IoT based Generator Condition Monitoring

A project report submitted for partial fulfilment of the requirement for the degree of

BACHELOR OF TECHNOLOGY
In
ELECTRICAL ENGINEERING

By

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CERTIFICATE

To whom it may concern

This is to certify that the project work entitled **IOT BASED GENERATOR CONDITION MONITORING** is the bonafede work carried out by **SOUMYAJIT DE (11701616023), MOHAMMED MUJAB SOLANKI (11701617014), PRATYUSH CHAKRABORTY (11701617010), ARPAN HALDER (11701617018)**, the students of B.Tech in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2019- 20, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

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Thanks to the fellow members of our group for working as a team.

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To

The Head of the Department
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Respected Sir,

In accordance with the requirements of the degree of Bachelor of Technology in the Department of Electrical Engineering, RCC Institute of Information Technology, We present the following thesis entitled “**IOT BASED GENERATOR CONDITION MONITORING**”. This work was performed under the valuable guidance of Mr. Sarbojit Mukherjee, Assistant Professor in the Dept. of Electrical Engineering. We declare that the thesis submitted is our own, expected as acknowledge in the test and reference and has not been previously submitted for a degree in any other Institution.

Yours Sincerely,

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ABBREVIATIONS AND ACRONYMS

IOT – Internet of Things

IC **-** Integrated Circuit

PCB – Printed Circuit Board

µC – Micro Controller

NO **-** Normally Open

NC **-** Normally Closed

COM – Common

LCD – Liquid Crystal Display

LED **-** Light Emitting Diode

POT – Potentiometer

AT – Attention Command

SMPS – Switch Mode Power Supply

ISM – Industrial, scientific and medical

USB – Universal serial bus

SPI – Serial Peripheral Interface

I^2C **–** Inter-Integrated Circuit

GPIO – General Purpose Input Output

API **–** Application Program Interface

AMR **-** Anisotropic Magnet Resistance

GMR**-** Giant Magnetoresistance

Abstract

In this report we present a IOT (Internet of Things) based solution for condition monitoring and predictive maintenance of generator set by establishing a communication between Electronic Hardware and Cloud Computing, popularly known as IOT based applications used especially for online and real time monitoring.

Generator is heart of any power system used for power generation. Generally Generator suffers from abnormal conditions such as over loading and vibrations, to predict these abnormalities an IoT based system is proposed to avoid unnecessary shutdowns. In the implementation of IOT based system, different sensors such as vibration sensors, current, temperature sensors are used to capture some essential parameters to monitor health condition of generator. Faults are being simulated using IOT based hardware equipment for test purpose and to create alters to the respected field operator on web page application. The signal obtained from vibration sensors of time domain are converted in to frequency domain by using algorithm in gateway and waveform patterns are analysed for fault detection. Edge analytics has been carried out locally and efficient early warning system was created based on trends observed on web application.

CHAPTER 1

(INTRODUCTION)

1.1 Introduction

In the present world scenario, increasing in renewable energy resources, especially wind energy and solar energy day by day, it is making necessary fossil power plants to operate in medium and peak load range to stabilize electrical grid. The higher number of load cycles associated with the medium and peak load Operation leads to thermo mechanical stressing of core components such as generators. This typically causes unexpected failures, aging of the machines, risk of damage, loss of production, unplanned maintenance etc. Therefore, vibration and temperature analysis are the important Monitoring techniques for the rotating machines. One important measure which can help unexpected generator damage is to monitor the generator operation and analyze the measured data irregularities. A continuous machine condition monitoring is needed which can reliability and accurately transfer the real time data from the equipment to the monitoring system such that any abnormality in the system can be founded easily and necessary corrective action can be taken without any time delay. A successful online monitoring can help to avoid unexpected trips and optimize outages. Different types of sensors can be used which can sense the key parameters which are needed to monitor continuously. The principal objective of these efforts is to increase overall reliability and availability of the equipment without loss of production as well as to plan for systematic maintenance in a cost-effective way. While vibration, thermal and current signature are the key analysis which can be applied to machines to monitor its health condition. Due to electrical and mechanical forces in rotating machines there exits vibrations which vibrate at different frequencies and amplitudes in the system and these vibrations may increase along with time and may lead to damage of the equipment. Therefore, it is essential to mitigate and analyze the behaviour of these vibrations for safe and reliable operation and there are several standards proposed to regulate the vibration levels in machines.

1.2 Problem Analysis

In the generator due to electrical and mechanical forces in rotating machines there exits vibrations which vibrate at different frequencies and amplitudes in the system and these vibrations may increase along with time and may lead to damage of the equipment. Therefore, it is essential to mitigate and analyze the behaviour of these vibrations for safe and reliable operation and there are several standards proposed to regulate the vibration levels in machines. The trends in the vibration frequency spectrum is simulated and observed frequently to know the problems such as unbalance, misalignment, bearing defect, resonance, looseness and electrical problems. Overloading, transient fluctuations and insulation failure will increase the temperature at bearings, windings and there will be variations in the stator current. Thermal and overload current monitoring is important to extend machine performance as the life of insulation decreases because of over temperatures, so these monitoring can be done by using temperature and current sensors and in this paper the signal obtained from these sensors is analysed by using analytics applied in edge devices. Edge computing provides a corrective solution for the delay in IOT applications and will not only act like intermittent connectivity and data analytics. Data from the sensors will be sent to edge enabled gateway in which local database has been created to store the data locally and rules are written such that any variation in the temperature and current parameters greater than its limits will create an alert at the end user instead of sending data for centralized data store where the data from all generator nodes will be sent for cloud analytics. This real time running mechanisms provides light weighted algorithms in edge level reduced the complexity in real time decision.

1.3 Overview and benefits of the project

Remote Control Technology's line of dependable, durable wireless remote switching systems can and will make money for you and your business. Wireless remote control benefits include:

No legal issues
Obtaining access to or traversing properties with hard lines is extremely difficult.

No copper wire to steal
As the price of copper increases, so does the possibility that your wire will be stolen. Using a wireless remote system means no wire for thieves to steal.

Extended range
Unlike much of the equipment on the market, Remote Control Technology's wireless remote equipment has long-range communication capabilities — up to 5 miles.

Eliminate the need for wire and conduit
Wire and conduit are expensive and high maintenance. Typical wear-and-tear, digging, rodent damage, theft, etc., are all examples of problems that can damage wire. RCT's wireless remote systems put an end to these drawbacks of wired technology.

Higher profits
Wireless remote switching systems eliminate the costly, labor-intensive process of trenching and laying wire. As a result, the contractor can enjoy an increased profitability of 200 percent or more in this facet of the job.

No FCC licensing required
RCT equipment does not require FCC licensing, whereas much of the other equipment on the market does. This is a significant benefit, as the FCC licensing process alone may take up to 8 weeks.

Less maintenance and servicing
In many states a contractor is obligated by law to maintain pumping systems for up to a year after its installation. RCT switching systems eliminate a majority of these maintenance and servicing issues by automating the job. Fewer service calls mean higher profits.

Reliability and compatibility
All of the components that a contractor puts into a project must interface with one another and have the utmost reliability. RCT wireless remote equipment has proven to be highly compatible with standard equipment used in most industries, as well as offering unparalleled reliability in use with programmable logic controllers (PLCs), various switches and relays, etc.

1.4 Organisation of thesis

The thesis is organised into eight chapters including the chapter of introduction. Each chapter is different from the other and is described along with the necessary theory required to comprehend it.

Chapter 2 deals with the literature reviews. From this chapter we can see before our project who else works on this topic and how our project is different and advance from those projects.

Chapter 3 deals with the theory required to do the project. The basic of operation of DS18B20 temperature sensor, ACS712 current sensor, piezoelectric vibration sensor and how to interface with Arduino Uno are described there.

Chapter 4 describes the detail circuit diagram of the whole prototype along with a simulation model made in software for primary testing of the logic

Chapter 5 deals with the hardware modelling of the projects. The main features, photographs, step by step operation of the prototype, component listing and the hardware interfacing of the required components are described here.

Chapter 6 describes the operation of the prototype circuit. A flow chart is presented on the actions which describes the principle of DS18B20 temperature sensor , ACS712 current sensor, piezoelectric vibration sensor detection. Once the values is measured by the sensor the controller display it over a 128X64 (0.96") OLED display and send it to a remote device through ESP8266 wifi module and ThingSpeak server.

Chapter 7 concludes the work performed so far. The possible limitations in proceeding research towards this work are discussed. The future work that can be done in improving the current scenario is mentioned. The future potential along the lines of this work is also discussed.

Chapter 8 References are listed in this chapter

Appendix A, B Hardware description and datasheets are listed here.

CHAPTER 2
(LITERATURE REVIEW)

The research papers helped us to develop the idea of the project and get details about the works done before under similar headings.

This paper [1] presents an IOT (Internet of Things) based solution for condition monitoring and predictive maintenance of generator set by establishing a communication between Electronic Hardware and Cloud Computing, popularly known as IOT based applications used especially for online and real time monitoring. In this proposed real time monitoring system a ADXL345 accelerometer, LM135 temperature sensor & ACS712 current sensor is used for monitoring of vibration, temperature and current respectively. These three analog values are taken in a multiplexing mode connected to a programmable microcontroller Arduino or raspberry pi. Then the values are then sent directly through a wifi module under tcp ip protocol to a dedicated ip that displays the data in real time chart form in any web connected pc / laptop/mobile for display. The real time data is also seen at the sending end upon a android app interfaced to the microcontroller. Many algorithms are written in Arduino such as FFT and simulations are written and processed according to the data received from sensors.

This paper [2] presents a real Time Condition Monitoring System for Industrial Motors. The aim is to design and implementation of IoT technology to monitor and diagnose the condition of Induction motors by recording key operation indicators. The proposed method comprises of an IoT based platform to collect and process the induction motor parameters. The data collected can be stored in the cloud platform and same can be accessed through the web page. And also, timely alerts will be received for any violation in desired limits of parameters under monitoring. The sensors proposed here are ADXL335 vibration sensor, LM35 temperature sensor, ACS712 current sensor and a voltage sensor which is measured by a voltage sensing circuit which produces an output voltage as per micro controller requirement. The sensors are connected to a Arduino Uno control board from where the are send to ThingSpeak server through ESP8266-01 wifi module. A web application is also proposed which will generate instant alert for any abnormal operation of the motor. When combined with computerized data processing techniques this acquisition hardware can be used successfully in the monitoring of motor without requiring access to motor.

The aim of this paper [3] is to propose an IoT based model for real-time condition monitoring of electrical machines, which addresses the challenges of data storage and scalability. The proposed model is evolved with an experimental setup having two sets of DC motor coupled to AC Generator and an IoT device to elucidate integrated monitoring and decision making. This IoT based vibration analytic model uses an IoT2040 Gateway with custom Linux OS image built for acquisition and streaming of vibration signals. The Python target application acquires DC motor’s shaft vibration using vibration sensors and communicates the data as events to cloud through serial device driver interface. The IoT service running in cloud receives the data from multiple machines through lightweight RESTful HTTP and records the same which are retrievable for analysis and algorithm development in any platform. The retrieved data have been analysed using the proposed statistical classification-based signal decomposition algorithm as well as time-frequency analysis to estimate the vibration thresholds of every machine connected to IoT cloud. Such estimated thresholds corresponding to different operating and environmental conditions maintained in cloud are used to build a repository of context specific solutions for machine conditions leading to improved maintenance decisions. The uniformity of threshold values obtained from IoT based model in comparison with that of analysis carried out on the machines locally using myRIO for data acquisition ensures the integrity of the proposed statistical classification algorithm and reliability of the IoT model for condition monitoring with assured scalability.

The system proposed [4] describes the system prototypes of continuous online monitoring of distribution transformer using IOT (internet of things). In this proposed real-time framework a voltage transformer, a current transformer and a lm35 temperature sensor for monitoring voltage, current, temperature respectively. These three analog values are taken in multiplexing mode connected to a programmable microcontroller Arduino uno. Then the values are then sent directly through a wifi module under tcpip protocol to a dedicated ip that display the data in real time chart form in any web connected pc / laptop/mobile for display. The real time data is also seen at the sending end upon a android app interfaced to the microcontroller .The supply of power is given through step down transformer 230/12v, which steps down the voltage to12v ac. This is converted to dc using a bridge rectifier and it is then regulated to +5v using a voltage regulator 7805 which is required for the operation of the arduino, 3.3 volt for the wifi unit and other component.

The proposed paper [5] focus on developing a low cost and easy handling temperature monitoring system, based on radio frequency for wireless data transmission. The wireless system module architecture consists of a power supply, a sensor and a main node system mainly based on wireless radio frequency (RF) technology. The benefits of this system are low cost, high range of temperature sensing, management of data, response to temperature alert, and accuracy of required documentation. The system uses a low-power and gives high-performance. With this utilization, it is possible to design a cost efficient, reliable and accurate system which is perfectly suitable for monitor parameters in harsh environment as required in the outdoor solar application. This device has been tested in a solar NABL lab (Indore, India), for temperature monitoring and compares data with the calibrated monitoring system used in the laboratory. The collected data were used to evaluate the system workability. Data has been taken for the whole year. Also, data shows that the system can measure and monitor the temperature at given distance ranges.

Thus, by going through all these papers we get a clear idea about the project and by alalyzing the problem we started making the prototype of the model.

CHAPTER 3
(THEORY)

3.1 IoT (Internet of Things)

IoT (Internet of Things) is an advanced automation and analytics system which exploits networking, sensing, big data, and artificial intelligence technology to deliver complete systems for a product or service. These systems allow greater transparency, control, and performance when applied to any industry or system.

IoT systems have applications across industries through their unique flexibility and ability to be suitable in any environment. They enhance data collection, automation, operations, and much more through smart devices and powerful enabling technology.

3.1.1 IoT − Key Features

The most important features of IoT include artificial intelligence, connectivity, sensors, active engagement, and small device use. A brief review of these features is given below

- **AI** − IoT essentially makes virtually anything “smart”, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks. This can mean something as simple as enhancing your refrigerator and cabinets to detect when milk and your favourite cereal run low, and to then place an order with your preferred grocer.
- **Connectivity** − New enabling technologies for networking, and specifically IoT networking, mean networks are no longer exclusively tied to major providers. Networks can exist on a much smaller and cheaper scale while still being practical. IoT creates these small networks between its system devices.
- **Sensors** − IoT loses its distinction without sensors. They act as defining instruments which transform IoT from a standard passive network of devices into an active system capable of real-world integration.
- **Active Engagement** − Much of today's interaction with connected technology happens through passive engagement. IoT introduces a new paradigm for active content, product, or service engagement.
- **Small Devices** − Devices, as predicted, have become smaller, cheaper, and more powerful over time. IoT exploits purpose-built small devices to deliver its precision, scalability, and versatility.

3.1.2 IoT − Advantages

The advantages of IoT span across every area of lifestyle and business. Here is a list of some of the advantages that IoT has to offer

- **Improved Customer Engagement** − Current analytics suffer from blind-spots and significant flaws in accuracy; and as noted, engagement remains passive. IoT completely transforms this to achieve richer and more effective engagement with audiences.
- **Technology Optimization** − The same technologies and data which improve the customer experience also improve device use, and aid in more potent improvements to technology. IoT unlocks a world of critical functional and field data.
- **Reduced Waste** − IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources.

- ❖ **Enhanced Data Collection** − Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

3.1.3 IoT − Disadvantages

Though IoT delivers an impressive set of benefits, it also presents a significant set of challenges.
Here is a list of some its major issues

- ❖ **Security** − IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers.
- ❖ **Privacy** − The sophistication of IoT provides substantial personal data in extreme detail without the user's active participation.
- ❖ **Complexity** − Some find IoT systems complicated in terms of design, deployment, and maintenance given their use of multiple technologies and a large set of new enabling technologies.
- ❖ **Flexibility** − Many are concerned about the flexibility of an IoT system to integrate easily with another. They worry about finding themselves with several conflicting or locked systems.
- ❖ **Compliance** − IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle.

3.1.4 Iot Software

IoT software addresses its key areas of networking and action through platforms, embedded systems, partner systems, and middleware. These individual and master applications are responsible for data collection, device integration, real-time analytics, and application and process extension within the IoT network. They exploit integration with critical business systems (e.g., ordering systems, robotics, scheduling, and more) in the execution of related tasks.

- ❖ **Data Collection**
  This software manages sensing, measurements, light data filtering, light data security, and aggregation of data. It uses certain protocols to aid sensors in connecting with real-time, machine-to-machine networks. Then it collects data from multiple devices and distributes it in accordance with settings. It also works in reverse by distributing data over devices. The system eventually transmits all collected data to a central server.
- ❖ **Device Integration**
  Software supporting integration binds (dependent relationships) all system devices to create the body of the IoT system. It ensures the necessary cooperation and stable networking between devices. These applications are the defining software technology of the IoT network because without them, it is not an IoT system. They manage the various applications, protocols, and limitations of each device to allow communication.

- **Real-Time Analytics**
  These applications take data or input from various devices and convert it into viable actions or clear patterns for human analysis. They analyze information based on various settings and designs in order to perform automation-related tasks or provide the data required by industry.
- **Application and Process Extension**
  These applications extend the reach of existing systems and software to allow a wider, more effective system. They integrate predefined devices for specific purposes such as allowing certain mobile devices or engineering instruments access. It supports improved productivity and more accurate data collection.

3.1.5 Internet of Things - Technology and Protocols

IoT primarily exploits standard protocols and networking technologies. However, the major enabling technologies and protocols of IoT are RFID, NFC, low-energy Bluetooth, low-energy wireless, low-energy radio protocols, LTE-A, and WiFi-Direct. These technologies support the specific networking functionality needed in an IoT system in contrast to a standard uniform network of common systems.

NFC and RFID
RFID (radio-frequency identification) and NFC (near-field communication) provide simple, low energy, and versatile options for identity and access tokens, connection bootstrapping, and payments.

- RFID technology employs 2-way radio transmitter-receivers to identify and track tags associated with objects.
- NFC consists of communication protocols for electronic devices, typically a mobile device and a standard device.

Low-Energy Bluetooth
This technology supports the low-power, long-use need of IoT function while exploiting a standard technology with native support across systems.

Low-Energy Wireless
This technology replaces the most power hungry aspect of an IoT system. Though sensors and other elements can power down over long periods, communication links (i.e., wireless) must remain in listening mode. Low-energy wireless not only reduces consumption, but also extends the life of the device through less use.

Radio Protocols
ZigBee, Z-Wave, and Thread are radio protocols for creating low-rate private area networks. These technologies are low-power, but offer high throughput unlike many similar options. This increases the power of small local device networks without the typical costs.

LTE-A
LTE-A, or LTE Advanced, delivers an important upgrade to LTE technology by increasing not only its coverage, but also reducing its latency and raising its throughput. It gives IoT a

tremendous power through expanding its range, with its most significant applications being vehicle, UAV, and similar communication.

Wi-Fi-Direct

Wi Fi-Direct eliminates the need for an access point. It allows P2P (peer-to-peer) connections with the speed of Wi-Fi, but with lower latency. Wi-Fi-Direct eliminates an element of a network that often bogs it down, and it does not compromise on speed or throughput.

3.1.6 Internet of Things - Common Uses

IoT has applications across all industries and markets. It spans user groups from those who want to reduce energy use in their home to large organizations who want to streamline their operations. It proves not just useful, but nearly critical in many industries as technology advances and we move towards the advanced automation imagined in the distant future.

Engineering, Industry, and Infrastructure

Applications of IoT in these areas include improving production, marketing, service delivery, and safety. IoT provides a strong means of monitoring various processes; and real transparency creates greater visibility for improvement opportunities.

The deep level of control afforded by IoT allows rapid and more action on those opportunities, which include events like obvious customer needs, nonconforming product, malfunctions in equipment, problems in the distribution network, and more.

Government and Safety

IoT applied to government and safety allows improved law enforcement, defense, city planning, and economic management. The technology fills in the current gaps, corrects many current flaws, and expands the reach of these efforts. For example, IoT can help city planners have a clearer view of the impact of their design, and governments have a better idea of the local economy.

Home and Office

In our daily lives, IoT provides a personalized experience from the home to the office to the organizations we frequently do business with. This improves our overall satisfaction, enhances productivity, and improves our health and safety. For example, IoT can help us customize our office space to optimize our work.

Health and Medicine

IoT pushes us towards our imagined future of medicine which exploits a highly integrated network of sophisticated medical devices. Today, IoT can dramatically enhance medical research, devices, care, and emergency care. The integration of all elements provides more accuracy, more attention to detail, faster reactions to events, and constant improvement while reducing the typical overhead of medical research and organizations.

3.2 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. 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. 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 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.

Figure 1: Arduino Uno development board

"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.

3.2.1 Pin Configuration of Arduino Uno development board

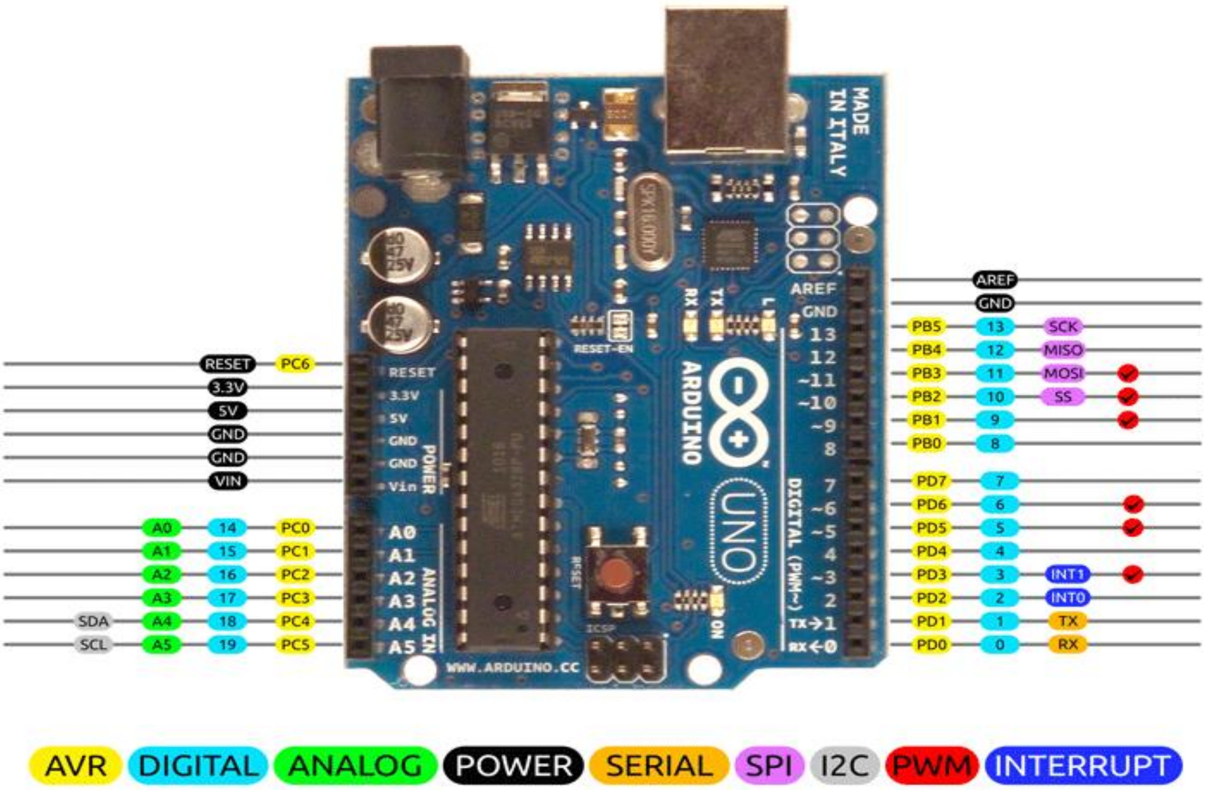


Figure 2: Pin Configuration of Arduino Development Board

3.2.2 Pin Description of Arduino Uno

Table 1: Pin Description of Arduino Uno

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

3.3 IC Temperature sensor

An IC Temperature Sensor is a two terminal integrated circuit temperature transducer that produces an output current proportional to absolute temperature. The sensor package is small with a low thermal mass and a fast response time. The most common temperature range is -55 to 150°C (-58 to 302°F). The solid state sensor output can be analog or digital.

