Electrical Engineering Department

Biomedical Engineering Program

Bachelor Thesis

Graduation Project

Design Of An Alarm System For MRI Suite

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ABSTRACT

With increasing use of X-ray devices for diagnostic or therapeutic purposes, and the lack of awareness among patients of the risks resulting from non-compliance with procedures and guidelines for security and safety, hospitals need emerged for the use of alarm systems to protect patients beneficiaries of the services provided to them in these sections. One of the most important of these devices - MRI - which depends on its work on the magnetic field tremendously up to 2 Tesla, and here lies the danger to access this section, especially if the possession of the patient's metal tools or was employed persons for wheelchairs or Pacemaker or medical screws used to install during bone injuries.

This project aims to provide the MRI suite with an alarm system. The alarm system includes three stages of warning and protection. The first stage uses optical sensor to detect and alarm the staff when the patient crosses the optical line. The second stage alarm works in the form of voice message if the visitor has metals. The motor driver circuit controls the suite door by a received signal through PIC from proximity inductive sensor.

ملخص المشروع

مع تزايد استخدام أنظمة وأجهزة التصوير بالأشعة لأغراض تشخيصية أو علاجية، وقلة الوعي لدى المرضى بالمخاطر المترتبة على عدم الالتزام بإجراءات وإرشادات الأمن والسلامة، برزت حاجة المستشفيات لاستخدام أنظمة إنذار لحماية المرضى المستفيدين من الخدمات المقدمة لهم في هذه الأقسام. أحد أهم هذه الأجهزة- جهاز التصوير بالرنين المغناطيسي- والذي يعتمد في عمله على مجال مغناطيسي هائل يصل إلى ٢ تسلا، ومن هنا تكمن خطورة الدخول إلى هذا القسم وخصوصاً إذا كان بحوزة المريض أدوات معدنية أو كان من الأشخاص المستخدمين للكراسي المتحركة أو لمنظم ضربات القلب أو البراغي الطبية المستخدمة في تثبيت العظام أثناء الإصابات.

يهدف هذا المشروع إلى تصميم وبناء نظام إنذار من عدة مراحل وذلك لحماية المرضى خلال توجههم لقسم التصوير بالرنين المغناطيسي. يعمل نظام الإنذار في مرحلته الأولى بالاعتماد على مجس و مستقبل ضوئي على إرسال إشارة صوتية من خلال متحكم دقيق إلى العاملين بالقسم تعلمهم باجتياز أحد ما للبوابة الأولى. و في المرحلة الثانية تم استخدام مجس استشعار حثي للكشف عن وجود أدوات معدنية بحوزة المريض. و في حال الكشف عن وجود مواد معدنية تصدر رسالة صوتية نصية تنذر بذلك و تصدر إشارة من خلال المتحكم الدقيق ومن ثم عبر دائرة تحكم خاصة إلى المحرك ليعمل على إغلاق البوابة الموصلة إلى غرفة التصوير. أما المرحلة الثالثة فهي يدوية وتعتمد على كبسة لفتح البوابة بعد التأكد من أن المريض تخلص من المعدن الذي بحوزته.

Table of Contents

List of Figures

List of Tables

Chapter One

Introduction

1.1 Overview
1.2 Related Works
1.3 Objectives
1.4 Project Importance
1.5 Time Plan
1.6 Economical Study
1.7 Report Road Map

Chapter One

Introduction

1.1 Overview:

MRI stands for Magnetic Resonance Imaging. It is a painless diagnostic procedure which allows physicians to see detailed images of the internal structures of the body without using X-rays. It uses a large magnet, radio waves and a computer to scan the body.

This technology is important because MRI scans illustrate more clearly than ever before, the difference between healthy and diseased tissue, and can provide important information about the brain, spine, joints and internal organs. It can lead to early detection and treatment of disease and has no known side effects. Consequently, physician will be better able to determine the most appropriate treatment.

Some types of medical implants are generally considered no acceptable for MRI examinations, while others may be acceptable for patients under high specific MRI conditions. Patients are therefore always asked for complete information about all implants before entering the room for an MRI scan. Several deaths have been reported in patients with pacemakers who have undergone MRI scanning without appropriate precautions [1].

So, it is important to know about metal anywhere in or on the body because the magnet is never turned off, and just by entering the scan room you come within the magnetic field. Certain metallic devices interfere with the scan, and their presence during the scan may cause injury. It is very important to know if you have a pacemaker or other implanted electrical device, a history of heart or brain surgery, cerebral aneurysm clips, shrapnel, or a history of getting metal fragments in patients eyes.

One of the main purpose for this project is to find an alarm system in MRI suit to protect patient who has metallic material or implemented device.

Figure (1.1): Strong magnetic field of MRI

1.2 Related Works

When we decided to work at this project, we searched hard to view the previous studies that related to our project represented by MRI safety system. So, we will view a related work about our project and its idea.

After our research, we get the following studies sharing some ideas with our project, list as follow:

1) MRI Suites: Safety Outside the Bore
Tobia Gilk, M.Arch .September/October2006s.

This paper discussed about hold unique dangers for patients and staff in MRI suite, high-strength clinical MRI scanners are up to 60,000 times the strength of the Earth's own ambient magnetic field. While exposure to magnetic energies has shown no harmful biological effects — unlike modalities that rely on ionizing radiation such as CT or conventional X-ray — there are still many accidents and incidents that jeopardize the safety of patients and staff in the MRI suite ,so from this paper we thought about system designed to alarm and protect patient and staff from this huge magnetic field .

2) MRI Safety at 3T versus 1.5T
JenniferJerroldsR.T.(R)(CT)(MR),ShaneKeeneMBA,RRT-NPS,CPFT, RPSGT2009.

The purpose of this article is to educate medical professionals on the safety concerns that arise when a healthcare organizations converts from a 1.5 Tesla MRI scanner to a 3 Tesla MRI scanner, so that huge magnetic field affect the existence of metallic part out and inside the MRI room and from this article we now that the protection must include circuits and sensors sensitive to metallic part to protect patient and staff and equipments.

3) MRI safety, Guidelines for safe MRI practice
MD.R.Ahsan,Muhammad I.Ibrahimy,2009

This paper talk about the existence of magnetic field in MRI suite it include information about the magnetic field inside and outside the room of MRI include A large superconducting magnet information that producing the main magnetic field.

Static magnetic fields are measured in Gauss (G) or Tesla (T), with 10,000 G being equal to 1T. Most high field magnets are 1.5T or 3T but systems up to 10T are commercialized. According to the most recent recommendations and guidelines provided by the United States Food and Drug Administration (FDA), clinical MR systems in the US are permitted to function on a routine clinical basis at static magnetic field strengths of up to 8.0 T. To put things in perspective, the earth's magnetic field varies from approximately 0.3 to 0.7 G between the equator and the poles, respectively. So 1.5T = 25,000 times the magnetic field of the earth.

Radio Frequency field (RF):A Radio Frequency pulse (a short burst of an electromagnetic radiation) is used in MRI to "excite" tissue protons by an exchange of energy. These protons give a signal in return. The RF spectrum typically used in MRI covers the same frequencies that are used by radio stations (around 100 MHz). The RF transmission can affect electronic devices.

Gradient magnets: They are smaller magnets, used to alter the main magnetic field and allow the signal from the patient to be spatially encoded into a picture. They are turned on/off very quickly during scanning, causing the knocking noise associated with MRI.

The most immediate danger associated with the environment is the attraction between the magnet and ferromagnetic metal objects. Those objects can become airborne projectiles. Even hand-held objects can be jerked free very suddenly as the holder moves closer to the magnet even, the magnet is not "off".so we wont to do system that NEVER bring any metal objects into the scanner rooms to protect patient and staff and material and implanted device especially metals in body.

1.3 Objectives:

The objectives of the project can be summarized as follows:

1. Study the safety protocols related to MRI suite.
2. Design an alarm system using optical sensor.
3. Build metallic detection circuit using inductive proximity sensor.
4. Design a control and matching system depending on microcontroller.
5. Build a safety mechanism (Door) that is operated manually.

1.4 Project Importance:

The main reason for selection this project is to design an alarm system to warn and protect patients and visitors in MRI suit from the huge magnetic field.

The importance of the project can be summarized as follows:

1. Patient protection and safety is the most important issue in radiology departments, especially in MRI suite.
2. Organizing the entrance and exit of patients and visitor to MRI suite is also very important for the department's staff in order to organize the working environment.
3. Organizing the working environment will improve the condition of the work and lead to better performance.

Have such system is economically important, since it saves and protects metallic equipment and tools with the patient and inside the suite from the hazards of magnetic field of MRI machine.

1.5 Time plan

The following table (1.1) illustrate how the time is managed through the semester.

Table (1.1): Time plan for first semester.

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Project determinations	■	■	■	■												
Data gathering	■	■	■	■	■	■	■	■	■	■	■	■	■			
Design and analysis				■	■	■	■	■	■	■	■	■	■	■		
Documentation		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table (1.2): Time plane for second semester.

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hard ware Design		■	■	■	■	■	■	■								
Implementation And Testing			■	■	■	■	■	■	■	■	■	■	■	■	■	■
Soft ware Design					■	■	■	■	■	■	■	■	■	■	■	■
Documentation					■	■	■	■	■	■	■	■	■	■	■	■

1.6 Economical Study

This section lists the overall cost of the components that will be used in implementing this project. The hardware components are listed in table (1.2).

Table (1.3): Total Cost table

Component	Quantity	Cost (JD)
DC Motor	2	40
Resistance	50	5
Inductive proximity sensor	2	18
Optical sensor	1	12
PIC	2	40
Conveyor	1	30
Project Model	1	50
Other components	5	50
Total Cost		245

1.7 Report Road Map:

The documentation for this project is divided into four chapters, the followings explain briefly, the contents of each chapter:

Chapter 1: Introduction

This chapter presents overview, related work, project objectives, importance of project, and economical study.

Chapter 2: Theoretical and physiological background

This chapter includes the Magnetic Resonance Imaging, Basis of Magnetic Resonance, Magnetic Field Gradients, Fourier Imaging Techniques, Quality Assurance, and Bioefects.

Chapter 3: Project Conceptual Design

This chapter includes general block diagram, Description of block diagram components.

Chapter 4: Project Design

This chapter includes description of design each circuit and calculation for infrared transmitter and infrared receiver ,and some picture descript the work of comparator and power circuit, and table descript motor direction.

Chapter 5: System Implementation And Testing

This chapter includes description of who system implemented and the ways of tested it. And include the flow chart of the project with software design. This chapter also includes conclusion and future work.

Chapter Two

Theoretical and physiological background

2.1 Magnetic Resonance Imaging
2.2 Basis of Magnetic Resonance
2.3 Magnetic Field Gradients
2.4 Fourier Imaging Techniques
2.5 Quality Assurance
2.6 Bioefects

Chapter Two
Theoretical and Physiological Background

2.1 Magnetic Resonance Imaging

MRI is a non-ionizing technique with excellent soft-tissue contrast and high spatial resolution (~1 mm). The temporal resolution is typically much slower than for ultrasound or CT, with scans lasting several minutes. The cost of MRI scanners is relatively high, and the large superconducting magnet requires special housing in clinical environments. The major uses of MRI are in the areas of brain disease, spinal disorders, angiography, cardiac assessment, and musculoskeletal damage.

2.2 Basis of Magnetic Resonance

The first requirement for MRI is to produce a strong, temporally stable and spatially homogeneous magnetic field within the patient. The majority of magnets use superconductor technology to produce the magnetic field. The superconducting wire must be able to carry a large current, which limits the material to certain alloys, particularly niobium-titanium, which is formed into multi stranded filaments within a copper conducting matrix.

This superconducting matrix is housed in a stainless steel can containing liquid helium at a temperature of 4.2 K. This can is surrounded by a series of radiation shields and vacuum vessels, with an outer container of liquid nitrogen being used to cool the outside of the vacuum chamber and the radiation shields. The most common fields for clinical scanning are 3-tesla systems, although systems operating at 7 tesla now exist for experimental human investigations.

When protons are placed in a strong external magnetic field, the interaction between their magnetic moments and the magnetic field means that they can align in two different configurations, commonly termed ''parallel'' and ''anti-parallel'' states, shown in Figure 2.1. The number of protons in each state is given by the Boltzmann distribution:

$$\frac{N_{\text{anti-parallel}}}{N_{\text{parallel}}} = \exp - \left[\frac{\Delta E}{kT}\right] = \exp - \left[\frac{\gamma h B_0}{2\pi kT}\right], \qquad 2.1$$

Where B0 is the strength of the magnetic field, k is Boltzmann's constant, h is Plank's constant, ΔE is the energy gap between the two states, and T is the temperature in Kelvin. The size of the MRI signal is proportional to the difference in populations between the two energy levels:

$$N_{\text{parallel}} - N_{\text{anti-parallel}} = N_s \frac{\gamma h B_0}{4\pi kT}, \qquad 2.2$$

Where, Ns is the total number of protons in the body. Despite large static magnetic fields, Equation 2.2 shows that at a proton, there is a population difference of only approximately ten protons between the parallel and anti-parallel orientations. In order to stimulate transitions between energy levels, electromagnetic energy has to be applied at a frequency (v) corresponding to the difference between the two levels:

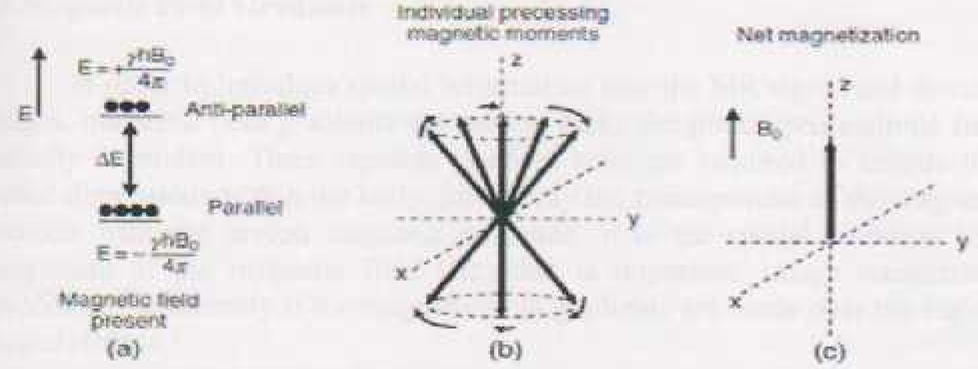

Figure (2.2): (a) Zeeman splitting of the proton energy levels induced by application of a static magnetic field. (b) Precession of all of the proton magnetic moments about the applied magnetic field. (c) Net magnetic moment at equilibrium aligned in the direction of the magnetic field.

$$\frac{h\omega}{2\pi} = \Delta E = \frac{\gamma h B_0}{2\pi} \Rightarrow \omega = \gamma B_0. \qquad \textbf{2.3}$$

If one considers each magnetic moment as a vector (Figure 2.1), then the equilibrium condition is characterized by the z-component of magnetization (Mz) being M0 (the total magnetization of the patient), with the transverse component (Mxy) equal to zero. After a pulse of radiofrequency (RF) energy has been applied, the magnetization is tipped from the z direction (Figure 2.1) into the transverse plane and precesses around the direction of the applied magnetic field at the Larmor frequency, given by v ¼ gB0. After spatial encoding using magnetic field gradients, the signal is detected via Faraday induction using an RF coil. Often, the same coil is used to transmit the RF energy and to detect the signal. There are many forms of coil, depending upon whether the RF field produced should be homogeneous over a large volume of the patient or only a small localized volume is to be investigated. Since Faraday's law states that voltage is proportional to the time-dependent rate of magnetic flux, a higher B0 field gives a higher precessional frequency and hence a higher signal voltage. Overall, therefore, the measured MRI signal is proportional to the square of the B0 value, providing a major impetus to the ever-increasing static magnetic fields.

