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Mechanical Engineering Department

Graduation Project

Chemistry Laboratory Mixing Machine

Project Team

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Abstract

Because of problems and dangerous that face the worker in the chemistry laboratory through making an experiment which cause a Poisson gases that make losses of equipment and humans , so that in this project a machine will be designed and implemented and controlled through PC that will give the worker ability to make an experiment in accuracy and safety and that will make the worker away from the experiment .

الملخص

نظرا للمشاكل والمخاطر التي قد يواجهها العمال في مختبرات الكيمياء خلال عمل التجارب الكيميائية , التي قد ينتج عنها غازات سامة والتي قد تضر بالعاملين .

هدف المشروع تصميم وتنفيذ تفاعلات يتم التحكم فيها من خلال الحاسوب مما يتيح للعمال عمل التجارب بدقة وأمان حيث يكون العامل بعيدً عن مكان التجربة .

يتيح المشروع للمستخدم التحكم بشكل يدوي وآلي في كميات التجربة ودرجة الحرارة وبالإضافة إلى ذلك يستطيع مراقبة المشروع من خلال واجهة المستخدم التي تتيح له التحكم بشكل كامل .

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Chapter One

Introduction

1.1 Overview

Chemistry is one of the oldest and most important sciencein the world,it is the study of matter and energy and the interactions between them, focus on the properties of substances and the interactions between different types of matter. chemistry is important in many different ways that affect our life , for example:

1)Food industries.

2)Cleaning.

3)Medicine.

4)Environmental issues.

And as we know, for all students of chemistry science and an industry depends on chemistry, they deal with the matter in laboratory to make experimental.

The result of these experimental may be a source of dangerous like poison gas ,fire and explosion .Some of this dangerous might be unexpected since the result of the reaction will depend in many variables such as amount of materials and temperature. On the other hand, the possibility of error will be high while implementing the experiment manually.

These dangers can't be expected and it varies from a simple damage to death and so we always have to think in our employee and student safety.

1.2 Project Goal

The main purpose of this project is to design and manufacture a machine that can be controlled by computer to mixing liquids samples, and Decrease the human interaction with the mixing process, in order to keep safety. .

1.3 Project importance

The importance of project it explained through three main objectives that will improve the process:-

1)-human safety: - in the previous section some dangerous of chemistry laboratory was explained ,such as poison gas, fair and explosion, that cause human and equipment losses ,this project will increase the safety by reducing the interaction between the human (student and Researcher) and the environmental of experimental.

Dangers are not removed, but it reduced, this mean that the human still the most important element in the safety.

2) The proposed automated machine should be accurate enough in order to be used in scientific research.

3) The machine will save time and effort to prepare and conduct an experiment.

1.4 Methodology

The project will be a mechatronics system, which is integration between multidisciplinary sciences; as represented by Figure1.1, which show the synergistic integration of three engineering fields. This integration achieves the project importance that we explained in section (1.3).

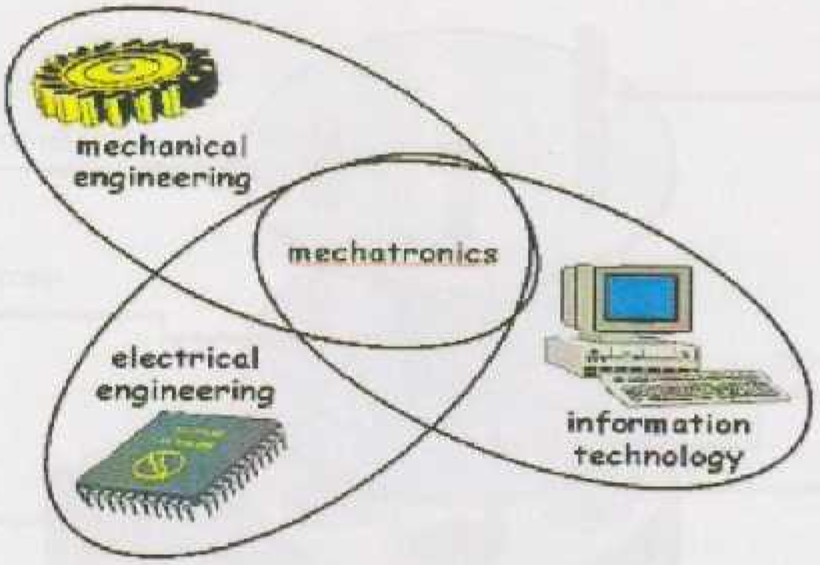


Figure 1.1 mechatronics system

The mean idea and machine operation principle could be explained through Figure1.2

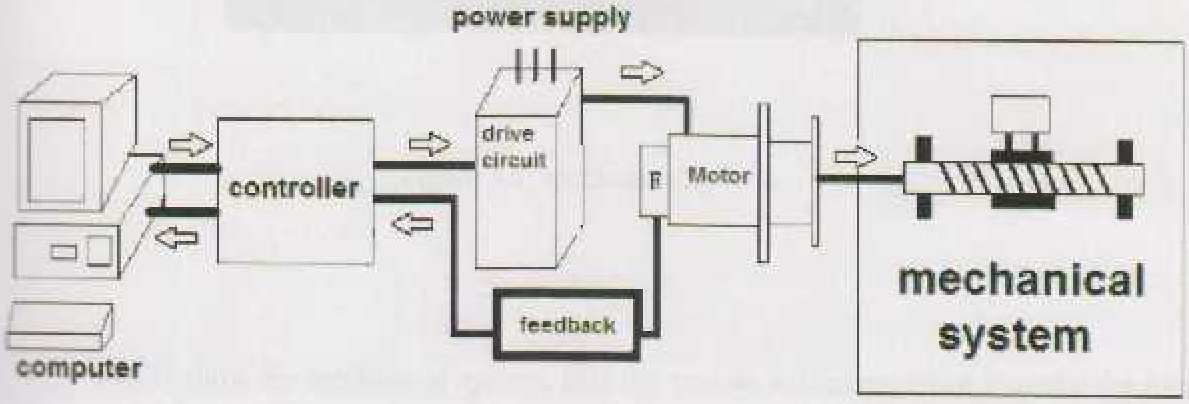


Figure1.2 machine operation principle

This system will reduce the interaction between people and the "mixing process", so this will not risk people's lives.

Each block in Figure 1.2 will explained as the following.

1.4.1 mechanical system

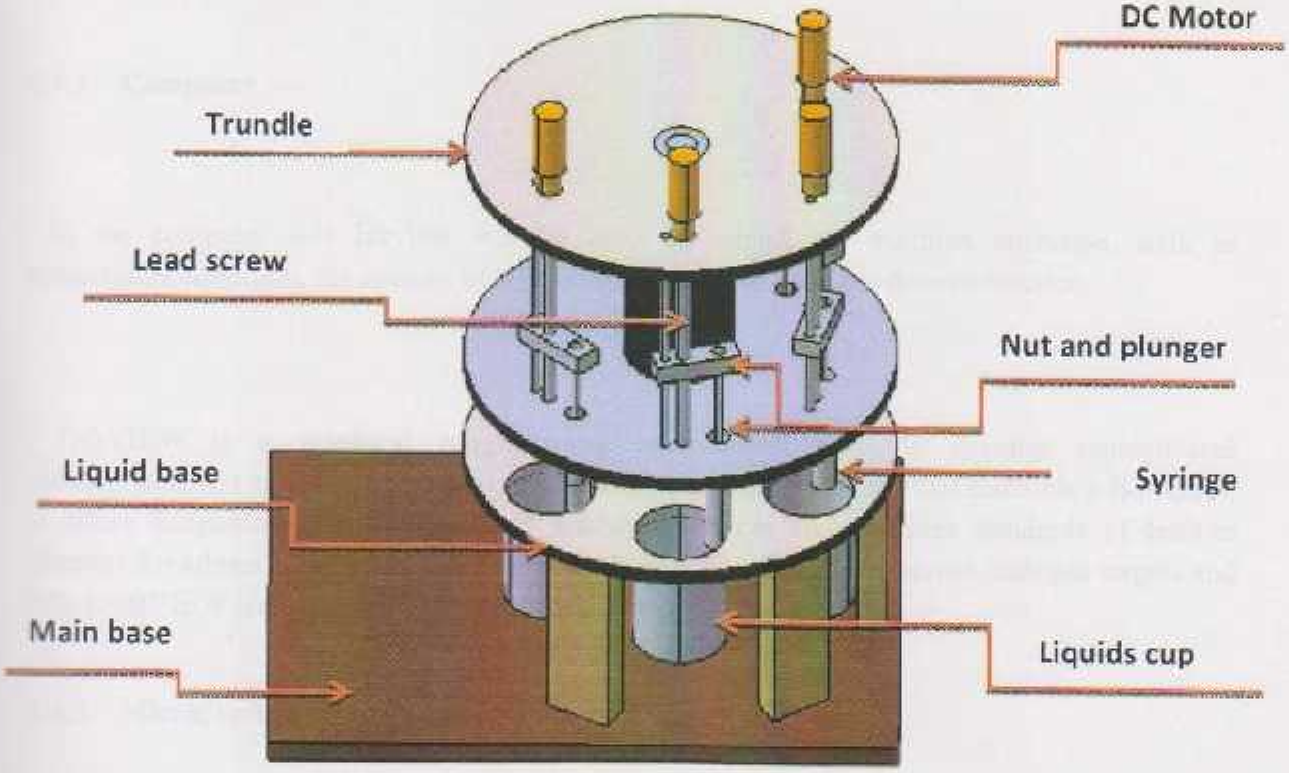


Figure 3.1: mechanical system

Figure (3.1) show the mechanical system, first the trundle will move down to make the four syringe in the liquids cup, then the each one of lead screw will pull the plungers to suck the liquids into the syringes, after the required amount of liquids being in the syringes, trundle again move up until the below syringes end reach a safe position

Then trundle start rotate to make one syringe above the mixing cup ,then it move down to make this syringe inside the mixing cup. after that the lead screw will push the plunger to inject the liquids, in the same time the oscillator start work in order to accelerate the mixing process.

Some of chemical reaction required energy to start, so that heater will be installed on oscillator, in order to increase the temperature.

1.4.2 Computer

In the computer side labview will be used to control the machine operation, such as temperature condition, the amount of liquids to be mixed to form the desired reaction.

LabVIEW is a graphical programming environment used to develop sophisticated measurement test and control systems, using graphical icons and wires that resemble a flowchart. It offers integration with thousands of hardware devices and provides hundreds of built-in libraries for advanced analysis and data visualization The LabVIEW across multiple targets and OSs LABVIEW hasa friendly user interface that will be easy to use.

1.4.3 Microcontroller

A microcontroller (sometimes abbreviated **µC**, **uC** or **MCU**) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications.

Mainly, there are three tasks that microcontroller will be able to do,

1) Interfacing with pc to receive command from labview.
2) Collect the data from the machine and send it to pc.
3) Controlling the actuator.
4) atmega328: from Atmel company, it easier to interface with PC . Its task to receive a command from labview and distribute the tasks to other microcontroller also it will collect the feedback data that other microcontroller receive it from the machine and send it to PC

1.4.4 Drive circuit

Microcontroller can't give an enough current to drive the motor so that, powercircuit will be used to drive motor's.

1.4.5 Electrical Motor

Electrical motors used to drive the mechanical system, in this project two kind of dc motor will be used:

1) Permanent Magnetic DC Motor (PMDC):Four DC motor are used in order to drive each one of the lead screw that pull and push the plunger to suck and inject the liquids.

2) Stepper Motor: Three stepper motor are used with different tasks, first one, to rotate the trundle, and the second to move the trundle up and down, the last one to drive the oscillator.

1.4.6 Sensors

The purpose of a sensor is to respond to some kind of an input physical property and to convert it into an electrical signal which is compatible with electronic circuits. We may say that a sensor is a translator of a generally nonelectrical valueinto an electrical value.

Tow kind of sensor will be used:

1-rotary encoder:

A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft to pulses. In this project it used to measure the angular displacement of motors.

2-Temperaturesensor: used to measure the cup temperature.

1.5 Project schedule

Process	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selected the project																
Collection the needed data																
Mechanical and electrical modeling																
Writing document																

CHAPTER TWO

Mechanical design and parts

2.1 introductions

This chapter considers the design of the machine, In order to understand the principle of operation and to obtain general idea about the motion. Understand the machine parts and mechanisms, in this chapter each one of machine parts are designed and explained.

First of all we divide the machine parts into two main types, the fixed parts and the movable part. Each of them will be explained in the next section. A general figure of machine shown in figure (2.1)

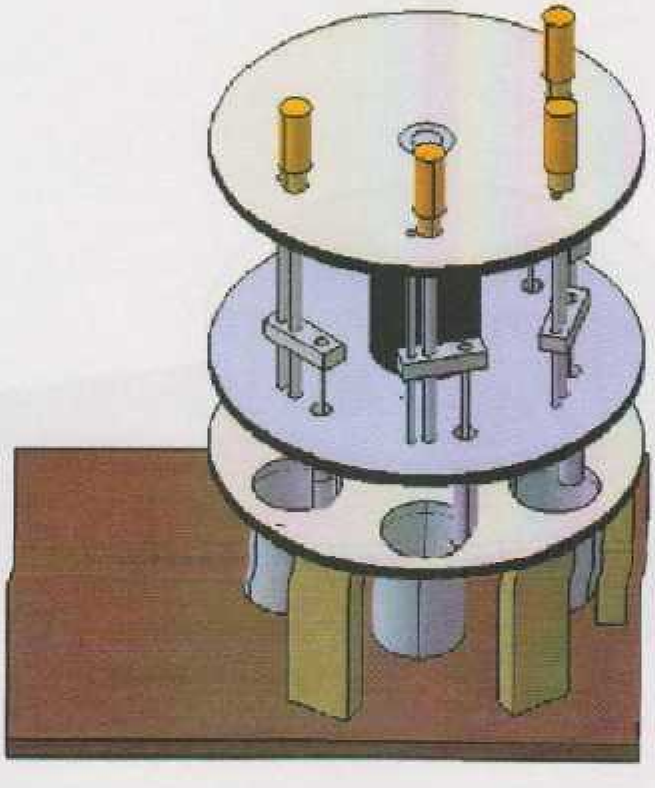


Figure (2.1) general figure of machine

2.2.1.1 Main base

Main base has square shape as shown in figure (2.2) and we install the electrical motors to drive screw that used for the trundle motion, and the mechanical oscillator under the reaction container to accelerate the mixing operation.

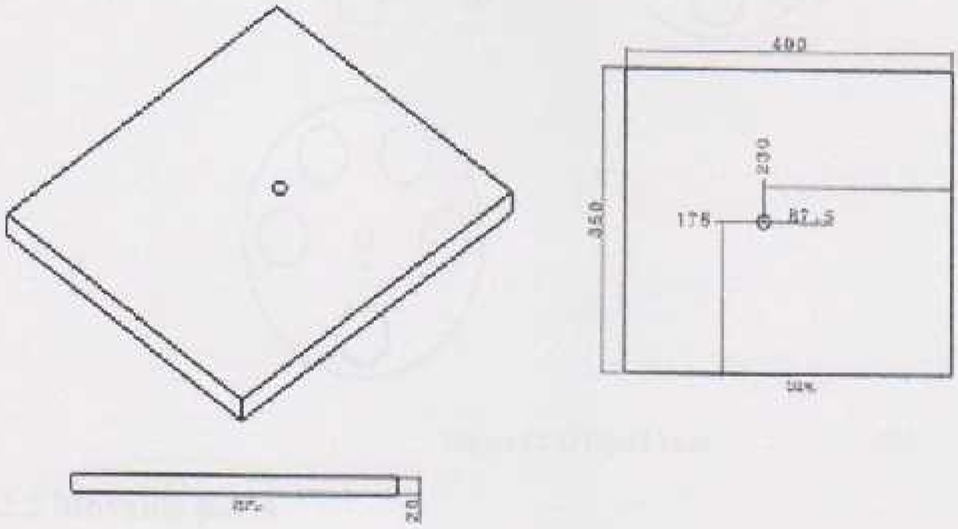


Figure (2.3) main base

2.2.1.2 Liquid base

It is a circular shaped disk with fivehollows, distributed in a constant angel along the disk, these hollows used to install the liquid containers, also the disk installed above the main base by three rectangular rods as shown in Figure (2.4).

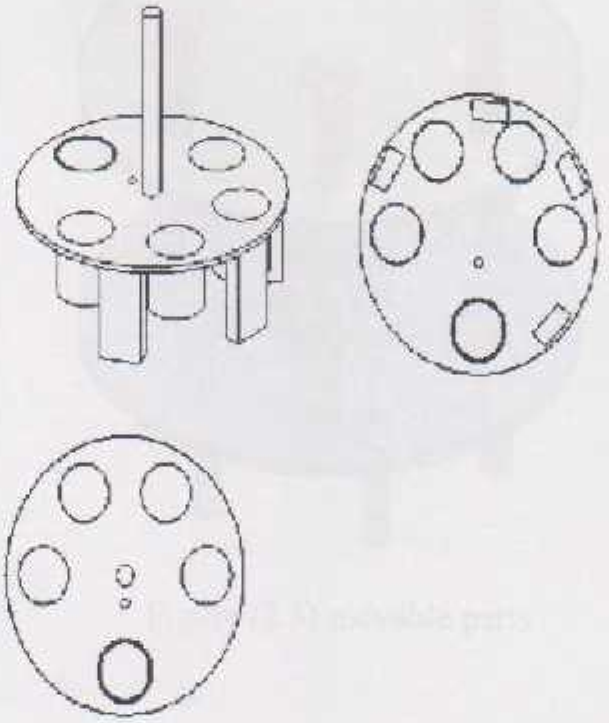


Figure (2.4) liquid base

2.2.2 Movable parts

Most of movable parts shown in figure (2.5) are made from plastic since it light and that allow to use small power electrical motor to drive these mechanisms. There are three basic motions in the machine:

1-vertical motion up and down to make the syringe below the surface of liquids

2-the second motion it also vertical to pull and push the plunger of syringe up and down.

3- Rotational motion about fixed axis to transfer all different liquids in the syringes to the mixing container.

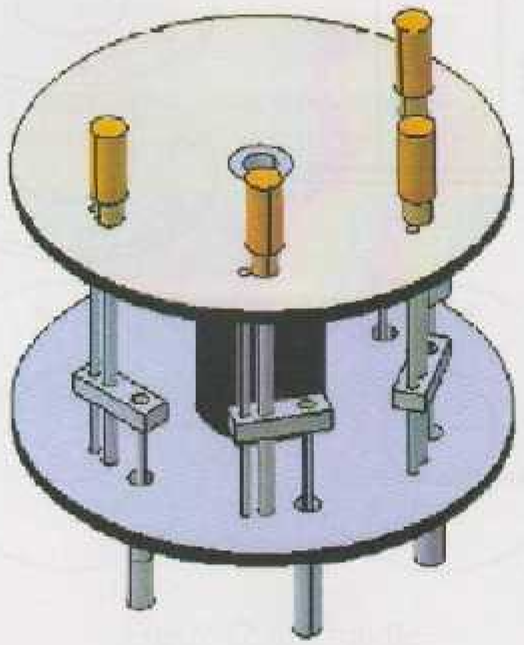


Figure (2.5) movable parts

2.2.2.2 Trundle

It is a cylindrical shape, with two circular disks at each ends as shown in figure (2.6). It will be movable in rotational motion about the slider; bearing will be used to achieve this motion.

The lower disk will be used to fix the syringe, and the upper disk shown will fix the motor that will drive the screw to pull and push the plunger.

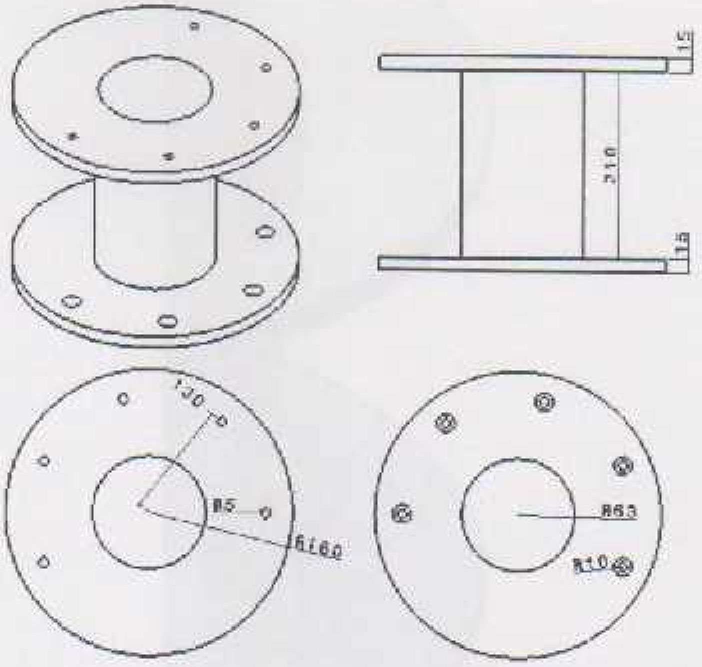


Figure (2.6) Trundle

2.2.2.3 syringe-plunger

Now we will explained the pull and push mechanism for the plunger, pull to fill the syringe and push to discharge the syringe. There is a four unit of syringe –plunger, all of them operate as the same way so we explained one of them.

