JUNE 2018 M.Sc. in Electrical and Electronics Engineering OSAMA SAADI ALSAMRAI

**UNIVERSITY OF GAZİANTEP**

**GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES**

# DEVELOPMENT OF MONEY COUNTING MACHINE BY ARM BASED MICROCONTROLLER

**M.Sc. THESIS**

**IN**

**ELECTRICAL AND ELECTRONICS ENGINEERING**

**BY**

**OSAMA SAADI ALSAMRAI**

**June 2018**

# Development of Money Countıng Machıne by ARM Based Mıcrocontroller

**M.Sc. Thesis**

**in**

**Electrical and Electronics Engineering**

**University of Gaziantep**

**Supervisor**

**Prof. Dr. Ergun ERÇELEBİ**

**by**

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**June 2018**

REPUBLIC OF TURKEY
UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
ELECTRICAL AND ELECTRONICS ENGINEERING

Name of the thesis: Development of Money Counting Machine by ARM Based Microcontroller
Name of the student: Osama Saadi ALSAMRIA
Exam Date: 18/06/2018
Approval of Graduate School of Natural and Applied Sciences

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This is to certify that we have read this thesis and that in our consensus; it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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**Osama Saadi ALSAMRAI**

# ABSTRACT


**DEVELOPMENT OF MONEY COUNTING MACHINE**

**BY ARM BASED MICROCONTROLLER**

**ALSAMRAI, Osama Saadi**

**M. Sc. in Electrical and Electronics Engineering**

**Supervisor: Prof. Dr. Ergun ERÇELEBİ**

**June 2018**

**68 Pages**

The money counting machine (MCM) is one of the miracles of the science. The different techniques have been used to design and develop a currency counting machine up to a high-level currency counting machine, which uses image processing to detect the currency type of the currency counter from the normal-type currency counting machine. These machines can detect both very fake money and can operate at high speed. These devices are quite expensive. This is why it is used in commercial areas such as banks, foreign exchange bureaus, and markets. However, with the recent development of microprocessor technology, improvements have been made to the design of these currency counting machines. In this thesis, the design and realization of money counting machine which both counts the money of different currencies and determines the fake money has been aimed. ARM Cortex-M4 based 32-bit teensy microcontroller has been used in the design of the currency counting machine. The developed MCM contains three sensors. Each one has certain action. Firstly, infrared sensor has been used to start and stop the machine. Secondly, ultraviolet sensor has been utilized to detect fake money. Finally, laser transmitter and receiver circuits have been used to count each currency pass through them.

The mechanical parts that consist of the roller which has rods in a continuous pattern and the roller move these rods with a particular fixed speed. The count result is displayed to the user using seven-segment LEDs. If the machine detects the counterfeit money, it automatically stops. The results are quite satisfactory. The developed machine counts money with high accuracy and high accuracy.



**Key Words:** Currency counter, Teensy 3.2 microcontroller, Cash validation, ARM Cortex M4, Fake Note Detection.

# ÖZET


**ARM TABANLI MİKRODENETLEYİCİ İLE PARA SAYMA MAKİNESİNİN GELİŞTİRİLMESİ**

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**Haziran 2018**

**68 Sayfa**

Para sayma makinesi (MCM), bilimin mucizelerinden biridir. Farklı teknikler, normal tipteki para sayma makinesinden para cinsinin türünü tespit etmek için görüntü işlemeyi kullanan, yüksek seviyeli para sayma makinesine kadar para sayma makinesinin tasarlanması ve geliştirilmesi için kullanılmıştır. Bu makineler hem miktarı çok sahte parayı tespit edebildiği gibi hem de yüksek hızda çalışabilirler. Bu cihazlar oldukça pahalıdır. Bu yüzden bankalar, döviz büroları ve marketler gibi ticari alanlarda kullanılır. Ancak, son zamanlarda mikro işlemci teknolojisinin gelişmesi ile bu para sayma makinelerinin tasarımda iyileştirmeler yapıldı. Bu tezde, farklı para birimlerinin parasını sayan ve sahte parayı tespit eden para sayma makinesinin tasarımı ve gerçekleştirilmesi amaçlanmıştır. Para sayma makinesinin tasarımında ARM Cortex-M4 tabanlı 32-bitlik Teensy mikro denetleyicisi kullanıldı.

Geliştirilen MCM üç sensör içerir. Her birinin belli bir eylemi var. İlk olarak, makineyi başlatmak ve durdurmak için kızılötesi sensör kullanılmıştır. İkincisi, sahte parayı tespit etmek için ultraviyole sensörü kullanılmıştır. Son olarak; lazer alıcı ve verici devreleri, üzerlerinden geçen her bir para birimini saymak için kullanılmıştır.

Sürekli bir modelde çubuklar bulunan merdaneden oluşan mekanik parçalar ve makara, bu çubukları belirli bir sabit hız ile hareket ettirir. Sayım sonucu yedi parçalı LED'lerde gösterilir ve sistem herhangi bir sahte not tespit edilirse saymayı durdurur. Sonuçlar, sayma ve sahte tespitte yüksek doğrulukta (% 100) nispeten yüksek hızlı sayım gösterir. sayım sonucu yedi parçalı LEDs kullanılarak kullanıcıya gösterilir. Makine sahte parayı tespit ederse otomatik olarak durur. Sonuçlar oldukça tatmin edici bulunmuştur. Geliştirilen makine yüksek hızla yüksek doğrulukla paraları saymıştır.



**Anahtar Kelimeler:** Para sayacı, Teensy 3.2 mikro denetleyici, para doğrulama, ARM Cortex M4, Sahte para tespiti.

*“To my Family  and Close Friends”*

## ACKNOWLEDGEMENTS

First of all, I thank Allah for having given me the strength to carry on this project and for blessing me with many great people who have been my greatest support in both .my personal and professional life

A sincere gratitude and appreciation goes to my supervisor, Prof. Dr. Ergun ERÇELEBİ for his knowledge, advice and support throughout my studies. A big thank you to all members of electric electronic engineering group past and present, .whom I was fortunate enough to work with

A special thanks must go to my friends (Khaled,Abdulrhman,Omar,Ivin,Worod,Asmaa,Ahmed) for their support and advice to me and thanks must go to my friends in Turkey and Iraq for their everlasting .friendship

Above all I thank my family (father, mother, brothers and sisters waives brother) who are the most important part of my life, who have always being there for me in all difficult circumstances, for their love, moral support, encouragement and .continuous prayers, for their faith in my ability during my experience in Turkey

This thesis dedicated to those most dear to me- my beloved family

# TABLE OF CONTENTS

Page

# LIST OF FIGURES

# LIST OF TABLES

**Page**

# LIST OF SYMBOLS / ABBREVIATIONS

| | |
|---|---|
| **MCM** | Money Counting Machine |
| **MCU** | Microcontroller unit |
| **ARM** | Advanced RISC Machine |
| **UV** | Ultraviolet |
| **AC** | Alternating Current |
| **DC** | Direct Current |
| **PCB** | Printed Circuit Board |
| **ATM** | Automatic Trailer Machine |
| **IDE** | Integrated Development Environment |
| **IC** | Integrated Circuit |
| **IR** | Infrared |
| **LED** | Light Emitting Diode |
| **LCD** | Liquid Crystal Display |
| **TTL** | Transistor-Transistor Logic |
| **I2C** | the Inter-Integrated Circuit |
| **I/O** | Input/output |
| **CPU** | Central processing unit |
| **EEPROM** | Electrically erasable programmable read-only memory |
| **KHz** | Kilohertz |
| **S** | Second |
| **SPI** | Serial Peripheral Interface |
| **SRAM** | Static Random-Access Memory |
| **USB** | Universal Serial Bus |
| **V** | Volt |
| **Ω** | Ohm |

| | |
|---|---|
| **µf** | Microfarad |
| **A** | Ampere |
| **FND** | Fake Note Detection |
| **CCM** | Currency Counting Machine |

# CHAPTER 1
# INTRODUCTION

## 1.1 General Introduction

A Money Counting Machine (MCM) is a machine that counts the money either piles of currencies or loose sets of money. It not only counters, but it also works as counterfeit currencies detector with the advanced available printing, copying, and the scanning technologies that available today. These machines are available as either completely mechanical machines or electronic machines [1]. Technological evolution is evidently visible nowadays. It can be seen on the different machines and devices that are used from the past to the present. Manual operations are gradually omitted by technological means [2].Counting machines have various types such as intelligent counting cum, Basic Note Counter, Hi-Speed Heavy Duty, and Counterfeit Detection Machines. They Cash counting machines, to the appropriate type of customers are available. Ideal and dependable are for small business houses, Retailers, Traders as well as jewelers. According to their suitability, all the types of business establishment can be used [3].

It, the first machine recorded for money counting, was invented in (1958) in China and fabricated by a minor banker (Zhi Tian Sie) who participated in the competition. A 3rd place was won by him. Zhi left the life at the age of 30 and model of him was lost until rediscovered by the EPR in the time tearing down his house. The machines that are modern counting in the developed technology are used by the Machine of Tokyo for counting the works of Shinagawa and they are entered in (1962). The markets for increased accuracy and speed were quickly dominated [1]. Edgar Bass who went on to create the universal company Teller mate invented this technology in 1979[5]. In 1981, they introduced computerized friction money counters the shape of the High-Speed machine which is called (REI), which speeder currency counting to Reach about 72,000 currencies per hour in addition, eliminating the need for manual separation and counting fully. It could be sort currencies, namely innovative Sorter

machine, according to the value of them and heavily damaged notes or even remove counterfeit [4].

In today's currency counting machines, various features are shown. Some of them can detect money security characteristics like ultraviolet inks, note density, magnetic inks and magnetic strip etc. There are various features that can make everyday contact facilitated due to identifying damaged and counterfeit currencies [5].There are various features that can make everyday contact facilitated. By cash can also be presented. The systems of electronic counting, without moving parts, are able to count all currencies; sum the value of all denominations counted and coins on the same machine. To count personal deposits or even of the cash drawers, they are generally used. They check for counterfeit, sort or even damaged Cush. It is used an LCD display with a backlight by the machine in order to the whole amount of the notes is clarified [6].Here, some cash counters cannot examine in a separate manner each coin or note, but it works by utilizing calibrated load cells in order to coin at a time or assess a number of notes and utilizing a steady updated and stored average weight determine the pieces number. They use machines in complex algorithms to know about the variation in the condition of the money arising from, humidity, and production variances [5].

The counters of electronic cash are designed in a small size, silent, battery made accurately and fast. The desktop counters were used by bank treasurer in order to control withdrawals or by dealers to count notes from money registers. We have to keep in mind that by model, their capability can be varied to count both notes and coins and in order to control standard bank packages or even for rolls of money to ensure the right manner. Counterfeiting is considered old like currencies, and it is rife everywhere many ages, in addition, it was named the world's second oldest vocation [5,6].It is known that in Greek city of Lydia around 600 B.C., Coinage of currency had started. Before producing the paper money, the famous one of the method of counterfeiting is involved mixing metals that are base with pure silver or even gold. A common practice was "pruning" the rims of the currency. It is famous for "clipping." The expensive minerals are collected like that and they can be used to manufacture fake coinage. An ancient type of fake coin is a fourteen in which a mineral core, that is based has been painted with mineral that is precious to look like its solid mineral counterpart [8].

In China, in the 13th century in the time paper money was produced, the wood of mulberry trees was made to prepare money. By checking arrival to the paper, the Sentinels there had been centralize around the forestry of mulberry, however; counterfeiters were punished by death [9]. Figure 1.1 shows the currency-counting machine for small business.

**Figure 1.1** money-counting-machine-for-small-business

Recently in the twentieth century, the evolutions in photocopy technology and computer were made it easy for people without developed practicing to duplicate currency in an easy manner. In responding, the engraving bureaus that is national started to implement new more developed systems of anti-counterfeiting like, multi-colored bills, holograms, devices that are embedded such as, micro printing, strips, inks and watermarks that has colors can be changed based on the angle of the light, in addition to using design features as the "Elution" that disables new photocopiers. The programs of Software like Photoshop have been sophisticated by the manufacturers of them to block manipulation that are scanned of currencies [10].There are also existed specks to counteract then, namely, procedures. Lately, a find of modern tests was made on U.S. federative reserve money to certain the bills that are authentic. They are done by utilizing fluorescence lifetime that described as

intrinsic. That makes it easy for detecting counterfeit money due to the significance in several of fluorescence lifetime at the time it is compared to money authentic [5].

By sophisticating printing methods for fake currencies became on par in addition to the initial currency. The urgent need is to validate currency authenticity that increased in a dramatic manner, rising demands for constant improvement towards counterfeit detection technologies. The processes were made to use (UV) detection that stands for Ultraviolet. The UV is based on the principle of detecting special types of inks that can be visible under the (UV) light. The motion that can be described as the auto is given by utilizing NI-IMAQ the reason is that method is low the polarization that based on the principle which not only the currency is made of paper, but it is a combination of paper, linen as well as cotton. Besides, from which of the tree bark, the currency that is prepared is famous as the figure balsam that also includes a big percentage of cellulose. The purest form of cellulose is cotton. Thus, Cellulose has a considerable component of the currency; as a result, it is safe to say that. In spite of different ingredients that have some causes on the angle that is polarization, the currency that is polarization angle can be close to that of cellulose as well as the angle will be taken by directing laser through the currency that is unique. We can make use of validation of the original currency from the ones that are forged [11].

Basic banknote counters can supply a count of the currencies that is total in the supply hopper. Some of them can also detect the bills of counterfeit either in a magnetic manner or by using a backlight. In many countries, ultraviolet detectors depend on the fact that real currencies have symbols that are fluorescent since they just show under an ultraviolet. In addition, for printing money, the used paper does not have any agents that are brightening which in a commerce manner make available fluorescent papers under black light. Both of the features can make notes that described as counterfeit and both of them are easier to be detected and harder to produce [12]. The stack of the bills is put in a part of the machine after that, one of the notes at a specific time in a mechanic manner is pulled. To count how many times a ray of light is cut. Currency can be calculated on the device. By comparing a shape of each currency towards style recognition criteria, it can find out the denominations of the bills and the way of much genuine money is put in its place [13]. They also are known as currency counters including a fake note detector built-in. The most popular machines are ultraviolet detection that is ultraviolet the machine

will check the Characteristics of the currency ultraviolet (Currency/ Money of a specific country) and the inks that is magnetic spontaneously can count the currency. Most of the Money counters stop and are alerted by the user in the time a counterfeit banknote is known [7].

In this study, the counter has been designed to count notes in addition to detect fake notes. The microcontroller type (Teensy 3.2) which is based on ARM Cortex M4 processor controls the whole system. The machine of the currency counting runs upon of principle of the breadth of the bundle, this machine works. In a continuous pattern, there is a roller that contains some rods moves them with a specific speed, moves the bundle of the currency. Then, it moves out money next to each other at a high as well as steady speed. A transducer can detect the numbers of different single notes that have passed out in front of it. For detecting fake, they based on using UV detection. The fake currency that is created by copier or printer that is colorful will give a shape that resting on the paper that can easy manner be shown at the time the UV of light is put over it. On The optical fiber are the actual notes that are printed. Besides, the fake paper is made from a paper that is thicker than the real one.

### 1.2 Objective of the thesis

The objective of this thesis is to develop a money counting machine that counts and finds fake money currency based on ARM microcontroller. The other specific objectives are as follows:

1. Use the ARM Microcontroller for programming the machine to Count every type of currency.
2. Find fake money in less time for the American dollar, Turkish lira and dinar Iraqi.
3. Create a design with less cost and simpler.
4. Provide more accuracy and reliability in counting money.
5. Increase productivity.
6. Protect your business from money fraud.
7. Contribute beneficial tools to the trade and industry.

### 1.3 Thesis Organization

This thesis is organized into five chapters:

Chapter One: The current chapter is the introduction to the general aspect of money counting machine, objectives of the thesis and the organization of the project.

Chapter Two: The Theoretical Study.

Chapter Three: Materials and Methodology.

Chapter four: Results and Discussion.

Chapter five: Conclusion and Future work.

# CHAPTER 2
# THE THEORETICAL STUDY

## 2.1 Overview

This chapter presents money counting machine types, applications, counterfeiting techniques, related works, microcontroller, ARM, Cortex-M4 and estimated expenditure.

## 2.2 General Introduction

The machine of money counting is based on the principle of a breadth of the bundle of currency, in a roller, we have rods in a pattern that is continuous, and it moves the rods with a specific speed. The speed remains constant as like in the Automated Teller Machine (ATM) and the rollers can move on the bundle of the currency. It moves out the currency that is single after each other at a steadfast as well as a very high speed. There are transducers that detect how many single currencies have passed out in front of it [3]. Money Counter provides an efficient, fast and easy manner in order to count stacks of money. Some of them can detect fake notes either in magnetic or by utilizing the ultraviolet light. They used UV Detector in money counters. The money that made by a printer that gives a shape that will be rested on the paper that in an easy manner can be seen in the time UV light is put over it. Figure 2.1 shows multi types of currencies under UV rays.


**Figure 2.1** Multi-currencies under UV rays

Outside the picture, small particles of toner can be in an effortless manner shown by a UV light. Counterfeit detectors, as well as Bill counters, have a UV light that incorporated with it. That the banknote is counterfeit, you will be alerted if a counterfeit bill runs through the machine. The sensors, that are magnetic, can run over each bill. It was made by looking for specific banknotes components that difficult to be seen by the eyes that are naked. Machines match and figure them out in the automatic manner and the piece against the components of the previous - programmed of legitimate bills. At the time of a suspicious note is found out, the operator will instantly alarm you. There are various ranges of constant machines like smart Counter with fake money detection machines, Basic Note counter, High-Speed duty money counting machine, Highly reliable for Banks, houses of business, retailers, Merchants, jewelry and nearly the whole business is established [2].

(a) LNCM (b) BNCM (c) Desktop Model

**Figure 2.2** Money Counting Machine Types

## 2.3 Money Counting Machine Types

### 2.3.1 Loose Note Counting Machines (table top model)

Loose Note Counting Machines (LNCM) is very user-friendly and economic loose currencies counter for worldwide banknotes and all types of currencies counting fewer amounts of cash and any type currencies in just 4 seconds. The LNCM machines are the best in terms of prices and they are user-friendly with excellent feature of UV detection [14].Figure 2.2(a) shows the external shape of the LNCM machine.

### 2.3.2 Bundle Note Counting Machines (Floor Model)

This type of machine is also called as High Speed counting machines, high speed machine (2/3/4 second) Counts100 notes in 2 sec, 3 sec & 4 seconds, accurate counting, 8-12 hours working for heavy cash /currency counting , automatic start/stop function, alarm for aborted count, count number verification. Figure 2.2(b) shows the external shape of the BNCM machine.

### 2.3.3 Desktop Model

Desktop model is compact model which is easy to carry anywhere lose currency counting machine, as well as bundle currency counting machine, also have desktop versions [1]. Figure 2.2(c) shows the external shape of the Desktop Model machine.

## 2.4 Applications of Money Counting Machine

1- Financial Institution and Bank.
2- Hospitals and Corporate
3- Schools and colleges.
4-Restaurants.
5- Airport authority.
6- Shopping malls.
7- Co-operatives
8- The railways.
9- Other transport services.
10- Showrooms and retail outlets.
11- Hotels.

## 2.5 Counterfeiting Techniques

It has occurred ever since humans considered the idea of items that are valuable. In addition, there has been an ongoing race between certified and counterfeiter since ever [15].

### 2.5.1 First-Line Inspection Methods

These methods are utilized immediately by retailers and vendors in order to determine the originality of the money being swapped. There are negative points about the methods that are not difficult to counterfeit much more than inspection traits that are second-line; the reason is, that they can be so clear to the counterfeiter towards a verifier. The methods are not expensive. Anyway, the appearance of the traits refers to the common population who can see clearly the measures that are safe. Many fraudulent notes can be spotted in a quick manner [16,36].

#### 2.5.1.1 Varied-Density Watermarks

A banknote is copied on in a controlled approach in order to vary the paper density. The watermarks can be done as well. These are clear at the time a bright light can shine onto the rear of the banknote. The various paper densities can cause different strength of light to make it pass through it, leading to the watermarked shape to be appearing on the obverse of the currency [3].

#### 2.5.1.2 Ultraviolet Fluorescence

Embedding fluorescent fibers into the paper, or printing UV inks onto the paper makes a form of optical verification easily utilized at counters. By exposing the currency to UV light, the ink or fibers fluoresce, revealing a pattern invisible under normal light [2].