Voltage Output IC Sensors

- Typically 10mV per degree C with nominal output correlated to 0K, 25°C.
- Some sensors have an offset at 0°C so that they can be used and read below 0°C without having to use a negative power supply.
- Non-linearity typically less than 1°C across their temperature range.

Current Output IC Sensors

- Nominal Output: 298 µA at 25°C
- 1 µA output per °C

Digital Output IC Sensors

- Have built in A-D Converters
- The number of digits in the A-D converter provides the resolution
- 10 Bit plus sign provides temperature resolved in increments of 0.25°C
- 12 Bit plus sign provides temperature resolved in increments of 0.0625°C

Where are IC Sensors used?

- On circuit boards to monitor and control temperature.
- In computers to control CPU temperature.
- In telecommunications applications (cell phones & PDA™).
- In some industrial immersion applications.

Strengths and Weaknesses of IC Sensors

Strengths:

- Analog or Digital outputs available
- Low cost
- Direct voltage, current or digital output needing no additional circuitry
- Linear output, no curve fitting
- Direct reading of temperature (1.000 = 100C and 298AµA = 298K or 25°C) on some analog devices
- Various communication interfaces

Weaknesses:

- Narrow temperature range: -55 to 150°C Max
- Wider interchangeability than most RTDs and thermistors
- Wide variation in accuracy between different models
- Small package sizes can be a barrier to low cost applications in some immersion designs

3.4 Comparison of IC temperature sensors with other types of temperature sensors

The analog IC solid state sensors provide an output as a voltage or current that is proportional with temperature without additional circuitry. The digital IC sensors provide an output that has been processed thru an integral A-D converter and is ready for input into digital control and monitoring systems. The IC sensors do not require linearization or other circuitry. The cost of IC sensors are also very competitive with, in some cases less costly than, RTD and thermistor sensors.

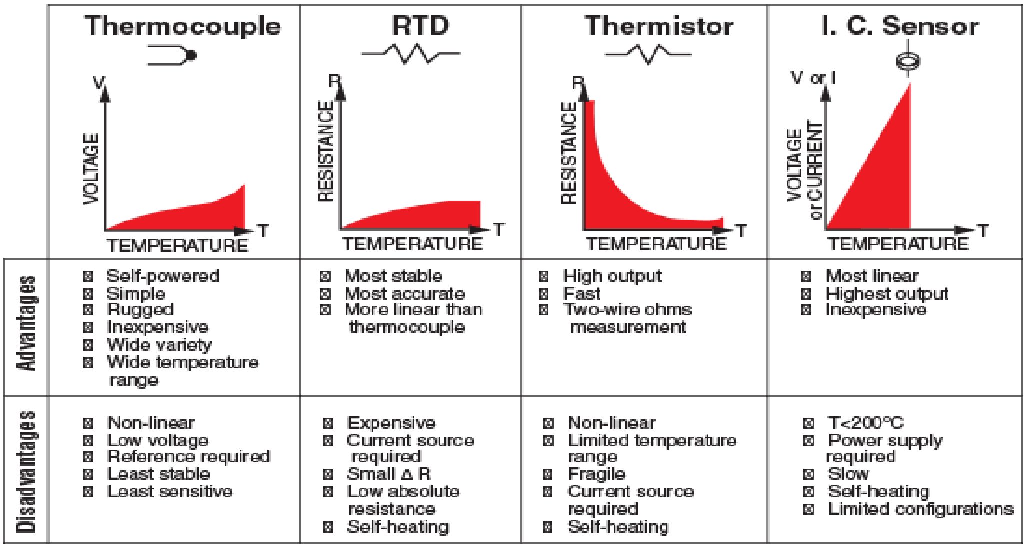


Figure 3: Comparison of different temperature sensors

3.5 DS18B20 Programmable Resolution 1-Wire Digital Temperature Sensor

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

3.5.1 Features of DS18B20 Temperature Sensor

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored in an On-Board ROM
- Multidrop Capability Simplifies Distributed Temperature-Sensing Applications
- Requires No External Components
- Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C Accuracy from -10°C to +85°C
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- User-Definable Nonvolatile (NV) Alarm Settings
- Alarm Search Command Identifies and Addresses Devices Whose Temperature is Outside Programmed Limits (Temperature Alarm Condition)

- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages
- Software Compatible with the DS1822
- Applications Include Thermostatic Controls, Industrial Systems, Consumer Products, Thermometers, or Any Thermally Sensitive System

3.5.2 Pin Configurations of DS18B20

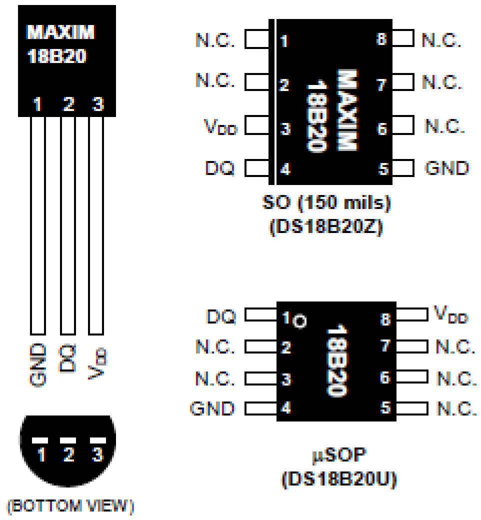


Figure 4: Pin Description of DS18B20

3.5.3 OVERVIEW OF DS18B20

The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte temperature register that stores the digital output from the temperature sensor. In addition, the scratchpad provides access to the 1-byte upper and lower alarm trigger registers (TH and TL) and the 1-byte configuration register. The configuration register allows the user to set the resolution of the temperature-to-digital conversion to 9, 10, 11, or 12 bits. The TH, TL, and configuration registers are nonvolatile (EEPROM), so they will retain data when the device is powered down.

The DS18B20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using one control signal. The control line requires a weak pullup resistor since all devices are linked to the bus via a 3-state or open-drain port (the DQ pin in the case of the DS18B20). In this bus system, the microprocessor (the master device) identifies and addresses devices on the bus using each device's unique 64-bit code. Because each device has a unique code, the number of devices that can be addressed on one bus is virtually unlimited. The 1-Wire bus protocol, including detailed explanations of the commands and "time slots," is covered in the *1-Wire Bus System* section.

Another feature of the DS18B20 is the ability to operate without an external power supply. Power is instead supplied through the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus signal also charges an internal capacitor (CPP), which then supplies power to the device when the bus is low. This method of deriving power from the 1-Wire bus is referred to as “parasite power.” As an alternative, the DS18B20 may also be powered by an external supply on VDD.

DS18B20 Block Diagram

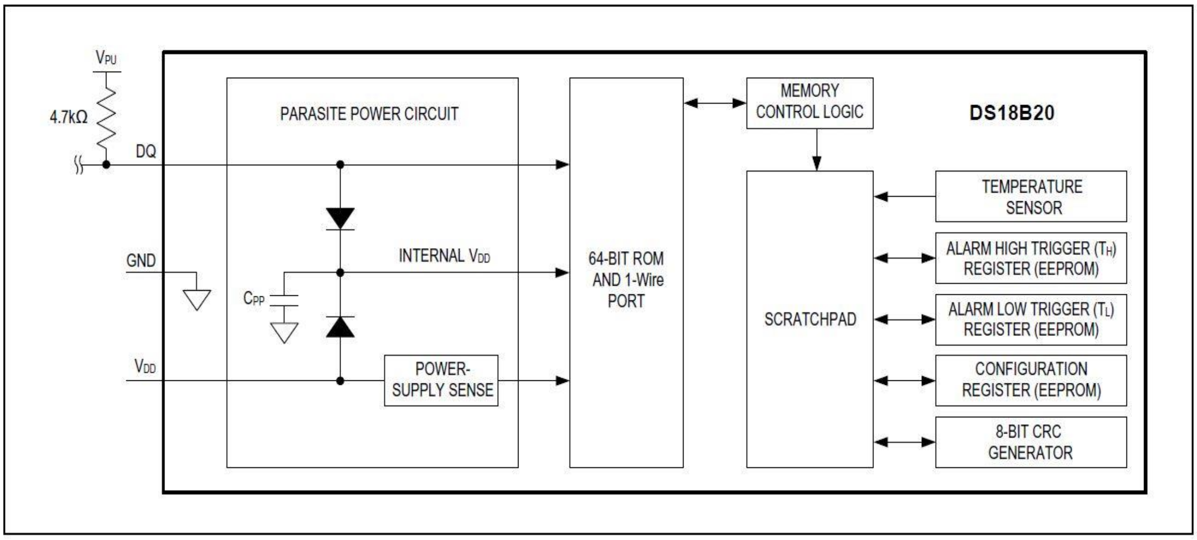


Figure 5: Block Diagram of DS18B20

3.5.4 OPERATION—MEASURING TEMPERATURE

The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up is 12-bit.

The DS18B20 powers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the master must issue a Convert T [44h] command. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its idle state. If the DS18B20 is powered by an external supply, the master can issue “read time slots” after the Convert T command and the DS18B20 will respond by transmitting 0 while the temperature conversion is in progress and 1 when the conversion is done. If the DS18B20 is powered with parasite power, this notification technique cannot be used since the bus must be pulled high by a strong pullup during the entire temperature conversion. The bus requirements for parasite power are explained in detail in the *Powering the DS18B20* section.

The DS18B20 output temperature data is calibrated in degrees Celsius; for Fahrenheit applications, a lookup table or conversion routine must be used. The temperature data is stored as a 16-bit sign extended two’s complement number in the temperature register (see Figure 13). The sign bits (S) indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. If the DS18B20 is configured for 12-bit resolution, all bits in the temperature register will contain valid data. For 11-bit resolution, bit 0 is undefined. For 10-bit resolution, bits 1 and 0 are undefined, and for 9-bit resolution bits 2, 1, and 0 are undefined. Table 1 gives examples of digital output data and the corresponding temperature reading for 12-bit resolution conversions.

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

Figure 6: Temperature Register Format

Table 2: Temperature/Data Relationship

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

Table 3: DS18B20 Function Command Set

COMMAND	DESCRIPTION	PROTOCOL	1-Wire BUS ACTIVITY AFTER COMMAND IS ISSUED	NOTES
TEMPERATURE CONVERSION COMMANDS				
Convert T	Initiates temperature conversion.	44h	DS18B20 transmits conversion status to master (not applicable for parasite-powered DS18B20s).	1
MEMORY COMMANDS				
Read Scratchpad	Reads the entire scratchpad including the CRC byte.	BEh	DS18B20 transmits up to 9 data bytes to master.	2
Write Scratchpad	Writes data into scratchpad bytes 2, 3, and 4 (T_H, T_L, and configuration registers).	4Eh	Master transmits 3 data bytes to DS18B20.	3
Copy Scratchpad	Copies T_H, T_L, and configuration register data from the scratchpad to EEPROM.	48h	None	1
Recall E^2	Recalls T_H, T_L, and configuration register data from EEPROM to the scratchpad.	B8h	DS18B20 transmits recall status to master.	
Read Power Supply	Signals DS18B20 power supply mode to the master.	B4h	DS18B20 transmits supply status to master.	

Note 1: For parasite-powered DS18B20s, the master must enable a strong pullup on the 1-Wire bus during temperature conversions and copies from the scratchpad to EEPROM. No other bus activity may take place during this time.
Note 2: The master can interrupt the transmission of data at any time by issuing a reset.
Note 3: All three bytes must be written before a reset is issued.

3.5.5 Interfacing the temperature sensor with the Arduino Uno

The one wire temperature sensor DS18B20 can be interfaced with most of the microcontroller. In this project it is connected with Arduino Uno. A 4.7 KΩ pullup resistor is required for the proper connection. The beauty of this temperature sensor is that it occupies only one digital I/O pin of the microcontroller. It can be possible to connect infinite number of sensors in the same pin because each sensor has a unique 64 bit address.

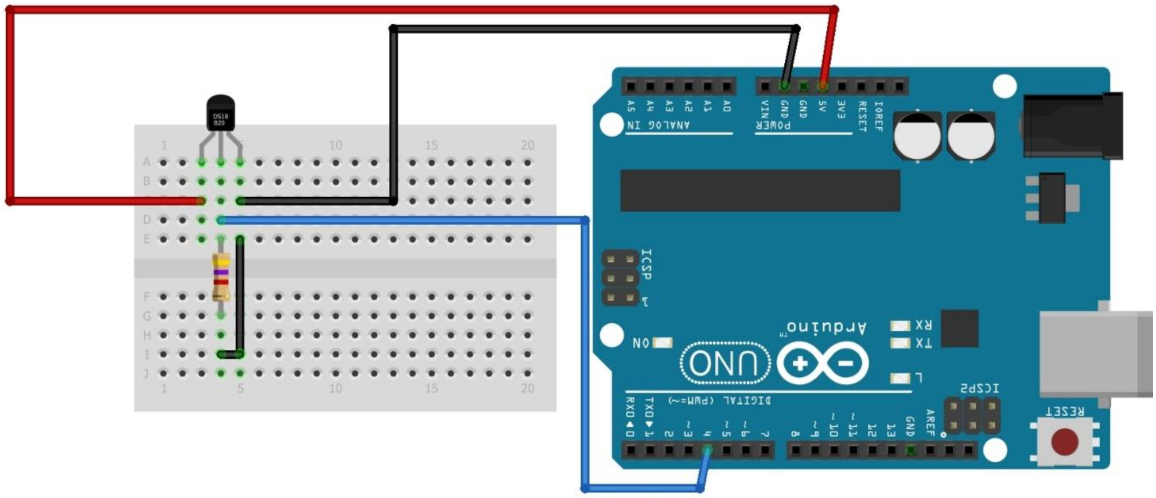


Figure 7: Interfacing DS18B20 with Arduino Uno

3.6 Hall effect current sensors

Hall-effect based sensing devices are widely used in keyboards, position sensors, proximity sensors, speed sensors, magnetic card readers, flow rate sensors, automotive sensors, current sensors etc. General features of Hall-effect based sensing devices are : true solid state, long life, high speed operation, no moving part, broad temperature range (-40◦C to +150◦C) and highly repeatable operation. In addition to these features, Hall-effect current sensors utilize the static and dynamic magnetic field measurement capability of Hall-effect based magnetic sensors to measure both dc and ac. The magnetic field produced by the current to be measured is sensed by a Hall-effect magnetic sensor, whose output gives indirect measurement of the current. The operating principle of Halleffect current sensors used in power electronic applications is briefly discussed in the following sections.

Applications of Analog Hall Effect Sensors

Analog Hall Effect Sensors are utilized for :

- Direct Current sensing in Clamp meters (also known as Tong Testers).
- Wheel speed detection for the anti-lock braking system, (ABS).
- Motor control devices for protection and indications.
- Sensing the availability of Power supply.

- Motion Sensing.
- Sensing the rate of flow.
- Sensing Diaphragm pressure in Diaphragm pressure gauge.
- Sensing Vibration.
- Sensing Ferrous Metal in Ferrous Metal Detectors.
- Voltage Regulation.

Applications of Digital Hall Effect Sensors

Digital Hall Effect Sensors are utilized for :

- Sensing the angular position of the crank shaft for the firing angle of the spark plugs.
- Sensing the position of the car seats and seat belts for air-bag control .
- Wireless Communications.
- Sensing Pressure.
- Sensing Proximity.
- Sensing rate of flow.
- Sensing position of Valves.
- Sensing position of Lens.

Advantages of Hall Effect Sensors

Hall Effect Sensors have the following advantages:

- As they are solid state devices, there is absolutely no wear and tear due to absence of moving parts.
- They are almost maintenance free.
- They are robust.
- They are immune to vibration, dust and water.

Disadvantages of Hall Effect Sensors

The Hall Effect Sensors have the following disadvantages: –

- They are not capable to measure current flow at a distance more than 10 cm. The only solution to overcome this issue is to use a very strong magnet that can generate a wide magnetic field.
- Accuracy of the measured value is always a concern as external magnetic fields may affect the values.
- High Temperature affects the conductor resistance. This will in turn affect the charge carrier’s mobility and sensitivity of Hall Effect Sensors.

3.7 Comparison of hall effect sensor with other type of sensors:

COMPARISON OF SENSOR TECHNOLOGIES				
	Reed	Hall	AMR	GMR
Sensing Element Size	Large	Small	Medium	Small
Construction	Mechanical	Solid State	Solid State	Solid State
Magnet Strength Required	Medium	High	Low	Low
Sensitivity	Medium	Low	High	High
Temperature Stability	Medium	Low	Medium	High
Power Consumption	Zero	Low	High	Low
Noise Immunity	High	Low	High	High
Switching Speed	Low	High	High	High
Mechanical Robustness	Low	Medium	High	High
Electrical Robustness	Low	Low	High	High
Double Switch Points	Yes	Possible	No	No

Figure 8: Comparison of different type of current sensors

3.8 ACS712 Hall Effect-Based Linear Current Sensor

The ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection. The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized Bi CMOS Hall IC, which is programmed for accuracy after packaging.

3.8.1 Features of ACS712 Current Sensor

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 80 kHz bandwidth ▪ Total output error 1.5% at TA = 25°C
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage

- ❖ Nearly zero magnetic hysteresis
- ❖ Ratio metric output from supply voltage

3.8.2 Functional block diagram of ACS712

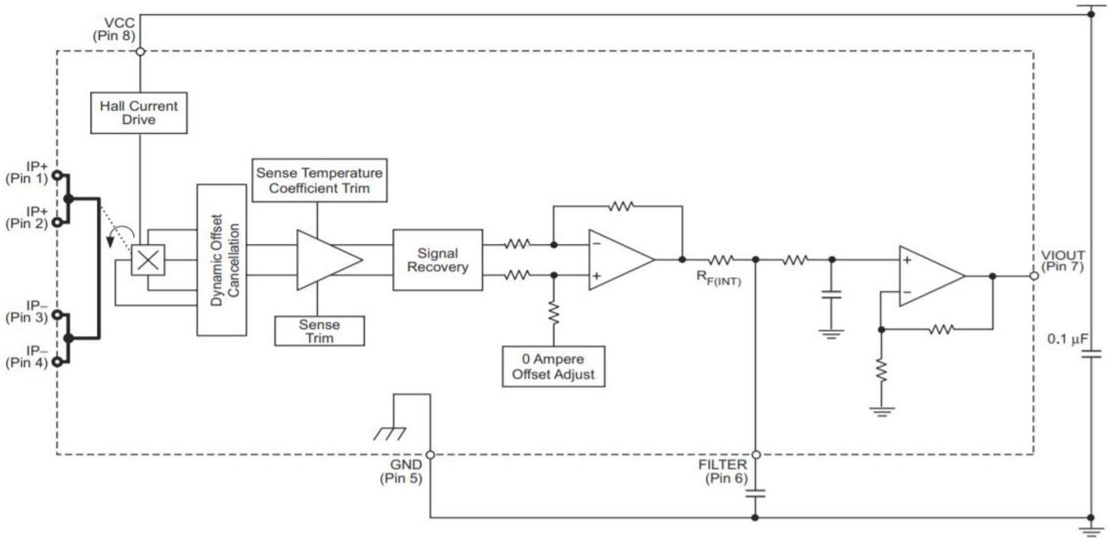


Figure 9: Block Diagram of ACS712

3.8.3 Pin Configuration of ACS712

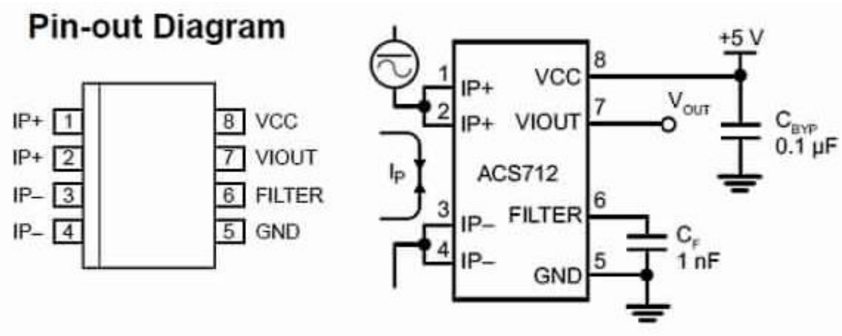


Figure 10: Pin Diagram of ACS712

Table 4: Pin description of ACS712

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

3.8.4 Working Principle of ACS712

The ACS712 current sensor is based on the principle of Hall-effect, which was discovered by Dr. Edwin Hall in 1879. According to this principle, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field. It is illustrated in the figure shown below. A thin sheet of semiconductor material (called Hall element) is carrying a current (I) and is placed into a magnetic field (B) which is perpendicular to the direction of current flow. Due to the presence of Lorentz force, the distribution of current is no more uniform across the Hall element and therefore a potential difference is created across its edges perpendicular to the directions of both the current and the field. This voltage is known Hall voltage and its typical value is in the order of few microvolts. The Hall voltage is directly proportional to the magnitudes of I and B. So if one of them (I and B) is known, then the observed Hall voltage can be used to estimate the other.

The ACS712 device is provided in a small, surface mount SOIC8 package. It consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. When current is applied through the copper conductor, a magnetic field is generated which is sensed by the built-in Hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conduction path, providing a linear relationship between the output Hall voltage and input conduction current. The on-chip signal conditioner and filter circuit stabilizes and enhances the induced Hall voltage to an appropriate level so that it could be measured through an ADC channel of a microcontroller. The pin diagram of ACS712 device and its typical application circuit is shown below. Pins 1, 2 and 3, 4 forms the copper conduction path which is used for current sensing. The internal resistance of this path is around 1.2 m?, thus providing low power loss. As the terminals of this conduction path are electrically isolated from the sensor leads (pins 5 through 8), the ACS712 device eliminates the risk of damaging the current monitoring circuit due to the high voltage on conduction side. The electrical isolation between the conduction current and the sensor circuit also minimizes the safety concerns while dealing with high voltage systems.

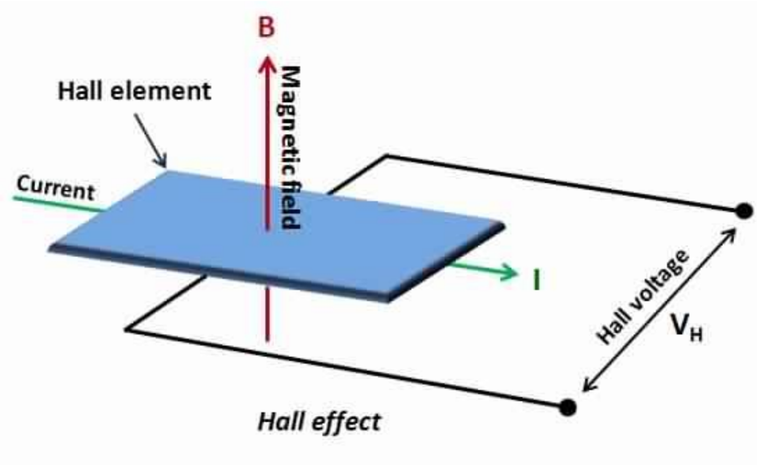


Figure 11: Working Principle of Hall Effect sensors

In low-frequency applications, it is often desirable to add a simple RC filter circuit at the output of the device to improve the signal-to-noise ratio. The ACS712 contains an internal resistor (R_F) connected between the the output of the on-chip signal amplifier and the input of the output buffer stage. The other end of the resistor is externally accessible through pin 6 (Filter). With this architecture, users can implement a simple RC filter through the addition of an external capacitor (C_F) between the Filter pin and ground. It should be noted that the use of external capacitor increases the rise time of the sensor output, and therefore, sets the bandwidth of the input signal. The maximum bandwidth of the input signal is 80 KHz at zero external filter capacitor. The bandwidth decreases with increasing C_F. The datasheet of ACS712 recommends to use 1 nF for C_F to reduce noise under nominal conditions.

