A

MINI PROJECT REPORT ON

"TEMPERATURE CONTROL OF POULTRY USING LM 35SENSOR"

Submitted in partial fulfillment of the Requirements for the award of degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the Mini Project work entitled "TEMPERATURE CONTROL OF POULTRY USING LM35 SENSOR". Submitted by N.VINAY (21R91A04G0), S.SANDEEP GOUD (21R91A04M9), P.VINOD KUMAR (21R91A04H7), R.BHANU PRAKASH (21R91A04K6), M.MANJUNADHA (21R91A04F0). In partial fulfillment of the requirements for the award of BACHELOR OF TECHNOLOGY in ELECTRONICS AND COMMUNICATION ENGINEERING in J.N.T.U.H, during the academic year 2024-2025.

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ABSTRACT

The "Temperature Control of Poultry Using LM35" project aims to automate the temperature regulation in poultry farms, ensuring optimal conditions for the health and productivity of the birds. Utilizing an Arduino microcontroller, the LM35 temperature sensor, an LCD display, and a DC fan, this system continuously monitors and adjusts the temperature within the poultry environment.Key components of the system include the LM35 temperature sensor, which provides accurate temperature readings, and the Arduino microcontroller, which processes these readings. The system is designed to automatically control a DC fan to cool the environment when the temperature exceeds a predefined threshold. An LCD display is used to provide real-time temperature readings to farm operators.

The system operates by continuously monitoring the ambient temperature inside the poultry house. When the temperature rises above the set point, the Arduino activates the DC fan to cool the environment. Once the temperature drops back to the desired range, the fan is turned off. This automated control mechanism ensures a stable and comfortable environment for the poultry, which is scrucial for their growth and health.

The "Temperature Control of Poultry Using LM35" project is designed to enhance the efficiency of poultry farming by maintaining optimal living conditions for the birds. This system not only improvesthe overall health and productivity of the poultry but also reduces manual labor and enhances energy efficiency through precise temperature management.

*Keywords: Temperature Control, Poultry Farming, LM35 Sensor, Arduino, Automated TemperatureRegulation, Poultry Health, DC Fan, LCD Display.

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LIST OF ABBREVIATIONS

IOT	-Interenet of Things
CPU	-Centeral Processing Unit
LCD	-Liquid Crystal Display
I2C	-Inter Integrated Circuit
DC	-Direct current

CHAPTER 1

INTRODUCTION

1.1 Introduction

Poultry farming is a critical sector of agriculture, providing a significant source of protein for human consumption. However, poultry are sensitive to temperature fluctuations, which can impact their growth, health, and productivity. Temperature control is crucial in poultry farming to maintain optimal conditions, ensuring the well-being and profitability of the farm. Maintaining optimal temperature conditions in poultry farming is crucial for the health and productivity of birds. Temperature significantly affects growth rates, feed conversion, and overall well-being. Hence, effective temperature control systems are essential for modern poultry operations.

The LM35 temperature sensor is a popular choice for monitoring temperature in agricultural applications due to its accuracy, linear output, and ease of integration. It provides an analog voltage output proportional to the temperature in Celsius, making it simple to interface with microcontrollers for real-time monitoring and control.

In a typical poultry house, the LM35 sensor can be strategically placed to monitor ambient temperature. This data can be used to adjust heating, cooling, and ventilation systems to maintain optimal conditions. Implementing a temperature control system using the LM35 sensor not only enhances bird welfare but also improves feed efficiency and reduces mortality rates.

The LM35 sensor, a widely used temperature sensor, offers high accuracy and reliability, making it an ideal choice for temperature control applications. This project aims to design and develop an automated temperature control system for poultry farming using the LM35 sensor. The system will monitor and regulate temperature levels, ensuring a comfortable environment for poultry, improving their health, and increasing farm productivity.the trolley. As customers move through the store, their selected items are instantly added to a digital cart, eliminating the need for manual scanning.

1.2 OBJECTIVE OF THE PROJECT

The main objective of using the LM35 temperature sensor for poultry temperature control is to maintain optimal environmental conditions for the birds . This sensor can accurately measure the temperature, allowing for precise adjustments to heating or cooling systems in poultry houses to ensure the birds health and productivity.

1.3 METHODOLOGY

The temperature control system for poultry using an LM35 sensor is a precise and reliable solution for maintaining optimal temperature conditions in poultry houses. The system utilizes the LM35 sensor to accurately measure the temperature, which is then compared to a setpoint value. If the temperature deviates from the setpoint, the system automatically activates heating or cooling elements to restore the desired temperature. This ensures a consistent and comfortable environment for the poultry, promoting healthy growth and productivity. The LM35 sensor's high accuracy and sensitivity enable precise temperature control, while its compact design and low power consumption make it an ideal choice for this application. The system's microcontroller-based design allows for easy programming and customization to meet specific poultry farming requirements.

The temperature control system also features advanced functionalities such as temperature alarms, data logging, and remote monitoring capabilities. These features enable farmers to monitor and control the temperature conditions remotely, ensuring prompt action can be taken in case of any temperature fluctuations.

1.4 EXISTING SYSTEM

The existing temperature control system for poultry using LM35 sensors provides a reliable and efficient solution for maintaining a comfortable environment. However, there is room for improvement in terms of scalability, remote monitoring, and integration with other smart farming technologies.

CHAPTER – 2

LITERATURE SURVEY

A literature survey on temperature control of poultry using LM35 sensors reveals a growing interest in automated temperature management systems for poultry farms. Various studies have proposed systems using LM35 sensors, microcontrollers, and programmable logic controllers (PLCs) to maintain optimal temperature ranges for poultry growth and health. For instance, a study by IJARCSSE (2020) presented a temperature control system using LM35 sensor and Arduino, while another study by IJERA (2019) described a system using LM35 sensor and PIC microcontroller. Additionally, research by IJSRP (2018) discussed an automated temperature control system using LM35 sensor and AVR microcontroller. Other studies have explored the integration of LM35 sensors with fuzzy logic controllers, Raspberry Pi, and wireless sensor networks to enhance temperature control and monitoring capabilities. Overall, the literature highlights the potential of LM35 sensors in improving poultry farming practices through precise temperature control, leading to enhanced growth rates, feed efficiency, and reduced mortality rates.

CHAPTER-3

BLOCK DIAGRAM

3.1 BLOCK DIAGRAM

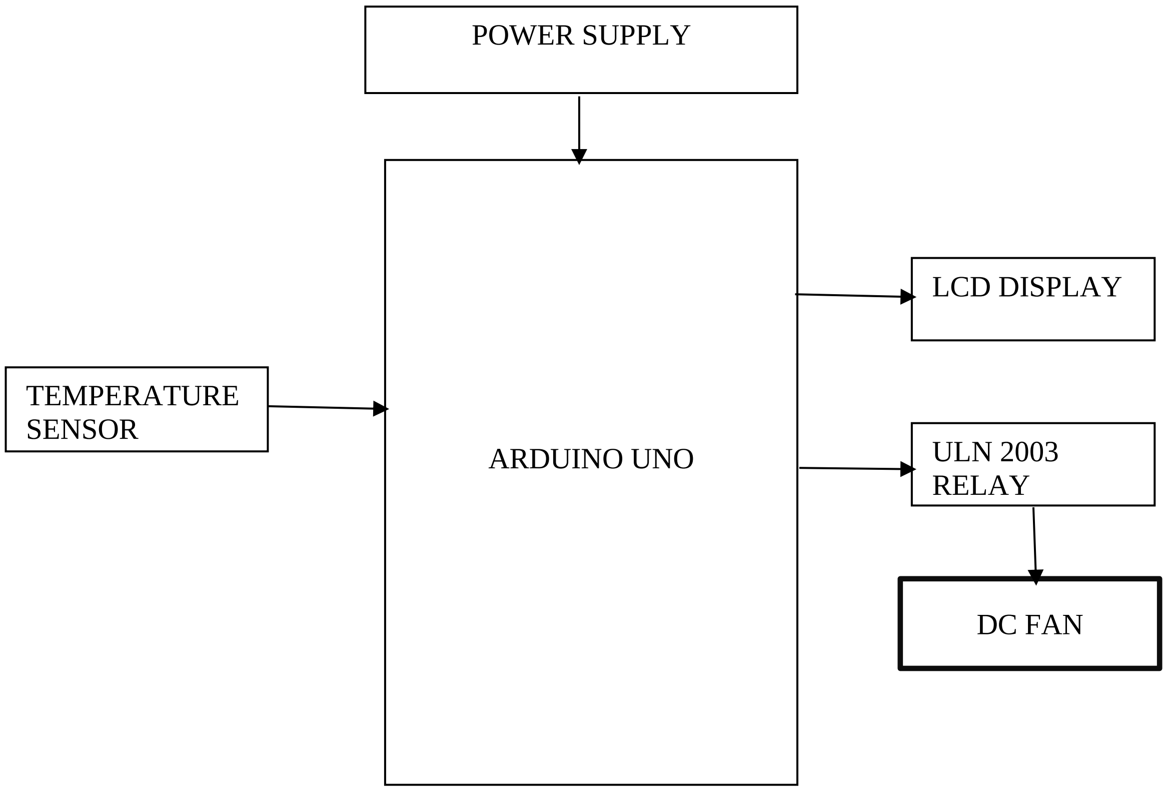


Fig 3.1: BLOCK DIAGRAM

Arduino UNO : Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button.

LCD Display : LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation. LEDs have a large and varying set of use cases for consumers and businesses, as they can be commonly found in smartphones, televisions, computer monitors and instrument panels.

ULN2003: The ULN2003 can be used as a Realy driver to control the heating/cooling devices,allowing the microcontroller to switch high-voltage loads using allow-voltage, control signal.

LM35 SENSOR: The LM35 series are precision integrated-circuit LM35 temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature

Power Supply : A power supply adapter that provides from 7 to 12V (Volts) of DC (Direct Current) is required. Some Arduino boards like UNO, MEGA and DUE, come with an AC socket that can be used to power the boards and to supply additional voltage if needed.

