UNIVERSITY OF ÇUKUROVA
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Ömer Barış ÖZLÜOYMAK **MSc THESIS**

COMPUTER CONTROLLED SALT PREPARING FOR DYEING PROCESS IN TEXTILE SECTOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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FEN BİLİMLERİ ENSTİTÜSÜ

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YÜKSEK LİSANS TEZİ

ELEKTRİK-ELEKTRONİK MÜHENDİSLİĞİ ANABİLİM DALI

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İmza :.....	İmza :.....	İmza :.....
Yrd.Doç.Dr. Murat AKSOY	Prof.Dr. Süleyman GÜNGÖR	Prof.Dr. Osman SERİNDAĞ
DANIŞMAN	ÜYE	ÜYE

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Enstitü Müdürü
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ÖZ

YÜKSEK LİSANS TEZİ

TEKSTİL SEKTÖRÜNDEKİ BOYAMA İŞLEMİNDE KULLANILAN TUZUN BİLGİSAYAR KONTROLLÜ HAZIRLANMASI

Ömer Barış ÖZLÜOYMAK

ELEKTRİK-ELEKTRONİK MÜHENDİSLİĞİ ANABİLİM DALI
FEN BİLİMLERİ ENSTİTÜSÜ
ÇUKUROVA ÜNİVERSİTESİ

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Prof. Dr. Süleyman GÜNGÖR
Prof. Dr. Osman SERİNDAĞ

Günümüzde tekstil işletmelerinde tuz; pamuk ve viskon elyafının reaktif ve direkt boyanması ile yumuşak su elde edilmesi sırasında su yumuşatma ünitelerinde bulunan reçinelerin temizlenmesi, olmak üzere iki farklı amaçla kullanılmaktadır. Reaktif boyama işleminde rafine edilmiş tuz kullanılırken, su yumuşatma ünitelerinde kaya tuzu veya yıkanmış tuz kullanılabilmektedir.

Boyamada kullanılan rafine tuzun fiyatı kaya tuzunun yaklaşık 1,5 katıdır. Tekstil işletmelerinin kapasitelerine bağlı olarak değişmekle birlikte ayda ortalama 40–50 tonlara varan tuz tüketimi düşünüldüğünde rafine tuz kullanımının giderler üzerindeki etkisi daha iyi anlaşılmaktadır. Bu nedenle, rafine tuz yerine kaya tuzu kullanarak, tuz maliyetinin düşürülebilmesi ve sabit özellikte (sertlik, pH, vb.) tuz çözeltisinin istenildiği zamanda ve miktarda boyama işlemine dahil edilebilmesi oldukça önemlidir.

Kurulan sistem sayesinde kaya tuzunun bilgisayar kontrollü otomasyonu yapılarak, işçilikten tasarruf sağlanması, bununla birlikte elde edilen saf tuz çözeltisinin sadece boyamada değil, aynı zamanda işletmelerin su yumuşatma sistemlerinde kullanılan reçinelerin rejenerasyonunda kullanılması ile reçine ömrünün uzatılması da öngörülmektedir. Ayrıca bilinen tuz rafinerizasyon işlemlerinde de enerji tasarrufu sağlanabilecektir.

Bu tez çalışmasında, boyama işleminde daha pahalı olan rafine tuz kullanımına alternatif olabilecek bilgisayar kontrollü kaya tuzu işleme prosesinin tasarımı yapılmış ve çözelti sertliğinin 0-2 Fr arasında olması için sistemin ne kadar süreyle çalışması gerektiğine ilişkin deneme sonuçları verilmiştir.

Anahtar kelimeler: LabVIEW, Kaya tuzu, Otomasyon, Tekstil, Boyama

ABSTRACT

MSc THESIS

COMPUTER CONTROLLED SALT PREPARING FOR DYEING PROCESS IN TEXTILE SECTOR

Ömer Barış ÖZLÜOYMAK

DEPARTMANT OF ELECTRICAL AND ELECTRONICS ENGINEERING
INSTITUTE OF NATURAL AND APPLIED SCIENCES
UNIVERSITY OF ÇUKUROVA

Supervisor : Assist. Prof. Dr. Murat AKSOY
Year : 2006, Page: 77
Jury : Assist. Prof. Dr. Murat AKSOY
: Prof. Dr. Süleyman GÜNGÖR
: Prof. Dr. Osman SERİNDAĞ

Salt at the textile factories is used for two aims. The first, at the reactive and direct dyeing of cotton and viscon fibre, and the other one, it is used for cleaning resin in water soften units to obtain soft water. While using refined salt for reactive dyeing process, rock salt or washed salt can be used at the water soften units.

Cost of the refined salt is 1,5 multiple as the rock salt. According to capacity of the factory, consumption of refined salt can be 40-50 tons per month. Also, it can be seemed that the difference of cost is important. By using rock salt, both the cost of salt will decrease at the beginning and the salt solution with continuously fixed property (hardness, pH) can be added to the dyeing process automatically.

Through building the system, it will obtain economy from work capacity, nevertheless obtained pure salt solution will use not only for painting, but also at the resin regeneration, which is used in water soften systems at factories. Consequently, it is anticipated lengthen the lifetime of resin. In addition that, it will provide energy saving for textile factories.

In this thesis, instead of using refined salt for dyeing process, which is very important for the cost, it was realized the using of rock salt by computer controlled automation system and experimental results were given depend on the running time for being hardness of the solution between 0 and 2 Fr.

Keywords: LabVIEW, Rock Salt, Automation, Textile, Painting.

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LIST OF SYMBOLS

CH : Channel

Fr : Francium (Hardness Ratio)

Gnd : Ground

g : Gram

Hz : Hertz

kHz : Kilo-Hertz

kΩ : Kilo-Ohm

L : Liter

M : Mol

mA : Mili-Ampere

μA : Micro-Ampere

mL : Mili-Liter

Rext : External Bios Resistor

V : Volt

VA : Volt-Ampere

W : Watt

Z : Impedance

LIST OF ABBREVIATIONS

AI	: Analog Input
CMOS	: Complementary Metal Oxide Semiconductor
CMRR	: Common-mode Rejection Ratio
DAQ	: Data Acquisition
DSA	: Dynamic Signal Acquisition
D/A	: Digital-Analog Conversion
EDTA	: Ethylenediaminetetraacetic Acid
GPIB	: General Purpose Interface Bus
GUI	: Graphical User Interface
I/O	: Input / Output
LabVIEW	: Laboratory Virtual Instrument Engineering Workbench
LVTTL	: Low Voltage Transistor Transistor Level
NRSE	: Nonreferenced Single Ended
PC	: Personal Computer
PCI	: Peripheral Component Interconnect
RF	: Radio Frequency
RSE	: Referenced Single Ended
SCADA	: Supervisory Control and Data Acquisition
SCXI	: Signal Conditioning Extensions for Instrumentation
TTL	: Transistor-to-Transistor Logic
VI	: Virtual Instrument
VXI	: VME Extensions for Instrumentation

1. INTRODUCTION

Until reactive dyes made their appearance in 1956, cellulosic fibre dyeing was carried out almost exclusively with dyes having affinities for the fibre after being dissolved in the dye-bath; this meant the dyes used were directly soluble or soluble in reduced form and were absorbed by the fibre and united to it by secondary bonds, or by internal depositing of the insoluble dye that remained trapped in the macromolecular of the fibre and sometimes united by secondary bonds.

With soluble type dyes there was the problem of an incompatibility between dye brightness and washing fastness, as to have the former, chromophore with small molecular weight are necessary, which give low washing fastness it being only possible to establish a few secondary bonds between the fibre and the dye molecule.

Although until 1895 attempts were made to fix the dyes on the cellulose by covalent bonds, no satisfactory results were obtained until 1954, when Ratee and Stephen discovered that the dye contained in a dichlorotriazinyl group could form covalent bonds with the cellulose at an alkaline pH and at a moderate temperature between 20-100°C. This brought about a very detailed analysis of the reactive behaviour of the mono and dichlorotriazinyl ring, in front of the compounds with amine and hydroxyl groups.

The reactive dyes are anionic, soluble in water and stable in water with a hardness that does not exceed 15°hydrotimetry. The absorption by the fibre is based on the same principles as for direct dyes with little affinity.

The dyeings have bright colours and good washing fastness even for boiling, but they have little fastness to hypochlorite.

Neutral electrolytes have a strong influence on reactive dye absorption. They act in the same way as described for direct dyes. i.e. neutralizing the electronegative charge of the fibre, although compared to direct dyes, more quantity of neutral electrolyte necessary, to reach 30-50 g/l instead of the quantities not exceeding 10 g/l.

The quantity of salt to be used depends on the dye concentration and the liquor ratio; for deeper dyeing the electrolyte concentration must be higher, whereas if liquor ratio is reduced the quantity of electrolyte required is less.

The reactive dye absorption phase takes place at neutral pH, as the raising of the pH provokes the dye reaction with the fibre or with the water, and if the dye has not been absorbed into the fibre, hydrolysis is increased.

It has also been observed that when the pH is over a value of 11, besides more hydrolysis there is also a reduction in exhaustion.

The dissolution of direct dyes entails no great difficulties since their molecule contains sulphonic groups that give it solubility. This can be modified by the presence of salts, above all polyvalent cations, in the bath.

For this reason the solution has to be prepared with soft water or still better with demineralised water since the use of hard water makes the operation difficult.

To prepare the dye solution, it is mixed with a small quantity of cold water and when a homogenous dough is obtained, enough hot water (about 80°C) to achieve complete dissolution by agitation is added. In a few cases it is necessary to briefly boil the solution. In all it is necessary to remember the limit of solubility of the dye. (Coganra et al., 1992).

Nowadays, salt at the textile factories is used for two aims. The first, at the reactive and direct dyeing of cotton and viscon fibre, and the other one, it is used for cleaning resin in water soften units to obtain soft water. While using refined salt for reactive dyeing process, rock salt or washed salt can be used at the water soften units.

For reactive dyeing, adding salt increases the substantivity. However, adding too much salt at once, which can cause irregular dyeing, adding salt is necessary as portion state. But this process requires more work capacity and its control is too hard. That’s why, instead of giving the salt during dye process as portion state, giving at the beginning is more advantageous both for product dyeing quality and procedure facility.

In this project, rock salt will be used instead of refined salt. Cost of the refined salt is 1,5 time higher than the rock salt. According to capacity of the factory, consumption of refined salt can be 40-50 tons per month. Also, it can be seemed that

the difference of cost is important. By using rock salt, both the cost of salt will decrease at the beginning and the salt solution with continuously fixed property (hardness, pH) can be added to the dyeing process automatically.

With this system, which will be developed for master thesis, it is aimed to realize of salt preparing automation. Precipitation, mix process and pH property of the solution will be realized by computer controlled automation, and hardness of the solution will be defined by manually.

Because of being high of refined salt cost, using rock salt will be cheaper than refined salt.

Instead of using refined salt for dyeing process, which is very important for the cost, using of the rock salt will be realized by computer controlled automation system. Thus, high quality on dyeing and repeatability are aimed.

In this system, after the process, it will be saved economy from the work capacity, nevertheless obtained pure salt solution will use not only for painting, but also at the resin regeneration, which is used in water soften systems at factories. Consequently, lengthen the lifetime of resin is anticipated. In addition that, it will provide energy saving for textile factories.

In the second chapter, some previous works were given to constitute a background for the system structure.

In the third chapter, material and methods were presented respectively. All used equipments, devices, etc. were introduced in material section and all steps of the system were given in the method section.

In the fourth chapter, results were presented.

And in the last chapter, future works are suggested.

2. PREVIOUS STUDIES

Asumadu et al. (1996), examined that the design of a low-cost virtual instrument to control volume and pH of nutrient solution in hydroponic plant production systems supporting life in space has been developed. The algorithms developed are computationally simple and very suitable for a single microprocessor-based LabVIEW Windows data acquisition board. The details of such a LabVIEW-based instrument are described by the researchers.

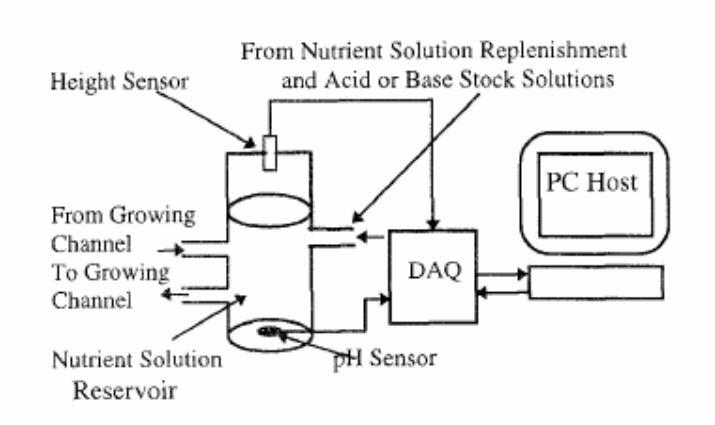


Figure 2.1. Nutrient Solution Height and pH Control (Asumadu et al., 1996)

Figure 2.1. shows the functional diagram used to measure the height (volume) and the pH of the nutrient solution in a hydroponic system. The data acquisition plug-in (DAQ) card is mounted in the host PC: which receives the height information from an ultrasonic sensor mounted on top of the tank and pH sensor inserted into the nutrient solution. The hydroponic system consists of a growing channel (for sweetpotatoes or peanuts), a nutrient solution reservoir and a pump to supply the nutrient solution to the growing channel. The nutrient solution must be increasingly replenished as the plant moves through the growth cycle. A submersible pump is engaged to replenish the nutrient solution if the percent error change in the nutrient solution height is larger than a predetermined value. The pH of the nutrient solution must be kept within a 5.5 to 6.5 range. Acid or base stock solutions are added when pH falls outside that range.

This paper shows how efficient algorithms can be implemented using National Instruments' LabVIEW virtual instrument GUI platform. It describes a fully automated microprocessor-based nutrient replenishment system for hydroponic crop production systems. The system measures and maintains a constant height (volume control) and pH for a nutrient solution. An ultrasonic sensor is used to measure the height and pH sensor is used to measure the pH. The algorithms are very efficient and require minimum hardware to implement. It is a low-cost system intended to be used in hydroponics systems but could have many applications as well.

Gimeno et al. (1999), informed that a Spanish type of dry fermented sausage, Chorizo de Pamplona, was manufactured with a mixture of (2.29%) different salts (NaCl, KCl, and CaCl2) with an equivalent ionic strength to that of the control manufactured with 2.6% NaCl. The use of this salt mixture affected the texture profile analysis (TPA), giving rise to a significant reduction in hardness, cohesiveness, gumminess and chewiness. Instrumental color values showed higher b* (yellowness) and L* (lightness) values. Sensory texture and color intensity yielded lower scores, but they were classified as acceptable. Principal component analysis was carried out with the instrumental measures. The two principal components explained 76.9% of the variance. Modified and control samples were separated by the first component, which explained 57.1% of the variance and was defined basically by texture parameters.

Chiou and Cheng (2001), noted that soybeans were soaked with water for 4 h, steam-cooked, inoculated with the conidia of Aspergillus oryzae, and incubated for 3 days for koji preparation. The koji was then mixed with water-soaked and steam-cooked soybeans (1:2, w/w), ground into paste, and supplemented with 15% ethanol and 12.5% NaCl or 3% ethanol and 6% NaCl for miso fermentation at 30 °C. Daidzin, genistin, daidzein, and genistein contents were extracted from the lyophilized and pulverized soybean powder or from the miso homogenate by a developed one-tube procedure and analyzed with an HPLC. After water soaking, daidzein and genistein contents increased markedly, whereas daidzin and genistin contents decreased. Further increases of daidzein and genistein contents and decreases of daidzin and genistin contents were observed after koji mold growth.

During fermentation, fungal and lactic acid bacterial (LAB) growth in the miso products was inhibited, whereas soluble protein contents increased much more rapidly in the low-salt miso products supplemented with 3% ethanol and 6% NaCl than the other products. When the 4- and 8-week-fermented miso products were cooked with tofu for sensory evaluation, flavor ratings of the low-salt products were higher than that of a popular commercial product. In both products, the most daidzins and genistins were hydrolyzed after 4 weeks of fermentation. The hydrolytic enzymes contributing to isoflavone transformation originated from soybeans after water soaking and from koji with mold growth. It was of merit that the low-salt fermented products were fairly acceptable in flavor rating and rich in daidzein and genistein contents after 4 weeks of fermentation.

Srinivasan et al. (1996), examined that protein and lipid oxidation and their inhibition by various washing media were monitored during the preparation of beef heart surimi-like material. Lipid oxidation was measured as increases in thiobarbituric acid (TBA)-reactive substances and conjugated dienes, and protein oxidation was determined as formation of protein carbonyls. Water-soluble antioxidant tripolyphosphate (0.2%) and lipid-soluble antioxidants propyl gallate (0.02%) and R-tocopherol (0.2%), added to the washing solution, were effective inhibitors of both lipid and protein oxidation. Ascorbate (0.2%) also inhibited lipid oxidation but caused an increase in protein carbonyls. Phosphate buffer (25 mM NaH2PO4/Na2HPO4), high final pH (7.0) of surimi pellet, and the presence of salt (0.1 M NaCl) all inhibited both protein and lipid oxidation during storage. Several processing options are thus available for the preparation of shelf-stable surimi-like material from beef hearts for possible utilization in formulated meat products.