#### 2.5.1.3 Intaglio Printing

The reason is that the printing process helps to guarantee for the soundness of the document. It, the currency, is submitted to a process printing high-pressure that can strengthen as well as raise the surface of the structure as well as the process. To use various what so-called: ‘alignments of lines’ that printed in this case, an image that is latent can be given and it can change the appearance of it that based on the angle at which the note can be seen. They used this method with ink that is optically variable; to give an interference that can show spectral colors during we view it in different angles [19].

#### 2.5.1.4 Micro text

The small text printed with the highest clarity of currencies produced from scanners that described as commercial or printers. This leads to the text to be an illegible manner, blurred in addition to announcing the illegitimacy of the currency. The method needs an equipment of specific printing, however; it adds to the manufacture of the currency, a little cost [19].

#### 2.5.1.5 Holograms and Kin grams (DOVIDs)

These methods became regularly more utilized in new forgery combat measures used on credit cards. They are now in an increasing manner on new checks and bank notes. In giving (DOVIDs) that stands for the diffractive optically variable image devices, the iridescent chips are added to the treaties that were printed. Holograms, as well as Kin grams, used them in it that is given by engraving micro profiles in addition to the films that are thermoplastic. They applied the hologram itself by utilizing light from, which is the interference, in sources with different ones and in a specific pattern. Kin grams are given in addition to polarization and chromatic effects. The result is an image of 3D full-color when it is illuminated from different angles. To create a similar effect, used stacked quantities of thin films with every layer that including properties of refractive, which is different. It is produced by varies under different viewing angles [18].

### 2.5.2 Second-Line Inspection Methods

Methods of second-line investigation are methods that cannot be used by your eyes. It demands an extra device to execute a verification task. They are harder to counterfeit and secure more than the methods that are visual, but the more security can add additional cost at both verification ends and the industrialization [17].

#### 2.5.2.1 Is check

With respect to interlaced printing which mentioned above, the methods based on a fixed pattern of lines or dots in order to because a ripple style when scanned or printed. Watermarks invisible can be done in these styles, like a special filters put in

the middle of the currency as well as the viewer, the hidden verification can reveal and verify the note as genuine [19].

#### 2.5.2.2 Fiber-Based Certificates of Authenticity

Depending on the traits light transmission of fiber-optics, we can make use of unparalleled formations of fibers, in this method, an integral part of the paper. To show hidden fiber aspects by using a scanner, to use the stance of the lightened ends (the one lightened as a result and the one deliberately lightened), the certifier has a fiber signature. Here, into a bit string and combined, the string can be converted by further data demanded (e.g. source and serial number). Anyway, combining them by a hash itself of cryptographic, it is marked by utilizing a key, but it has to be private and with the key of the corresponding public is made available. The result that is final of the point might be, onto the banknote, encoded (to certify a wide range of documents with various ones, this method is suitable) with the shape of verification number or a barcode or of some kinds. To verify the authenticity, they involve inverting in the aforementioned process. The number that controls can be verified by utilizing the general key initially utilized conformable to the private key. They reversed the Retail function and the authentic data string that extracted. The money can be scanned by preparing equal fiber illumination method that mentioned above. The document is genuine if the extracted data matches the observations of scanning. A high cost to the industrialization process of currencies when this technique is added, however; it is highly safe and hard to be replicated. For smaller-value currencies, it may be excessive, anyway; for notes that have large-value, money or even Checking requests. This method gives a warranty of the originality of the allegation [18].

#### 2.5.2.3 Feature Analysis & Color

Recently, many packages of image-processing software have the algorithm that is secret for detection to block currencies from being juggled in the applications of them. By looking for a fixed geometric style-five 1mm-big circles that arranged as a star of the four-pronged that can be a primary candidate, namely, visible in notes of older now-Outdated European coin and pounds sterling -they Category the images of currencies, in addition, to reject any processing further [20].

## 2.6 Related Works

Anju et al. (2016) [21] proposed counting machine uses the embedded system arduino for the functioning of the machine, it utilizes a sensing technology to sense the count entered and sends the corresponding signals to the input stations of the integrated circuit in the arduino board. The usage of arduino board makes the machine more precise in functioning. The arduino board on receiving the signals sends signals to input pins of a display that shows the number of the papers counted. The usage of arduino makes the interfacing of the display and programming of the proposed project more favorable. The desirable count of papers can be counted out from a bundle by inputting the number. The automatic paper counting machine finds a plentiful application in many fields and proposed as a remedial measure for the problem raised in the exam cell of the college (on counting papers like a question and answer sheets) which was displayed as a publication within the campus on various notice boards welcoming remedial measures. Figure 2.3 describes an efficient automatic framework for paper counting machine.

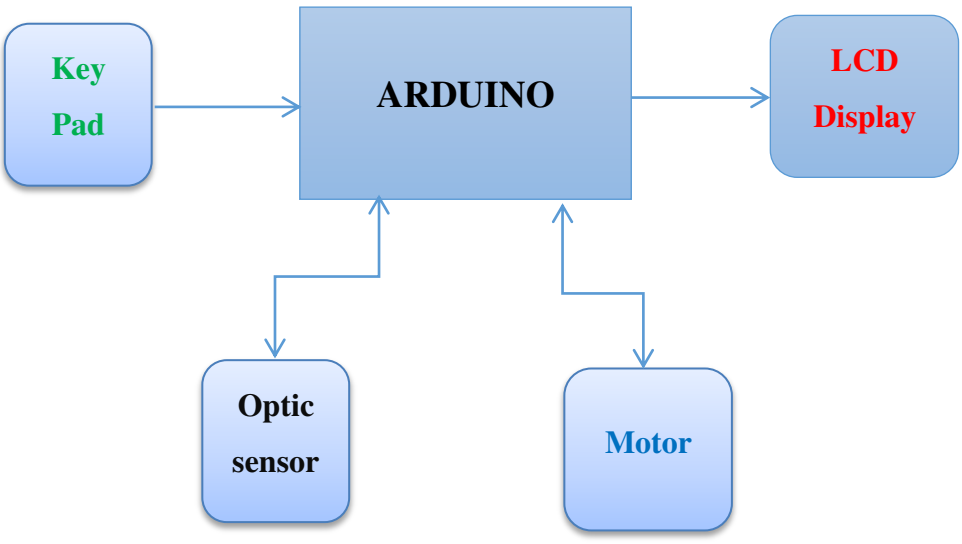



**Figure 2.3** Block diagram of Automatic paper counting machine

## 2.7 Microcontroller

A Microcontrollers or (MCU) is a computer-on-a-chip. It was with us for a many decades in our lives but their effect direct or indirect. Usually, these are used to be just data processors for execution performs comprehensive digital operations. It is a kind of microprocessor affirming efficiency and cost-effectiveness and low consumption in contrast to a microprocessor for general purpose used in a PC [22]. The microcontroller usually contains the memory and interfaces required for normal applications, while a general-purpose CPU requires extra chips to provide these tasks. The microcontroller can be described as an integrated circuit in a single chip. The microcontroller is a one-chip integrated circuit that includes all the parts required for the controller. The microcontroller usually contains RAM, CPU, (ROM/ EPROM / PROM), I / O - parallel and serial, interrupt controller and timers for example, ARM and 8051 and PIC and Atmel [23]. Figure 2.4 shows the microcontroller's classifications and table 2.1 Listed the difference between the basic types of microcontrollers.

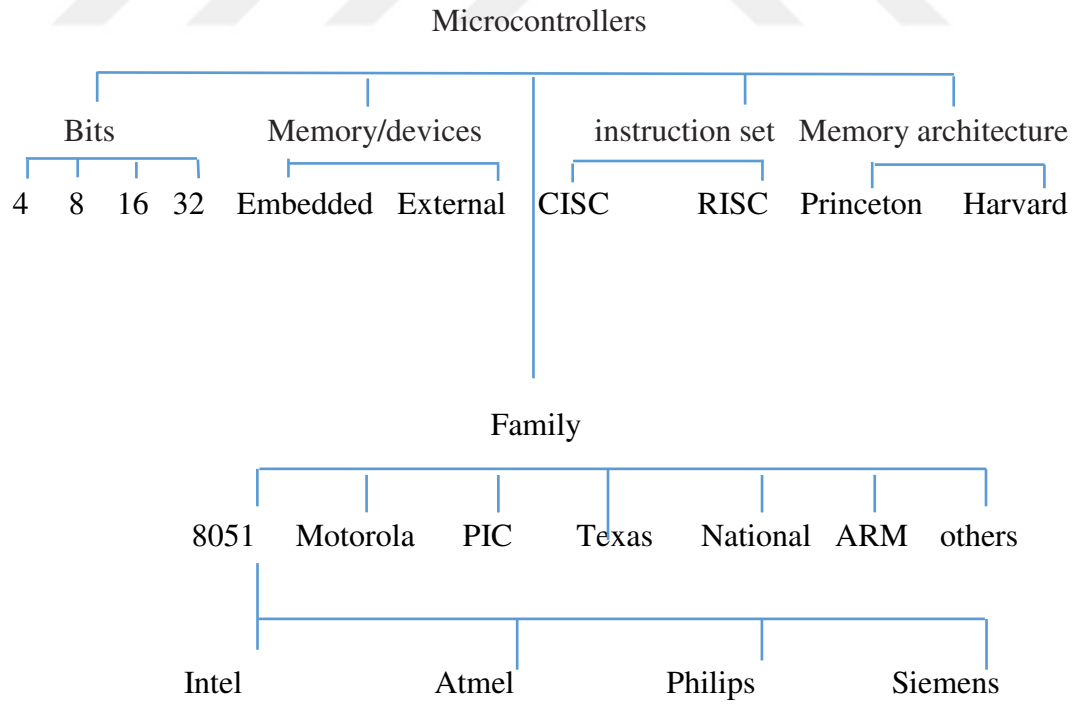



**Figure 2.4** microcontroller's classifications

**Table 2.1** explains the difference between the basic types of microcontrollers.

| **AVR** | **PIC** | **8051** | **ARM** |
|---|---|---|---|
| 8/32-bit | 8/16/32-bit | 8-bit for standard core | 32-bit mostly also available in 64-bit |
| UART, USART, SPI, I2C, (special purpose AVR support CAN, USB, Ethernet) | PIC, UART, USART, LIN, CAN, Ethernet, SPI, I2S | UART, USART,SPI,I2C | UART, USART, LIN, I2C, SPI, CAN, USB, Ethernet, I2S, DSP, SAI (serial audio interface), IrDA |
| 1 clock/ instruction cycle | 4 Clock/instruction cycle | 12 Clock/instruction cycle | 1 clock/ instruction cycle |
| Flash, SRAM, EEPROM | SRAM, FLASH | ROM, SRAM, FLASH | Flash, SDRAM, EEPROM |
| RISC | Some feature of RISC | CLSC | RISC |
| Modified | Harvard architecture | Von Neumann architecture | Modified Harvard architecture |
| Low | Low | Average | Low |
| Tiny, Atmega, Xmega, special purpose AVR | PIC16,PIC17, PIC18, PIC24, PIC32 | 8051 variants | ARMv4,5,6,7 and series |
| Very Good | Very Good | Vast | Vast |
| Atmel | Microchip Average | NXP, Atmel, Silicon Labs, Dallas, Cyprus, Infineon, etc. | Apple, Nvidia, Qualcomm, Samsung Electronics, and TI etc. |
| Average | Average | Very Low | Low |
| Cheap, effective | Cheap | Known for its standard | High speed operation Vast |
| Atmega8, 16, 32, Arduino Community | PIC18fXX8, PIC16f88X, PIC32MXX | AT89C51, P89v51, etc. | LPC2148, ARM Cortex-M0 to ARM Cortex-M7, etc. |

## 2.8 ARM Architecture

(ARM) firstly, Acorn RISC Machine and then Advanced RISC Machine, is a family of Reduced Instruction Set Computing (RISC) architectures for computer processors, configured for different environments. ARM of British company improved the permissions in addition to architecture for different corporates. They design their own products to execute one of these architectures-as (SOC) that stands for systems-on-chips and (SOM) that refer to Systems-On-Modules that includes memory, interfaces and radios etc. They design cores to execute this directions set and license the designs for many of companies which include the designs that are core to their own products [24]. It is known that the Processors that have a RISC architecture demand few transistors more than these with (CISC) that stands for a complex instruction set computing architecture like the x86 processors existing in most PC, which develops power consumption, cost, and thermal dispersion. Desired specifications in for portable, battery-powered and light devices-such as laptops, smartphones, tablet computers, and different embedded systems, which can consume huge amounts of electricity, it can be an efficient solution to the energy problem. Periodically, ARM holdings release updates to core and architectures designs. They support a 32-bit address space just pre-ARMv3 chips prepared before ARM holdings were shaped. In original Archimedes, it had smaller one and 32-bit arithmetic. The directions for ARM Holdings' cores contain instructions of 32-bit fixed-length, but recent versions of the architecture can support an instruction of changing-length set that gives both 32- and 16-bit instructions for code density that is improved. They provide some older cores as hardware implement of Java byte codes. It, the ARMv8-architecture that advertised in October 2011, supports it for a 64-bit address space as well as 64-bit calculate with its new 32-bit constant-length instruction set [25]. Figure 2.5 shows ARM Cortex.


**Figure 2.5** ARM Cortex

## 2.9 ARM Architecture Overview

The ARM architecture has developed to a point where it supports execute via a broad collection of performance points. Over two billion portions have shipped, establishing it as the predominant architecture via a lot of market sectors. The ARM has architectural simplicity and the processor has led to tiny implementations, and these allow devices in addition to power consumption that is low. The implementation performance, size, and even low power exhaustion remain attributes that considered key in the expansion of the ARM architecture [28]. The ARM is a (RISC) that stands for Reduced Instruction Set Computer, as it includes these typical RISC architecture traits:

1- A file of huge orderly register

2- A store or load architecture, when operations of data processing just runs on register contents, not in a direct manner on memory contents.

3- Addressing modes, with the entire load/store addressed being determined from instruction fields and register contents.

4- Fixed-length and uniform instruction fields, towards simplifying instruction decode.

The ARM architecture provides:

1-Controlling both shifter and the Arithmetic Logic Unit (ALU) in most data-processing instructions to maximize the use of a shifter and an ALU

2 -Auto-decrement and Auto-increment addressing modes to optimize program loops

3 -The instructions of Load and Store Multiple to maximize data throughput

4- Conditional execution was made for all instructions to maximize execution throughput. They allow the enhancements to basic RISC architecture ARM processors to achieve a good balance of high performance, low power consumption, small silicon area and small code size [30].

## 2.10 Benefits of Using ARM

1 -Low power consumption.

2 -Fast execution per watt.

3 -Inexpensive.

4 -Variety of core offerings.

5- In Marketing.

## 2.11 Cortex- M4

This model processor has been used in our study and we focus on it because it has excellent features. The ARM Cortex-M4 based digital signal controller for embedded applications requiring a high level of integration and low power dissipation. The newest member of the Cortex M Series of processors targeting microcontroller cores is ARM Cortex-M4 that concentrate on very cost sensitive and deterministic Interrupt driven environments. It depends on the ARMv7 Architecture in addition to Thumb®-2 ISA. It is upward compatible with the Cortex M3 Cortex M1 and Cortex M0 architectures. An ARMv7 Thumb-2 DSP (ported from the ARMv7-A/R profile architectures) were included by its improvements in providing 32-bit- instructions with SIMD (single instruction multiple data) DSP style multiply accumulates and saturating arithmetic It is a low-power processor that features low gate count, low interrupt latency, and low-cost debug. It includes floating point arithmetic functionality and processors are intended for deeply embedded applications that require fast interrupt response features the processor implements the ARMv7-M architecture profile. A next-generation core offers system enhancements like low power consumption, enhanced debug features, and a high level of support block integration. It is incorporated a 3-stage pipeline. It uses Harvard architecture. It supports single-cycle digital signal processing [26].Figure 2.6 shows Cortex-M4 Block Diagrams.

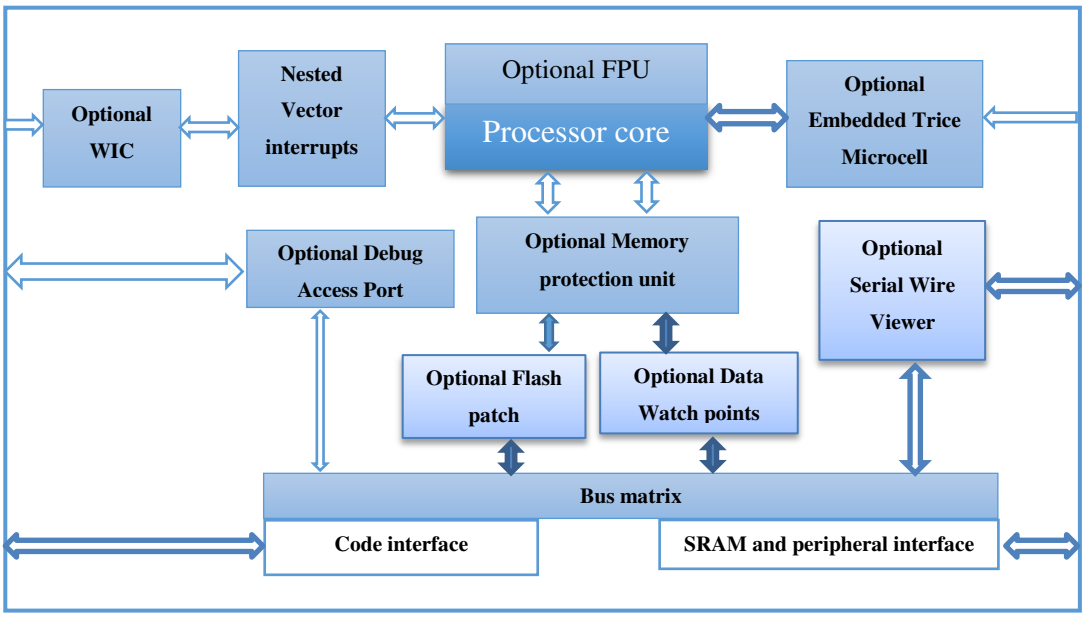



**Figure 2.6** Cortex-M4 Block Diagram

## 2.12 The Cortex-M4 processor features

1- The registers (32-bit).

2- The internal data path (32-bit).

3- The bus interface (32-bit).

4- The (Thumb) refer to Instruction Set Architecture (ISA).

5- It has three-stage pipeline design and data utilize the same address space

6- The addressing space (32-bit) and supporting 4GB of memory space.

7- On-chip bus interfaces based on AMBA (Advanced Microcontroller Bus Architecture) Technology, which allow pipelined bus operations for higher Productivity [25]. The (AHB/ASB to APB Bridge) shown in figure 2.7.

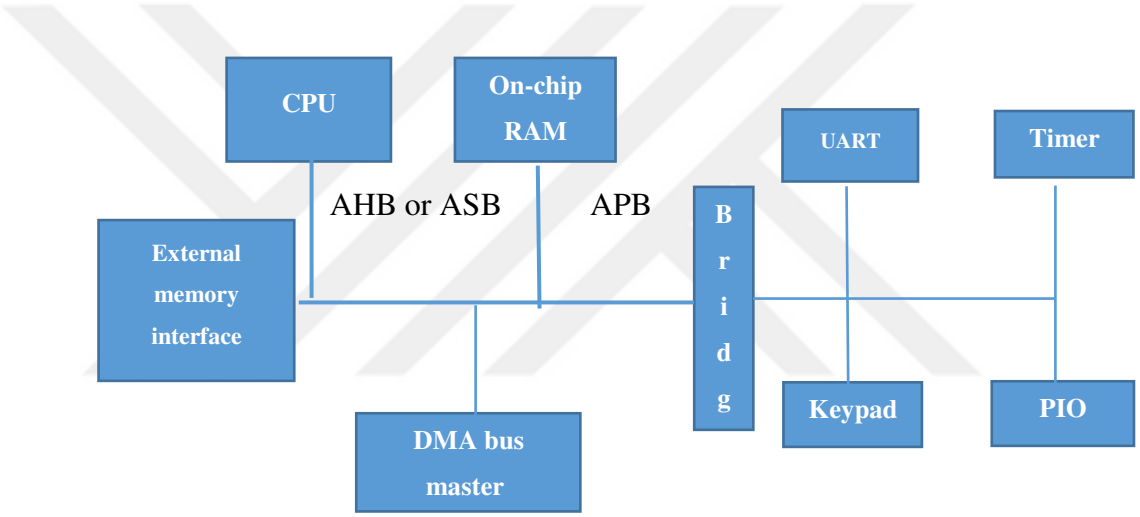



**Figure 2.7** (AHB/ASB to APB Bridge)

**Table 2.2** Differences Between AHB, ASB and APB.

| AHB | ASB | APB |
|---|---|---|
| High performance. | High performance. | Low power. |
| Pipelined operation. | Pipelined operation. | Latched address and control. |
| Multiple bus masters. | Multiple bus masters. | Simple interface. |
| It consists of master, slave, arbiter decoder. | It consists of master, slave, arbiter decoder. | It consist of APB bridge and slave. |

8- An interrupt controller called NVIC (Nested Vectored Interrupt Controller)

9- Supporting up to 240 interrupt requests and from 8 to 256-interrupt priority levels (Dependent on the actual device implementation).