As shown in figure (2.7), the plunger with the slider fixed together as ;so they will move in the same distance up or down.

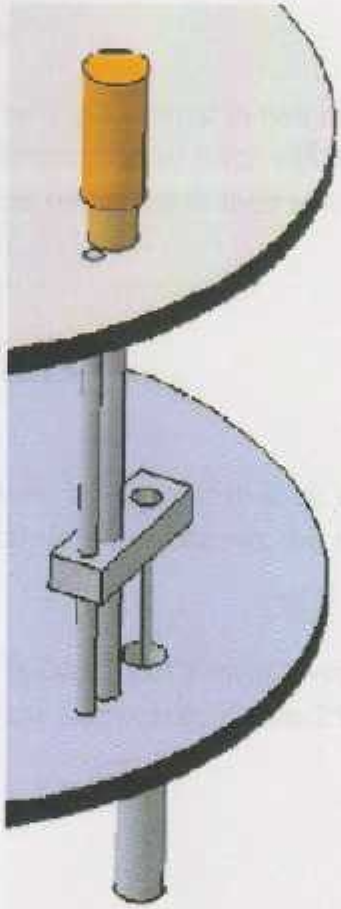


Figure (2.8) syringe-plunger

On the other hand, we can see the screw fixed with the motor shaft by coupler, so they will rotate by the same angel.

The slider and the screw is fixed together by a screw joint, to convert the rotational motion of motor to vertical linear motion.

2.3 dynamic analyses

Dynamic analyses will be implemented in two distinct parts: kinematics which is the study of motion without reference to the force which cause motion, and kinetics, which relates the action of forces on bodies to their resulting motions.

2.3.1 Plunger kinematics

The Plunger will be driven by a motor to suck and inject liquids, so a lead screw will be used to achieve this motion and convert the rotational motion of the motor to linear motion.

The lead of used screw is 2mm, that's mean every one revolution of the screw, the plunger will travel 2mm along the screw axis, Figure 2.9 show the mechanism.

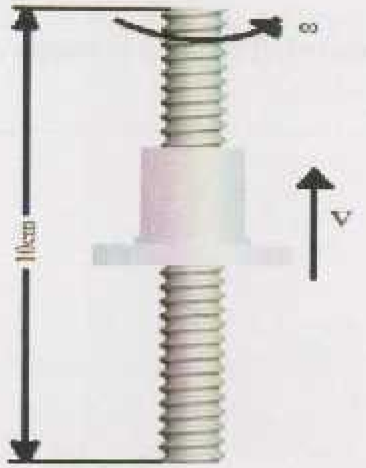


Figure 2.9: screw mechanism

The proposed Plunger velocity v_p can be expressed as:

$$v_p = \frac{s}{t} \quad \text{……} \quad (2.1)$$

s: Stroke of plunger

t: Time required filling the syringe completely.

v_p: plunger velocity.

$$v = \frac{10cm}{2sec} = 5cm/s = 0.05m/s$$

The plunger displacement described by the following equation:-

$s = l * \theta$ ....(2.2)

s: Plunger displacement in m

l:Lead of screw in m/rev

θ:Screw angular displacement in rev

To describe the plunger velocity, equation (2.2) differentiated with respect to time:-

$v_p = l * \dot{\theta}$ ....(2.3)

v_p:Plunger velocity

$\dot{\theta}$: Screw Angular speed

Then the angular velocity founded by equation (2.3) as following:

$$\dot{\theta} = \frac{v_p}{l}$$

$$\dot{\theta} = \frac{0.05 m/s}{0.002 m/rev} = 25\ rev/s = 1500\ rpm.$$

2.3.2 Plunger kinetics

The torque and force acting on a screw and nut assembly are shown in Figure2.10, the relationship between the torques and force is a strong function of the coefficient of friction, between the thread and nut.

Figure 2.10: torque-forces

To calculate the required torque, each force on the nut, must be defined.Figure 2.15 shows the axial force that acts on the nut.

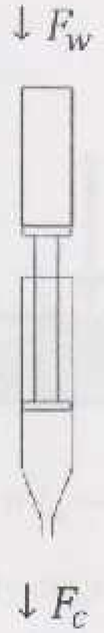


Figure 2.11: axial force

Where:

F_w: The gravitational force of the nut.

F_c: The required force due to orifice flow resistance.

Other values affect the torque but, it not axial:

f_c: It a force due to the friction between the nut and screw, and it determined by knowing the friction coefficient and the normal force.

$J\ddot{\theta}$: It is a required torque due to the inertia ofscrew.

There is a difference between the lifting and lowering torque, so the required torque in the both cases will be calculated, and evaluate the motor selection at the largest torque.

The first case is one in which the motion of the plunger occurs in the opposite direction of the acting force on the nut. This is commonly referred to as a case of lifting. free body diagram shown in Figure 2-12.

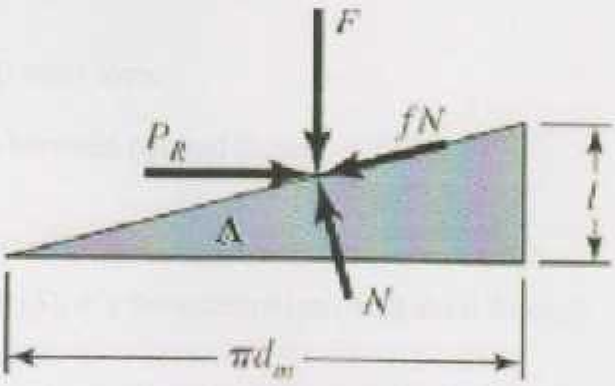


Figure 2.12: free body diagram of lifting the load

F :The summation of all axial force

P_R: required force to raise the load.

fN: A friction force acts oppose the motion.

λ: the lead angel.

d_m: The mean diameter of the thread contact.

l: The lead of screw.

By a victor analyses, the torque required due to axial force and friction is:

$$T_{load} = \left[\left(\frac{Fd_m}{2}\right)\left[\frac{l+\pi f d_m}{\pi d_m - fl}\right]\right] \quad (2.4)$$

Where:

d_m: The mean diameter of the thread contact.

l: The lead of screw.

F :The summation of all axial force

f:Coefficient of friction between nut and thread

The force (F) in equation (5), it's the summation of all axial force:

$$F = F_w + F_c \quad (2.5)$$

And the torque required due to the inertia of the screw:

$$T_{screwinertia} = J\ddot{\theta} \quad (2.6)$$

Where:

J: The inertia of screw.

$\ddot{\theta}$: Angular acceleration of screw.

Finally, the total torque required

$$T_{total} = T_{inertia} + T_{load} \quad (2.7)$$

The second case is one which the motion of the nut is in the same direction as a force load acting on the nut. In essence, this is referred to case of lowering a load, a free body diagram shown in Figure (2.13).

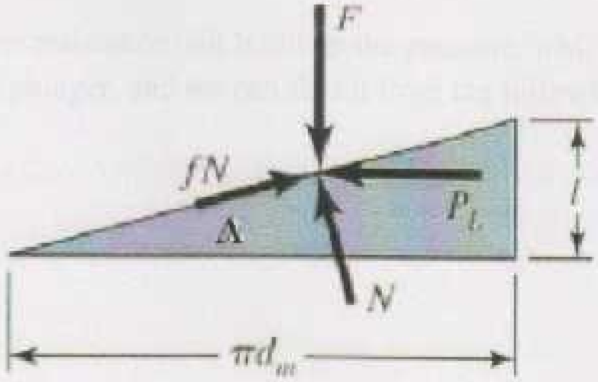


Figure (2.13) free body diagram of lowering the load

F :The summation of all axial force

P_R: required force to raise the load.

fN: A friction force acts oppose the motion.

λ: is the lead angel.

d_m: is the mean diameter of the thread contact.

l: The lead of screw

The required torque due to the screw inertia will be the same as the lifting case, but the torque due to gravitational and friction force will be:

$$T_{load} = \left(\frac{Fd_m}{2}\right)\left[\frac{\pi f d_m - l}{\pi d_m + fl}\right] \quad (2.8)$$

The force (F) in equation (7), it's also the summation of all axial force.

In lowering case the plunger will inject the liquid from the syringe, so in order to determine the total torque; flow resistance due to the syringe orifice should be added.

Must add the Orifice flow resistance will build up the pressure, which means it will need more torque to drive the plunger, and we can find it from the following equation:

$$F_c = \frac{w * K}{A} \quad (2.9)$$

Where

F_c: required force.

w: Flow rate.

K: A constant specific to orifice and it determine experimentally.

A: Plunger piston area

Equation (6) will be as following:

$$F = F_c + F_w \quad (2.10)$$

F: The total of axial force

Fc: Force due to orifice flow resistance

Then equation (9) used to find the total torque in the lowering case.

2.3.3 Trundle dynamics

Trundle has two degrees of freedom, first one is the motion vertically down and up, in order to make the syringe below the liquid surface. And the second is rotating about the slier by a constant angel displacement in each step to make one of syringes above the mixing container to inject liquids.

2.3.3.1 Trundle linear motion

This mechanism is the same as plunger, lead screw with prismatic joint used to achieve this motion, to determine the torque, velocity, and the motor power. the same equations in the last two sections will be used.

Trundle will move vertically as the following description:

1) When machine start, the trundle move down for a distance

$$S_1 = 10cm$$

2) In the inject stage trundle move down by a distance

$S_2 = 6cm.$

The load on the lead screw will be:

1) The weight of trundle

2) The friction between the nut and screw

If we assume that, the trundle required 10second to move the longest distanceS_1.

So, from equation (3) we determine the velocity

$$v_{t=} \frac{10cm}{10s} = 0.01m/s$$

Also the screw lead $l = 2mm/rev$, so from equation (2):

$$\dot{\theta} = \frac{0.05m/s}{0.002m/rev} = \frac{25rev}{s} = 1500rpm$$

In the same way, the required torque in the two cases lifting and lowering can founded by using equation (5) and (9) respectively

But the axial force in the tow cases will be just the trundle weight so equation (6) will be as following:

$$F = F_{wt} \quad \text{.......(2.11)}$$

2.3.3.2 Trundle rotating motion

Syringes are distributed along the disk by a fixed angel (approximately 50 degree). after the syringe suck the specific amount of needed liquids, only one syringe each time inject this liquid in one container, so the disk have to rotate about the slider by approximately 50 degree each time. When the syringe be above the mixing container, the trundle will go down and plunger inject the liquid in the container.

In figure 2.14 a free body diagram of the trundle rotating parts jointed with motor by a belt.

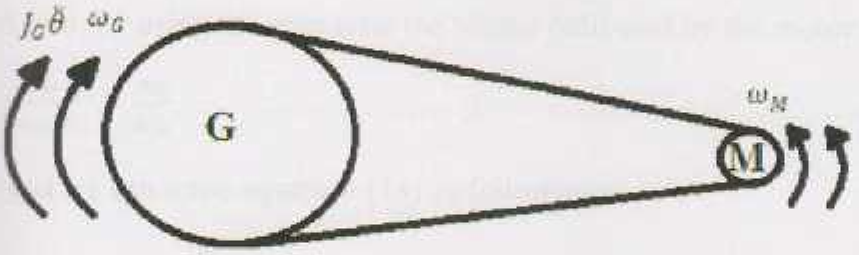


Figure 2.14: trundle free body diagram

The time needed to rotate the disk by 50 degree is 1.5 second also, the gear teeth areN_G, and the pinion teeth are N_M.

The motor angular speed calculated as following:

First find the trundle angular speed:

$$\omega = \frac{angel}{time}$$

$$\omega_{G} = \frac{50deg}{1.5s} = 33.3\ deg/s$$

Then the gear ratio will be used to find the required speed at the motor side:

$$\frac{\omega_M}{\omega_G} = \frac{N_M}{N_G} \quad \text{..........(2.12)}$$

And we can write equation (13) as following:

$$\omega_M = \omega_G \frac{N_M}{N_G}$$

The motor will work against the trundle inertia, in order to calculate the motor required torque we begin at the load side, and by using Newton second low:

$$T_{trundle} = (J_{trundle})\ddot{\theta}_{trundle} \quad \text{..........(2.13)}$$

Again, by using the gear ratio the torque delivered by the motor:

$$\frac{T_M}{T_{trundle}} = \frac{N_G}{N_M} \quad \text{..........(2.14)}$$

And we can write equation (14) as following:

$$T_M = T_{trundle} \frac{N_G}{N_M}$$

2.3.3 Oscillator dynamic

Oscillator is a disk driving by a stepper motor; it used to accelerate the mixing process, the disk installed directly to the motor as shown in the figure (2.15)

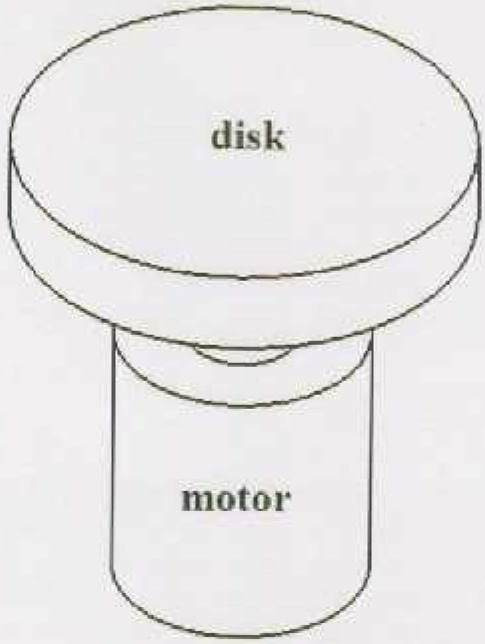


Figure 2.19: oscillator

$t = \frac{1}{f}$ ....(2.15)

Where

t: Time in second

f: Frequency in HZ

$t = \frac{1}{0.67} = 1.5\ s$

And by using equation ():

$$\omega = \frac{180\,deg}{1.5\,s} = 120\,deg/s$$

Also we can find the torque by using equation (2.13)

$$T_{disk} = (J_{disk})\ddot{\theta}_{disk}$$

Chapter Three

Control design

3.1 Overview

Control system is essential in this project to give desired motion, and it can be tuned according to the need of application.

Control system is a collection of components to construct an accurate machine. There are two types of control system, open-loop and closed-loop and all the components (physical system) can be represented by mathematical equation called transfer function. The DC motor will be modeled and transformed into transfer function. The entire component such as DC motor and hardware will be modeled and transformed into transfer function .after observing its natural characteristic, additional algorithm can be added in to computer(controller) in the form of program codes so all components will work accordingly with others to provide the desired response.

3.2 Overall Control Steps

Figure3.1. show the block diagram of closed loop system, the system will start by the required quantity (q) by the user. The data will go through software to microcontroller that gives the command to the circuit. The circuit will on the motor and move the mechanical hardware (nut) to the require position, that will beknown from the relation between therequired quantity, the lead of screw, so the motor angle will be sensed by the encoder and transform to the signal that can be read by the microcontroller.

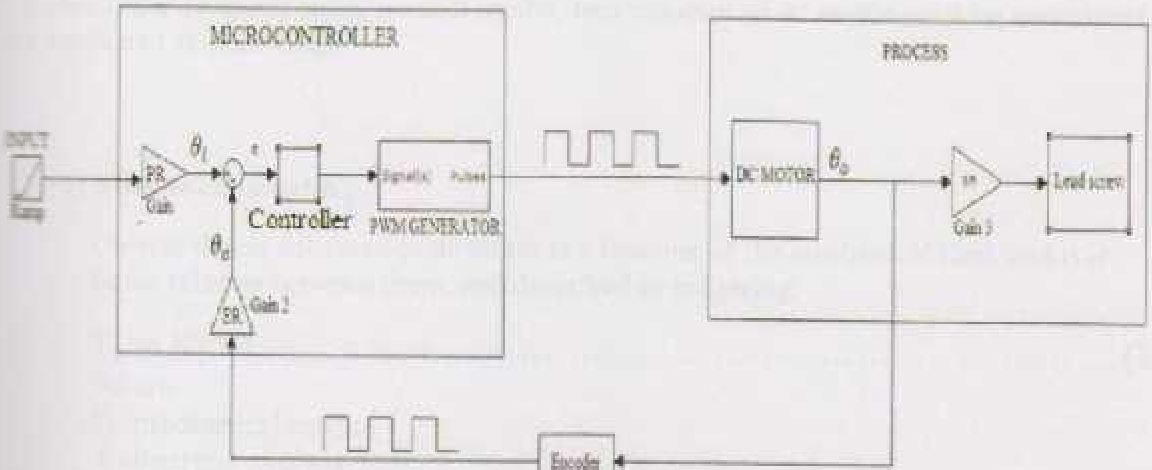


Figure 3.1: block diagram of closed loop system

The feedback data will then undergo data analysis and calculation in microcontroller. The microcontroller will continuously give the signal to the motor until the platform reach desired position given by the user.

Three gains are used as following:
1-PR: will be used to convert the required volume into required dc motor position.
2-ER: to convert the encoder feedback into dc motor position output.
3-SR: convert the rotational motion of dc motor into nut linear motion.

3.3 System Modeling

System modeling is a mathematical formula to represent a true designed system. Generally, these models are used to:

1) Provide an efficient technique to understand a real physical system.

2) Allow the behavior of a physical system to be determined.

The system has five permanent magnet dc motors (PMDC) the raising and lowering the plunger, and there is another three stepper motor for the following tasks:

1) First one move the trundle up and down and.

2) The second will used to rotate the trundle in order to make the syringe exactly above the mixing cup.

3) The last one will used as oscillator to decrease the mixing time.

Two of stepper motor will used with encoder in order to make sure, there is no step losing.
To obtain the dc motor mathematical model, two constant of dc motor must be considered, and are explained as following:

1) Torque constant K_τ

Current that is delivered to dc motor is a function of the mechanical load, and it is linear relation between them, and described as following:

$T_\tau = K_\tau * i$ ....(3.1)

Where
T_τ: mechanical torque
i: electrical current
K_τ: torque constant

2) **Back electromotive force (emf) constant** K_b

When the voltage applied to the armature, the armature conductor rotate in the magnetic filled that generates a voltage in the opposite polarity of the applied voltage, and described as following:

$$v_{emf} = K_b * \dot{\theta} \quad \text{...(3.2)}$$

Where

$\dot{\theta}$: angular speed

e: Back electromotive force

K_b: electromotive force constant

3.3.1 syringe-plunger position control

The method of controlling the amount of liquid in the syringe will be explained as following (see Figure 3.2:

1- The plunger is fixed to the nut, so the displacement of nut will be the same for the plunger.

2- Dc motor will drive the lead screw, and that will make the plunger to move.

3- By controlling the dc motor angle, plunger position could be controlled.

