DESIGN AND IMPLEMENTATION OF A MICROCONTROLLER BASED SYSTEM FOR CALIBRATION BENCH CONTROL IN A SECONDARY STANDDARD DOSIMETRY LAB (SSDL)

BY

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DEDICATION

To the gentle soul of my father who taught me
That much could be done with little.

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ABSTRACT

The objective of this thesis work is to design a real time module of calibration bench for use in Secondary Standard Dosimetry Laboratory. The implemented module consists of a microcontroller as the heart of the system, two sensors (position sensor, temperature sensor), electronic circuits, and a mechanical system for the longitudinal and vertical motion. An 8051 microcontroller provides signals to control the system and achieves the position of the Bench which is detected by the inductive proximity sensor (M30, 8mm, Metal), other function of the microcontroller is to process the data which is handled the temperature sensor (Precision Centigrade LM35). The calibration Bench module utilizes closed loop feedback system via a proximity sensor which is located on one of the Bench wheels, for a precise movement and accurate bench position. By utilization of digital logic in the form of microcontroller feedback signal, DC motors are used for powering the mechanical system. They are controlled via two H-bridge power FET transistors arrays, which provide the driving power and direction control. While the microcontroller controls the H-bridge through the optisolator.

The calibration bench system is designed, implemented, and then tested and the results show small difference in a desired position as compared to the manual adjustment. The accuracy of results is affected by the sensor resolution. The goal of the design is to increase the quality of the calibration process, decrease of exposure time for the personnel (occupational Dose Reduction).Thus good radiation protection introduced as the result of well calibrated instruments, so the implemented module maintains the main objectives of the proposed system and could be applicable for further applications

مستخلص

الهدف من هذه الاطروحة هوتصميم وحدة تحكم فى الزمن الحقيقى لطاولة المعايرة للاستخدام بمختبر المعايرة الثانوية (SSDL) . وحدة طاولة المعايرة المطبّقة تشتمل على متحكم دقيق(Microcontroller) والذى يمثل قلب النظام، محسّاسان (محسّاس درجة الحرارة ومحساس الموقع)، دوائر إلكترونية ،بالاضافة الى نظام ميكانيكي للحركة الطولية والعمودية.المتحكم الدقيق(microcontroller 8051) يزوّد النظام باشارات التحكم وينجز الموضع المراد من الطاوله انجازه والذى يتم الكشف عنه بواسطة محساس الموقع .وايضا من وظائف المتحكم الدقيق اجراء عمليات معالجة البيانات الصادرة من محساس درجة الحرارة. وحدة طاولة المعايرة المطبقة عبارة عن نظام تحكم الحلقة المغلقة العكسية وذلك عن طريق محسّاس التقريب الموضوع على احد اطارات الطاولة ليكون الناتج حركة دقيقة وموضع طاولة صحيح. ومن المكونات محركان لتشغيل النظام الميكانيكي وذلك باستخدام اشارات تحكم منطقية رقمية عكسية ، و يتم التحكم فيهما عن طريق قنطرتين كهربيتين من ترنزستورات من نوع (Power FET Transistor) والتي تزوّد المحركات بالقوة الدافعة وتتحكم في اتجاه الحركة ، بينما يزوّد المتحكم الدقيق القنطرتين بإشارات التحكم عبر عوازل الكترونية ضوئية (Optisolator).

تم تنفيذ وحدة طاولة المعايرة ثم تمت تجربتها ، و اظهرت النتائج اختلافا طفيفا في المسافة المطلوب من الطاولة إنجازها وذلك مقارنة بالمسافة المقاسة والمضبوطة يدويا . دقة النتائج المتحصل عليها متاثرة بدقة المحساس المستخدم.

الهدف من هذا التصميم هو زيادة جودة عمليات المعايرة، تقليل زمن التعرّض للعاملين بالوحدة(تقليل التعرض المهنى) ،وايضا بالامكان معايرة اكثر من عينة واحدة ومن ثم تقديم خدمة افضل فى مجال الوقاية من الاشعاع كنتيجة لاجهزة معايرة بصورة مثلى. الوحدة المطبّقة اوفت بالأهداف الرئيسية للنظام المقترح ويمكن أن يكون هذا النموذج قابل للتنفيذ في تطبيقات أخرى.

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CHAPTER ONE

INTRODUCTION

1.1. Introduction

X-rays were found to be powerful tools for use in medical diagnosis and therapy with a minimum risk. Other forms of ionizing radiation are Alfa, Beta, Gamma, and Neutron, which are used in daily life for medical and industrial purposes. However, researchers are challenged by the use of complex scientific instruments and techniques to make measurements of radiation reliable.

High accuracy in the radiation measurements (Dosimetry) of ionizing radiations is essential in assuring the quality of radiation measurements throughout the world and in comparing successfully clinical results on an international basis. This accuracy can only be achieved if calibrated radiation dosimeters are available. These meters must be checked regularly to maintain acceptable measurement performance.

1.2. Overview

One practical solution to maintain the calibration problem is the establishment of a wider network of calibration laboratories equipped with a reference instrument calibrated by one of the primary laboratories, which belong to the International Atomic Energy Agency (IAEA).

These calibration laboratories are called Secondary Standard Dosimetry Laboratories (SSDL), which are operating under prescribed procedures, careful maintenance of standards and consistency checks. SSDL is established to be a part of the national service of metrology with the responsibility of verifying field dosimeters by calibrating them against secondary standard instruments which are traceable to primary national and/or an international standard.

The main role of SSDL is to bridge the gap between the Primary Standard Dosemitry Laboratories (PSDL) and the user of ionizing radiation by enabling the transfer of dosimeter calibrations.

The Secondary Standard Dosemitry Laboratory (SSDL) of the Sudan Atomic Energy Commission (SAEC) is a member of the IAEA calibration laboratories network. The SSDL is facing a problem in positioning the calibration bench since the adjustment of the distance is done manually, which is time consuming and inaccurate positions. Control device should be added for saving time and to achieve accurate positions. The measured distance has significant magnitude influence on dose measurement, which needs high accuracy. It depends on the inverse square law this dependence means that any deviation or errors on the measurement of the distance leads to unreliable results. Another factor is the examination room temperature which is needed to be monitored for its importance in dose measurements and calibration consideration, so the proposed calibration bench should meet the requirements of the lab to achieve the protection goal [1].

1.3. Problem Definition

The procedure of the calibration process should be done in accurate and clear way to avoid any errors or uncertainties, since the SSDL is standard. There are many errors which affects the accuracy of the calibration thus make the measurements uncertainties. Some errors have no sign in usual but cause uncertainty; these types of error are estimated in the best possible way and corrected by repeating the measurements.

Other types of errors which cause uncertainties, which can not be estimated by repeated measurements, include not only unknown effects but also little known effects of influence quantities (temperature, pressure, etc).

One of the basic calibration facilities is the bench with positioning devices which represents one of the errors and uncertainty factors (first type),since the object position is very important in the calibration calculation, which depends on the distance between the fixed radiation source and the object to be irradiated (calibrated). Always the setting of the distance is the problem for the workers in SSDL because most of the SSDL use x-y laser alignment system or other type of distance measurement to set the variant distances. In our SSDL the distance determination is done manually so some deviation or error may occur, which leads to failed measurements and results. Also the temperature monitoring should be considered because it has an influence on results.

1.3.1. Problem Effects in the Process

There are many disadvantages of the manual adjustment of distance. Firstly, inaccurate position lead to unreliable results, hence measurements and calibration producers should be repeated, so power and time are consumed in manual adjustment. Secondly the exposure time is long to the personnel which lead to unsafe radiation protection

1.4. Project Objectives

The objectives of this project are to develop a useful calibration bench module based on a microcontroller, to control the position of the object (to be irradiated) against the radiation source and monitor the examination room temperature. The Calibration bench will be remotely access for saving time and power. The system should assure the radiation protection and achieves reliable calibration with accurate results.

1.5. Methodology and Tools

The proposed system is mainly based on a microcontroller as the brain of the system, beside the μ-controller there are some electronic components, software and a mechanical system for complementing the module.

a) Microcontroller and Electronic Components

A microcontroller chip from Intel 8051 family is used since it is an 8-bit μ-controller, inexpensive , universal component with wide spread vendors and developing tools. In addition to the 8051 μ-controller chip, many electronic components are used as follows:

- Position (proximity) sensor.
- Temperature sensor.
- Analogue to Digital Converter (ADC)
- Liquid Crystal Display (LCD).
- Computer type Keyes.
- Power FET Transistors for motor driving.
- Optocouplers.
- Switch Mode Power Supply (SMPS).

b) Mechanical Components

The basic mechanical components are two powerful DC motors used in the calibration of the bench module. They are used for the longitudinal and the vertical movements. The other mechanical parts are; the trolley with four wheels, the up/down lifting device, and the belt with pulleys for connecting the shaft with the motor.

c) Sensors Module

The proposed system requires some sensors to control the position and to monitor the temperature. These sensors need a conditioning stage in which an Analogue to Digital Converter (ADC) and a microcontroller are used.

d) Keyboard and LCD

The keyboard and LCD represent the user interface devices and they are important to maintain the ability of inputs in a form of the desired position via series of keys presses. The LCD displays the temperature and the bench current status.

e) Developing Tools

In developing any μ-controller based system, some helping tools and special kits are used to perform the work. These developing tools include hardware and software systems which are described as follows;

- The hardware developing tools such as a Personal Computer (PC) for modeling, simulation and testing, the In circuit Emulator for running the system software in its primary steps till it reaches the final setting, Erasable Programmable Read Only Memory (EPROM) programmer for copying the final code in final process into the code memory, and the basic laboratory equipments like a power supply, an oscilloscope, a function generator, and a multi meter for running and debugging the experiment.

- The software developing tools are MultiSim software for electronics schematic designing and simulation and Ultiboard software for the Printed Circuit Board (PCB) production. The two programs are parts of electronics workbench software.
- The C Compiler used is Keil software for editing the code and the compilation to generate the hex file which will be deposited on the code memory.

All the material and methods above should be taken under Considerations for their importance on system performance.

1.6 Literature Review

It is valuable to examine existing researches and innovations that are related to the technology used in this system. Since the SSDL calibration Bench Module is a robotic platform, this section gives historical background and literature review in the areas pertaining to the robotics and position control system. It also gives examples of implemented positioning platform and its contribution.

1.6.1. Research and Development of robotics platforms

The concept of a programmable machine dates back to eighteenth-century.In the nineteenth-century an American, Christopher Spencer, produced a programmable lathe called the *automat* that was capable of turning out screws, nuts, and gears. During World War II Robotic manipulator was developed to permit an operator to handle radioactive materials at a safe distance. One of early researchers Victor Scheinman, while working at Stanford University in 1970 demonstrated a computer

controlled manipulator that was powered by motors rather than by hydraulics, this device was extremely sophisticated and technically complex and in fact is still used today by a number of research centers [2].The International Atomic Energy Agency (IAEA) Developed positioning system for ionization chamber in the SSDL using laser beam devices (wolfer, Germany) the system consists of instruments that produce horizontal laser beam for radiation detector alignment, another instrument produce vertical laser beam to assist in precise position of the radiation detector, and adjusting source to detector distance (SDD). A meter scale (8m) fixed at the wall parallel to radiation beam is used to determined the distance of interest. The laser positioning system described above is completely manual operation.
One of the innovations platform is a controlled low cost mobile platform that is capable of very precise movement (1cm and 1degree) while being able to be upgraded for future applications, the vehicle is completely self contained, and is controlled via a microprocessor and two Complex Programmable Logic Devices (CPLDs) that were designed using VHDL. There are two DC motors that make up the electromechanical subsystem; the platform can be customized by the users for desired positions [3].

1.6.2. The implemented system review

The calibration Bench module designed to provide a precise position for objects to be irradiated. The design includes electronic and mechanical parts to be controlled by 8051 microcontroller. The controller receives movement commands from the user and performs the control functions to drive the platform motors, which are controlled via direction and power signals. Proximity sensor is used to feed back the bench position to the microcontroller. The calibration bench platform assists at the SSDL functionality in positioning and monitoring the examination room temperature. .A vertical movement is needed to maintain the perpendicularity of the sample to radiation beam. Monitoring the examination room temperature is always required in radiation dose calculations. The system main contributions are radiation safety, measurements quality, and the operational efforts reduction

1.7. Thesis Layout

This thesis consists of seven chapters'. Chapter two presents the principles of the SSDL and the Positioning sensors technology especially the inductive proximity sensors technique.

Design and implementation of the system hardware and software are presented in Chapters Three and Four. Chapter Fiver illustrates the Mechanical design of the Robotic calibration bench module. Chapter Six demonstrates the results and presents results analysis and interpretation. Chapter Seven provides the conclusion, contributions of the implemented system and outlines the further work can be done.

CHAPTER TWO

RADIATION METROLOGY

AND

SENSORS OVERVIEW

2.1. Radiation Quantities and Units

The radiation quantities, units and their symbols are defined and listed by the International Commission on Radiation Units and Measurements, (ICRU). The Becquerel (Bq) stands for the unit of activity of radio nuclides and the Gray (Gy) stand for the unit of absorbed dose. In 1977 the special name Sievert (Sv) was proposed jointly by ICRU and International Commission on Radiological Protection (ICRP) for the unit of dose equivalent and was approved by the 16th General Conference of Weights and Measures in 1979. No special name has been proposed for the SI unit of exposure [4].

2.2. SSDL Calibration Equipment and Facilities

SSDL was established for calibration of the dosimeters and other radiation measuring devices. The SSDL basically consists of examination room, which contains the radiation source, calibration bench, reference ionization chamber and manual positioning device. The other part of the lab is the control room with a control console and TV monitor.

2.3. Calibration Set-up for X-ray Source

A schematic diagram for calibrating dosimeters with X-rays is shown in Figure (2.1). This calibration set-up usually consists of an X-ray generator with a protective housing around the X-ray tube, initial diaphragm(D1), beam limiting diaphragm (D2) and shielding diaphragms (D3 and D4), shutter (S), filters (F), monitor chamber (M), absorbers for Half Value Layer (HVL) measurements (A), reference ionization chamber (R) and ionization chamber of the instrument to be calibrated (I). The different components of the calibration set-up should be mounted on a bench with suitable holders and trolleys for precise adjustment. These components, including holders and trolleys, should be rigidly mounted, produce the minimum scattered radiation and be totally outside the useful beam [1].

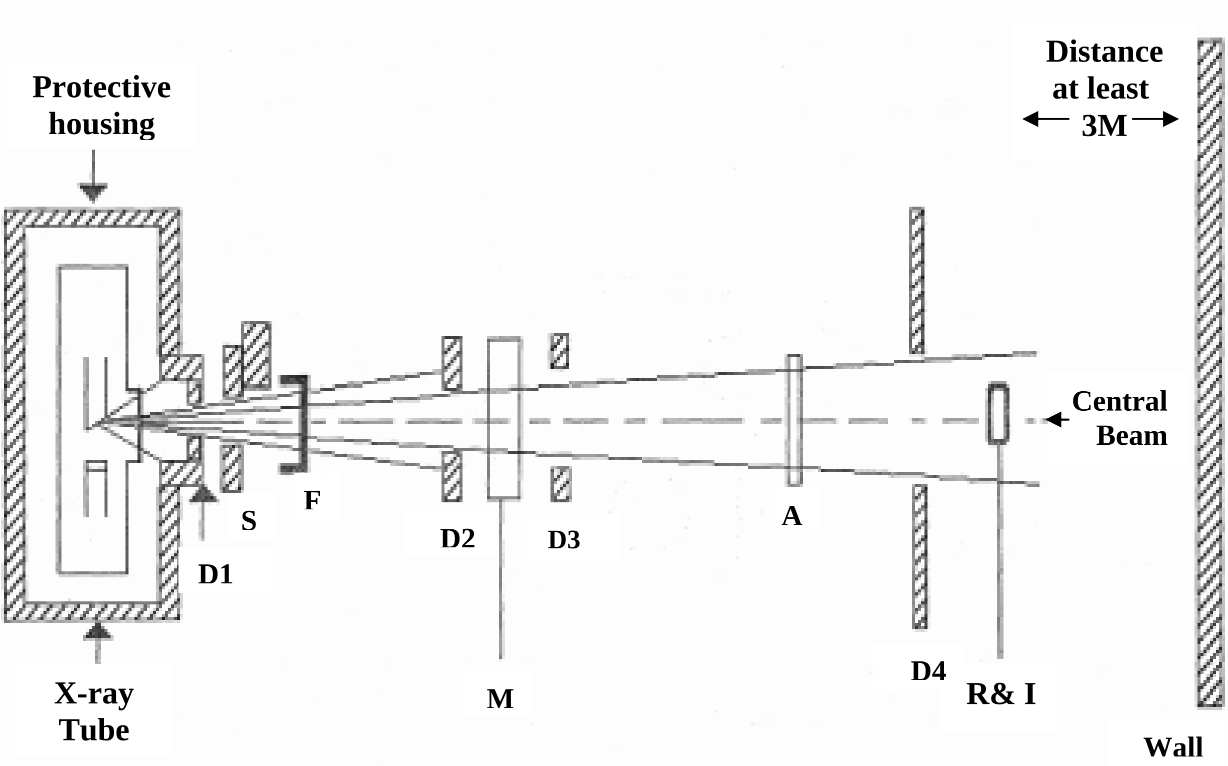

Figure (2.1) Schematic Diagram of a Calibration Set-Up for X-ray

2.3.1. X-ray Generators

Two X-ray generators are required, one for low energy X-ray qualities with a tube voltage range from about 10 to 60 kV and another for medium energy X-ray qualities with a voltage range from about 50 to 300 kV. At least 30 mA tubes current is desirable for the low energy and 10 mA for the medium energy range. Each X-ray generator shall have its own calibration bench. The effective focal spot size of the X-ray tube should be between 2 mm and 5 mm. A low inherent filtration required for the X-ray tube is to be used effectively down to the lower tube potentials. The inherent filtration of the lower energy tube should be no more than about

2 mm beryllium and for the higher energy tube not more than about 4 mm aluminum equivalent.

The X-ray generator should be of the constant potential type. The tube voltage should be continuously variable over its useable range and reset table at any voltage with a precision of ± 1 %.

A stabilizer should be used to reduce variation in voltage to less than 0.3 % for the expected changes in mains voltage or frequency.

The X-ray tube should be mounted in a protective (shielding) housing which would permit no appreciable radiation to emerge in any direction other than that of the useful beam. Calibrations should normally be in the range of 1 mGy/min to 10 mGy/min. (This corresponds to exposure rates of about 1 R/min to 100 R/min). The size of the laboratory and the shielding should be such that the contribution of scattered radiation at the measurement position does not exceed 5 % of the exposure rate.

The X-ray tube must be adjustable so that the X-ray beam can be accurately aligned with the axis of the calibration bench. After alignment the tube must be fixed rigidly in position [1].

2.3.2. Initial Diaphragm (D1)

This is often supplied as part of the X-ray tube housing, which should be just large enough to allow the transmission of the largest field expected to be used and as close as possible to the X-ray tube target [1].

2.3.3. Shutter (S)

This can be either two shutters or one dual-purpose shutter which serves two purposes as follows:

a) A safety shutter, which may be a part of the X-ray tube housing, to attenuate the radiation to a safe level for personnel, and thus to allow improved X-ray beam stability by making it unnecessary to switch the high potential to the X-ray tube on and off for each irradiation;

b) A fast-acting shutter, having a transmission of less than 0.1 %, to begin and to terminate each irradiation and which permits an operating time between full irradiation and zero irradiation of the chamber to be less than 0.1 % of the usual irradiation time. (The irradiation time should be corrected if necessary).Unless acting as an initial diaphragm (D1), the aperture of the shutter must be larger than the diameter of the X-ray beam at its position. A shutter thickness of about 1 mm lead for the low energy X-ray qualities (≤ 60 kV tube voltage) and a thickness of about 15 mm lead for the medium energy X-ray qualities (50 to 300 kV tube voltage) is necessary to achieve the required attenuation of the beam [1].