Absorption of electromagnetic energy by the spin system results in a non-Boltzmann distribution of the population levels, equivalent to a non equilibrium value of the Mz and Mxy components of magnetization. The return to thermal equilibrium is governed by two different relaxation times: T1 determines the return of Mz to M0, and T2 the return of Mxy to zero. Different tissues have quite different values of T1 and T2, as shown in Table 2.1, and these differences can be used to introduce contrast into MR images.

Table (2.1): Tissue relaxation times at 1.5 tesla

Tissue	T_1 (ms)	T_2 (ms)
Fat	260	80
Muscle	870	45
Brain (gray matter)	900	100
Brain (white matter)	780	90
Liver	500	40
Cerebralspinal fluid	2400	160

2.3 Magnetic Field Gradients

In order to introduce spatial information into the MR signal and thereby form images, magnetic field gradients are used to make the proton precessional frequency spatially dependent. Three separate gradient coils are required to encode the three spatial dimensions within the body. Since only the z-component of the magnetic field interacts with the proton magnetic moments, it is the spatial variation in the z-component of the magnetic field (Bz) that is important. Image reconstruction is simplified considerably if the magnetic field gradients are linear over the region to be imaged; that is,

$$\frac{\partial B_z}{\partial z} = G_z \quad \frac{\partial B_z}{\partial x} = G_x \quad \frac{\partial B_z}{\partial y} = G_y. \qquad 2.4$$

By convention, for human studies, the z direction lies along the head-to-foot axis; the y-axis corresponds to the vertical (spine to abdomen) direction, and the x-axis goes from side to side (right to left). The magnetic field, Bz , experienced by all nuclei with a common coordinate z, is:

$$B_z = B_0 + zG_z, \qquad 2.5$$

where Gz has units of tesla per meter. The corresponding processional frequencies (vz) of the protons, as a function of their position in z, are given by:

$$\omega_z = \gamma B_z = \gamma(B_0 + zG_z). \qquad 2.6$$

Analogous expressions can be obtained for the spatial dependence of the resonant frequencies in the presence of the x- and y-gradients. The requirements for gradient coil design are that the gradients be as linear as possible over the region being imaged, that they be efficient in terms of producing high gradients per unit current, and that they be fast in switching times for use in rapid imaging sequences. Copper is used as the conductor, with chilled-water cooling to remove the heat generated by the current. The simplest configuration for a coil producing a gradient in the z direction is a Maxwell pair, shown in Figure 2.2 (a), which consists of two separate loops of multiple turns of wire, each loop containing equal currents flowing in opposite directions. The magnetic field produced by this gradient coil is zero at the center of the coil

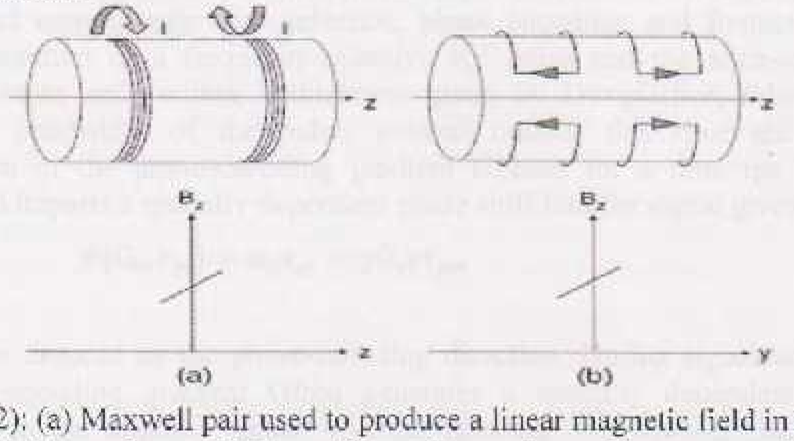

Figure (3.2): (a) Maxwell pair used to produce a linear magnetic field in the z direction. (b) Four-element Golay coils used to produce a linear magnetic field in the y direction.

and is linearly dependent upon position in the z direction over about one-third of the separation of the two loops. The x- and y-gradient coils are completely independent of the z-gradient coils: The usual configuration is to use four arcs of wire, as shown in Figure 2.2 (b). When the current in the gradient coils is switched rapidly, eddy currents can be induced in nearby conducting surfaces, such as the radiation shield in the magnet. These eddy currents, in turn, produce additional unwanted gradients that may decay only very slowly, even after the original gradients have been switched off. All gradient coils in commercial MRI systems are now ''actively shielded'' to reduce the effects of eddy currents. Active shielding uses a second set of coils placed outside the main gradient coils, the effect of which is to minimize any stray gradient fields. The MRI components shown in figure (2.3):

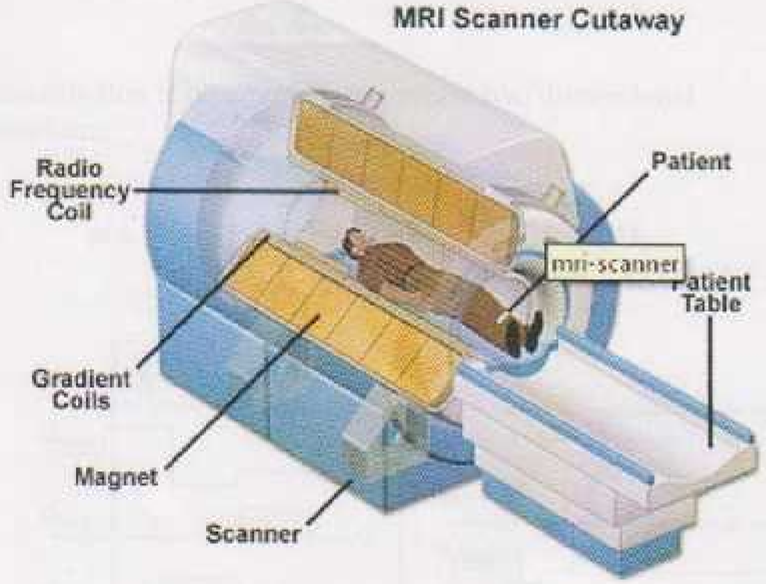

Figure (2.4): MRI components[1]

2.4 Fourier Imaging Techniques

Acquisition of the data required for conventional MRI comprises three independent components: slice selection, phase encoding, and frequency encoding. The combination of a frequency-selective RF pulse and the slice-select gradient excites protons only within a thickness given by Dv=gGslice, where Dv is the frequency bandwidth of the pulse; protons outside this slice are not excited. Application of the phase-encoding gradient Gphase for a time tpe prior to data acquisition imparts a spatially dependent phase shift into the signal given by:

$$\phi(G_y, \tau_{pe}) = \omega_y \tau_{pe} = \gamma G_y y \tau_{pe}, \quad 2.7$$

where y is denoted as the phase-encoding direction. During signal acquisition, the frequency-encoding gradient Gfreq generates a spatially dependent precessional frequency in the acquired signal. Overall, ignoring relaxation effects, the detected signal is given by:

$$s(G_y,\tau_{pe},G_x,t) \propto \int_{slice}\int_{slice} \rho(x,y)e^{-j\gamma G_x xt}e^{-j\gamma G_y y\tau_{pe}}dxdy, \quad \textbf{2.8}$$

where r(x,y) is the proton density (that is, the number of protons at a given (x,y) coordinate) and x is the frequency encoding dimension. If two variables are defined:

$$k_x = \frac{\gamma}{2\pi}G_x t, \quad k_y = \frac{\gamma}{2\pi}G_y\tau_{pe}, \quad \textbf{2.9}$$

then the acquired MRI signal can be expressed as:

$$S(k_x,k_y) \propto \int_{slice}\int_{slice} \rho(x,y)e^{-j2\pi k_x x}e^{-j2\pi k_y y}dxdy. \quad \textbf{2.10}$$

Image reconstruction is obtained by an inverse two dimensional Fourier transform:

$$\rho(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S(k_x,k_y)e^{+j2\pi(k_x x+k_y y)}dk_x dk_y. \quad \textbf{2.11}$$

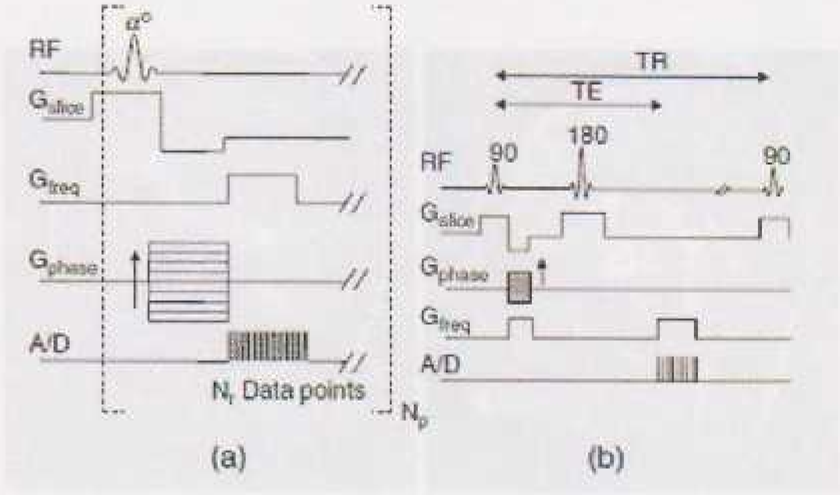

Figure (2.5): (a) Gradient-echo imaging sequence. (b) Spin-echo imaging sequence[6]

The two most commonly used sequences are shown in Figure 2.4 The gradient–echo sequence is used for rapid imaging, whereas the spin–echo sequence has a higher intrinsic sensitivity. Each imaging sequence is repeated Np times, with the phase-encoding gradient incremented for each repetition. These results in Np lines being acquired in the ky direction, and Nr points in the kx direction. Two delays are defined and can be altered by the operator: TE¼the echo time, which is defined as the delay between the middle of the initial RF pulse and the center of the data acquisition time. TR¼the repetition time, defined as the time between successive applications of the sequence. When the effects of T1 and T2 relaxation are taken into account, it can be shown that in a gradient–echo sequence, the image intensity I(x,y) is given by:

$$I(x,y) \propto \frac{\rho(x,y)\left(1-e^{-TR/T_1}\right)e^{-TE/T_2^*}\sin\alpha}{1-e^{-TR/T_1}\cos\alpha}, \quad 2.12$$

where T_2^* is the spin–spin relaxation time, including the effects of magnetic field inhomogeneity. For a spin-echo imaging sequence, the corresponding expression is:

$$I(x,y) \propto \rho(x,y)\left(1-e^{-TR/T_1}\right)e^{-TE/T_2}. \quad 2.13$$

The times TR and TE within the imaging sequence can be chosen to give different contrasts in the image. For example, Figure 2.5 shows the effects of increasing the TE on a simple brain scan acquired with a spin–echo sequence.

One of the most important technical developments in the past few years has been the introduction of parallel imaging, in which a degree of spatial encoding is performed by an array of small RF coils. Using this type of technology, the number of phase-encoding steps can be reduced up to a theoretical limit of the number of RF coils, thus speeding up data acquisition considerably. Most commercial systems now offer this capability under various acronyms, with acceleration factors up to an order-of-magnitude having been shown in developmental systems.

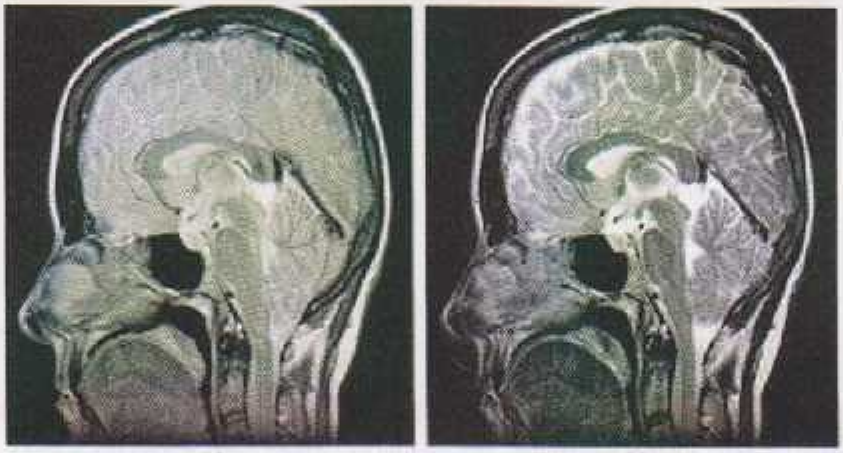

Figure (2.6): Sagittal images through the human brain with less (a) and more (b) T2 weighting.[6]

2.5 Quality Assurance

Quality assurance in MRI reflects the principles of image formation and display that determine the appearance of any medical image. Tests such as resolution, contrast, linearity, and sensitivity are a necessary part of evaluating equipment performance. The actual testing methods and the standards for performance are, of course, unique to MRI. There are two approaches to quality assurance measurements. Direct measurement of image quality through evaluation of end points such as imaging system uniformity is essential. Some imaging centers go further: they measure intermediate steps in the imaging process such as tip angle or gradient pulse shape to identify problems before they produce noticeable effects on image quality. A number of guides now exist for quality assurance in MRI.8−10 These guides cover the range and recommended frequency of quality assurance measurements of these measurements. Table 2-2 summarizes some of these recommendations.

