Palestine Polytechnic University

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Graduation Project

Design and Implementation a Table Top Autoclave

Project Team

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ABSTRACT

The "Design & Implementation of a Top Table Autoclave" project will be used to sterilize medical tools; it uses steam under pressure as sterilizing agent to kill the microorganisms on un-sterilized medical tools.

Steam under pressure is including production of steam in closed chamber to produce saturated steam which has more heat contents.

The motivation for this project based on the desire to gain experience and a greater depth of understanding the sterilization instrumentation, and implementing this design to achieve sterilization process.

This report contains the design for this project which was implemented.

ملخص المشروع

ان تصميم وبناء جهاز التعقيم هذا سوف يتم استخدامه في عمليه تعقيم الادوات الطبية حيث يستخدم البخار تحت الضغط كمادة تعقيم لقتل الجراثيم الموجودة على الأدوات الطبية.

كان الحافز لهذا المشروع على أساس الرغبة في اكتساب الخبرة والتعمق الكبير في فهم أليه تعقيم الأدوات، والرغبة في بناء هذا التصميم من اجل تحقيق عملية التعقيم.

ويتضمن هذا التقرير التصميم الذي استخدم في بناء المشروع.

Table of Contents

List of Tables

List of Figures

1

Introduction

1.1 Overview

1.2 Project Objectives

1.3 Scheduling Table

1.4 Estimated Cost

1.5 Project Risk Management

1.6 Report Contents

Chapter one

Introduction

1.1 Overview

It is obvious that Biomedical Engineering Technology has a great importance on the health-care field which makes our life safe by designing biomedical devices to achieve better diagnostic and treatment of diseases. Some of these devices are used as precautionary devices to decrease the ability of infection by killing the causes of diseases such as bacteria and viruses.

Our project "Design and Implementation of a Table Top Autoclave" that will be used as precautionary device to kill the microorganisms on medical instruments.

Steam under pressure at specified temperature for specific period of time is the process of killing the microorganisms.

The main aims are Designing and Implementation of a Table Top Autoclave; the device will be microcontroller based which controls the whole processes, procedures and errors' feedback.

1.2 Project Objectives

In this project we aim to design and implement a top table autoclave using PIC microcontroller to

1. Kill the microorganisms on the medical tools.
2. Control whole processes in the system using PIC microcontroller.
3. Use this design in medical field.

1.3 Scheduling Table

The timing management will divide the system hierarchy according to the actions:

T1: *Preparing to the project:* this stage of the project primarily aims to identify the contents of it, discuss the initial information, and evaluate the project tasks and levels.

T2: *The project analysis:* the analysis process includes extensive study for all possible design options of the project.

T3: *Conceptual Design:* project objectives, design block diagram that will be done and we will show how our system will work.

T4: *Studying project component and schematic analysis:* it is necessary to study the specifications of project components to meet the requirements of the project.

T5: *Preparing project parts:* determining the appropriate electrical and mechanical components that are suitable for our design.

T6: *Programming microcontroller:* writing subprograms from project, and testing them on subsystem circuits in order to build whole system program.

T7: *Hardware implementation:* include building electronic circuits, mechanical subsystems, and finally combining them together.

T8: *Testing the system:* testing the system, calibration, discovering the problems, and solve them.

T9: *Writing the documentation:* writing the documentation of project.

Table 1.1: The Task Duration

Task	Duration(weeks)	Dependencies
T1	3	-----
T2	3	-----
T3	4	T1,T2
T4	2	T3
T5	2	-----
T6	8	T5
T7	8	T5
T8	3	T6,T7
T9	20	-----

Table 1.2: Timing plane

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T1															
T2															
T3															
T4															
T9															
Task / Week	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
T5															
T6															
T7															
T8															
T9															

1.4 Estimated Cost

This section lists the overall cost of the components that are considered in implementing the system.

There are many electrical and mechanical parts with expected cost as follow.

Table 1.3: Hardware Cost

Component	Cost
Chamber	€150.00
Electrical parts	€200.00
Temperature sensor	€50.00
Mechanical parts	€500.00
Electronic components	€300.00
Total	€1200.00

1.5 Project Risk Management

There are a lot of risks that occur and we have to declare them in the early time of the project designing and manipulation, when we find a problem we should try to solve it without affecting on the whole project.

1.5.1 Hardware Risks

The most important hardware parts in our project are the PIC microcontroller, valves, level sensor, and temperature sensor. The predicted risks are:

- The temperature sensor, valves and level sensor does not respond.
- Wrong connection of microcontroller.
- Temperature sensor accuracy.

1.5.2 Group Risks

- Illness of one or more of group members.
- Group meeting difficulties.

1.5.3 Project Risks

- Inaccurate schedule.
- Latency of devices arrival.

Recovery

- Demand device at earlier time.
- Start working on the implementation earlier.
- Use alternate devices with the same functionality and less cost.

1.6 Report Contents

Our project is divided into seven chapters; these chapters could be described as follow:

Chapter 1: Introduction

This chapter presents overview, project objectives, project scheduling, estimated cost, and report contents.

Chapter 2: Theoretical Background

This chapter discusses the sterilization, types of sterilization, hardware related to the project, and theoretical background about project components.

Chapter 3: Project Conceptual Design

This chapter explains the project objectives, and project design block diagram.

Chapter 4: Detailed Technical Project Design

This chapter includes project phases, and subsystem detailed design.

Chapter 5: Software

This chapter includes software of the project and flowchart of the process.

Chapter 6: System Implementation and Testing

This chapter includes implementation and testing of our design.

Chapter 7: Conclusion and Future Work

This chapter includes conclusion and suggestions for development.

2

Theoretical Background

Before we start in project design, we must have strong theoretical background about the project and its components, so this chapter will discuss these topics:

2.1 Sterilization

- **2.1.1 Sterilization Definition**
- **2.1.2 Types of Sterilization**
- **2.1.3 Monitoring of Sterilization**

2.2 Autoclave

- **2.2.1 Autoclave Definition**
- **2.2.2 History of Autoclaves**
- **2.2.3 Theory of Operation**
- **2.2.4 Types of Autoclaves**

2.3 Project Theory

- **2.3.1: Main Idea**
- **2.3.2 How does Killing Occur**

2.4 Preparation for Sterilization

2.5 Project Components

Chapter Two

Theoretical Background

2.1 Sterilization

2.1.1 Sterilization Definition

Sterilization is a process that effectively destroys or eliminates all living microorganisms (such as bacteria, fungal spores, and viruses) from a medium, equipment, foods, medications, or biological culture medium. It is commonly used to preserve food products in the food and dairy industries. Sterilization can be achieved through application of heat, chemicals, irradiation, or filtration [9].

2.1.2 Types of Sterilization

Sterilization is classified into four categories according to nature of sterilizing agent, and these are the types of sterilization [5]:

1. Heat Sterilization.
2. Chemical Sterilization.
3. Ionizing Radiation Sterilization.
4. Sterile filtration.

Table 2.1: Sterilization Standards [5]

Sterilization Method	Standard(s)
Heat Sterilization	ISO 20857
Steam Sterilization	ISO 11134, ISO/DIS 17665-1,ISO/DIS 17665-2
Ethylene Oxide	ISO/DIS 11135-1, ISO/DIS 11135-2, ISO 10993-7
(Residuals)Radiation	ISO/DIS 11137-1, ISO/DIS 11137-2, ISO/DIS 11137-3
Others	ISO 10993 (1-18), ASTM E1766-95, F2347-03, F2103-1, F2064-00

2.1.2.1 Heat Sterilization

Heat sterilization can be either applied in many techniques depending on the type of what will be sterilized. These forms include Dry Heat, Moist Heat, Flaming, Incineration, and boiling in water for 15 minute.

1. **Dry Heat**

This technique of sterilization depends on heated air to inactivate and/or kill the microorganisms. It is used for instruments that can withstand high temperatures or that cannot be sterilized using other techniques, it is often used for glassware as it sterilizes and dries in one operation. In this technique the heat takes much longer to be transferred to organisms therefore, it usually requires higher temperatures and longer exposure times; which can be decreased using ventilation system to move the heated air inside the sterilizer [9].

The microbial death occurs due to destruction and coagulation of nucleic acids and proteins, also the reduction of water contents in bacterial spores.

The application of dry heat sterilization utilizes a dry oven-like environment. The air inside the chamber is heated and allowed to equilibrate to a constant temperature. The duration of the procedure is a factor of the applied temperature. The time and temperature may also vary depending on the nature of the material being sterilized. Table 2.2 provides guidelines for the sterilization of medical devices using dry heat [5].

Table 2.2: Temperatures and Time of dry sterilization [5]

Temperature Sterilization	Time
190°C(rapid heat)	6 min (unwrapped) 12 min (wrapped)
170°C	60 min
160°C	120 min
150°C	150 min
140°C	180 min
121°C	Overnight

Advantages

- Better for some products, e.g. Powder.
- Does not erode glass.
- Minimal rusting effect.
- Reaches some parts of instruments by conduction.

Disadvantages

- Long exposure times.
- Heat penetrates slowly and unevenly.
- Damages some rubber goods and burns fabric or, paper packages.

2. Steam Sterilization

This technique uses steam under pressure to kill microorganisms. Heating of instruments occurs by both steam penetration and heat conduction. The sterilization is dependent on the temperature, pressure, the duration of exposure to steam, packaging of the material and size of the load. It is important that the autoclave chamber be loaded correctly so that steam can circulate and penetrate [9].

The mechanism by which moist heat sterilization kills microbes is similar to that of dry heat sterilization. Proteins and nucleic acids coagulation occur quickly once a critical temperature is reached. For the same reasons that protein and nucleic acids destruction inhibit the ability of bacteria to replicate or continue metabolic processes [5].

Steam sterilization has temperature-time standards, these standards will be shown in the following table, Table 2.3

Table 2.3: Steam Sterilization Standards

Temperature °C	Time (Minute)
121	15-20
134	3-5

Advantages

- Very effective, because saturated steam carries seven times as much available heat as air at the same temperature
- Least expensive method of sterilization.
- Relatively low temperature requirements (compared to dry heat sterilization).
- Speed, process simplicity.
- Lack of toxic residues when compared to methods such as ethylene oxide sterilization.
- Since moist heat sterilization is performed in a pressurized environment, it can also be used to sterilize liquids.

Disadvantages

The disadvantage of moist heat sterilization comes from the presence of water and the use of elevated temperatures.

- Unsuitable for plastics with low melting points, powders, labile(unstable) materials, anhydrous oils (oils free of water) or synthetic and natural polymers that are readily degraded by hydrolysis.

3. **Flaming**

It is done to loops and straight-wires in microbiology labs. Leaving the loop in the flame of a Bunsen burner or alcohol lamp until it glows red ensures that any infectious agent gets inactivated [9].

Advantages

- Effective for small metal and glass objects.

Disadvantages

- Can't be used for large objects.
- Destroy sharp edges of medical tools.

4. **Incineration**

This technique will also burn any organism to ash. It is used to sanitize medical and other bio-hazardous waste before it is discarded with non-hazardous waste [9].

Advantages

- High efficiency in destroying the medical wastes.

Disadvantages

- Used only for destroying the medical wastes.

5. **Boiling in water for 15 minutes**

This will kill most vegetative bacteria and viruses'; therefore boiling is unsuitable for sterilization. However, since boiling kills most bacteria and viruses, it is useful for reducing microbe levels if no better method is available. Boiling is a simple process, and is an option available to most anyone most anywhere, requiring only water, enough heat, and a container that can withstand the heat [9].

Advantages

- Cheap method.
- Availability.

Disadvantages

- Unreliable method.

2.1.2.2 Chemical Sterilization

Other type of sterilization is Chemical sterilization. Heat sterilization provides the most reliable way of sterilization, but it is not always appropriate, because it will damage heat-sensitive materials such as biological materials, fiber optics, electronics, and many plastics, chemical sterilization implies use of chemical liquids and gases. There are many of chemical substances used in sterilization such as Ethylene oxide (formalin gas) and Chlorine bleach [5].

1. **Gas Sterilization**

It uses formalin, or more commonly, ethylene oxide gas (ETO). Now we want to explain ethylene oxide ETO gas method, ETO is an unstable ring structure capable of reacting via alkaline with functional groups found in nucleic acids and proteins in microorganism, this reaction destroys microorganism [5].

Advantages

- Relatively low temperature requirements (compared to heat sterilization).
- High degree of penetration of the ETO gas into the target device.
- Temperature and moisture sensitive materials are more readily sterilized via ETO than by heat sterilization methods.

Disadvantages

- The toxicity of the residual byproducts.
- This material may react with the functional groups of biomaterials.

2. Liquid chemical

Another form of sterilization and a part of chemical sterilization, however, sterilization is achieved by a period of immersion in a high level disinfectant, this method is rarely used.

Well known and home usable method is Chlorine bleach as liquid sterilizing agent. Household bleach consists of 5.25% sodium hypochlorite. Bleach will kill many organisms immediately, but for full sterilization it should be allowed to react for 20 minutes. Bleach will kill many, but not all spores. It is highly corrosive and may corrode even stainless steel surgical instruments [5].

Advantages

- Effective for heat sensitive instruments.

Disadvantages

- High toxicity for biologic materials.

- Long immersion time.
- Difficulty in determining effectiveness.
- Fresh solutions may be needed for each load.
- Health risks to those handling the solution.

2.1.2.3 Radiation Sterilization

Radiation sterilization is the most commonly used technique to sterilize biological material at present time.

The purpose of radiation sterilization is to destroy living organisms. Irradiation may also cause changes in the physical properties of items especially plastics, film, and electronic media.

The radiation systems have four forms:

- Gamma irradiators.
- Electron beam.
- X-ray.
- Ultraviolet light irradiation.

Gamma rays use a high energy cobalt or cesium source which is radioactive all the time but decays over time and requires periodic replacement. They are very penetrating and are commonly used for sterilization of disposable medical equipment, such as syringes, and needles. Gamma radiation requires bulky shielding for the safety of the operators; they also require storage of the radioisotope, which continuously emits gamma rays [5].

E-Beam irradiation involves the generation of a beam of electrons. The beam of electrons can be manipulated to achieve the desired dose by varying power and the exposure time. The sterilizing effect of e-beam irradiation on polymeric materials is similar to that of gamma irradiation except for less penetrability of the beam into target materials. The main effect of e-beam irradiation comes from the ionizing electrons that result in the destruction of nucleic acids and proteins required for cellular processes. One primary difference between gamma radiation and e-beam is that the electron beam can be focused on the target [9].

X-rays are less penetrating than gamma rays and tend to require longer exposure times, but require less shielding, and are generated by an X-ray machine. x-ray systems convert electricity into electromagnetic radiation. These systems do not emit any radiation when turned off.

Ultraviolet light irradiation is useful only for sterilization of surfaces and some transparent objects. Many objects that are transparent to visible light absorb UV. UV irradiation is routinely used to sterilize the interiors of biological safety cabinets between uses, but is ineffective in shaded areas, including areas under dirt (which may become polymerized after prolonged irradiation, so that it is very difficult to remove). It also damages many plastics, such as polystyrene foam [9].

Irradiation with particles may make materials radioactive, depending upon the type of particles and their energy, and the type of target material: neutrons and very high-energy particles can make materials radioactive, but have good penetration, whereas lower energy particles (other than neutrons) cannot make materials radioactive, but have poorer penetration.

Advantages

- Suitable for surface sterilization.