4- The damping constant due to the orifice was considered in section()

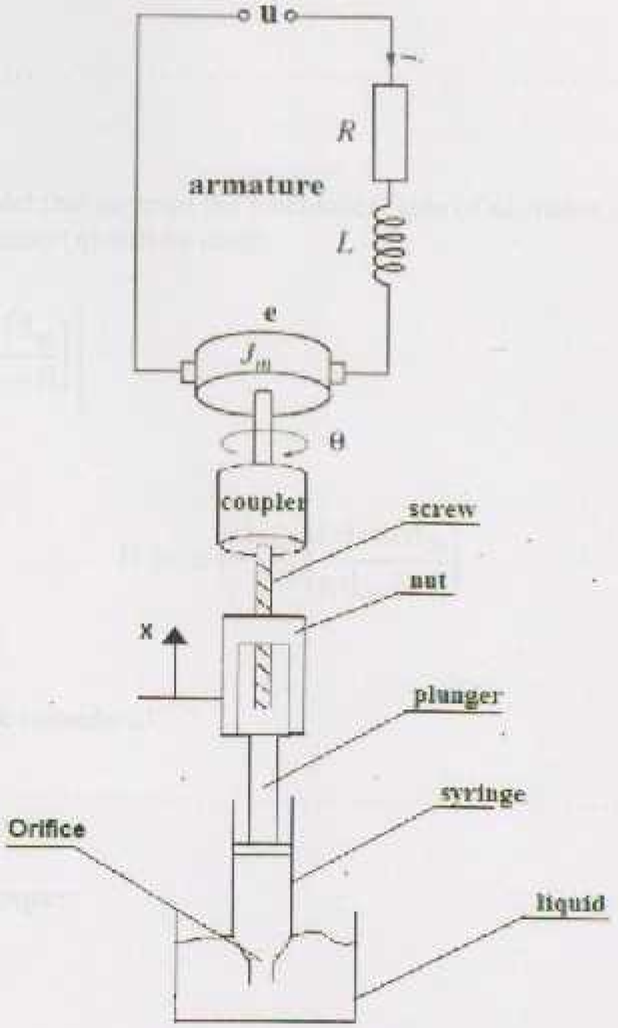


Figure3.2: block diagram of the system

Mathematical model that describe the electrical side of the system by using Kirchhoff law, in Figure (3.2) take a closed loop in the armature circuit that give:

$$u = Ri + L\frac{di}{dt} + e \qquad (3.3)$$

Where:

u: *input voltage*

R: *armature resistance*

L: *armature inductance*

i: *armature current*

e: *Back electromotive force*

From equation (2) and equation (3) could be written as following:

$$u = \frac{RT_\tau}{k_\tau} + L\frac{di}{dt} + K_b\dot{\theta} \quad \text{.........(3.4)}$$

In order to obtain the model that descript the mechanical side of dc motor:-
Equation (2.5) with gear ratio (n) will be used:

$$T_\tau = n\left[\left(\frac{Fd_m}{2}\right)\left[\frac{l + \pi f d_m}{\pi d_m - fl}\right]\right]$$

Assume that:

$$N = n\left(\frac{d_m}{2}\right)\left[\frac{l + \pi f d_m}{\pi d_m - fl}\right]$$

All the axial force must be considered:

$$F = m\ddot{x} + c\dot{x} + mg \quad \text{.........(3.5)}$$

Where:
m: *mass of nut and plunger*
c: *damper constant*

Then and by using equation (2.2) , equation (3.5) can be writing as following:

$$F = ml\ddot{\theta} + cl\dot{\theta} + mg \quad \text{.........(3.5a)}$$

Now subset equation(3.5a) in equation(2.5).

$$T_\tau = mlN\ddot{\theta} + clN\dot{\theta} + mNg \quad \text{.........(3.6)}$$

By equation (3.6). equation (3.4) is:

$$u = \frac{RmlN}{k_\tau}\ddot{\theta} + \frac{RclN}{k_\tau}\dot{\theta} + \frac{RmNg}{k_\tau} + L\frac{di}{dt} + K_b\dot{\theta} \qquad (3.7)$$

And if we assume the armature inductance is very small compared with armature resistance we can neglected it, and add the screw and motor inertia.
So, equation (3.7) is:

$$u = \left(\frac{RmlN}{k_\tau} + J_{eq}\right)\ddot{\theta} + \left(\frac{RclN}{k_\tau} + K_b\right)\dot{\theta} + \frac{RmNg}{k_\tau} \qquad (3.7a)$$

Assume:

$$a = \frac{RmlN}{k_\tau} + J_{eq}$$

$$b = \frac{RclN}{k_\tau} + K_b$$

$$q = \frac{RmNg}{k_\tau}$$

Equation (3.7a) is:

$$u = a\ddot{\theta} + b\dot{\theta} + q \qquad (3.8)$$

Taking the Laplace transform, equation (3-7a) is:

$$U(s) = as^2\theta(s) + bs\theta(s) + q(s) \qquad (3.9)$$

Now a transfer function can be obtained by write equation (3-8) as a ratio between the input ($U(s)$) and the output ($\theta(s)$):

$$\frac{\theta(s)}{U(s) - \frac{q}{s}} = \frac{1}{as^2 + bs} \qquad (3.3)$$

To calculate the total inertia from the motor side in Figure (3.6):

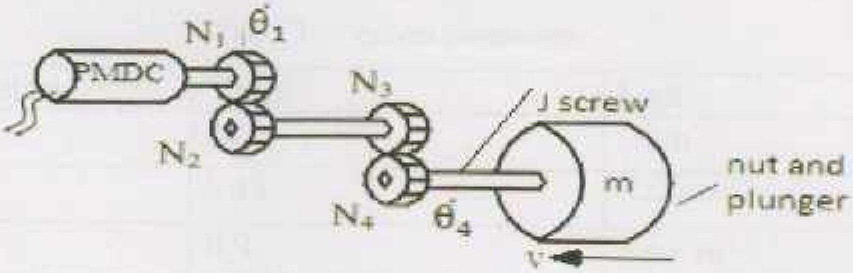


Figure (3.3) total inertia

$$\frac{1}{2}J_{eq}\dot{\theta}_1^{\ 2} = J_{motor} + \frac{1}{2}J_{SCREW}\dot{\theta}_4^{\ 2} \quad (3.11)$$

But:

$$\dot{\theta}_4 = \frac{N_1}{N_2}\frac{N_3}{N_4}\dot{\theta}_1$$

$\frac{N_1}{N_2}\frac{N_3}{N_4}$: the over all gear ratio

So, equation 3.12 becomes:

$$J_{eq} = J_{motor} + J_{SCREW}\left(\frac{N_1}{N_2}\frac{N_3}{N_4}\right)^2 \quad (3.12)$$

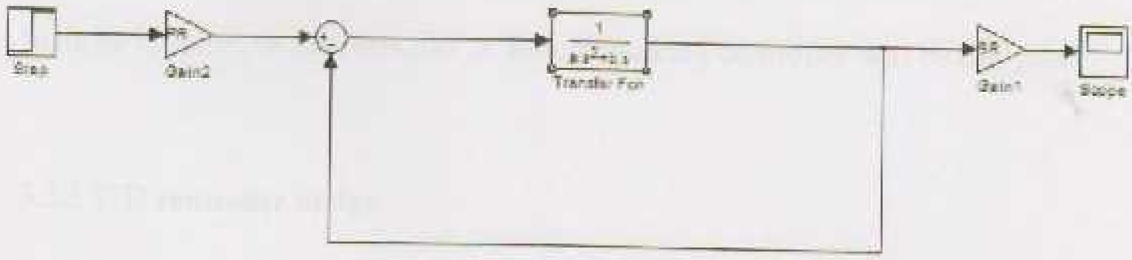
3.3.2 syringe-plunger simulation

Transfer function coefficient obtained from by substitute the system parameter in Table(3-1). now MATLAB/simulink could be used to study the response of the system, in order to decide which controller have to be used, since that depend on the required criteria of the output.

Table 3-1: system parameters

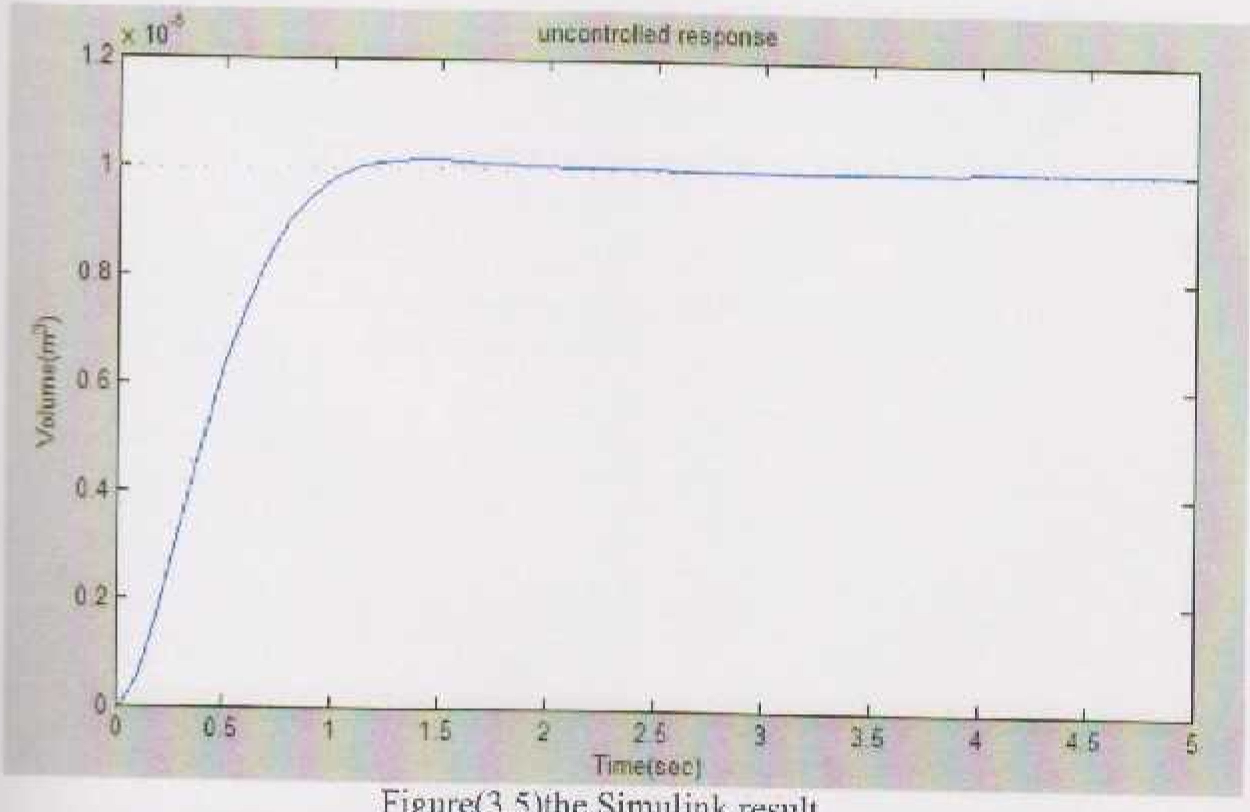
parameters	Value	Unit
R	28	Ohm
$K_\tau = K_b$	0.43	--------
J_{motor}	0.9	$kg * m^2$
J_{Screw}	$2.6x10^{-6}$	$kg * m^2$
d_m	0.012	m
l_{screw}	0.002	m
syrine redius	0.02	m
C	0.21	$N\frac{s}{m}$
Encoder	38	Pulse/rev
$m_{nut\ and\ plunger}$	0.065	kg
Over all Gear ratio	5.9:1	--------------
f	0.47	

Figure (3.4) show the simulink block of the uncontrolled system with 1ml as input.



Figure(3.4) Simulink of uncontrolled system

From Figure (3.5) the simulink result shows that:



Figure(3.5)the Simulink result

1-there is an overshoot and it will be deleted by using critical damping ratio in controller design

2-the transit settling time will be reduced to be 2 second

3-the steady state error look to be fine.

In order to improve the response ,a robust tracking controller will be designed.

3.3.3 PID **controller design**

From the criteria of controller design:

1-in order to have a no overshoot, critical damping ratio will be used which mean zeta (δ) =1.

2-from the settling time$T_s = 0.5sec$:

$T_s = \frac{4}{\sigma} \rightarrow \sigma = \frac{4}{0.5} = 8$

Figure (3.6) show the root locus :

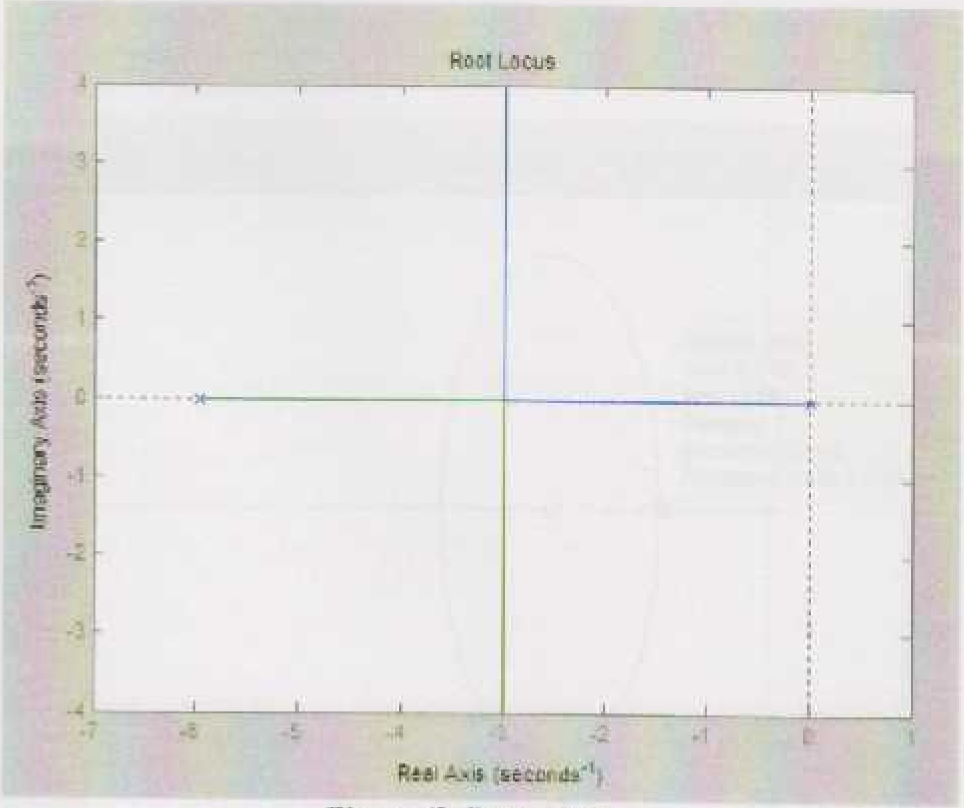


Figure (3.6) root locus

In order to achieve the required response a zero will be add at$\sigma = 8$ and this will be the D element in the PID controller

$G_D = (s + 8)$

Again root locus us sketched in Figure (3.7) with G_D in order to find the gain

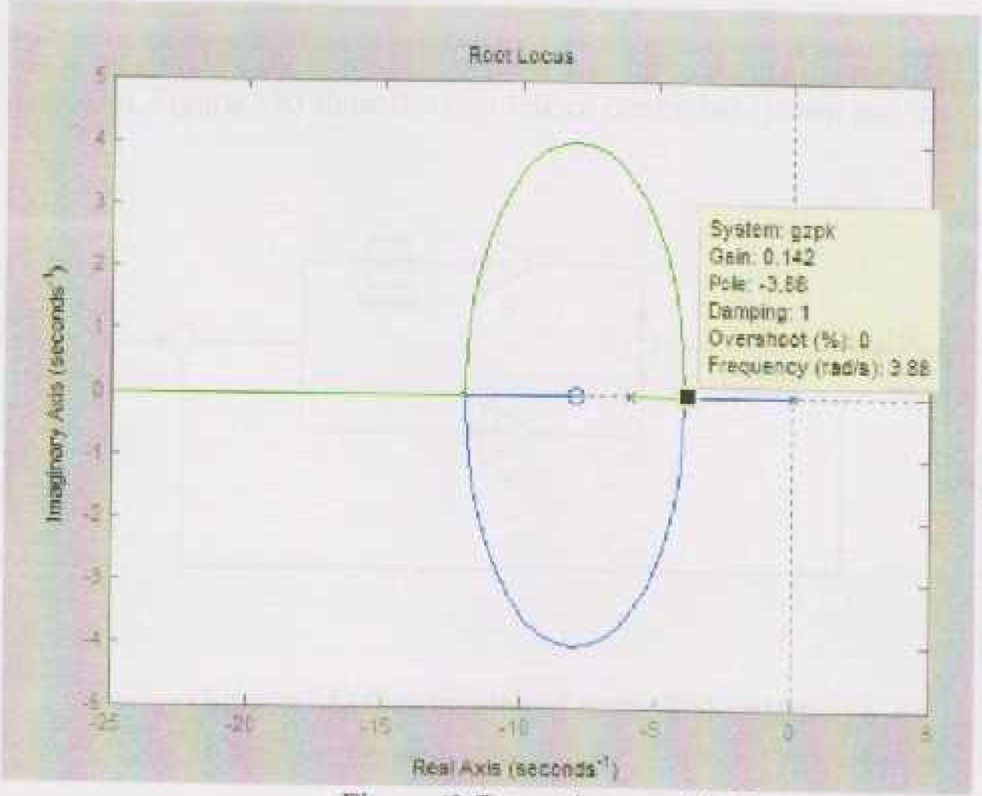


Figure (3.7) root locust with G_D

Root locus passes the point and the system still stable. From the last sketch of root locus for the PD compensated system, searching along the 1 damping ratio line in order to find

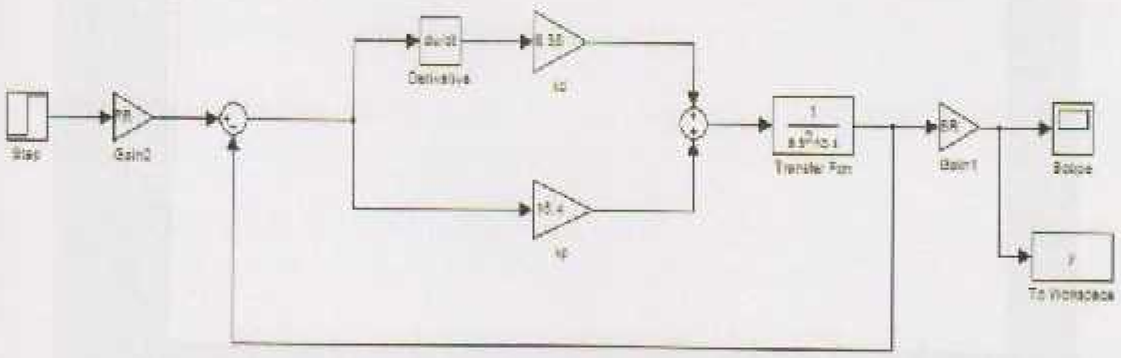
$K = 0.142 * 13.88 = 1.97$

Now gains ($K_P K_D$,) could be determined:

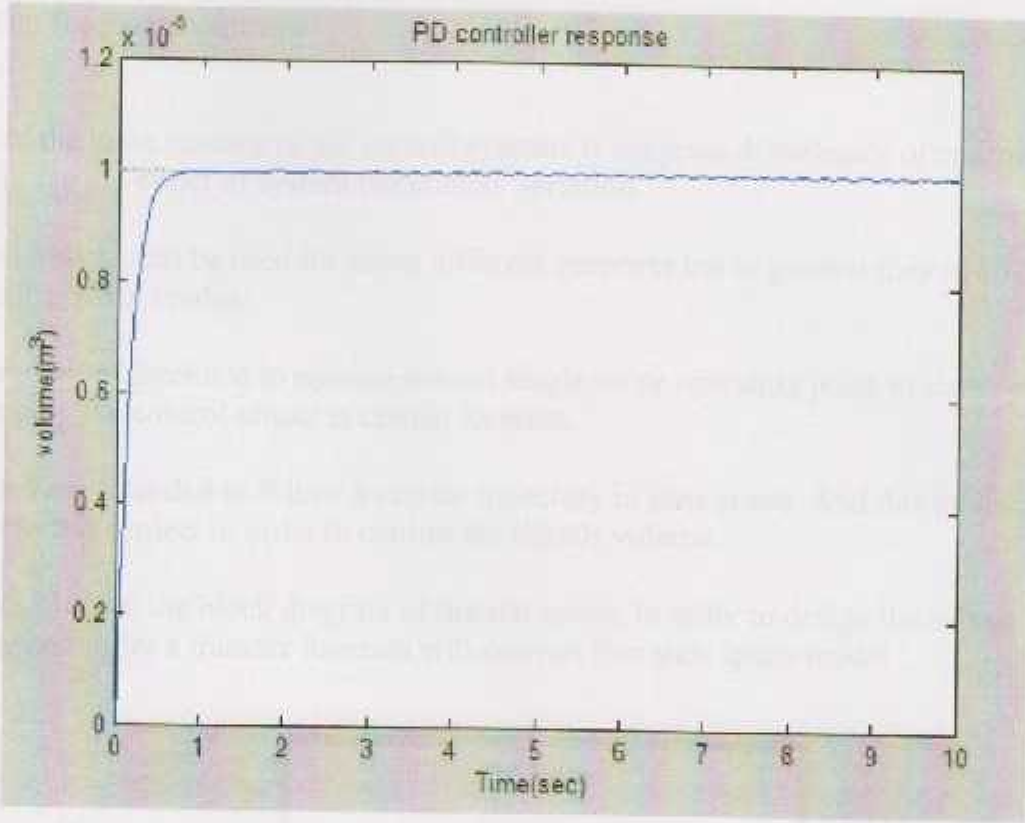
$G_{PID} = 1.97(s + 8) = 1.97s + 15.76$

$K_P = 1.97$
$K_D \ = 15.76$

Now we simulate the controlled system in order to ensure the required response is achieved. Figure(3.8) show the simulink of controlled system and the response



Figure(3.8) the simulink of controlled system


PD controller response
x 10^-5
volume(m^3)
Time(sec)
0
0.2
0.4
0.6
0.8
1
1.2
0
1
2
3
4
5
6
7
8
9
10

3.3.4 Stat feedback controller

One of the main reasons to use control systems is suppress disturbance of control object or minimize the effect of system parameters variation.

