media—including twisted pair, RF, powerline, and IP—enabling broad adaptability to different building types and infrastructures (Kraus et al., 2020). Integrating Internet of Things (IoT) technologies has elevated KNX's relevance by facilitating real-time monitoring, control, and automation. IoT integration enables dynamic interactions between sensors, actuators, and cloud services, providing users with enhanced control through mobile applications and web platforms(Swathika, 2022) (Srividya, 2021). For instance, in smart homes, KNX systems allow users to

remotely adjust lighting, monitor energy consumption, or manage HVAC systems to optimize comfort and efficiency(Conceic'ão et al., 2022). Additionally, KNX plays a vital role in advancing energy efficiency and sustainability. It supports the integration of renewable energy sources, such as solar panels, and enables predictive maintenance through IoT-based analytics. This capability is critical for reducing energy consumption and promoting environmentally friendly practices in smart buildings(Satheeskanth et al., 2022). By bridging traditional building control systems with cutting-edge IoT technologies, the KNX protocol offers a scalable and future-proof solution for building automation. Its robust architecture, compliance with international standards, and integration with IoT platforms underscore its pivotal role in modern smart environments(Hakiri et al., 2020).

In summary, the KNX protocol is more than just a communication standard; it is a transformative technology that underpins the evolution of smart buildings and cities. Its emphasis on interoperability, real-time control, and sustainability positions it as an indispensable tool for modern building automation.

The extensive application of KNX necessitates the development of educational activities and practical opportunities, particularly for students pursuing technical education. This enables future professionals to comprehend the dynamics of building automation systems, enhancing their ability to utilize or improve such systems efficiently.

This study has developed an experimental setup to allow associate degree students to design and implement applications

related to smart home systems. The developed setup introduces KNX simulator modules and the KNX software programming tool, ETS. Learning the KNX system offers numerous advantages for students. First, as KNX is an internationally recognized standard, it allows students to work with globally acknowledged technology. This increases their employability prospects after graduation and will enable them to participate in international projects.

2. KNX Protocol and Integration with Other Technologies:

Integration of KNX Protocol with Other Technologies The KNX protocol is widely recognized for its flexibility and capacity to integrate diverse technologies, enabling seamless communication between various building automation systems. Its role in enhancing system efficiency and improving user experience is significant, as it bridges traditional automation methods with modern digital frameworks. One fascinating application of KNX is the simulation of KNXnet/IP telegrams. Using tools like MATLAB/Simulink, researchers have been able to simulate and analyze the behavior of building automation systems. For instance, (López-Aguilar et al., 2018) demonstrated how tools like Wireshark can monitor and optimize data packets. This approach has gained popularity for its ability to simplify troubleshooting and improve overall system reliability (Bergmann et al., 2012). (Kraus et al., 2020) developed a prototype gateway that allows seamless communication between KNX and service-oriented device connectivity (SDC) to address the growing need for interoperability. By enabling integration with protocols like BACnet, Modbus, and Zigbee, this innovation provides a unified framework for diverse automation technologies. In another breakthrough, (Bovet & Hennebert, 2013) introduced a

Web of Things gateway for KNX networks, integrating web-based technologies through HTTP and RESTful APIs. This advancement enables KNX systems to operate within modern IoT ecosystems, enabling remote monitoring and controlling of devices. Research by (Guinard et al., 2009) supports this, showing how RESTful APIs simplify IoT integration and enhance system scalability. On the hardware side, (Han et al., 2010) developed KNX device nodes and binary output actuators using a Bus Interface Module (BIM). This design reduces device complexity, improves efficiency, and lowers costs. Similarly, (Pérez-Lombard et al., 2008) explored innovations to improve energy efficiency and make KNX systems easier to deploy in residential and commercial settings. User-friendly interfaces are another key focus area for KNX systems. (Wünsche, 2019) highlighted the importance of creating intuitive interfaces for managing devices like lighting and HVAC systems. These interfaces make automation accessible to a broader audience, even those without technical expertise. Similarly, (Page et al., 2016) emphasized how graphical user interfaces (GUIs) improve user interactions with building systems, simplifying the operation of complex technologies. (Neugschwandtner et al., 2007) developed a method to map KNX data to oBIX (Open Building Information Exchange) entities to bridge the gap between traditional automation systems and modern IT frameworks. This approach facilitates better communication between KNX systems and IT-based solutions. (Kastner et al., 2005) also emphasized the importance of aligning building automation protocols with IT systems for enhanced functionality and interoperability. Energy management is one of KNX's most impactful contributions. By incorporating energy

meters, motion sensors, and automated timers, KNX systems help reduce energy consumption and promote sustainability(Pérez-Lombard et al., 2008). Finally, integrating KNX with IoT technologies has significantly expanded its capabilities. (Bergmann et al., 2012) demonstrated how lightweight IoT protocols like MQTT and CoAP can enhance KNX's scalability and responsiveness. This hybrid architecture enables advanced IoT applications, such as predictive maintenance and AI-powered automation, further solidifying KNX's position as a cornerstone of modern building automation. Through these advancements, KNX proves its adaptability, facilitating the creation of more innovative, sustainable, and user-friendly building automation systems. Its ability to integrate with emerging technologies positions it as a vital tool for addressing the challenges of modern clever building design.

