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# Design and Construction of Magnetic Card Reader System

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***Abstract* —This paper aims to develop a magnetic card reader system using personal computer. The system is composed of magnetic cards, card reader circuit, personal computer based encoding software and a prototype door. The software on computer is developed with three main parts, data encoding, line printer (LPT) port interfacing and door control. The raw data from several cards are read by magnetic card head assembly and reader circuit. If the data which is read from the card is valid, the door will open and if not, alarm will trigger. Non-standard track-4 type phone cards are used as a security key for demonstration system.**

***Keywords*— magnetic card reader, encoding, LPT port, head assembly, reader circuit**

## I. Introduction

Beyond the twentieth century, the life styles of human are well developed and changed because of new technology. There are various kinds of materials which involved daily life of human. Among these technologies, memory cards are well organized by many applications and consumer devices.

Many people carry one or more magnetically encoded cards with them for accessing a range of services. Perhaps the most common example is the phone card, the credit card or bank ATM card, but increasingly they are being used for access control, employee time logging, customer loyalty schemes, club membership and other applications.

Magnetic card is a type of memory storage card including these technology facts and forms. A magnetic card is a rectangular plastic object (phone, credit/debit card) that contains either a magnetic object embedded within the card or a magnetic stripe on the exterior of the card. A magnetic card can store any form of digital data.

Magnetic card reader is an electronic device designed to read stored information from a magnetic card by swiping the card through a slot in the reader. About a hundred bytes of information can be stored on a magnetic card.

Because of their extensive use, most magnetic cards employ standards that describe the physical and magnetic characteristics for a magnetic stripe on a plastic card. Specifications for a storage format and information exchange are also defined by these standards. Some application examples of magnetic card are phone card, ATM (Automatic Teller Machine) cards, bank cards and security cards.

## II. Methodology

The magnetic card reader system is composed of a card reader circuit, software to read data from the magnetic cards, motor driver circuit and control system. The overview of the system is shown in Fig. 1.

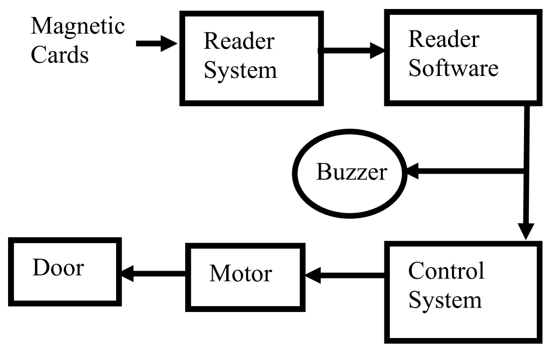


Fig. 1 Overview of the system

Firstly, the data from the magnetic cards is read with a magnetic card reader circuit. The data which is read from the cards is analyzed with stored data which is already stored in the software to determine whether the read data and stored data are equal or not. If they are equal, the DC motor driver will control the door to open and close. If the data is miss match, a buzzer alarm will trigger.

Fig. 2 is the block diagram of the magnetic card reader system. Card reader is composed of magnetic head for reading data from the cards. The reading signal is very small. So it is required to amplify. So, a good performance and high gain transistor to increase the current gain and amplifier to increase the voltage gain are required to develop.

To get low noise and high gain, high input impedance, operational amplifiers are very suitable in this case. The outputs from amplifiers are differential signal of positive and negative peaks. Then, the last section of the reader is to correct from analog signal to pure digital signal.

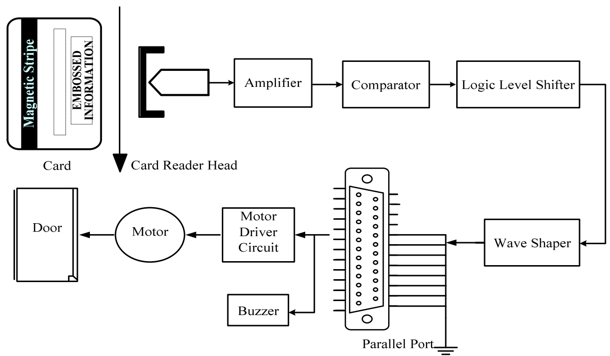


Fig. 2 Block diagram of magnetic card reader system

If the magnetic memory card's swipe has valid access code, the door control signal is sent from LPT port pin-4 and pin-5 to open the door. When the motor is driven as forward direction, door assembly will be moved to open the door. After several seconds, the motor will be driven as reverse direction and the door will be closed.