Control system can be used for many different purposes but in general they operate in two basic control modes:

1-as regulators, intended to operate around single set or operating point in state space, and keeping the control object at certain location.

2-as trackers, intended to follow a certain trajectory in state space. And this mode will be applied to this project in order to control the liquids volume.

Figure(3.9) show the block diagram of the stat space, In order to design the robust tracking controller a transfer function will convert into state space model :

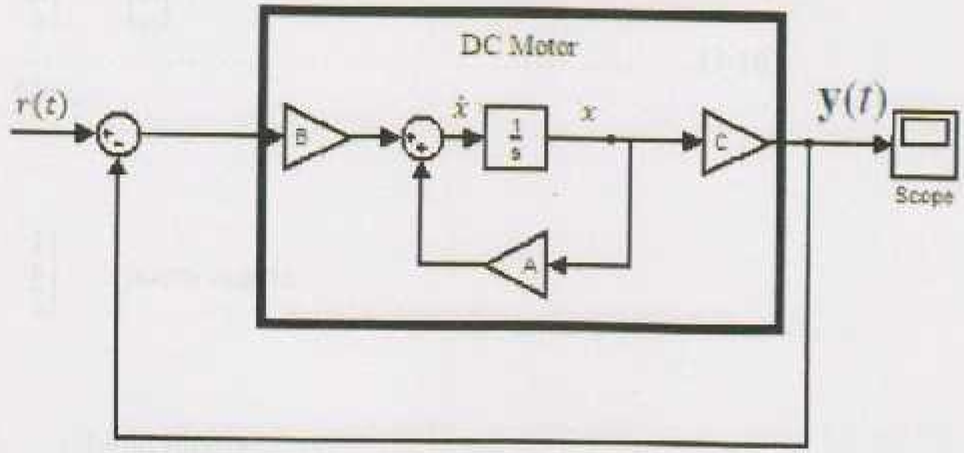


Figure (3.9) the block diagram of the stat space

$$\dot{x} = Ax + Bu$$
$$y = Cx \qquad \text{(3.13)}$$

In equation (3.9), Suppose:

$x_1 = \theta$
$x_2 = \dot{\theta}$

Equation () be:

$\dot{x}_1 = x_2$ ....(3.14)

$\dot{x}_2 = -\frac{b}{a} x_1 + \frac{1}{a} u$ ....(3.15)

Equation (3.13-3.14) in stat space form:

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & \frac{b}{a} \end{bmatrix} \vec{x} + \begin{bmatrix} 0 \\ \frac{1}{a} \end{bmatrix} u$$

....(3.16)

$y = [1 \quad 0] x$

Where:

$A = \begin{bmatrix} 0 & 1 \\ 0 & \frac{b}{a} \end{bmatrix}$ System matrix

$B = \begin{bmatrix} 0 \\ \frac{1}{a} \end{bmatrix}$ Input matrix

$C = [0 \quad 1]$ Output matrix

The pair (A, B) is controllable if and only if the controllability matrix

$M_c = [B \quad AB \ldots\ldots\ldots \quad A^{n-1}B]$ ....(3.17)
Has rank n.

By using matlab Code:

```
A=[0 1;0 -5.91];
B=[0 ;13.88];
Mc=ctrb(A,B);
r=rank(Mc);
```

Give rank =2 which means the system is controllable

Now the controlled system shown in Figure (3.10) will be designed in the following form:

$$u = -k\vec{x} + k_i\varphi$$

$$\dot{\varphi} = r(t) - y(t) = r - C\vec{x}$$ ....(318)

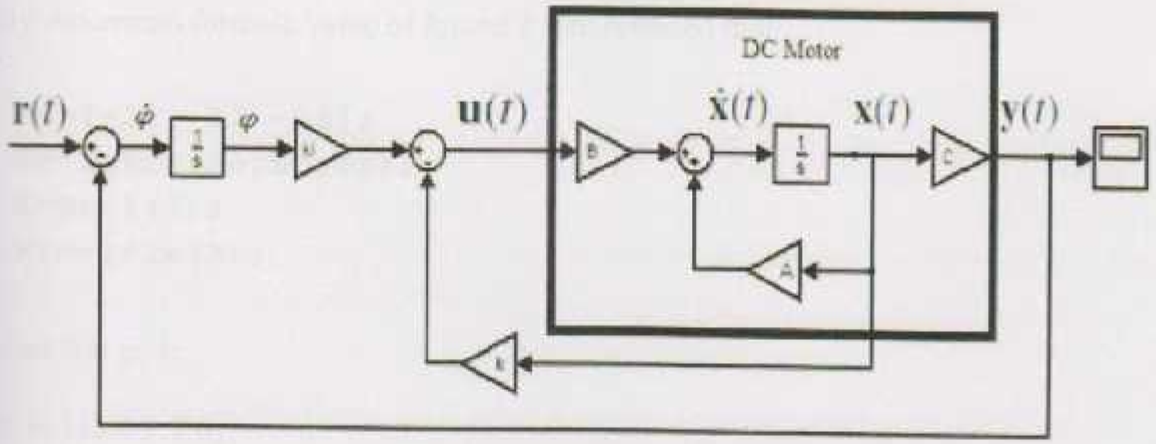


Figure (3.10) robust controller

Now we find the A_e *and* B_e that represent the closed loop system matrix:

$$A_e = \begin{bmatrix} A & 0 \\ C & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \frac{-b}{a} & 0 & 0 \\ 0 & \frac{1}{a} & 0 \end{bmatrix}$$

$$B_e = \begin{bmatrix} B \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{1}{a} \\ 0 \end{bmatrix}$$

For the design criteria:

1-$T_s = 0.5 sec$

2-$damping\ ratio = 1$

The poles must be place in to following value:

Poles =$[-12 \quad -12 \quad -18]$

By Ackerman formula value of $k_I and\ k$ are founded the:

```
Ps=[-12 -12 -18];
ke=acker(Ae,Be,Ps);
K=ke(1:2);
KI=-1*ke(3);
```

And that give:

K = [41.49 2.6]

K_I= [186.74]

Figure (3.11) step response of the robust tracking system controller:

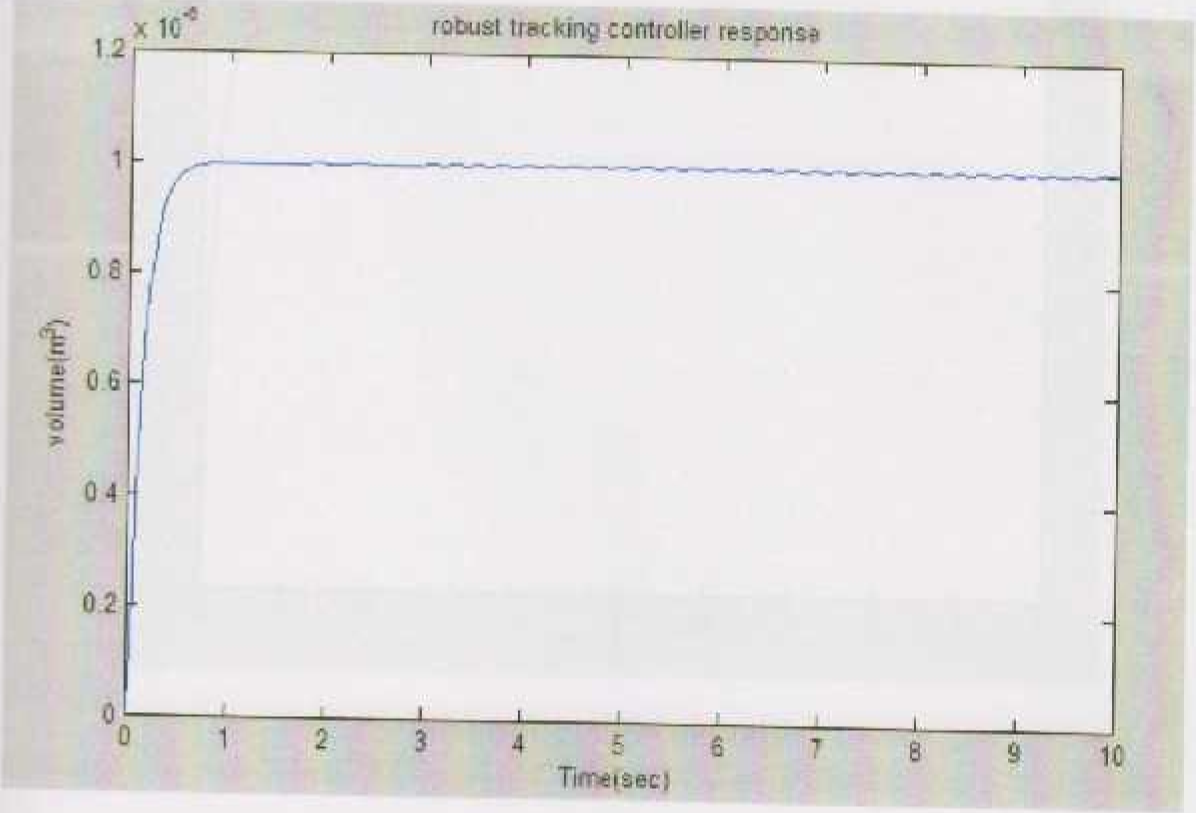


Figure (3.11) step response of the robust tracking system

3.3.5 Controller selection

From figure(3.12) and figure(3.13) ,The PD and the robust tracking controller improve the response in the same way, but by Comparison between the two controller when there is a disturbance ,we can see the performance of robust tracking controller to reject this disturbance effect at the same input as shown in the figure() and figure() .

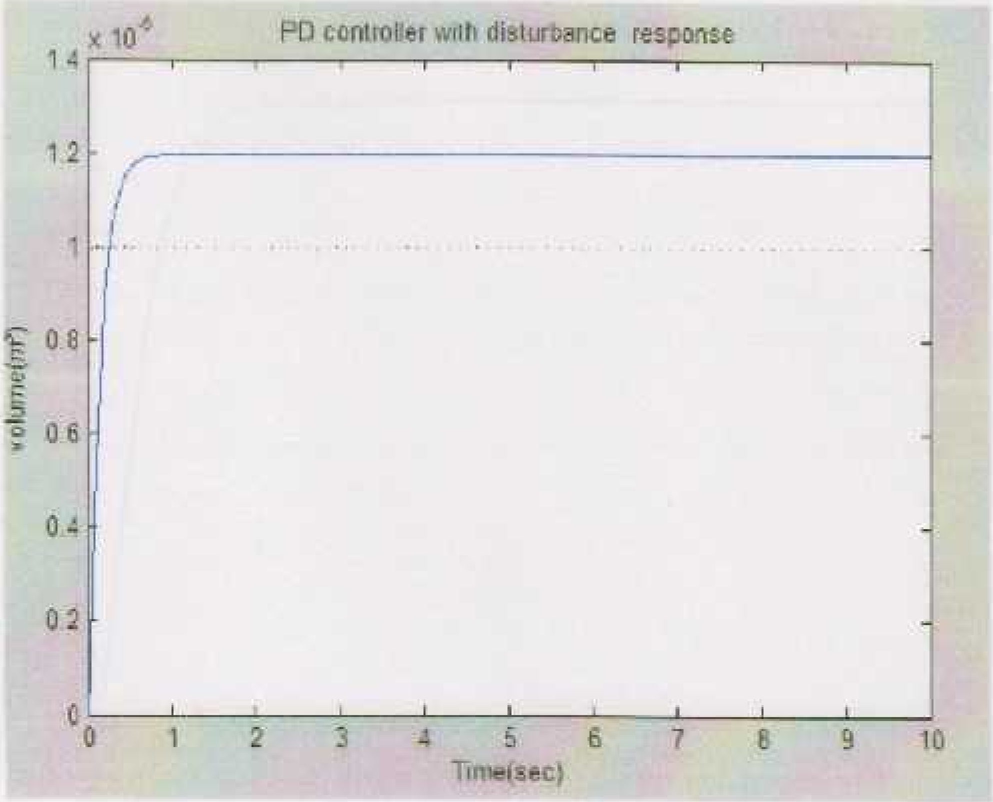


Figure (3.12)PD controller

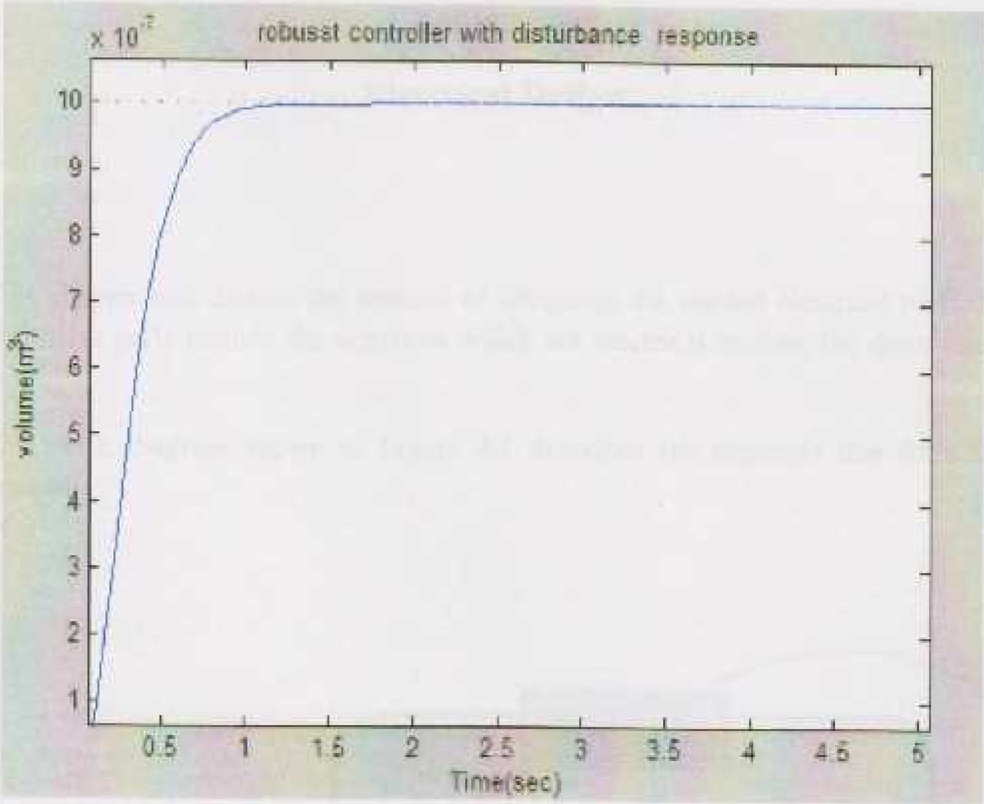


Figure (3.13) robust tracking controller

Chapter Four

Electrical Design

4.1 Introduction

This chapter will discuss the process of designing the needed electrical parts to operate the system; these parts include the actuators which are electrical motors, the drive circuits, and the controller.

The block diagram shown in Figure 4.1 describes the elements that form the entire system generally.

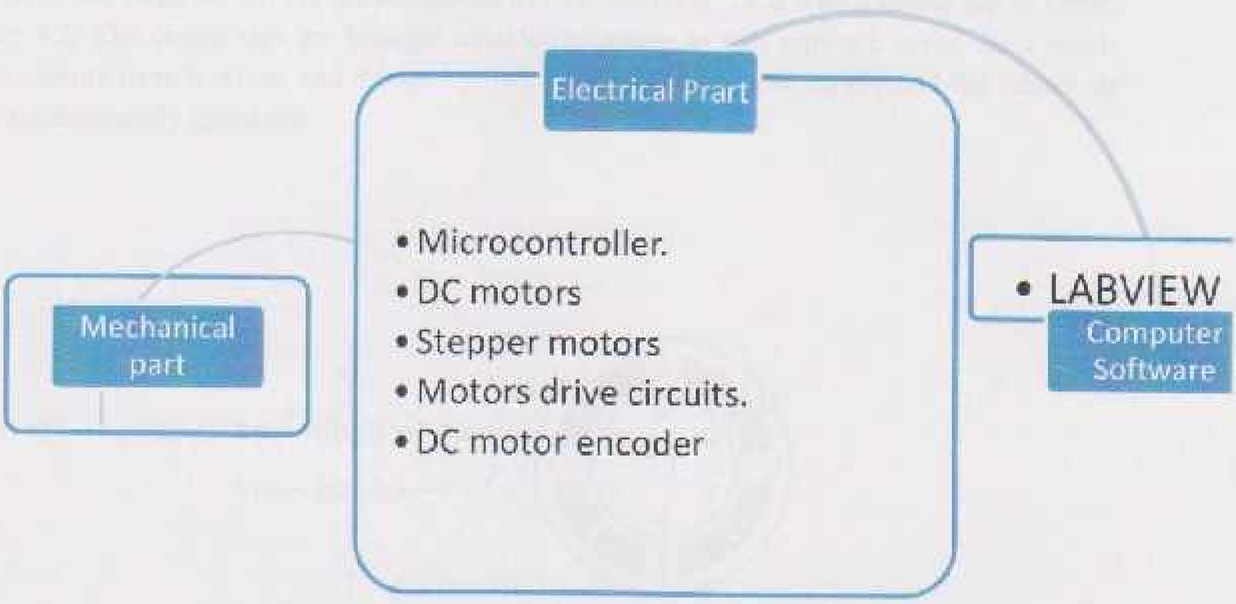


Figure 4.1 Basic Elements in the System

The electrical system includes two types of electrical motors, the first is stepper motors these motors are controlled by digital sequence generated by microcontroller and supplied to the motors throw drive circuits, the second type is the DC motors which are controlled by the controller using pulse width modulation technique.

The designing of steeper motors drive circuit will be discussed in this chapter.

4.2 MOTORs

The system includes three unipolar stepper motors and five DC motor to provide the needed motion.

4.2Stepper motor

Unipolar stepping motors are composed of two windings, each with a center tap as shown in Figure 4.2. The center taps are brought outside the motor as two separate wires. As a result, unipolar motors have 6 wires, and driven by tied the 4 coils to power supply and the center tap wire(s) are alternately grounded.

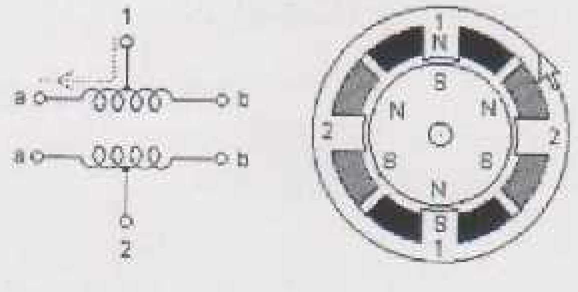


Figure 4.2 Unipolar stepper motor windings

4.3 MOTORs DRIVE CIRCUIT

Since the motor need a power that microcontroller can't deliver it, a power circuit will be used that increase the power of the control signal.

4.3.1 Designing of Motors Drive Circuit

Since the motors used in the systems are unipolar stepper motors with 4 poles for each motor, it is now required to design a drive circuit that transfer the digital signal produced by the Microcontroller and supply the motor with the required power as it donated in the motors datasheets.