TABLE 2.2 Quality Assurance Tests for MRI Systems

Frequency	*Tests*
Daily	Resonance frequency
	Signal-to-noise ratio
Monthly	Image uniformity
	Linearity, hard copy
Yearly	Magnetic field homogeneity
	RF pulse shape and amplitude
	Gradient pulse shape and amplitude

2.6 Bioefects:

The US Food and Drug Administration has published guidelines for safe operating characteristics of MRI systems.11 Manufacturers must follow these guidelines in order to obtain approval to market MRI devices. Exemptions to the guidelines require submission to the FDA of scientific evidence verifying the safety of patients if the guidance levels are exceeded. Under FDA guidance for clinical MRI, the maximum static magnetic field strength is 4 tesla and the maximum acoustic noise level (caused by thermal and mechanical stress in the magnet due to gradient switching) is 140 dB. The specific energy absorption rate and the time rate of change of the magnetic fields are addressed in three categories as "normal mode," "first level controlled," and "second level controlled." Normal mode refers to routine operation for patient studies. In first level controlled mode, a clear indication that the unit will operate in this mode must be visible to the operator and a positive action must be taken by the operator to initiate the scan. In second level controlled mode, security measures such as a key lock or a software password must be used. These parameters are described in Table 2-3. At the present time, there is no conclusive evidence for adverse biologic effects in normal patients scanned in MRI systems using parameters that have been approved by the FDA. There are areas of concern, however, that are being monitored in a number of studies. Some of these studies are described in the following section. Areas of concern are categorized according to the main physical features of MRI, namely, the static magnetic field, time-varying magnetic field, and RF energy.

Chapter Three

Project Conceptual Design

3.1 Introduction
3.2 General Block Diagram
3.3 Description of block diagram components
3.4 Site view of the system

Chapter Three

Project Conceptual Design

3.1 Introduction

In order to design and implement an alarm system or (protection system) to detect any piece of metal in or on the person body before entering the MRI scan room, it is desirable to detect first if there any person entering the radiology department or not. Therefore, it is important to implement an infrared transmitter and receiver circuits which provide a signal if there is anybody there.

3.2 General Block Diagram

In order to design and implement an alarm system for MRI department safety, the fist step is required to alarm the staff about the entrance of the person to MRI department. The second step is to design an alarm circuit to detect if there are metals or metallic devices or implants in or on the patients. If the patients have metals a voice message will loud and door will be closed

. The general block diagram of the alarm system for MRI department is shown in figure (3.1).

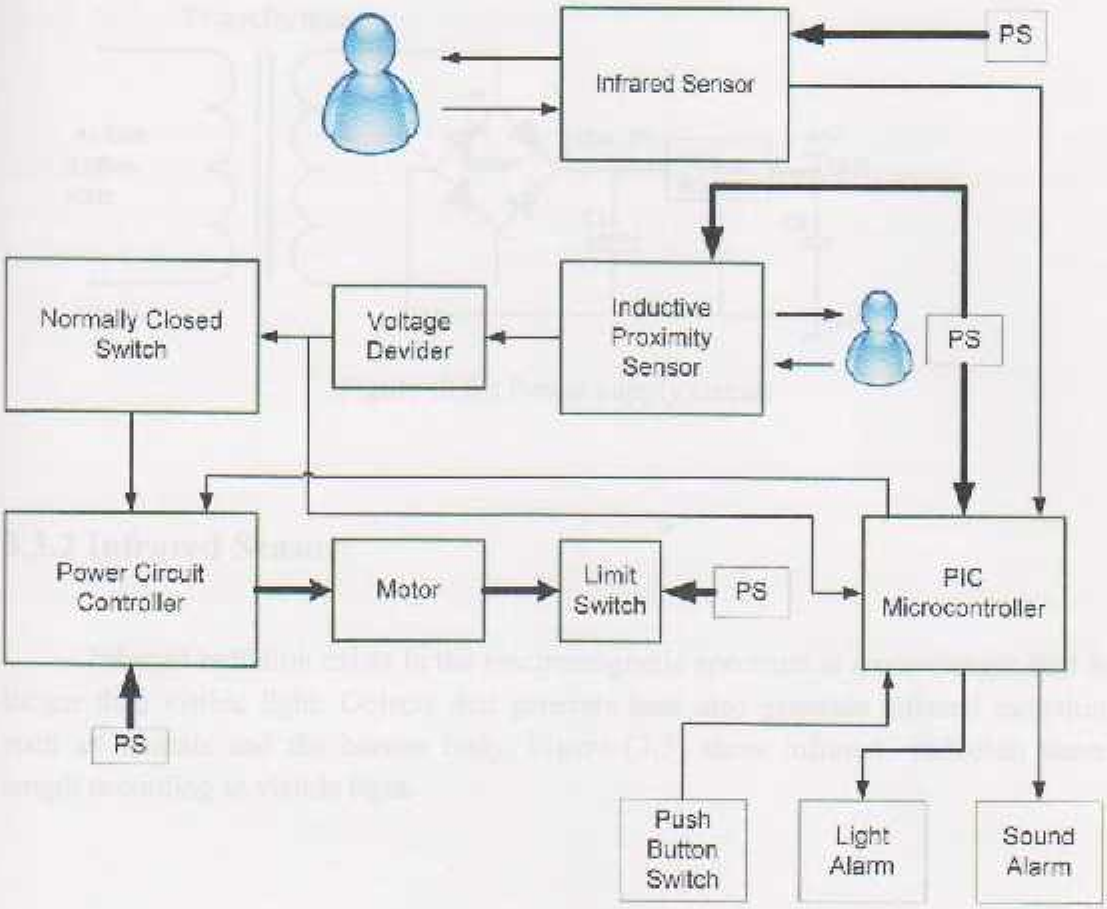

Figure (3.7): General block diagram

3.3 Description of block diagram components:

3.3.1 Power Supply:

A power supply is a system that supplies electrical energy to all project parts. This typically involves converting 220 volt AC to a well-regulated lower DC voltage for electronic devices.

Figure (3.2) illustrate that the power supply unit contains the following:

1. Transformer: To transform high AC voltage to lower AC voltage.
2. Rectifier: To convert the AC voltage to pulsating DC voltage.
3. Filter: To reduce the variations of output voltage of rectifier.
4. Regulator: To produce well-regulated DC voltage.

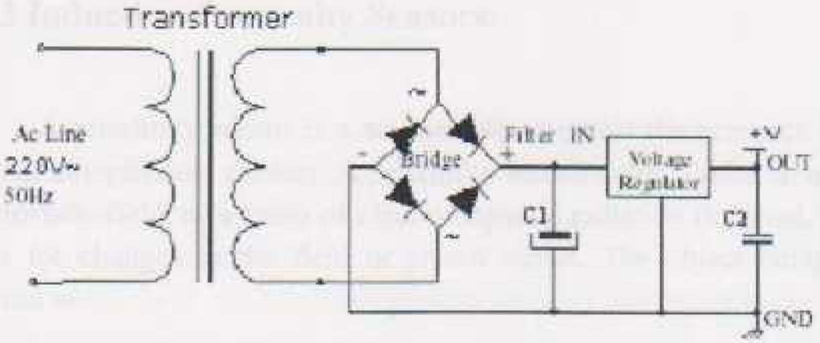

Figure (3.8): Power supply circuit

3.3.2 Infrared Sensor:

Infrared radiation exists in the electromagnetic spectrum at a wavelength that is longer than visible light. Objects that generate heat also generate infrared radiation such as animals and the human body. Figure (3.3) show infrared radiation wave length according to visible light.

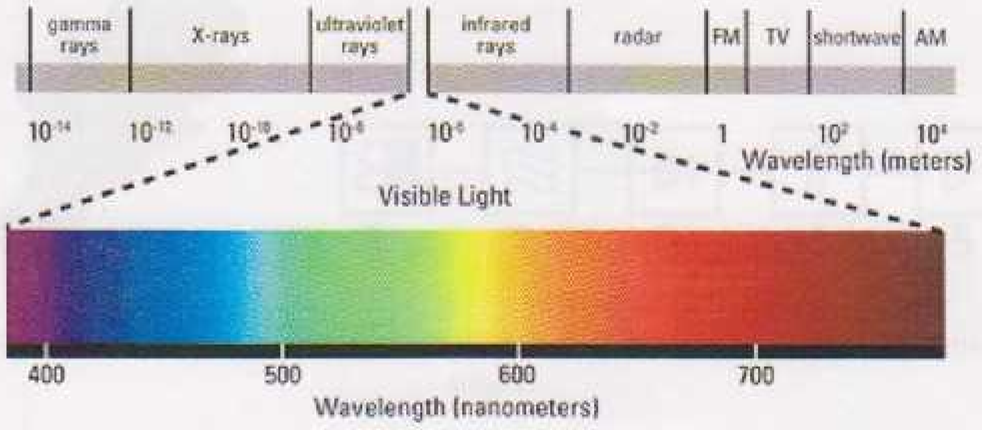

Figure (9.3): Infrared radiation wave length

The sensor uses the light absorption principle, with the light source an infrared light emitting diode (LED) emits light with wavelength approximately 850 nanometers, light reaches obstacle and reflects back. There it is picked up with phototransistor, Voltage in measurement point changes, and this change is proportional to picked up light intensity. In simple terms, the Sensor detects obstacles by comparing the amount of light emitted by the LED with the amount received by the photo-diode. The amount of obstacles present is inferred from the reduction in received light.

3.3.3 Inductive Proximity Sensors:

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. A proximity sensor often emits an electromagnetic or electrostatic field, or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to.

The maximum distance that this sensor can detect is defined "nominal range".

3.3.3.1 Element of a simple inductive sensor:

Figure (3.4) show: (a) inductive proximity sensor, and (b) element of a Simple Inductive Sensor.

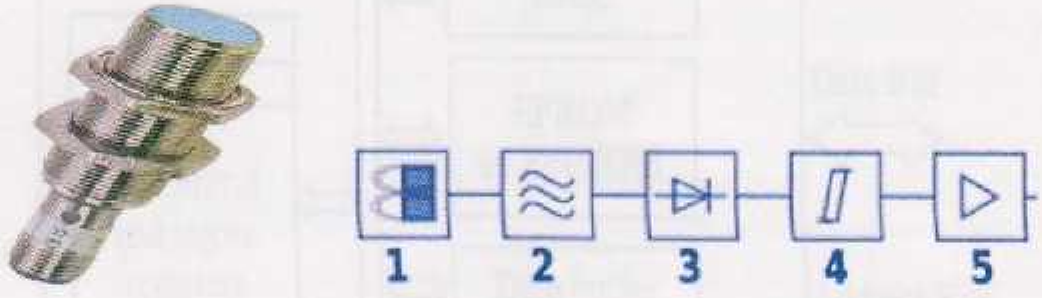

Figure (3.10): (a) inductive proximity sensor, (b) Element of a simple inductive sensor.

1. Field sensor.
2. Oscillator.
3. Demodulator.
4. Flip-flop.
5. Output.

3.3.4 PIC Microcontroller:

A microcontroller is a computer control system on a single chip. It has many electronic circuits built into it, which can decode written instructions and convert them to electrical signals.

They have a high concentration of on-chip facilities such as serial port, parallel input/output ports, timers, counters, interrupt control, analog-to-digital converters ,random access memory, read only memory, etc. these on-chip peripherals of a microcontroller make it powerful digital processors, the degree of control and programmability they provide significantly enhances the effectiveness of the application. Figure (3.5) show the PIC Microcontroller general block diagram:

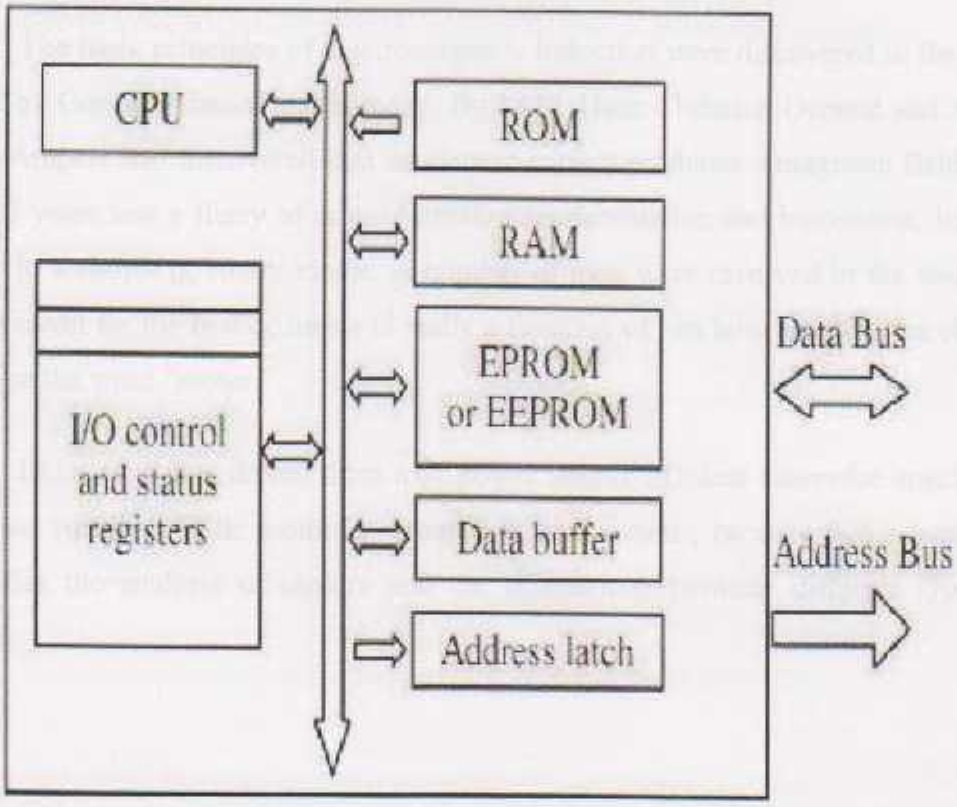

Figure (3.11): Microcontroller general block diagram.

3.3.5 Power circuit controller:

Its function is controlling the electrical energy given to the motor to control the door movement, and in this case dc motor is used.

3.3.6 DC Motors:

3.3.6.1 Introduction:

At the most basic level, electric motors exist to convert electrical energy into mechanical energy. This is done by way of two interacting magnetic fields; one stationary, and another attached to a part that can move. A number of types of electric motors exist. dc motors have the potential for very high torque capabilities (although this is generally a function of the physical size of the motor), are easy to miniaturize, and can be "throttled" via adjusting their supply voltage. DC motors are also not only the simplest, but the oldest electric motors.

The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss, and Faraday. By 1820, Hans Christian Oersted and Andre Marie Ampere had discovered that an electric current produces a magnetic field. The next 15 years saw a flurry of cross-Atlantic experimentation and innovation, leading finally to a simple dc rotary motor. A number of men were involved in the work, so proper credit for the first dc motor is really a function of just how broadly you choose to define the word "motor."

DC motors are, driven from a dc power supply . Unless otherwise specified , the input voltage to a dc motor is assumed to be constant , because that assumption simplifies the analysis of motors and the comparison between different types of motors.

