Smart Home Automation System

By

Ali Mohammad Tamimi Anas Radwan Barakat

Supervisor: Dr.Fouad Zaro

Submitted to the College of Engineering

In fulfillment of the requirement for the Degree of

Bachelor degree in Electrical Engineering

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Signature of the Head of the Department   Signature of the project supervisor

Name: Name:

Signature of the examining committee

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الملخص

نظام تحكم منزلي ذكي

يهدف هذا المشروع إلى تصميم وتطبيق نظام تحكم منزلي ذكي رخيص الثمن ومرن من حيث المزايا وقابل للتوسعة من حيث الحجم، اعتمادا على تكنولوجيا الأردوينو والاتصال اللاسلكي (Wi-Fi)، اضافة الى ذلك سيتم تطبيق مجموعة من الاساليب التقنية والبرمجية بحيث يتم تخفيف الاستهلاك الكهربائي في المنزل وتوفير أفضل تحكم بالأحمال الكهربائية المنزلية، كما وسيكون الوصول للنظام ممكنا من أي مكان بالعالم وباي وقت كان.

بشكل أساسي النظام سوف يعتمد على تكنولوجيا ولوحات الأردوينو، في البداية قمنا بتحديد الأجهزة المنزلية الكهربائية التي سيتم التحكم بها و عدد الغرف المنزلية ، ونوع المعلومات و البيانات التي سوف يقوم النظام بجمعها من البيئة الداخلية و الخارجية للمنزل، بناءً على ما سبق، قمنا بتصميم دائرة كهربائية عامة قادرة على القيام بكامل وظائف التحكم و جمع المعلومات من الحساسات الكهربائية المختلفة ، جميع هذه الدوائر الكهربائية سوف تكون متصلة بموقع على شبكة الإنترنت و ذلك باستخدام الاتصال اللاسلكي ال (Wi-Fi)، من ثم يتصل هذا الموقع بالمستخدم عن طريق تطبيق ذكي يعمل على نظام الأندرويد.

في نهاية هذا المشروع تمكنا من إنتاج نموذج نهائي لنظام تحكم منزلي ذكي كامل بحيث يكون مطبق على وحدة سكنية محددة عملنا عليها كعينة دراسية، بحيث يتم تعميم النظام لاحقا للاستخدام المنزلي التجاري العام. حيث أن النظام النهائي قادر على التحكم بالأدوات والأجهزة الكهربائية المنزلية المختلفة مثل: الإضاءة والمخارج الكهربائية (المقابس) ووحدات التكييف والتبريد، كما وقادر على عرض الاستهلاك الكهربائي المنزلي اللحظي وتوليد الطاقة الكهربائية من نظام الخلايا الشمسة المنزلي ودرجة الحرارة والرطوبة في كل غرفة على حدة، كما ويحتوي على نظام إنذار من الحريق والغازات السامة ونظام الإنذار من السرقة، كما ويمتلك النظام مجموعة من الآليات التي تعمل على ترشيد الاستهلاك الكهربائي المنزلي.

Abstract

Smart Home Automation System

The aim of this paper is to design and implement a cheap, flexible, scalable Smart Home Automation System based on Arduino Technology and Wi-Fi connection, in addition to apply specific techniques for power consumption reduction and load management. The system will be accessible anywhere, anytime.

The project will rely on Arduino Technology and NodeMCU boards, at the beginning we determined the electrical appliances to be controlled in the house, number of rooms to be controlled and type of information and data to be collected from indoor/outdoor environment, then we designed 3 general circuits that perform the whole process (master, indoor slave and outdoor slave), all will be connected to a cloud database that communicates with the user by an android application connected to the internet.

At the end of this project, we produced a fully working system (prototype) for small presentation room as a case study that could be generalized for residual use. The system is able to control all home electrical units and appliances like: lights, sockets, HVAC (Heating, Ventilating and air conditioning) units, fire, gas and intruder siren systems, in addition to monitor the real time power consumption, a PV system generation and the current room's temperature and humidity. Furthermore, the system is able to reduce power consumption using predefined algorithms.

إهداء

إلى أمي الحبيبة منبع المحبة والحنان، إلى من بذل الغالي والنفيس لأكون كما أنا عليه إلى والدي العزيز.

إلى من ذقت معهم طعم المحبة والأخوة إلى أخوتي وأسرتي.

إلى كل من علمني حرفاً أساتذتنا ومعلمينا العلماء.

إلى من ضاقت السطور ذكرهم إلى من كانوا قوت قلوبنا إلى أحبائنا وأصدقائنا الأعزاء.

إلى من كان سندا لنا بجهده ووقته ونصحه وعلمه إلى مشرفنا القدير الدكتور فؤاد الزرو.

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We would like to start with a special gratitude to our university for the help and support provided in its facilities for the past five years, and for our electrical engineering department for the large effort had been spent during our study to reinforce us with all knowledge needed.

And no thanks could be enough for our supervisor Dr.Fouad Zaro, for his support, effort and guidelines he gave us during the course, special thanks to Eng. Elias Maharmeh for his support, we would like also to thank Dr.Saleh Takroury, Eng.Obadah Qawasme, Eng.Alaa Tamimi and Eng.Mohammad Qaisi for their help.

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List of Abbreviations

SHAS	Smart Home Automation System.
IoT	Internet of Things
PC	Personal Computer
HVAC	Heating Ventilating Air Conditioning units
UPS	Uninterruptable Power Supply
I/O	Inputs/Outputs
USB	Universal Serial Bus
LAN	Local Access Network
PCB	Printed Circuit Board
I2C	Inter-Integrated Circuit
IP	Internet Protocol
C.T	Current Transformer
P.T	Potential Transformer
IS	Indoor Slave
OS	Outdoor slave
LDR	Light Dependent Resistor
PIR	Passive Infrared Sensor
Kbps	kilobytes per second
SCL	Serial Clock Line
SDA	Serial Data Addressing
ID	Identification
SRAM	Static Random Access Memory

EEPROM	Electrically Erasable Programmable Read-Only Memory
LED	Light Emitting Diode
DC	Direct Current
IR	Infra-Red
RH	Relative Humidity
CAD	Computer-aided drafting
IDE	Integrated Development Environment
Http	Hypertext Transfer Protocol
SDK	Software Development Kit
3D/2D	3 Dimensions/ 2 Dimensions.

1

Chapter One

Introduction

1.1 Introduction

1.2 Literature Review

1.3 Problem Statement

1.4 Objectives

1.5 Importance

1.6 Project scope

1.7 Time frame

1 Chapter One

1.1 Introduction

Smart home automation system (SHAS) is new trend has been started beside all new technological innovation we have today, this trend started when smart appliances became more popular, nowadays we have smartphone, smart tablets, smart cars, smart washing machines and the list goes on. Most of smart appliances became "smart" when you connect them to the internet, to give access and control power over their settings and configurations and give more technical and useful information about the process they do, from this point of view Smart home automation became a thing.

Internet of things (IoT) can be described as connecting everyday objects like smart phones, internet televisions, sensors and actuators to the internet where the devices are intelligently linked together to enable new forms of communication amongst people and themselves [1].

Smart home automation system opens the door for safer life, increasing comfort and more control over house energy and consumption which all leads to energy saving and load control [2]. This project is an application of Smart home automation system (SHAS) concept in which we apply Arduino technology to give the control over the whole system, in order to obtain a law cost, flexible, scalable, user friendly and power economical system.

1.2 Literature Review

In [2] a flexible standalone smart home system illustrated, this system had been built using Arduino-android application combination, the main purpose of this paper is to prove that a complete smart home system could be built using Arduino microcontroller without using any personal computers (PCs) or even high end microprocessors.

The author used an Ethernet connection for communication between the Arduino and the smartphone, so the commands is transferring from the smartphone (android application) to micro web-server inside the Arduino itself, and the data is transferred back from Arduino micro web-server to the android application.

The main final results of the paper is a fully working small prototype containing small circuit do basic control operations such as light, socket, HVAC (heating ventilating air conditioning units) and Security control with fully working android application.

In [3] a full smart home system design presented, the main purpose of this design is to find a solid way to communicate three main elements in the proposed system:

- A website server (User interface to communicate with the system).
- A personal computer as a Server.
- Arduino hardware.

The methodology used in this system depends on a website user interface so the user could interact with system by sending commands to the server (personal computer), then the server do the processing needed for that command and then send the actuator status to the Arduino hardware. On the other hand, Arduino hardware collects sensors data and sends it back to the server, then the server do the processing needed for these data and decide the best implementation of system's actuators, and send information about the process to the user by website page.

The main advantage of this smart system is the hardware/software capability gained using personal computer power. However, this leads to some drawbacks that could affect the system feasibility and stability, one large drawback is the cost, when we take in consideration the cost of using a personal computer which is higher than 500$ for a moderate unit that is 10 times higher than the cost of an Arduino circuit which could work as a master circuit for the system, and the cost of using uninterruptable power supply (UPS) for the computer that also cost at least 200$, all of this additional cost make the system less affordable and highly complicated, another important drawback of the system is the instable connection between the server computer and the Arduino hardware using Wi-Fi communication.

In [4] a smart home automation system proposed based on Bluetooth technology, the main purpose of this paper is to design and implement fully working, effective, flexible and cost efficient home automation system relying just on Bluetooth technology.

The methodology used in this particular system depends on two main parts

- Arduino hardware/software with Bluetooth module.
- Android application.

The process start form Arduino board collecting all sensors and digital I/O data and sends it to the user using Bluetooth communication, these data presented to the user using an android application with friendly user interface, then the user responds to the system by sending back commands to Arduino board.

To be mentioned that Arduino board also programmed in such algorithm allowing it to take some small actions by itself just depending on sensors data, these actions could be preprogramed or defined by user.

The main advantage of this system is simplicity, this system is simple in such way to reduce the cost of using special hardware/software tools. On the other hand, this simplicity came on reliability and practicality account, relying on Bluetooth communication is weak, because Bluetooth technology usually has limited connectivity range and it's not secure.

In [5], the author presented a concept design of Home Automation system based on internet website, the project aims to control electrical home units using a website accessible from anywhere worldwide, this website connected to a personal computer mounted in the house as a system server, this pc will be connected to a hardware controller from one side using USB or LAN connection, and from the other side the controller will be connected with all electrical equipment's and units, the author provided a full detailed control design and algorithms, but It lakes from any electrical designs like PCB (printed circuit board) or even simulation diagrams or schemes.

One large advantage for the system is scalability, the system design allow to connect any new house units using simple configuration and registration procedures, and because the system uses a PC (personal computer) server you could add large amount of devices and units, and worth to be mentioned that system designed in such way to be friendly with users who don’t have big experience with websites and computers like elderly and disability persons.

However, the system suffers from the following

- ❖ High Costs, although the design helped to make the system highly scalable but the layout made the system costly because of using separate personal computer as a server which costs over 500$ as mentioned before.
- ❖ Complexity, despite the system is user-friendly but it's complicated in design in such way that could affect efficiency and speed, because it offers multiple options to connect hardware units with system software, and this variety of choices came on system efficiency account.

1.3 Problem Statement

Smart Home Automation is a new trend that became more important day by day because of the increase in importance of load management and power consumption reduction, and the families with disability members and busy parents need of such systems, so in near future Smart Home will be a must. However, current available industrial SHAS is expensive and inflexible because each manufacturer focusing on certain electrical appliances over others to control, and most of these system depend on replacing the traditional electrical units with smart ones which increase the total system cost and make these systems hardly implemented in our market.

Our project is meant to provide a complete and finished solution prototype, this prototype intend to be cheap, flexible, scalable, and practical so it won't replace any traditional or old electrical units in the house, furthermore this project will provide different predefined and programmed scenarios to reduce power consumption which of course serve the need of healthier and less polluted environment.

1.4 Objectives

- Design and build fully working smart home automation system (SHAS) prototype.
- Implement cost and feature competitive system.
- Subject the system for power consumption reduction.
- Implement efficient power management techniques.
- Design the whole system so it could meet the Palestinian tendencies.
- Finishing our prototype in a professional way so it would be ready for marketing.
- Marketing our system in the local markets in first phase, to be marketed in Global markets later.

1.5 Importance

Smart home systems become much more popular and important day by day for many families, also integrating these systems with home solar systems and implementing smart and manual techniques for power consumption reduction and loads management, furthermore the need of these systems for families with elderly and disability members increased the importance of these smart systems, so building and implementing such systems locally is an important path to be taken, so we could produce a competitive system that open new market doors for our economy, rise new employment opportunities and develop the quality of technology in Palestine.

1.6 Project scope

In this project we implemented and designed a smart home system prototype based on Arduino technology and NodeMCU boards based on Wi-Fi connection, this project will be divided into separate circuits, each circuit will control all electrical appliances in a specific region defined for it and all are connected to central cloud database.

For easy implementation purposes we took a specific house as a case study to implement our system, then we could generalize our system for residual use.

In electrical design section, we designed all circuit using PCB (printed circuit boards) technology, so we ended with three finished electrical boards printed by professional specialized PCB manufacture and all electrical components and equipment are added and welded on these boards.

In mechanical design section, we designed a special in wall cases and covers for each circuit board and for some special electrical circuits and components need to be separated from the main board.

In Software section, we defined the main software and programming languages used for programming our system, and we designed a full flowchart for each software part in our system.

1.7 Timeframe

For tasks had been done in this course of our project see Table 1.1.

Table 1.1 Timeframe Table

Weeks Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Programming firebase Real-time database	■	■	■												
I2C communication programming			■	■	■										
Slaves programming					■	■	■								
Android application programming							■	■							
User interface For android								■	■	■					
Circuits testing and Soldering										■	■				
3D covers											■	■			
System testing												■	■		
Documentation														■	

2

Chapter Two

Main Design Concepts

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2 Main Design Concept

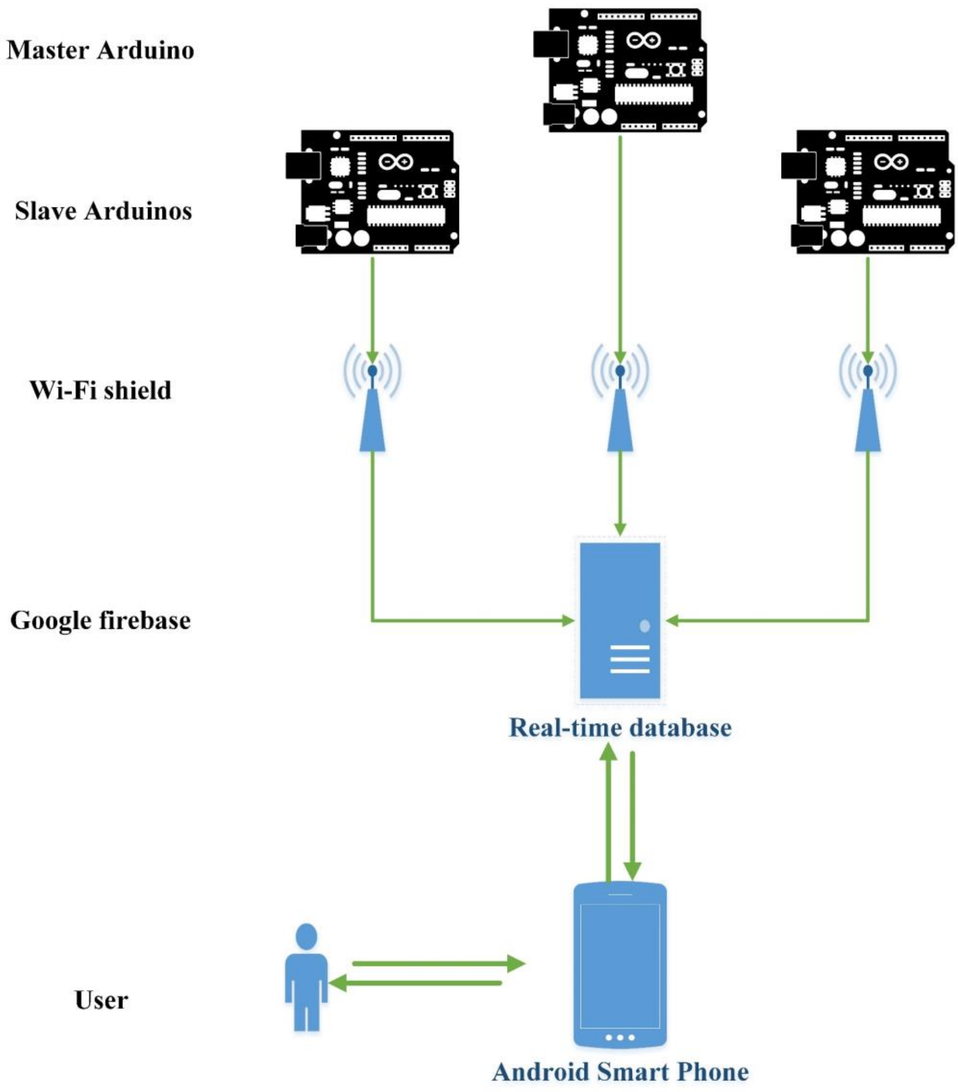
2.1 Introduction

In order to build price competitive system we designed our system to fully work using Arduino and NodeMCU boards over using personal computers as servers, and to make the system scalable we divided it into sections each section controlled by separate circuit called slave and a master circuit for electrical consumption and production monitoring and intruder siren system. All of these circuits connected to a central cloud database.

2.2 System Layout

Our system is divided into four main parts see Figure 2.1.

A. Android application to be controlled by user connected to internet.
B. Google firebase real-time database.
C. Master circuit.
D. Slave circuits.
E. Custom designed Wi-Fi shield.



Fⁱgure 2.1 Project layout

2.3 System main parts

2.3.1 Android application

The main user will communicate with the system using an android application loaded on android smartphone, the application have access to a specific predefined database for the system, the user will have database link and authentication key, Then the smart app send the authentication key and database link to Google firebase to check access, if it's OK then the real-time database let the app control master and slaves circuits by sending commands and receive information from the system see Figure 2.2 for android application flowchart.

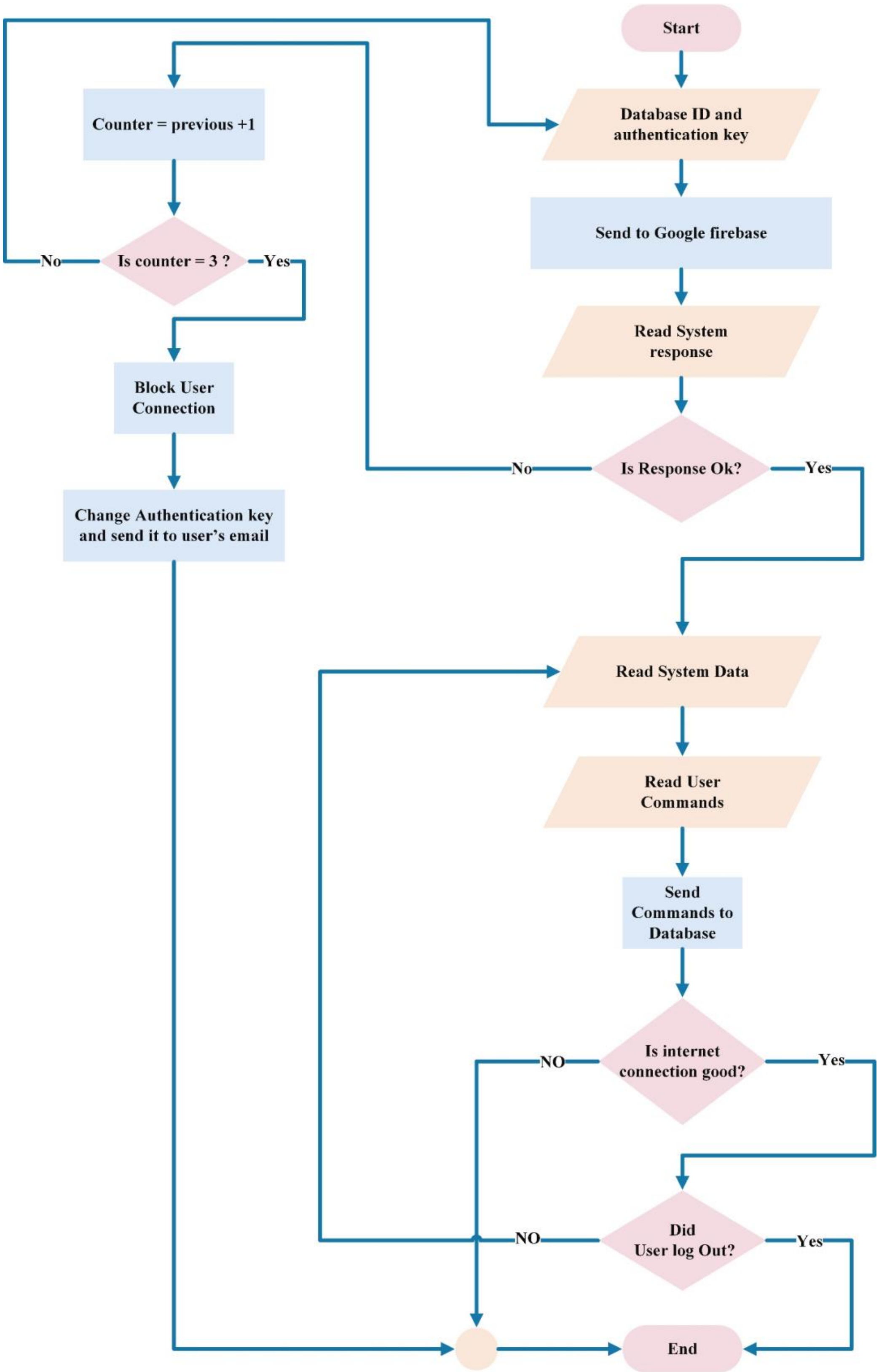


Figure 2.2 Android app flowchart

2.3.2 Google firebase real-time database.

In this project we relied on Google firebase, because it provides a robust and secure connection for both iOS and Android operating systems as well as NodeMCU boards, which leads to robust and secure system, and make this database much more reliable than any other alternatives see Figure 2.3.

For each smart home system we define a specific database link and authentication key, in each we generate a specific variables paths (child), in which we save our data and (commands and feedback) to be read and sent by both NodeMCU board and the Android app.

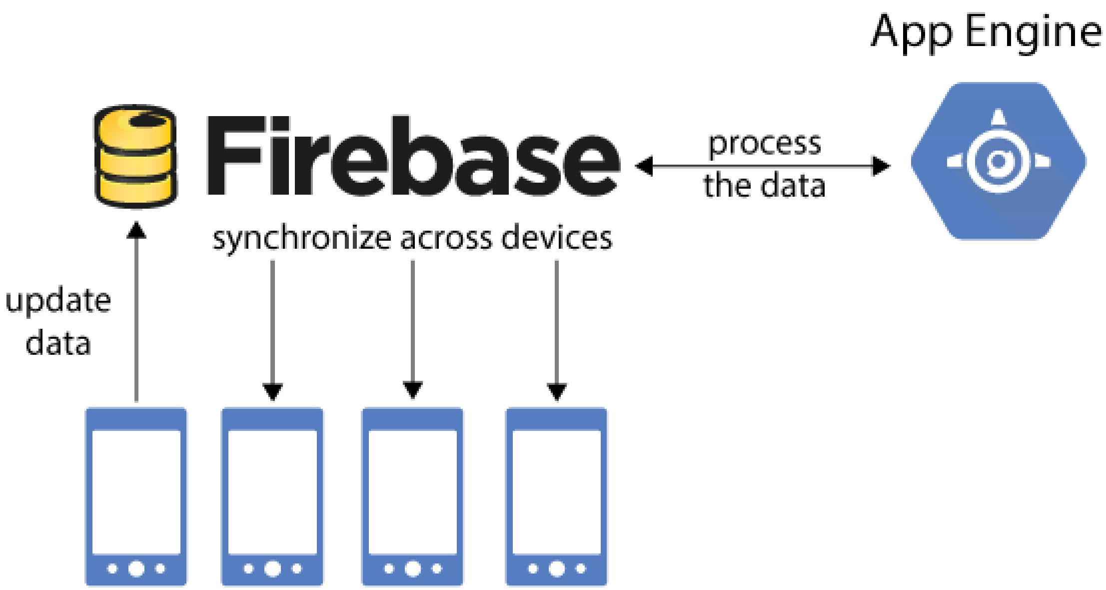


Figure 2.3 Wi-Fi shield for Arduino board [6].

2.3.3 Master Circuit

Our master circuit will act as a monitor device for both house electrical consumption and PV system production, and provides an intruder siren system capable to detect movement for different 14 PIR sensors.

The master circuit equipped with Hall Effect current sensor will be described later in this report and V.Ts for both

- Main house circuit breaker.
- Main PV system circuit breaker.

The board read both RMS value for both voltage and current, and then calculate the power each 10 seconds, and calculate the consumption/production energy for recent day, month and send them to the database, in which all the data stored in specific variable, then these data read by the android application and presented in statistics page see figure 2.4.

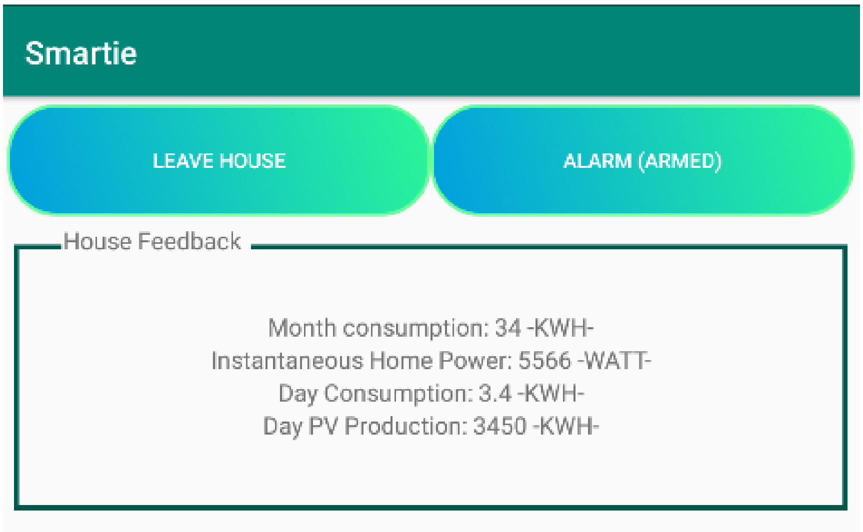


Figure 2.4 house feedback in the Android app

Furthermore, master circuit calculate 15 minute KW demand and send it to a public or private (as desired) online google sheet, for electrical distribution calculation, this data is very useful for users consumption reading and building distribution transformer loading curves, transformer diversified demand curves, load duration curve and accurate diversity factor table for electrical utility database, so distribution transformer capacity and expansion calculations will be much more accurate see figure 2.5 for online google sheet.

time	15_minute_watt demand	Monthly_demand
	30	30
3/18/2019 18:00:21	30	30
3/18/2019 18:15:21	30	30
3/18/2019 18:30:21	30	30
3/18/2019 18:45:21	22	22
3/18/2019 19:00:21	100	100
3/18/2019 19:15:26	69	69
3/18/2019 19:30:29	69	69
3/18/2019 19:45:32	69	69
3/18/2019 20:00:18	45	45
3/18/2019 20:15:12	103	103
3/18/2019 20:30:57	100	100
3/18/2019 20:45:11	144	144
3/18/2019 21:00:16	177	177
3/18/2019 21:15:12	177	177

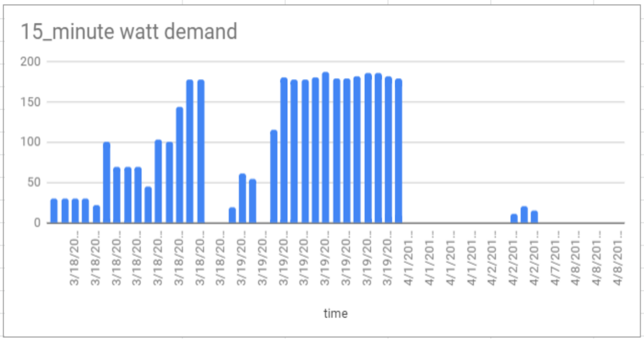


Figure 2.5 Google sheet online user_15_minute_watt demand

For intruder siren system, Master board read alarm system status form the database, if the system is armed and any of the 14 indoor attached PIR sensors detects any movement it will send a notification to the user smartphone and will fire an in-house alarm, and in the future we're planning to connect the alarm system with police station system for automatic dispatch in case of intruder detection see figure 2.6 for Master circuit block diagram.

In addition to all previous master circuit's features, the master circuit also provided with expected solar hours for each month these data provided by NASA, and the circuit compare at the end of each day the generated energy and peak instantaneous power measured during last day and compare them to both expected energy generation and peak power, after that it gives the user an indication of the PV system status, if the PV system is normal, or need a clean or maintenance see figure 2.7.

All software operation that the circuit should perform illustrated in Figure 2.8.

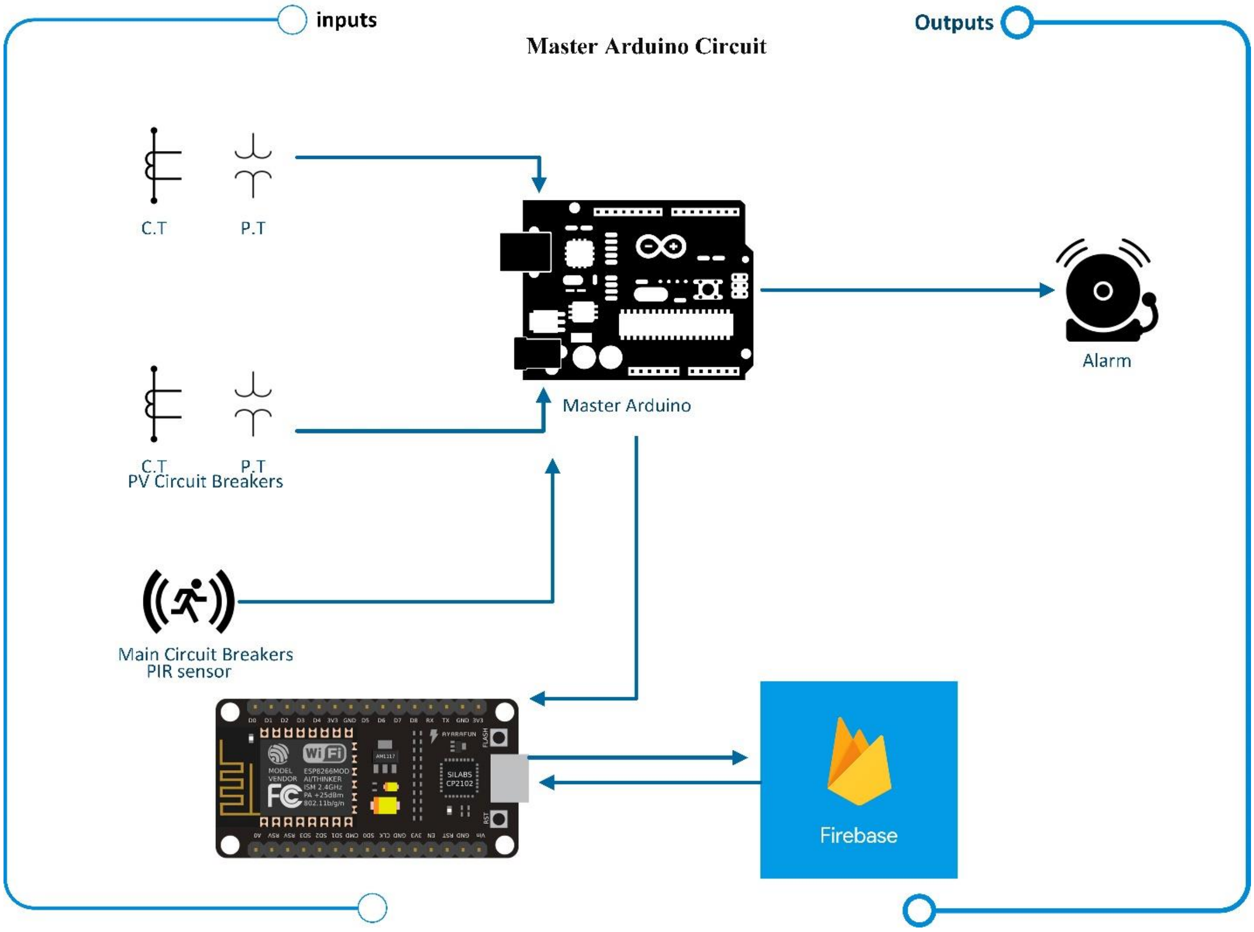


Figure 2.6 Master circuit block diagram.

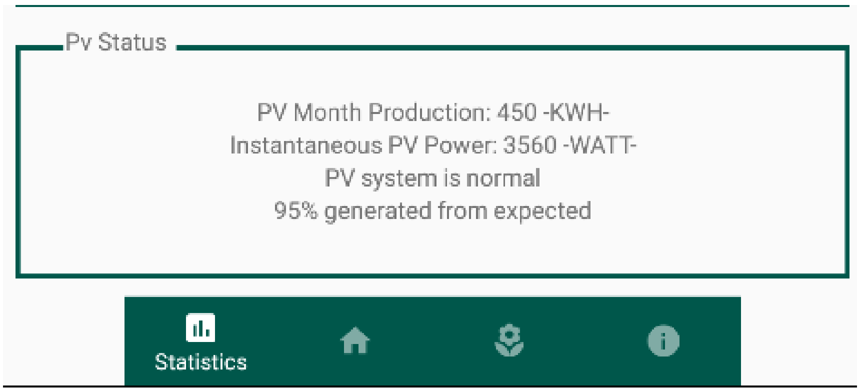


Figure 2.7 PV status Android app.

Master Circuit Program Flow Chart

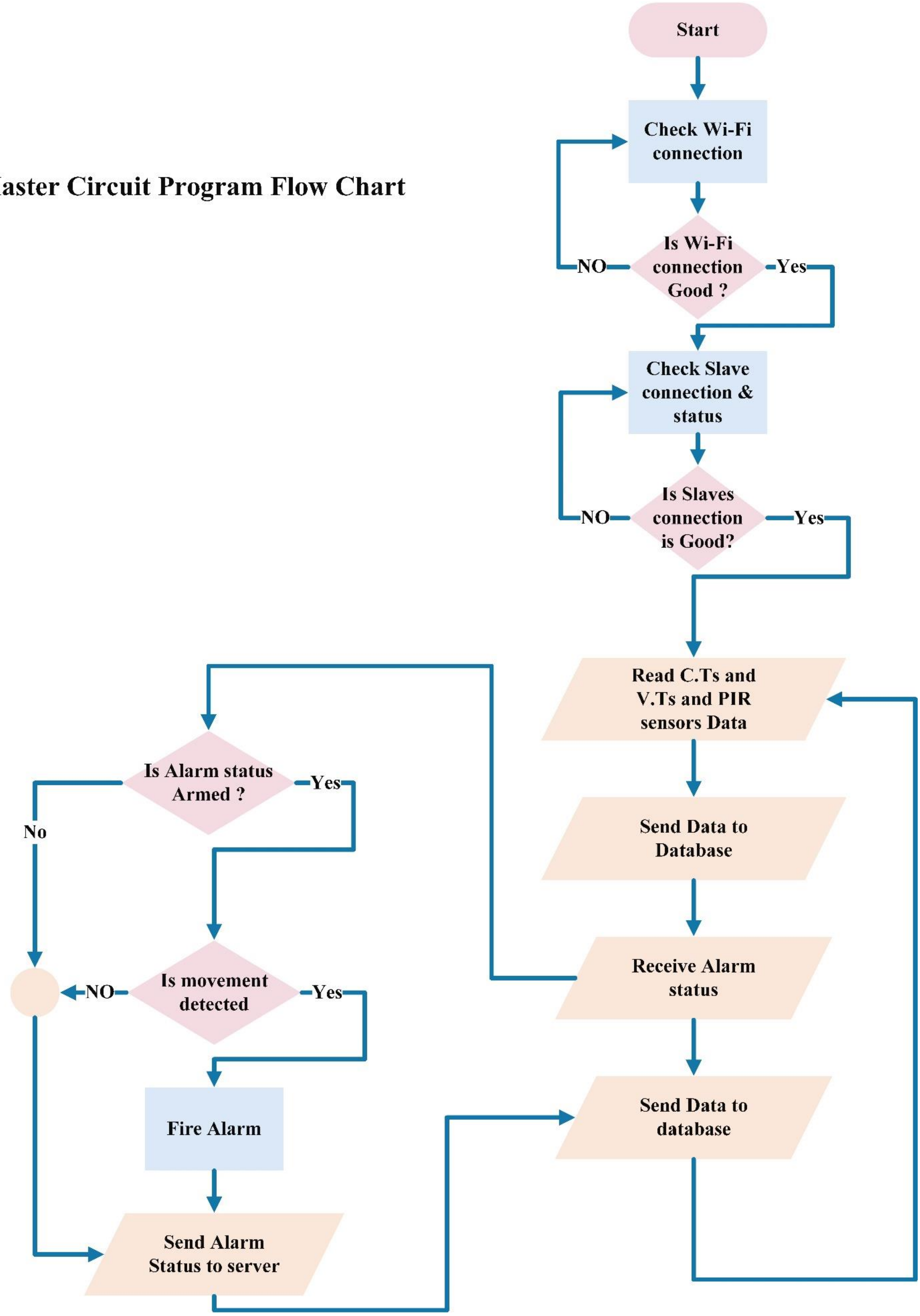


Figure 2.8 Master circuit flowchart.

2.3.4 Slave circuits

These circuits meant to perform all electrical operations and collecting data from Rooms and outside environment like: temperature, Humidity, Gas/Fire detection, intruder detection and light intensity.

We have two main types of standard slave circuits

a) Indoor slave (IS).
b) Outdoor slave (OS).

2.3.4.1 Indoor slave (IS)

This circuit will control all electrical appliances in its working region which is indoor room see Figure 2.9 and Figure 2.10 & 2.11 for circuit flowchart.

A. IS inputs:
    1. Lights On/Off switches.
    2. Windows up/down switches.
    3. Temp/humidity sensor.
    4. Light sensor LDR.
    5. Gas/fire sensor.
    6. PIR sensor.
    7. Hall Effect current sensor.
    8. V.T.

B. IS outputs:
    1. 5 X Light unit (on/off).
    2. 3 X Window (up/down).
    3. 8 X Sockets (on/off).
    4. An HVAC (heating ventilating air conditioning unit) unit remote controller.
    5. Alarm unit.

