**A Mini Project Report On**

**A HAND GESTURE CONTROL ROBOT**

**ABSTRACT**

A hand gesture-controlled robot is an innovative system that allows users to control a robot’s movements through simple hand gestures, eliminating the need for traditional remote controllers. The system employs sensors like an accelerometer or gyroscope mounted on a glove or handheld device to detect the orientation and movement of the hand. These sensor signals are processed by a microcontroller, such as Arduino or ESP32, which interprets the gestures into specific commands for the robot. The commands are then transmitted via a **wired connection** to the robot, enabling it to move forward, backward, left, or right based on the user’s hand position. This gesture control provides a more natural and intuitive human-machine interface.

The robot can be employed in applications where manual control is risky, such as hazardous material handling or military operations. It also serves educational and research purposes in robotics and human-computer interaction studies. The system offers real-time response, smooth motion control, and adaptability for various robot platforms. This technology demonstrates the potential of combining sensors, embedded systems, and gesture recognition for smart automation. Overall, a hand gesture-controlled robot enhances operational efficiency and safety while offering an engaging user experience.

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**Department of Electronics & Communication Engineering**

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To emerge as a premier institute of high-quality professional graduates who can contribute to economic and social developments of the Nation.

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| **Mission** | **Statement** |
| **IM1** | To have holistic approach in curriculum and pedagogy through industry interface to meet the needs of global competency. |
| **IM2** | To develop student with knowledge, attitude, employability skills, entrepreneurship, research potential and professionally ethical citizens. |
| **IM3** | To contribute to advancement of engineering and technology that would help to satisfy societal needs |
| **IM4** | To preserve, promote cultural heritage, humanistic values and spiritual values thus helping in peace and harmony in the society. |

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To impart quality technical education in Electronics & Communication with accent on creativity, innovation and research thereby producing competent engineers who can meet global challenges with societal commitment.

**Mission of the Department**

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| **Mission** | **Statement** |
| **DM1** | To impart quality education to students in Basic Sciences, Mathematics, Electronics and communication Engineering through innovative teaching- learning process. |
| **DM2** | To facilitate students to define, design, and solve engineering problems in the field of Electronics and Communications Engineering using various Electronic Design Automation (EDA) tools. |
| **DM3** | To encourage research culture among faculty and students thereby facilitating them to be creative and innovative through constant interaction with R & D organizations and Industry. |
| **DM4** | To include qualities, professional ethics and social responsibilities in students and faculty |

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**Program Outcomes (POs)**

**PO1. Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

**PO2. Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO3. Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

**PO4. Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO5. Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

**PO6. The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8. Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions

**PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

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**Department of Electronics & Communication Engineering**

**Program Educational Objectives**

|  |  |
| --- | --- |
| PEO1 | Graduates with fundamental and advanced knowledge in Sciences, Mathematics and in Engineering Subjects of Electronics, Communication and allied Engineering to become globally competent with a flair for lifelong learning. |
| PEO2 | Graduates capable in design, develop creative and innovative technologies in the field of Electronics and Communication Engineering, enabling them to work in multi-disciplinary teams to meet the societal needs. |
| PEO3 | Graduates capable in design, develop creative and innovative technologies in the field of Electronics and Communication Engineering, enabling them to work in multi-disciplinary teams to meet the societal needs. |

** KOMMURI PRATAP REDDY INSTITUTE OF TECHNOLOGY**

**Department of Electronics & Communication Engineering**

|  |  |
| --- | --- |
| **PSO1** | **Technical Knowledge:** An ability to understand the concepts of basic Electronics & Communication Engineering and to apply them to various areas like Signal processing, VLSI, Embedded Systems, Digital & Analog Devices etc. |
| **PSO2** | **Software tool Usage:** An ability to solve complex Electronics & Communication Engineering problems, using latest hardware and software tools, along with analytical skills to arrive at cost effective and appropriate solutions. |
| **PSO3** | **Successful Career:** Wisdom of social and environmental awareness along with ethical responsibility to have a successful career and to sustain passion and zeal for real-world applications using optimal resources as an entrepreneur. |

**Program Specific Outcomes**

**CONTENTS**

**Certificate ii**

**Acknowledgement iii**

**Abstract iv**

1. **INTRODUCTION** 1

**2. LITERATURE SURVEY**  4

**3. EXISTING SYSTEM** 8

**4. PROPOSED SYSTEM**  9

**5. EMBEDDED SYSTEMS** 11

5.1 Embedded systems 11

5.1.1 History 12

5.1.2 Tools 13

5.1.3 Resources 13

5.1.4 Real time issues 14

5.2 Need for Embedded System 14

5.2.1 Debugging 15

5.2.2 Reliability 16

5.3 Explanation of Embedded System 17

5.3.1 Software Architecture 17

5.3.2 Stand-alone Embedded System 18

5.3.3 Real time Embedded System 19

5.3.4 Network Communication Embedded Systems 19

5.3.5 Different types of processing units 20

5.4 Applications of Embedded Systems 21

5.4.1 Consumer Applications 21

5.4.2 Office Automation 21

5.4.3 Industrial Automation 21

5.4.4 Computer Networking 22

5.4.5 Telecommunication 23

**6.HARDWARE DESCRIPTIONS** 24

6.1 Micro Controller 24

6.1.1 Introduction to Micro Controller 24

6.2 AVR Arduino Micro Controller 25

6.3 Crystal Oscillator 26

6.4 Architecture 27

6.5 Regulated Power Supply 39

6.5.1 Introduction 39

6.5.2 Block Diagram 39

6.6 LED 49

6.7 MEMS Sensor 51

6.7.1 Pin Description 54

**7. SIMULATION TOOLS** 59

7.1 Express PCB 59

7.1.1 Preparing Express PCB for first use 59

7.1.2 The Interface 60

7.1.3 Design Consideration 61

**8.CODE** 67

**9.CONCLUSION** 71

**10.REFERENCE** 72

**LIST OF FIGURES**

|  |  |  |
| --- | --- | --- |
| **S.NO** | **TITLE** | **PAGE.NO** |
| 1 | Block Diagram | 9 |
| 5.1 | Modern Example of Embedded Systems | 12 |
| 5.2 | Network Communication of Embedded Systems | 20 |
| 5.3 | Automatic Coffee Maker Equipment | 21 |
| 5.4 | Fax Machine | 21 |
| 5.5 | Printing Machine | 21 |
| 5.6 | Robot | 21 |
| 5.7 | Computer Networking | 21 |
| 5.8 | Cell Phone | 23 |
| 5.9 | Web Camera | 23 |
| 6.1 | Micro controller | 24 |
| 6.2 | Architecture | 24 |
| 6.3 | Arduino Development Board | 25 |
| 6.4 | Crystal Oscillator | 26 |
| 6.5 | AVR Architecture | 28 |
| 6.6 | Pin Diagram of ATMega328 | 35 |
| 6.7 | Pin Diagram of ATMega328 in Detail | 36 |
| 6.8 | Regulated Power Supply | 39 |
| 6.9 | Circuit Diagram of RPS with Led Connection | 40 |
| 6.10 | Step Down Transformer | 41 |
| 6.11 | Bridge Rectifier: A full Rectifier using 4-diodes | 44 |
| 6.12 | DB107 | 44 |
| 6.13 | Construction of a Capacitor | 45 |
| 6.14 | Electrolytic Capacitor | 45 |
| 6.15 | Voltage Regulated | 47 |
| 6.16 | Resistor | 47 |
| 6.17 | Color Bands in Resistor | 49 |
| 6.18 | Inside a LED | 50 |
| 6.19 | Parts of a LED | 50 |
| 6.20 | Electrical Symbol and Polarities of LED | 50 |
| 6.21 | MEMS sensor MMA7260Q | 51 |
| 6.22 | Pin Connections | 52 |
| 6.23 | Schematic Diagram of 3-axis Accelerometer module circuit | 53 |
| 6.24 | Accelerometer with Recommended Connection Diagram | 55 |
| 6.25 | Application Circuit for a 3-axis Accelerometer | 56 |
| 6.26 | Graph of X Axis | 57 |
| 6.27 | Graph of Y Axis | 57 |
| 6.28 | Graph of Z Axis | 58 |
| 7.1 | Toolbar Necessary for the Interface | 60 |
| 7.2 | Setting up the Arduino IDE Preference | 63 |
| 7.3 | Installing the ESP32 Board Package | 64 |
| 7.4 | Selecting the Correct Board | 64 |
| 7.5 | Opening an Example Sketch from the Preference Library | 65 |
| 7.6 | Uploading the Sketch Successfully to the ESP32 Board | 65 |
| 7.7 | Serial Terminal Window | 66 |

**CHAPTER 1**

**INTRODUCTION**

The increasing demand for automation, safety, and efficiency in modern industrial environments has led to a substantial interest in intelligent surveillance and control systems. Industries are continuously evolving towards adopting cutting-edge technologies that can monitor, detect, and respond to hazardous situations while minimizing human intervention. Industrial plants, manufacturing units, chemical factories, and high-risk zones require robust surveillance mechanisms and rapid action systems to ensure the safety of personnel, machinery, and infrastructure. Traditional monitoring systems have largely relied on manual supervision, wired communication systems, and basic sensor modules. However, such systems often suffer from limitations such as restricted area coverage, delayed response times, lack of remote accessibility, and increased operational costs. To overcome these challenges, the integration of microcontrollers, smart sensors, wireless communication, robotics, and Internet of Things (IoT) platforms offers a promising solution.

This project introduces an Arduino-based industrial surveillance and control system that combines multiple technologies into a unified framework for comprehensive safety management. The core of the system is an Arduino microcontroller, a versatile and open-source platform widely known for its ease of programming, affordability, and flexibility in interfacing with various peripheral devices. The Arduino serves as the main processing unit, acquiring data from multiple input sensors, processing the information, and controlling output devices accordingly. The system incorporates a MEMS (Micro-Electro-Mechanical Systems) sensor module, which is capable of detecting vibrations, tilt, and movement. MEMS sensors play a critical role in identifying mechanical disturbances, equipment malfunctions, or structural instabilities, allowing immediate preventive action to be taken before severe damage or accidents occur.

To enhance accessibility and control, the system integrates a Bluetooth module. Bluetooth communication offers a reliable, low-power, and short-range wireless interface that allows operators to connect their smartphones or computers directly to the system. Through Bluetooth, users can view sensor readings, send control commands, and receive alerts without the need for physical interaction with the equipment. This feature significantly improves operator convenience, especially in scenarios where immediate on-site access is impractical or unsafe. Additionally, the inclusion of a robotic unit adds a dynamic and autonomous element to the surveillance process. The robot can be controlled remotely to navigate hazardous or restricted areas, gather environmental data, inspect equipment conditions, and even perform specific intervention tasks such as moving objects or extinguishing small fires. Robotics enhances the mobility and flexibility of the surveillance system, ensuring comprehensive coverage of the industrial site.

An LCD display is interfaced with the Arduino to provide a real-time visual representation of system parameters and sensor data. The LCD acts as a local monitoring terminal, displaying vital information such as vibration levels, system status, Bluetooth connectivity, and alerts. Operators can quickly assess the condition of the system through the LCD without requiring external devices. For wider accessibility and control beyond local proximity, the system incorporates IoT capabilities. By connecting the Arduino to an IoT platform, sensor data can be uploaded to cloud servers, where authorized users can monitor and control the system from anywhere via web or mobile applications. IoT integration not only enhances remote accessibility but also enables long-term data storage, trend analysis, predictive maintenance, and automated reporting. This holistic approach empowers industry managers to make informed decisions, optimize operations, and improve safety compliance.

Power management is a crucial aspect of any embedded system, especially in industrial environments where power fluctuations or interruptions are common. The system employs a regulated power supply unit that ensures stable voltage and current levels to all components. A regulated supply prevents potential damage caused by over-voltage or under-voltage conditions, ensuring consistent and reliable operation. The modular design of the proposed system allows for scalability and customization. Additional sensors, actuators, or communication modules can be integrated into the framework depending on the specific requirements of the industrial site. For example, gas sensors, fire detectors, RFID readers, or Wi-Fi modules can be added to enhance functionality further.

The proposed Arduino-based industrial surveillance and control system addresses several limitations of traditional systems. It minimizes human dependency by automating monitoring and response actions, improves response time to critical situations, reduces operational costs through wireless communication, and enhances data accessibility through IoT integration. The use of low-cost and widely available components such as Arduino, MEMS sensors, and Bluetooth modules makes the system economically feasible for deployment even in small and medium-sized enterprises. Furthermore, the system supports environmental sustainability by optimizing resource utilization, reducing energy wastage, and enabling predictive maintenance that extends the lifespan of industrial machinery.

In real-world applications, the system can be employed in various industries including manufacturing plants, chemical processing facilities, oil and gas refineries, warehouses, mines, and construction sites. In manufacturing units, the system can monitor machinery vibrations to predict equipment failure, track material handling robots, and provide real-time alerts in case of anomalies. In chemical plants, MEMS sensors can detect vibrations that indicate pipeline leaks or structural weaknesses, while the robot can inspect hazardous zones where human entry is unsafe. Warehouses can use the system for inventory monitoring, safety surveillance, and remote control of ventilation or lighting systems.

By harnessing the synergy of embedded systems, sensors, robotics, wireless communication, and IoT, the project demonstrates a forward-looking approach towards smart industrial management. The Arduino-based architecture simplifies system design, development, and maintenance, ensuring that the system remains user-friendly, cost-effective, and scalable for future expansions. With increasing awareness about industrial safety regulations, worker welfare, and operational efficiency, the implementation of intelligent surveillance and control systems such as the one proposed in this project is poised to become a standard practice in modern industries. The project not only contributes to technological advancement but also aligns with global initiatives promoting smart manufacturing, Industry 4.0, and digital transformation in the industrial sector.