The portions of the reader system are:

1. Magnetic head
2. Amplifier
3. Comparator
4. Logic level shifter
5. Wave shaper
6. Power supply

The portions of the control system are:

1. LPT port alarm circuit
2. LPT port door motor control circuit

## III. Design Considerations for Magnetic Card Reader System

### A. Amplifier

The main task of amplifier is to amplify small signal from head output.

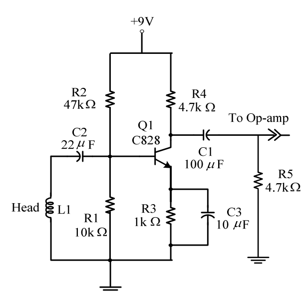


Fig. 3 Amplifier

Let the value of $R_{in}$ be 8kΩ. According to the Equation (1), $R_B$ is approximately equal to $R_{in}$.

$$R_{in} = \frac{R_B(h_{ib} + R_E)}{\frac{R_B}{\beta} + h_{ib} + R_E} \approx R_B \quad (1)$$

Therefore, $R_B$ = 8kΩ.

$$R_B = R_1 // R_2$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} \quad (2)$$

If the value of resistor $R_2$ is chosen 47kΩ, resistor $R_1$ can be calculated from Equation (2).

$$R_1 = 9.6\text{k}\Omega \approx 10\text{k}\Omega$$

Therefore, $R_1$ = 10kΩ is used in this design.

$R_B$ must be less than or equal $0.1\beta R_E$.

$$R_B \le 0.1\beta R_E$$

At the operation state, the current gain of the transistor is $I_c/I_b$ and can be expressed as 70 according to datasheet.

$$R_E \le 1.1\text{k}$$

Therefore, $R_E = R_3$ = 1kΩ is chosen in this circuit.

When the Q-point is at the center of the ac load line (midway between saturation and cutoff), a maximum signal can be obtained. So, $V_{CEQ}$ is set as follow:

$$\text{At the Q-point, } V_{CEQ} = \frac{V_{CC}}{2} = 4.5\text{V}$$

$I_c$=0.8mA is chosen for operational state. Therefore, $I_b$ can be got as:

$$I_b = \frac{I_c}{h_{FE}} = 0.01\text{mA}$$

At $V_{CEQ}$ = 4.5V, $R_E$ = 1kΩ and $I_c$ = 0.8mA, collector resistor $R_C$ can be calculated from Equation (3):

$$I_c R_C + R_E\left(1 + \frac{1}{\beta}\right) I_c = V_{CEQ} \quad (3)$$

$$R_C = 4.6125\text{k}\Omega \approx 4.7\text{k}\Omega$$

Therefore, $R_C = R_4$ = 4.7kΩ is used in this design.

$$A_v = \frac{-R_C // R_L}{R_E} \quad (4)$$

where; $R_C // R_L = \dfrac{R_C R_L}{R_C + R_L}$

$$A_v = \frac{-\frac{R_C R_L}{R_C + R_L}}{R_E}$$

$$R_L = 4.7\text{k}\Omega$$

Therefore, $R_L = R_5$ = 4.7kΩ is used in this circuit.

### B. Operational Amplifier

The purpose of first op-amp is to amplify voltage gain and to buffer different impedance circuit. The output of transistor does not match with digital section. The op-amp has a characteristic of high impedance input and low impedance output can improve as a buffering and impedance matching.