10- Support for various features for OS (Operating System) implementation such as a system tick timer, shadowed stack pointer.

11- Sleep mode support and various low power features.

12- Support for an optional MPU (Memory Protection Unit) to provide memory protection features like programmable memory, or access permission control [30].

## 2.13 Cortex-M4 Architecture

### 2.13.1 Programmer model

1) The processors can have unprivileged and privileged access levels:

- (Privileged access level) it can access to all sources in the processor.
- (Unprivileged access level) it means little memory areas are inaccessible, and some operations cannot be used [26].
- The isolation of unprivileged and privileged access levels allows system designers to evolve strong embedded systems.

2) The processor is also having two operational states. The figure 2.8 shows operational state.

- Debug state: When the processor is stopped (e.g., by the debugger, or after stopping a Breakpoint), it enters debug case and stops Implementing instructions.
- Thumb state: If the processor is executing program code (Thumb), it is in the Thumb state [27,31].

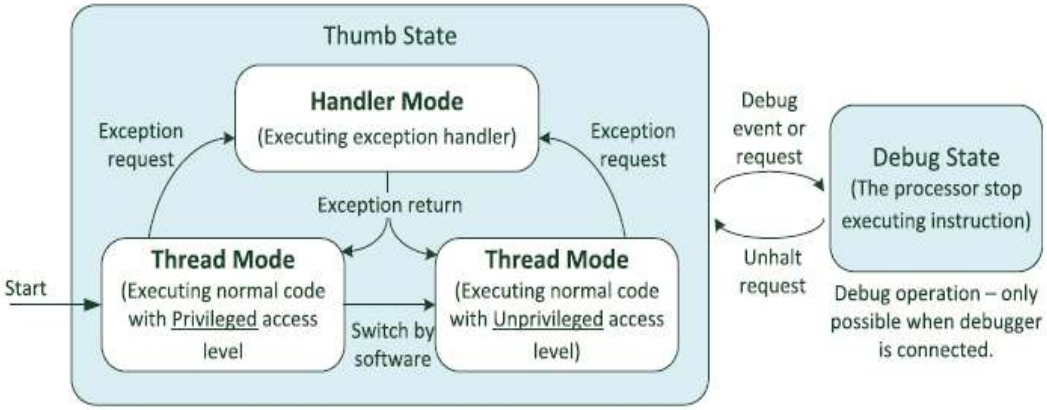



**Figure 2.8** Operational States from [31].

### 2.13.2 Register file

Because of the limited available area in the instruction set, number16-bit instructions can only access the low registers. It can be utilized with 32-bit instructions, and some with 16-bit instructions MSP is the default Stack Pointer. It is selected after reset, or when the processor is in Handler Mode. PSP can only be utilized in Thread Mode. The PSP is utilized when an embedded OS participates, where the stack for the OS kernel and application jobs are separated.

Link Register (LR) is used for holding the return address when calling a function or subroutine. At the end of the function or subroutine, the program control can return to the calling program and resume by loading the value of LR into the Program Counter (PC).Program Counter (PC) is readable and writeable: a read returns the current instruction address plus four. Writing to PC causes a branch operation. [31].the figure 2.9 below shows Register file.

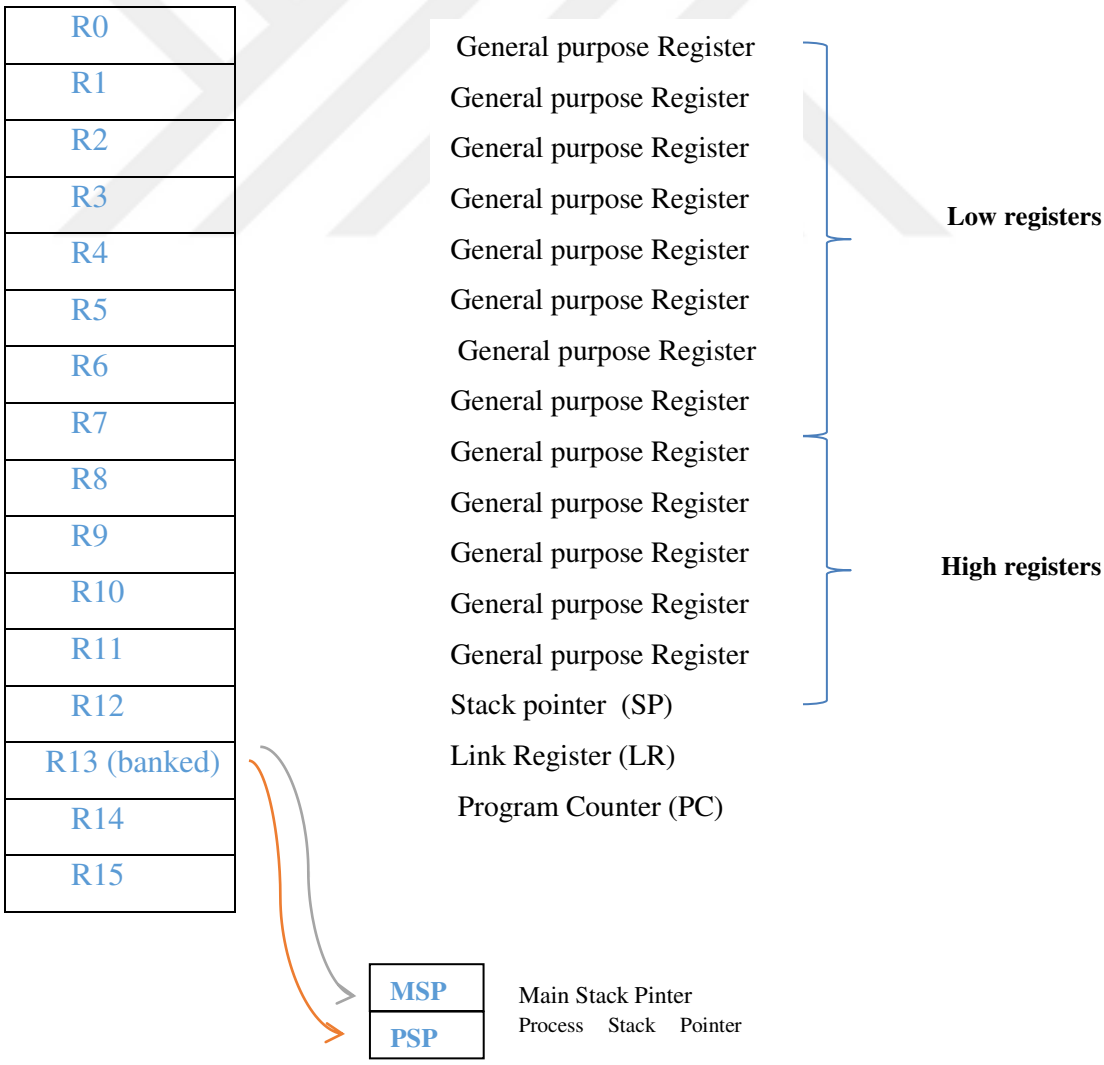



**Figure 2.9** Register file

### 2.13.3 Instruction Set

Classic ARM processors ware supporting both ARM-32 bit Instructions and Thumb 16 bit instructions shown in figure 2.10 below.

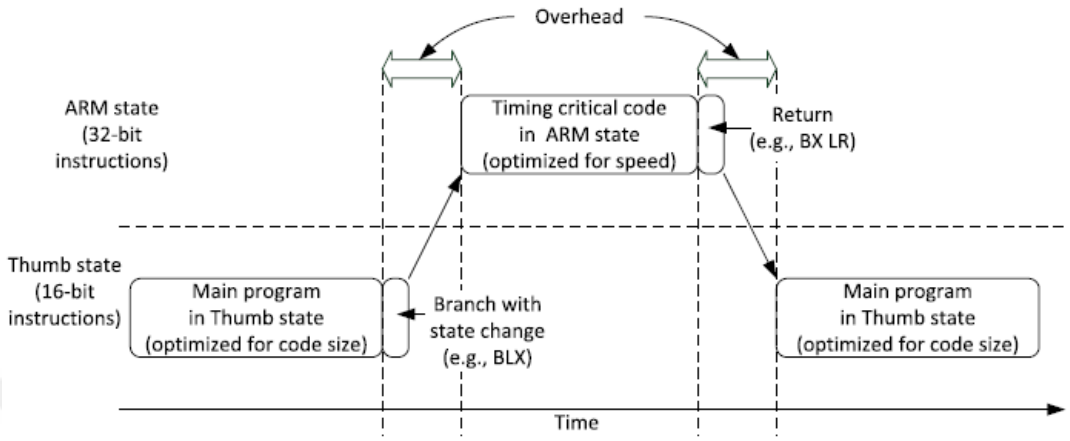



**Figure 2.10** Classic ARM processors support both ARM-32 bit Instructions and Thum16 bit instructions from [26].

ARM Cortex Instruction set introduced Thumb-2 technology; the Thumb instruction set is able to support both 16-bit and 32-bit instruction encoding. As shown in figure 2.11below

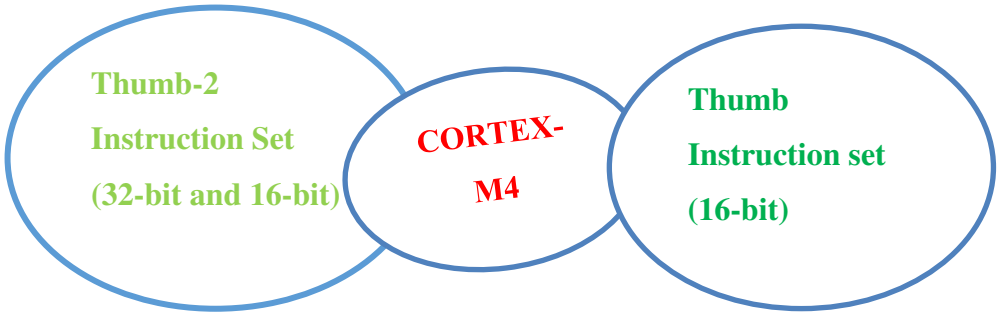



**Figure 2.11** support both 16-bit and 32-bit instruction encoding

In Thumb-2 technology, the Cortex-M processor has some Features over classic processors:

- No state switching overhead, saving both execution time and instruction space.

- No need to specify ARM state or Thumb state in source files, making software development easier.
- It is easier to get the best code density, efficiency, and performance at the same time.
- With Thumb technologies, the Thumb instruction set has been extended by a wide margin when compared to a classic processor [26].

### 2.13.4 Memory System

1- M4 processors do not include memories.

2- They come with a generic on-chip bus interface.

3- The microcontroller vendor will need to add the following items to the memory system:

• Program memory, typically flash

• Data memory, typically SRAM

• Peripherals

4- The provided bus interfaces on the Cortex-M processors are 32-bit, and based on the Advanced Microcontroller Bus Architecture (AMBA) standard as shown in figure 2.12 bellow [31,32].

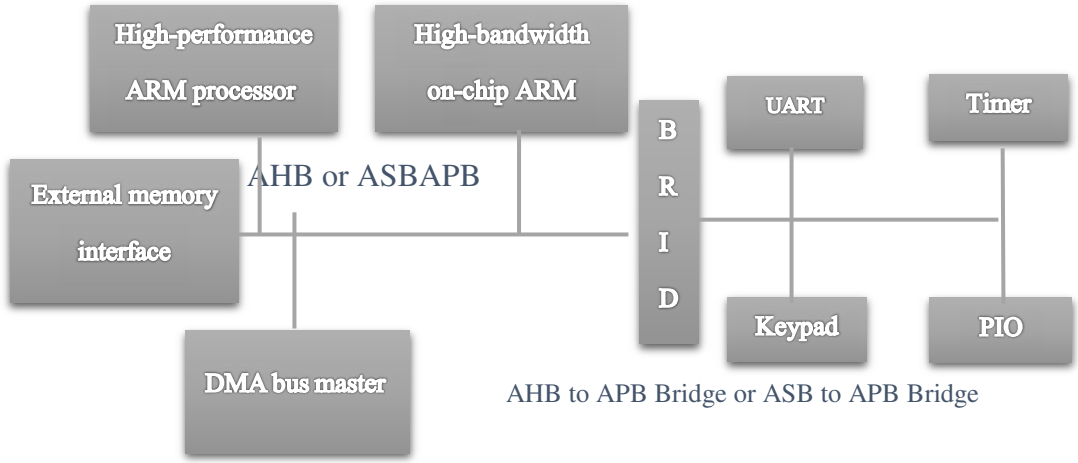



**Figure 2.12** AMBA based simple microcontroller

5- Bit Banding is a method of performing atomic bitwise modifications to memory. The importance of bit banding is that usually changing a word in memory requires a read modify-write cycle. If this operation is interrupted, there can be data loss. Bit-banding uses address space that aliases peripheral or SRAM address space, allowing

a single bit within a word to be manipulated by a reference to a byte at an aliased address [26]. This mechanism is showed with Table 2.2, Table 2.3.

**Table 2.3** SRAM Bit Banding and Alias Regions

| Address range | | | |
|---|---|---|---|
| Star | End | Memory Region | Instruction and Data Accesses |
| 0x2000.0000 | 0x2000.7FFF | SRAM bit-band region | Direct accesses to this memory rang behave as SRAM memory accesses .but this region is also bit addressable through bit-band alias. |
| Star | End | Memory Region | Instruction and Data Accesses |
| 0x2200.0000 | 0x220F.FFFF | SRAM bit-band alias | Direct accesses to this region are remapped to bit band region. A write operation is performed as read-modify-write. Instruction accesses are not remapped. |

**Table 2.4** peripheral memory Bit banding and alias regions

| Address range | | | |
|---|---|---|---|
| Star | End | Memory Region | Instruction and Data Accesses |
| 0x40000.0000 | 0x400F.FFFF | peripheral bit-band region | Direct accesses to this memory rang behave as peripheral memory accesses .but this region is also bit addressable through bit-band alias. |
| x42000.0000 | 0x43FF.FFFF | peripheral bit-band alias | Direct accesses to this region are remapped to bit band region. A write operation is performed as read-modify-write. Instruction accesses are not permitted. |

### 2.13.5 Exceptions and Interrupt Control

Exceptions are events that cause modifications into program influx. When one occurs, the processor abeyance the currently executing task and executes a part of the program called the exception handler. After the execution of the exception processor

is finished, the processor then continues normal program implementation [31]. Figure 2.13 shows the exceptions and interrupt contr

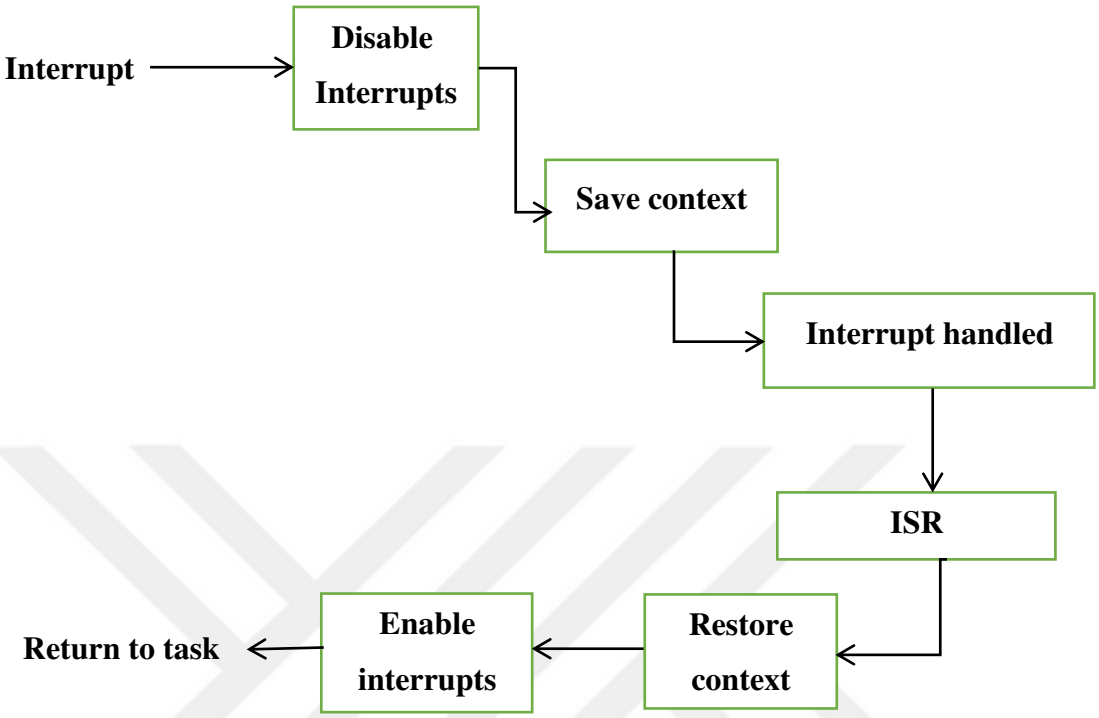



**Figure 2.13** Exceptions and Interrupt Control

Nested Interrupt Vector Controller (NIVC)

The NVIC handles the exceptions and interrupt configurations, prioritization, and interrupt masking. The NVIC has the following features:

1. Flexible exception and interrupt management
2. Nested exception/interrupt support.
3. Vectored exception/interrupt entry.
4. Interrupt masking.

## 2.14 Estimated Expenditure

In spite of estimating the expenditure, that is entire, in itself is for a project of this nature and is considered as a mean task, we try to present the facts that described as comprehensive. The Following table 2.5 is a list of processes as well as the hardware is prepared along with their costs in the project.

**Table 2.5** list of the hardware and processes used in the project along with their costs

| S.NO. | Name of device | Quantity | Cost per unit | Total cost |
|---|---|---|---|---|
| 1 | Microcontroller (Teensy 3.2) | 1 | 30$ | 30$ |
| 2 | 7 segment | 3 | 2$ | 6$ |
| 3 | IC CD 4033 | 3 | 1.12$ | 3.5$ |
| 4 | TCRT5000 | 1 | 1$ | 1$ |
| 5 | Relay 5 V | 2 | 4$ | 8$ |
| 6 | DC motor 5v | 1 | 5$ | 5$ |
| 7 | AC motor 110 | 1 | 8$ | 8$ |
| 8 | Capacitor 8 mf | 1 | 1.5$ | 1.5$ |
| 9 | LM 298 Motor Driver Breakout | 1 | 1.85 $ | 1.85 $ |
| 10 | Transformer (220to110) | 1 | 3.86 $ | 3.86 $ |
| 11 | IR sensor TX RX | 2 | 1.3$ | 2.6$ |
| 12 | Laser diode | 1 | 1$ | 1$ |
| 13 | Optec OPL550 Phototransistor | 1 | 2.5$ | 2.5$ |
| 14 | NPN Transistor MPS 2222 | 3 | 1.30$ | 3.9$ |
| 15 | UV LED | 2 | 1$ | 2$ |
| 16 | UV detector | 1 | 3$ | 3$ |
| 17 | lm 2904 IC | 1 | 0.99 $ | 0.99$ |
| 18 | Resistors | 35 | 1.18$ | 1.18$ |
| 19 | Power supply (220AC to 5 DC) | 1 | 3.89$ | 3.89$ |
| 20 | Buzzer | 1 | 2$ | 2$ |

# CHAPTER 3

# MATERIALS AND METHODOLOGY

## 3.1 Introduction

This chapter presents an experimental setup to money counting machine that including system hardware in addition to specify the hardware component used the mechanical parts and its algorithm.

## 3.2 Proposed System Design

The counter has been designed to count currencies in addition to detect counterfeiter currencies. The proposed money-counting machine consists of main parts as hardware consists of electronic Mechanical parts and software. The microcontroller type (Teensy 3.2) which is based on ARM Cortex M4 processor controls the whole system. IR sensor is used from TCRT5000 type (This sensor gives the order to start counting and stop). We used AC and DC motors to rotate money roller. IR transmitter, a receiver, and a laser sensor are used for the counting process. The mechanical parts of the design are the roller that has rods and continuous pattern. The roller can move the rods to a specific fixed speed. The UV sensor detects fake currencies. The data are shown via 7-segments to be displayed. Upon of money principle of the breadth of the bundle, this machine works. In a continuous pattern, there is a roller that contains some rods moves them with a specific speed, moves the bundle of the currency. Then, it moves out money next each other at a high as well as steady speed. The transducers detect of any single currencies that have passed out in front of it.