2.3.4. Filters (F)

For calibration purposes the X-ray beam normally requires additional filtration. This should be chosen so that the radiation qualities used in calibration are similar to those in use for radiotherapy. Filters made from metal of adequate purity should be mounted as close as possible to the shutter, with the highest atomic number filters nearest to the X-ray tube window. A suitable set of filters may be mounted on a wheel to facilitate changing.

Aluminum filtration alone may be used to achieve X-ray beams with half-value layers up to about 4 mm Al (about 0.15 mm Cu). For higher half-value layers copper filtration should be used [1].

2.3.5. Beam Limiting Diaphragm

This defines the size of the useful beam at the point of measurement and should be either adjustable or interchangeable. Its thickness should be sufficient to transmit less than 0.1 % of the radiation outside the useful beam.

This diaphragm may be made of steel or brass with a thickness of about 6 mm for the low energy range 15 mm for the medium energy range. At the plane of the chamber to be calibrated or tested, the field size should be as small as possible in order to reduce scattered radiation, and yet must be sufficiently large to uniformly irradiate the ionization detector [1].

2.3.6. Monitor Chamber (M)

For X-ray calibrations, unless the simultaneous irradiation method is used, a transmission ionization chamber should be positioned to accept the entire collimated beam after it has passed through the filters and the beam limiting diaphragm. All readings of the reference ionization chamber and of the instrument to be calibrated should be normalized via the monitor chamber readings [1].

2.3.7. Shielding Diaphragm (D3)

The effect on the monitor chamber of back-scattered radiation from the reference chamber and from the chamber to be calibrated is normally small; however, if it is found to be significant corrective action should be taken. It may be reduced by introducing a shielding diaphragm (D3) to shield the monitor chamber. This diaphragm may be adjusted to reduce penumbra but should not limit the useful beam. It is good to place all the components listed above as close to the target as possible consistent with the production of a narrow penumbra, in order to minimize scatter at the position of the ionization chambers.

The beam limiting (D2) and the shielding (D3) diaphragms may be mounted close to the two sides of the monitor chamber [1].

2.3.8. Additional Diaphragm (D4)

An additional adjustable or interchangeable diaphragm, somewhat further from the target may sometimes be used to reduce the penumbra still further, and it provides additional shielding to that given by the shielding diaphragm (D3) [1].

2.3.9. Ionization Chamber Support System (R, I)

When the substitution method of calibration is being used, the point of measurement of the reference ionization chamber and that of the ionization chamber of the instrument to be calibrated must be positioned alternately at the same point on the axis of the useful beam.

If the simultaneous irradiation method is being used for comparing thimble chambers of similar size and scattering properties, they must be fixed side by side or tip-to-tip symmetrically about the axis of the useful beam at the same distance from the source. The support system must be capable of adjustment, and of holding the chambers rigidly. The support should be wholly outside the X-ray beam in order to produce a minimum of scattered radiation at the measurement position. An interchange of the reference ionization chamber and the ionization chamber of the instrument to be calibrated should be possible using mechanical devices capable of easy and speedy operation. The support system should also be capable of holding a phantom (for the simultaneous irradiation method) or two phantoms (for the alternative irradiation method) when quantities in media other than air are to be determined. The central axis of the radiation beam should be determined radio graphically and defined optically. The support system should be sufficiently long to enable the source-chamber distance to be about equal to the source-skin distance

(SSD) used in radiation therapy; however, in practice, a longer distance is often necessary to accommodate beam shutter, filter wheel, monitor chamber, etc. For low-energy radiation (10 to 60kV) a distance of between 30 and 50 cm is recommended, while for medium-energy and high-energy radiation a distance of between 50 and 100 cm is recommended [1].

2.3.10. Absorbers for Half Value Layer measurements (A)

The absorbers used in the HVL measurements should be fixed approximately half way between the measurement chamber and the source; however, attention should be paid to the possibility of backscatter from the absorber to the monitor. Aluminum sheets with thicknesses between 0.02 and 5 mm are needed and should have a purity of 99.99 % for half-value layer measurements. Copper sheets from 0.1 to 5 mm thickness are also needed; however, they need not have high purity. An HVL absorber should have adequate uniform thickness and should be as homogeneous as possible, i.e. without air-holes, flaws, cracks, etc.

Where possible the accuracy of the thickness measurement should be ± 5 µm or ± 1 % whichever is the greater. To achieve this weighing may be required for foils thinner than about 0.5 mm: such foils must be sufficiently uniform in thickness [4].

2.4. Calibration Set-Up for Gamma-Rays

Gamma-ray calibration may be carried out with either a 60Co or 137Cs teletherapy unit. The activity of the source should be high enough to produce at least about 0.1 Gy/min (corresponding to an exposure rate of about 10 R/min) at 1 meter distance. The source should have adequate shielding and a variable size beam collimator. Any associated timing errors due, for example, to source or shutter transit times should be determined and appropriate correction applied if necessary. A gamma-ray source requires no additional filtration or monitor chamber. It should have its own built-in shutter and/or source storage arrangement. The exposure timer should be used to normalize measurements for different irradiation periods. The requirements of the calibration bench and of the ionization chamber support system are otherwise similar to those of a calibration set-up for X-rays. The availability of a gamma-ray beam is strongly recommended since it provides a continuously available reference source for constancy checks [1].

2.5. Instruments

SSDL contains many instruments to perform the calibration process. These instruments such as dose meters, time measuring devices, voltage source and all instruments that contribute in the process. Some of them are described as follows

2.5.1. Reference Instruments

An SSDL must have a secondary standard dosimeter, calibrated and recalibrated as necessary at a PSDL. This will normally be stored carefully under conditions which minimize the possibility of change in its calibration factor. It may be used for the routine calibration of other instruments, or it may be used solely to check from time to time the calibration of one or more tertiary (reference) standard instruments which are then used for routine calibrations. It is essential that a laboratory's secondary standard dosimeter and any reference standard dosimeters are maintained with the utmost care and should conform to IEC Publication 731 (1983) specifications for reference class instruments. A radioactive source should be available to provide an overall check on the Dosemitry system. The overall uncertainty attributed to the calibration of a field instrument is likely to be less when it is compared directly with a secondary standard rather than a tertiary level reference instrument. The difference is expected to be small, and in any case such differences must be balanced against the greater possibility of a change in the calibration factor of the secondary standard, if routinely used; it is emphasized that the whole work of the SSDL depends on the stability of the secondary standard instrument. A reference dosimeter usually consists of three basic units, the ionization chamber, the measuring assembly, and may also include a portable stability check source [4].

2.5.2. Ionization Chamber

The ionization chamber of a secondary standard dosimeter must have a high degree of long term stability and low energy dependence. Any variation in the response should not be greater than 0.5 % in a year.

Thimble ionization chambers for medium- and high-energy radiation measurements usually have sensitive volumes between about 0.1 cm^3 and about 1.0 cm^3. The change in response with energy of such chambers should be less than ± 2 % in the range of half-value layers from 2 mm Al to 3 mm Cu [4].

2.5.3 Measuring Assembly

The main purpose of this device is to measure the charge or current from the ionization chamber and convert it into a form suitable for display, control or storage. It may also provide a power supply for the ionization chamber polarizing potential. The long-term stability of the measuring assembly must be better than ± 0.5 % in a year. A display device must be provided for the visual presentation of data from which the value of the relevant radiation quantity can be derived.

The measuring assembly may be calibrated with the ionization chamber or the measuring assembly may be calibrated separately. In the latter case, the measuring assembly shall be calibrated in units of electrical charge or current. The measuring ranges of such a charge/current measuring instrument shall be appropriate for the ionization chamber(s) with which it is to be used [1].

2.5.4. Portable Stability Check Source

The purpose of a portable stability check source is to enable a constancy check to be made of the overall performance of the complete dosimeter and to ensure that no significant change occurs between calibration of the secondary standard at the PSDL and use for calibration at the SSDL. It must be noted that such a source should not under any circumstances be used for chamber calibration. Such a device should irradiate the ionization chamber uniformly. The geometrical relationship between the radioactive source and the chamber must be accurately repeatable so as to minimize the effect of small changes in chamber position. It must be possible to determine the **temperature** at the position of the ionization chamber.

To protect laboratory personnel from unwanted radiation the source should be adequately shielded and provided with a shutter which prevents escape of radiation when not in use.
In cases where a portable stability check source is not available, or is not sent with the secondary standard to the PSDL, the constancy of the secondary standard must be checked by the methods described above.

2.5.5. Monitoring Chamber

This is a parallel-plate transmission chamber whose sensitive volume should extend beyond the diameter of the largest beam required. As far as possible the radiation field should not be disturbed by the monitor chamber, and in particular it must not create shadows in the effective radiation beam. The walls should be sufficiently thin so as not to add significantly to the filtration of the beam. This may not be possible at lower radiation energies, and then the filtration added by this component should be included in the total filtration. If the chamber window thicknesses do not ensure electron equilibrium, care should be taken that the response of the chamber is not influenced by any variation in scattering conditions around the chamber during the measurement. The variation of response with energy of a monitor chamber should be less than ± 15 % in the range used, and should not exceed 0.5 % over the range of energies that may occur during a single calibration due to unwanted variation in tube voltage.

The current/charge measuring instrument to be used with the monitor chamber must have good repeatability. The standard deviation of a single measurement must not exceed 0.2 % with constant input current [1].

2.5.6. Other Dosimeters

Other suitable dosimeters may be needed as working standards, transfer and field instruments. They should take the place of a secondary standard instrument for general use in the SSDL, such as measurement of half-value layer or field uniformity, or for research or training programs, or for measurements at other institutions [1].

2.5.7. Stable Voltage Sources

The measuring assembly and the monitor instrument may include power supplies for the ionization chamber polarizing potential. If not, stable voltage sources with an appropriate range (for example 0-500 volts) are necessary for the reference and for the monitor ionization chambers [1].

2.5.8. Time Measurement

A timer may be used with a shutter to measure the irradiation time, or it may be used to control the measurement time without the use of a shutter. One timer may serve both functions, or separate timers may be used. An electronic timer is recommended and an uncertainty of time of exposure measurement of 0.1 % should be achieved. When the shutter is used to control the irradiation the influence of opening and closing time should be assessed [4].

2.5.9. Ambient Atmospheric Monitoring and Measuring Instruments

Appropriate instruments must be available to determine temperature and pressure, and monitor the relative humidity of the ambient air.

The thermometer, suitable for determining the air temperature in the vicinity of the ionization chambers, should be capable of temperature measurement within an uncertainty of ± 0.2 °C, and the barometer capable of determining atmospheric pressure with an uncertainty of less than ± 0.1 %. A portable precision aneroid barometer should be available if calibrations of dosimeters are to be carried out in the field.

In addition ambient monitoring equipment may be provided for continuously recording temperature, pressure, and humidity within the laboratory. The instruments used must have calibrations traceable to the national standards for pressure and temperature [4].

2.5.10. Distance Measuring Device

It must be possible to determine and maintain the chamber position relative to the source. The chamber position must be reproducible with an uncertainty of less than ± 0.5 mm for distances above 50 cm and should have less uncertainty at shorter distances [1].

2.5.11. Phantoms

When required a suitable phantom must be available for calibrations. For accuracy and consistency, there are advantages in using a water phantom but this sometimes presents practical problems and a phantom of suitable solid material is equally acceptable. Both types have been described and are available commercially. It should be noted that when the simultaneous irradiation method is to be used for in-phantom calibration, the phantom will require two holes; each accurately fitted to the type of ionization chamber to be used in it and located at the same depth in the phantom material [4].

2.5.12. SSDL Auxiliary Equipment

Some additional equipment may be useful if available for us in calibration setup and process these equipments are:

- Films or possibly a small fluorescent screen for checking adjustment of the beams;
- An apparatus for testing the atmospheric ventilation of ionization chambers;
- Personnel dosimeters for radiation safety monitoring;
- Desk or pocket calculator;
- Precision voltmeter and/or multimeter.
- A suitable micrometer for thickness measurement of filters and absorbers;
- Suitable balance for determining thickness of thin filters and absorbers by weighing;
- Portable radiation protection survey meters to check on radiation leakage from the X-ray tube, and on radiation levels in occupied areas [4].

2.6. Accuracy and Reliability of Dosimetry

It should be the goal of the SSDL to achieve the following accuracy for the calibration of users' instruments for radiation therapy

60Co gamma-rays X-rays

Reference-class instruments ± 1 % ± 2 %

Field-class instruments ± 2 % ± 3 %

These accuracy goals are given in terms of agreement in percent with the PSDL that calibrates the secondary standard instrument. Systematic uncertainties in the primary standard at the PSDL are not included in these figures. A reference-class instrument is an instrument whose performance and stability are sufficient for it to be used for calibrating other instruments; and a field-class instrument is an instrument whose performance and stability are sufficient for it to be used for ordinary routine measurements. These terms refer to the quality of the instruments, not to their use. A reference class instrument used for routine therapy-beam calibration is considered to be a field instrument.

The calibration accuracy achieved by an SSDL can be checked by comparing the calibration given to a working standard with that given by a PSDL, or by an inter-comparison of calibrations determined by several SSDL's. The difference between the calibration factors should not be significantly greater than the accuracy goals given above [4].

2.6.1. Overall Constancy Check

In order to ensure the reliability of the secondary standard instrument, all measurements that are periodically repeated under specified conditions should be considered part of a redundant constancy check. Careful records should be maintained of all measurements, and any deviation from an expected value should be investigated at once. Such a constancy check should include the use of the portable check source, measurements in a 60Co or 137Cs gamma-ray beam at a fixed position and comparison of the secondary standard instrument with another reference-class instrument. If the secondary standard instrument is also compared with another instrument in an X-ray beam, it will test constancy of energy response. It is preferable that the secondary standard chamber is compared with an ionization chamber of different size and construction, since it is very unlikely that the two will be in error in the same way.

At least three-fold redundancy should be established for this constancy check. Then as long as no discrepancies in the measurements are found, there can be a very high degree of confidence that the secondary standard has maintained a constant calibration factor. A careful, redundant constancy check combined with periodic tests of calibration accuracy, can reduce the need for periodic recalibration of the secondary standard to the point where many years can elapse between recalibrations. When a new secondary standard instrument is acquired, the redundant constancy check should be established, and if it can be arranged the instrument stability tested for at least a few weeks, before the instrument is sent to the PSDL for calibration. The procedure should be repeated immediately after the instrument returns from the PSDL, and at appropriate intervals thereafter [1].

2.7. Sensors Overview

A sensor is a technical converter, which converts a physical and chemical variable into different and easier evaluated variable usually an electrical signal. In other words a sensor is a device or a system that responds to a physical quality to produce an output that is a measure of that quality.

Sensors are comprised of two basic parts a sensing element that interacts with the environment, it is the primary part of a sensor, and determines the nature, selectivity and sensitivity of the sensor. The transducer is a device which reads the response of the sensing element and converts it into an interpretable and quantifiable term. There are many different types of sensors, classification schemes range from very simple to very complex. One way to classify a sensor is to consider the property of the element to be sensed. Also to consider the principal physics and operating mechanizes of the sensor. There are two types of sensors analog and Digital they are quite different in function, in application, and in low they are used in real world. An analogue sensor produces a continuously varying output. Some sensors that produce a digital output are more complicated, these sensors produce digital pulse [5].

2.8. Sensors Based Position Control

Since the position control is related to robotic Engineering technology, two types of sensors have to be used in many robotic systems:

1- Internal Sensors for measuring the internal parameters of the robotics.

2- External sensors for the measurement of the external reaction of robotics system.

2.8.1 The Internal Measurements Sensors

These sensors measure both kinematics and dynamic parameters of the robot. The usual kinematics is the joint positions, velocities and acceleration. Dynamic parameters as forces, torques and inertia are also important to monitor for the proper control. The most common joint (rotary) position transducers are Potentiometers, synchrous and resolvers, encoders, RVDT (Rotary Variable Differential Transformer) and INDUCTOSYNS, which are the most accurate one.

Rotary Encoders are digital position transducers which are the most convenient for computer interfacing. Incremental encoders are relative-position transducers which generate a number of pulses proportional with the motion. Their disadvantage is that this type of encoders must be initialized by moving them in reference position.

Absolute shaft encoders are attractive for joint control applications because their position is recovered immediately and they don’t accumulate errors as incremental encoder may do.

The absolute encoders have distance is measured by n-bit code (natural Binary, BCD) marked on each quantization interval of rotating scale. The absolute position is recovered by reading the specific code written on the quantization interval that currently faces the encoder reference maker. The number of code tracks on the scale increases proportionally with the desired measuring resolution, limiting the encoders' resolution.

Joint position sensors are usually mounted on the motor shaft. When mounted directly on the joint, position sensors allow feedback to the controller with the joint backlash, and drive train compliance parameter.

Angular velocity is measured by tachometer transducers. A tachometer generates DC voltage proportional to the shaft rotational speed. Acceleration sensors are based on Newton's second law. They are actually measuring the force which produces the acceleration of a known mass. Different types of acceleration transducers are known stress –strain gage, piezoelectric, capacitive, and inductive. Micro mechanical accelerometers have been developed. In this case the force is measured by measuring the strain in elastic cantilever beams formed from silicon dioxide by an integrated circuit fabrication technology. Strain gages mounted on the manipulators links are some times used to estimate the flexibility of the system mechanical structure. Strain gages mounted on specially profiled (square, cruciform beam or radial beam) shafts are also used to measure the joint shaft torques [6].

2.8.2 Exteroceptors Sensors

These are sensors that measure the positional or face-type interaction of the robot system with its environment; they can be classified according to their range as follows:

1- contact sensors
2- faraway sensors
3- proximity sensors

2.8.2.1 Contact Sensors

Contact sensors are used to detect the positive contact between two mating part and /or to measure the interaction forces and torques. One of Contact sensors is the tactile sensors which measure multitude of parameters of the touched object surface. The following section presents some types of Contact sensors:

a) Force Torque Sensors

This type of sensor to measure the interaction force and torques which appear, during the mechanical assembly operations, can be measured by sensors mounted on the joints or on the manipulator wrist. Wrist sensors are sensitive, small, compact and not too heavy, which recommends them for force controlled robotic applications.

b) Tactile Sensing

Tactile sensing is defined as the continuous sensing of variable contact forces over an area within which there is a spatial resolution. Tactile sensing is more complex than touch sensing which usually is a simple vectorial force/torque measurement at a single point. Tactile sensors mounted on the peripheral of the robotic system to measure contact force profile and slippage. The best known of tactile sensor technologies are: conductive elastomer, strain gage, piezoelectronic, capacitive and optoelectronic. These technologies can be further grouped by their operating principles.

Computer Systems Design Project tactile sensing is the result of a complex exploratory perception act with two distinct modes. First, passive sensing, which is produced by the “cutaneous” sensory network, provides information about contact force, contact geometric profile and temperature. Second, active sensing integrates the cutaneous sensory information with “kinesthetic” sensory information (the limb/joint positions and velocities).Various multi-sensor fusion techniques are available for this integration process [6].

2.8.2.2. Far Away Sensors

There are two types of far way sensors: range sensors and vision sensor for advance robotic application.

Range sensors measure the distance to objects in their operation area. Used for robotic system navigation range sensors are based on the two principles is Time - of - flight and triangulation.

Time-of-flight sensors estimate the range by measuring the time elapsed between the transmission and return of the pulse. A laser range finder is the best known sensor of this type. Triangulation sensors measure range by detecting a given point on the object surface from two different points of view at a known distance from each other.

