RESEARCH THESIS

Automation of Neutron Activation Analysis

A DISSERTATION SUBMITTED TO THE

DEPARTMENT OF

ELECTRONICS AND COMMUNICATION ENGINEERING,

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AS A PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN APPLIED PHYSICS & ELECTRONICS

SUBMITTED BY

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DECLARATION

This is to declare that this is my own Research work that I am doing for Masters of Science in Applied Physics and Electronics. No other part of this project has been submitted elsewhere or partially for the award of any degree or paper purpose. Any alternation or any material reproduced of this project has been properly acknowledged.

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ACCEPTANCE

This paper is submitted to the Department of Electronics and Communication Engineering of East West University. Also this is accepted as to style and content for the degree requirement for MASTERS OF SCIENCE in APPLIED PHYSICS AND ELECTRONICS under complete supervision of the undersigned.

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ABSTRACT

Utilization of power research reactor is often pursued due to increasing rate of the neutron activation analysis (NAA) activities. There are a lot of samples available obtained from different fields for measurement. Often requires a number of human interventions for data processing in NAA. Otherwise liquid nitrogen is wasted for proper utilization. Automation of NAA consists of some methods those can improve the efficiency and reliability of analysis. Automation of NAA requires a significant effort for the development and implementation of software, hardware and data management. The hardware requires a mechanical design for auto sample changer by pneumatic system. The job program for routine automation is provided by MAESTRO-32 software. When a counting is stopped, it executes an application program for serial interfacing with microcontroller. The microcontroller executes its instructions for sample changing by pneumatic system. The sample goes through the pneumatic system from rotary rack to the detector. Then the microcontroller sends an acknowledgement to the windows application program and the job program is started for next counting.

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Chapter 1
Introduction

1.0. INTRODUCTION

Neutron activation analysis (NAA) is a method for both qualitative and quantitative determination of elements in small amount of sample based on the measurement of characteristic radiation from radionuclides formed directly or indirectly by neutron irradiation of the material. This method was first discovered in 1936 by Hevesy and Levi [1], who determined the contents of Dy and Eu in a rare-earth mixture.

Neutron activation is a nuclear phenomenon. When a neutron interacts with a target nucleus a compound nucleus is formed. The compound nucleus has a certain finite life-time (10^{-13} — 10^{-15} seconds) during which it remains in a highly excited state due to the high binding energy and kinetic energy of the neutron in the nucleus. De-excitation of the compound nucleus can occur in different ways that are independent of the way the compound nucleus is formed. Each of these processes has a certain probability, depending on the nuclear cross-section of each mode, which is related to the excitation energy of the compound nucleus.

Hence the reactions may occur are elastic scattering (n,n), inelastic scattering (n,n'), radiative capture (n,γ), charge particle reactions (n,α), (n,p) or (n,2n) and fission reaction (n,f) depending on the nuclear cross-section of each mode. The most favorable and important nuclear reaction in NAA is radiative capture (n, γ), in which the excited nucleus goes to a lower energy state by the emission of one or more γ-rays. The resulting nuclide is usually radioactive, which is usually referred to as the radionuclides.

Thus, two main features of (n, γ) neutron activation analysis (NAA) are making its standardization potentially easyand accurate: the high penetrability of matter for neutrons and the existence of a delayed signal (besides the prompt gammas), viz. the characteristic radiation emitted in the decay with a specific half life of the unstable nuclei formed by (n, γ) reaction. Hence, standard and the studied sample can be excited simultaneously i.e., they can be co-irradiated, and the induced signals of both can be measured successively after a suited time following the end of irradiation. Other consequences of these two features are that NAA is a bulk analysis method with multi-elemental composition, that the relation between element concentration and measured signal is nearly matrix-independent, that matrix preparation can be kept simple - thus minimizing the risk for loss and contamination and that treatment of sample (and standard) after irradiation is possible.

Various neutron activation analysis techniques use neutron energies of a particular range for irradiation, e.g. low energy or thermal neutron (10^{-3} to 0.5 eV), mid range or 'epithermal' neutron (0.5 to 0.01 MeV}, and high energy or fast neutron (0.5 to 5 MeV). Other techniques use the entire spectrum of neutron energies. In general, the

cross-section for (n, γ) reactions decreases with increasing neutron energies ($\sigma \propto {}^{1}/_{\sqrt{E}}$) with the exception of resonance-capture cross- sections, which peak *at* specific neutron energy [2]. Thus, the thermal neutron cross-sections for many elements are high compared with those for other energy neutrons. For this reason, NAA by thermal neutrons is extremely sensitive for trace level work.

1.1. BACKGROUND STUDY

The basic requirement for neutron activation analysis is neutron source. The term neutron was first proposed by Rutherford in 1920 and finally discovered by Chadwick in 1932. There are different ways to obtain neutrons are used in nuclear chain reaction. Neutrons are produced from the radioactive decay of uranium atom. Uranium is a principle element in nuclear fission reaction because it's high fission probability. Nuclear fission was discovered by Lise Meitner , et al 1939.

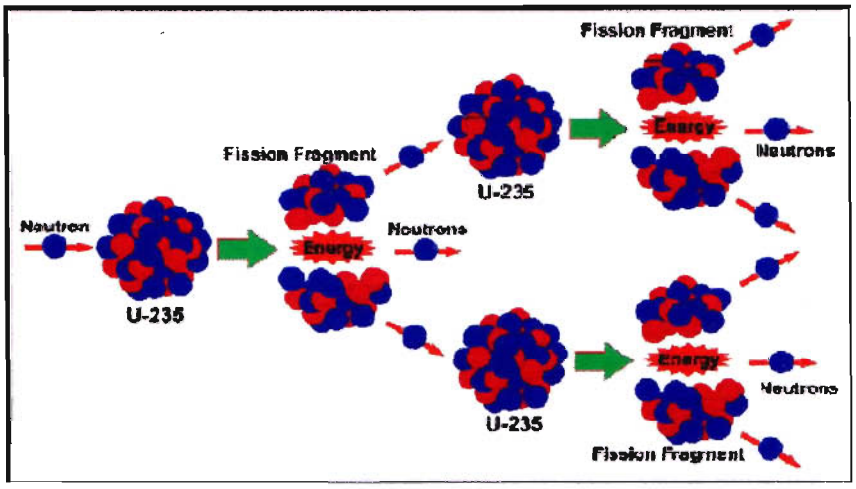

FIG 1.1: Nuclear chain reaction

When a uranium or other suitable nucleus fissions, it breaks up into a pair of nuclear fragments and releases energy. At the same time, the nucleus emits very quickly a number of fast neutrons, the same type of particle that initiated the fission of the uranium nucleus. This makes it possible to achieve a self-sustaining series of nuclear fissions; the neutrons that are emitted in fission produce a chain reaction, with continuous release of energy.

When a U-235 atom splits, it gives off energy in the form of heat and Gamma radiation, which is the most powerful form of radioactivity and the most lethal. When this reaction occurs, the split atom will also give off two or three of its "spare" neutrons, which are not needed to make either of the parts after splitting. These spare neutrons fly out with sufficient force to split other atoms they come in contact with. In theory, it is necessary to split only one U-235 atom, and the neutrons from this will split other atoms, which will split more so on and so forth. This progression does not take place arithmetically, but geometrically. All of this will happen within a millionth of a second.

According to figure-3.2 it's identified that a sample containing rare earth elements will become highly readioactive after an exposure by neutron capture. The binding energy of the neutron produce a compound nucleus in an excited state.Then the activated nucleus decays according to its characteristic half life and emit gamma quanta with specific energy. The quantity of radioactive nuclides is determined by measuring the intensity of characteristic gamma-ray lines in the spectra. The gamma ray emitted from each isotope will not have the same intensity. Therefore the specific gamma ray identifies the presence of particular element and their relative concentrations. The decay constant is inversely proportional to the radioactive half-life. Therefore according to the half life of the nuclides,different nuclides in the irradiated samples can be determined using gamma ray spectroscopy.

Nuclear fission usually occurs amongst the isotopes of the heaviest elements known as Uranium, Thorium etc. Fission is a form of nuclear transmutation because the resulting fragments are not the same element as the original atom. The two nuclei produced are most often of comparable but slightly different sizes, typically with a mass ratio of products of about 3 to 2, for common fissile isotopes Most fissions are binary fissions (producing two charged fragments), but occasionally (2 to 4 times per 1000 events), *three* positively charged fragments are produced, in a ternary fission.

1.2. FACILITIES AT BAEC

The Bangladesh Atomic Energy Commission (BAEC) has been operating the country's only research reactor, a 3 MW TRIGA Mark-II, for the last 28 years almost. The reactor is equipped with a number of irradiation facilities: dry central thimble (DCT),

FIG 1.2: HPGe Detector with MCA in BAEC

neutron beam tubes (tangential, radial piercing, radial-1 and radial-2), pneumatic transfer system, rotary specimen rack (Lazy Suzan), thermal column, etc.

Since its establishment, the BAEC TRIGA reactor has been playing pioneering role in scientific research and in providing services to the people. For example, the radioisotopes produced in this reactor are being used in different nuclear medicine centers of the country for both diagnostic and therapeutic purposes. On the other hand, with a view to opening a new avenue of fundamental and applied research in the country, a number of different experimental facilities were installed around the reactor in early nineties of the last century.

With the aim of socio economic development of the country, these facilities are being used in various fields of research and utilization, such as, isotope production, material research using neutron scattering, materials characterization by neutron radiography, qualitative and quantitative assessment of elements in variety of sample matrices and nuclear data measurements using neutron activation analysis as well as training and service as centers of excellence in Science & Technology.

1.3. UTILIZATION STATUS

1.3.1. Isotope Production

In Bangladesh, almost fourteen nuclear medicine centers and two Institute of Nuclear Medicine run by BAEC are serving millions of people and performing research to extend its application. The aim of radioisotope production using BAEC TRIGA reactor is to fulfill the local demand of short-lived medical radioisotopes and radiopharmaceuticals both for diagnosis and therapeutic purposes. The major facilities of radioisotope production include: ^{99}Tc generator production plant, ^{131}I production plant, ^{131}I Capsule production facility, Quality Assurance/Quality Control facility, etc.

1.3.2. Neutron Scattering

With a view to utilize the reactor for materials research, a Triple Axis Neutron Spectrometer (TAS) has been set up in the radial piercing beam port of the TRIGA MARK-II research reactor. The spectrometer is being effectively used for the studies of structural and characteristic properties of materials for their potential applications. The present scope of research using TAS facilities include: neutron powder diffraction studies for structural characterization of materials like metals, metallic oxides, alloys, ceramics, superconductors and various types of magnetic materials; small angle neutron scattering for determining shape, size and molecular weights of particles in various kinds of biological aggregates and polymers; and texture studies for identification of texture in industrial and structural materials. Various types of materials are studied by the diffraction and Small Angle Neutron Scattering (SANS) techniques using the TAS. For instance, the crystal and magnetic structures of a variety of ferrites, superconducting materials, alloys, amorphous materials, etc. have been studied in the diffraction method [**3**].

1.3.3. Neutron Radiography

Neutron Radiography (NR) facility has been installed at the tangential beam port of the TRIGA research reactor with a view to create opportunity for nondestructive testing of materials using the neutron beam. This beam port has been chosen in order to get a thermal neutron beam with minimum gamma content. The NR facility is being used for research on various materials and quality control of some industrial products. In the existing NR facility only direct film neutron radiography method is being used and characterized various types of materials. For example, detection of corrosion in aluminum, study of the quality of some industrial products (leather, rubber, ceramics, etc.), determination of defects in some shielding materials, determination of defects and water absorption behavior in some building materials, study of defects and water absorption behavior in various wood plastic composites and jute reinforced polymer composites[4].

1.3.4. Neutron Activation Analysis

In spite of advanced nuclear analytical methods developed (PIXE, XRF, TXRF, etc.) in Bangladesh, the (n,γ) reactor neutron activation analysis (NAA) is still preserving its role as a "workhorse" for the diversity of analytical work. Combined with computerized high resolution gamma-ray spectrometry, NAA offers mostly nondestructive, simultaneous multi-element analysis needed in many areas. In using NAA, the relative standardization method is being used in BAEC by employing multi-element standards and certified reference materials. However, the k_0- standardization approach will be implemented in near future. The NAA Group is also involved in nuclear data measurements. The activity of NAA lab of BAEC can be categorized into four dimensions, such as, Research & Development work (R & D), service, project and academic collaboration.

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Chapter 2
OBJECTIVE OF RESEARCH

2.0. SUMMARY

Utilization of power research reactor (RR) is often pursued by increasing the neutron activation analysis (NAA) activities. There are large amounts of samples exist on different fields of applications. Over the years, **International Atomic Energy Agency (IAEA)** has stimulated the worldwide NAA groups for activation analysis. There are some alternative techniques such as X-ray Fluorescence Spectroscopy (XRF), Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma (ICP) Spectroscopy those are not compared by NAA, in most of the NAA labs.

Often requires, a number of human intervention for data processing in NAA. In most of the cases the NAA service requests have to be rejected not because of lack of RR availability, but because of limited capacity in automation and data processing. So it emphasizes the relevance and urgent to support the development of NAA automation procedures and implementation. For this reason it is inevitable to different stages such as automatic sample changers both for irradiation and measurements, more efficient use of detectors, automated data handling and analysis procedures, faster quality control process and reporting software are addressed and developed for analysis.

2.1. BACKGROUND STUDY

NAA is used widely for the commercialization of research reactor services. Lack of automation has been identified which limit the ability of laboratories to service the needs of specific research fields, such as archaeology and epidemiology, where large numbers of samples are required.

Automation of NAA consists of methods those can improve the efficiency and reliability of analysis. Although many of the components already exist commercially and in various laboratories, there is no common interface that allows them to be integrated with local systems available in specific laboratories.

Automation of NAA requires a significant effort for the development and implementation of software, hardware and data management.

2.2. STATEMENT OF PROBLEM

The NAA method has been used in laboratory of INST for multi-element analysis. It is used for both qualitative and quantitative analysis. The total procedure of NAA in INST laboratory is a manual system.

The sample changing in detector is a human operating scheduled process. The sample has to be prepared in the preparation lab after irradiation in the Reactor. The

MAESTRO-32 is an emulation software which combined with multichannel buffer hardware and personal computer and MCA with remarkable power and flexibility.

The emulation continuously shows the spectrum being acquired, operating conditions and other operations such as peak location, insertion of regions of interest and display scaling.
But there are some disadvantages according to this process.

2.2.1. Scheduling Problem

In INST laboratory, the detector for samples counting is being used in the working time (10 am to 4.30 pm) only. so it is not be possible to count enough samples in a day. It is possible to count a lot of samples in term of short live delay but not possible in term of long live delay. If each sample takes two hours for counting, alomost four samples can be possible to count in a day.

2.2.2. Proper Utilization of Liquid Nitrogen

Germanium detectors are semiconductor diodes having a p-i-n structure in which the intrinsic (I) region is sensitive to ionizing radiation, particularly X-rays and gamma rays. Under reverse bias, an electric field extends across the intrinsic or depleted region. When photons interact with the material within the depleted volume of a detector, charge carriers (holes and electrons) are produced and are swept by the electric field to the P and N electrodes. This charge, which is in proportion to the energy deposited in the detector by the incoming photon, is converted into a voltage pulse by an integral charge sensitive preamplifier.

Because germanium has relatively low band gap, these detectors must be cooled in order to reduce the thermal generation of charge carriers (thus reverse leakage current) to an acceptable level. Otherwise, leakage current induced noise destroys the energy resolution of the germanium detector. Liquid nitrogen, which has a temperature of 77 °K is the common cooling medium for such detectors. The germanium detector is mounted in a vacuum chamber which is attached to or inserted into an LN_2 Dewar. The sensitive detector surfaces are thus protected from moisture and condensable contaminants.

But it is a matter that the liquid nitrogen used here only in working hours. Most of the time it is not used in the weekend even public holidays also. But liquid nitrogen is costly.

2.2.3. Human Intervention

Human intervention is needed for element analysis in NAA laboratory. The sample is changed by human in the sample holder for counting. In that case the geometry effect of samples are not same all the time. The spectrum data need to be saved after counting in personal computer. So NAA process requires human intervention continuously. Otherwise the sample changing by the human is sometimes dangerous because of radioactive decay from the sample.

2.3. PURPOSE OF RESEARCH

The aim of this research is to develop an automation of NAA method that can be used in the laboratory of Neutron Activation Analysis, Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Bangladesh. The protocol of automation run continuously without human intervention even non-working hours also. The design of the automation system is developed locally.

2.4. SIGNIFICANCE OF RESEARCH

The expected outcome from this research is a viable approach of doing NAA can be mentioned as follow:

- ✓ Appropriate Technology
- ✓ Saving of foreign currency
- ✓ Adoptation of Technology
- ✓ Proper time utilization
- ✓ Proper liquid nitrogen utilization
- ✓ Ensure quality control in term of geometry effect

Moreover neutron activation analysis has the potential to fulfill the requirements of a primary method of measurement. As such, NAA plays a pre-eminent role in national metrology capabilities. The fundamental difference in implementation and execution of prompt-gamma NAA (PGNAA), namely due to the requirement of neutron beams outside of RR core, puts it beyond the scope of this project. Overall objective of this project contribute to enhanced and sustainable RR utilization by increasing NAA capacity through automation, resulting in more opportunities to engage in scientific research and commercial services.

Chapter 3
NEUTRON ACTIVATION ANALYSIS

3.0. THEORY

Neutron activation is the irradiation of a nucleus with neutrons to produce a radioactive species, usually referred to as radionuclide. The number of radionuclide produced will depend on the number of target nuclei, the number of neutron and on the factor called cross section which defines the probability of activation occurring. If the product is radioactive, it will decay a characteristic half-life. Consequently, the growth of activity during irradiation will depend on the half-life of the product.

A neutron is absorbed by the target nucleus to produce a highly energetic state of the resulting nucleus containing an additional neutron and the excess energy is immediately lost, usually by emission of gamma ray, a photon or alpha particle. The energy of the neutron will affect the nature of the nuclear reaction which occurs and consequently the activation product.[1]

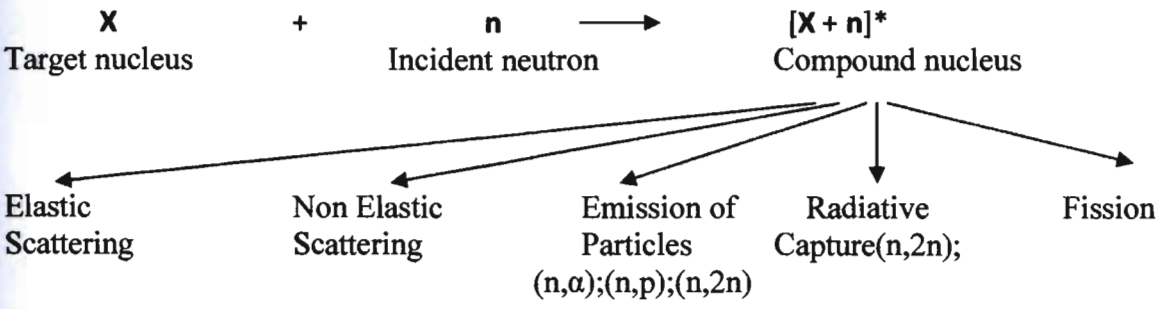

FIG-3.1: Different kinds of interactions

The radioactive capture reaction is denoted as

$$n + {}^{A}Z \rightarrow {}^{A+1}Z^{*} \rightarrow {}^{A+1} + \gamma$$

where

^{A}Z is the target nucleus

$^{A+1}Z^{*}$ is the compound nucleus

Neutrons can exhibit a wide range of energies. In a thermal nuclear reactor with an average energy is about 0.025 eV. A neutron generator is designed to produce fast neutrons with a energy of 14 MeV. The region between thermal and fast neutrons is called the epithermal region, extending from 0.5 eV to 1 MeV. The lower cutoff at 0.5 eV is

defined by the energy below which neutrons will not pass through 1 mm thick cadmium. It is therefore sometimes referred to as the cadmium cut off.

A neutron is absorbed by the target nucleus to produce a highly energetic state of the resulting nucleus containing an additional neutron and the excess energy is immediately lost, usually by emission of a gamma ray, a proton or an alpha particle. The energy of the neutron will affect the nature of the nuclear reaction which occurs and consequently the activation product.

3.1. VARIOUS TYPES OF ACTIVATION ANALYSIS

There are various kinds of methods for the neutron activation analysis. These methods are as follows:

- **Instrumental Neutron Activation Analysis (INAA):**
- **Radiochemical Neutron Activation Analysis(RNAA):**
- **Epithermal Neutron Activation Analysis (ENAA):**
- **Prompt Gamma Ray Neutron Activation Analysis(PGNAA):**

3.2. STANDARDIZATION APPROACHES

There are two main standardization approaches. They are:

3.2.1 Absolute NAA method

The elements to determined in a sample are made radioactive by irradiating the sample with neutrons and the radionuclide formed give of their characteristic radiation such as gamma rays, which are then identified and measured. The activity or number of detected gamma ray of a particular energy is directly proportional to the disintegration rate of the radionuclide, which is directly proportional to the amount of its parent isotope in the sample[2]. In a neutron induced reaction, the growth of th product is dependent on the size of neutron flux. The larger the neutron flux, the greater the rate at which interactions occur,

Activation rate $\propto$ Neutron flux (φ).....(3.1)

The activation rate is also directly proportional to the number of target nuclei present, i.e.,

Activation rate $\propto$ Number of nuclei present(N).....(3.2)

But the total number of atoms per gram is given by,

$$N = N_A / A \quad \text{.....(3.3)}$$

where, N_A is the Avogadro's number and represents the total number of atoms in the atomic weight A of any element.
The total number of target nuclei for a mass W of the element will be,

$$N = WN_A/ A \quad \text{.....(3.4)}$$

However, when there is more than one isotope present in an element, the number of target nuclei must be corrected for the isotopic abundance θ.

$$N = W \theta N_A/ A \quad \text{.....(3.5)}$$

The number of target nuclei is therefore proportional to the mass of the element present; therefore the activation rate is proportional to the mass of the element,

Activation rate α mass of element.....(3.6)

The relationship between activation rate, the number of target nuclei and the neutron flux can be expressed in terms of " cross-section" (σ),

$$\text{Activation rate} = \sigma \varphi N \quad \text{.....(3.7)}$$

where,

N is the number of target nuclei in atoms,
σ is the cross-section, in barn
φ is the neutron flux, in neutrons/cm^2s
Activation rate, in events/s

Substituting equation (3.7) into equation (2.4), we get

$$\text{Activation rate} = \frac{N_A \varphi W \theta}{A} \sigma \quad \text{.....(3.8)}$$

Cross sections are usually expressed in barns which are 10^{28} m^2
The activation rate,

$$\text{Activation rate} = \sigma_{\square} \phi_{th} N + I_{\square} \phi_{epi} N \quad \text{.....(3.9)}$$

However, if the product nuclide is radioactive, it will have a decay rate, which must be taken into account. The radionuclide produced will decay with a characteristic half-life. If there are N^* radioactive nuclei, the rate of decay of the nuclei is proportional to N^*, then

$$\text{Decay rate, } \frac{dN^*}{dt} \propto -N^*$$

$$\text{or, } \frac{dN^*}{dt} = -\lambda N^*$$

where λ is the decay constant, which has a characteristic value for each nuclide. If the equation is integrated between the limits N_0^* at the time zero and N^* remaining at the time t,

$$N^* = N_0^* \exp(-\lambda t) \quad \text{.....(3.10)}$$

In terms of half-life this can be written as ,

$$\frac{N_0^*}{2} = N_0^* \exp(-\lambda T_{1/2})$$

where, $T_{1/2} = \frac{ln2}{\lambda} = \frac{0.693}{\lambda}$

The growth of activity is governed by-

Production rate = Activation rate – Decay rate

$$\frac{dN^*}{dt} = \varphi \sigma N - \lambda N^*$$

The solution of the above equation gives

$$N^* = \varphi \sigma N \{1 - \exp(-\lambda t)\}/\lambda \quad \text{.....(3.11)}$$

The factor $\{1 - \exp(-\lambda t)\}$ is called the saturation factor. The activity or the disintegration rate (A_0) at the end of irradiation time t is then

$$A_0 = \lambda N^* = \varphi \sigma N \{1 - \exp(-\lambda t)\} \quad \text{.....(3.12)}$$

When the irradiation is very long the expression for activity becomes close to the maximum possible activity for a particular neutron flux called the saturation activity(A_s):

$$A_s = \sigma \phi N$$

It is possible to calculate the induced specific activity for a particular length of irradiation, knowing the nuclear constant for the nuclide of interest and the neutron flux:

$$A_0 = WN_A \varphi \sigma \theta \{1 - \exp(-\lambda t)/A \quad \text{.....(3.13)}$$

This is the basic equation used for NAA calculation in absolute method.

$$\text{So, } W = \frac{A_0 A}{N_A \varphi \sigma \theta \{1 - \exp(-\lambda t)\}} \quad \text{.....(3.14)}$$

Usually, in neutron activation analysis, the activity of the radionuclide is measured experimentally in a sample to deduce the unknown mass(W) of the element by the above equation.

Correction must be made for the decay period t_d , the cooling time (time from the termination of irradiation to the time of measurement),

$$W = \frac{A_0 A}{N_A \varphi \sigma \theta \{1 - \exp(-\lambda t)\} \exp(-\lambda t_d)} \quad \text{.....(3.15)}$$

All the factors on the right of the above equation are, in principle, known or can be measured. Thus, it can be possible to calculate the mass of the element.

