Design and Implementation of Microcontroller Based Security Door System using Fingerprint Recognition Technology

Nwankwo Nonso Prince , Alumona Theophilus , Nwankwo Vincent , Nwokeke .O. Albert

Abstract— **This paper presents a design and implementation of microcontroller based security door system using fingerprint technology. It utilizes fingerprint recognition technology to allow access to only those whose fingerprints are stored in the system database. The designed system eliminates the need for keeping track of keys, remembering a combination password, or PIN. Users can open the door by simply placing their finger(s) on the fingerprint scanner made available in the system. In this project implementation, the fingerprint module from Mixes Biometrics was used. It can store up to 750 finger prints on its own memory. The microcontroller (AT89C52) interacts with the module. Once an image is captured by the fingerprint scanner, the digital information is transferred to a digital signal processor (DSP) to generate a match. The first step in the matching process is conditioning the scanned fingerprint. Finger print readers rarely use the full fingerprint for identification. Rather, DSPs use algorithms to extract the unique features and patterns of each print to generate a unique digital code. The second step in the software flow is to take the code generated from the scanned image and compare it to a database of potential matches. The main important units of the system are; the microcontroller unit, the finger print module, the LCD display unit, the power supply unit, the buzzer unit, and the output unit (door). They were discussed in the write-up for proper understanding of the system. The AT89C52 microcontroller that was used to store all the assembly language of the system was programmed with the aid of a Top Universal Programmer.**

Index Terms— Fingerprint Recognition, Biometrics Recognition, Digital Signal Processing (DSP), Microcontroller, Liquid Crystal Display (LCD)

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I. INTRODUCTION

In the 21st century, the use of biometric based systems has seen an exponential growth. This is all because of tremendous progress in this field making it possible to bring down their prices, easiness of use and its diversified use in everyday life. Biometrics is becoming new state of art method of security systems. Biometrics are used to prevent unauthorized access to ATM, cellular phones , laptops , offices, cars and in many other applications where security is a priority. Biometric have brought significant changes in security systems making them more secure than before, efficient and cheap [1]. Fingerprint biometrics are also used in a variety of applications including electronic door locks, smart cards, vehicle ignition control systems, USB sticks with fingerprint controlled access, and many others. Digital signal processing elements in fingerprint scanners perform complex DSP functions such as filters, transforms, feature extraction, matching operations and other algorithms [2].

Fingerprint Security Systems have fascinated people for centuries. They have been used as a method of personal identification since ancient times. The two key aspects of most of the Fingerprint System biometric solutions are Finger Print identification and authentication [3]. The process of identification tells you who an individual is, or in the negative sense tells you who they are not. Finger Print Security Systems can be used to get rid of so many issues such as Physical Access Control, Health care Biometrics, Fingerprint and Biometrics Locks, Biometric Sensors and Detectors, RFID Tags, RFID Readers, Road Barriers, RFID Smart Card, CCTV, Metal Detectors, LED Search Lights, Fire Alarm, Finger Print Movement Control, Physical Access Control, Optical Fingerprint Scanners, Optical Sensors, Card Locks Card Access Control Systems, Fingerprint Technology, Digital Fingerprint, USB Fingerprint Reader etc.

Fingerprint System Authentication is a simpler process. It involves affirming or rejecting a claimed identity by matching a live template with an existing one [4].

II. STATE OF THE ART IN FINGERPRINT RECOGNITION

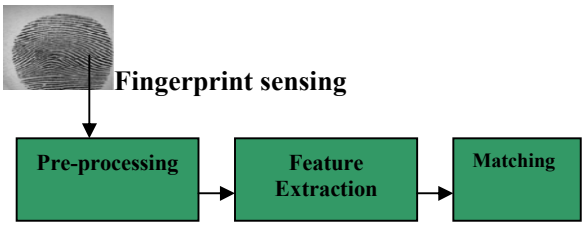

Fig.1. Main modules of a fingerprint verification system

The main modules of a fingerprint verification system shown in fig. 1 are: ***a. fingerprint sensing*****,** in which the fingerprint of an individual is acquired by a fingerprint scanner to produce a raw digital representation; ***b. pre-processing*****,** in which the input fingerprint is enhanced and adapted to simplify the task of feature extraction; ***c. feature extraction*****,** in which the fingerprint is further processed to generate discriminative properties, also called feature vectors; and ***d. matching*****,** in which the feature vector of the input fingerprint is compared against one or more existing templates.

