

## **FUNCTIONS OF EMBEDDED SYSTEMS:**

- **CONTROL FUNCTIONS**

- Embedded systems are frequently employed to oversee and manage the operation of other devices or systems. For instance, in the automotive domain, an embedded system is utilized in the engine control module of a car to oversee vital functions like fuel injection, ignition timing, and other engine parameters. This control function is crucial to ensure the proper functioning of the car's engine. By precisely regulating the fuel injection and ignition timing, the embedded system optimizes engine performance, enhances fuel efficiency, and reduces emissions. Similarly, in industrial systems like manufacturing and assembly lines, embedded systems play a significant role in governing and synchronizing the movement of robotic arms and conveyor belts. This enables precise control and coordination, leading to improved efficiency and productivity in industrial processes.

- **MONITORING FUNCTIONS**

- Embedded systems are capable of monitoring and collecting data from various devices or systems. For instance, in the context of a home security system, an embedded system is employed to constantly monitor the status of doors, windows, and detect any motion. This functionality is crucial for ensuring the safety and security of the system. By continuously monitoring the status of these entry points, the embedded system can promptly notify the homeowner of any unusual activities, such as open windows or potential break-ins. Moreover, embedded systems can gather data from diverse sources like temperature sensors and present it in a user-friendly format. This capability finds applications in various scenarios, such as monitoring room temperature, gas pipeline pressure, or building humidity.

- **COMMUNICATION FUNCTIONS**

- Advanced embedded systems have the capability to facilitate seamless communication between different devices or systems. For instance, smartphones employ embedded systems to establish internet connectivity and enable communication with various devices like wireless headsets. This functionality plays a crucial role in connecting devices/systems to each other and to the internet. In the case of smartphones, the embedded system empowers users to access a wide range of online services such as email, social media, and online shopping by providing internet connectivity. Additionally, the embedded system enables communication with other devices like wireless headsets, enabling hands-free phone calls. This versatile functionality is widely utilized in applications such as

connecting IoT devices, establishing and managing networked devices, and transmitting data to and from remote servers.

- DATA PROCESSING FUNCTIONS

- Embedded systems have the ability to perform data processing and analysis tasks as well. For instance, in a digital camera, an embedded system can process and compress the captured images, enabling the transformation of raw data into a more manageable and shareable format. This functionality is crucial for users to easily share images online or store them on various devices. Additionally, embedded systems can be utilized for data analysis purposes, such as examining sensor data to identify patterns or anomalies. This capability finds extensive applications in areas like image processing, signal processing, and data mining.

- ACTUATION FUNCTIONS

- Embedded systems are also employed for actuation purposes, which involves controlling the movement or position of mechanical systems. For instance, in a robotic arm, an embedded system can be utilized to govern and manipulate the arm's motion to interact with objects. This functionality plays a pivotal role in task automation and enables the realization of new capabilities. In the context of a robotic arm, the embedded system can be programmed to execute specific tasks like product assembly, welding, or painting. Actuation functions find widespread applications in industrial automation and robotics across various sectors, including manufacturing, agriculture, and construction.

- DISPLAY FUNCTIONS

- Embedded systems can also serve the purpose of information display, where they are utilized to present images, videos, and text on a screen. This functionality is crucial for delivering visual information to users. For instance, in digital signage, an embedded system can be employed to showcase advertisements, news, or other relevant content in public spaces. Display functions find extensive applications in various industries such as retail, transportation, and entertainment, where they play a significant role in conveying information to the target audience.

- POWER MANAGEMENT FUNCTIONS

- Embedded systems can also play a role in power management, which involves controlling and optimizing the power consumption of devices or systems. For instance, in a portable device, an embedded system can be utilized to efficiently manage the battery life and minimize power usage. This functionality is crucial for prolonging battery life and enhancing the energy efficiency of the device. In the

context of a portable device, the embedded system can reduce power consumption when the device is idle and optimize power usage during active operation. Power management functions are commonly employed in portable devices like smartphones and laptops, as well as in energy-efficient systems such as smart homes and buildings.

- **SAFETY FUNCTIONS**

- Embedded systems can also contribute to ensuring safety by monitoring the status of devices or systems and detecting potential safety risks. For instance, in an aircraft, an embedded system can be employed to constantly monitor the aircraft's condition and promptly identify any potential safety hazards. This functionality plays a vital role in maintaining the safe operation of the device or system.

To sum up, embedded systems are specialized computer systems integrated into various devices or products to fulfill specific functions. They can be applied in diverse areas such as control, monitoring, communication, data processing, and navigation. Embedded systems provide numerous advantages to both consumers and businesses, including enhanced efficiency, improved performance, increased convenience, enhanced security, and cost-effectiveness.

## **USES AND FUNCTIONS OF EMBEDDED SYSTEMS (APPLICATION)**

Embedded systems are used in a wide range of applications across various industries. They are often used to control and regulate other devices or systems. Some common uses of embedded systems include:

- ✓ **Consumer Electronics**

- Embedded systems power everyday devices such as smartphones, smart TVs, digital cameras, home appliances, and gaming consoles.
- There are countless examples like the one stated above such as printers, dishwashers, water dispensers, central cooling, and heating system, and whatnot! All of them are highly efficient and advanced, you only need to enter the instructions and the automated system takes care of the rest!