3.3.6.2 The equivalent circuit of a DC motor

The armature circuit is represented by an ideal voltage source E_A and a resistor R_A. This representation is really the Thevenin equivalent of the entire rotor structure, including rotor coils, interpoles, and compensating windings, if present. The brush voltage drop is represented by a small battery V_{brush} opposing the direction of current flow in the machine. The field coils, which produce the magnetic flux in the generator, are represented by inductor L_F and resistor R_F. The separate resistor R_{adj} represens an external variable resistor used to control the amount of current in the field circuit.

There are a few variatins and simplifications of this basic equivalent circuit. The brush drop voltage if often only a very tiny fraction of the generated voltage in a machine. Therefore, in cases where it is not too critical, the brush drop voltage may be left out or approximately included in the value of R_A. Also, the internal resistance of the field coils is sometimes lumped together with the variable resistor, and the total is called R_F. A third variation is that some generators have more than one field coil, all of which will appear on the equivalent circuit. Figure (3.6) show the equivalent circuit of a dc motor.

The internal generated voltage in this machine is given by the equation:

$$E_A = K\phi\omega \qquad 3.1$$

Where :

E_A: Armature voltage

k: Constant

Ø: Flux

ω: Speed of rotation

And the induced torque developed by the machine is given by :

$$\tau_{ind} = K\emptyset I_A \qquad 3.2$$

Where:

τ_{ind} : Induced torque.

k: Constant

Ø: Flux

I_A: Armature Current

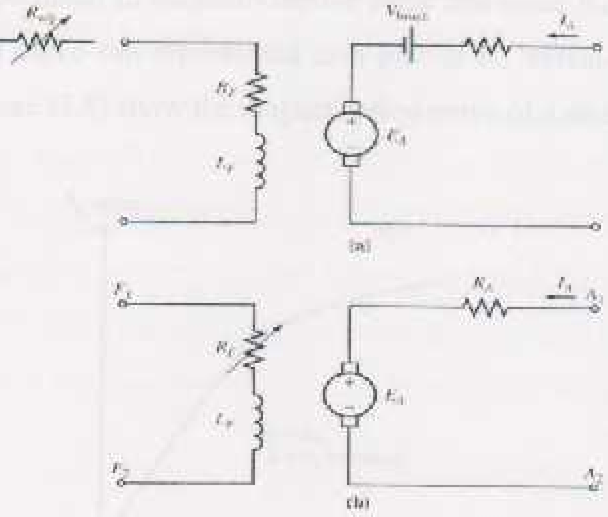

Figure (3.12): The equivalent circuit of a dc motor [11]

3.3.6.3 The Magnetization Curve of a DC Machine

EA is directly proportional to flux and the speed of rotation of the machine. EA is therefore related to the field current. Field current in a dc machine produces a field magneto motive force given by $F^F = N_F I_F$. Magneto motive force produces a flux in the machine in accordance with its magnetization curve. Figure (3.7) show the magnetization curve of a ferromagnetic material:

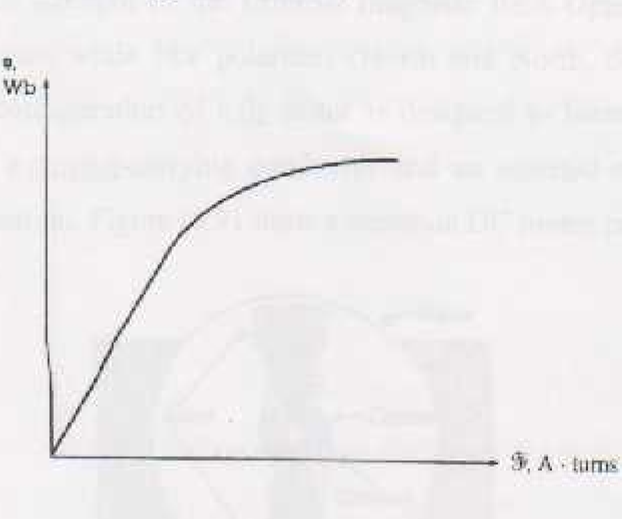

Figure (3.13): The magnetization curve of a ferromagnetic material [11].

Since If is proportional to magneto motive force and since E_A is proportional to flux, magnetization curve can represented as a plot of E_A versus field current for a given speed ω_0. Figure (3.8) show the magnetization curve of a dc machine:

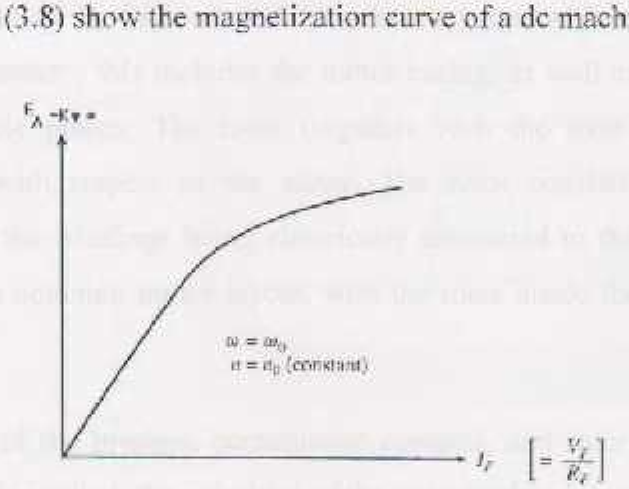

Figure (3.14): The magnetization curve of a dc machine [11]

3.3.6.4 DC Motors Principles of operation

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. Opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a dc motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion. Figure (3.9) show a common DC motor parts:

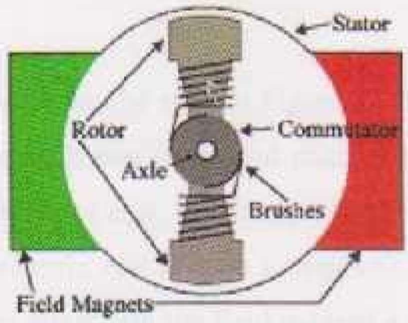

Figure (3.15): A common DC motor parts [12]

Every dc motor has six basic parts . axle, rotor (a.k.a., armature), stator, commutator, field magnet(s), and brushes. In most common dc motors, the external magnetic field is produced by high-strength permanent magnets. The stator is the stationary part of the motor . this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. Figure (3.14) shows a common motor layout, with the rotor inside the stator (field) magnets.

The geometry of the brushes, commutator contacts, and rotor windings are such that when power is applied, the polarities of the energized winding and the stator magnet(s) are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets. As the rotor reaches alignment, the brushes move to the next commutator contacts, and energize the next winding.

In real life, though, dc motors will always have more than two poles (three is a very common number). In particular, this avoids "dead spots" in the commutator.

3.3.6.5 Types of DC motors

There are five types of dc motors Separately excited and shunt dc motors, compounded dc motor, series dc motor and permanent – magnet dc.

Permanent magnet DC motor:

a) PM Brushed Motors:

A simple brushed motor can be seen in Figure (3.15). The electricity from the battery enters the motor through two leads and charges the brushes. These brushes make contact with the commutator ring. The current then runs through the wire coiled around the armature, this electric coil creates a magnetic field around the armature. The armature then rotates to align with the field magnet's magnetic field. At a certain point in the rotation the commutator switches the polarity of the armature. This switch continues the rotation and the cycle continues. The armature is attached to the axle of the motor which is the same axle that protrudes from the motor.

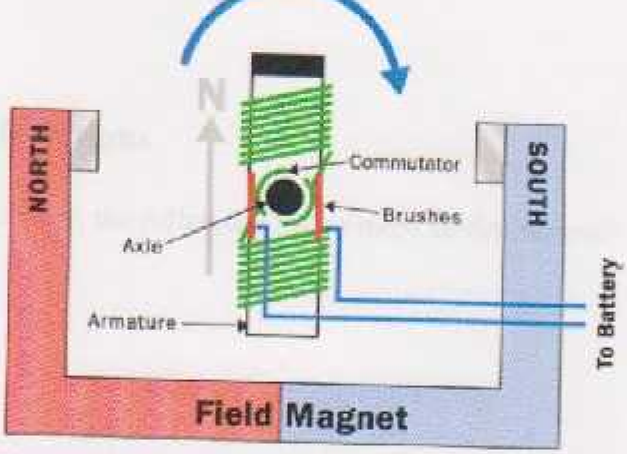

Figure (3.16): Simple Electric Motor [13]

Advantages of brushed motors are that they are relatively low cost compared to other types of electric motors. Brushed motors also make it very easy to control the speed and have a linear torque to speed curve. Disadvantages of the brushed motor are that the brushes are constantly scratching the commutator, creating friction and wear. This increases the maintenance of the motor and reduces the efficiency to levels of 75 to 80 %.

b) PM Brushless Motors:

A brushless motor operates on the same principles of electromagnetism that the brushed motor does. However the internal design of the motor is different. In a brushless motor the electromagnetic coils are stationary and the field magnet is replaced by many permanent magnets attached to the rotor. The coils are positioned and get charged in sequence such that the permanent magnets are forced to rotate.

A brushless motor controller is required to control the charging of the coils. Brushless motors are highly advantageous because they do not have the friction or wear created by the brushes in a brushed motor. This makes them 85 to 90% efficient and requires much less maintenance than brushed motors. Brushless motors are more expensive than brushed motors but can be cost effective over the long run due to their efficiencies. The first generation prototype will be made based on cost effectiveness.

but longer lasting, more efficient motors would be recommended for future generations.

3.3.6.6 DC motor efficiency calculations

To estimate the efficiency of a dc motor, the following losses must be determined:

1. Copper losses.
2. Brush drop losses.
3. Mechanical losses.
4. Core losses.
5. Stray losses.

To find the copper losses, we need to know the currents in the motor and two resistances. In practice, the armature resistance can be found by blocking the rotor and a small DC voltage to the armature terminals , such that the armature current will equal to its rated value. The ratio of the applied voltage to the armature current is approximately R_A.

The field resistance is determined by supplying the full-rated field voltage to the field circuit and measuring the resulting field current. The field voltage to field current ratio equals to the field resistance.

Brush drop losses are frequently lumped together with copper losses. If treated separately, brush drop losses are a product of the brush voltage drop V_{BD} and the armature current I_A.

The core and mechanical losses are usually determined together. If a motor is running freely at no load and at the rated speed, the current I_A is very small and the armature copper losses are negligible. Therefore, if the field copper losses are subtracted from the input power of the motor, the remainder will be the mechanical and core losses. These two losses are also called the no-load rotational losses. As long as the motor's speed remains approximately the same, the no-load rotational losses are a good estimate of mechanical and core losses in the machine under load.

3.4 Site view of the system

The following figure shows the site view of the MRI suite with an alarm and protection points in the department.

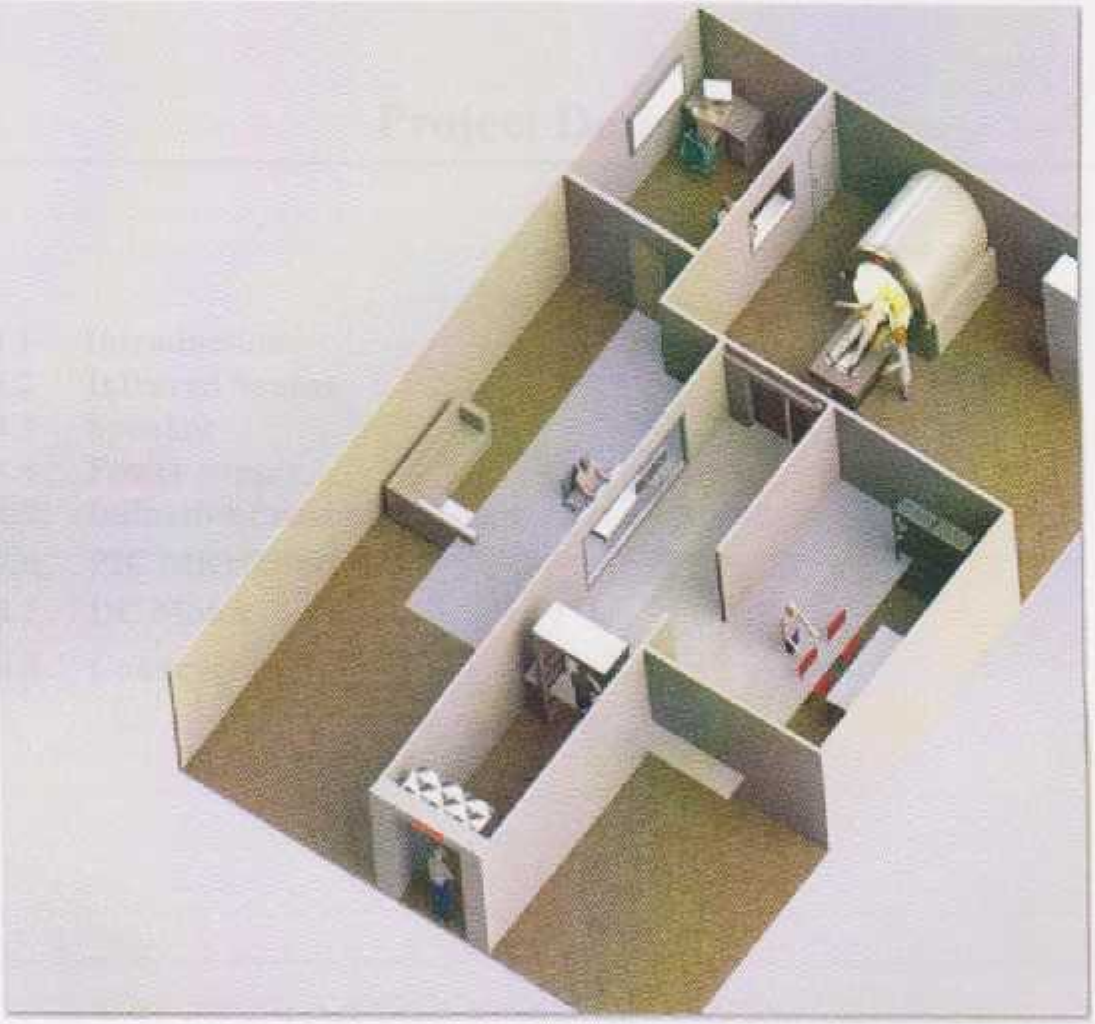

Figure (3.17): Site view of the MRI suite.

Chapter Four

Project Design

Chapter Four

Project Design

4.1 Introduction:

In the previous chapters, the construction and principle of operation for each part of block diagram were discussed; this will help to achieve the main goal of this project that is to design an alarm system for MRI suit .

In this chapter the project design will be discussed and the basic calculations will be done.