Vision is a complex sensing process. It involves extracting, characterizing and interpreting information from images in order to describe objects in environment. Vision sensors or a camera converts the visual information to electrical signals which are sampled and quantized by special computer system yielding a digital image. Solid state CCD (capacitive coupling Device) image sensors is the most suitable because of small size, light weight, and better electrical parameters. All the above advantages we couldn’t find in conventual's tube-type image sensors.

The digital image produced by a vision sensors, has to be further processed till an explicit and meaning full description of the visualized objects finally results. Digital image processing comprises more steps;

Preprocessing, segmentation, description, recognition and interpretation [6].

2.8.2.3 Proximity Sensors

Proximity Sensors detect objects which are near but without touching them. These sensors are used for near-field (object approaching or avoidance) robotic operations. Proximity sensors are classified according to their operating principle, inductive Hall Effect, capacitive, ultrasonic and optical. Inductive sensors are based on the change of inductance due to the presence of metallic objects. Hall Effect sensors are based on the relation that which exists between the voltage in a semiconductor material and the magnetic field across the material. Inductive and Hall Effect sensors detect only the proximity of ferromagnetic objects. Capacitive sensors are potentially capable of detecting the proximity of any type of solid or liquid materials. Ultrasonic and optical sensors are based on the modification of an emitted signal by objects that are in their proximity [7].

Inductive Proximity Sensors

The inductive proximity sensors were introduced in 1960's due to their reliability, high quality, inexpensive and ease of installation. They have conquered a wide range of applications.

Inductive proximity sensors operate under the electrical principle of inductance; it is the phenomenon where a fluctuating current, which by definition has magnetic component, induces an electromotive force (EMF) in a target object in (Henrys) H [7].

The figure (2.2) below shows the internal part of the inductive proximity sensor.

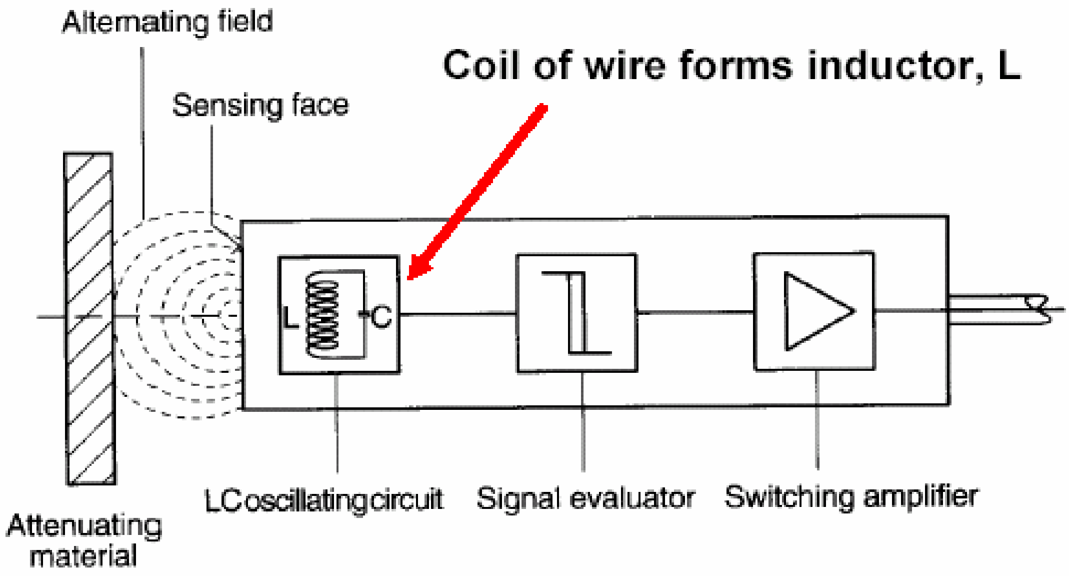

Figure (2-2) Inductive Proximity Sensor Internal Parts [8]

a) Inductive Sensor Design

Inductive proximity sensors operate under the electrical principle of inductance. Inductance is the phenomenon where a fluctuating current, which by definition has a magnetic component, induces an electromotive force (emf) in a target object. In circuit design, one measures this inductance in H (henrys). To amplify a device's inductance effect, a sensor manufacturer twists wire into a tight coil and runs a current through it.

An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. The oscillator generates a fluctuating magnetic field the shape of a doughnut around the winding of the coil that locates in the device's sensing face. When a metal object moves into the inductive proximity sensor's field of detection, eddy currents build up in the metallic object, magnetically push back, and finally dampen the Inductive sensors own oscillation field. The sensor's detection circuit monitors the oscillator's strength and triggers an output from the output circuitry when the oscillator becomes dampened to a sufficient level.

Designers should consider two types of inductive proximity sensors when selecting an inductive sensor; shielded and unshielded. When current generates in the sensor's coil the doughnut effect

it causes the proximity sensor to trigger when any object comes behind, along side or in front of the device. Shielding uses a ferrite core to direct the coil's magnetic field to radiate only from the sensor's detection face. Unshielded inductive proximity sensors are not completely unshielded. A peeled back ferrite core shielding in the unshielded case allows for a longer sensing distance, while still preventing sensing due to objects behind the detection face.

Understanding the operation, the magnetic nature, and the shielding of the inductive proximity sensor is helpful when considering the influences of target material, environment, and mounting restrictions on the sensor itself and in your design. Environmental conditions can have far and sweeping effects upon the inductive proximity sensor. These effects specifically refer to sensor life, but can only be related to premature failure of the inductive proximity sensor once installed into its component mounting position.

Normal operating temperatures for silicon based sensors circuitry are within the realm of (-25ºC to 70ºC) (-13ºF to 158ºF).Under any temperature conditions beyond these ranges, the circuitry becomes more prone to operating failure [5].

b) Inductive Sensor Selection

Inductive proximity sensors categorize in five specific types; cylindrical, rectangular, miniature, harsh environment, and special purpose. 70% of all inductive proximity sensor purchases are of the standardized cylindrical threaded barrel type. When one considers this statistic, it is easy to understand why a designer would specify into their application a general-purpose (or standardized) inductive proximity sensor. 70% of the time, he would be correct. Experience has shown, however, that applications in need of inductive sensing usually warrant the examination of a few additional design criteria.

These conditional criteria eliminate (or specify) the more special inductive proximity sensors available first before falling upon the general purpose inductive proximity sensor. The three guiding beliefs of inductive proximity sensor selection are target material, environment, and mounting restrictions. [7]

c) Target Materials and Sensor Types

In the world of inductive proximity sensors, not all metals are created equally. A standard detectable object made of an iron (ferrous) material. Other metallic materials, such as stainless steel, brass, aluminum, and copper have different influence over the inductive effect and are usually less detectable than iron. Different target material has different factors should be considered and multiply by the standard distance of the specific material, some examples below:

Stainless Steel = 0.8

Brass = 0.5

Aluminum = 0.4

Copper = 0.3

Manufacturer's terms for these special inductive proximity sensors are "non-ferrous sensing" or "all metal sensing." "Non-ferrous sensing" Inductive proximity sensors will detect non-ferrous metals such as aluminum better than they sense iron. "All metal sensing" inductive proximity sensors will detect all metallic materials at the same sensing distance.

The "non-ferrous sensing" or "all metal sensing" inductive proximity sensor will include two or three separate coils in the proximity sensor head while the general-purpose inductive proximity sensor will include only one coil. The main trades between a "non-ferrous sensing" or an "all metal sensing" type proximity sensor and a general-purpose proximity sensor are the cost and body size. "Non-ferrous sensing" and "all metal sensing" proximity sensors tend to be more expensive due to the increased number of coils required and have larger enclosures than their traditional inductive proximity sensor counterparts.

Intelligent semi-conductor microprocessors found in some modern inductive proximity sensors have the ability to detect the slow build up of metal filings or "chips" over time and teach the inductive proximity sensor to ignore their effects. Sensor suppliers call this specialized inductive proximity sensor a "chip immune" type.

Another type of inductive proximity sensor that is resilient against chip build up is the flat-pack proximity sensor. The slim profile of the flat pack proximity sensor when mounted with its sensing face exposed vertically is virtually unaffected by chip build up on its slim horizontal component [8].

d) Inductive Sensor Specification

In automation design, it is necessary for one to understand the precise technical definition of a component's behavior. The following definitions, if not the terminology itself, are unique to inductive proximity sensors. Therefore, it is important to describe and comprehend definitions before implementation of the inductive component into the application at present. Upon review an inductive proximity sensor data sheet displays many specifications that tell a designer how to implement the inductive device for the purposes of detecting a specific object [5].

e) Standard Detectable Object

When an inductive proximity sensor's data sheet refers to a standard detectable object, it tells the specified shape, size, and material which is used as the standard to examine the performance of the proximity sensor. This understanding is important because the detection distance of the inductive proximity sensor differs according to the shape and material of an object. Typically, the standard detectable object will be an iron plate with a thickness of 1mm and height and width of equal length to the diameter of the inductive sensor [8].

f) Detection Distance

Detection distance is the position at which the inductive proximity sensor operates when a "standard detectable object" is moved in front of the sensor in a defined manner. For an Inductive proximity sensor with an end (or "front") detection surface, the detection distance is determined by aligning the center line of the Inductive sensor with the center line of the standard detectable object. The standard detectable object is moved towards the face of the inductive proximity sensor until the proximity sensor changes states and the detection distance is determined. One of the issues that are examined when considering the detection distance of an inductive proximity sensor is the target material's capacity for conducting electricity. Materials that are highly conductive make poor targets for traditional inductive proximity sensors. Also, the target's thickness will have an influence of its detection. Thin materials are easier for an inductive proximity sensor to detect than thick materials. The principles of operation for an inductive proximity sensor shows the material conductance and thickness factor to detection distance behavior falls in line with the technology of the inductive proximity sensors. A conductive material will disperse eddy current and not allow them to build up thus making it harder to detect. A thin material due to its lack of ability to move current when compared to a thicker material causes a build up of Eddy currents, which allow for higher detection distances [8].

g) Reset Distance

The reset distance refers to the distance at which the inductive proximity sensor releases its output when the standard detectable object is removed from its field of detection. The difference in distance between the detection distance and the reset distance is called the "Distance differential." Typically, the distance differential is from 3% to 10% of the overall detection distance. The distance differential is incorporated into the design of the inductive proximity sensor to prevent the proximity sensor from having its output chatter due to noisy environments or detectable object vibrations.

Today's quality inductive proximity sensors can have trigger points that are repeatable to 1/10,000ths of an inch. Designers must be aware, however, that desired detectable object must approach the face of the inductive sensor to trip the output and then be removed from the inductive sensor's field of detection by the distance differential before another precise object trigger can occur [8].

h) Setting Distance

The setting distance describes the distance at which the inductive proximity sensor will trigger an output with the standard detection object even if the detection distance has been decreased due to temperature or voltage fluctuations. When implementing an inductive proximity sensor, the detectable object to sensor face calculations should begin with the setting distance specifications.

Not every design, however, will have the luxury of detecting the standard detection object described in the inductive proximity sensor data sheet's engineering section. In the cases of irregular object detection, the detecting distance cannot be estimated from the engineering data. In these cases, an operational check with the sample object is required. Take the detection object in question and approach the inductive proximity sensor until the output changes state. The distance determined is the "detection distance" of the target object and inductive proximity sensor combination. The Setting Distance for the target object can then be calculated by the following formula: New Setting Distance = (Detection Distance obtained by test with target object) X (Setting Distance of the standard detectable object)/ (Standard Detection distance of the standard detectable object). In other words, the object's setting distance is proportional to the standard detecting target's detection distance to setting distance ratio [8].

i) Mounting and Influence of Surrounding Metals

Figure (2.3) Inductive Proximity Sensor Mounting

Inductive proximity sensors come in a wide variety of body types. The Figure (2.3) shows Rectangular style inductive proximity sensor, the detection distance range from the sub-miniature (5.5mm X 5.5mm X 19mm) to the flat pack style (25mm X 10mm X 50mm) all the way up to the limit switch housing size (40mm X 40mm X 115mm). In the last case, the life of an inductive proximity sensor in limit switch housing will far outweigh the life of a typical limit switch. Limit switch life is on the order of 300K cycles while the similarly shaped inductive proximity sensor in limit switch housing can last up to 100K hours. Other advances in inductive proximity sensor miniaturization include separate in-line amplifier type. Inductive proximity sensors of this type come with sensing heads as small as 3mm in diameter and robotics cabling that allows the sensor head to move if needed.

Mounting requirements must be considered when implementing the inductive proximity sensor into your design otherwise you may encounter reduced sensing distance, false triggering, or no detection of the target. When an inductive proximity sensor is mounted into its sensing position, it is important to consider the effects of the mounting hardware itself and other metallic objects that may be present in the area of the sensor.

For the shielded type of inductive proximity sensor, the device can be embedded into a metallic mounting fixture up to the point when the sensor's face is at an equivalent height as the mounting surface. This embedded mount protects the inductive sensor from mechanical damage due to incidental contact with the target object. It is not recommended that a shielded inductive proximity sensor be recessed into a metal mounting surface. Objects, materials, or opposing surfaces that are not to be detection objects should remain clear of the Inductive sensor's face by a factor of 3 times the sensor's standard detection distance. For the unshielded type of inductive proximity sensor, the device cannot be completely embedded into a metallic-mounting fixture. Due to its extended sensing distance, the unshielded inductive proximity sensor is susceptible to the influences of surrounding metals. One does not only need to consider that objects, materials, or opposing surfaces must remain clear of the sensor's face by a factor of 3 times the sensor's standard detection distance. In addition, one must consider that the inductive proximity sensor must be clear of surrounding metals by its size (diameter in the case of a cylindrical proximity sensor) in every direction with a depth clearance of 2 times its standard detection distance. Failure to meet the inductive sensor's clearance requirements can lead to false detection or reduced sensing distances.

Mutual interference when multiple inductive proximity sensors are mounted in close proximity to one another either along side or in an opposing direction to another inductive proximity sensor, either inductive sensor can be subject to an effect called mutual interference. Mutual interference is created when the field of a proximity sensor couples with the detection coil field of another closely mounted proximity sensor. The result can create an inductance that can result in the generation of a beat frequency in one or both of the sensors. This, in turn, causes the output of the proximity sensor to chatter (switch on and off erratically). Mutual interference problems can be insidious due to their erratic nature. A sensing application where Inductive sensors are mounted side by side and closer then a manufacturer's mutual interference distance specifications can actually perform seamlessly at one time and then suddenly display signs of chattering and false detection at another time. Specifications for separation distance of proximity sensors that are mounted side by side can vary from sensor body type and by manufacturer. Always examine and adhere to the manufacturer's specification distances for mounting inductive proximity sensors to avoid potential mutual interference problems.If your application and sensing requirements demand your inductive proximity sensors to be mounted closer together, consider the following tips. The selection of a shielded type of inductive sensor allows for closer mounting. Of course, one could also specify a miniature inductive sensor. The smaller size means smaller sensing distances and less probably for mutual interference. In addition, some manufacturers of inductive proximity sensors offer alternate frequency types. Alternate frequency inductive sensors oscillate their magnetic coils at different cycle rates than their standard inductive proximity sensor counterparts. This prevents the inductive coupling that leads output chattering. Lastly, if close sensor mounting cannot be avoided, the inductive proximity sensors can be multiplexed. Turning off and on alternate inductive proximity sensors and taking alternate reads can be a quick solution to a mutual interference problem provided that your application accounts for the response time hit [8].

j) Inductive Proximity Sensors Conclusion

Today, the world's leading manufacturer of inductive proximity sensors can manufacture a 5.5mm X 5.5mm X 19 mm rectangular proximity sensors with an extended sensing range of 1.6mm

More inductive proximity sensors are sold worldwide than any other sensing technology. The inductive proximity sensor's durability, life, and resistance to dust and harsh environments have made it the designer's prime choice in sensing technology. Newly armed with the knowledge of selection techniques, specification nuances and implementation considerations will help you overcome the most common inductive proximity sensor application pitfalls.

CHAPTER THREE

CALIBRATION BENCH MODULE HARDWARE DESIGN

3.1. Hardware Design

The hardware system consists of electronic circuits and an electromechanical part which is a combination of motors, wheels and the scissor jack assembly .An electronic circuit's component has been chosen according to the rigid specification that should be there because of the nature of the system and also to achieve the quality of the circuits and economical considerations. Electronics workbench software package is used for the schematic, simulation and Printed circuit Boards design. So in this chapter the component functionality is described along with its software design.

3.2. Software Design

Multisim 2001 from Electronics Workbench is a complete system design tool that offers a large component database, schematic entry, full analog/digital simulation and Post processing features. To create the Printed Circuit Board (PCB) layout, the schematic is transferred to Ultiboard package, which offers a single, easy-to-use graphical interface for all the design [10]. Multisim 2001 provides all the advanced functionality needed to take designs from specification to production. Because the program tightly integrates schematic capture, simulation, PCB layout and programmable logic, the design will be confident. This package is free from the integration issues often found when exchanging data between applications from different vendors. Ultiboard, also from Electronics Workbench is used for Printed Circuit Board design. The ultiboard receives the schematic which sent from MultiSim then wiring and finishing process is done for PCB production [10].

3.3. Electronics Hardware Design

A microcontroller based embedded system for controlling the calibration bench position is a combination of hard ware and software code. The block diagram shown in Figure (3.1) represents the system hard ware. Each block is described in detail.

The microcontroller block is the heart of the system that governs the peripherals, which are the user interface, ADC section, motors driving circuitry and sensors interfacing section.

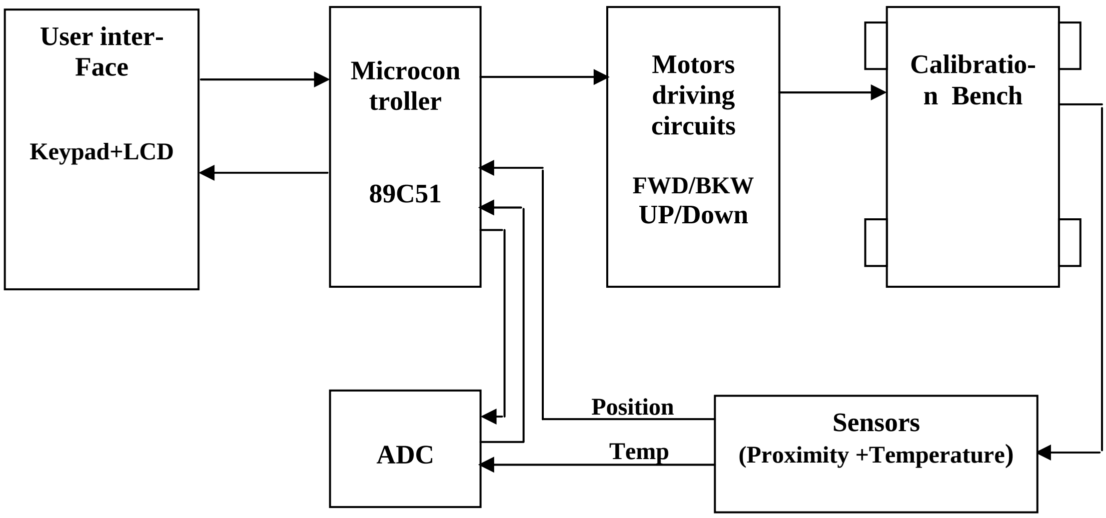

Figure (3.1) Calibration Bench Module Block Diagram

3.3.1. The Microcontroller

The Intel 8051 family microcontroller, specifically an AT 89C51 Microcontroller from Atmel Corporation, which has a wide selection of 8051 chips. The AT89C51 is a popular and inexpensive chip used in many projects and has 4 Kbytes of on chip flash RAM.