3.2:WORKING PRINCIPLE

The LM35 temperature sensor is widely utilized for precise temperature monitoring and control, including applications such as managing the environment for poultry. The working principle of the LM35 revolves around its ability to provide an analog voltage output that is linearly proportional to the temperature it measures. Specifically, the LM35 produces an output of 10 millivolts per degree Celsius. This means that at 25°C, the sensor outputs a voltage of 250 millivolts. This linear relationship between temperature and output voltage simplifies the process of converting the sensor's output into a readable temperature value.

In a poultry control system, the LM35 sensor's output is connected to an analog-to-digital converter (ADC) within a microcontroller. The microcontroller reads this analog voltage, converts it to a digital value, and then translates this value into a temperature reading using the known 10 mV/°C scale. This digital temperature data is then used by the microcontroller to make real-time decisions regarding the control of the poultry environment.

To regulate the temperature effectively, the microcontroller uses predefined temperature thresholds. For instance, if the target temperature range for optimal poultry growth is between 20°C and 25°C, the microcontroller continuously monitors the temperature readings from the LM35 sensor. If the temperature falls below 20°C, the microcontroller can activate a heater to increase the temperature. Conversely, if the temperature exceeds 25°C, the microcontroller can engage cooling mechanisms such as fans or ventilation systems. The control logic ensures that these adjustments are made promptly to maintain the desired temperature range.

3.3 SCHEMATIC DIAGRAM

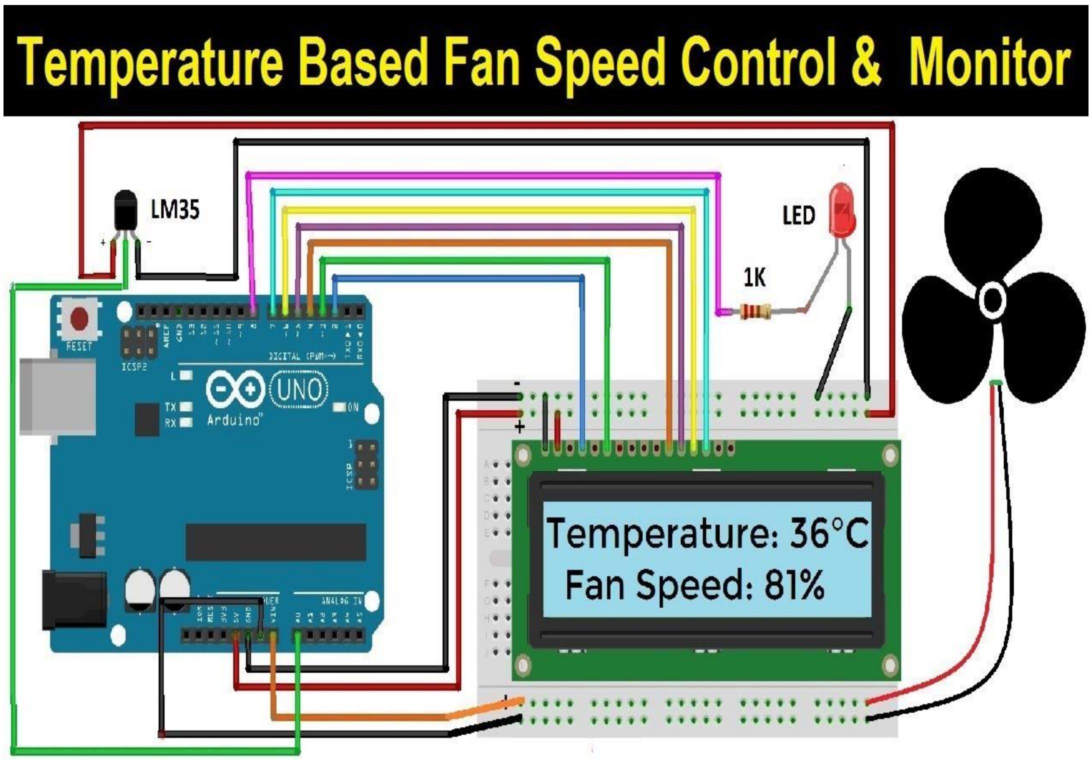


Fig:3.2: Schematic Diagram

CHAPTER-4

HARDWARE DESCRIPTION

4.1 ARDUINO UNO

Introduction to ARDUINO

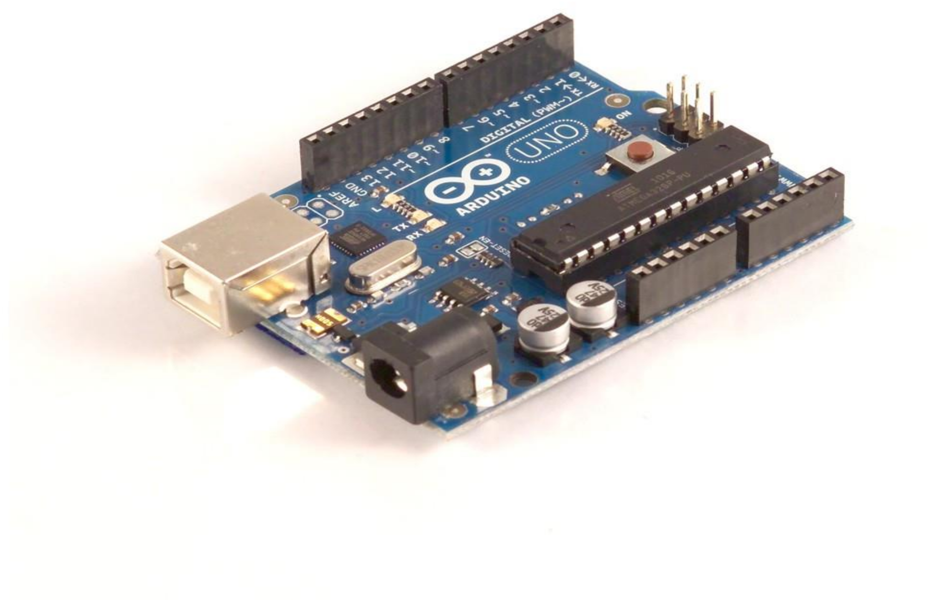


Fig 4.1: Arduino Uno

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worring too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards.

Features:

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 4.1: Features of Arduino Uno

OSH: Schematics, Reference Design, Board size

Arduino / Genuino Uno is open-source hardware! You can build your own board using the following files:

The Arduino/Genuino Uno can be programmed with the (Arduino Software (IDE)). Select "Arduino/Genuino Uno from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino/Genuino Uno comes preprogrammed with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available in the Arduino repository. The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then rese ing the 8U2.

On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

Differences with other boards

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Atmega328P

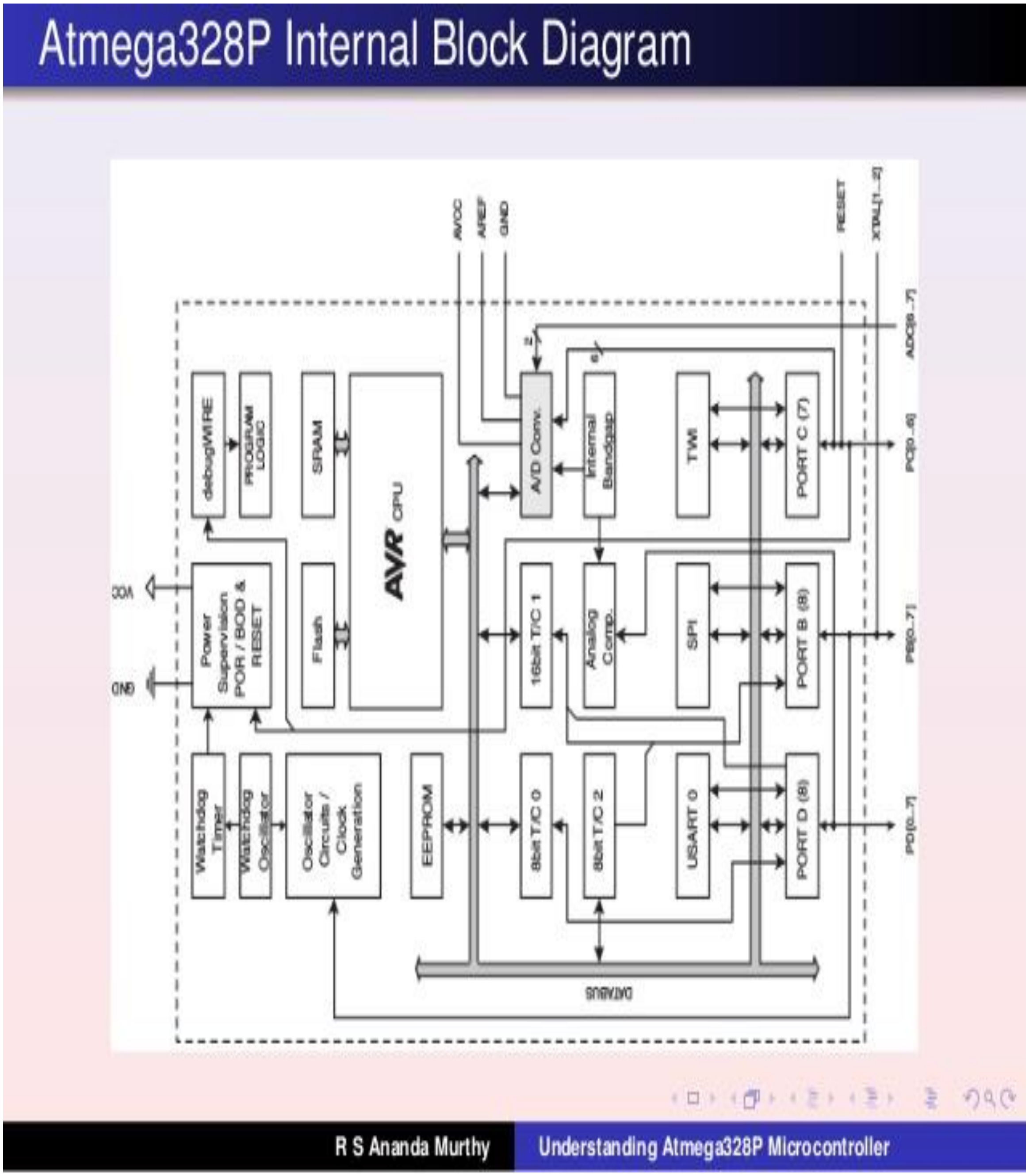


Fig 4.2: Atmega328P Overview

PIN DIAGRAM OF ATmega328p:

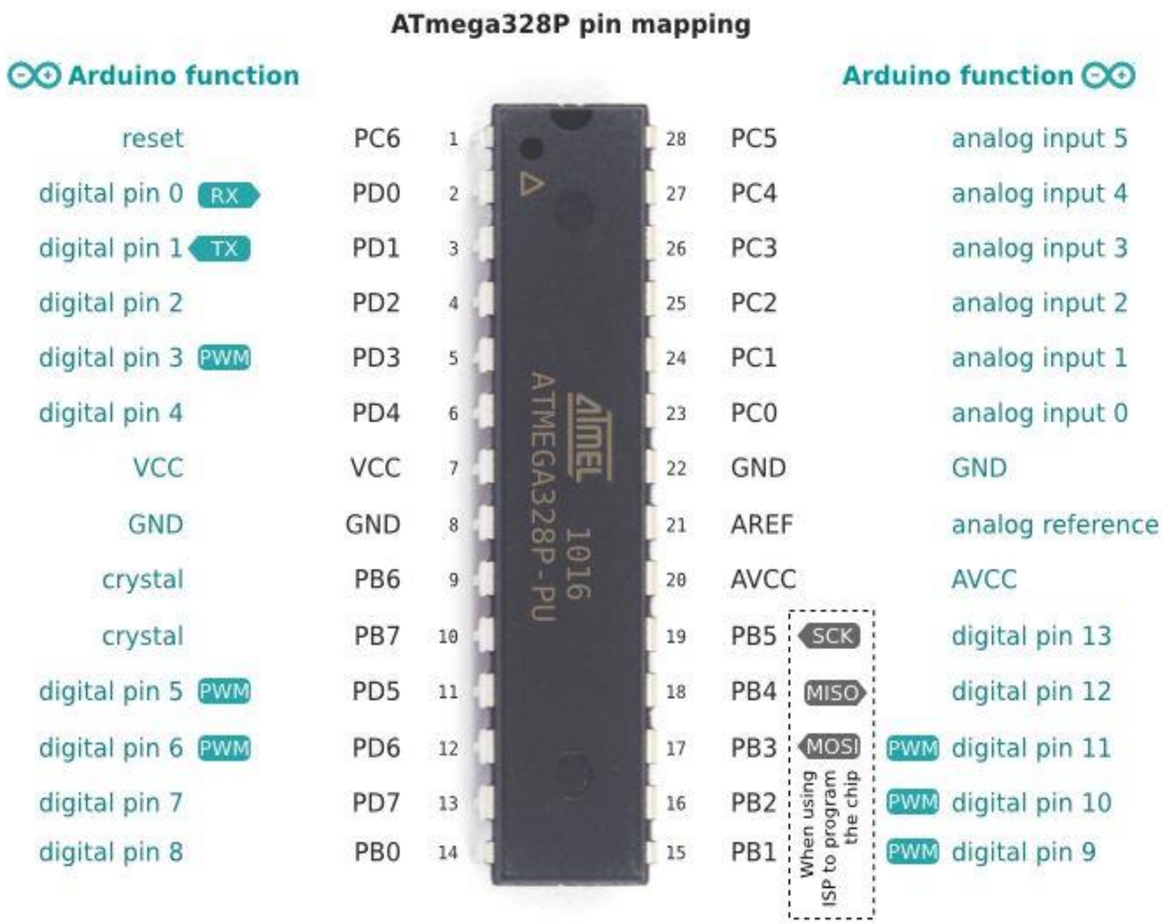


Fig 4.3:PIN Mapping

Power and Ground

The power supply voltage (5 volts) must be connected to the VCC input on pin 7. The ground connections are on pins 8 and 22.

Clock

Some sort of clock signal must be provided in order for the microcontroller to operate. On the ATmega328P the clock can come from one of three deferent sources. The selection of the clock source is done by program Ming fuse bits in the chip. A TTL-compatible clock signal can be generated externally by other logic and connected to the XTAL1 input (pin 9.) This probably the easiest way to generate the clock for the EE 459 projects. The lab has a supply of DIP oscillators in some of the more common frequencies. These output a TTL level square wave that can be fed directly into the microcontroller and to other chips. Alternatively, the processor can generate a clock if a crystal is connected to the XTAL1 and XTAL2 inputs. This method uses a plain crystal, not the DIP crystal oscillators as described above. The third method uses an internal oscillator that runs at approximately 8MHz. This is probably the least accurate way to generate a clock. Do not use this method if your project requires a clock running close to a specified frequency. The advantage of using the internal clock is that you do not need to provide any external signal and other functions are now available on pin 9. For example, it can now be used as Port B bit 6 (PB6) thus giving the microcontroller 22 I/O pins. In applications where the UART0 serial communications interface is being used, the choice of clock frequency determines the baud rates that can be used for transmitting and receiving serial data. The accuracy of the frequency of the baud rate depends on the clock frequency used for the microcontroller. If a high degree of accuracy is required, an external oscillator of the correct frequency will be needed.

Reset

The reset input (RESET, pin 1) must be in the high state for the processor to operate normally. This pin has an internal pull-up and does not have to be externally pulled-up to VCC in order for the processor to operate normally.

SPI Programming

The Flash memory on the ATmega328P is programed using connections to the reset input and three other pins: PB3, PB4 and PB5. These three I/O pins can be used for other purposes as long as the design allows the programming hardware to have sole access to these pins during the programming process. Make sure that none of these pins is used as in input from some source that will continue to drive a signal at the 328P while the reset line is in the low state.

I/O Ports

See the mapping between Arduino pins and ATmega328P ports. The mapping for the Atmega8, 168, and 328 is identical Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(),digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm. A maximum of 40mA is the value that must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller.

Port B (PB)

Port B on the ATmega328P has seven usable pins (PB0 through PB5 and PB7). A eighth bit, PB6, shares a pin with the XTAL1 input. If the chip is configured for an external clock, this pin is not available for I/O. Three of the pins (PB3, PB4 and PB5) are use for the SPI interface for programming the Flash memory. These pins should not be used as inputs connected to sources that will continue to drive signals at the 328P while in the reset state. 2.2.2 Port C (PC)

Port C on the 328P has six pins (PC0 through PC5). A seventh bit, PC6, shares a pin with the RESET input. By changing the configuration fuse settings this bit can be use for I/O. Most of the pins in PC are shared with the analog-to-digital converter so if the ADC function is used one or more pins will not be available for general purpose I/O. In addition, PC4 and PC5 are use for the I2C interface and will not be available for general I/O if I2C is used.

Port D (PD)

Port D on the 328P has eight pins (PD0 through PD7). Two of the pins, PD0 and PD1, are shared with the serial communications interface and cannot be used as I/O if the USART0 functions are used.

Timer/Counters

The ATmega328P contains three timers:

Timer/Counter0 - an 8-bit counter.

Timer/Counter1 - a 16-bit counter.

Timer/Counter2 - an 8-bit counter similar to Timer/Counter0 but with asynchronous clocking capability. The internal timers can be used to count events and generate an interrupt when a specified number of events has occurred. A common use of a timer is to implement a delay function by counting the number of internal clock cycles that occur. The example on the class web site in program at328-2.c and discussed below uses the 16-bit timer but the the procedure is similar for the 8-bit timers. To implements a delay _rst set the timer for \Clear Timer on Compare

Match" (CTC) mode using Output Compare Register A (OCR1A). The mode is set using four bits: WGM12 and WGM13 in TCCR1B, and WGM10 and WGM11 in TCCR1A. In most situations enabling the CTC interrupt is also required. This is done by setting the OCIE1A bit in the TIMSK1 register. In this mode the counter counts up to the value in OCR1A, generates an interrupt, clears the count and starts counting up again. Use the rate of the internal clock to calculate what count value the counter will need to count to. If the maximum value exceeds the range of the timer's 16-bit register (greater than 65,535), determine what value to use in the prescaler to divide the internal clock by (8, 64, 256 or 1024) before it reaches the timer. The maximum count value, after any prescaling, is loaded into the Output Capture Register (OCR1A). The prescaler is controlled by bits CS10, CS11 and CS12 in TCCR1B. The action of setting the prescaler bits to something other than all zeros starts the timer counting. To turn the timer o_, set the prescaler bits to all zero. When the counter reaches the maximum count value, it generates an interrupt, resets the count value to zero and continues to count. The user program should service the interrupt and take whatever action is necessary. Keep in mind that the counter does not stop and wait for the interrupt to be serviced. It continues to count regardless of when or if the user program services the interrupt.

In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analog Reference() function. There are a couple of other pins on the board:

- AREF. Reference voltage for the analog inputs. Used with analog Reference().
- Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

Arduino/Genuino Uno has a number of facilities for communicating with a computer, another Arduino/Genuino board, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The 16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins .

A Software Serial library allows serial communication on any of the Uno's digital pins.

The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino Software (IDE) includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino/Genuino Uno board is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nano-farad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino Software (IDE) uses this capability to allow you to upload code by simply pressing the upload button in the interface toolbar. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data. The Uno board contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110-ohm resistor from 5V to the reset line; for details.

Revisions

Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5V and with the Arduino Due that operates with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

4.2 Memory

The ATmega328 has 32 KB (with 0.5 KB occupied by the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from al preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions..