Overall, the integration of MEMS sensors, Bluetooth communication, robotic automation, LCD display, and IoT connectivity into a single Arduino-based platform offers a robust, reliable, and intelligent solution to address the growing demands of industrial surveillance and control. The system empowers industries to proactively monitor their operations, ensure safety compliance, and optimize performance through data-driven insights and automated interventions. This project demonstrates the potential of embedded systems and IoT technologies to revolutionize industrial environments, paving the way for safer, smarter, and more efficient industrial ecosystems.

**CHAPTER 2**

**LITERATURTE SURVEY**

1. **R. S. Hegde and K. R. Bhat (2018)**  
   Design and implementation of smart industrial safety monitoring using IoT. This paper focused on using IoT-based sensors for detecting gas, fire, and abnormal conditions in industrial zones.
2. **A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash (2015)**  
   Internet of Things: A survey on enabling technologies, protocols, and applications. The paper presented comprehensive IoT applications in smart industries and surveillance.
3. **P. R. Suresh, J. V. George, V. P. Mohan, and D. Sujatha (2014)**  
   A smart sensor network for industrial environment monitoring. They implemented sensor networks to monitor toxic gases and temperature in industries.
4. **S. Yadav and A. Sharma (2019)**  
   IoT based Industrial automation system using Arduino and cloud platform. This study demonstrated data acquisition through Arduino and control via IoT dashboards.
5. **M. S. Hossain and G. Muhammad (2016)**  
   Cloud-assisted Industrial Internet of Things (IIoT). The paper discussed how cloud-based analytics improve industrial monitoring and decision-making.
6. **N. A. Zainudin, M. R. Mahadi, and M. I. Saripan (2017)**  
   Smart surveillance robot for hazardous environment using Arduino and wireless communication. This paper designed a robot for hazardous area inspection and surveillance.
7. **C. K. Das, M. Sanaullah, and H. M. G. Sarower (2013)**  
   Development of a cell phone-based remote control system: An effective switching device for controlling industrial loads. They discussed GSM-based control of industrial equipment.
8. **J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami (2013)**  
   Internet of Things (IoT): A vision, architectural elements, and future directions. This highly cited paper outlined IoT systems and their industrial applications.
9. **S. Ehsan and B. Hamdaoui (2012)**  
   A survey on energy-efficient routing techniques with QoS assurances for wireless multimedia sensor networks. Relevant to sensor network optimization for industrial use.
10. **M. Kumar and K. S. Kumar (2020)**  
    Industrial automation using IoT and Arduino. The paper highlighted low-cost industrial automation techniques using Arduino, sensors, and IoT dashboards.
11. **R. Sundaram and A. Baskaran (2016)**  
    Intelligent industrial monitoring and controlling system using wireless sensor networks. They implemented real-time sensor monitoring using ZigBee and microcontrollers.
12. **R. Piyare and M. Tazil (2011)**  
    Bluetooth-based home automation system using cell phone. Early application of Bluetooth modules (HC-05) for wireless control applicable to industries.
13. **N. Sriskanthan and T. Karand (2002)**  
    Bluetooth-based home automation system. The paper presented a reliable Bluetooth communication protocol useful for small-scale control systems.
14. **A. Ghosh and S. K. Das (2017)**  
    A framework for deploying smart industrial monitoring system using wireless sensor networks and cloud computing. Combined cloud storage with real-time data capture.
15. **K. A. Vasantha, S. Valliappan, and A. S. A. Kumar (2019)**  
    IoT enabled smart industry management system using Raspberry Pi and sensors. Demonstrated monitoring of temperature, gas, and vibration data.
16. **S. Deepa and P. Devi (2018)**  
    IoT based industrial monitoring system using wireless sensor network and Raspberry Pi. They emphasized wireless data acquisition and remote visualization.
17. **P. C. Pinto, L. B. Almeida, and J. A. T. Machado (2012)**  
    Industrial control and automation using wireless sensor networks. Discussed reliability and deployment of sensor networks in industrial applications.
18. **T. S. Gunawan, M. Kartiwi, and A. Suryani (2015)**  
    Remote monitoring of temperature and humidity using IoT platform. The system demonstrated DHT11 sensor usage integrated with cloud platforms.
19. **S. Patel and A. Bhatt (2016)**  
    Industrial robot control using wireless communication. They developed a robot prototype controlled by Bluetooth for industrial applications.
20. **S. R. Gawande and R. R. Mudholkar (2016)**  
    Industrial surveillance and security using wireless sensor network. Demonstrated how WSN can be used for monitoring safety-critical industrial areas.
21. **D. B. Rawat and C. Bajracharya (2015)**  
    Cyber security for industrial control systems: A survey. Discussed the importance of securing IoT and wireless communications in industrial systems.
22. **S. Mittal and M. P. Singh (2019)**  
    Bluetooth based wireless industrial automation system using Arduino. Showed a system for controlling motors and relays via smartphone Bluetooth apps.
23. **A. G. Rajesh and C. Shoba (2019)**  
    Wireless surveillance robot using Arduino and Android application. Their robot could navigate and transmit real-time data for inspection tasks.
24. **P. S. Prasad, V. K. Reddy, and R. P. Kumari (2017)**  
    Industrial automation using IoT and embedded system. The authors proposed monitoring of temperature, humidity, and gas using embedded platforms.
25. **R. G. Smith and T. M. Johnson (2020)**  
    MEMS sensor integration for machine health monitoring. This paper showed how MEMS sensors detect vibrations and early signs of mechanical failure.
26. **S. B. Patil and P. V. Mane (2016)**  
    Smart industry management system using wireless sensor network. Focused on real-time status monitoring and anomaly detection.
27. **N. Mahalik and S. N. Patra (2006)**  
    Trends in industrial automation systems. The paper reviewed various technologies including sensors, embedded systems, and communications.
28. **M. H. Yassein, M. Q. Shatnawi, and B. A. Jararweh (2017)**  
    Industrial Internet of Things survey and open research issues. A survey of IIoT challenges and opportunities for intelligent manufacturing.
29. **M. V. Ramesh and S. Murthy (2011)**  
    Wireless sensor network-based industrial fire detection and control system. Early application of sensor networks in fire safety systems.
30. **V. H. Dange and V. J. Gadre (2020)**  
    Bluetooth enabled IoT system for smart industrial monitoring. Demonstrated combining Bluetooth and IoT for flexible industrial surveillance.

**CHAPTER 3**

**EXISTING SYSTEMS**

In conventional robot control systems, operation is primarily managed through remote controllers such as joysticks, switches, or handheld devices. These interfaces require the user to maintain constant attention and proximity to the control station, making them less convenient for dynamic or fast-paced environments. Additionally, many industrial and research robots are controlled using pre-programmed instructions written in specific programming languages. This approach, while reliable for repetitive tasks, lacks real-time adaptability and demands a certain level of technical expertise from the operator.

User interaction in such systems is limited, often involving button-based commands that do not offer intuitive control or feedback. Communication between the controller and robot is usually established through wireless modules like RF, IR, or Bluetooth, which can be affected by signal interference, range limitations, or latency issues. Furthermore, these systems often depend on a second person to assist with monitoring, safety, or operation—particularly in environments where robots perform critical or hazardous tasks. Overall, existing systems are functional but lack the seamless, natural interaction and autonomy that modern applications increasingly demand.

Transmitting Signal

ROBOT

Joystick /Hand held device

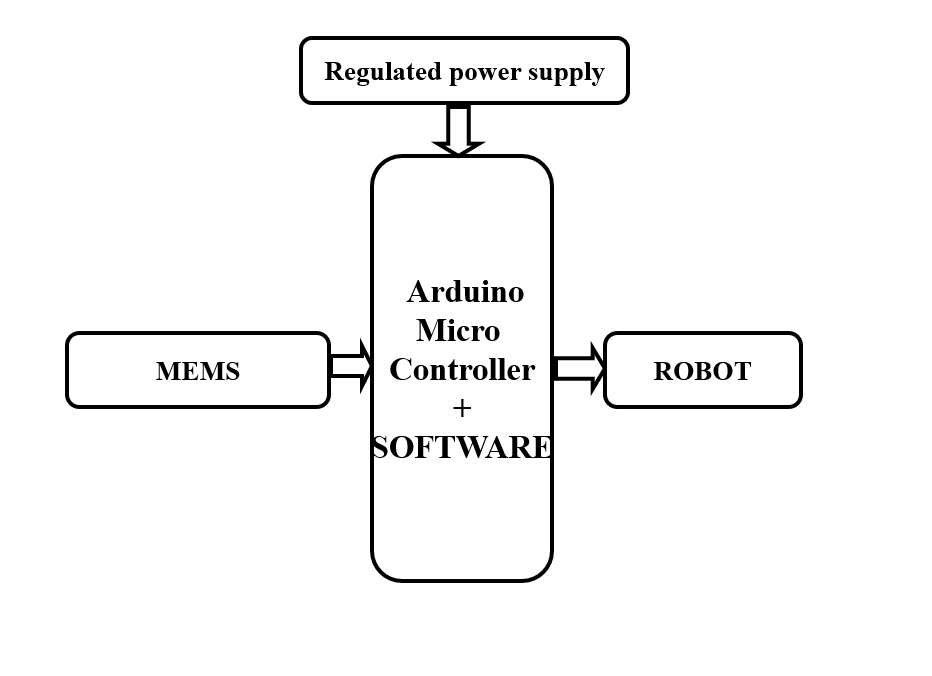
Received Signal

**CHAPTER 4**

**PROPOSED SYSTEMS**

The proposed system introduces a wired hand gesture-controlled robot that enhances user interaction by allowing intuitive and direct control through simple hand movements. It eliminates the need for traditional remote controllers and an additional operator by integrating a MEMS (Micro-Electro-Mechanical Systems) sensor such as an accelerometer or gyroscope to detect hand gestures. These sensors are embedded into a glove or held device worn by the user and are capable of accurately tracking the orientation, tilt, and motion of the hand. The sensor data is transmitted in real-time to a microcontroller, such as Arduino or ESP32, which processes the input and interprets specific gestures into directional commands (e.g., forward, backward, left, right).

Unlike wireless systems, this design uses a **wired connection** between the microcontroller and the robot, ensuring reliable data transmission without interference, latency, or power fluctuations commonly seen in RF or Bluetooth-based systems. This approach enhances the stability and precision of robot movement, making it highly suitable for applications that require accuracy and consistent performance, such as controlled environments, education labs, and prototype demonstrations. Furthermore, the system significantly reduces the learning curve for users, making robotic control more accessible even to non-technical individuals.



**FIG 1: BLOCK DIAGRAM**

**Explanation of Block Diagram for Hand Gesture Controlled Robot:**

The block diagram of the Hand Gesture Controlled Robot consists of two main sections: the transmitter (gesture capturing unit) and the receiver (robot control unit).

On the transmitter side, a camera module (such as a webcam or ESP32-CAM) captures real-time images or video of the user's hand gestures. The captured frames are processed by a gesture recognition algorithm implemented using OpenCV, MediaPipe, or a machine learning model that detects specific hand patterns like forward, backward, left, right, or stop. After recognizing the gesture, the corresponding command signal is generated and sent wirelessly using communication modules such as ESP-NOW or Wi-Fi via ESP32.

On the receiver side, another ESP32 or microcontroller receives the transmitted command and interprets the instruction. These commands are further fed into the motor driver circuit (like L298N) that controls the DC motors or servo motors of the robot. Based on the command, the motors rotate in specific directions to move the robot forward, backward, left, right, or halt. Additionally, a power supply module is provided to energize both the microcontroller and motor driver units.

Optional modules such as an LCD display can be attached to show the received gesture command, and buzzer indicators can notify command acknowledgment or warnings, ensuring better interaction between the user and the robot. This structure enables seamless, wireless, and touchless robot control via simple hand movements.

**CHAPTER 5**

**EMBEDDED SYSTEMS**

**5.1 Embedded Systems:**

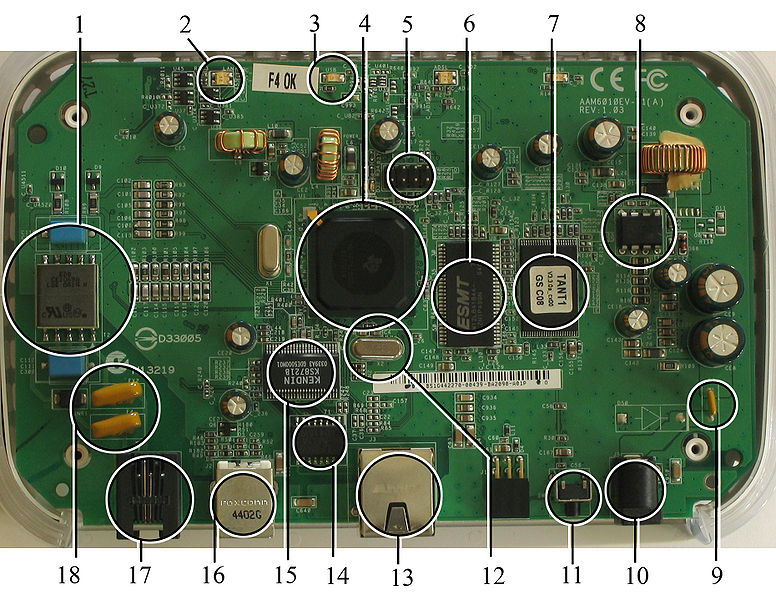
An embedded system is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today.

Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. For example, air traffic control systems may usefully be viewed as embedded, even though they involve mainframe computers and dedicated regional and national networks between airports and radar sites. (Each radar probably includes one or more embedded systems of its own.)