Notice that AT89C51-12PC, where C before the 51 stands for CMOS, which has low power consumption, 12 indicates 12 MHz, P is for plastic DIP package, C for commercial [11].

AT 89C51 is low power high performance powerful microcomputer which provides lightly-flexible and cost effective salutation for our calibration bench module.

Some of AT 89C51 microcontroller features: -

- Contains 4k bytes EPROM in system flash memory
- Compatible with MCS-51 product pin out and instruction set
- Fully static operation
- 128 X 8 bit internal RAM-on chip oscillator
- 32 programmable I/O lines
- Low power Consumption
- With 6 interrupts source
- 16 bit timer limiter

Since the system is built around AT89C51, the microcontrollers' pins will be described according to their function on the system as the **following:-**

Vcc Supply voltage

GND Ground

P0 Is an 8-bit open drain bi directional I/O port we use the entire port pin to connect the LCD

P1 Is an 8-bit bidirectional I/O port with internal pull-ups I/O port used for the 2 motor control signals, and motor need 4 signals to move in the 2 directions (2 signals for one direction)

P2 I/O port bi-directional with internal pull-ups we connect this port via keypad.

P3 Is an 8-bit bi-directional I/O port with internal pull-ups which pulled when being in the input to low logic as input port

P3.0 for Enable the LCD

P3.1 ADC pin 9

P3.2 ADC pin 7

P3.3 external input for proximity sensor output

P3.4 ADC pin 22, 6

P3.5 zero position limit switch

P3.6 RS Register selection (LCD)

P3.7 ADC pin 25

RST Reset input, a high on this pin for two machine cycles with the oscillator is running resets the device. No use for the other pins because these functions of (ALE/PROG-PSEN) is not used the Figure (3.2) shows the Reset connection [12].

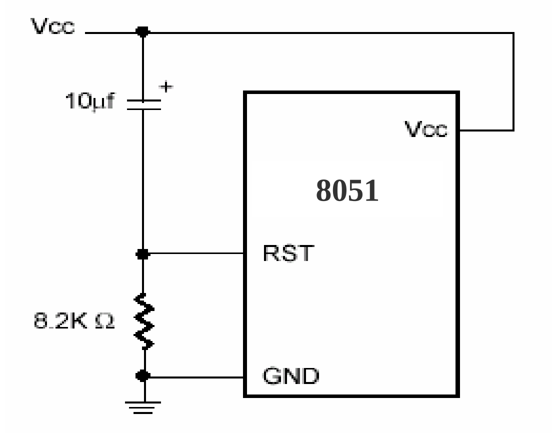

Figure (3.2) Microcontroller Reset Circuit

System Oscillator Clock

It is quite simple and reliable clock circuit as shown in Figure (3.3). It consists of crystal and ceramic resonator with external capacitors [12].

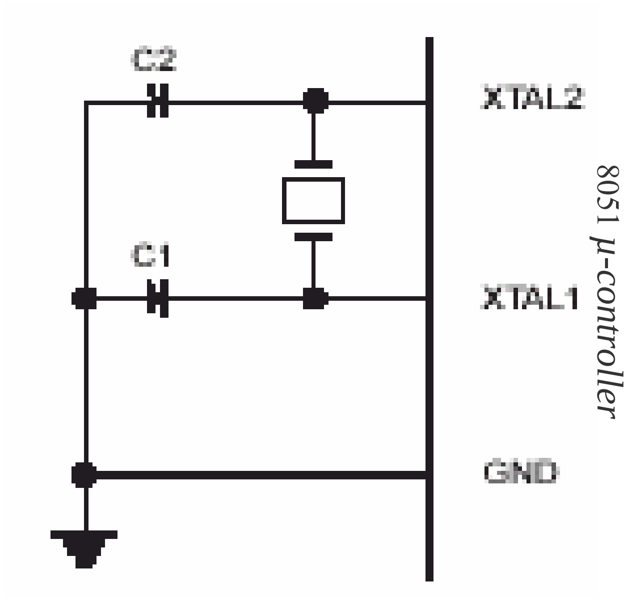

Figure (3.3) Microcontroller Clock Circuit

3.3.2 User interface

The second sub block in the main block diagram is the user interface elements, which are the LCD and keyboard.

3.3.2.1. LCD Operation and Connection

This section describes the operation and connection of the LCD. Then introduce how to program and interface the 2X16 LCD to an AT89C51 using C language.

a) LCD Operation

In recent years the LCD is finding widespread used replacing Light Emitting Diodes (seven segments or multi segment LEDs) this spread due to the flowing reasons:

1. The ability to display, characters, and graphics. This is contrast to (LEDs), which are limited to number and few characters.
2. Incorporation of the refreshing controller in to the LCD, thereby reliving the CPU of the task of refreshing the LCD. In contrast the LED must be refreshed by the CPU (or in some other way) to keep displaying the data.
3. The declining prices of LCD. So an LCD making the application much more users friendly and impressive [13].

b) LCD PIN Description and Connection

The LCD which we use has 14pins; the function of each pin is given in the table on the appendix D.

Vcc, Vss and Vee

While Vcc and Vss provide 45V and ground, respectively, VEE is used for controlling LCD contrast

RS Register Select

R/W Read/Write

R/W input allows the user to write information to the LCD or read information from it.

R/W=0 reading

R/W=1 when writing

E, enable

The enable pin is used by the LCD to latch information presented to its data pin. When data is supplied to data pins, a high to low pulse must be applied to this pin in order for the LCD to latch in the data present at the data pins, this pulse must be a minimum of 450ns wide.

D0 to D7

The 8bit data pins D0 D7, are use to send information to the LCD or read the contents of the (LCDs) internal registers.

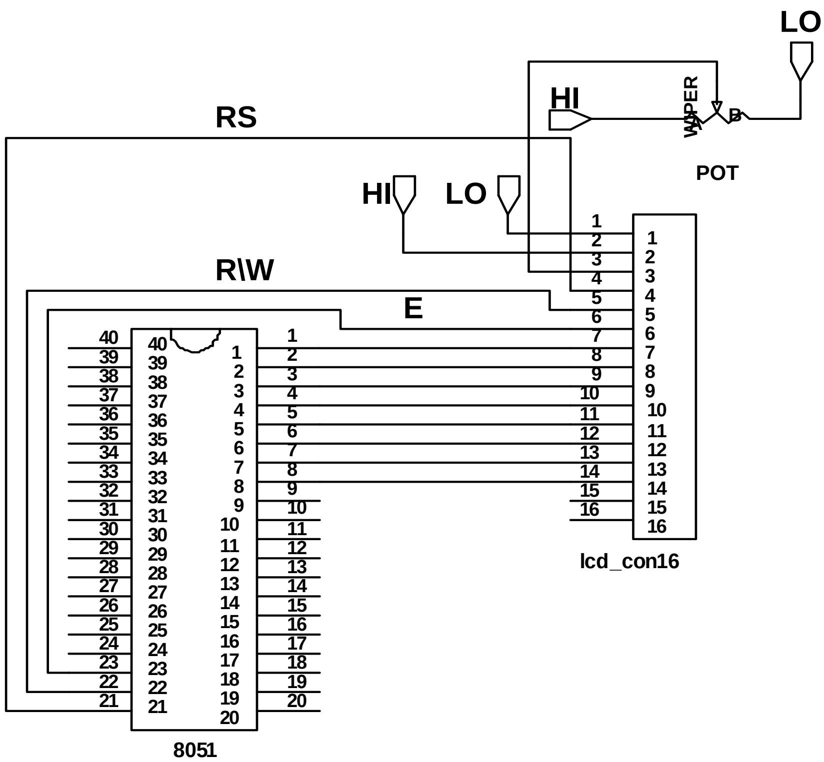

Figure (3.4) LCD Interface

c) LCD Interface with AT89C51

Figure (3.4) shows the LCD connection to the microcontroller. The LCD controller on system is operated in 8-bit mode. Instructions/Data are written to the display using the signal timing characteristics that shown in figure (3.5).

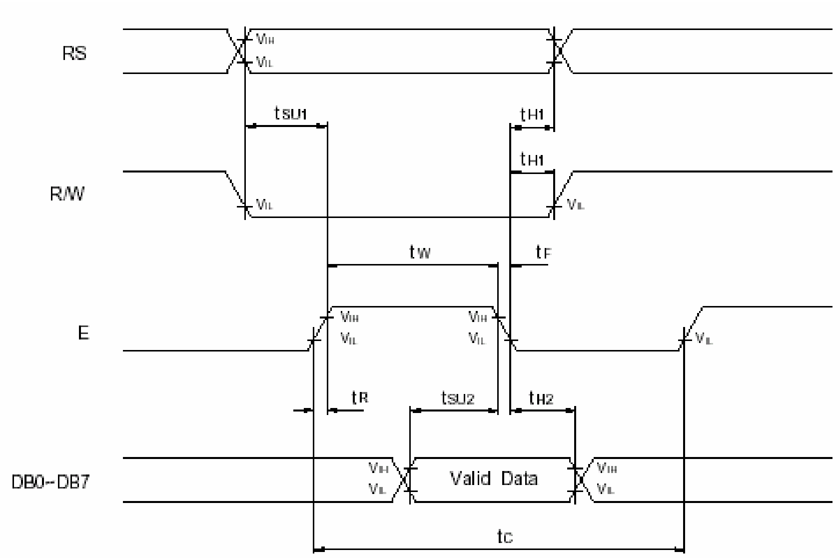

Figure (3.5) LCD Write Timing

When interface data is on 8-bit the higher order 4-bits is transferred first then the lower order 4-bits (DB0-DB3).

When operating in 8-bit mode, data is transferred using the full 8-bits bus DB0-DB7 [13].

3.3.2.2. Keyboard

Key board is the most essential user interface device. The basic under standing of its concepts, how it work and how interfaced it with the 8051 is so important issues. So the key bad fundamentals will discussed, along with key press and key detection mechanisms. Then we explain how a keyboard is interfaced to an 8051.

a) Keyboard Configuration

At the low level, keyboards are organized in a matrix of rows and columns, the microcontroller (CPU) access both rows and columns through port/ports. Therefore, with tow 8-bit ports, an 8X8matrix of keys can be connected to a micro controller. The key board is 4X4 matrix which connected to Port2 (P2.0 – P2.7) [14].

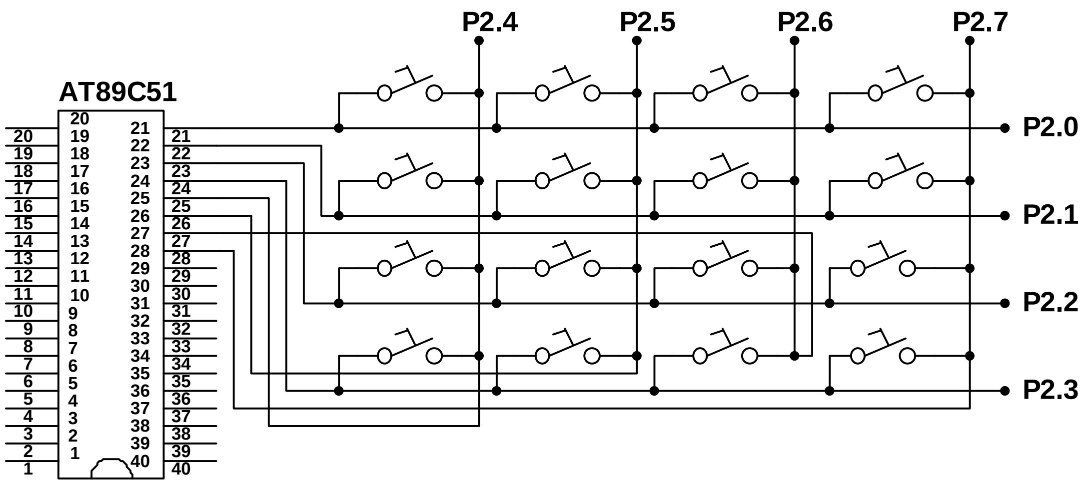

Figure (3.6) X-Y Matrix Keyboard

b) Key switch factors

The universal key characteristic is the ability to bounce. The key contacts vibrate open and close for number of mille Seconds (mS) when the key is hit and often when the key is released. These rapid pulses are not desirable to the human, so the key may be de-bounced using hardware or de-bounced using software program [14]. The implemented system keyboard de-bounce is software one in which the code program provides time delay loop in case of any key has been hit.

c) Scanning and Identifying the Keys

The figure above shows 4X4 Matrix key bad connected to the port 2. The rows are connected to the high nipple of the same port P2 is defined as an input port so when reading the input port will yield 1s for all columns. If all the rows are grounded and a key is pressed, one of the columns will have (0) since the key pressed provides the path to low condition. It is the function of the microcontroller to scan the key board continuously to detect and identify the key pressed how it is done is explained next [14].

d) Grounding the Rows and Reading the Columns

To detect a pressed key the microcontroller grounds all rows by prodding 0(low) to output latch, when it reads the columns. If the data read from the column is P2.7 - P2.4=1111 no key has been pressed and the process continues until a key press is detected [14].

3.3.3. Analogue to Digital Converter

This section explores an Analogue to Digital Converter (ADC) especially 0808/0809 ADC and its combination with the temperature sensor and the 8051 microcontroller.

3.3.3.1 ADC Devices

Analog to digital converters are the most used devices for data acquisition. Digital computer uses the discrete values, but in the physical world everything is continuous. Temperature, pressure, and humidity are few examples of physical quantities that we deal with every day. We use the transducers to get electrical quantities from the physical quean then we convert this analog electrical quant to digital numbers hence the microcontroller can read and precedes them.

An ADC has n-bit resolution where n can be 8,10,12,16 or even 24bits.the higher resolution ADC provides a smaller step size hence smallest change that can be discerned by an ADC, Also the conversion time is another major factor in judging an ADC.

The ADC chips are either parallel or serial in parallel ADC, we have 8or more pins dedicated to bringing out the binary data, but in serial ADC we have only one pin for data out.(0808/0809 is parallel ADC)

An ADC 0809 Chip have eight Analog Channels. ADC 0809 from national semi conductor an 8-bit analog to digital converter, 8 channel multiplexer and microprocessor compatible control logic. This chip has 8-analog Input, this feature allows us to monitor up to 8 different analog inputs using only a single chip

Notice that the ADC 0808 has an 8-bit data output. The 8-analog input channels are multiplexed and selected using the three address pins A, B and C [15].

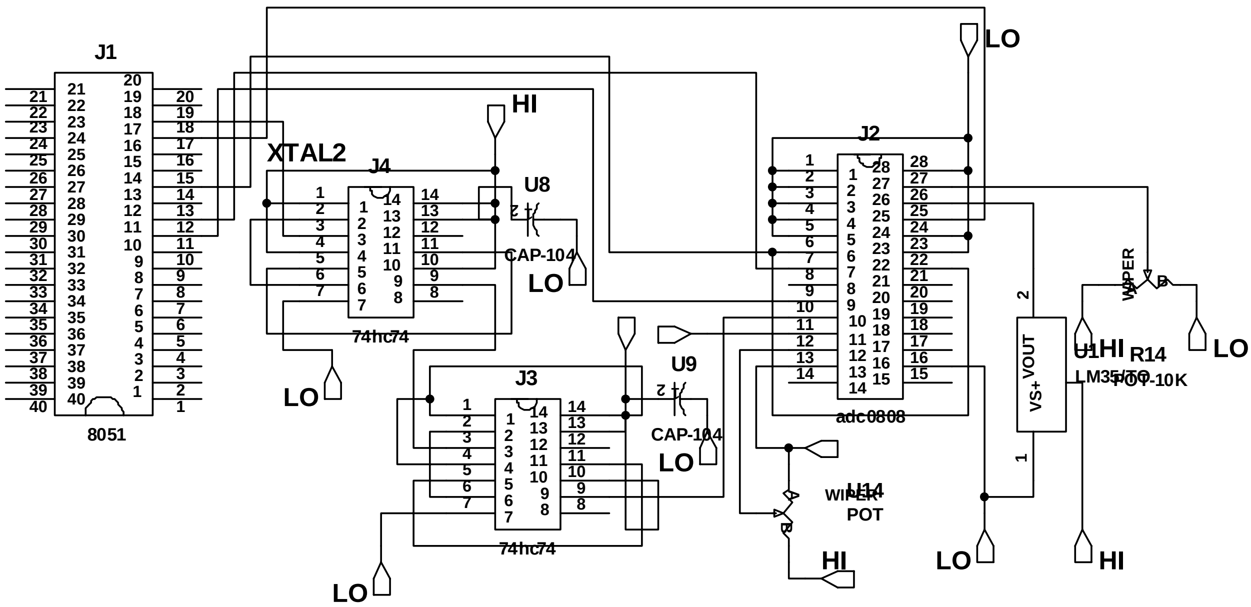

Figure (3.7) ADC and Temperature Sensor Connection

3.3.3.2 ADC 0808/0809 Features and Specification

- Easy interface to microprocces30rs
- No zero or full-scale adjust required
- 8-bits resolution
- Single supply 5VDc
- Low power 15mv
- 100micro second conversion time

Notice in the ADC 0808/0809 is no self-clocking and the clock must be provided from and external source to the CLK pin. Although the speed of conversion depends on the frequency of the clock connected to the CLK pin, it cannot be faster than 100 micro Seconds. For clocking the chip 47HC74 Flip-flop is used to divide the frequency by 4. The ADC and the CLK Pin are connected with the clock from XTAL2 of the 8051. [15]

3.3.4 Direct Current Motors and their Driving Circuitry

A direct current DC motor is widely used device that translates electrical pulses into mechanical movements. In the DC motors we have (+) and (–) leads when we connect them to DC voltage source motor will move in one direction if the direction reversed, it will move to another direction. The motor speed is indicated in rpm, the DC motor has two rpm no-load and loaded the manufacturer's data sheet gives the on-load rpm. We have two motors in our system, since we need the motor 1 to move in forward/backward; and motor 2 moves upward/downward [16].

3.3.4.1 Motor Control with Optisolators

The optisolator is used in many motor control applications Figure (3.8) shows the connections to DC motor using power MOSFET transistors. By using an optocoupler and separate power supplies the 8051 is protected from EMI created by the motor brushes [16].

The Figure (3.8) shows the connections using H-bridge of optocoupler and power FET transistors both to control the motors bi-directionally. The H-bridge consist of four power FET transistor (2 P-type, 2N-type).The MOSFETs.

By execution the below function motor 1 will fired on.

Motor 1 on ( )

P13=0

P10=0

Then following should happen:

1. Enable the N-type MOSFET first
2. Enable the P-type MOSFET

This sequence is important to enhance more protection for the electronics from the BEMF of the motor. So by the time delay in the code we avoid the EMF without using any hardware.

To stop the motor, P-type (MOSFET) disabled first for the above purpose. Spreading the power supplies of the motor and logic will reduce the possibility of damage to the control circuit; the separation of the power supplies also allows the use of high voltage motors if the load has been increased.

