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Intercom technology's mechanism and its industrial application

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Abstract

Intercom technology enables real-time, two-way communication, typically within a localized environment like a building or industrial facility. It has evolved from simple wired audio communication systems to advanced wireless, video-enabled, and IoT-integrated solutions. The mechanism behind intercom systems combines audio signal transmission, amplification, and signal processing, and in advanced systems, video integration and mobile connectivity. This technology finds widespread industrial applications in enhancing communication, security, and operational efficiency in sectors such as manufacturing, construction, transportation, and security.

Introduction

Intercom technology is a widely used communication system designed to facilitate real-time, two-way audio (and sometimes video) communication between different points, without the need for traditional telecommunication infrastructure. Initially developed for **simple in-building communication**, intercoms have evolved to become integral in **security**, **industrial operations**, and **emergency systems**.

In industrial environments, communication plays a vital role in ensuring safety, operational efficiency, and security. Intercom systems are commonly deployed in places like factories, hospitals, warehouses, and office buildings. They enable **instant voice transmission** between workers, security personnel, and management across large or complex facilities. This technology ranges from basic, wired setups to advanced wireless, video-enabled systems, offering flexibility depending on the application.

In industrial settings, where rapid and clear communication is essential for operational efficiency and safety, intercom technology plays a crucial role. From enabling quick communication between workers on the factory floor to enhancing security in large office buildings and industrial complexes, intercoms serve as the backbone of effective **internal communication**. They eliminate the delays associated with mobile phones or long-range radios, offering a more **focused** and **reliable** solution tailored to specific environments.

Components of an intercom system

Modern intercom systems consist of two components:

1. A Base Station
2. One Or More Substations

The base station, sometimes called a 'master station,' is the main component of an intercom system. It is installed at a property's entryway.

The base station is connected to one or more substations. Substations are installed at various points throughout the building, such as inside an apartment or office.

Intercom base stations:

Intercom system base stations enable visitors outside a building to communicate with visitors inside a building.

As the central piece of an intercom system, the base station controls the entire system. Installed at the property's entrance, the base station must be connected to power, a door release device, and every substation. You can either hardwire the base station to substations or connect them wirelessly.

Visitors use the base station to notify tenants of their arrival and communicate with any substation in the building.

Pro tip: When purchasing an intercom system, choose one that has a base station with a built-in camera. The camera adds a layer of security and convenience by letting tenants see who's at the door before letting them in.

Intercom substations:

Intercom system substations allow tenants inside the building to communicate with visitors outside the building. They also allow tenants to grant visitors access to the property through a 'door open' button.

Traditionally, substations were physical pieces of hardware that included a speaker and a microphone. You would have to install them at various points throughout the building and hardwire them directly to the base station.

Today, modern intercom systems ditch the substation hardware and instead rely on peoples' smartphones to act as the intercom substation. Not only does this allow tenants to open the door wherever they are, but it also allows them to see who is at the door through a live video call.

Pro tip: Find an intercom system that uses smartphones as the intercom's substations. You'll get more features, including video calls, remote property access, and keyless entry. Plus, you won't have to pay for additional hardware, wiring, and labor costs to install the intercom substations throughout your building.

Takeaways:

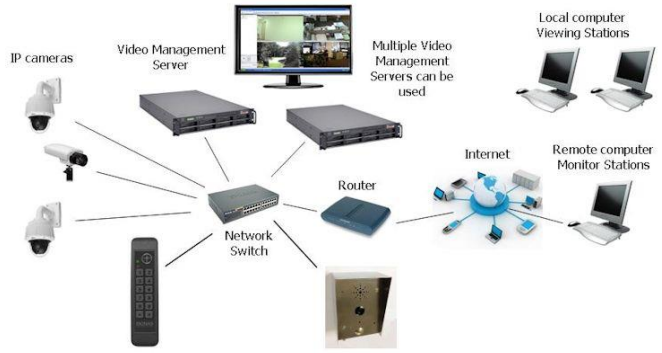
Intercom systems consist of two parts: base stations and substations.

