

**RFID DOOR LOCK WITH REALIZATION OF  
INTERNET OF THINGS  
FOR SMART HOME SYSTEM**

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**UNIVERSITI SAINS MALAYSIA**

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**RFID DOOR LOCK WITH REALIZATION OF  
INTERNET OF THINGS  
FOR SMART HOME SYSTEM**

**by**

**ZAFIRAH BINTI ZAINON**

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for the degree of  
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#### LIST OF ABBREVIATION

IOT	Internet of Things
RFID	Radio Frequency Identification
RF	Radio Frequency
M2M	Machine-To-Machine

ROM	Read Only Memory
RAM	Random Access Memory
ARPANET	Advanced Research Projects Agency Network
TCP/IP	Transmission Control Protocol/Internet Protocol
USB	Universal Serial Bus
PCB	Printed Circuit Board
GUI	Graphic User Interface
ICSP	In-Circuit Serial Programming
LED	Light Emitting Diode
PIR	Pyroelectric (Passive) InfraRed Sensor
RTC	Real Time Clock
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
DC	Direct Current
PWM	Pulse Width Modulation
IDE	Integrated Development Environment
IFTTT	If This Then That
NFC	Near Field Communication

## **ABSTRAK**

Rumah adalah tempat yang paling selesa buat kita. Oleh itu, keselamatan rumah adalah amat penting supaya kita dapat hidup bebas dan bahagia. Kunci pintu pintar ini dibina bersama RFID dan IoT untuk memberikan keselesaan, utiliti dan keselamatan.

Projek ini direka untuk pelaksanaan rumah pintar kos rendah supaya semua lapisan masyarakat dapat memanfaatkannya. Sistem ini juga memudahkan penghuni rumah untuk mengesan jumlah keluar dan masuk dari rumah tersebut. Antara perkara yang penting dalam projek ini adalah membina sistem kunci pintu yang mesra pengguna dan juga modul pengawal utama. Kunci pintu pintar ini memerlukan akses Wi-Fi untuk berhubung dengan emel penghuni.

Sistem ini menggunakan Arduino Uno sebagai mikropengawal. Tag atau kad RFID akan dikesan oleh pengimbas RFID dan data akan dihantar ke emel pengguna. Jika kad tersebut telah didaftar, motor servo akan berputar 90° untuk membuka kunci. Jika tidak, servo motor akan kekal berada dalam keadaan statik.

## **ABSTRACT**

Home is the most comfort place for us. Therefore, a home security system is very crucial for us to live freely and happily. This smart door lock with RFID and IoT implementation is developed to bring convenience, utility and security altogether.

Nowadays, the wireless communication are more towards low cost and low power consumption. Therefore, this project is designed for low cost smart home implementation as it is more affordable to the society. This system made easier for home occupant to track record of check-in and check-out of the house. There are two important parts in this project that need to be developed which are user friendly smart door lock system and main controller module. The smart door lock will require Wi-Fi access to communicate with the home occupant emails'.

The system will be controlled using the Arduino Uno microcontroller board. RFID tag or card will be sensed by the RFID reader, then the data is transmitted to the home occupant emails'. If the RFID tag or card bypass the reader, the reader will grant access and the servo will turn 90° to unlock the door. However, if the detected tag or card is not being approved by the reader, it will deny the access and stay initially static.

# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

Home is everyone's most important place. Home is the place where we feel the comfort and relaxing to stay in. Smart homes, on the other hand, are meant to provide good degree of functional automation which are expected to provide higher level of living comfort [11]. Home basically consists of numerous number of items that are expensive or priceless for us. Even though the financial loss may be covered by insurance, but the emotional consequence can leads us to trauma. Because this can be any time of burglary target, we must ensure our dear ones and house are always in secure and safe to live in.

According to the statistic, in the first quarter of this year (2016) there are 6662 cases of properties break ins [1]. The number of home burglaries is increasing throughout this year. This is mainly because today's criminals are able to pick locks and outsmart the home security systems [1]. Even though home with installed security system can be hacked by the intruders, so, home without any security system are more likely to be the target of incident. Security system can be very costly, but the loss of our belongings and family life are more priceless. The existing products such as Kaba Ilco Solitare Electro 850 [24] and Saflok MP2E MP2 RFID Contactless Lock [22] have their own added values but somehow those products are quite pricey and rarely to be found in Malaysia.