The difficulty of accuracy measurement of σ leads to the difficulty of measuring neutron

flux density φ and also the value of φ Changes depending on time and the location in most powerful neutron sources like nuclear reactors, sample and its container cause perturbation of neutron flux density(flux depletion and self shielding of neutrons), which is very difficult to evaluate precisely.
The calculation of the weight of the element in the sample can be made from the simple relation:

$$W_x = W_s * R_x / R_s \quad \text{.....(3.16)}$$

where

W_x = The weight of the element concerned in the sample to be analyzed
W_s = The weight of the element in the standard sample
R_x = The corrected counting rate of the full-energy peak of this gamma rays employed for the identification of the nuclide produced in the sample
R_s = The corrected counting rate of the full-energy peak of the same energy obtained with the standard sample.

Both counting rates must be measured under the same geometrical conditions, and both have to be normalized at fixed geometrical conditions. When the sensitivity of the activation analysis is defined as the activity per weight of an element in the sample, A/W the following eqn can be obtained:

$$A/w = \{\sigma\phi\theta w N_A (1- \exp(-\lambda t)) \exp (-\lambda t_d)\} / A_0 \quad \text{.....(3.17)}$$

Therefore the sensitivity will be greater the higher the cross-section, the higher the isotopic abundance, irradiation time and neutron flux density[3]

3.2.2 Comparative NAA method

From the point view of measuring the activity, it can be said that absolute measurement of activity is not always easy when a sample is not a thin point source. Consequently, a relative measurement method is invariably used, which is the most simple and accurate way of quantifying the concentration of an element. In the relative method an element, with a standard, is irradiated together, and both the sample and standard are counted under exactly the same condition by the same radiation detector. This procedure eliminates any uncertainty in the parameters in the decay scheme and detector efficiency.

The NAA equation by the comparative method is thus reduced to a simplification,

$$\frac{\textit{Weight of element "x" in sample}}{\textit{Weight of element "x" in standard}} = \frac{A_{x^*} \textit{ in sample} \times (e^{\lambda t})_{sam}}{A_{x^*} \textit{ in sample} \times (e^{\lambda t})_{std}}$$

$$W_{sam} / W_{std} = R_{sam} (e^{\lambda t})_{sam} / R_{std} (e^{\lambda t})_{std} \quad \text{.....(3.18)}$$

Knowing the counting rates of standard and sample, decay times of standard and sample and mass of the element in the standard, mass of the element in the sample can be calculated.[4]

3.3. CHARACTERISTICS OF NAA METHOD

With the advent of newer multi-elemental chemical methods such as atomic absorption spectroscopy (AAS), inductively coupled plasma spectroscopy (ICP) and total reflection X-ray fluorescence spectroscopy (TR-XRE), there has been much competition with NAA. Although there are many situations in which NAA has theoretically better analytical characteristics than other methods of elemental analysis, it is important to remain realistic in evaluating the role of NAA. Therefore, the most typical analytical characteristics of NAA are as follows:

- ✓ Sensitivity and applicability for minor and trace elements in a wide range of matrices.
- ✓ An inherent potential for accuracy compared to other analytical technique. Since the theoretical basis of NAA is well understood, a complete uncertainty budget can be made.
- ✓ The totally independent nature of the method as a nuclear-based property in contrast to the electronic nature of most other analytical techniques.
- ✓ The possibility of performing non-destructive analysis using instrumental neutron activation analysis.
- ✓ High specificity based on the individual characteristics of the induced radionuclides.
- ✓ The capability of INAA for multi-element determination, often allowing 30 to 40 elements to be determined in many matrices.

In cases where the induced radionuclides of trace elements are marked by matrix activity, radiochemical separation provides interference free detection limits close to the theoretical ones. Thus, in the radiochemical mode of NAA (RNAA) the technique has other advantageous feature [5]

3.4. ADVANTAGES AND LIMITATIONS OF NAA

NAA can be treated as the "referee" method due to its excellent sensitivity (down to the ppm, ppb or even to the ppt level) attainable for many elements. This allows NAA to be classified as an extremely powerful analytical method for which all sources of systematic or random variation are identifiable and predictable down to the limits of detection, so that, among a variety of other applications, it is eminently suited for the certification of reference materials.

NAA is bulk analysis method with multi – element composition, that the relation between element concentration and measured signal is nearly matix – independent, that matrix preparation can be kept simple thus minimizing the risk for loss and contamination and that treatment of sample after irradiation is possible.

NAA has some limitations, such as the dependence on an irradiation facility (preferably a nuclear reactor) and the threshold imposed by legal safety regulations for the

manipulation of radioactive materials. It is the comparatively lengthy analysis procedure. Indeed, in extreme trace analysis and if long-lived radionuclides are involved, irradiation periods of many hours or even days and measuring periods of tens of hours (per sample) are often required. Considerable decay periods, which are occasionally necessary to reduce disturbing [matrix] activities when non-destructive work is carried out. The way to remedy these inconveniences is by turning to larger samples, higher neutron fluxes and more efficient counting devices (i.e., larger Ge detectors).

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Chapter 4
EXPERIMENTAL FACILITIES

4.0. INTRODUCTION

In order to perform the NAA experiment, the basic requirements are the source of neutron preferably the nuclear reactor and the device to detect the gamma spectrum of irradiated samples, the germanium gamma spectrometry system is used. Some of those experimental facilities are given below:

4.1. NEUTRON SOURCE

A neutron source is a device that emits neutrons. There are a wide variety of different sources, ranging from hand-held radioactive sources to neutron research facilities operating research reactors. Depending upon neutron energy, neutron flux, size of the source, costs and government regulations, these devices find use in a diverse array of applications in areas of physics, engineering, medicine, nuclear weapons, petroleum exploration, biology, chemistry, nuclear power and other industries.

4.1.1. Small sized devices

Radioisotopes which undergo spontaneous fission

Certain isotopes undergo spontaneous fission with emission of neutrons. The most commonly used spontaneous fission source is the radioactive isotope californium-252. Cf-252 and all other spontaneous fission neutron sources are produced by irradiating uranium or another transuranic element in a nuclear reactor, where neutrons are absorbed in the starting material and its subsequent reaction products, transmuting the starting material into the SF isotope. Cf-252 neutron sources are typically 1/4" to 1/2" in diameter and 1" to 2" in length. When purchased new a typical Cf-252 neutron sources emit between 1×107 to 1×109 neutrons per second but, with a half life of 2.6 years, this neutron output rate drops to half of this original value in 2.6 years.

Radioisotopes which decay with alpha particles packed in a low-Z elemental matrix

Neutrons are produced when alpha particles impinge upon any of several low atomic weight isotopes including isotopes of lithium, beryllium, carbon and oxygen. This nuclear reaction can be used to construct a neutron source by intermixing a radioisotope that emits alpha particles such as radium or polonium with a low atomic weight isotope, usually in the form of a mixture of powders of the two materials. Typical emission rates for alpha reaction neutron sources range from 1×10^{6} to 1×10^{8} neutrons per second. As an example, a representative alpha-beryllium neutron source can be expected to produce approximately 30 neutrons for every one million alpha particles. The useful lifetime for these types of sources is highly variable, depending upon the half life of the radioisotope

that emits the alpha particles. The size and cost of these neutron sources are also comparable to spontaneous fission sources. Usual combinations of materials are plutonium-beryllium (PuBe), americium-beryllium (AmBe), or americium-lithium (AmLi). The neutron initiators of early nuclear weapons used a polonium-beryllium layers separated by nickel and gold until a neutron pulse was desired[1].

Radioisotopes which decay with high energy photons co-located with beryllium or deuterium

Gamma radiation with an energy exceeding the neutron binding energy of a nucleus can eject a neutron. Two examples and their decay products:

- $^{9}Be + >1.7$ Mev photon $\rightarrow$ 1 neutron + 2 ^{4}He
- ^{2}H (deuterium) + >2.26 MeV photon $\rightarrow$ 1 neutron + ^{1}H

Sealed tube neutron generators

Some particle_accelerator-based neutron generators exist that work by inducing nuclear fusion between beams of deuterium and/or tritium ions and metal hydride targets which also contain these isotopes.

4.1.2. Medium-sized devices

Plasma focus and plasma pinch devices

The plasma focus neutron source (see dense plasma focus, not to be confused with the so-called Farnsworth-Hirsch fusor) produces controlled nuclear fusion by creating a dense plasma within which ionized deuterium and/or tritium gas is heated to temperatures sufficient for creating fusion.

Light ion accelerators

Traditional particle accelerators with hydrogen (H), deuterium (D), or tritium (T) ion sources may be used to produce neutrons using targets of deuterium, tritium, lithium, beryllium, and other low-Z materials. Typically these accelerators operate with voltages in the > 1 MeV range.

High energy photoneutron/photofission systems

Neutrons (so-called photoneutrons) are produced when photons above the nuclear binding energy of a substance are incident on that substance, causing it to undergo giant_dipole resonance after which it either emits a neutron (photodisintegration) or undergoes fission (photofission). The number of neutrons released by each fission event is dependent on the substance. Typically photons begin to produce neutrons on interaction with normal matter at energies of about 7 to 40 MeV, which means that megavoltage photon radiotherapy

facilities may produce neutron_radiation as well, and require special shielding for it. In addition, electrons of energy over about 50 MeV may induce giant dipole resonance in nuclides by a mechanism which is the inverse of internal_conversion, and thus produce neutrons by a mechanism similar to that of photoneutrons[1].

4.1.3. Large sized devices

Nuclear fission reactors

Nuclear fission which takes place within in a nuclear reactor produces very large quantities of neutrons and can be used for a variety of purposes including power generation and experiments. Subcritical reactors can be also used.

Nuclear fusion systems

Nuclear fusion, the combining of the heavy isotopes of hydrogen, also has the potential to produce large quantities of neutrons. Small scale fusion systems exist for research purposes at many universities and laboratories around the world. A small number of large scale nuclear fusion systems also exist including the National Ignition Facility in the USA, JET in the UK, and soon the recently started ITER experiment in France.

High energy particle accelerators

A spallation source is a high-flux source in which protons that have been accelerated to high energies hit a target material, prompting the emission of neutrons[2].

4.2. NUCLEAR REACTOR

A nuclear reactor is a device in which a controlled nuclear chain reaction can be initiated ans sustained to produce enegy. During a nuclear fission not only a large quantity of energy is released, but also number of neutrons are also emitted and some of which can be utilized for causing fission of other nuclei. If this happens, then more neutrons will become available after the second generation of fission reaction. These can be further utilized to produce fission in the third generation .Thus the fission reactions, under favorable conditions, going through the chain without the intervention of any external agent, which means that the chain reaction can go on as self sustaining process. Since, some energy is released in each fission such self-sustained fission chain reaction of a large number of nuclei can release a very largy quantity of energy.

The principal of self-sustained fission chain reaction was first realized in practice by the famous Italian Physist Enrico Fermi in 1942. He and his members successfully operated the nuclear reactor or pile in the university of CHICAGO in the USA. The nuclear reactor is thus a device within which self sustained fission chain reaction may be made to proceed in a controlled manner.

4.2.1. TRIGA MARK- II Research Reactor

In general, samples are irradiated by 3 MW TRIGA MARK- II research reactor at the Atomic Energy Research Establishment (AERE), Savar, Dhaka. A partial view of the 3 MW TRIGA MARK- II research reactor is shown in Fig.4.1. The characteristic of this reactor is clear from the name "TRIGA" which is a combination of the words Training, Research, Isotope production and name of the manufacturing company GA (General Atomic Company, USA). This reactor attained critically in the 14th September, 1986 is the first nuclear reactor in Bangladesh. Through the successful implementation of the reactor project and subsequent reactor start-up, Bangladesh has entered the nuclear arena for the first time to create a base for peaceful uses of atomic energy in the country. The reactor has been designed for operation under three operation modes namely, Steady State Mode, Squeare Wave Mode and Pulse Mode.

The Steady state mode of operation could be performed under two cooling modes: Natural Convectin Cooling Mode (NCCM) and Forced Convection Cooling Mode (FCCM).

For pulsing with maximum reactivity insertions achieving a peak power of about 852 MW. The reactor is housed in a hall of 20.11m x 23.46m having a height of 17.37m. The control room and the equipment for ventilation and other services systems are located in the adjoining four storied building having same height as the reactor hall.[3]

Table 4.1: Principal design parameters of the TRIGA MARK- II reactor

Maximum steady state power level:	3 MW
Fuel element design:	
Fuel- moderator material	U-ZrH
Uranium content	20 wt %
Uranium enrichment	19.7% U-235
Burnable poison	0.47 wt % Erbium
Shape	Cylindrical
Overall length of fuel	38 cm (15 inch)
Outside diameter of fuel	3.63 cm (1.43 inch)
Cladding material	Type 304 stainless steel
Number of fuel elements:	100
Maximum excess reactivity:	7.69 % Δk/k
Reactivity loss due to equilibrium Xe:	2.5 % Δk/k
Number of control rods:	
Shim / safety	4
Regulating	1
Safety / transient	1
Total reactivity worth of control rods	12.785Δk/k
Reactor cooling:	Forced down flow of pool Water (above 500 kW)

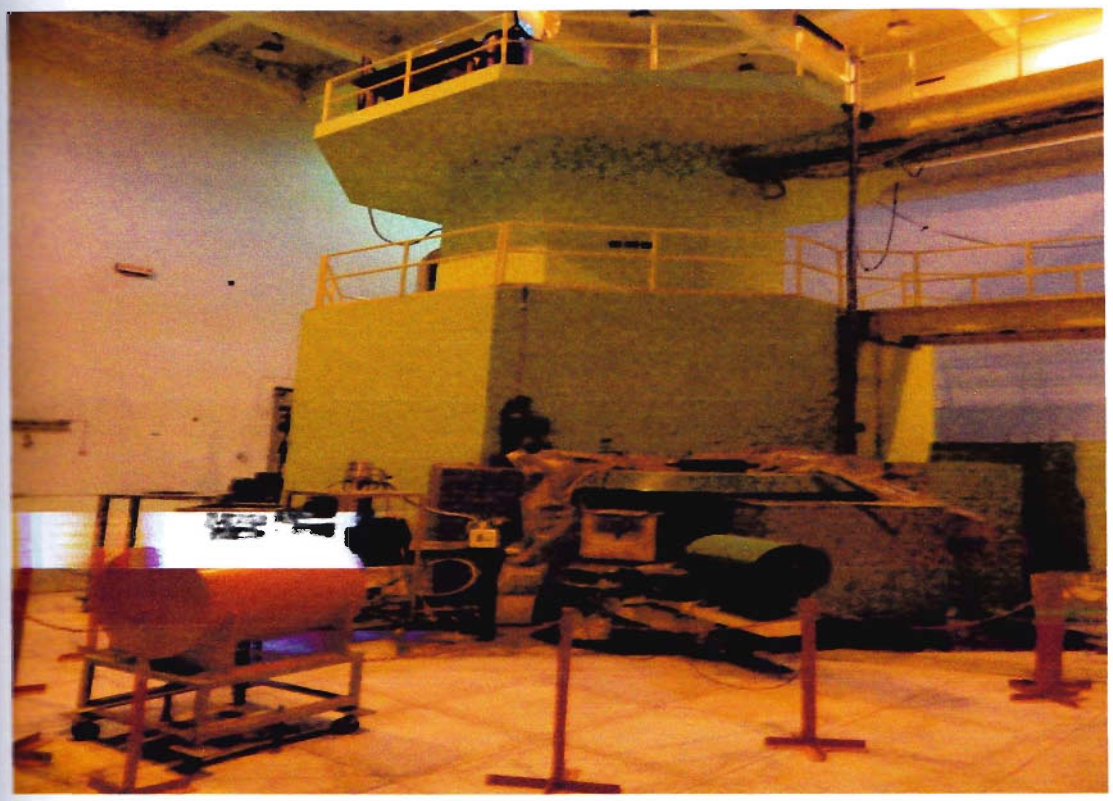

FIG 4.1: A partial view of TRIGA MARK-II RESEARCH REACTOR.

FIG 4.2: Upside view of TRIGA MARK-II RESEARCH REACTOR.

FIG 4.3: Control room of TRIGA MARK-II RESEARCH REACTOR.

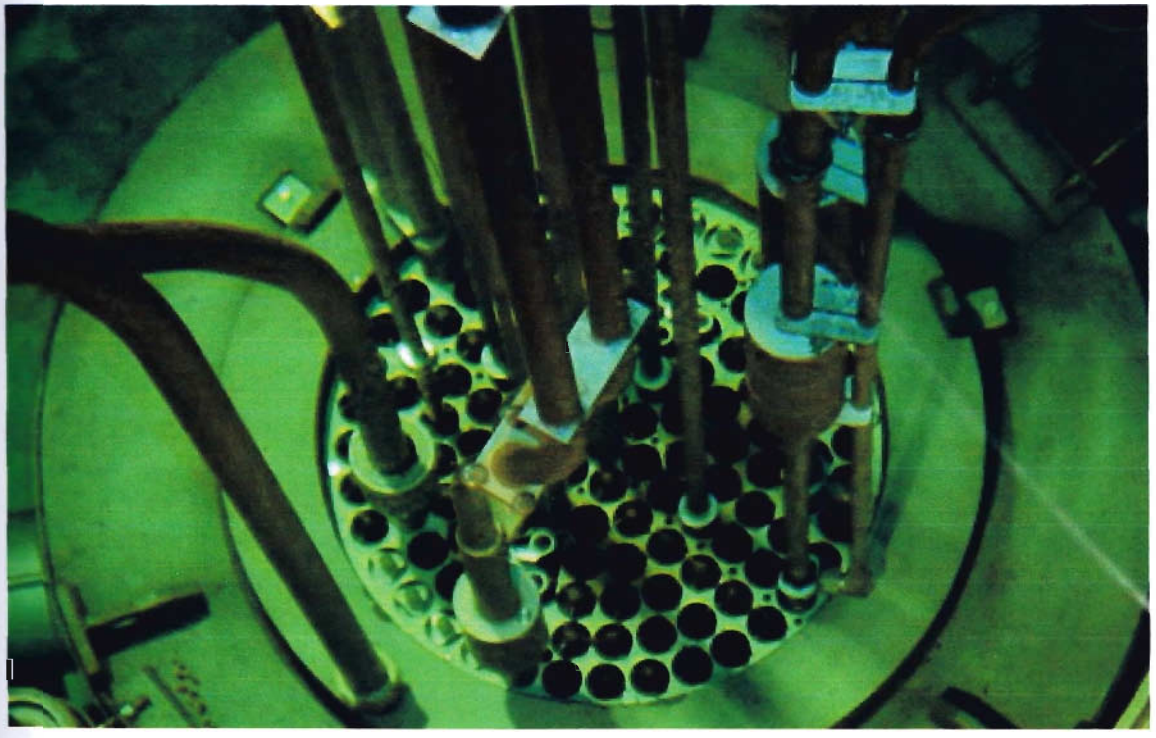

FIG. 4.4 : Cross-sectional view of TRIGA MARK- II reactor core

A brief description about the component of TRIGA MARK- II research reactor is given below:

4.2.1.1. Reactor core

The reactor core, which is the bottom of the reactor tank, has a 0.63 cm thick wall having an inside diameter of 2 m and a depth of 8.2 m. Fig. 4.4 shows the cross-sectional view of TRIGA MARK- II reactor core. The reactor core and reflector assembly is a cylinder approximately 1.1 m in diameter and 0.89 meter high. The reactor core consists of a lattice of fuel-moderator elements, graphite dummy elements and control rods. A graphite reflector and a 5 cm thick lead gamma shield surround the core. The entire assembly is bolted to a stand that rest on the bottom of the reactor tank. The outer wall of the reflector housing extends 0.8 m above the top of the core to ensure retention of sufficient water for after-heat removed in the event of a tank drain accident. Cooling of the core is provided by natural circulation of up to 500 kW power level and by forced down flow circulation of tank water for higher powers, which is, in turn, cooled and purified in external coolant circuits. In case of loss of cooling water in the reactor tank there is a provision of emergency core cooling system with roof top back up system.

4.2.1.2. Fuel-Moderation elements

There are total of 100 fuel elements in the reactor core. The fuel is solid, homogeneous mixture of Eu-ZrH alloy containing 20% by weight of uranium enriched to about 19.7% ^{235}U and about 0.47% by weight of Erbium. The H/Zr ratio is approximately 1.6. Each element is clad with 0.051 cm thick stainless steel can. Two sections of graphite are inserted in the can, one above and one below the fuel, to serve as top and bottom reflectors for the core.

4.2.1.3. Reflector

The reflector of TRIGA reactors is a ring shaped block of graphite that surrounds the core radially. It is 30.5 cm thick radially, with an inside diameter of 45.7 cm and height of 55.9 cm. The graphite is protected from water penetration by a leak-tight welded aluminum can.

4.2.1.4 Control rod

There are six boron carbide control rods-safety, shim and regulating operate in perforated aluminum guide tubes. Each control rod is a sealed aluminum tube containing powdered boron carbide as a neutron poison. The control rods are approximately 51 cm long.

4.2.1.5. Reactor Tank

The reactor tank consists of an aluminum vessel installed in the reactor shield structure. The tank has an inside diameter of approximately 1.98 m and a depth of 6.25 m. A 2 by 2 inch aluminum channel used for mounting the ion chambers and underwater lights is attached to the top of the tank.

4.2.1.6. Reactor shield

The reactor shield is a reinforced concrete structure standing 7.9 m above the reactor hall floor. The lower octagonal portion is 6.6 m across the flats. The beam ports are installed in the shield structure with tabular penetrations through the concrete shield and the reactor tank water, and they terminate either at the reflector assembly or at the edge of the reactor core. The radial shielding of the core is provided by a minimum of 2.29 m of concrete having a minimum density 2.75 g/cm3, 45.7 cm of water, 19 cm of graphite and 5 cm of lead. The heavy shield was made using locally available ilmenite and magnetite from beach sand of Cox's Bazar.

4.3 IRRADIATION FACILITIES

The TRIGA MARK- II research reactor is designed to provide intense fluxes of ionizing radiation for research, training and isotope production. Experiments with the TRIGA reactor can be carried out using the following facilities:

1. Rotary specimen rack (Lazy Susan)
2. Pneumatic transfer system
3. Central thimble
4. Beam port facilities

4.3.1. Lazy Susan

The Lazy Susan assembly consists of a stainless steel rack that holds specimens during irradiation and ring shaped, seal-welded aluminum housing. The rack supports forty-one (except one) evenly spaced tabular aluminum containers that serve as receptacles for the specimen containers. Each receptacle has an inside diameter of 1.25 inches (31.75 mm) and a height of 10.80 inches and can hold two specimen containers. The open bottom tube provides access for periodic testing of the bottom of the rotary specimen rack housing to determine the extent of accumulation of condensation as leaking water. The internal ring can be rotated around the core for the insertion or removal of samples. A single locking rod orients each tube with respect to the specimen removal tube. The internal rack is the rotated manually for equal irradiation of the samples from the drive mechanism on the center channel assembly. Axial flux distribution in Lazy Susan is given in table (4.3)

Table 4.2: Values of Neutrons flux (n/cm^2/sec) at TRIGA MARK-II Research Reactor, AERE, Savar, Dhaka.

Different position	Epithermal	Thermal
Average flux in reactor core	1.1×10^{13}	5.3×10^{13}
Central tube	1.5×10^{13}	5.56×10^{13}
Rotary rack (at the bottom)	0.26×10^{13}	0.75×10^{13}
G-ring (the last circle of fuel center)	1.0×10^{13}	2.0×10^{13}

4.3.2 Central thimble

The central thimble in the center of the core provides space for the irradiation of the samples at the point of maximum flux. It also provides a highly collimated beam of neutrons and gamma radiation when the water is pneumatically expelled from the section of the thimble above the core.

4.3.3 Beam port facilities

The beam ports provide tubular penetrations through the concrete shield and the reactor tank water, making beams of neutrons and gamma radiation available for a variety of experiments. There are four six-inch diameter beam ports divided into two categories- radial beam ports and tangential beam ports. There are three radial and one tangential beam ports in the TRIGA reactor.

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Chapter 5
GAMMA RAY SPECTROSCOPY SYSTEM

5.0 INTRODUCTION

Gamma ray spectroscopy is the quantitative study of the energy spectra of gamma-ray sources, in term of nuclear laboratories, geochemical or astrophysical. Gamma ray are highest energy from of electromagnetic radiation, being physically exactly likes all other forms (e.g. X rays, visible light, infrared, radio) except for higher photon energy and frequency, and shorter wavelength.

The gamma rays were discovered in 1900 by Villard. Gamma rays are electromagnetic waves of very short wavelength, even shorter than ordinary X-rays and consequently have a very high penetrating power. They are known to be emitted when a nucleus returns from a higher energy state that is excited state. A gamma ray photon is uncharged and created no direct ionization or excitation of the material through which is passes. The detection of gamma rays is therefore critically dependent on causing the gamma ray photon to undergo an interaction that transfers all or part of the photon energy to an electron in the absorbing material.

5.1. INTERACTION OF GAMMA RAY WITH MATTER

The nature of absorption process for gamma ray is essentially different from that of charged particles such as alpha and beta rays. A beam of gamma rays may lose energy but it does not slow down. A well collimated beam of gamma rays show a truly exponential absorption in matter. This is because photons are absorbed or scattered in a single event.