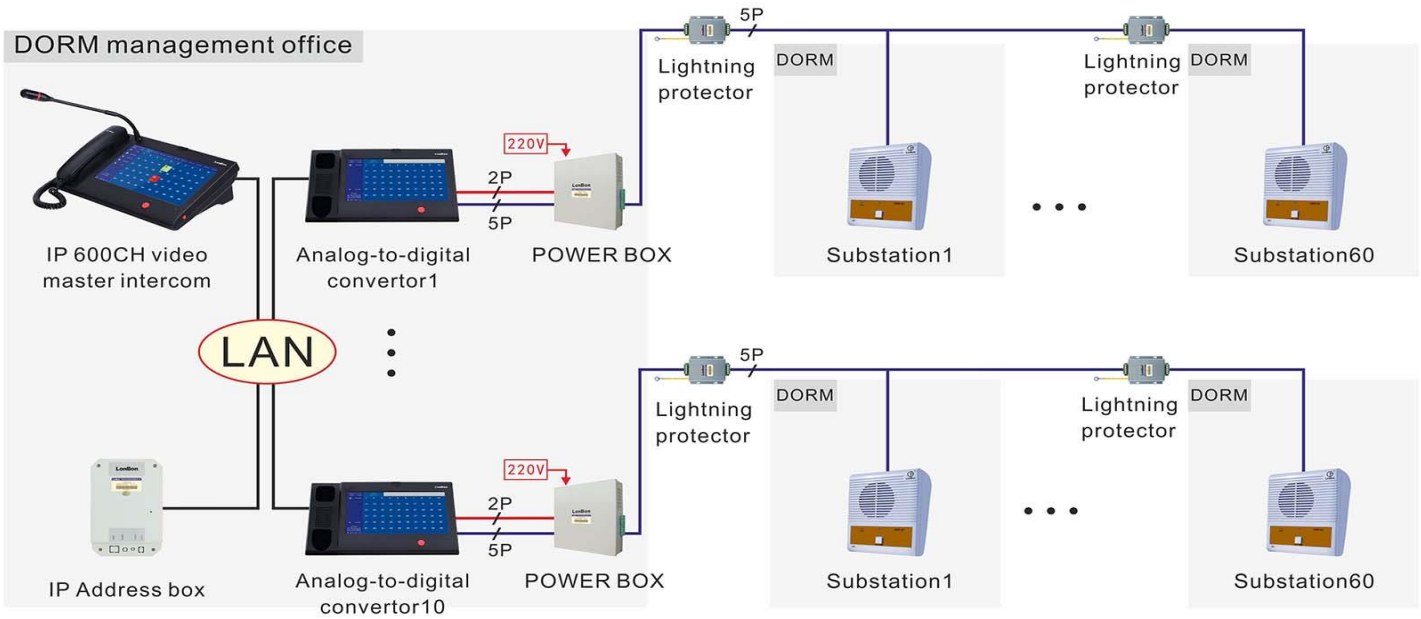
Base stations are installed at the entryway of the property and allow visitors to communicate with tenants. Substations are installed at various locations throughout the building and allow tenants to communicate with visitors and grant them access to the building.

Base stations are connected to substations through either a hardwired or a wireless connection. Additionally, intercom systems that use smartphones as their base stations save you money on hardware, wiring, and installation.

Recommendations:

- Install an intercom base station at the entryway of your building.
- Choose an intercom system with a camera that wirelessly connects to its substations.
- Smartphones make the best substations because they do not require purchasing and installing additional hardware.





How does an intercom system work?

An intercom system works by allowing visitors to call tenants in a building, then transmitting audio and video signals to substation devices so that tenants and visitors can communicate.

The base station *captures* audio and video and transmits them to substations. The substations then allow tenants to see and speak with visitors before giving them access to the building. Tenants can remotely unlock the door or gate by pressing a button on their device.

How to use an intercom

Here's a step-by-step guide on how to use an intercom:

- Use the intercom device at the door or gate to locate the tenant you want to call.
- Press a button or enter the tenant's code to call them.
- The tenant answers the call using their in-unit device, their cell phone, or a landline phone.
- If the tenant wants to grant access, they press a 'door open' button on their intercom device to remotely unlock the door or gate.

Hardware Architecture:

This system uses an embedded computer built on a single circuit board. This is a complete computer built on a single circuit board with a microprocessor, memory, input/ output (I/O), and other functions; it is the main working platform for the intercom.

The hardware of this system is built into the embedded system, including an MCU (microcontroller unit), a wireless module, an SD card (secure digital card) slot, a touch panel, a camera, a relay, an electronic lock, a buzzer, and a speaker. The use of microprocessors can be used to open doors and activate buzzers to sound warnings. However, to make it easier for residents to communicate with visitors, the system uses an instant messaging platform as a bridge.