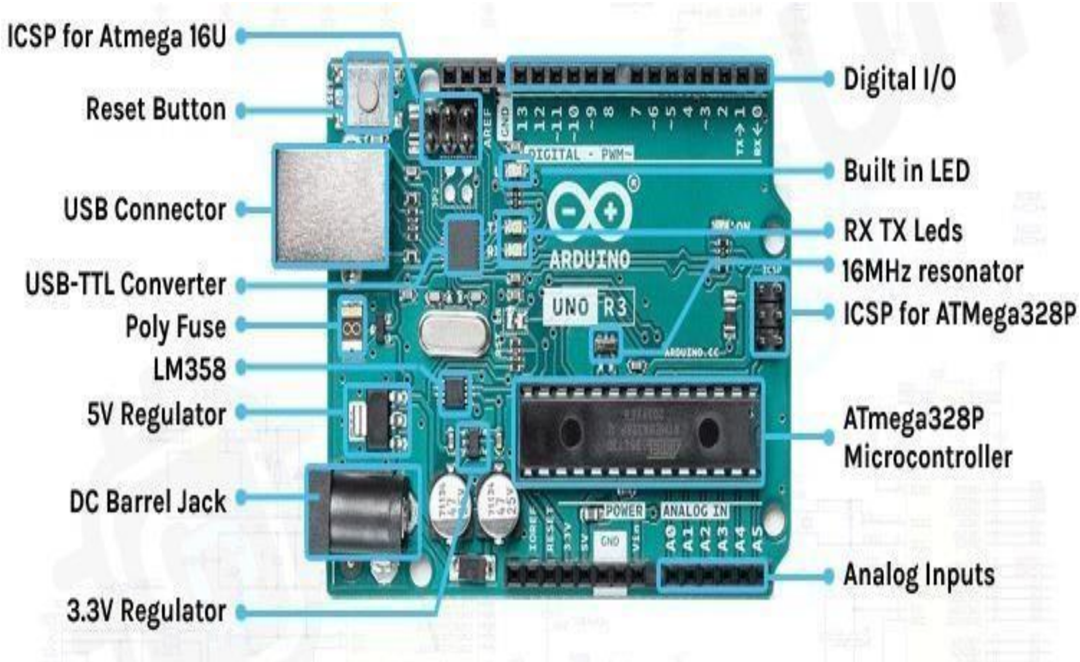


Fig :4.4**:** Arduino Uno Board

The Italian word "uno" means "one" and was chosen to represent the first release of Arduino Software. The Arduino Uno board is the first in a series of USB-based Arduino boards; it, along with version 1.0 of the Arduino IDE, served as the standard version of Arduino, which has since been superseded by newer releases. The ATmega328 on the board is preprogrammed with a boot loader, allowing it to be updated without the requirement of an external hardware programmer. While the Uno communicates via the original STK500 protocol, it does not use the FTDI USB-to-serial driver chip, unlike all previous boards.

- **Microcontroller:** The Arduino Uno is powered by the ATmega328P microcontroller chip, which is a high-performance 8-bit AVR microcontroller.
- **Clock Speed:** The ATmega328P operates at a clock speed of 16 MHz, providing relatively fast processing capabilities for various tasks.
- **Digital and Analog I/O Pins:** The board features 14 digital input/output pins (of which 6 can be used as PWM outputs) and 6 analog input pins. These pins can be used to connect various sensors, actuators, and other electronic components.

- **USB Connection:** The Arduino Uno can be connected to a computer via a USB cable, allowing for easy programming and communication with the board. The USB interface also provides power to the board.
- **Power Supply:** The Uno can be powered via USB connection or an external power supply (7-12V DC). It has a built-in voltage regulator that regulates the voltage to 5V, which can be used to power external components.
- **Programming Interface:** Arduino Uno can be programmed using the Arduino Integrated Development Environment (IDE), which is based on C and C++ languages. It offers a simple and beginner-friendly programming environment.
- **Compatibility:** The Uno is compatible with a wide range of sensors, shields, and modules designed for Arduino boards, making it easy to expand its capabilities.
- **Open Source:** Arduino Uno, like other Arduino boards, is open-source hardware, which means its design files are freely available for modification and redistribution. Overall, the Arduino Uno is an excellent choice for beginners and experienced hobbyists alike who want to create interactive electronic projects, prototypes, and DIY gadgets.

It provides a user-friendly platform for learning and experimenting with electronics and programming.

4.3 LCD DISPLAY :

Liquid crystals (LC) represent a distinct state of matter that combines characteristics of both liquids and crystalline solids. These fascinating materials exhibit properties of fluidity, allowing them to flow like liquids, while also possessing an ordered molecular structure akin to that of crystalline solids. The unique physical behaviour of liquid crystals arises from their molecular arrangement and responsiveness to external stimuli.

The molecular structure of liquid crystals plays a pivotal role in their behaviour.

Fig:4.5: LCD Display

A 16×2-character LCD is used. The operating voltage of the LCD is 5v and 80 x 36 x 12 mm is the module dimensions. In total it has 16 pins. To connect it with Arduino physically the specification of the LCD was followed and to give command to LCD from Arduino programmatically a Arduino library ‘liquid crystal.h’ was used.

Most 16x2 character LCDs are built around a Hitachi HD44780 or an equivalent controller chip. This chip simplifies the interfacing of the LCD with a microcontroller or other control circuitry. It provides basic functionality for controlling the display, managing cursor positions, and handling data read/write operations.

The 16x2 LCD modules commonly use parallel interfaces for communication with microcontrollers. These interfaces typically require a minimum of 4 data lines (4-bit mode) or 8 data lines (8-bit mode) along with control lines such as RS (Register Select), RW (Read/Write), and E (Enable). Additionally, there might be a contrast control pin (V0) to adjust the viewing contrast.

Rather than emitting light, the liquid crystal display screen works on the idea of blocking light. Because LCDs do not emit light, they require a backlight. We constantly utilize devices with LCD displays, which have replaced the use of cathode ray tubes. In comparison to LCDs, cathode ray tubes consume more energy and are also heavier and larger.

When opposed to cathode ray tube (CRT) technology, LCD technology allows for significantly thinner displays. Two polarized panel filters and electrodes are among the components that make up a liquid crystal display. LCD technology is utilised in notebooks and other electronic devices such as small computers to display images. A lens projects light onto a layer of liquid crystal.

The data register stores data that will be displayed. The process of controlling the display entails entering the data that will form the desired image. The main advantages of this LCD device are its low power consumption and low cost. The main disadvantages of this LCD
device are that it takes up a lot of space, it is slow, and its lifespan is reduced due to direct current. This LCD screen is used to display the availability of parking slots according to the instruction in the code. Advancements in LCD technology continue, with developments such as mini LED and micro LED backlighting, improved colour reproduction, and higher refresh rates. LCDs remain a competitive display technology in the rapidly evolving landscape of visual displays.

Pin	Symbol	Function
1	Vss	Ground
2	Vdd	Supply Voltage
3	Vo	Contrast Setting
4	RS	Register Select
5	R/W	Read/Write Select
6	En	Chip Enable Signal
7-14	DB0-DB7	Data Lines
15	A/Vee	Gnd for the backlight
16	K	Vcc for backlight

Table 4.2: Commands used in LCD

No.	Instruction	Hex	Decimal
1	Function Set: 8-bit, 1 Line, 5x7 Dots	0x30	48
2	Function Set: 8-bit, 2 Line, 5x7 Dots	0x38	56
3	Function Set: 4-bit, 1 Line, 5x7 Dots	0x20	32
4	Function Set: 4-bit, 2 Line, 5x7 Dots	0x28	40
5	Entry Mode	0x06	6
6	Display off Cursor off (clearing display without clearing DDRAM content)	0x08	8
7	Display on Cursor on	0x0E	14
8	Display on Cursor off	0x0C	12
9	Display on Cursor blinking	0x0F	15
10	Shift entire display left	0x18	24
12	Shift entire display right	0x1C	30
13	Move cursor left by one character	0x10	16
14	Move cursor right by one character	0x14	20
15	Clear Display (also clear DDRAM content)	0x01	1

4.4 POWER SUPPLY

Introduction

All digital circuits require regulated power supply. In this article we are going to learn how to get a regulated positive supply from the mains supply.

Power supply circuit

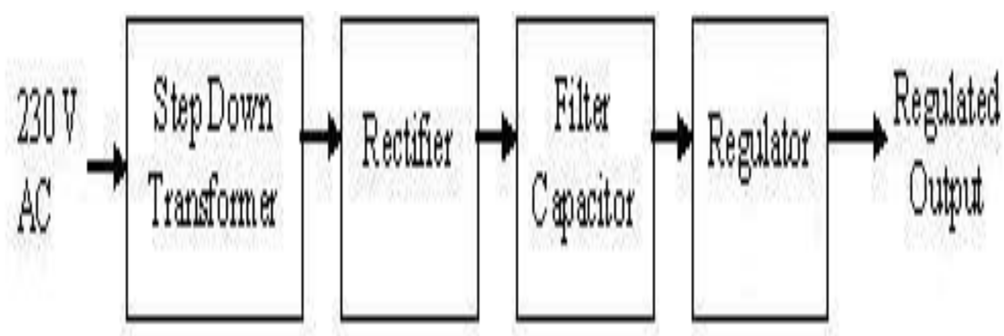


Fig 4.6: Block diagram of power supply

Transformer

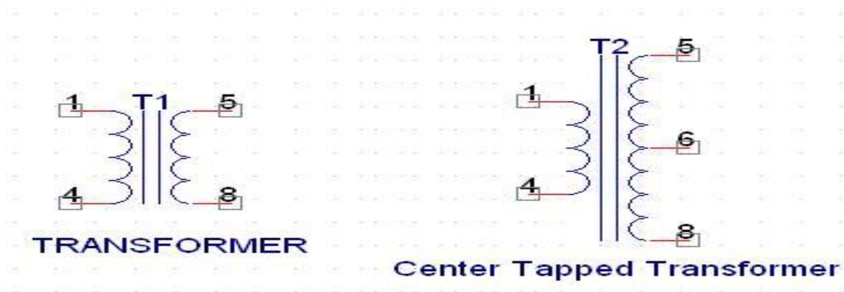


Fig 4.7: Transformers

A transformer consists of two coils also called as "WINDINGS" namely PRIMARY & SECONDARY. They are linked together through inductively coupled electrical conductors also called as CORE. A changing current in the primary causes a change in the Magnetic Field in the core & this in turn induces an alternating voltage in the secondary coil. If load is applied to the secondary then an alternating current will flow through the load. If we consider an ideal condition then all the energy from the primary circuit will be transferred to the secondary circuit through the magnetic field.

$$P_{primary} = P_{secondary}$$

So

$$I_p V_p = I_s V_s$$

The secondary voltage of the transformer depends on the number of turns in the Primary as well as in the secondary.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

4.5 Rectifier

A rectifier is a device that converts an AC signal into DC signal. For rectification purpose we use a diode, a diode is a device that allows current to pass only in one direction i.e. when the anode of the diode is positive with respect to the cathode also called as forward biased condition &

blocks current in the reversed biased condition.