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Physically embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

In general, "embedded system" is not a strictly definable term, as most systems have some element of extensibility or programmability. For example, handheld computers share some elements with embedded systems such as the operating systems and microprocessors which power them, but they allow different applications to be loaded and peripherals to be connected. Moreover, even systems which don't expose programmability as a primary feature generally need to support software updates. On a continuum from "general purpose" to "embedded", large application systems will have subcomponents at most points even if the system as a whole is "designed to perform one or a few dedicated functions", and is thus appropriate to call "embedded". A modern example of embedded system is shown in fig: 2.1.



**Fig 5.1: A modern example of embedded system**

Labeled parts include microprocessor (4), RAM (6), flash memory (7).Embedded systems programming is not like normal PC programming. In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost millions. Hiring a programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

**5.1.1 History:**

In the earliest years of computers in the 1930–40s, computers were sometimes dedicated to a single task, but were far too large and expensive for most kinds of tasks performed by embedded computers of today. Over time however, the concept of [programmable controllers](http://en.wikipedia.org/wiki/Programmable_controllers) evolved from traditional [electromechanical](http://en.wikipedia.org/wiki/Electromechanical) sequencers, via solid state devices, to the use of computer technology.

One of the first recognizably modern embedded systems was the [Apollo Guidance Computer](http://en.wikipedia.org/wiki/Apollo_Guidance_Computer), developed by [Charles Stark Draper](http://en.wikipedia.org/wiki/Charles_Stark_Draper) at the MIT Instrumentation Laboratory. At the project's inception, the Apollo guidance computer was considered the riskiest item in the Apollo project as it employed the then newly developed monolithic integrated circuits to reduce the size and weight. An early mass-produced embedded system was the Autonetics D-17 guidance computer for the [Minuteman missile](http://en.wikipedia.org/wiki/Minuteman_(missile)), released in 1961. It was built from [transistor](http://en.wikipedia.org/wiki/Transistor) [logic](http://en.wikipedia.org/wiki/Digital_circuit) and had a [hard disk](http://en.wikipedia.org/wiki/Hard_disk) for main memory. When the Minuteman II went into production in 1966, the D-17 was replaced with a new computer that was the first high-volume use of integrated circuits.

**5.1.2 Tools:**

Embedded development makes up a small fraction of total programming. There's also a large number of embedded architectures, unlike the PC world where 1 instruction set rules, and the Unix world where there's only 3 or 4 major ones. This means that the tools are more expensive. It also means that they're lowering featured, and less developed. On a major embedded project, at some point you will almost always find a compiler bug of some sort.

Debugging tools are another issue. Since you can't always run general programs on your embedded processor, you can't always run a debugger on it. This makes fixing your program difficult. Special hardware such as JTAG ports can overcome this issue in part. However, if you stop on a breakpoint when your system is controlling real world hardware (such as a motor), permanent equipment damage can occur. As a result, people doing embedded programming quickly become masters at using serial IO channels and error message style debugging.

**5.1.3 Resources:**

To save costs, embedded systems frequently have the cheapest processors that can do the job. This means your programs need to be written as efficiently as possible. When dealing with large data sets, issues like memory cache misses that never matter in PC programming can hurt you. Luckily, this won't happen too often- use reasonably efficient algorithms to start, and optimize only when necessary. Of course, normal profilers won't work well, due to the same reason debuggers don't work well.

Memory is also an issue. For the same cost savings reasons, embedded systems usually have the least memory they can get away with. That means their algorithms must be memory efficient (unlike in PC programs, you will frequently sacrifice processor time for memory, rather than the reverse). It also means you can't afford to leak memory. Embedded applications generally use deterministic memory techniques and avoid the default "new" and "malloc" functions, so that leaks can be found and eliminated more easily. Other resources programmers expect may not even exist. For example, most embedded processors do not have hardware FPUs (Floating-Point Processing Unit). These resources either need to be emulated in software, or avoided altogether.

**5.1.4 Real Time Issues:**

Embedded systems frequently control hardware, and must be able to respond to them in real time. Failure to do so could cause inaccuracy in measurements, or even damage hardware such as motors. This is made even more difficult by the lack of resources available. Almost all embedded systems need to be able to prioritize some tasks over others, and to be able to put off/skip low priority tasks such as UI in favor of high priority tasks like hardware control.

**5.2 Need For Embedded Systems:**

The uses of embedded systems are virtually limitless, because every day new products are introduced to the market that utilizes embedded computers in novel ways. In recent years, hardware such as microprocessors, microcontrollers, and FPGA chips have become much cheaper. So when implementing a new form of control, it's wiser to just buy the generic chip and write your own custom software for it. Producing a custom-made chip to handle a particular task or set of tasks costs far more time and money. Many embedded computers even come with extensive libraries, so that "writing your own software" becomes a very trivial task indeed. From an implementation viewpoint, there is a major difference between a computer and an embedded system. Embedded systems are often required to provide Real-Time response. The main elements that make embedded systems unique are its reliability and ease in debugging.

**5.2.1 Debugging:**

Embedded debugging may be performed at different levels, depending on the facilities available. From simplest to most sophisticate they can be roughly grouped into the following areas:

* Interactive resident debugging, using the simple shell provided by the embedded operating system (e.g. Forth and Basic)
* External debugging using logging or serial port output to trace operation using either a monitor in flash or using a debug server like the Remedy Debugger which even works for heterogeneous multi core systems.
* An in-circuit debugger (ICD), a hardware device that connects to the microprocessor via a JTAG or Nexus interface. This allows the operation of the microprocessor to be controlled externally, but is typically restricted to specific debugging capabilities in the processor.
* An in-circuit emulator replaces the microprocessor with a simulated equivalent, providing full control over all aspects of the microprocessor.
* A complete emulator provides a simulation of all aspects of the hardware, allowing all of it to be controlled and modified and allowing debugging on a normal PC.
* Unless restricted to external debugging, the programmer can typically load and run software through the tools, view the code running in the processor, and start or stop its operation. The view of the code may be as assembly code or source-code.

Because an embedded system is often composed of a wide variety of elements, the debugging strategy may vary. For instance, debugging a software (and microprocessor) centric embedded system is different from debugging an embedded system where most of the processing is performed by peripherals (DSP, FPGA, co-processor). An increasing number of embedded systems today use more than one single processor core. A common problem with multi-core development is the proper synchronization of software execution. In such a case, the embedded system design may wish to check the data traffic on the busses between the processor cores, which requires very low-level debugging, at signal/bus level, with a logic analyzer, for instance.

**5.2.2 Reliability:**

Embedded systems often reside in machines that are expected to run continuously for years without errors and in some cases recover by them if an error occurs. Therefore the software is usually developed and tested more carefully than that for personal computers, and unreliable mechanical moving parts such as disk drives, switches or buttons are avoided.

Specific reliability issues may include:

* The system cannot safely be shut down for repair, or it is too inaccessible to repair. Examples include space systems, undersea cables, navigational beacons, bore-hole systems, and automobiles.
* The system must be kept running for safety reasons. "Limp modes" are less tolerable. Often backups are selected by an operator. Examples include aircraft navigation, reactor control systems, safety-critical chemical factory controls, train signals, engines on single-engine aircraft.
* The system will lose large amounts of money when shut down: Telephone switches, factory controls, bridge and elevator controls, funds transfer and market making, automated sales and service.

A variety of techniques are used, sometimes in combination, to recover from errors—both software bugs such as memory leaks, and also soft errors in the hardware:

* Watchdog timer that resets the computer unless the software periodically notifies the watchdog
* Subsystems with redundant spares that can be switched over to
* software "limp modes" that provide partial function
* Designing with a Trusted Computing Base (TCB) architecture[6] ensures a highly secure & reliable system environment
* An Embedded Hypervisor is able to provide secure encapsulation for any subsystem component, so that a compromised software component cannot interfere with other subsystems, or privileged-level system software. This encapsulation keeps faults from propagating from one subsystem to another, improving reliability. This may also allow a subsystem to be automatically shut down and restarted on fault detection.
* Immunity Aware Programming

**5.3 Explanation of Embedded Systems:**

**5.3.1 Software Architecture:**

There are several different types of software architecture in common use.

* Simple Control Loop:

In this design, the software simply has a loop. The loop calls subroutines, each of which manages a part of the hardware or software.

* Interrupt Controlled System:

Some embedded systems are predominantly interrupt controlled. This means that tasks performed by the system are triggered by different kinds of events. An interrupt could be generated for example by a timer in a predefined frequency, or by a serial port controller receiving a byte. These kinds of systems are used if event handlers need low latency and the event handlers are short and simple.

Usually these kinds of systems run a simple task in a main loop also, but this task is not very sensitive to unexpected delays. Sometimes the interrupt handler will add longer tasks to a queue structure. Later, after the interrupt handler has finished, these tasks are executed by the main loop. This method brings the system close to a multitasking kernel with discrete processes.

* Cooperative Multitasking:

A non-preemptive multitasking system is very similar to the simple control loop scheme, except that the loop is hidden in an API. The programmer defines a series of tasks, and each task gets its own environment to “run” in. When a task is idle, it calls an idle routine, usually called “pause”, “wait”, “yield”, “nop” (stands for no operation), etc.The advantages and disadvantages are very similar to the control loop, except that adding new software is easier, by simply writing a new task, or adding to the queue-interpreter.

* Primitive Multitasking:

In this type of system, a low-level piece of code switches between tasks or threads based on a timer (connected to an interrupt). This is the level at which the system is generally considered to have an "operating system" kernel. Depending on how much functionality is required, it introduces more or less of the complexities of managing multiple tasks running conceptually in parallel.

As any code can potentially damage the data of another task (except in larger systems using an MMU) programs must be carefully designed and tested, and access to shared data must be controlled by some synchronization strategy, such as message queues, semaphores or a non-blocking synchronization scheme.

Because of these complexities, it is common for organizations to buy a real-time operating system, allowing the application programmers to concentrate on device functionality rather than operating system services, at least for large systems; smaller systems often cannot afford the overhead associated with a generic real time system, due to limitations regarding memory size, performance, and/or battery life.

* Microkernels And Exokernels:

A microkernel is a logical step up from a real-time OS. The usual arrangement is that the operating system kernel allocates memory and switches the CPU to different threads of execution. User mode processes implement major functions such as file systems, network interfaces, etc.

In general, microkernels succeed when the task switching and intertask communication is fast, and fail when they are slow. Exokernels communicate efficiently by normal subroutine calls. The hardware and all the software in the system are available to, and extensible by application programmers. Based on performance, functionality, requirement the embedded systems are divided into three categories:

**5.3.2 Stand Alone Embedded System:**

These systems takes the input in the form of electrical signals from transducers or commands from human beings such as pressing of a button etc.., process them and produces desired output. This entire process of taking input, processing it and giving output is done in standalone mode. Such embedded systems comes under stand alone embedded systems

Eg: microwave oven, air conditioner etc...

**5.3.3 Real-time embedded systems:**

Embedded systems which are used to perform a specific task or operation in a specific time period those systems are called as real-time embedded systems. There are two types of real-time embedded systems.

* Hard Real-time embedded systems:

These embedded systems follow an absolute dead line time period i.e.., if the tasking is not done in a particular time period then there is a cause of damage to the entire equipment.

Eg: consider a system in which we have to open a valve within 30 milliseconds. If this valve is not opened in 30 ms this may cause damage to the entire equipment. So in such cases we use embedded systems for doing automatic operations.

* Soft Real Time embedded systems:

These embedded systems follow a relative dead line time period i.e.., if the task is not done in a particular time that will not cause damage to the equipment.

Eg: Consider a TV remote control system, if the remote control takes a few milliseconds delay it will not cause damage either to the TV or to the remote control. These systems which will not cause damage when they are not operated at considerable time period those systems comes under soft real-time embedded systems.

**5.3.4 Network communication embedded systems:**

A wide range network interfacing communication is provided by using embedded systems.

Eg:

* Consider a web camera that is connected to the computer with internet can be used to spread communication like sending pictures, images, videos etc.., to another computer with internet connection throughout anywhere in the world.
* Consider a web camera that is connected at the door lock.

Whenever a person comes near the door, it captures the image of a person and sends to the desktop of your computer which is connected to internet. This gives an alerting message with image on to the desktop of your computer, and then you can open the door lock just by clicking the mouse. Fig: 2.2 show the network communications in embedded systems.



**Fig 5.2: Network communication embedded systems**

**5.3.5 Different types of processing units:**

The central processing unit (c.p.u) can be any one of the following microprocessor, microcontroller, digital signal processing.

* Among these Microcontroller is of low cost processor and one of the main advantage of microcontrollers is, the components such as memory, serial communication interfaces, analog to digital converters etc.., all these are built on a single chip. The numbers of external components that are connected to it are very less according to the application.
* Microprocessors are more powerful than microcontrollers. They are used in major applications with a number of tasking requirements. But the microprocessor requires many external components like memory, serial communication, hard disk, input output ports etc.., so the power consumption is also very high when compared to microcontrollers.
* Digital signal processing is used mainly for the applications that particularly involved with processing of signals

**5.4 APPLICATIONS OF EMBEDDED SYSTEMS:**

**5.4.1 Consumer applications:**

At home we use a number of embedded systems which include microwave oven, remote control, vcd players, dvd players, camera etc….



**Fig5.3: Automatic coffee makes equipment**

**5.4.2 Office automation:**

We use systems like fax machine, modem, printer etc…

**Fig5.4: Fax machine Fig5.5: Printing machine**

**5.4.3. Industrial automation:**

Today a lot of industries are using embedded systems for process control. In industries we design the embedded systems to perform a specific operation like monitoring temperature, pressure, humidity ,voltage, current etc.., and basing on these monitored levels we do control other devices, we can send information to a centralized monitoring station.



**Fig5.6: Robot**

In critical industries where human presence is avoided there we can use robot**s** which are programmed to do a specific operation.

**5.4.4 Computer networking:**

Embedded systems are used as bridges routers etc..



**Fig5.7: Computer networking**

**5.4.5 Tele communications:**

Cell phones, web cameras etc.