Therefore, to keep everything safe and under control, we may need to come out with better solution which is a smarter and cheaper smart home system for security and convenient to be used in every home. Smarter means that we can detect the entrance, movement and the changing activities and alarm both the away user and residents of any intruder or danger. Also, it will require RFID tag to identify the user and thus unlock the door. This smart home system basically consists of three different components which are home server, home gateway and smart home devices [5]. The server will provide storage, integration and distribution of the information collected. Next, the gateway is used to interconnect the access network and home network. Lastly, the devices will interact among them and external internet access function [5]. The advantage of having a gateway is that all configurations are done on a single device [12].

This project is mainly to provide a secure and affordable smart home security system. A home security system should provide security and safety for a home by alarming the residents from natural disaster, accidental or intrusion [4]. It started from the first step just before we enter the house, the door lock will require RFID recognition to avoid trespassing and intrusion. When somebody is entering the house, it will notify the user through the IoT. The ESP8266 Wi-Fi serial transceiver will send email to the home occupants.

## 1.2 Problem Statement

To catch up the enhancement of technology development, we must improve our surrounding be it the security side or the convenient and efficiency side. Imagine living in a house with a smart door lock, one that you use your personal verification to unlock it, or you shall give voice command and the smart home devices will execute the command. For instance, it can be said that smart home can really improve our lives.

Due to expansion of technology, we need to upgrade the traditional key to keyless RFID door lock. This can brings more convenient to user which are faster and easier to unlock the door.

Next, we need to detect early stage or emergency especially when we are away from home. In the research investigated by Gyanendra [7], it only implements RFID in the door lock system which is good in terms of keyless security identification but unable to inform home occupant of any emergency or intrusion.

Lastly, most available smart home systems are extremely expensive. This is mainly because, it is not yet commonly exposed throughout the world. It is a new kind of technology where the sources and products are still limited to users.

### **1.3 Objectives of Research**

In order to design the keyless smart door lock that connect with user via IoT, the following objectives need to be achieved:

1. To develop a keyless smart door lock using RFID
2. To develop a smart home security system that connect the device with the user through IoT.
3. To optimize the design making it more affordable and user friendly as it will send notification to user emails'.

### **1.4 Scope of Research**

The scope of this research is to develop a low cost smart home security system which connect user with the smart door lock. The project consists of hardware and software implementations. Arduino Uno has been used as the microcontroller with few other main components which are MFRC522 RFID reader, ESP8266 Wi-Fi transceiver and Power HD-3001HB servo motor. The software application used to program the hardware components was Arduino IDE. We also used commercially available software to send the email which is IFTTT and ThingSpeak to measure the data of the ESP8266 signal level. The design specifications of this project are low cost and user friendly. The project will not exceed the budget limit which is RM200 and the project should connect with user existing emails' so that user will not require to install additional application for the notification. The resulting product shall be an affordable and easy to find in our country.

## **1.5 Thesis Outline**

This project has been organized into five chapters including the first chapter which presents a brief introduction.

Chapter 2 will cover the literature review of the existing research on the smart home technology in IoT, RFID, and the communication system. The comparison between RFID, NFC, Bluetooth and Wi-Fi is also discussed here.

Chapter 3 briefly describes the overall methodology of this project. It includes all the project implementation and requirements which are flow chart, pictorial diagram, hardware developments and software developments.

Chapter 4 dominantly explained and discussed the overall results of this research project. This includes the results for both hardware and software systems.

Chapter 5 will sum up this project with summary, achievements, limitations and recommendations for the future improvement.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter will describe anything related to the smart home system including the Internet of Things (IoT), Radio Frequency Identification (RFID), Near Field Communication (NFC), Bluetooth, Arduino and few existing products in the market to be compared.