The term ?-interaction refers to the disintegration of atomic nuclei brought about by ?. The gamma ray photons are uncharged and cannot provide any direct excitation or ionization of the material through which they pass. Consequently the detection of gamma rays become complicated and is thus done by causing the gamma ray photon to undergo an interaction that transfers all or part of the photon energy to an electron in the absorbing material. Although a large number of possible interaction mechanisms are known for gamma- rays in matter, only three major types play an important rule in radiation measurements. They are

(a) Photoelectric effect
(b) Compton scattering
(c) Pair production

All these process partially or completely transfer gamma ray energy to electrons in the atom of the interacting medium. These processes are strongly depending on photon energy and the atomic number Z of the interacting material. Other effects such as Rayleigh scattering, Thomson scattering and others are much less important and so ignored in detection process. A brief description of the major processes are given below.

5.1.1. Photoelectric Effect

According to Einstein, when the light of sufficiently high frequency v is incident on a metallic surface, photons of energy hv strike the metal. A photon gives its energy to the electron and the electron is ejected from the metal. This phenomenon is known as photoelectric effect. Thus the photoelectric effect is an interaction process between the incident photon and the atom as a whole.

If the energy hv of the striking photon is less than the energy required to eject an electron out of the material, no electron will be ejected. The minimum energy needed to move an electron from the material is equal to hv_0 where v_0 is known as the threshold frequency and it depends upon the nature of the material. If the frequency of the incident light is just equal to the threshold frequency i.e. $v = v_0$ then the electron is just out of the material but its velocity is D. If v is greater than v_o then the difference in energy $(hv - hv_o)$ is used in giving kinetic energy to the electron. For example, if a k shell electron is ejected (Fig-5.1), the kinetic energy of the photoelectron is

$$E = hv - B_k$$

where,

E = kinetic energy of the photoelectron
B_k = binding energy of the photoelectron in k-shell
Hv = total energy of incident photon
h = Plank's constant = 6.63×10^{34} J.sec

The maximum kinetic energy of the photoelectrons is directly proportional to the incident frequency v and not its intensity.[1]

Probability of photoelectric effect

The probability of this process increases strongly with increasing Z of the material and with decreasing energy of the □ -ray. Therefore photoelectric is the most important process at low energy and the detector of high Z materials.

Full energy absorption

After the ejection of the photoelectron the atom is in an excited state, which returns to the ground state by emission of characteristic X-rays. These have extremely short range because of their low energy. The characteristic X-rays may travel some distance (typically a few millimeters or less) before being reabsorbed through photoelectric interactions with less tightly bound electron shells of the absorber atoms. Although escape of these X-rays can at times be significant, it is assumed that they are all also fully absorbed.

Thus the effect of the photoelectric absorption is the liberation of a photoelectron, which carries off the most of the □ -ray energy. If nothing escapes from the detector, then the sum of the kinetic energies of the electron that are seated must be equal to the original energy of the □ -ray photon and the total photon energy appears as secondary electron kinetic energy. Thus a mono-energetic □ -ray gives rise to a mono energetic peak in the energy distribution corresponding to

the incident photon energy. Photoelectric absorption cannot take place with an unbound electron because of energy and momentum non-conservation.

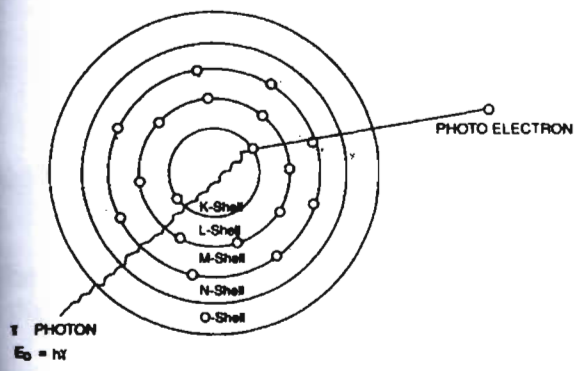


FIG 5.1 Photoelectric emission

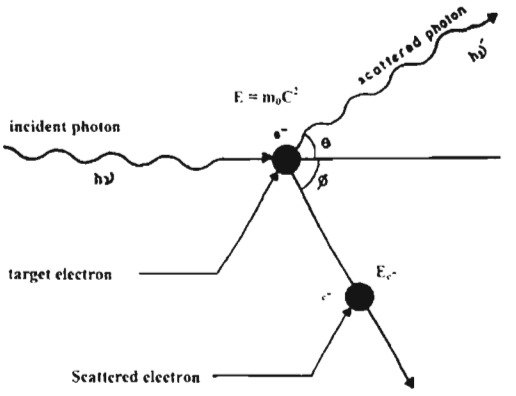


FIG 5.2 : Compton scattering of gamma radiation.

5.1.2. Compton Scattering

As the energy of the radiation increases Compton scattering replaces the photoelectric effect. In Compton scattering the incident photon is scattered by one of the loosely bound atomic electrons and photon moves off at an angle with its original direction and with less energy than it had initially, The Fig.5.2 shows the Compton scattering of gamma ray. The magnitude of energy loss depends on the angle of scattering. This can vary from zero to a large fraction of the incident gamma ray [2]. The energy imparted to the recoil electron is given by the equation:

h —h .....(5.1)

Where hv' is the energy of the scattered photon and can be expressed by the equation:

h = ———————— .....(5.2)

Thus,

h { 1— ———————— } .....(5.3)

where,

h = the incident photon energy
hv' = the scattered photon energy
the rest mass of electron
C = the velocity of light in vacuum
B = the angle between the incident and scattered gamma rays.

Putting different values in the equation (5.3) provides a response function with energy. Two extreme cases are:

1. When $\theta = 0^0$, hv = hv' then $E_e = 0$ i.e., scattering directly forward from the interaction point, E_e is found to be zero and no energy is transferred to the detector.
2. At the other extreme, when the gamma-ray is scattered and 0 the term within the second bracket in equator (5.3) is still less than one and so only a portion of the gamma-ray energy will be transferred to the recoil electron,

At intermediate scattering angles the amount of energy transferred to the electron must be between these two extremes. The inescapable conclusion is that at all scattering angles, less than 100% of the gamma-ray energy is absorbed within the detector.

Thus Compton recoil electrons appear with a wide energy spread, although they are derived from a mono energetic beam of incident gamma photon.

For hv >>m_0c^2, the cross-section for Compton scattering per atom is given approximately

$$\sigma_{comp} = \frac{\pi r_0 z}{2h\nu} [\ln(\Delta h\nu) + 1/2] \quad \text{.....(5.4)}$$

where,

hv is in MeV and r_o is the classical radius of electron having the value of

$r_o = e^2/mpc^2$.

So that cross-section for Compton scattering is proportional to atomic number Z and inversely proportional to the incident photon energy. In Compton scattering often a fraction of gamma energies are deposited because the scattered gamma ray can escape from the crystal. Therefore the output pulse will not correspond to full energy. If however, the detector is sufficiently thick, the scattered photon can be escape and therefore make secondary collisions. Because of multiple scattering it will be absorbed by photoelectric interaction, which becomes increasingly probable as the energy decreases.

5.1.3. Pair Production

Pair production is the process by which electromagnetic radiation can be absorbed and an electron-positron pair is created in the field of a nucleus due to absorption of high γ-rays. The positron is viewed as ejecting an electron from a negative energy state. The hole is the positron. There is a gap of $2m_0c^2$ between the two energy regions, for which at least 1.022 MeV of energy is required to create a positron. The total energy of pair is equal to the energy hv of the incident □ -ray i.e.

$$h\nu = T + 2m_0c^2 \quad \text{.....(5.5)}$$

where, T is the kinetic energy. So we obtain

$$T = h\nu - 2m_0c^2 \quad \text{.....(5.6)}$$

It was found that the possible values of the energy of a free electron either greater than $+m_oc^2$ or smaller than $-m_oc^2$ and that no possible energies for the electron exist between these two limits. This state of affairs is shown in Fig-5.3 where the shaded regions are those in which values of the energy exist.

In the pair production process, the γ -ray disappears and a positron and electron are produced. For the event of occur, the γ -ray energy must be larger than the pair i.e. $2m_oc^2$ = 1.022 MeV. The difference between the incident photon energy E_o and the 1.022 MeV of energy required to create the electron positron pair is imparted as kinetic energy of the two particles,

$$E_{e+} + E_{e-} = E_0 - 1.022 \text{ MeV}$$

where,

E_{e+} = Kinetic energy of the positron
E_{e-} = Kinetic energy of the electron.

The pair production cross section is given by

$$\sigma_{pp} \propto Z^2 \ln(h\nu)$$

i.e. the probability of occurrence of pair production varies directly as the square of atomic number of the absorbing materials and as logarithmic energy of the incident photon. This probability increases rapidly above the threshold energy ($2m_oc^2$). The interaction becomes prominent at the energy region 5-10 MeV

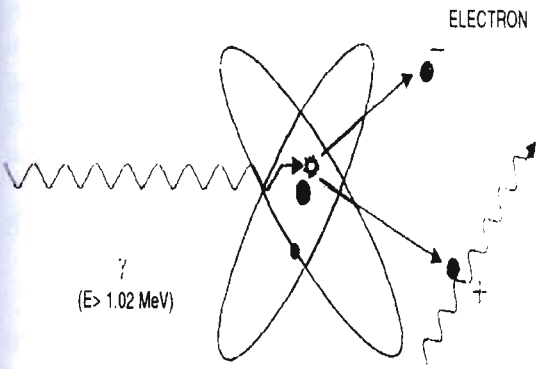


FIG 5.3 : pair production process

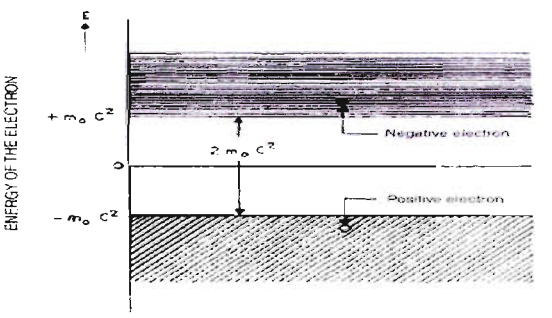


FIG 5.4 : Possible values of the energy of an electron according to the Dirac theory

5.1.4 Positron annihilation

If pair production occurs, the positron slows down in the material by successive collision. When the positron comes to rest, it combines with a nearby electron and then annihilates, producing two 0.511 MeV photons emitted in opposite directions due to energy and momentum conservation law .

$$e^+ + e^+ \rightarrow y + y$$

There exists the probability that one or both annihilation radiation interacts within the detector as follows:

Double photon escape

If both of the annihilation radiation escapes from the detector, the energy absorbed in the detector is $hv-2m_oc^2$; this is called double escape photon.

Single photon escape

If one of the annihilation radiation escapes from the detector and the other is absorbed by photoelectric process, the total energy absorbed in the detector becomes $hv = m_oc^2$. If one of annihilation radiation dissipated a partial energy in the detector, it comes to the continuum.

Full energy absorption

If both of the annihilation radiation is absorbed by photo electric process, the total energy absorbed in the detector will be equal to the incident □ -ray energy. The total absorption co-efficient can be written as,

$\mu = \mu_{P.E} + \mu_{C.S} + \mu_{P.P}$

where,

μ = Total absorption co-efficient
$\mu_{P.E}$ = Absorption co- efficient due to photoelectric effect
$\mu_{C.S}$ = Absorption co- efficient due to Compton scattering
$\mu_{P.P}$ = Absorption co- efficient due to pair production.

5.2 DETECTOR OVERVIEW

The choice of a particular detector for an application depends upon the gamma energy range of interest and resolution and efficiency requirements. Additional considerations include count rate performance, the stability of the detector for timing experiments, and of course, price. The detector must have sufficient material to absorb incident gamma ray energy. Thus a gas filled proportional counter is suitable for 14.4 keV gamma rays because probability of absorption of the gamma ray energy is too low. The types of detectors commonly used are categorized as

[1]Gas filled detectors, [2]Scintillation detectors, [3]Semiconductor detectors

Gas filled detectors are used for x-rays or low energy gamma rays. There can range from ionization chambers to proportional counters to Geiger-Mueller counters.

Scintillation detectors in conjunction with a photo multiplier tube to convert the light scintillation pulses into an electric pulse. Solid crystal scintillators such as CsI or NaI are commonly used, as well as plastics and various liquids.

Semiconductor detectors are newest types available, consisting of large crystal of very pure germanium or silicon or compound crystal. The superior resolution of these detectors have revolutionized data gathering for x-ray and gamma ray measurements.

5.3 HIGH PURITY GERMANIUM (HPGE) DETECTOR

High Purity Germanium (HPGe) detector is one type of semiconductor. The emitted gamma rays from the product nucleus are detected by the HPGe detector. An HPGe detector is a high quality precision system and is being widely used for gamma spectroscopic measurement because of their superior resolution compared to NI crystal. Semiconductor detectors produce the available free charge carriers which can be used for the detection and measurement of incident radiation.

To understand the working principle of semiconductor detector it is necessary to review the function of a p-n junction in reverse mode. If donor impurities are introduced into one side and acceptors into the other side of a single crystal of a semiconductor, say, germanium, a p-n junction is formed .

At the instant of formation of p-n crystal the p side has many holes (majority carriers), and the n is side has many electrons (also majority carriers).At first we consider the p- n crystal with no biasing voltage applied to it. Because of their mutual repulsion, the free electrons on the n side diffuse or spread in all directions. Some diffuse cross the junction, when a free electron leaves the n region, its departure creates a positively charged atom (a positive ion) in the n region. As it enters the p region, the free electron becomes a minority carrier. With so many holes around it, this minority carrier has a short life time, soon after entering the p region, the free electron will fall into a hole. When this happens, the hole disappears and the associated atom becomes negatively charged (a negative ion). Each time an electron diffuses across the junction, it creates a pair of ions. The circled plus sign are the positive ions and circle minus signs are negative ions.

These ions are fixed in crystal structure because of covalent bonding and cannot move around like the free electrons or holes. As the number of ions builds up, the region near the junction is depleted of free electrons and holes. This region is called depletion layer. Beyond a certain point, the depletion layer acts like a barrier to further diffusion of free electrons across the junction. The difference of potential across the depletion layer is called the barrier potential. At 25°C this barrier potential approximately equals 0.3 V for germanium diodes. Now if we apply reverse bias the diode `+' connects to the n side and `-' to the p side. The reverse bias forces free

electrons in the n region away from the junction towards the positive source terminal; also holes in the p region move away from the junction to the negative terminal. The departing electrons leave more positive ions near the junction, and the departing holes leave more negative ions. Therefore, the depletion region gets wider. The greater the reverse bias the wider the depletion layer becomes. The depletion layer stops growing when its difference of potential equals the source voltages. In the same way depletion, i.e., active volume for interaction of gamma rays is created in the semiconductor detectors. The depletion depth d is proportional to sqrt(V/N) , where V is the reverse bias voltage, N is the net impurity concentration in the bulk semiconductor material**[3].**

HPGe detectors are available in two relatively simple geometries:

1. The planer detector in which the electric field is fairly uniform and
2. The co-axial configuration in which the electric field varies inversely with the radial distance from the detector axis.

The gamma ray detection efficiency and response function for a HPGe detector are identical to those observed in a Ge(Li) detector of the same size and shape.

5.4 APPARATUS USED

The HPGe gamma spectrometry system has been used. This system consists of the following parts:

1) HPGe detector:
   - i) Cryostat
   - ii) Liquid nitrogen (LN2) dewar
   - iii) Preamplifier
2) Digital gamma spectrometer
   - i) Amplifier
   - ii) High voltage unit
   - iii) Analog to Digital Converter (ADC)
3) Shielding arrangement

The last 3 items are integrated in a box. The product of Canberra is called DSA and the product of ORTEC is called DSPEC.

5.5. HPGE DETECTOR

5.5.1.Cryostat

Typical detectors are mounted in a vacuum cryostat with a copper coldfinger immersed in liquid nitrogen. The crystal is clamped on the other end of the copper coldfinger. The cryostat (Fig-5.5) provides a path via the copper stem for usually the vacuum is maintained by a passive system, a molecular sieve and placed in the bottom of the coldfinger assembly. This molecular sieve absorbs any gaseous molecules, which can loose inside the cryostat and prevents them from depositing on the surface of the cryostat. Otherwise, the increasing surface contamination

on the crystal would result in increased surface currents, which, in turn, elevates the noise and broadens the resolution.

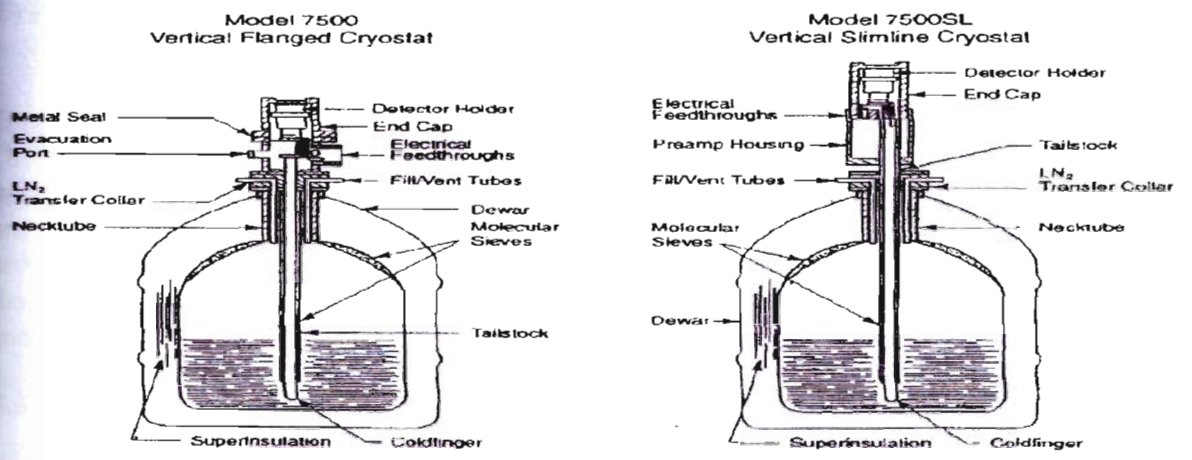


FIG 5.5 Photograph of Cryostat

5.5.2.Liquid Nitrogen (LN_2) Dewar

Germanium has relatively low band gap, these detectors must be cooled in order to reduce the thermal generation of charge carriers (thus reverse leakage current) to an acceptable level. Otherwise, leakage current introduced noise destroys the energy resolution of the detector. Liquid nitrogen (LN2), which has temperature of 77 ° K is the common cooling medium for such detectors. The detector is mounted in a vacuum chamber, which is attached to or inserted into an LN_2 Dewar. The sensitive detector surfaces are thus protected from moisture and condensable contaminants. The liquid nitrogen Dewar serves as reservoir of liquid nitrogen, while the cryostat provides a path via the cooper steam for heat transfer from the detector to nitrogen reservoir.

5.5.3.Preamplifier

The preamplifier associated with radiation detectors performs three essential functions:

a. Conversion of charge to voltage pulse
b. Signal amplification
c. Pulse shaping

Most preamplifiers in use today are charge sensitive and provide an output pulse with amplitude proportional to the integrated charge output from the detector. General-purpose preamplifiers have a RC feedback network which results in a quasi-step function output. For extremely low noise, the feedback resistor is eliminated and the output signal becomes a true step function, which builds in random staircase fashion and is reset by so called pulsed-optical feedback circuitry. For many high count rate and high resolution applications with HPGe detectors, the transistor reset preamplifier (TRP) offers the best performance.

There are two basic types of preamplifiers used in germanium detectors:

(a) Charge sensitive that employs either dynamic charge restoration (RC feedback),
(b) Pulse charge restores type (pulse optical or transistor reset) for discharging the integrator.

Absorption of photon by detector produces a current pulse at the preamplifier input. These pulses are too small to measure without amplification into a measurable electric signal. Therefore, the first element in a signal processing chain is a preamplifier that provides interference between the detector and pulse processing and analyzing electronics. The preamplifier has been located as close as possible to the detector to minimize the signal from noise and captive loading. It also serves as an impedance matcher, presenting high impedance to the detector to minimize loading, while providing a low impedance output to drive succeeding components.

5.6. DIGITAL GAMMA SPECTROMETRY

5.6.1. MCA Emulator

The Multichannel Pulse-Height Analyzer is the primary tool used in nuclear science to record the energy or time spectra available from nuclear radiation detectors. It is often referred to as an MCA (Multichannel Analyzer) or an MCB (Multichannel Buffer). The former term was common when the function was totally contained in a stand-alone instrument. With the advent of the Personal Computer, the auxiliary memory and display functions were shifted to a supporting computer, and the specialized hardware for the pulse-height histogramming was incorporated on a card that plugged into the computer back-plane, or interfaced to the computer via a USB or some other interface cable. Thus, the computer-interfaced MCA is sometimes called a Multichannel Buffer.

For the present experiment, MAESTRO-32 combined with the multichannel buffer (MCB) hardware and personal computer, emulated an MCA with remarkable power and flexibility. The MCB performs the actual pulse-height analysis, while the computer and operating system make available the display facility and data achieving hardware and drivers. The MAESTRO-32 software is the vital link that marries these components to provide meaningful access to the MCB via the user interface provided by computer hardware.

The MAESTRO-32 MCA emulation continuously shows the spectrum being acquired the current operating conditions and the available means. Buffers are maintained in the computer memory to which one spectrum can be moved for display and analysis, either from detector memory or from disk, while another spectrum is collected in the detector.

5.6.2. Analog to Digital Converter

The output from the main amplifier is a peak of nearly Gaussian shape with amplitude proportional to the gamma ray energy which enters the detector. The analog to digital converter (ADC) changes this pulse to a digital signal proportional to the pulse height which is deposited as a count in the appropriate channel number of the analyzer. The ADC may be a separate

module which is placed between the amplifier and the analyzer. The amplitude of the output pulse from the amplifier will be in the range 0 to 10V. The conversion gain of the ADC specifies the number of channel over which the amplitude range will be spread. It would be normal to use a conversion gain of 2048, 4096 and 8192 for multichannel gamma ray spectrometry.

5.7. SPECTROSCOPY AMPLIFIER

Spectroscopy amplifier is the main amplifier in the ray spectroscopy system. The pre amplifier output is fed in to the input of the spectroscopy amplifier to further amplify the signal and also to shape the signals. To optimize spectrometry performance, the spectroscopy amplifier is a key-unit in the gamma ray spectrometry system.

The major role of an amplifier is to convert the preamplifier output signals into a form most suitable for the measurement desired. The amplifier servers to shape as well as further amplify it. The amplifier increases the size of the small signal from the output of the pre amplifier to a pulse of amplitude up to 10 V. Normally there will be a course gain and a fine control for very precise setting of the amplifier gain.

In any counting system operating at count rates of greater than 100 counts per second, when choosing the amplifier pulse shape, there is always a conflict between increasing the signal to noise ratio and preventing pulse pileup. Since pulses from the radiation detectors occur randomly, one pulse from the detector may begin before the preceding detector pulse has terminated. By shortening the time duration of each pulse, pulse overlap can minimized. The amplification achieved in the amplifier is specified by gain of the amplifier, which is formally defined as the ratio of the output pulse height to the input pulse height. The gain of amplifier is usually the same for all pulses entering the amplifiers regardless of size. When the output pulse height is linearly proportional to the input pulse height, the amplifier is linear. For semiconductor detectors, semi Gaussian pulse shaping is best because one achieves better energy resolution with semi Gaussian shaping than with RC pulse shaping.

5.8. BACKGROUND RADIATION PROBLEM

All radiation detectors record some background signal due to the cosmic radiation that continuously bombards the earth's atmosphere and the existence of natural radioactivity in the environment. The background effect is very important for the present work, in detecting gamma rays by high purity germanium (HPGe) detector. The nature of this background varies greatly with size and type of detector and with the extent of shielding that may be placed around it. Sources of background radiation are conveniently grouped into five categories :

1. The natural radioactivity of the constituent materials of the detector itself.

2. The natural radioactivity of the ancillary equipment, supports, and shielding placed in the immediate vicinity of the detector.

3. Radiation's from the activity of the earth surface (terrestrial radiation) walls of the laboratory, or other far away structures.

4. Radioactivity in the air surrounding the detector.

5. The primary and secondary components of cosmic radiation. As the magnitude of the background ultimately determines the minimum detectable radiation level, it is most significant in those applications involving radiation sources of low activity.

5.9. SHIELDING ARRANGEMENT OF THE DETECTOR

The background radiation may cause great harm to the devices of the gamma ray spectrometry system. If such type of radiation are not properly protect, they can changes the physical properties of the devices. So shielding of the detector is essential. A second purpose of detector shielding is to provide a degree of isolation in laboratories where other radiation sources may be used or moved about during the course of a measurement. The shielding not only reduces the background resulting from cosmic radiation and from natural radioactive traces in the; building materials or in the surface of the earth, but also from nearly nuclear facilities and other radiation sources like air, which presumably contains trace of radioactive gases, radon (^{222}Rn) and (^{220}Th) etc. reduction of such type of radiation may be accomplished by maintaining *a* certain minimum distance between the source and sensitive materials or by putting a shield which will effectively absorbed the undesired radiations before they reach the detector. For low background, the conventional shielding materials are lead, steel, mercury and concrete. In our experiment, lead is used as shielding material around the HPGe detector. Because of its high density (11.4 gm/cc) and large atomic number (Z= 82) lead is the most widely used material for the construction of detector shields. A brief description of shielding arrangement used in the experiment is summarized in the **Table** 5.1.

Table 5.1: Description of shielding arrangement around the HPGe detector.