Disadvantages

- Expensive.
- Affect on biological materials.
- Need shielding.

2.1.2.4 Sterilization with Filtration

Certain media components are sensitive to heat; it is going to be damaged if it is heated, also some liquids would be damaged by heat, irradiation, and chemical sterilization; so they can be sterilized using mechanical filtration, a filter with pore size 0.2 μm will effectively remove bacteria. If viruses must also be removed, a much smaller pore size around 20 nm is needed. Normally filtration of media is used instead of sterilized media with an autoclave. To filter sterilized media, filter the water using a 0.45μm pore size filter, before using a 0.22μm pore size filter for final sterilization. This method is commonly used for sensitive pharmaceuticals and protein solutions in biological research [9].

Figure 2.1: Filters

2.1.3 Monitoring of Sterilization

The following two methods are used to monitor the effectiveness of sterilization.

1. **Chemical Monitoring**

Chemical indicators are used to provide visual confirmation that instruments have been exposed to adequate temperatures; however, they do not guarantee sterilization. These indicators are usually paper or tape strips which are impregnated with a dye. The dye changes color once the desired temperature is reached. Chemical indicators are to be used with each load.

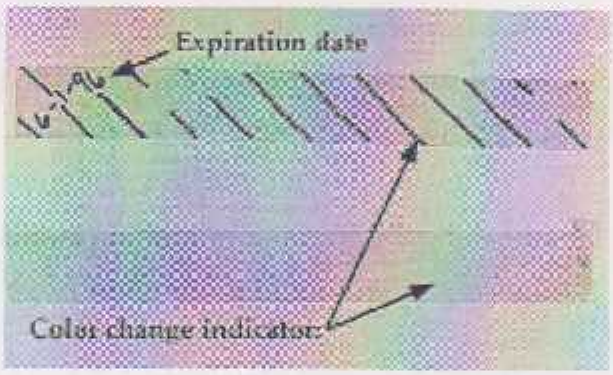


Figure 2.2: Color Change of Sterilization Indicators

2. **Biological Monitoring**

Biological indicators are used to demonstrate that sterilization has occurred. Biological monitors consist of tubes or paper strips containing "known" amounts of bacterial spores; these spores are deactivated during a successful sterilization process.

2.2 Autoclave

Medical instruments and tools that are used in medical field especially in operation rooms and clinics such as Scissors, Forceps, Needle Holders, Retractors, Scalpels, and Towel Clamps must be cleaned and disinfected from any microorganisms so that it will be safe when they are used.

Therefore a device must be used to perform required disinfection to these instruments and tools; this device is called an autoclave or sterilizer.

2.2.1 Autoclave Definition

An autoclave is a device that increases the boiling point of liquids by increasing the pressure, and it is used to sterilize medical tool. It was invented by Charles Chamberland in 1879.

It is called an autoclave because it is a device that automatically locks when the pressure rises (to avoid steam spraying out if you open it by accident). The word is French, and comes from the Greek "auto" for automatic and the Latin "clvis," for key (as in lock and key).

2.2.2 History of Autoclaves

Autoclave passed through several stages of development, side by side with the development in medical field, the following table summaries autoclave development hierarchy.

Table 2.4: Historical background about autoclaves

Year	Development
460-377 B.C.E	Hippocrates poured boiling water onto surgical instruments to clean them.
1681	Denis Papin's, invented the early version of autoclave called the steam pressure cooker
1768	Lazzaro Spallanzani discovered that it took 30 minutes to kill bacteria by heating them in sealed glass flasks
1862	Pasteur sterilized using boiling water at 15 pounds pressure for 15 minutes (commonly called "15 pounds for 15 minutes").
1880	Charles Chamberland finalized The current design of the autoclave
1889	The first commercial steam sterilization system intended for use on medical products

2.2.3 Theory of Operation

An autoclave is a pressure cooker; it operates by using steam under pressure as the sterilizing agent.

After the instruments and tools are packaged and inserted inside the chamber and close the door, the chamber will be filled with water to determined level, and then heaters will start heating till the sterilization temperature, this temperature will be fixed for specific period of time depend on that temperature, after that the steam will be expelled out the chamber and finally drying will begin. The following graph shows the stages of sterilization process.

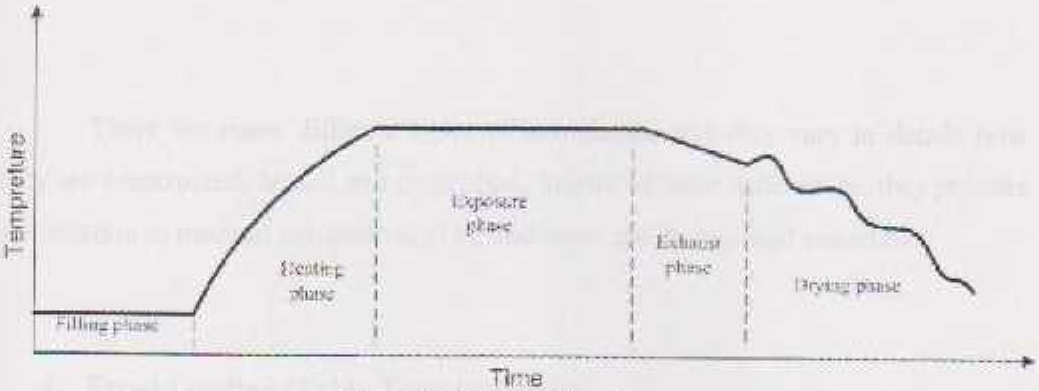


Figure 2.3: Sterilization Phases

The sterilization has the following phases:

1. Filling phase: in this phase, the chamber will be filled with water to a determined level.
2. Heating phase: this phase includes heating the water, tools and the chamber until the temperature reaches sterilization temperature, also it expels air from the chamber.
3. Exposure phase: this is the killing phase where the steam temperature maintained constant for period of time inversely dependent on the steam temperature.
4. Exhaust phase: after the exposure phase is completed, the steam inside the chamber will be exhausted out the chamber allowing pressure balance between atmosphere and chamber.
5. Drying phase: phase where the tools will be dried, it may be performed by chamber heat or external heaters.

2.2.4 Types of Autoclaves

There are many different types of autoclaves, and they vary in details how they are constructed, heated and controlled. Inspite of these differences, they provide sterilization to medical equipments [11], and these are the types of autoclaves:

1. **Front Loading (Table-Top) Autoclave**

Figure 2.4: Table Top Autoclave

2. **Stove Top Autoclave**

Figure 2.5: Stove Top Autoclave

2.3 Project Theory

2.3.1 Main Idea

Our design depends on the idea of killing microorganisms using steam under pressure as sterilizing agent.

High pressures increase the temperature of steam so the heat contents and killing power of steam will be increased. Most of the heating power of steam comes from its latent heat of vaporization. This is the amount of heat required to convert boiling water to steam. This amount of heat is large compared to that required to make water boil.

Steam at 100°C has almost seven times more heat than boiling water. Steam is able to penetrate objects with cooler temperatures when it contacts a cooler surface; it immediately condenses to water causing heat transfer to object and producing a decrease in steam volume concomitant with decrease in pressure at the point of condensation and draws more steam to the area.

Condensations continue so long as the temperature of the condensing surface is less than that of steam; once temperatures equilibrate, a saturated steam environment is formed.

2.3.2 How does Killing Occur

Moist heat is thought to kill microorganisms by causing coagulation of essential proteins. When beef are cooked at home, for example, it can become tough when roasted in a covered pan in the oven. But an addition of a little water in the bottom of the pan will make the beef tender.

Another way to explain this is that when heat is used as a sterilizing agent, the vibratory motion of every molecule of a microorganism is increased to levels that induce the cleavage of intermolecular hydrogen bonds between proteins. Death is therefore caused by an accumulation of irreversible damage to all metabolic functions of the organism.

2.4 Preparation for Sterilization

The objects being sterilized are wrapped in a double thickness of linen or other suitable material that is porous to pressurized steam, a special tape is applied to the wrapped packs, and special indicator strips are placed inside the pack to give the user an indication of whether the sterilization process was completed, there are marks on these indicators that become visible or change color when sterilized.

Figure 2.6: Wrapped Objects

2.5 Project Components

In this section we will explain theoretical background and properties of some project parts and components.

The design consists of the following components:

1. **Power Supply**

A power supply is a system that supplies electrical energy to all project parts. It converts one form of electrical current and voltage to another desired form. This typically involves converting 220 volt AC to a well-regulated lower DC voltage for electronic devices. It is also used to convert 220 volt AC to lower desired AC voltage (for example 12 volts AC).

The power supply unit contains the following:

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

2. **PIC Microcontroller**

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

They have a high concentration of on-chip facilities such as serial port, parallel input/output ports, timers, counters, interrupt control, analog-to-digital converters, random access memory, read only memory, etc. these on-chip peripherals of a microcontroller make it powerful digital processors. the degree of control and programmability they provide significantly enhances the effectiveness of the application [8].

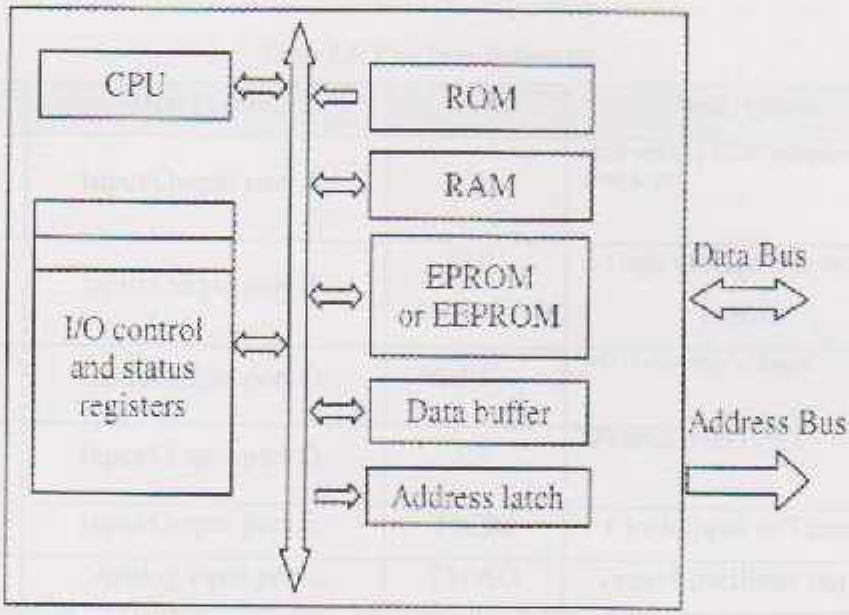


Figure 2.7: Microcontroller General Block Diagram

Features of PIC18F452:

- 32kBytes Program Flash Memory.
- 1536 Bytes RAM Memory.
- 256 Bytes EEPROM Memory.
- 8 channels 10-bit analog to digital converter.
- One 16-bit Timer and Four 8-bit Timers.
- 40MHz max operating frequency.
- 5 input/output ports (RA0-5, RB0-7, RC0-7, RD0-7, and RE0-2).

- 40 pin chip.

Pins of PIC18F452

Table 2.5: Pins Description [10]

Pin	Description	Pin	Description
RA0-5	Input/Output port A.	Vpp	High voltage ICSP programming enable pin.
RB0-7	Input/Output port B.	THV	High voltage test mode control.
RC0-7	Input/Output port C.	VREF+/-	A/D Reference Voltage
RD0-7	Input/Output port D.	SS	SPI Slave Select input.
RE0-2	Input/Output port E.	T0CKI	Clock input to Timer0.
AN0-7	Analog input port.	T1OSO	Timer1 oscillator output.
TX	USART Asynchronous Transmit.	T1OSI	Timer1 oscillator input.
SCK	Synchronous serial clock input.	T1CKI	Timer1/Timer3 external clock input.
SCL	Synchronous serial clock input/output for I2C mode.	PGD	programming data pin.
DT	Synchronous Data.	PGC	programming clock pin
CK	Synchronous Clock.	PGM	Low Voltage ICSP programming enable pin.
SDO	SPI Data Out (SPI mode).	INT	External interrupt.

SDI	SPI Data In (SPI mode).	RD	Read control for the parallel slave port.
SDA	Data I/O (I2C mode).	WR	Write control for the parallel slave port.
CCP1,2	Capture In/Compare Out/PWM Out.	CS	Select control for the parallel slave.
OSC1/ CLKIN	Oscillator In/External Clock In.	PSP0-7	Parallel slave port Data .
OSC2/ CLKO UT	Oscillator Out/Clock Out.	VDD	Positive supply for logic and I/O pins.
MCLR	Master Clear input. (Active low Reset).	VSS	Ground reference for logic and I/O pins.

