

Development of a Micro Universal Testing System for Accurate Material Property Analysis of Small Structures

Submitted in fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechatronics

by

Arjun V S (39090002)

Surya B (39090056)



**DEPARTMENT OF MECHATRONICS
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAACI 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

MAY - 2023

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Surya.B (39090056)**, **Arjun.V.S (39090002)** who have done the project work entitled "**Development of a Micro Universal Testing Machine System for Accurate Material Property Analysis of Small Structures**" under our supervision from June 2022 to May 2023.

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DECLARATION

We **Surya.B (39090056)** and **Arjun.V.S (39090002)**, hereby declare that the Project Report entitled “**Development of a Micro Universal Testing Machine System for Accurate Material Property Analysis of Small Structures**” done by us under the guidance of **Dr. J. Senthilkumar ,M.E.,Ph.D.** is submitted in fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

1. 

2. 

DATE:

PLACE:

SIGNATURE OF THE CANDIDATE

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I am pleased to acknowledge my sincere thanks to the Board of Management of SATHYABAMA for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to Dr. S. Prakash, M.E., Ph.D., Dean, School of Mechanical engineering and Head of the Department, Department of Mechatronics for providing me necessary support and details at the right time during the progressive reviews.

I Would like to express my sincere and deep sense of gratitude to my Project Guide Dr. J. Senthilkumar ,M.E. Ph.D., for his valuable guidance, suggestions and constant encouragement paved the way for the successful completion of my project work.

ABSTRACT

Using a variety of test methodologies, universal testing machines are used to monitor and analyze how raw materials and component behavior respond to tensile or compressive stresses in order to determine the physical and mechanical characteristics of these materials. increase. A single universal tester can be used to run a number of tests, as indicated by the word "universal" in the name. Tensile testing and compressive testing are two of the most popular test types. A micro-universal testing machine (UTM) system has been proposed to measure the microstructure of composite material properties. A composite is a combination of two materials that have different physical and chemical properties. Combining them creates materials that are specialized to perform specific tasks, such as being stronger, lighter, or more resistant to electricity. It can also improve strength and stiffness. The system is designed to verify composite material properties such as peak load, peak shift, tensile strength and yield point, and elongation, developed by analyzing stepper motor drive characteristics. In performance testing, the developed micro universal testing machine system performs to the 1828 micro universal testing machine standard. The developed micro universal testing machine system can be applied to microstructures. The proposed system consists of (I) sensor module, (II) measurement control module, (III) output stepper motor control module, and (IV) analysis UI software module. The sensor module contains a load cell for obtaining the precise load on the test material and encoders for obtaining the speed and direction of the stepper motor. Up and down traverses for receiving test articles. The measurement controller processes load and speed values and sends relevant digital data to the UI software, while automatically controlling the stepper motor rotation and direction as needed. The UI software was developed using Visual Studio to further analyses the parameters and display the load-displacement diagrams in an appropriate manner. The software also captures peak load (maximum), peak displacement (maximum), tensile strength and yield strength, which can be displayed in the associated test material user interface.

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CHAPTER – 1

1.0 INTRODUCTION

The need for micro-actuators is growing as the industry expands to exploit mechanical and electrical properties at the micro- and nano scale. Piezoelectric actuators and voice coil motors are commonly used as drive methods for micro actuators. Piezoelectric motors have high responsiveness, but low reproducibility and high cost. Voice coil motors (VCMs), on the other hand, are repeatable, low cost, and generally responsible. A VCM can be used as a micro actuator for actuation of a few millimeters. Much research has been done in North America, Europe, and Japan in the field of micro force measurement systems. Research on material properties in micro electromechanical systems (MEMS) focuses on research equipment and universities. Sandia Research Equipment performs failure analysis of MEMS materials and reliability testing of actuators. DARPA and Johns Hopkins University have conducted strain tests on poly-silicon as a MEMS material. A material characterization method using nano indentation was presented at Seoul National College. The Korea Progressed Organized of Science and Innovation (KAIST) is creating a strategy to test the distortion characteristics of gold holding wires for semiconductor bundles. KITECH has created a machine for testing mechanical material properties at the micro level. This research focuses on the development of test methods for material properties. A Micro Universal Testing Machine (UTM) is a highly versatile instrument for measuring the mechanical properties of materials at the micro scale. It is designed to apply a controlled load or strain to a sample of material and record the corresponding response. Capable of testing a wide run of materials counting metals, polymers, ceramics and composites, the micro-UTM can be used to perform a variety of mechanical tests such as tension, compression, bending and torsion. With high accuracy and precision, properties such as strength, stiffness, and elasticity can be measured with high accuracy. Micro UTMs are widely used in materials R&D, quality control, and manufacturing testing. They provide researchers and engineers with important insights into the behavior of materials at the micro scale, enabling them to design and develop new materials with specific mechanical properties. In addition to its high accuracy and versatility, the micro-UTM is highly

portable and inexpensive, making it an attractive option for small research projects and companies with limited budgets.

A Micro Universal Testing Machine (UTM) system is a complete test setup used to perform small-scale mechanical testing of materials or components. It includes the Micro-UTM itself, as well as the accessories and software needed to run the tests and analyze the results. A Micro-UTM system typically consists of the following components:

1. Micro UTM: The core component of the system, the micro-UTM, is a device that applies a load and measures the corresponding deformation or displacement of the specimen.
2. Load cell: A load cell is a transducer that converts the force exerted by the Micro-UTM into an electrical signal that can be measured and recorded.
3. Test equipment: A test fixture holds the specimen in place and applies a load to the specimen in a controlled manner. Different types of test fixtures are available depending on the type of mechanical testing to be performed.
4. Control unit: The control unit coordinates test procedures, controls load and deformation parameters, and records data.
5. Software: This software provides an easy-to-use interface for controlling the Micro-UTM and performing various types of mechanical tests. It also provides data analysis tools for processing and interpreting test results.

Micro-UTM systems can be used to perform various types of mechanical tests. B. Tensile, Compressive, Bending, and Fatigue Testing. It can also be used to measure properties such as elasticity, stiffness, toughness and fatigue strength. A micro-UTM system is a complete test setup that enables accurate and precise small-scale mechanical testing and analysis of materials or components. It includes a micro-UTM, load cell, test fixture, control unit and software and can be used to perform various types of mechanical tests and measure various mechanical properties.

1.1 PROPOSED SYSTEM

In this work, a widespread testing machine framework (UTM) for small scale basic fabric property estimations is proposed. This framework, which is utilized for strain, compression, rehashed vibration, and lean film peeling tests, was created by analyzing the drive characteristics of a voice coil motor (VCM), and consists of a sensor module, drive module, flag investigation module, and arrangement module. I'm here. Module In arrange to affirm the pertinence of the created micro-UTM framework to microstructures, we are conducting execution tests such as stack constrain, full stroke, lean film peeling, and rehashed stack tests. The proposed micro-universal testing machine system aims to provide an advanced and easy-to-use instrument for measuring the mechanical properties of materials at the micro scale.

The system builds on the existing capabilities of the micro-UTM and integrates new features and technologies to improve accuracy, versatility and ease of use. The proposed system includes advanced sensors and software that enable highly accurate and precise measurements of material properties such as strength, stiffness and elasticity. It also features a user-friendly interface that allows researchers and engineers to easily set up and run a wide range of mechanical tests including tensile, compression, bending and torsion tests. The system also includes advanced data analysis tools, giving researchers more opportunities to extract meaningful insights from the data and use them to design and develop new materials with specific mechanical properties. .

Another important feature of the proposed system is its portability and ease of use. Overall, the proposed micro-universal tester system represents a major advance in materials research and development, providing researchers and engineers with an advanced and easy-to-use tool for measuring the mechanical properties of materials at the micro scale. . Equipped with advanced sensors, software and data analysis tools, the system enables researchers to design new materials with specific mechanical properties and understand material behavior at the micro level.

The proposed system for the Micro Universal Test Machine (UTM) system is related to the development of new or improved techniques to enhance existing

Micro UTMs. Proposed systems may include improved accuracy and precision, real-time data analysis, automated test procedures, advanced mechanical test capabilities, and integration with other technologies. The proposed system aims to provide more efficient and accurate test results and extend the capabilities of micro-UTM systems for various applications. Proposed systems for Micro Universal Test Machine (UTM) systems include improvements or innovations to existing Micro UTM technology.

Here are some possible ideas for the proposed system.

1. Improved accuracy and precision: The proposed system may include improvements to load cells, test fixtures and control units to improve measurement accuracy and precision. This includes using more sensitive sensors, reducing noise and interference, and optimizing test parameters.
2. Real-time data analysis: The proposed system could include software that analyzes the data in real time, allowing immediate feedback and adjustment of the testing process. This enables faster and more efficient testing and improves the accuracy of results.
3. Automated test procedure: The proposed system could include automated testing procedures that minimize the need for manual intervention. This includes automated sample loading and placement, and automated data acquisition and analysis.
4. Advanced mechanical testing options: The proposed system may include new possibilities for mechanical testing such as: B. Ability to perform multiaxial loading or testing in high temperature or corrosive environments.
5. Integration with other technologies: The proposed system includes integration with other techniques such as scanning electron microscopy and atomic force microscopy, allowing simultaneous mechanical and structural analysis of samples.

CHAPTER – 2

2.0 LITERATURE SURVEY

Myung-Jin Chung et al, [1] Micro universal testing machine (UTM) System for material property measurement of micro structure is proposed. This system using for elongation, compression, repeat vibration, and thin film exfoliation test is developed by analysis of driving property of the voice coil motor (VCM), and consisted with sensing module, driving module, signal analysis module, and alignment module. To verify the applicability of developed micro UTM system in the micro structure, performance test is conducted. From the performance test, the developed micro UTM system has performance such as maximum force of 29.4 mN, unit force of 0.029 mN, full stroke of plusmn1 mm, unit stroke of 1 mum, respectively. Developed micro UTM system can be applicable in the micro structure.

Stephen Jose et al, [2] The thesis paper will be covering the grounds of what, how and why a Universal Testing Machine is used, an alternative to the generic Universal Testing Machine designs and how it is built. The primary objective of this thesis work is to design and build a Universal Testing Machine which can handle a load up to 10kN for polymer materials which is cost eective and modular. The operating system and electronic components are open-source leaving room for further development and compression test.

Kweon et al, [3] Micro UTM (Universal Testing Machines) are becoming increasingly popular for testing the mechanical properties of MEMS materials, metal thin films, and micro-molecule materials¹⁻². And, new miniature testing machines that can perform in-process measurement in SEM, TEM, and SPM are also needed. The size, load output and used in SEM, TEM, and SPM have been proposed. Bimorph type PZT precision actuator is used in displacement output of bimorph type UTM are 109×64×22(mm), about 35g, and 0.4 mm, respectively. The results of the analysis and basic properties of positioning system and the UTM system are presented. In addition, the experiment results of in-process measurement during tensile load in SEM and AFM are showed.

Wenqing Yin et al, [4] In order to solve the problems caused by using traditional materials in the experiments, such as complicated operation process, poor control, low testing accuracy, inconvenience of recording test data, lack of timely data processing and so on, the control of the tensile test must be improved. This paper in details analyzes the operational principle of the tensile test machine, on which a tensile test machine control program is proposed based on MCGS. By selecting the appropriate sensor and using PCI_1716 data acquisition card, a tensile testing machine control system's hardware platform is founded. The control system software based on MCGS, can monitor the process of tensile testing, display and record real-time testing data. Practice has proved that the tensile testing machine control system has many advantages of high accuracy, good real-time, stability, easy operation etc, which can meet the needs of practical applications.