#### **2.2 Internet of Things (IoT)**

##### **2.2.1 Introduction to Internet**

The Internet has tremendously impacted the world with its evolution. From connecting the remote computers through ARPANET, the introduction of TCP/IP protocol suite and the introduction of services like email and the World Wide Web (WWW) had extremely growth in terms of usage and traffic [14].

IoT can be defined as a set of technologies, systems and design principles associated with the emerging wave of Internet-connected things that are based on the physical environment [14]. IoT products can be classified into several categories which are: smart wearable, smart home, smart city, smart environment and smart enterprise [6]. A smart home system with IoT (Internet of Things) is

mainly connecting all the smart devices and users together through a network. Things will have more data and information associated with them and have the ability to communicate, produce information and become the integral part of World Wide Web [3]. The growth of smart home products increase the expectation of tomorrow's world. IoT offer specific object identification, sensor and connection capability as the basis for the development of independent cooperative services and applications [8].

This project is based on the Internet of Things (IoT) which consist of few main features which are linking physical and virtual objects, object identification, autonomous data capture and identification, communication, network connectivity, federation, global network infrastructure [2]. IoT is the network of things which connected to a network path to enable communication. The interconnection can be either hardware, software or any sensor. By connecting such devices, an intelligent and invisible network is created and available to access through the cloud [12]. The IoT system architecture is generally divided into three layers: the perception layer, the network layer and the application layer [8]. All the data and information obtained within IoT are stored in the cloud computing.

### **2.2.2 Cloud Computing**

Cloud computing is the delivery of on-demand computing resources from applications to data centers [13]. It can share resources, software and information to computers and other devices over the Internet [4]. Apple iCloud, Google Drive and Dropbox are the examples of this cloud computing. Cloud computing provides users with data storage and processing capabilities through the Internet. It is very practical as user can access the document saved anywhere and from any device as long as there is Internet connection. User will need to login to the provider's account for authentication.

## **2.3 Wireless Communication**

### **2.3.1 Introduction to Wireless Communication**

Today, wireless communication is one of the fascinating topic in this entire world. It permits user to communicate even from remote operated areas. The mobile telecommunication providers are competing among themselves from the first generation cellular system (1G), the second generation (2G), third generation (3G), to the existing fourth generation wireless system (4G), and now we have the upcoming advancement of wireless technology which is the fifth generation wireless system (5G) [26]. This improvement is needed in order to cater the increasing number of consumers and devices throughout the world.

### **2.3.2 Types of Wireless Communication**

Wireless communication can be varies from Infrared (IR) communication, satellite networks, broadcast radio, microwave radio, Bluetooth, ZigBee and low power wireless communication, the Wireless Fidelity (Wi-Fi).

Wi-Fi often used in our electronic devices to connect us with the world of Internet. Wi-Fi requires a router as a communication hub. Users can only connect within close proximity to router. Some advantages of Wi-Fi are easy for installation and high speed.

### **2.3.3 Radio Frequency Identification (RFID)**

Radio Frequency Identification (RFID) is a basic and inexpensive tracking technology that enable wireless data transmission [7]. It is a secured and efficient technology compared to other available networks. It can identify objects wirelessly without line-of-sight. RFID system is basically consist of a reader and tag. The tag, or the transponder is used to identify the user as it comes with its own unique ID. RFID is used in this project in order to authenticate and validate the user and automatically unlock the door [7]. Unique ID can be saved in the microcontroller for future recognition and to differentiate existing tag or intruder's tag. It also keeps the record of check-in and check-out of the user. The invention of RFID made security goes to the higher level as it offers security with a very little cost.

### 2.3.3.1 MFRC522 RFID Reader

The function of a reader, which is also known as transceiver is to activate the tags, structure the communication sequence with the tag and transfer data between the application software and tags [8]. Figure 2.1 shows the physical of MFRC522 RFID reader which is used in this project whereas Figure 2.2 illustrates the pin configuration of the reader.