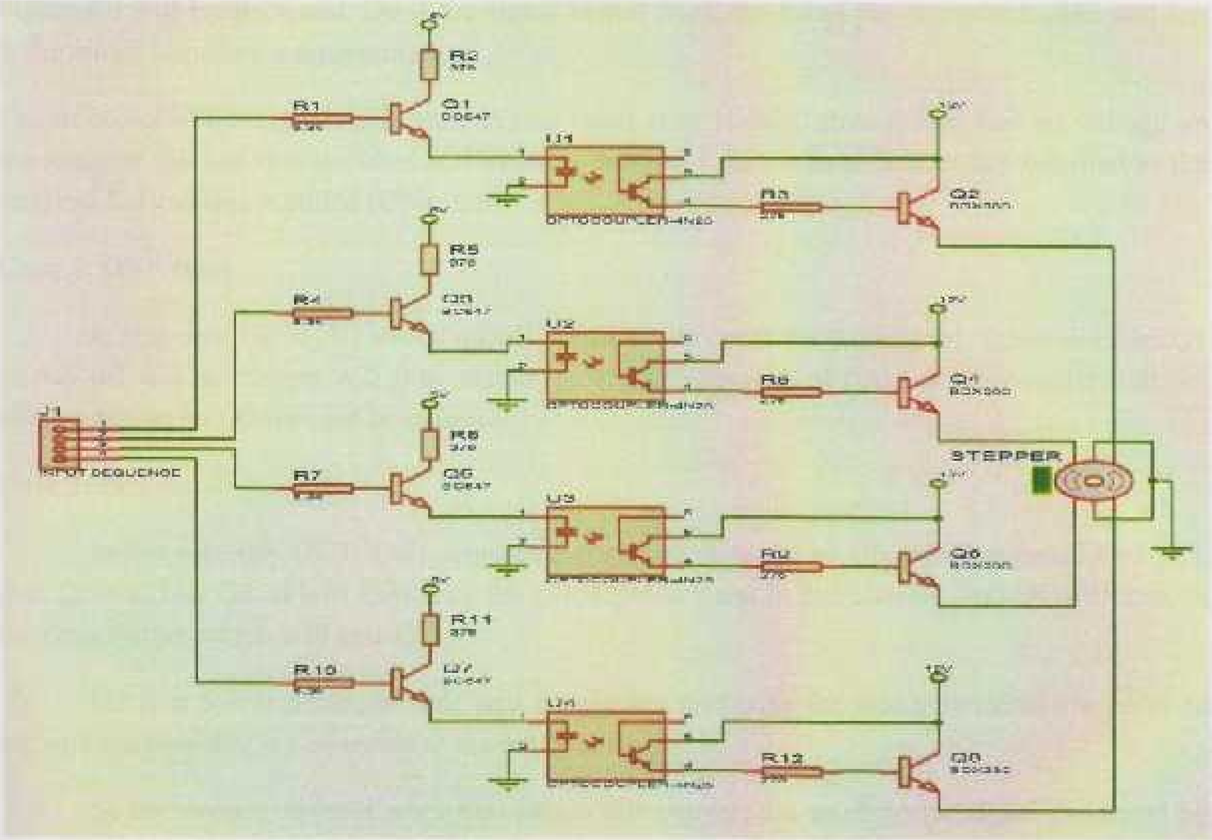


Fig 4.3 Motor Drive circuit

Figure 4.3 show the drive circuit, the motor poles are power from power transistors, and for isolation purpose the power transistor biased by an optocouplerto isolate the power connection between the Microcontroller and the power transistors.

The optocoupler is biased by a transistor which receives the digital signal from the Microcontroller.

Thus in our calculation we will design one pole drive circuit which will be applied for all the other poles.

4.3.2 Circuit Operation Principle

As we mentioned earlier in this chapter the digital sequence which control the motor rotation is produced by the microcontroller, this sequence is formed by four digital bits (0 0 0 1) since a four poles unipolar stepper motor will be used, 4 bits are shifted on the input of the motor drive circuit to generate the rotation.

To describe the operation of the drive circuit ,one pole connection which is shown in Figure 4.4 will be discussed. D0 is the signal comes from one bit of the microcontroller, and Zm is the motor impedance representation.

The microcontroller signal (D0) include two states 0 or 1, the 0 state means that no voltage on the terminal D0 and this is called (OFF) state, and the 1 state means 5 volts are supplied to the terminal D0 and this is called (ON) state.

Case 1: OFF state

In this case D0=0 [V] which means no input current at the base of Q1, this will make Q1 to stay off and no current will flow throw the emitter, because of that the optocoupler will not turn on and so on Q2 will not be biased.

Case 2: ON state

In this case the ARDUINO supplies digital logic 1 to the bit D0, which means D0=5 [V], thus D0 will bias Q1 as will shown by the calculations latest in this chapter, and Q1 will turn on the optocoupler which will bias Q2.

Q2 is a power transistor that will supply the power to the motor terminals in order to activate the pole that is connected to the emitter.

So the stepper driver is work like switch that convert the small power signal generated by the microcontroller to high power signal with specific values of voltage and current that can activate the desired motor pole.

4.3.3 Circuit equations and resistors finding

To find the resistance value, applying Kirchhoff's voltage low on this circuit in figure 4.4, four equations are produced, each equation describe the voltage summation of a specific loop.

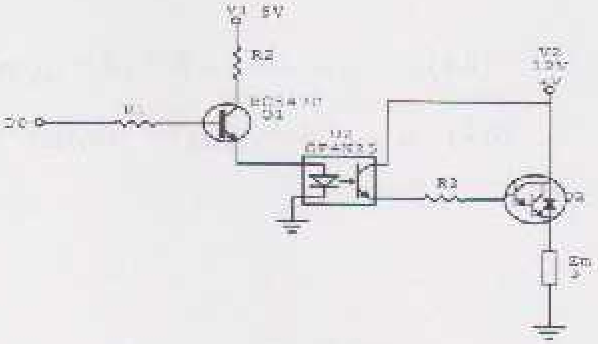


Figure 4.4 one pole drive circuit

$D_0 \to V_{R1} \to V_{BE} \to V_F$

$V_1 \to V_{R2} \to V_{CE} \to V_F$

$V_2 \to V_{CE(opt)} \to V_{R3} \to V_{BE(Q2)} \to V_m$

$V_2 \to V_{CE(Q2)} \to V_m$

V_m *is the voltage on the motor pole*

Loop 2:

$$D_0 - V_{R1} - V_{BE(Q_1)} - V_F = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

$$V_{R1} = I_{R1} \times R_1 = D_0 - V_{BE(Q_1)} - V_F \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

Loop 2:

$$V_1 - V_{R2} - V_{CE(Q_1)} - V_F = 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.3)$$

$$V_{R2} = I_{C(Q_1)} \times R_2 = V_1 - V_{CE(Q_1)} - V_F \dots\dots\dots\dots\dots\dots\dots (4.4)$$

Loop 3:

$$V_2 - V_{CE_{(OPT)}} - V_{R3} - V_{BE_{(Q2)}} - V_m = 0 \dots\dots\dots\dots\dots\dots\dots\dots (4.5)$$

$$V_{R3} = I_{B(Q_2)} \times R_3 = V_2 - V_{CE(OPT)} - V_{BE(Q2)} - V_m \dots\dots\dots.. (4.6)$$

Loop 4:

$$V_2 - V_{CE(Q_2)} - V_m = 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.7)$$

$$V_{CE(Q_2)} = V_2 - V_m \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4.8)$$

Chapter Five
Experimentations and Results

5.1 Introductions

This chapter contains , The practical result of the project , problems , conclusion , future work .

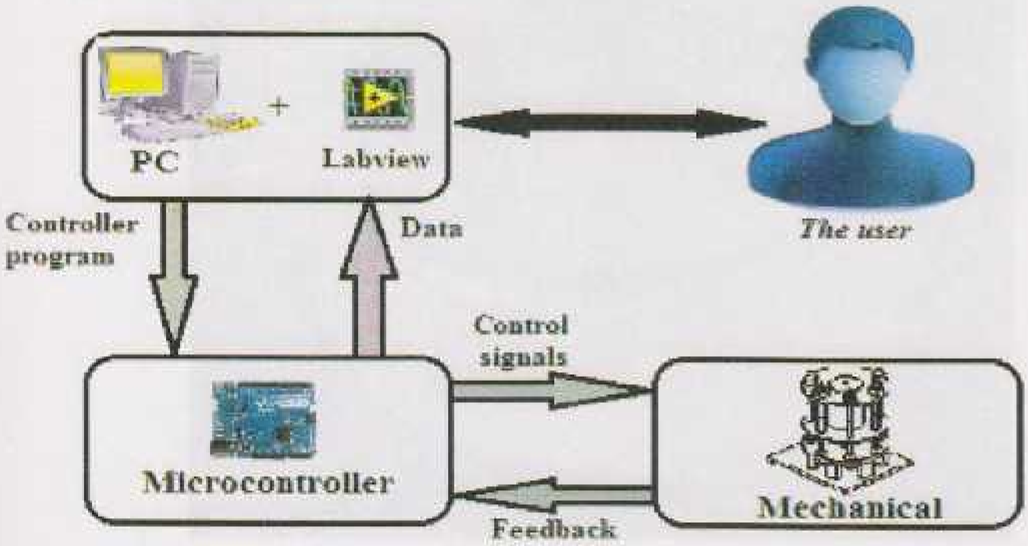


Figure 5.1: the overall system

5.2Mechanical parts:

Figure (5.2) show the general structure of the mechanical parts of the project:

Figure (5.2) project general structure

And in Figure (5.3) show the lead screw with the Gide in order to suck and inject the liquids:

Figure(5.3):lead screw mechanisms

5.3 LABVIEW interface:

Figure (5.4) show the graphical user interface in the labview side that used to control and monitor the process

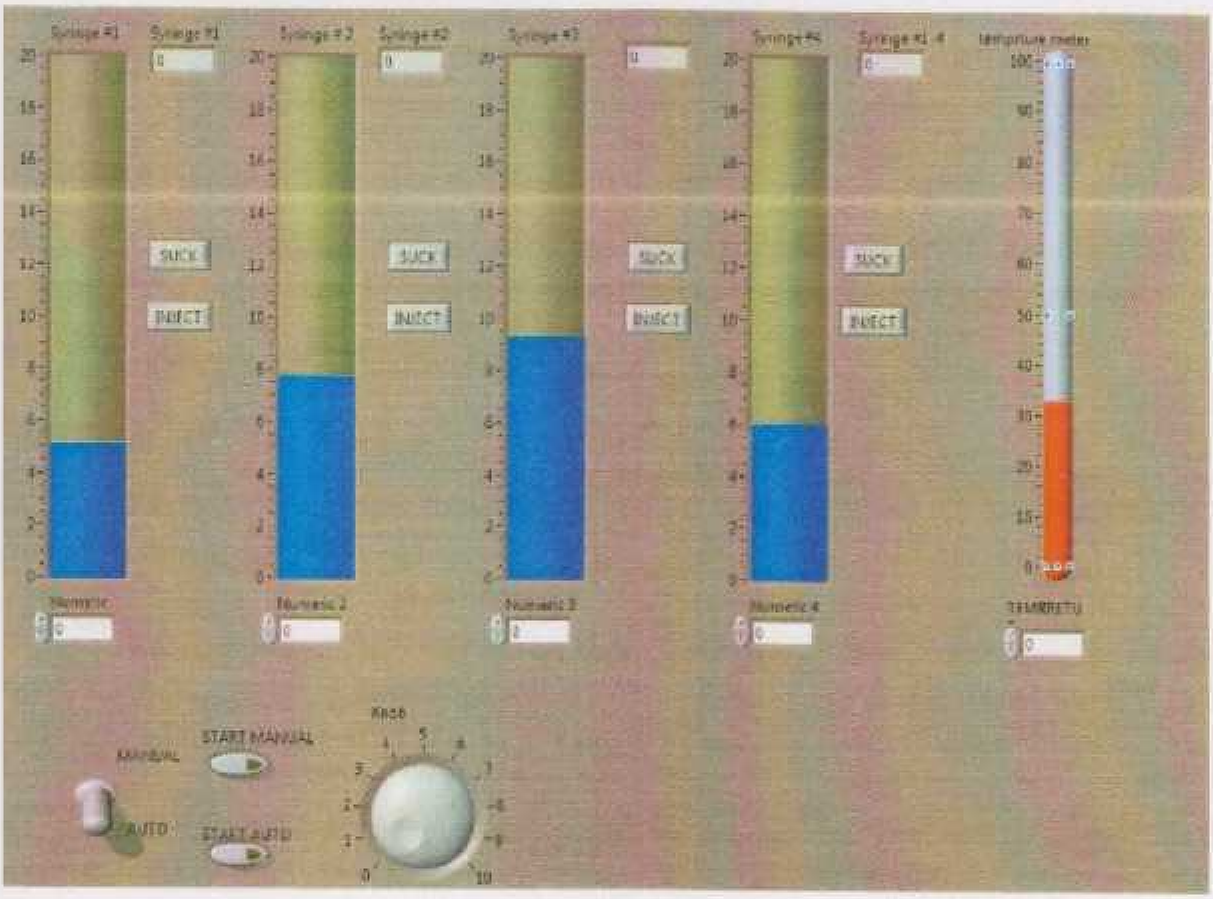


Figure (5.4): graphical user interface

The software that control this program shown in appendix A

5.4 Conclusion:

The project doesn't achieve its goal , dye to machining and assembly problems , affect the accuracy of the system . so there is no perfect results .

5.5 future works

The result achieved by this project can be basic point for future student to development this project in order to avoid current problems and give more features for the machine .

The development could be in many sides .

-software (labview)

In the software side a database could be add in order to management the data that sensors read from the experimental.

-Hardware

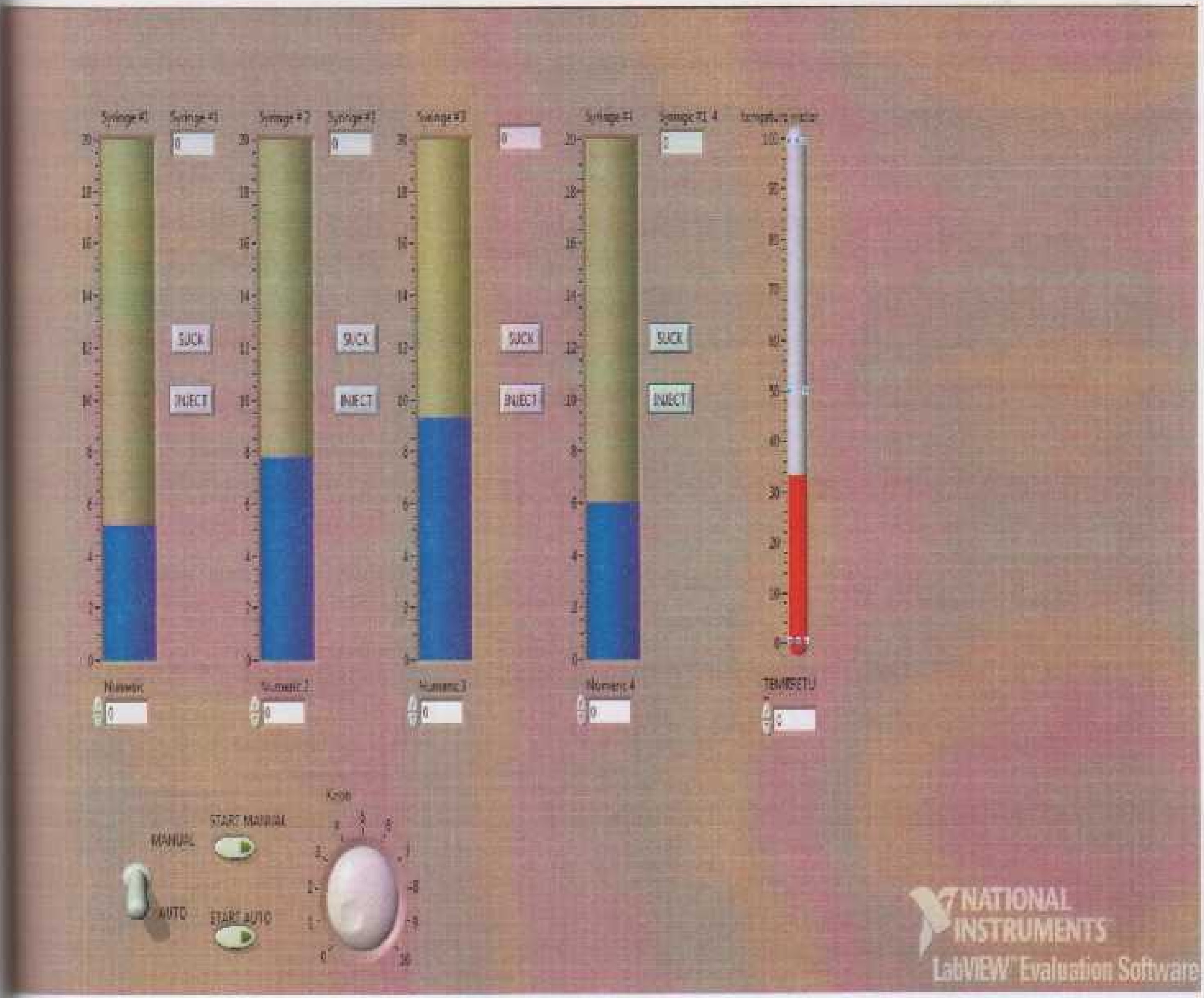
Many feature could be add to the hardware such as add a sensor that can read some properties of the mixing result such as if there is a gas or the energy that produced by the reaction.

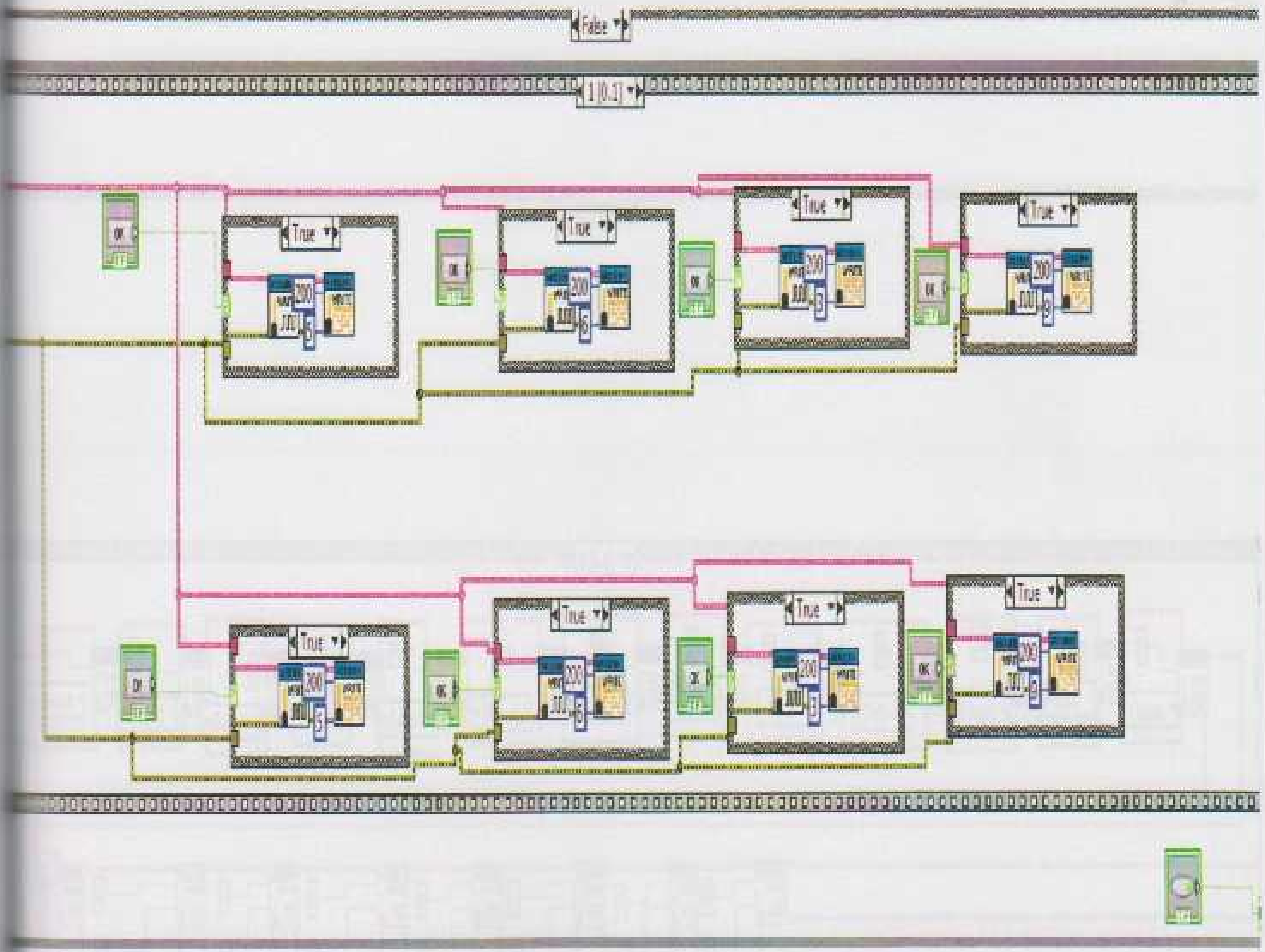
-This project is financed due Scientific Research of graduate study at PPU .