**Fig2.8: Cell Phone** **Fig2.9: Web camera**

**CHAPTER 6**

**HARDWARE DESCRIPTION**

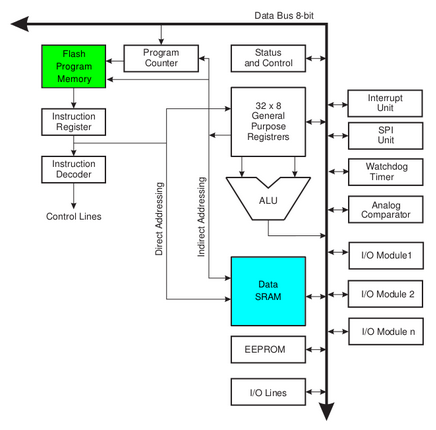
**6.1 Micro controller:**



**Fig: 6.1 Microcontrollers**

**6.1.1 Introduction to Microcontrollers:**

Circumstances that we find ourselves in today in the field of microcontrollers had their beginnings in the development of technology of integrated circuits. This development has made it possible to store hundreds of thousands of transistors into one chip.



**Fig: 6.2 Architecture**

That was a prerequisite for production of microprocessors, and the first computers were made by adding external peripherals such as memory, input-output lines, timers and other. Further increasing of the volume of the package resulted in creation of integrated circuits. These integrated circuits contained both processor and peripherals. That is how the first chip containing a microcomputer, or what would later be known as a microcontroller came about.

Microprocessors and microcontrollers are widely used in embedded systems products. Microcontroller is a programmable device. A microcontroller has a CPU in addition to a fixed amount of RAM, ROM, I/O ports and a timer embedded all on a single chip. The fixed amount of on-chip ROM, RAM and number of I/O ports in microcontrollers makes them ideal for many applications in which cost and space are critical.

**6.2 AVR-ARDUINO MICROCONTROLLER:**

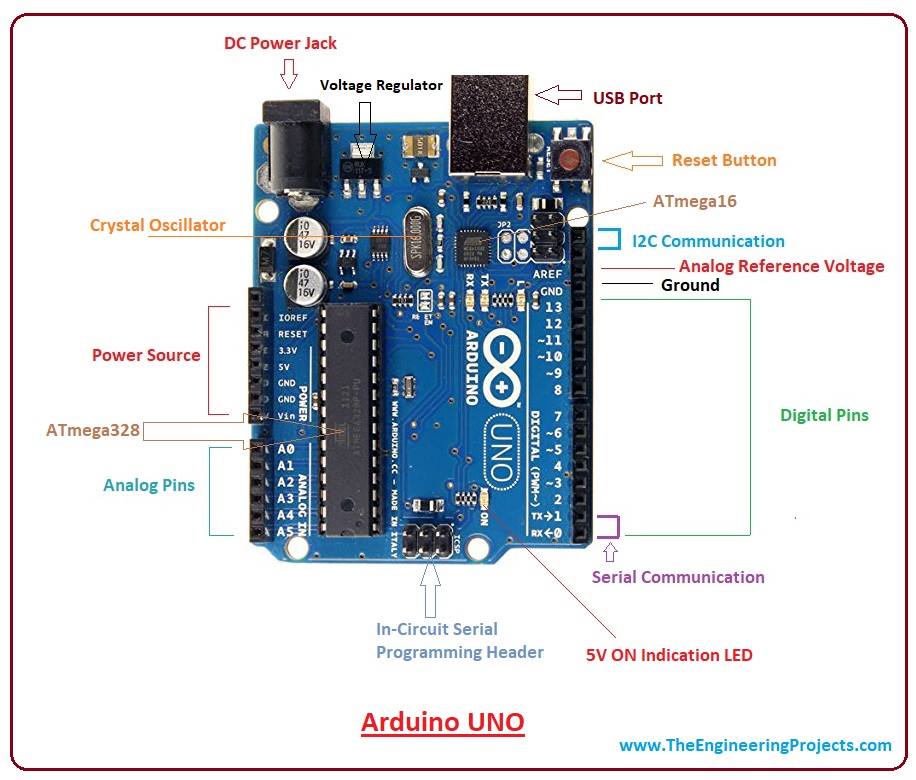


Figure 6.3 ARDUINO Development Board

The AVR is a modified Harvard architecture 8-bit RISC single chip microcontroller which was developed by Atmel in 1996. The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to One-Time Programmable ROM, EPROM, or EEPROM used by other microcontrollers at the time.

**6.3 Crystal Oscillator:**

XTAL1 and XTAL2 are input and output, respectively, of an inverting amplifier which can be configured for use as an On-chip Oscillator, Either a quartz

Crystal or a ceramic resonator may be used. The CKOPT Fuse selects between two different Oscillator amplifier modes. When CKOPT is programmed, the Oscillator output will oscillate a full rail-to-rail swing on the output. This mode is suitable when operating in a very noisy environment or when the output from XTAL2 drives a second clock buffer. This mode has a wide frequency range. When CKOPT is unprogrammed, the Oscillator has a smaller output swing. This reduces power consumption considerably.

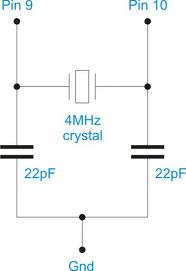
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Figure 6.4 crystal oscillator

This mode has a limited frequency range and it cannot be used to drive other clock buffers. For resonators, the maximum frequency is 8 MHz with CKOPT unprogrammed and 16 MHz with CKOPT programmed. C1 and C2 should always be equal for both crystals and resonators. The optimal value of the capacitors depends on the crystal or resonator in use, the amount of stray capacitance, and the electromagnetic noise of the environment. For ceramic resonators, the capacitor values given by the manufacturer should be used. The Oscillator can operate in three different modes, each optimized for a specific frequency range. The operating mode is selected by the fuses CKSEL3..1

**6.4 Architecture:**

**Memory:** It has **8 Kb** of Flash program memory (10,000 Write/Erase cycles durability), **512 Bytes** of EEPROM (100,000 Write/Erase Cycles). **1Kbyte** Internal SRAM

**I/O Ports:** 23 I/ line can be obtained from three ports; namely Port B, Port C and Port D.

**Interrupts:**  Two External Interrupt source, located at port D. 19 different interrupt vectors supporting 19 events generated by internal peripherals.

**Timer/Counter:** Three Internal Timers are available, two 8 bit, one 16 bit, offering various operating modes and supporting internal or external clocking.

**SPI (Serial Peripheral interface):** ATmega8 holds three communication devices integrated. One of them is Serial Peripheral Interface. Four pins are assigned to Atmega8 to implement this scheme of communication.

**USART:**One of the most powerful communication solutions is [USART](http://www.circuitstoday.com/how-to-establish-a-pc-micro-controller-usart-communication) and ATmega8 supports both synchronous and asynchronous data transfer schemes. It has three pins assigned for that. In many projects, this module is extensively used for PC-Micro controller communication.

**TWI (Two Wire Interface):** Another communication device that is present in ATmega8 is Two Wire Interface. It allows designers to set up a commutation between two devices using just two wires along with a common ground connection, As the TWI output is made by means of open collector outputs, thus external pull up resistors are required to make the circuit.

**Analog Comparator:** A comparator module is integrated in the IC that provides comparison facility between two voltages connected to the two inputs of the Analog comparator via External pins attached to the micro controller.

**Analog to Digital Converter:**Inbuilt analog to digital converter can convert an analog input signal into digital data of **10bit** resolution. For most of the low end application, this much resolution is enough.

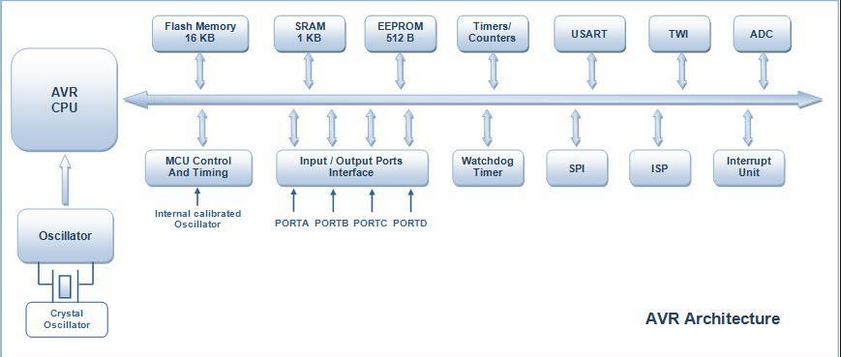


FIG 6.5 AVR Architecture

**Microcontroller:** Microcontroller can be termed as a single on chip computer which includes number of peripherals like RAM, EEPROM, Timers etc., required to perform some predefined task.

The computer on one hand is designed to perform all the general purpose tasks on a single machine like you can use a computer to run a software to perform calculations or you can use a computer to store some multimedia file or to access [internet](http://www.engineersgarage.com/articles/what-is-internet-history-working) through the browser, whereas the microcontrollers are meant to perform only the specific tasks, for e.g., switching the AC off automatically when room temperature drops to a certain defined limit and again turning it ON when temperature rises above the defined limit.

 There are number of popular families of microcontrollers which are used in different applications as per their capability and feasibility to perform the desired task, most common of these are [8051](http://www.engineersgarage.com/8051-microcontroller), **AVR** and [PIC](http://www.engineersgarage.com/articles/pic-microcontroller-tutorial) microcontrollers. In this article we will introduce you with **AVR** family of microcontrollers.

**AVR** was developed in the year 1996 by Atmel Corporation. The architecture of **AVR** was developed by Alf-Egil Bogen and Vegard Wollan. AVR derives its name from its developers and stands for **Alf-Egil Bogen Vegard Wollan RISC microcontroller**, also known as **A**dvanced **V**irtual **R**ISC. The AT90S8515 was the first microcontroller which was based on **AVR architecture** however the first microcontroller to hit the commercial market was AT90S1200 in the year 1997.

**AVR microcontrollers** are available in three categories:

1.      **TinyAVR** – Less memory, small size, suitable only for simpler applications

2.      **MegaAVR** – These are the most popular ones having good amount of memory (upto 256 KB), higher number of inbuilt peripherals and suitable for moderate to complex applications.

3.      **XmegaAVR** – Used commercially for complex applications, which require large program memory and high speed.

**Device architecture**

Flash, EEPROM, and SRAM are all integrated onto a single chip, removing the need for external memory in most applications. Some devices have a parallel external bus option to allow adding additional data memory or memory-mapped devices. Almost all devices (except the smallest TinyAVR chips) have serial interfaces, which can be used to connect larger serial EEPROMs or flash chips.

**Program memory**

Program instructions are stored in non-volatile flash memory. Although the MCUs are 8-bit, each instruction takes one or two 16-bit words.

The size of the program memory is usually indicated in the naming of the device itself (e.g., the ATmega64x line has 64 kB of flash while the ATmega32x line has 32 kB).

There is no provision for off-chip program memory; all code executed by the AVR core must reside in the on-chip flash. However, this limitation does not apply to the AT94 FPSLIC AVR/FPGA chips.

**Internal data memory**

The data address space consists of the register file, I/O registers, and SRAM.

**Internal registers**

The AVRs have 32 single-byte registers and are classified as 8-bit RISC devices.

In most variants of the AVR architecture, the working registers are mapped in as the first 32 memory addresses (000016–001F16) followed by the 64 I/O registers (002016–005F16).

Actual SRAM starts after these register sections (address 006016). (Note that the I/O register space may be larger on some more extensive devices, in which case the memory mapped I/O registers will occupy a portion of the SRAM address space.)

Even though there are separate addressing schemes and optimized opcodes for register file and I/O register access, all can still be addressed and manipulated as if they were in SRAM.

In the XMEGA variant, the working register file is not mapped into the data address space; as such, it is not possible to treat any of the XMEGA's working registers as though they were SRAM. Instead, the I/O registers are mapped into the data address space starting at the very beginning of the address space. Additionally, the amount of data address space dedicated to I/O registers has grown substantially to 4096 bytes (000016–0FFF16). As with previous generations, however, the fast I/O manipulation instructions can only reach the first 64 I/O register locations (the first 32 locations for bitwise instructions). Following the I/O registers, the XMEGA series sets aside a 4096 byte range of the data address space which can be used optionally for mapping the internal EEPROM to the data address space (100016–1FFF16). The actual SRAM is located after these ranges, starting at 200016.

**EEPROM**

Almost all AVR microcontrollers have internal EEPROM for semi-permanent data storage. Like flash memory, EEPROM can maintain its contents when electrical power is removed.

In most variants of the AVR architecture, this internal EEPROM memory is not mapped into the MCU's addressable memory space. It can only be accessed the same way an external peripheral device is, using special pointer registers and read/write instructions which makes EEPROM access much slower than other internal RAM.

However, some devices in the SecureAVR (AT90SC) family use a special EEPROM mapping to the data or program memory depending on the configuration. The XMEGA family also allows the EEPROM to be mapped into the data address space.

Since the number of writes to EEPROM is not unlimited — Atmel specifies 100,000 write cycles in their datasheets — a well designed EEPROM write routine should compare the contents of an EEPROM address with desired contents and only perform an actual write if the contents need to be changed.

Note that erase and write can be performed separately in many cases, byte-by-byte, which may also help prolong life when bits only need to be set to all 1s (erase) or selectively cleared to 0s (write).

**Program execution**

Atmel's AVRs have a two stage, single level pipeline design. This means the next machine instruction is fetched as the current one is executing. Most instructions take just one or two clock cycles, making AVRs relatively fast among eight-bit microcontrollers.

The AVR processors were designed with the efficient execution of compiled C code in mind and have several built-in pointers for the task.