3. KNX ETS 5: Infrastructure for Modern Building Automation

Based on the globally accepted KNX protocol, KNX ETS 5 software is essential for contemporary automation and intelligent building systems. The benefits of the KNX protocol, such as flexibility, system integration, and energy efficiency, have made it a global standard. With its flexible and intuitive interface, KNX ETS 5 makes it easier to develop, configure, and manage building automation projects. In residential and commercial buildings, it efficiently executes a range of automation scenarios, such as lighting, climate control, energy management, and security systems.

KNX ETS 5 is essential to education because it gives engineering students practical experience. Students can apply their theoretical knowledge to real-world situations using KNX-based

automation simulators created for educational reasons. These simulators aim to provide aspiring engineers with a thorough understanding of intelligent control systems, system integration, and energy efficiency. KNX ETS 5 promotes increased comprehension and adoption of building automation systems among wider audiences by aiding in the teaching process(Toylan & Cetin, 2019).

Technically speaking, current research focuses on improving KNX technology's performance and adaptability. Improvements in KNX device nodes and bus interface modules are especially significant. These modules increase system dependability and efficiency by optimizing communication between KNX devices and central control units. By focusing on efficiency and sustainability, these advancements guarantee quicker and more energy-efficient system operations, helping to shape the future of building automation systems(Han et al., 2010).

4. Home Automation Project Simulation with KNX

Control Panel for Automation of Smart Buildings Based on KNXA KNX-based control panel intended for intelligent building automation is shown in Figure 1. Lighting, switching, heating-cooling, and other vital systems can be controlled with the help of the popular KNX protocol, which allows various devices to communicate with each other without any problem (Association). How does the experiment set equipment work:

- *Power Source (640mA PSU),* the KNX system's power supply is its central component, providing all linked devices with the energy they require. It guarantees that the entire KNX bus line remains powered and functional with its 640 mA capacity.

- *IP Router,* remote access is made possible by the IP router, which links the KNX bus to an IP network. This allows you to keep an eye on and manage KNX.

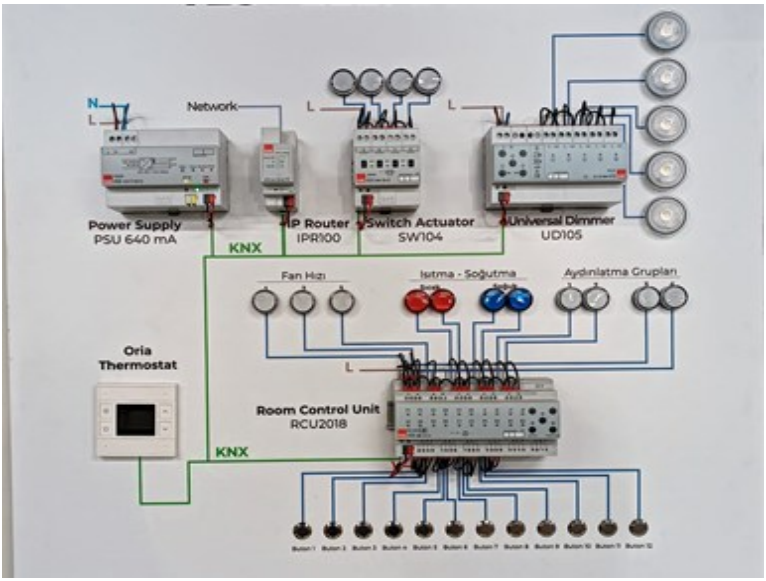


Figure 1. Experiment set panel (test elements)

This allows you to use an IP-based system or the internet to monitor and manage KNX devices from any location.

- *Switch Actuator*, the connected circuits' on/off switching is managed by this relay-based device. Its four channels offer dependable and effective control over lighting, outlets, and other loads (Jung, 2019).
- *Universal Dimmer, w*hether the lights are halogen, LED, or another dimmable variety, the dimmer controls their brightness. Its six channels allow for exact control of illumination levels, saving energy and producing the ideal atmosphere.
- *Oria Thermostat, b*y controlling the heating and cooling systems, the thermostat controls the ambient temperature. It

guarantees effective and comfortable climate control and is fully integrated with the KNX network.