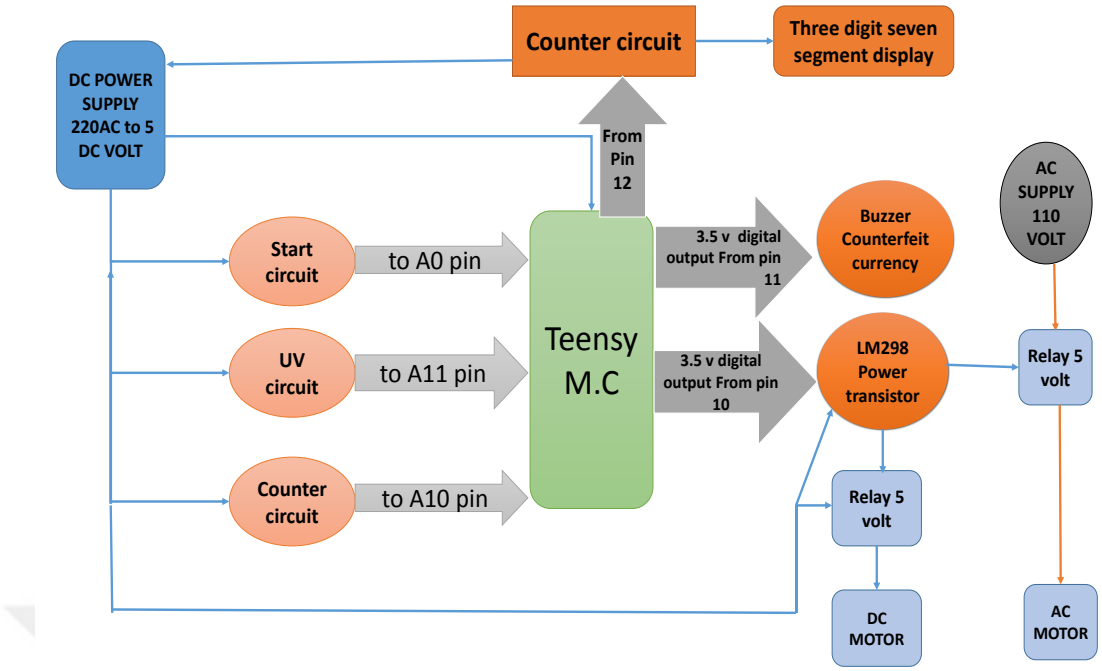



**Figure 3.1** block diagram to money counting machine

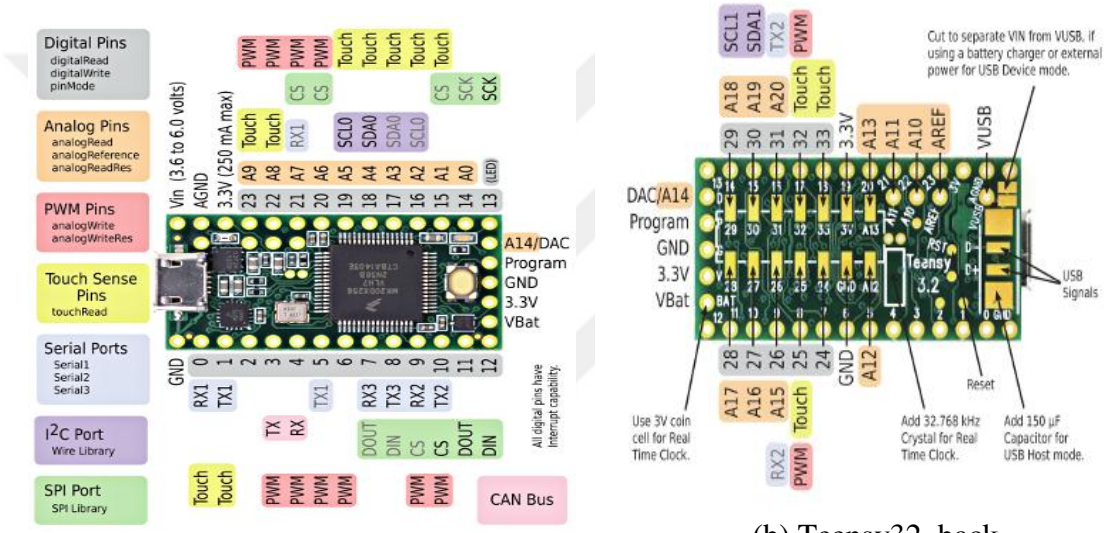
**Figure 3.2** Proposed money counting machine (shape, internal structure).

### 3.3 Hardware Design

The proposed system includes the flowing parts: The Microcontroller, Counter Circuit, Auto Start sensor, Motors system, Mechanical parts, Optical sensors system, UV source and detector and Power Supply.

#### 3.3.1 Microcontroller

The microcontroller is responsible on control all operation. Teensy 3.2 Microcontroller has 32-bit ARM processor is used in order to manage overall process.




(a)Teensy32 front

(b) Teensy32_back

**Figure 3.3** (Teensy 3.2) Microcontroller

The Teensy 3.2 (Shown in figure 3.3) USB Microcontroller Development Board (w/ Pins) is a whole USB-based Microcontroller expansion system. In an extremely small footprint, a capable of executing has several types of projects. All programming is executed by the USB port. It does not need a special programmer, Just a Basic, "Micro B" USB cable and a personal computer with a USB port. The Teensy 3.2 is a part of a teensy family that based on the architecture 32-bit instruction set. The Teensy 3.2 microcontroller consists of Cortex-M4 Processor (Details of this processor are described in the previous chapter 2). The rated Speed of this processor is 72 MHz and 96 MHz Overclock able. This micro controller has 64 Kbytes RAM, 256 Kbytes Flash Memory (192Mbytes/sec Bandwidth, 256 Bytes Cache), 2 Kbytes EEPROM. Teensy 3.2 has 34Pins Digital I/O (3.3V Voltage

Output and 5V Tolerant Voltage Input). It has 16 pins shared with analog, 21 Pins Analog Input (2 pins Converters, 12 pins Touch Sensing, 3 pins Comparators). It has one Pin Analog Output with 12 bits DAC Resolution and PWM Outputs 12 Pins. The (Teensy 3.2) is an advanced microcontroller that comes with boosted communication protocols such as, I2C, I2S Audio, SPI, Serial (With FIFOs, High Res Baud, Fast Clock), USB etc. The Figure 3.3 and Figure 3.4 show the external construction of the teensy and the schematic diagram respectively [34,35,43].

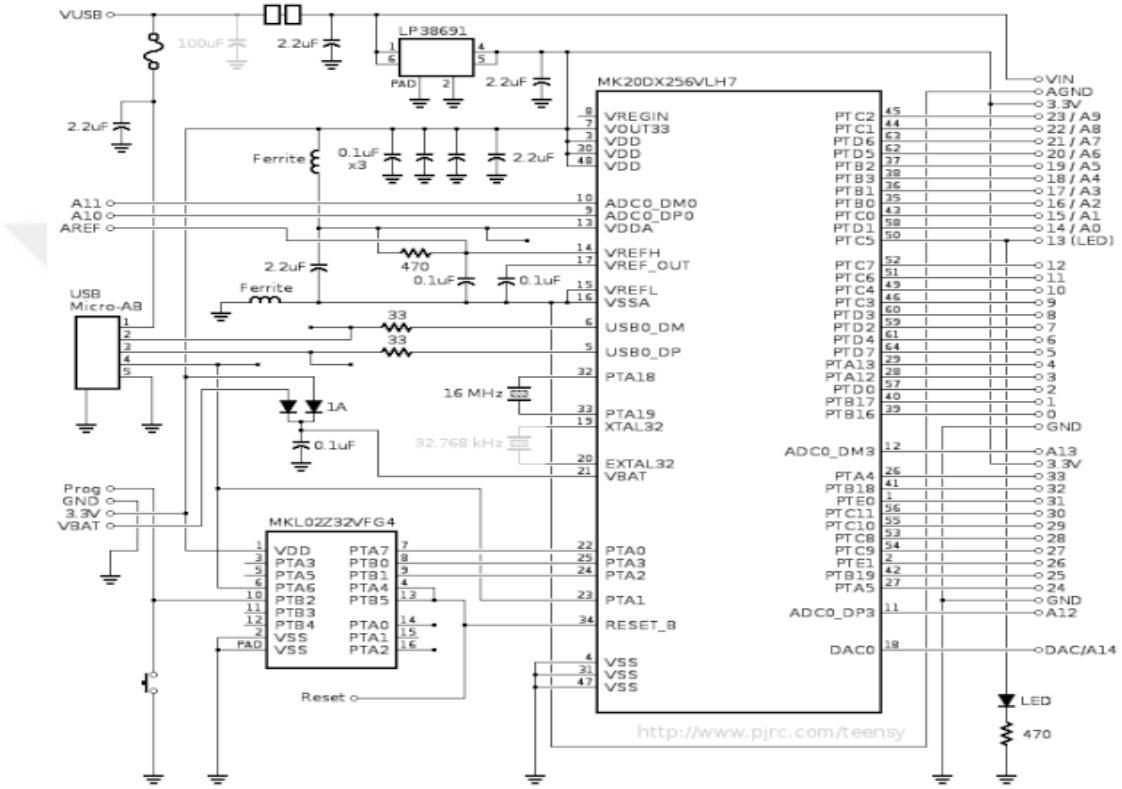



**Figure 3.4** Teensy 3.2 biased (Cortex-M4: MK20DX256VLH7)

Schematic from [33]

It is clear to be said that Micro-controllers are significant because they can contact different other devices, like motors, switches, sensors, memory, and even different microcontrollers. The methods of many interfaces are developed through several years in order to resolve the complicated troubles of arbitrage circuit design standards like cost, size, weight, manufacturability, and reliability. Several designs of the microcontroller can mix different approaches that are interfacing. In a form that is simplistic, a system of microcontroller can be shown as a system that can read from inputs (monitors), writes to outputs (controls) and even performs processing [3].

### 3.3.2 Counter Circuit

This circuit is a user interface that is used to control operation and see results. Figure 3.5 shows the counter circuit of the design and Figure 3.7 Schematic of Counter circuit.

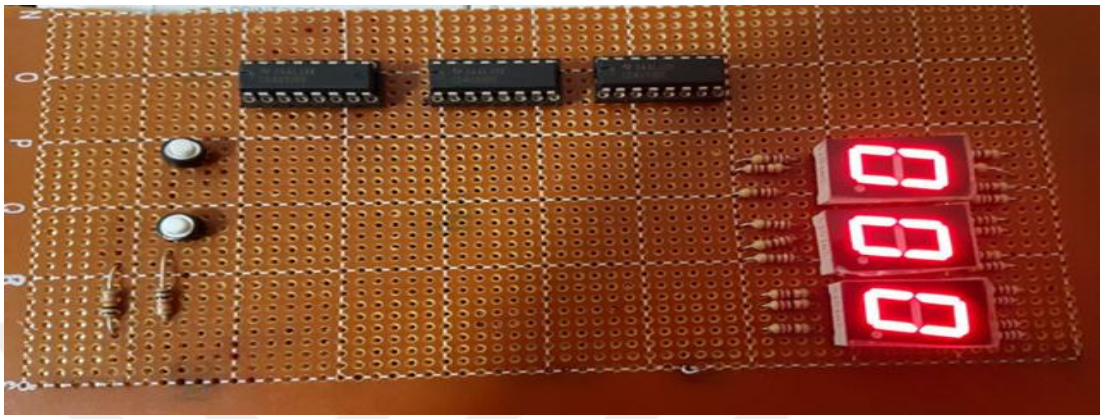
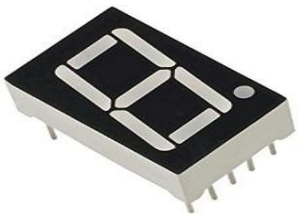
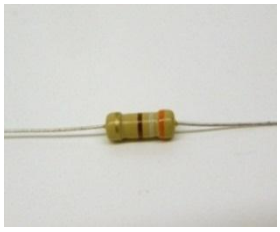


**Figure 3.5** Counter circuit

This circuit its function to show the number of the currency numerically and it consists of a three seven-segment display, three IC CD4033 and two Resistors (10KΩ) and 21 Resistors (260 Ω) etc.



(a) 7-Segent LED Display



(b) 10K Ω Resistor


(c) IC CD4033

**Figure 3.6** components of Counter circuit

#### 3.3.2.1 Seven-segment

A seven-segment display (SSD), or seven-segment indicator, is a form of the electronic display device for displaying decimal numerals that can be an alternative to the more complex dot matrix display. Seven-segment displays are widely used in digital clocks, electronic meters, basic calculators, and other electronic devices that

display numerical information. **7**segment displays is a component of 10 pin electronic that has eight LEDES and this inserted to displays number that starting from 0 to 9. In two configurations, it is available: common anode and cathode. They, all the 8 LED terminals, contain an end from the inside shorted and linked with the middle pins. As a common terminal (anode or cathode), it serves. They, the middle pin of both sides, are shorted together that serves as a common terminal. They are used, namely, 7 LEDs, to form the digits [40]. Figure 3.6(a) shows the 7-Segment LED Display.

### 3.3.2.2 IC CD4033

A Johnson counters IC commonly used in the digital display. It has a 5 stage Johnson decade counter with a decoder which converts the Johnson code to a 7 segment decoded output. Means it will convert the input into the numeric display which can be seen 7 segment display or with the help of LED. This device is particularly advantageous in display applications where power dissipation low and/or low package count is important [41]. Figure 3.6(c) shows the IC CD4033.

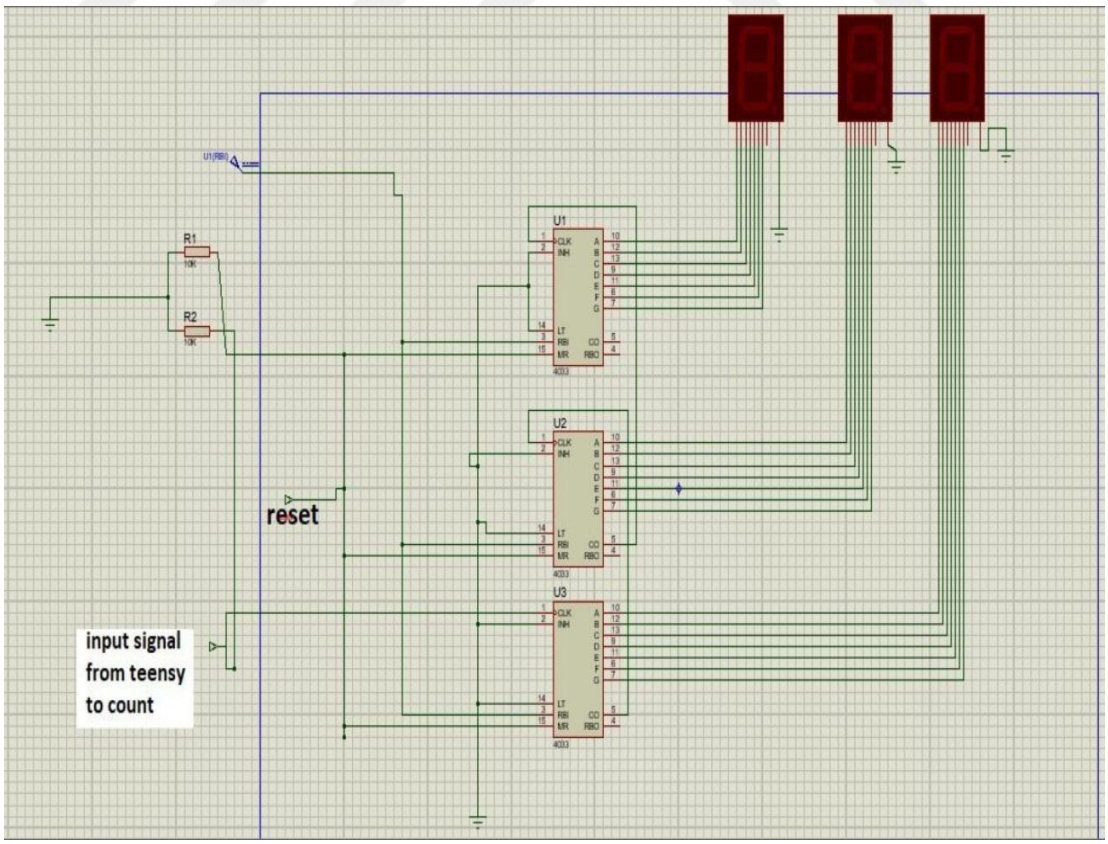



**Figure 3.7** Schematic of Counter circuit

### 3.3.3 Auto Start sensor

(TCRT5000 Reflective IR sensor) this sensor gives orders to the microcontroller unit (MCU) in order to start or stop the all the system. Figure 3.8 shows the external shape and the structure diagram of the TCRT5000 - Reflective Optical Sensor.

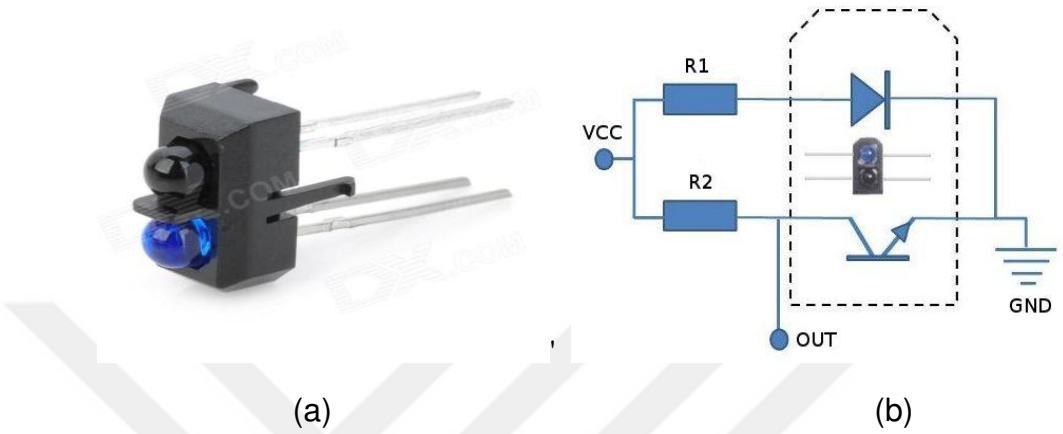



**Figure 3.8** TCRT5000 - Reflective Optical Sensor

As it is shown in the above figure that TCRT5000 is a sensor that is optical with transistor output as well as two Resistors (R1 (10K Ω), R2 (470 Ω)) the sensor composes of a LED emitting infrared (Light ,in this frequency [Hz], is not appeared to humans) and it , a phototransistor, is responsible for capturing infrared signals and altering natural light. It contains a shield that separating the receiver and the emitter based on the reflectivity of the surface. it can detect the color (in white or even black scale).The traits of dimensions (L x W x H in mm): 10.2 x 5.8 x 7.The peak of operating distance is 2.5mm.Operating Distance with efficiency much than 20% is 0.2mm to 15mm . The wavelength Emitter is 950nm). Current consumption is 1mA. One of the most important features of this sensor is the detection of reflective materials such as, paper and currency [45]. The following section will explain the principles of the work of this sensor. When the emission of infrared radiation in the part put money (hopper) in the device, in the case of a reflection of the radiation, this indicates the presence of paper or currency The sensor gives the order to start the operation device, MCM will be counting automatically when feeding in the hopper, Either in the case of non-refraction of radiation This is an indication that there is no currency or paper The sensor gives order stopping or wait for the device.

### 3.3.4 Electrical Motors

Electric motors have been taken important position in the industrial and commercial economic devices over the century. Electric motors operate through the interaction of magnetic flux and electric current. Electric motors are broadly classified into two categories: AC and DC. The basic principle of how a motor operates when the current passed through a coil creating magnetic force. A Motor is an electric power transformer to rotary energy or mechanical energy for work. Electric motors are used to operate several electrical machines and mechanical equipment [37]. This system has two systems: an AC motor system and DC motor system that used to rotate money rollers. Figure 3.11 shows Schematic of Motor system.