Moore (1993), developed that chronic aquatic toxic effects are seen from common salts on freshwater organisms when conductivities are above 1500 uhmos. Sodium chloride and sodium sulfate are commonly used salts for the dyeing of direct dyes on cellulose fiber. These salts can be removed only through RO or similar tertiary waste treatment methods. Less toxic, more easily removed salts not based on sodium, potassium, ammonia, chloride, phosphate, or sulfate chemistries have been investigated.

Alberghina et al. (1990), have investigated the effects of various electrolytes at different concentrations on dyeing equilibria of CI basic blue 3 with Dralon X-100, interpreting the data with the Donnan approach. We have tried to separate the contribution of the cations and anions in the electrolytes. The results indicate that both cations and anions have independent effects on dye sorption. With increasing salt concentration, the dye sorption decreases, but with sodium and ammonium sulphate, an unusual increase of dye sorption occurs at salt concentrations up to 0.5 mol/1.

Matre (1991), informed that Since the beginning of their history, textile mills have been pondering a similar question - How to reduce the costs of production, while at the same time improving the quality goods supplied to customers? In today's competitive textile market, especially with the low-priced imported goods around, the ones who discover an answer to this question will greatly strengthen their position in the market; the company that cannot keep up with the cost reduction/quality improvement programs will lose orders to the competition. Our company has been researching this topic for customers since its beginning. The MPI Dosing system for the automatic metering of liquid additions, the Combined Cool Rinse system of cooling and rinsing (from as high as 265 degrees F), and the Salt Dissolve system for the automated dissolving of dry salt (common and glauber's salt) are all developments by Thies which allow customers to reduce costs while improving quality. We recently introduced another way to help customers improve their products and profits.

Yang and Li (2000), noted that a high-temperature alkaline process for the single-bath, one-step dyeing of polyester/cotton blends or mixtures with disperse/reactive dyes was developed. The process is based on the selection of alkaline dyeable disperse dyes and high temperature stable reactive dyes. Conditions such as temperature and its profiles, dyeing time, pH, alkalinity, salt, dye structures, and concentrations were all examined. The advantages of this process include the savings of time, energy, water, and labor and the decrease or elimination of the chemicals for reduction cleaning of both the dyed goods and the dyeing vessels. The disadvantage is that the dye exhaustion could be lower than the conventional two-

step dyeings. However, the comparable shade depth is obtainable if the appropriate dyeing conditions and dye structures are selected.

Reddy et al. (1997), examined that for real-time control, it is usually desirable to formulate a mathematical model of the process to be controlled. Such a model assists in the selection of control parameters and enhances the understanding of the underlying processes. A mathematical model for two-dye mixtures is developed comprising a diffusion based model to account for dye penetration into the fiber and a nonlinear distribution function at the fiber surface based on the Langmuir isotherm. Since the behavior of dyes in mixtures often deviates from their behavior when used alone, the dyeing process cannot be modeled by a simple combination of single dye models. Numerical simulations of the behavior of direct cotton dye mixtures under varying conditions of temperature and salt concentration are also presented, and compared with experiments.

3. MATERIAL AND METHODS

This study will be carried out at the Çukurova University Electrical and Electronics Engineering Department Laboratory. Besides, Chemistry Department of the Çukurova University supported this project with their all resources. For this system, it will be used;

- ✓ "LabVIEW Version 8.0 Student Edition for Windows" as Computer Program
- ✓ Data Acquisition System (DAQ)
- ✓ Control Card
- ✓ Solenoid Valves
- ✓ Liquid Level Sensors
- ✓ pH Meter
- ✓ Pumps
- ✓ Tanks
- ✓ Computer
- ✓ Rock Salt
- ✓ Dosage Pumps

Required equipments for this system will be connected to the computer and it can be controlled by the software. By this way, system automation will be provided easily.

3.1. Material

3.1.1. LabVIEW (Laboratory Virtual Instrument Engineering Workbench)

In 1983, National Instruments began its search for an instrumentation software solution that would minimize the time needed to program instrumentation systems. Through its effort, National Instruments developed the LabVIEW virtual instrument concept intuitive front panel user interfaces combined with an innovative block diagram programming methodology.

In 1986, National Instruments introduced LabVIEW 1 on the Macintosh. Although the Macintosh was not widely used for measurement and instrumentation applications, National Instruments chose it because the operating system's graphical nature best accommodated the LabVIEW technology until the more popular operating systems could accommodate it.

By 1990, National Instruments had completely rewritten LabVIEW, combining new software technology with years of customer feedback. More importantly, LabVIEW 2 featured a compiler that made execution speeds of virtual instruments comparable with programs created in the C programming language.

As new graphical operating systems came of age, National Instruments had the opportunity to introduce the now mature LabVIEW technology on the other industry-standard controller platforms - PCs and workstations. In 1992, National Instruments introduced LabVIEW for Windows and LabVIEW for Sun based on the new portable architecture. (Fountain, T.)

LabVIEW is a program development environment, much like modern C or BASIC development environments, and National Instruments LabWindows/CVI. However, LabVIEW is different from those applications in one important respect. Other programming systems use text-based languages to create lines of code, while LabVIEW uses a graphical programming language, G, to create programs in block diagram form.

LabVIEW, like C or BASIC, is a general-purpose programming system with extensive libraries of functions for any programming task. LabVIEW includes libraries for data acquisition, GPIB and serial instrument control, data analysis, data presentation, and data storage. LabVIEW also includes conventional program development tools, so you can set breakpoints, animate the execution to see how data passes through the program, and single-step through the program to make debugging and program development easier.

A VI consists of an interactive user interface, a dataflow diagram that serves as the source code, and icon connections that allow the VI to be called from higher level VIs. More specifically, VIs are structured as follows:

• The interactive user interface of a VI is called the front panel, because it simulates the panel of a physical instrument. The front panel can contain knobs, push buttons, graphs, and other controls and indicators. You enter data using a mouse and keyboard, and then view the results on the computer screen.

• The VI receives instructions from a block diagram, which you construct in G. The block diagram is a pictorial solution to a programming problem. The block diagram is also the source code for the VI.

• VIs are hierarchical and modular. You can use them as top-level programs, or as subprograms within other programs. A VI within another VI is called a subVI. The icon and connector of a VI work like a graphical parameter list so that other VIs can pass data to a subVI.

With these features, LabVIEW promotes and adheres to the concept of modular programming. You divide an application into a series of tasks, which you can divide again until a complicated application becomes a series of simple subtasks. You build a VI to accomplish each subtask and then combine those VIs on another block diagram to accomplish the larger task. Finally, your top-level VI contains a collection of subVIs that represent application functions. (LabVIEW User Manual, 1998)

LabVIEW is a graphical programming system that uses familiar instrument front panels and a patented block diagram-based programming language to build software modules called virtual instruments (VIS). To create a VI the user first builds a front panel with knobs, switches, graphs, strip charts and so on. The front panel serves as an interactive interface for supplying inputs to and observing results from the instrumentation system. Creating a panel is as simple as drawing a picture. The user can develop custom controls or indicators by importing images from other packages, such as Paint.

To programme the VI, a block diagram is constructed-free from the many syntactical details of conventional programming languages. The functional blocks of the program are selected from a palette and connected together with wires to pass data from one block to the next. These blocks range from simple arithmetic functions to advanced data acquisition, analysis, network and file I/0 routines. LabVIEW has

extensive tools to develop, test and debug the system. The help window describes each icon and its connections. LabVIEW shows the type of data flowing between blocks (integer, string, array of reals etc.) by the colour and thickness of wires connecting these blocks. It immediately indicates wrongly wired connections (output to output for instance), and lists these problems in an error window. LabVIEW also features execution highlighting, single stepping, breakpoints and probes. (Fountain,T., 1992).

LabVIEW can command DAQ boards to read analog input signals (IVD conversion), generate analog output signals (D/A conversion), read and write digital signals, and manipulate the on-board counters for frequency measurement, pulse generation, etc. The voltage data goes into the plug-in DAQ board in the computer, which sends data into computer memory for storage, processing, or other manipulation. (Korrapati et al., 2002)

There are many other applications where LabVIEW can be used to design and develop cost-effective and user-friendly Internet-based VIS. These applications can be broadly categorized into four different areas (Swain et al., 2003):

- Remote Monitoring
- Remote Control
- Collaboration
- Distributed Computing

In this study, LabVIEW 8.0 version computer program developed by National Instruments Company was used. With this program, a user interface, a front panel with controls and indicators were built. This system was controlled by knobs, push buttons and the other input mechanisms. After building user interface, code using VIs and structures were added to control the front panel objects. Block diagrams contain this code.

3.1.2. Data Acquisition System

Data acquisition involves gathering signals from measurement sources and digitizing the signal for storage, analysis, and presentation on a personal computer (PC). Data acquisition (DAQ) systems come in many different PC technology forms

for great flexibility when choosing your system. Scientists and engineers can choose from PCI, PXI, CompactPCI, PCMCIA, USB, Firewire, parallel, or serial ports for data acquisition in test, measurement, and automation applications. There are five components to be considered when building a basic DAQ system (Figure 3.1):

·Transducers and sensors

·Signals

·Signal conditioning

·DAQ hardware

·Driver and application software

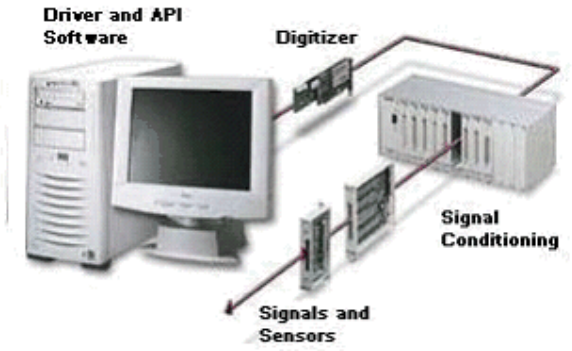


Figure 3.1. Data Acquisition System (Anonymous, 2006a)

Transducers

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective DAQ system can measure all of these different phenomena. A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current. The ability of a DAQ system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the DAQ hardware. Transducers are synonymous with sensors in DAQ systems. There are specific transducers for many different

applications, such as measuring temperature, pressure, or fluid flow. Table 3.1 shows a short list of some common transducers and the phenomena they can measure.

Table 3.1. Phenomena and Existing Transducers (Anonymous, 2006a)

Phenomena	Transducer
Temperature	Thermocouples Resistive Temperature Devices (RTDs) Thermistors
Light	Vacuum Tube Photo Sensors
Sound	Microphone
Force and Pressure	Strain Gauges Piezoelectric Transducers
Position and Displacement	Potentiometers Linear Voltage Differential Transformer Optical Encoder
Fluid	Head Meters Rotational Flowmeters
pH	pH Electrodes

Different transducers have different requirements for converting phenomena into a measurable signal. Some transducers may require excitation in the form of voltage or current. Other transducers may require additional components and even resistive networks to produce a signal. (Anonymous, 2006a)

Signals

The appropriate transducer converts the physical phenomena into measurable signals. However, different signals need to be measured in different ways. For this reason, it is important to understand the different types of signals and their corresponding attributes. Signals can be categorized into two groups:

·Analog Signals

·Digital Signals

Analog Signals

An analog signal can be at any value with respect to time. A few examples of analog signals include voltage, temperature, pressure, sound, and load. The three

primary characteristics of an analog signal include level, shape, and frequency (Figure 3.2).

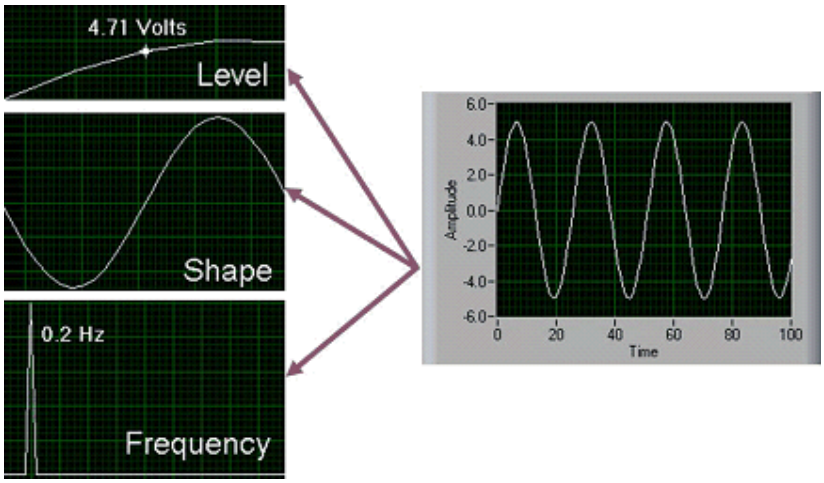


Figure 3.2. Primary Characteristics of an Analog Signal (Anonymous, 2006a)

Level

Since analog signals can take on any value, the level gives vital information about the measured analog signal. The intensity of a light source, the temperature in a room, and the pressure inside a chamber are all examples that demonstrate the importance of the level of a signal. When measuring the level of a signal, the signal generally does not change quickly with respect to time. The accuracy of the measurement, however, is very important. A DAQ system that yields maximum accuracy should be chosen to aid in analog level measurements.

Shape

Some signals are named after their specific shape – sine, square, sawtooth, and triangle. The shape of an analog signal can be as important as the level, because measuring the shape of an analog signal allows further analysis of the signal, including peak values, DC values, and slope. Signals where shape is of interest generally change rapidly with respect to time, but system accuracy is still important. The analysis of heartbeats, video signals, sounds, vibrations, and circuit responses are some applications involving shape measurements.

Frequency

All analog signals can be categorized by their frequency. Unlike the level or shape of the signal, frequency cannot be directly measured. The signal must be analyzed using software to determine the frequency information. This analysis is usually done using an algorithm known as the Fourier Transform.

When frequency is the most important piece of information, it is important to consider include both accuracy and acquisition speed. Although the acquisition speed for acquiring the frequency of a signal is less than the speed required for obtaining the shape of a signal, the signal must still be acquired fast enough that the pertinent information is not lost while the analog signal is being acquired. The condition that stipulates this speed is known as the Nyquist Sampling Theorem. Speech analysis, telecommunication, and earthquake analysis are some examples of common applications where the frequency of the signal must be known. (Anonymous, 2006a)

Digital Signals

A digital signal cannot take on any value with respect to time. Instead, a digital signal has two possible levels: high and low. Digital signals generally conform to certain specifications that define characteristics of the signal. Digital signals are commonly referred to as Transistor-to-Transistor Logic (TTL). TTL specifications indicate a digital signal to be low when the level falls within 0 to 0.8 Volts, and the signal is high between 2 to 5 Volts. The useful information that can be measured from a digital signal includes the state and the rate (Figure 3.3). (Anonymous, 2006a)

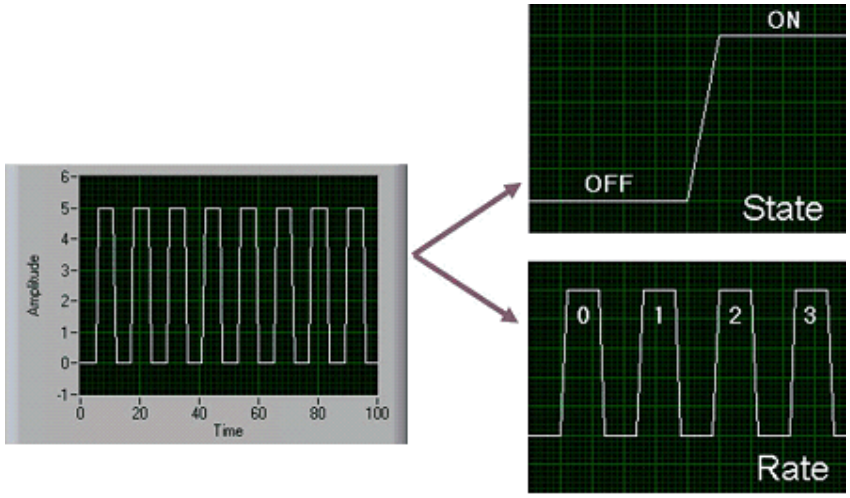


Figure 3.3. Primary Characteristics of a Digital Signal (Anonymous, 2006a)

State

Digital signals cannot take on any value with respect to time. The state of a digital signal is essentially the level of the signal – on or off, high or low. Monitoring the state of a switch – open or closed – is a common application showing the importance of knowing the state of a digital signal.