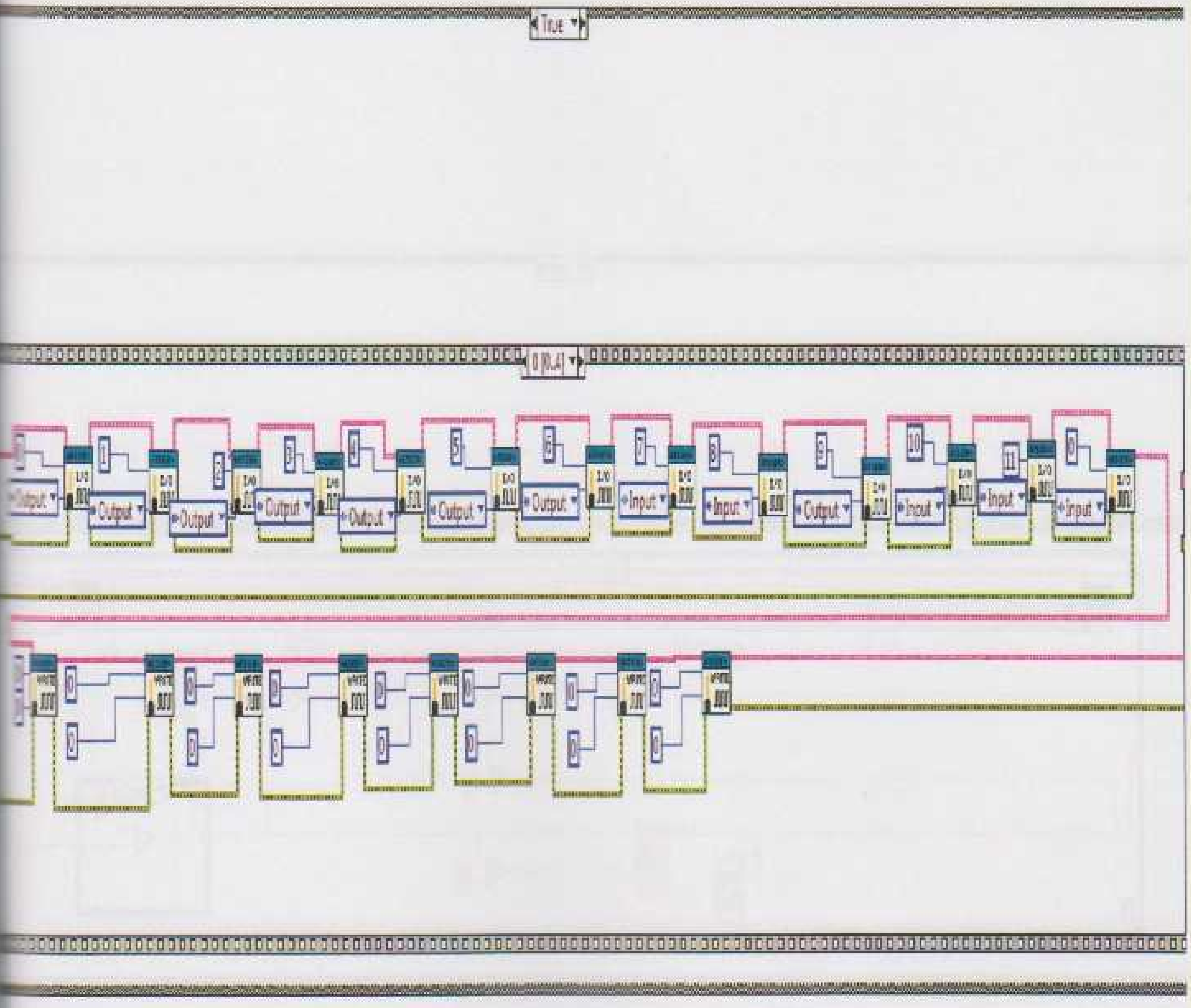
APPENDICES

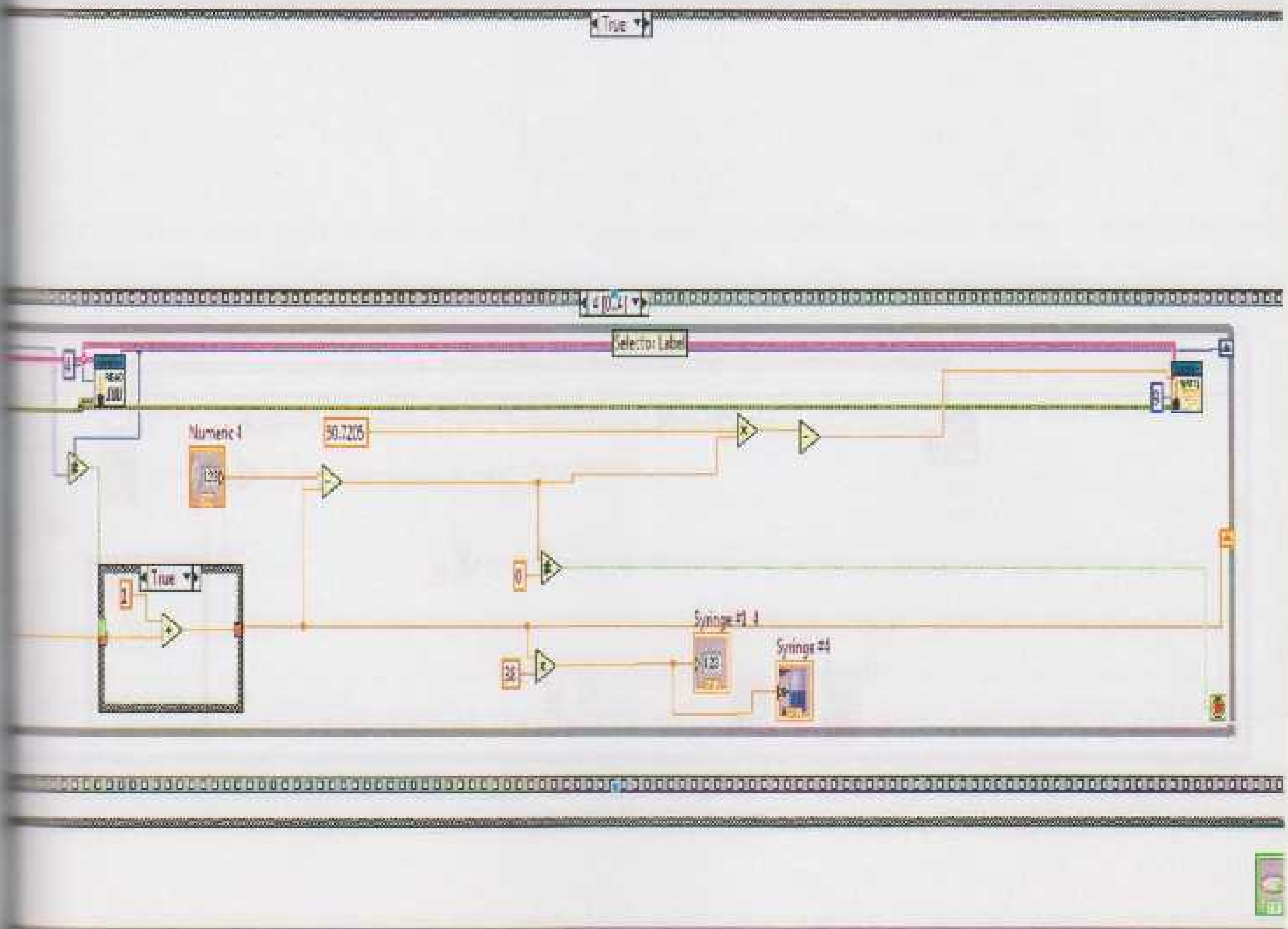
Appendix A

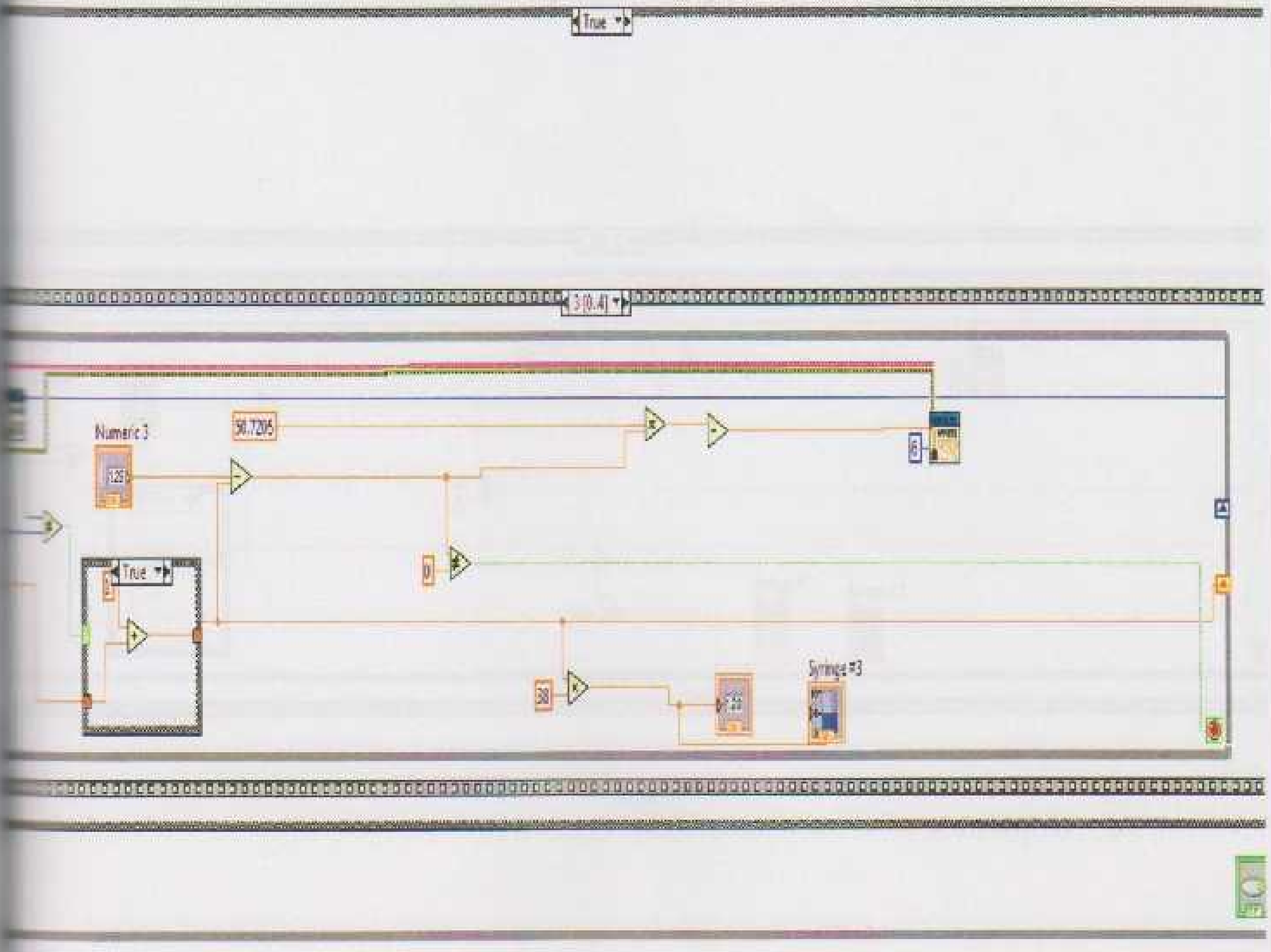
Labview Scripts


Syringe #1
Syringe #2
Syringe #3
Syringe #4
SUCK
INJECT
Numeric
Numeric 2
Numeric 3
Numeric 4
TEMPERETU
Knob
MANUAL
AUTO
START MANUAL
START AUTO
NATIONAL INSTRUMENTS
LabVIEW Evaluation Software

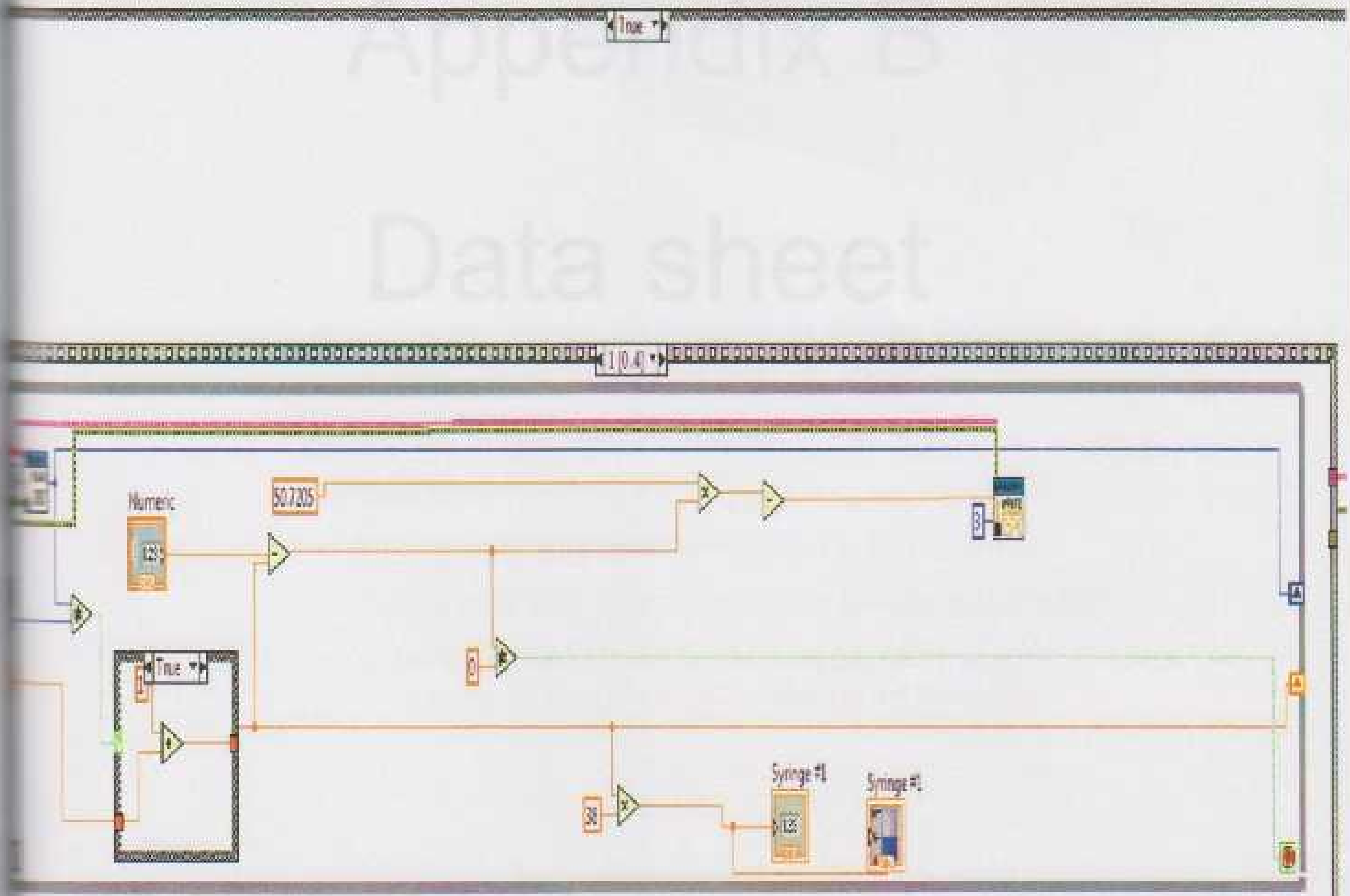

False
True
True
True
True
True
True
True
True


True
0 [0..4]
Output
Output
Output
Output
Output
Output
Output
Input
Input
Output
Input
Input
Input


True
Selector Label
Numeric 4
30.7205
True
Syringe #4


True
3 [0..4]
Numeric 3
58.7205
125
True
58
Syringe #3


True
Numeric 2
50.7205
True
Syringe #2
Syringe # 2

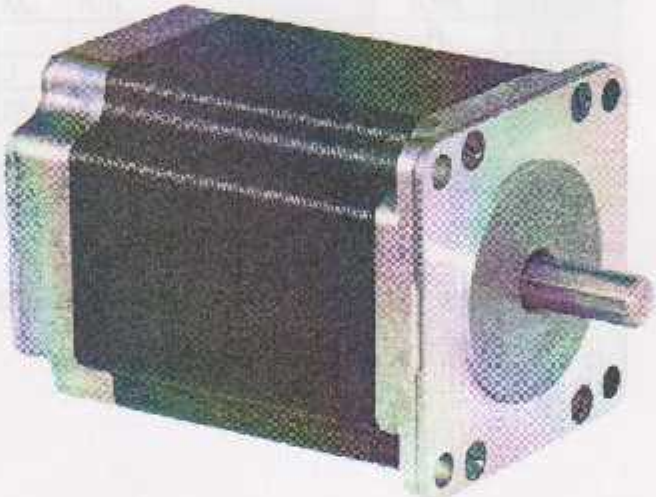

True
1 [0..4]
Numeric
50.7205
3
True
0
38
Syringe #1
Syringe #1

Appendix B

Data sheet

Technical Data
Edition 01/2003
HS200-GB-0103.doc

High-Performance Stepper Motors
HS200 Series



- **2-phase Hybrid Step Motor in Frame Size NEMA 23**
- **Holding Torque from 0,4 up to 1,6 Nm**
- **Peak Torque up to 2,8 Nm**
- **Full Step Angle 1,8°**
- **Direct Heat Dissipation from the Lamination**
- **Noise and Vibration optimized Shape of Lamination**
- **Linear Torque of up to 2,5 Times of the rated Current for short Acceleration/Deceleration Periods**

BAUTZ

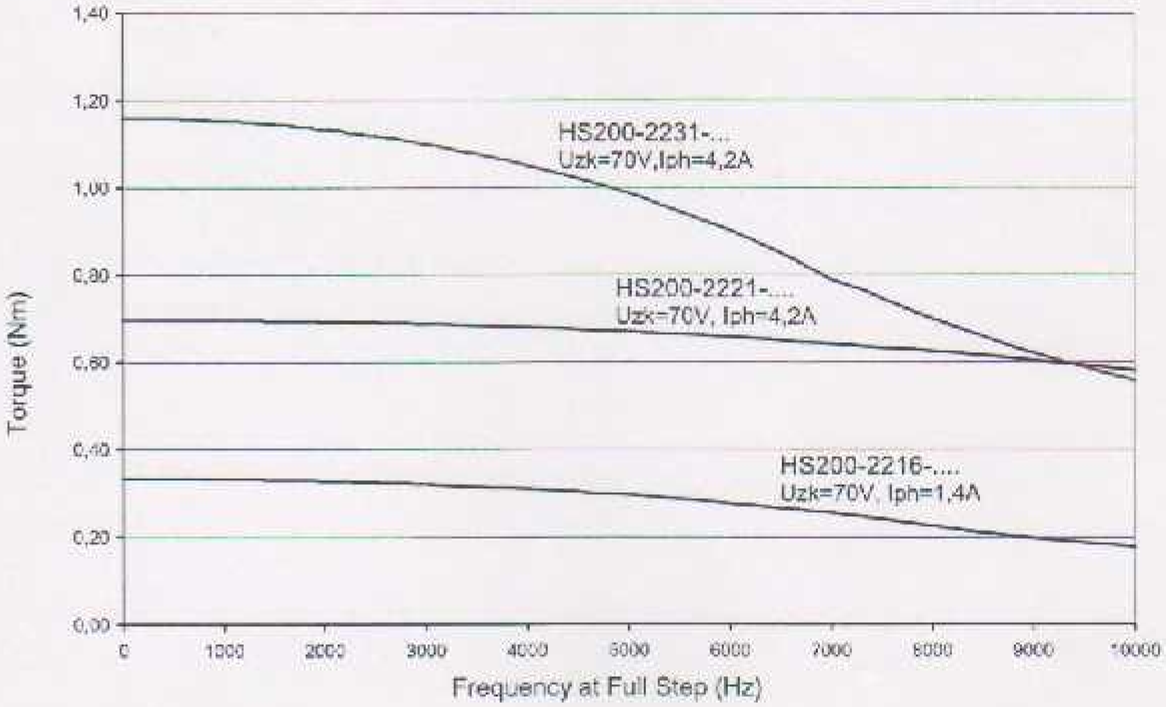
Technical Data (Standard Types)

			HS200-2216-0100AX08	HS200-2221-0300AX08	HS200-2231-0300AX08
Holding Torque (bipolar, 2 phases parallel connected)	M_H	Nm	0,47	0,98	1,63
Rated Current Phase (bipolar parallel)	I	A	1,4	4,2	4,2
Rated Current Phase (bipolar serial)	I	A	0,7	2,1	2,1
Step Angle		°	1,8	1,8	1,8
Angular Tolerance		%	5	5	5
Resistance per Phase	R_{ph}	Ω	4,6	0,7	1,1
Inductance per Phase	L_{ph}	mH	4,6	0,9	1,7
Residual Torque	M_P	Nm	0,02	0,04	0,07
Insulation Class			B	B	B
Rotor Inertia	J	$Kgm^{2x}10^{-3}$	0,008	0,022	0,034
Mass	m	kg	0,5	0,7	1,0

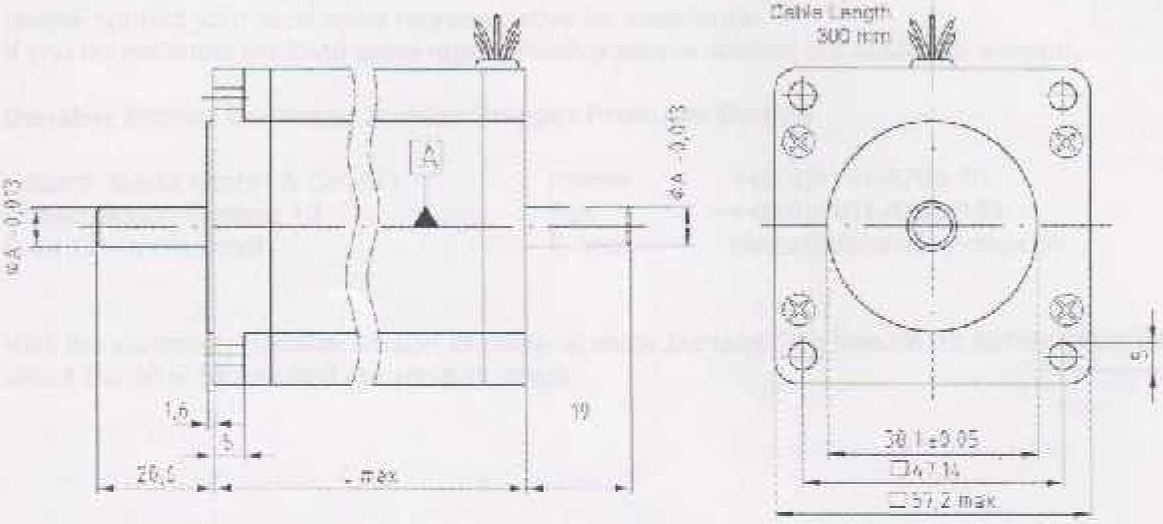
Standard Version: NEMA 23, smooth shaft
8 flying leads for serial or parallel connection

Further types and options for those series as well as stepper drives and other accessories are available upon request.