4.2 Infrared sensor:

Infrared sensor used in this project to detect the entrance of visitors and patients to radiology department. The used IR sensor has four pins, two of them is used for input power supply which is(12VDC), and the two other pins (a,b) as shown in Figure (4.1), connected to switch, when there is movement ,there is output and the switch connected to a, where when there is no movement, the output will be zero and the switch connected to b. this infrared sensor connected to PIC microcontroller which can accept the voltage that equal to 5VDC or less than it, and accept the current in(mA).

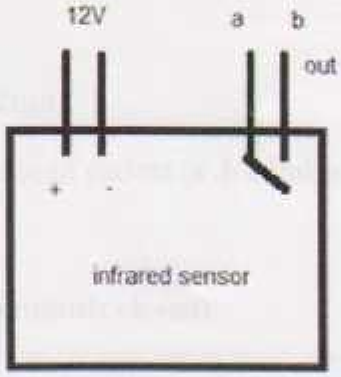

Figure (4.18): Pins of IR sensor.

By connecting a suitable resistor of high value (10KΩ), to protect PIC microcontroller from high voltage and leakage current, and to prevent it from short circuit with output switch of infrared sensor, and supply it with a suitable voltage for PIC (5VDC) and connect them to input (port D pin1), the infrared current will be in (mA) which is acceptable.

The idea in this stage is to give sound alarm in the radiology department when anybody enters the department, so that the connection of PIC microcontroller is necessary to control this alarm and to regulate the entrance of patients and visitors to the department.

The IR sensor used in this project has a fan rays and red light, when it detect any entrance to radiology department a sound alarm will occur and the red light will turn on, as it connected to PIC microcontroller and to speaker circuit. Figure(4.2) will illustrate this connection:

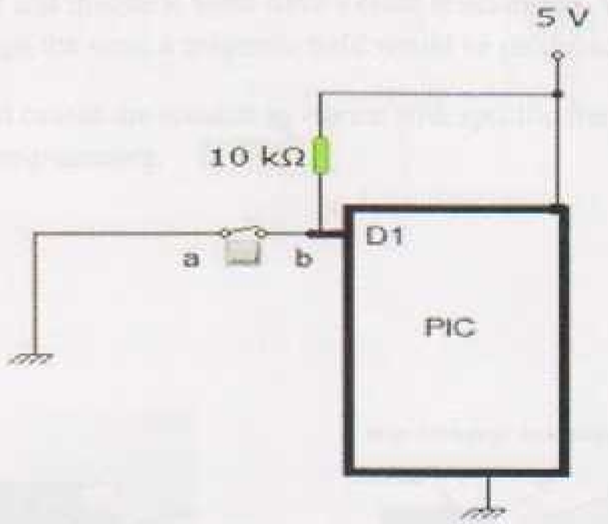

Figure (4.19): connection of IR sensor with PIC.

I $_{PIC} = (5 - 4.8)v/10K\Omega = 0.02mA$

//when the sensor detect the entrance of patient (a ,b terminals open).

$I_{infrared} = 5v/10K\Omega = 0.5mA$

//when there is no detection (ab terminals closed).

Where:

Vs: source voltage.

Vp: PIC voltage.

I pic: PIC current.

4.3 Speaker:

In first stage, speaker is used to give a sound alarm in the radiology department, when infrared sensor reveals entry to radiology department.

The alarm system is controlled by using a programmable PIC microcontroller, when the IR sensor detect the entrance to the department, PIC will has a pulsed square signal (on, off).

A speaker uses electromagnets to transform electric current into sound. Figure(4.3) (a) show the external shape of speaker, and (b) show the internal component of speaker.

Electric current and magnetic force have a close relationship. When an electric current is passed through the wire, a magnetic field would be produced.

Flowing current causes the speaker to vibrate with specific frequency according to the PIC programming.

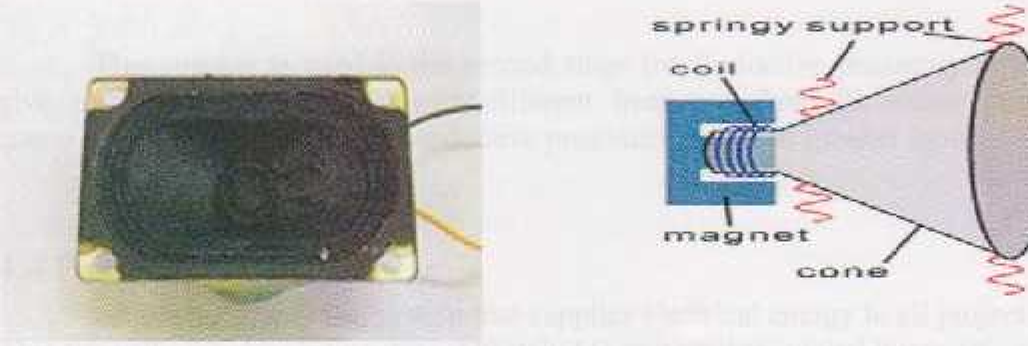

Figure (4.20): (a) external shape of speaker, (b) internal component of speaker.

The speaker will be supplied with 5 Vdc ,the internal resistor of the speaker that used in this project is (8Ω),Which connected to port B, to use command (fast input output port) with its programming, so when PIC has a continuous square signal as in Figure (4.4), at the input of the circuit of speaker, the speaker will give a sound alarm.

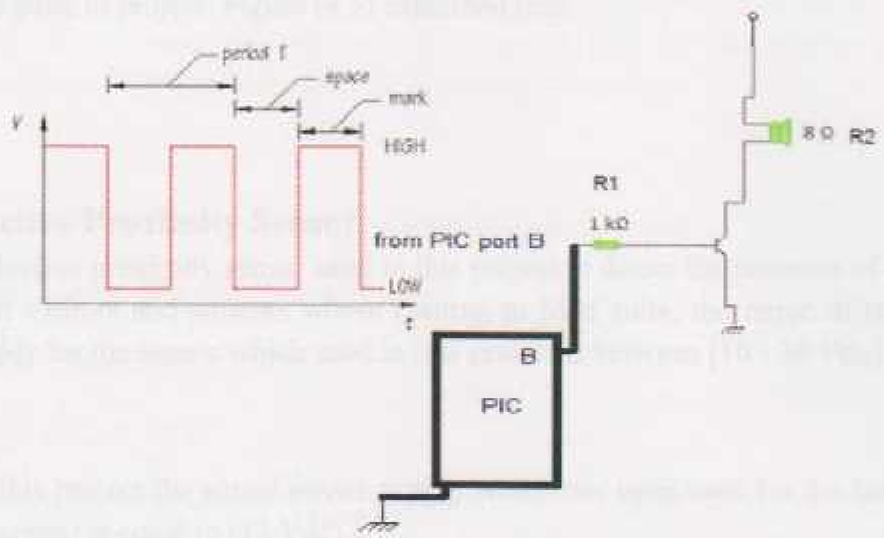

Figure (4.21): continuous square signal from PIC to speaker.

This speaker is used in the second stage too (inductive proximity sensor) to give a different sound alarm with different frequency from IR sensor stage. by connect 12V power supply from inductive proximity sensor to speaker input.

4.4 Power supply:

A power supply is a system that supplies electrical energy to all project parts. This typically involves converting 220 volt AC to a well-regulated lower DC voltage for electronic devices. It is also used to convert 220 volt AC to lower desired AC voltage.

In this project we use ready transformer for the power supply design. which convert the voltage from 220v to 12v. And this 12v is required for some part of project as supply voltage.

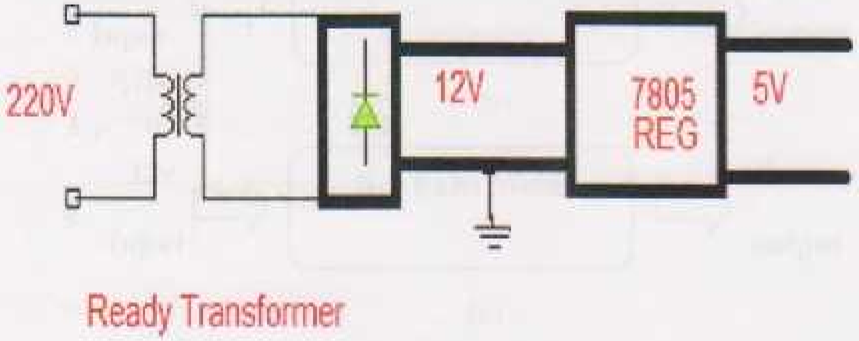

Figure (4.22): Power supply block diagram.

A regulator of number (LM7805) is used in this project with power supply design; it is regulated lower voltage to 5v, which we need as a supply voltage for some other parts in project. Figure (4.5) explained that.

4.5 Inductive Proximity Sensor

Inductive proximity sensor used in this project to detect the presence of metals or not with visitors and patients whose coming to MRI suite, the range of required power supply for the sensor which used in this project is between [10 - 30 Vdc].

In this project the actual power supply which has been used for the inductive proximity sensor is equal to (12 Vdc).

With the presence of metal, the inductive proximity sensor has an output voltage equal to the input. If there are no metal or metallic materials, the output will be zero.

Figure (4.6.a,b,c) illustrates the shape of proximity inductive sensor and the input and output values in two cases, the presence and the absence of metals.

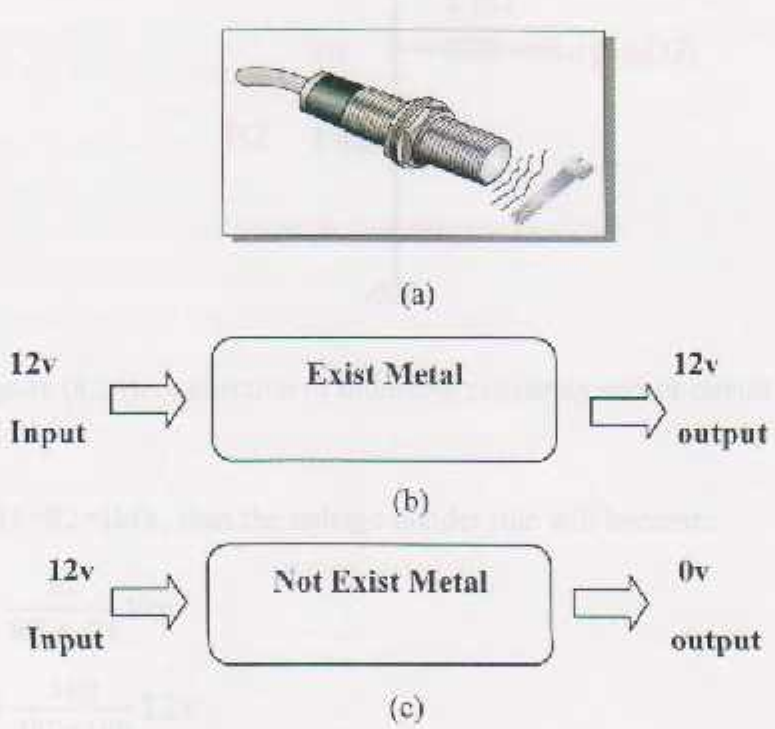

Figure (4.23): (a) Shape of proximity sensor, (b) Input and output values with presence of metal, (c) Input and output values with absence of metal

The idea in this stage of the project is to give sound and light alarms in the MRI suite when metals are detected. Because of that the connection of PIC microcontroller is necessary to control of the previous alarms.

This sensor has three wires with different three colors as follows:

Blue color: Ground wire.

Brown color: Input wire (vcc).

Black color: Output wire.

The output wire of inductive proximity sensor must be connected directly to the PIC, but the PIC required power supply is equal to (5 Vdc), so voltage divider will be used between the output wire of the sensor and input of a PIC microcontroller at (BORT D (pin 2)) as shown in the following circuit in Figure (4.7):

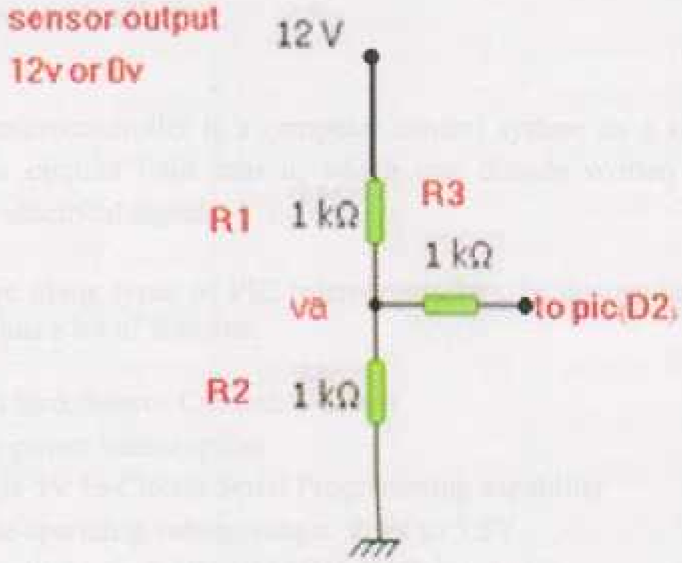

Figure (4.24): connection of inductive proximity sensor circuit

since R1=R2=1kΩ , then the voltage divider rule will become:

$$Va = \frac{R2}{R2 + R1} Vcc$$

$$Va = \frac{1k\Omega}{1k\Omega + 1k\Omega} 12v$$

$$Va = 6v$$

R3 is used to reduced the current to a value that is acceptable to the PIC in the range of (1-25 ma). The voltage is dropped also to 5v.

$$I_{PIC} = \frac{Va - Vpic}{R3}$$

$$I_{PIC} = \frac{6v - 5v}{1k\Omega}$$

$$I_{PIC} = 1mA$$

In the case, when there is no metal. then the inductive proximity sensor output equal to zero and no signal reaches to the PIC. That means the alarm system doesn't work.

4.6 PIC Microcontroller:

A microcontroller is a computer control system on a single chip. It has many electronic circuits built into it. which can decode written instructions and convert them to electrical signals.

There are many types of PIC microcontrollers. in this project (PIC 16F87A) used because it has a lot of features:

1) High Sink/Source Current: 1-25mA
2) Low-power consumption
3) Single 5V In-Circuit Serial Programming capability
4) Wide operating voltage range: 2.0V to 5.5V
5) Operating speed: DC - 20 MHz clock input
6) High performance RISC CPU
7) 10-bit multi-channel Analog-to-Digital converter
8) Timer0: 8-bit timer/counter with 8-bit prescaler
9) I/O Ports A,B,C,D,E
10) Oscillator crystal up to 4MH.