Rate

The rate of a digital signal defines how the digital signal changes state with respect to time. An example of measuring the rate of a digital signal includes determining how fast a motor shaft spins. Unlike frequency, the rate of a digital signal measures how often a portion of a signal occurs. A software algorithm is not required to determine the rate of a signal. (Anonymous, 2006a)

Signal Conditioning

Sometimes transducers generate signals too difficult or too dangerous to measure directly with a DAQ device. For instance, when dealing with high voltages, noisy environments, extreme high and low signals, or simultaneous signal measurement, signal conditioning is essential for an effective DAQ system. Signal

conditioning maximizes the accuracy of a system, allow sensors to operate properly, and guarantees safety.

It is important to select the right hardware for signal conditioning. Signal conditioning is offered in both modular and integrated forms (Figure 3.4). Signal conditioning accessories can be used in a variety of applications including:

· Amplification
· Attenuation
· Isolation
· Bridge completion
· Simultaneous sampling
· Sensor excitation
· Multiplexing

Other important criteria to consider with signal conditioning include packaging (modular versus integrated), performance, I/O count, advanced features, and cost. (Anonymous, 2006a)

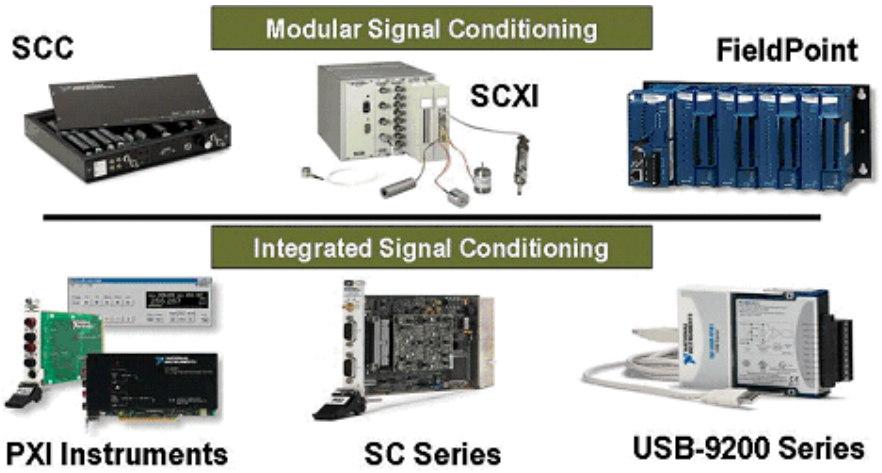


Figure 3.4. Signal Conditioning Hardware Options (Anonymous, 2006a)

DAQ Hardware

The DAQ hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them. Other data acquisition functionality includes:

· Analog Input/Output

· Digital Input/Output

· Counter/Timers

· Multifunction – a combination of analog, digital, and counter operations on a single device.

National Instruments offers several hardware platforms for data acquisition. The most readily available platform is the desktop computer. National Instruments offers PCI DAQ devices that plug into any desktop computer. In addition, NI makes DAQ devices for PXI/CompactPCI, a more rugged modular computer platform specifically for measurement and automation applications. For distributed measurements, National Instruments Compact FieldPoint platform delivers modular I/O, embedded operation, and Ethernet communication. For portable or handheld measurements, National Instruments DAQ devices for USB and PCMCIA work with laptops or PocketPC PDAs (Figure 3.5). (Anonymous, 2006a)

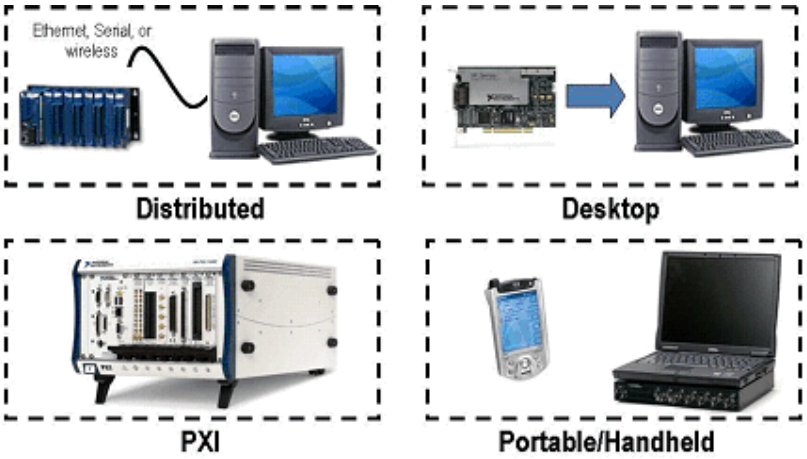


Figure 3.5. DAQ Hardware Options (Anonymous, 2006a)

Driver and Application Software

Driver Software

Software transforms the PC and the DAQ hardware into a complete data acquisition, analysis, and presentation tool. Without software to control or drive the hardware, the DAQ device will not work properly. Driver software is the layer of software that allows easy communication to the hardware. It forms the middle layer between the application software and the hardware. Driver software also prevents a programmer from having to do register-level programming or complicated commands in order to access the hardware functions. (Anonymous, 2006a)

Application Software

The application layer can be either a development environment in which you build a custom application that meets specific criteria, or it can be a configuration-based program with preset functionality. Application software adds analysis and presentation capabilities to the driver software. To choose the right application software, evaluate the complexity of the application, the availability of configuration-based software that fits the application, and the amount of time available to develop the application. (Anonymous, 2006a)

3.1.2.1. NI USB 6009 Data Acquisition Card (DAQ)

LabVIEW is used to communicate with hardware such as data acquisition, vision, and motion control devices, as well as GPIB, PXI, VXI, USB, RS232 and RS485 instruments. From these instruments, USB devices are more useful than the others. Therefore, in this thesis, it was used NI USB 6009 Data Acquisition Card (DAQ).

With plug-and-play USB connectivity, these devices are simple enough for quick measurements, but versatile enough for more complex measurement applications. The NI USB-6008 and USB-6009 include a ready-to-run data logger application that acquires and logs up to eight channels of analog data.

It has got 14-bit input resolution, at up to 48 kS/s. In addition that; this DAQ includes 8 single ended and 4 differential analog inputs. And it has 2 analog outputs which their resolutions are 12 bits. USB 6009 includes 12 digital I/O lines (TTL/LVTTL/CMOS) and 32-bit event counter.

Figure 3.6. NI USB 6009 Data Acquisition Card (NI-USB 6009 Manual, 2005)

As shown in Figure 3.6, the USB 6009 is ideal for a number of applications where economy, small size, and simplicity. (NI-USB 6009 Manual, 2005). With this Ready-to-Run Data Logger, several analog values like temperature, strain, voltage, current, etc. can be measured. Moreover, various pumps, valves, and other devices can be controlled by using its digital I/O channels. It would be connected via USB cable to the computer.

In Figure 3.7, the NI USB 6009 Data Acquisition Card Connection Diagram could be seen for measurement and instrumentation control.

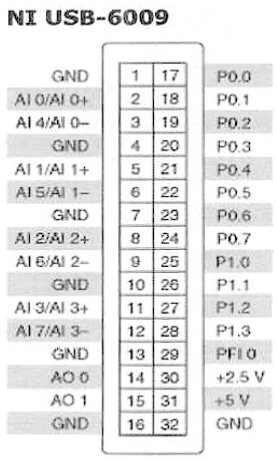


Figure 3.7. NI USB 6009 Data Acquisition Card Connection Diagram (LabVIEW Help, 2005)

The datasheet for NI USB 6009 Data Acquisition Card was given in Appendix A.

3.1.3. Control Card

In this system, a control card included 12 relays for instrument control was used during the study. The instruments consist of pumps and solenoid valves were opening or closing according to the program, respectively.

Relays on the card are active when ground has been applied to their contacts, 0,1 mA was recorded. When +5V has been applied to contacts, 50 µA was observed.

Used power relays for this card are produced by Ningbo Yinzhou Yonglin Electron Electrical Equip Co., Ltd. YL-221/(H)(14FF) model relays were used for the control card.

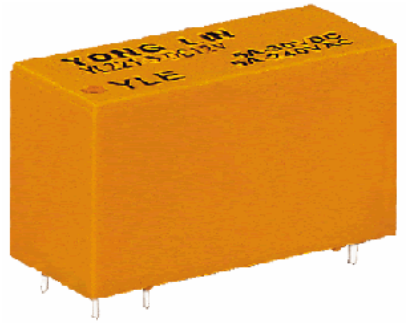


Figure 3.8. YL-221 Electromechanical Power Relay (Anonymous, 2006b)

In Figure 3.8 and 3.9, a photograph of the electromechanical power relay and its contact arrangement can be seen, respectively. Besides, its characteristic data graphs were given in Appendix B.

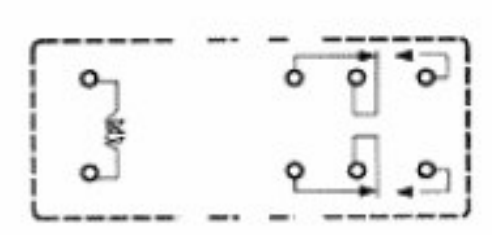


Figure 3.9. YL-221 Power Relay Contact Arrangement (Anonymous, 2006b)

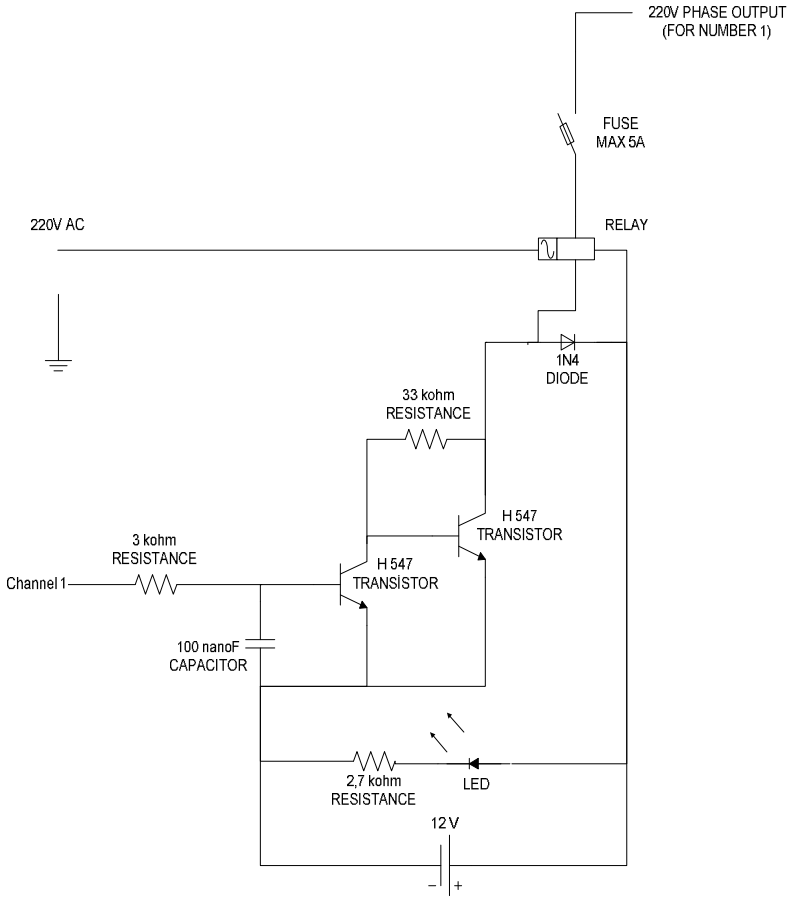


Figure 3.10. Schematic Equivalent of Control Card

Schematic equivalent of the control card is given in Figure 3.10. Only one channel diagram was shown here, because this schematic equivalent is same for each channel on the control card.

A photo for this card was given in Figure 3.11.

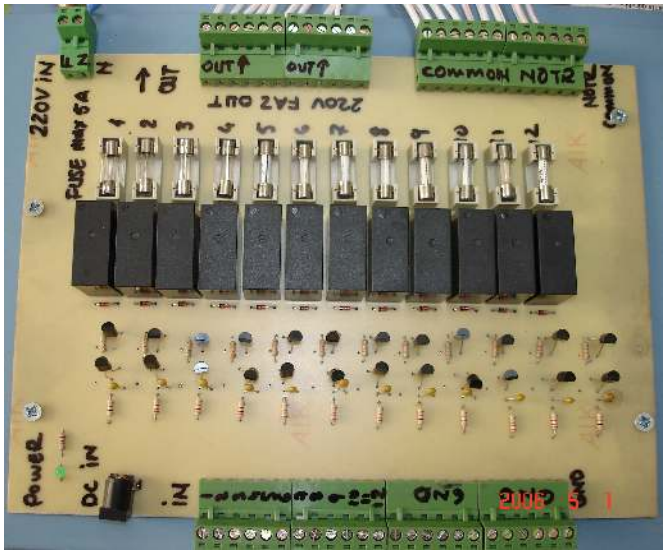


Figure 3.11. A Photograph of the Control Card

3.1.4. Solenoid Valves

"Normal closed" solenoid valves was used, which its operating pressure is 0,3-10 bar, for this system. These valves are running at 220 VAC, 50 Hz and their power inputs are 8,0 VA.

In this thesis, two type solenoid valves were used to control the system via computer. The first one is single input/single output type solenoid valve, which is shown in Figure 3.12.

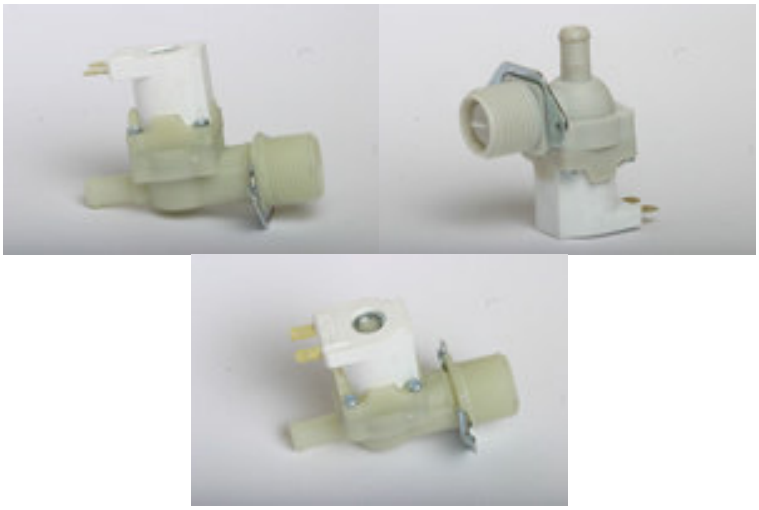


Figure 3.12. Photographs of Single Input/Single Output Type Solenoid Valves

And the other one is single input/double output type solenoid valve, which is shown at the Figure 3.13.

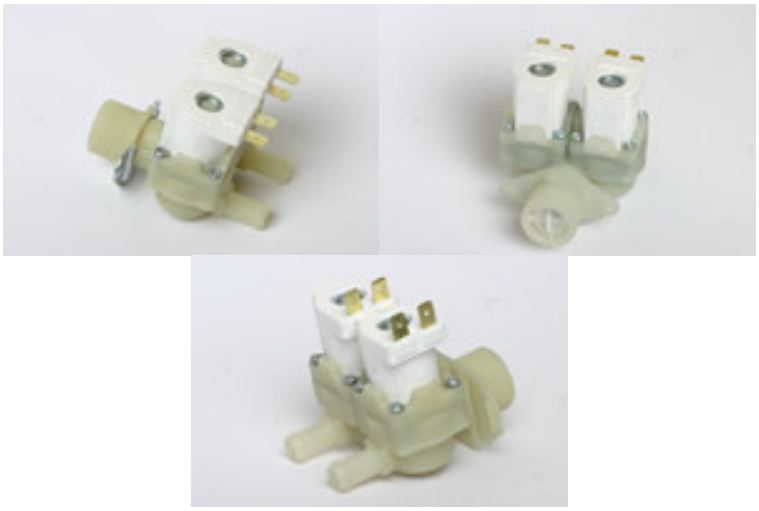


Figure 3.13. Photographs of Single Input/Double Output Type Solenoid Valves

These valves have a specific characteristic, which work with water pressure, if solenoids plug in. If solenoids plug out, solenoid valves won't be active and work.

3.1.5. Liquid Level Sensors

Liquid level sensors are used to detect liquid levels or interfaces between liquids such as oil and water or liquids and solids. Liquid level sensors can be defined as a sensor or transducer, or an integrated system, with instrumentation and control capabilities. Continuous or point level sensing can be chosen depending upon the application. Point liquid level sensors often trigger an alarm or turn off the system based upon a specific limit.

Some applications rely upon continuous liquid level monitoring. Continuous liquid level sensing can use a number of methods including pressure, ultrasound, and vibration. Pressure membrane liquid level sensors and differential liquid level sensors measure the pressure or change in pressure in a vessel such as a holding or storage tank. Ultrasonic / sonic liquid level sensors measure the length of time it takes for a reflected sound wave to return to a transducer. Vibrating / tuning fork

liquid level sensors use a piezoelectric crystal or other technology to vibrate a probe, then constantly monitor the presence, absence, increase or decrease of that vibration. In some applications, it is necessary to measure the level of a fluid without having direct contact with the media. In applications where the liquid is highly corrosive, non-contact meter technologies such as ultrasonic / sonic liquid level sensors and/or radar / microwave liquid level sensors may be optimal. Media type, surface properties, and temperature are a consideration when choosing ultrasonic liquid level sensors. For example, if a mixer is a part of the tank assembly, the fluid surface may include foam, waves, or additional turbulence.