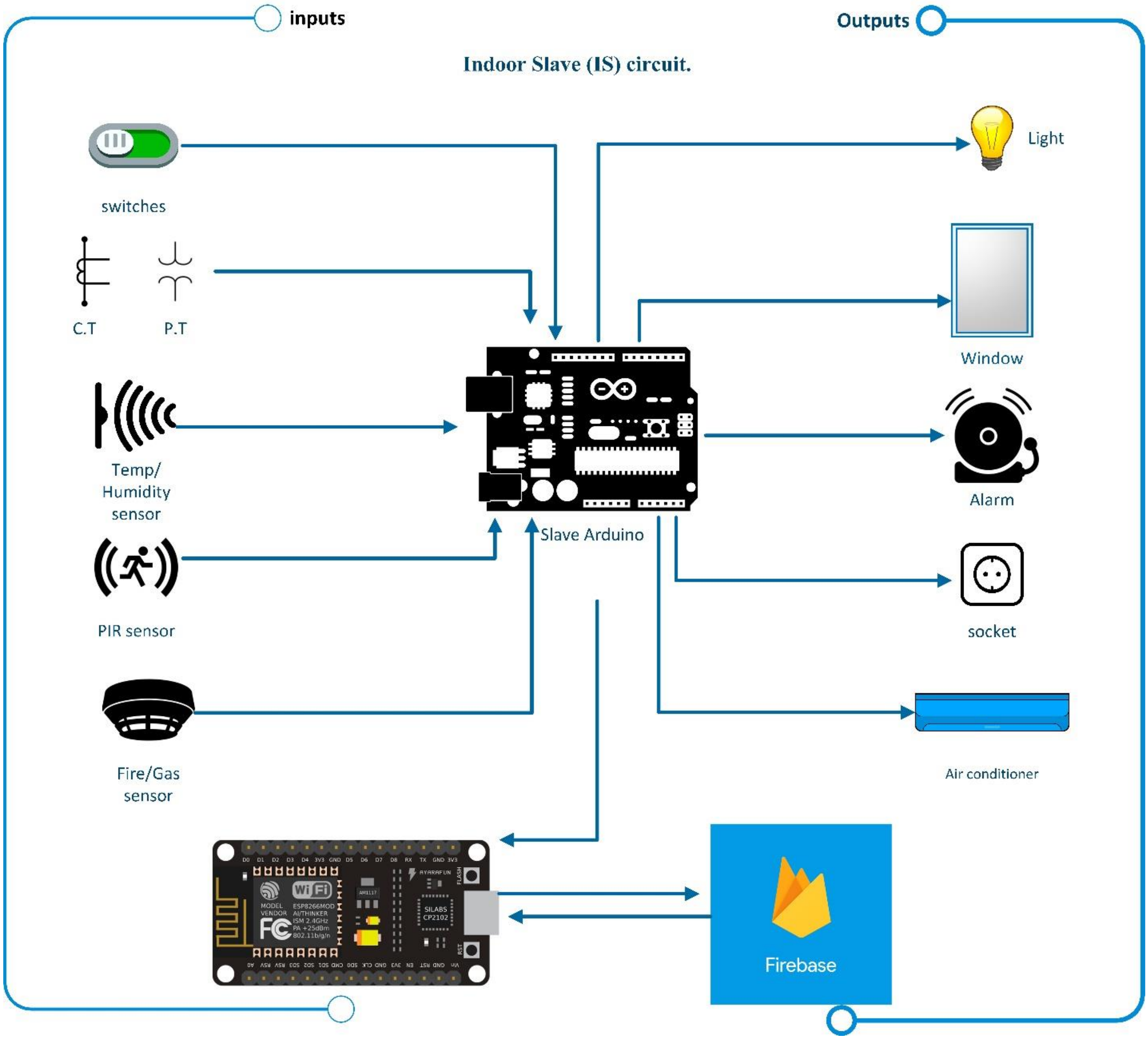


Figure 2.9 Indoor Slave block diagram.

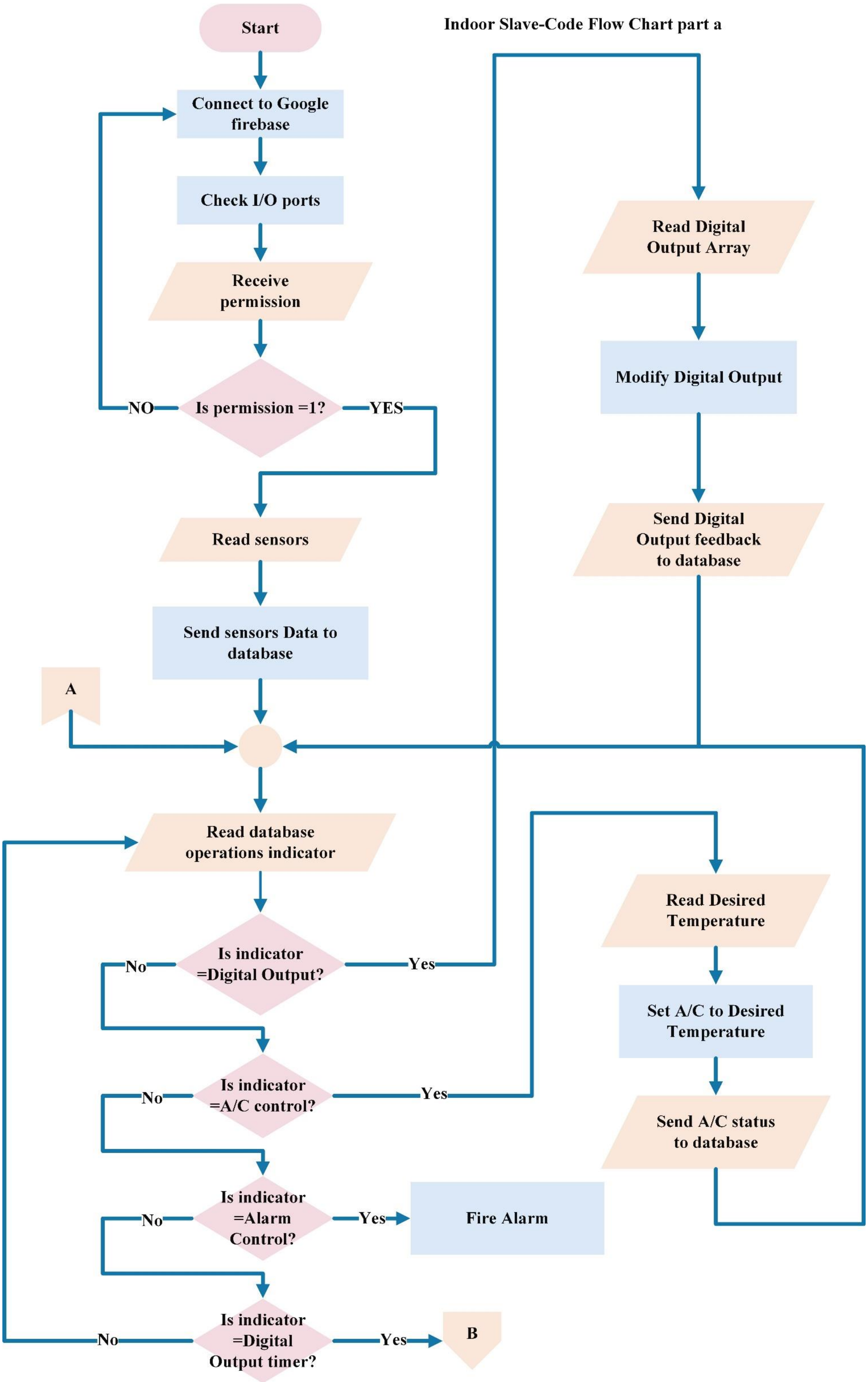


Figure 2.10 Indoor slave flow chart A.

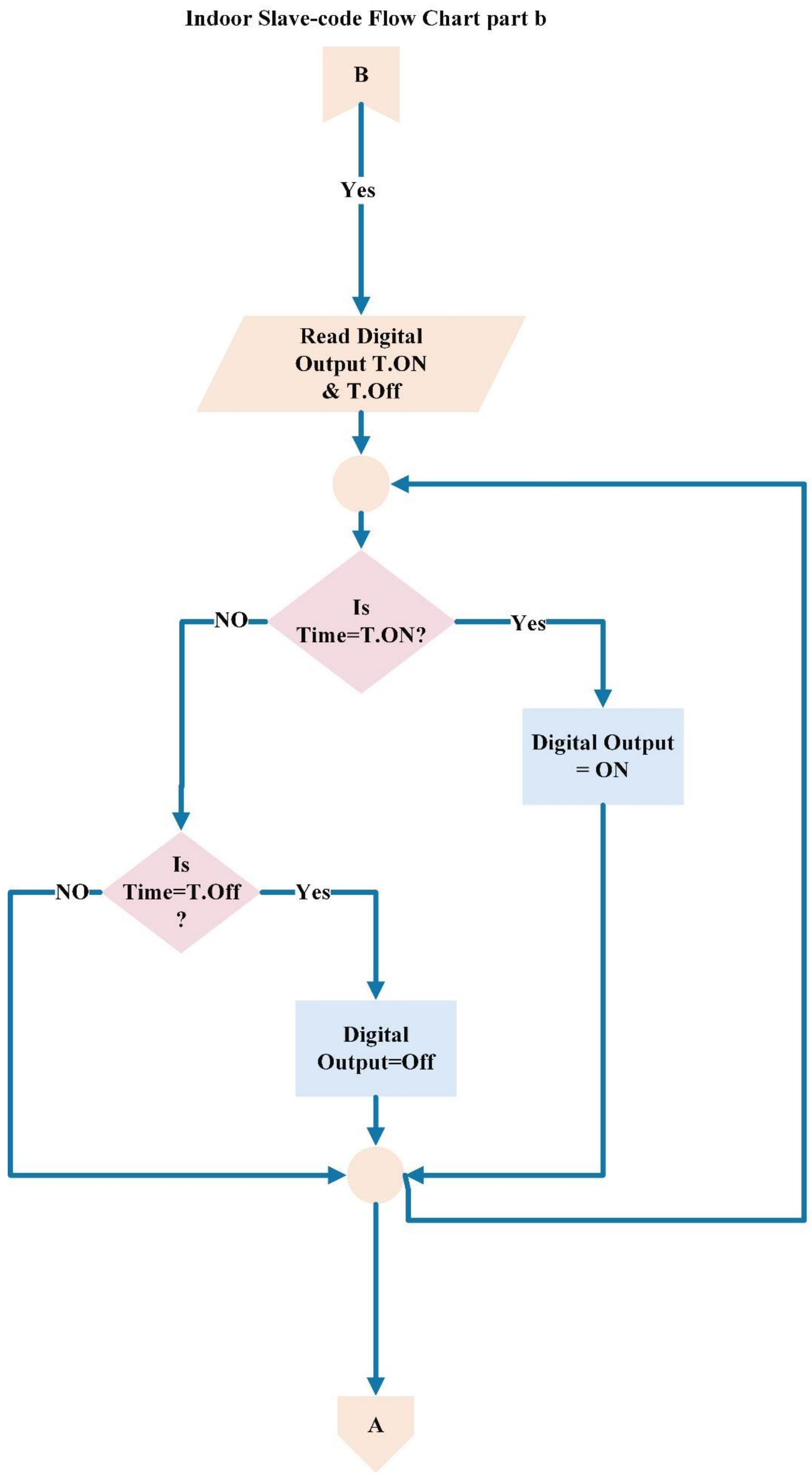


Figure 2.11 Indoor flow chart B.

For each electrical unit we provides 4 ways to control it see figure 2.12:

- In app switching on and off.
- Classical manual switches.
- Timing, in which each component will have on timer and off timer switch.
- Some predefined button like leave house.

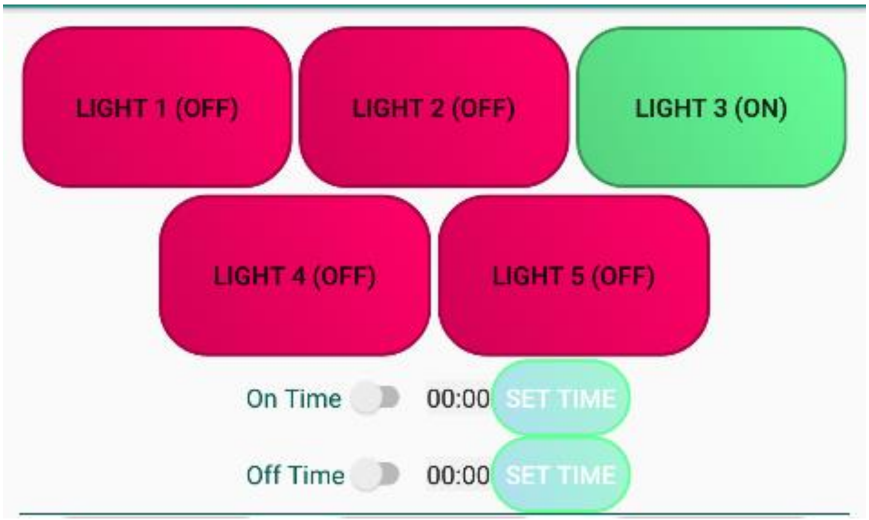


Figure 2.12 In app on/off buttons and timers.

For HVAC units, we provides central infra-red unit, which could control the unit as desired, cooling or heating and the temperature value see figure 2.13.

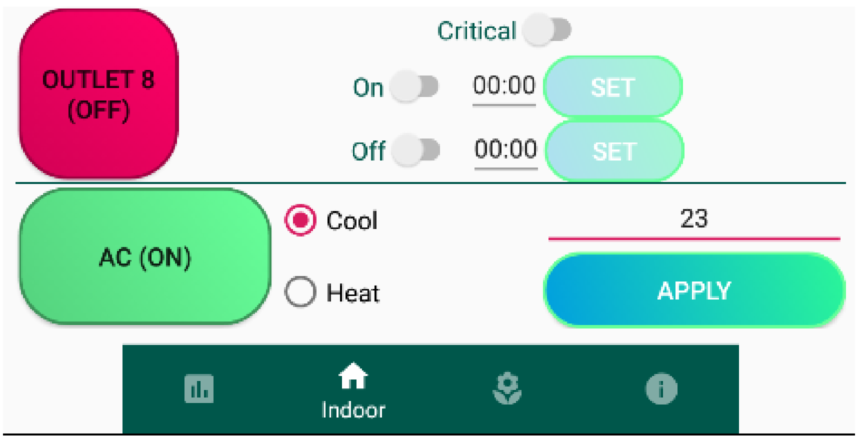


Figure 2.13 In app HVAC control.

Each indoor circuit able to monitor its region electrical consumption, and gives the user a feedback of the instantaneous power and recent month energy consumption see Figure 2.14.

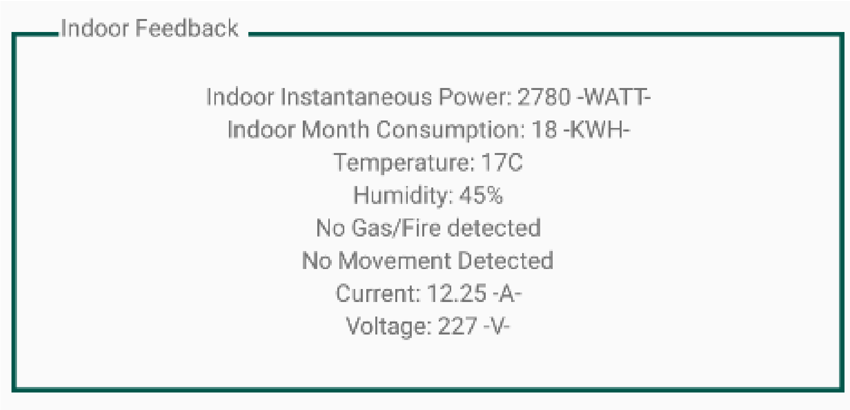


Figure 2.14 In app indoor slave feedback.

2.3.4.2 Outdoor slave (OS)

This circuit will control all electrical appliances in its working area, which include front and back yard areas see Figure 2.15 and Figure 2.16 for circuit flowchart.

OS Inputs:

1. Lights On/Off switches.
2. Temp/humidity sensor.
3. Light sensor LDR.
4. PIR sensor.
5. Hall Effect current sensor.
6. V.T.

OS Outputs:

1. 10 X Light unit.
2. 8 X Sockets.
3. Water pump.
4. Electrical gate.

For each electrical unit we provides 4 ways to control it:

- In app switching on and off.
- Classical manual switches.
- Timing, in which each component will have on timer and off timer switch.
- Some predefined button like leave house.

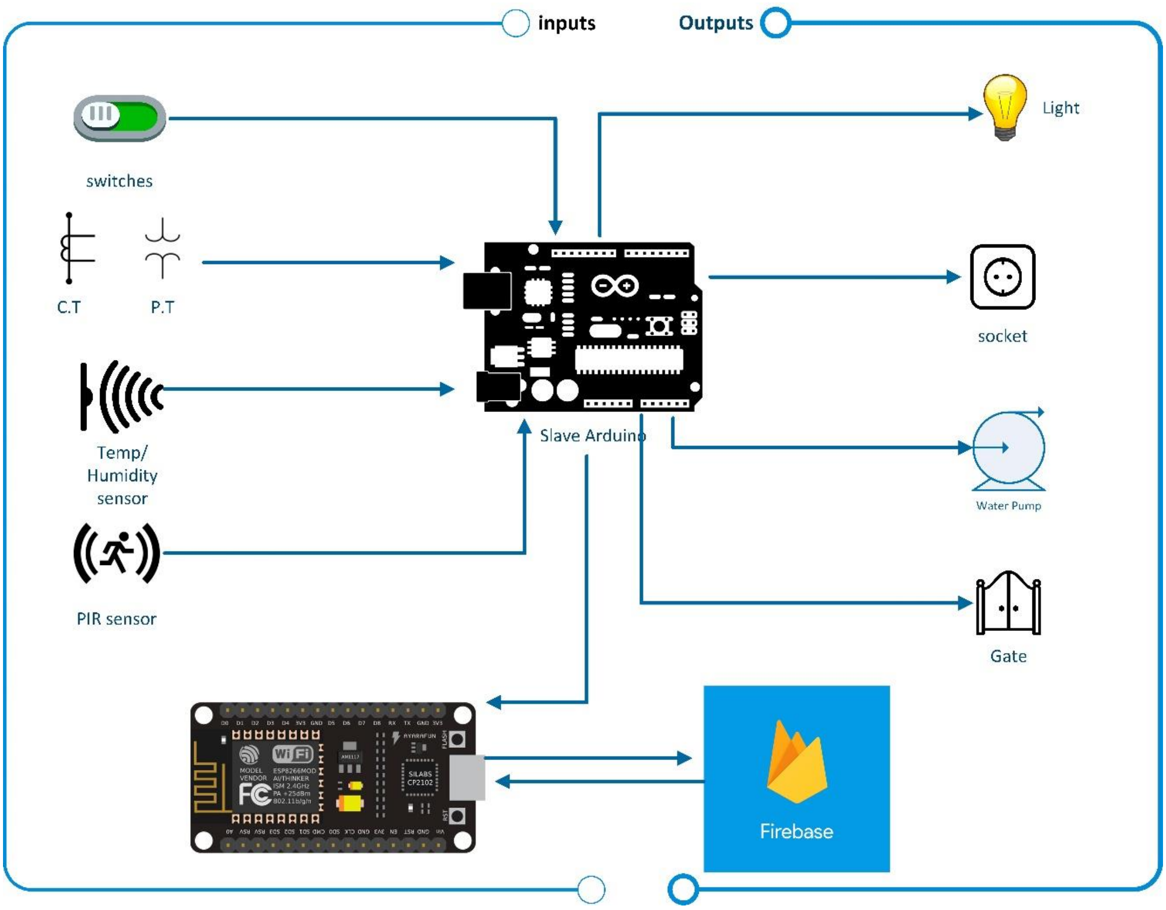


Figure 2.15 OS block diagram.

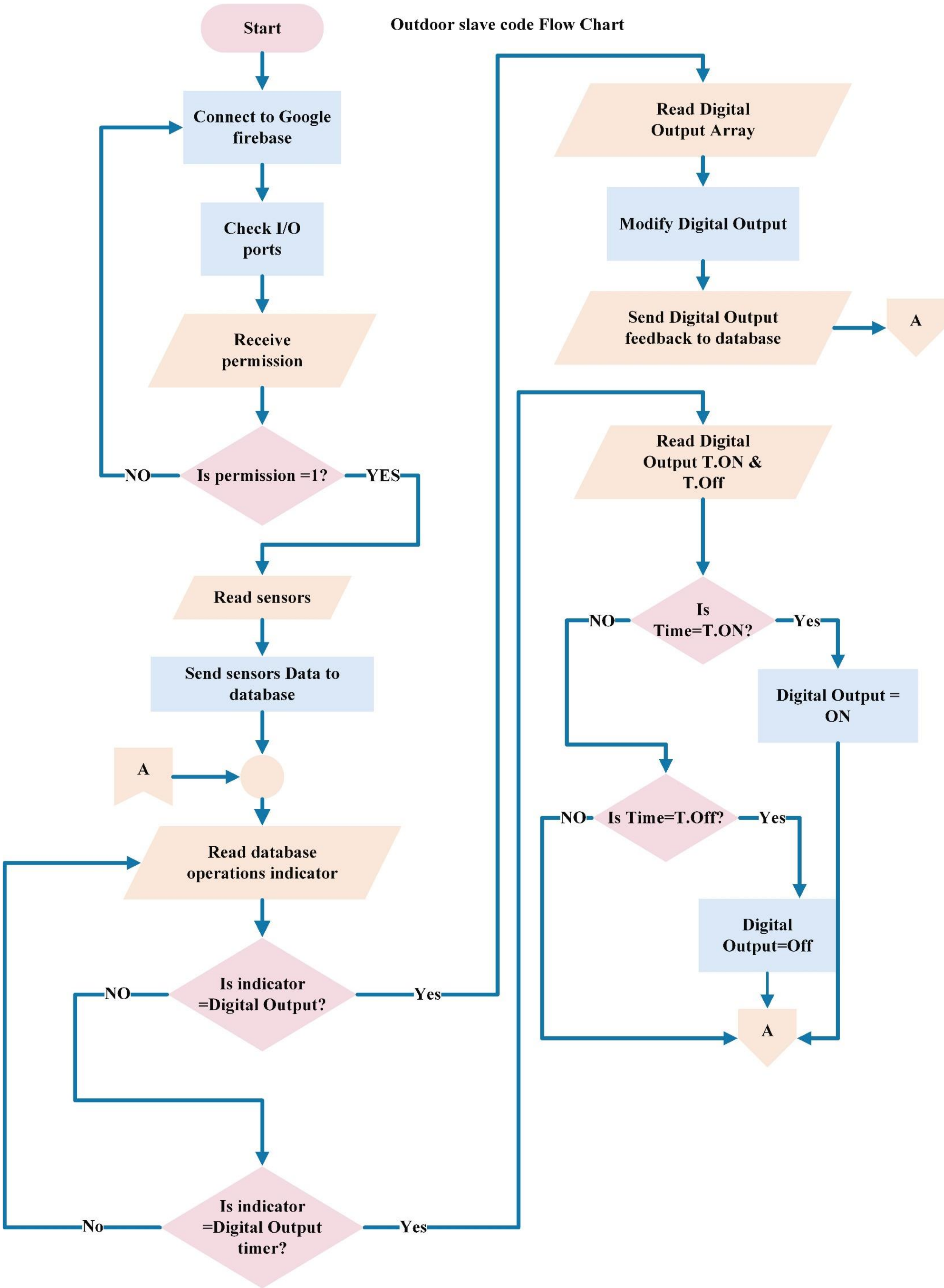


Figure 2.16 OS flowchart

2.3.5 Custom Wi-Fi shield.

In order to connect Arduino board to the internet and Google firebase database we used NodeMCU boards powered by esp8266 microcontroller which is capable to connect to Wi-Fi networks and provided with special function library for Google firebase.

The main large challenge we faced when connecting both board (Arduino and NodeMCU) and establishing bidirectional communication that Arduino boards is a 5v logic boards, and NodeMCU is a 3.3v logic boards, in order to solve this problem we used a logic shifter bridge that convert 3.3v to 5v and vice versa.

This logic converter containing 4-bidirectional channels each consists of the following circuit see figure 2.17.

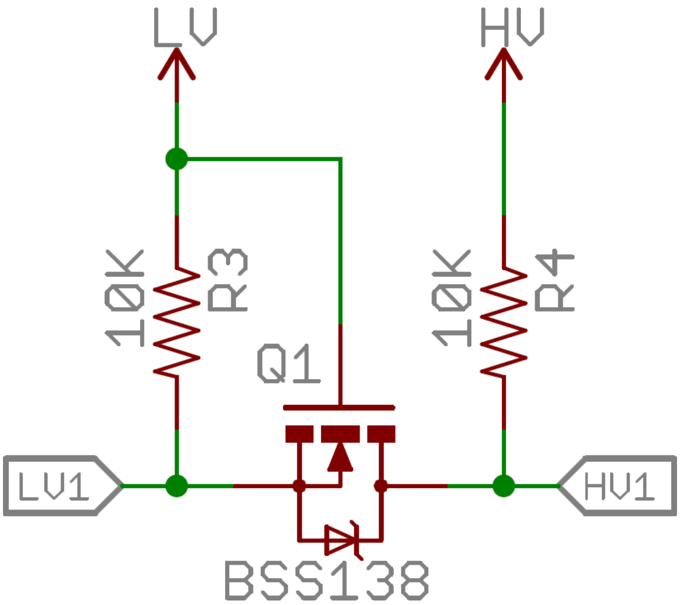


Figure 2.17 logic shifter circuit [7]

NodeMCU shield and Arduino board communicate using I2C serial communication to transfer data to and from Arduino board.

2.4 I2C Communication

Slave and master Arduino boards communicate with Wi-Fi shield NodeMCU board by (I2C) communication, this communication provide reliable and robust communication between different manufacturer boards, although it's much more simple than alternative communication types for microcontroller but yet it's the most used serial communication in microcontroller industry.

2.4.1 Why I2C communication?

- Simple, needs just two wires.
- Support multi masters, multi slaves devices.
- Supported for Arduino microcontroller.
- Supported for ESP8266 microcontroller.
- Support bidirectional data transmission.
- Best economical communication technology because it needs just two wires for the whole system could be connected as ring configuration.

2.4.2 How it works?

Well each device has a preset ID or a unique device address so the master can choose with which devices will be communicating.

The two wires, or lines are called serial clock (or SCL) and serial data (or SDA). The SCL line is the clock signal which synchronize the data transfer between the devices on the I2C bus and it’s generated by the master device. The other line is the SDA line which carries the data.

The two lines are “open-drain” which means that pull up resistors needs to be attached to them so that the lines are high because the devices on the I2C bus are active low. Commonly used values for the resistors are from 2k ohm for higher speeds at about 400 kbps, to 10k ohm for lower speed at about 100 kbps [8].

2.4.3 Protocol

The data signal is transferred in sequences of 8 bits. So after a special start condition occurs comes the first 8 bits sequence which indicates the address of the slave to which the data is being sent. After each 8 bits sequence follows a bit called Acknowledge. After the first acknowledge bit in most cases comes another addressing sequence but this time for the internal registers of the slave device. After the addressing sequences follows the data sequences as many until the data is completely sent and it ends with a special stop condition see Figure 2.12.

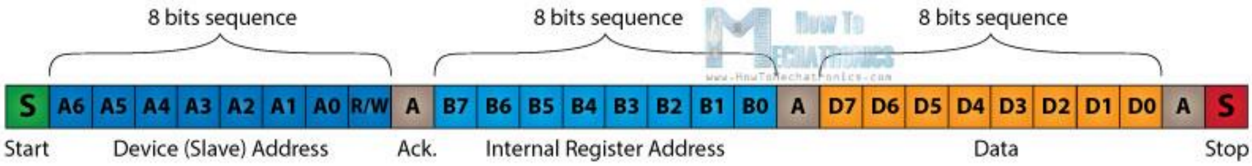


Figure 2.18 I2C Protocol [8].

2.5 Power and energy calculations.

In this section we're illustrating our technique in calculating voltage and current RMS values.

For voltage measuring we're using ZMPT101B voltage transformer, that converts voltage from AC range to DC sinusoidal wave form with 2.5v reference value, in order to calculate the RMS value we take 40 samples each cycle (i.e. one sample each 500 micro seconds), then we calculate the RMS value for the measured cycle using the following equation.

$$Vrms/cycle = \sqrt{\frac{\sum_{1}^{40} Vsample^2}{40}}$$

And for higher accuracy we take the average RMS value for 12 cycle, this process refreshed each 10 seconds, this calculation process used for both current and voltage and for current measuring we're using ACS712 Hall Effect IC.

Each 10 seconds we calculate the apparent power and add it to energy variables to calculate energy.

$$S\ (VA) = Vrms * Irms$$

To calculate the average power we need to calculate PF (power factor), and to do so we measure the time difference b/t voltage zero crossing sample and current zero crossing sample, as we have 20 sample per cycle

$$1\ x\ Cycle = 20ms\ for\ 50\ hz\ frequency$$

And

$$1\ x\ Cycle = 360\ degree$$

For 20 samples per cycle we have

$$1\ x\ sample = 1ms = 18\ degree.$$

Now we calculate the number of samples b/t voltage zero crossing sample and current zero crossing sample

$$V_0\ sample\ \# - I_0\ sample\ \# = N.$$

Now for power factor angle

$$\theta = 18 * N$$

$$PF = Cos(\theta)$$

Average power

$$P_{avg} = S * PF$$

$$Energy\ variable\ (Watt\ Hour) = prevoius\ value\ (watt\ Hour) + P_{avg}(watt) * (\frac{10}{3600})$$

.

2.6 Hardware

In this section we're listing our project hardware components with full description and working principle of each component.

1- Arduino MEGA

This Microcontroller is the main controller used in Slaves circuits for Board View see Figure 2.13 for Board Data sheet see Table 2.1

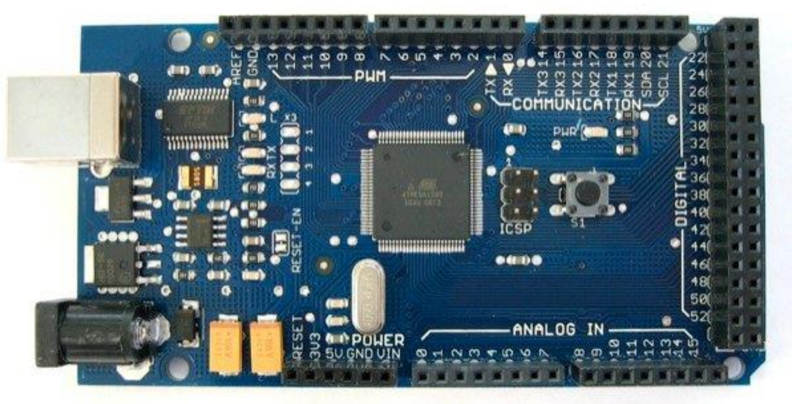


Figure 2.13 Arduino MEGA [9].

Table 2.1 Arduino Mega Data sheet

Microcontroller	ATmega2560
Operating Voltage	5V
Input voltage (recommended)	7-12V
Input voltage(limit)	6-20V
Digital I/O pins	54 (of which 15 provide PWM output)
Analogue input pins	16

DC Current per I/O pin	20 mA
DC Current for 3.3v pin	50mA
Flash memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHZ
LED_BUILTIN	13
Length	101.52mm
Width	53.3mm
Weight	37 g

2- Relays

The relay module is an electrically operated switch that allows you to turn on or off a circuit using voltage and/or current much higher than a microcontroller could handle. There is no connection between the low voltage circuit operated by the microcontroller and the high power circuit. The relay protects each circuit from each other. See Figure 2.15.

Figure 2.15 (5) V DC signal, (250) V AC relay 10/16 amp [9].

3- Gas/Fire sensor

The MQ series of gas sensors use a small heater inside with an electro-chemical sensor. They are sensitive for a range of gasses and are used indoors at room temperature. They can be calibrated more or less but a known concentration of the measured gas or gasses is needed for that. The output is an analogue signal and can be read with an analogue input of the Arduino. See Figure 2.16.

Figure 2.16 Gas/fire sensor [9].

4- PIR sensor

PIRs are basically made of a pyro electric sensor , which can detect levels of infrared radiation. Everything emits some low level radiation, and the hotter something is, the more radiation is emitted. The sensor in a motion detector is actually split in two halves. The reason for that is that we are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low. See Figure 2.17.

Figure 2.17 PIR sensor [9].

5- Humidity and temperature sensor

This is a multifunctional sensor that gives you temperature and relative humidity information at the same time. It can meet measurement needs of general purposes. It provides reliable readings when environment humidity condition in between 20% RH and 90% RH, and temperature condition in between 0°C and 50°C. See Figure 2.18.

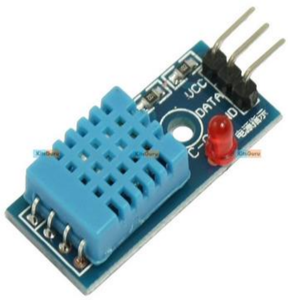


Figure 2.18 Temp/humidity sensor [9].

6- Light sensor

A photo resistor is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photo resistor can be applied in light-sensitive detector circuits, and light-activated and dark-activated switching circuits. See Figure 2.19.

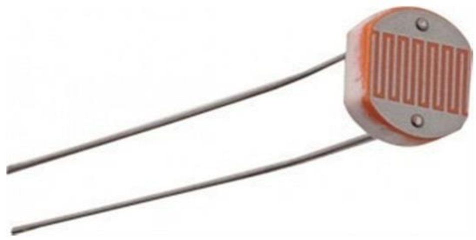


Figure 2.19 LDR sensor [9].

7- Current and voltage transformers (meter)

Current sensors operate as the sealed secondary of a current transformer while the conductor carrying the current to be measured functions as a one turns primary. Measurement accuracy can be improved by increasing the number of primary turns. Applications include detection of branch circuit overload and load drop or shutdown. See Figure 2.20.

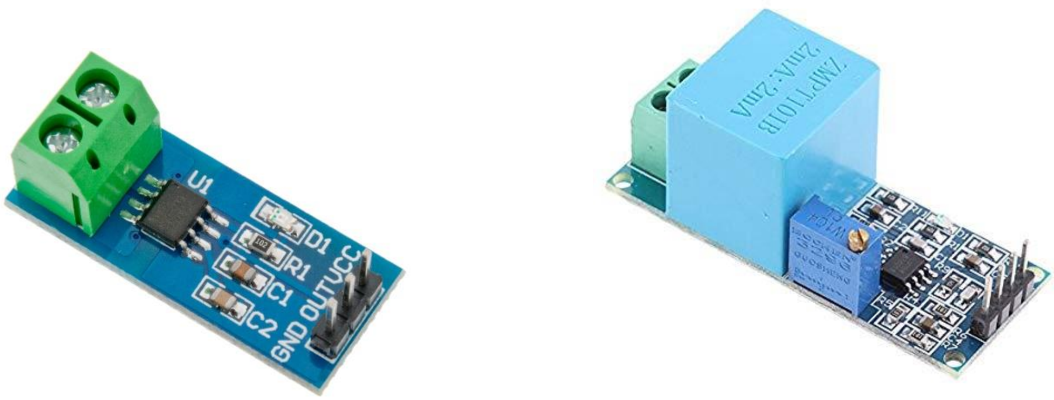


Figure 2.19 C.T/P.T meter [9].

8- Node MCU ESP8266 WIFI board

NodeMCU is an open source development board and firmware based in the widely used ESP8266 -12E WiFi module. It allows you to program the ESP8266 WiFi module with the simple and powerful LUA programming language or Arduino IDE. See Figure 2.21.

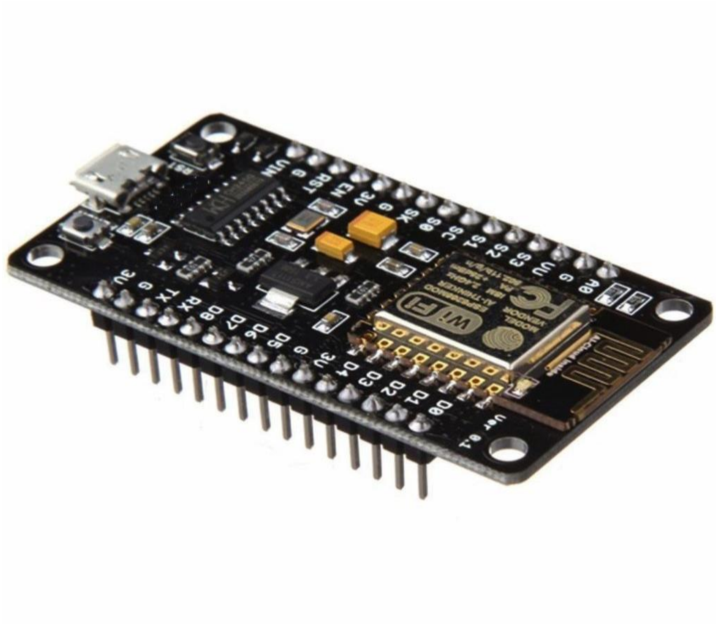


Figure 2.20 Node MCU[9]

9- Real time clock (RTC)

The DS3231 is a low-cost, extremely accurate I2C real-time clock (RTC) with an integrated temperature compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate timekeeping when main power to the device is interrupted. See Figure 2.22.

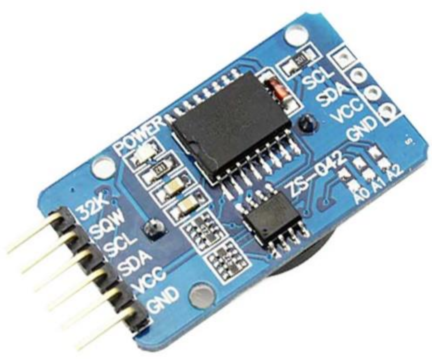


Figure 2.21 RTC board[9]

10- 4 channel logic level converter

A level shifter in digital electronics, also called a logic-level shifter, is a circuit used to translate signals from one logic level or voltage domain to another, allowing compatibility between ICs with different voltage requirements, such as TTL and CMOS. Many modern full featured systems use level shifters to bridge domains between low-power application processors running at 1.8 V and other system functions like sensors or other analog intensive applications running at 3.3 or 5V. See Figure 2.23.

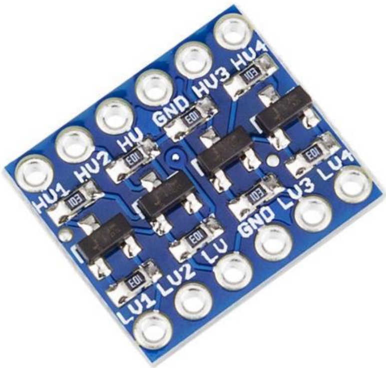


Figure 2.22 Node MCU[9]

2.7 Software

In this projects we used different software programs and programming languages to implement our designs, as shown in Table 2.1

Table 2.2 Main programs used in designing process.

Program	Use
Proteus version 8.1	Design Main Electrical Circuits PCB schemes
AutoCAD 2016	Design Case Study House
Shapr3D (based on CAD Software)	Design Wall mounted covers for PCB boards
Microsoft Visio 2016	Design project Diagrams and Flowcharts

For Programming language and programming software tools used see Table 2.2

Table 2.3 Programming languages used in this project.

Programming Language	Use
Arduino IDE software based on C/C++	Arduino programming
Http Commands + AT commands	Google firebase real-time database
android SDK based on Java	android Application programming

2.8 Case Study

For simplification purposes this project will rely on specific case study to be generalized later, this case study is a house consisting of:

1. 3 X Bedroom.
2. 1 X kitchen.
3. 1 X living room.
4. 1 X guestroom.
5. 3 X bathroom.
6. Front-back yard area.

- Each bedroom will be served byIS slave circuit.
- The guestroom, living room and kitchen will be served by oneIS slave circuit.
- Bathrooms and stairs region will be served by oneIS slave circuit.
- Front-back yard area will be served by OS slave circuit.

- ❖ Master circuit will be connected to all previous slave circuits.

A full 3D design had been sketched for our case study house, the positioning ofIS (room control slave), OS (Outdoor slave), master circuit and HVAC remote control covers shown in Figures

Figure 2.23 Master circuit cover

Figure 2.24 Bedroom

Figure 2.25 Living room

Figure 2.26 Office

3

Chapter Three

Electrical Design

3 Electrical Design

3.1 Introduction

In this chapter we introduce our PCB (printed circuit board) designs for all electrical circuits in our system, all circuits designs had been implemented on Proteus Software version 8.1, in second section of the chapter we're listing the electrical components in each circuits and description of the main role of it in the circuit, then in PCB section we're attaching the final schemes of PCB boards in 2D and 3D, finally we presented our 3D designs of Circuits covering.

3.2 Electrical Components

In This section we're all used components with expected End-customer prices.

3.2.1 Master Circuit

Table 3.1 Master board electrical components.

Item	Price NIS	Quantity	Total NIS
Arduino MEGA	120	1	120
Terminal block I2	0.3	16	5
LED Diode	0.3	4	1
Resistor	0.3	4	1
Voltage transformer	15	2	30
Buck converter	20	1	20
Relay(10A)	10	1	10
Speaker	50	1	50
PIR sensor	10	6	60
Power supply	30	1	30
Shield	70	1	70
current transformer(32A)	10	4	40
PCB Board	170	1	170
Circuit cover	100	1	100
Total			707 NIS

3.2.2 IS (Room Control Slave) Circuits

Table 3.2IS electrical components.