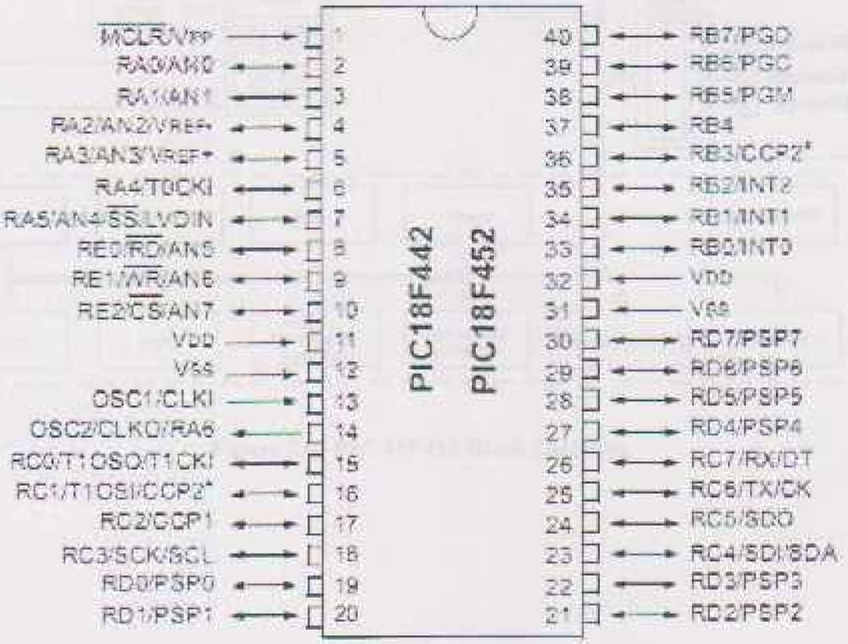


Figure 2.8: Pins of PIC 18F452 Microcontroller

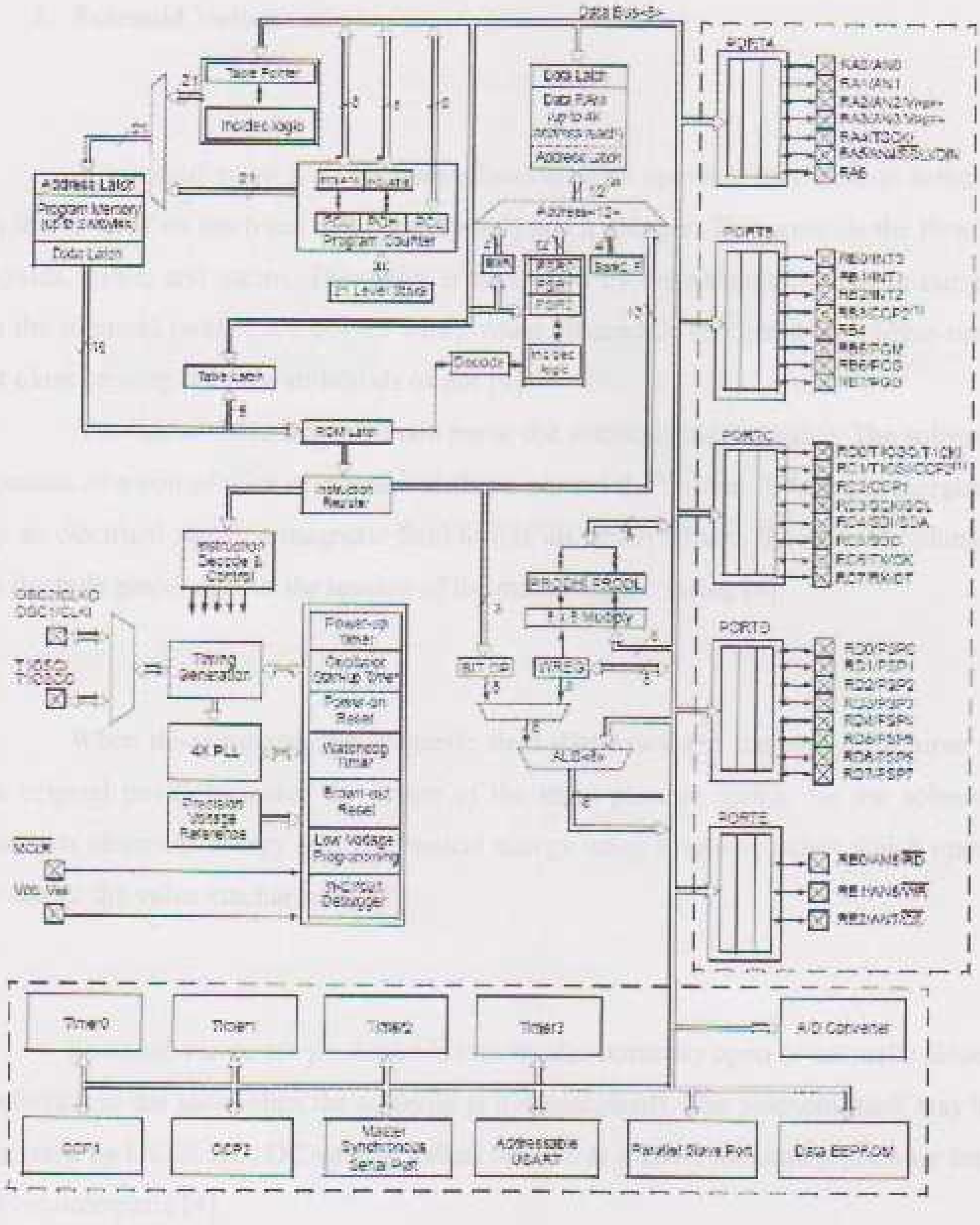


Figure 2.9: PIC 18F452 Block Diagram

3. Solenoid Valves

A solenoid valve is an electromechanical valve operated by a built-in actuator in the form of an electrical coil (or solenoid) and a plunger. This controls the flow of liquids, gases, and steam. This valve is controlled by the passage of electric current in the solenoid (which is a coil of wire), when electrically energized they either open or close causing the flow of liquids or not [4].

A solenoid valve has two main parts: the solenoid and the valve. The solenoid consists of a coil of wire of cylindrical shape around the bobbin. When it is energized by an electrical signal, a magnetic field builds up which attracts the movable plunger to the pole piece, against the tension of the main plunger spring [4].

When de-energized, the magnetic field dissipates and the plunger returns to its original position, under the action of the main plunger spring. So the solenoid converts electrical energy into mechanical energy using magnetic effect which opens or closes the valve mechanically [4].

Solenoid valves are produced in two modes normally open or normally closed (referring to the state when the solenoid is not energized). The solenoid itself may be operated by DC or AC. DC voltage valves operate at a lower maximum pressure than AC counterparts [4].

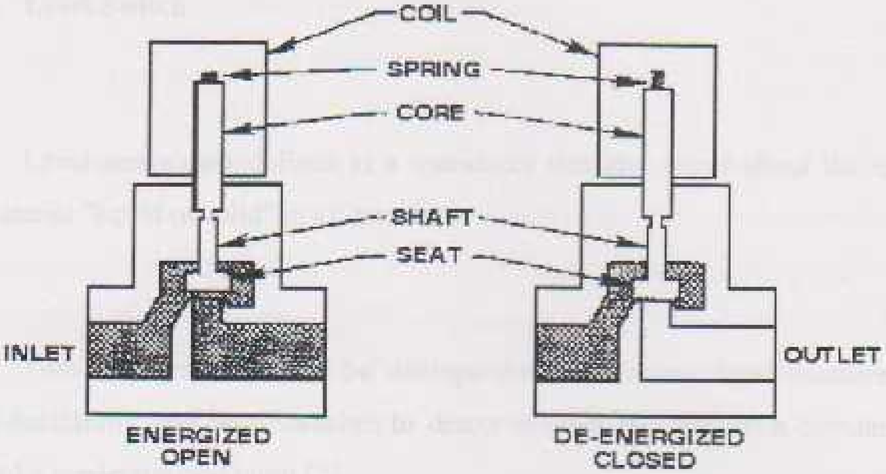


Figure 2.10: Energized and De-energized Solenoid Valve

Advantages of Solenoid Valves

- Speed of operation: The response time of solenoid valves is measured from the moment of electrical energizing to the point when a figure of 90% of the pressure rating is attained at the valve outlet. Most valves have a response time range from 20 to 80 milliseconds.
- A fail-safe (normally closed or normally open).
- Physical size and weight.
- Lower cost.

General Specifications for Solenoid Valves

- Temperature Considerations: includes the fluid maximum temperature and an ambient temperature range.
- Pressure Range: includes the maximum operating pressure.

4. **Level Switch**

Level sensors are defined as a transducer that give signal about the level of the material "liquid or solid" in a container.

Two different tasks can be distinguished, continuous level measurements "level indication" and level switches to detect whether the level of a container has reached a predetermined point [2].

These level switches can be used as an alarm device or as control switches, turning something on or off, such as a pump, or sending a signal to a valve. What makes a level switch special is that they have a switched output and can be either electromechanical or solid state, either normally open or normally closed [2].

Among the technologies for measuring level is capacitive or RF admittance, differential pressure, electrical conductivity or resistivity, mechanical or magnetic floats, optical units, pressure membrane, radar or microwave, radio frequency, rotation paddle, ultrasonic or sonic and vibration or tuning fork technology. Analog outputs from level switches can be current or voltage signals. Also possible is a pulse or frequency. Computer signal outputs that are possible are usually serial or parallel [2].

5. Temperature Sensor(Thermocouple)

Temperature-measuring instrument consisting of two wires of different metals joined at each end. One junction is placed where the temperature is to be measured, and the other is kept at a constant lower (reference) temperature. The temperature difference causes the development of an electromotive force that is approximately proportional to the difference between the temperatures of the two junctions. Thermocouples measure the temperature difference between two points [2].

Principle of Operation

When any conductor is subjected to a thermal gradient, it will generate a voltage. This is known as the thermoelectric effect. Any attempt to measure this voltage necessarily involves connecting another conductor to the "hot" end. This additional conductor will then also experience the temperature gradient, and develop a voltage of its own which will oppose the original [2].

The magnitude of the effect depends on the metal in use. Using a dissimilar metal to complete the circuit will have a different voltage generated, leaving a small difference voltage available for measurement, which increases with temperature. This difference can typically be between 1 and about 70 micro volts per degree Celsius for the modern range of available metal combinations. Certain combinations have become popular as industry standards, driven by cost, availability, melting point, chemical properties, stability, and output. The potential difference between the junctions, known as the Thomson effect, and is described by:

The Seebeck Voltage can be given in equation (2.1).

$$e = aT + \alpha_2 T^2 + \alpha_3 T^3 + ... + \alpha_n T^n ....(2.1)$$

Where e is the e.m.f. generated and T is the absolute temperature.

This is clearly non-linear, which is inconvenient for measurement applications. Fortunately, for certain pairs of materials, the terms involving squared and higher powers of T $(\alpha_2 T^2 + \alpha_3 T^3 + ... + \alpha_n T^n)$ are approximately zero and the e.m.f.–temperature relationship is approximately linear according to: $e = aT$

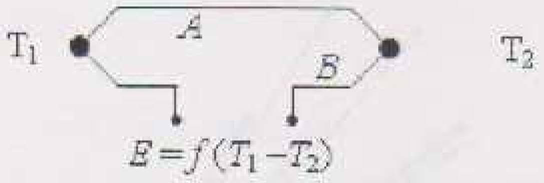


Figure 2.11: Thermocouple

Types of Thermocouples

Varieties of thermocouples are available, suitable for different measuring applications (industrial, scientific, food temperature, medical research, etc.). They are usually selected based on the temperature range and sensitivity needed.

Table 2.6: Types of Thermocouples [2]

Type	Range	Typical emf, mV	Common Name
B	870–1700	0.78	Pt30Rh, Pt6Rh
E	-200 to 870	29.0	Chromel–constantan
J	0–760	22.0	Iron–constantan
K	-200 to 1260	16.4	Chromel–alumel
N	0–1260	13.0	Nisil–nicrosil
R	0–1480	3.4	Pt13Rh, Pt
S	0–1480	3.3	Pt10Rh, Pt
T	-200 to 370	20.8	Copper–constantan

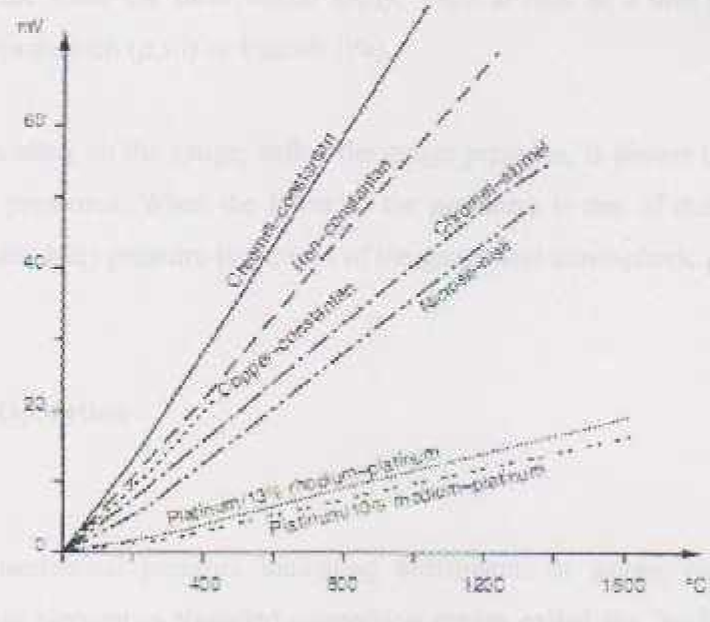


Figure 2.12: Thermocouple Curves

6. **Pressure Gauge**

Figure 2.13: Pressure Gauge

Instrument for measuring the condition of a fluid (liquid or gas) that is specified by the force the fluid would apply, when at rest, to a unit area, such as pounds per square inch (p.s.i) or Pascals (Pa).

The reading on the gauge, called the gauge pressure, is always the difference between two pressures. When the lower of the pressures is that of the atmosphere, the total (or absolute) pressure is the sum of the gauge and atmospheric pressures.

Principle of Operation

The mechanical pressure indicating instrument, or gauge, consists of an elastic pressure element; a threaded connection means called the "socket"; a sector and pinion gear mechanism called the "movement"; and the protective case, dial, and viewing lens assembly. The elastic pressure element is the member that actually displaces or moves due to the influence of pressure. When properly designed, this pressure element is both highly accurate and repeatable. The pressure element is connected to the geared "movement" mechanism, which in turn rotates a pointer throughout a graduated dial. It is the pointer's position relative to the graduations that the viewer uses to determine the pressure indication.

3

Project Conceptual Design

After completing the theoretical background about the project and its components, we will explain conceptual design of the project, this include the following points:

3.1 Detailed Project Objectives

3.2 Design Options

3.3 Block Diagram

3.4 Description of Block Diagram Components

Chapter Three

Project Conceptual Design

3.1 Detailed Project Objectives

In this project we want to achieve many objectives, these objectives are listed as following:

1. Kill the microorganisms such as bacteria and viruses that are existed on un-sterilized medical tools and cause diseases to human.
2. Use the PIC microcontroller, to control whole processes in the system including (temperature, time), and to use special sensors to perform the sterilization process.
3. Use this design in medical field especially in clinics and operation rooms to sterilize medical instruments and tools.

3.2 Design Options

Now we will show the options of project design including control unit options, temperature sensors options and programming language options.

3.2.1 Control Unit Options

We can control the processes of this project using:

- Microprocessor.
- PIC microcontroller.

In our project we used PIC Microcontroller; because it has all necessary parts (CPU, ROM, RAM, and timers) integrated inside one IC, while Microprocessor needs other ICs around it (like ROM, RAM and timers) to work and a lot of wire connection.

3.2.2 Temperature Sensor Options

There are many temperature sensors that can be used:

- Thermocouples.
- Thermistors.

We used thermocouple as a temperature sensor; it has ability to withstand with high temperatures and approximately linear direct relation between temperature and output voltage, in contrary with thermistors, inversely non-linear output respect to temperature variation, also it has long term stability.

3.2.3 Programming Language Options

To program the microcontroller we can use:

- Assembly language.
- C language.

PIC microcontroller can be programmed using C-language or assembly. We programmed the PIC microcontroller using C-language because it is easier.

3.3 Block Diagram

Here an overview of the project as a block diagram, the block diagram shows briefly the project parts of the system.