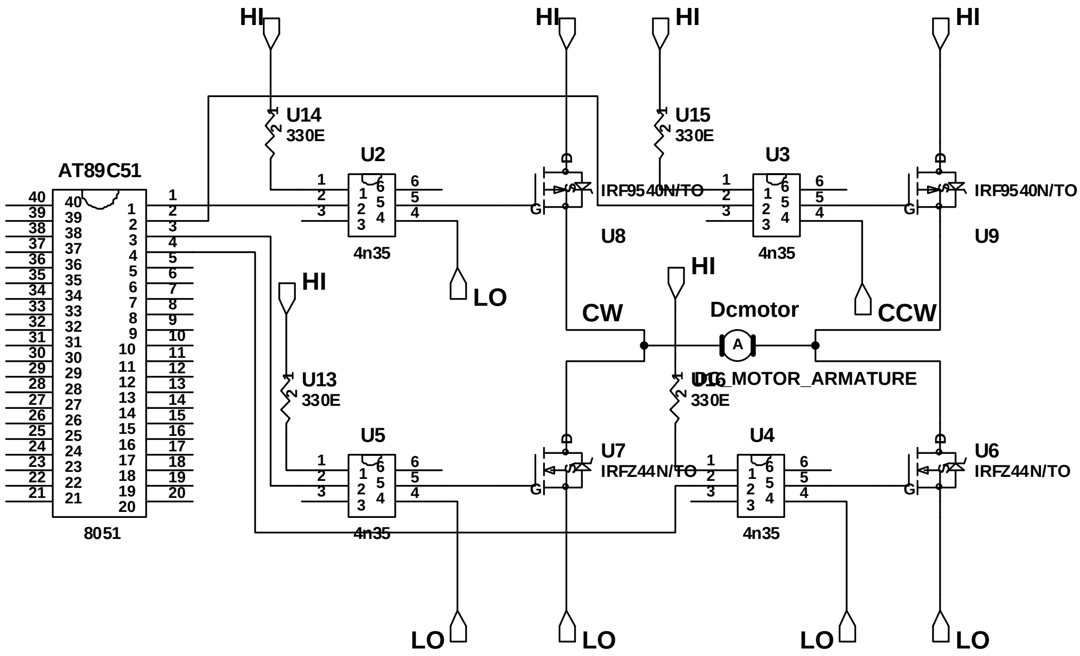

Figure (3.8) Motor Driving Circuit

3.3.4.2 Driving Components

The phototransistor 4N35 opt coupler is used. This chip has photo transistor optically coupled to infrared emitting diode. The efficient characteristics of the 4N35 are the flowing:

- AC line/digital logic isolator.
- Digital logic/digital logic isolator.
- High DC current transfer ratio.
- It meets the voltage and current limitations.

The power FET transistors we used are advanced process technology with low on resistance and fast switching. Since the system is closed loop control system DC motor is used with proximity sensor as feed back element, also the speed is not an effective factor in distance calculation [17].

3.3.5 Feedback Sensors

The sensor block consists of two sensors; the proximity sensor and temperature sensor, the main concepts and how these sensors work will discussed in this section briefly.

3.3.5.1 Temperature Sensor

LM35 temperature sensor is used for monitoring the examination room temperature, which is precision integrated circuit temperature sensor it's output voltage is linearly proportional to the Celsius (centigrade) temperature, the LM35 requires no external calibration since it's internally calibrated. It output 10mv for each degree of centigrade temperature [18].

Signal Conditioning and Interfacing the LM35 to the 8051

Signal conditioning is widely used in the world of data acquisition. Most of the sensors can produce an output in the form of the voltage, current, and resistance. However we need to convert these signals to voltage in order to send input to an ADC, this modification is signal conditioning.

When connecting LM35 to an ADC 0808, since the ADC has 8-bit resolution with a maximum of 2.56 in two steps and the LM35 produce 10mv for every degree of temperature change, the vine of the ADC was conditioned to produce V out of 2.56v for full scale output. Therefore, in order to produce the full scale V out of 2.56v for ADC. V reference need to be set to the value = 2.56 this makes V out of ADC correspond directly to the temperature as monitored by the LM35 [14].

3.3.5.2. The Proximity Sensor

The Proximity Sensor is the main feed Back element which determined the desired distance in shape of feed back digital pulses. The sensor type in our Design is non contact inductive proximity sensor the principle of this sensor is detailed in chapter2.

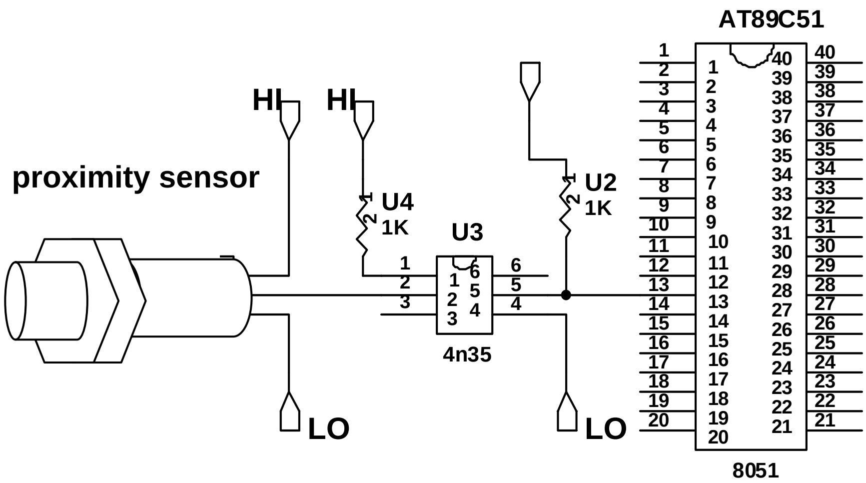

Figure (3.9) Proximity Sensor Interface

Figure (3.9) above shows the proximity sensor that is mounted at the wheel of the Calibration Bench Module. The Pulse of the sensor feed the micro controller with the distance count pulse. The p3.3 (interrupt pin of microcontroller) receives the pulses via Optocupler to protect the microcontroller port pin from damage.

Then the software code counts the distance pulses and compares it with the desired position required till the Desired Position achieved hence stopped the motor. At this moment the magnetic Brake will take place to ensure that the system stopped at the point of desired position.

CHAPTER FOUR

CALIBRATION BENCH SOFTWARE DESIGN

4.1. Introduction

Microcontrollers based systems need a code program to perform the implemented system functionality; the code program stored in external memory or on-chip code memory as done in the developed system. The code program inside the memory is hex file, which is generated from the program. The program should be written in assembly (machine language) or another high level language such as BASIC or C language.

Compilers produce hex file that deposed into the code memory (Internal ROM of the microcontroller). The size of the hex file which is produced by the compiler is one of the main concerns of microcontroller programming, for two reasons:

1- Microcontroller has limited on – chip ROM (code memory).

2- The code space for the 8051 is limited to 64 kilo byte.

The choice of the programming language affects the compiled program size. Assembly language produces a hex file that is much smaller than other programs, programming in assembly language is tedious and time consuming as well as any controller have its own assembly instruction set. C programming is less time consuming and much easier to write but the hex file size produced is much lager than if we used assembly language. The following are some of the major reasons for writing program in C language instead of other languages.

1- It is less time consuming to write in C than Assembly.

2- Easy to modify and update.

3- You can use C program code to other microcontroller with little or no modification; we can say that C language is universal language [14].

4.2. The Keil Compiler

Since we need to produce hex file, a compiler program should be there. Keil compiler is German compiler for C language editing and generating the other needed files. The Keil compiler is popular software with rich facilities such as editing, compiling and simulation. Its powerful features **include the following:**

1- Editor facilities for creating, modifying and correcting the program syntaxes.
2- Target Debugging and compilation.
3- Microcontroller and other peripheral simulation.

So we developed our control program code using the keil compiler, the running of the tests program using the Emulator, then in final stage we download into the ROM with the help of the programmer [19].

4.3. The Main Program Code

The main program includes many sub programs for the ADC, LCD AND Keyboard, and motor driven program these subprograms have been included in the main program. The main program and the sub programs are in Appendix C. In the main program there is a code for calibration the actual position calculation in case of charging the wheel diameter or if any deviation is appeared.

4.3.1. The Flow Chart

The Figure (4.1) in following pages shows the complete Program Code flow chart.

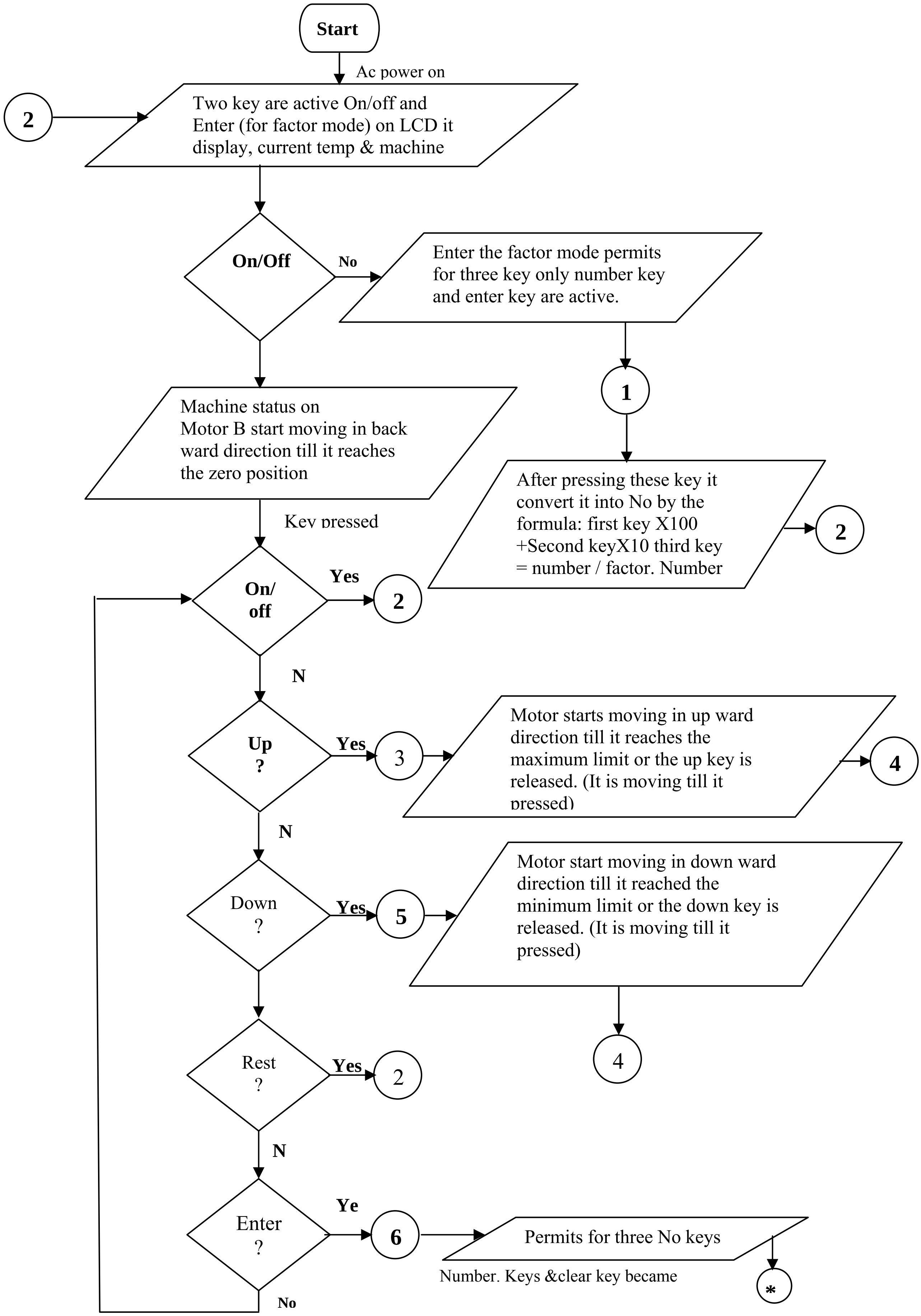

Figure (4.1) Flow chart of (SSDL) Bench Module Control Program Cont…

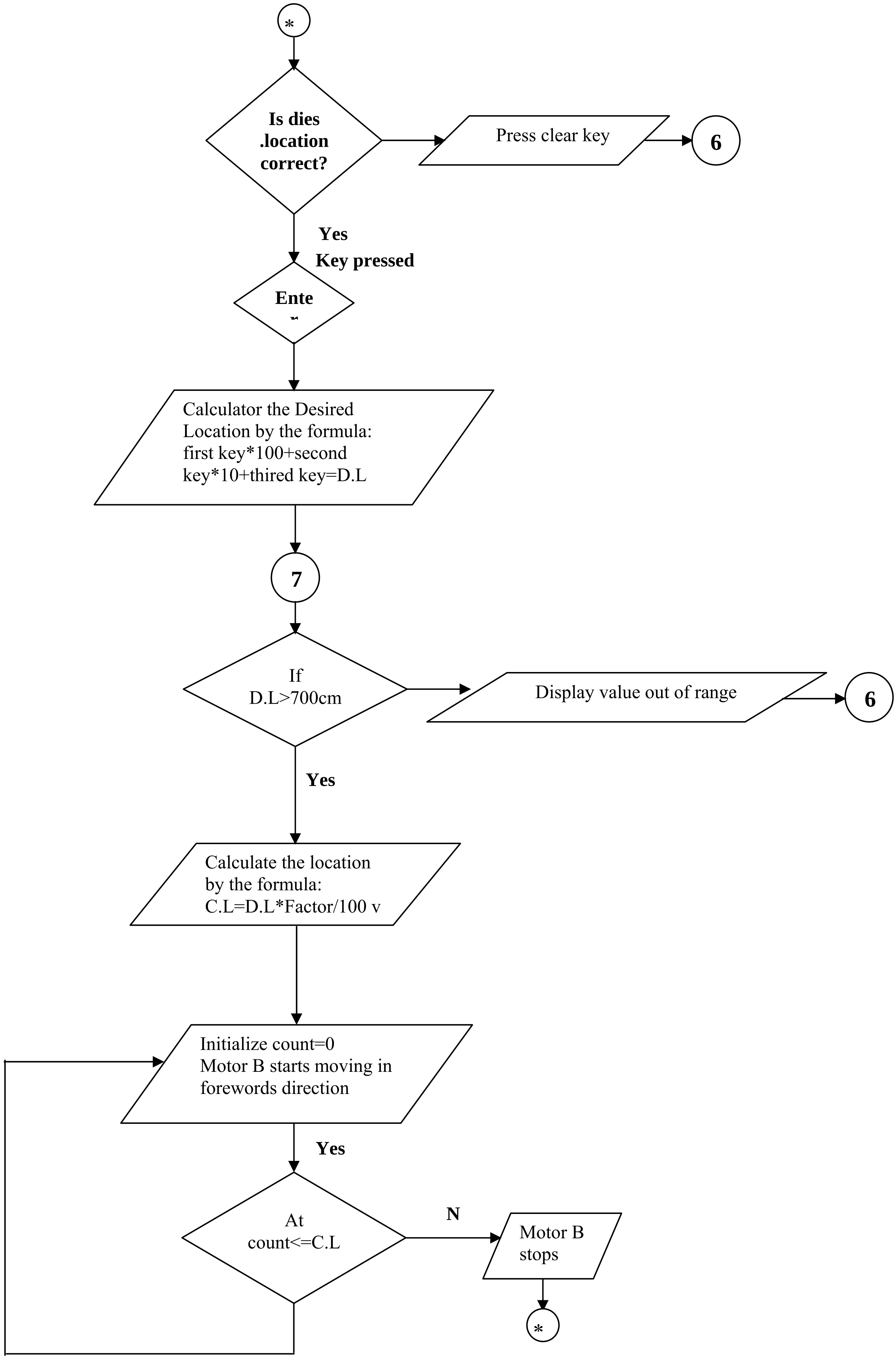

Figure (4.1) Flow chart of (SSDL) Bench Module Control Program Cont…

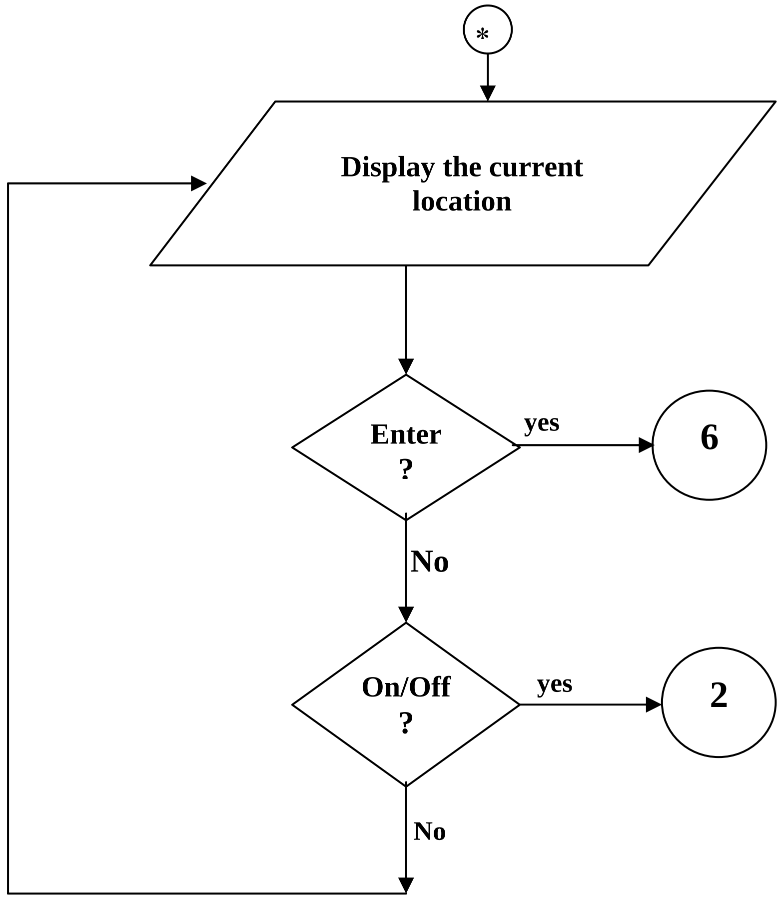

Figure (4.1) Flow chart of (SSDL) Bench Module Control Program

4.4. Functional Description and the User Interface Device

Inputs to the system are obtained from key via a series of key presses. The input will be in the form of longitudinal or/and vertical motion. There are two outputs displayed on the Calibration Bench LCD, first when the machine plugged on the Ac power the LCD Displayed the current examination room temperature and the machine status off, then

On/Off key is pressed the machine goes to zero position and the LCD displayed the machine status on.

Before on key is pressed you can press enter key, which lead the user to factor mode menu for factor correction if needed.

In case of machine status one of the **following can be done:**

1- By pressing the upward switch the table moves up also the LCD indicates upward moving status.

2- By pressing the downward switch the table moves down and the LCD indicates the Downward moving status.

3- Selecting the desired Distance by pressing three keys of number keys, and press enter key to execute the order. During the Bench is traveling the LCD display the current location till the Bench reaches the desired position then LCD display the desired position and the examination room temperature. The Figure (4.2) show the user interface device test board.

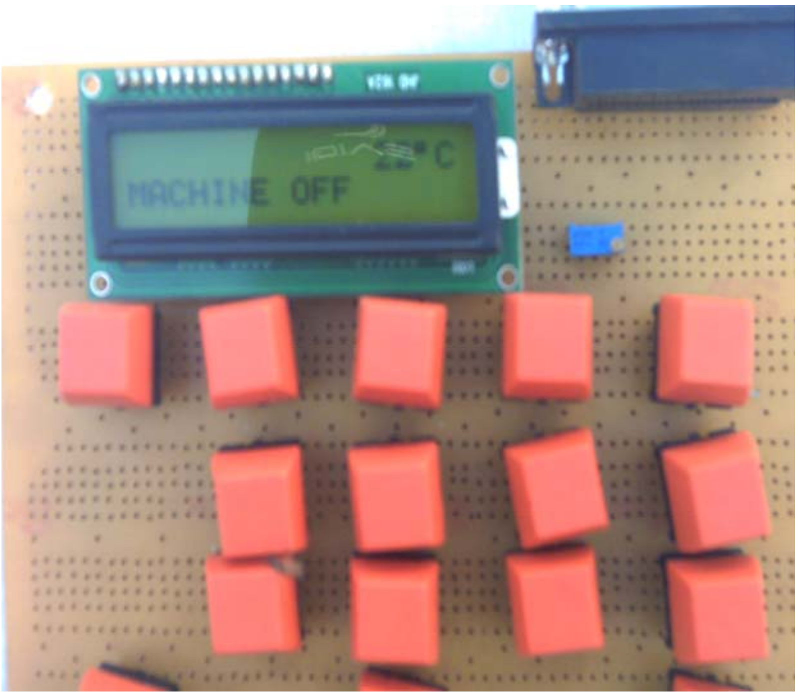

Figure (4.2) keyboard and LCD

CHAPTER FIVE

MECHANICAL SYSTEM DESIGN

5.1. Mechanical System Overview

In this section we will provide an overview of mechanical system concepts as related to the motion, where all considerations of motion are addressed by mechanics, as well as the transmission of forces through the use of simple machines. In our designed system the goal is a mechanical assembly and electronics are used to control the bench module.