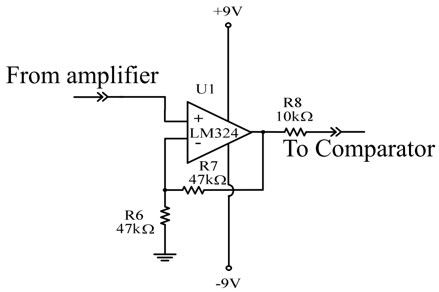


Fig. 4 Operational amplifier

$$A = 1 + (R_f / R_i) \qquad (5)$$

Assume the gain of the op-amp is 2. If $R_f$ ($R_7$) is chosen as 47kΩ, $R_i$ is calculated from Equation (5).

$$R_i = 47k\Omega$$

Therefore, $R_i = R_6 = 47k\Omega$ is used in this design.

### C. *LPT Port Door Motor Control Circuit*

The starting load of motor is usually twice of normal operation. So, for safety factor, 1.2A load current is expected before design.

The operating voltage $V_C$ of minimum 15V and load current $I_C$ of 1.5A is required to drive this motor. C1061 general purpose NPN transistor is used for this design.

Some important specifications of this transistor are:

$I_{Cmax}$ = 2.5 A
$I_{Bmax}$ = 25 mA
Current Gain = 80

This driver is reliable for H-Bridge. But $I_B$ of 1061 requires 25mA. Most of LPT port can source 5V and 5~25mA output. This is not good design to drive directly LPT port to driver. A buffer and current gain amplifier is required to solve this.

Two pairs of transistor is used as Darlington design. Darlington design is the best solution for current gain. C828 general NPN transistor is used to form a pair with C1061. Some typical values of C828 are:

$I_{Cmin}$ = 150 mA
Current Gain = 70

Thus, the total gain of one pair is :

$$\text{Total Current Gain} = h_{FE}(Q1) \times h_{FE}(Q2) = 80 \times 70 = 5600$$

So, to get 1.2 A load current, $I_b$ should be:

$$I_B = \frac{I_C}{h_{FE}} = 0.215 \text{ mA}$$

So, to limit base current of first transistor C828, $R_B$ can be calculated as follows:

$$V_B = 5V \text{ (Port Output)}$$

$$R_B = \frac{V_B - 2V_{BE}}{I_B} = 16.74 \text{ k}$$

So, $R_B = 22k\ \Omega$ is used in this design.

Thus, final circuit for H-Bridge is designed as follows:

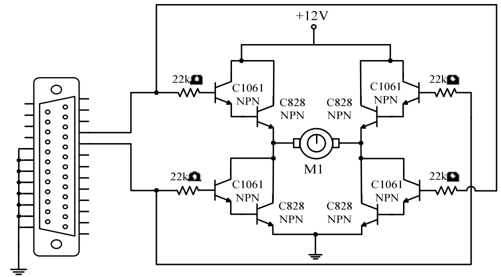


Fig. 5 Door motor control circuit

## IV. Design Software Implementation

$C^{++}$ software is used to develop required software for the system. This language is used for its stability and simplicity.

Software components of system are:

1. LPT port interfacing
2. Data acquisition
3. Data decoding
4. Data processing

### A. *Track 4 (Non Standard Track)*

Some ATM machine system, local telecom provider and local security system use non standard track or track 4. This track is used as read/write system such as ATM machine, pre-paid phone and card phone system.

Mostly, these cards use non standard and localized, private formats rather than standards. But card clocking parameter and data encoding technique are the same as standard tracks. The difference of these cards is data format. The most common format of telephone card is shown in Fig. 6.

First group of bytes are clocking bits (zero) as usual in another card. Clocking bits length is different from one card to another. Second group of data is card types such as 50 units card or 100 units card. These fields are expressed as 32 bits data field which encoding schemes are different in different countries. Data type fields contain area code, country code, ISP codes and some information of card. These fields are normally hard coded in card and not rewriteable in application field (for example, reader).