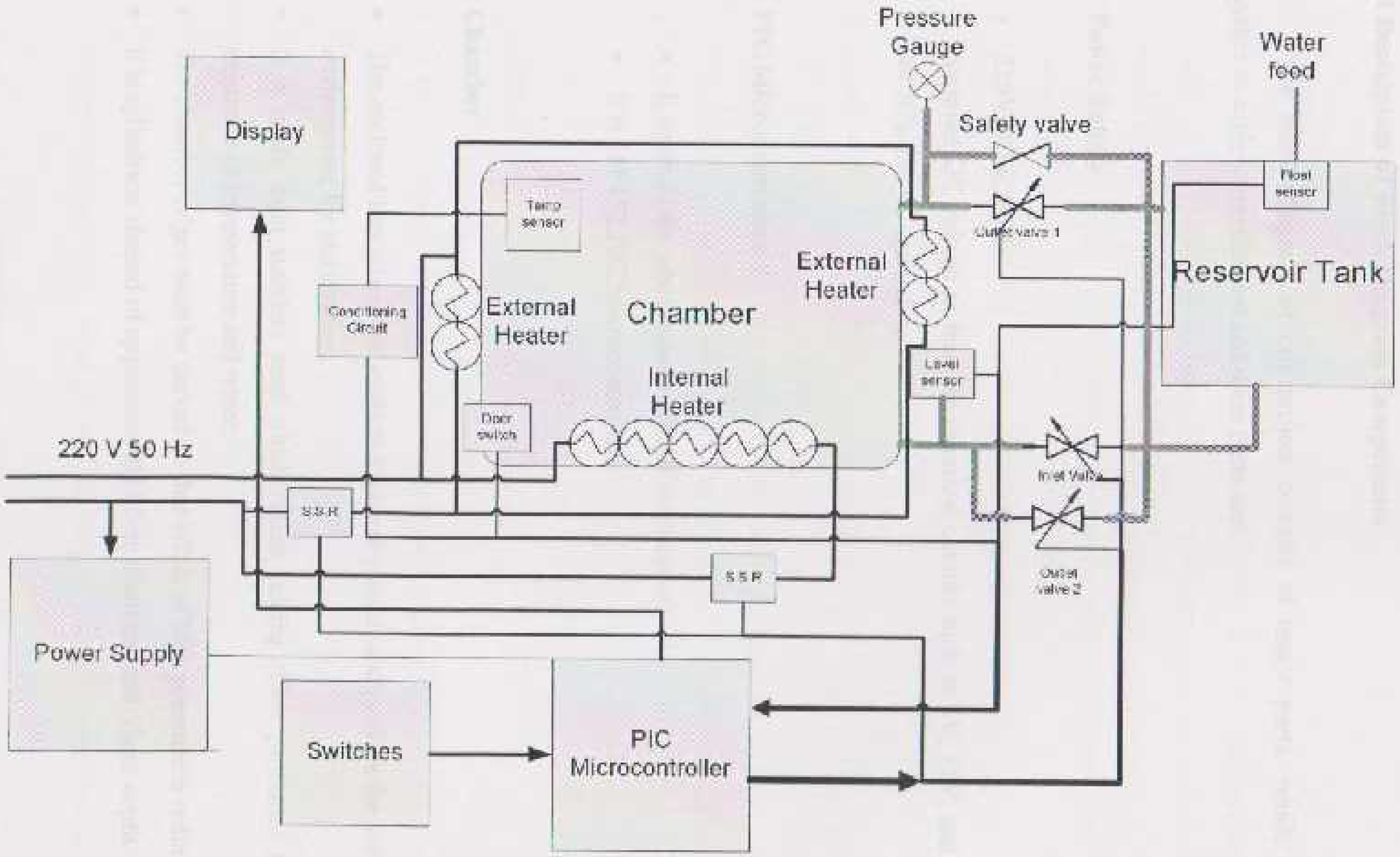


Figure 3.1: Project Block Diagram

3.4 Description of Block Diagram Components

The block diagram of our project consists of major parts, which work together to achieve sterilization and these parts are:

1. **Power Supply**

- 220V±10%, 50Hz.
- Supplies DC voltage to feed the electrical circuits such as 5V, 12V, and 24V for IC's, relays, and valves

2. **PIC Microcontroller**

- It controls the whole parameters of sterilization.
- It is 18F452 PIC Microcontroller.

3. **Chamber**

- The enclosed box where the medical tools are placed, and provide the suitable environment for sterilization.
- It is made from stainless steal which resists rusting effect produced from existence of temperature and water.
- The chamber edges must be curved so that effect of high pressure is reduced.
- It is cylindrical shaped of approximately 25cm diameter and 39cm depth.

4. **Heaters**

- The source of heat.
- There are two types of heaters are used, the first is used during the sterilization process to heat the water and transform it to steam, it is steam-water heater and placed inside the chamber.
- The second heater is used during sterilization and drying processes, it is externally placed.
- 220V AC, 50Hz, and approximately 1.4KW.

5. **Reservoir Tank**

- It reserves water to be used in sterilization to produce needed steam.
- It is used to condense the steam after completion of sterilization process.
- 3 Liter water volume.

6. **Switches**

- It allows us externally control the parameters of sterilization and select the mode of operation.

7. **Display**

- Display is the interface part that shows us the state and all machine variables (temperature and time), which gives us feedback about the setting values.

8. Valves

- It is used as control (inlet and outlet) and safety.
- Safety valve will work if the pressure increases to the maximum pressure; it opens allowing steam get out the chamber.
- Inlet valve is used to control the passage of water to the chamber from the reservoir tank.
- Outlet valve1 is used to allow the air going out the chamber before 95°C.
- Outlet valve2 is used to control the passage of steam from the chamber to the reservoir tank after completing the sterilization.

9. Level Switch

- Magnetic float switch is used to give feedback signal to microcontroller that water reaches the determined level.
- It is also used to feedback signal about water in the reservoir tank.

10. Temperature Sensor

- Temperature sensor is used to convert the temperature to electric current.
- It is a thermocouple temperature sensor

11. Pressure Gauge

- Instrument for displaying the pressure inside the chamber in P.S.I or Bar.

4

Detailed Technical Project Design

After completing the project theory and block diagram, we want to explain the design of this project in specific way, so these topics will be discussed in this chapter:

Chapter Four

Detailed Technical Project Design

4.1 Detailed Description of the Project Phases

The sterilization has the following phases:

1. Filling phase: the inlet valve is energized allowing water to enter the chamber until it reaches a determined level (level of 150Ml in the chamber), then this solenoid valve will be de-energized.

2. Heating phase: the heating elements are energized to heat the water, tools and chamber. The production of steam will expel the air outside the chamber through outlet valve1, when the temperature reaches nearly 95°C, the outlet valve1 will be closed. The process continues heating, production of steam and increasing the pressure until the temperature reaches the sterilization one.

3. Exposure phase: this is the killing phase where the steam temperature maintained constant for period of time inversely dependent on the steam temperature.

4. Exhaust phase: after the exposure phase is completed, the heating elements will be de-energized and let the steam going out the chamber through outlet valve2, therefore decreasing the pressure inside the chamber until it equilibrates with atmospheric pressure.

5. Drying phase: this cycle is performed in two ways. the first one if the user selects dry mode the objects will be dried using energized external heater for 15 minutes (45 seconds ON, 2 minutes OFF), the other one without selecting dry mode, the objects will be dried using the heat of the chamber but it will take longer time [7].

The following figure (4.1) shows the phases of the project.

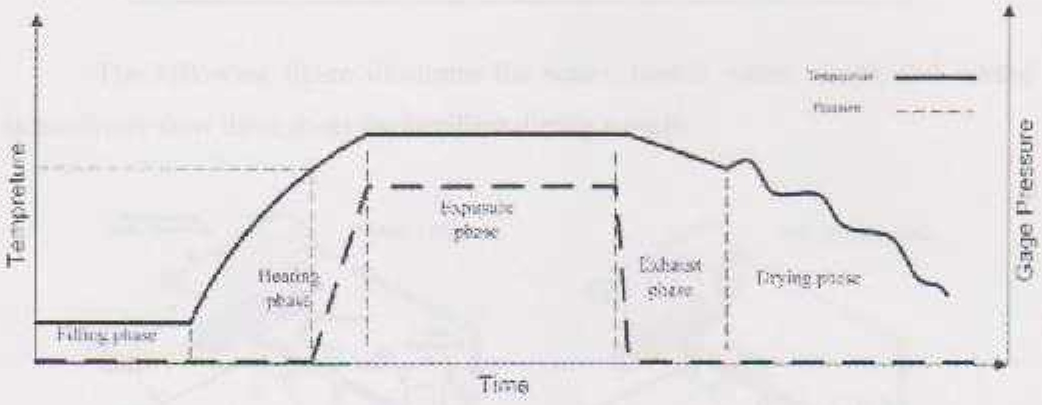


Figure 4.1: Sterilization Phases

From the graph we see that the pressure increase with the temperature, the following table shows the relation between the pressure and temperature.

Table 4.1: Temperature Pressure relationship [7]

Temperature	Pressure (P.S.I)
100	0
108.5	5
115.2	10
121	15
126	20
130.5	25
134.5	30

The following figure illustrates the water, heated water, steam, and vented steam/water flow throughout the sterilizer during a cycle.

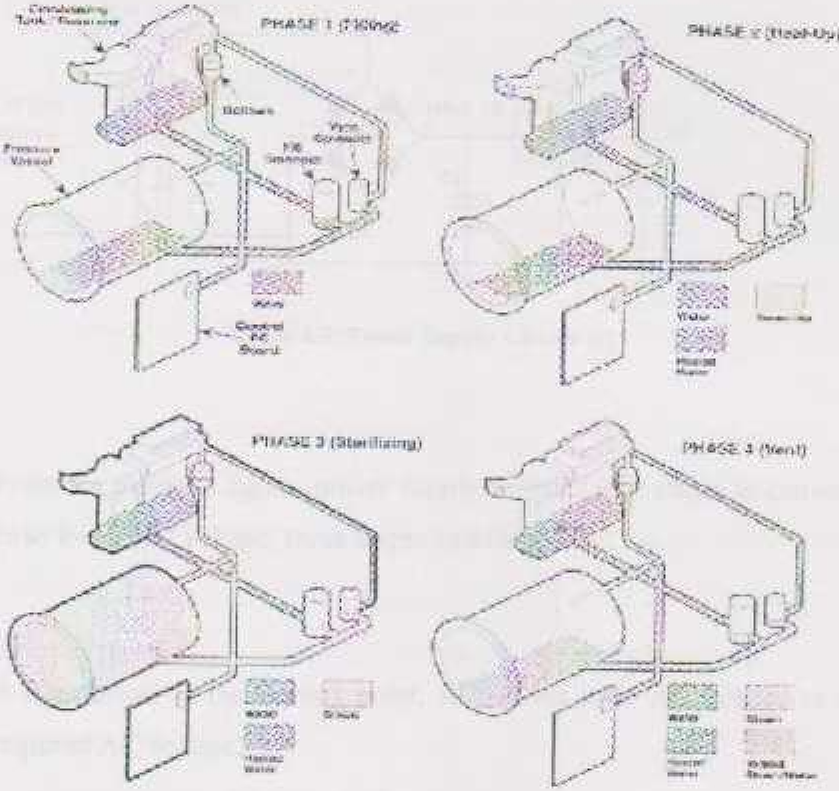


Figure 4.2: Detailed Sterilization Phases [7]

4.2 Subsystem Detailed Design

Now we will express the specification and schematics of subsystems of the project:

4.2.1 Power Supply

A power supply is a mean of providing electrical power to the project parts; it consists of many stages, as shown in figure (4.3).

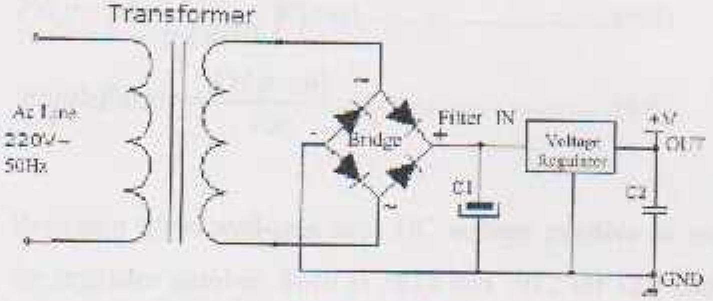


Figure 4.3: Power Supply Circuit [8]

From the previous figure, power supply contains four stages to convert 220V AC 50Hz to lower DC voltage, these stages as follows:

1. A transformer is the starting point, step down main AC voltage to a lower required AC voltage.

The output voltage at the secondary coil of the transformer depends on the turn's ratio, which is given using this formula: $n = \frac{N_S}{N_P} = \frac{V_S}{V_P}$..............(4.1)

2. Full wave rectifier changes an alternating current to non-regulated direct current.

   The peak input voltage to the rectifier is: $V(peak) = V_S(RMS) * \sqrt{2}$....(4.2)

   The output of the rectifier is: $V(out) = V(peak) - 1.4$......................(4.3)

3. The filter (C1) will smooth the voltage signal more and more.

   As mentioned the filter will smooth the voltage, but there is a ripple. The value of the capacitor and the resistor determine the limits of the ripple.

   $$Vdc = \left(1 - \frac{1}{2fR1C1}\right)V(out) \qquad (4.4)$$

   $$Vr(p-p) = \left(\frac{1}{FR1C1}\right)V(out) \qquad (4.5)$$

   $$RippleFactor = \frac{Vr(p-p)}{Vdc} \qquad (4.6)$$

4. Regulator gives well-regulated DC voltage positive or negative according to the regulator number. Such as 7812 and 7912 for 12V and -12V respectively.
5. The capacitor C2 was used to enhance stability of regulator.

The project needs 24,12,5 DC voltages. Maximum DC voltage needed is 24V so the input of regulator must be greater than 24V. 220V ac to 24Vac transformer must be used.

$\frac{Vp}{Vs} = \frac{220}{24} = 9.1$ → Turn ratio between primary and secondary is about 9:1.

Vs (p-p) = $24 * \sqrt{2} = 33.9V$

Vout (rectifier) = 33.9-1.4= 32.5V.

$$Vdc = \left(1 - \frac{1}{2fRlC1}\right)Voutrect$$

$$Vr(p-p) = \left(\frac{1}{FRlC1}\right)Voutrect$$

$$RippleFactor = 1\% = \frac{Vr(p-p)}{Vdc}$$

$$\left(\frac{1}{FRlC1}\right)Voutrect = 0.01\left(1 - \frac{1}{2fRlC1}\right)Voutrect$$

If C1 equal 1000μF by assumption, F is frequency equal 100Hz since full wave rectification, RL from calculation will be 1005Ω.

Vdc= 32.33V.

Vripple= 0.32

Vin regulator [31.98, 32.62]

Rectifier should be not less than 35V.

C1 value is 1000μF, 35V.

The valves are supplied with 24V DC voltage, three valves are used in the project, and every valve needs nearly 300mA, so the approximated load at 24V is 1A, 12V dc is used to energize the relays and to supply the amplifier; the load at 12V is nearly 1.5A, 5V DC is used to supply the digital integrated circuits, the approximated total load is 3A. The total load of all DC voltages needed is 6A. There are two heaters with 1.4KW so the approximated load of heaters is 14A.

The turn's ratio of the transformer is 9.1 so the approximated input current of the transformer is 0.7A ac so the maximum ac load is 15A.

4.2.2 Valve Control Circuit

The valves control the flow of water and steam in and out the chamber, solenoid valves are energized with 24V DC, so these valves can't be connected directly to the microcontroller.

To control them we will use the following circuit as control:

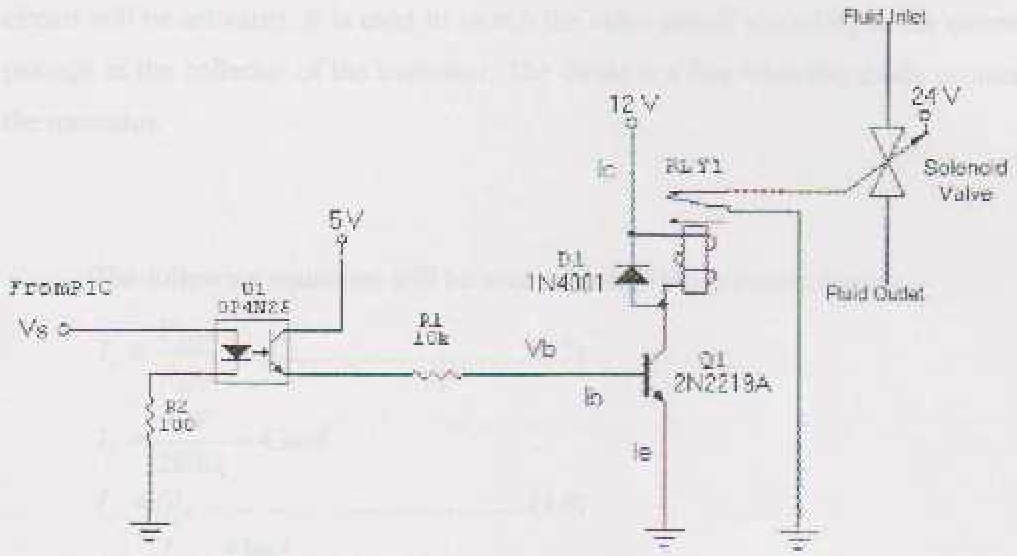


Figure 4.4: Valve Control Circuit

From the previous figure, valve control circuit contains two stages to energize and control the valve:

The opto-coupler is the first stage and it is used to isolate the microcontroller from the other parts of the circuit.