Low Background Shielding	Material	Lead (Pb)
	Form	Square
	Length	14.5 cm
	Height	12.5 cm
	Thickness	4 cm

References

[1] R.H. Pehl and F.S. Goulding, UCRL-l950, p-33 (1969)

[2] Canberra, Co-axial Ge Detector System Introduction Manual, August (1979)

[3] H.A. Enge, Introduction to Nuclear Physics, Addition-Wisely, p-192 (1983)

Chapter 6
AUTOMATION OF NAA

6.0. PROPOSED APPROACH AND STRUCTURE

A set of guideline needed that facilitate the successful implementation of NAA automation within NAA laboratories. The guidelines include the following consideration:

- Design and engineering of hardware components
- Depending on regulatory environment,
- Engineering aspects of the reactor
- Specific requirements of the laboratory

6.1. KEY COMPONENTS

The following four issues have been identified as being key components of Automation:

- Pneumatic transport systems
- Automatic sample changers
- Gamma spectrometry
- Data management, analysis and reporting

6.2. PROCEDURE OF AUTOMATION

The objective of the study is to implement the NAA automation using our locally design stucture. Mention can be made with:

- ✓ Automation of Emulation Software
- ✓ Interfacing between Computer and Micro Controller
- ✓ Pneumatic systems for bring out sample
- ✓ Rotary rack for sample container
- ✓ Pneumatic systems for transfer the sample
- ✓ Handshake signal from micro controller to computer

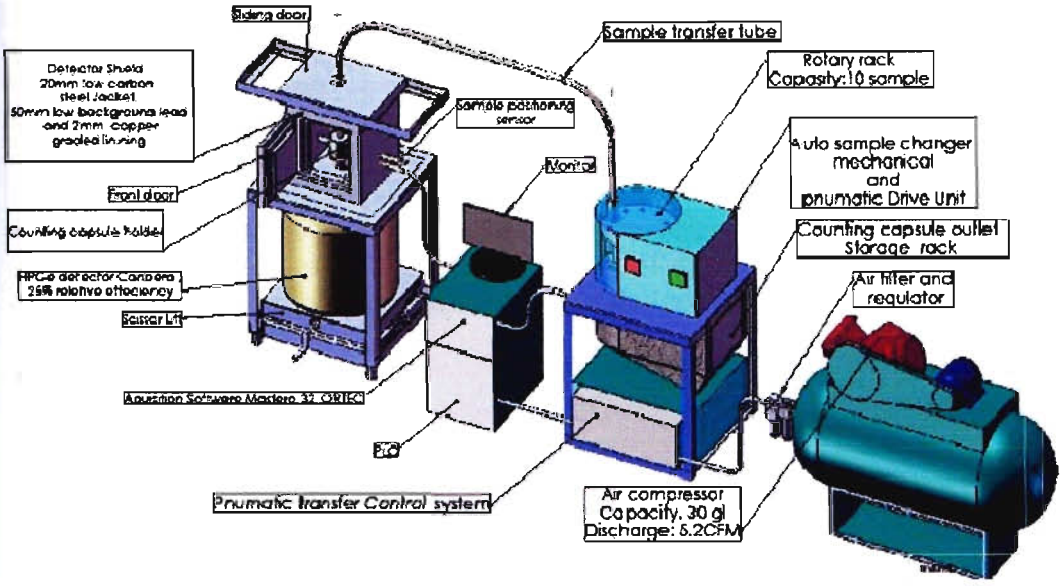


FIG 6.1: 3D Schematic diagram of NAA Automation

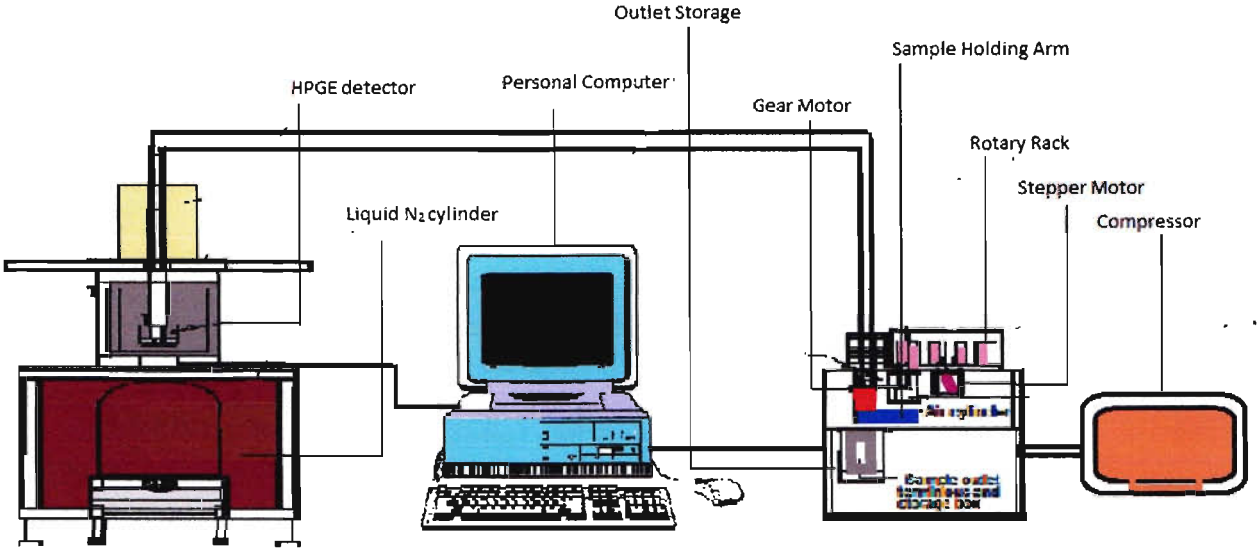


FIG 6.2: 2D Schematic diagram of NAA Automation

6.3. MATERIALS AND METHOD

- **Emulation Software**

The is an emulation software MAESTRO-32 which combined with multichannel buffer hardware and personal computer, emulates and MCA with remarkable power and flexibility. The emulation continuously shows the spectrum being acquired, operating conditions and other operations such as peak location, insertion of regions of interest and display scaling. It also offers the flexibility of constructing automated sequences or job stream.

- **Air Compressor**

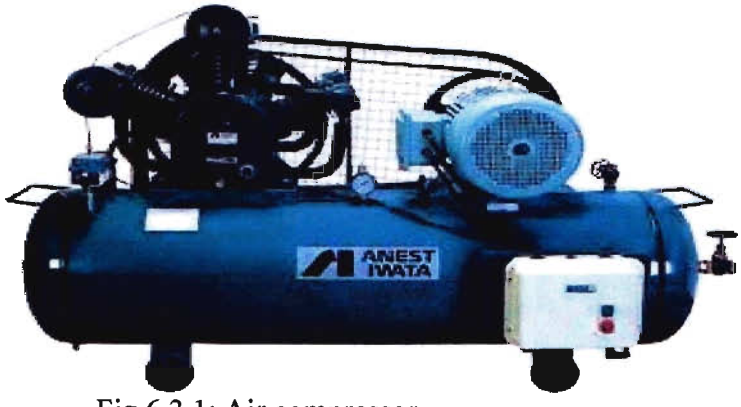


Fig 6.3.1: Air compressor

The sample transfer system from rotary rack to counting capsule house go through using air pressure compressure. It is not only use for transfer the sample from rotary rack to counting capsule house but also move to counting capsule outlet storage rack after finishing the countring.

- **Rotary Rack**

Rotary Rack contain the samples that transfer to the counting capsule house. According to design we can keep 10 samples in Rack.

- **Auto Sample changing Mechanical and Driving Unit**

Responsible for moving the Rotary Rack. Here Stepper Motor will be used for moving the Rack with a specific angle. There is a connecting arm which bring the sample from rotary rack to sample loading tube by Gear Motor. Microcontroller and motor driving circuit is needed for driving unit.

- **Pneumatic Transfer Control System**

FIG 6.3.2: Air cylinder

Air cylinder that on and off the bulb of air compressor for Pneumatic Transfer system. For this reason control circuit is needed to control the Pneumatic Transfer System.

- **Vertical Height Controller**

There is pneumatic device for control the hight of counting capsule house. Electrical circuit is used for up down the counting capsule house by air pressure.

6.4. BLOCK DIAGRAM OF AUTOMATION

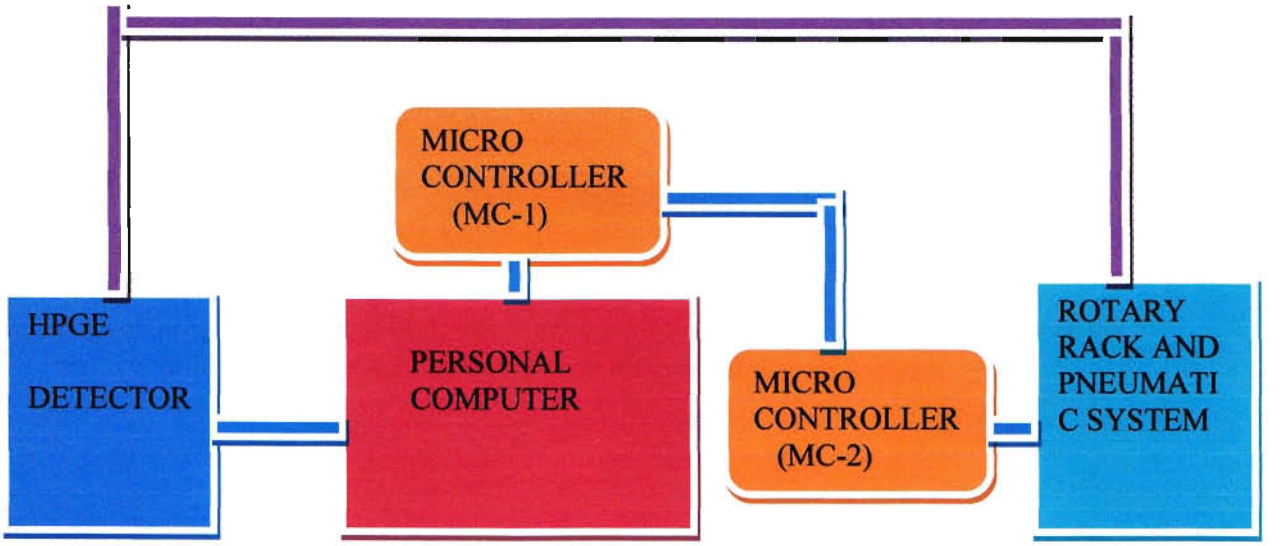


FIG 6.4: Block Diagram of Automation of NAA

6.5. STEPS OF AUTOMATION

The automation of NAA includes the following steps.

1. For the first time, Pneumatic Transfer System operates manually to move the sample from rotary rack to counting sample holder.

   (1)The sample falls in sample holding arm from rotary rack by gravitional force,(Initially the arm stays under rotary rack) .
   (2)Trigger the circuit of Gear motor, for moving the arm from rotary rack to loading tube with sample.
   (3)Air cylinder bulb on and the sample fly to sample holder in the HPGe detector.
   (4)The arm adjust to its previous stage.

   A Microcontroller based program controls all the above steps.

2. The automated program or job schedule located by Maestro-32 software for counting.

3. When the counting for the first sample is finished, the job is stopped for predefined time and executes a windows program to trigger the Micro controller that is MC-1. MC-1 read the instruction and then switch the circuit of Pneumatic transfer system that is responsible for out the sample from HPGe detector to sample outlet storage box.

4. MC-1 trigger another micro controller that is MC-2. MC-2 execute the following instruction:
   (1) Switching the stepper motor for moving the rotary rack. The next sample is fallen into the sample holding arm due to gravitional force.
   (2) Switch on the circuit of Gear motor for moving the arm to loading tube with next sample.
   (3) Air cylinder bulb on and the sample fly to sample holder in the HPGe detector.
   (4) The connecting arm adjust to its previous stage.
   (5) Trigger MC-1.
5. MC-1 send an acknowledgement to the Windows Program from where it is initiated.

6. The windows program is closed after getting the acknowledgement.

7. The job program is waited until the windows program is to be closed. Then it start the next counting because program is written to do next job.

Chapter 7
DEVELOPMENT OF JOB PROGRAM

7.0. EMULATION SOFTWARE

In this research work, ORTEC DSPEC jr and MAESTRO-32 Version 6 is used.

7.0.1. FEATURES OF EMULATION SOFTWARE [1]

- Windows 7 (32-bit and 64-bit) and Windows XP (32-bit) compatible.
- ORTEC CONNECTIONS 32- and 64-bit network connectivity: local and remote control for all supported instruments via a common GUI.
- Intuitive User Interface consistent with other ORTEC application software such as Gamma Vision and ScintiVision.
- Advanced "smart" analysis functions: Fast Peak Search, Region of Interest (ROI), Peak Fit, and Overlay Spectrum Comparison.
- Password protected functions
- Multiple Detector Interface (MDI): choose to view up to eight "live" and eight stored spectra simultaneously on a single PC.
- Automated "Jobs" for consistent and reliable data acquisition and reporting.
- NEW "List Mode," time-tagged data event gathering;

MAESTRO is a multichannel analyzer (MCA) "emulation" software package. When used in conjunction with a personal computer, and appropriate MCB hardware, MAESTRO constitutes an advanced "smart" multichannel analysis environment for use in a wide variety of scientific applications in industry, teaching, and research, including nuclear counting laboratories. The MAESTRO user interface provides live spectral display and control of hardware and provides a number of "smart" analysis tools. The spectrum display and manipulation has a common "look and feel" with other ORTEC spectroscopy products, such as Gamma Vision and Scintivision. Full control of acquisition and all MCB hardware features is provided. The software auto-detects the attached hardware, presenting the user with only those features specifically available for that hardware. For example, members of the ORTEC DSPEC series of digital HPGe gamma spectrometer systems provide full control of the digital filter, auto-PZ and Insight® oscilloscope mode. These features are displayed by the MAESTRO software when the DSPEC hardware is connected to the system. As a member of the ORTEC CONNECTIONS suite of software products, MAESTRO has the capability to fully support up to

250 detector systems across a local area network; a remote detector appearing to a local operator is no different to one physically attached to the local PC workstation.[1]

7.1. DISPLAY AND USER-INTERFACE

MAESTRO provides an intuitive user interface to simplify hardware control and both routine and advanced measurement processes. The most commonly used functions are implemented as "hot keys" or toolbar buttons for rapid access. The spectrum window is often the primary user focus when using MAESTRO and up to eight live detectors and eight saved spectra can be displayed concurrently. Full and expanded views of each spectrum are shown simultaneously. The spectrum expanded view can be zoomed in to examine a specific peak or energy region. Both windows display any marked Regions of Interest (ROIs), and the zoomed region is easily repositioned by simply clicking the new position in the full spectrum display.

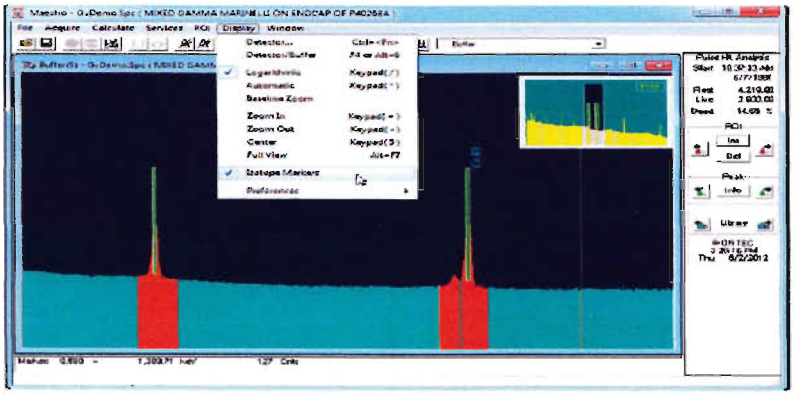


FIG 7.1: User Interface Feature

When viewing a live detector, the spectrum view is updated in real time and provides current spectral data, live peak calculations, and hardware properties even for remote instruments connected to different computers on the network. Viewing spectrum peaks, library energies, or regions of interest is simple with the convenient side panel buttons.

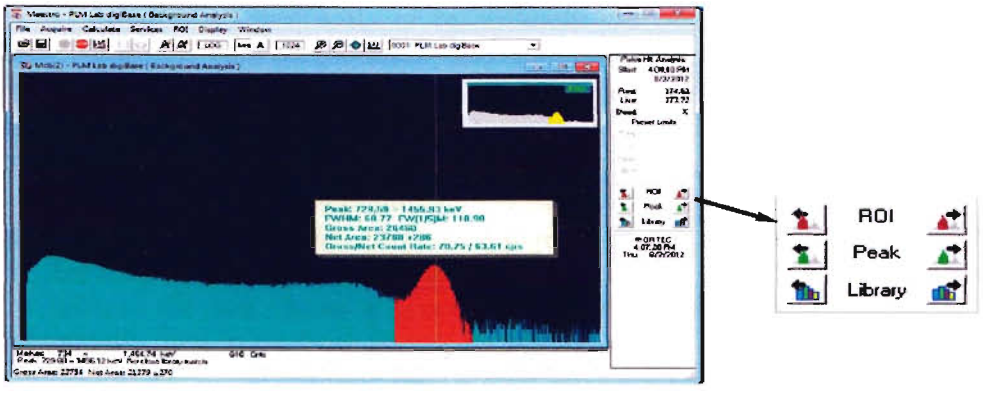


FIG 7.2: Some Library in User Interface

Working with individual Regions of Interest (ROIs) or calculating peak areas is easily accomplished with either the advance peak search or "rubber rectangle" features.
As many regions as desired may be marked, and these may be saved to an "ROI" file that can be recalled and applied later to a different spectrum. MAESTRO permits a wide choice of display options. Choose from a variety of color schemes, and display the spectrum as dots or filled bars. These settings can be used to create the optimal view for various lighting conditions or simply to suit your preference.**[1]**

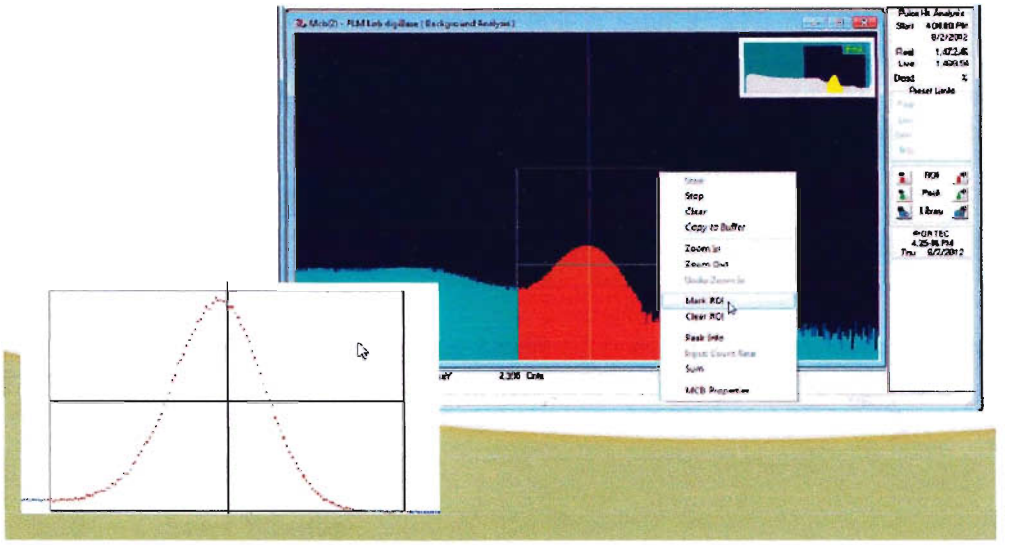


FIG 7.3: Region of Interest

7.2. AUTOMATION WITH JOBS

Although interfacing with MAESTRO from the toolbar and menus is simple and intuitive, this method of operation does not guarantee consistent processing that is often needed for measurements performed frequently or by different individuals. In these circumstances a more structured approach may be preferred, and simple text scripts called "Job" provide this capability in MAESTRO. The command set includes the most common operations, and has been expanded in Version 7 to include List Mode functions, closing MCB or Buffer windows, and enhancements to the "WAIT" command to improve efficiency.

Custom processes can also be implemented with the "RUN" command which launches any external application. Job Files may be run automatically when MAESTRO starts by including the path to the Job file as a command line argument in Windows shortcuts. This approach is frequently used to establish consistent processes from a common initiation point, and provides a simple method to run multiple Jobs in separate instances of MAESTRO.**[1]**

7.3. JOB FILES FOR AUTOMATION [2]

The MAESTRO .job file consist of one or more lines of ASCII text representing a series of commands that can automatie most of the function. A job file can be dispatched from the Run JOB file dialog accessed via the Service/Job Control menu selelection or by including the name of the .job file on the command line when MAESTRO is first started(e.g. MCA32 DEMO.JOB).

7.3.1. Summary of JOB Commands

A quick reference to the JOB Command is shown below:

1. **ASK_PASSWORD** - Asks for password that is used to lock the detectors. The actual lock/unlock is done with LOCK and UNLOCK respectively. This command is to set the internal password variable, $(PASSWORD), to the user input so the password will be available for use in the .JOB. The $(OWNER) variable is only used when locking detectors.example:.

   ASK_PASSWORD
   LOCK $(PASSWORD),$(OWNER) [,"Name"]..
2. **BEEP <frequ>,<duration>** - Produces an audible sound of <freq> Hz, lasting <duration> milliseconds.
3. **BEEP ID** – A numerical ID is given based on a desired system event. For example , BEEP 7 will exit the WINDOWS.

Id	Event
0	**Beep Speaker**
1	**Default Beep**
2	**Start Window**
3	**Asterisk**
4	**Exclamation**
5	**Critical Stop**
6	**Question**
7	**Exit Window**

4. **CALL "file.job"** – Execute another Job file as a subroutine.
5. **CHANGE_SAMPLE** - This command is used to control the CHANGE SAMPLE output and SAMPLE READY input BNC singals on the rear panel of MCB with sample changer control and is intended to initiate a hardware handshake sequence for advancing a sample changer. The SET_OUTPUT_HIGH command is sent to the currently selected detector, then the sample-ready status is monitored until the input is low and finally SET_OUTPUT_LOW command is sent and input is monitored until it returns to the high level again before proceeding.
   Note that if the sample changer controls are not able to make the SAMPLE_READY input so high very soon after the CHANGE SAMPLE signal is set(i.e. the normal state of the SAMPLE_READY is low; it is executed to go high immediately after the CHANGE SAMPLE condition is set and remain high while the sample changer is moving and returns to low when the sample changer is at its new position), it might be necessary to use the SEND_MESSAGE command to send a SET_OUTPUT_HIGH command, then

pause(with WAIT or some other time consuming command) and then send the CHANGE_SAMPLE command. Example:

```
SET_DETECTOR 1
START
LOOP 3
        WAIT
        FILL_BUFFER
        SEND_MESSAGE "SET_OUTPUT_HIGH"
        SET_DETECTOR 0
        SAVE "COVALT??.CHN"
        SET_DETECTOR 1
        CHANGE_SAMPLE
        CLEAR
        START
END_LOOP
```

6. **CLEAR** – This command clears the spectral data, real time and live time for the selected detector. The presets are not changed.
7. **DESCRIBE_SAMPLE** – This command accepts a 63-character description of the sample being analyzed. This description is saved with the spectrum using the SAVE COMMAND function and is included in the REPORT printout. This performs the same function as the SAMPLE DESCRIPTON function under the SERVICE menu.
8. **EXPORT "filename'** – Execute the Export function with specified file name. The remainder of the options are defined on the Export tab under FILE/SETTINGS...The filename can include any of the variables defined .
9. **FILL_BUFFER** – This command transfer the active detector data to buffer.
10. **IMPORT "filename"** - Execute the Import function with specified file name. The remainder of the options are defined on the Import tab under FILE/SETTINGS...The filename can include any of the variables defined .
11. **LOAD_LIBRARY "filename.extension"** – This command loads the specified .LIB or .MDB nuclide library and duplicates the function of Library File under the Service menu.
12. **LOCK "Pwd"[,"Name"]** – This command locks the current detector using "Pwd" as the password.
13. **LOOP <repetitions> ....END_LOOP** – This command pair executes multiple times allt he commands between LOOP AND END_LOOP. The number of execution time is specified by <repetitions>. Each command must be given on separate line.Example:

```
SET_DETECTOR 1
START
LOOP 3
        WAIT
        FILL_BUFFER
        SET_DETECTOR 0
        SAVE "COVALT??.CHN"
        SET_DETECTOR 1
```

```
        CLEAR
        START
END_LOOP
```

14. **LOOP SPECTRA...END_LOOP** – This command executes the commands withing the loop once for each spectrum stored in the Detector hardware. This command only workd for hardware that supports Field Mode.
15. **MARK_PEAKS** – This command does a Mariscotti-type peak search on the spectrum in the active detector or buffer window and duplicated the Calculate/Peak Search Command. The peak-search sensitivity is selected in Calculate/Settings.. Each peak found is marked as an ROI.If the buffer is calibrated, the width of the ROI is three times the calculated FWHM of the peak.
16. **QUIT** – Terminate the MAESTRO program and returns control to window.
17. **RECALL "file.chn"** – This command reads a disk filename to the buffer. The disk file must be in the format created by SAVE. Any DOS filename, including the drive and subdirectory, can be used. The resulting momory size of the buffer is the same as the memory size of the file.The file, live time and real time and restored. If the spectrum file has calibration information, the calibration parameters are used to set the calibration for the buffer.