3.8.5 Interfacing ACS712 with Arduino Uno

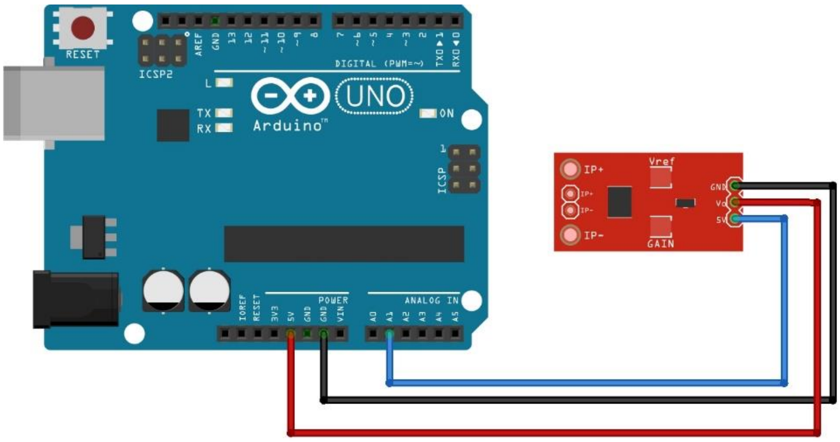


Figure 12: Interfacing ACS712 with Arduino Uno

3.9 Piezo Electric Vibration Sensor

A piezoelectric accelerometer utilizes the piezoelectric effect of certain materials to measure dynamic changes in mechanical variables, such as mechanical shock, vibration and acceleration. Like other transducers, piezoelectric accelerometers convert one form of energy into another and provide an electrical signal in response to the condition, property or quantity. Acceleration acts upon a seismic mass that is restrained by a spring or suspended on a cantilever beam, and converts a physical force into an electrical signal.

There are two types of piezoelectric accelerometers: high and low impedance. High impedance accelerometers have a charge output that is converted into a voltage using a charge amplifier or external impedance converter. Low impedance units use the same piezoelectric sensing element as high-impedance units, and incorporate a miniaturized built-in charge-to-voltage converter and an external power supply coupler to energize the electronics and decouple the subsequent DC bias voltage from the output signal.

Piezoelectric sensor is a kind of sensor made of piezoelectric effect produced by some dielectrics. The so-called piezoelectric effect refers to the phenomenon that when some dielectrics are deformed by external forces in a certain direction (including bending and stretching deformation), due to the polarization of internal charges, they will generate charges on the surface of the dielectrics. Piezoelectric materials can be divided into piezoelectric single crystals, piezoelectric polycrystals and organic piezoelectric materials. The most widely used piezoelectric sensors are various piezoelectric ceramics belonging to piezoelectric polycrystals and quartz crystals in piezoelectric single crystals. Other piezoelectric single crystals include lithium niobate, lithium tantalate, lithium gallate and bismuth germanate, which are suitable for high temperature radiation environment.

Main parameters of piezoelectric sensor

(1) Piezoelectric constant is a parameter to measure the strength of piezoelectric effect of materials. It directly affects the sensitivity of piezoelectric output.

(2) The elastic constants and stiffness of piezoelectric materials determine the natural frequency and dynamic characteristics of piezoelectric devices.

(3) For piezoelectric components of certain shape and size, their inherent capacitance is related to dielectric constant, and the inherent capacitance affects the lower frequency limit of piezoelectric sensors.

(4) In piezoelectric effect, the mechanical coupling coefficient is equal to the square root of the ratio of the converted output energy (e.g. electrical energy) to the input energy (e.g. mechanical energy); it is an important parameter to measure the electromechanical energy conversion efficiency of piezoelectric materials.

(5) The insulation resistance of piezoelectric materials will reduce the charge leakage, thus improving the low frequency characteristics of piezoelectric sensors.

(6) The temperature at which the piezoelectric material begins to lose its piezoelectric properties is called Curie point temperature.

Mechanism	Advantages	Disadvantages	Challenges
Vibration piezoelectric	No voltage source required Higher output voltage -Exploitation of waste mechanical energy -Cooperation with side-smaller cars applications (batteries, powering traffic lights, sings) -New hybrid vehicle-technology can be enhanced by its applicability	-Regular and constant inspections for moderate the effects of the heavy traffic loads -Not appropriate for large scale energy harvesting	Decreased coupling of thin-films

Figure 13: Advantage and disadvantages of Piezo-electric vibration sensor

3.9.1 Working Principle of Piezo Electric Vibration Sensor

A piezoelectric accelerometer consists of a mass attached to a piezoelectric crystal which is mounted on a case. When the accelerometer body is subjected to vibration, the mass on the crystal remains undisturbed in space due to inertia. As a result, the mass compresses and stretches the piezoelectric crystal. This force is proportional to acceleration in accordance with Newton's second law, F = ma, and generates a charge. The charge output is then converted into low impedance voltage output with the help of electronics.

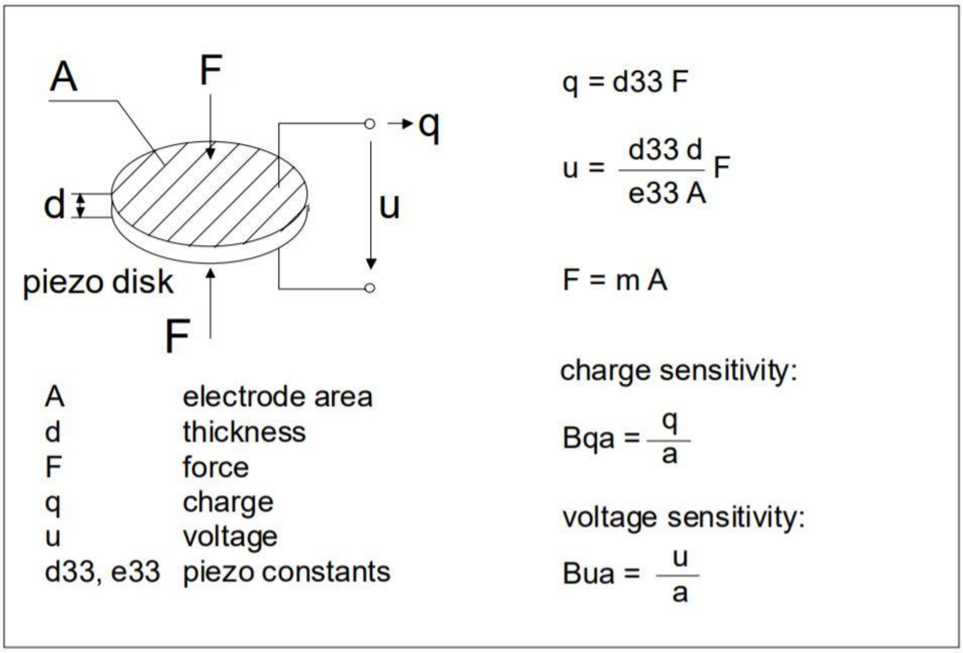


Figure 14: Working Principle of Piezo Electric Vibration Sensor

3.9.2 Benefits of Piezoelectric Accelerometer

The key benefits of piezoelectric accelerometers are:

- Wide frequency range
- No moving parts
- Excellent linearity over their dynamic range
- Low output noise
- Self-generating - no external power required
- Acceleration signal can be integrated to provide velocity and displacement

3.9.3 Applications

Major applications of piezoelectric accelerometers include:

- Engine testing - Combustion and dynamic stressing
- Ballistics - Combustion, explosion, and detonation
- Industrial/factory - Machining systems, metal cutting, and machine health monitoring
- Original equipment manufacturer - Transportation systems, rockets, machine tools, engines, flexible structures, and shock/vibration testers
- Engineering - Dynamic response testing, shock and vibration isolation, auto chassis structural testing, structural analysis, reactors, control systems and materials evaluation
- Aerospace - Ejection systems, rocketry, landing gear hydraulics, shock tube instrumentation, wind tunnel and modal testing.

3.9.4 Comparison of piezo electric vibration sensor with other type of vibration sensors

Sensor Type	Advantages	Disadvantages
Piezoresistive (strain gauge)	• Measures static acceleration • Robust	• Limited resolution • Only up to some kHz • Power supply required
Electrodynamic	• Measures static acceleration	• Only for low frequencies
Capacitive	• Measures static acceleration • Cheap manufacturing by semiconductor process	• Low resolution • Fragile

Figure 15: Comparison of different type of vibration sensors

3.9.5 Interfacing Piezo Electric Vibration Sensor with Arduino Uno

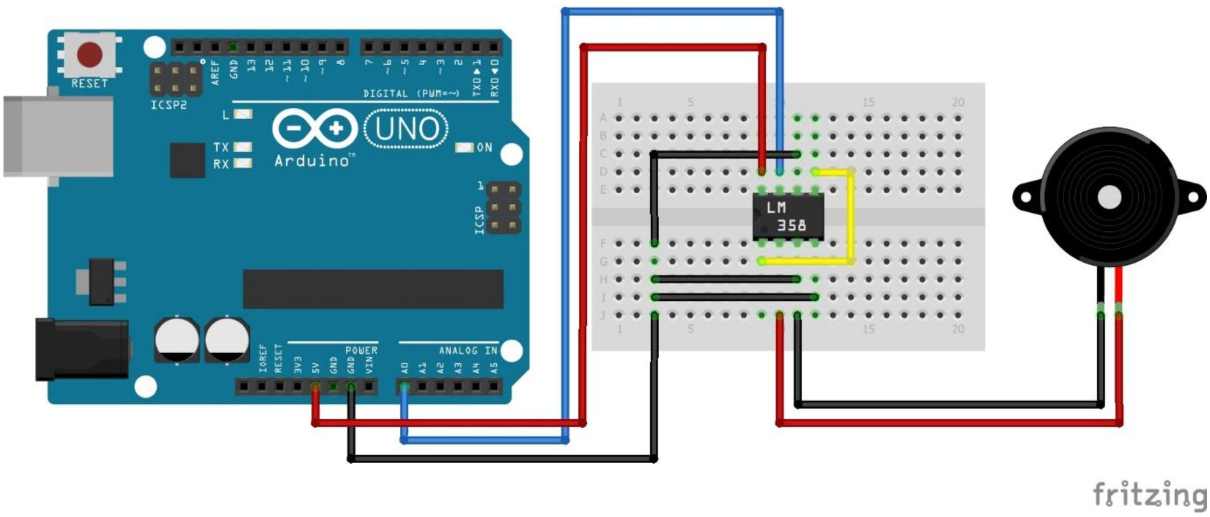


Figure 16: Interfacing Piezo Electric Vibration sensor with Arduino Uno

3.10 Overview of the Project

The following steps describes how to create a channel in ThingSpeak for a particular account . The channel is the identifier for a specific account.

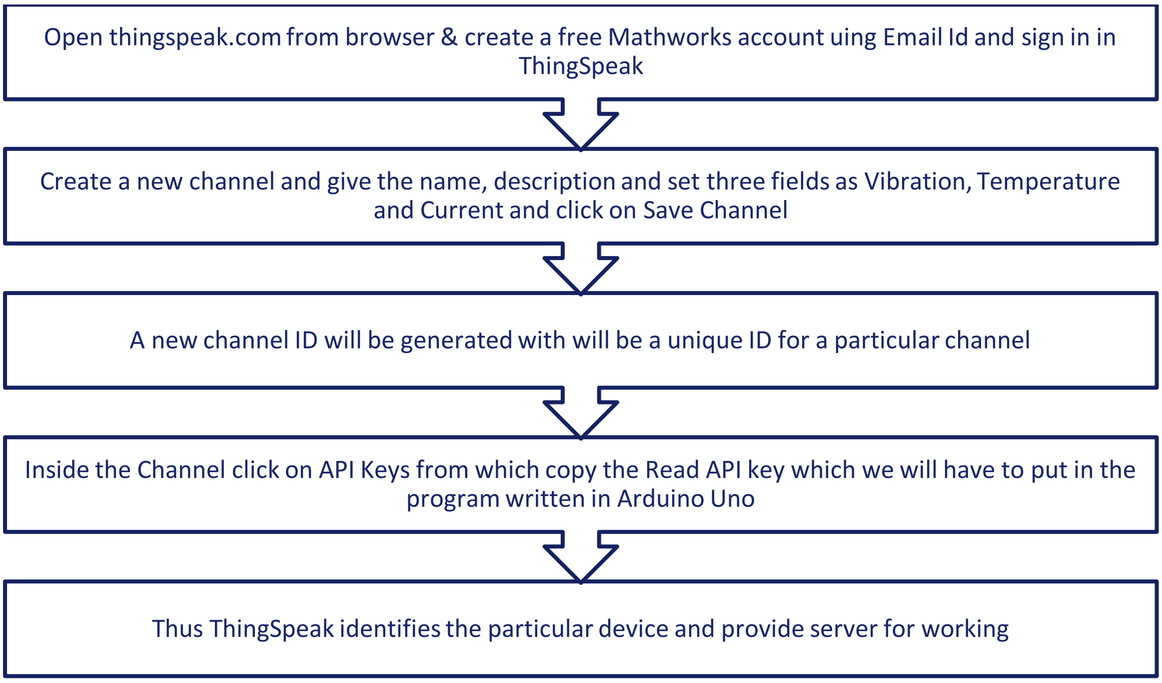


Figure 17: Creating a new channel in ThingSpeak

Once the Read API Key is generated the next job is to put it into coding which is written in Embedded C for proper communication between Arduino and ThingSpeak server through the ESP8266 Wi-Fi module

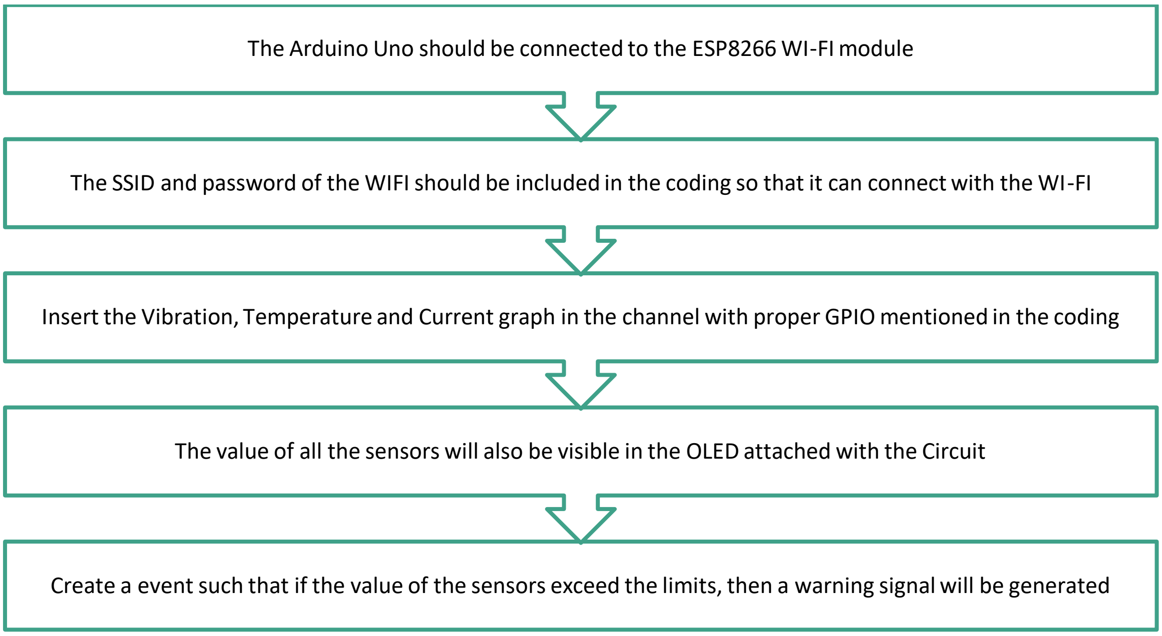


Figure 18: Working Process of the Monitoring System

CHAPTER 4
(CIRCUIT DIAGRAM & SIMULATION MODEL)

4.1 Circuit Diagram

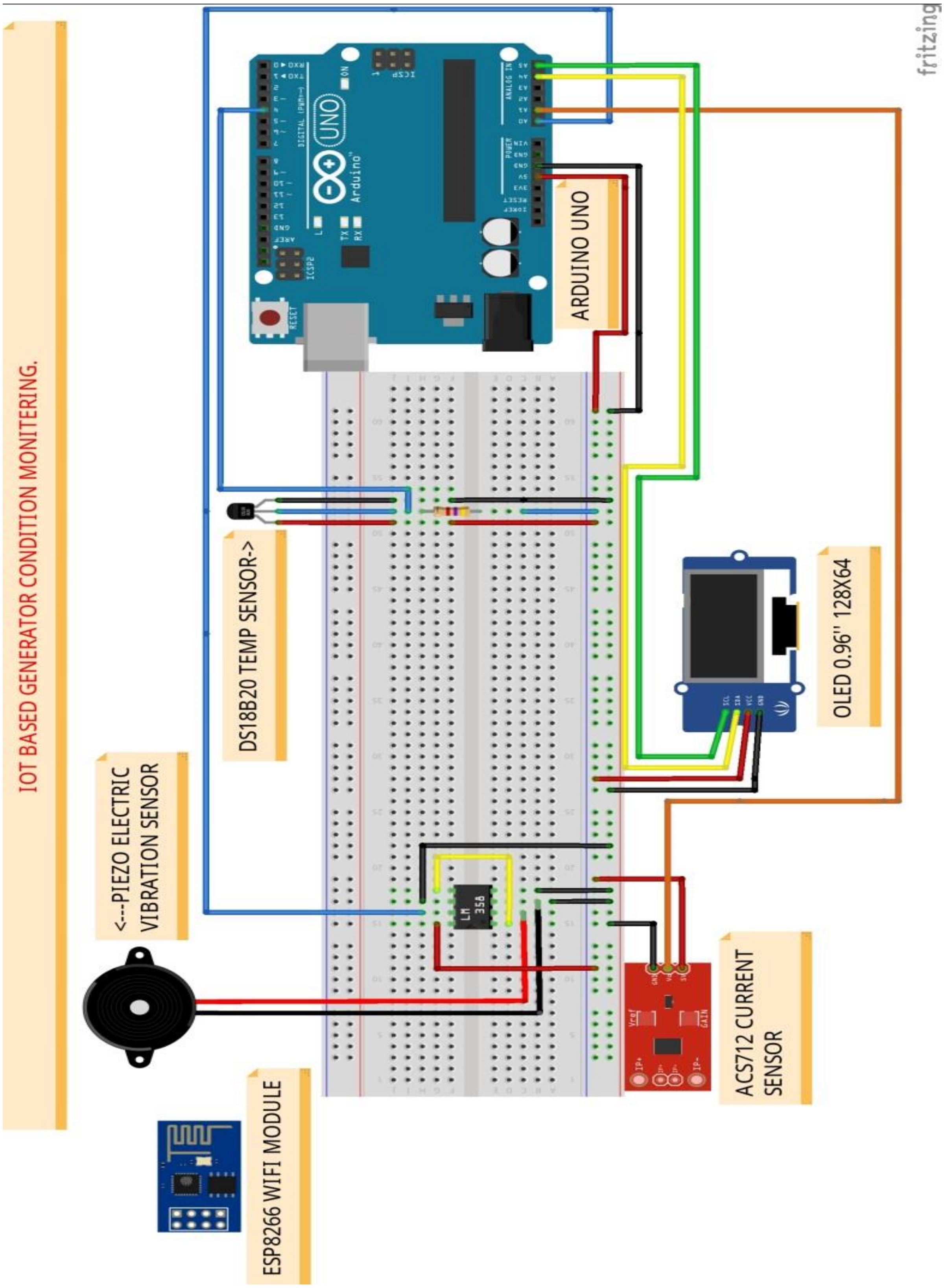


Figure 19: Circuit Diagram of the Monitoring System

4.2 Simulation Model (Made in Proteus 7.0)

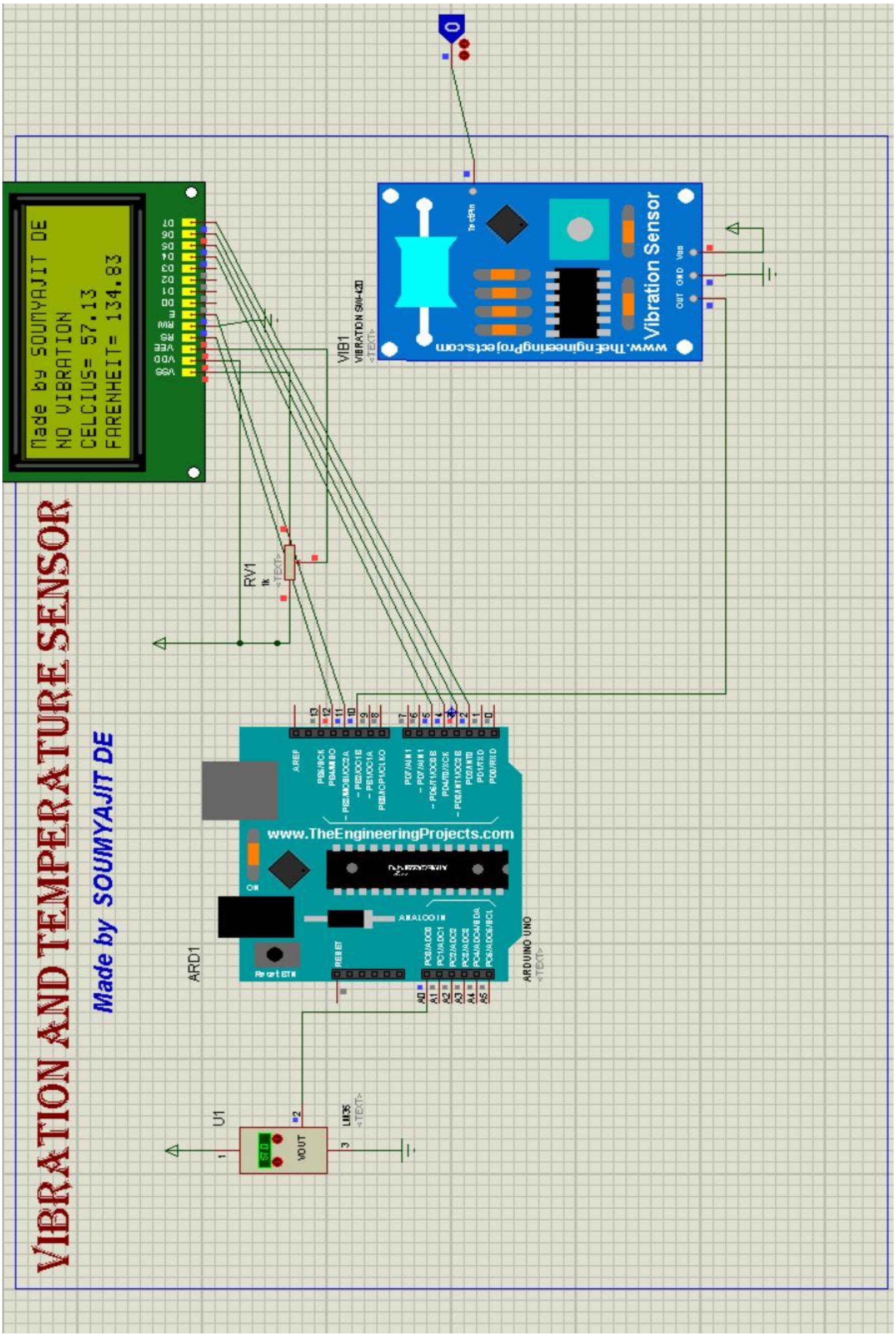


Figure 20: Simulation Model of the Prototype

CHAPTER 5
(HARDWARE MODELLING)

5.1 Main features of the prototype

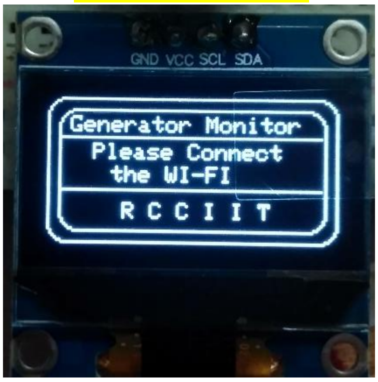
The features of the developed prototype are:

- Globally controlled (throughout the world)
- Real time temperature display in the OLED and mobile/laptop screen
- Secure control
- Buzzer alert system
- 5 Volt operation

5.2 Step by step operation of the prototype

1. Connect the DC Adapter (5V, 1A) to DC Jack.
2. Enable the pre-specified wi-fi (known SSID & password mentioned in the code)
3. After enabling the wi-fi check the circuit OLED display

Before connection



After connection

4. Open the ThingSpeak website and check the parameters in the channel as well as in the OLED
5. Monitor the parameters
6. If there is any abnormal readings found the OLED as well as the piezo buzzer will alert the technicians.