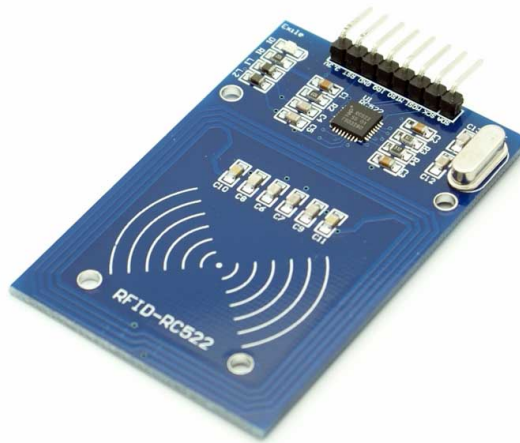


Figure 2.1: RFID Reader

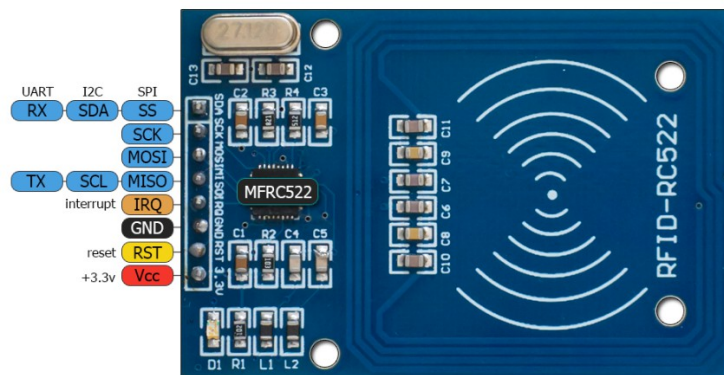


Figure 2.2: MFRC522 Pin Configuration

### 2.3.3.2 RFID Tag and Card

RFID tag is basically consist of unique ID which identify the owner of the tag. All RFID tags have the following essential components in common: antenna, integrated circuit and printed circuit board [8].

There are two types of RFID tags available in the market which are active tag and passive tag. Basically, active tag is a tag that contains its own power source meanwhile the passive tag is powered up by the radio frequency (RF) scan of the reader.



Figure 2.3: RFID Tag and Card

Figure 2.3 above are the devices used to complement the RFID reader. They operate at 13.56GHz frequency. For the card, the operating distance is 4cm whilst the tag operates at 2cm.

#### **2.3.4 Near Field Communication (NFC)**

Near Field Communication (NFC) is not something new in the technology industry. It operates at the same frequency (13.56MHz) as RFID readers and tags [16]. It is commonly used in smartphone to communicate with the NFC reader for contactless transaction. NFC also allows two devices to share information like contact details, photos or files. However, one of the devices must have Internet connectivity in order to perform the action.

#### **2.3.5 Bluetooth**

Bluetooth can also be used to send and receive signal to the system as it is based in wireless communication. It creates Personal Area Network (PAN) with high levels of security [19]. In order to operate Bluetooth the sender and receiver must be made of two compatible devices. The connection of Bluetooth seem to have such limitation of limited access range [4].

### 2.3.6 Wireless Local Area Network (WLAN)

WLAN is usually privately owned to connect some hosts in a single building. Each host in WLAN has an identifier and address. WLAN is a LAN connected to a router to expand the connection. This resulting the Wi-Fi which we are more familiar with.