Some liquid level sensing systems are programmable and will filter the variations in signal that are due to these factors. Radar / microwave liquid level sensors measure the microwave pulse emitted toward the process material; the pulse is reflected back by surface of material and picked up by a receiver. Level is inferred from the time of flight. This is a non-invasive method that is effective in various applications where suspended solids, slurries, and sludge are part of the fluid that is measured such as in the pulp and paper and wastewater industries. Radio frequency (RF) liquid level sensing is dependent upon the materials used to measure the capacitance or impedance of the liquid present or absent. In contact applications, a probe is top mounted or side mounted in a tank or vessel. A radio signal is emitted from a source. When the liquid media covers the probe, the liquid acts as an insulator between the wall and the probe. A change in the modulated signal is relayed to a switch for an alarm, or to a remote location where level status can be monitored or controlled. A material with a high dielectric constant will have a higher conductivity. The interaction of the chemical, the vessel wall material, and/or the material chosen for the sheath of the probe affects the total circuit. Instead of a radio frequency, electrical conductivity / resistance liquid level sensors use a low-voltage power source applied across separate electrodes. A conductive liquid contacting both probes completes a conductive circuit. Other liquid level sensors include mechanical / magnetic floats, air bubblers, and rotation paddles. These liquid level sensors may have an analog or digital output with an indicating display or other user interface. (Anonymous, 2006c).

In this thesis, liquid level sensors were used to measure levels of tanks. According to changing the resistance value of the sensor, liquid level could be determined by the help of computer.

As shown in Figure 3.14, resistance value of this sensor changes according to the situation of the arm. Liquid level information is transmitted via cables and DAQ to the computer.

Figure 3.14. Some Photographs of Liquid Level Sensor

As shown in Figure 3.15, a level graph was obtained from the sensor according to its altitude and resistance value.

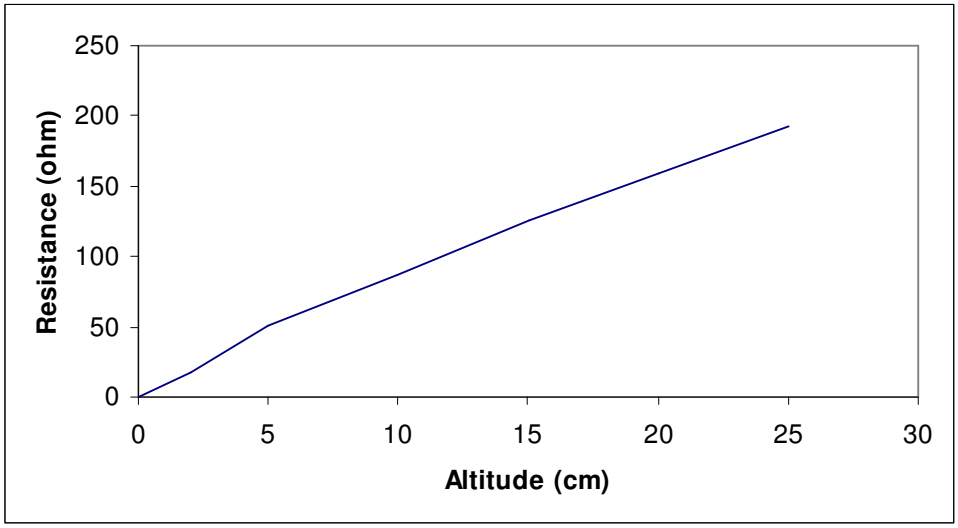


Figure 3.15. Level Graph for Liquid Level Sensor

3.1.6. pH Meter

In this project, it was aimed to measure pH property of the solution. A pH meter was used to measure pH value between 0 and 14, as shown in Figure 3.16.

Figure 3.16. Picture of Hanna Instruments pH-211 pH Meter

3.1.7.Pumps

In this study, pumps were used to circulate the chemical solution to mix chemicals, salt and water or to send liquid from a tank to another tank or discharge. Some photos of pumps in the system were given in Figure 3.17. Pumps, under tanks, are used for discharging and the others are used for circulating of the system. The power of used pumps for the system is 40W and each pump in the system takes 0,2A in maximum.

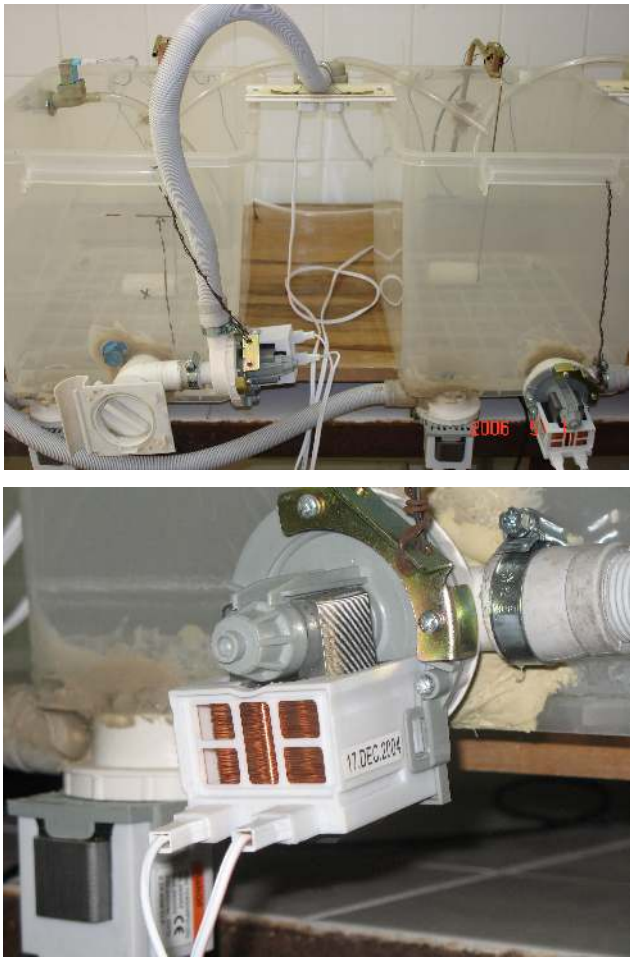


Figure 3.17. Some Photos of Pumps in the System

3.1.8. Tanks

To store and process the solution, it was necessary to use especially plastic tanks. Because of using NaOH, $MgCl_2$, Na_2CO_3 (anhydrous) and HCl (Hydrochloric acid) in this study, plastic type tanks were chosen. If another type tank like a steel type was used, they could damage to tanks day by day.

As shown in Figure 3.18, this photo of tanks was taken from left side of the system.

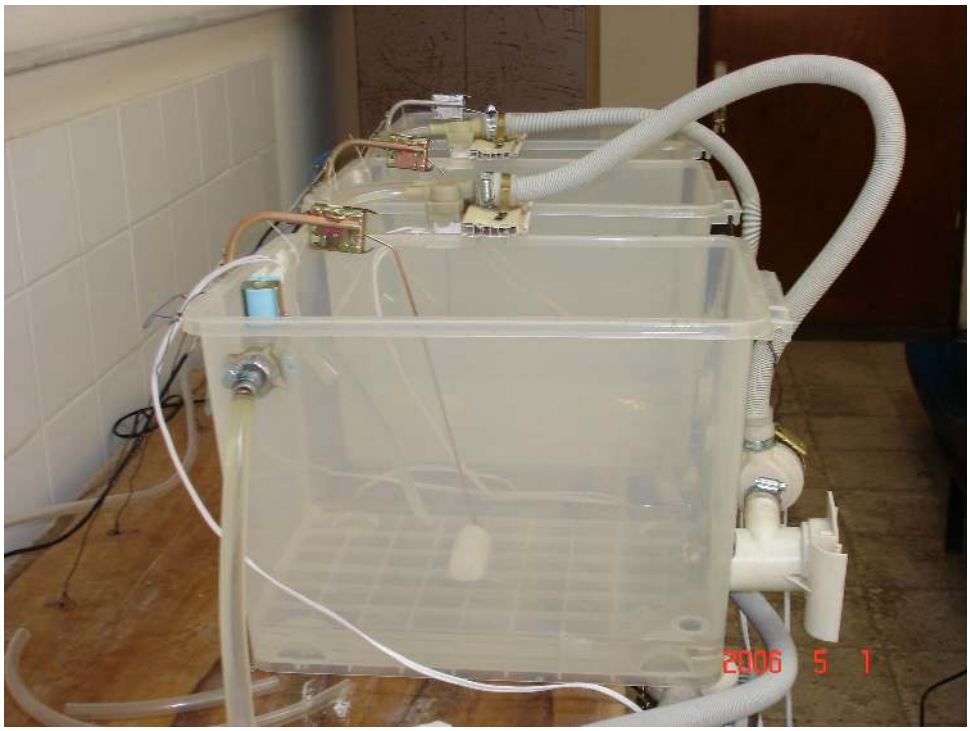


Figure 3.18. Left Side Views of Tanks

3.1.9.Computer

To run the program and control experimental environment (pumps, valves, etc.), a notebook computer was used on this system. Used computer, which is Satellite L10-102, has 40 GB Hard disc and 1,024 GB system memory, was made by TOSHIBA. To connect the system to the computer, it was profited by its USB 2.0 channel.

3.1.10. Rock Salt

This is the common name for the mineral "halite". Its chemical formula is NaCl. It can have impurities of gypsum ($CaSO_4$) and sylvite (KCl) but it is very rare to find potassium sulfate as a mineral, although occasionally polyhalite ($K_2Ca_2Mg(SO_4)_4.2H_2O$) is found associated with rock salt deposits. It is typically formed by the evaporation of salty water (such as sea water) which contains dissolved Na^+ and Cl^- ions. (Anonymous, 2006d).

Figure 3.19. Some Photos of Rock Salt (Anonymous, 2004)

3.1.11. Dosage Pumps

To add some chemicals (HCl, NaOH, $MgCl_2$ and Na_2CO_3) into the system, two dosage pumps were used. A solenoid valve is found on the dosage pump to pump these chemicals to tanks as metrical.

Help with this pump, required amount of chemical can be added to the system. In Figure 3.20, some photos were given for this dosage pump.

Figure 3.20. Some Photos of the Dosage Pump

3.2.Method

3.2.1.Parts of the Designed System

The main components of the proposed system were three tanks in which mixing process was occurred. The tanks which are integrated to the system in a certain order are called as solution tank, neutralisation tank and product tank. The other components were three pumps, three valves and three liquid level sensors. Also, two barrels controlled with electromechanical valves were used for adding the required chemicals such as NaOH, $MgCl_2$, Na_2CO_3 and HCL into the water in solution and neutralisation tanks to dissolve the salt and control the pH value of the mixture. The pH level of the mixture in the neutralisation tank was continuously measured by using a pH meter.

After the electrical and other (hose and fittings) connections of the system were done, the control and data acquisition cards (DAQ) and the computer were integrated to the system. After the completion of the system setup, the solution tank was connected to the water source and the system will start to walk on the computer as soon as the program is run. The water was taken into the solution tank through the solenoid valve which is mounted on the tank.

When the developed software controlling the whole process is activated, firstly a basic window appears on the screen for the selection of one in two starting alternatives. If the OK button is clicked, the cleaning process for the entire tanks is

begun. Unless the OK button is clicked, program waits for the five seconds to start for the purposed process.

After the liquid level in the first tank reaches the critical point which is described in the program as a percent value of full tank volume beforehand, the relay on the control card which controls the solenoid valve of the solution tank switches off the system so that flowing of the water from the source to the tank cuts off.

During the water flow, 400 g rock salt per one litre water was added to the solution tank at the same time. Before the mixing process which facilitates the dissolving of the rock salt and maintains the liquid homogenization, the mixture of 2,5 g NaOH, 0,05 $MgCl_2$, and 2 g Na_2CO_3 per one litre water was added to the solution tank from the first barrel.

After the addition of all necessary chemicals and rock salt into the solution tank, mixing process was performed for 10 minutes by the functions of a circulation pump and a solenoid valve with double channels.

After the mixing process completed, the mixture in the solution tank was kept for 10 hours without any activation to have a good mixture free from the sediments.

At the end of the tenth hour, while precipitation at the base of the solution tank which corresponds the 10% volume of the whole mixture was kept, the 90% volume of the mixture was moved to the neutralisation tank.

As soon as the liquid transfer between two tanks was completed, evacuation process for the sediment at the base of the solution tank was performed by the functions of solenoid valve and pump located at the bottom of the solution tank.

Immediately after the evacuation process completed, HCl from the acid barrel was released into the neutralisation tank to adjust pH level 6.0-6.5 for 21 seconds. Meanwhile, level information sensed real-time from the three liquid level sensors which transmit 800 samples per one second on 500 kHz and mounted on each tank was transferred to the computer continuously.

After the HCl addition is completed, successively, mixing with the help of the pump and solenoid valve with double channel and purifying processes were performed in the neutralisation tank. Duration of the mixing and the keeping processes in the neutralisation tank were programmed for 5 and 1 minutes,

respectively. Then the solution which is ready to use was transferred to the product tank.

At last step, solution in the product tank can be automatically discharged into wherever it will be used.

As mentioned before, at the end of the process, system was programmed so that one of the selections of cleaning for all tanks and starting the process should be made by the user. After the selection of cleaning for all tanks by clicking the OK button appearing on the computer screen, cleaning process for all tanks was started with the help of pumps and solenoid valves.

While the system runs, it is possible to wait the system in standby mode by clicking the "*stand-by button*", which will open the contacts of all relays, appeared on the screen. The system can again be activated by clicking the same button which has two different functions in turn. Also, there is an exit button for quitting from the program, which will be functional immediately after clicking the stand-by button.

While the system is running, all operation status of the equipments such as change in the level sensors position, being in the situation of opening or closing for the valves and pumps, etc. is synchronously monitored on the screen.

Some photos of the system and its front panel are shown in Figure 3.21 and 3.22, respectively.

Figure 3.21. Some Photos of the System

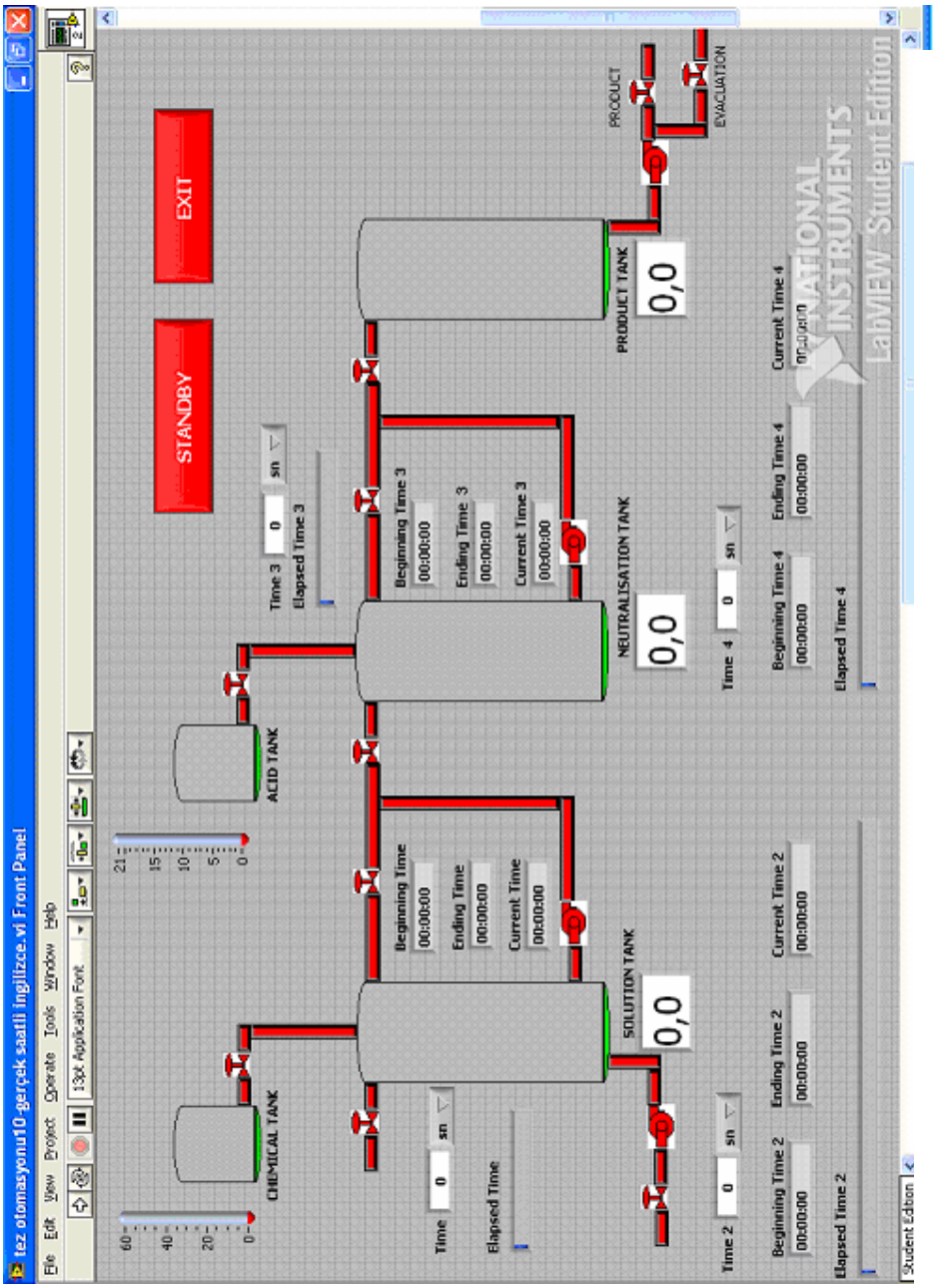


Figure 3.22. System Front Panel

3.2.2.The Diagram of Computer Controlled Salt Solution Preparing System

This study was carried out at the Çukurova University Electrical and Electronics Engineering Department Laboratory.