Prescribing the motion involves more than just saying that and object moved but the characteristics of the objects velocity and acceleration should be considered. To understand these concepts, we must examine the nature of force. Changes in the motion of an object are created by forces. Force is the push of a motor or pulls of gravity or muscles, the important characteristics are the magnitude and direction of the force, the mass previous state of motion of the object being affected. The opposition to motion is friction, so if nothing is trying to move there will be no fraction. However friction will be present when motion is attempted, even if the object is not yet moving [20].

5.1.1. Types of Friction

Static friction, which acts before the object begins to move, and Dynamic, which acts after the object beings moving. Static is usually stronger than dynamic friction. Also the torque and the moment of inertia measurement so important factor should be taken where considering designing a mechanical system. Torque is a force applied at a distance from a pivot when describing torques; one must include magnitude, direction and perpendicular distance from the pivot. For torques the line of action is circle centered on the pivot. As torque is a product of force and distance, one may be “traded” for the other. By apply more force closer to the pivot; one may produce the same torque. This concept of trading distance applied for force applied is a key to many simple machines. Complex machines are made up of moving parts such as levers, gears, cams, cranks, springs, Belts and wheels. Machines deliver a certain type of movement to a desired location from an input force applied some where else. Some machines simply convert one type of motion to an other type (rotary-to-linear) while there is a seemingly endless variety of machines ,they are all based upon simple machines include inclined planes, levers, wheels and axle, pulleys, and screws. It is important to remember that all machines are limited in their efficiency. No machine is 100 percent efficient in its effort, so the mechanical advantages gained must be considered, worth while of the extra energy that will be required to accomplish the job [20].

5.2. Robotic Calibration Bench Design

An embedded system has been designed to control the calibration bench of the SSDL. Since the robot is electronically controlled mechanical system (Mechatronics) the implemented bench is a robotic system, which consists of four basic components as the generic robot system. These components are: Manipulator (trolley), sensory device, controller, and power unit.

The trolley consists of four wheels and two motors, the aluminum base is made to fit the motors and the control board and the power supply unit .The design of the bench is symmetrical so that would be weight distribution over the drive wheels and the centre of the vehicle. This made it much easier for the movement with suitable balance, the design is regular quadrangular shape that has a side dimensions (40cmx50cm).this size permits the motors, control board, and the power supply are well mounted. Two cables take all the necessary connection to the power supply and the user interface terminal.

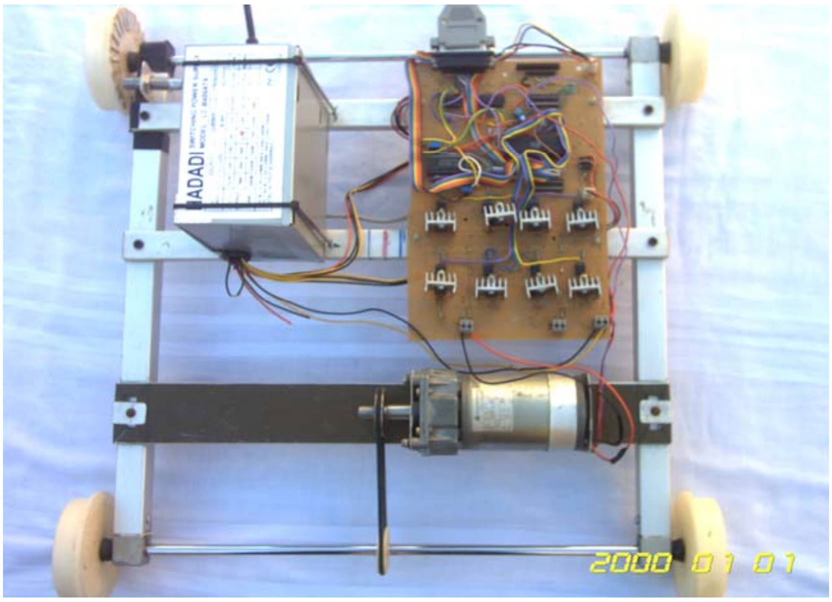

Figure (5.1) the Base of the Trolley

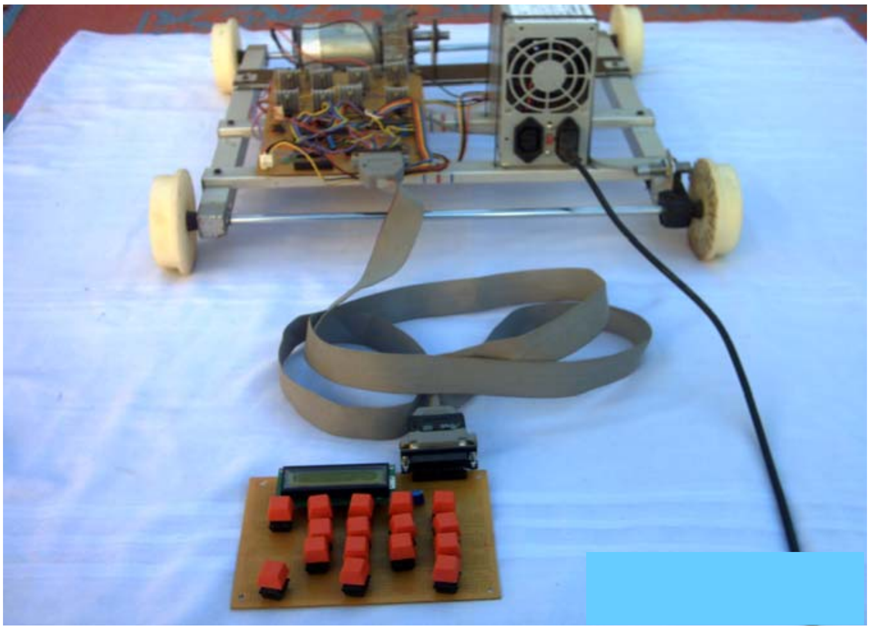

Figure (5.2) Bench Module Test Model

For proper control of the trolley we must know the state of the bench and its position to achieve this, sensory element must be incorporated. The proximity sensor is mounted (connected) to the trolley wheel; the temperature sensor is located on the control board. On the top of the bench TV camera is there to monitor the object position on the top of the bench and the object display (reading), the camera system represent a separate monitoring system just mounted o the bench.

The controller provides the intelligence to cause the bench to perform in the manner described by the user. Essentially the controller consists of:

- Controller to govern the process
- Memory to store the code defining the position and temperature.
- An interface to obtain sensory data and ancillary components.
- User interface unit.

All the above elements are mounted on the electronics control board except the user interface device. The power unit is a switch mode power supply (SMPS) which provide the power to all system components.

5.3. Longitudinal Motor Assembly

To provide the longitudinal motion the principles of rotary to linear motion conversion is used. This motion is concerned with taking the rotational motion and torque from the motor and producing a linear motion and force on the out put, belt and pulley has been used for this conversion. The Fig (5.3) shows the motor assembly for longitudinal movement.

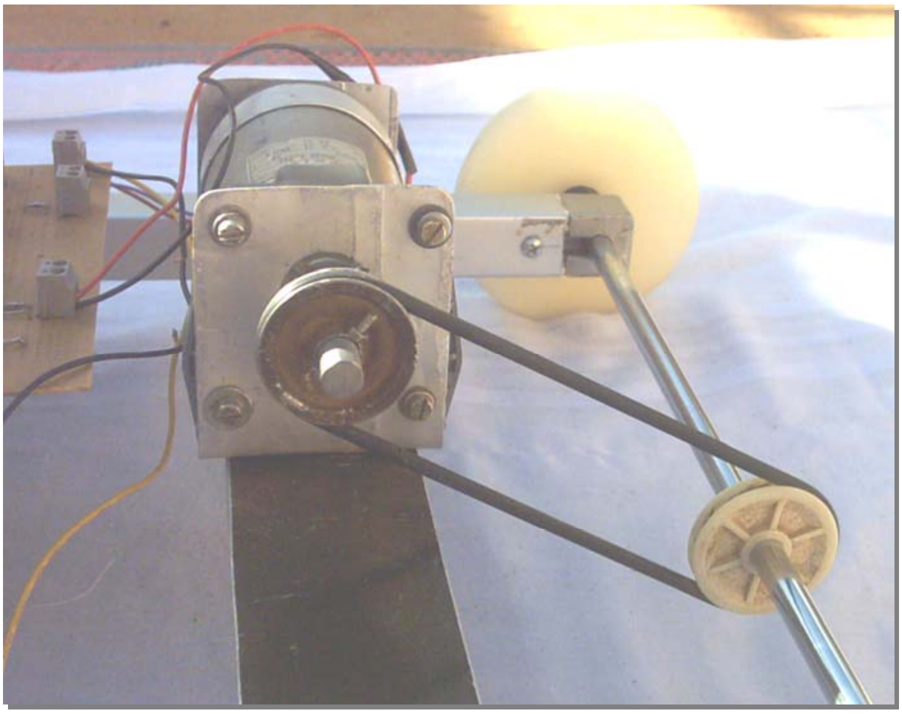

Figure (5.3) Longitudinal Motor Assembly

5.4. UP\Down Motor Assembly

To achieve an up\down motion of the upper side of the calibration bench, a motorized scissor jack is used. The motor is connected with a drive assembly that extends and retracts the jack through the displacement screw; a motor is for the rotation of a displacement screw, clockwise and counter clockwise in order to provide the raising and lowering of the frame portion of the scissor jack. The upper and lower limit switches limit the extension and retraction of the jack to defined peak and bottom points, the upper and lower limit switch mounted in a sealed housing that the jack moves in upward or downward direction the driving element or the displacement screw comes in direct contact with the limit switch then complete the limiting circuit. The figure below shows the motorized scissor jack in order that the invention may be fully understood.

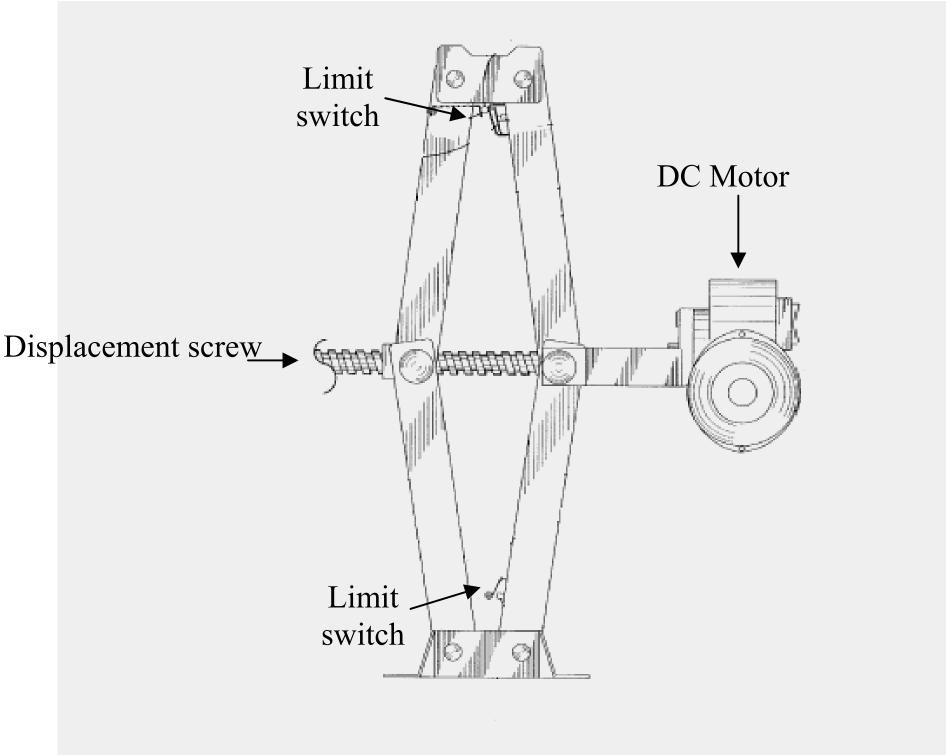

Figure (5.4) Scissor Jack Extends to the Upper Limit

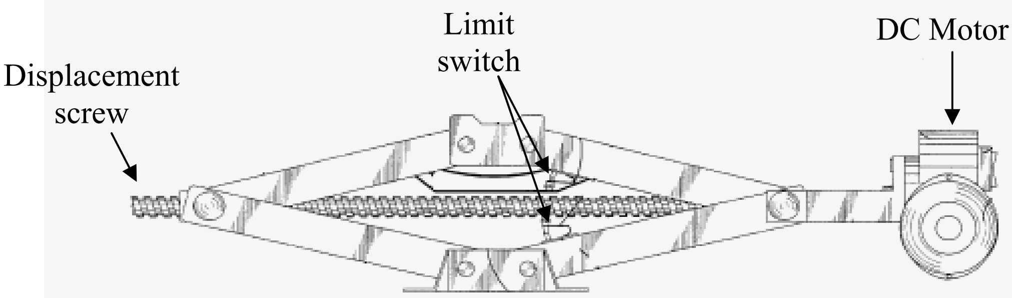

Figure (5.5) Scissor Jack Retracts to the Lower Limit

CHAPTER SIX

RESULTS AND DISSCUTION

6.1. Results

The calibration Bench module of the secondary standard Dosimetry Laboratory has been designed to contribute on the radiation protection process by enhancing the quality of calibration and reducing the time of process leading to good quality of radiation protection.

A microcontroller Based system in used in the Design and implementation of the Bench module. The system consist of, electronic components, sensors Module (proximity and temperature), a power supply, and a mechanical system. The calibration Bench module has the **following outputs:**

1- Calibration Bench longitudinal movement.
2- Upper side of the calibration Bench horizontal movement.
3- LCD data, which are the Examination Room temperature and the calibration Bench current status.

The Calibration Bench Module has been tested, and the results of the outputs are shown in Table (6.1) for the distances and Table (6.2) for the temperature as follows:

Table (6.1) Set Distance Vs Measured Distance

No	Set Distance	Measured Distance
1	100cm	100cm
2	120cm	120cm
3	190cm	189cm
4	250cm	250.4cm
5	320cm	320.6cm

Table (6.2) Result of Temperature Calibration

No	Bench module temp reading	Reference meter reading
1	38°C	37.8°C
2	35°C	34.7°C
3	36°C	35.9°C
4	38°C	38.02°C
5	32°C	32.01°C

6.2. Discussion

The main objective is to build an embedded Calibration Bench Module from start to complete system, which is professionally designed with reasonable cost. The system has been successfully designed, implemented and then tested for positioning the object to be irradiated in suitable position against the radiation source. In this Experiment the simple measuring tape is used to compare between the desired distance/position and the actual traveling distance, the result that is; the big desired distance/position a little bit deviated when compared to the small distances as shown in Table (6.1). This deviation is due to proximity sensor resolution and its operating distance which affects the accuracy of position. To get fine accuracy the sensor should be replaced with small operating distances one.

The vertical (up/down) movement is needed to achieve the perpendicularity of the radiation beam to the object to be irradiated. Simply, the vertical motion is just determined by pressing the up or down switches and the user determined the right position visually.

The examination room temperature is well adjusted with the help of reference thermometer (external), and the variable resistance in the ADC and temperature section on the electronic Board.

The LCD displays the temperature at the upper right side of the LCD and the machine status on the lower row of the LCD, when the machine is moving longitudinally LCD displays the increment of the distance counter till it reaches the desired distance. In case of vertical (up/down) movement the LCD shows the words "Moving Upward" or "Moving Downward".

The temperature measurement is good enough because of the simplicity of the temperature monitoring section and the repeatability of reading by the system to monitor the variety of the room temperature through the time. Since the proximity sensor resolution is poor, the positioning error have been there, also statistical analysis of distance data gives significant level 0.05% in both measurements. There is addition ratio to errors that is generated by the controller because the execution of instruction which takes number of cycles, because the code written with high level language syntax which is need long pipe line which effected the counting process. The expected outcomes and results of both position and temperature have been achieved with %95 accuracy (%5 error probabilities).

The bench designed to be a low cost solution and powerful module to achieve the objectives, the expandability on this system in much greater and different types of control aspects can be added. This research is using some of the latest and greatest technology that it has many advantages and useful features, the microcontroller, sensory devices, and electro mechanics component .that could be used in education experimentation with different types of robotics platform systems. The implemented project will also be used in current and future application. This research is an improved version of an old concept that now dedicated to specific purpose and can be generic robot platform systems. This calibration bench control system will also serve as starting point for other projects to come; the possibilities are only limited by human ingenuity.

CHAPTER SEVEN

CONCLUSIONS AND COMMENTS

7.1. Conclusion

The study and implementation has been dwelling on the SSDL especially on its calibration Bench section. Because of its importance in Radiation metrology and protection the SSDL concepts have been studied and reviewed. Then the main factors, which cause faults and uncertainty, are discussed. One of these important factors is the sample and the chamber position to the radiation source, the position problem solved by designing and implementing the Calibration Bench Module as well as monitoring the examination room temperature.

The 8051 microcontroller is a low cost, low power consumption and powerful controller. By utilizing these types of microcontrollers the implemented systems have a low cost design, since the number of electronics component used to build the systems is less. More over, such integrated chip supported with flash memory (code memory) that used safely to reorganize and reprogram the code to improve the system functionality.

Using a high level language compiler such as Keil compiler which is the most useful C compiler used by the most famous companies in electronic design field. This approach gives the features of enhancement and improvement of skills and knowledge in software engineering field.

Implementing the design with the help of schematics and simulation software before the real experimental use of the component is a good feature that makes the designer able to choose the perfect component and suitable PCB creation, which lead to well results in the performance of the implemented system.

The implemented system is a precision robotic platform that controls the position and monitors the examination room temperature. Since the system consists of electronic and mechanical parts it is an electromechanical system, with a smart user interface device.

This embedded control system is reduces the time, ease the work, monitor the examination room temperature, so effects at the quality and quantity of Calibration process as well as introduces perfect radiation protection.

This Research is conducted at Sudan Atomic Energy Commission SSDL in order to develop a calibration bench module that can be remotely customized by the lab personnel. By implementing this module the longitudinal and vertical positions can be controlled as well as monitoring the examination room temperature.

According to the Inverse square law ($1/r^2$) the radiation dose varies with distance since (r) is the distance between the radiation source and the object on the calibration bench, the developed controller will reduce the uncertainty due to distance/position faults and will help in reducing the errors associated with manual positioning of the radiation detectors which represent the sample to be irradiated.

By controlling the calibration bench from a control panel outside the examination room, this will reduce the possibility of occupational exposure to personnel, and will also reduce the operational efforts.

Because of the different types and models of meters (samples) to be calibrated the vertical (up/down) movements is needed to maintain the right position of the sample.