**MCU speed**

The AVR line can normally support clock speeds from 0 to 20 MHz, with some devices reaching 32 MHz. Lower powered operation usually requires a reduced clock speed. All recent (Tiny, Mega, and Xmega, but not 90S) AVRs feature an on-chip oscillator, removing the need for external clocks or resonator circuitry. Some AVRs also have a system clock prescaler that can divide down the system clock by up to 1024. This prescaler can be reconfigured by software during run-time, allowing the clock speed to be optimized.

Since all operations (excluding literals) on registers R0 - R31 are single cycle, the AVR can achieve up to 1 MIPS per MHz, i.e. an 8 MHz processor can achieve up to 8 MIPS. Loads and stores to/from memory take two cycles, branching takes two cycles. Branches in the latest "3-byte PC" parts such as ATmega2560 are one cycle slower than on previous devices

**Features:**

• High-performance, Low-power Atmel®AVR® 8-bit Microcontroller

**• Advanced RISC Architecture**

– 130 Powerful Instructions – Most Single-clock Cycle Execution

– 32 × 8 General Purpose Working Registers

– Fully Static Operation

– Up to 16MIPS Throughput at 16MHz

– On-chip 2-cycle Multiplier

**• High Endurance Non-volatile Memory segments**

– 8Kbytes of In-System Self-programmable Flash program memory

– 512Bytes EEPROM

– 1Kbyte Internal SRAM

– Write/Erase Cycles: 10,000 Flash/100,000 EEPROM

– Data retention: 20 years at 85°C/100 years at 25°C(1)

– Optional Boot Code Section with Independent Lock Bits

In-System Programming by On-chip Boot Program

True Read-While-Write Operation

– Programming Lock for Software Security

**• Peripheral Features**

– Two 8-bit Timer/Counters with Separate Prescaler, one Compare Mode

– One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture

Mode

– Real Time Counter with Separate Oscillator

– Three PWM Channels

– 8-channel ADC in TQFP and QFN/MLF package

Eight Channels 10-bit Accuracy

– 6-channel ADC in PDIP package

Six Channels 10-bit Accuracy

– Byte-oriented Two-wire Serial Interface

– Programmable Serial USART

– Master/Slave SPI Serial Interface

– Programmable Watchdog Timer with Separate On-chip Oscillator

– On-chip Analog Comparator

**• Special Microcontroller Features**

– Power-on Reset and Programmable Brown-out Detection

– Internal Calibrated RC Oscillator

– External and Internal Interrupt Sources

– Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and

Standby

**• I/O and Packages**

– 23 Programmable I/O Lines

– 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF

**• Operating Voltages**

– 2.7V - 5.5V (ATmega8L)

– 4.5V - 5.5V (ATmega8)

**• Speed Grades**

– 0 - 8MHz (ATmega8L)

– 0 - 16MHz (ATmega8)

**• Power Consumption at 4Mhz, 3V, 25oC**

– Active: 3.6mA

– Idle Mode: 1.0mA

– Power-down Mode: 0.5µA

**Brown-out Detector:**

If the Brown-out Detector is not needed in the application, this module should be turned off. If the Brown-out Detector is enabled by the BODEN Fuse, it will be enabled in all sleep modes, and hence, always consume power. In the deeper sleep modes, this will contribute significantly to the total current consumption. Refer to “Brown-out Detection” on page 38 for details on how to configure the Brown-out Detector.

Internal Voltage Reference the Internal Voltage Reference will be enabled when needed by the Brown-out Detector, the Analog Comparator or the ADC. If these modules are disabled as described in the sections above, the internal voltage reference will be disabled and it will not be consuming power. When turned on again, the user must allow the reference to start up before the output is used. If the reference is kept on in sleep mode, the output can be used immediately. Refer to “Internal Voltage Reference” on page 40 for details on the start-up time. Watchdog Timer If the Watchdog Timer is not needed in the application, this module should be turned off.

If the Watchdog Timer is enabled, it will be enabled in all sleep modes, and hence, always consume power. In the deeper sleep modes, this will contribute significantly to the total current consumption. Refer to “Watchdog Timer” on page 41 for details on how to configure the Watchdog Timer. Port Pins When entering a sleep mode, all port pins should be configured to use minimum power.

The most important thing is then to ensure that no pins drive resistive loads. In sleep modes where the both the I/O clock (clkI/O) and the ADC clock (clkADC) are stopped, the input buffers of the device will be disabled. This ensures that no power is consumed by the input logic when not needed. In some cases, the input logic is needed for detecting wake-up conditions, and it will then be enabled. Refer to the section “Digital Input Enable and Sleep Modes” on page 53 for details on which pins are enabled. If the input buffer is enabled and the input signal is left floating or have an analog signal level close to VCC/2, the input buffer will use excessive power.

**Power-on Reset:**

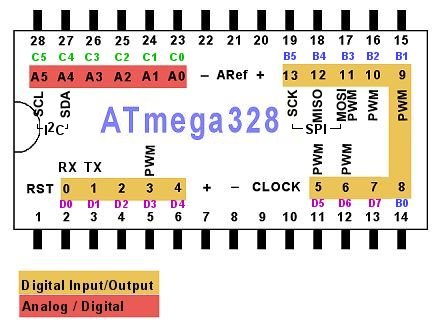
A Power-on Reset (POR) pulse is generated by an On-chip detection circuit. The detection level is defined in Table 15. The POR is activated whenever VCC is below the detection level. The POR circuit can be used to trigger the Start-up Reset, as well as to detect a failure in supply voltage.

A Power-on Reset (POR) circuit ensures that the device is reset from Power-on. Reaching the Power-on Reset threshold voltage invokes the delay counter, which determines how long the device is kept in RESET after VCC rise. The RESET signal is activated again, without any delay, when VCC decreases below the detection level.

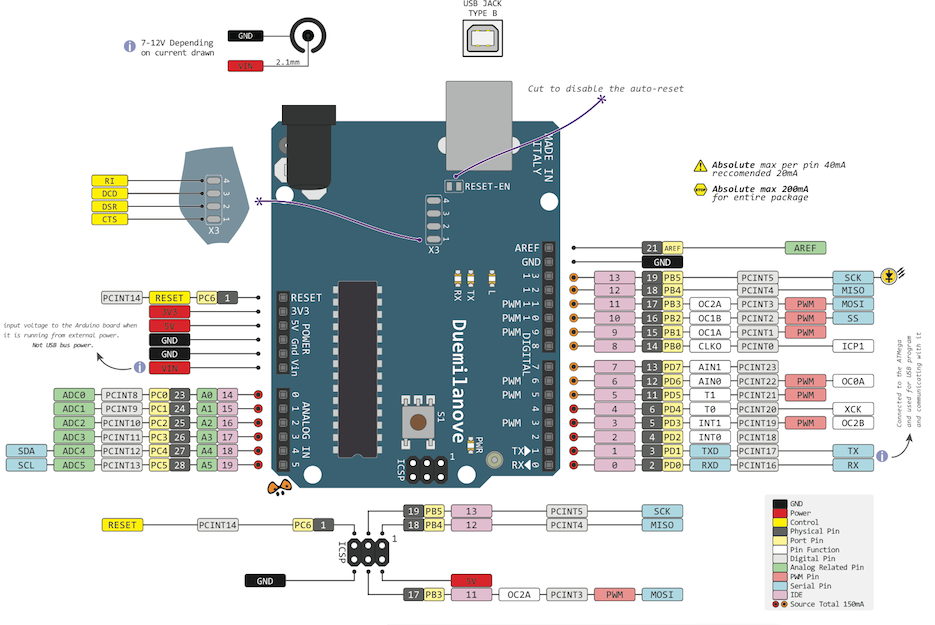
**External Reset**:

An External Reset is generated by a low level on the RESET pin. Reset pulses longer than the minimum pulse width (see Table 15) will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a reset. When the applied signal reaches the Reset Threshold Voltage – VRST on its positive edge, the delay counter starts the MCU after the time-out period tTOUT has expired.

**6.5 Pin diagram:**



**Fig.6.6 PIN DIAGRAM OF ATMEGA328**

****

**Fig.6.7 PIN DIAGRAM OF ATMEGA328**

**VCC**  
Digital supply voltage magnitude of the voltage range between 4.5 to 5.5 V for the ATmega8 and 2.7 to 5.5 V for ATmega8L

**GND**  
Ground Zero reference digital voltage supply.

**PORTB (PB7.. PB0)**

PORTB is a port I / O two-way (bidirectional) 8-bit with internal pull-up resistor can be selected. This port output buffers have symmetrical characteristics when used as a source or sink. When used as an input, the pull-pin low externally will emit a current if the pull-up resistor is activated it. PORTB pins will be in the condition of the tri-state when RESET is active, although the clock is not running.

**PORTC (PC5.. PC0)**

PORTC is a port I / O two-way (bidirectional) 7-bit with internal pull-up resistor can be selected. This port output buffers have symmetrical characteristics when used as a source or sink. When used as an input, the pull-pin low externally will emit a current if the pull-up resistor is activated it. PORTC pins will be in the condition of the tri-state when RESET is active, although the clock is not running.

**PC6/RESET**  
If RSTDISBL Fuse programmed, PC6 then serves as a pin I / O but with different characteristics. PC0 to PC5 If Fuse RSTDISBL not programmed, then serves as input Reset PC6. LOW signal on this pin with a minimum width of 1.5 microseconds will bring the microcontroller into reset condition, although the clock is not running.

**PORTD (PD7.. PD0)**

PORTD is a port I / O two-way (bidirectional) 8-bit with internal pull-up resistor can be selected. This port output buffers have symmetrical characteristics when used as a source or sink. When used as an input, the pull-pin low externally will emit a current if the pull-up resistor is activated it. PORTD pins will be in the condition of the tri-state when RESET is active, although the clock is not running.

**RESET**Reset input pin. LOW signal on this pin with a minimum width of 1.5 microseconds will bring the microcontroller into reset condition, although the clock is not running. Signal with a width of less than 1.5 microseconds does not guarantee a Reset condition.

**AVCC**  
AVCC is the supply voltage pin for the ADC, PC3 .. PC0, and ADC7..ADC6. This pin should be connected to VCC, even if the ADC is not used. If the ADC is used, AVCC should be connected to VCC through a low-pass filter to reduce noise.

**Aref**  
Analog Reference pin for the ADC.

**ADC7 .. ADC6**

ADC analog input there is only on ATmega8 with TQFP and QFP packages / MLF.

**PORTS**

Term "port" refers to a group of pins on a microcontroller which can be accessed simultaneously, or on which we can set the desired combination of zeros and ones, or read from them an existing status. Physically, port is a register inside a microcontroller which is connected by wires to the pins of a microcontroller. Ports represent physical connection of Central Processing Unit with an outside world. Microcontroller uses them

The [Atmega8](http://www.protostack.com/product_by_model.php?model=IC-ATMEGA8-16PU) has 23 I/O ports which are organized into 3 groups:

* Port B (PB0 to PB7)
* Port C (PC0 to PC6)
* Port D (PD0 to PD7)

We will use mainly 3 registers known as **DDRX, PORTX**&**PINX**. We have total four PORTs on my ATmega16. They are **PORTA, PORTB, PORTC** and **PORTD**. They are multifunctional pins. Each of the pins in each port (total 32) can be treated as input or output pin.

**Applications**

AVR microcontroller perfectly fits many uses, from automotive industries and controlling home appliances to industrial instruments, remote sensors, electrical door locks and safety devices. It is also ideal for smart cards as well as for battery supplied devices because of its low consumption.

EEPROM memory makes it easier to apply microcontrollers to devices where permanent storage of various parameters is needed (codes for transmitters, motor speed, receiver frequencies, etc.). Low cost, low consumption, easy handling and flexibility make ATmega8 applicable even in areas where microcontrollers had not previously been considered (example: timer functions, interface replacement in larger systems, coprocessor applications, etc.).

In System Programmability of this chip (along with using only two pins in data transfer) makes possible the flexibility of a product, after assembling and testing have been completed. This capability can be used to create assembly-line production, to store calibration data available only after final testing, or it can be used to improve programs on finished products.