- *Room Control Unit, t*his multipurpose device serves as the brains behind a room's automation requirements. It manages a number of tasks, including climate management, curtain and lighting control, and more. The proper actions are performed once commands from buttons or other inputs are analyzed.
- *Climate Control and Fan Speed, i*n order to ensure ideal airflow and temperature regulation, these sections concentrate especially on controlling fan speeds and climate systems, such as VRF or fan-coil units.
- *Lamps and Buttons,* users can interact with the system by turning lights or devices on and off using the buttons at the bottom of the panel. As indicators, the bulbs at the top display the state of several outputs.

The KNX bus line allows seamless communication between all devices. Remote access and control are made possible by the IP router, which connects the system to the IP network. Lighting functions like turning lights on and off and dimming them are handled by devices like the Switch Actuator and Universal Dimmer. Comfort and climate are expertly controlled thanks to the Oria Thermostat and Room Control Unit. The system offers the highest level of flexibility and usability by allowing users to engage with it remotely or through physical buttons.

By improving energy efficiency, enabling remote control, and providing a smooth, user-friendly experience, this KNX-based technology intelligently automates buildings. This system offers comfort, control, and convenience whether it is controlling the lighting, controlling the temperature, or automating everyday chores.

4.1 Building Structure:

Figure 2 shows the ETS5 software interface for configuring and managing a KNX-based building automation project. This interface provides information about the building structure and group address organization used for communication between devices.

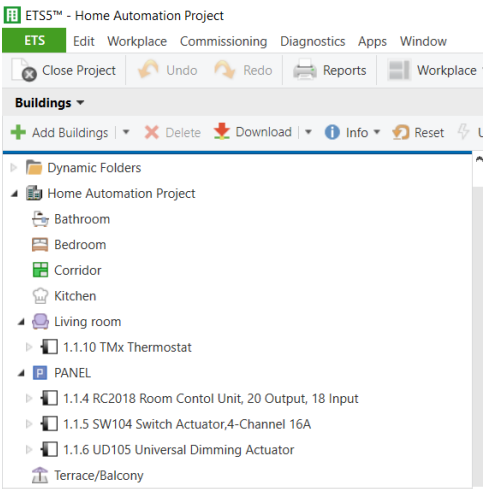


Figure 2. ETS5 software interface

This section represents the hierarchical organization of the building and its devices. The main project structure organizes different zones (rooms) and their devices. The zones are defined as the bathrooms, bedrooms, corridors, kitchen, living rooms, and terrace/balcony.

The TMx Thermostat in the living room controls the temperature. The panel contains three devices: the Room Control Unit, the Switch Actuator, and the Universal Dimming Actuator. The Room Control Unit is a central controller with 20 outputs and 18 inputs to manage multiple systems. The Switch Actuator is a 4-

channel actuator that switches high-current circuits (16A). The Universal Dimming Actuator controls dimmable lights in the living room.

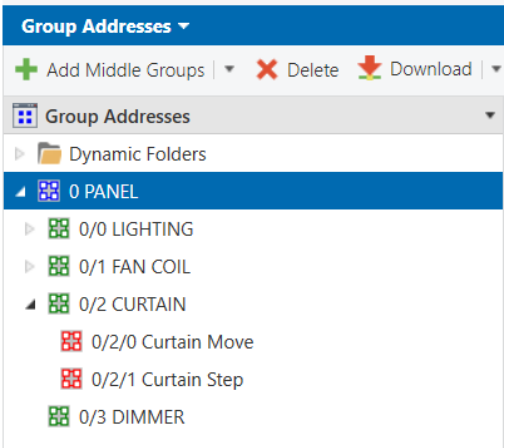


Figure 3. ETS5 group addresses the interface

4.2 Group Addresses:

This section organizes KNX group communication logic. Group Addresses represent logical links that allow devices to interact.

Figure 3 shows the ETS5 (Engineering Tool Software) interface in the Group Addresses section of a KNX building automation project. In KNX systems, Group Addresses represent the logical connections facilitating communication between devices.