The transistor is the second stage, it is used as switch and amplifies the current that comes from the emitter of the phototransistor of the opto-coupler, when current passes through the base, and then the current through the collector energizes the relay.

Relay is magnetic switch that contains a coil and a metal when current passes through it magnetic field produced, this will contact the two metal and the next circuit will be activated. It is used to switch the valve on/off according to the current passage in the collector of the transistor. The diode is a free wheeling diode protects the transistor.

The following equations will be used to design the previous circuit.

$$I_c = \frac{V_{RLY}}{R_{RLY}} \quad \text{.......................................(4.7)}$$

$$I_c = \frac{12V}{280\Omega} \approx 43mA$$

$$I_c = \beta I_B \quad \text{.......................................(4.8)}$$

$$I_B = \frac{I_c}{\beta} = \frac{43mA}{100} = 0.43mA$$

$$V_B \approx 0.7V \quad \text{.......................................(4.9)}$$

$$I_B = \frac{V_c - V_B}{R_1} \quad \text{.......................................(4.10)}$$

$$R_1 = \frac{V_i - V_B}{I_B} = \frac{5 - 0.7}{0.43} = 10K\Omega$$

4.2.3 Temperature Conditioning Circuit

The temperature sensor feedback the temperature to PIC microcontroller, the output of this sensor is small; it must be amplified to be used.

To amplify the voltage from the temperature sensor, we used the following circuit:

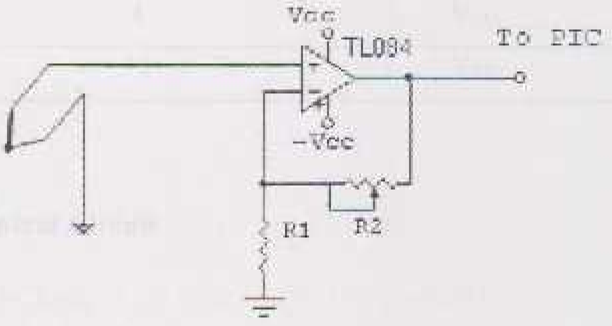


Figure 4.5: Temperature Sensor Circuit

The output of temperature sensor is connected to non-inverting input of amplifier TL084ACN.

The gain of circuit: $A_v = \frac{R_1 + R_2}{R_1} = 1 + \frac{R_2}{R_1}$ ....(4.11)

The reference voltage of the analog digital converter is 5V and it is 10bit analog digital converter so the number of levels is 2^{10}=1024 level. The voltage of each level =5/1024= 4.88mV. The sensitivity of the temperature sensor is 25µV/°C so the gain of the amplifier will be 4.88/0.0250=195. We use R_1=120Ω, then R_2=194*120 → R_2=23KΩ.

Supply voltage for TL084ACN Op-Amp up to ±18V, it has four operational amplifiers on single chip; the following table shows the Pins configuration of TL084ACN Operational Amplifier.

Table 4.2: Pins configuration of Tl084ACN amplifier

Pin Number	Function
2,6,9,13	Inverting inputs
3,5,10,12	Non-inverting inputs
1,7,8,14	Outputs
4	V_{CC}
11	V_{EE}

4.2.4 Heater Control Circuit

The heaters are controlled by PIC microcontroller and it is AC energized, so there must be circuit used to control the operation of the heaters depending on the signal from the PIC microcontroller.

Here we will show the circuit that performs the previous operation:

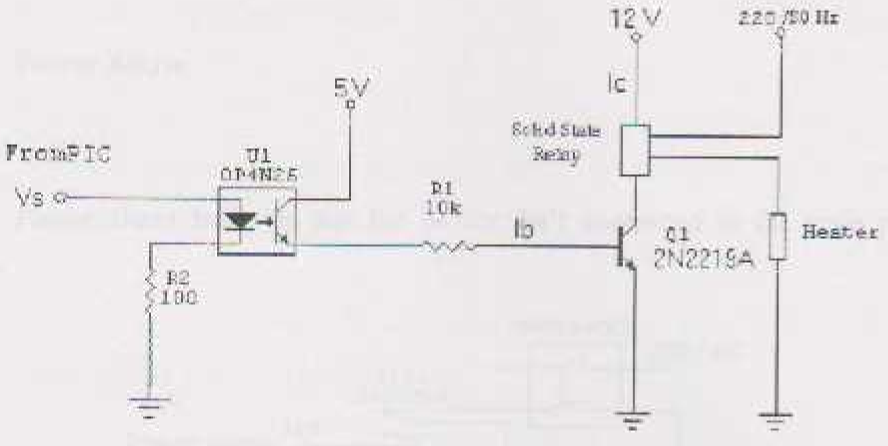


Figure 4.6: Heater Control Circuit

This circuit works as the circuit of valve control with solid state relay instead of mechanical relay.

Solid State Relay is an electronic switch, which unlike an electromechanical relay, contains no moving parts. It can be made as photo-coupled SSR, transformer-coupled SSR, and hybrid SSR. SSR's are faster than electromechanical relays and it provide an isolation barrier between the control logic and a high voltage load.

4.2.5 Warning Alarms

To enhance the efficiency and the safety of this project, alarm system must be used to feedback the errors and control the system when some errors occurred.

The project includes the following alarms:

1. **Power Alarm**

Power alarm indicates that the device isn't connected to the main power supply.

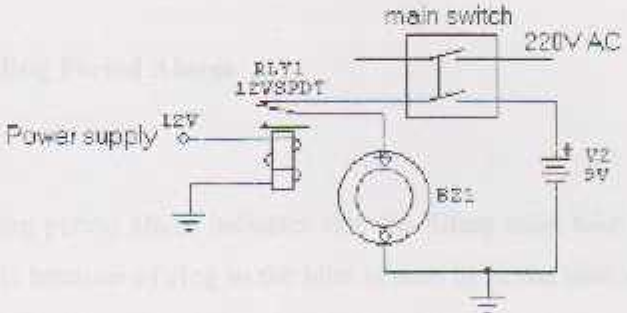


Figure 4.7: Power Alarm Circuit

2. **High Temperature Alarm**

The high temperature alarm indicates an excess of 3°C difference between the set temperature and the temperature measured inside the chamber. The high temperature alarm sounds when the temperature is 3°C above the set temperature setting and finishes the process.

When the buzzer alarm, this indicates that the temperature increased due to incorrectly controlled heaters, so the process must be finished to reduce the effect of temperature on tools and to avoid destruction of internal heater when all amount of water are evaporated.

3. **Reservoir Tank Empty Alarm**

Reservoir tank empty alarm indicates that there is no water in it; the process will stop until the operator fills the tank.

4. **Long Filling Period Alarm**

Long filling period alarm indicates that the filling stage take longer time than set time; so this is because of clog in the inlet system or in the inlet valve. This alarm stops the system and demands maintenance for the inlet system.

5. **Door Open Alarm**

Door open alarm indicates that the door isn't strongly closed; the process will not begin until the door closed.

If the door is opened during the process the program will be interrupted and the process will be finished.

4.2.6 Sterilization Modes

There are different types of tools that can be sterilized using autoclaves, these types varying in the ability to withstand with temperature, so autoclaves must be suitable for these types of tools.

Autoclaves have many modes of sterilization depending on the type of tool and instrument; here we will show the modes of operation of this project.

Table 4.3: Sterilization Modes

	Sterilization Temperature [C]	Sterilization Time [min]	Drying Time [min]
Gloves, catheters and rubber material in general	121	20	14
Surgical instruments, empty glassware	134	5	9
Textiles, porous material in general, empty glassware and anyhow all things that are temperature-proof.	134	7	14
Wrapped Instruments.	121	20	15

4.3 User-System Interface

User system interface is the communication between the user and the device; through it the user can control the parameters of sterilization and mode selection. And it also gives information about the parameters during the process. It contains keypad and display.

4.3.1 Switches

Switches will enable the user to do the following.

1. Select the mode of operation.
2. Control the device during alarms.
3. Starting and stopping the process.

4.3.2 Display

Display shows the sterilization parameters and stages etc. we used 7-segment, and these devices can show the following:

1. Temperature.
2. Time.

Light Emitting Diode (LED) will be used to display the following:

1. The process stages such as filling water, heating, etc.
2. Power indication.
3. Warning alarms such as over heating, door open, etc.
4. Mode indication.

4.4 Over All Control System Design

Over all control system design contain the connections of PIC microcontroller and all other electronic parts, which is in appendixA.

5

Software

To control the previous described project we must used a programmed PIC microcontroller. so this chapter will express the following

5.1 Flow Charts

5.1.1 Program Flowchart

5.1.2 User Flowchart

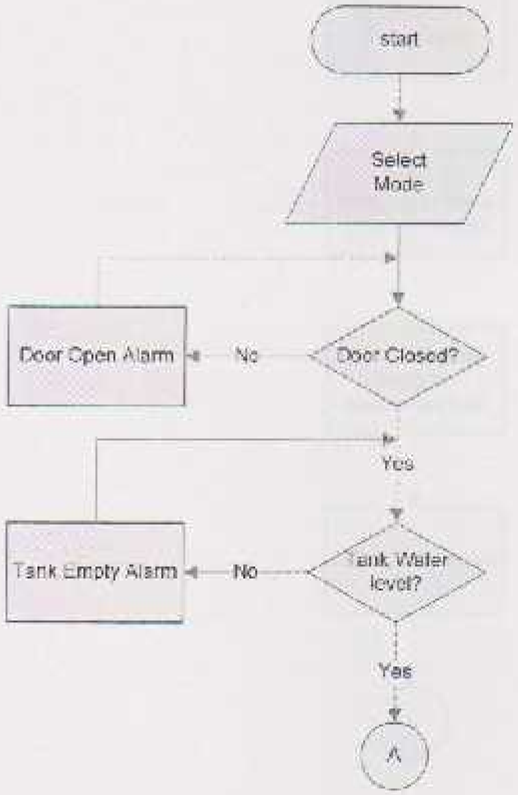
5.2 Software needed for the project

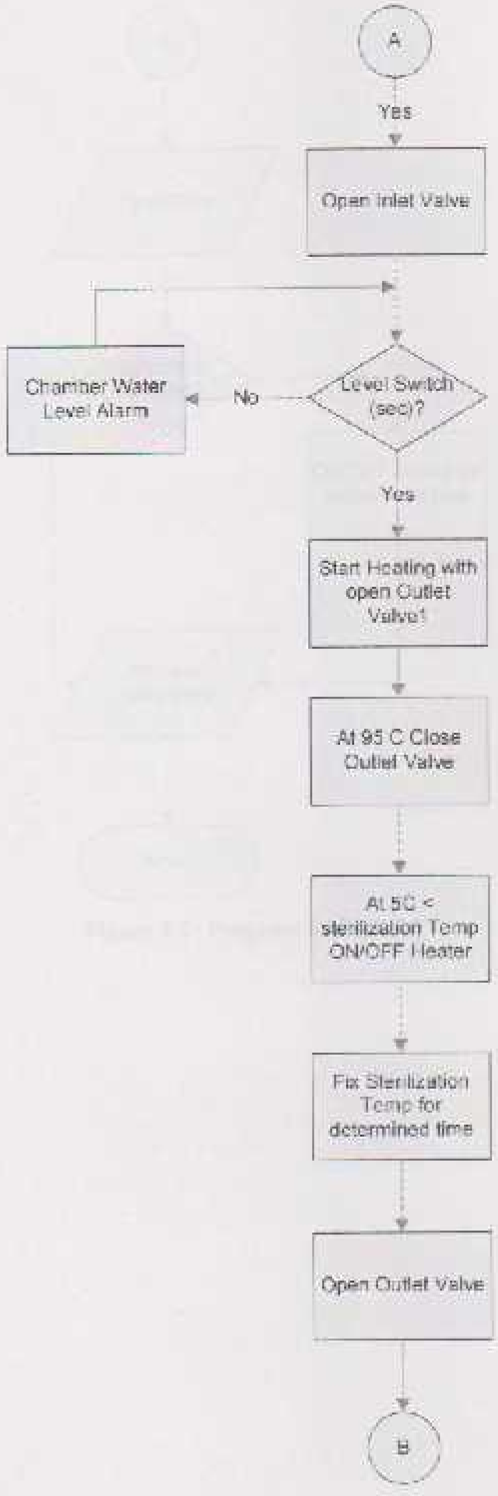
Chapter Five
Software

5.1 Flow Charts

A flow chart illustrates the steps of the process by visualizing the processes.

5.1.1 Program Flow Chart




A
Yes
Open Inlet Valve
Chamber Water Level Alarm
No
Level Switch (sec)?
Yes
Start Heating with open Outlet Valve1
At 95 C Close Outlet Valve
At 5C < sterilization Temp ON/OFF Heater
Fix Sterilization Temp for determined time
Open Outlet Valve
B

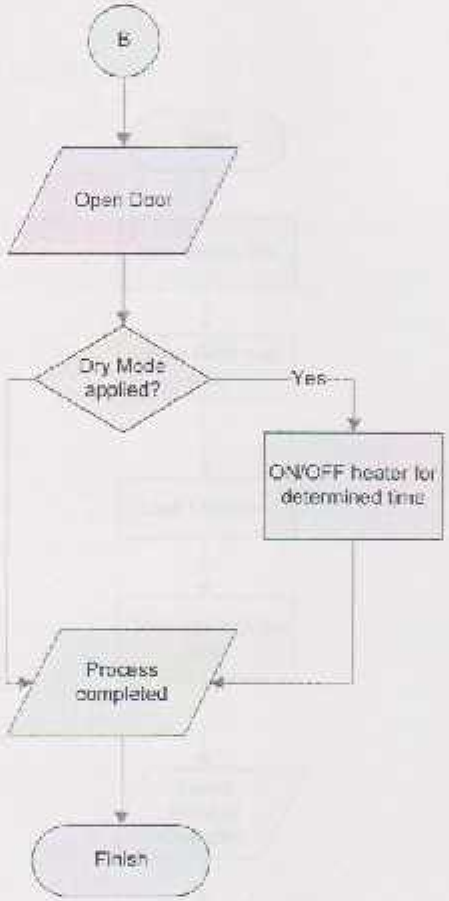


Figure 5.1: Program Flowchart

5.1.2 User Flow Chart

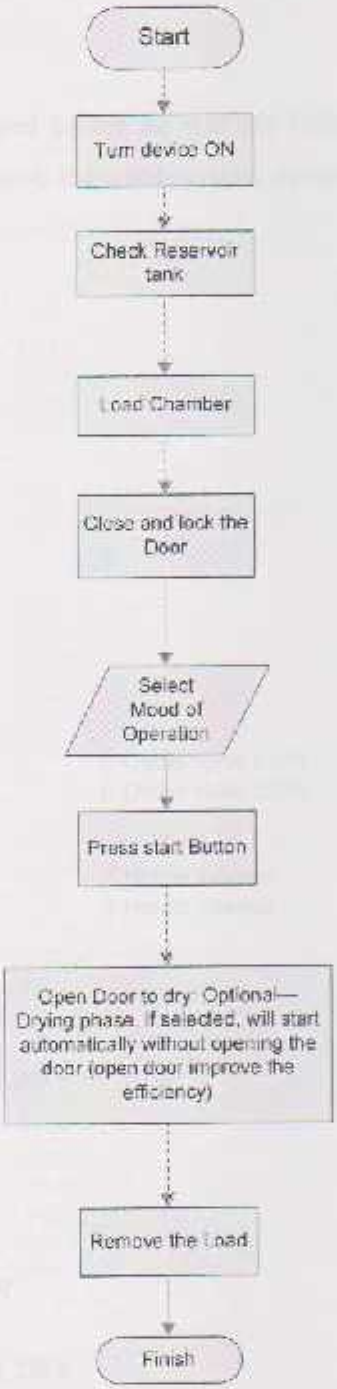


Figure 5.2: User Flowchart

5.2 Software Needed for the Project

In our project described earlier we will use C-language to program the PIC microcontroller so that it controls the whole system of autoclave.