4.6.a Pin Diagram:

The Figure (4.8) below will show the PIC pin diagram in details:

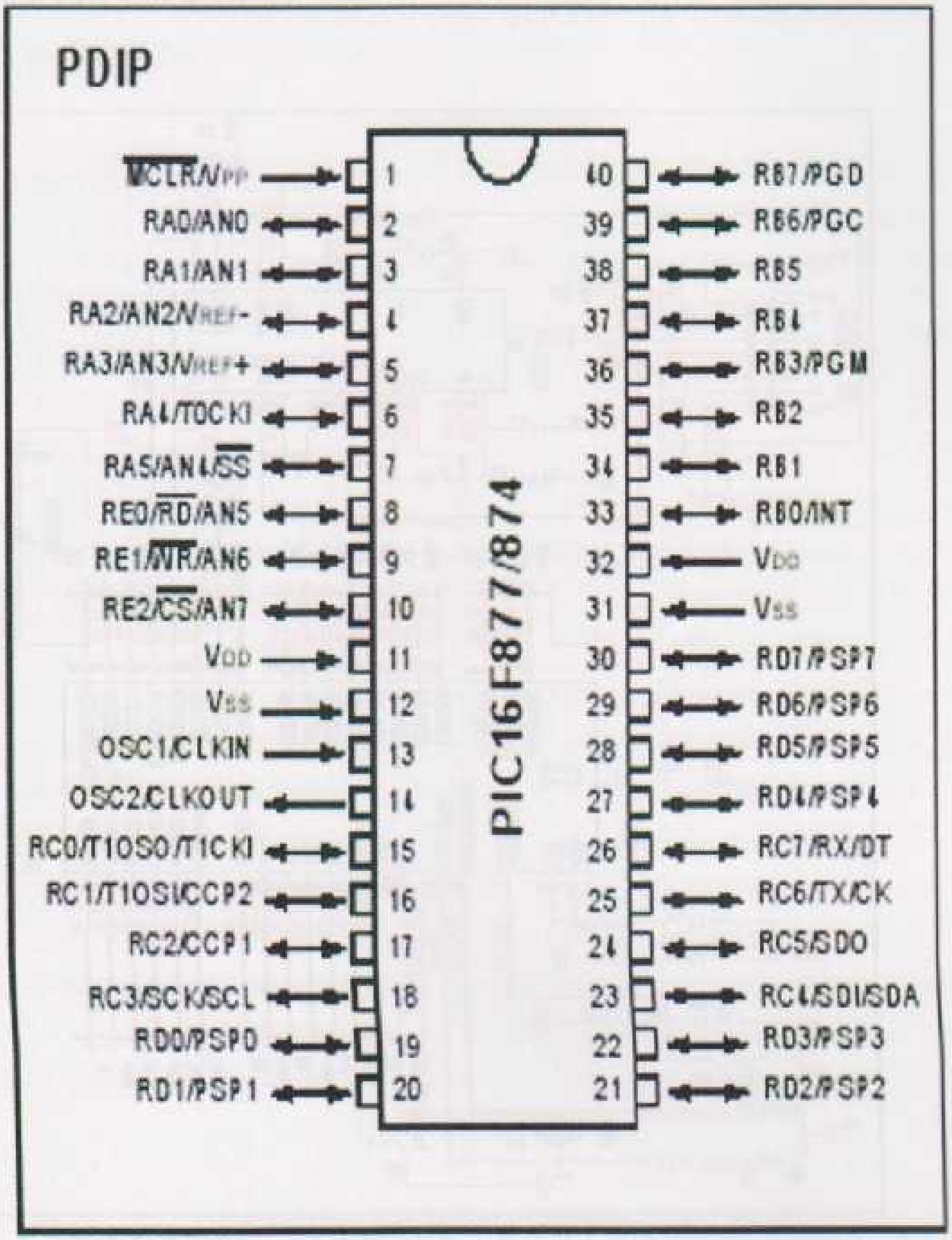

Figure (4.25): PIC pin diagram.

4.6.b PIC Connections:

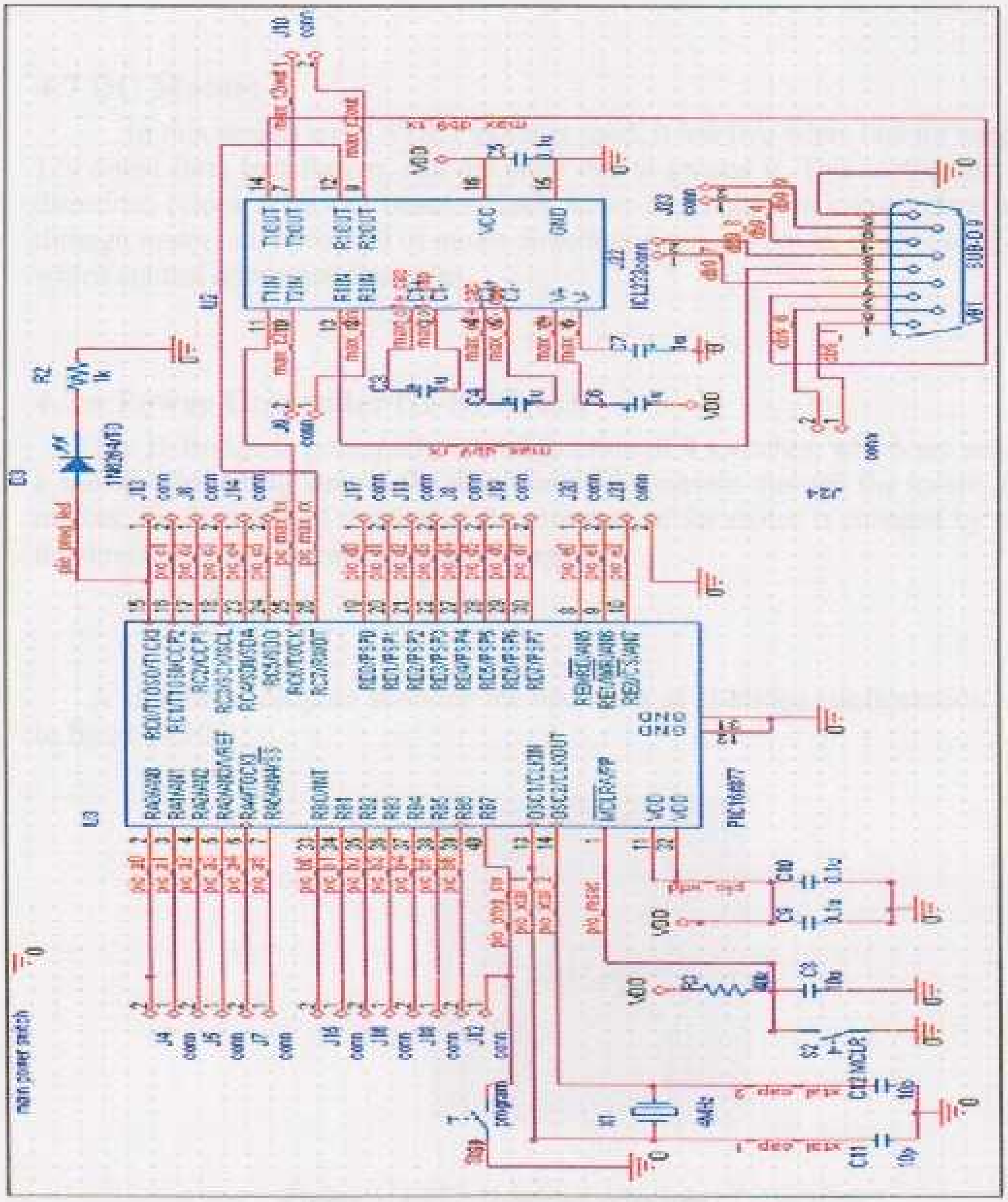

Figure (4.26): PIC connection.

In PIC connection its necessary to use and connect (MAX 232) to convert the digital output comes from PIC to serial connection (RS 232) which connect the microcontroller with computer to load the programs we write it by computer on PIC as illustrated in previous Figure (4.9) .

4.7 DC Motor:

In this project a (12 VDC) motor is used, it has two wires 0ne for supply it by 12v direct from transformer, and the other one to ground it. This motor rotate in two directions (clock wise and counter-clock wise) depending on current flow direction through motor. so, to control of motor directions must use power controller(H-Bridge) which control of current directions.

4.7.a Power Controller (H-Bridges):

The H-Bridge is principally a configuration of 4 switches, which are switched in a specific manner to control the direction of the current through the motor. (For DC motors, the direction of rotation of the armature of the motor is changed by changing the direction of the current flowing through it).

A simplified diagram showing the operation of H-bridge configuration is shown in figure (4.10):

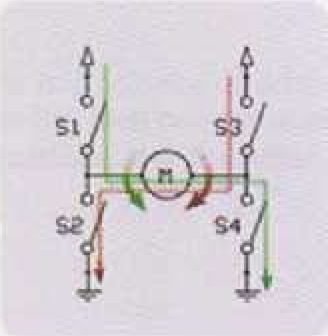

Figure ·(4.27): H-bridge principle of operation

There are two possible paths for the current:

1) The red path, where the current is directed to the motor through the switches S3 and S2, is causing the motor to turn clockwise.
2) The green path, where the current is directed to the motor through the switches S1 and S4, is causing the motor to turn counter-clockwise.

In this project the four switches are replaced with four NPN transistors (BC547) and four resistors (300Ω) , in order to electronically control the flow of current in the motor, hence, allowing us to control the direction of the motor from the PIC microcontroller. Port D at pin3 (D3) and Port C at pin4 (C4) is used to connect H-Bridge circuit to PIC. Figure (4.11) show the circuit connections for H-bridge.

When voltage on (D3) equal to 5v (from PIC)and voltage on (C4) equal zero (from PIC too), then the two transistors T1 and T4 must reach to saturation (Icollector reach to saturation) to make transistors completely closed to allow the signal from pic to pass and then be able to rotate the motor in counter-clockwise direction. And the other two transistors T2 and T3 stay open and no signal pass through them.

$$I_B = \frac{(Vpic - Vbe)}{(R)}$$ (Vbe−Vbase-emitter)

$$I_B = \frac{(5 - 0.7)}{(300\Omega)}$$

$IB = 14mA$, Since I_B reach to saturation that means Ic reach to saturation too because Ic = I_B*β

In the case to rotate motor in clockwise direction, the voltage on(D3) equal to be zero and on (C4) equal to 5V, then two transistors T2 and T3 will reach to saturation as the previous equations, and the other two transistors T1 and T4 stay open.

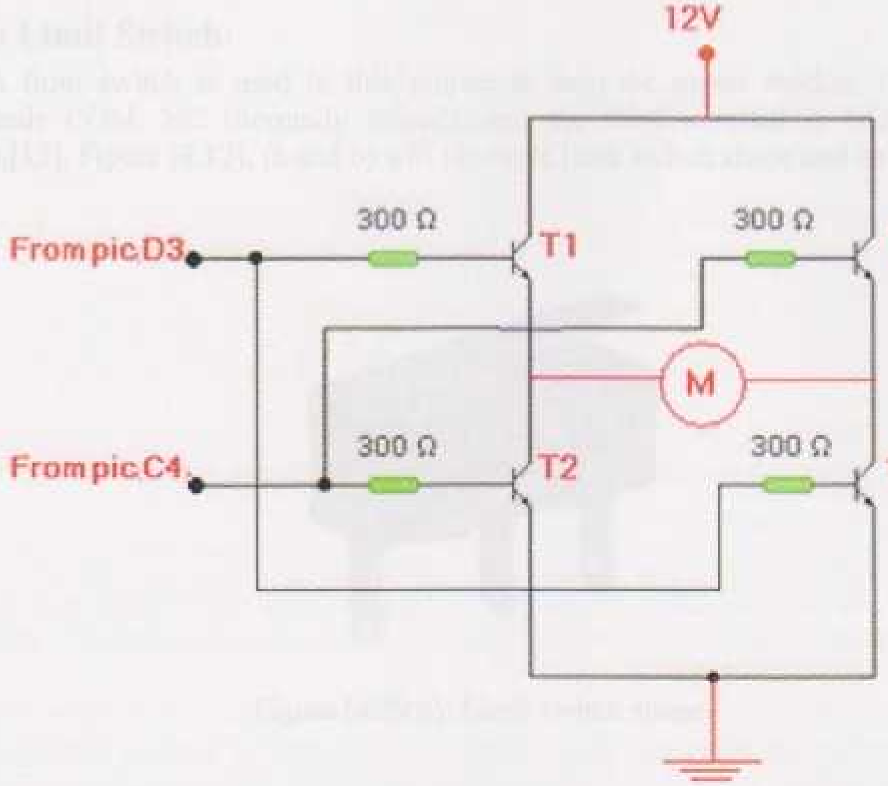

Figure (4.28): Circuit of power controller (H-Bridge).

According to the transistors state, the motor direction will be determined as shown in table 4.1:

Table (4.1): States of Transistors and Motor Behavior.

T1	T2	T3	T4	Motor Direction
OFF	ON	ON	OFF	clockwise
ON	OFF	OFF	ON	Counterclockwise
OFF	OFF	OFF	OFF	stop

When motor is clockwise the door moves forward, and when the motor is counterclockwise the door moves backward.

4.7.b Limit Switch:

A limit switch is used in this project to stop the motor motion. It has three terminals COM, NC (normally closed), and the third terminal is NO (normally open),[13], Figure (4.12), (a and b) will illustrate limit switch shape and its terminals:

Figure (4.29.a): Limit switch shape.

Figure (4.30.b): Limit switch terminals.

Two terminals of previous have been used in project, COM and NC to convert limit switch like any normal switch, and then connect it to H-Bridge. NO terminal is not used. As shown in Figure (4.13):

Figure (4.31): Limit switch terminals are used and not used.

In this project two limit switches are used to control motor motion in two directions (clockwise and counter-clockwise), which are connected to H-bridge.

According to its connection with H-bridge, limit switches take place between Vcc and transistors as show in Figure (4.14). One of them (limit switch1) put between Vcc and collector of transistor T1 to stop motor motion in counter-clockwise direction. And the other (limit switch2) put between vcc and collector of transistor T3 to stop motor motion in clock-wise direction. That's means, this two limit switches becomes as voltage provided to motor (Vcc).