This system enhances a traditional intercom with modern wireless technology, allowing residents to control entry into their home remotely via a smartphone. Since intercoms are often located outside or in building lobbies without wired network connections, this system uses a wireless transmission module for communication. Visitors interact with a touch panel similar to traditional intercoms, entering the floor number, which triggers the system to send their information to the resident.

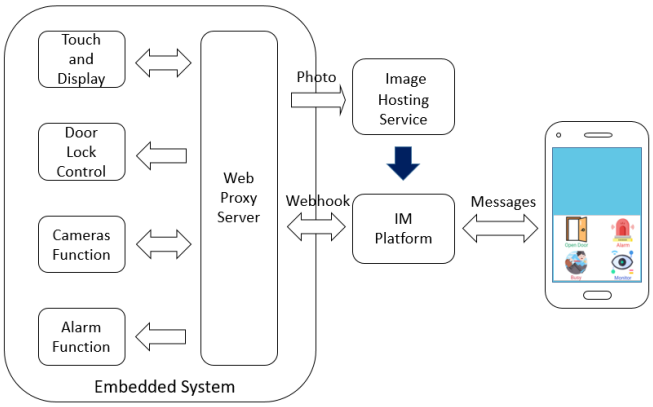
The resident receives a photo and messages from the visitor through an instant messaging app on their smartphone. The resident can choose to open the door, sound an alarm, or respond with a message. The visitor's photo is stored in the cloud and can be viewed anytime, allowing the resident to identify the visitor remotely, even when they're not home. If needed, the resident can request a live feed by pressing the "Watch" button.

For door security, the system uses a cathode lock, which requires an external power source to unlock. The embedded system doesn't provide enough power for the lock, so it uses a relay to control the door's opening and closing. If the resident notices suspicious activity, they can activate an alarm via the app, which triggers a buzzer to scare away potential intruders and alert neighbors.

Overall, the system improves security, convenience, and remote accessibility for residents.

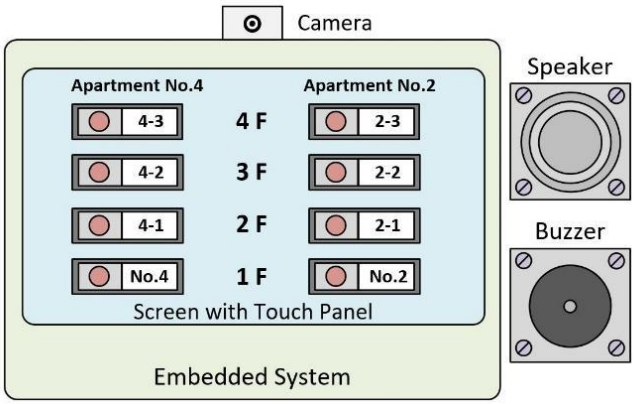
Software Framework:

The system integrates an embedded and instant messaging platform to develop various functions through the web services on the WoT. The embedded system is used as a host for the intercom and as a chatbot server for this system. The functionality of the instant messaging software on smartphones is designed through an instant messaging platform, and communication between the platform and the software takes place through messages. The embedded system and the instant messaging software platform collaborate through the webhook mechanism.

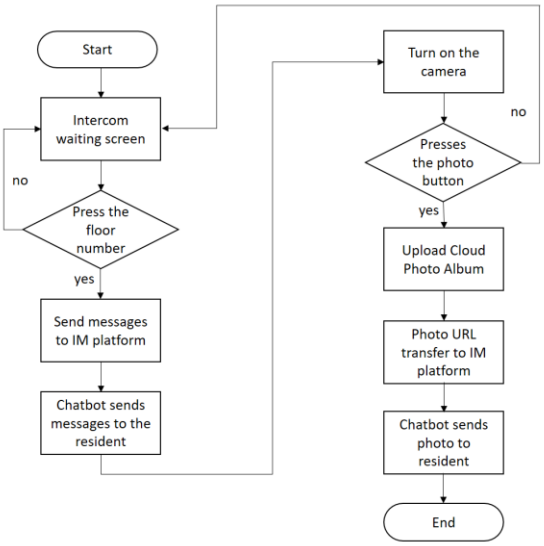


The developed functions of the embedded system use a common programming language that provides a touch and display function, a door lock control function, a camera function, and an alarm function. The system functions by integrating the embedded system's web proxy server and wireless network module with cloud services such as image hosting services and instant messaging platforms to provide web services for the residents and visitors. The embedded system provides visitors with an intercom interface that uses touch screens instead of the traditional pushbutton switches. Visitors click on the touch screen as if they were using a keyboard or a mouse, and the system is programmed to activate the relevant software functions in an event-driven manner. The system not only allows visitors to send messages and photos to the residents' smartphone instant messaging software after pressing the floor number.