Torque Characteristics
(Connection bipolar, parallel)



Dimensions



all dimensions in mm

	Length (Lmax)	Shaft (ØA)
HS200-2216	41 mm	6,35 mm
HS200-2221	55 mm	6,35 mm
HS200-2231	77 mm	8 mm

subject to change without notice

Sales and Service

We are committed to quality customer service. In order to serve you in the most effective way please contact your local sales representative for assistance.
If you do not know the local sales representative please contact our customer support.

Danaher Motion Customer Service Stepper Products Europe

Eduard Bautz GmbH & Co. KG	Phone	+49(0)6151-8796-10
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D-64331 Weiterstadt	E-Mail	bautz@danaher-motion.de

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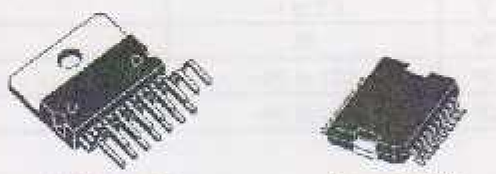
DUAL FULL-BRIDGE DRIVER

- OPERATING SUPPLY VOLTAGE UP TO 46 V
- TOTAL DC CURRENT UP TO 4 A
- LOW SATURATION VOLTAGE
- OVERTEMPERATURE PROTECTION
- LOGICAL "0" INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY)



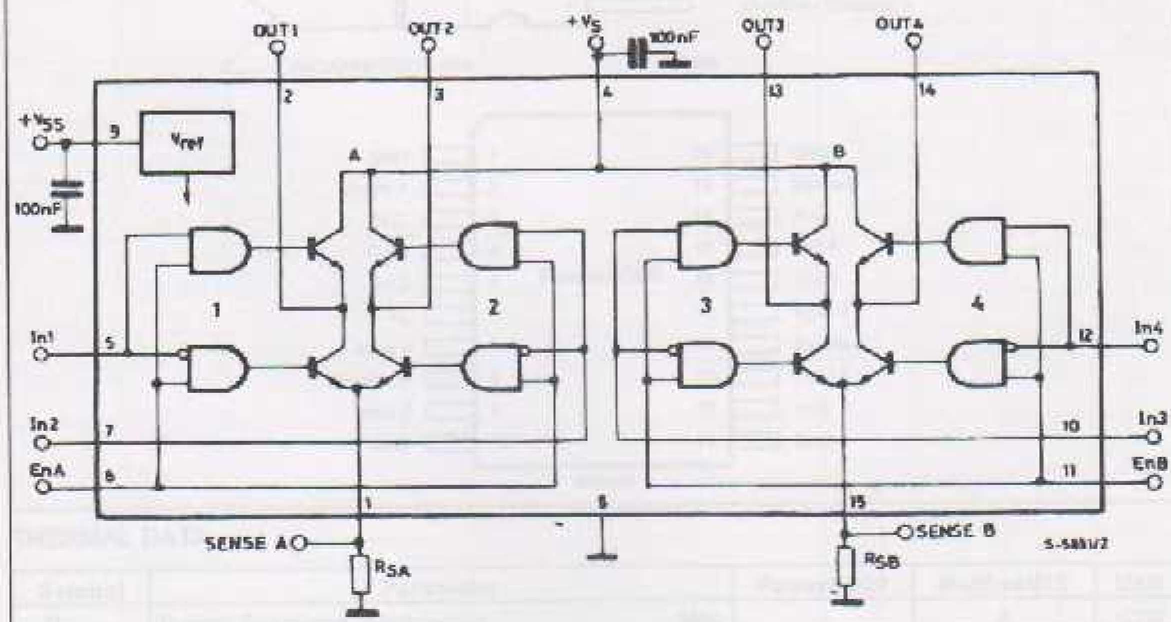
Multiwatt15 PowerSO20

ORDERING NUMBERS : L298N (Multiwatt Vert.)
L298HN (Multiwatt Horiz.)
L298P (PowerSO20)

DESCRIPTION

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

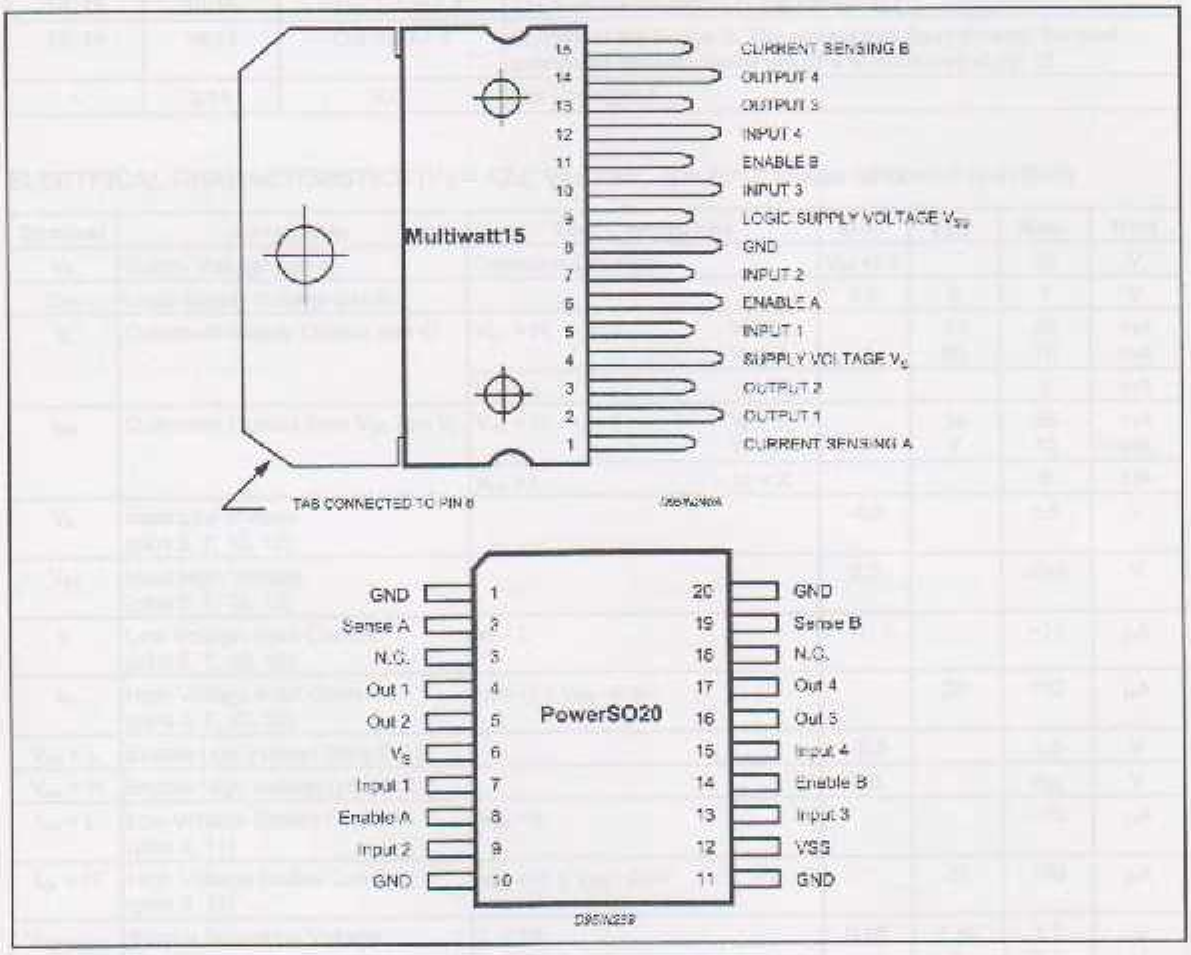
BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_S	Power Supply	50	V
V_{SS}	Logic Supply Voltage	7	V
V_I, V_{en}	Input and Enable Voltage	–0.3 to 7	V
I_O	Peak Output Current (each Channel) – Non Repetitive (t = 100μs) –Repetitive (80% on –20% off; t_{on} = 10ms) –DC Operation	 3 2.5 2	 A A A
V_{sens}	Sensing Voltage	–1 to 2.3	V
P_{tot}	Total Power Dissipation (T_{case} = 75°C)	25	W
T_{op}	Junction Operating Temperature	–25 to 130	°C
T_{stg}, T_j	Storage and Junction Temperature	–40 to 150	°C

PIN CONNECTIONS (top view)



THERMAL DATA

Symbol	Parameter		PowerSO20	Multiwatt15	Unit
$R_{th\ j\text{-}case}$	Thermal Resistance Junction-case	Max.	–	3	°C/W
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	13 (*)	35	°C/W

(*) Mounted on aluminum substrate

PIN FUNCTIONS (refer to the block diagram)

MW.15	PowerSO	Name	Function
1;15	2;19	Sense A; Sense B	Between this pin and ground is connected the sense resistor to control the current of the load.
2;3	4;5	Out 1; Out 2	Outputs of the Bridge A; the current that flows through the load connected between these two pins is monitored at pin 1.
4	6	V_S	Supply Voltage for the Power Output Stages. A non-inductive 100nF capacitor must be connected between this pin and ground.
5;7	7;9	Input 1; Input 2	TTL Compatible Inputs of the Bridge A.
6;11	8;14	Enable A; Enable B	TTL Compatible Enable Input: the L state disables the bridge A (enable A) and/or the bridge B (enable B).
8	1,10,11,20	GND	Ground.
9	12	VSS	Supply Voltage for the Logic Blocks. A100nF capacitor must be connected between this pin and ground.
10; 12	13;15	Input 3; Input 4	TTL Compatible Inputs of the Bridge B.
13; 14	16;17	Out 3; Out 4	Outputs of the Bridge B. The current that flows through the load connected between these two pins is monitored at pin 15.
–	3;18	N.C.	Not Connected

ELECTRICAL CHARACTERISTICS (V_S = 42V; V_{SS} = 5V, T_j = 25°C; unless otherwise specified)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
V_S	Supply Voltage (pin 4)	Operative Condition		V_{IH} +2.5		46	V
V_{SS}	Logic Supply Voltage (pin 9)			4.5	5	7	V
I_S	Quiescent Supply Current (pin 4)	V_{en} = H; I_L = 0	V_i = L V_i = H		13 50	22 70	mA mA
		V_{en} = L	V_i = X			4	mA
I_{SS}	Quiescent Current from V_{SS} (pin 9)	V_{en} = H; I_L = 0	V_i = L V_i = H		24 7	36 12	mA mA
		V_{en} = L	V_i = X			6	mA
V_{iL}	Input Low Voltage (pins 5, 7, 10, 12)			–0.3		1.5	V
V_{iH}	Input High Voltage (pins 5, 7, 10, 12)			2.3		VSS	V
I_{iL}	Low Voltage Input Current (pins 5, 7, 10, 12)	V_i = L				–10	µA
I_{iH}	High Voltage Input Current (pins 5, 7, 10, 12)	Vi = H ≤ V_{SS} –0.6V			30	100	µA
V_{en} = L	Enable Low Voltage (pins 6, 11)			–0.3		1.5	V
V_{en} = H	Enable High Voltage (pins 6, 11)			2.3		V_{SS}	V
I_{en} = L	Low Voltage Enable Current (pins 6, 11)	V_{en} = L				–10	µA
I_{en} = H	High Voltage Enable Current (pins 6, 11)	V_{en} = H ≤ V_{SS} –0.6V			30	100	µA
$V_{CEsat(H)}$	Source Saturation Voltage	I_L = 1A I_L = 2A		0.95	1.35 2	1.7 2.7	V V
$V_{CEsat(L)}$	Sink Saturation Voltage	I_L = 1A (5) I_L = 2A (5)		0.85	1.2 1.7	1.6 2.3	V V
V_{CEsat}	Total Drop	I_L = 1A (5) I_L = 2A (5)		1.80		3.2 4.9	V V
V_{sens}	Sensing Voltage (pins 1, 15)			–1 (1)		2	V

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
T_1 (V_i)	Source Current Turn-off Delay	0.5 V_i to 0.9 I_L (2); (4)		1.5		μs
T_2 (V_i)	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		0.2		μs
T_3 (V_i)	Source Current Turn-on Delay	0.5 V_i to 0.1 I_L (2); (4)		2		μs
T_4 (V_i)	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.7		μs
T_5 (V_i)	Sink Current Turn-off Delay	0.5 V_i to 0.9 I_L (3); (4)		0.7		μs
T_6 (V_i)	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.25		μs
T_7 (V_i)	Sink Current Turn-on Delay	0.5 V_i to 0.9 I_L (3); (4)		1.6		μs
T_8 (V_i)	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.2		μs
fc (V_i)	Commutation Frequency	I_L = 2A		25	40	KHz
T_1 (V_{en})	Source Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (2); (4)		3		μs
T_2 (V_{en})	Source Current Fall Time	0.9 I_L to 0.1 I_L (2); (4)		1		μs
T_3 (V_{en})	Source Current Turn-on Delay	0.5 V_{en} to 0.1 I_L (2); (4)		0.3		μs
T_4 (V_{en})	Source Current Rise Time	0.1 I_L to 0.9 I_L (2); (4)		0.4		μs
T_5 (V_{en})	Sink Current Turn-off Delay	0.5 V_{en} to 0.9 I_L (3); (4)		2.2		μs
T_6 (V_{en})	Sink Current Fall Time	0.9 I_L to 0.1 I_L (3); (4)		0.35		μs
T_7 (V_{en})	Sink Current Turn-on Delay	0.5 V_{en} to 0.9 I_L (3); (4)		0.25		μs
T_8 (V_{en})	Sink Current Rise Time	0.1 I_L to 0.9 I_L (3); (4)		0.1		μs

1) 1)Sensing voltage can be –1 V for t ≤ 50 μsec; in steady state V_{sens} min ≥ – 0.5 V.
2) See fig. 2.
3) See fig. 4.
4) The load must be a pure resistor.

Figure 1 : Typical Saturation Voltage vs. Output Current.

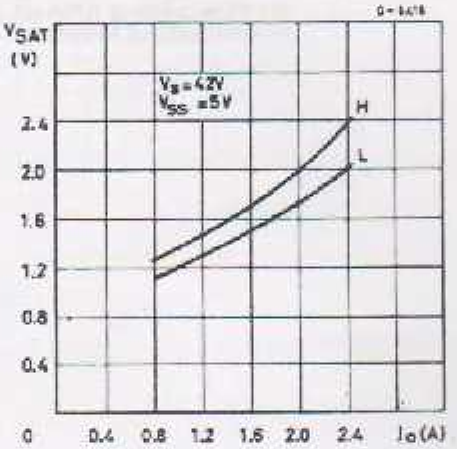
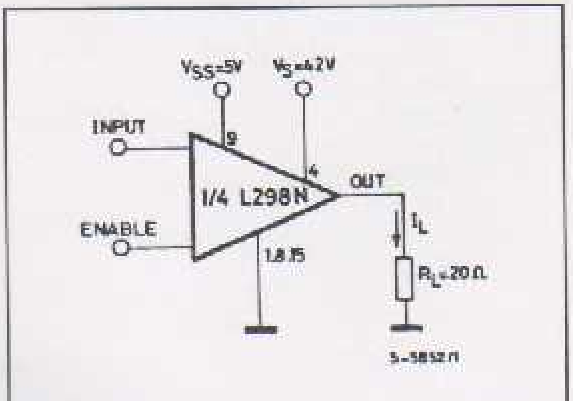


Figure 2 : Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = H

Figure 3 : Source Current Delay Times vs. Input or Enable Switching.

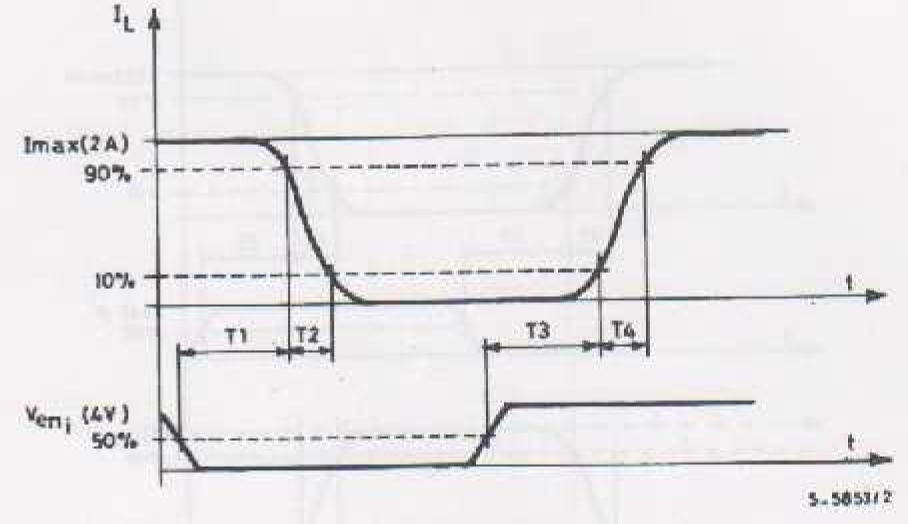
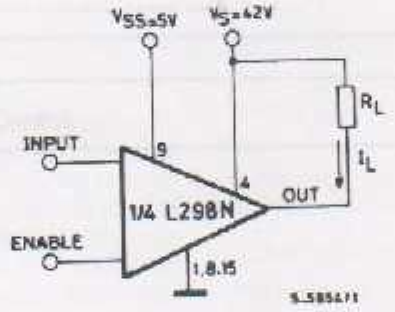


Figure 4 : Switching Times Test Circuits.



Note : For INPUT Switching, set EN = H
For ENABLE Switching, set IN = L

Figure 5 : Sink Current Delay Times vs. Input 0 V Enable Switching.