    This command has the same function as Recall under the FILE menu.
18. **RECALL_CALIB "file.chn"** - This command loads only the buffer calibration parameters from the calibration data stored with a spectrum.
19. **RECALL_ROI "file.roi"** – This command marks the ROI channels in the buffer or Detector to conform to the table in the disk file, created by SAVE_ROI or Save File.. under the ROI menu. The data contents of the Detector or buffer are not altered by this operation. The previous ROIs are cleared.

    This command has the same function as Recall File... under ROI. It can be used in genrating reports that look for specific isotopes. For example a calibration spectrum is run containing ^{57}Co and ^{137}Cs and ROIs marked on the 122-keV and 662-keV peaks.The calibration is saved as spectrum file COBCS.CHN and as ROI file cobcs.ROI
    The command sequence is:

```
.
RECALL_CALIB "COBCS.CHN"
RECALL_ROI "COBCS.ROI"
REPORT "COBCS,RPT"
,.
```

20. **REM [TEXT]** – This line is a comment and is ignored during command processing.
21. **REPORT "filename"** – This command produces a list of areas,activities, and peak shapes for all the ROIs marked in the spectrum, The ROI data is presented in either columns or paragraphs, according to the format most recently selected in the ROI Report dialog. If user does not specify a filename, the report will be sent to the default windows printer for the PC. If specifiy a filename , the report will be sent to an ASCII text file that can be used by other programs or printed later. The loop count value can be included in the filename by typing tree question marks in the text where the loop count is to be inserted.
22. **RUN "program"** – This command executes an application named "program". This is

typically an .EXE or .PIF filename. Note that the program might not run to completion before the .JOB file exists, unless it is run at higher priority or the WAIT "program" command is used.

23. **RUN_MINIMIZED "program"** – Same as RUN command above, except that the application is run initially as an icon, rather than as a normal window.
24. **SAVE "[d:][\path\]file[.chn]"** – This command, which has the same function as Save As... under the FILE menu,save the currently active buffer to a disk file. The disk filename can be any valid filename: the drive[d:],path[\path\] and extension[.chn] .Also, the current drive and directory are used by default when the optional path specification is not supplid. The loop count value can be included in the filename by typing three question marks(???) in the text where the loop count is to be inserted.
25. **SAVE_ROI "[d:][\path\]file[.roi]** – This command, which has the same functin as Save File.. under the ROI menu,saves a table of channel numbers that have the ROI set for the active Detector or buffer in a disk file. The contents of the spectrum are not altered by this operation. The disk filename can be any valid filename,with optional elements as described for the SAVE command,above. The default extension is .ROI. The loop count value can be included in the filename by typing three question marks(???) in the text where the loop count is to be inserted. The loop count replaces "???" whereever it appears.
26. **SEND_MESSAGE "command"** – This command is used to send NIM-488 commands to the active Detector. This can be used to perform any operations of the Detector that are desired. The text must be in the syntax expected by the detector. If the response from the detector does not end with a command accepted message, this command will exit with error. If a user attempts to use this command to send destructive command to a locked Detector, the JOB will fail. Use UNLOCK to unlock the detector before using SEND_MESSAGE, and LOCK afterward.example:

```
.
SET_DETECTOR 1
STOP
CLEAR
SEND_MESSAGE "SET_GAIN_FIN 2048"
SEND_MESSAGE "SET_GAIN_COARSE 100"
.
```

27. **SET_BUFFER** – Selects the buffer, same as SET_DETECTOR 0.
28. **SET_DETECTOR <number>** - This selects the active detector or the buffer. The detector number can be 1 to 999 according to the detector configuration, or 0 for the buffer. Also, SET_DETECTOR without an argument is used to switch to the previously selected detector. If a Detector is selected that does not exist, no change is made. The detector number is the number shown on the Toolbar and the detector pick list.
    The JOB processor expects one or more numerals as the argument to this command, entered with or without quotaion marks. The JOB processor will also accept the loop counter as an argument to the function as long as it is in quotation marks. For example you could use "$(loop1)" to sequence through the detecto list, provided the detector list is in numerical sequence.
29. **SET_NAME_STRIP "file.chn"** – This command can be used before STRIP to select a disk filename to be used subsequently by the STRIP command.

30. **SET_PRESET_CLEAR** – This command clears the presets for the active detector. Presents can only be changed when an MCB is not counting.
31. **SET_PRESET_COUNT <count>** - This command sets the ROI peak count preset for the active detector. The preset is set to the entered value. With this preset condition the detector stops counting when any ROI channel's content reaches this value. If no ROIs are marked in the Detector that detector never meets this condition.
32. **SET_PRESET_INTEGRAL <count>** - This command sets the ROI integral count preset value for the active detector. The preset is set to the entered value. With this preset condition, the detector stops counting when the sum of all counts in all channels marked with an ROI reaches this limit. If no ROIs are marked in the detector , detector never meets this condition.
33. **SET_PRESET_LIVE <seconds>** - This command sets the Live time preset for the active detector. The preset is set to the entered value. With this condition, the detector stops counting when the live time reaches this limit, unless some other preset condition occurs first. The live time is the real time minus the dead time. This command has the same funciton as the Live Time field on the presets tab under Acquie/MCB Properties.
    The job processor expects one or more numerals as the argument to this command, entered with or without quotation marks. The JOB processor will also accept the loop counter as an argument to the function as long as it is set in quotation marks. For example one could use the loop counter to collect a series of spectra with increasing ROI integral counts by appending zeroes to the loo counter to obtain 1000 counts, then 2000 and so on.
34. **SET_PRESET_REAL <seconds>** - This command sets the Real time preset for the active detector. The preset is set to the entered value. With this condition, the detector stops counting when the real time reaches this limit, unless some other preset condition occurs first. This command has the same funciton as the Real Time field on the presets tab under Acquie/MCB Properties.
    The job processor expects one or more numerals as the argument to this command, entered with or without quotation marks. The JOB processor will also accept the loop counter as an argument to the function as long as it is set in quotation marks. For example one could use the loop counter to collect a series of spectra with increasing ROI integral counts by appending zeroes to the loop counter to obtain 1000 counts, then 2000 and so on.
35. **SET_PRESET_UNCERTAINTY <uncert limit>,<low chan>,<high chan>** - For the DSPEC only, this sets the statistical preset to the uncertainty based on the countsin the region between the low and high channels.
36. **SMOOTH** – This command smooths the data in the active buffer window. Its function is the same as Smooth under the Calculate menu. A five-point, area-preserving , binomical smoothing algorithm is used. The original contents of the buffer are lost.
37. **START** – This command initiates data collection in the seleced detector. This function is same as Start under the Acquire menu.
38. **START_OPTIMIZE** - For the DSP-type only this stars the optimize function for the detector.
39. **START_PZ** – This starts the pole-zero functin for the detector. It is automatically included in the optimized function.
40. **STOP** – This command stops data collection in the active detector.If the detector has

already been stopped, no operation occurs.This command has the same function as Stop under the Acquire menu.

41. **STOP_PZ** – This stop the pole-zero function for the detector.Note that the pole-zero function is not complete when this is used.The Pole Zero function should be allowed to complete automatically.
42. **STRIP <factor>,["file.chn"]** – This command strips the disk spectrum specified in the SET_NAME_STRIP command or in the command itself from the spectrum in the buffer and stores the results in the buffer.
43. **UNLOCK "Pwd"** - Unlocks the current detector using "Pwd".
44. **VIEW "i"** - Moves the "i" th stored spectrum to position 0.
45. **WAIT [<seconds>]** – This command suspends execution of the JOB until either the active detector stops counting or for a fixed number of seconds.
46. **WAIT "program"** – This command suspends execution of JOB until the named program stops execution. If the program does not stop, the JOB will not continue.
47. **WAIT_AUTO** - For the DSPEC only this waits unitl the optimize function is complete.
48. **WAIT_CHANGER**- For MCBs with sample changer controls this waits until the sample reday signal on the rear panel is present. It is used in conjunction with the SEND_MESSAGE function for more control over the sample changer than is provided by the CHANGE_SAMPLE command.
49. **WAIT_PZ** - This waits until the pole-zero function is complete.
50. **ZOOM <i>** - Changes the size of MEASTRO window.

7.3.2. JOB File Variable

Variable have been added to .job file feture to allow more flexibility and control of the JOBS.They can be used anywhere in .job file.example

$(FullPath) = D:\USER\SOIL\SAM001.SPC >> Full pathname of the spectrum file

Then

$(FullBase) = D:\USER\SOIL\SAM001 >> Full pathname but without extension
$(FileExt) = SPC >> File Extension
$(FileDir) = D:\USER\SOIL >> Directory of the spectrum file
$(ShortPath)= SAM001.SPC >> Relative pathname of the spectrum file
$(ShortBase)= SAM001 >> Relative pathname without Extension

Similarly

$(McaDir) >> MAESTRO Directory
$(CurDir) >> Current Directory
$(Loop) >> Current value of the loop counter
$(Loop1) >> Loop counter plus 1
$(Bel) >> Ascii Bell character
$(Password) >> Value entered in ASK_PASSWORD command
$(Owner) >> Value entered in ASK_PASSWORD command

7.3.3. Sample JOB Program

```
SET_DETECTOR 1
SET_PRESET_CLEAR
SET_PRESET_LIVE 100

CLEAR
START

   LOOP 10
        WAIT
        FILL_BUFFER

        SET_DETECTOR 0

        DESCRIBE_SAMPLE "This is sample ???"
        SAVE "[d:][\path\]file???[.chn]"

        RUN "interfacing.exe"
        WAIT "interfacing.exe"

        WAIT 60

        SET_DETECTOR 1
        CLEAR
        START

   END_LOOP
```

This program might be modified for various purposes. There are different instruction like **CALL** for call subroutine, **CHANGE_SAMPLE** for sample changing, **LOAD_LIBRARY** for load nuclide library,**RECALL** for reads the spectral data,**RECALL_ROI** for sets the ROIs from table in the file, **REPORT "PRN"** for print the file etc. These instruction can be used for make the job program more smooth and flexible.

References

[1] ORTEC . MAESTRO V7.
Available : http:// www.orteconline.com/download/MAESTRO.pdf

[2] ORTEC.MAESTRO^{R} 32 – MCA Emulator for Microsoft^{R} .Available:
http://web.mit.edu/8.13/8.13d/.../Ortec-MAESTRO-software-manual.pdf

Chapter 8
INTERFACING USING COMPUTER PROGRAM

8.0. INTRODUCTION

Computer Programming Language is a formal constructed language designed to communicate instructions to a machine, particularly a computer. Programming languages can be used to create programs to control the behavior of a machine or to express algorithms.

There are different kinds of programming languages. Ada, Pascel,C, C++,C#, Java, Python, Pearl, Php etc. These are the common languages that are used widely for various purposes. As we say that MAESTRO 32 Emulation software is used for gamma spectrometry is designed by a programming language. Otherwise different kinds of programming language can interact with each other via different protocol **[1].**

Here the program is written in C# to communicate with micro controller (Arduino uno)via **serial port.** Because it is easy to interface between C# and Arduino. Though it is possible to interfacing between Arduino Micro Controller and Java or C programming language.

8.1 Tools for Progamming Language

- Personal Computer
- IDE (Microsoft Visual Studio2008)

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs for Microsoft Windows, as well as web sites, web applications and web services. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentatio Foundation, Windows Storeand Microsoft Silverlight. It can produce both native code and managed code..

There are some steps mentioned here for writing program:

8.1.1. Get the Microsoft Visual Studio .

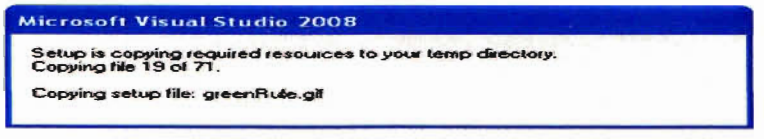
http://www.microsoft.com/en-us/download/details.aspx?id=10823

8.1.2. Setup Microsoft Visual Studio 2008 [2]

In this step-by-step tutorial we will install Visual Studio 2008 Standard Edition on Windows XP Pro SP2 or SP3.

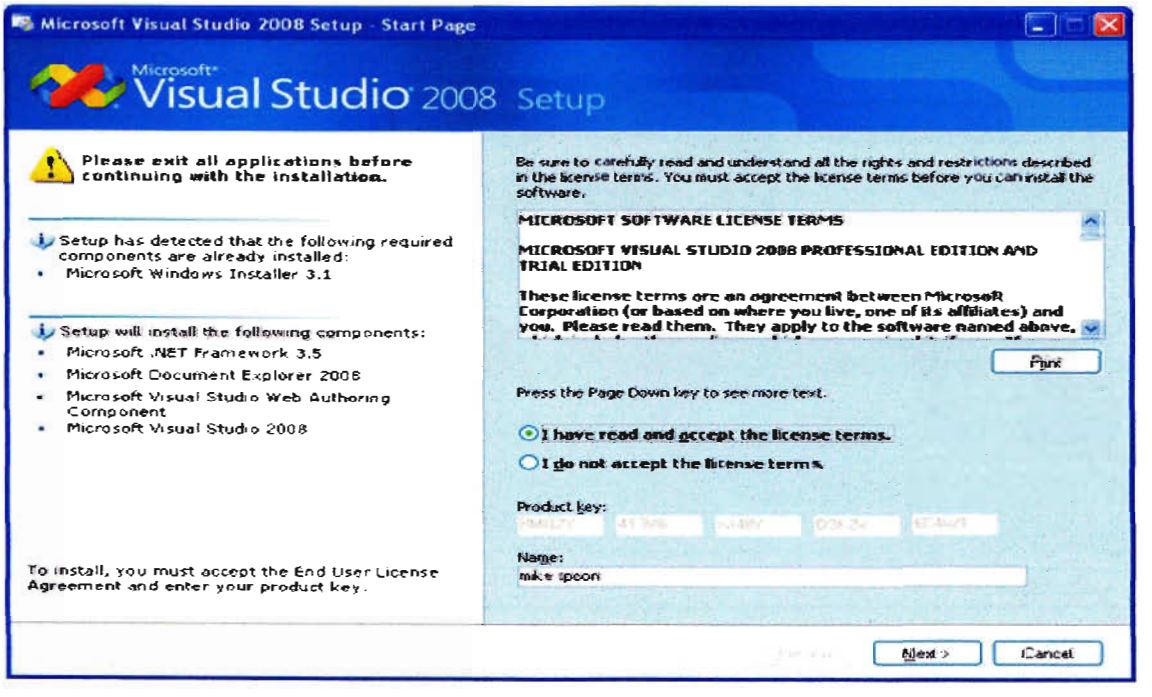
Any pre requirement prior to the installation will be checked and verified by the setup wizard. The VS 2008 DVD is needed. Insert the DVD into the DVD drive, the Autorun will be executed, displaying the following Windows form. Click the View ReadMe button to read the readme information. Then click the Install Visual Studio 2008 link to start the installation.

The setup wizard will start copying needed files into a temporary folder. Just wait.

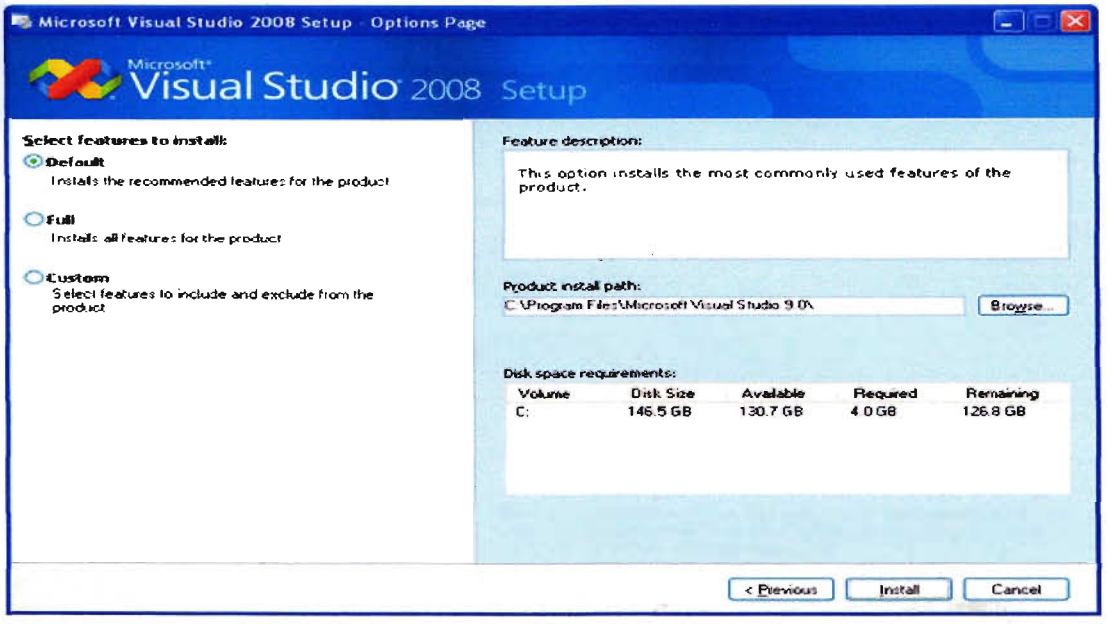


In the welcome setup wizard page enable the tick box to send the setup experience to Microsoft if it is wanted. In this case just leave it unchecked. Just wait for the wizard to load the installation components.

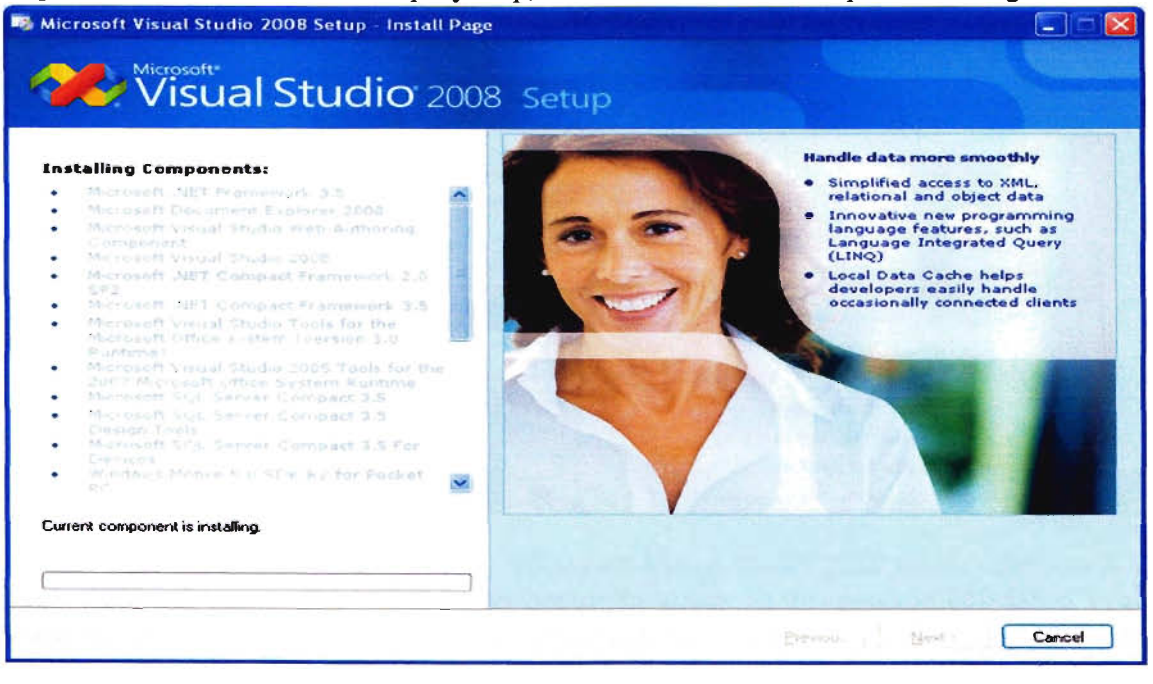
The setup wizard will list down all the required components need to be installed. Any already installed components will also be mentioned. Notice that VS 2008 needs .NET Framework version 3.5. Key in the Product key and accept the license terms. Then click the Next button.



In the installation type, as usual we have three choices: **Default, Full** or **Custom**. In this case we select the Full installation type and accept the default installation path given. The installation path and the required space for every installation type also displayed when select it.

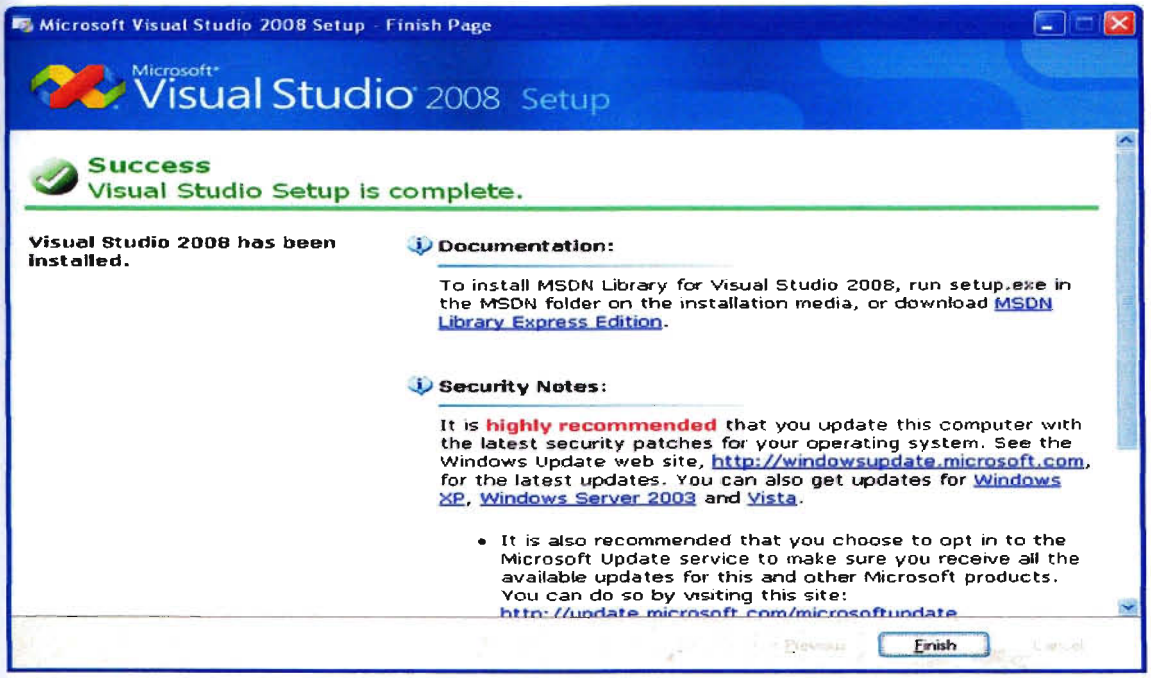


In this case, select the Full and click the Install button. Full installation required around 4.3 GB of space. Just wait and see the step-by-step, Visual Studio 2008 components being installed.

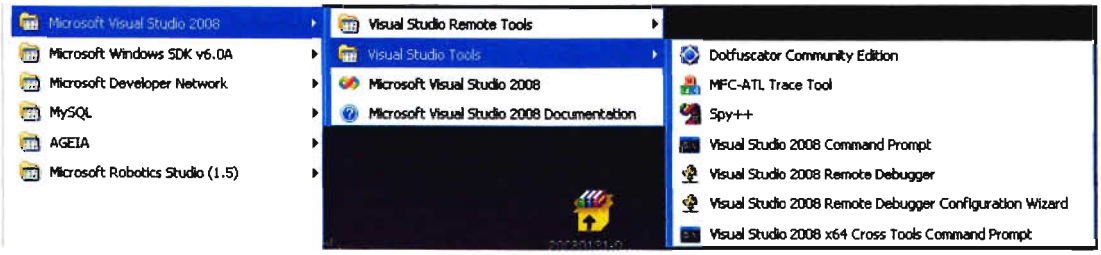


Any component that failed to be installed will be marked with the red cross mark instead of the

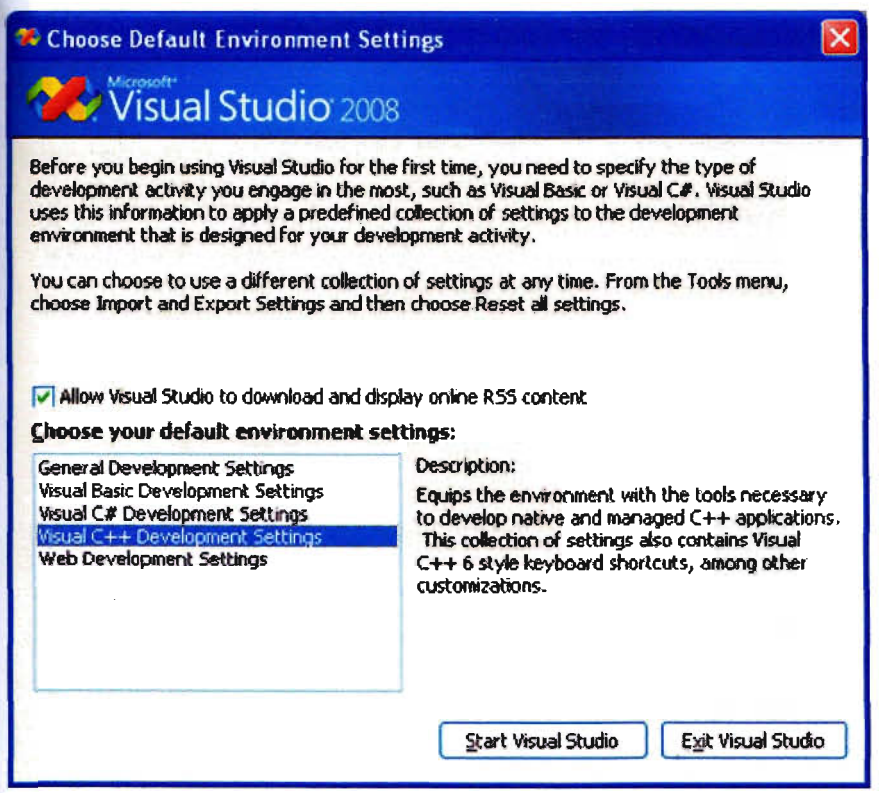
green tick for the successful. After the installation is completed successfully, install the documentation (MSDN library) by following the instruction mention in the above Figure. In this case we just exit the setup wizard by clicking the Finish button.