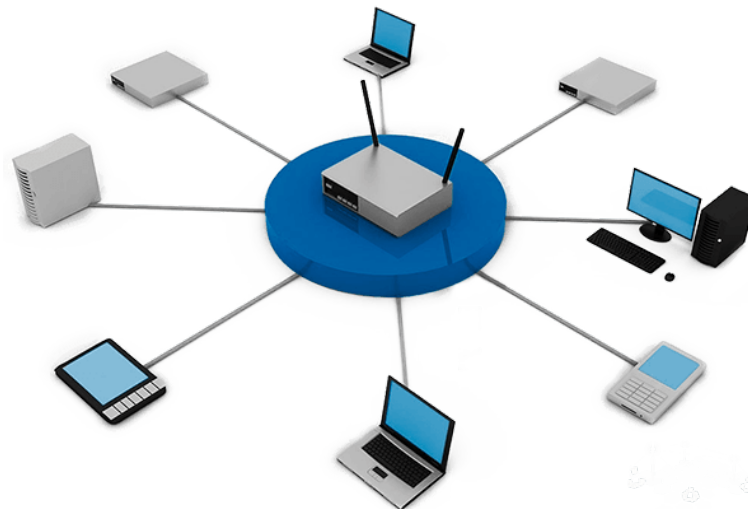


Figure 2.4: Wireless Local Area Network

### 2.3.6.1 ESP8266 Wi-Fi Serial

ESP8266 is most commonly used Wi-Fi transceiver. It is a highly integrated chip designed to enable the enhancement of technology for the new connected world. The device was developed with on-board processing and storing capabilities that allow it to be integrated with other application specific devices such as sensors through its GPIO pins. Attention (AT) commands can be used to connect to Wi-Fi networks and open TCP connections without running TCP/IP stack.

Figure 2.5 shows the physical of ESP8266 Wi-Fi Serial.

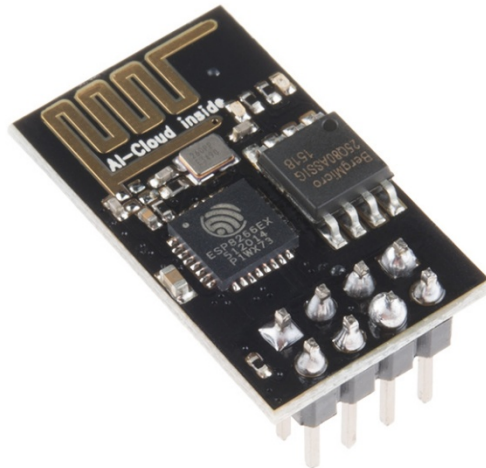


Figure 2.5: ESP8266 Wi-Fi Serial

ESP8266 Wi-Fi Serial consists of eight pins. Table 2.1 below describes the pin diagram of the device.

Table 2.1: The pin diagram description of ESP8266

<b>Label</b>	<b>Description</b>
VCC	3.3V power supply
GND	Ground
TX	Data transmission
RX	Data receiving
CH_PD	Chip power down (active LOW)
GPIO0	General purpose I/O 0
GPIO2	General purpose I/O 2
RST	Reset (active LOW)

### 2.3.7 Difference between RFID, NFC, Bluetooth and Wi-Fi

Table 2.2 compares the data of different types of wireless communication available these days which are RFID, NFC, Bluetooth and Wi-Fi. As we can see, the RFID can only connect in 1 way direction, this is why we need to have separated devices for RFID which are the transceiver and the transponder.

Table 2.2: The difference between RFID, NFC, Bluetooth and Wi-Fi [20]

<b>Specification</b>	<b>RFID</b>	<b>NFC</b>	<b>Bluetooth</b>	<b>Wi-Fi</b>
Maximum coverage range	3m	10cm	100m	100m
Frequency of operation	Varies	13.56MHz	2.4GHz	2.4GHz, 5GHz
Communication	1 way	2 way	2 way	2 way
Data rate	Varies	106, 212, 424Kbps	22Mbps	144Mbps
Application	Tracking system	Credit card payment	Communication between telephone and peripherals	Wireless Internet

## 2.4 Microcontroller and Microprocessor

### 2.4.1 Microcontroller

A microcontroller is a complete system on a single chip. It is like any computer, consist of Read Only Memory (ROM), Random Access Memory (RAM), Timers, Input-Output (I/O) ports and peripherals embedded in a single chip. It is a specially designed microprocessor for control application [15]. Microcontroller is using Harvard architecture which program and data are stored in separate memory [17]. Microcontrollers are widely used in washing machine, microwave, car and telephone. Researchers often prefer microcontrollers for embedded systems.

### **2.4.2 Microprocessor**

Microprocessor is an electronic chip that operate as the central unit processing (CPU) of a computer [15]. It has no internal memory and input/output ports. The ROM, RAM and I/O ports are added externally to the chip. It is generally used in unspecific application like games, photo editing and developing software [18]. They demand for high amount of resources like the memory and I/O ports [18]. Different from microcontroller, microprocessor is using Von Neumann architecture which only consist of one bus. This bus is used for both data transfer and instruction fetches.

