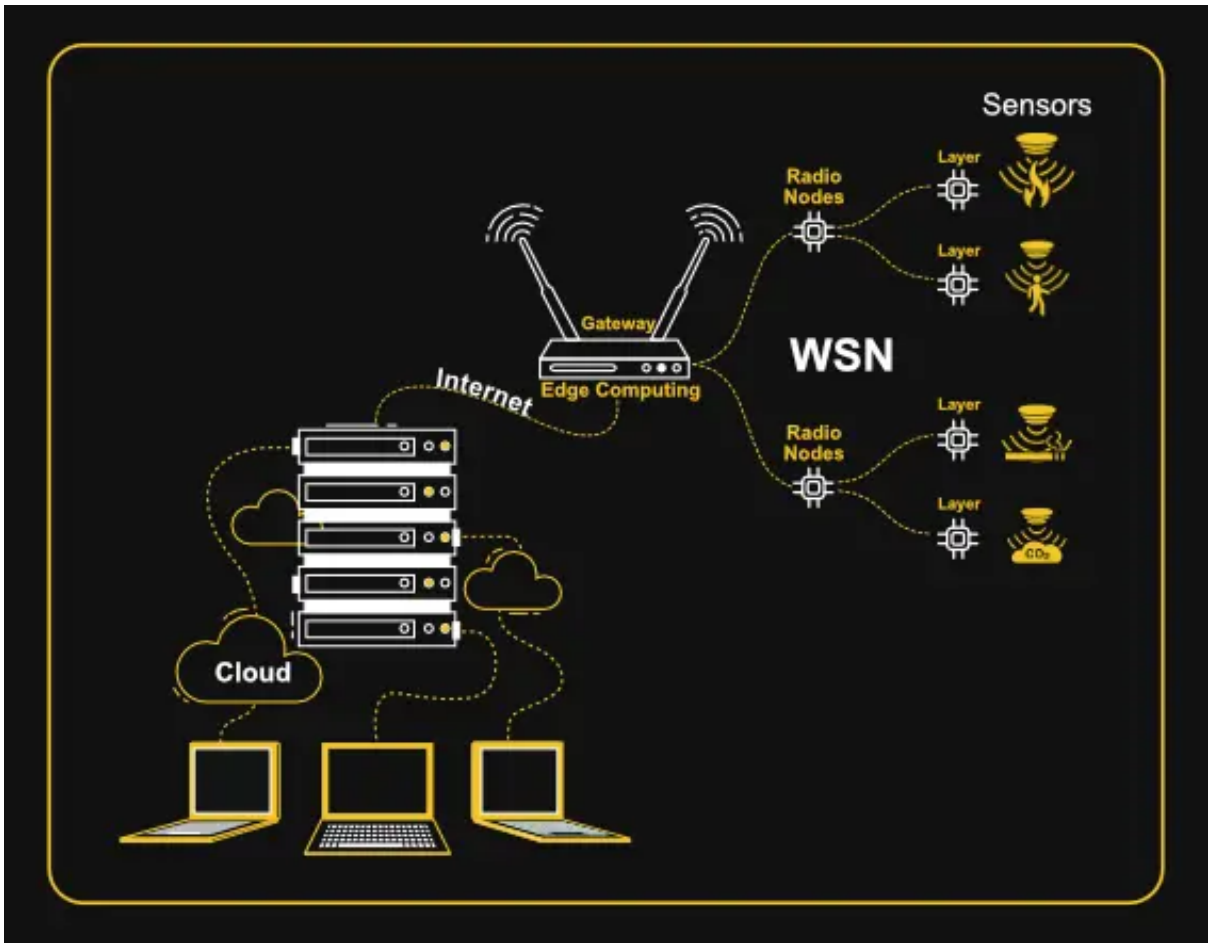
UNIT 2

Wireless Sensors Network

A Wireless Sensor Network (WSN) is a network of interconnected sensor nodes that communicate with each other wirelessly to collectively gather and transmit data from their surrounding environment. These sensor nodes are equipped with various types of sensors, processing capabilities, and wireless communication modules, allowing them to monitor, collect, and transmit data from different points in a physical space.