The templates of approved users of the biometric system, also called clients, are usually stored in a database. Clients can claim an identity and their fingerprints can be checked against stored fingerprints [5].

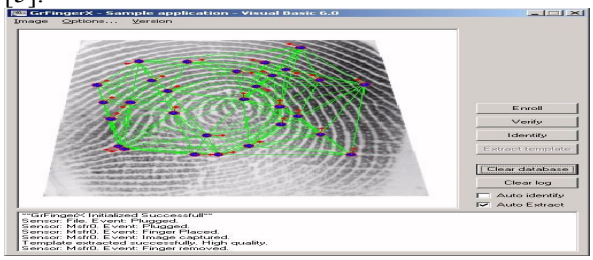

Fig. 2. Sample Application of Fingerprint Technology

A. Fingerprint Pre-processing and Feature Extraction

A fingerprint is composed of a pattern of interleaved *ridges* and *valleys*. They smoothly flow in parallel and sometimes terminate or bifurcate. At a global level, this pattern sometimes exhibits a number of particular shapes called *singularities*, which can be classified into three types: *loop*, *delta* and *whorl*. **Fig. 3** below represents an example of loop and delta singularities (the whorl singularity can be defined as two opposing loops). At the local level, the ridges and valleys pattern can exhibit a particular shape called *minutia*. Singularities at the global level are commonly used for fingerprint classification, which simplifies search and retrieval across a large database of fingerprint images [6]. Based on the number and structure of loops and deltas, several classes are defined, as shown in **Fig. 4 below.**

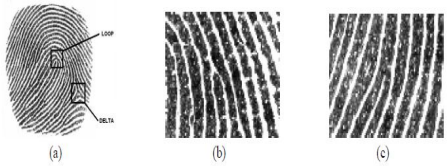

Fig. 3. Figerprint Signularirteis: (a) Loop and Delta Signlaties, (b) Ridge Ending, and (c) Ridge Bifurcation

Fig. 4. The Six major Fingerprint classes: (a) arch, (b) Tented arch, (c) Left Loop, (d) Right Loop, (e) Whorl, and (f) Twin – Loop

III. SYSTEM IMPLEMENTATION

The designed system (microcontroller based security door system using fingerprint recognition technology) comprises of the following main hardware units;

1. The Microcontroller Unit (AT89c52).
2. The Liquid Crystal Display (LCD) Unit.
3. The Fingerprint Module.
4. The Buzzer Unit.
5. The Actuator / Output Unit (Door).
6. The Regulated Power Supply Unit

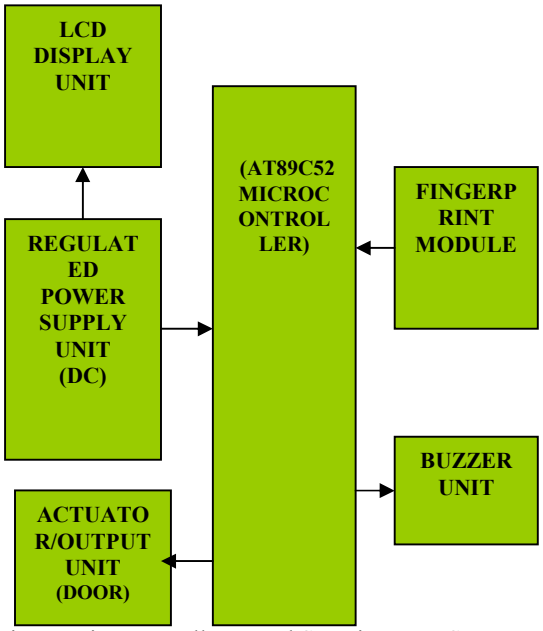

Fig. 5. Microcontroller Based Security Door System using Fingerprint Recognition Technology