Rectifier can be classified as follows:

1) Half Wave Rectifier

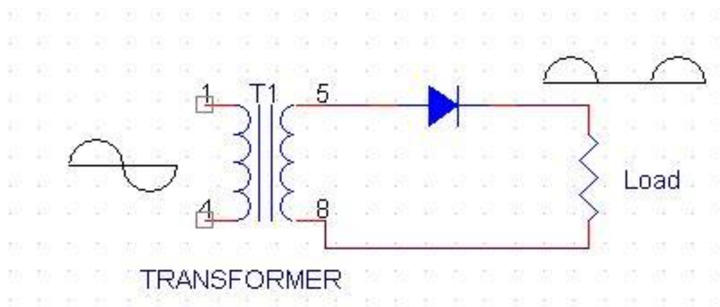


Fig 4.8: Half wave rectifier

This is the simplest type of rectifier as you can see in the diagram a half wave rectifier consists of only one diode. When an AC signal is applied to it during the positive half cycle the diode is forward biased & current flows through it. But during the negative half cycle diode is reverse biased & no current flows through it. Since only one half of the input reaches the output, it is very inefficient to be used in power supplies.

2) Full wave rectifier.

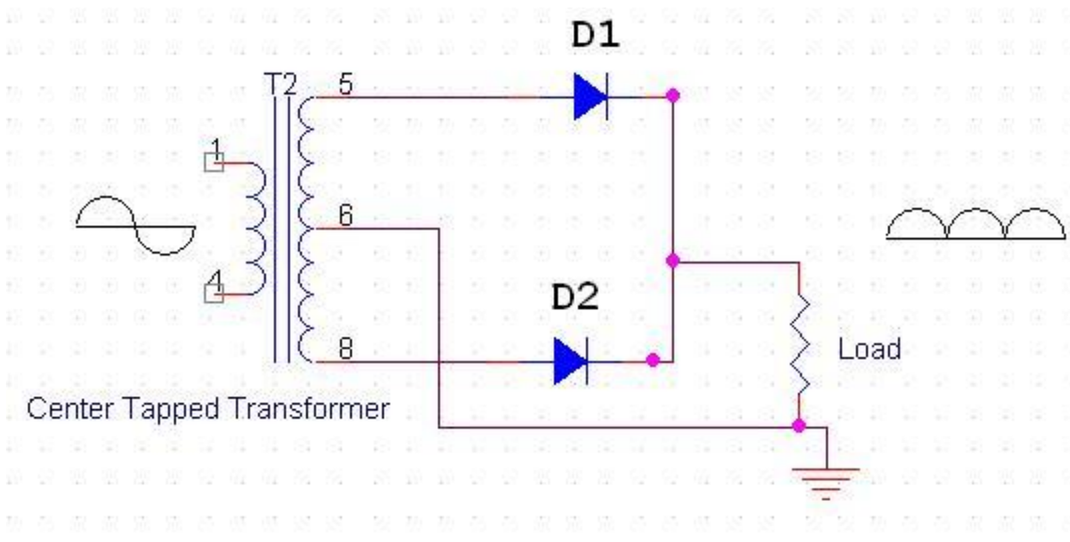


Fig 4.9: Full wave rectifier

Half wave rectifier is quite simple but it is very inefficient, for greater efficiency we would like to use both the half cycles of the AC signal. This can be achieved by using a center tapped transformer i.e. we would have to double the size of secondary winding & provide connection to the center. So during the positive half cycle diode D1 conducts & D2 is in reverse biased condition. During the negative half cycle diode D2 conducts & D1 is reverse biased. Thus we get both the half cycles across the load.

One of the disadvantages of Full Wave Rectifier design is the necessity of using a center tapped transformer, thus increasing the size & cost of the circuit. This can be avoided by using the Full Wave Bridge Rectifier.

3) BridgeRectifier

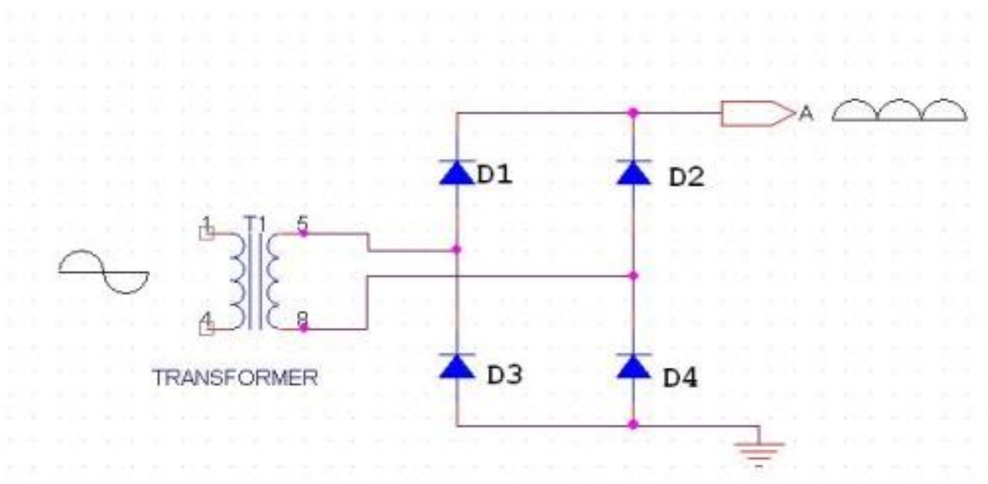


Fig 4.10: Bridge Rectifier

As the name suggests it converts the full wave i.e. both the positive & the negative half cycle into DC thus it is much more efficient than Half Wave Rectifier & that too without using a center tapped transformer thus much more cost effective than Full Wave Rectifier.

Full Bridge Wave Rectifier consists of four diodes namely D1, D2, D3 and D4. During the positive half cycle diodes D1 & D4 conduct whereas in the negative half cycle diodes D2 & D3 conduct thus the diodes keep switching the transformer connections so we get positive half cycles in the output.

If we use a center tapped transformer for a bridge rectifier we can get both positive & negative half cycles which can thus be used for generating fixed positive & fixed negative voltages.

Filter Capacitor

Even though half wave & full wave rectifier give DC output, none of them provides a constant output voltage. For this we require to smoothen the waveform received from the rectifier. This can be done by using a capacitor at the output of the rectifier this capacitor is also called as "FILTER CAPACITOR" or "SMOOTHING CAPACITOR" or "RESERVOIR CAPACITOR". Even after using this capacitor a small amount of ripple will remain.

We place the Filter Capacitor at the output of the rectifier the capacitor will charge to the peak voltage during each half cycle then will discharge its stored energy slowly through the load while the rectified voltage drops to zero, thus trying to keep the voltage as constant as possible.

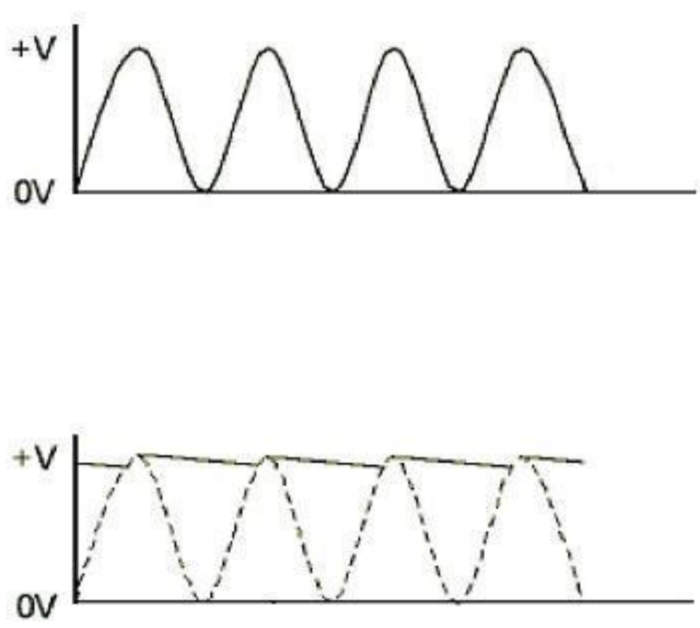


Fig 4.11: Filter capacitor

If we go on increasing the value of the filter capacitor then the Ripple will decrease. But then the costing will increase. The value of the Filter capacitor depends on the current consumed by the circuit, the frequency of the waveform & the accepted ripple.

$$C = \frac{V_r F}{I}$$

Where,

Vr= accepted ripple voltage. (should not be more than 10% of the voltage)

I= current consumed by the circuit in Amperes.

F= frequency of the waveform. A half wave rectifier has only one peak in one cycle so F=25hz Whereas a full wave rectifier has Two peaks in one cycle so F=100hz.

Voltage Regulator

A Voltage regulator is a device which converts varying input voltage into a constant regulated output voltage. Voltage regulator can be of two types

1) Linear Voltage Regulator is also called as Resistive Voltage regulator because they dissipate the excessive voltage resistively as heat.

2) Switching Regulators.

They regulate the output voltage by switching the Current ON/OFF very rapidly. Since their output is either ON or OFF it dissipates very low power thus achieving higher efficiency as compared to linear voltage regulators. But they are more complex & generate high noise due to their switching action. For low level of output power switching regulators tend to be costly but for higher output wattage they are much cheaper than linear regulators.