#### 3.3.4.1 AC Motor system

The function of this system is to rotate the first roller to pull the money off the money placement part and passing it through the count and detection process. This system includes a (110V) motor, a Capacitor for the operating the start point (8 µf), transformer from 220V to 110V in addition to (LM298 Motor Driver Breakout) and Relay (5v) to control by receiving Orders from the microcontroller.


(a) LM298 (b)AC Motor(110V) (c) Relay 5v (d) Transformer

**Figure 3.9** AC Motor system components

#### 3.3.4.1.a AC Motor

AC motor is an electric motor driven by an alternating current. it commonly consists of two basic parts, an outside stationary stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft that is given a torque by the rotating field. AC motors are efficient, durable, quiet and flexible, making them a viable solution for many power generation needs. There are two main types of AC motors depending on the type of rotor used the

synchronous and asynchronous. The synchronous motor rotates at the same rate as the frequency of the supply current, a fact that gives the motor its name. Synchronous motors are constructed of a stator. Synchronous motors are utilized in a lot of applications. Induction motors are the simplest and most rugged electric motor available. Induction motors are among the most commonly used type of motor in the world [3, 27, 37] Figure 3.9(b) shows AC Motor (110V).

#### 3.3.4.1.b Relay

The definition of the relay is described as an electrically operated switch. A lot of them utilize an electromagnet to run mechanically in contrast, principles that are operating can also be used as a changing mechanism. They are used where they can significantly by controlling a circuit via a low power signal (with whole electrical insulation in the middle of controlled circuits) or many circuits have to be controlled by a signal. In long-distance telegraph circuits, the first relays were used and recurrence the coming signal in the same circuit and after that resending it to another place. They were utilized extensively in early in computers and in telephone exchanges to execute logical operations. In this design, the function of the relay is to control the operation and extinguishing of the motor. It can be as a circuit breaker off by taking the orders from the microcontroller [3].

#### 3.3.4.1.c Transformer

There are two types AC main voltage levels around the world are 110 V and 220 V, The level that has been used in the USA is 110 V, while European countries and a lot of Asian countries have used the level of 220 V. People who bring importantly electrical devices from foreign countries can be noticed many differences in the voltage level. Therefore, they face problems when they try to operate these devices on their voltage level due to the difference in the required level of the input voltage. For that, it was used 220 to 110V converters available to solve the above matter. A transformer is considered as an apparatus that is electrically designed to convert current that is alternating from one voltage to other [47]. It can be designed for "step up" and "step down" voltages. However, they are based on the principle of magnetic induction. A transformer is a completely static solid-state apparatus without moving parts. Under normal operating conditions, a transformer has a long and trouble-free life. In a simplified form, it contains two or more coils of insulated wire wound on a

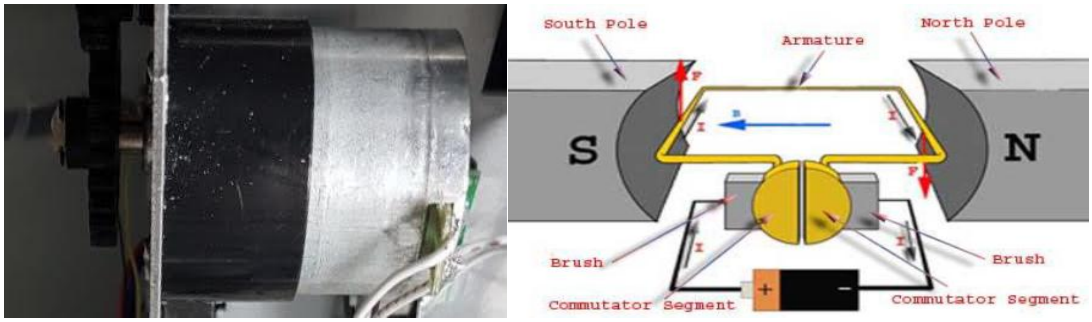
laminated steel core. If there is an induced voltage in one of the two coils that is called the primary, this voltage will magnetize the iron core. After that, the voltage is induced in the second coil that is called the secondary coil. The voltage ratio or the voltage change between the two coils is depending on the turn's ratio of these coils [46] Figure 3.9 (d) shows Transformer**.**

#### 3.3.4.1.d LM298 (Motor Driver Breakout)

The L298 is a monolithic circuit that is integrated. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL (transistor-transistor logic) logic levels and drive inductive loads such as solenoids, relays, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor [48]. It was used to fit the voltage between the relay voltage (5v) and the (teensy) micro-controller voltage (3.5v) In order to increase the accuracy of control in the operation and extinguishing of motors. Figure 3.9(a) shows LM298.

### 3.3.4.2 DC Motor systems

The function of this stage is to rotate the last roller after passing through the counting and detection process. This system includes DC motor (5 V), LM298 Motor Driver Breakout and relay (5V) for control by receiving orders from the microcontroller a function it as (circuit breaker). Figure 3.10 shows the DC motor which has used in the design. Figure 3.10 shows the DC motor which has used in the design.




A) Prototype of DC motor B) Components of a DC motor

**Figure 3.10** DC motor

#### 3.3.4.2.1 DC motor

It is an electric motor that runs on direct current (DC). The DC motor was utilized to run machinery. It, DC motors, can run in a direct manner from batteries that can be recharged providing the power that is motive for the first electric cars. In our days, they are still can be found in small applications as disk drives and toys.in addition to large size to run paper machines and steel mills [38]. The Modern DC motors operated always in association with electronic devices. There are two types of DC motor - brush and brushless DC Motor. Brushed DC electric motor generates torque directly from DC power supplied to the motor by utilizing internal commutation. It consists of in stationary magnets (permanent or electromagnets) and rotating electrical magnets. Brushless DC motors use a rotating permanent magnet or soft magnetic core in the rotor, stationary electrical magnets on the motor housing. It has Advantages, Provide excellent speed control for acceleration and deceleration, Easy to understand design and Simple, and cheap drive design [37].

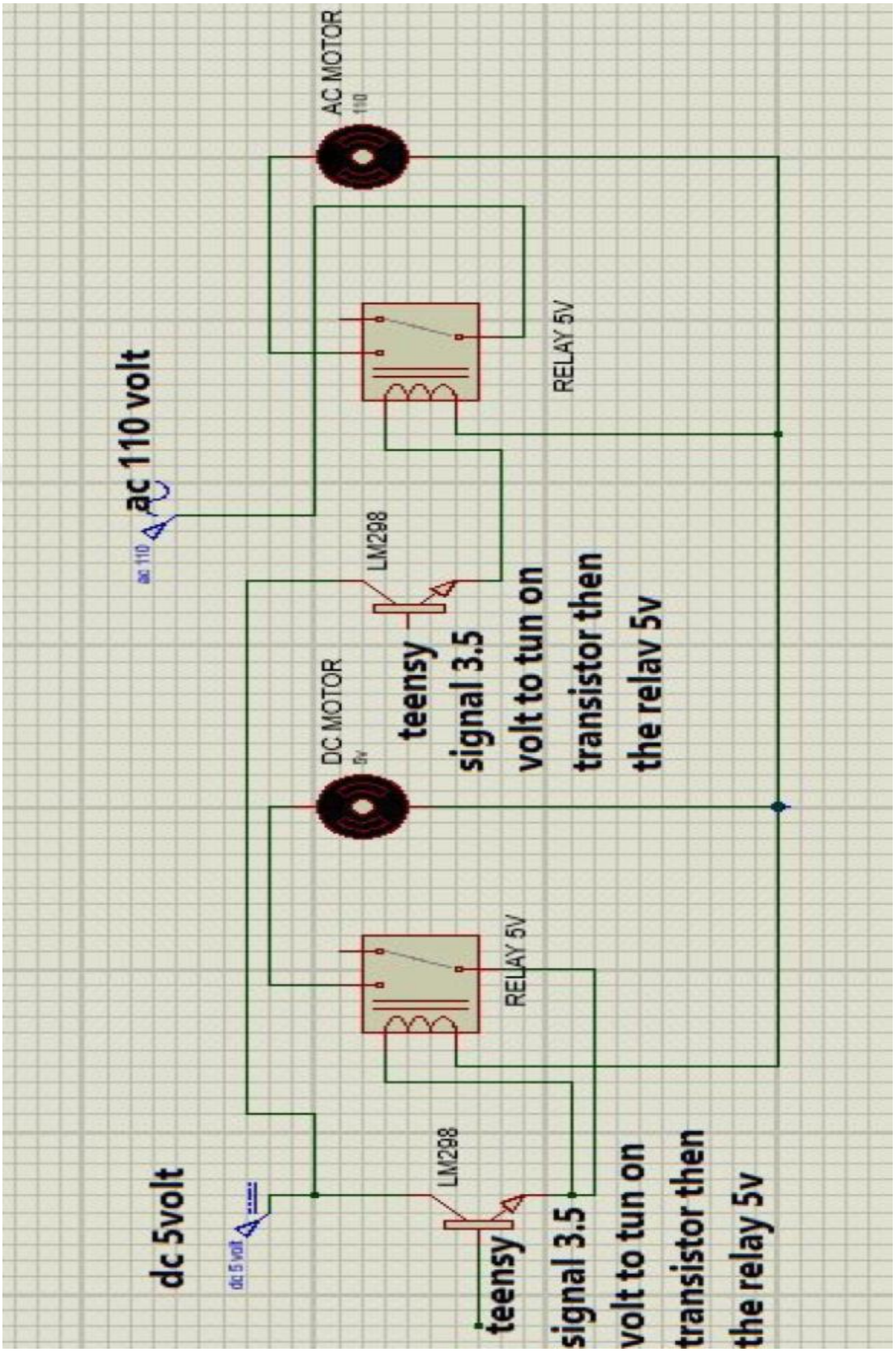



**Figure 3.11** Schematic of Motor system

### 3.3.5 Mechanical parts

Mechanical part it has a roller, which has rods in a continuous pattern, where the roller moves these rods with a particular fixed speed. Figure 3.12 shows the Mechanical parts which were used in the design.

**Figure 3.12** Prototype for Mechanical parts

This part is one of the most important parts of this study. It maintains a fixed counting pattern and constant speed that is an integral part of the electronic as well as electrical parts which are required to complete this study. The mechanical design of this study includes two stages, starting from the withdrawal of funds through the process of counting and fake money detection, ending with the delivery of currency consists of different rollers and shafts in shapes and models.

(a) Roller for first stage (b) first stage tying AC motor (c) last stage tying with DC motor

**Figure 3.13** Prototype for all Mechanical parts components

The first stage of the mechanical part consists, which pulls the currency from the feeding part and drives it through the sensors of detection. As well as counting process. It consists of two cylinders along with a number of different pulleys. This part is accomplished through tying the AC motor (110V) which is binding by two rollers. We used this motor because this step needs a high power to move the system and maintain a coordinate with the accurate pattern. It is considered the most important part of the mechanical design. In the last stage, it takes the currency from

the first stage and inserts it in the completion part through tying the DC motor (5V). Figure 3.13 shows the Prototype for all Mechanical parts components

### 3.3.6 Optical sensors system

These sensors detect each note pass through it and return the signal to the microcontroller as shown in figure 3.14 and figure 3.18.

(A)Left, optical transmitter (B) right optical receiver arranged with roller

**Figure 3.14** Optical sensor

It consists of 5 MM IR transmitter and receiver LED TX RX PAIR, Laser diode**,** Optec OPL550 Phototransistor to increase accuracy and NPN Transistor MPS 2222 as s switch and Resistors. These (counting sensors) have two infrared transmitter and infrared receivers. The first one emits an infrared signal by two infrared firing, for each side has a sensor in order to prevent the damaged money or the torn from the pass with the other good currencies. Then according to the changing voltage in the period of the passes notes; the machine can accurately count the number of the notes. Also we used a Laser diode**,** Optec OPL550 Phototransistor sensor in addition to the transmitter and reserve laser to increase the accuracy of the device.

**Figure 3.15** 5mm IR transmitter and receiver LED TX RX pair

### 3.3.6.1 IR transmitter and Receiver LED

The transparent LED can be transmitter while the dark blue one is the receiver. Using this high power 5 mm, IR LED Transmitter and Receiver pair used to build wireless remotes for appliances, distance sensors, object sensors, color sensors, line sensors, distance sensors, etc. It can be directly connected to a microcontroller, with only a few current limiting resistors and require no complex circuit for getting it work. It has features (Size: 5mm LED, Wavelength: 940nm wavelength (most commonly used), 100 mA continuous, 1000 mA pulse, Approx. 1.6V forward voltage [49]. Figure 3.15 shows the 5MM IR transmitter and receiver led TX RX pair.


(a) Laser Diode – transmitter (b) OPL550 Sensor

**Figure 3.16** transmitter and reserve laser

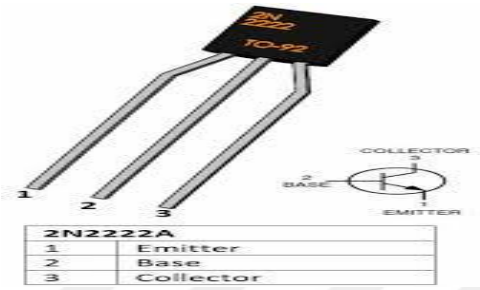
### 3.3.6.2 Laser diode

Laser Diode is a fun little red laser that emits a laser beam that can be similar to a laser pointer when given 5 Volts of power it has Specifications:(5mW Max Light Power,5V Operating Voltage DC,40mA Max Operating Current, 650nm Laser Wavelength,-10 C to 40 C Operating Temperature)[50]. Figure 3.16(a) shows the Laser Diode – transmitter

### 3.3.6.3 (OPL550) Phonologic sensor

The definition of OPL550, Optec Technology, is a family of photo logic sensors. It characterizes is a compatible the level of logic output which can be driven up to 8 TTL loads without adding circuitry. The applications that are suitable for the OPL550 series include; machine automation, an end of travel sensor assembly line automation, machine safety, non-contact reflective object sensor and door sensors. It can be said that the components of this series include an NPN output transistor on a

single silicon chip, a photodiode, voltage regulator, an amplifier, and Schmitt trigger. All devices in this series contain a Phonologic® chip, which can be encapsulated in the package of molded plastic side-looking one with a lens that is integral. This provides an enhanced optical coupling, grouped with a mechanical protection. The hysteresis traits of the Schmitt trigger on every device can offer an immunity that is high towards noise on input and VCC and it has a sensitivity property for the wavelength between 650 to 1100 nm [51]. Figure 3.16(b) shows the OPL550 Sensor.




| 2N2222A | |
|---|---|
| 1 | Emitter |
| 2 | Base |
| 3 | Collector |

**Figure 3.17** NPN Transistor MPS 2222

### 3.3.6.4 Transistor

The definition of a transistor is a device that is a semiconductor that utilized to switch or amplify power and electronic signals. It is consisted of semiconductor materials sometimes with, it can be said, and at least three terminals for connecting a circuit that is external. A voltage is applied to a pair of the transistor's terminals and controlled to the current through other pairs of stations. Due to the controlled (output) power is higher than the controlling (input) power. It, a transistor, can amplify a signal. In our days, several of the transistors are individually packaged, but a lot of them can be found hidden in integrated circuits. It is considered the most common (BJT) bipolar of the junction transistor, in addition, it contains two types of bipolar transistors that can be so named the reason is that they can be conducted by utilizing both the carriers of majority and minority. The (BJT) that refer to the bipolar junction transistor is considered the first kind of transistor to be big produced. It is a blend of two junction diodes as well as created of a layer that is thin of p-type semiconductor located in the middle of two n-type semiconductors (an n–p–n transistor) or ,as it is seen , a thin layer of n-type semiconductor located in the middle of  This produces the structure two p–n junction, (base-emitter junction and a base-collector junction, detached by a thin area of semiconductor famous as the base area

(two junction diodes wired together without sharing an intervening semiconducting area will not produce a transistor) [42]. Figure 3.17 shows the MPS 2222 NPN Transistor.

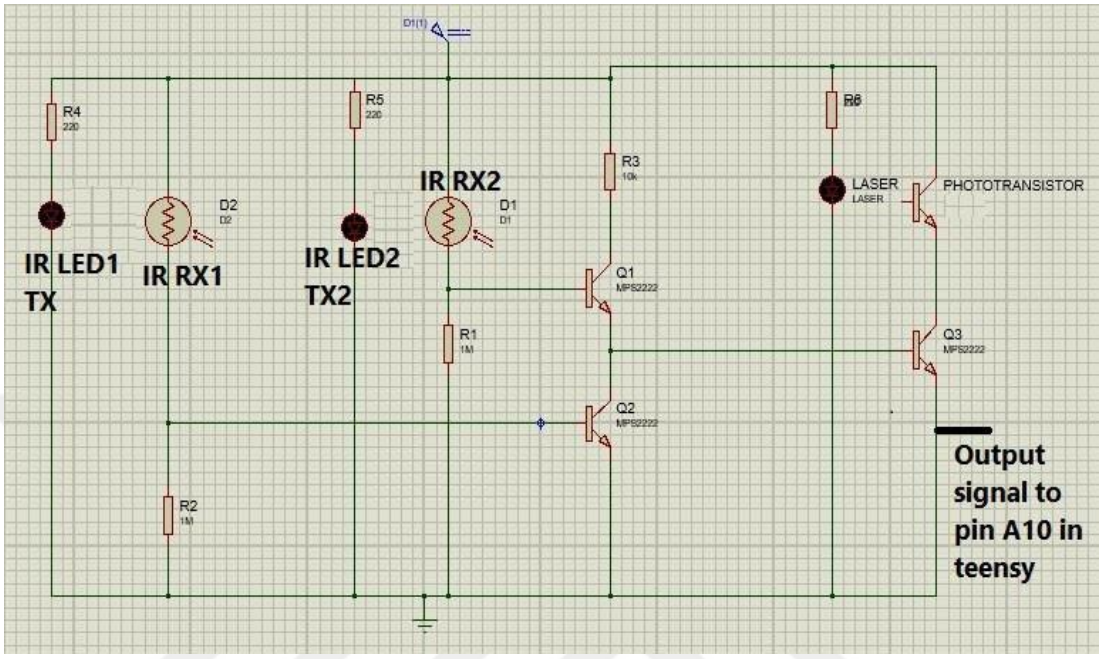



**Figure 3.18** Schematic of optical sensors circuit for detecting each note pass through it

### 3.3.7 UV source and detector system

It consists of two UV LED emitter, UV Detector (UV filter and UV sensor) and LM2904 (strengthening the released signal from UV detector to fit the MCU volt). This system is designed to detect the fake notes by UV Reflected from the currency and analyze it by UV detector; as a result, the change in voltage according to the program and control it upon the original currencies and except for that, it must be fake. The machine will alarm if the banknote does not have ultraviolet character as shown in Figure 3.19 and Figure 3.21.

**Figure 3.19** UV Fake money circuit

#### 3.3.7.1 Ultraviolet Light (UV)

It is an electromagnetic radiation with a wavelength shorter than of visual light, but it is considered longer than soft X-rays; the spectrum consists of electromagnetic waves with frequencies higher than those that humans identify as the color violet**.**

#### 3.3.7.2 UV (LED)

The UV LED is used to help the counterfeit sensor circuit in detecting the fake money. When the money is illuminated, the light will reflect it if it is fake money, on the other hand, real money will absorb the light illuminated by the UV LED as shown in figure 3.20(a) [53].

#### 3.3.7.3 UV Detector

UV detectors functions on the capacity of many compounds are to absorb light in the wavelength range 180 to 350 nm. The sensor cell generally consists of a cylindrical cavity about 1 mm and a few mm long, having a capacity that ranges from about two microliters to eight micro-liters. The fixed wavelength it has a sensitivity of about 1 x 10-8 g per ml at one signal to noise ratio of four that are the UV detector (fixed and variable wavelength) the conductivity detector that is electrical, the fluorescence detector and the detector of refractive index. Those detectors are used in over 95% of all analytical applications [3]. Light from a UV light sources passes through the sensor onto a photoelectric cell, the output from which is electronically modified and presented on a potentiometric recorder. By interposing a monochromatic between the light source and the cell, light of a specific wavelength can be selected for detection as a result, improving the detector selectivity as shown in figure 3.20(b).

#### 3.3.7.4 LM2904 (Dual Operational Amplifier)

(LM 2904) consists of two built-in amplifiers. These amplifiers have high gain as well as they are internally frequency compensated, these are designed for the operation from a single power supply for a large range of voltages. We can also operate them from multiple power supplies as well. LM-2904 operates on the 3.3V power supply it is the most common power supply in digital systems, it also available in small size. They are available in the latest technology DSBGA and in all the conventional OP-AMP circuits. It has a lot of unique features in comparison to the

other standard amplifiers. These features include a large DC voltage gain: 100dB, wide bandwidth, common mode input voltages consists of ground, large output voltage swing: 0V DC to VCC -1.5V DC, Wide power supply ranges (3V~26V) etc. it can be used in different places like DC gain blocks, active filters, transducer amplifiers, general signal conditioning, general signal amplification etc. as shown in figure 3.20(c).