Any apps on smartphones need to be installed before use. If written as a web application, there are concerns about information security, such as anonymous attacks on web pages. In this study, the instant messaging software already installed on the smartphone successfully integrates with the embedded system to control the WoT devices through the instant messaging platform, thus enhancing the smart control capability of the residents' smartphones without needing to install an app. The system uses web services as the integration interface, activates the webhook service in the channel of the instant messaging platform, and then integrates the embedded system's chatbot server to ensure the system's security. The system mainly uses the chatbot of the instant messaging platform and designs "Open Door", " Watch", "Alarm", and "Busy" menus for the resident to use by the instant messaging software of a smartphone. The proposed functional flow is described as follows.



Function Flow of the Intercom:



Function Flow of the Chatbot Service:

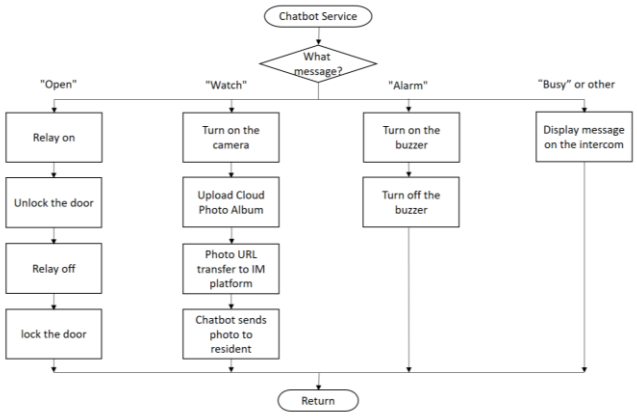
The resident can click on one of the "Open Door", "Watch", "Alarm", and "Busy" menus on the instant messaging software, and the system will perform the corresponding programming functions of the chatbot server through the instant messaging platform. These functions of the chatbot service are described as follows:

1. Door lock control function: when the chatbot server receives the "Open Door" message from the resident, the system can successfully drive the relay to control the door lock. The door can be locked automatically when the door is closed.
2. Camera function: when the chatbot server receives the "Watch" message from the resident, the system can drive

the camera to take pictures and send back the doorway photos to the resident in real time.

3. Alarm function: when the chatbot server receives the "Alarm" message, the buzzer can make a sound in time.
4. Touch and display function: when the chatbot server receives a "busy" or not reserved system message from the resident, the system can display the message directly on the touch screen of the intercom.

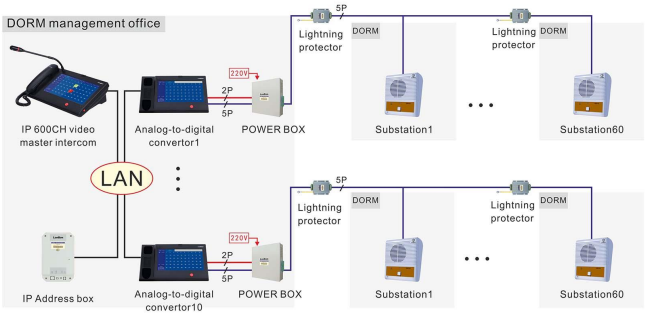
After executing the above actions, the chatbot service will return to a standby mode.



INDUSTRIAL APPLICATIONS

1. **Industrial Communication and Coordination:**

- Remote Monitoring and Control: Industrial intercom systems can be integrated with control systems to allow operators to communicate and monitor different areas of a plant or factory. This improves operational efficiency and enables workers to coordinate in real-time, especially in large-scale operations.
- **Factory Floor Communication:** Intercoms connect workers across noisy environments, allowing them to communicate effectively without having to leave their workstations.



2. **Safety and Emergency Situations:**

- Emergency Communication: In hazardous industries (like oil, gas, or manufacturing), intercom systems are used for rapid communication during emergencies, ensuring swift evacuation or alerting necessary personnel.
- Hands-Free Communication: Industrial intercoms often come with hands-free or voice-activated features, which are especially helpful for workers in environments where they can't easily manipulate devices, such as those wearing protective gear.