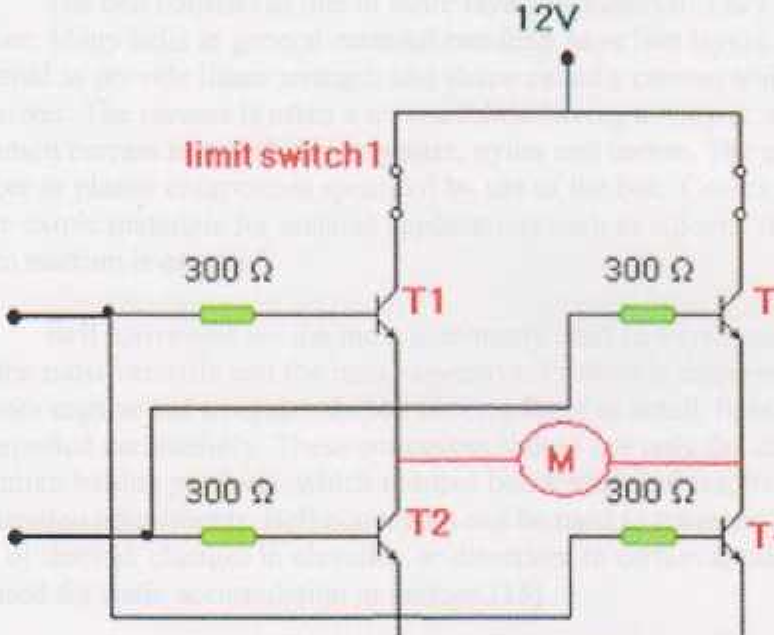

Figure (4.32): Limit switch terminals connections.

In normal case, the two limit switches must be closed to supply the motor by 12v and then rotate it in two directions. And to stop motor motion there is two cases:

1) When motor is rotate in counter-clockwise, it will be reached finally to limit switch1 and open it so, no voltage reaches to T1 and T4. because of that the motor motion in this direction will stop.
2) When motor is rotate in clockwise, it will be reached finally to limit switch2 and open it so, no voltage reaches to T2 and T3. because of that the motor motion in this direction will stop.

4.8 Conveyor belt

conveyor belt (or belt conveyor) consists of two or more pulleys, with a continuous loop of material - the conveyor belt - that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport industrial and agricultural materials, such as grain, coal, ores, etc. generally in outdoor locations. Generally companies providing general material handling type belt conveyors do not provide the conveyors for bulk material handling. In addition there are a number of commercial applications of belt conveyors such as those in grocery stores.[14]

The belt consists of one or more layers of material. They can be made out of rubber. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a woven fabric having a warp & weft. The most common carcass materials are polyester, nylon and cotton. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential.

Belt conveyors are the most commonly used powered conveyors because they are the most versatile and the least expensive. Product is conveyed directly on the belt so both regular and irregular shaped objects, large or small, light and heavy, can be transported successfully. These conveyors should use only the highest quality premium belting products, which reduces belt stretch and results in less maintenance for tension adjustments. Belt conveyors can be used to transport product in a straight line or through changes in elevation or direction. In certain applications they can also be used for static accumulation or cartons.[15]

It is considered a labor saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volumes with smaller storage space and with less labor expense. Figure (4.15.a,b,c) show different views of conveyor belt.

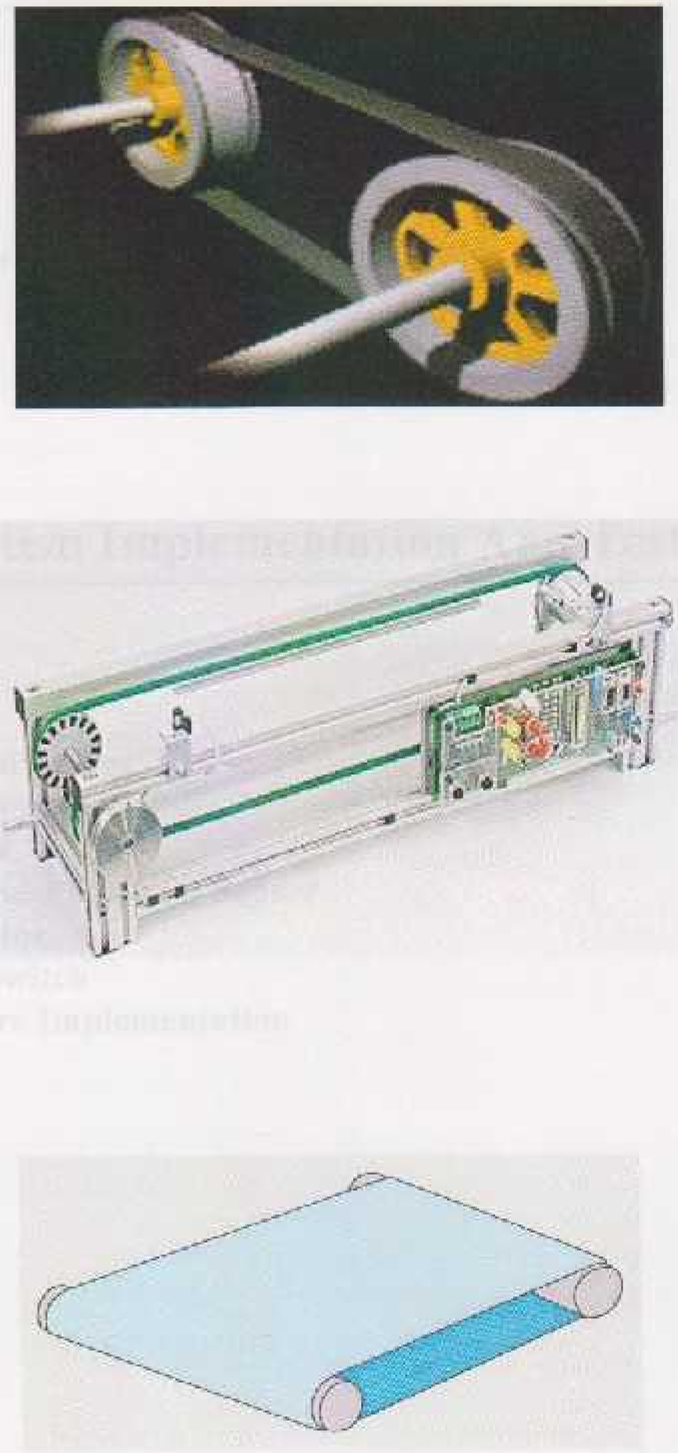

Figure (4.33.a.b.c): Different views of conveyor belt.

According to this project a 12vdc motor was used in conveyor design, and by opposite the polarity of the motor the direction of conveyor rotate will exchange. The conveyor size is 50cm in length and 17cm in width to be suitable for project model.

Chapter Five

System Implementation And Testing

5.1 Infrared Sensor
5.2 Power supply
5.3 Speaker
5.4 Inductive Proximity Sensor
5.5 DC Motor
5.6 Limit Switch
5.7 Software Implementation

Chapter Five

System Implementation And Testing

This chapter demonstrates the methods and procedures used to implement, test, and examine the system operation and behavior. System testing is an important step in implementing whole system.

5.1 Infrared sensor

Infrared sensor implemented by using power supply(5vdc), ground wire, switch, and resistor, and they are connected to PIC microcontroller (port D pin 1), to give the required alarm (sound) with red light from infrared sensor.

Infrared sensor was tested by checking the output signal when there is any entrance to radiology department.

5.2 Power supply

Power supply implemented by using transformer to give 12Vdc and regulator (7805) to give 5v. for each system need 12v or 5v as input power supply .was tested by checking the input and output power for each.

5.3 Speaker

Speaker was implemented by using power supply (12vdc), ground wire, transistor and one resistor, connected with PIC microcontroller to give required sound alarm.

Speaker was tested by checking the output signal when there is any entrance to radiology department, and when there are metallic material.

5. 4 Inductive Proximity Sensor:

Inductive proximity sensor implemented by using power supply (12v),ground wire, and three resistors to connect it with PIC microcontroller (D2) to do the required alarms (light and sound).

Inductive proximity sensor was tested by checking the output signal when there are metallic material or there aren't.

5.5 DC Motor:

DC motor implemented by using power supply (12v), ground wire, and H-bridge power controller (four transistors and four resistors) connected with PIC microcontroller (D3,C4) to make motor and then the door rotate in two directions.

DC motor was tested by testiing H-bridge power controller by applying digital signals (5V or zero) from PIC on pins (D3 and C4), to be sure that the motor rotate in tow directions.

5.6. Limit Switch:

Limit switches implemented by connecting it between the power supply (12v) and collectors of transistors (T1 and T3) of H-bridge power controller to limit door motion in two directions.

Limit switches were tested by making the door reach and hit with it, and then door motion must stop in two directions.

5.7 Software Implementation

5.7.1 Flow Charts

A flow chart illustrate the steps of the process by visualizing the process. Figure (5.1.a.b) shows the flow chart of first, second, and third stages of project.

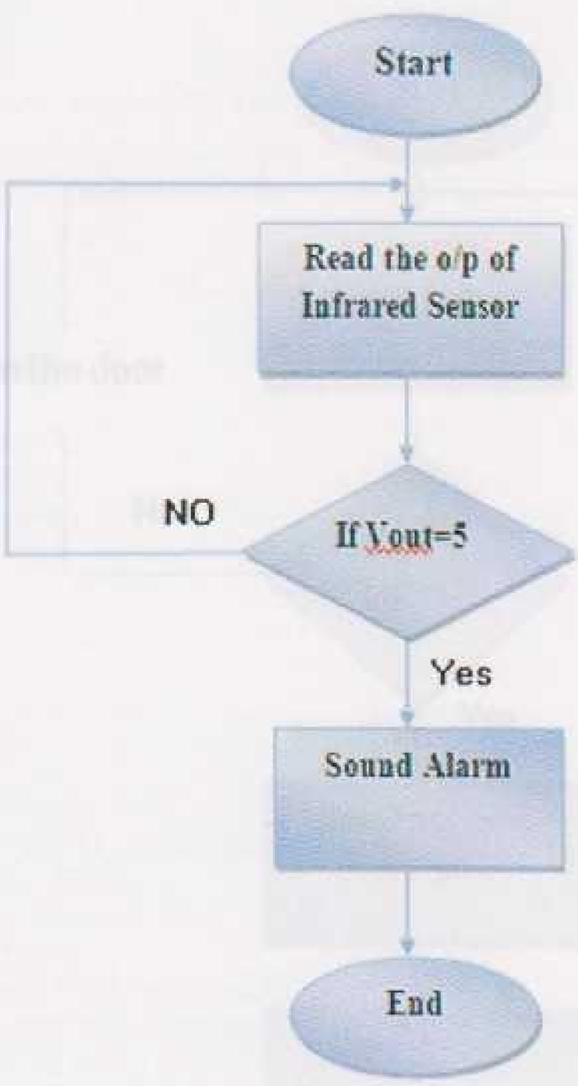

Figure (5.1.a): Flow Chart of first stage.

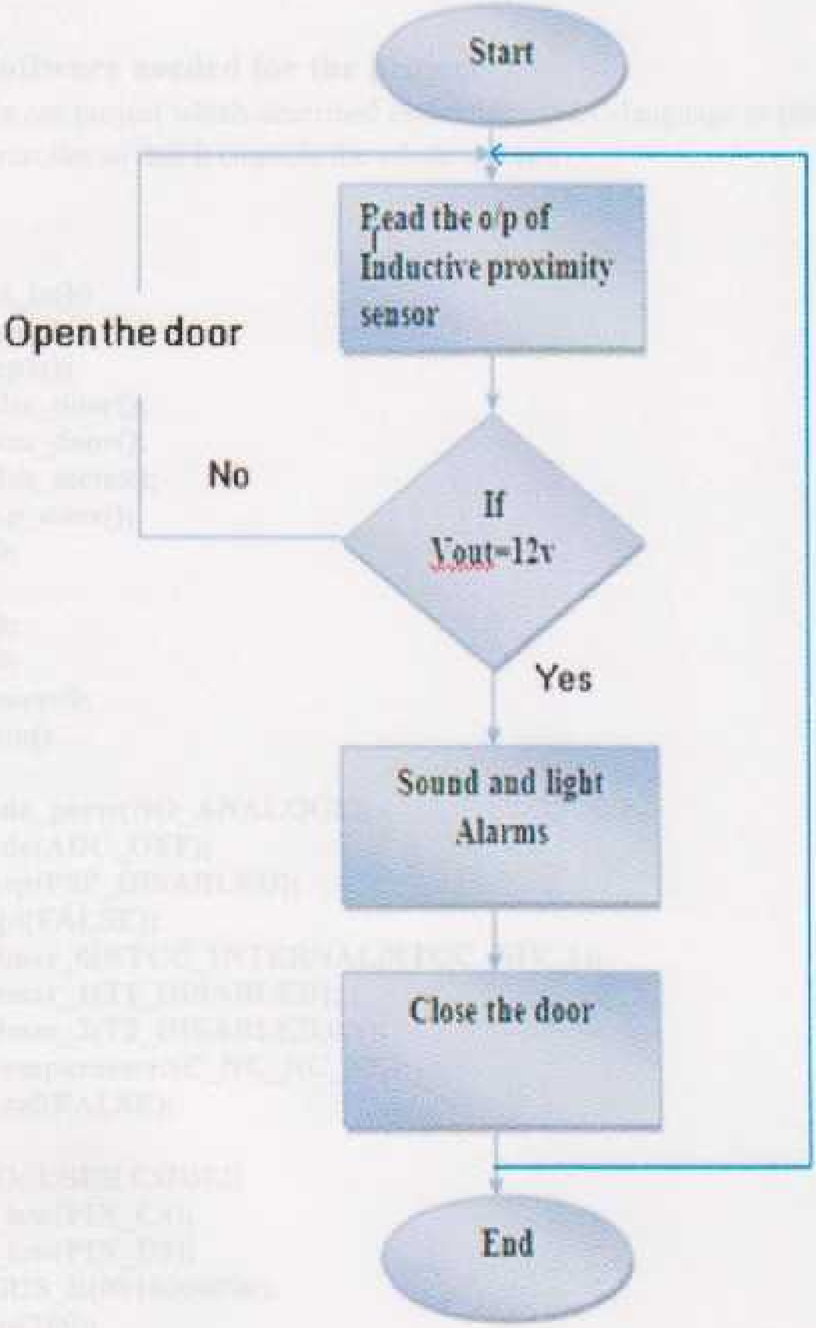

Figure (5.2.b): Flow Charts of second and third stages.