### **2.4.3 Arduino UNO**

Arduino is open source AVR microcontroller board based on the ATmega328. The board consists of 16 MHz ceramic resonator, 14 digital

input/output pins, 6 analog inputs, a USB connection, a power jack, an ICSP header and a reset button. The input voltage for Arduino Uno is 5V from the USB adapter. However, in order to permit the stability of the board, the power supply should be between 7V to 12V. On the other hand, if it exceeds 12V, the microcontroller board might be damaged due to voltage overload.

This board does not use FTDI USB-to-serial driver chip but it has Atmega16U2 programmed as a USB-to-serial converter. It has its own programming open source software named Arduino IDE. This software use C language. Figure 2.6 shows the physical of Arduino Uno.

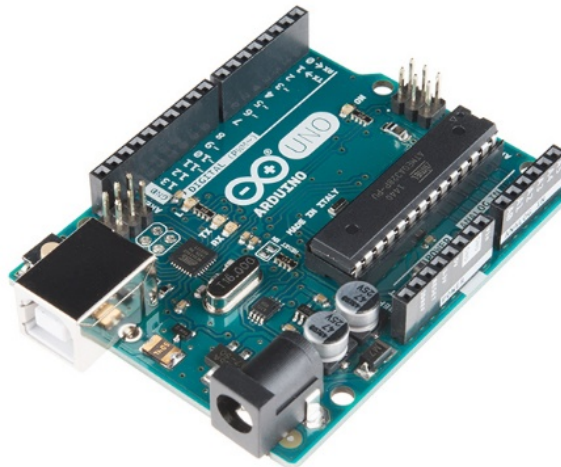


Figure 2.6: Arduino Uno Microcontroller Board

Figure 2.7 below shows further details of the specific configuration of Arduino Uno.

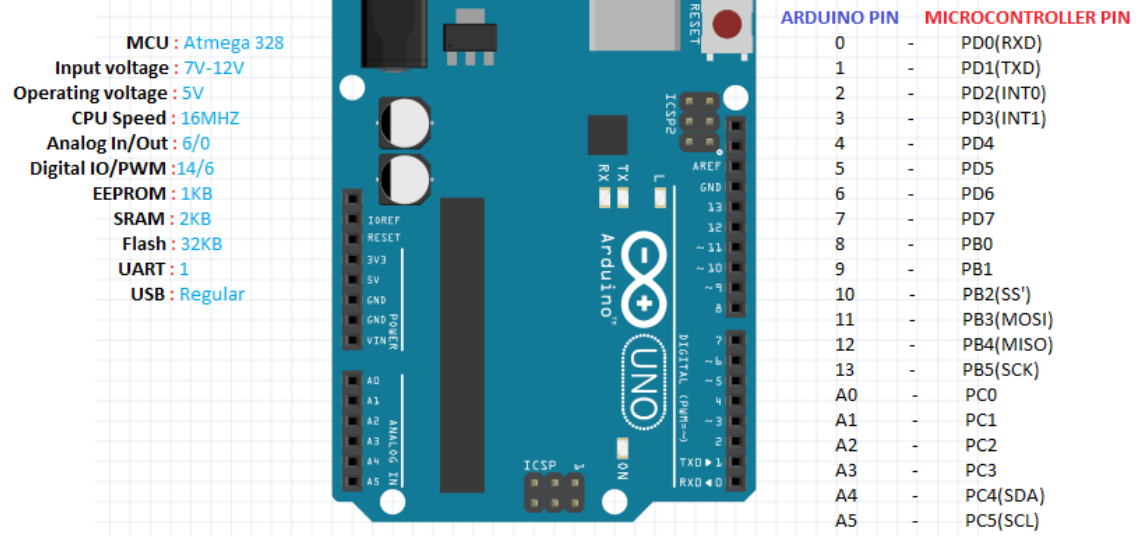


Figure 2.7: Arduino UNO Pin Configuration

Table 2.3 indicates the specification of Arduino Uno.