Components of WSN

- **Sensors:** Sensors in WSN are used to capture the environmental variables and which is used for data acquisition. Sensor signals are converted into electrical signals.
- **Radio Nodes:** It is used to receive the data produced by the Sensors and sends it to the WLAN access point. It consists of a microcontroller, transceiver, external memory, and power source.

- **WLAN Access Point:** It receives the data which is sent by the Radio nodes wirelessly, generally through the internet.
- **Evaluation Software:** The data received by the WLAN Access Point is processed by a software called as Evaluation Software for presenting the report to the users for further processing of the data which can be used for processing, analysis, storage, and mining of the data.

Advantages

- **Low cost:** WSNs consist of small, low-cost sensors that are easy to deploy, making them a cost-effective solution for many applications.
- **Wireless communication:** WSNs eliminate the need for wired connections, which can be costly and difficult to install. Wireless communication also enables flexible deployment and reconfiguration of the network.
- **Energy efficiency:** WSNs use low-power devices and protocols to conserve energy, enabling long-term operation without the need for frequent battery replacements.
- **Scalability:** WSNs can be scaled up or down easily by adding or removing sensors, making them suitable for a range of applications and environments.
- **Real-time monitoring:** WSNs enable real-time monitoring of physical phenomena in the environment, providing timely information for decision making and control.

Disadvantages

- **Limited range:** The range of wireless communication in WSNs is limited, which can be a challenge for large-scale deployments or in environments with obstacles that obstruct radio signals.
- **Limited processing power:** WSNs use low-power devices, which may have limited processing power and memory, making it difficult to perform complex computations or support advanced applications.
- **Data security:** WSNs are vulnerable to security threats, such as eavesdropping, tampering, and denial of service attacks, which can compromise the confidentiality, integrity, and availability of data.

- **Interference:** Wireless communication in WSNs can be susceptible to interference from other wireless devices or radio signals, which can degrade the quality of data transmission.
- **Deployment challenges:** Deploying WSNs can be challenging due to the need for proper sensor placement, power management, and network configuration, which can require significant time and resources.

Participatory Sensing

Participatory Sensing is an approach to data collection and interpretation in which individuals, acting alone or in groups, use their personal mobile devices and web services to explore interesting aspects of their worlds systematically—ranging from health to culture.

Que 2.13. What is Participatory Sensing (PS) ? Explain the phases of PS process.

Answer

1. Participatory sensing is the process whereby individuals and communities use mobile phones and cloud services to collect and analyse systematic data for use in discovery.
2. Sensing by the individuals and groups of people contributing sensors information to form a body of knowledge.
3. Applications of PS include retrieving information about weather, environment information, pollution, waste management, road faults, health of individuals and group of people, traffic congestion, urban mobility, etc.
4. Participatory sensing has many challenges such as security, privacy, reputation and ineffective incentives to participating entities.

Phases of a PS process :

1. Phase 1 is coordination phase, in which the participants of PS process organise after identifying the sources.
2. Next two phases, *i.e.*, phases 2 and 3 involve data capture, communication and storage on servers or cloud.
3. Next two phases *i.e.*, phase 4 and 5 involve PS data processing and analytics visualisation and knowledge discovery.
4. Last phase *i.e.*, phase 6 is for initiating appropriate actions.

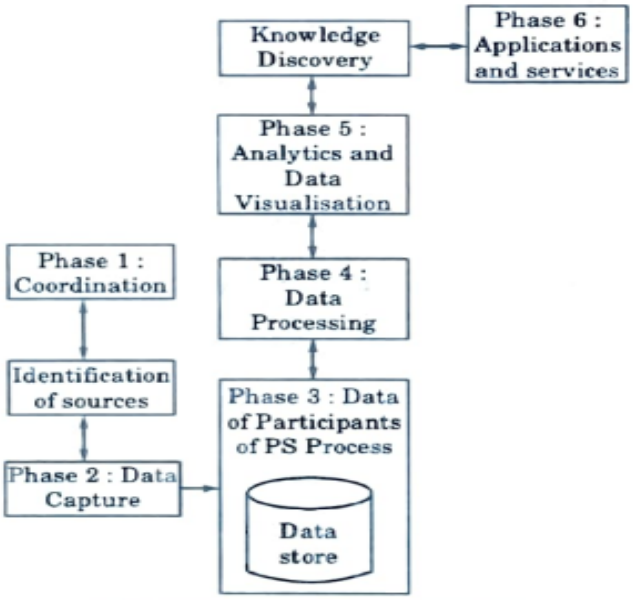


Fig. 2.13.1. Phases of PS process.