A. The Microcontroller Unit (AT89c52)

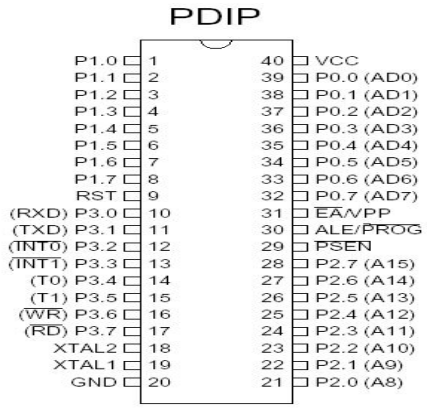

Fig. 6. Pin Configuration of AT89c52 Microcontroller

The AT89C52 microcontroller is used to store all the assembly language program of the system. It has 8 bit microprocessor, an on chip flash memory, decoders for decoding or locating data in memory, internal clock timers and counters for counting / synchronizing logic operations in the microcontroller. It has an external clock generator circuit called the crystal oscillator. The AT89C52 is a powerful microcomputer that provides a highly flexible and cost effective solution to many embedded control applications [7].

The AT89C52 Provides the Following Features:

1. 8 Kbytes of on-chip flash memory
2. 256 bytes of on chip RAM
3. 32 programmable I/O lines
4. Two 16 bit timer/counter
5. Full duplex serial port
6. On-chip oscillator and clock circuitry.

In addition, the AT89C52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The idle mode stops the CPU while allowing the RAM, timer/counter. Serial port and interrupt system to continue functioning. The power down modes saves the RAM contents but freezes the oscillator disabling all other chips functions until the next hardware resets.

B. The Liquid Crystal Display (LCD) Unit

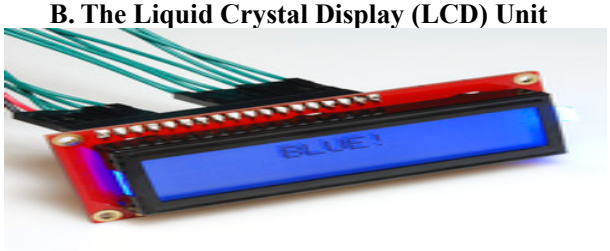

Fig. 7. Image of the LCD used in the Designed System

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is the most common module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being; LCDs are economical, have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on [8]. A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The LCD has two registers; Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD [9]. The LCD is used to display the status of the system, it also acts as a link between the microcontroller and the outstand world. Information displayed by the LCD includes; Door open, Door closed, Access Granted, Access Denied, etc.

C. SM630 Fingerprint Module

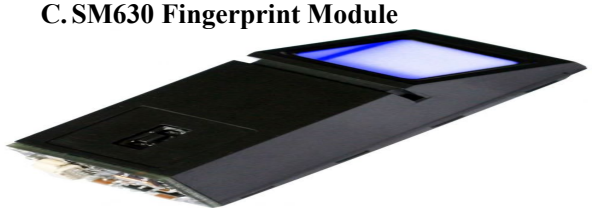

Fig. 8a. Image of the SM630 Fingerprint Module

SM630 background highlight optical fingerprint verification module is the latest release of Miaxis Biometrics Co., Ltd. It consists of optical fingerprint sensor, high performance DSP processor and Flash. It boasts of functions such as fingerprint Login, fingerprint deletion, fingerprint verification, fingerprint upload, fingerprint download, etc. Compared to products of similar nature, SM630 enjoys the following unique features:

∗ Self-proprietary Intellectual Property

Optical fingerprint collection device, module hardware and fingerprint algorithm are all self developed by Miaxis.

∗ High Adaptation to Fingerprints

When reading fingerprint images, it has self-adaptive parameter adjustment mechanism, which improves imaging quality for both dry and wet fingers. It can be applied to wider public.

∗ Algorithm with Excellent Performance

SM630 module algorithm is specially designed according to the image generation theory of the optical

fingerprint collection device. It has excellent correction & tolerance to deformed and poor-quality fingerprint.

∗ Easy to Use and Expand

Users do not need to have professional know-how in fingerprint verification. User can easily develop powerful fingerprint verification application systems based on the rich collection of controlling command provided by SM630 module. All the commands are simple, practical and easy for development.

∗ Integrated Design

Fingerprint processing components and fingerprint collection components are integrated in the same module. The size is small. And there are only 4 cables connecting with HOST, much easier for installation and use.

Remark

1. Fingerprint ID starts from 0
2. Fingerprint storage capacity: 768
3. If the ID is wrong in the command, module will responds as parameter error:
   0x4D + 0x58 + 0x30 + 0x02 + 0x40 + 0x35 + 0x4C
4. If a user place different finger at the first time or the fingerprint quality is poor, module will responds as fingerprint processing failure:

   0x4D + 0x58 + 0x30 + 0x02 + 0x40 + 0x34 + 0x4B
5. If there is no finger at the scanner after 10 seconds the system was powered / on, module will respond as time-out.