Item	Price NIS	Quantity	Total NIS
IR diode	2	1	2
Arduino MEGA	120	1	120
Terminal block I2	0.3	50	15
LED	0.3	20	6
Resistor	0.2	35	7
Buck converter	20	3	60
Relay(10A)	10	6	60
Power supply	30	1	30
current transformer(16A)	10	1	10
current transformer(10A)	10	1	10
Relay(16A)	12	14	168
Speaker	50	1	50
Voltage transformer	15	1	15
Temperature sensor	16	1	16
PIR sensor	10	1	10
Light sensor	2	1	2
Buffer IC	8	3	24
Gas sensor	15	1	15
Headers	150	0.067	10
Circuit cover	100	1	100
PCB	200	1	200
Shield	70	1	70
Total			1000

3.2.3 OS (Outdoor slave) Circuit

Table 3.3 OS electrical components.

Item	Price NIS	Quantity	Total NIS
Arduino MEGA	120	1	120
Terminal block I2	0.3	50	15
LED Diode	0.3	20	6
Resistor	0.2	35	7
Buck converter	20	3	60
Relay(10A)	11	10	110
Power supply	30	1	30
current sensor (16A)	10	1	10
current sensor (10A)	10	1	10
Relay(16A)	12	10	120
Siren	50	1	50
Buffer IC	8	3	24
Temperature sensor	18	1	18
PIR sensor	10	6	60
Voltage transformer	15	1	15
Circuits cover	100	1	100
Shield	75	1	75
PCB	200	1	200
Headers	0.067	150	10
Total			1040

3.3 PCB Schemes

In this project we designed 3 main PCB (printed circuit board) boards, one is a master PCB board, OS (Outdoor-slave) PCB board and IS (Indoor-slave) PCB boards. All PCB boards designed using Proteus software ver. 8.1.

For trace's width calculations we have 2 types of traces:

- Signal trace that represent all signals from-into Arduino boards.
- Power traces that represent phase traces, 16 Amp phase for power circuits and 10 Amp phase for lighting circuits.

3.3.1 Traces widths

- For signal trace width we chose 1.2 mm width which is s standard in PCB design.
- For 10 Amp trace we chose 3.75 mm width.
- For 16 Amp trace we chose 4.5 mm width.

3.3.2 Calculations

First, the Area is calculated:

Area [mils^2] = (Current [Amps]/ (k*(Temp_Rise [deg. C])^b))^(1/c) (3.1)

Then, the Width is calculated:

Width [mils] = Area [mils^2]/ (Thickness [oz]*1.378[mils/oz]) (3.2)

For IPC-2221 external layers: k = 0.048, b = 0.44, c = 0.725

- For 16A traces:

$$\text{Area} = \left(\frac{16}{0.048 * 50^{0.44}}\right)^{1/0.725} = 281.01(mils^2)$$

$$\text{Width} = \frac{281.01}{1 * 1.378} = 204(\text{mils})$$

204 mils =5.18/2=2.56 mm

Average Ambient Temp. =50 C^o Temp. Rise = 20 C^o.

- For 10A traces:
-

$$\text{Area} = \left(\frac{10}{0.048 * 50^{0.44}}\right)^{1/0.725} = 146.95(mils^2)$$

$$\text{Width} = \frac{146.95}{1 * 1.378} = 107(\text{mils})$$

107 mils =2.71 /2=1.355mm

Average Ambient Temp. =50 C^o Temp. Rise = 20 C^o.

3.3.3 PCB 3D view

Master PCB top and bottom view shown in Figure 3.1.

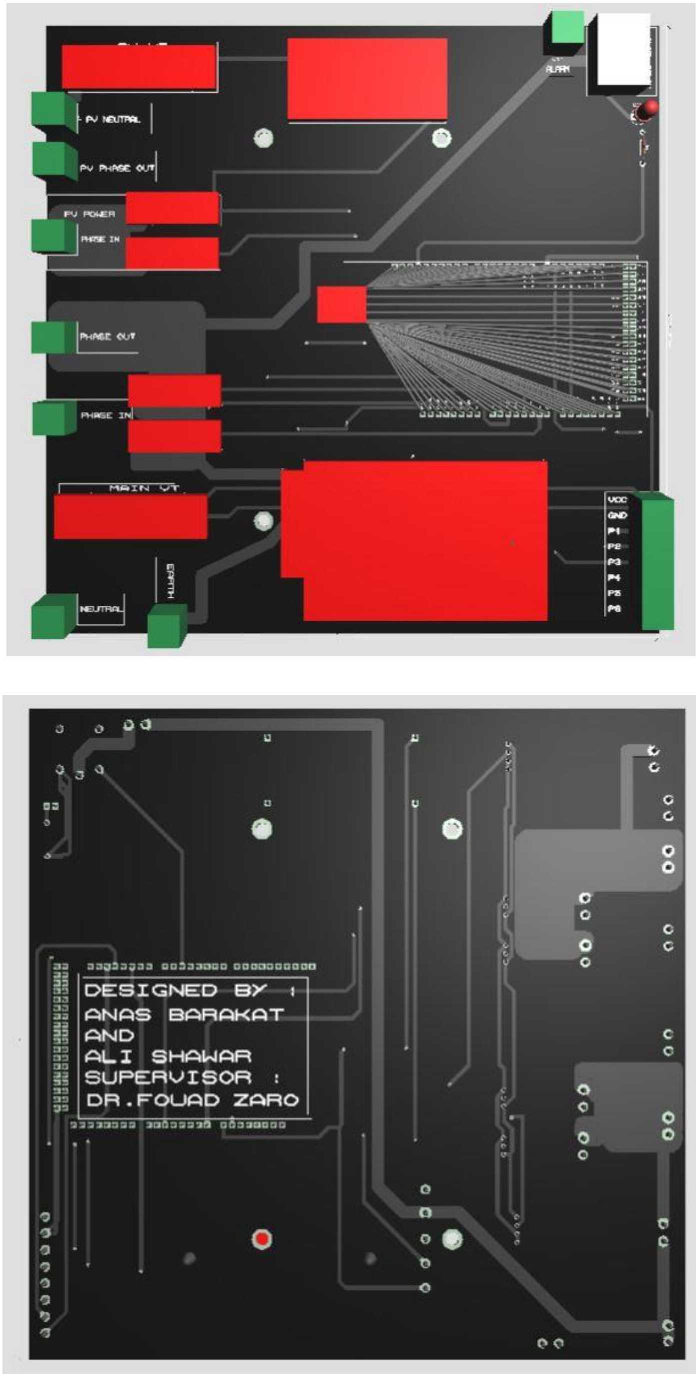


Figure 3.1 Master PCB top view b. Master PCB bottom view.

IS (room control slave) PCB top and bottom shown in Figure 3.3.

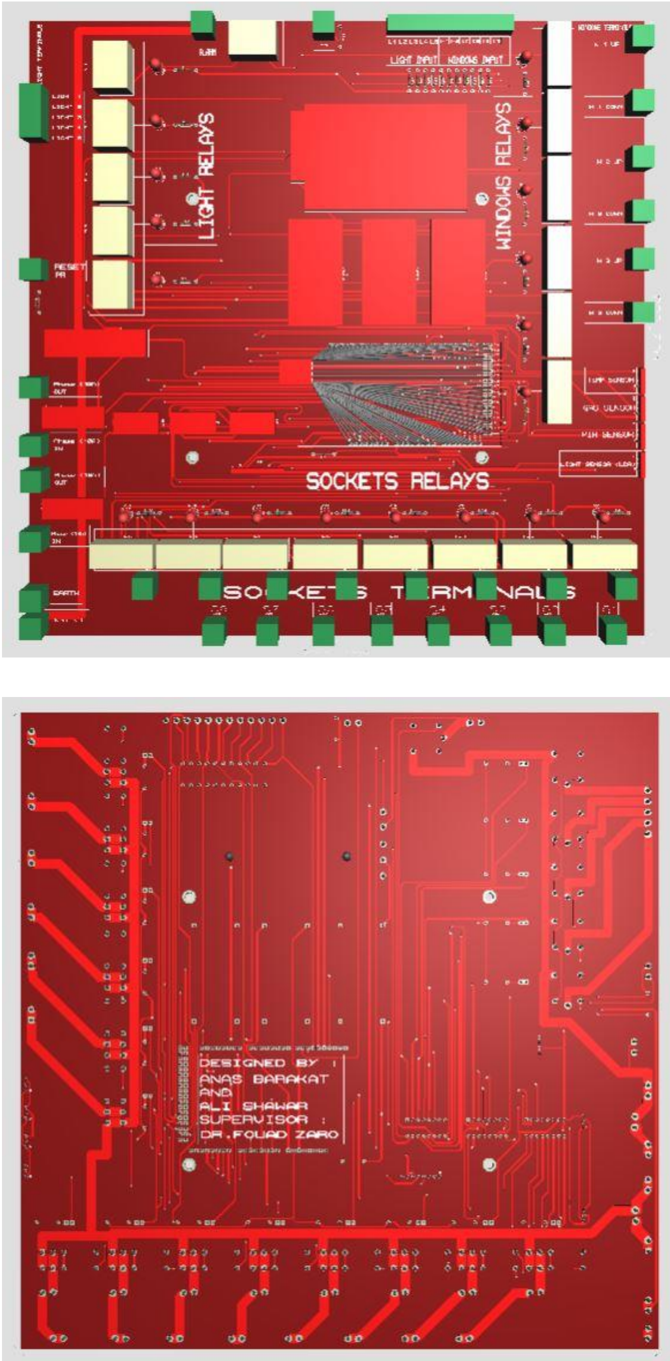


Figure 3.2 top and bottom view.

For OS (Outdoor slave) PCB top and bottom view shown in Figure 3.5.

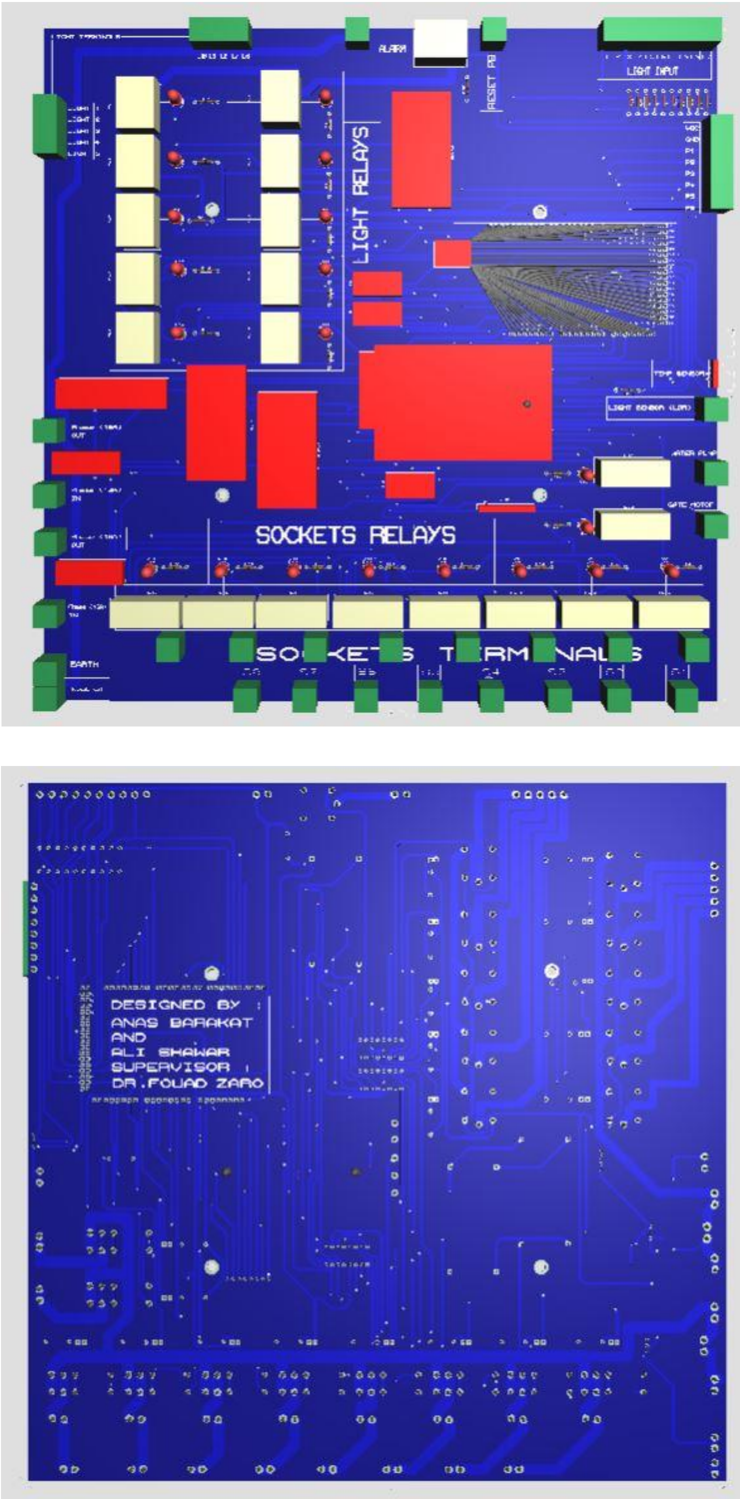


Figure 3.3 OS top and bottom view.

For Wi-Fi shield PCB top and bottom view shown in Figure 3.6

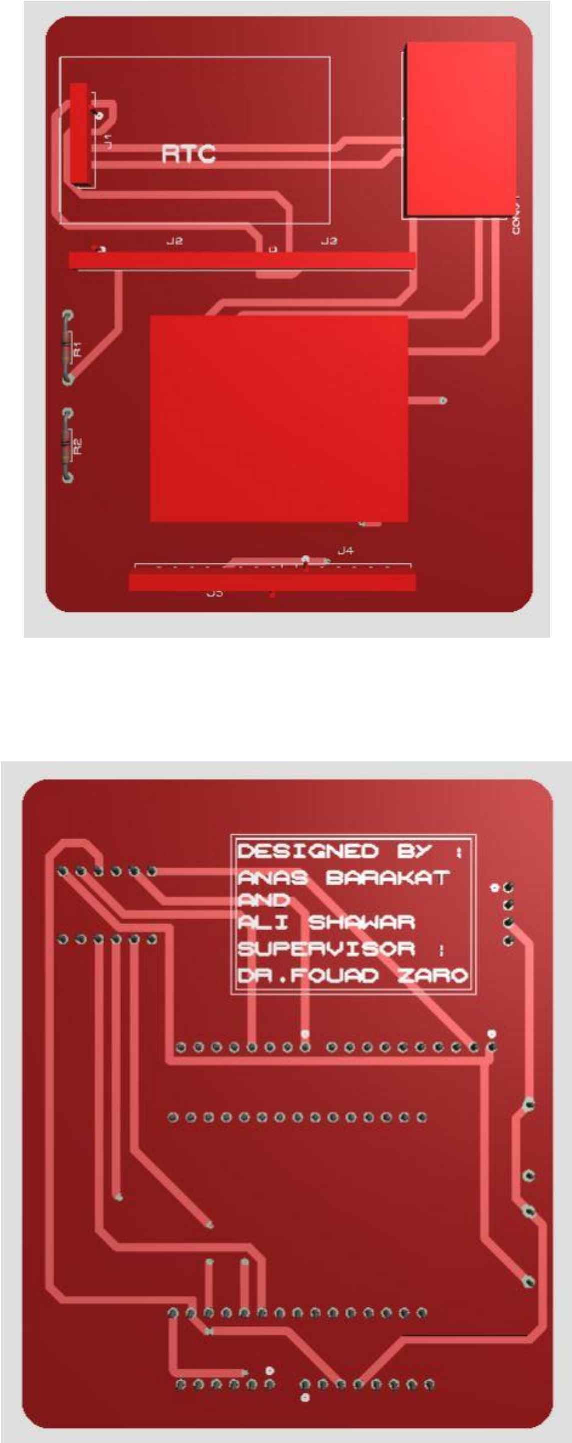


Figure 3.6 WIFI shield top and bottom view.

3.4 Wall mounted Covers

In this section we present our special designed wall mounted covers and frames, all of the following 3D designs designed using Shapr3D, it's a CAD software works with AutoCAD and Solid works, the main idea of these designs is to be printed using 3D printer by polymer materials.

We designed 3 covers for three main components, one is for the master PCB board, the second for slave's circuits and finally a cover for HVAC (heating ventilating air conditioning) unit's remote controller and Gas/fire sensor circuit.

3.4.1 Master Board Cover

This cover consists of three parts, an In wall frame which will be hidden inside the wall with 8mm depth and will be mounted using 4 screws, then an On wall frame will cover the circuit from the outside and also mounted using 4 screws, the third part is a top Cover will be attached with the On Wall Mounted part by 4 Magnet pairs, this particular part is meant to be transparent for easy presenting purposes but for actual production it will be color and material customizable to meet the main house decoration. For the design layout and dimensions see Figures 3.7-3.11

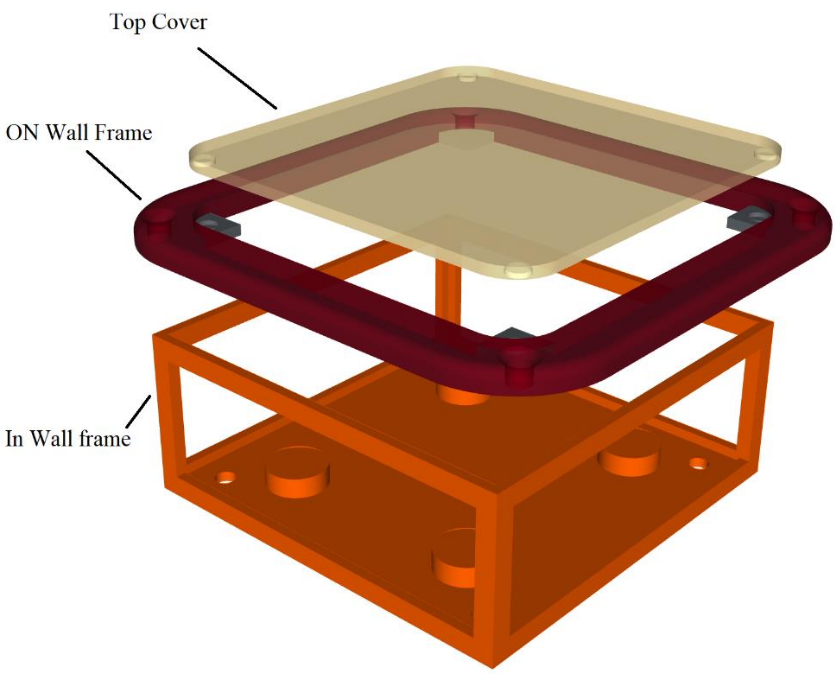


Figure 3.4 Master board cover layout

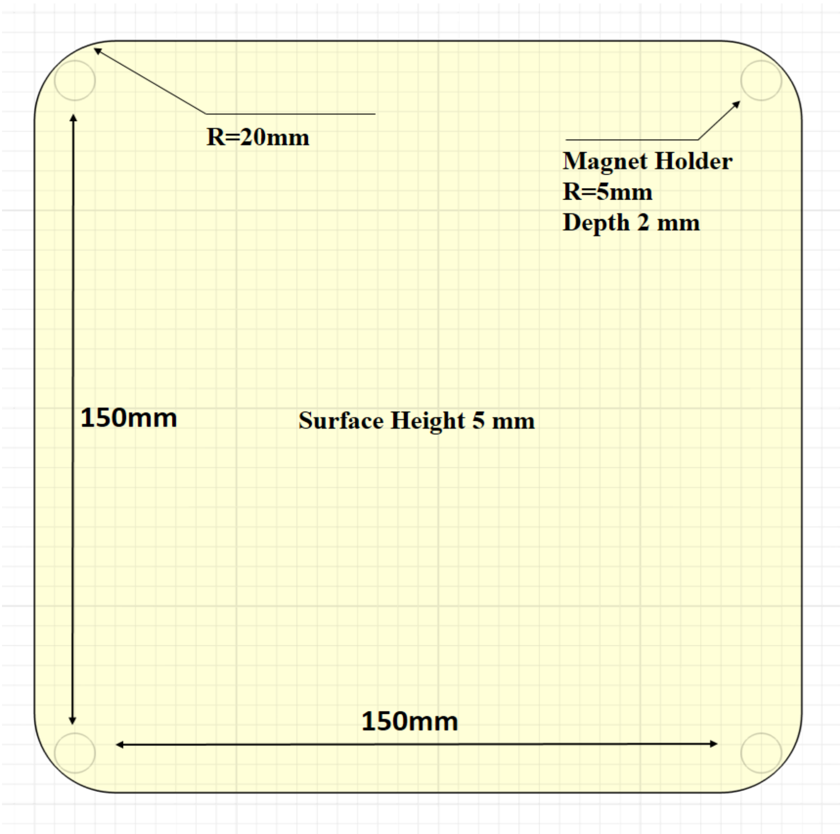


Figure 3.5 Master's top cover dimensions

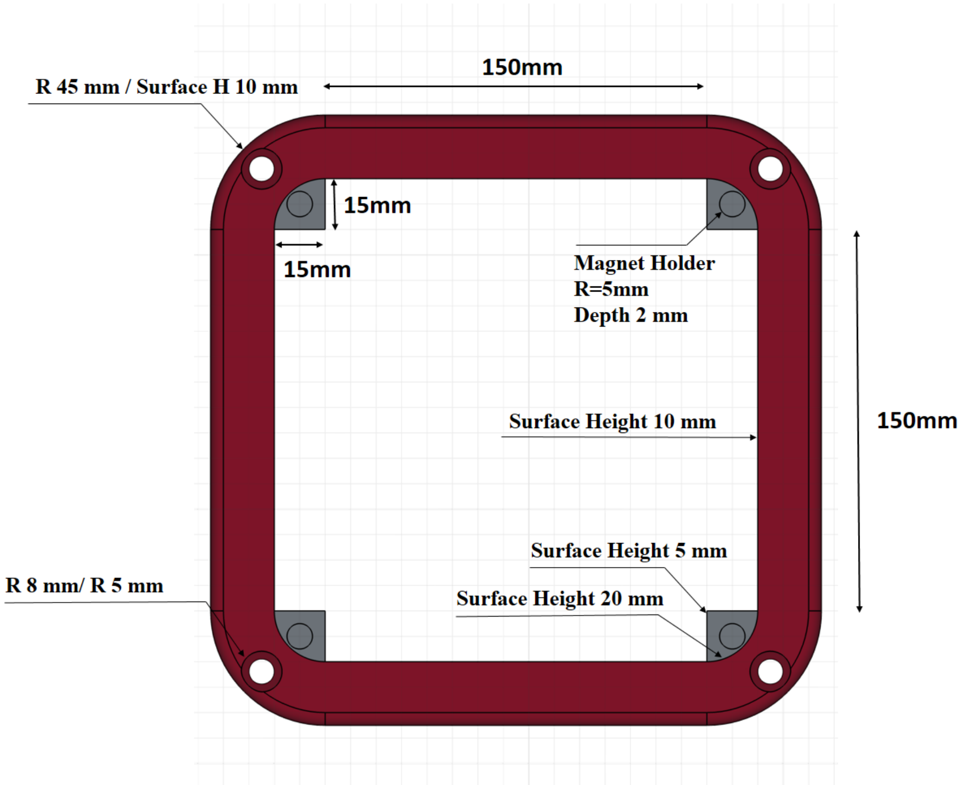


Figure 3.6 Master's on wall frame dimensions

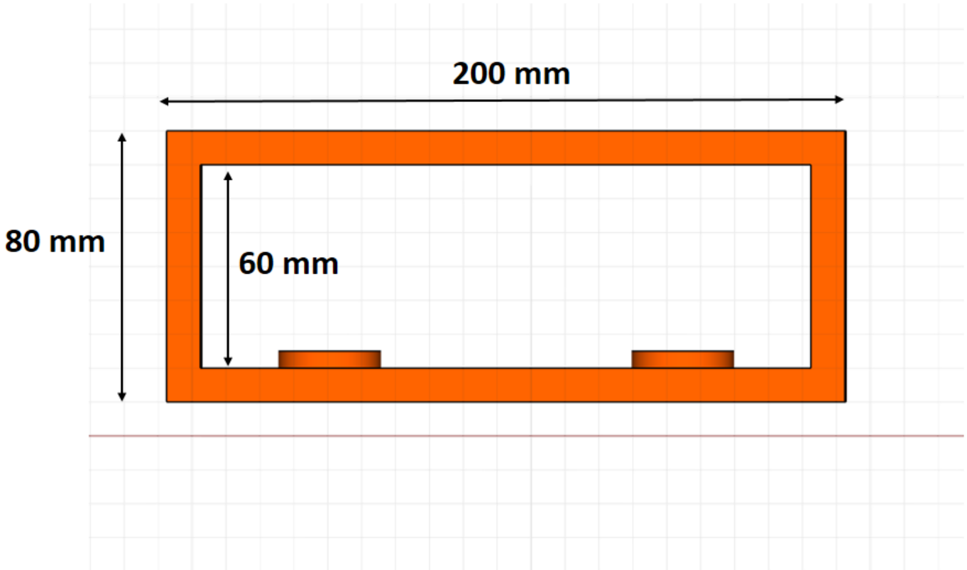


Figure 3.7 Master's in wall frame side dimensions

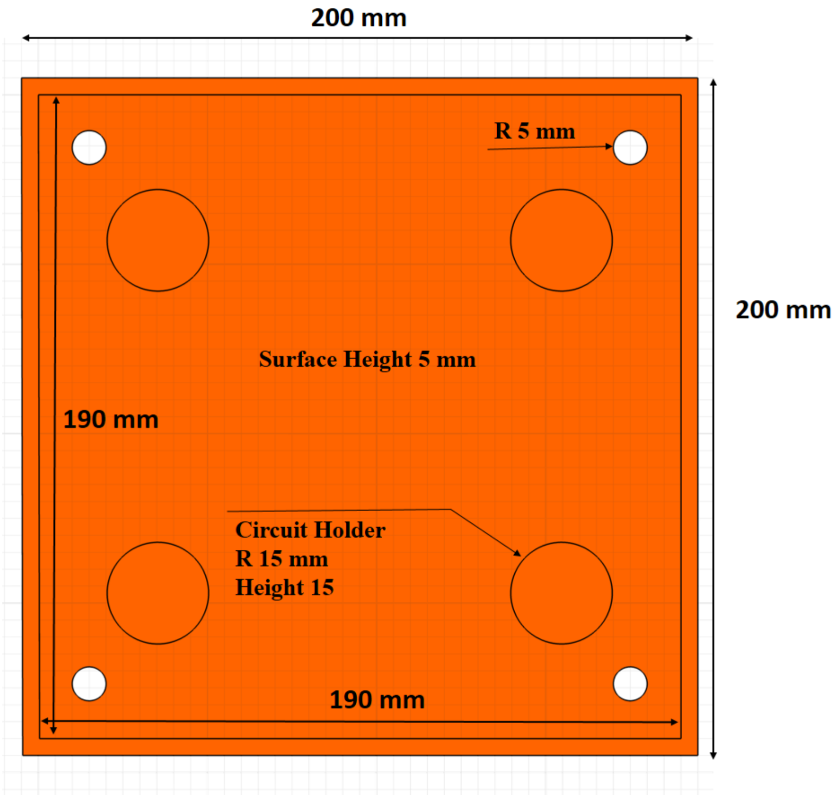


Figure 3.8 Master's in wall frame dimensions

3.4.2 Salve's circuits cover

This Cover designed for bothIS (room control slave) circuits and OS (Front-Back Yard control slave), as in master's cover, this design layout consists of 3 parts, on wall frame, In wall frame and top cover. For cover layout and dimensions see Figures 3.12-3.16.

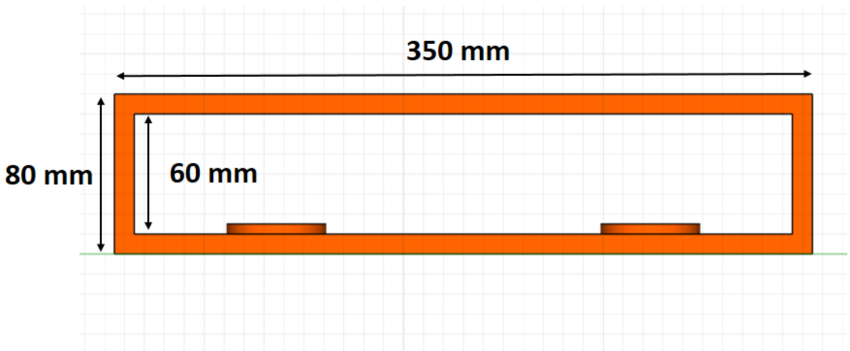


Figure 3.9 Slave's in wall frame side dimensions

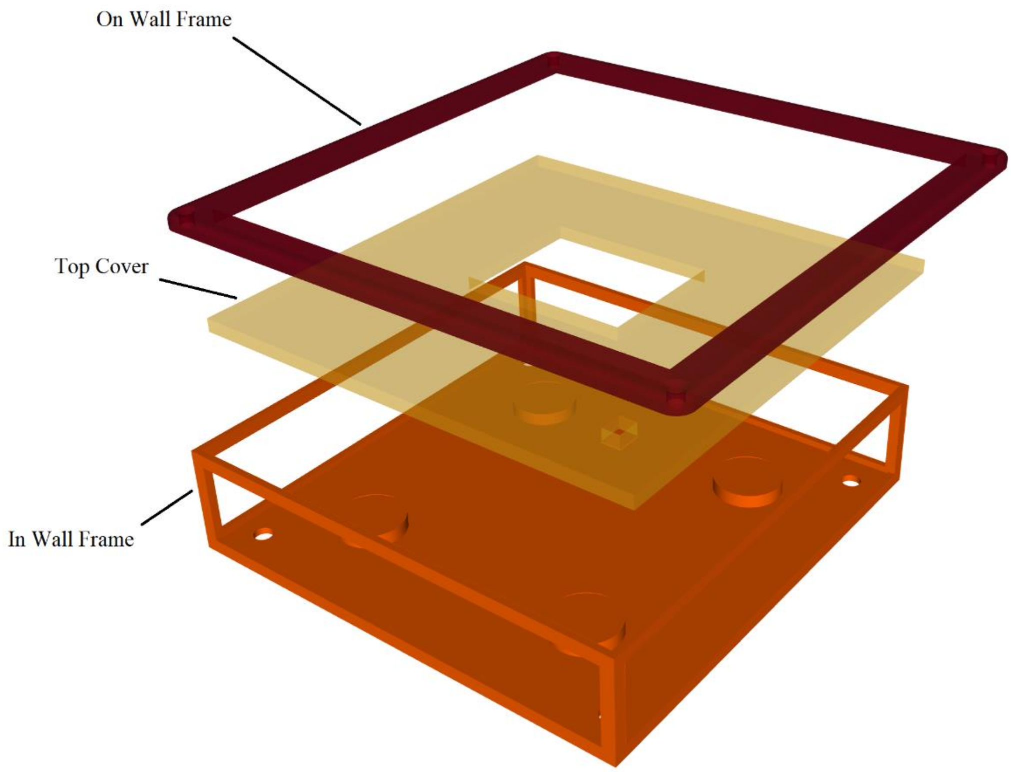


Figure 3.10 Slave's cover main layout

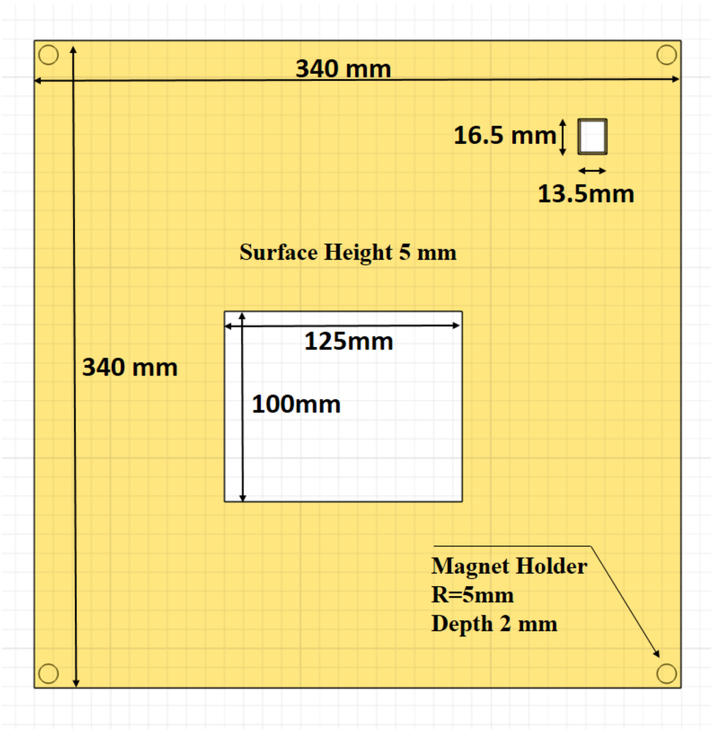


Figure 3.11 Slave's top cover dimensions

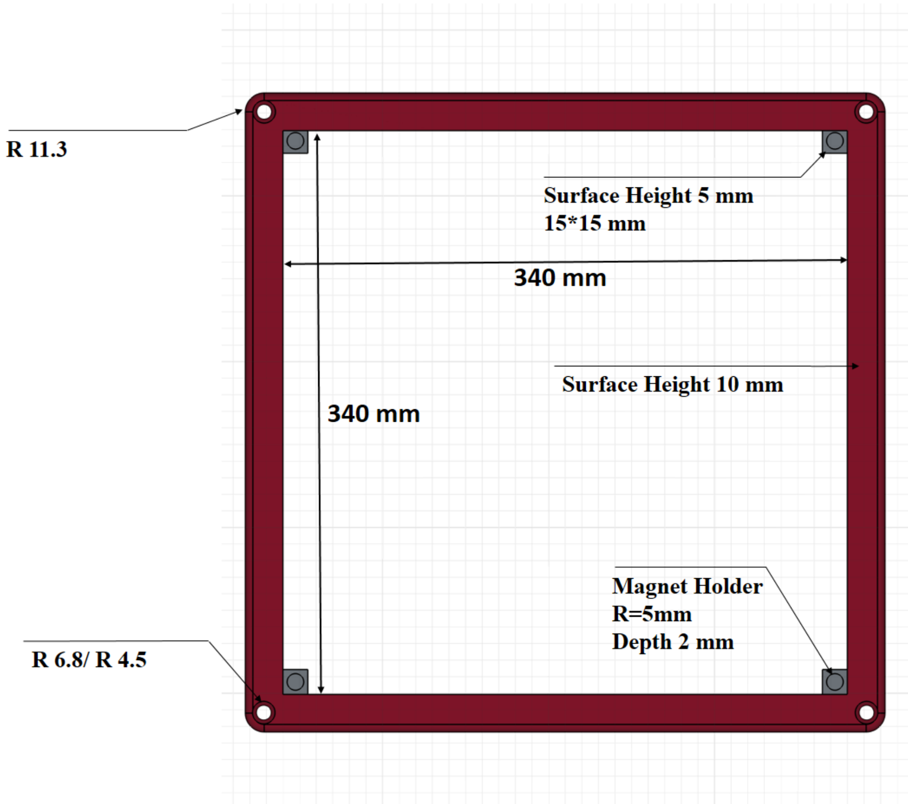


Figure 3.12 Slave's on wall frame dimensions

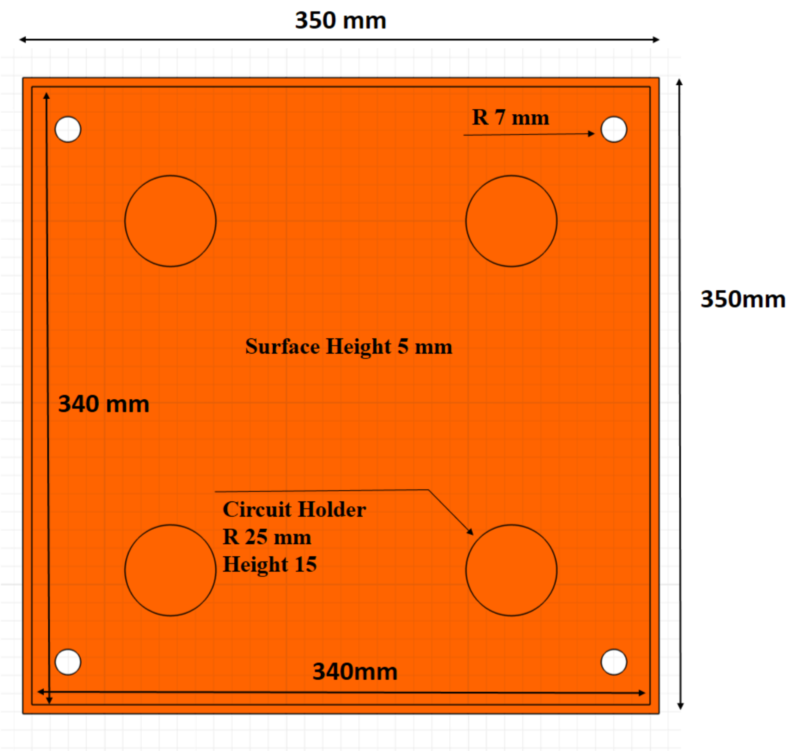


Figure 3.13 Slave's in wall frame dimension

3.4.3 HVAC Remote controller cover

This cover designed to be placed on rooms ceiling so it could reach the HVAC (heating ventilating air conditioning) unit and control it from any angle, also it has the Fire/gas sensor on top of it for gas and fire detection, this cover consists of two main parts top cover and side cover both on wall. The side cover will be mounted using either screw terminals or adhesive material and the top cover will attach to the side cover using two magnet pairs. For main cover layout and dimensions see Figures 3.17-3.19.