5.3 Some Pictures of readings in the OLED

Figure 21: Some normal readings during operation

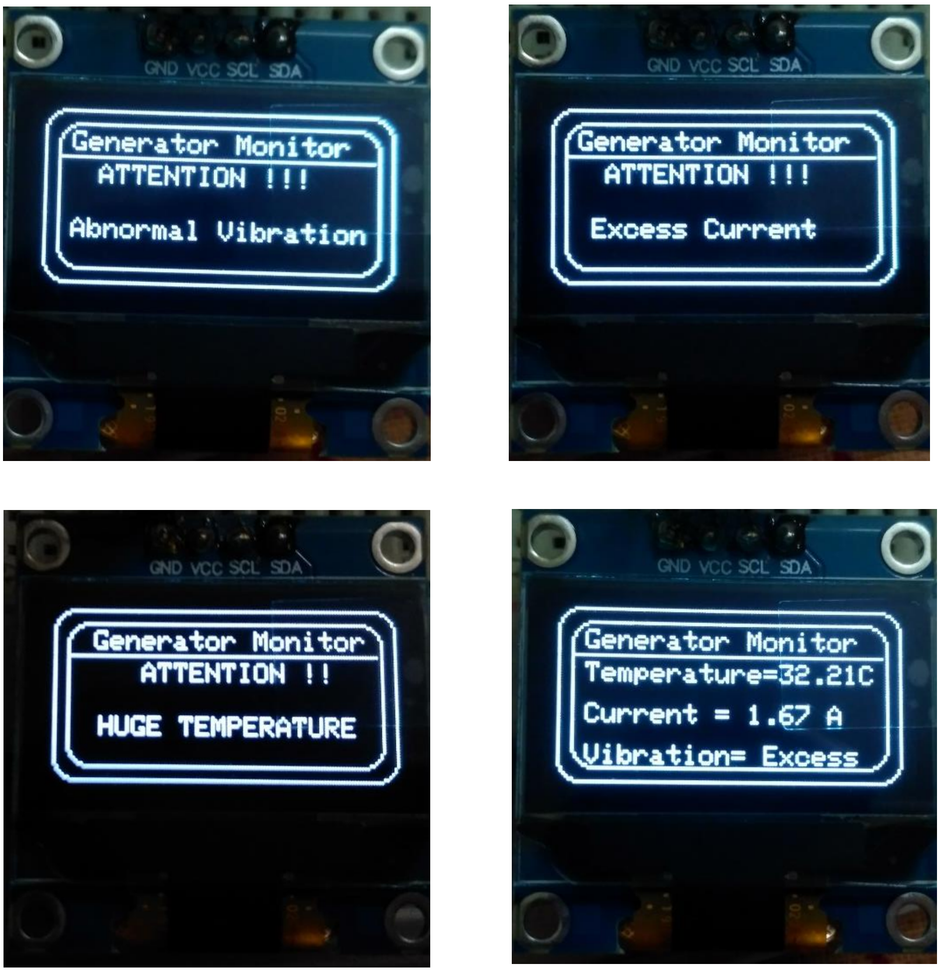


Figure 22: Readings during some abnormal conditions

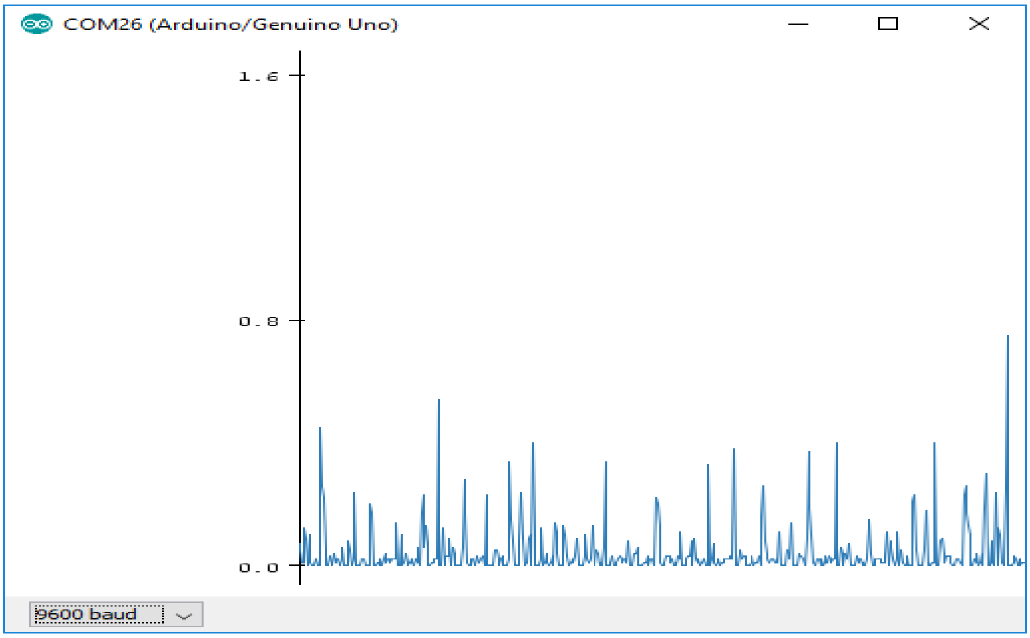


Figure 23: Graph of Vibration Sensor in Arduino Serial Plotter

5.4 Components Required

Table 5: Component Listing

SL. NO.	COMPONENTS	QUANTITY
1	ARDUINO UNO BOARD	1
2	ACS712 CURRENT SENSOR (30AMPS)	1
3	DS1B820 TEMPERATURE SENSOR	1
4	DISC PIEZO	1
5	OLED (128X64) (0.96’’)	1
6	ESP8266 WIFI MODULE	1
7	BLANK PCB (KS100)	1
8	4.7K Ω RESITANCE	2
9	JUMPER WIRE	8
10	SINGLE STRAND WIRE	3m
11	MALE PIN HEADER	1
12	FEMALE PIN HEADER	1
13	LM-358 DUAL OPAMP IC	1
14	100K POTENTIOMETER	1
15	100K Ω RESITANCE	1
16	1MΩ RESITANCE	1
17	0.1μf ELECTROLYTIC CAPACITOR	1
18	220K Ω RESITANCE	1

5.5 Hardware Connection

5.5.1 OLED Graphic Display Interfacing with Arduino Uno

The OLED module shown in the figure 23 is a very popular module available in the market. There are many variants of this module available in market, having different resolutions, communication protocol or pixel colours. They do not require backlight since the display creates its own light. Hence, they consume less power. Both I2C and SPI based OLED modules are available in market. Arduino Uno can communicate with this module using I2C communication protocol.

Pin Description

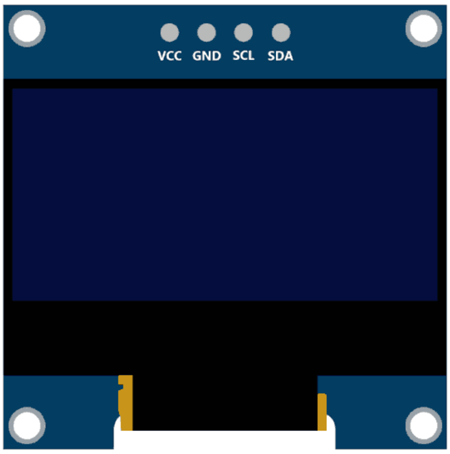


Figure 24: 128 X 64 I2C based OLED Module

VCC: This is the power pin for the module. A supply of 3.3V or 5V can be provided to this pin to power the display.

GND: This is the ground pin for the module.

SCL and SDA: These are the serial clock and serial data pins for I2C Interface.

Interfacing Diagram

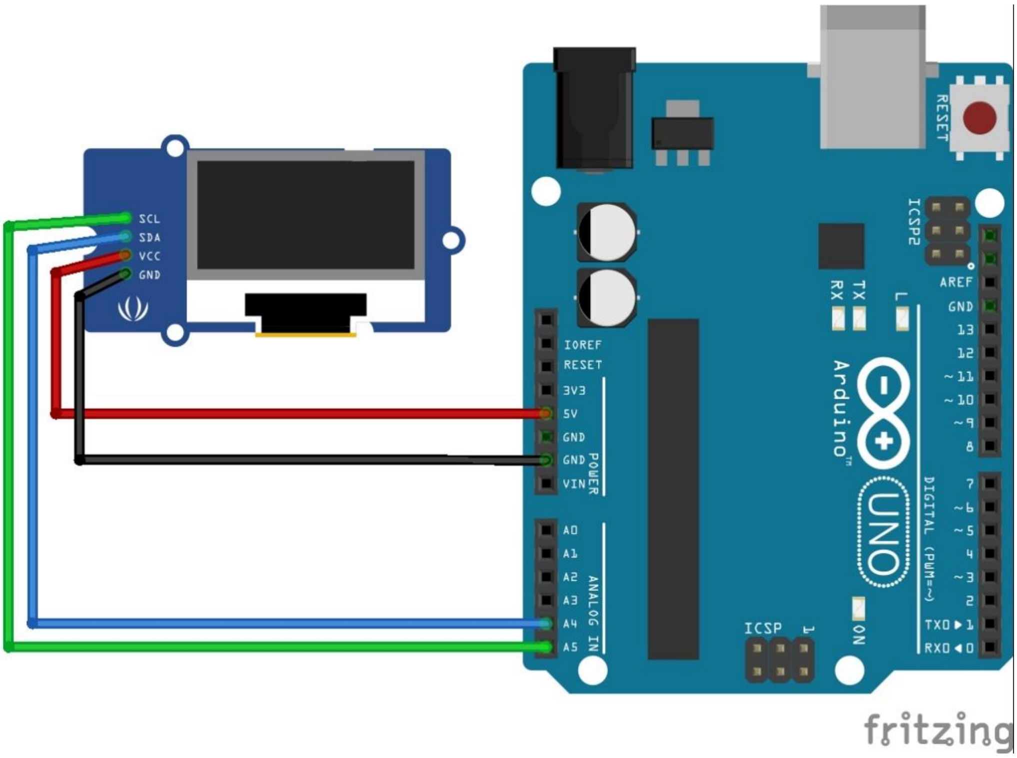


Figure 25: Interfacing OLED with Arduino Uno

5.5.2 ESP8266 WI-FI Module Interfacing with Arduino Uno

ESP8266 is a wifi SOC (system on a chip) produced by Espressif Systems . It is an highly integrated chip designed to provide full internet connectivity in a small package. ESP8266 can be used as an external Wifi module, using the standard AT Command set Firmware by connecting it to any microcontroller using the serial UART, or directly serve as a Wifi-enabled micro controller, by programming a new firmware using the provided SDK.

Pin Description

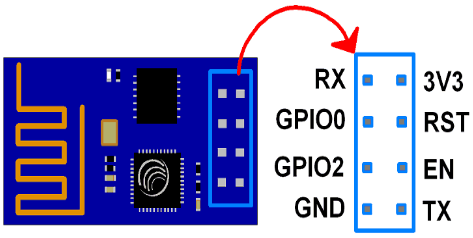


Figure 26: ESP8266 WI-FI Module

3V3: - 3.3 V Power Pin.

GND: - Ground Pin.

RST: - Active Low Reset Pin.

EN: - Active High Enable Pin.

TX: - Serial Transmit Pin of UART.

RX: - Serial Receive Pin of UART.

GPIO0 & GPIO2: - General Purpose I/O Pins. These pins decide what mode (boot or normal) the module starts up in. It also decides whether the TX/RX pins are used for Programming the module or for serial I/O purpose.

Interfacing Diagram

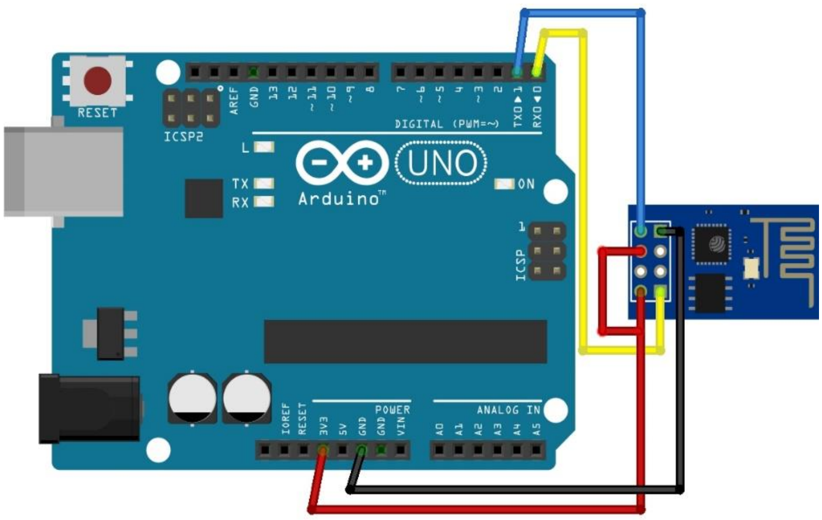


Figure 27: Interfacing ESP8266 with Arduino Uno

CHAPTER 6
(LOGIC & OPERATION)

6.1 Introduction

After assembling the system, what remains is to observe its operation and efficiency of the system. The total system is divided in several sub systems, like

- Arduino Uno Section
- Sensors (DS18B20, ACS712, Disc Piezo)
- OLED Section

The operation of the whole circuit is depending on every section performance.

6.2 Flow Chart

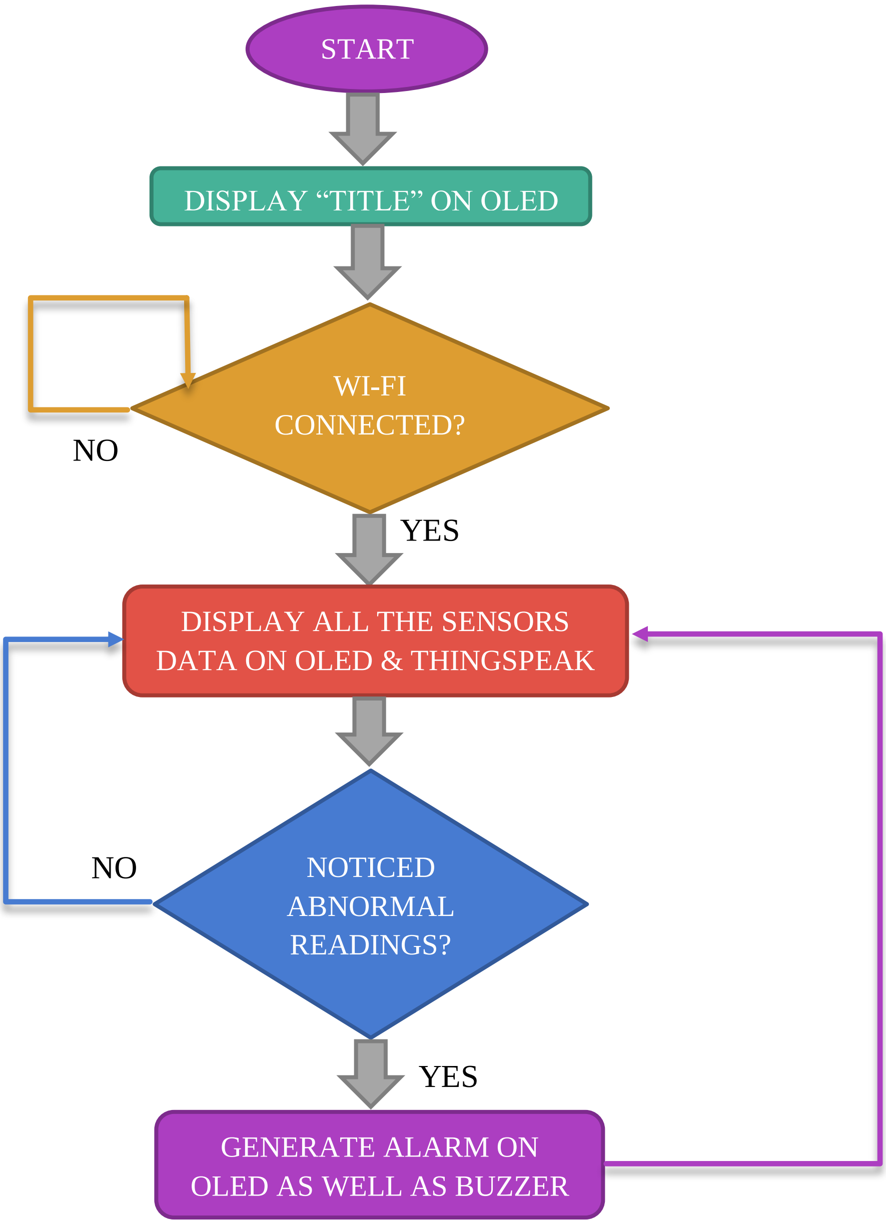


Figure 28: Flow Chart of the Program

6.3 Principle and Operations

The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (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.

6.3.1 Advantages of Arduino Uno

- It comes with an open supply hardware feature that permits users to develop their own kit
- The software of the Arduino is well-suited with all kinds of in operation systems like Linux, Windows, and Macintosh, etc.
- It also comes with open supply software system feature that permits tough software system developers to use the Arduino code to merge with the prevailing programing language libraries and may be extended and changed.

6.3.2 Disadvantages of Arduino Uno

- The operation of the circuit depends on the working internet connection. If the working internet connection is not available then it will not run.
- It also depends on the free server provided by the third party, if the free server is not working then it will not run.
- One major advantage of Arduino Uno is its size. It cannot be fitted in small circuits.

6.4 ThingSpeak Platform

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak. With the ability to execute MATLAB code in ThingSpeak you can perform online analysis and processing of the data as it comes in. ThingSpeak is often used for prototyping and proof of concept IoT systems that require analytics.

Some of the key capabilities of ThingSpeak include the ability to:

- Easily configure devices to send data to ThingSpeak using popular IoT protocols.
- Visualize your sensor data in real-time.
- Aggregate data on-demand from third-party sources.
- Use the power of MATLAB to make sense of your IoT data.
- Run your IoT analytics automatically based on schedules or events.
- Prototype and build IoT systems without setting up servers or developing web software.
- Automatically act on your data and communicate using third-party services like Twilio or Twitter.

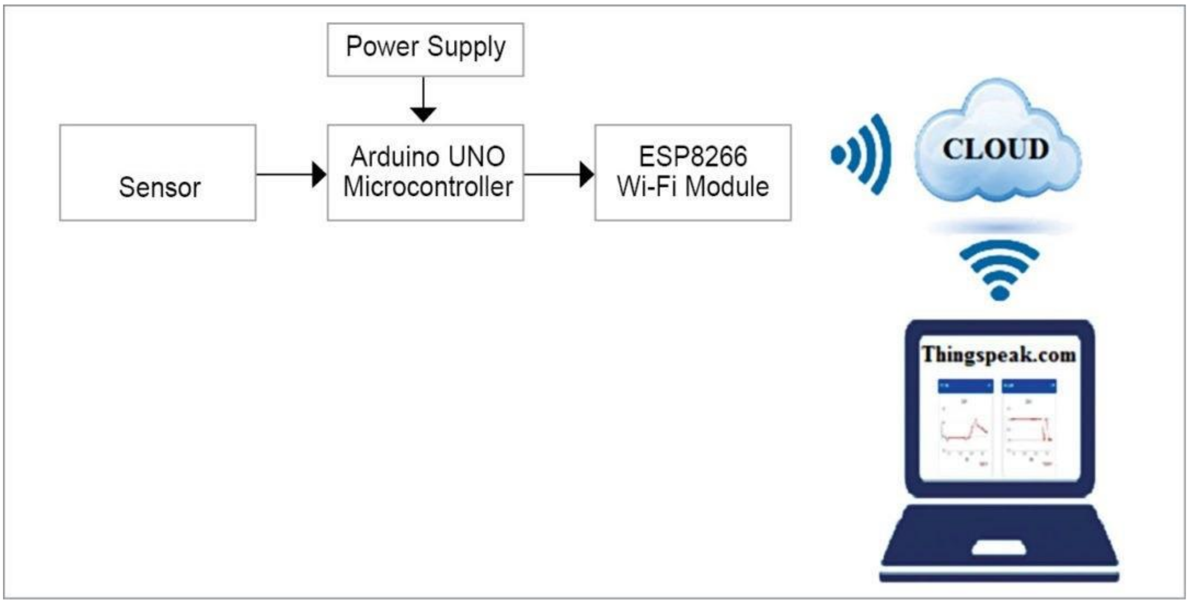


Figure 29: ThingSpeak Working Principle

6.5 ACS712 Current sensor features

- Measures both AC and DC current
- Available as 5A, 20A and 30A module
- Provides isolation from the load
- Easy to integrate with MCU, since it outputs analog voltage

6.6 DS18B20 Sensor features

- Programmable Digital Temperature Sensor
- Communicates using 1-Wire method
- Operating voltage: 3V to 5V
- Temperature Range: -55°C to +125°C
- Accuracy: ±0.5°C
- Output Resolution: 9-bit to 12-bit (programmable)
- Unique 64-bit address enables multiplexing
- Conversion time: 750ms at 12-bit

6.7 Piezoelectric Vibration Sensor features

- These sensors contain as Impedance value ≤500Ω.
- These sensors generally operate in a temperature range of approximately -20°C to +60°C.
- These sensors are to be kept at a temperature between -30°C to +70°C to prevent them from degradation.
- These sensors have very low Soldering temperature.
- Strain sensitivity of a piezoelectric sensor is 5V/µƐ.
- Due to its high flexibility Quartz is the most preferred material as a piezoelectric sensor.

CHAPTER 7

(CONCLUSION & FUTURE SCOPE)

7.1 Conclusion

Here we developed a circuit which will monitor the external physical conditions (Temperature, Current & Vibration) of a generator using IOT. It also limits the problem of lack of proper conditioning and maintenance of the machines. It consist of various parts namely Arduino Uno, ESP8266 Wi-Fi module, DS18B20 Temperature Sensor, ACS712 Current Sensor, Piezo Electric Vibration sensor, OLED, WI-FI device. First it needs to be check whether our module is connected to Wi-Fi or not. If it is connected, it will directly show the sensors data on OLED as well as on ThingSpeak platform. It continuously monitors the conditions of the generator. Whenever the sensors data crosses the predefined set limits the OLED and Buzzer will start the alarming system.

7.2 Cost estimation of the project

In this project we have used the cheapest IOT module Arduino Uno. So the total cost of the project is reduced compare to the other IOT project. The total estimated cost of the complete project is listed in table 6.

Table 6: Costing of the Project

SL. NO.	COMPONENTS	QUANTITY	PRICE (Rs)
1	ARDUINO UNO BOARD	1	350
2	ACS712 CURRENT SENSOR (30AMPS)	1	80
3	DS1B820 TEMPERATURE SENSOR	1	200
4	DISC PIEZO	1	10
5	OLED (128X64) (0.96’’)	1	250
6	ESP8266 WIFI MODULE	1	150
7	BLANK PCB (KS100)	1	40
8	4.7K Ω RESITANCE	2	2
9	JUMPER WIRE	8	40
10	SINGLE STRAND WIRE	3m	45
11	MALE PIN HEADER	1	5
12	FEMALE PIN HEADER	1	5
13	LM-358 DUAL OPAMP IC	1	15
14	100K POTENTIOMETER	1	10
15	100K Ω RESITANCE	1	1
16	1MΩ RESITANCE	1	1
17	0.1μf ELECTROLYTIC CAPACITOR	1	10
18	220K Ω RESITANCE	1	1
19	IC Base (8 Pin)	1	5
TOTAL			**1,220**

7.3 Result

The experimental model was made according to the circuit diagram and the results were as expected. The ThingSpeak website and the OLED show the sensors data as soon as it is connected to the Wi-Fi. Whenever the sensors data crosses the predefined set limits the OLED and Buzzer will start the alarming system.

7.4 Future Scope of the Project

Right now, we are only making an alarming system to operate, in future we will try to add relay to trip the generator in case of severe fault. We are using ThingSpeak platform to operate our module, in future will try to develop own app platform or website platform for our module, because in case this ThingSpeak server stop to work in future we may face problem.