Yanfang Li et al, [5] The purpose of study is to investigate a new control algorithm for hydraulic universal testing machine based on extenics. As the variable stiffness of testing specimen affects load stiffness, the theoretical analysis and simulation study of the effect of variable load stiffness on the system were investigated. The degree and tendency of the effect of variable load stiffness on the control quality and accuracy are given. Furthermore, a new extension control algorithm for hydraulic universal testing machine was presented in this paper. The results show that this new control strategy can solve the problems of variable structure parameters of hydraulic universal testing machine, and can realize switch smoothly in variable control modes.

Zhao Shushang et al, [6] A measurement and control system is designed according to the requirement of digital transformation to the WJ-10 universal tension and compression testing machine. This system is made up of two parts :The data acquisition system based on C8051F020 and the monitoring system based on the virtual instrument LABVIEW The physical quantities (such as tension, pressure, deformation, temperature, etc.)of the specimen during the tension and compression experiment are digital and graphical display and storage by using this system. The historical data, curves can be called to be compared to the current experimental data.

Xiao Yan-jun et al, [7] MCGS (Monitor and Control Generated System, Universal Monitoring System) is a set of configuration software for rapidly constructing and generating computer monitoring system. It can provide solutions, which solve practical engineering program, and also be run on the Microsoft (all 32-bit Windows platform). The data, which is acquainted on site, can be displayed with a variety of ways, such as animation, alarm processing, process control, real-time curve, the historical curve and the report output. It takes full advantage of the Windows' features, such as graphics, good interface consistency, easy-to-use, so it has a more widespread application in the automation field. The tensile test machine control system was designed on the basis of MCGS software industrial control system.

Du Jingqing et al, [8] Based on the relationship between pressure and flux of thin-walled hole, a new idea is proposed for hydraulic testing machine. Using transducer and computer technique, hydraulic system is formed by SCM(single chip micropy), needle valve, frequency converter and electric machine, to complete stress and strain rates control. This idea has been realized in traditional hydraulic pressure testing machine and hydraulic universal testing machine, and some excellent results have been obtained. According to the theory and practice, the new idea can meet the need of constant stress and strain rates testing, and replace proportional valve and servo valve, thereby it can be widely applied for various hydraulic testing machines.

Tsuyoshi Furushima et al, [9] It is known that the surface roughness on the free surface increases with increasing plastic strain. When the size of material is scaling down in to micro scale, the ratio of surface roughness to the thickness becomes large in micro metal forming compared with macro-scale forming. Thus, the surface roughening behavior of metal foils is an important factor in micro metal forming. To clarify the surface roughening behavior of the metal foils, in-situ observation is required under bi-axial tension state. In this study, the method of in-situ observation of surface roughening during plastic deformation is developed. The hand-size stretching test is developed and installed on the confocal laser micro scope which can evaluate quantitative 3D profile of surface with high resolution. The effect of strain state such as equi-biaxial on surface roughening

behavior is investigated experimentally. By using developed in-situ observation method, it became possible to evaluate the process of changing the surface under various strain states.

Hitomi Tsunozaki et al, [10] The effect of material thickness from 0.05 to 0.5 mm on the surface roughening and fracture strain is investigated under a uni-axial tensile state. The relative surface roughening to the thickness becomes large when the thickness is thin. In addition, the fracture strain decreases with decreasing thickness. To clarify the effect of strain condition, a small Marciniak multiaxial test is conducted. The continuous observation of surface roughening and onset of local necking for a metal foil with 0.05 mm is conducted under an equi-biaxial tensile condition. The surface roughness increases with increasing plastic strain under any strain conditions. The most concaved part which is formed by surface roughening behaviour leads to the local necking and fracture. Consequently, it is found that the surface roughening behaviour strongly affects the ductile fracture behaviour at micro scale.

Huerta. E et al, [11] In this work, the design, construction, calibration and compliance measurement of a universal testing machine for tension tests of materials in film geometry are presented. A commercial load cell of 220 N and sensitivity of 1.2345 mV/V is used to measure the applied load. Material strain is measured by movement of the crosshead displacement of the machine with a digital indicator with 0.001 mm resolution and 25 mm maximum displacement, connected to a PC through an interface. Mechanical strain is achieved by an electric high precision stepper motor capable to obtain displacement velocities as low as 0.001 mm/s. The stress-strain data acquired with a GPIB interface are saved as a file with a home-made program developed in LabView 7.0. Measurements of the elastic modulus and yield point of a commercial polymer film (500 HN Kapton) were used to validate the performance of the testing machine. The obtained mechanical properties are in good agreement with the mean values reported by the supplier and with the values obtained from a commercial machine, taking into account the limitations of thin film testing and experimental conditions.

Mandeep Singh et al, [12] The tensile test always delivers an in-depth understanding of true stress-strain relationship. However, it is not easy for the

researchers to understand and evaluate the tensile properties of micro-specimens. This paper presents a research work aiming at the design and manufacturing of a small universal test machine (UTM) for measuring the mechanical properties of the miniaturised samples. The newly developed machine is sensitive to small loads and permits to obtain the stress-strain curves for thin materials. This portable UTM consists of a stepper motor, a load cell, a linear variable differential transformer (LVDT), a load cell amplifier and a data acquisition system. Copper based small and thin (50 μm) tensile test samples were tested on this machine at room temperature, and the calculated results were compared with the test results derived from a commercial UTM (METEX - 1 kN) to justify the validation of the developed apparatus. The obtained mechanical properties are in good agreement with the values obtained from a commercial UTM. To confirm the possibility of in-situ microobservation, the surface roughness analysis has been conducted on the developed apparatus for pure copper foils under 3D laser-confocal microscope. Finally, it is concluded that this kind of testing apparatus could be manufactured within a manageable budget.

Miao Zhonghua et al, [13] The stress and displacement control of the universal testing machine in material testing is a complex process. In order to ensure the accuracy of the test control process, this paper uses the feedforward PID control algorithm to control the universal testing machine to achieve flexible and accurate control purposes. The hardware implementation of the feedforward PID control algorithm is implemented by FPGA, and an accurate and efficient control system is constructed. The actual test shows that the control system achieves good displacement and stress control effects on the universal testing machine, and the control performance is improved.

CHAPTER – 3

3.0 AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM

The purpose of this project report is the design and development of a micro universal testing machine for the precise and accurate measurement of mechanical properties of small samples with load capacities ranging from 1 N to 100 N. Affordable test systems that can be used for research and quality control purposes and can be used in a variety of industries.

3.2 OBJECTIVE

Micro universal testing machine is to provide a comprehensive overview of the instrument and its applications in materials science and engineering, highlighting its components, testing capabilities, limitations, future developments, and the importance of proper sample preparation and testing standards.

3.3 SCOPE OF THE PROJECT

- The mechanical properties (tensile, compressive, etc.) of a given specimen are tested on a micro universal testing machine through the activity of pliable, compressive or transverse stretch. This machine got its title since it can perform diverse tests on diverse sorts of materials. All tests are performed according to specific ASTM and ISO standards.
- The scope of the micro universal testing machine is broad, including materials science, mechanical engineering, microelectronics, and biomedical engineering, with diverse applications in various industries. The machine's testing capabilities and use of testing standards, as well as future developments in technology, are also within its scope.

CHAPTER – 4

4.0 MATERIALS AND EXPERIMENTAL METHODS

4.1 HARDWARE REQUIREMENTS

- PC
- Arduino uno
- Hx711(ADC)
- A4988 stepper motor driver
- Load cell (10kg)
- NEM917 Stepper motor

4.1.1 Analog-To-Digital Converter (HX711)

An Analog-to-Digital Converter (ADC) could be a gadget that changes over analog signals into advanced information. The HX711 is a specific type of ADC that is commonly used in applications such as load cells and strain gauges. The HX711 is a highly accurate, low-cost ADC that operates on a 2-wire interface (clock and data), making it easy to interface with microcontrollers or other digital systems. It has a programmable gain amplifier (PGA) that allows for amplification of the input signal, which is useful for applications where the input signal is small. The HX711 has a resolution of up to 24 bits, meaning it can convert an analog signal into a digital value with a very high degree of precision. It also has a built-in noise reduction circuit that helps to filter out external sources of noise and interference, ensuring that the output data is accurate and reliable. Overall, the HX711 is a versatile and reliable ADC that is well-suited for a wide range of applications that require high-precision analog-to-digital conversion, such as load cells and strain gauges.



Figure: 4.1 - HX711 (Analog-To-Digital Converter)

4.1.2 Stepper Driver (A4988)

The TB6600 is a stepper motor driver controller commonly used for precise control and high-performance driving of bipolar stepper motors. It operates with a power supply voltage typically ranging from 9V to 42V and can handle peak currents up to 4.5A. The controller supports microstepping, allowing for smoother and more precise motor movements with selectable resolutions from full-step to 1/32-step. It offers protection features such as overcurrent, over-temperature, and reverse polarity protection. Control of the TB6600 is achieved through a pulse and direction interface, where the direction pin determines motor rotation direction, and the pulse pin receives pulses for step control. Additional cooling may be required, depending on the current levels used. The TB6600 finds applications in CNC machines, 3D printers, robotics, and other systems that require accurate stepper motor control. Detailed instructions for configuration, wiring, and usage should be consulted in the manufacturer's datasheet and user manual.

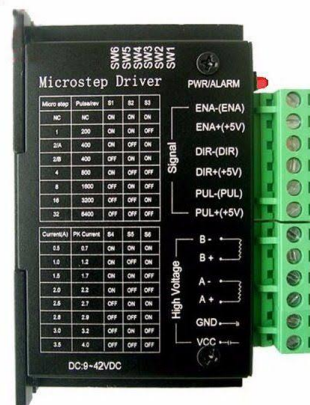


Figure: 4.2 - Stepper Driver

4.1.3 Stepper Motor

The Stepper motor could be a particular sort of stepper engine that's commonly utilized in different applications such as robotics, automation, and movement control frameworks. A stepper engine could be a sort of electric engine that moves in discrete steps instead of ceaselessly turning like a conventional motor. The stepper motor has a high torque-to-size ratio, making it suitable for applications that require high precision and control. It has a step angle of 1.8 degrees, meaning

it moves in 200 steps for a full rotation. The motor has four phases, and each phase is energized in a specific sequence to produce the desired motion. The stepper motor is a bipolar stepper motor, which means that it has two coils, and each coil must be driven separately. It requires a stepper driver, such as the A4988 driver.



Figure: 4.3 - Stepper Motor

4.1.4 Power Supply Unit (Arduino Uno)

The Arduino Uno can be powered using either an external power supply unit (PSU) or through the USB port from a computer. The recommended voltage for the external PSU is between 7 and 12 volts. When using an external PSU, the voltage is regulated by the onboard voltage regulator to provide a stable 5-volt supply to the board. The Arduino can also be powered using a 9-volt battery connected to the power jack on the board. However, in this case, the voltage regulation is the responsibility of the battery and not the onboard voltage regulator. The recommended voltage range for the external power supply unit (PSU) is between 7 and 12 volts, with a maximum limit of 20 volts. The power supply unit can be connected to the DC power jack on the board, which is located next to the USB port. When an external PSU is used, the board's onboard voltage regulator takes care of providing a stable 5-volt supply to the board. However, if the input voltage is close to the lower limit of the recommended range, the regulator may become less efficient, which may cause the board to malfunction. If the input voltage is above the recommended range, it can damage the board. The Arduino Uno can also be powered through the USB port from a computer. In this case, the voltage supplied to the board is typically 5 volts. However, the maximum current draw is limited by the USB specifications, which is typically around 500mA. it's

important to note that in this case, the voltage regulation is the responsibility of the battery and not the onboard voltage regulator. Therefore, the voltage supplied to the board may not be as stable compared to using an external PSU.