   0x4D + 0x58 + 0x30 + 0x02 + 0x40 + 0x33 + 0x4A.

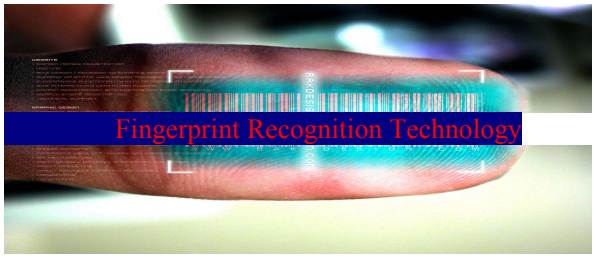

Fig. 8b. Thumb Print

D. The Buzzer Unit

The buzzer / alarm unit consist of a transistor, a resistor and a loud speaker. The base of the NPN transistor was connected to the microcontroller via a 1k ohms resistor**.** The emitter was grounded and the negative terminal of the loud speaker was connected to the collector of the NPN transistor. The positive terminal of the loud speaker was connected to the 12v power supply. The buzzer produces an audible sound anytime an unregistered user (a user whom name is not found in the system database) tries to gain access. The alarm sounds for 3 seconds before going off. The alarm circuit is shown in fig. 9 below.

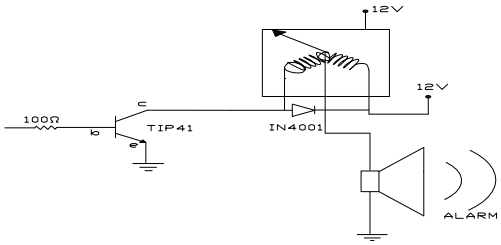

Fig. 9. The Alarm Unit / Section

E. The Actuator / Output Unit (Door)

The actuators used for this project are relays which function by connecting or disconnecting the socket terminals from supply, in order to either open or close the door. The choice of the relay used was based on the following ratings:

- Voltage rating – 12V (switching voltage).
- Contact rating – 10A.
- Coil rating – 100mA (max. coil current).

To switch the relay, it requires a transistor switching circuit to amplify the current from the microcontroller to a value that can energize its coil. The unit that handles this switching is the ULN2003A IC. Fig. 10 below shows how it was connected to the relay and the microcontroller.

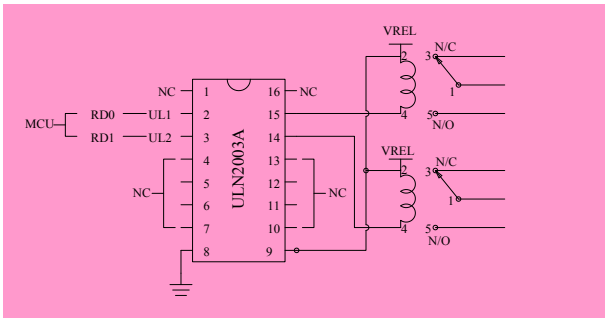

Fig. 10: ULN2003A IC Connection to the Relay and Microcontroller

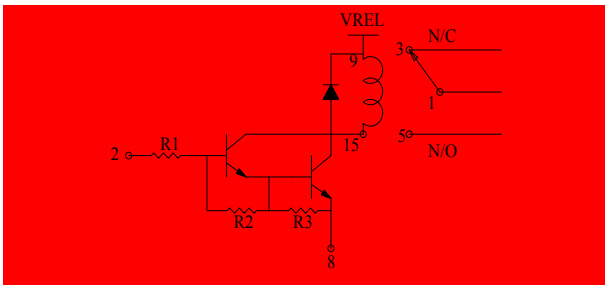

Fig. 11. Darlington pair making up the ULN2003 IC

Fig. 12: Designed system under construction (Prototype)

Fig.13: Designed system after construction (Prototype)