Diagrams of the computer controlled salt solution preparing system for the dyeing process in textile sector were shown for basic and detailed in Figure 3.23 and Figure 3.24, respectively.

As the characteristic of used computer program, the system which can be described here like a SCADA style program and its components were represented by figures.

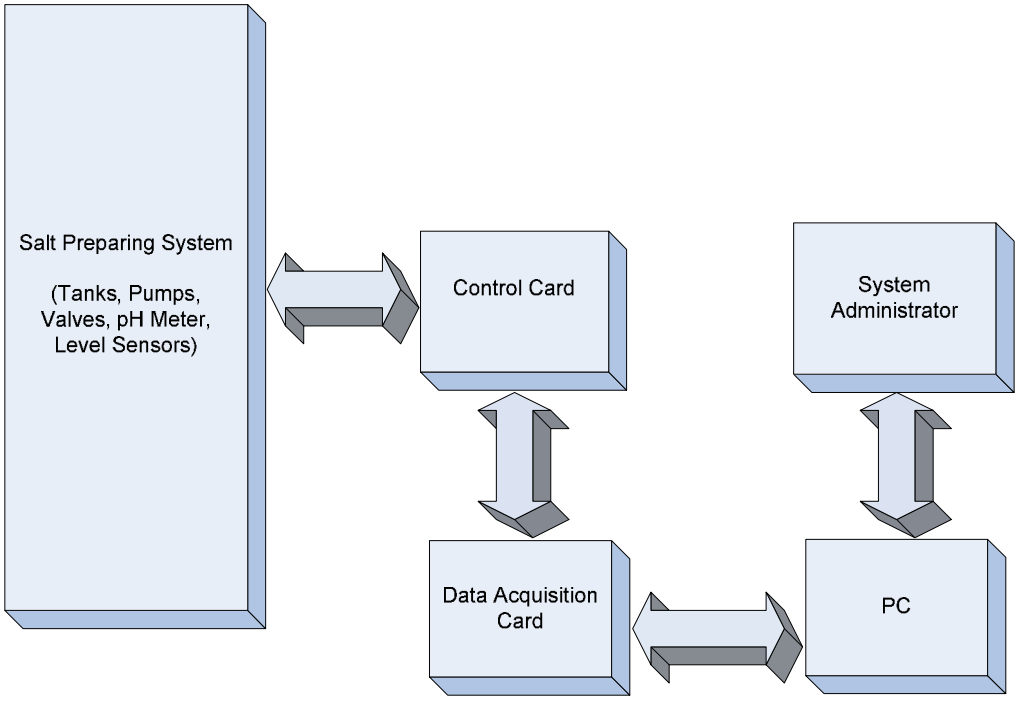


Figure 3.23. Basic Diagram of the System

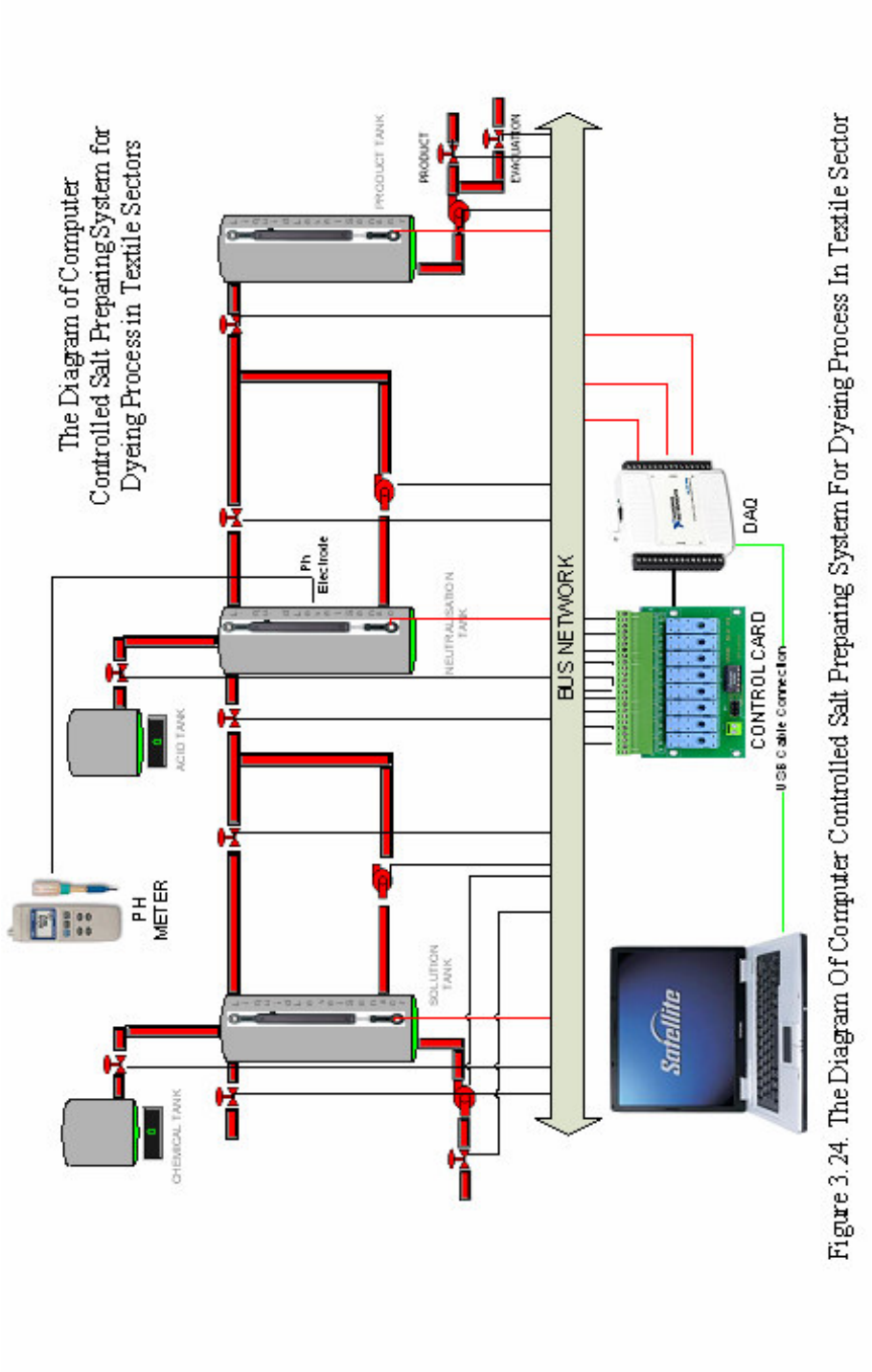


Figure 3.24. The Diagram Of Computer Controlled Salt Preparing System For Dyeing Process In Textile Sector

3.2.3.Developed Software and its Flow Diagrams

The software which was developed by using LabVIEW 8.0 is a program, which includes 51 steps for the system automation. The flow diagrams of the system were shown in Figure 3.25 and Figure 3.26, respectively.

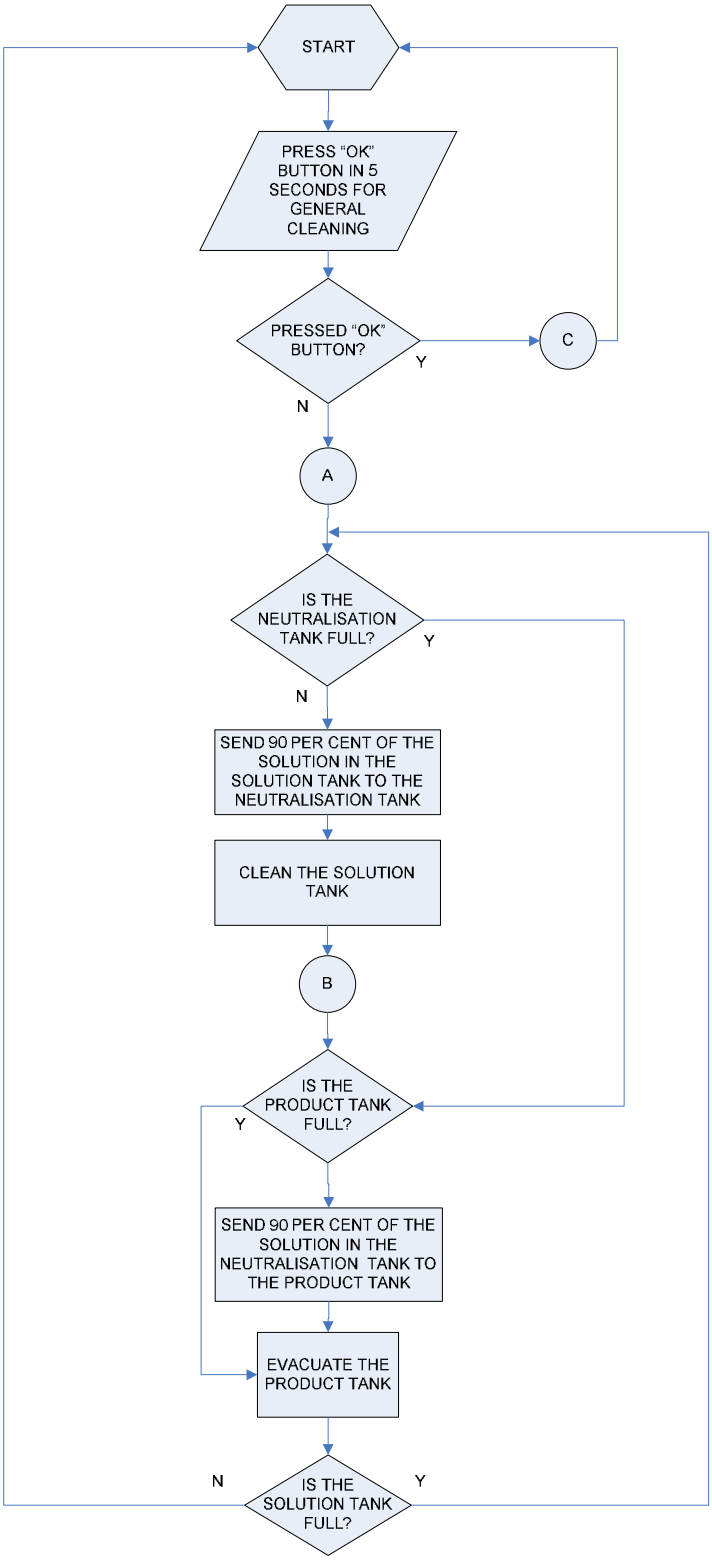


Figure 3.25. The Diagram of the Whole System

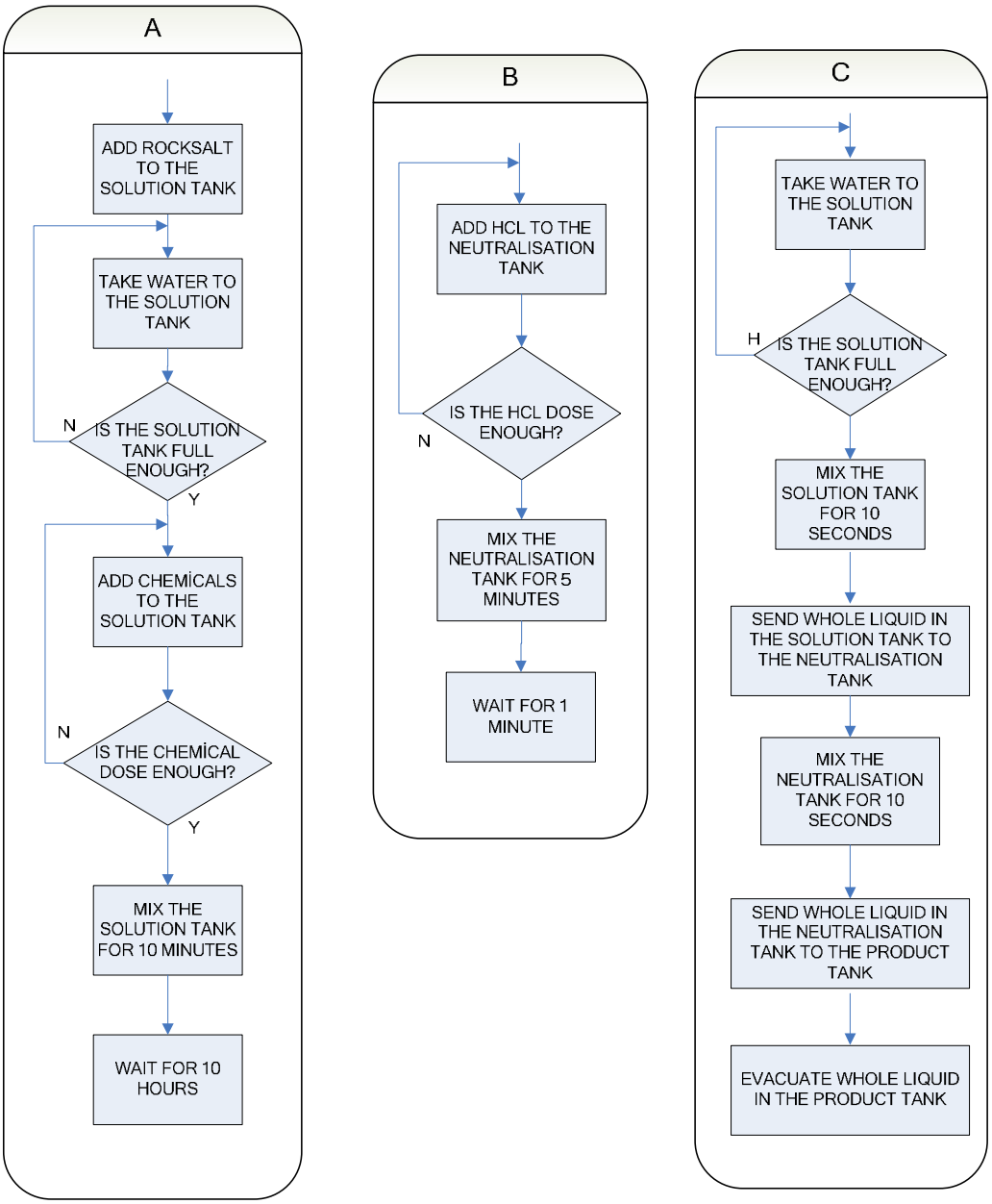
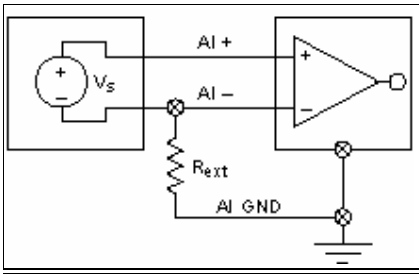
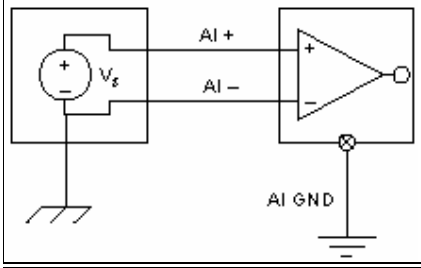
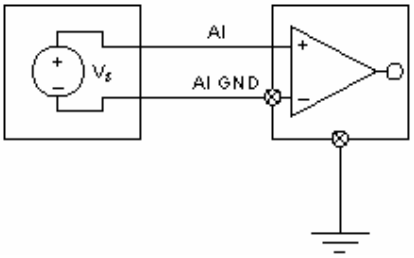
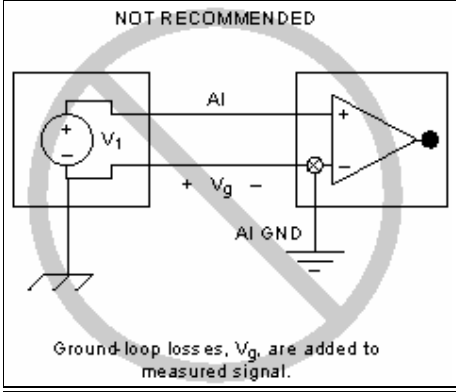
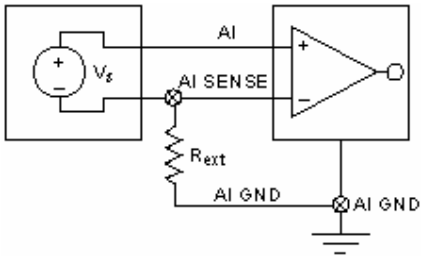
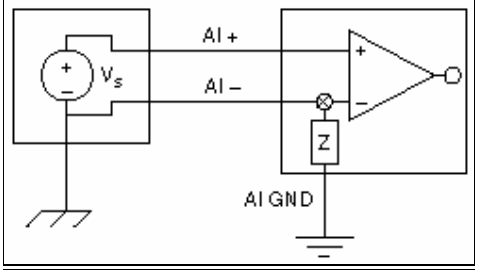
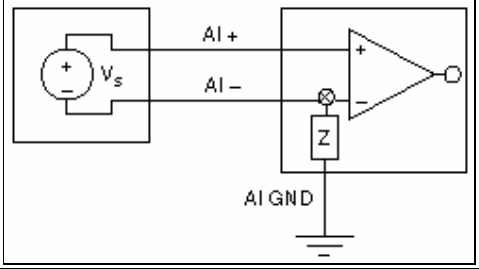
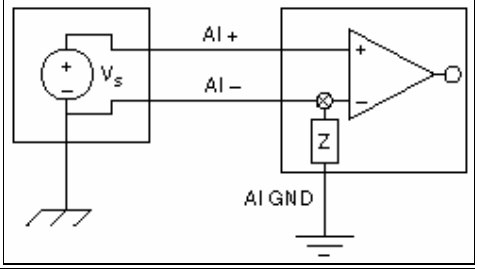