This is the program code

```
#include<p18f452.h>
#include<delays.h>
#include<adc.h>

#pragma config WDT = OFF
#pragma config LVP = OFF
#pragma config OSC = HS


#pragma interrupt an
void an(void)
        {
        int dcount;
        TRISD=00;
        TRISE=00;
        PORTDbits.RD1=1;                // Outlet valve 1 ON
        PORTDbits.RD2=1;                // Outlet valve 2 ON
        PORTAbits.RA1=1;
        PORTAbits.RA2=1;
        PORTDbits.RD3=0;                // Heater external
        PORTDbits.RD4=0;                // Heater internal
        dcount= 00;

                // 45 second delay
        while (dcount<=35)
                {
                Delay10KTCYx( 250 );
                ++dcount;
                }

        PORTE= 0b111;
        dcount= 00;

                // 15 second delay
        while (dcount<=12)
                {
                Delay10KTCYx( 250 );
                ++dcount;
                }
```

```
        PORTE=0b101;
        PORTDbits.RD1=0;        // outlet 1 open
                while (1);
        }

#pragma code high_vector=0x08
void high_vector (void)
        { _asm goto aa _endasm }
#pragma code
void fun1 (void);

        /***********Declarations***********

                        Inputs
Door switch                     RB0
level tanke switch              RB1
champer level switch            RB2
mode select                     RB3
start                           RB4
Read timer15                    RB5
Read timer3                     RB6
Dry select                      RB7

                        Outputs
Inlet valve                     RD0
outlet 1 valve                  RD1
Outlet valve 2                  RD2
Heater external                 RD3
Heater internal                 RD4
digit 3 temp                    RD6
Set Timer                       RD7

Phase decoder                   RA1
Phase decoder                   RA2
                        Phase decoder
00                              Filling water
01                              Heating
10                              sterilization
11                              exhaust

Display temp                    RC0-RC7

PORTE                           Error code
000                             Normal
001                             water tanke
010                             close door
011                             high temp
100                             Drying
101                             complete
110                             clog
111                             zamer
/**********************************/
int temp,t, dry, st, dcount;
```

```
float a,b, c;

void main(void)
        {
        // ports (B,C,D,E) declaration
        TRISB 0xFF;             // Input
        TRISD= 00;              // Output
        TRISE= 00;              // Output
        TRISC= 00;              // Output
        PORTE= 00;              // Normal state led
        PORTD= 00;
        PORTC= 00;
        fan1();
        while (PORTBbits.RB4==1)
                {
                        // Mode select
                if (PORTBbits.RB3==0)
                        st=121;
                else
                        st=134;

                        // Dry Select
                if (PORTBbits.RB7==0)
                        dry=0;
                else
                        dry=1;
                }

                        //check water in tanke
        while (PORTBbits.RB1==0)
                PORTE=0b001;            // fill water in tank
        PORTE=0b000;                    //Normal status

                        //check door closer
        while (PORTBbits.RB0==1)
                PORTE=0b010;            // close door
        PORTE=0b000;                    //Normal status
        PORTDbits.RD0=1;                // inlet valve fill water

                        // 1 minute delay
        dcount=00;
        while (dcount<=48)
                {
                PORTAbits.RA1=0;
                PORTAbits.RA2=0;
                Delay10KTCYx( 250 );
                ++dcount;
                }
        PORTDbits.RD0=0;                // Stop filling water
        INTCON = 0b10010000;            // Enable interrupt
        INTCON3=0b00011100;             // Enable interrupt
        while (1)
                {
```

```
            fun1 ();            // ADC Function
            if (temp<93)
                {
                PORTAbits.RA1=1;
                PORTAbits.RA2=0;
                PORTDbits.RD1=1;        // Open outlet valve 1
                PORTDbits.RD3=1;        // External heater ON
                PORTDbits.RD4=1;        // Internal heater ON
                }
            else
                break;
        }

PORTDbits.RD1=0;                // Close outlet valve 1
PORTDbits.RD4=0;                // Turning internal heater off

while (1)
        {
        fun1 ();
        if (temp<(st-5))
            {
            PORTDbits.RD3=1;        //External Heater ON
            }
        else
            break;
        }
while (1)
        {
        fun1 ();
        if (temp<st)
            {
            PORTDbits.RD3=1;        //External heater ON
            Delay10TCYx( 60 );
            PORTDbits.RD3=0;        //External heater OFF
            Delay10TCYx( 40 );
            }
        else
            break;
        }
PORTAbits.RA1=0;
PORTAbits.RA2=1;
if (PORTBbits.RB3==0)
        {
        while (PORTBbits.RB5==0)
            {
            fun1 ();
            PORTDbits.RD7=1;
            if (temp<st)
                {
                PORTDbits.RD3=1;            // Heater external ON
                Delay10TCYx( 500 );
                }
            else if (temp>(st+3))
```

```
                        {
                        PORTDbits.RD3=0;                // Heater external OFF
                        Delay10TCYx( 500 );
                        }
                }
        }
else
        {
        while (PORTBbits.RB6==0)
                {
                PORTDbits.RD7=1;
                fun1 ();
                if (temp<st)
                        {
                        PORTDbits.RD3=1;          // External heater ON
                        Delay10TCYx( 500 );
                        }
                else if (temp>(st+3))
                        {
                        PORTDbits.RD3=0;          // External heater OFF
                        Delay10TCYx( 500 );
                        }
                }
        }
PORTAbits.RA1=1;
PORTAbits.RA2=1;
PORTDbits.RD7=0;                // Reset timer
PORTC =0b00000000;              // Temp reset
PORTDbits.RD6=0;                // Temp Digit 3 reset
PORTDbits.RD1=1;                // Outlet valve 1 ON
PORTDbits.RD0=1;                // Inlet valve ON
dcount=00;
                // Delay for 10 seconds
while (dcount<=8)
        {
        Delay10KTCYx( 250 );
        ++dcount;
        }
PORTDbits.RD0=0;
PORTDbits.RD2=1;                // Outlet valve 2 ON
dcount=00;
                // Delay for two minutes
while (dcount<=94)
        {
        Delay10KTCYx( 250 );
        ++dcount;
        }
INTCON = 0b00000000;            // Disable interrupt
INTCON3=0b00011100;             // Disable interrupt
while(!PORTBbits.RB5&&dry)
        {
        PORTE = 0b100;
```

```
        PORTDbits.RD7=1;
        PORTDbits.RD3=1;          // External heater ON
        dcount=00;
                        // 45 second delay
        while (dcount<=35)
                {
                Delay10KTCYx( 250 );
                ++dcount;
                }
        PORTDbits.RD3=0;          // External heater OFF
        dcount=00;
                // Delay for two minutes
        while (dcount<=84)
                {
                Delay10KTCYx( 250 );
                ++dcount;
                }
        }

    PORTDbits.RD7=0;              // Reset timer
    PORTDbits.RD3=0;              // External Heater OFF
    PORTDbits.RD4=0;              // Internal Heater OFF
    PORTE= 0b111;
    dcount=00;
                // 15 second delay
    while (dcount<=12)
        {
        Delay10KTCYx( 250 );
        ++dcount;
        }
    PORTE= 0b101;
    PORTDbits.RD1=1;              // Outlet valve 2 ON
    PORTDbits.RD2=1;              // Outlet valve 2 ON
    while(1);
    }// end prog

void fun1 (void)
    {
    OpenADC(ADC_FOSC_8 & ADC_RIGHT_JUST & ADC_8ANA_0REF,ADC_CH0 &
ADC_INT_OFF );                    // ADC configuraion
    SetChanADC(ADC_CH0);
    Delay10TCYx( 5 );
    ConvertADC();                 // Start conversion
    while( BusyADC() );           // Wait for ADC conversion
    temp= ReadADC();              // Read result and put in temp
    CloseADC();

                // Binary To Decimal Conversion
    t=temp%100;
    if(temp>99)
        PORTDbits.RD6=1;
    else
        PORTDbits.RD6=0;
```

```
a=i/10;
b=i%10;
a=a*16;
a=a+b;
PORTC=a;
}
```

6

System Implementation and Testing

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

Chapter Six

System Implementation and Testing

System implementation and testing are performed on subsystems and all system. These subsystems are:

6.1 Mechanical system implementation and testing

The mechanical system implementation and testing includes combining the chamber with water tank, safety valve, electrical valves, pressure gauge, and water level sensor. The heaters are placed to the chamber one inside the chamber and the other outside the chamber. The following picture shows mechanical system implementation.

Figure 6.1: Mechanical system

After building the mechanical system we tested it manually, by adding 150ml of water in chamber and start heating until the pressure reached 3 bar.

6.2 Electrical and electronic subsystems implementation and testing

1. **Display**

Display composed from seven segments to show temperature and time they are build on a single board to be placed on the front of the device; this board is connected to PIC board using connectors and data cable.

Display board test was performed by connecting it with PIC loaded with subprogram to display time and temperature. Figure (6.2) shows the implementation of display board.

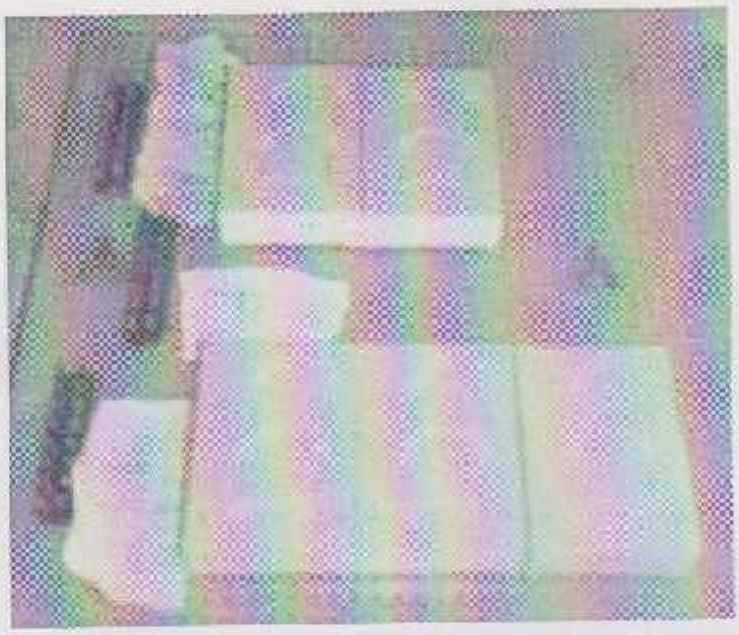


Figure 6.2: Display board

2. **Heaters and valves control circuits**

Heaters are controlled using solid state relay and valves are controlled using mechanical relay.

The implementation of heaters and valves control circuits was performed by combining opto-couplers with transistors to relays finally.

Heaters and valves control circuit were tested by applying an external signal to energize and de-energize the heaters and valves. The following figure shows the implementation of heaters and valves control circuits.

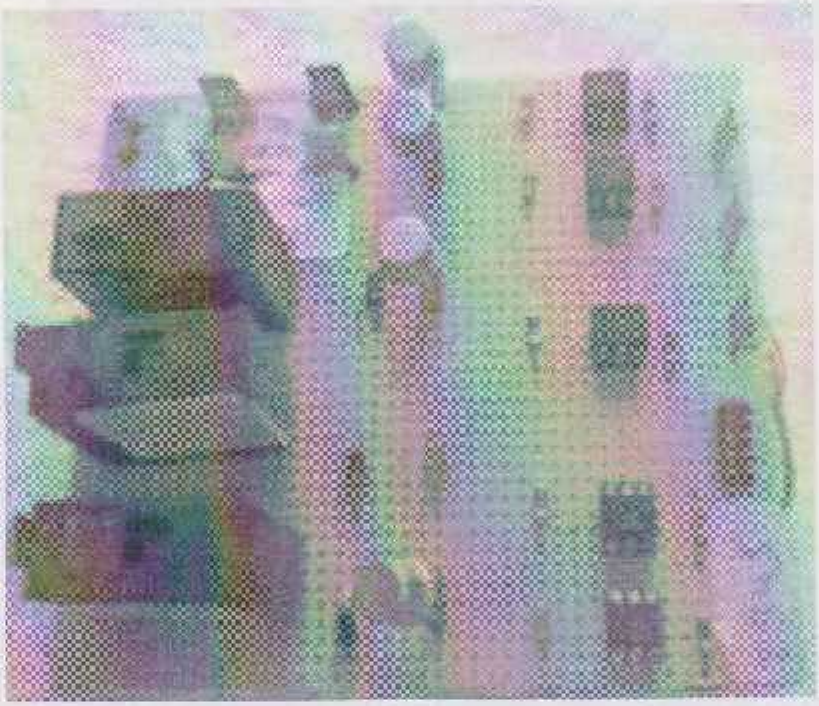


Figure 6.3: Heaters and valves control board

3. Power alarm.

Power alarm circuit implemented in simple way using relay energized by supply voltage, and buzzer as indicator. It was tested and working properly.

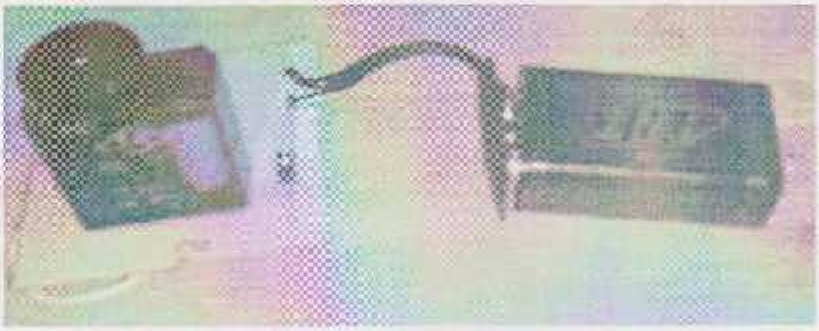


Figure 6.4: Power alarm board

4. PIC microcontroller and its circuits.

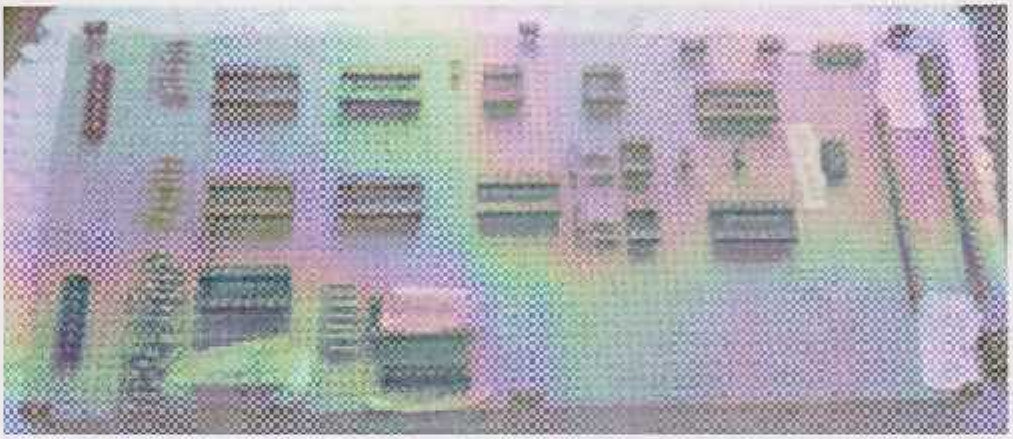


Figure 6.5: Main (PIC) board

PIC microcontroller is the main circuit and contain

- PIC microcontroller.