Monitoring the examination room temperature will also be useful since the temperature is always required for radiation dose calculations.

7.2. Recommendations

The implemented Calibration Bench Module is a remote control positioning system, since the operation and the calibration process is done from outside the machine room. the system disadvantage that is using a long data cable according to the allowed bench traveling distance, the moving of this cable will damage it, so we strongly recommend that wireless remote control from the control cabinet will be a better solution.

To avoid the power cables damages due to the continuous movement, sliding brush can be added instead of the power cables.

Monitoring the room pressure also is an important issue in calibration process so pressure monitoring system will be a valuable element if added to calibration Bench module.

Since the radiation source is the main risk in the radiation protection precautions and the Calibration Bench Module is there to improve the radiation protection management, the Calibration Bench Module can be connected with the x-ray system to provide center lock with the main x-ray generator or natural radioactive source.

The Calibration Bench Module can be a generic system to be used in other control applications.

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Main Program

```
#include<reg51.h>
#include<adc808.h>
#include<motor_drv.h>
void system_off_stg();
extern int keyval();
extern int key;
char cm;
unsigned char chk=0,*disp,enter_chk,num_chk=0;
unsigned char num_1,num_2,num_3,num_chk_dup=0;//
void current_position();
unsigned int get_keyval;
int desire_position;
char *sys_off="MACHINE OFF.";
unsigned char *str_factor="ENTER THE FACTOR.";
unsigned char *str_position="ENTER POSITION.";
unsigned char *str_valmax="VALUE OUT OF RANGE.",ptr_counter=0;
float factor=100;
long unsigned duty;
void delay_max();
void delay500();
void goto_zero_position();
void goto_desire_position(int);
{for(i=0;i<6500;i++);
 }*/

static j;
static count,count1,var,var1;
main()
{  P35=1;P33=1;IT1=1;IE=0x8A;
   TMOD=0x01;//IP=0x0A;
          lcd_init();
          temp();
          system_off_stg();
          while(1)//WHILE1
          {      temp();
                    enter_chk=0;
                    get_keyval=keyval();
                    switch(get_keyval)//SWITCH1
                    {
                              case 13:                    //FOR (ON)
                              {   goto_zero_position();
           P35=1;
                                        get_keyval=0;
                                        chk=1;
                                        delay_max();
                                        lcd_cmd(0x01);      // command to clear lcd
                                        current_position();
                                        break;
                              }  //END OF CASE13
                              case 15:            //FOR ENTER   FActor mode
                              {
                                        enter_chk=1;
                                        lcd_cmd(0x01);
                                        while((*str_factor!='.'))   //WHILE STR_factor
```

```
                {
                        lcd_data_wr(*str_factor);
                        str_factor++;
                        ptr_counter++;
                }//END OF WHILE STR_FACTOR
                str_factor-=ptr_counter;
                ptr_counter=0;
                lcd_cmd(0xC5);
                lcd_cmd(0x0E);
        while(enter_chk==1)     //check for Enter key
        {
                get_keyval=keyval();
                if(get_keyval==15)      //FOR ENTER
                {
            enter_chk=0;
                        num_chk=0;
                        lcd_cmd(0x01);
                        lcd_cmd(0x0E);

                        temp();
                        system_off_stg();
                        break;
                }
                if(get_keyval>=0 && get_keyval<=9)  //All number keys are enabled
                {
                        num_chk++;
                        if(num_chk==1)
                        {
                                num_3=get_keyval;
                                lcd_data_wr(48+num_3);
  lcd_data_wr(0x2E);   //for displaying dot
                        }
            if(num_chk==2)
                  {
                          num_2=num_3;
                                num_3=get_keyval;
                                lcd_data_wr(48+num_3);
                        }
                        if(num_chk==3)
                        {
                                  num_1=num_2;
num_2=num_3;
                                  num_3=get_keyval;
                                  lcd_data_wr(48+num_3);
                                  factor=(num_1 * 100)+ (num_2 * 10) + num_3;
                                  num_1=num_2=num_3=0;
                        }
                }
                if(get_keyval==11)                      //FOR CLEAR
                {
                        num_1=num_2=num_3=0;
                        num_chk=0;
                        lcd_cmd(0x01);
                        while((*str_factor)!='.')   //WHILE STR_POSITION
                        {
                                lcd_data_wr(*str_factor);
                                str_factor++;
```

```
                                        ptr_counter++;
                                }//END OF WHILE STR_FACTOR
                                str_factor-=ptr_counter;
                                ptr_counter=0;
                                lcd_cmd(0xC5);
                        }
                }
        }
}
while(chk==1)       //WHILE CHK  and ALL KEYS ARE ENABLED
{
        get_keyval=keyval();
        switch(get_keyval)//SWITCH2
        {
                        case 12:  //MOTOR CASE FOR MOVING UPWORDS
                        {
                                lcd_cmd(0x01);
                                lcd_cmd(0x85);
                                lcd_data_wr('M');
                                lcd_data_wr('O');
                                lcd_data_wr('V');
                                lcd_data_wr('I');
                                lcd_data_wr('N');
                                lcd_data_wr('G');
                                lcd_cmd(0xC4);

                                lcd_data_wr('U');
                                lcd_data_wr('P');
                                lcd_data_wr('W');
                                lcd_data_wr('A');
                                lcd_data_wr('R');
                                lcd_data_wr('D');
                                lcd_data_wr('S');
                                while(P2==0xBD)
    {MOTOR1_P2_OFF();
     MOTOR1_P1_ON();    //motor_up();
                }/* motor();
   lcd_cmd(0x80);
   lcd_data_wr(count+48);
   */
                                lcd_cmd(0x01);
                                current_position();
                P1=255;
   break;
 }
                        case 14:   //MOTOR CASE FOR MOVING DOWNWORDS
                        {
                                lcd_cmd(0x01);
                                lcd_cmd(0x85);
                                lcd_data_wr('M');
                                lcd_data_wr('O');
                                lcd_data_wr('V');
                                lcd_data_wr('I');
                                lcd_data_wr('N');
                                lcd_data_wr('G');
                                lcd_cmd(0xC4);
```

```
                                        lcd_data_wr('D');
                                        lcd_data_wr('O');
    lcd_data_wr('W');
    lcd_data_wr('N');
                                        lcd_data_wr('W');
                                        lcd_data_wr('A');
                                        lcd_data_wr('R');
                                        lcd_data_wr('D');
                                        lcd_data_wr('S');

   while(P2==0xBB)     //Motor continues to move till the down key is released.
    {//motor_down();
     MOTOR1_P1_OFF();
     MOTOR1_P2_ON();
     }
    P1=255;
                                        lcd_cmd(0x01);
                                        current_position();
    break;
                              }
                              case 13:          // FOR OFF
                              {   TH0=0x2D;cm=26;
          TL0=0x15;
                 TR0=1;
                                        get_keyval=0;
                                        chk=0;
                                        while(cm)
           { if(P2==0xE7)
      {while(TF0!=1);
                     TF0=0;
                    cm--;
             }
      else
       break;
     }
                                        TR0=0;
    lcd_cmd(0x01);
    lcd_data_wr('R');
    lcd_data_wr('E');
    lcd_data_wr('L');
    lcd_data_wr('E');
    lcd_data_wr('A');
    lcd_data_wr('S');
    lcd_data_wr('E');
    lcd_data_wr(' ');
    lcd_data_wr('K');
    lcd_data_wr('E');
    lcd_data_wr('Y');
    while(P2==0xE7);
    lcd_cmd(0x01);
                                        temp();
                                        system_off_stg();
                                        break;
                              }
                              case 16:          //FOR RESET
                              {
                                        goto_zero_position();
```

```
                    break;
                }
                case 15:        //FOR ENTER
                {
                    enter_chk=1;
                    lcd_cmd(0x01);
                    while((*str_position)!='.')        //WHILE STR_POSITION
                    {
                        lcd_data_wr(*str_position);
                        str_position++;
                        ptr_counter++;
                    }//END OF WHILE STR_POSITION
                    str_position=str_position-ptr_counter;
                    ptr_counter=0;
                    lcd_cmd(0xC5);
                    lcd_cmd(0x0E);
                    while(enter_chk==1)
                    {
                        get_keyval=keyval();
                        if(get_keyval==15)        //FOR ENTER
                        {
                            enter_chk=0;
                                    num_chk=0;lcd_cmd(0x01);
lcd_cmd(0x85);
                                    lcd_data_wr('M');
                                    lcd_data_wr('O');
                                    lcd_data_wr('V');
                                    lcd_data_wr('E');
                                    lcd_data_wr('D');
                                    lcd_data_wr('(');
                                    lcd_data_wr('C');
                                    lcd_data_wr('M');
                                    lcd_data_wr(')');
                                //goto_zero_position();

    goto_desire_position(desire_position);  //After u have entered the location within range
                                    lcd_cmd(0x01);
                                    lcd_cmd(0x0E);


                                    current_position();
                                    break;
                        }
                        if(get_keyval>=0 && get_keyval<=9)  // All number
keys are enabled
                        {
                            num_chk++;
                            if(num_chk==1)
                            {
                                    num_3=get_keyval;
                                    lcd_data_wr(48+num_3);
                            }
                         if(num_chk==2)
                         {    num_2=num_3;
                                    num_3=get_keyval;
                                    lcd_data_wr(48+num_3);
                            }
```

```
            if(num_chk==3)
            {   num_1=num_2;
                num_2=num_3;
                num_3=get_keyval;
                lcd_data_wr(48+num_3);
                desire_position=(num_1 * 100)+
(num_2 * 10) + num_3;
                if(desire_position>700)
                {
                  num_chk=0;
                  lcd_cmd(0x01);
                  lcd_cmd(0x82);
                  while((*str_valmax)!='.')
                  {
                      lcd_data_wr(*str_valmax);
                          if(ptr_counter==12)
                      lcd_cmd(0xC5);
                      str_valmax++;
                          ptr_counter++;
                      }
                  str_valmax-=ptr_counter;
                      ptr_counter=0;
                  delay_max();
                      lcd_cmd(0x01);
                      while((*str_position)!='.')
                      {
                      lcd_data_wr(*str_position);
                          str_position++;
                          ptr_counter++;
                      }//END OF WHILE
STR_POSITION
                      str_position-=ptr_counter;
                      ptr_counter=0;
//                    lcd_cmd(0x0E);
                      lcd_cmd(0xC5);
                }

            }
        }
        if(get_keyval==13)                    //FOR 0FF
        {
            chk=0;
            enter_chk=0;
            lcd_cmd(0x01);
            temp();
            system_off_stg();
            break;
        }
        if(get_keyval==11)                    //FOR
CLEAR
        {
                num_1=num_2=num_3=0;
                num_chk=0;
                lcd_cmd(0x01);
```

```
                                                                while((*str_position)!='.')
                                                                {
                                                                        lcd_data_wr(*str_position);
                                                                        str_position++;
                                                                        ptr_counter++;
                                                                }//END OF WHILE STR_POSITION
                                                                        str_position-=ptr_counter;
                                                                        ptr_counter=0;
                                                                lcd_cmd(0xC5);
/*                                                              if(num_chk==0)
                                                                {
                                                                        num_chk=0;
                                                                        lcd_cmd(0x01);
                                                                        break;
                                                                }
                                                                if(num_chk==3)
                                                                {
                                                                        lcd_cmd(0x0E);
                                                                        lcd_cmd(0xC7);
                                                                        num_chk--;
                                                                }
                                                                if(num_chk==2)
                                                                {
                                                                        lcd_cmd(0x0E);
                                                                        lcd_cmd(0xC6);
                                                                        num_chk--;
                                                                }
                                                                if(num_chk==1)
                                                                {
                                                                        lcd_cmd(0x0E);
                                                                        lcd_cmd(0xC5);
                                                                        num_chk--;
                                                                }
                                                                        lcd_cmd(0x0C);*/
                                                }
                                        }
                                }
                        }       //END SWITCH2
                }       //END OF CHK
        }       //END OF WHILE1
}       //END OF MAIN
void system_off_stg()   //FUNCTION FOR MACHINE STATUS
{       delay();
        lcd_cmd(0xC0); // 2nd line on lcd to display m/c status
        while((*sys_off)!='.')
        {
                lcd_data_wr(*sys_off);
                sys_off++;
                ptr_counter++;
        }
        sys_off-=ptr_counter;
        ptr_counter=0;
        num_1=num_2=num_3=0;
}
void current_position()   //FUNCTION FOR CURRENT POSITION
{
//      lcd_cmd(0x01);
```

```
            lcd_data_wr('C');
            lcd_data_wr('u');
            lcd_data_wr('r');
            lcd_data_wr('r');
            lcd_data_wr('e');
            lcd_data_wr('n');
            lcd_data_wr('t');
            lcd_data_wr(' ');
            lcd_data_wr('P');
            lcd_data_wr('s');
            lcd_data_wr('t');
            lcd_data_wr('(');
            lcd_data_wr('c');
            lcd_data_wr('m');
            lcd_data_wr(')');
            delay();
            lcd_cmd(0xC5);
            lcd_data_wr(48+num_1);
            lcd_data_wr(48+num_2);
            lcd_data_wr(48+num_3);
   num_1=num_2=num_3=0;
}
void delay_max()
{
            unsigned i;
            for(i=0;i<65530;i++);
}
void goto_zero_position()
{   var1=0;                              //FOR TIMER0 COUNT
   motor_back();
   //delay500();
   //TR0=1;
   while(P35);    //  switch to stop motor at zero position
   TR0=0;
   MOTOR2P2_OFF();
   P35=1;
   P1=255;
            //delay();
            lcd_cmd(0x01);
            lcd_data_wr('z');
            lcd_data_wr('e');
            lcd_data_wr('r');
            lcd_data_wr('o');
            delay_max();
            lcd_cmd(0x01);
            num_1=num_2=num_3=0;
            current_position();
}
void goto_desire_position(int disp)   //FOR DESIRED POSITION
 {  int cl=disp*factor/100;   //calculated location
    var=0;//lcd_cmd(0xC5);
   motor_forward();IE=0x8F;
   if(cl>0)
    while(count<=cl);
   MOTOR2P1_OFF();
   if(count>cl)
     {
```

```
      motor_back();
      while(count>cl)
       count--;
      MOTOR2P2_OFF();TR0=0;
     }
    IE=0x8A;
    TR1=0;
    count=0;
    P1=255;
 }
void timer_1() interrupt 2  //EXT. INT. 1  P3.3 This is called when sensor comes in contact with metal
{
  while(P33==0);
  lcd_cmd(0xC5);
  lcd_data_wr((count)/100+48);
  lcd_data_wr((count-(count)/100*100)/10+48);
  lcd_data_wr((count-count/10*10)%10+48);
  P33=1;count++;
}
void timer0() interrupt 1   //TIMER0 ISR
{
            TF0=0;TL0=0x86;
            if(var1%2==0)
    {
                        TH0=0x49;
                MOTOR2P2_OFF();
    }
   else
   {
                        TH0=0x49;MOTOR2P2_ON();
   }
   var1++;
}
void timer1() interrupt 3  //TIMER1 ISR
 {TF1=0;TL1=0x86;
  if(var%2==0)
   {TH1=0x49;
    MOTOR2P1_OFF();
   }
   else
   {TH1=0x49;MOTOR2P1_ON();
   }
   var++;
 }

void delay500()
 {
  unsigned k;
  for(k=0;k<=40000;k++);
 }
```

ADC 0808 program

```
#include<reg51.h>
#include<lcd_iop.h>
#include<intrins.h>
void adc_init_ch0();
void adc_init_ch1();
void adc_ch0_process();
void adc_ch1_process();
void SOC();
void ALE();
void ACTOE();
void EOC();
void lcd(unsigned char);
sbit ale=P3^4;
sbit eoc=P3^2;
sbit oe=P3^1;
sbit sc=P3^4;
void temp_sensor_display();
void temp();
void delay1()
{unsigned int i;
 for(i=0;i<65533;i++);
}
unsigned val1,val2,val;
//main()
//{
 //lcd_cmd(0x);
 //P10=0;
 //while(1)
void temp()
 {
 adc_init_ch0();
 //temp_sensor_display();
 adc_ch0_process();
 adc_init_ch1();
 adc_ch1_process();
 temp_sensor_display();
 }
//}
void SOC()
{
 sc=1;
 _nop_();_nop_();
 sc=0;
}
void ALE()
{
 ale=1;
 _nop_();_nop_();
 ale=0;
}
void EOC()
{
 while(eoc==0);
}
```

```
void ACTOE()
{
 oe=1;
 ACC=P0;
 //val=ACC;
 //val1=48+val/20;
 //val2=48+(val/2)%10;
 oe=0;
}
/*void timer0_13mode() interrupt 1
{
     P34=~P34;
     TF0=0;
     TR0=0;
     TH0=0xFF;
     TL0=0x06;
              TR0=1;
}*/
void temp_sensor_display()
  {
  //while(1)
  lcd_cmd(0x8C);        //  to display at right top corner on lcd
  lcd_data_wr(val1);
  lcd_data_wr(val2);
  lcd_data_wr(0xdf);     //for degree mark
  lcd_data_wr(67);       //for C mark
  //lcd_cmd(0xC0);
  //lcd_data_wr(48+val/10);
  //lcd_data_wr(48+val%10);
   delay1();
  }
void adc_init_ch0()
{
 P37=0;
 ale=0;
 eoc=1;
 oe=0;
 sc=0;
 /*TH0=0xFF;
 TL0=0x09;
 TMOD=0x00;
 IE=0x82;*/
 //lcd_init();
 //lcd_cmd(0x80);
 //TR0=1;
}
void adc_init_ch1()
{
 P37=1;
 ale=0;
 eoc=1;
 oe=0;
 sc=0;
 /*TH0=0xFF;
 TL0=0x09;
 TMOD=0x00;
 IE=0x82;*/
```

```
 //lcd_init();
 //lcd_cmd(0xC0);
}
void adc_ch0_process()
{
  ALE();
  SOC();
  EOC();
  P0=255;
  //P11=0;
  ACTOE();
  val=ACC;
}
void adc_ch1_process()
{
  ALE();
  SOC();
  EOC();
  P0=255;
  //P11=0;
  ACTOE();
  val=val-(121-ACC);
  val1=48+val/20;
  val2=48+(val/2)%10;
}
```

Key Board program

```
sfr P2=0xA0;
int key;
void delay10();
int keyval()
{

        P2=0xFE;                //ROW 1

                if(P2==0xEE)
                {       while(P2==0xEE);delay10();
                        while(P2==0xEE);
                                key=1;
                                return key;
                }
                if(P2==0xDE)
                {       while(P2==0xDE);delay10();
        while(P2==0xDE);
                                key=3;
                                return key;
                }
                if(P2==0xBE)
                {       while(P2==0xBE);delay10();
         while(P2==0xBE);
                                key=11;                         //clear
                                return key;
```

```
}
if(P2==0x7E)
{       while(P2==0x7E);delay10();
                        while(P2==0x7E);
                        key=2;
                        return key;
}

P2=0xFD;                        //ROW 2
if(P2==0xED)
{       while(P2==0xED);delay10();
                        while(P2==0xED);
                        key=4;
                        return key;
}
if(P2==0xDD)
{       while(P2==0xDD);delay10();
                        while(P2==0xDD);
                        key=6;
                        return key;
}
if(P2==0xBD)
{       while(P2==0xBD);delay10();
                        while(P2==0xBD);        //UP
                        key=12;
                        return key;
}
if(P2==0x7D)
{       while(P2==0x7D);delay10();
                        while(P2==0x7D);
                        key=5;
                        return key;
}
P2=0xFB;                        //ROW 3
if(P2==0xEB)
{       while(P2==0xEB);delay10();
                        while(P2==0xEB);
                        key=7;
                        return key;
}
if(P2==0xDB)
{       while(P2==0xDB);delay10();
                        while(P2==0xDB);
                        key=9;
                        return key;
}
if(P2==0xBB)                            //DOWN
{       while(P2==0xBB);delay10();
                        while(P2==0xBB);
                        key=14;
                        return key;
}
if(P2==0x7B)
{       while(P2==0x7B);delay10();
                        while(P2==0x7B);
                        key=8;
                        return key;
```

```
                }

        P2=0xF7;    //ROW 4
                if(P2==0xE7)          //   ON or OFF
                {    delay10();
                   //        while(P2==0xE7);
                             key=13;
                             return key;
                }
                if(P2==0xD7)
                {    while(P2==0xD7);delay10();
                             while(P2==0xD7);
                             key=0;
                             return key;
                }
                if(P2==0xB7)
                {    while(P2==0xB7);delay10();
                             while(P2==0xB7);
                             key=15;
                             return key;             //ENTER
                }
                if(P2==0x77)
                {    while(P2==0x77);delay10();
                             while(P2==0x77);            //RESET
                             key=16;
                             return key;
                }
    else
      return 20;
   P2=255;
}
void delay10()
 {
  unsigned  d;
  for(d=0;d<6500;d++);




 }
```