Six Phases PS process

• Phase 1 coordination, in which the participants of PS process organise after identifying the sources

• Phase 2 and 3 data capture, communication and storage on servers or cloud.

• Phases 4 and 5—PS data processing and analytics, visualization and knowledge discovery.

• Phase 6 is for initiating appropriate actions.

1. During the Coordination phase the participants need to either organize themselves, or be recruited by some other entity (e.g. city authorities) within the context of a sensing campaign, and the objective of the campaign needs to be communicated among all of them.
2. Then the participants spend some predetermined amount of time to capture (Capture phase) the desired sensing modalities using their mobile phone applications or custom designed applications for the sensing campaign.
3. The collected data are transferred (Transfer & Storage phase) to the data collection system through the phone connectivity options and stored in Internet servers (private or public). The data are then subject to

pre- processing (Process phase) so that the privacy of the data collectors i s preserved, and access control rules are added so that the data can be accessed anytime by only authorized individuals or services.

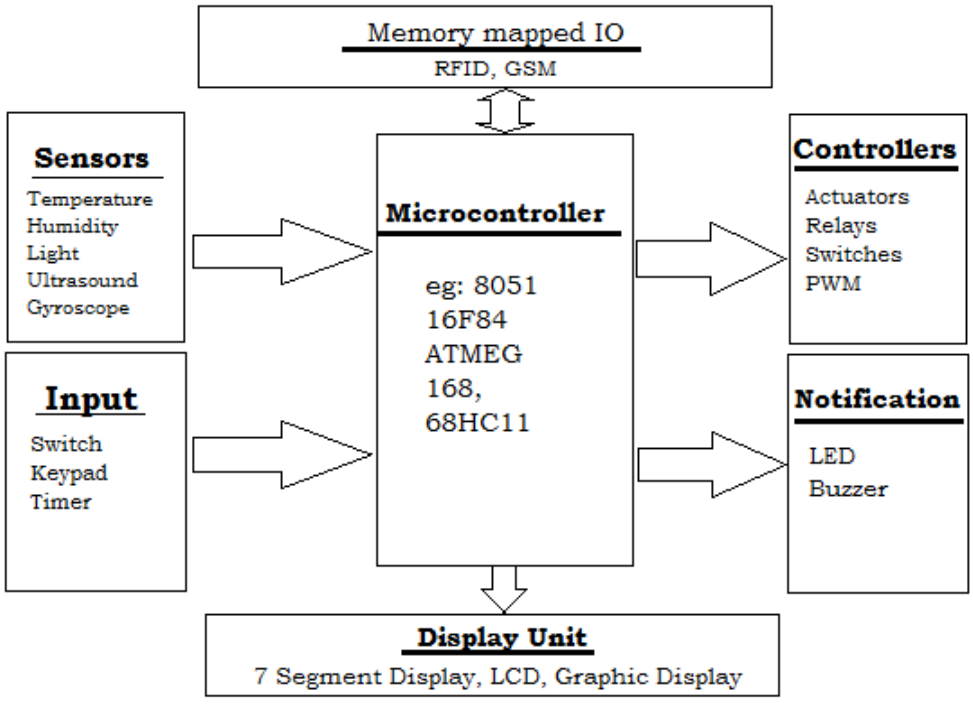
4. The collected data are analyzed by relevant analysis tools, aggregated(if possible), correlated with each other in order to detect patterns, and in the end visualized for better understanding for the target group of the campaign (Analysis and Visualization phase).
5. Last but not least, certain actions (Action phase) may be taken by individuals or city authorities

Applications of PS

- Retrieving information individual and group of people
- Weather, environment information, pollution
- Information for waste management, road faults
- Health, traffic congestion and urban mobility

Embedded Devices (System) in (IoT)

It is essential to know about the embedded devices while learning the IoT or building the projects on IoT. The embedded devices are the objects that build the unique computing system. These systems may or may not connect to the Internet.