Last field is phone units or amount of cashes which left in card. Normally, this field is encoded as binary format in phone cards. In the units area, each time a unit is used, then a bit is set to blank or simply erased by phone card reader rather than re-writing. Generally, the first ten units are fused in factory as test. So, there is 10-bits blank between card information and units field.

| | | | |
|---|---|---|---|
| Clocking Bits(Zeros) | Card Information(32 bits) | Factory Test(10bits) | Units(100 to 256 bits) |

Fig. 6 Non-Standard Track's Data Format [2]

*B. Flow Charts for Magnetic Card Security System*

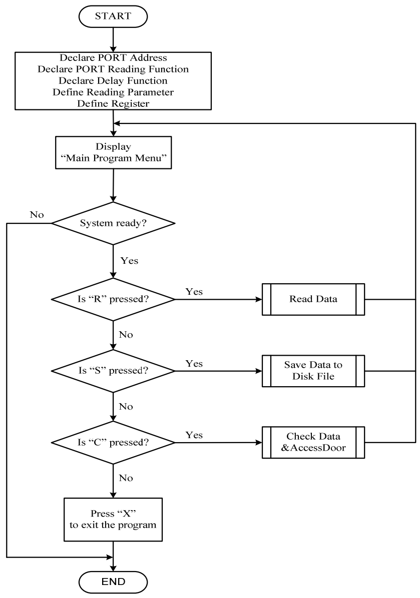


Fig. 7 Software Flow Chart for Main Program

The operation of software for this system is shown in Fig. 7. Firstly, the initialization process is started. The port address, port reading function, delay function, reading parameters and registers must be initialized.

The "Main Program Menu" will appear on the PC. And then it will check the system ready or not. If the system is not ready, it will exit the program. If the system is ready, it will continue step by step. If "R" key is pressed, the system will go to the "Read Data" loop and after finishing the reading, it will go to the main program menu.

If "S" key is pressed, the system will go to the "Save Data" loop and then go to the main program menu. If "C" key is pressed, the system will go to the "Check Data and Access Door" loop. If the reading data is allowed, the motor will start rotating and open the door to give the person the permission to enter the building.

Then the motor will stop and wait 30seconds for entering time of the person. And then the motor will rotate reverse direction. Then the door closes and the motor will stop. Otherwise, the reading data is not allowable; the buzzer alarm will be triggered. If the "X" key is pressed, the system will exit the program.

The "Read Data" loop is shown in Fig. 8. Firstly, data buffer is cleared and assume that lastlevel and levelnow are high. It will display "Acquiring Data" on PC. Then it will read the input data from the magnetic card by using parallel port. Since the input data is from the 3rd bit of the input. It will shift 3 bits right.

The maximum ticks counter is set to 2000 ticks and the maximum ticks for the gap is nearly 500 ticks because there are nearly ten bits at the gap. If the ticks counter is greater than 2000, the data is absent or swipe error. So ticks counter is limited to less than 2000.

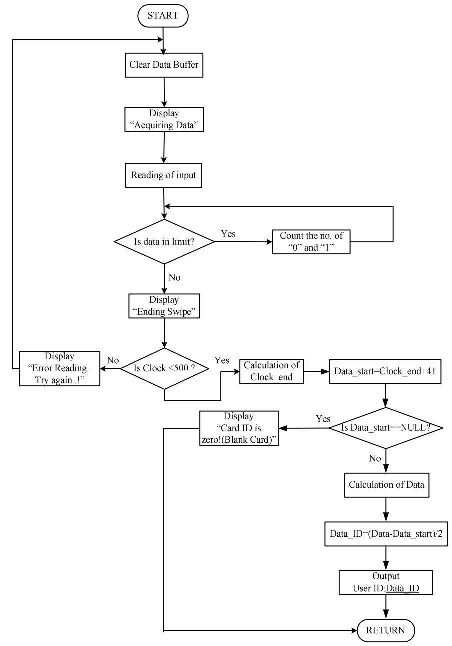


Fig. 8 Flow chart for data reading

While the ticks counter is less than 2000, it will read the input data. If the levelnow is equal to lastlevel, it will wait until levelnow is not equal to lastlevel. If the levelnow is not equal to lastlevel, it will count the number of "zero". If the levelnow is equal to lastlevel, it will count the number of "one". The data format is "clocking bits <gap> id <gap> data". When the gap is reached, the ticks counter is over 500.