The most commonly available Linear Positive Voltage Regulators are the 78XX series where the XX indicates the output voltage. And 79XX series is for Negative Voltage Regulators.

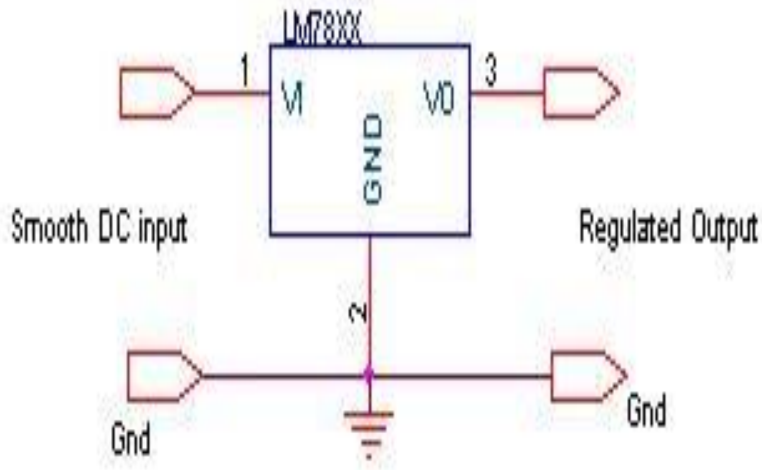


Fig 4.12: Voltage Regulator

After filtering the rectifier output the signal is given to a voltage regulator. The maximum input voltage that can be applied at the input is 35V.Normally there is a 2-3 Volts drop across the regulator so the input voltage should be at least 2-3 Volts higher than the output voltage. If the input voltage gets below the Vmin of the regulator due to the ripple voltage or due to any other reason the voltage regulator will not be able to produce the correct regulated voltage.

Circuit diagram:

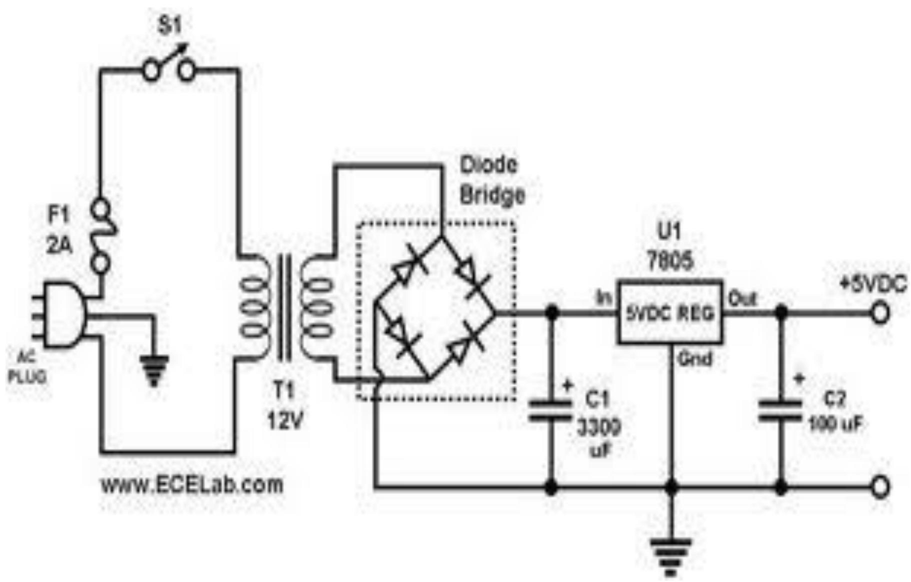


Fig 4.13: Voltage regulator power supply

IC 7805:

7805 is an integrated three-terminal positive fixed linear voltage regulator. It supports an input voltage of 10 volts to 35 volts and output voltage of 5 volts. It has a current rating of 1 amp although lower current models are available. Its output voltage is fixed at 5.0V. The 7805 also has a built-in current limiter as a safety feature. 7805 is manufactured by many companies, including National Semiconductors and Fairchild Semiconductors.

The 7805 will automatically reduce output current if it gets too hot. The last two digits represent the voltage; for instance, the 7812 is a 12-volt regulator.

SPECIFICATIONS	IC 7805
V_{out}	5V
V_{ein} - V_{out} Difference	5V - 20V
Operation Ambient Temp	0 - 125°C
Output I_{max}	1A

Table-4.3:IC7805 Specifications

4.6 LM35 TEMPERATURE SENSOR:

The LM35 sensor series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature.

Working of Temperature Sensor:

The above temperature sensor has three terminals and required Maximum of 5.5 V supply. This type of sensor consists of a material that operates according to temperature to vary the resistance. This change of resistance is sensed by the circuit and it calculates the temperature. When the voltage increases then the temperature also rises. We can see this operation by using a diode.

Temperature sensors directly connected to microprocessor input and thus capable of direct and reliable communication with microprocessors.

The sensor unit can communicate effectively with low-cost processors without the need for A/D converters.

An example of a temperature sensor is LM35. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. The LM35 operates at -55˚ to +120˚C.

The basic centigrade temperature sensor (+2˚C to +150˚C) is shown in the figure below.

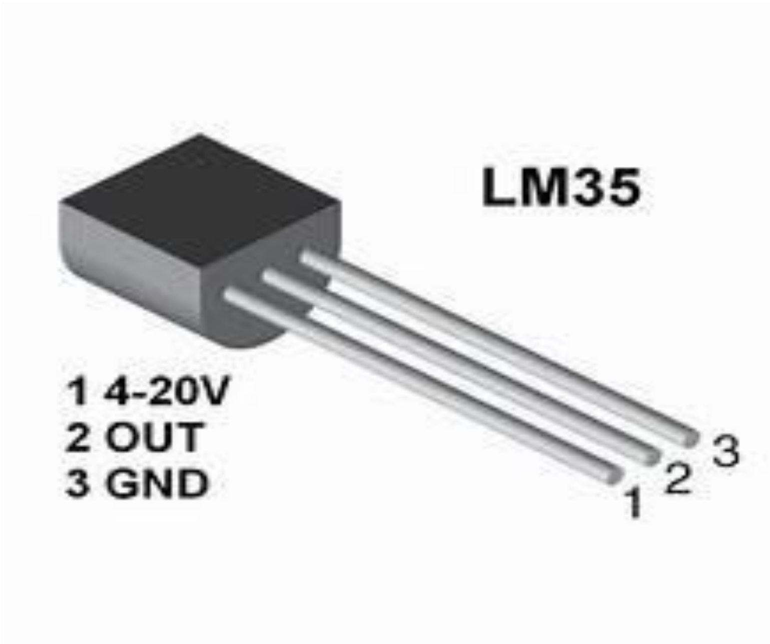


Fig:4.14 LM35 Temperature Sensor

TEMPERATURE LM 35 SENSOR SPECIFICATIONS

LM35 Sensor Specification The LM35 series are precision integrated-circuit LM35 temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 sensor thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 sensor does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55° to +150°C temperature range, while the LM35C sensor is rated for a -40° to +110°C range (-10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D sensor is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

LM35 Sensor Circuit Schematic

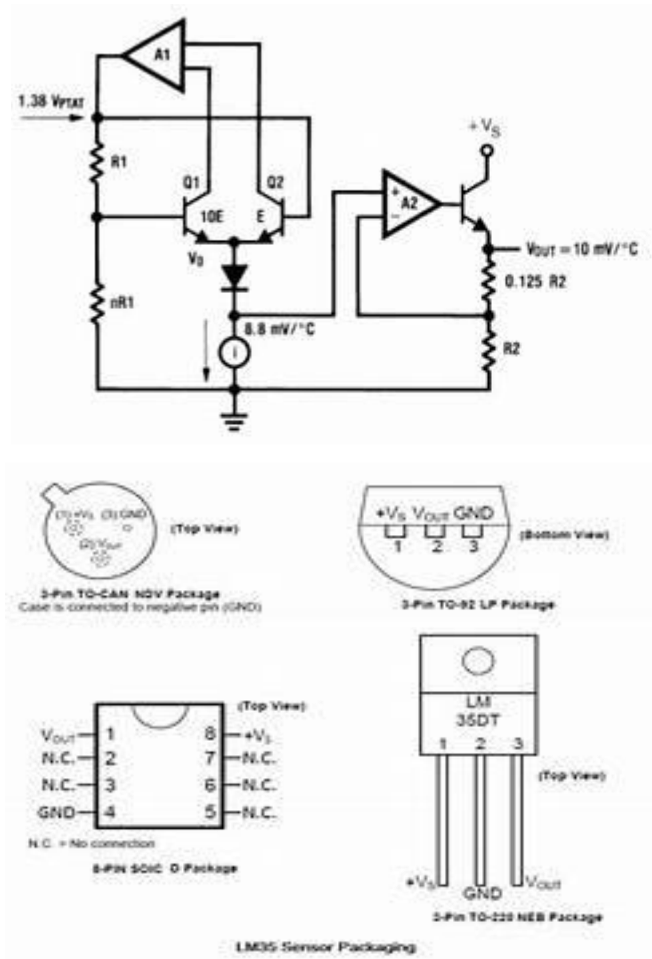


Fig:4.15:Sensor Schematic

LM35 Sensor Sources

There are several manufacturers of this popular part and each has LM35 sensor specs, datasheets and other free LM35 downloads. This amplifier is available from the following manufacturers. National Semiconductor On Semiconductor Texas Instruments Fairchild Semiconductor STMicroelectronics Jameco Electronics Analog Devices.

LM35 Sensor Background and Applications

Most commonly-used electrical temperature sensors are difficult to apply. For example, thermocouples have low output levels and require cold junction compensation. Thermistors are nonlinear. In addition, the outputs of these sensors are not linearly proportional to any temperature scale. Early monolithic sensors, such as the LM3911, LM134 and LM135, overcame many of these difficulties, but their outputs are related to the Kelvin temperature scale rather than the more popular Celsius and Fahrenheit scales. Fortunately, in 1983 two I.C.'s, the LM34 Precision Fahrenheit Temperature Sensor and the LM35 Precision Celsius Temperature Sensor, were introduced. This application note will discuss the LM34, but with the proper scaling factors can easily be adapted to the LM35.