Components of Embedded Systems

1. Hardware **2.** Software **3.** Firmware

Examples of Embedded Systems

- Digital watches
- Washing Machine
- Toys
- Televisions
- Digital phones
- Laser Printer
- Cameras
- Industrial machines
- Electronic Calculators
- Automobiles
- Medical Equipment

Application of Embedded System

- Home appliances
- Transportation
- Health care
- Business sector & offices
- Defense sector
- Aerospace
- Agricultural Sector

Characteristics of an Embedded System

- **Performs specific task:** Embedded systems perform some specific function or tasks.
- **Low Cost:** The price of an embedded system is not so expensive.
- **Time Specific:** It performs the tasks within a certain time frame.
- **Low Power:** Embedded Systems don’t require much power to operate.

- **High Efficiency:** The efficiency level of embedded systems is so high.
- **Minimal User interface:** These systems require less user interface and are easy to use.
- **Less Human intervention:** Embedded systems require no human intervention or very less human intervention.
- **Highly Stable:** Embedded systems do not change frequently mostly fixed maintaining stability.
- **High Reliability:** Embedded systems are reliable they perform tasks consistently well.
- **Use microprocessors or microcontrollers:** Embedded systems use microprocessors or microcontrollers to design and use limited memory.
- **Manufacturable:** The majority of embedded systems are compact and affordable to manufacture. They are based on the size and low complexity of the hardware.

Advantages of Embedded System

- Small size.
- Enhanced real-time performance.
- Easily customizable for a specific application.

Disadvantages of Embedded System

- High development cost.
- Time-consuming design process.
- As it is application-specific less market available.

Que 2.15. **Explain the basic concept of embedded system.**

Answer

1. Embedding means embedding function software into a computing hardware to enable a system function for the specific dedicated applications.
2. A device embeds software into the computing and communication hardware, and the device functions for the applications.
3. Embedded system consists of the following components :
   - **a. Embedded software :**
     - i. Software consists of instructions, commands and data.
     - ii. A computing and communicating device needs software.
   - **b. Bootloader :**
     - i. Bootloader is a program which runs at the start of a computing device, such as microcontroller unit (MCU).
     - ii. A bootloader initiates loading of system software (OS) when the system power is switched on, and power-on-self test completes.
     - iii. Bootloader may also facilitate the use of system hardware and networking capabilities.

c. **Operating system :**

i. An operating system facilitates the use of system hardware and networking, capabilities.

ii. When a load of the OS into RAM completes then the MCU starts the normal operational runtime environment.

iii. The OS enables memory allocation to different processes, and prioritizing of the processes enables the use of network hardware and device hardware functions and execution of software components and processes.

d. **Real-time operating system :**

i. Real-Time Operating System (RTOS) is an OS that enables real-time execution of processes on computing and communication hardware.

ii. RTOS uses prioritization and priories allocation concept to enable the execution of processes in real-time.

e. **Integrated development environment :**

i. Integrated development environment (IDE) is a set of software components and modules which provide the software and hardware environment for developing and prototyping.

ii. An IDE enables the codes development on a computer, and enables the codes to be executed on the hardware platform.

iii. IDE enables software that communicates with the internet web server or cloud server.

f. **Simulator :** It is software that enables development on the computer without any hardware, and then prototyping hardware can be connected for embedding the software and further tests.

g. **APIs :** Software consists of device Application Programming Interfaces (APIs) and device interface for communication over the network and communication circuit/port(s) which also includes a middleware.

h. **Device interfaces :** A connectivity interface consists of communication APIs, device interfaces and processing units.

Overview of IoT hardware platforms (Arduino, Raspberry Pi, etc.)

Arduino:

Arduino is an open-source electronics platform that is easy to use and is designed for beginners. It is based on a microcontroller and provides an environment for building and programming projects in a simple and intuitive way. The Arduino platform is widely used for building IoT projects because it is low-cost and has a vast community of developers. Arduino boards can be programmed using the Arduino IDE (Integrated Development Environment) which is available for Windows, Mac, and Linux.