CHAPTER 8
(REFERENCE)

1. D.Swathi, MD.Yaseen, Dr.T.Anil Kumar, **“IoT based Condition Monitoring of Generators and Predictive Maintenance”** Proceedings of the 2nd International Conference on Communication and Electronics Systems (ICCES 2017), Pg. 725- 729

2. Ayushi Gajbiye, Prajakta Zodpe, Zamin Abbas, Hatim Patanwala, Christopher Paul, Prof. Pramod Gadge, **“Iot Based Condition Monitoring Of An Induction Motor”** IOSR Journal of Engineering (IOSRJEN) Pg. 33-40

3. D.Ganga and V. Ramachandran, *“**IoT based Vibration Analytics of Electrical Machines”*** DOI 10.1109/JIOT.2018.2835724, IEEE Internet of Things Journal IoT-2770-2017 Pg. 1- 12

4. Deepraj Duttachowdhury, Vivek Patil, Arya Parab, Raj Patel,Karuna Nikum **“Transformer Monitoring and Control Using Iot”**, IOSR Journal of Engineering (IOSRJEN), Volume 10, Pg. 40-43

5. Rashmi Singh and S.P Singh, **“Development of a Low Cost Wireless Temperature Monitoring System for Industrial & Research Application”** , School of Energy and Environmental Studies, Devi Ahilya University, Khandwa Road, Indore 452001, India, 07 Feb 2015

APPENDIX A

(HARDWARE DESCRIPTION)

Resistor

Figure 30: Resistor

Resistance is the opposition of a material to the current. It is measured in Ohms Ω. All conductors represent a certain amount of resistance, since no conductor is 100% efficient. To control the electron flow (current) in a predictable manner, we use resistors. Electronic circuits use calibrated lumped resistance to control the flow of current. Broadly speaking, resistor can be divided into two groups viz. fixed & adjustable (variable) resistors. In fixed resistors, the value is fixed & cannot be varied. In variable resistors, the resistance value can be varied by an adjuster knob. It can be divided into (a) Carbon composition (b) Wire wound (c) Special type. The most common type of resistors used in our projects is carbon type. The resistance value is normally indicated by color bands. Each resistance has four colors, one of the bands on either side will be gold or silver, this is called fourth band and indicates the tolerance, others three band will give the value of resistance (see table). For example, if a resistor has the following marking on it say red, violet, gold. Comparing these coloured rings with the color code, its value is 27000 ohms or 27 kilo ohms and its tolerance is ±5%. Resistor comes in various sizes (Power rating).The bigger the size, the more power rating of 1/4 watts. The four color rings on its body tells us the value of resistor value.

Color Code of the resistor

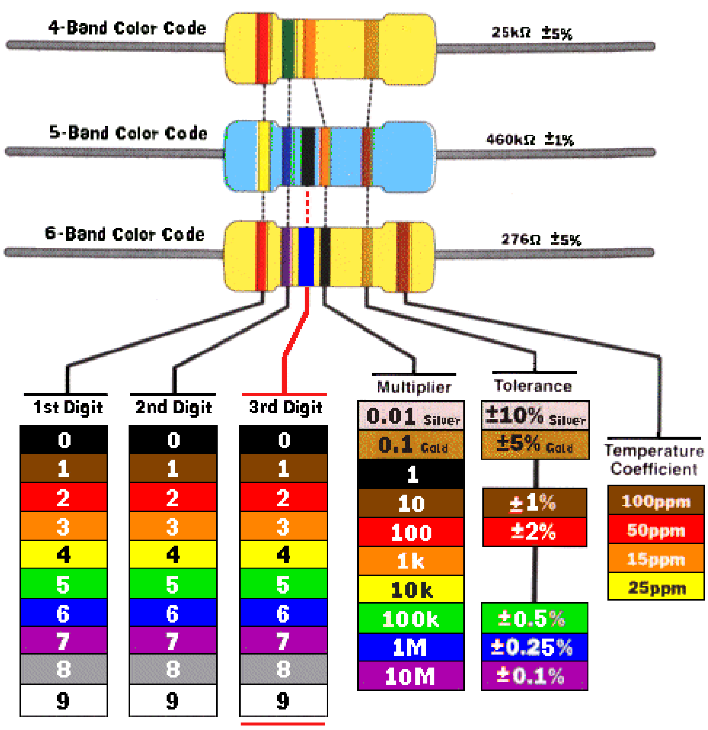


Figure 31: Color Code of resistor

OLED

An organic light-emitting diode (OLED) is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This organic layer is situated between two electrodes; typically, at least one of these electrodes is transparent. OLEDs are used to create digital displays in devices such as television screens, computer monitors, portable systems such as smart phones, handheld game consoles and PDAs. A major area of research is the development of white OLED devices for use in solid-state lighting applications.

Figure 32: 128X64 OLED Module

Specifications:

- High-resolution at 128x64 pixels
- 160 degrees viewing angle
- Lower power consumption: only 0.06W with normal use
- Power supply AC3V-5V, working very well with Arduino
- Working temperature: -30 degrees to 70 degree Celsius
- Dimensions: L27.8 x W27.3 x H4.3 mm
- Compatible 3.3v and 5.0v chip I/O level
- Driver IC SSD1306

Piezo buzzer

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or keystroke. A piezoelectric element may be driven by an oscillating electronic circuit or other audio signal source, driven with a piezoelectric audio amplifier. Sounds commonly used to indicate that a button has been pressed are a click, a ring or a beep.

Figure 33: Piezo Buzzer

Blank PCB

A **printed circuit board** (**PCB**) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs can be *single sided* (one copper layer), *double sided* (two copper layers) or *multi-layer* (outer and inner layers). Multi-layer PCBs allow for much higher component density. Conductors on different layers are connected with plated-through holes called vias. Advanced PCBs may contain components - capacitors, resistors or active devices - embedded in the substrate.

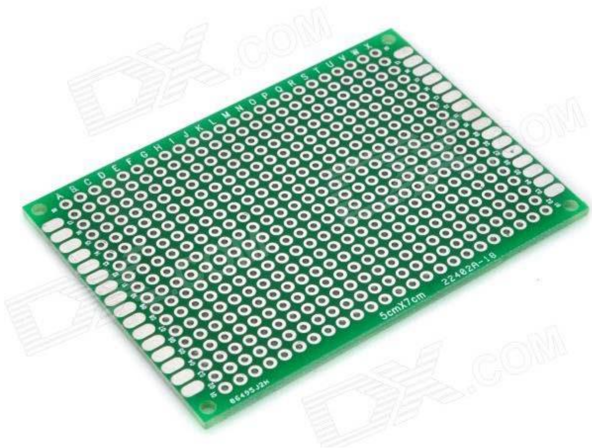


Figure 34: Blank glass epoxy PCB Board

FR-4 glass epoxy is the primary insulating substrate upon which the vast majority of rigid PCBs are produced. A thin layer of copper foil is laminated to one or both sides of an FR-4 panel. Circuitry interconnections are etched into copper layers to produce printed circuit boards. Complex circuits are produced in multiple layers. Printed circuit boards are used in all but the simplest electronic products. Alternatives to PCBs include wire wrap and point-to-point construction. PCBs require the additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as components are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

ESP8266 WI-FI Module

ESP8266 is a wifi SOC (system on a chip) produced by Espressif Systems . It is an highly integrated chip designed to provide full internet connectivity in a small package. ESP8266 can be used as an external Wifi module, using the standard AT Command set Firmware by connecting it to any microcontroller using the serial UART, or directly serve as a Wifi-enabled micro controller, by programming a new firmware using the provided SDK.

Figure 35: ESP8266 WI-FI Module

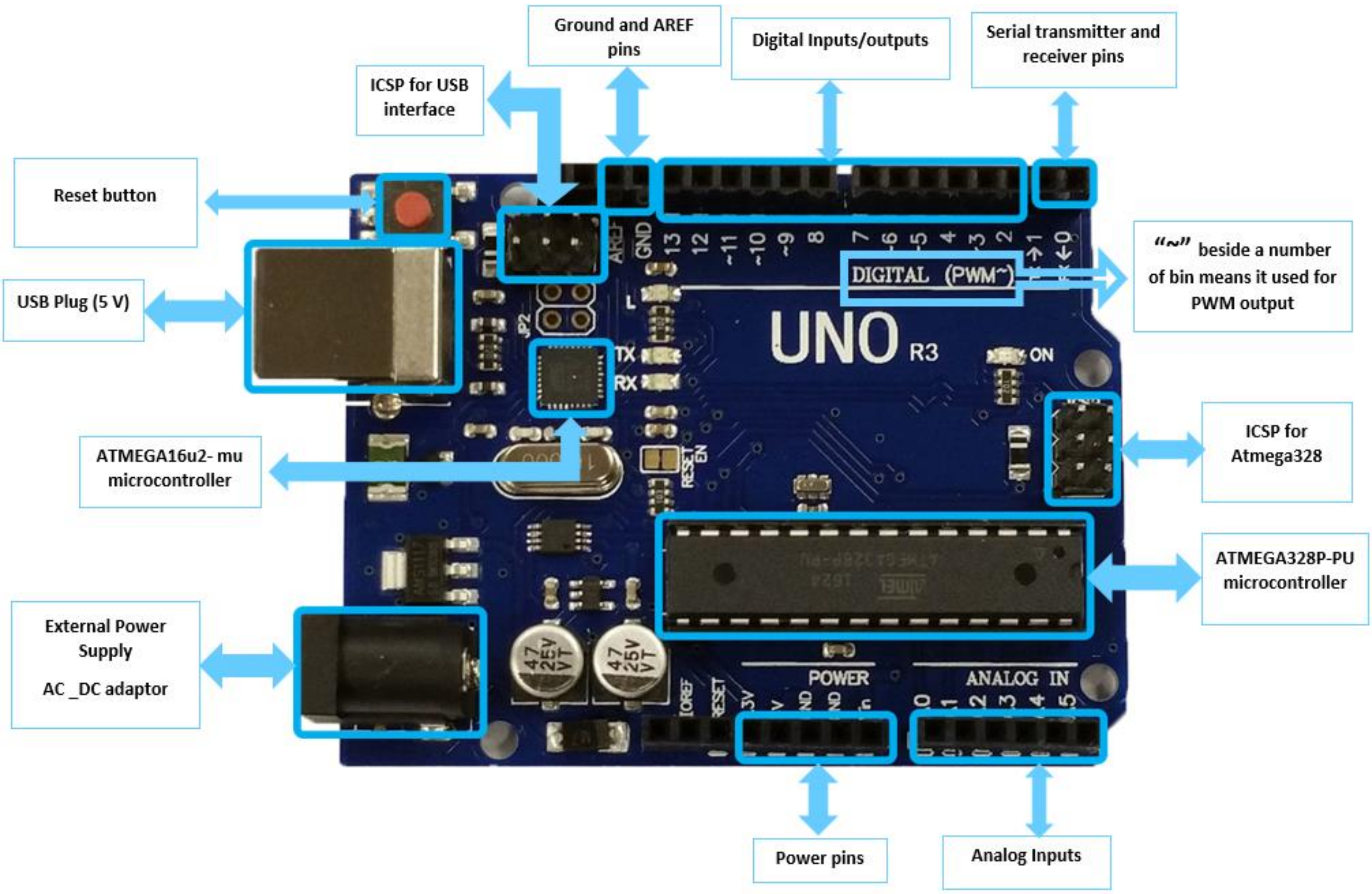
Features

- ✓ 802.11 b / g / n wireless standards
- ✓ STA / AP modes support
- ✓ TCP / IP protocol stack, One socket
- ✓ Supports serial data bits: 5/6/7/8 bits
- ✓ Supports serial parity: none
- ✓ Supports serial stop bits: 1/2 bit
- ✓ KEY button: modes configuration
- ✓ WiFi operation current: continuous transmission operation: ≈70mA (200mA MAX), idle mode: <200uA
- ✓ Serial WiFi transmission rate: 110-460800bps

APPENDIX B

(DATASHEETS)

Arduino Uno R3



INTRODUCTION

Arduino is used for building different types of electronic circuits easily using of both a physical programmable circuit board usually microcontroller and piece of code running on computer with USB connection between the computer and Arduino.

Programming language used in Arduino is just a simplified version of C++ that can easily replace thousands of wires with words.

ARDUINO UNO-R3 PHYSICAL COMPONENTS

ATMEGA328P-PU microcontroller

The most important element in Arduino Uno R3 is ATMEGA328P-PU is an 8-bit Microcontroller with flash memory reach to 32k bytes. It's features as follow:

• High Performance, Low Power AVR

• Advanced RISC Architecture

- 131 Powerful Instructions – Most Single Clock Cycle Execution
- 32 x 8 General Purpose Working Registers
- Up to 20 MIPS Throughput at 20 MHz
- On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory Segments

- 4/8/16/32K Bytes of In-System Self-Programmable Flash program memory
- 256/512/512/1K Bytes EEPROM
- 512/1K/1K/2K Bytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Data retention: 20 years at 85°C/100 years at 25°C
- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by On-chip Boot Program
- True Read-While-Write Operation
- Programming Lock for Software Security

• Peripheral Features

- Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
- One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
- Real Time Counter with Separate Oscillator
- Six PWM Channels
- 8-channel 10-bit ADC in TQFP and QFN/MLF package
- Temperature Measurement
- 6-channel 10-bit ADC in PDIP Package
- Temperature Measurement
- Programmable Serial USART

- Master/Slave SPI Serial Interface
- Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator
- Interrupt and Wake-up on Pin Change

• Special Microcontroller Features

- Power-on Reset and Programmable Brown-out Detection
- Internal Calibrated Oscillator
- External and Internal Interrupt Sources
- Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby

• I/O and Packages

- 23 Programmable I/O Lines
- 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

• Operating Voltage:

- 1.8 - 5.5V

• Temperature Range:

- -40°C to 85°C

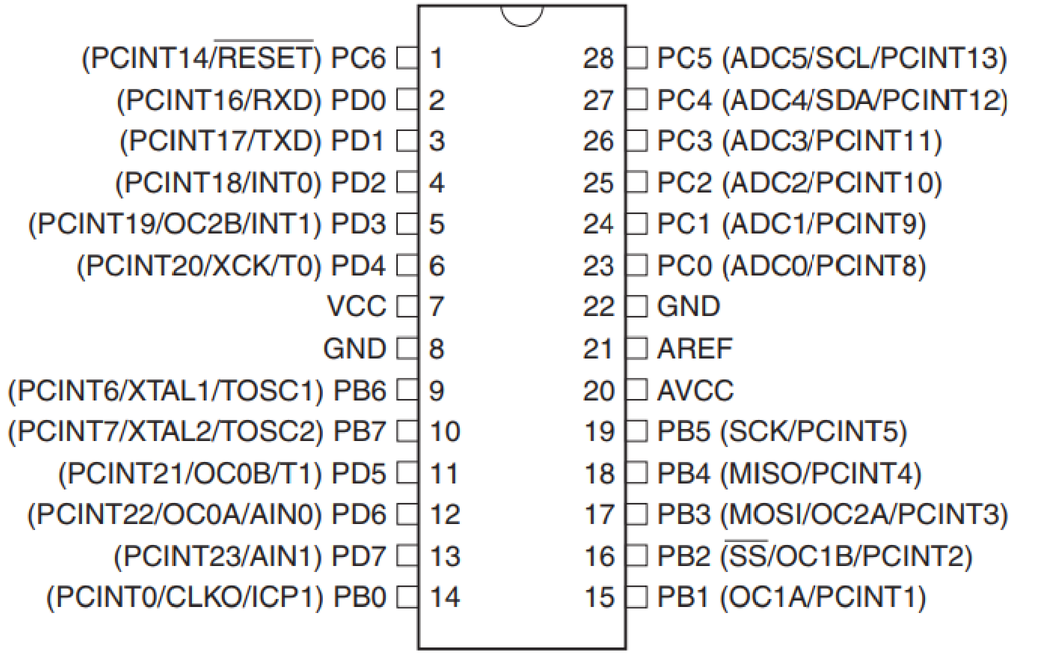
• Speed Grade:

- 0 - 4 MHz@1.8 - 5.5V, 0 - 10 MHz@2.7 - 5.5.V, 0 - 20 MHz @ 4.5 - 5.5V

• Power Consumption at 1 MHz, 1.8V, 25°C

- Active Mode: 0.2 mA
- Power-down Mode: 0.1 µA
- Power-save Mode: 0.75 µA (Including 32 kHz RTC)

- Pin configuration



ATMEGA16u2- mu microcontroller

Is a 8-bit microcontroller used as USB driver in Arduino uno R3 it's features as follow:

- High Performance, Low Power AVR

- Advanced RISC Architecture
  - 125 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz

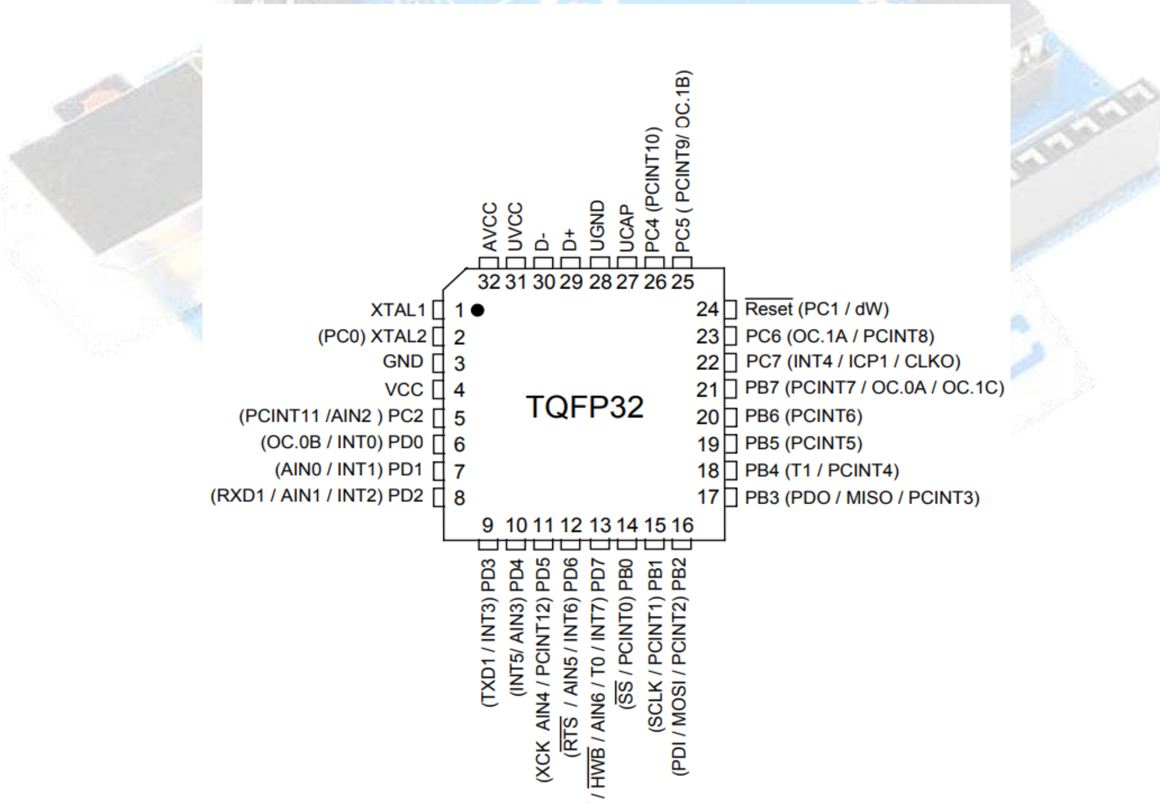
- Non-volatile Program and Data Memories
  - 8K/16K/32K Bytes of In-System Self-Programmable Flash
  - 512/512/1024 EEPROM
  - 512/512/1024 Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/ 100,000 EEPROM
  - Data retention: 20 years at 85˚C/ 100 years at 25˚C

- Optional Boot Code Section with Independent Lock Bits
- In-System Programming by on-chip Boot Program hardware-activated after reset
- Programming Lock for Software Security

- USB 2.0 Full-speed Device Module with Interrupt on Transfer Completion
  - Complies fully with Universal Serial Bus Specification REV 2.0
  - 48 MHz PLL for Full-speed Bus Operation: data transfer rates at 12 Mbit/s
  - Fully independent 176 bytes USB DPRAM for endpoint memory allocation
  - Endpoint 0 for Control Transfers: from 8 up to 64-bytes
  - 4 Programmable Endpoints:
    - IN or Out Directions
    - Bulk, Interrupt and Isochronous Transfers
    - Programmable maximum packet size from 8 to 64 bytes
    - Programmable single or double buffer
  - Suspend/Resume Interrupts
  - Microcontroller reset on USB Bus Reset without detach
  - USB Bus Disconnection on Microcontroller Request
- Peripheral Features
  - One 8-bit Timer/Counters with Separate Prescaler and Compare Mode (two 8-bit PWM channels)
  - One 16-bit Timer/Counter with Separate Prescaler, Compare and Capture Mode(three 8-bit PWM channels)
  - USART with SPI master only mode and hardware flow control (RTS/CTS)
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- On Chip Debug Interface (debug WIRE)
- Special Microcontroller Features
  - Power-On Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Five Sleep Modes: Idle, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 22 Programmable I/O Lines
  - QFN32 (5x5mm) / TQFP32 packages

- Operating Voltages
  - 2.7 - 5.5V
- Operating temperature
  - Industrial (-40°C to +85°C)
- Maximum Frequency
  - 8 MHz at 2.7V - Industrial range
  - 16 MHz at 4.5V - Industrial range

- Pin configuration



OTHER ARDUINO UNO R3 PARTS

Input and Output

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 a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 k Ohms. 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.
- 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 connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

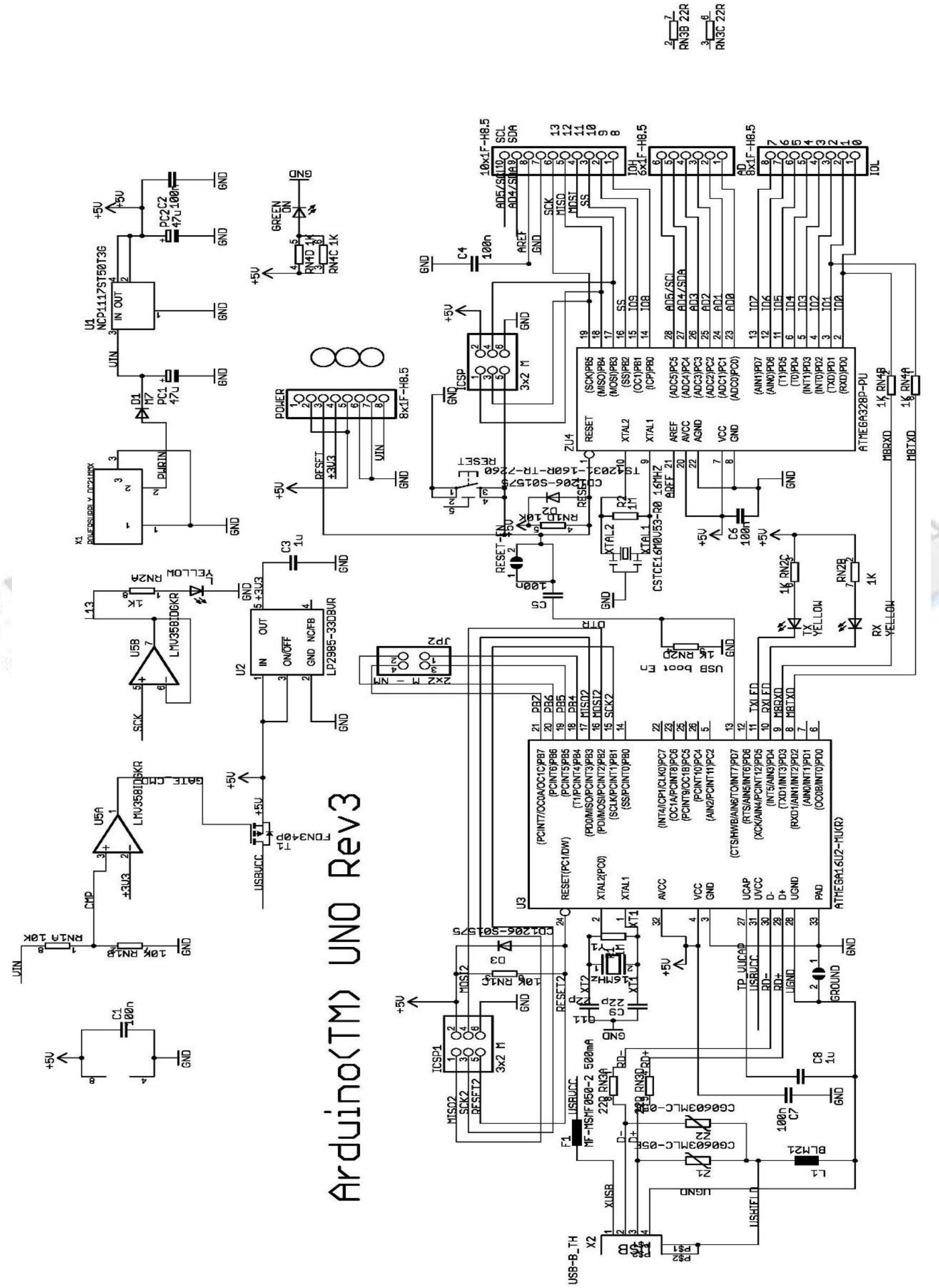
The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e.1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