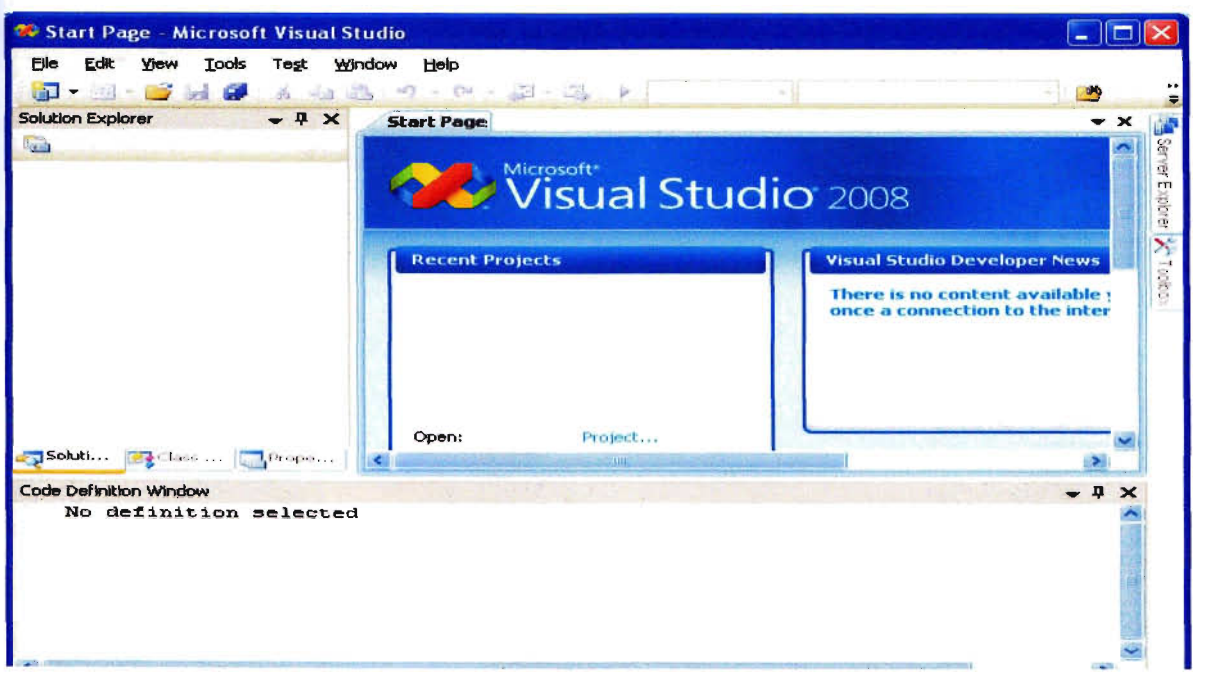
The Windows Start menu for Visual Studio 2008 is shown below.



Launch Visual Studio 2008 by selecting Microsoft Visual Studio 2008 menu > Microsoft Visual Studio 2008 sub-menu. Depending on programming needs, in this case we will select Visual C# Development Settings. So, when VS 2008 launched, now and later, all the settings are default to VC# The VS 2008 IDE will change the development settings to the respective type when we choose to create a project in that type when the IDE already opened next type. Select Start Visual Studio button.

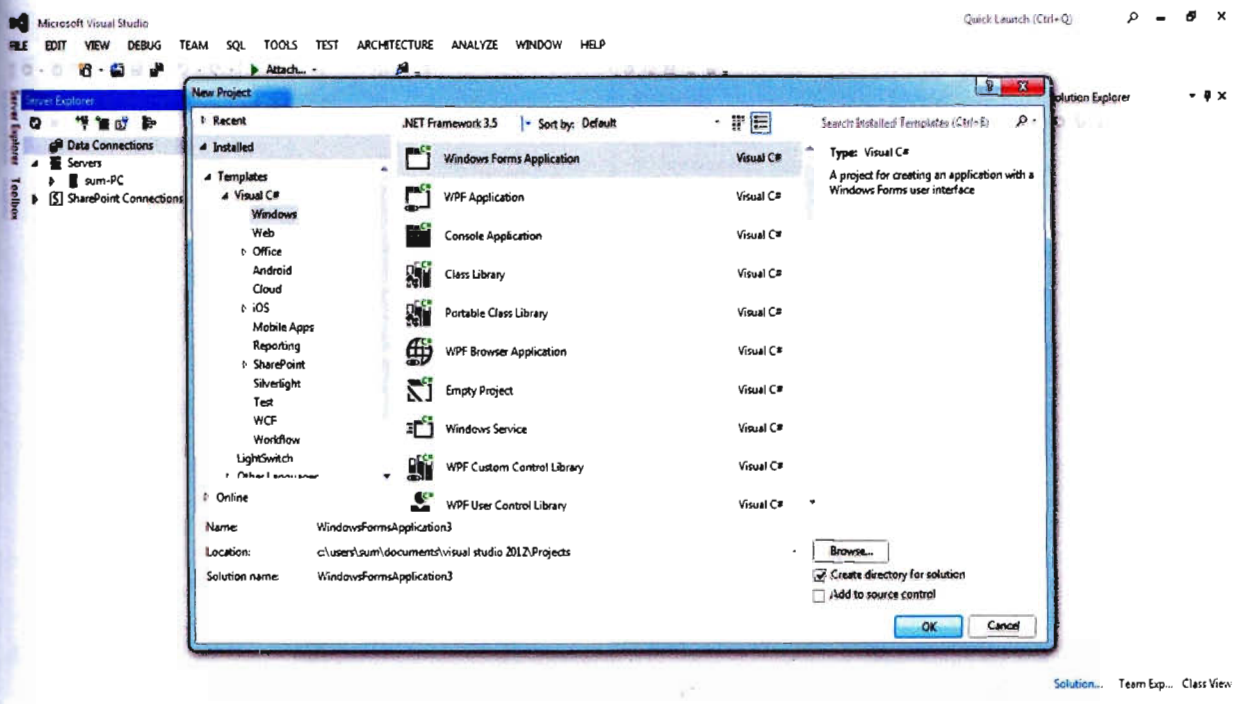


Well, the following is the VS 2008 IDE.

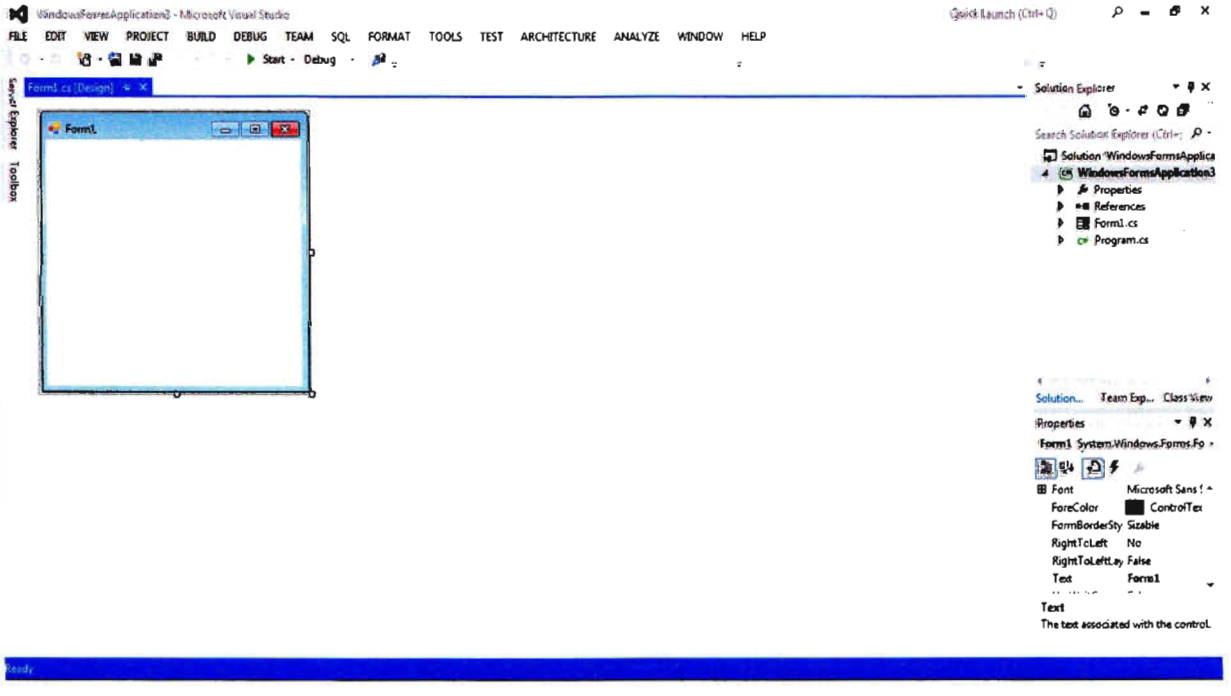


Thus end of setup of Visual Studio 8.

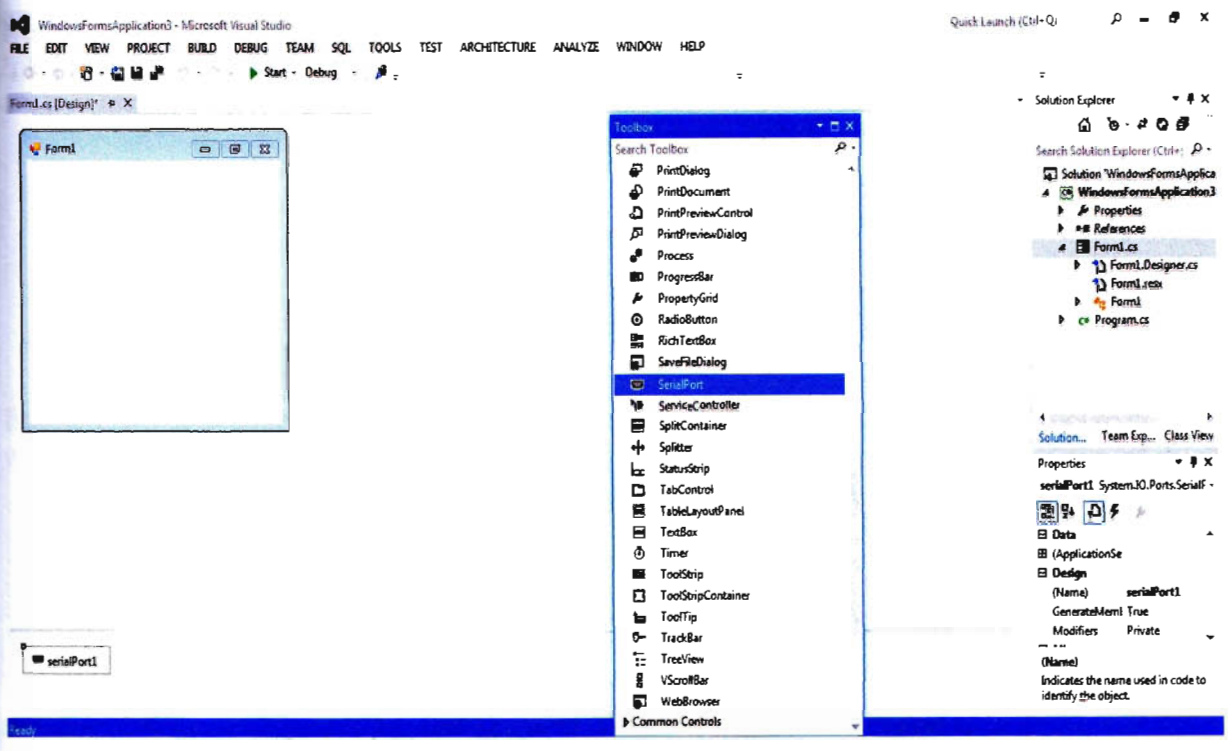
8.1.3.Now Create new Project by FILE/New/Project..



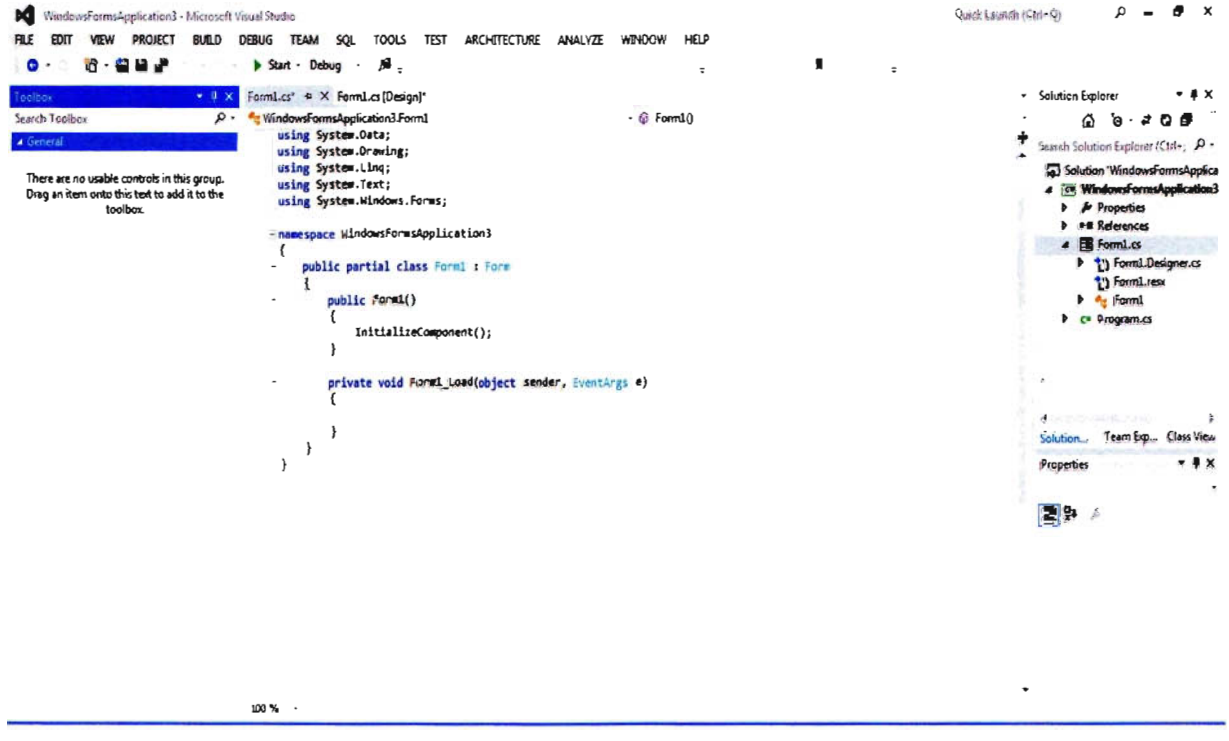
At the right side solution explorer of the project



From the Toolbox select SerialPort and drag and drop on the Form Window



Press double click on the Form which show the code window.



Now it is needed to write code on Form1.cs. Here there are some way of naming convention. Like the name of Project, Form Name etc. As we didn't mention any name for Form1.cs. There are two main parts Form1.cs in term of our project.

- ```
  public Form1()
  {
  InitializeComponent();

  serialPort1.PortName = "COM4";
  serialPort1.BaudRate = 9600;
  serialPort1.Open(); [3]
  }
  ```

But before this the micro controller (Arduino uno) should be setup as COM port. Otherwise it will show error.

- ```
  private void Form1_Load(object sender, EventArgs e)
  {
  serialPort1.Write("1");
  State = true;

  serialPort1.Write("0");
  State = false;

  if (serialPort1.IsOpen) serialPort1.Close();
  this.Close(); [3]
  }
  ```

8.2. WRITE PROGRAM

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Windows.Forms;

namespace WindowsFormsApplication3
{
    public partial class Form1 : Form
    {
        bool State = false;
        public Form1()
        {
            InitializeComponent ();

            serialPort1.PortName = "COM4";
            serialPort1.BaudRate = 9600;
            serialPort1.Open();
        }
        private void Form1_Load(object sender, EventArgs e)
```

```
        {
                serialPort1.Write("1");
                State = true;

                serialPort1.Write("0");
                State = false;

                if (serialPort1.IsOpen) serialPort1.Close();
                this.Close();
        }
        private void Form1_FormClosing(object sender, FormClosingEventArgs e)
        {

        }
        private void serialPort1_DataReceived(object sender,
System.IO.Ports.SerialDataReceivedEventArgs e)
        {
            try
            {