There are many different types of Arduino boards available, but they all share the same basic features. They have digital and analog inputs and outputs, which allow them to interact with a wide range of sensors and actuators. They also have built-in communication protocols such as USB, UART, SPI, and I2C, which allow them to communicate with other devices.

Raspberry Pi:

Raspberry Pi is a low-cost, credit-card-sized computer that was designed for education and experimentation. It is based on an ARM processor and is capable of running a full-fledged operating system. Raspberry Pi boards are more powerful than Arduino boards and have more RAM and processing power. This makes them suitable for more complex IoT projects.

Like Arduino, Raspberry Pi has a large community of developers and enthusiasts, which makes it a popular choice for building IoT projects. Raspberry Pi boards can run a variety of operating systems including Raspbian, Ubuntu, and Windows 10 IoT Core. They can also be programmed using a variety of programming languages including Python, JavaScript, and C/C++.

Compared to Arduino, Raspberry Pi has more built-in connectivity options such as Ethernet, Wi-Fi, and Bluetooth. It also has a built-in HDMI output, which makes it easy to connect to a monitor or TV. These features make Raspberry Pi a popular choice for building IoT projects that require more connectivity options and graphics capabilities.

Which one to choose?

The choice between Arduino and Raspberry Pi depends on the specific requirements of your IoT project. If you are building a simple project that only requires basic sensing and actuation, then Arduino is a good choice. It is easy to use and is designed for beginners. On the other hand, if you are building a more complex project that requires more processing power and connectivity options, then Raspberry Pi is a better choice.

Que 2.17. | Describe Arduino platform for IoT. Also give its architecture.

Answer

1. Arduino boards modules and shields are popular AVR MCU-based products.
2. Each board has clear markings on the connection pins, sockets and in-circuit connections.
3. Arduino boards are easy to program. For example, Arduino Uno board is a robust as well as widely used board to get started with electronics and coding.
4. The analog input pins and PWM pins in the board can connect sensors, actuators and analog circuits.
5. The digital I/O pins can connect On-Off states, set of On-Off states, digital input forms sensors, digital outputs to actuators and other digital circuits.

Architecture of Arduino board :

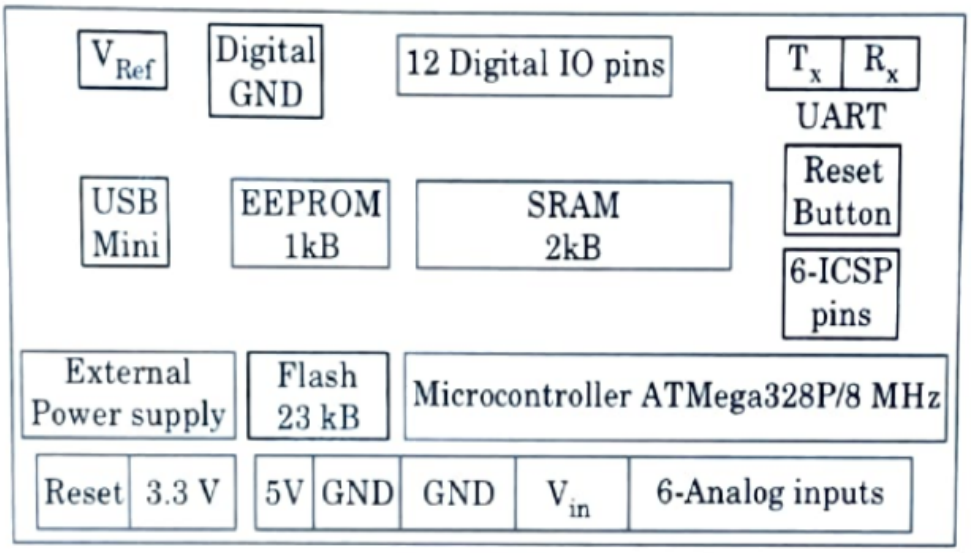


Fig. 2.17.1.