LCD Code

```
//#include<reg51.h>
#include<intrins.h>
//sbit P20=0xa0;
sbit E=P3^0;
//sbit RW=P3^7;
sbit RS=P3^6;
void delay();
#define LCD_CMD_WR 0xF4//0x2d00
#define LCD_DATA_WR          0xF5//0x2d01
```

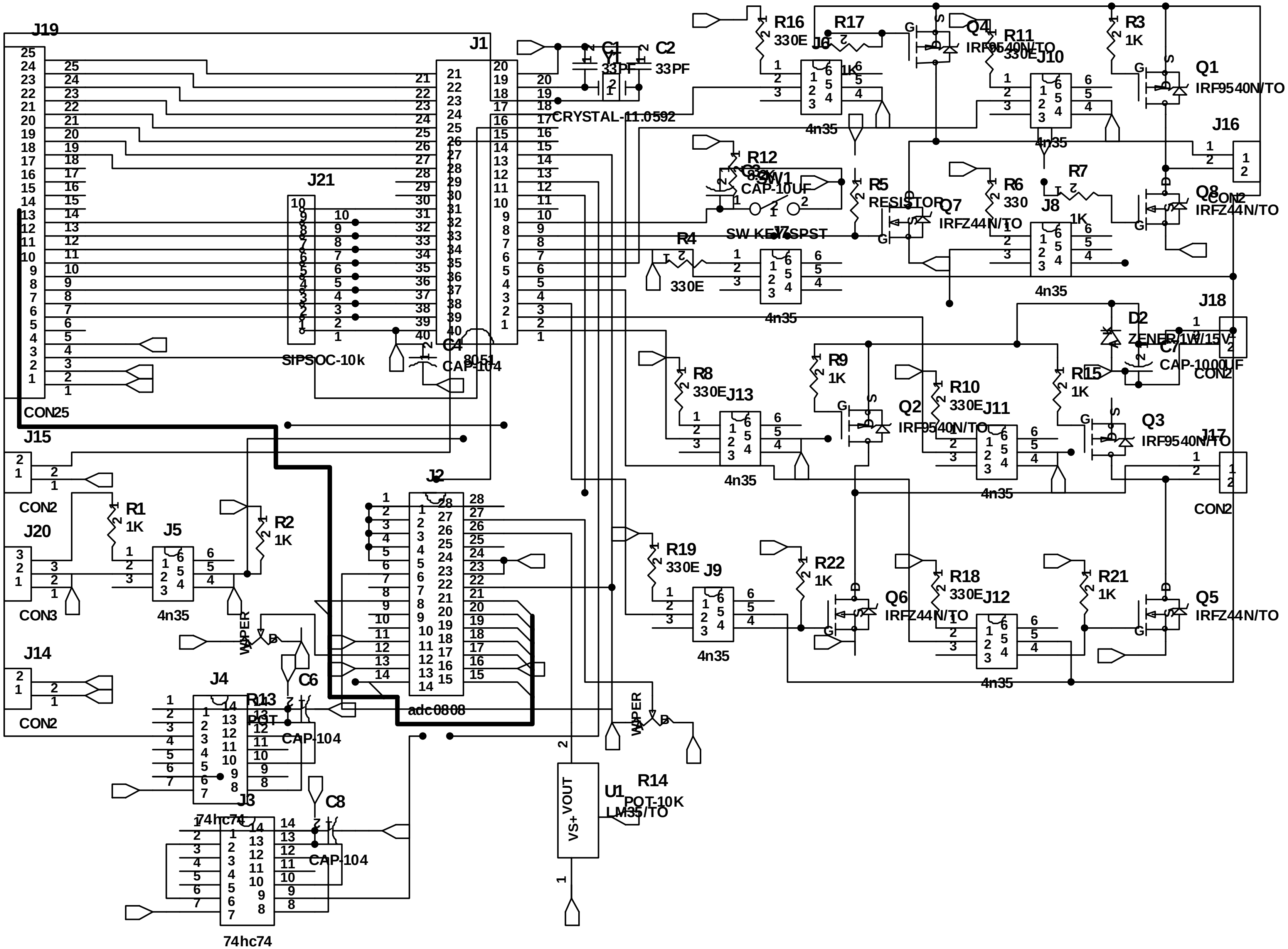
```
#define  LCD_STATUS_RD 0xF6//0x2d02
#define  LCD_DATA_RD            0xF7//0x2d03
//void busy();
void lcd_init();
void lcd_data_wr(unsigned char);
void lcd_data_rd();
void lcd_cmd(unsigned char);
unsigned a[]={0x38,0x0C,0x01,0x06,0x80,0};
static char i;
unsigned c;
void lcd_init()
{while(a[i]!=0)
  {
   delay();
   lcd_cmd(a[i]);
   i++;
  }
}
/*void busy()
{P07=1;
 RS=0;
 RW=1;
 E=1;
 while(P07);
 }*/
void lcd_cmd(unsigned char val)
{P0=val;
 RS=0;
 //RW=0;
 E=1;
 _nop_();
 _nop_();
 E=0;
}
void lcd_data_wr(unsigned char val)
{delay();
 P0=val;
 RS=1;
//RW=0;
E=1;
_nop_();
_nop_();
E=0;
 }
void delay()
{for(c=0;c<650;c++);
 //P20=~P20;
}
```

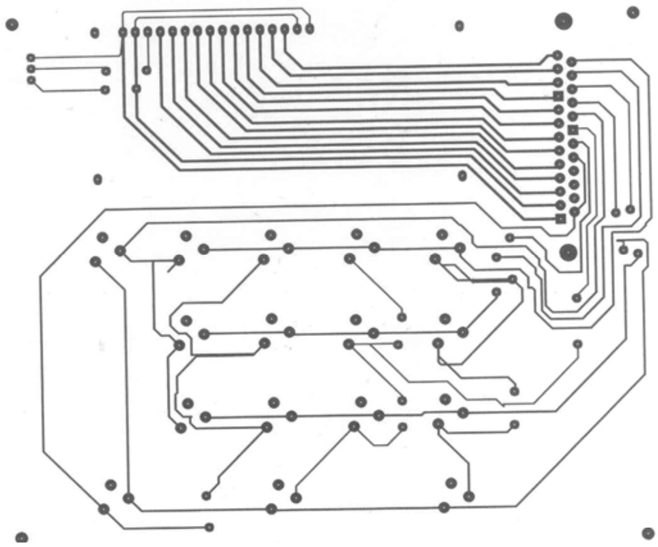
Motor Program

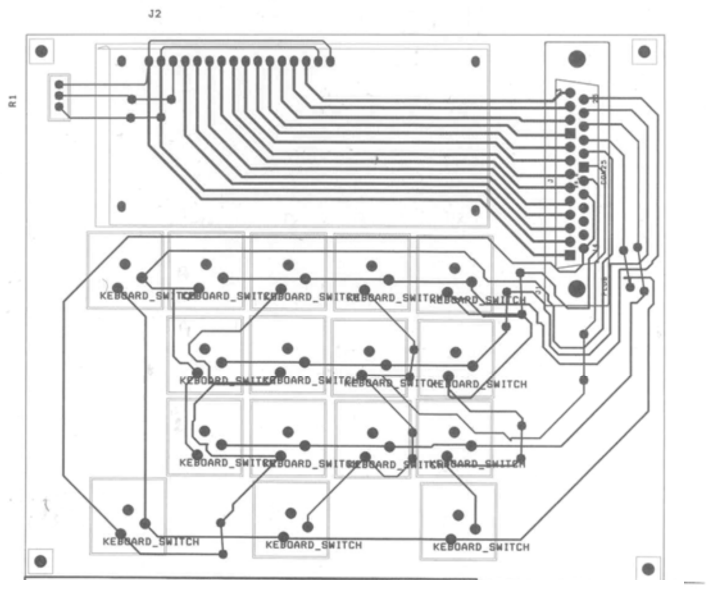
```
//#include<reg51.h>
//#include<lcd_iop.h>
void motor_forward();
void motor_back();
//void motor_down();
//void motor_up();
void MOTOR1_P1_ON();
void MOTOR1_P1_OFF();
void MOTOR1_P2_ON();
void MOTOR1_P2_OFF();
void MOTOR1P1_ON();
void MOTOR1P1_OFF();
void MOTOR1P2_ON();
void MOTOR1P2_OFF();
void delay();
double speed,value;


//P1=0xFF;

/*motor()
{

        //TR1=1;
  //while(1)
     //{//while(
     // if(P33==0)
    MOTOR1_P1_ON();
                //delay();
     // else
                //delay();
      //MOTOR1_P2_ON();
                //delay();
                //MOTOR1_P2_OFF();
                //delay();
     //}
}*/

void MOTOR1_P1_ON()
{
        P13=0;    //  Always enable N-type mosfet first to enhance protection
        P10=0;
}
void MOTOR1_P1_OFF()
{
        P10=1;    // Always disable the P-type mosfet first
        P13=1;
}
void MOTOR1_P2_ON()
{
        P12=0;
        P11=0;
}
void MOTOR1_P2_OFF()
```

```
{
            P11=1;
            P12=1;
}
void MOTOR2P1_ON()
{
            P17=0;
            P14=0;
}
void MOTOR2P1_OFF()
{
            P14=1;
            P17=1;
}
void MOTOR2P2_ON()
{
            P16=0;
            P15=0;
}
void MOTOR2P2_OFF()
{
            P15=1;
            P16=1;
}
void motor_forward()
{ MOTOR2P2_OFF();   // Disable the another direction first before enable the desired direction
  MOTOR2P1_ON();
}
void motor_back()
{
 MOTOR2P1_OFF();
 MOTOR2P2_ON();
}
/*void motor_up()
 {
  void MOTOR1_P2_OFF();
  void MOTOR1_P1_ON();
 }
void motor_down()
  {
   void MOTOR1_P1_OFF();
   void MOTOR1_P2_OFF();
  }*/
/*void delay()
{unsigned i;
 for(i=0;i<65535;i++);
  //for(j=0;j<65535;j++);
}*/
```

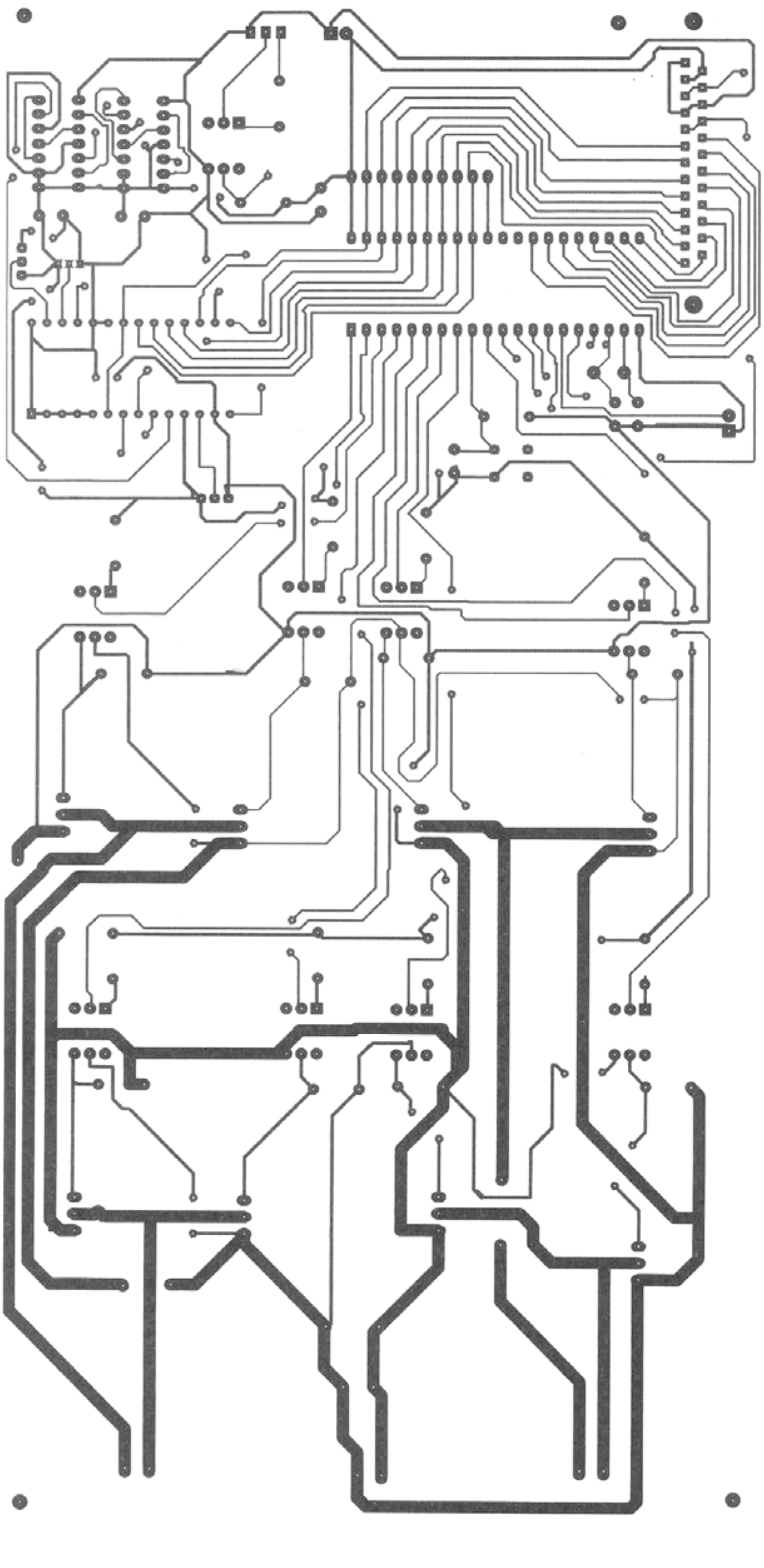
Complete system - Schematic Diagram



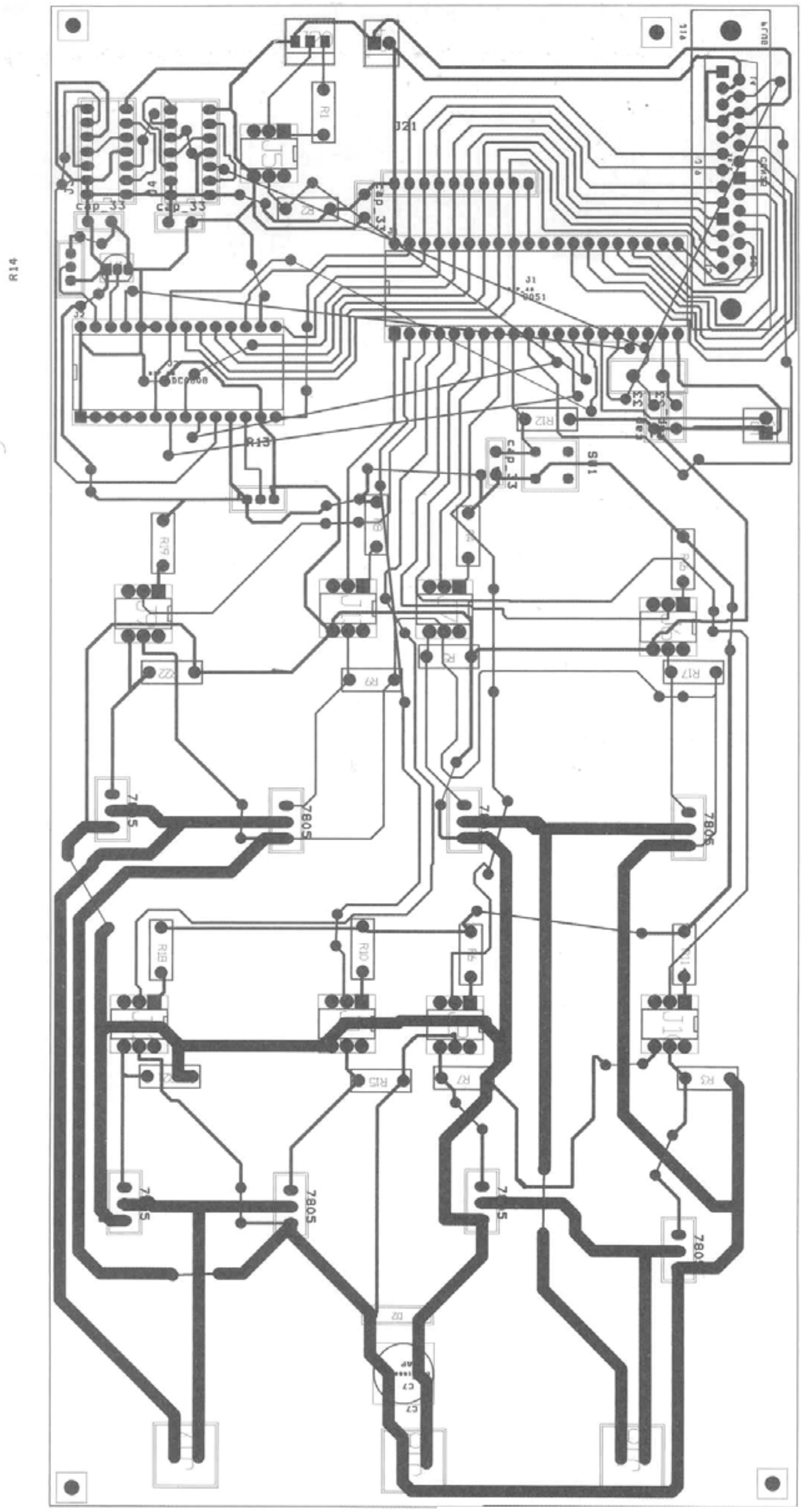




KEYBORAD AND LCD PCB



MAIN BOARD PCB LAYOUT



MAIN BOARD PCB LAYOUT

LCD Pin Description

Pin	**symbol**	**1/0**	**Description**
1	Vss	- -	Ground
2	Vcc	- -	+ 5V power supply.
3	VEE	- -	Power supply to control contrast.
4	RS	I	RS = 0 to select command register, RS = 1 to select date register
5	R/W	I	R/W = 0 for write, R/W =1 for read
6	E	I/O	Enable
7	DB0	I/0	The 8-bit data bus
8	DB1	I/0	The 8-bit data bus
9	DB2	I/0	The 8-bit data bus
10	DB3	I/0	The 8-bit data bus
11	DB4	I/0	The 8-bit data bus
12	DB5	I/0	The 8-bit data bus
13	DB6	I/0	The 8-bit data bus
14	DB7	I/0	The 8-bit data bus