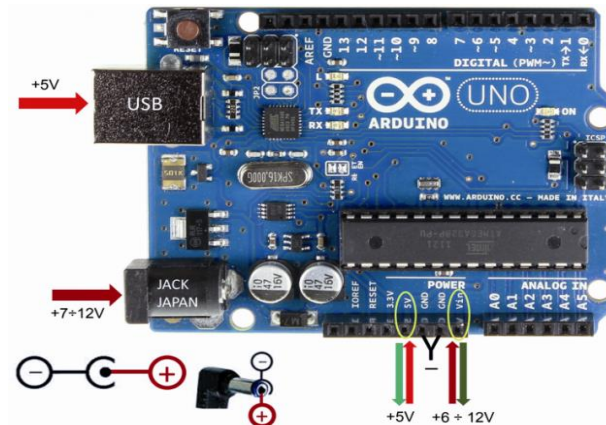


Figure: 4.4 – Arduino Uno Board

4.1.5 ATmega-328 Micro Controller

The ATmega-328 is basically an Progressed Virtual RISC (AVR) microcontroller. Underpins up to 8-bit information. The ATmega-328 has 32 KB of inside memory. This microcontroller has numerous other properties. The ATmega 328 has 1 KB of electrically erasable programmable read-only memory (EEPROM). This property appears that when control is expelled from the microcontroller, it can store information and give comes about indeed after control is connected. Also, the ATmega-328 has 2 KB of inactive arbitrary get to memory (SRAM). Other properties are portrayed afterward. The ATmega 328 has a few diverse highlights that make it one of the foremost prevalent gadgets on the showcase nowadays. These highlights incorporate progressed RISC engineering, amazing execution, moo control utilization, real-time counter with autonomous oscillator, 6 PWM pins, programmable serial USART, program bolt for computer program security, up to 20 MIPS It comprises of throughput, etc. ATmega-328 is basically utilized with Arduino. ATmega328 is an 8-bit microcontroller. It can handle information sizes up to 8 bits. AVR based microcontroller. Built-in memory is approximately 32KB. It works from 3.3V to 5V and has the capacity to hold information when control is expelled from the inclination terminals. Its extraordinary highlights incorporate

cost-effectiveness, microcontroller utilization, program boot for security purposes, and a real-time counter with free oscillator.

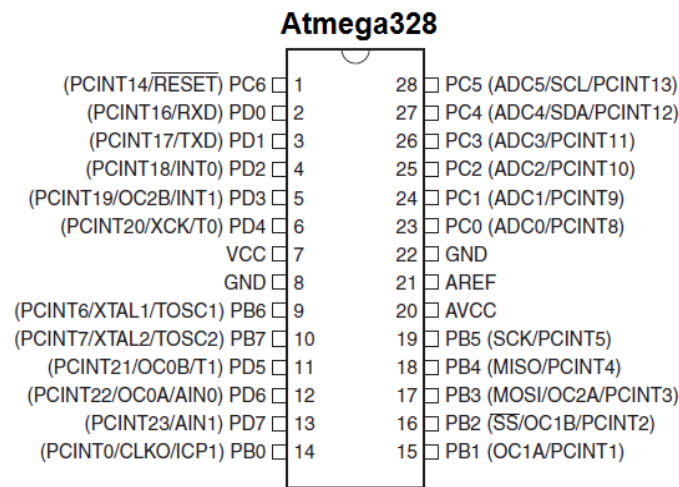


Figure: 4.5 - Pin Diagram of ATmega32

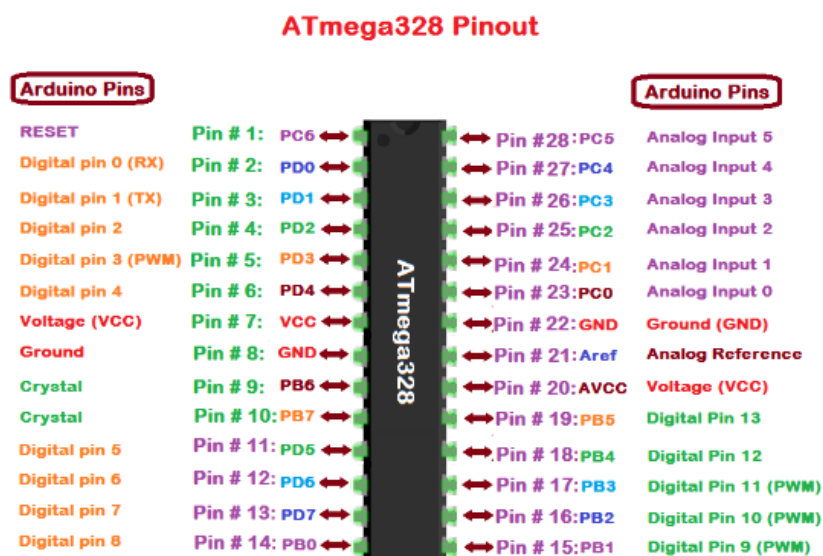


Figure: 4.6 – ATmega328 Pinout

4.1.6 ALU – Arithmetic Logic Unit

The Number juggling Rationale Unit (ALU) is an basic component of a CPU that performs number juggling and rationale operations on parallel information. The ALU is dependable for executing numerical operations, such as expansion, subtraction, increase, and division, as well as consistent operations, such as AND, OR, and NOT. The ALU comprises several registers, including an accumulator,

which stores intermediate results during computation. The control unit of the CPU is responsible for sending commands to the ALU, dictating which operation to perform and how to handle the data. During arithmetic operations, the ALU processes binary data by adding, subtracting, multiplying, or dividing the data. These operations involve shifting and complementing the data as needed to produce the desired result. For example, if the CPU needs to add two numbers, it sends the numbers to the ALU, which adds them together and stores the result in the accumulator. Logical operations involve comparing binary data and producing a logical result. For example, if the CPU needs to determine if two numbers are equal, it sends the numbers to the ALU, which compares them and produces a logical output of true or false. Logical operations are also used to manipulate individual bits within binary data. For example, the CPU can use a logical AND operation to clear a specific bit in a binary number. The ALU is designed to perform simple, low-level instructions quickly, making it a critical component of the CPU's overall performance. CPUs can vary in the number of bits that the ALU can process at once, with common sizes being 8, 16, 32, or 64 bits. The ALU could be a basic component of a CPU that performs number-crunching and rationale operations on double data. It comprises several registers, including an accumulator, and is controlled by the CPU's control unit. The ALU is designed to perform simple, low-level instructions quickly, making it a crucial factor in the CPU's overall performance.

4.1.7 Status Register

A Status Register, also known as a Flag Register, is a special enroll in a computer's central handling unit (CPU) that stores the results of arithmetic and logical operations. It is a set of binary flags that provide information about the state of the CPU and the outcome of the previous instruction. The Status Register typically contains a set of individual flag bits that are used to indicate specific conditions or events. The number and meaning of these flags can vary depending on the CPU architecture, but some common examples include:

1. Zero Flag (ZF): Indicates whether the result of an operation was zero. On the off chance that the result was zero, the hail is set to 1, something else, it is set to.

2. Carry Flag (CF): Indicates whether a carry occurred during an expansion or a borrow amid a subtraction operation.

3. Sign Flag (SF): Indicates whether the result of an operation was negative. If the result was negative, the flag is set to 1, otherwise, it is set to 0.

The Status Register is used by the CPU to make decisions about what to do next based on the outcome of previous instructions. For example, in conditional branches, the CPU checks the value of one or more flags in the Status Register to determine whether to execute the branch instruction or skip it. Programmers can also access the Status Register directly to check the status of the flags and modify them if necessary. This can be useful in situations where specific conditions need to be checked or set based on the outcome of previous instructions. In summary, the Status Register is a special register in a CPU that stores the comes about of math and coherent operations within the frame of individual flags. The flags provide information about the state of the CPU and the outcome of the previous instruction and are used by the CPU to make decisions about what to do next. Programmers can also access and modify the Status Register directly for specific purposes.

4.1.8 Global Interrupt Enable

Global Interrupt Enable (GIE) is a feature found in many microcontrollers and CPUs that allows interrupt requests to be enabled or disabled globally. Interrupts are a mechanism that allows the CPU to respond quickly to external events and perform tasks in real-time. When the GIE is enabled, the CPU can respond to interrupt requests, and interrupt service routines can be executed. Interrupts can be activated by equipment occasions, such as a button press or a flag from a sensor, or software events, such as a timer or a communication signal. When an interrupt occurs, the CPU pauses its current task and begins executing the interrupt service routine. Interrupts are typically given a priority level, which determines which interrupt will be handled first in the event of multiple interrupts occurring simultaneously. The GIE feature allows the programmer to control the flow of interrupts and determine when they are allowed to occur. Disabling the GIE prevents any interrupts from being handled, allowing the CPU to focus on its current task without being interrupted. Enabling the GIE allows the CPU to

respond to interrupt requests and perform the necessary interrupt service routines. The GIE feature is particularly important in real-time systems, where quick response times are critical. By enabling and disabling interrupts as needed, the programmer can ensure that the system is responsive to external events while also ensuring that critical tasks are not interrupted unnecessarily. The Global Interrupt Enable is a feature found in many microcontrollers and CPUs that allows interrupt requests to be enabled or disabled globally. It allows the programmer to control the flow of interrupts and determine when they are allowed to occur, which is particularly important in real-time systems.

4.1.9 Copy Storage

The BLD (Bit Stack) and BST (Bit STore) instructions are used to manipulate individual bits within registers in the Register File of a microcontroller or CPU. These instructions utilize the T-bit as the source or goal for the worked bit. The BST instruction duplicates a bit from a enlist within the Enroll Record into the T-bit. The BLD instruction duplicates a bit from the T-bit into a bit in a enroll within the Enroll Record. The T-bit is a temporary register that is often used in bit manipulation operations. It is a single-bit register that can hold the value of a bit that has been extracted from a register in the Register File or is being prepared for insertion into a register. By using the BLD and BST instructions, programmers can manipulate individual bits within a register without affecting the other bits in the register. This can be useful in situations where specific flags or status bits need to be set or cleared based on certain conditions. In summary, the BLD and BST instructions use the T-bit as a temporary register for manipulating individual bits within registers in the Register File of a microcontroller or CPU. The T-bit can hold the value of a bit that is being extracted from or prepared for insertion into a register, allowing programmers to manipulate specific bits without affecting the other bits in the register.

4.1.10 Stack Pointer

The Stack Pointer (SP) could be a enlist in a computer framework that's utilized to keep track of the area of the last value that was included to the stack. The stack may be a information structure that's utilized to store brief information and return addresses when a work is called. When a work is called, the current esteem of the

Program Counter (PC) is pushed onto the stack, in conjunction with any parameters that were passed to the work. This makes a modern stack outline, which contains the local variables and any other information that's required by the work. As the work executes, it may thrust extra values onto the stack or pop values off the stack because it completes operations or returns values. The Stack Pointer is utilized to keep track of the current best of the stack, which is the area of the foremost as of late pushed esteem. When the work returns, the return address is popped off the stack and the Stack Pointer is overhauled to point to the following esteem within the stack. This permits the program to continue execution from the point where it cleared out off some time recently the work was called. The Stack Pointer is a critical component of many computer systems, particularly those that use a stack-based architecture. It is used extensively in high-level programming languages and is essential for managing the flow of data and control in complex software applications. The Stack Pointer is a register that is used to keep track of the location of the most recently pushed value on the stack in a computer system. It is essential for managing the flow of data and control in complex software applications and is used extensively in high-level programming languages.