In KNX systems, Group Addresses are organized using a three-level structure, Main Group, Middle Group, and Sub Group, to categorize control operations systematically. This structure ensures that communication is organized in an orderly and systematic

manner. Here, Panel (Main Group: 0) is used for general system-wide control addresses. Lighting (Middle Group: 0/0) is the address used for lighting control. Lights connected via KNX are controlled via this group address. Fan Coil (Middle Group: 0/1) is reserved for controlling HVAC fan coil units. This group is used to manage temperature and climate systems. Blind (Middle Group: 0/2) is the group address reserved for curtain and blind control. Blind Movement (Subgroups) sends commands to open and close blinds. Blind Step (Subgroups) set blinds to a specific position or step. The dimmer (Middle Group 0/3) is the address for lighting dimmer control. Dimmer actuators allow adjustment of the brightness levels of lights.

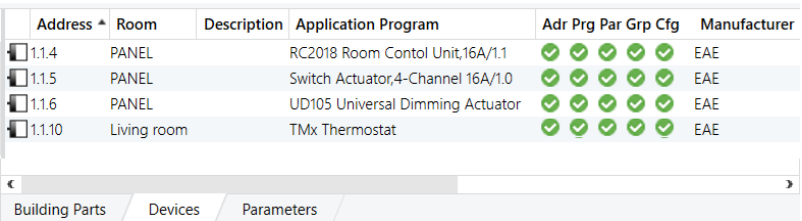


Figure 4. Addressing, programming, and configuring the interface of devices in ETS

Figure 4 provides detailed information about the devices' addressing, programming and configuration status in the ETS. Each device in the KNX system has a unique physical address. For example, 1.1.4 and 1.1.5 represent the physical addresses of the devices in the network. The room column indicates the physical location or room where the devices are installed. For example, "PANEL" and "Living Room" are mentioned. This helps you understand which zone or area the devices belong to.

The description column describes the functions of the devices. For example, the RC2018 Room Control Unit is a room control unit that is usually used to manage lighting and blinds.

The application program column shows the name and version information of the programs running on the devices. For example: RC2018 Room Control Unit, 16A/1.1, is the program version of the room control unit. Switch Actuator, 4 Channel 16A/1,0, is the program version of the 4-channel switching actuator. The programs are used to configure the functionality of the devices.

Adr, Prg, Par, Grp, Cfg (Addressing, Programming, Parameterization, Group Objects, Configuration), these columns indicate whether certain operations in the KNX system have been completed:

- ✓ Adr: Physical address assignment completed.
- ✓ Prg: Programming completed.
- ✓ Par: Parameter configuration completed.
- ✓ Grp: Group objects set.
- ✓ Cfg: Device fully configured.

The Manufacturer column indicates the manufacturer of the device. EAE manufactures all devices in the image. Building parts, devices, and parameter tabs are used to manage and configure devices in the ETS software.

Conclusion

Learning the KNX system provides students with valuable skills in building automation and innovative building technologies. These skills offer technical knowledge and prepare students to design and implement creative solutions that increase energy efficiency, comfort, and safety.

Students develop a solid foundation in electrical and electronic principles that enable them to install and connect KNX devices. They learn how components such as sensors, actuators, and power supplies work and gain knowledge on how to install power and signal lines properly. Since KNX is an open standard for building automation, it provides its users with expertise in data communication, device addressing (physical and group addresses), and system topology.

Understanding KNX certification standards also helps them understand the importance of compliance. With these experimental setups, students become proficient in using ETS (Engineering Tool Software), an essential tool for programming KNX devices. They learn to handle tasks such as addressing devices, creating group objects, and configuring parameters. Over time, they gain confidence in installing, testing, and commissioning complete KNX systems. Additionally, users discover how to integrate various systems such as lighting, HVAC (heating, ventilation, air conditioning), security systems, energy management, and blinds control.

This allows them to design intuitive user interfaces and create imaginative scenarios such as automatic lighting for energy saving. Students develop the ability to plan KNX network topologies, whether linear, star, tree, or hybrid. They learn to scale and adapt KNX devices for large projects, analyze system needs, and select the proper devices for specific applications. Troubleshooting becomes second nature as they learn to diagnose and fix problems in KNX systems. They practice debugging, data analysis, and reviewing system logs to optimize performance. They also gain

skills in system updates and maintenance. Students understand how KNX systems contribute to energy efficiency. They gain the ability to design solutions that reduce energy consumption, such as implementing timers, motion sensors, or energy meters for intelligent control. Users also learn how to integrate KNX systems with IoT devices and ensure seamless communication between different systems. Their ability to work with APIs and protocol converters (for example, for KNX-Zigbee integration) prepares them for modern, connected building environments.

Learning KNX is about acquiring technical knowledge and designing intelligent systems that make buildings more efficient, comfortable, and future-proof. Whether working on a small residential project or an extensive commercial integration, a skilled KNX expert plays a vital role in shaping the buildings of tomorrow.

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