5.7.2 Software needed for the project

In our project which described earlier we used C-language to program the PIC microcontroller so that it controls the whole system.

```
#use fast_io(b)
void beep1();
void beep2();
void Colse_door();
void Open_door();
void Falsh_metal();
void Stop_door();
int1 k=0;
long i;
nt1 m=0;
int1 p=0;
long timerr=0;
void main()
{
setup_adc_ports(NO_ANALOGS);
setup_adc(ADC_OFF);
setup_psp(PSP_DISABLED);
setup_spi(FALSE);
setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
setup_timer_1(T1_DISABLED);
setup_timer_2(T2_DISABLED,0,1);
setup_comparator(NC_NC_NC_NC);
setup_vref(FALSE);

// TODO: USER CODE!!
output_low(PIN_C4);
output_low(PIN_D3);
SET_TRIS_B(0b10000000);
delay_us(100);
output_low(PIN_C4);
restart_wdt();
delay_us(100);
output_low(PIN_D3);
//printf("Hi");
output_low(PIN_b6);
delay_us(100);
while(true){
m=0;
restart_wdt();
if(input(PIN_D2)==1){
delay_us(200);
Falsh_metal();
```

```
m=1;
}
restart_wdt();
if(input(PIN_D1)==1){
beep1();
delay_us(150);
p=1;
}
restart_wdt();
if(input(PIN_B7)==0){
Colse_door();
delay_ms(4000);
Open_door();
output_low(PIN_D3);
}


if(p==1){
while(timerr<=1300){
if( m==0){beep1();}
if(input(PIN_D2)==1){
// printf("Metal");
delay_us(100);
Falsh_metal();
p=0;
m=1;
 }
 //delay_ms(1);
 timerr++;
}
p=0;
if (m==0){
Open_door();
delay_ms(4000);
output_low(PIN_D3);
}
    }

timerr=0;
}
     }
void beep1(){
//printf("PEEP1");
delay_ms(1);

restart_wdt();
delay_us(200);
output_high(PIN_b6);
delay_us(240);
output_low(PIN_b6);
delay_us(240);
restart_wdt();
```

```
delay_us(100);
}

void beep2(){
//printf("PEEP2");
delay_ms(1);

i=0;
while(i<=1000){
restart_wdt();
output_high(PIN_b6);
delay_us(440);
output_low(PIN_b6);
delay_us(230);
i++;
}
}
void Falsh_metal(){
//printf("Falsh_metal");
delay_ms(1);

restart_wdt();
delay_us(100);
output_high(PIN_D0);
delay_us(10);

output_high(PIN_C0);

beep2();
output_low(PIN_D0);
delay_us(10);
output_low(PIN_C0);
beep2();
}


void Open_door(){
restart_wdt();
delay_us(100);
//printf("Open Door");

delay_ms(1);
restart_wdt();
output_high(PIN_D3);
output_low(PIN_C4);
}
void Colse_door(){
restart_wdt();
delay_us(100);
//printf("Close Door");
delay_ms(1);
restart_wdt();
```

```
output_high(PIN_C4);
output_low(PIN_D3);
}
```

Conclusion and Future Work

1) Conclusions

The project purpose was to design an alarm system for MRI suite, and the system consists of three stages:

1. first stage was to design and build a special entrance to radiology department that give a sound massage when a person be counted through by using optical sensor.

2. second stage was to design and build a warning system for patient going to MRI suite using inductive proximity sensor that is sensitive to the presence of metallic parts in possession of patient .

3. by using special PIC microcontroller the system will operate to alarm the patient from the huge magnetic field and immediately the gate will close.

4. third stage was to design private gate that protect patient whom carry metals from magnetic field by using DC motor and private controller circuit to close the gate when the patient come to this suite with metals .

5. In this case ,a voice message will alarm the staff and the patient about the existence of metals.

6. after the patient removes all the metallic material and tools ,the staff inside MRI suite will push a manual switch to entrance permission

2) Recommendations

Future modifications can be carried out so system performance and efficiency is improved, these modifications include:

1. Implementation the system by using other types of sensors.

2. Improved the system by adding voice alarm or LCD to hear and to display messages.

3. Improved the system by connect it to staff mobile phone to alarm them when there is any person has metal or metallic material inside the MRI suite.

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APPENDIX

PIC16F87X
Data Sheet

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

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PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

Devices Included in this Data Sheet:

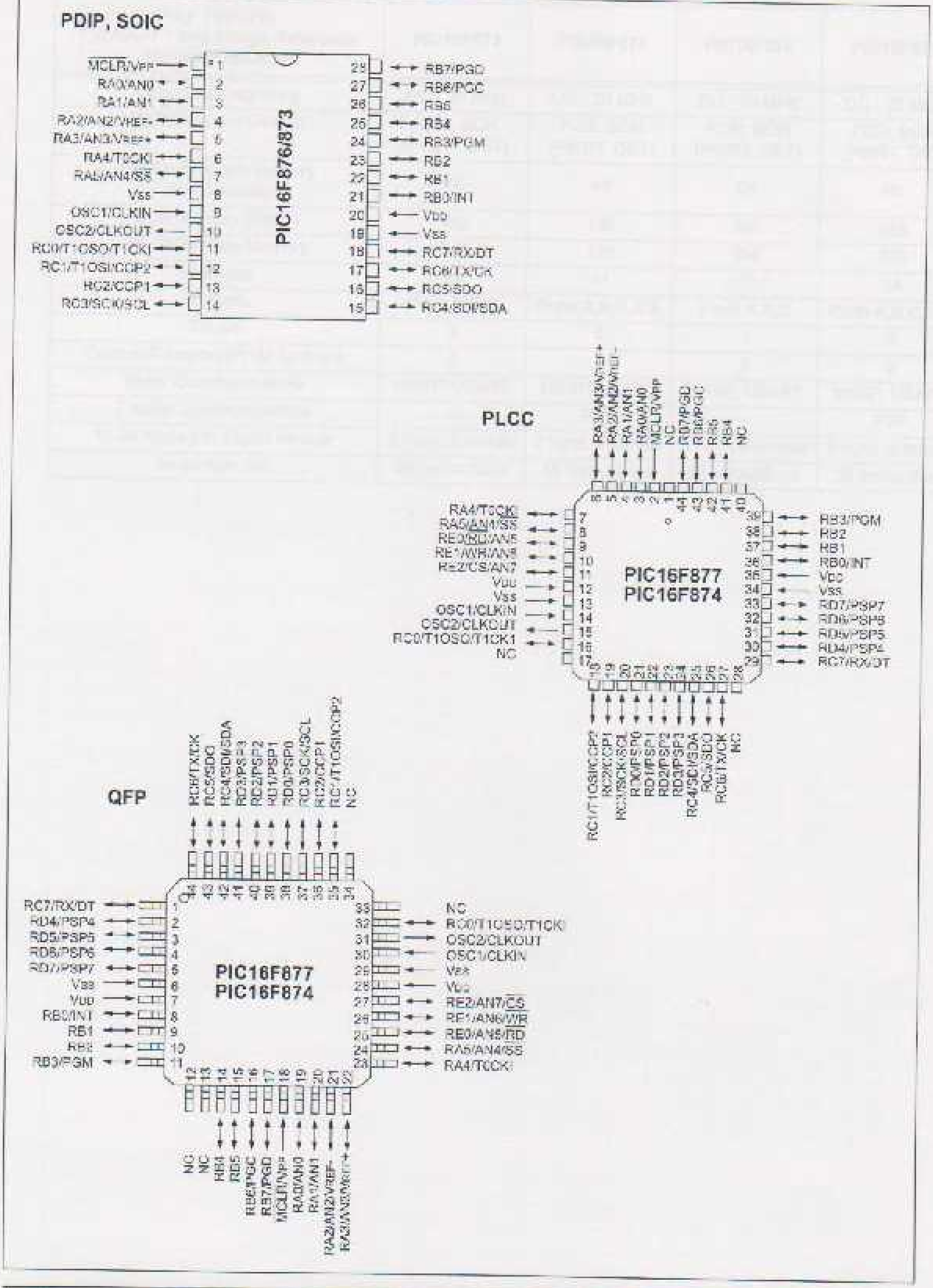
- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77

Pin Diagram

Pin Diagrams



Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

FAIRCHILD
SEMICONDUCTOR®

BC546/547/548/549/550

Switching and Applications

- High Voltage: BC546, V_{CEO}=65V
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560

TO-92

1. Collector 2. Base 3. Emitter

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546	80	V
	: BC547/550	50	V
	: BC548/549	30	V
V_{CEO}	Collector-Emitter Voltage : BC546	65	V
	: BC547/550	45	V
	: BC548/549	30	V
V_{EBO}	Emitter-Base Voltage : BC546/547	6	V
	: BC548/549/550	5	V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C

Electrical Characteristics T_a=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			15	nA
h_{FE}	DC Current Gain	V_{CE}=5V, I_C=2mA	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		90	250	mV
		I_C=100mA, I_B=5mA		200	600	mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		700		mV
		I_C=100mA, I_B=5mA		900		mV
V_{BE} (on)	Base-Emitter On Voltage	V_{CE}=5V, I_C=2mA	580	660	700	mV
		V_{CE}=5V, I_C=10mA			720	mV
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA, f=100MHz		300		MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz		3.5	6	pF
C_{ib}	Input Capacitance	V_{EB}=0.5V, I_C=0, f=1MHz		9		pF
NF	Noise Figure : BC546/547/548	V_{CE}=5V, I_C=200uA		2	10	dB
	: BC549/550	f=1KHz, R_G=2KΩ		1.2	4	dB
	: BC549	V_{CE}=5V, I_C=200uA		1.4	4	dB
	: BC550	R_G=2KΩ, f=30~15000MHz		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

Typical Characteristics

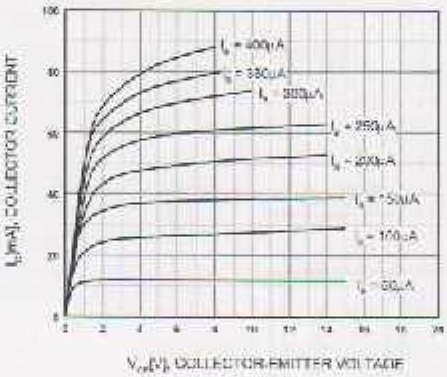


Figure 1. Static Characteristic

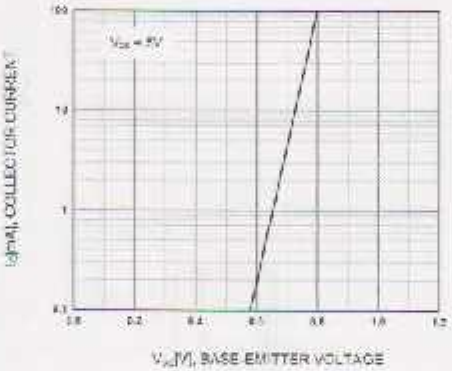


Figure 2. Transfer Characteristic

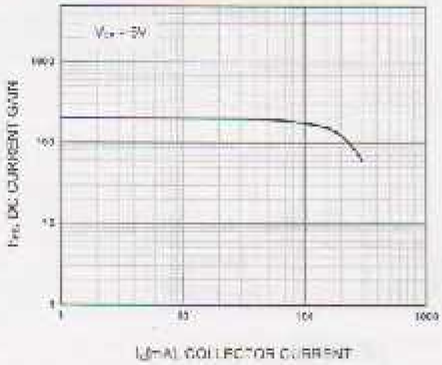


Figure 3. DC current Gain

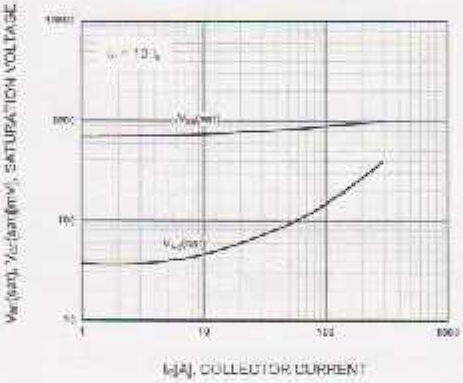


Figure 4. Base-Emitter Saturation Voltage Collector-Emitter Saturation Voltage

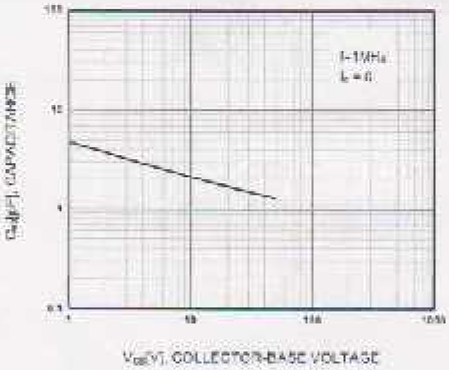


Figure 5. Output Capacitance

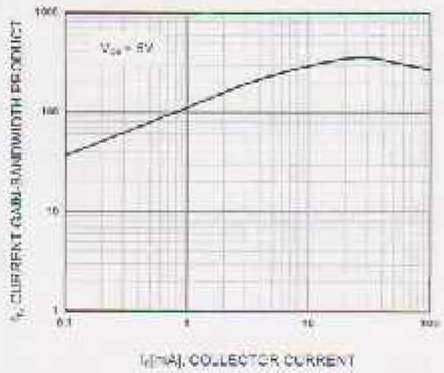
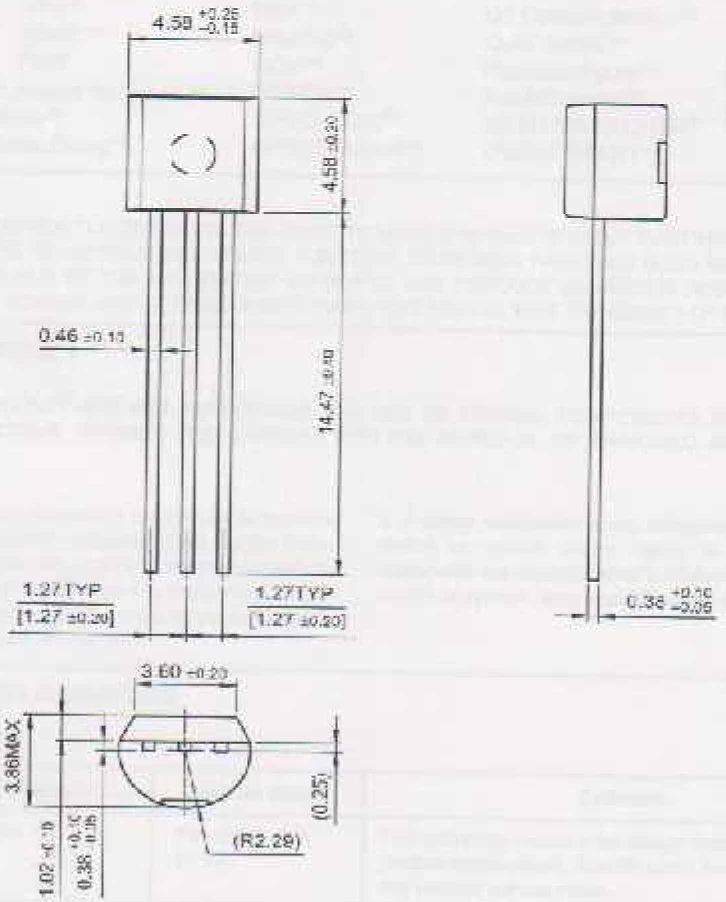


Figure 6. Current Gain Bandwidth Product

Package Dimensions

TO-92



Dimensions in Millimeters

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Datasheet Identification	Product Status	Definition
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No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.