            }

            catch (Exception ex)
            {

            }

        }
    }
}
```

By the way the sample program could be modified for various reasons. Here we just trigger the Micro controller to execute its own instruction and then closed by itself. But the logic may be different for other purposes. The program may be needed to be in wait state until terminating the pneumatic transfer system. Even terminating the pneumatic transfer system the micro controller send a signal to the program then the program will has to receive the signal and then closed by itself.

References

[1] WIKIPEDIA. Programming Language.
Available : http://en.wikipedia.org/wiki/Programming_language

[2] TENOUK.COM. Steps on how-to install and use the Visual Studio 2008
Available : http://www.tenouk.com/installusevisualstudio20081.html

[3] TECHNICANA. Connect to the Arduino with C#
Available: http://www.technicana.com/physical-computing/73-connect-to-the-arduino-with-c-.html

Chapter 9
MICROCONTROLLER UNIT

9.0. OVERVIEW OF MICROCONTROLLER

In present research work microcontroller is needed for switching the electronic circuits that are used in various purposes. As an example, the rotary rack moves by using stepper motor. The stepper motor moves with a sequence of continuous pulses that are sequentially generated by microcontroller. Otherwise gear motor, air piston, pneumatic control system etc. are triggered by microcontroller also**[1].**

Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. Current models feature a USB interface, 6 analog input pins, as well as 14 digital I/O pins which allow the user to attach various extension boards**[2].**

The Arduino Uno is a microcontroller board based on the **ATmega328** (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started**[3].**

9.0.1. CONFIGURATION[3]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

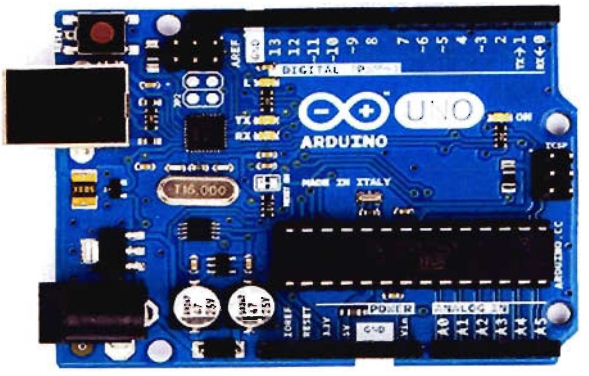


FIG 9.1: Arduino uno single board micro controller

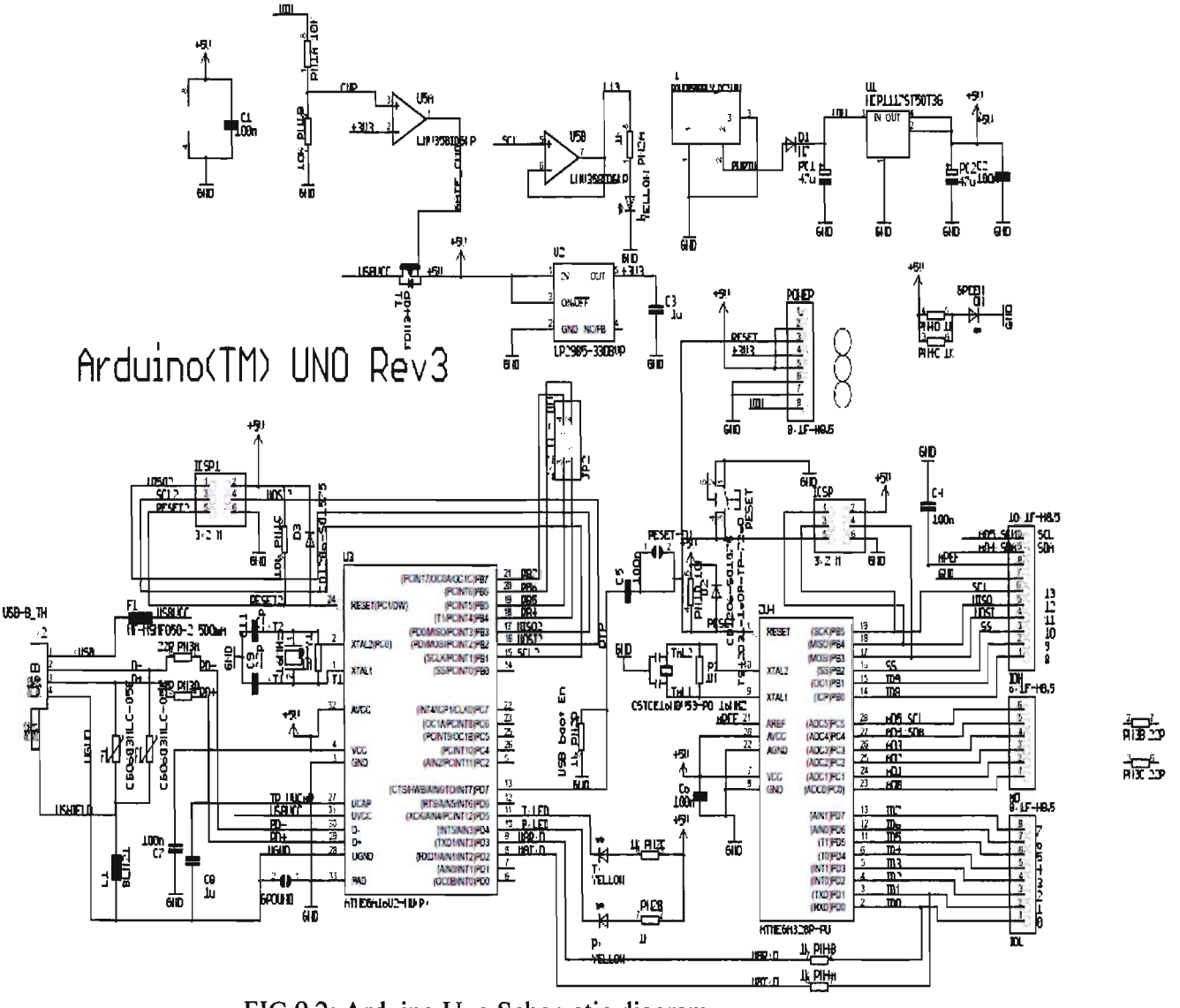


FIG 9.2: Arduino Uno Schematic diagram

9.0.2. POWER SOURCE

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts**[3].**

9.0.3. MEMORY

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library) **[3].**

9.0.4. INPUT AND OUTPUT

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), anddigitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.

PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library. There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().

Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board**[3].**

9.1. GETTING STARTED WITH ARDUINO ON WINDOWS[4]

9.1.1. Get an Arduino board and USB cable

In this tutorial, we assume the using of an Arduino Uno, Arduino Duemilanove, Nano, Arduino Mega 2560 , or Diecimila. If there is another board, then read the corresponding page in this getting started guide.

Also also need a standard USB cable.

9.1.2. Download the Arduino Environment

Get the latest version from the http://arduino.cc/en/Main/Software
When the download finishes, unzip the downloaded file. Make sure to preserve the folder structure. Double-click the folder to open it. There should be a few files and sub-folders inside.

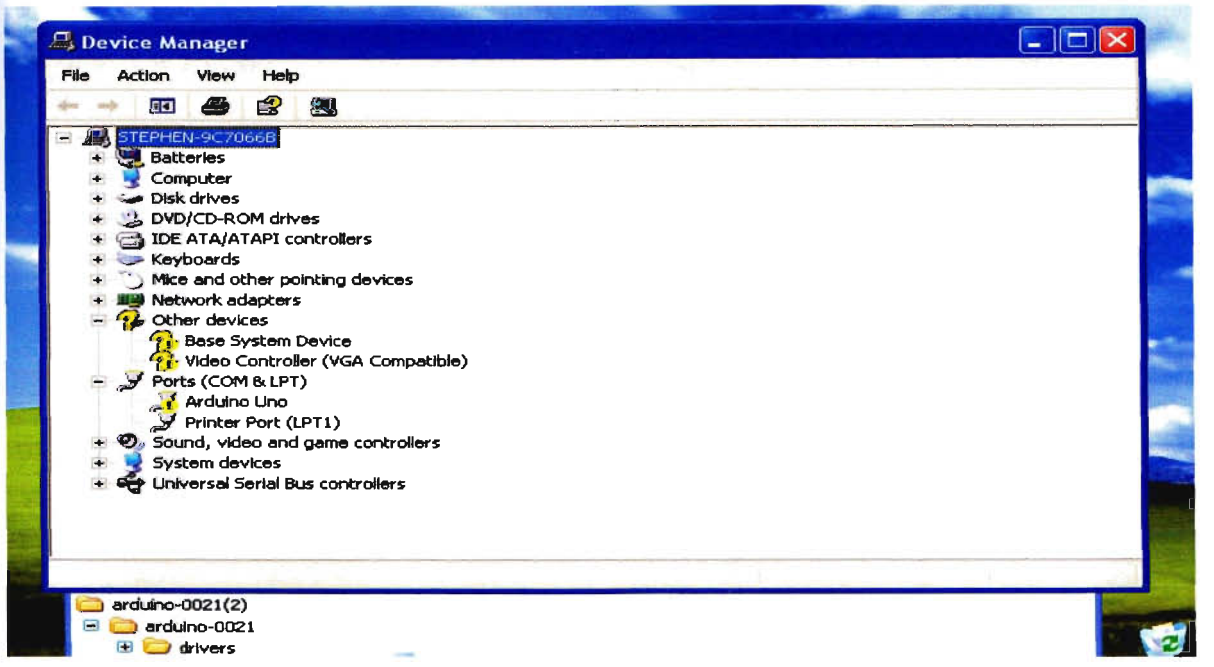
9.1.3. Connect the Board

The Arduino Uno, Mega, Duemilanove and Arduino Nano automatically draw power from either the USB connection to the computer or an external power supply. If you're using an Arduino Diecimila, you'll need to make sure that the board is configured to draw power from the USB connection. The power source is selected with a jumper, a small piece of plastic that fits onto two of the three pins between the USB and power jacks. Check that it's on the two pins closest to the USB port.

9.1.4. Install the Driver Software[5]

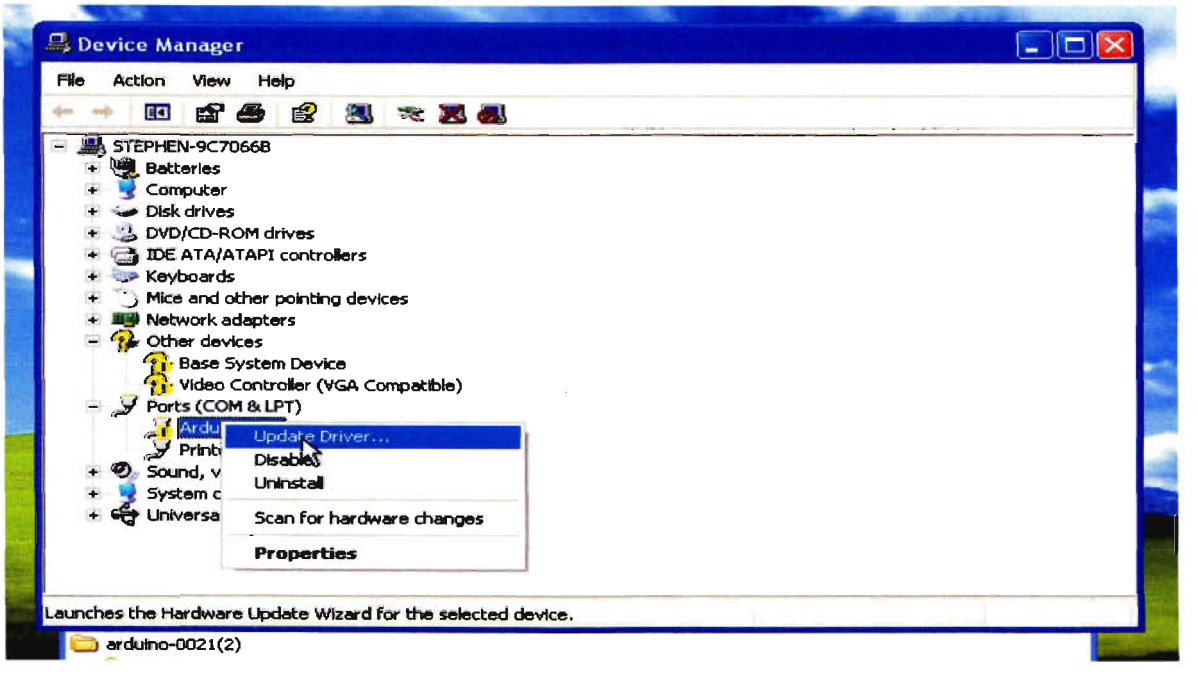
Installing drivers for the Arduino Uno or Arduino Mega 2560 with Windows 7, Vista, or XP:
Plug the board and wait for Windows to begin it's driver installation process. After a few moments, the process will fail, despite its best efforts.

Click on the Start Menu, and open up the Control Panel. While in the Control Panel, navigate to System and Security. Next, click on System. Once the System window is up, open the Device Manager.



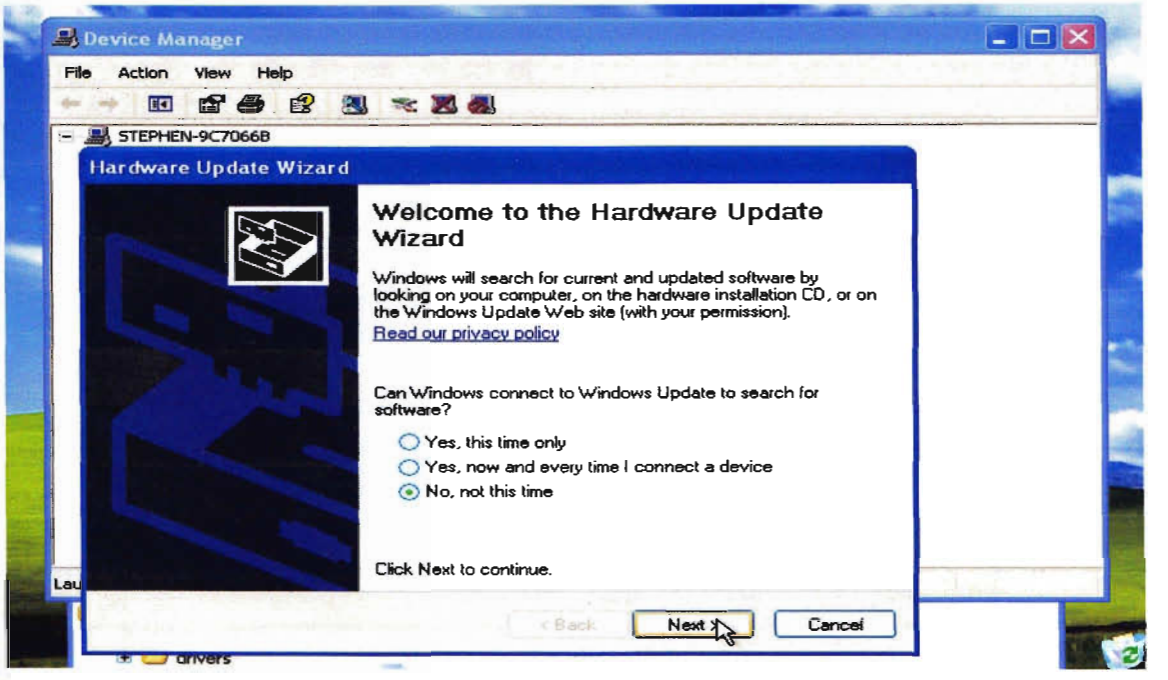
Look under Ports (COM & LPT). an open port named "Arduino UNO (COMxx)". If there is no COM & LPT section, look under "Other Devices" for "Unknown Device".

Right click on the "Arduino UNO (COmxx)" port and choose the "Update Driver Software" option.

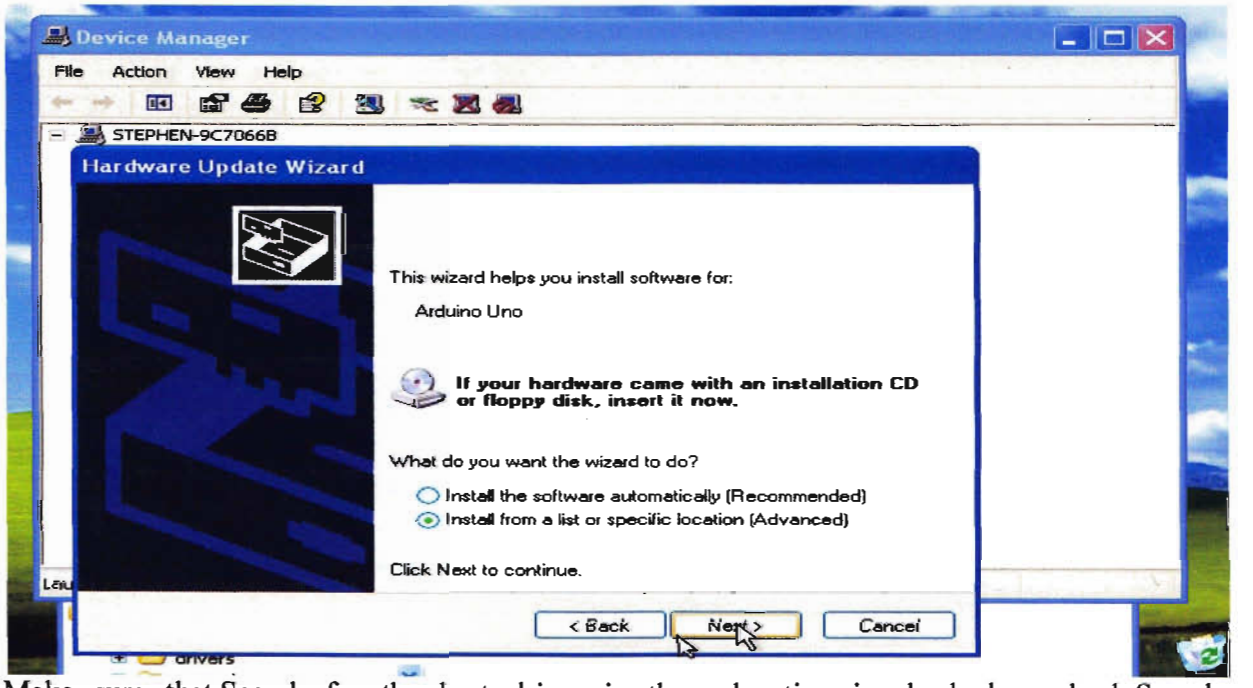


Next, choose the "Browse my computer for Driver software" option.

When asked Can Windows connect to Windows Update to search for software? select No, not this time. Click next.

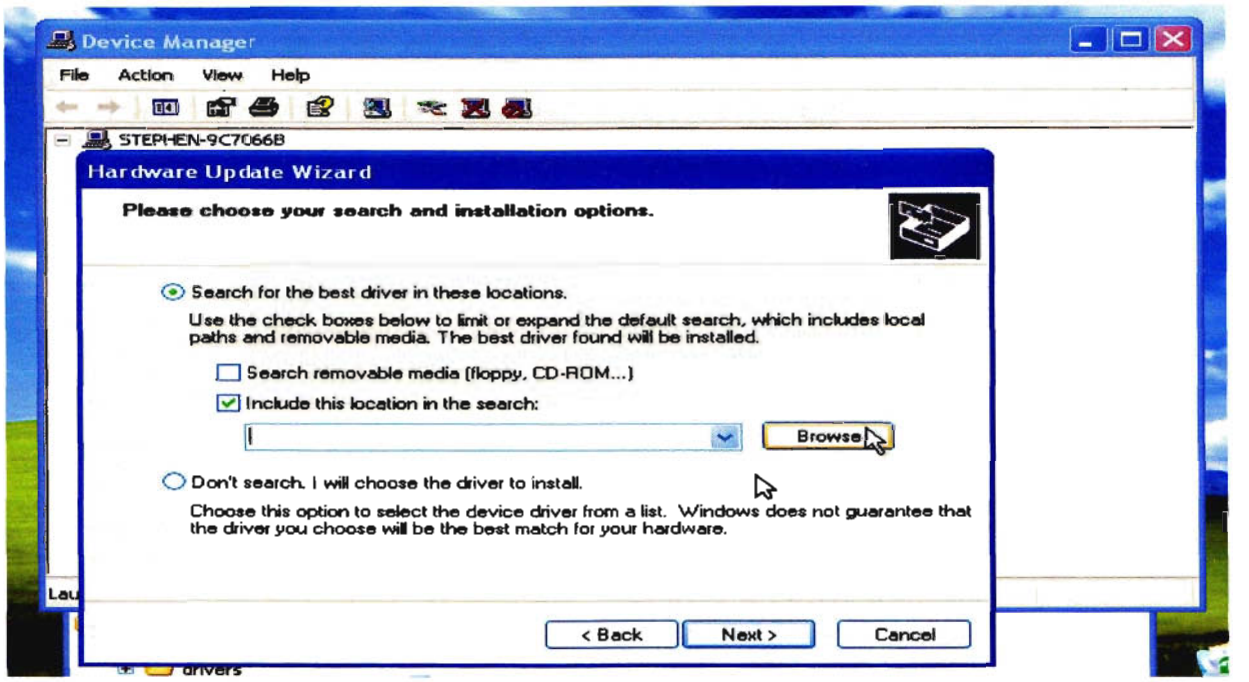


Select Install from a list or specific location

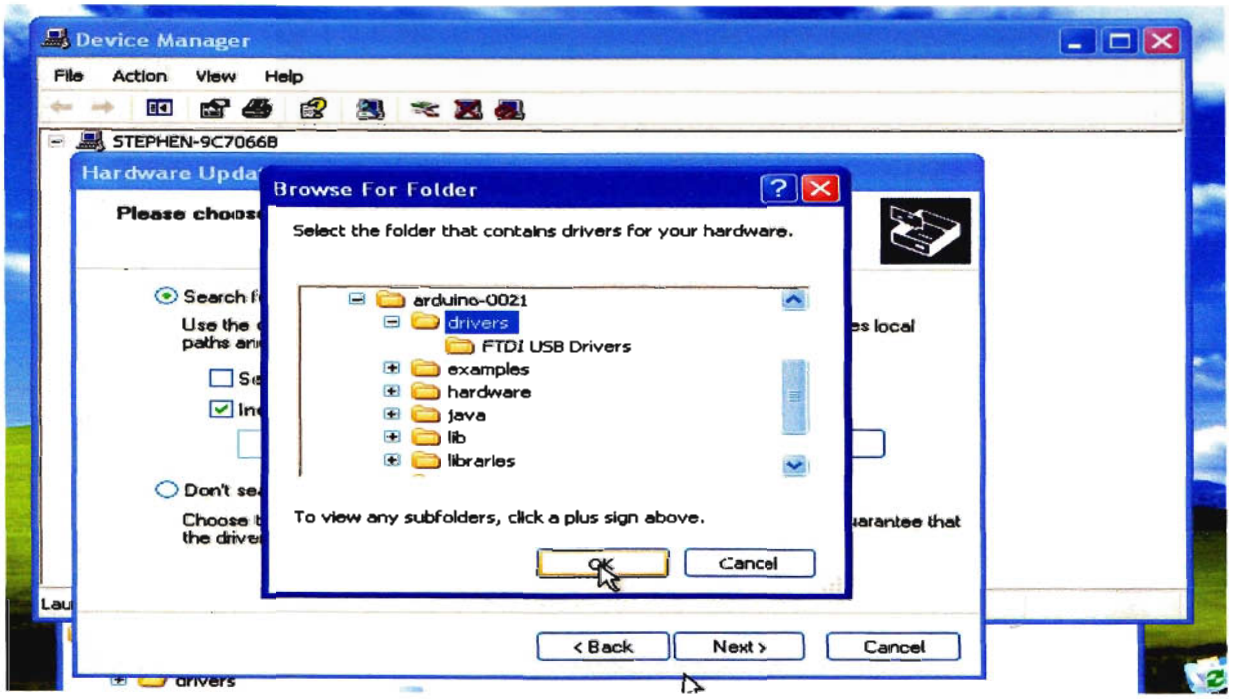


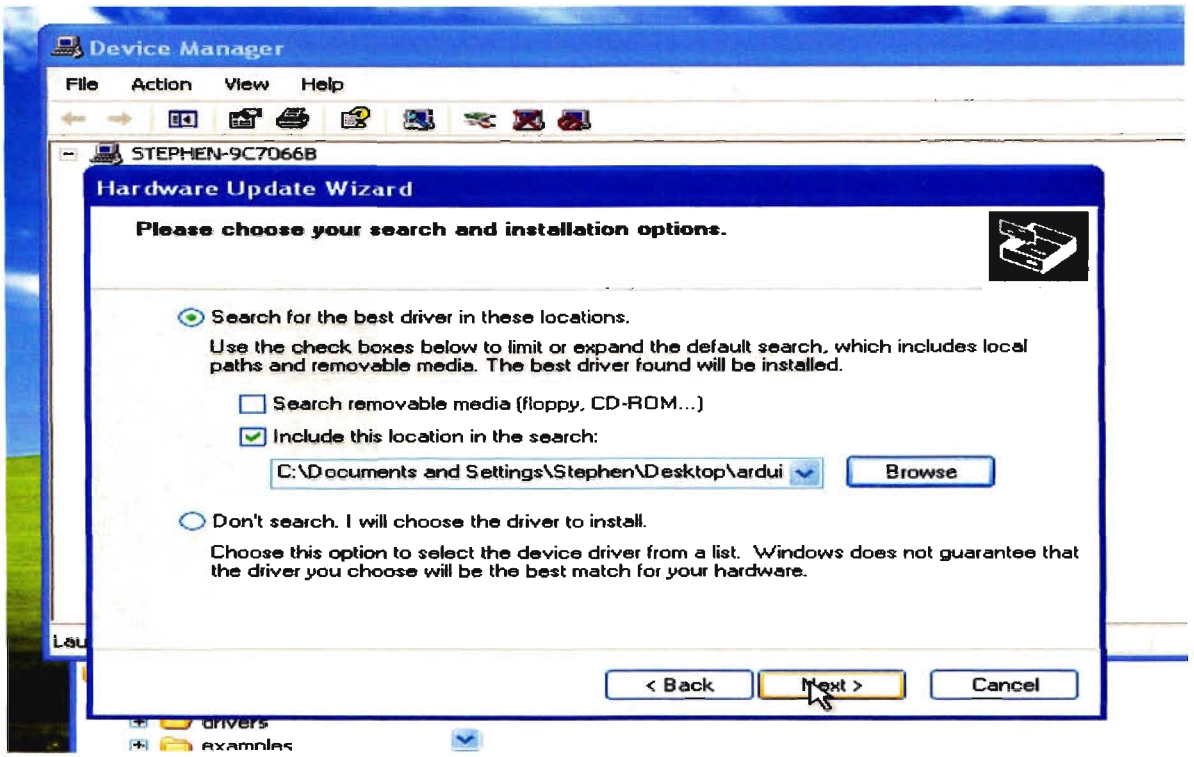
Make sure that Search for the best driver in these locations is checked; uncheck Search removable media; check Include this location in the search and browse to the drivers/FTDI USB

Drivers directory of the Arduino distribution. Click next.

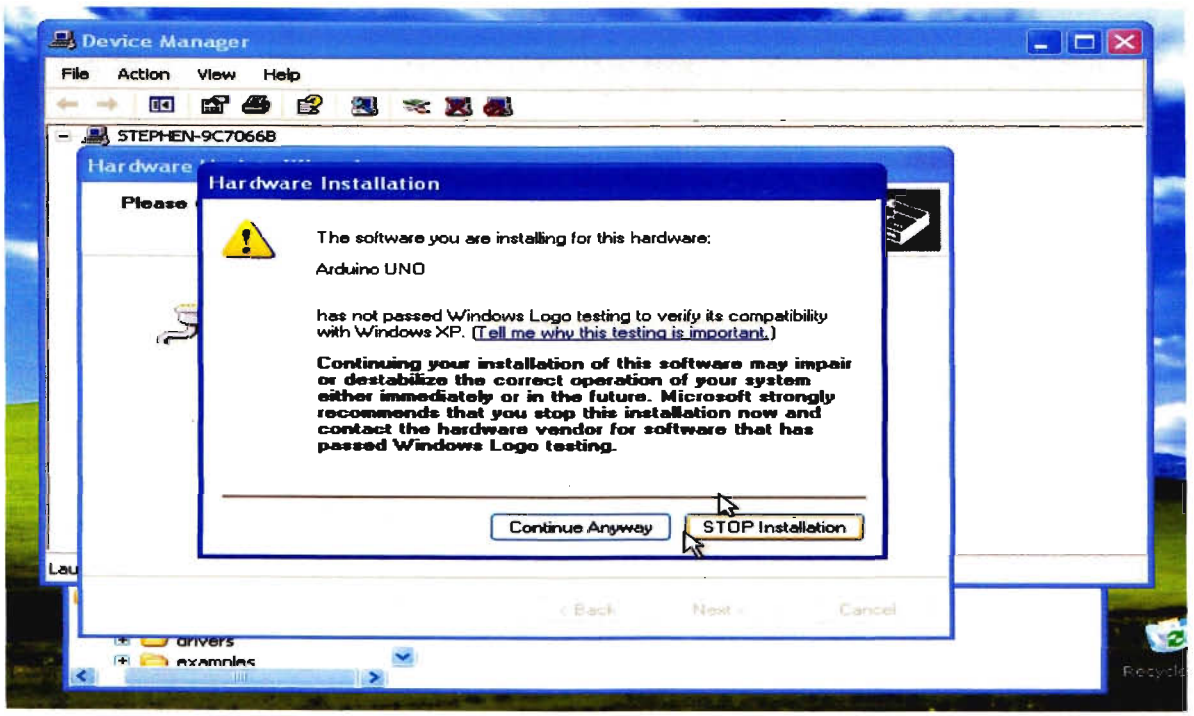


Show the path for drivers in the arduino folder where it is located



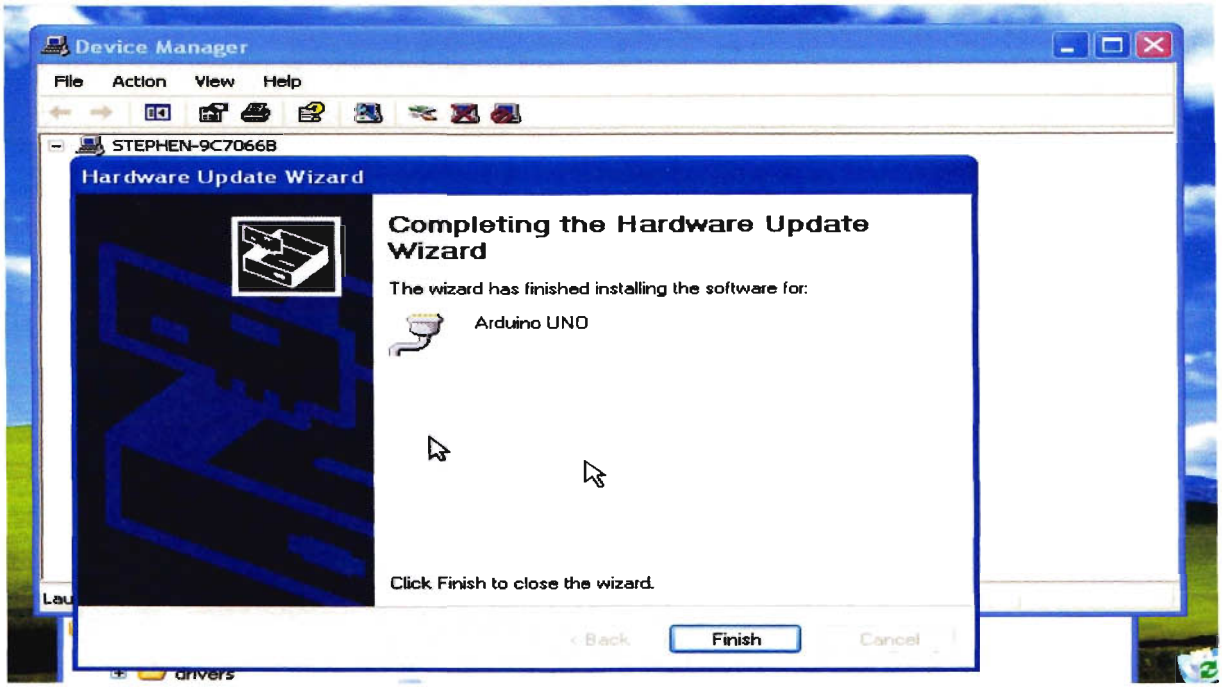


Click Continue Anyway

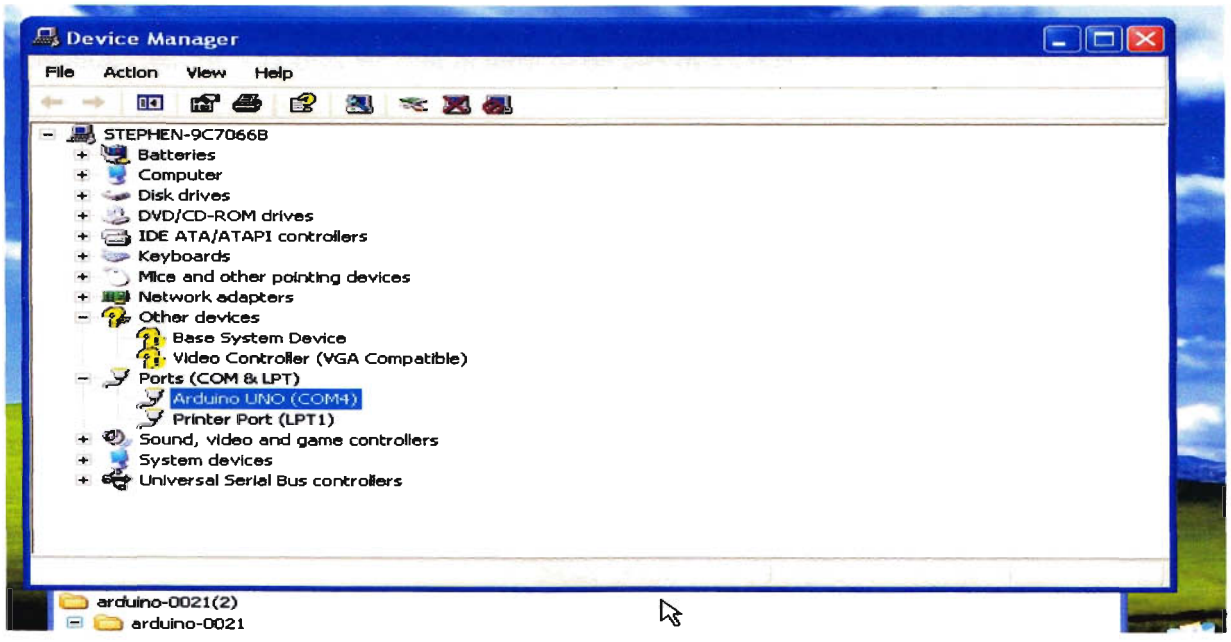


The wizard will search for the driver and then tell that a "USB Serial Converter" was found.

Click finish.



The new hardware wizard will appear again. Go through the same steps and select the same options and location to search. This time, a "USB Serial Port" will be found.

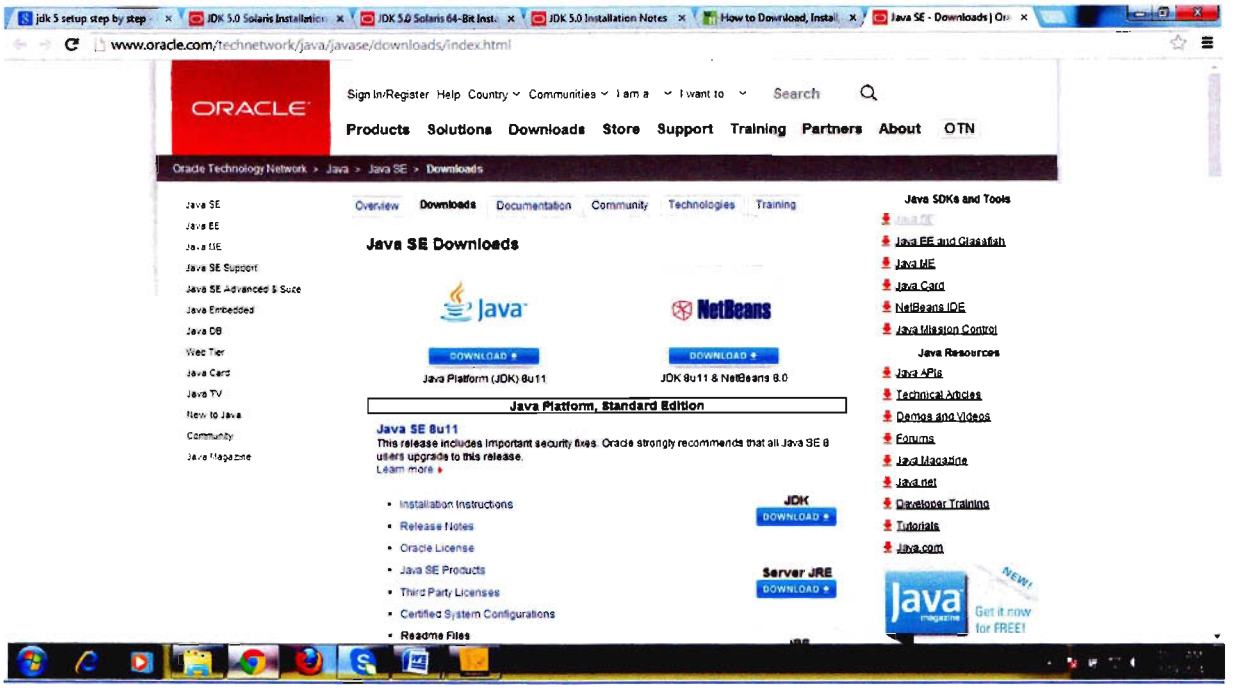


Double-click the Arduino application.
It shows error if the minimum version of JDK(5) is not installed properly.

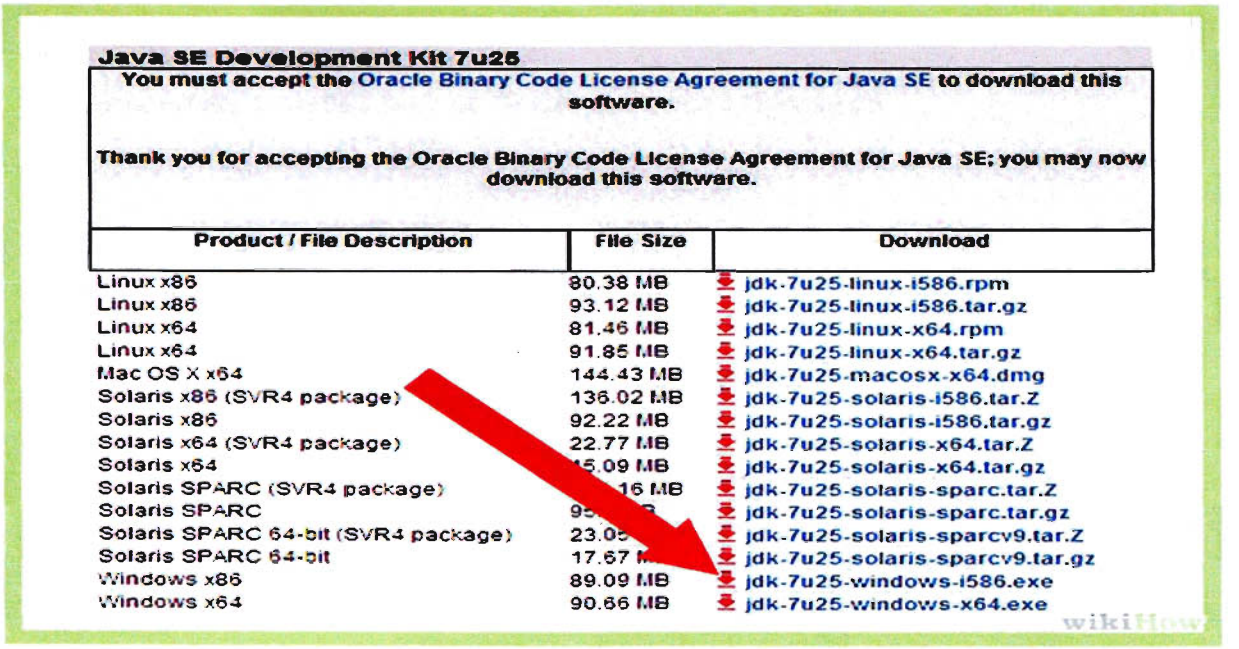
9.1.5 JDK Setup [6]

Get the JDK from the download link.

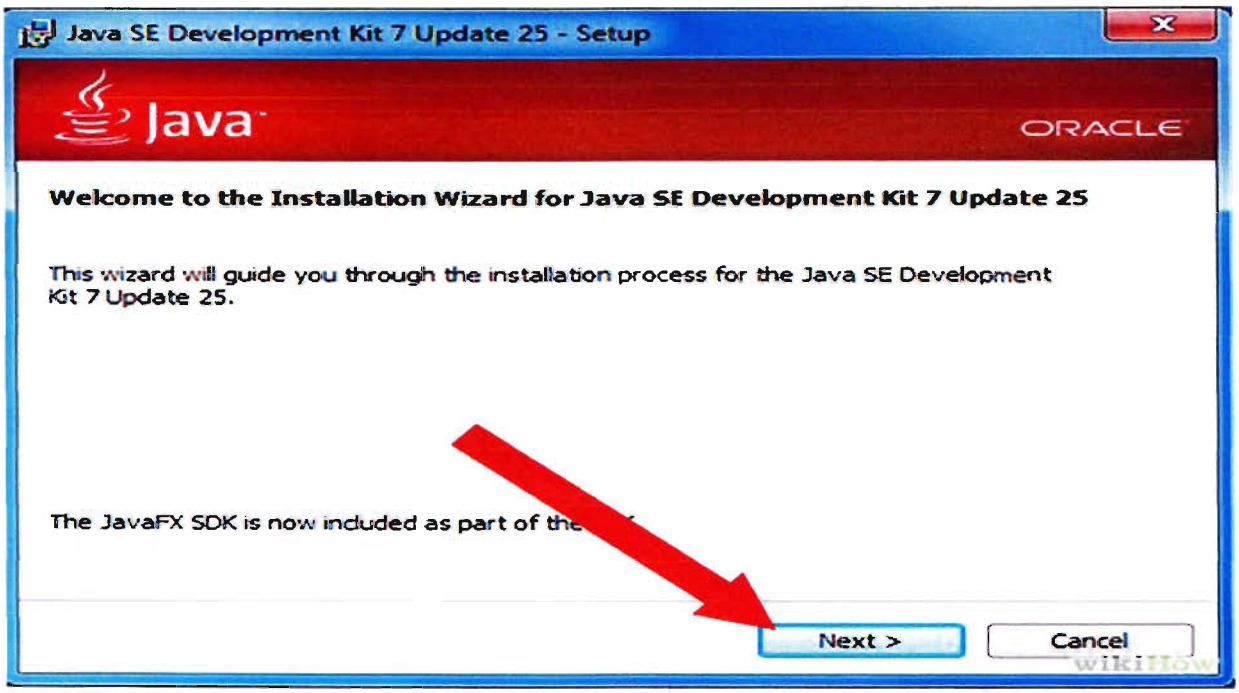
http://www.oracle.com/technetwork/java/javase/downloads/index.html



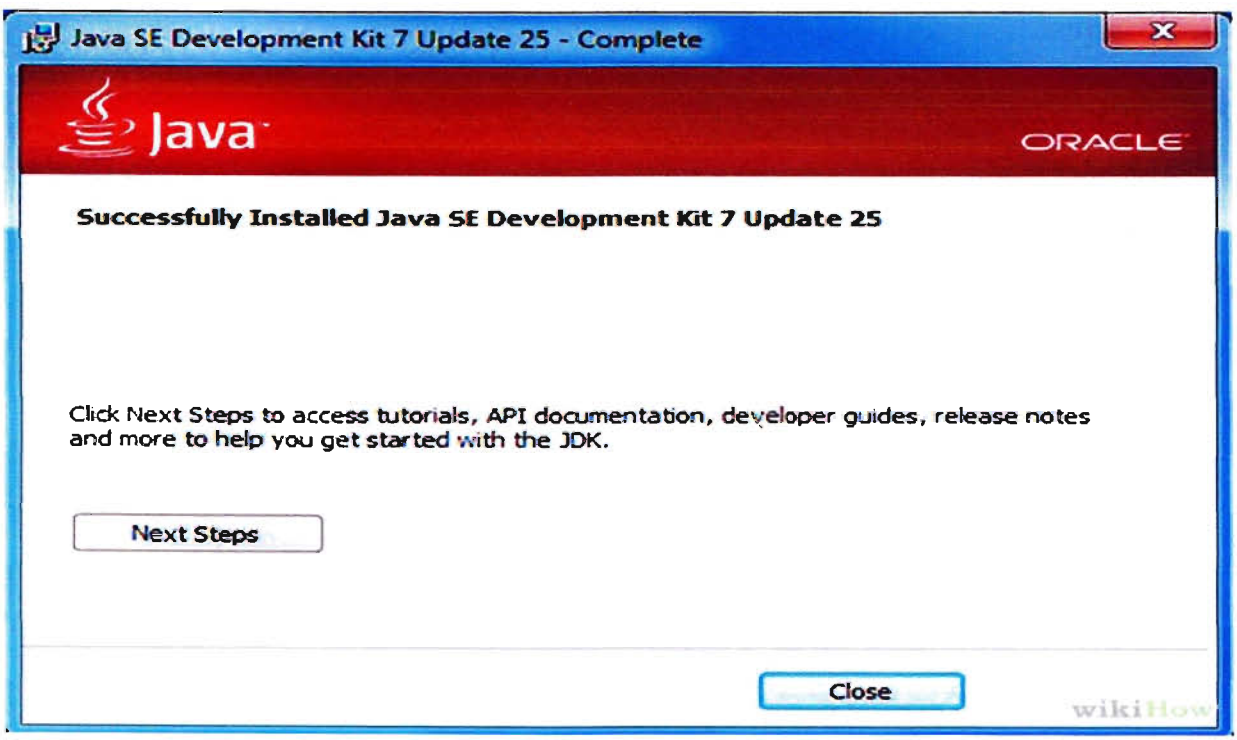
Download jdk for windows version in term of 64 bits or 32 bits



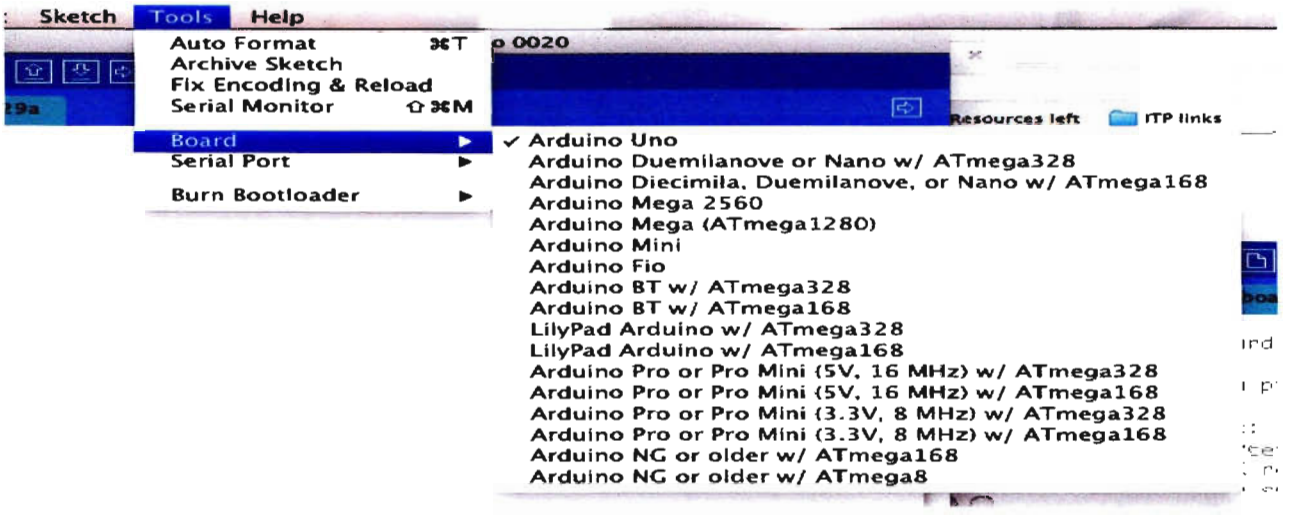
Accept the terms of service and choose the correct OS corresponding for the specific JDK, Once the download is complete, double click the file to begin the installation of JDK.



After the initial installation is done, a pop up asking where the source java files will be .



9.1.6. Select the Board



9.2 CIRCUIT DIAGRAM

9.2.1. Equipments

1. Arduino UNO (2 Pieces)
2. Stepper Motor (1 Piece)
3. Gear Motor (1 Piece)
4. L293d (1 Piece)
5. npn transistors
6. 12 volt air cylinder
7. 5-12 volt relay

9.2.2. Control Circuit

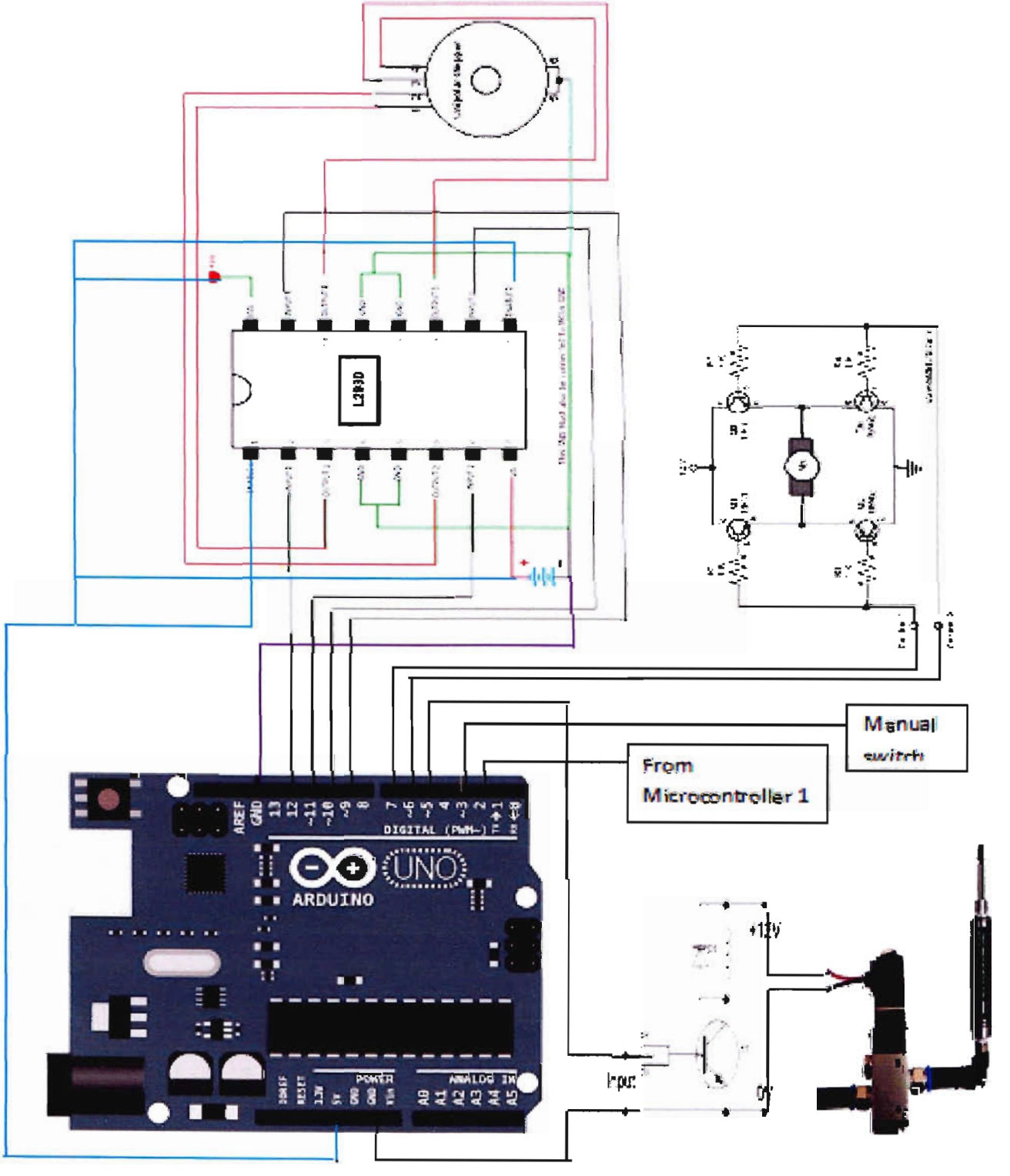


FIG 9.3:Circuit diagram of Microcontroller-2

9.3. PROGRAMMING

9.3.1. Program for ARDUINO -1