Figure 3.26. The Flow Chart of the System for Three Situations

3.2.4.Measurement System Types and Signal Sources

The type of input signal source (grounded or floating) and the configuration of the measurement system (differential, single-ended, psuedodifferential) determine how you connect signals to measurement devices. The following table provides an application-independent summary of analogue input connections. The resistors in the figures are not the same as those for measuring current, resistance, and strain. (LabVIEW Help, 2005)

Table 3.2. Measurement System Types and Signal Sources (LabVIEW Help, 2005)

Input	Signal Source Type	
	Floating Signal Source (Not Connected to Building Ground)	Grounded Signal Source
	Examples: Ungrounded thermocouples, signal conditioning with isolated outputs, battery devices	Example: Instruments with nonisolated outputs
Differential (DIFF)		
Ground Referenced Single-Ended (RSE)		
Nonreferenced Single-Ended (NRSE)		
Psuedodifferential		
R_{ext} is the external bias resistor that you add.		

3.2.4.1. Differential Measurement System

A differential measurement system has neither of its inputs tied to a fixed reference, such as earth or building ground. A differential measurement system is similar to a floating signal source in that the measurement is made with respect to a floating ground that is different from the measurement system ground. Hand-held, battery-powered instruments and DAQ devices with instrumentation amplifiers are examples of differential measurement systems.

The following figure shows an implementation of an 8-channel differential measurement system used in a typical NI device. Analogue multiplexers are used in the signal path to increase the number of measurement channels when there is only a single instrumentation amplifier. For this device, the pin labelled AIGND, the analogue input ground, is the measurement system ground. (LabVIEW Help, 2005)

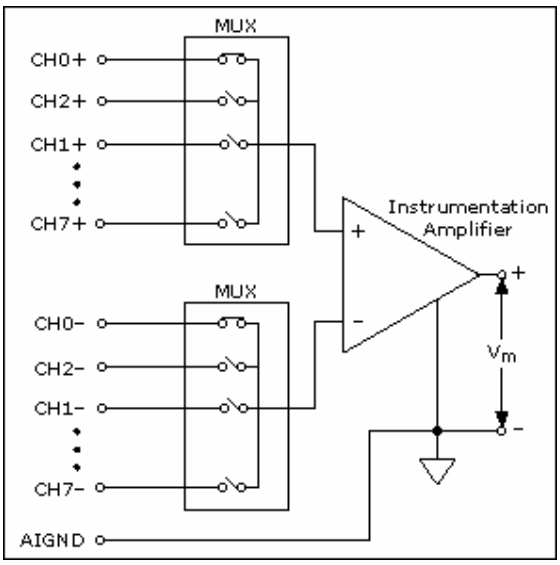


Figure 3.27. Differential Measuring System (LabVIEW Help, 2005)

3.2.4.2. Referenced and Nonreferenced Single-Ended Measurement Systems

Referenced and nonreferenced single-ended measurement systems are similar to grounded sources in that the measurement is made with respect to ground. A

referenced single-ended (RSE) measurement system measures voltage with respect to the ground, AIGND in the figure, which is directly connected to the measurement system ground. The following figure shows an 8-channel referenced single-ended measurement system. (LabVIEW Help, 2005).

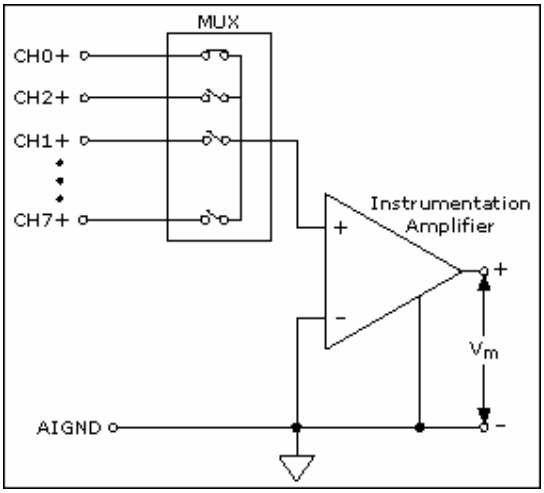


Figure 3.28. Referenced Single-Ended Measuring System (LabVIEW Help, 2005)

DAQ devices often use a variant of the referenced single-ended measurement technique, known as nonreferenced single-ended (NRSE). The following figure shows an NRSE system.

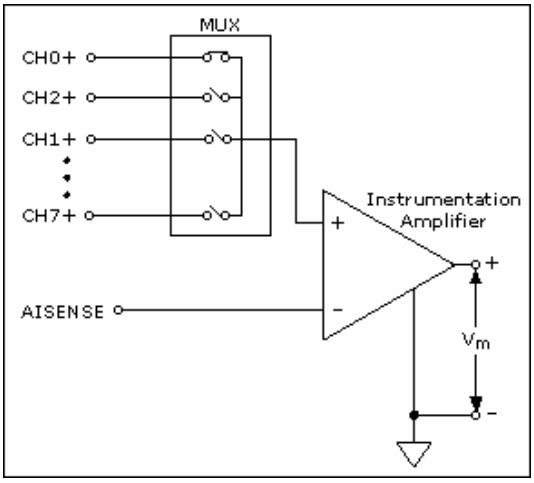


Figure 3.29. Nonreferenced Single-Ended Measuring System (LabVIEW Help, 2005)

In an NRSE measurement system, all measurements are still made with respect to a single-node analogue input sense, but the potential at this node can vary with respect to the measurement system ground (AIGND). The previous figure illustrates that a single-channel NRSE measurement system is the same as a single-channel differential measurement system. (LabVIEW Help, 2005).

3.2.4.2.(1). Referenced Single-Ended Measurement for Liquid Level Sensors of the System

Used liquid level sensors on the system were designed for referenced single-ended measurement. It was profited by +5V of the data acquisition card and 3 kΩ resistance for measurement.

In Figure 3.30, a graph relating to the referenced single-ended measurement system design was shown for each liquid level sensor.

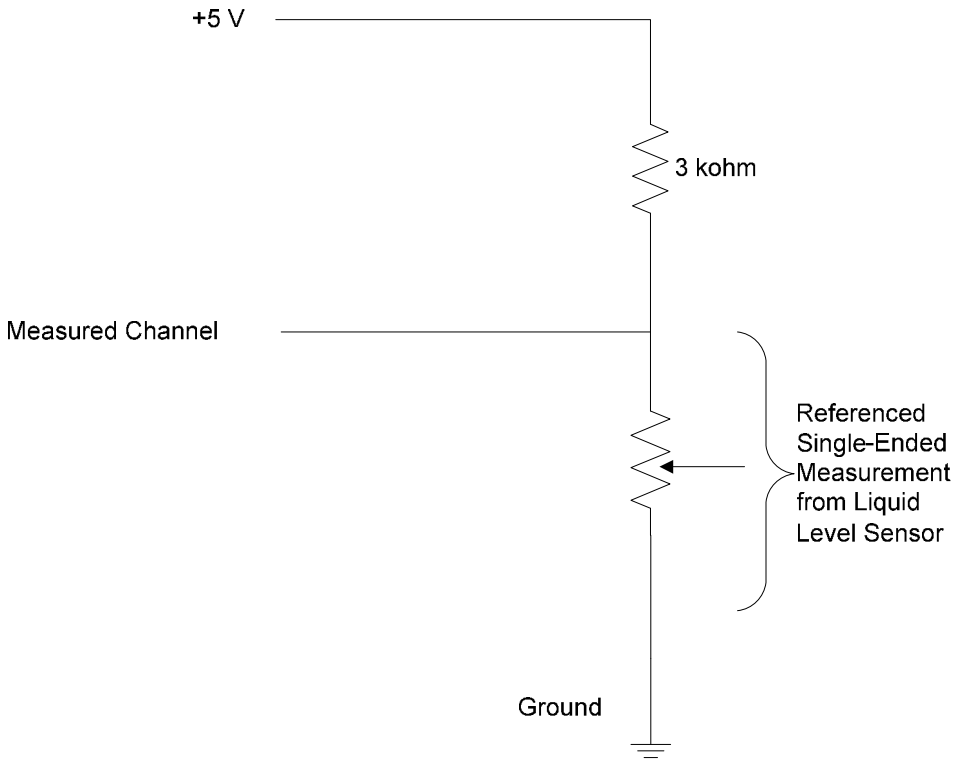


Figure 3.30. Referenced Single-Ended Measurement System Design for Liquid Level Sensors

3.2.4.2.(2).Program Part for Each Liquid Level Sensor and Their Mathematical Equations

To obtain liquid level values of the system, some mathematical equations used in the computer program were developed for each sensor. With the help of these equations, liquid levels of each tank were defined and monitored. The following figure provides a program part for each liquid level sensor and their mathematical equations successively.

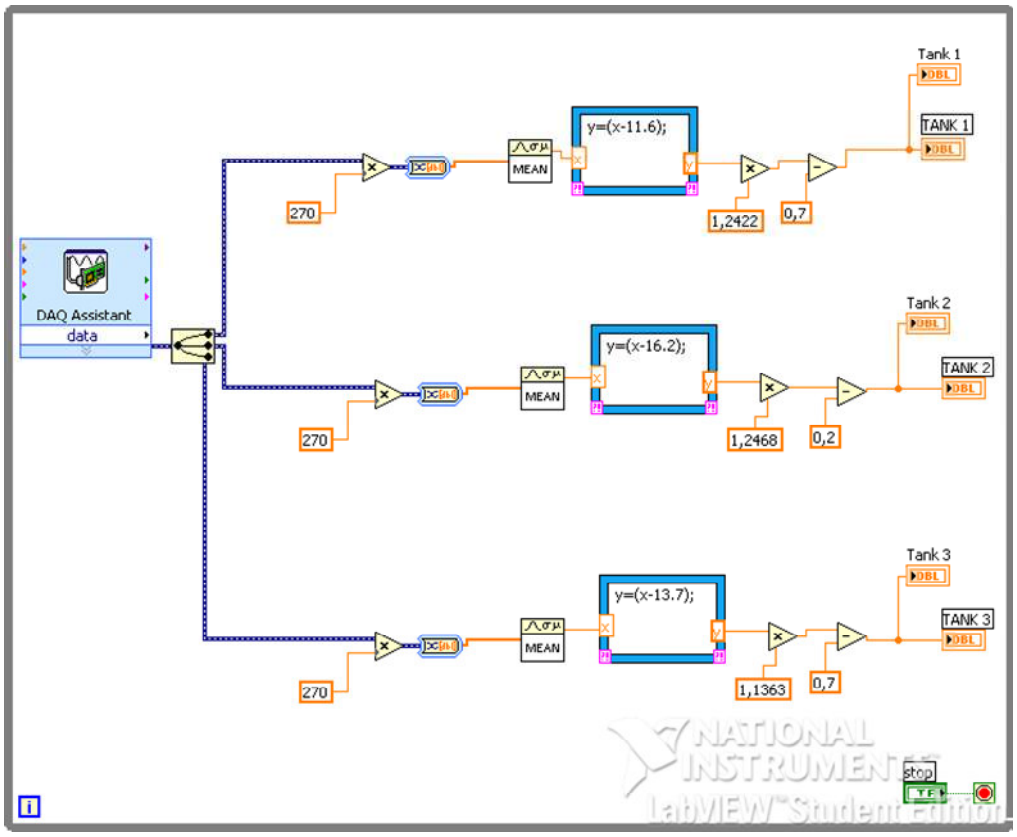


Figure 3.31. A Program Part for Each Liquid Level Sensor

3.2.4.3.Pseudodifferential Measurement System

A pseudodifferential measurement system combines some characteristics of a differential input channel and a referenced single-ended (RSE) input channel. Like a differential input channel, a pseudodifferential measurement system exposes both the positive and negative sides of the channel. You connect the positive and negative

inputs to the respective outputs of the unit under test. The negative input is tied to system ground through a relatively small impedance (designated as Z_l in the diagram below). The impedance between the negative input and ground may include both resistive and capacitive components. The positive and negative sides of the input channel are separated by a larger impedance (designated by Z_{in}).

Pseudodifferential input configurations are common in simultaneous sampling and dynamic signal acquisition (DSA) devices that do not employ a multiplexed signal architecture. A pseudodifferential system is well-suited for measuring the output of floating or isolated devices under test such as battery-powered instruments or most accelerometers. The pseudodifferential setup can also be used to measure referenced signals if the signal reference potential does not differ greatly from the ground potential of the measurement device. However, ground loops may pose an issue if the potential of the negative leg of the signal differs significantly from chassis ground. In general, a differential input offers a better common-mode rejection ratio (CMRR) than a pseudodifferential input. (LabVIEW Help, 2005).

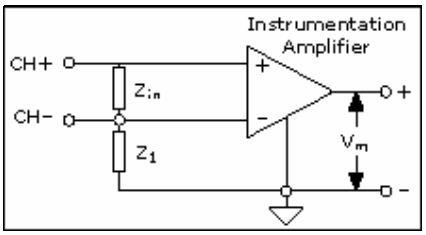


Figure 3.32. Pseudodifferential Measurement System (LabVIEW Help, 2005)

3.2.4.4.Floating Signal Sources

In a floating source, the voltage signal is not connected to any absolute reference or any common ground, such as earth or building ground as shown in the following figure.

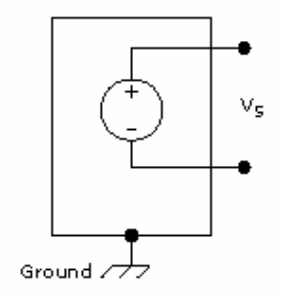


Figure 3.33. Floating Signal Sources (LabVIEW Help, 2005)

Floating signal sources are also called nonreferenced signal sources. Some common examples of floating signal sources are batteries, thermocouples, transformers, and isolation amplifiers. Notice in the figure that neither terminal of the source is connected to the electrical outlet ground, so each terminal is independent of the system ground. (LabVIEW Help, 2005).

3.2.4.5. Measuring Floating Signal Sources

You can measure floating signal sources with both differential and single-ended measurement systems. In the case of the differential measurement system, however, make sure the common-mode voltage level of the signal with respect to the measurement system ground remains in the common-mode input range of the measurement device. A variety of phenomena—for example, the instrumentation amplifier input bias currents—can move the voltage level of the floating source out of the valid range of the input stage of a DAQ device. (LabVIEW Help, 2005).

3.2.4.6. Grounded Signal Sources

A grounded source is one in which the voltage signals are referenced to a system ground, such as earth or building ground, as shown in the following figure.

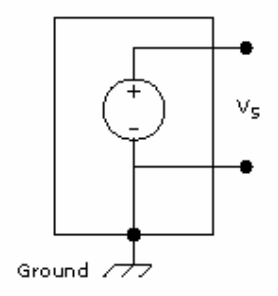


Figure 3.34. Grounded Signal Sources (LabVIEW Help, 2005)

Because such sources use the system ground, they share a common ground with the measurement device. The most common examples of grounded sources are devices that plug into the building ground through wall outlets, such as signal generators and power supplies. (LabVIEW Help, 2005).