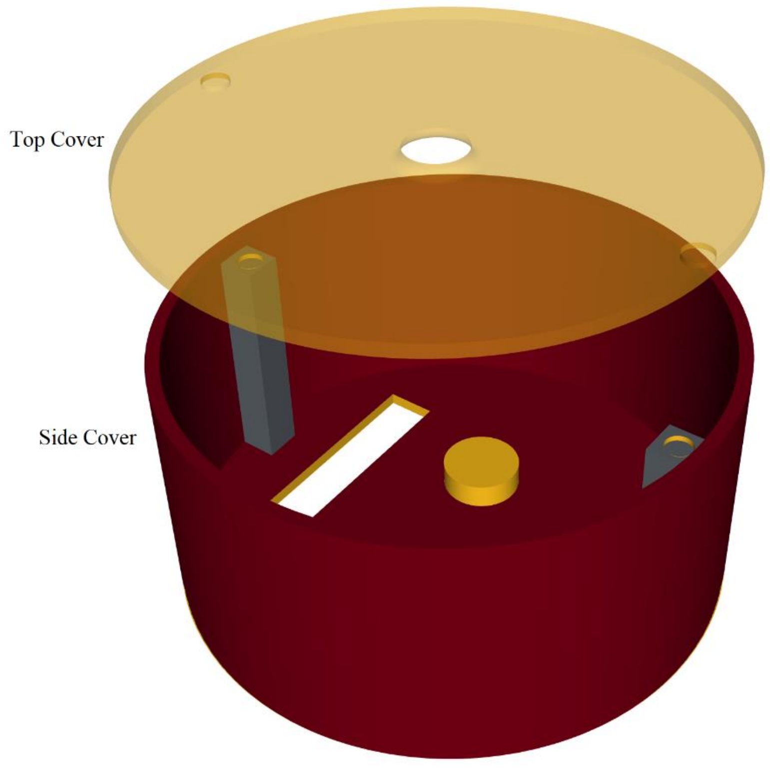


Figure 3.14 Remote's main cover layout

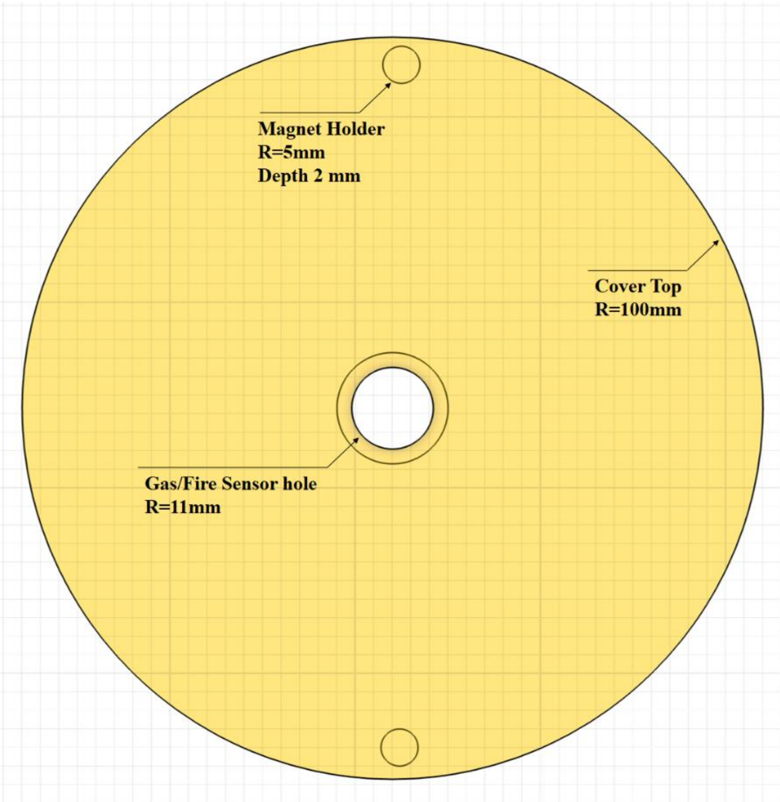


Figure 3.15 Remote's top cover dimensions

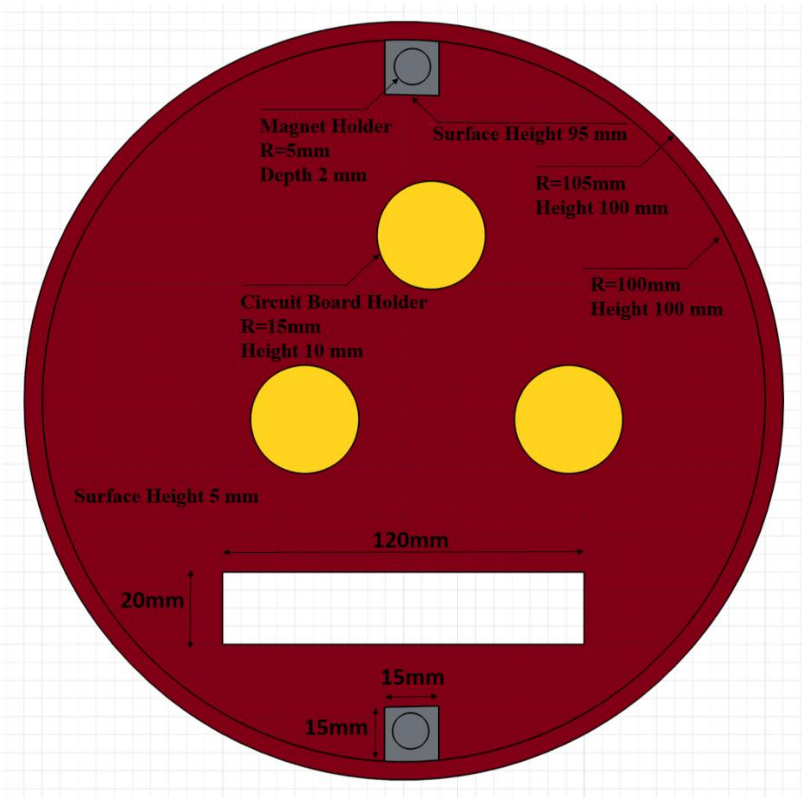


Figure 3.16 Remote's side cover dimensions

4

Chapter Four

Results and Recommendations

4 Results & Recommendations

4.1 Introduction

In this chapter we're presenting our last result, features and future improvements for this project, on the other hand after almost 9 months of development we have some recommendations we would to share for any future development on similar projects,.

4.2 Results

At the end of this course we had designed and produced 4 main PCB circuits, and a small presentation room for project illustration and presentation.

Worth to be mentioned that all circuit boards (Indoor, Outdoor and Master) are separated hardware, and could be used separately and independently, they all connected to central database, but all have access to the internet and this method of controlling highly improve system stability, speed and flexibility.

4.2.1 Master circuit features

The master circuit board able to do the following:

- Measure main house instantaneous power up to 10.5 kW (Max. 42Arms and 250Vrms).
- Measure recent day and month house energy consumption.
- Measure main PV system instantaneous power up to 10 kW (Max. 42Arms and 250Vrms).
- Measure recent day and month PV system energy Production.
- An intruder siren system with 6 PIR inputs.
- All previous mentioned featured uploaded to special firebase database URL and presented/controlled using Android smart app.
- Measure 15-watt demand and upload it to online public google sheet for utility 15-kW demand, transformers and feeders load calculations.

For finished circuit see figure 4.1.

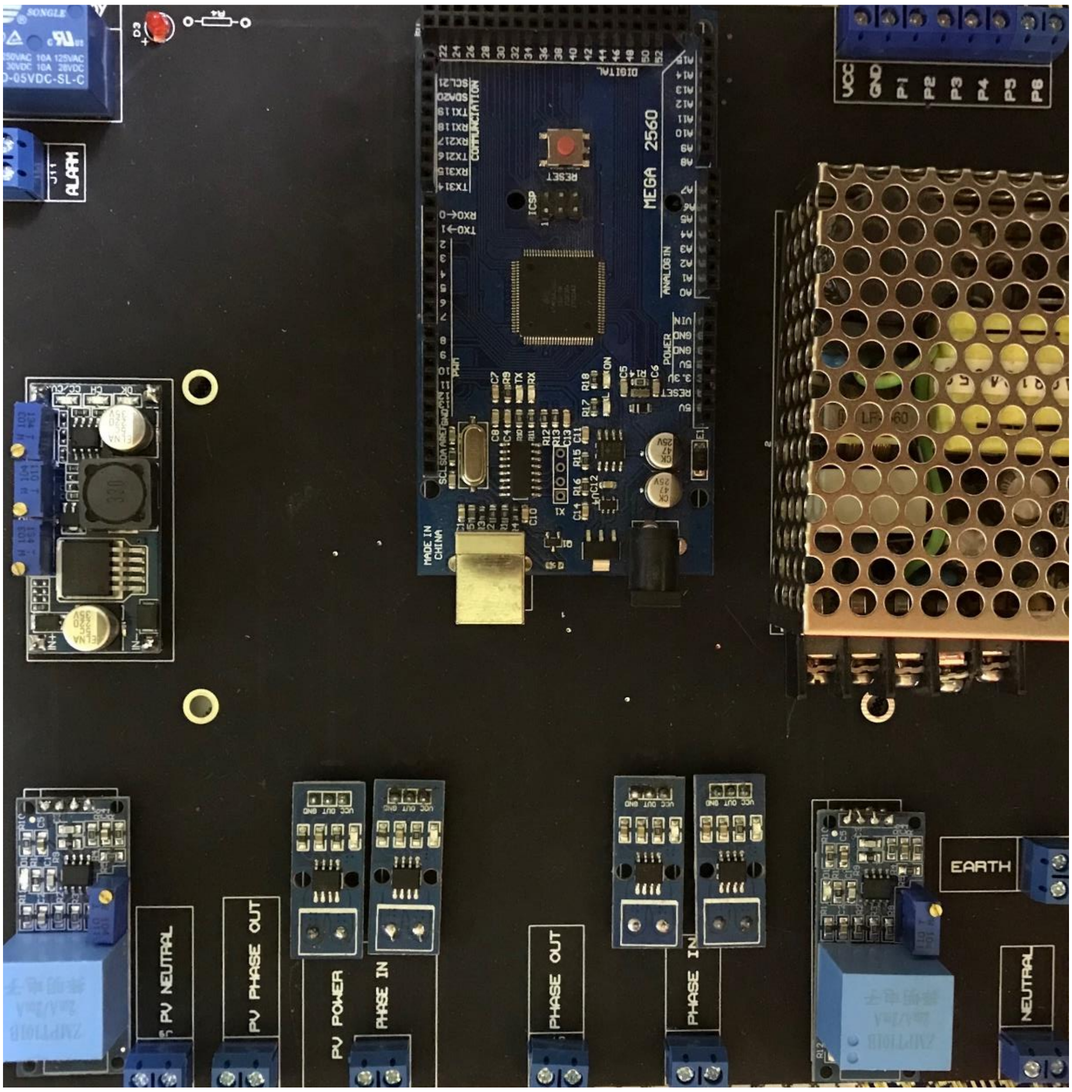


Figure 4.1 Master circuit.

4.2.2 Indoor circuit features

The indoor circuit board able to do the following:

- Control 5 separated light unites by on/off button, by on-time/off-time, by custom made button and scenarios (like leave home button).
- Control 8 separated outlet unites by on/off button, by on-time/off-time, by custom made button and scenarios (like leave home button).

- Control 3 separated electric window unites by up/down button, by up-time/down-time, by custom made button and scenarios (like leave home button).
- Control HVAC units using IR central sender able to control AC mode (heat/cool) and AC temperature.
- Measure main room instantaneous power up to 5000 kW (Max. 21Arms and 250Vrms).
- Measure month house energy consumption.
- Read room temperature and humidity.
- Fire/gas detection sensor which automatically open all connected windows.

All previous mentioned featured uploaded to special firebase database URL and presented/controlled using Android smart app.

For finished circuit see figure 4.2.

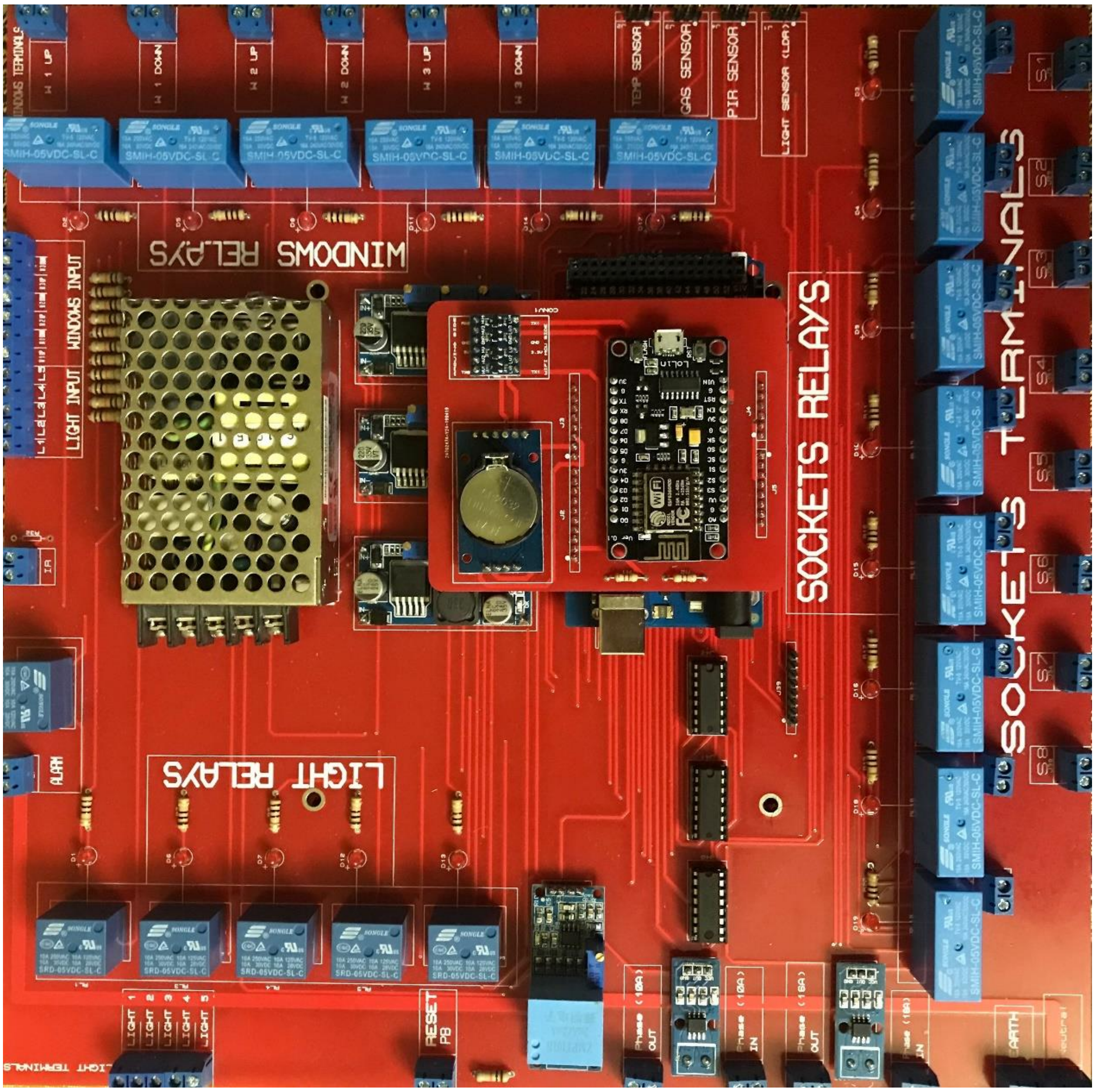


Figure 4.2 Indoor circuit.

4.2.3 Outdoor circuit features

The outdoor circuit board able to do the following:

- Control 10 separated light unites by on/off button, by on-time/off-time, by custom made button and scenarios (like leave home button).
- Control 8 separated outlet unites by on/off button, by on-time/off-time, by custom made button and scenarios (like leave home button).
- Control water pump by on/off button, by on-time/off-time, by custom made button and scenarios (like leave home button).
- Control one gate by on/off button.
- Measure main room instantaneous power up to 5000 kW (Max. 21Arms and 250Vrms).
- Measure month house energy consumption.
- Measure outdoor temperature and humidity.
- Detect outdoor movement for automatically activates some loads and lights.
- All previous mentioned featured uploaded to special firebase database URL and presented/controlled using Android smart app.

For finished circuit see figure 4.3.

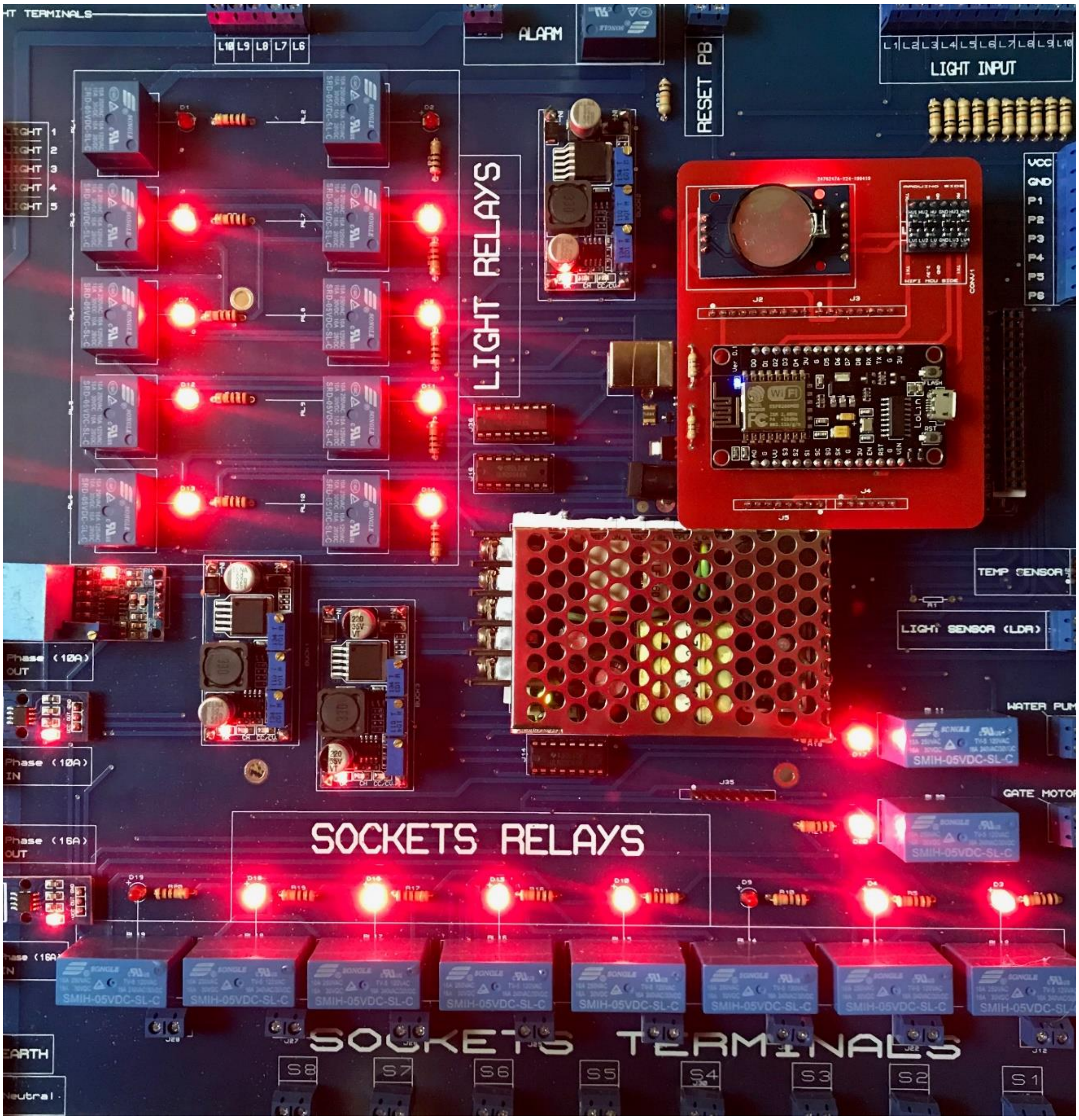


Figure 4.3 Outdoor circuit.

4.2.4 Wi-Fi shield board

This circuit board is provided with NodeMCU Wi-Fi controller, precise real-time clock, Arduino i2c connection, and logic level shifter.

For finished board see figure 4.4.

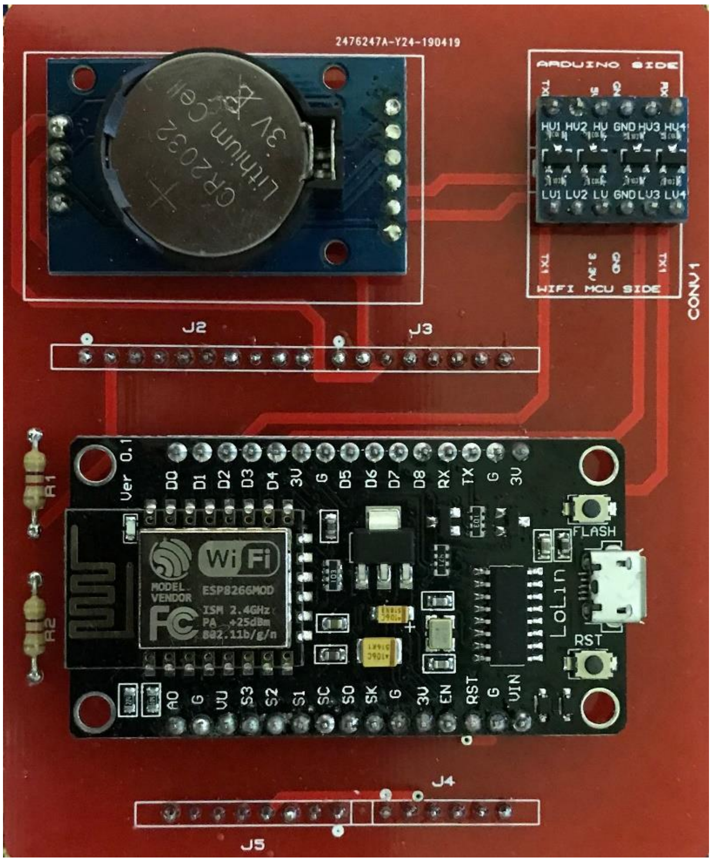


Figure 4.4 shield board.

4.3 Android app.

On large feature of our project is a custom Android app that present and control all system features and components for app see figure 4.5-4.7.

Figure 4.5 main screen.

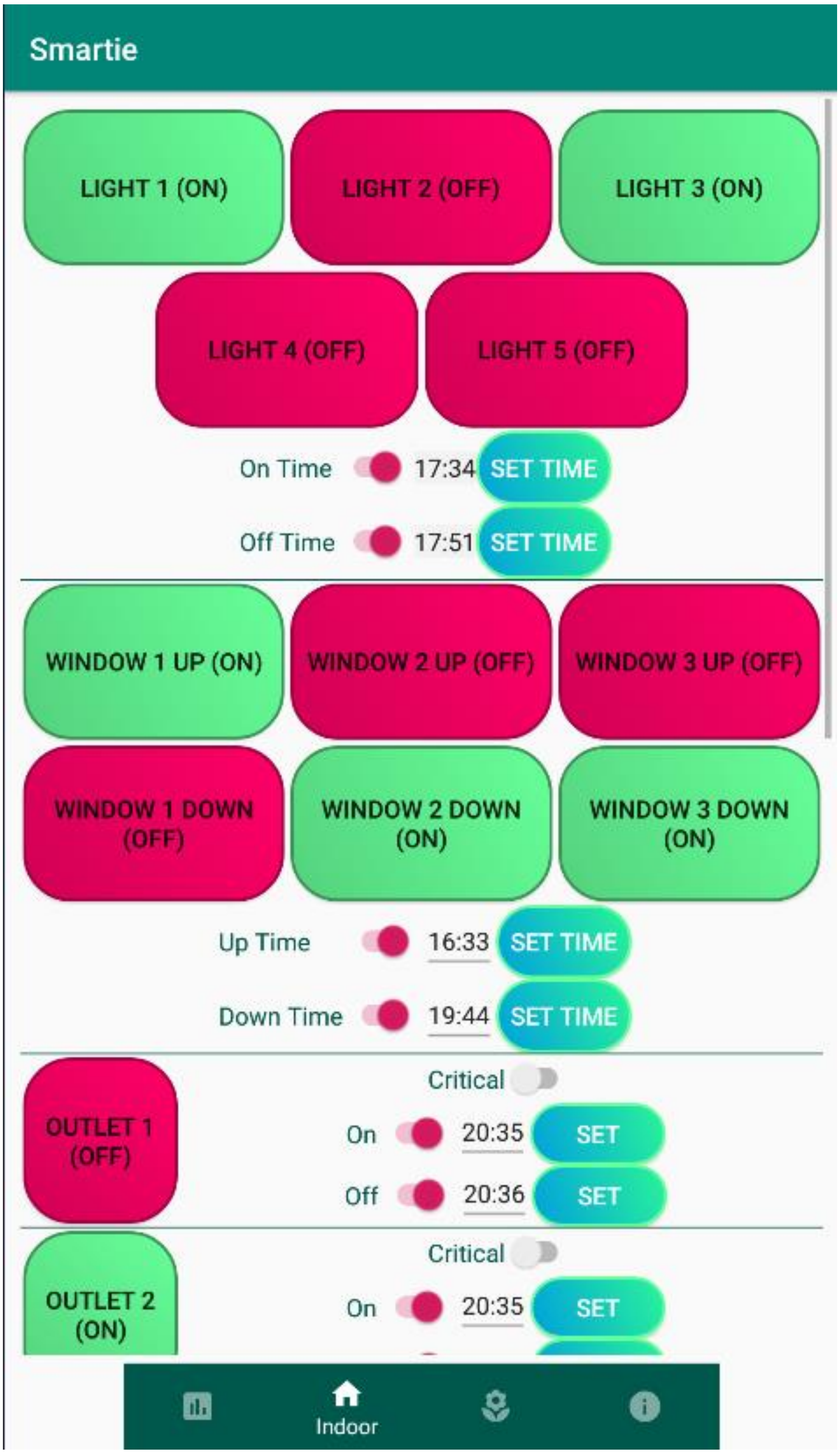


Figure 4.6 Indoor screen

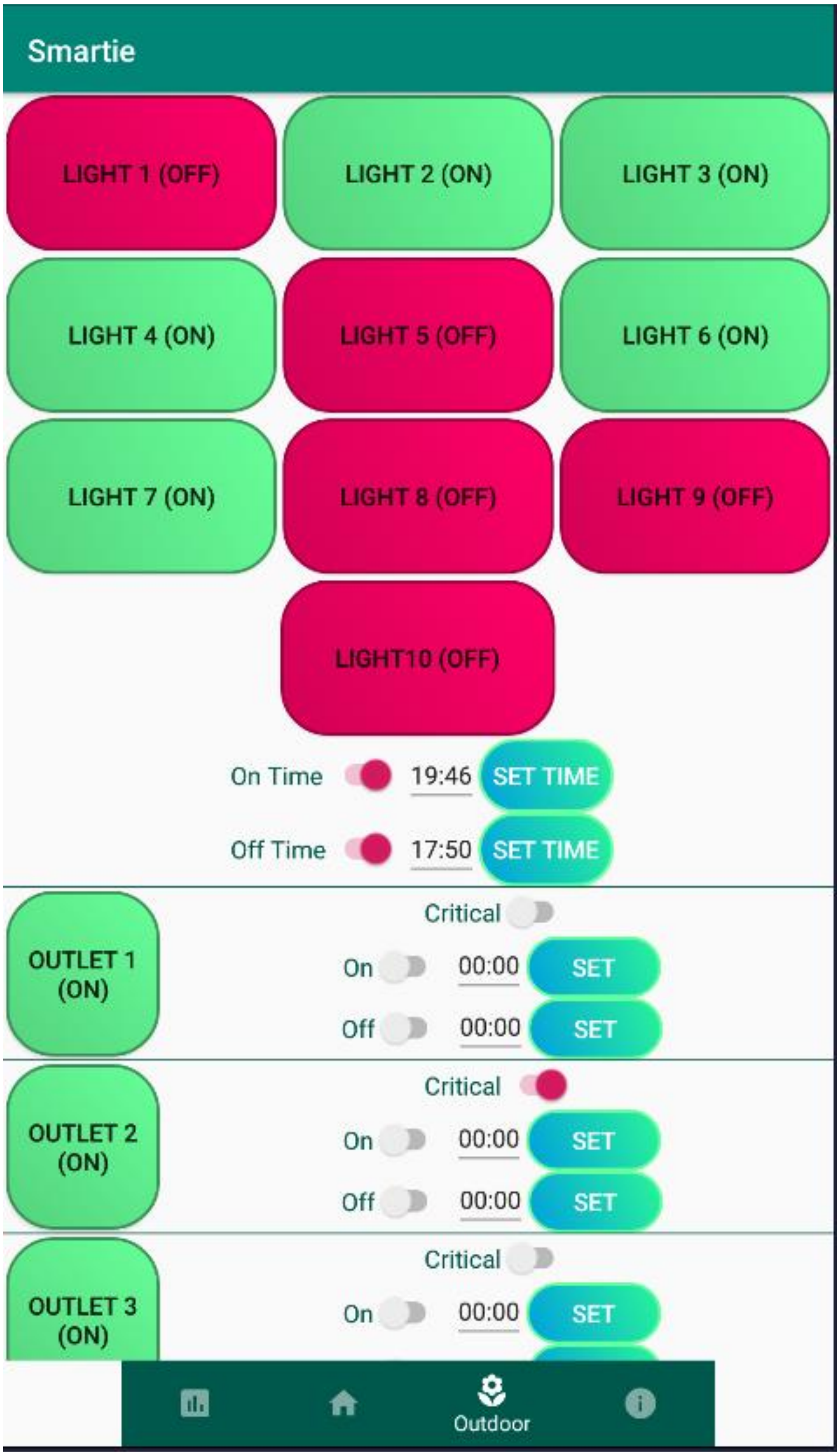


Figure 4.7 Outdoor screen.

4.4 Small presentation room.

In polytechnic university labs we did build a small room as a presentation for our system (see figure 4.8-4.9) contains the following:

- Main C.B panels with 5 C.B.
- Master circuit.
- Intruder siren system.
- 2 PIR sensors.
- Gas/fire sensor.
- IR central sender.
- Heater/cooler as HVAC presentation.
- Electric window.
- Electric wood gate
- Indoor circuit with 4 light, 3 window and 1 reset switches.
- 6 light units 2 outdoor, 4 indoor.
- 8 outlets, for both indoor and outdoor.
- Electric water pump.

Figure 4.8 Presentation room.

Figure 4.9 Presentation room.

4.5 Response time

In following table 4.1 we recorded actual response time from Android app commands to system circuits under different internet connection speeds.

Note: The list of commands below had been taken in different times for different circuits (Indoor and outdoor) and different commands (on/off and on-time/off-time).

Table 4.1 Response time.

Command #	command status	act time (sec)	feedback time (sec)
1	Succeed	1.28	2.18
2	Succeed	1.08	1.88
3	Succeed	1.07	2.57
4	Succeed	1.73	3.54
5	Succeed	0.98	1.5
6	Succeed	1.5	2.41
7	Succeed	1.6	2.58
8	Succeed	1.51	2.41
9	Succeed	1.46	2.19
10	Succeed	2.53	3.32
11	Succeed	1.34	2.13
12	Succeed	1.86	2.83
13	Succeed	3.67	4.89
14	Succeed	2.11	3.21
15	Succeed	2.98	3.86
16	Succeed	1.94	3.04
17	Succeed	2.04	2.73
18	Succeed	1.2	2.11
19	Succeed	4	6
20	Succeed	1.85	2.59
21	Succeed	1.11	1.79
22	Succeed	0.86	1.5
23	Succeed	1.43	2.53
24	Succeed	1.19	1.9
25	Succeed	1.08	2.19
26	Succeed	2.8	3.49
27	Succeed	1.31	2.22
28	Succeed	0.99	1.69
29	Succeed	1.29	2.47
30	Succeed	1.45	2.26
31	Succeed	0.9	1.41
32	Succeed	0.8	1.43

33	Succeed	1.16	2.19
34	Succeed	1.54	2.7
35	Succeed	1.89	2.89
36	Succeed	1.78	2.54
37	Succeed	0.95	2.45
38	Succeed	1.4	2.23
39	Succeed	1.84	2.47
40	Succeed	1.13	1.92
41	Succeed	1.2	1.9
42	Succeed	1.31	2.37
43	Succeed	6.78	8.21
44	Succeed	1.74	3.14
45	Succeed	1.56	2.27
46	Succeed	1.4	2.04
47	Succeed	4.5	4.98
48	Succeed	1.61	2.24
49	Succeed	1.44	1.95
50	Succeed	1.13	1.67
Average	100%	1.746	2.6602

4.6 Components temperature

In the following table we're listing all indoor & outdoor power components temperature with the maximum allowed temperature under different loading levels.

Component	Ambient temp. (C⁰)	No load All relays are off (C⁰)	50% of relays are on (C⁰)	100% of relays are on (C⁰)	Max temp. (Data sheet) (C⁰)
Buck converter 1	25	33	47	62	125
Buck converter 2	25	32	34.5	42.5	125
Buck converter 3	25	32	42	48	125
NodeMCU controller	25	33.5	39	41	125
Arduino Regulator	25	34	42	51	125
Buffer1	25	29.5	32	41	150
Buffer2	25	29.7	37.6	45.5	150
Buffer3	25	30	40	48	150
Relay	25	29.5	36	36	75
Power supply	25	35.6	43.5	52	70

4.7 Recommendations

In this section we have some recommendation to be taken in consideration for future development and improvement for this project and/or other similar project.

- Supplying Arduino board with 6.5v power supply is the most suitable and stable case, although Arduino company says "input Voltage recommended = 5-12", 12v power supply cause high power dissipation in Arduino regulator and may cause thermal tripping for the board.
- Energize each 7 AC relays with separate power supply or regulator like lm2596.
- Supply Hall Effect sensor ACS712T by separate precise 5v power supply or by Arduino 5v terminals, because this specific sensor is highly sensitive to harmonics and noises and need a precise voltage to work probably and precisely.
- For Such large PCBs and large amount of component to be powered, use 25 watt or higher power supply because it reaches high temperature that could affect the system stability in long term use.
- Arduino code sketch should be less than 75% of Arduino memory size, because large size sketch files could cause instability in Arduino performance.
- For i2c connection,
    - I2c wire should be less than 1 meter long for stable connection and data transfer.
    - Don’t make two requests in a row without delay less than 50ms.
    - Don’t make transmit data two times in a row without delay less than 50ms.
    - Use 4.7 K ohm pull-up resistor on both SDA and SCL.
    - Don’t use delay function in Arduino interrupt function.
- For PCB designing, Proteus software is powerful enough but so hard to use and rely on, instead we recommend Multisim software.
- For 3.3v to 5v level shifting, we recommend bi-directional logic level shifter with MOSFET devices instead of other elements.
- For more precise Current measurement, use current transformer instead of ACS712T.
- Make sure that all components are working under normal conditions mentioned in their datasheets.

References

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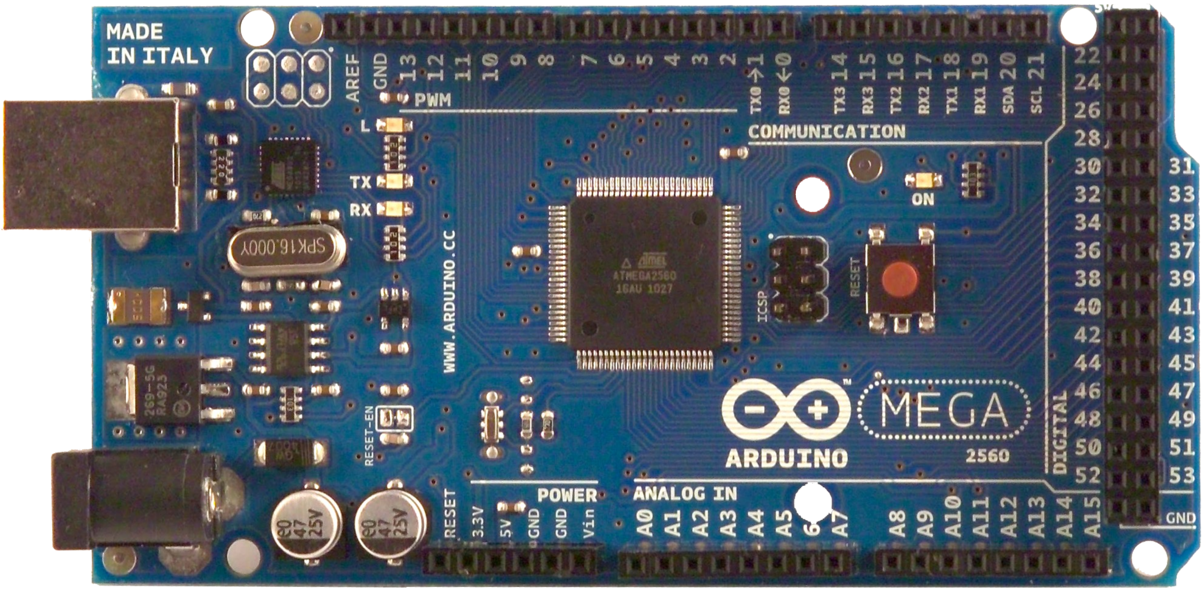
Appendices

In this section we're attaching all design components, equipment and devices datasheets.

Arduino MEGA 2560



CE

Product Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Index

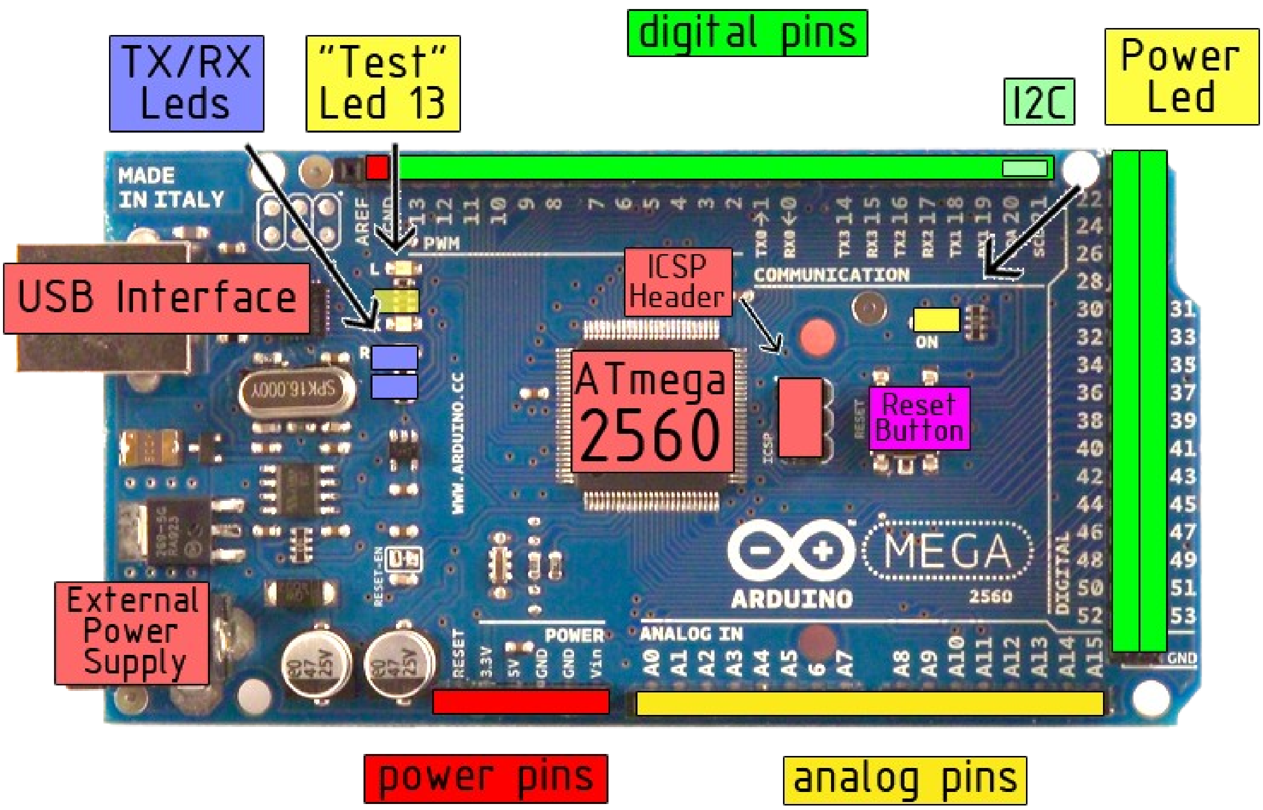
Technical Specification

EAGLE files: arduino-mega2560-reference-design.zip Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

the board



Power

The Arduino Mega2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega 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 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Duemilanove and Diecimila.
- **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.
- **I^2C: 20 (SDA) and 21 (SCL).** Support I^2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I^2C pins on the Duemilanove.

The Mega2560 has 16 analog inputs, 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 analogReference() function.

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.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Mega's digital pins.

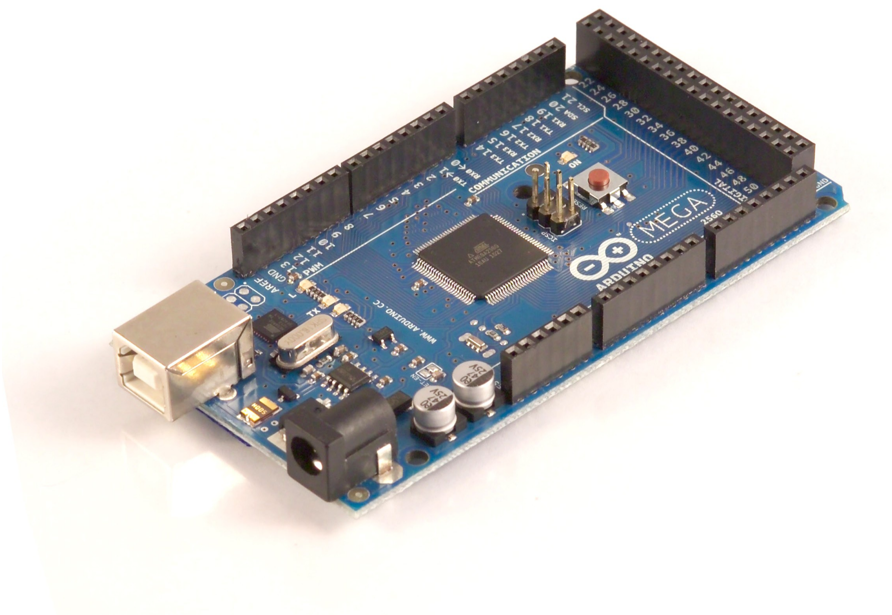
The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. To use the SPI communication, please see the ATmega2560 datasheet.