F. The Regulated Power Supply Unit

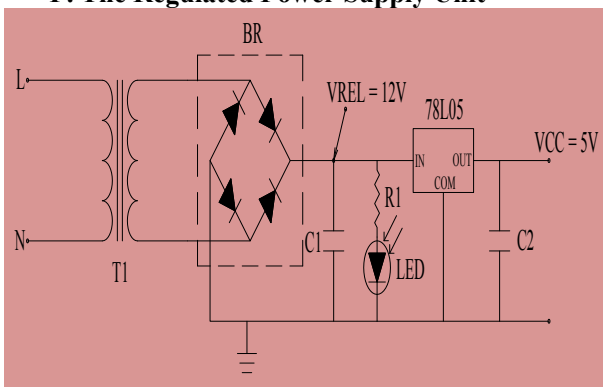

Fig. 14. (5v) Regulated Power Supply

The figure 14 above shows the power supply unit that is used to power the designed system. The transformer is used to step-down 220v (ac) to 12vac. The bridge rectifier comprising of four diodes are used to rectify the signal at the secondary side of the transformer (convert it from 12vac to 12vdc). Because of some ripples present at the DC voltage, the capacitor was employed to filter the signal, while the Light Emitting Diode (LED) acts as an indicator, to show that the power supply circuit is working. Since the microcontroller uses a voltage between (3.5v – 6.5v), the 7805v regulator was considered appropriate to help regulate the 12vdc to 5vdc, which is the best voltage level for the designed system.

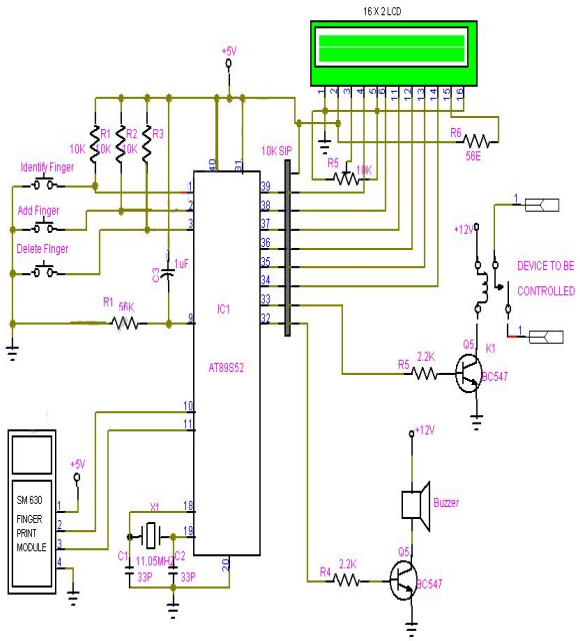

Fig. 15: Complete circuit diagram of the security door system (using fingerprint technology)

IV. SOFTWARE IMPLEMENTATION

Any microcontroller development system is a combination of hardware necessary for microcontroller based design with the software necessary to control the hardware. Hence the hardware is of no use without proper software development. In this project, the software used is the Assembly Language.

The steps taken in assembling the program is summarized as follows:

1. Type the program in notepad.
2. Save it as “securitydoor.asm” in drive C: /
Ensure that drive C: / has the 3 applications (A51, OHS51 and L51) required to assembly the program.
3. Launch the “run” command from the start menu and type the commands
a51. securitydoor.asm
l51. securitydoor.obj
ohs51. securitydoor.obj

And then click OK; In case of syntax error in program code, program will not be compiled and HEX file would not be generated. Errors need to be corrected in the original program file (the one typed in Notepad) and the source file compiled again. The best approach is to write and test small, logical parts of the program to make debugging easier. The PM-51 Macro Assembler was used for this project. The term PM-51 belongs to an entire family of single-chip microcomputers, all of which have the same processor design. They use the same instruction set, but differ slightly in Memory mapped special function registers and on-chip ROM

and RAM. The assembler is a software tool- a program-designed to simply the task of writing computer programs. It performs the clerical task of translating symbolic code into executable object code. This object code may then be programmed into one of the PM-51 processor to which the 8051 belongs.

RESULTS

The result of these processes led to a security door which can be opened by fingerprint. The door opens automatically when the right fingerprint stored in the database is entered and it remains open for (10 seconds) before closing back (automatically).

CONCLUSION

The design and implementation of microcontroller based security door system (using fingerprint technology) has been proven to be a reasonable advancement in door security system technology and access control. The work done here is original and has not been published. The fingerprint module interface has expanded the flexibility of the multi-functional Microcontroller. This is a major breakthrough in digital design, control system and technological advancement in general.

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