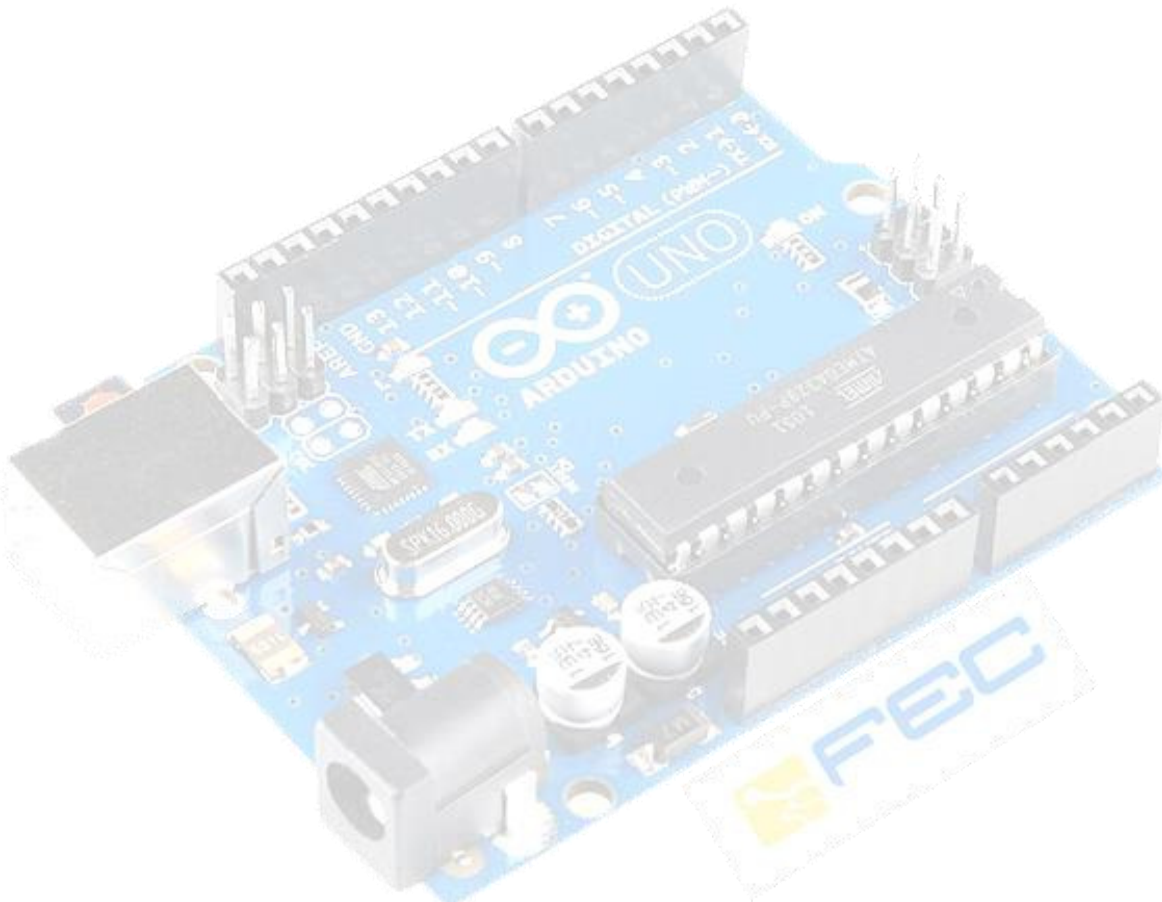
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- AREF: Reference voltage for the analog inputs. Used with analogReference().
- 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.

ARDUINO UNO R3 SCHEMATIC DIAGRAM





Click [here](#) for production status of specific part numbers.

DS18B20

Programmable Resolution 1-Wire Digital Thermometer

General Description

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

Applications

- Thermostatic Controls
- Industrial Systems
- Consumer Products
- Thermometers
- Thermally Sensitive Systems

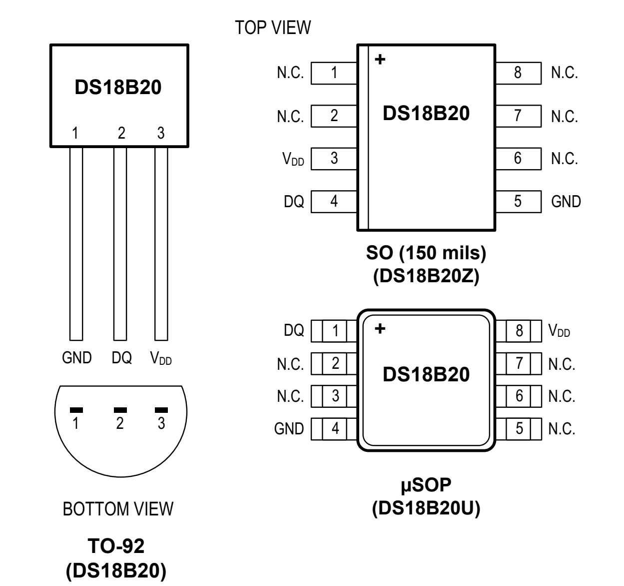
***Ordering Information* appears at end of data sheet.**

1-Wire is a registered trademark of Maxim Integrated Products, Inc.

Benefits and Features

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Reduce Component Count with Integrated Temperature Sensor and EEPROM
  - Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
  - ±0.5°C Accuracy from -10°C to +85°C
  - Programmable Resolution from 9 Bits to 12 Bits
  - No External Components Required
- Parasitic Power Mode Requires Only 2 Pins for Operation (DQ and GND)
- Simplifies Distributed Temperature-Sensing Applications with Multidrop Capability
  - Each Device Has a Unique 64-Bit Serial Code Stored in On-Board ROM
- Flexible User-Definable Nonvolatile (NV) Alarm Settings with Alarm Search Command Identifies Devices with Temperatures Outside Programmed Limits
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages

Pin Configurations



19-7487; Rev 6; 7/19

Absolute Maximum Ratings

Voltage Range on Any Pin Relative to Ground ....-0.5V to +6.0V
Operating Temperature Range .... -55°C to +125°C
Storage Temperature Range .... -55°C to +125°C
Solder Temperature ....Refer to the IPC/JEDEC J-STD-020 Specification.

These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

DC Electrical Characteristics

(-55°C to +125°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V_{DD}	Local power (Note 1)		+3.0		+5.5	V
Pullup Supply Voltage	V_{PU}	Parasite power	(Notes 1, 2)	+3.0		+5.5	V
		Local power		+3.0		V_{DD}	
Thermometer Error	t_{ERR}	-10°C to +85°C	(Note 3)			±0.5	°C
		-30°C to +100°C				±1	
		-55°C to +125°C				±2	
Input Logic-Low	V_{IL}	(Notes 1, 4, 5)		-0.3		+0.8	V
Input Logic-High	V_{IH}	Local power	(Notes 1,6)	+2.2		The lower of 5.5 or V_{DD} + 0.3	V
		Parasite power		+3.0			
Sink Current	I_L	$V_{I/O}$ = 0.4V		4.0			mA
Standby Current	I_{DDS}	(Notes 7, 8)			750	1000	nA
Active Current	I_{DD}	V_{DD} = 5V (Note 9)			1	1.5	mA
DQ Input Current	I_{DQ}	(Note 10)			5		µA
Drift		(Note 11)			±0.2		°C

Note 1: All voltages are referenced to ground.
Note 2: The Pullup Supply Voltage specification assumes that the pullup device is ideal, and therefore the high level of the pullup is equal to V_{PU}. In order to meet the V_{IH} spec of the DS18B20, the actual supply rail for the strong pullup transistor must include margin for the voltage drop across the transistor when it is turned on; thus: $V_{PU\_ACTUAL} = V_{PU\_IDEAL} + V_{TRANSISTOR}$.
Note 3: See typical performance curve in Figure 1. Thermometer Error limits are 3-sigma values.
Note 4: Logic-low voltages are specified at a sink current of 4mA.
Note 5: To guarantee a presence pulse under low voltage parasite power conditions, V_{ILMAX} may have to be reduced to as low as 0.5V.
Note 6: Logic-high voltages are specified at a source current of 1mA.
Note 7: Standby current specified up to +70°C. Standby current typically is 3µA at +125°C.
Note 8: To minimize I_{DDS}, DQ should be within the following ranges: GND ≤ DQ ≤ GND + 0.3V or V_{DD} – 0.3V ≤ DQ ≤ V_{DD}.
Note 9: Active current refers to supply current during active temperature conversions or EEPROM writes.
Note 10: DQ line is high (“high-Z” state).
Note 11: Drift data is based on a 1000-hour stress test at +125°C with V_{DD} = 5.5V.

AC Electrical Characteristics–NV Memory

(-55°C to +125°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
NV Write Cycle Time	t_{WR}			2	10	ms
EEPROM Writes	N_{EEWR}	-55°C to +55°C	50k			writes
EEPROM Data Retention	t_{EEDR}	-55°C to +55°C	10			years

AC Electrical Characteristics

(-55°C to +125°C; V_{DD} = 3.0V to 5.5V)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Conversion Time	t_{CONV}	9-bit resolution	(Note 12)			93.75	ms
		10-bit resolution				187.5	
		11-bit resolution				375	
		12-bit resolution				750	
Time to Strong Pullup On	t_{SPON}	Start convert T command issued				10	µs
Time Slot	t_{SLOT}	(Note 12)		60		120	µs
Recovery Time	t_{REC}	(Note 12)		1			µs
Write 0 Low Time	t_{LOW0}	(Note 12)		60		120	µs
Write 1 Low Time	t_{LOW1}	(Note 12)		1		15	µs
Read Data Valid	t_{RDV}	(Note 12)				15	µs
Reset Time High	t_{RSTH}	(Note 12)		480			µs
Reset Time Low	t_{RSTL}	(Notes 12, 13)		480			µs
Presence-Detect High	t_{PDHIGH}	(Note 12)		15		60	µs
Presence-Detect Low	t_{PDLOW}	(Note 12)		60		240	µs
Capacitance	$C_{IN/OUT}$					25	pF

Note 12: See the timing diagrams in Figure 2.
Note 13: Under parasite power, if t_{RSTL} > 960µs, a power-on reset can occur.

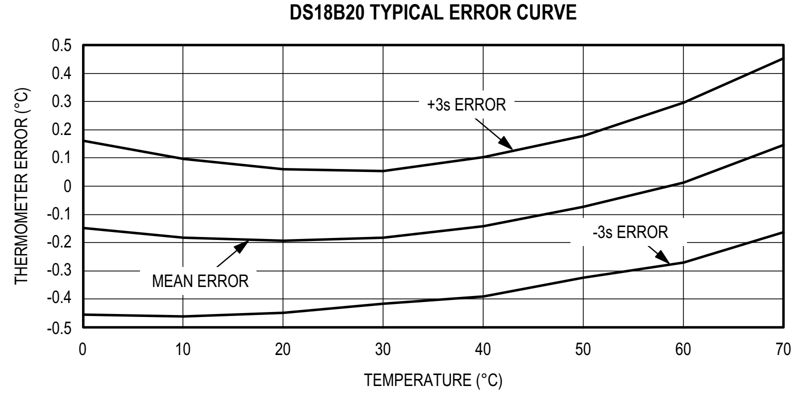


Figure 1. Typical Performance Curve

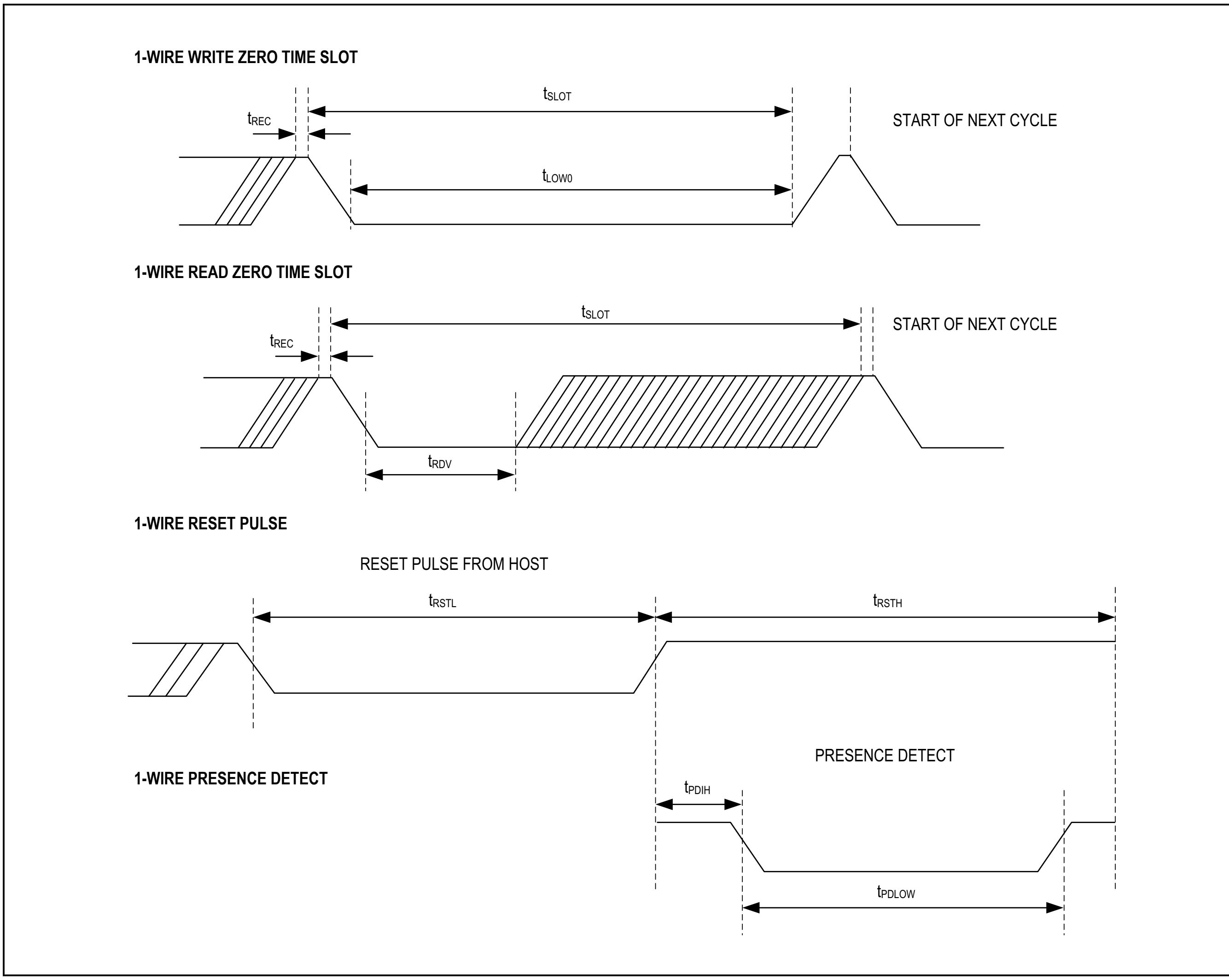


Figure 2. Timing Diagrams

Pin Description

PIN			NAME	FUNCTION
SO	µSOP	TO-92		
1, 2, 6, 7, 8	2, 3, 5, 6, 7	—	N.C.	No Connection
3	8	3	V_{DD}	Optional V_{DD}. V_{DD} must be grounded for operation in parasite power mode.
4	1	2	DQ	Data Input/Output. Open-drain 1-Wire interface pin. Also provides power to the device when used in parasite power mode (see the *Powering the DS18B20* section.)
5	4	1	GND	Ground

Overview

Figure 3 shows a block diagram of the DS18B20, and pin descriptions are given in the *Pin Description* table. The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte temperature register that stores the digital output from the temperature sensor. In addition, the scratchpad provides access to the 1-byte upper and lower alarm trigger registers (T_H and T_L) and the 1-byte configuration register. The configuration register allows the user to set the resolution of the temperature-to-digital conversion to 9, 10, 11, or 12 bits. The T_H, T_L, and configuration registers are nonvolatile (EEPROM), so they will retain data when the device is powered down.

The DS18B20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using one control signal. The control line requires a weak pullup resistor since all devices are linked to the bus via a 3-state or open-drain port (the DQ pin in the case of the DS18B20). In this bus system, the microprocessor (the master device) identifies and addresses devices on the bus using each device's unique 64-bit code. Because each device has a unique code, the number of devices that can be addressed on one bus is virtually unlimited. The 1-Wire bus protocol, including detailed explanations of the commands and "time slots," is covered in the *1-Wire Bus System* section.

Another feature of the DS18B20 is the ability to operate without an external power supply. Power is instead supplied through the 1-Wire pullup resistor through the DQ pin when the bus is high. The high bus signal also charges an internal capacitor (C_{PP}), which then supplies power to the device when the bus is low. This method of deriving power from the 1-Wire bus is referred to as "parasite power." As an alternative, the DS18B20 may also be powered by an external supply on V_{DD}.

Operation—Measuring Temperature

The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up is 12-bit. The DS18B20 powers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the master must issue a Convert T [44h] command. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its idle state. If the DS18B20 is powered by an external supply, the master can issue "read time slots" (see the *1-Wire Bus System* section) after the Convert T command and the DS18B20 will respond by transmitting 0 while the temperature conversion is in progress and 1 when the conversion is done. If the DS18B20 is powered with parasite power, this notification technique cannot be used since the bus must be pulled high by a strong pullup during the entire temperature conversion. The bus requirements for parasite power are explained in detail in the *Powering the DS18B20* section.

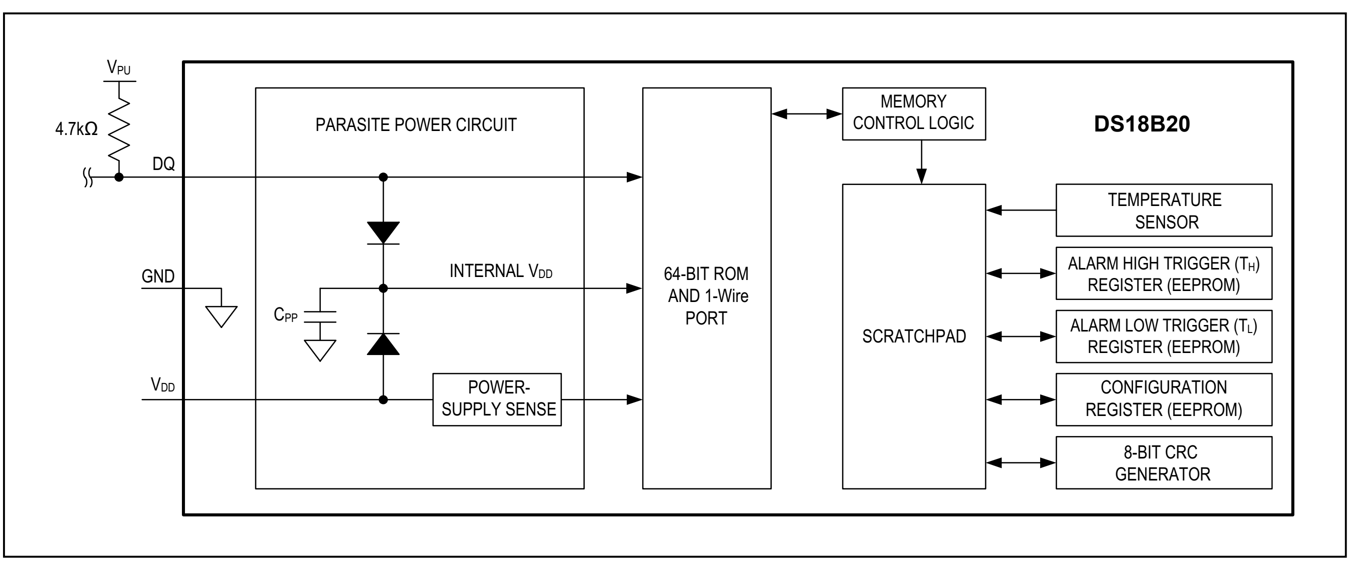


Figure 3. DS18B20 Block Diagram

The DS18B20 output temperature data is calibrated in degrees Celsius; for Fahrenheit applications, a lookup table or conversion routine must be used. The temperature data is stored as a 16-bit sign-extended two's complement number in the temperature register (see Figure 4). The sign bits (S) indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. If the DS18B20 is configured for 12-bit resolution, all bits in the temperature register will contain valid data. For 11-bit resolution, bit 0 is undefined. For 10-bit resolution, bits 1 and 0 are undefined, and for 9-bit resolution bits 2, 1, and 0 are undefined. Table 1 gives examples of digital output data and the corresponding temperature reading for 12-bit resolution conversions.

Operation—Alarm Signaling

After the DS18B20 performs a temperature conversion, the temperature value is compared to the user-defined two's complement alarm trigger values stored in the 1-byte T_H and T_L registers (see Figure 5). The sign bit (S) indicates if the value is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. The T_H and T_L registers are nonvolatile (EEPROM) so they will retain data when the device is powered down. T_H and T_L can be accessed through bytes 2 and 3 of the scratchpad as explained in the *Memory* section.

Only bits 11 through 4 of the temperature register are used in the T_H and T_L comparison since T_H and T_L are 8-bit registers. If the measured temperature is lower than

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	BIT 15	**BIT 14**	**BIT 13**	**BIT 12**	**BIT 11**	**BIT 10**	**BIT 9**	**BIT 8**
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

Figure 4. Temperature Register Format

Table 1. Temperature/Data Relationship

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

**The power-on reset value of the temperature register is +85°C.*

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
S	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Figure 5. T_H and T_L Register Format

DS18B20 Operation Example 1

In this example there are multiple DS18B20s on the bus and they are using parasite power. The bus master initiates a temperature conversion in a specific DS18B20 and then reads its scratchpad and recalculates the CRC to verify the data.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	44h	Master issues Convert T command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for the duration of the conversion (t_{CONV}).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20s respond with presence pulse.
Tx	55h	Master issues Match ROM command.
Tx	64-bit ROM code	Master sends DS18B20 ROM code.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.

DS18B20 Operation Example 2

In this example there is only one DS18B20 on the bus and it is using parasite power. The master writes to the TH, TL, and configuration registers in the DS18B20 scratchpad and then reads the scratchpad and recalculates the CRC to verify the data. The master then copies the scratchpad contents to EEPROM.

MASTER MODE	DATA (LSB FIRST)	COMMENTS
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	4Eh	Master issues Write Scratchpad command.
Tx	3 data bytes	Master sends three data bytes to scratchpad (T_H, T_L, and config).
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	BEh	Master issues Read Scratchpad command.
Rx	9 data bytes	Master reads entire scratchpad including CRC. The master then recalculates the CRC of the first eight data bytes from the scratchpad and compares the calculated CRC with the read CRC (byte 9). If they match, the master continues; if not, the read operation is repeated.
Tx	Reset	Master issues reset pulse.
Rx	Presence	DS18B20 responds with presence pulse.
Tx	CCh	Master issues Skip ROM command.
Tx	48h	Master issues Copy Scratchpad command.
Tx	DQ line held high by strong pullup	Master applies strong pullup to DQ for at least 10ms while copy operation is in progress.

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
DS18B20	-55°C to +125°C	3 TO-92	18B20
DS18B20+	-55°C to +125°C	3 TO-92	18B20
DS18B20/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20-SL/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20-SL+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20U	-55°C to +125°C	8 FSOP	18B20
DS18B20U+	-55°C to +125°C	8 FSOP	18B20
DS18B20U/T&R	-55°C to +125°C	8 FSOP (3000 Piece)	18B20
DS18B20U+T&R	-55°C to +125°C	8 FSOP (3000 Piece)	18B20
DS18B20Z	-55°C to +125°C	8 SO	DS18B20
DS18B20Z+	-55°C to +125°C	8 SO	DS18B20
DS18B20Z/T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20
DS18B20Z+T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20

+Denotes a lead-free package. A "+" will appear on the top mark of lead-free packages.