4.1.11 Reset and Interrupt Handling

Reset and Interrupt Handling are two important concepts in computer systems that ensure proper operation and prevent errors. A Reset is a process of restoring a system or device to its original state. In microcontrollers and CPUs, a reset is typically used to initialize the system and ensure that it is in a known state before executing the main program. The reset process typically involves setting the program counter and other registers to their initial values and clearing the memory and peripheral devices. In embedded systems, a reset may be triggered by a hardware signal, a software command, or a power-on event. Interrupt Handling is a mechanism that allows a system to respond to external events or signals quickly and efficiently. Interrupts are signals that are sent by external devices, such as sensors, timers, or communication interfaces, to notify the system of an event that requires immediate attention. Interrupts allow the system to perform time-critical tasks without wasting CPU cycles persistently surveying the input gadgets. When an hinder happens, the CPU incidentally suspends its current assignment and executes an Hinder Benefit Schedule (ISR) to handle the occasion. Once the ISR

is complete, the CPU resumes the interrupted task. Reset and Interrupt Handling are related concepts because both involve the manipulation of the CPU's program flow and registers. After a reset, the system typically enables the interrupts and sets up the Interrupt Vector Table (IVT), which is a table that contains the addresses of the ISR for each interrupt. When an interrupt occurs, the CPU looks up the ISR address in the IVT and jumps to the appropriate routine. In summary, Reset and Interrupt Handling are critical concepts in computer systems that ensure proper operation and prevent errors. Reset initializes the system to a known state, and Interrupt Handling allows the system to respond to external events quickly and efficiently. Both concepts involve the manipulation of the CPU's program flow and registers and are essential for the proper functioning of microcontrollers and CPUs.

4.2 MEMORY DESCRIPTION

The ATmega 328 has three types of memory. EEPROM, SRAM, etc.

4.2.1 Flash Memory

Flash memory is a type of non-volatile computer memory that can be electrically erased and reprogrammed. It is commonly used in microcontrollers, digital cameras, USB flash drives, and other electronic devices where data needs to be stored permanently or semi-permanently. Flash memory operates by using an array of memory cells that can store a binary value of 0 or 1. Each memory cell consists of a floating-gate transistor that can hold an electrical charge. When a voltage is applied to the gate of the transistor, electrons are either trapped or released from the floating gate, which changes the charge and thus the value stored in the memory cell. To write data to a flash memory cell, a high voltage is applied to the cell's control gate, which allows electrons to tunnel through a thin insulating layer and onto the floating gate. To erase the cell, a higher voltage is applied to the control gate, which removes the charge from the floating gate and restores the cell to its default state. Flash memory has several advantages over other types of non-volatile memory, such as EEPROM and EPROM. It is faster, more reliable, and requires less power to operate. It is also less expensive to manufacture and can store a larger amount of data in a smaller physical space. In

addition to its use in electronic devices, flash memory is also commonly used in solid-state drives (SSDs) and other high-performance storage devices. It is also used in some microcontrollers as program memory or to store configuration data. Flash memory is a type of non-volatile computer memory that can be electrically erased and reprogrammed. It operates by using an array of memory cells that can store a binary value of 0 or 1, and it is commonly used in electronic devices, SSDs, and high-performance storage devices. Flash memory is faster, more reliable, and requires less power to operate than other types of non-volatile memory, and it can store a larger amount of data in a smaller physical space.

4.2.2 Static Random Access Memory (SRAM)

Static Random Access Memory (SRAM) may be a sort of volatile computer memory that stores information employing a network of flip-flops, which are basic logic circuits that can hold a binary state of 0 or 1. SRAM is commonly used in microprocessors, cache memory, and other high-speed applications where fast access to data is required. SRAM operates by using a combination of transistors and capacitors to store data. Each memory cell in an SRAM chip consists of six transistors and two capacitors, which form a flip-flop that can store a binary value. The state of the flip-flop is determined by the charges stored on the two capacitors, which represent the two possible values of 0 or 1. One advantage of SRAM is its fast access time, which is typically measured in nanoseconds. This makes it ideal for use in microprocessors and other high-speed applications that require fast access to data. Additionally, SRAM does not require refreshing, as it does not rely on a charge that leaks away over time, unlike Dynamic Random Access Memory (DRAM). However, SRAM has some disadvantages as well. It is more expensive than other types of memory, such as DRAM, and it requires more power to operate. SRAM also has a lower storage density, meaning that it can store less data in a given physical space than other types of memory. In summary, SRAM is a type of volatile computer memory that stores data using a network of flip-flops. It is commonly used in microprocessors, cache memory, and other high-speed applications that require fast access to data. While SRAM has some advantages, such as its fast access time and lack of need for refreshing, it is more expensive and requires more power to operate than other types of memory.

4.2.3 Electrically Erasable Programmable Read Only Memory (EEPROM)

Electrically Erasable Programmable Examined As it were Memory (EEPROM) could be a sort of non-volatile computer memory that can be electrically modified and deleted. EEPROM is commonly utilized in microcontrollers, embedded systems, and other electronic devices where data needs to be stored semi-permanently and updated as needed. EEPROM operates by using a grid of memory cells that can store a binary value of 0 or 1. Each memory cell consists of a floating-gate transistor that can hold an electrical charge. To write data to an EEPROM cell, a high voltage is applied to the cell's control gate, which allows electrons to tunnel through a thin insulating layer and onto the floating gate, thereby changing the charge and thus the value stored in the memory cell. To erase the cell, a higher voltage is connected to the control door, which expels the charge from the floating gate and restores the cell to its default state. One advantage of EEPROM is its ability to be reprogrammed multiple times, which makes it ideal for use in applications where data needs to be updated as needed. EEPROM is also less expensive and requires less power to operate than other types of non-volatile memory, such as Flash memory. However, EEPROM has some disadvantages as well. It has a slower access time than other types of memory, such as SRAM, and it has a limited lifespan, meaning that it can only be reprogrammed a certain number of times before it begins to degrade. Additionally, EEPROM has a lower storage density than other sorts of memory, such as Streak memory. In summary, EEPROM could be a sort of non-volatile computer memory that can be electrically modified and deleted. It is commonly utilized in microcontrollers, implanted frameworks, and other electronic gadgets where information needs to be stored semi-permanently and updated as needed. While EEPROM has some advantages, such as its ability to be reprogrammed multiple times and its lower cost and power requirements, it also has some disadvantages, such as its slower access time and limited lifespan.

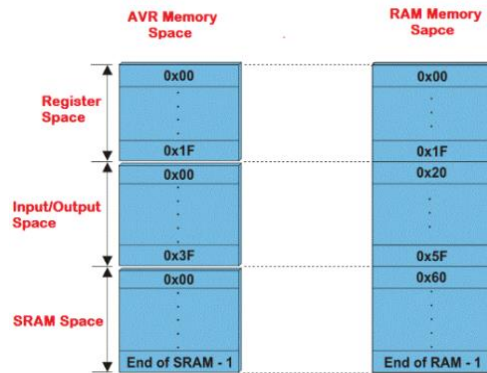


Figure: 4.7– EEPROM (Electrically Erasable Programmable Read Only Memory)

4.2.4 Registers

- Registers are little, quick capacity units found interior the CPU.
- Registers are utilized to hold information and instructions that are being processed by the CPU.
- Registers are organized into different types, each with a specific purpose, such as holding data, holding addresses, or holding instructions.
- Registers are faster than other types of computer memory, such as RAM or disk storage, because they are located inside the CPU and have very short access times.

7	0	Addr.
R0		0x00
R1		0x01
R2		0x02
...		
R13		0x0D
R14		0x0E
R15		0x0F
R16		0x10
R17		0x11
...		
R26		0x1A
R27		0x1B
R28		0x1C
R29		0x1D
R30		0x1E
R31		0x1F

Figure: 4.8 – Registers

4.2.5 ATmega328 and Arduino

- The ATmega328 is an 8-bit microcontroller chip developed by Atmel Corporation. It is part of the AVR family of microcontrollers and is based on the Harvard architecture.
- The ATmega328 contains a clock speed of up to 20 MHz and can operate on a voltage range of 1.8V to 5.5V.
- It has 32 KB of streak memory, 2 KB of SRAM, and 1 KB of EEPROM.
- The ATmega328 includes a number of built-in peripherals, including 6 analog-to-digital converter (ADC) channels, 3 timers, and several communication interfaces such as SPI, I2C, and USART.



Figure: 4.9 - ATmega328 and Arduino

4.2.6 Universal Asynchronous Receiver/Transmitter (UART)

A Widespread Non concurrent Receiver/Transmitter (UART) may be a sort of computer equipment gadget that's utilized for serial communication. It is commonly found in microcontrollers, embedded systems, and other electronic devices that require communication with other devices or systems. Here is a detailed explanation of how UART works:

1. Overview: A UART is responsible for converting parallel data from a computer or microcontroller into serial data for transmission over a communication line, and vice versa. UARTs are typically used to communicate with other electronic devices, such as modems, GPS receivers, and other microcontrollers.

2. Components: A typical UART consists of a transmitter, a receiver, and a buffer. The transmitter is responsible for converting parallel information into serial information and transmitting it over a communication line. The receiver is responsible for receiving serial data and converting it back into parallel data. The buffer is used to temporarily store data during the transmission or reception process.

3. Baud Rate: The baud rate is the speed at which information is transmitted over a communication line. It is measured in bits per second (bps). The baud rate is typically set by a software program or by a configuration register in the UART device. The baud rate must be set to the same value on both the transmitting and receiving devices in order for successful communication to occur.

4. Error Detection and Correction: UARTs include several features for error detection and correction, such as parity checking and framing errors. Parity checking is a method of detecting errors in transmitted data by adding an extra bit to each data packet. Framing errors occur when a data packet is incorrectly framed, such as when the begin and halt bits are lost or within the off-base position.

5. Flow Control: Stream control could be an instrument for overseeing the stream of information between two gadgets. UARTs incorporate a few stream control instruments, such as equipment stream control and program stream control. Equipment stream control is overseen by the RTS (Request to Send) and CTS (Clear to Send) signals, whereas program stream control is managed by the XON and XOFF characters. UARTs are a critical component in modern computer systems and electronic devices, providing reliable and efficient serial communication between devices. Flow control mechanisms are essential in scenarios where data is transmitted over a limited bandwidth or where the receiving device may not be able to process incoming data as fast as it is being sent. Without flow control, data packets may be dropped, leading to errors, retransmissions, and inefficient data transfer.

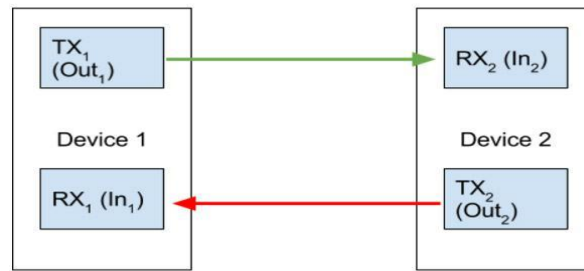


Figure: 4.10 - Hardware connection diagram for UART

The equipment association graph for UART typically involves connecting the transmitter and receiver pins of the UART device to the corresponding pins on the receiving device or system.

Here is a detailed explanation of the hardware connection diagram for UART:

1. **UART Device:** The UART device typically has four pins: TXD (transmitter), RXD (receiver), GND (ground), and VCC (power supply). The TXD stick is utilized to transmit serial information to the getting gadget or framework, whereas the RXD stick is utilized to get serial information from the accepting gadget or framework. The GND stick is associated to the ground of the getting gadget or framework, whereas the VCC stick is associated to the control supply of the UART device.
2. **Receiving Device:** The receiving device or system also typically has four pins: TXD (transmitter), RXD (receiver), GND (ground), and VCC (control supply). The TXD stick of the getting gadget is associated to the RXD stick of the UART gadget, whereas the RXD stick of the getting gadget is associated to the TXD stick of the UART gadget. The GND stick of the accepting gadget is associated to the GND stick of the UART gadget, whereas the VCC stick of the getting gadget is associated to the VCC stick of the UART gadget.
3. **Serial Communication Line:** The UART device and the receiving device or systems are typically connected using a serial communication line, such as a twisted pair cable or a USB cable. The serial communication line is utilized to transmit and get the serial information between the two gadgets.