Connect PIC microcontroller IC with board and connect needed supply voltage

- Temperature amplification circuit.

Implemented using close loop non-inverting amplifier that amplifies the output voltage of the thermocouple, to be processed in the PIC. Was build and connected to PIC loaded with sub program that read temperature and display it, then affected by known temperature conditions and give right results.

- Timer.

This circuit was build using 555 timer and counter, this timer start working by signal from PIC and send signal to PIC when the time is finished. It was build and tested that gave right results.

- Error driver.

To display the errors of and alarms. It is implemented using 3X8 decoder, the input of the decoder from the PIC.

It was implemented and tested successfully.

7

Conclusion and Recommendations

7.1 Conclusions

7.2 Recommendations

Chapter Seven

Conclusion and Recommendations

7.1 Conclusions

1. Our project will sterilize the medical tools using steam under pressure as sterilizing agent.
2. This project is microcontroller based, which control the whole processes in the device.
3. This device will be suitable for operation room, emergency room, dental clinic, and clinics.

7.2 Recommendations

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

1. Implementation the system by using other types of sensors.
2. Improve the system by adding LCD to display the temperature, time, Errors, and messages to the user.
3. Rebuild the system by adding a system to open and close door automatically (for safty).
4. Adding printer to print a report about sterilization.
5. Develop washing system to reduce the effect of calcification.

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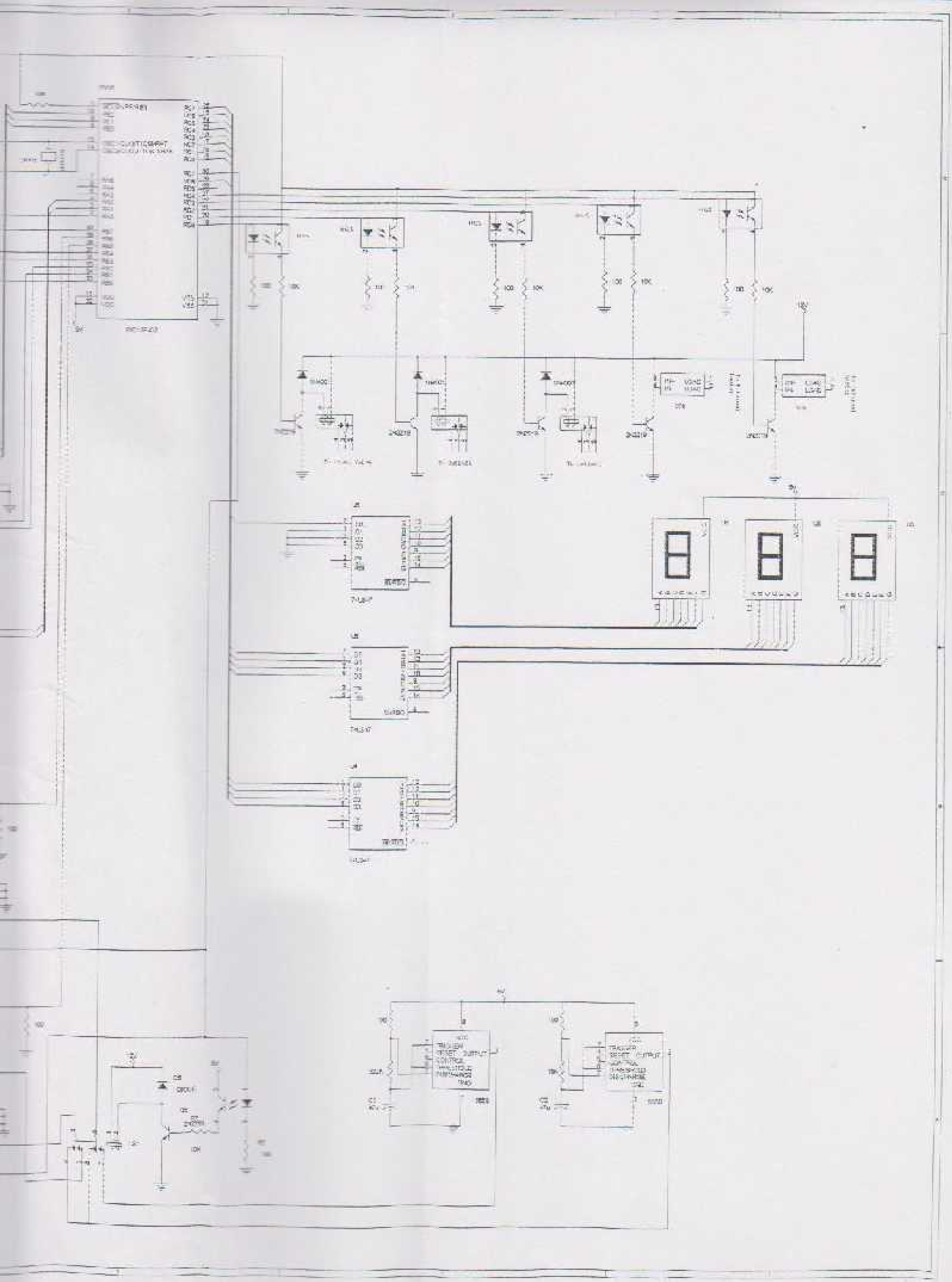
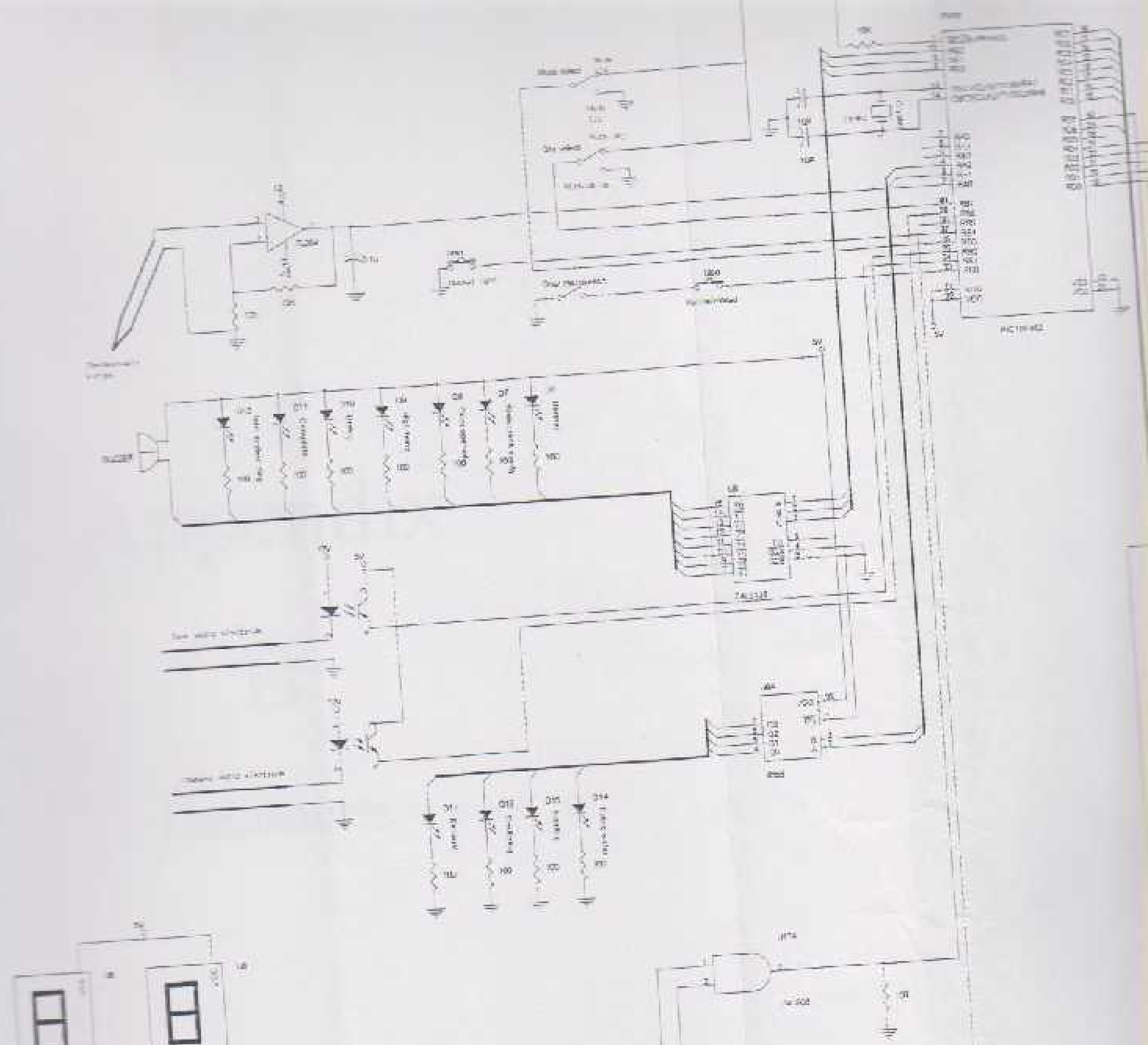
Appendix

A

Over All Control System Design



TRIGGER
RESET
CONTROL
THRESHOLD
DISCHARGE
GND
10K



Appendix

B

Datasheets

PIC18FXX2
Data Sheet

High-Performance, Enhanced Flash Microcontrollers with 10-Bit A/D

Pin Diagrams (Cont.'d)

DIP

Note: Pin compatible with 40-pin PIC16C7X devices.

DIP, SOIC

* RB3 is the alternate pin for the CCP2 pin multiplexing.

1.0 DEVICE OVERVIEW

This document contains device specific information for the following devices:

- PIC18F242
- PIC18F252
- PIC18F442
- PIC18F452

These devices come in 28-pin and 40/44-pin packages. The 28-pin devices do not have a Parallel Slave Port (PSP) implemented and the number of Analog-to-Digital (A/D) converter input channels is reduced to 5. An overview of features is shown in Table 1-1.

The following two figures are device block diagrams sorted by pin count: 28-pin for Figure 1-1 and 40/44-pin for Figure 1-2. The 28-pin and 40/44-pin pinouts are listed in Table 1-2 and Table 1-3, respectively.

TABLE 1-1: DEVICE FEATURES

Features	PIC18F242	PIC18F252	PIC18F442	PIC18F452
Operating Frequency	DC - 40 MHz	DC - 40 MHz	DC - 40 MHz	DC - 40 MHz
Program Memory (Bytes)	16K	32K	16K	32K
Program Memory (Instructions)	8192	16384	8192	16384
Data Memory (Bytes)	768	1536	768	1536
Data EEPROM Memory (Bytes)	256	256	256	256
Interrupt Sources	17	17	18	18
I/O Ports	Ports A, B, C	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C, D, E
Timers	4	4	4	4
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, Addressable USART	MSSP, Addressable USART	MSSP, Addressable USART	MSSP, Addressable USART
Parallel Communications	—	—	PSP	PSP
10-bit Analog-to-Digital Module	5 input channels	5 input channels	8 input channels	8 input channels
RESETS (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)
Programmable Low Voltage Detect	Yes	Yes	Yes	Yes
Programmable Brown-out Reset	Yes	Yes	Yes	Yes
Instruction Set	75 Instructions	75 Instructions	75 Instructions	75 Instructions
Packages	28-pin DIP 28-pin SOIC	28-pin DIP 28-pin SOIC	40-pin DIP 44-pin PLCC 44-pin TQFP	40-pin DIP 44-pin PLCC 44-pin TQFP

MC1455, MC1455B, NCV1455B

Timers

The MC1455 monolithic timing circuit is a highly stable controller capable of producing accurate time delays or oscillation. Additional terminals are provided for triggering or resetting if desired. In the time delay mode, time is precisely controlled by one external resistor and capacitor. For astable operation as an oscillator, the free−running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output structure can source or sink up to 200 mA or drive MTTL circuits.

- Direct Replacement for NE555 Timers
- Timing from Microseconds through Hours
- Operates in Both Astable and Monostable Modes
- Adjustable Duty Cycle
- High Current Output Can Source or Sink 200 mA
- Output Can Drive MTTL
- Temperature Stability of 0.005% per °C
- Normally ON or Normally OFF Output

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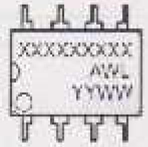
MARKING DIAGRAMS



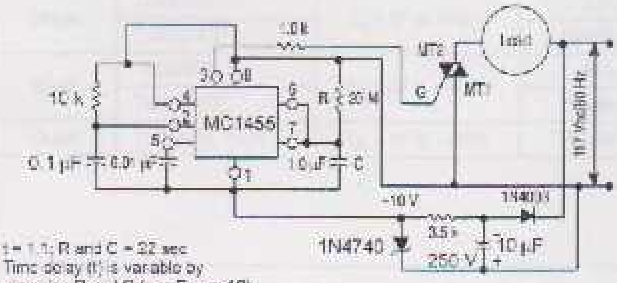
P1 SUFFIX
PLASTIC PACKAGE
CASE 626

D SUFFIX
PLASTIC PACKAGE
CASE 751

xx	= Specific Device Code
A	= Assembly Location
WL, L	= Wafer Lot
YY, Y	= Year
WW, W	= Work Week

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page of this data sheet. *(Create − Named − OrderingInfoText.)*



t = 1.1 R and C = 22 sec
Time delay (t) is variable by changing R and C (see Figure 16).

Figure 1. 22 Second Solid State Time Delay Relay Circuit

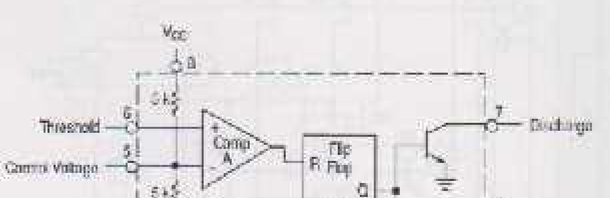
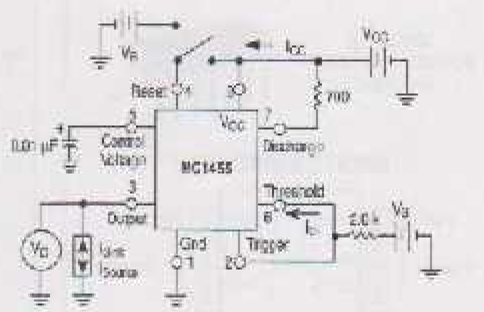


Figure 2. Representative Block Diagram



Test circuit for measuring DC parameters (to set output and measure parameters):
a) When $V_S \geq 2/3\ V_{CC}$, V_O is low.
b) When $V_S \leq 1/3\ V_{CC}$, V_O is high.
c) When V_O is low, Pin 7 sinks current. To test for Reset, set V_O high, apply Reset voltage, and test for current flowing into Pin 7. When Reset is not in use, it should be tied to V_{CC}.