Then it will finish the "for" loop. After looping clocking bits, data start can be reached by adding 41 to the clocking bits end (Data_Start = Clk_End + 41). The number of ID is 41. After that, check whether the Data_Start is equal NULL or not.

If it is true, it will display "Card ID is zero! (BLANK CARD)".If not, it will loop for the data bits (n). After that pure data can be got by {(n – Data_Start)/2}. The total number is divided by 2 for encoding. And then display "User ID: Data_ ID:"

## V. Test and Results

Fig. 9 Testing the constructed circuit

Fig. 10 is the initialization process which shows the Main Program Menu to check the system is ready or not. If the system is ready, it will go to the corresponding routines depends on the keyboard hit 'R', 'S', 'C' or 'E'.

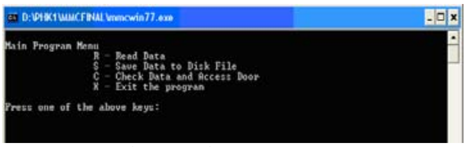


Fig. 10 Main program menu

Fig. 11 shows the result after the blank card has been read.


Fig. 11 Read data from the blank card

Fig. 12 is the result of the card data which is read by software for the 97 units card. The card ID is 97.

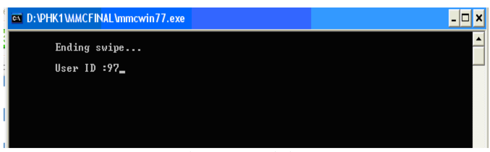


Fig. 12 Card data

Fig. 13 shows the saving box. After the data has been read and needs to be saved, the data is saved in the "DATA" file which was built in software. If it needs to be saved, press Y. If not, press N.


Fig. 13 Data saving

Fig. 14 and 15 show the result after checking the read data with the stored data. If the data which is read from the card is same with the data which is stored in the "DATA" file, it will show "Access OK, Door open" as shown in Fig. 14.

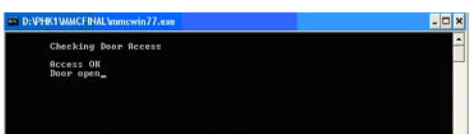


Fig. 14 Data checking (Access OK)

If the data which is read from the card is different from the data which is stored in the "DATA" file, it will show "Access Denied" as in Fig. 15.


Fig. 15 Data checking (Access Denied)

## VI. Conclusions

The system is tested on constructed design with prototype door. Software and hardware are tested with three magnetic cards and personal computer (Pentium processor IV, 256 MB RAM). Magnetic card reader works with tested cards and reads well for both clocking and data bits. This reader design can read raw data and digitized data. So, any types of single track with self clocking works well with this reader design. Only requirement is encoding with software. Clocking pulsed and time duration are needed to change depend on types of cards.

Data saving and retrieving is also worked with tested cards. Encoding system can save data to "DATA" file and can compare with current reading data. If the data is valid, a message can show and the door will open. If the data is not correct or card is blank ID, alarm will trigger and "Access denied" message will show to user.

Borland $C^{++}$ 5.02 is used to develop required software for system. Magnetic card security system can be built in practical application by using this circuit as a sample. By using LPT port interfacing, hardware interfacing is simpler and less circuit components than others. Windows XP and later operating system are not acceptable to system I/O from user interface directly. So a Dynamic link library (DLL) interfacing techniques is used to control LPT port. A system kernel DLL file, "InpOut32. DLL", is used in this software.

Overall hardware components of this system has been built and successfully implemented for security purpose. The security system in this paper is relatively cheaper and highly sophisticated design.

Since card reader hardware is only targeted on raw data and clocking bits, this reader design can be capable of reading any magnetic card with self clocking.

Encoding section is based on software routine. Clock, data bits duration and data format are hard coded in software to read these tested cards only. But, by changing clock and data bit duration, data format and encoding of other cards can easily be developed without altering main codes.

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