4.7 ULN2003

The **ULN2003A** is an integrated circuit produced by Texas Instruments. It consists of an array of seven NPN Darlington transistors capable of 500 mA, 50 V output.

The ULN2003 can be used as a Realy driver to control the heating/cooling devices,allowing the microcontroller to switch high-voltage loads using allow-voltage control signal. The ULN2003 is a high-voltage, high-current Darlington transistor array IC, widely used for driving loads like relays, solenoids, and motors in various applications. It features seven NPN Darlington transistors in a single package, capable of handling up to 50V and 500mA per channel. With input compatibility for TTL and CMOS logic levels, the ULN2003 is versatile and easy to integrate. Built-in diodes provide protection for inductive loads, ensuring reliable operation. Its compact 16-pin DIP or SOIC package saves board space, making it ideal for applications like relay drivers, motor drivers, LED drivers, and power supplies. By using the ULN2003, designers can efficiently drive high-current loads without external transistors, saving space and enhancing reliability. In temperature control systems, like poultry farming, the ULN2003 can drive heaters, fans, or pumps, providing a robust and dependable solution.

Fig 4.16: ULN2003

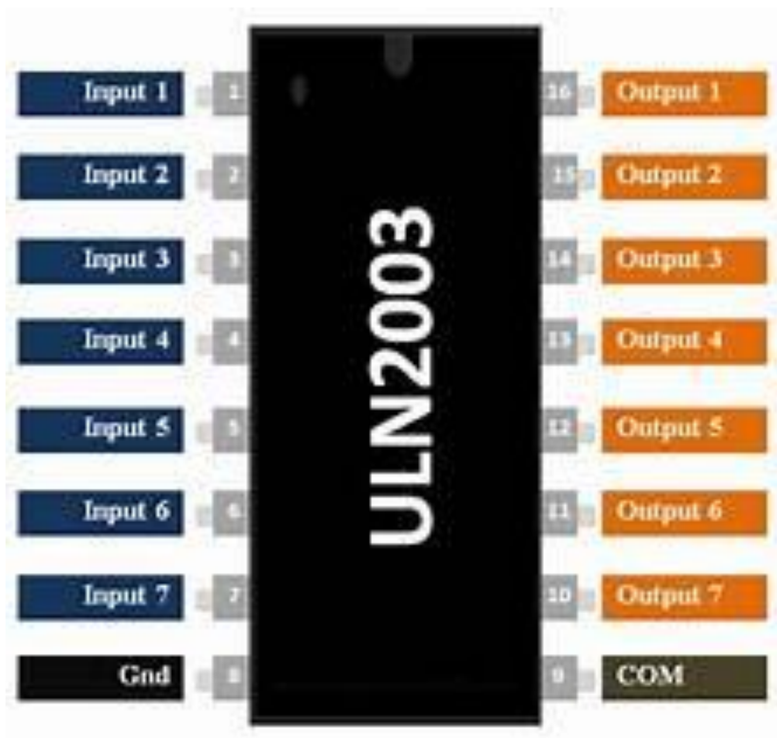


Fig4.17:ULN2003PIN

4.8 DC FAN

A DC fan is a type of fan that uses direct current (DC) electricity to rotate its blades and create airflow. It operates on low voltage, typically 12V or 24V, making it safe and energy-efficient. DC fans are designed to provide high efficiency, quiet operation, and compact design, making them ideal for various applications.

The benefits of DC fans include energy savings, increased reliability, flexibility, and low noise. They consume less power than traditional AC fans while providing similar airflow, reducing energy costs and environmental impact. With fewer moving parts and no brushes, DC fans are more reliable and longer-lasting. They can be easily integrated into various applications, including electronics, automotive, and HVAC systems, and are suitable for noise-sensitive applications.

DC fans are widely used in various applications, including electronics cooling, automotive, HVAC systems, and medical devices. In electronics cooling, DC fans are used in computers, servers, and other electronic devices to cool components. In automotive, DC fans are used in vehicles for heating, ventilation, and air conditioning (HVAC) systems. In HVAC systems, DC fans are used in residential and commercial HVAC systems for air circulation and ventilation. In medical devices, DC fans are used in medical equipment, such as MRI machines and hospital ventilation systems.

In the context of poultry temperature control, DC fans can be used to circulate air, maintain a comfortable temperature, and improve ventilation in the poultry house. By providing a consistent and reliable airflow, DC fans can help to reduce temperature fluctuations, improve air quality, and promote healthy growth and productivity in poultry.

Fig4.18:DC fan

CHAPTER-5

SOFTWARE DESCRIPTION

Introduction to Software

In this chapter the software used and the language in which the program code is defined is mentioned and the program code dumping tools are explained. The chapter also documents the development of the program for the application. This program has been termed as “Source code”. Before we look at the source code we define the two header files that we have used in the code.

Required Equipment:

- A computer (Windows, Mac, or Linux)
- An Arduino-compatible microcontroller (anything from this guide should work)
- A USB A-to-B cable, or another appropriate way to connect your Arduino-compatible microcontroller to your computer (check out this USB buying guide if you’re not sure which cable to get).

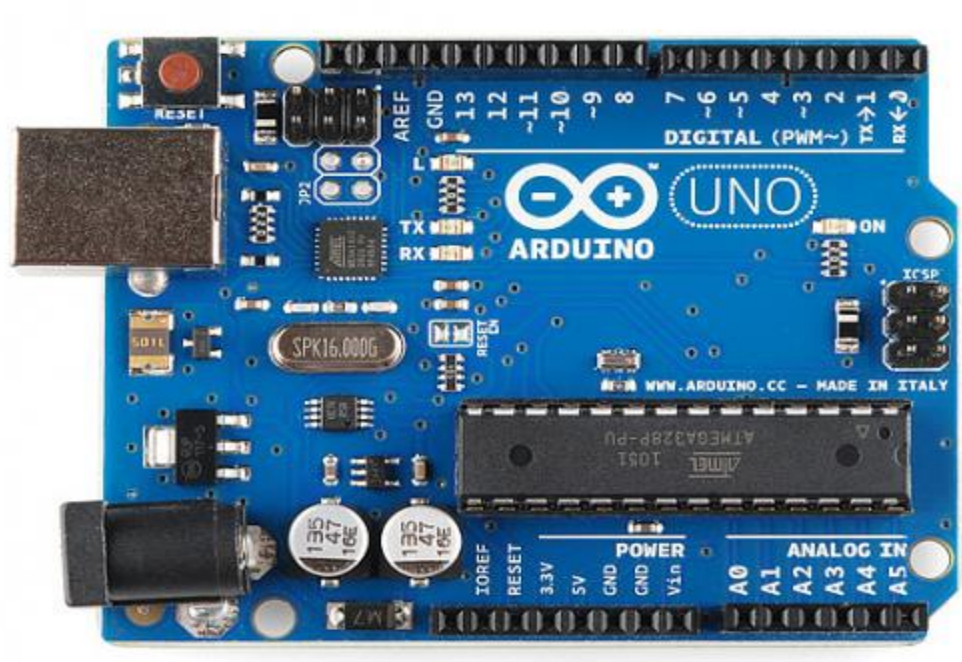


Fig 5.1: An Arduino Uno

Fig 5.2: An A-to-B USB Cable

(a) Suggested Reading

If you're new to Arduino in general, you want to check out this tutorial to familiarize yourself with everyone's favorite microcontroller platform.

What is an Arduino?

If you're ready to get started, click on the link in the column on the left that matches up with your operating system, or you can jump to your operating system here.

- Windows
- Mac
- Linux

Windows

This page will show you how to install and test the Arduino software with a Windows operating system (Windows 8, Windows 7, Vista, and XP).

Windows 8, 7, Vista, and XP

- Go to the Arduino download page and download the latest version of the Arduino software for Windows.
- When the download is finished, un-zip it and open up the Arduino folder to confirm that yes, there are indeed some files and sub-folders inside. The file structure is important so don't be moving any files around unless you really know what you're doing.
- Power up your Arduino by connecting your Arduino board to your computer with a USB cable (or FTDI connector if you're using an Arduino pro). You should see the an LED label 'ON' light up. (this diagram shows the placement of the power LED on the UNO).
- If you're running Windows 8, you'll need to disable driver signing, so go see the Windows 8 section. If you're running Windows 7, Vista, or XP, you'll need to install some drivers, so head to the Windows 7, Vista, and XP section down below.

driver installation. Some older versions of Arduino Uno come with unsigned drivers. This Windows 8 comes with a nice little security 'feature' that 'protects' you from unsigned issue has been addressed in newer releases of the Arduino IDE, but if you run into issues, you can try this fix first. For a nice, step-by-step tutorial with pictures click here, otherwise the steps are outlined below.

To *temporarily* disable driver signing:

- From the Metro Start Screen, open Settings (move your mouse to the bottom-right-corner of the screen and wait for the pop-out bar to appear, then click the Gear icon)
- Click 'More PC Settings'
- Click 'General'
- Scroll down, and click 'Restart now' under 'Advanced startup'.
- Wait a bit.
- Click 'Troubleshoot'.
- Click 'Advanced Options'
- Click 'Windows Startup Settings'
- Click Restart.
- When your computer restarts, select 'Disable driver signature enforcement 'from the list.

To *permanently* disable driver signing (recommended, but has some minor security implications):

- Go to the metro start screen
- Type in “cmd”
- Right click “Command Prompt” and select “Run as Administrator” from the buttons on the bottom of your screen
- Type/paste in the following commands: bcdedit -set loadoptions DISABLE_INTEGRITY_CHECKS bcdedit -set TESTSIGNING ON
- Reboot!