4. Configuring the UART: Before communication can occur between the UART gadget and the getting gadget or system, the UART device must be configured to the correct baud rate, data format, and flow control settings. This can be done using a software program or by configuring the UART device using configuration registers.

The hardware connection diagram for UART involves connecting the transmitter and receiver pins of the UART device to the corresponding pins on the receiving device or system, and configuring the UART device to the correct settings. This enables reliable and efficient serial communication between the two devices.

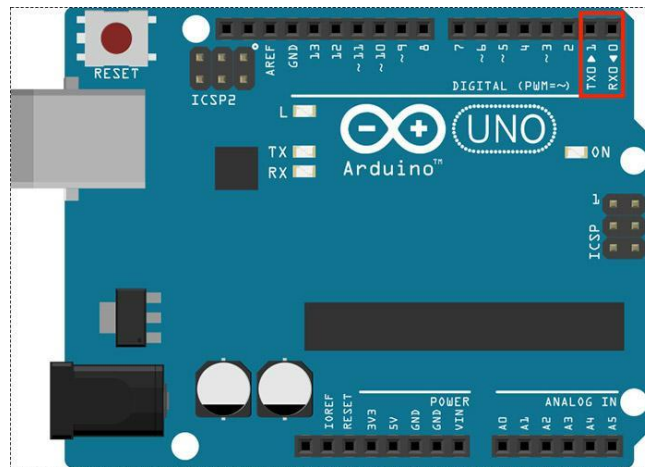


Figure: 4.11 - GPIO 0 and GPIO 1 are Serial RX and TX. Any GPIO pin can be used as Serial RX or TX with the Software Serial library

GPIO stands for General Purpose Input/Output. These are digital pins on a microcontroller, such as an Arduino, that can be configured to either input or output a digital signal. In other words, they can either read digital signals from sensors or other devices, or they can send digital signals to control actuators or other devices. In many microcontrollers, including the ATmega328P used in the Arduino Uno, GPIO pins are multiplexed with other capacities such as Analog-to-Digital Converters (ADCs), Pulse-Width Balance (PWM) outputs, and Serial communication pins. This means that a single pin can be used for multiple functions, depending on how it is configured. GPIO 0 and GPIO 1 are two specific pins on the ATmega328P that are dedicated to Serial communication, and are typically used as the Serial RX and TX pins when using the hardware Serial port.

The hardware Serial port provides a fast and reliable way to communicate with other devices, such as a computer or another microcontroller. However, it is also possible to use any other GPIO pin on the ATmega328P for Serial communication utilizing the Computer program Serial library. This library permits the client to indicate any two GPIO pins as the RX and TX pins for Serial communication. Whereas the Program Serial library is not as fast or reliable as the hardware Serial port, it provides a way to use additional GPIO pins for Serial communication when the hardware Serial port is already in use. When using GPIO pins for input, it is important to remember that they are digital and can only read high or low signals. This means that they cannot read analog signals directly, but can be used in conjunction with ADCs to read analog signals by converting them to digital signals. Additionally, input pins may need to be pulled up or pulled down with resistors to avoid floating inputs. When using GPIO pins for output, it is important to remember that they can only drive a limited amount of current. To drive larger loads such as motors or LEDs, it may be necessary to use additional components such as transistors or relays to handle the current. PWM outputs can also be used to control the brightness of LEDs or the speed of motors by rapidly switching the output on and off. Overall, GPIO pins provide a flexible and versatile way to interface with the physical world using a microcontroller. With careful configuration and use of additional components when necessary, they can be utilized to control a wide extend of sensors, actuators, and other gadgets.

A UART data packet looks like this:

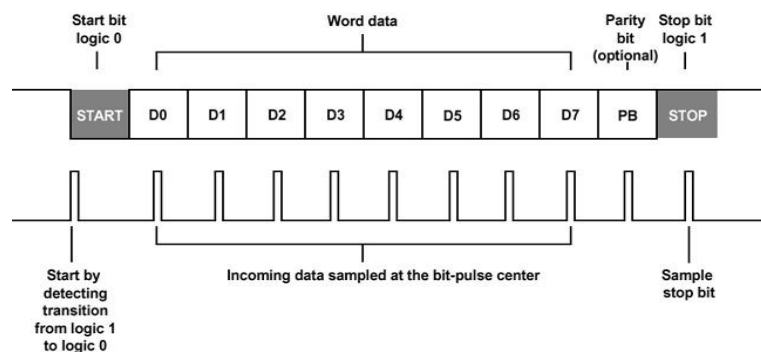


Figure: 4.12 - UART Data packet visualized / ©electric imp

UART (All inclusive Offbeat Receiver/Transmitter) may be a common communication convention utilized to transmit and get serial information between microcontrollers, sensors, and other electronic devices. The UART data packet is a series of bits that are transmitted one after the other, without any clock signal to synchronize the data transfer. Each data packet typically includes a start bit, information bits, an discretionary equality bit, and one or more halt bits. The begin bit is continuously a rationale moo flag and shows the start of a new data packet. It is followed by the data bits, which can be any number of bits from 5 to 9 depending on the UART arrangement. The information bits are taken after by an discretionary equality bit, which is utilized for mistake checking and can be set to indeed, odd, or no equality. At long last, one or more halt bits are sent to show the conclusion of the information bundle. Stop bits are always a logic high signal. To visualize the UART data packet, imagine a series of square waves with varying durations and voltages. The start bit is a square wave with a low voltage, followed by a series of square waves representing the data bits. The number of data bits can vary, but typically ranges from 5 to 9. The optional parity bit is typically added after the data bits, and it is a square wave with a low or high voltage depending on the parity setting. Finally, one or more stop bits are added to indicate the end of the data packet. The stop bits are square waves with a high voltage and their duration depends on the UART configuration. When the UART receiver receives a data packet, it looks for the start bit to begin capturing the data. Once the start bit is detected, the receiver begins capturing the data bits, optionally checking the parity bit, and finally detecting the stop bits to complete the data packet. The receiver then processes the data and may generate an interrupt or other signal to indicate that new data is available. The UART data packet is a simple yet versatile communication protocol that enables serial data transfer between electronic devices.. The data bits can vary in length, and the parity bit can be used for error checking. The start and stop bits are always fixed, with the start bit being a low voltage square wave and the stop bit(s) being a high voltage square wave.

The UART protocol is commonly used in embedded systems, such as microcontrollers and sensors, to transmit and receive data over serial communication channels. The UART protocol is asynchronous, which means that data is transmitted without a common clock signal between the transmitter and

receiver. Instead, the timing of the data transmission is based on the baud rate, which is the rate at which bits are transmitted over the communication channel. In addition to the standard UART protocol, and the LIN (Local Interconnect Network) protocol. The USART protocol extends the UART protocol by providing the ability to use synchronous communication, while the LIN protocol is a specialized variant used for automotive applications. In terms of hardware, UART communication typically involves connecting the TX (transmit) and RX (receive) pins of the UART-enabled devices. In some cases, the UART signals may need to be converted to different voltage levels using level shifters or transceivers, especially when communicating between devices with different voltage requirements. Overall, the UART protocol is a widely used and reliable communication protocol in embedded systems, with a range of different configurations and hardware implementations available. Particularly in embedded systems. It is a simple and reliable serial communication protocol that enables data transmission between devices using only a few wires, typically TX (transmit), RX (receive), and ground. UART is widely used in applications such as microcontrollers, sensors, and various other electronic devices, where serial communication is required.

Table: 4.1 C++ Reference for Initializing and Using Arduino Serial and Software Serial

Serial and software Serial purpose method	Code	Explanation
Constructor (Software Serial only)	Defines the GPIO pins that act as UART RX and TX lines software. serial communication (2, 3);	Define a serial connection between the RX line of GPIO 2 and the TX line of GPIO 3.

Begin	Defines the baud rate (transmission speed) of the serial connection in the range of 4800 to 115200 communications. Start (9600);	Communication via the serial "Comms" port is at 9600 baud.
Print	comms.println Writes human-readable byte data over a serial link. ("Hello World");	Writes bytes corresponding to Hello World (human readable characters)
Write	Write raw byte data over serial link comms.write(45).	Write the byte with value 45.
available	If (comms.available()) evaluates to true if data is available over the serial link.	Enter an if statement if the data can be read over the serial connection.
Read	comms.read(); to read data from a serial connection	read from serial connection

UART (Universal Asynchronous Receiver/Transmitter) is a half-duplex communication protocol. This means that data can only be transmitted in one direction at a time. When transmitting data, the UART transmitter sends data to the UART receiver, which cannot transmit data at the same time. Once the transmission is complete, the roles of the transmitter and receiver can switch, allowing for bidirectional communication. This half-duplex nature of UART is due to the fact that the protocol uses only two wires (TX and RX) for communication, and

does not include a separate wire for simultaneous transmission in both directions, as is the case with full-duplex communication protocols.

The half-duplex nature of UART makes it well-suited for applications where bidirectional communication is not required, or where only occasional transmissions are needed. It is commonly used in embedded systems where resources are limited, and where real-time communication is not critical. The UART protocol is also popular in computer communication applications, such as serial ports and RS-232 connections. One advantage of the half-duplex nature of UART is that it simplifies the hardware required for implementing the protocol. Because there is no need for separate wires for simultaneous transmission in both directions, fewer wires and hardware components are required. This makes UART a cost-effective and efficient solution for many applications. However, the half-duplex nature of UART also has some limitations. For example, in applications where real-time communication is critical or where high data transfer rates are required, full-duplex communication protocols may be a better choice. Additionally, because UART only supports communication between two devices, it may not be suitable for applications where communication between multiple devices is required. In such cases, other communication protocols such as SPI or I2C may be more appropriate.

4.2.7 Serial Peripheral Interface (SPI)

There are some key points about Serial Peripheral Interface (SPI):

1. Data is transmitted and received in a "shift register" format, where data is shifted bit by bit in both the transmitting and receiving devices.
2. SPI can be configured to use different clock frequencies, data formats, and modes depending on the requirements of the application.
3. SPI is commonly used in applications such as sensor interfaces, memory devices, and display drivers.
4. However, SPI is faster and more flexible than UART, making it suitable for applications where high data transfer rates and complex data formats are required.

5. Additionally, SPI can support multiple slave devices connected to the same bus, making it suitable for applications where multiple devices need to communicate with a single controller.

6. SPI is a versatile and widely used communication protocol that provides a reliable and efficient way to communicate between microcontrollers and other embedded devices.

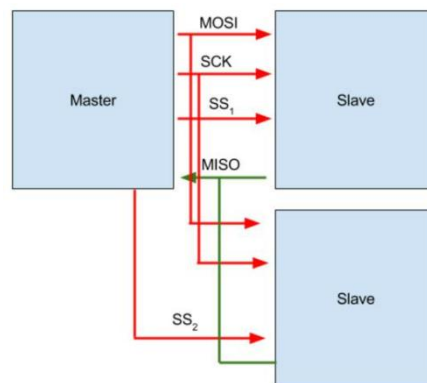


Figure: 4.13 - Slaves connected to a single master

In an SPI communication setup, multiple slave devices can be connected to a single master device. The master device is responsible for controlling the communication with each slave device, selecting one at a time to exchange data. When a master wants to communicate with a specific slave, it sends a signal on the Slave Select (SS) line to select that particular slave. The SS line is typically active low, which means that when it is pulled low, it indicates to the slave device that the master wants to communicate with it. The other slave devices, whose SS lines are not selected, remain inactive during this time. Once the master has selected a particular slave, it can then send data to or receive data from that slave using the MOSI and MISO lines. The clock signal on the SCLK line ensures that the data transfer is synchronized between the master and slave. After the data transfer is complete, the master can release the SS line, which signals to the selected slave device that the communication session is over. The master can then select another slave device and repeat the process. This approach of connecting multiple slave devices to a single master allows for efficient

communication between devices while using minimal wires or points. However, it is important to ensure that the SS lines of each slave device are properly managed to avoid conflicts or errors in communication.