**6.5 REGULATED POWER SUPPLY:**

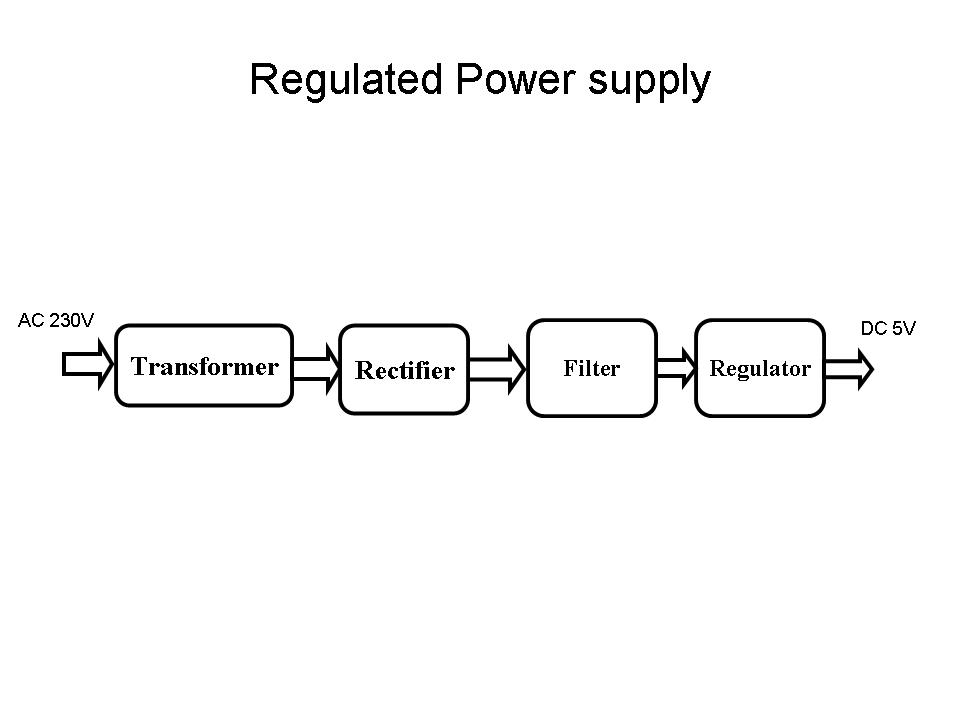
**6.5.1 Introduction:**

Power supply is a supply of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

A power supply may include a power distribution system as well as primary or secondary sources of energy such as

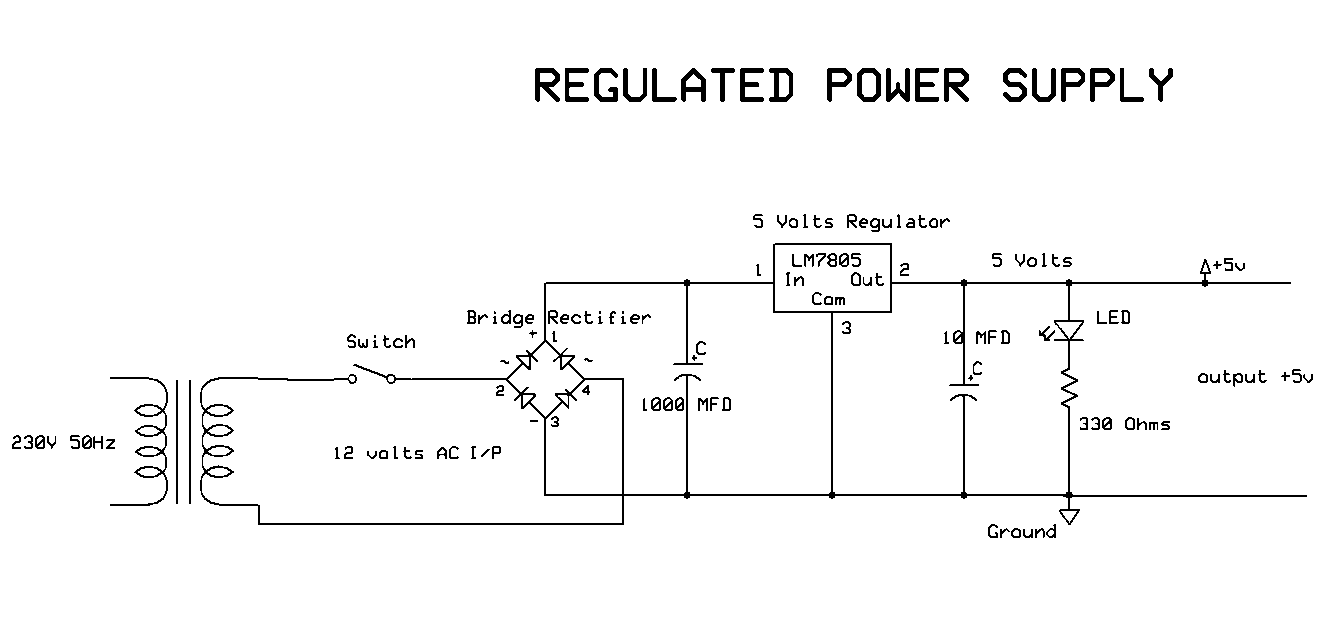
* Conversion of one form of electrical power to another desired form and voltage, typically involving converting AC line voltage to a well-regulated lower-voltage DC for electronic devices. Low voltage, low power DC power supply units are commonly integrated with the devices they supply, such as computers and household electronics.
* Batteries.
* Chemical fuel cells and other forms of energy storage systems.
* Solar power.
* Generators or alternators.

**6.5.2 Block Diagram:**

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**Fig 6.8 Regulated Power Supply**

The basic circuit diagram of a regulated power supply (DC O/P) with led connected as load is shown in fig: 6.8.



**Fig 6.9 Circuit diagram of Regulated Power Supply with Led connection**

The components mainly used in above figure are

* 230V AC MAINS
* TRANSFORMER
* BRIDGE RECTIFIER(DIODES)
* CAPACITOR
* VOLTAGE REGULATOR(IC 7805)
* RESISTOR
* LED(LIGHT EMITTING DIODE)

The detailed explanation of each and every component mentioned above is as follows:

**Transformation:** The process of transforming energy from one device to another is called transformation. For transforming energy we use transformers.

**Transformers:**

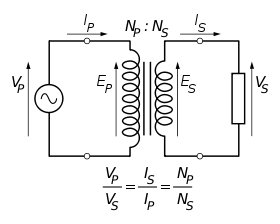
A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors without changing its frequency. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

If a load is connected to the secondary, an electric current will flow in the secondary winding and electrical energy will be transferred from the primary circuit through the transformer to the load. This field is made up from lines of force and has the same shape as a bar magnet.

If the current is increased, the lines of force move outwards from the coil. If the current is reduced, the lines of force move inwards.

If another coil is placed adjacent to the first coil then, as the field moves out or in, the moving lines of force will "cut" the turns of the second coil. As it does this, a voltage is induced in the second coil. With the 50 Hz AC mains supply, this will happen 50 times a second. This is called MUTUAL INDUCTION and forms the basis of the transformer.

The input coil is called the PRIMARY WINDING; the output coil is the SECONDARY WINDING. Fig: 6.10 shows step-down transformer.

****

**Fig 6.10: Step-Down Transformer**

The voltage induced in the secondary is determined by the TURNS RATIO.



For example, if the secondary has half the primary turns; the secondary will have half the primary voltage.

Another example is if the primary has 5000 turns and the secondary has 500 turns, then the turn’s ratio is 10:1.

If the primary voltage is 240 volts then the secondary voltage will be x 10 smaller = 24 volts. Assuming a perfect transformer, the power provided by the primary must equal the power taken by a load on the secondary. If a 24-watt lamp is connected across a 24 volt secondary, then the primary must supply 24 watts.

To aid magnetic coupling between primary and secondary, the coils are wound on a metal CORE. Since the primary would induce power, called EDDY CURRENTS, into this core, the core is LAMINATED. This means that it is made up from metal sheets insulated from each other. Transformers to work at higher frequencies have an iron dust core or no core at all.

Note that the transformer only works on AC, which has a constantly changing current and moving field. DC has a steady current and therefore a steady field and there would be no induction.

Some transformers have an electrostatic screen between primary and secondary. This is to prevent some types of interference being fed from the equipment down into the mains supply, or in the other direction. Transformers are sometimes used for IMPEDANCE MATCHING.

We can use the transformers as step up or step down.

**Step Up transformer:**

In case of step up transformer, primary windings are every less compared to secondary winding. Because of having more turns secondary winding accepts more energy, and it releases more voltage at the output side.

**Step down transformer:**

Incase of step down transformer, Primary winding induces more flux than the secondary winding, and secondary winding is having less number of turns because of that it accepts less number of flux, and releases less amount of voltage.

**Rectification:**

The process of converting an alternating current to a pulsating direct current is called as rectification. For rectification purpose we use rectifiers.

**Rectifiers:**

A rectifier is an electrical device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid-state diodes, vacuum tube diodes, mercury arc valves, and other components.

A device that it can perform the opposite function (converting DC to AC) is known as an inverter.

When only one diode is used to rectify AC (by blocking the negative or positive portion of the waveform), the difference between the term diode and the term rectifier is merely one of usage, i.e., the term rectifier describes a diode that is being used to convert AC to DC. Almost all rectifiers comprise a number of diodes in a specific arrangement for more efficiently converting AC to DC than is possible with only one diode. Before the development of silicon semiconductor rectifiers, vacuum tube diodes and copper (I) oxide or selenium rectifier stacks were used.

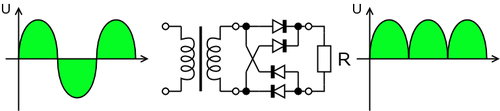
**Bridge full wave rectifier:**

The Bridge rectifier circuit is shown in fig: 3.3.7, which converts an ac voltage to dc voltage using both half cycles of the input ac voltage. The Bridge rectifier circuit is shown in the figure. The circuit has four diodes connected to form a bridge. The ac input voltage is applied to the diagonally opposite ends of the bridge. The load resistance is connected between the other two ends of the bridge.

For the positive half cycle of the input ac voltage, diodes D1 and D3 conduct, whereas diodes D2 and D4 remain in the OFF state. The conducting diodes will be in series with the load resistance RL and hence the load current flows through RL.

For the negative half cycle of the input ac voltage, diodes D2 and D4 conduct whereas, D1 and D3 remain OFF. The conducting diodes D2 and D4 will be in series with the load resistance RL and hence the current flows through RL in the same direction as in the previous half cycle. Thus a bi-directional wave is converted into a unidirectional wave.

Input Output

****

**Fig 6.11: Bridge rectifier: a full-wave rectifier using 4 diodes**

**DB107:**

Now -a -days Bridge rectifier is available in IC with a number of DB107. In our project we are using an IC in place of bridge rectifier. The picture of DB 107 is shown in fig: 6.12.

**Features:**

* Good for automation insertion
* Surge overload rating - 30 amperes peak
* Ideal for printed circuit board
* Reliable low cost construction utilizing molded
* Glass passivated device
* Polarity symbols molded on body
* Mounting position: Any
* Weight: 1.0 gram



**Fig 6.12: DB107**

**Filtration:**

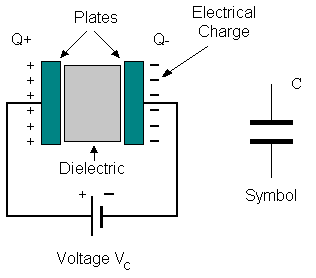
The process of converting a pulsating direct current to a pure direct current using filters is called as filtration.

**Filters:**

Electronic filters are electronic circuits, which perform signal-processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones.

**Introduction to Capacitors:**

The Capacitor or sometimes referred to as a Condenser is a passive device, and one which stores energy in the form of an electrostatic field which produces a potential (static voltage) across its plates. In its basic form a capacitor consists of two parallel conductive plates that are not connected but are electrically separated either by air or by an insulating material called the Dielectric. When a voltage is applied to these plates, a current flows charging up the plates with electrons giving one plate a positive charge and the other plate an equal and opposite negative charge this flow of electrons to the plates is known as the Charging Current and continues to flow until the voltage across the plates (and hence the capacitor) is equal to the applied voltage Vcc. At this point the capacitor is said to be fully charged and this is illustrated below. The construction of capacitor and an electrolytic capacitor are shown in figures 6.13 and 6.14 respectively.

****

**Fig 6.13: Construction Of a Capacitor Fig 6.14:Electrolytic Capaticor**

Units of Capacitance:

Microfarad  (μF) 1μF = 1/1,000,000 = 0.000001 = 10-6 F

 Nanofarad  (nF) 1nF = 1/1,000,000,000 = 0.000000001 = 10-9 F

 Pico farad  (pF) 1pF = 1/1,000,000,000,000 = 0.000000000001 = 10-12 F

**Regulation:**

The process of converting a varying voltage to a constant regulated voltage is called as regulation. For the process of regulation we use voltage regulators.

**Voltage Regulator:**

A voltage regulator (also called a ‘regulator’) with only three terminals appears to be a simple device, but it is in fact a very complex integrated circuit. It converts a varying input voltage into a constant ‘regulated’ output voltage. Voltage Regulators are available in a variety of outputs like 5V, 6V, 9V, 12V and 15V. The LM78XX series of voltage regulators are designed for positive input. For applications requiring negative input, the LM79XX series is used. Using a pair of ‘voltage-divider’ resistors can increase the output voltage of a regulator circuit.

It is not possible to obtain a voltage lower than the stated rating. You cannot use a 12V regulator to make a 5V power supply. Voltage regulators are very robust. These can withstand over-current draw due to short circuits and also over-heating. In both cases, the regulator will cut off before any damage occurs. The only way to destroy a regulator is to apply reverse voltage to its input. Reverse polarity destroys the regulator almost instantly. Fig: 3.3.11 shows voltage regulator.



**Fig 6.15: Voltage Regulator**

**Resistors:**

A resistor is a two-terminal electronic component that produces a voltage across its terminals that is proportional to the electric current passing through it in accordance with Ohm's law:

*V* = *IR*

Resistors are elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).

The primary characteristics of a resistor are the resistance, the tolerance, maximum working voltage and the power rating. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance is determined by the design, materials and dimensions of the resistor.

Resistors can be made to control the flow of current, to work as Voltage dividers, to dissipate power and it can shape electrical waves when used in combination of other components. Basic unit is ohms.

**Theory of operation:**

**Ohm's law:**

The behavior of an ideal resistor is dictated by the relationship specified in Ohm's law:

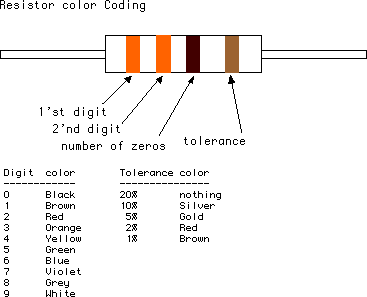
V = IR

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I) through it where the constant of proportionality is the resistance (R).