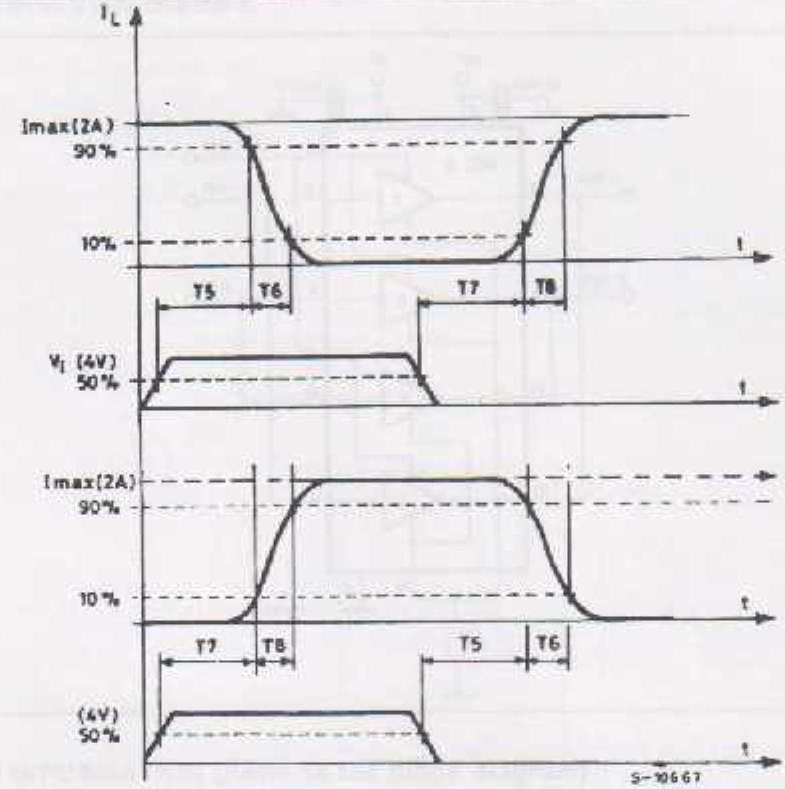
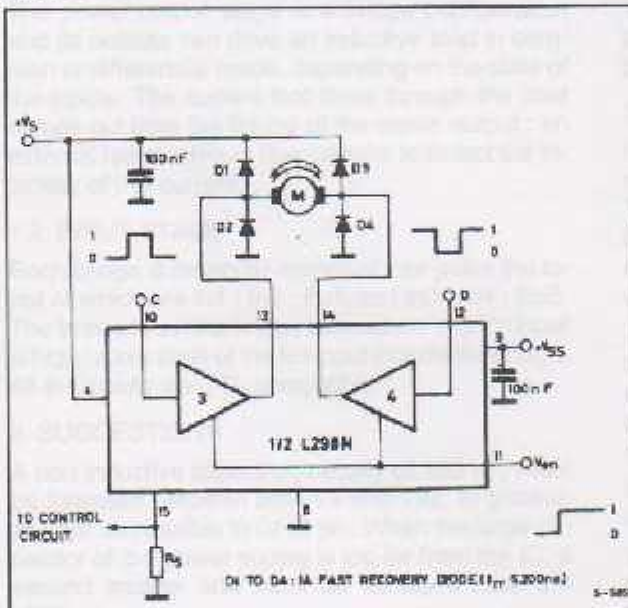


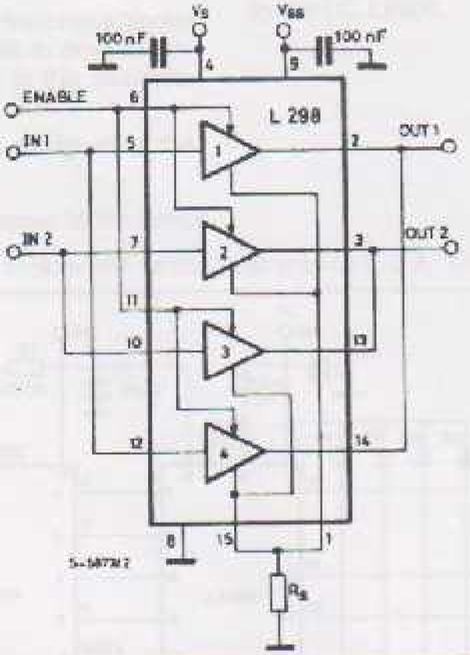
Figure 6 : Bidirectional DC Motor Control.



Inputs		Function
V_{en} = H	C = H ; D = L	Forward
	C = L ; D = H	Reverse
	C = D	Fast Motor Stop
V_{en} = L	C = X ; D = X	Free Running Motor Stop

L = Low H = High X = Don't care

Figure 7 : For higher currents, outputs can be paralleled. Take care to parallel channel 1 with channel 4 and channel 2 with channel 3.



APPLICATION INFORMATION (Refer to the block diagram)

1.1. POWER OUTPUT STAGE

The L298 integrates two power output stages (A ; B). The power output stage is a bridge configuration and its outputs can drive an inductive load in common or differenzial mode, depending on the state of the inputs. The current that flows through the load comes out from the bridge at the sense output : an external resistor (R_{SA} ; R_{SB}.) allows to detect the intensity of this current.

1.2. INPUT STAGE

Each bridge is driven by means of four gates the input of which are In1 ; In2 ; EnA and In3 ; In4 ; EnB. The In inputs set the bridge state when The En input is high ; a low state of the En input inhibits the bridge. All the inputs are TTL compatible.

2. SUGGESTIONS

A non inductive capacitor, usually of 100 nF, must be foreseen between both Vs and Vss, to ground, as near as possible to GND pin. When the large capacitor of the power supply is too far from the IC, a second smaller one must be foreseen near the L298.

The sense resistor, not of a wire wound type, must be grounded near the negative pole of Vs that must be near the GND pin of the I.C.

Each input must be connected to the source of the driving signals by means of a very short path.

Turn-On and Turn-Off : Before to Turn-ON the Supply Voltage and before to Turn it OFF, the Enable input must be driven to the Low state.

3. APPLICATIONS

Fig 6 shows a bidirectional DC motor control Schematic Diagram for which only one bridge is needed. The external bridge of diodes D1 to D4 is made by four fast recovery elements ($t_{rr} \leq 200$ nsec) that must be chosen of a VF as low as possible at the worst case of the load current.

The sense output voltage can be used to control the current amplitude by chopping the inputs, or to provide overcurrent protection by switching low the enable input.

The brake function (Fast motor stop) requires that the Absolute Maximum Rating of 2 Amps must never be overcome.

When the repetitive peak current needed from the load is higher than 2 Amps, a paralleled configuration can be chosen (See Fig.7).

An external bridge of diodes are required when inductive loads are driven and when the inputs of the IC are chopped ; Shottky diodes would be preferred.

This solution can drive until 3 Amps In DC operation and until 3.5 Amps of a repetitive peak current.

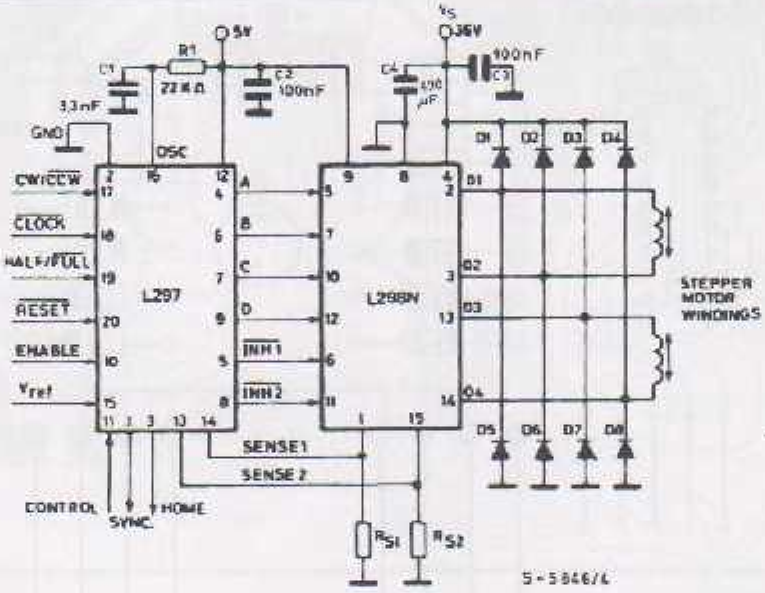
On Fig 8 it is shown the driving of a two phase bipolar stepper motor ; the needed signals to drive the inputs of the L298 are generated, in this example, from the IC L297.

Fig 9 shows an example of P.C.B. designed for the application of Fig 8.

Fig 10 shows a second two phase bipolar stepper motor control circuit where the current is controlled by the I.C. L6506.

Figure 8 : Two Phase Bipolar Stepper Motor Circuit.

This circuit drives bipolar stepper motors with winding currents up to 2 A. The diodes are fast 2 A types.



$R_{S1} = R_{S2} = 0.5\ \Omega$

D1 to D8 = 2 A Fast diodes { $V_F \leq 1.2$ V @ I = 2 A; $t_{rr} \leq 200$ ns }

Figure 9 : Suggested Printed Circuit Board Layout for the Circuit of fig. 8 (1:1 scale).

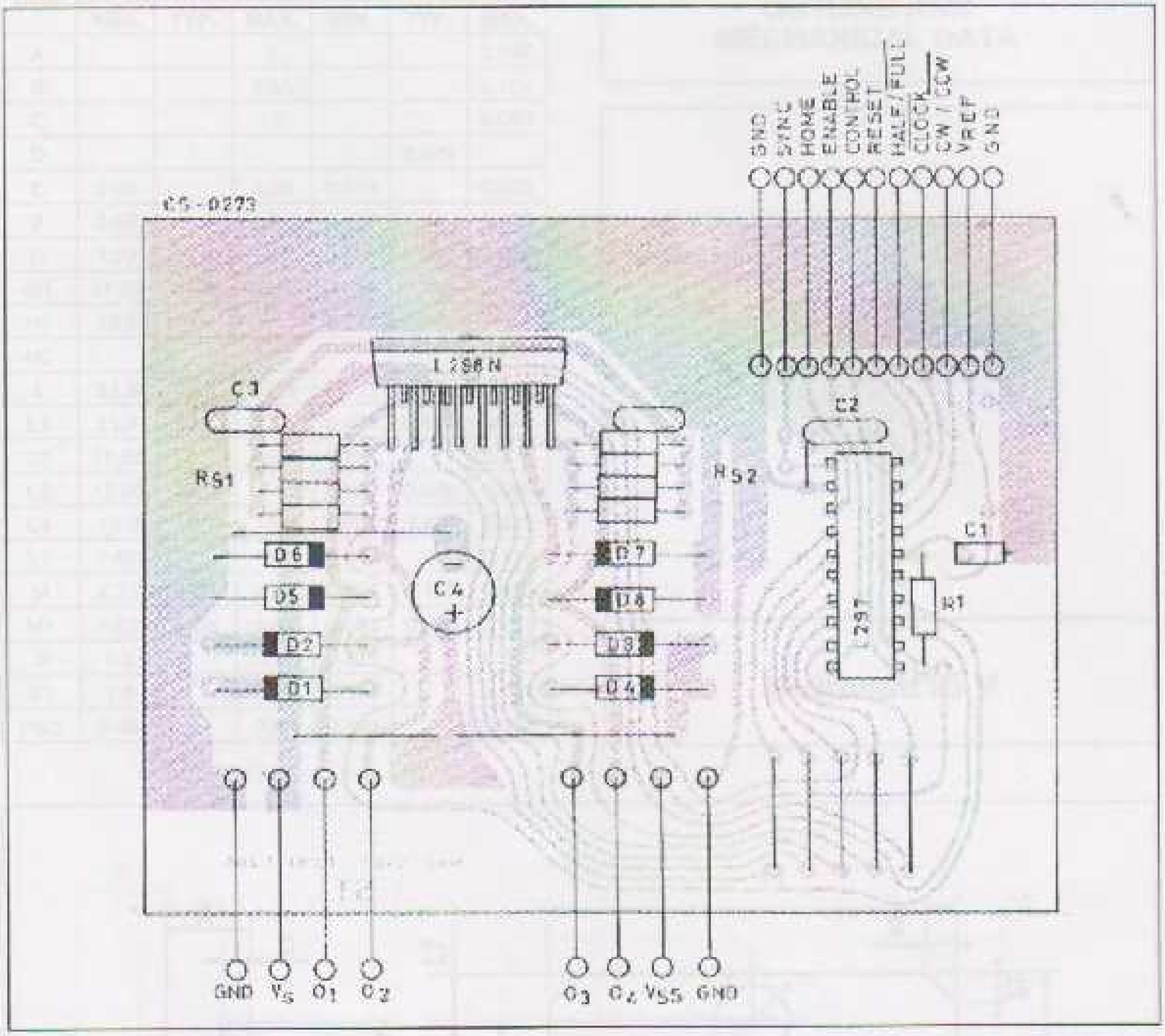
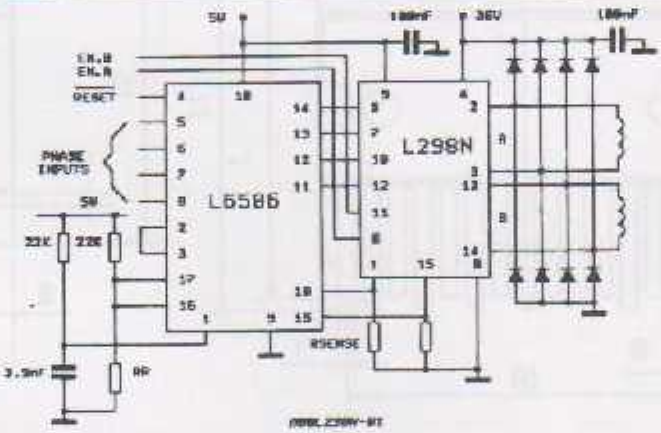


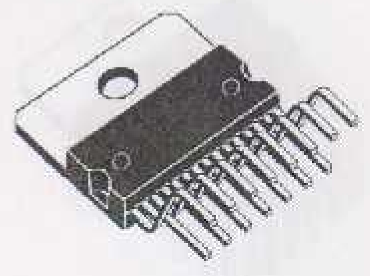
Figure 10 : Two Phase Bipolar Stepper Motor Control Circuit by Using the Current Controller L6506.



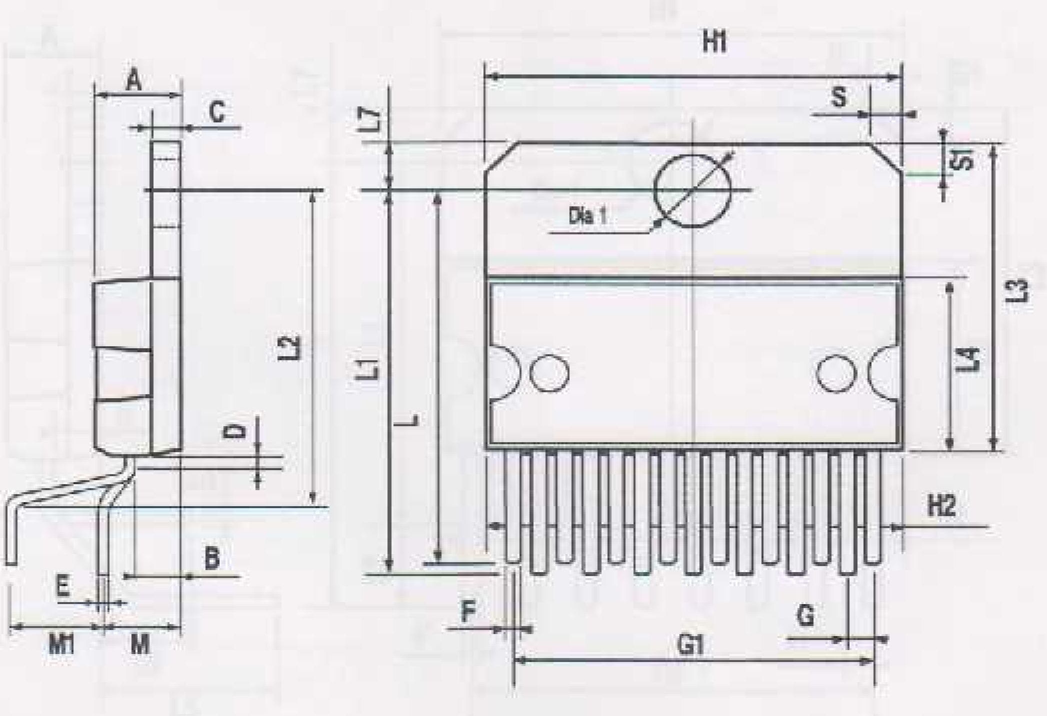
R_R and R_{sense} depend from the load current

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
D		1			0.039	
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.02	1.27	1.52	0.040	0.050	0.060
G1	17.53	17.78	18.03	0.690	0.700	0.710
H1	19.6			0.772		
H2			20.2			0.795
L	21.9	22.2	22.5	0.862	0.874	0.886
L1	21.7	22.1	22.5	0.854	0.870	0.886
L2	17.65		18.1	0.695		0.713
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L7	2.65		2.9	0.104		0.114
M	4.25	4.55	4.85	0.167	0.179	0.191
M1	4.63	5.08	5.53	0.182	0.200	0.218
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

OUTLINE AND MECHANICAL DATA

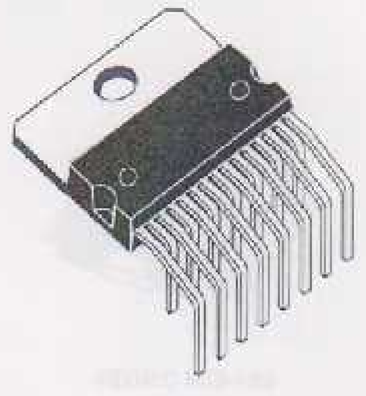


Multiwatt15 V

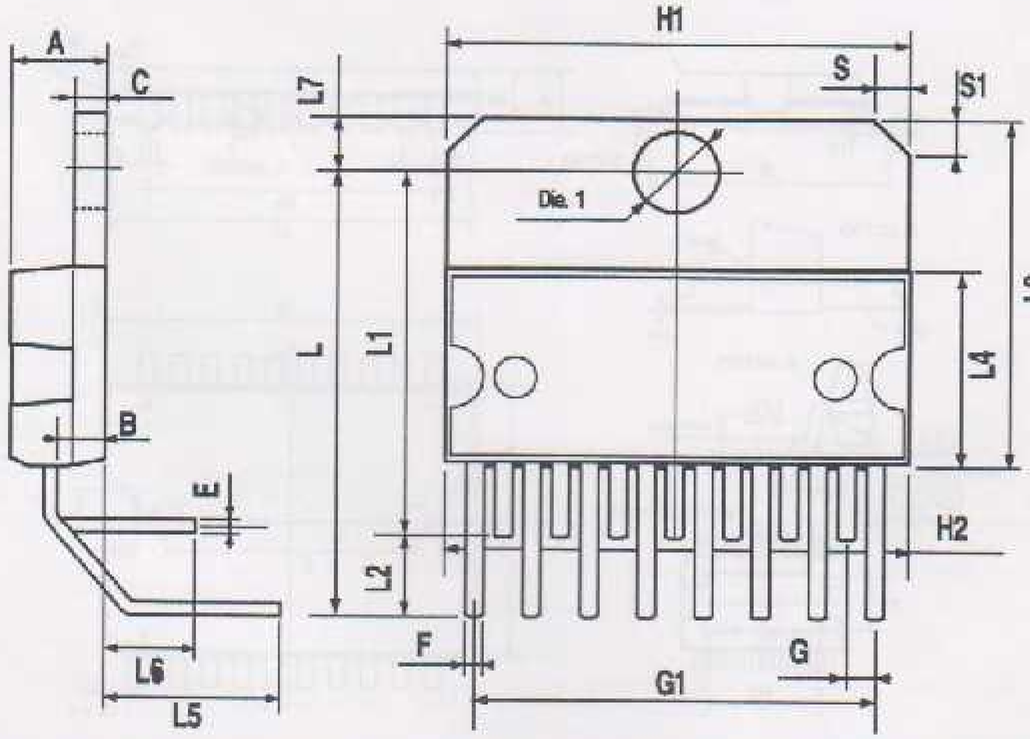


DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
E	0.49		0.55	0.019		0.022
F	0.66		0.75	0.026		0.030
G	1.14	1.27	1.4	0.045	0.050	0.055
G1	17.57	17.78	17.91	0.692	0.700	0.705
H1	19.6			0.772		
H2			20.2			0.795
L		20.57			0.810	
L1		18.03			0.710	
L2		2.54			0.100	
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L5		5.28			0.208	
L6		2.38			0.094	
L7	2.65		2.9	0.104		0.114
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
Dia1	3.65		3.85	0.144		0.152

OUTLINE AND MECHANICAL DATA



Multiwatt15 H



DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			3.6			0.142
a1	0.1		0.3	0.004		0.012
a2			3.3			0.130
a3	0		0.1	0.000		0.004
b	0.4		0.53	0.016		0.021
c	0.23		0.32	0.009		0.013
D (1)	15.8		16	0.622		0.630
D1	9.4		9.8	0.370		0.386
E	13.9		14.5	0.547		0.570
e		1.27			0.050	
e3		11.43			0.450	
E1 (1)	10.9		11.1	0.429		0.437
E2			2.9			0.114
E3	5.8		6.2	0.228		0.244
G	0		0.1	0.000		0.004
H	15.5		15.9	0.610		0.626
h			1.1			0.043
L	0.8		1.1	0.031		0.043
N	10° (max.)					
S	8° (max.)					
T		10			0.394	

(1) "D and F" do not include mold flash or protrusions.
- Mold flash or protrusions shall not exceed 0.15 mm (0.006").
- Critical dimensions: "E", "G" and "a3".

OUTLINE AND MECHANICAL DATA

JEDEC MO-166

PowerSO20