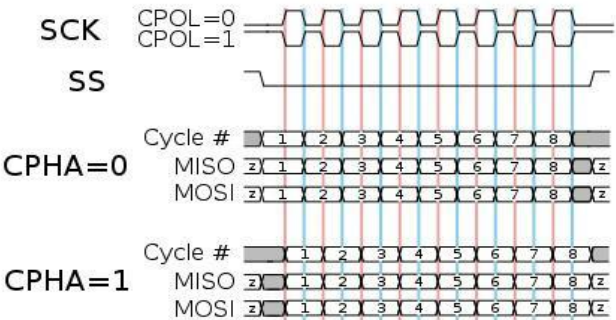


Figure: 4.14 - CPOL and CPHA settings visualized

CPOL and CPHA are two settings that define the clock signal used by SPI (Serial Peripheral Interface) communication. CPOL (Clock Polarity) determines the idle state of the clock signal, which is the state of the clock when no data is being transferred. CPOL has two possible settings: CPOL = 0: The idle state of the clock signal is low (0). CPOL = 1: The idle state of the clock signal is high (1). CPHA (Clock Phase) determines when the data is sampled on the clock signal. CPHA also has two possible settings: CPHA = 0: Data is sampled on the leading (first) edge of the clock signal, which is the transition from the idle state to the active state. CPHA = 1: Data is sampled on the trailing (second) edge of the clock signal, which is the transition from the active state to the idle state.

Table: 4.2 - Four different combinations of CPOL and CPHA

	CPHA = 0 (“first edge” of the clock signal)	CPHA = 1 (“second edge” of the clock signal)
CPOL = 0 (idle 0)	• “SPI mode 0” • Data collection begins when the clock first transitions from 0 (idle) to 1. • Data acquisition occurs	• “SPI mode 1” • Data collection begins when the clock first transitions from 0 (idle) to 1. • Data acquisition occurs at

	on the rising edge of the clock signal (0→1).	the falling edge of the clock signal (1→0).
CPOL = 1 (idle 1)	• “SPI mode 2” • Data collection begins when the clock first goes from 1 (idle) to 0. • Data acquisition occurs on the rising edge of the clock signal (0→1).	• “SPI mode 3” • Data collection begins when the clock first goes from 1 (idle) to 0. • Data acquisition occurs at the falling edge of the clock signal (1→0).

In SPI communication, the Clock Extremity (CPOL) and Clock Stage (CPHA) are two parameters that decide the timing and edge of the clock flag. There are four unmistakable combinations of CPOL and CPHA that can be utilized in SPI communication, each with their own advantages and disadvantages:

Mode 0: CPOL = 0, CPHA = 0 - In this mode, the clock signal is idle low (CPOL = 0) and data is sampled on the leading edge of the clock signal (CPHA = 0). This is the most common mode used in SPI communication.

1. Mode 1: CPOL = 0, CPHA = 1 - In this mode, the clock signal is idle low (CPOL = 0) and data is sampled on the trailing edge of the clock signal (CPHA = 1).

2. Mode 2: CPOL = 1, CPHA = 0 - In this mode, the clock signal is idle high (CPOL = 1) and data is sampled on the leading edge of the clock signal (CPHA = 0).

3. Mode 3: CPOL = 1, CPHA = 1 - In this mode, the clock signal is idle high (CPOL = 1) and data is sampled on the trailing edge of the clock signal (CPHA = 1).

The choice of which mode to use depends on the specific requirements of the SPI devices being used. Some devices may require a specific mode to operate

correctly or may be more tolerant to noise in certain modes. It is important to carefully read the datasheets of the devices being used and configure the SPI communication accordingly.

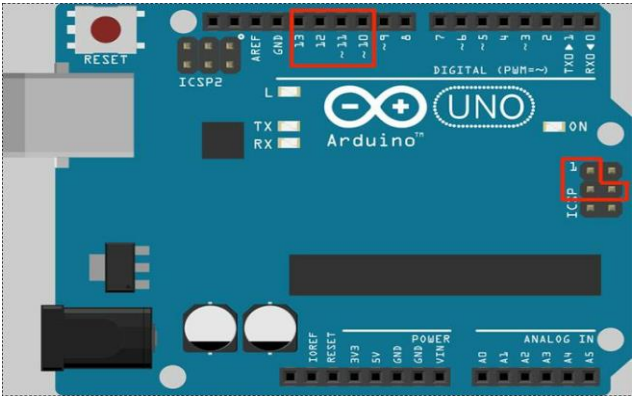


Figure: 4.15 - The MOSI, MISO, and SCK pins are broken out on the ICSP headers as well as on GPIO 11, GPIO 12, and GPIO 13

MOSI, MISO, and SCK are the three signals used in SPI (Serial Peripheral Interface) communication protocol. MOSI stands for Master Out Slave In, MISO stands for Master In Slave Out, and SCK stands for Serial Clock. ICSP (In-Circuit Serial Programming) headers are used to program microcontrollers in-circuit. These headers provide direct access to the programming pins of the microcontroller.

Table: 4.3 - C++ reference for initializing and using the Arduino SPI.

SPI Method Purpose	Code	Explanation
Constructor	Defines the clock speed, data bit order (most significant bit first or least significant bit first). and SPI mode SPI. begin Transaction (SPISettings (14000000, MSBFIRST,	SPI mode 0 defines a 14MHz SPI connection, data transfer is MSB first

	SPI_MODE0));	
Digital Write	Selects the slave device connected to this GPIO pin digital write (10, LOW).	To select a slave device, set the GPIO pin low. Then move the pen up to deselect the slave.
Transfer	Transfer bytes to the selected slave SPI. send (0x00);	Send value 0 as bytes
End Transaction	End an SPI transaction (must be called after digitalWrite(high) is called on the SS line) SPI.endTransaction	end the SPI transaction

SPI (Serial Peripheral Interface) is a full-duplex communication protocol. This means that data can be transmitted simultaneously in both directions between the master and slave devices. In SPI communication, data is transferred in a synchronized way between the master and slave devices. The master sends data on the MOSI (Master Out Slave In) line, and at the same time, the slave sends data on the MISO (Master In Slave Out) line. The clock signal on the SCLK (Serial Clock) line ensures that the data transfer is synchronized between the master and slave. Because SPI is full-duplex, both the master and slave devices can transmit and receive data at the same time. The full-duplex nature of SPI makes it well-suited for applications where both high-speed data transfer and bi-directional

communication are required, such as in data acquisition systems, sensor networks, and memory devices. However, it's important to ensure that the data transfer rates between the master and slave devices are properly matched to prevent data loss or errors.

4.2.8 Inter-integrated circuit (I²C)

Inter-Integrated Circuit (I²C) could be a serial communication convention utilized for low-speed communication between microcontrollers, sensors, and other gadgets . I²C uses a simple two-wire interface consisting of a data line (SDA) and a clock line (SCL). The SDA line is bidirectional and is used for transmitting and receiving data between devices, while the SCL line is used to synchronize the data transfer between the devices. In I²C communication, devices are connected in a master-slave configuration, where one device acts as the master and the others act as slaves. The master device initiates and controls the communication with the slave devices by sending start and stop conditions on the bus. If the slave device acknowledges the address, the master can then transfer data to or from the slave device by toggling the SCL line and transmitting data on the SDA line. Once the data transfer is complete, the master sends a stop condition on the bus to indicate that the communication session is over. I²C supports various speeds ranging from 100 Kbps to 5 Mbps, depending on the capabilities of the devices involved. It also supports multi-master configurations, where multiple master devices can communicate on the same bus. Overall, I²C is a simple and versatile communication protocol that is widely used in embedded systems and other electronic devices. It provides a low-cost, low-speed communication option that is well-suited for connecting a wide range of devices together.

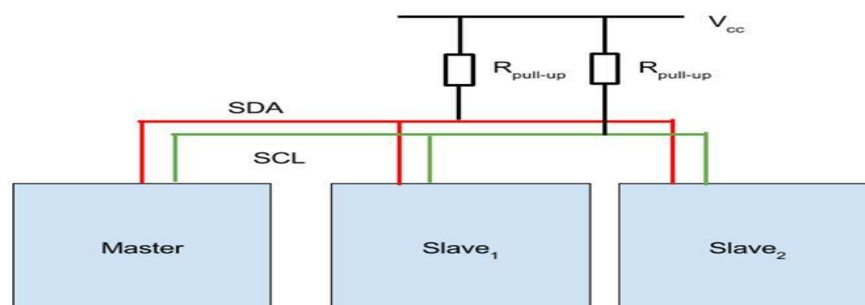


Figure: 4.16 - I²C hardware connection diagram

In I²C communication, devices are connected together in a bus topology, with multiple devices connected to the same two-wire interface. The hardware connection diagram for an I²C system typically consists of the following components:

- Master device:** The master device is the device that initiates and controls the communication on the I²C bus. It is responsible for generating the clock signal and sending start and stop conditions on the bus.
- Slave devices:** Slave devices are the devices that receive commands and data from the master and send back responses. Multiple slave devices can be connected to the same bus, each with its own unique address.
- SDA line:** The SDA (Serial Data) line is used for bidirectional communication between the master and slave devices. This line carries the data that is being transferred between the devices. The master generates clock pulses on this line to indicate the timing of the data transfer.
- Pull-up resistors:** Pull-up resistors are used to ensure that the SDA and SCL lines are in the high state when no devices are actively transmitting on the bus. These resistors are typically connected to the SDA and SCL lines between the devices and the power supply.

To connect devices in an I²C system, the SDA and SCL lines are connected to each device in parallel, with each device connected to the same two lines. The master device then communicates with each slave device on the bus by sending commands and data over the SDA line while generating clock pulses on the SCL line. Each device on the bus has a unique 7-bit address that is used by the master to identify and communicate with the device. The first byte transmitted by the master on the bus is the slave device address, followed by a read/write bit indicating whether the master wants to read or write data. The hardware connection for an I²C system is simple and flexible, making it a popular choice for low-speed communication between microcontrollers, sensors, and other devices.

For Arduino Uno, connect as follows:

- **SDA:** Analog Pin 4
- **SCL:** Analog Pin 5

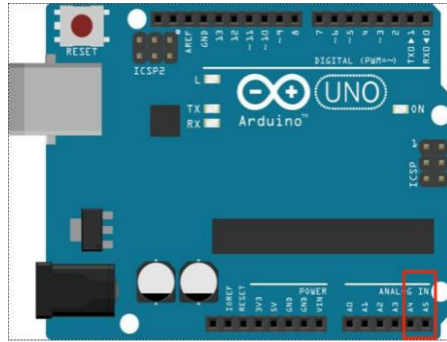


Figure: 4.17 - I²C (Wire) SDA is Analog Pin 4 (A4). SCL is Analog Pin 5 (A5).

In Arduino boards, the Wire library is used to implement I²C communication. The SDA and SCL lines for the I²C transport are associated to specific pins on the Arduino board. In the case of the Arduino Uno and other similar boards, the SDA line is associated to analog stick 4 (A4), whereas the SCL line is associated to analog stick 5 (A5). These pins are labeled as A4 and A5 on the board and are located next to the digital pins. Although these pins are labeled as analog pins, they can be utilized for both analog and computerized input and yield operations. In the case of I²C communication, they are configured to operate as digital pins and the I²C bus. When using the Wire library in Arduino, The library provides functions for sending and accepting information over the transport. The library takes care of producing the clock beats and sending begin and halt conditions on the transport, making it easy to implement I²C communication on the Arduino platform.