T&R = Tape and reel.

**TO-92 packages in tape and reel can be ordered with straight or formed leads. Choose "SL" for straight leads. Bulk TO-92 orders are straight leads only.*

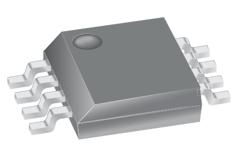
Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

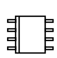
Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% at $T_A = 25°C$
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kV_{RMS} minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage

TÜV America
Certificate Number:
U8V 06 05 54214 010

Package: 8 Lead SOIC (suffix LC)



Approximate Scale 1:1 

Description

The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope ($>V_{IOUT(Q)}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power

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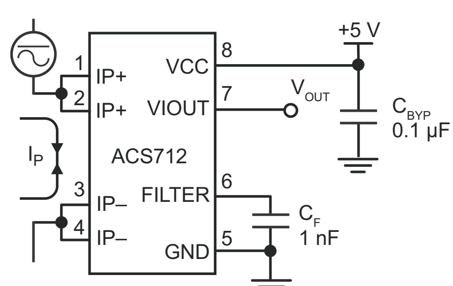
Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}. that varies linearly with the uni- or bi-directional AC or DC primary sensed current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

Description (continued)

loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor leads (pins 5 through 8). This allows the ACS712 current sensor to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

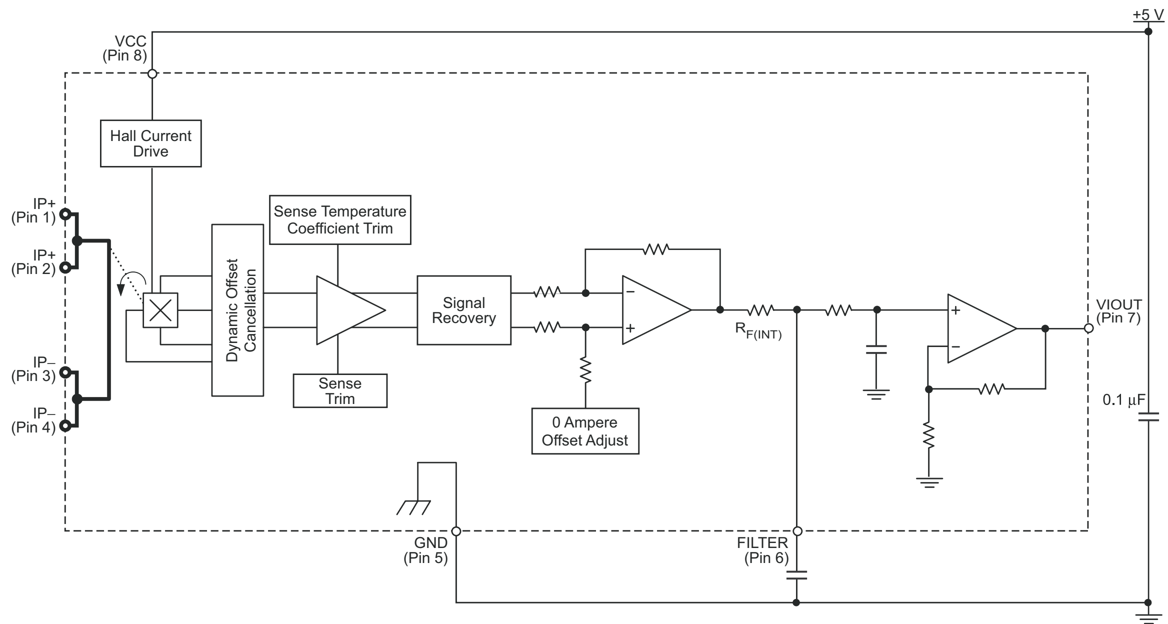
*Contact Allegro for additional packing options.

Absolute Maximum Ratings

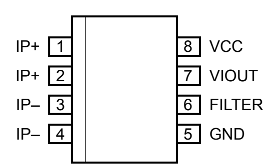
Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Reinforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	184	V_{peak}
Basic Isolation Voltage	$V_{ISO(bsc)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	1500	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	354	V_{peak}
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	ºC
Maximum Junction Temperature	T_J(max)		165	ºC
Storage Temperature	T_{stg}		–65 to 170	ºC

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

COMMON OPERATING CHARACTERISTICS[1] over full range of T_A, C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
ELECTRICAL CHARACTERISTICS						
Supply Voltage	V_{CC}		4.5	5.0	5.5	V
Supply Current	I_{CC}	V_{CC} = 5.0 V, output open	–	10	13	mA
Output Capacitance Load	C_{LOAD}	VIOUT to GND	–	–	10	nF
Output Resistive Load	R_{LOAD}	VIOUT to GND	4.7	–	–	kΩ
Primary Conductor Resistance	$R_{PRIMARY}$	T_A = 25°C	–	1.2	–	mΩ
Rise Time	t_r	$I_P = I_P(max)$, T_A = 25°C, C_{OUT} = open	–	5	–	μs
Frequency Bandwidth	f	–3 dB, T_A = 25°C; I_P is 10 A peak-to-peak	–	80	–	kHz
Nonlinearity	E_{LIN}	Over full range of I_P	–	1.5	–	%
Symmetry	E_{SYM}	Over full range of I_P	98	100	102	%
Zero Current Output Voltage	$V_{IOUT(Q)}$	Bidirectional; I_P = 0 A, T_A = 25°C	–	V_{CC} × 0.5	–	V
Power-On Time	t_{PO}	Output reaches 90% of steady-state level, T_J = 25°C, 20 A present on leadframe	–	35	–	μs
Magnetic Coupling[2]			–	12	–	G/A
Internal Filter Resistance[3]	$R_{F(INT)}$			1.7		kΩ

[1]Device may be operated at higher primary current levels, I_P, and ambient, T_A, and internal leadframe temperatures, T_A, provided that the Maximum Junction Temperature, $T_J(max)$, is not exceeded.

[2]1G = 0.1 mT.

[3]$R_{F(INT)}$ forms an RC circuit via the FILTER pin.

COMMON THERMAL CHARACTERISTICS[1]

			Min.	Typ.	Max.	Units
Operating Internal Leadframe Temperature	T_A	E range	–40	–	85	°C
					Value	Units
Junction-to-Lead Thermal Resistance[2]	$R_{\theta JL}$	Mounted on the Allegro ASEK 712 evaluation board			5	°C/W
Junction-to-Ambient Thermal Resistance	$R_{\theta JA}$	Mounted on the Allegro 85-0322 evaluation board, includes the power consumed by the board			23	°C/W

[1]Additional thermal information is available on the Allegro website.

[2]The Allegro evaluation board has 1500 mm^2 of 2 oz. copper on each side, connected to pins 1 and 2, and to pins 3 and 4, with thermal vias connecting the layers. Performance values include the power consumed by the PCB. Further details on the board are available from the Frequently Asked Questions document on our website. Further information about board design and thermal performance also can be found in the Applications Information section of this datasheet.

x05B PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–5	–	5	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	180	185	190	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 185 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	21	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.26	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.054	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.008	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P =±5 A, T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, $T_{J(max)}$, is not exceeded.

[2]Percentage of I_P, with I_P = 5 A. Output filtered.

x20A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–20	–	20	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	96	100	104	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 100 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	11	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.34	–	mV/°C
		T_A = 25°C to 150°C	–	–0.07	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.017	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.004	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P =±20 A, T_A = 25°C	–	±1.5	–	%

[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2]Percentage of I_P, with I_P = 20 A. Output filtered.

x30A PERFORMANCE CHARACTERISTICS T_A = –40°C to 85°C[1], C_F = 1 nF, and V_{CC} = 5 V, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_P		–30	–	30	A
Sensitivity	Sens	Over full range of I_P, T_A = 25°C	64	66	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, T_A = 25°C, 66 mV/A programmed Sensitivity, C_F = 47 nF, C_{OUT} = open, 2 kHz bandwidth	–	7	–	mV
Zero Current Output Slope	$\Delta I_{OUT(Q)}$	T_A = –40°C to 25°C	–	–0.35	–	mV/°C
		T_A = 25°C to 150°C	–	–0.08	–	mV/°C
Sensitivity Slope	ΔSens	T_A = –40°C to 25°C	–	0.007	–	mV/A/°C
		T_A = 25°C to 150°C	–	–0.002	–	mV/A/°C
Total Output Error[2]	E_{TOT}	I_P = ±30 A, T_A = 25°C	–	±1.5	–	%

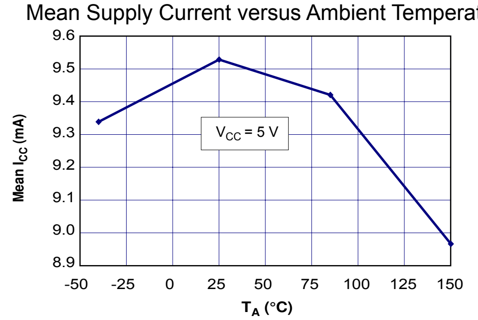
[1]Device may be operated at higher primary current levels, I_P, and ambient temperatures, T_A, provided that the Maximum Junction Temperature, T_J(max), is not exceeded.

[2]Percentage of I_P, with I_P = 30 A. Output filtered.

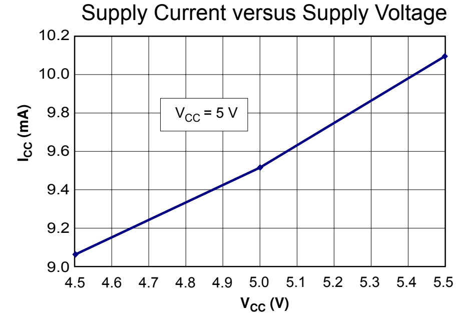
Characteristic Performance

I_P = 30 A, unless otherwise specified

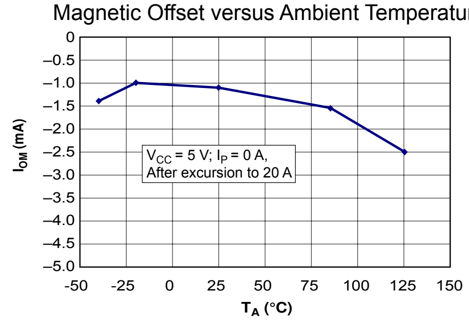
Mean Supply Current versus Ambient Temperature



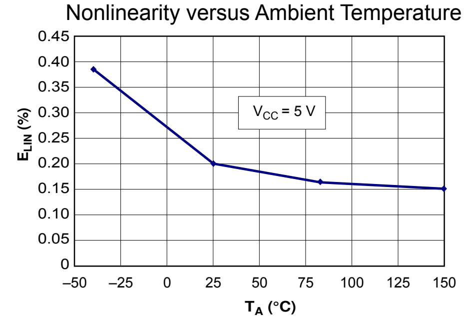
Supply Current versus Supply Voltage



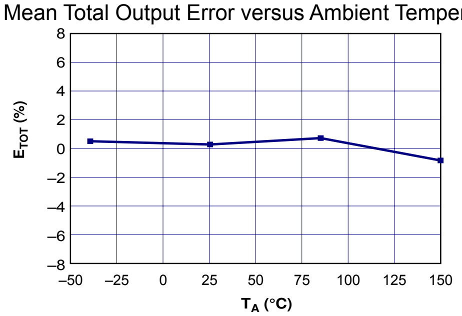
Magnetic Offset versus Ambient Temperature



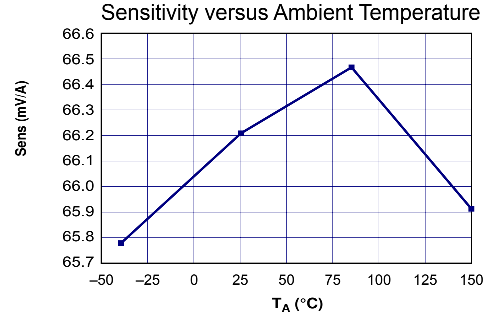
Nonlinearity versus Ambient Temperature



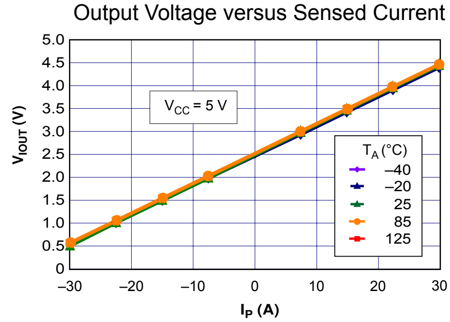
Mean Total Output Error versus Ambient Temperature



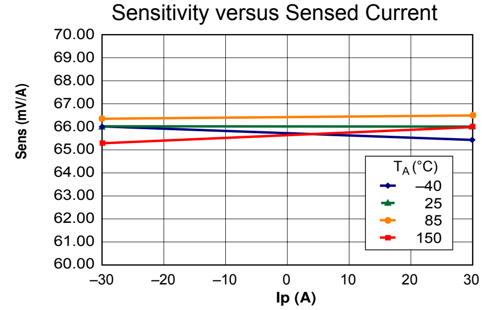
Sensitivity versus Ambient Temperature



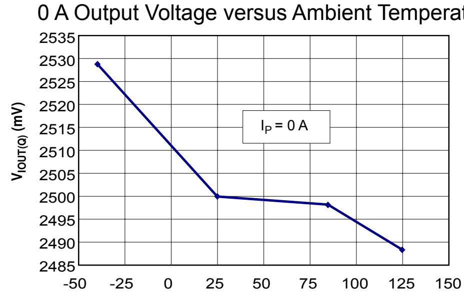
Output Voltage versus Sensed Current



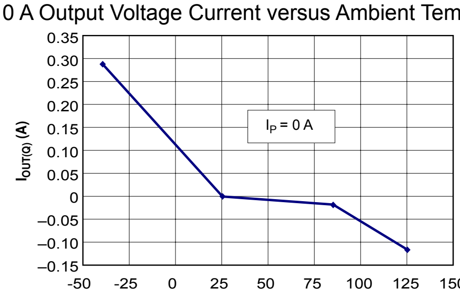
Sensitivity versus Sensed Current



0 A Output Voltage versus Ambient Temperature

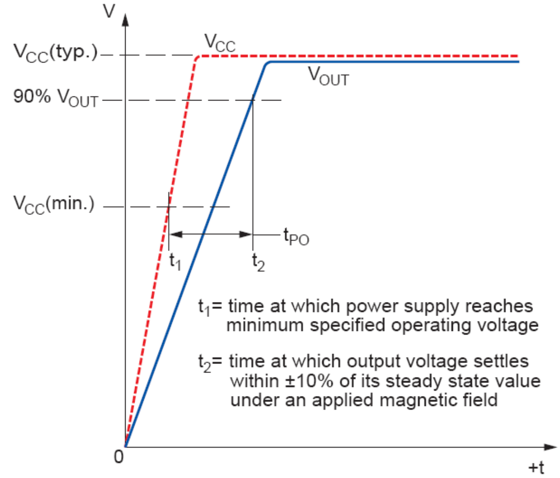


0 A Output Voltage Current versus Ambient Temperature

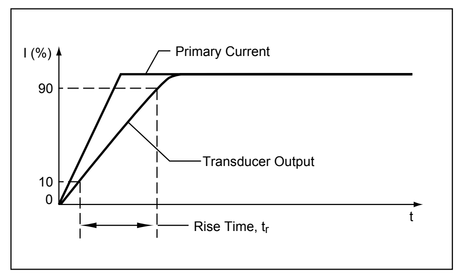


Definitions of Dynamic Response Characteristics

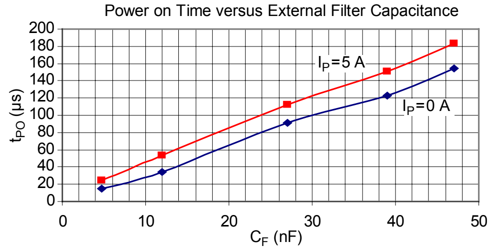
Power-On Time (t_{PO}). When the supply is ramped to its operating voltage, the device requires a finite time to power its internal components before responding to an input magnetic field. Power-On Time, t_{PO} , is defined as the time it takes for the output voltage to settle within ±10% of its steady state value under an applied magnetic field, after the power supply has reached its minimum specified operating voltage, V_{CC}(min), as shown in the chart at right.



Rise time (t_r). The time interval between a) when the sensor reaches 10% of its full scale value, and b) when it reaches 90% of its full scale value. The rise time to a step response is used to derive the bandwidth of the current sensor, in which $f(-3\text{ dB}) = 0.35/t_r$. Both t_r and $t_{RESPONSE}$ are detrimentally affected by eddy current losses observed in the conductive IC ground plane.

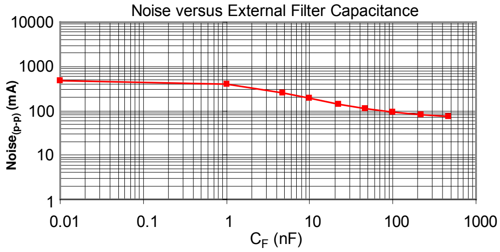


Power on Time versus External Filter Capacitance



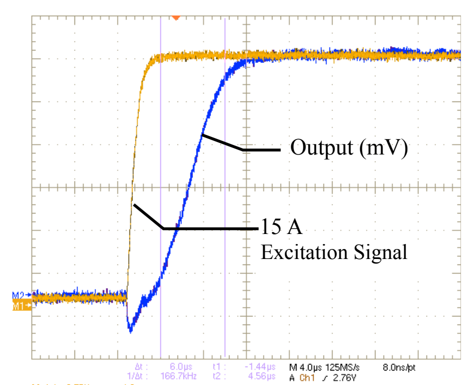
Noise vs. Filter Cap

Noise versus External Filter Capacitance

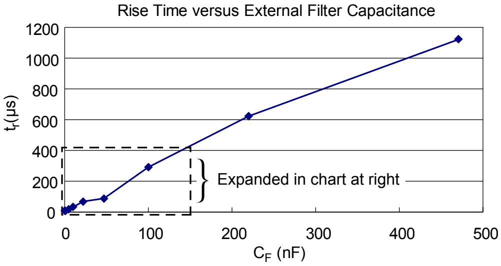


Step Response

T_A=25°C

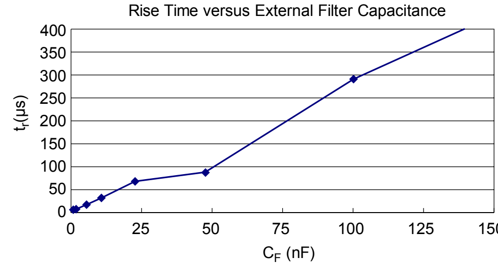


Rise Time versus External Filter Capacitance

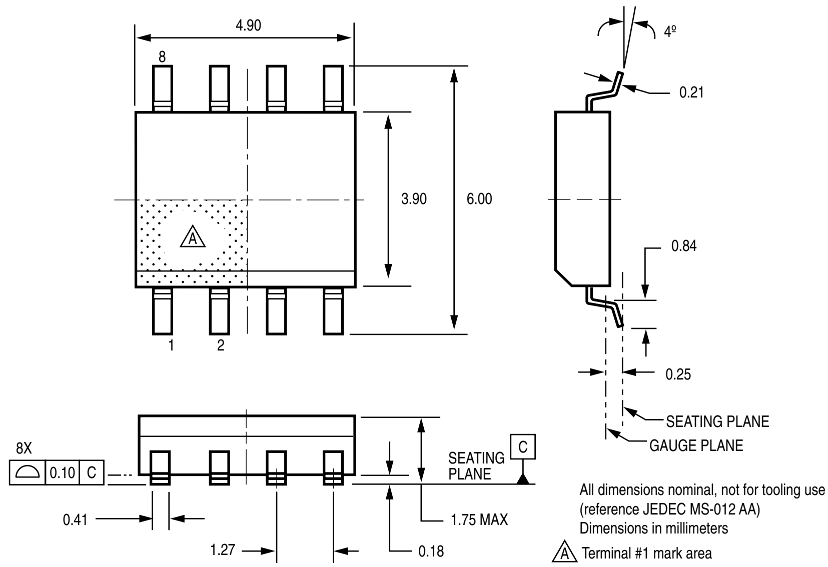


C_F (nF)	t_r (µs)
0	6.6
1	7.7
4.7	17.4
10	32.1
22	68.2
47	88.2
100	291.3
220	623.0
470	1120.0

Rise Time versus External Filter Capacitance

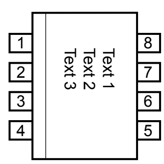


Package LC, 8-pin SOIC



Package Branding

Two alternative patterns are used



ACS712T *R*LC*PPP* *YYWWA*	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
	R	Operating ambient temperature range code
	LC	Package type designator
	PPP	Primary sensed current
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week
	A	Date code: Shift code

ACS712T *R*LC*PPP* *L...L* *YYWW*	ACS	Allegro Current Sensor
	712	Device family number
	T	Indicator of 100% matte tin leadframe plating
	R	Operating ambient temperature range code
	LC	Package type designator
	PPP	Primary sensed current
	L...L	Lot code
	YY	Date code: Calendar year (last two digits)
	WW	Date code: Calendar week

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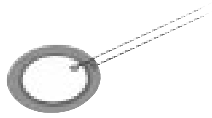
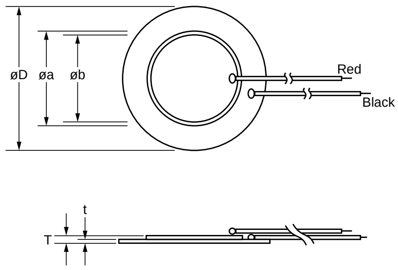
Piezoelectric Sound Components

Piezoelectric Diaphragms

■ Features

1. Clear sound
2. Ultra thin and lightweight
3. No contacts: therefore, no noise and highly reliable
4. Low power consumption for voltage type





■ Applications

Clocks/Calculators/Digital camera/Various alarms
(Burglar alarms, etc.)