3.2.4.7. Measuring Grounded Signal Sources

A grounded signal source is best measured with a differential or an NRSE measurement system. If you use an RSE measurement system with a grounded source, the result is typically a noisy measurement system often showing power-line frequency (60 Hz) components in the readings. Ground-loop introduced noise can have both AC and DC components, introducing offset errors and noise in the measurements. The potential difference between the two grounds causes a current to flow in the interconnection. This current is called ground-loop current.

However, you can still use an RSE measurement system if the signal voltage levels are high and the interconnection wiring between the source and the measurement device has a low impedance. In this case, the signal voltage measurement is degraded by ground loop, but the degradation may be tolerable. You must observe the polarity of a grounded signal source before connecting the signal to a ground-referenced measurement system because the signal source can be short-circuited to ground, which can damage the signal source. (LabVIEW Help, 2005).

3.2.5. Chemical Equations of the System

To determine system design, some experimental analyses were done and system was established according to these experimental results. With the help of these calculations, waiting-mixing times and chemical-acid-rock salt rates which are necessary for the solution were determined. In actual fact, it was profited by using these results to realize the computer program.

Chemical calculations were given below;

3.2.5.1. The Saturation Process

- 0,6955 g rock salt was dissolved in 50 mL water. 2 mL pH=10 buffer solution was added into the mixture and was titrated with 0,05 M EDTA 2,5 mL. Thus, EDTA volume, which is 0,8 mL, was found for 50 mL distilled water.

$$1{,}7\,mL\ EDTA \cdot \frac{0{,}05\,mol EDTA}{1000\,mL} \cdot \frac{1\,mol Ca}{1\,mol EDTA} \cdot \frac{40\,g}{1\,mol Ca} = 3{,}4 \cdot 10^{-3}\ g\ Ca \qquad (3.1)$$

$$\%Ca = \frac{3{,}4 \cdot 10^{-3}}{0{,}6955} \cdot 100 = \%0{,}49 Ca \qquad (3.2)$$

- 0,6508 g rock salt was dissolved in 50 mL water. Steps were repeated as above. 2,4 mL EDTA was spent and spending EDTA (=0,8 mL) was found for 50 mL distilled water.

$$1{,}6\,mL\ EDTA \cdot \frac{0{,}05\,mol EDTA}{1000\,mL} \cdot \frac{1\,mol Ca}{1\,mol EDTA} \cdot \frac{40\,g}{1\,mol Ca} = 3{,}2 \cdot 10^{-3}\ g\ Ca^{2+} \qquad (3.3)$$

$$\%Ca = \frac{3{,}2 \cdot 10^{-3}}{0{,}6508} \cdot 100 = \%0{,}49 Ca \qquad (3.4)$$

The rock salt includes 0,49 % volume Ca.

Saturated rock salt solution was prepared. (45 g rock salt / 100 g water)

First Experiment:

10 mL solution was taken from the saturated rock salt solution. 2 mL pH=10 buffer solution (NH_4^+/NH_3) was added onto this solution and titrated with 0,01 M EDTA in the presence of Erio Chrom Black T indicator. EDTA volume (0,8 mL) was found for 10 mL distilled water. 15,5 mL EDTA was spent for the saturated rock salt solution.

$$15{,}5\ \text{mL} - 0{,}8\ \text{mL} = 14{,}7\ \text{mL EDTA} \tag{3.5}$$

$$14{,}7\,mL\ EDTA \cdot \frac{1L}{1000mL} \cdot \frac{0{,}01mol}{1L\,EDTA} \cdot \frac{1molCa}{1molEDTA} \cdot \frac{1molCaCO_3}{1molCa} \cdot \frac{100g}{1molCaCO_3} \cdot$$

$$\frac{1000mg}{1g\,CaCO_3} \cdot \frac{1Fr}{10mg\,CaCO_3} \cdot \frac{1000}{10} = 147Fr \tag{3.6}$$

Second Experiment:

10 mL solution was taken from the saturated rock salt solution and steps were repeated as above. 15,4 mL EDTA was spent. (0,8 mL EDTA for 10 mL distilled water)

$$15{,}4\ \text{mL} - 0{,}8\text{mL} = 14{,}6\ \text{mL EDTA} \tag{3.7}$$

$$= 146\ \text{Fr} \tag{3.8}$$

Third Experiment:

14,9 mL EDTA was spent for 10 mL saturated solution. (0,8 mL EDTA for 10 mL distilled water)

$$1{,}49\ \text{mL} - 0{,}8\ \text{mL} = 1{,}41\ \text{mL} \tag{3.9}$$

$$= 141\ \text{Fr} \tag{3.10}$$

$$Average = \frac{146+147+141}{3} = 145 Fr \tag{3.11}$$

If necessary Na_2CO_3 was calculated,

$$145 Fr \cdot \frac{10 mg\, CaCO_3}{1 Fr} \cdot \frac{1 g}{1000 mg} \cdot \frac{1 mol}{100 g\, CaCO_3} \cdot \frac{1 mol CO_3}{1 mol} \cdot$$

$$\frac{1 mol \mathrm{Na_2CO_3}}{1 mol CO_3} \cdot \frac{106 g}{1 \mathrm{mol Na_2CO_3}} = 1{,}537 g\ \mathrm{Na_2CO_3} \tag{3.12}$$

3.2.5.2. The Precipitation Process

First Experiment:

10 mL saturated rock salt water was taken. 2,5 g/L NaOH (0,25 g/100 mL solution was prepared and 10 mL sample was taken from this solution) and 8 mL $MgCl_2$ (0,05 g/L) were added onto this solution. At the last, 2 g/L Na_2CO_3 was added onto it. (0,2 g/100 mL water-10 mL was taken from this solution). This solution was mixed for 20 minutes and waited until precipitation finishes. Surface of the solution became clear completely after 8 hours later. 10 mL solution was taken from this surface and the pH value was defined by a pH meter. pH value was between 10 and 11. It was titrated with 0,01 M EDTA, which was spent 0,1 mL.

$$0{,}1 mL \cdot \frac{0{,}01 mol}{1000 mL} \cdot \frac{1 mol\, Ca}{1 mol\, EDTA} \cdot \frac{100 g}{1 mol\, CaCO_3} \cdot \frac{1000 mg}{1 g} \cdot$$

$$\frac{1 Fr}{10 mg} \cdot \frac{1000}{10} = 1 Fr \tag{3.13}$$

It was diluted for 4 times and measured 4 Fr approximately.

Second Experiment:

Steps were repeated as above. The main difference was that; while saturated solution, NaOH and $MgCl_2$ mixture was mixed, Na_2CO_3 was added into this mixture during 20 minutes. It was waited 8 hours for precipitation and at the end of this time, the solution became clear completely. 10 mL solution was taken and defined its pH value. (pH=10-11). It was titrated with 0,01 M EDTA, which was spent 0,1 mL.

0,1 mL EDTA --------- 1 Fr (3.14)

Diluted for 4 times --------- 4 Fr . (3.15)

Third Experiment:

During this experiment, only $MgCl_2$ wasn't added into the solution. The precipitation finished completely after 8 hours later. 10 mL solution was taken and titrated with 0,01 M EDTA. 0,2 mL EDTA was used for this study.

0,2 mL EDTA --------- 2 Fr (3.16)

Diluted for 3 times --------- 6 Fr (3.17)

4. RESULTS AND DISCUSSION

In this study, after building and working of the system; chemical studies, which are made in the chemistry laboratory, were compared with the system process.

Because of determining system consistency, every experiment was done 3 repeated. At the end of every experiment, chemical analyses were realized as taking samples from the product tank.

In this system; 6, 8, 10 and 12 hours precipitation were done. No experiment was done under 6 hours. The reason for this is that, there are no possibilities for the solution produced to have hardness in the range of 0-2 Fr as a result of the studies conducted at the laboratory and industrial practices.

The aim of this study is to determine the required time to keep the hardness of the solution between 0 and 2 Fr.

During chemical analyses of samples; 10 mL solution sample was taken and 2 mL buffer solution (NH_4^+/NH_3) was added onto this solution and titrated with 0,01 M EDTA in the presence of Erio Chrom Black T indicator. The dose of used EDTA is determined according to change of the solution color. As a result of this study, the hardness degree of the solution was determined according to precipitation time.

4.1. At The End of Sixth Hours

4.1.1. First Experiment

First Analysis

6 mL EDTA solution was used for 10 mL solution.

$$6\,mL\ \ EDTA\ \cdot\frac{1\,L}{1000\ mL}\cdot\frac{0{,}01\,mol}{1\,L\ EDTA}\cdot\frac{1\,mol\ Ca^{2+}}{1\,molEDTA}\cdot\frac{1\,mol\ CaCO_3}{1\,mol\ Ca^{2+}}\cdot$$

$$\frac{100\ g}{1\,mol\ CaCO_3}\cdot\frac{1000\ mg}{1\,g\ CaCO_3}\cdot\frac{1\,Fr}{10\,mg\ CaCO_3}\cdot\frac{1000}{10}=60\ Fr \qquad (4.1)$$

Second Analysis

5 mL EDTA solution was used for 10 mL solution.

$$5\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 50\,Fr \qquad (4.2)$$

Third Analysis

6 mL EDTA solution was used for 10 mL solution.

$$6\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 60\,Fr \qquad (4.3)$$

The average of the first experiment;

$$Average1 = \frac{60 + 50 + 60}{3} = 56{,}66\,Fr \qquad (4.4)$$

4.1.2. Second Experiment

First Analysis

9 mL EDTA solution was used for 10 mL solution.

$$9\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 90\,Fr \qquad (4.5)$$

Second Analysis

6 mL EDTA solution was used for 10 mL solution.

$$6mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 60\,Fr \qquad (4.6)$$

Third Analysis

6 mL EDTA solution was used for 10 mL solution.

$$6\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 60\,Fr \qquad (4.7)$$

The average of the second experiment;

$$Average2 = \frac{90 + 60 + 60}{3} = 70\,Fr \qquad (4.8)$$

4.1.3. Third Experiment

First Analysis

6 mL EDTA solution was used for 10 mL solution.

$$6\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 60\,Fr \qquad (4.9)$$

Second Analysis

8 mL EDTA solution was used for 10 mL solution.

$$8\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 80\,Fr \qquad (4.10)$$

Third Analysis

8 mL EDTA solution was used for 10 mL solution.

$$8\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 80\,Fr \qquad (4.11)$$

The average of the third experiment;

$$Average3 = \frac{60 + 80 + 80}{3} = 73{,}33\,Fr \tag{4.12}$$

General average for sixth hours experiments;

$$Average = \frac{56{,}66 + 70 + 73{,}33}{3} = 66{,}66\,Fr \tag{4.13}$$

The hardness of the solution is very high. Moreover, the solution surface was not clear enough during the experiment.

4.2. At The End of Eighth Hours

4.2.1. First Experiment

First Analysis

2,8 mL EDTA solution was used for 10 mL solution.

$$2{,}8\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 28\,Fr \tag{4.14}$$

Second Analysis

3 mL EDTA solution was used for 10 mL solution.

$$3\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 30\,Fr \qquad (4.15)$$

Third Analysis

2,5 mL EDTA solution was used for 10 mL solution.

$$2{,}5\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 25\,Fr \qquad (4.16)$$

The average of the first experiment;

$$Average1 = \frac{28 + 30 + 25}{3} = 27{,}66\,Fr \qquad (4.17)$$

4.2.2. Second Experiment

First Analysis

2 mL EDTA solution was used for 10 mL solution.

$$2\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 20\,Fr \qquad (4.18)$$

Second Analysis

1,7 mL EDTA solution was used for 10 mL solution.

$$1{,}7\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 17\,Fr \qquad (4.19)$$

Third Analysis

1,9 mL EDTA solution was used for 10 mL solution.

$$1{,}9\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 19\,Fr \qquad (4.20)$$

The average of the second experiment;

$$Average2 = \frac{20+17+19}{3} = 18{,}66\,Fr \qquad (4.21)$$

4.2.3. Third Experiment

First Analysis

1,9 mL EDTA solution was used for 10 mL solution.

$$1{,}9\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 19\,Fr \qquad (4.22)$$

Second Analysis

2 mL EDTA solution was used for 10 mL solution.

$$2\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 20\,Fr \qquad (4.23)$$

Third Analysis

1,8 mL EDTA solution was used for 10 mL solution.

$$1{,}8\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 18\,Fr \qquad (4.24)$$

The average of the third experiment;

$$Average3 = \frac{19 + 20 + 18}{3} = 19\,Fr \qquad (4.25)$$

General average for eighth hours experiments;

$$Average = \frac{27{,}66 + 19 + 18{,}66}{3} = 21{,}77\ Fr \tag{4.26}$$

The hardness of the solution is still high. But solution surface was clearer than sixth hours experiment.

4.3. At The End of Tenth Hours

4.3.1. First Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1 mL\ EDTA \cdot \frac{1L}{1000 mL} \cdot \frac{0{,}01 mol}{1L\ EDTA} \cdot \frac{1 mol\ Ca^{2+}}{1 molEDTA} \cdot \frac{1 mol\ CaCO_3}{1 mol\ Ca^{2+}} \cdot$$

$$\frac{100\ g}{1 mol\ CaCO_3} \cdot \frac{1000 mg}{1\ g\ CaCO_3} \cdot \frac{1\ Fr}{10 mg\ CaCO_3} \cdot \frac{1000}{10} = 1\ Fr \tag{4.27}$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1 mL\ EDTA \cdot \frac{1L}{1000 mL} \cdot \frac{0{,}01 mol}{1L\ EDTA} \cdot \frac{1 mol\ Ca^{2+}}{1 molEDTA} \cdot \frac{1 mol\ CaCO_3}{1 mol\ Ca^{2+}} \cdot \frac{100\ g}{1 mol\ CaCO_3} \cdot$$

$$\frac{1000 mg}{1\ g\ CaCO_3} \cdot \frac{1\ Fr}{10 mg\ CaCO_3} \cdot \frac{1000}{10} = 1\ Fr \tag{4.28}$$

Third Analysis

0,2 mL EDTA solution was used for 10 mL solution.

$$0{,}2\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 2\,Fr \tag{4.29}$$

The average of the first experiment;

$$Average1 = \frac{1+1+2}{3} = 1{,}33\,Fr \tag{4.30}$$

4.3.2. Second Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \tag{4.31}$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.32)$$

Third Analysis

0,2 mL EDTA solution was used for 10 mL solution.

$$0{,}2\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 2\,Fr \qquad (4.33)$$

The average of the second experiment;

$$Average2 = \frac{1+1+2}{3} = 1{,}33\,Fr \qquad (4.34)$$

4.3.3. Third Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.35)$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1mL\ EDTA \cdot \frac{1L}{1000mL} \cdot \frac{0{,}01mol}{1L\,EDTA} \cdot \frac{1mol\,Ca^{2+}}{1molEDTA} \cdot \frac{1mol\,CaCO_3}{1mol\,Ca^{2+}} \cdot \frac{100\,g}{1mol\,CaCO_3} \cdot$$

$$\frac{1000mg}{1g\,CaCO_3} \cdot \frac{1Fr}{10mg\,CaCO_3} \cdot \frac{1000}{10} = 1Fr \qquad (4.36)$$

Third Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1mL\ EDTA \cdot \frac{1L}{1000mL} \cdot \frac{0{,}01mol}{1L\,EDTA} \cdot \frac{1mol\,Ca^{2+}}{1molEDTA} \cdot \frac{1mol\,CaCO_3}{1mol\,Ca^{2+}} \cdot \frac{100\,g}{1mol\,CaCO_3} \cdot$$

$$\frac{1000mg}{1g\,CaCO_3} \cdot \frac{1Fr}{10mg\,CaCO_3} \cdot \frac{1000}{10} = 1Fr \qquad (4.37)$$

The average of the third experiment;

$$Average3 = \frac{1+1+1}{3} = 1Fr \qquad (4.38)$$

General average for tenth hours experiments;

$$Average = \frac{1{,}33+1+1{,}33}{3} = 1{,}22\,Fr \qquad (4.39)$$

At the end of tenth hours, the solution was become clear. As it can be seen from results, the desired hardness was achieved ten hours later.

At the laboratory conditions, the desired hardness was achieved eight hours later. There are 2 important differences;

a.) Distilled water was used for experiments at the laboratory. Whereas; in the system experiments were done with tap water. Besides, the own hardness of the tap water is 30 Fr. With the adding of the rock salt and chemicals, the hardness of the solution was measured 145 Fr before the process.

b.) Special and qualified chemicals were used for experiments, which are carried out at the laboratory. On the other hand, chemicals, which were used in the system, have lower quality.

At the last, 12 hours experiments were realized to see the system stability.