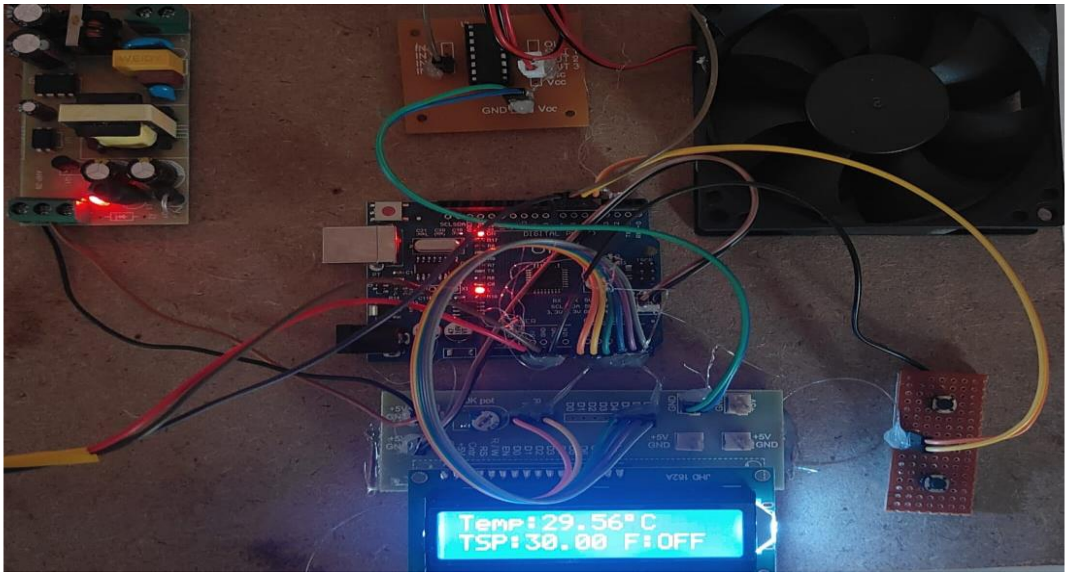
Windows 7, Vista, and XP

Installing the Drivers for the Arduino Uno (from Arduino.cc)

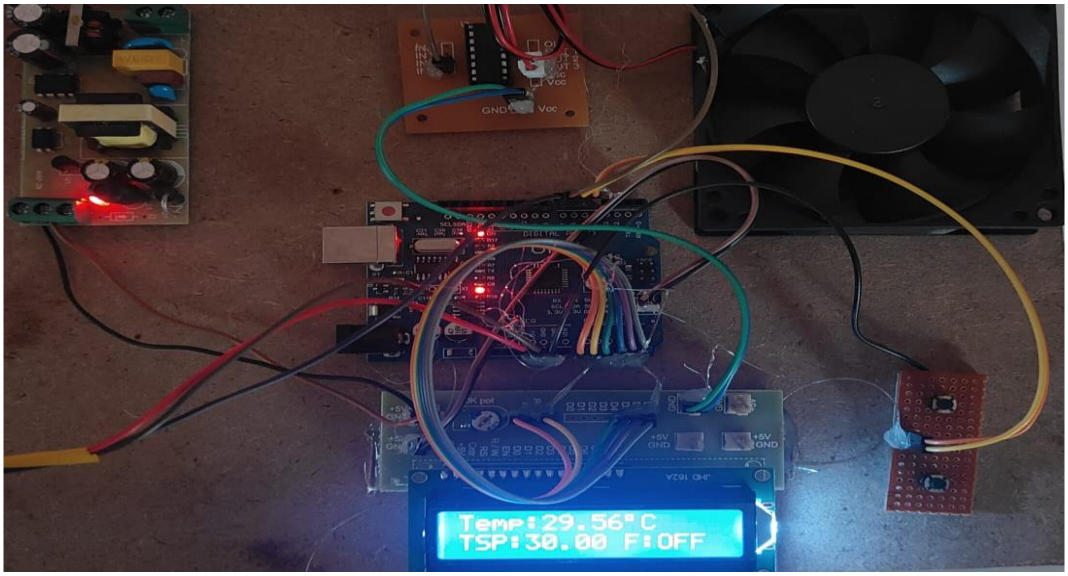
- Plug in your board and wait for Windows to begin its driver installation process
- After a few moments, the process will fail, despite its best efforts
- Click on the Start Menu, and open up the Control Panel
- While in the Control Panel, navigate to System and Security. Next, click on System
- Once the System window is up, open the Device Manager

CHAPTER-6

RESULTS



Room Temperature is less than the Temperature set point(fan off)



Room Temperature is more than the temperature set point(fan on)

ADVANTAGES & DISADVANTAGES

Advantages:

- Accuracy: The LM35 is known for its accuracy in temperature measurement. It has a typical accuracy of ±0.5°C, which is sufficient for maintaining the ideal temperature range for poultry.
- Simplicity: The LM35 is relatively simple to use. It provides an analog output that is directly proportional to the temperature, making it easy to interface with microcontrollers or other monitoring systems.
- Cost-Effective: LM35 sensors are relatively inexpensive compared to other temperature sensors, making them a budget-friendly option for temperature control in poultry houses.
- Low Power Consumption: The LM35 consumes very little power, which is beneficial for long-term use and in systems that are powered by battery or low-energy sources.
- Wide Temperature Range: The LM35 can measure temperatures from -55°C to 150°C, covering a wide range suitable for various environmental conditions, although poultry houses typically require a much narrower range.
- Linear Output: The output voltage of the LM35 increases linearly with temperature, which simplifies the process of temperature measurement and control.

Disadvantages:

- Analog Signal: The LM35 provides an analog output, which may require additional analog-to-digital conversion if interfacing with digital systems. This can introduce complexity and potential for errors if not handled properly.
- Sensitivity to Temperature Fluctuations: While accurate, the LM35 can be sensitive to rapid temperature changes or fluctuations, which might require additional filtering or calibration in some applications.
- Environmental Factors: The LM35 may not be ideal for environments with high humidity or corrosive conditions without additional protective measures, as these factors can affect sensor performance and longevity.

- Limited to Temperature Measurement: The LM35 only measures temperature and cannot provide additional environmental data (e.g., humidity, air quality) that might be relevant for comprehensive poultry management.
- Power Supply Dependency: While low power, the LM35 still requires a stable power supply. Any fluctuations in the power supply can affect the sensor’s performance and accuracy.
- Calibration Required: The sensor might need periodic calibration to maintain accuracy over time, especially if used in harsh or fluctuating conditions.

APPLICATIONS

- Automated Heating: Control heaters to maintain optimal temperatures for poultry growth.
- Cooling Systems: Regulate air conditioning units to prevent overheating.
- Ventilation: Manage fans and ventilation systems to ensure proper air circulation.
- Climate Control: Integrate with comprehensive climate control systems for stable conditions.
- Temperature Logging: Record temperature data for historical analysis and trend monitoring.
- Alarm Systems: Activate alarms if temperatures deviate from preset ranges.
- Energy Management: Optimize energy use by adjusting heating and cooling based on real-time data.
- Brooder Control: Ensure consistent temperature in brooders for newly hatched chicks.
- Egg Incubation: Maintain precise temperatures in incubators for successful egg hatching.
- Fan Speed Control: Adjust fan speeds based on temperature readings to maintain comfort.
- Temperature Profiling: Map temperature variations within poultry houses to identify and address hot or cold spots.
- Remote Monitoring: Use in IoT systems for remote temperature monitoring and control.
- Emergency Systems: Implement backup systems to maintain temperature if primary systems fail.
- Regulatory Compliance: Ensure compliance with temperature-related regulations and standards for poultry farming.
- Data-Driven Decisions: Analyze temperature data to make informed decisions on environmental adjustments and management practices.

CONCLUSION

The LM35 temperature sensor is a valuable asset for managing temperature control in various applications. Its precision in measuring temperature, coupled with its simplicity and low cost, makes it an excellent choice for creating and maintaining optimal environmental conditions. The LM35's ability to provide accurate, linear temperature readings allows for effective regulation of heating, cooling, and ventilation systems, ensuring that conditions are consistently ideal for processes such as poultry farming or any other temperature-sensitive operations. Despite its advantages, the LM35 does come with certain considerations. Its analog output, while straightforward, may necessitate additional analog-to-digital conversion when interfacing with modern digital systems. Additionally, the sensor must be protected from extreme environmental conditions to preserve its accuracy and longevity.Regular calibration and maintenance are also required to ensure ongoing reliability and performance. Overall, the LM35 sensor offers a practical and cost-effective solution for temperature control, enabling efficient management of environmental conditions. Its integration into temperature regulation systems enhances operational efficiency and ensures that the environments being monitored are maintained at optimal levels, ultimately supporting better outcomes in applications ranging from poultry farming to industrial processes

FUTURE SCOPE

The future scope of using the LM35 sensor for temperature control in poultry environments is promising, particularly as technology advances and integration becomes more sophisticated. One significant area for development is the enhancement of sensor accuracy and reliability. While the LM35 is effective for many applications, incorporating advanced sensors with improved precision and stability could further optimize temperature management. Future sensors might offer better resistance to environmental factors such as humidity and dust, ensuring more accurate readings in diverse conditions.

Another exciting advancement is the integration of the LM35 sensor with Internet of Things (IoT) technology. By connecting the temperature control system to the cloud, real-time monitoring and remote management can be achieved. Poultry farmers could access temperature data from anywhere via smartphones or computers, receive alerts if temperatures deviate from the desired range, and adjust settings remotely. This connectivity would also enable the collection of extensive data over time, allowing for the analysis and optimization of temperature control strategies based on historical trends.

Moreover, future systems could benefit from machine learning and artificial intelligence. Advanced algorithms could analyze temperature data to predict and prevent potential issues before **they** arise. For instance, AI could identify patterns and suggest adjustments to heating and cooling systems based on not only current but also historical and predictive data. This proactive approach could lead to even more efficient temperature control and enhanced poultry welfare.

Finally, integrating renewable energy sources with the temperature control system could contribute to sustainability. Combining solar or wind energy with LM35-based systems could reduce operational costs and environmental impact. Future developments might include energy-efficient heating and cooling technologies that work seamlessly with sensor-based control systems, creating a more eco-friendly and cost-effective solution for poultry temperature management.

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