```
void setup()
{
 pinMode(13, OUTPUT);
 // Switch the circuit of of compressor for out the sample
 pinMode(11, OUTPUT);
//Trigger another Arduino board for execute
 Serial.begin(9600);
}
void loop()
            {
              if(Serial.available())
                  {
                   int c = Serial.read();
                   if (c == '1')
                      {
                      digitalWrite(13,HIGH);
                      delay(100000);
                      digitalWrite(13,LOW);

                      digitalWrite(11,HIGH);
                      delay(3000);
                      digitalWrite(11,LOW);
                      }
                      else if (c == '0')
                             {
                              digitalWrite(13,LOW);
                              digitalWrite(11,LOW);
                              }
                   }
            }
```

9.3.2. Program for ARDUINO -2

```
#include <Stepper.h>

const int stepsPerRevolution = 200;
// change this to fit the number of steps per revolution
const int buttonPin = 2;      // the status for triggered pin
const int manualPin = 3;      // the status for manual pin

int buttonState = 0;      // variable for reading the incoming pulse
int manualState = 0;      // variable for reading the manual pin pulse
```

```
pinMode(5, OUTPUT);
pinMode(6, OUTPUT);
pinMode(7, OUTPUT);

Stepper myStepper(stepsPerRevolution, 12,11,10,9);

void setup() {
  // initialize the pushbutton pin as an input:
  pinMode(buttonPin, INPUT);

  myStepper.setSpeed(20);
  // initialize the serial port:
  Serial.begin(9600);

}
void loop() {
  // read the state of the incoming pulse:
  buttonState = digitalRead(buttonPin);
  manualState = digitalRead(manualPin);

  if (buttonState == HIGH) {

      buttonState = 0;
      // step one revolution  in one direction:
      myStepper.step(20);

      delay(5000);
       // switch on the circuit of gear motor :

      digitalWrite(5,HIGH);
      delay(15000);

      // switch on the circuit of pneumatic system :
      digitalWrite(7,HIGH);
      delay(60000);
       // switch on the circuit of gear motor:
      digitalWrite(6,HIGH);
      delay(10000);

  }

if (manualState == HIGH) {

      manualState = 0;

      delay(5000);
       // switch on the circuit of gear motor :

      digitalWrite(7,HIGH);
      delay(15000);
```

```
      // switch on the circuit of pneumatic system :
      digitalWrite(5,HIGH);
      delay(60000);
       // switch on the circuit of gear motor:
      digitalWrite(6,HIGH);
      delay(10000);

   }
}
```

Here the first program is programmed into Arduino-1 microcontroller, just trigger the pneumatic control circuit of Compressor therefore switch on the air cylinder and out the sample to outlet storage . Then it trigger the another Arduino-2 microcontroller which is responsible for the following task.

- Switch on the Stepper Motor and move the rotary rack.
- Switch on the Gear Motor and move the connecting arm.
- Switch on the bulb of air cylinder for control the pneumatic system that transfer the sample to sample holder above the detecor.
- After that Switch the Gear Motor and move the connecting arm to its previous state.

By the way, both the program code could be changed according to the changing of mechanical system.

References

[1] WIKIPEDIA. Microcontroller.Available:http://en.wikipedia.org/wiki/Microcontroller

[2] WIKIPEDIA.Arduino.Available:http://en.wikipedia.org/wiki/Arduino

[3] Arduino.Arduino Uno.Available:http://arduino.cc/en/Main/arduinoBoardUno

[4] Arduino.Getting started with Arduino.Available:http://arduino.cc/en/guide/windows

[5] Arduino. Installing the arduino uno under Windows XP.
Available: http://arduino.cc/en/Guide/UnoDriversWindowsXP

[6] wikiHow.How to download,install and run JDK and Eclipse.
Available:http://www.wikihow.com/Download,-Install,-and-Run-JDK-and-Eclipse

Chapter 10
RESULT AND DISCUSSION

The automation of neutron activation analysis was a great challenge in NAA laboratory. The total design and development is locally processed by our manpower. The automation follows some methodology. Some are hardware related and some are software related.

The job program for automation process is already tested in Maestro-32 software. It works properly. A little bit changes may be needed to make it more flexible. It can be run from command prompt by writing a script.

Interfacing process is done by windows program that is written in C# programming language. When the job program executes this program, it communicates with Arduino Microcontroller by serial port. The program works well and no time related problem occurs.

Arduino microcontroller is responsible for various tasks. As it trigger the pneumatic control system circuit for switch on the air cylinder control valve to out the sample by using compressor. It is not completed. Otherwise move the rotary rack using stepper motor is another instruction written in controller program. There are ten samples would be kept in the rotary rack as ten steps provide in one revolution. The number of steps can be changed. Each step is generated by the pulse of microcontroller, so it is not be possible to rotate the rack without pulse of microcontroller. It is seriously checked in different ways. The sample holding arm moves by gear motor which rotates a small angle by controller program. When the program stops pulsing then gear motor stops due to its hard gear configuration.

The electronic driver circuit for stepper motor is tested where a motor driving chip is used. It works normally but after a few hours the chip may be hot, so there is a risk of chip burn. This can be solved by heatsink or another better driver circuit of stepper motor. The gear motor is used by two electronic circuits for bi-directional functionality. It is ok.

The air cylinder control valve for compressor can not be tested .The pneumatic control system and control circuit is in under development. Otherwise there is height measurement protocol is needed in detector shield. Soon these will be completed then the automation can be start with whole phase.

Chapter 11
CONCLUSION

The Neutron activation analysis is non destructive method for element analysis. But it requires human intervention due to gamma counting. Therefore the geometry effect of the samples are not same all the time. The liquid nitrogen is used only in the working hours otherwise it is wasted though liquid nitrogen is very costly. There are lot of samples can not be counted in a single day. So utilization of power research reactor is often pursued by increasing the NAA activities. It may be possible to use multiple detector in a single laboratory but HPGe detector is expensive to buy.

The automation of NAA will help to overcome these types of problem. It will helpful for saving of foreign money. Better adopt of technology and customization will be more easier. But it should be cost effective.

The pneumatic system should be brought out from the present state to make it more cost effective. Proper utilization of power is also necessary. By this, the purpose of automation reduce all complexity and will make a new environment of Neutron Activation Analysis.