4.4. At The End of Twelfth Hours

4.4.1. First Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1 mL\ EDTA \cdot \frac{1 L}{1000 mL} \cdot \frac{0{,}01 mol}{1 L\ EDTA} \cdot \frac{1 mol\ Ca^{2+}}{1 molEDTA} \cdot \frac{1 mol\ CaCO_3}{1 mol\ Ca^{2+}} \cdot$$

$$\frac{100\ g}{1 mol\ CaCO_3} \cdot \frac{1000 mg}{1\ g\ CaCO_3} \cdot \frac{1 Fr}{10 mg\ CaCO_3} \cdot \frac{1000}{10} = 1 Fr \qquad (4.40)$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.41)$$

Third Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.42)$$

The average of the first experiment;

$$Average1 = \frac{1+1+1}{3} = 1\,Fr \qquad (4.43)$$

4.4.2. Second Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.44)$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1 mL\ EDTA \cdot \frac{1 L}{1000 mL} \cdot \frac{0{,}01 mol}{1 L\ EDTA} \cdot \frac{1 mol\ Ca^{2+}}{1 molEDTA} \cdot \frac{1 mol\ CaCO_3}{1 mol\ Ca^{2+}} \cdot \frac{100 g}{1 mol\ CaCO_3} \cdot$$

$$\frac{1000 mg}{1 g\ CaCO_3} \cdot \frac{1 Fr}{10 mg\ CaCO_3} \cdot \frac{1000}{10} = 1 Fr \qquad (4.45)$$

Third Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1 mL\ EDTA \cdot \frac{1 L}{1000 mL} \cdot \frac{0{,}01 mol}{1 L\ EDTA} \cdot \frac{1 mol\ Ca^{2+}}{1 molEDTA} \cdot \frac{1 mol\ CaCO_3}{1 mol\ Ca^{2+}} \cdot \frac{100 g}{1 mol\ CaCO_3} \cdot$$

$$\frac{1000 mg}{1 g\ CaCO_3} \cdot \frac{1 Fr}{10 mg\ CaCO_3} \cdot \frac{1000}{10} = 1 Fr \qquad (4.46)$$

The average of the second experiment;

$$Average2 = \frac{1+1+1}{3} = 1 Fr \qquad (4.47)$$

4.4.3. Third Experiment

First Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot$$

$$\frac{100\,g}{1\,mol\,CaCO_3} \cdot \frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.48)$$

Second Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.49)$$

Third Analysis

0,1 mL EDTA solution was used for 10 mL solution.

$$0{,}1\,mL\ EDTA \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0{,}01\,mol}{1\,L\,EDTA} \cdot \frac{1\,mol\,Ca^{2+}}{1\,molEDTA} \cdot \frac{1\,mol\,CaCO_3}{1\,mol\,Ca^{2+}} \cdot \frac{100\,g}{1\,mol\,CaCO_3} \cdot$$

$$\frac{1000\,mg}{1\,g\,CaCO_3} \cdot \frac{1\,Fr}{10\,mg\,CaCO_3} \cdot \frac{1000}{10} = 1\,Fr \qquad (4.50)$$

The average of the third experiment;

$$Average3 = \frac{1+1+1}{3} = 1\,Fr \qquad (4.51)$$

General average for twelfth hours experiments;

$$Average = \frac{1+1+1}{3} = 1\,Fr \tag{4.52}$$

If whole obtained values are shown on a diagram;

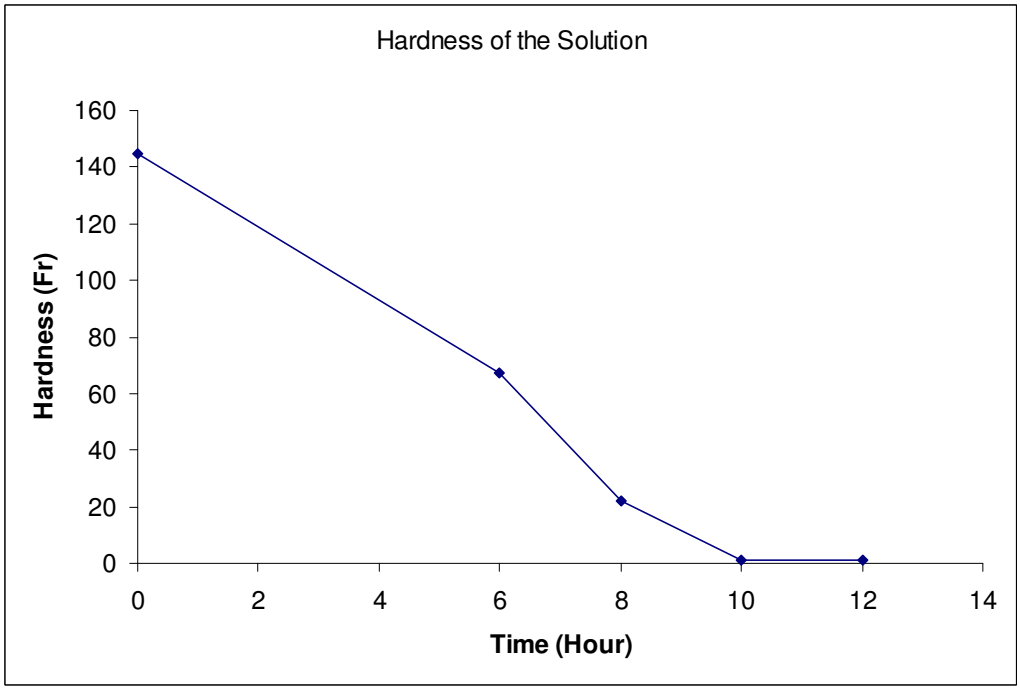


Figure 4.1. Changing the Hardness of the Solution According to the Time

Consequently, the harness of the solution reached to the stability at the end of tenth hours.

5. CONCLUSION AND FUTURE WORK

In this thesis, instead of using refined salt, which is very important for the cost on dyeing process, rock salt is used in the automation system. In the mean time, high quality on painting and repeatability were aimed in the present study.

After the process, one of the facilities of the system is saving work capacity. Nevertheless, obtained pure salt solution will not use only for painting, but also at the resin regeneration, that is used in water soften systems at the factories. Consequently, it anticipates lengthen lifetime of resin. In addition it will provide energy saving for textile factories.

For future works; besides using equipments in the system, flow meters can be used to determine the solution / liquid dose, which pass through pipes. Required sensors can be used for determine pump / valve faults to alert the administrator concerned.

By this way, the system can be improved with the different equipments in the future.

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BIOGRAPHY

I was born in Adana, Turkey, on February 03th, 1976. I graduated from İsmail Safa Özler Anatolia High School, Adana, in 1994. I received my BS degree in Electrical and Electronics Engineering Department from the Fırat University, Elazığ, Turkey, in 1999. Then, I worked for TÜBİTAK Adana University-Industry Joined Research Centre between 2000 and 2002 in Adana. After I resigned from the Research Centre, I worked for General Directorate of Rural Services as an engineer in Erzurum until the year of 2005. I have completed my military obligation in 2004. I have been working at the University of Çukurova Agriculture Faculty Department of Agricultural Machinery since 2005, in Adana.

My areas of interest include automation systems, software development and instrumentation.

I am a member of Chamber of Electrical Engineers since 1999.

APPENDIX A

NI USB-6009

Low-Cost Multifunction DAQ for USB

NI USB-6008, NI USB-6009

- Small, portable multifunction data acquisition devices
- 12 or 14-bit input resolution, at up to 48 kS/s
- Built-in, removable connectors for easier and more cost-effective connectivity
- 2 true DAC analog outputs for accurate output signals
- 12 digital I/O lines (TTL/LVTTL/CMOS)
- 32-bit event counter
- Student kits available

Operating Systems
- Windows 2000/XP
- Mac OS X
- Linux

Recommended Software
- LabVIEW
- LabWindows/CVI

Measurement Services Software (included)
- NI-DAQmx Base
- Ready-to-Run Data Logger

NEW

Product	Bus	Analog Inputs[1]	Input Resolution (bits)	Max Sampling Rate (kS/s)	Input Range (V)	Analog Outputs	Output Resolution (bits)	Output Rate (Hz)	Output Range (V)	Digital I/O Lines	32-bit Counter	Trigger
USB-6009	USB	8 SE/4 DI	14	48	±1 to ±20	2	12	150	0 to 5	12	1	Digital
USB-6008	USB	8 SE/4 DI	12	10	±1 to ±20	2	12	150	0 to 5	12	1	Digital

[1] SE = single ended, DI = differential

Hardware Description

The National Instruments USB-6008 and USB-6009 multifunction data acquisition devices provide reliable data acquisition at a low price. With plug-and-play USB connectivity, these devices are simple enough for quick measurements, but versatile enough for more complex measurement applications.

Software Description

The NI USB-6008 and USB-6009 include a ready-to-run data logger application that acquires and logs up to eight channels of analog data. For more functionality, NI-DAQmx Base software is a multiplatform driver with a subset of the NI-DAQmx programming interface. Use it to develop customized DAQ applications with NI LabVIEW or C-based development environments.

Recommended Accessories

The USB-6008 and USB-6009 have built-in connectivity, so no additional accessories are required.

Common Applications

The USB-6008 and USB-6009 are ideal for a number of applications where economy, small size, and simplicity are essential, such as:

- Data logging – Log environmental or voltage data quickly and easily
- Academic lab use – The low price facilitates student ownership of DAQ hardware for completely interactive lab-based courses. Academic pricing available. Visit ni.com/academic for details.
- Embedded OEM applications

Information for Student Ownership

To supplement simulation, measurement, and automation theory courses with practical experiments, NI has developed the USB-6008 and USB-6009 student kits that include LabVIEW Student Edition and a ready-to-run data logger application. These kits are exclusively for students, giving them a powerful, low-cost hands-on learning tool. Visit ni.com/academic for more details.

Information for OEM Customers

For information on special configurations and pricing, please visit ni.com/oem.

Ordering Information

NI USB-6008[1] 779051-01
NI USB-6009[1] 779026-01
NI USB-6008 Student-kit[1,2] 779320-22
NI USB-6009 Student-kit[1,2] 779321-22

[1] Includes NI-DAQmx Base Software, NI-Ready-to-Run Data Logger Software, and a USB cable.
[2] Includes LabVIEW Student Edition

NATIONAL INSTRUMENTS

Low-Cost Multifunction DAQ for USB

Specifications

Typical at 25 °C unless otherwise noted.

Analog Input

Absolute accuracy, single-ended

Range	Typical at 25 °C (mV)	Maximum (0 to 55 °C) (mV)
±10	14.7	138

Absolute accuracy at full scale, differential[1]

Range	Typical at 25 °C (mV)	Maximum (0 to 55 °C) (mV)
±20	14.7	138
±10	7.73	84.8
±5	4.28	58.4
±4	3.59	53.1
±2.5	2.56	45.1
±2	2.21	42.5
±1.25	1.70	38.9
±1	1.53	37.5

[1] Input voltages may not exceed the working voltage range

Number of channels ..... 8 single-ended / 4 differential
Type of ADC ..... Successive approximation

ADC resolution (bits)

Device	Differential	Single-Ended
USB-6008	12	11
USB-6009	14	13

Maximum sampling rate (system dependent)

Device	Maximum Sampling Rate (kS/s)
USB-6008	10
USB-6009	48

Input range, single-ended ..... ±10 V
Input range, differential ..... ±20, ±10, ±5, ±4, ±2.5, ±2, ±1.25, ±1 V
Maximum working voltage ..... ±10 V
Overvoltage protection ..... ±35 V
FIFO buffer size ..... 512 B
Timing resolution ..... 41.67 ns (24 MHz timebase)
Timing accuracy ..... 100 ppm of actual sample rate
Input impedance ..... 144 kΩ
Trigger source ..... Software or external digital trigger
System noise ..... 0.3 LSB_{rms} (±10 V range)

Analog Output

Absolute accuracy (no load) ..... 7 mV typical, 36.4 mV maximum at full scale
Number of channels 2
Type of DAC ..... Successive approximation
DAC resolution ..... 12 bits
Maximum update rate ..... 150 Hz, software-timed
Output range ..... 0 to +5 V
Output impedance ..... 50 Ω
Output current drive ..... 5 mA
Power-on state ..... 0 V
Slew rate ..... 1 V/µs
Short-circuit current ..... 50 mA

Digital I/O

Number of channels ..... 12 total
8 (P0.<0..7>)
4 (P1.<0..3>)
Direction control ..... Each channel individually programmable as input or output
Output driver type
USB-6008 ..... Open-drain
USB-6009 ..... Each channel individually programmable as push-pull or open-drain.
Compatibility ..... CMOS, TTL, LVTTL
Internal pull-up resistor ..... 4.7 kΩ to +5 V
Power-on state ..... Input (high impedance)
Absolute maximum voltage range ..... -0.5 to +5.8 V

Digital logic levels

Level	Min	Max	Units
Input low voltage	-0.3	0.8	V
Input high voltage	2.0	5.8	V
Input leakage current	–	50	µA
Output low voltage (I = 8.5 mA)	–	0.8	V
Output high voltage (Push-pull, I = -8.5 mA)	2.0	3.5	V
Output high voltage (Open-drain, I = -0.6 mA, nominal)	2.0	5.0	V
Output high voltage (Open-drain, I = -8.5 mA, with external pull-up resistor)	2.0	–	V

Counter

Number of counters 1
Resolution ..... 32 bits
Counter measurements ..... Edge counting (falling edge)
Pull-up Resistor ..... 4.7 kΩ to 5 V
Maximum input frequency ..... 5 MHz
Minimum high pulse width ..... 100 ns
Minimum low pulse width ..... 100 ns
Input high voltage ..... 2.0 V
Input low voltage ..... 0.8 V

Power Available at I/O Connector

+5 V output (200 mA maximum) ..... +5 V typical
+4.85 V minimum
+2.5 V output (1 mA maximum) ..... +2.5 V typical
+2.5 V output accuracy ..... 0.25 % max
Voltage reference temperature drift ..... 50 ppm/°C max

Physical Characteristics

If you need to clean the module, wipe it with a dry towel.

Dimensions (without connectors) ..... 6.35 by 8.51 by 2.31 cm
(2.50 by 3.35 by 0.91 in.)
Dimensions (with connectors) ..... 8.18 by 8.51 by 2.31 cm
(3.22 by 3.35 by 0.91 in.)
Weight (without connectors) ..... 59 g (2.1 oz.)
Weight (with connectors) ..... 84 g (3 oz.)
I/O Connectors ..... USB series B receptacle
(2) 16-position (screw-terminal) plug headers
Screw-terminal wiring ..... 16 to 28 AWG
Screw-terminal torque ..... 0.22 to 0.25 N•m
(2.0 to 2.2 lb•in.)

Bus Interface

USB specification	USB 2.0 full-speed
USB bus speed	12 Mb/s

Power Requirement

USB (4.10 to 5.25 VDC)	80 mA typical 500 mA maximum
USB Suspend	300 µA typical 500 µA maximum

Environmental

The USB-6008 and USB-6009 are intended for indoor use only.

Operating Environment	
Ambient temperature range	0 to 55 °C (tested in accordance with IEC-60068-2-1 and IEC-60068-2-2.)
Relative humidity range	10% to 90%, non-condensing (tested in accordance with IEC-60068-2-56.)
Storage Environment	
Ambient temperature range	-40 to 85 °C (tested in accordance with IEC-60068-2-1 and IEC-60068-2-2.)
Relative humidity range	5% to 90%, non-condensing (tested in accordance with IEC-60068-2-56.)
Maximum altitude	2,000 m (at 25 °C ambient temperature)
Pollution Degree	2

Certifications and Compliances

The USB-6008 and USB-6009 are designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1
- CAN/CSA C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label, or visit ni.com/certification, search by model number or product line, and click the appropriate link in the Certification column.

Voltages

Connect only voltages that are within the absolution maximum limits of the connection point. See pertinent specification section for appropriate limits.

Hazardous Locations

The USB-6008 and USB-6009 are not certified for use in hazardous locations.

Electromagnetic Compatibility

Emissions	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Immunity	Industrial levels per EN 61326:1997 + A2:2001, Table 1
EMC/EMI	CE, C-Tick, and FCC Part 15 (Class A) Compliant

Note: The USB-6008 and USB-6009 may experience temporary variations in analog input readings when exposed to radiated and conducted RF noise. Device returns to normal operation after RF exposure is removed.

CE Compliance CE

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety)	73/23/EEC
Electromagnetic Compatibility Directive (EMC)	89/336/EEC

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit ni.com/certification, search by model number or product line, and click the appropriate link in the Certification column.

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NI Factory Installation Services (FIS) is the fastest and easiest way to use your PXI or PXI/SCXI combination systems right out of the box. Trained NI technicians install the software and hardware and configure the system to your specifications. NI extends the standard warranty by one year on hardware components (controllers, chassis, modules) purchased with FIS. To use FIS, simply configure your system online with ni.com/pxiadvisor.

Calibration Services

NI recognizes the need to maintain properly calibrated devices for high-accuracy measurements. We provide manual calibration procedures, services to recalibrate your products, and automated calibration software specifically designed for use by metrology laboratories. Visit ni.com/calibration.

Repair and Extended Warranty

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APPENDIX B

YL-221 ELECTROMECHANICAL POWER RELAY CHARACTERISTIC DATA GRAPHS

YL-221 POWER RELAY CHARACTERISTIC DATA GRAPHS