**Power dissipation:**

The power dissipated by a resistor (or the equivalent resistance of a resistor network) is calculated using the following:

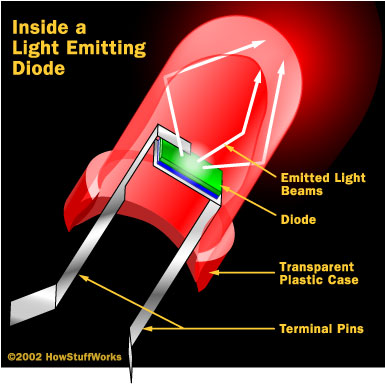
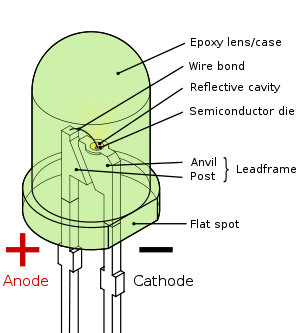
P = I^2 R = I V = \frac{V^2}{R}

** **

**Fig 6.16: Resistor Fig 6.17: Color Bands In Resistor**

**6.6. LED:**

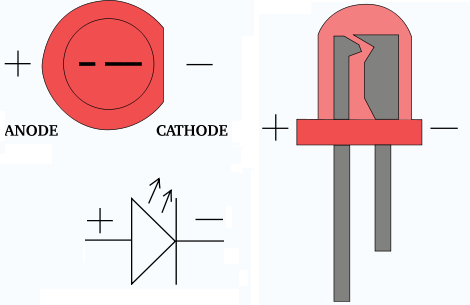
A light-emitting diode (LED) is a semiconductor light source. LED’s are used as indicator lamps in many devices, and are increasingly used for lighting. Introduced as a practical electronic component in 1962, early LED’s emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness. The internal structure and parts of a led are shown below.

**Fig 6.18: Inside a LED Fig 6.19: Parts Of a LED**

**Working:**

The structure of the LED light is completely different than that of the light bulb. Amazingly, the LED has a simple and strong structure. The light-emitting semiconductor material is what determines the LED's color. The LED is based on the semiconductor diode.



**Fig 6.20: Electrical Symbol & Polarities of LED**

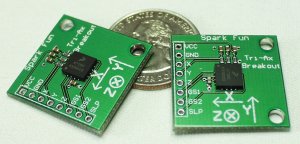
LED lights have a variety of advantages over other light sources:

* High-levels of brightness and intensity
* High-efficiency
* Low-voltage and current requirements
* Low radiated heat
* High reliability (resistant to shock and vibration)
* No UV Rays
* Long source life
* Can be easily controlled and programmed

Applications of LED fall into three major categories:

* Visual signal application where the light goes more or less directly from the LED to the human eye, to convey a message or meaning.
* Illumination where LED light is reflected from object to give visual response of these objects.
* Generate light for measuring and interacting with processes that do not involve the human visual system.

**6.7 MEMS sensor**



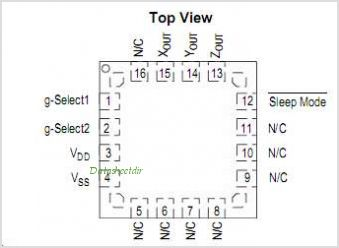
**Fig6.21 MEMS sensor MMA7260Q**

The MMA7260Q is a 3-axis accelerometer .An accelerometer measures acceleration (change in speed) of anything that it's mounted on. Single axis accelerometers measure acceleration in only one direction. Dual-axis accelerometers are the most common measure acceleration in two directions, perpendicular to each other. Three-axis accelerometers measure acceleration in three directions.

Accelerometers are very handy for measuring the orientation of an object relative to the earth, because gravity causes all objects to accelerate towards the earth. A two-axis accelerometer can be used to measure how level an object is.

(This would be a good place to fill in equations to calculate a body's angle from the X and Y accelerations on the body).

With a three-axis accelerometer, you can measure an object's acceleration in every direction.



**Fig6.22 Pin Connections**

This three-axis accelerometer is essentially a carrier board or breakout board for Freescale’s MMA7260QT MEMS (micro-electro-mechanical systems) accelerometer; we therefore recommend careful reading of the MMA7260QT datasheet (199k pdf) before using this product. The MMA7260QT is a great IC, but its small, leadless package makes it difficult for the typical student or hobbyist to use. The device also operates at 2.2 V to 3.6 V, which can make interfacing difficult for microcontrollers operating at 5 V. This carrier board addresses both issues while keeping the overall size as compact as possible.

**Working of MMA7260Q sensor:**

The schematic for the 3-axis accelerometer is shown below. The device can be powered directly through the Vcc/3.3 V pin using a supply that is within the MMA7260QT’s acceptable power supply range of 2.2 V to 3.6 V. Alternatively, the board can be powered by higher voltages, up to 16 V, using the VIN pin, which connects to a low-dropout 3.3 V regulator. In this configuration, the Vcc/3.3 V pin can serve as an output to be used as a reference voltage or power source for other low-power devices (up to around 50 mA, depending on the input voltage).

The sensitivity selection pins GS1 and GS2 are pulled up to the Vcc line, making the default sensitivity 6g; these pins can be pulled low by a microcontroller or through jumpers. For 5 V microcontroller applications, the lines should not be driven high. Instead, the microcontroller I/O pin can emulate an open-drain or open-collector output by alternating between low output and high-impedance (input) states. Put another way, if you are using a 5 V microcontroller, you should make your sensitivity selection I/O lines inputs and rely upon the internal pull-ups on the GS1 and GS2 lines if you want them to be high. It is always safe for you to drive these lines low.

Each of the three outputs is an RC-filtered analog voltage that ranges from 0 to Vcc. For 5 V applications, the outputs will range from 0 to 3.3 V. The 3.3 V output can be used as a reference for analog-to-digital converters to gain full resolution samples. Otherwise, your conversions will be limited to 66% of the full range (e.g. an 8-bit ADC will yield numbers from 0 to 168).

|  |
| --- |
|  |

**Fig 6.23 schematic diagram of 3-axis accelerometer module circuit**

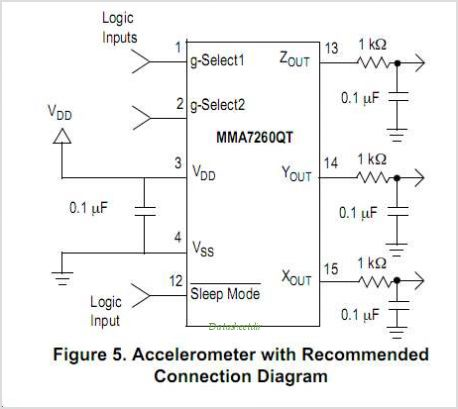
**Specifications:**

1. Dimensions: 0.8" x 0.55" x 0.11" (without header pins)
2. Operating voltage: 3.3-16 V
3. Supply current: 1.35 mA
4. Output format: 3 analog voltages (one signal for each axis)
5. Output voltage range: 0-Vcc (0-3.3 V for VIN > 3.3 V)
6. Sensitivity range: ±1.5g, 2g, 4g, or 6g (selectable using pins GS1 and GS2; default is ±6g)
7. Weight without header pins: 0.03 oz (0.85 g)
8. Included components

A 10x1 strip of 0.1" header pins and two shorting blocks are included, as shown in the left picture below. These components do not come soldered in. You can break the strip into sub-strips and solder them in as desired, or you can solder wires directly to the board for more compact installations. The shorting blocks can be used as sensitivity range selectors as shown in the right picture below, or you can simply control the sensitivity range by using a microcontroller to drive the appropriate range-selector pins low.

**6.7.1 Pin Descriptions**

These pin descriptions refer to Sparkfun's breakout board. Sparkfun has helpfully added the necessary capacitors and resistors to each output pin so you don't have to. Here is the [schematic of the Sparkfun breakout board](http://www.sparkfun.com/datasheets/Accelerometers/Tri-Ax-Schematic-v01.pdf).



**Fig 6.24 Accelerometer with recommended connection diagrm**

The pins of the accelerometer are as follows:

1. Vcc - Voltage, 3.3V
2. GND - Ground
3. X - X axis output, 0 - 3.3V
4. Y - Y axis output, 0 - 3.3V
5. Z - Z axis output, 0 - 3.3V
6. GS1 - G-select 1
7. GS2 - G-select 2
8. SLP - sleep

The GS1 and GS2 pins allow you to set the accelerometer's sensitivity, depending on how much force it will be subjected to in your application. For low-force activities like measuring the tilt of an object, the lowest setting, 1.5g, is probably enough. If it's going to be attached to a crash-test dummy, you might want to set the sensitivity to the full 6G, or get a better accelerometer. To set the sensitivity, connect the GS1 and GS2 pins as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **GS1** | **GS2** | **G-range** | **Sensitivity** |
| GND | GND | 1.5g | 800mV/g |
| GND | 3.3V | 2g | 600mV/g |
| 3.3V | GND | 4g | 300mV/g |
| 3.3V | 3.3V | 6g | 200mV/g |

**Table 1:GS1 and GS2 pin connection**

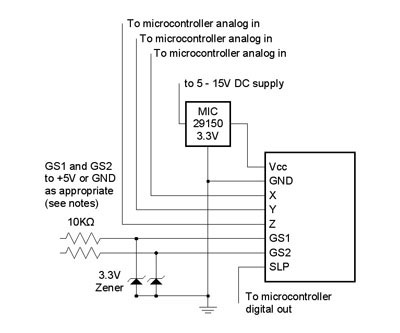
In the schematic below, the accelerometer is connected to a PIC microcontroller running on 5V, so a 3.3V zener diode and 10Kohm resistor were added to the GS1 and GS2 pins to limit the incoming voltage to 3.3V.

The sensitivity of the accelerometer can be changed on the fly, so you could connect the GS1 and GS2 pins to pins of your microcontroller and change the sensitivity by taking the appropriate microcontroller pins high or low.

The sleep pin puts the accelerometer in a low-current inactive mode. To put the accelerometer to sleep, take the sleep pin low. To activate the accelerometer, take it high (3.3v). Note: I originally had a 3.3V zener diode and 10Kohm resistor connecting the sleep pin to the PIC, but I found that I had to eliminate them in order to get consistent performance. Your mileage may vary --[tigoe](http://itp.nyu.edu/physcomp/sensors/Profiles/Tigoe)

**Microcontroller Connections**

To connect the accelerometer to a PIC, use this schematic:

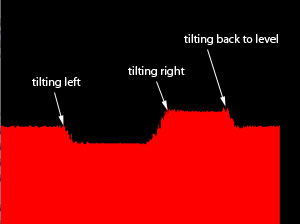


**Fig6.25 Application circuit for a 3-axis accelerometer**

**Parts list:**

* MMA7260Q accelerometer on Sparkfun breakout board
* MIC29150-3.3BT 3.3V voltage regulator
* 2 - 10Kohm 0.25-watt resistors
* 2 - 1N5226B-T 3.3V zenar diodes

This graph shows the X axis. The accelerometer starts level, and then is tilted to the left, then to the right, then level again:



**Fig 6.26 graph of X axis**

This graph shows the Y axis. The accelerometer starts level, and then is tilted forward, then back, then level again:



**Fig 6.27 graph of Y axis**

This graph shows the Z axis. The accelerometer is kept level, but raised up in a quick motion, then lowered quickly. Moving up produces a sudden increase in force (and voltage) followed by a sudden decrease when the movement's stopped, then finally the voltage levels out again. Moving down has the opposite effect.



**Fig 6.27 graph of Z axis**

If you were using the accelerometer to navigate in a virtual 3D space, you'd have to factor in the sudden decelerations that occur at the end of moving up or down, or the virtual object you're moving would probably have a very bouncy movement.

**Electrical Characteristics**

The MMA7260Q operates on 2.2 to 3.6VDC, and uses very little current (500uA). It has three analog outputs, one for each axis. Acceleration on each axis generates a voltage from 0 to approximately 3.3V.

When there's no acceleration on a given axis, the output for that axis outputs half the supply voltage, or about 1.65V. With acceleration in a positive direction along the axis, the output voltage for that axis rises. With negative acceleration along the axis, the voltage goes down. In other words:

* at rest the voltage is in the middle;
* at full forward acceleration, the voltage is at its highest;
* at full backward acceleration, the voltage is at its lowest.

**Applications:**

Accelerometers are real workhorses in the sensor world because they can sense such a wide range of motion. They're used in the latest Apple Power books (and other laptops) to detect when the computer's suddenly moved or tipped, so the hard drive can be locked up during movement. They're used in cameras, to control image stabilization functions. They're used in pedometers, gait meters, and other exercise and physical therapy devices.

**CHAPTER 7**

**SIMULATION TOOLS**

This project is implemented using following software’s:

* Express PCB – for designing circuit
* Arduino IDE compiler - for compilation part

**7.1 Express PCB:**

Breadboards are great for prototyping equipment as it allows great flexibility to modify a design when needed; however the final product of a project, ideally should have a neat PCB, few cables, and survive a shake test. Not only is a proper PCB neater but it is also more durable as there are no cables which can yank loose.

Express PCB is a software tool to design PCBs specifically for manufacture by the company Express PCB (no other PCB maker accepts Express PCB files). It is very easy to use, but it does have several limitations.

It can be likened to more of a toy then a professional CAD program.

It has a poor part library (which we can work around)

It cannot import or export files in different formats

It cannot be used to make prepare boards for DIY production

Express PCB has been used to design many PCBs (some layered and with surface-mount parts. Print out PCB patterns and use the toner transfer method with an Etch Resistant Pen to make boards. However, Express PCB does not have a nice print layout. Here is the procedure to design in Express PCB and clean up the patterns so they print nicely.

**7.1.1 Preparing Express PCB for First Use:**

Express PCB comes with a less then exciting list of parts. So before any project is started head over to Audio logical and grab the additional parts by morsel, ppl, and tangent, and extract them into your Express PCB directory. At this point start the program and get ready to setup the workspace to suit your style.

Click View -> Options. In this menu, setup the units for “mm” or “in” depending on how you think, and click “see through the top copper layer” at the bottom. The standard color scheme of red and green is generally used but it is not as pleasing as red and blue.

**7.1.2 The Interface:**

When a project is first started you will be greeted with a yellow outline. This yellow outline is the dimension of the PCB. Typically after positioning of parts and traces, move them to their final position and then crop the PCB to the correct size. However, in designing a board with a certain size constraint, crop the PCB to the correct size before starting.