Programming

The Arduino Mega2560 can be programmed with the Arduino software (download). For details, see the reference and tutorials.

The Atmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.



Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Mega contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Mega has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega is designed to be compatible with most shields designed for the Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega and Duemilanove / Diecimila. **Please note that I^2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).**

How to use Arduino

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino is a cross-platoform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. *http://arduino.cc/en/Guide/HomePage*

Linux Install

Windows Install

Mac Install

Once you have downloaded/unzipped the arduino IDE, you can Plug the Arduino to your PC via USB cable.

Blink led

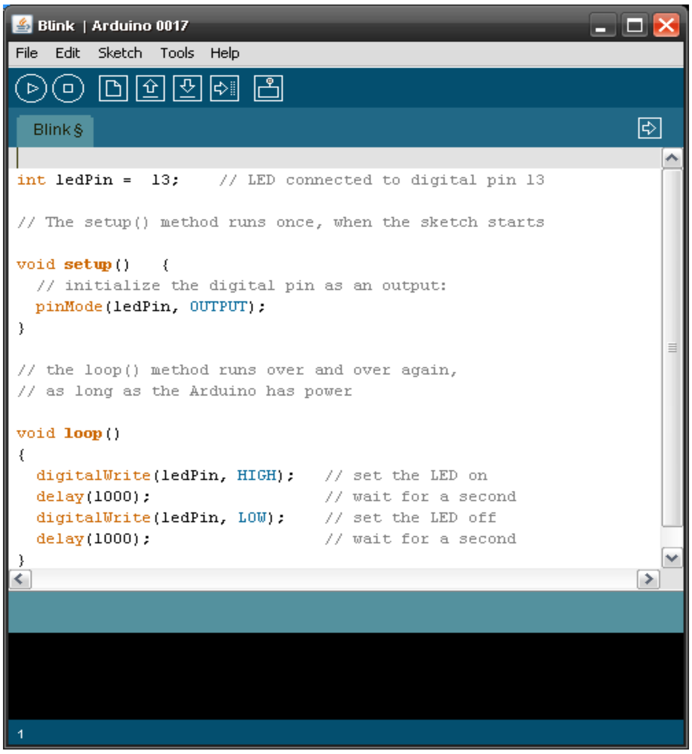
Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select

File>Sketchbook> Arduino-0017>Examples> Digital>Blink

Once you have your skecth you'll see something very close to the screenshot on the right.

In **Tools>Board** select MEGA

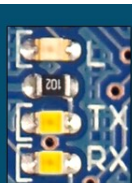
Now you have to go to **Tools>SerialPort** and select the right serial port, the one arduino is attached to.



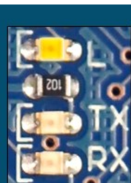
Done compiling.

Press Compile button (to check for errors)

Upload

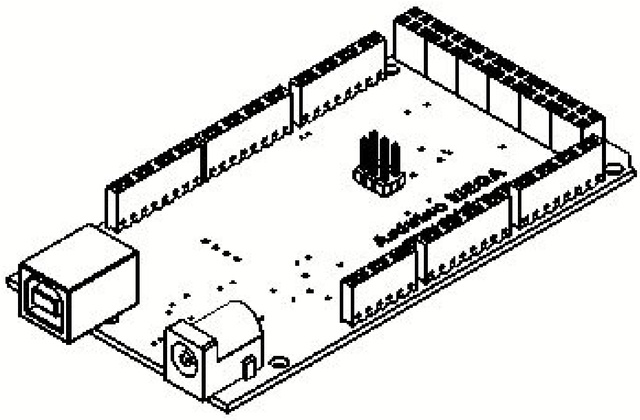


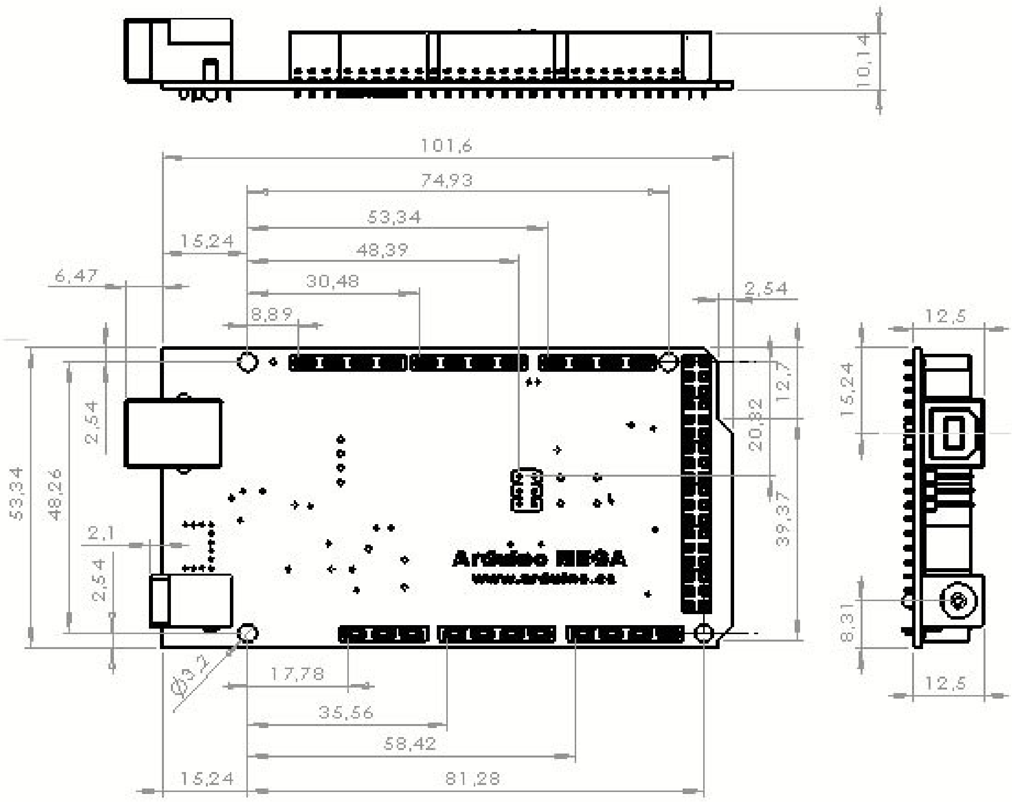
TX RX Flashing



Blinking Led!

Dimensioned Drawing





Terms & Conditions

1. Warranties

1.1 The producer warrants that its products will conform to the Specifications. This warranty lasts for one (1) years from the date of the sale. The producer shall not be liable for any defects that are caused by neglect, misuse or mistreatment by the Customer, including improper installation or testing, or for any products that have been altered or modified in any way by a Customer. Moreover, The producer shall not be liable for any defects that result from Customer's design, specifications or instructions for such products. Testing and other quality control techniques are used to the extent the producer deems necessary.

1.2 If any products fail to conform to the warranty set forth above, the producer's sole liability shall be to replace such products. The producer's liability shall be limited to products that are determined by the producer not to conform to such warranty. If the producer elects to replace such products, the producer shall have a reasonable time to replacements. Replaced products shall be warranted for a new full warranty period.

1.3 EXCEPT AS SET FORTH ABOVE, PRODUCTS ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." THE PRODUCER DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING PRODUCTS, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE

1.4 Customer agrees that prior to using any systems that include the producer products, Customer will test such systems and the functionality of the products as used in such systems. The producer may provide technical, applications or design advice, quality characterization, reliability data or other services. Customer acknowledges and agrees that providing these services shall not expand or otherwise alter the producer's warranties, as set forth above, and no additional obligations or liabilities shall arise from the producer providing such services.

1.5 The Arduino™ products are not authorized for use in safety-critical applications where a failure of the product would reasonably be expected to cause severe personal injury or death. Safety-Critical Applications include, without limitation, life support devices and systems, equipment or systems for the operation of nuclear facilities and weapons systems. Arduino™ products are neither designed nor intended for use in military or aerospace applications or environments and for automotive applications or environment. Customer acknowledges and agrees that any such use of Arduino™ products which is solely at the Customer's risk, and that Customer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

1.6 Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products and any use of Arduino™ products in Customer's applications, notwithstanding any applications-related information or support that may be provided by the producer.

2. Indemnification

The Customer acknowledges and agrees to defend, indemnify and hold harmless the producer from and against any and all third-party losses, damages, liabilities and expenses it incurs to the extent directly caused by: (i) an actual breach by a Customer of the representation and warranties made under this terms and conditions or (ii) the gross negligence or willful misconduct by the Customer.

3. Consequential Damages Waiver

In no event the producer shall be liable to the Customer or any third parties for any special, collateral, indirect, punitive, incidental, consequential or exemplary damages in connection with or arising out of the products provided hereunder, regardless of whether the producer has been advised of the possibility of such damages. This section will survive the termination of the warranty period.

4. Changes to specifications

The producer may make changes to specifications and product descriptions at any time, without notice. The Customer must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." The producer reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The product information on the Web Site or Materials is subject to change without notice. Do not finalize a design with this information.

Enviromental Policies

The producer of Arduino™ has joined the Impatto Zero® policy of LifeGate.it. For each Arduino board produced is created / looked after half squared Km of Costa Rica's forest's.

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - 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 progam memory (ATmega48PA/88PA/168PA/328P)
  - 256/512/512/1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
  - 512/1K/1K/2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[(1)]
  - Optional Boot Code Section with Independent Lock Bits
    - In-System Programming by On-chip Boot Program
    - True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler 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 I^2C 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 for ATmega48PA/88PA/168PA/328P
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - 0 - 20 MHz @ 1.8 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P:
  - Active Mode: 0.2 mA
  - Power-down Mode: 0.1 µA
  - Power-save Mode: 0.75 µA (Including 32 kHz RTC)

8-bit AVR® Microcontroller with 4/8/16/32K Bytes In-System Programmable Flash

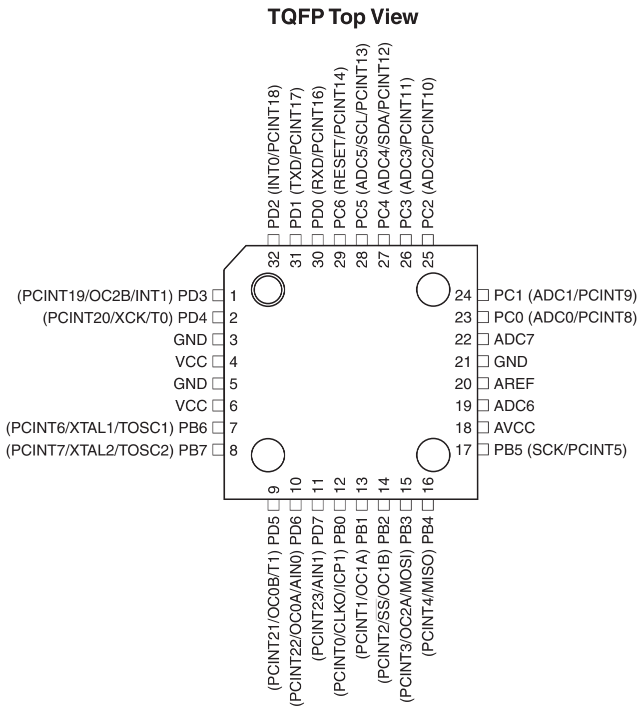
ATmega48PA
ATmega88PA
ATmega168PA
ATmega328P

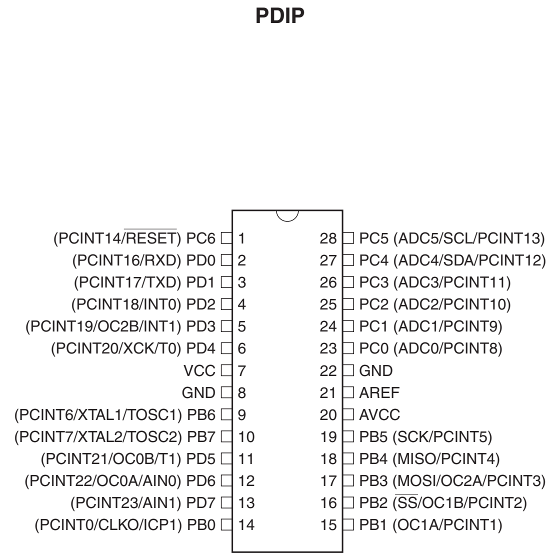
Summary

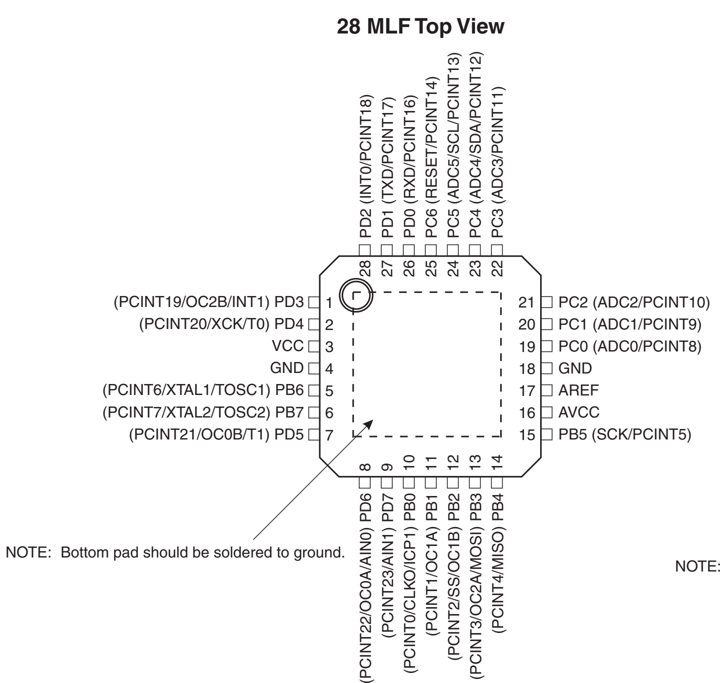
Rev. 8161CS–AVR–05/09

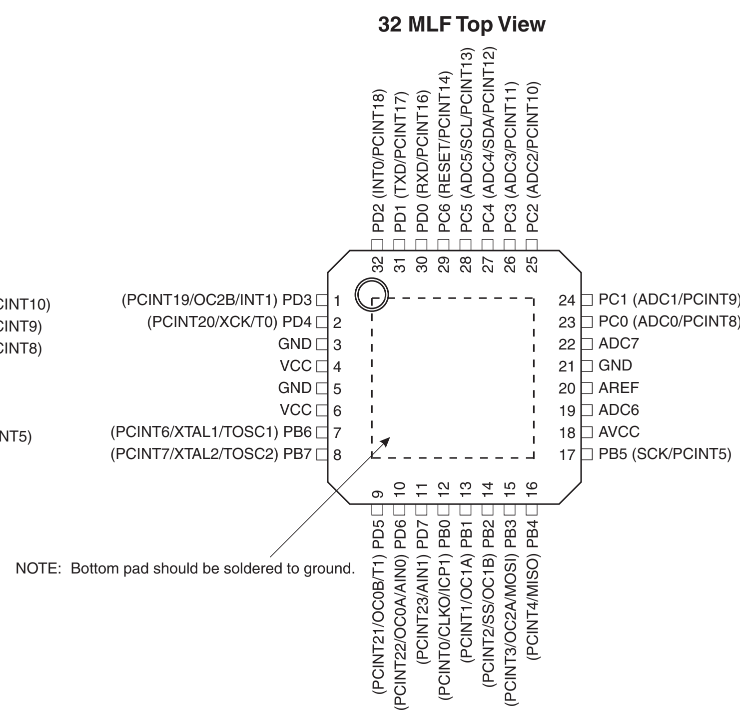
1. Pin Configurations

Figure 1-1. Pinout ATmega48PA/88PA/168PA/328P









1.1 Pin Descriptions

1.1.1 VCC

Digital supply voltage.

1.1.2 GND

Ground.

1.1.3 Port B (PB7:0) XTAL1/XTAL2/TOSC1/TOSC2

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB7..6 is used as TOSC2..1 input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

The various special features of Port B are elaborated in ”Alternate Functions of Port B” on page 76 and ”System Clock and Clock Options” on page 26.

1.1.4 Port C (PC5:0)

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC5..0 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

1.1.5 PC6/$\overline{\text{RESET}}$

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. The minimum pulse length is given in Table 28-3 on page 308. Shorter pulses are not guaranteed to generate a Reset.

The various special features of Port C are elaborated in ”Alternate Functions of Port C” on page 79.

1.1.6 Port D (PD7:0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

The various special features of Port D are elaborated in "Alternate Functions of Port D" on page 82.

1.1.7 AV_{CC}

AV_{CC} is the supply voltage pin for the A/D Converter, PC3:0, and ADC7:6. It should be externally connected to V_{CC}, even if the ADC is not used. If the ADC is used, it should be connected to V_{CC} through a low-pass filter. Note that PC6..4 use digital supply voltage, V_{CC}.

1.1.8 AREF

AREF is the analog reference pin for the A/D Converter.

1.1.9 ADC7:6 (TQFP and QFN/MLF Package Only)

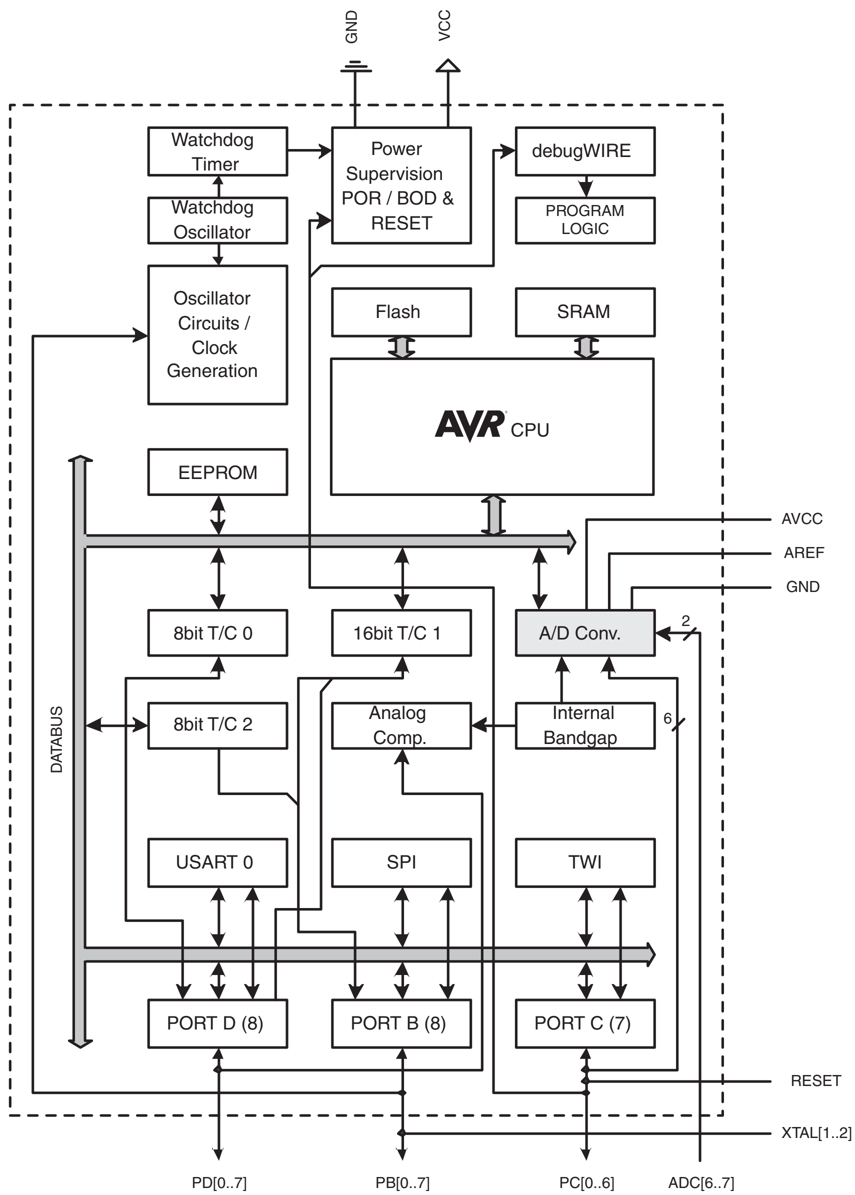
In the TQFP and QFN/MLF package, ADC7:6 serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

2. Overview

The ATmega48PA/88PA/168PA/328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48PA/88PA/168PA/328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

2.1 Block Diagram

Figure 2-1. Block Diagram



The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega48PA/88PA/168PA/328P provides the following features: 4/8/16/32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 256/512/512/1K bytes EEPROM, 512/1K/1K/2K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

The device is manufactured using Atmel's high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega48PA/88PA/168PA/328P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega48PA/88PA/168PA/328P AVR is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

2.2 Comparison Between ATmega48PA, ATmega88PA, ATmega168PA and ATmega328P

The ATmega48PA, ATmega88PA, ATmega168PA and ATmega328P differ only in memory sizes, boot loader support, and interrupt vector sizes. Table 2-1 summarizes the different memory and interrupt vector sizes for the three devices.

Table 2-1. Memory Size Summary

Device	Flash	EEPROM	RAM	Interrupt Vector Size
ATmega48PA	4K Bytes	256 Bytes	512 Bytes	1 instruction word/vector
ATmega88PA	8K Bytes	512 Bytes	1K Bytes	1 instruction word/vector
ATmega168PA	16K Bytes	512 Bytes	1K Bytes	2 instruction words/vector
ATmega328P	32K Bytes	1K Bytes	2K Bytes	2 instruction words/vector

ATmega88PA, ATmega168PA and ATmega328P support a real Read-While-Write Self-Programming mechanism. There is a separate Boot Loader Section, and the SPM instruction can only execute from there. In ATmega48PA, there is no Read-While-Write support and no separate Boot Loader Section. The SPM instruction can execute from the entire Flash.

3. Resources

A comprehensive set of development tools, application notes and datasheets are available for download on http://www.atmel.com/avr.

4. Data Retention

Reliability Qualification results show that the projected data retention failure rate is much less than 1 PPM over 20 years at 85°C or 100 years at 25°C.

5. Register Summary

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xFF)	Reserved	–	–	–	–	–	–	–	–	
(0xFE)	Reserved	–	–	–	–	–	–	–	–	
(0xFD)	Reserved	–	–	–	–	–	–	–	–	
(0xFC)	Reserved	–	–	–	–	–	–	–	–	
(0xFB)	Reserved	–	–	–	–	–	–	–	–	
(0xFA)	Reserved	–	–	–	–	–	–	–	–	
(0xF9)	Reserved	–	–	–	–	–	–	–	–	
(0xF8)	Reserved	–	–	–	–	–	–	–	–	
(0xF7)	Reserved	–	–	–	–	–	–	–	–	
(0xF6)	Reserved	–	–	–	–	–	–	–	–	
(0xF5)	Reserved	–	–	–	–	–	–	–	–	
(0xF4)	Reserved	–	–	–	–	–	–	–	–	
(0xF3)	Reserved	–	–	–	–	–	–	–	–	
(0xF2)	Reserved	–	–	–	–	–	–	–	–	
(0xF1)	Reserved	–	–	–	–	–	–	–	–	
(0xF0)	Reserved	–	–	–	–	–	–	–	–	
(0xEF)	Reserved	–	–	–	–	–	–	–	–	
(0xEE)	Reserved	–	–	–	–	–	–	–	–	
(0xED)	Reserved	–	–	–	–	–	–	–	–	
(0xEC)	Reserved	–	–	–	–	–	–	–	–	
(0xEB)	Reserved	–	–	–	–	–	–	–	–	
(0xEA)	Reserved	–	–	–	–	–	–	–	–	
(0xE9)	Reserved	–	–	–	–	–	–	–	–	
(0xE8)	Reserved	–	–	–	–	–	–	–	–	
(0xE7)	Reserved	–	–	–	–	–	–	–	–	
(0xE6)	Reserved	–	–	–	–	–	–	–	–	
(0xE5)	Reserved	–	–	–	–	–	–	–	–	
(0xE4)	Reserved	–	–	–	–	–	–	–	–	
(0xE3)	Reserved	–	–	–	–	–	–	–	–	
(0xE2)	Reserved	–	–	–	–	–	–	–	–	
(0xE1)	Reserved	–	–	–	–	–	–	–	–	
(0xE0)	Reserved	–	–	–	–	–	–	–	–	
(0xDF)	Reserved	–	–	–	–	–	–	–	–	
(0xDE)	Reserved	–	–	–	–	–	–	–	–	
(0xDD)	Reserved	–	–	–	–	–	–	–	–	
(0xDC)	Reserved	–	–	–	–	–	–	–	–	
(0xDB)	Reserved	–	–	–	–	–	–	–	–	
(0xDA)	Reserved	–	–	–	–	–	–	–	–	
(0xD9)	Reserved	–	–	–	–	–	–	–	–	
(0xD8)	Reserved	–	–	–	–	–	–	–	–	
(0xD7)	Reserved	–	–	–	–	–	–	–	–	
(0xD6)	Reserved	–	–	–	–	–	–	–	–	
(0xD5)	Reserved	–	–	–	–	–	–	–	–	
(0xD4)	Reserved	–	–	–	–	–	–	–	–	
(0xD3)	Reserved	–	–	–	–	–	–	–	–	
(0xD2)	Reserved	–	–	–	–	–	–	–	–	
(0xD1)	Reserved	–	–	–	–	–	–	–	–	
(0xD0)	Reserved	–	–	–	–	–	–	–	–	
(0xCF)	Reserved	–	–	–	–	–	–	–	–	
(0xCE)	Reserved	–	–	–	–	–	–	–	–	
(0xCD)	Reserved	–	–	–	–	–	–	–	–	
(0xCC)	Reserved	–	–	–	–	–	–	–	–	
(0xCB)	Reserved	–	–	–	–	–	–	–	–	
(0xCA)	Reserved	–	–	–	–	–	–	–	–	
(0xC9)	Reserved	–	–	–	–	–	–	–	–	
(0xC8)	Reserved	–	–	–	–	–	–	–	–	
(0xC7)	Reserved	–	–	–	–	–	–	–	–	
(0xC6)	UDR0	USART I/O Data Register								189
(0xC5)	UBRR0H					USART Baud Rate Register High				193
(0xC4)	UBRR0L	USART Baud Rate Register Low								193
(0xC3)	Reserved	–	–	–	–	–	–	–	–	
(0xC2)	UCSR0C	UMSEL01	UMSEL00	UPM01	UPM00	USBS0	UCSZ01 /UDORD0	UCSZ00 / UCPHA0	UCPOL0	191/206

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0xC1)	UCSR0B	RXCIE0	TXCIE0	UDRIE0	RXEN0	TXEN0	UCSZ02	RXB80	TXB80	190
(0xC0)	UCSR0A	RXC0	TXC0	UDRE0	FE0	DOR0	UPE0	U2X0	MPCM0	189
(0xBF)	Reserved	–	–	–	–	–	–	–	–	
(0xBE)	Reserved	–	–	–	–	–	–	–	–	
(0xBD)	TWAMR	TWAM6	TWAM5	TWAM4	TWAM3	TWAM2	TWAM1	TWAM0	–	239
(0xBC)	TWCR	TWINT	TWEA	TWSTA	TWSTO	TWWC	TWEN	–	TWIE	236
(0xBB)	TWDR	2-wire Serial Interface Data Register								238
(0xBA)	TWAR	TWA6	TWA5	TWA4	TWA3	TWA2	TWA1	TWA0	TWGCE	239
(0xB9)	TWSR	TWS7	TWS6	TWS5	TWS4	TWS3	–	TWPS1	TWPS0	238
(0xB8)	TWBR	2-wire Serial Interface Bit Rate Register								236
(0xB7)	Reserved	–		–	–	–	–	–	–	
(0xB6)	ASSR	–	EXCLK	AS2	TCN2UB	OCR2AUB	OCR2BUB	TCR2AUB	TCR2BUB	158
(0xB5)	Reserved	–	–	–	–	–	–	–	–	
(0xB4)	OCR2B	Timer/Counter2 Output Compare Register B								156
(0xB3)	OCR2A	Timer/Counter2 Output Compare Register A								156
(0xB2)	TCNT2	Timer/Counter2 (8-bit)								156
(0xB1)	TCCR2B	FOC2A	FOC2B	–	–	WGM22	CS22	CS21	CS20	155
(0xB0)	TCCR2A	COM2A1	COM2A0	COM2B1	COM2B0	–	–	WGM21	WGM20	152
(0xAF)	Reserved	–	–	–	–	–	–	–	–	
(0xAE)	Reserved	–	–	–	–	–	–	–	–	
(0xAD)	Reserved	–	–	–	–	–	–	–	–	
(0xAC)	Reserved	–	–	–	–	–	–	–	–	
(0xAB)	Reserved	–	–	–	–	–	–	–	–	
(0xAA)	Reserved	–	–	–	–	–	–	–	–	
(0xA9)	Reserved	–	–	–	–	–	–	–	–	
(0xA8)	Reserved	–	–	–	–	–	–	–	–	
(0xA7)	Reserved	–	–	–	–	–	–	–	–	
(0xA6)	Reserved	–	–	–	–	–	–	–	–	
(0xA5)	Reserved	–	–	–	–	–	–	–	–	
(0xA4)	Reserved	–	–	–	–	–	–	–	–	
(0xA3)	Reserved	–	–	–	–	–	–	–	–	
(0xA2)	Reserved	–	–	–	–	–	–	–	–	
(0xA1)	Reserved	–	–	–	–	–	–	–	–	
(0xA0)	Reserved	–	–	–	–	–	–	–	–	
(0x9F)	Reserved	–	–	–	–	–	–	–	–	
(0x9E)	Reserved	–	–	–	–	–	–	–	–	
(0x9D)	Reserved	–	–	–	–	–	–	–	–	
(0x9C)	Reserved	–	–	–	–	–	–	–	–	
(0x9B)	Reserved	–	–	–	–	–	–	–	–	
(0x9A)	Reserved	–	–	–	–	–	–	–	–	
(0x99)	Reserved	–	–	–	–	–	–	–	–	
(0x98)	Reserved	–	–	–	–	–	–	–	–	
(0x97)	Reserved	–	–	–	–	–	–	–	–	
(0x96)	Reserved	–	–	–	–	–	–	–	–	
(0x95)	Reserved	–	–	–	–	–	–	–	–	
(0x94)	Reserved	–	–	–	–	–	–	–	–	
(0x93)	Reserved	–	–	–	–	–	–	–	–	
(0x92)	Reserved	–	–	–	–	–	–	–	–	
(0x91)	Reserved	–	–	–	–	–	–	–	–	
(0x90)	Reserved	–	–	–	–	–	–	–	–	
(0x8F)	Reserved	–	–	–	–	–	–	–	–	
(0x8E)	Reserved	–	–	–	–	–	–	–	–	
(0x8D)	Reserved	–	–	–	–	–	–	–	–	
(0x8C)	Reserved	–	–	–	–	–	–	–	–	
(0x8B)	OCR1BH	Timer/Counter1 - Output Compare Register B High Byte								132
(0x8A)	OCR1BL	Timer/Counter1 - Output Compare Register B Low Byte								132
(0x89)	OCR1AH	Timer/Counter1 - Output Compare Register A High Byte								132
(0x88)	OCR1AL	Timer/Counter1 - Output Compare Register A Low Byte								132
(0x87)	ICR1H	Timer/Counter1 - Input Capture Register High Byte								133
(0x86)	ICR1L	Timer/Counter1 - Input Capture Register Low Byte								133
(0x85)	TCNT1H	Timer/Counter1 - Counter Register High Byte								132
(0x84)	TCNT1L	Timer/Counter1 - Counter Register Low Byte								132
(0x83)	Reserved	–	–	–	–	–	–	–	–	
(0x82)	TCCR1C	FOC1A	FOC1B	–	–	–	–	–	–	131
(0x81)	TCCR1B	ICNC1	ICES1	–	WGM13	WGM12	CS12	CS11	CS10	130
(0x80)	TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	–	–	WGM11	WGM10	128

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
(0x7F)	DIDR1	–	–	–	–	–	–	AIN1D	AIN0D	244
(0x7E)	DIDR0	–	–	ADC5D	ADC4D	ADC3D	ADC2D	ADC1D	ADC0D	261
(0x7D)	Reserved	–	–	–	–	–	–	–	–	
(0x7C)	ADMUX	REFS1	REFS0	ADLAR	–	MUX3	MUX2	MUX1	MUX0	257
(0x7B)	ADCSRB	–	ACME	–	–	–	ADTS2	ADTS1	ADTS0	260
(0x7A)	ADCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	258
(0x79)	ADCH	ADC Data Register High byte								260
(0x78)	ADCL	ADC Data Register Low byte								260
(0x77)	Reserved	–	–	–	–	–	–	–	–	
(0x76)	Reserved	–	–	–	–	–	–	–	–	
(0x75)	Reserved	–	–	–	–	–	–	–	–	
(0x74)	Reserved	–	–	–	–	–	–	–	–	
(0x73)	Reserved	–	–	–	–	–	–	–	–	
(0x72)	Reserved	–	–	–	–	–	–	–	–	
(0x71)	Reserved	–	–	–	–	–	–	–	–	
(0x70)	TIMSK2	–	–	–	–	–	OCIE2B	OCIE2A	TOIE2	157
(0x6F)	TIMSK1	–	–	ICIE1	–	–	OCIE1B	OCIE1A	TOIE1	133
(0x6E)	TIMSK0	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	105
(0x6D)	PCMSK2	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16	68
(0x6C)	PCMSK1	–	PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8	68
(0x6B)	PCMSK0	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	68
(0x6A)	Reserved	–	–	–	–	–	–	–	–	
(0x69)	EICRA	–	–	–	–	ISC11	ISC10	ISC01	ISC00	65
(0x68)	PCICR	–	–	–	–	–	PCIE2	PCIE1	PCIE0	
(0x67)	Reserved	–	–	–	–	–	–	–	–	
(0x66)	OSCCAL	Oscillator Calibration Register								37
(0x65)	Reserved	–	–	–	–	–	–	–	–	
(0x64)	PRR	PRTWI	PRTIM2	PRTIM0	–	PRTIM1	PRSPI	PRUSART0	PRADC	42
(0x63)	Reserved	–	–	–	–	–	–	–	–	
(0x62)	Reserved	–	–	–	–	–	–	–	–	
(0x61)	CLKPR	CLKPCE	–	–	–	CLKPS3	CLKPS2	CLKPS1	CLKPS0	37
(0x60)	WDTCSR	WDIF	WDIE	WDP3	WDCE	WDE	WDP2	WDP1	WDP0	54
0x3F (0x5F)	SREG	I	T	H	S	V	N	Z	C	9
0x3E (0x5E)	SPH	–	–	–	–	–	(SP10) [5.]	SP9	SP8	12
0x3D (0x5D)	SPL	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	12
0x3C (0x5C)	Reserved	–	–	–	–	–	–	–	–	
0x3B (0x5B)	Reserved	–	–	–	–	–	–	–	–	
0x3A (0x5A)	Reserved	–	–	–	–	–	–	–	–	
0x39 (0x59)	Reserved	–	–	–	–	–	–	–	–	
0x38 (0x58)	Reserved	–	–	–	–	–	–	–	–	
0x37 (0x57)	SPMCSR	SPMIE	(RWWSB)[5.]	–	(RWWSRE)[5.]	BLBSET	PGWRT	PGERS	SELFPRGEN	284
0x36 (0x56)	Reserved	–	–	–	–	–	–	–	–	
0x35 (0x55)	MCUCR	–	BODS	BODSE	PUD	–	–	IVSEL	IVCE	44/62/86
0x34 (0x54)	MCUSR	–	–	–	–	WDRF	BORF	EXTRF	PORF	54
0x33 (0x53)	SMCR	–	–	–	–	SM2	SM1	SM0	SE	40
0x32 (0x52)	Reserved	–	–	–	–	–	–	–	–	
0x31 (0x51)	Reserved	–	–	–	–	–	–	–	–	
0x30 (0x50)	ACSR	ACD	ACBG	ACO	ACI	ACIE	ACIC	ACIS1	ACIS0	242
0x2F (0x4F)	Reserved	–	–	–	–	–	–	–	–	
0x2E (0x4E)	SPDR	SPI Data Register								169
0x2D (0x4D)	SPSR	SPIF	WCOL	–	–	–	–	–	SPI2X	168
0x2C (0x4C)	SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR0	167
0x2B (0x4B)	GPIOR2	General Purpose I/O Register 2								25
0x2A (0x4A)	GPIOR1	General Purpose I/O Register 1								25
0x29 (0x49)	Reserved	–	–	–	–	–	–	–	–	
0x28 (0x48)	OCR0B	Timer/Counter0 Output Compare Register B								
0x27 (0x47)	OCR0A	Timer/Counter0 Output Compare Register A								
0x26 (0x46)	TCNT0	Timer/Counter0 (8-bit)								
0x25 (0x45)	TCCR0B	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00	
0x24 (0x44)	TCCR0A	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	
0x23 (0x43)	GTCCR	TSM	–	–	–	–	–	PSRASY	PSRSYNC	137/159
0x22 (0x42)	EEARH	(EEPROM Address Register High Byte) [5.]								21
0x21 (0x41)	EEARL	EEPROM Address Register Low Byte								21
0x20 (0x40)	EEDR	EEPROM Data Register								21
0x1F (0x3F)	EECR	–	–	EEPM1	EEPM0	EERIE	EEMPE	EEPE	EERE	21
0x1E (0x3E)	GPIOR0	General Purpose I/O Register 0								25

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Page
0x1D (0x3D)	EIMSK	–	–	–	–	–	–	INT1	INT0	66
0x1C (0x3C)	EIFR	–	–	–	–	–	–	INTF1	INTF0	66
0x1B (0x3B)	PCIFR	–	–	–	–	–	PCIF2	PCIF1	PCIF0	
0x1A (0x3A)	Reserved	–	–	–	–	–	–	–	–	
0x19 (0x39)	Reserved	–	–	–	–	–	–	–	–	
0x18 (0x38)	Reserved	–	–	–	–	–	–	–	–	
0x17 (0x37)	TIFR2	–	–	–	–	–	OCF2B	OCF2A	TOV2	157
0x16 (0x36)	TIFR1	–	–	ICF1	–	–	OCF1B	OCF1A	TOV1	134
0x15 (0x35)	TIFR0	–	–	–	–	–	OCF0B	OCF0A	TOV0	
0x14 (0x34)	Reserved	–	–	–	–	–	–	–	–	
0x13 (0x33)	Reserved	–	–	–	–	–	–	–	–	
0x12 (0x32)	Reserved	–	–	–	–	–	–	–	–	
0x11 (0x31)	Reserved	–	–	–	–	–	–	–	–	
0x10 (0x30)	Reserved	–	–	–	–	–	–	–	–	
0x0F (0x2F)	Reserved	–	–	–	–	–	–	–	–	
0x0E (0x2E)	Reserved	–	–	–	–	–	–	–	–	
0x0D (0x2D)	Reserved	–	–	–	–	–	–	–	–	
0x0C (0x2C)	Reserved	–	–	–	–	–	–	–	–	
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	87
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	87
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0	87
0x08 (0x28)	PORTC	–	PORTC6	PORTC5	PORTC4	PORTC3	PORTC2	PORTC1	PORTC0	86
0x07 (0x27)	DDRC	–	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	86
0x06 (0x26)	PINC	–	PINC6	PINC5	PINC4	PINC3	PINC2	PINC1	PINC0	86
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0	86
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0	86
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0	86
0x02 (0x22)	Reserved	–	–	–	–	–	–	–	–	
0x01 (0x21)	Reserved	–	–	–	–	–	–	–	–	
0x0 (0x20)	Reserved	–	–	–	–	–	–	–	–	

Note:
1. For compatibility with future devices, reserved bits should be written to zero if accessed. Reserved I/O memory addresses should never be written.
2. I/O Registers within the address range 0x00 - 0x1F are directly bit-accessible using the SBI and CBI instructions. In these registers, the value of single bits can be checked by using the SBIS and SBIC instructions.
3. Some of the Status Flags are cleared by writing a logical one to them. Note that, unlike most other AVRs, the CBI and SBI instructions will only operate on the specified bit, and can therefore be used on registers containing such Status Flags. The CBI and SBI instructions work with registers 0x00 to 0x1F only.
4. When using the I/O specific commands IN and OUT, the I/O addresses 0x00 - 0x3F must be used. When addressing I/O Registers as data space using LD and ST instructions, 0x20 must be added to these addresses. The ATmega48PA/88PA/168PA/328P is a complex microcontroller with more peripheral units than can be supported within the 64 location reserved in Opcode for the IN and OUT instructions. For the Extended I/O space from 0x60 - 0xFF in SRAM, only the ST/STS/STD and LD/LDS/LDD instructions can be used.
5. Only valid for ATmega88PA.

6. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
ARITHMETIC AND LOGIC INSTRUCTIONS					
ADD	Rd, Rr	Add two Registers	Rd ← Rd + Rr	Z,C,N,V,H	1
ADC	Rd, Rr	Add with Carry two Registers	Rd ← Rd + Rr + C	Z,C,N,V,H	1
ADIW	Rdl,K	Add Immediate to Word	Rdh:Rdl ← Rdh:Rdl + K	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two Registers	Rd ← Rd - Rr	Z,C,N,V,H	1
SUBI	Rd, K	Subtract Constant from Register	Rd ← Rd - K	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with Carry two Registers	Rd ← Rd - Rr - C	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with Carry Constant from Reg.	Rd ← Rd - K - C	Z,C,N,V,H	1
SBIW	Rdl,K	Subtract Immediate from Word	Rdh:Rdl ← Rdh:Rdl - K	Z,C,N,V,S	2
AND	Rd, Rr	Logical AND Registers	Rd ← Rd • Rr	Z,N,V	1
ANDI	Rd, K	Logical AND Register and Constant	Rd ← Rd • K	Z,N,V	1
OR	Rd, Rr	Logical OR Registers	Rd ← Rd v Rr	Z,N,V	1
ORI	Rd, K	Logical OR Register and Constant	Rd ← Rd v K	Z,N,V	1
EOR	Rd, Rr	Exclusive OR Registers	Rd ← Rd ⊕ Rr	Z,N,V	1
COM	Rd	One's Complement	Rd ← 0xFF − Rd	Z,C,N,V	1
NEG	Rd	Two's Complement	Rd ← 0x00 − Rd	Z,C,N,V,H	1
SBR	Rd,K	Set Bit(s) in Register	Rd ← Rd v K	Z,N,V	1
CBR	Rd,K	Clear Bit(s) in Register	Rd ← Rd • (0xFF - K)	Z,N,V	1
INC	Rd	Increment	Rd ← Rd + 1	Z,N,V	1
DEC	Rd	Decrement	Rd ← Rd − 1	Z,N,V	1
TST	Rd	Test for Zero or Minus	Rd ← Rd • Rd	Z,N,V	1
CLR	Rd	Clear Register	Rd ← Rd ⊕ Rd	Z,N,V	1
SER	Rd	Set Register	Rd ← 0xFF	None	1
MUL	Rd, Rr	Multiply Unsigned	R1:R0 ← Rd x Rr	Z,C	2
MULS	Rd, Rr	Multiply Signed	R1:R0 ← Rd x Rr	Z,C	2
MULSU	Rd, Rr	Multiply Signed with Unsigned	R1:R0 ← Rd x Rr	Z,C	2
FMUL	Rd, Rr	Fractional Multiply Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULS	Rd, Rr	Fractional Multiply Signed	R1:R0 ← (Rd x Rr) << 1	Z,C	2
FMULSU	Rd, Rr	Fractional Multiply Signed with Unsigned	R1:R0 ← (Rd x Rr) << 1	Z,C	2
BRANCH INSTRUCTIONS					
RJMP	k	Relative Jump	PC ← PC + k + 1	None	2
IJMP		Indirect Jump to (Z)	PC ← Z	None	2
JMP(1)	k	Direct Jump	PC ← k	None	3
RCALL	k	Relative Subroutine Call	PC ← PC + k + 1	None	3
ICALL		Indirect Call to (Z)	PC ← Z	None	3
CALL(1)	k	Direct Subroutine Call	PC ← k	None	4
RET		Subroutine Return	PC ← STACK	None	4
RETI		Interrupt Return	PC ← STACK	I	4
CPSE	Rd,Rr	Compare, Skip if Equal	if (Rd = Rr) PC ← PC + 2 or 3	None	1/2/3
CP	Rd,Rr	Compare	Rd − Rr	Z, N,V,C,H	1
CPC	Rd,Rr	Compare with Carry	Rd − Rr − C	Z, N,V,C,H	1
CPI	Rd,K	Compare Register with Immediate	Rd − K	Z, N,V,C,H	1
SBRC	Rr, b	Skip if Bit in Register Cleared	if (Rr(b)=0) PC ← PC + 2 or 3	None	1/2/3
SBRS	Rr, b	Skip if Bit in Register is Set	if (Rr(b)=1) PC ← PC + 2 or 3	None	1/2/3
SBIC	P, b	Skip if Bit in I/O Register Cleared	if (P(b)=0) PC ← PC + 2 or 3	None	1/2/3
SBIS	P, b	Skip if Bit in I/O Register is Set	if (P(b)=1) PC ← PC + 2 or 3	None	1/2/3
BRBS	s, k	Branch if Status Flag Set	if (SREG(s) = 1) then PC←PC+k + 1	None	1/2
BRBC	s, k	Branch if Status Flag Cleared	if (SREG(s) = 0) then PC←PC+k + 1	None	1/2
BREQ	k	Branch if Equal	if (Z = 1) then PC ← PC + k + 1	None	1/2
BRNE	k	Branch if Not Equal	if (Z = 0) then PC ← PC + k + 1	None	1/2
BRCS	k	Branch if Carry Set	if (C = 1) then PC ← PC + k + 1	None	1/2
BRCC	k	Branch if Carry Cleared	if (C = 0) then PC ← PC + k + 1	None	1/2
BRSH	k	Branch if Same or Higher	if (C = 0) then PC ← PC + k + 1	None	1/2
BRLO	k	Branch if Lower	if (C = 1) then PC ← PC + k + 1	None	1/2
BRMI	k	Branch if Minus	if (N = 1) then PC ← PC + k + 1	None	1/2
BRPL	k	Branch if Plus	if (N = 0) then PC ← PC + k + 1	None	1/2
BRGE	k	Branch if Greater or Equal, Signed	if (N ⊕ V= 0) then PC ← PC + k + 1	None	1/2
BRLT	k	Branch if Less Than Zero, Signed	if (N ⊕ V= 1) then PC ← PC + k + 1	None	1/2
BRHS	k	Branch if Half Carry Flag Set	if (H = 1) then PC ← PC + k + 1	None	1/2
BRHC	k	Branch if Half Carry Flag Cleared	if (H = 0) then PC ← PC + k + 1	None	1/2
BRTS	k	Branch if T Flag Set	if (T = 1) then PC ← PC + k + 1	None	1/2
BRTC	k	Branch if T Flag Cleared	if (T = 0) then PC ← PC + k + 1	None	1/2
BRVS	k	Branch if Overflow Flag is Set	if (V = 1) then PC ← PC + k + 1	None	1/2
BRVC	k	Branch if Overflow Flag is Cleared	if (V = 0) then PC ← PC + k + 1	None	1/2

Mnemonics	Operands	Description	Operation	Flags	#Clocks
BRIE	k	Branch if Interrupt Enabled	if (I = 1) then PC ← PC + k + 1	None	1/2
BRID	k	Branch if Interrupt Disabled	if (I = 0) then PC ← PC + k + 1	None	1/2
BIT AND BIT-TEST INSTRUCTIONS					
SBI	P,b	Set Bit in I/O Register	I/O(P,b) ← 1	None	2
CBI	P,b	Clear Bit in I/O Register	I/O(P,b) ← 0	None	2
LSL	Rd	Logical Shift Left	Rd(n+1) ← Rd(n), Rd(0) ← 0	Z,C,N,V	1
LSR	Rd	Logical Shift Right	Rd(n) ← Rd(n+1), Rd(7) ← 0	Z,C,N,V	1
ROL	Rd	Rotate Left Through Carry	Rd(0)←C,Rd(n+1)← Rd(n),C←Rd(7)	Z,C,N,V	1
ROR	Rd	Rotate Right Through Carry	Rd(7)←C,Rd(n)← Rd(n+1),C←Rd(0)	Z,C,N,V	1
ASR	Rd	Arithmetic Shift Right	Rd(n) ← Rd(n+1), n=0..6	Z,C,N,V	1
SWAP	Rd	Swap Nibbles	Rd(3..0)←Rd(7..4),Rd(7..4)←Rd(3..0)	None	1
BSET	s	Flag Set	SREG(s) ← 1	SREG(s)	1
BCLR	s	Flag Clear	SREG(s) ← 0	SREG(s)	1
BST	Rr, b	Bit Store from Register to T	T ← Rr(b)	T	1
BLD	Rd, b	Bit load from T to Register	Rd(b) ← T	None	1
SEC		Set Carry	C ← 1	C	1
CLC		Clear Carry	C ← 0	C	1
SEN		Set Negative Flag	N ← 1	N	1
CLN		Clear Negative Flag	N ← 0	N	1
SEZ		Set Zero Flag	Z ← 1	Z	1
CLZ		Clear Zero Flag	Z ← 0	Z	1
SEI		Global Interrupt Enable	I ← 1	I	1
CLI		Global Interrupt Disable	I ← 0	I	1
SES		Set Signed Test Flag	S ← 1	S	1
CLS		Clear Signed Test Flag	S ← 0	S	1
SEV		Set Twos Complement Overflow.	V ← 1	V	1
CLV		Clear Twos Complement Overflow	V ← 0	V	1
SET		Set T in SREG	T ← 1	T	1
CLT		Clear T in SREG	T ← 0	T	1
SEH		Set Half Carry Flag in SREG	H ← 1	H	1
CLH		Clear Half Carry Flag in SREG	H ← 0	H	1
DATA TRANSFER INSTRUCTIONS					
MOV	Rd, Rr	Move Between Registers	Rd ← Rr	None	1
MOVW	Rd, Rr	Copy Register Word	Rd+1:Rd ← Rr+1:Rr	None	1
LDI	Rd, K	Load Immediate	Rd ← K	None	1
LD	Rd, X	Load Indirect	Rd ← (X)	None	2
LD	Rd, X+	Load Indirect and Post-Inc.	Rd ← (X), X ← X + 1	None	2
LD	Rd, - X	Load Indirect and Pre-Dec.	X ← X - 1, Rd ← (X)	None	2
LD	Rd, Y	Load Indirect	Rd ← (Y)	None	2
LD	Rd, Y+	Load Indirect and Post-Inc.	Rd ← (Y), Y ← Y + 1	None	2
LD	Rd, - Y	Load Indirect and Pre-Dec.	Y ← Y - 1, Rd ← (Y)	None	2
LDD	Rd,Y+q	Load Indirect with Displacement	Rd ← (Y + q)	None	2
LD	Rd, Z	Load Indirect	Rd ← (Z)	None	2
LD	Rd, Z+	Load Indirect and Post-Inc.	Rd ← (Z), Z ← Z+1	None	2
LD	Rd, -Z	Load Indirect and Pre-Dec.	Z ← Z - 1, Rd ← (Z)	None	2
LDD	Rd, Z+q	Load Indirect with Displacement	Rd ← (Z + q)	None	2
LDS	Rd, k	Load Direct from SRAM	Rd ← (k)	None	2
ST	X, Rr	Store Indirect	(X) ← Rr	None	2
ST	X+, Rr	Store Indirect and Post-Inc.	(X) ← Rr, X ← X + 1	None	2
ST	- X, Rr	Store Indirect and Pre-Dec.	X ← X - 1, (X) ← Rr	None	2
ST	Y, Rr	Store Indirect	(Y) ← Rr	None	2
ST	Y+, Rr	Store Indirect and Post-Inc.	(Y) ← Rr, Y ← Y + 1	None	2
ST	- Y, Rr	Store Indirect and Pre-Dec.	Y ← Y - 1, (Y) ← Rr	None	2
STD	Y+q,Rr	Store Indirect with Displacement	(Y + q) ← Rr	None	2
ST	Z, Rr	Store Indirect	(Z) ← Rr	None	2
ST	Z+, Rr	Store Indirect and Post-Inc.	(Z) ← Rr, Z ← Z + 1	None	2
ST	-Z, Rr	Store Indirect and Pre-Dec.	Z ← Z - 1, (Z) ← Rr	None	2
STD	Z+q,Rr	Store Indirect with Displacement	(Z + q) ← Rr	None	2
STS	k, Rr	Store Direct to SRAM	(k) ← Rr	None	2
LPM		Load Program Memory	R0 ← (Z)	None	3
LPM	Rd, Z	Load Program Memory	Rd ← (Z)	None	3
LPM	Rd, Z+	Load Program Memory and Post-Inc	Rd ← (Z), Z ← Z+1	None	3
SPM		Store Program Memory	(Z) ← R1:R0	None	-
IN	Rd, P	In Port	Rd ← P	None	1
OUT	P, Rr	Out Port	P ← Rr	None	1
PUSH	Rr	Push Register on Stack	STACK ← Rr	None	2

Mnemonics	Operands	Description	Operation	Flags	#Clocks
POP	Rd	Pop Register from Stack	Rd ← STACK	None	2
MCU CONTROL INSTRUCTIONS					
NOP		No Operation		None	1
SLEEP		Sleep	(see specific descr. for Sleep function)	None	1
WDR		Watchdog Reset	(see specific descr. for WDR/timer)	None	1
BREAK		Break	For On-chip Debug Only	None	N/A

7. Ordering Information

7.1 ATmega48PA

Speed (MHz)	Power Supply	Ordering Code[2]	Package[1]	Operational Range
20[3]	1.8 - 5.5	ATmega48PA-AU ATmega48PA-MMH[4] ATmega48PA-MU ATmega48PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

Note: 1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive).Also Halide free and fully Green.
3. See ”Speed Grades” on page 306.
4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP)

7.2 ATmega88PA

Speed (MHz)	Power Supply	Ordering Code[2]	Package[1]	Operational Range
20[3]	1.8 - 5.5	ATmega88PA-AU ATmega88PA-MMH[4] ATmega88PA-MU ATmega88PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

Note: 1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive).Also Halide free and fully Green.
3. See "Speed Grades" on page 306.
4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)

7.3 ATmega168PA

Speed (MHz)[3]	Power Supply	Ordering Code[2]	Package[1]	Operational Range
20	1.8 - 5.5	ATmega168PA-AU ATmega168PA-MMH[4] ATmega168PA-MU ATmega168PA-PU	32A 28M1 32M1-A 28P3	Industrial (-40°C to 85°C)

Note: 1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.

2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive).Also Halide free and fully Green.
3. See "Speed Grades" on page 312.
4. NiPdAu Lead Finish.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28M1	28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)
28P3	28-lead, 0.300" Wide, Plastic Dual Inline Package (PDIP)

7.4 ATmega328P

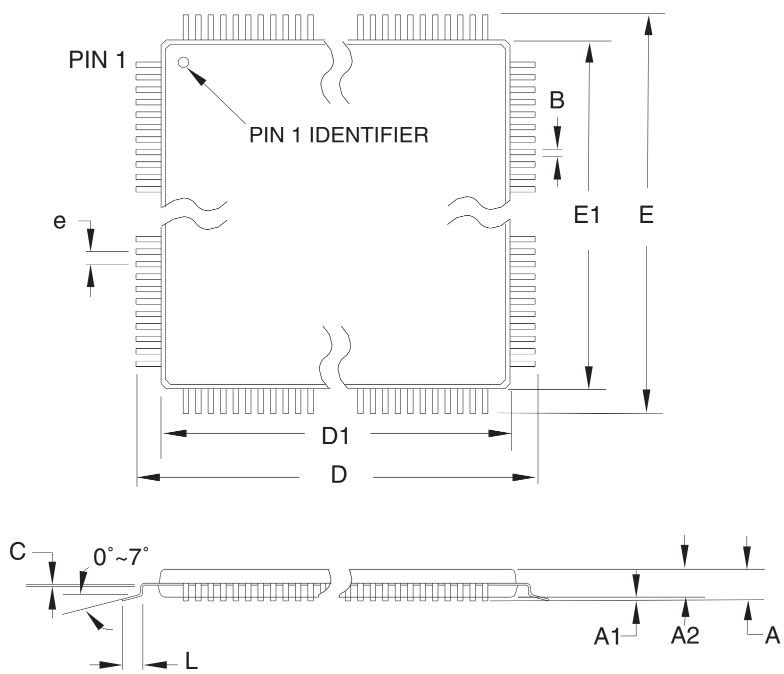
Speed (MHz)	Power Supply	Ordering Code[2]	Package[1]	Operational Range
20[3]	1.8 - 5.5	ATmega328P- AU ATmega328P- MU ATmega328P- PU	32A 32M1-A 28P3	Industrial (-40°C to 85°C)

Note:
1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging complies to the European Directive for Restriction of Hazardous Substances (RoHS directive).Also Halide free and fully Green.
3. See Figure 28-1 on page 316.

Package Type	
32A	32-lead, Thin (1.0 mm) Plastic Quad Flat Package (TQFP)
28P3	28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP)
32M1-A	32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50 mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF)

8. Packaging Information

8.1 32A



COMMON DIMENSIONS
(Unit of Measure = mm)

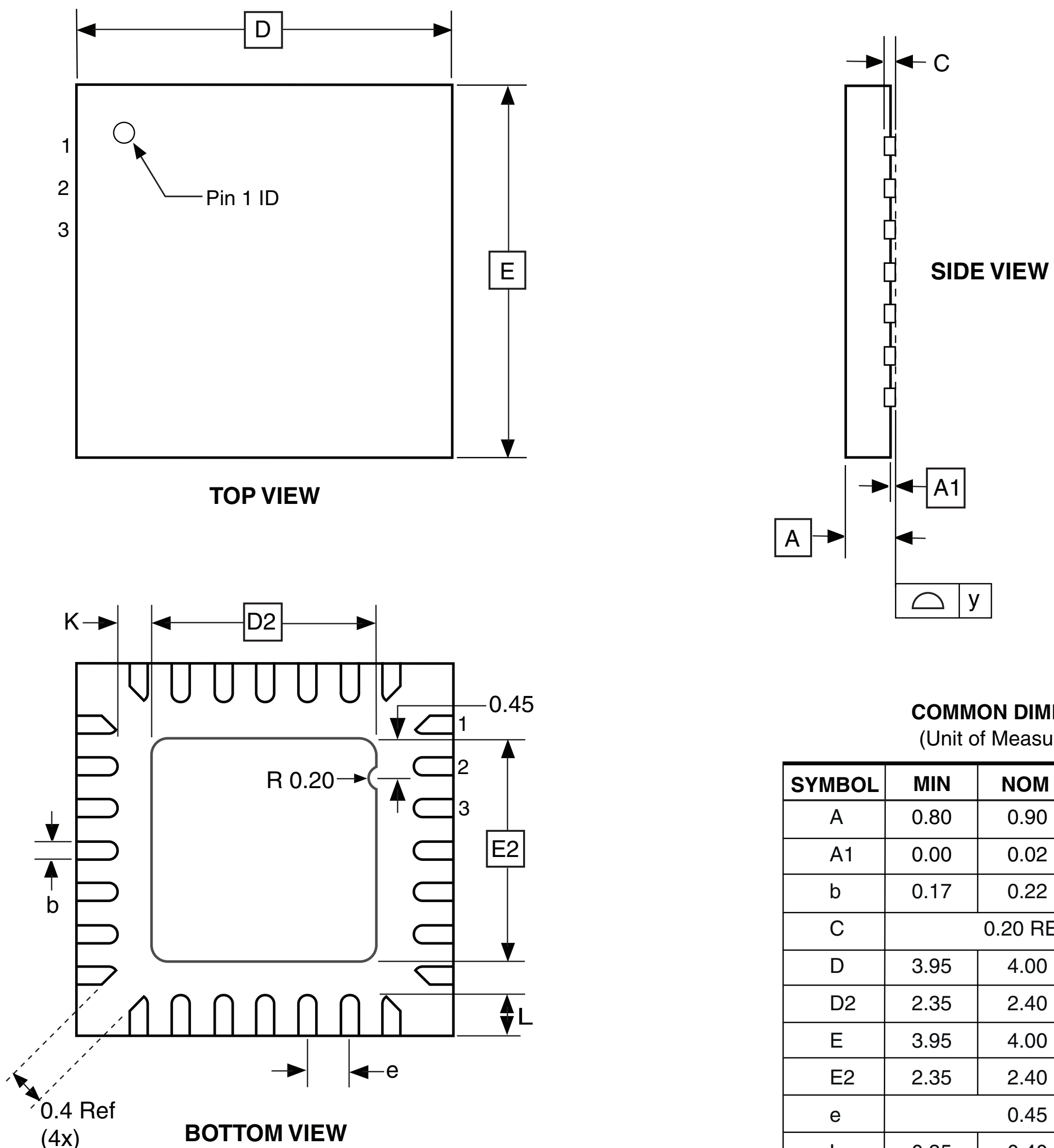
SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	1.20	
A1	0.05	–	0.15	
A2	0.95	1.00	1.05	
D	8.75	9.00	9.25	
D1	6.90	7.00	7.10	Note 2
E	8.75	9.00	9.25	
E1	6.90	7.00	7.10	Note 2
B	0.30	–	0.45	
C	0.09	–	0.20	
L	0.45	–	0.75	
e	0.80 TYP			

Notes:
1. This package conforms to JEDEC reference MS-026, Variation ABA.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is 0.25 mm per side. Dimensions D1 and E1 are maximum plastic body size dimensions including mold mismatch.
3. Lead coplanarity is 0.10 mm maximum.

10/5/2001

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**32A,** 32-lead, 7 x 7 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch, Thin Profile Plastic Quad Flat Package (TQFP)	32A	B

8.2 28M1



Note: The terminal #1 ID is a Laser-marked Feature.

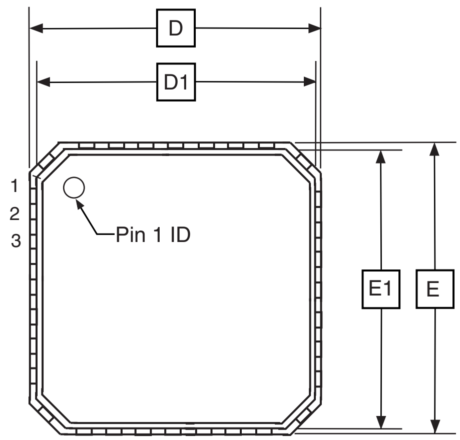
COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	0.80	0.90	1.00	
A1	0.00	0.02	0.05	
b	0.17	0.22	0.27	
C		0.20 REF		
D	3.95	4.00	4.05	
D2	2.35	2.40	2.45	
E	3.95	4.00	4.05	
E2	2.35	2.40	2.45	
e		0.45		
L	0.35	0.40	0.45	
y	0.00	–	0.08	
K	0.20	–	–	

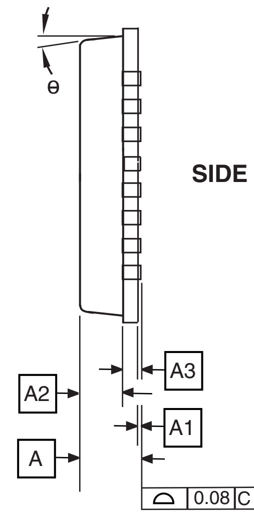
10/24/08

	TITLE	GPC	DRAWING NO.	REV.
Package Drawing Contact: packagedrawings@atmel.com	**28M1,** 28-pad, 4 x 4 x 1.0 mm Body, Lead Pitch 0.45 mm, 2.4 x 2.4 mm Exposed Pad, Thermally Enhanced Plastic Very Thin Quad Flat No Lead Package (VQFN)	ZBV	28M1	B

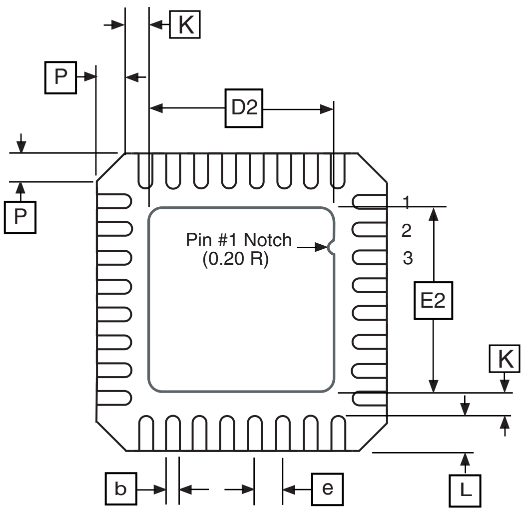
8.3 32M1-A



TOP VIEW



SIDE VIEW



BOTTOM VIEW

COMMON DIMENSIONS
(Unit of Measure = mm)

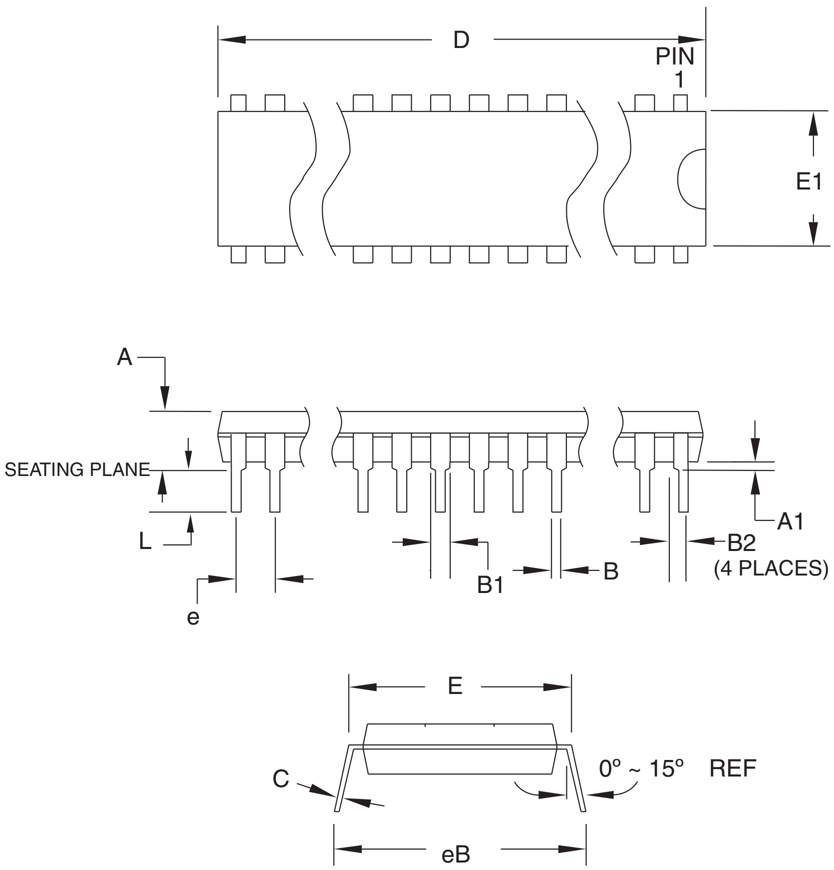
SYMBOL	MIN	NOM	MAX	NOTE
A	0.80	0.90	1.00	
A1	–	0.02	0.05	
A2	–	0.65	1.00	
A3		0.20 REF		
b	0.18	0.23	0.30	
D	4.90	5.00	5.10	
D1	4.70	4.75	4.80	
D2	2.95	3.10	3.25	
E	4.90	5.00	5.10	
E1	4.70	4.75	4.80	
E2	2.95	3.10	3.25	
e		0.50 BSC		
L	0.30	0.40	0.50	
P	–	–	0.60	
θ	–	–	12^{o}	
K	0.20	–	–	

Note: JEDEC Standard MO-220, Fig. 2 (Anvil Singulation), VHHD-2.

5/25/06

	TITLE	DRAWING NO.	REV.
ATMEL 2325 Orchard Parkway San Jose, CA 95131	**32M1-A**, 32-pad, 5 x 5 x 1.0 mm Body, Lead Pitch 0.50 mm, 3.10 mm Exposed Pad, Micro Lead Frame Package (MLF)	32M1-A	E

8.4 28P3



Note: 1. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	4.5724	
A1	0.508	–	–	
D	34.544	–	34.798	Note 1
E	7.620	–	8.255	
E1	7.112	–	7.493	Note 1
B	0.381	–	0.533	
B1	1.143	–	1.397	
B2	0.762	–	1.143	
L	3.175	–	3.429	
C	0.203	–	0.356	
eB	–	–	10.160	
e	2.540 TYP			

09/28/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**28P3**, 28-lead (0.300"/7.62 mm Wide) Plastic Dual Inline Package (PDIP)	28P3	B

9. Errata

9.1 Errata ATmega48PA

The revision letter in this section refers to the revision of the ATmega48PA device.

9.1.1 Rev. D

No known errata.

9.2 Errata ATmega88PA

The revision letter in this section refers to the revision of the ATmega88PA device.

9.2.1 Rev. F

No known errata.

9.3 Errata ATmega168PA

The revision letter in this section refers to the revision of the ATmega168PA device.

9.3.1 Rev E

No known errata.

9.4 Errata ATmega328P

The revision letter in this section refers to the revision of the ATmega328P device.

9.4.1 Rev D

No known errata.

9.4.2 Rev C

Not sampled.

9.4.3 Rev B

- **Unstable 32 kHz Oscillator**

1. **Unstable 32 kHz Oscillator**

   The 32 kHz oscillator does not work as system clock.

   The 32 kHz oscillator used as asynchronous timer is inaccurate.

   Problem Fix/ Workaround

   None

9.4.4 Rev A

- **Unstable 32 kHz Oscillator**

1. **Unstable 32 kHz Oscillator**

   The 32 kHz oscillator does not work as system clock.

   The 32 kHz oscillator used as asynchronous timer is inaccurate.

   Problem Fix/ Workaround

None

10. Datasheet Revision History

Please note that the referring page numbers in this section are referred to this document. The referring revision in this section are referring to the document revision.

10.1 Rev. 8161C – 05/09

1. Updated ”Features” on page 1 for ATmega48PA/88PA/168PA/328P.
2. Updated ”Overview” on page 5 included the Table 2-1 on page 6.
3. Updated ”AVR Memories” on page 16 included ”Register Description” on page 21 and inserted Figure 7-1 on page 17.
4. Updated ”Register Description” on page 44.
5. Updated ”System Control and Reset” on page 46.
6. Updated ”Interrupts” on page 57.
7. Updated ”External Interrupts” on page 70.
8. Updated ”Boot Loader Support – Read-While-Write Self-Programming, ATmega88PA, ATmega168PA and ATmega328P” on page 277.
9. Inserted ”ATmega168PA DC Characteristics” on page 315.
10. Inserted ”ATmega328P DC Characteristics” on page 316.
11. Inserted ”ATmega168PA Typical Characteristics” on page 375.
12. Inserted ”ATmega328P Typical Characteristics” on page 399.
13. Inserted Ordering Information for ”ATmega168PA” on page 432.
14. Inserted Ordering Information for ”ATmega328P” on page 433.
15. Inserted ”Errata ATmega328P” on page 438.
16. Editing updates.

10.2 Rev. 8161B – 01/09

1. Updated ”Features” on page 1 for ATmega48PA and updated the book accordingly.
2. Updated ”Overview” on page 5 included the Table 2-1 on page 6.
3. Updated ”AVR Memories” on page 16 included ”Register Description” on page 21 and inserted Figure 7-1 on page 17.
4. Updated ”Register Description” on page 44.
5. Updated ”System Control and Reset” on page 46.
6. Updated ”Interrupts” on page 57.
7. Updated ”External Interrupts” on page 70.
8. Inserted Typical characteristics for ”ATmega48PA Typical Characteristics” on page 327.
9. Updated figure names in Typical characteristics for ”ATmega88PA Typical Characteristics” on page 351.
10. Inserted ”ATmega48PA DC Characteristics” on page 314.

11. Updated Table 28-1 on page 317 by removing the footnote from Vcc/User calibration
12. Updated Table 28-7 on page 323 by removing Max value (2.5 LSB) from Absolute accuracy, V_{REF} = 4V, V_{CC} = 4V, ADC clock = 200 kHz.
13. Inserted Ordering Information for ”ATmega48PA” on page 430.

10.3 Rev. 8161A – 11/08

1. Initial revision (Based on the ATmega48P/88P/168P/328P datasheet 8025F-AVR-08/08).
2. Changes done compared to ATmega48P/88P/168P/328P datasheet 8025F-AVR-08/08:
    - Updated ”DC Characteristics” on page 313 with new typical values for I_{CC}.
    - Updated ”Speed Grades” on page 316.
    - New graphics in ”Typical Characteristics” on page 326.
    - New ”Ordering Information” on page 430.

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Literature Requests
www.atmel.com/literature

ESP-01 WiFi Module

Version1.0

sherry@aithinker.com

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.

Table of Contents

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.

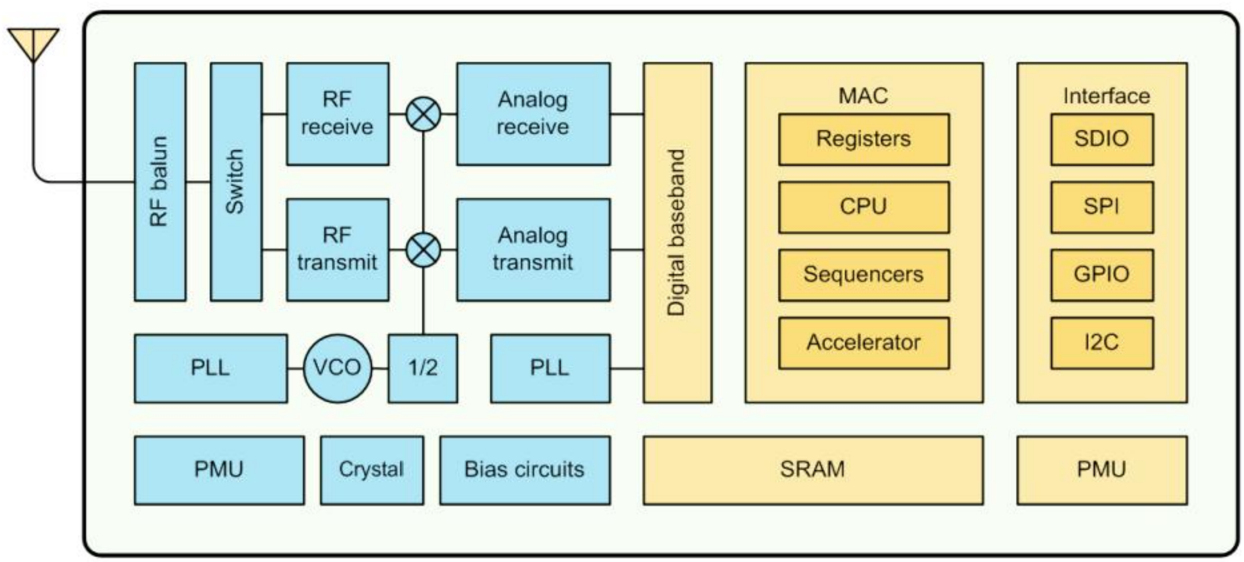


Figure 1 ESP8266EX Block Diagram

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。

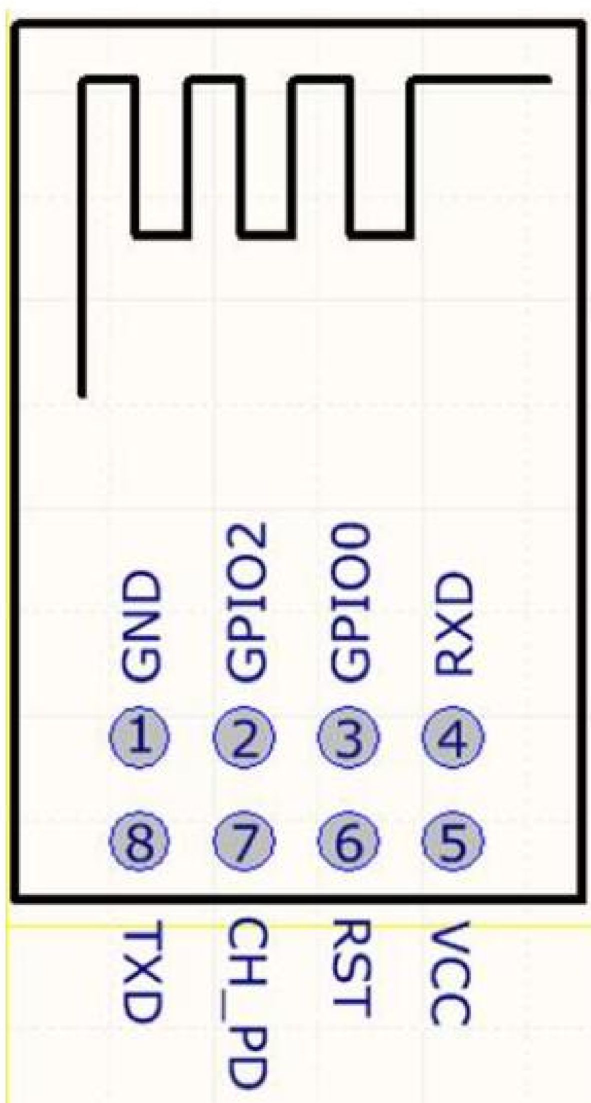


Table 2 ESP-01 Pin design

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

3. Packaging and Dimension

The external size of the module is 14.3mm*24.8mm*3mm, as is illustrated in Figure 3 below. The type of flash integrated in this module is an SPI flash, the capacity of which is 1 MB, and the package size of which is SOP-210mil. The antenna applied on this module is a 3DBi PCB-on-board antenna.

Figure 3 [Module Pin Counts, 8 pin, 14.3 mm *24.8 mm *3.0 mm]

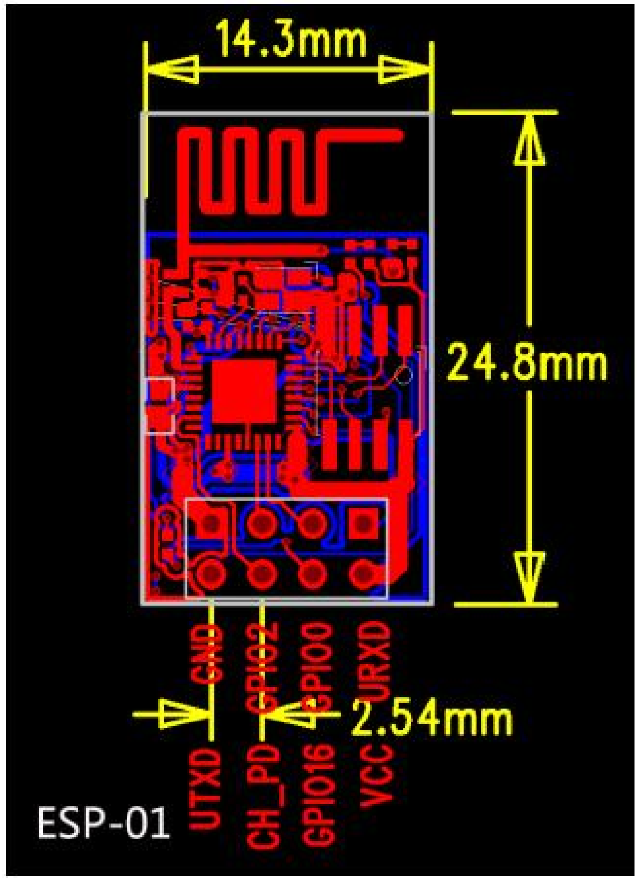


Figure 4 Top View of ESP-01 WiFi Module

Table 5 Dimension of ESP-01 WiFi Module

Length	Width	Height	PAD Size(Bottom)	Pin Pitch
14.3 mm	24.8 mm	3 mm	0.9 mm x 1.7 mm	2.54 mm

4. Functional Descriptions

4.1. MCU

ESP8266EX is embedded with Tensilica L106 32-bit micro controller (MCU), which features extra low power consumption and 16-bit RSIC. The CPU clock speed is 80MHz. It can also reach a maximum value of 160MHz. ESP8266EX is often integrated with external sensors and other specific devices through its GPIOs; codes for such applications are provided in examples in the SDK.