(a) UV LED (b) UV Detector (c) lm 2904 IC

**Figure 3.20** UV source and detector system components.

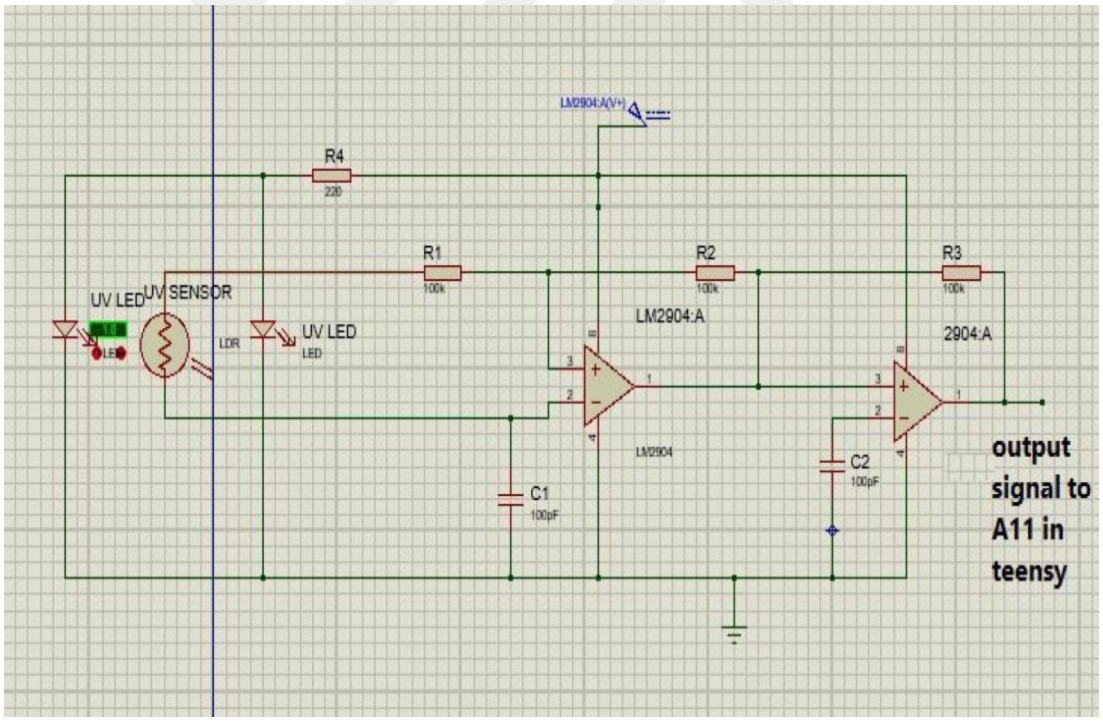



**Figure 3.21** Schematic of UV source and detector circuit

### 3.3.8 Buzzer

A buzzer is audio signaling device, usually be electronic, it widely uses in the automotive electronics, computer, Electronic toys, copier, printer, alarm, a used in

Sound devices, telephones. Its warning is issued in continuous or intermittent form or a beep sound [2].

### 3.3.9 Switch mode power supply

Switch mode power supplies (SMPS) are now so necessary for the most of our home appliances. Old-fashioned linear power supplies based on mains frequency transformers have disappeared, mainly because of their cost, their large size and weight. The power supply takes mains voltage (120 V or 230 VAC) with power ranging from a few Watts to several hundred Watts. The primary function of a power supply is to convert this voltage to a suitable DC voltage [3]. In most of the electronic devices, it needs a power supply for converting AC voltage to a regulated DC voltage. The reason is to be suitable for all electronic and electrical parts of the device. All the parts of our design (money counting machine) operating on 5V DC source, except (AC motor) it depends on AC (110V) source. Figure 3.22shows the Structure of the switch mode power supply.

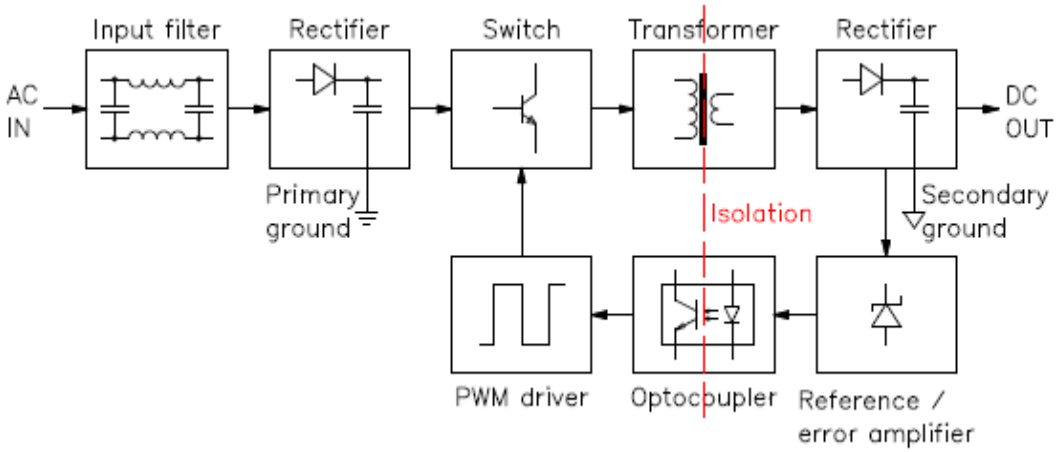



**Figure 3.22** Structure of a SMPS.

## 3.4 Counter Algorithm

The counter algorithm has been designed by using C language and using Integrated Development Environment (IDE) to upload the program into MCU. The algorithm is illustrated in figure 3.23

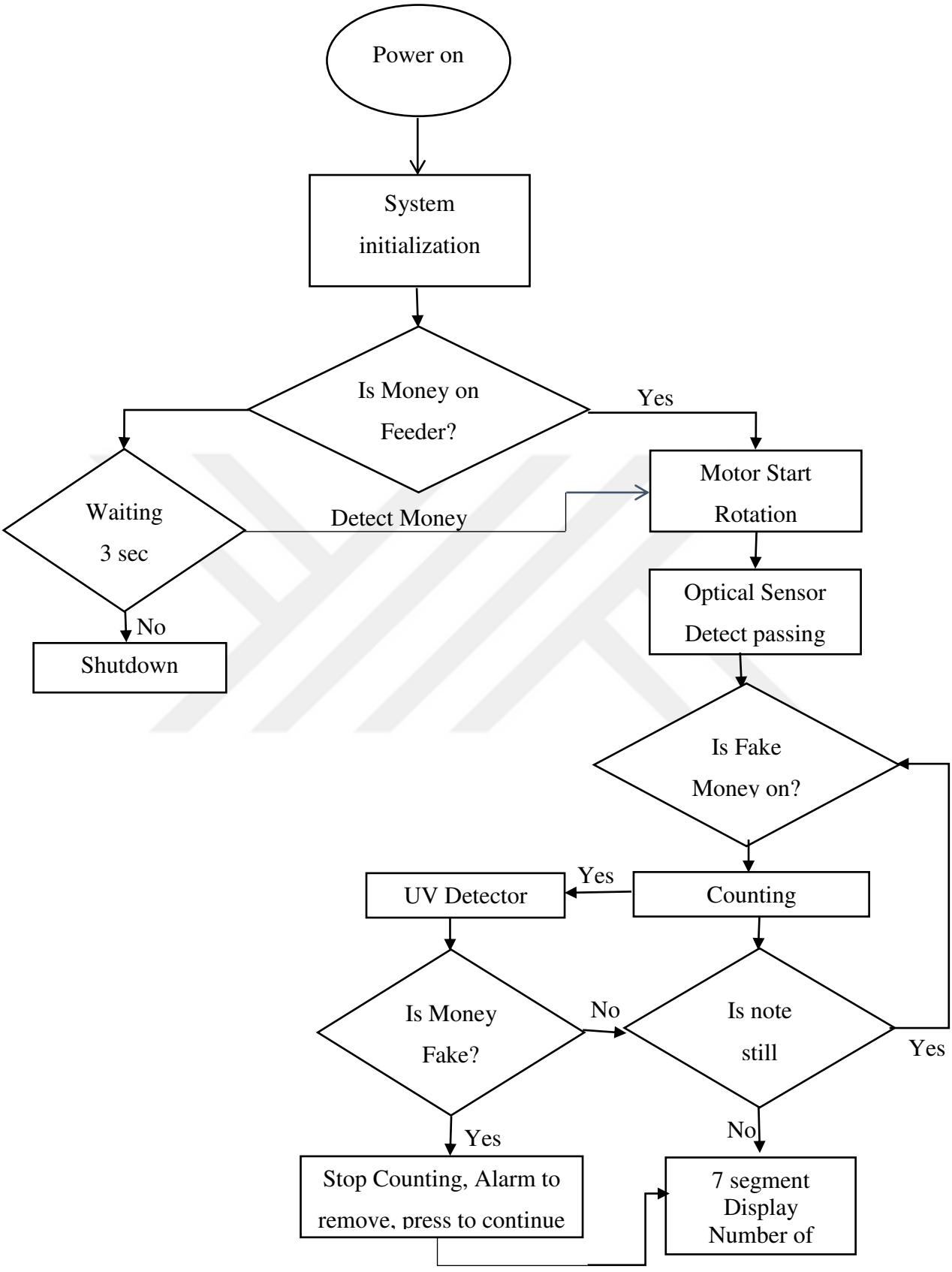


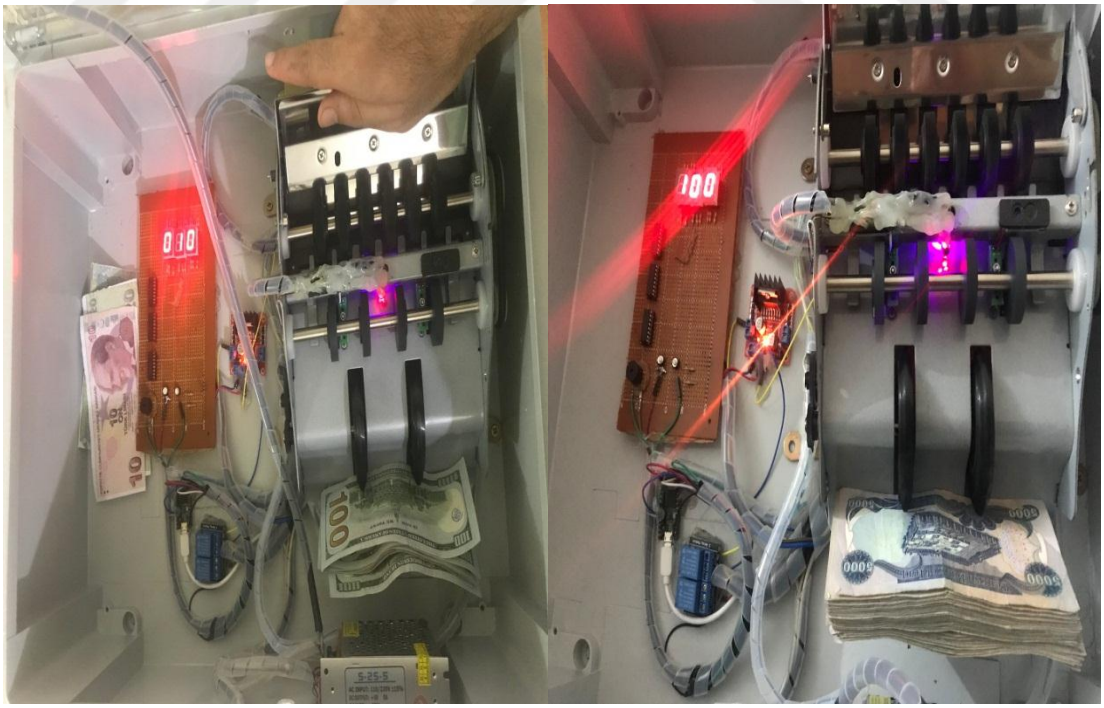

**Figure 3.23** Money Counter and Fake detection algorithm

# CHAPTER 4
# RESULTS AND DISCUSSION

This chapter presents the results of the experiment of the money counter machine. The tests include three factors: the counter accuracy, the percentage of error speed and fake detection accuracy which described in detail in this chapter.

## 4.1 Counting Test

In this part, the accuracy of counting money with different currency types and number was tested. First, we have tested 10 currencies for three currencies types (US dollar, the Turkish lira and Iraqi Dinar) dollars, the counter counted exactly all of them without errors, then used 100 notes of those currencies and the results showed that that the counter counts the number exactly without any problem or error. Figure 4.1 (a) and (b) shows the counting results for 10 and 100 currencies respectively.




(a) (b)

**Figure 4.1** the counting result for (a) 10 notes, (b) 100 notes

### 4.2 Counting Speed Test

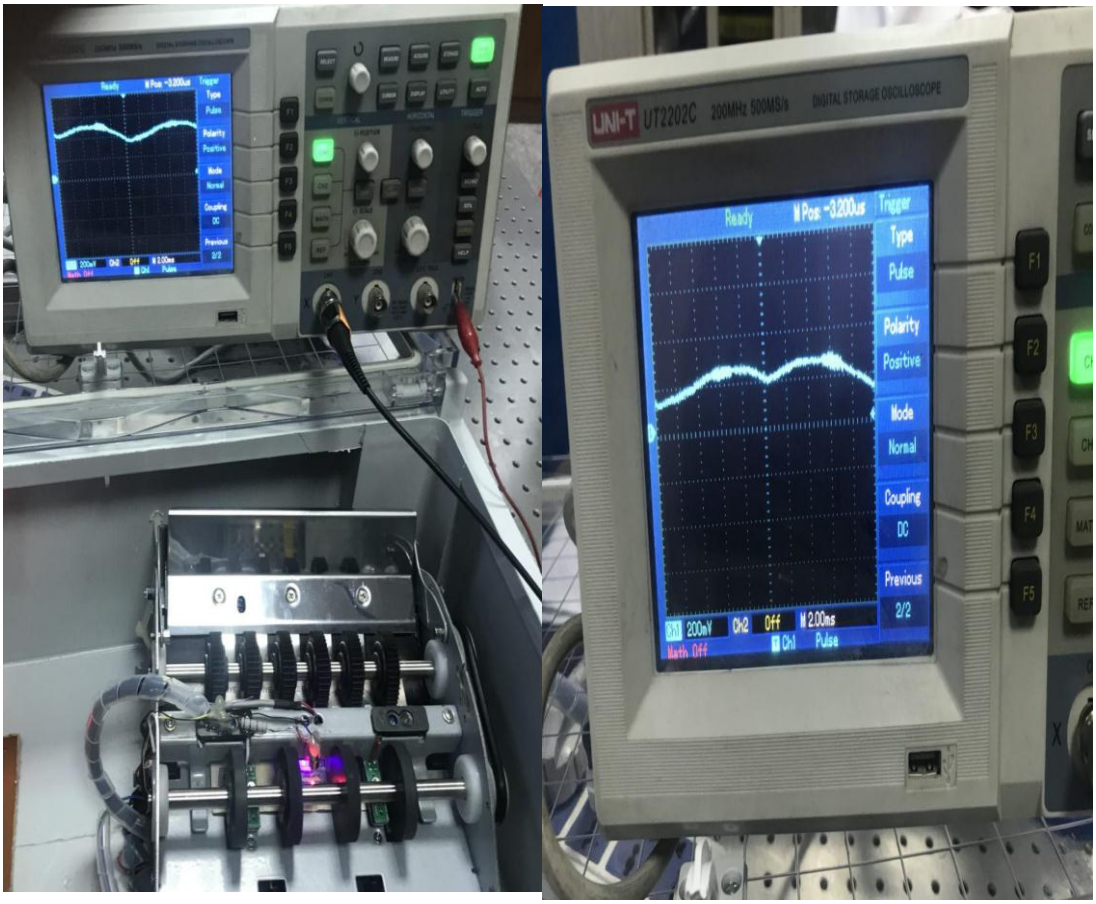
In this part, the counting speed and determine the average notes counting per second were tested. We took 10 notes and calculated the time that the counter could finish the counting process. The results are shown that the counter complete counting 10 notes in (0, 68) part of a second, so the speed of the counter is 10 notes / (0, 68) part of a second. Figure 4.2 shows the counting speed time.


**Figure 4.2** The counting time requested for count 10 notes

### 4.3 Counterfeit currency detection Results

This test is used to check the capacity of the system to detect fake currency. The method is based on transmit UV light and to detect reflected light and to convert it

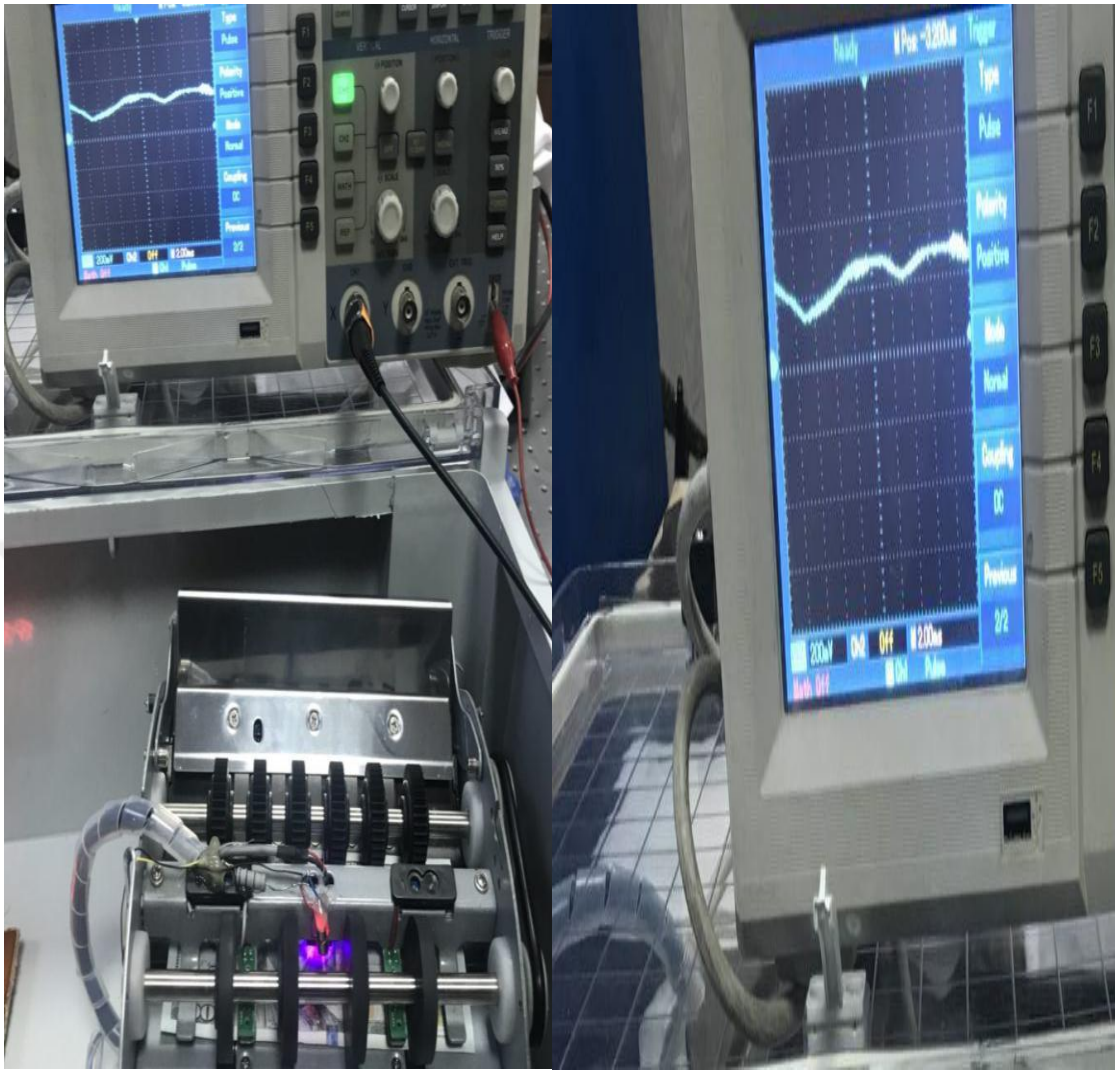
into the voltage based on resident light. At first, we checked the output voltage of UV detector from different original notes types as shown in figure 4.3(a), 4.3(b) figure 4.4(a), 4.4(b) and figure 4.5(a), 4.5(b) and the output voltage from fake notes as shown in figure 4.6.