Fig: 7.1 show the toolbar in which the each button has the following functions:



**Fig 7.1: Tool bar necessary for the interface**

* The select tool: It is fairly obvious what this does. It allows you to move and manipulate parts. When this tool is selected the top toolbar will show buttons to move traces to the top / bottom copper layer, and rotate buttons.
* The zoom to selection tool: does just that.
* The place pad: button allows you to place small soldier pads which are useful for board connections or if a part is not in the part library but the part dimensions are available. When this tool is selected the top toolbar will give you a large selection of round holes, square holes and surface mount pads.
* The place component: tool allows you to select a component from the top toolbar and then by clicking in the workspace places that component in the orientation chosen using the buttons next to the component list. The components can always be rotated afterwards with the select tool if the orientation is wrong.
* The place trace: tool allows you to place a solid trace on the board of varying thicknesses. The top toolbar allows you to select the top or bottom layer to place the trace on.
* The Insert Corner in trace: button does exactly what it says. When this tool is selected, clicking on a trace will insert a corner which can be moved to route around components and other traces.
* The remove a trace button is not very important since the delete key will achieve the same result.

**7.1.3 Design Considerations:**

Before starting a project there are several ways to design a PCB and one must be chosen to suit the project’s needs.

Single sided, or double sided?

When making a PCB you have the option of making a single sided board, or a double sided board. Single sided boards are cheaper to produce and easier to etch, but much harder to design for large projects. If a lot of parts are being used in a small space it may be difficult to make a single sided board without jumpering over traces with a cable. While there’s technically nothing wrong with this, it should be avoided if the signal travelling over the traces is sensitive (e.g. audio signals).

A double sided board is more expensive to produce professionally, more difficult to etch on a DIY board, but makes the layout of components a lot smaller and easier. It should be noted that if a trace is running on the top layer, check with the components to make sure you can get to its pins with a soldering iron. Large capacitors, relays, and similar parts which don’t have axial leads can NOT have traces on top unless boards are plated professionally.

Ground-plane or other special purposes for one side

When using a double sided board you must consider which traces should be on what side of the board. Generally, put power traces on the top of the board, jumping only to the bottom if a part cannot be soldiered onto the top plane (like a relay), and vice- versa.

Some projects like power supplies or amps can benefit from having a solid plane to use for ground. In power supplies this can reduce noise, and in amps it minimizes the distance between parts and their ground connections, and keeps the ground signal as simple as possible. However, care must be taken with stubborn chips such as the TPA6120 amplifier from TI. The TPA6120 datasheet specifies not to run a ground plane under the pins or signal traces of this chip as the capacitance generated could effect performance negatively.

**Arduino compiling**

Arduino is not the only IDE that helps you compile code for ESP32 and flash it into the microcontroller. There is ESP−IDF which is the official development framework for ESP32, which provides much more flexibility in terms of configuration options. However, it is hardly as intuitive and user−friendly as the Arduino IDE, and if you are starting out with ESP32, Arduino IDE is ideal to get your hands dirty. Also, with the number of supporting libraries built for ESP32 in Arduino, courtesy of the huge developer community, there's hardly any functionality of ESP32 which can't be realized with the Arduino IDE. ESP-IDF is more suitable for the more advanced and experienced programmers, who need to stretch ESP32 to its limits. If you are one of those, you are looking for the [ESP−IDF Getting Started Guide](https://docs.espressif.com/projects/esp-idf/en/latest/esp32/get-started/index.html). Others can follow along.

Installation Steps

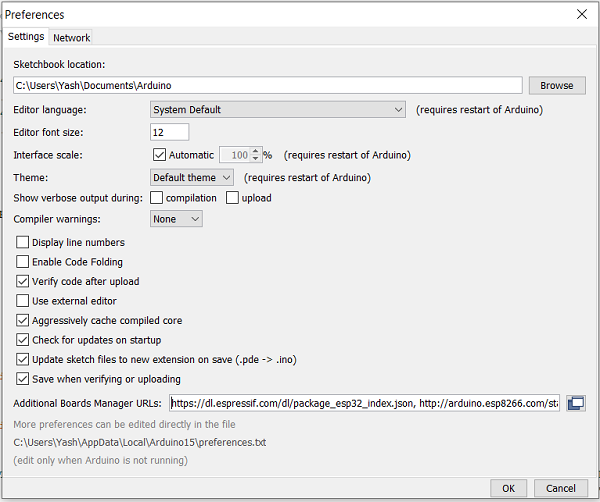
Now, to install the ESP32 board in the Arduino IDE, you need to follow the below steps −

* Make sure you have Arduino IDE (preferably the latest version) installed on your machine
* Open Arduino and go to File −> Preferences
* In the Additional Boards Manager URL, enter

https://dl.espressif.com/dl/package\_esp32\_index.json

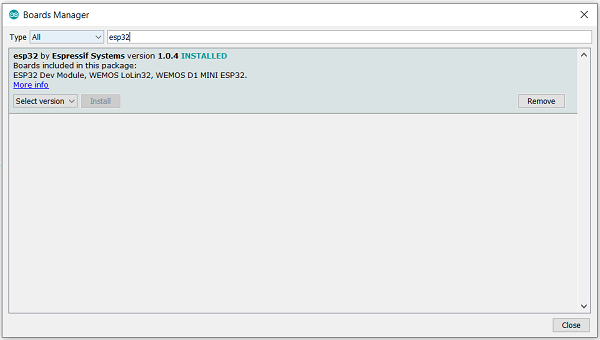
In case you have an existing JSON file's URL in the preferences (this is likely if you've installed ESP8266, stm32duino, or any such additional board in the IDE), you can just append the above path to the existing path, using a comma. An example is shown below, for ESP8266 and ESP32 boards −

http://arduino.esp8266.com/stable/package\_esp8266com\_index.json, https://dl.espressif.com/dl/package\_esp32\_index.json



**Fig 7.2 Setting up the Arduino IDE preferences**

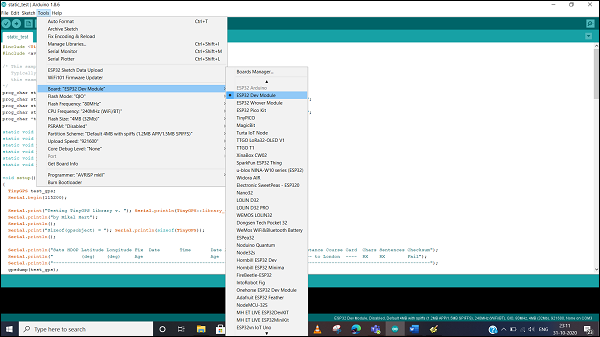
* Go to Tools −> Board−> Boards Manager. A pop−up would open up. Search for ESP32 and install the **esp32** by **Espressif Systems** board. The image below shows the board already installed because I had installed the board before preparing this tutorial.



**Fig 7.3 Installing the ESP32 board package**

Verifying the Installation

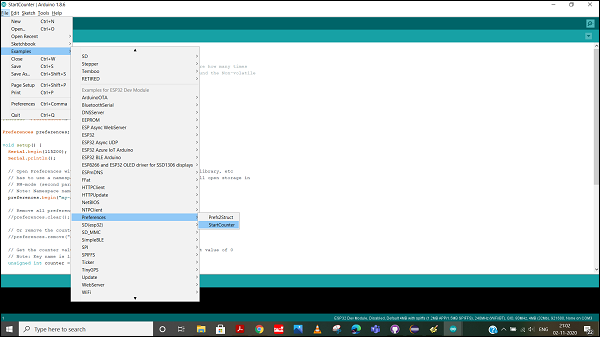
Once your ESP32 board has been installed, you can verify the installation by going to Tools −> Boards. You can see a whole bunch of boards under the **ESP32 Arduino** section. Choose the board of your choice. If you are not sure which board best represents the one you have, you can choose **ESP32 Dev Module**.



**Fig 7.4 Selecting the correct board**

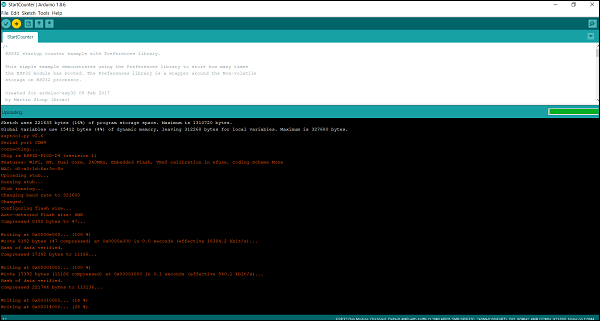
Next, connect your board to your machine using the USB Cable. You should see an additional COM Port under Tools−> Port. Select that additional port. In case you see multiple ports, you can disconnect the USB and see which port disappeared. That port corresponds to ESP32.

Once the port is identified, pick any one example sketch from File −> Examples. We will choose the StartCounter example from File −> Examples −> Preferences −> StartCounter.



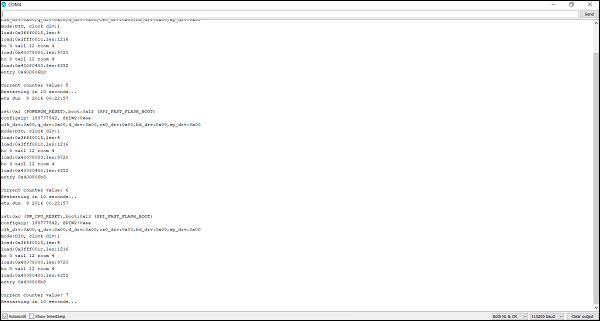
**Fig 7.5 Opening an example sketch from the Preferences library**

Open that sketch, compile it and flash it into the ESP32 by clicking on the Upload button (the right arrow button, besides the Compile button).



**Fig 7.6 Uploading the sketch successfully to the ESP32**

Then open the Serial Monitor using Tools −> Serial Monitor, or simply by pressing Ctrl + Shift + M on your keyboard. You should see the counter value getting incremented after every ESP32 restart.



**Fig 7.7 Serial Terminal Window**

**CHAPTER 8**

**CODE**

#include <Wire.h>

#define ADXL345 0x53

// Motor pins

#define IN1 2

#define IN2 3

#define IN3 4

#define IN4 5

void setup() {

Serial.begin(9600);

Wire.begin();

// Initialize ADXL345

Wire.beginTransmission(ADXL345);

Wire.write(0x2D); // Power register

Wire.write(0); // Reset

Wire.endTransmission();

delay(10);

Wire.beginTransmission(ADXL345);

Wire.write(0x2D); // Power register

Wire.write(8); // Measure mode

Wire.endTransmission();

// Motor pin setup

pinMode(IN1, OUTPUT);

pinMode(IN2, OUTPUT);

pinMode(IN3, OUTPUT);

pinMode(IN4, OUTPUT);

}

void loop() {

int x = readAxis(0x32);

int y = readAxis(0x34);

int z = readAxis(0x36);

Serial.print("X: "); Serial.print(x);

Serial.print(" Y: "); Serial.print(y);

Serial.print(" Z: "); Serial.println(z);

controlRobot(x, y);

delay(200);

}

int readAxis(byte axisReg) {

int16\_t value = Wire.read() | (Wire.read() << 8);

return value;

}

void controlRobot(int x, int y) {

int threshold = 150;

if (y > threshold) {

moveForward();

} else if (y < -threshold) {

moveBackward();

} else if (x > threshold) {

turnRight();

} else if (x < -threshold) {

turnLeft();

} else {

stopMotors();

}

}

void moveForward() {

digitalWrite(IN1, HIGH);

digitalWrite(IN2, LOW);

digitalWrite(IN3, HIGH);

digitalWrite(IN4, LOW);

}

void moveBackward() {

digitalWrite(IN1, LOW);

digitalWrite(IN2, HIGH);

digitalWrite(IN3, LOW);

digitalWrite(IN4, HIGH);

}

void turnLeft() {

digitalWrite(IN1, LOW);

digitalWrite(IN2, HIGH);

digitalWrite(IN3, HIGH);

digitalWrite(IN4, LOW);

}

void turnRight() {

digitalWrite(IN1, HIGH);

digitalWrite(IN2, LOW);

digitalWrite(IN3, LOW);

digitalWrite(IN4, HIGH);

}

void stopMotors() {

digitalWrite(IN1, LOW);

digitalWrite(IN2, LOW);

digitalWrite(IN3, LOW);

digitalWrite(IN4, LOW);

}

**CHAPTER 9**

**CONCLUSION**

The development of a hand gesture-controlled robot using a wired interface showcases a significant step forward in intuitive and accessible robotic control systems. This project successfully replaces traditional remote controllers with a more natural method of interaction—hand gestures—using MEMS sensors such as accelerometers and gyroscopes. These sensors accurately capture the orientation and motion of the hand, which are then processed by a microcontroller (like Arduino) to generate corresponding movement commands for the robot.

Unlike wireless systems that may suffer from latency, signal loss, or interference, the use of a wired communication link ensures stable, secure, and uninterrupted data transmission between the controller and the robot. This improves the reliability and precision of the robot’s response, making it highly suitable for controlled environments where accuracy is essential.

Additionally, the system eliminates the need for a second operator, enabling a single user to operate the robot effectively through simple gestures. This contributes to a more streamlined and cost-effective solution, particularly in educational setups, research labs, and prototype development scenarios where simplicity and reliability are important.

The project highlights how the integration of MEMS sensors, embedded systems, and gesture recognition technology can be harnessed to create low-cost, responsive, and user-friendly robotic applications. It also opens up future possibilities for enhancements such as wireless expansion, AI-based gesture prediction, and broader real-world applications in industries like healthcare, military, and automation. Overall, this system provides a foundation for further innovation in human-machine interaction.

**CHAPTER 10**

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