I²C communication is a popular protocol for connecting microcontrollers, sensors, and other devices in embedded systems. It uses a simple two-wire interface, consisting of a serial information (SDA) line and a serial clock (SCL) line, to transmit information between gadgets. The I²C convention requires that each gadget on the transport includes a interesting 7-bit or 10-bit address that's utilized to recognize the gadget and start communication. The ace gadget sends a begin condition on the transport, taken after by the gadget address and a read/write bit to show the course of information exchange. The slave device responds with an acknowledgement (ACK) bit, and the master and slave exchange data over the

SDA line while synchronized by clock pulses on the SCL line. The communication is terminated by a stop condition sent by the master.

The Wire library in Arduino provides a simple and easy-to-use interface for implementing I²C communication on the Arduino platform. The library includes functions for initializing the I²C bus, sending start and stop conditions, reading and writing data, and handling errors and timeouts. When using the Wire library, the SDA and SCL pins are configured for I²C communication by default, and the library takes care of generating the clock pulses and managing the bus. This allows developers to focus on the higher-level logic of their application rather than the low-level details of the I²C protocol. Overall, the combination of the I²C protocol and the Wire library makes it easy to add communication capabilities to Arduino projects and enables developers to create complex embedded systems with multiple devices communicating over the I²C bus.

Table: 4.4 - C++ reference for Arduino I²C initialization and usage.

I²C(Wire) Method Purpose	Code	Explanation
Begin	Start the library and join the I ² C bus as either master or slave. <code>Wire.begin();</code>	Join the I ² C bus as a master. If an address is provided as a method parameter, the Arduino will join the bus as a slave at that address.
Begin Transmission	Configure Arduino as I ² C master: Slave with specified address and start transmission	Slave at hex address 0x68 and start transmission

Write	Wire.write(0x6B); Write byte data over the I ² C bus.	Write byte data with value 0x6B over the I ² C bus.
Request From	Requests a specific number of bytes from the slave with the specified address. It has the ability to release the I ² C line or hold it for further communication. The requested bytes are placed in a buffer to be read later by a Wire.read() call.	Request 6 bytes from the slave with address 0x68. Release the I ² C line after the request is complete. If the last parameter is wrong, the Arduino will hold his I ² C line for further communication and not allow other devices to communicate through it.
Read	Read bytes placed in the buffer after transfer from the slave device. This method is called after a call to Wire.requestFrom Wire.read(). called.	Reads a byte from the buffer (after calling request From). To read 2 bytes from the buffer, you need to call this method twice. example: Wire.read();
End Transmission	End the current transmission. Has the ability to release the I ² C line or hold it for further communication Wire.endTransmission(true);	End the transfer and release the I ² C line.

A half-duplex UART (All inclusive Off beat Receiver/Transmitter) may be a sort of serial communication convention in which information is transmitted and received on a single communication line, but not at the same time. In other words, the UART can either transmit data or receive data, but it cannot do both simultaneously. In a half-duplex UART communication, the transmitting device first sends the data on the communication line, and then switches to a receive mode to

wait for a response from the receiving device. Once the data is received by the receiving device, it sends a response back to the transmitting device, and then switches back to a receive mode to wait for the next data transmission. This process continues back and forth between the two devices.

4.2.9 Applications

- Serial communication between microcontrollers: UART is commonly used in microcontroller-based systems to communicate with other microcontrollers or peripheral devices.
- Wireless communication: UART is used in wireless communication protocols such as Bluetooth and Wi-Fi to transmit data between devices.
- Debugging and programming: UART is commonly used for debugging and programming microcontrollers, as it provides a simple and reliable way to communicate with the device.
- Computer interfaces: UART is used in various computer interfaces, such as RS-232 and USB-to-UART converters, to enable communication between a computer and external devices.
- GPS and navigation systems: UART is used in GPS and navigation systems to transmit and receive location data.
- Home automation: UART is used in home automation frameworks to communicate with savvy gadgets such as indoor regulators, light switches, and entryway locks.
- Robotics: UART is used in robotics applications to enable communication between different parts of a robot, such as sensors, motors, and controllers.
- Automotive applications: UART is used in automotive applications such as motor control units (ECUs), tire weight checking frameworks, and infotainment systems.

4.3 SOFTWARE REQUIREMENTS

- Arduino IDE
- Embedded C

4.3.1 ARDUINO IDE - 1.8.5

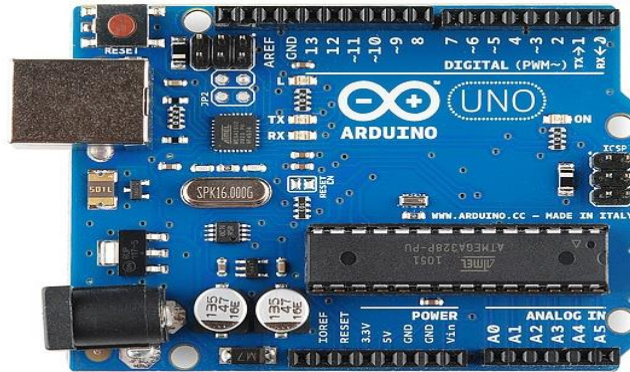


Figure: 4.18 – Arduino Uno

Arduino IDE (Coordinates Improvement Environment) adaptation 1.8.5 is an open-source program instrument that's utilized to type in, compile, and transfer code to Arduino boards. It could be a cross-platform application that runs on Windows, macOS, and Linux working frameworks. The IDE gives a user-friendly interface for composing and uploading code to the board. It incorporates a code editor with sentence structure highlighting, auto-completion, and other highlights that make it simple to compose and investigate code. The IDE also incorporates a library chief that permits clients to seek for and introduce libraries that give pre-written code for common assignments. One of the key highlights of the Arduino IDE is its bolster for a wide extend of Arduino sheets, counting the well known Arduino Uno, Nano, and Mega sheets, as well as numerous others. The IDE too incorporates back for different communication conventions such as I2C, SPI, and UART, which makes it simple to interface with outside sensors, shows, and other components. Another include of the Arduino IDE is its serial screen, which permits clients to see and send information to the board by means of the serial harbour. This is useful for debugging and testing code, as well as for sending commands and data to the board in real-time. The Arduino IDE could be a effective and user-friendly instrument that empowers clients to rapidly and effortlessly compose and transfer code to Arduino sheets. Its support for a wide range of boards and communication protocols, as well as its library manager and serial monitor, make it a prevalent choice for fledglings and experienced clients alike.

1. Board Supervisor: The Arduino IDE incorporates a board director that permits clients to download and introduce extra board definitions for a wide extend of Arduino-compatible sheets. This makes it easy to add support for new boards and to keep up to date with the latest hardware releases.
2. Code verification: The IDE includes a verification tool that checks the code for errors and highlights syntax and other issues. This helps users to catch errors before uploading the code to the board, saving time and avoiding potential problems.
3. Sketchbook: The IDE includes a sketchbook that serves as a central repository for all of the user's sketches (Arduino programs). This makes it easy to organize and manage multiple projects and to switch between them quickly.
4. Examples: The IDE includes a wide range of example sketches that demonstrate how to use different features of the Arduino platform. These can be a great starting point for beginners and can help users to learn new programming concepts and techniques.
5. Plug-ins: The Arduino IDE is highly extensible and supports a wide range of plugins that provide additional features and functionality. These can include everything from code editors and syntax highlighting to code generators and other tools.
6. Version control: The IDE integrates with version control systems such as Git, allowing users to manage and track changes to their code over time

4.3.2 Embedded C:

Embedded C is a programming language that is specifically designed for use in embedded systems, which are computing systems that are integrated into other devices or products. These devices often have real-time requirements and limited hardware resources, which means that the programming language must be optimized for efficiency and reliability. Embedded C is based on the C programming dialect, which could be a general-purpose programming dialect that's broadly utilized within the computer program industry.

However, Embedded C includes additional features and restrictions that make it suitable for use in embedded systems. Some of these features include:

1. Coordinate get to to equipment: Implanted C gives coordinate get to to the equipment assets of the inserted framework, such as the memory, input/output ports, and clocks. This allows the programmer to write code that is highly optimized for the specific hardware platform.
2. Limited resources: Embedded systems often have limited resources such as memory, processing power, and energy. Embedded C is designed to work efficiently with these limited resources, using techniques such as code optimization, memory management, and power management.
3. Real-time prerequisites: Numerous inserted frameworks have real-time prerequisites, meaning that they must respond to inputs and events within a specific time frame. Embedded C includes features such as interrupt handlers and timers that allow the programmer to write code that meets these real-time requirements.
4. Debugging and testing: Embedded systems are often difficult to debug and test due to their integration with other hardware and software components. Embedded C includes features such as inline assembly code and debugging tools that make it easier to debug and test embedded software.
5. It could be a subset of the C programming dialect: Implanted C may be a subset of the C programming dialect, which means that it includes a limited set of features from C that are relevant to embedded systems. For example, Embedded C does not include dynamic memory allocation or the use of the standard input/output library.
6. It is hardware-dependent: Embedded C is closely tied to the hardware platform on which it is running. This means that code written in Embedded C is not easily portable to other hardware platforms without modification.
7. It is widely used: Embedded C is widely used in the embedded systems industry and is the programming language of choice for many developers working on embedded systems.

8. It is compatible with popular development tools: Embedded C can be used with popular development tools such as Integrated Development Environments (IDEs) and compilers.

9. It requires specialized knowledge: Developing software for embedded systems requires specialized knowledge of both the hardware and the software. Programmers who work on embedded systems must have a deep understanding of the hardware platform and the programming language they are using.

10. It is utilized in a wide extend of applications: Inserted C is utilized in a wide extend of applications, counting car, therapeutic, mechanical, and customer hardware. Examples of embedded systems that use Embedded C include pacemakers, automotive engine control units, and home automation systems.

Embedded C is a highly specialized programming language that is optimized for use in embedded systems. It provides direct access to hardware resources, works efficiently with limited resources, meets real-time requirements, and includes features for debugging and testing. Embedded C is an essential tool for developers who are building embedded systems, such as those used in automotive, medical, and industrial applications.

4.4 CAD RENDER



Figure: 4.19 – Top view of Micro Universal Testing Machine

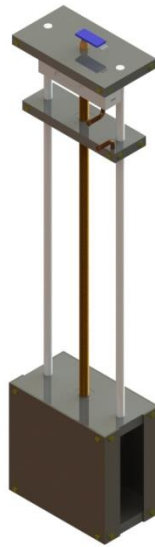


Figure: 4.20 – Isometric view of Micro Universal Testing Machine



Figure: 4.21 – Right view of Micro Universal Testing Machine

4.5 SETUP IMAGES OF THE MICRO UNIVERSAL TESTING MACHINE



Figure: 4.22 – Top view of Micro Universal Testing Machine

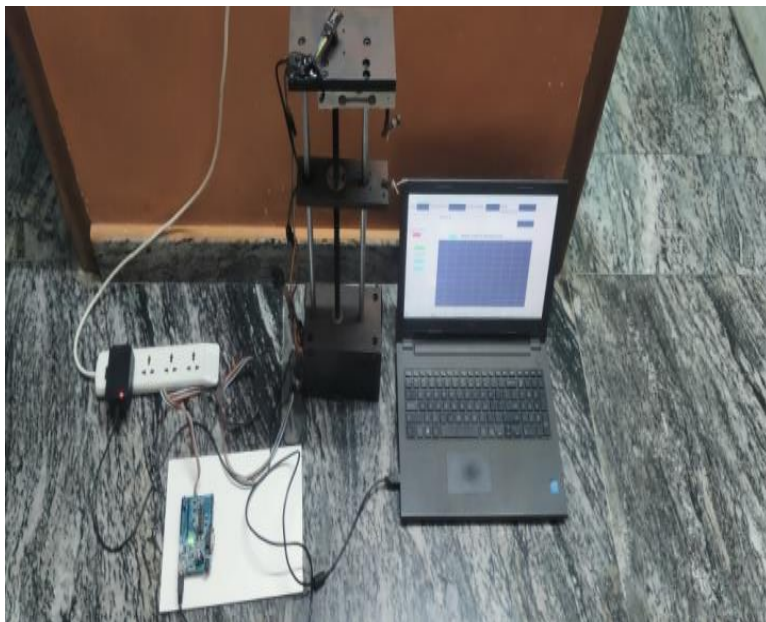


Figure: 4.23 – Full setup of Micro Universal Testing Machine

CHAPTER - 5

5.0 RESULTS AND DISCUSSION

A micro universal testing machine is a highly specialized instrument used to evaluate the mechanical properties of small-scale materials or components. This machine is capable of performing a wide range of tests, including compression, tension, and bending tests, and can measure parameters such as stress, strain, and modulus of elasticity. In the project report, it can be concluded that the micro universal testing machine is an essential tool for researchers and engineers working in the fields of materials science, mechanical engineering, and microelectronics. The machine's capacity to supply exact and exact information on the mechanical properties of small-scale materials is vital within the plan and improvement of different smaller scale electromechanical frameworks (MEMS) and nano gadgets. The project report can discuss the various components of the micro universal testing machine, such as the load cell, actuator, and displacement sensor. The report can also highlight the different types of tests that the machine can perform and the parameters that can be measured. Additionally, the project report can discuss the advantages and limitations of the micro universal testing machine. For example, the machine's ability to provide precise measurements on small-scale materials can lead to more accurate predictions of the performance of MEMS and nano devices. However, the machine's small size may limit the range of materials that can be tested. Overall, the micro universal testing machine is an important instrument in the field of materials science and engineering. Its ability to provide accurate and precise data on small-scale materials is crucial for the development of new and innovative MEMS and nano devices.