External Drive Type

Part Number	Resonant Frequency (kHz)	Resonant Impedance (ohm)	Capacitance (nF)	Plate Size dia. D (mm)	Element Size dia. a (mm)	Electrode Size dia. b (mm)	Thickness T (mm)	Plate Thickness t (mm)	Plate Material
7BB-12-9	9.0 ±1.0kHz	1000 max.	8.0 ±30% [1kHz]	12.0	9.0	8.0	0.22	0.10	Brass
7BB-15-6	6.0 ±1.0kHz	800 max.	10.0 ±30% [1kHz]	15.0	10.0	9.0	0.22	0.10	Brass
7BB-20-3	3.6 ±0.6kHz	500 max.	20.0 ±30% [1kHz]	20.0	14.0	12.8	0.22	0.10	Brass
7BB-20-6	6.3 ±0.6kHz	350 max.	10.0 ±30% [1kHz]	20.0	14.0	12.8	0.42	0.20	Brass
7BB-20-6L0	6.3 ±0.6kHz	1000 max.	10.0 ±30% [1kHz]	20.0	14.0	12.8	0.42	0.20	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-27-4	4.6 ±0.5kHz	200 max.	20.0 ±30% [1kHz]	27.0	19.7	18.2	0.54	0.30	Brass
7BB-27-4L0	4.6 ±0.5kHz	300 max.	20.0 ±30% [1kHz]	27.0	19.7	18.2	0.54	0.30	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-35-3	2.8 ±0.5kHz	200 max.	30.0 ±30% [1kHz]	35.0	25.0	23.0	0.53	0.30	Brass
7BB-35-3L0	2.8 ±0.5kHz	200 max.	30.0 ±30% [1kHz]	35.0	25.0	23.0	0.53	0.30	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-41-2	2.2 ±0.3kHz	250 max.	30.0 ±30% [1kHz]	41.0	25.0	23.0	0.63	0.40	Brass
7BB-41-2L0	2.2 ±0.3kHz	300 max.	30.0 ±30% [1kHz]	41.0	25.0	23.0	0.63	0.40	Brass (with Lead Wire: AWG32 Length 50mm)
7NB-31R2-1	1.3 ±0.5kHz	300 max.	40.0 ±30% [120Hz]	31.2	19.7	18.2	0.22	0.10	Nickel Alloy

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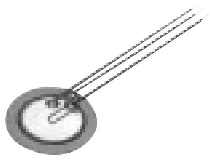

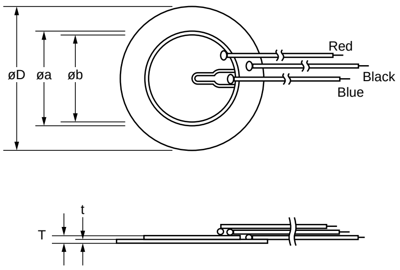

Self Drive Type

Part Number	Resonant Frequency (kHz)	Resonant Impedance (ohm)	Capacitance (nF)	Plate Size dia. D (mm)	Element Size dia. a (mm)	Electrode Size dia. b (mm)	Thickness T (mm)	Plate Thickness t (mm)	Plate Material
7BB-20-6C	6.3 ±0.6kHz	500 max.	8.5 ±30% [1kHz]	20.0	14.0	12.8	0.42	0.20	Brass
7BB-20-6CL0	6.3 ±0.6kHz	800 max.	8.5 ±30% [1kHz]	20.0	14.0	12.8	0.42	0.20	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-27-4C	4.6 ±0.5kHz	200 max.	18.0 ±30% [1kHz]	27.0	19.7	18.2	0.54	0.30	Brass
7BB-27-4CL0	4.6 ±0.5kHz	350 max.	18.0 ±30% [1kHz]	27.0	19.7	18.2	0.54	0.30	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-35-3C	2.8 ±0.5kHz	200 max.	26.0 ±30% [1kHz]	35.0	25.0	23.0	0.53	0.30	Brass
7BB-35-3CL0	2.8 ±0.5kHz	200 max.	26.0 ±30% [1kHz]	35.0	25.0	23.0	0.53	0.30	Brass (with Lead Wire: AWG32 Length 50mm)
7BB-41-2C	2.2 ±0.3kHz	250 max.	24.0 ±30% [1kHz]	41.0	25.0	23.0	0.63	0.40	Brass
7BB-41-2CL0	2.2 ±0.3kHz	350 max.	24.0 ±30% [1kHz]	41.0	25.0	23.0	0.63	0.40	Brass (with Lead Wire: AWG32 Length 50mm)
7SB-34R7-3C	3.1 ±0.3kHz	150 max.	24.0 ±30% [1kHz]	34.7	25.0	23.4	0.50	0.25	Stainless

■ Node Diameter

Part Number	Node Diameter (mm)
7BB-20-6C	ϕ13.5
7BB-27-4C	ϕ17.5
7BB-35-3C	ϕ22.5
7BB-41-2C	ϕ26.5

• Sound diaphragms without feedback electrode also have the same node diameters.

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■ Notice (Soldering and Mounting)

1. Applying load on the center area of the diaphragm may cause cracking in the ceramic element. When the diaphragm is supported by the edge, the load should be applied only around the edge.
2. Please consult with Murata or Murata representative if soldering of the component is needed.

■ Notice (Handling)

1. Please do not touch the component with bare hand because electrode may be corroded.
2. The component may be damaged if mechanical stress exceeding specifications is applied.
3. Take care to protect operating circuit from surge voltage resulting from excessive force, falling, shock or temperature change.
4. If DC voltage is applied to the component, silver migration may occur. Please pay full attention to avoid subjecting the component to DC voltage for long periods.
5. The resistor should be used as shown in Fig. A. A suitable resistance value should be chosen, preferably 1kΩ to 2kΩ. Instead of this measure, a diode may also be applied as shown in Fig. B.

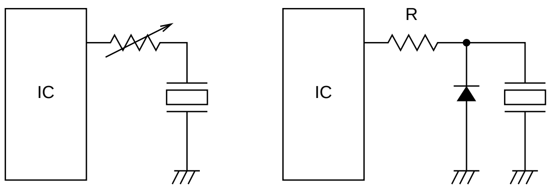


Fig. A Fig. B

6. Avoid excessive pulling of lead wire because wire may break or soldering point may come off.

WINSTAR Display

OLED SPECIFICATION

Model No:

WEA012864D-03

WINSTAR DISPLAY CO., LTD

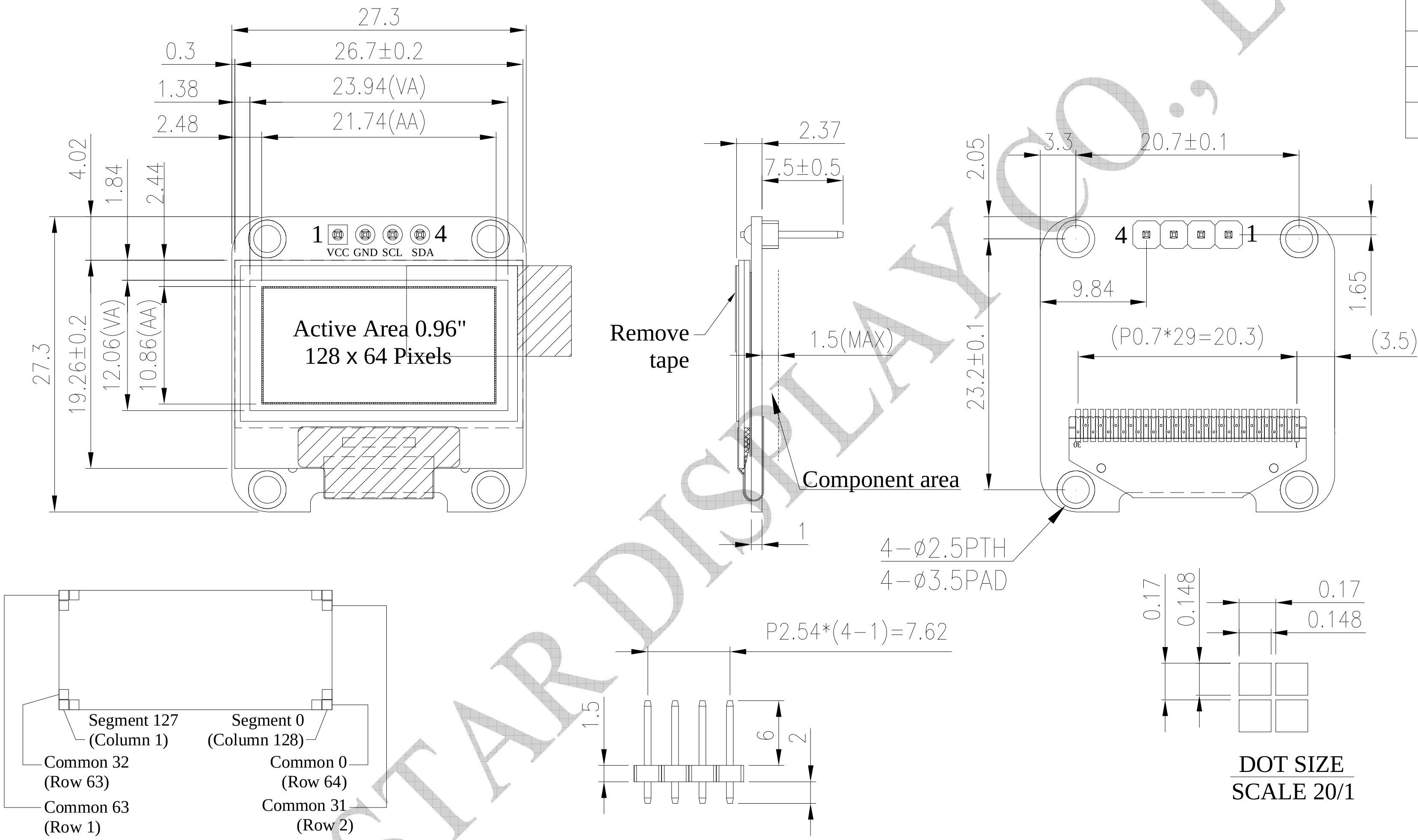
General Specification

Item	Dimension	Unit
Dot Matrix	128 x 64 Dots	—
Module dimension	27.30 x 27.30 x 2.37	mm
Active Area	21.74 x 10.86	mm
Pixel Size	0.148 x 0.148	mm
Pixel Pitch	0.17 x 0.17	mm
Display Mode	Passive Matrix	
Display Color	Monochrome	
Drive Duty	1/64 Duty	
IC	SSD1306BZ	
Interface	I2C	
Size	0.96 inch	

WINSTAR DISPLAY CO., LTD

Contour Drawing & Block Diagram

PIN No.	SYMBOL
1	VCC
2	GND
3	SCL
4	SDA



SCALE 1/1

The non-specified tolerance of dimension is 0.3 mm .

WINSTAR DISPLAY CO., LTD

Interface Pin Function

No.	Symbol	Function
1	VCC	Power supply input: 2.8 – 5.2V
2	GND	Ground
3	SCL	When the I2C interface is selected, then D0 serves as the serial clock input pad (SCL) and D1 serves as the serial data input pad (SDAI).
4	SDA	

Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Supply Voltage for Logic	VCC	1.65	5.5	V
Operating Temperature	TOP	-40	+80	°C
Storage Temperature	TSTG	-40	+85	°C

Electrical Characteristics

DC Electrical Characteristics

Item	Symbol	Condition	Min	Typ	Max	Unit
Supply Voltage for Logic	VCC	—	2.8	3.3	5.2	V
Input High Volt.	VIH	—	0.8×VCC	—	VCC	V
Input Low Volt.	VIL	—	0	—	0.2×VCC	V
Output High Volt.	VOH	—	0.9×VCC	—	VCC	V
Output Low Volt.	VOL	—	0	—	0.1×VCC	V
50% Check Board operating Current	ICC	VCC=3.3V	—	12.0	20.0	mA

WINSTAR DISPLAY CO., LTD

ESP-01 WiFi Module

Version1.0

sherry@aithinker.com

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Notice

Product version upgrades or other reasons, possible changes in the contents of this manual. AI-Thinker reserves in the absence of any notice or indication of the circumstances the right to modify the content of this manual. This manual is used only as a guide, Ai-thinker make every effort to provide accurate information in this manual, but Ai-thinker does not ensure that manual content without error, in this manual all statements, information and advice nor does it constitute any express or implied warranty.

1. Preambles

ESP-01 WiFi module is developed by Ai-thinker Team. core processor ESP8266 in smaller sizes of the module encapsulates Tensilica L106 integrates industry-leading ultra low power 32-bit MCU micro, with the 16-bit short mode, Clock speed support 80 MHz, 160 MHz, supports the RTOS, integrated Wi-Fi MAC/BB/RF/PA/LNA, on-board antenna.

The module supports standard IEEE802.11 b/g/n agreement, complete TCP/IP protocol stack. Users can use the add modules to an existing device networking, or building a separate network controller.

ESP8266 is high integration wireless SOCs, designed for space and power constrained mobile platform designers. It provides unsurpassed ability to embed Wi-Fi capabilities within other systems, or to function as a standalone application, with the lowest cost, and minimal space requirement.

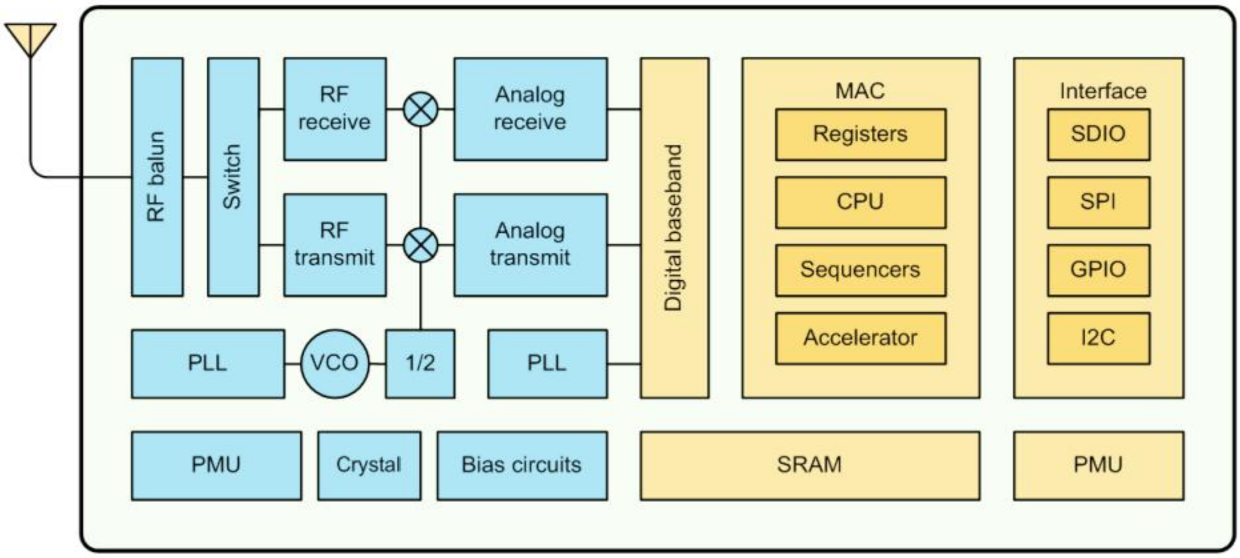

Figure 1 ESP8266EX Block Diagram

ESP8266EX offers a complete and self-contained Wi-Fi networking solution; it can be used to host the application or to offload Wi-Fi networking functions from another application processor.

When ESP8266EX hosts the application, it boots up directly from an external flash. In has integrated cache to improve the performance of the system in such applications.

Alternately, serving as a Wi-Fi adapter, wireless internet access can be added to any micro controllerbased design with simple connectivity (SPI/SDIO or I2C/UART interface).

ESP8266EX is among the most integrated WiFi chip in the industry; it integrates the antenna switches, RF balun, power amplifier, low noise receive amplifier, filters, power management modules, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area.

ESP8266EX also integrates an enhanced version of Tensilica's L106 Diamond series 32-bit processor, with on-chip SRAM, besides the Wi-Fi functionalities. ESP8266EX is often integrated with external sensors and other application specific devices through its GPIOs; codes for such applications are provided in examples in the SDK.

Espressif Systems' Smart Connectivity Platform (ESCP) demonstrates sophisticated system-level features include fast sleep/wake context switching for energy-efficient VoIP, adaptive radio biasing. for low-power operation, advance signal processing, and spur cancellation and radio co-existence features for common cellular, Bluetooth, DDR, LVDS, LCD interference mitigation.

1.1. Features

- 802.11 b/g/n
- Integrated low power 32-bit MCU
- Integrated 10-bit ADC
- Integrated TCP/IP protocol stack
- Integrated TR switch, balun, LNA, power amplifier and matching network
- Integrated PLL, regulators, and power management units
- Supports antenna diversity
- Wi-Fi 2.4 GHz, support WPA/WPA2
- Support STA/AP/STA+AP operation modes
- Support Smart Link Function for both Android and iOS devices
- Support Smart Link Function for both Android and iOS devices
- SDIO 2.0, (H) SPI, UART, I2C, I2S, IRDA, PWM, GPIO

- STBC, 1x1 MIMO, 2x1 MIMO
- A-MPDU & A-MSDU aggregation and 0.4s guard interval
- Deep sleep power <10uA, Power down leakage current < 5uA
- Wake up and transmit packets in < 2ms
- Standby power consumption of < 1.0mW (DTIM3)
- +20dBm output power in 802.11b mode
- Operating temperature range -40C ~ 125C

1.2. Parameters

Table 1 below describes the major parameters.

Table 1 Parameters

Categories	Items	Values
WiFi Paramters	WiFi Protocles	802.11 b/g/n
	Frequency Range	2.4GHz-2.5GHz (2400M-2483.5M)
Hardware Paramaters	Peripheral Bus	UART/HSPI/I2C/I2S/Ir Remote Contorl
		GPIO/PWM
	Operating Voltage	3.0~3.6V
	Operating Current	Average value: 80mA
	Operating Temperature Range	-40°~125°
	Ambient Temperature Range	Normal temperature
	Package Size	14.3mm*24.8mm*3mm
	External Interface	N/A
Software Parameters	Wi-Fi mode	station/softAP/SoftAP+station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network) / download and write firmware via host
	Ssoftware Development	Supports Cloud Server Development / SDK for custom firmware development
	Network Protocols	IPv4, TCP/UDP/HTTP/FTP
	User Configuration	AT Instruction Set, Cloud Server, Android/iOS App

2. Pin Descriptions

There are altogether 8 pin counts, the definitions of which are described in Table 2 below。

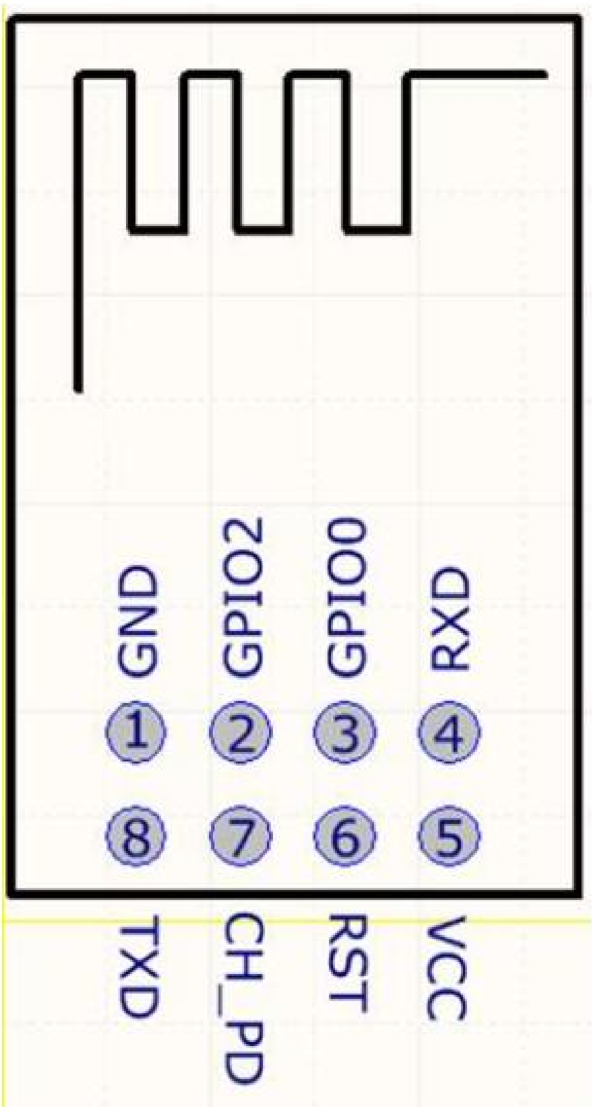

Table 2 ESP-01 Pin design

Table 2 Pin Descriptions

NO.	Pin Name	Function
1	GND	GND
2	GPIO2	GPIO,Internal Pull-up
3	GPIO0	GPIO,Internal Pull-up
4	RXD	UART0,data received pin RXD
5	VCC	3.3V power supply (VDD)
6	RST	1) External reset pin, active low 2) Can loft or external MCU ,
7	CH_PD	Chip enable pin. Active high
8	TXD	UART0,data send pin RXD

Table 3 Pin Mode

Mode	GPIO15	GPIO0	GPIO2
UART	Low	Low	High
Flash Boot	Low	High	High

Table 4 Receiver Sensitivity

Parameters	Min	Typical	Max	Unit
Input frequency	2412		2484	MHz
Input impedance		50		Ω
Input reflection			-10	dB
Output power of PA for 72.2Mbps	15.5	16.5	17.5	dBm
Output power of PA for 11b mode	19.5	20.5	21.5	dBm
Sensitivity				
DSSS, 1Mbps		-98		dBm
CCK, 11Mbps		-91		dBm
6Mbps (1/2 BPSK)		-93		dBm
54Mbps (3/4 64-QAM)		-75		dBm
HT20, MCS7 (65Mbps, 72.2Mbps)		-72		dBm
Adjacent Channel Rejection				
OFDM, 6Mbps		37		dB
OFDM, 54Mbps		21		dB
HT20, MCS0		37		dB
HT20, MCS7		20		dB

4.5. Absolute Maximum Ratings

Table 7 Absolute Maximum Ratings

Rating	Condition	Value	Unit
Storage Temperature		-40 to 125	°C
Maximum Soldering Temperature		260	°C
Supply Voltage	IPC/JEDEC J-STD-020	+3.0 to +3.6	V

4.6. Recommended Operating Conditions

Table 8 Recommended Operating Conditions

Operating Condition	Symbol	Min	Typ	Max	Unit
Operating Temperature		-40	20	125	°C
Supply voltage	VDD	3.0	3.3	3.6	V

4.7. Digital Terminal Characteristics

Table 9 Digital Terminal Characteristics

Terminals	Symbol	Min	Typ	Max	Unit
Input logic level low	V_{IL}	-0.3		0.25VDD	V
Input logic level high	V_{IH}	0.75VDD		VDD+0.3	V
Output logic level low	V_{OL}	N		0.1VDD	V
Output logic level high	V_{OH}	0.8VDD		N	V

Note: Test conditions: VDD = 3.3V, Temperature = 20 ℃, if nothing special is stated.

5. RF Performance

Description	Min.	Typ.	Max	Unit
Input frequency	2400		2483.5	MHz
Input impedance		50		ohm
Input reflection			-10	dB
Output power of PA for 72.2Mbps	15.5	16.5	17.5	dBm
Output power of PA for 11b mode	19.5	20.5	21.5	dBm
Sensitivity				
CCK, 1Mbps		-98		dBm
CCK, 11Mbps		-91		dBm
6Mbps (1/2 BPSK)		-93		dBm
54Mbps (3/4 64-QAM)		-75		dBm
HT20, MCS7 (65Mbps, 72.2Mbps)		-72		dBm
Adjacent Channel Rejection				
OFDM, 6Mbps		37		dB
OFDM, 54Mbps		21		dB
HT20, MCS0		37		dB
HT20, MCS7		20		dB

Table 10 RF Performance

6. Power Consumption

Parameters	Min	Typical	Max	Unit
Tx802.11b, CCK 11Mbps, P OUT=+17dBm		170		mA
Tx 802.11g, OFDM 54Mbps, P OUT =+15dBm		140		mA
Tx 802.11n, MCS7, P OUT =+13dBm		120		mA
Rx 802.11b, 1024 bytes packet length , -80dBm		50		mA
Rx 802.11g, 1024 bytes packet length, -70dBm		56		mA
Rx 802.11n, 1024 bytes packet length, -65dBm		56		mA
Modem-Sleep①		15		mA
Light-Sleep②		0.9		mA
Deep-Sleep③		10		uA

Table 11 Power Consumption

❶Modem-Sleep requires the CPU to be working, as in PWM or I2S applications. According to 802.11 standards (like U-APSD), it saves power to shut down the Wi-Fi Modem circuit while maintaining a Wi-Fi connection with no data transmission. E.g. in DTIM3, to maintain a sleep 300mswake 3ms cycle to receive AP's Beacon packages, the current is about 15mA.

❷ During Light-Sleep, the CPU may be suspended in applications like Wi-Fi switch. Without data transmission, the Wi-Fi Modem circuit can be turned off and CPU suspended to save power according to the 802.11 standard (U-APSD). E.g. in DTIM3, to maintain a sleep 300ms-wake 3ms cycle to receive AP's Beacon packages, the current is about 0.9mA.

❸ Deep-Sleep does not require Wi-Fi connection to be maintained. For application with long time lags between data transmission, e.g. a temperature sensor that checks the temperature every 100s ,sleep 300s and waking up to connect to the AP (taking about 0.3~1s), the overall average current is less than 1mA.

7. Reflow Profile

Table 12 Instructions

T_S max to T_L (Ramp-up Rate)	3°C/second max
Preheat Temperature Min.(T_S Min.) Temperature Typical.(T_S Typ.) Temperature Min.(T_S Max.) Time(T_S)	 150°C 175°C 200°C 60~180 seconds
Ramp-up rate (T_L to T_P)	3°C/second max
Time Maintained Above: --Temperature(T_L)/Time(T_L)	 217°C/60~150 seconds
Peak Temperature(T_P)	260°C max. for 10 seconds
Target Peak Temperature (T_P Target)	260°C +0/-5°C
Time within 5°C of actual peak(t_P)	20~40 seconds
T_S max to T_L (Ramp-down Rate)	6°C/second max
Tune 25°C to Peak Temperature (t)	8 minutes max