Table 2.3: Arduino UNO Specifications

<b>Microcontroller</b>	ATmega328
<b>Operating Voltage (OV)</b>	5 V
<b>Recommended input voltage</b>	7 V to 12 V
<b>Limit of input voltage</b>	6 V to 20 V
<b>Digital I/O Pin</b>	14 ( of which 6 provides PWM output )
<b>Analog Input Pin</b>	6
<b>DC Current per I/O Pin</b>	40 mA
<b>DC Current for 3.3V Pin</b>	50 mA
<b>Flash Memory</b>	32 KB (ATmega328) of which 0.5 KB used by boot loader
<b>SRAM</b>	2 KB (ATmega328)
<b>EEPROM</b>	1 KB (ATmega328)
<b>Clock Speed</b>	16MHz
<b>Length</b>	68.6mm
<b>Width</b>	53.4mm
<b>Weight</b>	25g

## 2.5 Power HD-3001HB Servo Motor

In this project, we were using HD-3001HB servo motor in order to lock and unlock the door. This servo motor operates at 6V supply voltage. The stall torque of

this servo motor is 4.4kg/cm, which is enough to rotate the aluminum blade attached to it.



Figure 2.8: Power HD-3001HB Servo Motor

Table 2.4 below describes the further specification of HD-3001HB servo motor:

Table 2.4: Power HD-3001HB Servo Motor Specification

Specifications	
Modulation	Analog
Weight	43g
Dimension	40.7 x 20.5 x 39.5mm
Supply voltage	6V
Stall Torque	4.4kg/cm
No load running speed	0.12sec/60°
Storage Temperature	-20°C~60°C
Dead bandwidth	≤4us

## 2.6 Comparison to Existing Products

There are few similar products in the market today. In this project, we chose Kaba Ilco Solitaire Electro 850, Saflok MP2E MP2 RFID Contactless Lock and another no-brand RFID door lock to compare due to their similarities.

Kaba Ilco Solitaire Electro 850 is featuring with tamperproof design. It comes with emergency keycard, mechanical key and electronic override. It can

audit trail record up to 360 lock transactions. It is retails for RM2007.90 with shipping charge and extra 7% tax will be applied during checkout [24].

Saflok MP2E MP2 RDID Contactless Lock can accepts up to 16 keycard types which are 14 for access and another two for programming including Master, Guest, Alternate Guest, and Emergency [22]. This product retails for RM1610.69 and the administer system cost RM10638.54. It can audit trail record up to 5900 lock transactions.

The no-brand RFID is door lock is built in metal case which is waterproof. It only retails for RM375.65. The user capacity can be up to 15000 users. It contains Weigand 26 output port which enable us to add extra RFID reader [23]. However, the reliability of this product is doubted because it is meant for hobbyist do it yourself (DIY) kit rather than real home usage.

Table 2.5 below shows the main details of few existing similar products comparison.

Table 2.5: Comparing to existing products sold over the Internet

Product	Price in US\$	Price in RM	Pros	Cons
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 <p>Kaba Ilco Solitaire Electro 850 [24]</p>	<p>US\$395 + US\$75.11 shipping charge</p>	<p>RM1687.10 + RM320.80 = RM2007.90</p>	<p>-Reliable -Audit trail record for last 360 lock transaction</p>	<p>-Expensive -7% tax applied</p>
 <p>Saflok MP2E MP2 RFID Contactless Lock [22]</p>	<p>US\$377.11 + Key management administer System 6000 US\$2491</p>	<p>RM1610.69 + RM10638.54 = RM12249.23</p>	<p>-Reliable -Audit trail record for last 5900 lock transaction</p>	<p>-Too expensive</p>
 <p>No Brand RFID Door Lock [23]</p>	<p>US\$87.95</p>	<p>RM375.647</p>	<p>-Cheap -Weigand 26 output ports ( can add many RFID readers )</p>	<p>-Not reliable</p>

Table 2.5 shows the differences between existing products that have been well researched. Kaba Ilco Solitaire 850 is the most ideal door lock due to reliability and moderate price. However, the aim of this project is to ensure all level of consumers are afford to install the smart door lock at home. Therefore, we must come out with a cheaper and reliable solution. This RFID door lock is not just