Que 2.19. **Write short note on Netduino.**

Answer

1. Netduino is an open-source electronics prototyping platform based on the .NET micro-framework.
2. It uses the ARM Cortex-M 32-bit RISC ARM processor core as a 32-bit ARM-microcontroller.
3. The Netduino boards are designed to be pin-compatible with most Arduino shields.
4. Applications can be built on Windows (with Visual Studio), or on Mac OS (with Xamarin Studio).
5. It is more powerful than Arduino platform.
6. Programming used to embed Netduino are written in C#(C sharp) which make it more powerful and use high-level language constructs.
7. Netduino board consist of 22 General Purpose Input/Output (GPIO) ports with 6 Pulse Width Modulation (PWM) hardware, 4 UARTs (serial communication), I2C, and SPI (Serial Peripheral Interface Bus) and 6 ADC channels.

Que 2.20. **Write short note on Raspberry Pi. Also give its architecture.**

Answer

1. Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse.
2. Its capable of doing everything we except from a desktop computer.
3. Most commonly used programming languages in Raspberry Pi are Python, C, C++, Java, Scratch and Ruby.
4. The Raspberry Pi includes hardware and software which provides high performance computing and graphics.
5. The basic set up for Raspberry Pi includes HDMI cable, monitor, keyboard, mouse, 5 volt power adapter for raspberry Pi, LAN cable, 2 GB micro SD card (minimum).

Architecture of Raspberry Pi board :

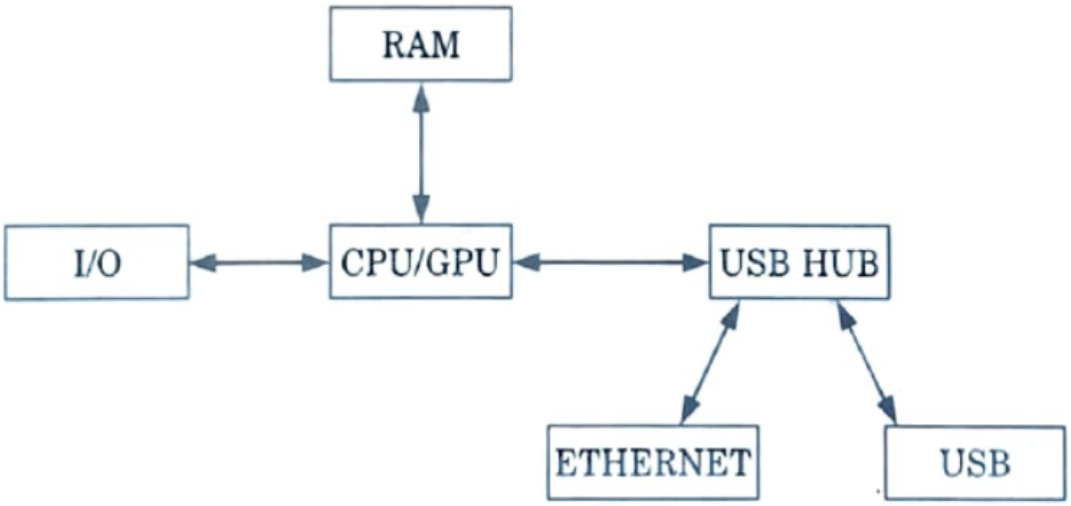


Fig. 2.20.1.

Que 2.21. What are the features that make Raspberry Pi board to be used widely ?

Answer

1. Computer-like prototyping easy for developing media server.
2. Coding in Python, C++ and the libraries.
3. Software runs on multiple environments, python, scratch, squeek, IDLE, C, Linux and BSD OSes, Windows 10 and several OSes with external keyboard and display monitor.
4. Flexibility and ease of connecting the hardware to external systems, connectivity of RPi takes place through two USB hosts hub and ethernet connector.
5. Connectivity to the extended memory through a micro SD slot.

Que 2.22. **Briefly describe BeagleBone board.**

Answer

1. BeagleBone X15 (BB-X15) is a single-board computer for computing and communication.
2. BB runs on the OS Linux, RSIX OS, FreeBSD, OpenBSD and additional distributions of Linux such as Ubuntu boards.
3. The SoC uses the processor (ARM Cortex A15 Core) and DSP processor (TMS320C64x plus multimedia 4 GB eMMC) for graphic and video.
4. The power required is 2W. Memory on-board is 2GB, plus in the memory support plus and microSD cards.
5. BB applications are for media, 2D and 3D graphics, and video servers.