Figure 3. General Test Circuit

March, 2004 − Rev. 8

Publication Order Number:
MC1455/D

Order this document by TL081C/D

MOTOROLA

TL081C,AC
TL082C,AC
TL084C,AC

JFET Input Operational Amplifiers

These low–cost JFET input operational amplifiers combine two state–of the–art linear technologies on a single monolithic integrated circuit. Each internally compensated operational amplifier has well matched high voltage JFET input devices for low input offset voltage. The BIFET technology provides wide bandwidths and fast slew rates with low input bias currents, input offset currents, and supply currents.

These devices are available in single, dual and quad operational amplifiers which are pin–compatible with the industry standard MC1741, MC1458, and the MC3403/LM324 bipolar products.

- Input Offset Voltage Options of 6.0 mV and 15 mV Max
- Low Input Bias Current: 30 pA
- Low Input Offset Current: 5.0 pA
- Wide Gain Bandwidth: 4.0 MHz
- High Slew Rate: 13 V/μs
- Low Supply Current: 1.4 mA per Amplifier
- High Input Impedance: 10^{12} Ω

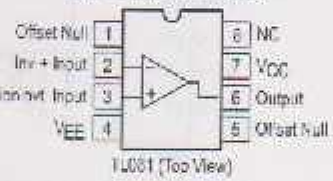
JFET INPUT OPERATIONAL AMPLIFIERS

SEMICONDUCTOR TECHNICAL DATA

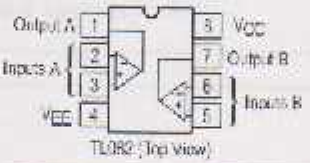
P SUFFIX
PLASTIC PACKAGE
CASE 626

D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

PIN CONNECTIONS



TL081 (Top View)



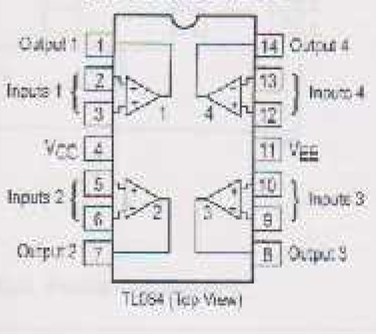
TL082 (Top View)

ORDERING INFORMATION

Op Amp Function	Device	Operating Temperature Range	Package
Single	TL081CD	T_A = 0° to +70°C	SO–8
	TL081ACP		Plastic DIP
Dual	TL082CD	T_A = 0° to +70°C	SO–8
	TL082ACP		Plastic DIP
Quad	TL084CN, ACN	T_A = 0° to +70°C	Plastic DIP

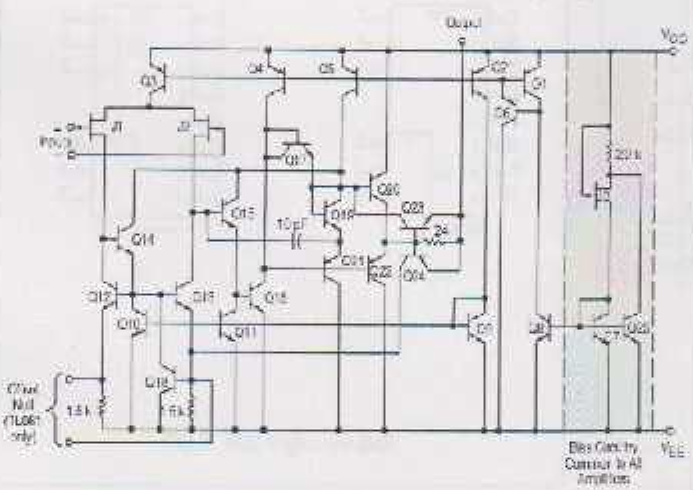
N SUFFIX
PLASTIC PACKAGE
CASE 646

PIN CONNECTIONS



TL084 (Top View)

Representative Circuit Schematic (Each Amplifier)



 Rev 1

3-to-8 line decoder/demultiplexer; inverting — 74HC/HCT138

PIN DESCRIPTION

PIN NO.	SYMBOL	NAME AND FUNCTION
1, 2, 3	A_0 to A_2	address inputs
4, 5	$\overline{E}_1$, $\overline{E}_2$	enable inputs (active LOW)
6	E_3	enable input (active HIGH)
8	GND	ground (0 V)
15, 14, 13, 12, 11, 10, 9, 7	$\overline{Y}_0$ to $\overline{Y}_7$	outputs (active LOW)
16	V_{CC}	positive supply voltage

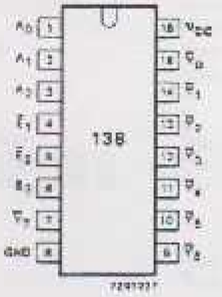


Fig.1 Pin configuration.

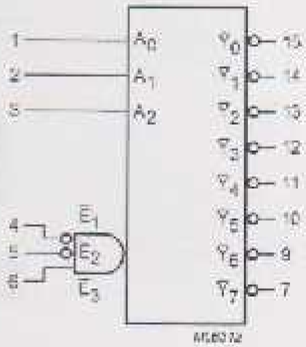


Fig.2 Logic symbol.

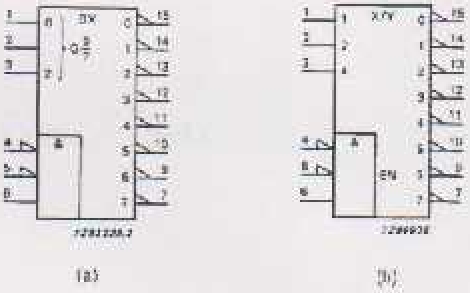


Fig.3 IEC logic symbol.

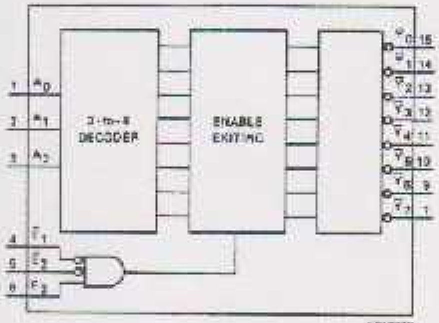


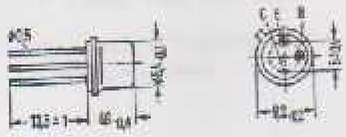
Fig.4 Functional diagram.

NPN Silicon Planar Transistors

2 N 2218
2 N 2219
2 N 2218 A
2 N 2219 A

2 N 2218, 2 N 2219, 2 N 2218 A, and 2 N 2219 A are epitaxial NPN silicon planar transistors in TO 39 case (5 C 3 DIN 41873). The collector is electrically connected to the case. The transistors are particularly suitable for use as high-speed switches of medium performance.

Type	Ordering code
2 N 2218	Q62702-F109
2 N 2219	Q62702-F133
2 N 2218 A	Q62702-S29
2 N 2219 A	Q62702-F59



Approx. weight 1.5 g

Dimensions in mm

Maximum ratings

		2 N 2218 2 N 2219	2 N 2218 A 2 N 2219 A	
Collector-base voltage	V_{CBO}	60	75	V
Collector-emitter voltage	V_{CEO}	30	40	V
Emitter-base voltage	V_{EBO}	5	6	V
Collector current	I_C	0.8	0.8	A
Junction temperature	T_j	175	175	°C
Storage temperature range	T_{stg}	−65 to +200		°C
Total power dissipation (T_{amb} ≤ 25 °C)	P_{tot}	0.8	0.8	W
Total power dissipation (T_{case} ≤ 25 °C)	P_{tot}	3	3	W

Thermal resistance

Junction to ambient air	R_{thJA}	≤ 188	≤ 188	K/W
Junction to case	R_{thJC}	≤ 50	≤ 50	K/W

'46A, '47A, 'LS47
feature

- Open-Collector Outputs Drive Indicators Directly
- Lamp-Test Provision
- Leading/Trailing Zero Suppression

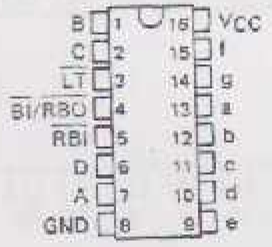
'48, 'LS48
feature

- Internal Pull-Ups Eliminate Need for External Resistors
- Lamp-Test Provision
- Leading/Trailing Zero Suppression

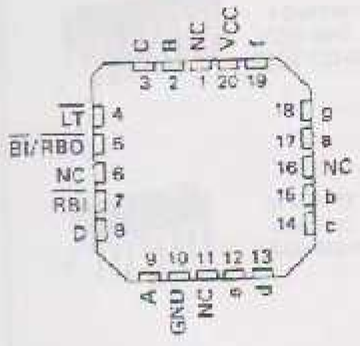
'LS49
feature

- Open-Collector Outputs
- Blanking Input

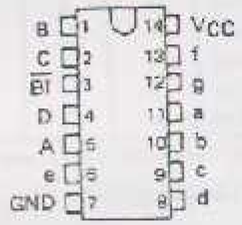
SN5446A, SN5447A, SN54LS47, SN5448,
SN54LS48 . . . J PACKAGE
SN7446A, SN7447A,
SN7448 . . . N PACKAGE
SN74LS47, SN74LS48 . . . D OR N PACKAGE
(TOP VIEW)



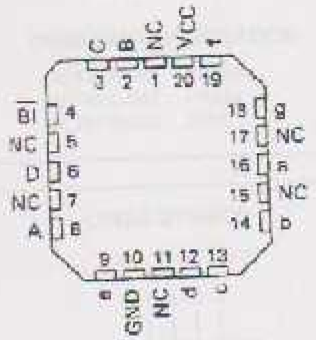
SN54LS47, SN54LS48 . . . FK PACKAGE
(TOP VIEW)



SN54LS49 . . . J OR W PACKAGE
SN74LS49 . . . D OR N PACKAGE
(TOP VIEW)



SN54LS49 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

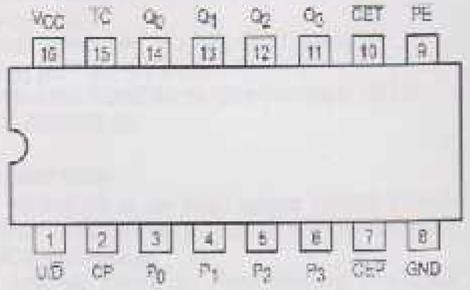
MC54/74F168
MC54/74F169

4-STAGE SYNCHRONOUS BIDIRECTIONAL COUNTERS

The MC54/74F168 and MC54/74F169 are fully synchronous 4 stage up/down counters. The F168 is a BCD decade counter; the F169 is a modulo 16 binary counter. Both feature a preset capability for programmable operation, carry lookahead for easy cascading, and a U/D̄ input to control the direction of counting. All state changes, whether in counting or parallel loading, are initiated by the LOW-to-HIGH transition of the clock.

- Asynchronous Counting and Loading
- Built-In Lookahead Carry Capability
- Presettable for Programmable Operation

CONNECTION DIAGRAM (TOP VIEW)

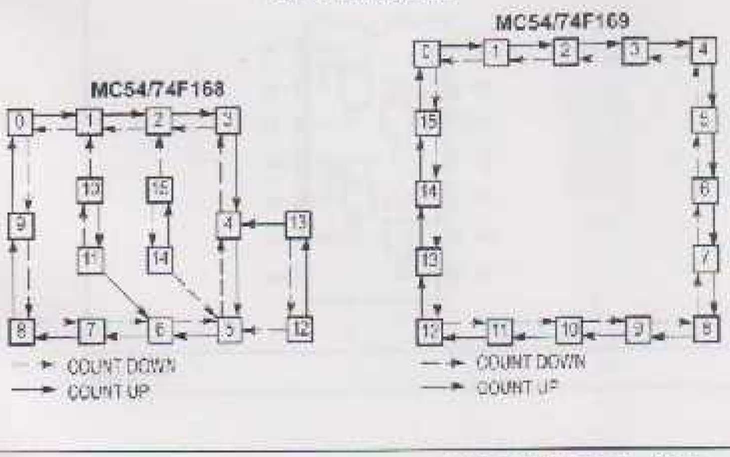


MODE SELECT TABLE

PE	CEP	CET	U/D	Action on Rising Clock Edge
L	X	X	X	Load ($P_n \rightarrow Q_n$)
H	L	L	H	Count Up (Increment)
H	L	L	L	Count Down (Decrement)
H	H	X	X	No Change (Hold)
H	X	H	X	No Change (Hold)

H = HIGH Voltage Level; L = LOW Voltage Level; X = Don't Care

STATE DIAGRAMS



4-STAGE SYNCHRONOUS BIDIRECTIONAL COUNTERS

FAST™ SCHOTTKY TTL

J SUFFIX
CERAMIC
CASE 620-09

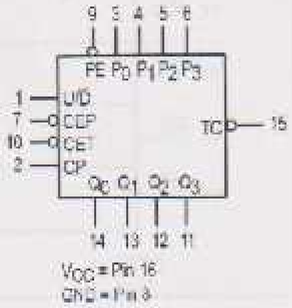
N SUFFIX
PLASTIC
CASE 648-08

D SUFFIX
SOIC
CASE 751B-03

ORDERING INFORMATION

MC54FXXXJ	Ceramic
MC74FXXXN	Plastic
MC74FXXXD	SOIC

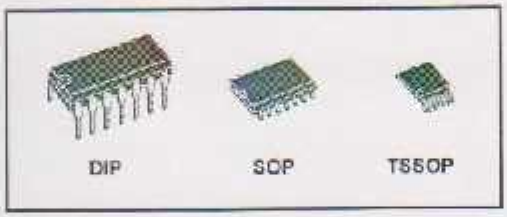
LOGIC SYMBOL



M74HC08

QUAD 2-INPUT AND GATE

- HIGH SPEED:
  t_{PD} = 7ns (TYP.) at V_{CC} = 6V
- LOW POWER DISSIPATION:
  I_{CC} = 1µA(MAX.) at T_A=25°C
- HIGH NOISE IMMUNITY:
  V_{NIH} = V_{NIL} = 28 % V_{CC} (MIN.)
- SYMMETRICAL OUTPUT IMPEDANCE:
  $|I_{OH}|$ = I_{OL} = 4mA (MIN)
- BALANCED PROPAGATION DELAYS:
  $t_{PLH} \cong t_{PHL}$
- WIDE OPERATING VOLTAGE RANGE:
  V_{CC} (OPR) = 2V to 6V
- PIN AND FUNCTION COMPATIBLE WITH 74 SERIES 08



ORDER CODES

PACKAGE	TUBE	T & R
DIP	M74HC08B1R	
SOP	M74HC08M1R	M74HC08RM13TR
TSSOP		M74HC08TTR

DESCRIPTION

The M74HC08 is an high speed CMOS QUAD 2-INPUT AND GATE fabricated with silicon gate C^2MOS technology.

The internal circuit is composed of 2 stages including buffer output, which enables high noise immunity and stable output.

All inputs are equipped with protection circuits against static discharge and transient excess voltage.

PIN CONNECTION AND IEC LOGIC SYMBOLS