(a) (b)

**Figure 4.3** the output signal from UV detector for original 5 TL

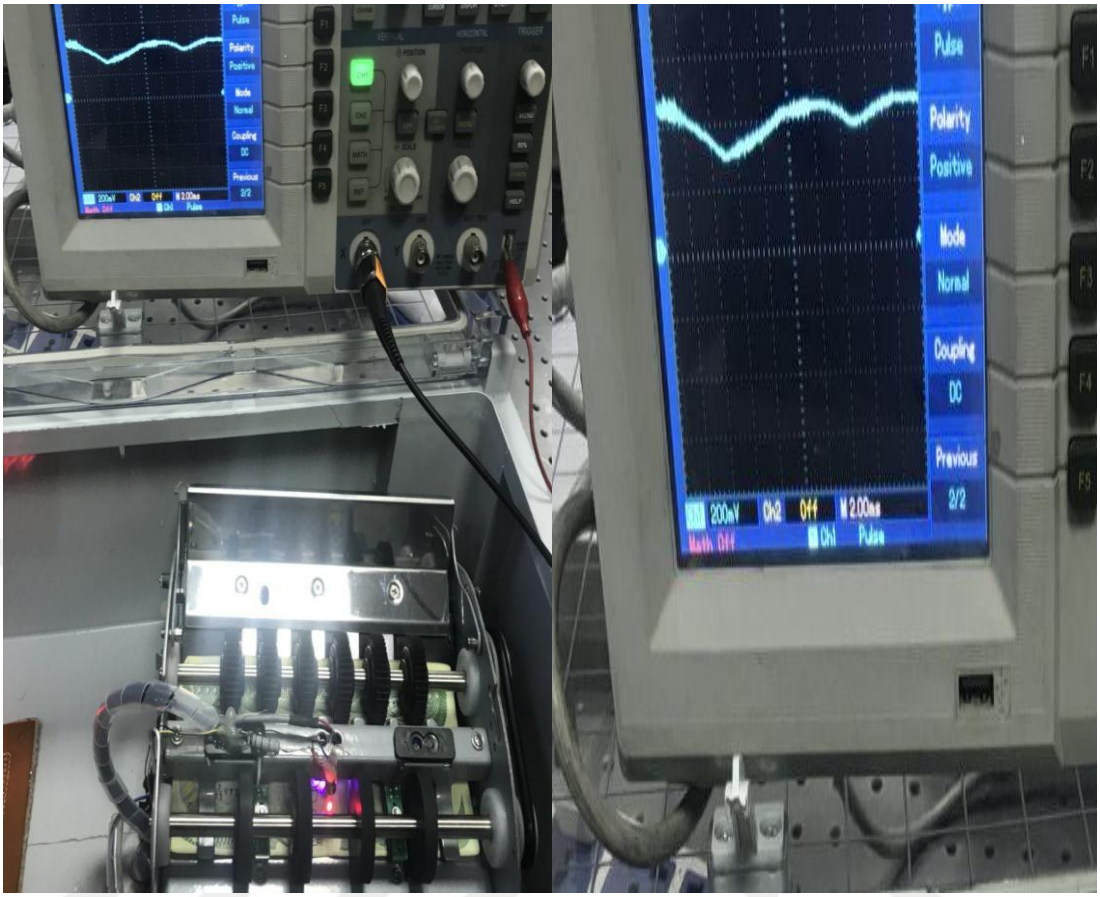
In figure 4.3 the original 5 Turkish liras pass through the counter. Figure 4.3a shows the Turkish lira note under the UV detector. Figure 4.3b shows the output voltage value from detector.



(a) (b)

**Figure 4.4** the output signal from UV detector for original 100 USD

Figure 4.4 shows the output signal from UV detector when original 100 US Dollar pass through the counter. Figure 4.4a shows the original US Dollar note under the UV detector. Figure 4.4b shows the output voltage value from detector.

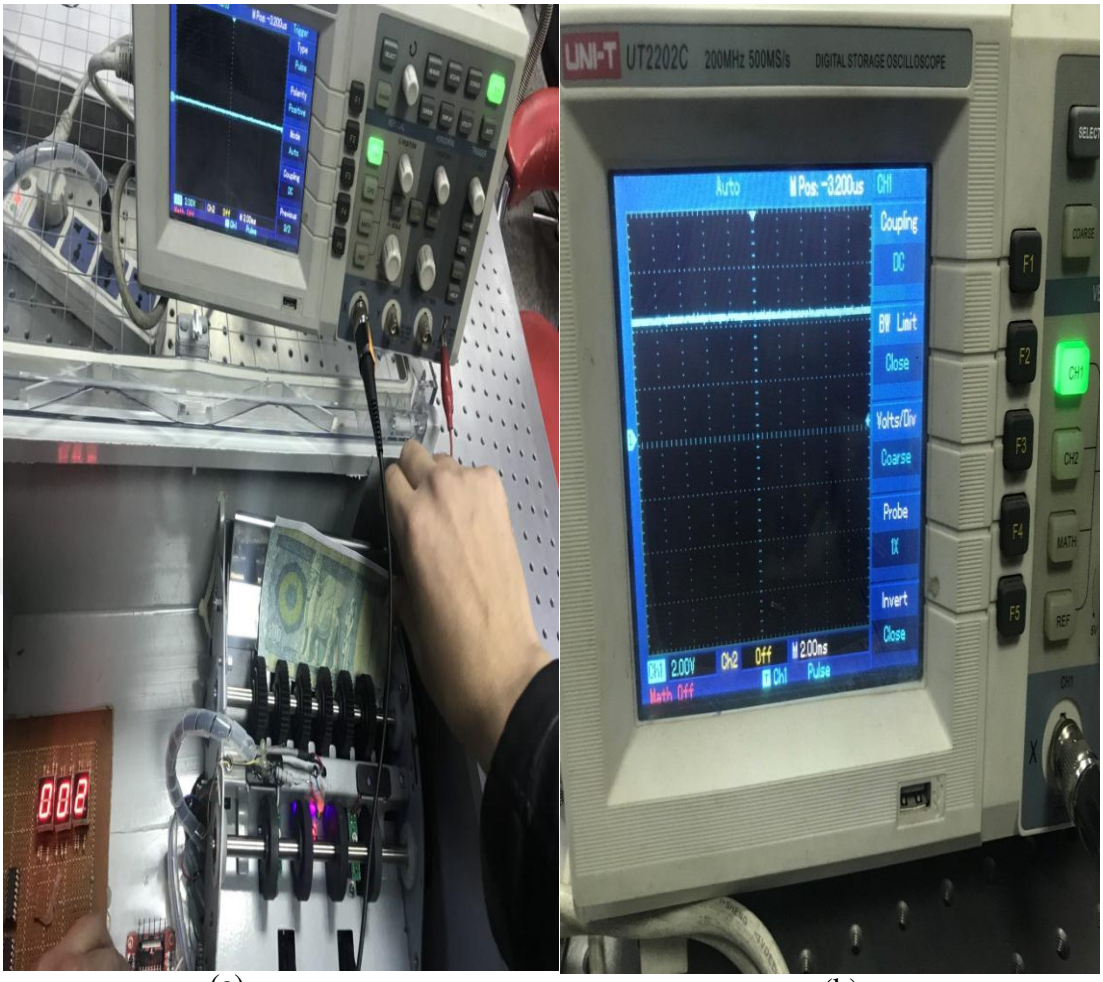



(a) (b)

**Figure 4.5** the output signal from UV detector for original 10000 IQD

Figure 4.5 shows the output signal from UV detector when original 10000 Iraqi Dinar pass through the counter. Figure 4.5a original Iraqi Dinar note under the UV detector. Figure 4.5b shows the output voltage value from detector.

As shown from figure 4.3b, figure 4.4b and figure 4.5b, the output voltage from detector when original notes pass is small (in millivolt) which is in range between 140 millivolt to 160 millivolt.




(a) (b)

**Figure 4.6** the output signal from UV detector when fake 500 Iraqi Dinar (printed currency) passes through the counter

As shown in figure 4. 6, (a) fake 500 Iraqi Dinar under the UV detector, (b) the output voltage value from detector. The output voltage from detector when fake notes pass is higher than original notices which is in range between 4 volts to 4.3 volts. Depending on results, we have defined the range of fake and original notes in the microcontroller program to detect fake notes based on these values. Then, we had tested the capacity of the counter to detect fake notes. We have put several fake notes within a number of original notes, the results show that the counter starts counting and when the fake note pass the counter stop counting and alarm (buzzer). There is a fake note as a result, it is waiting until a user presses "start" again, then, and detecting another fake note it can stop again, as shown in figure 4.7

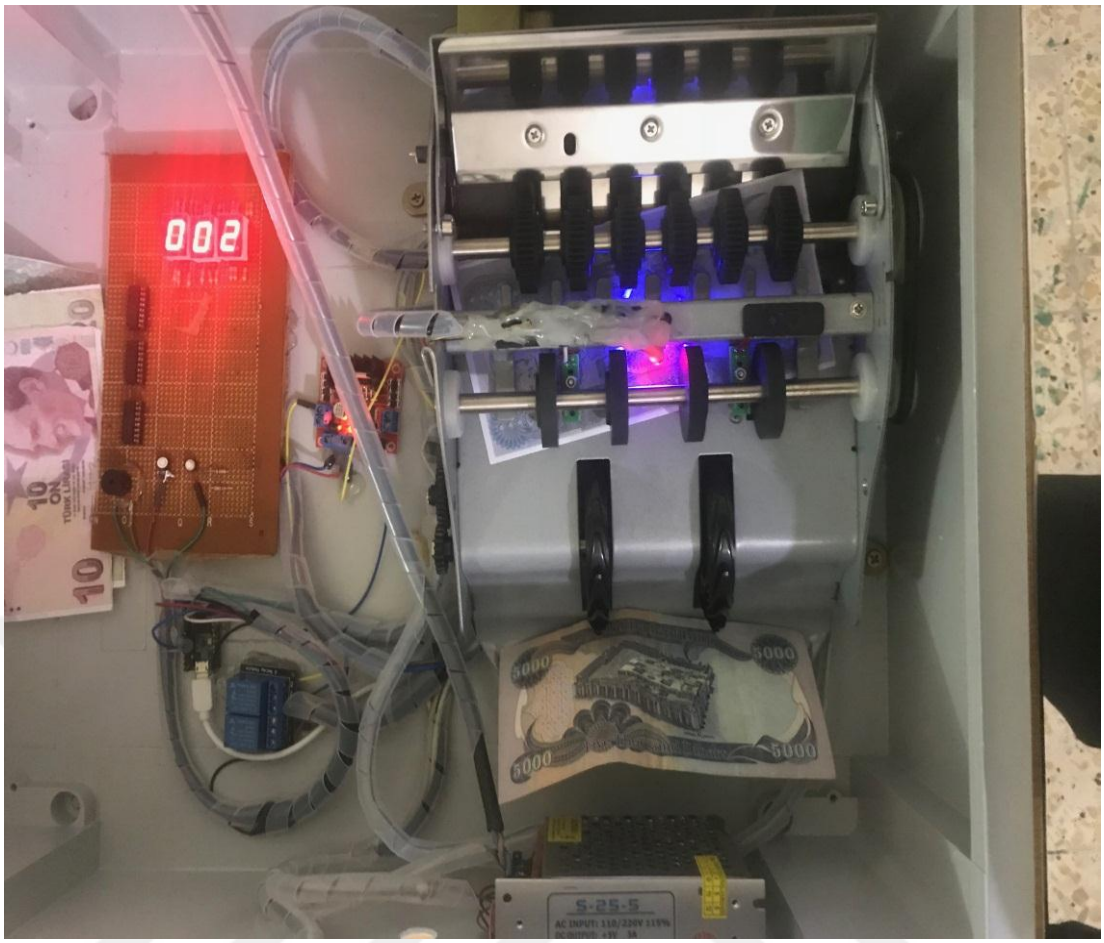



**Figure 4.7** counter operation when detect fake note.

The results show that the counter successfully detects all fake notes of different currency with 0 percentage error, so we can consider it 100% efficient in detect fake notes.

### 4.4 Heavy Work Test Results

This test is used to check the operation of a counter in daily real works under heavy work and to check the problems and errors that system may subject to heavy work. We have put it in an exchange office for one day and compared the results with the specialized commercial counter used by the office, table 4.1 shows the currency counted, the number of notes counted hourly, the courting speed and fake notes detect within 12 hours work.

**Table 4.1** The secret and covers messages information

| Hour | Commercial counter result | | | Proposed counter Results | | |
|---|---|---|---|---|---|---|
| | Number of notes | Fake note Detect | Counting Time | Number of notes | Fake note Detect | Counting Time |
| 9:00 AM | 375 | 0 | 23 s | 375 | 0 | 26 s |
| 10:00 AM | 4000 | 2 | 241s | 4000 | 2 | 272 s |
| 11:00 AM | 3400 | 7 | 205s | 3400 | 7 | 231 s |
| 12:00 AM | 15000 | 0 | 905 s | 15000 | 0 | 1020 s |
| 1:00 PM | 200 | 0 | 12 s | 200 | 0 | 14 s |
| 2:00 PM | 1425 | 0 | 86 s | 1425 | 0 | 97 s |
| 3:00 PM | 343 | 1 | 21 s | 343 | 1 | 23 s |
| 4:00 PM | 157 | 0 | 9 s | 157 | 0 | 10 s |
| 5:00 PM | 233 | 0 | 14 s | 233 | 0 | 15 s |
| 6:00 PM | 2800 | 0 | 169 s | 2800 | 0 | 190 s |
| 7:00 PM | 1200 | 0 | 74 s | 1200 | 0 | 80 s |
| 8:00 PM | 1900 | 0 | 115 s | 1900 | 0 | 129 s |

As shown in the table, the proposed system counts the notes efficiently and the counted speed is very close to the commercial one. Also, the proposed system works perfectly without any hung or problem through the daily work test, so it can be used as an authorized low-cost counting machine.

# CHAPTER 5
# CONCLUSION AND FUTURE WORK

## 5.1 Conclusion

We have designed money counting machine based on ARM- Cortex M4 processor. The (teensy 3.2) microcontroller has used to implement the design. The practical tests showed that this device accomplished the counting process quickly. The speed of counting reaches to 10 notes / (0, 68) part of a second. With errors present 0 % (high accuracy), automatically starting and more than that, it is able to detect the counterfeit currency by ultra-violet (UV) technique.

Many currency types, (Turkish lira, Iraqi dinar, US dollar), were tested and shown the device can detect all counterfeited money with efficiently 100%.

The designed device is a low cost depending on available manufacturing material in a local market. The machine can be considered reliable at work.

## 5.2 Future work

1-Designing money counting system that can count the money based on the money types and categories.

2- Using an image processing and artificial intelligence for detecting Counterfeit and spoilage Currency.

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# APPENDECES

## APPENDIX A

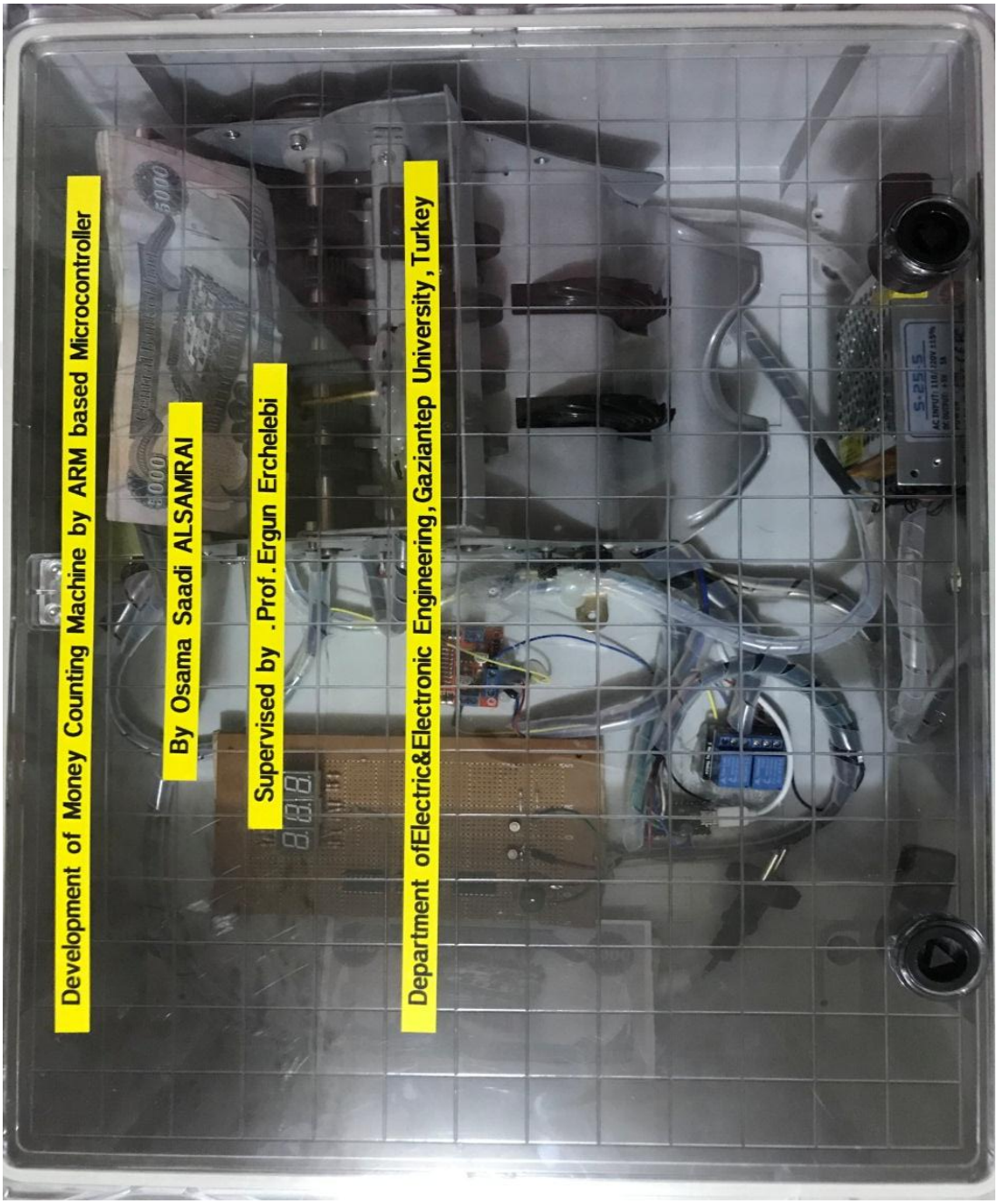
### The code by using C language

```
int a;
int b;
int c;
Void setup ()
{
Pin Mode (12, OUTPUT); //counter circuit
Pin Mode (11, OUTPUT); //warning buzzer
Pin Mode (10, OUTPUT); //dc and ac motor start
Pin Mode (9, OUTPUT); //reset counter
Digital Write (9, HIGH); delay (300); digital Write (9, LOW);
{
Void loop ()
{
//start sensor
 c=analog Read (A0); //input signal from start sensor
  If(c<1020)
 {
digital Write (10, HIGH) ;
}
//if input signal of start sensor less than 5 volt start the system
  Else
 {
```

```
delay (3000); //else stop system
digitalWrite(10,LOW);digitalWrite(9,HIGH);delay(300);digital
Write(9,LOW);
}
//UV SENSOR CODE
b=analog Read (A11); //input signal from UV sensor
If (b>250) {digital Write (11, HIGH); //if Counterfeit currency
the buzzer warning on
Else
Delay (1000); //wait
Digital Write (11, LOW);
}
//COUNTER CODE
a=analog Read (A10); //input signal from IR & laser sensors to
count currency
If (a>=1000)
{
Digital Write (12, HIGH);
}
Else if (a<1000)
{
digital Write (12, LOW);
}
Delay (12);
}
```