3. **Access Control and Security**

- **Gate Control and Entry Management:** Intercom systems are used to control access to industrial facilities, verifying personnel or vehicle entry to restricted areas.
- **CCTV Integration:** Some intercom systems integrate with security cameras to provide audio and visual identification at entry points. This is common in warehouses, power plants, and other high-security industrial facilities.

4. **IoT and Smart Industry Integration**

- **Automation and Process Control:** In modern industrial applications, intercom systems can be connected to the Internet of Things (IoT) platforms. This enables automated alerts and communication related to machine status, safety issues, or maintenance requirements.
- **Data Analytics:** With the integration of intercoms into IoT ecosystems, industries can collect communication data, analyze it, and optimize their operations based on patterns of communication and response times.

5. **Public Address Systems**

- **Broadcasting Announcements:** In large industrial complexes, intercom systems are used as public address systems for general announcements, shift changes, safety alerts, or important operational updates.

6. **Mining and Hazardous Environments**

- **Communication in Remote Locations:** In industries such as mining or oil drilling, where the operations are spread out across remote areas, intercoms are vital for maintaining communication between base stations and field workers, especially in hazardous or underground environments.
- **Explosion-Proof Intercoms:** Specialized intercom systems are used in environments where explosive gases or chemicals are present, ensuring safe and reliable communication without sparking hazards.

7. **Wireless Intercom Systems**

- **Flexibility in Mobile Operations:** Wireless intercoms are frequently used in industrial environments where workers are mobile, such as in logistics, shipping yards, or large

manufacturing plants. They provide flexibility and eliminate the need for extensive cabling infrastructure.

Implementation:

Hardware Implementation:

The system was constructed using hardware devices such as an embedded system, a touch panel, a camera, a relay, an electronic lock, and a buzzer. In addition, there is also a touch panel with a built-in speaker, and the electronic lock uses a cathode lock as the control of the lock. The prototype of the system hardware is assembled from the embedded system, the touch panel, and the camera components.

As the voltage of the GPIO (general-purpose input/output) pin of the embedded system is not sufficient to drive the door lock switch, this system therefore needs an external power supply provided to the door lock. The system uses relays to drive the door lock switch using the high and low levels of the relays that use small currents to control large currents. The 5 V output of the embedded system provides power to the relay. The IN pin of the relay is connected to the GPIO 4 of the embedded system, and a ground wire is connected to any ground pin of the embedded system. Next, the buzzer power supply is set in the GPIO 21 of the embedded system, and a ground wire is connected to any ground pin of the embedded system.
The power supply provides the power to the cathode lock, and the ground wire connects to the relay's COM pin and connects the cathode lock's positive terminal to the NO pin of the relay. After the prototype of the embedded system hardware is wired, it is necessary to download the IMG file obtained after decompression of the OS, import it to the SD card, and install the hardware version of the operating system to provide the deployment of the various functions of the system.

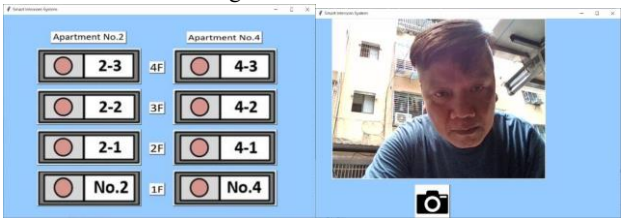
Software Deployment:

- Setup Image Hosting Service:

The image hosting service provides a new album function using OAuth 2 and does not require a callback URL. The site offers developers to store photos, and the client side obtains photos through the application using client ID and secret authentication.

- Setup Bot Function on the Channel of the Instant Messaging Platform:

The instant messaging platform allows the developer to create a channel and use the bot function. Implementation requires two securely linked channels to the resident's smartphone and the visitor's intercom through the webhook service.