4.2. Memory Organization

4.2.1. Internal SRAM and ROM

ESP8266EX WiFi SoC is embedded with memory controller, including SRAM and ROM. MCU can visit the memory units through iBus, dBus, and AHB interfaces. All memory units can be visited upon request, while a memory arbiter will decide the running sequence according to the time when these requests are received by the processor.

According to our current version of SDK provided, SRAM space that is available to users is assigned as below:

▪RAM size < 36kB, that is to say, when ESP8266EX is working under the station mode and is connected to the router, programmable space accessible to user in heap and data section is around 36kB.)

▪ There is no programmable ROM in the SoC, therefore, user program must be stored in an external SPI flash.

4.2.2. External SPI Flash

This module is mounted with an 1 MB external SPI flash to store user programs. If larger definable storage space is required, a SPI flash with larger memory size is preferred. Theoretically speaking, up to 16 MB memory capacity can be supported.

Suggested SPI Flash memory capacity:

▪OTA is disabled: the minimum flash memory that can be supported is 512 kB;

▪OTA is enabled: the minimum flash memory that can be supported is 1 MB.

Several SPI modes can be supported, including Standard SPI, Dual SPI, and Quad SPI.

Therefore, please choose the correct SPI mode when you are downloading into the flash, otherwise firmwares/programs that you downloaded may not work in the right way.

4.3. Crystal

Currently, the frequency of crystal oscillators supported include 40MHz, 26MHz and 24MHz. The accuracy of crystal oscillators applied should be ±10PPM, and the operating temperature range should be between -20°C and 85°C.

When using the downloading tools, please remember to select the right crystal oscillator type. In circuit design, capacitors C1 and C2, which are connected to the earth, are added to the input and output terminals of the crystal oscillator respectively. The values of the two capacitors can be flexible, ranging from 6pF to 22pF, however, the specific capacitive values of C1 and C2 depend on further testing and adjustment on the overall performance of the whole circuit. Normally, the capacitive values of C1 and C2 are within 10pF if the crystal oscillator frequency is 26MHz, while the values of C1 and C2 are 10pF<C1, C2<22pF if the crystal oscillator frequency is 40MHz.

4.4. Interfaces

Table 6 Descriptions of Interfaces

Interface	Pin Name	Description
HSPI	IO12(MISO) IO13(MOSI) IO14(CLK) IO15(CS)	SPI Flash 2, display screen, and MCU can be connected using HSPI interface.
PWM	IO12(R) IO15(G) IO13(B)	Currently the PWM interface has four channels, but users can extend the channels according to their own needs. PWM interface can be used to control LED lights, buzzers, relays, electronic machines, and so on.
IR Remote Control	IO14(IR_T) IO5(IR_R)	The functionality of Infrared remote control interface can be implemented via software programming. NEC coding, modulation, and demodulation are used by this interface. The frequency of modulated carrier signal is 38KHz.
ADC	TOUT	ESP8266EX integrates a 10-bit analog ADC. It can be used to test the power-supply voltage of VDD3P3 (Pin3 and Pin4) and the input power voltage of TOUT (Pin 6). However, these two functions cannot be used simultaneously. This interface is typically used in sensor products.
I2C	IO14(SCL) IO2(SDA)	I2C interface can be used to connect external sensor products and display screens, etc.

Interface	Pin Name	Description
UART	**UART0:** TXD (U0TXD) RXD (U0RXD) IO15 (RTS) IO13 (CTS) **UART1:** IO2(TXD)	Devices with UART interfaces can be connected with the module. Downloading: U0TXD+U0RXD or GPIO2+U0RXD Communicating: UART0: U0TXD, U0RXD, MTDO (U0RTS), MTCK (U0CTS) Debugging: UART1_TXD (GPIO2) can be used to print debugging information.
		By default, UART0 will output some printed information when the device is powered on and is booting up. If this issue exerts influence on some specific applications, users can exchange the inner pins of UART when initializing, that is to say, exchange U0TXD, U0RXD with U0RTS, U0CTS.
I2S	**I2S Input:** IO12 (I2SI_DATA) ; IO13 (I2SI_BCK); IO14 (I2SI_WS); **I2S Output:** IO15 (I2SO_BCK); IO3 (I2SO_DATA); IO2 (I2SO_WS).	I2S interface is mainly used for collecting, processing, and transmission of audio data.

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

8. Schematics

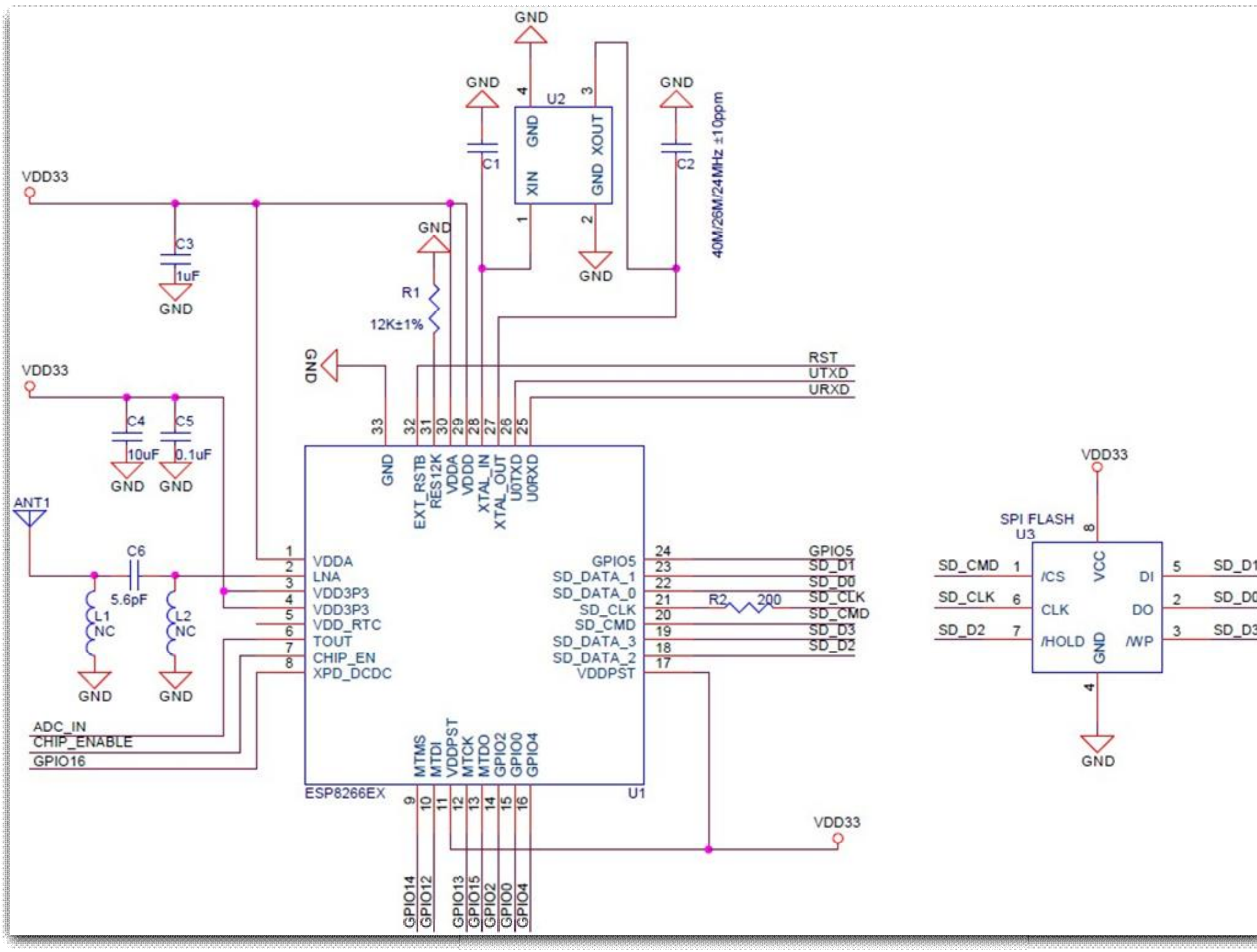


Figure 4 Schematics of Esp-01 WiFi Module

HC-SR501 PIR MOTION DETECTOR

Product Discription

HC-SR501 is based on infrared technology, automatic control module, using Germany imported LHI778 probe design, high sensitivity, high reliability, ultra-low-voltage operating mode, widely used in various auto-sensing electrical equipment, especially for battery-powered automatic controlled products.

Specification:

- Voltage: 5V – 20V
- Power Consumption: 65mA
- TTL output: 3.3V, 0V
- Delay time: Adjustable (.3->5min)
- Lock time: 0.2 sec
- Trigger methods: L – disable repeat trigger, H enable repeat trigger
- Sensing range: less than 120 degree, within 7 meters
- Temperature: – 15 ~ +70
- Dimension: 32*24 mm, distance between screw 28mm, M2, Lens dimension in diameter: 23mm

Application:

Automatically sensing light for Floor, bathroom, basement, porch, warehouse, Garage, etc, ventilator, alarm, etc.

Features:

- Automatic induction: to enter the sensing range of the output is high, the person leaves the sensing range of the automatic delay off high, output low.
- Photosensitive control (optional, not factory-set) can be set photosensitive control, day or light intensity without induction.
- Temperature compensation (optional, factory reset): In the summer when the ambient temperature rises to 30 ° C to 32 ° C, the detection distance is slightly shorter, temperature compensation can be used for performance compensation.
- Triggered in two ways: (jumper selectable)
  - non-repeatable trigger: the sensor output high, the delay time is over, the output is automatically changed from high level to low level;
  - repeatable trigger: the sensor output high, the delay period, if there is human activity in its sensing range, the output will always remain high until the people left after the delay will be high level goes low (sensor module detects a time delay period will be automatically extended every human activity, and the starting point for the delay time to the last event of the time).
- With induction blocking time (the default setting: 2.5s blocked time): sensor module after each sensor output (high into low), followed by a blockade set period of time, during this time period sensor does not accept any sensor signal. This feature can be achieved sensor output time "and" blocking time "interval between the work can be applied to interval detection products; This function can inhibit a variety of interference in the process of load switching. (This time can be set at zero seconds – a few tens of seconds).
- Wide operating voltage range: default voltage DC4.5V-20V.
- Micropower consumption: static current <50 microamps, particularly suitable for battery-powered automatic control products.
- Output high signal: easy to achieve docking with the various types of circuit.

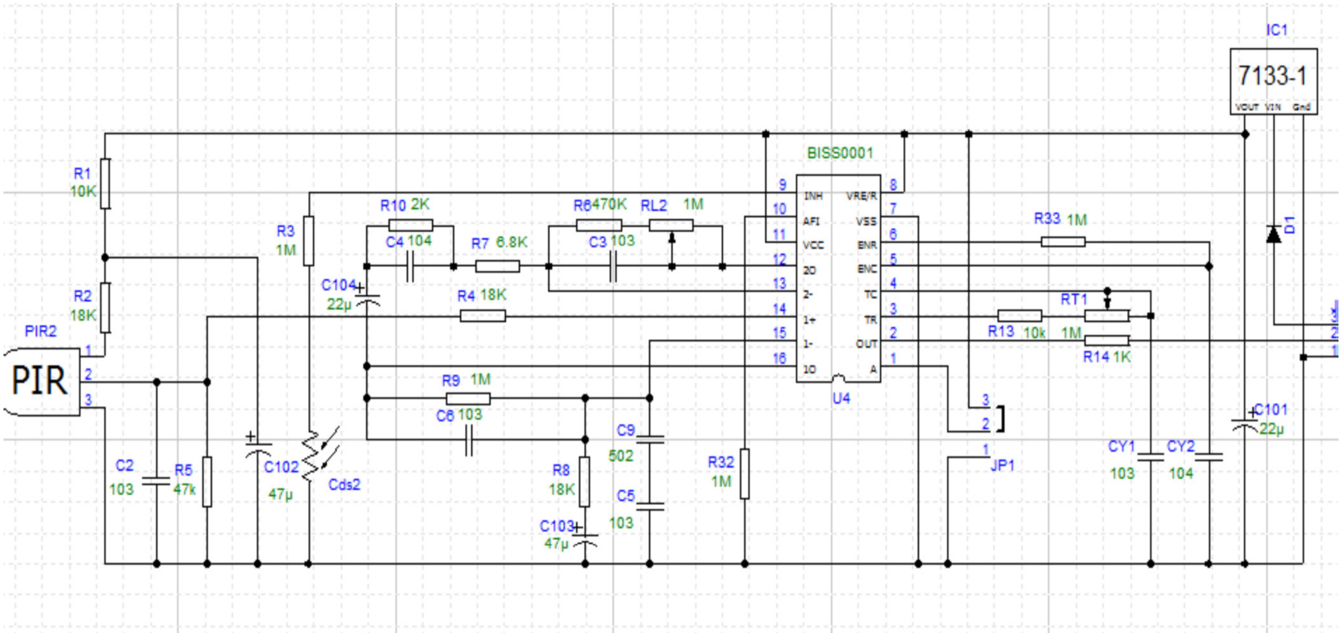
Adjustment:

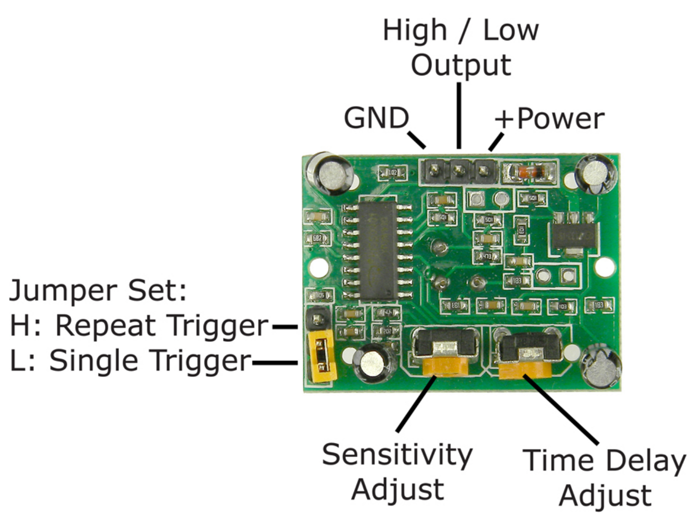
- Adjust the distance potentiometer clockwise rotation, increased sensing distance (about 7 meters), on the contrary, the sensing distance decreases (about 3 meters).
- Adjust the delay potentiometer clockwise rotation sensor the delay lengthened (300S), on the contrary, shorten the induction delay (5S).

Instructions for use:

- Sensor module is powered up after a minute, in this initialization time intervals during this module will output 0-3 times, a minute later enters the standby state.
- Should try to avoid the lights and other sources of interference close direct module surface of the lens, in order to avoid the introduction of interference signal malfunction; environment should avoid the wind flow, the wind will cause interference on the sensor.
- Sensor module with dual probe, the probe window is rectangular, dual (A B) in both ends of the longitudinal direction
  - so when the human body from left to right or right to left through the infrared spectrum to reach dual time, distance difference, the greater the difference, the more sensitive the sensor,
  - when the human body from the front to the probe or from top to bottom or from bottom to top on the direction traveled, double detects changes in the distance of less than infrared spectroscopy, no difference value the sensor insensitive or does not work;
- The dual direction of sensor should be installed parallel as far as possible in inline with human movement. In order to increase the sensor angle range, the module using a circular lens also makes the probe surrounded induction, but the left and right sides still up and down in both directions sensing range, sensitivity, still need to try to install the above requirements.

HC-SR501 PIR MOTION DETECTOR





1 working voltage range :DC 4.5-20V

2 Quiescent Current :50uA

3 high output level 3.3 V / Low 0V

4. Trigger L trigger can not be repeated / H repeated trigger

5. circuit board dimensions :32 * 24 mm

6. maximum 110 ° angle sensor

7. 7 m maximum sensing distance

Product Type	HC--SR501 Body Sensor Module
Operating Voltage Range	5-20VDC
Quiescent Current	<50uA
Level output	High 3.3 V /Low 0V
Trigger	L can not be repeated trigger/H can be repeated trigger(Default repeated trigger)
Delay time	5-300S(adjustable) Range (approximately .3Sec -5Min)
Block time	2.5S(default)Can be made a range(0.xx to tens of seconds
Board Dimensions	32mm*24mm
Angle Sensor	<110 ° cone angle
Operation Temp.	-15-+70 degrees
Lens size sensor	Diameter:23mm(Default)

Application scope

•Security products

•Body induction toys

•Body induction lamps

•Industrial automation control etc

Pyroelectric infrared switch is a passive infrared switch which consists of BISS0001 ,pyroelectric infrared sensors and a few external components. It can au
open all kinds of equipments, inculding incandescent lamp, fluorescent lamp, intercom, automatic, electric fan, dryer and automatic washing machine, etc.
It is widely used in enterprises, hotels, stores, and corridor and other sensitive area for automatical lamplight, lighting and alarm system.

Instructions

Induction module needs a minute or so to initialize. During initializing time, it will output 0-3 times. One minute later it comes into standby.
Keep the surface of the lens from close lighting source and wind, which will introduce interference.
Induction module has double -probe whose window is rectangle. The two sub-probe (A and B) is located at the two ends of rectangle. When human body r
to right, or from right to left, Time for IR to reach to reach the two sub-probes differs.The lager the time diffference is, the more sensitive this module is. Wh
body moves face-to probe, or up to down, or down to up, there is no time difference. So it does not work. So instal the module in the direction in which mos
activities behaves, to guarantee the induction of human by dual sub-probes. In order to increase the induction range, this module uses round lens which ca
from all direction. However, induction from right or left is more sensitivity than from up or down.

Data Sheet

Light dependent resistors

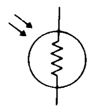
NORP12 RS stock number 651-507
NSL19-M51 RS stock number 596-141

Two cadmium sulphide (cdS) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Guide to source illuminations

Light source	Illumination (Lux)
Moonlight	0.1
60W bulb at 1m	50
1W MES bulb at 0.1m	100
Fluorescent lighting	500
Bright sunlight	30,000

Circuit symbol



Light memory characteristics

Light dependent resistors have a particular property in that they remember the lighting conditions in which they have been stored. This memory effect can be minimised by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values.

NORP12 (**RS** stock no. 651-507)

Absolute maximum ratings

Voltage, ac or dc peak	320V
Current	75mA
Power dissipation at 30°C	250mW
Operating temperature range	-60°C to +75°C

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	- -	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

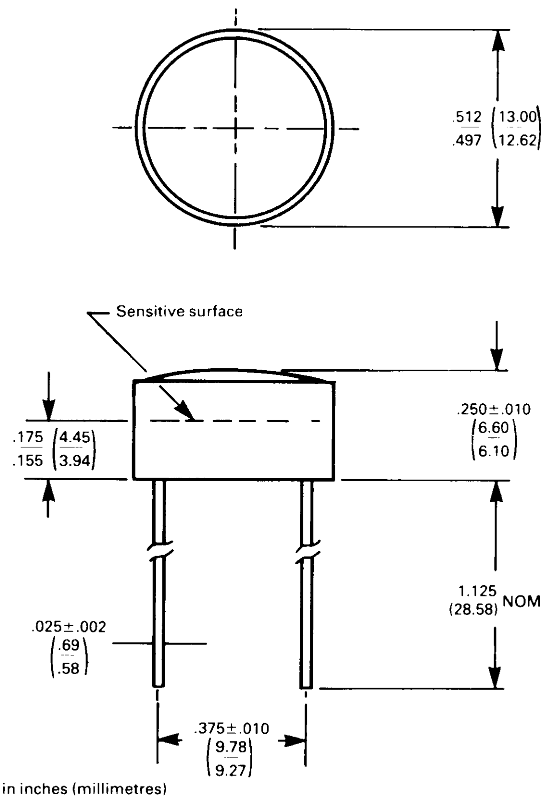
1. Dark to 110% R_L
2. To 10 × R_L

R_L = photocell resistance under given illumination.

Features

- Wide spectral response
- Low cost
- Wide ambient temperature range.

Dimensions



Units in inches (millimetres)

Figure 1 Power dissipation derating

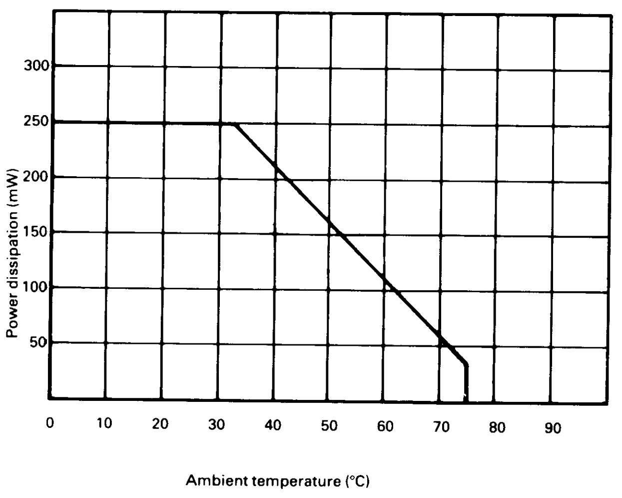
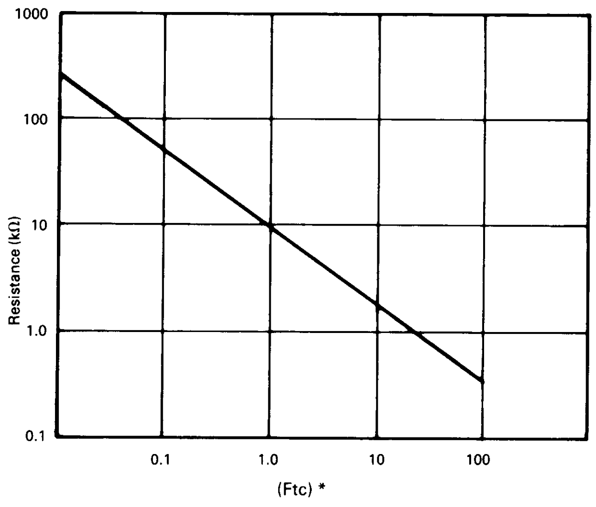
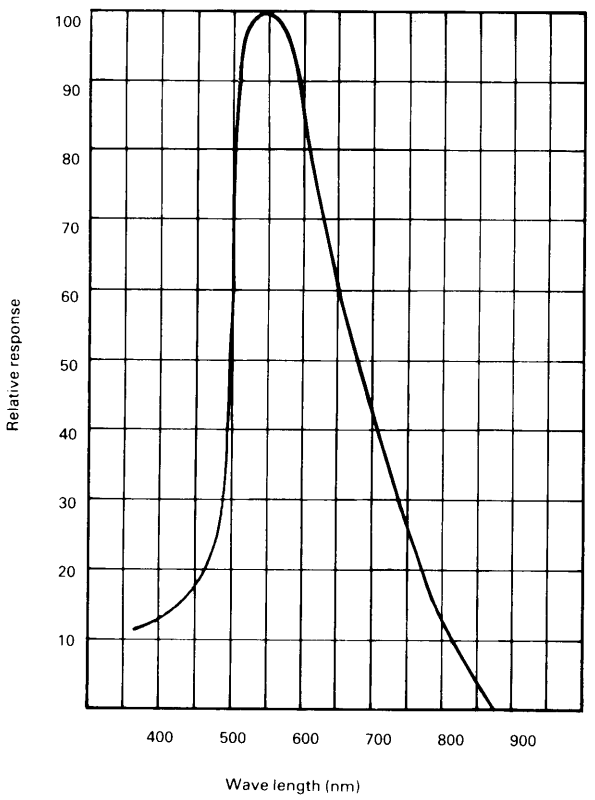


Figure 3 Resistance as a function of illumination



*1Ftc=10.764 lumens

Figure 2 Spectral response



Absolute maximum ratings

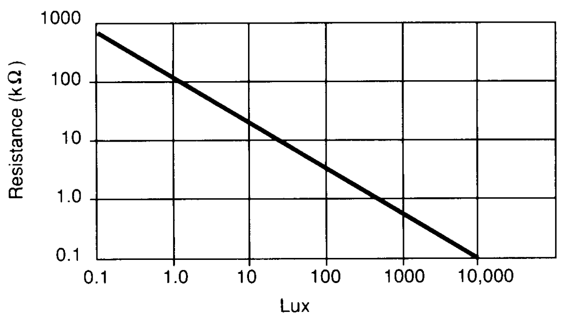
Voltage, ac or dc peak ____________ 100V
Current ____________ 5mA
Power dissipation at 25°C ____________ 50mW*
Operating temperature range ____________ -25°C +75°C

*Derate linearly from 50mW at 25°C to 0W at 75°C.

Electrical characteristics

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	10 lux 100 lux	20 -	- 5	100 -	kΩ kΩ
Dark resistance	10 lux after 10 sec	20	-	-	MΩ
Spectral response	-	-	550	-	nm
Rise time	10ftc	-	45	-	ms
Fall time	10ftc	-	55	-	ms

Figure 4 Resistance as a function illumination



Dimensions

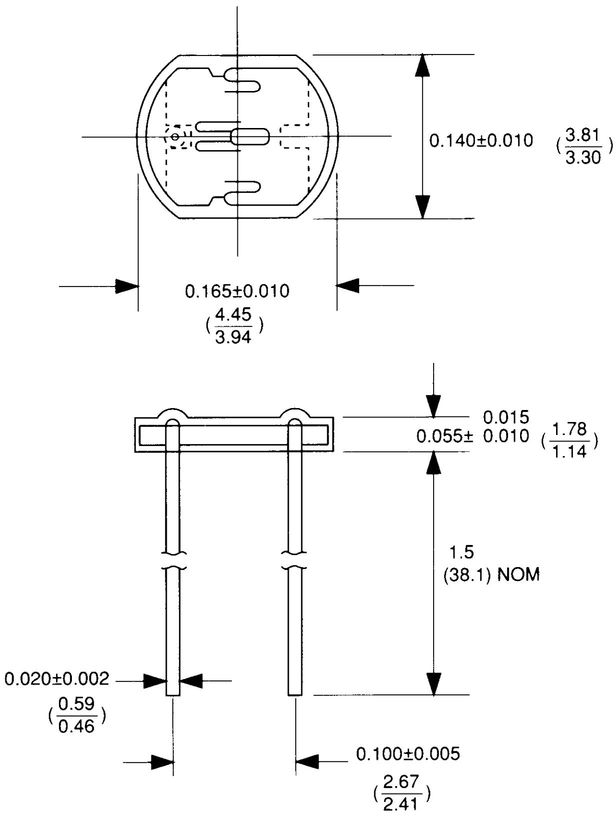
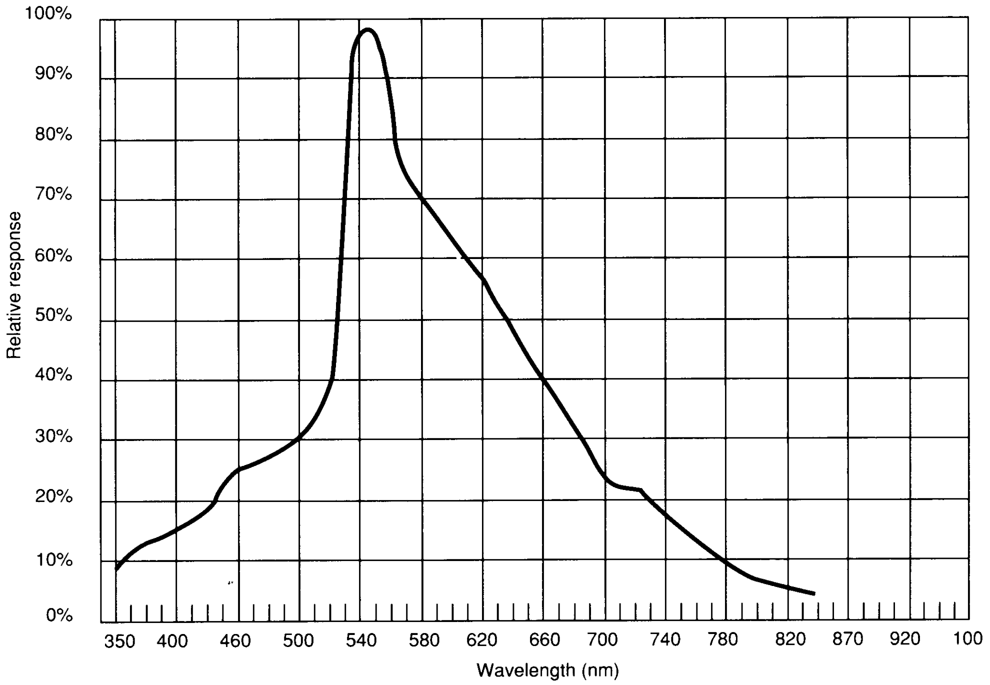
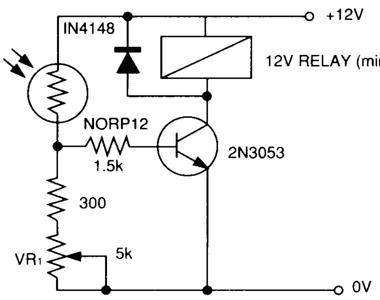


Figure 5 Spectral response



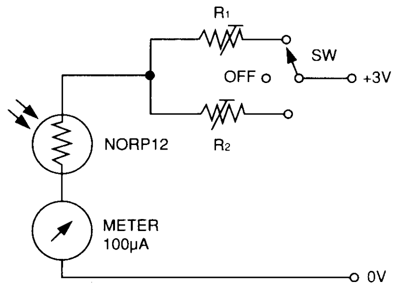
Typical application circuits

Figure 6 **Sensitive light operated relay**



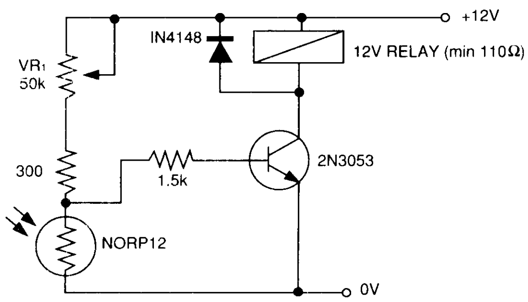
Relay energised when light level increases above the level set by VR_1

Figure 9 **Logarithmic law photographic light meter**



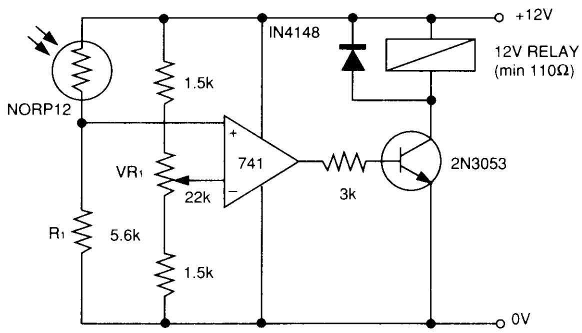
Typical value $R^1 = 100k\Omega$
$R^2 = 200k\Omega$ preset to give two overlapping ranges.
(Calibration should be made against an accurate meter.)

Figure 7 **Light interruption detector**



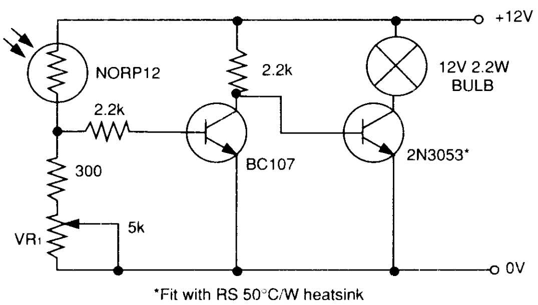
As Figure 6 relay energised when light level drops below the level set by VR_1

Figure 10 **Extremely sensitive light operated relay**



(Relay energised when light exceeds preset level.)
Incorporates a balancing bridge and op-amp. R_1 and NORP12 may be interchanged for the reverse function.

Figure 8 **Automatic light circuit**



Adjust turn-on point with VR_1

MQ-2 Semiconductor Sensor for Combustible Gas

Sensitive material of MQ-2 gas sensor is SnO_2, which with lower conductivity in clean air. When the target combustible gas exist, The sensor's conductivity is more higher along with the gas concentration rising. Please use simple electrocircuit, Convert change of conductivity to correspond output signal of gas concentration.

MQ-2 gas sensor has high sensitity to LPG, Propane and Hydrogen, also could be used to Methane and other combustible steam, it is with low cost and suitable for different application.

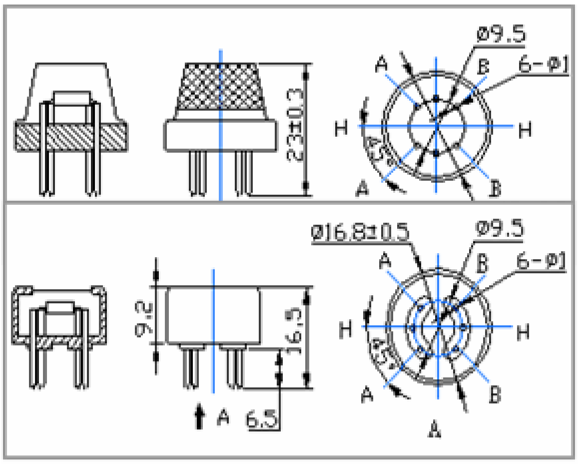
Character

*Good sensitivity to Combustible gas in wide range
* High sensitivity to LPG, Propane and Hydrogen
* Long life and low cost
* Simple drive circuit

Application

* Domestic gas leakage detector
* Industrial Combustible gas detector
* Portable gas detector

Configuration

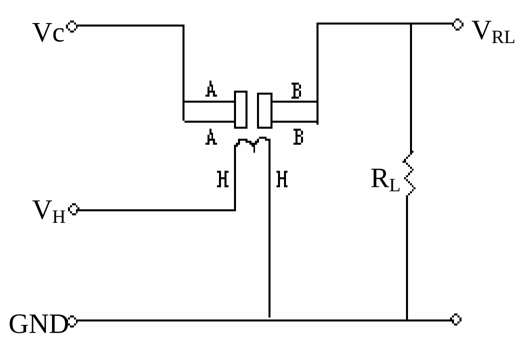


Technical Data

Model No.			MQ-2
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Combustible gas and smoke
Concentration			300-10000ppm (Combustible gas)
Circuit	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Tem.）
	Heater consumption	P_H	≤900mW
	Sensing Resistance	R_s	2KΩ-20KΩ(in 2000ppm C_3H_8)
	Sensitivity	S	Rs(in air)/Rs(1000ppm isobutane)≥5
	Slope	α	≤0.6($R_{5000ppm}/R_{3000ppm}$ CH_4)
Condition	Tem. Humidity		20℃±2℃；65%±5%RH
	Standard test circuit		Vc:5.0V±0.1V； V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

Basic test loop

T



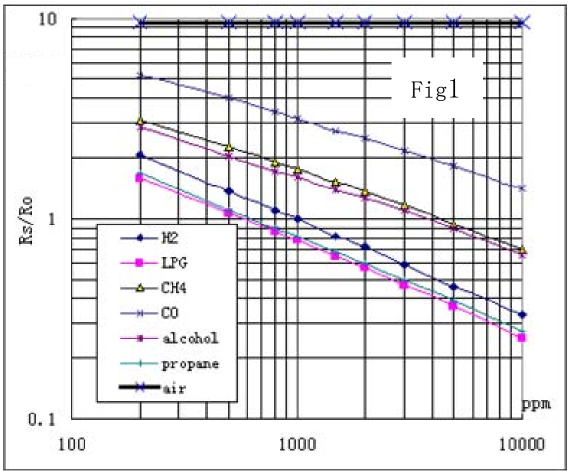
The above is basic test circuit of the sensor. The sensor need to be put 2 voltage, heater voltage（VH） and test voltage（VC）. VH used to supply certified working temperature to the sensor, while VC used to detect voltage (VRL) on load resistance （RL） whom is in series with sensor. The sensor has light polarity, Vc need DC power. VC and VH could use same power circuit with precondition to assure performance of sensor. In order to make the sensor with better performance, suitable RL value is needed:

Power of Sensitivity body(Ps):

$Ps=Vc^2 \times Rs/(Rs+RL)^2$

Resistance of sensor(Rs): Rs=(Vc/VRL-1)×RL

Sensitivity Characteristics



Influence of Temperature/Humidity

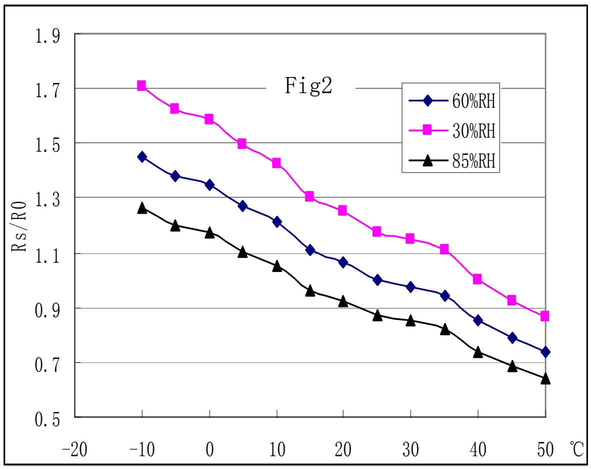


Fig.1 shows the typical sensitivity characteristics of the MQ-2, ordinate means resistance ratio of the sensor **(**Rs/Ro**)**, abscissa is concentration of gases. Rs means resistance in different gases, Ro means resistance of sensor in 1000ppm Hyrogen. All test are under standard test conditions.

Fig.2 shows the typical temperature and humidity characteristics. Ordinate means resistance ratio of the sensor (Rs/Ro), Rs means resistance of sensor in 1000ppm Butane under different tem. and humidity. Ro means resistance of the sensor in environment of 1000ppm Methane, 20℃/65%RH

Structure and configuration

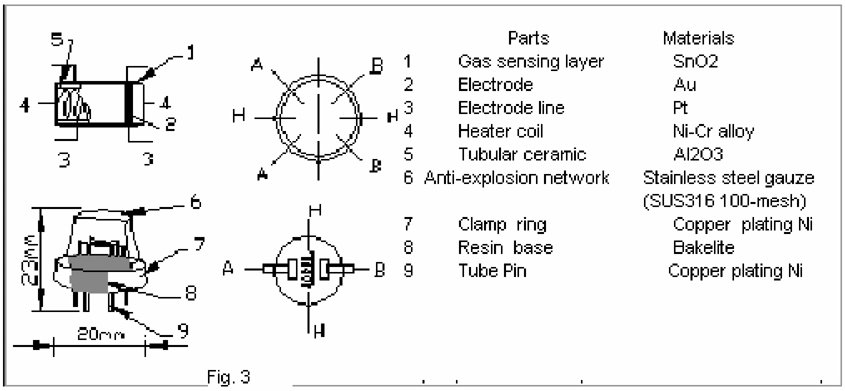


Fig. 3

Structure and configuration of MQ-2 gas sensor is shown as Fig. 3, sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-2 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current.

Notification

1 Following conditions must be prohibited

1.1 Exposed to organic silicon steam

Organic silicon steam cause sensors invalid, sensors must be avoid exposing to silicon bond, fixature, silicon latex, putty or plastic contain silicon environment

1.2 High Corrosive gas

If the sensors exposed to high concentration corrosive gas (such as H_2Sz, SO_X, Cl_2, HCl etc), it will not only result in corrosion of sensors structure, also it cause sincere sensitivity attenuation.

1.3 Alkali, Alkali metals salt, halogen pollution

The sensors performance will be changed badly if sensors be sprayed polluted by alkali metals salt especially brine, or be exposed to halogen such as fluorin.

1.4 Touch water

Sensitivity of the sensors will be reduced when spattered or dipped in water.

1.5 Freezing

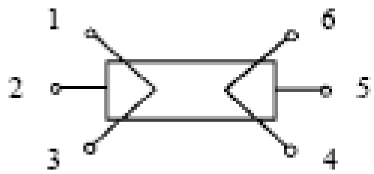
Do avoid icing on sensor'surface, otherwise sensor would lose sensitivity.

1.6 Applied voltage higher

Applied voltage on sensor should not be higher than stipulated value, otherwise it cause down-line or heater damaged, and bring on sensors' sensitivity characteristic changed badly.