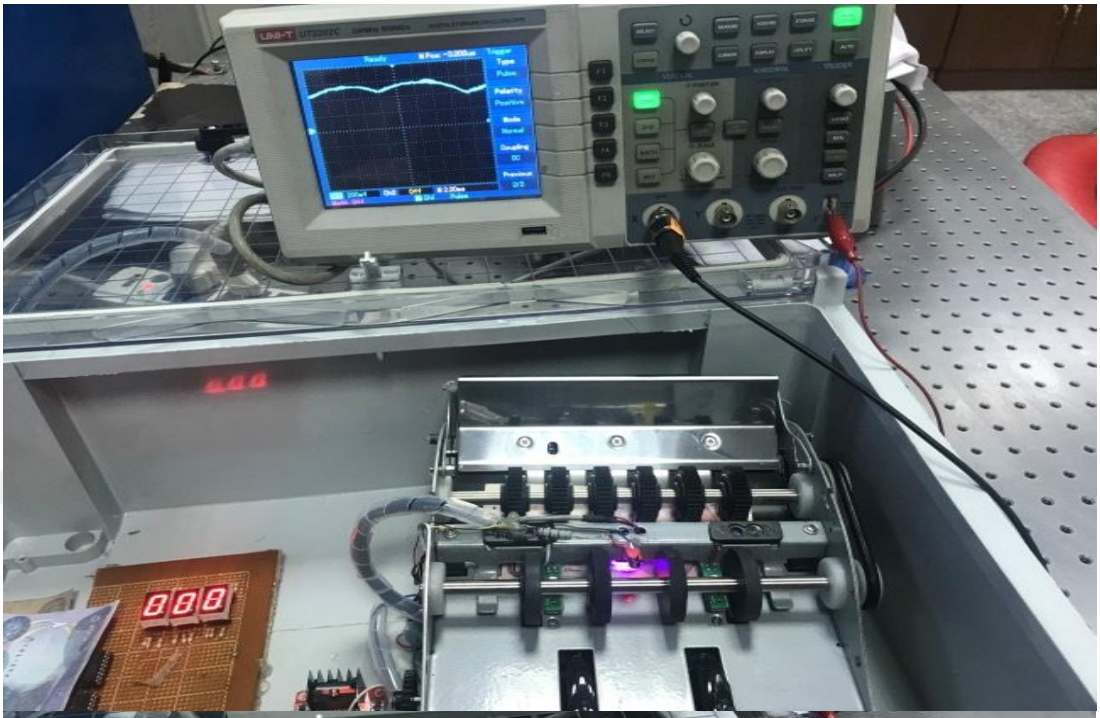
# APPENDİX B

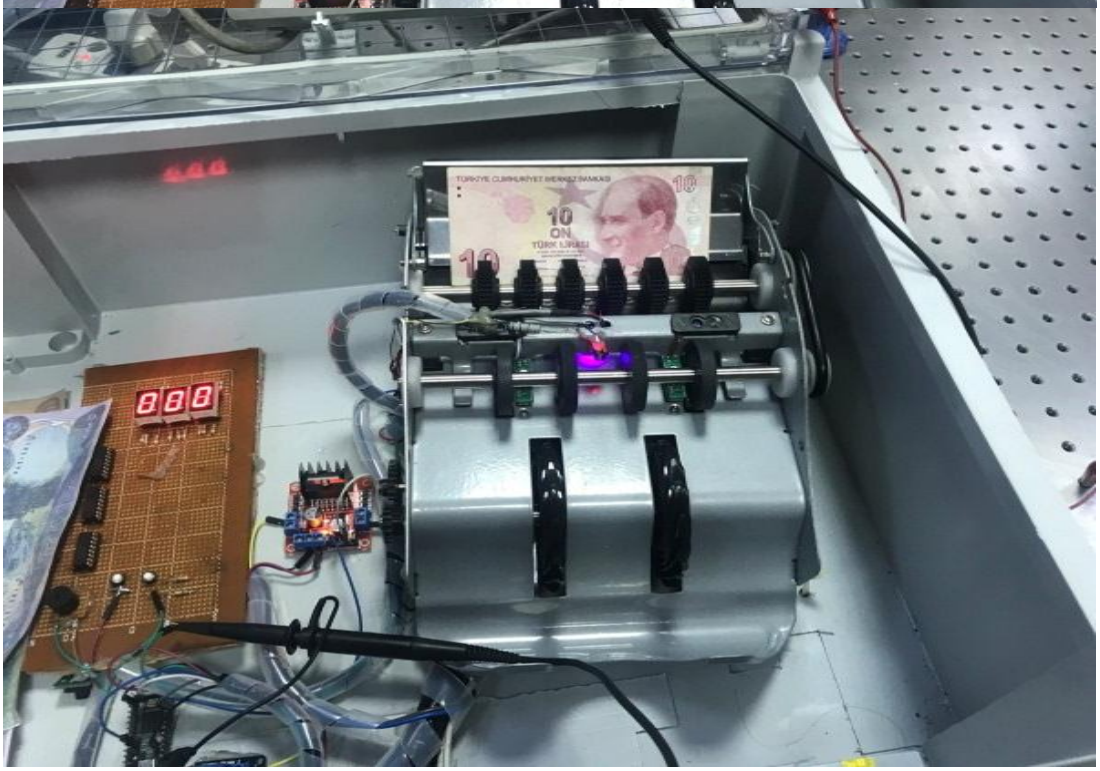
## Outer shape for the proposed project

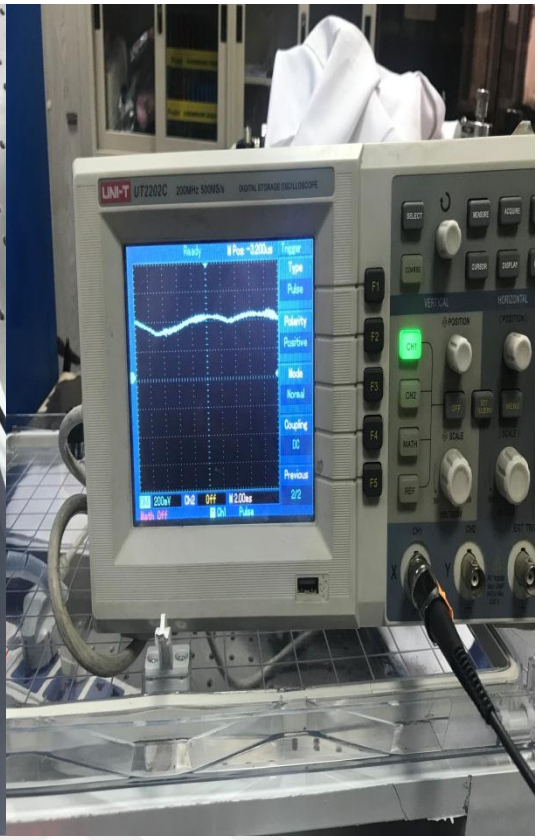


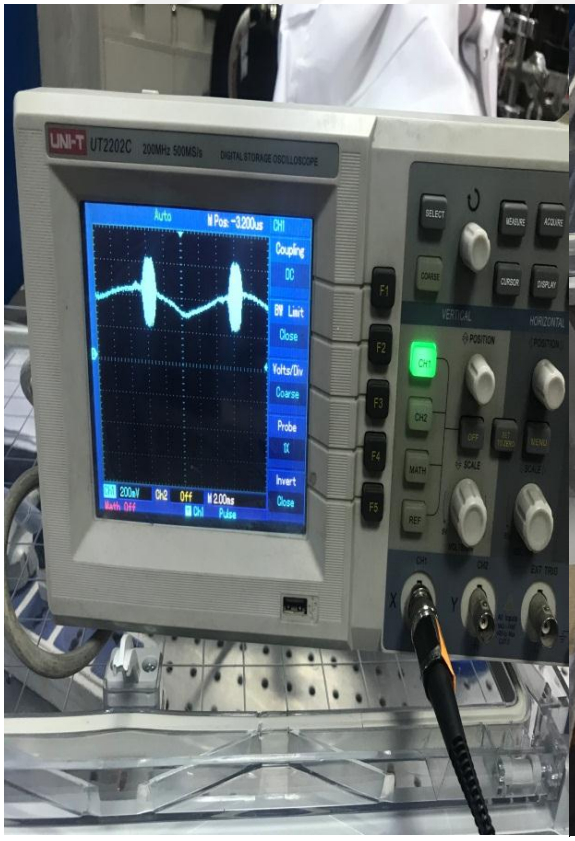
# APPENDİX C

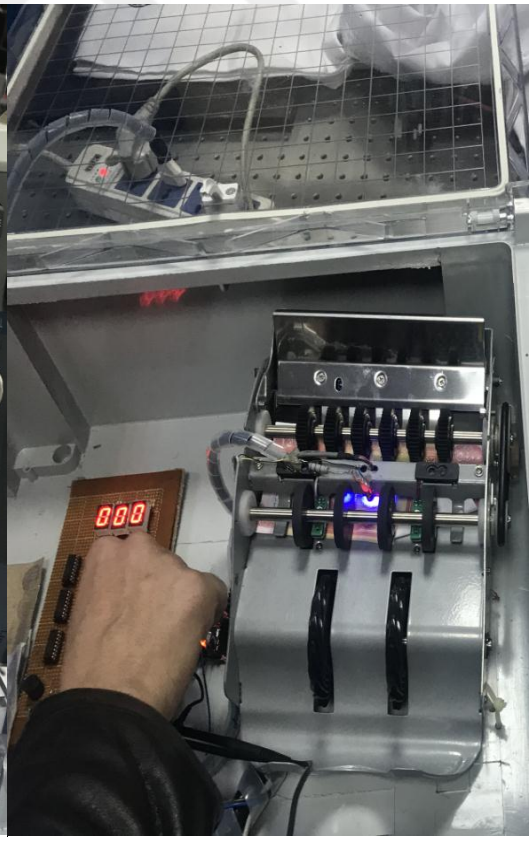
## More results





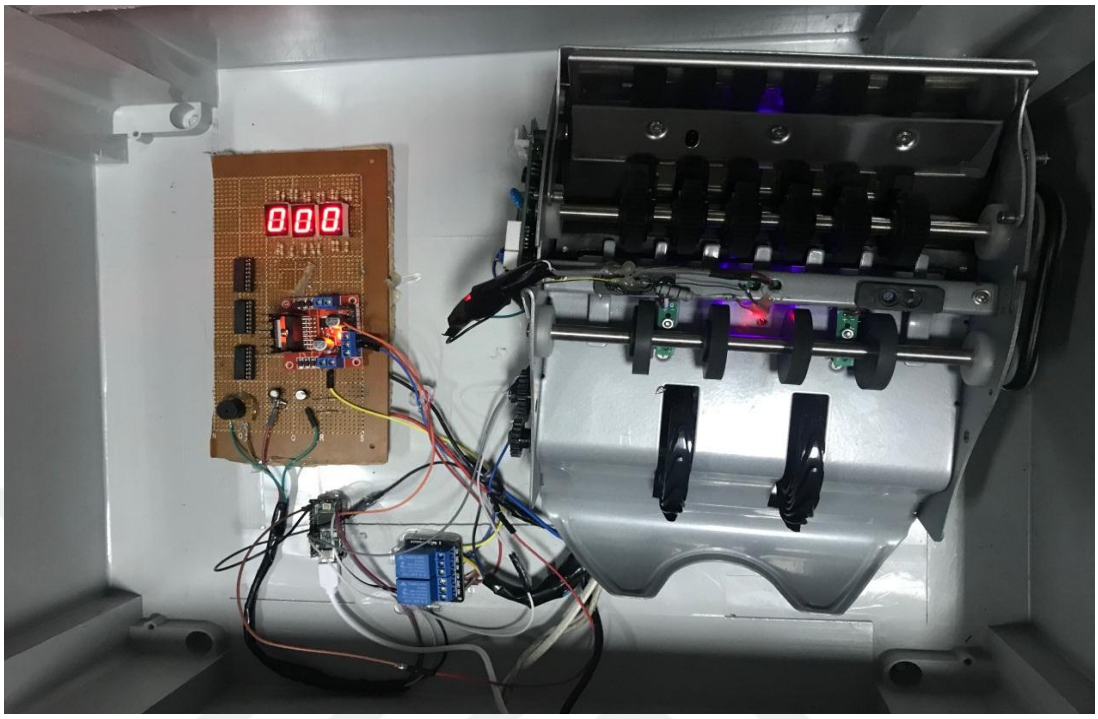

UNI-T UT2202C 200MHz 500MS/s DIGITAL STORAGE OSCILLOSCOPE

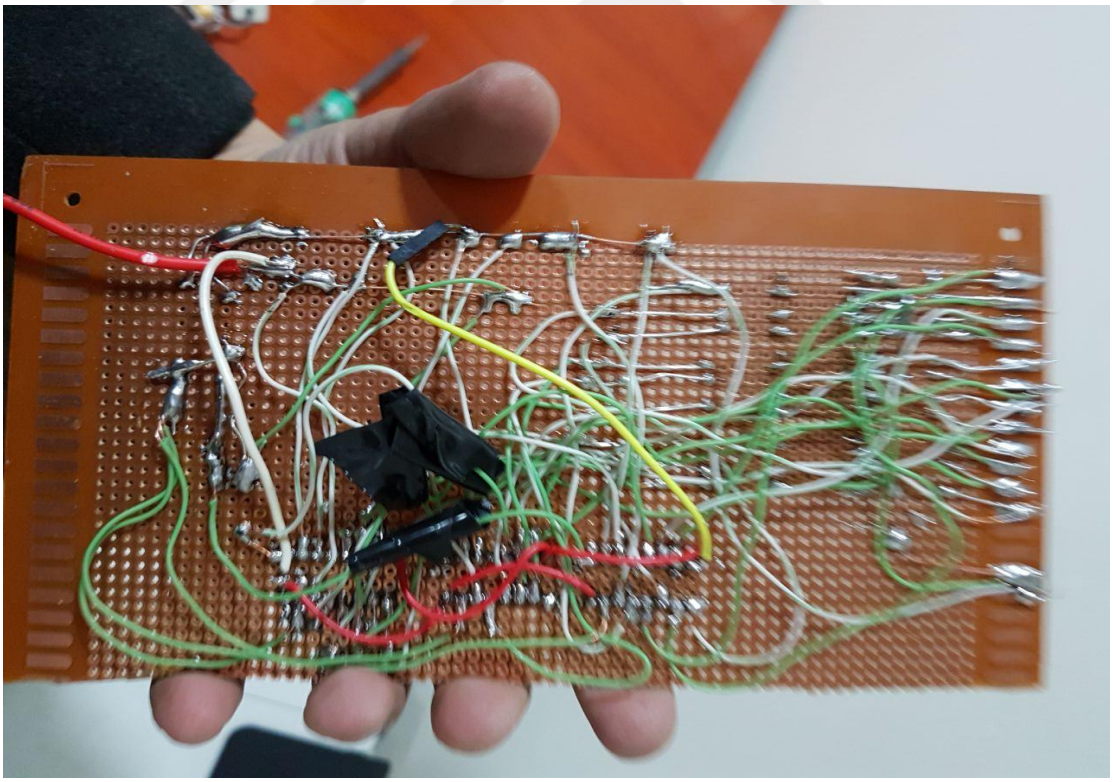

UNI-T UT2202C 200MHz 500MS/s DIGITAL STORAGE OSCILLOSCOPE

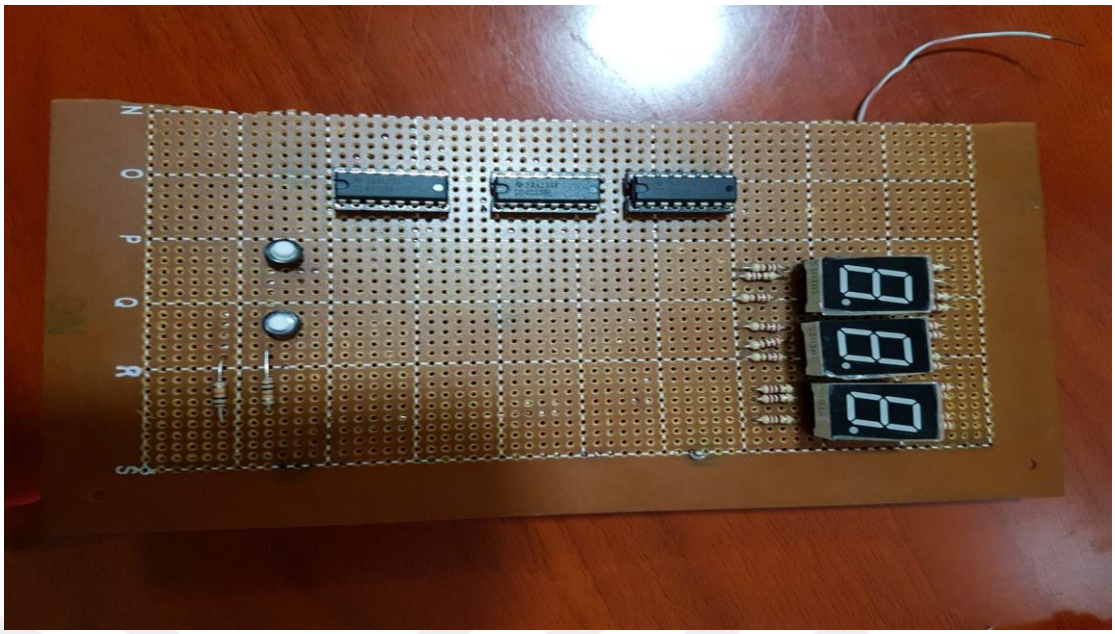


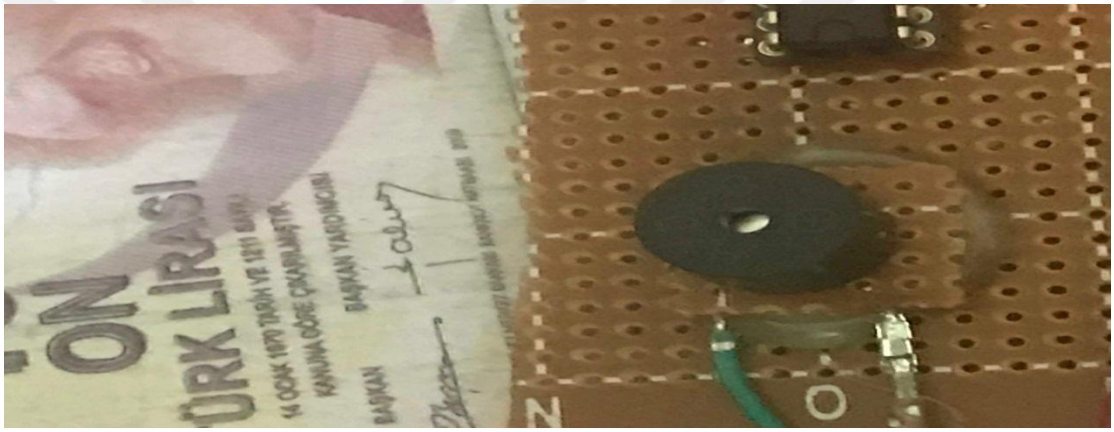
# APPENDİX D

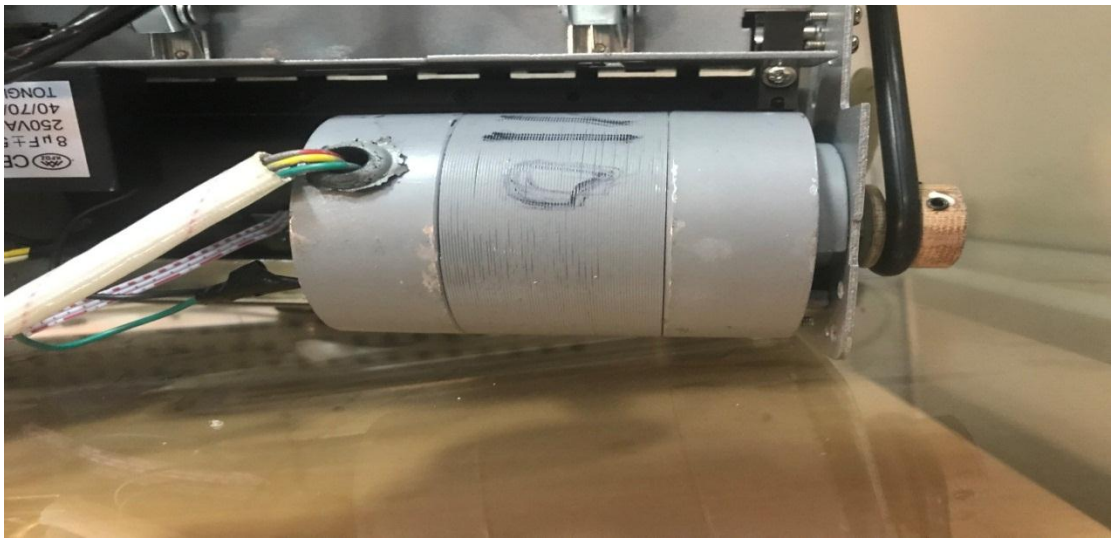
## More components before the finishing








ÜRK LİRASI




S-25-5
CAUTION !