- ✓ **Automotive**

- Embedded systems control various functions in vehicles, including engine management, anti-lock braking systems (ABS), airbag deployment, entertainment systems, and navigation.
- The automotive industry has revolutionized itself by using embedded systems for introducing new concepts in the market.
- Modern-day cars use cruise control, airbags, emission control system, and navigation systems among many other functions, all having an embedded system which works synchronously with each other.
- Hybrid vehicles with higher efficiency and lesser pollution are a result of modern embedded systems otherwise the older versions were contributing to the world pollution on a large scale.
- Embedded systems have led to better engine control, the concepts such as brake-by-wire and drive-by-wire are the products of embedded systems.
- New safety systems such as Electronic Stability Control ESP, Traction control system TCS, Anti-lock Braking System ABS have been developed by using embedded systems.

#### ✓ **Industrial Automation**

- Embedded systems are employed in industrial machinery and equipment for tasks such as process control, monitoring, data acquisition, robotics, and factory automation.

#### ✓ **Medical Devices:**

- Embedded systems are crucial in medical devices like pacemakers, defibrillators, infusion pumps, patient monitoring systems, and diagnostic equipment.
- Embedded systems are used widely in the medical field, from manufacturing an artificial robotic limb to large-scale imaging techniques that are non-invasive in nature, embedded systems cover everything.
- Some of the imaging techniques involving embedded systems include MRI, PET scan, CT scan, SPECT scan, which are powered by industrial computers.
- Modern embedded electronic stethoscopes are also being used by high-budgeted hospitals in the developed countries.
- Embedded medical devices match the symptoms of patients with already existing files on the system to determine the disease, hence decreasing the workload of the physicians.
- Vital sign monitors and insulin pumps used in hospitals also imply embedded systems.

✓ **Aerospace and Defense**

- Embedded systems play a vital role in aerospace and defense applications, including aircraft control systems, avionics, radar systems, missile guidance, unmanned aerial vehicles (UAVs), and satellite systems.

✓ **Internet of Things (IoT)**

- Embedded systems are integral to IoT devices, enabling connectivity, data collection, and control in various domains, such as smart homes, smart cities, agriculture, healthcare, and wearables.

✓ **Telecommunications**

- Mobile embedded systems and network embedded systems are an ever-growing category of the embedded systems, all thanks to their sophisticated functionality and compact design manufacturing.
- Embedded systems are used in telecommunications equipment, including routers, switches, modems, network switches, and base stations for wireless communication.

✓ **Energy and Utilities**

- Embedded systems help monitor and control energy generation, distribution, and consumption in power plants, smart grids, renewable energy systems, and home energy management.

✓ **Motes**

- Motes are also called sensor nodes, and can gather and process sensory information, communicating that sensory information to the other parts or nodes of a Wireless Sensor Network.
- A Wireless Sensor Network is a dedicated system of sensors that detect and record changes in the environment, the data collected by these motes are sent to a central location via GPS.
- These motes help in detecting the changes in air pollution, humidity, air pressure, noise pollution, and other environmental conditions using the embedded system.

✓ **Avionics**

- Embedded systems didn't spare avionics at all, modern-day airplanes use modern navigation devices such as the inertial navigation system INS, which helps in calculating the orientation and velocity of a moving object without any external reference.

- Modern-day GPS systems have led to better air traffic and navigation control leading to greater security and satisfaction of the passengers. It has provided more safety and efficiency in flights, all thanks to embedded systems!
- ✓ **Transportation**
  - Embedded systems are found in transportation systems like traffic control systems, railway signaling, ticketing systems, fare collection, vehicle tracking, and fleet management.
- ✓ **Smart Cards**
  - Every other person who works today has a smart card, they are the new wallets and need of the hour as everyone cannot carry a hefty amount of cash in a wallet or a purse. A smart card is the ultimate source of convenience in many ways and has become the utmost necessity of everyone.
  - Smart cards have several types based on their purpose of use, but the manufacturing and design are relatively similar in all of them.
  - Smart cards are available in many forms nowadays and surprisingly they make use of embedded system technology as well.
- ✓ **Security Systems**
  - From the most primitive times human beings have been most concerned with their security, as time passed, Intruders found new ways of theft and robbery, this problem was solved by security systems including cameras and alarms which involve embedded systems.
  - Security cameras and large-scale security systems are designed using embedded systems, they are commonly used these days for protecting offices, homes, and banks as well.
  - Nowadays, Embedded System Security is another growing field, which is involved in the protection of embedded systems from cyber-attacks.
- ✓ **Banking**
  - The banking sector has also reaped many benefits of the technology involving the embedded systems.
  - ATM, automated teller machine, security systems used in banks, online transaction systems have embedded systems as their core elements.
  - A detailed account of the working of an ATM has been explained in one of my previous articles on the real-life examples of the embedded systems.
- ✓ **Robotics**

- Robots have replaced humans in many aspects with the entry of Artificial intelligence in the field, which has served as the cherry on top.
- Robotics involves embedded systems that are sophisticated enough to carry out complex tasks efficiently and precisely which cannot be carried out by humans in such a manner.

These are just a few examples, and embedded systems have a vast range of applications in almost every industry where real-time control, monitoring, and automation are required.