1.7 Voltage on wrong pins

For 6 pins sensor, if apply voltage on 1、3 pins or 4、6 pins, it will make lead broken, and without signal when apply on 2、4 pins



2 Following conditions must be avoided

2.1 Water Condensation

Indoor conditions, slight water condensation will effect sensors performance lightly. However, if water condensation on sensors surface and keep a certain period, sensor' sensitivity will be decreased.

2.2 Used in high gas concentration

No matter the sensor is electrified or not, if long time placed in high gas concentration, if will affect sensors characteristic.

2.3 Long time storage

The sensors resistance produce reversible drift if it's stored for long time without electrify, this drift is related with storage conditions. Sensors should be stored in airproof without silicon gel bag with clean air. For the sensors with long time storage but no electrify, they need long aging time for stbility before using.

2.4 Long time exposed to adverse environment

No matter the sensors electrified or not, if exposed to adverse environment for long time, such as high humidity, high temperature, or high pollution etc, it will effect the sensors performance badly.

2.5 Vibration

Continual vibration will result in sensors down-lead response then repture. In transportation or assembling line, pneumatic screwdriver/ultrasonic welding machine can lead this vibration.

2.6 Concussion

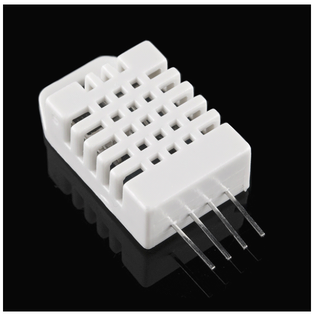
If sensors meet strong concussion, it may lead its lead wire disconnected.

2.7 Usage

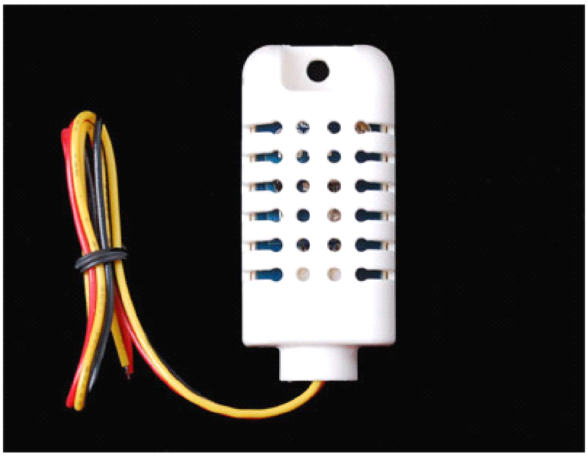
For sensor, handmade welding is optimal way. If use wave crest welding should meet the following conditions:

2.7.1 Soldering flux: Rosin soldering flux contains least chlorine
2.7.2 Speed: 1-2 Meter/ Minute
2.7.3 Warm-up temperature：100±20℃
2.7.4 Welding temperature：250±10℃
2.7.5 1 time pass wave crest welding machine

If disobey the above using terms, sensors sensitivity will be reduced.



Standard AM2302/DHT22



AM2302/DHT22 with big case and wires

Digital relative humidity & temperature sensor AM2302/DHT22

1. Feature & Application:

*High precision
*Capacitive type
*Full range temperature compensated
*Relative humidity and temperature measurement
*Calibrated digital signal
*Outstanding long-term stability
*Extra components not needed
*Long transmission distance, up to 100 meters
*Low power consumption
*4 pins packaged and fully interchangeable

2. Description:

AM2302 output calibrated digital signal. It applys exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(100m) enable AM2302 to be suited in all kinds of harsh application occasions. Single-row packaged with four pins, making the connection very convenient.

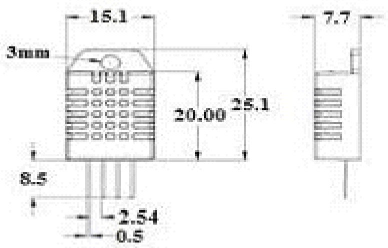
3. Technical Specification:

Model	AM2302	
Power supply	3.3-5.5V DC	
Output signal	digital signal via 1-wire bus	
Sensing element	Polymer humidity capacitor	
Operating range	humidity 0-100%RH;	temperature -40~80Celsius
Accuracy	**humidity +-2%RH**(Max +-5%RH);	temperature +-0.5Celsius
Resolution or sensitivity	humidity 0.1%RH;	temperature 0.1Celsius
Repeatability	humidity +-1%RH;	temperature +-0.2Celsius
Humidity hysteresis	+-0.3%RH	
Long-term Stability	+-0.5%RH/year	
Interchangeability	fully interchangeable	

Thomas Liu (Sales Manager)

Email: thomasliu198518@aliyun.com

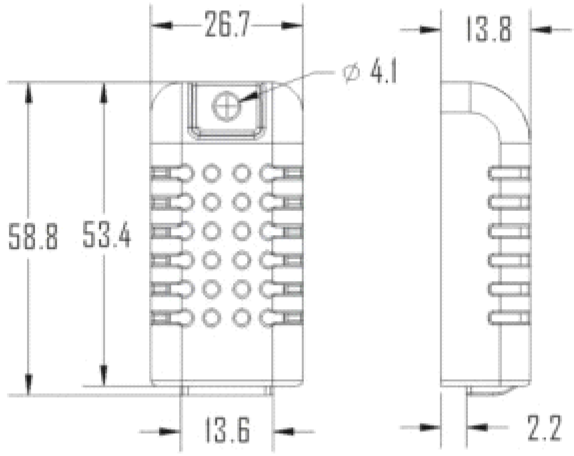
4. Dimensions: (unit----mm)



Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD—power supply
2	DATA–signal
3	GND
4	GND

Standard AM2302's dimensions as above

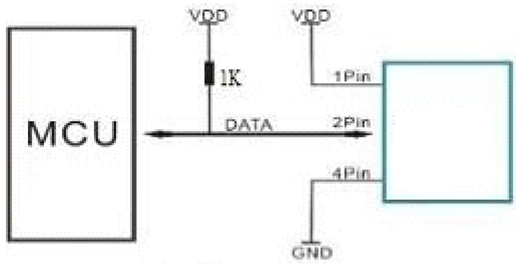


Big case's dimensions as above

Red wire--power supply, Black wire--GND

Yellow wire--Data output

5. Electrical connection diagram:



6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-5.5V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

1-wire bus is used for communication between MCU and AM2302. (Our 1-wire bus is specially designed, it's different from Maxim/Dallas 1-wire bus, so it's incompatible with Dallas 1-wire bus.)

Illustration of our 1-wire bus:

Thomas Liu (Sales Manager)

Email: thomasliu198518@aliyun.com

DATA=16 bits RH data+16 bits Temperature data+8 bits check-sum

Example: MCU has received 40 bits data from AM2302 as

0000 0010 1000 1100 **0000 0001 0101 1111** **1110 1110**

16 bits RH data 16 bits T data check sum

Here we convert 16 bits RH data from binary system to decimal system,

0000 0010 1000 1100 → 652

Binary system Decimal system

RH=652/10=65.2%RH

Here we convert 16 bits T data from binary system to decimal system,

0000 0001 0101 1111 → 351

Binary system Decimal system

T=351/10=35.1℃

When highest bit of temperature is 1, it means the temperature is below 0 degree Celsius.

Example: **1**000 0000 0110 0101, T= minus 10.1℃

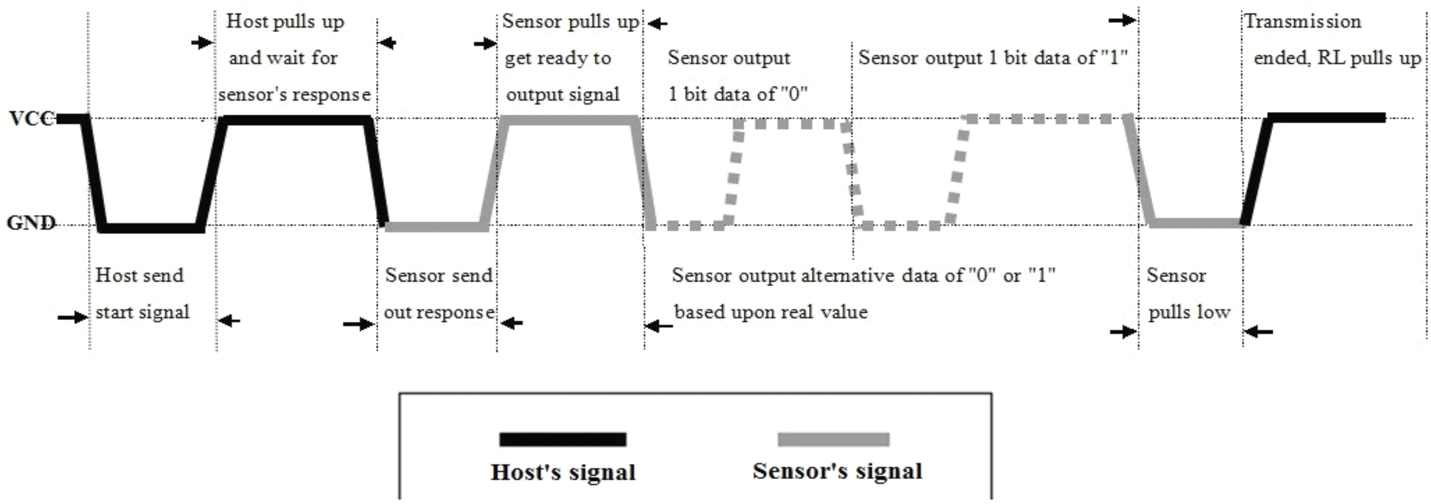
16 bits T data

Sum=0000 0010+1000 1100+0000 0001+0101 1111=1110 1110

Check-sum=the last 8 bits of Sum=1110 1110

When MCU send start signal, AM2302 change from standby-status to running-status. When MCU finishs sending the start signal, AM2302 will send response signal of 40-bit data that reflect the relative humidity and temperature to MCU. Without start signal from MCU, AM2302 will not give response signal to MCU. One start signal for one response data from AM2302 that reflect the relative humidity and temperature. AM2302 will change to standby status when data collecting finished if it don't receive start signal from MCU again.

See below figure for overall communication process, **the interval of whole process must beyond 2 seconds.**



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1) Step 1: MCU send out start signal to AM2302 and AM2302 send response signal to MCU

Thomas Liu (Sales Manager)

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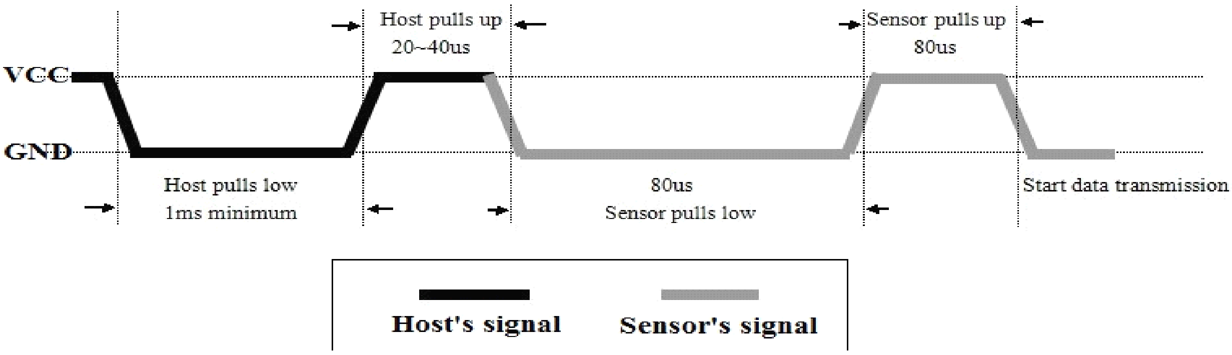
Data-bus's free status is high voltage level. When communication between MCU and AM2302 begins, MCU will pull low data-bus and this process must beyond at least 1~10ms to ensure AM2302 could detect MCU's signal, then MCU will pulls up and wait 20-40us for AM2302's response.

When AM2302 detect the start signal, AM2302 will pull low the bus 80us as response signal, then AM2302 pulls up 80us for preparation to send data. See below figure:



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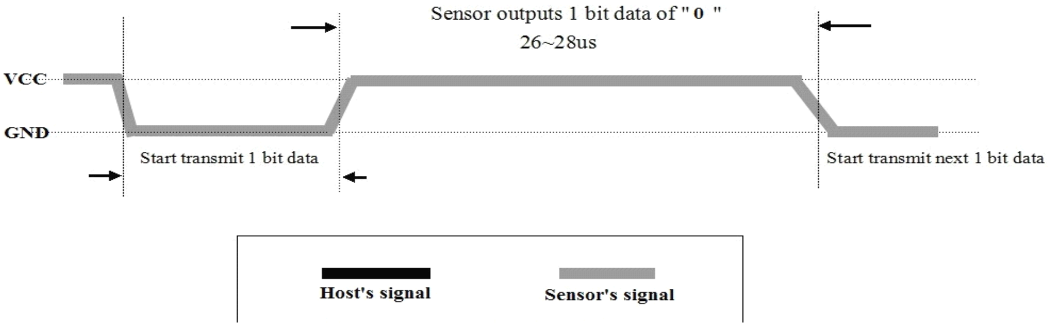
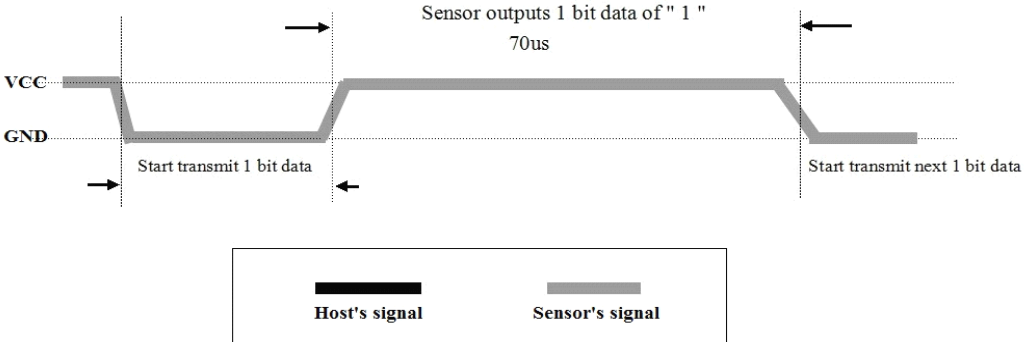
2). Step 2: AM2302 send data to MCU

When AM2302 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0". See below figures:





Attention:

If signal from AM2302 is always high-voltage-level, it means AM2302 is not working properly, please check the electrical connection status.

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7. Electrical Characteristics:

Items	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	6	V
Current supply	Measuring	1		1.5	mA
	Stand-by	40	Null	50	uA
Collecting period	Second		2		Second

8. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The AM2302 sensor can recover after working in abnormal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere AM2302's sensitive-elements and debase AM2302's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the AM2302 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the AM2302 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

AM2302 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase AM2302's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius.
* Avoid using the sensor under dew condition.
* Don't use this product in safety or emergency stop devices or any other occasion that failure of AM2302 may cause personal injury.

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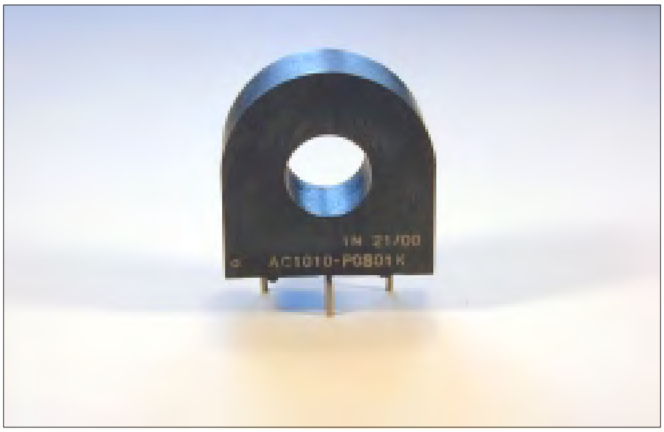
AC1010 • 10 Amp Current Transformer

Low Cost 50/60Hz Current Transformers

Applications
- Sensing Overload Current
- Ground fault detection
- Metering
- Analog to Digital Circuits



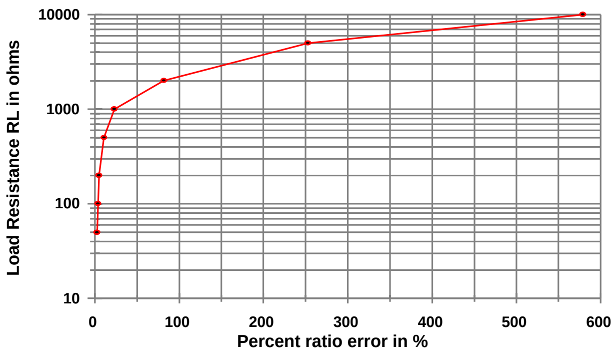
Electrical Specifications @ 20°C ambient

Electrical Specifications	
Primary Current	10A nom., 60 A max.
Turns Ratio	1000:1 nominal
Volt per Amp Ratio at 10A for 100 ohm load	0.100 V/A
Volt per Amp Ratio at 1A for 100 ohm load	0.097 V/A
DC Resistance at 20°C	41.8 ohms
Dielectric Withstanding Voltage (Hi-pot)	4KVrms

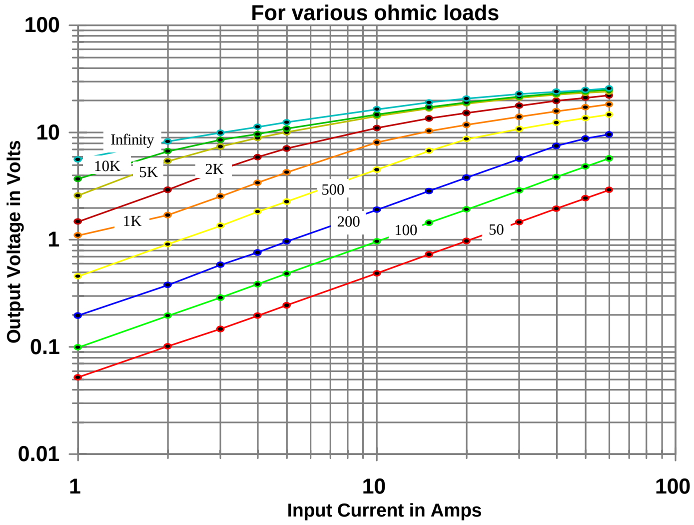
Mechanical Specifications	
Case	Polycarbonate
Encapsulant	Epoxy
Flammibility	Conforms to UL94-VO
Terminals	Pins Ø 0.80mm
Marking	Date Code (W/Y) 1010, Dot at start pin
Approximate Weight	16.3 grams
Tolerance	±0.2mm

Environmental Specifications	
Storage Temperature	-55° to +130°C
Insulation Resistance	100 megohms min.

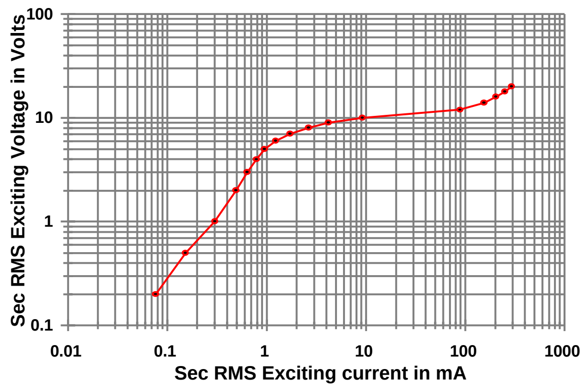
%RE vs RL at Rated primary current (AC1010)



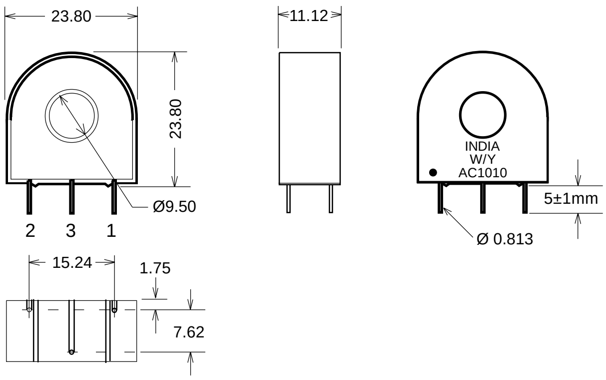
Output Volts vs Input Current
For various ohmic loads



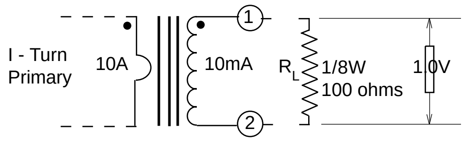
Typical Excitation Curve (AC1005~AC1020)



Dimensions



Notes:
1) Unless requested, the terminating resistor and the one-turn primary are not supplied
2) Pin 3: Normally for mechanical support only but will be used on center tapped designs



SONGLE RELAY

松乐继电器 ® SONGLE RELAY	RELAY ISO9002	SRD

1. MAIN FEATURES

- Switching capacity available by 10A in spite of small size design for highdensity P.C. board mounting technique.
- UL,CUL,TUV recognized.
- Selection of plastic material for high temperature and better chemical solution performance.
- Sealed types available.
- Simple relay magnetic circuit to meet low cost of mass production.

2. APPLICATIONS

- Domestic appliance, office machine, audio, equipment, automobile, etc.
  (Remote control TV receiver, monitor display, audio equipment high rushing current use application.)

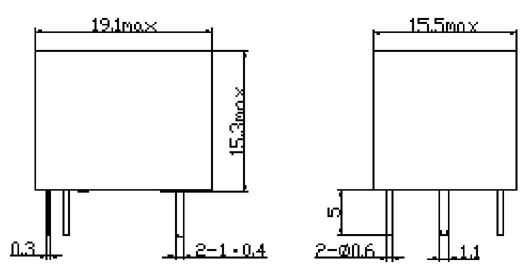
3. ORDERING INFORMATION

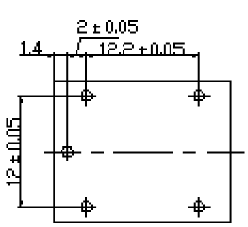
SRD	XX VDC	S	L	C
Model of relay	Nominal coil voltage	Structure	Coil sensitivity	Contact form
SRD	03、05、06、09、12、24、48VDC	S:Sealed type	L:0.36W	A:1 form A
				B:1 form B
		F:Flux free type	D:0.45W	C:1 form C

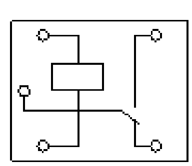
4. RATING

CCC	FILE NUMBER:CH0052885-2000	7A/240VDC
CCC	FILE NUMBER:CH0036746-99	10A/250VDC
UL /CUL	FILE NUMBER: E167996	10A/125VAC 28VDC
TUV	FILE NUMBER: R9933789	10A/240VAC 28VDC

5. DIMENSION(unit:mm) DRILLING(unit:mm) WIRING DIAGRAM







6. COIL DATA CHART (AT20°C)

Coil Sensitivity	Coil Voltage Code	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (Ω) ±10%	Power Consumption (W)	Pull-In Voltage (VDC)	Drop-Out Voltage (VDC)	Max-Allowable Voltage (VDC)
SRD (High Sensitivity)	03	03	120	25	abt. 0.36W	75%Max.	10% Min.	120%
	05	05	71.4	70				
	06	06	60	100				
	09	09	40	225				
	12	12	30	400				
	24	24	15	1600				
	48	48	7.5	6400				
SRD (Standard)	03	03	150	20	abt. 0.45W	75% Max.	10% Min.	110%
	05	05	89.3	55				
	06	06	75	80				
	09	09	50	180				
	12	12	37.5	320				
	24	24	18.7	1280				
	48	48	10	4500	abt. 0.51W			

7. CONTACT RATING

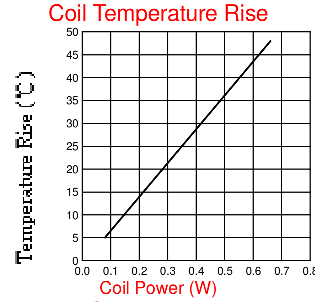
Item \ Type	SRD FORM C	SRD FORM A
Contact Capacity Resistive Load (cosΦ=1)	7A 28VDC 10A 125VAC 7A 240VAC	10A 28VDC 10A 240VAC
Inductive Load (cosΦ=0.4 L/R=7msec)	3A 120VAC 3A 28VDC	5A 120VAC 5A 28VDC
Max. Allowable Voltage	250VAC/110VDC	250VAC/110VDC
Max. Allowable Power Force	800VAC/240W	1200VA/300W
Contact Material	AgCdO	AgCdO

8. PERFORMANCE (at initial value)

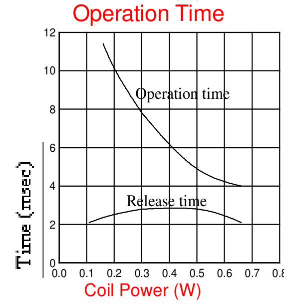
Item \ Type	SRD
Contact Resistance	100mΩ Max.
Operation Time	10msec Max.
Release Time	5msec Max.
Dielectric Strength Between coil & contact Between contacts	 1500VAC 50/60HZ (1 minute) 1000VAC 50/60HZ (1 minute)
Insulation Resistance	100 MΩ Min. (500VDC)
Max. ON/OFF Switching Mechanically Electrically	 300 operation/min 30 operation/min
Ambient Temperature	-25°C to +70°C
Operating Humidity	45 to 85% RH
Vibration Endurance Error Operation	 10 to 55Hz Double Amplitude 1.5mm 10 to 55Hz Double Amplitude 1.5mm
Shock Endurance Error Operation	 100G Min. 10G Min.
Life Expectancy Mechanically Electrically	 10^7 operations. Min. (no load) 10^5 operations. Min. (at rated coil voltage)
Weight	abt. 10grs.

9.REFERENCE DATA

Coil Temperature Rise

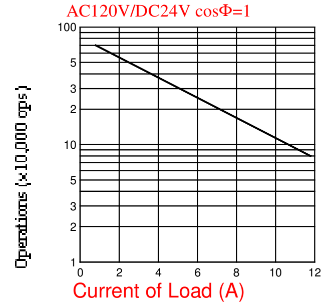


Operation Time

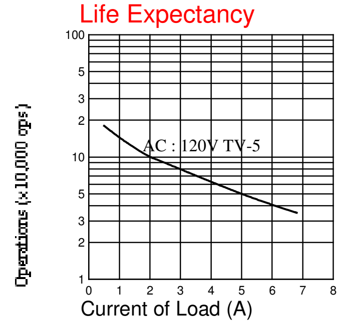


Life Expectancy

AC120V/DC24V cosΦ=1



Life Expectancy



松乐继电器 ® SONGLE RELAY	NingBo Songle Relay Co.,LTD.	SMIH

TUV File No.R9933789

1、SPST through DPDT contact arrangements.
2、5KV dielectric,coil to contact.
3、Standard type and plastic sealed type available.
4、High sensitivity type for low coil consumption is available.
5、For electrical device in control system,e.g heating controllers. servo motors,solenoid valves,lifting magnets etc.

♦COLL SPECIFICATION [at25degrees]

Coil Sensitivity	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (ohm±10%)	Power Consumption (w)	Pull-in Voltage (VDC)	Drop-out Voltage (VDC)	Max-Allow Able Voltage(VDC)
High Senstivity	3	120	17	abt 0.54w	75%Max	5%MIn	130%
	5	71	47				
	6	60	68				
	9	40	155				
	12	30	270				
	18	20	600				
	24	15	1100				
Standard Sensitivity	3	150	12.5	Abt 0.72w	75%Max	5%MIn	130%
	5	89	36				
	6	75	50				
	9	50	115				
	12	37.5	200				
	18	25	450				
	24	18.7	820				

♦CONTACT RATING

Contact Form	SPDT
Contact Capacity Resistave Load(cos∅=1) Inductiv Load(cos∅=0.4) L/R=7msec	16A 240VAC 16A 125VAC 5A 120VAC 5A 24VDC
Contact Material	AgCdo

♦NOTE: Contact rating 1:16A/240VAC

♦PERFORMANCE[at initial value]

Contact Rsistance	100 mhom Max
Operate time	15 msec. Max
Release time	10 msec. Max
Dielectric Strength Between coil & contact Between contacts	 5000VAC 50/60Hz(1min) 1000VAC 50/60Hz(1min)
Insulaton Resistance	100M ohm Min(500VDC)
Max. ON/OFF Switching Mechanically Electrically	 300 ops/min 30 ops/min
Operating Ambient temp	-30 to 70degrees
Operating Humidity	45 to 85% RH
Vibration Damage Limits Operating Extremes	 10 to 55Hz Double Amp.1.5mm 10 to 55Hz Double Amp.1.5.mm
Shock Damage Limits Operating Extremes	 100G 10G
Life Expectancy Mechanically Electrically	 1,000,000 ops. Min(no load) 100,000 ops. Min(at rated coil volt.)
Weight	abt.13grs

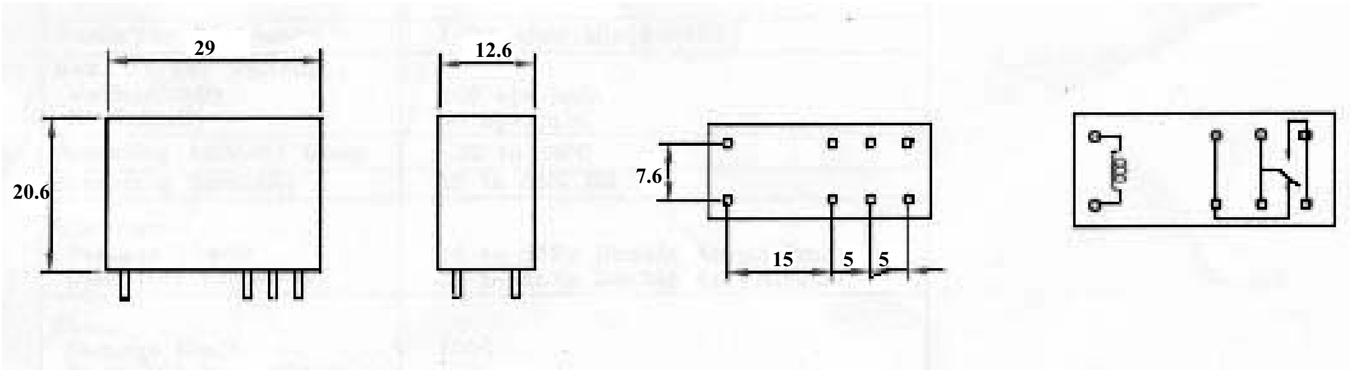
♦ORDER INFORMATION

SMIH — **12VDC** — **S** — **L** — **C**

Model of relay	Nminal coil voltage	Structure	Coil sensitivity	Contact form
SMIH	03,05,06,09,12,24VDC	S:Sealed type	L:0.54w	A: 1 form A
		F:Flux free type	D:0.72w	B: 1 form B
				C: 1 form C

SONGLE RELAY

♦OUT LINE DIMENSIONS [UNIT:mm] PCB LAYOUT[UNIT:mm] WIRING DIAGRAM



AC1020 • 20 Amp Current Transformer

Low Cost 50/60Hz Current Transformers

Applications

- Sensing Overload Current
- Ground fault detection
- Metering
- Analog to Digital Circuits

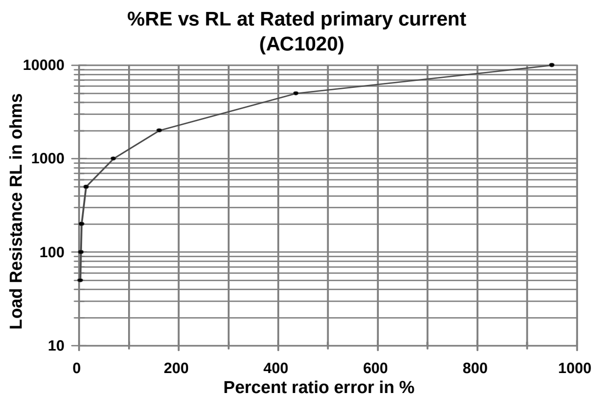
- Competitive pricing due to high volume production
- Manufactured in an ISO-9001:2000, TS-16949:2002 and ISO-14001:2004 certified Talema facility
- Fully RoHS compliant

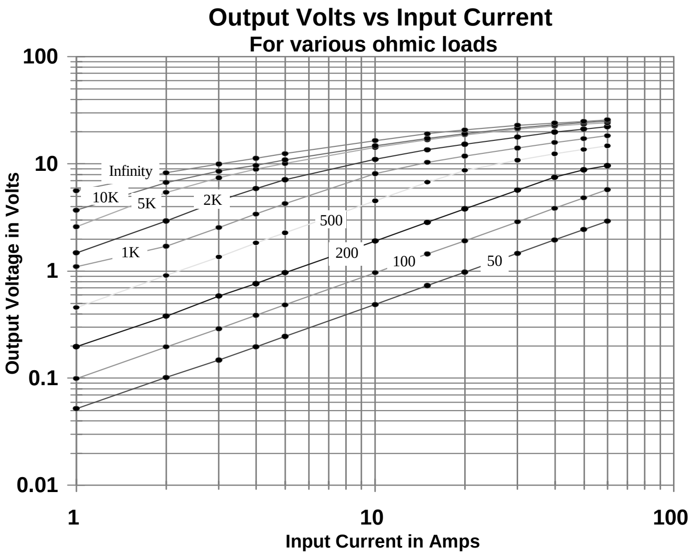
Electrical Specifications @ 20°C ambient

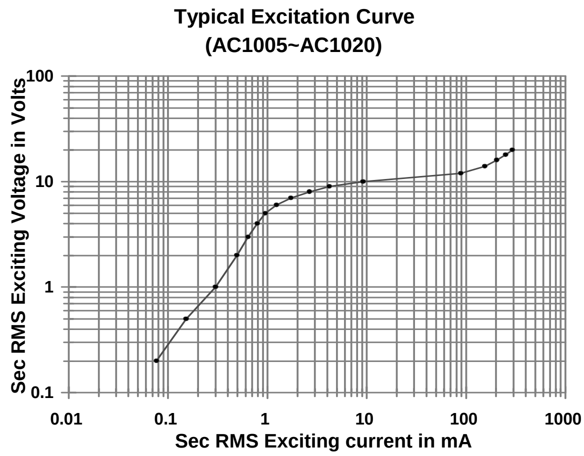
Electrical Specifications	
Primary Current	20A nom., 60 A max.
Turns Ratio	1000:1 nominal
Volt per Amp Ratio at 20A for 100 ohm load	0.100 V/A
Volt per Amp Ratio at 2A for 100 ohm load	0.097 V/A
DC Resistance at 20°C	41.8 ohms
Dielectric Withstanding Voltage (Hi-pot)	4KVrms

Mechanical Specifications	
Case	Polycarbonate
Encapsulant	Epoxy
Flammibility	Conforms to UL94-VO
Terminals	Pins Ø 0.80mm
Marking	TALEMA Date Code (W/Y) AC1020, Dot at start pin
Approximate Weight	16.3 grams
Tolerance	±0.2mm

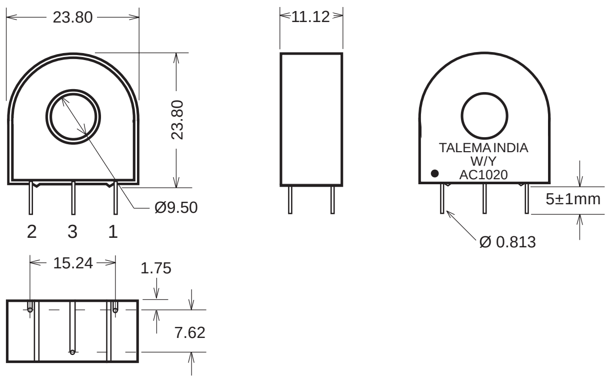
Environmental Specifications	
Storage Temperature	-55° to +130°C
Insulation Resistance	100 megohms min.





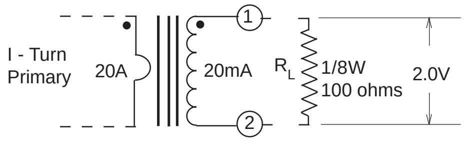


Dimensions



Notes:

1) Unless requested, the terminating resistor and the one-turn primary are not supplied
2) Pin 3: Normally for mechanical support only but will be used on center tapped designs



Model: SCT-013 **Rated input current: 5A/100A**

Characteristics: Openning size: 13mm*13mm,

Non-linerity±3%（10%—120% of rated input current）

1m leading wire, standard Φ3.5 three core plug output.

Current output type and voltage output type (voltage output type built-in sampling resistor)

Purpose: Used for current measurement, monitor and protection for AC motor, lighting equipment, air compressor etc

Core material: ferrite

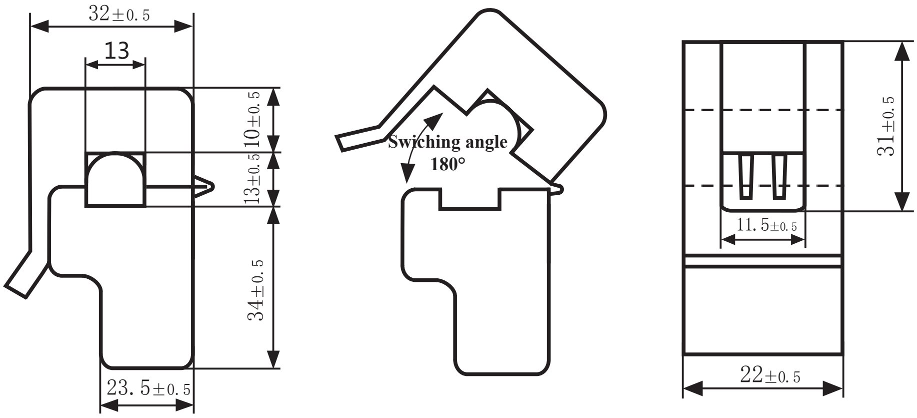
Mechanical strength: the number of switching is not less than 1000 times(test at 25℃)

Safty index: Dielectric strength(between shell and output)1000V AC/1min

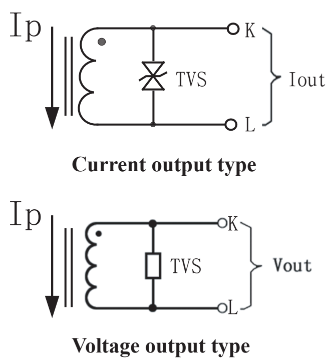
Fire resistance property: In accordance with UL94-Vo

Work temperature: -25℃～+70℃

Outline size diagram: (in mm)



Front View Side View



Schematic diagram

Three-core plug size

	X	Y	
2.5mm Audio Plug	11.9	2.5	Optional
3.5mm Audio Plug	15.0	3.5	standard

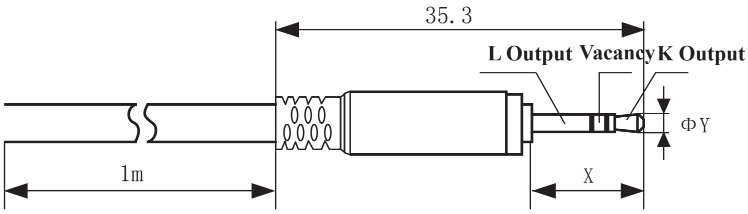


Diagram for standard three-core plug

Table of technical parameter:

Model	SCT-013-000	SCT-013-005	SCT-013-010	SCT-013-015	SCT-013-020
Input current	0-100A	0-5A	0-10A	0-15A	0-20A
Output type	0-50mA	0-1V	0-1V	0-1V	0-1V
Model	SCT-013-025	SCT-013-030	SCT-013-050	SCT-013-060	SCT-013-000V
Input current	0-25A	0-30A	0-50A	0-60A	0-100A
Output type	0-1V	0-1V	0-1V	0-1V	0-1V

※ Output type: voltage output type built-in sampling resistor, current output type built-in protective diode.

Tel: 86-13933609279 Fax: 86-7929499-804 skype:macymeng1
Web (China): www.yhdc.com Web (Latvia): www.yhdc.lv