Que 2.23. **Write the features of BeagleBone board.**

Answer

Features of BeagleBone board are :

1. Single-board computer and communication board.
2. Prototyping ease for media, graphics and video servers needing IoT applications.
3. IDEs for BB includes environment for code development in Python, Scratch, Squeek, Cloud9/Linux, C, Linux.
4. Programmability for number of times downloading of codes takes place through USB port during edit-test-debug cycles of development.
5. Flexibility and ease of connecting the extended memory and hardware connectivity board to external sockets for the 2-channel PCI peripheral connect interconnect express (PCIe) slot (which also functions and WiFi adapted), stereo audio, Ethernet x2 and micro SD slot.
6. Extended interfacing capabilities using 157 GPIO pins.

Que 2.24. **Write short note on Intel Galileo board.**

Answer

1. Intel Galileo boards are Arduino certified boards for development and prototyping.
2. A Galileo is based on the Intel Pentium architecture which includes features of single threaded single core and 400 MHz constant speed processor.
3. No separate graphic and video processors support is included in the board.

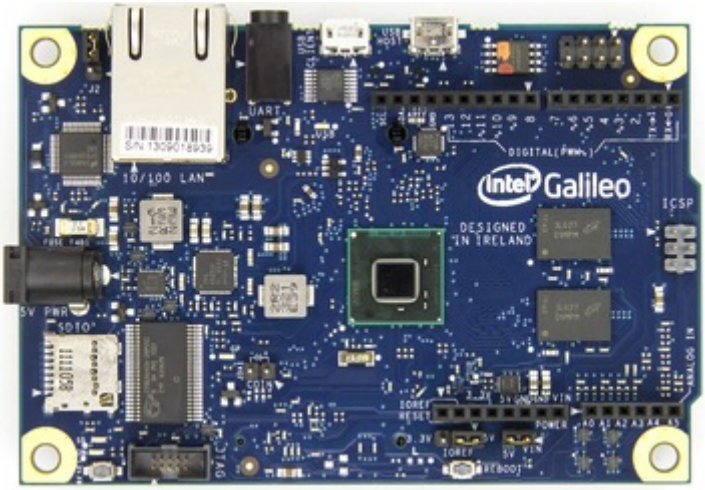
4. The Galileo is hardware and software pin-to-pin compatible with shields the designed for Arduino Uno R3 and Arduino IDEs.
5. Galileo additionally provides large 8 MB SPI flash to store firmware (Bootloader) and enables the users to incorporate Linux firmware calls in Arduino sketch programming.
6. Galileo supports a set of 30 sensors and accessories for Arduino.

Que 2.25. **What are the features that make Intel Galileo boards to be used widely ?**

Answer

Features of Galileo boards are :

1. It has single board computations and networking support.
2. IDE latest version and appropriate OS from open source.
3. IDE and software runs on multiple environments, Linux, Windows and Mac OS X.
4. Programmability number of times on downloading of codes through USB port, which enables the number of times download occurs during edit-test and debug cycles.
5. Flexibility and ease of connecting the extended memory and hardware connectivity board to external a full-sized mini-PCI Peripheral Connect Interconnect Express (PCIe) slot, Ethernet port socket, Micro-SD slot.
6. Extended interfacing capabilities using SPI.



Que 2.26. | **Write short notes on ARM cortex.**

Answer

1. The ARM Cortex-M is a group of 32-bit RISC ARM processor cores.
2. They are intended for microcontroller use, and have been shipped in tens of billions of devices.
3. The cores consist of the Cortex-M0, Cortex-M0+, Cortex-M1, Cortex-M3, Cortex-M4, Cortex-M7, Cortex-M23, Cortex-M33, Cortex-M35P.
4. The Cortex-M4 / M7 / M33 / M35P cores have an FPU silicon option, and when included in the silicon these cores are known as "Cortex-Mx with FPU" or "Cortex-MxF", where 'x' is the core number.
5. The ARM Cortex-M family is ARM microprocessor cores which are designed for use in microcontrollers, ASICs, ASSPs, FPGAs, and SoCs.
6. Cortex-M cores are commonly used as dedicated microcontroller chips, but also are "hidden" inside of SoC chips as power management controllers, I/O controllers, system controllers, touch screen controllers, smart battery controllers, and sensors controllers.