The project report can also discuss the applications of the micro universal testing machine in various fields such as aerospace, automotive, and biomedical industries. For example, the machine can be used to evaluate the strength and durability of small components used in aerospace or automotive applications, or to assess the mechanical properties of biomaterials for implantable medical devices. Furthermore, the project report can discuss the different types of specimens that

can be tested using the micro universal testing machine, such as thin films, fibers, and microstructures. The report can also highlight the importance of proper sample preparation and handling to obtain accurate and reliable test results. The project report can also cover the various testing standards and protocols used in micro universal testing, such as ASTM and ISO standards. These standards provide guidelines for the preparation of specimens, testing procedures, and data analysis, ensuring consistency and accuracy in testing. Finally, the project report can discuss future developments and advancements in micro universal testing technology. These may include improvements in accuracy and precision, the development of new testing techniques, and the integration of micro universal testing with other analytical techniques such as microscopy and spectroscopy. The micro universal testing machine is an important instrument in materials science and engineering. The project report can provide an overview of the machine's components, testing capabilities, applications, and limitations, as well as highlight the importance of proper sample preparation and testing standards. Furthermore, the report can discuss the future developments and advancements in micro universal testing technology, which will continue to advance the field and contribute to the development of new and innovative materials and devices.

CHAPTER – 6

6.0 CONCLUSIONS

In conclusion, the micro universal testing machine is an essential tool for evaluating the mechanical properties of small-scale materials or components. Its ability to perform a wide range of tests and measure parameters such as stress, strain, and modulus of elasticity is crucial in the design and development of various micro electromechanical systems (MEMS) and nano devices. The project report has discussed the various components of the micro universal testing machine, its testing capabilities, applications, and limitations. It has also highlighted the importance of proper sample preparation and testing standards in obtaining accurate and reliable test results. The report has shown that the micro universal testing machine has diverse applications in various fields, such as aerospace, automotive, and biomedical industries. Its ability to evaluate the mechanical properties of small-scale materials and components can lead to the development of innovative materials and devices that can improve the performance and reliability of many applications. Furthermore, the project report has discussed the future developments and advancements in micro universal testing technology. These advancements are expected to improve the accuracy and precision of the machine, introduce new testing techniques, and integrate the machine with other analytical techniques to provide a more comprehensive understanding of material properties. In conclusion, the micro universal testing machine is a critical instrument in materials science and engineering.

Its testing capabilities, diverse applications, and future developments will continue to contribute significantly to the advancement of the field and the development of new materials and devices. The project report has also highlighted some of the limitations of the micro universal testing machine. For example, its small size may limit the range of materials that can be tested, and the preparation of small-scale specimens can be challenging. Furthermore, the machine's high cost and complexity may limit its accessibility to some researchers and engineers. Despite

these limitations, the benefits of using the micro universal testing machine outweigh its drawbacks. Its ability to provide accurate and precise data on small-scale materials and components is crucial in the design and development of innovative technologies that can improve the performance and reliability of various applications. In summary, the micro universal testing machine is a valuable instrument in materials science and engineering. Its testing capabilities, applications, and future developments are significant in advancing the field and the development of new materials and devices. While the machine has limitations, its benefits make it an essential tool for researchers and engineers working in the fields of materials science, mechanical engineering, and microelectronics.

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ANNEXURE

- The review paper titled “Micro Universal Testing Machine System for Material Property Measurement of Micro Structure - a review “by J.Senthilkumar, V.S.Arjun, B.Surya has been presented in ICAARS 2022 conducted by PSG college of technology, Coimbatore on 9th December 2022.
- The research paper titled “Development of a Micro Universal Testing System for Accurate Material Property Analysis of Small Structures” by J.Senthilkumar, V.S.Arjun, B.Surya has been presented in ICDTM 2023 conducted by SASTRA Deemed University, Thanjavur, 2023.
- Filed a design Patent titled “Development of a Micro Universal Testing System for Accurate Material Property Analysis of Small Structures” on may 2023.



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Micro Universal Testing Machine System for Material Property Measurement of Micro Structure

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Abstract: Universal testing machines are used to determine the physical and mechanical properties of raw materials and components by measuring and analysing their behaviour under various tensile or compressive forces using various test methods. increase. The "universal" part of the name refers to different types of tests that can be run with the same universal tester. Tensile and compressive strength are among the most commonly performed types of tests.

A micro-universal testing machine (UTM) system has been proposed to measure the microstructure of composite material properties. A composite is a combination of two materials that have different physical and chemical properties. Combining them creates materials that are specialized to perform specific tasks, such as being stronger, lighter, or more resistant to electricity. It can also improve strength and stiffness.

The system is designed to verify composite material properties such as peak load, peak shift, tensile strength and yield point, and elongation, developed by analysing stepper motor drive characteristics. Performance tests are performed to confirm the applicability of the developed micro-universal tester system to microstructures. In performance testing, the developed micro universal testing machine system performs to the 1828 micro universal testing machine standard. The developed micro universal testing machine system can be applied to microstructures.

The proposed system consists of (I) sensor module, (II) measurement control module, (III) output stepper motor control module, and (IV) analysis UI software module. The sensor module contains a load cell for obtaining the precise load on the test material and encoders for obtaining the speed and direction of the stepper motor. Up and down traverses for receiving test articles. The measurement controller processes load and speed values and sends relevant digital data to the UI software, while automatically controlling the stepper motor rotation and direction as needed. The UI software was developed using Visual Studio to further analyse the parameters and display the load-displacement diagrams in an appropriate manner. The software also captures peak load (maximum), peak displacement (maximum), tensile strength and yield strength, which can be displayed in the associated test material user interface.

INTRODUCTION

As the industry expands to exploit mechanical and electrical properties at the micro- and nanoscale, the need for micro actuators is increasing. Piezoelectric actuators and voice coil motors are commonly used as drive methods for micro actuators. Piezoelectric motors are highly responsive, but have poor reproducibility and are expensive. Voice coil motors, on the other hand, are repeatable, inexpensive, and generally responsive. A micro actuator can be a voice coil motor that moves in millimeters. Much research has been done in the field of microforce measurement systems in North America, Europe and Japan. Research on material properties in micro-electromechanical systems is concentrated in research institutes and universities. Sandia Research Instruments performs material failure analysis and actuator reliability testing for micro-electromechanical systems. A material used in micro-electromechanical systems, polysilicon has undergone stress testing at DARPA and Johns Hopkins University. A material characterization method using nanoindentation was presented at Seoul National University. A method for testing the deformation characteristics of gold bonding wires for semiconductor packages has been developed by the Korea

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Development of a Micro Universal Testing System for Accurate Material Property Analysis of Small Structures

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Abstract: Using a variety of test methodologies, universal testing machines are used to monitor and analyse how raw materials and component behaviour respond to tensile or compressive stresses in order to determine the physical and mechanical characteristics of these materials. increase. A single universal tester can be used to run a number of tests, as indicated by the word "universal" in the name. Tensile testing and compressive testing are two of the most popular test types. A micro-universal testing machine (UTM) system has been proposed to measure the microstructure of composite material properties. A composite is a combination of two materials that have different physical and chemical properties. Combining them creates materials that are specialized to perform specific tasks, such as being stronger, lighter, or more resistant to electricity. It can also improve strength and stiffness. The system is designed to verify composite material properties such as peak load, peak shift, tensile strength and yield point, and elongation, developed by analysing stepper motor drive characteristics. Performance tests are performed to confirm the applicability of the developed micro-universal tester system to microstructures. In performance testing, the developed micro universal testing machine system performs to the 1828 micro universal testing machine standard. The developed micro universal testing machine system can be applied to microstructures. The proposed system consists of (I) sensor module, (II) measurement control module, (III) output stepper motor control module, and (IV) analysis UI software module. The sensor module contains a load cell for obtaining the precise load on the test material and encoders for obtaining the speed and direction of the stepper motor. Up and down traverses for receiving test articles. The measurement controller processes load and speed values and sends relevant digital data to the UI software, while automatically controlling the stepper motor rotation and direction as needed. The UI software was developed using Visual Studio to further analyse the parameters and display the load-displacement diagrams in an appropriate manner. The software also captures peak load (maximum), peak displacement (maximum), tensile strength and yield strength, which can be displayed in the associated test material user interface.

1.1 INTRODUCTION

The need for micro actuators is rising as more industries use mechanical and electrical properties at the micro- and nano scale. The most common driving techniques for tiny actuators are voice coil motors and piezoelectric actuators. The responsibility of a piezoelectric motor is considerable, but its cost and repeatability are minimal. The voice coil motor (VCM), in contrast, offers great repeatability, low cost, and all-purpose responsibility [1-2]. For many millimetre actuations, VCM can be used as the micro actuator.

There are numerous studies being done in North America, Europe, and Japan in the field of micro force measurement systems. The focus of university and research instrument research is on the material properties of micro electro-mechanical systems (MEMS). Failure analysis and actuator reliability testing are carried out for MEMS material at the Sandia research instrument. Poly-silicon used as a MEMS material is put through an elongation test at Johns Hopkins University and DARPA. The method of material property analysis utilising nano-indentation is presented at Seoul National University. The

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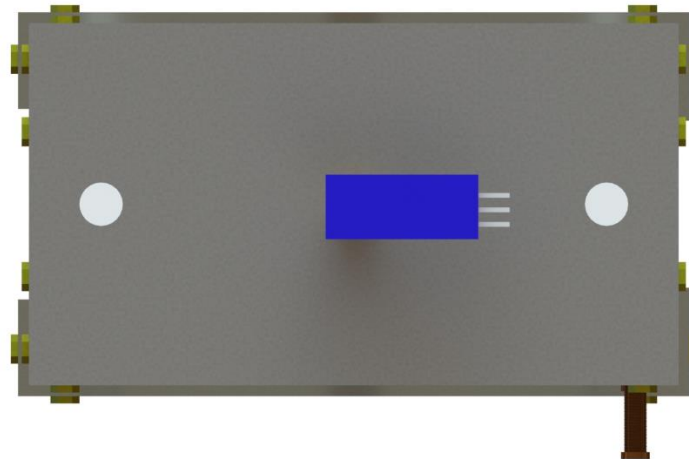
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