- Setup Web Proxy Service:

Due to the embedded system's limited resources, to collaborate with the resident smartphone through the internet this system uses a lightweight and free web proxy server to connect the embedded system to the internet and provide web service capability. As shown in Figure 10, the web proxy service establishes a public address that translates to the local host port, through which it can connect to the chatbot server on the embedded system.

```
if event.message.text=="Open Door":
    message = TextSendMessage(text="The door already opened.")
    GPIO.output(4,GPIO.HIGH)
    line_bot_api.reply_message(event.reply_token, message)
    time.sleep(2)
    GPIO.output(4,GPIO.LOW)
```

- Software Operational Architecture:

The software's functional architecture is shown in Figure 11. This system has two main web services: an instant messaging platform and a chatbot server. The instant messaging platform provides a way for the instant messaging software on the resident's smartphone to communicate with the platform through messages. The instant messaging platform activates different bot services according to the messages from the residents and uses a webhook service to notify the

chatbot server on the embedded system and then executes the specific codes of the chatbot server to control devices in an event-driven manner. If a visitor presses a floor button, the chatbot server executes specific codes in an event-driven manner and triggers a webhook service to notify residents.

```
if event.message.text=="Alarm":
    GPIO.output(21,GPIO.HIGH)
    time.sleep(2)
    GPIO.output(21,GPIO.LOW)
```

Method	Sender	Receiver	Sending Method
Reply	bot	Sent message user	Chatbot passively replies to user messages
Push	bot	Specific users or groups	Chatbot proactive push

System Implementation and Results:

The standby screen of the system is shown in Figure 12a. When the visitor presses the floor number button, the system finds the user ID according to the floor number, runs the program of this system, and sends the system message to the resident's smartphone through messaging API.

Then, the system activates the camera to take a picture of the visitor, and the image is displayed on the system screen

After the visitor presses the make photo button, the system uploads the photo to the image hosting service website. It then notifies the chatbot server to run the program to obtain the visitor's photo and to send it to the resident according to the image URL. The resident receives a photo of the visitor, and then decides whether to open the door. The resident can click on one of the "Open Door", "Watch", "Alarm", and "Busy" menus on the instant messaging software. After the resident presses any of the buttons, the instant messaging platform will execute the program code that is mapped to the message.

The system has two separate channels in the implementation, each with a webhook URL corresponding to the chatbot function. The push function is a system that sends messages to the resident after the visitor presses the floor number. The callback function is used after the resident sends a message by the chatbot server to control a door lock, buzzer, or related device. When the instant messaging platform receives messages from residents who want to control door locks, buzzers, or related devices, it executes different messaging APIs based on different event messages. These messages are passed to the chatbot server of the embedded system through a webhook service that can determine the object and type of various messages and execute the codes to control each pin circuit of the embedded system to achieve the purpose of the set execution function.

The resident clicks the "Open" button when the instant messaging software sends a text message to the messaging API. The text message is then transmitted to the chatbot server through the instant messaging platform, and the event is triggered to execute a specific function according to the message. The system will give high power to the GPIO 4 pin to allow the relay to energize. The relay will trigger the door lock to open and then automatically disconnect after 5 s, and then, the door can be locked automatically When a resident clicks the "Alarm" button, the instant messaging software uses messaging API to send a text message through the messaging platform to the chatbot server to trigger an alert event and perform specific program functions based on the message. This alert event will control the GPIO 21-pin high power to activate the buzzer for 5 sec.

The future scope of intercom technology involves:

1. **AI-Powered Automation**: Smarter, more intuitive communication through AI, enabling personalized responses and voice recognition.
2. **IoT Integration**: Seamless control of smart homes and offices, connecting intercoms to various devices for enhanced convenience.
3. **Cloud-Based Systems**: Remote access, scalability, and data storage, offering greater flexibility for users and businesses.
4. **Enhanced Security**: Integration with facial recognition, video intercoms, and AI-driven security features.
5. **Mobile & 5G Connectivity**: App-based control and faster, more reliable communication through mobile devices and 5G networks.

Conclusion:

Mechanism behind Intercom Technology: Intercom systems use audio, video, or both to enable communication between two or more points. They rely on wired or wireless connections, transmitting signals via IP networks, radio waves, or analog circuits. Modern intercoms use microphones, speakers, cameras, and digital interfaces to facilitate real-time communication. IP-based intercoms connect over the internet, allowing for remote access and integration with other systems like smartphones or IoT devices.

Industrial Application & Conclusion: In industries, intercoms are used for **security**, **access control**, and **communication** across large facilities (factories, warehouses). They integrate with surveillance and alarm systems to enhance safety and operational efficiency. Modern intercoms in industries streamline communication, ensuring better **workforce coordination**, **monitoring**, and **emergency responses**. Their continued evolution will support smarter, connected industrial operations.

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